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ZĂCĂMINTELE DE PETROL ŞI GAZE ALE ROMÂNIEI

DE

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Sommaire

L e s g i s e m e n t s d e p é t r o l e e t d e g a z d e R o u m a n i e. Au cours des 122 années d'existence de l'industrie extractive de pétrole de Roumanie, ont y été découvertes plus de 350 structures productives, chacune constituée souvent de plusieurs gisements.

Les accumulations de pétrole et de gaz sont disséminées dans toutes les unités structurales majeures à dépôts sédimentaires. Ainsi, dans le domaine carpathique on connait des structures productives dans le flysch des Carpathes Orientales, dans l'avant-fosse carpathique, dans la dépression de Transylvanie et la dépression pannonique et, dans l'avant-pays de celui-ci, dans la plate-forme moldave, dans le promontoire nord-dobrogéen, dans la dépression pré-dobrogéenne et dans la plate-forme moesique. Dans toutes les unités mentionnées il y a des accumulations de pétrole et de gaz, à l'exception de la dépression de Transylvanie qui est exclusivement gazéifère.

Les hydrocarbures sont localisés dans des formations géologiques dont l'âge commence par la partie supérieure altérée du soubassement métamorphique (Précambrien), continue ensuite par le Dévonien, le Trias, le Dogger, le Malm-Crétacé inférieur, l'Albien, le Sénonien, l'Eocène, l'Oligocène, le Burdigalien-Helvétien, le Tortonien, le Sarmatien, le Méotien, le Pontien, le Dacien et s'acheve par le Levantin.

Les accumulations de pétrole et de gaz sont situées à des profondeurs qui varient de 80 à 4890 m, le gisement le plus profond étant placé dans le Dévonien de la plate-forme moesique.

Les pièges très variées ont été en général déterminées par les facteurs structuraux, stratigraphiques, paléogéomorphiques et hydrogéologiques.

Les types de gisement et leur distribution s'expliquent par l'évolution géologique spécifique à chaque unité structurale majeure à part.

CONTENT

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I. INTRODUCTION

122 years ago Romania was reported in international statistics with 1977 barrels of oil, being the only country in the world with production between 1857—1858. It was also then that petroleum necessary for the illumination of the city of Bucharest, which constituted the first attempt of the kind in the world, was obtained, with the building of the Rîfov refinery near Ploieşti.

Since that time, the oil industry has been continuously developing, maintaining Romania among the world's first countries as regards the volume of production up to the beginning of World War II. The prospection, exploration, drilling and production activity has intensified still more, extending to almost all the areas of the country in the last 35 years. The results of this activity are mirrored in the oil and gas level of production and are recorded in several published papers, among which "Geology of Romanian Hydrocarbon Deposits" which appeared in 1975.

The selling out of the mentioned paper within a few days and the subsequent requests, both in and abroad, underline the need for elaborating and publishing such books more often, according to the volume of new primary data and to the evolution of conceptions in the field of petroleum geology.

During the four years that elapsed since the coming out of "Geology of Romanian Hydrocarbon Deposits", several thousand kilometres profile-shooting have been recorded, processed and interpreted, over 7 million metres have been drilled in this country, which is equivalent to about 4,000 exploratory boreholes and development wells, and several oil and gas fields have been discovered. These works provided new data that, analysed and synthetized, completed the image on the geological and formation conditions of the fields in most oil basins, such as the

Moesian Platform, the North-Dobrogean Promontory and the Predobrogean Depression, the Transylvanian Depression and the Pannonian Depression. At the same time, the conceptions about the geological structure of the Romanian territory as a whole developed. Besides, the works of the World Petroleum Congress in Tokio (1975) and the subjects at the 10th Congress in Bucharest (1979) brought about some orientations of the papers on prospection and exploration that took into account especially the part played by temperature and the metamorphic basement in the formation of hydrocarbon deposits. The results obtained allowed a series of reconsiderations in point of hydrocarbon distribution, of future geological units and of work methods.

We may addto this some "suggestions" made by the readers of the book published in 1975; they derive mainly from the incomplete description of some oil basins. This is the case, first, of the Moesian Platform, within which not each productive structure was dealt with separately, as were the other units, only the representative accumulations being described.

Under such circumstances, arose the necessity of elaborating the present paper, which benefited by the information obtained up to 1 June 1978. In drawing it up we started, in the first place, from the published syntheses and from the new primary data obtained in the last four years. Articles with restricted subject matter, manuscripts and oral information have been only little used.

Taking into account the vast and complex character of this paper, its author has been faced with an immense, sometimes, anachronic and contradictory bibliographic inventory. Only the elements which are useful for attaining our end, that is, the presentation and the attempt to find out the formation conditions of deposits, have been selected, enumeration of or comment on diverging opinions being avoided.

One of the numerous such difficulties the author had to overcome is the chronostratigraphic terminology, especially in the case of the Neogene. Taking into consideration the debates as well as the progress recorded in this field in recent years (M o t a ş et al., 1976), although unmaterialized into a quasiunanimously accepted form as yet, the old terminology has been adopted in this paper. It should be added that the cores of about 20,000 wells spread all over the country could not be totally reexamined in the light of the new discussions and proposals. Along the same line and for similar reasons the separation of the Buglovian as an independent stage could not be given up in the case of the Transylvanian Depression and the Moldavian Platform, the more so as the respective deposits make up a geological-productive entity.

In dealing with the various structural units of interest for hydrocarbons, a larger space has been devoted to the new areas which are less known in the relevant literature and, above all, to the Moesian Platform. As compared to other geological — productive units, the Moesian Platform, discovered and rendered completely profitable (as a petroleum basin) after World War II, contains the greatest number of deposits, distributed on an enormous stratigraphic interval, beginning with the Devonian and ending with the Upper Pliocene (the Dacian).

Hoping that the present paper represents a step forward as regards the knowledge on the Romanian hydrocarbon deposits and that it mirrors some of the strivings and achievements of those who dedicated themselves to the oil prospecting, exploration and exploitation, and to geological research in general, the author kindly thanks the Institute of Geology and Geophysics that allowed its publication.

II. STRUCTURAL UNITS OF INTEREST FOR THE ROMANIAN HYDROCARBON DEPOSITS

The most important component element in the geological structure of the Romanian territory is the Carpathian Chain. Within it one may distinguish, on geological and geographical criteria, the East Carpathians, the South Carpathians, and the Apuseni Mountains. Outside the Carpathian Chain lie the Moldavian Platform, North Dobrogea with the Predobrogean Depression and the Moesian Platform. Between the mountainous arc of the East Carpathians and the South Carpathians, on the one hand, and the Foreland units, on the other hand, lies the Carpathian Foredeep. Behind this mountainous arc, the three main branches of the Romanian Carpathians enclose the Transylvanian Depression. Beyond the Apuseni Mountains and the South Carpathians, in the west of the country, the Pannonian Depression can be noticed (Plate I).

The East Carpathians develop between the northern boundary of the country and the Dîmbovița Valley. They include a central core consisting of metamorphic rocks and Triassic and Jurassic sedimentary deposits, that is the Crystalline-Mesozoic zone, bordered by the flysch zone outwards (the Cretaceous and the Paleogene) and by the Transcarpathian zone inwards. The Crystalline—Mesozoic zone is made up of three islands (compartments): a northern one which can be followed from Maramureș to the Trotuș Valley, a median one, corresponding to the Perșani Mountains and a south-eastern one, partly identified with the Leaota Mountains. The outer flysch (the Cretaceous and the Paleogene) is to be found along the East Carpathians and marks successive stages in the latters' formation, by its zones. The Transcarpathian unit, including also the so-called "Maramureș Depression" (Grigoraș, 1961), consists of Upper-Jurassic, Cretaceous, and Paleogene deposits partly showing flysch characteristics. This unit lying between the Crystalline-Mesozoic zone and the Oaș-Gutîi-Călimani volcanic chain extends on the territory of the USSR and of the Hungarian People's Republic. As far as the magmatites of the mentioned volcanic chain are concerned, they are represented in most cases by andesitic lavas and, subordinately, by rhyolites, dacites and basalts.

Among the three units of the East Carpathians the Crystalline-Mesozoic zone is not of prospect for hydrocarbons, while the flysch zones provide favourable conditions for the formation and preservation of oil and gas fields, by the succession of deposits, the beds arrangement and evolution of the region.

The South Carpathians are bounded by the Dîmboviţa Valley on the east and by the Danube on the south-west. They consist of crystalline schists and, here and there, Paleozoic non-metamorphosed or weakly metamorphosed rocks as well as Mesozoic deposits. The crystalline formations and the Paleozoic deposits are sometimes crossed by igneous rocks, especially by granites and granodiorites. The South Carpathians are characterized by a nappe structure. The autochthon, generally, consist of epizone schits with granitic intrusions and sedimentary deposits that rise up to the Upper Cretaceous on the stratigraphic scale. The formations overlying the autochthon tectonically make up the Getic Nappe and consist especially of crystalline schists that are overlain by Paleozoic and Mesozoic deposits. The latter are sometimes pierced by banatites. The South Carpathians are not of interest for hydrocarbons.

The Apuseni Mountains lie north of the Mureş Valley. They consists of crystalline schists showing various metamorphic degrees and, locally, of Paleozoic, Mesozoic and Tertiary deposits. The above formations contain eruptions of various age, beginning with granites, Permian magmatites, diabases (Jurassic-Lower Cretaceous), banatites (Upper Cretaceous-Paleogene) and ending with various Neogene effusive rocks. The Apuseni Mountains, too, are not of interest for petroleum and gas.

The Carpathian Foredeep is a depression filled with halogen, molasse and coal deposits, outflanking the East Carpathians and the South Carpathians and developing between the northern boundary of the country and the Danube. This depression that appeared at the beginning of the Miocene and extended afterwards, overlies a Carpathian basement in the inner flank and a platform basement in the outer flank. Thus, crystalline schists and Paleozoic formations belonging to the pre-Alpine regenerate basement as well as Mesozoic and Paleogene deposits under geosyncline facies are to be found in the epiorogenic flank, under the foredeep molasse (Dumitrescu, Săndulescu, 1968); the upper molasse overlies directly the platform Mesozoic and Paleozoic formations in the outer flank.

Within the foredeep one can distinguish a lower molasse consisting of Lower Miocene marine and lagoonal deposits, which is found in the internal part of the zone and an upper molasse, which is subsequent to the Tortonian movements and consists especially of brackish and lacustrine deposits, developing in the foredeep inner and outer flanks. As the upper molasse extends much on the platform sunk edges, the boundary between the foredeep and the foreland is conventionally situated along the Pericarpathian fault; the latter is a tectonic accident marking the limit of the lower molasse thrust over the platform formations. In fact, the platform basement extends also beyond this regional tectonic accident.

Being thus delimited, the Carpathian Foredeep was divided into three subunits: the Miocene subzone, developing north of the Trotuş; the Mio-Pliocene zone, located between the Trotuş and the Dîmboviţa; the Getic Depression, lying between the Dîmboviţa and the Danube.

The whole territory of the Carpathian Foredeep is of particular interest for hydrocarbons.

The geologists working in the Romanian petroleum industry use also the term "the Precarpathian Depression" with the meaning given it by Grigoraş (1961). According to this author, the Precarpathian Depression represents a premountain depression formed in front of the Carpathian Crystalline-Mesozoic cores and consisting of the Cretaceous flysch zone, the Paleogene flysch zone and the foredeep. Its formation began at the end of the Carboniferous. The term "Precarpathian Depression" is also used in the USSR and the Polish People's Republic with a different meaning.

The Transylvanian Depression, such as it is known today, formed in the Miocene. Its sedimentary deposits overlie a basement consisting of crystalline schists and Jurassic, Triassic, Lower Jurassic, Lower Cretaceous, Upper Cretaceous, Paleogene and Lower Miocene formations. The Transylvanian Depression is a unit propitious to the hydrocarbon formation.

The Pannonian Depression develops only partially (the eastern side) on the Romanian territory. It is as old as the Transylvanian Depression. Its basement consists of the Apuseni Mountains and the South Carpathians crystalline formations that are sunk and, locally, especially north of the Mureş, overlain by Permian-Triassic, Jurassic, Cretaceous-Paleogene and Lower Miocene formations. This depression had also an evolution that favoured the formation and preservation of petroleum and gas fields.

Beside the major structural intra-Carpathian units, there are several much smaller intramontan depressions that formed in the Tertiary, containing deposits of variable thickness. Some of them are worth mentioning: Beiuş, Mureş, Caransebeş, Haţeg, Petroşani, Brezoi-Titeşti, Ţara Bîrsei, Sf. Gheorghe, Ciucurilor etc.

The Moldavian Platform represents the prolongation of the East-European Platform on the Romanian territory. It is made up of the metamorphosed Precambrian basement and of non-metamorphosed deposits belonging to the Rifo-Cambrian-Ordovician, Silurian, Devonian, Carboniferous, Jurassic, Cretaceous, Eocene and Neogene. In the western part of this unit the basement is represented by the greenschist formation. During its evolution, the Moldavian Platform benefited, locally, by moments favouring the formation and accumulation of hydrocarbons.

North Dobrogea and the Predobrogean Depression correspond to a region showing a complex geological constitution, including what has already been defined as "the Orogen" and "the North-Dobrogean Promontory" "the Bîrlad Depression" and the Danube Delta. The axial zone of this region consists of metamorphic formations, frequently outcropping in North Dobrogea and sinks westwards, northwards and eastwards being progressively overlain by Neogene, Cretaceous, Jurassic, Triassic, Paleozoic and, probably, Precambrian deposits. North Dobrogea is an old geosyncline whose evolution ended during the Kimmerian movements (Bleahu et al., 1967), while the Predobrogean Depression represents a foredeep that functioned as such during the terminal Triassic and the Jurassic. The

Predobrogean Depression would correspond to "the Scythian Platform" (Bogdanof et al., 1964). The North Dobrogean Orogen (North—Dobrogea) and the Predobrogean Depression develop between the green-schist zone, from which they are separated by the Peceneaga—Camena fault, and the Moldavian Platform, conventionally delimited by a system of faults succeeding along the line S Bacău—Găiceana—Glăvănești—Bîrlad—Murgeni. This region is also of interest for petroleum and gas.

The Moesian Platform represents the structural unit which is delimited by the Carpathian Foredeep, the Pre-Balkans and the North-Dobrogean Orogen, belonging only partly to Romania. It is bounded by the Peceneaga—Camena fault to the north-east. The Moesian Platform, like the Scythian Platform, extends eastwards under the Black Sea waters, constituting a section of the Romanian offshore. This platform consists of metamorphic rocks and of an almost complete sequence of deposits, beginning with the Cambrian and ending with the Quaternary. The respective sedimentary deposits overlie a heterogeneous basement consisting of crystalline schists, in the western part, and of the greenschist formation, in the eastern part. The prospecting and exploration activities carried out in the last 24 years showed the petroleum and gas potential in the area between the Carpathian Foredeep and the Danube.

It follows from the above short presentation that the major structural units of interest for petroleum and gas developing on the Romanian territory are: the East Carpathians, the Carpathian Foredeep, the Transylvanian Depression, the Pannonian Depression, the Moldavian Platform, the Scythian Platform, the North—Dobrogean Promontory and the Moesian Platform. The stratigraphic constitution, the structural arrangement of the sedimentary deposits, the geological evolution, the accumulation formation conditions and the description of the deposits within each mentioned structural unit will be dealt with in the following chapters.

III. EVOLUTION OF THE GEOLOGICAL RESEARCHES FOR HYDROCARBONS IN ROMANIA

The year 1857 is considered the beginning of the petroleum extractive industry in Romania, as it is the year when the first oil production — 1977 barrels — was registered in the official statistics. The gas production industry sprang up later on, in 1909, when the first gas field was discovered with the well 2 Sărmășel, in Transylvania.

As a matter of fact, petroleum exploitation existed before 1857, as mentioned in different historic documents. Thus, "Codex Bandinus" records that in 1646 there were a lot of pits at Mosoare and Păcura from which petroleum was extracted and used by the natives especially as a medicine. Later, in "Descriptio Moldaviae", Dimitrie Cantemir reported the presence of hot springs with mineral resin on the Tazlăul Sărat banks. In 1837, count Demidov wrote that it was only at Păcureți that 225 t of petroleum were extracted yearly at that time. In 1840 the first oil distillery was built at Lucăcești and four years later the second "oil pump" sprang up. If, apart from these precise reports, the interpretation of the content of other charters is also considered, we come to the conclusion that petroleum exploitations by pits have existed on the Romanian territory since the 16th, probably 15th century.

The discovery of the oil deposits was made by freeholder peasants, according to surface criteria, as petroleum springs, combustible gas leakages, boilers, mud volcanoes or "pîcle", tar sands.

The achievement of the distilleries which produced illuminating oil (lampant) and the lubricants, more and more required both in and abroad stimulated the Romanian oil industry beginning with the year 1855. The meeting of the ever growing needs led to the intensification of the activity of "prospecting" and sinking by the feeholder peasants. Thus, the deposits of Colibași, Băicoi, Matița, Apostolache, Sărata-Monteoru, Lucăcești, Zemeș-Tazlău, Solonț, Tescani, Cîmpeni, etc. were discovered and exploited (Preda, 1957).

Concomitantly, new petroleum refineries were built at Tîrgoviște, Ploiești, Monteoru, Buzău, Buhuși, Moinești. Mention should be made of the fact that the important discoveries made until then are the work of the poor peasants, the first "prospectors" of the oil deposits.

The existence of oil-field development in Romania drew the attention of the interested companies from abroad and, consequently, foreign specialists came to see them — Coquand (1867), Capellini, Fuchs and Sarasin (1873), Tietze, Paul and Olzewski; they handed over notes and papers briefly presenting the geology and the richness of the oil deposits of Romania.

Without neglecting the merits of the above-mentioned descriptive notes it is worth mentioning the fact that almost all the synthesis papers drawn up until now state that the scientific research period, the conception activity regarding the hydrocarbon origin and the formation conditions of the oil and gas fields in our country started as far back as Cobîlcescu's activity.

Cobîlcescu, an active field researcher, travelled all over the flysch zone and the Carpathian Foredeep, starting from Moldavia up to Transylvania, apart from the sector between the Dîmbovița and the Olt rivers. The results of his activity were presented on the occasion of the reception at the Romanian Academy (1887) and they can be synthetized as follows : petroleum comes from the hydrocarbons released from depth during the volcanic eruptions ; the eruptions which gave rise to petroleum in Moldavia took place in the Miocene and those in Muntenia and Oltenia, in the Upper Pliocene ; Petroleum is found in the Oligocene, Saliferous and Pliocene formations in Romania. The hydrocarbon-bearing formations are folded and constitute anticlines, cleft by deep fissures ; all the folds of the petroliferous zones are parallel to the Carpathian crests ; petroleum is hosted in the anticlinal axes where it is often accompanied by salt massifs. Excepting the mineral hypothesis of the hydrocarbon origin, today obsolete, Cobîlcescu's contribution to the foundation of the petroleum deposits geology was of a great importance especially due to the precision of his data on the distribution of the accumulations.

After a short period of pause (1887—1900) the investigations concerning the petroleum deposits in Romania were methodically resumed and extended about the date of the foundation of the Geological Institute due to Mrazec. For 40 years, until 1930 "...the geology of the Romanian petroleum identified itself with this scientist... not only as concerns the problems connected to the Romanian petroleum but also the geology of this mineral..." (Preda, 1957, p. 439). The complexity of the geological setting of the regions of interest for hydrocarbons made Mrazec collaborate with famous researchers, such as Murgoci for Oltenia, Teisseyre and Botez for Muntenia, Atanasiu for Moldavia and Vancea, Ciupagea for Transylvania (Ştefănescu et al., 1977). The activity of Mrazec and his collaborators developed in two directions: the field researches having in view the clearing up of the stratigraphy and tectonics of the zones and the synthesis papers including the conception on the problems connected with the petroleum geology, both as regards the origin and the emplacement of the deposits. The number of Mrazec's papers on the oil and accumulations in Romania is great enough. Among them it is worth mentioning the papers drawn up on the occasion of the Petroleum International Congress held in 1907 and the lectures on the petroleum deposits given in Sorbon (1921) and Prague (1931).

As regards the petroleum and gas origin, Mrazec was the first Romanian scientist who endorsed the organic theory. According to Mrazec the hydrocarbon formation is due to a process of bituminization of the organic matter which consists in its enrichment in carbon and hydrogen and oxyreduction. The rocks in which bituminization takes place are clayey, siliceous or calcareous and constitute the mother rock. Therefore, in Romania, it is Mrazec who established the generality of the bituminization phenomenon in nature.

Mrazec also studied the associated waters, that is the fluids which accompany petroleum in deposits. According to him there is no important and nondegraded hydrocarbon accumulation without mineralized waters. Consequently, there must exist a causality relation between hydrocarbons and mineralized waters. The formation waters are "connate" or "fossil" waters, trapped by the sinking of the "geosynclines" where the sediments deposited. Analysing these fluids, Mrazec came to the conclusion that they always had a mineralization higher than the marine or lagoonal waters. The bromine in the respective waters points to their marine origin and the iodine, which is missing in the aquatic medium, comes from the sea beings, it indicating the organic nature of petroleum.

Referring to the origin of the Romanian petroleum, Mrazec considers that it was formed during the period of regression that followed after the uplift of the Carpathian flysch and lasted from the Eocene till the Miocene. According to the above-mentioned author, the Paleogene flysch deposits located in the Eocene and Oligocene are primary, that is they are to be found in the same formation with the source rocks. The Lower Miocene accumulations have a similar situation because petroleum has been generated by the saliferous formation. The hydrocarbons hosted in more recent reservoirs, that is of Sarmatian and Pliocene age, result, by vertical migration, from the saliferous and Paleogene source rocks.

Mrazec's most important contribution as concerns the petroleum geology is the discovery, defining and explanation of the formation mechanism of the diapir folds. Together with Teisseyre, he proved that the salt massifs at Băicoi and Ţintea and the rocks which accompany them appear in the fractured, younger beds of the Pliocene. According to Mrazec, the diapir folds or the piercing core folds consist of uplifts up to the vertical of the salt beds. The formation of diapir folds is due to the folding movements and took place after the deposition of the last pierced formation, probably in the Lower post-Levantine.

By his activity, the results obtained and his conception, Mrazec holds the first place among the Romanian geologists who contributed to the development of the petroleum industry and founded a real school, able to continue his ideas and results of his work.

Murgoci was one of Mrazec's valuable collaborators. Although a supporter of the inorganic origin of petroleum, he had a great contribution in the drawing up of the synthesis papers referring to Oltenia. Almost half a century later in Oltenia the researches were resumed and intensified and led to favourable economic results and to the confirmation of Murgoci's ideas concerning the structure.

After Mrazec, the Romanian geology was dominated by Prof. Macovei, also a supporter of the organic origin of petroleum. As a matter of fact, beginning with Mrazec the debates on the hydrocarbon origin existed no longer because almost all the geologists who worked in Romania assimilated this hypothesis.

Concerning the petroleum origin in the Carpathians, Macovei came to the conclusion that the Oligocene dysodile schists constitute the main source-rock. The Cretaceous black shales also present characters of source-rocks ; however, the lack of reservoirs, of preservation beds as well as of favourable structural conditions did not make possible the formation of accumulations which could be worked out on the basis of these schists. Macovei also defined the characteristics of the petroleum source-rocks and classified them according to the lithofacies.

Unlike Mrazec, Macovei considered that the formation waters do not represent the fossil fluids of the former sedimentary basins but the formation water from the planktonic organisms which provided the primary organic matter necessary for the bituminization process. It was released by the organic matter decomposition.

Macovei, a good conoisseur of the Romanian deposits, contributed to the completion of the second edition of Engler and Hoefer's petroleum monography. At the International Congress on Petroleum held in Paris, Macovei presented a study on "The Present State of the Romanian Petroliferous Fields" (1937) ; a year later (1938) he published the book "The Petroleum Deposits" on the petroleum origin, the formation conditions of the deposits, the accumulation, distribution, etc.

I. Atanasiu was another well-known researcher in the domain of the hydrocarbon deposits. He pointed out, for the first time, the problem of the mother rocks, older than the Cretaceous ones, considering the Lias schists of the Banat as possible source-rocks and presuming the existence of bituminous schists in the Ordovician of the Moldavian Platform (Năslavcea schists). A t a n a s i u also insisted on the extension of the prospecting work for petroleum beyond the Carpathian Domain, eastwards, in the northern part of the Moldavian Platform where the existence of petroleum is probable. It is also worth mentioning the study of the geological structure of the regions of interest in Muntenia where the diapirism is considered important in the formation of the hydrocarbon accumulations. Referring to the Transylvanian Depression, A t a n a s i u considered that here the gases from the known deposits could have been filtered from petroleum deposits generated by the Oligocene bituminous schists (Ileanda Mare beds).

First time supporter of the deep origin and then accepting M r a z e c's idea that the bituminization phenomenon is general in sediments of any age, under certain conditions of salinity, P o p e s c u-V o i t e ş t i pointed out that all the Neogene petroliferous deposits in Romania, the Dacian inclusively, include source-rocks. Another hypothesis formulated by P o p e s c u-V o i t e ş t i, somehow in connection with the idea of the hydrocarbon deep origin, states that the Romanian petroleum is the result of the transformation, under the influence of pressure and temperature, of the organic matter included in the formations deposited in the geosynclinal areas. Although the above-mentioned hypothesis was criticized at that time (P r e d a, 1957), the latest researches carried out abroad (K l e m m e, 1972; C o n n a n, 1974, etc.) and in our country (P a r a s c h i v, 1977) have pointed out that temperature is an essential factor in the genesis, migration, accumulation and preservation of hydrocarbons. An important place in P o p e s c u-V o i t e ş t i's activity was held by the problems connected to the saliferous formations and, implicitly, those of the hydrocarbon deposits.

P r e d a was another famous petroleum geologist of our country. He was positively in favour of the petroleum autochthony in all the formations in which it occurred on condition that their deposition should have taken place in a saline medium. P r e d a was also supporter of the research for hydrocarbons of the territories belonging to the Romanian Carpathian Foreland.

Important contributions to the development of the science of the hydrocarbon genesis and formation of the deposits were also brought by G r o z e s c u, Ş t e f ă n e s c u, M u r g e a n u, F i l i p e s c u, O n c e s c u, B ă n c i l ă, G a v ă t, V a n c e a, G r i g o r a ş, C i u p a g e a, etc.

Among the foreign geologists, K r a u s (1923) mooted the question of the petroleum autochthony in the Dacian and the Meotian, a question supported by H l a u s c h e k (1950) later on. He ascertained that the Dacian deposits contain naphtenic petroleum whilst the Meotian, Sarmatian and Helvetian deposits have paraffin petroleum. It results that the respective petroleums come from different sources. H l a u s c h e k's statement corresponds to the results of the researches carried out in

USSR, USA, Austria, etc. where it has been ascertained that the naphtenic hydrocarbons prevail in recent formations with smaller depths, and as the depth increases, that is in older formations, the paraffin hydrocarbons predominate.

The petroleum origin, the deposit formation, questions on the tectonics of the flysch zone, on the palaeontology of the Pliocene deposits, etc. were also dealt with competence in the various papers of Krejci-Graf (1929, 1936) and Renz.

The before mentioned aspects constitute a synthesis of the evolution of the main ideas, belonging to the most famous representatives of the Romanian geology, concerning the hydrocarbon origin and the formation conditions of the deposits.

Referring to the stage of thinking at the level of the years 1948—1949, we could mention the following main ideas: the petroleum organic theory, supported by Mrazec, was imposed and accepted without reservation by all Romanian geologists; as regards the mother rocks, it is unanimously accepted that the Oligocene dysodile schists, the Cretaceous black shales and even the Aquitanian-Burdigalian bituminous schists are included in this category of rocks; the notion of source-rock could be extended to a larger number of formations, such as the Ordovician schists, the Lias bituminous schists, the Eocene clays, the Miocene, even Pliocene pelites; the anticlinal conception on traps dominated and became almost exclusive; the formation mode of the folded structures, especially of the diapir ones, as presented and explained by Mrazec, was imposed practically without reservation; the perspective surfaces for hydrocarbons were limited to the flysch zone, the Miocene and Mio-Pliocene zone of the foredeep, as well as to the Transylvanian Depression; there were suggestions to surpass the boundaries of the Carpathian Foredeep, geophysical prospectings and drillings being carried out in the foreland units with that end in view.

The nationalization of the petroleum industry in Romania constituted an important moment as concerns the evolution, orientation, organization and intensification of the geological activity for petroleum and gases.

The largest profit of the nationalization was the concentration of the whole industry in a single organization. It gave the possibility of a complete documentation and the formation of a general unitary view on the activity.

In the first years after the nationalization some studies and reports were drawn up in order to inventory the main geological formations of prospect and the directions of the future activity. Conditions for intensifying and diversifying the geological and geophysical works, both in the field and in laboratories, were created, while the proper equipment was provided. The main scientific results of this activity will be further synthetized.

As regards the petroleum origin, no specific studies have been made, the organic nature being taken into account.

Considering the widening of the field of activity in all the geological units of the Carpathian Orogen and the Carpathian Foredeep, the necessity of a permanent concern with the criteria of diagnosing the hydrocarbon source rocks was felt, with a view to identifying such formations. At the same time, the investigation of the geological conditions and evolution of the oil basins was achieved. Numerous studies made during about 20 years by Anton (1973), V. Cerchez (1967) showed that, using the geochemical, petrographic, biostratigraphic indices, the Moesian Platform Middle Triassic, Dogger, Albian, Tortonian-Sarmatian and Pliocene deposits, the East Carpathian Cretaceous black shale deposits, the Eocene clayey deposits, the Oligocene dysodile schists, the Miocene schists and clays, the Carpathian Foredeep Meotian, Pontian and Dacian pelites, the Pannonian Depression Miocene and Pliocene pelites etc. can be considered as possibly hydrocarbon source formations. The Carboniferous pelites, the Devonian limestones and dolomites, the Silurian and Ordovician graptolite schists etc. might be also source formations as they show petrographic, chemical-physical and biostratigraphic indications favouring such opinions, but they have not been analysed so far. It is noteworthy that geochemical, petrographic, biostratigraphic, ecological criteria have been taken into account by the recent studies in diagnosing the source rocks. The identification of a large number of hydrocarbon source formations confirms the hypotheses put forward by Mrazec and supported by Popescu-Voitești, Preda and others concerning the generalization of bituminization, implying the presence of the source rocks in all the deposits formed "since there have existed sedimentation and life on earth" (Preda, 1957, p. 440). These conclusions agree with the results obtained in other countries (Hedberg, 1967), constituting a strong argument in favour of the autochthonous nature of the deposits.

The investigations achieved abroad (Klemme, 1972; Tissot et al., 1975; Vasoievici et al., 1969 etc.) and in Romania (Negoiţă, 1970; Cristian et al., 1971; Paraschiv, 1977) underlined the particular part played by temperature in the hydrocarbon genesis, migration, accumulation and preservation. At present the temperature factor is considered as important as the source rock or the reservoir rock in the formation of the oil and gas fields. The new conclusions, determining certain orientations of the prospecting and exploration activity, made necessary geothermal studies throughout the Romanian territory (Paraschiv, Cristian, 1978) as well as the use of several criteria for establishing the thermic effect upon the organic substance during the evolution of the geological formations of interest. Thus, several biostratigraphic studies attempted to determine the degree of metamorphism of the vegetal organic substance (Balteş, 1975, 1976 etc.).

The most important efforts in the last 30 years aimed at investigating and identifying some new types of traps, taking into account the fact that the stratigraphic and structural problems diversified and became more complicated as the prospecting and exploration works extended beyond the Mio-Pliocene zone with diapir folds.

In connection with the diapir fold zone, it is noteworthy that the activity carried out in Romania after the publication of the works drawn up by Mrazec, Macovei, Popescu-Voitești, Fl. Olteanu (1951), Gr. Popescu (1951) etc. accumulated numerous data that, together with the older ones, had to be re-examined in the light of the knowledge on the diapirism (Trusheim, 1960; Halbouty, 1967). Gh. Olteanu's (1965) concerns and the symposium on this subject in 1973 (Paraschiv et al., 1973; Pătruț et al., 1973; Dicea, Popescu, 1973 etc.) constitute such an attempt. The re-examination of this problem confirmed, once more, the exactness of the conclusions reached by Mrazec 50—60 years ago. Other remarks may be also mentioned. In the first place, the diapir folds formed on either flanks of the foredeep, on the internal one, with Carpathian basement, and on the external one, with platform basement. Considering this distribution, one can infer that the primer of salt removal was not only constituted by the folding movements but also by the disjunctive tectonics. Nevertheless the folding movements played an important part in the evolution of these diapirs.

The salt dynamics was determined by and took place simultaneously with the thickening of the sedimentary cover and, therefore, with the pressure and temperature increase. Against a background of more or less continual movements, two moments of increased intensity can be distinguished: one, corresponding to the Attian phase, the other, corresponding to the Wallachian diastrophism. Where the deposit cover was too thick, compact and devoid of important tectonic accidents (especially in the zone with platform basement), the salt could not cross the more recent deposits, remaining sealed in various traps.

On the occasion of some geological mappings in the north-eastern part of the Transylvanian Depression, Pătruț (1958) noticed an important structural unconformity between the post-Helvetian and the pre-Tortonian deposits. The subsequent seismic prospections and wells proved that the post-Helvetian deposits have a specific tectonics which is of domal type or, on the east and west sides, of diapir type and was generated by the Tortonian salt movement. The halokinetical structure of the post-Helvetian deposits is quite different from that of the older deposits.

A few seismic profiles achieved in 1974 on the Prahova and Provița valleys as well as some previous data suggest, at least in the internal half of the Mio-Pliocene subzone with Carpathian basement, the existence of an important structural unconformity. In this area the diapir anticlines overlie, at least, partially, some Paleogene synclines and the other way round. This observation, that should be checked, reveals a situation which is similar to that in the Transylvanian Depression or in Germany (Trusheim, 1960), differing from the latter by the fact that, as a result of the Burdigalian age of the Subcarpathian lower salt formation, the unconformity must be placed at the Miocene/Pliocene boundary. Another difference would consist in the fact that in the Mio-Pliocene subzone the initiating of the salt movement was constituted by the folding movements, which implies the existence of a halotectonics, while the Transylvanian salt movement is especially due to the energy of the paleorelief covered by halites and to the geostatic pressure, which indicates that the phenomenon is of halokinetic nature.

Referring also to the folded structures one should mention the observation occasioned by the ultra deep investigations of the sedimentary deposits, either by geophysical means or by drillings, namely the vertical structure migration that was noticed in the Neogene zone outside the Carpathians and, especially, in the Transylvanian Depression. In the latter unit such migrations are found in the Tortonian, Buglovian and Sarmatian having taken place during several stages. The phenomenon was explained (Ciupagea et al., 1970) by the existence of some intraformational gaps or by differential compactings; but this unconformity might be also due to the salt movement (the cryptodiapirism) varying in intensity at different times during its evolution in several sectors of the structure.

Speaking about the Carpathians one should mention also the int nsification of the flysch zone exploration, the well data confirming the latter's nappe and scale structure. The most important nappe is represented by the median-marginal unit (Băncilă, 1958) whose breadth (the distance from its front to its root) may reach 35 km. The median-marginal unit covers and protects almost completely the external unit within which occurred the most favourable conditions for hydrocarbon genesis and accumulation. This parautochthon (the external unit), in its turn, consists of folds and scales, very complicated oil bearing structural elements.

Undertaking and intensifying the survey of the Carpathian Foreland units, the anticlinal conception on the structures of interest for hydrocarbons, which had been the only one up to that time, began to lose its authority. Gradually, the idea of faulted monoclines gained ground. But as the investigated depth increased, several superimposed tectonic stages were found, so that the same vertical drillings crossed faulted monoclines as well as structures of domal type. Some of the latter structures represent morphostructures or shrinkage pseudostructures. Such cases are quite frequent in the Moesian Platform and in the Pannonian Depression. The folded structures overlie the monoclinal ones in the sectors where the Carpathian Foredeep deposits (including the Getic Depression) overthrust the foreland units.

The improvement of the geophysical investigation methods and the great number of wells allowed the identification of some old, buried reliefs that controlled the hydrocarbon distribution. These reliefs offer the whole range of paleogeomorphic traps (Martin, 1966) found in the Moesian Platform, the North–Dobrogean Promontory, the Carpathian Foredeep (the Getic Depression inclusively), and in the Pannonian Depression. Apart from other cases, the metamorphosed basement altered surface with reservoir properties in the Pannonian Depression, the

Transylvanian Depression and, probably, the North-Dobrogean Promontory, as well as the altered zones associated with karst in the Moesian Platform Lower Cretaceous belong to this category. The facies variations existing in almost all the potential formations, influencing the rock reservoir properties and the hydrocarbon distribution have constituted difficult problems in the prospecting and exploration activities carried out in recent years. This is due to the fact that the lithological traps, to which the secondary dolomitization zones belong, and the reefal deposits can only be determined by very expensive wells at present.

The geological complexity of our country offers numerous examples of traps formed by the contribution of the structural, stratigraphic, paleogeomorphic, hydrogeological and other factors. Consequently, as the knowledge increases, the Romanian geology has to examine the "obscure and subtle" (Leversen, 1966) and mixed traps existing in all the explored formations and units.

One could infer from the above statements that the main concerns have concentrated on the trap determination and study in recent years, as the existence of the hydrocarbons was proved in all the Romanian sedimentary basins. But the trap study alone was not found to be sufficient for the discovery of new deposits, even in the proved petroliferous regions, while the distribution of the hydrocarbon accumulations does not always take into account the structural background such as it appears today. As a result, a new concept on the deposit formation arose. It implies the study of the accumulation conditions as well as an analysis of the possibilities of destruction by migration, of some secondary deposit formation during the following movements (Gavăt, 1964). Thus, it was necessary to draw up complex studies including chapters devoted to the basin paleogeography with a view to identifying the best accumulation zones in the most important moments of their evolution. Such works, dealing with formations or the whole sedimentary, have been periodically brought up to date as the knowledge increases.

The evolution of the geological conceptions on the origin and formation conditions of the hydrocarbon deposits, as presented above, would not have been possible without the technical progress recorded in the prospecting and exploration methods, which represent the necessary instruments for checking these conceptions. Therefore, a short review of the mentioned methods is imperative.

The prospection methods have been gradually used in Romania, as the necessary apparatus was available and according to the technical and technological improvements. When the number of such methods increased, they were used according to the knowledge and the specific character of each region, that is, according to the geological knowledge and acces conditions. After the World War II all the known methods were used in the Romanian geological activity in a rational order and, as a rule, they were mixed methods; nevertheless, some of them, such as the seismic prospection, prevailed.

The geological mapping was successfully applied in the Carpathian sedimentary formation zones, in the Transylvanian Depression, on the western part of the Pannonian Depression, in Maramureş, in the foredeep and wherever outcrop sedimentary formations previous to the Quaternary. Several maps, on different scales, including six plates on a scale of 1 : 500,000 appeared at the Geological Institute before 1944. The other six plates were edited after the foundation of the Geological Committee, when the systematic printing of the country's atlas began. The intensification of the research works after the nationalization called for a detailed mapping of the whole pre-Quaternary sedimentary, according to an unitarian geological conception. This enterprise started in 1951 and lasted for over 10 years, gradually covering all the zones containing Tertiary and Mesozoic deposits. The respective works took into account all the previous studies and allowed the drawing up of the maps on a scale of 1 : 20,000 and 1: 25,000 and, on this basis, the synthesis on a scale of 1: 100,000 and 1: 500,000. Most of the possibly petroliferous structures in the flysch zone, in the Maramureş Depression, in the Transylvanian Depression and, partially, in the foredeep were identified by mapping. At the same time, the geological maps were useful for determining the hydrocarbon possibilities and for scheduling the geophysical prospection and exploration works. The maps were checked, corrected and completed with new data according to the progress of the other methods and criteria, beginning with the paleontology and ending with the deep wells.

In the last 20 years geomorphological prospections for hydrocarbons have been carried out in Romania. They proved efficient enough, even in the zones covered by recent piedmont deposits (Paraschiv, 1965), contributing to the identification of some oil deposits in the Getic Depression.

The contribution of the surface observations diminished as the investigated depth increased and the works in the zones containing Quaternary deposits intensified. The tasks of the surface observations were replaced by the core drills.

Since 1905 the gravimetric works have covered the whole Romanian territory reaching a density of 1—4 stations/km^2 (Ştefănescu et al., 1977). Initially they were performed by Eötvös who used the torsional balance in the Pannonian Depression and Transylvania; then they were operated in the hilly zone of Muntenia and in Oltenia under I. Gavăt's control. The gravimetric measurement performed by the torsional balance proved satisfactory in the survey of the Pliocene formations and the diapir anticlines. After 1936 the torsional balance was replaced by static gravimeters of the Thyssen, Truman, Carter, Graf-Askania, Sterneck-Askania, Orden etc. types. Maps of the Bouguer and residual anomalies were drawn up on the basis of the gravimetric measurements; they contributed to the deciphering of the major geological structures, to the delimitation of the big structural units and to the identification of some important uplifts. They also served to the schedule of the following works, such as the seismic profile network and even the wild cat wells.

Using the detailed gravimetric measurements, some interesting results were obtained; they are connected with the direct determination of the water-gas boundary in several deposits located in the Transylvanian Depression (Tănăsescu, 1971).

The magnetometric prospections were performed throughout the country reaching also the density of 1—4 stations/km². Such works were introduced in Romania in 1872 (Ştefănescu et al., 1977). They were also applied to the hydrocarbon field in the Banat, Oltenia, Muntenia and Moldavia and were first performed by the vertical magnetic variometers in stations situated at distances of 0.5—2.5 km from one another (Ştefănescu, 1957). The vertical component variation map, drawn on the basis of the measurements performed, served, as did the gravimetry, to the deciphering of the major structures of the country and even to the identification of some tectonic alignments of interest for oil and gas.

The electrometry was performed, in a semidetailed network, on about 50% of the country's area of prospect. This method was introduced by the former petroleum companies and was performed by the Schlumberger firm for deciphering the structural conditions of the Pliocene deposits in Muntenia and Oltenia. Both before and after the war, when the electromagnetic prospections extended to the Moesian Platform, Transylvania and the Banat, the VES (vertical electrical soundings) device was used. The investigated depth reached 1,000 m, while the interpretation of the data benefited by the resistivity measurments performed on the cores (samples) or by the well log. The best results were obtained in the Mio-Pliocene zone, where the Pontian deposits, showing low resistivities, allowed the mapping of some structural elements as minimum zones. The electrometry was also efficient in the Transylvanian Depression. The salt formation existing here constituted a strongly resistive key horizon which could be easily examined by the crossed transmitter and telluric current method. As the electrometric anomalies generally corresponded to the irregular salt accumulations, they were surveyed afterwards by the seismic method, thus identifying or revaluating important domal structures.

The seismometry was the main and most efficient geophysical method used in Romania; it covered 90% of the country's area of prospect for hydrocarbons reaching a density of 0.1—1.8 km profile/km².

The seismic prospection was applied by the former petroleum companies, first, as refraction seismics, in the zone of the salt domes. Later on it extended and was almost completely replaced by the reflexion seismics (1935). Before 1944 the discrete seismic recording was almost exclusively used in a few sectors in Muntenia, Oltenia, Moldavia. After the nationalization, the seismic activity greatly developed both quantitatively and technologically. The reflexion seismics with continuous profiling prevailed. When required by the geological and morphological coditions, the continuous profiling works were mixed, completed or replaced by the simple discrete recording or by the three dimensional discreet recording. Sometimes the reflexion seismic profiles were accompanied by refraction works that determined the thickness of the sedimentary deposits or the main lithological contrasts, generally, corresponding to the limits of some lithofacial cycles.

Between 1948–1960 the research was achieved by the oscillographic seismic stations, while the field technology consisted of single stations or single sounders. In the following 10 years (1961–1970) the works were achieved especially by analogical seismic stations and a more advanced technology was used, namely multiple source stations and multiple receivers. Finally the digital recording and processing of data have been used since 1970. At the same time the field technology improved by the use of the C.D.P. faulting. The technical and technological improvement led to the resuming of the prospections in certain zones and to the repetition of numerous profiles which provided additional and better information.

Although the country's area of prospect was covered by seismic prospections in proportion of 90%, the geological problems in the surveyed zones have not been completely elucidated. This is the case of the structure of the Lower Miocene and Paleogene formations in the Getic Depression, of the Lower Miocene and Paleogene deposits in the Mio-Pliocene subzone, of the pre-Neogene in the Transylvanian Depression and the Scythian Platform, of the Moesian Platform Triassic and Paleozoic. The mentioned formations lie at a great depth in the zones showing a complicated tectonics and a difficult access.

The Romanian territory was also partially covered by radiometric and geochemical works that did not furnish satisfactory results for the end in view (the petroleum research).

The range of prospecting methods included also the core drill that proved useful enough in the Comănești Basin, in the Carpathian Foredeep, in the Transylvanian Depression, the Pannonian Depression, the Moesian Platform, the Scythian Platform and the Moldavian Platform. The core drills contributed to the solving of some stratigraphic and structural problems and even to the discovery of some oil and gas fields.

Referring again to the geophysical field, namely to the logging investigation, it is worth mentioning the fact that the electric log was introduced in 1930 and was used in the well investigation (Ștefănescu, 1975). This device represents a particular form of electric prospection which was adapted to the bore hole conditions in order to allow the identification of the strata crossed by drillings, on the basis of electrical parameters. The rapidity, accuracy and low cost of the electric log determined its spreading and generalization in all the fields. After 1950, as the apparatus and technology improved, new electrical methods were used, beginning with BKZ, the DRR Romanian variant, inclusively, and ending with the inductive log. At the same time radioactive and geochemical methods for investigating the bore holes were introduced and generalized. Since the geophysical and geochemical methods replaced the core samples to a great extent, it was necessary to organize the processing and the qualitative and quantitative interpretation of the geophysical information. Efforts are being made today for solving such problems by computers.

New concerns connected with the subsurface geology (Ştefănescu et al., 1977), materialized by some stratigraphic key correlations, structural interpretations and geological sections, occurred about 1924. As the electric logging and, sometimes, the core samples are not available, conventional and lithological keys are used in drawing up such interpretations, according to the indications of the drillers. The first maps with isobaths and sections accompanying a study on the Buştenari oilfield (Filipescu, 1925) were reported between 1921–1925. Such proceedings are still used especially by the State control inspectorates for the main deposits at Gura Ocniţei, Moreni, Băicoi etc. (Ştefănescu et al., 1977). The structural schemes and the geological sections for the realization of which geophysical keys had been also included, generalized and became an usual obligation, being utilized for the projection of new wells and in the exploration activity.

The examination of the physical-geological conditions of the Romanian deposits constitutes another side of activity to which the Romanian specialists devoted. Thus, in 1912, I. Tănăsescu performed temperature measurements in wells in order to study the geothermal conditions in connection with the formation seating and the oil presence in the deposits. Not long afterwards (1924) Gavăt began the study on the physical deposit conditions with a view to estimating the reservoirs. Later on some instruments for investigating the producing wells were reported (Gavăt, 1928). Such concerns greatly developed to the periodical organized survey of the wells, namely the measurements of pressure, temperature, the oil and gas analyses both under surface and bottom conditions, the water analyses. The processing and interpretation of the respective data with a view to guiding the rational exploration of the deposits and increasing the petroleum recovery final factor constituted a main object after the World War II.

Coming back to the immense and varied geological and geophysical prospection activity, it is worth mentioning the fact that it was not an end in itself but aimed at preparing certain areas and units for a more difficult and more expensive exploration, namely for drilling.

The pits made by the autochthonous peasants constituted the beginning of the Romanian drilling activity. The latter developed further according to the progress recorded in the field of installation building and technology as well as according to the economical results obtained and the interests of the extraction organisms. At the same time the technological improvements enabled a much more rapid well drilling, the reaching of ever greater depths and, as a rule, the decrease of the price of these works.

In 1862, after a long period during which the pits had been used in Romania, the well drilling was introduced; the first works of this kind were achieved at Mosoare (Constantinescu, Prodrom, 1957). Up to 1928, when the rotatory drilling was introduced, the wells had been drilled according to various devices, the most frequent of which was the Canadian system, then the Pennsylvanian system and, later, the hydraulic system. The revolutionizing of the drilling activity took place about 1930 when the electric log was introduced. But an intensification of this activity was recorded after the nationalization of petroleum industry. The following table shows the considerable increase of the investigated areas.

TABLE 1

Year	Total Drilling (thousand m)	Exploitation		Investigation	
		(thousand m)	%	(thousand m)	%
1918	85	80	94	5	6
1936	395	371	94	24	6
1941	253	227	88	26	12
1950	657	367	56	290	44
1955	870	365	42	505	58
1968	1,654	497	31	1,157	69
1977	1,833	1,016	55	817	45

The development of this activity could be achieved, first, by resuming and intensifying the works in the already known petroleum areas, after which the exploration extended rapidly enough throughout the Carpathian Foredeep and the Moldavian flysch zone as well as throughout the Transylvanian Depression. It was also in the years immediately following the nationalization that the research by deep wells started on other major structural units, too, first of all in the Getic Depression, then in the Moesian Platform, the Transcarpathian zone (Maramureş), the Moldavian Platform, the North-Dobrogean Promontory and the Predobrogean Depression, the Danube Delta and the Pannonian Depression, inclusively.

The intensification of the petroleum activity was more evident and earlier than the gas activity which has intensified since 1959 (Fig. 1). The growth of the drilling volume for gas was determined by both the execution of a large number of wells in the Transylvanian Depression and, especially, by the research development outside the Carpathians, namely in the Moldavian Platform, the Moesian Platform, the Getic Depression and, to a certain extent, in the Mio-Pliocene subzone.

The development of the research drilling has been characterized by the execution of about 20,000 stratigraphic and exploration wells totalizing about 24,000,000 m in the last 35 years. These wells and those carried out before 1944 allowed a good knowledge of all the areas of prospect for hydrocarbons reaching the depth of 3,200—3,500 m. The investigation of the sedimentary deposits below 3,500—4,000 m was, therefore, imperative. In the last 10 years special programmes have been drawn up with a view to examining systematically the respective formations. More than 100 stratigraphic and exploration wells exceeding the depth of 4,000 m finished the drilling by the end of 1978. The maximum depth in Romania is of 6,503 m and was reached at the Ciuboţi well, but the future programme stipulates the drilling of some wells reaching 8,000 and 10,000 m.

The complex of geological, geophysical and drilling works carried out in the course of 122 years provided extremely rich information allowing the achievement of exceptional progress in the knowledge on the stratigraphy, the setting of the beds and the geological evolution of the Romanian territory, as will be noticed in the next chapters. At the same time hydrocarbon deposits were found on all the major structural units containing sedimentary deposits. Thus, after the discovery of petroleum in the flysch zone and in the Miocene and Mio-Pliocene subzones, the first Transylvanian

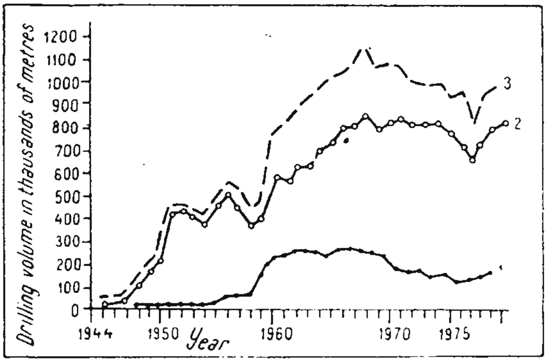

Fig. 1. — Evolution of the research drilling within the period 1944—1978. On the ordinate, the drilling volume in thousands m; 1, research metric length for gases; 2, research metric length for oil; 3, research metric length total (oil + gases).

gas deposit was found by well no. 2 Sărmăşel in 1909. Much later, in 1950, the first producing well in the Getic Depression yielded oil at Şuţa Seacă. Petroleum was found in Maramureş (the Transcarpathian flysch zone) about the same time. Six years later (1956) the first oil deposit in the Moesian Platform was identified in the Ciureşti area. The first petroleum accumulation in the North—Dobrogean Promontory was found at Independenţa in 1958. Between 1961—1963 the first industrial gas productions in the Moldavian Platform were reported at Roman-Secueni and in the Bîrlad Depression (the Scythian Platform), at Adjud. The Teremia deposit in the Pannonian Depression was discovered in 1963.

Since the beginning of the Romanian petroleum industry approximately 350 petroleum and gas productive structures have been identified. Most of them comprise several hydrodynamic units consisting of tectonic blocks, independent productive lenses or horizons. Before 1941 only 30 petroleum and gas structures had been discovered; 16 of them lay in the Prahova District, 3 in the Dîmboviţa District, 3 in the Bacău District and 8 in the Transylvanian Depression.

The Pliocene formations and their terms (Levantine, Dacian, Pontian, Meotian), the Sarmatian, the Helvetian and the Oligocene formations proved productive before the World War II. After 1944 the list of productive hydrocarbon formations was completed with the Tortonian in Transylvania, the Moesian Platform, the Predobrogean Depression, the Moldavian Platform, and, possibly, the Neogene zone and the Pannonian Depression; the Burdigalian in the Neogene zone; the Eocene in the East

Carpathians and, possibly, the Getic Depression; the Upper Cretaceous, Albian, Neocomian, Dogger, Triassic and Devonian in the Moesian Platform (possibly, the Cretaceous in the Pannonian Depression, too); the altered upper part of the metamorphosed basement in the Pannonian Depression and Transylvania. All the formations and major structural units contain both petroleum and gas with the exception of the Transylvanian Depression which is exclusively gas-bearing.

The investigations carried out on larger areas and at greater depths led to the discovery of some deposits at ever greater depths. The maximum depth was reached in the Bibeşti Devonian (NW Craiova) containing oil that proved productive at the depth of 4,890 m.

The deposits discovered and their revaluation allowed the extraction development, from about 280 t oil in 1857 to about 15.0 million t oil in 1977 and from 0.5 billions m^3 gas in 1944 to over 27 billions m^3 gas in 1977. Two stages can be distinguished in the evolution of the oil production. One stage began in 1857 when the production was 280 t/year and reached a climax in 1936 when about 8.8 million t were extracted; the other stage corresponds to the period after the World War II. The levels of production attained in the latter stage constitute the concrete, numerical expression of the geological and geophysical research contribution to the development of the Romanian petroleum industry.

IV. EAST CARPATHIAN FLYSCH AND THE CARPATHIAN FOREDEEP

As has been mentioned, within the East Carpathians, one can distinguish three main zones showing features that are characteristic of the structural units, namely: the Crystalline-Mesozoic zone or the Central Carpathian zone, bounded by the Transcarpathian flysch zone to the west and by the Carpathian flysch to the east. The Carpathian flysch is bounded by the molasse zone or the Carpathian Foredeep towards the exterior. Except the Crystalline-Mesozoic zone the other three mentioned units (zones) contain hydrocarbon deposits and are still of interest for oil and gas.

A) TRANSCARPATHIAN FLYSCH ZONE

The Transcarpathian flysch structural unit is delimited by the Central Carpathian zone on the east and extends westwards under the Oaş-Gutîi-Călimani eruptive chain. This unit prolongs longitudinally north-westwards on the territory of the Soviet Union.

The Transcarpathian flysch zone and, especially the Maramureş sector belonging to it, was investigated as a result of the seeps in the vicinity of the Săcel locality that have concerned the Romanian and foreign researchers since the beginning of the last century.

The geological mappings covered the whole area of the structural unit dealt with, which allowed the drawing up of detailed maps, on a scale of 1 : 25,000, for almost the whole region.

The gravimetric prospections that started in 1950 reached a density of 1 point/4 km² and, on about 20% of the area, the frequency of the measurements was 3 points/km². The region was also covered by aeromagnetic prospections.

The first core drills were achieved in 1881, the respective activity having been resumed in successive stages. Beside the oil pits and the core drills, about 35 wells have been drilled so far, reaching the depth of 2,400 m.

The works carried out indicated that the Transcarpathian zone consists of Upper Jurassic, Lower Cretaceous, Upper Cretaceous, Paleogene and Neogene deposits, accumulated during two sedimentation cycles: the Upper Jurassic-Neocomian and the Upper Cretaceous-Neogene.

The Neocomian-Tithonian (possibly, partly Kimmeridgian) deposits are known in the vicinity of the Poiana Botizei locality and are represented, from bottom to top, by: sandstones, microdetrital or oölitic limestones, sometimes associated with radiolarites, marno-limestones with siliceous accidents, brown-cherry coloured, limy schists and *Aptichus* marno-limestones (M u t i h a c, I o n e s i, 1975). These deposits appear as very small tectonic klippes and were regarded as the last south-eastern Pennine klippe showings.

The second sedimentation cycle began in the Cenomanian and continued up to the Lower Miocene. Within the Upper Cretaceous a sequence of conglomerates and sandstones (the gritty conglomerate formation) was separated in the base; it belongs to the Cenomanian and is overlain by a gritty-clayey Turonian horizon which is, in its turn, overlain by Senonian marno-limestones. The mentioned deposits would represent the Upper Cretaceous littoral-neritic facies. The latter consists of Cenomanian-Turonian grey marls, overlain by Turonian-Senonian red-brick marls and marno-limestones (the Puchow facies).

The Paleogene corresponds to a more unstable stage in the evolution of the Transcarpathian zone, being partly represented by deposits showing flysch characteristics.

The Danian-Paleocene represents a sedimentary formations consisting of transitional elements between the red marl facies and the Flysch deposits (M u t i h a c, I o n e s i, 1975), namely an alternation of red-cherry coloured clays and thin limy sandstone strata.

Three facies zones (D i c e a et al., 1979) were distinguished within the Eocene: the epicontinental facies represented by detrital deposits making up Turbuţa beds followed by marls and marno-limestones; the littoral-neritic facies, with Lower Eocene sandstones and conglomerates (the Prislop conglomerates), limestones and marls (the Vaser marls), the latter belonging to the Upper Priabonian; the flysch facies, which is predominantly marly-gritty, in the inner part of the region, and, gritty-conglomerate towards the eastern margin. Within the flysch facies one can distinguish an internal zone marked by a Lower Eocene predominantly clayey sequence in the base, followed by a (Middle Eocene) marly-clayey-gritty one and by an upper gritty one, and an external zone corresponding to the eastern sector, where the Eocene consists of conglomerates followed by a (Middle Eocene) gritty-clayey sequence and of Upper Eocene-Lower Oligocene sandstones (the Voroniciu sandstone).

The sedimentary deposits of Oligocene-Lower Miocene age were grouped into several lithofacial units. In the base was separated the Valea Carelor bed formation comprising Wildflysch deposits. The latter are of Lower Oligocene-Middle Oligocene age. The Oligocene schistose clayey-marly formation follows; it consists of marls and schistose black clays, sometines, looking like typical "dysodiles", similar to those in the external flysch or in the Ileanda beds. This formation, which shows three subfacies, individualized by their lithological nature, belongs to the Middle Oligocene. The Borşa sandstone formation consists of limy, micaferrous, friable sandstones with fine, medium and coarse granulation and of marl, clay, clayey schist and even "dysodiles" schist intercalations completing the profile. The Borşa sandstone formation is of Oligocene age, the deposition of this term continuing, as it seems, also in the Lower Miocene. The Oligocene formations change southwards (north-west of the Transylvanian Depression) into platform facies.

The Oligocene flysch deposits are overlain by a strong molasse formation belonging to the Lower Miocene (the Salva beds). The Tortonian with dacite tuffs and salt overlies transgressively the structures generated towards the end of the Lower Miocene. Terrigenous formations (sands, sandstones, marls) as well as pyroclasts representing the Sarmatian and the Pliocene, end the sedimentary succession which can reach 5,000—6,000 m in thickness[2].

Eruptive formations represented by subvolcanic bodies of pyroxene andesites outcrop in the Transcarpathian flysch zone. They pierce the crystalline, the Cretaceous and the Paleogene deposits and erupted in the Neogene, being similar to the Ţibleş and Călimani subvolcanic formations.

Both plicative and disjunctive tectonic elements can be distinguished in the structural arrangement of the sedimentary deposits in the Transcarpathian zone; they formed during the Meso-Cretaceous(?), Savian and, especially, Styrian movements.

According to some recent syntheses (Dicea et al., 1979), in the Maramureş sector of the Transcarpathian zone can be distinguished three structural units among which there exist overthrust relations, namely: the Maramureş autochthon, the Lăpuş Nappe (or the Wildflysch nappe) and the Botiza Nappe (Dumitrescu, 1957). In the southern part of Maramureş, the Lăpuş unit constitutes the parautochthon of the Botiza Nappe. Within the mentioned units there are structural elements of second order, overthrust folds inclusively. According to Mutihac (Mutihac, Ionesi, 1975) the Klippe and Transcarpathian flysch zone represent, on the whole, a single nappe zone overthrusting the post-tectonic cover of the Crystalline-Mesozoic unit. The Lăpuş and Botiza units, together with the Şetrev unit (at the lower part of the nappe) constitute scales of the Transcarpathian Nappe.

[2] I. Donos. Thesis of doctor's degree (1978) (manuscript). University Bucureşti.

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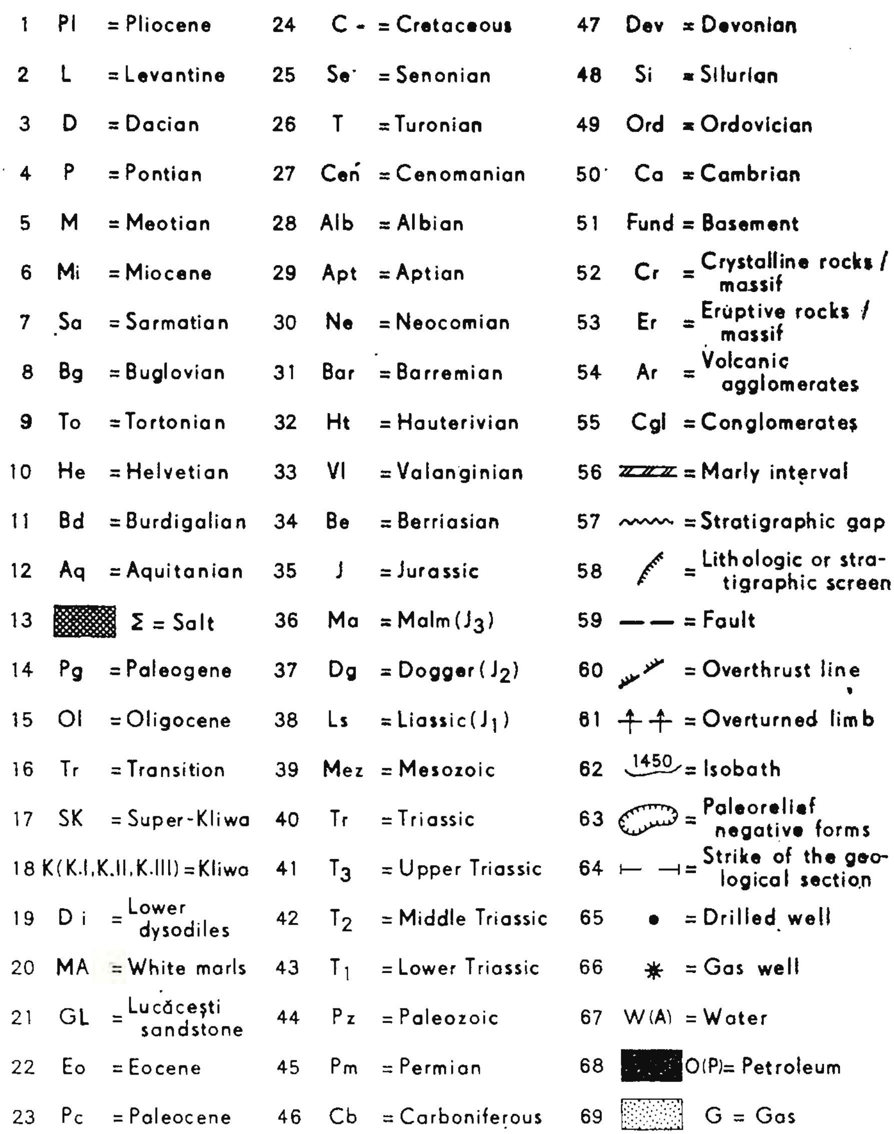

Fig. 2. — Legend of figures and plates.

1, Pliocene; 2, Levantine;3, Dacian; 4, Pontian; 5, Meotian; 6, Miocene; 7, Sarmatiane; 8, Buglovian; 9, Tortonian; 10, Helvetian; 11, Burdigalian; 12, Aquitanian; 13, salt; 14, Paleogene; 15, Oligocene; 16, transition; 17, Super-Kliwa; 18, Kliwa; 19, lower dysodiles; 20, white marls; 21, Lucăcești sandstone; 22, Eocene; 23, Paleocene; 24, Cretaceous; 25, Senonian; 26, Turonian; 27 Cenomanian; 28, Albian; 29, Aptian; 30, Neocomian; 31, Barremian; 32, Hauterivian; 33, Valanginian; 34, Beriasian; 35, Jurassic; 36, Malm; 37, Dogger; 38, Liassic; 39, Mesozoic; 40, Triassic; 41, Upper Triassic; 42, Middle Triassic; 43, Lower Triassic; 44, Paleozoic; 45, Permian; 46, Carboniferous; 47, Devonian; 48, Silurian; 49, Ordovician; 50, Cambrian; 51, basement; 52, crystalline; 53, eruptive; 54, volcanic agglomerates; 55, conglomerates; 56, marly interval; 57, stratigraphic gap; 58, lithologic screen; 59, fault; 60, overthrust line; 61, overturned limb; 62, isobath; 63, negative forms of paleorelief; 64, direction of the geological section; 65, drilled well; 66, gas well; 67, water; 68, oil; 69, gases.

Among the disjunctive tectonic elements, the most important seems to be the Dragoş Vodă fault. The characteristic features south of this tectonic accident are determined by a fault network trending approximately N—S and showing an overthrust tendency west-eastwards. The anticline and syncline folds are locally developed. The importance of the plicative elements increases north of the Dragoş Vodă fault. The Săcel anticline, which was proved oil bearing, is among the anticlines occurring in the respective sector (Fig. 3).

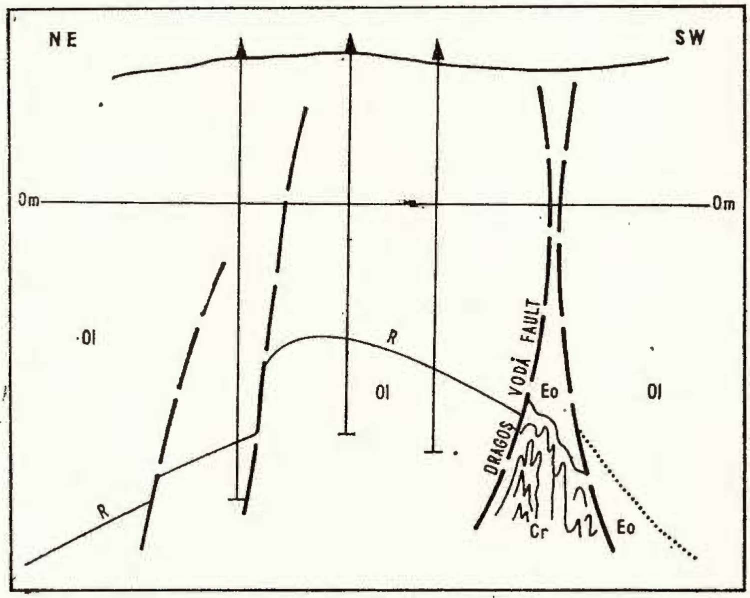

Fig. 3. — Geological section through the Săcel structure (Maramureş): R, guide mark in the Oligocene.

The stratigraphic and structural frame of the Transcarpathian zone offered favourable conditions for the hydrocarbon genesis, accumulation and preservation. Thus, the reservoir rocks might also include the Upper Cretaceous and Eocene sandstones and conglomerates and, especially, the Oligocene psamites and psephites in the Valea Carelor bed formation, seemingly productive at Săcel, and the Borşa sandstone formation. The determinations carried out on the surface [3] showed that the porosity of the Valea Carelor sandstones is 0.78—5.60%, and the permeability 10 mD. Considering that these arenyte bodies produce oil at Săcel, the acknowledgement of supplementary fissural porosity and permeability must be added.

The protective rocks are found in the same lithofacial units that contain reservoir rocks.

[3] *Quoted papers*, point 2.

Some lithological screens might be only locally present, which is due to the lithofacial variations in the zone.

The presence of the source rocks, especially at the Paleogene level, is indicated by several geochemical indexes. Thus, the Vaser bituminous marls, the pelite sequences in the Valea Carelor bed formation and the Oligocene schistose formation are marked by a high content, sometimes over 6% organic carbon. The microelement content of many Paleogene pelite horizons (Mn, V, Co, Cu, Zn, Pb etc.) is also high. The hydrocarbons in rock reach almost 5,000 ppm. A few marl and bituminous clay levels provided to 1.8% oil schist. The mentioned indexes constitute arguments for assigning some Paleogene rock sequences to the hydrocarbon source formations.

The specific tectonic style, the lithofacial variations and the geological evolution of the region were propitious to the formation of a variety of traps : structural, stratigraphic, lithological and, possibly, paleogeomorphic.

Within the Maramureş sector of the Transcarpathian zone, the Săcel anticline has been explored since 1880 (Fig. 3). According to the mapping data, the mentioned anticline trends E—W, is about 9 km long and is crossed diagonally by the Sălişte-Săcel fault. The dips of the beds are of 20—60°. The anticline is asymmetrical and divided into several tectonic blocks at the Oligocene level.

An oil deposit with primary gas-cap, probably located in the Lower Oligocene sandstones of the Valea Carelor formation, is known within the Săcel structure. The respective sandstones were grouped into two complexes (I + II), with apparent thicknesses of 120 m and 70m, respectively. The average effective thickness of the reservoir is about 25 m. The initial production of the wells varied between 1 and 10 t/day oil. Owing to the very small permeability, the daily production decreased in a short time interval. Gas and oil traces (to 1 t/day) from the Oligocene sandstones were obtained on the Sălişte structure as well as poor oil productions in the Ieud Paleogene anticline, also in the mentioned region which is adjacent to the Dragoş Vodă fault.

The traps in the Săcel-Sălişte-Ieud sector are of structural lithological type, while the deposits are stratiform.

B) EAST CARPATHIAN FLYSCH AND THE CARPATHIAN FOREDEEP

These two zones make up what has been defined as the Precarpathian Depression, a term used by its author (Grigoraş, 1961) to designate the Alpine Orogen segment developing on the Romanian territory, between the Carpathian Crystalline-Mesozoic core and the front platforms. The studies drawn up later (Dumitrescu et al., 1962; Dumitrescu, Săndulescu, 1968 etc.) underlined the fact that the respective area corresponds to two district zones behaving like structural units, representing two stages in the evolution of the Carpathian geosyncline. The stratigraphic, structural and paleogeographic characteristics determined also different hydrocarbon genesis, accumulation and preservation conditions, which justifies their definition as distinct units, also taking into account the hydrocarbon interest.

The internal limit of the East Carpathian flysch zone is represented by an overthrust line (the central line), along which the Cretaceous flysch formations sink tectonically and are overthrust by the western Crystalline-Mesozoic ones. This tectonic contact is visible especially on the eastern side of the Maramureş Massif in the northern sector. South of the latter, the tectonic contact is almost completely hidden either by the Pliocene-Quaternary volcanic formations or by post-tectonic deposits belonging to the Upper Cretaceous.

The external limit of the flysch zone, that is the contact with the molasse zone (the Carpathian Foredeep) also corresponds to a tectonic line, partly identified with the border of the medio-marginal nappe (the Tarcău Nappe). In front of the Putna-Straja, Bistriţa, Oituz and Vrancea semiwindows, the external limit is represented by the border of the external unit (the marginal unit). Further south and south-west, the external side is covered transgressively by the foredeep Sarmatian-Pliocene molasse. These deposits gradually overlie the innermost terms of the flysch zone westwards, so that the Miocene molasse overlies directly the metamorphic formations of the Getic Nappe, west of the Dîmboviţa Valley.

Unlike the East Carpathian flysch developing between the northern boundary of the country and the Dîmboviţa River, the Carpathian Foredeep prolongs also west of the mentioned river, reaching the Danube. Its external limit was conventionally established on the Pericarpathian line including the Bibeşti-Tinosu fault which is the latter's western correspondent. Along the respective fault the folded lower molasse deposits overthrust the quasihorizontal upper molasse deposits. Therefore the Pericarpathian fault marks, towards the exterior, the lower molasse distribution area. As far as the upper (Sarmatian-Pliocene, occasionally also Upper Tortonian) molasse is concerned, it extends much outside; it is not folded and overlies the Mesozoic and older deposits of the platform.

The study of the geological constitution and evolution of the Carpathian flysch and the Carpathian Foredeep aiming at a knowledge of the useful mineral substance potential has been a particular concern since the end of the last century. This concern was materialized in a large number of geological-geophysical works and studies. Initially, the geological mappings and the core drills were used, being later, as the technique improved, associated with the gravimetric, magnetometric, electrometric, seismic, geochemical prospections and wells to the depth of 6,000 m. These structural-facial units were investigated as follows:

The whole area showing natural outcroppings was covered by geological mappings. Detailed and ultradetailed mappings have been achieved both in the flysch zone and in the foredeep since 1950. Their results were materialized by geological maps on a scale of 1 : 20,000, 1 : 25,000 and 1 : 100,000. The average frequency of the observations was about 25—35 points/km². The geological mapping provided important information on the stratigraphic succession, the lithofacial variations, the geological evolution in the flysch zone and in the molasse zone and on the identification of some structures that proved partly productive later on.

Gravimetric surveys were carried out throughout the region. The density was 1—2 points/km^2 in the East Carpathian sector and 1 point/5 km^2 in the foredeep. A density of 3 points/km^2 was recorded on an area of 15% of the foredeep.

The magnetometric prospections covered the whole mentioned area reaching a higher density east of the Dîmboviţa River (1—2 points/km^2) and somewhat lower (1 point/10 km^2) in the Getic Depression.

The gravimetry and the magnetometry were used as methods preceding the seismic, electrometric prospections and the core drills, the results of the respective methods representing a qualitative frame. Some attempts at using the gravimetry as a direct method, in the Mio-Pliocene zone, provided some unconvincing data.

Electric prospections were achieved on about 50% of the region, the electrical vertical sounding being the most used method. The latter method had a frequency of 1 sounding/7 km^2, while its average investigation depth was about 1,000 m west of the Dîmboviţa River. The electric prospections aimed at deciphering the geological conditions in the Subcarpathian fold zone. The results of this activity were checked by seismic surveys and wells.

The seismic prospections covered almost the whole Getic Depression and about 60% of the territory situated east of the Dîmboviţa River. The flysch zone and the Miocene zone in Moldavia benefited less by these works owing to the difficult seismic-geological conditions and the particularly complicated tectonic style which led to less convincing results. Among the devices used in the latter sectors, the three dimensional discrete recording proved more adequate to the specific seismic-geological conditions, being used for about 65% of all the seismic surveys. In the Mio-Pliocene zone in Muntenia and the Getic Depression the continuous profiling method prevailed, while the controlled directional reception method was only little used. The seismic prospections constituted the main method for identifying most of the structures in the molasse zone in Oltenia and Muntenia.

Geochemical prospections were achieved only experimentally on some restricted areas, but the results obtained were not convincing.

Over 6,000 exploration wells have been drilled so far, of which 3,500 in the flysch zone and in the East Carpathian Foredeep. Some of these wells reached the depth of 6,000 m.

The exploration works carried out during the 120 years of activity provided a better knowledge, especially at the depth of 0—3,500 m, on both the geological-structural conditions and the oil and gas potential. The knowledge on the geological formations lying below the depth of 3,500 m as well as on a part of the flysch zone is reduced.

1. Stratigraphic and Lithologic Peculiarities of the Mesozoic and Neozoic Sedimentary

As has already been shown, the East Carpathian core is represented by the Crystalline-Mesozoic or Central Carpathian zone consisting of metamorphic rocks and of Triassic and Jurassic sedimentary formations overlying directly the central crystalline. These deposits are integrated into the basement (Băncilă, 1958). The Mesozoic and Tertiary formations outside the central core are characterized, in general, by a succession containing younger elements outwards, so that Cretaceous rocks prevail in the vicinity of the Crystalline-Mesozoic zone, Paleogene deposits prevail further outwards, while the Neogene formations prevail in the farthest zones. Accordingly, three main zones resulted, namely the Cretaceous flysch zone, the Paleogene flysch zone and the molasse zone. They include, in their turn, structural units of second and third orders.

The particular geological complexity of the East Carpathians, the large number of researchers studying this mountainous region, the different criteria adopted and the long research period (over 100 years) determined various conceptions in the zoning of the flysch deposits and an extremely complicated and varied terminology.

The geological syntheses drawn up in the last 20—25 years resemble one another from the point of view of the geological zoning but differ in point of terminology. Thus, Băncilă (1958) distinguishes within the East Carpathian flysch five units, namely (inwards-outwards): the west internal unit, the east internal unit, the middle-internal unit, the middle-marginal unit and the external unit.

The geological map of Romania (Dumitrescu et al., 1962) shows also five units, generally corresponding to those determined by Băncilă, but named (in the same order) as follows: the Ceahlău unit, the curbicortical flysch unit, the black shale unit, the Tarcău unit, the marginal unit.

In a more recent synthesis, Ionesi (Mutihac, Ionesi, 1975) distinguishes also five units, called: the Ceahlău unit, the Teleajen unit, the Audia unit, the Tarcău unit and the Vrancea unit.

The synthesis concerning the Carpathian-Balkan regions (Dumitrescu, Săndulescu, 1974) mentions eight units in the same area, namely: the Baraolt Nappe, the Ceahlău Nappe, the Bobu Nappe, the Curbicortical Flysch Nappe, the Macla-Zagon Nappe, the Audia Nappe, the Tarcău Nappe and the marginal fold unit. In other words, three new units are discussed in this paper, namely the Baraolt Nappe, the Bobu Nappe and the Macla-Zagon Nappe.

The geologists in the oil industry adopted the zonality and terminology proposed by Băncilă (1958). The same point of view is also reflected in the present paper.

The above sketched formation zonality is followed, with a few exceptions, from the northern boundary of the country to the Dîmbovița Valley.

In the evolution of the Carpathians the depositions of some flysch formations took place towards the end of the Jurassic and lasted up to the Lower Miocene. There were stages, during this time interval, when deposits that do not show the stratonomic and genetic characteristics of the flysch formations accumulated (Mutihac, Ionesi, 1975).

a) The Cretaceous flysch zone develops between the Suceava Valley and the Dîmboviţa Valley, including deposits whose age varies between the Tithonian (Dumitrescu, Săndulescu, 1974) and the Senonian. This stratigraphic sequence seems to be interrupted in the internal part by some gaps at the Upper Albian and Turonian-Senonian levels.

The innermost Cretaceous flysch unit is the west-internal unit [4] overlying a Carpathian basement and consisting of thick flysch deposits with massive sandstone and conglomerate banks, corresponding to the Sinaia, Comarnic-Bistra and Zăganu beds. Deposits belonging to the Vraconian-Eocene cycle lie at the southern end of the unit.

The east-internal unit was separated outside the mentioned unit. It consists of Cretaceous (beginning with the Hauterivian), Paleogene and Miocene deposits (the Breaza syncline). According to Băncilă (1958), the Cretaceous deposits are characteristic of the east-internal unit; they include the curbicortical series, the Cotumba-Tătaru sandstone, with transition to the Dumbrăvioara series, Vraconian-Cenomanian marls and marno-limestones, beds with *Inoceramus*, with transition to Senonian red marno-limestones (Gura Beliei beds). The Paleogene is developed in the marly-clayey Şotrile facies containing sandstone intercalations.

The middle-internal unit follows the previous one at the exterior and is represented by Cretaceous deposits in the black shale facies; it consists of bituminous dark clayey pelites. The age of the black shales varies between the Hauterivian and the Upper Albian. Three horizons are distinguished in the composition of the black shales : a basal spherosiderite horizon, a schistose-gritty horizon and an upper gritty-glauconitic horizon. The last one is overlain by a horizon of red clays with tuffites and, sometimes, radiolares. Generally, the black shales lack reservoir rocks. North of Bistriţa and south of Covasna, they are overlain by an arenyte horizon, the Prisaca-Siriu sandstone, respectively (Băncilă, 1958) which is of Upper Cretaceous-Lower Eocene age and, locally, may reach 600—700 m in thickness.

As indicated by the mapping and drilling data, the black shales are characteristic not only of the Cretaceous flysch but are also present in the Paleogene flysch zone. Taking into account the bituminous character of the black shales which suggests that they might constitute hydrocarbon source rocks, the definition of their stratigraphic and structural position has theoretical implications on the hydrocarbon prospects in the various units of the flysch zone.

[4] According to Dumitrescu, Săndulescu (1974), the innermost unit is the Baraolt Nappe.

The Cretaceous flysch zone consists, on the whole, of strongly tectonized deposits, most of which outcrop and have been eroded. As a result, this zone is generally regarded as not of prospect for hydrocarbons.

b) The Paleogene flysch zone consists, at the surface, of Cretaceous, Paleogene, Miocene and, only locally, Pliocene deposits. But the Paleogene formations are the most widespread. The Cretaceous and, especially, the Paleogene deposits show facies variations that, associated with the regional tectonic relations, determined the separation of this zone into two tectonic units: the medio-marginal unit and the external unit (B ă n c i l ă, 1958).

The medio-marginal unit, situated outside the medio-internal unit (Audia) comprises mainly Cretaceous and Paleogene deposits. From the Buzău Valley, the respective deposits gradually sink south-westwards under newer Miocene and Pliocene formations. Towards the exterior, the medio-marginal unit comes into contact with the external unit or with the Neogene zone. From the stratigraphic and structural constitution viewpoint, the medio-marginal unit was divided (B ă n c i l ă, 1958) into two subunits: the median subunit and the marginal subunit.

The median subunit covers the western part of the medio-marginal flysch, being overthrust by the Audia unit. It consists of Cretaceous, Paleogene and Miocene deposits.

The Cretaceous comprises two main deposit sequences: a lower sequence, developed in the black shale facies (Hauterivian-Upper Aptian ?) reaching 200—250 m in thickness and an Upper sequence of Vraconian-Senonian age, consisting of striped clays, marno-limestones,limestones and sandy limestones reaching about 1,500 m in thickness.

The Eocene is represented by the Tarcău sandstone series, 1,000—2,000 m in thickness, followed by schistose clays with sandstones (the Podu Secu beds-the Plopu beds).

The Oligocene covers the depressive zones and consists of sandstones (Fusaru), marno-limestones and of an upper horizon (the Vinețișu beds), represented by marls and sandstones. The whole succession reaches 1,200—1,500 m in thickness. West of the Buzău Valley, the Oligocene undergoes lithofacial variations changing into the mixed facies of the Pucioasa beds.

The Miocene is present in the Slănic syncline where it contains a continuous stratum succession, from the Burdigalian to the Sarmatian.

The marginal subunit, situated outside the previous one, consists of Cretaceous, Paleogene and Miocene deposits.

On the whole, the Senonian sequence is similar to that in the median subunit, the pre-Senonian formations lacking.

The Eocene shows an intermediary facies, marked by the presence of the Tarcău type sandstone and gritty limestones with marl intercalations. Towards the exterior, but in the same subunit, the Eocene becomes ever more limy, being marked by a lower limy-gritty horizon (300—400 m) and an upper marly-clayey horizon (150—200 m).

The Oligocene shows two facies, namely, the bituminous Kliwa facies and the Pucioasa facies. The following terms individualize in the Kliwa facies, from bottom to top : the Lucăceşti sandstone (20—30 m), the lower menilite horizon and the bituminous marl horizon (30—60m), the dysodile schist horizon (50—100m), the lower Kliwa sandstone horizon, (200—250m) with dysodile schist intercalations, the Podu Morii bed horizon (50—200m), the upper Kliwa sandstone horizon (150—500m) and the upper menilites (10—12m). The Pucioasa facies is present west of the Prahova River in the following succession : lower Pucioasa beds (50 m), lower dysodile schists (40—150 m), upper Pucioasa beds (1,100 m) with gritty Fusaru intercalations, the Vineţişu-Izvoarele beds, (70—300m) and the upper dysodiles (100—200 m).

The Miocene forms several synclines to the south-west of the medio-marginal unit, where the latter sinks under newer deposits. It is the question, first, of the Slănic and Drajna synclines. The Miocene consists of Burdigalian, Helvetian and Tortonian salt overlain, sometimes, by post-tectonic Pliocene formations. Beside these, it should be mentioned also the Miocene and Meotian deposits in the Comăneşti intramontan basin, the last represented by the Sarmatian, 400—600 m in thickness, overlying unconformably the Paleogene of the medio-marginal nappe and the external unit. The Sarmatian contains a conglomerate basal horizon and a marly-gritty upper horizon with coal and hydrocarbons (migrated from the Paleogene).

In the external unit the Paleogene flysch develops under the medio-marginal nappe overthrust and outcrops, practically, only in the Putna-Straja, Dumesnic, Mitocul lui Bălan, Bistriţa-Piatra Neamţ, Oituz-Slănic and Putna—Vrancea tectonic windows or semiwindows. This unit contains Cretaceous, Paleogene and Miocene deposits.

The Lower Cretaceous is represented by the black shales of the Streiu beds, while the Upper Cretaceous is represented by the Tisaru beds which are equivalent to the striped clays in the Audia unit, and by the Lepşa beds (250 m).

The Eocene shows two facies : an external one or the Caşin facies, consisting of bituminous marno-limestones with sandstone intercalations (700 m), limy marls (100 m) and marls with sandstone intercalations (Bisericani beds = 300 m); an internal one, the Greşu facies, consisting of bituminous marno-limestones with sandstones and conglomerates, limy and gritty marls and alternations of limy sandstones, clays, limestones and conglomerates (Greşu beds, about 350 m, and Bisericani beds).

The Oligocene shows approximately the same succession as in the marginal subunit, namely (from bottom to top) : the Lucăceşti sandstones (0—30 m), the lower menilite and bituminous marl horizon (40—80 m), the dysodile schists (80 m), the Kliwa sandstone (120—260 m), the dysodile and upper menilite horizon (150 m) and the transition horizon (the Gura Şoimului beds = 80—140 m), represented by an alternation of marls, dysodile schists, menilites and conglomerates. It is noteworthy that the Oligocene deposits are not regularly distributed and may lack totally or partially, owing to erosion, as is the case of the Bistriţa, Putna-Vrancea semiwindows or the Măgura-Caşin, Băile Slănic-Nineasa, Ciunget, Muntele Uture zones.

The Miocene consists of a basal series including conglomerates and an upper sequence of sandstones and marls (Hîrja beds).

Referring to the Paleogene flysch which shows a greater economic importance than the Cretaceous flysch, the following things should be underlined :

The Cretaceous deposits, and especially the Paleogene ones, present lateral facies variations.

The Cretaceous is marked by two main deposit sequences : a lower sequence, developed in the black shale facies, possibly mother rocks, but lacking important reservoirs ; it is found, under different names, in the medio-marginal and external Audia units ; an upper sequence in which the Upper Cretaceous, represented by the striped clay horizon (Vraconian), is found in the marginal and external Audia units, being named Tisaru beds in the latter unit ; stratigraphic equivalences may be also found for the rest of the Upper Cretaceous.

The Eocene in the Tarcău sandstone facies, which is predominantly, arenyte, showing reservoir rock properties, gradually changes outwards into more pelite and more limy facies. Thus, the frequency of the massive sandstones decreases in the marginal subunit changing gradually into a rhythmical gritty-clayey composition and, into gritty-limy and limy intercalations, eastwards. The Eocene also decreases gradually in thickness from 2,500 m in the Tarcău sandstone facies zone to 700–1,000 m in the marginal subunit.

The Oligocene, which is the main formation of interest for hydrocarbons, shows two principal facies : in the median subunit, the Fusaru facies which changes into the Kliwa facies in the marginal subunit and, then, in the external unit. These facies differentiations take place against a bituminous general common background propitious to the hydrocarbon genesis. From the lithological point of view, the common background is manifested by the presence of the bituminous lutites and silicolites (dysodile clayey schists, marls and menilites).

The Fusaru sandstone facies is characterized by the presence of metric and suprametric thick packets (the Fusaru sandstones), similar to the Tarcău sandstones. Rhythmical clay and gritty, sometimes blackish bituminous marl sequences are intercalated among the sandstone packets. The Paleogene habit of these sequences resembles that of the Krosno beds, in the northern half of the flysch zone ; these sequences are known under the name of Pucioasa beds in the median part and south-westwards in the Paleogene flysch where the rhythms are more frequent and the rocks show a finer granulation. The Vinețișu beds, which lie in the upper third of the Oligocene, constitute an exception, preserving the characteristic features of the Krosno beds.

The essential feature of the Kliwa sandstone facies is the wide distribution, in the lithologic column, of the quartzose arenyte material. The latter appears, mainly, as metric and suprametric Kliwa sandstone banks occurring even in the base of the sequence, under the first menilite level, thus forming the Lucăcești sandstone horizon. The massive sandstones make up two horizons in the nappe; these horizons are separated by the Podu Morii beds, representing a marly-limy, partially, synchronous flysch packet which is lithologically similar to the Vineţişu beds. The Oligocene decreases gradually in thickness, from 1,300 m in the Tarcău facies developing zone in the median subunit, to 800 m, in the marginal and external units. As has already been shown, thickness variations are also recorded longitudinally in this last unit, owing to erosion (?). The transversal thickness decrease affects, mainly, the sandstone packets which also undergo a partial substitution by conglomerates and microconglomerates with green schist elements within the external unit.

c) The Carpathian Foredeep, as it was defined in a previous chapter develops at the exterior of the Carpathian Chain, along it. Between the Suceava Valley and the Buzău Basin, the formations making up the foredeep come into tectonic contact with the external or median-marginal unit of the Paleogene flysch. The Paleogene flysch side sinks normally under the Neogene south-westwards while, west of the Dîmboviţa River, the Neogene zone formations exceed completely also the Cretaceous flysch units, overlying transgressively the South Carpathian Crystalline-Mesozoic core.

Taking into account the stratigraphic and structural characteristics, within the Carpathian Foredeep, three subzones can be separated, namely:

— the Miocene subzone, between the Suceava Valley and the Buzău Valley;

— the Mio-Pliocene subzone, between the Trotuş Valley and the Dîmboviţa Valley; within it, the sector between the Buzău Valley and the Prahova Valley is known also under the name of "the diapir fold zone";

— the Getic Depression, situated between the Dîmboviţa Valley and the Danube.

The oldest sedimentary deposits known in the molasse zone belong to the Getic Depression Cretaceous. The most numerous data concerning the Paleogene deposits were obtained also in this subzone; this is due to the outcropping of the respective deposits in the northern margin, on the one hand, and to the fact that the Paleogene could be crossed by wells at the usual drilling depth.

With the exception of the Lower Cretaceous, which is characteristic of the west internal unit and was identified by the wells drilled at Stîlpeni and, possibly, at Băiculeşti, in the rest of the depression west of the Dîmboviţa, the Cretaceous, crossed by wells, seems to belong completely to the post-tectonic cover of the Getic Nappe. It consists of a basal, conglomerate complex, found on the border and an upper complex consisting of marl and sandstone alternations reaching 2,000 m in thickness. Gas indications were pointed out in the upper complex, at Govora.

The Eocene is, comparatively, better investigated also in the Getic Depression on the border of which it consists mainly of conglomerates and, only locally, of organogenous limestones. Within the depression the Eocene remains completely psephite west of the Amaradia Valley (Ţicleni, Cîlnic), while, east of the respective river, it consists of a conglomerate basal complex and of an upper complex in flysch facies (the Şotrile facies) with sandstone levels. Outside the Getic Depression, the Eocene is considered to undergo the facial variation tendencies found in the Paleogene flysch zone.

According to the data available so far, the Oligocene seems to show two facies in the molasse zone basement. One facies represents the outward continuation of the Kliwa facies, the other is similar, to a certain extent, to the Pucioasa bed facies. The former is known in the Miocene and Mio-Pliocene subzones, while the latter is characteristic especially of the Getic Depression. A gradual transition seems to take place in the northern extremity of the Mio-Pliocene subzone.

The Oligocene in the Kliwa facies is better represented in the Buzău and Prahova valleys where it sinks normally under the Neogene forming the northern border of the foredeep. The lithological characteristics and the Oligocene succession in this sector remain such as they have been described above. Northwards, in the Miocene zone (Tescani) a succession similar to the one in the Paleogene flysch external unit is found, differing from the latter by the fact that the frequency and thickness of the Kliwa sandstones are lower owing to the influence of the conglomerates with greenschist elements. Simultaneously, the total thickness of the formation decreases to 500 m. In the Getic Depression the Oligocene consists of rhythmical sequences of the Pucioasa bed type among which are intercalated gritty complexes (Vîlcele, Boţeşti) similar to the Fusaru sandstones and, sometimes, even conglomerate intercalations. This basic composition shows great variations, the arenyte and pelite sequences substituting one another laterally, longitudinally and vertically. The Oligocene average thickness is 1,000—1,250 m in this part of the Neogene.

The ultradeep wells performed in recent years have no longer reached Paleogene deposits south of the Moreni-Şuţa Seacă-Slătioarele-Ţicleni structure line, but only Lower Miocene formations overlying tectonically various terms of the Moesian Platform sedimentary. This indicates that the external limit of the sedimentary basin was farther north of the Bibeşti-Tinosu line (the equivalent of the Pericarpathian line) during the Paleogene.

The Miocene is represented by all its stages and is found throughout the foredeep.

The Aquitanian seems to develop in continuity with the Oligocene ending in fact, the Paleogene sedimentation cycle. Its deposits show partly a lagoonal facies. It is difficult to know the Aquitanian thickness owing to the tectonic deformations which took place after the deposition and caused the agglomeration of a bulk of deposits in certain sectors. In general, it is agreed that the average normal thickness does not exceed 500 m.

The Burdigalian, generally overlying transgressively the Aquitanian or the older formations, represents the first molasse term of the Carpathian Foredeep. It consists almost throughout of conglomerates whose thickness reaches 700—800 m. The conglomerates in the Moldavian Miocene subzone are characterized by the greenschist prevalence. The local characteristics of the conglomerate facies are expressed by several denominations, such as the Pleșu-Pietricica, Brebu, Fedeleșoiu, Loviștea conglomerates etc. Lately some geologists have assigned to the Burdigalian also the lagoonal deposits with gypsum, the gypsum breccias, the salt sedimentary breccias, and, subordinately the clays that formerly were assigned to the Aquitanian and were known under the name of "Salt formation".

The Helvetian, which is found throughout the Neogene zone, consists of a marly-sandy series reaching 2,000 m in thickness. Within its succession two subdivisions can be distinguished regionally: a lower, predominantly sandy-gritty sequence with red marl intercalations and an upper, predominantly marly dark grey sequence with gypsum and sand, sandstone and conglomerate intercalations at the upper part. In the Getic Depression the terminal arenyte depositions constitute a distinct complex at the upper part of the Helvetian. Owing to the lithofacial variations, the limit between the two complexes is not clear and does not always appear at the same stratigraphic level. In the eastern Muntenia and in Moldavia, the lower sequence is known as "the red horizon", while the upper sequence is known as "the grey horizon". If, on the internal side of the depression, the Helvetian changes into a coarser, conglomerate facies, on the internal side, north of the Bibești-Tinosu fault, the psamite ratio decreases, the respective deposits becoming predominantly pelite with ever rarer gritty-clayey intercalations. The drilling data indicate that the Lower Miocene sedimentary basin did not extend outside the present Pericarpathian line.

The Tortonian represents the formation ending the Carpathian molasse marine cycle. Within it four lithostratigraphic terms were separated (Fl. Olteanu, 1951; Gr. Popescu, 1951), from bottom to top (Fig. 4):

— the tuff and marl horizon with globigerinae consisting, mainly, of greenish dacite cinerites with marl and tuffaceous sandstone intercalations reaching 10—15 m in thickness (Govora); in the bending Carpathian zone, the sandstones intercalated in the predominantly limy tuff horizon make up the "Răchitașu sandstones";

— the salt breccia horizon contains a great variety of Carpathian and extra-Carpathian rocks with which associate a second generation of salt massifs; the thickness of the breccia horizon varies from a few metres to 600—700 m, the salt being lenticular;

— the radiolare schist horizon (to 150 m in thickness), consisting of bituminous schistose clays, resembling the Oligocene dysodile schists from a petrographic and, to a certain extent, geochemical viewpoint;

— the horizon of the marls with *Spirialis* consisting of marls with thin sandstone or tuff intercalations reaching 150—200 m in thickness. The horizon is equivalent to the Tarhan beds and, possibly, Ciocrac beds in Caucaz (Saulea, 1967).

The Sarmatian (the Buglovian inclusively) is marked by a succession of brackish water deposits that may exceed 2,000 m in thickness. The Buglovian marks the transition from the marine to the brackish deposition by its paleontologic content. The clays and marls with sandstone intercalations are rich in pyrite and totalize about 100 m in thickness. The Sar-

Era	Period	Epoch	Stage (Substage)		Thickness m	Lithology	Facies	Accumulation of hydrocarbon ● petroleum ✱ gas
QUATERNARY					50-100	Conglomerates, pebbles, sands and marls	Continental	
TERTIARY	NEOGENE	PLIOCENE	Levantine		1000-2500	Sands, clays, marls, coal intercalations	Lacustrine	● ✱
			Dacian		100-500	Sands, marls and coals in the base	Lacustrine	● ✱
			Pontian		200-1200	Marls in the west, marls and sands in the north and the east	Brackish sweet water intercalation	● ✱
			Meotian		50-700	Sandstones, sands and marls	Brackish sweet water intercal.	● ✱
		MIOCENE	SARMATIAN	Kersonian	200	Sandstones, limestones	Brackish	●
				Bessarabian	200	Sandstones, sands and marls	Brackish	
				Volhinian		Marls and sands	Brackish	●
				Buglovian	100	Marls	Marine Brackish	
			TORTONIAN	upper	150 250	Sandy marls with Spirialis Schist with Radiolaria	Marine	
					600	Salt breccia with salt massifs	Lagoonal	
				lower	10-100	Tuff with Globigerina	Marine	
			HELVETIAN	upper	1700	Marls, gypsums, sandstones	Marine Lagoonal	
				lower	500	Conglomerates, sandstones	Marine Lagoonal	●
			Burdigalian		500	Conglomerates, marls, sands	Marine Lagoonal	
	PALEOGENE	OLIGOCENE	Aquitanian		100	Marls, breccia, salt, gypsums	Lagoonal	
			upper		20-50	Upper menilites and dysodiles	Marine euxinic	
					500	Upper Kliwa sandstone	Marine	●
			middle		200-250	Podul Morii beds	Marine	
			lower		500-700	Lower Kliwa sandstone	Marine	●
					120-200	Dysodile schists	Marine euxinic	
					20-40	Lower menilites	Marine euxinic	
		EOCENE	upper		200	Sandstones and marls	Marine	

Fig. 4. — Stratigraphic column in the Mio-Pliocene subzone (according to E. Hristescu and Gh. Olteanu).

matian proper shows a transgressive character, the respective deposits overlying, sometimes, the Eocene on some of the Getic Depression anticlines. The Volhynian consists of marls with *Ervilia*, sandstone and boulders. The Bessarabian consists of bituminous dysodiliform schists, limy sandstones marno-limestones and cinerites; sometimes (the Otăsău Valley-the Olt Valley) it is marked by the presence of the conglomerates and sandstones. The Chersonian contains a packet of sands, sandstones and conglomerates in the base and marls and dysodiliform schists at the upper part. The Sarmatian is predominantly pelite on some structures within the depression (Cîlnic, Urdari, Strehaia etc.), while it is sandy on other structures (Bălteni, Ţicleni, Bustuchini etc.).

The Pliocene, represented by all its stages, is followed along the East and South Carpathians, from the Trotuş Valley to the Danube. It constitutes the final molasse term deposited in sweet water facies. The Pliocene consists of a sequence of pelite and psamite deposits containing mother, reservoir and protective rocks.

The Meotian overlies transgressively the older formations with the exception of the Sarmatian-Pliocene zone in Moldavia, the eastern part of Muntenia and the north-western part of Oltenia, where it overlies the Sarmatian in continuity of sedimentation. The Meotian consists of an alternation of sandstones and sands in which the marls prevail. The arenytes prevail in the lower part of the profile. The thickness of the Meotian

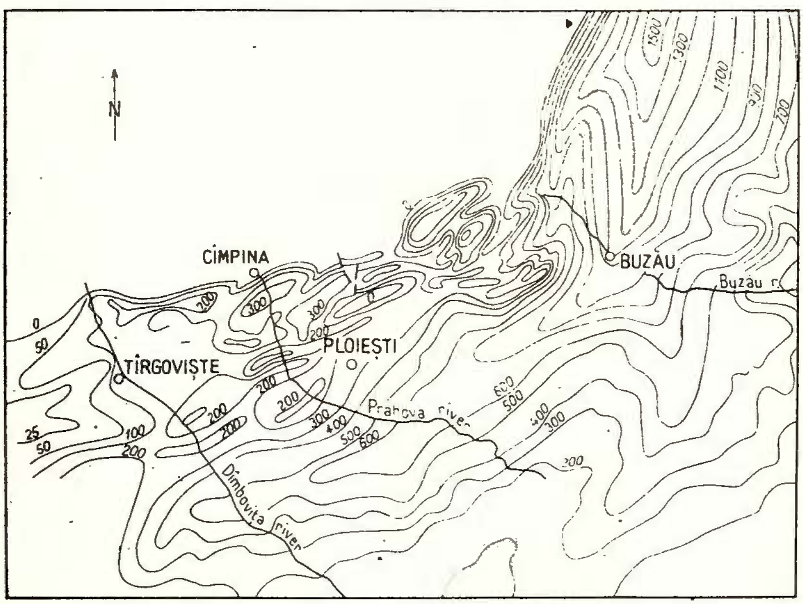

Fig. 5. —Meotian isopachytes in the Mio-Pliocene subzone (according to V. A g h e o r g h i e s i i and M. P î r v u).

varies from the complete absence on some structures in the Getic Depression to 100—1,500 m in the bending Carpathian sector (Fig. 5).

The Pontian follows, as a rule, the Meotian in continuity of sedimentation and, by its predominantly pelite character, constitutes a protective screen for the deposits located in the older reservoirs. Locally, it contains sand intercalations which are more frequent towards the Carpathian bending sector, and lumachelle limestones on the internal margin of the sedimentary basin. The Pontian thickness increases from 120 m in the central part of the Getic Depression (Pitești) to 400 m (Bălteni) and even 1,200 m in the eastern sector of the Mio-Pliocene subzone.

The Dacian consists of an alternation of sands, marly sands and sandy fossiliferous marls, with sequences of sandstones and gravels with crossed stratification. Lignite intercalations associated with coal clays lie at the upper part. The fauna indicates a water sweetening. The total Dacian thickness varies from 500 m to 1,000 m, while greater thicknesses correspond to the eastern sector of the Mio-Pliocene subzone.

The Levantine represents the last Pliocene substage. Its composition is predominantly arenyte, with sands and sandstones changing into gravels and conglomerates towards the upper end. The arenytes are separated by marly intercalations constituting at the same time also protective screens for some hydrocarbon accumulations.

The molasse deposits end by a sand, sandstone and gravel horizon (the Cîndești gravels) of Pleistocene age.

2. General Characteristics of the Structure

The tectonic edifice of the flysch and molasse formations is the result of an intense and lasting diastrophism process determined by the Alpine orogenesis. The sense and intensity of the tectonic loading were not uniform on the whole area lying between the Crystalline-Mesozoic zone and the foreland, showing strong differences, especially between the sectors east and west of the Dîmbovița River.

In the sector between the Suceava Valley and the Dîmbovița Valley the tangential movements were much stronger, probably, owing to the more active foreland underpushing. Thus a complicated structural edifice resulted showing relations of successive overthrusts outwards. Such relationships are to be found both in the Cretaceous and Paleogene flysch zones and in the foredeep. According to the synthesis drawn up by Băncilă (1958), there are six units in the eastern succession. Their denominations, which are also mentioned in the stratigraphy chapter, are the following:

— the west-internal unit = the Ceahlău unit (Dumitrescu et al., 1962);
— the east-internal unit = the curbicortical flysch unit;
— the median-internal unit (Audia) = the black shale unit;
— the medio-marginal unit = the Tarcău sandstone unit;
— the external unit = the marginal unit;
— the Pericarpathian unit = the internal zone of the Carpathian Foredeep.

According to a recent synthesis (D u m i t r e s c u, S ă n d u l e s c u, 1974), the west-internal unit (the Ceahlău unit and the Baraolt Nappe) belongs to the "internides" taking into account the fact that the main unconformities affecting the respective deposits took place during the Cretaceous. The other four flysch units belong to the "externides", taking into account the fact that the east-internal and medio-internal nappes (Audia) formed during the Burdigalian-Helvetian, while the medio-marginal (Tarcău) and external (marginal) units formed during the New Styrian phase. As has been mentioned before, the lower molasse thrust over the platform deposits took place during the Middle Sarmatian.

The first three of the six mentioned units develop in the Cretaceous flysch zone, the next two, in the Paleogene flysch zone, while the last one corresponds to the foredeep. These units are delimited by important tectonic accidents (lines) showing a regional character. Thus the Crystalline-Mesozoic zone comes into contact with the Cretaceous flysch zone along the central line; the two internal units are separated by the Lutu Roşu line; the east-internal unit is delimited at the exterior by the east-internal line; the median-internal unit, by the Audia line; the medio-marginal nappe, by the marginal line, and the external unit, by the external line.

The mentioned overthrust lines along which the flysch units shifted eastwards, represent planes with strong dips (30—50°) tending rapidly to decrease in depth, so that the overthrust ampleness does not exceed, as a rule, 10—12 km. The medio-marginal unit, which is the most important nappe in the Carpathians, is an exception; its ampleness (thrust), checked by drilling, exceeds 35 km (Plate II). Various nappes known in the relevant literature as the Tazlău Nappe, the marginal nappes and the Putna Nappe were assigned (D u m i t r e s c u et al., 1962) to this unit which identified with the Tarcău Nappe. Longitudinally, the overthrusts diminish gradually southwards and south-westwards disappearing in some cases. This is also the case of the contact between the Paleogene flysch and the internal flank of the foredeep, which lose their tectonic character west of the Buzău Valley. But other tectonic lines prolong also beyond the Dîmboviţa Valley, under the Neogene cover. For instance, the Lutu Roşu line was followed south of Stîlpeni and the unit corresponding to the west-internal one might reach the Danube Defile where the Sinaia beds in the Severin Nappe thrust over the Upper Cretaceous (C o d a r c e a, 1940).

It has already been shown that the most important of all the Carpathian flysch units from the economic point of view are the external unit and the medio-marginal nappe. The former, which constitutes a parautochthon (?) supported by the Pericarpathian unit, shows the best hydrocarbon accumulation conditions. The latter is a very wide nappe offering the protection of the parautochthon hydrocarbon accumulations.

The tectonic details of the formations in the flysch zones is characterized by scales, faulted folds and by normal folds which are parallel to the Carpathian Chain. The faulted folds prevail in the Cretaceous flysch zone; they are sometimes associated with wide normal, usually, syncline folds consisting of conglomerate, little competent deposits. The Paleogene flysch zone is marked by the development of the fault folds, with the external flank laminated, making up, on the whole, a scale structure, and by normal folds (Plate III).

As far as the molasse zone subunits are concerned, it is noted that the Miocene subzone generally shows some overthrust anticlines which are strongly folded and similar to those in the Paleogene flysch zone. The tectonics of the Neogene formations shows a particular character determined by the halotectonic process, in the Mio-Pliocene subzone. The salt formation pierces, sometimes, here the whole cover of Miocene and Pliocene deposits forming diapir folds whose salt cores outcrop. Although the diapir folds are present throughout the internal zone of the foredeep up to the Bibeşti-Tinosu line, the shift of the salt mass is considered to be due to the tangential and oscillating movements of the crust (I. Atanasiu, 1948; Gavăt, 1964, etc.).

The diapir folds range north-southwards along several main alignments, mirroring various piercing stages, namely:

— the overshed diapirs corresponding to the Ocniţa, Vîlcăneşti, Măgurele, Apostolache structures etc., situated on the internal foredeep side;

— the Ţintea, Moreni, Gura Ocniţei exaggerated diapirs developing in the median sector of the Mio-Pliocene zone;

— the Bucşani, Ariceşti, Ploieşti, Ceptura-Urlaţi attenuated diapirs etc.;

— the Mărgineni, Măneşti-Vlădeni cryptodiapirs.

Within the first two diapir categories the salt bodies may pierce completely the Pliocene cover forming outcropping salt massifs; on the attenuated diapir alignment the salt reached the Meotian and Pontian levels, while on the outermost alignment the salt rock agglomeration brought about only the deformation of the cover Pliocene.

With a few exceptions, the most important structures in the Mio-Pliocene zone lie on two main echelons; one is represented by the Surani-Copăceni-Vîlcăneşti-Cîmpina-Ocniţa-Valea Reşca-Doiceşti-Şotînga alignment, which is situated on the internal foredeep side at the contact with the Paleogene flysch and is marked by overshed diapirs, with the southern flank sunk and overthrust by the northern flank; the other consists of the Ţintea-Băicoi-Floreşti-Moreni-Gura Ocniţei-Răzvad-Tîrgovişte anticlines, which constitute exaggerated diapirs with outcropping salt cores and asymmetrical flanks. The seismic profiles operated in 1974 on the Prahova and Proviţa valleys as well as some older drilling data seem to indicate that the synclines determined north and south of the median diapir alignment (Ţintea-Tîrgovişte) appear only at the Neogene level and that they overlie some Paleogene anticlines (Fig. 6, 7). Such unconformities were also pointed out at the Tortonian salt base in the Transylvanian Depression. The latest observations suggest that the Neogene tectogenesis in the Mio-Pliocene zone is of predominantly halokynetic and not halotectonic nature.

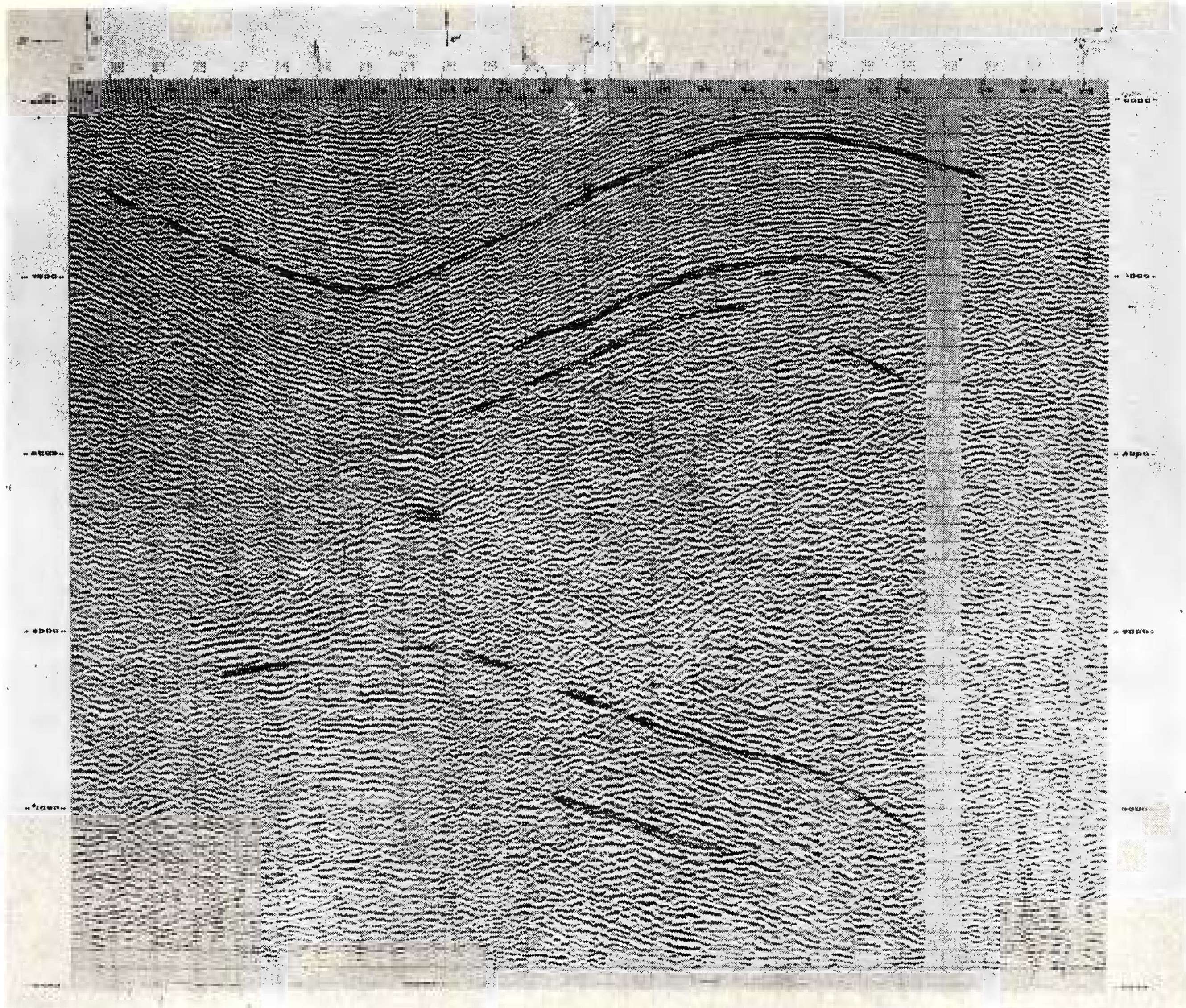

Fig. 6. — Seismic profile on the Prahova Valley in the Mio-Pliocene subzone.

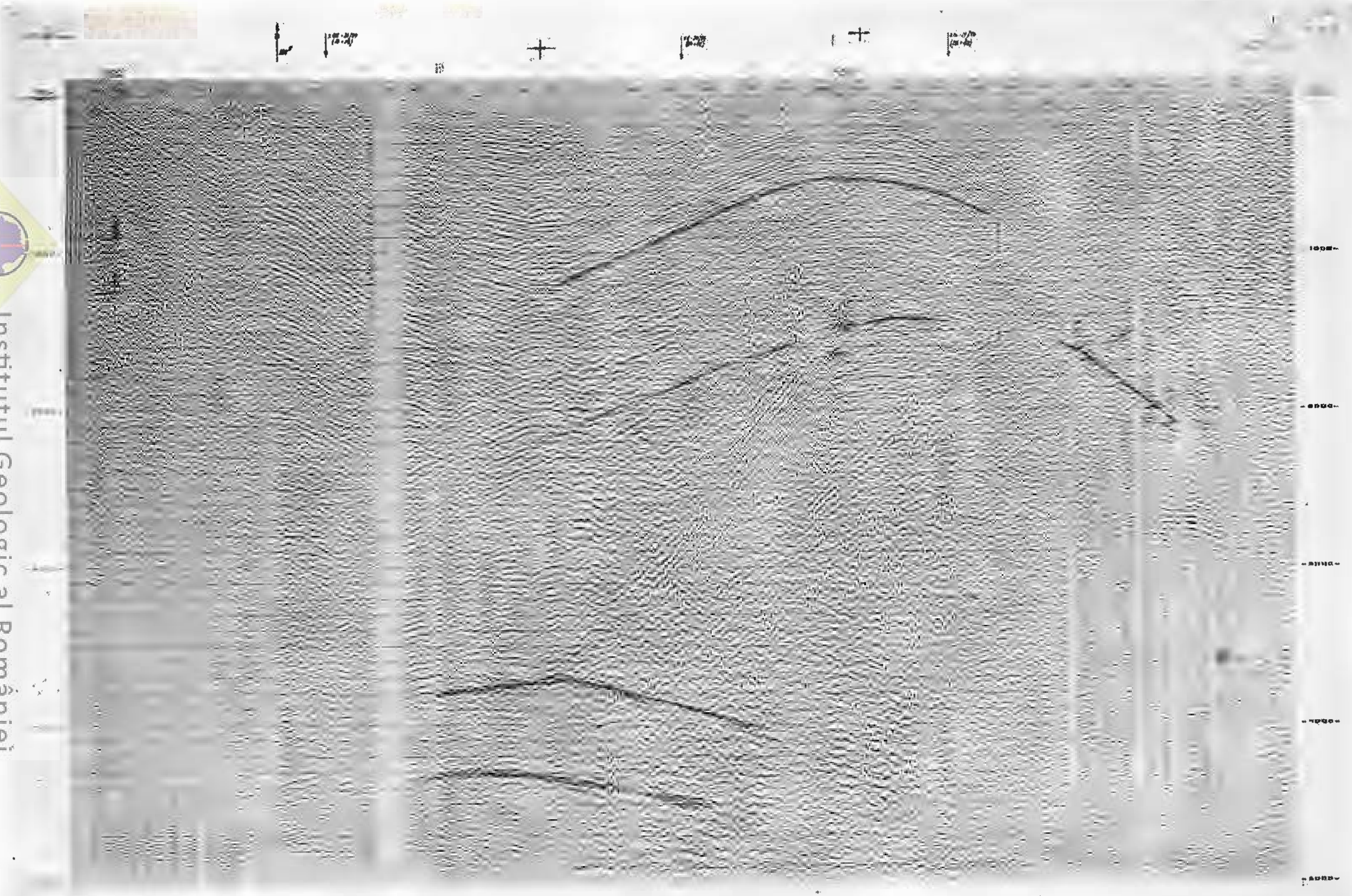

Fig. 7. — Seismic profile on the Provița Valley in the Mio-Pliocene subzone.

The thickness and lithofacies variations indicate that, on the whole, the respective structural elements formed and evolved simultaneously with the sedimentation, at least in the Pliocene (Krejci-Graf, 1933; Stille, 1953). But the existence of some synclines with hydrocarbon impregnations, such as those at Drăgăeşti, Aninoasa and Matiţa raise interpretation problems concerning the deposit formation and the evolution of the region; this interpretation still needs additional data and a special study.

It is also noteworthy that the Mio-Pliocene zone diapirism decreases gradually southwards, that is, towards the platform boundary. The amplitude of the Neogene structures decreases accordingly.

The plicative elements are crossed by numerous faults, some of which trending longitudinally, others, transversally, with implications on the fluid distribution. But it seems that the main diapir structures are located along some ruptural accidents with regional character, along which the heat flow might have shown greater intensities than previously, thus influencing favourably both the salt plasticity and ascension and the factors conditioning the hydrocarbon genesis and accumulation.

Unlike the East Carpathians, where the sedimentation area shifted gradually outwards, a sinking of the internal zones took place in the Getic Depression after the Laramian phase, allowing the sedimentation basin to extend also inwards to the Crystalline-Mesozoic core. The post-Laramian phases determined the folding of the sedimentary cover and the outlining of some alignments which are parallel to the Carpathian system. A few positive structures functioning as real ridges (Stîlpeni-Ciofrîngeni-Govora, Piteşti-Glîmbocelu), remained emerged for longer or shorter periods of time, when the denudation removed partly the sedimentary cover. As a result, the stratigraphic succession shows discontinuities varying in time and importance. The biggest gaps are found in the apex zones of the positive structures, while on their flanks a tendency of completing the stratigraphic profile is noticed. But most of the structures remained almost permanently covered by waters, showing a relative continuous Mio-Pliocene stratigraphic succession.

Taking into account the main diastrophism phases, two structural stages can be distinguished within the tectonic arrangement of the Tertiary formations in the Getic Depression. A lower stage, containing the succession from the Eocene to the Tortonian which was folded in the Savian and Styrian phases, when the major structural alignments of the Getic Depression formed; an uper stage, of Attian and Wallachian age, corresponding to the Sarmatian-Pliocene cycle. The latter's deposits overlie transgressively the Miocene, Paleogene and even Cretaceous formations, generally moulding the older structures. The role played by the disjunctive tectonics in the detail evolution of the structures and in the fluid distribution should be underlined also in the Getic Depression.

As in the Mio-Pliocene zone, the main structural alignments of the Getic Depression are found in the latter's northern and median parts, consisting of the following anticlines: Stîlpeni-Băiculeşti-Ciofrîngeni-Govora-Slătioru; Şuţa Seacă-Glîmbocelu-Piteşti-Slătioarele; Bustuchini-Socu-Ţicleni-Bîlteni.

3. Geological Evolution of the Carpathian Flysch and the Carpathian Foredeep

The region between the Crystalline-Mesozoic zone and the Carpathian Foreland is marked by an almost continuous succession of deposits, beginning with the Upper Jurassic and ending with the Pliocene. This sedimentary, predominantly terrigenous, succession reaches 18 km in thickness in the Focşani region. From the genetic point of view, most of the Cretaceous and Tertiary deposits belong to the flysch (the Lower Cretaceous-Paleogene) and molasse (Neogene) formations.

The nappe structure, the detail structural arrangement and the lithological variation of the beds are the result of both the platform underpushing process and the movements affecting the flysch area, the molasse zone and the surrounding regions. The sedimentary bulk was subject to some new strong tangential movements against a background of continuous subsidence movements with rare phases of regional or local uplift of the basin bottom. On the other hand, vertical movements with rhythmical character took place in the Cretaceous and Paleogene; they are indicated by the recurring lithological sequences of the flysch facies. This rhythmicity could be explained also by the turbidity currents.

The configuration of the flysch area showed, along its evolution, uplifted or sunk parts that controlled the sedimentation of some geological formations. Thus it is worth mentioning the existence of some periodical cordillieras. The basin was divided more strongly especially after the Savian and Styrian phases. The absence of the coal and evaporites in the Cretaceous and Paleogene indicate that the sedimentation took place in an open sea. On the contrary, the great thickness and facies variations, the presence of the coal, anhydrites and salt rocks, of the molasse deposits in general, in the Neogene, point to the basin division and silting.

The formation of cordillieras, barriers and shoulders influenced the facies of some Cretaceous and Tertiary deposits. From this point of view, it is worth remembering that the Oligocene sequences of dysodile, menilite schists and bituminous marls as well as other similar Aquitanian, Tortonian and Sarmatian sequences that, by their petrographic and geochemical characteristics, suggest euxinic deposition environment in waters devoid of current circulation. One should also bear in mind the fact that at the end of the Paleogene and Miocene cycles, in the Burdigalian and Tortonian, respectively, the emmersion of the depression area started by the cordilliera, crest and shoulder zones which led to the basin division and to the appearence of lagoons, where the evaporites deposited. The lagoons covered, as a rule, the syncline zones and were separated from the forming anticlines.

If the oscillating movements influenced the thickness and facies of the sedimentary formations, it should be underlined that the main factor determining the nappe structure and the detail arrangement of the beds and which also lends a characteristic feature to the region, is the platform underpushing process associated with the plicative movements. The latter took place during several Alpine orogenesis phases. Of course the plicative movements did not have the same intensity in time and space. Generally speaking, the Cretaceous diastrophism phases were more strongly felt in the internal flysch sector and in the Getic Depression. In the rest of the flysch zone and in the foredeep the tectonic movements culminated in the Savian, New Styrian and Attian phases. The succession of the folding phases and the effect of the latter were synthetized and presented in several papers among which those belonging to Stille (1953), Grigoraş (1961), Dumitrescu, Săndulescu (1968) etc.

According to a relatively recent paper (Dumitrescu, Săndulescu, 1968), within the area delimited by the Crystalline-Mesozoic zone and the foreland units were felt the movements of the Alpine cycle, which correspond to the Austrian (Meso-Cretaceous), Subhercinian, Laramian, Old Styrian, New Styrian, Moldavian, Attian and Wallachian. The main movements that determined the formation of the present Carpathian structure might be grouped into two periods : one corresponds to the Middle and Upper Cretaceous generating the Dacides (Internides) and may be named the paroxysmal Dacidic (Internidic) period ; the other corresponds to the Lower and Middle Miocene, when the Moldavides (Externides) formed, and may be called the Moldavidic (Externidic) paroxysmal period.

The Old Austrian phase (the end of the Aptian) is noticed in the South Carpathians and in the East Carpathian Crystalline-Mesozoic zone.

The Austrian or Meso-Cretaceous phase (between the Albian and the Cenomanian) determined the thrust of the Maramureş central crystalline massif over the Flysch zone.

The Laramian phase (the end of the Cretaceous) achieves the major structure of the Dacides. During this phase formed the Ceahlău (West-Internal) and Getic nappes overlying even Senonian deposits.

The Savian phase manifested in the Upper Oligocene-Aquitanian by movements determining the appearence of the Burdigalian salt lagoonal facies. After this phase the Carpathian domain extended outwards by its foredeep, south of the Băicoi-Moreni-Şuţa Seacă-Slătioarele-Piteşti-Ţicleni line.

The overthrust of the East-Internal (the curbicortical flysch) and Audia (the black shales) units took place in the Old Styrian phase (Burdigalian-Helvetian).

The movements during the New Styrian (the end of the Helvetian) and even intra-Tortonian phases led to the formation of the important Tarcău (medio-marginal) and marginal (external) nappes. It was then that the Upper Helvetian-Tortonian bituminous-saliferous facies appeared.

After the period corresponding to the Moldavides (the New Styrian phase) formed the big depressions (the Transylvanian Depression, the

Pannonian Depression) that take part to the structure of the Carpathian system (D u m i t r e s c u, S ă n d u l e s c u, 1968).

The Moldavian (S t i l l e, 1953) or Attian (intra-Sarmatian) phase leads to the tectonic relations along the Pericarpathian line and the latter's western equivalent, namely the Bibeşti-Tinosu fault.

The Wallachian phases, located in the Pleistocene, is responsible for the folding of the Cîndeşti gravels, the uplift of the Pericarpathian zone and the Pliocene lake silting. It constituted a very important diastrophic phase for the Romanian territory but it had a predominantly vertical (positive) character.

The diastrophic phases can be followed especially in the marginal zones of the sedimentation areas, where they better materialized by successive advances or retirements of the marine waters.

The Burdigalian and Tortonian salt rocks played an important structural-genetic part in the evolution of this region not only in the Mio-Pliocene subzone between the Buzău and the Dîmboviţa (called also "the diapir fold zone") but also in the other subzones. Thus the Burdigalian salt seems to have functioned as sliding in the overthrust fold formation in the external unit of the Paleogene flysch. The wells identified diapir folds in various evolution stages west of the Dîmboviţa, namely at Şuţa Seacă, Dragomireşti, Slătioarele, Piteşti etc.

The predominantly and continuously uplifted position of the folds with salt cores constituted "calling centers" for the hydrocarbons that were generated in the depressed adjacent zones.

According to the recent conception, which seems to be supported also by recent seismic data, the salt as well as the whole Miocene molasse in the Carpathian basement zone accumulated especially in the synclinores formed by the Paleogene deposits. As the plicative movements determined the uplift of the old anticlines, the salt molasse slid and deposited on the bottom of the synclines where it formed diapir folds. But this hypothesis has to be supported by new data, such as those obtained in 1974.

4. Conditions of Genesis, Accumulation and Preservation of Hydrocarbons

In the course of the geological history of the flysch and Carpathian Foredeep zone, a mostly terrigene, thick cover of deposits accumulated; it consists of clays, marls, sands, sandstones, conglomerates and limestone sequences. Within this strong sedimentary cover there are reservoir rocks, protecting compact formations and pelitic rocks, possibly hydrocarbon-source rocks. The geological and industrial activity developed 120 years already proved the petroleum-gas potential of the Paleogene and Neogene deposits pointing out and turning to account numerous commercial deposits. Consequently, the recent geological studies have been directed mostly to the determination of the trapping conditions.

Referring to the reservoir rocks, the Paleogene, Miocene and Pliocene rocks, developed in the zone of the Paleogene flysch and in the foredeep, therefore where they are associated with the cover rocks, are of a great importance.

The researches carried out some years ago with a view to determining the petroleum output of different formations in the flysch zone established that the gritty intercalations of the black shale series (presumed source rocks) cannot be considered reservoir rocks, as their porosity is of maximum 3.8 per cent and permeability of 0—2.45 mD.

The Eocene of the medio-marginal unit, developed in the Tarcău facies, presents banks of massive sandstone with average porosities of 12 per cent and permeabilities of 24 mD. Locally (at Ursei) the values of the physical parameters reach 20 per cent and 215 mD respectively. However, towards the exterior of the units, that is in the sense of the gradual substitution of the sandstones with limestones and marly limestones, the reservoir qualities of the Tarcău Eocene deteriorate.

The Oligocene includes reservoir rocks both in the Fusaru facies and especially in the Kliwa facies. During this period, the strong arenitic supplies, which led to the formation of the sandstone sequences (sometimes massive) with reservoir properties, alternated all the time with pelitic deposits in bituminous facies. In the Krosno-Fusaru facies, the sandstones had porosities of 2—17.6 per cent, whilst the permeabilities do not exceed 1 mD. Locally, the supply, however, can be ensured by fracturing permeability. In the Kliwa sandstone facies, there are three main terms with sandstone and microconglomerate beds, as follows : the Lucăceşti sandstone horizon, the Kliwa sandstone horizon, and the transition horizon. In certain sectors important psamitic sequences are pointed out in other terms, too, which develop in a predominantly pelitic facies : the white marl horizon, the lower menilite and dysodile horizon, and the upper menilite and dysodile horizon (the super-Kliwa complex, in the base of the last). In the medio-marginal unit, the Kliwa Oligocene reservoirs have porosities of 10—12 per cent and permeabilities of 2—60 mD. Much higher values, 30 per cent and 215 mD, have been found at Boţeşti (the Getic Depression). The Oligocene in the external unit frequently presents average porosities of 14 per cent and permeabilities of 1—100 mD. In the Carpathian bending zone, the values of the physical parameters are small ; in the zone of the Văleni-Buştenari spur they increase substantially, the porosity reaching 30 per cent and the permeability 1,300 mD.

The Burdigalian-Helvetian is also one of the members where the granular rocks with reservoir properties are strongly developed in the whole Carpathian Foredeep. Generally speaking, it may be said that the physical parameters of the Burdigalian-Helvetian reservoirs are characterized by reduced values in Moldavia and the eastern part of Muntenia and higher and higher values to the west, up to Ţicleni (in Oltenia). Thus, the Burdigalian microconglomerates have porosities of 6.3—22.5 per cent, whilst the basal Helvetian sandstones and sands present values varying from 5 to 30 per cent for porosity and from 0 to 2,500 mD for permeability.

In the Comăneşti basin and south of the Trotuş, up to the Danube, reservoir rocks with good physical properties are apt to be found in the

Buglovian-Sarmatian, too. The thickness of the Buglovian-Sarmatian sandstones and sands varies within wide limits, from 2—3 m to 105 m, according to the conditions of deposition and the intensity of the pre-Meotian denudation. The physical properties, the permeability and porosity respectively, seem to improve from the east to the west, as shown by the extreme values of 10—30 per cent and 16—668 mD.

The Meotian helds an important place among the formations with reservoir rocks, from the Carpathian bending zone up to the Danube. In the eastern part of the Mio-Pliocene subzone (Berca), the Meotian total thickness reaches about 700 m (Fig. 8, 9). It includes sands and sandstones

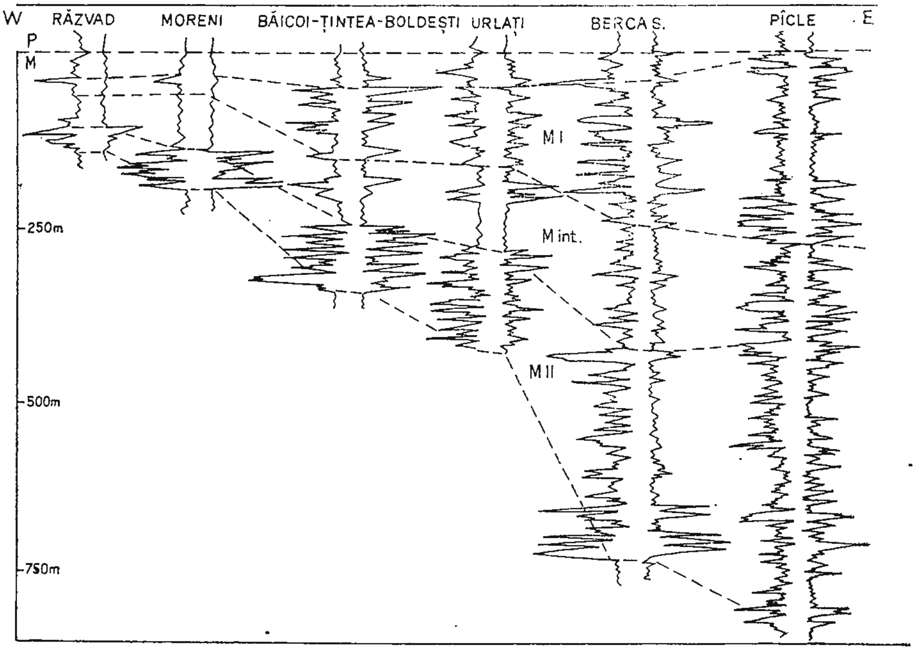

Fig. 8. — Correlation on the E-W direction of the electric log diagraph, belonging to the Meotian interval in the Mio-Pliocene subzone.

grouped into two complexes which totalize 27 beds. To the west, the Meotian thickness is continuously reduced, so that at Boldeşti it has 300—400 m; the sands are grouped into three complexes, called M I, M int. and M II. The same thickness and reservoir grouping is found at Moreni-Gura Ocniţei, where M III corresponds, in fact, to the complex M II at Băicoi. From here up to the meridian Ochiuri-Răzvad westwards, the Meotian thickness decreases gradually so that in the maximum elevation zone of the Piteşti-Slătioarele anticlinorium this substage does not occur. However, it has been pointed out on the flanks of the anticlinorium. To the west, up to Oltenia, the Meotian reaches again 400 m in thickness.

The reservoirs of this substage have porosities of 8—40 per cent and permeabilities of 2—3,500 mD.

The Pontian consists of psamitic intercalations, particularly in the Carpathian bending zone where it proved to be productive just as west of the Dîmbovița, on the Vața and Slătioarele structures.

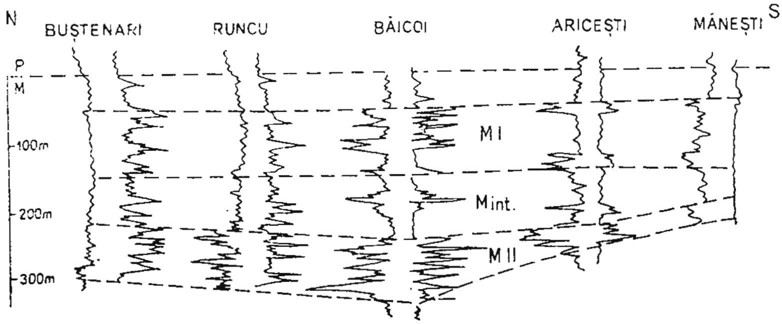

Fig. 9. — Correlation on the N—S direction of the electric log diagraph, belonging to the Meotian interval in the Mio-Pliocene subzone.

The Dacian offers numerous sandstone and sand beds, those located in the base having better conditions of protection. In their zone of upmost interest (Moreni), the Dacian reservoirs have been grouped into the complexes Dräder, Moreni, group II, and group I (Fig. 10). The values of the Dacian sand porosities do not substantially exceed those of the older formations, namely 20—40 per cent, and the permeability is 0.1—412 mD.

The Levantine also includes numerous sandy sequences which, however, are protected by impermeable covers only in places.

The Eocene, Oligocene, Miocene and Pliocene reservoirs are surrounded by horizons made up of compact rocks which can form protecting covers. Thus, the Eocene sandstones are overlain by the Plopu beds and the Lucăcești sandstone horizon is overlain by the horizon of the bituminous, white marls and the lower menilites ; the Kliwa sandstone horizon and the super-Kliwa complex are overlain by the menilite and the upper dysodile horizon; the transition horizon is overlain by the deposits of the medio-marginal nappe. The Burdigalian microconglomerates, the Tescani beds sandstones and, locally, those of the Cîmpeni series are assigned to the pelitic horizons of the respective formations, followed by the mostly pelitic, Helvetian grey series. In the absence of the latter, the protecting cover can be formed by the Tortonian evaporites or directly by the Meotian and Pontian marls. Screens with local or regional developments are apt to be found in the Sarmatian, as well. The reservoirs in the Pliocene base are always protected by the Meotian marly horizon as well as by the almost pelitic Pontian. In the Dacian, the impermeable cover is represented by the marly-clayey complex but, as mentioned before, they are tight only on limited areas, as in the Levantine.

With regard to the hydrocarbon source rocks, the black shales and the Streiu beds have to be mentioned firstly. Older source formations are not out of question but against the stratigraphic and structural background of the Paleogene flysch and of the foredeep, further discussion would be purely theoretical. According to the recent studies, the black shales are characterized by an organic carbon content of about 0.67—3.12 per cent,

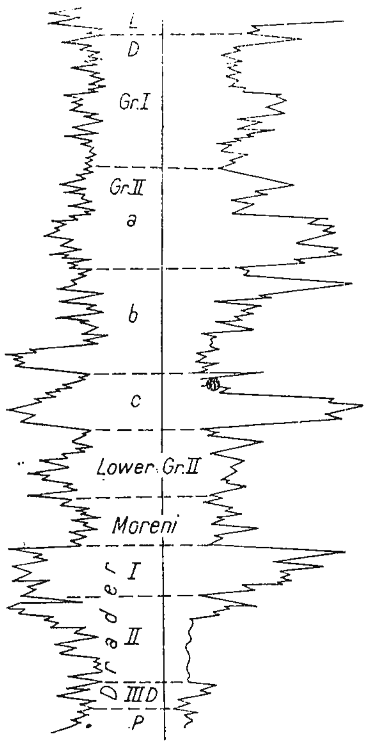

Fig. 10. — Representative profile of the Dacian in the Mio-Pliocene subzone.

on an average of 1.7 per cent, a total sulphur up to 1 per cent, the Trask reducing power of 1 per cent, as well as by a hydrocarbon content of 74.9—572 p p m. In the pelitic intercalations of the Tarcău gritty series, the organic carbon does not exceed 0.03—0.19 per cent. It is worth mentioning that neither in the Krosno-Fusaru beds, nor in the Bisericani beds there are better geochemical indices.

Almost all the Romanian and foreign geologists, who dealt in one way or another with the petroliferous problems of the Carpathian flysch and foredeep, consider that the Oligocene pelitic horizons in the Kliwa sandstone facies, the bituminous, white marls respectively, the lower and upper menilites and dysodiles constitute source rocks. These premises have been confirmed by the results of the subsequent geochemical analyses, rendered in Table 2.

At first, the Aquitanian was considered the main source formation in the Neogene zone. The minute studies carried out later pointed out that, due to the reduced volume of bituminous rocks, the Aquitanian had only a secondary contribution to the formation of the hydrocarbon deposits.

The Helvetian pelites of the grey upper series can be included among the mother rocks. They contain 0.06—0.65 per cent organic carbon, the Trask reducing power is 0.35 per cent, and the content in soluble organic matter is of 0.37 per cent. Nickel and vanadium are also present. Besides the above-mentioned pelites, one has to consider the Radiolarian shale horizon of the Tortonian constituted of schistose, bituminous clays, similar, from the petrographic and geochemical point of view, to the Oligocene dysodile schists.

The question of the origin of the Pliocene hydrocarbons seems to have been cleared up by the complex analyses and studies carried out recently (Anton, 1973), according to which the petroleum and gas of the Meotian, Pontian and Dacian occur in the source formations. The main geochemical indices of the Meotian, Pontian and Dacian are given in Table 2.

The studies on the temperature distribution in the basement of the structural units of interest for hydrocarbons (Paraschiv, Cristian, 1976) show that, within the zone of the Carpathian flysch and foredeep, the geothermal gradient exceeds the normal value, being situated between 3.5—5° C/100 m. Most of the deposits are placed between the curves of 3.5—4.5° C/100 m. Temperature seems to increase towards the margins of the region as the metamorphic basement rises, therefore simultaneously with the reduction of the thickness of the sedimentary deposits.

The relatively high values of the temperature gradient and the thermal effect of the tangential and halokinetic movements constituted a background favourable for the hydrocarbon generation, migration and accumulation.

The waters associated to petroleum and gas, found in the bore-holes, have different characteristics according to the geological formation, the depth and the paleogeographic evolution of the respective region. As a result, in the East Carpathian flysch and the Carpathian Foredeep there are all kinds of waters, from waters pointing to a stabilized hydrodynamic regime (chlorocalcic, chloromagnesian) and to infiltration waters (sulphate-sodic and bicarbonate-sodic).

The chlorosodic waters, with mineralizations of 25—180 g/l, predominate in the Neogene flysch zone. Bicarbonate-sodic waters have been pointed out near by the half-windows or in the Sarmatian of the Comănești basin.

In the Miocene subzone of the foredeep, where the deposits are well protected, there are only chlorocalcic waters with mineralizations of 50—230 g/l.

TA

Results of the geochemical analyses carried
(according to

Formation	Lithologic character	Organic carbon	Bitumen A[1]	Bitumen C[1]	Asphaltenes[1]	Hydrocarbons[1]
Dacian	Clayey marls	0.09—0.30	0.01—0.06	0.01—0.05	6—10	30—42
Pontian	Marls	0.50—0.98	0.02—0.14	0.01—0.05	8—27	20—65
	Marly clays	0.45—0.74	0.03—0.46	0.01—0.02	16—26	36—60
	Limy Siltstones	0.29—0.39	0.02—0.03	0.02—0.03	10—15	25—32
Meotian	Marls	0.35—0.50	0.05—0.08	0.02—0.04	10—15	45—61
	Clayey marls	0.31—0.95	0.02—0.06	0.01—0.04	4—3.0	30—37
	Marls and marly siltstones	0.34—1.04	0.03—0.05	0.01—0.02	25—26	28—74
	Marly siltstones	0.25—1.4	0.06—0.08	0.01—0.02	6—27	53—68
Oligocene	Clays	0.36—2.50	0.03—1.98	0.01—0.50	12.3—48.0	32.2—62.8
	Limy and dolomite argillites	0.15—7.65	0.02—0.75	0.02—0.37	10.9—42.5	31.9—60.8
	Siliceous siltstones	0.10—2.25	0.01—0.25	0.01—0.06	3.5—38.6	30.0—64.0

1, per cent; 2, milligrams oxide/100 g rock.

The Mio-Pliocene subzone, intensely fragmented tectonically, contains all types of water particularly in the northern (internal) part. The chlorocalcic waters are the most frequent ones. The mineralization varies from 5 to 200 g/l in the Dacian, from 70 to 115 g/l in the Pontian, from 9 to 350 g/l in the Meotian, from 31 to 242 g/l in the Sarmatian, and from 130 to 300 g/l in the Helvetian.

In the Getic Depression all types of water occur but the bicarbonate-sodic and sulphato-sodic waters have a much more reduced share as compared with the Mio-Pliocene subzone.

BLE 2

out on Pliocene and Oligocene rocks
S. Anton)

Nonhydro-carbons[1]	Total S / S from sulphates	Total Fe / FeO[1]	CRo[2]	CRm[2]	Trask	pH
45–54	0.01–0.06 / 0.01–0.06	4–5.5 / 1–4.5	0.49–6.49	2.50–2.60	0.25–0.70	8.6
26–73	0.04–0.12 / 0.04–0.18	4.65–6.3 / 1.2–2.3	0.28–1.77	1.19–3.61	0.30–0.92	8.4–8.5
33–59	0.01–0.08 / 0.01–0.08	4.3–5.6 / 1.9–2.3	0.39–3.18	1.69–3.18	0.69–0.97	8.5
46–59	0.04–0.06 / 0.02–0.04	4.1–4.9 / 2–2.5	1.7–2.9	3–3.4	0.40–0.50	8.6
25–50	0.07–0.10 / 0.06–0.08	2.5–3.2 / 1.3–1.5	1.30–4.5	2.8–5.3	0.30–1.40	8.6
53–67	0.02–0.07 / 0.01–0.06	6.34–8.56 / 2.5–3.7	1.72–2.48	0.72–1.26	0.18–0.56	9.7–8.8
23–65	0.07–0.14 / 0.01–0.09	4.4–7.4 / 1.8–2.6	1.86–3.60	1.35–2.68	0.75–1.21	8.7–8.9
37–45	0.08–0.12 / 0.04–0.06	1.68–3.79 / 1.2–1.6	1.12–3.12	2.40–4.08	0.40–0.67	8.3–8.6
33.8–64.9	0.06–5.73 / 0.01–0.74	2.91–8.96 / 0.2–3	1.15–18.62	0.65–11.80	0.39–4	2.7–9.7
37.9–63.8	0.08–4.60 / 0–0.85	1.6–5.8 / 0.03–0.7	0.38–12.88	0.25–14.70	1.5–3.5	7.1–9.7
35.0–67.5	0.02–2.18 / 0–0.19	0.91–6.10 / 0.03–0.8	0.52–11.20	0.11–12.96	1–4.8	4.5–9.2

5. Hydrocarbon Deposits

In the area delimited by the Crystalline-Mesozoic zone and the Foreland petroleum and gas deposits are apt to be found both in the Paleogene flysch zone and in the Carpathian Foredeep.

a) **Paleogene Flysch Zone.** With the exception of accumulations of a less importance the deposits of the Paleogene flysch zone are grouped in the Tazlău-Moinești-Slănic zone, delimited by the Tazlăul Mare Valley to the north and by the Cașin Valley to the south. Here, the productive structures occur in the external unit, the medio-marginal unit and the Comănești basin. Among them, the external unit includes the most important hydrocarbon accumulations. In this unit, the bituminous, white marls, the Oligocene dysodiles and menilites are considered the main source rocks. The reservoirs are represented by the Lucăceşti sandstone, the Kliwa sandstone, the transition horizon, and less by the horizons of the bituminous, white marls, the lower and upper menilites. The productive structures occur as normal and overthrust folds disposed in parallels and trending from the north to the south. The medio-marginal nappe, when not eroded, constitutes a very good cover for the accumulations of the external unit Oligocene.

The study of the deposit distribution between the Bistriţa and the Slănic-Oituz half-windows (Fig. 11) indicates that they appear along six,

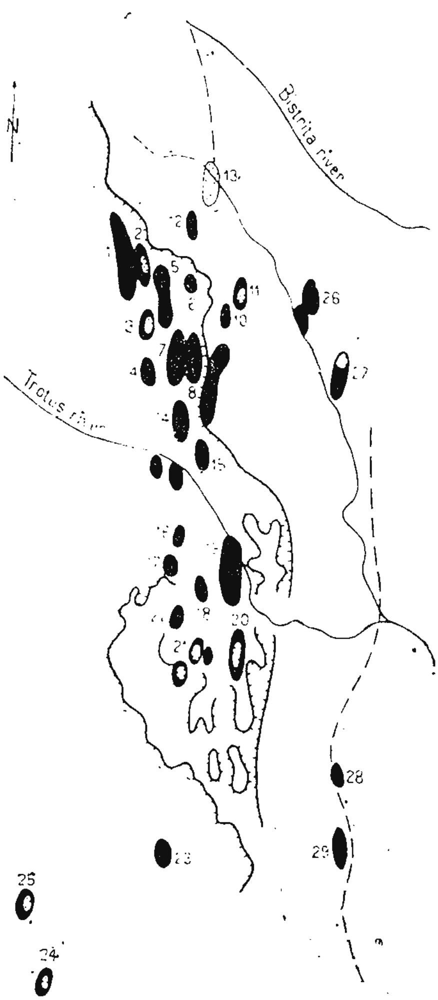

Fig. 11. — Distribution of hydrocarbon deposits in the Paleogene flysch zone and in the Miocene subzone in Moldavia. 1, Geamăna ; 2, Gropile lui Zaharache ; 3, Chilii W ; 4, Taşbuga, ; 5, Toporu-Chilii ; 6, Arşiţa ; 7, Zemeş-Cilioaia ; 8, Foale-Moineşti ; 9, Uture-Moineşti town ; 10, Cucueţi ; 11, Mihoc ; 12, Frumoasa ; 13, Tazlăul Mare ; 14, Comăneşti ; 15, Văsieşti ; 16, Dărmăneşti W ; 17, Dofteniţa ; 18, Păcuriţa ; 19, Dofteana-Bogata ; 20, Slănic-Ferăstrău ; 21 Cerdac ; 22, Slănic-Băi ; 23, Lepşa ; 24, Ghelinţa 25, Ojdula ; 26, Cîmpeni ; 27, Tescani ; 28, Caşin ; 29, Cîmpuri.

major alignments: I, Geamăna; II, Gropile lui Zaharache, Chilii W, Taşbuga; III, Toporu-Chilii-Cilioaia W; IV, Zemeş-Cilioaia, Moineşti W; V, Arşiţa, Foale-Tazlău-Moineşti, Văsieşti; VI, Tazlăul Mare, Mihoc, Cucueţi, Solonţ-Moineşti town, Văsieşti.

The above-mentioned productive structures, situated between the Bistriţa half-window to the north and the Oituz-Slănic to the south, could also be classified, according to their mode of concentration around the major uplift zones, into two accumulations subzones. The former corresponds to the southern margin of the Bistriţa half-window where the deposits Geamăna, Gropile lui Zaharache, Chilii W, Taşbuga, Toporu, Arşiţa, Zemeş, Foale, Moineşti, Moineşti-Solonţ, Cucueţi, Mihoc, Frumoasa and Tazlăul Mare have been found under the marginal nappe. The latter is situated on the northern margin of the Oituz-Slănic half-window and includes the accumulations Slănic-Băi, Cerdac, Slănic-Ferăstrău, Dofteana-Bogata, Păcuriţa and Dofteniţa (Fig. 11). Between these two uplift zones there is the Comăneşti Sarmatian basin which overlies both the parautochthon and the medio-marginal unit. Within this basin, the petroleum is produced by the Comăneşti, Văsieşti and Dărmăneşti W structural elements. South of the Slănic-Oituz half-window appears the Lepşa accumulation. West of the above-mentioned productive subzones, also within the external unit, petroleum and gas deposits have been pointed out at Ghelinţa and Ojdula fields.

In the Moldavian petroliferous region, hydrocarbon accumulations of a less importance have been found in the medio-marginal unit in the Zemeş, Geamăna, Comăneşti, Văsieşti, Păcuriţa and Dofteana-Bogata structures. They occur in the Eocene Tarcău sandstones, the Lucăceşti sandstone (Podei), as well as in the Oligocene Kliwa sandstones (Dofteana-Bogata).

Petroleum and gas deposits of a less importance are also found on some structures in the Eocene and Oligocene of the flysch zone in Muntenia, at Cătiaşu, Poseşti, Vîrfuri-Vişineşti, Cosminele, etc.

The objectives of interest in the external unit in the nappe or in the Miocene of the Comăneşti basin are sometimes productive within the same structural elements and form common deposits. Therefore, the review of the petroleum and gas deposits should begin with the structures of the external unit as about 90 per cent of the hydrocarbon volume is found in the Oligocene of the before-mentioned unit.

The Geamăna structure (1, Fig. 11) represents the northernmost oil field in the Tazlău-Slănic sector of the Moldavian Paleogene flysch. The numerous wells drilled here first crossed the medio-marginal nappe and then penetrated the Miocene, Oligocene and Eocene of the external unit. The Lower Eocene covers the facies of the Doamna beds and the Upper Eocene that of the Bisericani beds. The Oligocene develops in the normal succession, being constituted (from bottom to top) of the Lucăceşti sandstone, the lower menilites and the bituminous white marls, the lower dysodiles, the Kliwa sandstone, the upper dysodiles and menilites, as well as the Gura Şoimului beds (the transition horizon). The Miocene is represented by the salt formation.

The Geamăna structural element has a shape of an overthrust fold, trending N—S with a deviation to the E. At the same time, this fold is affected by a lot of transversal and longitudinal faults which divide it into more than 40 tectonic blocks (Fig. 12).

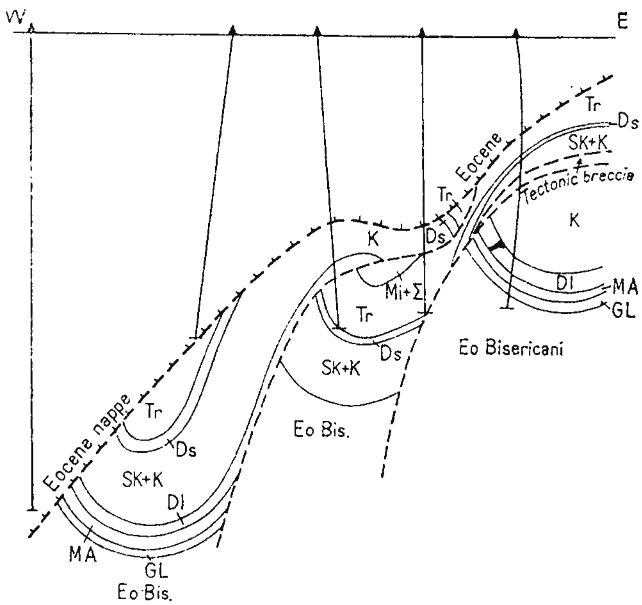

Fig. 12. — Geological section through the Geamăna S-Zemeş W structure (according to I. M a t e i).

The saturated reservoirs consist of sandstones belonging to the Kliwa horizon, the transition horizon (the "super-Kliwa" term inclusively) and the nappe Eocene, the last one at the contact with the Oligocene productive complexes. The traps are of the structural or mixed type (stratigraphic-structural); the deposits can be massive, stratiform or tectonically screened.

The thickness of the saturated sandstones varies from 1.3 to 85.9 m, the average porosity of various sandy horizons is of 14—25 per cent, the permeability (the fissural permeability inclusively) of about 25 mD, the initial pressure 77 kgf/cm^2 and the saturation pressure 67 kgf/cm^2. The petroleum specific gravity is 0.830 kgf/dm^3 in the transition horizon.

The Gropile lui Zaharache structure (2, Fig. 11), situated south of the Bistriţa half-window, is delimited by the Geamăna scale to the west and by the Toporu anticline to the east. The existence of this structure, as well as of the other folds and overthrust folds with hydrocarbons, has been established by means of the deep-drillings, starting from the tectonic style, the frequency and direction of the folds found in half-windows where the external unit outcrops.

The stratigraphic sequence under the medio-marginal nappe, with small variations of facies and thickness, is common to all the structures of the external unit :

— the horizon of the Lucăceşti sandstone, 25—30 m thick ;

— the horizon of the white marls and lower menilites (20—80 m), with intercalations of dysodiles and hard siliceous sandstones ;

— the horizon of the lower dysodiles, 30—100 m thick ;

— the horizon of the Kliwa sandstone 210—350 m thick, consisting of an alternation of white or white-rusty siliceous sandstones and dysodile schists ;

— the horizon of the upper dysodiles and menilites (60—80 m), with sandstone intercalations ;

— the transition horizon, constituted of microconglomerates, limy, siliceous sandstones (the Kliwa type), clays and dysodiles. The horizon has variable thicknesses probably due to the pre-Tortonian erosion.

The Gropile lui Zaharache structure occurs as an asymmetrical anticline, striking N—S and overthrust to the east. The western flank of this anticline is overthrust by the Geamăna scale. This structure is crossed by numerous transversal and longitudinal faults. Along the faults trending N—S, it is worth mentioning the one in the eastern flank, along which the axial zone overthrusts the eastern syncline as well as the fault that separates the axial zone from the rest of the western flank.

The hydrocarbon accumulations are located in the transition horizon, the horizon of the upper dysodiles as well as the horizon of the Kliwa sandstone, in the eastern zone. In the western zone, yield the "hard series" and the "sandy series", probable equivalents of the transition horizon. In the horizon of the Kliwa sandstone (block E_3) one can notice free gas accumulations. The other objectives of interest yield petroleum and gas from depths varying from one block to another.

The main parameters of the rocks with reservoir properties are characterized by the average values, as follows : porosity 6—13 per cent, permeability 0.1—18.4 mD, connate water saturation 35—40 per cent. The minimum values of porosity and permeability are specific to the hard series, whilst the maximum values, to the Kliwa sandstone. The initial pressure gradient of the deposit is of 8.3 kgf/cm^2/100 m, and the temperature gradient of 3.5°C/100 m. The lithological and structural factors (variation of porosity and permeability) contributed to the formation of the traps in this zone.

The Chilii W anticline (3, Fig. 11) belongs to the same structural alignment as the Gropile lui Zaharache scale, the former being located south of the latter.

In the stratigraphic sequence one can notice the reduction of the thickness up to the disappearance of the transition horizon and even of the Kliwa sandstone in the southern part of the fold, probably as a result of the erosion preceding the emplacement of the medio-marginal nappe.

The structure represents an asymmetric anticline, with an eastern vergence, which overthrusts the Toporu fold along a longitudinal fault. Transversely, it has been pointed out the presence of at least four faults which divide the structure into four blocks.

The bore-holes drilled at Chilii W indicated hydrocarbon accumulations in the Lucăceşti sandstone, the white marls, the Kliwa sandstone and the transition horizon, where the last two terms are to be found. According to the exploitation data, it seems that the four productive horizons constitute two distinct hydrodynamic units; the former corresponds to the Lucăceşti sandstone and the white marls and the latter to the Kliwa sandstones and the transition horizon. The reservoirs belonging to the lower hydrodynamic unit contain petroleum and dissolved gas, whilst those pertaining to the upper hydrodynamic unit, petroleum with primary gas cap. The traps are of the structural type and only to a less extent of the mixed type (structural-stratigraphic).

The really saturated thickness of the productive horizons varies from 7.5 to 77.7 m. The average porosity is of 14.2 per cent, except the transition horizon which has 10 per cent. The connate water saturation reaches 40 per cent in the transition horizon and 35 per cent in the other complexes. The factor of the volume reduction is 1.12, the petroleum specific gravity 0.872 kgf/dm^3, and the initial pressure 100 kgf/cm^2.

The Taşbuga structure (4, Fig. 11) develops south of the Chilii W anticline, within the same alignment, which starts from Gropile lui Zaharache.

In the stratigraphic sequence of the external units the Oligocene is sometimes missing, so that, due probably to the erosion preceding the formation of the medio-marginal nappe, the Eocene of this unit contacts directly the Eocene of the par-autochthon.

The tectonic style of the structure can be, in general, compared with that of the other folds in the region, with the difference that here the degree of complication is marked. At one time, in the northern sector of Taşbuga three scale-folds seem to superpose (Fig. 13), among which the first two upper scales are productive. In the southernmost part, known as "the Asău structure", only a single scale is productive.

Up to now, petroleum accumulations have been identified only in the Kliwa sandstone horizon and the transition horizon; these two objectives seem to constitute separate hydrodynamic units.

The Toporu-Chilii anticline (5, Fig. 11) appears in the Bistriţa half-window and continues south of it, under the overthrust of the medio-marginal unit.

The Oligocene of the external unit, corresponding to the Toporu-Chilii structure, much pushed eastwards, lies between the overthrust ssurface of the medio-marginal nappe and the surface along which this scale overthrusts the eastern (Zemeş) structure. As a result, in different sectors of the structure the development of the Oligocene horizons is not uniform, being not found, in general, in the lower terms (Lucăceşti sandstone, white marls and lower dysodile) and partly or totally absent in the transition horizon. The structural image of this zone is also complicated enough, sometimes impossible to be rendered.

Since 1952, hydrocarbon accumulations have been pointed out in the transition horizon and locally in the upper menilites. The mediocre physical parameters of the reservoir are reflected in the weak behaviour of the wells (very small petroleum production). The discontinuity of the productive zone is added to the above-mentioned facts.

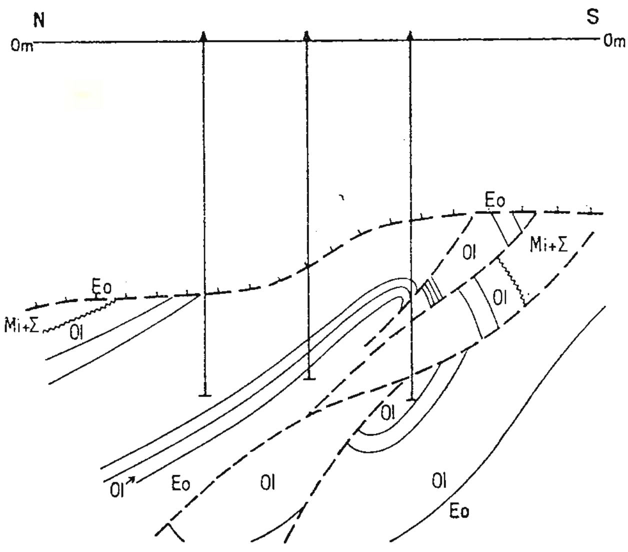

Fig. 13. — Geological section through the Taşbuga structure (according to P. Albu).

The Arşiţa productive structure (6, Fig. 11) develops immediately south of the Bistriţa half-window and continues, under the medio-marginal nappe, with the Foale-Tazlău productive zone.

The Oligocene deposits appear as an asymmetric fold, trending NNW—SSE, with the western flank descending strongly and intercepted under the Toporu-Chilii structure overthrust and the eastern flank faulted. The above-mentioned fold is affected by several longitudinal and transversal faults.

The production tests carried out at several wells indicated the existence of hydrocarbon accumulations in the Kliwa sandstone horizon and the transition horizon, the super-Kliwa term, inclusively. The latter contains petroleum with primary gas cap, and the former, petroleum and dissolved gas. The traps are of the structural type.

The reservoir thickness ranges between 11—50 m, the average porosity between 13—15 per cent, connate water saturation between 35—40 per cent, the factor of the volume reduction 1.1, the petroleum density 0.886 kgf/dm^3.

The Zemeş-Cilioaia E structure (7, Fig. 11) attracted the geologists' attention on the petroleum natural occurrences since the last century. The petroleum exploitation by wells started in 1905, the "autochthonous" Oligocene being the main objective. Beginning with 1959, in the central-western part of the Zemeş oil field there have been carried out several additional tests of the transition horizons and then of the Oligocene overlying the tectonic breccia, a new productive scale being determined. In this way, under the medio-marginal nappe two productive scales have been defined, a lower one corresponding to the Zemeş structure and an upper scale representing the Cilioaia E fold-scale (Fig. 14).

The Zemeş structure is constituted, from bottom to top, of the horizon of the lower menilites and white marls (100 m), also called K_4; the Kliwa sandstone horizon, divided into K_1, K_2 and K_3 complexes, characterized by marked lithologic and thickness variations; the upper menilite horizon with frequent sandstone intercalations at the upper part, and the transition horizon. It follows the Cilioaia E scale which starts with a mostly sandy complex (about 200 m thick), called the Oligocene II horizon. The Eocene I deposits, predominantly pelitic, and the Oligocene I horizon, constituted of Kliwa sandstone banks, separated by compact dysodile intercalations, overthrust the Oligocene II horizon (Fig. 15). The Cilioaia E scale is overlain by the medio-marginal nappe.

The two scales mentioned above are affected by longitudinal and transversal faults, which divide them into several tectonic blocks.

In the Zemeş scale, the fluid hydrocarbons accumulated in the Kliwa horizon and the transition horizon; in the Cilioaia scale, the hydrocarbon deposits occur in the Oligocene II and Oligocene I.

The average parameters of the deposits have the following values: the effective average porosity 14 per cent, connate water saturation 35 per cent; petroleum specific gravity 0.873 (Zemeş) — 0.865 kgf/dm^3 (Cilioaia), volume reduction factor 1.05, solution ratio at the saturation pressure 50.5 NMc/cm. At Zemeş, the Kliwa sandstone horizon is exploited with water injection; the other members are productive under dissolved gas conditions.

The Foale-Tazlău-Moineşti structure (8, Fig. 11) is one of the old petroleum field in Moldavia. The first petroleum drillings have been achieved here since 1912. There followed geophysical prospecting works with a view to the structure determination by magnetometric, gravimetric and seismic methods.

The Foale stratigraphic succession does not rise difficult problems as compared with the Oligocene classic profile in the external unit. This structure represents an overthrust fold (Fig. 16), 12 km in length and 2 km in width. It trends N—S and is deviated eastwards. The Foale-Tazlău-Moineşti structure is separated from the neighbouring folds by longitudinal

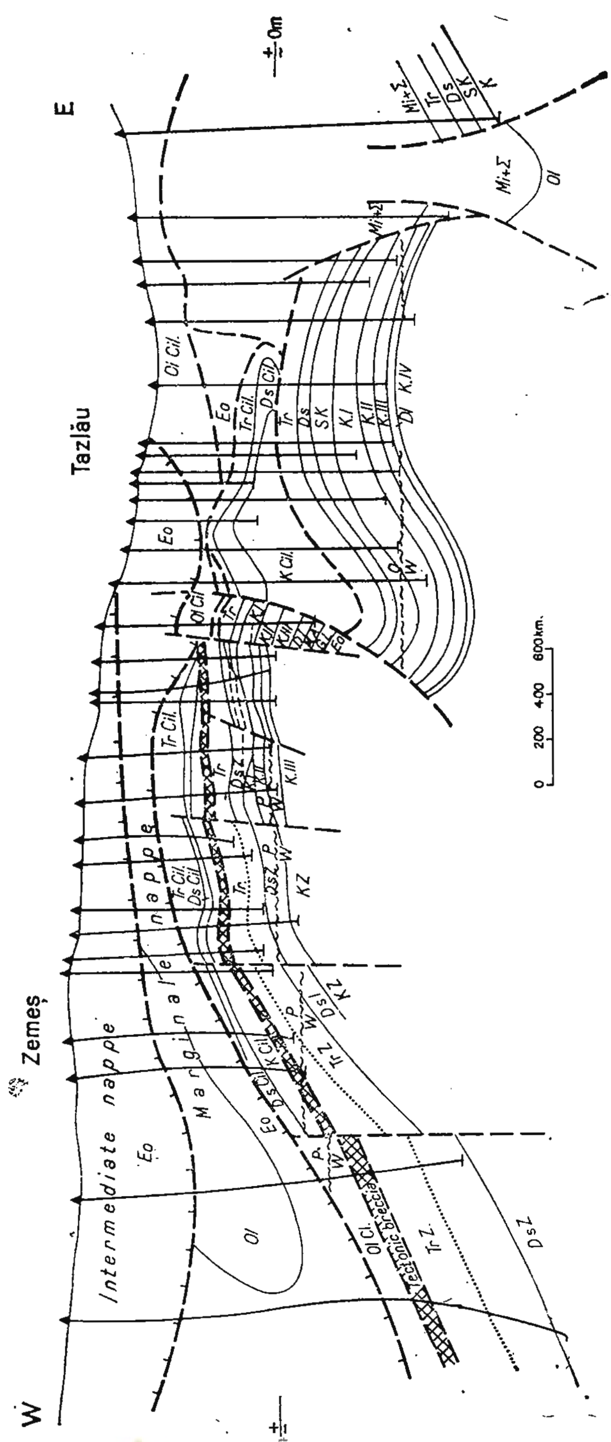

Fig. 14. — Geological section through the Zemeș-Cilioala and Tazlău structures (according to G h. G i u r g i u).

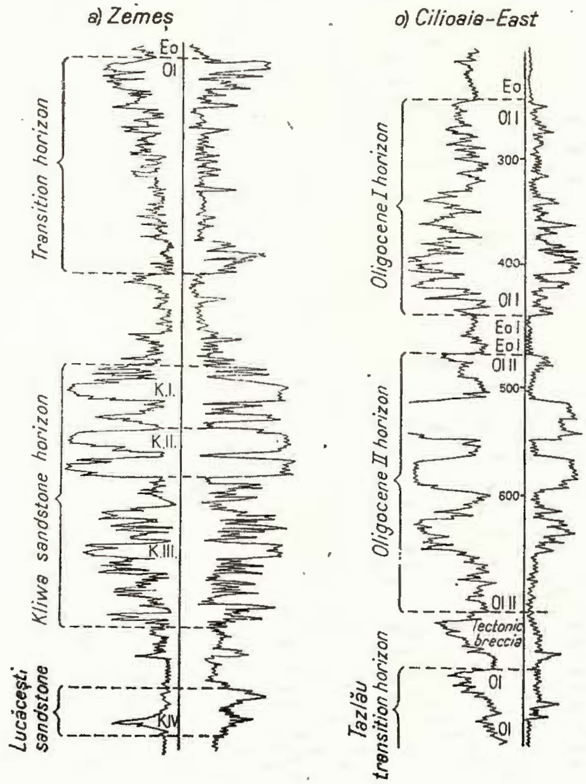

Fig. 15. — Zemeş- Cilioaia structure. Oligocene and Eocene type profiles (according to Gh. Giurgiu et al.).

faults. The dips vary within wide limits, from 10° on the western flank to about 40° on the eastern one. Apart from the longitudinal faults there are numerous transversal faults, some of them with a tight character.

The fluid hydrocarbons are located in the Eocene of the Doamna beds (well 101), the Lucăceşti sandstone, in the lower menilites and white marls (K_4), the Kliwa sandstone horizon with its three complexes K_1 K_2, K_3, the super-Kliwa complex, as well as the transition horizon. Except complex IV at Foale and Tazlău, the water-petroleum contact has the same isobathic value. In the zones with dysodile intercalations better developed in thickness and horizontally (Pietrosu zone) the respective accumulation behaved as a stratified deposit, pointing out the lithofacial variation in all directions.

The average porosity is 14—15 per cent, permeability 21.6 mD, connate water saturation 35 per cent, deposit pressure 93—132 kgf/cm². The formation waters are chlorocalcic, with concentrations of 14—128 g/l. The geothermal gradient is 2.1°C/100 m.

The deposit regime and the exploitation methods are different. There are horizons and blocks which continue to be productive under con-

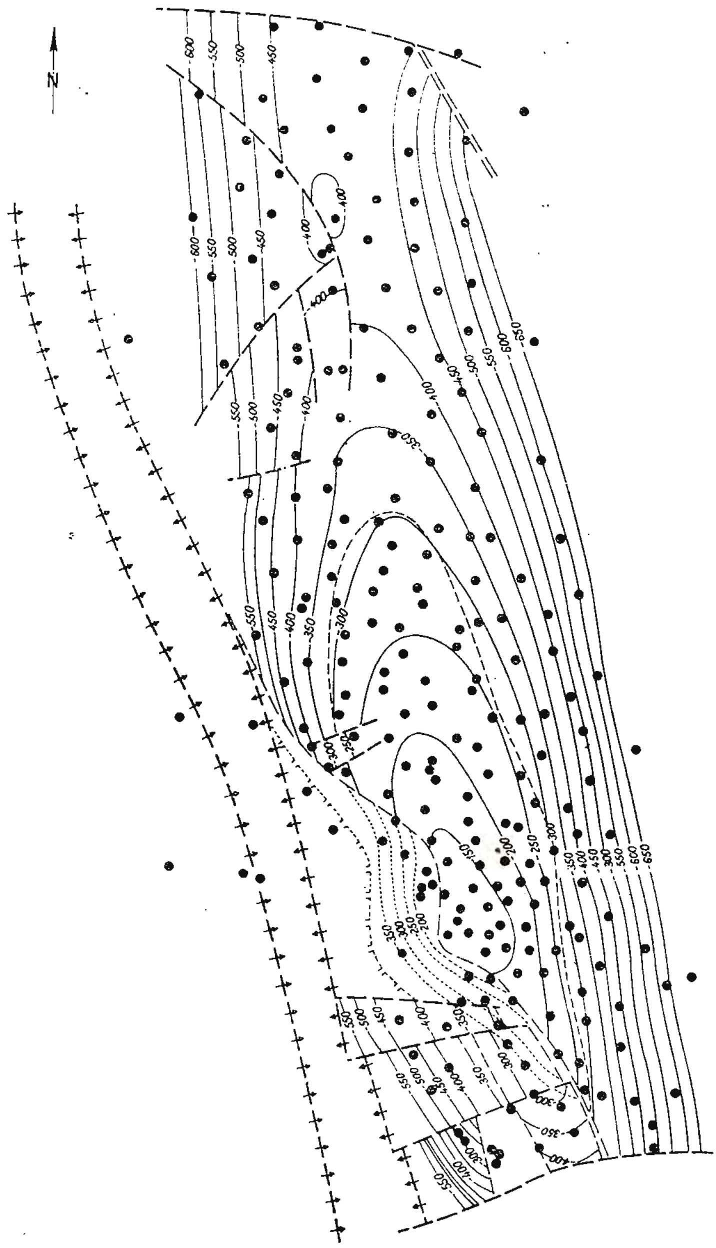

Fig. 16. — Foale-Moinești structure. Structural map at the top of Kliwa sandstone (according to Tr. Mocuța et al.).

ditions of dissolved gas; others reacted favourably when processes of water or gas injections have been applied.

The Uture-Moinești town structure (9, Fig. 11) belongs to a regional alignment which begins with the Tazlăul Mare anticline in the Bistrița half-window and continues to the south beyond Văsiești. To the same effect, the respective alignment sinks continuously after several ruptural accidents. The Uture-Moinești structural element has been prospected by means of geological research, gravimetry, magnetometry and seismometry.

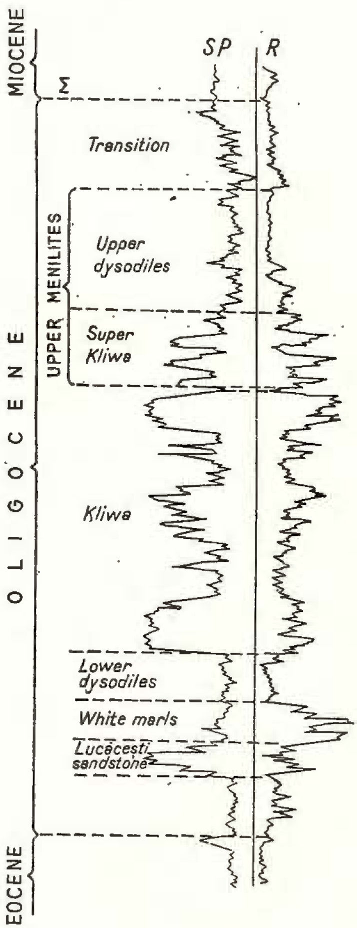

Fig. 17. — Oligocene type profile in the Stănești-Modîrzău zone (Uture-Moinești town structure).

The autochthonous Oligocene presents significant lithologic and thickness variations, both at the level of the Kliwa sandstone and the transition horizon. The stratigraphic sequence does not differ from that known in this region (Fig. 17), the only differences concern the thickness.

Thus, the Lucăceşti sandstone is reduced to a thickness of 10—20 m, the white marls to 60—80 m, the lower dysodiles horizon to 20—70 m. The Kliwa sandstone occurs as banks 1—10 m thick totalizing 110—250 m. The super-Kliwa horizon, developed against that of the upper dysodiles, in their base, varies from 30 to 80 m. The upper dysodiles reach maximum 130 m. The transition horizon, which is missing in some zones, may reach 50 m.

The Uture-Moineşti town structure represents an anticlinal (Fig. 18) trending N—S, parallel to the Foale-Tazlău-Moineşti overthrust from which it is separated by a longitudinal tectonic accident. Seven more important faults have been identified in this region, which divide the structure and determine its sinking from the north to the south.

In the Uture-Moineşti town sector, the Eocene of the Doamna beds (wells 1300, 1302), the Kliwa sandstone and the transition horizon yield petroleum and gas. The water-petroleum and gas-petroleum contacts differ from one zone to another and even within the same zone.

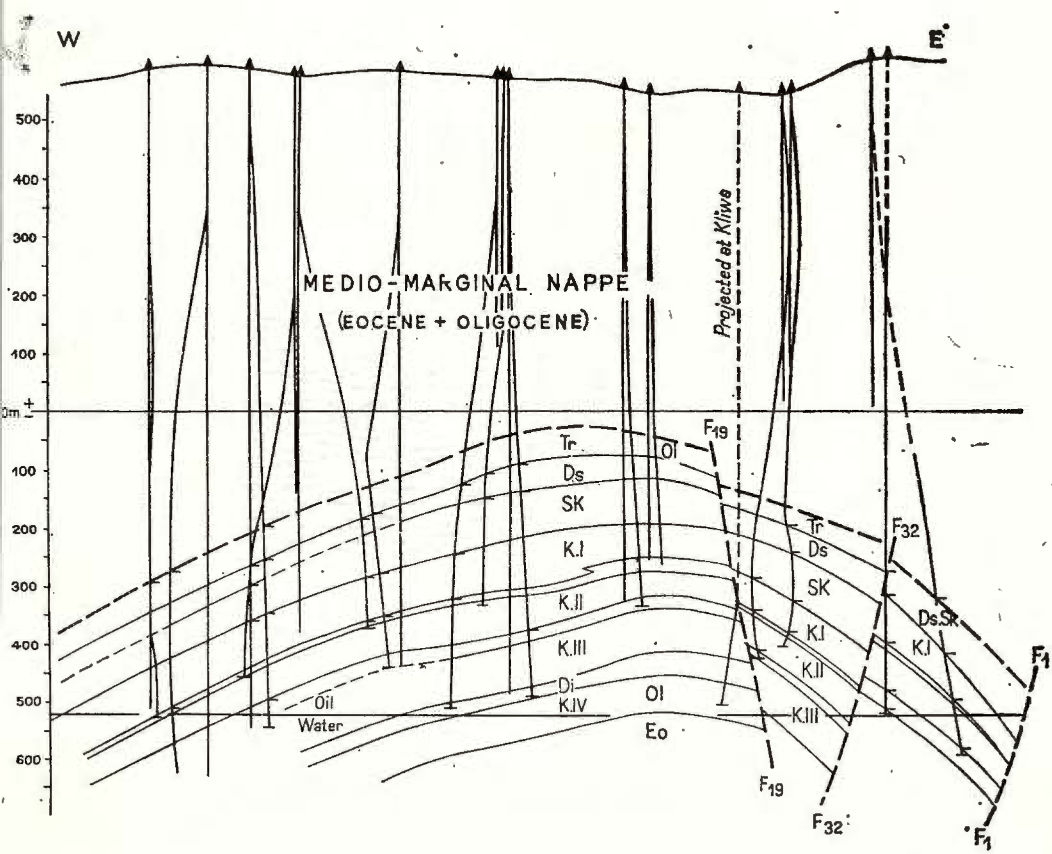

Fig. 18. — Geological section on the Uture-Moineşti town structure (according to C. M o i s e).

The effective saturated thickness of the reservoirs varies from 9.1 to 61.8 m ; the average porosity is 15 per cent, connate water saturation 38 per cent, volume reduction factor 1.12—1.26, petroleum specific density 0.840—0.880 kgf/dm^3, initial pressure 85—210 kgf/cm^2, geothermal gradient 4°C/100 m (Stăneşti)—2.2°C/100 m (Moineşti). The deposits are in an advanced stage of exploitation.

The Cucueţi oil field (10, Fig. 11) is placed in the northern prolongation of the Uture-Moineşti town structure and overlies a positive culmination of the same major alignment. As a result, the stratigraphic succession and the lithofacial aspects are relatively similar. However, the structure seems to be formed of two parallel undulations, separated by a longitudinal fault.

The hydrocarbons are located in the transition horizon, proved to produce petroleum since 1955. The deposit protection is ensured by a tar plug formed in the place where the transition horizon outcrops. The working of the Cucueţi accumulation has been achieved by two wells.

The hydrocarbon saturated average thickness of the reservoir is of 13 m. Porosity is 15 per cent, connate water saturation 38 per cent, volume reduction factor 1.12, petroleum specific density 0.840 kgf/dm^3. The trap is of the paleogeomorphic type.

The Mihoc structure (11, Fig. 11) represents a culmination within the Tazlăul Mare-Mihoc-Uture-Moineşti town major alignment. This structure, situated in the outcropping zone of the external unit, has been researched by geological mappings, geophysical prospections and drillings. The first productive well was drilled in 1956.

The Oligocene of the external unit is constituted of the terms described for the structures mentioned before. At Mihoc, however, one can notice a reduction of the Kliwa sandstone thickness due either to the thickening of the lower dysodile complex towards NE or to the development of the upper menilite horizon towards S. The Miocene, which also constitutes the protective cover of the Oligocene reservoirs, is formed of compact clays and marls, intercalations of sandstone and salt-bearing breccia, in the base.

The Mihoc structure occurs as an anticline, slightly bent to the east, with the eastern (external) flank sunk along an important tectonic accident. This anticline is crossed by transversal faults that divide it into six blocks. The faults are not impervious.

The bore-holes drilled up to now indicated the existence of a petroleum deposit with primary gas cap in the Kliwa sandstone horizon as well as of a free gas deposit in the transition horizon. The deposit located in the Kliwa sandstone corresponds to a stratigraphic trap as the latter closes in the north simultaneously with the thickness reduction and even the total disappearance of the reservoir.

For the Kliwa sandstone horizon, better studied, the effective thickness is 24.6 m, porosity 18 per cent, connate water saturation 30 per cent, volume reduction factor 1.09, and petroleum specific density 0.861 kgf/cm^2.

The Frumoasa anticline (12, Fig. 11), together with the Mihoc and Tazlăul Mare structures, occurs in the Bistrița half-window, where the deposits of the external unit outcrop. This region has been mapped, then its research has been completed by geological prospections and drillings. The first bore-holes were drilled in 1964 ; up to the present 35 wells have been carried out.

In the stratigraphic succession the super-Kliwa horizon is not separated by the Kliwa sandstone horizon, forming a single lithostratigraphic term. Also the number and frequency of the sandstone intercalations in the super-Kliwa complex are reduced as compared to more southern structures. The thickness of the transition horizon varies from 0 to 50 m.

The Frumoasa structure is an asymmetrical anticline. Like at Mihoc, the eastern flank sinks along a longitudinal accident. The western part, including the apex zone of the Frumoasa anticline, is tectonically overlain by the Doamna scale. South of the outcrop, the Frumoasa structure sinks continuously and then disappears under the Paleogene of the Doamna scale. The anticline is divided into tectonic blocks of several longitudinal faults.

At Frumoasa, petroleum accumulations occur in the super-Kliwa complex and the transition horizon, which seem to be hydrodynamically separated. The traps are of structural type and the deposits are stratiform, dome-shaped. The average porosity of the reservoirs is about 15 per cent, connate water saturation 33 per cent, volume reduction factor 1.135, petroleum specific density 0.870 kgf/dm^3. The deposit pressure seems to be equal to the hydrostatic one and the geothermal gradient is almost 2.5°C/100 m.

The Tazlăul Mare anticline (13, Fig. 11) lies in the Paleogene flysch zone, at the contact with the Miocene zone. This structure has been pointed out by the geological mapping. The geophysical works, few in number, had an experimental character.

As regards the stratigraphy of the region, two more significant aspects are worth mentioning : on the one hand, a certain decrease of the thickness of the Oligocene terms belonging to the external unit concomitantly with an increase of the psamitic share and, on the other hand, the pointing out of the conglomeratic and microconglomeratic character of the transition horizon with greenschist elements.

The Tazlăul Mare fold is, in fact, a brachianticlinal, widely arched, with the two flanks divided by longitudinal faults. The transversal faults which affect it do not seem to be tight.

The flow tests point to the presence of free gas deposits in all the six Oligocene horizons, that is Lucăcești sandstone, lower menilites and white marls, lower dysodiles, Kliwa sandstone, upper dysodile and transition horizon. As a result of the analyses carried out, the Tazlăul Mare anticline is considered an exclusively gaseous structure, containing rich gases. The gas composition is, as follows : methane 93.26 per cent, ethane 3.81 per cent, propane 1.76 per cent, isobutane N 0.59 per cent, and pentane 0.29 per cent. The condens average content is about 14 t/16 Nm^3 gas.

The Comănești structure (14, Fig. 11) corresponds, in fact, to the western flank of the Comănești post-tectonic basin, namely to the Leorda-Văsiești-Dărmănești basin. In this sector, the Comănești basin is constituted of Sarmatian and Meotian deposits unconformably overlying a Paleogene relief.

The Paleogene formations, belonging to the medio-marginal unit, are represented by Eocene and Oligocene. As regards the Eocene, it may be divided into two horizons : in the base, the Tarcău sandstone horizon (about 600 m) constituted of micaferrous sandstones with clayey cement, schistose, coaly sandstones, separated by red and cherry-coloured clayey intercalations ; at the upper part, the horizon of the Podu Secu-Plopu beds, 120—140 m thick, predominantly clayey. The Oligocene is incompletely developed due to the pre-Sarmatian erosion which removed, partly or totally, the upper terms. Here, the Lucăcești sandstone is 40 m in thickness, the horizon of the bituminous white marls and lower menilites reaches 100 m, the lower dysodile schists, with sporadic sandstone intercalations 40 m, and the Kliwa sandstone horizon is constituted of several psamitic subhorizons separated by thin dysodilic intercalations. The two last terms are found only in the north-eastern part of the zone. The Sarmatian and the Meotian totalize maximum 800 m and are characterized by a rumpled tectonics, specific to the medio-marginal nappe, associated with numerous longitudinal and transversal faults. The Sarmatian covers a pre-existent relief, constituting settling structures. It seems that some of the Paleogene basement faults are found again in the Sar matian-Meotian cover of the post-tectonic basin. On the whole, the Sarmatian deposits dip to the east, towards the centre of the Comănești intermontane depression.

The Comănești structure consists of three accumulation members which produce petroleum : the Eocene sandy horizon in Tarcău facies, the Oligocene Lucăcești sandstone horizon and several Sarmatian sandy-gritty complexes. These accumulations are placed in mixed traps, constituted by structural, stratigraphic and paleogeographic factors. The Eocene deposits are massive while the Oligocene and the Sarmatian ones are predominantly stratiform. It is considered that the petroleum of the Sarmatian migrated from the Paleogene flysch.

The values of the Comănești deposit parameters are, as follows : porosity 10 per cent, connate water saturation 35 per cent, volume reduction factor 1.08—1.117, petroleum specific density 0.859 (Eocene)—0.849 (Oligocene and Sarmatian).

The Văsiești structure (15, Fig. 11) is also located in the Comănești post-tectonic basin, east of the accumulation zones mentioned before. The geological conditions are somehow similar to the above-mentioned ones. From the Neogene of the Comănești basin, the wells penetrated into the medio-marginal nappe and then they met with the external unit with its characteristic stratigraphic sequence.

Tectonically, an unconformity occurs among the structural elements of the three superposed units. Thus, at the level of the external unit, the Oligocene appears in two anticlines trending N—S, separated by a longitudinal fault. In the medio-marginal unit, the Eocene presents a slight fold which does not superpose any of the two rumpled elements of the autochthon. The Neogene, unconformably overlying a broken relief, presents a large anticline. The arrangement of the beds is complicated by the presence of numerous faults of different ampleness and trendings.

The wells drilled till now pointed out petroleum accumulations in the two anticlines of the external unit, at the level of the Kliwa (and super-Kliwa) sandstone horizon and the transition horizon, as well as in the Eocene of the medio-marginal nappe, in two gritty horizons. The traps are of structural type and the deposits are stratiform, dome-shaped.

The average values of the main deposit parameters are, as follows :

	Oligocene	Eocene
effective porosity (per cent)	13—15	10.9
connate water saturation (per cent)	35—40	35
volume reduction factor	1.278	1.278
petroleum specific density (kgf/dm^3)	0.878	0.887

The Dărmănești W structure (16, Fig. 11), situated to the north, probably on the same alignment with the Doftenița scale, has been researched with several wells. One of them (well 15) crossed the medio-marginal nappe and then reached the Oligocene of the external unit at 2,210 m. The flow tests indicated that the transition horizon is productive, with enough modest petroleum output (2.5 t/day).

The Doftenița structure (17, Fig. 11) appears in the Slănic-Oituz half-window. It continues to the north under the deposits of the marginal unit, where the Kliwa sandstone horizon of the external unit Oligocene yielded petroleum in two wells. As a matter of fact, this structure is an overthrust fold, with an eastern vergence, very disrupted from the tectonic point of view. It makes impossible to establish some key marks. The deposit parameters have the following average values : porosity 11 per cent, connate water saturation 32 per cent, volume reduction factor 1.05, petroleum specific density 0.870 kgf/dm^3.

The Păcurița structure (18, Fig. 11) develops in the southernmost part of the Comănești Depression, whose basement is constituted of the Paleogene formations of the medio-marginal nappe and, partly, in the south-western sector, of the Paleogene of the external unit.

The wells drilled at Păcurița revealed a very complicated geological situation. Under the Sarmatian of the Comănești basin there is the Tarcău subunit, followed by the intermediary subunit, both of them being components of the medio-marginal nappe, and then the external unit (Fig. 19).

In the Păcurița structure petroleum accumulations have been identified both in the external unit and in the two subunits of the medio-marginal nappe. In the external unit, the petroleum existence has been proved in the transition horizon, at a depth of 1,296—1,316 m. In the intermediary unit hydrocarbons have been obtained from the Eocene and Oligocene. Here, the Oligocene is represented only by the base of the

Kliwa sandstone and the lower horizons. The other upper terms have been planed by the Tarcău subunit. In the Tarcău subunit the hydrocarbons are located in the Tarcău Eocene sandstones.

The Dofteana-Bogata structure (19, Fig. 11), determined by drilling, was proved productive in 1954. Apart from the Sarmatian of the Comănești Depression, the wells drilled at Bogata crossed the deposits of the medio-marginal nappe and, partly, those of the external unit.

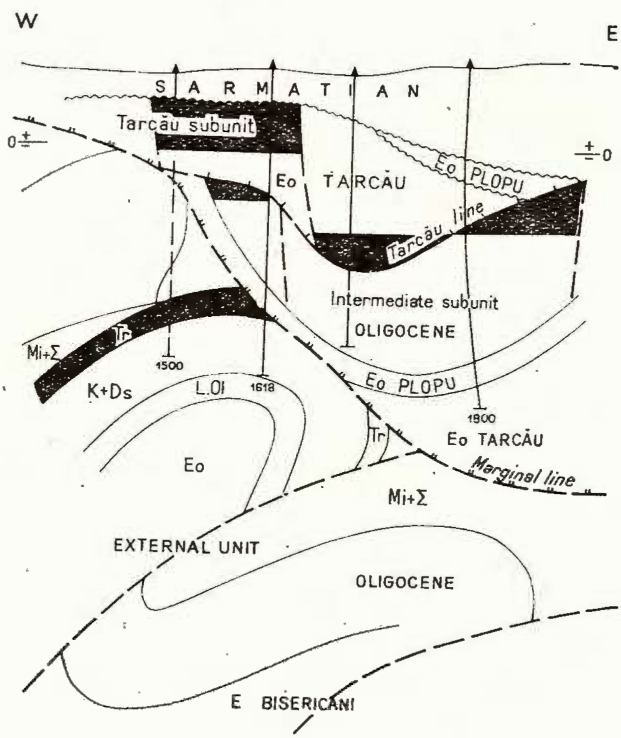

Fig. 19. — Geological section through the Păcurița structure (according to D. C a m i n s c h i).

In the external unit, the stratigraphic sequence is normal. The Lucăcești sandstone is about 25 m thick; the lower menilites and the white marls, together with the sandstone intercalations, totalize 50 m; the lower dysodile schists do not exceed 55 m in thickness; the Kliwa sandstone (200—250 m) presents wide lithofacial and thickness variations; the upper dysodiles (50—60 m) include numerous intercalations of petroliferous sandstones; the transition horizon is not found in the whole zone, being probably eroded.

The Dofteana-Bogata zone makes itself conspicuous by the existence of some overthrust folds with an eastern vergence which overthrust one another successively from the west to the east. Among them the Dofteana structure is the most significant. It has a normal western flank, well developed, with 25—30° dips, and an eastern flank, associated with a longitudinal fault, relatively reduced, with dips great enough (Fig. 20). The latter overthrusts the former towards the east. The structure is complicated due to the presence of numerous faults.

Up to the present, petroleum deposits have been pointed out in the following members : a) the Oligocene of the external unit, both at Dofteana and at Bogata, in the Lucăcești sandstone and sometimes also in the lower menilites and the white marls, the Kliwa sandstone horizon, the super-Kliwa complex, and the transition horizon; it is worth mentioning the Oligocene irregular development on both structures; b) the Eocene and the Oligocene in this nappe, also with an irregular development and of a relatively reduced industrial importance.

The average parameters of the deposit are, as follows: porosity 16 per cent, permeability 50 mD, connate water saturation 35 per cent, volume reduction factor 1.05—1.1, petroleum specific density 0.870—0.900 kgf/dm^3, deposit pressure with 30 per cent higher than the hydrostatic one, the geothermal gradient 3.6°C/100 m.

The Slănic-Ferăstrău structure (20, Fig. 11) is situated south of the Dofteana-Bogata structure. Here, the external unit Oligocene has a common

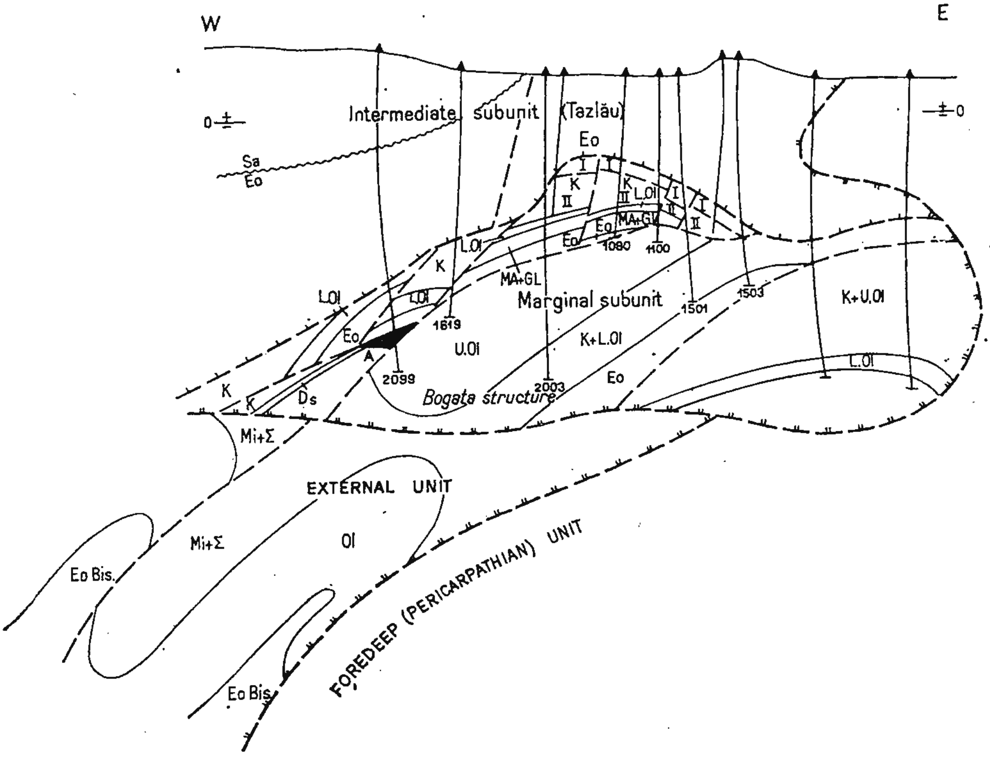

Fig. 20. — Geological section through the Dofteana-Bogata structure (according to D. Caminschi).

profile and development. The structure represents an asymmetrical anticline, with a normal western flank and an eastern one disturbed by a longitudinal fault. Other transversal accidents divide the fold into several blocks. Hydrocarbon accumulations occur in the transition horizon. They consist of petroleum with primary gas cap and are massive and stratiform.

The physical parameters of the deposit have the following average values : effective porosity 12 per cent, permeability 34.2 mD, petroleum specific density 0.816—0.845 kgf/dm^3, initial deposit pressure 60.6—96.5 kgf/cm^2.

The Cerdac zone (21, Fig. 11) consists of three overthrust folds trending N—S, known as Cerdac W, Cerdac centre, Cerdac E. The Oligocene of the central unit, the objective of interest here, has a normal sequence. The structures affected by longitudinal and transversal faults are divided into several tectonic blocks. The wells drilled up to now emphasized hydrocarbon accumulations in the transition horizon on the three anticlines, whilst the Kliwa sandstone horizon and the super-Kliwa complex are productive only on the Cerdac W and Cerdac E structures. In this zone there are accumulations of petroleum with a primary gas cap.

The Slănic-Băi structure (22, Fig. 11) is located near by the margin of the Slănic-Oituz half-window, where there were petroleum rudimentary exploitations in the past. The Slănic-Băi overthrust fold is divided into several tectonic blocks, among which two proved to be productive at the level of the transition horizon. The only parameter determined positively is the petroleum density of 0.875 kgf/dm^3.

The Lepşa structure (23, Fig. 11) is situated south of the Slănic-Oituz half-window. It is an overthrust fold trending N—S, divided into several tectonic blocks. From the 11 wells drilled in this region, three had weak hydrocarbon potentials from the super-Kliwa complex and the transition horizon. 3 m^3/day of petroleum with 10 per cent water have been obtained at the well 1 (1,000—1,062 m), in the super-Kliwa complex. In the transition complex, the wells 2 (990—1,020 m) and 6 (1,550—1,563 m) produced 2 m^3/day petroleum with gas, variable brackish water potentials with about 50 per cent petroleum. It is explained by the extremely reduced permeabilities of the reservoirs, a characteristic of the external unit Oligocene at the East Carpathians bending zone. The average porosity is 12 per cent, connate water saturation 38 per cent, volume reduction factor 1.1, petroleum specific density 0.856 kgf/dm^3.

As mentioned before, the external unit develops to the west, under the medio-marginal zone, on about 35 km from the face of the latter. This fact has been proved with the wells drilled at Ghelinţa and Ojdula which revealed, besides the existence of the external unit, two hydrocarbon accumulations.

The Ghelinţa structure (24, Fig. 11) is situated west of the Putna-Vrancea half-window and seems to represent an overthrust fold, trending N—S. A first well drilled here penetrated from the medio-marginal nappe into the external unit Oligocene at 2,046 m deep and crossed it up to 3,276 m (1,230 m thick). The Oligocene lower horizons did not yield at the flow tests; in the transition horizon 3 m^3/day of petroleum have been obtained after treatments and shootings at 2,200 m deep. At the depth interval of 2,106–2,138 m, the well yielded 6 m^3/day of petroleum. Other two flow tests, carried out successively at 2,050–2,090 m and 1,958–1,982 m, pointed to the presence of gas (60,000 m^3/day) and condens (8 m^3/day).

The Ojdula structure (25, Fig. 11), belonging to the westernmost alignment in the external unit, is placed at more than 25 km west of the margin of the medio-marginal nappe. It is the basic element according to which it has been ascertained that the location of the thrust of the last unit mentioned before over its parautochthon (the external unit) could be of about 35 km or more.

The first wells (914 and 100), drilled at Ojdula, crossed the medio-marginal nappe and came upon the Oligocene of the external unit at depths of 2,000–2,104 m. In the transition horizon, well 914 produced gas at two intervals: 2,400–2,430 m, 54,000 m^3/day gas and brackish water with 23 g/l; 2,200–2,230 m, 53,000 m^3/day pit gas with 41 per cent CO_2. The pressures were of 102 kgf/cm^2. Well 100, at a depth of 2,230–2,503, belonging to the transition horizon, produced 4,000 m^3/day mixed gas with 60.8 per cent CO_2.

In the flysch zone in Muntenia, there are several indications of petroleum and gas, among which the most significant are those at Cătiaşu, Poseşti, Vîrfuri-Vişineşti and Cosminele.

The Cătiaşu structure (1, Fig. 22) represents the periclinal zone of a Paleogene anticline belonging to the Homorîciu spur. Eocene deposits outcrop in the Tarcău sandstone facies overlain by the Oligocene, developed in the Fusaru and Pucioasa facies, to the south. The petroleum occurrences determined the drilling of two deep wells, one of them (well 56) produced petroleum from the Tarcău sandstone, at a depth of 1,622–1,700 m. Initially, the discharge was of 4 t/day, then it decreased rapidly to 1 t/day and the behaviour of the well could not be improved. The petroleum specific weight is of 0.860 kgf/dm^3.

The Poseşti structure (2, Fig. 22) constitutes a faulted monocline determined in the Pliocene deposits of the Drajna syncline. The deposit is hosted in the Meotian basal complex, constituted of thin beds of sands. It is productive only on the southern flank of the Drajna syncline. The screen is represented by a longitudinal fault, trending NE–SW. Laterally, to the east and west, the accumulation is delimited by transversal faults. The average thickness of the reservoirs is 10 m, porosity 27 per cent, connate water saturation 30 per cent, volume reduction factor 1.04, petroleum specific density 0.875–0.898.

The Stîrmini-Vişineşti structure (3, Fig. 22) belongs to the medio-marginal unit and is constituted of Oligocene (which outcrops), Eocene and Cretaceous. This structure represents a fold trending E–W and is affected by longitudinal and transversal faults. Some wells drilled in the Stîrmini-Vişineşti anticline emphasize petroleum and gas accumulations with condens in the Eocene Tarcău sandstones. At the flow tests, brackish water was often obtained concomitantly with hydrocarbons. The behaviour of wells is not conclusive enough. The best discharges have been noticed at well 8 Vîrfuri which produced 10 t/day petroleum with 16 per cent impurities, within the interval 1,220—1,244 m. The very high deposit pressure (203.6 kgf/cm^2) points to the existence of small-sized accumulations, lithologically or tectonically screened.

The Cosminele structure (4, Fig. 22) occurs as an anticline with faulted limbs on the western prolongation of the Văleni spur. The Oligocene in Kliwa facies, outflanked by the Lower Miocene, appears in the axis of this anticline. At Cosminele, small accumulations of gas are found in the Eocene and of petroleum in the Oligocene and the Helvetian. This structure has to be further researched by drillings.

In the same zone of the Paleogene flysch in Muntenia the drillings pointed out the presence of other hydrocarbon accumulations characterized by small sizes, very reduced discharges or complicated geological and technical conditions. It is the case of the Izvoarele (Homorîciu spur) and Vulcana-Pucioasa structures with gas in the Eocene.

b) **Miocene Subzone in Moldavia.** It represents the northern sector of the Carpathian Foredeep, situated to the north of the Putna Valley, and comprises four petroleum-bearing structures, among which only two of them (Cîmpeni and Tescani) are producing. In most of this region the Lower Miocene outcrops, within which it is worth mentioning the two horizons developed south of the Neamţu Valley : a lower horizon, predominantly gritty and sandy with intercalations of red marls, called the Saliferous "red horizon" or the "Tescani beds", overlying in continuity the Burdigalian conglomerates ; an upper horizon, predominantly marly, grey-coloured, known as the "Saliferous grey horizon" or the "Cîmpeni beds". The Miocene subzone also includes the Tortonian and the Sarmatian (south of Pietricica).

On the whole, the sector between the Moldova and Rîmnicul Sărat valleys is characterized by a structure in scales, with an eastern vergence, delimited towards the exterior, only north of the Trotuş, by the Pleşu-Pietricica major anticlinal line.

The petroleum deposits are located in the Tescani beds (partly of Burdigalian age) and less in the Cîmpeni beds, in the Tortonian and Sarmatian, at depths of 200—900 m. On the Tescani structure, industrial hydrocarbon accumulations have also been identified in the Oligocene of the Miocene zone, developed in a facies similar to that known in the external unit (the Kliwa sandstone facies).

The Cîmpeni oil field (26, Fig. 11) is situated in the middle of the Miocene zone and is constituted of two anticlinal folds : Cîmpeni and Cîmpeni W. The main structure (Cîmpeni) has been worked since 1903. The Cîmpeni W structure has been later discovered. The main structural element has the shape of a normal anticline, affected by partly tight faults (Fig. 21). Petroleum is found in the Lower Miocene, divided into several complexes and gritty and marly-gritty packets, whose individuality cannot be traced on long distances. The depth of these productive beds varies from 200 to 900 m. The very small output (1—4 t/day) of the wells is explained by the reduced permeability of the strata. The Cîmpeni accumulations are hosted in mixed traps, formed of structural and lithological factors. The deposit parameters have the following average values :

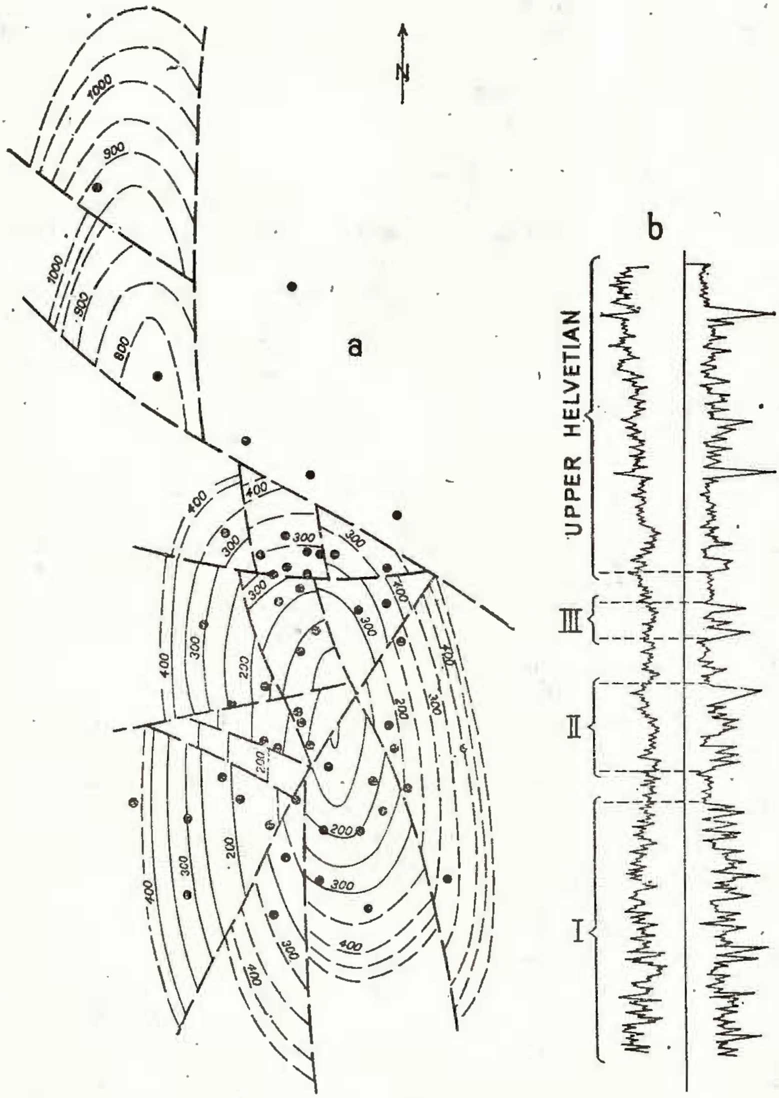

Fig. 21. — Cîmpeni structure : a, structural scheme at a guide mark in the Helvetian ; b, representative Helvetian-Burdigalian profile (according to D. C a m i n s c h i).

porosity 14 per cent; connate water saturation 40 per cent; deposit initial pressure 50 kgf/cm^2; petroleum specific density 0.815—0.837 kgf/dm^3.

The Tescani structure (27, Fig. 11) is located south-east of Cîmpeni and constitutes a productive field of an analogous value. Here, there are two objectives of interest for hydrocarbons: the former corresponds to the Lower Miocene (Tescani beds), the geological conditions and the behaviour resembling those of the Cîmpeni deposits; the latter belongs to the Oligocene, the Kliwa horizon.

The wells drilled at Tescani revealed a 3,400 m thick section, formed of Oligocene and Miocene. The Oligocene could not be crossed entirely, only up to the white marl horizon, overlain by the lower dysodiles and menilites, the Kliwa sandstone horizon (about 400 m) and the upper menilite and dysodile horizon. It is worth mentioning the frequency of the green conglomerates even in the dysodile mass.

At the Oligocene level, the structure appears as an anticlinal with a faulted eastern flank and divided into tectonic blocks, often strongly deviated.

The Lower Miocene petroleum accumulations have been produced since 1908. The Oligocene contains petroleum with primary gas cap.

The Caşin structure (28, Fig. 11) represents an anticline trending N—S, whose axis is surrounded by two longitudinal faults. This structure belongs to the Pericarpathian unit and is situated close by the Caşin-Bisoca fault. Petroleum is found in the Tortonian sandstones and its working started a long time ago, by means of pits. Lately, five more wells have been drilled here. Two of them belong to different blocks, have very small Tortonian petroleum discharges. These deposits cannot be exploited, at least for the moment, because of the tectonic complications, lithofacial variations, discontinuous character of the accumulations and the unsatisfying behaviour of the wells.

The Cîmpuri-Vizantea structure (29, Fig. 11) also belongs to the Pericarpathian unit. Here the Tortonian and Sarmatian deposits form a small basin which, in the western part, comes into tectonic contact with the Lower Miocene and, in the eastern part, rests on the Caşin-Bisoca fault. In detail, this small basin is slightly refolded as narrow anticlines and synclines, with a faulted axis. Numerous transversal faults have also been emphasized.

The petroleum existence in the Sarmatian base has been pointed out on one of the anticlines determined by research works. Discharges of 5—6 t/day of petroleum have been obtained by swabbing from a single well (no. 8). The petroleum from Cîmpuri is light, 0.809 kgf/dm^3.

Apart from the productive structures mentioned before, in the Miocene subzone in Moldavia numerous indications of petroleum and gas are also known in other points connected especially with the outcrops of the formations of interest for hydrocarbons. When these indications were more abundant they have been exploited with rudimentary means since past centuries. Considering the present degree of knowledge and the modern geological views on the petroleum and gas prospectives of the flysch and Carpathian Foredeep, the surface indications as well as the old exploitations lost their determining character and therefore we shall not present them in this paper.

c) **Mio-Pliocene Subzone in Muntenia.** It is situated between the Rîmnicu Sărat and Dîmbovița valleys. This region is characterized by the halokinetic (diapir) origin of most of the structures which are disposed along at least five main alignments, parallel, in general, to the Carpathian chain. As mentioned before the diapirism develops differently according to the closeness or remoteness from the Paleogene flysch zone and the basement on which the folds have formed.

The Mio-Pliocene subzone constitutes one of the most prolific zones of accumulation in Romania in which numerous hydrocarbon deposits, located in Oligocene, Burdigalian-Helvetian, Sarmatian, Meotian, Pontian, Dacian and Levantine have been discovered.

Getting over some deposits placed in the Oligocene, it has been ascertained that the Burdigalian-Helvetian hydrocarbons occur in paleogeomorphic traps, on the flanks of some major anticlines (Teiș, Moreni, Runcu-Buștenari), under the plane of unconformity of the Meotian transgression. As a result, it has been ascertained that the petroleum found in these formations comes from the Meotian.

The Sarmatian accumulations are placed in the Middle Bessarabian (Boldești, Țintea) or the Volhynian-Buglovian (Ricești-Mărgineni) in paleogeomorphic, structural, stratigraphic and mixed traps. Generally, they are considered to represent primary deposits (Hristescu, Olteanu, 1973).

The Meotian contains the most important hydrocarbons in the Mio-Pliocene subzone and, according to the recent studies (Anton, 1973), they are to be found in the formation which generated them. On the northern, higher border of the region there are practically only petroleum accumulations; the gas share increases towards the south.

The Pontian, generally pelitic, contains petroleum and especially gas accumulations in the eastern part of the Mio-Pliocene subzone (Bărbuncești) where there are sand intercalations. It is considered (Hristescu, Olteanu, 1973) that the Pontian pelites represent the source rock both for the proper deposits and for some of the Meotian and Dacian ones.

The Dacian, the second important productive formation (after the Meotian) of the Mio-Pliocene subzone is constituted of petroleum and free gas deposits, generated by the pelites of the same formation and probably by the Pontian ones.

The Levantine yielded petroleum at Ochiuri and Moreni, and gas at Boldești.

Most of the Burdigalian-Helvetian accumulations form deposits in common with the Meotian ones, and most of the productive zones of the formations of interest overlap within the same structural elements.

For this reason, it is proper to present the deposits in the Mio-Pliocene subzone according to structures not to productive formations. This presentation will start with the structures of the northernmost range, developed near by the contact with the Paleogene flysch. Most of these structures are "overflow" diapir folds, characterized by a weak northern flank and a lower, abrupt, southern flank, affected by faults and overthrust. This structural range starts from Surani-Cărbuneşti and continues at Vîlcăneşti, Cîmpina, Ocniţa, up to Şotînga.

The Surani-Cărbuneşti structure (5, Fig. 22) is located on the northwestern border of the Calvini centroclinal fold, at the contact with the Văleni spur. In this zone, the petroleum deposits were pointed out by core drills in 1960.

The wells drilled at Surani-Cărbuneşti crossed a sequence of strata, from the Oligocene till the Pliocene. The Oligocene, only partly crossed, consists of : the lower Kliwa sandstone (385 m), formed of an alternation of sands and clays ; the Podu Morii beds (510 m), constituted of a lower pelitic series, a complex of Kliwa sandstones, followed by a series of clays and marls ; the upper Kliwa (390 m), made up of massive banks of Kliwa sandstone, with rare intercalations of clays and an alternation of clays and thin sands ; the super-Kliwa (220 m), divided into 12 complexes, constituted of an alternation of sands and clays.

The Helvetian appears on the northern side and the axial zone of the Cărbuneşti-Bîsceni structure. It is predominantly marly, with sandstone intercalations, the total thickness being of maximum 740 m.

The Meotian (125—300 m) is constituted of unconsolidated sands and marly intercalations.

Tectonically, the Surani zone represents a fold at the Oligocene level (Bîsceni-Cărbuneşti-Ariceşti), the Pliocene syncline at Surani and of a Mio-Pliocene diapir fold, also at Surani.

At Surani-Cărbuneşti, petroleum accumulations are to be found in Oligocene, Helvetian and Meotian. This petroliferous field is characterized by discontinuous petroleum saturated surfaces and a variation of the extension of the productive surfaces. At the Meotian level, the traps are of structural or stratigraphic type ; in the Helvetian they are structural and in the Oligocene there are structural and stratigraphic traps.

The deposit parameters have the following average values : porosity 27—29 per cent, permeability 100—300 mD, connate water saturation 22—30 per cent, volume reduction factor 1.04—1.08, petroleum specific density 0.830—0.900 kgf/dm^3. The deposit pressure is lower than the hydrostatic one, and the geothermal step (32 m/ °C) is close to the normal average.

The Copăceni-Opăriţi-Predeal-Sărari structure (6, Fig. 22) produced oil and gas since 1905 (Copăceni) and extended after 1962. This structure is also placed at the contact with the Paleogene flysch (the Văleni spur). Here, the main structural element consists of the Copăceni faulted fold, trending NE—SW, in which the Meotian of the southern flank is caught under the Oligocene overthrust of the northern flank, in fact the

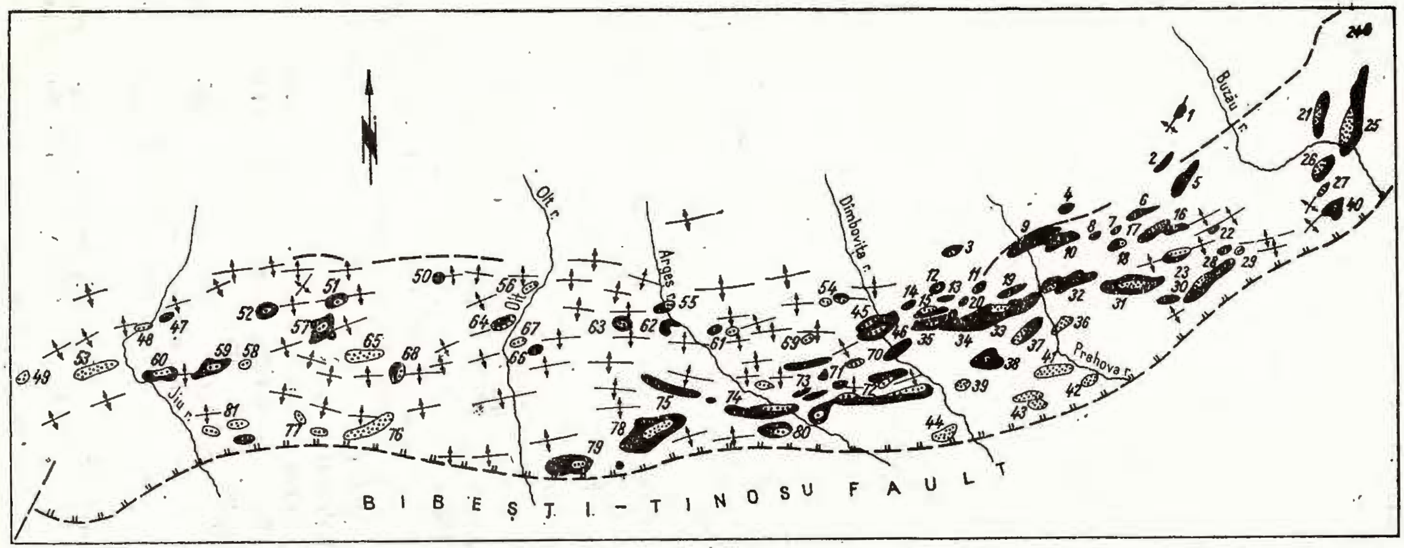

Fig. 22. — Distribution of the oil and gas deposits in the Paleogene flysch zone of Muntenia, in the Mio-Pliocene subzone and the Getic Depression. a, Paleogene flysch of Muntenia : 1, Cătiașu ; 2, Popești ; 3, Vîrfuri-Vișinești ; 4, Cosminele ; b, Mio-Pliocene zone : 5, Surani- Cărbunești ; 6, Copăceni-Opăriți ; 7, Scăioși ; 8, Vîlcănești ; 9, Buștenari-Runcu ; 10. Cîmpina-Gura Drăgănesii ; 11, Colibași ; 12, Glodeni ; 13, Valea Reșca, ; 14, Șotînga ; 15, Aninoasa ; 16, Matița-Podenii Noi ; 17, Păcureți ; 18, Măgurele ; 19, Siliștea ; 20, Ochiuri ; 21, Plopeasa ; 22, Apostolache ; 23, Podenii Vechi ; 24, Bisoca, 25, Arbănași-Berca ; 26, Bărbuncești ; 27, Grăjdana ; 28, Tătaru ; 29, Malu Roșu ; 30, Ceptura-Urlați ; 31, Boldești ; 32, Băicoi-Țintea ; 33, Moreni-Gura Ocniței ; 34, Gura Ocniței W-Răzvad ; 35, Teiș-Viforîta ; 36, Aricești ; 37, Mărgineni ; 38, Bucșani ; 39, Brătești ; 40, Sărata-Monteoru ; 41, Mănești-Vlădeni ; 42, Frasin-Brazi ; 43, Fînta-Gheboaia ; 44, Gura Șuții ; 45, Drăgăești ; 46, Dragomirești ; c, Getic Depression : 47, Tg. Jiu ; 48, Tămășești ; 49, Bala ; 50, Folești ; 51, Alunu ; 52, Colibași ; 53, Strîmba-Rogojelu ; 54, Botești ; 55, Vîlcele ; 56, Căzănești ; 57, Bustuchini ; 58, Socu ; 59, Țicleni ; 60, Bîlteni ; 61, Colibași ; 62, Merișani ; 63, Săpunari ; 64, Băbeni ; 65, Grădiște ; 66, Urși ; 67, Galicea ; 68, Românești ; 69, Dobrești ; 70, Ludești ; 71, Bogați — Priboieni ; 72, Șuța Seacă-Leordeni ; 73, Glîmbocelu ; 74 ; Călinești-Oarja ; 75, Slătioarele ; 76, Zătreni ; 77, Hurezani-Pisuu Stejarului ; 78, Vața ; 79, Otești ; 80, Siliștea-Cireșu ; 81, Bibești-Sărdănești.

Oligocene of the Văleni spur; towards the east, the Opăriţi faulted anticline is outlined where the Oligocene is transgressively overlain by the Helvetian; in the easternmost part of faulted fold is pointed out at Predeal-Sărari.

The hydrocarbon accumulations have been discovered, as follows: at Copăceni, in the Oligocene of the northern flank and the Oligocene and the Meotian of the overthrust southern flank; at Opăriţi, in the lower Kliwa, Podu Morii and upper Kliwa horizons; at Predeal-Sărari in the upper Kliwa and Podu Morii. The reservoirs are saturated with petroleum. At Opăriţi a primary gas cap is to be found in the Oligocene. The physical parameters vary, as follows: porosity 19.6—35 per cent, permeability 7.7—181 mD, connate water saturation 33.6 per cent, volume reduction factor 1.142, petroleum specific density 0.825—0.430 kgf/dm³. The traps are of structural type. The deposits yield under dissolved gas drive and, in the old sectors, under gravity drive.

The Scăioşi structure (7, Fig. 22) appears as a faulted fold situated south of the Copăceni-Predeal-Sărari overthrust major line. The petroleum accumulations are located in the Meotian of the southern flank, sealed by the Scăioşi longitudinal fault. The productive zone has been worked with four wells, the initial discharge being of 15—28 t/day. At present the production activity has ceased in this zone because of the very reduced productivity of the wells.

The Vîlcăneşti structural zone (8, Fig. 22) seems to represent the southern prolongation of the Runcu S major dislocation, along which the salt-bearing Miocene overthrusts the Pliocene of the southern syncline. Here, the petroleum production has been obtained from the Dacian, in two wells, and from the Pontian, in a single well. The Dacian productive beds inundated by water about 30—60 per cent in 2—3 month interval. Now, the production activity has ceased due to the increase of the impurities percentage.

The Buştenari-Runcu oil field (9, Fig. 22) is also situated in the zone where the Oligocene of the Văleni spur overthrusts the Miocene deposits. The Pliocene transgressively overlies most of this overthrust and also masks it. In this zone as a matter of fact there are two structures: Buştenari — to the north, and Runcu — to the south, both of them representing asymmetrical anticlines, affected by faults. In front of the Runcu anticline, one can notice piercings of the Burdigalian salt core, so that this fold could be assigned to the diapir structures.

In the petroliferous field south of the town of Cîmpina, petroleum is yielded by the upper horizon of the Kliwa sandstone (the Buştenari sandstone) only along the northern flanks of the Buştenari and Runcu structures; the sandstones and sands in the lower half of the Helvetian along the southern flank at Buştenari and the northern flank at Runcu; and the Meotian horizons M I, M int. and M II on both structures, but especially on the Runcu anticline.

This region has been worked since 1857 and it seems to have started with the Oligocene formations, then the Meotian (1882) and the Helvetian ones (1921). The main parameters of the petroleum deposits are, as follows :

	Meotian	Helvetian	Oligocene
thickness (m)	5—29	7.6—22	4—37
porosity (mD)	25.8	23	25
water saturation (per cent)	27	30	27
volume factor	1.40—1.262	1.11—1.20	1.056—1.10
petroleum specific density (kgf/dm^3)	0.830—0.833	0.820	0.865—0.870

In the last 15 years experiments of water injections have been carried out for the Meotian. The results obtained are promising ; however, the use of this method has been restricted because of the inadequate technical state (uncemented cassings) of the old wells.

The traps are of structural, paleogeomorphic and mixed type. The deposits can be assigned to the stratiform and massive types. They are productive under dissolved gas and gravity regime.

The Cîmpina-Drăgăneasa structure (10, Fig. 22) is situated approximately in the western prolongation of the Buştenari anticline, in the Vrăjitoarea fault zone. The research of the region started 100 years ago, the first accumulations being discovered in 1860, and the industrial exploitation dates back in 1896.

The structure represents a faulted anticline, with a different stratigraphic sequence on the two flanks, more complete on the southern flank (Fig. 23).

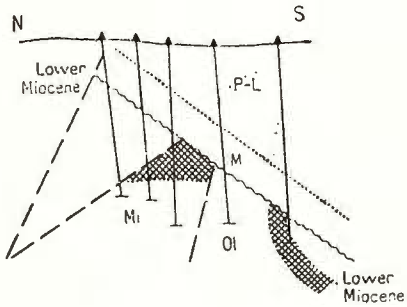

Fig. 23. — Diapir structure of Cîmpina (according to N. Grigoraş).

At Cîmpina-Drăgăneasa petroleum accumulations occur in the Meotian, Helvetian and Oligocene. The parameters, the displacement method as well as the trap types are practically similar to those known at Runcu-Buştenari.

North of Gura Drăgănesii, a faulted monocline develops at the level of the Pliocene formations. A small petroleum accumulation, researched and recovered since the last century, is located in the Meotian deposits of the before-mentioned monocline, at *Vîrful Drăgănesii*.

The Colibaşi-Ocniţa structure (11, Fig. 22) is located in the western prolongation of the Miocene deposits overthrusting the Pliocene deposits, as known at Cîmpina-Drăgăneasa. The petroleum accumulations are also found in the Meotian deposits transgressively overlying the Helvetian. The structure exploration started in 1835 with the shallow Meotian of the northern flank (M I and M II). In 1951, the Meotian of the downdropped southern side began to be worked, too (M int. and M II). Near by the overthrust line, small amounts of petroleum have been obtained from the Helvetian, as well. The average parameters of the deposits have the following values: porosity 23 per cent, connate water saturation 40 per cent, volume reduction factor 1.05–1.22, petroleum specific density 0.830–0.840 kgf/dm³.

In the Ocnița sector, the anticline seems to be affected by a transversal fault which shifts its axis towards the north, in the continuity of that known westwards, at the Valea Reșca (G r i g o r a ș, 1961).

The Glodeni structure (12, Fig. 22) occupies a northern position as compared to the Cîmpina-Colibași alignment and represents a faulted fold with the southern flank overthrust by the northern one. The apex zone, much uplifted, has been eroded up to the Burdigalian level. The Meotian of the southern flank, protected by the Pontian marls, is also interesting from the petroleum point of view. The working of the structure began with pits in 1903. There followed the drilling of wells, whose initial output was of about 30 t/day. The deposit energy is due to the expansion of the gases from solution and locally (the blocks C and D) probably to the expansion of the gas cap.

The Valea Reșca (13)-*Doicești-Șotînga structure* (14, Fig. 22) represents the western prolongation of the Cîmpina-Colibași line, affected by numerous transversal faults which outline three uplifts (blocks), continuously displaced towards the south as we come near the Dîmbovița River. The hydrocarbon deposits are hosted in the Meotian, at depths of 500–1,000 m. The thickness of the productive strata is 1.5–7 m, porosity 15–30 per cent, connate water saturation 30–40, petroleum specific density 0.860 kgf/dm³. The traps are of the structural type.

The Aninoasa structure (15, Fig. 22) appears as a syncline comprised between the Valea Reșca-Doicești-Șotînga anticline to the north and the Teiș-Răzvad-Gura Ocniței uplift to the south (Fig. 24). Within this syncline, in which the Meotian transgressively overlain the Pucioasa Oligo-

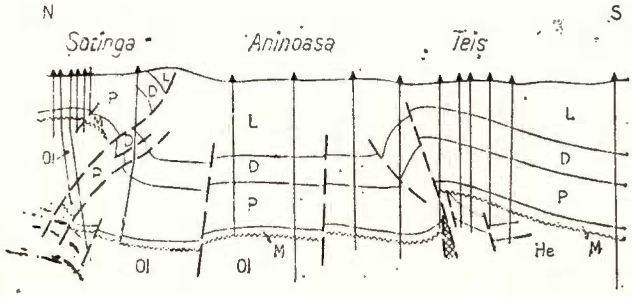

Fig. 24. — Geological section through the Aninoasa structure (according to N. G r i g o r a ș).

cene, the Pliocene presents a slight vaulting. Petroleum accumulations with a primary gas cap have been pointed out in the horizons M I, M int. and M III. In the northern sector of the structure one can notice the existence of a small volume of hydrocarbons in a Paleogene sandy complex, at the contact with the Meotian, under the unconformity plane. Among the productive horizons M III presents the most important lithologic variations. The petroleum strata are 1,600—1,800 m deep, and the main parameters of the deposits present the following values : the effective thickness of the sands saturated with hydrocarbons 1.5—6.5 m, porosity 30 per cent, permeability 115.4—1,853 mD, connate water saturation 20—30 per cent, deposit initial pressure 168.5—191.5 kgf/cm², saturation pressure 119—128 kgf/cm², bottom temperature 51—63°C.

As a trap, the Aninoasa deposit resembles the Drăgăești or Matița productive synclines or the Griffithsville deposit in West Virginia (USA) (Landes, 1959). The explanation of this type of accumulation requires a special study.

South of the productive structural alignment, developed at the contact with the Paleogene flysch zone between Surani-Cărbunești and Șotînga, there is another structural line which includes the Apostolache, Matița-Podenii Noi, Păcureți, Măgurele anticlines or blocks ; Siliștea anticline is included conventionally too. Unlike the alignments to the north and the south, this structural line is characterized by hydrocarbon accumulations of reduced sizes and value.

The Matița-Podenii Noi structure (16, Fig. 22) represents, on the whole, a tectonized syncline which rises and gets narrow from the west to the east. This syncline is bordered by the Scăioși fault to the north and by the Coada Malului-Valea Dulce accident to the south (Fig. 25). The Pontian is the main productive formation and the Meotian is the secondary one. Due to the very complicated tectonics of the region and the obvious lithologic variations, the petroleum accumulations, more substantial on the Matița northern flank of the respective syncline, have a discontinuous character. The discharges obtained vary from 1 to 15 t/day in each well, with a tendency of rapid decrease. The traps are of combined type, to which the structural, stratigraphic and paleogeomorphic (asphalt plug) factors contributed differently. In this region, both at Matița and at Podenii Noi, tar sands are to be found in some sectors in which the Meotian and the Dacian outcrop.

The Păcureți (17)-Măgurele structure (18, Fig. 22) is situated in the western prolongation of the overthrust line which starts at Tega, continues to Apostolache, Podenii Noi, N Păcureți and up to Măgurele. The axial culmination appears at Păcureți, where the Sarmatian outcrops in the anticline apex. West of Păcureți, to Măgurele, the anticline axis sinks continuously after a series of transversal faults, so that this fold is almost completely overlain by the scale consisting of the Tortonian with salt and the Sarmatian.

The hydrocarbon accumulations are found in the Meotian, Pontian and Dacian, at depths of 100—2,300 m. Recently the Măgurele productive sector has extended to the west where the Pontian and the Meotian petroliferous sands can exceed 2,500 m.

From the geologic (structural) and accumulation conditions point of view, two sectors are individualized on this structure: the former at Păcureți, with both flanks faulted and with petroleum impurities in the Meotian, Pontian and Dacian, to the north and the south of the fold axis;

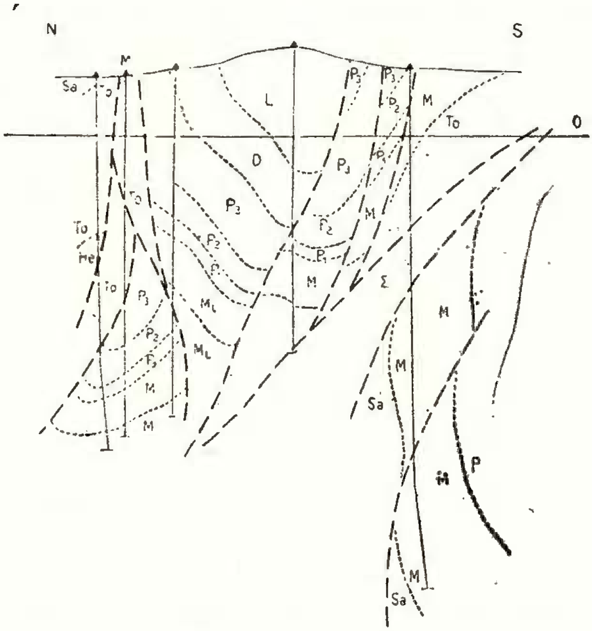

Fig. 25. — Geological section through the Matița Podenii Noi structure (according to D. Culcer)

the latter at Măgurele, with hydrocarbons, in the Meotian, Pontian, and, occasionally, the Dacian under the overthrust of the Miocene deposits. In the Meotian, the existence of the primary gas cap has been pointed out in both sectors.

Referring to the behaviour and exploitation conditions mention should be made of the difficulties caused by the sand instability, the petroleum great density (freezing point at 42 °C) at Măgurele and by the exaggerated decline of the Păcureți wells.

As regards the new productive sector at Măgurele, it is characterized by more constant daily capacities which, initially, are of about 30 t/well.

The main deposit parameters are, as follows:

	Dacian	Pontian	Meotian
thickness of productive strata (m)	7—9	7—17	3—6.4
porosity (per cent)	27	20	27
connate water saturation (per cent)	30	40	30—35

volume reduction factor	1.20	1.10	1.14–1.17
petroleum specific density (kgf/dm^3)	0.860	0.830	0.820–0.860

The Siliştea structure (19, Fig. 22) is a cryptodyapir anticline, trending E–W, affected by four transversal faults. The petroleum deposit, located in the complex M I (Meotian) has been worked since 1907. The average thickness of the pay bed does not exceed 6.5 m, porosity 28 per cent, connate water saturation 35 per cent, specific density 0.840 kgf/dm^3. The trap is structural and the deposit is stratiform.

The Ochiuri anticline (20, Fig. 22), with a salt core outcropping, presents an eastern prolongation which seems to make the connection with the Moreni-Gura Ocniţei major, more external alignment. Westwards, the Ochiuri salt massif continues probably with another structure — the Gorgota structure — whose direction and position is close to that of the Aninoasa productive syncline.

At Ochiuri, the Meotian transgressively overlies the Helvetian, the salt — probably of Lower Miocene age — or directly the Oligocene.

The productive formations are represented by Helvetian, Meotian, Dacian, and Levantine. Petroleum traces have also been pointed out in the Oligocene of the Pucioasa facies. The Helvetian had a modest petroleum production SW and SE of the salt massif. The trap is of paleogeomorphic type (truncated bed under unconformity), and the deposit energy is due to the solution gas expansion and the synclinal water drive. The Meotian — about 130 m thick — includes three sand horizons: M I, M int. and M III, productive E and S of the salt massif. M II, found on other structures, occurs in a marly facies. Within the Dacian — about 200 m thick — the Drăder, Moreni and group II complexes (from bottom to top) are productive, both on the northern and the southern flank. The Levantine contains petroleum only in the basal horizon (group I), on the northern flank of the anticline.

The third tectonic alignment could be constituted of the Plopeasa-Podenii Vechi structures.

The Plopeasa productive field (21, Fig. 22) corresponds to a monocline of the Pliocene deposits, divided by a NE–SW fault, assumed (Grigoraş, 1961) to represent the southern end of the Pericarpathian fault. The hydrocarbons are located in several gritty-sandy horizons belonging to the Meotian and the Pontian. In the eastern compartment of the structure accumulations of petroleum and associated gas are known only in the Meotian, whilst in the western compartment there are only small reserves of free gases in the Meotian and the Pontian.

The Apostolache structure (22, Fig. 22) represents a faulted, fold with a deep-seated salt core. The objective of interest is constituted by the Meotian of the southern flank, entrapped under the overthrust of the Meotian of the northern flank. The objective has been worked through pits since 1910. After the First World War, the research activity has been resumed with wells placed along the fault line. The petroleum reserves, very reduced, identified in four tectonic blocks at depths of 180—450 m, were produced till 1963, when the field was closed.

The Podenii Vechi structure (23, Fig. 22) appears as an anticline trending E—W, about 6 km long and 2 km wide. The dip of the layers is 5—15°. The wells drilled here up to 5,917 m deep opened an almost continuous stratigraphical sequence, from the Levantine to the Helvetian, which was not crossed entirely although the drilling reached about 2,800 m.

Among the formations opened by wells, only the Meotian and the Pontian ones proved to be productive. Thus, petroleum accumulations are to be found in the complexes M II — members *a*, *b*, *c* — and M I — members *c* and *d*; a primary gas cap has been determined at the level of the horizons *d* and *c* of M I and "Meotian gas"; free gases are found in M I, members *a* and *b*, "Meotian gas" I, II, III, and in the Pontian, members *a* and *b*. The reservoirs have porosities of 25 per cent, water saturation 35 per cent, petroleum density 0.850 kgf/dm^3.

The fourth structural alignment includes the Bisoca, Arbănaşi-Berca, Bărbunceşti, Grăjdana and Tătaru anticlines.

The Bisoca anticline (24, Fig. 22) represents a diapir fold with a salt core at the surface. It includes the Meotian, consisting of an alternation of marls, sands and sandstones, the Sarmatian mainly formed of marls with thin intercalations of sandstones and marly sands, as well as other older formations.

On the Bisoca structure, petroleum has been obtained from the Sarmatian at two wells and brackish water with petroleum traces from the Meotian at the third well. Well 11 had, on a nozzle of 2.5 mm, 17 t/day petroleum, gas ratio 97 m^3/m^3, in the interval 1,303—1,308 m (Sarmatian). The petroleum density at +15°C is of 0.822 kgf/dm^3. From the same layer, but in a more uplift position (433—440 m), the well 12 yielded 8 t/day petroleum.

The Berca-Arbănaşi structure (25, Fig. 22) is an anticlinal fold, strongly tectonized. The system of longitudinal faults affecting this structure has a mobile character which determines the inversion of the relations between the two flanks from one end to another of the structure. Thus, at Arbănaşi, the eastern flank is more uplifted, overthrusting the western one, whilst at Berca, the eastern flank is more uplifted and shows a slight tendency of overthrusting the western one. However, the Sarmatian outcrops in the anticlinal axis in the Berca sector. In their turn, the two flanks are fragmented by transversal faults, mostly tight.

The existence of numerous faults as well as the outcropping or the high position of the Meotian saturated with hydrocarbons led to the partial or local deterioration of the protection conditions of the hydrocarbons, as indicated by the presence of numerous mud volcanoes at Pîcle and Berca S.

The mapping and the wells drilled, which reached a maximum depth of 3331.5 m, pointed out a sequence of beds starting with the Levantine and ending with the Sarmatian. Here, in the bending area of the Foredeep, the Sarmato-Pliocene deposits become very thick and, moreover, more arenaceous. For instance, the Meotian, which has 3—4 psamitic horizons in the Moreni-Boldeşti classic zone, presents 27 sand beds belonging to M I (beds 1—18) and M II (beds 19—27) at Berca-Arbănaşi.

The hydrocarbon accumulations are located in the Meotian sands. The number of the productive sands differ from one block to another. The nature and distribution of fluids within this structure are, as follows : Arbănaşi eastern flank : petroleum ; Beciu eastern flank : petroleum ; Beciu western flank : petroleum ; Pîcle eastern flank : petroleum, primary gas cap, free gas ; Pîcle western flank : petroleum, primary gas cap, free gas ; Berca eastern flank : petroleum, primary gas cap, free gas.

Considering the before-mentioned facts, it results that on the Berca-Arbănaşi structure, the eastern flank is productive in all sectors, whilst the western flank yields hydrocarbons only at Pîcle and Beciu. Their exploitation started in 1894 at Arbănaşi and continues nowadays.

The main parameters of the deposits are, as follows : effective thickness of each sand 1.2—112.2 m, porosity 24 per cent, connate water saturation 34 per cent, petroleum specific density 0.850 kgf/dm^3. The displacement regime is mixed, the energy being due to the solution gases, the gas cap extension (locally — at Berca S) and due to the drive of the syncline water and gravity.

The Bărbunceşti structure (26, Fig. 22) contains accumulations of petroleum, associated and free gas. This productive zone corresponds to a structural detail on the eastern flank of the Lapoş anticline (Fig. 26), complicated by numerous longitudinal and transversal faults, partly with a tight character.

The wells drilled up to depths of maximum 3,700—3,800 m crossed the whole pile of deposits whose age begings with the Levantine and ends with the Helvetian. Among the formations which have horizons with reservoir properties, only the Meotian and the Pontian proved to be productive. The Meotian reservoirs have been grouped into seven complexes (M7—M1), and the Pontian reservoirs into three complexes (P 3 — P 1). In their turn, these complexes are constituted of several members. The first complexes in the Meotian base (M 7—M 4) contain petroleum and associated gases (primary gas cap inclusively), and the other three Upper Meotian complexes and the Pontian are saturated with free gas. The thickness of each productive horizon with petroleum varies from 1.09 to 22.74 m, porosity is 24 per cent, connate water saturation 26 per cent, petroleum specific density 0.861 kgf/cm^2.The traps are of structural and lithologic types.

The Grăjdana structure (27, Fig. 22) constitutes probably an undulation on the major syncline bottom outlined between the Lapoş uplift to the north and the Monteoru uplift to the south. Some wells drilled on this deep structure rendered evident modest accumulations of petroleum in three Meotian complexes, equivalent to the horizons M 7, M 6, and M 5 at Bărbunceşti and of free gas in the Meotian (complexes 2,3 and locally 7) and the Dacian. The initial discharges, generally small (10—15 t/day) recorded an obvious decrease, so that after 2—6 months of production they diminished to 0.5—2 t/day. This behaviour is due both to the litho-

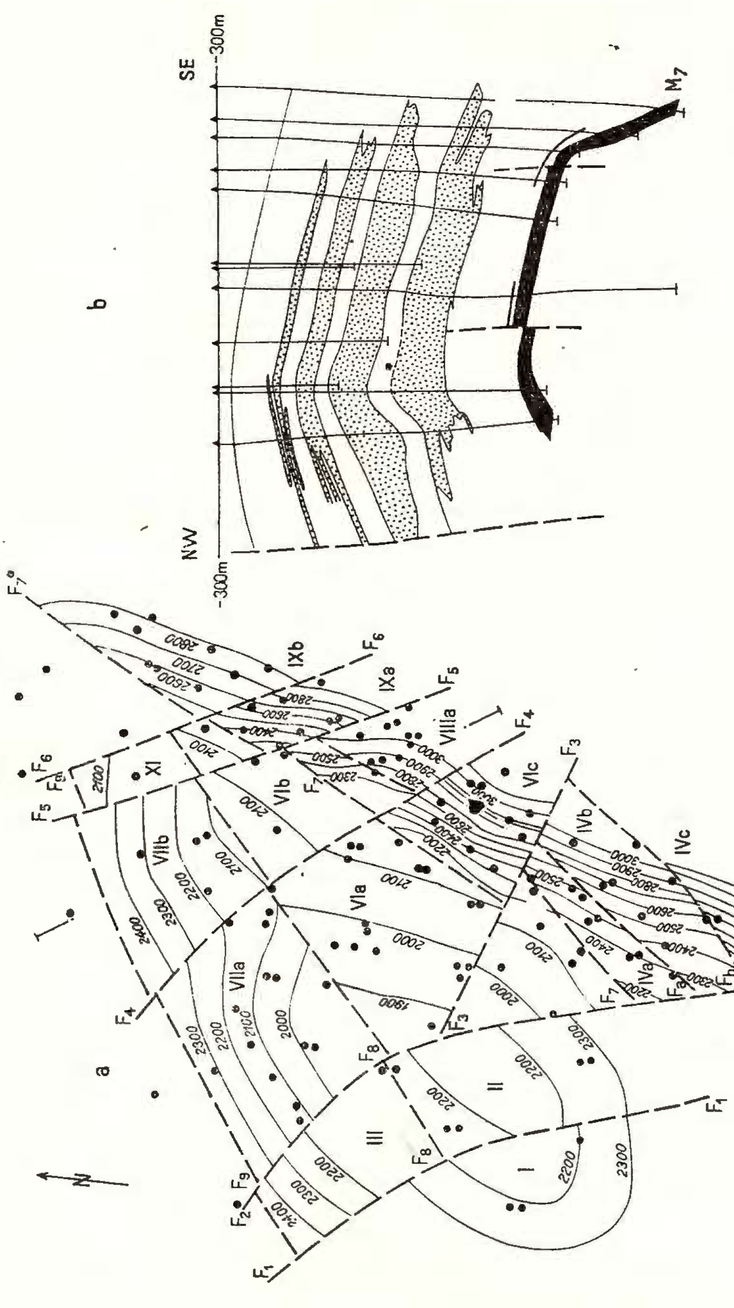

Fig. 26. — Bărbuncești structure.
a, structural map at the marker M_7 ; b, geological cross section (according to M. R u c ă r e a n u).

logic variation of the productive layers and to the marked breaking up of the structure.

The Tătaru petroliferous zone (28, Fig. 22) corresponds to the western, more sunk periclinal of the anticline with the same name in whose axis the Meotian outcrops. The petroleum is loaded in the Meotian sands, protected by the Pontian marls. The first wells, drilled in the period 1925—1935, had initial output of 10—15 t/day. The drillings carried out here up to a depth of 700 m in the years 1963—1966 started with 2—4 t/day petroleum and then in a short period of time the production decreased to 1.5 t/day. The imperfect protection conditions of this deposit are reflected in the petroleum great specific density (0.894 kgf/dm³). The trap is of structural type.

South and west of the Tătaru zone there are two anticlines of a great importance — Ceptura-Urlaţi and Boldeşti—whose assigning to the regional alignments is very difficult.

The Ceptura-Urlaţi structure (29, Fig. 22), and its eastern prolongation at *Malu Roşu* (30), represents an asymmetrical anticline, about 20 km long, trending NE—SW. In the eastern part of the anticline the Pontian outcrops, while towards W the structure sinks up to Chiţorani. The southern flank of the structure is much downdropped along a directional fault. Apart from it, the anticline is also affected by other longitudinal and transversal accidents which divide it into numerous tectonic blocks.

The Meotian is the main productive formation; it is 350—400 m thick and is constituted of marls with sand intercalations. The reservoirs of interest on the Ceptura-Urlaţi structure have been grouped into complexes M I, M int. and M II. Between the boundary P/M and the complex MI, there are sand intercalations which sometimes contain hydrocarbons in an uplifted structural position. Besides the Meotian, traces of petroleum and gas industrial accumulations have been pointed out in the Pontian, the gas accumulations occurring in the easternmost part of the structure, known as "Malu Roşu". Also in the south-eastern sector of the anticline modest discharges of petroleum and free gas have been outlined from the Sarmatian. It follows that the Sarmatian is saturated with petroleum, associated and free gas, the Meotian with petroleum, associated gas (including a primary gas cap) and free gas, and the Pontian is saturated only with free gas.

The traps of Malu Roşu-Ceptura-Urlaţi-Chiţorani are of structural and partly of mixed type, lithologic and paleogeomorphic respectively. The deposits are stratiform and produce under dissolved gas conditions and the influence of the gas cap extension.

The Boldeşti anticline (31, Fig. 22), trending E—W, is 12 km long and about 2.5 km wide. The axial zone of the structure is affected by two longitudinal faults with opposite falls. The northern side of the anticline is downdropped along one of the above-mentioned faults.

The wells drilled at Boldeşti, among which the deepest one achieved 4,865 m, crossed entirely the Pliocene and the Sarmatian and partly the Helvetian. The exploration of the anticline and the pointing out of the deposits took place during three stages. The first stage began in 1923 when the Dacian gas accumulations were discovered. The second stage ended in 1928 when a gas well at the Dacian (1 RA) reached the Meotian gas with condens being found at the level of the horizon M I. The third stage began in 1950 and is marked by the discovery of the Sarmatian petroleum deposit.

The Sarmatian is represented by the Volhynian and Bessarabian and consists of marls with intercalations of sands, oölitic sandstones and conglomerates. Limestones are found on the southern side where the Sarmatian sequence is completed. The Sarmatian psamitic horizons have been grouped into five members, among which only the complexes I and III, slightly unconformable, proved to be productive; this fact points to an intraformational disharmony.

The Meotian, about 400 m thick, consists of marls with sand intercalations, grouped into complexes M II, M int., M I, and "gas" complex, the last formed of gas packets I, II, III.

The Pontian, almost exclusively marly, forms the cover of the Meotian deposits.

The Dacian, 250—300 m thick, is made up of sands, marls, clays and coal intercalations. The sands of interest have been grouped into 10 members (D 1—D 10). They are saturated with gas in the most uplifted sectors of the structure. The basal member (D1) corresponds to the term Drăder on other productive zones.

The Levantine is constituted of sands with intercalations of marls and clays. The sands can be divided into several packets among which the packets L 1—L 15 contain gas in the apex zone of the anticline

In short, the Sarmatian contains petroleum accumulations, the Meotian has petroleum with primary gas cap, and the Dacian and the Levantine are characterized by exclusively gassy deposits.

The main parameters of the deposits are, as follows:

Formation	Thickness of each sand bed (m)	Porosity (%)	Connate water saturation (%)	Petroleum specific density (kgf/dm^3)
Sarmatian	3—20	8—21	27—29	0.840
M II	9.5—22.9	21	25	0.840
M int.	3.8—7	20	31	0.840
M I	5.3—15	23	28	0.840
M gas	2.8—5.1	23	28	0.840
Dacian	2.4—15.1	25	30	—
Levantine	2.4—7.1	25	30	—

The Boldeşti traps are of structural or mixed type, stratigraphic and paleogeomorphic respectively (the Sarmatian ones). The deposits are stratiform. The reservoir energy is due to the expansion of the solution gas and the drive of the primary gas cap. Water injection has been applied successfully at the Sarmatian.

NW of the Boldeşti anticline, there is the main structural alignment of the Mio-Pliocene zone, constituted of the classical diapir folds of Ţintea-Băicoi, Filipeşti-Moreni-Gura Ocniţei-Răzvad and Viforîta-Teiş. They accumulated the biggest volume of reserves in the Foredeep, so that they can be assigned to the category of "giant" deposits (Paraschiv, Olteanu, 1970).

The Ţintea-Băicoi-Floreşti-Călineşti structure (32, Fig. 22) represents a diapir fold with the salt massif at surface. The salt outcropping is associated with a complex of axial faults along which the halites migrated; the two flanks had different vertical movements, so that the northern compartment could overthrust the southern one. The diapir salt massifs appear under various forms (Fig. 27) due to the geological conditions specific to each sector separately. The anticline is affected by numerous faults.

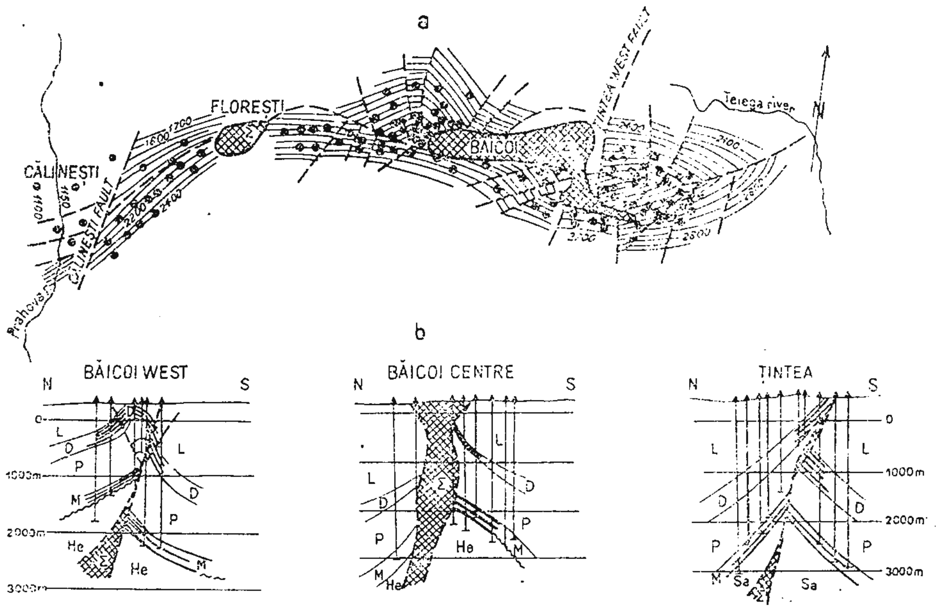

Fig. 27. — Ţintea-Băicoi structure.
a, structural scheme at the top of the Meotian ; b, variation of the salt massif form and the position of the producing strata (according to Gh. Olteanu).

The Băicoi anticline is constituted of formations belonging to Pliocene Sarmatian, Helvetian and Aquitanian. The existence of the Paleogene is also assumed, although well 6009 did not get out of the Miocene up to the depth of about 6,000 m. A significant stratigraphic gap associated with an angular unconformity occurs between the Pliocene and the Miocene. This gap does not appear only at Băicoi; it is characteristic of the whole Carpathian Foredeep.

On the Băicoi-Ţintea anticline, several objectives belonging to the Dacian, Meotian and Sarmatian proved to be productive since 1862. In the westernmost part of the structure, petroleum indications have been pointed out in the Helvetian, too.

The Sarmatian proved to be productive on the southern flank, east of "Băicoi-salt". The Meotian, with its complexes M II, M int., M I and M gas, is saturated with hydrocarbons on both flanks. The Dacian, through Dräder and locally (Ţintea) the upper horizons, is productive on both flanks at Ţintea, on the southern flank at Băicoi-salt (the central compartment) and the northern flank at Băicoi. These objectives contain petroleum accumulations. The Meotian petroleum saturated zones are accompanied by primary gas cap. The Meotian (M I and M II) also includes gas deposits in the Floreşti-Călineşti sector. The Băicoi-Ţintea traps are of structural and paleogeomorphic type (Sarmatian), while the deposits are stratiform. The energy of the deposits is furnished by the expansion of the associated gas and, locally, by the syncline water pushing. Locally secondary recovery methods are applied successfully.

The Gura Ocniţei-E-Moreni-Piscuri-Filipeşti structure (33, Fig. 22) represents the central sector of the Ţintea-Băicoi-Moreni-Răzvad-Tîrgovişte diapir alignment that develops on a length of about 18 km, between the Călineşti fault to the east and the Valea Morţii fault to the west. This anticline is the most typical diapir fold (Fig. 28) and contains the most important Romanian oil deposits. The salt core outcrops on a distance of 6 km between Gura Ocniţei and Piscuri.

The first oil pits on the structure were drilled at Moreni S within the period 1890—1898, for the exploitation of the Dacian and Levantine. Still, the first oil production on the structure was recorded in 1898; it reached 544 t, probably, from the Levantine. At the beginning of the 20 th century the first wells reaching the depth of about 200 m were drilled, which enabled the indentification of the Dacian deposits in 1904. Ten years later (1914) the Meotian started being exploited on the northern flank, where it lies at a smaller depth. Between 1927—1929 the Meotian productive beds on the southern flank were crossed. The subsequent works indicated the oil presence in the Helvetian at Gura Ocniţei (1924) and in the Oligocene underlying the Buglovian salt at Moreni (1966).

Numerous wells carried out on the structure up to the depth of 4,500 m identified a succession of deposits consisting of the Levantine, Dacian, Pontian, Meotian, Helvetian, Burdigalian salt and the upper part of the Oligocene.

The Oligocene, which develops in flysch facies, is predominantly clayey (the Pucioasa facies) at Gura Ocniţei, where it was found under the Meotian, while it is clayey with siliceous sandstone intercalations at Moreni. The Oligocene was not completely crossed within the structure.

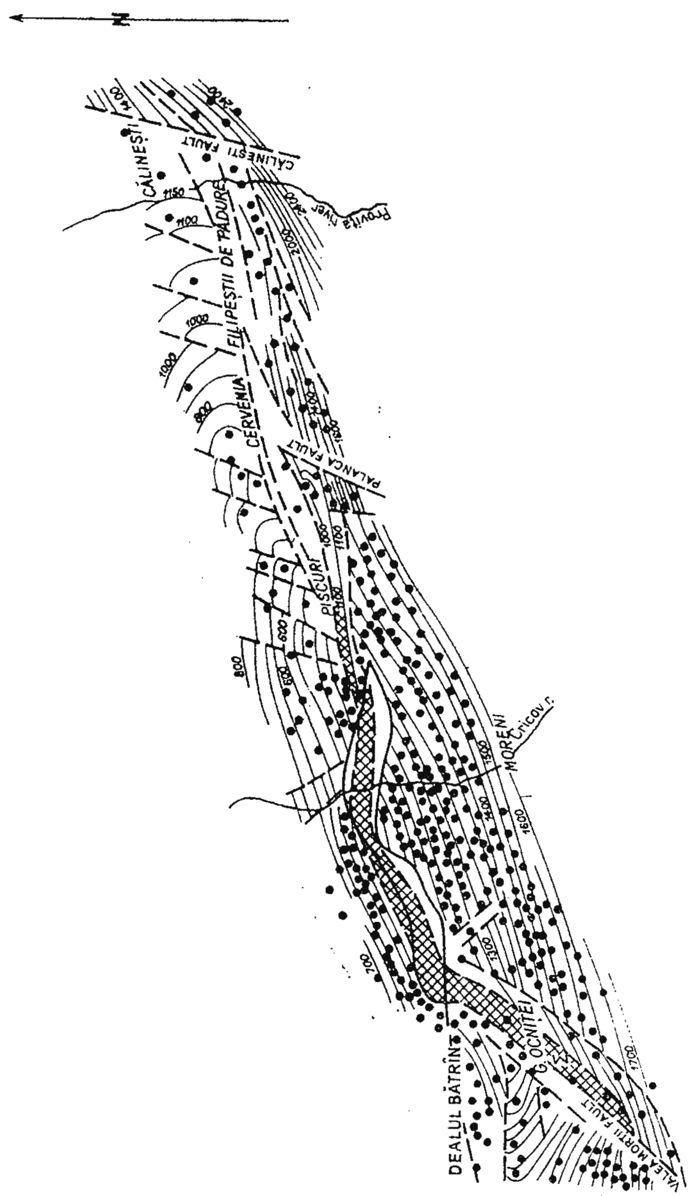

Fig. 28. — Structural map of the Gura Ocniței-Moreni-Filipeștii de Pădure anticline, at the top of the Meotian (according to G h. O l t e a n u).

The Aquitanian-Burdigalian is known in the Moreni zone; it consists of gritty anhydrites and weakly sandy marls in the base and of grained salt rocks containing clay and gray marls in the upper half. The saliferous Burdigalian formation is responsible for the diapirism of the Moreni structure.

The Helvetian probably comes next to the Aquitanian-Burdigalian in continuity of sedimentation and is unconformably overlain by the Meotian. The Helvetian, whose thickness is rather variable, consists of the lower red horizon which is made up of an alternation of calcareous sandstones and sands with marl intercalations frequently red-brown whose dips can reach 60—78°.

The Meotian overlies transgressively and unconformably the Helvetian and, locally, the Oligocene. It is made up of marls and sands, the latter being grouped into the complexes M III, M int., M II and M I. The complex M III at Moreni and Gura Ocniţei corresponds to the complex M II at Băicoi and Boldeşti; the complexes M I and M II at Moreni constitute an equivalent to the group M I at Băicoi-Ţintea (Fig. 29).

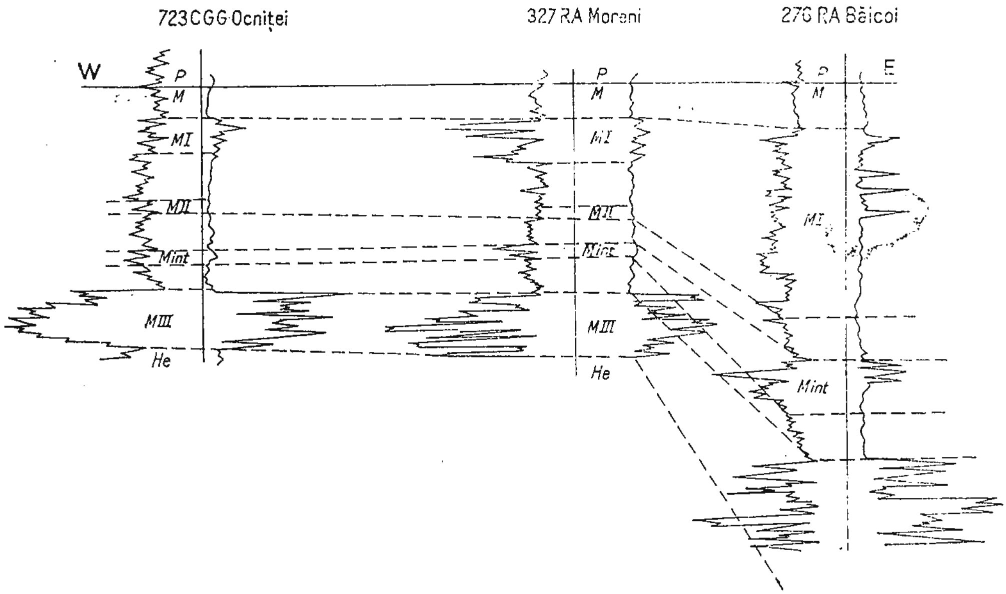

Fig. 29. — Correlation of the stratigraphic terms of the Meotian of the Ţintea-Băicoi and Gura Ocniţei-Moreni-Filipeşti structure (according to Gh. Olteanu).

It must be mentioned also the fact that there are lithological and thickness differentiations within the same structure between the Meotian on the south flank and the Meotian on the north flank. Stratigraphically, the basal term of the Meotian (M III) corresponds to the Middle Meotian horizon, developed in brackish water facies with mesohaline and polyhaline fauna, with *Dosinia meotica, Ervilia minuta, Rotalia beccarii.* The Meotian thickness is reduced from about 300 m in the last sector, to about 150 m in the west extremity of the structure. Reductions in thickness are also found from the flank to the apex zone which suggests the synsedimentary formation of the respective structure.

The exclusively marly Pontian follows the Meotian in continuity of sedimentation and is about 500 m thick in the west and about 800 m in the east sector.

The Dacian is made up of sands and sandstones with marl intercalations and clays. The frequency and thickness of the sands is greater in the lower part of the contour where lignite intercalations occur. The thickness of the Dacian varies to the same effect as the Pliocene terms, a thickness of about 300 m at Gura Ocniței and 350—400 m at Călinești and only 200 m in the apex zone being recorded. The sands and sandstones of interest have been divided into several complexes, from bottom to top, as follows: Dräder, Moreni, Middle Dacian, Gros and Upper Dacian (Fig. 10). The Levantine consists of a lower marly horizon with *Helix* and *Planorbis* and of an upper horizon made up of weakly consolidated sands, gravels and clay intercalations. The Levantine reaches a thickness of 200 m near the salt massif and 500—600 m on the flanks.

The Moreni diapiric fold is disturbed by several tectonic accidents, the most important of which being the axial fault system and the Valea Morţii fault, along which the salt could be ejected. It is also along the axial fault system that the creeping and the overthrust of the south flank by the north flank took place. Beside the Valea Morţii and Călinești faults that bound this structure to the west and east, one of the several transversal accidents should be also mentioned: the Palanca fault between the Filipeşti sector, with unproductive Dacian, and the Moreni sector, where the Dacian sand complexes are saturated with petroleum.

The outcropping salt has an irregular contour, increasing in width on a distance of 300—1,000 m. The salt massif dips northwards at Filipești and Bana and has a vertical position at Moreni and Gura Ocniței. The shape of the salt massif also varies within the structure (Fig. 30).

The productive formations at Gura Ocniței E-Moreni-Piscuri-Filipești are the Helvetian, the Meotian, the Dacian and the Levantine. Petroleum traces and salt water have been also recorded in the Moreni Oligocene (about 1, 800 l petroleum with a specific gravity of 0.850 kgf/dm^3).

The Helvetian contains petroleum at Gura Ocniței, Moreni and Filipești. The productive areas have a reduced extension, while petroleum is accumulated in the truncated beds that come into contact with the Meotian on the unconformity plane.

The Meotian is productive throughout the structure, both on the south flank and the north flank. As a matter of fact, the Meotian reservoirs provided 49.5 per cent of the structure production, that is, the same percentage reached by the Dacian.

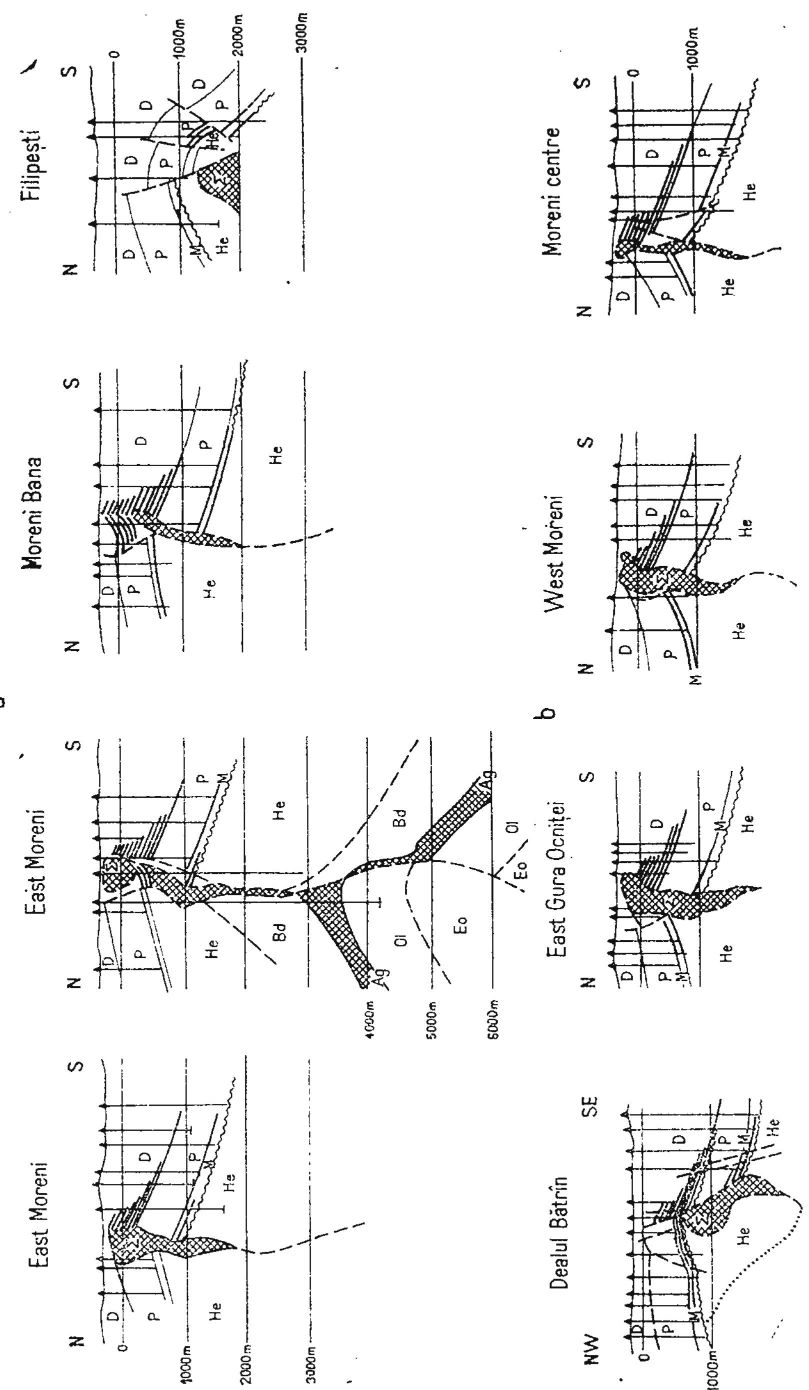

Fig. 30. — Variation of the salt massif form and the position of the producing strata on the Gura Ocniței-Moreni-Filipești structure (according to G h . O l t e a n u).

The Dacian contains hydrocarbons throughout the structure, with the exception of the Florești sector. The Dräder is the most important of the Dacian members of interest, the other terms being characterized by restricted productive areas. The exploitation of the Dacian meets with some difficulties due to the sand instability.

The Levantine contains petroleum on the south flank, at Moreni, near the salt massif, at the depth of 200—350 m. Owing to the very viscous petroleum, the exploitation of this deposit could only be achieved by the steam cyclic injection.

All the productive formations contain petroleum and associated gas, including primary gas cap (locally) in the Meotian and even in the Dacian (Piscuri). Exclusively gas horizons (free gas) were found in the Dacian at Bana.

The main physical parameters of the deposits vary as follows:

	Meotian	Dacian	Levantine
porosity (per cent)	25—30	31—33	29.5—31
connate water saturation (per cent)	20—25	19—50	20—29
volume reduction factor	1.18—1.26	1.04—1.21	1.00—1.08
petroleum specific gravity (kgf/dm^3)	0.84	0.88	0.88—0.95

Concerning these parameters, it is worth remembering the fact that the Meotian contains exclusively paraffinic petroleum (C), while the Dacian is characterized by non-paraffinic (A) and semi-paraffinic (B) petroleum. The Dacian has also paraffinic petroleum, but only in an extremely few isolated wells situated near the salt core at Bana and Gura Ocniței, which suggests that it migrated from the Meotian. This fact is an argument in favour of the different source of the Dacian and Meotian petroleums, which means that the hydrocarbons are to be found in the formations that generated them. For supporting the same conception, one should add that the Dacian associated gas contains 10—30 per cent CO_2 while the Meotian associated gas contains maximum 1 per cent CO_2.

The water mineralization increases with depth and, generally, from the syncline towards the salt massif. Thus the Meotian is characterized by concentrations of 150—200 g/l, while the Dacian waters have 20—50 g/l. All the waters are of chlorocalcic type. The deposits yielded under elastic regime and by the solution gas expansion. The traps are of structural and paleogeomorphic (the Helvetian) type, while the deposits are stratiform.

The Răzvad-Gura Ocniței W structure (34, Fig. 22) represents a segment of the major diapir anticline (Țintea-Tîrgoviște), bounded by the Valea Morții fault to the east and the Mahalaua fault to the west (Fig. 31). The geological state in this sector is somewhat similar to that at Gura Ocniței E- Moreni. Still, there are two different elements that arrest one's attention. Here, in the apex zone,the Pliocene overlies directly the Oligocene of Pucioasa facies that, in its turn, is overlain by Helvetian deposits in pericline and on the flanks.

A secondary arch, known under the name of "Dealul Bătrîn", lies north of Răzvad-Gura Ocniţei W uplift; the Dacian crops in its crest. This secondary structure represents a connection between the Ochiuri and Răzvan-Gura Ocniţei W diapirs.

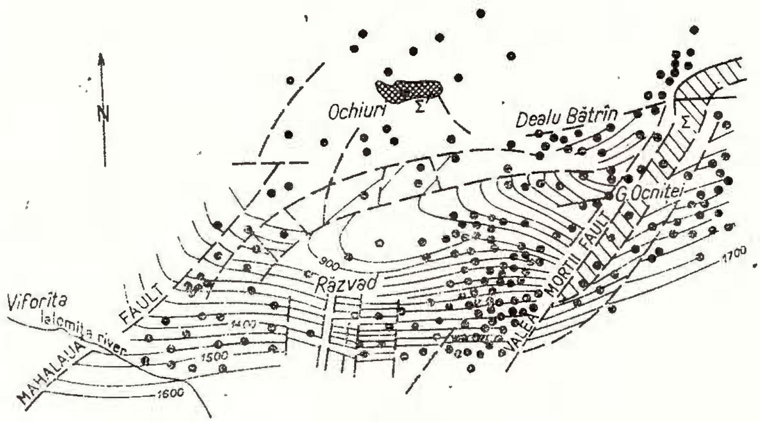

Fig. 31. — Structural map of the Răzvad-Gura Ocniţei anticline (according to Gh. Olteanu).

The main productive formation on this structure is the Meotian (M III, M int. and M I). In the apex zone the Dräder is also petroleum saturated. The truncated Helvetian beds add on the flanks and in the pericline sectors; they are hydrocarbon saturated at the contact with the Meotian, along the unconformity.

The Teiş-Viforîta zone (35, Fig. 22) constitutes the western extremity of the major Ţintea-Tîrgovişte anticline that develops west of the Mahalaua fault. It is bounded by the Teiş fault to the north and west. The Teiş-Viforîta zone corresponds to a diapir anticline with the fallen northern flank (included in the Aninoasa structure) and an uplifted southern one that extends south of the Teiş fault as a monocline.

This region is made up of the Burdigalian salt, the Helvetian and the Pliocene. The productive areas are located in the Meotian and in the truncated Helvetian beds, at their contact with the Meotian. There is a hydrodynamic communication between the Helvetian beds as well as between them and the overlying Meotian. The water-petroleum contact is tabular which justifies the inclusion of the respective accumulations among the massive deposits. The Meotian, consisting of the complexes M III, M int. and M I, is productive throughout the zone. In fact, only M I is hydrocarbon saturated in the central and eastern blocks.

Initially the Meotian had also primary gas cap. In fact, the Dacian had initially a gas cap in the apex zone of the structure. More important among these accumulations are those belonging to the Meotian. The main parameters of the Helvetian deposits are: porosity 22%, connate water saturation 65%, volume reduction factor 1.21, petroleum specific gravity 0.845 kgf/dm³. The traps are of structural and paleogeomorphic type.

A series of folds with much smaller dimensions and with damped diapirism (cryptodiapirism) are to be found south of the above presented structures. They have not a regular disposition, therefore, structural ranges with regional character are not easily arranged in a line. According to recent research (Pătruţ et al., 1973) the latter seem to correspond to a platform basement, while the former (except, probably, those situated south of the Buzău Valley) belong to the internal Carpathian basement. A first group of southern structures includes the Ariceşti, Mărgineni, Bucşani and Brăteşti brachyanticlines.

The Ariceşti structure (36, Fig. 22) represents a faulted brachyanticline with a sunk eastern compartment. Apart from the Pliocene, the region is made up of the Sarmatian and the Tortonian. The wells drilled here identified hydrocarbon deposits in the Sarmatian, Meotian, Dacian and Levantine. The Sarmatian was found on the flanks overlying the structure with ever newer terms towards the axial zone, which indicates that the statigraphic profile variation is a consequence of transgression and not of the pre-Meotian denudation. As a result, the Sarmatian forms petroleum stratigraphic traps (e.g. well no. 105) on the pericline and on the flanks of the anticline. The Meotian, about 250 m in thickness, is characterized by four sand complexes: M III and M int. with petroleum and associated gas (including primary gas cap); M II with petroleum, associated gas and free gas, and M I which is free gas saturated. The Dacian contained free gas in four complexes (G VIII—G V), while the Levantine had gas productions through four members called G IV—G I. The traps at Ariceşti are of structural and stratigraphic type, while the deposits are stratiform.

The Mărgineni anticline (37, Fig. 22) trending ENE-WSW is 8 km long and is disturbed by several faults. One of these faults, having a longitudinal character, separates the northern compartment, which is sunk, from the rest of the structure, which is more raised. The wells drilled at Mărgineni to the depth of 6,000 m identified an almost complete stratigraphic succession that starts with Levantine and ends at a certain depth with the Burdigalian salt.

Hydrocarbon accumulations have been known at Mărgineni since 1935 in the central Sarmatian compartment, in the central and western Meotian zones (M III, M int. M II, and M I) and in the Dacian (Dräder and undivided Dacian). The Sarmatian, M III, M int. and M II contain petroleum (M III contained also primary gas cap), while M I and the Dacian are characterized by the presence of free gas. Traces of petroleum have been also obtained (maximum 700 l/day, by swabbing) from the Helvetian, at the depth of 4,220—4,700 m in well no. 913. The structural and paleogeographic factors (in the Sarmatian) contributed to the formation of the traps at Mărgineni.

The Bucşani brachyanticline (38, Fig. 22) is situated south of Gura Ocniţei. It represents a cryptodiapir fold, similar to that at Ariceşti, divided by numerous faults, the most important of which affects the south flank. The salt core intercepted under the Pliocene, partially pierces also the Meotian in the axial zone of the structure. In addition to the Tortonian salt, whose age was established without any convincing arguments, the anticline consists also of the Sarmatian and the Pliocene. The complexes M II and M int., that are found on other structures, are replaced by marls here.

The hydrocarbon deposits are located in the Meotian and the Dacian. Their exploitation started in 1934 and 1942, respectively. Petroleum indications were found in the Tortonian, too (Grigoraş, 1961). The Meotian shows two sand complexes : M III and M I. The complex M III was, in its turn, divided into two members, M IIIa and M IIIb, the latter being present only in the western part of the anticline. The lower member M IIIb is petroleum saturated and the overlying member M III contains free gas. The sands in the complex M I are petroleum saturated. The Dacian contains petroleum, associated gas (including the primary gas cap) and free gas in the Dräder and in the series of undivided sands.

The main characteristics of the deposits at Bucşani could be synthetized as follows :

	M III	M I	Dacian
thickness (m)	3.5—13	4.5—5.3	3—25
porosity (per cent)	20	20	25—37
connate water saturation (per cent)	22	40	25—30
volume reduction factor	1.37	1.37	1.06
petroleum specific gravity (kgf/dm³)	0.83	0.83	0.84

The Meotian deposits yielded in an active hydrodynamic regime, while the others yielded in mixed regime. The traps are of structural and stratigraphic type.

The Brăteşti dome (39, Fig. 22) has been explored up to the depth of 5,591 m, the following stratigraphic succession being found : Pliocene, Sarmatian, Tortonian (without salt), Helvetian-Burdigalian salt, Upper Cretaceous (the last term belonging to the platform).

Only two small gas accumulations in the Dacian divided into two complexes : „a" and „b", were found on this structure.

The southernmost productive structures situated around or on the contact between the foredeep and the platform are : Sărata-Monteoru, Măneşti-Vlădeni, Brazi-Frasin, Finta-Gheboaia and Gura Şuţii.

The Sărata-Monteoru structure (40, Fig. 22) represents an anticline located in the zone of contact between the Carpathian Foredeep and the Moesian Platform. It is well expressed morphologically and it was, therefore, eroded in the uppermost sector up to the Sarmatian level. The deposits forming this structure, that is, the Helvetian, the Tortonian, the Sarmatian and the Pliocene, are strongly tectonized as a result of their position in the contact zone.

Petroleum accumulations and free gas of little importance have been identified in the Sarmatian and Meotian at Sărata-Monteoru. The exploitation of the Meotian petroleum deposits started in 1845 by pits. In 1925 began the exploitation by galleries within which horizontal and vertical boreholes were drilled, reaching the depth of about 150 m at 20 m distance from one another. This exploitation system could be applied as the deposit is degasificated and the aquiferous beds have low capacity. In recent years the exploitation by galleries has been stopped and the mine became a museum. Petroleum accumulations and free gas have been identified in the Sarmatian in recent years too as the investigation of the structure was resumed.

The Mănești-Vlădeni dome (41, Fig. 22) was identified by geophysical prospections and then confirmed by drilling in 1937, when gas was found out. Later on the structure proved to be exclusively gas-bearing, the hydrocarbons having been accumulated in the Meotian and in the Dacian. The main productive formation is the Dacian whose gas contains 97.6 %—98.6 % methane.

The Brazi-Frasin structural zone (42, Fig. 22) represents a slight anticline crossed by faults and divided into several blocks. Out of the 20 wells drilled in this region only 6 proved to be productive : 5 at Brazi and 1 at Frasin. The gas-bearing formations are : the Meotian, only at Brazi and the Dacian, both at Brazi and Frasin. After 26 days of exploitation, the well at Frasin was flooded by water so that the respective accumulation could not prove its economic value.

The Finta-Gheboaia structure (43, Fig. 22) belongs to the external border of the Carpathian Foredeep. The wells drilled here revealed the whole succession of deposits from the Levantine to the Helvetian. The structure is made up of two culminations : a northern one, at Gheboaia and a southern one, at Finta. According to the interpretation achieved at the Dacian-Pontian boundary, the Gheboaia culmination appears about 80 m higher than the Finta culmination.

The structure is exclusively gas-bearing, the hydrocarbons being located in the Meotian and in the Dacian. Locally, at the contact with the Meotian, the Sarmatian is also productive. The sandy beds of interest belonging to the Lower Dacian have been divided into three members (*a*, *b* and *c*). The traps are of structural and paleogeomorphic type.

The Gura Șuții structure (44, Fig. 22) lies to the west of the Dîmbovița River, but, from a geological viewpoint and taking into account the accumulation conditions, it is obvious that it must be integrated into the same unit as the Finta-Gheboaia and Frasin-Brazi structures. The stratigraphic succession here is similar to that at Finta, the wells penetrating deposits of Levantine to Helvetian age. The structure looks like a brachyanticline trending NE—SW and crossed by two transversal faults.

As almost all the structures on the southern sunk border of the Carpathian Foredeep, the Gura Şuţii brachyanticline is exclusively gas-bearing. The Meotian is the main productive formation. Locally, at the contact with the Meotian, gas was identified in the Sarmatian, too. The physical parameters of the deposit show the following average values: porosity 25 per cent, initial connate water saturation 22 per cent, effective permeability 225 mD. The methane content of the gas is 96—99 per cent. The exploitation regime is influenced by the active hydrodynamic factor. The Meotian trap is of structural type, and the Sarmatian trap is of mixed type, that is, paleogeomorphic-stratigraphic (lithological and permeability variation)-structural.

The Dîmboviţa Valley crosses two productive structures, Drăgăeşti and Dragomireşti, belonging to different ranges and developing both in the Mio-Pliocene zone and in the Getic Basin.

The Drăgăeşti structure (45, Fig. 22) was identified by geomorphologic prospecting (Paraschiv, 1965) and confirmed by the seismic and drilling works afterwards. The Quaternary and the Levantine outcrop and the wells reached the Oligocene that underlies directly the Meotian in the central zone. The structure represents a faulted and complicated anticline tending to raise northwards, that is, towards the Boţeşti anticline. The central fault F_1, by its unsteady character, creates such a relationship among the various compartments that it seems either a faulted fold or a syncline (Fig. 32). The dip of the formations is of the order 5°—7°.The Meotian formation is of interest among the four members (from top to bottom) *a*, *b*, *c* and *d* that are hydrodynamically separated in most cases. Some of these members present local developments as a result of the lithological variations. The bed *d* contains petroleum and the beds *a*, *b* and *c* contain petroleum with primary gas cap. The bed *a* also contains free gas. The thickness of these gritty-sandy reservoirs is 2.79 to 9.37 m, the porosity is 22 per cent to 27 per cent, the connate water saturation is 20 per cent to 30 per cent, the volume reduction factor is 1.21, the petroleum specific gravity is 0.857 kgf/dm³. The initial pressure of the deposits was 140—170 kgf/cm² and the bottom-hole temperature 53° to 67°C. The water salinity is 115 g/l, the fluids belonging to the category of chlorocalcic waters. During exploitation, some difficulties arose as a result of the sand instability and the blockage of the beds by the drilling mud. The traps are of structural and stratigraphic type and the deposits are stratiform. It is worth mentioning that the Drăgăeşti oil field corresponds to a productive syncline that lies on the same major alignment where the syncline folds contain petroleum and gas deposits at Aninoasa and Matiţa-Valea Dulce.

The Dragomireşti structure (46, Fig. 22) seems to continue westwards the Teiş-Viforîta-Moreni alignment. It represents a cryptodiapir fold trending NE—SW, with the north-western flank more raised and slightly pushed over the south-eastern one. The structure consists of Oligocene, Aquitanian-Burdigalian (with salt) and Pliocene deposits.

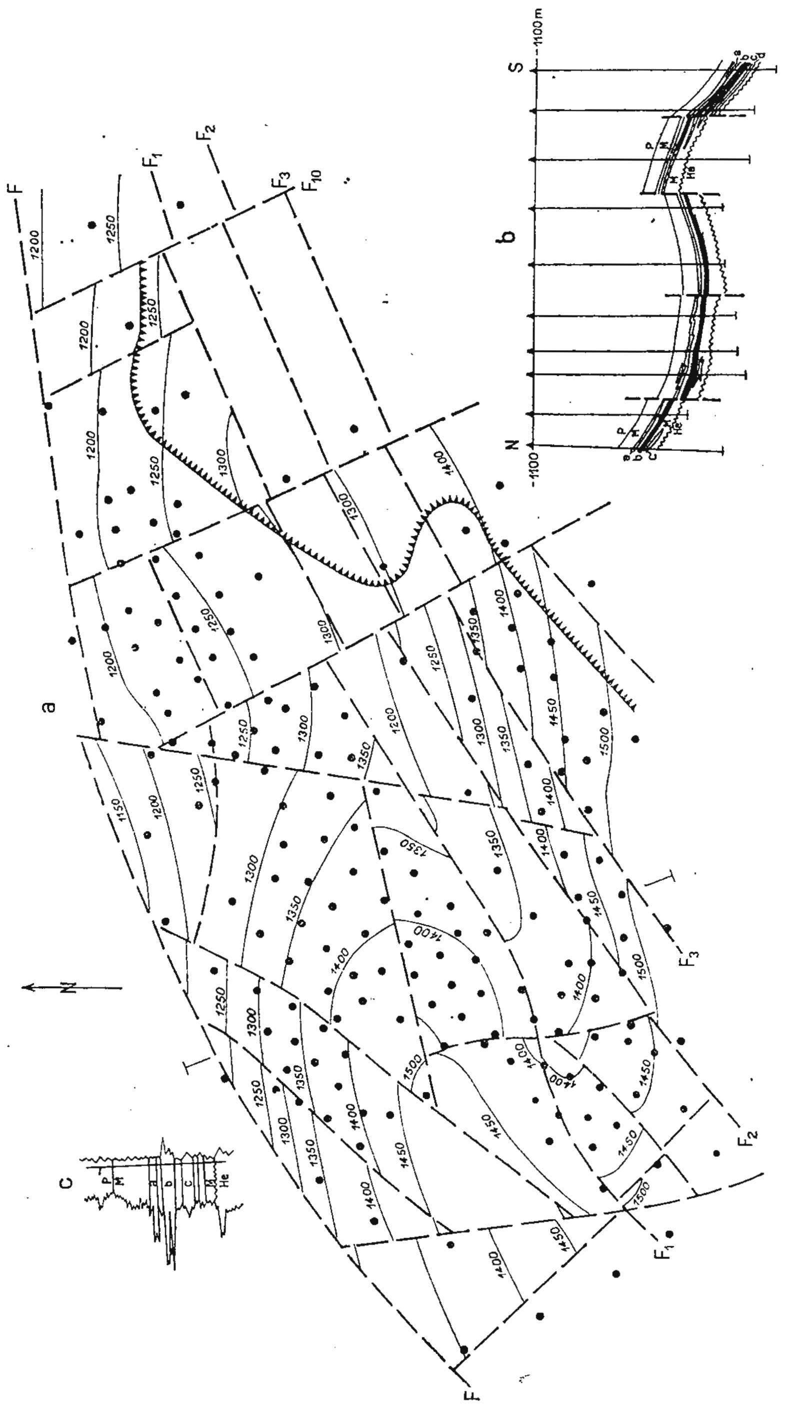

Fig. 32. — Drăgăești structure.
a, structural map at the top of the Meotian; b, geological cross section; c, Meotian type profile (according to G h. O l t e a n u).

Hydrocarbons in the Helvetian (truncated beds) and in the Meotian, which consists of the complexes M III, M int. and M I, were discovered at Dragomirești. The Helvetian and the complex M III, which are productive on the southern flank, contain petroleum ; M int. contains petroleum with primary gas cap and free gas on the northern flank ; M I is exclusively gas-bearing also on the northern flank. The traps formed under the influence of the structural and paleogeographic (the Helvetian) factors. The deposits are of stratiform type.

d) **Getic Depression.** It represents the western segment of the Carpathian Foredeep, between the Dîmbovița and the Danube. Although the Getic Depression is an integral part of this unit, it shows some stratigraphic and structural peculiarities as well as conditions for the formation of hydrocarbon deposits. The fact accounts for the presentation of the productive structures in a subchapter different from the one dealing with the Mio-Pliocene zone.

First, it must be mentioned that the Miocene, which is less affected by erosion than in the region east of the Dîmbovița, is found in complete sequence, has a larger distribution and is a component part of most of the structures. Consequently, the frequency, size and number of hydrocarbon accumulations in the Getic Depression Miocene substantially exceeds those of the Mio-Pliocene zone.

Secondly, it should be noted that the diapirism, which is characteristic of the region between the Dîmbovița and the Buzău, played an insignificant part in the tectogenesis of the sector situated west of the Dîmbovița Valley. Indeed, diapir folds actually exist only in the south-eastern part of the Getic Depression on the Șuța Seacă-Slătioarele (Pitești) and Dragomirești alignments. The consequence of this fact lies in the quieter, less broken character of the anticlines of interest.

On the whole, the structures are disposed in echelons parallel to the direction of the Carpathians, but these alignments are no longer so perfect, clear as those of the Mio-Pliocene zone (Fig. 22).

To the east of the Dîmbovița, a zonality of hydrocarbon distribution arises, in the sense that, in the northern sector, which is more raised, only petroleum deposits exist ; petroleum deposits with primary gas cap lie to the south ; only gas fields are found on the southern sunk margin. Such a distribution confirms G u s s o v's principle (1954). This regularity is no longer so evident in the Getic Depression, numerous gas structures being present also on the raised northern border of the region. On the whole, the segment between the Dîmbovița and the Danube comprises more gas accumulations (is more gas-bearing) than the region between the Dîmbovița and the Buzău. It might be even said that the frequency and importance of the gas deposits decreases continually within the boundaries of the Carpathian Foredeep, from the Danube towards the northern frontier of the country.

The productive anticlines of the Getic Depression are disposed on about eight structural alignments. The northernmost one with very small, predominantly gas-bearing deposits, is made up of the Tg. Jiu, Tămăşeşti and Bala structures.

The Tg. Jiu structure (42, Fig. 22), situated south of Tg. Jiu, represents effectively a block structure, in the sense that the anticline is surrounded by faults with various throws. The wells drilled here penetrated the whole sequence of deposits that starts with the Quaternary and ends with the Helvetian-Burdigalian. Hydrocarbon accumulations were found in the Helvetian and in the Sarmatian deposits. The Helvetian contains petroleum in the lower conglomerate horizon as well as free gas in the gritty horizon. The Sarmatian contains petroleum with primary gas cap.

The gas-bearing Tămăşeşti zone (48, Fig. 22) lies west of the Tg. Jiu structure, but on the same structural alignment. This sector consists of Oligocene, Helvetian, Sarmatian and Pliocene deposits. At the Meotian level the structure appears as a western hemianticline crossed and sealed by a fault eastwards. Lower, in the Miocene, tectonic complications arise in the form of Oligocene thrusts over the Helvetian. Small gas accumulations in the Upper Meotian are to be found at Tămăşeşti.

The Bala structure (49, Fig. 22) probably represents the western continuation of the Văianu anticline. A slight undulation trending NE—SW and surrounded by faults appears at Bala against a NW—SE monocline background. A well drilled here up to the Senonian deposits (2,300 m) contained gas in the Tortonian at the depth of about 1,100—1,160 m. The output and pressures varied as a function of nozzles, that is 17,000—27,000 m^3/day with 40—70 kgf/cm^2.

Another structural alignment consisting of the Foleşti, Alunu, Colibaşi and Strîmba anticlines appears south-west of the three productive zones presented above. According to some geologists, the Colibaşi and Alunu folds would belong to the same echelon as the Tg. Jiu-Tămăşeşti structure. The anticlines of the second alignment are somewhat more developed and contain larger accumulations, especially oil deposits.

The Foleşti anticline (50, Fig. 22) represents a structural detail of the Măgura Slătiorului-Govora-Ocnele Mari anticlinorium. At the Oligocene level the Foleşti structure appears as a brachyanticline with the apex in the Bistriţa Valley, whence it sinks eastwards and westwards. This structural element is crossed by longitudinal and transversal faults that divide it into several blocks. On the surface, in the highest zone, the Helvetian outcrops, being overlain by the Tortonian, the Sarmatian and the Meotian on the flanks. At a considerable depth the wells crossed the complete section of the Helvetian, Aquitanian-Burdigalian with salt, Oligocene and the upper part of the Eocene. Fluid hydrocarbons with associated gas in the Oligocene were identified at Foleşti. The average porosity of the reservoir is about 20 per cent, the effective permeability 10 mD, the connate water saturation 50 per cent, the volume reduction factor 1.400 m, the petroleum specific gravity 0.862 kgf/dm^3, the initial reservoir pressure 250 kgf/cm^2 and the geothermal gradient 3°C/100 m. The deposit yields a small production as a result of the low reservoir permeability.

The Alunu structure (51, Fig. 22) represents a faulted anticline that develops west of the Olteț Valley. Helvetian and Meotian hydrocarbon accumulations were discovered here. The Helvetian contains petroleum, primary gas cap and free gas horizons. The Meotian contains only free gas. The petroleum deposit is characterized by low oil outputs with high G.O.R.

The Colibași structure (52, Fig. 22) is an anticline trending ENE—WSW, raising continuously west-eastwards (about 700 m). This anticline is divided into several blocks by a dense network of faults whose throw varies from 30 to 300 m. The wells drilled at Colibași penetrated deposits belonging to the Pliocene, Sarmatian, Helvetian and Oligocene. The Helvetian, which is a formation of first interest, consists of a conglomerate horizon including, probably, also the Burdigalian in the lower part, fol-

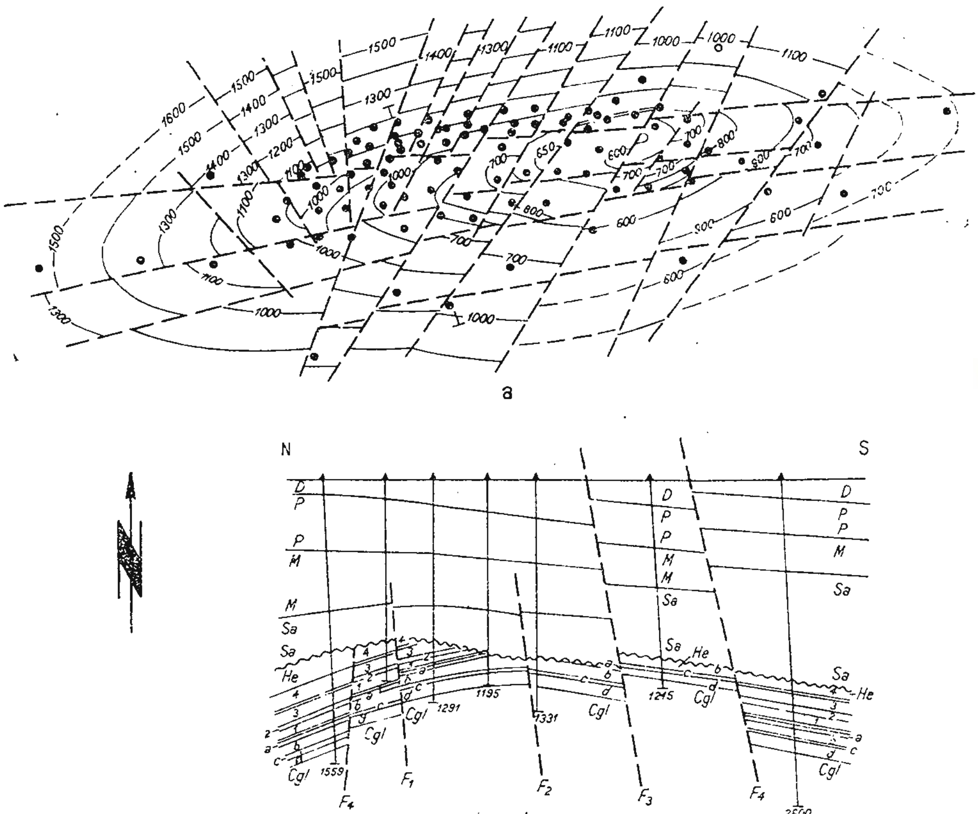

Fig. 33. — Colibași structure (Gorj district).
a, structural map at a Helvetian guide mark; b, geological cross section (according to V. Brînzan).

lowed by a sand horizon divided into nine complexes (to which the tenth one, represented by conglomerates, is added). The Sarmatian, which is predominantly marly and has sand intercalations, overlies the Helvetian unconformably. The Meotian and the other Pliocene terms probably follow in continuity of sedimentation.

At Colibaşi were found petroleum deposits and free gas in the Helvetian and Sarmatian and only free gas in the Meotian. The traps are of structural and mixed types, stratigraphic (lithofacial) and paleogeomorphic, respectively.

The Strîmba-Rogojelu structure (53, Fig. 22) was identified by seismic prospections in 1962. Later on the core drills and the deep wells confirmed the existence of an anticline crossed by longitudinal and transversal faults (Fig. 34). These wells investigated the structure up to the Sarmatian level that supports unconformably the Meotian and the other Pliocene terms. The Meotian, as a gas formation, contains a sequence of sandy beds

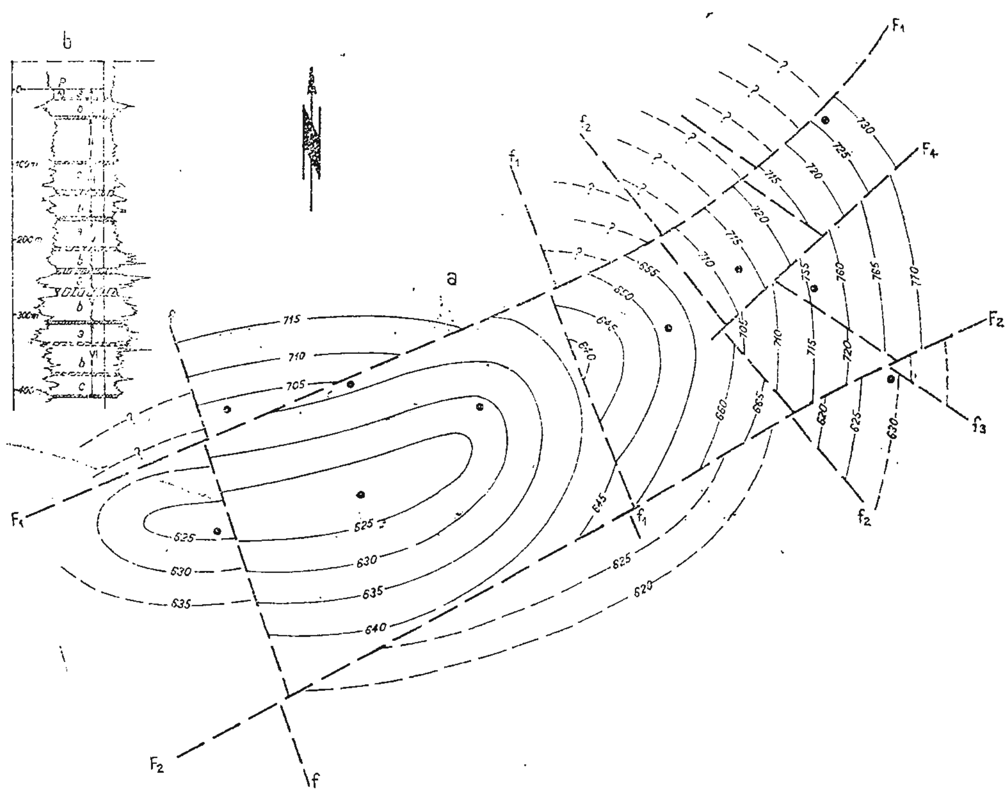

Fig. 34. — Strîmba-Rogojelu structure.
a, structural map at the complex III of the Meotian ; b, Meotian type profile (according to C. Săvulescu).

separated by marly intercalations. The respective sandy beds proved productive and were grouped into six complexes, some of them consisting of 2—3 members. The effective porosity of the reservoirs is 14 per cent—22 per cent, the connate water saturation 25 per cent—46 per cent, the initial pressures 80-114 kgf/cm², the reservoir temperature 39—52°C. The structure is completely outlined and ready to be exploited.

The next productive structural alignment located south of the previous one might consist of the Boțești, Vîlcele and Căzănești structures. This structural belonging seems to be conventional at one moment, so long as the relationships between the Boțești and Vîlcele structures entail discussion.

The Boțești structure (54, Fig. 22) lying at the Oligocene level, constitutes a brachyanticline crossed by longitudinal and transversal faults. The stratigraphic succession, determined by drillings, starts with the Pliocene, continues with the Sarmatian, Tortonian and Helvetian, which, occasionally may lack as a result of erosion, and ends with the Oligocene in the Pucioasa facies. Hydrocarbon saturated horizons were identified in the Oligocene base, in only one well, and also in the Meotian on the northern flank, in the eastern extremity of the structure. About 30,000 m³/day gas on a nozzle of 4.5 mm, the bottom-hole pressure 217 kgf/cm² were recorded from the Oligocene. From the Meotian gas was also obtained in several wells as well as petroleum with G.O.R., which means that a big gas dome

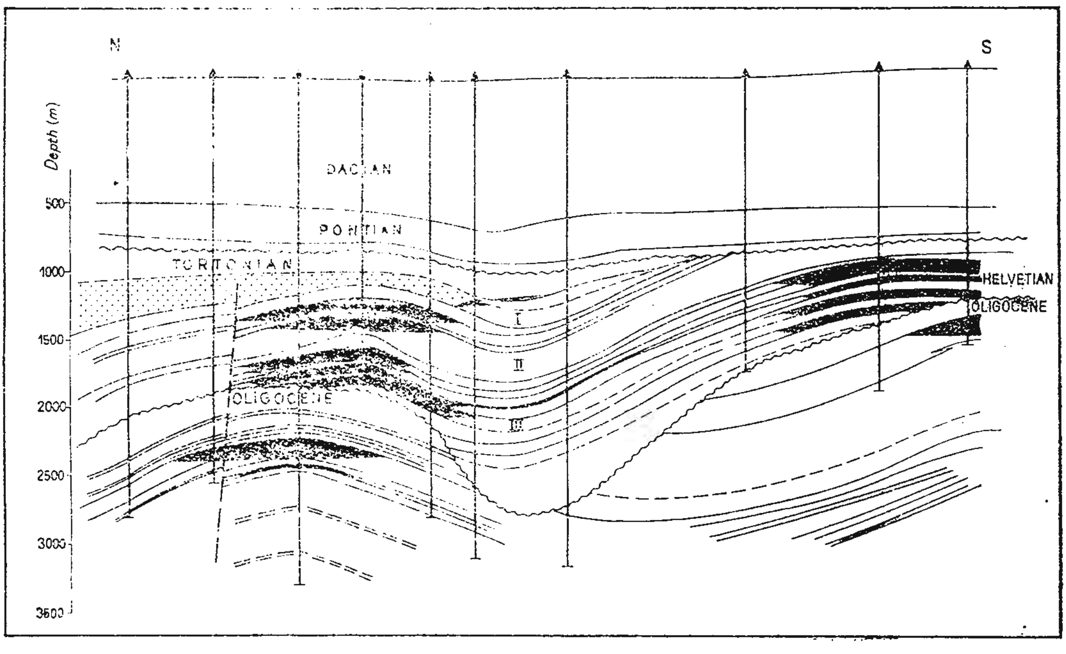

Fig. 35. — Geological cross section through the Vîlcele structure indicating the pre-Helvetian paleorelief (according to Gh. Popa).

with a narrow petroleum belt formed. The traps are structural and, locally, stratigraphic (the Meotian) type.

The Vîlcele zone (55, Fig. 22) represents a Paleogene anticline overlain by Helvetian, locally, Tortonian and Sarmatian deposits as well as Pliocene formations, all of them moulding and borrowing, on the whole, the Oligocene structural shape. The Vîlcele anticline was raised and eroded as a consequence of the Savian folding phase. Among the relief forms generated during the mentioned phase one should mention a transversal valley, about 700 m deep, in the southern part of the structure, which was filled up with Helvetian deposits afterwards (Fig. 35, 36, 37). These deposits together with the newer overlying formations compacted according to their lithologic nature and thickness, therefore depending on the depth of the valley, sketching a syncline on the Paleogene anticline side. Apart from these complications, the Vîlcele structural element is crossed by numerous faults trending longitudinally and transversally (Fig. 38).

Hydrocarbons were found in the Oligocene and Helvetian at Vîlcele. The main productive sequences in the Oligocene are the petroleum complexes A and B. Industrial petroleum productions were obtained in a few wells and from some horizons below the complex B. The Helvetian members (from top to bottom) H_1, H_2 and H_3 contain hydrocarbons. The members H_3 and H_2 contain gas with a narrow petroleum belt while the member H_1 contains only free gas.

	Helvetian	Oligocene
porosity (per cent)	17–27	24.4–24.6
permeability (mD)	14.5–225	18–510
connate water saturation (per cent)	30–40	18.5–26.4
volume reduction factor	1.33–1.34	1.29
petroleum specific gravity (kgf/dm³)	0.805–0.840	0.875
pressure gradient (kgf/cm²/100)	10	15
geothermal step (m/°C)	3	3

In the Helvetian, which is thicker, the porosity, permeability and hydrocarbon saturation decrease with depth. But the petroleum specific gravity decreases in inverse ratio to depth, so that only gas is found in the upper complex. The associated waters are of chlorocalcic type.

The Căzănești zone (56, Fig. 22) constitutes a structural detail (faulted monocline) on the southern flank of the Govora-Ocnele Mari anticline. Three wells at a small depth indicated gas in the Upper Tortonian gritty levels. But production data showed an output decreasing tendency proving the lenticular character of the accumulation.

Another echelon develops west of these structures; it is made up of the most important productive anticlines of the Getic Depression lying west of the Olt, that is the Bustuchini, Socu, Ţicleni and Bîlteni structures.

The Bustuchini anticline (57, Fig. 22) was identified by seismic prospectings. The numerous wells drilled reaching the depth of 4,500 m sho-

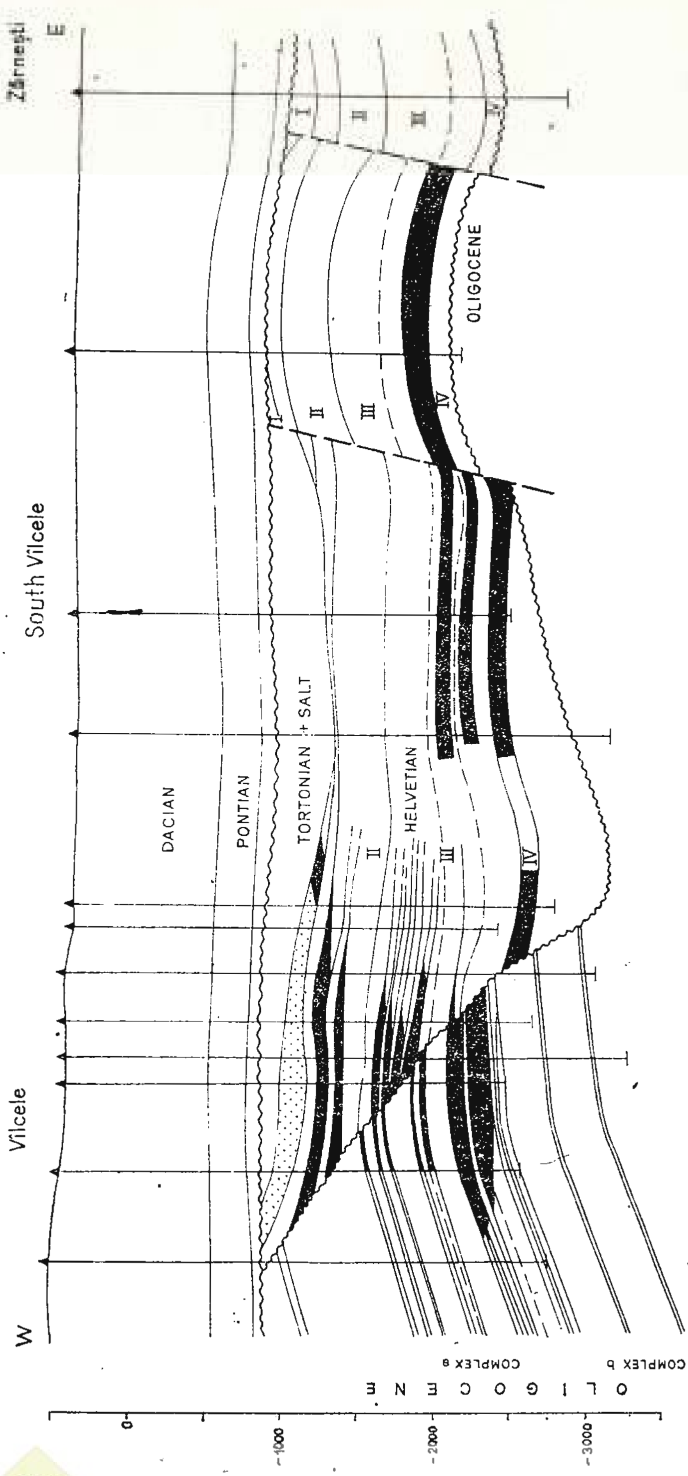

Fig. 36. — Longitudinal geological section through the Vilcele, indicating the pre-Helvetian paleorelief (according to Gh. Popa).

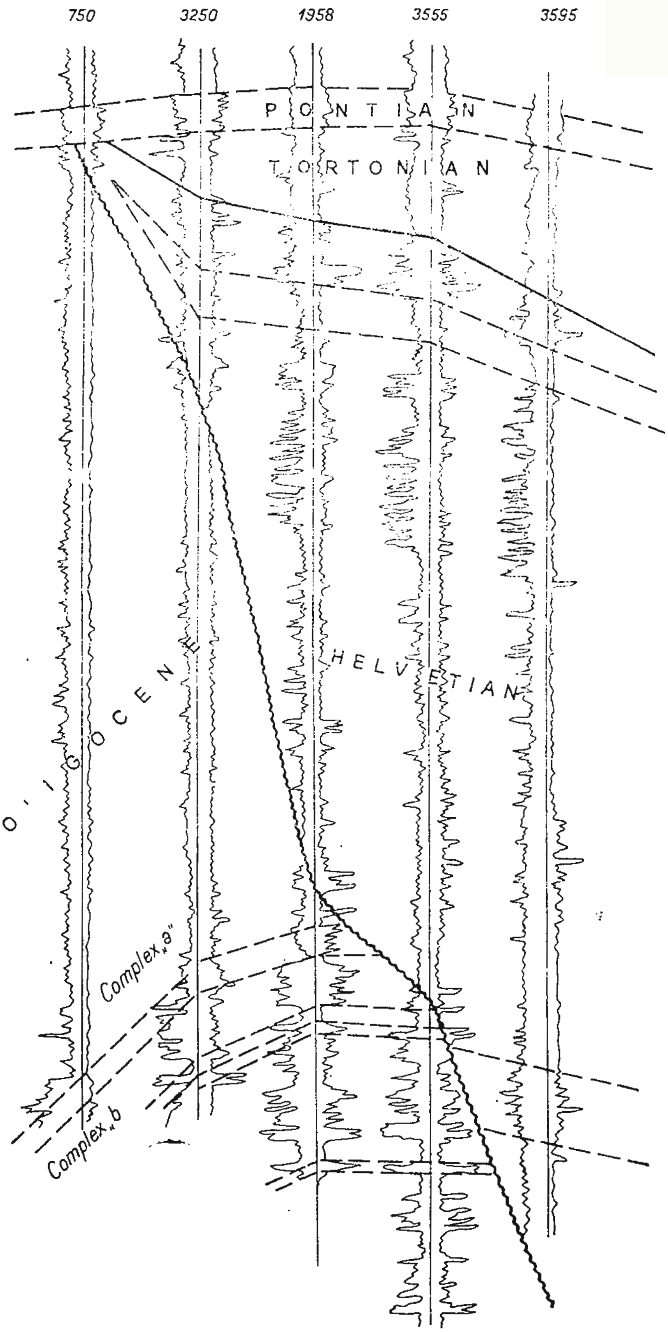

Fig. 37. — Vîlcele structure. Paleorelief resulting from the correlation of the electric diagrams (according to Gh. Popa).

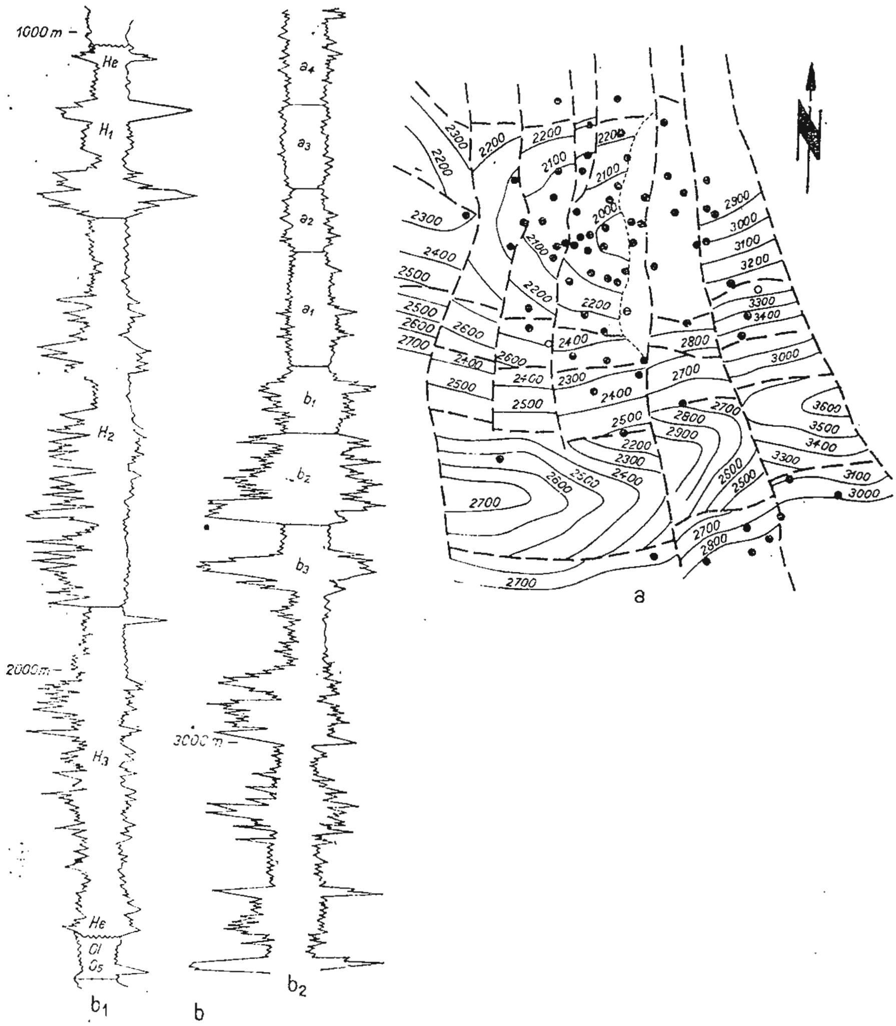

Fig. 38. — Vilcele (Argeș). structure
a, structural map at an Oligocene guide mark ; b, Helvetian (b_1) and Oligocene (b_2) type profiles (according to I. Moldovan).

wed that the stratigraphic sequence is made up of the Pliocene, Sarmatian, Helvetian-Burdigalian and the Oligocene, the last one in facies of Pucioasa. The Oligocene sequence was not completely penetrated, but only a section of 115 m. The Burdigalian consists of an alternation of sandstones, microconglomerates and clays, the psamite rocks being grouped into nine members (B_1—B_9). The Helvetian, which is 1,500—2,000 m thick, contains

12 gritty and partially microconglomerate complexes, noted H transition, H_1-H_{12} (Fig. 39). In the structure apex a part of the Helvetian sequence lacks, owing to the intraformational gaps, suggesting positive synsedimentary movements of the respective anticline. The Sarmatian consists of marls, sandstones and sands, the latter being grouped into four complexes (Sa VIII—Sa V). The lower complex (VIII) is represented by coarse sands; the next two terms (VII, VI) consist of sands with marl intercalations; the last complex (V) consists of gritty marls with sand and sandstone intercalations.

The Bustuchini anticline is an asymmetric fold trending E—W and crossed by very many longitudinal and transversal faults that divide it into numerous tectonic blocks. The fault throws is of 300—450 m, which makes them impervious as a rule. The dip of the beds varies between 2° and 4° in the Pliocene, 5° and 7° in the Sarmatian and 15—25° in the Helvetian-Burdigalian.

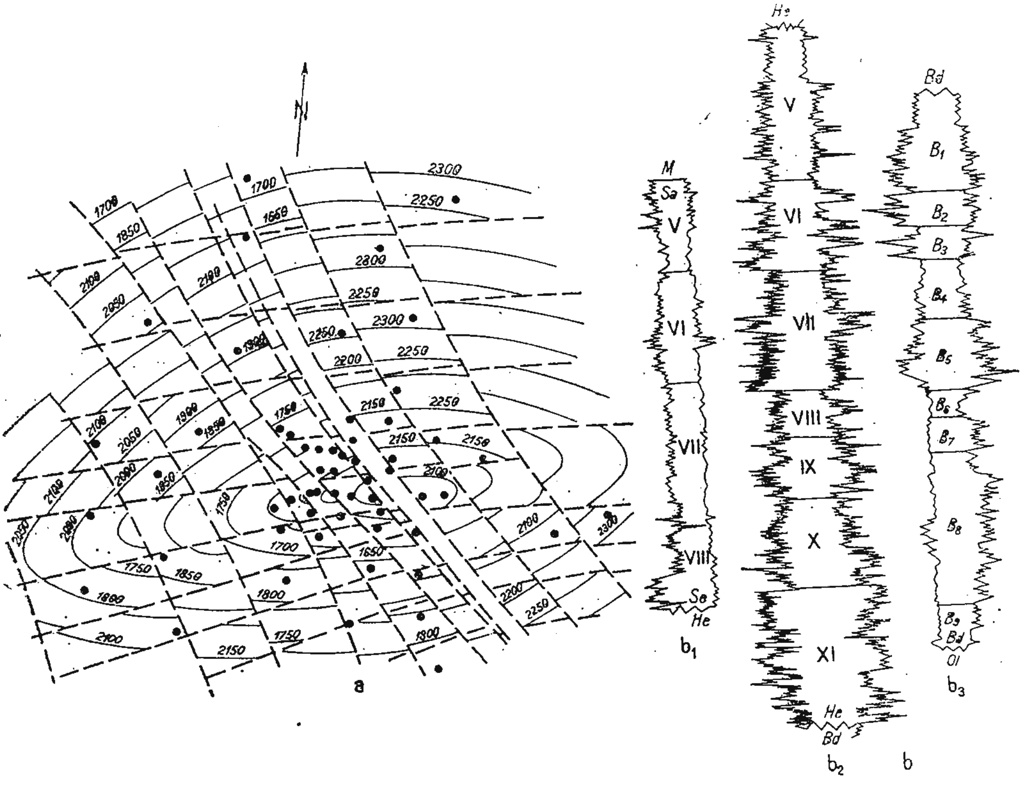

Fig. 39. — Bustuchini anticline.
a, structural map at a Helvetian guide mark; b, Sarmatian (b_1), Helvetian (b_2) and Burdigalian (b_3) type profiles (according to V. B r i n z a n).

The hydrocarbons are located in the Burdigalian, Helvetian and Sarmatian. The Burdigalian accumulates petroleum, associated gas, and free gas. The complexes corresponding to the terms IX—V are saturated with petroleum, associated gas and free gas. The Helvetian IV — I contains only free gas. The Sarmatian contains also free gas, both at Bustuchini and in the western sector at Licurici.

The average parameters of the deposits are as follows :

	Burdigalian	Helvetian	Sarmatian
porosity (per cent)	14	15—23	23—25
connate water saturation (per cent)	41	41	41
volume reduction factor	1.530	1.530	—
petroleum specific gravity (kgf/dm^3)	0.870	0.870	0.840
pressure gradient ($kgf/cm^2/100$ m)	1.17	1.17	1.17
geothermal gradient (°C/100 m)	3	3.5	4

The traps are of structural, stratigraphic(lithological) and paleogeomorphic type. The deposits are stratiform or massive (H X, H XI).

The Socu anticline (58, Fig. 22) is situated on the Gilort Valley, between the Țicleni and the Licurici structures.Although the wells drilled here reached the Helvetian, they found hydrocarbons only in the Meotian, which is exclusively gas-bearing. The Meotian consists of sandy marls. A sand bed which is 4—6 m in thickness and called M I is intercalated at the upper part of the mentioned marls, while a sand complex reaching 60—70 m in thickness develops in the base of these sandy marls making up M II. The predominantly pelite series between them makes up M int. Gas accumulated in all these terms, but as regards the potential M II is the most important.

The Țicleni anticline (59, Fig. 22) was identified by mappings in 1910 and confirmed by seismometry. The wells drilled on this structure up to the depth of 6,000 m penetrated the Pliocene, the Sarmatian, the Helvetian-Burdigalian, the Paleogene(mostly conglomerate) and a flysch Upper Cretaceous sequence. Among these formations the Helvetian, the Sarmatian and the Meotian are of interest for hydrocarbons.

The Helvetian is over 1,600 m in thickness and includes eight gritty-sandy complexes (H I—H VIII) whose lithological composition and thickness vary within the structure. Each complex, in its turn, consists of several members. The upper complex H I consists of four members (H I 1, 2, 3, 4) and is in unconformable relation with the complex H II. The beds 2, 3 and 4 of the complex H I lack in the structure apex, which means that this complex overlies transgressively the older terms.

The Sarmatian consists of bituminous marls with limestone intercalations and of sands that prevail in the median segment of the profile.

The Sarmatian thickness decreases towards the structure apex. The Sarmatian is bounded by two unconformities.

The Meotian reaches 335 m in thickness and consists of a lower marly-sandy sequence and of an upper marly sequence.

The Ţicleni anticline is disturbed by numerous faults rather radially disposed (Fig. 40) that divide it into several blocks, hydrodynamically separated in most cases.

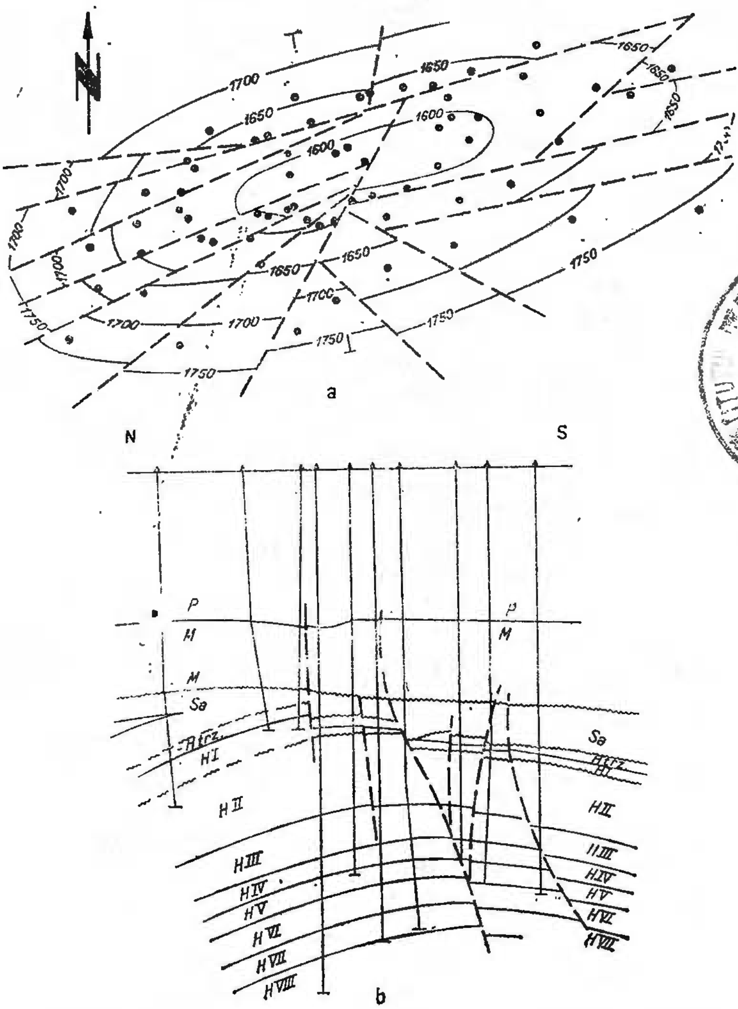

Fig. 40. — Ţicleni anticline.
a, structural map at the guide mark H III; b, geological cross section (according to R. Ioachimciuc et al.).

The hydrocarbons are distributed as follows : the Helvetian yields petroleum, the complexes H V, H IV and H III containing also oil with primary gas cap ; the Sarmatian contains petroleum through its complexes Sa V, VI, VII and lower Sa, the most important unit being Sa VIII ; the Lower Meotian contains petroleum, while M III, M II, M int. and M I contain free gas.

The parameters of the deposits are the following :

	Helvetian	Sarmatian	Meotian
porosity (per cent)	7—7.34	24.2—33	18.4—35
permeability (mD)	0—4700	0—697	5.2—2454
connate water saturation (per cent)	8. 7—46	22.2—24.5	32.5
volume reduction factor	1.57—1.24	1.27—1.32	1.25
petroleum specific gravity (kgf/dm^3)	0.84—0.89	0.84	0.85
gas/oil ratio (Nm^3/m^3)	147—220	100—125	90
pressure gradient ($kgf/cm^2/100$ m)	0.64—0.92	—	—
geothermal step (m/°C)	33	33	33

The deposit waters show mineralizations of 55—250 g/l in the Helvetian and 6—172 g/l in the Sarmatian. The iodine content reaches 26 mg/l. The waters are of chlorocalcic type.

The deposits yield in mixed regime. Some of the horizons are characterized by an active hydrodynamic regime which allowed the achievement of recovery factors of about 60 per cent (Sa VIII).

The traps are of structural and mixed, stratigraphic and paleogeomorphic type, respectively. The deposits are stratiform.

The Bîlteni anticline (60, Fig. 22) is the first productive structure discovered in Oltenia. It is separated from the Ţicleni anticline by a structural saddle. The stratigraphic sequence and the tectonic style are actually similar to those of the neighbouring structure. The following formations proved productive at Bîlteni ; the Helvetian (locally) with petroleum, the Sarmatian with petroleum and primary gas cap, the Lower Meotian with petroleum and free gas and the Upper Meotian with free gas. The types of traps and deposits are similar to those at Ţicleni.

An important structural range lies in the eastern part of the Getic Depression ; it is made up of the Colibaşi (Argeş), Merişani, Săpunari, Băbeni, Grădişte anticlines, with deposits located especially in the Helvetian.

The Colibaşi structure (61, Fig. 22) was determined by seismic prospecting and represents a brachyanticline divided into several blocks at the Helvetian level. The wells drilled at Colibaşi pierced the Pliocene, Sarmatian (?), Helvetian and Oligocene deposits. The Meotian lacks in the axial zone, developing mostly on the southern flank. Among the penetrated formations the Helvetian and the Pontian proved to contain hydrocarbons.

The Helvetian reservoirs show a narrow petroleum band with primary gas cap or gas with condens. The Pontian contains only gas.

The Merişani-Drăganu Structure (62, Fig. 22) was discovered by geophysical prospecting. A careful study of the relief shows that the Argeş terraces are deformed in front of this anticline, which proves that the fold formation process in the respective region has continued up to the present.

The deposits making up the Merişani anticline belong to the Pliocene, Helvetian-Burdigalian, Oligocene and Eocene. The structure represents an anticline disturbed by numerous faults. The hydrocarbons were found in the Oligocene (the horizons a and b) and in the Helvetian (several horizons). The separation of the productive complexes in the Helvetian is rather difficult owing to the two erosion surfaces bordering it and, especially, owing to the lithological variations. The decrease of pressure and production in a short time as well as the varied behaviour of the wells during the producing process are characteristic of the Merişani-Drăganu field. The traps are of structural and combined (especially lithological) type and the deposits are stratiform.

The Săpunari structure (63, Fig. 22) appears at the Oligocene level and is a brachyanticline trending NW—SE being divided into three tectonic blocks. The Pliocene overlies directly the Oligocene in the structure apex, while the Paleogene is overlain by Burdigalian-Helvetian deposits on the flanks. Beside the Pliocene and the Miocene, the wells at Săpunari crossed the Oligocene completely and the Eocene partially. Hydrocarbon accumulations were identified in the Eocene and Oligocene. The Eocene contains free gas, while the various Oligocene horizons in a few blocks are saturated with petroleum, associated gas and free gas. During the producing process the wells showed the same behaviour as in the Colibaşi field, namely the decrease of pressure and output in a very short time.

The Băbeni anticline (64, Fig. 22) seems to represent the westward continuation, after a structural saddle, of the Lăunele anticline. The anticline consists of Pliocene, Sarmatian, Helvetian-Burdigalian and Paleogene deposits. The Paleogene was only partially crossed. Several sandstone complexes, which seem to be equivalent to those at Vîlcele, were found in the Oligocene. The Helvetian consists of two main lithostratigraphic units : a lower one, predominantly gritty, with microconglomerate elements and with pelite intercalations, often brown chocolate-like; an upper one, predominantly grey. The passing from one horizon to another is gradual from a lithological viewpoint, which determined the geologists working on the respective field speak about an "Intermediary Helvetian" horizon (Fig. 41). It is worth remembering also the heterogeneity of the geological conditions along the structure which were entailed by the lithological variations, the fossilized reliefs and the complicated enough tectonics. In point of structure, the Băbeni zone is an anticline divided into very many blocks, often hydrodynamically separated.

The hydrocarbon accumulations are located in the Oligocene and especially in the Helvetian. The Oligocene yields petroleum in the eastern pericline zone (well no. 4236), known under the name of Cremenari, at the depth of 3,380–3,386. The Lower (basal) and Intermediary Helvetian contains petroleum with primary gas cap. The Upper Helvetian, which is more developed in the eastern zone of the structure, is only gas saturated. The traps are of structural and mixed (stratigraphic-lithologic and paleo-

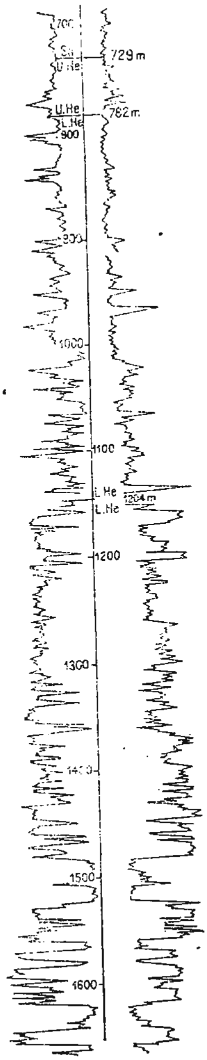

Fig. 41. — Type profile of the Helvetian of Băbeni.

geomorphic) type, while the deposits are stratiform and, partially, (in the basal Helvetian), massive.

The Grădiştea structure (65, Fig. 22) is domelike trending approximately E–W. The dome is crossed by two longitudinal faults and a few transversal disjunctive tectonic accidents (Fig. 42) delimiting blocks that are individualized in point of fluid distribution, physical productive features and deposit size. The structure contains free gas accumulated in the Sarmatian. The productive sands were grouped into six complexes called, from top to bottom, Sa I—Sa VI. The depth of the gas strata varies between 192 and 1,570 m. The traps are of structural and mixed type.

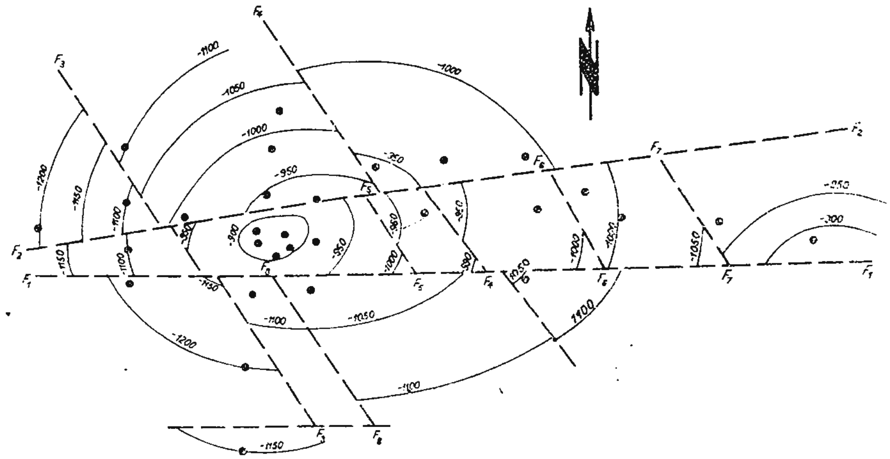

Fig. 42. — Grădiștea anticline. Structural map at a Sarmatian guide mark (according to I.C.P.P.G. Cîmpina).

Another structural echelon with predominantly gas-bearing accumulations of little importance lies south of the Băbeni-Grădiștea line. It comprises the Urși, Galicea and Româneşti structures, where the formations of interest are represented by the Helvetian, Tortonian and Sarmatian.

The Urși deposit (66, Fig. 22) represents a structural detail (a vault) on the southern flank of the Galicea-Româneşti uplift. One of the wells drilled at Urși penetrated the stratigraphic sequence from the Quaternary to the Oligocene. The latter term is overlain by the massive salt of uncertain age, followed by terrigenous Tortonian (?) and Sarmatian deposits that are characterized by strong lithofacial variations. The Sarmatian is, in its turn, unconformably overlain by the Pliocene.

Petroleum accumulated in the Tortonian (wells nos. 1280, 2667) and in three Sarmatian complexes (lower, middle, upper). The depth of the productive beds is of 715—1,275 m.

At Galicea (67, Fig. 22) gas was found in two sectors. The lower, sandy and intermediary Helvetian segments yielded in the eastern part of the structure (wells nos. 24 and 54). In the western part of the structure gas was only obtained from the intermediary Helvetian segment. Gas was also identified in the Galicea structure (the Roești sector inclusively), by five other wells.

A brachyanticline was tested at *Româneşti-Roşiile* (68, Fig. 22). Its flanks are abrupt and pierced by an Oligocene core in the centre. The gritty productive horizons belong to the Helvetian and to the Sarmatian, in only one well. Three productive complexes numbered from top to bottom, I, II, IV are to be found in the Helvetian. The complex IV contains petroleum and free gas, the complex II contains only petroleum and the complex I contains free gas. The porosity of the reservoirs is 12—29.9 per cent and the permeability is 343—1,625 mD. The pressure gradient reaches 11.2 kgf/cm^2/100 m and the geothermal step, 25.4 m/°C.

One of the most prominent structural alignments in the eastern half of the Getic Depression lies south of the above structures. Important petroleum deposits were identified within this alignment consisting of the Şuţa Seacă, Glîmbocelu, Călineşti-Oarja and Moşoaia structures which continue, probably, westwards with the Zătreni and Hurezani-Piscu Stejarului gas-bearing anticlines. A few local structural elements were also identified between this big anticlinorium and the one at Boţeşti-Vîlcele. Some of them proved productive as in the case of the oil and gas fields at Dobreşti, Ludeşti and Bogaţi-Priboieni.

The Dobreşti structure (69, Fig. 22) represents a slight domal fold on the major synclinal bottom that separates the great uplifts Şuţa Seacă-Glîmbocelu and Boţeşti. Several wells were drilled on this dome; they showed that the Pliocene overlies various terms, such as the Oligocene, Helvetian or Sarmatian as a result of the denudation that affected the region in the pre-Meotian. At Dobreşti was obtained free gas from the Meotian which consists of marls and sand intercalations.

The Ludeşti anticline (70, Fig. 22) continues westwards the Teiş-Viforîta-Dragomireşti alignment. It is crossed by several tectonic accidents, of which the most important is the Ludeşti fault, that borders the productive zone to the south. The Ludeşti anticline acted as a an uplifted zone during the pre-Meotian so that the Pliocene overlies directly the Oligocene here. The formation of interest is the Meotian with its two sand members "*a*" and "*b*". The Meotian "*b*" (basal) contains petroleum and primary gas cap, while the Meotian "*a*" is marked by petroleum accumulations, primary gas cap and free gas. The main parameters of the petroleum deposits are: effective thickness 1.5—2.5 m, porosity 28 per cent, connate water saturation 20 per cent, volume reduction factor 1.12, petroleum specific gravity 0.850 kgf/dm^3.

The Bogaţi productive zone (71, Fig. 22) overlies a structural detail on the northern flank of the Slătioarele-Piteşti-Goleşti anticlinorium. According to one of the structural interpretation alternatives, the Bogaţi zone extends eastwards with the Strîmbu productive area which is assigned to the Şuţa Seacă-Stratoneşti structure by most geologists. As in the case of Dobreşti, the Pliocene overlies transgressively and unconformably various terms, namely the Sarmatian, Helvetian or Oligocene. At the Meotian level the Bogaţi structure appears as an anticline trending E—W and is divided into several tectonic blocks. Taking into account the distribution of the Paleogene and Miocene formations, the Bogaţi structure appears as an apophysis of the Slătioarele-Goleşti anticline which trends NE–SW.

Hydrocarbon accumulations were identified in the Helvetian and Meotian sandstones and sands. The lithological variation which is found in the Meotian, often determines the lenticular character of the sand intercalations. The Helvetian yields petroleum at Bogaţi S, while the Meotian has petroleum and, probably, primary gas cap at Bogaţi N-Priboieni. The Meotian traps are of mixed, namely structural-stratigraphic (lithological) type, while the Helvetian traps are predominantly paleogeomorphic. Petroleum is produced as a result of the expansion of the gas that came out of the solution. The exploitation of the Meotian deposits was difficult owing to the sand instability.

The Şuţa Seacă structure (72, Fig. 22) represents the eastern segment of the anticlinorium developing between the Dîmboviţa and the Vedea Valley and extending along the Lucieni (on the Dîmboviţa), Cobia, Stratoneşti, Glîmbocelu, Topoloveni, Goleşti, Moşoaia, Slătioarele localities. According to the geologists working in the respective region (the author of this paper inclusively), the Şuţa structure extends westwards up to the Glîmbocelu fault and hence south-westwards, through Gura Foii and Leordeni, up to the Argeş River.

The wells on the Şuţa Seacă structure reached the depth of 6,040 m and crossed the Neogene, the Paleogene, the folded Cretaceous of the flysch zone out of which the Platform Miocene entered at the depth of 5,900–6,000 m. The Eocene develops in the Şotrile facies and the Oligocene in the Pucioasa facies. The Aquitanian-Burdigalian consists of conglomerates and coarse sandstones reaching 900 m in thickness, as well as salt clays. The saliferous deposits which were found in abnormal (diapir) position on the southern flank had been initially assigned to the Tortonian. Later on one of the wells drilled on the northern flank, at Cobia, intercepted and crossed the whole saliferous series that overlies the Oligocene and underlies the Helvetian-Burdigalian red series (Fig. 43). The Helvetian-Burdigalian consists of predominantly red gritty-sandy deposits in the lower part and of predominantly grey marls with sand intercalations in the upper part. These two lithofacial terms and especially the latter, are found only on the flanks, where they were not subject to denudation. The Tortonian, probably conformable over the Helvetian, is also found on the flanks and consists of all the four terms : the marls with *Globigerina*, the salt breccia, the radiolarite schists and the *Spirialis* marls. Sometimes the Sarmatian overlies the Tortonian in continuity of sedimentation; sometimes it overlies unconformably the various Miocene terms or the Oligocene. The Lower Sarmatian is prevailingly marly, the Middle Sarmatian is sandy, while the Upper Sarmatian consists of marls and sands. Like the other Miocene formations, the Sarmatian has a sporadic distribution as a result of the pre-Pliocene denudation. It is to be found on flanks, on periclines and in the negative paleorelief zones. The Meotian overlies unconformably deposits of various age. It consists of marls with sand and sandstone intercalations. A psamite horizon is individualized in the base as a rule; it is called M III in the eastern half of the structure. This is the stratigraphic equivalent of M II east of the Dîmboviţa River and the overlying marly horizon would be synchronous with the horizons M II, M int. and M I at Moreni-Gura Ocniţei. The Meotian sandy-gritty basal member is to be found also in the western part of the anticline which is heterochronous, representing a facies of the transgression that took place east-westwards. As a result, the Meotian thickness, about 145 m, in the Şuţa Seacă and Cobia sectors decreases up to 20—30 m at Leordeni. The gritty-sandy basal complex lacks in the apex zone and on the northern flank and it undergoes lithofacial and thickness variations on the southern flank, so that these psamites have a lenticular development west of the Găeşti town meridian. Sandstone lenses occasionally appear in the upper part of the Meotian too. The Pontian is exclusively marly, while the Dacian and the Levantine appear as a succession of sands, marls and coal intercalations.

From a tectonic point of view the Şuţa Seacă structure is a diapir fold longitudinally (Cobia fault) and transversally faulted.

The Cobia fault, a complex of tectonic accidents in fact, along which the more uplifted central zone and northern flank slightly overthrust the southern flank, enabled the salt migration from the depth to the Meotian level. Among the transversal accidents with facial structural and fluid distribution implications the Pădureni, Butoiu and Glîmbocelu faults are worth mentioning (Fig. 43). On the whole, the structure raises steadily from the east to the west at the level of the Paleogene, Miocene and Lower Pliocene formations. Another characteristic of this anticline is the fact that it ramifies towards its extremities, east (Lucieni) and west (Leordeni). The dips increase with depth. Thus the Pliocene has 4—22°, the Sarmatian 5—68°, the Helvetian-Burdigalian 30—80°. According to the seismic prospectings, the Şuţa Seacă anticline is also identified at great depths, both in the Getic Depression deposits and in those assigned to the Moesian Platform.

Petroleum deposits in the Meotian, Sarmatian and Helvetian were identified on the Şuţa Seacă structure. The Meotian is productive on the whole southern flank and, only locally, (Pădureni, Lucieni), on the northern flank and the eastern pericline. It contains petroleum, seldom with primary gas cap and, free gas in only one case. The Sarmatian was found with petroleum and with very reduced primary gas cap at Cobia N and on the eastern pericline, at Lucieni. The Helvetian yields only on the northern flank, at Cobia and at Strîmbu. Excepting only a tectonic block at Strîmbu, the Helvetian contains exclusively petroleum accumulations.

The traps on the Şuţa Seacă structure are of structural and mixed (stratigraphic and paleogeomorphic) type, while the deposits are stratiform and, sometimes, (in the Helvetian), massive.

The main parameters of the deposits are :

	Meotian	Sarmatian	Helvetian
porosity (per cent)	23—30	25	26
permeability (mD)	230	480	—
connate water saturation (per cent)	21—25	16	30
volume reduction factor	1.13—1.20	1.16—1.26	1.24
petroleum specific gravity (kgf/dm³)	0.840—0.900	0.840	0.840
pressure gradient (kgf/cm²/100 m)	8.4—9.8	9.9—10.9	—
geothermal step (m/°C)	23—38.8	33	—

It is worth mentioning, in connection with the above parameters, the fact that the Meotian contains paraffinic petroleum with specific gravity 0.840 kgf/dm³ south of the Glîmbocelu fault and the asfalten petroleum (A) occurs west of this tectonic accident. More than that, the Upper Meotian sands contain petroleum of the *A* type at Căţeasca (Leordeni) and the basal sand is marked by petroleum of *C* type. In short, the Meo-

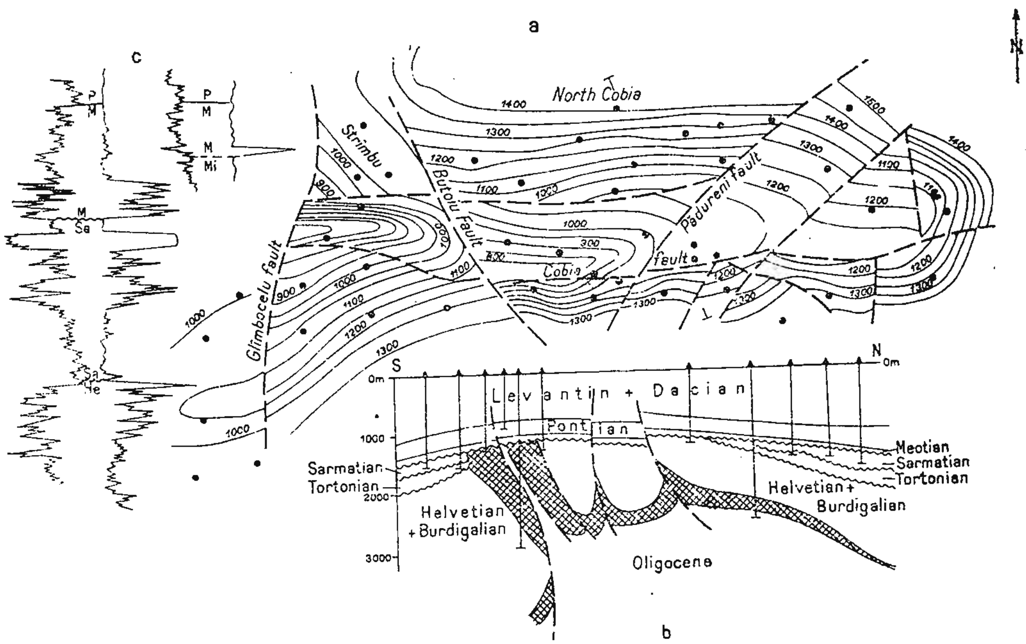

Fig. 43. — Şuţa Seacă structure.
a, structural map at the top of the Meotian ; b, geological cross section ; c, Meotian, Sarmatian and Helvetian type profiles.

tian contains petroleum of *C* type that changes into petroleum of *A* type west of the Glîmbocelu fault; the Sarmatian and Helvetian contain semi-paraffinic petroleums (type *B*).

The geothermal step is 33—38,8 m/°C on the whole structure. But the geothermal step decreases very much, up to 23 m/°C on the Budiș-teni-Leordeni ramification west of the Glîmbocelu fault, where the petroleum quality changes, too. This decrease might be due to either a different heat flow of the block lying west of the Glîmbocelu fault, or to the more southern position of this compartment situated nearer to the Bibești-Tinosu dislocation which is characterized by higher temperatures.

The exploitation regime of the deposits varies. The energy of most accumulations is due to the gas escape from the solution, but a mixed regime was also found. The Leordeni sector is marked by a very active water drive. The water injection was successfully applied both to the Meotian at Șuța Seacă, Cobia and Gîrleni, and to the Sarmatian at Cobia N. The deposits are in the last exploitation stage.

The Glîmbocelu structure (73, Fig. 22) is the continuation of the Șuța Seacă anticline west of the Glîmbocelu fault, according to an interpretation variant. The Glîmbocelu fault seems to determine a certain throw of the structure segments. The Glîmbocelu anticline is bounded by the Topoloveni fault to the west. The wells drilled here crossed the Pliocene, the Helvetian and the Oligocene. The Helvetian deposits appear discontinuously on the flanks and in the negative paleorelief zones, so that the Meotian overlies directly the Oligocene on the greatest part of the structure. The Meotian, in its turn, consists of a sand bed, sometimes overlain by a marl packet. The Meotian showing this lithofacial composition is known in the axial zone and on the northern flank. But it develops southwards reaching a thickness of 6—10 m up to 60—80 m and the number of sandy members increases at the same time. Thus, according to the geological studies, the Meotian in the maximum development zone (Topoloveni) comprises four sandy-gritty members of interest, one of them (complex 4) consisting of two beds (*a* and *b*). The hydrocarbons are located in the Meotian and in the isolated Helvetian patches and consists of petroleum accumulations, primary gas cap and, more rarely, free gas. The Meotian, which is productive especially on the southern flank, is marked by a very active hydrodynamic regime. The Meotian traps are structural and stratigraphic; the Helvetian traps are paleogeomorphic. The deposits may be assigned to the stratiform and massive types (in the Helvetian).

The Călinești-Oarja productive zone (74, Fig. 22) was identified in 1967 and corresponds to the southern flank of the Pitești-Golești uplift. This zone is bounded by the Topoloveni fault to the east and by a fault complex, in the Hințești sector, which separates it from the Moșoaia productive field to the west.

The Pitești-Golești anticlinorium flank is progressively overlain by ever thicker deposits belonging to the Helvetian, Tortonian and Sarmatian in its southward sinking. An increase in thickness as well as the appearance of new sandy beds are found also in the Meotian where four complexes of interest (*a*, *b*, *c* and *d*) were delimited. The Călineşti-Oarja productive field, which extends westwards up to Albota, corresponds to this flank zone, along which increases in thickness and pinching out of beds, lithological variations both in the direction of the structure and transversally take place. The distribution, thickness and lithofacies of the Miocene and Meotian formations suggest that the uplift we refer to began to extinguish and gradually lose its "personnality", immediately after the Savian phase, up to the Meotian.

The Neogene beds show a monoclinal disposition corresponding to the anticlinorium flank in the Călineşti-Oarja zone. This monocline is crossed by numerous longitudinal and transversal faults that divide it into several blocks, most of which are hydrodynamically separated.

The main productive formation on the structure is the Meotian, namely the complexes (from top to bottom) *a*, *b*, *c* and *d*. The term "*a*" followed by "*b*", advances the most towards the structure apex, while the beds "*c*" and "*d*" in the lower part of the Meotian are found in flank positions, their distribution being controlled by the pre-Meotian paleo-relief, too. Hydrocarbon impregnations were found completely isolated at the Meotian contact with the truncated beds, belonging to the Miocene. The most important petroleum productive members in the Meotian are the horizons "*b*" and "*c*". The lower packet "*a*" is predominantly gas-bearing and the upper term "*a*" and the member "*d*" did not show an industrial hydrocarbon potential (Fig. 44).

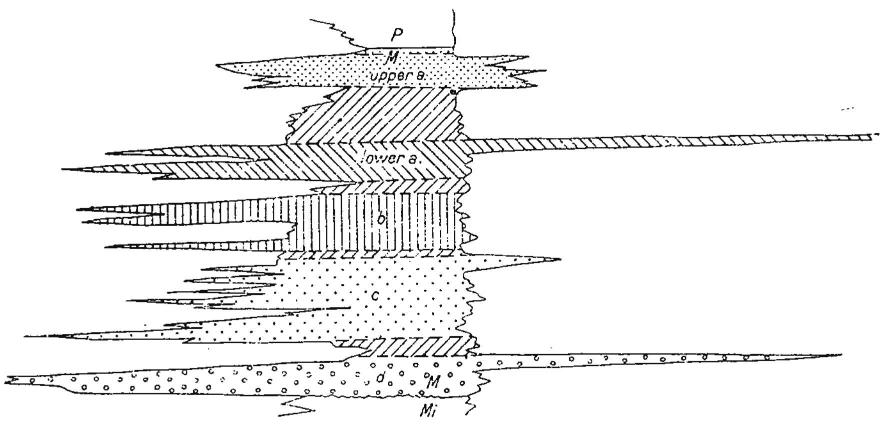

Fig. 44. — Meotian type profile on the Călineşti-Oarja structure.

The main parameters of the deposit show the following average values : porosity 24 per cent, connate water saturation 25 per cent, volume reduction factor 1.144, petroleum specific gravity 0.873 kgf/dm³.

The Slătioarele structure (75, Fig. 22) is the westernmost segment of the anticlinorium beginning at the Dîmboviţa River and ending in the vicinity of the Vedea Valley. The region is overlain by Levantine and Dacian deposits at the surface. A diapir salt massif (Lower Miocene) outcrops in the axial zone. According to the drilling data, the stratigraphic sequence consists of Pliocene, Sarmatian, Helvetian-Burdigalian and Paleogene deposits. The Eocene and the Oligocene of the Pucioasa type were found in the apex zone, under the Pliocene, in a facies which is similar to the Şotrile one. The Paleogene is overlain by deposits belonging to the Helvetian-Burdigalian, namely the "red" sandy-gritty horizon and to the Sarmatian on the flanks ; the latter occurs in the southern sector and in the western pericline where it consists of marls and sands that disappear towards the axial zone and the southern flank extremities. The Pontian, which is almost completely marly has still a sand bed in the profile base. The Dacian and the Levatine make up a sand sequence with marl intercalations and thin coal strata.

As results from the drilling data, the Paleogene and Lower Miocene in the apex structure overthrust the Helvetian of the more sunk southern flank. The Sarmatian and especially the Pliocene overlie transgressively all this complex structure. At the same time the Slătioarele anticline is crossed by longitudinal and transversal faults influencing the fluid distribution.

Hydrocarbon accumulations are found in the Helvetian, Sarmatian, Meotian and Pontian. The Helvetian petroleum is located, as a rule, at the contact with the Meotian or in some isolated gritty levels. The best results (petroleum) in the case of the Helvetian were obtained in the eastern half of the southern flank, at Moşoaia and Hinţeşti. The Sarmatian yields petroleum in the western half of the structure, in the blocks II, III and IV. The Meotian is the most important unit at Slătioarele, containing petroleum on the southern flank in the blocks II and III. The exploitation is achieved by water injection in the greatest part of the block II and it takes place in dissolved gas regime in the block III. The Pontian also offers poor petroleum accumulations on the southern flank and in the latter's eastern sector, where a marly sand stratum appears in its base.

The high petroleum viscosity and the unconsolidated character of the Meotian and Sarmatian sands made difficult the extraction, especially in the western part of the structure. The traps are of structural and mixed (stratigraphic, including lithologic and paleogeomorphic) type.

The Zătreni gas-bearing structure (76, Fig. 22) develops on either banks of the Olteţ River. In spite of several seismic and drilling data, it is difficult to state whether the Zătreni anticline represents a western continuation of the Şuţa-Glîmbocelu-Slătioarele alignment, the more so as there are differences between these structural elements concerning the stratigraphic succession, the tectonic style, nature and type of accumulations.

The wells drilled here, reached the depth of 4,500 m, and penetrated the formations of Pliocene, Sarmatian, Tortonian (without salt) and Helvetian age. The structure is a brachyanticline, with approximately symmetric flanks trending NE—SW at the Meotian and Sarmatian levels. The longitudinal and transversal faults determined so far divide this anticline into 11 tectonic blocks.

The main productive formation at Zătreni-Tetoiu is the Sarmatian with its complexes II and III. Gas is also obtained from the Meotian, only locally (a well). The strong lithological changing, associated with the variation of the reservoir porosity and permeability, is manifested in the different behaviour of the wells and in the decrease of the gas pressures and output in a relatively short time. The traps are of structural and stratigraphic (lithologic) nature.

The Hurezani-Piscu Stejarului structure (77, Fig. 22) seems to be the western continuation of the same tectonic alignment that begins with the Zătreni-Tetoiu anticline. This structure was identified by seismic prospectings. The wells drilled in this region reached the depth of 3,171 m and crossed the Pliocene and, partially, the Sarmatian. The last mentioned stage was penetrated maximum 1,550 m in thickness and consists of marls and sands, the reservoirs being grouped into 5 complexes, numbered (from top to bottom) Sa V-Sa IX. The Meotian reaching 650—800 m in thickness, has four sand complexes (M I—M IV), three of which yield gas. The Pontian consists of marls and sandy marls, while the Dacian and the Levantine consist of sands, microconglomerates and sandstones with marl and coal intercalations.

The structure is a slight anticline vault with two culminations: one at Piscu Stejarului and another at Hurezani. The anticline is crossed by longitudinal and transversal faults which are partly impervious (Fig. 45).

Only free gas accumulations, located in the complexes V—IX of the Sarmatian and in the horizons I, III and IV of the Meotian were discovered at Hurezani-Piscu Stejarului. The productions obtained at each unit or at several units, tested together, vary between 10,000 and 175,000 m^3/day. The distribution of the accumulations is uniform on the whole structure, the number of the gas-bearing beds varying from one tectonic block to another.

A new structural line develops in front of the Slătioarele-Piteşti anticline; it is made up of the Vaţa, Oteşti and Drăganu-Călina undulations. This structural line, by its divergent direction, almost perpendicular to the Slătioarele-Piteşti-Glîmbocelu anticlinorium and by its much more quiet tectonic style, indicates that it overlies a platform basement. In fact, the wells at Spineni (4,605 m) and Mitrofani (6,021 m) drilled in this structure echelon came from the Carpathian Foredeep Lower Miocene into the Moesian Platform Sarmatian and Mesozoic. Taking into account also the stratigraphic succession found at Cobia the Carpathian basement is almost sure not to extend outside the western continuation of the Băicoi-Moreni-Tîrgovişte-Slătioarele alignment.

The Vaţa structure (78, Fig. 22) was identified by a complex of geophysical works consisting of gravimetry, magnetometry, electrometry and seismics carried out between 1936 and 1954. The first favourable results (hydrocarbons) on this structure were recorded in 1953.

The wells drilled here crossed the Pliocene, the Sarmatian and, partially, the Helvetian. The last, crossed within a thickness of over 1,000 m, consists especially of pelites and shows strong dips (30—50°). The Helvetian underlies directly the Meotian in the apex zone. The Sarmatian, in its turn, maintained only on the flanks, in the pericline zones or in the

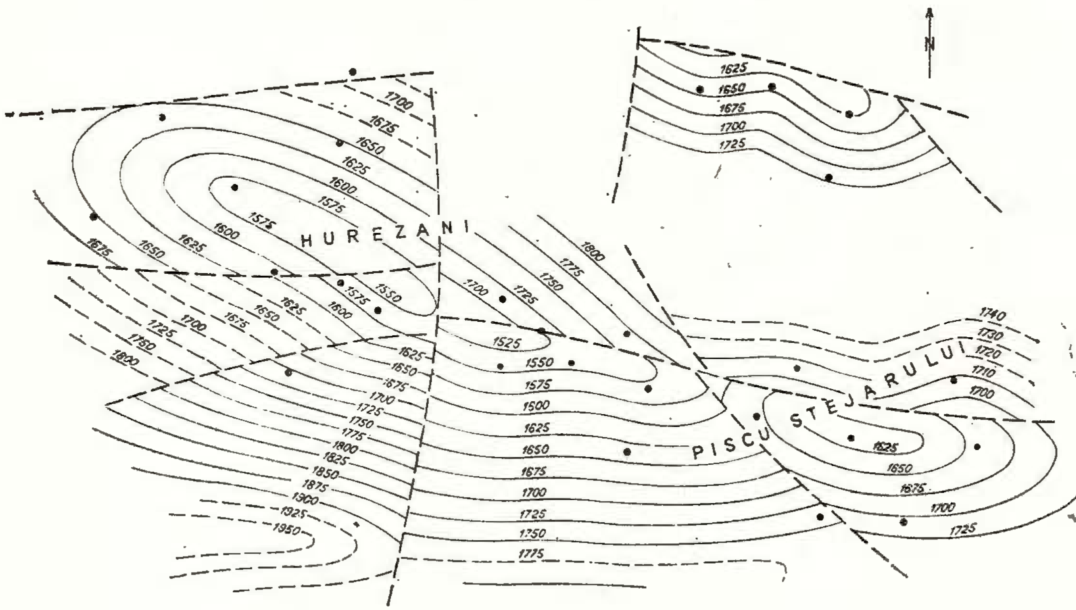

Fig. 45. — Hurezani-Piscu Stejarului structure. Isobaths at the level Sa VII (according to V. Brînzan).

structural saddles. The marls prevail in this stage base, while an alternation of sandstones, sands and marls was found towards its upper part. The Meotian overlies transgressively and unconformably the Sarmatian and the Helvetian. It develops up to 115 m in the axial zone of the anticline and on the southern flank. Lithologically, the respective stage consists of an alternation of marls and sands, the latter being grouped into six complexes numbered according to the deposition order, from 1 to 6. The sands 2, 3, 4 and 5 add successively, on the southern flank and in the pericline zones. This means that, against a background of rhythmical oscillating movements, the Vaţa anticline preserved a predominantly raised position in the Lower Pliocene, and that there are intraformational hiatuses, the most important being located at the end of the packet 2 and the base of the packet 4. In order to complete the stratigraphic description of the Meotian it is useful to register the strong lithological variation that is found longitudinally and transversally on this flank and which is ever more subsident southwards, where some of the sands of interest have a lenticular character. The Pontian is marly. Only in the axial zone and on the southern flank a gas saturated sand bed appears in its base. The Dacian and the Levantine develop in the facies characteristic of the Carpathian Foredeep.

The dips determined in the Vaţa brachyanticline vary between 3—5° in the Pliocene and 15—50° in the Miocene. Numerous longitudinal and transversal accidents divide the structure into tectonic blocks (Fig. 46) in which the fluid distribution varies. At Vaţa were found hydrocarbons

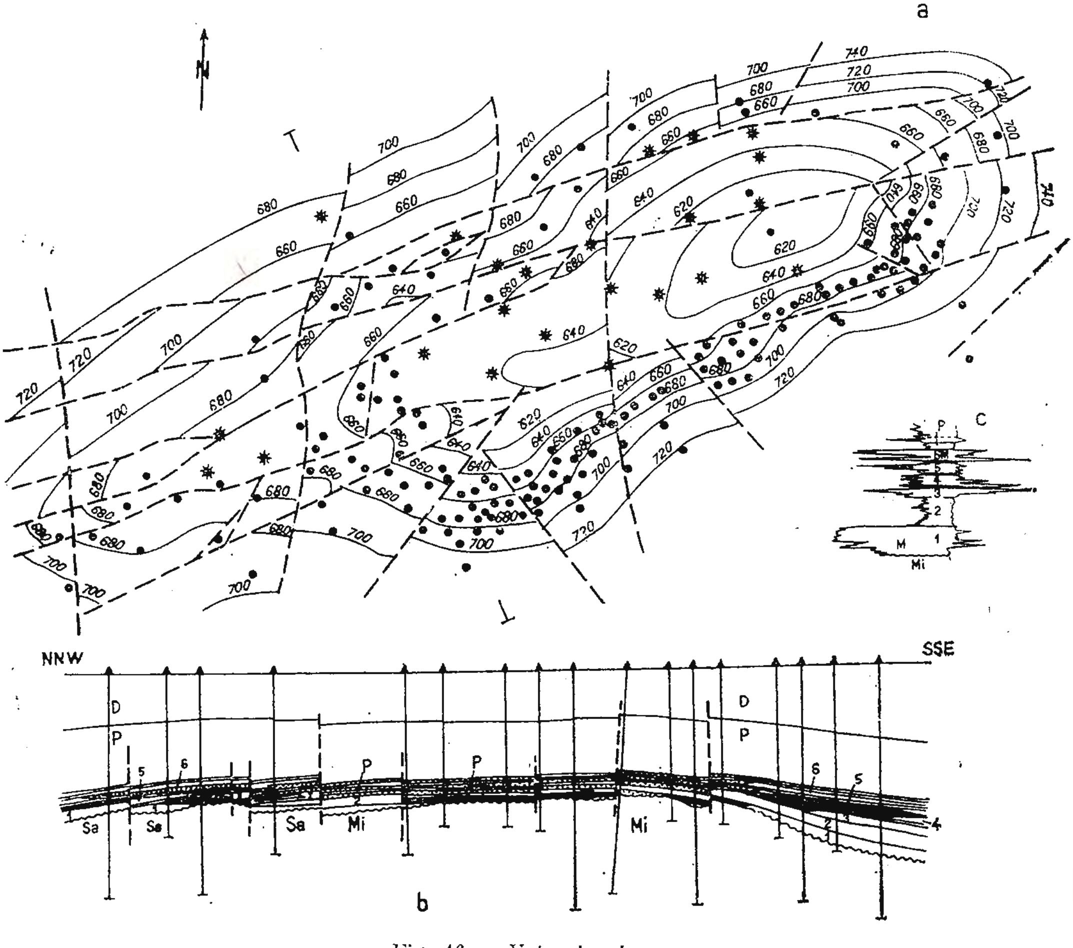

Fig. 46. — Vaţa structure.
a, structural map at the top of the Meotian ; b, geological cross section ; c, Meotian type profile (according to L. C r i s t e a et al.).

in the six sandy Meotian complexes and in the Pontian. M_1 (in the Meotian base) contains petroleum with primary gas cap; M_2 yields petroleum only in one tectonic block (K); M_3, with the exception of the block K which contains also primary gas cap, is only petroleum saturated; M_4 contains petroleum, while M_5 and M_6 contain free gas. An explanation is necessary in connection with the complex M_5 that yielded petroleum with great gas ratio at well no. 831; 0.2 t/day petroleum were registered at well 830. The petroleum saturated zones are located on the southern flanks and in the pericline zones in most cases. The Pontian is exclusively gas-bearing.

It results from the above presentation that the Vaţa traps are of structural (sands M_1 and M_6) and mixed (stratigraphic-lithological) type; the deposits are stratiform. The main parameters of the accumulations on the Vaţa structure show the following average values: porosity 26–31 per cent, effective permeability 200–2,000 mD, connate water saturation 17–30 per cent, volume reduction factor 1.07, petroleum specific gravity 0.925 kgf/dm^3, solution oil ratio 24.5 Nm^3/m^3. The complex M_1 is marked by the marginal water drive and the gas cap detente, the other complexes generally owe their energy to the gas expansion.

The Oteşti structure (79, Fig. 22) is a large vault within which the Pliocene shows dips of about 2°. The stratigraphic sequence of the region is somewhat similar to that on the Vaţa anticline, excepting the Meotian which is characterized by an increase in the sand ratio that may become massive at one time. As in the western sector of the Vaţa structure, the Meotian sands are not consolidated which entails great difficulties in the extraction process. The hydrocarbon accumulations at Oteşti are located in the sands of the upper part of the Meotian, near the boundary with the Pontian. They were divided into two complexes, numbered from top to bottom, M_1 and M_2. The complex M_1, in its turn, is divided by marl, sometimes, impervious intercalations into three members called $M_{1a\ sup}$, M_{1a} and M_{1b}. These terms do not show a continuous development, changing laterally into marls or compact sandstones. Still, the stratum M_1 seems to have a more constant presence. The structure is divided by three faults of which only one (*f* 3) seems to have implications in the fluid distribution.

As regards the hydrocarbon saturation the stratum $M_{1a\ sup}$ contains petroleum, the strata M_{1a} and M_{1b} contain petroleum with primary gas cap and the complex M_2 shows a free gas accumulation of no importance, only locally. As a result of the reduced degree of cementation, the sands have very high permeability that varies between a few mD and 5D, but the petroleum viscosity, under reservoir conditions, is about 180 cP. The deposit yields in dissolved gas regime, with the exception of one sector (zone I), where the primary gas cap detente was felt.

The Siliştea-Cireşu structure (80, Fig. 22) is a slight anticline vault situated south-east of the Călineşti-Oarja productive zone, in the vicinity of the contact between the foredeep and the platform. The tectonic style of the region, the stratigraphic succession and, especially the lithological composition of the Meotian are similar to those of the Vața structure. The formation of interest is also the Meotian within which six complexes (*a-f*) were delimited. Among these, "*d*", "*e*" and "*f*" contain petroleum with primary gas cap making up a massive deposit with tabular water-petroleum limit. The complexes "*a*" and "*c*" and, locally, "*d*" and "*e*" contain free gas, constituting stratiform deposits.

The Bibești-Sărdănești deposit (81, Fig. 22), situated also in the vicinity of the contact between the foredeep and the Moesian Platform, represents a northern extension of the Bibești-Bulbuceni important productive zone, where several superposed geological formations proved of interest; these formations consist of the Platform Devonian and Triassic, the Carpathian Foredeep Sarmatian and Meotian. Free gas from the Sarmatian and Meotian was obtained in this northern sector, at Bibești-Sărdănești where the Neogene geological and tectonic constitution is identical with the one that is going to be presented at the Bibești-Bulbuceni structure in the Moesian Platform.

Apart from the structures and zones presented above, oil and gas seeps were also indentified in the Getic Depression, but in very small amounts or associated with salt waters, on numerous anticlines and in various formations beginning with the Upper Cretaceous and ending with the Pontian. Among them one should mention, in the first place, the gas obtained from the Sarmatian on the *Drăganu-Călina structure* (in two wells) and from the Meotian of the *Dienci block* (a well). The significance of these seeps was generally clarified, but there are still some zones where the investigations have to be resumed.

V. TRANSYLVANIAN DEPRESSION

The Transylvanian Depression represents a major structural element of the post-tectonic Carpathian Orogen, corresponding to a subsident and young area that overlies a heterogeneous basement belonging to the three branches of the Romanian Carpathians — the East Carpathians, the South Carpathians and the Apuseni Mountains (Dumitrescu, Săndulescu, 1968, 1969). The Transylvanian Depression formed in its present shape after the Styrian movements.

The discovery, in 1909, of some commercial gas deposits brought about the intensification of the research in the Transylvanian Depression by a complex of works consisting in geological mappings, geophysical surveys and wells that covered the whole area of this unit.

The geological mappings were achieved throughout the depression area, 95 per cent of the observations had a semidetail character thus enabling the drawing up of geological maps on a scale of 1 : 25,000.

The gravimetric surveys covered the whole territory of the Transylvanian Depression. About 25,000 km² of this area were investigated by one station on one km², 8,800 km² (in the central zone) by two stations on one km² and about 4,000 km² by 4—40 stations on one km².

The Bouguer gravimetric map, achieved according to these measurements, shows that, on the whole, the Transylvanian Depression acts like a minimal zone against the three Carpathian branches. A few regional anomalies can be distinguished against the gravimetric minimum background; among them, local anomalies of the second and third orders can be noticed, being variously trended. The maps of the second derived indicate that most gas-bearing domes correspond approximately to some negative gravimetric anomalies. The minimum gravimetric effect of the gas-bearing domes is probably due to the density difference brought about by the hydrocarbon presence in the dome of the positive structures, in contrast with the aquiferous syncline.

In recent years gravimetric measurements of great detail have been also carried out experimentally with a view to determining the contour of the gas-bearing zones on several productive or investigated structures.

Magnetometric surveys were achieved on an area of about 8,800 km^2 by one station per 5 km^2 and on an area of 3,000 km^2 by one station per 1 km^2. The results of these measurements were used for achieving some maps of the ΔZ isoanomals. According to the aeromagnetic map of the country, drawn up in 1968 on a scale of 1 : 500,000, the Transylvanian Depression appears as a maximum anomaly assigned to "a large intrusive crust" (Ciupagea et al., 1970).

Electrometric surveys were carried out, in the central and southern parts of the depression, by vertical electrical sounding (VES), by dipole electrical sounding (DES) and by telluric currents. Such works aimed at identifying a resistive horizon at the salt level, numerous positive and negative anomalies being obtained. Many of the positive anomalies correspond to the domal structures, but there are also cases when the latter are marked by negative anomalies. Considering the above situation the necessity of checking the local electrical anomalies by seismic works and by drills occurred in order to establish the structural significance of these anomalies. Anyway, the electrical prospection proved efficient in the Transylvanian Depression, contributing to the discovery of several important gas-bearing structures.

Radiometric investigations were carried out experimentally and with unconvincing results in some places in Transylvania.

The seismic regional, semidetail or detail surveys covered more than 20,000 km^2 with a density reaching 1.8 km/km^2 in the most important zones. The works could be achieved especially by the use of the continuous profiling method and, where the seismic keys lacked or the hardly accessible terrain did not permit profile recordings, seismosounding was achieved. Also, in order to know the basement structure, about 10,000 km^2 refraction seismic profile with regional character was achieved between 1963–1966. The seismic surveys proved to be the basic method for investigating the structure of the basin sediment, especially after 1963 when their efficiency increased, by the use of magnetic recording apparatus.

The investigation of the Transylvanian Depression was completed by drilling, about 1,200 wild cats, structural and exploration wells have been drilled so far totalizing about 2,500,000 m. Over 80 of them crossed the Tortonian salt, investigating older formations. The maximum depth reached is 4,533 m at Filitelnic and 4,505 m at Band, in the central basin zone.

1. Stratigraphic and Lithologic Peculiarities of the Sedimentary Cover

The Transylvanian Depression developed on a heterogeneous basement consisting of two superimposed structural complexes: the folded basement and its post-tectonic cover (Săndulescu, Visarion, 1979). The former complex consists of crystalline schists and ophiolites, sedimentary deposits of Permian (?) — Lower Cretaceous age associated with magmatites. The latter complex consists of Upper Cretaceous, Paleogene and Lower Miocene formations. This succession constituting the depression basement is overlain by the proper depression deposits of Tortonian up to Upper Pliocene age. The sedimentary deposits of the post-tectonic cover and of the depression may reach 6,000 m in thickness in the most sunk zones of the Transylvanian Basin. More than 3,800 of them belong to the post-Helvetian formations.

Almost the whole sedimentary succession, belonging, to the basement and to the depression proper, outcrops on the latter's border and is known from the numerous studies and papers published, the synthesis achieved by Vancea (1960) and Ciupagea et al. (1970) inclusively.

The crystalline basement shows a series of uplifted and depressive zones succeeding from north-west to south-east. It consists of serricite-chlorite schists, quartzites, micaschists and, seldom, metamorphosed limestone intercalations. The degree of metamorphism increases in the Pogăceaua zone, the basement consisting of muscovite and biotite gneisses, quartzite micaschists, amphibolites, crystalline limestones (Ciupagea et al., 1970).

The oldest sedimentary formations belong to the Permian (?) crossed by wells on the eastern margin, at Ibănești, where they are represented by conglomerates constituted by quartzite, serricite, chlorite schists of Verrucano type, being considered of Lower Permian age on the analogy of the conglomerates in the Apuseni Mountains.

The Triassic was identified only in a few wells. In the south-east of the depression, at Mercheașa-Jibert, it consists of an alternation of red marls, diabase, gray and green clays and gabbros with jasper, limestones and clayey schist intercalations (at the lower part). At Agnita-Ghijasa, where the basement is more uplifted, the Triassic begins with reddish conglomerates overlain by marno-limestones, limestones and dolomites that may be compared to the Codru domain Triassic (Ciupagea et al., 1970).

The Jurassic crossed by the Band well seems to be represented only by the Malm and Dogger and consists of yellowish compact limestones, resembling those outcropping west of Turda.

The Lower Cretaceous recorded in the surrounding structural units was identified also in the Transylvanian Depression at Grînari, Band, Şalcău and Alămor. A succession of blackish gray marls, brown-reddish clays with sandstone and conglomerate intercalations containing a microfauna specific to the Barremian-Aptian was found at Grînari in the south-west of the depression. This series is overlain by gray limestones with rare blackish and gritty, probably, Albian marl intercalations. The Barremian-Aptian continues the Jurassic limy series in the Band well. The Cretaceous limestones could be separated thanks to their microfauna content (*Orbitolina*). The Aptian consisting also of *Orbitolina* limestones was identified at Şalcău, on the northern flank of the Cenade-Agnita uplift. As far as the Alămor zone is concerned, one of the wells drilled here crossed the Albian deposits under the Upper Cretaceous, which is about 450 m in thickness and consists of gray sandstones, crystalline schist, conglomerates and blackish compact marls.

The post-tectonic cover begins with the Upper Cretaceous (Senonian and, locally, Cenomanian) that outcrops on the mountainous chain margin, south-west of Cluj, south of Sebeş and south-east of Făgăraş, where it consists of marls, sandstones and conglomerates (the Senonian is developed in the Gosau facies). Within the depression the Upper Cretaceous, that may reach about 100 m in thickness, was found at Buneşti-Gherla, Puini, Mociu, Filitelnic, Alămor etc.; it is developed in flysch facies with the exception of the Alămor zone, where it shows also Gosau facies.

The Paleogene overlies transgressively the Upper Cretaceous or even the folded basement. It is well developed and outcrops on the northern western and southern sides of the depression, being marked by great facies variations. According to the drilling data, the Paleogene lacks or is incompletely developed in the centre of the depression. The respective deposits were assigned to the Paleocene, Eocene, and Oligocene. The Paleocene could be followed only on restricted zones and it was assigned by most researchers to the Eocene and dealt with together with the Ypresian.

The Eocene reaches 2,000 m in thickness. The Eocene-Paleocene consists of two marine series alternating with two (striped) continental series on the northern and north-western borders of the basin that was the object of recurring and important investigations.

The lower striped clay series (Răileanu, Saulea, 1956), found in the north-western part of the basin, shows various features. The base of this member contains laterite soils, maximum 8 m in thickness, lying on the eruptive rocks (andesites and dacites). The latter are overlain by red clays with gravels. In the Jibou area, the lower continental series was divided into three horizons: the lower red horizon about 1,000 m in thickness; the sweet water limestone horizon (or the Rona limestone) 400 m in thickness. The lower striped clay series is only 150 m in thickness in the Cluj region owing to the disappearance of the limy horizon and, probably, of the lower horizon. The age of the lower continental series was assigned either to the Danian or to the Eocene or to the Danian-Lower

Lutetian (G r i g o r a ş, 1961) or only to the Ypresian-Upper Lutetian in the Cluj region.

The lower marine series (R ă i l e a n u, S a u l e a, 1956) comprises the following horizons in the Jibou and Cluj regions : the lower gypsum and *Anomya* marno-limestones, 30—70 m in thickness; the *Nummulites perforatus* limestone bank (1—3 m); the gray clay horizon, 30—100 m; the lower coarse limestone horizon (6—12 m) which changes laterally into sandstones.

The series of upper striped clays reaching about 60 m in thickness consists of red, violet-blue or green clays and thin sands.

The upper marine series, about 100 m in thickness, consists of the following terms : the Cluj beds, represented by limestones with lenticular gypsum intercalations at the lower part; the *Nummulites fabiani* marls (10 m); the Briozoa marls (30—50 m). The upper marine series becomes predominantly limy including also reef limestones.

The Eocene was found in the northern half of the depression, at Pogăceaua, Miheş, Lujerdiu, Brădeşti, Dîrja and Vima. Here it consists, from the base upwards, of striped marls with conglomerates, gray marls, reddish clays with sand and limestone intercalations reaching 300—750 m in thickness (C i u p a g e a et al., 1970). The Aiud, Copşa Mică, Cenade, Şeica, Ruşi, Şaclău, Daia Sibiului, Nucet and Mercheaşa wells crossed the reddish clays (in the base) and gritty limestones with *Nummulites* and *Panopea* reaching 100—870 m in thickness.

The Oligocene outcrops on the northern and north-western margins of the depressions as well as in some places in the south-western and south-eastern sectors. The respective deposits are marked by greater facies variations than those in the Eocene.

In the Cluj region outcrop the following lithostratigraphic units which were separated by R ă i l e a n u, S a u l e a (1956):

a) The Mera beds (about 20 m) consisting of an alternation of marls and clays, sands, limy sandstones and coarse limestones that are strongly fossiliferous. North of Jibou the Mera beds were divided into two horizons : the Curtuiuş horizon (in the base) and the Ciocmani horizon.

b) Tic beds, also consisting of an alternation of red, gray or greenish clays, sands, sandstones and coal reaching 200 m in thickness; in the Jibou region, the equivalent of the Tic beds is constituted by the Ileanda Mare beds that contain a packet of yellowish, bituminous marls disposed in plates and resembling the East Carpathian dysodile schists.

c) Almaş Valley beds (150 m) consisting of conglomerate, sandstones (in the base), lumachelle limestones, sands and red-cherry coloured clays with sand intercalations. The lithological complexes, such as they were separated in the Cluj region, can no longer be recognized at Jibou. Two gritty horizons, separated from a clayey one, can be distinguished here. Further east the gritty facies invades the Almaş beds throughout.

East of the Jibou region, the Oligocene facies is similar to the Miocene facies consisting of an alternation of marls and marly clays with limy, sometimes, curbicortical sandstones. The Oligocene gets thicker, becoming more flysch-like north-eastwards, therefore towards the Bîrgău Mountains and Lăpuş Mountains.

The wells drilled south of the Turda-Deda line did not find the Oligocene inside the Transylvanian Depression. There are positive data referring to the presence of the Oligocene deposits in only one well situated in the vicinity of the Bistriţa town, north of the Turda-Deda line. Formations in flysch facies reaching about 700 m in thickness were found here; they overlie directly the crystalline schist basement. The Oligocene area might extend a great deal in the northern part of the depression, in the lowered zones where the wells could not cross the whole Miocene succession.

The Aquitanian belongs to the Paleogene sedimentation cycle. It is represented by what was once separated as "Sînmihai beds", now included in the upper part of the Almaş Valley beds.

The Burdigalian marks the beginning of the Miocene sedimentation cycle, with the exception of the north-eastern part of Transylvania (Ileanda-Lăpuş), where the Lower Miocene is in continuity of sedimentation with the Paleogene, having the same predominantly pelite facies. The Burdigalian is represented by the Coruş beds in the base, on the northern side of the depression and by the Chechiş beds at the upper part, both lithostratigraphic units reaching 200—500 m in thickness. The Coruş beds consist of sands with weak clay, sandstone and conglomerate intercalations. The Chechiş beds are represented by marly clays. On the southern side, near Sibiu, the Burdigalian cosisting of breccias, marls and sands, overlies directly either the Făgăraş Mountain crystalline or the limy Eocene of the Porceşti type. Inside, the Burdigalian deposits represented by reddish conglomerates, gray marls and sandstones were found especially on the depression side, in the Buneşti-Gherla, Dîrja, Lujerdiu, Sic, Puini, Mociu, Stupini, Ucea wells etc. The Burdigalian absence or weak development in the central part of the Transylvanian Depression seems to be due to the pre-Tortonian erosion. It is noteworthy that the microfauna of the deposits crossed by wells indicates the Lower Burdigalian presence, while the existence of the Upper Burdigalian has not been confirmed.

The Helvetian (about 1,000 m) covers great areas on the northern and south-western sides of the basin, being included in the comprehensive units of the Hida and Salva beds. Lithologically, the Helvetian consists of gray-reddish marno-clays with sand, sandstone and, seldom, conglomerate and gravel intercalations. This rhythmical sedimentation alternation constitutes a thick series (4.000 m) in the Năsăud region and is called the Salva beds, containing deposits from the terminal Oligocene to the Tortonian. Within the depression, the Helvetian was identified by several wells and consists of a marno-clayey complex with sand, sandstone and gray-reddish gravel intercalations containing a microfauna which is similar to that in the Hida beds. The Helvetian, like the Burdigalian, is found sporadically in the central part of the Transylvanian Basin, which is due to the pre-Tortonian denudation.

The stratigraphic succession presented above belongs to the Transylvanian Depression basement. The sedimentary cover, in its turn, is characteristic of the depression and may be separated into two sedimentary cycles: Tortonian-Sarmatian and Pliocene.

The Tortonian (1,000—2,000 m) constitutes the first term of a sedimentation cycle, the respective deposits being transgressively disposed. The profile of the Tortonian deposits is quite similar to that in the Carpathian Foredeep, consisting of the following stratigraphic members: the dacite (Dej, Perşani) tuff horizon, reaching a few hundred metres; sometimes the tuff horizon begins with conglomerates that can be locally replaced by sandstones and marly clays with globigerinae; the salt horizon (0—1,800 m) having a wide but discontinuous distribution in the basin; the salt appears as post-sedimentary agglomerations, generating domal and diapir structures; the radiolarium schist horizon, about 10 m thick; the *Spirialis* marl horizon (200 m).

The same succession was found both on the margins and inside the depression. Beginning with the central basin zone the lithostratigraphic succession of the Tortonian contains more and more psamite sequences eastwards as a result of the massive contribution of the sediments coming from the East Carpathians, that were undergoing uplift movements (Ciupagea et al., 1970). In the western part of Transylvania the Tortonian develops locally in the Leitha limestone facies or in the detrital facies (gravels and conglomerates).

The Sarmatian is represented by the Buglovian, Volhynian and Bessarabian.

The Buglovian comprises the beds developing, as a rule, in continuity of sedimentation with the Tortonian, between the Ghiriş tuff and the Borşa-Turda-Iclod dacite tuff. The Hădăreni tuff together with its equivalent, the Gădălin tuff, as well as the Ghiriş tuff appear only in the western part of the basin. Inside the depression the Buglovian was identified in all the wells drilled, having the same lithological constitution and reaching maximum 800 m in thickness. Some lithological differentiations, namely the exclusively marly facies in the western part, can be noticed. Then a marly-sandy facies appears gradually towards the centre, while predominantly marly deposits develop eastwards. The zone containing the largest number of psamite accumulations corresponds to the Dej-Făgăraş alignment.

The Volhynian-Bessarabian (900—1,700 m) covers most of the depression area and is almost always in continuity of sedimentation with the Buglovian, from which it is separated by the Ghiriş tuff in the central and western zones of the basin. The respective deposits are represented by an alternation of marls and sands with sandstone, tuff and limestone intercalations. The limestones are found in the upper part of the Sarmatian, in the vicinity of the Pliocene boundary. The sands are also more frequent at the upper part of the Sarmatian where they form banks of

10—60 m thick. The basal section of the Volhynian-Bessarabian is predominantly marly. Conglomerate or sandstone levels are intercalated in the marginal zones of the depression, namely in the Sarmatian. Also, some volcanic tuffs (Sărmăşel, Şincai, Rîciu, Zaul, Urca tuffs etc.) with more or less regional developments, can be noticed in the stratigraphic profile of the Volhynian-Bessarabian. The thickness of the deposits increases from the exterior towards the interior of the depression, the greatest values being recorded between the two Tîrnava rivers. The upper limit of the Sarmatian is situated at the level of the *Elphidium craespinae* zone.

The seismic prospections and the exploration wells carried out in recent years indicated several disharmonies in the Middle and Upper Miocene sedimentary series. These disharmonies seem to mark the limits between the Pliocene and the Bessarabian, Volhynian and Buglovian and Buglovian-Tortonian.

The Pliocene (150—800 m) overlying unconformably various stratigraphic terms consists of marls, sands, sandstones, seldom, dolomite and white limestones. Conglomerate intercalations are found occasionally. It was generally noticed that the marls prevail in the Pliocene base, including the Bazna tuff, too, while the sands prevail at the upper part. Important horizontal lithological variations are noticed. Thus the Pliocene generally shows a marly facies in the western part of the depression and then changes into an alternation of sands and marls in the central zone, getting more and more sands on the eastern side. According to the studies made by C i u p a g e a et al. (1970), it seems that the Pliocene deposits of the Transylvanian Depression belong to the Pontian and, occasionally, to the Upper Meotian. The territory of the Transylvanian Depression seems to have been emerged between the end of the Bessarabian and the Upper Meotian.

The Quaternary is represented by predominantly fluvial deposits.

2. General Characteristics of the Structure

As has already been shown, the Transylvanian Depression formed in the present configuration after the Styrian movements (Helvetian) by the sinking of a territory showing a heterogeneous geological constitution and belonging to the three Romanian Carpathian branches: the East Carpathians, the South Carpathians and the Apuseni Mountains. The formations making up this area may be grouped into three superimposed structural complexes: the folded basement, the post-tectonic cover and the Neogene formations of the depression (S ă n d u l e s c u, V i s a r i o n, 1979).

The lower stage, marked by strong folds and overthrust nappes, comprises older formations than the Neocretaceous, considering that the age of the main tectogeneses that achieved the folded basement structure is Meso-Cretaceous (S ă n d u l e s c u, V i s a r i o n, 1979). The middle stage corresponding to the post-tectonic cover is characterized by ruptural and wide plicative deformations. This stage includes Upper Cretaceous to Helvetian deposits.

According to the synthesis drawn up by C i u p a g e a et al. (1970), three major uplift zones can be distinguished in the Transylvanian Depression basement : the W Sic zone, the Blaj-Pogăceaua zone and the Ilimbav-Benţid-Gurghiu zone. These big uplifts are separated by lowered zones (Fig. 47), defined as the Teiuş-Beclean, Alămor-Deleni-Reghin and Ucea-Odorhei-Deda depressive zones. While the sedimentary deposits do not reach sometimes 2,000 m in thickness on the uplifted zones, they exceed 6,000—7,000 m in thickness in the sunk zones.

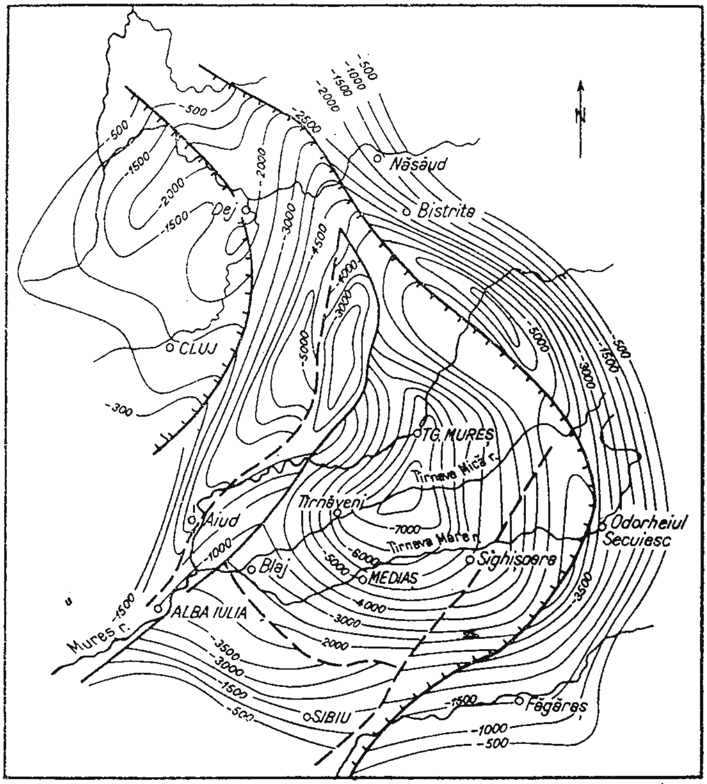

Fig. 47. — Structural map of the Transylvanian Depression at the top of the crystalline basement (according to T r. I c h i m).

According to the same synthesis (C i u p a g e a et al., 1970), the major structural units corresponding to the folding basement of the Transylvanian Depression are represented by overthrust nappes. The recent investigations (S ă n d u l e s c u, V i s a r i o n, 1979) led to the conclusion that in the depression basement lies an ophiolite zone, developing in the centre and west of the Transylvanian Basin and which is bounded by the Apusenide (septentrional and/or Northern Metaliferrous) elements and by the central-east Carpathian units to the east. All these units, the ophiolite massif inclusively, represent nappe units.

It is worth underlining again the fact that numerous elements that are common to the East Carpathians, the South Carpathians and the Apuseni Mountains are identified in the structural arrangement of the pre-Tortonian formations; they partly outcrop and prolong under the depression cover.

The seismic and drilling data suggest that the Paleogene and the Lower Miocene terms of economic interest form normal, large folds, some of them with regional extension and crossed by faults. These formations are characterized by large zones of accumulation after which they gradually disappear towards the uplift flanks and, first of all, on the north-western and south-eastern flanks of the Pogăceaua uplift. The dips of the beds, determined in the wells vary within very large limits, from 1° to 85° respectively.

The sedimentary cover filling up the depression zones corresponds to the Tortonian, Sarmatian (the Buglovian inclusively) and the Pliocene and is distributed to three zones with concentric disposition (Plate III).

a) The external monoclinal zone which is evident on the north, west and south sides where the beds slightly dip towards the interior of the basin; the east side is not yet well known, although some gas-bearing domes have been recently identified here.

b) The diapir fold zone situated farther inwards, which is strongly folded and shows salt outcroppings on the Dej-Beclean-Ideciul-Sovata-Praid-Corund-Lueta-Mercheașa-Ocna Sibiului-Ocna Mureșului; in fact the diapir fold zone bounds the depression only in the eastern and western parts. The salt horizons and the Dej tuff occurrences in the north, in the Someș Valley and in the south, in the Olt Valley represent normal outcroppings of the beds continually rising on the border; the diapir salt bodies cross sometimes also the Pliocene, proving the recent age of the salt movements;

c) The brachyanticline zone situated in the central part of the basin. The structural elements here cover large areas on which the beds dip 1—15°. The synclines showing variable shape and size surround the positive structures. With a few exceptions the synclines and anticlines of the central zone are not crossed by faults. The orientation of the structures is quite varied; nevertheless a zone trending NW—SE (north of the Mureș River), another one situated between the Mureș and the Hîrtibaci trending E—W and a third one between the Hîrtibaci and the Olt rivers trending N—S could be separated (Fig. 48).

There is an almost complete unconformity between the structure of the post-Helvetian and the pre-Tortonian deposits which indicates that the setting of the strata belonging to the last stage was mainly determined by the salt movement which, by its particular plasticity, favoured all forms of diapirism. The structural conformity between the salt surface and the covering deposits confirms, once more, the causal relations existing between them. The salt tectonic effect decreases gradually from the Tortonian to the Pliocene, which suggests that the salt shifting and the fold formation process had a lasting character with some intensifications in the diastrophic phases. The duration of the structure formation must

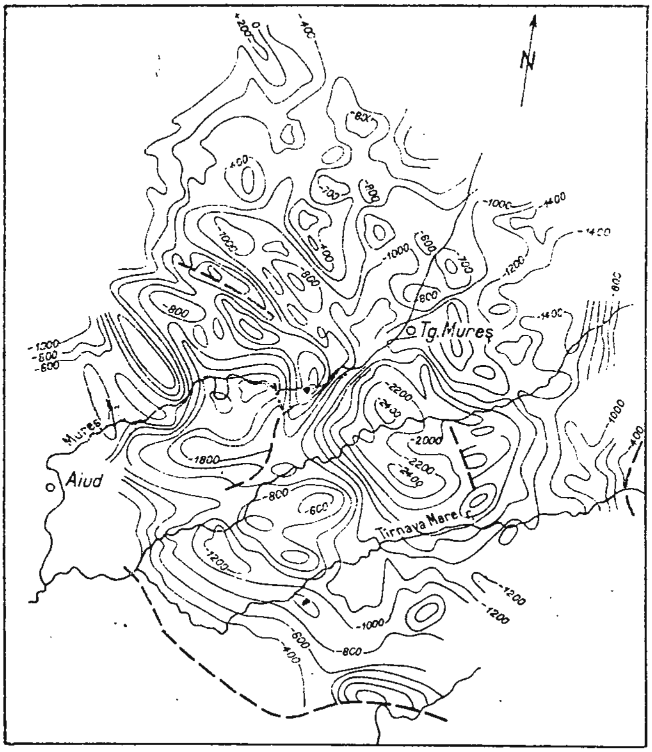

Fig. 48. — Structural map of the Transylvanian Depression at a Buglovian guide mark (according to Tr. Ichim).

be correlated to the continuity of the accumulation process of the cover deposits. Under the weight and pressure of these deposits the salt shifted almost permanently (Fig. 49).

The salt in the Transylvanian Depression shows a diversity of diapir folds. The embrional cryptodiapir structures prevail in the centre of the basin, while folds with outcropping salt cores are found towards the border. This fact as well as the generally reduced thickness of the halites in the centre of the centroclinal fold suggest a salt migration from the deepest (central) zone towards the basin margins. The strong diapirism on the eastern and western sides of the depression should be connected with the older system of tectonic accidents, surrounding this great structural unit and which was reactivated during the various diastrophic phases. The respective accidents acted as screens along which the salt could later cross the sedimentary cover easier. But, as proved by geothermal data, this deep fault zone is characterized by mofette manifestations and by a stronger heat flow than in the centre of the basin. Under such conditions, the increased geothermal gradient probably, determined, an increased salt plasticity and therefore an "exagerated" diapirism.

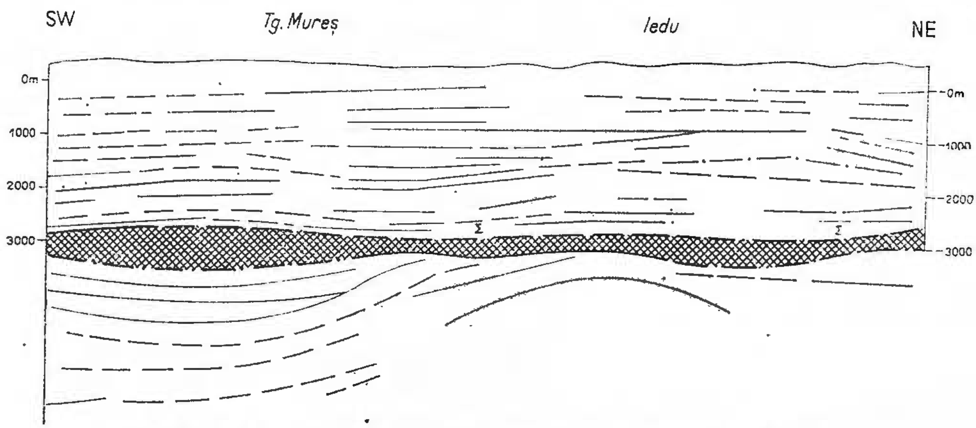

Fig. 49. — Seismic profile in the Transylvanian Depression S of Tg. Mureş.

Within the upper structural substage, structural unconformities were noticed almost throughout the depression area, but especially in the latter's eastern part (Fig. 50). The respective unconformities determined

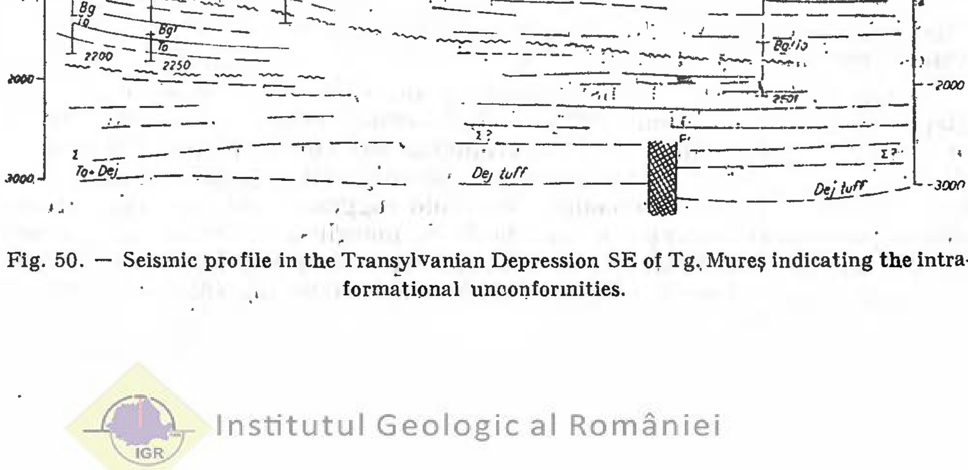

Fig. 50. — Seismic profile in the Transylvanian Depression SE of Tg. Mureş indicating the intraformational unconformities.

the shifting of the structure apex. These apices migrate and are not superimposed (e.g. Filitelnic, Corunca, Nadeş etc.). According to some authors (Ciupagea et al., 1970), the unconformities are due to several causes, namely : the rough relief of the Crystalline-Mesozoic basement ; the unconformities ; the variable thicknesses of the salt bed and the diversity of diapirism of the latter ; the facies change ; the weak dip of the beds etc.

Considering the fact that almost all the geologists studying the Transylvanian Depression shared the opinion that the domes represent the effect of the salt movements, the main cause of the unconformities is considered to consist in the differentiations in the salt accumulation and the varying shift intensity correlated to the diastrophic phases. One should also bear in mind the differential compactness determined by the lithofacial variations.

3. Geological Evolution of the Transylvanian Depression

Within the long evolution preceding the formation of the Transylvanian Depression, the period corresponding to the post-tectonic (Upper Cretaceous-Lower Miocene) stage is the best known and the most interesting as regards the hydrocarbon prospects.

At the end of the Cretaceous a part of the territory corresponding to the present Transylvanian Depression sank marking the first stage in the evolution of this unit (Mutihac, Ionesi, 1975). Several islands and crests were not covered by waters ; they partly identify with the three basement uplifts, namely : W Sic, Pogăceaua and Ilimbav-Odorhei-Gurghiu. The sea waters covering the Transylvanian Basin communicated north and north-west with the Paleogene waters in the Pannonian Depression and with those in the Transcarpathian zone.

During the Eocene the sedimentation seems to have taken place on the same areas as in the Cretaceous. The oscillating movements that affected rhythmically the basin bottom, at least in the northern part, determined the advance and retirement of the sea waters in several stages, which is suggested by the existence of two series of marine deposits, separated by two continental series. It is also then that the marginal tectonic accidents were reactivated, a process accompanied by the sinking of the basin bottom, by the invasion of the Tortonian sea and by strong effusive manifestations. As a result, the Dej tuff deposited, covering almost the whole depression area. Later on the Transylvanian Basin became an immense lagoonal domain, which led to the accumulation of some important salt deposits. It seems that the salt did not overlie the basin like a continuous cover, but accumulated as big lenses varying in thickness.

As the subsidence movement continued and intensified under the pressure of the accumulating Tortonian, Buglovian-Sarmatian and Pliocene deposits, owing to its plasticity, the salt, shifted and accumulated as "salt pillows", while on the sides it accumulated as "salt walls" or "salt stocks" influencing the arrangement of the cover beds. The formation of the halokinetic structures generally having no equivalent in the pre-

Tortonian formations, constituted a long lasting process which is correlated to the basin sedimentation process, a fact proved by the gradual disappearance of the salt tectonic effect from the Tortonian towards the Pliocene. The salt movement and accumulation process associated with the deformation of the overlying bed might have recorded greater intensities during the main diastrophic phases. The position and orientation of the salt accumulations might have been determined by the pre-existent relief and by several older tectonic accidents which were reactivated and transmitted to the post-Helvetian sedimentary cover together with a stronger heat flow, as is suggested by the thermal waters in the Filitelnic and Brătei pre-Tortonian. The apex of the sunk salt massifs modified, probably, during the salt accumulation, under the influence of the general basin movements, of the lithologic variations, of the compacting process and of the supposed local intraformational gaps, determining unconformities at the level of the Buglovian-Sarmatian formations (Fig. 51).

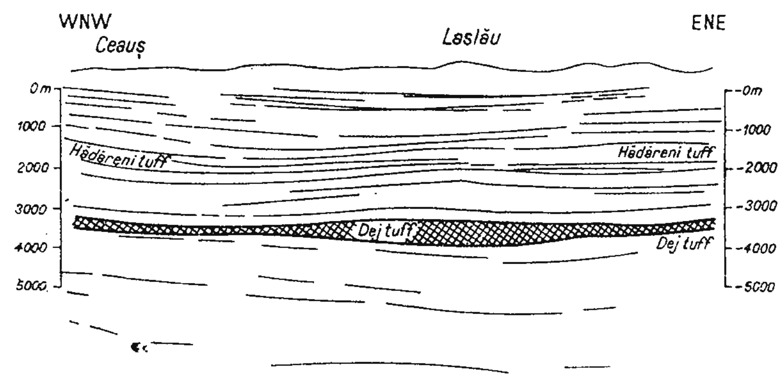

Fig. 51. — Seismic profile in the central part of the Transylvanian Depression indicating intraformational unconformities.

Throughout the Sarmatian the forming domes maintained a generally more uplifted position than the neighbouring zones and acted as "calling centres" for the hydrocarbons that formed in the adjacent synclines.

The subsidence process of the Transylvanian Basin lasted intermitently up to the Pliocene being simultaneous with the Carpathian rising. These compensating movements kept active the deep fractures bounding the depression. Volcanic eruptions took place in several stages along these fractures ; they are indicated by the large number of tuff beds intercalated in the post-Helvetian sedimentary deposits. But the East Carpathians seem to have undergone the strongest positive movements of all the neighbouring regions, thus furnishing most of the detrital material that deposited in the basin. The above statement is confirmed by the lithological variation throughout the basin at the level of the Tortonian and even

Sarmatian formations which become ever more gritty and even conglomerate west-eastwards. Some gritty horizons lying on the eastern margin of the basin can be followed up to the region situated west of the central part, where they gradually change into pelites.

During the Pliocene, probably at the end of the Pontian (C i u p a g e a et al., 1970) the territory of the Transylvanian Depression rised throughout, becoming land.

4. Conditions of Genesis, Accumulation and Preservation of Hydrocarbons

The geological mappings and exploration drilling in the Transylvanian Depression, identified a stratigraphic succession reaching 6,000—8,000 m in thickness and consisting of an alternation of clays, marls, sandstones, sands and conglomerates. Some of the strata offer favourable hydrocarbon genesis, accumulation and preservation conditions. Other strata, such as the pre-Senonian sedimentary deposits, belonging to the depression basement are of little prospect as they were subject to emergence and erosion for a long period of time and seem to have a very complicated tectonics.

As far as the reservoir rocks are concerned, they are to be found in all the Tertiary formations, from the Eocene to the Pliocene. The microconglomerates, sandstones and Eocene limestones should be mentioned as they produced salt water in numerous wells, thus proving their storing and yielding capacity. The Oligocene might be taken into consideration because of the sandstones and sands belonging to the Tic and the Almaș Valley beds and because of the psamite sequences in the Salva beds to the east. The Burdigalian and the Helvetian extend on a great area within the depression and include numerous sand, sandstone and microconglomerate horizons or layers. Their storing capacity was checked by production tests (with salt waters) in several wells. The most important reservoir rocks are known in the Upper Miocene, where the Tortonian and Sarmatian sandstones and sands show average porosities 20 per cent and permeabilities 0.1—1,000 mD, yielding gas on numerous structures. The physical properties of these reservoirs deteriorate with depth owing to the rock compactness. Thus the Tortonian sandstones situated at the depth of more than 2,800—3,000 m offer very weak productions (up to 10,000 m^3/day gas) or do not produce even after special treatments. Also, the frequency, thickness and physical properties of the Upper Miocene reservoirs decrease from east to west and north-west, which was thoroughly illustrated in a previous paper (V a n c e a, 1960). Good reservoirs are also found in the Pliocene but they benefit only locally by protection conditions.

The protection rocks are also found throughout the stratigraphic series of the depression. The Eocene clays, marls, marno-limestones and gypsum belonging to the two marine series may be assigned to this category. The Oligocene, by its marl beds, clays and bituminous schists (in the Ileanda beds) offer protection conditions. The Lower Miocene impervious horizons are present in the Chechiș beds and, locally, in the Hida beds if they were not subject to the pre-Tortonian erosion. The salt and the clayey series in the Tortonian base make up a protection cover for the Lower Miocene and the Paleogene throughout the central zone of the Transylvanian Depression. Almost all the pelite horizons and intercalations separating the Tortonian, Buglovian, Sarmatian and, sometimes, basal Pliocene sandstone and sand complexes add to them. The impervious character of these pelite intercalations is proved by the fact that the majority of the productive sand and sandstone complexes have various water-gas limits, therefore constituting separate hydrodynamic units. Some of the protection pelite horizons were removed and the deposits were depleted (destroyed) north of the Tîrnava Mare and, especially, north of the Mureş, where the gas formation has been subject to erosion.

The same pelite rocks represented by clays, marls and marno-limestones mentioned in connection with the protection conditions are considered likely to be hydrocarbon source rocks. Among them, of most interest are the bituminous schists in the Ileanda beds, the radiolarian schists and, generally, all the marly horizons belonging to the Tortonian and Sarmatian. Although the respective formations were not the object of any special geochemical studies, the results of the research carried out on some deposits of similar age in the Carpathian Foredeep and the Pannonian Depression (A n t o n, 1973) justify such statements. As a matter of fact, the recurring alternation within considerable thicknesses of possible hydrocarbon source rocks, to which add the favourable structural and protection factors, explain the gas richness of the Transylvanian Depression.

The geothermal studies made in recent years (P a r a s c h i v, C r i s t i a n, 1976) indicate that the Transylvanian Depression behaves in an unitary way as regards the depth temperatures. The lowest values, 3°C/100 m, respectively, are found in the centre of the basin where the new sedimentary deposits reach maximum thicknesses. As the distance from the eastern, northern and southern margins decreases, therefore, as the thickness of the sedimentary deposits decreases and important dislocation lines appear, the value of the geothermal gradients increases, namely from 3°C/100 m to 5°C/100 m and even more. As compared to the Pannonian Depression, the Transylvanian Depression shows much lower temperature values. The fact might be explained not so much by the upper mantle thickening to 25—30 km, as, especially, by the greater thickness of the Tertiary and Mesozoic deposits. The relatively low geothermal gradient associated with the recent age of the formations of interest explain, to a certain extent, the exclusively gaseous nature of the hydrocarbons generated by the Tortonian and Sarmatian formations.

The productive domes and the adjacent zones are characterized by the presence of waters of $CaCl_2$, $MgCl_2$ and $NaHCO_3$ types, whose mineralization is lower than the one in the Carpathian Foredeep, varying, as a rule, between 30 and 95 g/l. The deep and well protected strata contain chlorocalcic and chloromagnesian waters. As the depth decreases, mixed or only vadose waters appear. Of course, the type and mineralization of the waters indicate the sealing degree of the deposits and, implicitly, the prospects of finding commercial accumulations. The fossil deposit waters contain iodine and bromine which are revaluated in some watering places.

5. Gas Deposits

Hydrocarbon emanations have been known for a long time in the Transylvanian Depression, but the first commercial gas deposit was discovered accidentally only in 1909, by the well no. 2 Sărmăşel. The latter, like the well no. 1 Sărmaş, which had been previously drilled, was projected for the exploration of the potassium salts which were supposed to exist in the Tortonian salt formation. The well Sărmăşel no. 2 started the drilling in November 1908 and in the following year reached a horizon of gas with high pressures, yielding 864,000 m^3/day in free gas eruption at the depth of 302 m. This important discovery brought about an intensification of the geological research, especially after 1949.

74 gas fields (Fig. 52) have been discovered in the Transylvanian Depression so far; 13 of them were discovered before 1948 and the other 61 structures, after 1948. The natural gas in these structures is located in the Tortonian, Buglovian [5], Sarmatian and, very seldom, in the Pliocene deposits which, together, make up "the gas formation".

The number and size of the gas-bearing horizons vary from one structure to another according to the thickness of the Upper Miocene sedimentary deposits, to the lithofacies and to the geological evolution. From this point of view the genesis of the structural elements and the post-Pontian denudation played an important part. Taking into account these conditions and criteria, the gas-bearing domes in the Transylvanian Depression might be distributed into five groups:

— the central group, consisting of large domes, where the gas formation may reach 3,000 m in thickness, with very many productive horizons and, generally, protected by Pliocene deposits such as the Delureni, Crăeşti-Ercea, Bozed, Păingeni, Dumbrăvioara, Ernei, Tg. Mureş, Acăţari, Corunca, Săuşa, Suveica, Filitelnic, Laslăul Mare, Delenii (Saroş), Bazna, Nadeş, Prod-Seleuş structures;

— the northern group where the gas formation outcropping was more and more eroded to ist total removal in the vicinity of the Someş; the number of productive horizons decreases accordingly; this group consists of the Beudiu, Enciu, Strugureni, Puini, Ţaga, Buza, Fîntînele, Sărmăşel, Silivaş, Sînmartin de Cîmpie, Ulieş, Şincai, Grebeniş, Zâul de Cîmpie, Şăulia, Dobra, Sînger, Iclănzel, Vaidei, Luduş;

— the western group consisting of the Lechinţa-Iernut, Bogata, Cucerdea, Cetatea de Baltă, Velţ and Tăuni domes, is characterized by the gradual substitution of the psamite complexes, by the pelites and by the reduction up to disappearance of the reservoir horizons towards the Apuseni Mountains;

[5] In the field geology the specialists in the gas industry separate the Buglovian substage from the Sarmatian, which will be reflected in the present paper.

— the southern group represented by the Copşa Mică, Noul Săsesc, Petiş, Birghiş, Ruşi and Ilimbav, where the halokinetic becomes less important towards the South Carpathians so that at one moment there are no diapir anticlines but faulted anticlines (Ruşi) or shrinking structures

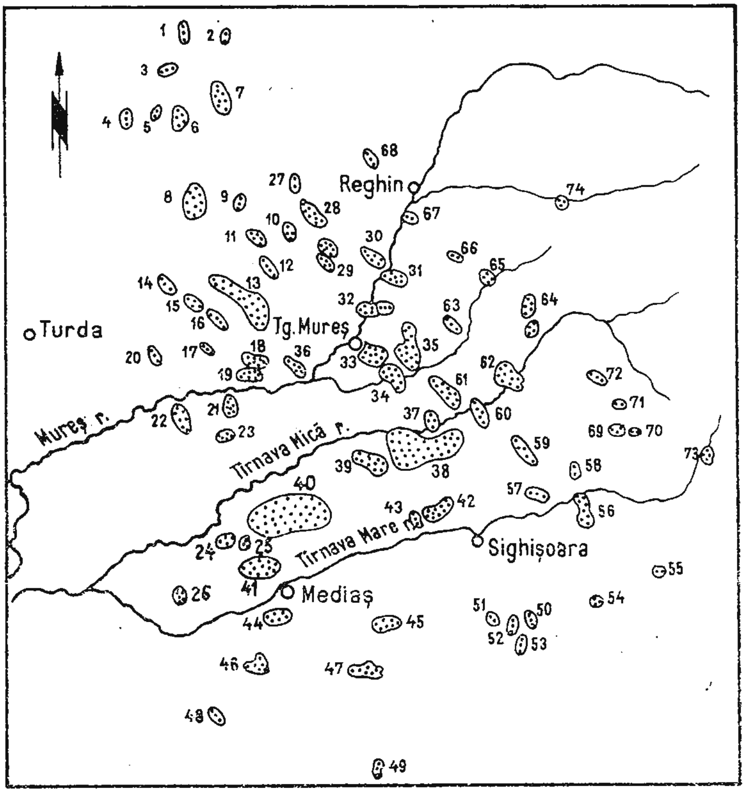

Fig. 52. — Map of the distribution of gas deposits in the Transylvanian Depression. 1, Beudiu ; 2, Enciu ; 3, Strugureni ; 4, Puini ; 5, Ţaga ; 6, Buza ; 7, Fîntînele ; 8, Sărmăşel ; 9, Silivaş ; 10, Sînmartin ; 11, Ulieş ; 12, Şincai ; 13, Grebeniş ; 14, Zăul ; 15, Şăulia ; 16, Dobra ; 17, Sînger ; 18, Iclănzel ; 19, Vaidei ; 20, Luduş ; 21, Lechinţa-Iernut ; 22, Bogata ; 23, Cucerdea ; 24, Cetatea de Baltă ; 25, Velţ ; 26, Tăureni ; 27, Delureni ; 28, Crăeşti-Ercea ; 29, Bozed ; 30, Păingeni ; 31, Dumbrăvioara ; 32, Ernei ; 33, Tg. Mureş ; 34, Acăţari ; 35, Corunca ; 36, Săuşa ; 37, Suveica ; 38, Filitelnic ; 39, Laslău Mare ; 40, Delenii ; 41, Bazna ; 42, Nadeş ; 43, Prod-Seleuş ; 44, Copşa Mică ; 45, Noul Săsesc ; 46, Petiş ; 47, Bîrghiş ; 48, Ruşi ; 49, Ilimbav ; 50, Daia-Ţelina ; 51, Netuş ; 52, Retiş ; 53, Bărcut ; 54, Buneşti-Criţ ; 55, Beia ; 56, Cristuru ; 57, Eliseni ; 58, Chedia ; 59, Şoimuş ; 60, Sîngeorgiu de Pădure ; 61, Gălăţeni ; 62, Ghineşti-Trei Sate ; 63, Miercurea Nirajului ; 64, Măgherani ; 65, Dămieni ; 66, Feleac ; 67, Voivodeni ; 68, Lunca ; 69, Tărceşti ; 70, Benţid ; 71, Firtuşu ; 72, Cuşmed ; 73, Brădeşti ; 74, Ibăneşti.

(Ilimbav); as a result, the importance of the accumulations decreases constantly southwards;

— the eastern group comprises smaller structures; the tectonic complication of these structures increases reaching the shape of exaggerated and faulted diapirs; the frequency of the unconformities within the gas formations is higher; the protection conditions deteriorate owing to the increasing number of psamites and the partial invasion of the reservoirs by CO_2. The following gas-bearing structures belong to this group: Daia-Ţelina, Netuş, Retiş, Bărcut, Buneşti-Criţ, Beia, Cristur, Eliseni, Chedia, Şoimuş, Sîngeorgiu de Pădure, Gălăţeni, Ghineşti-Trei Sate, Miercurea Nirajului, Măgherani, Dămieni, Teleac, Voivodeni, Lunca, Tărceşti, Benţid, Firtuşu, Cuşmed, Brădeşti and Ibăneşti.

a) The northern group, as has already been mentioned, comprises 20 gas-bearing domes (1—20, Fig. 52).

The Beudiu structure (1, Fig. 52) is situated in the northernmost part of the Transylvanian Depression. It represents an anticline trending N—S, in the axis of which outcrops the Buglovian. One of the wells drilled on this structural element (well no. 3) had gas from the Buglovian (?) at the depth of 612—630 m. Initially the stratum yielded about 19,000 m^3/day gas with 1,680—4,320 l salt water. After some time the pressure decreased from 41 kgf/cm^2 to 13 kgf/cm^2, the well being closed; then the well did not flow owing to the water flooding.

The Enciu anticline (2, Fig. 52) was identified by the geological mappings and the core drills operated in the region. The Volhynian outcrops in the structure axis. Well no. 3 penetrated the whole succession of deposits up to the salt formation (1,305 m) and met a sand gas-bearing horizon in the Buglovian at the depth of 402—448 m. The production was 29,000 m^3/day and the pressure 39—41 kgf/cm^2. The exploitation works will continue.

The Strugureni anticline (3, Fig. 52) represents a structural detail in the zone of the Fîntînele-Beudiu major anticline. The Volhynian outcrops in the structure axis. Two wells, nos. 1 and 2, were drilled; the latter crossed the whole succession of deposits up to the salt formation (1,324 m) and met, in the Tortonian, a gas-bearing layer that yielded between 9,600—92,000 m^3/day; the pressure was 17—60 kgf/cm^2.

The Puini structure (4, Fig. 52) was identified by surface mappings and then controlled by seismic works. The Volhynian outcrops in the region.

The central well, no. 6, penetrated a succession of strata beginning with the Senonian, continuing with the Burdigalian-Helvetian, Tortonian, Buglovian and ending with an important Volhynian sequence.

The structure is like a dome, elongated north-southwards, but the axis migrates westwards at a certain depth, owing to the various unconformities. The dips of the strata are 1—4°.

The wells drilled at Puini identified three gas-bearing horizons, each of them constituting an arbitrary grouping of strata. The superficial member (at the depth of about 470 m) and the upper part of the horizon I (564—798 m) belong to the Buglovian; the lower half of the horizon I and the horizon II (816—920 m) are of Tortonian age (Fig. 53). The effective thickness of each productive complex varies between 11 and 25 m, the porosity between 10 per cent and 23 per cent and the connate water saturation between 35 per cent and 45 per cent.

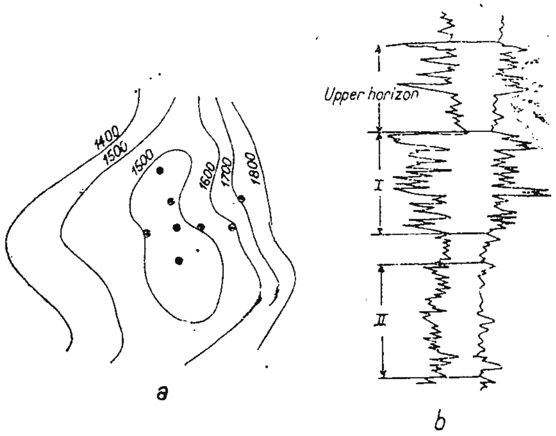

Fig. 53. — Puini structure. a, structural image at the Lower Miocene level; b, Buglovian and Tortonian type profile.

The outputs obtained were 3,500—55,000 m^3/day/well, small amounts of gas being pointed out in the (lower) horizon II. The pressure gradient is 0.94—1.03, increasing with depth. The gas consists of 99.4 per cent methane, 0.09 per cent ethane, 0.02 per cent propane. The specific gravity is 0.556 kgf/dm^3. The associated waters are of chlorocalcic type with mineralizations of 62—91 g/l.

The Țaga structure (5, Fig. 52) lies in the vicinity of the Puini structure being similar in shape to the latter. Two of the wells drilled here contained gas from the Tortonian. The productive section is between 510 and 1,160 m deep. The productions obtained were between 14,000 and 55,000 m^3/day/well, according to the respective horizon and nozzle.

The Buza anticline (6, Fig. 52) is situated in a zone where the Sarmatian outcrops. The identification of the structure was achieved by surface mapping and by core drills. Two deep wells were drilled after gas had been identified in one of the core drills. One of them, well no. 3, had gas traces in the Tortonian and Buglovian. Greater productions, up to 11,200 m^3/day with 1,500—2,000 l salt water, were obtained at several Tortonian strata at the depth of 802—1,252 m.

The Fîntînele structure (7, Fig. 52) is an oval-shaped dome with the axis trending NW—SE. The dip of the strata does not exceed 6°. The Sarmatian outcrops, while the wells drilled here since 1968 have penetrated the whole succession of strata up to beneath the salt formation. The Buglovian and the Tortonian show numerous sandy complexes of which 11 are gas-bearing. Three complexes (II, II—III, III) belong to the Buglovian while eight (IV—X, including the interval V—VI) belong to the Tortonian.

The Sărmăşel dome (8, Fig. 52) is the first gas field discovered in the Transylvanian Depression. It lies in a region where the Sarmatian outcrops and was identified by geological mappings.

Several wells were drilled on the structure, the deepest of them reaching 2,974 m. The stratigraphic sequence and the geological limits are the following: Sarmatian-Buglovian 336 m (therefore the thickness of the uneroded Sarmatian is 336 m), Buglovian-Tortonian 1,100 m, the salt formation 2,067—2,961 m. At the latter depth the Dej tuff was intercepted. It is worth mentioning that the salt reaches 900 m in thickness.

The dome is oval-shaped, slightly elongated north-southwards. The dip of the strata varies between 1°30′ and 6°.

At Sărmăşel are known 15 productive horizons: four (I—IV) in the Sarmatian, seven (V—XI) in the Buglovian and four (XII—XV) in the Tortonian. The reservoirs consist of sands and sandy marls. The average porosity of the sands is 21.6 per cent, while that of the siltstones is 16.2 per cent.

The gas consists of 98.94—99.63 per cent methane and 0.27—0.78 per cent ethane. The heating power is 8,056—8,970 kcal/m^3 at 15° and 760 mmHg. The waters are of chlorocalcic type.

The Silivaş structure (9, Fig. 52) lies between the Sărmăşel and Crăeşti domes. One of the wells drilled at Silvaşu de Cîmpie produced gas from the Tortonian at the depth of 1,675—2,080 m. The production recorded varies between 15,000 and 25,000 m^3/day/well.

The Sînmartinu de Cîmpie dome (10, Fig. 52) is elongated NW—SE and is relatively small. The wells drilled penetrated the Sarmatian, Buglovian and Tortonian formations consisting of marls, sandy marls and sands. The reservoir rocks were grouped into 11 complexes (I—XI) to which add also intermediary marly horizons. 10 complexes and intermediary horizons were proved gas-bearing so far; two of them are in the Sarmatian and eight in the Tortonian. The production obtained varies between 3,300 and 145,000 m^3/day gas.

The Ulieş structure (11, Fig. 52) comprises two domal culminations trending NW—SE and called Ulieş W and Ulieş E. The structure was identified by geological surveys. The wells drilled so far crossed the Sarmatian, Buglovian and Tortonian up to the salt formation identifying 20 productive complexes (superficially, I—X and intermediary horizons) at Ulieş W and 10 complexes (superficially, I—X) east of Ulieş. The average depth of the productive strata is between 247 m and 1,642 m. The effective thickness of each member is 1.7—105.22 m, the porosity 12—20 per cent and the connate water saturation 35—50 per cent.

The Şincai dome (12, Fig. 52) is one of the oldest gas fields in the Transylvanian Depression. It was identified by geological mappings. The first wells were drilled between 1911 and 1912 reached the depth of 365 m. They identified some gas accumulations on this structure. Sarmatian deposits outcrop in the region, but Pliocene formations are found only in a restricted sector.

The Pliocene is represented by sands and limy marls. The Sarmatian consisting of a sequence of sandstones, sands and marls is about 650 m in thickness and comprises five dacitic tuff layers (the tuff of Ercea, Rîciu, Galda, Sărmășel and Şincai). The Buglovian (about 640 m) is predominantly marly. It consists of six sandy complexes with thin tuff intercalations. The Tortonian (about 950 m) is also marked by the prevalence of marls within which three sandy complexes can be identified. The Pogăceaua well drilled on the Şincai dome met, under the Tortonian salt, the Eocene overlying the crystalline schist basement.

The Șincai structure represents a dome which is slightly elongated NW—SE and with the NE flank a little more abrupt. The dip of the structure is 4—7°, more rarely 10° and even 20°. The structure is perfectly reflected in the relief shapes.

The Şincai dome comprises 11 productive complexes : one (I) in the Sarmatian, three (II—IV) in the Buglovian and seven (V—XI) in the Tortonian. Some of these complexes belonging to the Sarmatian and Buglovian vary in extension and thickness, having, sometimes, lenticular development. "The Şincai sands" (Sarmatian) as well as the complex III are marked by the presence of conglomerates and cross bedding; these elements suggest temporary intraformational discontinuities of sedimentation. As a matter of fact, even the structure apex is vertically displaced owing to the Upper Miocene unconformities. Under such circumstances the traps are of structural and lithological types.

The productive sands show effective porosities 9.38—20.79 per cent and permeabilities 0.5—638.4 mD. The gas contains 99.5 per cent CH_4 and 0.5 per cent N_2. The specific gravity (kg/m^3) at 0°C is 0.556. The heating power does not differ considerably from that determined on the neighbouring structures, 8,121—8,984 kcal/m^3, respectively.

The Grebeniș anticline (13, Fig. 52) was identified by electrometric surveys and confirmed by seismic prospections; it is trending NW—SE and is asymmetrical in the sense that the SW flank is more abrupt than the NE flank.

The whole gas-bearing formation was crossed up to the salt formation in the Grebeniș area. It consists of an alternation of marls, marly sands and sands. Most of the reservoir horizons are found throughout the structure. But there are also units showing a lenticular development. The traps are therefore of structural and lithological types.

There are 19 productive complexes, intermediary horizons and lens groups on the Grebeniș anticline; they belong to the Sarmatian (4), Buglovian (4) and Tortonian (11). The porosity of these strata is 21—9 per cent, while the average permeabilities are 70—14 mD, decreasing with depth.

The Zăul de Cîmpie brachyanticline (14, Fig. 52) is situated in a zone where the Sarmatian outcrops. The structure was identified by surface mapping.

The Sarmatian, partially eroded in the apex zone, is 800 m in thickness. The remaining stratigraphic sequence is almost similar to that at Şincai with fewer lithological variations of the Sarmatian and Tortonian complexes. The Sarmatian is about 350 m in thickness, the Buglovian, about 500 m and the Tortonian, about 2,100 m, including the salt formation (790 m).

The structure represents a brachyanticline trending NW—SE, slightly asymmetrical, with the western flank more abrupt. The dip of the strata varies between 14° and 22°.

The Zăul structure contains a productive complex in the Sarmatian, seven complexes in the Buglovian and three in the Tortonian. The average porosity of the sands is 16.7—22 per cent; the average porosity of the sandstones is 6—15.3 per cent, while that of the siltstones is maximum 16.7 per cent. The permeability is 1.7—74.8 mD. The gas is made up of 99.4 per cent methane and 0.6 per cent ethane. Its heating power is 8,056—8,970 kcal/m^3.

In fact, the Zăul de Cîmpie structural element develops more southeastwards including also the *Şăulia* and *Dobra culminations* (15, 16, Fig. 52) which are characterized by facies variations and different behaviour of the wells during production tests. Gas was pointed out in a few Buglovian and Tortonian complexes on these two culminations.

The Sînger brachyanticline (17, Fig. 52) is situated in the "Transylvanian Plain" where the gas formation was partially removed. The structure was identified by geological mapping. The first well, drilled in 1949, on the basis of the surface surveys proved the existence of gas on this structural element.

The Lower Sarmatian outcrops in the Sînger brachyanticline zone. The Buglovian is 370—400 m in thickness and consists of an alternation of marls and sandstones. The Tortonian consists almost exclusively of marls.

The Sînger brachyanticline is trending NW—SE. The dips of the strata are remarkably high (8°—45°) as compared to the other domes, which suggests that the structure is crossed by a longitudinal fault.

The exploratory wells indicated the existence of gas in four sandy complexes which are less than 450 m deep and belong to the Buglovian.

The Iclănzel gas field (18, Fig. 52) corresponds to an anticline trending NW—SE, within which the dip of the strata is 3—8°. The wells drilled here crossed the gas formation up to the salt formation, identifying 16 productive members belonging to the Sarmatian, Buglovian and Tortonian. Some of these units show lithological variations and permeability barriers. The various sandy and silty beds with regional or local developments were grouped into 10 complexes.

The Vaidei dome (19, Fig. 52) lies south of the Iclănzel structure. It is eliptical, trending NW—SE at the horizon VIII level. The structure apex shifts westwards at a certain depth. The Sarmatian outcrops and is not productive. Nine gas units were identified in the Buglovian and the

Tortonian ; they were grouped into six complexes (VI—XI). The exploration activity continues.

The Luduş dome (20, Fig. 52) is perfectly oval, the dip of the strata being 2—4°. The wells operated on this structure met reservoir rocks only in the Sarmatian. Weakly sandy marls with reservoir properties develop also in the uppermost part of the Buglovian. There are eight productive complexes (II—VIII and a marno-sandy zone between the units VII and VIII).

The depth of the gas-bearing beds does not exceed 860 m. The average effective thickness is between 2.10 and 9.62 m, the porosity between 10.5—18.24 per cent, the connate water saturation 17—23 per cent, the reservoir pressure 27—71 kgf/cm², while the temperature is between 18—35°C. The structure is completely outlined and put into operation.

b) The western group consists of six gas-bearing structures (21—26, Fig. 52).

The Lechinţa-Iernut structure (21, Fig. 52) consists of two culminations : one at Lechinţa, the other at Iernut.

On the latter culmination well no. 2 had gas productions at five Buglovian horizons and at a Sarmatian one. The maximum output was recorded on the interval 722—798 m, namely 18,500—35,900 m³/day gas ; generally 5,000—6,000 m³/day gas and even less were obtained from the other strata. The wells at Lechinţa (1, 12) behaved similarly in some Buglovian and Tortonian horizons.

The Bogata de Mureş structure (22, Fig. 52) was discovered by geophysical research, namely by seismic surveys. The Sarmatian outcrops in the dome apex and the Pliocene is still preserved on the flanks. Gas seeps appear in the zone.

The wells drilled at Bogata de Mureş, reaching the salt formation, showed that the Sarmatian (about 105 m) has some sand and sandy marl complexes. The Buglovian (about 250 m) and the Tortonian (nearly 900 m in thickness) develop an exclusively marno-clayey facies.

The dome is asymmetrical, elongated NW—SE, with the NE and SW flanks more abrupt. The dip of the strata is 1°30'—40°. The north-westward closing of the structure becomes stronger at the Upper Sarmatian level. A west-eastward shift of the structure axle can be noted at the ever older horizons (Fig. 54).

Seven productive complexes (I—VII) located only in the Sarmatian are known at Bogata de Mureş. The sands and sandy marls making up the reservoir show porosities of 14—20.7 per cent, the values being lower for the inferior strata and the sandy marls. The siltstone intercalations show porosities of 4.8—13.2 per cent. The permeability varies between 0 and 544 mD. The connate water saturation is 30 per cent. Owing to the great permeability variation of the lower horizons, the pressure is not uniformly redistributed throughout the deposit, local depressive zones being found (e.g. the complex VII). The gas saturated zones of the upper horizons seem to be displaced (pushed) north-westwards (Fig. 54).

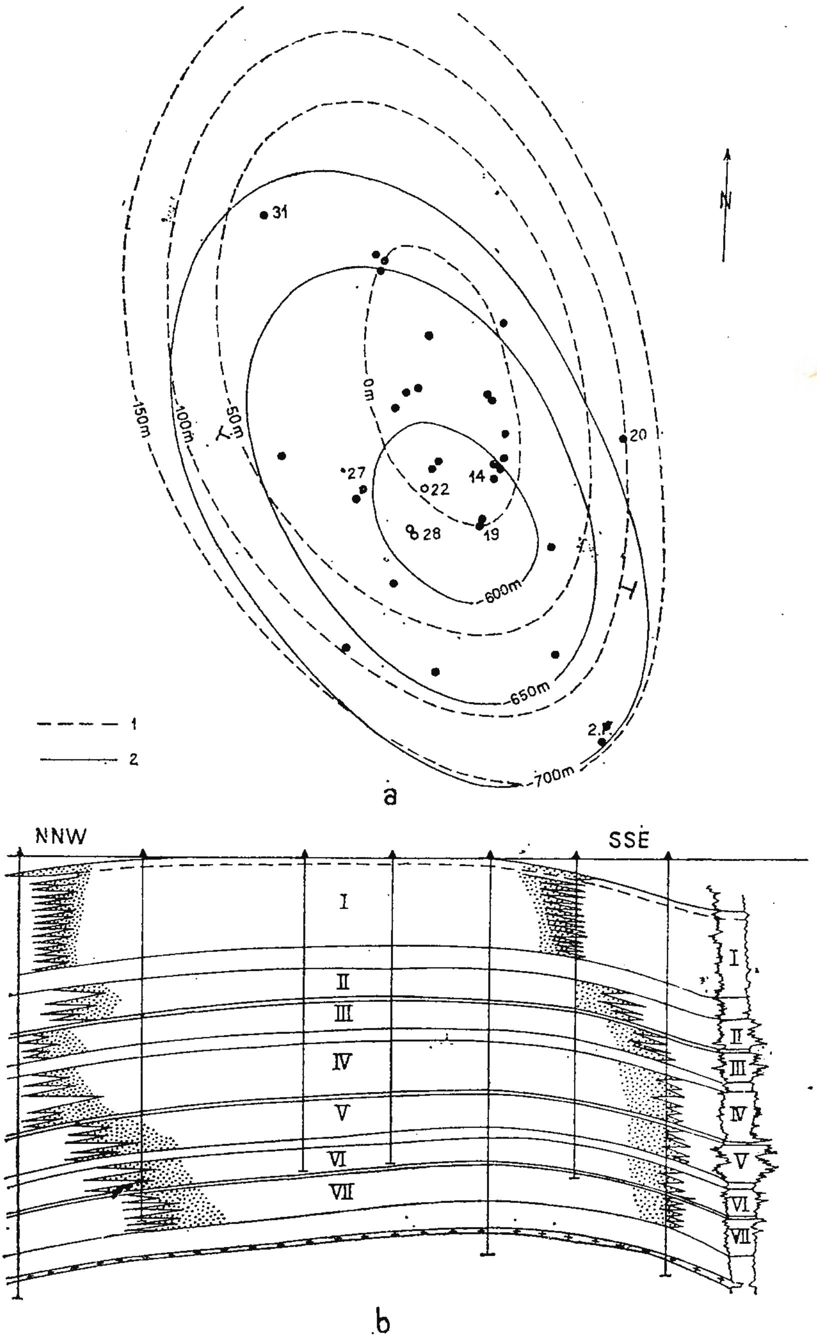

Fig. 54. — Bogata de Mureș dome.
a, structural map at the level of complex I (1) and complex VII (2) (according to P. Svoronos et al.).

The gas consists of 98.97—99.54 per cent methane, 0.55—1.03 per cent ethane. The gas density is 0.557 and the heating power 8,080—8,990. The deposit waters are of chlorocalcic type. The salt concentration is 82.9—91.5 g/l. The hydrodynamic factor is also active in the complexes II, III, IV, VIII.

The Cucerdea structure (23, Fig. 52), situated south-east of the Lechinţa-Iernut deposit, was identified by seismic works in 1966. It represents an anticline trending approximately N—S, with the NE flank probably faulted. One of the wells drilled here (well no. 2) pointed out 13,800 m³/day gas and 300 l salt water at the depth of 1,158—1,180 m and 7,000 m³/day gas at the depth of 1,130—1,092 m.

The Cetatea de Baltă dome (24, Fig. 52) lies in a zone where Pliocene and Sarmatian deposits outcop. Being morphologically expressed, the structure was identified by geological mappings in 1946 and then checked by drilling.

The Sarmatian is eroded only in the central part of the dome. The Pliocene adds on the flanks. The Ghiriş tuff, representing the Sarmatian-Buglovian limit, was found at the depth of about 720 m. Most of the wells drilled stopped in the Buglovian, considering the fact that the latter's basal part as well as the Tortonian, identified by the well no. 30, and the Saroş and Bazna wells, develop in marno-clayey facies.

The dome is elongated east-westwards. The dip of the strata is frequently 1°30—5°, seldom, 7° and even 15°.

There are seven productive complexes at Cetatea de Baltă, located in the Sarmatian (I—IV) and Buglovian (V—VII). The sand and sandstone horizons are not uniformly developed and resemble some lenticular bodies sometimes. The reservoirs are represented by sands and sandy marls. The former have porosities of 23.4—27.6 per cent, while the latter have 19.4—22.5 per cent. The permeability varies between 3.8—85.5 mD.

The gas consists of methane (98.8—99.5 per cent) and ethane (0.5—1.2 per cent). The heating power is 8,056—8,979 kcal/m³. The associated waters are of chlorocalcic type with mineralizations 30—33 g/l. The energy of the deposits consists in the elastic gas detente, while the hydrodynamic factor is also active in the case of the four lower complexes.

The Velţ structure (25, Fig. 52), situated between the Delenii and Cetatea de Baltă domes, proved productive at the Buglovian and Sarmatian levels. The first well drilled at Velţ yielded 6,000—17,000 m³/day gas at the depth of 750—950 m. The gas saturated section is supposed to be thicker.

The Tăuni dome (26, Fig. 52) was identified by geological mappings in 1940. The first well that yielded was drilled in 1949.

The Pliocene (300 m) including also the Meotian, outcrops and is 247 m in thickness (V a n c e a, 1960). The Sarmatian (about 900 m) consists only of marls and gritty marls with the exception of two sand beds. The Buglovian and the Tortonian consist of compact marls. The salt formation is 222 m in thickness here.

The Tăuni dome is oval, elongated WNW—ESE. The dip of the strata is 0°45'—5° making the structure hardly perceptible at the surface.

Considering the strong substitution of the Sarmatian and Buglovian psamites by pelites in the western part of the Transylvanian Depression, the reservoir rocks are represented by Meotian marly sand and sandy marl horizons lying at the depth of 300—1,000 m.

c) The central group comprises 17 gas-bearing structures (27—43, Fig. 52) at present.

The Delureni structure (27, Fig. 52) is the northern prolongation of the Crăiești-Ercea anticline. The positive structural shape is to be found only at the Tortonian level, disappearing gradually in the younger deposits. Consequently, the seven productive horizons belong to the Tortonian. Commercial gas productions were obtained at the depth of 1,550—2,150 m. They varied between 13,000 and 128,000 m^3/well, while the pressure varied between 98—190/185—195 kgf/cm^2.

The Crăiești-Ercea structure (28, Fig. 52) is an anticline trending NW—SE. The dip of the strata is 4—12°. This anticline was identified by seismic prospections in 1965.

The wells drilled on the structure indicated that the gas formation consists of a sequence of marls and sands grouped into several complexes of which 12 are productive: one (I) in the Sarmatian, three (II—IV) in the Buglovian and eight (V—XII) in the Tortonian. Each of these complexes has an effective saturated thickness between 17 and 62 m, the average porosity 14—18 per cent, the connate water saturation 35—40 per cent, the reservoir pressure 51—217 kgf/cm^2.

The research is finished and the structure is put into operation.

The Bozed gas-field (29, Fig. 52) corresponds to two culminations identified also by seismic prospections.

The Buglovian and the Tortonian have two (I, II) and eight (III—X), respectively gas complexes and intermediary horizons. Some of them are not developed throughout the structure owing to the lithologic variation they undergo. As a result, the traps at Bozed are of structural and lithological type. The effectively saturated thickness of each of the 12 gas units is 4.47—42 m, the average porosity 17 per cent, the water saturation 35 per cent and the reservoir pressure 124—260 kgf/cm^2. The geological research is finished and the structure is being exploited.

The Păingeni dome (30, Fig. 52) corresponds, on the surface where the Pliocene and the Upper Sarmatian outcrop, to a syncline which is perpendicular to the depth structure. This syncline gradually migrates south-eatwards in the case of the older Volhynian, Buglovian and Tortonian formations forming a structural saddle which separates the Păingeni and Dumbrăvioara domes. At a certain depth the Păingeni area represents a gas dome which is elongated NW—SE.

The gas formation was crossed up to the depth of 2,666 m and contains numerous horizons with reservoir properties separated by pelite intercalations. The wells drilled identified five productive horizons of which one (I) belongs to the Sarmatian, three (II—IV) to the Buglovian and the last one (V) to the Tortonian. A sand lens appears between the horizons II and III, in addition. The gas contains 99.45—99.88 per cent methane, 0.10—0,20 per cent ethane and 0.12 propane (only in the horizon III).

The Dumbrăvioara structure (31, Fig. 52), situated NE of Tg. Mureş, is crossed by the Mureş River. Sarmatian deposits outcrop. It was identified by seismic works.

Several wells were drilled on the Dumbrăvioara structure; the first and deepest of them reached 2,501 m, crossing the following stratigraphic succession: Quaternary + Sarmatian = 412 m, Buglovian = 840 m and Tortonian = 1,250 m. Taking into consideration the neighbouring structures, the Tortonian salt formation might be found at the depth of about 2,550 m. The Tortonian, partially crossed, consists of compact marls alternating with partly compact and weakly fissured sandstones or permeable sandstones. Within the Tortonian four gas complexes were delimited, numbered (from bottom to top) X—VII. Some of the sandstones of the respective complexes change into sands, others change into sandy marls. The Buglovian is represented by marly sands alternating with sandstones, sands and tuffs. Three complexes with lenticular development, numbered VI—IV may be also distinguished here. The Sarmatian consists of sands, sandy marls, marls and thin tuffs. The reservoir rocks were grouped into three gas complexes: III—I. The Quaternary consists of sands, sandstones and clays, seldom, of gravels.

From a tectonic point of view the Dumbrăvioara structure is a brachyanticline trending NW—SE, with dips of 3 —5°, seldom 10°. The Sarmatian deposits are eroded on a section of about 250 m in the axial zone. As in the case of the previous structural elements the dome apex undergoes shifts at a certain depth owing to the disharmonies.

The productive complexes generally show a sandy-marly character. Their main average physical parameters are: effective porosity 16—20 per cent, absolute permeability 20—50 mD, connate water saturation 35—45 per cent.

The gas analysis identified about 99 per cent methane and very small amounts of ethane and propane.

The Ernei structure (32, Fig. 52), lying south of Dumbrăvioara, shows a similar geological state, but better accumulation conditions reflected in the larger number of productive units, namely 16, of which five (I—V) in the Sarmatian, five (V—VI; VI—IX) in the Buglovian and six (IX—X, X—XIV) in the Tortonian. The structure is being exploited.

The Tîrgu Mureş dome (33, Fig. 52) was determined by seismic prospections (Fig. 55). About a third of its area corresponds to the Mureş town subsurface.

The wells drilled so far crossed the gas formation which consists of 14 productive complexes: six in the Sarmatian, four in the Buglovian and four in the Tortonian. Some of the contradictory results obtained at the production tests might be due to the strata being blocked by drilling mud and, probably, to the lithological and permeability variations.

The Acăţari structure (34, Fig. 52) lies south of the Tg. Mureş dome and might be a prolongation of the latter. The production tests operated at a few wells drilled at Acăţari indicated the gas presence in the Tortonian (four complexes) and in the Buglovian (one complex).

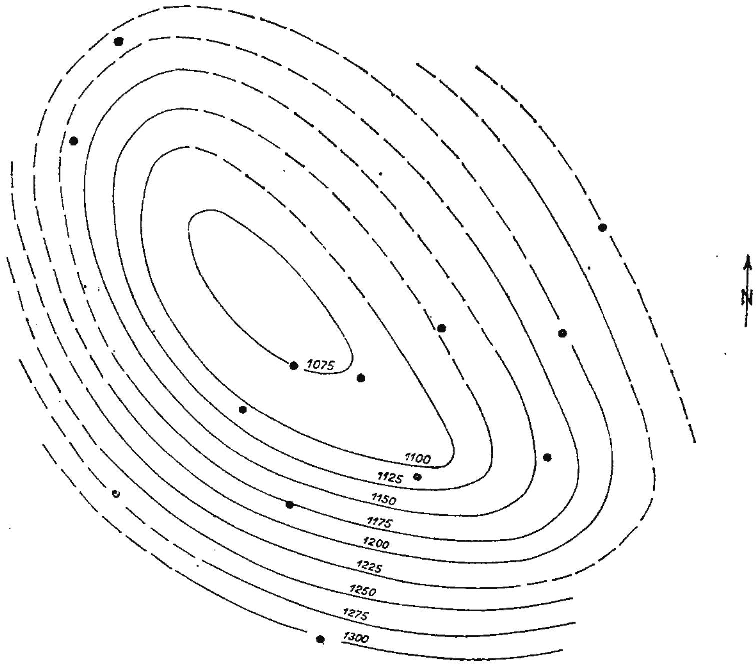

Fig. 55. — Tg.Mureş dome. Structural image at the level of complex VI in the Sarmatian base (according to M. Bîrlogeanu).

The Corunca structure (35, Fig. 52) is partially covered by Pliocene deposits, the Sarmatian (?) being present only in its apex. This structure consisting of two culminations was identified by seismic prospections. The geological and deposit conditions are similar to those on the Dumbrăvioara structure. 14 productive complexes are known at Corunca : four (I—IV) in the Sarmatian, five (V—IX) in the Buglovian and five (X—XII) in the Tortonian.

The Săuşa brachyanticline (36, Fig. 52) was identified by seismic prospections in 1965. The wells drilled here crossed the whole gas formation (up to the salt) within which several sand, sandstone and gritty-sandy marl horizons appear. Seven such complexes (III—IX) and three intermediary horizons (III—IV, V—VI and VIII—IX) proved gas-bearing.

The Tortonian is exclusively marly and therefore lacks hydrocarbon accumulations on a section of 700 m, above the salt formation. The productive units have the average porosity 16—21 per cent, the connate water saturation 35—40 per cent, the initial deposit pressure 68.5—189 kgf/cm² and the stratum temperature 37°—60°.

The Suveica structure (37, Fig. 52) lies north of the Filitelnic dome. The wells drilled in this zone contained gas, the output being stronger in two horizons belonging to the Buglovian and the Tortonian.

The Filitelnic structure (38, Fig. 52) lies south of Tg. Mureş, in a region with outcropping Pliocene formations. It was identified by mappings and then searched in detail by seismic prospections.

Numerous exploration and exploitation wells were drilled at Filitelnic, the deepest of them reaching 4,533 m. The stratigraphic succession is the following: Senonian about 700 m, Eocene about 30 m, Tortonian 1,350 m, Pliocene 550 m. The Tortonian, Buglovian and Sarmatian consist of a sequence of marno-clays and sands grouped into 23 complexes.

The Filitelnic structure represents a brachyanticline trending ENE—WSW, with two culminations (Fig. 56), at the Sarmatian level. Owing to the disharmony of the strata, three structural culminations outline in the Buglovian and Tortonian; one of them corresponds to the Laslău dome. The general trending of the structure remains the same, namely E—W. The dip of the strata is very low, namely 1—4° in the Pliocene and 2—6° in the Miocene.

The productive tests identified and outlined 23 productive complexes and intermediary horizons located as follows: Sarmatian (12 complexes) A, B, B—I, I, II, III, III—IV, V, V—VI, VI, VII; Buglovian (five complexes) VIII, IX, X, XI, XII; Tortonian (six complexes) XIII, XIII–XIV, XIV, XV, XVI and XVII. The depth of these production strata is 600—3,200 m.

The Laslău dome (39, Fig. 52) is outlined as a positive structure only below the Sarmatian level (Fig. 56), where it appears as a component (culmination) of the Filitelnic major anticline.

The production tests indicated the gas presence in the horizons VIIIb, IXa, X, XIa, XIb, XIIa, XIIb, XIIIa, XIIIb, XIV, XV and XVI. The average depth of these units is between 2,022 m and 3,119 m. Each complex varies between 20 and 75 m in thickness. The reservoir pressure is 228—334 kgf/cm², therefore somewhat higher than the hydrostatic pressure. The temperature recorded indicates 53—78°C, being equivalent to the geothermal step of 40 m/°C. The gas contains 99.22—99.54 per cent methane, 0.09—0.12 per cent ethane and 0.01—0.04 per cent propane. The deposit waters are of chlorocalcic type.

The Delenii (Saroş) *dome* is situated about 12 km north of Mediaş (40, Fig. 52) in a region where the Sarmatian outcroppings are covered by the Pliocene on the flanks. This structure, identified by surface prospections since 1924, constitutes one of the old gas-bearing fields of the Transylvanian Depression (Fig. 57).

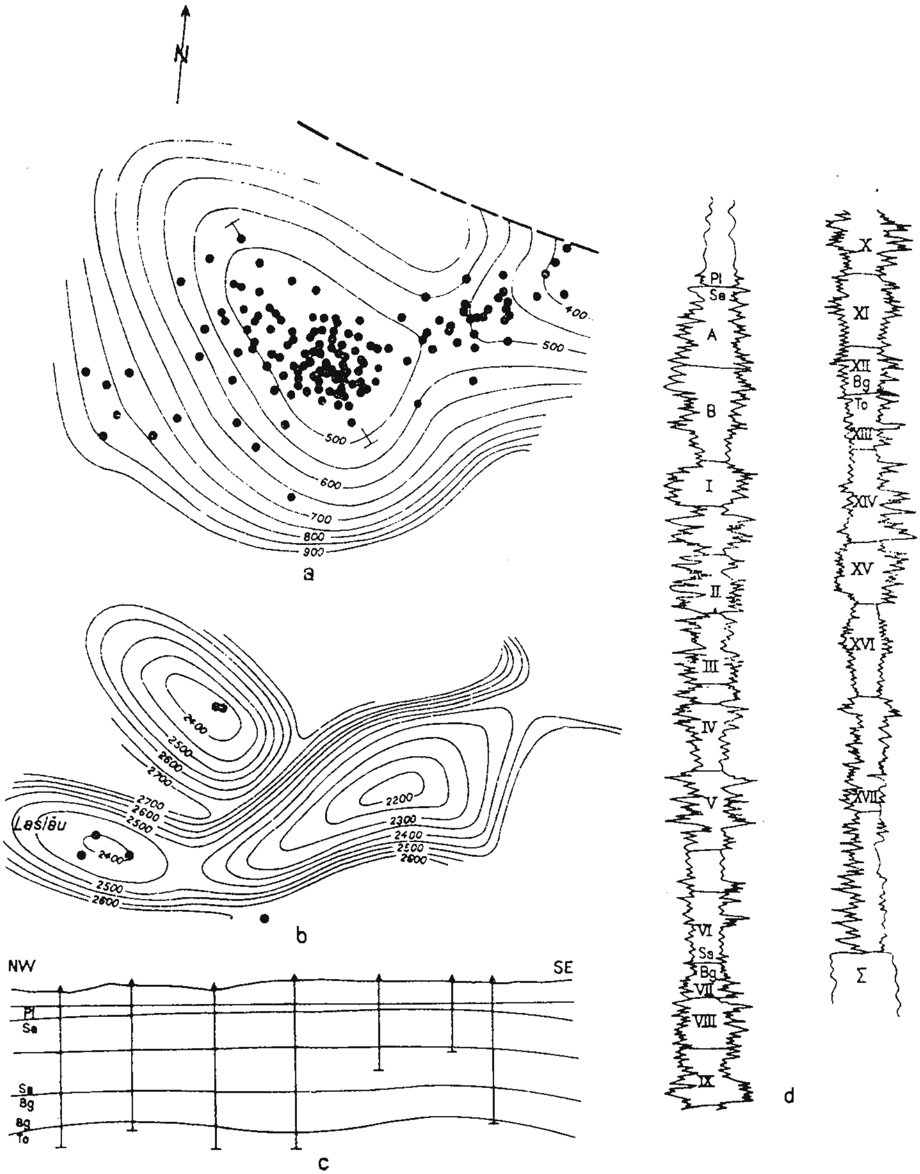

Fig. 56. — Filitelnic structure.
a, structural image at a guide mark of the Sarmatian base ; b, structural image at a Tortonian guide mark ; c, geological section in the structure central zone ; d, Sarmatian, Buglovian and Tortonian type profile (according to M. Bîrlogeanu).

The stratigraphic profile of the structure does not differ considerably from the sequence found at Filitelnic. The Sarmatian is about 750 m in thickness, the Buglovian about 750 m and the Tortonian over 550 m. Unlike the eastern domes (Filitelnic, Corunca etc.), the Tortonian shows an almost exclusively marly facies. The Buglovian base presents the same characteristic. Only on the eastern flank of the structure (at Hărănglab) a few marly sand sequences develop in the lower part of the Buglovian and in the upper part of the Tortonian (the gas-bearing complexes X, XI and XII), constituting classic lithological traps, explored and revaluated.

The structure is eliptical, elongated E—W. The dip of the strata, determined by drills, is 2—4°.

The Delenii dome comprises 13 productive complexes: the first six (I—VI) belong to the Sarmatian, another six (VII—XI, plus intermediary IX—X) to the Buglovian and one complex (XII) to the Tortonian. The traps are of structural and mixed types. Most of them are controlled by the domal, unfaulted structure.

The physical properties of the reservoirs vary within very large limits. For instance, the porosity is 2.5—34.7 per cent, while the permeability is 0.8—702 mD, the frequency of the lower values increasing with depth.

The gas contains 99.25—99.5 per cent methane and the rest up to 100 per cent ethane and nitrogen. The heating power is 8,056—8,970 kcal/m^3. The deposit waters are of chlorocalcic type with mineralization of about 50 g/l. None of the 13 productive units underwent the influence of the hydrodynamic factor.

The Bazna dome (41, Fig. 52) lies about 7 km NE of Mediaş, in a region covered by Pliocene deposits, with the exception of the domal apex where the Sarmatian outcrops.

The structure was indentified by surface mappings; gas seeps appear and iodine salt waters with curative properties are known within this area.

The numerous wells drilled on this dome indicated a normal succession of strata. The Pliocene is a few metres thick in the apex zone reaching 600 m towards the synclines. In the Meotian base is found the Bazna tuff, a gray andesitic cinerite only 4—5 cm in thickness, intercalated in

Fig. 57. a,b,c — Delenii dome.

a, structural map at the level of the Hădăreni tuff (e. l. lithologic screen of the complex IX); b, geological section indicating the distribution of the gas accumulations; c, Sarmatian, Buglovian and Tortonian type profile (according to D. Rusu and V. Dumitru).

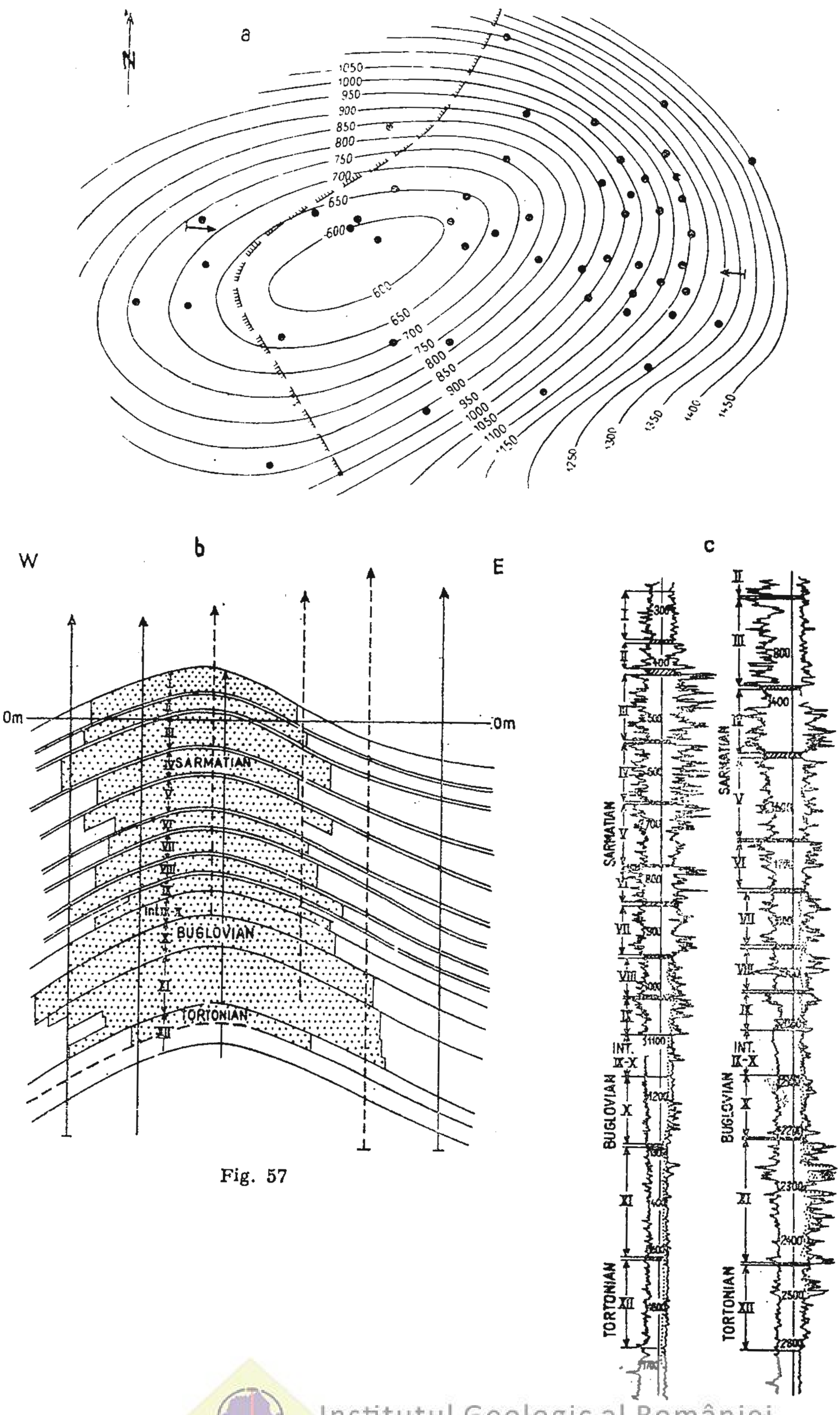
a
N
b
W
E
0m
SARMATIAN
BUGLOVIAN
TORTONIAN
c
SARMATIAN
BUGLOVIAN
TORTONIAN

Fig. 57

a packet of slaty marls with white faces. The Sarmatian is about 700 m in thickness and the Buglovian 600—650 m. Both the Buglovian base and the Tortonian show a marly-clayey facies.

The structure is oval, trending E—W (Fig. 58). The dip of the strata is 2—4° in the Sarmatian and increases in the Buglovian and Tortonian. Owing to the intraformational unconformities, the dome apex is displaced southwards at a certain depth and the shape of the structure becomes slightly asymmetrical.

Eight gas-bearing complexes are known on the Bazna dome, six in the Sarmatian (II—VII) and two (VIII + ZM) in the Buglovian. In addition there are three horizons with uncommercial productions. The traps are of structural (vaulted) type.

The reservoirs have porosities 4.7—26 per cent and permeabilities 1.3—228 mD, the values being somewhat lower in the Buglovian owing to the increasing number of pelite fractions.

The gas contains 99.16 per cent methane and 0.84 per cent ethane and has a heating power close to that indicated by the Delenii structure. The deposit water is of chlorocalcic type, the mineralization slightly exceeding 50 g/l. The syncline water is active in all the deposits with the exception of the complexes II and III.

The Nadeș dome (42, Fig. 52) is situated in the central part of the Transylvanian Depression which is covered by Pliocene deposits. The structure was identified by geological mapping. On this basis the first well proving the gas presence was drilled here in 1930—1931.

The stratigraphic succession does not differ from that frequently found in the basin. Under the Pliocene (about 600 m), which seems to include also the Meotian, the Sarmatian (about 300 m), the Buglovian (480 m) and the Tortonian were found. Unlike the Delenii and Bazna structures, the Tortonian and the Buglovian base contain sandstone and sand intercalations.

The structure represents a dome which is slightly elongated NE—SW, with the SE flank more abrupt. The dip of the strata is 3—7°. Owing to the same unconformities, the depth apex shifts about 2 km westwards as compared to the surface apex.

The gas in the Nadeș dome is accumulated in fine sands and sandy marls grouped into 22 gas-bearing complexes : 15 in the Sarmatian, 4 in the Buglovian and 3 in the Tortonian. The reservoirs have the average effective porosity of 16.8—30 per cent and the permeability of 39.2—1,256 mD, both values decreasing with depth.

The gas contains 96.5—99.6 per cent methane and 0.4—4 per cent N_2. The heating power is 8,072—8,988 kcal/m^3. The waters have a mineralization of 74.6—143 g/l and are of chlorocalcic and chloromagnesian types.

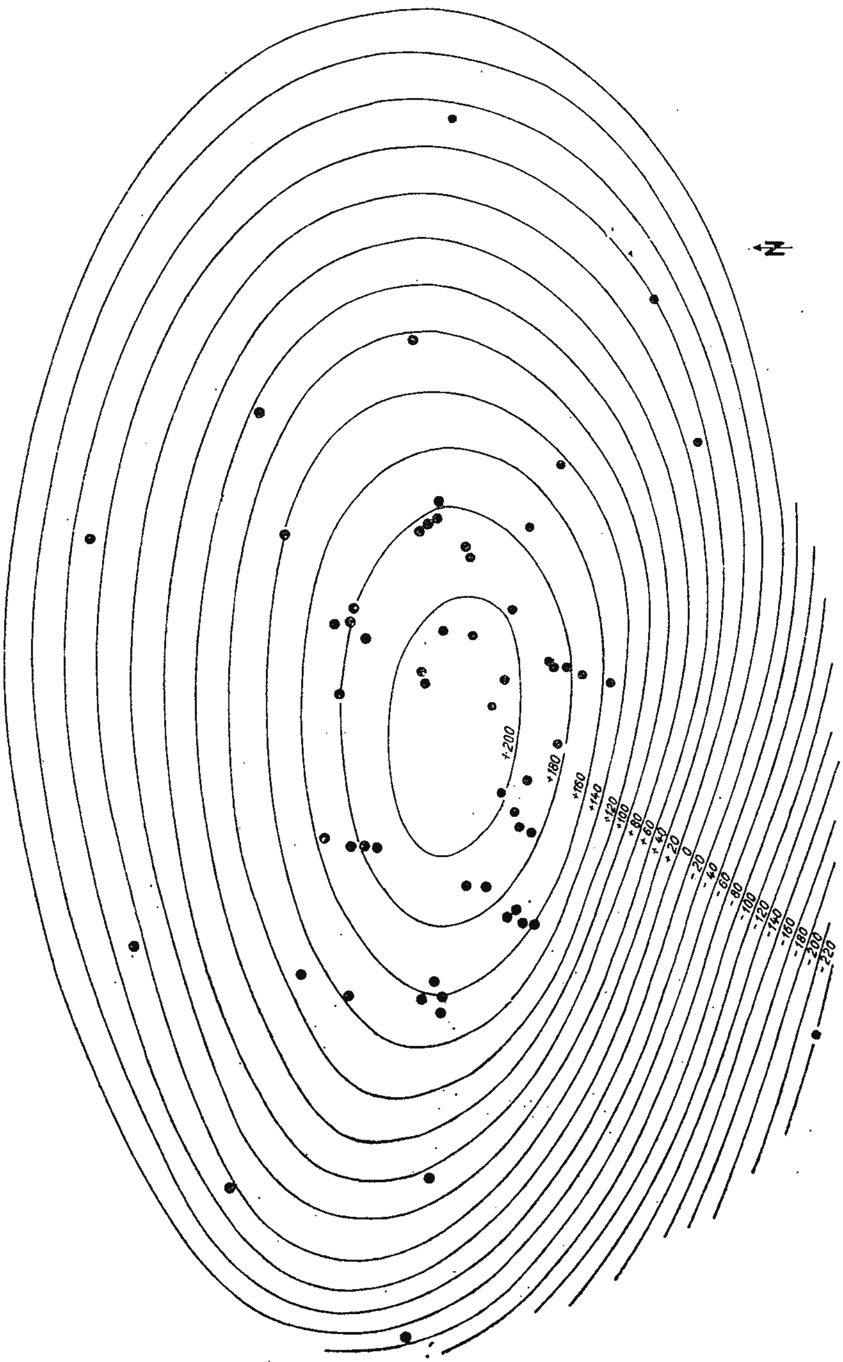

Fig. 58. — Bazna dome. Structural image at the top of the complex II in the Sarmatian (according to M. Bîrlogeanu).

The Prod-Seleuş zone (43, Fig. 52) lies in the southern prolongation of the Nadeş dome, representing, probably, the latter's continuation. Commercial gas accumulations in the Sarmatian, Buglovian and the upper part of the Tortonian were identified here.

d) The southern group consists of six gas-bearing structures (44—49, Fig. 52) without taking into account the Alămor zone with uncommercial hydrocarbon accumulations.

The Copşa Mică dome (44, Fig. 52) lies in a region where the Pliocene deposits outcrop. This structure was determined by geological mapping in 1928. Five years later the exploration well no. 5 was drilled; it free erupted at the depth of 764 m during the drilling process, then the gas took fire. The free eruption lasted intermitently up to 1944.

The following stratigraphic succession was found by the wells in the apex zone: the Pliocene, 190 m from the surface continuing with another 43 m below the Bazna tuff; the Sarmatian, about 800 m, consisting of seven sand complexes; the Buglovian, between 980—1750 m, characterized by a marly facies; the Tortonian was identified between 1,750 m and 2,320 m, including the salt formation (1,999—2,320 m); the Tortonian, in its turn, overlies the Eocene which consists of nummulite and amphistegine limestones, sand, sandstones, gray clays, red gravel, again limestones, limy breccias and reddish marls.

The structure is eliptical with the big axis trending NW—SE. The deep dome apex appears 750 m displaced as compared with the surface apex south-westwards at the level of the Bazna tuff and of the horizons V and VI. The dip of the strata is 2—3°.

The Copşa Mică dome includes nine productive complexes (I—IX) consisting of sands, marly sands and sandy marls belonging to the Sarmatian and Buglovian. As it is located in the western part of the Transylvanian Depression, the Tortonian has no reservoir rocks because the psamites that developed eastwards were replaced by marls here. At the level of the complexes II and III, where several core analyses were available, the effective porosity is 20.6—34.2 per cent and the permeability is 1.5—952 mD. The psamite CO_3Ca content varies between 5.6—29.3 per cent, the higher values being characteristic of the sandy marl horizons.

The gas contains 99.2—99.5 per cent methane and 0.5—0.8 per cent ethane. Its density is 0.556 kgf/dm^3, while the heating power is 8,090—8,990 kcal/m^3. The associated waters are of mixed type, chlorocalcic, chloromagnesian and sodium bicarbonate, respectively; the latter indicate an imperfect sealing in the case of some horizons.

The traps are structural, vaulted and unfaulted. The energy of the deposits is due to the elastic gas extension, associated with the syncline water drive. The latter is not manifested also at the level of the horizon V.

The Noul Săsesc dome (45, Fig. 52) is completely covered by Pliocene deposits whose thickness varies between 100—200 m in the central part and over 600 m on the flanks. The structure was identified by geological mapping. The first wells indicating gas were drilled in 1930—1940.

Under the Pliocene deposits that seem to include, in their base, also the Meotian which is about 100 m in thickness ((V a n c e a , 1960), the Sarmatian was also found at the depth of 250—1082 ; it consists of a succession of marls and sands with 17 thin dacitic tuff intercalations. The Buglovian (1,082—1,850 m) contains sand and sandy marl intercalations. The Tortonian was crossed within a section of about 800 m. It consists of marno-clays and of salt which was not completely crossed, in the basal part, on about 250 m.

The dome is oval at the surface trending N—S. The structure elongates E—W with depth, as the axis shifts. Thus the structure is a brachyanticline (in shape) at the Hădăreni tuff level, with the apex 2 km displaced west of the one formed by the surface formations (Fig. 59). The dip of the strata belonging to the Pliocene is about 1°, reaching 2—4°.

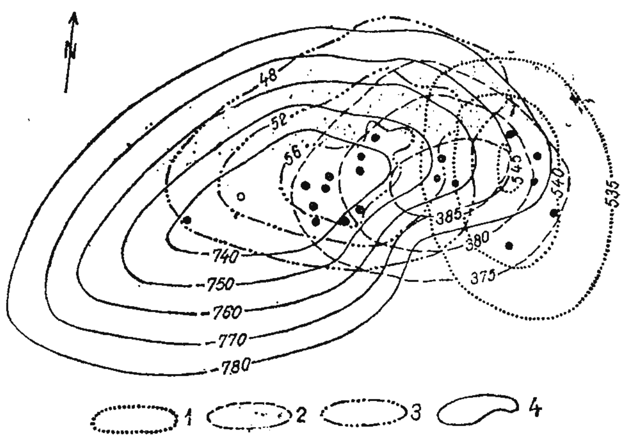

Fig. 59. — Structural image of the Noul Săsesc dome. 1, at the level of the Ighiş tuff ; 2, at the limit Pl/Sa ; 3, at the horizon I; 4, at the Hădăreni tuff (according to A. V a n c e a).

15 productive complexes (I—XV) were identified on the Noul Săsesc structure ; eight (I—VIII) belong to the Sarmatian and seven (IX—XV) to the Buglovian. The porosity of the reservoirs is between 6.5 per cent (in sandstones) and 35.8 per cent, while the permeability is between 1.6 and 969 mD.

The gas consists of 97.8—99.5 per cent methane and 0.5—2 per cent ethane. A small amount of condens also accumulates at the leakage of the separators ; it comes from the last (lower) two productive strata. The gas specific gravity is 0.556 kgf/dm^3. The lower heating power varies between 8,023—8,979 kcal/m^3. The mineralization of the associated waters increases with depth.

The Petiş structure (46, Fig. 52) is domal in shape and lies southwest of the Copşa Mică gas field. The first well drilled here contained gas from the Sarmatian and Buglovian, with maximum productions of 174,000 m³ and the pressure 75/82 kgf/cm² (in the Sarmatian).

The Bîrghiş anticline (47, Fig. 52) trending E—W and determined by seismic prospections, proved productive at the Sarmatian level where a production of 25,000 m³/day gas was recorded.

The Ruşi structure (48, Fig. 52) represents a faulted axial anticline trending NW—SE. The dip of the strata is 10—40°. The gas-bearing formation on this structure shows several sand and sandstone horizons that are flooded. As the structure is complicated and the reservoirs have a strongly pelite character, the gas production is poor, lending a very small importance to this accumulation.

One of the four wells drilled (well no. 2) produced gas with salt water at the depth of 598—610 m, west of the Ruşi structure at *Alămor.*

The respective stratum belongs to the Sarmatian-Buglovian and is represented by sandy marls that change, laterally, into marls.

The Ilimbav structure (49, Fig. 52) is the southernmost gas field in the Transylvanian Depression. The Upper Sarmatian deposits are crossed in its axis. The flanks are covered by Pliocene deposits that may reach 500 m in thickness. The structure was identified by geological mapping and was put into operation 16 years later.

The Sarmatian is about 450 m in thickness and includes three complexes (I—III) of gray-whitish sands with marl intercalations.The Buglovian is marked by sands of maximum 3 m in thickness at the upper part.These sands were grouped into two complexes (IV and V). The lower part of the Buglovian is exclusively marly. The Tortonian consists of marls with sand and salt intercalations. From the Tortonian at the depth of 996 m, one of the wells penetrated the crystalline basement which consists of chlorite-sericitic schists.

The structure represents a weak asymmetrical fold (Fig. 60) trending N-S.

Of the eight sand complexes the first four, belonging to the Sarmatian (I—III) and Buglovian (IV), proved gas-bearing. The productive complexes reach 230 m in thickness. The porosity of the lower horizons varies between 28—32 per cent, the connate water saturation is 22 per cent. The free potential productions were 1 :500,000 m³/day at the horizons I + II, 935,000 m³/day at the horizon III and 600, 000 m³ /day at the horizon IV. The pressure recorded initially was 25.2 (the horizons I+II)—44 kgf/cm² (the horizon IV). The reservoir temperature is between 19° and 24°C.

Since 1961 the Ilimbav structure has functioned as a natural underground reservoir, storing gas in the warm months and removing it during wintertime.

e) The eastern group consists of 25 gas-bearing structures (50—74, Fig. 52).

The Daia-Ţelina structure (50, Fig. 52) was identified by geological exploration works between 1929—1931. But the depth anticlinal axis does not seem to coresspond to the surface one, so that the structural conditions of the members of interest are not yet clear enough.

Several wells, of which one reached the salt formation, were drilled at Daia-Țelina and in the surrounting area. The production tests indicated the gas presence and commercial amounts in several horizons belonging to the Sarmatian, Buglovian and Tortonian.

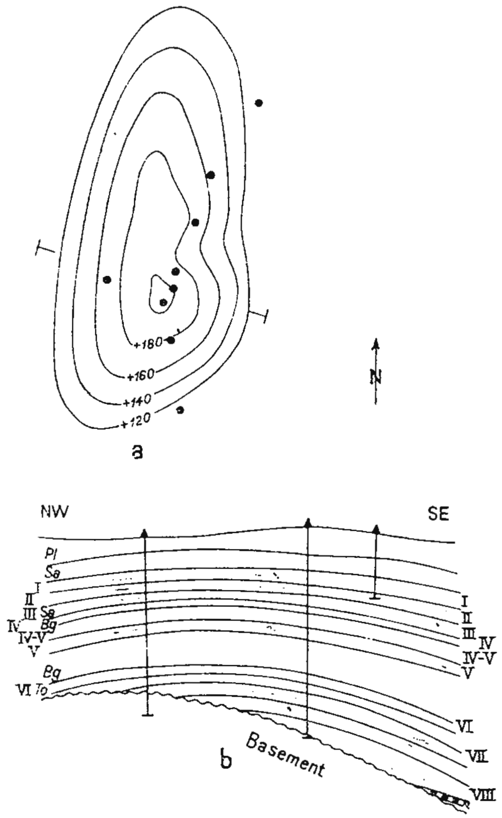

Fig. 60. — Ilimbav structure.
a, structural image at the Buglovian level; b, geological cross section (according to M. Bîrlogeanu).

The Netuș structure (51, Fig. 52) is to be found at the Tortonian and Volhynian levels. Some strata situated near the Tortonian-Buglovian limit, at the depth of 1,080—1,100 m produced 35,000 m³/day gas on a nozzle of 6 mm, the pressure being 105/108 kgf/cm².

The Retiș structure (52, Fig. 52) represents an apophysis of the Daia-Țelina anticline. The Retiș tectonic element constitutes a "hidden" structure existing only at the Tortonian level. Several horizons (about six) situated at the depth of 910—1,765 m produced gas. Of course the respective horizons are of Tortonian age. The production was 21,000—90,000 m³ and the pressure 89—157/95—157 kgf/cm².

The Bărcut structure (53, Fig. 52) is also a prolongation of the Daia-Țelina alignment. Gas was obtained at the depth of 1,580—1,680 m (Tortonian). The production varied between 60,000 and 121,000 m^3/day gas, the pressure was 50/80 kgf/cm^2, the nozzle 5–6 mm.

The Buneşti-Criţ structure (54, Fig. 52) is situated on the SE side of the basin where the Sarmatian deposits outcrop. The structure was investigated by geological mapping, carried out in several stages, core drills, electrometric and seismic prospections.

The upper part of the Sarmatian (Bessarabian), which outcrops, consists of marls, sands and conglomerates with dacitic tuff intercalations. The Volhynian and the Buglovian contain several sand and sandstone complexes separated by marl intercalations. The upper sands contain sweet waters, which means that they are not protected and, therefore, come into contact with the vadose waters. But the lower sands contain salt water with mineralization 84 – 108.8 g/l. The Tortonian, which was crossed up to the salt formation (2,420 m), consists of a succession of marno-clays and sands.

The Buneşti dome is oval at the surface with the longitudinal axis trending NW–SE. The southern flank and therefore the closing of the structure in this sector is less obvious. The dip of the strata is quite variable. It is 4–17° at the surface and 15–32° in the wells, sometimes, associated with friction mirrors. The depth structural image is not yet clear enough. The mentioned elements as well as the marginal position of the structure within the depression suggest the existence of some faults crossing the Upper Tortonian deposits and, perhaps, a stronger plicative tectonics.

Five wells were drilled at Buneşti-Criţ between 1934–1937. A first well pointed out gas eruption and salt water from the Upper Tortonian and hydrocarbon traces in the Sarmatian at the depth of 270–298 m. In 1972 well no. 5 was drilled; it produced 57,200 m^3/day wet gas with 140 kgf/cm^2 pressure from the Upper Tortonian (1,484–1,492 m).

The Beia brachyanticline (55.Fig. 52) trending NE–SW, seems to be crossed by a fault in the north pericline zone.

The wells drilled so far crossed the whole gas formation which is of Buglovian and Tortonian age here. A sequence of marls and sandy marls, sands and sandstones develops above the salt formation at the depth of 1,537 m (well no. 1)–1,600 m (well no. 2). Among the strata with reservoir properties belonging to the Tortonian, seven horizons contained gas with production of 65,000–1,000,000 m^3/day.

The Cristur structure (56, Fig. 52) was investigated, first, by geological mapping, considering the fact that the Sarmatian outcrops, then, by core drills and seismic works. The geological mapping suggests the existence of a brachyanticline elongated NW–SE. At a certain depth the seismics showed that the structure shifts about 1.5 km westwards and the "brachyanticline" consists of two domelike culminations: the northern culmination was called Cristur-Filiaşi, the southern one, Feleag. The dip of the strata varies between 5° and 25°. This fact indicates not only a more complicated tectonics, as the diapirs are nearer, but also a crossed sedimentation of certain stratigraphic members.

The Sarmatian is only 250 m in thickness, the rest of 500 m being eroded. It contains, together with the Buglovian (950 m) and the Tortonian (crossed up to the salt formation), several sandy, partly, gritty and siltstone complexes separated by clays and marls. The drilling and production tests identified 10 gas-bearing complexes, nine of which (I—VIII + the intermediary horizon II—III) are located in the Tortonian and one in the Buglovian. The salt waters on this structure are used as balnear therapy at the Cristuru Secuiesc bathing place.

The Eliseni dome (57, Fig. 52), probably consisting of two culminations, is slightly elongated E—W. The structure was identified by seismic prospections.

Several wells were drilled at Eliseni reaching various depths. One of them (well no. 1) crossed the whole Tortonian and also the salt formation. Out of the numerous sand, sandstone and sandy marl horizons, 7 complexes showed commercial gas productions at the flow tests. One complex (I) is situated in the Sarmatian, four complexes (II, II—III, III and IV) in the Buglovian and the other two (V and VI) in the Tortonian. Uncommercial gas productions were pointed out in the intermediary horizon I—II. This structure is characterized by very strong lithological variations affecting the horizons with reservoir properties. Consequently, some of the productive terms show various porosity, permeability, production and even fluid contents. Taking into account the above situation, one can speak of mixed traps formed under the influence of the structural and lithological factors.

The Chedia dome (58, Fig. 52) is a small structure identified by geological mapping and checked by seismic prospections. The Pliocene outcrops at the surface showing a more marly facies than that known in the respective area.

The wells drilled on this structure crossed the Sarmatian (about 800 m), the Buglovian (360 m) and the Tortonian (up to the salt formation — well no. 5). The Chedia vaulting is slightly elongated E—W. The dip of the strata is 3—9°. Several gas horizons are known on this structure; one of them belongs to the Sarmatian, four to the Buglovian-Tortonian.

The Şoimuş anticline (59, Fig. 52) was determined by mapping in 1955. Apart from the apex zone, where the Upper Sarmatian outcrops, the Pliocene deposits outcrop, too.

The wells drilled here indicated the gas presence in 12 sand and sandstone complexes. One complex (A) lies in the Sarmatian, two complexes (I + the interval I—II) in the Buglovian and nine (II—X) in the Tortonian. Each productive stratum varies between 13—15 per cent, the connate water saturation between 35 — 40 per cent, the pressure 145 — 254 kgf/cm^2, the temperature 50—82°C.

The Sîngeorgiu de Pădure dome (60, Fig. 52) is covered by Pliocene deposits. It was identified by geological mapping and then studied in detail by seismic prospections at a certain depth.

The Sarmatian was found under the Pliocene, which is, generally, sandy and consists of psamites with coarse grain. The Buglovian and the Tortonian undelying the Sarmatian consist of marls alternating with thick sand, partially cemented and even conglomerate complexes reaching about 350 m in thickness (in the Tortonian); this indicates that the source of detrital material is near.

The Sîngeorgiu de Pădure dome is oval , trending NE-SE. Owing to the same intraformational unconformities the structure axis migrates at a certain depth. The dip of the strata is 1—5°.

15 sand complexes were separated within the whole Mio-Pliocene series, nine of them being productive : four (I-IV) in the Lower Pliocene and five (V-IX) in the Sarmatian. Within the horizon I the porosity varies between 7.94—28.8 per cent, while the permeability varies between 31.5—777.8 mD. The CO_3Ca content of sands and marly sands in the complex I is 7.9—12.2 per cent.

The gas consisting of methane (99.2 per cent) and nitrogen (0.8 per cent) has the specific gravity 0.557 kgf/dm^3 and the heating power 8,039—8,951 kcal/m^3. The waters are of chlorocalcic type with concentration 61.6—92.5 g/l. Salt waters having high temperatures (V a n c e a , 1960) were obtained from the Tortonian conglomerates.

The Gălăţeni anticline (61, Fig. 52) is situated in a region where the Pliocene deposits outcrop. This structure could be identified by seismic prospections. The anticline trends NW—SE, just like the Sîngeorgiu de Pădure gas field. The structure is not conformable vertically owing to at least three unconformity levels corresponding to the limits between the Pliocene and the Sarmatian, the Volhynian and the Buglovian, the Buglovian and the Tortonian, respectively.

The production tests at Gălăţeni indicated the gas presence in the Tortonian and Buglovian, unlike the neighbouring anticline Sîngeorgiu de Pădure which has a more lowered structural position and where the hydrocarbons are located only in the Sarmatian. The best results were obtained at the well no. 12, namely three gas horizons in the Tortonian and another three in the Buglovian.

The Ghineşti-Trei Sate structure (62, Fig. 52) lies east of the Sîngeorgiu de Pădure anticline, in the same region covered by Pliocene deposits. The structure was pointed out by mappings first and then checked by seismic prospections. Owing to the difficult access, the geophysical prospecting of the structure could not be achieved under the best conditions. According to the seismic and drilling data available, it seems that there is no structural concordance vertically owing to the same unconformities verified on other anticlines of the eastern group. If the structure trends NW-SE at the Sarmatian level, at a Tortonian key mark, the Ghineşti-Trei Sate anticline seems to trend N—S, constituting a prolongation of the Măgherani structural element.

The stratigraphic succession is similar to that at Sîngeorgiu de Pădure. But from a lithological point of view, a stronger variation is observed, which makes difficult the correlation of the well profiles in this sector.

Several exploration wells, indicating the gas presence in the Tortonian, Buglovian and Sarmatian, were drilled at Ghineşti-Trei Sate.

Small productions were, generally, obtained from the Tortonian, below 10,000 m^3/day, as a rule, and, only exceptionally, 74,000 m^3/day. The-Buglovian and the Sarmatian behaved better, their daily productions reaching 175,000 m^3/day well. The exploration works will continue in this region.

The Miercurea Nirajului dome (63, Fig. 52) was identified by mapping. After the drilling of several exploration wells and the discovery of gas on the structure, arose the necessity of completing the prospection works by seismic surveys (Fig. 50).

The wells drilled at Miercurea Nirajului crossed a section which is 2,501 m in thickness resembling the Sîngeorgiu de Pădure profile from the lithostratigraphic viewpoint. Six sandy complexes were identified in the region crossed by drillings ; only the first three, lying in the Sarmatian, proved productive. A fourth one belonging to the Buglovian behaves very badly. These strata also produce with salt water. The gas consists of methane (99.4 per cent) and ethane (0.6 per cent). The waters have NaCl concentration 77.16 g/l and are of chlorocalcic type.

The Măgherani structure (64, Fig. 52) is a dome trending N—S and comprising two culminations. The Pliocene outcrops (at the surface) and the wells drilled here crossed the Sarmatian, Buglovian and Tortonian to the depth of 2,703 m (well no. 5). The Sarmatian and Buglovian reservoirs are water saturated, while the Tortonian (well no. 5) contained gas from two horizons situated at the depth of 2,317—2,478 m.

The Dămieni structure (65, Fig. 52), which is not yet clearly outlined, was identified by seismic prospections. Its relations to the Teleac and Chiheru northern domes have not been specified so far. As in the neighbouring sectors, a tectonic concordance does not seem to exist at a certain depth here too. More than that, the situation at Dămieni seems to be complicated by a fault. Some of the wells drilled at Dămieni to the depth of 3,200 m (Tortonian) identified gas in the Sarmatian (1,284—1,312 m), Buglovian (1,640—1,650 m) and Tortonian (220—2,600 m).

The Teleac structure (66, Fig. 52) lies in a region where the Sarmatian outcrops being periclinally overlain by the Pliocene. This structure was identified by mapping and detailed by seismic profiles.

The Sarmatian is about 1,200 m in thickness. It consists of marls in the upper part, to the depth of 300 m and of sands with very few protective marl intercalations. The Buglovian (about 600 m in thickness) is predominantly sandy. The Tortonian consists of pelites on the first 450 m, while psamite horizons appear in the base.

The Teleac structure is a dome elongated NW—SE. The dip of the surface strata is 3—9°.

Between 1940—1944 two wells were drilled, of which one (well no. 2) had poor gas productions at the depth of 97—148 m. The other one, although reaching 780 m in depth and achieving 17 flow tests, had no positive economic results. The works have been resumed on the structure in recent years. Thus, commercial gas productions were obtained at two Buglovian horizons (well no. 5).

The Voivodeni structure (67, Fig. 52) lies about 6 km south—west of Reghin town. It was identified by seismic prospections carried out between 1968—1969. It is a dome elongated NW—SE. The northern sector of the dome has not a clear tectonic image. Three wells drilled here (1, 2 and 11) contained gas from the Sarmatian and Tortonian. The Buglovian reservoirs are water saturated.

The Lunca brachyanticline (68, Fig. 52) was discovered and then studied in detail by seismic prospections. According to some recent interpretation attemps liable to modifications, the brachyanticline is symmetrical and trends WNW—ESE (Fig. 61). The wells drilled at Lunca crossed

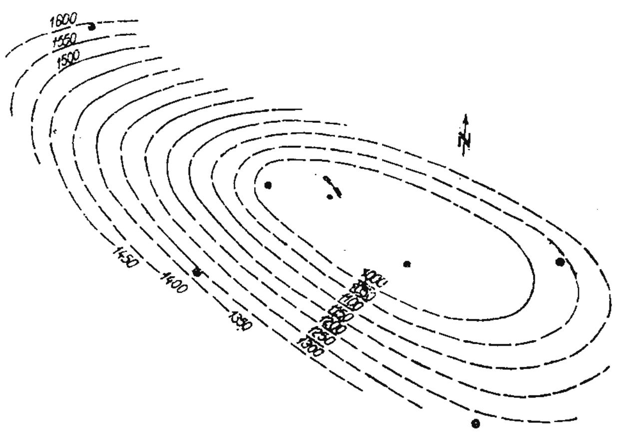

Fig. 61. — Structural map of the Lunca dome at a Tortonian guide mark (according to M. Bîrlogeanu).

the gas sequence reaching the salt formation. One of them (well no. 6) contained gas from three Tortonian horizons situated at the depth of 894—1048 m. The productions obtained are 10860-61640 m^3/day. The gas contains 98.9-99.02 per cent methane.

The Tărcești structure (69, Fig. 52), determined by geological mapping and seismic prospections, might belong, together with the Benţid dome, to the same major anticline trending E—W. According to this tectonic conception, a separating fault seems to exist between the two component culminations. Three of the wells drilled at Tărceşti contained mixed gas in the Tortonian and Buglovian. Modifications of the relation between CO_2 and hydrocarbons, which are similar to those at Benţid, are found in the first well (no. 1) at the depth of 296—1,268 m. For instance, the CO_2 content was 85.2 per cent on the basal interval (1,200—1,368) decreasing constantly to 1.1 per cent on the upper interval (296—344 m). An increase of the methane and nitrogen percentage corresponds to this. The other components, such as the ethane and the propane maintain their percentage. The great lithofacial variations taking place here influence the physical parameters of the reservoirs, the behaviour of the operating wells and even the structural images at various stratigraphic levels.

The Benţid structure (70, Fig. 52) lies west of the diapir fold alignment in a region covered by Pliocene deposits, some of which are andesite agglomerates and lava flows. The respective structural element was identified by seismic prospections in 1962.

The Pliocene is represented by an alternation of marls, sands and conglomerates, sandstones, sands and marls. The Tortonian contains a marl complex in the upper part, overlying the salt formation; the tuff horizon follows and, finally, the basal conglomerates. On this structure the Tortonian overlies directly the metamorphosed basement consisting of sericite-chlorite schists, black graphite shales and quartzites.

The Benţid structure represents a brachyanticline (Fig. 62) outlined against a monocline background, in fact the eastern side of the Transylvanian Depression.

The wells drilled at Benţid identified mixed gas in the crystalline, Tortonian and Buglovian. A production of 216,000 m^3/day was recorded in the upper altered part of the crystalline schist basement.

The apparent thickness of each complex with reservoir properties varies between 16 m and 45. 5 m. The porosity of the altered crystalline is about lo per cent and that of the sedimentary reservoirs is 11 per cent. The connate water saturation does not exceed 20 per cent in the crystalline and about 50 per cent in the sedimentary.

The free gas obtained from the altered crust of the basement contains 89.3 per cent CO_2, 6.3 per cent CH_4 and 4.4 per cent N. The Tortonian productive complexes contain 77.6—57.6 per cent CO_2, 42.6—11 per cent CH_4 and 4—4.4 per cent N_2. In general the carbon dioxide volume increases with depth. The great CO_2 volume indicates that the structure lies in the moffete aureola zone outlining along the diapir folds. The average pressure of the gas accumulations is about 190 kgf/cm^2 and the reservoir temperature is about 75°C.

The Firtuşu anticline (71, Fig. 52) represents a structural detail on the northern flank of the Benţid structure. Two wells drilled here crossed the Pliocene, the Sarmatian, the Buglovian and, partly, the Tortonian (on a section of 756 m in thickness). The Tortonian sand intercalations (on six intervals) and the Buglovian sand intercalations (one interval) are gas saturated, consisting of 68.7—98.9 per cent CO_2, 0.8—14.2 per cent CH_4 and other components. Unlike on the Benţid structure, the CO_2 content decreases with depth, from 98.9 per cent in the Buglovian (1,246—1,342 m) to 68.7—70 per cent in the Tortonian (1,918—2,002 m). The Sarmatian, which is very sandy, contains salt waters, while the Pliocene contains sweet waters. The exploration of the anticline, whose axis shifts eastwards at a certain depth, continues.

The Cuşmed anticline (72, Fig. 52) trending NW—SE, was determined by seismic prospections. A first well drilled here crossed the Sarmatian, the Buglovian and, partly, the Tortonian (on a section 1,100 m thick). During the flow tests mixed gas, methane, nitrogen (23.3—31.8 per cent) and carbon dioxide (27.8 per cent) were obtained from the upper part of the Buglovian and Sarmatian; the carbon dioxide was only found in the Buglovian base.

The Brădeşti structure (73, Fig. 52) is situated SE of Benţid and about 7 km NE of Odorhei; it was identified by seismic surveys and core drills. It represents a narrow anticline with assymmetric flanks, trending NW-SE. One of the wells drilled here pointed out commercial gas production (21,200—60,800 m³/day) from the lower part of the Buglovian (1,170—1,290 m). The gas consists of 99 per cent methane, CO_2 lacking, although

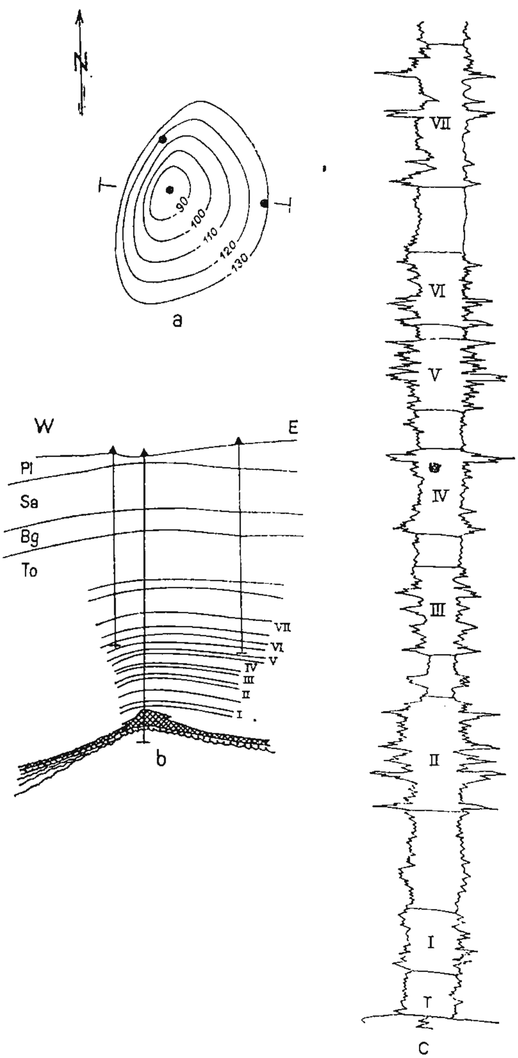

Fig. 62. — Benţid structure. a, structural image at the Burdigalian/Tortonian boundary; b, geological section through the central zone of the structure; c, Buglovian and Tortonian type profiles (according to IFLGS).

the structure lies east of the diapir fold alignment, much nearer to the Neogene magmatism, as compared to the other anticline presented above.

The Ibănești zone (74, Fig. 52) is crossed by the Gurghiu River and belongs to the synclinorium developing east of the diapir fold alignment up to the East Carpathian border. A well (no. 4911) was drilled under axial structural conditions to the depth of 3,028 m in this zone covered by volcanic agglomerates. The respective well crossed the Pliocene, the Sarmatian, the Buglovian and, partly, the Tortonian without intercepting the salt formation. The section crossed is marked by a sequence of marno-clays, sands and sandstones. Flow tests were carried out in several psamite horizons, but gas was pointed out only in one horizon (1,590—1,594 m) ; the output varied between 22,600 and 28,000 m^3/day depending on the nozzle ; CO_2 lacked and the cassing pressure was 110—135 kgf/cm^2.

One can infer from the above presentation that the mixed gas, containing especially CO_2, was found on the Târcești, Benţid, Firtuşu and Cuşmed structures, situated westwards and in the immediate vicinity of the fault system controlling the salt diapirs. A recent analysis of the data obtained in the zone led to the conclusion that the nonhydrocarbon gas (CO_2, N_2, He) is of plutonic origin. It migrated from a certain depth along the mentioned fault and infiltrated in the permeable and porous strata. The nonhydrocarbon gas forms "enclaves" either in the hydrocarbon saturated zones or in the aquiferous of the structures belonging to this region, suggesting that they were naturally "injected" after the formation of the methane deposits.

VI. PANNONIAN DEPRESSION

This structural unit represents an internal depression bounded by the Alps to the west, the Tatra Mountains to the north, the Apuseni Mountains and the Banat Mountains to the east and the Dinaric Mountains to the south. On the Romanian territory, the Pannonian Depression is only represented by its eastern side that leans against the Apuseni Mountains and the Banat Mountains, forming several gulfs that close eastwards.

The knowledge of the Pannonian Depression was achieved by geological mappings, geophysical and geochemical prospections and by drillings. Detailed geological mappings were carried out throughout the zones with natural outcrops in the vicinity of the mountainous massifs.

80 per cent of the respective unit, with a density of 1 point on km^2, was surveyed by gravimetric prospections. The density was of 1.1 stations/km^2 in the Oradea—Borş region, on an area of 3,830 km^2.

The magnetometric prospections covered 90 per cent of the depression area with the density of 1 point/10 km^2. The works were denser, namely 1 point/km^2, on 5 per cent of the area, within the investigated region.

Electrometric prospections were carried out in the Arad—Timişoara region, on an area of about 2,000 km^2, with a density of 0.18 km profile/

km^2 and in the Oradea—Salonta region, on an area of 1,675 km^2, with a density of 0.32 km profile/km^2.

Seismic reflection and refraction prospections have been carried out since 1942. The regional seismic refraction works, surveying the evolution of the basement surface, were achieved almost throughout the depression. The seismic reflection prospections covered about 80 per cent of the area, to a detail and semidetail degree. The density differs according to the perspectives, the seismogeological complications of the investigated regions and the quality of the information obtained. Seismic prospections were achieved only to a regional scale in the Zarand and Lugoj basins. All these works contributed to the making out of the sedimentary cover structure.

Geochemical research was carried out in the northern sector of the Pannonian Depression corresponding to the surroundings of the town of Zalău and in the Banat. As in the case of other Romanian major structural units, the results of the geochemical prospectings were not conclusive.

Core drills, especially on the eastern border where the sedimentary deposits have a reduced thickness and in some western uplifted areas, have been carried out since 1950. The respective drillings contributed to the solving of some stratigraphic, structural problems and even to the discovery of some hydrocarbon accumulations.

Initially the deep drilling activity aimed at the prospecting of the coal in the Oaş Basin. Later on, the hydrocarbon research, and more recently, the recovery of thermal waters were taken into consideration. The growth and diversification interest in the Pannonian Depression brought about a revival of the drilling activity, especially after 1945. Over 1,000 wells reaching 3,894 m (the deepest one at Girişu de Criş) could thus be drilled.

The totality of the achieved works offered a good knowledge of the Pannonian Depression as regards the stratigraphic sequence, the lithofacial variations, the arrangement of the strata and the geological evolution. As far as the intramontan basins (gulfs) are concerned, the research of the deep geological formations belonging to them was limited.

1. Stratigraphic and Lithofacial Peculiarities of the Sedimentary Cover

The stratigraphic sequence of the sedimentary deposits on the eastern side of the Pannonian Depression belonging to the Socialist Republic of Romania, is not uniform and differs from one sector to another, according to the geological and geophysical data available. Thus, the crystalline basement occasionally pierced by eruptive masses, south of the Crişul Alb, is directly overlain by Miocene and Pliocene deposits. Upper Cretaceous and Eocene formations were only locally found, under the Miocene. In the central sector, delimited, on the whole, by the Crişul Alb and the Barcău, the sedimentary cover is completed with Paleozoic (?) and Mesozoic formations, representing the continuation of the Bihor autochthon and of the Codru Nappe system. They are followed by the Miocene and the Pliocene. Finally, the northern sector, situated beyond the Plopiş Mountains prolongation (north of the Barcău River) is characterized by the presence of the Cretaceous and Paleogene deposits in flysch facies, overlain by the Middle and Upper Miocene and the Pliocene.

The metamorphic depression basement outcrops on the eastern border and in a few islands within the basin, where it is made up of mesozonal and epizonal crystalline schists. It gradually falls westwards, prolonging under the Neogene and older sedimentary deposits and further extending as sunk crests. Inside the depression, the basement was touched by numerous wells that identified phyllites, quartzites, chloritic mica schists, sericite-chlorite schists, amphybole schists, gneisses, as well as magmatic rocks, granites, granodiorites, diorites, metagabbros, diabases and melaphyrs, respectively.

The oldest formations of the sedimentary cover are made up of red detrital deposits found by a few wells at Borş, Oradea, Toboliu (N) and Turnu (S); their Permian or Lower Triassic age is presumed.

The Triassic was identified in some wells in the northern (Mihai Bravu) and central Pannonian Depression compartments (Borş, Oradea, Toboliu). The Triassic with a thickness of 360 m is predominantly conglomerate and overlies directly the crystalline basement at Mihai Bravu. In the central zone, it consists of conglomerates that change into sandstones, clays and clayey schists with anhydrite and gypsum diaclases, followed by dolomites and partially black, bituminous limestones, in the upper part.

The Jurassic, found on the east border and in several wells at Oradea, Toboliu and Sînandrei, follows the Triassic after a sedimentary hiatus. The respective deposits are represented by compact blackish grey limestones and dolomite limestones.

The Cretaceous was identified in all the three compartments but it is better developed in the central and northern sectors. The Cretaceous is marked by important facies variations. Thus, in the central sector, at Borş, Oradea and Biharea, the Lower Cretaceous consists, in the base, of massive, grey reefal limestones, 300 m thick, whose Barremian age was established by microfauna. The calcareous series extends on another 600 m, the respective deposits being assigned to the Aptian, on lithofacial criteria. The wells in the northern sector at Baia Mare, Carei, Pişcolţ, Chişlaz, Abrămuţ indicated occassionally alternations of black marly-clayey shales, glauconitic sandstones, conglomerates and limestones with orbitolines belonging to the Upper Aptian-Middle Albian. Beginning with the Upper Cretaceous, the sedimentary area extends, partially including the southern compartment of the Pannonian Depression. The Upper Cretaceous has a flysch detrital facies represented by calcareous sandstones, clayey-marls with thin sandstone intercalations, calcite veins. All this Senonian flysch sequence is about 900 m. In the southern compartment, the Upper Cretaceous, identified as patches, consists of grey clays, marls with passings to sandstones and conglomerate intercalations in the base. The Upper Cretaceous south of the Mureş may reach 900 m in thickness.

Lying generally in the deeper depression zones, these deposits seem to be still in uncoformable relations with the adjacent formations.

In the Laramian phase, the Pannonian Depression raised and evolved as land for a long period of time, with the exception of a few limited zones, where the sedimentation was resumed in the Eocene. The northern depression extremity also ranges among these zones. Here, the wells drilled at Nisipeni, Carei and Pişcolţ indicated that the Eocene, 1,000 m thick, develops in the flysch facies consisting of an alternation of grey sandstones with calcite diaclases and marno-clays. A conglomerate calcareous litoral facies is found, instead in the Chioaru Basin. South of the Mureş, the Eocene is marked by the same restricted development, lying in the sunk sectors at greater depth. It is represented by calcareous breccias, conglomerates, conglomerate sandstones and black shales, reaching 300 m in thickness.

The Lower Miocene (Upper Burdigalian-Lower Helvetian) was identified by some wells drilled in the Mădăraş, Ardud structures, as well as south of the Mureş. Sandstones, microconglomerates and reddish marl intercalations were found in this last compartment,for instance, at Poeni-Ciavoş. In the Moraviţa and Şipet-Şoşdea structures, it is made up of clays, sands and red sandstone and gravel intercalations. They reach about 250 m in thickness. According to the microfauna content and to the resemblence to the similar deposits in Yugoslavia, the respective deposits in the Banat were assigned to the Helvetian.

The Tortonian, the first cover depression term, overlies transgressively the deposits of different age. It was first identified on the depression border and around the crystalline massifs inside it (Heghişa, Măgura Şimleului) where it is represented by marls, tufite sandstones and Leitha limestones. Farther inside the basin, the Tortonian was recognized in numerous wells. Thus, in the northern compartment, the wells at Tăuţi, Măgherăuş, Coaş, Mădăraş, Cherechiu-Săcuieni, Ciocaia, Abrămuţ, Borş, etc. crossed an alternation of sands and sandstones with marls accompanied sometimes by *Lithothamnium* limestones and tuffs and clay intercalations reaching maximum 600 m in thickness. In the Banat, the Tortonian is found at Moraviţa, Secueni, Foeni-Ceavoş, Şandra, Satchinez, Calacea, Cherestur, etc. with different developments from one zone to another. Generally, the Tortonian begins with a conglomerate horizon, followed by a predominantly pelitic one in the case when it overlies directly the metamorphic basement. Both horizons contain a microfauna association specific to the zone with *Sphaeroidina* bulloides that is characteristic of the Upper Tortonian.

The Sarmatian, like the Tortonian, crops out on the basin border, but it was also met by wells in the Mădăraş, Borş, Arad-Felnac, Şipet-Şoşdea, Şandra, Cherestur structures. It is generally made up of an alternation of sands, sandstones and marls and even marly limestones towards the lower part. Microconglomerate intercalations seldom occur. The Sarmatian reaches 20—700 m in thickness in the sunk sectors at greater depth, unaffected by the pre-Pliocene erosion. The microfauna content points surely to the presence of the Volhynian and Bessarabian. The Kersonian was not proved from the paleontological point of view and seems to correspond to a sedimentary hiatus. The relationship between the Sarmatian and the Tortonian is not clear enough. The lithofacial affinity, that cannot be generalized, suggests continuity of sedimentation between the two terms, in certain zones.

The Pliocene covers the whole area of the Pannonian Depression marking a new transgression phase. From a lithological viewpoint the Pliocene deposits may be grouped into two great units : a lower one, prevailingly pelitic, with sandstone and sand layers ; a second one, prevailingly psamitic, consisting of sands, sandstones, with marl and clay intercalations. All these deposits reach 2,900 m in thickness ; their thickness varies according to the distance from the mountainous border and their position towards certain basement uplifts in the region.

The drilling data obtained so far indicate that this terminal sequence of the sedimentary cover in the Romanian sector of the Pannonian Depression represents an equivalent of the extra-Carpathian Pontian and Dacian. Locally, at Pişcolţ, Chişlaz etc. there are paleontological arguments in favour of the existence of a Pannonian equivalent of the extra-Carpathian Upper Meotian, too, overlying transgressively the Bessarabian.

The terminal part sequence of the Neogene was presented according to the conception belonging to the geologists working in the petroleum industry. They do not use the term "Pannonian" *s.s.* It should be mentioned that there is also another opinion, accompanied by numerous arguments, according to which one can speak about the existence of the Pannonian *s.s.*, as the base of the deposits making up the last sedimentary subcycle belongs to the Upper Bessarabian with *Congeria ornithopsis*. The respective species marking the A Pannonian zone, was also met in the Upper Bessarabian in Oltenia and Muntenia (M a r i n e s c u, 1972).

2. General Characteristics of the Structure

The stratigraphic succession found in the Pannonian Depression could be separated into two stages, according to the structural seating : a lower, strongly folded and metamorphosed one, corresponding to the basement, and an upper one, represented by the partially folded sedimentary cover that moulds the pre-existent morphostructural elements. The pre-Tortonian sedimentary cover, in its turn, could be grouped into several structural substages; the last, post-Helvetian one is proper to the depression, while the other belong to its basement.

Considering the matter from a regional viewpoint, the metamorphosed basement falls east-westwards, therefore, towards the depression center. Against this monocline background one can distinguish a series of structural spurs or promontories, real buried mountainous massifs that crop in the Apuseni Mountains or in the South Carpathians in the Banat, and sink, as a rule, by steps, east-westwards. This basement configuration outlines a series of very evident uplifts and depression zones in a profile trending

N—S (Plate IV). The lower structural stage morphology may partially reflect the major structural basement features, regenerated during the Cretaceous diastrophism phases but inherited from the pre-existent structure. After the Cretaceous these basement features functioned as active elements, up to the Neogene (ex. the uplifts Calacea-Şandra, Teremia-Cherestur, Turnu etc.).

The Carpathian Orogen was subject to repeated and intense diastrophic movements in the Paleozoic and Mesozoic; they undoubtedly took place in the Pannonian Depression, too. The respective movements generated, reactivated and amplified a complicated system of tectonic accidents and brought about the folding of the formations as well as the forming (in the Turonian) of the Codru and Biharia nappes. As a matter of fact, the structural configuration of the basement and the fault network that divides into a multitude of blocks, are the main elements that had a great impact on the Pannonian Depression evolution, checking the sedimentation and determining the arrangement of the sedimentary cover (Upper Miocene and Pliocene).

The isobath map made at the Neogene base or at the basement surface (Fig. 63) as well as the regional profile drawn up on the direction N—S (Plate IV) confirm the brittle tectonic style of the sedimentary cover which is specific to the Pannonian Depression. Out of these shivers, a few major morphostructural elements can, nevertheless, be reconstituted. Thus, starting from the north, one can notice the existence of a depression zone, with maximum sinking in the vicinity of the localities Carei and Marghita, where the metamorphic basement sinks to the isobath of 3,000–3,400 m. It would represent the Carei Depression that, in its turn, is divided into smaller basins (Chioarului, Silvaniei) separated by crests, like those at Mădăraşi, Supuru and others.

The Carei Depression is closed on the south by the Mihai Bravu uplift which is in fact the extension of the Plopiş Mountains to the west.

Between the Plopiş Mountains and the Inand-Salonta uplift, a new depression zone has formed at Biharea, where the metamorphic basement gets down to 5,400 m below sea level, a value expressing the maximum sedimentary cover thickness on the Romanian territory. The Biharea Depression trends eastwards, towards the Borod Basin. The thickness of the sedimentary deposits decreases again in front of the Mihai Bravu structural promontory which is, in fact, the western prolongation of the Pădurea Craiului Massif.

The Zarand-Socodor Depression lies south of the Inand-Salonta uplift up to the crest at Arad-Turnu; the thickness of the sedimentary deposits reaches 3,000—3,200 m here. This depressed zone is divided into two small basins by the sunk basin at Chişinău Criş which trends ESE—WNW.

The last important uplifted zone is the one at Seceani-Calacea-Satchinez which seems to represent a sunk ramification of the Poiana Ruscă Mountains. The crystalline basement sinks by 1,150 m here, from Seceani to Şandra, on a distance of about 25 km. The Variaş graben,

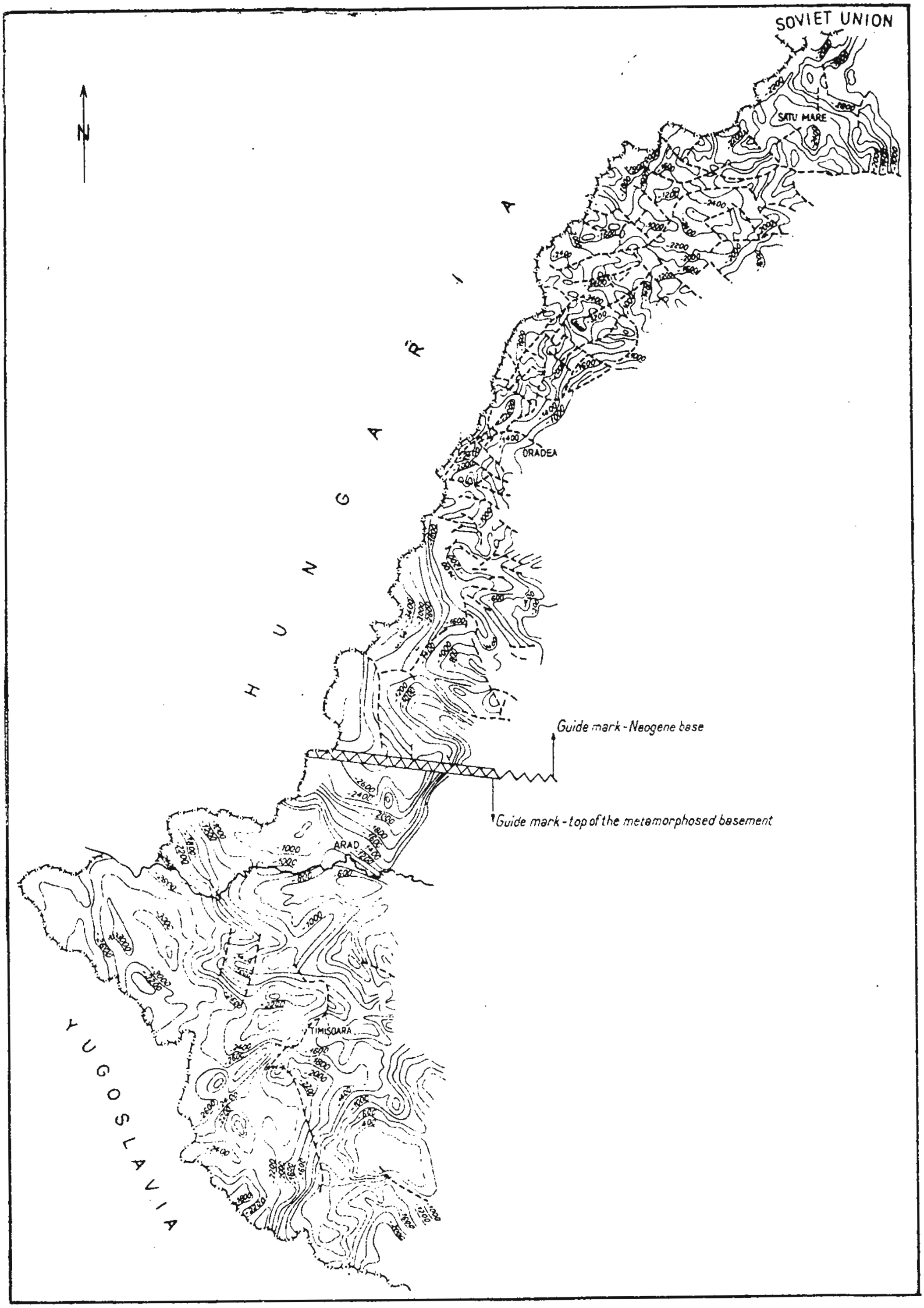

Fig. 63. — Structural map of the Pannonian Depression at the base of the Neogene (N of Mureș) and at the topthe basement (in southern part).

with maximum depths of 3,200 m, forms between the Arad-Turnu and Seceani-Şandra Massifs. The latter mountainous massif bounds northwards another depressed zone which is maximum 2,800 m in depth. The geographic centre of this depression, that does not correspond to the sunk zone reaching maximum depth, is marked by the course of the Timiş River. South-westwards, the Timiş Depression closes on the Banat Carpathian curvature.

In order to complete the list of the major morphostructures, it is necessary to mention the Teremia-Cherestur crest, that comes from Yugoslavia (from Kikinda-Mokrin), continues on the Romanian territory to the west of the town of Sînicolaul Mare and then reaches Hungary, at Ferencsalas-Szeged. The Kikinda-Teremia-Szeged uplift is bounded by the Sînicolaul Mare graben (—3,000 m) on the east and by the big Makkö "pit" on the west ; the latter develops on the territory of the S.F.R. of Yugoslavia and the Hungarian People's Republic.

The sunk massifs, in their turn, have their own relief of the order II and III, consisting of culminations and saddles, divided into tectonic blocks. All these details, including the tectonic accidents, are mirrored in the sedimentary cover seating that forms creeping structures.

Taking into account the above presentation it is obvious that the dip of the Tertiary and Mesozoic strata is quite varied. The dips may reach 90° in the central and north compartments with Paleozoic and Mesozoic formations, implied in folded structures and even overthrusts. Sometimes the Upper Cretaceous and Paleogene deposits develop in flysch facies. The Miocene cover is marked by values of 4—30° and the Pliocene, by dips of 1—10°.

3. Geological Evolution of the Pannonian Depression

The Pannonian Depression, like the Transylvanian Depression, formed, in the shape known today, in the Tortonian. But parts of it functioned also before the Tortonian, as sedimentary basins dependent on those of the Carpathian geosyncline.

The maps showing the distribution of the formations older than the Miocene lead to the conclusion that, as regards the pre-Neogene evolution, the Pannonian Depression territory could be divided into two compartments : one situated north of the Inand-Salonta shoulder, with a Mesozoic sedimentary and quite developed and varied Paleogene that suggests the presence and persistence of a geosynclinal regime ; a southern one, comprising the south Crişana half and the Banat, with a reduced pre-Miocene limited to the Upper Cretaceous and Paleogene. The latter compartment functioned as a rigid shield, also suggested by the epicontinental character of the overlying deposits.

Returning to the northern domain, which is fragmentary enough and heterogeneous, one should mention that it functioned partly as sedimentary basins from the Permo-Triassic to the end of the Cretaceous, occassionally, even in the Paleogene. That reminds one, to a certain extent, the evolution of the Transcarpathian flysch and the North Apuseni Mountains zone. Nevertheless, the process of sedimentation seems to have been interrupted in several stages, corresponding to the old and new Kimmerian, Austrian and Laramian phases.

The period that followed the pre-Gosau phase corresponds to a general sinking of the Pannonian Depression, allowing the Senonian Sea to invade considerable zones, belonging to both compartments. The east side of the depression, which develops on the Romanian territory rised, the whole surface being subject to denudation. Between the Laramian phase and the new Styrian phase, the territory situated west of the Apuseni Mountains and the Banat South Carpathians underwent, alternatively vertical movements in a contrary direction, suggested by the sporadical, presence of the Eocene and Lower Miocene formations. Their sedimentation areas generally overlie the sunk zones outlined by the basement that functioned as gulfs or sea branches.

The repeated and, in most cases, long periods of emergence of the Pannonian Depression territory, when the intensity of the movements varied both in time and space, considering its structure consisting of tectonic blocks, determined the formation of several varied enough and energetic paleoreliefs. Generally, the major relief shapes correspond to the basement configuration, being transmitted during various evolution stages. Where the crystalline schists were exposed to the subaerial action they were subject to alteration and transformed into real reservoirs, on thicknesses that can reach 180 m. It goes without saying that the alteration process was not uniform but varied according to the rock nature, to the exposition time and to the tectonization (fissure) degree of the respective zones.

In the Tortonian (the New Styrian phase), the greatest part of the Pannonian Depression sank, allowing the sea waters to penetrate first in the depressed zones and then in the sectors characterized by moderate relief. The major uplifts and other local positive forms could only be covered in the Pliocene functioning as islands up to that time. Moreover, some of these uplifts (Măgura Şimleului, Măgura Bîcului etc.) remained emerged up to the Levantine and after.

A new rising of the east Pannonian Depression border took place towards the end of the Sarmatian, being suggested by the absence of the Kersonian and almost the whole Meotian. Naturally, the emergence was accompanied by denudation, a new relief generation resulting. The Pannonian territory sank again towards the end of the Meotian entering completely the subaquatic realm, with the exception of a few islands. By the end of the Pliocene, occasionally, up to the Pleistocene, the Pannonian Basin was completely sealed, becoming land.

The repeated sedimentogenesis and denudation phases, the vertical play in different senses and with different intensities, the existence of several relief generations, determined a certain stratigraphic sequence with important local cessations of deposition, variations of facies and in thickness, pseudostructures. This evolution, which is generally favourable to the genesis and accumulation of hydrocarbon deposits, offers a great range of trap types.

4. Conditions of Genesis, Accumulation and Preservation of Hydrocarbons

As results from the brief presentation of the chapter on stratigraphy, there are several lithostratigraphic terms with reservoir rock properties on the east border of the depression. They are represented by the upper part of the fissured and altered crystalline basement, the Triassic conglomerates and sandstones, the Upper Cretaceous sands and sandstones, the Paleogene sandstones, the Helvetian and Tortonian psephites and psamites, the sandstones in the Pliocene base and the psamite lenses within the Pontian etc. But not all these reservoirs are of equal interest.

The altered and fissured basement upper part turned out to be productive at Şandra, Satchinez, Variaş, Turnu, Pordeanu, Cherestur, Salonta and Ciocaia and has porosities of 5—16 per cent and permeabilities of 0—130 mD.

The Helvetian, Tortonian and Pliocene (?) conglomerates and sandstones, that are productive at Calacea, Satchinez, Şandra, Variaş, Cherestur, Pordeanu, Abrămuţ, Borş etc. have porosities of 8—27 per cent and permeabilities of 5—300 mD.

The sandstones and sands in the Pliocene base and within the Pontian marly series, with hydrocarbons at Calacea, Satchinez, Teremia, Suplacu de Barcău etc., are characterized by porosities of 15—27 per cent and permeabilities of 1—640 mD.

As far as the protection conditions are concerned it is found that the only pelitic cover with regional development is the marly-clayey sequence in the Pliocene base. It protects both the Meotian and Pontian and even older reservoirs with which it comes into contact on the surface of unconformity. Compact and impervious pelite or carbonate sequences are also found at the Miocene, Paleogene and Mesozoic levels, but they show local developments, their limited distribution area being due either to the deposition or to erosion.

Taking into account the petrographic criteria, the bituminous character, the colour and the result of some special analyses, several deposit sequences are considered as possible source rocks ; their age varies between the Triassic and the Pliocene.

In the Triassic, the wells at Livada, Toboliu, Borş and Oradea indicated the presence of some black bituminous limestones and marnoclays. The Upper Cretaceous in the northern and central compartments of the depression (Chişlaz, Borş) is characterized by sequences of black pelite facies. Important dark grey pelite deposits make up the Tortonian, especially in the northern and central compartments. Finally, the most important and widespread possible source rocks are included in the predominantly pelite series in the Pliocene base. These deposits together with the Miocene pelite rocks on the Calacea, Satchinez, Şandra, Turnu, Teremia, Cherestur, Sîntana and Sînmihai structures were dealt with in some special studies.

The sedimentological study made by the mineralogical-petrographic and geochemical analyses showed the existence of the reducing environment characterized by the bivalent iron (pyrite, siderite, leptochlorite, glauconite) that favoured the transformation of the organic matter into hydrocarbons in the sedimentogenesis and diagenesis phases of the Miocene and Pliocene deposits. The geochemical study of the organic matter proved the presence of the source rocks represented by the Miocene marls and by the Pliocene marls and marly limestones, by the organic carbon content (0.05—1.81 per cent), the hydrocarbon extract and the Phillippi reports. In general, the Pliocene deposits proved richer in organic matter than the Miocene ones. The geochemical analyses carried out on soluble organic matter extracts in cores and on petroleums, led to the conclusion that the evolution of the extract/organic carbon ratio and hydrocarbons/organic carbon ratio takes place according to the distance from the metamorphic basement, that is, under the intense and determining thermic influence. All the petroleums resemble one another as to their detailed composition. The rock extracts contain saturated hydrocarbons identical with one another and with other petroleums as regards the composition, whence the conclusion of the common origin of the organic matter. The evolution stage of the residual hydrocarbon composition in the rock extracts indicates that in the complex migration process when the light aromatics and the heavy saturated are preferentially retained by rocks, the light saturated hydrocarbons could migrate (laterally). All the obtained results lead to the conclusion that the petroleum deposits in the Pannonian Depression Miocene and Pliocene deposits (south of the Mureş) are autochthonous, lying in the formations they generated.

The studies on the distribution of temperatures in the Romanian territory subsoil (Paraschiv, Cristian, 1976) show that among the Romanian units of petroleum interest, the Pannonian Depression presents the greatest geothermal gradients, behaving, on the whole, like a hot reservoir. The average value of the geothermal gradients inside it differs, according to the depth and zone, as follows:

	at 500 m b.s.l.	at 1000 m b.s.l.	at 2000 m b.s.l.
The south sector (°C/100 m)	6.2	5.8	5.6
The north sector (°C/100 m)	6.9	6.5	5.8

Against the general background of raised temperatures where the gradients show greater and greater values towards the eastern side of the depression, therefore as the thickness of the sedimentary deposits decreases, several local anomalies appear, such as those at Şandra-Satchinez-Calacea-Variaş, Arad-Turnu, Biharea, Sîniob-Chişlaz-Galoşpetru etc. For instance, the geothermal gradient reaches 7.1°C/100 m at Calacea and it is 9.4°C/100 m at Suplacu de Barcău, where the metamorphic basement is found at the depth of 100 m. It results from the above examples and the general distribution of temperatures that the mentioned anomalies correspond to some metamorphic basement crests that are sunk in the Neogene deposits. The local anomalies betray even the detail tectonic features of the buried crests, namely the existence of some blocks, faults, structural saddles etc. The strong heat flow in the Pannonian Depression might be due, as in the case of other basins of the same type (B a l l y, 1975), to the earth crust reduction in thickness that reaches about 25 km in front of this unit and to the existence of some deep faults, which is proved by the fact that numerous anomalies are associated with non-hydrocarbon gas of plutonic origin (CO_2, N_2, He etc).

The geothermic regime of the Pannonian Depression was quite favourable to the hydrocarbon genesis, migration and accumulations in the geological formations reaching the depth of 2,000—3,000 m. The temperature constituted, theoretically, a destructive factor, especially in the case of the pre-Neogene formations lying beyond the depth of 3,000 m (at 160—170°C).

All the four types of waters were determined in the Pannonian Depression: $CaCl_2$, formation waters; $MgCl_2$, mixed waters; $NaHCO_3$ and Na_2SO_4, waters of continental origin.

The fissured and altered basement zone contains waters of $CaCl_2$, $MgCl_2$ and $NaHCO_3$ type, with mineralizations between 0.5 and 35 g/l. In general, on the eastern border of the basin, with a more reduced sedimentary cover consisting of previous shore deposits, the basement contains vadose waters, of $NaHCO_3$ type, without direct microcomponents for waters associated with the hydrocarbon deposits. Traces of naphthenic acids and phenols are found westwards, as the vadose water infiltration and circulation decrease. The $MgCl_2$ waters have a very limited distribution. The formation waters ($CaCl_2$) are present in the south-western part of the Banat and in the north-western part of the depression (Foeni, Pişcolţ, Otomani).

The Permo-Triassic and the Jurassic are characterized by waters unassociated with the hydrocarbon accumulations. All the four types were identified in the Cretaceous and Paleogene, some of them having direct microcomponents (naphthenic acids, phenols).

The Miocene contains fluids of 5—38 g/l mineralization. The existent waters here are of the $CaCl_2$, $MgCl_2$ and $NaHCO_3$ types. A zonality in the genetic sense is to be noticed in their distribution east-westwards, the vadose water zone being, of course,outlined in the vicinity of the border. Some of the waters of the $NaHCO_3$ type as well as the other more developed types contain naphthenic acids and phenols.

Waters having below 20 g/l mineralization are to be found in the Pliocene. They reach 53 g/l only locally (Cărpiniş). Among the four types, the Na_2SO_4 waters were found only at Suplacu de Barcău, where the Na_2SO_4 infiltrations brought about the hydrocarbon deposit weathering. Otherwise, the zonality pointed out within the Miocene is, on the whole, found in the Pliocene, too. It is noteworthy that the great Calacea-Şandra-Variaş accumulation zone belongs to the $NaHCO_3$ type waters, with direct indexes for waters associated with the petroleum and gas accumulations.

5. Hydrocarbon Deposits

The Pannonian Depression proved its oil potential by the discovery of several deposits,located in the upper fissured-altered part of the metamorphosed basement, in the Miocene and Pliocene. The Upper Cretaceous yields in only one well, at Chişlaz. Superposed deposits, often having a common origin and communicating with one another were found on most productive structures. Consequently, the following presentation of the hydrocarbon deposits, taking into account the oil and gas structures and not the geological formations, seems to be the most adequate.

Examining the hydrocarbon deposit distribution map (Fig. 64) one can conclude that it is divided into two regions : one, which is the most important, corresponding to the southern part of the Pannonian Depression (Banat), another, which is situated north of the Inand-Salonta shoulder.

The Foieni accumulation (1, Fig. 64) is known in the southern extremity of the Banat ; it represents the continuation of the Yugoslavian gas structure Medja on the Romanian territory. One of the wells drilled here produced about 5 t/day oil. The productive horizon is located in the Pliocene base at the depths of 1,676—1,670 m. About 74,000 m^3/day gas, on a nozzle of 7 mm, pressures of 80—105/100 kgf/cm^2 were obtained above it, in the Pontian, at the depth of 1,402—1,492 m. Petroleum traces were also pointed out in another well (well n. 6 Foieni), drilled later on.

It is also in the southern part of the Banat that the *gas deposit at Sînmartin* is situated (2, Fig. 64), being located in an elongated vaulted structure, with the eastern flank faulted. The Pliocene was proved productive on this structure, at the depth of 1,398—1,378 m, from where it produced about 80,000 m^3/day gas from only one well.

The assymmetrical Tomnatec anticline (3, Fig. 64) was pointed out north-west of Sînmartin. Two of the wells drilled here contained gas from the basal Pliocene gritty-sandy reservoirs, equivalent to the packet "*f*" at Teremia.

The main deposits in the southern part of the Pannonian Depression correspond to the *Calacea-Satchinez-Şandra-Variaş crest*, situated at about 45 km north-east of Timişoara.

This uplift has been researched since 1941, first by gravimetric and magnetometric methods, then by seismic and electrometric prospections and finally, by wells.

Numerous exploration and development wells crossed the whole sedimentary cover, penetrating the crystalline schist basement. The latter is made up of metamorphosed sedimentary rocks consisting of phyllites, quartzites, mica schists, sericite-chlorite and amphybolic schists, gneisses and magmatic rocks, represented by granites, granodiorites, diorites, metagabbros, diabases and melaphyrs.

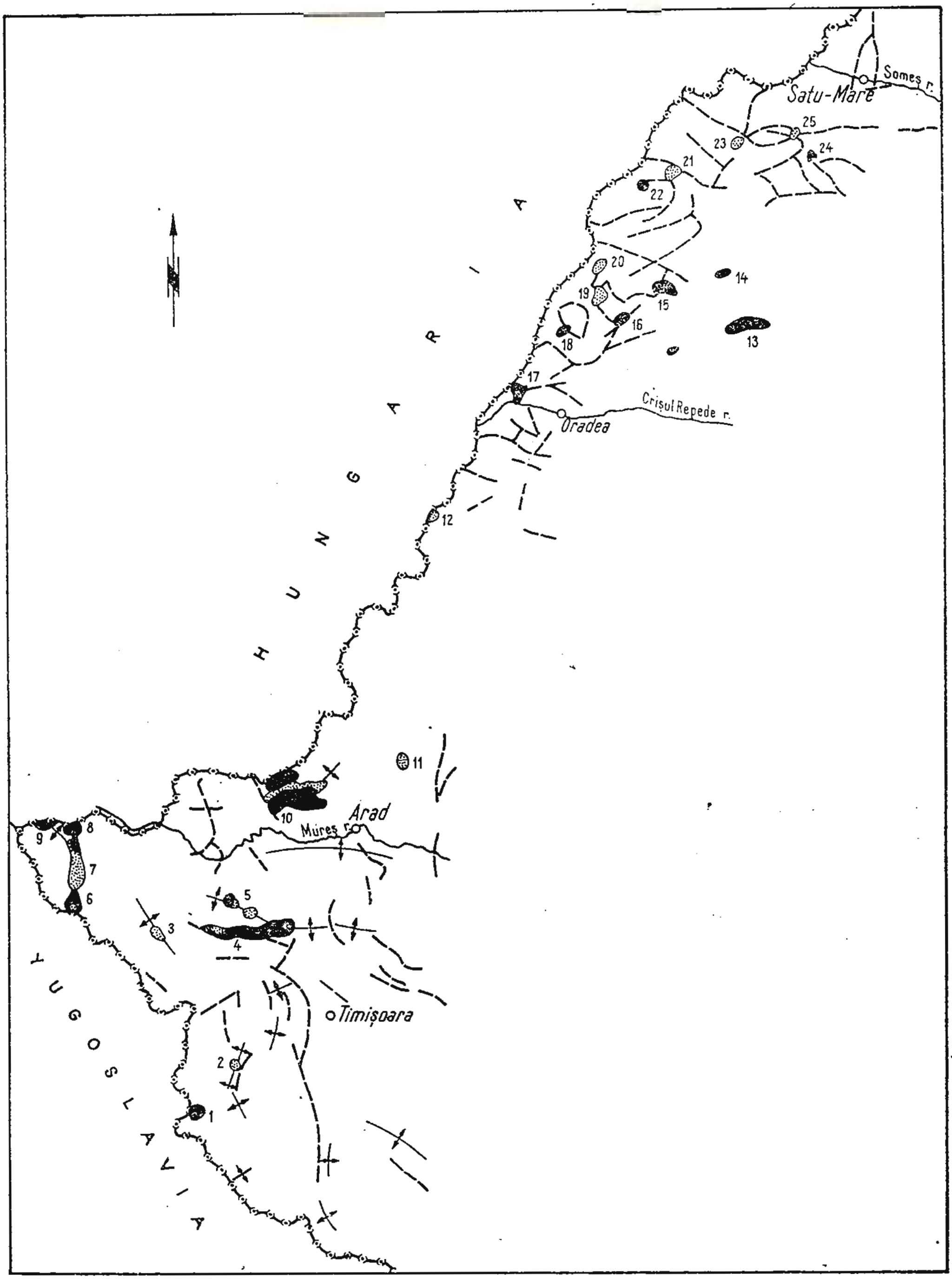

Fig. 64. — Map of the distribution of hydrocarbon deposits in the Pannonian Depression.
1, Foieni ; 2, Sînmartin ; 3, Tomnatec ; 4, Calacea-Satchinez-Şandra ; 5, Variaş ; 6, Teremia ; 7, Cherestur , 8, Pordeanu ; 9, Cherestur N ; 10, Turnu ; 11, Sîntana ; 12, Salonta ; 13 Suplacu de Barcău ; 14, Păţal ; 15 , Abrămuţ ; 16, Sîniob ; 17, Borş ; 18, Mihai Bravu ; 19, Ciocaia ; 20, Săcueni ; 21, Pişcolţ ; 22, Curtuiuşeni ; 23, Carei ; 24, Mădăraş ; 25, Moftinu.

The basement is overlain by sedimentary deposits of various age. Conglomerates and sandstones reaching 150 m in thickness, followed by compact marls were found in certain sectors. These two complexes seem to belong to the Helvetian and the Tortonian. A limy sandstone and sand horizon, 15—45 m in thickness, develops on the western flank at Şandra, at the contact between the Tortonian and the Sarmatian.

The Sarmatian consists of a sandstone and sand sequence, uniformly distributed, as a result of their partial removal by the pre-Pliocene denudation.

The Pliocene, that follows the Sarmatian, may be 20 to 2,000 m in thickness. It starts with different terms along the sunk crest, indicating that the last and most important marine transgression began from the west (Şandra), that is from the sunk sector, covering the whole massif gradually until it overlapped the raised sector at Seceani. A gritty-sandy or marly-limy complex is found, as a rule, in the Pliocene base; it is slightly heterochronous representing a lithofacies of the post-Miocene transgression in which paleontological elements specific to the Upper Meotian were found. The sequence continues with a predominantly marly complex within which two horizons with sandstones and sands, each being about 150 m in thickness, develop in the western, lower pericline at Şandra. These horizons decrease very rapidly in thickness southwards disappearing completely. Farther eastwards, that is in the Satchinez and Calacea sectors, only lenticular sands appear at different stratigraphic levels. Predominantly psamite deposits consisting of sands and sandstones, with microconglomerate and clay intercalations develop at the upper part of the Pliocene. The sedimentary sequence ends with the Quaternary, which consists of an alternation of sands, clays and conglomerates, terrace deposits and alluvions.

The structure corresponds to a buried mountainous massif that sinks east-westwards (Fig. 65), outlining against this lowering background three culminations, at Calacea (the highest one), Satchinez and Şandra (4, Fig. 64). An apophysis trending WNW, towards Variaş (5, Fig. 64) develops in front of the Calacea locality. The crystalline schists crest is overlain by the Neogene sedimentary that it moulds, inheriting its general configuration. In detail, the massif and the sedimentary cover are crossed by faults, some of which forming real seals; they divide the uplift into several blocks.

The first hydrocarbon traces on the Calacea-Satchinez-Şandra uplift were pointed out in 1968. The wells drilled afterwards showed that the petroleum and gas accumulation is situated at the level of the metamorphic basement for the Satchinez (including the Biled sector, the southern prolongation of this culmination), Şandra and Variaş zones; in the Miocene, on all the four zones and in the Pliocene, at Calacea and Satchinez. A great deal of the tectonic blocks constitute separate hydrodynamic units, so that more than 35 deposits were defined on the Calacea and Satchinez structures.

The depth of the productive strata increases proportional to the major structure sinking. Thus, the depth of the oil and gas horizons corresponds to the isobaths of 763—1,096 m at Calacea, to 1,220—1,670 m at Satchinez, to 1,862—1,958 m at Variaş and to 1,960—2,120 m at Şandra.

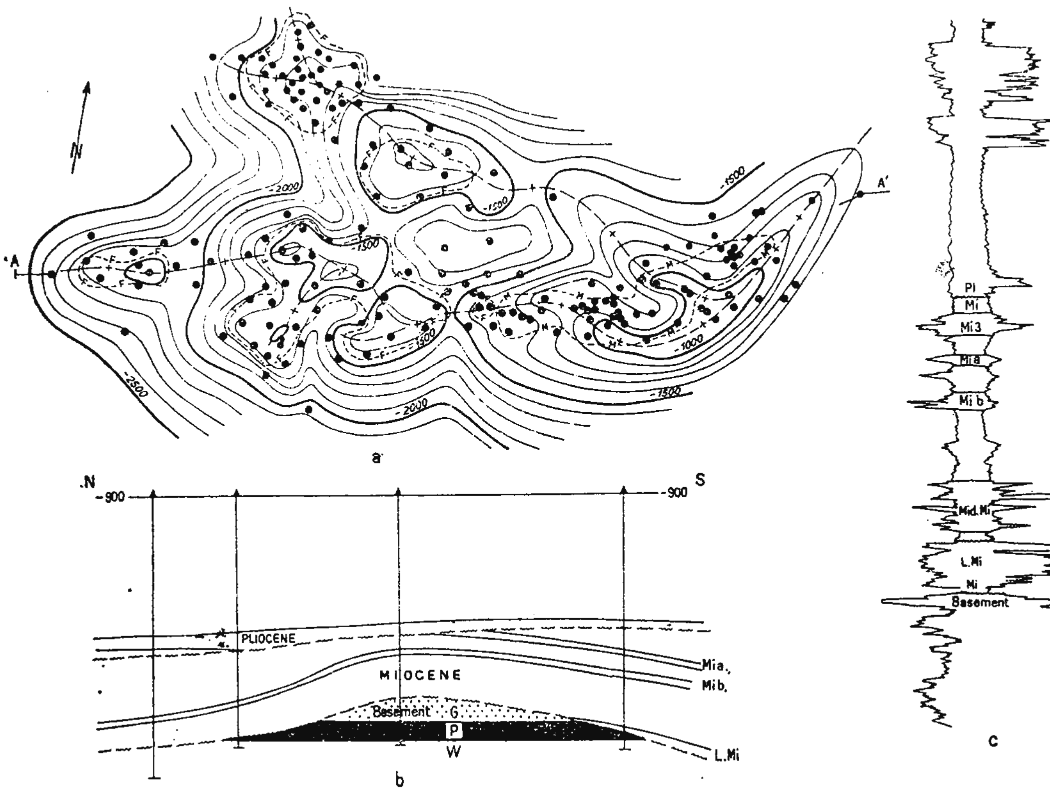

Fig. 65. — Calacea-Satchinez-Şandra-Variaş uplift.
a, morphostructural image at the surface of the metamorphosed basement; b, geological cross section in the Satchinez zone; c, Lower Pliocene, Miocene and altered basement type profiles (according to Tr. Ichim and D. Paraschiv).

Although the Calacea culmination (zone) lies in the highest position, it is noteworthy that the upper part of the basement is not productive here. The fact is due to the structural inversion that took place within the respective massif after the Sarmatian. In the Miocene the Calacea culmination was situated in a lower position than that at Şandra, which is proved by the existence of some thick Helvetian and Tortonian deposits on this last culmination. Besides, as the basement remained protected at Calacea, it was no longer subject to alteration, so that it does not have reservoir properties (Fig. 66).

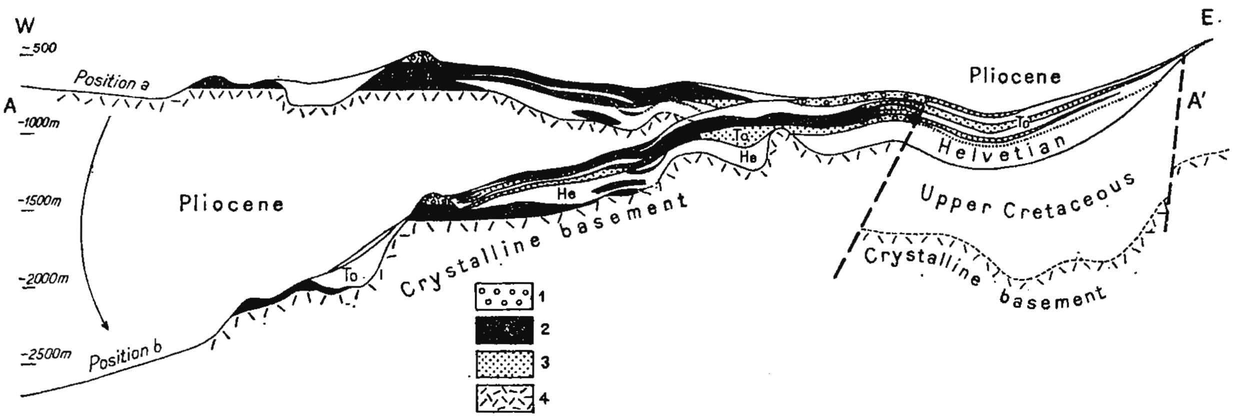

Fig. 66. — Geological section along the Şandra-Satchinez-Calacea uplift. Position a, the massif at the end of the Miocene ; position b, the massif at the end of the Pliocene.
1, gas deposits ; 2, oil deposits ; 3, sandstones and aquiferous sands ; 4, crystalline basement (according to Gh. Popa).

The basement ranges among the mixed traps, to the achievement of which the structural and paleogeographic factors contributed. These reservoirs contain petroleum and some blocks also contain primary gas cap. Two of the wells drilled here produced CO_2 at the basement level. This non-hydrocarbon gas of plutonic origin migrated from the depth to one of the faults and accumulated, as it seems, under the shape of an enclave into the structure aquiferous. The hydrocarbon deposits are of massif type, often constituting the same hydrodynamic units as the Miocene or the Pliocene that overlies it. The initial oil productions were 7—50 t/day for each well. The reservoir shows effective thicknesses of 10—105 m, greater where it corresponds to the granitic rocks that are fissured up to great depths. The average porosity is of 16 per cent, the permeability of 3—130 mD, the connate water saturation of about 42 per cent.

The Miocene is marked also by mixed but somewhat more complex traps. The influence of the structural stratigraphic and paleogeographic factors is evident here. The Miocene contains petroleum accumulations, sometimes, with primary gas cap (at Calacea). The initial oil productions were 13—51 t/day. The deposits are independent or common with those in the basement or the Pannonian. The main reservoir parameters are the following : thickness 2—81.7 m, porosity 18—27 per cent, permeability 5—300 mD, connate water saturation 25—47 per cent.

The structural traps prevail in the Pliocene, but the mixed ones are also present, being achieved by the contribution of the stratigraphic and paleogeographic factors. Petroleum acumulations formed in the Pliocene and also primary gas cap, at Satchinez. The Pliocene reservoirs have 2.5—14m in thickness, porosities of 23—25 per cent, permeabilities of 5—640 mD, connate water saturation of 24—32 per cent.

The petroleum produced on all the structures is of *C* type (parafinic), with density of 0.79—0.81 kgf/dm^3. A weak specific gravity decrease is noticed towards the upper part of the saturated section. The viscosity is below 1 cP. The gas/oil ratio varies between 57 and 168 Nm^3/m^3. The initial reservoir pressures indicated values of 99—235 kgf/cm^2, somewhat greater than the hydrostatic pressure, the gradient being of 10.5—10.9 kgf/cm^2/100 m. The geothermal step is 24 m/°C, reaching 15 m/°C at Calacea.

The associated waters of the basement are of $CaCl_2$ and $MgCl_2$ type with concentrations of 4—19 g/l. Continental waters of vadose (HCO_3) type are sometimes also present. The waters of $NaCO_3$ type with mineralizations of 7—26 g/l prevail in the Pliocene. The Pliocene and Miocene waters contain also phenols, ammonium (from traces to 90 mg/l) and bromine (up to 11.25 mg/l), elements that indicate the existence of hydrocarbon accumulations.

The regime of the deposits is varied. The petroleum accumulations without primary gas cap owe their energy to the expansion of gas from the solution. The basement and, generally, the reservoirs of fissured types are characterized by water drive. The deposits with primary gas cap have a mixed regime: the gas cap detente-dissolved gas. The water injection is applied to some of the blocks.

The Teremia-Cherestur productive zone corresponds to another great uplift in the Banat which develops from Kikinda (Yugoslavia); it passes on the Romanian territory and continues in Hungary up to the north-west of the Szeged town. Along it, one can notice a series of positive and negative structural elements of second order, many of which offering favourable conditions for the hydrocarbon accumulations.

The Teremia-Cherestur crest is surrounded by the Sînicolau Mare depressed zone on the east and by the large pit at Makkö, on the west; the latter is perhaps the deepest pit in the whole Pannonian Depression; the Pliocene and the Upper Miocene reach over 5,500 m in thickness here. As a matter of fact, this large pit constituted the main zone for hydrocarbon supply of the respective crest, which is proved by the fact that the Algyö deposit, the most important one in the Pannonian Depression, is situated in front of it. Also, the reservoirs disposed on the western flank of the Kikinda-Teremia-Szeged uplift are saturated with hydrocarbons and are more productive than those on the eastern flank that contain accumulations of little value, only locally.

The Teremia-Cherestur uplift was examined by gravimetric, magnetometric, seismic works and core-drills, the seismic prospections being the most efficient.

The complex of works pointed out, along the major uplift, a few structural culminations at Teremia (6, Fig. 64), Cherestur S and Cherestur centre (7), Pordeanu (8) and Cherestur N (9) (Fig. 67), with hydrocarbons in the upper altered basement part and in the Pliocene base.

Among the productive zones within the mentioned area the oldest exploitation is that at Teremia, the continuation of the Yugoslavian Mokrin structure on the Romanian territory. The stratigraphic sequence and the tectonic style at *Teremia* are, on the whole, similar to those on the Şandra-Calacea uplift. What strikes here is the evolution of the crystalline schist crest, namely its continuous sinking which started in the Upper Miocene and ended in the Pontian. This evolution is reflected by the various Neogene terms that regularly exceed one another on the uplift flank till they succed in covering also the apex structure zone, in the Pontian.

The Pliocene basal series of interest for petroleum and gas was divided into six members, called *a*, *b*, *c*, *d*, *e* and *f*, from bottom to top. The member *a*, unconformable on the older sedimentary formations, is known only on the western flank and the northern pericline being 1—40 m in thickness. The member *b* is the main unit at Teremia. Its sandstones, known on the eastern flank, change into marls on the opposite flank. The complex *d* is screened in the crest zone and the term *e* at Teremia joins the complex *f*.

The structural image drawn up at a basal Pliocene key (Fig. 68) renders in the most suggestive way the periclinal character of the Teremia zone. But this pericline is divided into several hydrodynamically separated blocks. The dip of the strata does not exceed 5°, as a rule.

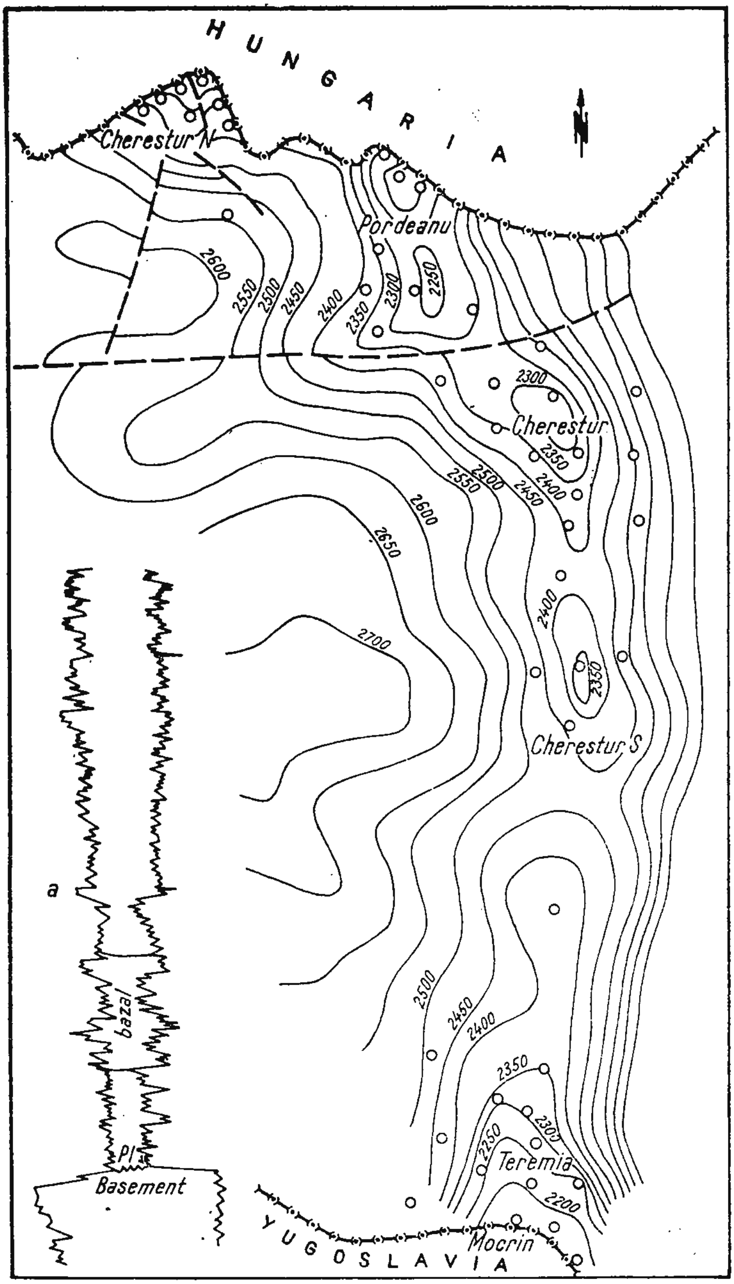

Fig. 67. — Morphostructural image at the surface of the metamorphosed basement of the Teremia-Cherestur buried massif (according to T r. I c h i m and M. P o p a).
a, Pliocene type profile.

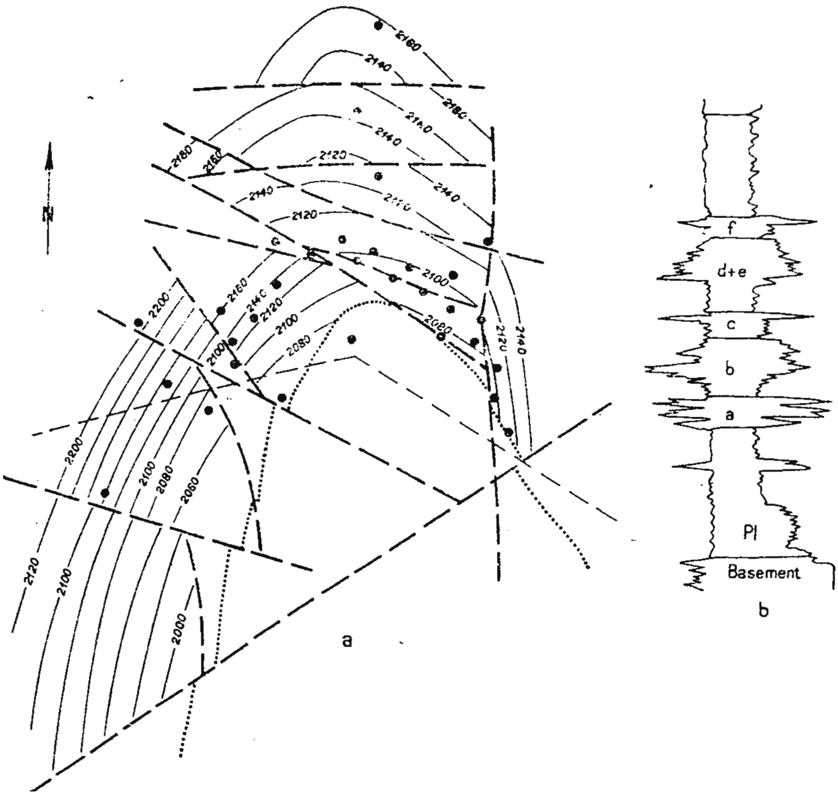

Fig. 68. — Teremia structure.
a, structural map at the Pliocene bottom (packet a) ; b, basal Pliocene type profile (according to I.C.P.P.G. Cîmpina).

All these six members are saturated with hydrocarbons, as follows : the terms *a* and *b* contain petroleum and associated gas ; the term *c* contains only gas but it communicates with the packets *a* and *b* ; the terms *d* and *e* contain also petroleum, and associated gas ; the packet *f* (productive at Tomnatec) contains only gas but it also seems to communicate with the reservoirs *d* and *e*. Under these circumstances, the six packets of interest might be grouped into two hydrodynamic units ; a lower one, consisting of the members *a*, *b* and *c* and an upper one consisting of the terms *d*, *e* and *f*. The members $a + b$ and $d + e$ contain petroleum with associated gas in some blocks, their initial productions being of 3—42 t/day petroleum ; but the respective terms contain only gas in other blocks. The section saturated with hydrocarbons lies at various depths, according to the productive and block unit. The lower hydrodynamic units (the sands $a + b + c$) proved hydrocarbon saturated between the isobaths 2,010 and

2,231 m, and the upper hydrodynamic unit (the sands $d + e + f$), between 1,823 ans 2,091 m (b.s.l.).

Taking into account the above data one can state that various types of traps appear at Teremia, but most of them are mixed, resulting from the interaction of the structural, stratigraphic and paleogeographic factors.

Coming back to the reservoirs they are characterized by the following parameters : thickness 1—15 m for each member, average porosity 21.4—24.2 per cent (the values increase as the depth decreases), permeability 0.61—5 mD, the connate water saturation established in correlation to the permeability is of 34.06—39.14 per cent and the volume reduction factor 1.095—1.410.

The oil specific gravity is greater in the member *a* (0.900 kgf/dm^3) and smaller in the packet *b* (0.800 kgf/dm^3). The petroleum viscosity varies between 0.8 and 2.9 cP. according to the gas ratio. The associated gas contains methane in proportion of 81—91 per cent and carbon dioxide 0.6—20 per cent.

The initial reservoir pressures (210—219 kgf/cm^2) were near to the hydrostatic pressure. The geothermal step is of about 25 m/°C.

The Cherestur S—Cherestur centre (7, Fig. 64), *Pordeanu* (8) *and Cherestur N deposits* (9, Fig. 67) develop north of Teremia. The Pordeanu culmination continues on the territory of the Hungarian People's Republic where it forms the deposit at Kiszombor, while the structural element at Cherestur N lies on the southern flank of the Ferencsallas uplift in Hungary.

Hydrocarbon accumulations are found on the mentioned structural elements located in the altered zone of the metamorphic basement and in the Neogene predominantly conglomerate basal horizon (Fig. 67). The latter was provisionally assigned to the Pliocene, but its age is uncertain.

The basement of the region we refer to, consists of mica schists, biotite gneisses, quartzites, amphybole schists with epidote. The metamorphic formations are, in their turn, pierced by granites.

The Pliocene (probably, also the Upper Miocene) overlies transgressively and unconformably the basement and consists of an alternation of marls, clays, sandstones and conglomerates. The basal complex, which is an unit of interest in the region, has a maximum thickness of 100 m and is represented by conglomerates, microconglomerates sandstones, and sands. The thickness of the conglomerate complex decreases to its complete (Pordeanu, Cherestur) disappearance in the crest zone of the Cherestur-Pordeanu uplift. The psephites change into psamites and then into pelites (well no. 6) laterally, on the uplift flanks. The Pliocene section, which follows the basal horizon, also undergoes lithofacial variations. Thus it has a pelite facies on the eastern flank, while becoming predominantly arenyte on the western flank.

The culminations existing along the Teremia-Pordeanu-Cherestur N crest are defined by saddles of the order of 100 m in depth (difference of elevation). The strata show dips of 7—25° in the Neogene base. The dip value decreases to 6—11° in the upper part of the conglomerates and in the overlying horizons.

At the basement level, the reservoir shut off is achieved as a sinuous contour that expresses, on the whole, the contact between the altered zone and the compact one. The initial water-oil contact may be marginal or tabular. This contact is 2,240 m b.s.l. at Pordeanu and Cherestur N, at the basement level, and 2,220 m at the basal complex. An oil deposit was formed on the Pordeanu uplift, while also free gas or associated gas accumulations were pointed out at Cherestur S + centre and at Cherestur N.

The main physical parameters on the Pordeanu and Cherestur N culminations, where the available information was more complete, show the following average values :

	Conglomerates	Basement
effective porosity (per cent)	17	6
absolute permeability (mD)	187	32
connate water saturation (per cent)	1.2	24.2

The pressure gradient of 12.22 kgf/cm^2/100 m is much higher than the hydrostatic pressure. The geothermal gradient hardly exceeds 5°C/ 100 m.

The oil is of *C* paraffinic type having the specific gravity of 0.820 kgf/dm^3 and the freezing point at 24°C. The associated gas contains about 80 per cent methane. CO_2 was also pointed out in proportion of 2—6 per cent.

The formation waters are of the $CaCl_2$ or $NaHCO_3$ types in the basement and of the NaCl or $NaHCO_3$ types in the basal complex. Their mineralization is of the order of 6—10.6 g/l.

The Turnu structure (10, Fig. 64) overlies a metamorphic basement crest that develops from the Poiana Ruscă Mountains and extends westwards in Hungary. In its westwards sinking, this buried crest outlines several culminations which are separated by structural saddles. The positive forms, such as those at Turnu (the S. R. of Romania), Battonya, Veg Totkomlos and Pusztföldvar (the Hungarian People's Republic) offer favourable conditions for the hydrocarbon accumulations.

The Turnu-Arad region was surveyed by gravimetric, magnetic, electrometric, seismic, geochemical methods and core drills. The first deep well was drilled in 1964.

The stratigraphic succession and the evolution of the structure do not differ essentially from those of the uplifts presented above. The crystalline basement, crossed by several wells, consists of sericite-chlorite schists, quartzite-chlorite schists and of granites. Several wells crossed arkosic sandstones that might be of Permian age, over the basement, in the eastern sector of the (Turnu E) structure. On the flanks or in the negative relief zones, the basement is overlain by the Sarmatian, which is represented by gravels and conglomerates in the base, which are followed by marno-limestones (well no. 24). Almost on the whole structure, the Pliocene overlies directly the crystalline schists and shows the same composition as on the Calacea-Satchinez-Şandra structure. The basal part, which contains sandstone and sand intercalations, was divided into four complexes (I—IV). Finally, the sedimentary succession ends with the Quaternary that overlies the whole region.

At the basement level, the Turnu structure appears as a great uplift made up of three crests trending E—W (the Turnu uplift), of which a northern ramification (Turnu N) develops. The other two uplifts are separated by a fault (Fig. 69). The crests forming the Turnu structure are,

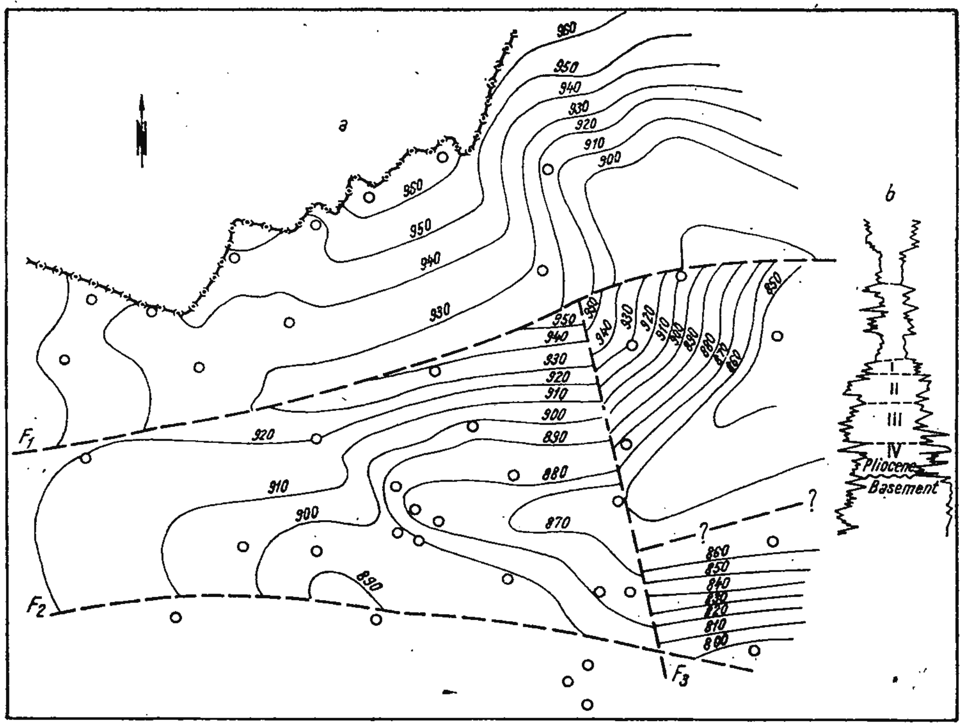

Fig. 69. — Turnu structure.
a, structural image at a guide mark from the Pliocene base ; b, basal Pliocene type profile.

in their turn, crossed by transversal faults whose throw reaches 100 m. Many of these faults seem to check the fluid distribution on the structure.

The wells drilled so far identified hydrocarbon accumulations in the upper altered part of the basement, in the arkosic (Permian?) sandstones and in the first three complexes (I—III) in the Pliocene basal series.

The basement contains petroleum in the block B at the depth of 878—889 m below sea level, and gas in the block C_1 at the depth of 810—

817 m. The productions obtained were of maximum 12 m^3/day oil and 35,600 m^3/day gas for each well. The effective thickness of the hydrocarbon saturated section is of 6—8.5 m, the average porosity of 20 per cent and the connate water saturation of about 50 per cent.

The arkosic sandstones are petroleum productive at Turnu E in the wells nos. 75, 76, 81, 83, 85, 566 etc. that yield 8—38 t/day for each well with rather small G.O.R.

Within the Pliocene, the complex III yielded maximum 10 m^3/day petroleum with 30 per cent impurities from the depth of 856—865 m b.s.l. Its behaviour improves considerably in the western extremity of the structure. The complex II is petroleum saturated (818—846 m b.s.l.), depending on the tectonic block. The complex I, productive between the isobaths —826 and —830 m, contains only free gas. The main productive terms at Turnu are the complex II and, to a certain extent, the complex I. The effective thickness of the Pliocene reservoirs varies between 3 and 6 m for each complex; their porosity is of 3.8—38.1 per cent, the permeability 0—517 mD and the connate water saturation 22.6—53.5 per cent.

The oil is of paraffinic type, with specific gravity of 0.814 kgf/dm^3 and the viscosity of 1.9°E. The gas contains 54—65 per cent methane and 30.8—43 per cent carbon dioxide. The formation waters show mineralizations of 8—14.8 g/l. The iodine is also present reaching 0—5.08 g/l.

The initial pressure was of 970 kgf/cm^2 at the basement level and of 890—940 kgf/cm^2 in the Pliocene. The complexes I and II in the Pliocene are characterized by low pressures (gradient of 7.5 kgf/cm^2/100 m), while the complex III and the basement show higher pressures than the hydrostatic column, which proves that the wells produce formation waters in eruptions. The geothermal step is of about 19 m/°C.

The altered basement may be ranged among the mixed traps and the massive deposits. The arkosic sandstone horizon forms a stratigraphic trap. The Pliocene basal complexes IV and III, which do not cover the whole structure, also constitute stratigraphic traps, while the complexes II and I form structural and, locally, lithological traps.

The Sîntana structure (11, Fig. 64) represents a northern apophysis of the Arad-Turnu uplift that extends northwards, sinking up to the Zarand-Socodor Depression. One of the first wells drilled here contained carbon dioxide in proportion of 94 per cent from the upper altered part of the basement, the daily production being of about 50,000 m^3/day at the depth of 2,147—2,114 m. Another weel drilled later on, about 550 m WSW from the first one, was placed in a compact basement zone, so that it did not produce. But the Neogene, which was crossed on the interval 2,130—2,095 m, yielded unmeasurable quantities of carbon dioxide and small amounts of petroleum and salt water. The oil is of paraffinic type having the specific gravity of 0.833 kgf/dm^3. The yielded gas had the following composition : CO_2—91 per cent, CH_4 — 7.8 per cent, C_2H_6 — 0.3 per cent, C_3H_8 — 0.2 per cent, C_4—C_{10} less than 0.005 per cent and H_2 — 0.2 per cent.

The Sîntana structure ends the group of deposits belonging to the south Banat zone, which is dominated, as could be seen by the accumulations located in the Şandra-Calacea-Teremia-Cherestur and Turnu uplifts. The second group of deposits belonging to the north Criş zone develops from Sîntana northwards, namely from Salonta. They are of much less value and predominantly gas-bearing. Within the northern zone the accumulations forming the Suplacu de Barcău alignment are of greater importance.

The Salonta structural element (12, Fig. 64) represents the eastern pericline of the Sarkadkeresztur structure in Hungary. A well drilled at Salonta contained 38,000 m^3/day gas and 24 m^3/day condens, having pressures of 300/160 kgf/cm^2 from the upper altered part of the metamorphic basement.

The Suplacu de Barcău structure (13, Fig. 64) was pointed out by mappings and core drills. It represents a monocline plunging towards NNW and crossed by a longitudinal (E—W) fault (Fig. 70). The strata show small dips, namely 3—4°. This structure, which is sealed southwards by the Barcău fault, constitutes, in fact, a step of the Plopiş crystalline spur, which is overlain by Neogene deposits in its north-western sinking.

The sedimentary succession consists of Pliocene and, only locally, Sarmatian deposits. The crystalline is overlain by a horizon of gravels and sands in the base ; the thickness of the horizon depends on the shape of the pre-existing relief and may reach 140 m. A predominantly pelite horizon follows ; it consists of clays and marls with fine sand intercalations and, towards the upper part, lignite strata. The sedimentary sequence ends with a packet formed of sands with crossing structure and with marl and clay intercalations.

The reservoir situated at the depth of 80—450 m is represented by the basal gravel and sand horizon, which is protected by the intermediary, predominantly pelite, horizon. The average porosity of the sands is about 28 per cent, the permeability 0.3—3.12 mD and the connate water saturation 18 per cent.

The Suplacu de Barcău deposit contains oil without primary gas cap. The oil, which is oxidated to a great extent, is of *A* type (asphalten), with specific gravity of 0.960 kgf/dm^3 and the viscosity is of 1,900—3,100 cP. As a result of this high viscosity, the deposit could only be commercially exploited by the successful application of the combustion and of the steam cyclic injection.

West of the Suplacu de Barcău deposit, as the basement downdrops and the sedimentary cover gets thicker, three structures were identified at Păţal, Abrămuţ and Sîniob.

The seismic prospections carried out in *the Păţal area* (14, Fig. 64) identified two brachyanticlines within which the Upper Miocene and the Pliocene overlie directly the crystalline schists. A well drilled on the eastern brachyanticline yielded 37,000—240,000 m^3/day gas on a nozzle of 5—22 mm from the Sarmatian (at the depth of 1,276—1,262 m). A second well

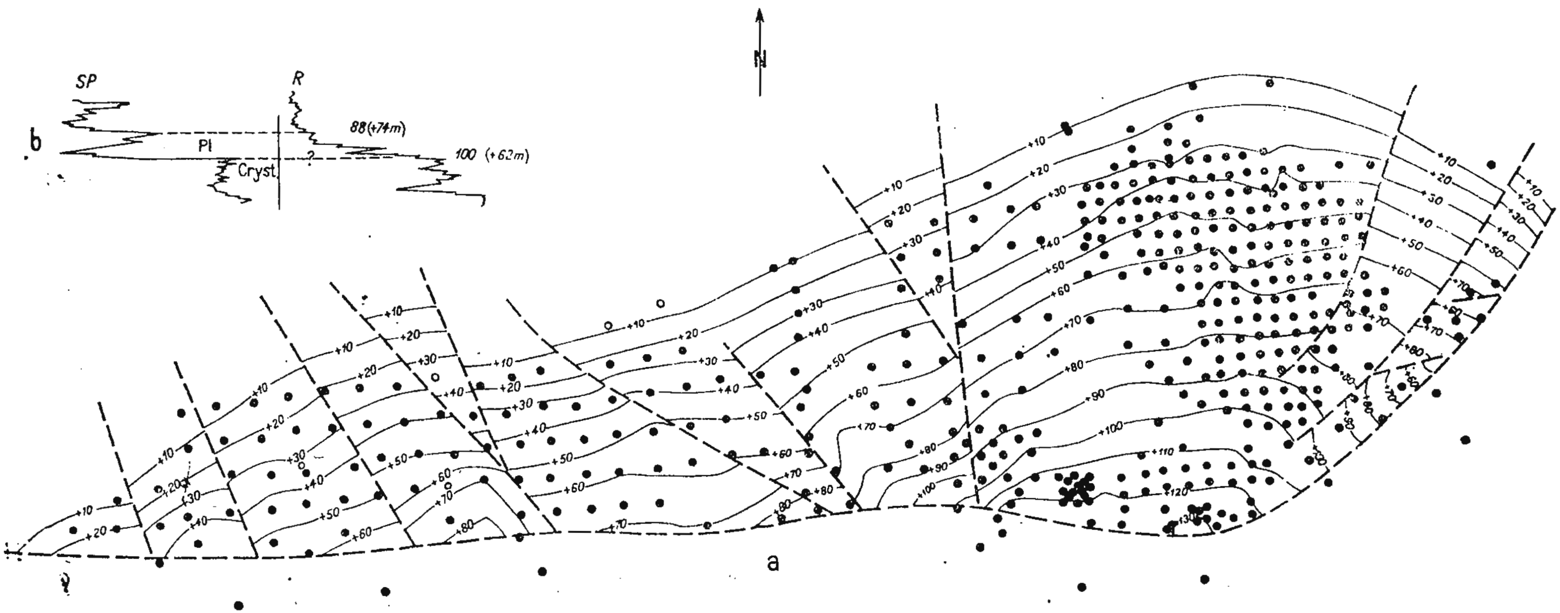

Fig. 70. — Suplacu de Barcău structure.
a, structural map at the Pliocene bottom ; b, basal Pliocene type profile (according to I.C.C.P.G. Cîmpina).

yields about 40 t/day oil from the altered metamorphic basement (1,388–1,328 m).

The Abrămuț structure (15, Fig. 64) could be identified by seismic prospections and deciphered by deep drills afterwards. It appears as a vault trending E–W (Fig. 71). The periclinal extremities of the structure are crossed by faults. The vault amplitude (closing) is of maximum 250 m

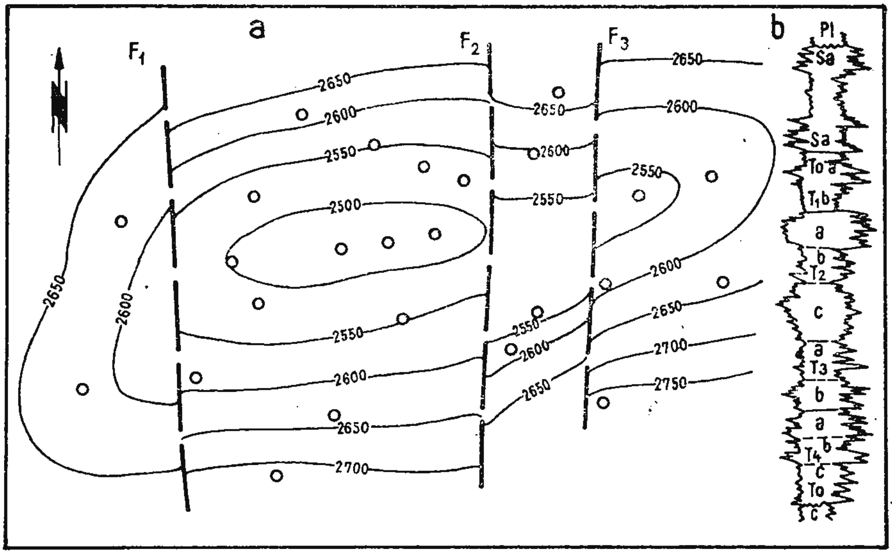

Fig. 71. — Abrămuț structure.
a, structural map at a Tortonian guide mark ; b, Sarmatian and Tortonian type profile (according to I. Bucur).

The deepest wells drilled in the Abrămuț region reached the Cretaceous. They support the Tortonian (about 500 m) made up of predominantly gritty deposits with clay and tuff intercalations. The Tortonian is overlain by the Pliocene consisting of a lower marly horizon with gritty banks and sands and of an upper, predominantly psamite horizon. The Miocene series might also include the Lower Sarmatian, which is represented by a succession of marls and sandstones reaching 200–240 m in thickness.

The Tortonian constitutes the productive formation by its marly sandstone horizons, while the protective cover is constituted by the Sarmatian (?) and basal Pliocene marly-gritty horizons. The Tortonian with sandstones was separated into four complexes named, from top to bottom, T_1–T_4, each complex, in its turn, consisting of two or three members (*a*, *b* and, sometimes, *c*). The hydrocarbons are found at the depth of 2,550–2,750 m, as follows : oil with great gas ratio — T_4b, T_3a_4, T_3a_2, T_2c ; gas with condens — T_4a, T_3b, T_3a_3, T_3a, T_2c. The packet T_3b seems to be the most important productive term, being followed by T_3a and T_4a. The data available so far indicate that the sanstone packets are hydrodynamically separated. Considering the important permeability variations of the Tortonian reservoirs the trap is of structural type, with strong lithological influences.

The Abrămuţ deposit is characterized by relatively small petroleum productions, with great gas ratio. This output as well as the pressures decrease within a short period of time. The initial fluid hydrocarbon production per well was 1—40 m³/day with gas ratio of 500—10,000 Nm³/m³.

The initial reservoir pressure was of 310—322 kgf/cm², a gradient of 11.66 kgf/cm²/100 m resulting. The thermal gradient is of 4.5°C/100 m. The saturation pressure is 250—310 kgf/cm², the differential pressures are 15—250 kgf/cm². The reservoir average porosity is of 11.3 per cent, the absolute permeability of 12 mD, the connate water saturation 47 per cent. The oil is of paraffinic type, with the specific gravity of 0.824—0.830 kgf/dm³. The condens specific gravity is of 0.770 kgf/dm³. The reservoir energy is due to the solution gas expansion and the gas cap detente is also present in the complexes T_3a_4 and T_3a_2.

The Sîniob structure (16, Fig. 64) lies south of Abrămuţ and probably belongs to a tectonic compartment of the same major structure. The seismic prospections and the exploration wells pointed out a monocline here, with the dip north-westwards, divided by two longitudinal faults into three step blocks. The stratigraphic succession and the productive formation are the same as those at Abrămuţ. Very poor oil productions (1—8 m³/day) and gas were obtained at the depth of 2,228—2,330 m, thus indicating the bad properties of the reservoir rocks. The behaviour and low petroleum potential of the deposit do not make the continuation of the research necessary in the region.

The Borş structural zone (17, Fig. 64) represents an ensemble consisting of at least three blocks pointed out by the dip drills after the seismic prospection indications.

The geological sequence consists of the crystalline schist basement, the Triassic, the Lower Cretaceous and the Senonian, the Miocene (Tortonian and Sarmatian) and the Pliocene.

Hydrocarbon accumulations were found in the Tortonian which, from a lithofacial viewpoint, consists of two horizons : a lower gritty one, microconglomerate, marno-limestone and marl intercalations and an upper marly one. Four complexes, numbered, from top to bottom, I—IV, were separated within the lower horizon.

Petroleum output was also obtained in three blocks from all the four complexes, at the depth of 2,500—2,900 m. But the productions are small, varying between several hundred litres per day and 20 m³/day and decrease in a very short period of time. At present, none of the about 20 wells drilled has a production over 3 t/day. This behaviour of the wells is due to the extremely reduced permeability, generally below 2 mD.

The Mihai Bravu structure (18, Fig. 64) corresponds to the flank of an uplift which develops in the Romanian-Hungarian frontier zone. This uplift falls by steps eastwards, along some faults trending NE—SW. The faults dividing the Mihai Bravu pericline seem to screen the structure.

The basement, intercepted by wells, is overlain by either Triassic or Miocene or, sometimes, even Pliocene deposits.

The productive formation is represented by the Miocene. The latter consists of microconglomerates with clayey cement, marno-limestones and gritty clays. The Miocene deposits at Mihai Bravu belong to the Sarmatian, with the exception of two wells (1021 and 4038) where the Tortonian was identified, and are 90—720 m in thickness. The reservoir rocks of interest are grouped into two complexes corresponding to the Miocene basal and terminal parts. 3.5—8 m^3 liquid hydrocarbons and about 22,000 m^3 gas were obtained from these complexes at the depth of 1,970—2,080 m at the well no. 4013. The second well (603) yielded 12.5 m^3/day oil with 30—40 per cent impurities. The research of the zone continues.

The Ciocaia structure (19, Fig. 64) lies west of the structural elements at Abrămuţ and Sîniob. It was pointed out by seismic prospections and drilling.

Some of the wells drilled at Ciocaia reached the crystalline basement which is overlain by the Miocene. One well also crossed the Cretaceous (500 m) consisting of sandstones, clays, and blackish marno-limestones. The Miocene, represented by the Tortonian and the Sarmatian consists of conglomerates, sandstones, and marl and marno-limestone intercalations that reach 120—360 m in thickness. Locally, the sandstone and conglomerate banks were grouped into 5 complexes numbered from top to bottom, I—V. The Pliocene shows the same composition as throughout the depression, that is, a lower predominantly pelite series and an upper, predominantly gritty-sandy one.

The Ciocaia structure respresents an ensemble of four tectonic blocks of which those in the south-east sector are lower and those in the north west sector are about 300 m raised.

The hydrocarbons are located in the crystalline basement upper part (gas), in the Miocene (liquid and gaseous hydrocarbons) and in the sandy intercalations in the Pliocene lower part (liquid and gaseous hydrocarbons). The liquid hydrocarbon production was of 5·7—14 m^3/day with the gas ratio of 1,500—3,000 N m^3/m^3 in the Miocene (depth 2,640—2,830 m) and of 0.7—1·5 m^3/day with 30,000—45,000 m^3 gas (carbon dioxide) in the Pliocene. One of the Pliocene upper horizons (1,710—1,728) produced 60,000 m^3/day pure CO_2 (99 %). The Miocene accumulation seems to be a gas deposit with condens, which should be checked. The presence of the carbon dioxide in the Pliocene is probably connected with a deep fracture that affects the region.

North of Mihai Bravu and in the vicinity of the Ciocaia deposit lies the *Săcueni structure* (20, Fig. 64) that is dome shaped and extends westwards, on the territory of the Hungarian People's Republic.

The basement is directly overlain by the Miocene (Tortonian and Sarmatian) consisting of tuffs, conglomerates and sandstones and, then, by the Pliocene, in front of this structure. Within the predominantly pelite Pliocene base series one can distinguish two sandy complexes (I and II), separable into groups of two and three members that contain gas on the structure. The complex II (lower) with depths of 1,725–1,760 m had productions of 1,100—3,300 m^3 gas and 600—900 l condens/day and the complex I (upper), 55,000—88,000 m^3 gas and 14,500 l condens/day.

Another productive echelon, predominantly gas-bearing structures, comprising the deposits at Pișcolț, Carei, Moftinu, and Mădăraș, can be distinguished north of Secueni. The Curtuiușeni structure adds to them.

The Pișcolț structure (21, Fig. 64) is domeshaped, seismicaly determined and confirmed by drilling. This structure is faulted in its eastern pericline zone. The dips of the strata are of 2—5° in the Pliocene and increase to 60° in the Eocene (Fig. 72).

The wells drilled in the region reached the crystalline schist basement, overlain by Cretaceous and, then, by Eocene deposits. The Miocene (Tortonian and Sarmatian) that follows consists of Dacitic tuffs, sandstones, sands and marls. The Pliocene lower part contains more sand than the previous structures.

The productive units are represented by the Tortonian three horizons (well 704), the Sarmatian — a horizon (wells 702, 704, 4017) and the Oligocene — three horizons. As a result of the facies variation in the Miocene and Pliocene mixed traps are also present beside the structural traps.

The reservoirs are about 55 m in thickness in the Miocene and 4—9·5 m (each productive term), in the Pliocene. The porosity is 25 — 27 per cent and the connate water saturation is 65—69 per cent. The gradient of pressure reaches 11.4 $kgf/cm^2/100$ m and the geothermal step, 19—22 m/°C. The seven gas saturated reservoirs seem to constitute separate hydrodynamic units.

The Curtuiușeni structure (22 Fig. 64), which is a brachyanticline with the northern flank more developed, lies west of the above mentioned dome. The Tortonian and the Sarmatian were productive on this structure. The first term produced (at well 780) 7—9 m^3/day oil and 53,00 m^3/day gas, with salt water. The upper Sarmatian part had gas at three wells, between the depth of 1,189 m and 1,166 m. The productions were of 50,000—75,000 m^3/day, the pressure 99/110 kgf/cm^2.

The Carei deposit (23, fig. 64) is located in a faulted brachyanticline structure. The wells drilled here crossed a sequence of Cretaceous, Eocene and Neogene deposits. Among these, the Pliocene yielded gas with productions of 28,000—30,000 m^3/day at the depth of 664—638 m. The pressures recorded were of 65 kgf/cm^2. Other Neogene units on the structure contain thermal waters that are object of exploitation.

The Mădăraș structure (24, Fig.64) was identified by seismic prospections and core drills. It is situated on the western, sunk prolongation of the Bîcu crystalline which is overlain by Miocene and Pliocene deposits.

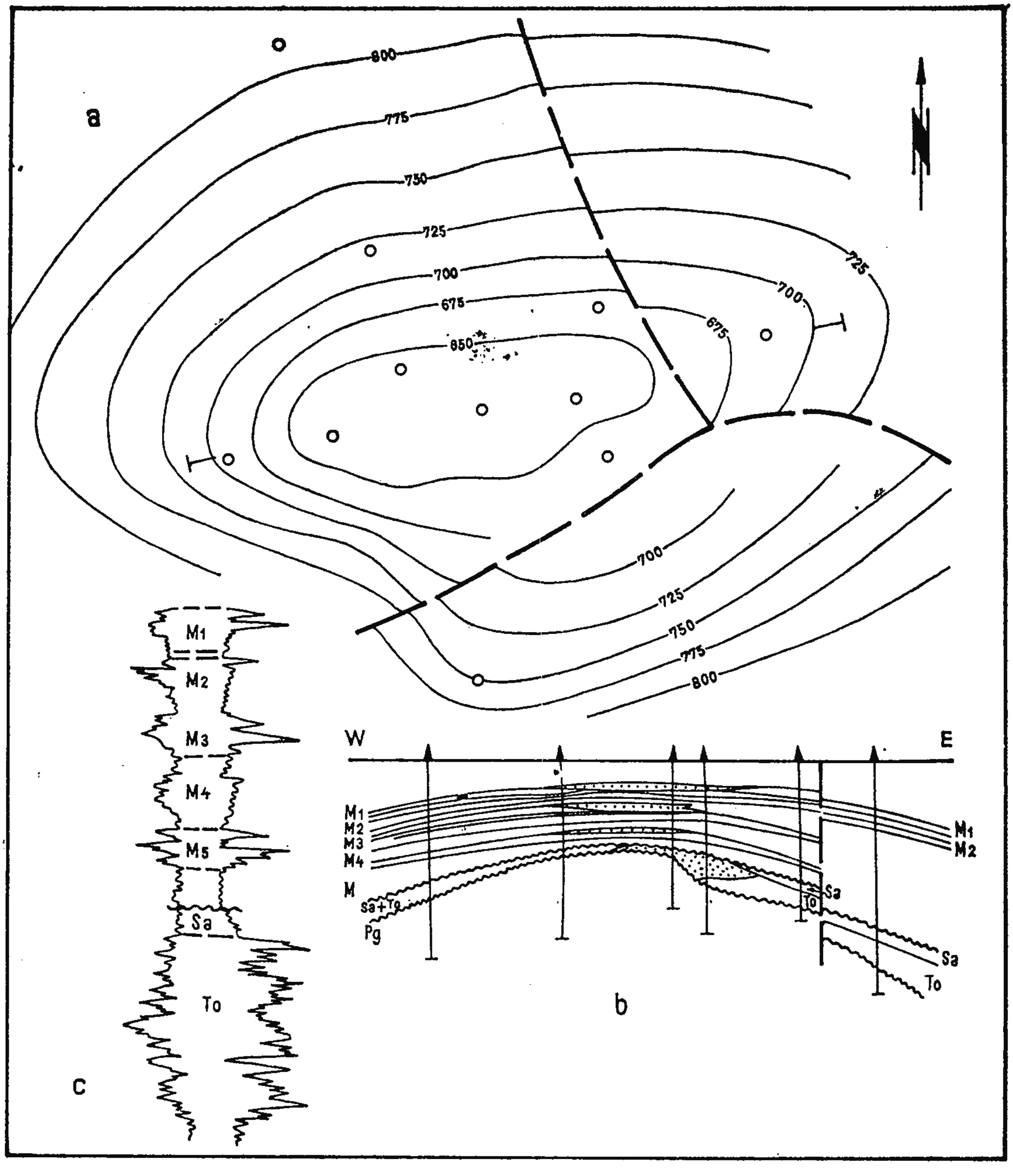

Fig. 72. — Pișcolț structure.
a, structural image at a level of the Pliocene base ; b, geological section in the central zone of the structure ; c, basal Pliocene and Miocene type profile (according to L. P o n t a).

In its sinking, the basement surface shows a series of structural details, including the compartments delimited by faults, which are also reflected in the sedimentary cover. The positive forms of the basement relief are overlain, as a rule, directly by the Pliocene. The Sarmatian and, then, the Tortonian are also present in the sunk pericline sectors. The Tortonian can reach 60 m in thickness, consisting of marly sandstones, gritty limestones, clays and tuffs. One of the Tortonian sandstone banks, 10—15 m in thickness, contained oil in two wells at Mădăraş. The Sarmatian consists of marly sandstones, clays and gritty limestones reaching maximum 235 m. A Sarmatian sandstone packet also produced gas, in the well 219. The Pliocene develops in its classic form.

Well No. 9 Mădăraş started with 29 t/day oil and, after producing 273 t, the production decreased to 1 t/day, proving that the reservoir has low permeabilities. The Sarmatian, with gas, had 12,000 — 23,000 m^3/day, the production and the pressures recording continual decreases.

A more raised tectonic block can be distinguished in the vicinity of *the Moftinu locality* (25, Fig. 64), west of Mădăraş, against the same descending background of the Bîcu crest. A well drilled here produced 17,000 m^3/day gas, from the basal Pliocene horizon, at the depth of 773—778 m. Later on, three more wells were drilled, that did not yield hydrocarbons, being placed under different structural conditions.

Asphalt deposits at *Derna-Tătăruş*, have been known and exploited in the northern part of the Pannonian Depression for a long time. They are located in the Pliocene sands that outcrop in the vicinity of the western end of the crystalline island in the Plopiş Mountains.

Apart from the oil and gas accumulations presented above, hydrocarbon traces were also pointed out on other structures of the Pannonian Depression, both in the south and north regions.

VII. MOLDAVIAN PLATFORM

The Moldavian Platform is, in fact, the western prolongation of the East-European Platform on the Romanian territory. The western boundary of the Moldavian Platform was conventionally established on the Pericarpathian fault, along which the folded flysch and foredeep formations come into contact with the foreland quasi-horizontal deposits. As a matter of fact, the pre-Sarmatian cover, together with the platform basement extend also beyond (west) the Pericarpathian fault, tectonically underlying the Carpathian Foredeep lower molasse and the East Carpathian flysch deposits. The southern conventional boundary is the line S Bacău-Găiceana-Glăvăneşti-Bîrlad-Murgeni marked by a system of faults, although the basement and the sedimentary cover, which are characteristic of the Moldavian Platform, extend south of this line, constituting the external flank of the Predobrogean Depression.

The territory of the Moldavian Platform was the object of some reconnaissance, semidetailed and detailed mappings throughout the zones with natural outcrops.

Gravimetric prospections covered the whole area, a research network with a density of 1 point at 5 km². The density is more than 1 point/km² on a perimeter of about 1,800 km².

The magnetometric prospections were carried out throughout the platform with an average density of 1 point per 5 km². The density was 1 point/km² on 70 per cent of the area.

The electrometry, by the vertical electric sounding method, covered about 5,000 km², to a semidetail degree (1 point/6 km²).

Seismic prospectings were carried out on almost 11,000 km² corresponding to the zones of interest for hydrocarbons. The density of the profiles was 0.1 km profile/3 km² on about 7,350 km², and 1.06 km profile/km² on about 3,600 km².

The Moldavian Platform was investigated by over 700 core drills and by wells of medium and great depth that reached maximum 4,513 m.

1. Stratigraphic and Lithologic Peculiarities of the Sedimentary Cover

The Moldavian Platform basement is conceived by the present paper as heterogeneous, belonging to two great domains. One situated east of the Rădăuți-Bacău-Adjud line, represented by Precambrian metamorphosed rocks, namely, paragneisses, ocular gneisses, mica schists, granites (Todireni); a western domain with greenschists, found at Bacău, Tîrgu Neamț and on the Soviet territory, at Hodnovici, Mostiska and Pîneana (Paraschiv and Paraschiv, 1978). Tectonic relationships are likely to exist between these two domains, the greenschists overthrusting the metamorphic basement and some of the old East-European Platform sedimentary deposits.

This presumed overthrust line generally corresponding to the Siret Valley, is suggested by a zone of strong gradient on the gravimetric map, by the results of the seismic prospections, by the Silurian facial features and by the continual decrease of the geothermal step (from 30 m/°C to 21 m/°C) in the wells of the Roman-Secueni gas-bearing field, as the distance from the Pericarpathian region increases eastwards.

The sedimentary cover of the region between the Prut and the Pericarpathian fault differs to a certain extent in point of succession and thickness, according to the basement it overlies. In the eastern domain, the succession starts with detrital deposits representing the terminal Precambrian, the Lower Cambrian and the Upper Ordovician; but the oldest term proved in the greenschists zone is the Silurian, the existence of the Cambrian being also possible.

The succession of pre-Silurian deposits consists of blackish-clayey schists and grey or reddish, partially clayey, hard sandstones which are 500—600 m in thickness (at Iași). The paleontological studies (Iliescu, 1974; Patrulius, Iordan, 1974) indicate an age previous to the Upper Ordovician for most of these deposits, within which the presence of some bituminous schists should be mentioned.

The Silurian, represented by the Wenlockian and Ludlovian, varies between 0 m and 1,230 m in thickness (Rădăuți) and overlies two relatively distinct facies. It is made up of limestones with limy and clayey sandstone intercalations, quartz sandstones and hard clayey schists in the eastern Epialgomian sector (Săndulescu, 1974). The Silurian resembles the facies of the clays and the schists with graptolithes, becoming more clayey and bituminous in the western Epibaikalian sector (D. Paraschiv, Muțiu, 1973). Locally, the sedimentary cycle in the Silurian continues to the Eodevonian, represented by subcontinental and continental deposits of the Old Red Sandstone type.

The Middle Devonian consisting of russet and grey sandstones or limestones, over 200 m in thickness, was found on the west side (Tg. Neamț, Bodești, Bacău, Roman).

The Carboniferous is present on the same downdropped zones of the platform in front of the foredeep. It consists of quartz and marno-clayey sandstones and limy sands. The microfauna determined in the Roman-Bacău zone seems to resemble that of the Culm facies.

The Mesozoic starts with marno-limestones, limestones, limy sandstones and Middle Jurassic siliceous sandstones; it continues with marno-limestones, brick-red breccious conglomerates, Upper Jurassic cherry-coloured compact clays and marls with anhydrite elements; marno-limestones, chalky marls with flint concretions, glauconitic-Cretaceous limestones and marly-limestones, representing the Cenomanian. The latter covers almost the whole platform, like a plate. The Lower Cretaceous or the Turonian-Senonian are also found locally. The Jurassic deposits were pointed out only on the west and south sides of the respective units.

The Eocene covers transgressively the Cretaceous and was generally preserved as patches.

The Tortonian overlies directly the Eocene, the Cretaceous and, sometimes, the Paleozoic. It outcrops in the bank of the Prut but it was also found in wells almost throughout the platform with thicknesses reaching 400 m. From a lithofacial viewpoint, the Tortonian undergoes many variations. In the north-eastern part of Moldavia, it consists of prevailingly reefal limestones with *Lithothamnium* and, locally, gypsum. The Tortonian, 20—30 km in width, consists of marno-limestones, sandstones and sands south of Ștefănești, along the Prut Valley. This stratigraphic term in the other parts of the platform consists of a complex of anhydrites and tuffs placed between a supraanhydrite-predominantly marly (the marls with *Spiratella*) complex and an infraanhydrite complex, represented by an alternation of sandstones, sands, marls and even limestones. The latter complex, studied thoroughly, was divided into several horizons (infra C, C, B, A, A_1 and A_2), in the zone of maximum development, as it is of interest for hydrocarbons. The respective terms do not show a uniform distribution, their limits reflecting the shore line variation. Among them, the C horizon seems to have the greatest extension.

The Buglovian consists of marly sandstones, marls and cavernous fossiliferous limestones and marls. The Sarmatian consists of the Volhynian, Kersonian and Bessarabian substages that occur successively, according to their age, north-southwards, reaching about 3,000 m in thickness on the downdropped sides of the platform. In general, the Sarmatian consists of a lower, predominantly marly sequence with sand intercalations and an upper-sandy-gritty sequence that, sometimes, overlies unconformably the former. The latter sequence outcrops within the platform and is not of interest for hydrocarbons.

The Meotian outcrops north of Bîrlad town, while it was identified by drillings farther south, under the Levantine and Dacian deposits.

Of the above presented succession, the Tortonian and Sarmatian deposits proved of interest for hydrocarbons.

2. General Characteristics of the Structure

The Moldavian Platform is, on the whole, a vast monocline that sinks by steps westwards and southwards, in front of the two depressive zones (the Carpathian Foredeep and the Predobrogean Depression). The fall by steps takes place along some regional tectonic accidents (Fig. 73), whose throw varies between 20 and 1,200 m.

Against the general westward and southward plunging background, various structural details, such as slight vaultings, hemianticlines and hemisynclines, promontories appear ; they are more frequent in the Neogene than in the Mesozoic. Most of them must represent shrinkage structures generated by the sunk paleoreliefs. Secondary faults with different trendings, which delimit numerous tectonic blocks, can also be distinguished within the platform steps.

The platform deposits come into contact with the foredeep formations in the western part, at the Neogene level, along the Pericarpathian line. As has been already mentioned, the platform deposits continue also beyond this overthrust line; they are suggested by seismic prospections and by wells, within a width of 5—20 km (Plate II).

3. Geological Evolution of the Moldavian Platform

The unitarian evolution of the Moldavian Platform territory, such as it was described in the present paper, began after the Ardenian diastrophism when oscillating movements took place; their amplitude and trend could differ within the platform, considering the block structure characterizing it.

Since the Cambrian, the territory corresponding to the Moldavian Platform has functioned alternatively, especially as land and, less, as sedimentary basin; this is proved by the incomplete succession and the relatively reduced thickness of the deposits overlying the basement. When it became a sedimentary basin, the depth of the waters was rather small.

During the Lower Paleozoic, the west platform side seems to have acted more like an uplifted zone, with the exception of the Rădăuţi region.

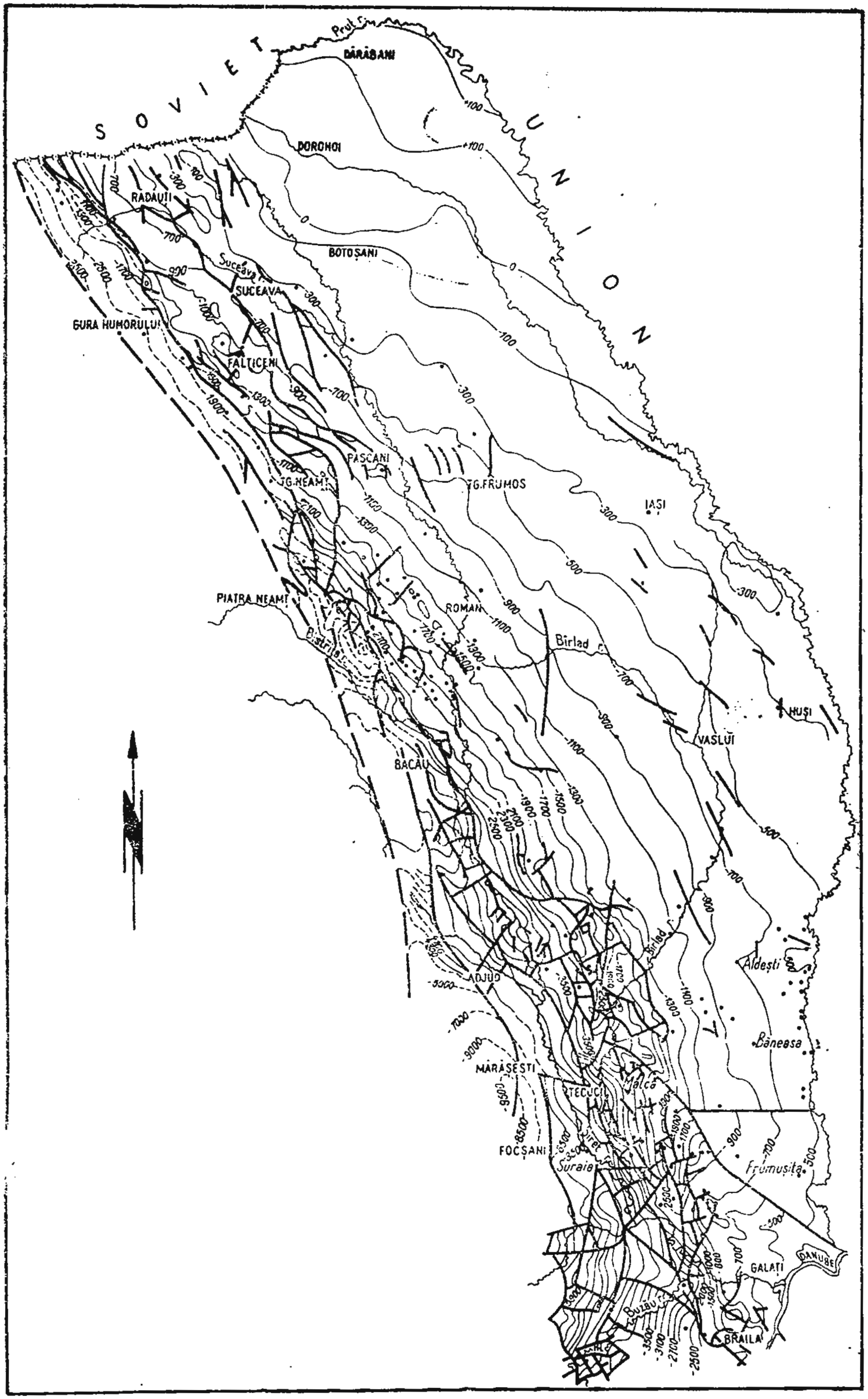

Fig. 73 — Structural map of the Moldavian Platform, North-Dobrogean Promontory and the Bîrlad Depression at a guide mark from the Tortonian bottom (according to I.C.P.P.G.).

From the Devonian (after the Caledonian movements) to the Sarmatian, the west and south sides underwent stronger vertical negative movements; this fact is reflected in the deposition of some supplementary stratigraphic terms (the Devonian, Carboniferous, Jurassic, Eocene) with greater thicknesses (especially the Neogene). This phenomenon could be connected with the formation of the adjacent depressive zones (the Carpathian Foredeep and the Predobrogean Depression) and to their migration towards the exterior.

The numerous and long denudation phases, that determined the partial removal of the sedimentary cover, did not favour the hydrocarbon deposit formation and preservation. That is why, from the geological evolution viewpoint (this fact was confirmed by the results obtained) only the lower platform side, which sank more, showed better conditions; it represents a more active sedimentary zone, favouring the facies variations and at the same time underwent oscillating movements of great amplitude which entailed various trap conditions.

4. Conditions of Genesis, Accumulation and Preservation of Hydrocarbons

In spite of the relatively calm tectonic regime marking the Moldavian Platform, an alternation of rocks that may function as reservoirs, protective screens and hydrocarbon source, is found in the sedimentary stratigraphic succession.

Reservoir rocks, with regional or local development, are found from the Vendian to the Sarmatian. To this category also belong the Vendian, Cambrian and Ordovician sandstones and quartzites, protected either by the clayey schist intercalations proper to the respective series or by the Silurian clays and marno-limestones. The Cambrian and Ordovician sandstones and quartzites are diagenized and compact enough so that the improvement of the reservoir rock properties depends on the fissuring degree which is quite variable. The Devonian sandstones and the Carboniferous psamitic intercalations are worth considering, but only on very restricted zones, according to their distribution area and the poor protection conditions. The carbonate deposits and the sandstone members belonging to the Jurassic and the Cretaceous might have the same local importance. The Tortonian constitutes one of the main platform reservoirs by the sandstones in the infraanhydrite complex, overlying unconformably the various Eocene, Cretaceous, Jurassic and Paleozoic terms. These sandstones have porosities of 2.7 – 14 per cent and permeabilities of 0.15 – 50 mD. Although they do not show a regional spread as the Tortonian deposits, the basal Sarmatian sandstones and sands can be taken into account. They have porosities of 2 – 20 per cent and permeabilities of 0 – 100 mD.

Since there are no special studies on the petroleum potential, the petrographic composition, the bituminous character and the colour of the sedimentary deposits have been taken into account when supporting such views. Taking into consideration such criteria, the Vendian and Cambrian clayey schist intercalations, the Silurian clays and marno-limestones, the clay and marno-limy intercalations in the infraanhydrite series, as well as the Tortonian supraanhydrite marly series, the Sarmatian clays, marls and gritty marls could be considered as possibly hydrocarbon source rocks. These lithological terms, in their turn, may constitute also protective screens by their pelite and compact character.

The paleotemperatures played a most important part in the hydrocarbon genesis, migration and accumulation. From this point of view, the platform west and south side seems to be more favoured because it sank more, on the one hand, and because the geothermal gradient increases, as has been mentioned, being 3—4°/100 m, on the other hand. Taking into account the age, thickness and depth of the sedimentary deposits and judging by the paleotemperatures the Neogene is expected to have generated only gas. Liquid hydrocarbons might be found at much greater depths, in the sectors overlain by the foredeep molasse and flysch deposits. On the other hand, taking into consideration the temperature-time relation, the Paleozoic and, possibly, the Mesozoic formations might have generated oil, eventually gas and condens.

The potential and characteristics of the aquiferous in the Moldavian Platform reservoirs were less checked and studied. In the light of the data obtained, the succession of Vendian, Cambrian and Ordovician deposits is characterized by waters with hydrodynamically stabilized regime, of the $CaCl_2$ type with mineralizations that reach 105 g/l. Sometimes they contain iodine to 4.2 g/l and bromine to 210 mg/l. The Cretaceous contains, as a rule, sodium hydrocarbonate and sodium sulphate waters with reduced mineralizations of 8—28 g/l. In the Tortonian and Sarmatian, the waters vary, sometimes, within short distances, from sodium sulphate and sodium bicarbonate to chloromagnesian and chlorocalcic waters. The rather variable mineralization shows the average values of 37—77 g/l. The maximum values can reach 110 g/l. In general the mineralizations decrease from bottom to top, that is, in the same sense that the passage from the chlorocalcic and chloromagnesian to the sodium bicarbonate waters is achieved. One can note the existence in variable proportions of the iodine (19—29 mg/l), bromine (10—34 mg/l) and ammonium (50—120 mg/l). Only traces of naphtenic acids were noticed.

5. **Hydrocarbon Deposits**

Hydrocarbons were found in the Moldavian Platform only in the Tortonian and Sarmatian. These accumulations are located on the western downdropped side, which, sometimes, lies under the overthrust of the Carpathian units. The Tortonian accumulations are located, as a rule, in structural traps of the faulted monocline type. The Sarmatian accumulations lie in mixed traps with a well marked lithological (lenticular) character. Excepting the Roman-Secueni productive zone (Sarmatian) with a discontinuous development covering a considerable area, the other accumulations are of small to very small dimensions and values.

Hydrocarbon accumulations at the Tortonian level are found at Frasin-Gura Humorului, Mălini and Cuejdiu; the Sarmatian, exclusively gas-bearing, is productive in the Valea Seacă, Roman-Secueni and Bacău zones (Fig. 74).

The Frasin-Gura Humorului zone (1, Fig. 74) belongs to a Moldavian Platform sunk step, overlain by the Lower Miocene molasse and the Paleogene flysch deposits which are disposed in nappe. The structure

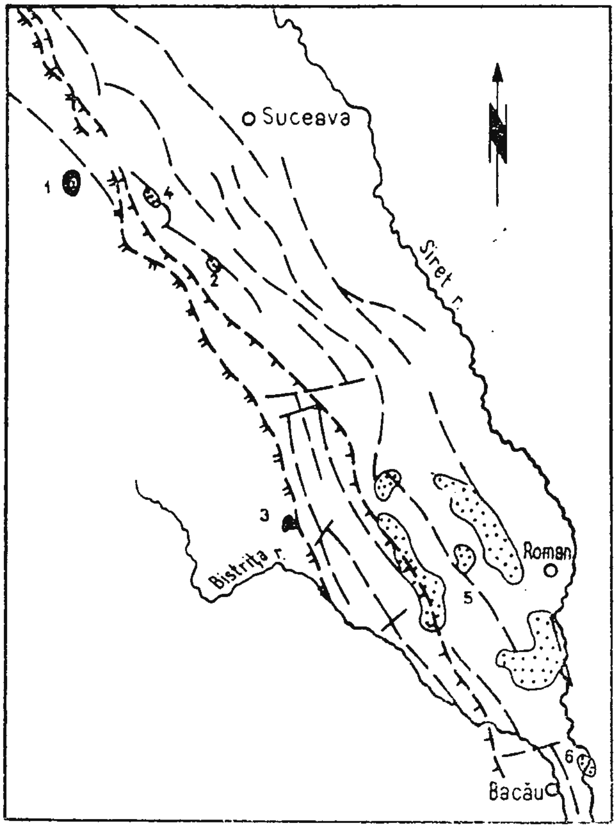

Fig. 74. — Distribution of the hydrocarbon deposits in the Moldavian Platform.
1, Frasin; 2, Mălini; 3, Cuejd; 4, Valea Seacă; 5, Roman-Secueni; 6, Bacău.

represents a monocline, with the westward dipping strata, crossed by faults and divided into blocks (Fig. 75). This structure could be identified by seismic prospections, the anhydrite horizon constituting a characteristic key mark. Later on, the structural image was defined more accurately by deep wells.

From the Lower Miocene folded and overlapped molasse, the wells at Frasin-Gura Humorului crossed the Tortonian, 150—180m thick, that, in its turn, overlies the Upper Cretaceous (probably Campanian). The Tortonian starts with the detrital infraanhydrite complex (about 130 m in thickness) made up of sandstones grouped into three members (*A*, *B*

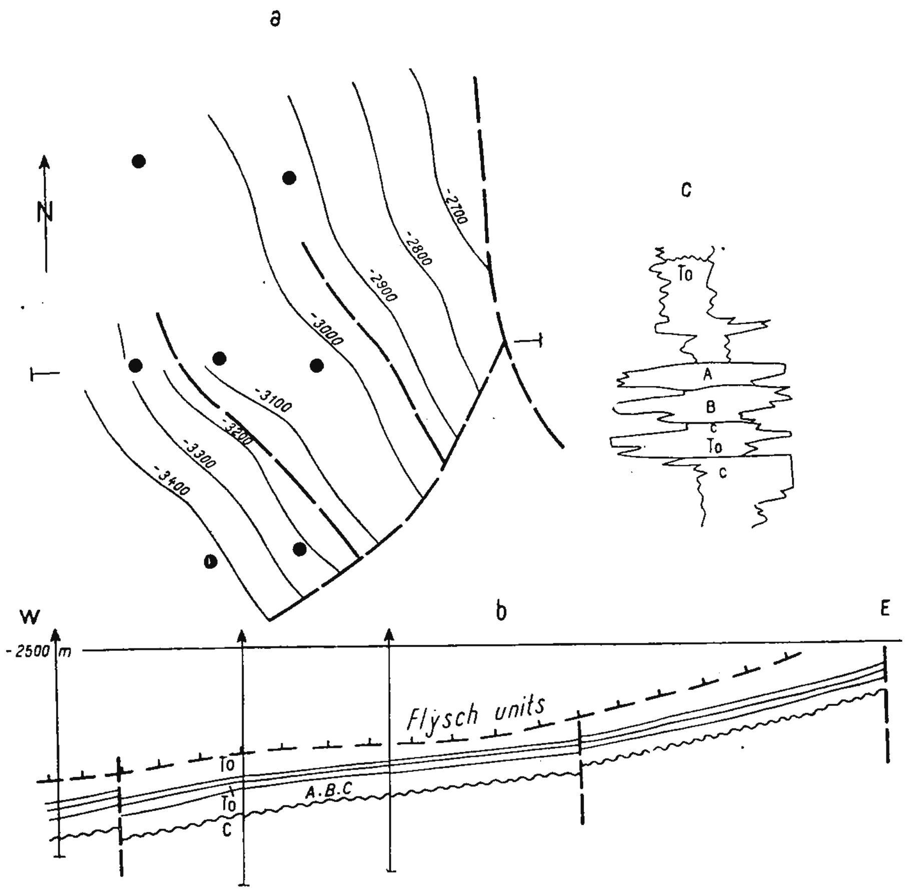

Fig. 75. — Frasin-Gura Humorului zone.
a, structural map at a Tortonian guide mark; b, geological cross section; c, Tortonian type profile (according to C. Paraschiv).

and *C*). The latter are separated by marly intercalations that are 8—10 m in thickness. The lower detrital complex is protected by the anhydrite horizon whose tickness varies between 14 and 25 m. The anhydrites are followed by the complex of marls with *Spiratella* that ends the section of the platform deposits.

The hydrocarbons accumulated in the horizons *A* and *B*, as the term *C* is water saturated. The depth of the productive horizons is between about 3,400 and 3,920 m. The results of the flow tests suggest that the horizons *A* and *B* constitute separate hydrodynamic units. At one well (915), the stratum *A* produced 34 m^3/day fluid hydrocarbons (condens) and 89,000 m^3/day gas, and the stratum *B* produced 33 m^3/day fluid hydrocarbons (condens) and 135,000 m^3/day gas.

The reservoirs are effectively saturated within a thickness of 8—20 m ; their porosity is of 12—14 per cent and the permeability is of 0.15—0.83 mD. The liquid flow towards the bore might be due to the fissure permeability. The density of the liquid hydrocarbons, varies between 0.775 and 0.800 kgf/dm^3. The deposit pressure (about 315 kgf/cm^2) is below the hydrostatic column pressure.

The Mălini structure (2, Fig. 74) is also situated on the Moldavian Platform west side, but on a higher step, outside the Pericarpathian line. It is like a faulted structural spur appearing against the general dipping background in front of the Carpathians. This structure was identified by seismic prospections.

The stratigraphic succession is identical with that on almost the whole structure, namely, the Cretaceous is overlain by the Tortonian which, in its turn, underlies the Sarmatian. The Tortonian comprises all its three terms, that is, the infraanhydrite complex with the horizons *A*, *B* and *C*, the anhydrites and the marls with *Spiratella*, supraanhydrite complex (Fig. 76).

The hydrocarbons are located in the members *A* and *B*, which constitute structural traps of the faulted monocline type.

The only well that yielded (115 Mălini) had 140,000 m^3/day gas with 0.65 m^3/day condens from the horizon *A*, (2,163—2,172 m) and 104,000 m^3/day gas with 4 m^3/day condens and 12 m^3/day salt water from the horizon *B* (2,177—2,190 m). The condens specific gravity is 0.777 kgf/dm^3. There were other three dry development wells.

The Cuejdiu structure (3, Fig. 74) in the vicinity of the Piatra Neamț town, corresponds to a platform sunk step, overthrust by the Miocene molasse and the Paleogene flysch. Fragments of a hemianticline at the level of the foreland Miocene deposits appear within this step crossed by secondary faults.

Oil traces in the infraanhydrite complex were identified in the first well drilled at Cuejdiu (4504). The anhydrite complex and, probably, a part of the horizon *A* (at the depth of 4,479—4,519 m) yielded about 4,000 l salt water with 43 per cent oil.

Among the deposits located in the Sarmatian, the northernmost belongs to the *Valea Seacă structure* (4, Fig. 74). This structure represents a monocline with a western dipping of the strata, faulted by the major Păltinoasa-Mălini accident. The dip of the Sarmatian deposits is of about 4°.

The gas accumulations are located in the base of the Sarmatian predominantly pelitic series, divided into five horizons (*A*—*E*) of which only the horizon *B* proved productive by its members I, II, III and IV. The depth of the productive strata varies between 1,818 and 1,986 m. Each complex seems to constitute a separate hydrodynamic unit. The traps are of structural (faulted monocline) and mixed (lithological-structural) type.

The reservoir consists of limy sandstones and gritty marls, with average porosity of about 20 per cent, permeability of 0.3—81.6 mD and

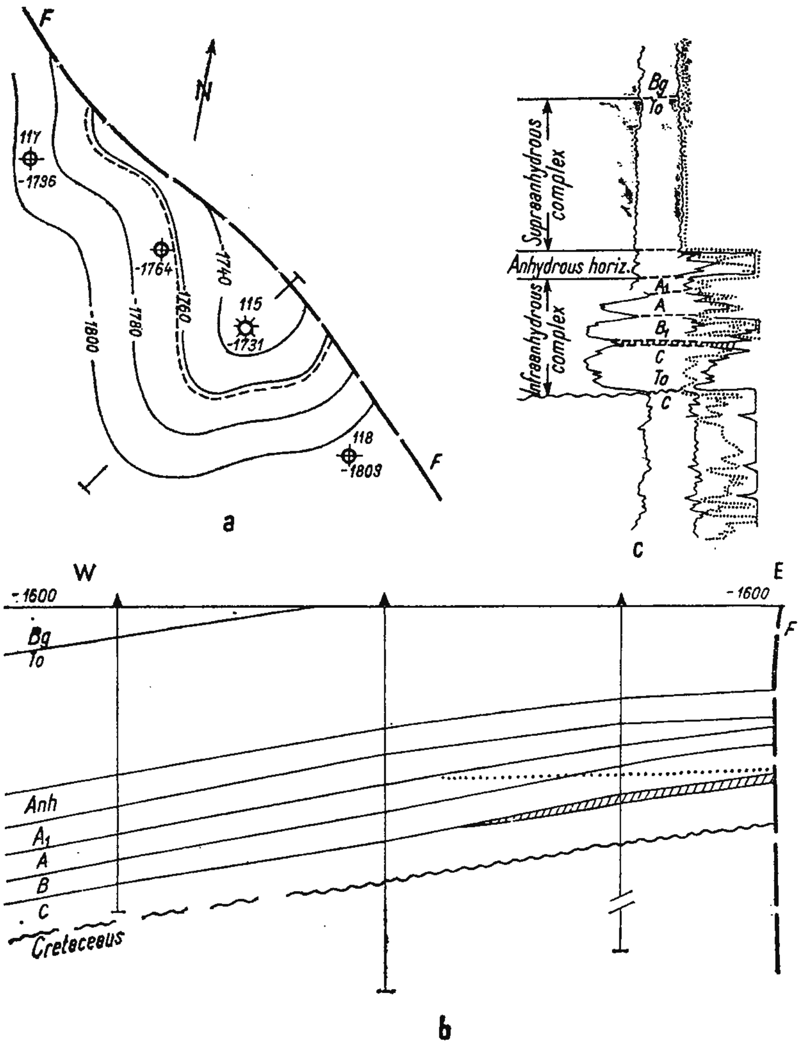

Fig. 76. — Mălini structure.
a, structural map at a Tortonian guide mark ; b, geological cross section ; c, Tortonian type profile (according to C. Paraschiv).

the connate water saturation of 40 per cent. The gas productions obtained per well were of 18,000—71,000 m³/day. They contain methane in proportion of 95.6—98.9 per cent. The initial reservoir pressure is of 200—210 kgf/cm² and the geothermal gradient is of 2.9°C/100 m.

The gas-bearing Roman-Secueni zone (5, Fig. 74), which is the most important one in Moldavia, represents, from the structural point of view,

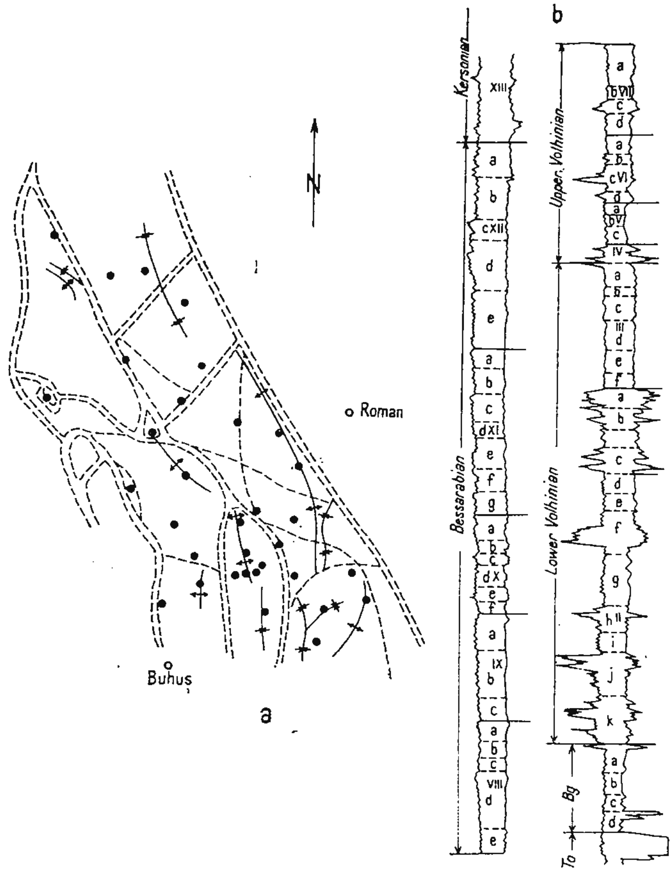

Fig. 77. — Roman-Secueni producing zone.
a, structural sketch at the Sarmatian level; b, Sarmatian and Buglovian type profiles (according to T. Perescu).

a monocline with the SWS dipping strata, in front of the Carpathian flysch. The monocline is crossed by three main longitudinal faults that divide it into as many steps, in the region of interest (Fig. 77). Several structural datails consisting of positive and negative forms develop within these steps, at the Sarmatian and Tortonian levels. They probably represent compact structures. Several tectonic blocks of various dimensions and shapes were also identified, the fault throw being of maximum 175 m. The mentioned structural details exert only a small influence on the hydrocarbon distribution ; the contribution of the lithological factor rather than that of the structural element is recognized in the formation of this vast but discontinuous gas field.

The wells drilled in the Roman-Secueni zone penetrated a sequence of deposits belonging to the Devonian, Carboniferous, Jurassic, Cretaceous, Eocene, Tortonian and Sarmatian. As indicated by the wells 102 Bacău and 5001 Bodeşti, this succession overlies the greenschist series, which is strongly folded and consists of gritty argillites and fine grey-greenish sandstones that contain a paleocenosis with *Protosphaeridium*.

The gas-bearing formation belongs to the Sarmatian (including the Buglovian). The Buglovian is about 165 m in thickness and begins with anhydrites (10—15 m in thickness), followed by marls, sandy marls and sand banks. Four reservoir members (*a*, *b*, *c*, *d*) were separated here; they form the complex I.

The Sarmatian overlies unconformably the Buglovian, being completed and continually thickening westwards. Its maximum thickness is of 2,950 m. This sedimentary sequence consisting of marls, clays and limy sandstones is characterized by a strong lithological variation. As a result, the sandstone and sand strata show, in most cases, a lenticular development and cannot be noticed on distances longer than 200—300 m. Generally, it is found that the amount of psamites increases east-westwards, which suggests that the agents carrying the terrigenous detrital material originated in the Carpathian area. The strata with reservoir properties were grouped into 12 complexes (II—XIII) each of them being divided into several terms (*a*—*g*). The complexes II—VII belong to the Volhynian, VIII—XII, to the Bessarabian and the complex XIII, to the Kersonian. The latter overlies the Bessarabian unconformably. It is noteworthy that although the lithostratigraphic units (complexes) at Roman-Secueni are numbered like those in the Predobrogean Depression, they are not equivalent to them.

The traps identified in the region are of mixed (lithological and structural) type. The Roman productive zone is, on the whole, a huge pelite mass (probably gas source rocks) that contain a great number of lenticular bodies with reservoir properties. The extracted cores (samples) showed that the respective reservoirs consist, as a rule, of sandstone centimetric strata and films, sands and sandy marls. The gas productions and the behaviour of the wells varied within very wide limits. The effective thickness of the lenticular bodies is of 0.8—1.5 m each, the average porosity of 20 per cent in sands and of 10 per cent in the sandy marls, the permeability of 0.1—160 mD, the average saturation in gas was 60 per cent in sands and 10 per cent in the sandy marls. The gas is poor, containing 0.6—8.6 t condens per 1,000,000 m^3 gas and, only incidentally, 39.8 t /1,000,000 m^3.

The initial pressure of the productive strata varies with depth, between 101 and 284 kgf/cm². The gradient of pressure is of 11.0 kgf/cm²/100 m, which is explained by the lenticular character of the reservoirs. The geothermal step differs from one block to another; its decrease (therefore a rising in temperature) being recorded eastwards, as one gets nearer to the major fault (the Siret fault) from 27 m/°C to 21 m/°C.

Among the peculiarities of the Roman-Secueni gas field one should mention the contradiction between the logg indications and the result of the flow tests which is a consequence of the lithofacial variation, as well as of the continuous decrease of the gas productions and the pressure in a short period of time.

The Bacău deposit (4, Fig. 76), is situated south of the Bacău town. The structure identified by seismic prospections represents a faulted "structural nose" that appears against the platform monocline background. The fault throw does not exceed 60 m.

The gas reservoirs located in the lower part of the Sarmatian were divided into five horizons, numbered in the deposition order, *A—E*. The horizons, in their turn, consist of several members of limy sandstones and gritty marls with lenticular developments. After the flow tests only the lenticular bodies belonging to the horizons *B* and *C*, namely the complexes I, II, III and IV proved productive at the depths of 1,820—2,045 m b.s.l. The average effective porosity is of about 20 per cent, the permeability of 7 mD and the connate water saturation of 30 per cent.

The gas productions vary between 43,000 and 100,000 m³/day per each well. The hydrocarbons consist of poor gas with a methane content of 95.6—98.9 per cent. Small amounts of condens were also identified. The reservoir pressure varies between 187 and 237 kgf/cm². The geothermal gradient increases up to 3.8°/C/100 m, which is explained by the deposit position in the vicinity of the Siret line.

Beside the mentioned deposits, gas traces were also obtained, in small amounts, in other Moldavian Platform zones, such as *Iași*, *Hîrlău*, *Pașcani*, etc.; this fact suggests that the Sarmatian has a generating potential but, at the same time, it has no reservoirs capable of valuable accumulations.

VIII. NORTH DOBROGEA AND THE PREDOBROGEAN DEPRESSION

North Dobrogea and the Predobrogean Depression correspond to the territory between the greenschist massif, delimited by the Peceneaga-Camena fault to the NE, and the margin of the East-European Platform. In this region there are sectors known as "North Dobrogea", the "North-Dobrogean Promontory" and the "Predobrogean Depression". Referring to the last subunit, only two extreme sectors — the Bîrlad Depression to the west and the Danube Delta to the east — develop on the territory of Romania, whilst the intermediary part — the Bolgrad Depression — lies on the territory of the Soviet Union.

As a matter of fact, North Dobrogea, with its NW prolongation under the Neogene and Mesozoic deposits, the North-Dobrogean Promontory respectively, represents an old geosyncline (the North-Dobrogean Orogen). The final consolidation of North Dobrogea took place probably during the Kimmerian movements. The Predobrogean Depression is in fact the foredeep of the North-Dobrogean geosyncline, outlined during the terminal Triassic and manifested as such during the Jurassic, as well (B l e a h u et al., 1967).

Till 1957, this region was known very little, only on the basis of the geological mappings, regional gravimetric and magnetometric workings and core drills. The initial aim was to emphasize the major characteristic features of the structure, its relationships with the neighbouring geological units and the facies under which the Neogene develops. After the discovery of the petroleum deposits in the Sarmatian at Văleni (USSR) and in the Pliocene at Independența, the geological research was intensified. The gravimetric and magnetic prospections became more frequent, the seismic researches were used on a large scale and the deep drillings extended. Further on the activity was focused particularly on the North-Dobrogean Promontory. In the Predobrogean Depression, the rhythm was more slowly, imposed by the difficulties of access (broken relief or deltaic environment) as well as by the insufficient and unsatisfactory seismic data. Consequently, the Danube Delta was investigated by means of gravimetric and magnetometric prospections only in 1962, seismic researches in 1966, and drilling in 1968. At present, the North-Dobrogean Promontory and the Predobrogean Depression are practically investigated by all basic methods — geological mappings, geophysical prospections and drillings.

All this region has been mapped. Because of the reduced number of natural openings, the mapping made possible only to get a partial image on the sedimentary sequence and the strata arrangement.

The gravimetric prospections, started in 1936, covered the whole surface, the density being of 1 point — 4 points/km². The results obtained have been materialized in a gravimetric map (Bouguer anomaly) which emphasizes a positive regional anomaly which overlaps the North-Dobrogean Orogen. The isogam curves show a decrease tendency from the south to the north, pointing to the existence of a promontory towards depth.

The magnetic prospections have been carried out since 1940 with a density of 1 point/km² on the whole territory. The anomalous map ΔZ renders evident a positive anomaly in South Moldavia, in fact a prolongation of the anomaly in North Dobrogea. Within this regional anomaly there are local magnetic perturbations, generally disposed to N—S.

The electrical prospections, carried out according to the vertical electrical sounding (VES), covered about 55 per cent of the whole surface. In the southern half their density is of 1 station/6 km². The conductivity contrasts, that is the electrical marks obtained, have different significances. In the zone of the North-Dobrogean Promontory they correspond to the basement surface, on its western and eastern flanks to the limy horizon in the Sarmatian base, and in the Bîrlad region this contrast indicates the surface of the Tortonian anhydrite horizon.

The first seismic prospections were carried out in 1953 and covered the whole surface, with a density of 0.5 km/km². The data obtained made possible the specification of the detailed structure of the region up to a depth of 2,500—3,000 m. Below this depth, the reflections are not always satisfactory qualitatively and quantitatively.

Up to now, more than 400 wells, the deepest one reaching 5,451 m, have been drilled on the North-Dobrogean Promontory and the Predobrogean Depression.

1. Stratigraphic and Lithologic Peculiarities of the Sedimentary Cover

The basement and the old sedimentary cover of the studied region belong to two distinct domains. The internal domain, corresponding to the North-Dobrogean Orogen, is characterized by an older, Baikalian, lower, structural stage, with meso- and epizonal metamorphic rocks, intruded by eruptive rocks, and by an upper, structural stage, consisting of Cambro-Ordovician (?), Silurian, Devonian and Carboniferous formations, intensely folded, partly metamorphosed (Lower Paleozoic) and pierced by eruptive rocks. The most uplifted zone of the orogen seems to be located N of the Danube, between the Prut and the Siret rivers, where prevalently formations of the metamorphic, old basement have been found under the Neozoic sedimentary deposits. The other domain, corresponding to the external flank of the North-Dobrogean Orogen foredeep, identifies itself with the south-western border, more and more downdropped, of the East-European Platform, characterized by an Epialgonian, metamorphosed basement, overlain by quasihorizontal Upper Precambrian and Paleozoic deposits. In the north-westernmost part of the Predobrogean Depression, the basement is represented by greenschists. The unitary sedimentary cover of the territory between the greenschist zone and the East-European Platform should have to start with the formations deposited after the Kimmerian movements, which mark the beginning of the North Dobrogea cratonic evolution.

According to the drilling data, the sedimentary cover of the region, in its most downdropped zone (the Predobrogean Depression), is 7,000—10,000 m thick, both on the territory of Romania and of the Soviet Union.

The terminal Precambrian (Vendian or Valdai Series), known in the USSR on the southern, downdropped margin of the East-European Platform, is constituted of marine deposits of shallow water and includes clays, aleurites and grey sandstones.

The Lower Paleozoic (Cambrian, Ordovician, Silurian), also found on the downdropped margin of the platform, consists of argillites, quartz sandstones and, more rarely, sericitic aleurites (300 m), limestones, sometimes organogenous, associated with dolomites, argillites and anhydrites.

The Middle Devonian, which appears at Crasna and Bîrlad, is formed of red sandstones and limestones with argillite intercalations. The drillings performed east of the Prut pointed out a clayey series with intercalations of clayey limestones and sandstones of Upper Silurian(?)-Gedinnian age, about 1,000 m thick, called the "Iargorin formation". Here, a sequence of predominantly lagoonal and subcontinental deposits, in an almost complete succession, about 1,900 m thick, has been also assigned to the Devonian.

The Carboniferous presence on the Romanian territory of the Scythian Platform is questionable. A packet of grey dolomites and brown-yellow diagenized limestones, about 400 m thick, found out with the bore-hole 17 Huruești, has been assigned to the Dinantian. It is also assumed the existence of the Lower Carboniferous in the Danube Delta, at well 12 Rosetti which, under the Permo-Triassic eruptions, opened a packet of grey limestones, similar to those at Tulcea, described by Mirăuță (1966). To the east of the Prut, on the Soviet Union territory, the Carboniferous deposits become thicker, in a certain sector including the Dinantian and the Namurian.

As regards the North-Dobrogean Orogen, overlying a mesometamorphic basement (Orliga), the stratigraphic sequence seems to begin with the Megina Series volcanites, metamorphosed in the epidote amphibolite facies of the greenschists. This formation also occurs in bore-holes north of the Danube, on the Prut-Siret interfluve. It could be of Cambrian age (Mirăuță, 1966). A phyllite-quartzitic series (Boclugea formation), metamorphosed in the greenschist facies, follows concordantly. Graphitous quartzites, black limestones and phyllitic schists, slightly metamorphosed, the last being of Silurian age, are found in continuity of sedimentation. They concordantly underlie limestones with quartzite intercalations, quartzites ardesian schists and fossiliferous limestones belonging to the Eodevonian. There follow Mesodevonian flysch deposits, associated with silicolites (the Mahmudia Hills). The Paleozoic sequence ends with the Carapelit formation assigned to the Lower Carboniferous, without certain paleontologic arguments. It is surrounded by two series of intrusive rocks, mainly granites. The drillings carried out north of the Danube, on the Prut-Siret interfluve, met with microconglomerates, sandstones and reddish and violaceous clays which suggest the Carapelit formation. The pebbles of the conglomerates found out by some Matca wells contain Devonian microflora on the basis of which these coarse detrital deposits are considered of Carboniferous age.

On the external flank of the Predobrogean Depression, in the Danube Delta, there are subcontinental detrital deposits represented by sandstones and aleurites with intercalations of conglomerates, limestones and effusive rocks at the lower part. These deposits are predominantly red and are considered to represent the Lower Triassic, possibly the Permian, too.

In the Bîrlad Depression, the Permo-Triassic is represented by detrital deposits, about 1,000 m thick, which can be grouped into two complexes: a lower complex, made up of anhydrite sandstones, partly ferruginous, with dolomite intercalations; an upper complex constituted of similar rocks without anhydrite.

In the area of the North-Dobrogean Orogen, the Lower Triassic, as well as the other Triassic formations, present a marine facies, formed of conglomerates and clayey schists. The Middle and Upper Triassic seem to appear only in North Dobrogea and the Danube Delta. They consist of characteristic deposits, mostly of Alpine type. The Middle Triassic (300—700 m thick) is formed of fossiliferous limestones and dolomites and the Upper Triassic (450 m thick) of an alternation of thin beds of limestones, marly-limestones, sandstones and argillites.

The Permo-Triassic is followed by a sequence of deposits belonging to the Jurassic-Cretaceous cycle. It starts with the Dogger, possibly the Upper Lias, and lasts, with some interruptions till the Campanian.

In the base, this cycle includes Bajocian-Callovian, detrital deposits represented by schists and marls with *Bositra buchi*, sandstones and organogenous limestones which can reach 800 m in thickness.

On the southern border of the Danube Delta, at well 12 Maliuc, a sequence of grey-blackish limestones is found; it exceeds 1,000 m in thickness and, according to the palynologic content, represents the Dogger. It indicates that, within the Scythian Platform, the Middle Jurassic has significant lithofacial variations.

The Upper Jurassic-Lower Cretaceous (Barremian, Valanginian, Hauterivian) is about 1,300 m thick and consists of neritic-reefal deposits, organogenous limestones, calcarenites, detrital limestones, pseudo-oolitic limestones and dolomites, respectively. At Aldeşti, the Tithonian is represented by sandstones with siliceous cement. It is overlain by a striped detrital series with gypsums in the base. In the Danube Delta, the terrigene deposits with gypsums could start earlier, even in the Neocomian; to the NE, in the Soviet Union, such formations start in the Kimmeridgian.

During the Austrian phase it seems that the whole region between the greenschist zone and the East-European Platform uplifted becoming land, so that the Barremian-Aptian interval corresponds to a stratigraphic gap. The sedimentation is resumed during the Albian and in places even at the end of the Aptian. The Albian has been undoubtedly identified in a single well (Aldeşti), where it is constituted of limestones and marnolimestones. The other Upper Cretaceous terms (Cenomanian and Campanian) have a reduced thickness and include glauconitic calcareous sandstones, marls, marno-limestones and chalky limestones. The Upper Cretaceous has been pointed out on the external margin of the Bîrlad Depression. Here, it is also discussed the Eocene existence; however, various sequences of thin glauconitic sandstones with nummulites are connected with the Tortonian distribution area and therefore they have been assigned to the Miocene.

The Tortonian lies in the northern part of the Bîrlad Depression. It is constituted of the same lithostratigraphic terms as the Moldavian Platform, namely a complex of reefal limestones, limy tuffs and anhydrites, surrounded by two detrital complexes. The limy facies passes laterally (Ghidigeni, Polocin) to a gritty-marly facies. East of the Bîrlad River and south of the town of Bîrlad, the Tortonian is represented only by a sandstone horizon which, after its passing to limestones southwards, cannot be traced any longer.

The Sarmatian, transgressively overlying different stratigraphic terms, occurs under conditions similar to those known on the western margin of the Moldavian Platform with the difference that the psamite share increases continuously to the south and the thicknesses exceed 3,500 m in the link zone between the Predobrogean Depression and the Carpathian Foredeep. To the east, therefore from the Siret to the Prut, and to the south, from Bîrlad to Galați, the Sarmatian thickness is reduced to 400—500 m.

The Pliocene, undoubtedly represented by the Meotian, Dacian and Levantine, is predominantly psamitic. In the base of the Pliocene profile, the pelitic intercalations are more frequent and thicker, capable to protect the hydrocarbon accumulations.

2. **General Characteristics of the Structure**

As known, in North Dobrogea, the Paleozoic and the Triassic formations, as well as the Lower Jurassic flysch deposits, are intensely folded. These deposits are grouped into two zones representing two stages in the geosyncline evolution, namely an internal, western zone (Măcin Zone) where the Paleozoic formations predominate and an external, eastern zone (Tulcea) with deposits predominantly of Triassic age. Outside the latter zone, the drillings indicated the existence of a third zone (the Predobrogean Depression) where the Jurassic formations, folded in the internal side of the depression, prevail. These folds, including older formations as well, gradually disappear towards the exterior, the beds become quasihorizontal on the opposite flank to the Predobrogean Foredeep, corresponding to the downdropped margin of the East-European Platform (Plate V). The relationships among the three above-mentioned zones seem to be tectonic, the internal units overthrusting the external ones along two important accidents — the Luncavița-Consul and the Sf. Gheorghe faults.

To the E—SE, the North-Dobrogean Orogen plunges, being covered first by remnants of the Jurassic deposits, then by the Babadag basin Cretaceous. On the opposite side, the Prut-Siret interfluve maintained uplifted a longer period of time. As a result, between Galați and Cudalbi, after the Pliocene or the Sarmatian there followed the metamorphic formations assigned to the Cambrian. To the NW and W, the crystalline basement gradually begins to plunge, being covered first by the Carapelit beds (?), then by Devonian deposits and finally by Triassic and Jurassic formations. Toward the boundary with the Moldavian Platform, under the Neogene cover, the North Dobrogean sunk crest is also overlain by Cretaceous terms (Fig. 78). The before-mentioned facts lead to the conclusion that North Dobrogea has a zone of maximum uplift between Măcin and Cudalbi (which could be called the Galaţi Culmination), then it plunges and is gradually covered, towards SE, NW, W and N, by deposits more and more recent and less and less folded to the periphery (Plate V). Much more outside, the Paleozoic and Mesozoic deposits rise again, in the East-

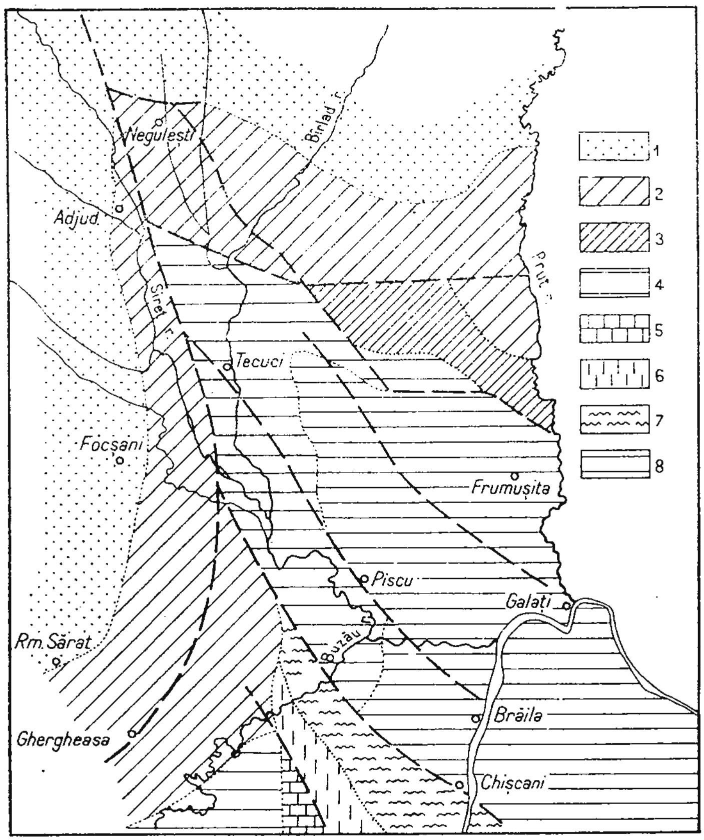

Fig. 78. — Distribution of the pre-Neogene formations on the North-Dobrogean Promontory and the Bîrlad Depression. 1, Cretaceous ; 2, Jurassic ; 3, Triassic ; 4, Carboniferous ; 5, Devonian ; 6, Silurian ; 7, greenschists ; 8, metamorphosed basement (according to C. Barbu et al.).

European Platform margin, outlining, between this and the Galaţi Culmination, a downthrown zone with a more complete sequence of deposits known as the Predobrogean Depression. The northern segment of this unit, also called the "Bîrlad Depression", with the axis on the Adjud-Rogojești line, rises towards the Prut and goes down in the Precarpathian Depression (Fig. 79). The other segment, corresponding to the Danube Delta, with the axis approximately on the Sulina Arm line, shows a tendency of sinking eastwards, therefore to the Black Sea off shore.

Against the dome-shaped background outlined before one can notice numerous structural elements of the II and III ranges, consisting of fold-scales, anticlinal and synclinal folds, downdropped reliefs, settling structures, faults and tectonic blocks. The structural folds appear more strikingly in

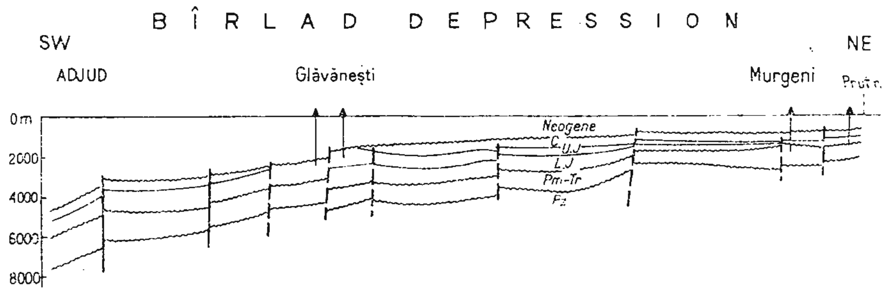

Fig. 79. — Longitudinal geological section through the Bîrlad Depression.

North Dobrogea where the Paleozoic and the Triassic outcrop. They may be easily noticed on the inner side of the Predobrogean Depression, too. The paleoreliefs and the settling structures are very obvious in the Neogene base, on the Prut-Siret interfluve (Fig. 73), pointing to a preferential orientation of the former hydrographic network towards N, NW and W, that is towards the Focșani Depression and its prolongation to Adjud. These paleoreliefs transmitted their form to the covering Neogene deposits which occur as promontories, spurs, "structural noses", hemianticlines and domes. The faults, with different orientation and throws, are to be found in the whole region; however, they occur more frequently on the North-Dobrogean Promontory and the external margin of the Predobrogean Depression. There are two tendencies in their orientation: a NW—SE tendency which characterizes the North-Dobrogean Orogen and promontory (even Central Dobrogea), indicating the direction of the II and III range structures; an E—W or ESE—WNW, proper to the northern region of the Scythian Platform; after that the Moldavian Platform sinks in the Predobrogean Depression (Fig. 80). One of these accidents, as a matter of fact a system of faults on the S Bacău-Găiceana-Glăvănești-Bîrlad-Murgeni line, has been considered conventionally the boundary between the Moldavian and the Scythian platforms. Between the two main tendencies there are intermediary directions, especially in the Bîrlad Depression.

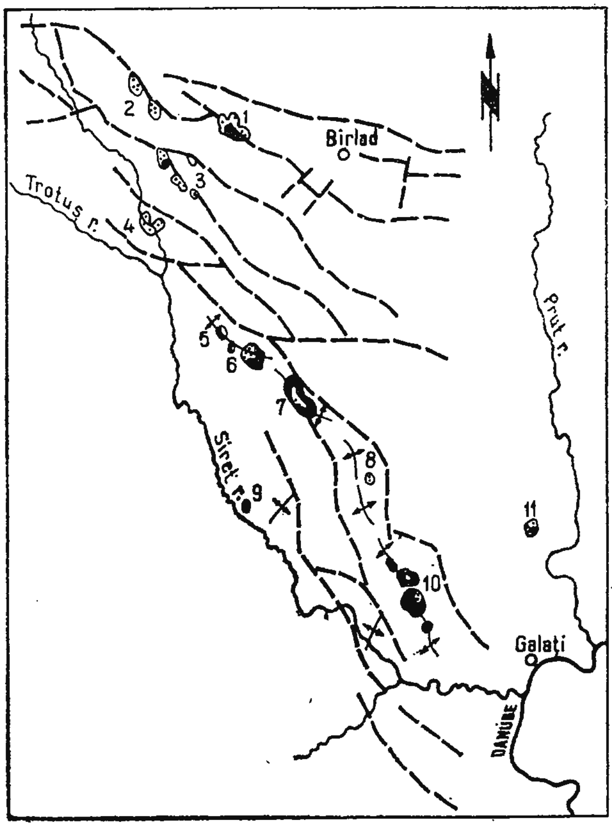

Fig. 80. — Distribution of the hydrocarbon deposits in the North-Dobrogean Promontory and the Bîrlad Depression.
1, Glăvăneşti ; 2, Găiceana ; 3. Neguleşti ; 4, Adjud-Homocea ; 5, Buciumeni ; 6, Ţepu ; 7, Matca, 8, Cudalbi ; 9, Suraia ; 10, Independenţa ; 11, Frumuşiţa.

3. Geological Evolution of the North-Dobrogean Promontory and the Predobrogean Depression

Until the Kimmerian movements, most of the territory between the Moesian and the Moldavian platforms functioned as a geosyncline whose area continuously migrated from the greenschist zone to the exterior, as against the East-European Platform. During the Lower Jurassic, the main sedimentary trough shifted to the domain of the present Predobrogean Depression. The consolidation of the old geosyncline took place in stages, the first stage at the end of the Hercynian orogenesis and the second in the new Kimmerian phase.

After the cratonization of the North-Dobrogean domain (in the new Kimmerian phase), it remained exondated and submitted to denudation, with some intermittences, till the Tortonian. In the Predobrogean Foredeep and in the NW and SE extremities, more downdropped, of the old orogen, sedimentation continued almost during all the Jurassic and the Lower Cretaceous time span. Except the Dogger, predominantly detrital-terrigene, this cycle includes carbonatic deposits. The zone of maximum subsidence migrating outwards, the Jurassic deposits are thicker towards the interior of the depression, and the Lower Cretaceous deposits towards the exterior. It occurs very clearly in the Danube Delta, where the Dogger of Maliuc in calcareous facies (it suggests the possibility of the Dogger to pass to a carbonatic facies in the zone of maximum subsidence) is about 1,000 m thick. The Middle Jurassic-Lower Cretaceous cycle ends with lagoonal deposits. Locally, in the Bîrlad Depression and the Babadag basin, sedimentation, mainly detrital, was resumed in the Upper Cretaceous and ceased in the sub-Hercynian or Laramian phase. Except the short and local return of the sea in the Cenomanian and in the Campanian, the whole Scythian Platform functioned as land, between the Laramian and the New Styrian phases. Gradually, the margin of the former uplift began to go down, making possible for the Tortonian, Sarmatian and Pliocene to invade progressively and to cover it with more and more recent terms, towards the Cudalbi-Măcin sector. It is only in the Pontian that a significant regression, resulting in a regional gap, took place. The filling up of the basin and the region uplift occurred in the Levantine and the Pleistocene, a part of the surface (the Danube Delta) being in course of colmation.

During the geologic history, so long and complex, of the North-Dobrogean massif, on its margins deposited a pile of sediments, thicker and thicker towards the exterior, characterized by a facies variation, narrowings or strata thickenings, stratigraphic unconformities and structural disturbances.

4. Conditions of Genesis, Accumulation and Preservation of Hydrocarbons

The stratigraphic sequence, varied enough, the heterogeneous structure and the complex evolution of the North-Dobrogean Orogen and the Predobrogean Depression are found again under conditions only locally favourable for the hydrocarbon genesis, accumulation and preservation.

Reservoir rocks appear especially in the Mesozoic and the Neozoic. As regards the Paleozoic sandstones, limestones and dolomites in the Scythian Platform external zone, they are found at great depths and underwent a diagenesis process which reduced their porosity and permeability. Consequently, they count as potential reservoirs in the intensely fissured zones and within the promontory where they are to be found at smaller depths.

In the Mesozoic, the Triassic sandstones, limestones and dolomites are the most significant reservoirs. In the Moesian Platform these formations proved their petroliferous capacity up to depths of 3,500—3,800 m. The same attention has to be paid to the Middle Jurassic sandstone, the

Malm-Lower Cretaceous limestones and dolomites also productive in the Moesian Platform.

The Neogene has reservoirs at the basal Tortonian level, in the northern part of the region where the porosities are of 10—14 per cent and the permeabilities of 70 mD. The Sarmatian contains sandstones and sands on the whole profile, but they are protected only in the basal part where pelites have a greater share. Here, the porosity may reach values of 20 per cent and the permeability of 150 mD. The basal Pliocene presents a similar situation, especially in the south of the region where it directly overlies the crystalline basement.

The question of the source rocks has not been treated in special studies. It is of lesser interest for the folded, partly anchimetamorphosed Paleozoic of the North-Dobrogean Orogen. From this point of view, our attention is directed first to the Iargorin Series in the external flank of the Predobrogean Depression, constituted of important pelitic sequences. The Devonian lagoonal series and the Carboniferous marno-limestone, in comparison with the Moesian Platform, may be assigned to the possible source formations. However, east of the Prut, these deposits have a stressed bituminous character and contain up to 4.25 per cent organic carbon. Hydrocarbon indications have been recorded from some wells on the Soviet Union territory.

In the Mesozoic one could count on the Middle Jurassic pelitic series and the Malm clayey limestones. The samples got from some wells in the USSR contained bitumens A (0.01—0.04 per cent) on the fissures and the cavities of the Kimmeridgian limestones and syngenetic bitumens (0.03—2.1 per cent) in the Dogger terrigene deposits.

In the Neozoic, the part of the source rocks could be played by the Tortonian, Sarmatian and Pliocene pelitic sequence, formations which proved to be productive.

The pelitic or compact limy series and sequences, mentioned before, also constitute protecting covers for the Paleozoic, Mesozoic and Neogene reservoir rocks.

The studies on the geothermal gradient variations (Paraschiv, Cristian, 1976) lead to the conclusion that the highest values (4°/100 m) are superposed to the downdropped crest of the North-Dobrogean Promontory basement. Laterally, towards the Predobrogean and Focşani depressions, the values decrease to 3°/100 m. This temperature distribution indicates that the axial zone of the North-Dobrogean Promontory offered the best conditions (from the geothermal point of view) for the hydrocarbon genesis, migration and accumulation. In the neighbouring depression sectors, the organic matter accumulated in the Neogene probably remained in an imature stage and could supply only gaseous hydrocarbons. Such theoretical premises have been ascertained up to now by the results obtained from drillings to a depth of 2,000—2,500 m. The prospect of the discovery of petroleum deposits is open in the zones with thicker sedimentary deposits, eventually of Mesozoic age.

The deep waters yielded by wells present different characteristic features, according to the stratigraphic complex and the evolution stages of the sectors taken into account.

The Vendian and Cambro-Ordovician complex contains chlorocalcic waters of stabilized hydrodynamic regime, with mineralizations of 105 g/l. Here the presence of iodine and bromine has been emphasized. The Lower Permo-Triassic in the USSR is characterized by chlorocalcic and chloromagnesian waters with mineralizations of 40—90 g/l, pH = 5.5—8.6 and high concentrations of iodine (24 mg/l) and bromine (187 mg/l). The Upper and Middle Triassic in the Danube Delta presents chlorocalcic and chloromagnesian waters, with small mineralizations (3—10 g/l), pH = 6.8—7.7, a very reduced content in iodine and bromine (10 mg/l and 5 mg/l, respectively). The Lower Cretaceous includes chlorocalcic waters whose mineralizations reach 55 g/t. The iodine and bromine content is low, and the naphtenic acids are missing. In the Tortonian and particularly in the Sarmatian there are chlorocalcic, chloromagnesian, bicarbonatosodic and sulphosodic waters. The mineralization varies from some g/l to 110 g/l (average 35—77 g/l), decreasing from bottom to top. The amount of iodine, bromine and ammonium is of 19—29 mg/l, 10—34 mg/l and 50—120 mg/l. The naphtenic acids are missing almost entirely.

5. **Hydrocarbon Deposits**

The map of the deposit distribution (Fig. 80) shows that the North-Dobrogean Promontory accumulated more hydrocarbons than the Bîrlad Depression. It can be explained, on the one hand, by its more uplifted position as against the neighbouring units, gaining from the accumulation of a deposit sequence with better reservoir properties (sandstones, sands) and constituting a "call" zone for petroleum and gases formed in the more sunk regions and, on the other hand, by the existence of some higher geothermal gradients which can exceed 4°C/100 m, very favourable for the hydrocarbon genesis, migration and accumulation.

Most of the deposits are situated nearby the unconformity in the Neogene base or those which surround the Sarmatian. In this case the productive terms are represented by Paleozoic (Matca, Ţepu, Buciumeni), Tortonian, Sarmatian and, locally, Meotian. Gas indications at tester have been also recorded from the Jurassic in the Danube Delta, at wells 5 Obretin (Malm) and 9 Stipoc (Dogger) but they have not been confirmed by the flow tests.

The traps in the Bîrlad Depression and the North-Dobrogean Promontory are the result of the participation of several factors: stratigraphic, structural, lithofacial and paleogeographic. The settling structures, the steps formed by faults, truncations of beds on the unconformably surfaces, the fossil reliefs moulded by the basal Neogene deposits and the lithologic variations of some Sarmatian and Pliocene horizons contributed to the hydrocarbon accumulation and preservation in this region.

The distribution of the deposits in the North-Dobrogean Promontory draws the attention to the fact that the zones of preferential accumulation have not been determined by the general disposition of the Neogene formations, proper to the Carpathian Foredeep but by their detailed structure, imprinted by the basement configuration. Certainly, almost all the deposits in this area are aligned to the promontory crest zone determined by the uplift of the basement, constituted of metamorphites and folded, old Paleozoic deposits.

As regards the Bîrlad Depression, here there are only modest accumulations, often non-commercial, almost exclusively gaseous. This fact is explained by the geological evolution of the region as well as by the smaller geothermal gradients, which determined the alteration degree of the organic matter not to reach the threshold of petroleum generation, often remaining in an imature stage.

In the north, at the contact with the Moldavian Platform there is the *Glăvăneşti productive structure* (1, Fig. 80), may be the most important one in the Bîrlad Depression. It was rendered evident by the seismic workings carried out in 1959, preceded by gravimetric prospections. The Sarmatian-Buglovian is the member of interest.

As known, in the Bîrlad Depression the Buglovian and the Sarmatian reservoir beds have been grouped into 9 complexes, numbered from I to VIII (as there are two complexes numbered with IV and IV' respectively) in the order of their deposition (Fig. 81). The complex Sa I corresponds to the Buglovian, the complex Sa II (with 9 members, numbered a-i) to the Volhynian, the terms Sa III, IV and IV' to the Bessarabian, and Sa V-Sa VIII to the Kersonian. At Glăvăneşti, the wells drilled in the structure apex found only the complexes III—VIII, the other two terms occurring on flanks, particularly towards SW.

The Glăvăneşti structure is dome-shaped, slightly elongated to E—W and disturbed by faults which divide it into 5 tectonic blocks (Fig. 82). Some of these faults are tight, so that they control the fluid distribution. The Glăvăneşti structure itself lies nearby the Corbeanca-Glăvăneşti-Putredeni regional accident.

The hydrocarbon saturated reservoirs correspond to the complexes III—VIII. They contain free gas, except the packets *b* and *c* of complex III, with petroleum and primary gas cap. Free gas is found at depths of 892—1,405 m b.s.l. and petroleum at 1,400—1,448 m b.s.l. The traps are of mixed type, structural, lithological and stratigraphic factors contributing to their formation.

The deposit physical parameters are characterized by porosity 15—28 per cent, permeability 0.22—35 mD, connate water saturation 30—40 per cent, volume reduction factor 1.19. The initial pressures range between 105—162 kgf/cm^2, that is 10.3 kgf/100 m. The geothermal step is 38 m/°C.

The petroleum yielded has a specific density of 0.808 kgf/dm^3, being of *C* type. The average viscosity does not exceed 1.12 °E. The saturation pressure is 134 kgf/cm^2 and the solution ratio 43 Ncm/cm. The differential pressure varies from 2.88 to 42 kgf/cm^2. The gas output ranged between 18,000—100,000 cm/day per well. These gases are rich; they contain 90 per cent methane, 3—10 per cent ethane, 1—6 per cent propane. The condens amount is 84—505 g/N cm.

The chlorocalcic formation waters have mineralizations of 63.4—73.6 g/l.

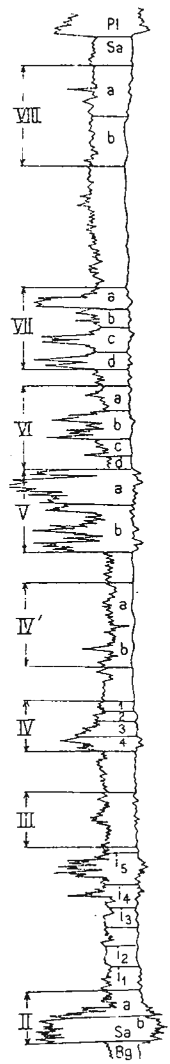

Fig. 81. — Sarmatian type profile of the Birlad Depression (according to P. Svoronos et al.).

Mention should be made of the presence of gases (about 5,000 cm/day) associated with brackish water in the Tortonian at Putredeni.

To the west and south-west of the Glăvăneşti structure there are small gas accumulations on some structural elements, represented by slight

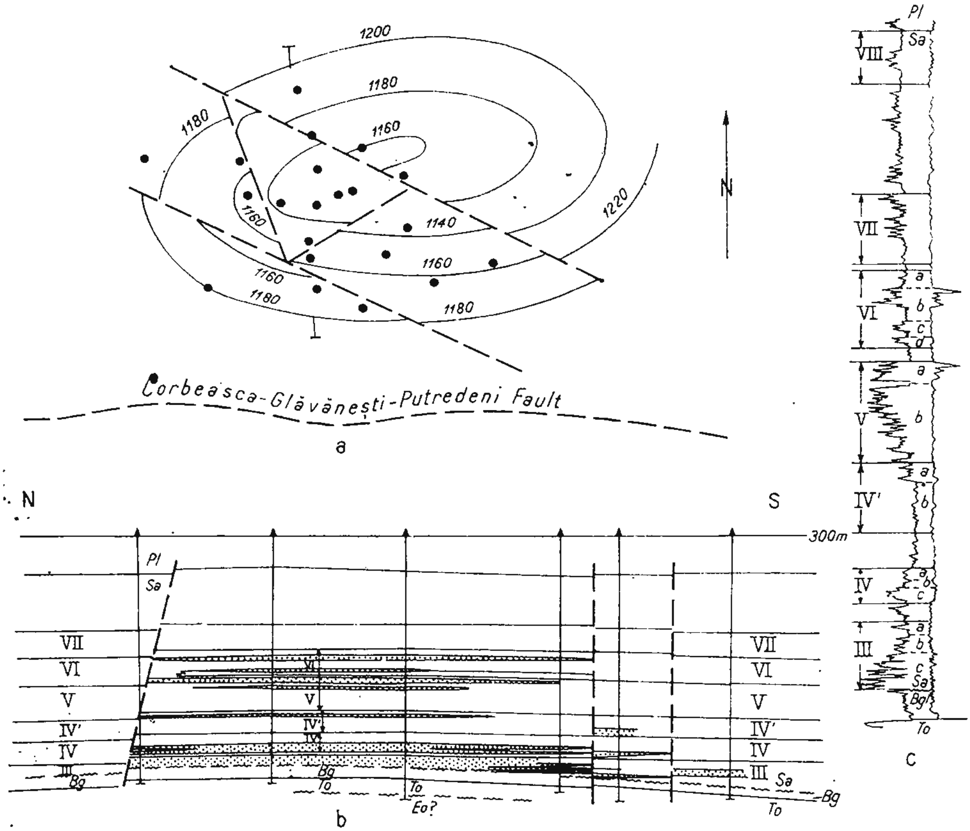

Fig. 82. — Glăvănești structure.
a, structural map at a Sarmatian guide mark ; b, geological cross section ; c, Sarmatian type profile (according to E. Bîrsan and V. Dumitru).

anticlinal or hemianticlinal archings and tectonic blocks. These productive structural elements are usually aligned along regional faults. Thus, west of the Găiceana-Glăvănești fault lies the *Găiceana faulted hemianticline* (2, Fig. 80), with gas and condens in the complexes II and S intermediary (II—III). *The Negulești block* (3, Fig. 80), with gas at Sa IV, Sa VI' and Sa VI and petroleum at Sa intermediary of block III, is placed on a southern alignment from Podul Turcului to Corbeasca. Finally, SW of the Jugani-Lespezi fault the *Adjud-Homocea gas field* (4, Fig. 80), where Sa V, Sa VI and Sa VII proved to be productive.

All the structural elements mentioned before are characterized by an almost identical Sarmatian stratigraphic profile. Generally, the porous and permeable strata undergo great lithologic variations on restricted spaces which confer a predominantly lenticular character to the traps concerned.

Under these conditions, the deposit physical parameters range within very wide limits. Thus, the average porosity is 7 per cent (in marly sands) — 26 per cent ; permeability 0.1—212 mD, connate water saturation 28—43 per cent, volume reduction factor at the saturation pressure 1.190.

Gases contain methane 93—97 per cent, ethane 1.77—3.47 per cent and propane 0.73—1.67 per cent. The condens ammount is 12—60 g/Ncm. The petroleum of Hurueşti has a specific density of 0.850 kgf/dm^3. The initial pressures ranged between 100—240 kgf/cm^2, at depths of 1,000—2,300 m which is equivalent to a gradient of 10.2 kgf/100 m. The geothermal step attains 27 m/°C.

The formation waters are of chlorosodic type, passing to bicarbonatosodic and sulphosodic waters as the formation depth becomes smaller. Mineralization varies from 24 to 76 g/l. The presence of iodine, bromine and naphtenic acids has been emphasized.

The gas fields mentioned before point to some technico-geological questions, namely the discontinuity of accumulations due to lithologic variations and the output and pressure fall during a relatively short time span, the shutting off of the beds with drilling fluids during their opening, etc.

On the northern downdropped end of the North-Dobrogean Promontory there are four productive structures at Buciumeni, Ţepu, Matca and Cudalbi.

At *Buciumeni* (5, Fig. 80) gas has been yielded by a single well at the upper part of the Paleozoic, at the contact with the Tortonian. 85,500 cm/day have been reported from a 6 mm nozzle, at a pressure of 125/125 kgf/cm^2 and a depth of 2,958—2,949 m.

On the *Cudalbi culmination* (8, Fig. 80), the Sarmatian proved to be productive at depths of 1,882—1,850 m, where about 45,000 cm/day gas have been reported from a 6 mm nozzle, at a pressure of 80/110 kgf/cm^2. In this sector, like at Buciumeni, the exploration workings continue.

The Matca (7, Fig. 80) and *Ţepu* (6, Fig. 80) *culminations* constitute the most important accumulation zone at the northern downdropped end of the North-Dobrogean Promontory.

The wells drilled in this zone opened a sequence of strata which begins with folded clay sandstones, conglomerates and intercalations of clay shales and limestones, belonging to the Paleozoic (probably the Carboniferous). The Tortonian formed predominantly of calcarenites, unconformably follows and then, after a short discontinuity, the Sarmatian. It is formed of organogenous limestones (30—40 m) in the base and marly limestones with arenite intercalations (maximum 400 m) at the upper part. The Pliocene is represented by a Meotian lower arenitic complex, a Pontian arenitic-pelitic complex and a Dacian-Levantine, locally Quaternary upper arenitic complex. The Pliocene thickness reaches 1,800 m.

Up to the present, the Paleozoic, Tortonian, Sarmatian and Meotian formations proved to be productive in the Matca-Ţepu zone.

The Paleozoic proved its productive capacity at Matca, where six wells yielded petroleum and two wells gas. According to these results, the Paleozoic seems to contain a petroleum deposit with primary gas cap. The depth of the petroleum saturated strata ranges between 2,200—2,250 m. The hydrodynamic relationships of the Paleozoic accumulations with the Neogene ones are not specified well enough, although some elements indicate that they are in direct contact.

The Tortonian yields petroleum and gas both at Matca and at Țepu. The hydrocarbons are placed on both Tortonian collecting horizons, called T_1 and T_2 (Fig. 83). As in the Paleozoic, it seems that the petroleum deposits with primary gas cap formed in the Tortonian, as well. Petroleum is of type *C*, paraffin, with a specific density of 0.850 kgf/dm^3, at 15°C and 1 kgf/cm^2. At an average depth of 2,315 m, the bottom pressure is of 193,5 kgf/cm^2, a value inferior to the hydrostatic column pressure; the geothermal gradient reaches 4°C/100 m.

In the Sarmatian there are at least two productive complexes: Sa basal and Sa intermediary. Sa basal yields petroleum only at Matca and gas on both culminations. At Matca, this member contains petroleum with primary gas cap. The present degree of knowledge does not permit one to specify if at Țepu there is a petroleum zone or only a free gas reservoir. The intermediary Sarmatian produces gas only at Țepu.

The Meotian yielded gas only at Țepu, in a single well, at a depth of about 1,500 m.

The distribution on the vertical of the Matca-Țepu hydrocarbons points out that petroleum has a greater share in the lower horizons while the upper member contains only gas.

More to the south, on the south-western side of the North-Dobrogean Promontory, towards the Focșani Depression, a well drilled at *Suraia* (9, Fig. 80) (3952) yielded petroleum in three Sarmatian strata of 4,066—4,167 m deep. Initially, these strata produced 1.3—5.4 cm/day petroleum and 7,000—4,000 cm/day gas. As the well was exploited intermittently by swabbing a longer period of time, the output showed a tendency of decrease up to 4 t/day.

The structure represents a faulted monocline, the strata showing a tendency of uplift vanishing and truncation, (in the base) towards the south.

Independența (10, Fig. 80) is another significant petroliferous field between the Siret and the Prut rivers. The structure corresponds to the culmination zone of the North-Dobrogean Promontory whose basement outlines three morphostructural culminations. The Neogene deposits cover these culminations and, by settling, lend their form to them, namely dome-like structures, growing more and more indistinct as the strata are more recent.

The crystalline schists basement is directly overlain by the Pliocene, locally the Sarmatian, too. The Pliocene is constituted of a sequence of sands and marls. The Pliocene psamitic deposits of interest have been grouped into 17 strata which, in their turn, form 6 complexes numbered,

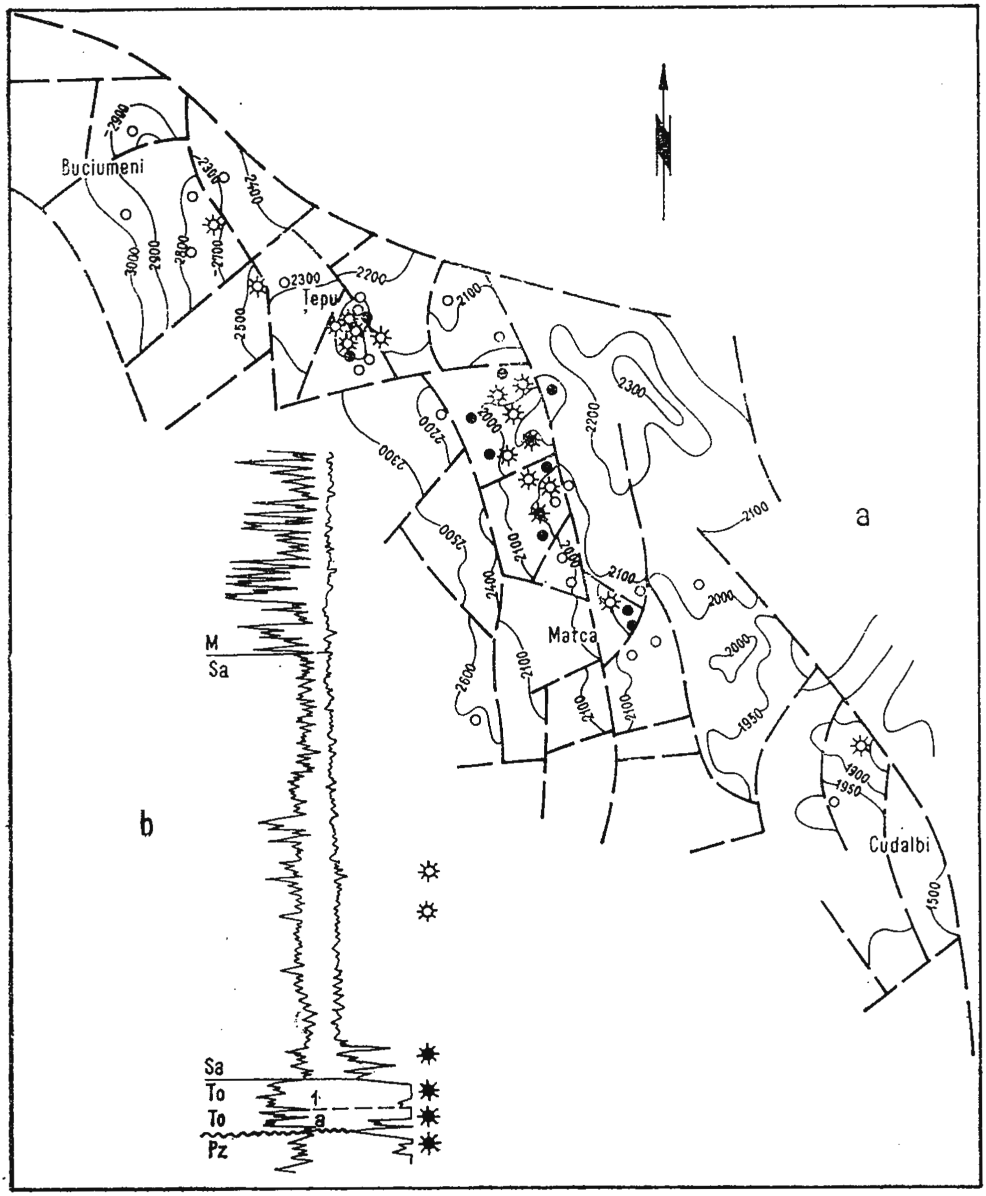

Fig. 83. — Cudalbi-Matca-Ţepu-Buciumeni sector.
a, structural map at a guide mark of the Sarmatian base (according to C. Mihăilescu and C. Paraschiv); b, Tortonian, Sarmatian and Meotian type profiles.

from bottom to top, I–VI. Some of the basal horizons are truncated in the apex zone of the domes. The Pliocene strata 2, 3, and 4 contain free gas, the strata 5, 11, 12, 13, 14, 15 and 17 petroleum, associated and free gas, and the strata 10 and 16 are saturated with petroleum and associated gas. The Sarmatian is saturated with hydrocarbons only locally. The depth of the productive strata ranges between 450–650 m.

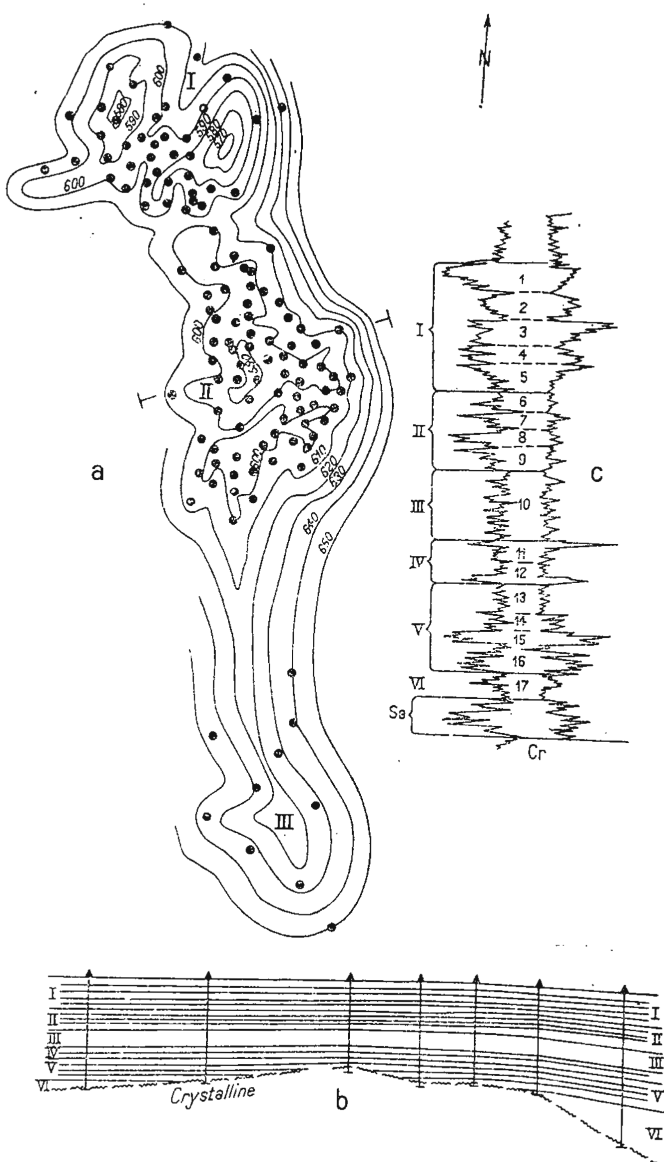

Fig. 84. — Independenţa oil field.
a, structural map at pay sand 11 (Pliocene); b, geological cross section; c, Pliocene and Sarmatian type profiles (according to Gh. Stancu).

The three domes, probably disturbed by faults, too, have been numbered, from the north to the south, with I, II, III (Fig. 84). Among them, dome II had a better behaviour, the dome III being of the least importance. The traps may be structural, stratigraphic (lithologic), paleogeomorphic and mixed.

The effective thicknesses of the reservoirs are of 1.5—9.7 m, average porosity 30 per cent, permeability 600—800 mD, connate water saturation 20 per cent, volume reduction factor 1.05.

The deposit contains oxidated petroleum, with a specific density of 0.930 kgf/dm^3. The solution ratio is 15 N m^3/m^3. The deposit initial pressure was 43—47 kgf/cm^2 and the saturation pressure 35—55 kgf/cm^2. The geothermal step (33 m/°C) is close to the average one.

In general, the reservoirs are constituted of unconsolidated sands. Therefore, any lack of balance in the deposit causes the sand movement into the well hole. Another difficulty is brought about by the breaking of the natural isolation (formed of the thin marly intervals) by the waters from the adjacent horizons, when the pressures in the petroleum strata decrease. It leads to the flood of the deposits.

In the easternmost part of our country, at *Frumușița* (11, Fig. 80) several wells were drilled, which had petroleum and gas indications in the Sarmatian and the Pliocene, under structural conditions somehow similar to those at Independența. The best results have been recorded from well 3707 in the Sarmatian (565—574 m deep) where 6,000—7,000 l petroleum and 16—16,000 l brackish water have been obtained by swabbing in 10 hours. As for the rest, the Sarmatian presented only tracks of petroleum and gas. The Meotian yielded, at well 3702 (224—252 m deep), about 11,600 m^3/day gas on a 8 mm nozzle, at a pressure of 10/16 kgf/cm^2. The drillings carried out subsequently in extension pointed out only hydrocarbon tracks, indicating the local character of the Pliocene and the Sarmatian accumulations.

IX. MOESIAN PLATFORM

The Moesian Platform includes the geological unit which stretches on both sides of the Danube lower course, bordered by the Carpathian Foredeep to the north, the Balkanids to the south and the North-Dobrogean Orogen to the north-east.

To the north and west, the platform boundary has been conventionally established on the Bibești-Tinosu line, a southern equivalent of the Pericarpathian fault. Along it, the folded formations of the lower molasse of the Carpathian Foredeep overthrust the quasihorizontal deposits belonging to the Lower Sarmatian and the Neogene cover of the platform. In fact, the Mesozoic and the Paleozoic of the Moesian Platform continue to the north beyond the Bibești-Tinosu fault where they underlie tectonically the more recent deposits of the foredeep.

Southwards, the real boundary should correspond to the Brestinca-Preslav flexure; however, it has been accepted to place it more to the north, along the North Prebalkan fault or the "Balkanid frontal line" (B o n c e v, 1974).

To the NE, the Moesian Platform extends up to the Peceneaga-Camena fault which separates it from the North-Dobrogean Orogen. To the E, the Moesian Platform continues under the Black Sea basin, on a distance which could not have been controlled rigurously.

The geological knowledge of the surface delimited before was ensured, in a first stage, by the geological mappings (where possible), reconnaissance gravimetric, magnetic and electrical prospections, as well as by two wells.

Since 1951, when the Tulenovo petroleum deposit (Bulgaria) was discovered, the geological activity has intensified using the gravimetric, magnetometric and seismic prospection together with core drills. This intensification became more and more obvious after 1956, a year which marks the discovery of the first petroleum accumulation on the Romanian territory (at Ciureşti).

Geological mappings at the scale 1 : 20,000 and 1 : 100,000 m have been effectuated in the whole Dobrogean sector of the Moesian Platform and, in places, in the Romanian Plain, too.

The gravimetric prospections covered almost the entire surface, except the Black Sea Continental Shelf, with a density of 1—4 points/km^2. The Bouguer indicates two zones with distinct gravimetric regimes: a northern and a southern zone. In the former, the isogal distribution is more calm, with values which decrease continuously from the south to the north, with a general orientation to E—W up to the meridian of the town of Urziceni and to NE—SW, east of it.

On the whole, the isogal curves outline the southern and south-eastern flanks of the utmost anomaly situated in the Carpathian Foredeep. The southern zone is characterized by a gravimetric regime strongly disturbed by anomalies of a high intensity.

The magnetic measurements have been effected in the whole Moesian Platform, including the off-shore area, with a network of 1 point/5 km^2 up to 1.2 points/km^2. The magnetic anomaly map is characterized by a very irregular contour of the isodynam lines which describe a field strongly disturbed by numerous anomalies, with different amplitudes and orientations. These isodynam lines may be grouped into two zones, separated by the zero isodynam line, which approximately follows the thalweg of the Ialomiţa Valley. In the eastern zone, the isodynam curves have high values, outlining a field of anomalies whose density exceeds 300 γ, almost reaching 600 γ at Palazu Mare. The western zone is dominated by the low values of the isodynam curves. Some more important perturbations are noticed in the region delimited by the Jiu and the Dîmboviţa valleys.

By electric prospecting only a part of the Moesian Platform has been investigated, achieving a density of 1 point/6 km^2. The vertical electrical sounding has been particularly used. The results obtained made possible to individualize, within the investigated deposits, three distinct resistivity intervals: a superficial one, with a resistivity ranging between 15—70

Ωm, due to the wide lithofacial variations; an interval characterized by small values (3—10 Ωm) corresponding to the Pliocene conductive formations; a lower interval with resistivities of the hundreds or even thousands Ωm, corresponding to the Mesozoic carbonatic formations. The isoohm maps show, on the one hand, a diminution of the resistivity values from the south to the north in the sense of the sinking of the Mesozoic limestone plates and, on the other hand, suggest that the maximum anomalies correspond to the uplift zones, whilst the minimum electric anomalies identify with the sinking zones.

Apart from the classical prospecting methods, radiometric and emanometric surveys have been also used. The results obtained are not conclusive as the radiometric anomalies, determined by the natural gamma-radiation variations and the radon amount in the ground are not connected with the presence of the hydrocarbon accumulations (in the depth), but with the lithologic diversity of the superficial layer. It is worth mentioning the important amount of geochemical prospections carried out particularly in the zones characterized by reduced thicknesses of the sedimentary formations. Although most of the geochemical anomalies correspond to some seismic discontinuities caused by faults, the results of this method cannot be considered conclusive because after drilling control it has been ascertained that they overlap some industrial hydrocarbon deposit only to a small extent and only when they are supported by undoubtful seismic data.

The seismic reflection proved to be the basic method used in the prospecting of the geological formations of interest. Such works have been carried out more or less minutely in the whole platform, except Central Dobrogea, the network being of about 1.50 km of profile/km^2. Until 1961, the prospections were fulfilled according to the oscillographic method. In the period 1961—1972 analogical stations were used and in 1973 the digital technique was introduced. In numerous cases, the profiles accomplished according to the recent techniques and method of recording and processing supplied further information.

The discovery, every year, of new petroleum and gas fields determined the intensification of the research drilling, so that during the last 22 years, in the Moesian Platform more than 7,000 wells were drilled, the deepest one (922 Ghergheasa) reaching 6,204 m.

The data supplied by the geophysical, geochemical and drilling works have been studied and then synthetized in a lot of scientific reports and studies.

At present, the geological knowledge of the Neozoic and the Mesozoic formations, within the limits of 3,500 m deep, reached an advanced degree. Below 3,500 m, the seismic prospection (of reflection and refraction) offered, in general, dispersed, poor and contradictory information. As a result, the structural arrangement of the Permo-Triassic deposits on the northern border of the platform, as well as the intimate structure of the Paleozoic formations, is very little known.

1. Stratigraphic and Lithologic Peliculiarities of the Sedimentary Cover

The basement of the Moesian Platform has been found in two distinct regions. The former corresponds to Central Dobrogea and its NW prolongation, under more recent formations of the Romanian Plain. Here the basement is represented by the greenschist formation and the Palazu and Cocoşu metamorphosed formations. The latter is situated in the western part of the Romanian Plain, rendered evident by the wells 4501 Budeşti, 1, 3020, 3028 Priseaca and 3317 Oporelu which pointed out epizone and mesozone crystalline schists. In certain sectors of the Balş-Optaşi uplift, these crystalline schists are pierced by granitic, dioritic and gabbroic magmatic bodies.

The crystalline schists occurring on the Balş-Optaşi uplift are probably older than the greenschists. The absolute age of the latter is of 542—596 mil. years (Giuşcă et al., 1967).

The Karelian (?) and Baikalian heterogeneous basement is overlain by a very thick sequence of deposits, the result of four major sedimentary cycles: Cambrian(?)-Upper Carboniferous, Permian-Triassic, Upper Lias-Senonian (Eocene in places) and Neogene. In its turn, this sequence of deposits can be divided into several lithofacial cycles, each of them presenting different conditions as regards the genesis, accumulation and preservation of the petroleum and gas deposits.

The sedimentary cover of the Moesian Platform starts with a terrigene lithofacial cycle (the lower detrital cycle) which lasts from the Cambrian (?) till the Eifelian. In its base, one can notice a mostly psamitic series, 800—900 m thick, constituted of arkosian sandstones and quartzites, at the lower part, followed by orthoquartzites and sandstones, more and more clayey. In the eastern part of the platform, the gritty-quartz formation unconformably overlies the greenschists, while in the western part the relationships of this formation with the metamorphic basement are unknown as it has not been crossed entirely.

The stratigraphic sequence continues with mostly pelitic deposits, which can get to thicknesses of 2,000 m. These deposits are formed of clays, argillites, clayey and limy schists, limestone banks and intercalations of limy sandstones and marls, more and more frequent and thicker towards the terminal part of this series.

The Paleozoic detrital cycle ends with a predominantly gritty series, maximum 215 m thick. This horizon is represented by quartzitic sandstones with intercalations of quartzitic microconglomerates, small pebbles, siliceous-clayey sandstones, gritty clays, argillites, limestones and dolomites. The prevailing red colour and the paleontologic content of the gritty formation plead for the Eifelian and remind of the Old Red Sandstone.

The transition from one lithofacial unit to another, within the lower detrital cycle, seems to take place gradually, the question of gaps being raised within the three terrigene formations.

In the orthoquartzitic complex of the basal gritty series one determined a palynoprotistologic assemblage, little developed and poorly preerved which, in other sedimentary basins, characterizes the Cambrian nd even the upper part of the Precambrian (Paraschiv, Beju, 1973). Forms of achritarchs, indicating the Lower Ordovician have been also found in the pelitic sequences intercalated in the upper half of the same series. Considering the forms of graptolites (Murgeanu, Spasov, 1968) and achritarchs found at Bordei Verde the basal part of the overlying pelitic formation is of similar age. Achritarchs and chitinozoa, specific to the Middle Caradoc-Ashgill, have been identified in the cores recovered from an upper stratigraphic level, at the wells 1052 Țăndărei and 523 Bordei Verde, represented by clayey marls and tufaceous clays. As at the well 523 Bordei Verde the Upper Ordovician directly overlies the gritty-sandy series, a Middle Ordovician sedimentary gap is admitted at least partly; this statement is also supported by the presence of some Caradoc tuff horizons. The fauna of graptolites and brachiopods, as well as the microfauna determined in the eastern part of the platform, in Dobrogea and the Balş-Optaşi sector, indicate that the pelitic sequence includes Wenlockian, Ludlovian and Eodevonian in its upper half. Apart from some doubtful microfloral indications, no other elements in favour of the Landoverian presence have been found. The microfloral evolution, the microfacial elements (the presence of some conglomerates) as well as the variation of the strata dips also plead for a sedimentary interruption at the Silurian/Devonian boundary, at least in the uplift zones.

Mention should be made of the fact that the lower detrital cycle, formed of two predominantly psamitic series separated by a pelitic series, starts in the Cambrian (?) and lasts till the Eifelian. Within this time span the sedimentation process was interrupted, at least locally, during the Cambrian, the Middle Ordovician, the Llandoverian and at the end of the Silurian. These gaps would synchronize with the phases of Sardian, Taconian and Ardenian movements.

The second lithofacial cycle corresponds to the strong group of limestones and dolomites whose deposition lasted from the Givetian till the end of the Visean, in places till the Namurian. As the lower terrigene group, the carbonate-evaporitic group has variable thicknesses, lacking entirely on the former uplift zones (Bordei Verde, Balş-Optaşi, Strehaia-Vidin uplift) and getting thicker (up to 2,000—2,200 m) in the Periș-Urziceni, Roșiori-Alexandria and the Lom-Craiova downthrown sectors.

The carbonate cycle begins with a complex of organogenous dolomites and limestones, 250 m thick. It probably overlies in continuity of sedimentation the Devonian gritty formation, as suggested by the gradual transition from sandstones to dolomites. Due to its character of transition from the subcontinental to the marine-lagoonal medium, this complex is characterized by a wide lithologic variety, including dolomites, dolomitic limestones, organogenous limestones, sandstones, clays and anhydrites of Givetian age.

Up in the stratigraphic series, it follows the dolomitic complex whose thickness varies from some metres to 1,000 m (Călărași). This series consists almost of dolomites and dolomitic limestones. The proper limestones have a reduced share, being found towards the upper part of the profile. Like in the complex mentioned before, here the evaporitic products appear, too, either filling the rock diaclases or as gypsum and anhydrite aggregates or only as thin intercalations. The frequency of the anhydrite elements diminishes towards the upper part of the complex, being substituted gradually by calcite in the sealing off of the rock fissures. Apart from the fissures, partly sealed off, the dolomitic complex is also characterized by the presence of vacuolas and caverns. Among the dolomite varieties, the bituminous dolomites are the most widespread. The primary character of most of the dolomites is pointed out by the evaporite paragenesis and confirmed by the microscopic analyses. The fauna, macrofauna and especially the microfauna determined indicate the Frasnian and Famennian age of the dolomitic complex.

The carbonate-evaporitic cycle ends with the Carboniferous formation, about 1,200 m thick (at Călăraşi). This formation is constituted of a multitude of lithologic varieties, namely subnodular limestones, compact limestones, silicified limestones, organogenous limestones, gritty limestones, calcarenites, dolomitic limestones, dolomites, clayey dolomites, clays and even thin intercalations of sandstones and conglomerates. The dolomites and the dolomitic limestones have a reduced share and an irregular distribution probably connected with their secondary origin (secondary dolomitization processes).

Microfacial analyses, macrofauna, microfauna as well as microflora determined indicate that the calcareous formation deposited in a marine medium during the Visean. In the east of the platform it seems that the deposition of this formation started earlier in the Tournaisian (as pointed out by the presence of *Siphonodella isosticha* C o o p e r, at Călăraşi) and lasted till the Namurian (as indicated by the Periş profile). Under the above-mentioned conditions, the existence of a stratigraphic gap, almost general in the Moesian Platform corresponding to the Tournaisian and even to the Lower Visean is clearly outlined. As a matter of fact such a situation has already been proved in South Dobrogea, on either side of the Romanian-Bulgarian boundary.

Roughly speaking, the deposition of the Paleozoic carbonate-evaporitic group ends concurrently with the Sudete phase and the second detritogene group (the middle detrital group) begins, which lasts until the end of the Dogger, excepting the Middle Triassic marine episode.

The Carboniferous detrital formation is individualized in the base of the middle detrital group ; it is mostly represented by terrigene deposits, sometimes associated with coals. As mentioned before, the thickness of the terrigene detrital formation varies from some metres up to 565 m, the maximum value being recorded in the Roşiori-Alexandria depression zone (at Vlaşin and Peretu). This formation is constituted of clays, schistose argillites, marls, marno-limestones, organogene limestones, dolomites, siliceous sandstones, graywackes, metagraywackes, tufites, coals, etc. Among the mentioned lithological types, marls and argillites prevail. Sandstones and limestones have reduced thicknesses and lenticular developments. The abundance of incarbonized plants and of coals as well as the evaporitic cement of some sandstone levels certify the overwhelming influence of the continental environment and point to the paralic or lagoonal character of the sedimentation in different sectors of the platform.

According to the microfaunal and particularly to the microfloral elements the Carboniferous detrital formation deposited during the Namurian, in certain sectors even during the Visean and, in places (SE Bucureşti, N Craiova), lasted until the Westfalian and the beginning of the Stephanian (at Brădeşti). In the western half of the platform, the detrital formation overlies various Visean terms, while east of Bucureşti, a continuity of sedimentation seems to exist between this formation and the subjacent calcareous formation. The first major sedimentary cycle in the Moesian Platform ends with the Silezian detritogene formation.

The Asturian phase marks the rising in a body of the whole Moesian Platform and, therefore, a new gliptogenesis stage. The sedimentation is resumed in the Permo-Triassic when three great lithostratigraphic units formed : the lower red formation, the carbonate formation and the upper red formation, all of them resembling the German Triassic to a certain extent.

The lower red formation occurs as a predominantly continental facies and consists of a complex of sandstones surrounded by two pelitic complexes. The basal pelitic complex is formed of argillites with anhydrite films and dolomite crystals, gritty-ferruginous clays, intercalations of gypsiferous sandstones, conglomerates and magmatites, results of at least three eruption phases (acid and basic). In front of the uplift zones, the basal complex, which seems to belong to the Permian, becomes arenitic, even conglomeratic.The gritty complex is constituted of sandstones, some of them siliceous, cherry-coloured, with intercalations of clays and microconglomerates. The upper pelitic complex is made up of clay, gritty clays, marls, intercalations of marno-limestones and sandstones : the last two complexes are of Triassic age. The deposits of the lower red formation unconformably overlie various Paleozoic terms, constituting the filling of the relief and of the pre-existent structural forms. For this reason, their thickness varies from some metres to more than 2,600 m (at Liţa).

The overlying carbonate formation consists of limestones and marno-limestones, siltic limestones, organogene limestones, calcarenites, secondary, dolomites, clays and dolomitic marls, anhydrites and salts sometimes in alternation with volcanogene rocks. Halites occur only locally, in the south of the platform, at Putinei, Chiriacu and Studina. Limestones sometimes contain organic matter dispersed in the rock. The macrofossils determined include species pointed out in the Anisian- Ladinian interval locally the Werfenian, too (Fig. 85). In other words, on the downdropped zones the deposition of the carbonatic formation started in the Lower Triassic (even in the Permian), was generalized during the Anisian and ended in the Ladinian. The relationships of the carbonate formation with the adjacent lithostratigraphic terms are of discontinuity.

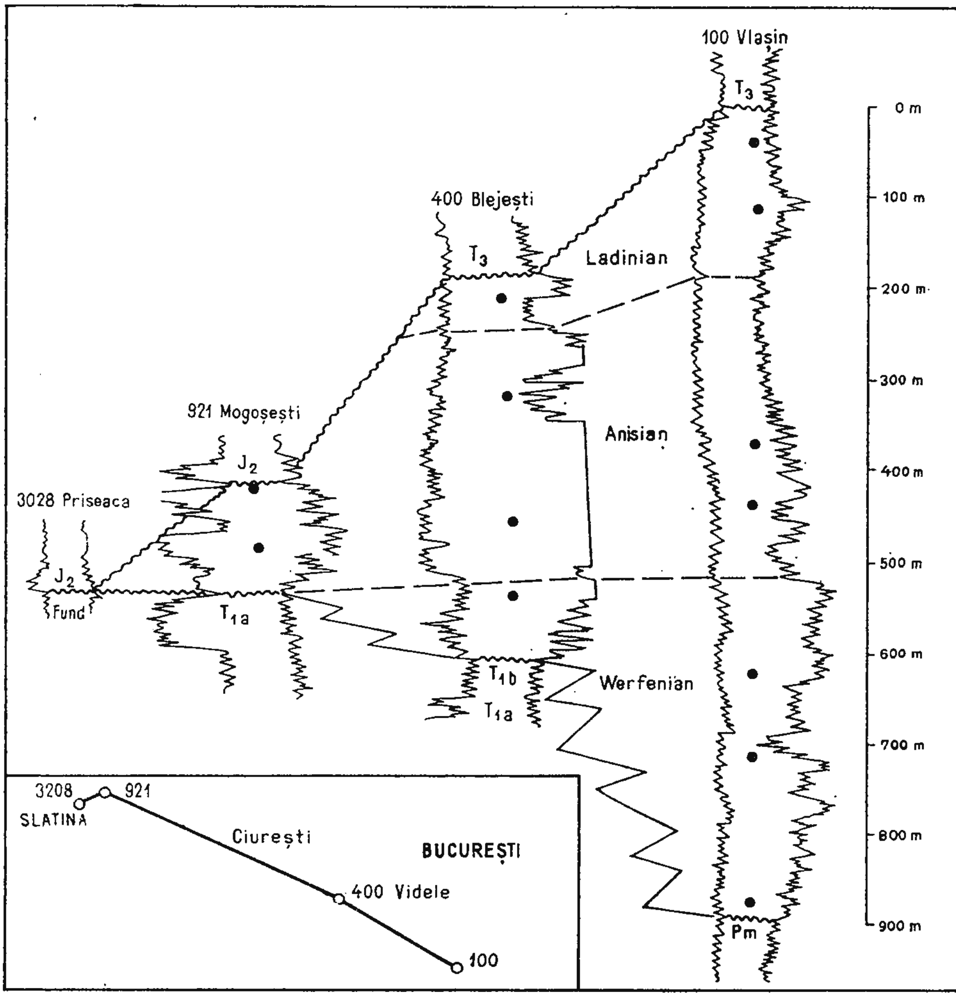

Fig. 85. — Carbonatic Triassic formation-correlation of some well profiles.

The upper red formation of continental and lagoonal facies, like the lower red formation, is constituted of clays, marls, sandstones and sands grouped into three complexes in the zone of full development (Băilești). The lower and middle complexes, characterized by a greater share of the psamites, contain microfloral associations similar to those described in the Alpine Carnian and the German Lower Keuper. Within the upper term, prevailingly pelitic, characeae in association with ostracods have been described, which point to the Upper Triassic age (Keuper). In the northern sector of the platform, products of the basic magmatism have been pointed out, representing the fourth phase of the Permo-Triassic cycle.

The second major sedimentary cycle (Permo-Triassic) ends with the upper red formation. At the end of the Triassic, the Romanian sector of the Moesian Platform rises, becoming land. A new period of very active denudation followed, during which some of the pre-Jurassic deposits, particularly those belonging to the upper red series, have been removed. Taking into account that the Permo-Triassic formations deposited over a pre-existent relief and that they have been affected by the pre-Jurassic denudation, the spreading area, their thickness and the relations with the adjacent terms are different.

Concurrently with the Dogger, in places since the Toarcian, the sedimentation process has been resumed by marine terrigene deposits. This formation deposition, which marks the beginning of the third major sedimentary cycle in the Moesian Platform and, at the same time, the last lithostratigraphic term of the middle detrital group, lasts till the Lower Callovian. It is represented by sands, siliceous sandstones, marls and clays of a grey-blackish colour, with *Posidonia*.

The Jurassic terrigene formation appears in most of the Moesian Platform; however, it is lacking in its west and easternmost more uplifted parts. As a result, the Jurassic detrital formation undergoes large variations of thickness. The maximum values (500—600 m) are found between the Jiu and the Olt valleys (Fig. 86), where this formation is represented by a gritty-sandy lower complex and a marly upper complex.

The lower complex is constituted of sandstones and predominantly siliceous sands, here and there limey, clayey, marly, bituminous and even coaly (Spineni). Levels of oolitic organogene limestones, of siderites and conglomerates are present, too. The upper complex is formed of marls and clays, often bituminous, ferruginous clays, marly limestones and marno-limestones. In the southern part, between the Olt and the Argeş rivers, the upper complex also includes a bank of sandstones and sands (Do).

In the central-northern sector of the platform, where the marine terrigene series reaches its maximum, the available paleontologic elements indicate, as mentioned before, the Toarcian-Lower Callovian age. As we approach the western and particularly the easternmost part of the platform, the thickness of the series decreases as against the basal terms, so that the pre-existent relief is covered by younger and younger strata.

Beginning with the Upper Callovian, the geological conditions change, so that the terrigene sedimentation is replaced again by the carbonatic sedimentation; this situation, with small exceptions, will last till the end of the Cretaceous. During this time interval, the formations of the fourth lithofacial cycle, the upper carbonatic group respectively, are deposited.

Within the post-Dogger evolution of the Romanian sector of the Moesian Platform, one can notice a first stage which corresponds to the Malm and the Lower Cretaceous, when limestones, mainly reefal and

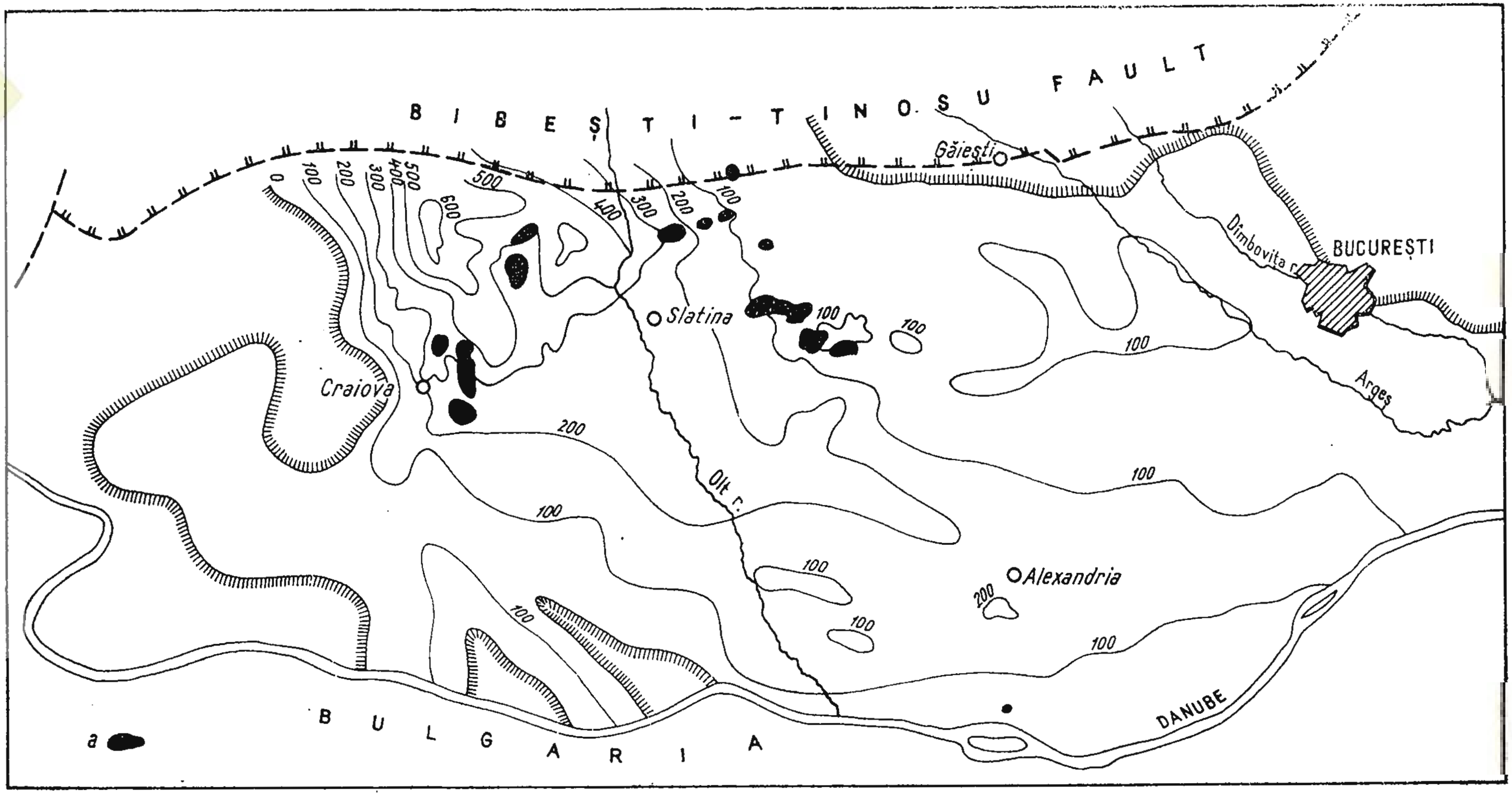

Fig. 86. — Isopachyte map of Middle and Lower Jurassic deposits. a, hydrocarbon deposits.

perireefal, marno-limestones and dolomites were deposited, on a thickness of 300—1,400 m. The microfacial analyses as well as the paleontologic elements (calpioneles) indicate a continuity of sedimentation between the Jurassic and the Cretaceous.

In the central sector of the platform, the Malm and the Lower Cretaceous are represented by a pelagic facies. To the east and the west, this facies passes gradually to a neritic-reefal, even lagoonal facies (in the easternmost part). Moreover, in certain zones in the east of the platform, the Tithonian and the Barremian-Aptian seem to be lacking. As a result, some lithologic differentiations have been emphasized in the Malm-Lower Cretaceous. Thus, microgranular (pelitomorphous) limestones, marly limestones, marno-limestones and marls are apt to be found in the pelagic facies zone. The zone of the neritic-reefal facies is characterized by pure limestones, organogene limestones and dolomites of a white, white-yellowish, very seldom white-grey colour. More to the east (Jugureanu-Bordei Verde) there are argillites, marls, grey, greenish or reddish sandstones, and anhydrites (the Purbeckian-Wealdian facies).

During the Aptian, the Moesian Platform rose, determining the exondation of the territory concerned. The process of sedimentation was resumed during the Albian. The deposits mark the beginning of a new accumulation period. The marine transgression gradually extended to the west, from Dobrogea, comprising the western part of the platform only in the Upper Albian, even the Cenomanian. Taking into account the transgressive character and the evolution of the territory north of the Danube, the Albian is represented by different facies. Thus, west of the meridian of the town of Roşiori, the Albian is characterized by grey-greenish marls and marno-limestones. The marly and limey sandstones and the gritty limestones prevail in the zone between the meridians of the towns of Roşiori and Urziceni. Limestones, marls, sandstones and glauconitic sands appear to the east and south-east of Urziceni and conglomerates in Dobrogea. In some zones east of the Argeş and west of the Jiu, the Albian is missing (Fig. 87).

The deposition process, resumed during the Albian, continues with temporary and local interruptions, till the end of the Senonian, interval within which 300—800 m deposits accumulated. They have generally a marly-limey character, with strong intercalations of pure limestones. The Senonian is characterized by the presence of the chalky limestones, too.

At the end of the Cretaceous, the platform rose again most of the Moesian territory remaining in the subaerial domain till the Tortonian-Sarmatian. In the south of Oltenia, in South Dobrogea and in the region south of Urziceni-Slobozia, the sea waters came back, for a short time, in the Middle Eocene, when limestones, marno-limestones, clays and sandstones deposited on a thickness of 20—250 m.

The third major sedimentary cycle in the Moesian Platform and, at the same time, the fourth lithofacial group, ends with the Middle Eocene.

The sequence of sediments continues with the fifth (and the last) lithofacial group, the upper detrital group respectivelly (Neogene), product of the (last) Tortonian-Quaternary sedimentary cycle. Within this time interval, an almost exclusively terrigene sequence, deposited; it consists of sands, sandstones, clays, marls, marno-limestones and, more rarely, limestones. These formations totalize some metres in the Danubian sector and Dobrogea, becoming thicker (6,000 m) on the south-eastern border

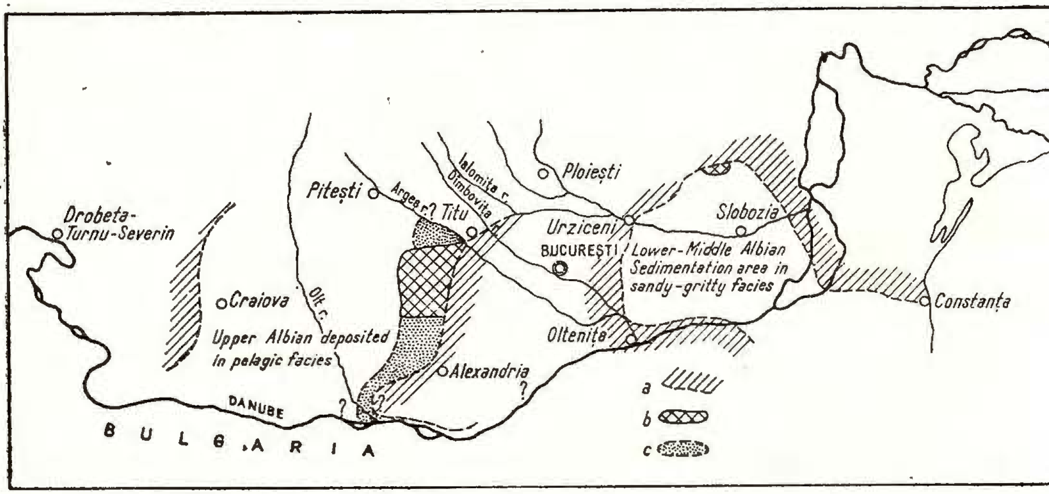

Fig. 87. — Distribution area and the facies zones of the Moesian Platform Albian. a, emerged zone ; b, oil producing area ; c, gritty-limy facies development zone.

of the platform. On the whole, the increase of the thickness occurs both towards N—S, in the sense of the sinking of the platform in front of the Carpathian Foredeep, and towards W—E, to the big subsidence zone in front of the Carpathian bending zone. Within this sequence discontinuities have been noticed at the Tortonian-Sarmatian boundary, in the Sarmatian, at the contact between the Sarmatian and the Pliocene. It is presumed that the frequency of the sedimentation interruptions, even of limited proportions, is greater.

The Tortonian deposits, predominantly marine, are represented by partly reefal limestomes, limy sandstones with anhydrite intercalations and, in places, by conglomerates. These formations appear on the northern border of the platform, in Dobrogea, as well as in some sectors characterized by a negative paleorelief (Titu-Videle-Glavacioc-Moara Săracă). The fauna and microflora determined characterize the Upper Tortonian (the *Spiratella* marl horizon). The data obtained recently north of Craiova seem to indicate that, at least in this region, the Tortonian deposited in a complete series.

The Sarmatian is represented by all its terms, the Bessarabian being the most widespread. Lithologically, the Sarmatian is mainly pelitic, but the marls and the sandy marls are associated with intercalations of sands and sandstones, whose frequency and distribution area partly depend on the pre-existent relief. This is the case of the intermediary zone of the platform, from the meridian of the town of Costeşti up to the locality of Făurei, where a horizon of sandstones and sands, 5—50 m thick, develops in the Sarmatian base. Southwards, therefore in the most uplift zone of the platform, this horizon changes the facies, passing to gritty limestones and pure limestones. More to the north (the downdropped zone of the platform) and to the west, it does not occur. Within the marly complexes of the Sarmatian, Meotian and even of the Pontian, numerous intercalations of sands, most of them with a lenticular development, appear as well.

The Meotian, whose distribution area is more reduced than that of the Sarmatian has, roughly speaking, a similar lithologic constitution. However, one can notice that in the eastern and westernmost parts of the basin the frequency and the thickness of the sandstone and sand intercalations increase, whilst in the central part the marly facies predominates.

The Pontian exceeds the Meotian deposition area, sometimes overlying directly the Sarmatian or the Cretaceous. This stage is prevailingly marly. A 20—30 m thick sand horizon appears in the Craiova-Slatina-Drăgăşani sector, at the upper part of the Pontian profile. East of the Buzău-Călăraşi line, this stage becomes more and more sandy as it sinks and gets thicker to the north, so that at Ghergheasa-Balta Albă, the psamite share is almost equal to that of pelites.

The terminal sequence of the upper detrital group, of Dacian-Quaternary age, is mostly constituted of sands and sandstones in association with marls, clays and coaly intercalations, totalizing 100—1,500 m in thickness.

At the end of the Pliocene and during the Quaternary, the Dacic basin has been filled and the territory corresponding to the Moesian Platform has become land.

Summing up the above-mentioned things, we may conclude that the sedimentary cover of the Moesian Platform comprises formations whose age begins with the Cambrian and ends with the Quaternary. It is distributed to four major sedimentary cycles, as follows : Cambrian-Carboniferous, Permian-Triassic, Jurassic-Cretaceous (in places Eocene, too) and Tortonian-Quaternary.

From the lithologic point of view, an important criterion as concerns the hydrocarbon accumulations, the sedimentary cover may be divided into five lithofacial groups. Geochronologically, they may be assigned to :

— the lower detrital group : Cambrian(?)-Eifelian;

— the lower carbonatic group : Givetian-Visean (in places the Namurian, too);

— the middle detrital group : Namurian-Callovian (with a carbonatic episode belonging to the Middle Triassic);

— the upper carbonatic group : Oxfordian-Senonian (in places the Middle Eocene, too);
— the upper detrital group : Tortonian-Quaternary.

2. General Characteristics of the Structure

Bordered by the Carpatho-Balkan Orogen and by the North-Dobrogean Orogen, the Moesian Platform reacted in a proper way upon all the movements which took place in the neighbouring depressions. Its geological formations (deposits) were affected and deformed several times.

The basement of the region, heterogeneous as regards the age and the petrographic constitution, has, in detail, a complicated structure. On the whole, it is envolved in some major uplift and sunk major zones which seem to have been individualized since the Baikalian orogenesis when the last greenschist chains in Central Dobrogea consolidated. The structural configuration of the basement and its movement tendencies played an important part in the facies distribution and the tectonics of the sedimentary formation.

The Caledonian, Hercynian and Alpine movements which followed had an unsignificant influence on the Moesian Platform from the folded tectonics point of view; however, this influence was felt differentiatedly, in time and space, depending on the mobility or rigidity of the basement compartments.

The movements of the Moesian territory and of the surrounding regions are reflected in the vertical variations of the facies; they are particularly marked by a series of gaps which make possible the division the sedimentation cycles and subcycles. In certain zones, especially in the uplift zones, the deposits accumulated during these cycles also present structural planes, slightly different, which, to a certain extent, would justify the presentation of the bed arrangement on structural substages.

In the Moesian Platform, the following major uplift zones are known: Strehaia-Vidin, Leu-Balş-Optaşi, North Bulgarian and Central Dobrogean. The depressions Lom-Craiova, Roşiori-Alexandria, Călăraşi and Focşani are also emphasized as negative forms of large sizes. These structural elements of the first range, appearing at the basement level, had an active character for a long time, so that they are recorded till the end of the Triassic, with more and more diminished amplitudes. Moreover, Central Dobrogea could not be completely covered by waters, being still an emersion zone (Fig. 88).

The Strehaia-Vidin uplift is located in the westernmost part of the platform where its presence and outline at the basement level indicate a maximum gravimetric anomaly of high intensity. According to the seismic and drilling data, the basement is situated at 4,500—5,000 m deep. It is overlain by Cambro-Ordovician deposits as well as by the whole Paleozoic sequence, including the Upper Carboniferous and the Permo-Triassic. The Strehaia-Vidin uplift appears as an arching, trending NE-SW, which seems to go on, parallel to the Carpathians, under the foredeep tow-

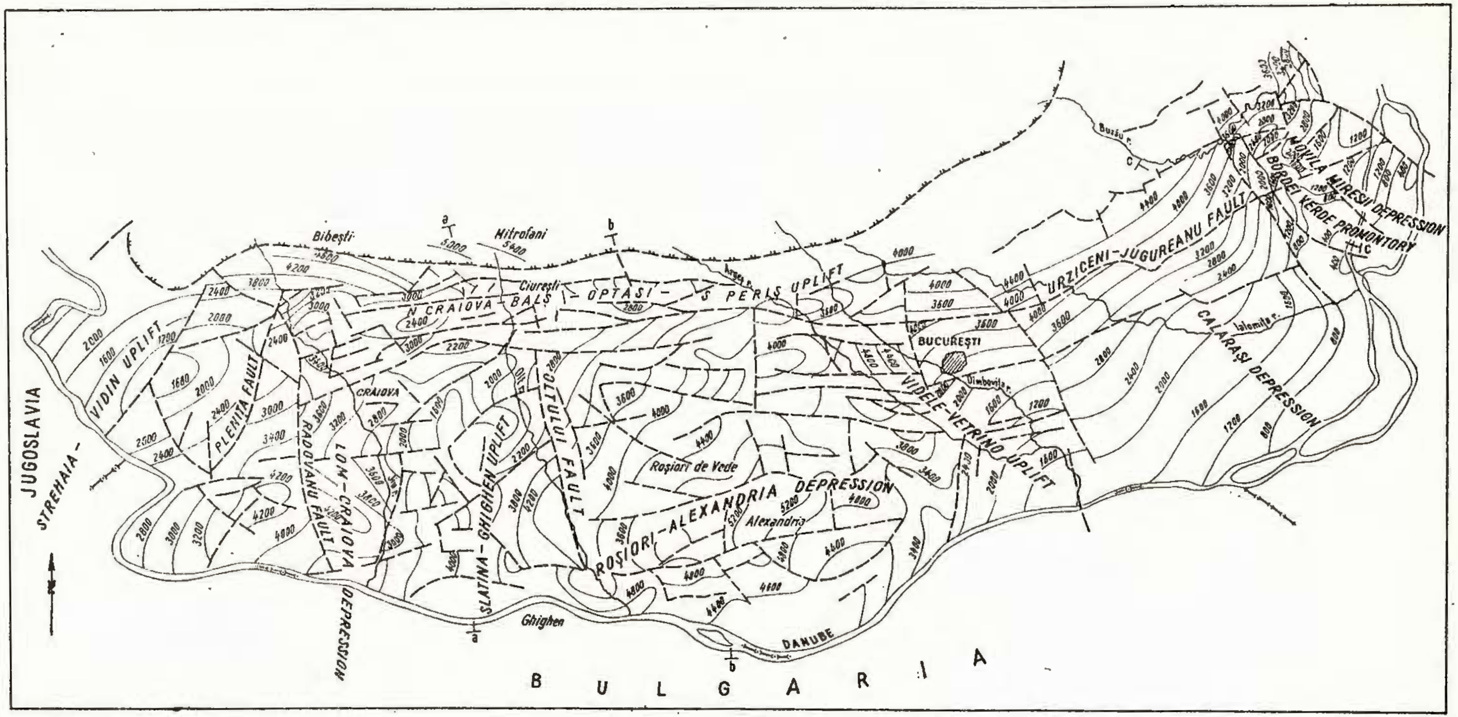

Fig. 88. — Morphostructural map of the Moesian Platform at the top of the pre-Permian deposits.

ards E—W. The flanks and periclines of this uplift are branched into spurs sunk on different directions, towards the adjacent depression zones.

The Leu-Balş-Optaşi uplift, situated in the central-western part of the platform, is represented, at the basement level, by a positive gravimetric and magnetometric anomaly. This uplift is a real massif in whose axis occur the crystalline basement (Cucueţi, Optaşi) and the deposits belonging to the Lower Paleozoic, directly overlain by the Jurassic or Permo-Triassic (Fig. 88). The striking of the massif is, at first, E-W, then it is deviated and sunk southwards, indicating its prolongation on the Bulgarian territory, on the direction of the Ghighen positive structure. On the opposite part, there also is a tendency of sinking east of Optaşi and then the massif seems to branch. One branch continues to E—W, south of Periş, and the other to SE, from Vlaşin to the North Bulgarian uplift (Vetrino). Besides the general movements of the Moesian Platform, the Leu-Balş-Optaşi massif underwent proper movements, particularly in its axial zone, indicated by numerous gaps during the Lower and Middle Paleozoic, Triassic and Jurassic. Taking into account its marginal position, in the proximity of the Carpathian Orogen, the Balş-Optaşi uplift also experienced, to a small extent, the effect of the folding movements. Thus is explained the fact that within the wide arching outlined by the sedimentary cover at all levels, except the Neogene deposits, some intensely faulted anticlines and hemianticlines are also observed. Most of the structural elements of the second and third range are, in fact, blocks which seem to be fragments ("pieces") of anticlinal structures. Also as a consequence of its vicinity with the Carpathian Orogen, delimited by deep-seated fractures, the Leu-Balş-Optaşi uplift constituted the background of some repeated magmatic phenomena which lasted until after the Middle Triassic.

The North Bulgarian uplift is situated in the south-eastern part of the platform. In fact, north of the Danube, there is only the prolongation on the Romanian territory of an uplift with the apex in the area of the locality of Vetrino (Bulgaria). In the central zone of this uplift, the oldest deposits which appear under the Mesozoic cover belong to the Eodevonian, and the basement might be found at depths of 2,500—3,000 m. On the whole, at the Paleozoic level, the uplift occurs as a wide arching. After several alternative exondations and sinkings, beginning with the Lower Cretaceous the apex zone of the North Bulgarian uplift is under a subaerial regime.

The Central Dobrogean uplift (Bordei Verde), situated in the SE part of the Moesian Platform, is delimited by two deep-seated disjunctive accidents trending NW-SE, that is the Peceneaga-Camena fault to the NE and the Capidava-Ovidiu fault to the SE. This massif is constituted of the Ripho-Cambrian greenschists of the basement, locally covered by Neojurassic formations and Aptian detrital deposits. Towards NW, the sedimentary cover also includes Paleozoic, Mesozoic and Neogene formations.

The major downdropped zones of the Moesian Platform, represented either by depressions relatively large, more or less elongated, or by corridors, are characterized by predominantly negative movements which favoured the accumulation and preservation of some deposit sequences, thicker and more complete. These downdropped zones are placed on the negative forms of the basement structure and, except some discontinuities and changes, preserved the Paleozoic major structural character till the end of the Triassic.

The Lom-Craiova Depressions is located in the southern part of the Moesian Platform and separates the Strehaia-Vidin uplift from the Leu-Balş-Optaşi massif, including its prolongation towards Ghighen. Northwards, this depression appears as a corridor extended under the deposits of the Carpathian Foredeep. In the central zone, the basement may sink up to 8,000—10,000 m. Considering the sequence and the thickness of the sediments, it seems that the Lom-Craiova Depression underwent continuous subsidence movements, from the Paleozoic till the Neozoic, more stressed in the Mesozoic (particularly on the Bulgarian territory).

The Roşiori-Alexandria Depression lies in the central-southern part of the platform, separating the North Bulgarian uplift, its western prolongation inclusively (Maslarevo-Totleben-Ghighen-Slatina), from the Leu-Balş-Optaşi massif. On the whole, the Roşiori-Alexandria Depression represented a moslty subsidence zone in the Paleozoic and the Triassic. As a matter of fact, only the lower red formation (Permian and Lower Triassic) totalizes about 2,600 m in thickness. This downdropped sector of the platform has some branchings which make the connection with the Lom-Craiova and Urziceni-Călăraşi depressions.

The Călăraşi Depression, widely open to the Carpathian Foredeep, separates the Central Dobrogean massif, on the one hand, from the North Bulgarian and Leu-Balş-Optaşi uplifts, on the other hand. It appears at the level of the Paleozoic deposits and, to a smaller extent, in the Triassic.

The Focşani Depression is located in the north-eastern part of the Moesian Platform and is closely connected with the Carpathian Foredeep. It represents the most active accumulation zone, especially in the Neogene. According to the geophysical measurements, partly controlled by drillings, the sediment thickness reaches about 18 km, from which 6 km belong to the Sarmatian, Pliocene and Quaternary. It is not out of question that this depression should have been outlined, in its western part, before the Neogene. Anyhow, its active subsidence character has been maintained up to now, as shown by the distribution and orientation of the hydrographic network in the Romanian Plain. A ramification of this important depression zone, known as the Movila Miresii Depression, extends towards SE, separating the Bordei Verde Promontory from the North-Dobrogean Promontory.

As mentioned before, the first range major structural elements characterize the arrangement of the Paleozoic beds and, to a smaller extent, that of the Triassic beds (Fig. 1). However, at the level of the Cretaceous and Neogene, the structural image is completely different, in the sense that, on the whole, these deposits become thicker, dipping and sinking from S to N (Fig. 89). This fact does not need any explanation taking into account that, starting with the Tortonian, most of the Moesian Platform

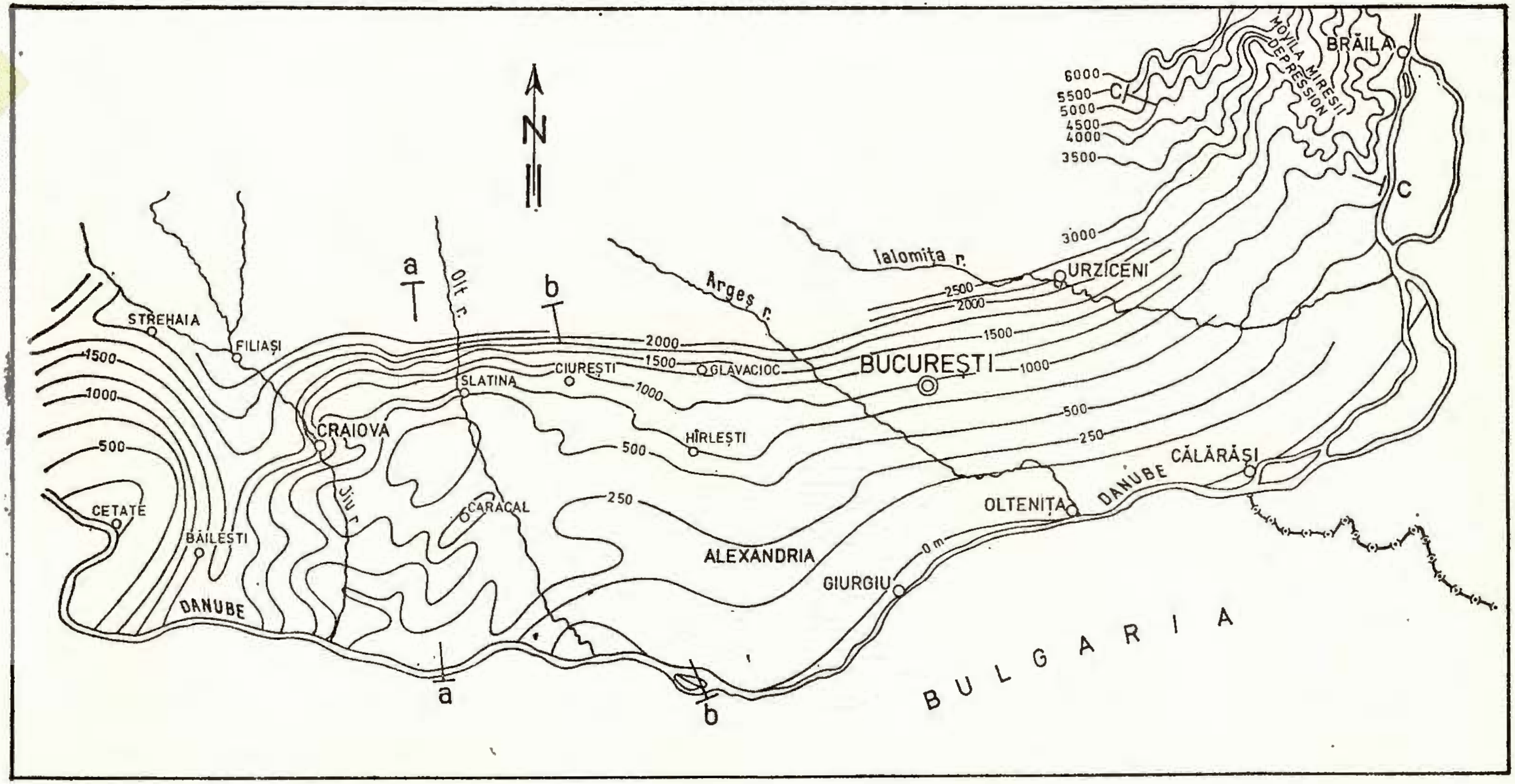

Fig. 89. — Morphostructural map of the Moesian Platform at a guide mark of the Neogene base.

constitutes the external flank of the Carpathian Foredeep. The sinking to the north takes place along some fault lines, generally parallel to the Carpathian system.

Against this major background of faulted monocline there occur numerous structural details generated by the variety and energy of the paleoreliefs, the thickness, nature of the sediments, the density and ampleness of the tectonic accidents and, to a very small extent (on the northern margin), by the rumpled movements.

When comparing the arrangement of beds in two moments, remote one from another, that is at the end of the Carboniferous (Fig. 88) and the middle of the Neogene (Fig. 89), we get two structural images, substantially different. Thus in the Paleozoic, the northern part of the platform constitutes the most uplift zone, dominating the Danube southern sector with 2,000—4,000 m (Plate VI). It means that the Paleozoic formations sunk from the north to the south. In the Neogene, the situation changed, the northern margin of the platform sunk continuously as a result of the outward shifting of the Carpathian Foredeep, so that the Neozoic and Malm-Cretaceous deposits sunk from the south to the north. This situation is observed west of the Urziceni-Călăraşi line. To the east of this line, all the bed sequence sinks to the periphery of the respective horst, therefore in front of the foredeep (Fig. 90), as a result of the permanent uplift position of Central Dobrogea.

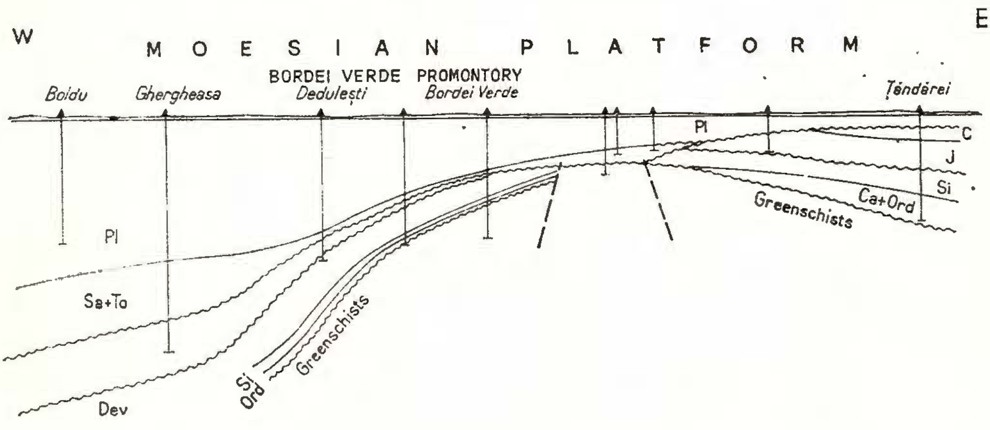

Fig. 90. — Longitudinal geological section in the Bordei Verde region (according to I. Pătruț).

In conclusion, in the evolution of the Moesian Platform there were three main moments which determined the major features of the geological formations. They correspond to the Baikalian, Neovariscan-Paleokimmerian and Styrian movements.

The detail structural arrangement, common to all the deposit sequence is the breakable one, imprinted by an impressing fault network, at first sight chaotically distributed. However, two dominant directions may be distinguished : an E—W direction, including the most significant faults of the platform, with a regional extension, which affect the whole sedimentary massif, including the Pliocene, and another direction, somehow perpendicular to the former, including faults of smaller account, often with a local development.

From the north to the south, the Bibeşti-Tinosu fault is the first tectonic accident which is worth mentioning; it is the counterpart of the Pericarpathian line, after which the folded deposits of the foredeep overlap the quasihorizontal deposits of the platform.

Other disjunctive accidents, mainly trending E—W, are the Boldu and Ghergheasa faults, in the NE part of the platform. They screen the Boldu, Bobocu and Balta Albă, Ghergheasa and Roşioru gas deposits. More to the SW, the Sinaia-Bărăitaru alignment has been emphasized, which seems to continue to the west, from Periş, Brîncoveanu up to Slatina. Along it there occur the hydrocarbon accumulations with the same name, the Serdanu, Dumbrava, Negreni oil fields inclusively. In the NW part of the platform an important tectonic accident seals the Brădeşti and Făureşti deposits (N Craiova); in the central-northern sector there is the Oporelu screen-fault which, after a southern deviation, continues to Cieşti. The Urziceni-Jugureanu fault, with its possible prolongation up to Căscioarele-Stoeneşti, constitutes one of the most important disjunctive accidents of the platform. Its throw may reach 300 m, the southern compartment constituting the downdropped block. Between the Argeş and the Olt rivers, there are other four important alignments which played an important part in the formation of the hydrocarbon deposits : the Cartojani fault and NW of it the Ciureşti N-Bîrla, Ciureşti S-Ciolăneşti, Bragadiru and Videle faults. There are also other tectonic accidents trending E-W, but the above-mentioned ones are enough for the pointing out of the tectonic style of the platform and the contribution of the faults-steps in the formation of the oil and gas deposits.

Some remarks are more significant in connection with the system of folds parallel to the Carpathian Orogen, important from the economic point of view. Firstly, mention should be made of the fact that between the direction of the Bibeşti-Tinosu fault and the platform faults there is no perfect comparison. The latter intersect the Pericarpathian fault and seem to continue in the foredeep basement, under the overthrust plane determined at the molasse level. Similar relations are also noticed between the Moldavian Platform and the Miocene zone or the Paleogene flysch zone. Secondly, the disjunctive accidents mentioned above are faults formed in fact, mostly reactivated, during the Neogene as a result of the outlining and evolution of the Carpathian Foredeep. Many of them are synsedimentary faults, the Urziceni-Jugureanu fault being a typical example as on both sides of the accident the Sarmatian-Tortonian thickness (less of the Meotian) differs from 50 to 100 m. In the third place, it is worth mentioning the fact that the main faults developed between the Bordei Verde Promontory and the Dîmboviţa River, namely the Sinaia-Bărăitaru and

Urziceni-Jugureanu faults, have a very inclined plane, the accidents migrating in time from the south to the north, that is in the sense of the increase of the subsidence rate during the Neogene. Moreover, in the Sinaia-Bărăitaru zone one can notice a differentiation of the tectonic style within the Neogene deposit sequence. Thus, whilst at the Sarmatian level (the base of the term) we may talk about a faulted monocline, with a northward sinking, the Pliocene structure migrates with almost 1 km northwards and occurs as a slight anticline, very elongated (more than 10 km) as it is a gravitational sliding structure. However, all the other structural elements in the north-easternmost part of the platform (Boldu, Ghergheasa, Roşioru) have a dome-like form at the Pliocene level. In the fourth place the fault throw varies generally according to the geological guide mark. At the northern margin of the platform (Craiova-Slatina-Optaşi zone), the throw of some disjunctive accidents reaches 1,000 m in the Triassic when oscillatory movements had exceptional amplitudes and intensities. At the Neogene base, the difference, among the blocks seems to be of maximum 300 m, usually of 20—100 m. Most of the faults may be followed only in the pre-Neogene formations as well as at the guide mark which indicates the beginning of the fourth sedimentation cycle. In the Neogene and especially in the Pliocene, the disjunctive accidents cannot be identified or are followed with difficulty either because of the reduction of the throw or because of the lack of lithological contrasts (therefore speed contrasts).

The second category of faults includes the disjunctive accidents trending N—S or NW—SE. Among them, the Peceneaga-Camena fault is the most important; it delimits the Moesian Platform from the North-Dobrogean Orogen. Also in the eastern sector there occurs a system of faults, lying in the extension of the Capidava-Ovidiu line, which delimits the Bordei Verde Promontory to the west. At the Neogene level, the differences among the blocks do not exceed 100 m. To the west, there is the Belciugatele fault system which, together with the above-mentioned line, surrounds the Călăraşi Depression. The Olt fault, with a throw of 600—800 m at Slatina, borders the Roşiori-Alexandria Depression to the west. The Radovanu disjunctive accident corresponds, more or less, to the axis of the Lom-Craiova Depression and the Dîrvari and Pleniţa faults seem to surround the Vidin-Strehaia uplift.

To N—S and NW—SE, besides the disjunctive accidents, there are numerous small promontories or structural "noses" separated by downdropped zones. More frequent in the sectors characterized by the reduced thickness of the sedimentary deposits, these structural forms are considered to represent sunk paleoreliefs (crests) covered and moulded by the sedimentary cover. Mention should be made of the fact that such "morphostructures" are practically found at the level of all Paleozoic, Mesozoic and Neozoic formations and they are maintained on the vertical. Moreover, most of them were active during the evolution of the platform, determining lithofacial variations and controlling the distribution of the hydrocarbon accumulations. For instance, reefs developed on some of the mentioned structural noses and most of the deposits of the platform accumulated in such morphostructures, associated with transversal faults (E—W). Due to their active character the "paleoreliefs" could be due to tectonic factors. In these circumstances, the age of some promontories should be as early as the Hercynian diastrophism, or earlier.

3. Geological Evolution of the Moesian Platform

After the Baikalian orogenesis, when the last chain of greenschists seem to have been consolidated, the region lying between the Carpathian Foredeep and the Prebalkans constituted the emplacement of a unitary sedimentary basin, the so-called the "Moesian Basin" whose individuality continued, with some exceptions, until the end of the Cretaceous. The main events which occurred during this long geological history are reflected in the stratigraphic sequences, the lithologic nature of the deposits, the faunal remains as well as in the arrangement of beds.

As mentioned before, the Baikalian orogenesis and the older movements led to the finishing off of the major structural lines as well as of the detailed tectonics of the platform basement. Some of these major lines continued to be active until the end of the Triassic, others (in the east) until the Neogene, influencing the lithofacies, sequence, thickness and arrangements of beds. During the Baikalian emersion, the basement was submitted to denudation; it led to the appearance of a quite varied and strong relief, adapted to the structure and rock nature.

The first sedimentation cycle begins with coarse deposits (different types of sandstones, microconglomerates, even conglomerates) formed in a marine environment. The character of the sediments indicates important positive movements in the neighbouring regions, strong erosion and transport on relatively small distances. An equilibrium of the movements which affected the basin and the surrounding land was achieved gradually and rhythmically. This equilibrium was first reflected in the pelitic sequences within the gritty-quartzitic formation and then in the stable sedimentation regime, which led to the accumulation of an important sequence of clays and argillites with intercalations of Ordovician and Silurian limestones and sandstones. At the same time a fragmentation of the basin bottom took place, associated with the formation of submarine shelf, which led to the settling particularly in the Silurian of a stagnant sedimentary environment of the Euxinic reducing type. The studies carried out with a view to defining the conditions of sedimentation pointed out that, in the Silurian, pH $= 6.2-7.8$ and eH$=0$ was either above the bed of sediments or it corresponded to its surface. In such an environment accumulated the argillites and gritty argillites rich in hydrotroilite and pyrite reaching in certain sectors 1,500 m in thickness. This situation characterized the Ordovician -Eodevonian stratigraphic interval. During the same period, rises of the basin bottom, accompanied by volcanic manifestations, took place on certain areas. It explains the stratigraphic gaps at the level of the Middle Ordovician, Llandoverian and at the Silurian-Devonian boundary, as well as the presence of cinerites in the Ordovician and Silurian.

The first signs of the deterioration of the equilibrium previously established appear during the Eodevonian. More and more gritty sequences occur in the series of clays, argillites and argillitic shales, and the deposition of the gritty formation, representing the last term of the first detrital group, takes place during the Eifelian. The relatively progressive emplacement of the clayey fraction with psamitic or psephitic material presumes a mass uplift of the region, both in the portion covered by waters and in the emersed sectors. The energy of the relief became more prominent and led to a recrudescence of the erosion. Among the paleontological elements identified, there are remains of agnothas and placoderms, beside psilophytale plants (*Hyenia*, *Aneurophyton*) which define the environment during the deposition of the gritty formation. The environment may be characterized as subcontinental, with freshen waters, of the Old Red Sandstone type. The climate is presumed to have been warm and arid which permitted the precipitation of gypsum and anhydrites occurring both as thick banks and precipitating as cement of some sandstones. The geochemical facies underwent radical changes. The euxinic geochemical conditions have been replaced by conditions specific to the subcontinental environment, strongly oxidated, improper to the hydrocarbon formation.

Givetian and Neodevonian constitute another important period in the evolution of the platform. During this period the mostly lagoonal deposits of the dolomite-evaporitic formation accumulate. The essential feature of these deposits is the absence, almost total, of the detrital material, the terrigene sedimentation being replaced by the process of the chemical precipitation. The complete ceasing of the supply of terrigene material on the land presumes either its ideal peneplanation or rather negative vertical movements in the whole Moesian domain, especially in the emersed sectors. The breaking up of the Moesian basin into lagoons and sea arms favoured the appearance of a generally stagnant, isolating environment. At the same time the sulphate of the organic matter, subjected to the bacteriologic action, entered into sulphurous combinations, giving rise to iron sulphides (pyrite, hydrotroilite) and hydrogen sulphide. A very acid environment, improper to the aerobic life, developed.

The conditions of the stagnant, isolating environment are gradually attenuated toward the end of the Neodevonian, so that depositions of limestones take place in a wide-open sea in the Dinantian. This change of environment seems to have taken place after the Breton diastrophism when an almost entire exondation of the Moesian territory and the formation of intrusive magmatic bodies (gabbros, diorites, meladiorites) took place.

As mentioned before, the Dinantian is formed of pure marine limestones, with numerous horizons of organogenous limestones and some detrital sequences. Primary dolomites occur in places, particularly towards the upper part of the limy series, indicating the beginning of the breaking up of the Dinantian basin. Secondary dolomites are also to be found but they have an irregular distribution. As against the Devonian, during the Dinantian the climate became slightly cooler and more humid, evidence of the abundance of the plant remains in the terrigene sequences of the limy formation. Simultaneously with the beginning of the calcareous phase, the euxinic reducing character is attenuated. Unlike the Devonian, the Dinantian limestones have no longer a sulphur smell in fresh breaking. The limit eH=0 corresponds to the surface of the accumulated sediments, and the value of pH exceeds 7.5.

At the end of the Dinantian, the bottom of the Moesian basin rises again, the areas corresponding to the eastern—and westernmost parts of the platform being exondated. Like in the geosynclinal areas, the Sudete phase constitutes the beginning of the breaking up of the Dinantian basin. At the same time, it marks the change of the deposit characters, the process of chemical precipitation being replaced by the terrigene sedimentation. The deposition of the lower carbonatic (Paleozoic) group ends and the accumulation of the Silezian-Triassic detrital group begins. The Sudete movements reactivated and amplified the fault system and also the magmatic processes considering the Visean and Silezian cinerite levels. The movement of the tectonic blocks of a different sense and intensity led to the division of the basin into several gulfs and small basins, bordered by emersed blocks. Between the gulfs and the basins there was an intercommunication. At the same time there were connections with the great mesogean basin, as indicated by the marine fauna and especially by the presence of Fusulinids in several wells on the northern margin of the platform. The sedimentation has a torrential character and the Namurian-Westphalian sequence, predominantly pelitic, is characterized by the presence of coals and coaly marls.

The positive movements, the increase of the land share, the breaking up of the basins as well as the humid climate contributed to the silting of the gulfs and to the small basin formation in the Namurian and Westphalian. In this way, in the Asturian phase the whole surface of the Moesian Platform became land; it followed an intense denudation process. As a matter of fact, some sectors corresponding to the Strehaia, N Craiova-Balş-Optaşi and Bordei Verde uplifts rose earlier. Here, the denudation action was stronger; it managed to remove a great part of the Paleozoic deposits and sometimes to reach the basement. In the south of the Moesian Platform and in the Lom-Craiova Depression, where the intensity of the positive movements was more reduced, the Silezian deposits and their cover were preserved to a great extent.

The sedimentation was resumed during the Permo-Triassic first on the downdropped zones and then on the northern uplift ones, except the Chilia-Strehaia, Iancu Jianu-Făureşti sectors and the Bordei Verde Promontory which were exondated until the Jurassic.

We come to the conclusion that, during the Paleozoic and the Triassic, the northern and north-western margin of the platform — the Strehaia-Vidin and N Craiova-Balş-Optaşi "massifs" — had a more uplift position all the time as indicated by the more reduced thickness of the sedimentary deposits as well as by the larger number of stratigraphic unconformities. The Bordei Verde Promontory had a similar position but unfortunately its apex remained exondated all the time so that here trapping conditions and first of all protection conditions could not be ensured at the level of the Paleozoic and the Mesozoic.

The lower red formation, corresponding to the Permian and the Lower Triassic as concerns the age, by its lithologic nature, crossed stratification, the colouring of the deposits points to a continental and subcontinental, strongly oxidating deposition environment. Therefore the interest for this series is limited especially to the aspect of the reservoir rocks. One must bear in mind the extraordinary instability of the territory of the Moesian Platform, characterized by vertical movements of a particular ampleness and intensity, which led to the sinking of more than 1,000 m, the reactivation of the profound dislocations and of the effusive magmatism, in at least three phases, the defining of some zones of continental, lacustrine and lagoonal facies associated with acid and basic magmatic rocks.

The subcontinental evolution of the Moesian basin was interrupted for a short period of time during the Lower-Middle Triassic when the sea waters are to be found in the central part of the Moesian Platform. Unlike the lower red formation, the Triassic transgression, starting in the Roşiori-Alexandria Depression earlier, comes to cover most of the N Craiova-Balş-Optaşi-S Periş uplift during the Anisian.

Towards the end of the Mesotriassic, the basin is again broken up into several lagoons in which anhydrite and, in the south of the platform, halite are deposited. It is worth bearing in mind the fact that the evaporites form, without continuity, the cover of the horizon of dolomites and limestones which may be considered mother or reservoir rocks. Little by little, the subcontinental regime settles again in the Upper Triassic. The upper red formation is characterized by a distribution area more reduced than that of limestones and dolomites even than that of the lower red formation.

Although there is a great bulk of information at our disposal it is difficult to make specifications on the relations among the three Permo-Triassic lithostratigraphic units in the downdropped zones and especially on the continuity of the subcontinental series deposition. At present we can only affirm that, on the uplifted zones, the carbonatic formation overpasses the lower red formation overlying the different terms of the Paleozoic. After the Middle Triassic, in the carbonatic formation as well as the lower red formations underwent a strong denudation process. As a result of the Upper(?) Triassic deposits the paleovalleys and generally the former relief was fossilized.

At the end of the Triassic, the territory north of the Danube rose, becoming land and submitted to denudation almost during the whole Lias. The process of denudation was so intense that, until the beginning of the Dogger, the Moesian territory reached the peneplain stage.

During the Upper Lias-Dogger, the platform sinks again, bringing about the resuming of the sedimentation process first in the central-northern zone and then towards the western-and easternmost parts of the Moesian domain. The basal gritty formation is followed by the formation of clays and grey-blackish marls. In the Upper Lias-Dogger pelitic formations there were identified bituminous or coaly clays, in places real sapropelites, which point to favourable conditions of accumulation and transformation of the organic matter into bitumens.

The second detrital lithofacial group ends with the Dogger. Now a new relative equilibrium is achieved between the basin and the surrounding land, as shown by the reduction, even the ceasing of the supply of terrigene material.

It is worth mentioning the fact that, beginning with the Jurassic, the major structural elements of the platform, except the Bordei Verde Promontory, have no longer determined the distribution and the configuration of the sedimentation areas. During the Upper Lias-Dogger, the zone of maximum subsidence crossed obliquely the N Craiova-Balş-Optaşi-S Periş uplift. During the Malm and the Lower Cretaceous the domain of pelagic sedimentation settled down exactly to the area of this great and old uplift. During the Albian, the deposition process was resumed starting from Dobrogea and the south-east of the platform and then it extended westwards, finally covering the surface corresponding to the Roşiori-Alexandria and Lom-Craiova depressions. The above-mentioned remarks indicate that the Moesian basin was broken up during the Jurassic and Cretaceous and lost its constant unit during the Paleozoic.

The second carbonatic lithofacial group begins in the Malm, with a general sinking of the platform which made possible the accumulation of pelagic deposits. The eastern and westernmost parts rise progressively and rhythmically as indicated by the alternation of pelagic and reefal limestones, then only by the reefal and perireefal limestones accumulated on these submersed platforms. In the central basin sector, the accumulation of the pelagic deposits continued till the Aptian. The easternmost part of the platform rose again more, as shown by the Puberckian carbonatic-evaporitic facies as well as by the continental-evaporitic character of the Lower Cretaceous.

Theoretically, the central basin constituted an environment favourable for the accumulation and transformation of the organic matter although the geochemical analyses do not confirm such a supposition. The reservoir rocks formed only when some of the carbonatic rocks present favourable porosities and permeabilities or when such properties were achieved subsequently diagenetically. The carbonatic plaforms, characterized by shallow and aerated waters, as proved by the development of the reefs, were not favourable for the accumulation, protection and transformation of the organic matter but they constituted an environment propitious for the deposition of the reservoir rocks.

The rising and exondation, at least partial, of the Moesian Platform take place at the end of the Lower Aptian, when continental, terrigene deposits accumulated. After a short denudation phase the Albian transgression follows, which begins from Dobrogea to the west. The facies variation as well as the transgressive character of the Albian make the respective deposits present locally properties of source rocks, reservoir rocks or cover rocks. These conditions were best achieved in the transition zone from the western marly-calcareous facies to the eastern gritty facies, a zone developed between Alexandria and Titu.

The immersion of the Moesian Platform lasted from the Albian till the end of the Cretaceous when, under the influence of the Laramian diastrophism, it rose again. A short period of immersion of the sectors adjacent to the Varna and Lom depressions took place in the Paleogene. As a matter of fact, it is presumed that, on the Bulgarian territory of the Lom Depression, the sedimentary basin lasted uninterruptedly till the Eocene.

The Cenomanian-Turonian calcareous and marly-calcareous deposits, with sandstone intercalations, point to a precarious equilibrium of dynamic factors, as indicated by the fine terrigene material supply in the emersed regions.

Predominantly chalky deposits accumulated during the Senonian; towards the end of it, tuffites, associated with the Laramian diastrophism, accumulated, too. The lack of phosphates in the chalky, marly-calcareous and calcareous-gritty deposits with flints is assigned to the depth (more than 200 m) of the Senonian waters. The post-Albian evolution of the platform favoured the deposition of some reservoir rocks (chalky limestones) in the Senonian.

The Moesian Platform evolved as land during the Paleogene and the Lower Miocene. Directed by the different intensity of the positive movements, the predominantly calcareous nature of the rocks in the western part and their varied scale in the eastern part, denudation gave rise to a very strong relief, represented by typical forms of erosion, karstic forms and abrasion surfaces. Among the forms of erosion one can notice some main valleys, such as Paleojiu, Paleoargeş, and Paleoialomiţa, tributary to the basin corresponding to the foredeep which, at a certain moment, seem to have drained the land lying between the Carpathians and the Balkans, the latter inclusively. The flow direction of the rivers from the south to the north is maintained by the absence of accumulation basins in the Oligocene (except the Varna-Camcia Depression) and the Lower Miocene, south of the Danube, as well as by the progressive depth of the valleys, e.g. the Paleojiu and Paleoargeş, as we come near to the Carpathian Foredeep. These elements, which at first sight have a pure paleogeographic significance, are of a special geological interest, first because they give indications on the moment when the tilting movement of the platform took place, more precisely when it began to dip from the south to the north in front of the Carpathians. Taking into account those data as well as the evolution of the Carpathian geosyncline, this moment would correspond to the Savian diastrophism, when the Miocene foredeep was outlined. Secondly, because these old rivers generated paleodeltas, formations of interest for hydrocarbons. We also mention that, in the west of the platform, the Miocene paleovalleys sank so much as they crossed the whole pile of Mesozoic sedimentary deposits, reaching the Paleozoic. In such cases (Brădeşti), the valleys intersected and partly overlapped Triassic reliefs.

The process of sinking of the Moesian Platform in front of the Carpathians begun in the Savian phase, became more obvious towards the end of the Miocene. This sinking is not uniform, the sinking angle increases from N to NW according to a line which would pass through the localities of Craiova, Slatina, Bucureşti, Urziceni, S Ianca. The territory beyond this line has been surrounded by the proper platform and the territory lying north of the line constitutes the "adjacent intermediary zone" (Grigoraş, 1961).

The final stage of the evolution of the Moesian Platform began with the Tortonian when waters flooded the northern margin of the foreland and advanced transgressively first to the former paleovalleys and other negative forms of relief. During the Sarmatian the whole area north of the Danube constituted the external flank of the Carpathian Foredeep. With some rhythmical variations of the shore line the sedimentary basin continued till the end of the Pliocene and, in places, in the lacustrine form, till the Quaternary.

4. Conditions of Genesis, Accumulation and Preservation of Hydrocarbons

The long and complex evolution of the Moesian Platform favoured the accumulation of an important sequence of deposits consisting alternatively of reservoir rocks, impervious rocks and possible hydrocarbon source rocks.

The first objective showing reservoir properties, in the deposition order, is the gritty quartzite series which can reach 700 m in thickness. Its old age suggests an advanced diagenesis with negative effect on the porosity and permeability. These sandstones must be taken into account as fissured reservoirs at least. They are well protected by the pelite cover formed of clays, argillites and by the graptolite schists belonging to the Ordovician and Silurian.

The next term is the Devonian gritty formation, namely the Eifelian in the Old Red Sandstone facies. These sandstones were tested at Rîmeşti, where they proved their reservoir properties producing salt waters.

Taking into account the primary porosity (about 10 per cent) and the system of fissures and caverns they contain, the Givetian and Neodevonian dolomites represent, undoubtedly, reservoirs, checked especially north of Craiova.

Within the dolomite series there are compact limestone horizons playing a protecting part.

The (Dinantian) carboniferous limy formation is marked by fissured limestone and cavern levels and by dolomites with local development. This formation is protected by the Silesian detrital series.

The Permo-Triassic contains reservoir rocks in all its lithostratigraphic terms. These properties were proved in numerous zones where the respective formations are productive. The regional studies indicate that the sandstone and sand levels of the red lower formation have porosities 1—39.8 per cent and permeabilities 0—199 mD; the Middle Triassic limestones and dolomites, 0—15.3 per cent and 0—56 mD, respectively (without taking into account the fissural permeability); the red upper formation sandstones, 0—23 per cent and 0—650 mD. The various clay beds, compact limestones and Permo-Triassic anhydrites might constitute protecting screens.

Good, predominantly siliceous reservoirs, consisting of sandstones and sands are found in the Dogger. The porosity varies between 15—24 per cent and the permeability between 40—700 mD here. The overlying complex of *Posidonia* clays is both the protector and the hydrocarbon source. Locally, the Malm limestones and dolomites may show moderate collector properties. The improvement of the permeability depends on the diagenesis degree of the respective rocks.

The Lower Cretaceous, usually defined as "Neocomian", contains dolomite and porous reefal limestones as well as a series of fissured and cavernous carbonated rocks with porosities of 13—25 per cent and permeabilities 0.3—200 mD.

The Albian offers reservoirs with porosities 4—25 per cent and permeabilities 0—100 mD. These reservoirs are overlain by the Upper Cretaceous marno-limestones.

Granular reservoirs (sands, compact sandstones) are generally known in the Tortonian and Sarmatian. The porosities reach 30 per cent, while the permeabilities vary between 0 and 3,500 mD. The respective reservoirs are protected by the marno-clayey series from the Sarmatian, Meotian and Pontian.

The Meotian and Pontian contain sandstone and sand intercalations protected by marly and marno-sandy horizons. The porosity varies between 12 and 30 per cent, while the permeability reaches 1,200 mD.

Sandy, sandstone and microconglomerate beds are very frequent in the Dacian and Levantine, but they benefit only locally by protection conditions. That is why they are almost completely invaded by sweet waters.

The list of source rocks might include: the Ordovician-Silurian argillito-graptolite schist formation, the Middle Triassic carbonated series, the Devonian dolomite-evaporitic formation, the marno-clayey complex with *Posidonia* from the Dogger, the Albian marls and marno-limestones and, generally, the Upper Cretaceous marls, the Tortonian, Sarmatian, Meotian and even Dacian pelite horizons. The chemical analyses carried out at the Middle Triassic, Dogger and Albian levels show the following geochemical indexes:

	Triassic	Dogger	Albian
carbon (per cent)	0.01—0.84	0.33—0.41	0.05—0.90
mineral reducing capacity (MgO_2/100 g rock)	0.14—24.7	1.5 —6.33	0.10—1.96
organic reducing capacity			

(MgO_2/100 g rock)	0.11—3.88	0.33—3.41	0.05—0.90
total reducing capacity (MgO_2/100 g rock)	0.60—24.7	1.88—11.60	0.23—4.26
pyrite sulphur (per cent)	0.01—8.0	?	0.1—1.4
bitumen A (per cent)	0.002—0.18	0.12—0.47	0.006—0.3
bitumen C (per cent)	0.002—0.23	0.05—0.30	?

At the same time the research carried out indicated the presence of nickel and vanadium in the bitumens A and C, which proves the source rock characteristics of the analysed samples.

As far as the Sarmatian and the Pliocene are concerned, no synthetical geochemical study has been drawn up so far, but such papers do exist for the Subcarpathian Pliocene of Muntenia, which deposited in the same sedimentary basin and under, partially, similar conditions. As has been shown in one of the previous chapters, A n t o n (1973) reaches the conclusion, in one of his studies, that the oil and gas in the Pliocene deposits are autochthonous.

According to some relatively recent papers (P a r a s c h i v, 1977; P a r a s c h i v , C r i s t i a n, 1976), the Moesian Platform is characterized by geothermal gradients of 1.5°C/100 m—6°C/100 m.

The highest values were recorded west of the Argeș River, in the most uplifted zone of the metamorphic basement and, especially, in the sector of the Videle—Cartojani structures (Fig. 91). As the crystalline

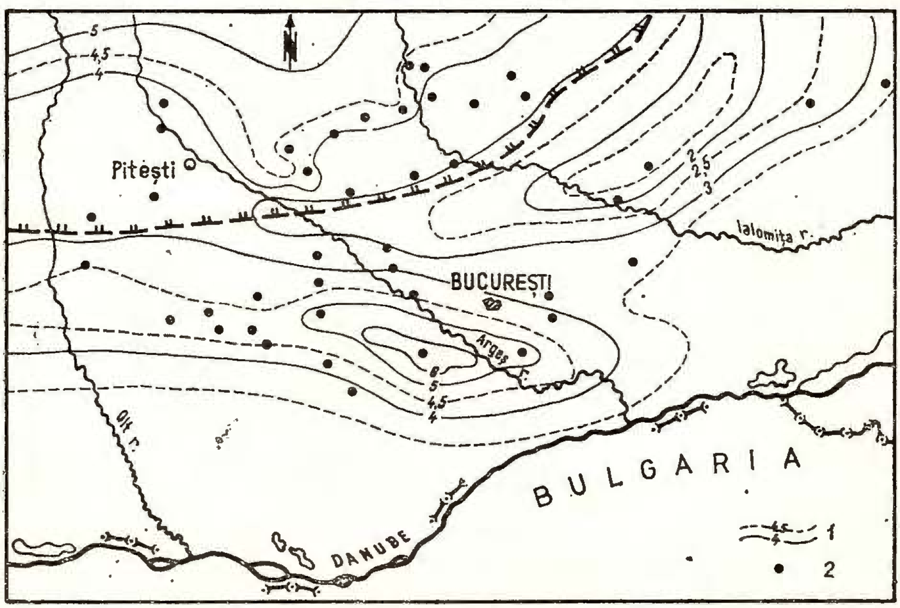

Fig. 91. — Variation of geothermal gradient within the Moesian Platform (at the 1,000 m isobath) 1, isogradient curves ; 2, oil and gas deposits.

basement sinks northwards and southwards, therefore as the sedimentary cover becomes thicker, the geothermal gradient decreases to 3°C/100 m. In contrast with the western half which is "hot" enough, the eastern part of the platform outlines a geothermal minimum anomaly where the lowest values, 1.5—2°C/100 m, correspond to the sector situated between Urziceni and Rîmnicu Sărat. From here the temperature increases with depth in all directions, also as the basement or the older sedimentary deposits uplift.

Taking into account the variation of the geothermal gradient, as it has already been presented, it is obvious that most of the geological formations containing source rocks, reservoir rocks and protecting screens benefited by a paleotemperature propitious to the fluid and gaseous hydrocarbon formation. The western part of the platform is much more favoured as the fluid hydrocarbons could form starting with the depth of 1,000 m, while the sedimentary deposits lying east of the Dîmbovița River sank to 2,500—3,000 m for reaching the minimal threshold, about 60°C. Other factors are also worth mentioning, especially the rock age, considering that time compensates, partially, for the temperature. Instead, the maximum threshold of the fluid phase, corresponding to about 120—140°, may be found at the depth of 2,000—2,500 m in the western compartment and at the depth of 6,000—8,000 m in the eastern compartment. Gas, first, with condens and, then, only methane, is expected to be found below the above mentioned depths.

As will be seen in another chapter, the relation between temperature and the hydrocarbon nature + distribution is amazingly confirmed within the Moesian Platform. Indeed, the sector west of the Argeș is characterized by the existence of numerous and important, predominantly, oil deposits. The eastern sector is marked by small and, predominantly, gas-bearing deposits, with the exception of the Bordei Verde Promontory that benefited by a more favourable geothermal regime.

The distribution of the deposits presented above seems more authentic taking into account the existing information, when the platform territory was well investigated to the depth of 3,000—3,500 m. But considering the formations lying at great depths, deposits containing oil and gas with condens might exist in the eastern part of the platform.

The study of the over 125 productive structures discovered so far shows that the types of traps on the Moesian Platform are determined by the tectonic style, the sedimentogenesis and the geological evolution of the investigated area. Thus structural, stratigraphic, lithological, paleogeomorphic and mixed traps could form. Such hydrocarbon accumulation conditions were achieved on the whole platform and throughout the basin evolution. Still, a closer analysis, reveals differentiations becoming clearer in time and space. For instance, the traps located in the pre-Jurassic formations are closely related to the great structural elements, especially to the N Craiova—Balș—Optași—S Periș uplift. The deposits formed in the post-Jurassic period are controlled especially by disjunctive tectonic accidents and prevail in the eastern and central sectors of the platform.

The vaulted structural traps are found on the northern side and, especially, in the N Craiova—Balş—Optaşi—S Periş uplift zone. It is not known whether the deformation of the strata is due to local movements, to the existence of some paleoreliefs whose shape was inherited by the sedimentary cover or to both causes. Such structural traps are known at Sîmnic—Gherceşti, Iancu Jianu, Făureşti (?), Oporelu, Ciureşti N, Ciureşti S. Vaulted structural traps also appear in the Pliocene, in the vecinity of the Carpathian bending. Some of them are: the Inoteşti, Bărăitaru, Roşioru, Ghergheasa, Balta Albă structures. Being situated in the immediate vicinity of the Pericarpathian fault, this zone underwent the effects of the foredeep plicative movements. The gravitation effect should be also mentioned.

The monoclinal structural traps, which are screened by faults, are, generally, characteristic of the Moesian Platform, and, especially of the compartment developing east of the Teleorman River. The biggest deposits in the Carpathian Foreland, such as Videle, Cartojani, Preajba (partially), Jugureanu etc. are located in such traps.

The stratigraphic traps are associated with the great uplift zones which are characterized by the higher frequency of the stratigraphic gaps, the increased duration and intensity of the denudation processes and by sensible angular unconformities. This is the case of the N Craiova—Balş—Optaşi—S Periş uplift and of the Bordei Verde Promontory. Such accumulations were found also in the rest of the platform, always accompanying the great stratigraphic unconformities (Mesocretaceous, pre-Tortonian or pre-Sarmatian). Deposits of this type were identified at Brădeşti, Iancu Jianu, Oporelu in the Lower Triassic; at Ciureşti in the Upper Triassic; at Siliştea—Rîca in the Albian; at Jugureanu in the Senonian and Tortonian; on the Bordei Verde Promontory in the Sarmatian and Meotian etc.

The lithological traps were frequent enough, even if they were partially investigated on the Moesian territory. Their presence is attested in terrigenous, biogenous and chemical precipitation deposits. They appear most frequently in the form of a lenticular development of some arenyte bodies at the Lower Paleozoic, Silezian, Upper Triassic, Dogger, Sarmatian and Meotian levels. The majority of the respective accumulations have local importance. The most typical and extended lithological traps correspond to the Meotian deposits at Deleni (oil) and Bilciureşti (gas). Another kind of lithological traps concerns the reef deposits marked by higher porosity and permeability values as compared to the detrital limestones, and especially, to the surrounding chemical precipitation carbonate rocks. Some of the deposits discovered in the central sector of the, Moesian Platform, (Talpa, Petreşti — Corbii Mari — Poiana, Serdanu Brîncoveanu etc.) benefited by such (biogenous) conditions. Similar situations are also found in the western part of Oltenia. Finally, the porosity and permeability variation of the carbonate rocks, which was determined by the diagenetic processes and, especially, by dolomitizations and fissures favoured the hydrocarbon accumulation at Ciurești, Vultureanca etc.

The paleogeomorphic traps show the important part played by the paleoreliefs in the formation of the hydrocarbon accumulations. From a structural-genetic point of view, the old reliefs transmitted their shape to the cover deposits; their compactation brought about deformations (morphostructures) used by the fluids in the gravitational separation process. Pseudostructures, such as promontories, hemianticlines, sunk crests are known throughout the platform, being associated with the main unconformities, and, especially, on the Bordei Verde Promontory and on the N Craiova—Balș—Optași—S Periș uplift. From a stratigraphic point of view, one can note the deposition and preservation of some deposits within a paleovalley, in the form of a "shoestring"; the petrophysical characteristics of these deposits allowed the hydrocarbon accumulation on this negative relief. The most typical example is the zone situated west of București, where numerous and important deposits (Preajba, Siliștea—Șopîrlești, E Hîrlești, Blejești, Videle) are known along the paleovalleys filled up by the basal Sarmatian terms (Fig. 92). Finally, the most important fossilized valleys, such as the Paleojiu, Paleoargeș, might have formed paleodeltas during the Sarmatian. According to this conception, the immense development and the particular productivity of the NNE Craiova Sarmatian seem to be also due to (at least, partially) the deltaic origin of the deposits.

The mixed traps show the largest distribution, resulting from the interaction between two or several factors: structural, stratigraphic, lithologic, paleogeomorphic. It might be even said that there are no "pure" types of traps on the Moesian Platform taking into account the fact that, against the major vaulting background and against the monocline stratum disposition background (the structural factor) take place stratum trunkations under or above the unconformity plane (the stratigraphic factor) porosity and permeability variations or lenticular developments of some horizons or complexes (the lithological factor) and, in some cases, paleoreliefs, with sedimentogenetic and structural-genetic implications. This situation will be found when each productive structure is investigated.

One can conclude that the trap formation was determined by the structural factor in the first place, then, by the lithofacial variation, by the paleogeomorphic evolution and by the stratum trunkations, the last two factors being associated.

The complex studies carried out within the Moesian Platform point out the fact that the sedimentary deposits, accumulated from the Cambrian to the Quaternary, developed under various conditions that favoured or not the oil and gas generation, accumulation and preservation. The properties of the waters stored in the porous-pervious strata reflect, among other things, the way in which these conditions were achieved.

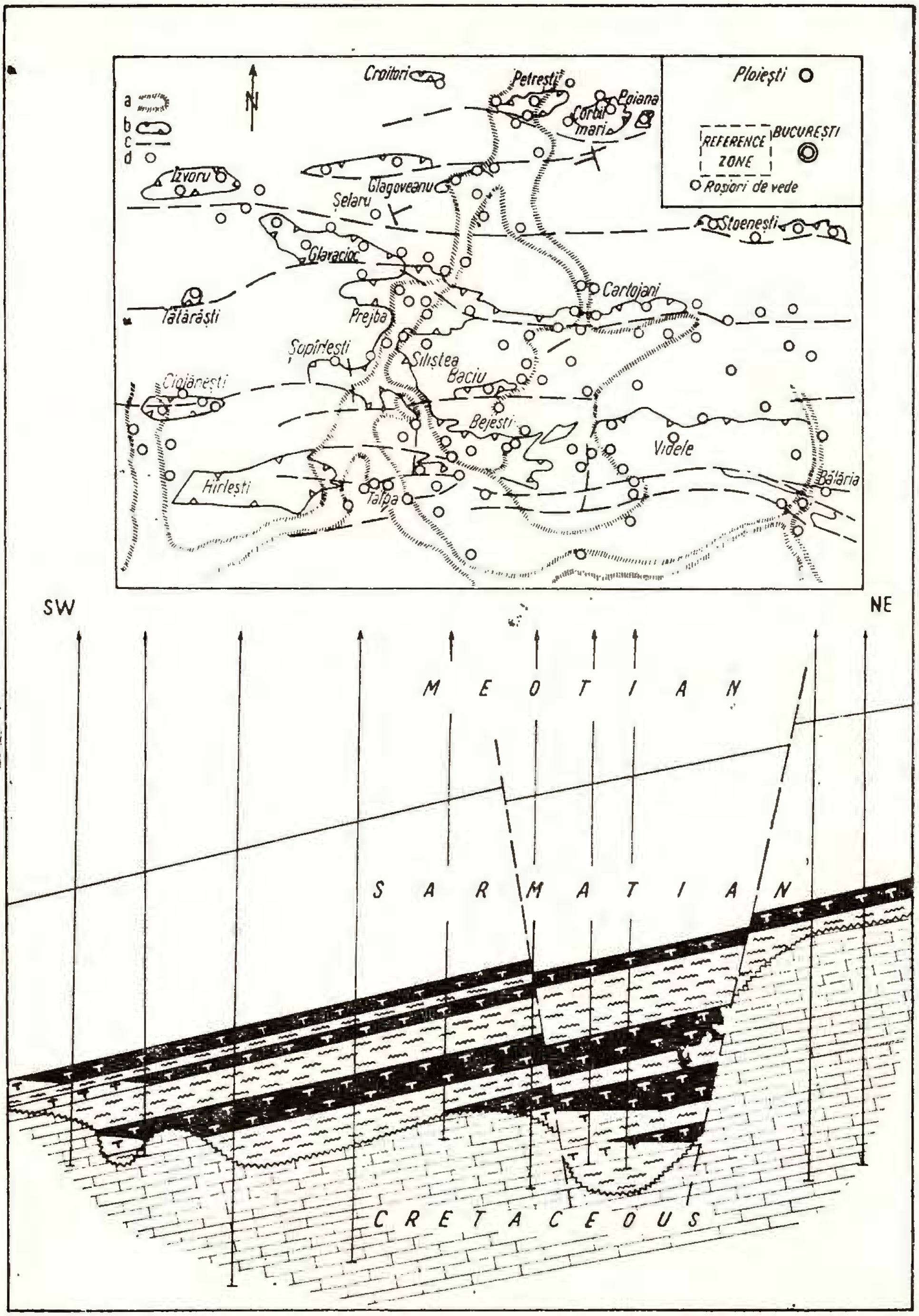

Fig. 92. — Paleovalleys and paleogeomorphic traps west of București.
a, outline of the paleovalleys ; b, hydrocarbon deposits ; c, faults ; d, wells.

According to the analyses and syntheses carried out on the Moesian Platform, four genetic types of waters were found; some of them indicate a closed hydrodynamic regime, namely the chlorocalcic ($CaCl_2$) waters and the chloromagnesian ($MgCl_2$) waters, others come from infiltrations, such as the sodium sulphate ($NaSO_4$) and the sodium bicarbonate ($NaHCO_3$) waters.

Almost all the formations of interest containing waters of $CaCl_2$ and $MgCl_2$ type are weakly mineralized, the salt concentration being frequently below 50 g/l. The fact is due to the geological evolution of the Moesian Platform which is characterized by numerous immersion and gliptogenesis phases on the one hand, and to the process of chemical transformation of the fluids on the other hand. At the same time, the low mineralizations might be due to the initially low salt concentration of the marine waters buried in sediments.

Among the four existing types, only the chlorocalcic and the chloromagnesian waters identify with the deposit waters, associated or not with the hydrocarbon accumulations. The sodium-bicarbonate waters are also present; when they are associated with the oil and gas deposits they contain direct microcomponents, such as naphtene acids, phenols and sulphide hydrogen. Taking into account the chemical content, several hydrogeological units were separated[6] vertically, namely: Paleozoic, Triassic, Jurassic-Neocomian, Albian, Upper-Cretaceous-Sarmatian and Lower Pliocene (Meotian-Pontian). Each of these units shows various mineralizations depending on the lithofacial composition and the geological evolution of the platform. Thus the Paleozoic (6—40 g/l) and the Jurassic-Neocomian (5—150 g/l) are characterized by lower mineralizations as compared to the Lower and Upper Triassic (5—166 g/l). The Middle Triassic, in its turn, being predominantly carbonate, contains waters whose concentration exceeds only exceptionally loo g/l, while the salinity of the waters in the adjacent quasicontinental sediments varies between 122—166 g/l. The Albian shows the least mineralized waters of the platform. As compared to the Upper-Cretaceous—Sarmatian (Figs. 93, 94), the Meotian fluids have a lower salt concentration (9—40, seldom 100 g/l).

A zonal disposition of the four genetic types is noted within each hydrogeological unit indicating the water evolution determined by the flow direction of the fluids on the main geological formations of interest.

A first conclusion arising from the hydrogeological zoning maps is that the eastern part of the Moesian Platform (east of the Ialomiţa River) maintained a more uplifted position during the Paleozoic, Mesozoic and Neozoic, so that closing protection conditions for the fluids accumulated in the sediments could not be provided here. Consequently, only waters of $NaSO_4$ and $NaHCO_3$ types are to be found east of the Ialomiţa River. The second conclusion is that the zone containing vadose waters ($NaSO_4$ and $NaHCO_3$) in the eastern part of the platform extended gradually west-

[6] Arch. I.C.P.P.G. Bucureşti.

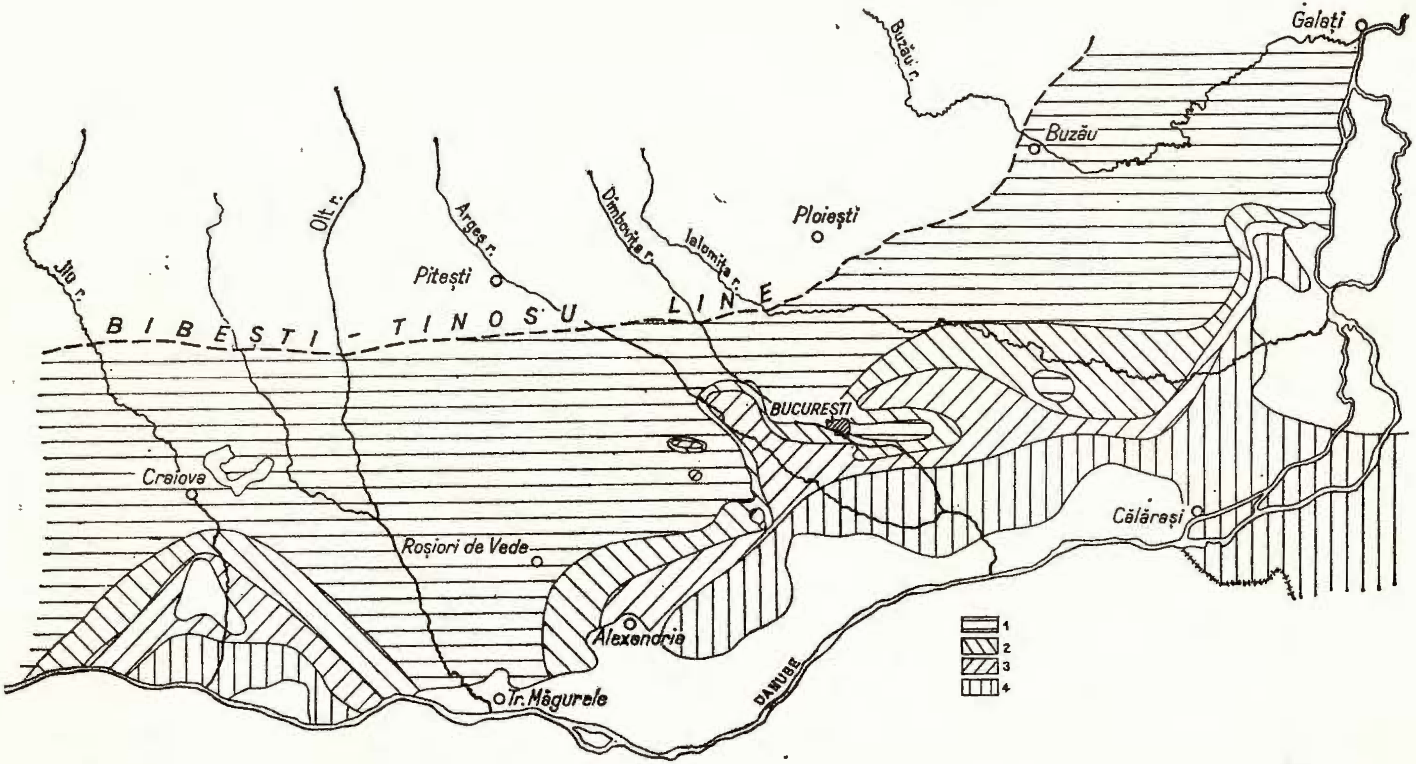

Fig. 93. — Map of the distribution of associated water types in the Moesian Platform Sarmatian (according to G h. P a l a d e and C. T r i f u l e s c u).

1, zones with waters of the type $CaCl_2$; 2, zones with waters of the type $MgCl_2$; 3, zones with waters of the type $NaHCO_3$; 4, zones with waters of the type $NaSO_4$.

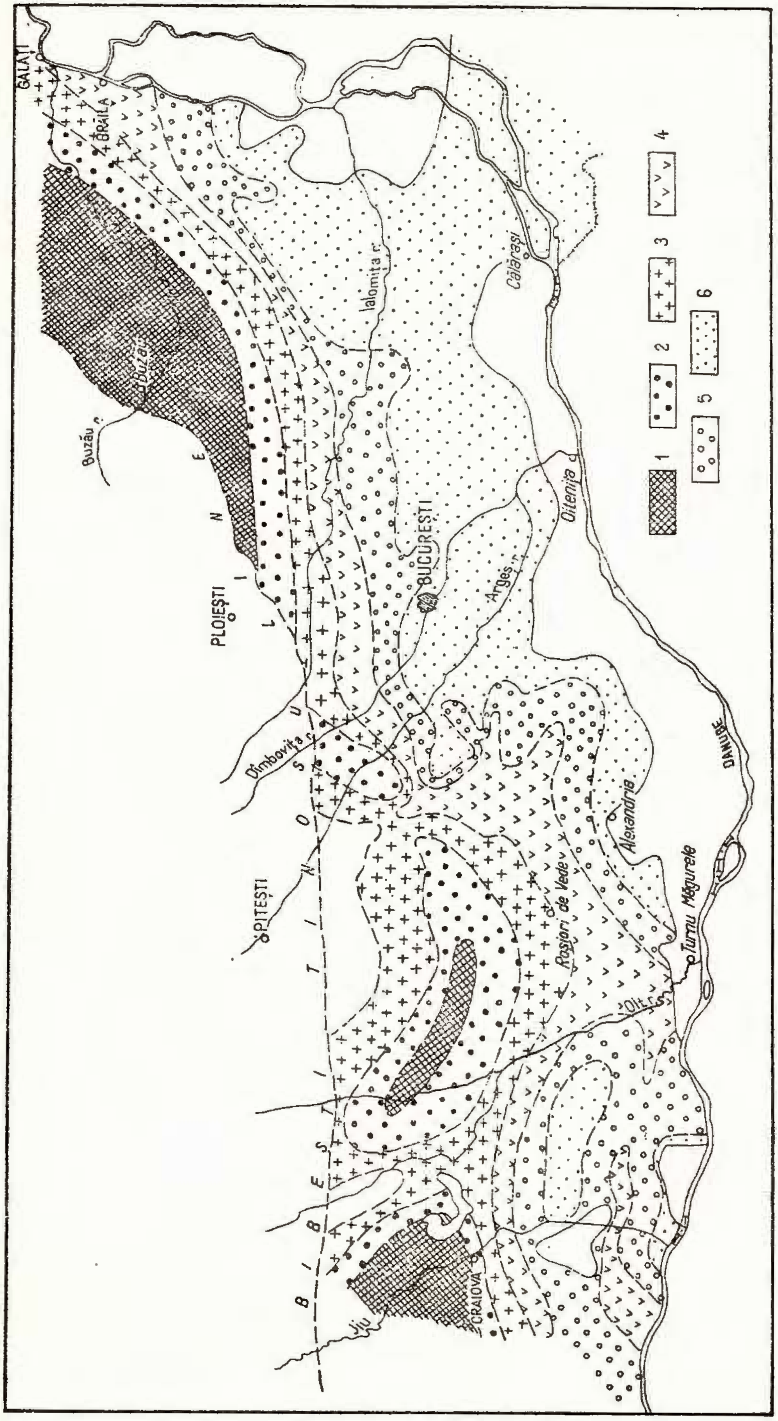

Fig. 94. — Map of the associated waters mineralization of the Moesian Platform Sarmatian.

1, mineralizations over 100 g/l; 2, mineralizations between 80-100g/l; 3, mineralizations between 60—80 g/l; 4, mineralizations between 40—60 g/l; 5, mineralizations between 20—40 g/l; 6, mineralizations less than 20 g/l (according to Gh. Palade and C. Trifulescu).

wards, along the Danube, beginning with the Jurassic deposits, continuing with the Neocomian, Albian ones and ending with the Sarmatian and Meotian deposits, so that a shifting, rotation, of the flow direction and of the sense of the water evolution took place. This direction was west-eastwards, towards the median zone during the Triassic, east-westwards in the Jurassic, and Lower Cretaceous, while ,beginning with the post-Neocomian formations, it was ever more evident south-northwards. The deterioration of the protection conditions and the contamination of the deposit fluids with vadose waters in the southern part of the platform began in the Paleogene and intensified in the Sarmatian-Pliocene, when, the respective unit, sinking in front of the Carpathians, remained emerged and subject to erosion in the Danube zone and south of the latter, which made possible the infiltration of the surface waters.

The chlorocalcic, chloromagnesian and, seldom, the sodium bicarbonate waters contain both indirect microcomponents, such as the bromine, the iodine, the ammonium, the boron, and direct microcomponents, namely naphthenic acids, phenols and sulphide hydrogen.

5. **Hydrocarbon Deposits**

The Moesian Platform, one of the most important oil and gas-bearing basin of Romania, proved its productive potential a quarter of a century ago. During the short period of time which passed from the discovery of the first deposit (at Ciurești) the prospecting and exploration activity developed intensively, so that the number of the petroleum and gas accumulations increased, reaching the figure 126 (Fig. 95).

The hydrocarbon deposits are located in the Devonian, Lower Triassic, Middle Triassic, Upper Triassic, Upper Lias-Dogger, Malm, Neocomian, Albian, Senonian, Tortonian, Sarmatian, Meotian, Pontian and Dacian. It is an enormous stratigraphic interval which points out that, during its evolution, the Moesian Platform benefited, almost all the time, by conditions favourable for the genesis, accumulation and preservation of hydrocarbons. Correlatedly, the depths of the oil and gas fields vary very much, from 350 m to almost 4,900 m.

The number and sizes of the productive members, as well as the hydrocarbon nature, vary from one structure to another, according to the ampleness of the structural elements, the thickness of the sedimentary deposits, their lithofacies and the geological evolution of the different compartments which form the platform. Considering these conditions and criteria, the productive structures of the Moesian Platform may be grouped into four zones of accumulation : Bordei Verde zone, eastern zone, central zone and western zone.

a) **The Bordei Verde Zone.** It corresponds to the Însurăței-Bordei Verde Promontory and includes nine oil fields (1—9, Fig. 95), among which the Oprișenești one holds the first place. The Meotian is the main productive term of this zone. On three structures (Oprișenești, Lișcoteanca

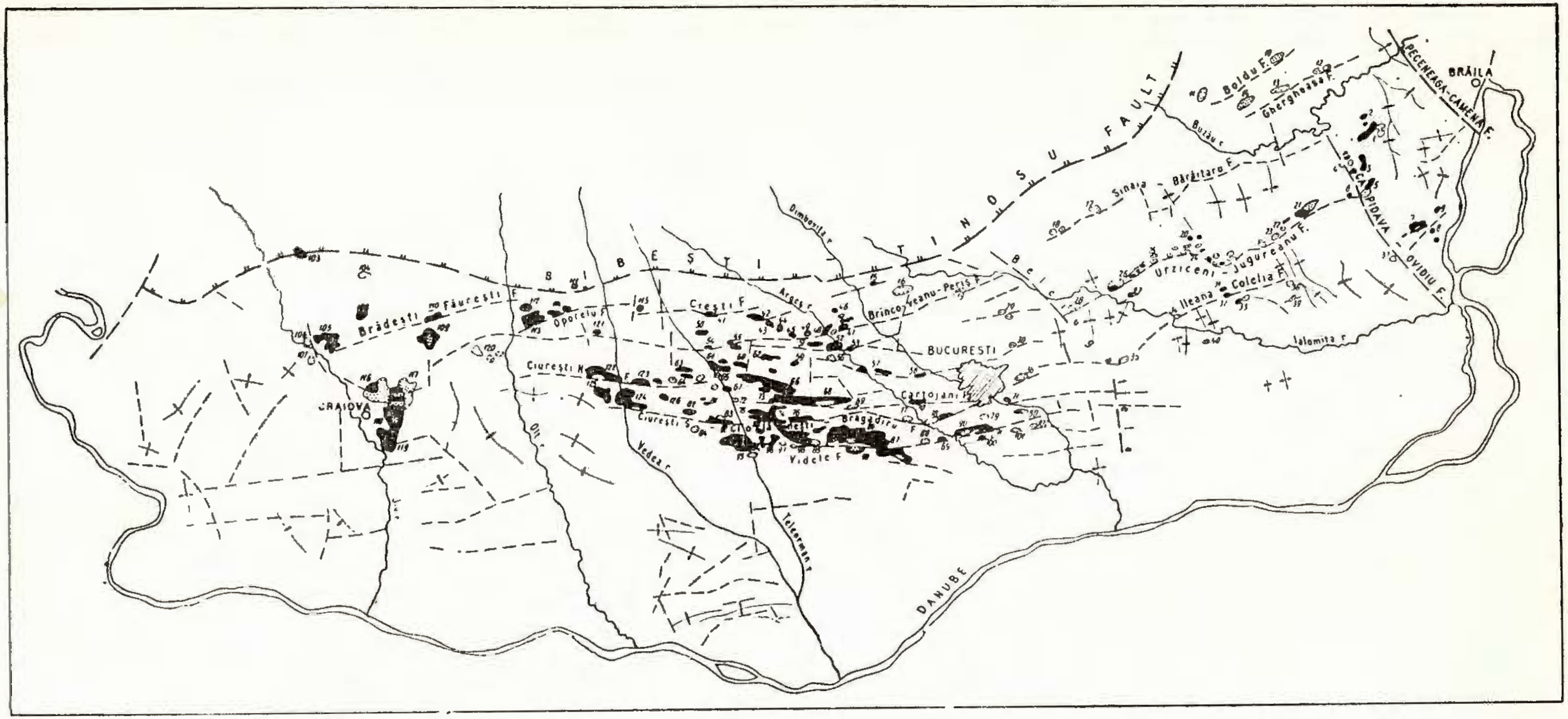

Fig. 95.—Map of the distribution of hydrocarbon deposits of the Moesian Platform ; 1, Oprișenești ; 2, Plopu ; 3. Bordei Verde E ; 4, Bordei Verde W ; 5, Lișcoteanca ; 6, Filiu ; 7, Scheiu ; 8, Bertești ; 9, Stăncuța ; 10, Boldu ; 11, Bobocu ; 12, Balta Albă ; 13, Gherghesa ; 14, Roșioru ; 15, Corni ; 16, Bilciurești ; 17, Sinaia ; 18, Bărăitaru ; 19, Periș ; 20, Lipănești ; 21, Jugureanu ; 22, Odăeni ; 23, Padina ; 24, Brăgăreasa ; 25, Gîrbovi ; 26, Urziceni ; 27, Mănăsia ; 28, Fierbinți ; 29, Moara Vlăsiei ; 30, Pasărea ; 31, Colelia N ; 32, Colelia centre ; 33, Colelia S ; 34, Malu ; 35, Ileana ; 36, Cozieni ; 37, Victoria ; 38, Nicolești ; 39, Amara ; 40, Orezu ; 41, Gliganu ; 42, Vultureanca ; 43, Drăghineasa ; 44, Vișina ; 45, Croitori ; 46, Titu ; 47, Serdanu ; 48, Brîncoveanu ; 49, Broșteni ; 50, Humele ; 51, Petrești ; 52, Corbii Mari ; 53, Poiana ; 54, Recea ; 55, Dumbrava ; 56, S Corbii Mari ; 57, Stoenești-Căscioarele ; 58, Bolintin Deal, 59, Glogoveanu ; 60, Ștefan cel Mare ; 61, Izvoru ; 62, Șelaru ; 63, Strîmbeni ; 64, Căldăraru ; 65, Popești-Palanga ; 66, Glavacioc ; 67, Tătărești ; 68, Cartojani ; 69, Mîrșa ; 70, Grădinari-Domnești ; 71, Cățelu ; 72, Negreni ; 73, Preajba centre ; 74, Preajba S ; 75, Siliștea-Șopîrlești ; 76, Baciu ; 77, Buturugeni ; 78, Bragadiru ; 79, Popești-Leordeni ; 80, Bălăceanca ; 81, Rîca ; 82, Siliștea-Gumești ; 83, Ciolăncești ; 84, Ciolănești S ; 85, Blejești ; 86, Videle ; 87, Bălăria ; 88, Gorneni ; 89, Novaci ; 90, Dumitrana ; 91, Jilava ; 92, Hîrlești ; 93, Hîrlești NE ; 94, Hîrlești E ; 95, Brătășani ; 96, Talpa ; 97, Talpa E ; 98, Cosmești ; 99, Coșoaia ; 100, Copăceni ; 101, Berceni ; 102, Postăvari ; 103, Bibești ; 104, Vîrteju ; 105, Brădești ; 106, Sfîrcea ; 107, Pitulați ; 108, Melinești ; 109, Iancu-Jianu ; 110, Făurești ; 111, Spineni ; 112, Deleni ; 113, Oporelu ; 114, Constantinești ; 115, Ciești ; 116, Sîmnic ; 117, Ghercești ; 118, Cîrcea ; 119, Malu Mare ; 120, Slatina ; 121, Negreni ; 122, Ciurești N ; 123, Bîrla ; 124, Ciurești S ; 125, Bacea ; 126, Surdulești.

and Filiu) commercial outputs have been obtained from the Sarmatian; at Oprişeneşti, the Lower Cretaceous is added to the two formations of economic interest (Meotian and Sarmatian).

The bore-holes drilled in this region indicated that the greenschist basement, during its continuous sinking to NW and S, is progressively covered by Cambro-Ordovician, Silurian, Devonian and Dinantian formations. These formations are transgressively and unconformably overlain by Malm-Neocomian deposits. The Sarmatian overlies a relief grafted on different members, beginning with greenschists and ending with the Lower Cretaceous. After a short phase of emersion, the Meotian ingression took place, suggested by the advance of some of its horizons, later and later as we go from the west to the east. The nearness of the shore is indicated by the more psamitic character of the Meotian and the ripple-marks and running water traces pointed out in the Sarmatian and Meotian deposits. Under the conditions mentioned before there resulted a significant lithofacial variation, on the one hand, and a thickening of the Meotian deposits towards W and NW, on the other hand. Thus, in the Berteşti-Stăncuţa sectors, the Meotian is represented only by one or two packets (in places, it is entirely missing), while in the above-mentioned direction their number increases, so that on the Oprişeneşti structure there are seven packets. These packets have a counterpart on the productive structures of the promontory. The outlined evolution favoured the formation of stratigraphic and lithologic gaps. The Pontian, Dacian and Levantine deposits complete the stratigraphic sequence of the region; they do not raise special questions.

The Oprişeneşti structure (1, Fig. 95) is situated in a region covered by Quaternary deposits. It is the seismic prospection that pointed out this structure which represents a faulted monocline, dipping towards NW. The screen function of the hydrocarbon accumulations is fulfilled by a gliding system of faults intercepted by some other accidents with a transversal orientation. The screen faults seem to constitute the prolongation to the east of the Tg. Fierbinţi-Urziceni-Jugureanu major accident. Only some of the Oprişeneşti tectonic accidents are tight. The dip of the Neogene beds is of 3—4°.

On the Oprişeneşti structure, hydrocarbon accumulations have been rendered evident in the Lower Cretaceous, Sarmatian and Meotian, these members totalizing 24 hydrodynamic members.

The Lower Cretaceous is characterized by an area of uninterrupted distribution due to the pre-Neogene, denudation and, together with the Sarmatian, it forms common massive deposits.

The Sarmatian, formed of chalky limestones and hard limestones like the Lower Cretaceous, has a porosity of 8—26 per cent, absolute permeability 17—48 mD, connate water saturation 35 per cent, initial pressure 164 kgf/cm^2, deposit temperature 68°C, petroleum specific density 0.900 kgf/dm^3 at 15° and 1 kgf/cm^2. The saturation pressure — 82—147kgf/cm^2 — has higher values towards the upper part of the structure. The

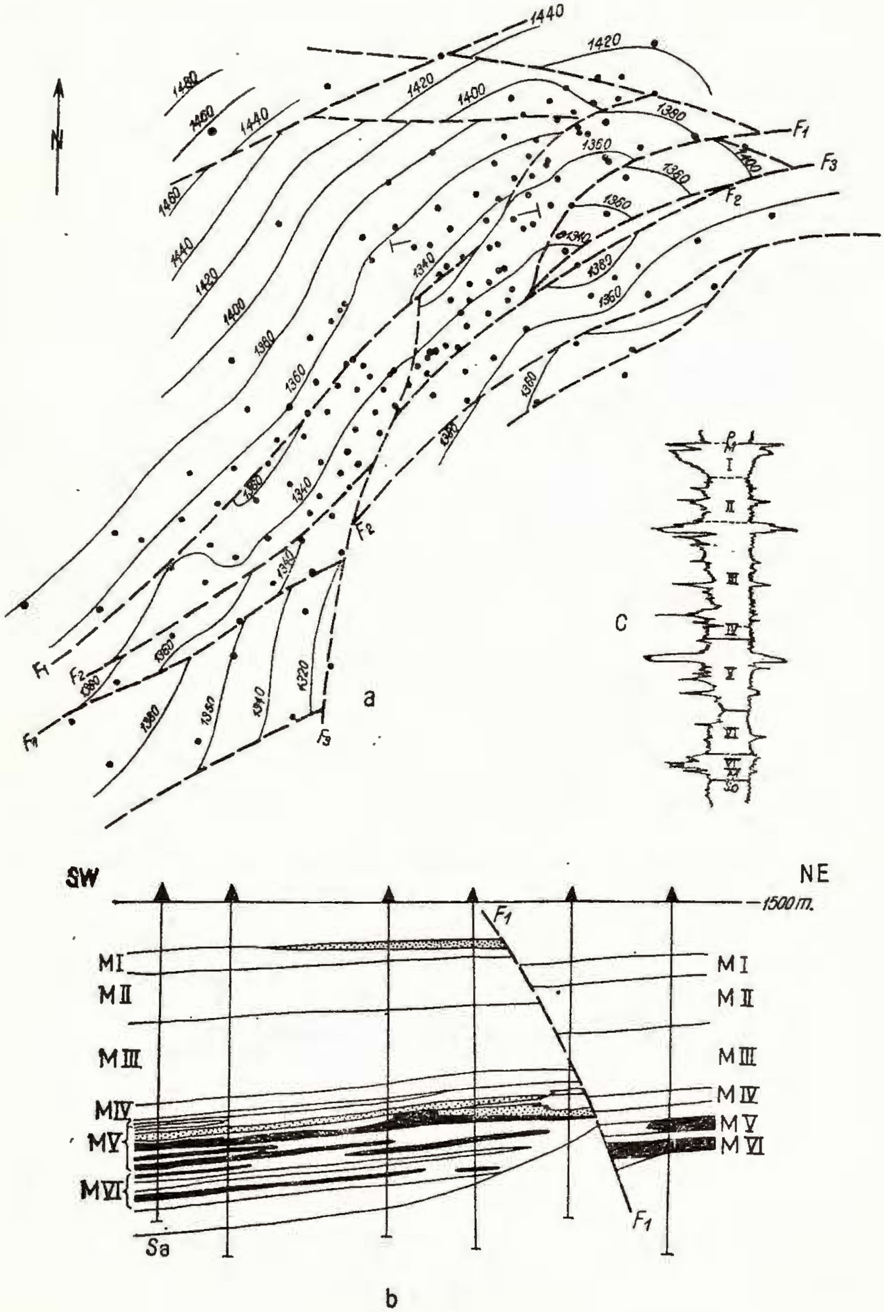

Fig. 96. — Oprișenești structure.
a, structural map at the limit P/M ; b, geological cross section ; c, Meotian type profile (according to I.C.P.P.G. Cîmpina).

Lower Cretaceous and Lower Sarmatian yield under the influence of an active water regime.

The Meotian is constituted of an alternation of fine sands, fine calcareous sandstones, oolitic sandstones and marls. It has been divided into seven complexes, noted from top to bottom I—VIII. Complexes VII and VI form the filling of the former relief; they do not occur on the whole structure (Fig. 96). The Lower Cretaceous, Sarmatian and Meotian VII, VI and V contain petroleum and associated gas. Complexes V, IV, III, II and I of the Meotian are saturated with free gas. The average depth of the productive formations varies from 1,620 m at M VII, 1,580 m at M VI to 1,370 m at M I.

The Oprişeneşti traps are mostly of the mixed type. Four of them are due to the stratigraphic factors and seven to the structural factors.

The thickness of the reservoirs is quite different. In the Meotian, each complex has thicknesses ranging between 2—12.5 m; the Sarmatian totalizes 38 m. The average porosity varies from 25 per cent to 30.2 per cent, permeability 57—3,224 mD, volume reduction factor 1.119—1.200. Petroleum specific density is 0.900 kfd/dm^3 at 15°. The deposit initial pressure varied from one complex to another from 166 to 142 kgf/cm^2 depending on depth, being equal to the hydrostatic one. The differential pressures recorded (0—13.46 kgf/cm^2) point to the permeability variations. The solution gas/oil ratio was 47 Nm^3/m^3 in the Meotian. The deposits distinguish themselves by high temperatures, the geothermal step being of about 26 m/°C. At present, some of the Meotian members are being exploited, the pressure being maintained by water injection.

The Plopu deposits (2, Fig. 95) are disposed along two structural steps outlined to the north of the Oprişeneşti productive field and characterized by the same geological conditions. The Meotian includes further terms in its base as shown by the Însurăţei-Bordei Verde Promontory which progressively sank from the north to the south, being flooded by the sea waters. The productive beds belong to the Meotian and consist of sandstones and sands. Reservoir porosity is 25 per cent, effective permeability 125 mD, connate water saturation, 30 per cent, initial pressure 200 kgf/cm^2 (at 2,030 m), saturation pressure 130 kgf/cm^2. Petroleum specific density is 870 kgf/dm^3 at 15°C and 1 kgf/cm^2. Exploited until now by primary methods, the Plopu deposits will be submitted to water injection processes in the future.

The Bordei Verde E structure (3, Fig. 95) is located south of the Oprişeneşti structure. Drlilings carried out on this structure and its surroundings reached the greenschist basement which is unconformably overlain by Ordovician, Silurian, Devonian, Jurassic, Cretaceous and Neogene. As a result of the numerous denudation stages which affected this region — more uplifted during the geological history — the pre-Neogene formations have been totally or partly eroded, so that they are characterized by a discontinuous distribution. Besides the stratigraphic unconformity between the Sarmatian and the Pliocene, interruptions of sedimentation are possible in the Meotian, too. It seems that these unconformities control the hydrocarbon accumulations on the whole promontory. Among the geological formations in the Bordei E sector, it is only the Meotian that proved to be of interest for hydrocarbons.

The Bordei Verde E structure is represented by a hemianticline which sinks continuously from the south to the north; its zone of maximum uplift (axial) is surrounded by two longitudinal faults which enclose the main block, with the best behaviour in production. The structure is also affected by other transversal faults which divide it into several compartments. The dip of the beds is 2—5°.

The Meotian, proved to be productive in 1968, has been divided into eight packets which also occur totally or partly on the other deposits within the promontory. Among the delimited complexes, the basal ones which contain petroleum are of utmost importance while the upper packets (VI and V) yield petroleum with associated gas cap or free gas (?) only in places. The members VII and VIII are to be found on the whole structure and form structural traps, while the complexes V and VI represent mixed, structural-stratigraphic traps. Due to the specific local conditions, it seems that the four productive complexes constitute a single hydrodynamic unit, a petroleum deposit with primary gas cap respectively. The depth of the productive beds ranges between 1,250—1,450 m.

The main physical parameters of the deposit are: effective porosity 29—34 per cent, permeability 20—1,000 mD, connate water saturation 25—30 per cent, petroleum specific density 0.911 kgf/dm^3, initial pressure 136—140 kgf/cm^2, saturation pressure 40—110 kgf/cm^2. The deposit water is of the chlorocalcic type with mineralizations of 15—65 g/l. Up to now the deposit was exploited by means of the proper energy; in the future it will be exploited according to conventional methods (water injection).

The Bordei Verde W deposits (4, Fig. 95), located in the Meotian, are situated on the western flank of the Bordei Verde Promontory and are controlled by three structural alignments. The northern alignment (Perişoru) contains petroleum and gas in the packets M V—M VII; the central alignment, made up of two compartments — western (wells 751,763) and eastern (wells 560, 567, 580, etc.) — is practically exclusively gassy at the level of the packets M II—M V; the southern alignment (wells 753,778) contains petroleum, too. These alignments are divided into numerous blocks. The tectonic breaking up is accompanied by a marked lithofacial variation of the Meotian reservoirs. It influences the distribution and the reduced sizes of the accumulations.

At Perişoru, petroleum was obtained at depths of 1,380—1,546 m in eruption or by swabbing. The output varied from 5 to 22 t/day, with variable percentages of impurities. Gas was also emphasized in M V at a depth of 1,372—1,375 m, the daily output being of 19,000—69,000 m^3/well, on nozzles of 3—6 mm.

Within the two compartments of the central alignment, packets M II—M V contained gas at depths of 1,225—1,375 m. According to the nozzle and the horizon, the daily output of a well varied from 12,000 to

62,000 m^3, and the pressures oscillated within values of 28—112/58—120 kgf/cm^2.

On the southern alignment, M VI proved to be productive (e.g. well 753) at a depth of 1,286—1,304 m, with outputs of 25 m^3/day, nozles of 4 mm and pressures of 20/16 kgf/cm^2.

The rapid evolution of the impurities, pressure and outputs of hydrocarbons characterize these accumulations of little account.

The Lişcoteanca structure (5, Fig. 95) has been rendered evident by means of the seismic prospections. The petroliferous and gassy output is known since 1971.

The exploration wells drilled on this structure and its surroundings crossed the whole deposit sequence from the Quaternary to the greenschist basement. Among them, the Sarmatian and Meotian sequences present the hydrocarbon prospects. The Sarmatian transgressively and unconformably overlies Paleozoic and Mesozoic terms. A sedimentary discontinuity appears between the Sarmatian and the Meotian.

The Lişcoteanca arching represents a paleogeographic structure, determined by a pre-Sarmatian relief (crests), later moulded by the younger deposits which sank and lent the shape of a buried crest. This morphostructure presents two culminations — a northern and a southern culmination — disturbed by faults. Among the disjunctive tectonic accidents the most important is the longitudinal fault (SSW—NNE) which affects the eastern sector of the region. The dip of the beds is 2—5° (Fig. 97).

In the Sarmatian two petroleum deposits have been emphasized: one at Lişcoteanca N, of a small size, the other at Lişcoteanca S, constituted of five complexes (M I—M V), contains hydrocarbons, as follows:

Meotian V (the basal term) has petroleum on both culminations;

Meotian IV includes two small petroleum accumulations, lithologically screened, on either of the two structural elements.

Complexes M III, M II and M I are exclusively gas-bearing.

The Sarmatian reservoir consists of meso-and microcrystalline limestones, calcarenites, calcareous and marly sands. Their average porosity is 19.5 per cent. The Meotian reservoir, formed of sandstones and sands, is characterized by a porosity of 24.5 per cent. Connate water saturation seems to be 30 per cent, both in the Sarmatian and in the Meotian.

Other physical parameters are:

	Sarmatian	Meotian
absolute permeability (mD)	115	60
initial pressure (kgf/cm^2)	100	100
saturation pressure (kgf/cm^2)	61	61
volume reduction factor	1.147	1.147
petroleum specific density (kgf/dm^3)	0.91	0.91

The Meotian free gas contains 97.86 per cent methane, 1.16 per cent ethane, 0.26 per cent propane, 0.11 per cent butane, 0.03 per cent pentane.

The deposit waters are of the chlorocalcic type, with mineralizations of 2.8—6.0 g/l in the Sarmatian and of 13.0—70.0 g/l in the Meotian.

The Filiu accumulation (6, Fig. 95) was rendered evident on the western margin of the Însurăţei-Bordei Verde Promontory in the second half of the year 1974. This structure is represented by a faulted monocline,

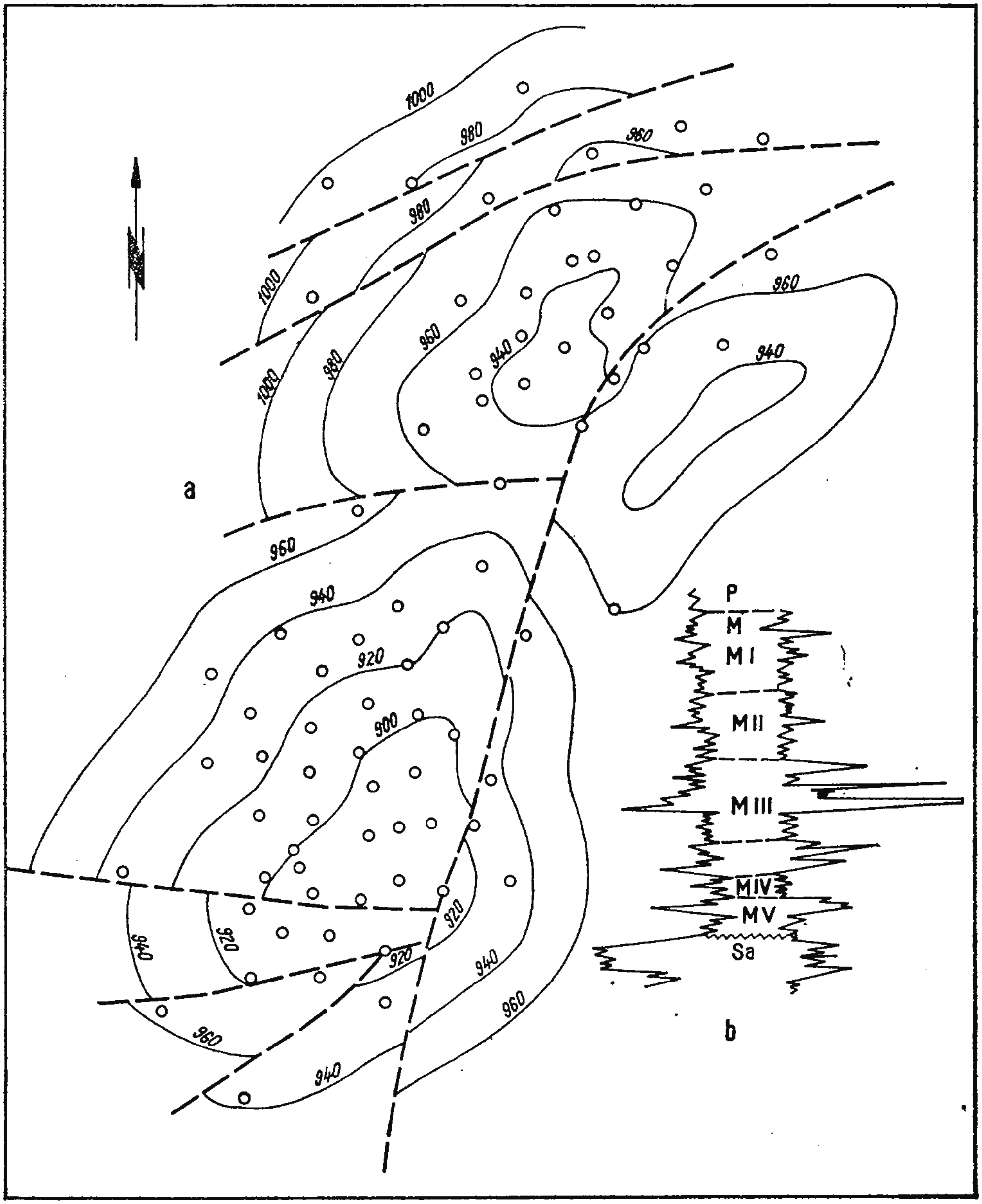

Fig. 97. — Lişcoteanca structure. a, structural map at the guide mark M III; b, Meotian type profile.

dipping towards NW. The productive complex, consisting of Sarmatian gritty limestones, occurs at depths of 1,300—1,350 m. Its output of a single well (831) is of about 20 t/petroleum.

The Berteşti-Scheiu deposits (7, 8, 9, Fig. 95) correspond to the „root" of the Însurăţei-Bordei Verde Promontory characterized by the successive disappearance, towards Central Dobrogea, of all the pre-Neogene stratigraphic terms, to which the Sarmatian is added in places. The truncated beds, determined by the continuous rise of the greenschist basement until it outcrops, often has an intraformational character, particularly at the Pliocene base, and is associated with the monoclinal disposition of the Neogene deposits.

The wells drilled in this region revealed that under the Pliocene, often incomplete (sometimes the Meotian is lacking entirely), there are either remnants of the former formations (Sarmatian, Jurassic, Paleozoic), preserved as patches, or greenschists. Besides the disappearance or the unequal development, the Neogene terms also undergo important local lithofacial variations, offering conditions favourable for the formation of the stratigraphic, lithologic and paleogeomorphic traps.

The Neogene beds sink generally towards WNW, with dips of 2—5°; however, they are involved in several structural details. Thus, in the northwestern part, corresponding to the Berteşti sector, the monoclinal disposition is practically undisturbed up to the Berteşti-Stăncuţa fault (Fig. 98). East of it there is a depression area, of tectonic origin, in which the Neogene thickness increases as against the Meotian and probably the Sarmatian, too, from 350—400 m to 800 m (well 50). By compaction, the Sarmatian-Pliocene deposits lent the pseudosynclinal shape of the tectonic depression. Beyond the Cuza Vodă fault, the Pliocene appearing as a structural "nose" sinks northwards to the Movila Miresii depression (fig. 98). Besides the mentioned pseudostructures, several faults with implications in the distribution of the hydrocarbon accumulations have been determined, as well.

Considering the above-mentioned geological conditions and the economic results obtained, in the "root" zone of the Însurăţei-Bordei Verde Promontory three accumulation sectors have been defined: *the Berteşti sector* (7), corresponding to the monocline screened by the Berteşti-Stăncuţa fault; *the Stăncuţa sector* (8), as a matter of fact respresenting a pseudopericline; *the Scheiu sector* (9), a structural "nose" where, unlike the other sectors, the Upper Jurassic proved to be of interest, too.

The Berteşti deposit is located in the Meotian (packets M I and M II) at depths of 450—520 m. It contains petroleum, in places with gas cap and, possibily, free gas. The petroleum output, associated with brackish water in different proportions, varied from 2 to 56 m³/day at each well. The gas output was of 4,340—12,000 m³/day.

At Stăncuţa, petroleum accumulations appear in the Meotian and in places in the older formations (Paleozoic) at the contact with the Pliocene . Very few wells tested up to now have outputs of 1.5—8 m³/day petroleum with impurities.

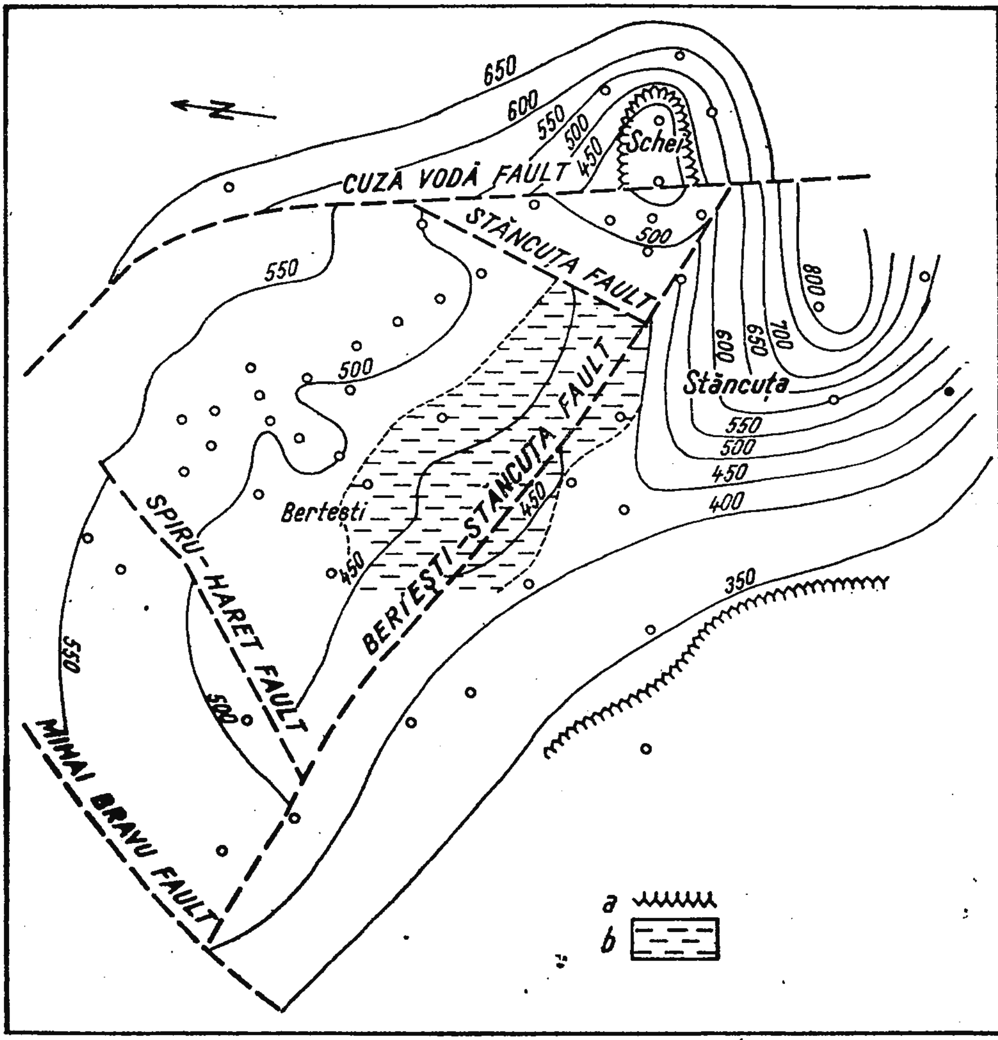

Fig. 98. — Bertești-Stăncuța-Schei zone. Structural interpretation at the Neogene base. a, boundary of Meotian deposits ; b, Meotian pelite facies development zone.

In the Schei sector, a well drilled up to a depth of 679 m reached, under the Pontian, limestones and dolomites belonging to the Upper Jurassic. At the flow tests carried out within the interval 486—422 m 4,500 l petroleum and brackish water were swabed, static level 100 m, dynamic level 150 m. Water mineralization was 26 g/l. In the Scheiu periclinal zone, wells previously drilled reached the Meotian which contains petroleum.

b) **The Eastern Zone.** It may be conventionally delimited between the Însurăţei-Bordei Verde Promontory and the Dîmboviţa River. The characteristic feature of the zone is given by the mainly gassy, small-sized deposits, formed here which range along five main alignments (10—40, Fig. 95) : Boldu-Bobocu, Balta Albă-Roşioru, Periş-Sinaia, Moara Vlăsiei-Urziceni-Jugureanu and Cozieni-N Nicoleşti. There are very few accumulations outside the above-mentioned alignments.

It is well-known the fact that east of the Dîmboviţa River the Neogene deposits have a continuous development as concerns the thickness, reaching the maximum in front of the Carpathian bending zone. As a result, Sarmatian (in places associated with the Tortonian), Meotian and Pontian are the main productive formations in this zone. The area of interest for the Miocene deposits is located in the median part of the zone, whilst the prospect surfaces of the Meotian and especially of the Pontian shift successively towards NE. Neocomian, Albian and Senonian proved their economic potential only on a few structures and blocks, particularly belonging to the Moara Vlăsiei-Urziceni-Jugureanu alignment. Dacian yielded gas only on a single structure (Moara Vlăsiei).

The predominantly gassy nature of the hydrocarbons and the relatively small sizes of the deposits whould be the result of the reduced geothermal gradient which, in this zone, falls up to 1.5 °C/100 m. The low temperatures and the young age of the Neogene deposits seem to have delayed the process of hydrocarbon formation, the organic matter generally remaining in a immature stage. However, in case of the Bordei Verde Promontory, where the Neogene reduced continuously its thickness and leans upon older and older formations in a strongly faulted zone and also has a greater geothermal gradient (up to 4°C/100 m), more numerous deposits, predominantly petroliferous, could form.

In the north-westernmost part of the platform there is a group of five, dome-like structures which yield gas since the Pontian and range along two alignments. These structures are, as follows : Boldu, Bobocu, Balta Albă, Ghergheasa and Roşioru.

The Boldu structure (10, Fig. 95), located 16 km south of the town of Rîmnicu Sărat, contains free gas accumulations in the weakly consolidated sands of the Pontian. In this zone, the Pontian has been divided into five complexes, each complex being formed of several packets. At Boldu, the complexes P V — 9, 10, 11, P IV — 11, 12, 13, 15, upper, lower and P II — 22 c proved to be productive. Each complex constitutes independent hydrodynamic units.

The structure is dome-shaped and presents dips of 2—6°.

The effective thickness of each productive packets varies from 1.25 to 3.22 m, porosity 20—23 per cent, connate water saturation 35—40 per cent, deposit initial pressure 236—275 kgf/cm², temperature of the gas strata 290—295°C.

The Bobocu structure (11, Fig. 95), in the north-easternmost part of the Moesian Platform, yields gas since the Pontian. The section opened by the 10 wells drilled on this structure has been divided into four complexes, noted from bottom to top P I – P IV. Each complex is constituted of several sand beds. Among the Pontian lithofacial terms, complexes P II- beds 4 and 5 and P III- beds 1, 2, 3, are productive. They are 2,500–2,600 m deep. The outputs vary from 30,000 to 87,000 m^3/day for each well, depending on the bed and nozzle. At the level P III, under stationary regime, the bed pressure was 308 kgf/cm^2, pointing to the existence of an abnormal gradient (12.3 kgf/cm^2/100 m). At the depth of 2,540 m temperature is 65°C, indicating that the geothermal gradient is only 2.2°C/100 m.

Interesting for this zone is the structural disharmony between the complexes P II and P III as a result of the thickening of the last term (P I) due to the adding of new beds to the north.

The Balta Albă structure (12, Fig. 95) has the shape of a dome elongated towards E-W. Like the other structures on the north-eastern margin of the Moesian Platform, the Balta Albă structure yields in the Pontian. It has been separated into several complexes and packets among which the members P II, P II bis, P III-2, 3, 4, 5, P IV-1, 2, 3, 4, P IV bis – 1,2, P V – 1, 2, 3, 4 contain free gas.

The thickness of each of the productive members varies from 1 to 5.85 m. The average initial pressures, on packets, range between 200–248 kgf/cm^2 (gradient 10·7 kgf/cm^2/100 m), temperatures 55 – 66°C (gradient 2.47 °C/100 m). The other physical parameters do not differ from those of the Boldu and Ghergheasa structures.

The Ghergheasa dome (13, Fig. 95) is located in a zone covered by recent deposits. The structure, seismically determined, represents a brachyanticline with slightly asymmetric flanks and dips of 1°30′–3°30′. It is worth mentioning the fact that, unlike the structural elements representing faulted monoclines which will be presented further on, the Ghergheasa arching, beside the other four domes, represents a brachyanticline, result of the folding movements which took place within the Carpathian Foredeep. From this point of view, the structures Ghergheasa, Balta Albă, Roșioru, Boldu and Bobocu achieved the transition to the foredeep folds.

The wells drilled here since 1960 reached a maximum depth of 6,204 m (well 922), the well bottom remaining in the Malm. The Jurassic, consisting of limestones, is 920 m thick. It is directly overlain by the Sarmatian (2,152) m), then by the Meotian (658 m), Pontian (600 m), Dacian, Levantine, Quaternary (1,878 m totally).

The Pontian, made up of a sequence of marls, sandy marls and sands, has been divided into several complexes, among which five contain gas. Within these complexes there have been identified 17 gas-bearing sand horizons, each of them probably constituting separate hydrodynamic units. In this case, the productive horizons have different depths, between 2,345 m and 1,892 m under the sea level. Most of the traps are structural. There are also mixed traps (structural and lithologic), e.g. terms P II 3, P III 1, P IV 4, P V 1, 3, 4 (Fig. 99).

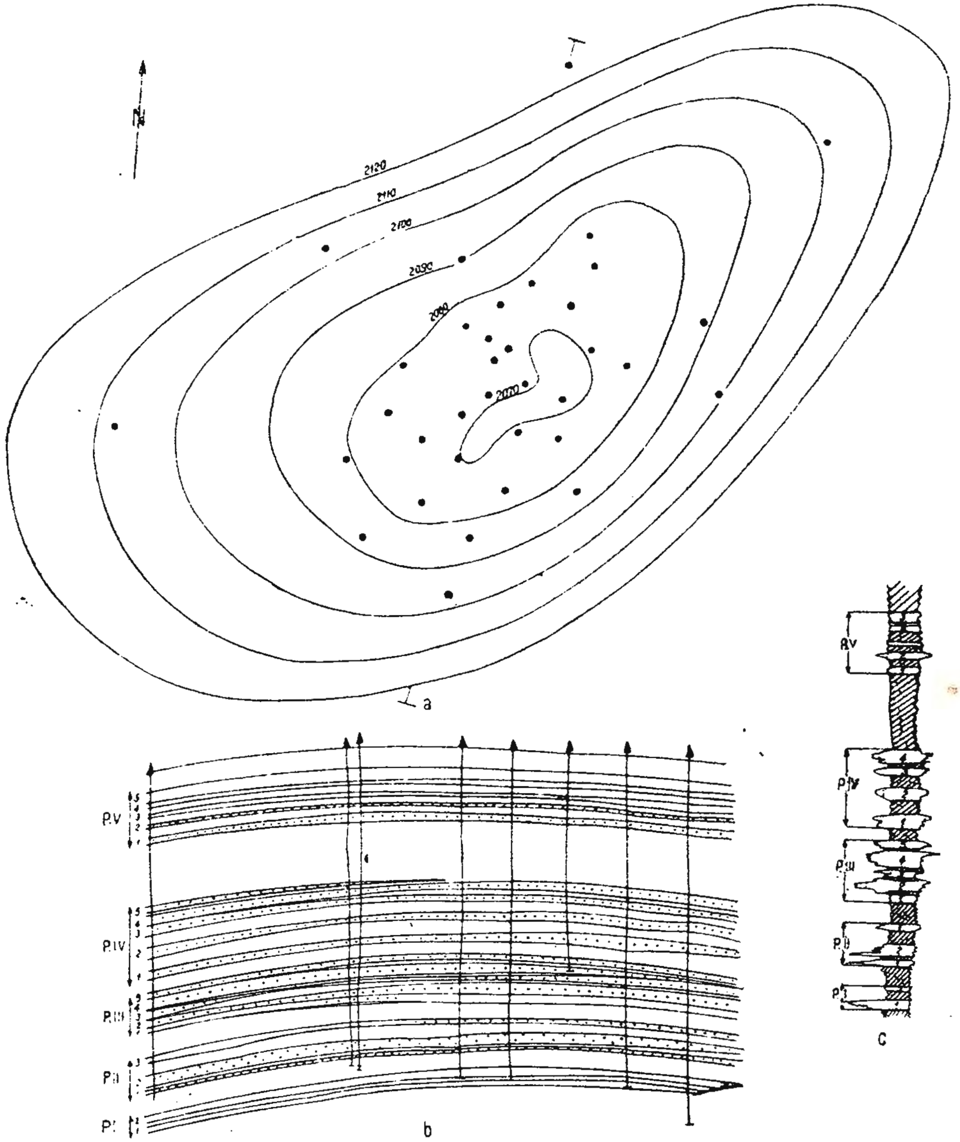

Fig. 99. — Ghergheasa dome.
a, structural map at a Pontian guide mark ; b, geological cross section ; c, Pontian type profile (according to E. B î r s a n and L. C r i s t e a).

The reservoirs are constituted of fine-grained marly sands, generally unconsolidated with marly intercalations. The effective thickness of each of them ranges between 1—14 m. Other physical parameters are : porosity

17—24 per cent, permeability 17—120 mD, connate water saturation 32—42 per cent. The pressure varies from 202 to 252 kgf/cm², that is a gradient of 10.5 kgf/cm²/100 m. The significant variations of the permeability led to differential pressures of 4—40 kgf/cm². The deposit regime is characterized by the gas elastic detente. Free gases contain 99.1—99.7 per cent methane. Associated waters are weakly mineralized (maximum 6 g/l) and made difficult the interpretation of the well log. They are of the $CaCl_2$ type. The geothermal step is 44 m°C.

The main difficulty in the process of exploitation is the migration of the sand from the formation, accompanied by high water floods of the bed.

The Roşioru structure (14) proved to be productive since 1960 and was put into operation seven years later. The gas-bearing formation is represented by the Pontian. It consists of an alternation of very fine and fine-grained siliceous sands, sandy marls and gritty marls.

The structure has the shape of a dome elongated towards NNE-SSW, within which the beds present dips of 2—3° in the periclinal zones and 4—9° on the flanks.

The productive terms are: P I—1,2; P II—1, 2, 3; P III—2, 3, 4, 5, 6; P IV—1,4 a, 4 b; P V —1, 2; 14 members in all. The depth of these beds ranges between 1,920 m—2,404 m. The gas accumulations are limited either by marginal waters or by bottom waters. The pressure gradient is about 10.6 kgf/cm²/100 m and the temperature gradient of only 2.25°C/100 m. The effective porosity of the beds is 18—26 per cent, absolute permeability 40—140 mD, connate water saturation 25—38 per cent. The gas is of 97 per cent methane. The deposit waters have low mineralizations (1—15.6 g/l).

In the central-northern part of the platform there are two gas accumulations—Corni and Bilciureşti—both controlled by the lithologic factor.

The Corni gas accumulation (15, Fig. 95) is located in a marly sand bed, corresponding to the Meotian median part. Within this zone only a single well (43) gave a favourable result (gases). At 2,109—2,113 m deep it yielded 23,000 m³/day and 100 l brackish water, with a mineralization of 74 g/l.

The Bilciureşti gas field (16, Fig. 95), situated on the northern margin of the platform, near by the Pericarpathian fault, was rendered evident in 1962. The productive term is the packet "a" of the basal Meotian, lying near the contact (unconformable) with the Sarmatian.

As a matter of fact, the reservoir represents a sandy lens developed on a length of 9 km and a width of 2.3 km. In other words, the deposit is lithologically screened. The beds sink to the north with dips of 2—5°.

The water/gas limit of the deposit has been established at the isobath 1,900m. The effective porosity of the sands is about 28 per cent, permeability 100 mD, connate water saturation 30 per cent, initial pressure 222 kgf/cm², temperature 52°C. The gases contain 99.43 per cent methane, 0.13 per cent ethane, 0.08 per cent propane. The deposit waters are chlorocalcic, with mineralizations of 56—72 g/l.

South of Bilciureşti, the Sinaia, Bărăitaru and Periş productive structures have been emphasized along a disjunctive tectonic accident.

The Sinaia structure (17, Fig, 95) represents a screened monocline north of the Bărăitaru-Sinaia-Brădeanu fault. The Neogene deposits sink northwards with dips of 3—6°.

Within the Sinaia structure free gas was emphasized at the upper part of the Meotian, at depths of 2,500—2,600 m. The productive Meotian has been divided into nine sandy horizons, separated by marno-clays. The thickness of each horizon is of 5—9.5 m, average porosity 20 per cent, connate water saturation 30 per cent, initial pressure 265—290 kgf/cm², temperature 64°C, corresponding to a very high geothermal step (45 m/°C). The gas contains 98.6 per cent methane, 0.50 per cent ethane and 1 per cent heavier fractions.

The Bărăitaru structure (18, Fig. 95) represents a monocline screened southwards by a tectonic accident with the same name. The "Bărăitaru" screen is, in fact, a normal fault, with a throw of 20—50 m, which reminds us of the Urziceni-Jugureanu fault as concerns the great dip of its plane (about 2,000 m within a depth interval of 2,500—3,000 m).

At Bărăitaru, gas deposits occur in the Sarmatian and the Meotian. The Sarmatian proved to be productive in its median part, at depths of 3,326—3,500 m where it yielded, depending on the well and nozzle (3—7 mm), 33,000—175,000 m³/day for each tested bed, with dynamic pressures of 185—310 kgf/cm². The cassing pressures are unknown as most of the flow tests have been carried out with a retainer. It is of interest to point out that the gas-bearing beds alternate with water-bearing beds. The associated water mineralization is 62—78 g/l.

The Meotian proved its gas potential at the well 13, for the first time, which yielded about 50,000 m³/day, with pressures of 230—250 kgf/cm².

The Periş structure (19, Fig. 95) was investigated by geophysical and drilling methods, the deepest well (909) reaching 5,315 m. The geological formations met by the wells are represented, from bottom to top, by Devonian and Dinantian limestones and dolomites, followed by detrital deposits with intercalations of Silezian organogenous limestones. The Carboniferous is unconformably overlain by the Malm-Cretaceous calcareous sequence. The Neogene, with the Tortonian as the basal term, constitutes the last cycle of sedimentation.

At the level of the Mesozoic and Neogene-Quaternary, the Periş structure is situated on the faulted monoclinal background, dipping northwards. One of the accidents trending WSW-ENE (the Periş fault) seals, in its rise, the structure to the south. The Periş fault is a normal tectonic accident, with a very inclined plane.

Up to now, at Periş, hydrocarbon accumulations have been identified in the Lower Cretaceous, Sarmatian and Meotian.

The Lower Cretaceous yielded petroleum with initial outputs of 3—23 m³/day and brackish water, in variable proportions, at seven wells.

As the fracturing degree of the carbonatic deposits at the upper part of the Neogene is quite varied, the wells had a different behaviour.

The Sarmatian, exclusively gassy, produced gas in three wells (909, 102, 103). At well 909 (2,802—2,792 m deep) the gas output was of 31,000—49,000 m^3/day, pressure 193—127/210—196 kgf/cm^2.

The Meotian yielded free gas in three complexes : *A*, *B*, *C*. The most important complex is the complex *C* which produced gas in four wells. The output was 43,000—90,000 m^3/day, on the nozzle of 5—7 mm. The average porosity of the Meotian deposits is 20 per cent, water saturation 40 per cent, bottom temperature 49—57°C, deposit pressure 155—187 kgf/cm^2. The area of interest for the Meotian is delimited , to the south, by another fault, not by the main screen (Periş) of the structure.

The Lipăneşti structure (20, Fig. 95) lies between the Periş-Sinaia and Moara Vlăsiei-Jugureanu productive alignments. At the level of the Lower Cretaceous, the Lipăneşti structure appears as dome -shaped arching, probably the result of the Meso-Cretaceous denudation. At the Senonian and the Neogene level, it occurs as a monocline, longitudinally and transversally faulted.

According to geologic and economic criteria, the Lipăneşti structure has been divided into two compartments : an eastern compartment with better results and a western compartment in which only a single well is productive.

The economic objective is constituted by the upper part of the Lower Cretaceous consisting of fissured limestones and calcarenites. On this structure some wells produced 2—35 m^3/day petroleum with variable percentages of impurities. The very contradictory results are considered to be due to the variation of the fracturing degree and the alteration of the deposit situated immediately below the Meso-Cretaceous unconformity. The depth of the productive beds ranges between 2,798—2,828 m. Gasifications during drilling have been pointed out in the Senonian, Sarmatian and Meotian.

South of Lipăneşti, in the eastern part of the platform, the most significant disjunctive tectonic accident, the Moara Vlăsiei-Urziceni-Jugureanu fault, has been emphasized ; it seals numerous petroleum and gas accumulations, e.g. at Jugureanu, Padina, Brăgăreasa, Gîrbovi, Urziceni, Fierbinţi, Moara Vlăsiei (Fig. 95).

The Jugureanu-Odăeni deposits (21, 22, Fig. 95), entered into operation in 1963, are superposed to a monocline affected by the Tg. Fierbinţi-Urziceni-Jugureanu fault (Fig. 100). This structure also includes the well 15 Odăeni with gas from the Sarmatian. The drilling activity pointed out petroleun accumulations with primary gas cap in Albian, Senonian and basal Sarmatian and free gas deposits in Albian and Meotian.

The Albian deposit consists of glauconitic fine sands and intercalations of marls, its thickness reaching 150 m. The effective porosity is 29 per cent, connate water saturation also 29 per cent, permeability 400—700 mD, initial pressure 195 kgf/cm^2, temperature 60°C. The water-petroleum limit has been found at 1,864 m and the gas-petroleum contact at 1,840 m b.s.l. Petroleum is exploited by the bottom water injection of the deposit.

The Senonian is formed of chalky limestones, gritty limestones, calcareous sandstones and marno-limestones, totalizing 60 m in thickness. The uniformity of the reservoir rock influences the initial distribution of fluids and productivity. The Senonian deposits have been divided into

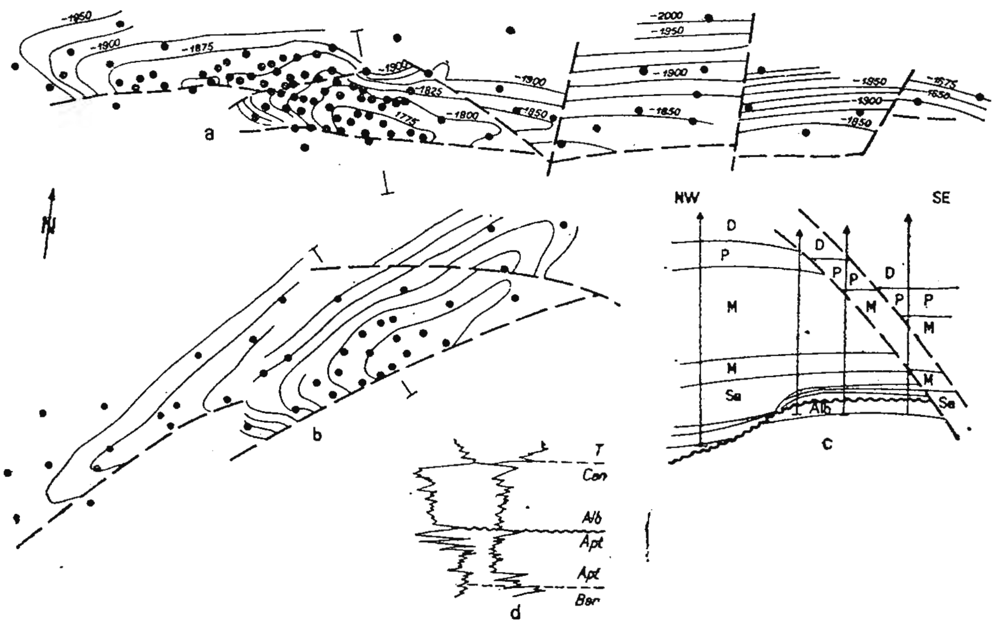

Fig. 100. — Jugureanu structure.
a, structural map at the Sarmatian level ; b, structural map at the Albian level ; c, geological cross section ; d, Albian type profile (according to I.C.P.P.G.).

three complexes noted, from bottom to top, I, II, III. These complexes are saturated with hydrocarbons but the productive surfaces have different extensions. The main physical parameters and factors of the deposit are : average porosity 24 per cent, connate water saturation 32 per cent, absolute permeability 36 mD, initial pressure 195 kgf/cm^2, temperature 60°C. The deposit is exploited according to primary methods.

The Sarmatian is constituted of chalky, microgranular limestones with intercalations of fine sandstones, about 60 m thick. The correlation of the Sarmatian on this structure permitted the separation of six members noted, form top to bottom, "*a*" — "*f*". Due to the configuration of the pre-existent relief and probably due to some local intraformational gaps, not all these objectives appear on the whole structure. The calcareous sandstones and the chalky limestones with reservoir properties may reach 50 m in thickness. They are characterized by average porosities of 24 per cent, connate water saturation 32 per cent, absolute permeability 36 mD. Petroleum specific density is 0,850 kgf/dm³. The pressure gradient does not exceed that of the hydrostatic column and the geothermal step reaches 36.4 m/°C. The trap is of mixed type (structural-stratigraphic). The deposit average depth is 1,930 m.

The Meotian is exclusively gas-bearing.

The Albian, Senonian and Sarmatian are in an advanced stage of exploitation.

The Padina structure (23, Fig. 95) appears as a faulted arching, trending WSW—ENE. The surface of interest is divided into two compartments (western and eastern). The eastern compartment contains hydrocarbons in the Albian, Senonian, Sarmatian+Tortonian and Meotian. The western compartment yields petroleum in the Lower Cretaceous only at the well 571 and free gas in the Meotian at two-three wells. Further on the stress is laid on the eastern compartment.

The Albian unconformably overlies the Lower Cretaceous; it is constituted of marls, sandstones and especially glauconitic sands. The Albian arenites have been grouped into five packets, I, II, III, IV, V (from bottom to top). In the central zone of the structure the bed **b** of the packet V disappears, indicating an intraformational unconformity. All the five Albian packets contain petroleum with primary gas cap. The initial water-petroleum contact varies, according to the packet and the tectonic block, from 2,020 to 1,905 m, and the gas-petroleum limit from 2,004 to 1,888 m. Porosity is 29—30 per cent, connate water saturation 25—39 per cent, absolute permeability 42—260 mD, initial pressure 193—203 kgf/cm², temperature 50—53°C which indicates a very high geothermal step (47 m/°C). Petroleum specific density is 0.890—0.899 kgf/dm³. The petroleum initial output was 25—160 m³/day for each well. In the future, conventional methods (water injection) are to be used.

The Senonian is formed of chalky limestones, calcareous sandstones and marno-limestones. Considering the aspect of the well log, the Senonian has been divided into three packets : lower, middle and upper. The middle packet, with a typical outline on the geophysical diagraphy, is traced on the regional scale and constitutes a correlation key mark. Tested with four-five wells at Padina (wells 124, 127, 133, 374, 619 ,etc.) the Senonian produced 19,000—47,000 m³/day gas, at pressures of 143—159 /155—160 kgf/cm². Only a single well yielded petroleum, as well.

The basal Sarmatian, sometimes associated with the Tortonian, is characterized by the existence of a large gas cap, bordered by a narrow petroleum strip. The hydrodynamic relationships between the Tortonian and the Sarmatian are unknown; however, it is assumed that they constitute a common deposit. Because of the similar lithofacial features (sandstones, gritty limestones), the Neogene-Senonian boundary cannot be always delimited with certainty, and the hydrodynamic relationships are unknown, too. It is also presumed that the Senonian deposit is separated from the Miocene one.

The Meotian contains gas in at least five sand packets. In these deposits the gas is not uniformly distributed due to the structural element as well as to the lithostratigraphic factors.

The Brăgăreasa structure (24, Fig. 95) yields hydrocarbons in the Lower Cretaceous, Senonian, Sarmatian and Meotian.

On the whole, the Bărăgăreasa structure represents a monocline, disturbed by the Urziceni-Jugureanu longitudinal fault to the south. Within the northern compartment, known as the "Brăgăreasa structure" a lot of faults have been identified, which divide this compartment into several blocks. Considering the geographic location and the geological-productive features of the formations of interest, these blocks have been grouped into three sectors : the western sector, the central sector and the eastern sector.

At Brăgăreasa W the following formations are productive : the Lower Cretaceous — petroleum with gas cap ; the Senonian — petroleum with gas cap ; the Sarmatian — free gas ; and the Meotian — free gas. At Brăgăreasa "centre", deposits have been reported from the Lower Cretaceous-petroleum ; the Senonian — petroleum with gas cap ; the Sarmatian — petroleum, sometimes with gas cap, and in the marly horizon only free gas ; the Meotian — free gas. The Brăgăreasa E sector yields gas only in the Meotian.

At the level of the Lower Cretaceous, this structure appears as a sunk hillock, result of the Meso-cretaceous denudation processes. The reservoir is constituted of microcrystalline limestones and fractured pseudoolitic limestones, associated with calcarenites at the upper part of the profile. These calcarenites seem to be the counterpart of the Urziceni productive horizon. The present outputs are 2.5—13 t/day for each well. The water-petroleum contact occurs at the isobath 2,465 m and the gas-petroleum limit (in the western block) at 2,375 m. The fluid contacts are tabular and the deposit is massive. The deposit initial pressures is 222—248 kgf/cm^2 as against the saturation pressure-about 132 kgf/cm^2. At the depth of the productive strata, temperature reaches 73°. Petroleum specific density, under standard conditions, is 0.890 kgf/dm^3.

The Senonian consists of chalky limestones,gritty limestones and limy sandstones. From the petrographic and geophysical point of view, it may be divided into three packets — lower, middle and upper — like at Padina . In the western sector, the Senonian yielded petroleum (well 11) with maximum outputs of 26 m^3/day and gas (wells 5 and 102), whose output varied from 25,000 to 40,000 m^3/day. In the central sector, the Senonian produced petroleum at the well 51 ; at other wells the results are not conclusive.

The Sarmatian, jointly with the Tortonian, is characterized by gas accumulations, sometimes bordered by petroleum narrow strips. The petroleum maximum output was 25 m^3/day at pressures of 90/140 kgf/cm^2 (well 54), and the gas output was 71,000 m^3 (well 29).

The Meotian is exclusively gas-bearing. Its best behaviour was recorded at well 27 — 172,000 m^3/day, at a pressure 110/124 kgf/cm^2.

The Gîrbovi productive sector (25, Fig. 95) is located along the Tg. Fierbinţi-Urziceni-Jugureanu major fault; it has an intermediary position as against the Urziceni and Brăgăreasa deposits. The stratigraphic sequence and the tectonic style of Gîrbovi do not differ essentially from those of the neighbouring productive sectors.

The Sarmatian, sometimes associated with the Tortonian, and the Meotian are gas-bearing members. The Sarmatian-Tortonian yielded gas at wells 19, 20, 62, at depths of 2,445—2,525 m.On the nozzle of 4—7 mm, the outputs were of 29,000—80,000 m^3/day for each well, pressures of 150—175 kgf/cm^2. The Meotian is saturated with gas at the sand level at its upper part, corresponding to depths of 1,435—1,588 m. The daily output/well (wells 3, 7, 9, 61) was 10,000—107,100m^3, on nozzles of 2 — 7 mm, at pressures 105—128/113—170 kgf/cm^2. The Meotian gas consists of 98.4 per cent methane, 1.01 per cent ethane, 0.4 per cent propane, 0.13 per cent butane. Gas density is 0.567 kgf/dm^3.

The Urziceni structure (26, Fig. 95) is determined by the same major tectonic accident — the Fierbinţi-Urziceni-Padina-Jugureanu fault.

On this structure, the deepest well (904 Urziceni) reached 6,002 m, the well-bottom being in the Devonian. The Devonian deposits are overlain by Dinantian limestones and dolomites, followed by Permo-Triassic, Upper Jurassic, Cretaceous and Neogene formations.

The deposit sequence crossed by wells is characterized by a monoclinal disposition, the dips being of 4—7°. Within the northern compartiment, coresponding to the Urziceni structure, this region is affected by several faults which divide it into several blocks, partly tight (Fig. 101).

The Urziceni structure has hydrocarbon accumulations in the Lower Cretaceous, Sarmatian and Meotian. Petroleum traces were also pointed out in the Albian (well 145). The most developed productive surface belongs to the Lower Cretaceous, at about 2,950 m deep. The Sarmatian is characterized by a narrow zone of petroleum with primary gas cap, situated at about 2,400 m deep. The Meotian contains gas at the level of the packets 7,5 (lower complex) 4, 3, 2, 1 (upper complex). The depth of the Meotian productive beds varies from 1,250 m to 1,500 m.

The Lower Cretaceaus deposit is determined by the existence of a calcarenite level, which plays the role of a reservoir, situated at the upper part of the carbonatic sequence. The detrital calcarenites have porosities 27 per cent, permeability 600 mD, connate water saturation 23 per cent. The initial pressure was 254 kgf/cm^2 as against the saturation pressure — 202 kgf/cm^2. The deposit average temperature is 55°C. The average output/well does not exceed 45 t/day.

The Sarmatian deposit is formed of limy sandstones and sands. It proved to be productive in the blocks III and V. The average values of the physical parameters of the Sarmatian are : porosity 25 per cent, permeability 1,000 m D, connate water saturation 27 per cent, initial pressure

241 kgf/cm² — equal to the saturation pressure — average temperature 52°C. The Cretaceous and Sarmatian petroleum is of A_3 type with a density of 0.900—0.920 kgf/dm³.

The Meotian productive beds consist of sands with porosities 28—30 per cent and permeabilities 75—300 mD. The gas includes 99.84 per cent methane, 0.09 per cent ethane and 0.07 per cent propane. CO_2, less than 1 per cent, also appears at some wells.

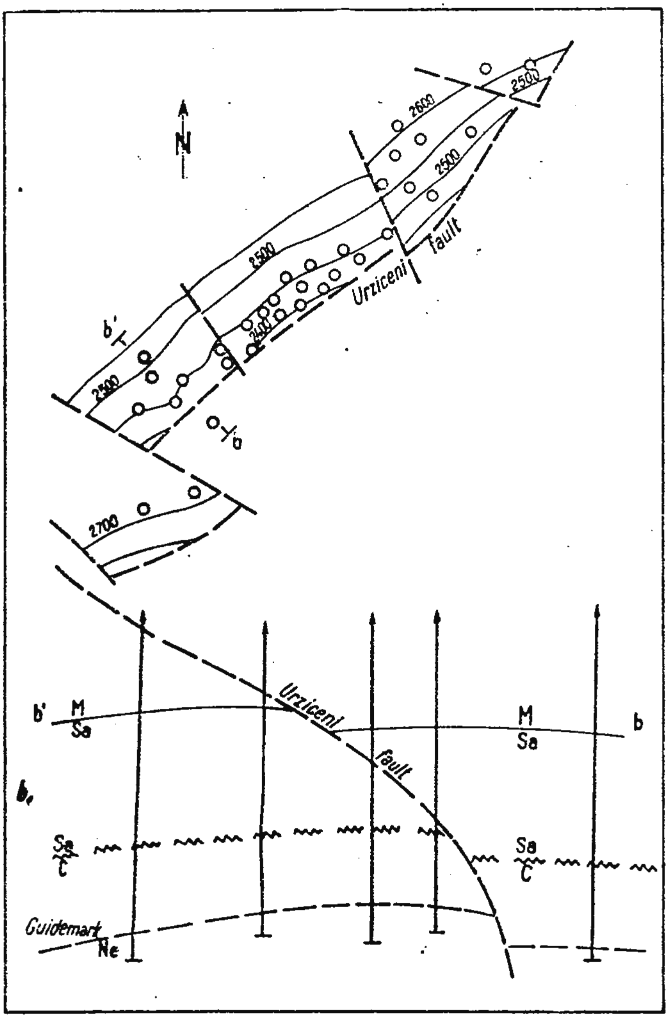

Fig. 101. — Urziceni structure.
a, structural map at the Neocomian surface; b, geological cross section (according to L. Cristea).

The Meotian productive zone lies in the western part of the structure, while the Sarmatian and the Lower Cretaceous are productive in the eastern part.

The Manasia accumulation (27, Fig. 95) is controlled by a tectonic accident parallel to the Urziceni fault, situated south of it.

At Manasia, the first favourable result was obtained with well 182 which yielded, by means of swabbing, 11.5 m^3/day, representing 50 per cent petroleum and 50 per cent water, from the Lower Cretaceous. The deposit conditions are still unknown; however, it is assumed they are similar to the Urziceni ones.

The Fierbinți structure (28, Fig. 95) is located west of Urziceni, along the same major screen. Its main objective is the gas-bearing Meotian. As regards the Sarmatian, it produced petroleum only in a single well and gas in another one.

This structure represents a monocline, dipping to the north. The screen fault has a throw of 50—100 m. Other secondary accidents divide the interest zone into blocks.

The productive Meotian is constituted of two complexes: a basal complex, formed of three packets (*a*, *b*, *c*) and an upper complex, towards the contact with the Pontian. The Lower Meotian is 1,745—1,860 m deep and the Upper Meotian 1,280—1,330 m. The initial pressures were 181—201 kgf/cm^2 and 140—144 kgf/cm^2, respectively. The geothermal step is 38 m/°C, average porosity 22 per cent, permeability 100 mD, connate water saturation 30 per cent. The gas includes 99.36 per cent methane.

The Moara Vlăsiei structure (29, Fig. 95) lies in the westernmost part of the Urziceni-Jugureanu alignment. On this structure, free gas accumulations have been emphasized in the Meotian and Dacian. As a matter of fact, Moara Vlăsiei is the only structure within the Meosian Platform where the Dacian had commercial gas deposits.

By its basal part, the Meotian yielded gas at wells 2456 and 2457, at depths of 1,648—1,848 m. On nozzles of 5—9 mm, 29,000-233,000 m^3/day have been obtained for each tested interval at pressures of 175/190 kgf/cm^2. The gas includes 98 per cent methane. The deposit water is characterized by mineralizations of 70 g/l.

The Dacian proved to be productive at wells 2452 and 2545, at depths of 730—838 m, where it yielded 16,000—23,000 m/day for each well. The associated waters are practically drinking waters, therefore they have a very poor mineralization. During the flow tests the sweet waters drew important amounts of unconsolidated sand.

South of the Moara Vlăsiei-Urziceni-Jugureanu alignments there are gas deposits, except the Colelia deposits which include petroleum, too. The distribution of these accumulations indicate the fact that the participation of the disjunctive tectonic accidents in the sealing of the deposits diminished in favour of the lithologic and stratigraphic factors. The promontories trending N-S become more evident preferential elements in the hydrocarbon accumulations.

The Pasărea accumulation (30, Fig. 95) yielded gas only at a single well (175) at a depth of 823—814 m, at the Upper Meotian level. On nozzles of 2.5—5 mm, the outputs were of 8,900—28,000 m^3/day at pressures of 69—72/69—76 kgf/cm^2.

The Colelia N structure (31, Fig. 95), rendered evident by the seismic prospections, proved its petroleum output in 1965. The productive objectives are represented by Aptian porous and fractured limestones and the Albian sands and glauconitic sandstones.

At the level of the Meso-cretaceous unconformity, the structure appears as a hemianticline (probably a downdropped relief) sinking towards NW. In the eastern sector it is divided by a fault which also constitutes a seal. The wells drilled beyond this tectonic accident proved to be dry from the hydrocarbon point of view. The dips of the beds are of 3—6°.

The productive objectives, 1,700—1,800 m deep, are characterized by modest petroleum outputs and low pressures, which determine the exploitation to be achieved since the initial phase by deep-well pumping. The two productive formations seem to be hydrodynamically separated; consequently they belong to two different types : the Aptian is a massive deposit, whilst the Albian forms a stratiform deposit. Both are characterized by dissolved gas regime. The saturated thickness of the Albian differs according to the position of the wells on the structure. For the Albian, the average thickness is about 15 m. The porosity of the limestones varies from 14 to 28 per cent and of the sands and glauconitic sandstones from 20 to 31 per cent. Petroleum is of type B, semiparaffin, with a density of 0.920 kgf/dm^3. The waters, characterized by a poor mineralization (20—30 g/l) are of chlorocalcic type.

The Colelia centre accumulation (32, Fig. 95) produced only at a single well (202) whose output was of 3 m^3/day petroleum with 12 per cent impurities (depths of 1,653—1,642 m), at the Albian level. It yielded by swabbing.The result is a local, favourable condition; it cannot be extended with wells drilled later on.

The Colelia S structure (33, Fig. 95) contains petroleum and gas accumulations in the Tortonian, Sarmatian and Meotian. As regards the Cretaceous, which yields petroleum on the Colelia N structure, it has no prospect here. This structure proved its productive potential in 1966.

The stratigraphic sequence and the Cretaceous and Neogene lithofacial characteristics are similar to those of the Colelia N structure. At the Neogene base, the structure occurs as a monocline affected by longitudinal faults trending SW—NE ; the dip of the beds is of 3—8°.

The Tortonian, represented by limestones and calcareous sandstones, seems to be saturated only with gas (wells 189, 191, 192). The basal Sarmatian, constituted of limestones, contains petroleum with primary gas cap. The Meotian is saturated with free gas, especially in the eastern part of the structure. The depth of the Tortonian and Sarmatian members is of 1,250—1,320 m and of the Meotian members of 780—950 m. The initial petroleum outputs were of 12—15 t/day and the gas outputs of 20,000—35,000 m^3/day. The petroleum specific density is 0.805 kgf/dm^3. The deposit average pressure of the Sarmatian is a little higher than the pressure of the hydrostatic column, the temperature gradient is below the normal value (41°C at 1,200 m).

The Malu accumulation (34, Fig. 95) corresponds to a brachyanticline structural trap, trending NNW-SSE ; it is divided by a transversal fault (SW—NE).

A first well (180), drilled in 1974, pointed out a gas accumulation at a depth of 1,318—1,314 m, corresponding to the Meotian base. On the nozzle of 5 mm, 41,000 m^3/day were obtained, at a pressure of 125/0 kgf/cm^2. The sand bank at a depth of 1,268—1,260 m seems to present gas prospects. Besides the structural element, the gas accumulation seems to be also controlled by the stratigraphic factor.

The Ileana gas deposit (35, Fig. 95) occurs in a structural trap,in the Meotian. More precisely, against the monoclinal background of the region a promontory is outlined, probably the result of the settling of the Neogene deposits covering a pre-Sarmatian relief. This promontory trends SW-NE and is transversally disturbed by a fault with sealing properties. Three of the wells drilled at Ileana yielded gas in the Sarmatian and the Meotian.

The Sarmatian yielded at wells 197 and 203, at depths of 1,031—940m and 982—942 m, respectively. At well 197, the outputs were of 19,000, 28,000 and 35,000 m^3/day, on nozzles of 4,5 and 6 mm, respectively. The pressures varied from 68 to 76 kgf/cm^2.

The Meotian yielded gas at depths of 633—620 m. The outputs were of 14,000—65,000 m^3/day, at pressures of 34—61/50—62 kgf/cm^2, on nozzles of 4—11 mm.

The Cozieni accumulation (36, Fig. 95) seems to be controlled by the same screen fault, determined at Ileana. Among the six wells drilled here, well 245 opened the most complete section ((1,300 m), the well-bottom being in the Lower Cretaceous. The flow tests emphasized gas indications (well 244 = 2,700 m^3/day) in the Sarmatian terminal complex, productive at Ileana too, as well as industrial outputs in the Meotian (wells 245, 246).

The productive beds are 627—622 m deep. The outputs vary from 15,700 m^3 to 46,000 m^3/day, at pressures of 50—59—65 kgf/cm^2, on nozzles of 5—9 mm.

The Victoria accumulation (37, Fig. 95) lies west of the Însurăţei-Bordei Verde Promontory. The local structural conditions are of lithologic type, favoured by the Meotian monoclinal disposition.

Among the wells drilled in this region, well 56 reached 836 m (the well-bottom in the Malm), yielded gas in the Meotian, at 403—398 m deep. An output of 13,300 m^3/day, at a pressure of 37/37 kgf/cm^2 was obtained on a nozzle of 5 mm, and 33, 900 m^3/day, at a pressure of 36/37 kgf/cm^2 on a nozzle of 8 mm. The productive bed has a lenticular development ; it was not pointed out by the neighbouring wells (16, 17, 100, 115).

The Nicoreşti accumulation (38, Fig. 95) is situated in a hemianticlinal tectonic block. Well 28, drilled in this block, pointed out gas accumulations at depths of 697—694 m and 680—673 m, in the Meotian. The output was of 30,000 m^3/day, at pressures of 58—60 kgf/cm^2, on a nozzle of 6 mm.

The Amara gas accumulation (39, Fig. 95) was proved by well 16 which reached 2,250 m deep. The oldest formation revealed by this well belong to the Carboniferous (Silezian) which is directly overlain by the Malm, then the Cretaceous and the Senonian, inclusively. The Neogene, which ends the sedimentary sequence, is represented by the Senonian and the Pliocene.

The arrangement of beds is quasimonoclinal. This region is disturbed by some faults trending SW-NE.

The gas accumulation was rendered evident at the Meotian level, at 680—674 m. The output was of 48,000 m^3/day. At the depth of 677 m, temperature was of 40° indicating that the geothermal gradient exceeds the normal value. The trap seems to be structural.

The Orezu accumulation (40) seems to be located on the same structural alignment as the Ileana and Cozieni productive zones. Among the wells drilled at Orezu-Raşi, well 190 produced gas at depths of 681—679 m and 675—672 m, from the Meotian. According to the nozzle (3·5—6 mm), the output varied from 11,400 m^3/day, at pressures of 58—60/61—62 kgf/cm^2. The static pressure was of 63 kgf/cm^2, therefore inferior to the pressure of the hydrostatic column. The Orezu accumulation seems to correspond to a lithostratigraphic trap.

c) **The Central Zone.** It includes the deposits lying between the Dîmboviţa and the Teleorman rivers (41—102, Fig. 95). Westwards, this zone locally exceeds the Teleorman Valley and comprises the deposits Strîmbeni, Căldăraru, Rica , Siliştea-Gumeşti and Ciolăneşti. This western boundary corresponds to a transversal fault which can be traced east of Cieşti up to east of Surduleşti.

The central zone is characterized by numerous and important deposits, predominantly petroliferous, located in Malm-Neocomian, Albian, Tortonian+Sarmatian and Meotian. The Senonian represents a local economic member. The Meotian constitutes an exclusively gas-bearing formation. The presence of the Albian in transition facies (limy-gritty) and of the Lower Cretaceous in reefal facies is specific to this zone. The paleogeomorphic traps occur frequently at the Sarmatian and Tortonian level.

The density and the considerable sizes of the deposits, as well as the predominantly liquid state of the hydrocarbons are due both to the lithofacial development and the favourable evolution of the Lower Cretaceous, the Albian and the Tortonian-Sarmatian, and to the high geothermal gradient which reaches 6°C/100 m in the Videle-Cartojani sector.

Further on we shall describe briefly the productive structures and the hydrocarbon accumulations, from the north to the south.

The Gliganu structure (41, Fig. 95) is sealed by an important fault (Cieşti fault) which continues westwards up to Cieşti. Other transversal faults divide the Gliganu compartment into blocks.

Two of the wells drilled on this structure yielded petroleum and gas from the Neocomian and Albian. In the eastern block, well 3100 yielded brackish water with petroleum traces from the Neocomian and 9,500 m^3/day gas from the Albian, on a nozzle of 7 mm, at pressures of 5/23 kgf/cm^2. The productive bed is located at the depth of 2,434–2,422 m. In the western block, well 2033 yielded about 9 t/day petroleum and brackish water at a depth of 2,688–2,653 m from the Neocomian. The variations of porosity and permeability determined a chaotical distribution of the fluids within this structure.

South of the Gliganu structure, a group of deposits have been pointed out, which are no longer screened by major longitudinal accidents but by faults or local stratigraphic-lithologic barriers.

The Vultureanca (42, Fig. 95) — *Drăghineasa* (43, Fig. 95) — *Vişina* (44, Fig. 95) — *Croitori* (45, Fig. 95) *productive sector* corresponds to a range of four structures determined by some local faults, which glide (Fig. 102).

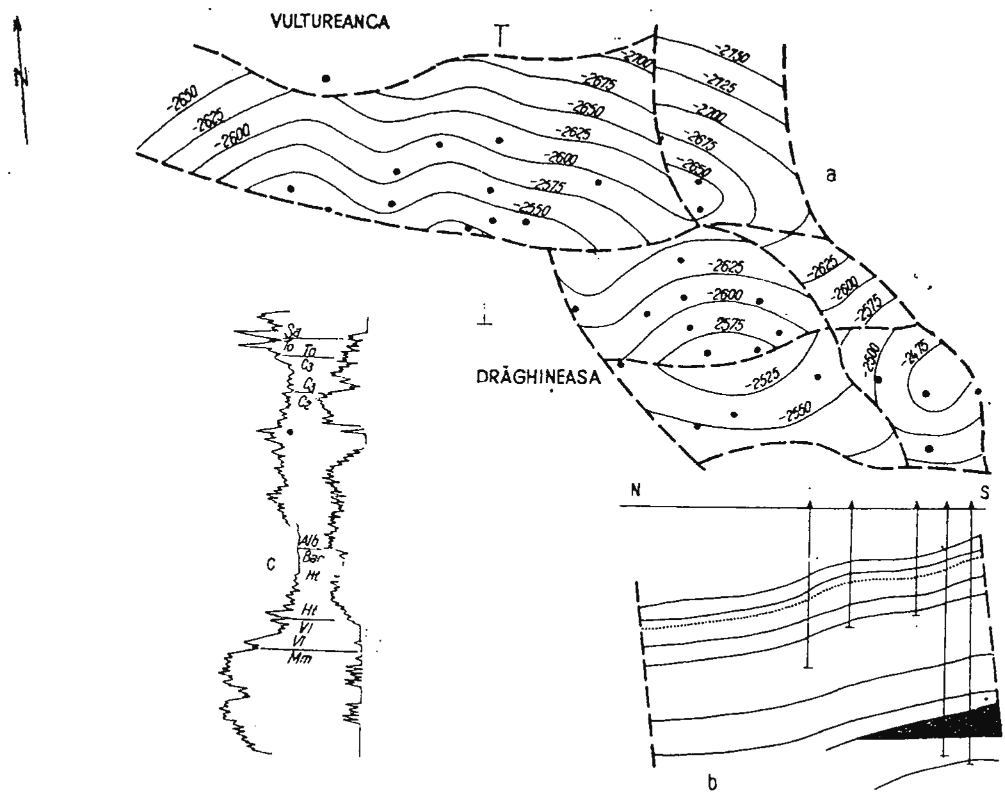

Fig. 102. — Vultureanca-Drăghineasa producing zone.
a, structural map at the Malm-Cretaceous level; b, geological cross section; c, Malm-Cretaceous type profile (according to C. Stănculescu).

The deepest wells drilled in this sector reached the Jurassic; they emphasize petroleum and gas deposits, as follows:

Malm-Neocomian	— at Vultureanca, petroleum;
	— at Drăghineasa, petroleum;
Albian	— at Vultureanca, petroleum with primary gas cap;
	— at Drăghineasa, petroleum;
	— at Vişina, petroleum;
	— at Croitori, petroleum with primary gas cap.
Sarmatian 3	— at Vultureanca, petroleum with primary gas cap;
	— at Drăghineasa, petroleum;
	— at Vişina, petroleum.

The Malm-Cretaceous and the Neogene deposits dip to the north; some archings are locally outlined against the monoclinal background. The dip of the beds is of 2—3°. This zone is disturbed by numerous longitudinal and transversal faults, partly tight.

The Malm-Neocomian and the Albian are characterized by fractured, carbonatic deposits, whilst the Sarmatian 3 is constituted of sandstones. The maximum depth of the hydrocarbon accumulations is of 2,690 m b.s.l. The main physical parameters of the deposits are, as follows:

	Malm-Neocomian	Albian	Sarmatian
effective porosity (%)		9—19	25
permeability (mD)		20—120	
connate water saturation (%)		28—50	37
initial pressure (kgf/cm^2)	270	240	220
saturation pressure (kgf/cm^2)	190	240	
deposit temperature (°C)	122	110	105
petroleum specific density (kgf/dm^3)	0,85	0,85	0,858

The gas density is 0.597—0.613 kgf/dm^3. The deposit waters are of chlorocalcic type, with mineralizations of 75—90 g/l.

Mention should be made of the variation of the matrix porosity and of the fracturing gradient of the carbonatic collectors belonging to the Malm-Lower Cretaceous, which determined the formation of local screens.

The following four structures overlap a promontory trending NE—SW, which favoured the accumulation of the reefal and perireefal deposits during the Lower Cretaceous.

The Titu structure (46, Fig. 95) represents the northernmost part of a promontory, faulted longitudinally and transversally, which develops and is better outlined southwards, in the zone of the deposits Brîncoveanu, Serdanu, Petreşti-Corbii Mari-Poiana.

At Titu, three of the drilled wells revealed petroleum indications at the Albian level. A first well (1652) at 2,930—2,838 m deep, yielded 1—12 t/day petroleum at the Albian level. The two other wells (1661 and 1655) produced brackish water (20—22 g/l) with little petroleum (maximum 1.5 t/day).

The Serdanu deposit (47, Fig. 95) occurs in the Barremian-Aptian formations constituted of vacuolar, fissured, microcrystalline limestones and dolomites, probably of a reefal origin. They have been divided into two packets : packet II (lower) about 180 m thick, and packet I (upper) 40—50 m thick. These two productive packects are separated by a horizon of marly limestones. The average porosity of the microcrystalline limestones is 4—9 per cent; when they are diagenized it reaches 12 per cent. The permeability is particularly achieved by means of the fissural and cavernous system, indicated by the mud loesses of the pit. Initially the wells yielded about 30 m^3/day petroleum with 25—30 per cent impurities. The petroleum density is 0.848 kgf/dm^3 at a temperature of 15° and 1 kgf/cm^2. The two productive packets which seem to form a common deposit are characterized by an active hydrodynamic regime. The associated waters are of $MgCl_2$ and $CaCl_2$ type, poorly mineralized (1.7—10 g/l) and in general of a blackish colour.

The Brîncoveanu deposit (48, Fig. 95) was discovered in 1968. The reservoir, of Cretaceous age (Fig. 103), is divided into four subdivisions. From bottom to top they are, as follows : the Albian sandstones; the calcareous packet I, 20—35 m thick consisting of fissurated, hard, gritty limestones; the intermediary calcareous packet (10—30 m), represented by marno-limestones and weakly fissurated, hard dolomites; the calcareous packet II, constituted of strongly fissurated limestones and dolomites, as indicated by the mud loesses during the drilling. The above-mentioned terms are protected by the Upper Cretaceous marls and marno-limestones. Porosity varies from 6.5 per cent for limestones to 12 per cent for dolomites and 15 per cent for the Albian sandstones. Permeability varies from 0 to some thousands mD. Connate water saturation is 30—40 per cent. The petroleum density is of 0.830 kgf/dm^3 at a temperature of 20° and a viscosity of 1.9 c.P. This deposit is characterized by an active hydrodynamic regime. The deposit waters are of $MgCl_2$ and $CaCl_2$ type, with salt concentrations of 3—3.7 g/l. In these waters, the presence of the naphtenic acids has been emphasized, too.

North of Serdanu, there are two more productive wells in a block hydrodynamically separated.

The Broşteni gas accumulation (49, Fig. 95) that seems to align the Vultureanca-Brîncoveanu screen fault, was identified by the well no. 22. The latter indicated the presence of gas in the Sarmatian. The well crossed the productive strata at the depth of 2,408—2,452 m, yielding 28,000—58,000 m^3/day gas, pressure 120/300 kgf/cm^2, on nozzles of 5 and 7 mm in diameter. It is interesting to note, that above this interval, the stratum marking the upper part of the gritty Sarmatian complex, proved saturated with water. Another three wells drilled nearby did not have economic results.

The Humele petroleum deposit with associated gas (50, Fig. 95) is located in the Lower Cretaceous at the depth of 2,440—2,520 m.

Only one mixed, structural-stratigraphic trap was identified within this structure. The reservoir is made up of hard limestones and of fissured marly-limestones whose $CaCO_3$ content varies between 74 per cent and

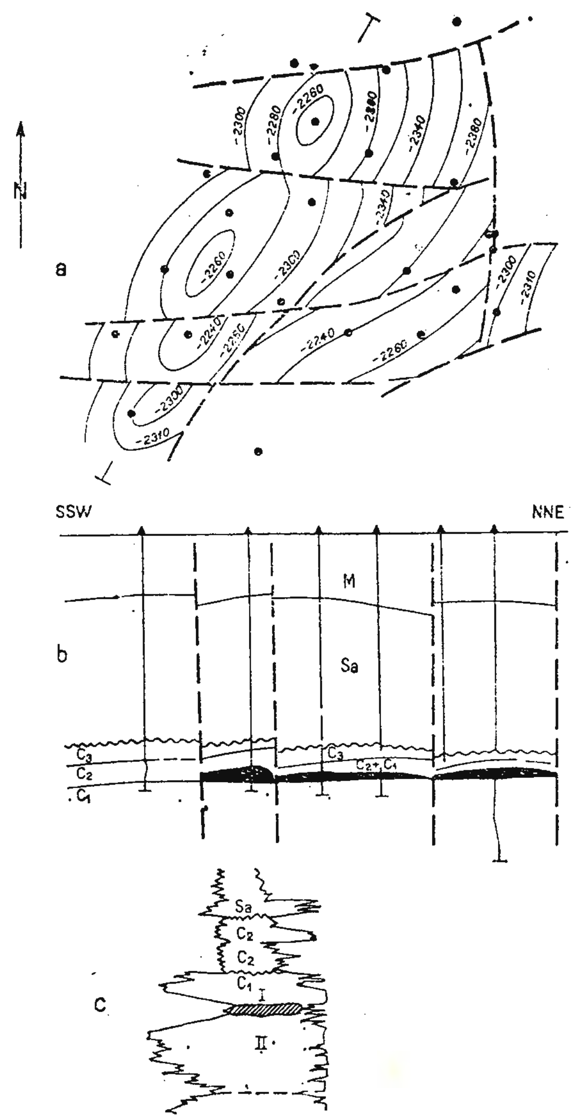

Fig. 103. — Brîncoveanu structure.
a, structural map at the Cretaceous level; b, geological cross section; c, basal Sarmatian and Cretaceous type profiles (according to I.C.P.P.G.).

85 per cent. The reservoir rock is of fissured type, as it is not permeable in the matrix. The storing capacity was estimated at 15.2 t/ha × m. The effective permeability is about 32 mD. The initial pressure of the deposit, measured at the depth of 2,501 m, was 231 kgf/cm². The deposit regime is thought to be determined by the interaction between the gas expansion and the bottom water driving. The petroleum specific gravity is 0.864 kgf/dm³. The deposit waters belong to the chlorocalcic type. They contain agressive CO_2 (22 mg/l) and sulphide hydrogen (6.12 mg/l).

The next group of accumulations that formed immediately south of those presented above, is dominated by the important deposits at Petreşti-Corbii Mari-Poiana.

The Petreşti (51)-*Corbii Mari* (52)-*Poiana* (53, Fig. 95) structural echelon contains hydrocarbons in the Lower Cretaceous and Sarmatian.

The region is covered by horizontal Quaternary deposits; that is why it was prospected by seismic methods. The latter confirmed the general tectonic style, namely, the existence of a monocline crossed by an important longitudinal disjunctive accident, the Petreşti-Corbii Mari-Poiana fault. The respective fault that duplicates at a given moment, bounds northwards a tectonic block consisting, at the Cretaceous and Sarmatian levels, of three slight vaultings, called, from W to S, Petreşti, Corbii Mari and, Poiana, respectively. Northwards, the major block is bounded by another tectonic accident, the Obislav fault (Fig. 104).

The section of interest for hydrocarbons belonging to the Lower Cretaceous consists of fissured and cavernous cryptocrystalline limestones, an alternation of hard and less hard rocks that seems to show no porosities and permeabilities, organogenous reefal limestones which are intensely diagenized with fissures and caverns, all of them having the matrix saturated with petroleum, and, finally, at the uppermost part, green glauconitic sandstone of 3—5 m in thickness, possibly hydrocarbon saturated when its cementation degree is lower.

The Sarmatian 3, which overlies the Cretaceous unconformably, consists of an alternation of limestones, sandstones, marly sandstones and marls. In the lower sector of the region there are 5 gritty sequences with reservoir properties named, from top to bottom *a*, *b*, *c*, *d* and *e*. The members *a*, *b* and *c* are found throughout the structure, while the terms *d* and *e* are present only in the negative forms of the pre-Neogene relief.

The hydrocarbon accumulations are located in the Corbii Mari Lower Cretaceous. Only a few wells produced in the Petreşti and Poiana Lower Cretaceous. The Sarmatian also yields oil and gas on all the three culminations; the most important petroleum compartment is represented by the Petreşti uplift.

The thickness of the petroleum saturated reservoir depends on the pre-Neogene relief shapes, on the reservoir position on the structure, on the lithofacial variation and on the degree of the rock diagenesis. The average porosity of the Cretaceous reservoir is of about 10 per cent. The permeability reaches 6,000 mD in fissures and caverns, decreasing to 9 mD in the matrix. The connate water saturation is of about 30 per cent.

The daily productions obtained were of 3—250 t/oil well with specific gravity of 0.887 and viscosity of 5.5 cP in the Cretaceous. Along the same line, it should be mentioned that while the initial deposit pressure showed values of 203—205 kgf/cm², the saturation pressure is of only 8—15 kgf/cm² and the solution gas ratio is of 1.1—9.5 Nm³/m³. This means that the oil is gas subsaturated. The deposit lying in the Cretaceous is characterized

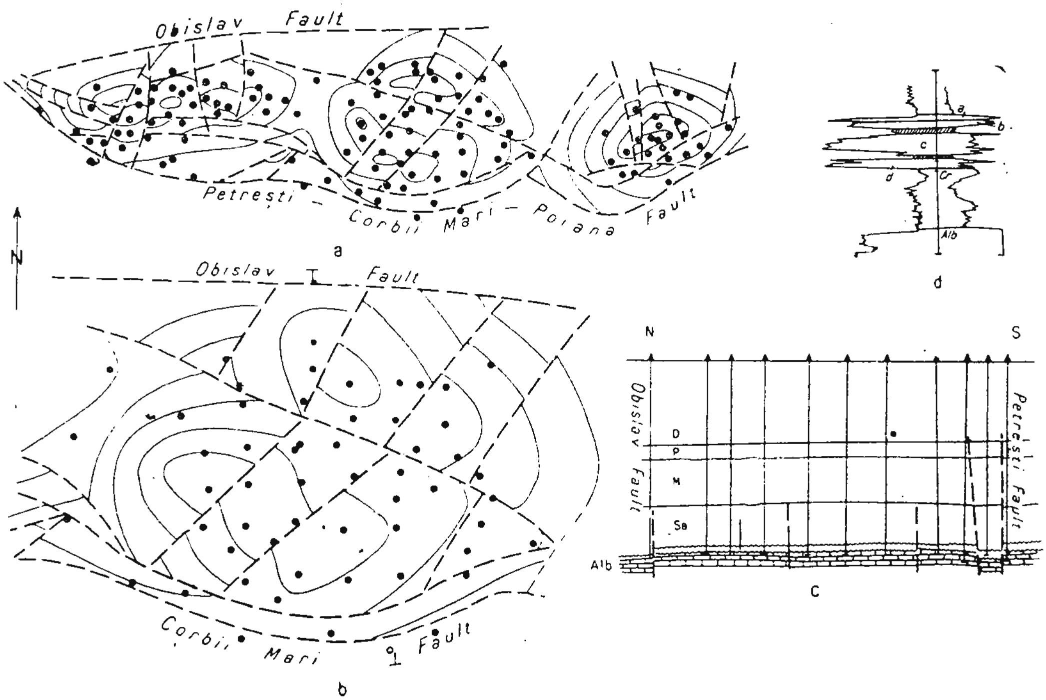

Fig. 104. — Petreşti-Corbii Mari-Poiana zone.
a, structural scheme at the Sarmatian level; b, structural scheme of the Corbii Mari sector at a Cretaceous guide mark; c, geological cross section; d, basal Sarmatian and Albian type profiles (according to I.C.P.P.G. Cîmpina).

by a very active hydrodynamic regime. The efficiency of this regime is proved by the fact that, in the first seven years of exploitation, when about 4.5 mil. t petroleum were produced, the reservoir pressure decreased only by 8 kgf/cm².

The Sarmatian in the Petreşti-Corbii Mari-Poiana region reproduces the Cretaceous configuration, forming settling structures. An important primary gas cap bounded by narrow oil bands accumulated in the Sarmatian reservoirs at Corbii Mari. The average porosity of the granular type of reservoirs reaches almost 25 per cent and the permeability is of 500—600 mD. The connate water saturation is between 28—29 per cent. The initial pressure is 190 kgf/cm^2 being equal to the saturation pressure. But at Poiana the petroleum is gas subsaturated, the saturation pressure decreasing to 27 kgf/cm^2. The solution gas ratio at Corbii Mari is 109 Nm^3/m^3 and at Poiana, 9 Nm^3/m^3. The Sarmatian petroleum differs from the Cretaceous one, in the sense that it is lighter (specific gravity 0.832 as compared to 0.837 kgf/dm^3), gas saturated (the solution gas ratio 109 Nm^3/m^3 as compared to 1.1 Nm^3/m^3) and has a lower viscosity (0.79 cP as compared to 5.5 cP). This fact suggests that the source of the hydrocarbons in the two formations is different and the protective screens are impervious. Only incidentally (at one well) in the vicinity of a fault heavy (Cretaceous) oil was identified in the Sarmatian, which implies the local intercommunication between the Miocene and the Cretaceous.

The Recea accumulation (54, Fig. 95) is controlled by the same disjunctive tectonic accident that screens the Dumbrava deposit. The Albian, which is the productive formation, yielded 31 m^3/day oil with 5 per cent salt water, at the first well (34) drilled on the structure at the depth of 1919—1912 m. The wells drilled afterwards contained either only 2.6—13 m^3 /day petroleum with impurities or gas exclusively. These results point out the fact that the Recea accumulation consists of a petroleum band with primary gas cap.

The Dumbrava structure (55, Fig. 95) contains hydrocarbon deposits in the Lower Cretaceous, the Albian and the Sarmatian. The first two terms offer carbonatic reservoirs, while the third one offers granular collectors.

The Cretaceous and Neogene deposits are characterized by a monoclinal disposition. The strata fall slightly northwards, the dips reaching 8°. The structure is affected by four longitudinal faults (Fig. 105) that divide it into four accumulation zones and by other transversal faults of secondary importance. A slight vault can be noticed at the Sarmatian level; it was probably determined by the pre-Neogene paleorelief.

On the Dumbrava structure were identified five traps, four of which are mixed and one (in the Sarmatian) is structural. Two of them are located in the Lower Cretaceous, two in the Albian and one in the Sarmatian. The main physical parameters of the deposits have the following values:

	Lower Cretaceous	Albian	Sarmatian
hydrocarbon nature	oil	oil+gas dome	oil
effective porosity (%)	—	13	25
effective permeability (mD)	4	7	376
connate water saturation (%)	—	50	25
initial pressure (kgf/cm^2)	233	203	147

saturation pressure (kgf/cm^2)	23	203	110
temperature (°C)	102	90	82
water-oil contact (m.b.s.l.)	2175—2000	1836—1882	1555
petroleum specific gravity (kgf/dm^3)	0.857	0.841	0.835

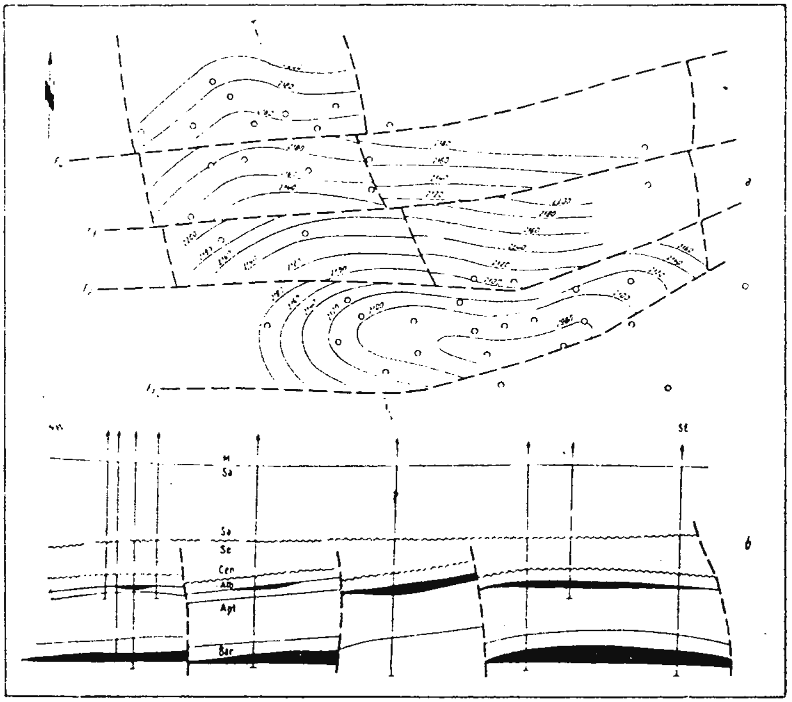

Fig. 105. — Dumbrava structure.
a, structural map at a Lower Cretaceous guide mark; b, geological cross section (according to L. C r i s t e a).

The initial oil productions were 2—28 t/day/well in the Lower Cretaceous, 1—11 t/day/well in the Albian and 22 t/day in the Sarmatian.

South of Petreşti-Corbii Mari-Poiana a system of faults, whose continuity and relations are not yet well determined, controls the S Corbii Mari, Căscioarele-Stoeneşti, Bolintin Deal deposits by the eastern ramification of these tectonic accidents and the Glogoveanu, Ştefan cel Mare, Izvoru, Şelaru deposits by the western ramification.

The S Corbii Mari accumulation (56, Fig. 95) was identified by the well no. 227. This well reached the Lower Cretaceous level, where its bottom remained. The existence of a vault at the Sarmatian level, probably, reflects the pre-existent relief configuration. After several successive tests the Sarmatian proved to contain gas at the depth of 1,714—1,722 m. The production measured on nozzles of 5—7 mm was 46,000—65,500 m^3/day, the pressures being of 92—115/110—124 kgf/cm^2. The condens was also pointed out. The result obtained suggests that the basal Sarmatian morphostructure is screened southwards by a fault.

The Stoenești-Căscioarele structure (57, Fig. 95) contains hydrocarbon accumulations in the Sarmatian basal horizon (Sa 3) which was divided into four members, named *a*, *b*, *c* and *d*. The packets *d* and *c* are predominantly marly. The traps are of stratigraphic type. The section saturated with petroleum and gas is between the isobaths —1,299 and —1,313 m. The porosity of the reservoirs varies from 10 per cent to 27 per cent. The average permeability is about 500 mD. The connate water saturation shows average values of 30 per cent. The initial reservoir pressure is almost equal to the hydrostatic pressure. The petroleum has the specific gravity of 0.840 kgf/dm^3. The reservoir regime is determined by the marginal water drive and by the gas detente of the primary gas cap. The gradient of temperature remains high, namely about 4°C/100 m. The reservoir waters are of $CaCl_2$ type, having low mineralizations (4—10 g/l).

The Bolintin Deal accumulation (58, Fig. 95) lies east of the Stoenești-Căscioarele deposit, along the same screen fault. One of the wells drilled here (no. 1325) produced from the Sarmatian, oil and brackish water (5.5 g/l), the stationary level 150 m, the dynamic level 900 m.

The Glogoveanu structure (59, Fig. 95) which is productive at the Albian level, represents a monocline, with the strata falling (2—3°) northwards. The screen is represented by a fault trending E—W. Within the northern compartment corresponding to the Glogoveanu structure other faults were also identified; they are perpendicular to the first one which divides the respective compartment into several blocks.

The Glogoveanu reservoir, represented by the Albian, consists of two types of rocks : marly limestones to gritty, hard limestones (60—80 per cent carbonates) capable of storing fluids only in fissures and glauconitic, mesogranular, porous and, at the same time, fissured sandstones (9—25 per cent carbonates). Both types of rocks show fissures.

The Glogoveanu Albian contains oil and, only locally, very limited gas cap. The water-oil contact is at the depth of 1,790—1,824 m. There are two hydrodynamic units on the structure, one in the western sector, the other in the eastern compartment. The porosity varies between 16.3 and 21 per cent, the average permeability is about 30 mD and the connate water saturation is 37.4 per cent. The petroleum specific gravity is 0.864 kgf/dm^3. The deposit has been exploited by primary methods up to the present but it will benefit by the water injection.

A separate compartment with oil and primary gas cap was identified in the basal Sarmatian in the eastern extension of the main deposit; it is called "Glogoveanu E." Another three impervious transversal faults were identified in the zone, beside the main accident; they divide the compartment into hydrodynamically separated blocks. The blocks Ia_1

and Ia_2 contain exclusively petroleum at the depth of 1,545—1,597 m. The productions did not exceed 10 t/day per each well. The eastern block Ib (well no. 584) seems to be exclusively gas-bearing.

The Ştefan cel Mare (60) — Izvoru deposits (61, Fig. 95) correspond to different tectonic compartments: Ştefan cel Mare, formed of two productive sectors (north) and Izvoru (south). The geological formations of interest are the Neocomian, the Albian and the Sarmatian.

The Neocomian develops in perireefal facies, represented by fissured crypto- and microcrystalline limestones. The Albian, the main productive term, consists of limy or siliceous sandstones, gritty limestones and, subordinately sands and marls. The basal Sarmatian, in its turn, consists of sandstones, sands and thin marl and limestone intercalations.

The Cretaceous and Sarmatian deposits have a monoclinal disposition, with dips of 3—5° northwards. Several faults, including the one which separates the Ştefan cel Mare compartment from the Izvoru compartment, cross the region. The Şelaru accumulation lies in the eastern prolongation of the Izvoru deposit after an interruption caused by a few transversal faults.

The Lower Cretaceous contains oil accumulations, possibly, also gas cap. The Albian is saturated with oil and associated gas, including gas cap. The same hydrocarbon disposition is supposed to exist at the Sarmatian level, too. The Lower Cretaceous yields petroleum up to the maximum depth of 1,855 m b.s.l. and the Albian to 1,609 m b.s.l. The productive Sarmatian is found at the depth of 1,160 m—1,350 m b.s.l. The porosities are 14.3 per cent in the Albian and 25.1 per cent in the Sarmatian. The connate water saturation was estimated at 40 per cent in the Albian and 30 per cent in the Sarmatian 3. The initial pressure was 184—188 kgf/cm² in the Neocomian and 140—154 kgf/cm² in the Albian. The petroleum specific gravity is 0.880 kgf/dm³ under the surface conditions.

The Ştefan cel Mare-Izvoru zone is characterized by small petroleum productions that vary between 2 and 10 t/day per each well.

The Şelaru accumulation (62, Fig. 95) formed in the eastern prolongation of the Izvoru deposits. It was identified by only one well (109) which produced salt water with 20 per cent petroleum from the Albian at the depth of 1,696—1,685 m. The dynamic level is 850 m. The water mineralization is 68 g/l.

The next echelon of productive structures is made up of the Strîmbeni, Căldăraru, Popeşti-Palanga and Glovacioc deposits.

The Strîmbeni (63)-*Căldăraru* (64, Fig. 95) deposits were identified in 1961 and their exploitation started 12 years later.

The 70 wells drilled in the zone crossed the whole succession of strata reaching the Permian; only the Albian deposits proved to be productive. As almost throughout the central sector of the Moesian Platform, the Albian consists of limestones, marno-limestones, gritty limestones, gritty and glauconitic sandstones separated into five members called, from bottom to top, *a*, *b*, *c*, *d*, *e*. The last two packets affected by denudation are only locally found. Within the Albian two sandstone levels were also identified : a lower limy one and an upper-glauconitic one. The respective arenyte episodes seem to associate with an intraformational gap. The $CaCO_3$ content of the Albian reservoirs varies between 40 and 80 per cent.

The Strîmbeni-Căldăraru zone is crossed by three longitudinal accidents and another four transversal faults which divide it into tectonic blocks. The Albian deposits that, generally, sink northwards, outline a slight local vaulting; it is probably the reflex of a paleorelief it overlies.

The Strîmbeni-Căldăraru Albian contains petroleum, occassionally with gas cap and, sometimes, (in two blocks) only free gas. The contacts between fluids vary to a great extent, as a result of the reservoir variation, of the disappearance of some productive terms on either side of the mentioned unconformity plane and of the tectonic complications. The water-oil limit was found at the isobaths 1,352–1,556 m, the gas-oil contact at 1,300–1,342 m, and the gas-water limit at 1,295–1,362 m. The effective average porosity is 15 per cent (the hydrocarbons are stored in the pores and in the microfissures), the connate water saturation 50 per cent, the permeability 2—5 mD, the initial pressure 145 kgf/cm^2 (corresponds to the saturation pressure), and the geothermal gradient is 4.7°C/100 m. The oil specific gravity is of 0.840 kgf/dm^3.

The Popești-Palanga accumulation (65, Fig. 95) corresponds to a vault shaped structural detail which is situated south of the Ștefan cel Mare-Izvoru screen-fault. One of the wells drilled here, tested at the Albian level (1,627—1,592 m) had favourable results, concretized by 20,000—42,000 m^3/day gas, pressure 40—68/50—95 kgf/cm^2.

The Glovacioc structure (66, Fig. 95) proved productive at the Albian level which consists of three lithofacial units, from top to bottom, A_1, A_2 and A_3. The complex A_3 is formed of marly sandstones with fine grains. The term A_2, the main member in the region, consists of gritty limestones, calcarenites, pseudoöolitic limestones with limy and gritty marl intercalations. The complex A_1, gradually disappears so that it is of very little importance.

The structure represents a faulted monocline, slightly vaulted, trending E—W, the dip of the strata being 3—50° northwards. The monoclinal disposition is complicated by a series of longitudinal and transversal faults that divide the region into several tectonic blocks. The deposit is characterized by primary gas cap which is more developed in the western part of the structure and bordered by an oil band. The reservoir pressure is lower than the hydrostatic column equivalent (about 140 kgf/cm^2 at the depth of 1,520 m) and the geothermal step is a little higher than the normal one (27 m/°C). Initially the wells produced 7—15 t/day oil, with 10—30 per cent salt water and the gas ratio about 1,000 Nm^3/m^3. The oil has a density of 0.880 kgf/dm^3 and the viscosity 1.5 cP. The associated gas (the gas cap) with 97.4 per cent methane and 5.6 g/m^3 natural gasoline may be assigned to the poor gas category. The solution gas ratio at the saturation pressure is about 50 Nm^3/m^3. The reservoir waters are of chlorocalcic type.

The important Cartojani fault whose throw reaches 250 m, together with its prolongations, constituted an important obstacle for the hydrocarbon migration, allowing the formation of the Tătărăşti, Cartojani, Mîrşa, Grădinari-Domneşti and Căţelu accumulations.

The Tătărăşti accumulations (67, Fig. 95) were identified by the wells nos. 596 and 130. The well no. 596 crossed the Neogene and, partially, the Cretaceous reaching the depth of 1,687 m, its bottom remaining in the Albian. During the flow test, the upper part of the Albian sandstones (1,473 – 1,468) produced 15,000 m^3/day gas with salt water, on a nozzle of 6.5 mm, pressure 105/127 kgf/dm^3. In the same zone, eastwards, well no. 130 that crossed a similar profile, yielded salt water with 30 per cent oil, dynamic level 800, from the Albian.

The different and contradictory behaviour of the wells in this region attest the existence of lithological traps at the Albian level.

The Cartojani structure (68, Fig. 95) develops on an area of 18 km in length and 1 – 2 km in width and was proved productive in 1959.

The main screen of the hydrocarbon accumulations is formed by the Cartojani fault, with a throw of 60 – 250 m and, generally, parallel to the Blejeşti-Clejani-Bălăria fault. Other faults were also identified in the region; they are perpendicular to the first one, and, partly, impervious dividing the structure into tectonic blocks (Fig. 106).

The Cartojani productive units are grouped into three independent complexes, namely: the Sarmatian 3 (*a*, *b*, *c*, and *d*), the Sarmatian 1, which contain oil and primary gas cap, and the Meotian, which is exclusively gas-bearing.

The effective average porosity of the Sarmatian reservoirs is about 25 per cent and the absolute permeability in Sa 3 is 400 – 1,000 mD. The connate water saturation is about 25 per cent. The initial pressure is 100 kgf/cm^2 in Sa 3 and 95 kgf/cm^2 in Sa 1; these values are only a little lower than the pressure exerted by the hydrostatic column. The saturation pressure must have been equal to the initial reservoir pressure. The solution gas ratio was estimated at 24.8 Nm^3/m^3. The petroleum volume reduction factor is 1.08. The petroleum has the specific gravity of 0.900 kgf/dm^3 under standard conditions. The members *a*, *b* and *c* within the Sa 3 form structural traps and have *C* type petroleum, while the basal member *d*, which represents a characteristic paleogeomorphic trap, seems to contain *B* type petroleum. The reservoir waters are of $CaCl_2$ type, with mineralization of 10 – 60 g/l in Sa 3 and 22 – 32 g/l in Sa 1. Sa 3 is exploited by water injection both in the aquiferous zone and in the gas cap.

The Meotian collector sands are located in the base, at the contact with the Sarmatian (probably near a local stratigraphic unconformity) and develop in the central part of the structure. Their effective thickness decreases eastwards and westwards as a result of the facies lateral variation (the sands change gradually into marls). The productive Meotian represents a lithological trap under these circumstances.

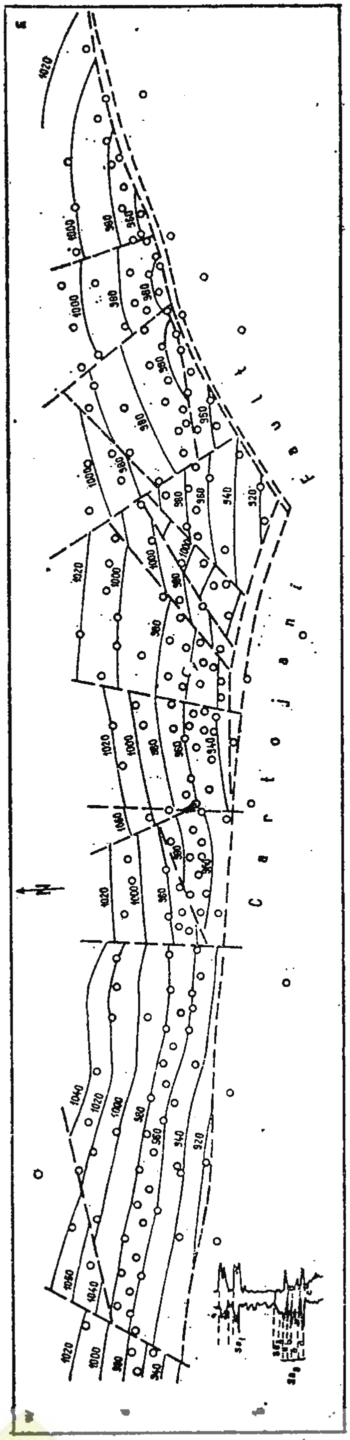

Fig. 106. — Cartojani structure.
a, structural map at a Sarmatian guide mark ; b, Sarmatian and Meotian type profiles.

The exclusively gas-bearing Meotian arenytes are marked by the average porosity of 25 per cent, connate water saturation 25 per cent, initial pressure 92 kgf/cm². The water mineralization is 25 g/l.

The Mîrşa deposit (69, Fig. 95) aligns the Domneşti-Podişor fault which is probably the eastern continuation of the Cartojani disjunctive accident. It is a gas deposit, confirmed by three wells so far. The deepest of them, 1720, reaching the depth of 1,216 m, crossed the succession of Sarmatian, Pliocene (up to 1,120 m) and, partially, Cretaceous deposits, its bottom remaining in the Barremian. The flow tests indicated gas traces in the Sarmatian and free gas in the Meotian upper part at the depth of 790–775 m. The pressure varies between 48–60/58–60 kgf/cm² on nozzles of 4.5–6.5 mm and the production between 17,600–370,000 m³/day. The other two wells also produced gas from the Meotian but with smaller output.

The Grădinari deposit (70, Fig. 95) lies east of the Cartojani structure and has been exploited since 1966. The respective deposit belongs to the Sarmatian 3 whose total thickness does not exceed 40 m. The productive complex, as in the neighbouring structures, consists of three members *a*, *b* and *c* (from top to bottom) represented by limy sandstones, sands and gritty marls.

The Cretaceous and Neogene deposits dip northwards by 2–3°. The Cartojani-Grădinari fault that screens the deposit southwards has a throw of 40–70 m. Other secondary faults trending N–S divide the structure into several blocks.

The Sarmatian 3 contains petroleum with associated gas up to the isobath of maximum 930 m. The main physical parameters of the deposit are: porosity 30–36 per cent, the permeability 540–1,350 mD, the connate water saturation 25–45 per cent, the initial pressure at the isobath of 900 m = 92 kgf/cm², the bottom temperature 51°C, the petroleum specific gravity 0.890 kgf/cm³. The gas consists of 96.74 per cent methane and 3.26 per cent hydrocarbons, heavier than the methane $+CO_2$. The reservoir waters have mineralizations of 6–14 g/l.

The Căţelu accumulation (71, Fig. 95) belongs to the basal Sarmatian involved in a mixed, structural-stratigraphic trap. Against a monoclinal background dipping northwards and crossed by a fault trending E–W, the gritty-sandy layer in the Sarmatian base develops locally according to the pre-existent relief configuration.

The productive stratum, about 860 m deep, furnished weak oil productions (1.5–3 m³/day) with impurities, at wells nos. 347 and 550.

Several oil and gas deposits were identified between the two big screen accidents, the Cartojani fault and the Videle fault; some are controlled by the tectonic factor (local faults), some by the stratigraphic and paleogeographic factors. Taking into consideration the complexity of factors that determined them, these deposits will not be presented in the order indicated by the structural criterion (tectonic alignments).

The Negreni-Preajba accumulation (72, Fig. 95) seems to range a tectonic accident which would represent the western prolongation of the Cartojani-Preajba S fault.

One of the wells drilled here (2015) tested the upper part of the Albian (A_1), where 24,000—65,000 m^3/day gas, were obtained with pressure of 90—106/104—110 kgf/cm^2. The Negreni-Preajba trap is due to lithological variations.

The Preajba N-centre deposits (73, Fig. 95) belong to a complex of geological conditions, whose style is determined by the monoclinal disposition of the strata and by the fault high frequency on the one hand and by the existence of some paleoreliefs of the filled paleovalley type. The Senonian, the basal Sarmatian and the Sarmatian 3, varying between 1,000 and 1,300 m in depth, proved their productive potential in the respective sector. The most important of these units is the Sarmatian 3 which is spread throughout the sector and divided into three members *a*, *b* and *c*. The basal Sarmatian settled and was preserved only in a paleovalley trending NNE—SSW. Within the basal Sarmatian were separated the members *d*, *e*, *f*, *g*, whose existence is conditioned by (from bottom to top) the depth and configuration of the valley. The Senonian, although productive only in some wells so far, is found throughout the sector, except the paleovalley where it was eroded.

The above mentioned units contain petroleum, while small gas cap was still identified only locally.

The average porosity of the Sarmatian term varies between 22 and 26 per cent. The permeability is 0.1—730 mD. The connate water saturation is between 32 and 40 per cent. The CO_2Ca content of the Sarmatian 3 varies between 4 and 40 per cent. The initial reservoir pressure was 95—110 kgf/cm^2 and the temperature 52—60°C. The petroleum specific gravity is 0.900 kgf/dm^3 and the waters are of chlorocalcic types, with mineralization of 63 g/l.

The deposits correspond to mixed structural, stratigraphic and paleogeomorphic traps.

The Preajba S deposits (74, Fig. 95) were discovered in 1963. They correspond to a paleogeomorphic trap formed along a paleovalley (Paleoargeş). The respective relief was eroded in the Senonian, Turonian and Cenomanian deposits and then filled up by the Sarmatian basal terms — and possibly by the Tortonian basal terms which resemble a "shoestring sand trap".

The basal Sarmatian and, only locally, the Albian yield in the respective zone. The basal Sarmatian, which is predominantly arenytic, was divided into three members called, from top to bottom *d*, *e* and *f*; the latter are 0—50 m, 0—80 m and 0—30 m in thickness, respectively. The upper terms of the basal Sarmatian, namely the members *a*, *b* and *c* settled throughout the region but they do not contain hydrocarbons at Preajba S. The area where develop the packets *d*, *e* and *f* varies, being, as a rule, more restricted for the lower terms, because of the pre-existent relief configuration.

The Preajba S paleovalley is, in its turn, crossed by several faults, which divide it into sealed blocks (Fig. 92).

The fluid distribution is rather irregular because of the basal Sarmatian lithological variations. The three productive packets seem to be hydrodynamically separated in general. The oil strata were found at the depth of 1,050—1,140 m. The initial production was 2—35 t/day oil for each well. The initial pressure was between 90.5 and 110.5 kgf/cm², and the saturation pressure 73 kgf/cm². The average porosity is 23—24 per cent and the connate water saturation 33—36 per cent. The reservoir temperature reached 51—55°C. The petroleum specific gravity is 0.926 kgf/dm³.

The Siliştea-Şopîrleşti structure (75, Fig. 95) is characterized by a monoclinal disposition of the strata both at the Cretaceous and the Neogene levels. The productive units on this structure are the Albian, the basal Sarmatian and the Sarmatian 3.

The Albian consists of gritty limestones and limy sandstones, grouped into three members (from bottom to top) A_2 — lower; A_1 and A_2. This development is found only in the western part of the structure, as the upper term A_1 was eroded in the central and eastern parts. The packet A_2 — lower contains petroleum, gas cap and, possibly, free gas, while the packets A_2 upper + A_1 are saturated with petroleum and gas cap. The Albian is productive at the depth of 1,050—1,350 m.

The basal Sarmatian of Siliştea type, made up of weakly consolidated sands with marly intercalations is found only in the Siliştea zone. It contains petroleum accumulations at the depth of 900—1,050 m. The sandrushes, which make the exploitation difficult, are characteristic of the basal Sarmatian.

The Sarmatian 3 consists of sands, weakly cemented, limy sandstones, marly sands and sandy marls. The packets "*c*" of Siliştea and Şopîrleşti types having a discontinuous distribution due to the pre-Sarmatian relief configuration as well as *a* + *b*, which are present throughout the structure, were separated within this complex. The Sarmatian 3 is petroleum saturated and is found at the depth of 945—1,050 m.

The main physical parameters of the deposits are:

	Albian	Basal Sa	Sa 3
thickness (m)	2—30	4—50	8—30
porosity (per cent)	21	26.5	20—26.5
permeability (mD)	20—25	500—600	500—600
connate water saturation (per cent)	36	30.2	30.2—40
initial pressure (kgf/cm²)	120	95	94—100
reservoir temperature (°C)	55	51	5—53
petroleum specific gravity (kgf/cm²)	0.920	0.940	0.90—0.940

The respective deposits, which produced by their own energy up to the present, will be exploited by conventional methods.

The Baciu structure (76, Fig. 95), where about 50 wells were drilled, proved its productive potential in 1964. The main member of interest is the Sarmatian which is divided, as on the other structures, into the members *a*, *b* and *c*.

The Cretaceous and Neogene deposits, crossed at Baciu dip northwards by 2—3° and slightly mould the buried paleoreliefs. These deposits are crossed by longitudinal and transversal faults that divide the structure into blocks.

The Sarmatian 3 contains petroleum with gas cap. The water-petroleum contact was found at 805—825 m b.s.l. and the gas petroleum limit, at 786—797 m b.s.l.

The main physical parameters of the deposits are: average porosity 20—30 per cent, permeability 0—4,000 mD, connate water saturation 20—30 per cent, the initial pressure 82.6 kgf/cm^2 (at the depth of 805 m), saturation pressure 55 kgf/cm^2, reservoir temperature 58°C, petroleum specific gravity 0.900 kgf/dm^3. The marginal waters are of chlorocalcic type, with mineralizations of 60 g/l. The deposit is exploited by water injection.

The Buturugeni gas accumulation (77, Fig. 95) is located in the upper part of the Meotian, at the depth of 878—606 m. The only productive well in this structure yielded about 85,000 m^3/day. Another two neighbouring wells, achieved with a view to extending the gas accumulation, had no economic result.

The Bragadiru structure (78, Fig. 95) lies south-east of Bucureşti city. It proved its productive potential in 1967. The member of interest is the Sarmatian 3, which is unitary and is 7—17 m in thickness. The respective complex is made up of sands, sandstones and limestones.

The structure resembles a monocline, the strata falling northwards. The strata dip by 2—3° at the Cretaceous and Neogene levels. The major tectonic accident that forms the screen of the hydrocarbon accumulations southwards is the Clinceni-Bragadiru fault.

The Sarmatian 3 at Bragadiru is saturated with oil, associated gas and free gas. The block I contains gas, the gas-water contact being 680m b.s.l. The blocks IIa and IIb have oil and gas cap. The water-oil limit is situated at the isobath 697 m and the gas-oil contact, at 680 m.

The effective porosity of the Sarmatian 3 is 36 per cent, the permeability 83 mD, the connate water saturation 45 per cent, the initial pressure 70 kgf/cm^2 (at the isobath 680 m), the reservoir temperature (at 770 m b.s.l.) reaches 36°C. The petroleum specific gravity is 0.880 kgf/dm^3. The gas contains 99.58 per cent methane and the rest of maximum 0,50 per cent consists of heavier fractions. The associated waters are of bicarbonato-sodic type, with mineralization of 3—6 g/l.

The Popeşti-Leordeni accumulation (79, Fig. 95) is located in the Meotian, at the depth of 575—565 m. Well no. 66 which produced on various nozzles, between 4 and 10 mm, is the only one having economic results in the zone; it produced 10,000—40,000 m^3/day gas, pressures 33—45/36—48 kgf/cm^2. Although it lies in the vicinity of the fault that screens the Bălăceanca deposit, the trap conditions of the Popești-Leordeni accumulation are not clear enough.

The Bălăceanca structure (80, Fig. 95) proved productive at the basal Sarmatian and basal Meotian levels. The Neogene monoclinal disposition is disturbed by the presence of two longitudinal faults functioning as a screen and of three impervious transversal faults.

The Sarmatian contains petroleum, sometimes associated with gas cap. The depth of the strata is of 575—525 m. The oil productions are 1—21 t/day for each well and the gas productions vary between 26,000 and 31,000 m^3/day.

The Meotian is gas-bearing, yielding 30,000—42,000m^3/day at the depth of 500—550 m. Only one well (553) yielded oil from the Meotian.

Another two small deposits, Rîca and Siliștea-Gumești, are located in the opposite (western) part of the central zone.

The Rîca Albian deposit (81, Fig. 95) was put into operation in 1965. The Albian reservoirs form four complexes in the zone; they are numbered, from top to bottom, A_1, A_2, A_3 and A_4. Among them, only the complexes A_1 and A_2 — upper are saturated with petroleum and dissolved gas. The respective complexes seem to be separated hydrodynamic units.

The Albian is monoclinally disposed, its strata falling eastwards. The deposits are screened by an impervious fault (?) to the west. The screen might be, in fact, of lithological nature.

The depth of the productive strata does not exceed 1,450 m. The average effective porosity is of about 15 per cent, the average permeability is of 1 mD, the connate water saturation of 50 per cent, the initial pressure of 125 kgf/cm^2 (at the average depth of 1,380 m), the temperature of 64°C, the petroleum specific gravity of 0.900 kgf/dm^3. The reservoir water is of chlorocalcic type with mineralizations of 50—80 g/l. The gas contains 97 per cent methane. The output is of 1.2 t/day with 89 per cent impurities for each well.

The Rîca deposit belongs to the transition zone of the Albian facies, where the pelites change gradually into arenytes eastwards. This fact accounts for the low productivity of the wells. It also accounts for the assigning of the respective traps to the lithological type.

The Siliștea-Gumești structure (82, Fig. 95) lies between the Strîmbeni-Rîca and Ciolănești alignments to the north and south, respectively. This structure, crossed by faults, is made up of two compartments: a northern one, called Siliștea N and a southern one, called Siliștea. The Albian represents the productive formation in both compartments.

An oil band with primary gas cap was identified at Siliștea at the depth of 1,250—1,300 m. The maximum productions obtained (well no. 2360) were 25 m^3/day oil with 30 per cent impurities.

The Albian yielded gas in the southern compartment (Siliștea). A narrow oil band was also found in the eastern block of this compartment.

A system of disjunctive accidents belonging to the Ciolănești-Blejești-Clejani-Videle-Bălăria alignment was found south of the above accumulations; the most important deposits in the Moesian Platform are to be found along it. Some of them are the Videle-Blejeşti and Bălăria deposits (Fig. 95). Their brief characterization will be made below.

The Ciolăneşti structure (83, Fig. 95) proved its productive potential in 1964 and was put into operation six years later.

The wells drilled on the structure crossed the whole succession of strata from the Quaternary to the Lower Cretaceous. Among these formations the Albian and the Sarmatian proved of interest for hydrocarbons.

Against the monoclinal background dipping northwards, the Cretaceous appears slightly vaulted and is crossed, together with the Senonian, by three longitudinal faults and by another four transversal accidents.

The Albian consisting of gritty limestones, limy sandstones, glauconitic sandstones and marly sandstones was divided into three complexes: $Albian_2$ lower, $Albian_2$ upper and $Albian_1$. These members have petroleum with primary gas cap. The complex 2 lower seems to contain free gas. The thickness of each of the three complexes varies between 4 and 30 m. The water-oil limit was found at the depth of 1,205–1,255 m and the oil-gas contact, at 1,190–1,240 m b.s.l. The porosity is 12–16 per cent, the permeability 0.3–2 mD, the connate water saturation 50 per cent, the initial pressure 117–120 kgf/cm², the reservoir temperature 57°–59°, the petroleum specific gravity 0.920 kgf/dm³. Although crossed by a system of fissures, the productivity of the deposits is low (2–7 t/day per well).

The Sarmatian is saturated with gas.

The Ciolăneşti South gas accumulation (84, Fig. 95) was identified in the sandy strata from the Meotian base, at the depth of 647–683 m. The only well with gas in this zone, 155, yielded 19,000–46,000 m³/day, on nozzles of 4.5–7 mm. The stratum pressure is a little lower than the pressure exerted by the hydrostatic column. The trap seems to be of lithological type.

The Blejeşti structure (85, Fig. 95), situated west of the Videle great oil field, was identified in 1960. The wells drilled reached the Permo-Triassic level pointed out the existence of some hydrocarbon accumulations in the Lower Cretaceous, the Sarmatian and the Meotian.

At the level of the Cretaceous and Neogene formations the structure is like a monocline with the strata falling northwards (Fig. 107). The region is crossed by numerous tectonic accidents, including the Blejeşti-Videle-Bălăria system that bounds the accumulations southwards.

The upper section of the Neocomian, where some hydrocarbons accumulated, consists of microcrystalline limestones, chalk limestones, organogenous limestones, limy sandstones and glauconitic sandstones. After a gap, marked by the absence of the Albian, follows the Turonian, and, locally, the Senonian.

The Sarmatian consists of limy sandstones, marly sands and sandstones and friable sands which have been separated into three members: *a*, *b* and *c*.

The Meotian consisting of a succession of marls and sands is marked by the lenticular development of the reservoirs.

The Blejești hydrodynamic units are represented by the Lower Cretaceous, Sa 3 *c*, Sa 3 *a* + *b*, and the Meotian. The Lower Cretaceous and the Sarmatian contain oil, Sa 1 has locally also primary gas cap and the Meotian is saturated with free gas.

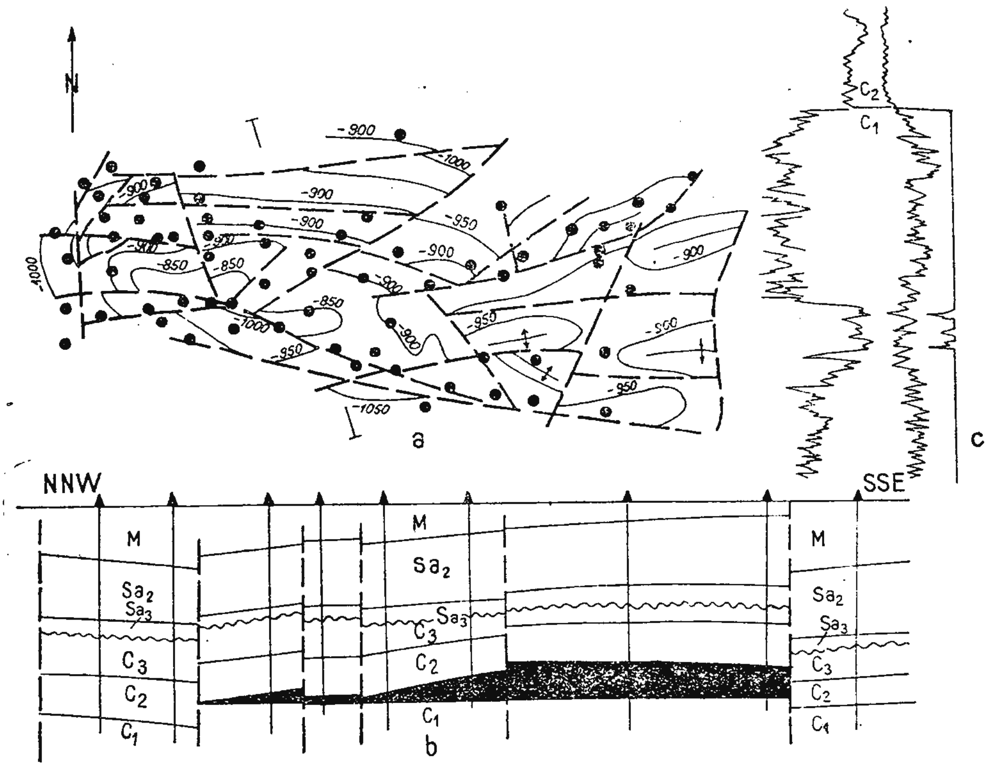

Fig. 107. — Blejești oil field.
a, structural map at a Lower Cretaceous guide mark ; b, geological cross section ; c, Lower Cretaceous type profile (according to E. Manole).

The main physical parameters of the Cretaceous and Sarmatian deposits are :

	Cretaceous	Sarmatian
porosity (per cent)	12.37	26.5
connate water saturation (per cent)	51.58	70
initial pressure (kgf/cm^2)	92	80

reservoir temperature (°C)	52	49
petroleum specific gravity (kgf/dm³)	0.92	0.94
reservoir water mineralization (g/l)	12–6	15–6

The dislocation of the Cretaceous oil takes place by the natural advance of the tabular water, the pressure remaining at the initial value since 1964.

The Videle structure (86, Fig. 95) situated about 45 km south-west of Bucureşti, accumulated the most important amount of oil as compared to the other structures of the Moesian Platform.

The region is covered by horizontal, Quaternary deposits so that the deep structures could only be identified by geophysical methods. Initially gravimetric and magnetometric investigations were carried out; they were followed by seismic prospections. Core drills were achieved at the same time. The respective works together with the numerous wells of medium depth confirmed the tectonic style which is common to the whole platform, at the Neogene level, mainly a monocline falling by steps northwards, along some accidents trending E–W. Here the accident, which constitutes the main screen, is represented by the Blejeşti-Clejani-Videle-Bălăria fault system. Other numerous tectonic accidents, parallel or perpendicular to the first one were also identified here; they influence variously the hydrocarbon distribution (Fig. 108). The structural ensemble sketched above develops on an area which is 20 km long and 7 km wide.

The deepest drills on the Videle structure reached the Triassic level which they crossed within a thickness of 100 m. The Triassic consists of limestones and dolomites. The Middle and Upper Jurassic follows unconformably; their deposits reach 700 m. The Dogger consists of sandstones and clays (100 m), while the Malm consists of carbonate deposits. The Cretaceous is only 300 m thick; about 200 m belong to the Lower Cretaceous-represented by microcrystalline limestones, organogenous limestones, and chalk limestones; about 100 m belong to the Upper Cretaceous (Cenomanian, Turonian, Senonian) consisting of cryptocrystalline limestones, chalk limestones, marno-limestones and marls. The Albian is not present on the structure. After an important gap, corresponding to the Paleogene and Lower Miocene, when a rather varied relief had formed, the Sarmatian deposition followed. The new cycle has started since the Upper Tortonian in the zones with negative relief shapes. The Tortonian and Sarmatian deposits can be separated into two lithostratigraphic units: a lower complex, predominantly gritty-sandy, belonging to the basal Sarmatian and, sometimes, to the Upper Tortonian, and an upper complex, predominantly pelitic. The thickness and number of the basal complex terms vary according to the pre-existent relief shapes. Thus Sa 3, the first term that fossilizes the paleorelief, has an irregular distribution. Its thickness varies between about 80 m (W) and 5–6 m (E). The Sarmatian 3 was divided into four members, numbered from top to bottom, Sa 3, *a*, *b*, *c* and *d*. Only the first three packets are of interest for hydrocarbons. The stratum "*a*" is found throughout the region, while the stratum "*b*", which is present

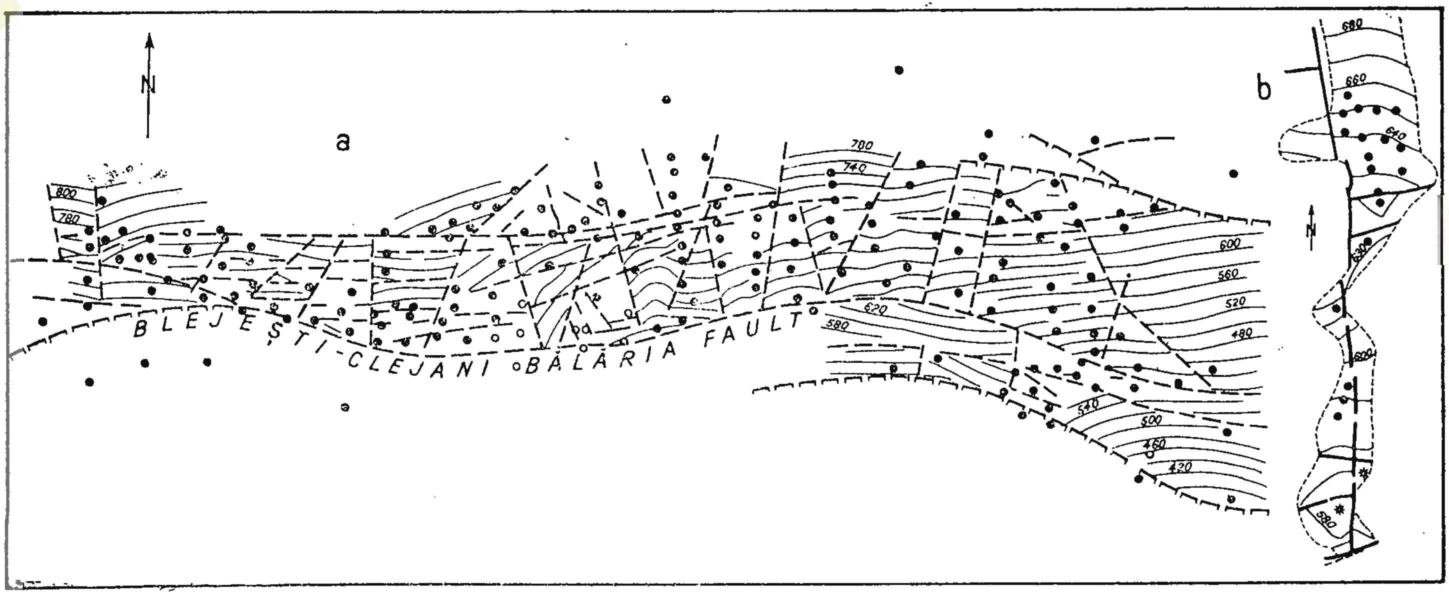

Fig. 108. — Videle structure.
a, structural map at a guide mark of the Sarmatian base; b, paleovalley filled with deposits Sa_2 (according to A. Bociu and E. Manole).

in the western sector of the structure, decreases to its disappearance in the eastern part of the region. The strata "*c*" and "*d*" are generally present on the paleovalley and dolines. A marl packet, 2—12 m thick, intervenes between the strata $a + b$ (the main productive unit of the structure) and the stratum *c*; it allows a hydrodynamic isolation. The Sarmatian 3*c* consists of unconsolidated sands.

The same paleorelief determined also the sedimentation character; generally, the old valleys are marked by more psamitic deposits resembling some bands or "shoestring" sands as is the case of Sa 2 from the central part of the structure where it reaches 50—60 m in thickness (Fig. 108). The Sarmatian is overlain by the Pliocene and Quaternary that reach 600—650 m in thickness. The Meotian develops in a predominantly marly facies with sand bands, the Pontian is exclusively pelitic while the Dacian, Levantine and Quaternary make up a sequence of sandstones, microconglomerates, marls, clays and coal intercalations.

The first hydrocarbon traces on the Videle structure were obtained in 1959. Since then more than 600 wells have been drilled; they identified several productive terms situated at the depth of 450—800 m. These terms, often representing separate hydrodynamic units, are:

The Lower Cretaceous, oil deposits with production of 4 m^3/day per well;

The Sarmatian 3 *c*, oil deposits with production of 15—20 m^3/day per well;

The Sarmatian 3 $a + b$, oil deposits with production of 0.4—202 m^3/day per well;

The Sarmatian 2, oil deposits with gas cap, production of 10—35 m^3/day per well;

The Sarmatian 1 (lenticular), oil deposits with production of 14—47 t/day per well;

The Meotian, free gas deposits with production of 22,000—60,000 m^3/day per well.

The effectively hydrocarbon saturated thickness of the reservoirs varies within very large limits. The average porosity of the Sarmatian and Meotian is about 30 per cent and the permeability of 0—3,000 mD. The connate water saturation, which is higher in the Lower Cretaceous (51.6 per cent) decreases in the Sarmatian (18—23 per cent). The gradient of pressure is 10—10.3 kgf/cm^2/100 m in the Lower Cretaceous and in Sa 3 *c* and 9.5—9.8 kgf/cm^2/100 m in Sa 2, Sa 1 and in the Meotian. The saturation pressure does not exceed, as a rule, 10 kgf/cm^2. The oil is subsaturated with gas (0.3—6.3 Nm^3/m^3 ratio). Generally, the oil from the Videle structure is heavy and viscous. The density shows minimum values of 0.925 kgf/dm^3 and viscosity of 10 cP near the gas-oil limit. The values increase up to 1.043 kgf/dm^3 and 33 cP, respectively towards the water/oil limit. The average oil density on the structure is 0.940 kgf/dm^3. But the viscosity increases from the central zone of the structure where it is 10—33 cP towards the eastern and western extremities where it reaches 85 cP and even 101 cP. As a matter of fact the high petroleum viscosity is the main characteristic of the Videle deposits. The water viscosity under bottom conditions is 0.5—7 cP. The regime of the deposits undergoes the elastic influence of the rock-fluids system. The active water influence is felt at the Cretaceous and Sa 3 *c* levels. The associated waters are of $CaCl_2$ and $MgCl_2$ type, containing 1.2—6 g/l saltness. The Sarmatian $a + b$ and the Sarmatian *c* are exploited by the intra- and extracontoural water injection to a great extent. The Videle structure is marked by high temperatures that determine the highest geothermal gradient in the Moesian Platform, 5°/100 m in the Cretaceous and Sarmatian and 6°C/100 m in the Meotian, respectively.

Beside the oil high viscosity, the exploitation of the deposits is rendered difficult by the mobility of the Sarmatian sands; filters are used in order to overcome this difficulty. The water injection is applied to several units on the structure and the steam cyclic injection and the underground combustion are experimented.

Considering the uplifting tendency found at the Lower Cretaceous level, which is suggested by the latter's reduced depth and thickness (condensed sedimentation?), the Videle zone might correspond to an old petroleum structure whose hydrocarbons partly migrated to the Neogene.

The Bălăria productive zone (87, Fig. 95) lies east of Videle. The hydrocarbon accumulations on this structure were identified at the Lo Cretaceous, Sarmatian and Meotian levels.

The stratigraphic succession at Bălăria is similar to that at Videle-Blejeşti where the wells drilled reached the Permo-Triassic. These formations, especially the Cretaceous and the Neogene, are monoclinally disposed, with dips of 3—7° northwards. The complete picture of this structural zone includes several longitudinal and transversal faults that delimit a series of tectonic blocks, which determine the hydrocarbon distribution. The Coşoaia deposit lies in the southern extension of this zone.

The Lower Cretaceous is productive only locally, in the vicinity of the southern fault. The Sarmatian 3, the main term of interest in the region, consists of four members called, from top to bottom *a*, *b*, *c* and basal. The distribution of these members is controlled by the pre-Sarmatian relief configuration. Thus, the basal term *c* that forms a separate hydrodynamic entity, is only found in the zones with negative paleorelief shapes generally corresponding to a paleovalley. The members *a* and *b* are spread almost throughout indicating that the sedimentation extended at the respective time. The other Sarmatian complexes, Sa 2 and Sa 1 are found all over the zone but they are marked by important lithofacial variations.

The units corresponding to the Lower Cretaceous and Sarmatian contain petroleum. Sa 1 lower seems to contain gas cap, too. The Meotian contains free gas. The hydrodynamic units determined in the zone are: the Neocomian, Sa 3 *c*+ basal, Sa 3 $a + b$, Sa 2, Sa 1 and the Meotian.

At the Sarmatian level, which is the main productive unit, were found the following physical parameters: effective porosity 31 per cent, connate water saturation 34 per cent, initial pressure 58—64 kgf/cm², saturation pressure 10 kgf/cm^2, petroleum specific gravity 0.940 kgf/dm^3, reservoir temperature 45–48°.

As this is a heavy oxidated oil deposit, successful experiments of hydrocarbon exploitation by combustion were carried out at Bălăria. They will be industrially achieved soon.

The Gorneni gas accumulation (88, Fig. 95) seems to lie in the western prolongation of the Novaci-Dumitrana productive structure. One of the two wells carried out at Gorneni (1542) contained gas in the Meotian, at the depth of 502–490 m. The production varied between 16,000–38,000 m^3/day, on nozzles of 4–10 mm. The bottom pressure (44 kgf/cm^2) proved lower than the pressure exerted by the hydrostatic column.

The Novaci oil accumulation (89, Fig. 95) was identified by two productive wells (1446, 1466) which yielded from the basal Sarmatian, at the depth of 526–554 m, 2–5 t/day oil with impurities that reach 50 per cent The Novaci accumulation is not likely to extend.

The Dumitrana deposit (90, Fig. 95), located in the Sarmatian 3, was put into operation in 1970. The basal arenytic horizon of the Sarmatian is marked by a thickness of 6–30 m, according to the configuration of the relief it covers. The average thickness, effectively saturated with oil is 5.6 m. The other parameters and physical factors are : effective porosity 28 per cent, absolute permeability 25–225 mD, connate water saturation 38 per cent, initial pressure 55 kgf/cm^2 (the depth of the productive stratum is 500–620 m), the bottom temperature 28°C, the petroleum specific gravity 0.920 kgf/dm^3, the average production per well 34.5 m^3/day fluid with 16 per cent oil. The deposit is exploited by primary methods, but the *in situ* combustion is proposed. The traps are of mixed, structural-stratigraphic-lithological type.

The Jilava deposit (91, Fig. 95) was identified in the limy sandstones of the basal Sarmatian, at the depth of 595–610 m. The structure represents a monocline against which a slight promontory is noticed, which gradually disappears northwards, before reaching the Dumitrana fault. At least another two faults were identified in the zone ; one is longitudinal, probably impervious, dividing the deposit into two blocks and the other is transversal, also probably impervious, in the eastern extremity.

Each well drilled so far, especially in the northern block, yielded 0.5–13 m^3/day oil.

The hydrocarbon accumulations identified south of the Ciolăneşti-Blejeşti-Clejani-Videle-Bălăria step are much less important and are controlled to a great extent by the stratigraphic and lithological factors. Tectonic screens are also present. This group consists of 11 productive structures.

The Hîrleşti structure (92, Fig. 95) proved productive in 1958 when it was identified by seismic prospections. The units of interest are divided into three complexes, numbered, from top to bottom A_1, A_2 and A_3 (Fig. 109). The reservoir consists of calcarenites, limy sandstones, gritty limestones, pseudoölitic limestones, marly limestones, marly sandstone and gritty marl intercalations, all of them being more or less affected by fissures. These complexes are separated by marly horizons or marly limestones which are 20—60 m in thickness. The most important Albian member is the complex A_1, of 25 m in thickness. It changes into marls westwards and tapers (disappears) eastwards. Small accumulations were also identified in the packet A_2, while the term A_3 showed oil and gas traces only in three wells. The reservoir average porosity is about 14 per cent. The fine pores retain an important amount of (connate) water that reaches 50 per cent of their volume. The initial pressure, 108 kgf/cm^2, is hardly

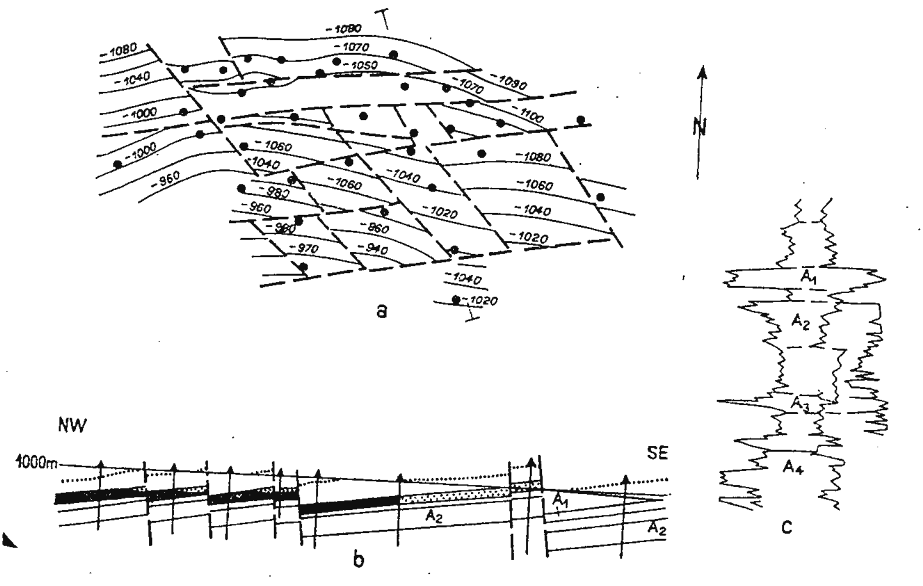

Fig. 109. — Hîrlești producing zone.
a, structural map at an Albian guide mark; b, geological cross section; c, Albian type profile (according to I.C.P.P.G.).

lower than the hydrostatic pressure. The initial production of the well was 4—6 t/day oil with 60 per cent impurities and 60 Nm^3/m^3 gas ratio. During exploitation the production per well decreased to 1—2 t/day oil, the impurities reached 80 per cent and the gas ratio increased to 35,000—40,000 Nm^3/m^3. The growth of the water percentage is due to a system of fissures and to the differential pressure. The oil is of A_3 type with specific gravity of 0.900 kgf/dm^3 and viscosity under deposit conditions of 14 cP. Less than 5 per cent sulphur is present. The associated gas contains 98—99.5 per cent methane and 0.49—3.8 g/m^3 condens. The deposit waters are of $CaCl_2$ type with mineralization 25—45 g/l and 0.5—2.6 per cent iodine.

The Hîrlești E productive structure (94, Fig. 95) corresponds to a faulted monocline; the major tectonic accident screens the accumulations southwards. Commercial oil productions were obtained on this structure from the Albian (stratum A_1) and from the basal Sarmatian.

The Albian contained petroleum in the wells nos. 151 and 161 at the depth of 1,200—1,214 m. The output varies between 5 and 38 t/day oil with impurities that quickly reached 90 per cent.

The basal Sarmatian, only locally sedimented as "shoestring sand traps" filling the tahlweg of a paleovalley, produced 4—5 t/day oil in well no. 158 at the depth of 979—954 m. Other wells carried out on the structure showed that the accumulations, both at the Albian and the Sarmatian levels are small in size.

Lately the stratum A_1 of the Albian has yielded salt water with oil also at well no. 1655, which is situated north-west of the structure presented above; this is the *Hîrleşti NE sector* (93). The drilling operations continue.

The Brătăşani accumulation (95, Fig. 95) is known under the name of "Hîrleşti S", which indicates its geographical position. A first well (no. 138) drilled here produced 15 m^3/day salt water with 20 per cent oil from the Albian stratum A_1. Another four wells drilled later proved sterile as regards the hydrocarbons, the respective trap being of lithological nature. As in the case of Hîrleşti, the screens correspond to some impervious barriers.

The Talpa structure (96, Fig. 95) is located about 60 km south-east of Bucureşti and was put into operation in 1972. The stratigraphic succession, which was crossed to the Lower Cretaceous level, does not differ from that of the big neighbouring structures Videle and Blejeşti. As far as the Cretaceous sequence is concerned one should point to the absence of the Albian, which is productive at Hîrleşti and on other structures.

At the Lower Cretaceous level, the Talpa structure, probably, corresponds to a reefal body. The Cretaceous and Neogene deposits that sink northwards show dips of 3—5°. Beside this general monoclinal disposition and the existence of some morphostructures generated by the buried paleoreliefs, the geometry of the strata is disturbed by numerous faults that divide the region into several tectonic blocks.

At Talpa were obtained commercial hydrocarbons from the Lower Cretaceous, the basal Sarmatian, the Sarmatian 3 and the Meotian. The first three units contain oil, while the last one contains free gas.

34 of the 40 wells drilled on the structure crossed also the Lower Cretaceous which consists of microcrystalline, oölitic, organogenous and detrital limestones.

The basal Sarmatian sedimented and preserved only in a paleovalley zone where it reaches maximum 100 m in thickness. It was divided into two packets, from top to bottom, *e* and *f* respectively. The oil accumulated only in the packet *e*. The basal Sarmatian consists of reworked Cretaceous material, namely detrital, organogenous, oölitic, gritty limestones and limy sandstones.

The Sarmatian 3 is 30—40 m in thickness and consists of the three porous-pervious packets *a*, *b* and *c* (from top to bottom); these packets consist of limy sandstones, gritty limestones, detrital limestones partially fissured. All the three packets contain petroleum.

The Meotian develops in a pelite facies with lens sand shaped and sandstone intercalations which are partly gas saturated.

The main physical parameters of the deposits are :

	Lower Cretaceous	Basal Sarmatian	Sarmatian 3
porosity (per cent)	24	25	26
permeability (mD)	1–4000	0.4–140	0.4–8000
connate water saturation (per cent)	40	39	30
petroleum specific gravity (kgf/cm^2)	0.94	0.94	0.94

The associated water is of chlorocalcic and chloromagnesian type with mineralization of 10 g/l.

The depth of the productive reservoirs varies between 500 and 1,150 m.

The pressure gradient is normal and the geothermal gradient reaches 4°C.

The E Talpa gas accumulation (97, Fig. 95) benefits by only one well (no. 1675) situated north of the same accident screening the main deposit at Talpa.The gaseous hydrocarbons are located in the upper part of the Meotian at the depth of 541–544 m. The production obtained on nozzles of 5–8 mm was 8,700–20,000 m^3/day, the pressure was 35/45 kgf/cm^2.

The Cosmeşti gas accumulation (98, Fig. 95) is located in the Meotian base (643–610 m) where only one well (1680) yielded 5,800–62,000 m^3/day depending on the nozzle and stratum. Pressures of 30–52/17–55 kgf/cm^2 were recorded.

The trapping conditions of this accumulation are not yet clear although the position of the accumulation in the regional structural context, the development of the Meotian and its content suggest a lithological screening.

The Coşoaia deposit (99, Fig. 95) lies south of the major screen delimiting the important deposits at Videle-Bălăria. The reservoir is represented by thin marly sand and Sarmatian siltstones developing above the arenyte basal horizon which is occasionally calcareous. The productive zone, which is proved by 6–7 wells, belongs to a tectonic block which is adjacent to the S Videle-Bălăria fault system and bordered by im pervious tectonic accidents. The trap seems to be influenced by the structural and lithofacial factors. The petroleum strata were found at the depth of 579–607 m. They produced 0.5–5 m^3/day oil.

The Copăceni gas accumulation (100, Fig. 95) lies in the Meotian base. The only productive well in the respective sector (well no. 585) produced 25,000 m^3/day at the depth of 361–343 m, with pressures of 25/27 kgf/cm^2 on a nozzle of 9 mm. The accumulation is of very little value.

The Berceni structure (101, Fig. 95) resembles a promontory divided into two blocks by a fault, trending NW–SE.

The wells crossed the Sarmatian-Pliocene deposits, 450—500 m in thickness, overlying transgressively and unconformably the Lower Cretaceous limestones which are only partly crossed.

So far industrial oil productions have been obtained from the Sarmatian in five wells and industrial gas productions from the Meotian in one well. Oil traces were also identified at the Lower Cretaceous level. The depth of the productive strata does not exceed 470 m in the Sarmatian and 400 m in the Meotian. The three oil wells in the western block soon flooded; well no. 1,564 in the eastern block behaved better.

The Postăvari gas deposit (102) is located in a sand stratum of Meotian age, whose depth varies between 394 and 414 m. The structure is a hemianticline, probably, the result of some buried relief shapes, crossed by a fault trending SW—NE. Three of the wells drilled so far proved productive, yielding between 7,600 and 270,000 m^3 /day gas with pressures of 2—37/2—38 kgf/cm^2. The deposit is practically explored.

Beside the deposits presented above, hydrocarbon traces were also identified in the central and eastern zones on numerous other structures or tectonic blocks, such as the *Ghimpați sector*, where the amounts of oil obtained in three wells do not allow an economic exploitation and the *Nenciulești* and *Buzescu blocks*, which proved to be gas-bearing, yielding 12,000—30,000 m^3/day/well.

d) **The Western Zone.** It develops between the Teleorman River to the east and the Jiu River to the west. The eastern boundary corresponds to the last deposits located in the Dogger and to the line from which the Albian, changing the facies, accumulates eastwards commercial amounts of hydrocarbons. The western boundary is determined by the last deposits of the platform.

The western zone is characterized by oil deposits located in old Devonian, Triassic, Lower and Middle Jurassic formations that have not yet yielded east of the Teleorman River. Subsidiarily, a few accumulations located in the Malm, Neocomian, Sarmatian and Meotian are worth mentioning. Some traces were also pointed out in the Senonian.

The accumulations in the western zone are situated round the N Craiova-Balş-Optaşi uplift, being controlled both by quasi-domal structures (morphostructures) and disjunctive tectonic accidents.

24 productive structures and isolated accumulations (103—126, Fig. 15) are known in the western zone; they will be concisely presented below.

The Bibeşti-Bulbuceni structure (103) is situated on the northern side of the Moesian Platform near the contact with the Getic Depression.

The over 50 wells drilled so far, some of which exceeding the depth of 5,000 m, crossed a succession of deposits starting with the Pliocene and ending with the Paleozoic. The oldest formations, represented by dolomites and dolomite sandstones, belong to the Devonian. The Permo-Triassic (400—600 m) follows unconformably and transgressively; it consists of the three lithostratigraphic units known in the platform:

the lower red formation, the carbonatic formation and the upper red formation. The Triassic is overlain by the Upper Jurassic and occasionally, probably the Dogger. The Neogene which follows,starts with the Tortonian locally and, possibly, with the Helvetian. The Tortonian, which is 100—400 m in thickness, seems to be represented by all the four terms, beginning with the *Globigerina* tuff horizon and ending with the *Spirialis* marl horizon. The Sarmatian of 2,700 m in thickness indicates a hypersubsidence regime during its deposition. It consists of the following horizons, from bottom to top : Sa X*i*—Sa X*a* gritty-limy, Sa Xtr-Sa IX*a* marno-gritty, Sa VIII sandy and the horizon VII—V marly. The Meotian (500—600 m) consists of a basal sandy-marly complex and of an upper, predominantly pelite, one. The rest of the Pliocene shows the lithofacial characteristics that are specific to the Carpathian Foredeep.

The structure of the region is not clear enough at the Paleozoic and Triassic levels. The existence of a domal shape (Fig. 110) can be admitted as a work hypothesis. Two positive structures, Bibeşti and Bulbuceni, appear at the Miocene level.The dip of the Paleozoic and Mesozoic strata varies between 15° and 22°, while the dip of the Neogene strata varies between 2° and 6°.

Oil deposits have been identified only at Bibeşti in the Devonian, Permo-Triassic (T_1A_1) and Sarmatian (Sa X*i*, Sa X*h* and Sa X*g*). Gas accumulations were found both at Bibeşti and Bulbuceni in the Sarmatian and Meotian. The sequence of deposits containing hydrocarbon accumulations is about 3,400 m in thickness at the depth of about 4,900—1,400m. Other hydrodynamic units that cannot be entirely specified might also exist within this sequence.

The Bibeşti Paleozoic and Triassic seem to make up a single hydrodynamic unit. The water-oil contact is situated at the isobath 4,700—4,720 m.

The Paleozoic reservoir is represented by porous and fissured dolomites, while the Permo-Triassic one is represented by the porous sandstones of the red lower series. The initial oil production was of 20—60 t/day. The porosity measured on the cores (samples) indicates 9—11 per cent. The connate water saturation is 24 per cent. Pressures of 500 kgf/cm² and temperatures of 142°C were recorded in the initial phase. The oil is paraffinic (type *C*) with the density of 0.855 kgf/dm³. Both oil and the associated gas contain 7.6—12.4 per cent H_2S (in gas).

Most of the Triassic section did not yield, although the cores extracted show oil permeations. The fact is due to the low porosity (3.5—8.5 per cent) and permeability (0—15 mD).

Oil accumulations with primary gas cap were also identified in the Sarmatian horizons Sa X*i*, Sa X*h* and Sa X*g*. In front of these units the water-oil limit is between 3,870 and 3,800 m b.s.l. and the gas-oil limit is at the depth of 3,745 m. The average porosity of Sa X is 10 per cent and the connate water saturation is 43 per cent. The initial pressure was 400 kgf/cm² and the temperature 125°C. The petroleum specific gravity decreases a little, reaching 0.820 kgf/dm³.

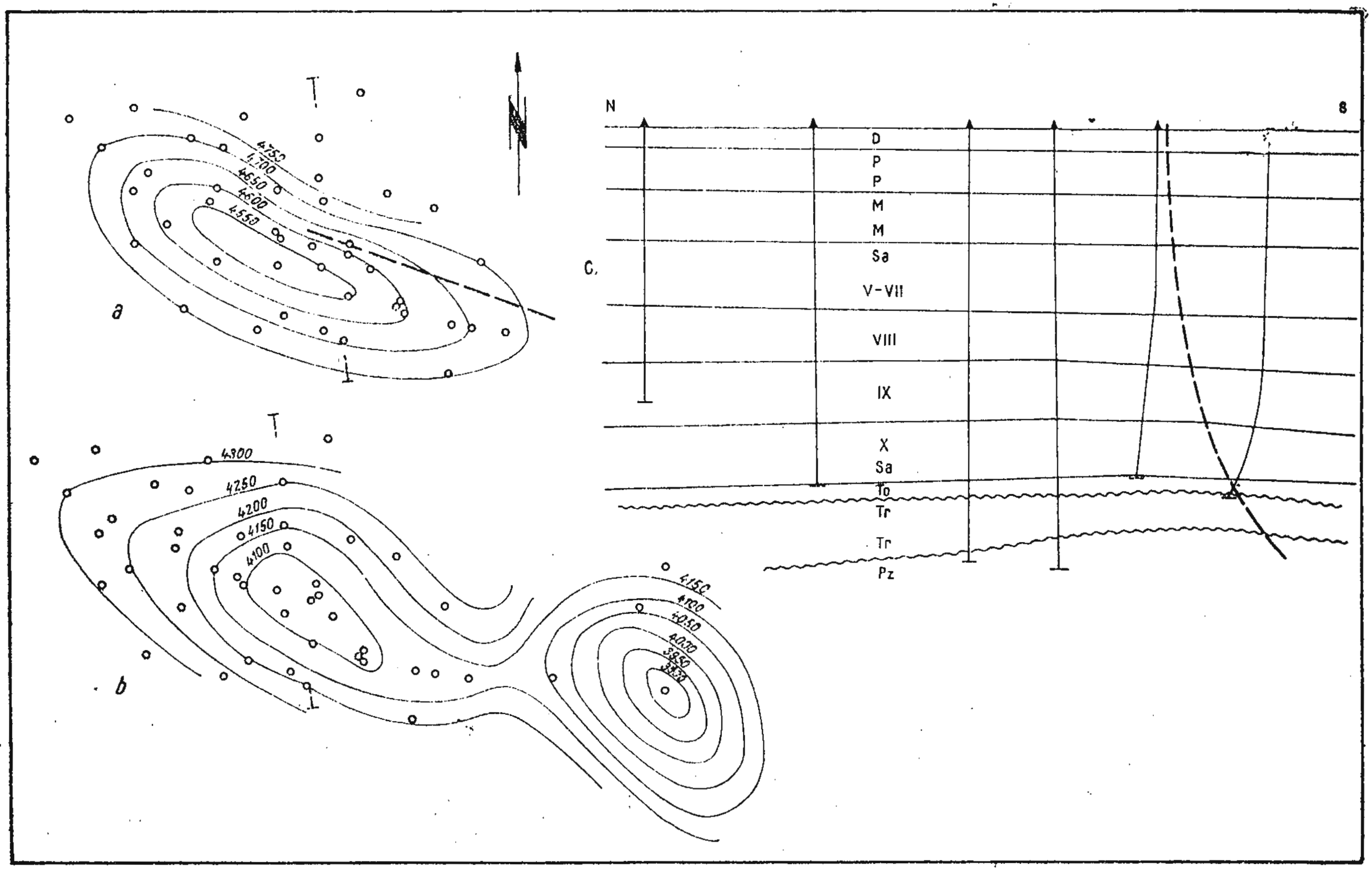

Fig. 110. — Bibeşti-Bulbuceni structure.
a, morphostructural map of the Paleozoic relief ; b., structural map of the pre-Miocene relief ; c, geological cross section (according to F l. L a n g a).

With the exception of the three lower horizons (Sa X*g*, X*h*, X*i*), which are saturated with oil, the other eighteen Sarmatian and Meotian complexes contain free gas. Among them the complexes Sa X*c*, *d*, *e*, *f* represent free gas deposits with retrograde behaviour. The terms Sa IX (*b* — *h* + int.) are characterized by porosities of 10—17 per cent and water saturation 35—40 per cent. Sa VIII, which is the best reservoir, has average porosities of 25 per cent and connate water saturation 40 per cent. Sa VII—V and the Meotian have the same saturation value and their porosity decreases to 18 per cent. The gas productions varied between 20,000 and 150,000 m^3/day/well.

As regards the petroleum and gas vertical distribution, the results of the flow tests show that the oil and heavy fraction content decreases towards the upper part of the hydrocarbon saturated profile, so that only poor gas is to be found in the terminal Sarmatian and Meotian.

The Vîrteju gas accumulations (104, Fig. 95) were identified in 1970 by well no. 50, projected on the basis of seismic prospections. Although another five wells were drilled later on, the structural conditions of this gas-bearing field with only two productive wells (nos. 50 and 58) have not been enough clarified. Petroleum has been recently pointed out in the Triassic.

The gas-bearing series in well no. 50 is at the depth of 1,220—2,536 m, where the six complexes proved productive alternataing with the flooded sandy complexes. The productions obtained, depending on the depth and the diameter of the nozzle, varied between 45,000—170,000 m^3/day, while the pressures varied between 100—180/96—197 kgf/cm^2. Gas was identified in well no. 58 only in three intervals situated at the depth of 2,309—1,656 m. The productions obtained were 85,000—150,000 m^3/day and the pressures 100—140/105—160 kgf/cm^2.

The Brădeşti structure (105, Fig. 95) contains oil and gas deposits in the Triassic, Jurassic and Sarmatian.

The region is covered by Levantine deposits and by Quaternary fluvial accumulations. The prospection works started with the gravimetry and magnetometry and continued with seismic surveys between 1969—1970. Against the general northward sinking background of the platform, the seismic prospections indicated a promontory with the same sinking sense, trending N—S and crossed by a fault in the southern extremity.

The wells drilled at Brădeşti crossed a succession of deposits reaching the Upper Devonian inclusively, which is probably overlain by the Upper Visean. The Silesian (without the Stephanian)follows after another discontinuity of sedimentation and, then, the Triassic follows unconformably. The Triassic deposits, in their turn, are directly overlain by the Sarmatian as a result of the Miocene erosion; the latter was caused by a paleovalley ("Paleojiul") originating in the Prebalkans and having the outlet in the Precarpathian Miocene basin (Fig. 111). The Sarmatian is followed by the Pliocene.

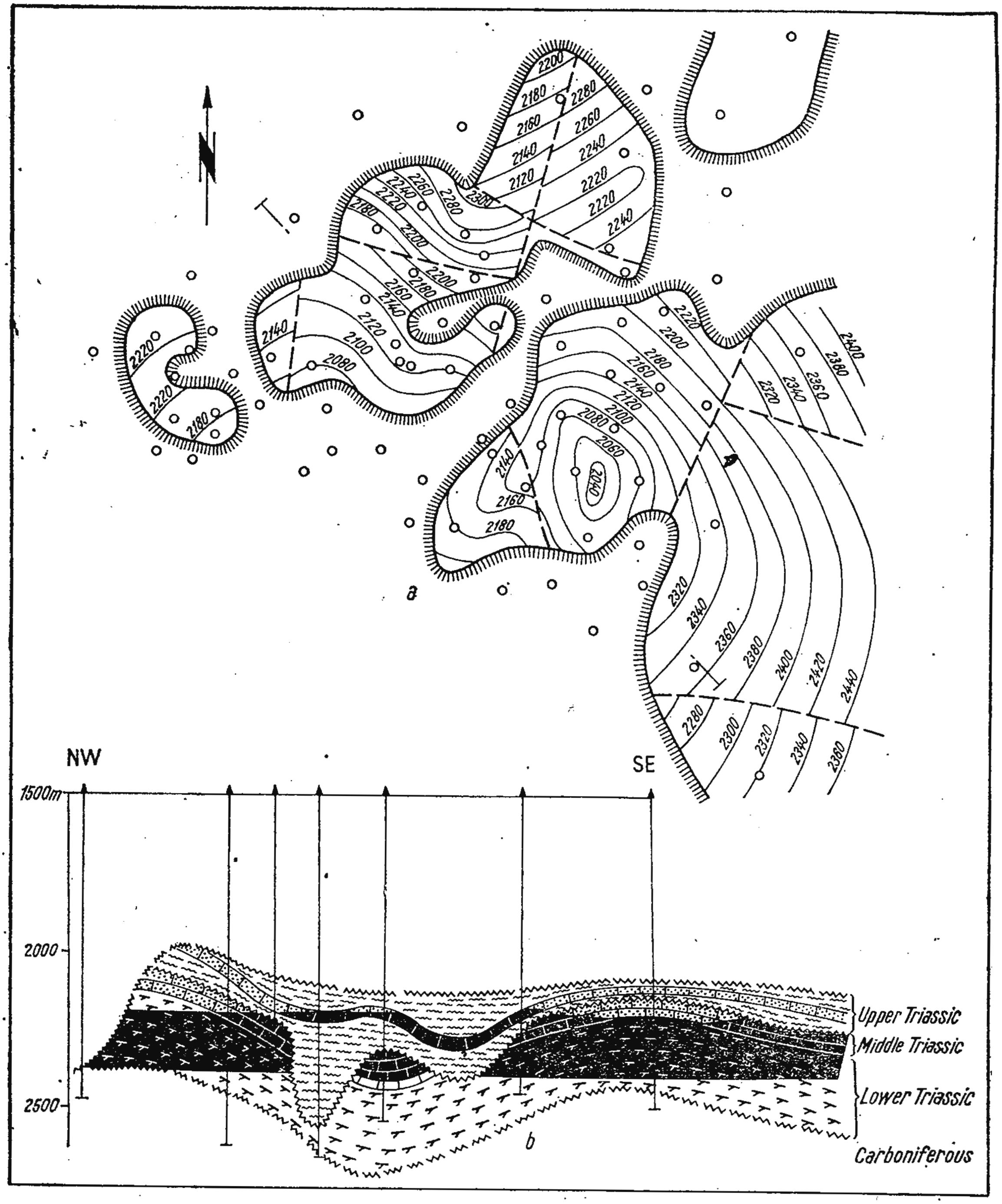

Fig. 111. — Brădești structure.
a, structural map at the level T2-a (according to R. Ioachimciuc); b, geological cross section.

After the discovery of the deposit in 1970, it was found that the deep structure of the respective sector is much more complicated than indicated the seismic image and that the exploration activity raises difficult problems. Interpreting the whole available material one can conclude that the Triassic moulds the Paleozoic structure and is therefore implied, probably, in a sealing vaulting which is crossed by numerous apparently impervious longitudinal and transversal faults. After the deposition of the Middle Triassic the region uplifted, being subject to denudation. On this occasion the running waters removed, partially or totally, the Triassic deposits from an important area of the region, reaching the Paleozoic here and there (Fig. 111). Later on, probably, in the Upper Triassic, the negative relief was buried by predominantly pelite deposits constituting lithological barriers within the distribution area of the lower red formation and the Triassic carbonatic formation that show reservoir properties. In the Neogene a new generation of valleys (it is a question of an inheritance of the river bed direction) sank both in the old river bed zone and laterally, removing partially the Triassic deposits.The Sarmatian transgression that followed filled also these valleys with pelite deposits forming other impervious barriers. After the northward sinking of the platform margin in the Sarmatian or, later, the old hydrodynamic equilibrium was destroyed determining the redistribution of the hydrocarbons previously accumulated. Thus the oil and gas, migrating laterally from the north, impregnated the Lower Triassic sandstones, the Middle Triassic dolomites, the horizon with breccias and Upper Triassic limestones, all of them being situated among the channels sealed with impervious sediments. According to another hypothesis, the Triassic hydrocarbons might have regenerated after the sinking of the region beginning with the Upper Miocene. Anyway the deposit formed during or after the Sarmatian since the Volhynian marno-clays make up the protection cover of the Brădeşti accumulations.

As regards the Triassic, the hydrocarbons are located in T_1 (T_{1a}, T_{1b}, T_{1c}), T_2(T_{2a}, T_{2b2}, T_{2b3}) and T_3(T_{3a}). The Triassic traps are of structural, stratigraphic and paleogeomorphic type. The three Triassic terms are hydrocarbon saturated (oil with primary gas cap) at the depth of 2,200—2,500 m. Each term is saturated with oil and gas within a thickness of 8.7 and 43 m. The porosity, to which also adds the fissural space, varies from 2.7 to 28 per cent and the permeability varies between 0.1 and 2,700 mD.The connate water saturation may be 16—51 per cent, according to the distance from the limits of the oil deposits. The volume reduction factor is higher at T_1 (1.240) and lower at T_3 (1.188). The lower red series contains heavier oil (0.860 kgf/dm^3) as compared to the Mesotriassic dolomites (0.820). The initial pressure of the deposit was 210—245 kgf/cm^2. The oil viscosity is only 0.1—0.21 cP. The associated waters are of chlorocalcic type with mineralization of 50—70 g/l. The geothermal step has a normal value (33.6 m/°C). The deposit is exploited by primary methods under the active influence of the marginal water. Experiments for the application of the conventional methods are carried on (water injection).

The Sfîrcea gas deposit (106, Fig. 95) was identified by three wells which showed that the structure is represented by a promontory sinking southwards and crossed by a screen fault northwards. The first well drilled here (well no. 550) produced gas from 12 intervals belonging to the Sarmatian and totalizing a productive section over 1,100 m thick, namely between 1,202 and 2,362 m. The reservoir rocks lying in the base of the gas-bearing section, which is more compact and less pervious, provided a production of 9,000—11,000 m^3/day. The production increased to 10,000—125,000 m^3/day towards the median part of the productive section, while 50,000—60,000 m^3/day for each tested interval were recorded in the terminal part of the gas saturated zone. The pressures behaved accordingly, being 10/30—145/60 kgf/cm^2. Another well drilled in the zone (well no. 83) contained gas from two intervals situated at the depth of 2,064—2,378 m. The daily output was 21,600—158,000 m, pressures 80/170/90—175 kgf/cm^2.

The Pitulaţi gas accumulation (107, Fig. 95) is known from only one well (no. 81). Being tested at the depth of 1,999—1,986 m, in the Sarmatian, it produced 25,000—45,000 m^3/day with pressures of 70—170/90—175 kgf/cm^2. One has to do with the same Sarmatian productive series found at Sfîrcea and Brădeşti.

The Melineşti structure (108, Fig. 95) represents a structural detail in the western pericline zone of the Iancu Jianu uplift. A slight vaulting crossed by faults was identified at the Triassic level; the first productive well (oil) was drilled here in 1967.

The over 15 wells drilled later on showed that, in the Melineşti region, the Paleozoic is unconformably overlain by the Permo-Triassic; the latter is represented by all the three lithofacial terms, the lower red formation, the carbonatic formation and the upper red formation, respectively. The Upper Triassic, in its turn, is also unconformably overlain by the Dogger and the whole sequence of deposits known on the platform to the Quaternary inclusively.

The lower part of the Mesotriassic, which is predominantly dolomite and corresponds to the Anisian, constitutes the productive formation. Two packets with reservoir rocks, a lower one ($T2a_1$) and an upper one ($T2\ a_2$ and $T2\ a_3$) were separated in the Anisian dolomite complex; they seem to constitute two hydrodynamic units separated by a compact limy horizon. The oil accumulations were found in the six productive wells at the depth of 2,750—2,900 m.

The physical factors and parameters of the deposits are: average effective thickness 16 m, effective porosity 10—23 per cent, initial oil saturation 70—75 per cent, petroleum specific gravity 0.875 kgf/dm^3, initial pressure 280 kgf/cm^2, saturation pressure 70 kgf/cm^2, geothermal gradient 3.5°C/100 m.

The deposit waters are of chlorocalcic type, with mineralizations of 80—136 g/l.

The Iancu Jianu structure (109, Fig. 95) was identified and outlined by seismic prospections which had been preceded by gravimetric and magnetometric surveys.

The Iancu Jianu structure resembles a dome (Fig. 112) strongly affected by faults, trending NW—SE or SW—NE, dividing it into 79 blocks. The fault throw varies between 10 and 500 m, often influencing the hydrocarbon distribution. The dip of the strata does not, generally, exceed 5°.

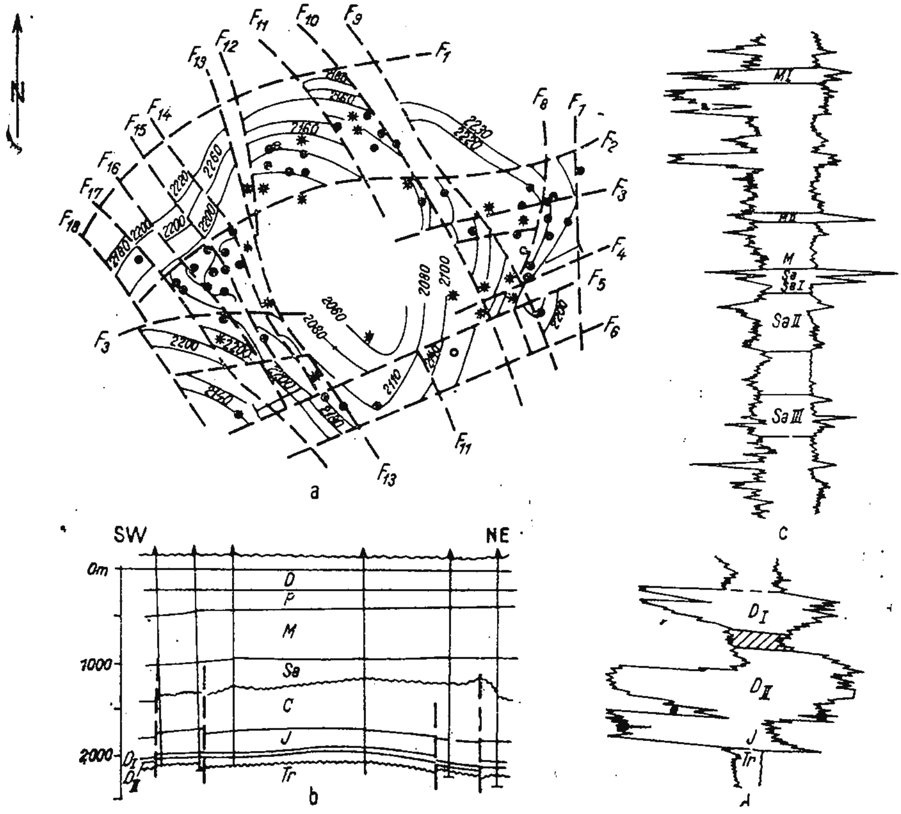

Fig. 112. — Iancu Jianu structure.
a, structural map at the Dogger level; b, geological cross section; c, Sarmatian type profile; d, Dogger type profile (according to I.C.P.P.G. Cîmpina).

Several wells operated at Iancu Jianu since 1957 crossed a succession of strata of Ordovician, Silurian, Triassic (especially on the flanks), Jurassic, Cretaceous, Sarmatian and Pliocene age.

The deposits at Iancu Jianu, which were discovered in 1957, were put into operation three years later. The hydrocarbons are stored in the Triassic, Dogger, Sarmatian and Meotian. The Triassic had industrial oil productions in one well, gas in four wells and traces of oil with salt water in another well. The main deposits are located in the sandstones from the Dogger I and II. The reservoirs are hydrodynamically separated owing to the existence of a clay horizon of 8—10 m in thickness. The Dogger gritty complex is protected by the clayey-marly horizon reaching 180—300 m in thickness.

The Dogger reservoirs consist of fine to coarse siliceous sandstones. Microconglomerates were also pointed out in the base of the packet D II. The effective thickness of the reservoirs is 10—40 m in the case of D II and 8—18 m in the case of D I. The average porosity is lower in the case of the lower packet (17.4 per cent) and higher in the case of the upper packet (20.5). The porous space is partially filled with calcite, but the porosity and, especially, the permeability of the sandstones improved as a result of the rock fissuration, which is demonstrated by the fluid loss in the stratum during the drilling of the wells. Under such conditions the permeability varies within very wide limits, the average permeability being about 240 mD at D II and 140 mD at D I. The connate water saturation has average values of 29 per cent and 25 per cent, respectively. The oil is of *C* type (paraffinic) with specific gravity 0.840 kgf/dm^3 at 1 kgf/cm^2 and 20°C and dynamic viscosity 0.6 cP. The solution gas ratio at the saturation pressure is 140 Nm^3/m^3. The condens density is 0.720—0.790 kg/dm^3.

The Dogger on the Iancu Jianu structure contains oil, gas and condens. The productive dome is represented mainly by an immense gas cap with condens bounded by oil bands. The importance of the latter varies from one block to another.

The Jurassic productive strata are found at the depth of 2,200—2,400 m. They have different water/hydrocarbon limits. As a matter of fact, the respective limit varies from one tectonic block to another. The small dips of the strata often determine an overlapping of the gas, oil and water saturated sections.

The initial oil and condens production was 6—240 t/day well, this variation being caused mainly by the position of the wells within the structure, by the distance from the water or gas saturated zones.

The average pressure of the deposits is about 225 kgf/cm^2 representing a gradient of 9.5 kgf/cm^2/100 m. The geothermal step is 22.2 m °C. The regime of the deposits located in the two reservoirs is different. The basal packet (D II) owes its energy to the marginal water and to the primary gas cap drive as well as to the expansion of the solution gas.

The domal shape of the Iancu Jianu structure is much less obvious at the Neogene level. Free gas accumulations were identified here in three Sarmatian horizons numbered, from bottom to top, Sa III, Sa II and SaI and in two Meotian horizons called M II and M I. These reservoirs consist of predominantly limy sandstones and sands, sandstones and marly sands. Each stratum varies between 1.5—7 m in thickness. The average porosity is 22 per cent in the Sarmatian and 24 per cent in the Meotian. The average water saturation is 35 per cent both in the Sarmatian and Meotian. The free gas contains 99.78 per cent methane. The waters are of chlorocalcic type in the Sarmatian and in the Dogger. Their mineralization varies between 60 and 150 g/l. The Meotian contains waters of CO_3HNa type with mineralizations of 2.84—104 g/l.

The Iancu Jianu traps are of structural type within the Dogger as are those in the Sarmatian and Meotian. On the whole, the Neogene productive horizons might be regarded as mixed traps with an important contribution of the lithologic factor. Finally, the Triassic accumulations are typically paleogeomorphic. The deposits on this structure reached the final exploitation stage.

The Făurești structure (110, Fig. 95) represents the northern prolongation of the Iancu Jianu uplift being 500—700 m lower than the latter.

The approximately 50 wells drilled at Făurești since 1970 indicated that the Silurian, seldom, the Eodevonian deposits are overlain unconformably and transgressively by the Jurassic (seldom, also the Triassic), which is, in its turn, overlain by the Malm, Cretaceous and, finally, by the Neogene.

The productive formation is represented by the Upper Liassic-Dogger. The latter is 200—400 m in thickness and consists of two horizons : a lower gritty-sandy one (80—120 m) which is assigned to the Upper Liassic-Middle Dogger (Bajocian) and an upper clayey-marly one (80—300 m in thickness). The lower horizon, in its turn, bordered by pelite formations (Silurian-Devonian in the base, followed by the Dogger) consists, as in the case of Iancu Jianu, of two complexes : D_2, in the lower part, and D_1, in the upper part. A packet of compact, marno-limestone rocks is found between the respective complexes that constitute separate hydrodynamic units.

From a structural point of view, the Făurești zone seems to represent a slight anticline crossed by numerous faults whose throw is reduced (20—100 m), which allows local communications of the fluids among the blocks and complexes. The ensemble of blocks has been numbered by letters (*A*, *B*, *C* and *D*) and figures, north-southwards (Fig. 113).

As it has already been mentioned, the hydrocarbons consisting of oil with primary gas cap (the last one covering 53 per cent of the productive area) are located in both Jurassic sandy complexes. The complex D I yields oil in the blocks C_2, B_4, C_4 and gas in the compartments C_3, B_3, C_5, while the complex D II has oil in the blocks C_3, B_5 and gas in the compartment C_5.

The reservoir, which is made up of two complexes, may reach 30—40 m effective thicknesses. The effective porosity is 19 per cent and the absolute permeability is 120 mD, which are very good values for the depth of 2,800—3,100 m. The connate water saturation is about 27 per cent. The pressure gradient is 9.4 kgf/cm²/100 m and the geothermal gradient is 3.3°C/100 m. The oil of paraffinic type has the specific gravity of 0.843 kgf/dm³. The energy of the two deposits behaving almost identically, is determined by the gas-cap detente.

The Spineni accumulation (111, Fig. 95) is located in a tectonic compartment belonging to the Spineni hemianticline. A first well (no. 4 Spi-

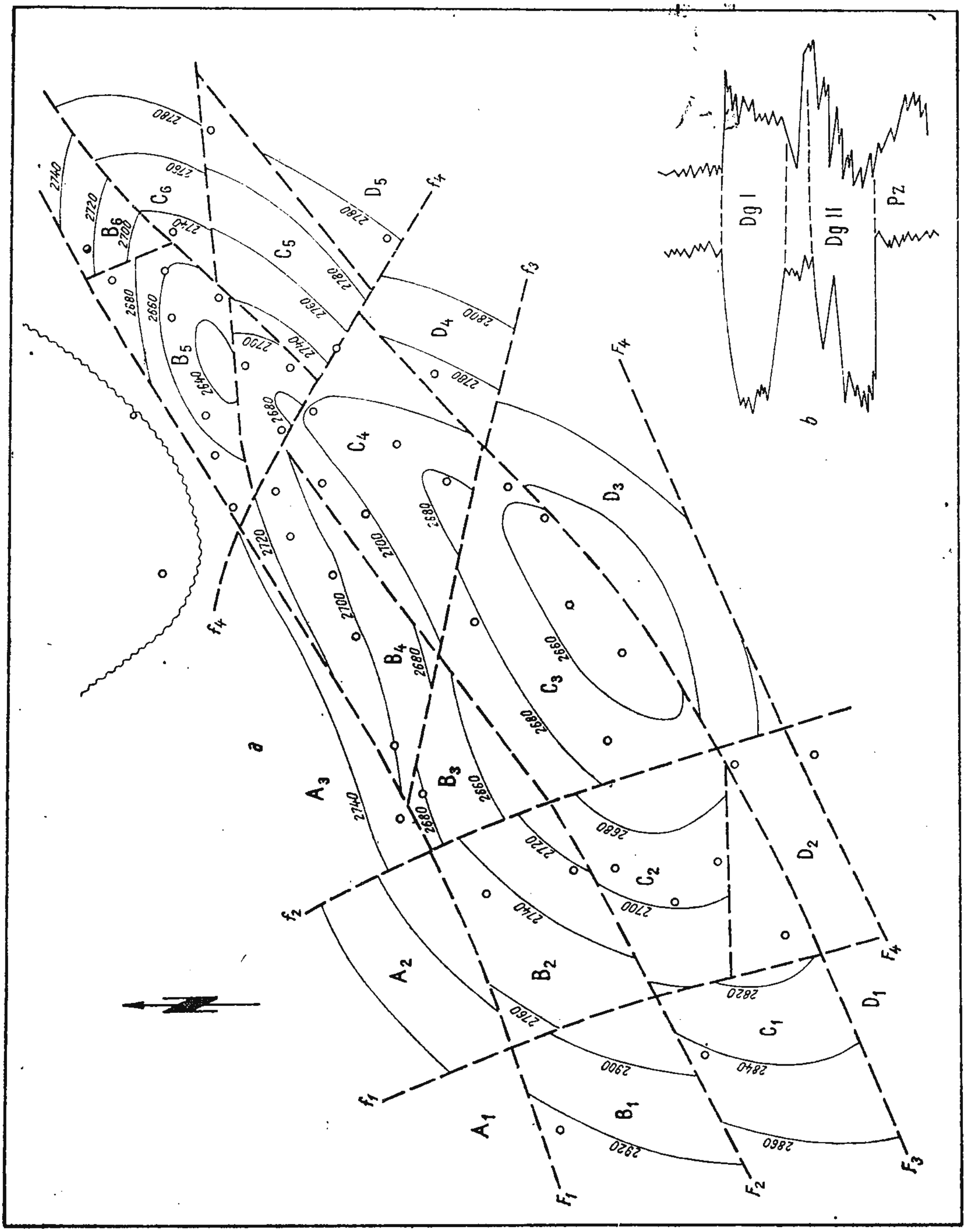

Fig. 113. — Făurești structure.
a, structural map at the guide mark D I; b, Dogger type profile.

neni) drilled in 1968 identified hydrocarbons in the upper part of the Dogger gritty complex at the depth of about 4,600 m. The well was put into operation with initial production of 26 t/day oil and 100,000 m^3/day gas, but the output decreased to 1.8/day oil with 60 per cent impurities and 1,700 m^3/day gas in a relatively short period of time. Finally, the exploitation was stopped owing to some technical difficulties.

The Deleni oil deposit (112, Fig. 95) was discovered in 1965. Over 50 wells were drilled in the area of interest, some of them reaching the platform basement. The Meotian is the term of interest here. According to the detailed studies, the Meotian in the Deleni zone was divided into four complexes : M_1, M_2, M_3, M_4. The complex M_1, in its turn, consists of three members, *a*, *b* and *c*. Among them, only the member *a*, at the contact with the Pontian, proved productive. The Neogene strata are characterized by a monoclinal seating, falling northwards. Their dip is 2—3°. The productive area is divided into three blocks, numbered I, II and III. The effective thickness of the stratum M_{1a} is 2.46—2.55 m. The average porosity was 28.55 per cent, the connate water saturation 30 per cent, the average permeability 1 mD, the initial pressure 62 kgf/cm^2 and the saturation pressure 30 kgf/cm^2, which means that the elastic pressure is 32 kgf/cm^2 at the average depth of 580 m b.s.l.

The oil specific gravity under standard conditions is 0.938 kgf/dm^3. In the initial phase the deposit energy was due to the detente of the rock-fluids system. After the saturation pressure has been reached, a dissolved gas regime appears. The deposit was further exploited by water injection.

The Deleni deposit is a typical case of lithological trap, being thus screened southwards and eastwards.

The Oporelu (113)-*Constantinești* (114, Fig. 95) deposits are located north-east of the Ciurești structure resembling a vaulting trending WSE—ENE and divided into tectonic blocks by a system of longitudinal and transversal faults (Fig. 114). One of these blocks, situated in the eastern extremity of the structure, is known under the name of Constantinești.

The productivity of the structure was proved in 1967 by well no. 20 Oporelu. The oil and gas accumulations are located in the Dogger sandstones, in the Middle Triassic dolomites and in the Lower Triassic siliceous sandstones.

Lithologically, the Dogger consists of siliceous and limy sandstones, the Middle Triassic consists of whitish or grayish-greenish dolomites with rare limestone, clay and marl intercalations, while the Lower Triassic consists of reddish or yellowish to whitish siliceous sandstones.

As compared to the total thickness of the dolomites, only their upper part is oil saturated. The productive section has 9—18 per cent porosities and 0.6—50 mD permeabilities. The dolomites having porosities and permeabilities below 9 per cent and 0.6 mD, respectively, are not hydrocarbon saturated, except the fissural space. The average connate water saturation is 30 per cent.

The Oporelu deposit is an oil and condens accumulation. The initial pressure of 322 kgf/cm², was equal to the saturation pressure. The deposit temperature is 124°C.

The initial production of the wells yielding from the Dogger varies between 18—47 t/day, with 8.12 per cent impurities, while the Middle Triassic production varies between 20—80 t/day, with 8—35 per cent

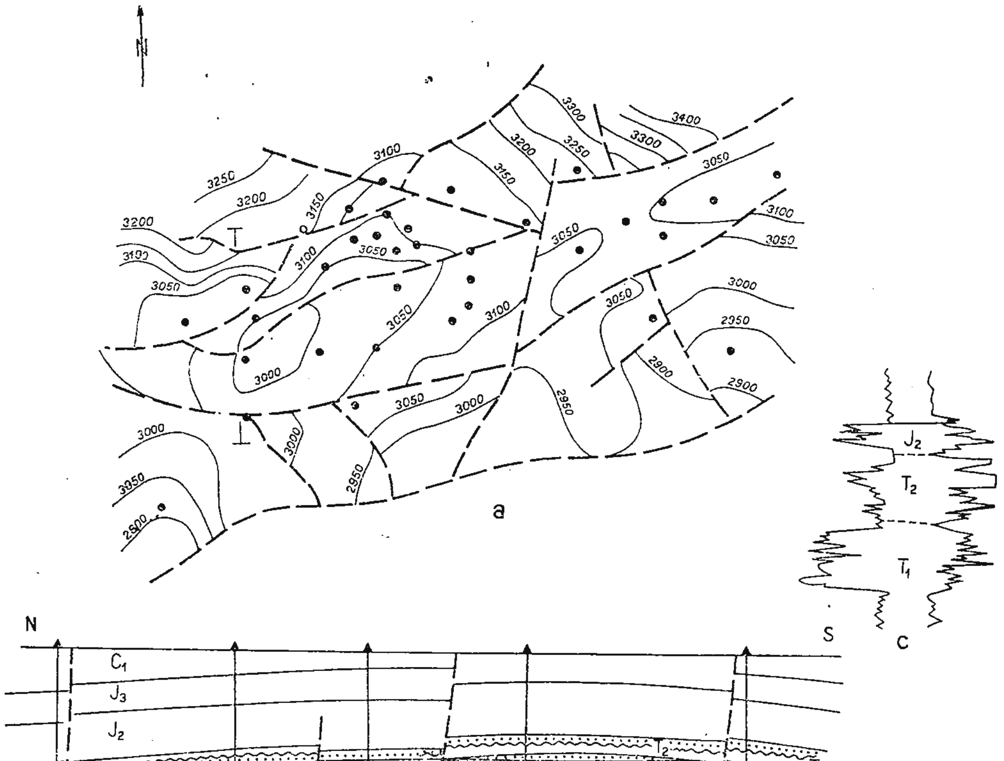

Fig. 114. — Oporelu structure.
a, structural map at the Triassic level ; b, geological cross section ; c, Middle Jurassic and Triassic type profiles (according to I.C.P.P.G. Cîmpina).

impurities. The gas-oil ratio is quite variable, namely between 200—300 m³/m³ and 1,000 m³/m³. The Lower Triassic productive wells yielded between 17—60 t/day with 1.4—54 per cent impurities.

The oil is paraffinic, of *C* type, with specific gravity of 0.820 kgf/dm³. The volume reduction factor is 1.724 and the dynamic viscosity 1.47 cP at 20°C.

The associated waters having a mineralization of 21 g/l, are of chlorocalcic type, chloride group, sodium subgroup.

The production regime of the deposit is mixed, the energy being furnished by the dissolved gas and the gas cap detente.

The Cieşti deposit (115, Fig. 95) corresponds to a hemianticline within the Stolnici-Cieşti promontory. The Cieşti hemianticline is delimited by a transversal tectonic accident on the south. A longitudinal fault running through the axial zone, divides the structure into two tectonic blocks (Fig. 115).

The formation of interest on this structure is represented by the Middle Triassic (T_2) and was identified by well no. 3700 Cieşti.

The pay horizon consists of microgranular limy dolomites, weakly fissured and cavernous of 110—120 m in thickness and of dolomite sandstones about 30 m thick, generally comprising three packets of limy sandstones and dolomitizated limestones with marly limestone or limy marl intercalations. The whole complex is protected by an impervious horizon consisting of compact clays and marly micro-gritty argillites about 10 m in thickness lying in the Dogger base.

The oil accumulated both in the matrix and in the fissural system. The tabular oil-water contact is at the depth of 3,354 m b.s.l. Admitting the existence of a gas cap, the oil/gas contact was estimated at 3,325 m b.s.l.

The deposit is of massive type and its average thickness in the zone saturated with oil is 34 m, of which only about 37 per cent represents the effective thickness.

The mechanism of the oil running consists in the elastic detente of the rock-fluids system with the expansion of the bottom water and the gas cap drive.

All the wells drilled up to now yield in natural eruption with productions of 50—112 t/day well, 30 per cent average impurities and 200—300 Nm^3/m^3 gas oil ratio.

The static pressure is 335 kgf/cm^2 (at the depth of 3,585 m) and the dynamic pressure 330 kgf/cm^2.

The physical parameters of the reservoirs are: porosity between 9.08—20.6 per cent, absolute permeability between 1.9—36.9 mD and the connate water saturation between 19.9 and 35.8 per cent.

The saturation pressure is 326 kgf/cm^2 and the reservoir temperature is 130—133°C.

The oil having the average specific gravity of 0.854 kgf/dm^3 is of *B* type with the freezing point at 16°C.

The associated waters are of chlorocalcic type, group chlorides, subgroup sodium, class S_1, with mineralization 700 kg/wg.

The Sîmnic (116)-*Ghercești* (117)-*Circea* (118)-*Malu Mare* (119, Fig. 95) *deposits* represent a major hydrocarbon accumulation zone controlled by an uplift of first order and by the structural details of this zone. The first positive result in the region was recorded in 1958 and about 180 wells have been drilled since then.

The deepest wells (120, 134) penetrated the whole stratigraphic profile, beginning with the Quaternary and ending with the Permian where they stopped. As compared to the stratigraphic succession specific

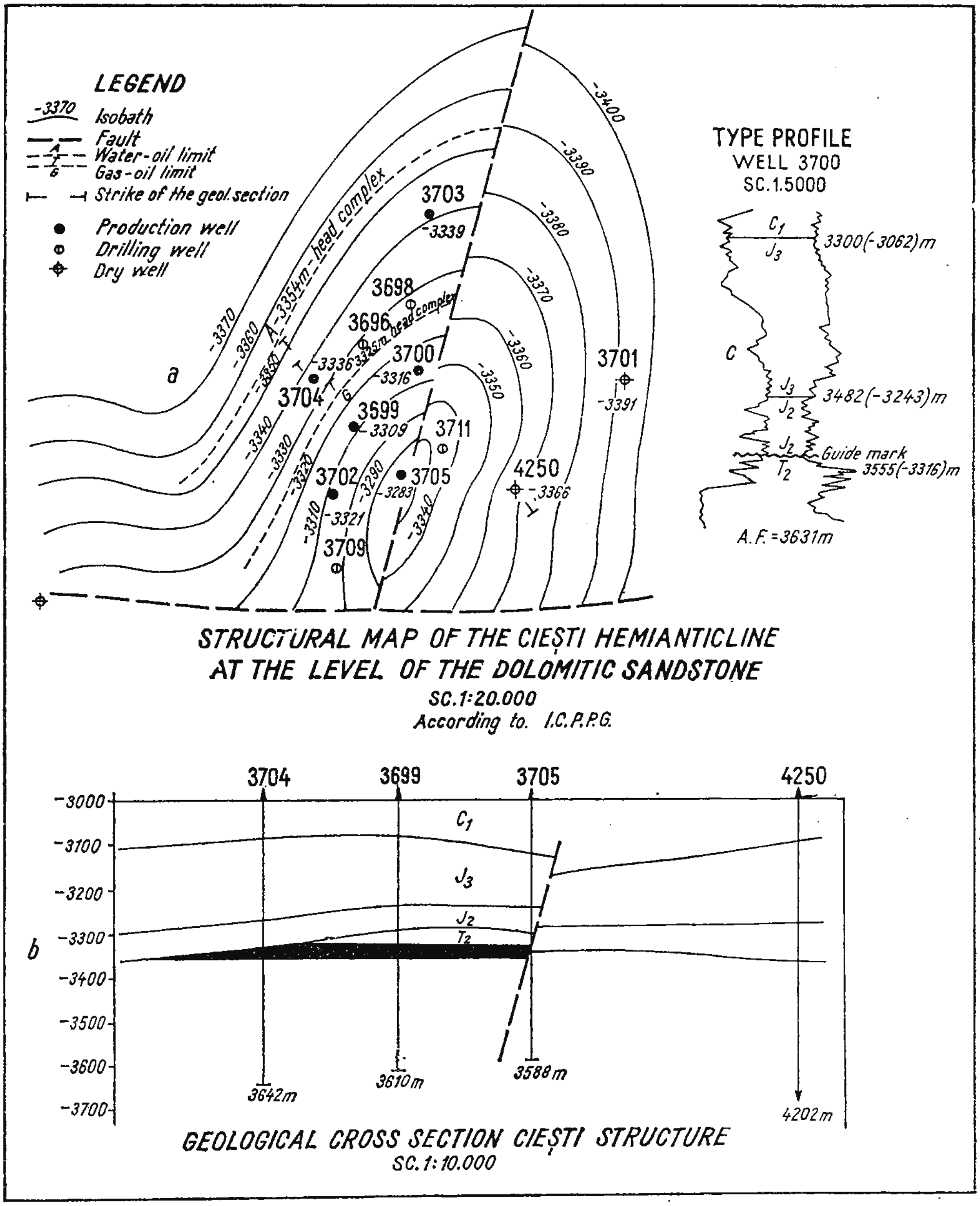

Fig. 115. — Ciești structure.
a, structural map at a Middle Triassic guide mark ; b, geological cross section ; c, Middle Triassic and Jurassic type profiles (according to I. Stoica).

to the western part of the Moesian Platform, the wells in the Sîmnic-Malu Mare zone pointed out some local gaps brought about by the gliptogenesis following the Jurassic. It is the question, first, of the absence of the Cretaceous and even the Jurassic deposits in an area corresponding to an important paleovalley known as "Paleojiul" (Paraschiv, 1975) that crossed the Sîmnic-Malu Mare zone approximately in the direction S—N.

From a structural point of view, there are four culminations along the Sîmnic-Malu Mare uplift as well as numerous tectonic accidents (Fig. 116), whose throw varies between 5 and 15 m thus constituting an insufficient interval for sealing the hydrocarbons. Therefore, as regards the hydrodynamic aspect, one can speak of only two distinct units in the region : the Sîmnic culmination and the Ghercești-Cîrcea-Malu Mare culminations.

The hydrocarbons are located in the Dogger complexes I (D I) and II (D II). The upper member, Dogger I, has a narrow oil band situated round the big gas cap throughout the four structures. The same situation is found at the Dogger II level in the Malu Mare sector. Free gas deposits are known in some blocks at Sîmnic in the Dogger I and in both complexes (D I and D II) at Malu Mare. Of the total hydrocarbon saturated volume 74 per cent represents the gas cap, 20.8 per cent, the oil zones and 5.2 per cent the free gas zones.

The water-oil contact corresponds to the isobath of 1,617 m at Sîmnic and 1,584—1,592 m at Ghercești-Malu Mare. The gas-oil limit seems to correspond to the isobath 1,608 m at Sîmnic and 1,575—1,578 m at Ghercești.

The average porosity of the two Dogger productive terms is 19.7 per cent, while the permeability varies between a few mD and 1,000 mD. The connate water saturation is about 30 per cent. The pressure gradient (8.9 kgf/cm^2) is lower than that exerted by the hydrostatic pressure. The geothermal step indicates 29.6 m/1°C. The petroleum specific gravity is about 0.810 kgf/cm^2, depending on the distance from the gas cap zone. The waters are of chlorocalcic type, with mineralizations varying between 80 and 115 g/l.

Owing to the existence of a gritty-sandy facies with frequent compact zones consisting of clayey-siliceous material, the production and behaviour of the wells were quite variable.

The structural elements of second order in the region dealt with are recognized, on the whole, also at the Pontian level, as five vaultings : Sîmnic, Ghercești, Cîrcea, Malu Mare and Urechești. The throw of these vaultings crossed by pervious faults is maximum 100 m.

The Pontian in the zone of the five structures is marked by the existence of a sand bed, bordered by pelite deposits. The effective thickness of the sand bed varies between 2 and 30 m. The average porosity is 34 per cent, the permeability is about 230 mD and the connate water saturation 25 per cent.

The Pontian sands contain free gas, especially on the Sîmnic and Ghercești vaultings. The Urechești and Cîrcea culminations are of little

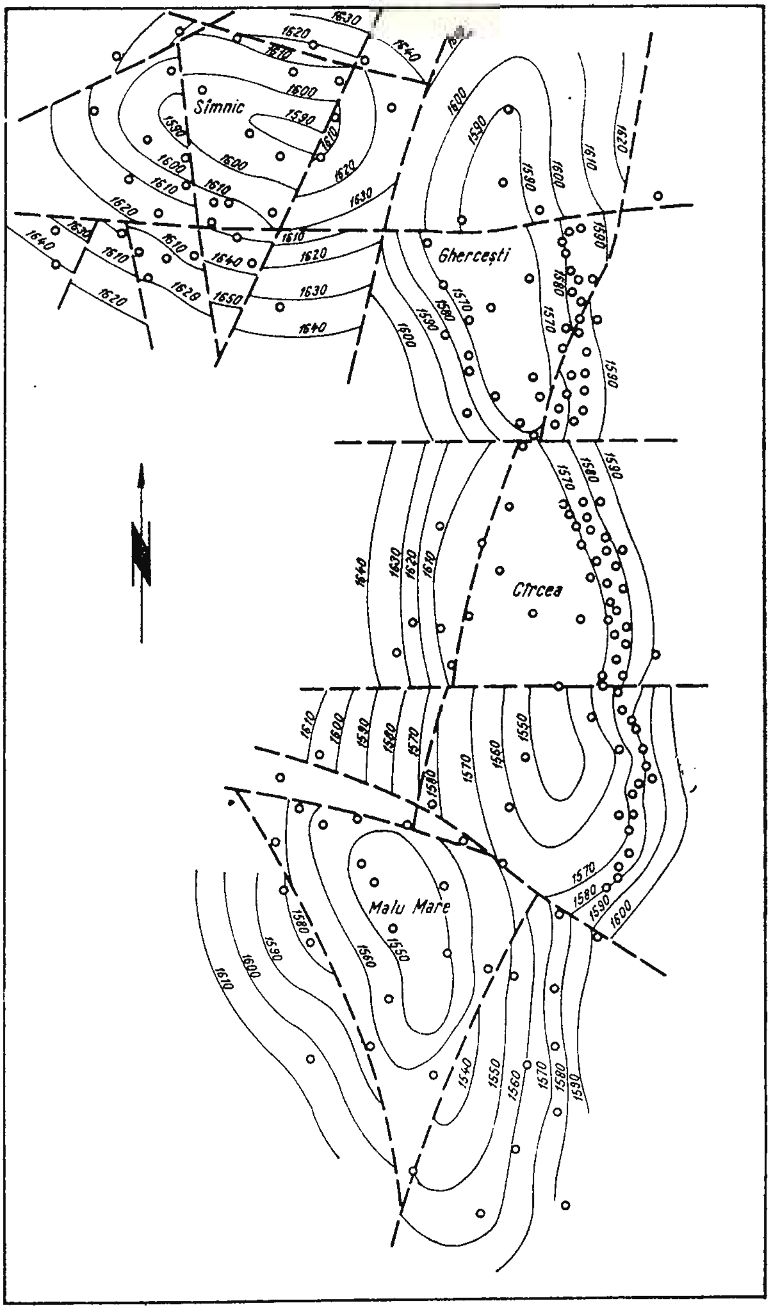

Fig. 116. — Sîmnic-Ghercești-Cîrcea-Malu Mare producing zone. Structural map at a Dogger guide mark (according to V. B r î n z a n).

importance, while the southern element Malu Mare lacks gas at the Pontian level. The hydrocarbons are represented by poor gas containing 97.85 per cent methane, 0.04 per cent ethane, 0.01 per cent propane, while the rest consists of carbon dioxide and nitrogen.

The initial pressures were 24 kgf/cm^2 and the temperature 23°C. The deposit was put into operation in 1958.

The Slatina structure (120, Fig. 95) contains free gas accumulations in the Meotian. Some of the wells drilled in the region penetrated the whole succession of sedimentary deposits reaching the basement. This magmatic basement is, sometimes, overlain directly by the Permo-Triassic lower red series.

The Meotian, which is the productive formation, consists of an alternation of sands, sandstones and marls. The members of interest are found in the lower half of the Meotian profile and have been separated, from top to bottom, into the strata *a*, *b*, *c* and *d*.

The Neogene is characterized by a monoclinal disposition being crossed by numerous faults, dividing the structure into 12 blocks. The dip of the strata is of the order 2—5°.

These gas accumulations were found in three blocks, as follows:
the block IV, the strata b_1, $b_2 + b_3$, c and d;
the block VI, the stratum b_1;
the block VII, the strata a, $b_1 + b_2$, c and d.

The depth of the deposits varies between 1,026 and 1,180 m, while the production varies between 30,000 and 61,500 m^3/day/well. The thickness of each productive stratum is 3—10.5 m, the porosity 20—23 per cent, the connate water saturation 35—38 per cent, the pressure gradient 9.6 kgf/cm^2, the geothermal gradient 3.8°C/100 m (therefore it exceeds the normal gradient), the gas density 0.562—0.593 kgf/cm^2. The gas composition: methane = 95 per cent, ethane = 1.48 per cent, propane = 0.86 per cent, butane = 0.32 per cent, CO_2 = 1.42 per cent.

The strong lithofacial variation of the Meotian is characteristic of the Slatina structure, which entailed the formation of some mixed, predominantly lithological traps.

The Negreni deposit (121, Fig. 95) lies on the western flank of the Optași promontory and appears as a slight hemianticline developed in the direction W—E at the Dogger level (gritty collector cap). The southern closing of this hemianticline seems to be achieved by a longitudinal tectonic accident.

The hydrocarbons are located in a sandstone layer, locally developed, belonging to the Dogger. Taking into account the existing information, one can state that the oil deposit is small and has a zone with gas cap. The contacts gas/oil and oil/water were estimated at 2,363 m b.s.l. and 2,368 m b.s.l., respectively. The daily production of each well, on Ø 9 mm, is between 63—72 t/day. The impurities do not exceed 6 per cent and the gas-oil ratio is 570 Nm^3/m^3. The reservoir pressure, under stationary conditions, is 241.33 kgf/cm^2 and the dynamic pressure is 181.33 kgf/cm^2.

The productive bed has effective porosities of 15 per cent, absolute permeabilities between 20—30.6 mD and connate water saturation 20 per cent. The saturation pressure could not be determined in the expansion autoclave as the wells produce with gas excess. The temperature of the deposit reaches 105°C. The oil is paraffinic, of *C* type, with the average specific gravity 0.822 kgf/dm³. The waters are of chlorocalcic type with mineralization about 457 kg/wg.

The Ciurești N structure (123, Fig. 95) is a tectonic element of second order within the N Craiova-Balş-Optași-S Periș uplift. It is a vaulting with the eastern pericline prolonged, the latter being known under the name of "*Bîrla sector*". The tectonic style is, generally, the same both at the Dogger level and at the Lower Cretaceous level. The whole structure is crossed by a complex system of faults having a narrow throw in general (Fig. 117).

The deepest wells drilled in the region (e.g. wells nos. 237, 260) reached the Paleozoic. The Devonian carbonate deposits are overlain by the detrital-volcanogenous formation (the lower red series), which, in its turn, is covered by the Triassic carbonate formation and, locally, by the upper red formation. The latter is unconformably overlain by the Dogger underlying the Malm-Cretaceous carbonate deposits. The sedimentary sequence ends with the Neogene-Quaternary terrigenous formations.

Oil deposits with primary gas cap in the Upper Triassic, Dogger, in the Malm-Neocomian complexes C_1 and C_2 and in the Sarmatian as well as free gas deposits in the Lower Cretaceous complexes C_4 and C_5 and in the Senonian were identified on the Ciurești structure. The oil accumulations in the Bîrla sector do not contain primary gas cap.

The Triassic consisting of two productive horizons (Tr_1 and Tr_2), together with the Dogger, which is represented only by the upper complex (D_1), make up a common deposit. The initial oil-water contact is at the isobath of 1,842 m and the gas-oil limit, at 1,805 m.

The Malm-Neocomian was conventionally divided into five complexes, C_1—C_5 (from bottom to top) belonging stratigraphically as follows : C_1 = Tithonian-Valanginian ; C_2, C_3 and C_4 = Hauterivian ; C_5 = Barremian. The hydrocarbons accumulated in the fissures of the complex C_1 ; the storing possibilities of the complex C_2 depend on the matrix pores and fissures ; the complex C_3, being compact, does not yield ; the complexes C_3 and C_5, marked by the high frequency of the marly limestones and of the marno-limestones proved saturated only locally, at Ciurești N (blocks II + III).

The complexes C_1 and C_2 having bottom water and marginal water, respectively, form a single hydrodynamic unit. The water-oil limit varies according to the apparently accidental compactness of the rocks. The gas-oil contact was estimated at the isobath of 1,515 m.

The Senonian consisting of chalk limestones contains only gas locally, at Ciurești N (blocks II, IV and V).

The Sarmatian proved saturated with hydrocarbons consisting of developed gas cap with a very thin oil band in a few blocks. Gas traces were also pointed out in the Meotian.

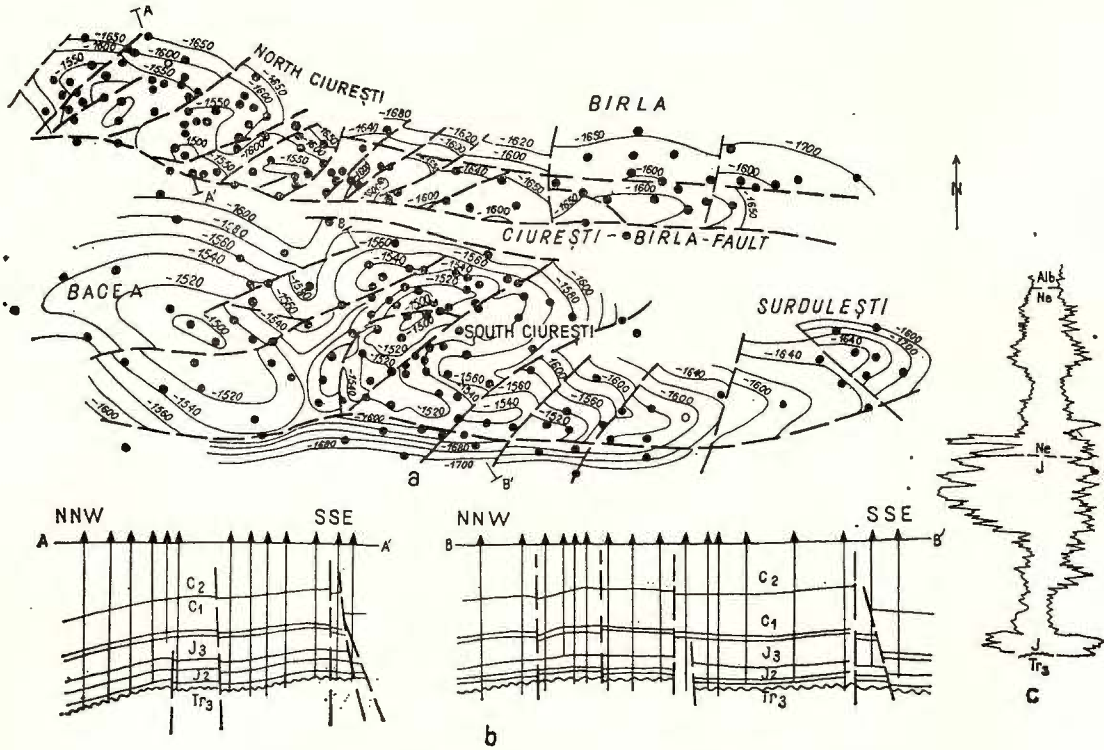

Fig. 117. — Ciureşti producing sector,
a, structural map at a Lower Cretaceous guide mark ; b, geological cross sections ; c, Lower Cretaceous and Jurassic type profiles (according to I.C.P.P.G. and D. Paraschiv).

The main productive members are characterized by the following physico-geological parameters :

	Tr	Dg	C_1-C_2
porosity (per cent)	24	20—21	20
permeability (mD)	80	25—60	—
connate water saturation (per cent)	25	25—37	55
initial pressure (kgf/cm²)		92—180	
reservoir temperature (°C)	87	87	72—79

The paraffinic oil of *C* type has the specific gravity 0.830 kgf/dm³.

The regime of the Triassic and Dogger deposits is due to the detente of the associated gas (in solution and in the gas cap); it is also due to the detente of the rock-fluids system in the western sector of the structure. The oil flows, first, under the influence of the rock-fluid detente and then under the impact of the bottom waters in the case of the complexes C_1 and C_2.

The Ciurești S (124)-*Bacea* (125)-*Surdulești* (126, Fig. 95) *productive structure* contains oil accumulations in the Upper Triassic, Dogger and Malm-Neocomian reservoirs. Oil traces were also pointed out in the Meotian.

At the Dogger level the Ciurești S-Surdulești structure appears as a faulted vaulting elongated and trending approximately W—E.

The oil is stored in the Upper Triassic gritty complex and in the Dogger base as well as in a sandstone complex which disappears gradually south-northwards owing to erosion.

The Triassic accumulation lies throughout the apex zone of the structure, where the respective reservoir comes into contact with the Dogger, forming a common reservoir. In the Upper Triassic the average porosity of the reservoir is 24 per cent, the permeability 56 mD and the connate water saturation 25 per cent. The saturation pressure is 55 kgf/cm^2 and the temperature 83—87°C. The average production per well was initially 30—40 t/day, decreasing to 9 t/day with 88 per cent water at present. The oil in both formations is paraffinic of *C* type. The water-oil limit is tabular. The waters are of chlorocalcic type with mineralizations of 570 kg/wg.

The average porosity of the Jurassic sandstones is 20—21 per cent, the permeability 50—56 mD and the connate water saturation 30—37 per cent.

In the first stage the Dogger-Triassic deposit produced under elastic regime. Later on the water injection was applied, aiming at the pressure maintainance.

The Ciurești S-Surdulești structure appears as a lobed vaulting (Fig. 117) at the Neocomian level; it is sealed by the Tufeni-Surdulești major tectonic accident on the south. The structure shows an apophysis called Tufeni-Surdulești (126) NE of this accident; the Bacea vaulting (125) appears on the west, being separated by a saddle. The whole structure is crossed by a system of faults with a relatively small throw, insufficient for forming screens.

The last productive formation, the Malm-Neocomian, is divided into five complexes C_1—C_5 (from bottom to top), as at Ciurești N.

In the complex C_1 (100—160 m in thickness) the oil is stored in fissures, while in the complexes C_2 and C_3 (35—50 m in thickness) it accumulated both in the matrix and in the fissures. The complexes C_4 and C_5, which are characterized by the high frequency of the marly limestones and marno-limestones, did not yield oil. The fissural system existing in the complexes C_1, C_2 and C_3 suggests that the oil accumulations in these complexes form a single hydrodynamic unit.

A low piezoconductivity coefficient and an irregular lateral passage to the compactness zone without oil are generally noticed. The compactness of the rocks in certain sectors of the deposit determined a variation of the oil-water limit, which is not similar on the whole structure.

The Malm-Neocomian collectors have average porosities of 16—20 per cent and permeabilities 0.04—1 mD.

The oil was stored in structural, partly, lithological traps and the deposit is massive showing a tabular oil-water contact.

As regards the deposit regime, owing to the weakly developed fissural system and the lateral passage from porous to hard, compact limestones, that is the low piezoconductivity, initially, the oil yielded under the impact of the rock-fluids system detente (locally, a dissolved gas regime could develop), while the impact of the bottom waters finally contributed to the oil expulsion from the pores and fissures.

The wells yield from the complex C_1 2.8—6.6 t/day with 86—91 per cent impurities and 50.5 m^3/m^3 R.G.T.

The average reservoir pressure was 155 kgf/cm^2 at the beginning and decreased to 80—100 kgf/cm^2 later on. As the hydrodynamic regime developed the reservoir pressure increased again reaching 100 kgf/cm^2.

The reservoir temperature is 79°C. The oil, having the specific gravity of 0.830 kgf/dm^3, is paraffinic of *C* type. The chlorocalcic waters have the mineralization of 64.5 g/l.

X. GENERAL REMARKS AND CONCLUSIONS ON THE ROMANIAN OIL AND GAS FIELDS

The prospection and exploration activity started with the natural oil and gas seeps prevailing in the flysch zone and the Carpathian Foredeep, extending throughout the Romanian territory, covered by recent sedimentary deposits, including the Danube Delta and the Black Sea continental shelf.

During the 122 years of activity attested by official documents, several geological and geophysical works were achieved, consisting in mapping, gravimetric, magnetometric (including aero-) electrometric, seismic, geochemical prospections and drillings reaching the depth of 6,500 m. These surveys were accompanied by analyses and laboratory studies enabling a good knowledge of the investigated units. The concrete results of this activity consist in the discovery of over 350 major productive structures belonging to : the East Carpathian flysch, the Carpathian Foredeep, the Transylvanian Depression, the Pannonian Depression, the Moldavian Platform, the North-Dobrogean Promontory, the Predobrogean Depression and the Moesian Platform (Plate I). The first four mentioned regions belong to the Carpathian domain, while the last four make up the latter's foreland. The East Carpathian Crystalline-Mesozoic zone, the Harghita-Călimani-Oaş Neogene volcanic chain, the South Carpathians and the Apuseni Mountains, which are component elements of the Carpathian domain, consisting of crystalline schists, eruptive rocks or unmetamorphosed formations, but intensely tectonized and outcropping, did not benefit by conditions favourable to the oil and gas accumulation formation.

The productive structural units correspond totally or partially to some oil and gas basins of platform, premontan and intramontan type (Brod, 1953; Beca, Vîsoţki, 1968). Thus, some of the formations of interest of the Moesian Platform and the Moldavian Platform might be regarded as platform basins; other such deposits (Neogene), together with the Carpathian Foredeep units, belong to some premontan (Pericarpathian) oil basins; finally the Transylvanian Depression and the Pannonian Depression, both of them internal depressions, might be regarded as intramontan basins taking into account the hydrocarbon deposit formation conditions.

The classification of the structural units into the mentioned types of basins takes into consideration their evolution, shape and age, the thickness of the sedimentary deposits, the stratigraphic succession, the lithofacial characteristics, the structural aspects, the shape and size of the traps etc.

The sedimentary basins on the Romanian territory accumulated deposits showing a variable lithological composition and thickness depending on their age, but especially on their geological evolution. The most active accumulation processes took place in the Carpathian flysch zone and in the foredeep, where the folded sedimentary of the latter two zones and the unfolded sedimentary of the underlying platform may exceed 15—20 km. Very thick deposits (3—18 km) are found also on the sunk sides of the platforms (e.g. the Focşani Depression). Considering their recent age and the moderate subsidence process, the internal depressions accumulated not so thick sedimentary deposits. The most incomplete and small sedimentary sequence is found in the foreland units and, especially in the Moldavian Platform that maintained a more emerged position during its evolution. The Moesian Platform, surrounded by the Carpathian-Balkan geosyncline and by the North-Dobrogean geosyncline, functioned as a "mobile platform" (Răileanu et al., 1968) for a long time, accumulating a very thick pile of deposits in a complete enough succession, from the Cambrian to the Quaternary.

During their evolution, the Romanian sedimentary basins benefited by conditions favourable to the hydrocarbon generation, accumulation and preservation, not only in the Tertiary, but also in the Mesozoic and Paleozoic. The presence of some deposits with reservoir properties alternating with possibly source rock sequences involved in various structural and pseudo-structural shapes, strengthens the above statement.

The reservoir rocks consist of clastics and carbonates, namely: conglomerates, sandstones, sands, siltstones, calcarenites, porous limestones and primary dolomites as well as diagenized compact rocks, such as the altered crystalline schists and the eruptive, the hard fissured sandstones, the altered and fractured limestones, including the karst, the secondary dolomites etc.

The oldest formations with reservoir properties correspond to the upper altered crust of the metamorphic basement that proved its storing-yielding capacity in the Pannonian Depression, the Transylvanian Depression and the North-Dobrogean Promontory. The number of accumulations located in the metamorphic formations has increased considerably lately in our country, which corresponds to the results obtained in other countries (Porfiriev et al., 1977). The sedimentary series contains reservoir rocks, from the Cambrian to the Pliocene, as follows: the Cambro-Ordovician is characterized by quartzite sandstones; the Middle Devonian (Eifelian) also by predominantly quartzite sandstones, of the Old Red Sandstone type; the Middle and Upper Devonian by the primary dolomites; the Dinantian by porous limestones and secondary dolomites; the Lower Permian-Triassic contains sandstones and microconglomerates; the Middle Triassic is characterized by dolomites and porous limestones; the Upper Triassic and Dogger contain sandstones; the Malm-Neocomian offers carbonate reservoirs, especially of reefal type; the Albian is marked by gritty limestones, limy sandstones and even glauconitic sands; the Senonian contains chalk limestones. All these reservoirs are characteristic of the Carpathian Foreland and especially of the Moesian Platform (where they were analysed and tested) with the exception of the Cotumba sandstone (Cretaceous) which belongs to the East Carpathian flysch that offered poor hydrocarbon productions.

The Paleogene, together with the Lower Miocene contain gritty, seldom, gritty-limy sequences being located in the Carpathian flysch, the Carpathian Foredeep and less, in the Transylvanian Depression. The most important hydrocarbon saturated reservoirs are known in the East Carpathians, in the Tarcău sandstone facies (Eocene) and in the Kliwa sandstone facies (Oligocene) as well as in the Getic Depression Paleogene. The Lower Miocene, namely the Burdigalian-Helvetian proved its storing and yielding capacity in the Carpathian Foredeep and is still being investigated in the Transylvanian Depression.

The Tortonian and the Sarmatian show reservoirs of granular type, proved productive on all the eight major structural units of interest for hydrocarbons. Porous carbonate reservoirs and especially fissured (cavernous) reservoirs were identified locally (the Moesian Platform).

The Pliocene, which is found both on the Carpathian units and on the platforms, is characterized by numerous sequences of sands and sandstones with excellent porosities and permeabilities, from the Meotian to the Levantine. It should be noted that the Pontian shows a predominantly pelite facies.

The reservoir qualities, that is, the porosity and permeability of the rocks belonging to the above enumerated formations vary within extremely large limits. This variation is mainly due to the petrographic-mineralogic, geothermal factors, to the rock age, the basin evolution and the tectonic factors that can bring about very many and often, unforeseen local influences.

Generally, the porosity decreases with depth and depending on the deposit age, as a result of the compacting process and the chemical transformations. Thus, the primary porosity of the strata between 500 and 2,000 m shows the most frequent average values of 20—33 per cent, in the Moreni-Dacian (31—33%), the Moreni (25%—30%) and Şuţa Seacă (23%—30%), Meotian, the Ţicleni Sarmatian (24.2%—33%), the N Cobia (26%) and Ţicleni (maximum 34%), Helvetian, the Jugureanu Albian (29%), in the Brădeşti Triassic (maximum 28%). Accordingly, the respective reservoirs are characterized by permeabilities of 3,000—4,000 mD. The same formations found at the depth of 4,000—4,500 m have very low porosities and especially permeabilities, as follows :

Formation	Depth (m)	Porosity (%)	Permeability (mD)
Sarmation-Bibeşti	4043—4120	1.1—15.3	0—15.7
Helvetian-Mărgineni	4024—4288	0.2—11.4	0.1—1.1
Triassic-Bibeşti	4386—4478	0.2—18.8	0—1.3

Owing to the very low permeabilities, many strata impregnated with oil, as the core samples indicated, did not yield at the production tests.

A main element determining the rock porosity (the specific gravity inclusively) is the presence and prevalence of the carbonates (CO_3Ca) that accelerate the diagenetic processes (the cementation and the recrystallization) under the influence of pressure (the gravitational factor) and temperature leading to the clogging of the pores and fissures. The diagenesis stage is also influenced by the age of the geological formations.

There is a certain relation between the porosity and the permeability, but it is often obscure and variable, especially at a great depth, owing to the influence of some factors such as the rock texture, the fissuration degree and even the temperature influencing the fluid viscosity.

The economic and scientific results obtained in Romania and in other parts of the world (H e d b e r g, 1967), allowed a considerable extension of the source formations. Consequently, it was concluded that the Romanian territory showed favourable conditions for hydrocarbon generation during its evolution from the Lower Paleozoic to the end of the Pliocene. Such propitious conditions are supposed to have existed during the Ordovician, Silurian and Eodevonian, when the schistose-clayey series with graptolites deposited in the Moesian Platform and in the Moldavian Platform. The oxido-reducing environment seems to have existed also during the deposition of the Givetian-Neodevonian dolomitic-evaporitic series, where commercial hydrocarbon accumulations were also discovered. Similar conditions, attested by the identified deposits are valid also for the Middle Triassic carbonatic-evaporitic series in the Moesian Platform, and probably in the Scythian Platform. The Dogger *Posidonia* marno-clays are accepted as source rocks, considering the geochemical, mineralogical and biostratigraphical favourable indexes and the existence of several oil deposits in the subjacent sandstones. The bituminous facies also characterizes the Cretaceous black shales in the East Carpathians. Positive indexes are in favour also of the Albian in the Moesian Platform. The East Carpathian flysch Oligocene offers the most typical characteristics of bituminous rocks associated with favourable geochemical indexes, and especially with the presence of numerous oil and gas fields. We refer, in the first place, to the bituminous sequences of the Oligocene Kliwa facies, but also to the important pelite mass belonging to the Pucioasa Oligocene and to the transition facies mass. Overlooking the Aquitanian-Burdigalian evaporitic deposits, which were overrated in the past with regard to their contribution to the foredeep oil and gas genesis, numerous geologists think that the hydrocarbons stored in the Helvetian-Burdigalian lie in the formations generating them, and consequently lend a genetic importance to the pelite sequences in the respective series. The recent identification of numerous deposits in the Transylvanian Depression, the Pannonian Depression, the Carpathian Foredeep and the Moldavian Platform, as well as the chemical analyses in the Pannonian Depression lead to the conclusion that the Tortonian pelite facies, often associated with evaporites and volcanic rocks, was very prolific. The Sarmatian pelites may also be important although not supported by geochemical criteria.

The long controversy on the Pliocene hydrocarbon origin seems to have ended as a result of the analyses and studies achieved in the Carpathian Foredeep and in the Pannonian Depression. The results of the respective investigations (A n t o n, 1973) led to the conclusion that the Pliocene (Meotian, Pontian and Dacian) pelites show geochemical indexes justifying their assignation to the source rocks.

The development of the surface and depth researches, the discovery of new hydrocarbon deposits, whose stratigraphic position, corroborated by the results of the geochemical analyses, tended to consolidate the conception according to which the Romanian oil and gas fields are autochthonous, although a few accumulations of little value might have formed by the hydrocarbon vertical migration.

The various source rocks viewed in the light of the lithofacies, the geochemical, mineralogical, biostratigraphic indexes and the age, require the reconsideration of the conception on the deposition environment of the respective formations and of the formation conditions of the deposits. Thus, possible mother rocks may show both clay-gritty facies (with its variations) and carbonatic or evaporitic facies. The mineralization of the waters where the organic matter deposited is variable, the content being from a few grams (Dacian) to 300 g/l (Triassic, Aquitanian-Burdigalian and Tortonian). Many possible hydrocarbon generating rocks contain also coal (Carboniferous, Liassic, Dogger, Pliocene). Also, a series of source rocks, such as the Middle and Upper Devonian, the Middle and Upper Triassic, the Oligocene, the Aquitanian-Burdigalian and the Tortonian are associated with evaporitic formations, but the major significance of the halites and anhydrites is the indication of closed basins (Hedberg, 1967). It is also worth mentioning the fact that some source rocks, such as the Ordovician, Silurian, Silesian (?), the Triassic, the Oligocene, the Tortonian, the Sarmatian and the Pliocene in the various major structural units contain also volcanic rocks (lavas, tuffs, agglomerates). Such cases are also pointed out in the Neogene in Japan, Sumatra, Argentina etc. (Hedberg, 1977).

A decisive factor of the hydrocarbon genesis, migration, accumulation and preservation is the temperature of the buried sediments. According to the geothermal studies drawn up recently (Paraschiv, Cristian, 1977), the Romanian structural units of petroliferous interest are characterized by low geothermal gradients of 1.5–7°C/100 m (Fig. 118). The lowest values (1.5–2°C/100 m) were pointed out in the eastern part of the Moesian Platform, while the highest values (7°C/100 m) were recorded in the Pannonian Depression. The low values are generally characteristic of the hypersubsident zones that accumulated thick sedimentary deposits during the Neogene : the sunk margins of the platforms, the external flank of the foredeep, the Transylvanian Depression. The positive anomalies are closely connected to the zones where the thickness of the sedimentary (generally old) formations decreased and therefore, to the zones where the metamorphic basement lies at smaller depths.

The frequency and size of the deposits are great and the liquid hydrocarbons prevail in the regions with the high geothermal gradients to the depth of 3,200–3,500 m. The "cold" regimes with young (Neogene) deposits contain exclusively or predominantly gas-bearing deposits of little value. This means that in the regions with minimum geothermal anomalies and with young formations the organic matter remained in an immature transformation stage, without reaching the minimum threshold of oil generation. This situation is in a perfect agreement with the results obtained abroad (Klemme, 1972; Connan, 1974; Tissot, 1975 etc.) and underlines the importance of the geothermal factor in the formation of hydrocarbon deposits.

In general, there is a direct correlation between the amount of sediments and that of the generated hydrocarbons. But correction coefficients are necessary, being determined especially by the basin evolution and by the paleotemperatures. Thus, it seems that the too rapid sedimentation rhythm (hypersubsidence) as in the case of the Focşani Depression during the Neogene, was not propitious enougth to the hydrocarbon generation as it did not favour the maturing of the organic substance.

On the eight major structural units were found all the types of traps, namely : structural, stratigraphic, paleogeomorphic, hydrogeological and mixed.

The majority and the most important traps are of structural type. The folded structures with all their diversity of shapes prevail in the East Carpathian flysch, in the foredeep and in the Transylvanian Depression. The simplest plicative elements are the domes, which are characteristic of the Transylvanian Depression and the external side of the Car-

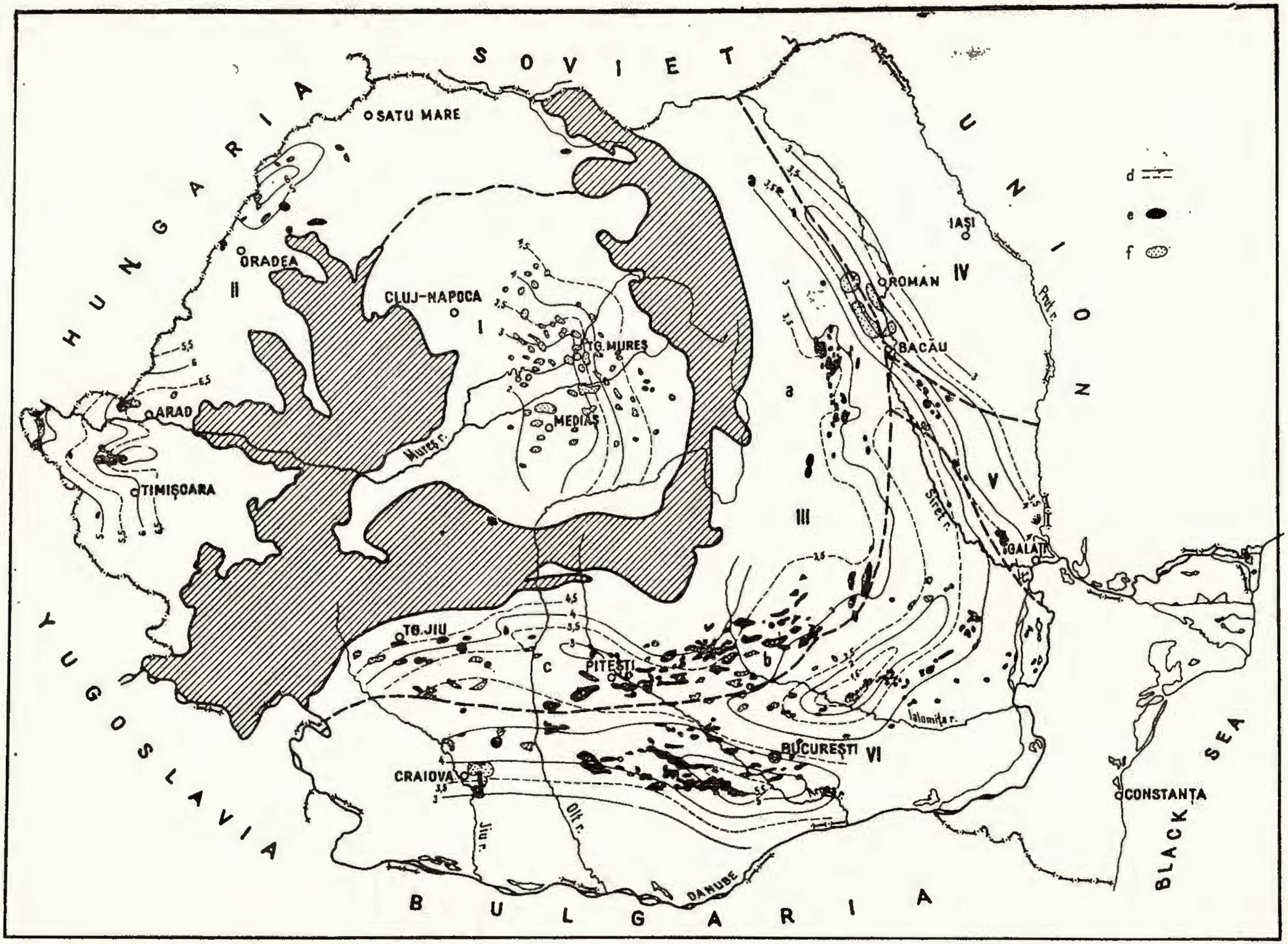

Fig. 118. — Relation between the geothermal gradient and the distribution of the Romanian hydrocarbon deposits (according to D. Paraschiv and M. Cristian).
I, the Transylvanian Depresion; II, the Pannonian Depresion; III, the East Carpathian flysch and the Carpathian Foreep: a, flysch zone; b, diapir fold zone; c, the Getic Depression; IV, the Moldavian Platform; V, the North-Dobrogean Promontory and the Predobrogean Depression; VI, the Moesian Platform; d, geothermal isogradient curves; e, oil deposits; f, gas deposits.

pathian Foredeep, in Muntenia and Oltenia; the most complicated plicative elements are the overthrust folds and the overthrusts, varying in size, which characterize the East Carpathian flysch and, to a certain extent, the internal flank of the molasse zone. The movement of the Burdigalian and Tortonian salt played an important, even decisive part in the formation of the structural traps both in the Transylvanian Depression and in the Mio-Pliocene subzone and in the Paleogene flysch. The disjunctive tectonics determined the structural character of the traps in the foreland units and, to a certain extent, in the Pannonian Depression.

The stratigraphic and lithological traps formed as a result of the variation of the accumulation conditions and determining the appearance or the pinching-out of the beds, the lithological irregularity (the reef deposition inclusively) expressed by the variation of the porosity and permeability values, are present in all the petroliferous regions. Their frequency increases on the margin of the sedimentary basins, delimited by the Carpathian massifs and within these basins, where persisted crests, uplifts, emerged and submerged positive reliefs (the Pannonian Depression, the Scythian and the Moesian Platform).

The paleogeomorphic traps, a term used with the meaning assigned to it by Martin (1966), except the reef deposits that should be included among the stratigraphic traps, were identified in all the regions of interest and, first of all, in the foreland units. They are frequent in the Pannonian Depression, where the numerous crests of the basement remained emerged up to the Pliocene, some of them even to the Quaternary. Their large number, economic importance, variety of shapes, the special methods necessary for their investigation and identification justify their belonging to a special trap category (type).

From a theoretic point of view, the hydrogeological traps might exist in all the Romanian petroleum basins. But they have been identified only in the Transylvanian Depression so far.

Not only simple deposits were identified on the Romanian territory; a large series of traps formed against the background of some monoclinal or folded structures that might allow the gravitational separation of fluids; they were achieved by the contribution of other factors, such as the stratigraphic, paleogeographic and lithologic factors. These are the "mixed traps" (Levorsen, 1967) which are present in all the regions.

According to their shape, the Romanian hydrocarbon deposits are stratiform, massive and irregular (Gavăt, 1964). The stratiform accumulations have the greatest distribution, being present on all the units of interest, but, especially, on those belonging to the Carpathian domain. The massive deposits constitute, as a rule, a characteristic of the fissured reservoirs. It is the case of the altered zone of the metamorphic basement in the Pannonian Depression, of the carbonate Malm-Cretaceous formations in the Moesian Platform, locally, on the Kliwa facies sandstones, of the Burdigalian-Helvetian sandstones in the Neogene zone coming into contact, on the unconformity plane, with the Pliocene reservoirs saturated with oil etc. The irregular deposits correspond to the lenticular developments of the porous strata and of some paleogeomorphic traps. Such lenses are to be found in all the units and formations of prospect. Although numerous, they contain a small hydrocarbon volume as compared to the stratiform and massive deposits.

During the 122 years of activity, over 350 productive structures with oil and/or gas were discovered on the Romanian territory. Although the sedimentary deposits with prospects for hydrocarbons were not systematically and wholly explored, some conclusions can be drawn from the survey of the distribution of the accumulations discovered.

The most numerous structural elements with oil and gas are found in the Moesian Platform (126), followed by the Carpathian Foredeep (74), the East Carpathian flysch (30), the Pannonian Depression (25), the North-Dobrogean-Promontory and the Bîrlad Depression (11) and the Moldavian Platform (6). Therefore, the last accumulations were discovered in the Moldavian Platform (6). Taking into consideration the size of the deposits, the most important is the Carpathian Foredeep, which seems to confirm the principle according to which the volume of the generated hydrocarbons is correlated to the volume of the sedimentary deposits. As a matter of fact, this correlation is also found in the case of Transylvania, the Getic Depression and the Moldavian Platform.

All the productive structures in Transylvania, the Pannonian Depression, the Moldavian Platform, the North-Dobrogean Promontory (?) and the Bîrlad Depression, about 75 per cent of the foredeep petroliferous structures and about 50 per cent of those belonging to the Moesian Platform are genetically linked to the Neogene formations, among which the Tortonian, Sarmatian, Meotian and Dacian ones are more important. Taking into account the fact that most hydrocarbons lie in the formations generating them, therefore regarding the vertical migration of the oil and gas as unsignificant, one can conclude that the most prolific formations belong to the Neogene. In reaching this conclusion one has still some doubts generated by the insufficient research and therefore the partial identification of the structures lying at a great depth, on the one hand, and by the evolution of each geological unit, which suggests that numerous accumulations might have been destroyed during the temporary emergences and the deterioration of the protection conditions, on the other hand.

Referring again to the hydrocarbon stratigraphic distribution one should mention the statistic data provided by Perodont (1966) and the study drawn up by Kuznețov and Modelevski (1976), according to which the Tertiary contains about 35 per cent of the world reserves and 50 per cent of the hydrocarbon deposits, the Mesozoic about 53 per cent and 19.5 per cent respectively, while the Paleozoic contains maximum 12 per cent of the reserves and 30.5 per cent of the deposits. It is noteworthy that the Romanian territory is characterized by a particular development of the Tertiary deposits.

The analysis of the stratigraphic hydrocarbon distribution reveals also the relation existing between the position of the accumulations and the main sedimentary gaps. Indeed, the majority of the known deposits are grouped round the stratigraphic unconformities. Thus, the metamorphic basement of the Pannonian Depression forms deposits in common with the Neogene, these two terms coming into direct contact. A similar situation is found at Bibeşti, where the productive Devonian underlies directly the Triassic with which it forms a hydrodynamic unit. The Triassic carbonatic formation (T_2) is in unconformable relation with the adjacent terms, the Dogger inclusively, with which it forms unitary deposits at Brădeşti, Oporelu, Ciureşti N, Ciureşti S etc. The basal complex of the productive Dogger is separated from the older terms by a strong unconformity plane. The Neocomian and Albian accumulations are all situated on either side of the Meso-Cretaceous unconformity. The Sarmatian and the Senonian (sometimes the Tortonian) make up common deposits in the Moesian Platform. The gas formation is affected by at least three unconformities in Transylvania. The Pliocene base, which is productive in almost all the units of the country, is separated from the older terms by a discontinuity plane etc. One can infer, from these examples, that most hydrocarbon accumulations lie on either side of some stratigraphic unconformities. The explanation of this phenomenon was the subject of discussion abroad, so that further comments on this issue are not necessary.

All the eight major structural units contain oil and gas accumulations with the exception of the Transylvanian Depression which is exclusively gas-bearing. The conclusion is valid if we take into account the post-saliferous deposits of the latter unit. The Sarmatian-Pliocene is predominantly gas-bearing also in the molasse zone, but only in the sectors corresponding to the strongly subsident part of the sedimentation basin. That is why the exclusively gas-bearing character of the post-Helvetian in the Transylvanian Depression might be determined by the evolution of this region, characterized by a certain subsidence rate depending on the transformation rhythm of the organic matter. Referring to the East Carpathian bending zone (the Focşani Depression) where the subsidence process was even stronger than in Transylvania, the transformation of the organic matter into hydrocarbons seems to have taken place still later.

In the extra-Carpathian units, where both oil structures and gas structural elements are known, exclusively gas-accumulations are found in the more lowered zones of the oil and gas basins. The number of oil deposits increases constantly towards the lowered sides of the basins. Finally, the most uplifted zones of the proved productive units are characterized by aquiferous structures. This is very obvious in the Carpathian Foredeep, at the Neogene formation level, and in the Moesian Platform. This distribution, initially assigned to G u s s o w's principle (1954), might be better explained by the temperature impact on the hydrocarbon physical state.

Studying further the relation between the liquid and gaseous hydrocarbons along the Carpathian Foredeep and the Paleogene flysch zone it is noticed that the gas amount increases continuously north-southwards and north-westwards. Thus, if there is only one gas structure (Tazlău) and only a few oil deposits with primary gas cap accumulations in the Moldavian flysch and Miocene subzone, the number of exclusively gas-bearing structures and horizons in the Mio-Pliocene subzone of Muntenia increases considerably westwards. Such deposits lie outside the main diapiric Băicoi-Moreni-Tîrgovişte alignment. Finally, the frequency of the free gas deposits increases still more, in front of the South Carpathian crystalline, invading the whole Getic Depression to the vicinity of the northern border.

The mentioned variation of the relation between oil and gas cannot be explained only by applying Gussow's principle and that of the hydrocarbon retrograde evolution. With a view to finding additional arguments, two things should be mentioned. First of all, the gas accumulations are associated with the less tectonized, calmer structures that could offer preservation conditions. Indeed, the calmest structure, a classic brachyanticline in the Paleogene flysch zone is that of Tazlăul Mare. Such structural elements are more frequent on the foredeep external side with platform basement in the Mio-Pliocene subzone. The same calm style is characteristic of the Getic Depression folds, too. The complete absence of the gas deposits on the east side of the Transylvanian Depression corresponding to the diapirs with outcropping salt cores constitutes a supplementary element proving that the complicated structures, the exaggerated diapir folds inclusively, did not favour the gaseous hydrocarbon accumulation and preservation. More than that, the size and importance of the gas accumulations in Transylvania decrease outwards as the degree of tectonic complication of the structures increases (and the Neogene sedimentary decreases in thickness). Secondly, the gaseous hydrocarbons seem to be more abundant in the younger formations, especially in the Sarmatian-Pliocene formations which are very widespread west of the Buzău river. The explanation would have as a starting point the temperature-time relation in the hydrocarbon formation, in other words, the temperature deficit of these formations was not partially compensated by time (the formation being young) so that the organic matter could not reach the minimum threshold for the oil generation. The presence of some free gas deposits in the Getic Depression Helvetian (Colibaşi-Argeş, Vîlcele, Băbeni, Galicea, Bustuchini etc.) and even Paleogene (Boţeşti, Merişani, Săpunari etc.) implies another explanation, namely the influence of the tangential movements, on the hydrocarbon physical state expressed also as heating power. It is known that the Getic Depression is characterized by a larger plicative tectonics at the Lower Neogene and Paleogene levels, as compared to the rest of the foredeep and the flysch zone.

Another general remark refers to the disposition of the productive structures on the accumulation zones. Two tendencies arise in this sense. In the Paleogene flysch zone, in the Carpathian Foredeep and in the foreland units, in the Mesozoic and Tertiary, most of the deposits are lineary disposed along some major structural elements. Within the Carpathian flysch zone and the foredeep, these structural alignements correspond to some regional folds broken up by saddles and faults. The structural echelon in the foreland units represent especially faults parallel to the diapiric folds to a certain extent. The platform margins fall gradually in front of the Carpathians along many of these faults. The deposits which do not show the mentioned disposition are not subject to the influence of the structural factors, being controlled by other factors, such as the basement uplifts (in the Moesian Platform), the existence of some reef bodies (also in the Moesian Platform), the paleoreliefs and the lithofacial variations.

The distribution of the deposits appears rather chaotic in the internal depressions and in the Moesian Platform (at the pre-Cretaceous formation level). This "disorder" in the deposit distribution is caused by the shape and trending of the basement uplifts which are sunk in the Neogene deposits, by the pre-Neogene paleoreliefs and by the facies variations which determine the type and size of the traps.

A careful analysis of the distribution maps of the hydrocarbon accumulations, especially in the Moesian Platform and in the Pannonian Depression reveals the fact that in some formations, the preferential accumulation zones do not take into account the present major structural features, but correspond to the geological context of the basin during the deposition of the respective stratigraphic terms. For exemple, the Triassic and Dogger deposits are grouped round the old Craiova-Balş-Optaşi uplift. Since the Cretaceous this uplift has lost its characteristics so that the eastern, more uplifted sector of the Moesian domain polarized around it the Lower Malm-Cretaceous and Albian accumulations. Confronting the isopachyte maps and those of the deposits at the Dogger and Middle Triassic levels one can notice that the hydrocarbon accumulations are located in the marginal zone with reduced thicknesses, which suggests that the oil and gas migrated from the centre towards the periphery of the respective sedimentary basins.

Although present in all the eight major structural units, the oil and gas accumulations are not uniformly distributed in the basins but are grouped into a few preferential zones. The conditions favouring such concentrations are somehow different.

The most important preferential accumulation zone within the Carpathian flysch is located in the external unit, in the vicinity of the Moineşti town. The main favourable factors here are : 1, the existence of the Kliwa facies consisting of sandstones with excellent reservoir properties alternating with pelite, possibly source rocks ; 2, the presence of a medio-marginal nappe acting as protection cover ; 3, the existence of two uplifted zones manifested by the outcropping of an external unit in the Bistriţa and Oituz-Slănic semiwindows, round which the oil deposits are grouped.

The most important deposit group in Romania is to be found in the Carpathian Foredeep, generally corresponding to the diapiric folds (the Ploieşti-Tîrgovişte-Piteşti zone). The factors favouring these important accumulations are : 1, a succession of Tertiary deposits with numerous sand, sandstone, marl and clay sequences, the latter showing geochemical indexes characteristic of the source rocks ; 2, a folded structure represented by anticlines and synclines which are very well individualized and have considerable amplitudes; 3, the diapirism which determined a favourable evolution from the point of view of the structogenesis of the accumulation conditions and protection conditions of the deposits; 4, the diapir anticlines formed gradually, permanently maintained uplifted positions and constituted calling zones for the hydrocarbons generated in the neighbouring sectors; 5, the diapir salt functioned as a protection screen without permitting (with a few exceptions) the vertical migration of the oil and gas (Walters, 1940; Landes, 1959). At the same time, the salt movement probably determined an increase of the geothermal gradient in the vicinity of the diapir structures. Another preferential accumulation zone is situated in Oltenia and corresponds to the main Bustuchini-Socu-Ţicleni-Bîlteni alignment, which is an equivalent (small in size) of the important Băicoi-Moreni-Tîrgovişte-Piteşti echelon. The favourable factors are the same, except the diapirism, partly compensated by a considerable development of the Sarmatian and Helvetian deposits.

Three preferential accumulation zones are also present in the Moesian Platform. In the western part of this unit, corresponding to the Craiova-Balş-Optaşi uplift, are grouped the deposits located in the Paleozoic, Triassic, Jurassic. The most important accumulation zone in the Carpathian Foreland is situated west of Bucureşti. This zone constitutes a reply of the platform to the huge deposits at Băicoi-Moreni-Tîrgovişte (in the foredeep), by the symmetrical position on either side of the foredeep axis and by its importance. West of Bucureşti, in the median part of the Moesian Platform, the Tortonian, the Meotian, and especially the Cretaceous and the Sarmatian yield hydrocarbons. The hydrocarbon agglomeration here was determined by the favourable evolution of the Lower Cretaceous and Sarmatian facies as well as by the presence of the Tortonian deposits, showing partially reservoir properties. The existence of some screening faults offered imprevious seals to the hydrocarbons accumulated in front of them. This zone corresponds to a positive geothermal anomaly characterized by the greatest temperature gradients in the Carpathian Foreland, namely 5–6°C/100 m. The third preferential accumulation zone lies in the eastern part of the platform (Bordei Verde). The favourable factors consist in the existence of an important uplift, the Bordei Verde Promontory, bounded by a sunk zone, the prolongation of the Focşani Depression. Numerous pinching out of the strata, facies variations and faults against a constantly eastward uplifting background constituted the propitious framework for the formation of the oil and gas deposits at Oprişeneşti, Bordei Verde, Lişcoteanca, Jugureanu etc. This accumulation zone also corresponds to a positive geothermal anomaly.

In the North-Dobrogean Promontory and the Bîrlad Depression appears a preferential accumulation zone overlying the longitudinal crest (in the basement) of the promontory marked by the Independenţa, Matca, Ţepu deposits. The main favourable factor in these two sectors consists in the local structural conditions determined by the details of the buried paleorelief.

A large but discontinuous gas field is to be found in the Roman-Bacău sector, in the Moldavian Platform. It is characterized by the presence of numerous sand and sandstone lenses in the Sarmatian clays, against a regional monoclinal background. Like the Videle sector, the Roman-Bacău gas field corresponds to a positive geothermal anomaly appearing round the "Siret fault" which separates the two zones with different basement : a Precambrian, metamorphosed basement consisting of greenschists on the west. The central part of the Transylvanian Depression is the most prolific. It is characterized by a thick section of Neogene sediments, by an almost equal ratio of pelites and psamites, by calm domes showing considerable size and amplitudes. The size and value of the accumulations gradually decrease towards the margins, owing to the lithofacial changes, the complicated structures and the less favourable evolution (intraformational gaps). In the south and east extremities, where the gas formation shows a shore, coarse facies, the sands and conglomerates are washed by waters, while some sandy intercalations contain gas.

The most important deposits in the Pannonian Depression correspond to the Calacea-Satchinez-Şandra-Variaş buried crest . The respective region remained predominantly uplifted up to the Pliocene, determining the accumulation of some deposits with good reservoir properties in the Neogene and constituting calling centres for the hydrocarbons generated in the adjacent zones. This preferential accumulation zone is also marked by a high geothermal gradient. The second zone corresponds to the Teremia-Cherestur-Pordeanu buried crest which benefited by the same conditions as the previous one.

The examination of the preferential accumulation zones throughout the country reveals the fact that the margins of the platforms, although more sunk, polarized most of the oil and gas deposits as compared to the more uplifted platform sectors. This situation might be explained by the paleogeographic evolution (in the past the sides of the platforms acted partly as uplifted zones), but especially by their particular mobility during the Neogene. The sinking process associated with the basement fracturing, constituted positive factors determining some more favourable geothermal conditions. At the same time, the mobility of the platform borders brought about the intensification of the migration and fluid gravitational separation processes.

The above considerations raise the question of the "moment" of the formation of the hydrocarbon deposits. Taking into account the very different age of the productive formations and accepting the autochthonous origin of the oil and gas, it is necessary to admit that the formation of the Romanian deposits underwent several stages.

It has already been mentioned that the oldest hydrocarbon saturated reservoirs are of Devonian, Triassic and Middle Jurassic age and that they were found in the Moesian Platform. As their existence is connected with the old Craiova-Balş-Optaşi uplift, one may infer that the respective deposits formed in the pre-Cretaceous. An older age assigned to them does not seem justified as the Devonian, which is productive at

Bibeşti, is transgressively overlain by the Triassic, also impregnated with oil. The Triassic, in its turn, seems to be directly overlain by the Malm deposits. In addition, several accumulations located in the Triassic make up common deposits to those in the Dogger (Ciureşti, Oporelu, Iancu Jianu ?).

The Lower Cretaceous and Albian deposits grouped in the eastern part of the platform are often independent from the Sarmatian-Pliocene ones and consequently must have formed during the Upper Cretaceous.

The accumulations in the Paleogene flysch zone are younger than the Styrian phase when the medio-marginal unit protecting these deposits formed. As far as most accumulations in the Carpathian Foredeep are concerned (the sunk foreland margins inclusively) they seem to have formed gradually from the Styrian phase to the Levantine as the subsidence process intensified and the zone axis migrated. About the same time the redistribution of the older accumulations took place, especially on the external (epiplatform) foredeep flank. This fact is proved by the Brădeşti deposit located in the Triassic and protected by the Sarmatian pelites. Most of the accumulations in the internal depressions seem to be of similar age.

The physical and chemical analyses of the liquid and gaseous hydrocarbons, although carried out in time, according to different techniques, methods and criteria, indicate that differentiations appear in the oil and gas comparison.

A first remark reveals that the strata lying at small depths or outcropping, irrespective of age, generally contain heavy oil (e.g. the Moreni Levantine, the Matiţa-Podenii Noi-Pliocene, the Suplacu de Barcău-Pliocene etc.). The oil becomes lighter with depth under perfect protection conditions. Secondly, it is found that the Dacian fluid hydrocarbons are predominantly asphaltic. The paraffin content increases down the stratigraphic scale, in the Meotian and Miocene (C a s i m i r, 1934), most of the oils become paraffinic (H l a u s c h e k, 1950; W a l t e r s, 1960; C r e a n g ă et al., 1962; G r i g o r a ş, P e t r i ş o r, 1963). The same analyses show that there are no intermediary types between the Dacian asphaltic oils and the Meotian paraffinic ones, which constitutes an indication of the various source (H l a u s c h e k, 1950). Thirdly, it is worth mentioning that the oil in the Miocene formation coming into contact with the productive Pliocene along the unconformity line is the same as the Meotian oil, which suggests their common origin. But when examining each productive formation it is found that there are different types of oil within the same deposit, horizon or stratum. Beside this variation, it is worth mentioning the sulphide presence in the hydrocarbon chemical composition of the Oporelu and Bibeşti deposits located in Triassic + Dogger and Devonian, respectively. Both deposits lie at the depth of over 3,300 m and are located in carbonatic reservoirs.

Metallic constituents, the most of which being the vanadium and the nickel, were poined out in the oils as well as in the rocks, making up the productive formations or in the supposed hydrocarbon generating deposits. They probably come from the source rocks as metals initially connected with the organic substance (Landes, 1959). The associated or free gas may contain in various proportions two or several components from the hydrocarbon series. The poorest gas was found in the Transylvanian Depression, where CH_4 exceeds, sometimes 99 per cent. The rich gas is, as a rule, associated with the oil deposits. Nonhydrocarbon elements were also identified in the gas composition of numerous deposits : CO_2, N_2, O_2, H_2S, He etc. The major components (CO_2 and N_2) reach 99 per cent of the gas volume in some deposits, while the minor components (O_2, H_2, Ar, CO_2, H_2S) reach less than 1 per cent.

The frequency and concentration of the nonhydrocarbon constituents are much higher in the Carpathian Orogen units (the Transylvanian Depression, the Pannonian Depression, the East Carpathians) than in the foreland units. Within the main oil and gas basins, the nonhydrocarbon component concentrations vary according to the distance from the deep faults, enabling the migration of the elements of internal origin, to the position of the metamorphic or volcanic basement, to the age of the accumulations, to the age of the productive formations, to the position of the wells on the structure and to the duration of the deposit exploitation.

The most important CO_2 and N_2 accumulations are of plutonic origin, and also, partly, H_2 and CO_2. The metamorphism of the organic substances and the hydrocarbon weathering are responsible for the CO_2, N_2, O_2, H_2, H_2S partial generation. The rock radioactive disintegration or diagenesis led to the formation of He, CO, Ar, CO_2. Some of the N_2, O_2, Ar come from the atmosphere and from the waters of infiltration. The revaluation of these nonhydrocarbon constituents started by the exploitation of the Ciocaia CO_2 deposit; such gas will be used in the application of the secondary or tertiary methods of oil recovery.

The deposit pressures are generally equal to the pressures exerted by the hydrostatic column. Lower values occur seldom enough, being characteristic of the reservoirs with high permeabilities and regional developments in the foreland units. Higher values than the hydrostatic pressures occur frequently in the Carpathian Foredeep and less in the other units. Abnormal pressures are found in the formations showing strong lithofacial variations including rock advanced diagenesis stages and in the tectonically complicated zones. It is the case of the gray Helvetian, the Oligocene in Pucioasa facies, the Cretaceous of the East Carpathian flysch etc.

The data provided by the deep drillings indicate the existence of abnormal pressures in another two zones, these pressures may be variously explained. Thus, the pressure gradient is 1.54 $kgf/cm^2/10$ m in the Moreni diapir fold zone. This high value might be due both to the tangential movements which affected the region and to the structural complications and the lithofacial variations in the region. Another situation was found in the maximum subsidence zone at the Sarmatian and Pliocene levels, where the Mitrofani and Tinosu wells indicated gradients of 1.70—1.84

kgf/cm^2/10 m. The mentioned pressures might be explained by the fact that, in this recent hypersubsidence zone, the intensity of the process of fluid expulsion from the rock pores was exceeded by the rhythm of the sediment accumulation, thus occurring abnormal pressures.

Some remarks on the geothermal gradient were made in the first part of this chapter. In addition, it is worth mentioning the fact that, apart from the average thermicity variation of the different geological units and subunits, the vertical distribution of temperatures also varies (Paraschiv, Cristian, 1966). The geothermal gradient tends to decrease with depth in all the units of interest for petroleum. The increase of the geothermal gradient towards the surface is obvious at the depth of 1,000—500 m, especially in the East Carpathians, the Carpathian Foredeep, the Transylvanian Depression and in the Pannonian Depression. This situation was interpreted in a recently published paper (Paraschiv, Cristian, 1976).

The geological and exploitation surveys carried out in the 122 years of activity, attested by official documents, provided a detail and semidetail degree research of the eight major structural units and of all their formations of interest to the depth of 3,200—3,500 m. The fact allowed the discovery of the main deposits and of most of the small and very small accumulations, found at the respective depth. A less profound knowledge was achieved, at the same depths, in the zone with very complicated tectonics, corresponding to the Paleogene flysch and the East Carpathian Miocene zone. The geological formations situated at the depth of over 3,200—3,500 m on the units where the sedimentary touched such thicknesses are also regarded as explored regionally or in semidetail. Considering this situation, the following natural question arises: what will be the future activity of the Romanian petroleum geology?

A first target is the exploitation in detail of the formations lying at the depth of less than 3,200—3,500 m, including the "obscure and subtle" traps (Levorsen, 1966) that play an important part. Secondly the exploration of the units lying at the depth of over 3,200—3,500 m will continue. Special efforts will be also made for the efficient prospection and exploration of the formations with very complicated tectonics in the East Carpathian flysch and the Neogene zone. The exploration of the Black Sea off shore has also started. At the same time inventory and, possibly, revaluation studies on the tar sands will be made. The reservoir engineering will associate with the efforts made for the increasing of the final recovery factor of the reserves. These are the basic tendencies of the future activity which correspond, in fact, to those of the other petroleum producing countries in the world.

Concerning the means and methods for the solving of the future geological problems, the stress will be laid on the improvement of the execution processing and interpretation of the results of the geophysical and, especially, seismic prospections; one must add the diversification and improvement of the laboratory analyses, the studying and synthetizing of all the available data with a view to improving the projection of the exploration works. But the most efficient and valuable method, which cannot be replaced either by the execution rhythm or the improvement of the inventory methods, remains the geological thinking. Therefore the maximum efforts should be made for attaining this purpose.

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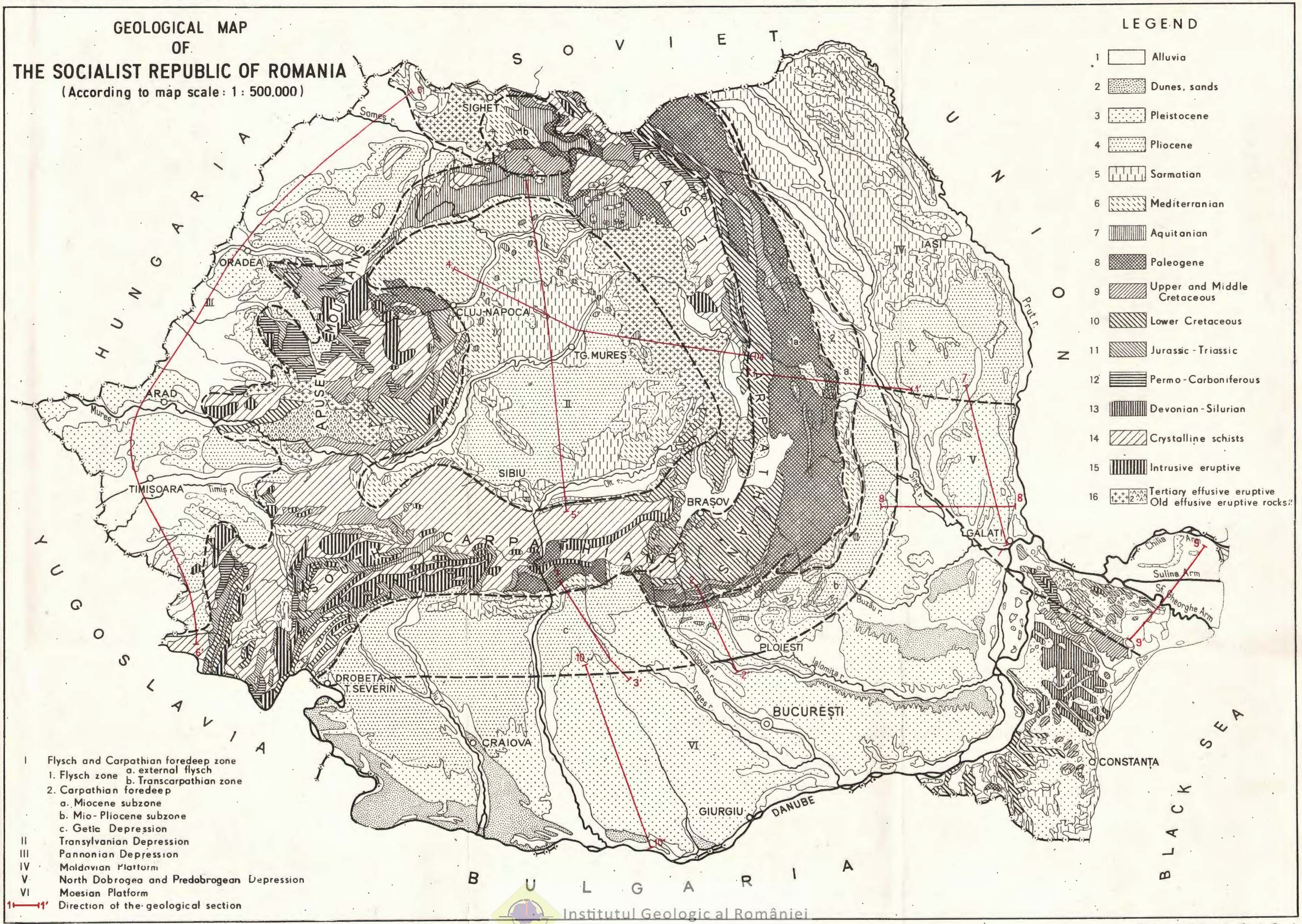

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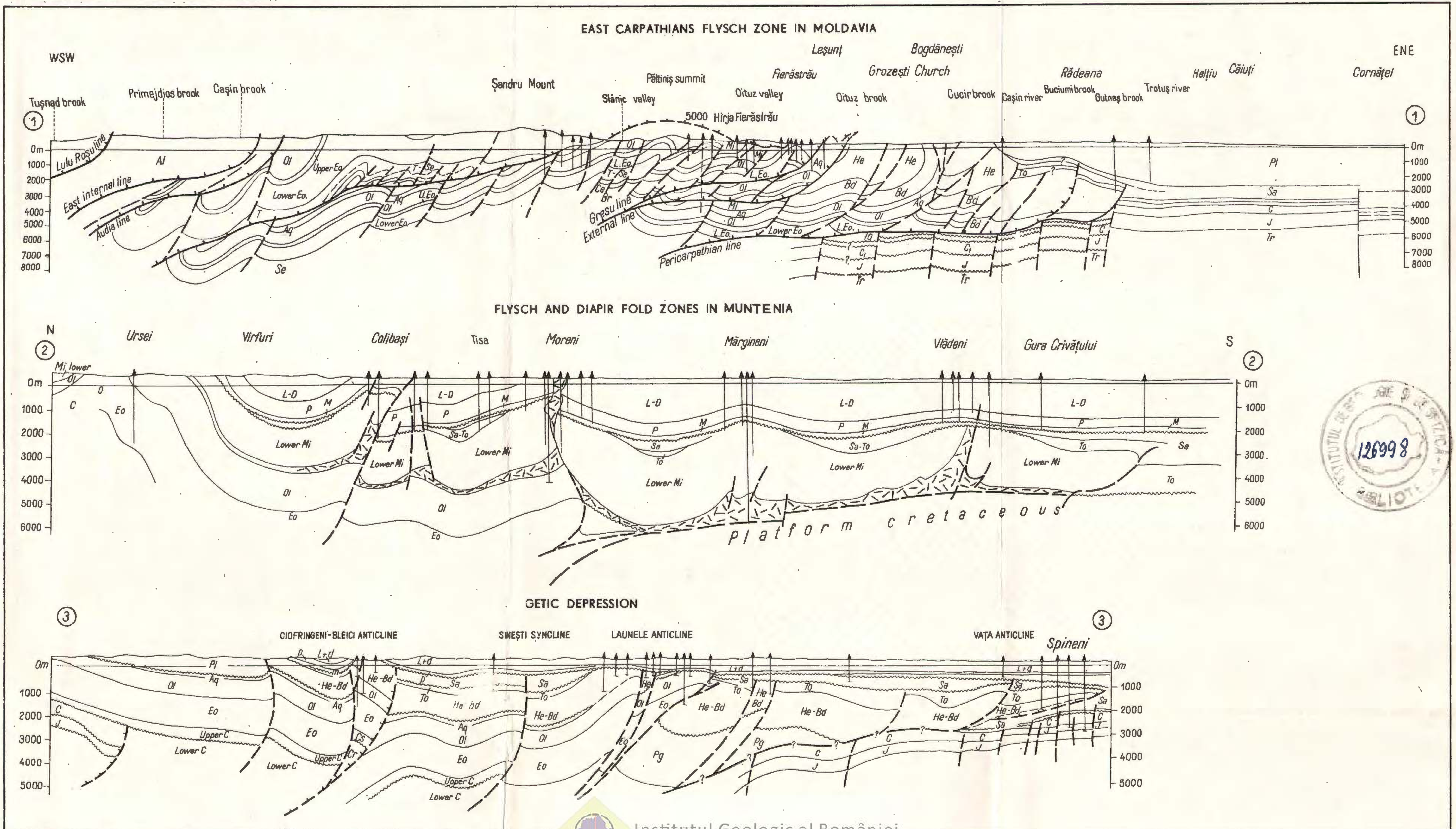

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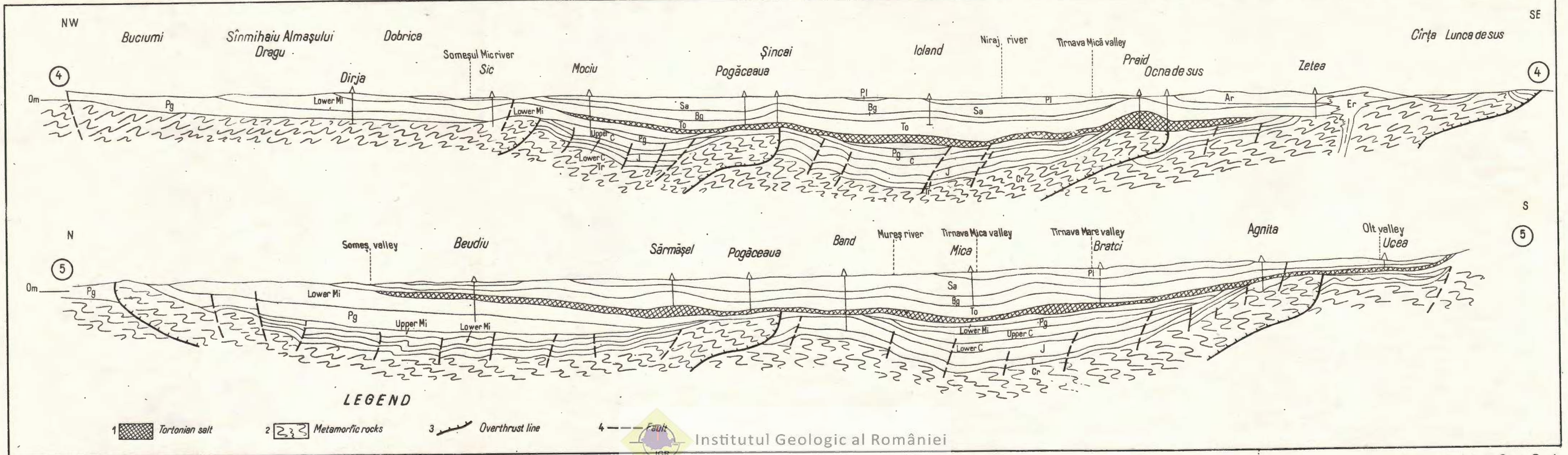

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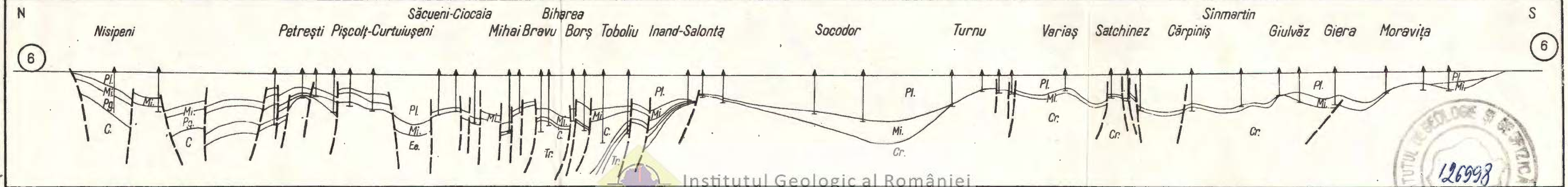

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GEOLOGICAL SECTIONS IN NORTH DOBROGEA AND THE PREDOBROGEAN DEPRESSION

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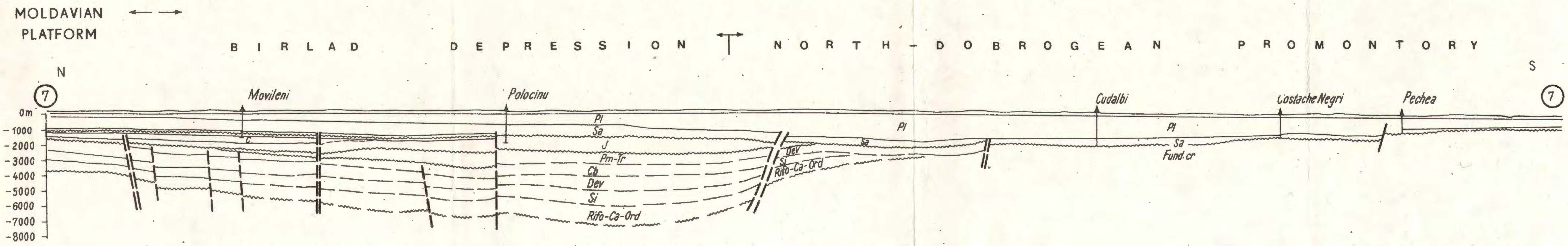
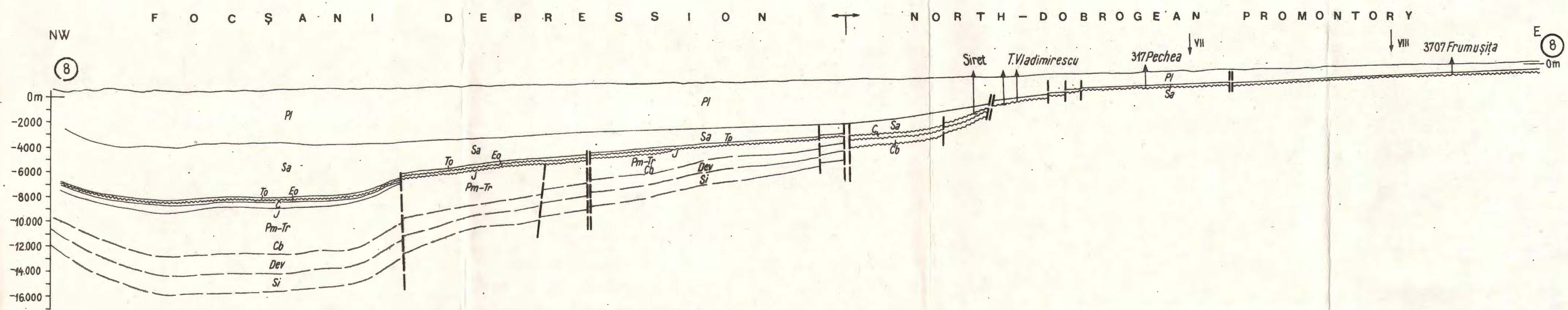
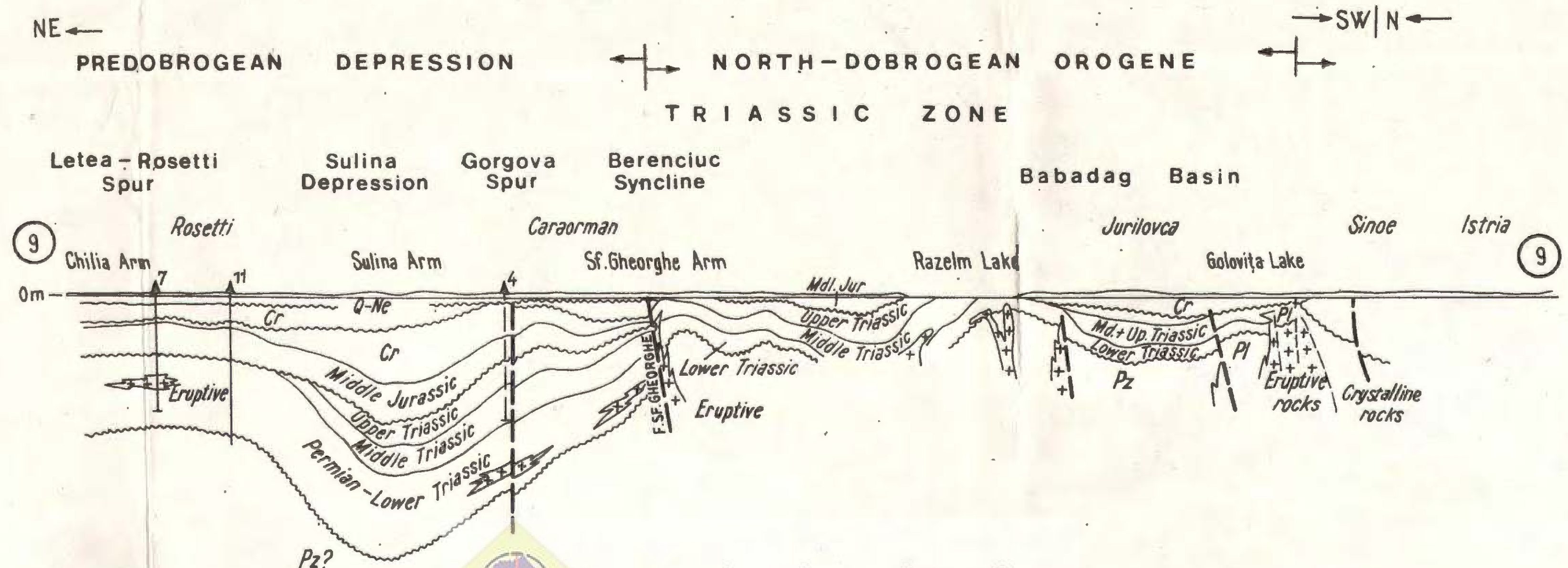
4. NORTH DOBROGEAN PROMONTORY - BÎRLAD DEPRESSION



5. NORTH-DOBROGEAN PROMONTORY - FOCŞANI DEPRESSION



6. NORTH DOBROGEA - DANUBE DELTA



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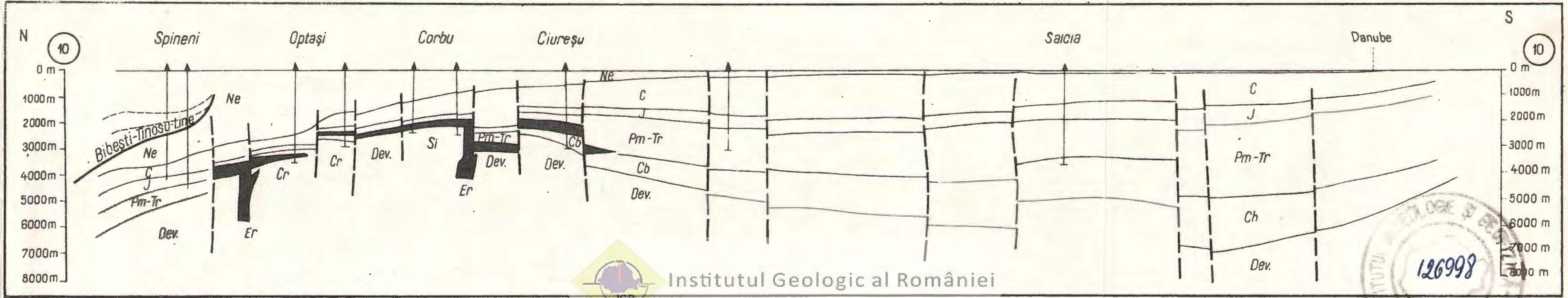

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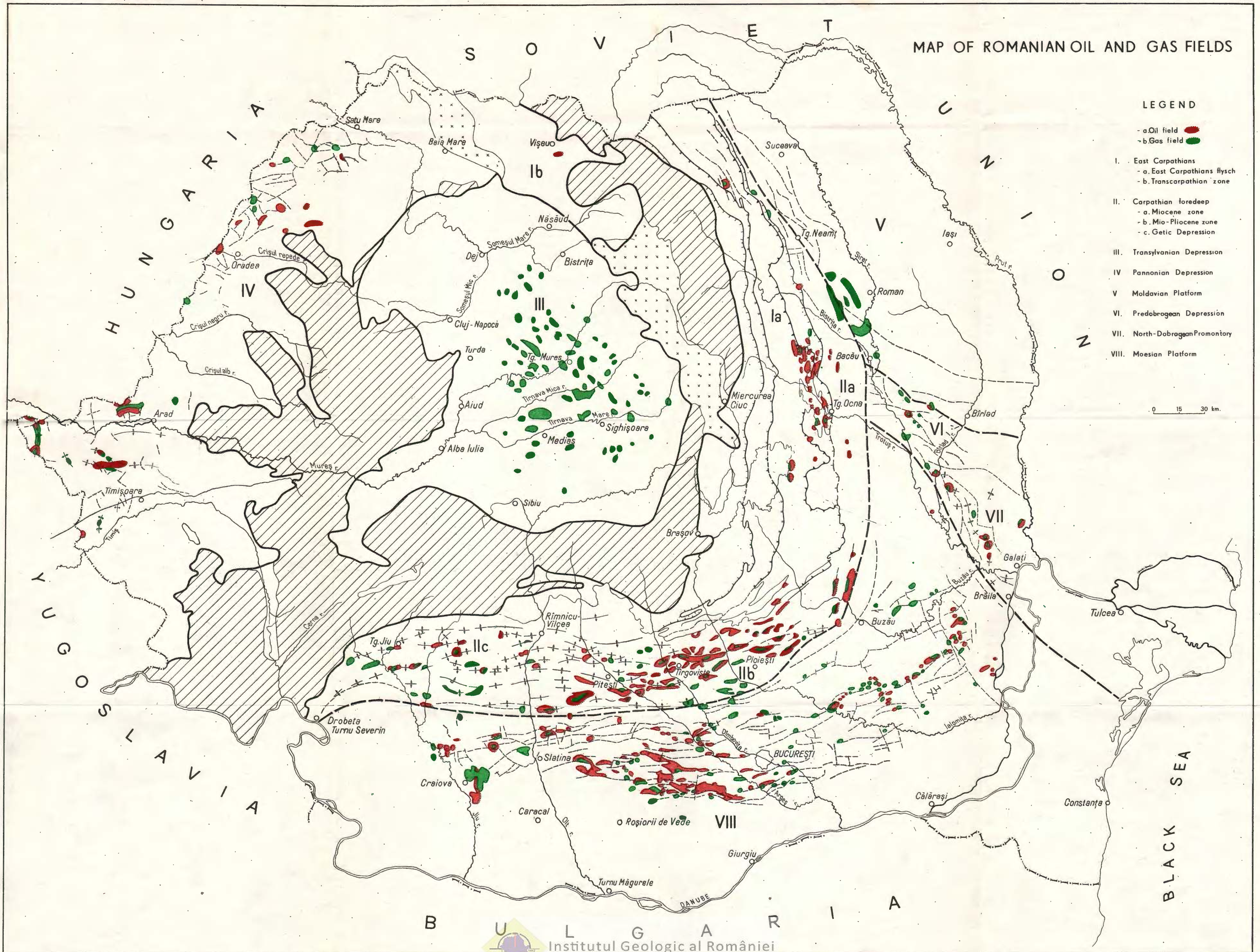
MAP OF ROMANIAN OIL AND GAS FIELDS
LEGEND
- a. Oil field
- b. Gas field
I. East Carpathians
- a. East Carpathians flysch
- b. Transcarpathian zone
II. Carpathian foredeep
- a. Miocene zone
- b. Mio-Pliocene zone
- c. Getic Depression
III. Transylvanian Depression
IV Pannonian Depression
V Moldavian Platform
VI. Predobrogean Depression
VII. North-Dobrogean Promontory
VIII. Moesian Platform
0 15 30 km.
S O V I E T U N I O N
H U N G A R I A
Y U G O S L A V I A
B U L G A R I A
BLACK SEA
Satu Mare
Baia Mare
Vişeu
Suceava
Năsăud
Tg. Neamţ
Iaşi
Oradea
Crişul repede
Someşul Mare r.
Dej
Bistriţa
Roman
Siret r.
Prut r.
Someşul Mic r.
Cluj-Napoca
Crişul negru r.
Turda
Tg. Mureş
Bistriţa r.
Bacău
Crişul alb r.
Tîrnava Mica r.
Tîrnava Mare
Miercurea Ciuc
Tg. Ocna
Aiud
Arad
Sighişoara
Mediaş
Bîrlad
Alba Iulia
Trotuş r.
Bîrlad r.
Mureş r.
Timişoara
Timiş r.
Sibiu
Braşov
Galaţi
Buzău r.
Brăila
Cerna r.
Rîmnicu-Vîlcea
Buzău
Tulcea
Tg. Jiu
Ploieşti
Tîrgovişte
Piteşti
Drobeta Turnu Severin
Ialomiţa r.
Dîmboviţa r.
Slatina
BUCUREŞTI
Craiova
Argeş
Călăraşi
Constanţa
Caracal
Olt r.
Jiu r.
Roşiorii de Vede
Giurgiu
Turnu Măgurele
DANUBE
Ia
Ib
IIa
IIb
IIc
III
IV
V
VI
VII
VIII

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