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STRATIGRAPHIC DISTRIBUTION AND BIOZONATION OF TITHONIAN PRAECALPIONELLIDS AND CALPIONELLIDS FROM THE SOUTH CARPATHIANS

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-Project 362 Tethyan-Boreal Cretaceous Correlation
-Jurassic-Cretaceous Boundary W.G.

Key words: Chitinoidellids. Semichitinoidellids. Calpionellids. Tithonian. Biozones. Tethys. South Carpathians. Romania.

Abstract: Stratigraphic distribution and biozonation of Tithonian praecalpionellids (Chitinoidellidae TREJO, 1975, and Semichitinoidellidae NOWAK, 1978) and calpionellids (Calpionellidae BONET, 1956) have been examinated into two pelagite/hemipelagite sequences from the South Carpathians. Consequently, the following successive biozones are distinguished: Chitinoidella Zone (late Early to earliest Late Tithonian) divided into Dobeni and Boneti Subzones; Praetintinnopsella Zone (early Late Tithonian *p.p.*) with its lower boundary close to the Early-Late Tithonian limit; Crassicollaria Zone (Late Tithonian *p.p.*), including Parvula (*nom. nov.*), Intermedia and Colomi Subzones; and Calpionella Zone with its first Alpina Subzone (Early Berriasian *p.p.*). The base of the last zone (boom of small- to medium-sized *Calpionella alpina*), practically admitted as Tithonian-Berriasian and Jurassic-Cretaceous boundaries, is an obvious event.

1. Introduction

Stratigraphic distribution and biozonation of Tithonian praecalpionellids (Chitinoidellidae TREJO, 1975, and Semichitinoidellidae NOWAK, 1978) and calpionellids (Calpionellidae BONET, 1956) have been investigated into two basinal (*s.l.*) carbonate formations from the South Carpathians: Marila Formation in the Reşiţa Basin (cover of Getic Nappe, Median Dacides) and Greben Formation in the Sirinia Basin (cover of inner Danubian Domain, Marginal Dacides) (see: Codarcea, 1940; Săndulescu, 1984). These Jurassic-Early Cretaceous intramarginal basins (as well as other ones) appear as satellite ones of the main Severin Basin, with stretched continental and partially oceanic crusts (Săndulescu, 1994).

The related results acquired and here presented prove the high-resolution potential of these microorganisms in their corresponding time-interval. The same results are parts of new data included in the unpublished annual reports on the stratigraphy of sedimentary deposits around the Jurassic-Cretaceous boundary (Pop et al., 1992-1997).

2. Lithostratigraphy

Some short lithostratigraphic and biostratigraphic data on the above mentioned formations are useful in order to better integrate the examined sequences.

2.1. Marila Formation (late Early Tithonian to early Late Berriasian). The first name of these limestones, namely Judinakalk of Kudernatsch (1855), was much later abandoned and replaced by the current Marila Limestones by Răileanu et al., (1957). Subsequently, both the lithology and biostratigraphy of this formation were more or less described and documented in many works, such as: Mutihac (1957, 1959, 1964), Răileanu et al. (1961, 1964), Filipescu & Dragastan (1963), Năstăseanu (1964, 1979), Bădăluţă-Năstăseanu & Năstăseanu (1964), Pop (1974, 1976, 1989), Bădăluţă (1975), Morariu (1976), Patrulius et al. (1976), Bucur (1988, 1992), Bucur et al. (1982), Bucur & Oros (1987), Avram et al. (1987), Pop et al. (1992, 1993, 1995, unpubl.), Melinte (1992), Pop & Grigore (1997, unpubl.) and others.

In absence of an adequately designated original stratotype of Marila Formation, we propose here a lectostratotype situated in the left slope of the Miniş valley (upper course), about 150-250 m upstream of its confluence with Mândrişag brook, at 6.5 km SSW of Anina, Caraş-Severin District, cropping out along Oraviţa-Anina highway escarpment, where it is accessible and relatively well exposed (Figs. 1, 2; Crivina sections).

Marila Formation is an important litho-

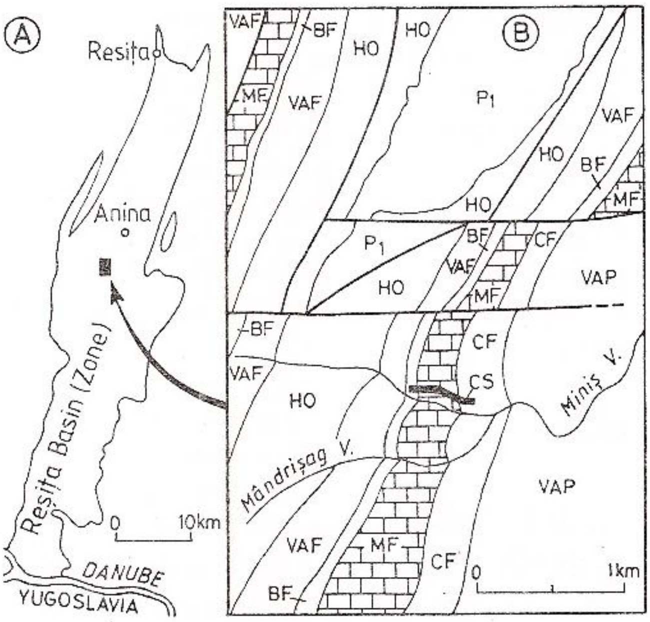

Fig. 1 - Marila Formation in its lectostratotype area (eastern flank of Anina anticline) and the location of Crivina sections in the Reşiţa Basin. P_1, Early Permian red beds deposits; HO, Hettangian to Early Oxfordian deposits; VAF, Valea Aninei Formation (Late Oxfordian-Early Kimmeridgian, cherty pelagites and allodapic calciturbidites): BF, Brădet Formation (Late Kimmeridgian-late Early Tithonian *p.p.*, marly nodular limestones); MF, Marila Formation (late Early Tithonian *p.p.*-early Late Berriasian, Maiolica limestone type); CF, Crivina Formation (early late Berriasian *p.p.*-Late Valanginian *p.p.*, marlstone and limestone interbeds): VAP, Late Valanginian *p.p.*-Aptian deposits, including thick Urgonian type limestones (Barremian-Aptian). Simplified according to the Geological map of Romania, 1:50,000, Anina sheet (Năstăseanu & Savu, 1971).

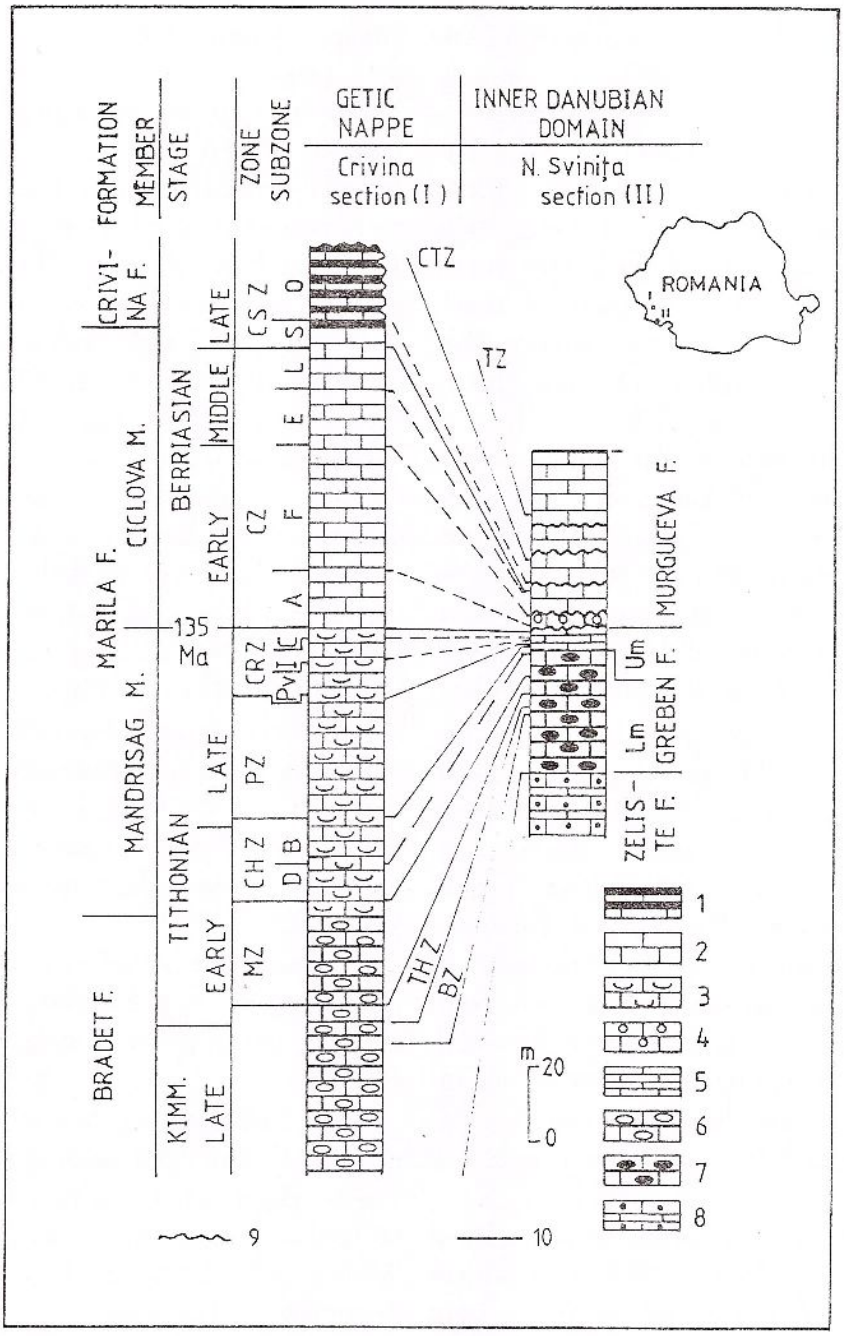

Fig. 2 – Formations and facies in the Crivina (Reşiţa Basin) and N Sviniţa (Sirinia Basin) sections and their correlations. Lithology: 1, marlstone and pelagic limestone interbeds; 2, pelagites (micrites/biomicrites) of Maiolica type; 3, pelagites with bioturbations and allodapic calciturbidite interbeds; 4, allodapic calciturbidites and carbonate debris flows in the base of Murguceva F.; 5, thin bedded gray-greenish pelagites with rare allodapic calciturbidites and nodular/protonodular interbeds (Um = upper member, Greben F.); 6, gray-greenish marly nodular limestones including some allodapic calciturbidite interbeds (Brădet F.); 7, reddish and polychrome nodular limestones (Lm = lower member, Greben F.); 8, interbedded cherty pelagites and allodapic calciturbidites (Zelişte F., Oxfordian p.p.- Early Kimmeridgian);); 9, syn-sedimentary erosional hiatus; 10, fault. Biozones (zone = Z; subzone = SZ): BZ, Borzai Z; THZ, Tithonica Z; MZ, Malmica Z; CHZ, Chitinoidella Z with D, Dobeni SZ and B-Boneti SZ; PZ, Praetintinnopsella Z; CRZ, Crassicolaria Z with Pv-Parvula SZ, I-Intermedia SZ and C-Colomi SZ; CZ, Calpionella Z with A-Alpina SZ, F-Ferasini SZ, E-Elliptica SZ and L-Longa SZ; CSZ, Calpionellopsis Z here only with S-Simplex SZ and O-Oblonga SZ; CTZ, Calpionellites TZ-Tintinnopsella Z.

stratigraphic unit (100-250 m thick) in the Jurassic and Early Cretaceous succession (Anina Group) of the Reşiţa Basin, and largely widespread in this area (see: Năstăseanu, 1964; Răileanu et al., 1964). This formation mainly consists of bedded white to cream-coloured micrites and biomicrites (pelagites) of Maiolica type, with rare nodular cherts and very thin interbedded marlstones. It conformably overlies Brădet Formation (Late Kimmeridgian to late Early Tithonian), formed of grayish and greenish marly nodular limestones (50-100 m thick), and underlies Crivina Formation (early Late Berriasian to Late Valanginian *p.p.*), represented by irregularly interbedded marly micrite/biomicrite and marlstones (100-200 m thick). The boundaries of Marila Formation are often transitional and slightly diachronous.

According to our data, in the type section as well as in other ones, Marila Formation may be divided into two subunits: Mândrişag Member (*nom. nov.*) in its lower part (Tithonian sequence), after the name of Mândrişag brook, and Ciclova Member (*nom. nov.*) in its upper part (Berriasian sequence), after the name of Ciclova valley situated south of Oraviţa town. In the same valley, east of Ciclova Montană village, a parastratotype of this second member is admitted. The limit between the two members is gradual and oscillates around the Tithonian-Berriasian boundary (Fig. 2).

Mâdrişag Member is often characterized by bioturbated limestones, including pelagites and interbedded allodapic calciturbidites, mud flows sometimes variously mixed with allodapic sediments and forming very thick interbeds (up to 1.5 m thick), and locally carbonate debris flows. The micritic aggregate of pelagites, mainly consisting of neomorphosed particles of calcareous nannofossils, comprises more or less abundant calcitized radiolaria, *Globochaete alpina*, sponge spicules, praecalpionellids, calpionellids, *Saccocoma* sp., calcispheres, microbivalves, rare aptichi, planktonic and benthonic foraminifera, belemnites, etc. The bioturbation traces are marked by intraclasts and burrow-fillings often combined with geopetal structures. The allodapic calciturbidites are of peloid-bioclastic packstone, wackstone and grainstone types with their grains derived from the adjacent shallow water carbonate platforms. Except for micritic intraclasts and matrix, the allodapic grains consists of peloids, bioclasts (crinoids, neomorphosed bivalves, algal crusts, calcareous algae, corals, benthonic foraminifera etc.), oncoids, rare ooids etc. (see: Pop, 1976).

Ciclova Member is represented by more homogeneous pelagites containing calcitized radiolaria, *Globochaete alpina*, calpionellids, calcispheres, rare thin-shelled microbivalves, aptychi, planktonic and benthic foraminifera, belemnites etc., without or with very scarce bioturbation traces. Thin to very thin marlstone interbeds are also rare. In its topmost part, the pelagites gradually become slightly marly. However, some local interbeds of allodapic calciturbidites bearing rich infralittoral foraminifera and algae are noticed (Bucur & Oros, 1987).

Synsedimentary deformation by slumping, indicating westward slides, were observed in a lot of outcrops of Marila Formation (Pop, 1976).

This formation occurs within several longitudinal anticlines and synclines from the Reşiţa Basin area, formed by compressional tectonics during the Austrian (Late Aptian-Albian *p.p.*) and mainly Laramian (Late Senonian) tectogenesis.

Marila Formation is assigned to late Early Tithonian-early Late Berriasian interval particularly on the basis of praecalpionellid and calpionellid zones (Pop, 1974; this paper). In the designated lectostratotype, its lower boundary is placed 5 m below the base of Chitinoidella Zone, while its upper one is situated within the calpionellid Simplex Subzone (Fig. 2). A few ammonite moulds are also known: *Pseudosubplanites grandis* (MAZENOT) in the upper part of calpionellid

Ferasini Subzone, and *Fauriella* cf. *boissieri* (PICHET) as well as *F. latecostata* (KILIAN) in some upper levels (see Mutihac, 1959; Pop, 1974; Patrulius et al., 1976; Bucur et al., 1982). *Spiticeras (Negreliceras) paranegreli* DJANELIDZE, found in the terminal level of the same formation (stratotype) by Avram et al. (1987) or rather in the basal Crivina Formation, suggests the same age of its upper boundary.

The facies of Marila Formation shows that its carbonate sediments, essentially of planktonic origin, and in part derived from the adjacent shallow carbonate platform mainly redeposited by turbidity currents, have accumulated in the eastern slope area of Reşiţa Basin, under the aragonite compensation depth (ACD) and above the calcite compensation depth (CCD) (Pop, 1976). Several connected factors have controlled the appearance and intensive accumulation of its sediments: a) Late Jurassic deformations inducing an important change in basinal hydrodynamic system, probably from prevailing restricted circulation of sea water (bottom currents) during the formation of underlying nodular limestone with a regressive facies, to an open one favouring upwellings, high planktonic productivity, a high rate of sedimentation and a CCD drop; b) an active subsidence connected with synsedimentary faulting, causing among other factors resedimentations, slides, intraformational debris flows, and supply of allodapic shallow-water carbonate sediments from the adjacent carbonate platforms (mostly eastern one) (see also Foucarde et al., 1993). Overlying marlstone-limestone alternations of Crivina Formation with a generally upward shallowing facies suggest a humid climate and a fluctuant relative sea-level.

2.2. Greben Formation (Late Kimmeridgian to earliest Early Berriasian). Named after the name of a site on the Danube (about 4 km upstream of Sviniţa village), this formation groups the former "upper nodular limestone horizon" and "compact limestone horizon" of Răileanu (1953) (Pop in Pop et al., 1996, unpubl.). The red nodular limestones, of Rosso Ammonitico type facies, locally rich in ammonite moulds and aptychi, were the object of many investigations: Tietze (1872), Schafarzik (1892), Koch (1912), (fide Răileanu, 1953), Codarcea (1940), Răileanu (1953, 1960), Răileanu & Năstăseanu (1960), Răileanu & Popescu (1964), Rusu (1970), Avram (1976, 1984), Patrulius et al. (1976), Morariu (1977, 1980), Antonescu & Avram (1980), Pop (1986, 1989), Pop et al. (1992, 1994, 1996, unpubl.), Melinte (1992), Pop & Grigore (1997, unpubl.), Grigore (in press) and others.

The stratotype (35 m thick) of the Greben Formation is situated about 500-700 m NNE of Sviniţa, Mehedinţi District, in the right slope of Vodânişki brook, along a communal road and above it (N Sviniţa section) (Fig. 3). Lower part of this formation, including its lower boundary, is well exposed in a small brook (Rigol brook) about 1 km west of Sviniţa near the Orşova-Moldova Veche road (W Sviniţa section). A parastratotype of the same formation is well exposed along the highway escarpment at Munteana, about 1 km downstream of Danube-Sirinia river confluence (Munteana section).

Greben Formation is a condensed (10-35 m thick) but impressive lithostratigraphic unit, in the Hettangian to Early Albian sedimentary succession (Almaj Group) of the Sirinia Basin. This formation consists mainly of reddish and polychrome nodular limestones, with some dominant reddish marlstone interbeds, which conformably overlies Zelişte Formation (Oxfordian *p.p.*-Early Kimmeridgian) made up of interbedded pelagites and allodapic calciturbidites with frequent banded and nodular cherts (about 25 m thick in its stratotype, W Sviniţa section), and unconformably underlies Murguceva Formation (Early Berriasian *p.p.* to Late Hauterivian *p.p.*) represented by bedded pelagites of Maiolica type, named Mur-

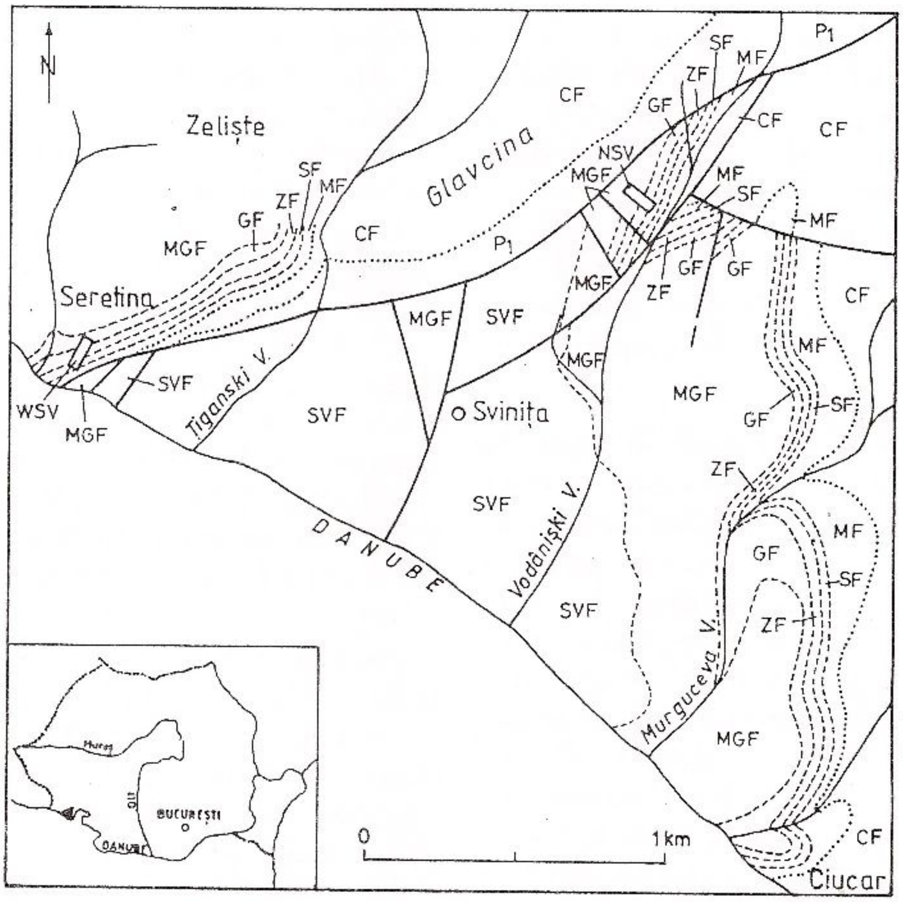

Fig. 3 – Greben Formation (GF) in the Svinița area and the location of N Svinița (NSV) and W Svinița (WSV) sections. Other formations: P1, Early Permian red bed deposits including volcaniclastics and rhyolite to basaltoid rocks; CF, Glavcina F. (Hettangian-Sinemurian), alluvial-lacustrine conglomerats, sandstones and some sandy-shaly interbeds with coal; MF, Munteana F. (Pliensbachian to Aalenian) mainly crinoidal limestones and sandstones (stratotype in the Munteana section on the Danube) , and crinoidal calcarenites with hematitic hardground (Bajocian-Early Callovian); SF, Serentina F. (Middle- Late Callovian), red nodular marly limestones (stratotype in the WSV, Rigol brook); ZF, Zeliște F. (Oxfordian-Early Kimmeridgian) cherty pelagites and allodapic calciturbidite interbeds (stratotype in the WSV); GF, Greben F. (Late Kimmeridgian to basal Berriasian), red nodular limestone complex (stratotype in the NSV); MGF, Murguceva F. (Early Berriasian to Late Hauterivian *p.p.*), pelagites of Maiolica type; SVF, Svinița F. (Late Hauterivian *p.p.* to Albian *p.p.*), marlstones and marly limestone interbeds often affected by land slides.

guceva Formation (Avram, 1976).

In the type section as well as in other ones, Greben Formation includes a lower member more developed (about 30 m thick) representing a nodular limestone complex, and an upper one (about 5-6 m thick), constituted mainly of gray-greenish thin-bedded pelagites. The boundary between the two subunits is marked by the first pelagite bed devoid of nodular fabric (Fig. 5).

The lower member displays a wide variety of carbonate rocks, comprising red nodular limestone, subnodular (proto-nodular) limestones, allodapic calciturbidites, reddish interbedded marlstones, locally intraformational breccias (debris flows) and some transitional terms.

Nodular limestones consist of generally centimetre scale more or less marly micritic/biomicritic nodules, often poorly sorted and variously shaped (ovoidal, angular, irregular, flattened, lenticular, flame-like, in place deformed, etc.), frequently forming some chaotical fabrics. Internodular relationships also vary from the sharp contacts to warpping and even stylotitic ones. In some beds, along with above nodules, other ones with own nodular texture may be recognized. Some redish nodules are ammonite molds with corrosion traces. There is no evidence of organic encrustation on the nodules. The red marlstone matrix is more or less abundant, poorly sorted and often richer in bioclast and small pelagite intraclasts than the adjacent nodules. Matrix-nodules relationships are either sharp contacts or commonly transitional and diffuse ones. Thus in the matrix-rich beds, the nodules are mostly distinguished by their lighter shades. There are also microdiapiric contacts between matrix and nodules. In some poorly bedded and matrix-rich intervals, the textures of nodular limestones remind the olistostrome facies (Fig. 5), in which the light gray calcarenite pebble reworked from the underlying calciturbidites are present.

In the subnodular fabrics (limestone-rich and marlstone-rich) the nodules are only slightly or partially differentiated and often show a fluidal structure.

The nodular fabrics and the bedding of this member are both vertically and laterally variable so that their lithological correlation is difficult.

The above nodules include more or less abundant planktonic microbioclasts, such as: calcitized radiolaria, *Globochaete alpina, Saccocoma* sp. (common to abundant), calcispheres, sponge spicules, microbivalves, globigerinids, chitinoidellids (subcommon). Aptychi and belemnites are also encountered. According to SEM observations, their micritic mass is formed of badly preserved particles of planktonic nannofossils. At some stratigraphic levels, some thin interbeds of reddish marlstones are known. They are poorly sorted and in place contain ammonite, aptychi, belemnites and rare brachiopods. The available data show that these marlstone interbeds represent very condensed intervals, sometimes associated with important hiatuses (Pop & Grigore, 1997). The traces of bioturbation are scarce.

Several interbedded gray calcarenites and calcirudites, often graded, are also present. They are calciturbidite whose carbonate grains derive from an adjacent carbonate platform, subsequently redeposited within the basinal slope area by the turbidity currents. Their grains consist of different bioclasts of crinoids, sparitized bivalves, calcareous algae, corals, benthic foraminifera, peloids, micro-oncoids, ooids etc. Micritic intraclasts are associated. The calciturbidites form some medium to thick beds with more or less irregular lower surfaces indicating erosional processes.

Without being exhausted, the lithological aspects of nodular limestones suggest multiple and successive redepositions and retexturations of some unconsolidated marly sediments, alternating with more or less lithified and thin-bedded micritic ones, originally accumulated within the area of seismically unstable eastern slope of the Sirinia Basin.

It is admitted that such an environment should involve: a slow rate of deposition of alternating marly and micritic sediments, climatically induced by orbital variation and/or a sea-level fluctuation; restricted hydrodynamic regime favouring winnowing bottom currents; differential early submarine diagenesis and solutions of two groups of sediments; seismically and tectonically unstable slope releasing slides, mud flows, debris flows and turbidity currents. The subsequent diagenesis have amplified nodular fabrics (see: Farinacci & Elmi, 1981; Foucade et al., 1993).

The upper member of Greben Formation consists of thin-bedded gray-greenish or pinkish pelagites, representing a very condensed sequence, which incorporates rare interbeds of grayish nodular and subnodular limestones as well as fine-grained allodapic calciturbidites. Their fabrics are comparable with some corresponding ones from the lower member. Accordingly, these limestones are included into Greben Formation because their facies shows a closer affinity with this formation than with the overlying one. Moreover the younger Murguceva Formation occurs after an important synsedimentary erosional unconformity with a regional extension (Rusu, 1970; Avram, 1976; Pop, 1986, 1989 and unpublished data). The same formation begins with a basal member (about 2-10 m thick) made up of allodapic calcarenites/calcirudites (calciturbidites), and breccias, in place combined with slumps, which is upwardly followed by typical Maiolica pelagites, with some slides, lesser calciturbidite interbeds and related synsedimentary erosional hiatuses.

Regressive facies and chronostratigraphic position of Greben Formation in the sedimentary succession commonly show an environmental evolution of the eastern slope of Sirinia Basin comparable with that of Reşiţa Basin, but with some differences. The above environments controlling the origin of nodular limestones were induced also by the Late Jurassic (extensional and compressional) deformations during the Late Kimmeridgian, following an Oxfordian-Early Kimmeridgian stage of maximum flooding, probably with the highest relative sea-level and an active thermal subsidence, corresponding to the post rift-like evolution of this area, in which the sediments of Zelişte Formation have accumulated. The nodular limestone paleoenvironments have persisted later than in the Reşiţa Basin, till the end of Tithonian, lastly with a deepen trend. Thus the typical environments favouring Maiolica sediment deposition have started within the Sirinia Basin later (lower Early Berriasian) than within the Reşiţa Basin (late Early Tithonian).

Present age of Greben Formation (Late Kimmeridgian to earliest Early Berriasian) is accepted on the ammonite, praecalpionellids, calpionellids and partially nannofossil zones. Following ammonite zones (Grigore, in press) has identified: Acanthicum, Cavouri and Beckeri (Late Kimmeridgian) in the lower part of lower (nodular) member, and Hybonatum/Albertinum, Verruciferum and Richteri (Early Tithonian) in its partially upper part. Within the last 7 m thick of the same member we have distinguished Chitinoidella Zone (late Early to basal Late Tithonian), with Dobeni and Boneti Subzones, successively followed within upper member by Praetintinnopsella Zone, (early Late Tithonian), Crassicollaria Zone with Parvula, Intermedia and Colomi Subzones, (Late Tithonian *p.p.*) and basal Calpionella Zone (or Alpina Subzone, Early Berriasian *p.p.*) (Figs. 5, 6). Other contributions in this respect belong to Răileanu (1953), Răileanu & Năstăseanu (1960), Rusu (1970), Avram (1976, 1984), Pop (1986, 1989) and others. The age of uppermost part of this formation is also documented by nannofossil Conusphaera mexicana and partly Polycostella beckmannii Zones by Melinte (1992).

In an interval of about 15 m thick under the base of Chitinoidella Zone from the lower member we have recently remarked four successive biozones of calcisphere: Moluccana, Borzai, Tithonica and Malmica. The base of Tithonica Zone, very close to the Kimmeridgian-Tithonian boundary, is situated about 15 m under the top of the same member or about in its median level (Pop, in Pop et al., 1996 unpubl.) (Fig. 2).

Finally, the Tithonian examined sequences represent the Mândrişag Member of Marila Formation (lectostratotype, Crivina section) and upper third of lower member as well as upper member of Greben Formation from Sirinia Basin (stratotype, N Sviniţa section, Figs. 2, 4 a-c, 5).

3. Paleontological notes

Tithonian chitinoidellids (Chitinoidellidae TREJO, 1975), semichitinoidellids (Semichitinoidellidae NOWAK, 1978) and calpionellids (Calpionellidae BONET, 1956) represent three small related groups of Tethyan planktonic microorganisms, which are distinguished by the different nature of their tests: microgranular (calcite crystallites bounded by a dark organic matter), combined microgranular and hyaline and only hyaline, respectively (Bonet, 1956; Borza, 1966; Remane, 1971, 1984; Aubry et al., 1975; Reháková & Michalik, 1993, 1997).

Table 1 Chitinoidellid genera and species from the South Carpathians

Family: Chitinoidellidae TREJO, 1975.
Type genus: *Chitinoidella* DOBEN, 1963.

Genus *Chitinoidella* DOBEN, 1963 (type-species: *Ch. boneti* DOBEN, 1963).
- *Chitinoidella boneti* DOBEN, 1963 (Pl.I, Figs. 34-37, 39).
  Synonymy: *Tintinnopsella carpathica* (MURGEANU et FILIPESCU, 1933), in: Furrazola-Bermúdez (1965). According to Borza (1965).
- *Chitinoidella elongata* POP, 1997 (Pl. I, Fig. 38).
  Synonymy: *Chitinoidella boneti* DOBEN *p.p.*, in: Borza (1969). According to Pop (1997).

Genus *Dobeniella* POP, 1997 (type-species: *D. cubensis* (FURRAZOLA-BERMÚDEZ, 1965)).
- *Dobeniella cubensis* (FURRAZOLA-BERMÚDEZ, 1965) (Pl. I, Figs. 27-29).
  Synonymy: *Tintinnopsella cubensis* FURRAZOLA-BERMÚDEZ, according to Borza (1966).
  Chitinoidella cubensis (FURRAZOLA-BERMÚDEZ), according to Borza (1966). Revised by Pop (1977).
- *Dobeniella bermudezi* (FURRAZOLA-BERMÚDEZ, 1965) (Pl. I, Figs. 22-24).
  Synonymy: *Tintinnopsella bermudezi* FURRAZOLA-BERMÚDEZ, 1965. According to Borza (1966).
  Chitinoidella bermudezi (FURRAZOLA-BERMÚDEZ), in: Borza (1966). Revised by Pop (1997).
- *Dobeniella tithonica* (BORZA, 1969) (Pl. I, Figs. 25, 26).
  Synonymy: *Chitinoidella tithonica* BORZA, 1969. According to Pop (1997).

Genus *Almajella nom. nov.* (type-species: *A. cristobalensis* (FURRAZOLA-BERMÚDEZ, 1965)).
- *Almajella cristobalensis* (FURRAZOLA-BERMÚDEZ, 1965) (Pl. I, Figs. 30-33).
  Synonymy: *Calpionella cristobalensis* FURRAZOLA-BERMÚDEZ, 1965. According to Borza (1966).
  Chitinoidella cristobalensis (FURRAZOLA-BERMÚDEZ), in: Borza (1966). Revised by Pop (1997).
  Cubanella cristobalensis (FURRAZOLA-BERMÚDEZ, 1965), in: Pop (1997), p. 932, 936, Figs. 1:6; 2:10, 11. Name changed in this paper for reason of homonymy.

Genus *Longicollaria* POP, 1997 (type-species: *L. dobeni* (BORZA, 1966)).
- *Longicollaria dobeni* (BORZA, 1966) (Pl. I, Figs. 1-4).
  Synonymy: *Chitinoidella dobeni* BORZA, 1966. According to Pop (1997).

Genus *Borziella* POP, 1997 (type-species: *B. slovenica* (BORZA, 1969)).
- *Borziella slovenica* (BORZA, 1969) (Pl. I, Figs. 16, 17).
  Synonymy: *Chitinoidella slovenica* BORZA, 1969. According to Pop (1997).

Genus *Aninella nom. nov.* (type-species: *A. insueta* (ŘEHÁNEK, 1986)).
- *Aninella insueta* (ŘEHÁNEK, 1986) (Pl. I, Fig. 21).
  Synonymy: *Chitinoidella insueta* ŘEHÁNEK, 1986. According to Pop (1997 a).
  Cylindrella insueta (ŘEHÁNEK, 1986), in: Pop (1997), p. 933, 937, Figs. 1:9; 2:16. Name changed in this paper for reason of homonymy.

Genus Carpathella POP, in press (type-species: *C. rumanica* POP, in press).
- *Carpathella rumanica* POP, in press (Pl. I, Figs. 18-20).

Genus *Daciella* POP, 1997 (type-species: *D. banatica* POP, in press).
- *Daciella banatica* POP, in press (Pl. I, Figs. 10-12).
- *Daciella almajica* POP, in press (Pl. I, Figs. 13-15).
- *Daciella danubica* POP, in press (Pl. I, Figs. 5-7).
- *Daciella svinitensis* POP, in press (Pl. I, Figs. 8, 9).

In the examined sequences from the South Carpathians we have been recognized the majority of these microorganisms (Pl. I-IV). Some of them, particularly the chitinoillids formerly assigned to the single genus *Chitinoidella*, were taxonomically revised and regrouped into several new genera. Other new taxa have also been identified (Pop, 1997, in press; Tab. 1)

Unfortunately, the names only of two chitinoidellid genera recently proposed by Pop (1977) are homonyms and here replaced by other ones: *Almajella* (nom. nov., after the name of Almaj Mts., Romania) instead of *Cubanella* (*Cubanella* FRANGANILLO, 1926, fide Loeblich & Tappan, 1988) and *Aninella* (nom. nov., after the name of Almaj Mts., Romania) instead of *Cylindrella* (*Cylindrella* SHARP, fide Slipinski, 1992) (see: Table 1).

Among the semichitinoidellids only *Praetintinnopsella andrusovi* has been remarked, but other possible taxa with two-layered test are in course of study.

Late Tithonian to Early Berriasian calpionellids are represented by all known taxa, such as: small *Tintinnopsella carpathica*, small, large and elongated varieties of *Calpionella alpina*, *Crassicollaria massutiniana*, *Cr. intermedia*, *Cr. brevis*, *Cr. parvula*, *Cr. colomi*, and *Lorenziella hungarica*. Former *Tintinnopsella remanei* is considered a synonym of *Lorenziella hungarica* according to their similar test (Durand-Delga, 1994 personal information). Some new surprising events are the first occurrences of small *Tintinopsella longa* (Pl. II, Fig. 22, length/width ratio over 1.5) and of *Remaniella* aff. *catalanoi* POP, 1996, in the Parvula Subzone (Crassicolaria Zone).

The morphology of chitinoidellid species suggest some possible phyletic relationships among them, such as: *Chitinoidella boneti* → *Ch. elongata; Dobeniella tithonica - D. cubensis - D. bermudezi* whose evolutionary succession remains to be clarified; *Daciella danubica-Almajella cristobalensis; Daciella danubica - D. svinitensis*; and *Daciella banatica - D. almajica.*

Up to now, the direct ancestors of chitinoidellids are unknown. Taking into account the obvious morphological resemblance between some chitinoidellids and calpionellids, a corresponding ancestor-descendant relationship is admitted, following indirectly and/or directly several parallel lineages (clades). They are: *Chitinoidella boneti* → *Praetintin-*

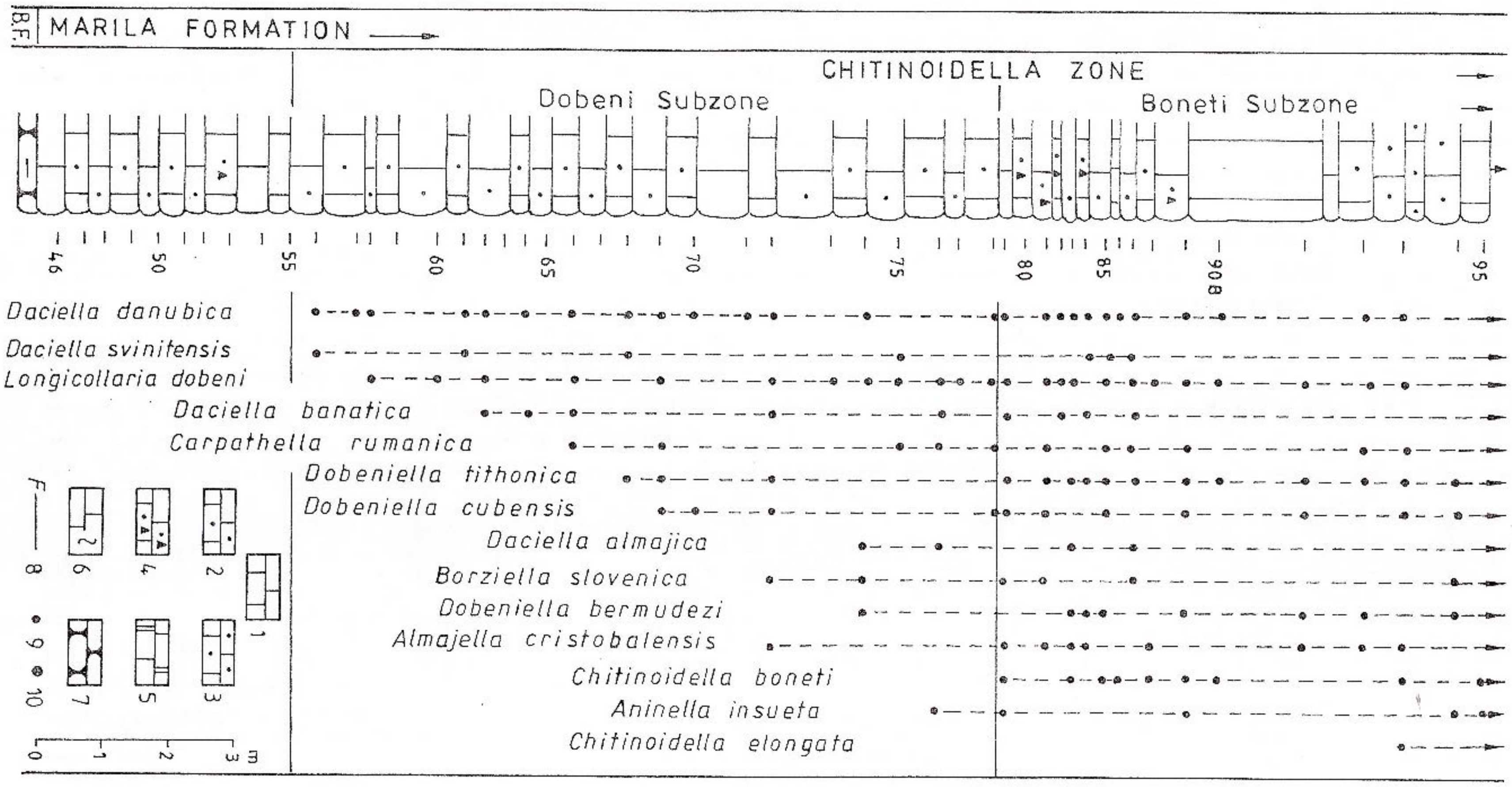

Fig. 4 a-c – Praecalpionellid and calpionellid distribution in the Mândrişag Formation (Reşiţa Basin): Lithology: 1, pelagites; 2, partial peloid-bioclastic pellagites; 3, allodapic peloid-bioclastic calciturbidites; 4, partial peloid-bioclastic and intraclastic pelagites; 5, dolosparitic pelagites; 5, karstic interval; 7, marly nodular limestones (Brădet Formation, Late Kimmeridgian to late Early Tithonian *p.p.*); 8, fault. Relative frequency: 8, rare (< 10 specimens); 10, common (10-25 specimens).

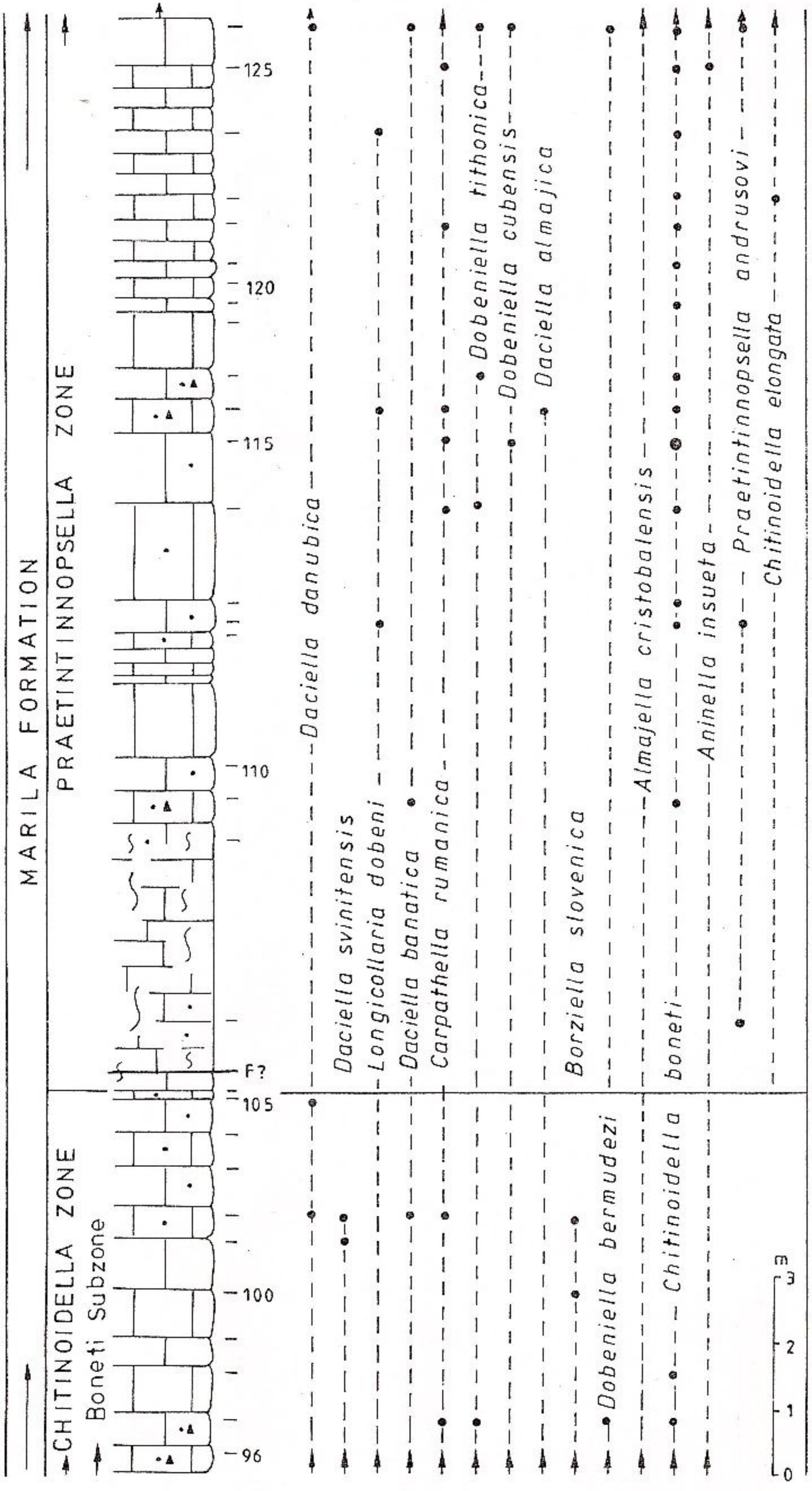
MARILA FORMATION
CHITINOIDELLA ZONE
Boneti Subzone
PRAETINTINNOPSELLA ZONE
96
100
105
F?
110
115
120
125
Daciella danubica
Daciella svinitensis
Longicollaria dobeni
Daciella banatica
Carpathella rumanica
Dobeniella tithonica
Dobeniella cubensis
Daciella almajica
Borziella slovenica
Dobeniella bermudezi
Almajella cristobalensis
Chitinoidella boneti
Aninella insueta
Praetintinnopsella andrusovi
Chitinoidella elongata
0
1
2
3
m

Fig. 4 b

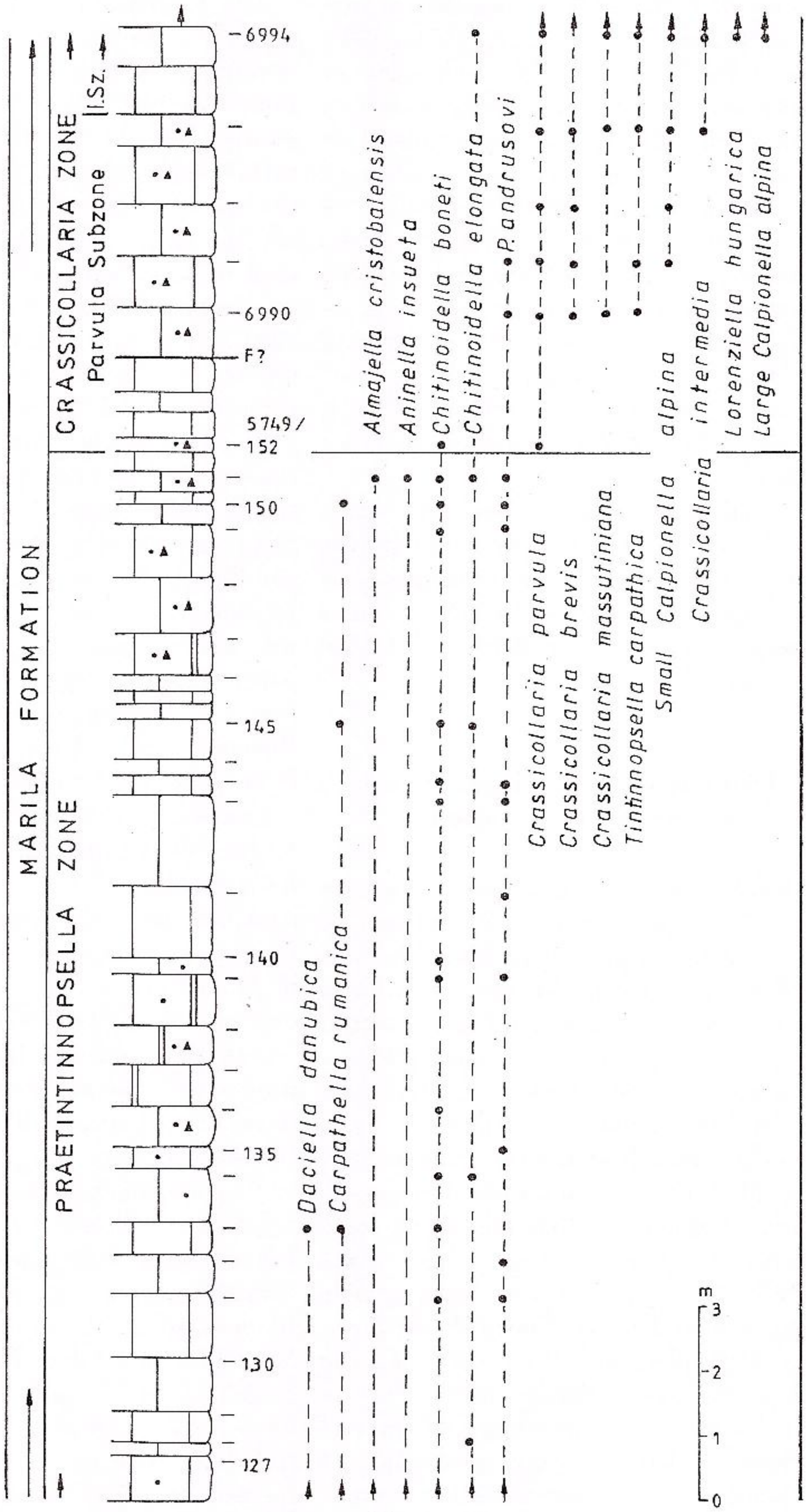
MARILA FORMATION
PRAETINTINNOPSELLA ZONE
CRASSICOLLARIA ZONE
Parvula Subzone
I.Sz.
6994
6990
F?
5749/
152
150
145
140
135
130
127
Daciella danubica
Carpathella rumanica
Almajella cristobalensis
Aninella insueta
Chitinoidella boneti
Chitinoidella elongata
P. andrusovi
Crassicollaria parvula
Crassicollaria brevis
Crassicollaria massutiniana
Tintinnopsella carpathica
Small Calpionella alpina
Crassicollaria intermedia
Lorenziella hungarica
Large Calpionella alpina
m
0
1
2
3

Fig. 4 c

nopsella andrusovi → *Tintinnopsella carpathica* (see: Borza, 1969; Remane, 1971, 1985); *Chitinoidella boneti* → *Ch. elongata* → *Tintinnopsella longa*; *Carpathella rumanica* → *Calpionella alpina; Daciella danubica* → *Crassicollaria parvula; Daciella banatica* → *Crassicollaria brevis; Daciella almajica* → *Crassicollaria intermedia; Daciella svinitensis* → *Crassicollaria massutiniana*; and *Borziella slovenica* → *Lorenziella hungarica.* It is interesting also to point out that the species of *Dobeniella* genus (with composed collar) partially remind *Remaniella* species (Pop, 1997, in press). However, further related data are necessary.

This polyphyletic evolution from chitinoidellids to calpionellids suggests that at least first stratigraphic occurrences of calpionellids species represent rather independent events situated close to the lower boundary of Crassicollaria Zone.

4. Tithonian praecalpionellid and calpionellid biozonation

In the above mentioned sequences, we have examined the stratigraphic distribution of praecalpionellids and calpionellids, particularly of recently identified taxons, in order to better estimate their biochronologic potential (Figs. 4 a-c; 5, 6, 7). Following successive biozones have been distinguished: Chitinoidella Zone with Dobeni and boneti Subzone; Praetintinopsella Zone, Crassicollaria Zone including Parvula Intermedia and Colomi Subzones. Berriasian Calpionella Zone comprising only first subzone (Alpina Subzone) is also added because its base constitutes at the same time the upper boundary of Crassicollaria Zone. First stratigraphic occurrence (FO) of some taxons is the main criterion of biozonation and the separated biozones are of interval zone type. Relative unitary assemblages of corresponding taxons characterize their stratigraphic intervals.

4.1. Chitinoidella Zone (late Early to earliest Late Tithonian).

This biozone was introduced by Enay & Geyssant (1975) in the Betic Cordillera (Spain), where it covers the stratigraphic interval between a level placed within upper Fallauxi (ammonite) Zone and the base of Crassicollaria Zone (Fig. 7). Later on, the same zonal interval (*s.l.*) was also used by some authors in other areas including Reşiţa and Sirinia basinal ones (Pop, 1986, 1989). Afterwards, Grandesso (1977) has restricted the Chitinoidella Zone to an interval defined by FO of chitinoidellids and the FO of *Praetintinnopsella andrusovi*, the second event representing the base of newly proposed Praetintinnopsella Zone. Chitinoidella Zone *s.str.* was then divided by Borza (1984) into Dobeni and Boneti Subzones on the basis of FO of *Chitinoidella boneti.* This restricted biozone with above subzones is also used in the present paper. Other variants of praecalpionellid zonation were proposed or used by Nowak (1978), Řehánek (1990), Atrops et al. (1991), Olóriz et al. (1995), Grün & Blau (1997) and others.

Consequently, Chitinoidella Zone is defined by the FO of chitinoidellids, often of *Logicollaria dobeni*, and the lower boundary of the next biozone. Its corresponding intervals in the examined sequences (Figs. 2, 4 a, b, 5) are of 24 m thick within Marila Formation and only of 7 m thick within Greben Formation.

– Dobeni Subzone. Its lower boundary coincides with the zonal one, which is situated in the upper part of Fallauxi (ammonite) Zone (Enay & Geyssant, 1975), while its top is given by the base of next subzone. The lower boundary of this subzone is normally indicated by FO of *Longicollaria dobeni.*

In the intervals of Dobeni Subzone (about 10 m thick in Marila Formation and about 5 m thick in Greben Formation), the chitinoidellids are generally rare (under 10 specimens per sample) and represented in order of their successive appearance by the following species: *Longicollaria dobeni, Daciella danubica, D. svinitensis, D. banatica, D. alma-*

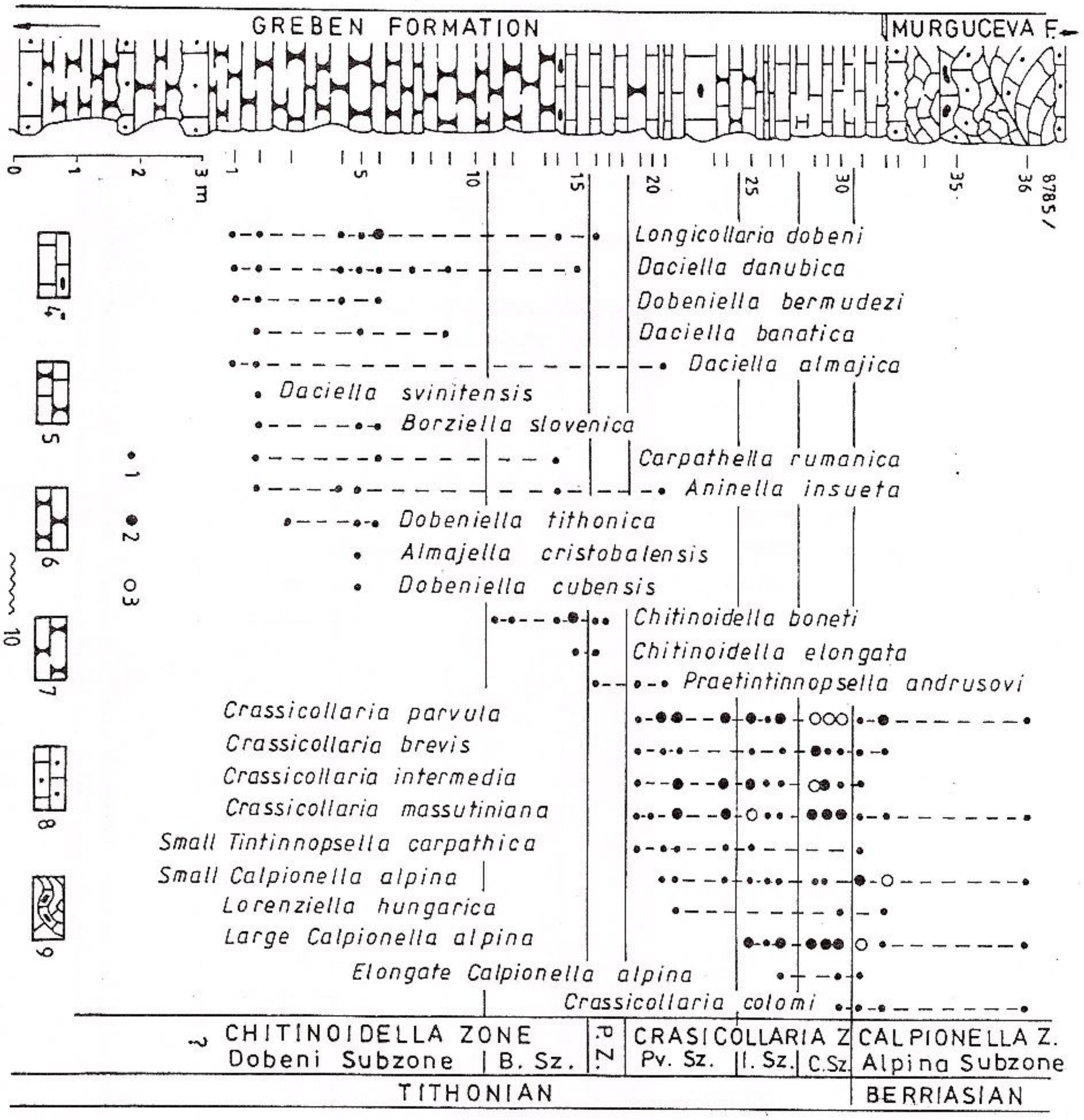

Fig. 5 – Praecalpionellid and calpionellid distribution in the upper part of Greben Formation (Sirinia Basin). Frequency: 1, rare (< 10 specimens); 2, common (10-25 specimens); 3, abundant (> 25 specimens). Lithology: 4, bedded gray-greenish pelagites with rare nodular cherts; 5, subnodular pelagites; 6, typical red nodular limestones; 7, olistostroma-like red nodular limestones; 8, allodapic calcarenites and calcirudites (calciturbidites); 9, slump; 10, synsedimentary erosional hiatus.

jica, Borziella slovenica, Carpathella rumanica, Aninella insueta, Dobeniella bermudezi, D. tithonica, D. cubensis and *Almajella cristobalensis* (Figs. 4 a, 5, 6). Other microbioclasts associated having a fluctuant frequency are *Saccocoma* sp., *Globochaete alpina*, calcitized radiolaria, calcispheres, sponge spicules, thin-shelled bivalves and other microproblematics.

– Boneti Subzone. This subzone is defined by the FO of *Chitinoidella boneti*, probably within the ammonite Ponti Zone, and the lower boundary of the next zone. Accordingly its interval (12 m thick in Marila Formation and 1.6 m thick in Greben Formation) comprises the upper Ponti and basal Microcanthum Zones. The assemblage of this subzone includes also generally rare *Chitinoidella*

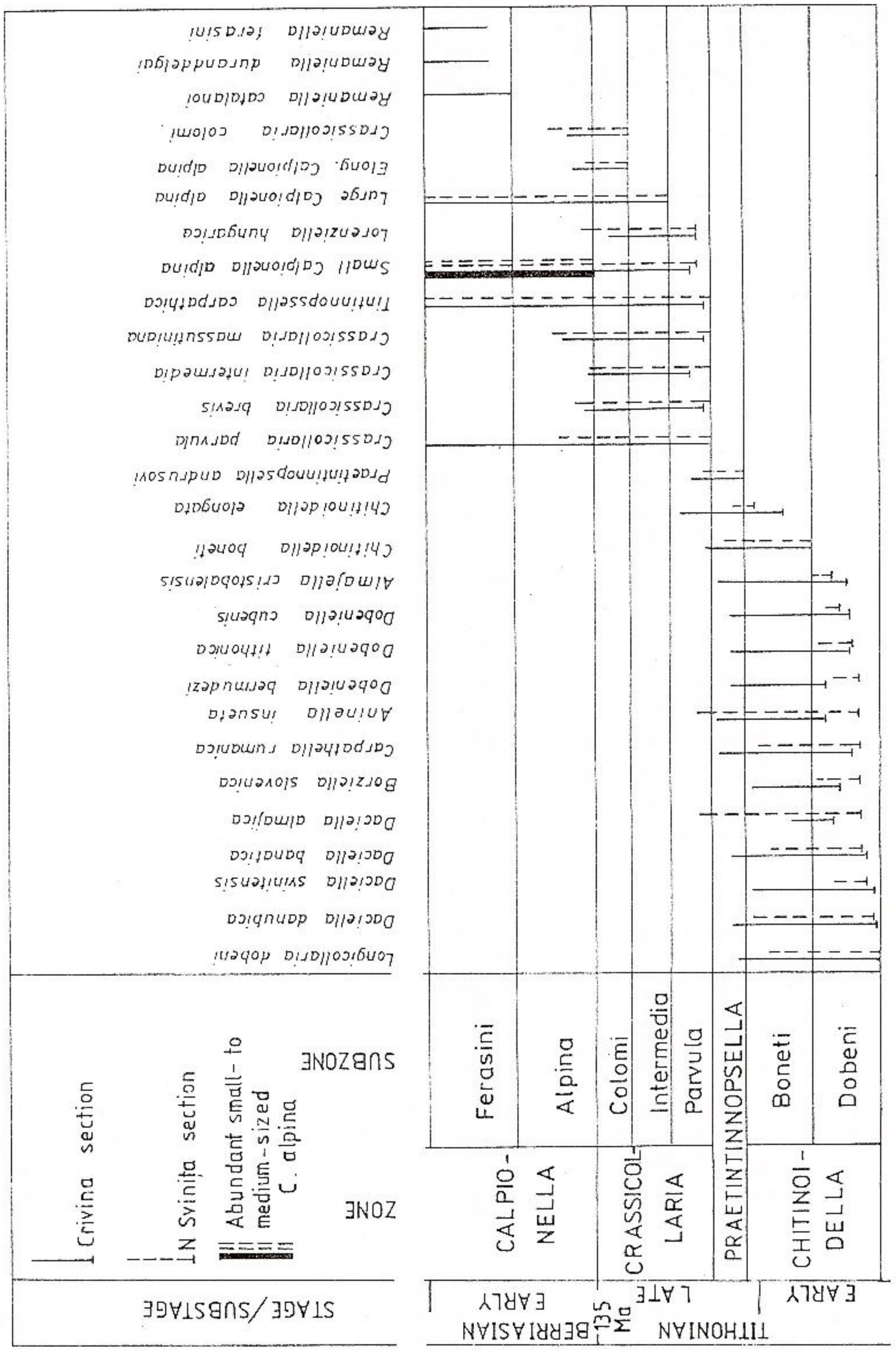

Fig. 6 – Comparative stratigraphic distribution of praecalpionellids and calpionellids in the Mândişag Member of Marila Formation (Reşiţa Basin) and the upper part of Greben Formation (Sirinia Basin).

boneti (common within a few beds), along with *Ch. elongata* and the chitinoidellid species persisting from the preceding subzone (Figs. 4 a, b, 5, 6). The other microbioclasts also persists within this subzone but with a gradually diminution of *Saccocoma* sp. frequency.

4.2. Praetintinnopsella Zone (early Late Tithonian *p.p.*). This biozone is delimited by the FO of *Praetintinnopsella andrusovi* approximately in the lower or median part of Microcanthum Zone (Simplisphinctes Subzone of Olóriz & Tavera, 1981, fide Cecca et al., 1989) and the base of Crassicollaria Zone. Its interval is stratigraphically very restricted within Microcanthum Zone and includes the lithostratigraphic sequences of about 32 m thick within Marila Formation (possibly exaggerated thickness by faulting) and 0.6 m thick within Greben Formation (Figs. 4, b, c, 5). Some chitinoidellid species from the precending zone decline and disappear within this zone, such as : *Longicollaria dobeni, Daciella danubica, D. banatica, Carpathella rumanica, Dobeniella tithonica, D. cubensis* and *Almajella cristobalensis*; other species persist on its whole interval: *Daciella almajica, Aninella insueta, Chitinoidella boneti* and *Ch. elongata* (Fig. 6). Some rare *Semichitinoidella* sp. are present. Other above mentioned microfossils also persist in a similar manner.

4.3. Crassicollaria Zone (Late Tithonian *p.p.*). This widely accepted standard zone is defined by the FO of calpionellids and the base of first Berriasian zone (Calpionella Zone) (Remane, 1963; Allemann et al., 1971). The lower boundary is commonly difficult to determine precisely for several reasons among which are the rarity of calpionellid in its basal part and often their poor preservation, unfavourable to specific determination. A phyletic control of this event is already proved by the transition from *Praetintinnopsella andrusovi* to *Tintinnopsella carpathica* (Remane, 1971, 1985, 1986). The last related data reveal that the FO of other calpionellid species are close to the same boundary and could be independent events derived from their polyphyletic descendance (on parallel lineages) from praecalpionellids. These calpionellids are *Crassicollaria brevis, Cr. intermedia, Cr. parvula, Cr. massutiniana*, small *Calpionella alpina, Lorenziella hungarica* (Pop, 1997, in press) and *Tintinnosella longa*. If it is an accurate interpretation, it results that calpionellid occurrence may be represented by the FO of one of above mentioned species. For exemple, in the examined sequences, this event is given by the FO of *Crassicollaria parvula* in the Marila Formation, and by simultaneous FO of five species in a thin nodular bed of Greben Formation, namely *Crassicollaria parvula, Cr. brevis, Cr. intermedia, Cr. massutiniana, Tintinnopsella carpathica* and *T. longa*. (Figs. 4 c, 5). Consequently, the definition of lower boundary of Crassicollaria Zone by the FO of a single species needs further comparative data. Till then, the FO of small *Tintinnopsella carpathica* already proposed (Remane, 1971) may be retained as boundary event. It is placed in the upper Microcanthum Zone (Enay & Geyssant, 1975). However, according to our data, an alternative solution should be the FO of *Crassicollaria parvula* (Figs. 4 c, 7).

The interval of this biozone is of about 15 m thick within Marila Formation (Fig. 4 c, partially drawn) and 3.4 m thick within Greben Formation (Fig. 5).

In the Crassicollaria Zone, its assemblage is obviously dominated by the species pertaining to the genus with the same name (Remane, 1963; Allemann et al., 1971). Unfortunately their evolution was not marked by important events useful in biochronology. Thus *Calpionella alpina* was used for the subdivision of this zone. However, there is not a consensus on this problem. Several variants of the subdivision of Crassicollaria Zone have been proposed by Remane (1963), Pop (1974, 1994), Remane et al. (1986), Lakova (1993), Reháková (1995) and Grün & Blau, (1997). We maintain here our last subdivision of Crassicollaria Zone into Parvula, Intermedia and

Colomi Subzones (Pop, 1994, 1996 b). Only the name of the first subzone (former Remanei Subzone) is changed, because T. remanei is now considered an abandoned taxon (see: Pop, 1997).

– Parvula Subzone. It is defined by the lower boundary of Crassicollaria Zone and the base of the next subzone. The interval of this subzone equals that of former A1 (Remane, 1963) or Remanei Subzone (Remane et al., 1986). In its lowermost part, the calpionellids are rare and then some of them become common. Assemblage of this subzone consists of *Crassicollaria parvula, Cr. intermedia, Cr. massutiniana, Cr. brevis*, associated with rare and small *Tentinnopsella carpathica, T. longa, Calpionella alpina* and *Lorenziella hungarica*. Some praecalpionellids persist in its basal part, such as: *Daciella almajica, Aninella insueta, Chitinoidella boneti, Ch. elongata* and *Praetintinnopsella andrusovi* (Figs. 4 c, 5, 6). *Remaniella* aff. *catalanoi* was remarked in the upper part of this subzone (Fig. 5, sample no. 24). Other microfossils mentioned in the precending biozones also persist with a variable frequency. A clear decline of *Saccocoma* sp. is noticed.

– Intermedia Subzone. This subzone is distinguished by the FO of large *Calpionella alpina* and the base of the third subzone. As a whole, its interval corresponds to former A 2 subzone (Remane, 1963), lower Intermedia Subzone (Remane et al., 1986), lower Cr. massutiniana Subzone (Lakova, 1993) and Brevis Subzone (Reháková, 1995). The assemblage of this subzone includes *Crassicollaria parvula, Cr. intermedia, Cr. massutiniana, Cr. brevis* (often common to abundant), large *Calpionella alpina* (common), scarce *Lorenziella hungarica*, rare small *Tintinnopsella carpathica* and small *Calpionella alpina*. Elongate *Calpionella alpina* also occurs in the uppermost part of this subzone, while *Saccocoma* sp. disappears in its middle part. Other mentioned microfossils are present.

– Colomi Subzone. This last subzone is defined by the FO of *Crassicollaria colomi* and the base of Calpionella Zone. Its subzonal event is approximately concurrent with the FO of elongate *Calpionella alpina* (= homeomorph of *C. eliptica*), an useful additional criterion in recognation of lower boundary of Colomi Subzone (Pop, 1994). Generally the interval of this subzone may be correlated with that of A 3 subzone (Remane, 1963).

Within Colomi Subzone, the index species is rare and occurs along with *Crassicollaria parvula* (abondant), *Cr. massutiniana*, large *Calpionella alpina* (common) and rare *Cr. brevis, Cr. intermedia*, elongate *Calpionella alpina*, small *C. alpina*, small *Tintinnopsella carpathica* and *Lorenziella hungarica*. A frequencial diminution of *Crassicollaria* species within this subzone is noticed (Fig. 5).

4.4. Basal Calpionella Zone (lower Early Berriasian). The lower boundary of this zone is marked by sudden increase in frequency of small - to medium - sized spherical *Calpionella alpina* (Remane, 1963, 1971, 1986; Allemann et al., 1971; Remane et al., 1986; Pop, 1994, 1996; Lakova, 1994). It seems that this event is given by a large proliferation of the small *Calpionella alpina* persisting from the preceding zone. It is an obvious event in the investigated sequences, which is situated very close (a bit lower) to the base of ammonite Jacobi Zone and provisionally admitted as Tithonian-Berriasian and Jurassic-Cretaceous boundaries (Alemann et al., 1971; Enay & Geyssant, 1975). Other possible variants of system boundary are largely commented by Remane (1986, 1991), Hoedemaeker (1987), Zakharov et al. (1996) and others.

Except for *Crassicollaria parvula*, some other Calpionellid species and varieties persist a little later than the lower boundary of Calpionella Zone but under a reduced frequency, such as: *Crassicollaria brevis, Cr. intermedia, Cr. massutiniana, Cr. colomi*, elongate and large *Calpionella alpina*, small *Tintinnopsella carpathica* and *Lorenziella hungarica* (Figs. 5, 6).

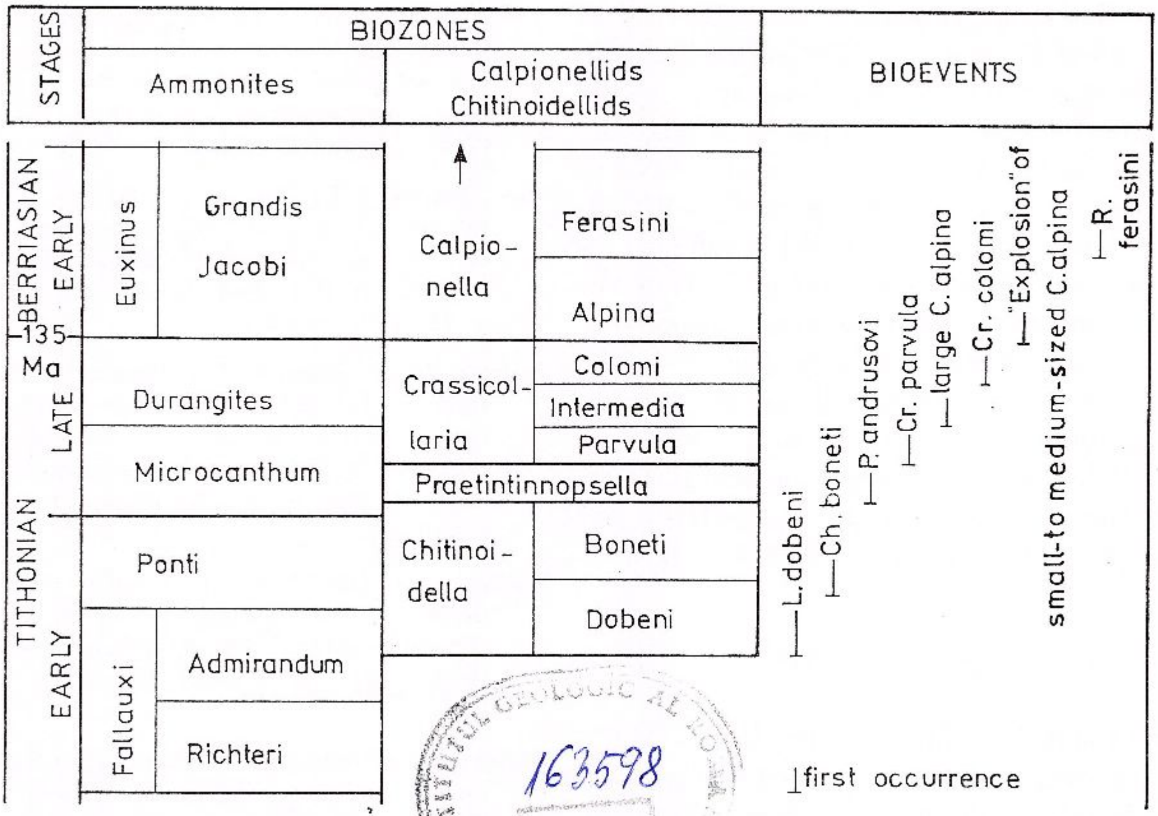

Fig. 7 – Praecalpionellid and calpionellids biozones and bioevents in the Mândrişag Member of Marila Formation (Reşiţa Basin) and the upper part of Greben Formation (Sirinia Basin) and their probable correlation with ammonite zones, according to Enay & Geyssant (1975) and Cecca et al. (1989).

5. General conclusion

Stratigraphic distribution of Tithonian praecalpionellids and calpionellids within Marila and Greben Formations, pertaining to two different basins from the South Carpathians, is favourable to their biozonation into three successive biochronologic units: Chitinoidella Zone (late Early to earliest Late Tithonian) including Dobeni and Boneti Subzones; Praetintinnopsella Zone (early Late Tithonian) with its base close to the Early-Late Tithonian (*sensu gallico*); and Crassicollaria Zone (Late Tithonian *p.p.*) comprising Parvula, Intermedia and Colomi Subzones. Sudden proliferation of small- to medium-sized *Calpionella alpina* at the base of Calpionella Zone is an evident event, which is provisionally admitted as Tithonian-Berriasian and Jurassic-Cretaceous boundaries (Fig. 7).

The same distribution is also favourable to a polyphyletic interpretation of their evolution from chitinoidellids, through semichitinoidellids, to calpionellids, following several parallel lineages. This evolution was marked by many related events proving a high biochronologic potential of these microorganisms, which needs nevertheless further data.

Above biozonation is a new contribution to the knowledge of the ages of the lower part of Maiolica limestones (late Early to Late Tithonian) of Marila Formation and of the upper part of the nodular limestone complex (late

Early Tithonian to earliest Early Berriasian) of Greben Formation. The carbonate sediments of above formations have accumulated within the outer slope areas of Reşiţa and Sirinia basins respectively, generally with a comparable evolution, but partially with different environments, controlled by different influence of Late Jurassic tectonics. Thus the transition from restricted environments admitted for nodular limestone genesis to the open ones favouring upwellings, high planktonic productivity and CCD fall corresponding to Maiolica sediment deposition begins earlier (late Early Tithonian) in the Reşiţa Basin and later (Early Berriasian) in the Sirinia Basin.

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Plate I

Tithonian chitinoidellids and semichitinoidellids from the Marila Formation (MF, Crivina section) from the samples no. 5749/(56-152) (Fig. 4 a-c) and Greben Formation (GF, N Sviniţa section) from the samples no. 8785/(1-18) (Fig. 5) and (224-243). For each figure are successively given: formation, sample number, zone and subzone (Chitinoidella Zone=CZ, with Dobeni Subzone=DSZ and Boneti Subzone=BSZ; Praetintinnopsella Zone=PZ).

Figs. 1-4 — *Longicollaria dobeni* (Borza, 1966): **1, 2**, GF (226) CZ, DSZ; **3**, MF (94) CZ, BSZ; **4**, GF (236) CZ, BSZ.

Figs. 5-7 — *Daciella danubica* Pop, (in press): **5** (holotype), **6**, GF (228 b, 226) CZ, DSZ; **7**, MF (87) CZ, BSZ.

Figs. 8, 9 — *Daciella svinitensis* Pop, (in press): **8** (holotype), **9** (paratype), GF (228 b, 2) CZ, DSZ.

Figs. 10-12 — *Daciella banatica* Pop, (in press): **10** (holotype), **12** (paratype), GF (2, 5) CZ, DSZ; **11**, MF (81) CZ, BSZ.

Figs. 13-15 — *Daciella almajica* Pop, (in press): **13**, MF (85) CZ, BSZ; **14** (holotype); **15**, GF (2, 230 b) CZ, DSZ.

Figs. 16, 17 — *Borziella slovenica* (Borza, 1969): **16**, GF (225) CZ, DSZ; **17**, MF (89 A) CZ, BSZ.

Figs. 18-20 — *Carpathella rumanica* Pop, (in press): **18** (holotype); **19**, (paratype) GF (226) CZ, DSZ; **20**, GF (6) CZ, DSZ.

Fig. 21 — *Aninella insueta* (Řehánek, 1986) (nomen novum): MF (76)CZ, DSZ.

Figs. 22-24 — *Dobeniella bermudezi* (Furrazola-Bermúdez, 1965): **22, 23**, MF (94, 85) CZ, BSZ; **24**, GF (225) CZ, DSZ.

Figs. 25, 26 — *Dobeniella tithonica* (Borza, 1969): **25**, MF (126) PZ; **26**, MF (90) CZ, BSZ.

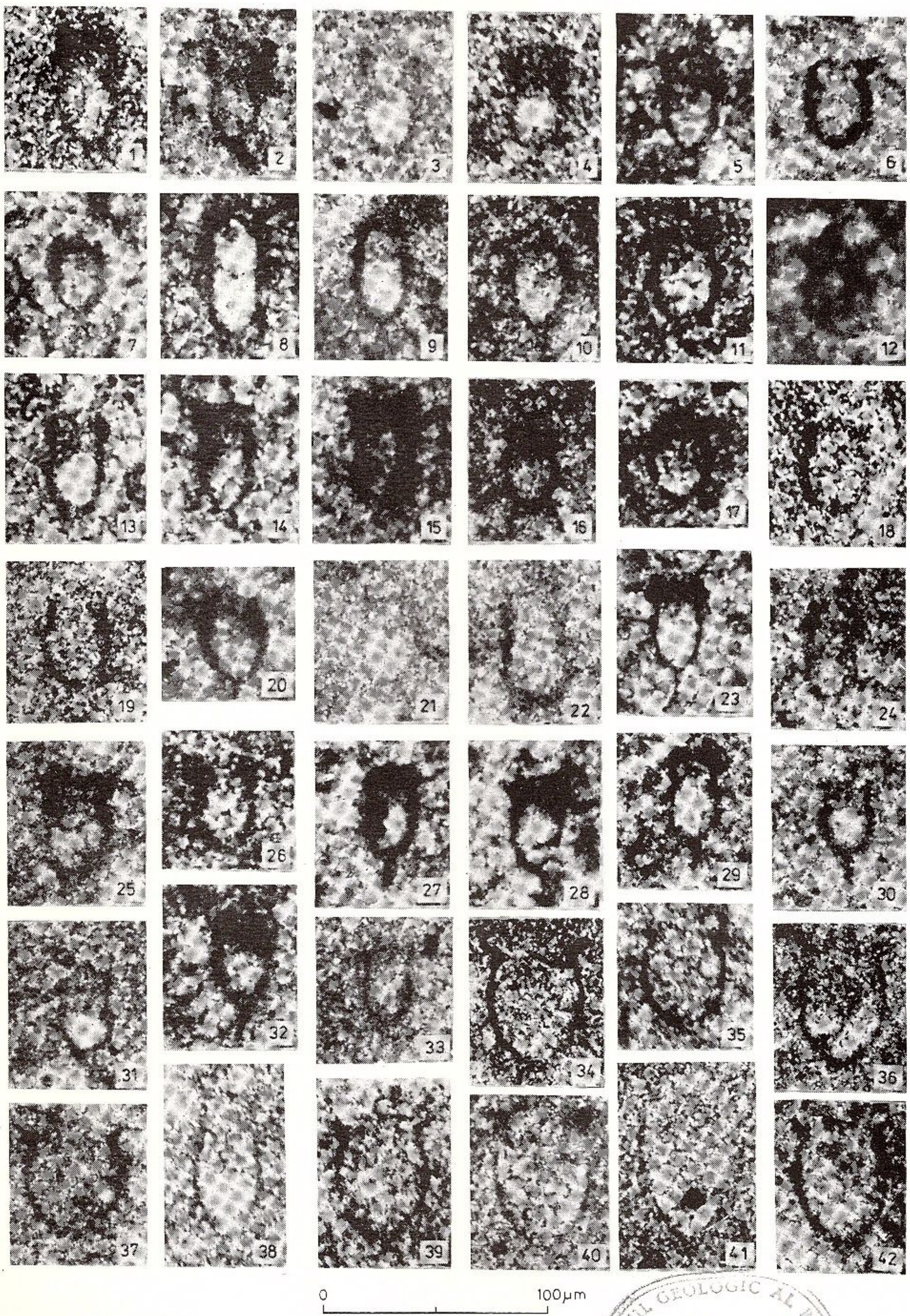
Figs. 27-29 — *Dobeniella cubensis* (Furrazola-Bermúdez, 1965): **27, 28**, MF (85) CZ, BSZ; **29**, MF (79) CZ, BSZ.

Figs. 30-33 — *Almajella cristobalensis* (Furrazola-Bermúdez, 1965) (nomen novum): **30**, GF (234) CZ, DSZ; **31, 32, 33**, MF (83, 85, 79) CZ, BSZ.

Figs. 34-37, 39 — *Chitinoidella boneti* Doben, 1963: **34; 35, 37**, GF (236, 236, 239) Cz, BSZ; **36**, MF (136) PZ.

Fig. 38 — *Chitinoidella elongata* Pop, 1997: holotype, MF (123) PZ.

Figs. 40-42 — *Praetintinnopsella andrusovi* Borza, 1969: **40, 41**, MF (139, 149) PZ; **42**, GF (239) PZ.



Geological Institute of Romania, Rom. J. Stratigraphy, 77, 4, 1998

Plate II

Late Tithonian calpionellids from the Greben Formation (Fig. 5). Sample numbers are given between paranthesis

Crassicollaria Zone, Parvula Subzone

Figs. 1-6 — *Crassicollaria parvula* REMANE, 1962: 1 (19); **2-4, 6**, (21); **5** (22).

Figs. 7-13 — *Crassicollaria brevis* REMANE, 1962: **7, 9-13** (22); **8** (19).

Figs. 14-17 — *Crassicollaria massutiniana* (COLOM, 1948): **14, 15** (19); **16** (22); **17** (24).

Figs. 18, 19 — *Crassicollaria intermedia* (DURAND-DELGA, 1957): **18, 19** (22).

Figs. 20, 21 — *Tintinnopsella carpathica* (MURGEANU & FILIPESCU, 1933): **20, 21** (19).

Fig. 22 — *Tintinnopsella longa* (COLOM, 1939): (19), small form.

Fig. 23 — *Calpionella alpina* LORENZ, 1902: (22), small form.

Crassicollaria Zone, Intermedia Subzone

Fig. 24 — *Calpionella alpina* LORENZ, 1902: (25), small form.

Figs. 25, 26 — *Calpionella alpina* LORENZ, 1902: (26), large forms.

Figs. 27, 28 — *Crassicollaria intermedia* (DURAND-DELGA, 1957): (26).

Fig. 29 — *Crassicollaria massutiniana* (COLOM, 1948): (26).

Fig. 30 — *Crassicollaria brevis* REMANE, 1962: (26).

Plate II

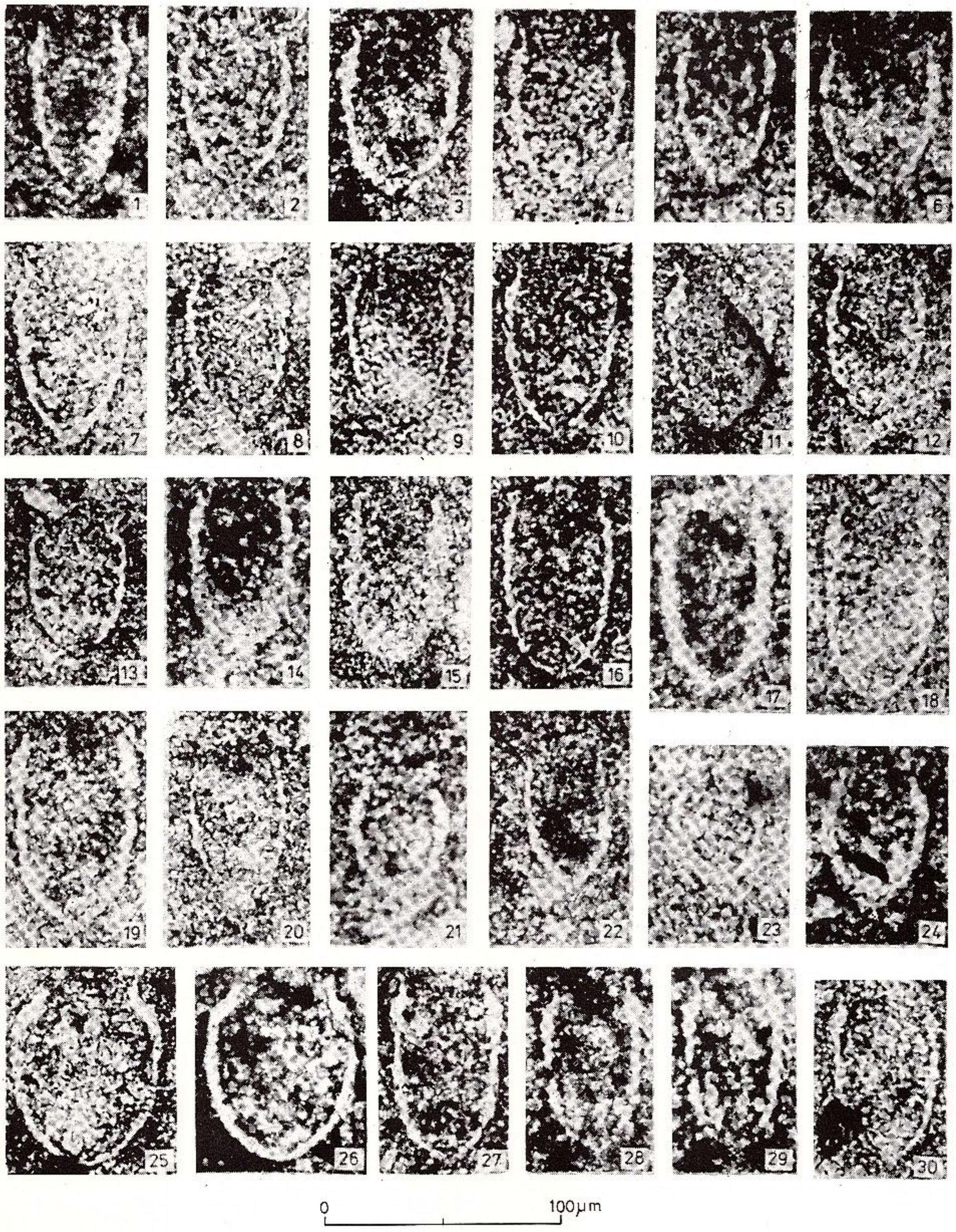

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Plate III

Late Tithonian calpionellids from the Greben Formation (Fig. 5). Sample numbers are given between parenthesis.

Crassicollaria Zone, Colomi Subzone

Figs. 1-6 — *Crassicollaria colomi* DOBEN, 1963: **1, 3** (28); **4** (29); **5, 6** (30).

Figs. 7-9 — *Crassicollaria parvula* REMANE, 1962: **7** (29); **8** (30); **9** (28).

Figs. 10, 11 — *Crassicollaria brevis* REMANE, 1962: (29).

Figs. 12-15 — *Crassicollaria intermedia* (DURAND-DELGA, 1957): **12, 13** (28); **14** (29); **15** (30).

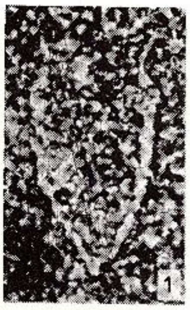
Figs. 16-18 — *Crassicollaria massutiniana* (COLOM, 1948): **16, 17** (28); **18** (30).

Fig. 19 — *Calpionella alpina* LORENZ, 1902: (30) elongate form.

Figs. 20-24 — *Calpionella alpina* LORENZ, 1902: **20, 21-23** (28); **24** (29), large forms.

Figs. 25-27 — *Calpionella alpina* LORENZ, 1902: **25** (28); **26** (29); **27** (30), small forms.

Figs. 28, 29 — *Lorenziella hungarica* KNAUER & NAGY, 1963: (29).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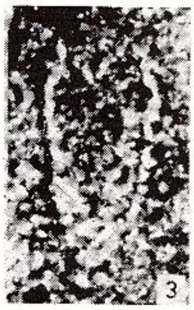
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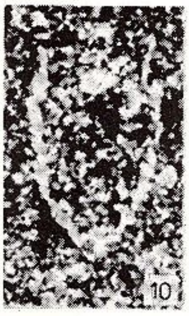
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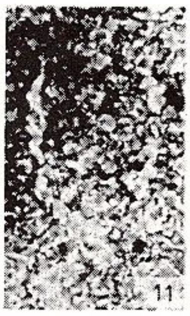
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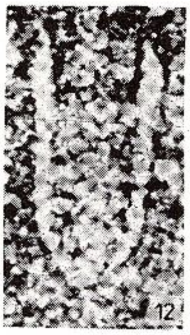
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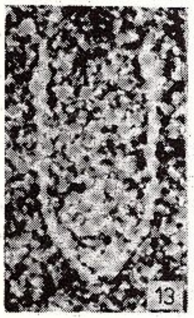
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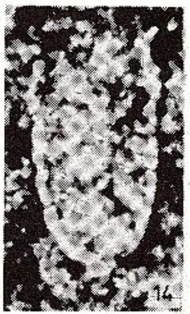
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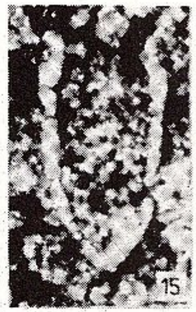
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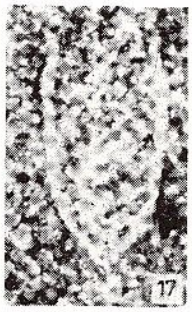
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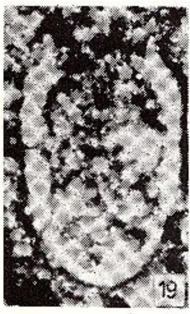
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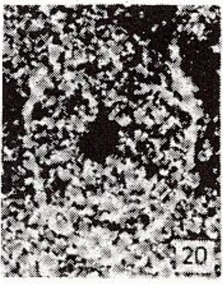
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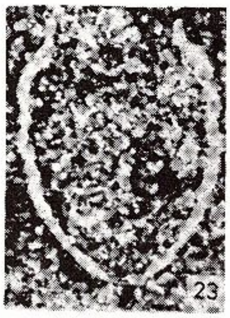
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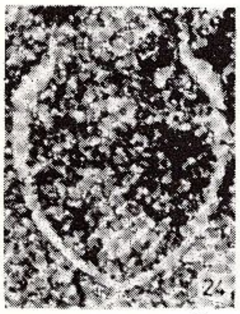
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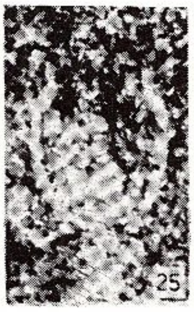
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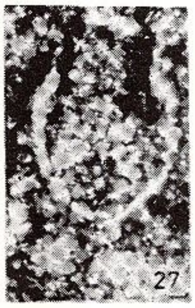
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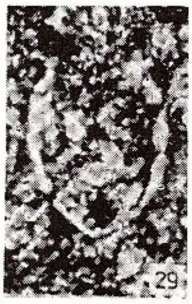
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Plate IV

Early Berriasian calpionellids from the uppermost Greben and basal Murguceva Formations (Fig. 5). Sample numbers are given between parenthesis.

Calpionella Zone, Alpina Subzone

Figs. 1-4 — *Calpionella alpina* LORENZ, 1902: **1** (31); **2-4** (32). Small- to medium-sized forms.

Fig. 5 — *Calpionella alpina* LORENZ, 1902: (31), elongate form (or *C. elliptica* homeomorph).

Figs. 6-10, 13 — *Calpionella alpina* LORENZ, 1902: **6-9** (31); **10, 13** (32), large forms.

Figs. 11, 12 — *Crassicollaria parvula* REMANE, 1962: (32).

Figs. 14-18 — *Crassicollaria brevis* REMANE, 1962: **14, 15** (31); **16, 17**, (32); **18** (36).

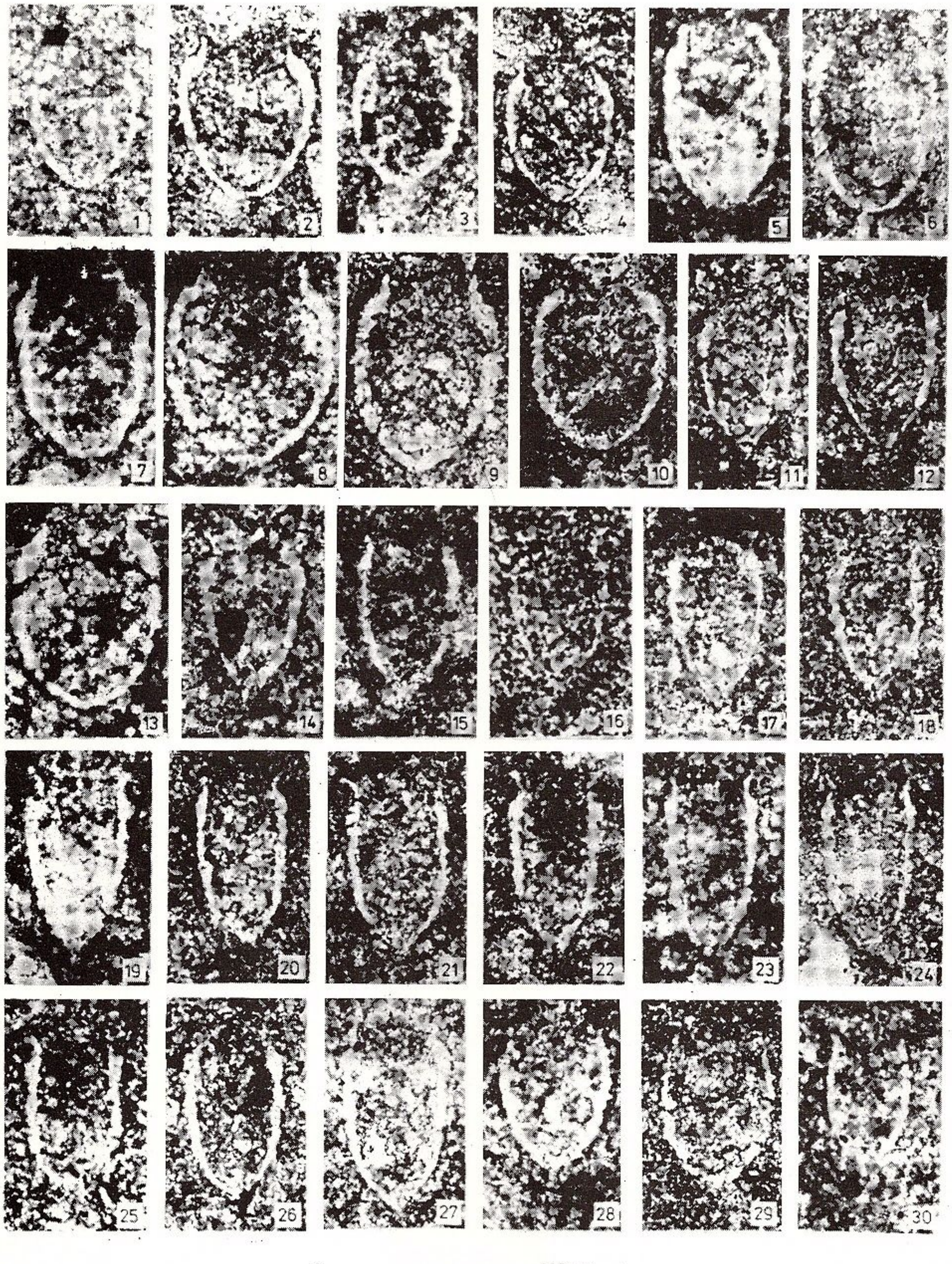
Fig. 19 — *Crassicollaria colomi* DOBEN, 1963: (32).

Figs. 20-26 — *Crassicollaria intermedia* (DURAND-DELGA, 1957): **20-22** (31); **23-27** (32).

Fig. 27 — *Crassicollaria massutiniana* (COLOM, 1948): (32).

Figs. 28-30 — *Tintinnopsella carpathica* (MURGEANU & FILIPESCU, 1933).

Plate IV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Rom. J. Stratigraphy, 77, 4, p. 27–35, Bucureşti, 1998

BOREAL IMMIGRANTS INTO THE VALANGINIAN SUCCESSIONS OF THE ROMANIAN CARPATHIANS

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IGCP-362
Tethyan and Boreal
Cretaceous

Key words: Lower Cretaceous. Valanginian. Paleogeography. Ammonites. Nannofossils. Carpathians. Romania.

Abstract: The revised and completed inventories of the ammonite, foraminifera and nannofossil assemblages of the Carpathian Valanginian successions pointed out the presence here of some boreal immigrants and/or some taxa descending from boreal ancestors. These data were discerned in both the central Carpathian (= Transylvanides and Median Dacides, sensu Săndulescu, 1984) and the outer Carpathian (= Outer and Marginal Dacides) structural units. They lead to the conclusion of a larger (than considered until now) Boreal-Tethyan connection during the early Late Valanginian, felt in the nectonic, benthic and planktonic fossil assemblages.

1. Introduction

The Romanian geological literature offered in the last 30 years some data concerning the presence within the Carpathian Late Valanginian of both the Boreal fossils and/or those presumed as descending from Boreal ancestors. Thus, Turculeţ (1963), Neagu (1975 a, 1975 b), Avram (1988) and Melinte (1992) emphasized these kinds of data on the Boreal or common Boreal and Tethyan species of ammonites, foraminifera, once more ammonites and also nannofossils, respectively. Moreover, Avram, Grădinaru (1993) offered grounds for considering the Tethyan genus *Jeanthieuloyites* as discending from the Boreal genus *Polyptychites* and constituting a link between this Valanginian genus and the Hauterivian genus *Spitidiscus*.

All these data indicate a real faunal borrowing from the Boreal domain to the Tethyan one during the Valanginian time-span, and not an accidental migration or even a post-mortem shell drifting into the Tethyan area.

2. The Carpathian fossil assemblages of mixed Tethyan and Boreal Valanginian species

Four fossiliferous sites/successions of Valanginian age, where Boreal immigrants have

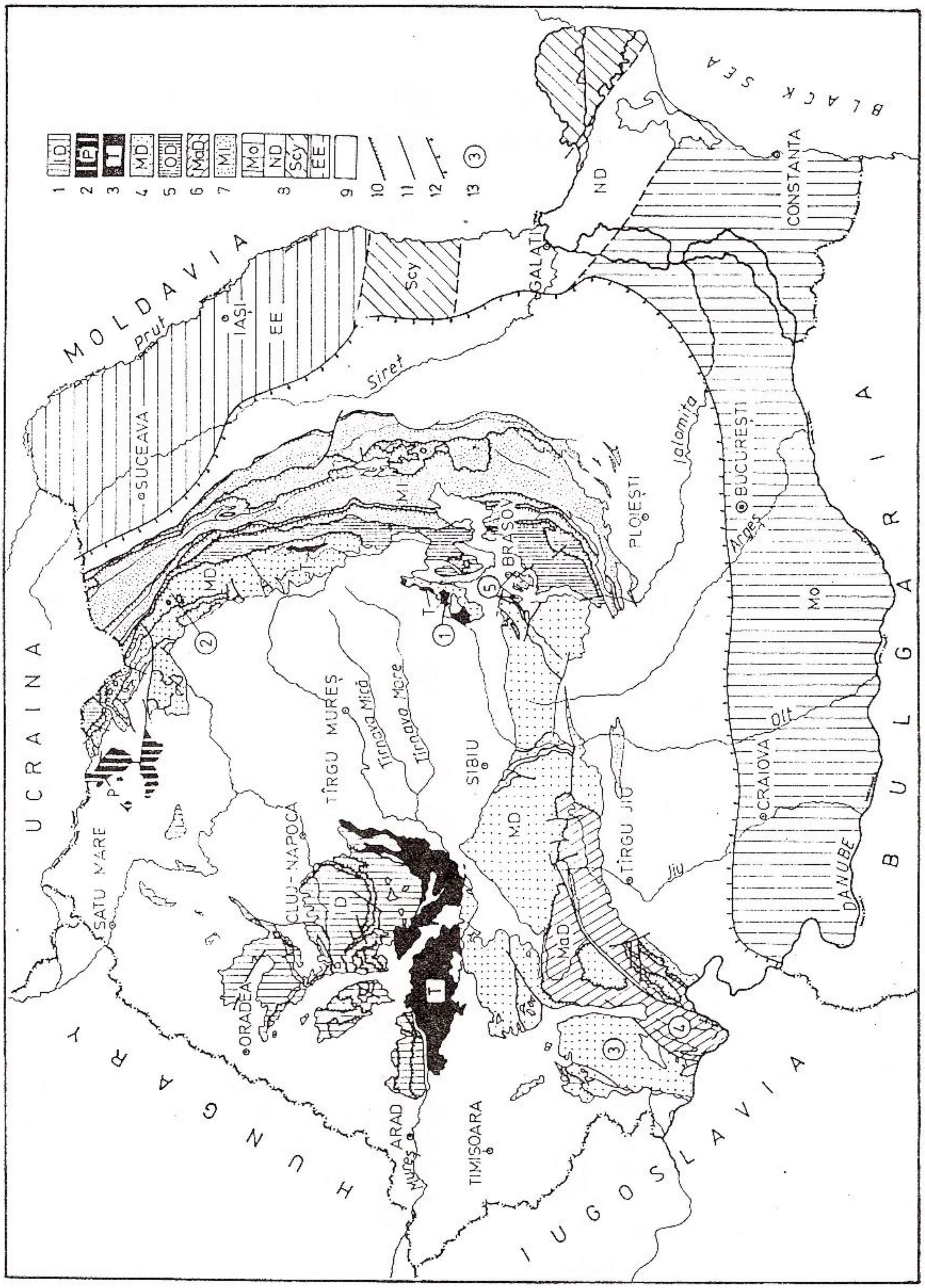

Fig. 1 – The structural map of Romania (after Săndulescu, 1984), with the location of the sites where Boreal-related species were recorded in the Late Valanginian deposits. 1, Inner Dacides; 2, Transylvanides; 3, Pienides; 4, Median Dacides; 5, Outer Dacides; 6, Marginal Dacides; 7, Moldavides; 8, Carpathian Foreland units (Mo=Moesian Platform; ND=North Dobrogea; Scy= Scythian Platform; EE=East European Platform); 9, post-tectonic cover; 10, nappes; 11, faults; 12, flexures; 13, areas displaying Boreal-related species.

been identified in Romania so far, namely (from the inner to the outer structural units of Carpathians): (1) the Carhaga Formation, within the Perşani Mts (East Carpathians); (2) the Muncelu sandstones and conglomerates, on the Moldova valley (East Carpathians); (3) the Crivina marls, in the Reşiţa region (western end of the South Carpathians); (4) the Murgugeva Formation, in the Sviniţa region (western end of the South Carpathians). To the sites above one should add (5) the Braşov Formation, developed in the Codlea town area (eastern end of the South Carpathians) where some ammonite species with presumed Boreal ancestors were recorded (Fig. 1).

2.1. The Carhaga Formation

This lithostratigraphic unit belonging to the Transylvanides (= the structural units coming from the main Carpathian suture zone, fide Săndulescu, 1984), developed within the Perşani Mts, is preserved as variously sized olistoliths of marls, marly limestones, calcarenites and breccias±chert, partly fossiliferous, the Late Jurassic-Barremian succession of which being restored (Patrulius, Avram, 1976) on the ground of their ammonite content. Some Upper Valanginian marly olistoliths of this succession offered in the Chioveş valley (almost 200 m upstream its mouth) and in the Carhaga valley (near the Chioveş valley mouth) several ammonite species: *Bochianites oosteri* (SARASIN & SCHÖNDELMAYER), *Spitidiscus* ex gr. *incertus* (D'ORBIGNY) (=? *Jeanthieuloyites* sp.), *Eleniceras transylvanicum* (JEKELIUS), *Pseudobelus bipartitus* (D'ORBIGNY) in the former site, and *Phyllopachyceras winkleri* (UHLIG), *Bochianites oosteri*, *Neolissoceras grasianum* (D'ORBIGNY), *Olcostephanus* sp. (very crushed), ? *Lyticoceras* sp. aff. *L. bifalcatum* (v. KOENEN) [cited by Avram, 1988, as *Polyptychites* aff. *laticosta* (v.KOENEN), but doubtfully identified because of its bad preservation], and *Pseudobelus bipartitus* in the latter (Patrulius, Avram, 1976; Avram, 1988, revised).

The foraminifer assemblage of the same sequence is dominated by *Ophtalmidium carinatum marginatum* (WISNIOWSKI) and *O. michalskii* (WISNIOWSKI), species of high frequency in the sub-basin of Northern Poland (Neagu, 1975 a, 1975 b).[1]

Moreover, the nannofloras there contain, beside several cosmopolitan and Tethyan species of the upper part of the Speetonia colligata Zone (= late Early and early Late Valanginian, Melinte, 1992), some others, namely: *Crucibiscutum salebrosum* (BLACK) JAKUBOWSKI, *Micrantholithus speetonensis* PERCH-NIELSEN, *Tegumentum striatum* (BLACK) TAYLOR, *Zeugrhabdothus sisyphus* (GARTNER)CRUX, *Sollasites horticus* (STRADNER) CEPEK & HAY and *S. lowiei* (BUKRY) ROTH, recognised until now only in the Boreal realm, in the North Sea area, England, Germany and Poland (Perch-Nielsen, 1979; Crux, 1989; Jakubowski, 1987; Mutterlose, 1991, 1992, 1993).

2.2. The Muncelu sandstones and conglomerates

The Muncelu sandstones and conglomerates, Valanginian - (?) Hauterivian in age (Popescu, Patrulius, 1964) are exposed in the south-eastern part of the central East Carpathian Bucovinian Nappe (in the Median Dacides), along the Moldova valley (Fig. 1). They are transgressively dispossed upon the Tithonian-Valanginian Aptychus Beds (Săndulescu, 1973) and comprise dark greenish or blackish calcareous sandstones and polygenous conglomerates (Turculeţ, 1971). Along the Moldova valley, between the Sadova and Pojorâta villages, the first level of this

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[1] As in the Carhaga Formation, the foraminifer assemblage of the Valanginian- Lower Aptian lithostratigraphic units of the Dâmbovicioara-Braşov region, as a whole, are by far dominated (183 from 248) by species common to North Germany, North Poland and Anglo-Parisian basin (Neagu, 1975 a).

lithostratigraphic unit, the so-called "Subconglomerate breccia" (Turculeţ, 1968) offered an assemblage of Valanginian belemnites: *Duvalia lata* (Bl.), *D. lata constricta* Uhlig, *D. urnula* (Duval), *Pseudobelus bipartitus* (Bl.), while its own succession yielded a specimen of *Polyptychites [P.* cf. *quadrifidus* (v. Koenen) in Turculeţ, 1963, here revised as *P.* cf. *michalskii* (Bogoslowski)], all these species supporting a (Middle) Valanginian age.

It is to point out the transgressive position of the Muncelu sandstones and conglomerates over the top of the Aptychus Beds, here proved as being also Valanginian in age by a specimen of *Duvalia dilatata* (Bl.) recorded in the grey-reddish limestones from Gura Sadovei by Mutihac (1968). These facts argue for an intra-Valanginian break in sedimentation between the top of the Aptychus Beds and the Muncelu sandstones and conglomerates.

The nannofossil species recorded in the matrix of *Polyptychites* are partly Tethyan or cosmopolitan, and partly Boreal, namely: *Micrantholithus speetonensis, Crucibiscutum salebrosum, Tegumentum striatum, Sollasites horticus* (Pl. II).

2.3. The Crivina marls

The Crivina marls appear as a mainly pelitic rock-sequence, Latest Berriasian-Late Valanginian in age, within the Median Dacides, at their western end of exposure in the South Carpathians (Reşiţa region). Their ammonite content, revised and supplied by Avram (1990), is entirely composed of Tethyan species: *Leptoceras brunneri* (Ooster), *L.* aff. *studeri* (Ooster), *Spiticeras (S.) tenuicostatum* Dj. in the (still Berriasian) lowermost layers, *Thurmanniceras* aff. *pertransiens* (Sayn), *T.* cf. *gratianopolitense* (Sayn), *T.* cf. *gueimardi* (Sayn), *Sarasinella eucyrta* (Sayn), *Kilianella* aff. *ischnotera* Sayn, *K.* aff. *bochianense* Sayn, *K. roubaudiana* (d'Orbigny), *Olcostephanus (O.) sublaevis* Spath, *Karakaschiceras* cf. *inostranzewi* (Karakasch) and *Bochianites neocomiensis* (d'Orb.) in the rock-sequence of the Lower Valanginian Pertransiens and Campylotoxus Zones, and also, *Saynoceras verrucosum* (d'Orbigny), *Bochianites* cf. *oosteri* (Sarasin & Schöndelmayer) and *B. neocomiensis* in the Verrucosum zone of the Upper Valanginian (Avram, 1990).

The nannofossil assemblage there, pertaining to the upper part of the Speetonia colligata zone, also contains some of the Boreal species recognised in the Carhaga Formation, too, namely: *Crucibiscutum salebrosum* and *Micrantholithus speetonense*, in the range-interval of *Saynoceras verrucosum*; as the former of these species appears in the Lower Valanginian, only the latter, the range of which starts a little later, etablishes the early Late Valanginian age of the sample.

2.4. The Murguceva Formation

The Berriasian (locally Upper Tithonian)-early Upper Hauterivian Murguceva Formation, developed within the Marginal Dacides (or "Danubian Autochthon") in Banat (SW Romania) also offered some indications on the Boreal immigration within the Tethyan domain. This formation is built up of pelagic, bedded, white or light-grey cherty limestones (Avram, 1984), the fossil content of which being also used for the nannofossil zonation, correlated with the standard zonation by ammonites and tintinnids (Melinte, 1992). As in the above-mentioned sections, the Murguceva Formation type-section displays a nannofossil assemblage of Speetonia colligata zone (Middle Valanginian) including the Boreal species *Crucibiscutum salebrosum* and *Micrantholithus speetonensis*, in an interval (MO30-MO38) also characterised by *Olcostephanus* spp. (MO32, MO34), *Bochianites* cf. *neocomiensis* (MO36), and a tintinnid assemblage of the Calpionellites zone (up to the level MO33).

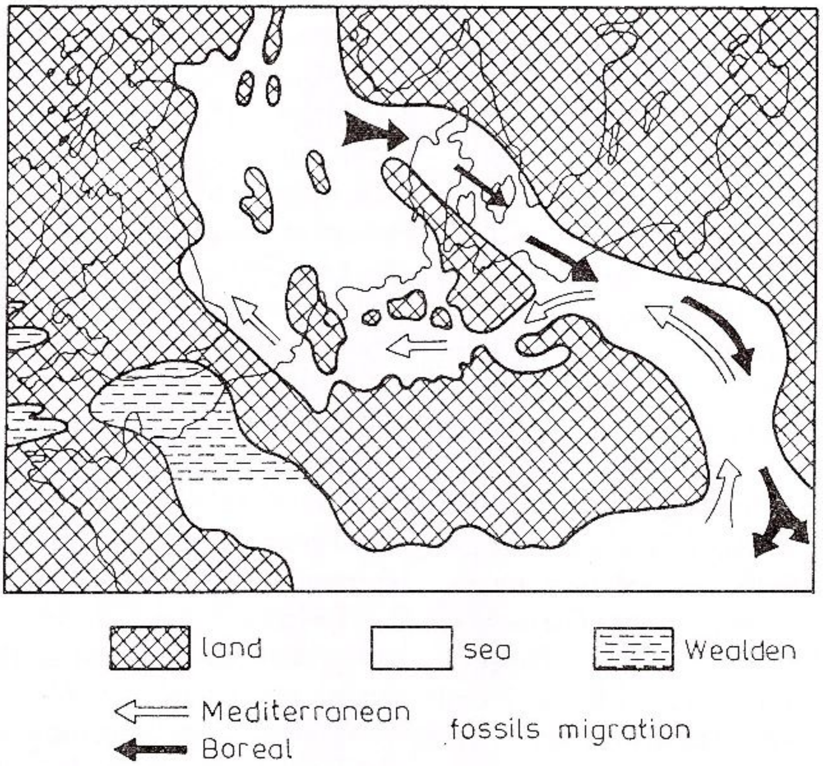

Fig. 2 - Paleogeographic reconstruction showing the biota exchanges between the Carpathian trough and Polish sub-basin of the Boreal realm during the Verrucosum zone time-span (after Kutek et al., 1989, completed).

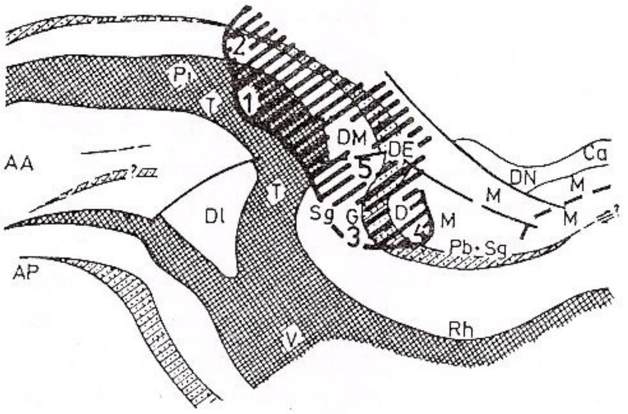

Fig. 3 - The restored picture of the Carpathian trough during the earliest Cretaceous (after Săndulescu, 1984), with the presumed area of Boreal influences. AA=Austroalpine; DI=Inner Dacides; AP=Apulian microplate; V=Vardar ocean; T=Transylvanides; Pi=Pienides; Sg=Supragetic; G=Getic; DM=Median Dacides; DE=Outer Dacides; D=Marginal Dacides; M=Moesian Platform; DN=North Dobrogea; Ca=Alpine Crimea; Pb+Sg=Prebalkan and Stara Planina; Rh=Rhodope; 1-5=fossiliferous sites.

3. Tethyan taxa presumably descending from Boreal immigrants into the Carpathian troughs

Recently, Avram, Grădinaru (1993) have presumed the Boreal origin of the genus *Jeanthieuloyites* COOPER, 1981, based on some of its Romanian species displaying a typical Polyptychites-like ornamentation, but accompanied by constrictions.

These Romanian species were found within the latest Lower Valanginian ?- Late Valanginian (up to the Trinodosum zone) condensed basal bed of the marly and calcareous Braşov Formation, exposed in a quarry near the Codlea town (Inner Carpathian Bend, almost 15 km west of Braşov). Among the numerous ammonite species of this bed were counted representatives of *Kilianella* (a fragmentary example, supporting the Late Valanginian age), *Paquiericeras (Julianites)* cf. *mourrei* (VERMEULEN), *Subastierianbalkanica* (TZANKOV) and *S. inordinata* (TZANKOV), *Karakaschiceras* cf. *biassalense* (KARAKASCH) and *Rodighieroites lamberti* (SAYN) (pointing to the Verrucosum zone interval), and *Himantoceras* cf. *trinodosum* THIEULOY, *Haploceras (Neolissoceras) desmoceratoides* WIEDMANN, *Sarasinella* cf. *sakalavense* (BESAIRIE), *Criosarasinella* cf. *furcillata* THIEULOY and *Rodighieroites cardulus* COMPANY (characteristic of the Trinodosum zone). A check on the above-mentioned age is due to the latest Valanginian species *Eleniceras transsylvanicum* (JEKELIUS), recorded in the very next limestone bed of the same formation (Avram, Grădinaru, 1993).

The *Jeanthieuloyites* representatives in the above assemblage are: *J. keiserlingiformis* AVRAM & GRĂDINARU, *J. trapezoidalis* AVRAM & GRĂDINARU and *Jeanthieuloyites* n. sp. ind. As for the boreal origin of the genus, this is encouraged by the distinct ornamentation of the first of these species, reminding that of *Polyptychites keyserlingi* NEUMAYR & UHLIG, but displaying also 6 deep, prorsiradiate constrictions per whorl, up to the end of its phragmocone (Pl. I, Figs. 2 a-c), beside the suture line of *Holcodiscus* type. It was considered by the authors as the most conservative species of the genus and, taking into consideration its ontogenetic evolution, proterogenetically announcing the Hauterivian genus *Spitidiscus*, a link between *Polyptychites* (Boreal, but with immigrants into the Tethyan realm) and this last Tethyan genus.

The above interpretation comes to argue once more the importance of migrations in evolutionary radiations: it seems that some representatives of *Polyptychites* migrated into the Tethyan domain during the latest Early Valanginian and evolved in the new environmental conditions towards the genus *Jeanthieuloyites*, then spreading within the large area from France to Madagascar.

On the other hand, the stratigraphic position of the Braşov Formation, transgressively overlapping the Stramberg-type white massive limestones, capped by a bed of almost 20 cm thick pelletal-intraclastic calcarenite bearing agglutinant forams, corals, algae, chaetetids and diceratids indicative of a Berriasian-Early Valanginian age (Grădinaru, Bărbulescu, 1989), points once more to the intra-Valanginian break in sedimentation, as the Lower Cretaceous succession of the Bucovinian nappe also does (see above). It also allows to specify the time of the sea-level rising after this break in sedimentation as being the latest Early Valanginian.

4. Paleobiogeography

The fossil immigration from the Boreal domain into the Carpathian trough during the early Late Valanginian is strongly related to the sea-level rising, a phenomenon emphasized by the latest Lower Valanginian stratigraphic gap as in the Tethyan central Carpathian areas (i. e. Braşov-Codlea region) so in presumably

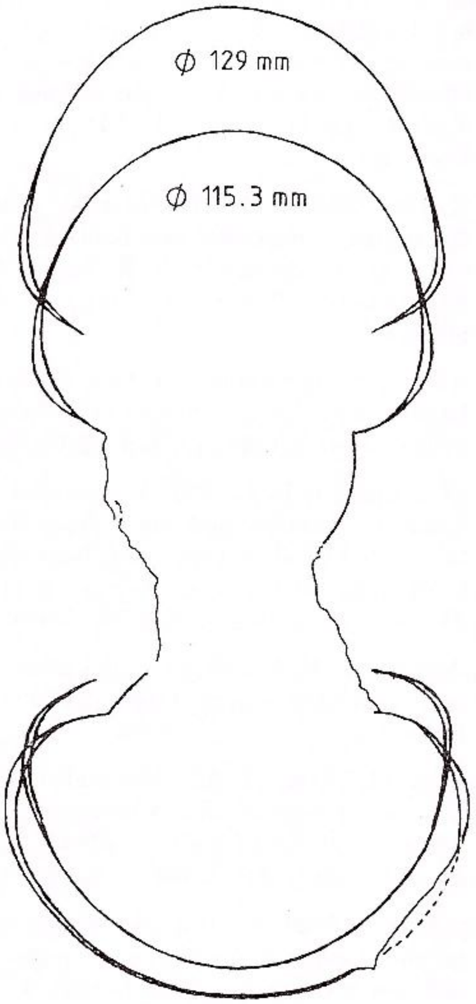

Fig. 4 - Whorl sections of *Polyptychites* cf. *michalskii* (BOGOSL.) at the diameters of 115.3 and 129 mm.

the most neighbouring plate area of the Boreal domain - in the Tomaszow syncline of central Poland.

By ammonite evidences, in the latter region, Kutek et al. (1989) carried out a sketch-map showing the Tethyan faunal migration into the Polish sub-basin of the Boreal realm during the Verrucosum-zone time span. This picture is here presented in Figure 2, the only modification being the acceptation of a migration in the contrary sense, from the Boreal, towards the Tethyan areas. This migration southwards seems to be important, taking into account the presence in several regions of the northern slope of the Carpathian trough (i. e. the Median, Outer and Marginal Dacides) of the Boreal immigrants, up to the main suture area of the basin (= the Transylvanides) (Fig. 3). The Boreal borrowings affected the plankton (nannofossils), the benthos (foraminifers) and, locally, the nectonic faunas (ammonites), too.

The above described picture is only the local manifestation of the widespread transgression during the early Late Valanginian, felt in sedimentation and/or fossil content in Spain (Hoedemaeker, 1995), South France (Autran, 1993), England and Germany (Rawson, 1973, 1994; Kemper et al., 1981), Poland (see above), etc. This transgression caused the fossil immigration in both directions, but while the immigrants from Tethys into the Boreal domain were more frequent and repeatedly signalled (Rawson, 1973; Kemper et al., 1981; Kutek et al., 1989), those coming to the contrary direction were scarcer and less emphasized (Thieuloy, 1977; Kotetichvili, 1983).

5. Systematics

Class **Cephalopoda** LEACH, 1817
Order **Ammonoidea** ZITTEL, 1884
Suborder **Ammonitina** HYATT, 1889
Family **Olcostephanidae** HAUG, 1910
Subfamily **Polyptychitinae** SPATH, 1924
Genus *Polyptychites* PAVLOW, 1892
Polyptychites cf. *michalskii* (BOGOSLOWSKI)
Pl. I, Figs. 1 a-c; text-Fig. 4

Type reference: *Olcostephanus Michalskii* BOGOSLOWSKI, 1902, p. 49-52, pl.XV, figs. 1 a-b, 2 a-b (lectotype chosen and refigured by Bodilevski, 1962, pl. LX, figs. 1 a-b), 3 a-b, 7.

Other references: *Polyptychites* cf. *quadrifidus* v. KOENEN, Turculeţ, 1963, p. 60-61, text-figs. 1 a-c.

Description. An old/herontic example, displaying a tendency of uncoiling of the last half-whorl; its body chamber is more than half a whorl long (seen in spite of the bed preservation of the sutures). Related to the gentle uncoiling of the last whorl, the umbilicus is narrower in the inner whorls as against the last one. The whorl section is depressed, sub-oval to sub-trapeze-shaped, with a steep umbilical wall, convergent sides and large, rounded ventrum, but deformed by postdepositional stress, in the body chamber area (Fig. 3). Its ornamentation consists of 28 periumbilical ribs on the last whorl, which cross radially and gently flexuous the sides, and are bifurcated forward at 1/3 of the whorl-height. Usually, between the bifurcate ribs, a single rib is intercalated, that of variable length (in places joined to the bifurcate ones at the base of the sides; the 1:3 ratio between the umbilical and ventral ribs is almost constant: on the last whorl, 23 umbilical ribs correspond to 67 ventral ones. All the ribs cross curved towards the aperture the ventral area.

Measurements:

ϕ	O	H	W	W/H
130.5 mm	48 (0.367)	44 (0.337)	55 (0.40)	1.24
115	37.2 (0.32)	40.5 (0.34)	51.4 (0.44)	1.28
106.8	32 (0.30)	39.6 (0.37)	54 (0.50)	1.36
(75)	15	36.5	57	1.56

Remarks. The above described example stands near to the *Polyptychites ramulicosta* PAVLOW - *P. michalskii* (BOGOSLOWSKI) group, and also to *P. quadrifidus* v. KOENEN by its lateral ornamentation, but by its whorl section it is nearer the individual figured as *Olcostephanus* cf. *michalskii* var. by Bogoslovski (1902, p. 52, pl. XL, figs. 6 a-c). It is different from all the mentioned species by more numerous periumbilical ribs (but at a significant larger size) than the type-specimens.

Occurrence: *Polyptychites michalskii* was recorded in the Middle Valanginian of the East European Platform, fide Bodylevskii (1962).

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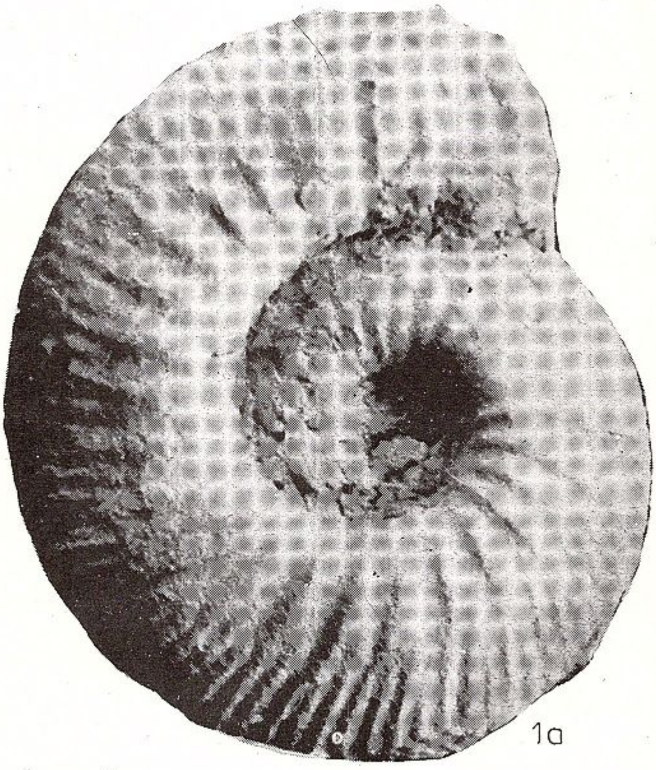
Plate I

Figs. 1 a–c — *Polyptychites* cf. *michalskii* (BOGOSLOWSKI). x 0.77. Moldova valley, "Piatra Străjii" quarry; preserved in Museum of Bucovina, dept. of Natural Sciences, no. 1418/36.

Figs. 2 a–c — *Jeanthieloyites keyserlingiformis* AVRAM & GRĂDINARU, holotype. x 1. "Piatra Mare" quarry, near the Codlea town; preserved in the University of Bucharest/Laboratory of Geology repository, no. 00614.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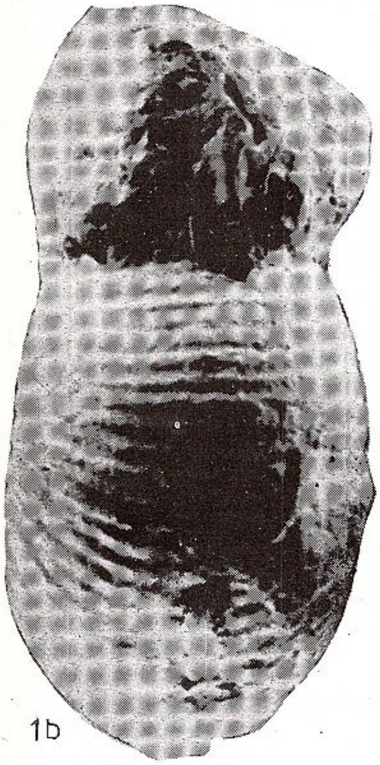
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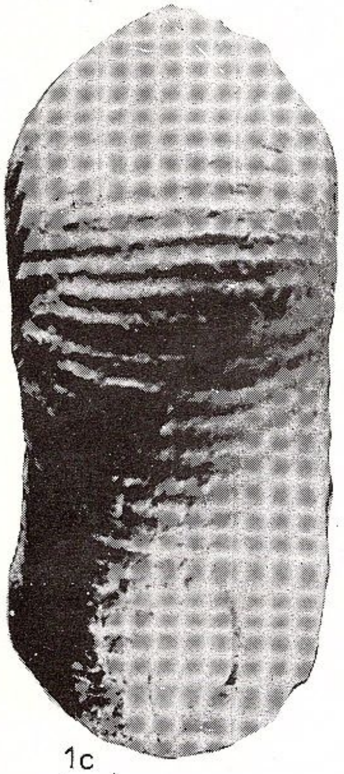
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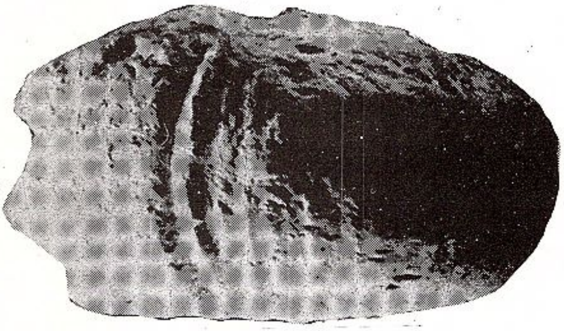
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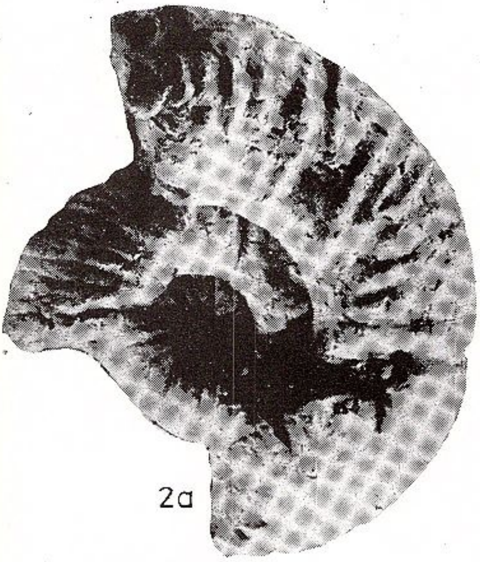
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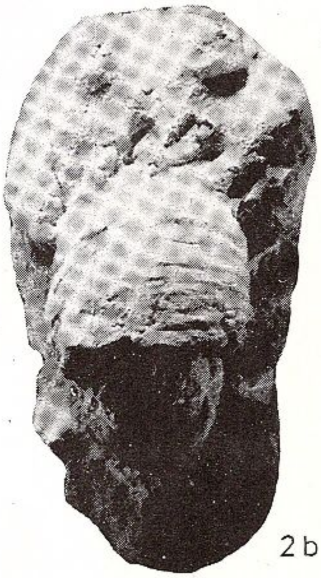
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Plate II

Figs. 1, 2 — *Speetonia colligata* BLACK (same specimen); Sviniţa, Murguceva Formation (MO 30).

Fig. 3 — *Cruciellipsis cuvillieri* (MANIVIT) THIERSTEIN; Sviniţa, Murguceva Formation (MO 30).

Fig. 4 — *Micrantholithus obtusus* STRADNER; Perşani Mts, Carhaga valley, Carhaga Formation.

Fig. 5 — *Conusphaera mexicana* TREJO; Carhaga valley, Carhaga Formation.

Figs. 6, 7 — *Micrantholithus speetonensis* PERCH-NIELSEN: 6, Carhaga valley, Carhaga Formation; 7, Moldova valley, Muncelu sandstones and conglomerates.

Fig. 8 — *Micrantholithus hoschulzii* (REINHARDT) THIERSTEIN; Moldova valley, Muncelu sandstones and conglomerates.

Figs. 9, 10 — *Tegumentum striatum* (BLACK) CRUX; Sviniţa, Murguceva Formation (MO 33).

Fig. 11 — *Zeughrabdothus sisyphus* (GARTNER) CRUX; Moldova valley, Muncelu sandstones and conglomerates.

Fig. 12 — *Grantarhabdus medii* BLACK; Reşiţa region, Crivina marls (S 98 in Melinte, 1992).

Fig. 13 — *Rhagodiscus asper* (STRADNER) REINHARDT; Reşiţa region, Crivina Marls (S 100).

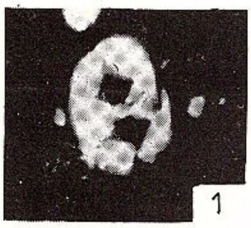
Figs. 14, 15 — *Cretarhabdus angustiforatus* (BLACK) BUKRY; Sviniţa, Murguceva Formation (MO 38).

Figs. 16, 17 — *Tegumentum stradneri* THIERSTEIN; Reşiţa region, Crivina marls (S 96).

Fig. 18 — *Crucibiscutum salebrosum* (BLACK) JAKUBOWSKI; Carhaga valley, Carhaga Formation.

Fig. 19 — *Biscutum constans* (GORKA) BLACK; Carhaga valley, Carhaga Formation.

Except figures 15 and 17 which are in light, all the others are in crossed-nicols; all, LM x 2500.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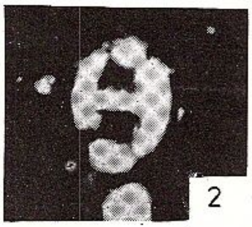
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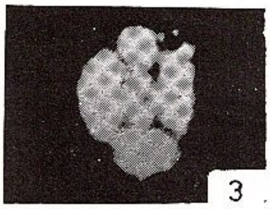
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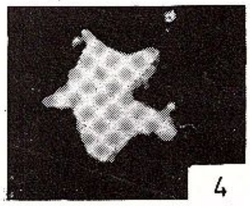
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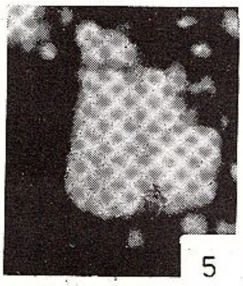
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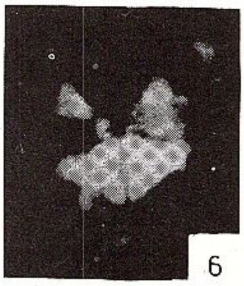
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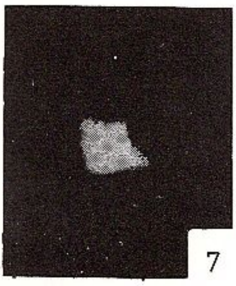
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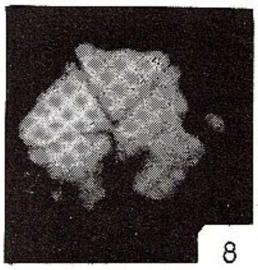
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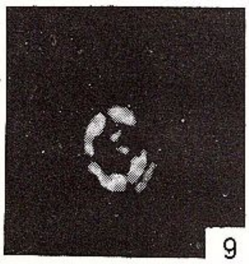
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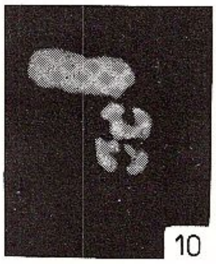
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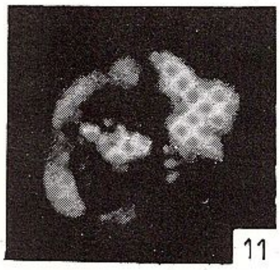
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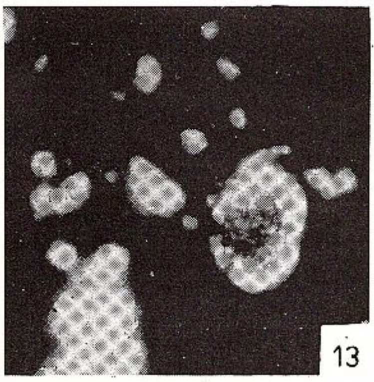
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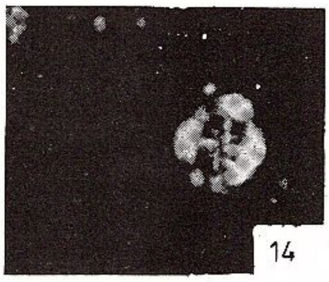
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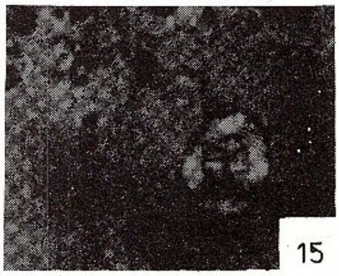
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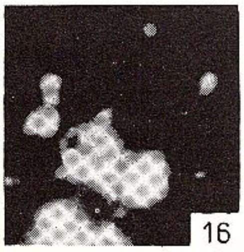
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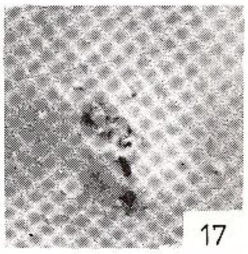
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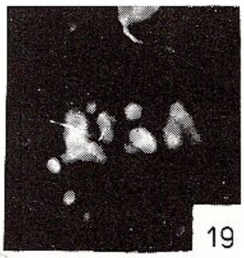
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Rom. J. Stratigraphy, 77, 4, p. 37–46, Bucureşti, 1998

THE HAUTERIVIAN–BARREMIAN STAGE BOUNDARY IN SVINIŢA AREA (BANAT, SW ROMANIA)

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IGCP-362
Tethyan and Boreal
Cretaceous

Key words: Lower Cretaceous. Hauterivian-Barremian boundary. Integrate paleontology. Ammonites. Dinoflagellate cysts. Nannofossils. Sviniţa region. South Carpathians. Romania.

Abstract: The genus *Pseudothurmannia* offers the best marker at the Hauterivian-Barremian stages boundary. Its range interval seems to be better defined as index species by *Pseudothurmannia picteti* than by *P. angulicostata*. The same interval is also characterised by the first record of Pulchelliids (*Psilotissotia* spp.) and is a little preceded by the first Cheloniceratinae (*Paraspiticeras*) and by a very significant evolutionary step in dinoflagellate assemblages (from the biozone with *Oligosphaeridium complex* and *Druggidium deflandrei*, to the biozone with *Dingodinium albertii* and *Meiourogoniaulax stoveri*, fide Antonescu, Avram, 1980). On the other hand, the first markers of the Lower Barremian as accepted by Hoedemaeker et al. (1993) pertain to the family Holcodiscidae, a group fully developed in Hauterivian. All these facts lead us to consider the Pseudothurmannia beds (= P. angulicostata zone in litt.) as the base of the Barremian stage.

1. Introduction

The Upper Hauterivian-Lower Barremian fossiliferous rock-sequences were recognised in Romania in several regions, namely:

1. in the Central Carpathian structural units (or "the Median Dacides", sensu Săndulescu, 1984), in the East Carpathian Hăghimaş Mts and the South Carpathian Codlea-Braşov and Dâmbovicioara areas;
2. in the inner structural units of the East Carpathians (or "the Outer and Marginal Dacides", sensu Săndulescu, 1984), in the Baraolt and Ceahlău nappes, and also, in the Sviniţa area, respectively;
3. in the outer structural units of the Carpathians (or "the Moldavides", ibidem), in the Audia Nappe;
4. in the southernmost foreland unit of the Carpathians, i. e. the Moesian Platform (for details, see Avram, 1988).

But in almost all these regions the ammonite inventories are relatively poor in fossils or are offered by disparate exposures so that they are not proper to a detailed biostratigraphic study at the Hauterivian-Barremian boundary. In fact, only in the Sviniţa village area (the SW end of the South Carpathians, by the Danube, Fig. 1 A) the conditions of the fossil richness and stratigraphic continuity necessary to this study are most favourable.

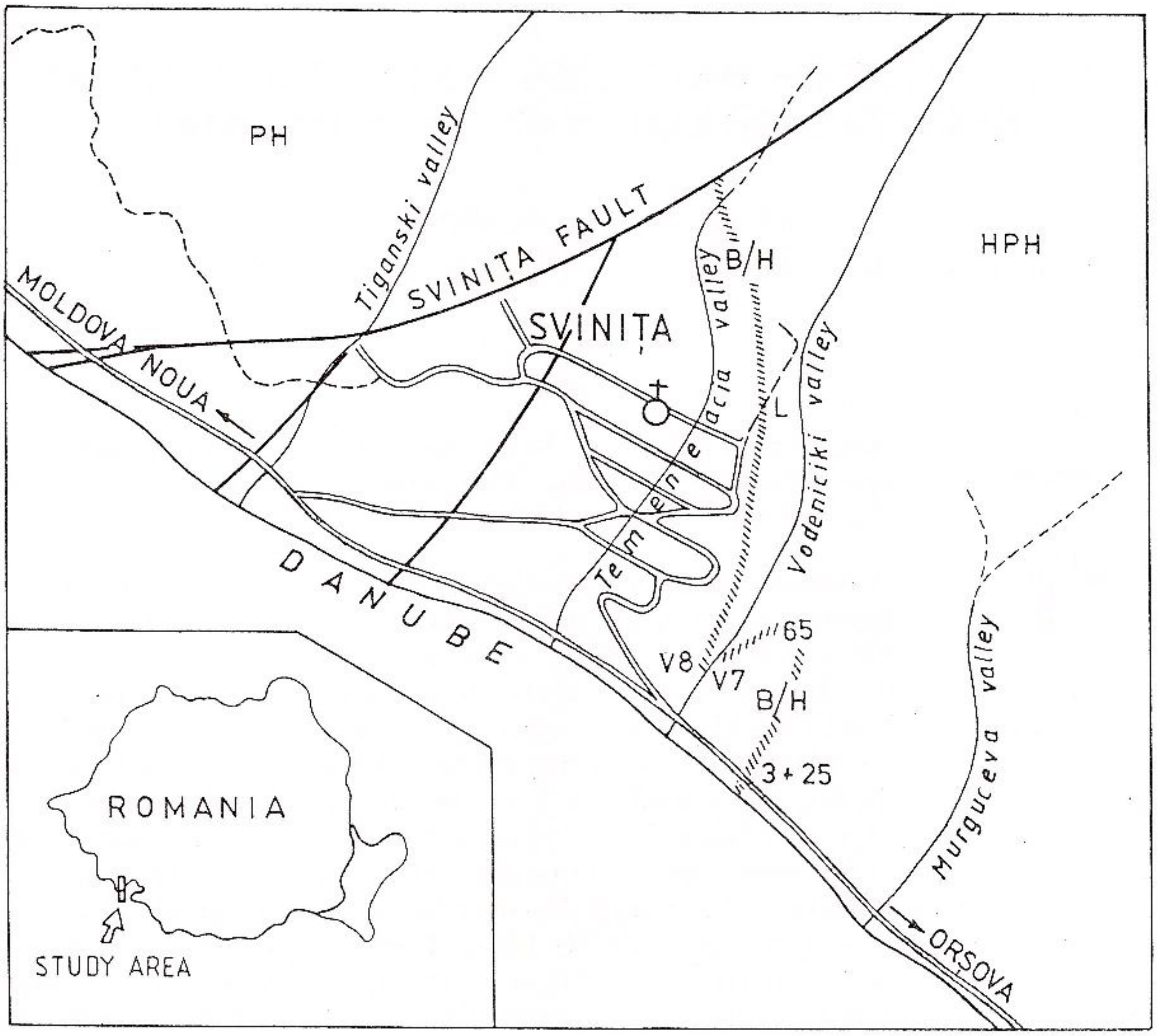

Fig. 1 – Location of the studied sections crossing the Hauterivian-Barremian boundary (L, V7-V8, 65, 3+25) in the Sviniţa area. Inset shows the location of the study area within Romania). PH=pre-Hauterivian sedimentary formations; HPH=Hauterivian + pre-Hauterivian sedimentary formations.

There, the Hauterivian-Barremian boundary beds are characterised by a gradual change in lithologies from the variable thick/thin-bedded clayey limestones of the Vodeniciki Member upwards to the marly/marlstone sequence of the Temeneacia Member of the Sviniţa Formation (Avram, 1976, 1994). The ammonite remains are relatively frequent but almost always crushed and, partly fragmentary, in these conditions difficult to be accurately identified (the pyritised ammonite nuclei appear above the boundary, in the proper Lower Barremian marly sequence). The boundary beds are exposed along the path running from Sviniţa to the mouth of the only tributary on the right of the Vodeniciki Valley (L, in the Fig. 1), in the Vodeniciki Valley (V7, V8, in the same Fig. 1), on the path on the left side of the Vodeniciki Valley (65) and in the cutting of the Orşova-Sviniţa highway along the Danube side (3+25), this last with its lower part gravitationally dislocated, but compared with section L on the ground of nannofossil evolutionary events. The first and the last of these sites have been recently sampled, while the fossils yielded by the second were published by

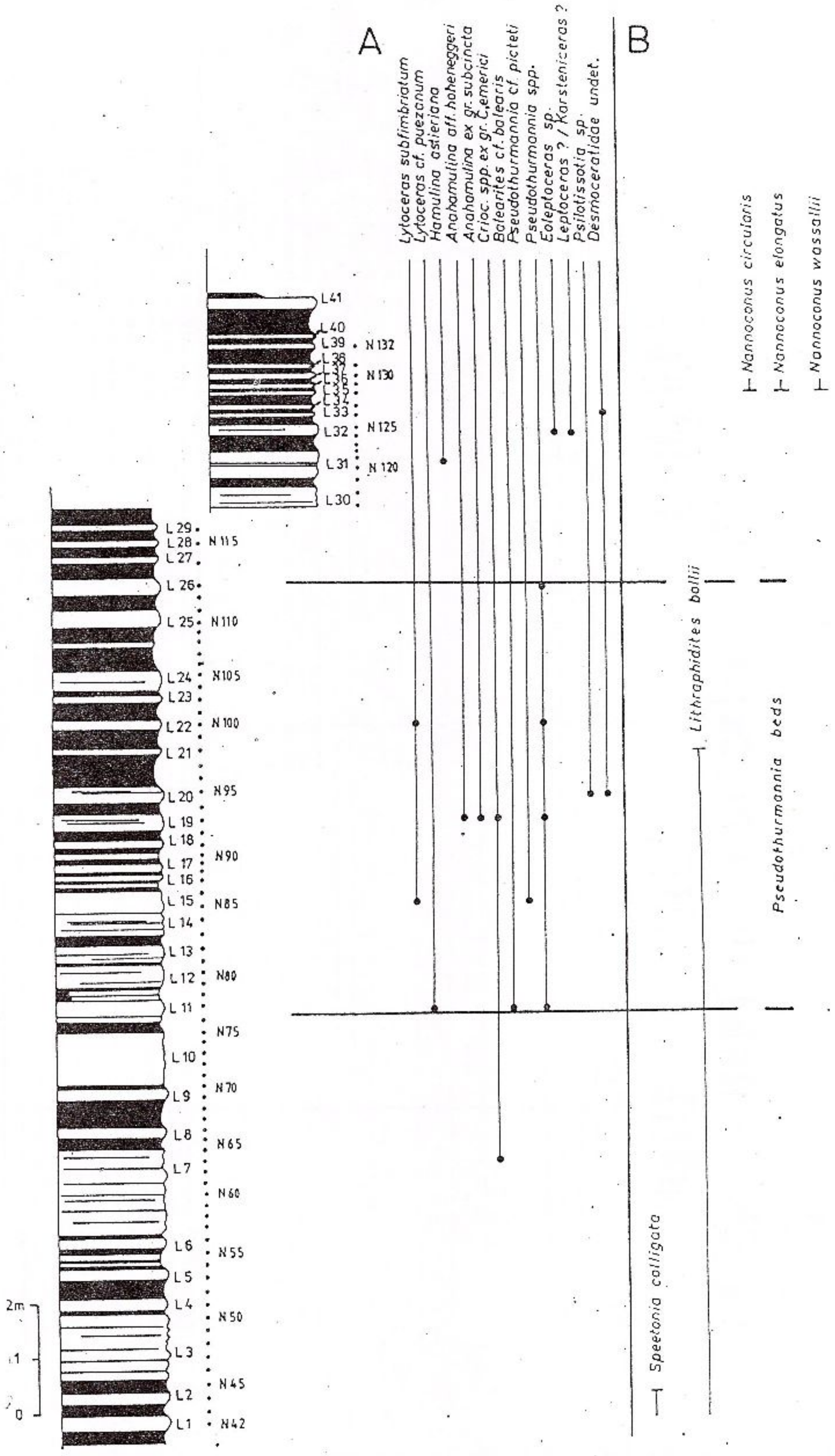

Fig. 2 – The ammonite and nannofossil Upper Hauterivian-lowermost Barremian assemblages in the Site L, north of Sviniţa village.

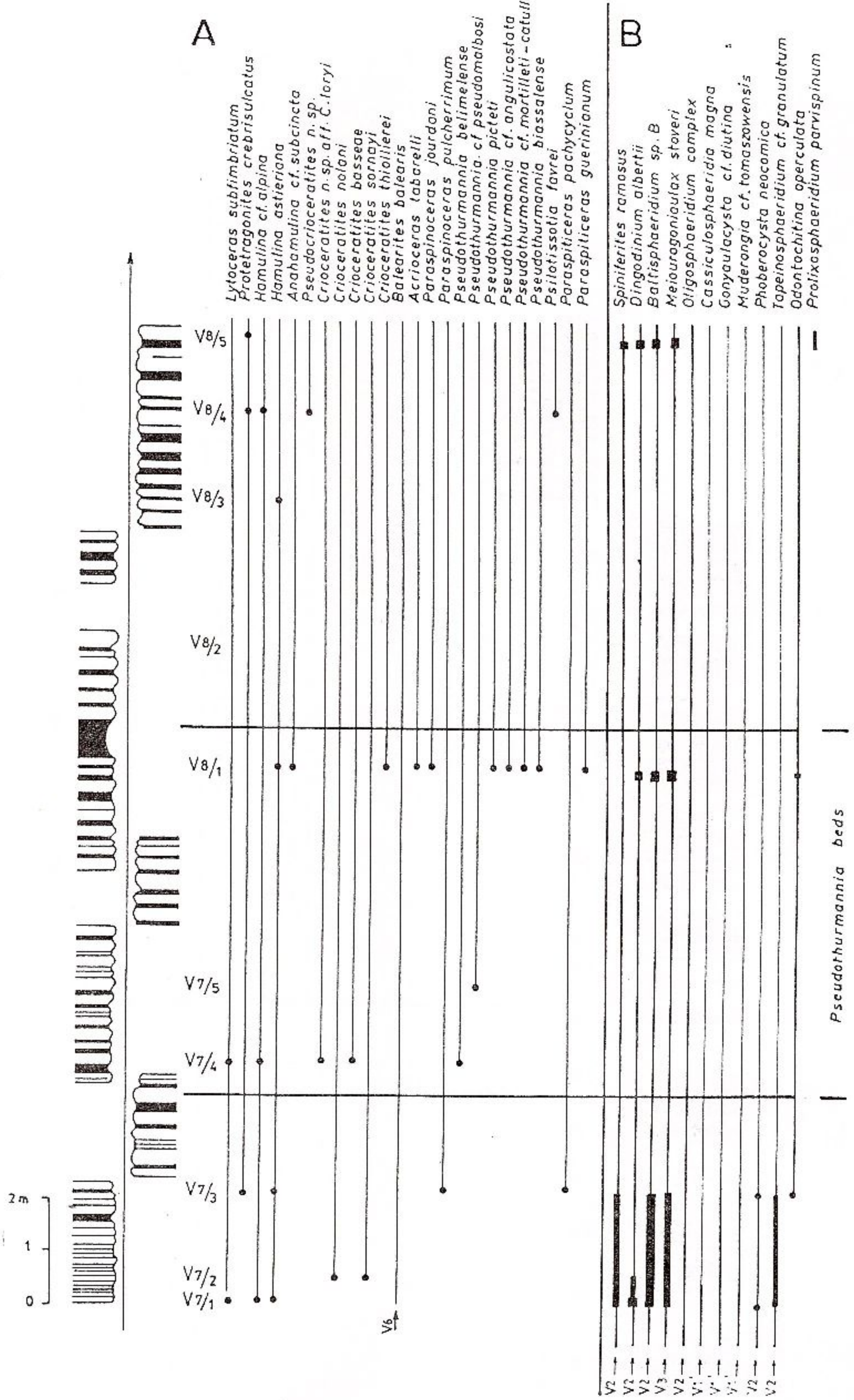

Fig. 3 – The ammonite and dinoflagellate cysts assemblages at the Hauterivian-Barremian boundary along the Vodeniciki valley (V7-V8).

Avram (1983, 1988, 1994) and by Antonescu, Avram (1980).

2. General view on the ammonite, dinoflagellate and nannofossil assemblages succession at the Hauterivian-Barremian boundary in Sviniţa area

The ammonite, dinoflagellate and nannofossil evolution in the Hauterivian-Barremian boundary beds of the three main from the four mentioned sections is shown in the text-figures 2, 3, and 4. All these biostratigraphic data are assembled together in the table on figure 5, where the sections are correlated by comparison to the thickness of the beds, taking as datum the top of the Pseudothurmannia interval, and by the main events in nannofossil evolution.

It is easily observable that the main ammonite marker at the boundary is the genus *Pseudothurmannia*. As underlined by one of us (E. A.) in 1983, in the Sviniţa area, the "Pseudothurmannia" zone could be better defined by *P. picteti* SARKAR than by *P. angulicostata* (D'ORBIGNY) due to the presence of the former in almost the whole interval of the genus (L 15; V8/1); on the other hand, the lower part of the genus range-interval is characterised by *Pseudothurmannia pseudomalbosi* (SARASIN & SCHÖNDELMAYER) (V7/5) and *P. belimelense* DIMITROVA (V7/4), while in its upper part *P.* cf. *angulicostata* (D'ORBIGNY), *P.* ex gr. *mortilleti* (PICTET & LORIOL)- *catulloi* (PARONA) and *P. biassalense* DIMITROVA are developed (L 19-21; V8/1; 65; 3+25/1-2; 3+25/4).

Apart from the phylloceratid *(Hypophylloceras, Holcophylloceras, Phyllopachyceras)* and lytoceratid *(Lytoceras* s. str., *Eulytoceras, Protetragonites)* representatives, which are frequent but biostratigraphically less important, in the same interval were recorded species of *Hamulina, Paraspinoceras* and *Crioceratites* coming from the Balearis zone, such as *H. alpina* D'ORBIGNY (3+25/4, V7/3-V8/1), *H. astieriana* D'ORBIGNY (L 31; V7/1-V8/3; 3+25/14), *P. jourdani* (ASTIER) (V8/1), *C.* sn. sp. aff. *C. loryi* (SARKAR) (V7/4), *C. basseae* (SARKAR) (V7/4), *C. munieri* (SARASIN & SCHÖNDELMAYER) (65), *Crioceratites* very near (or even typical) *C. emerici* LEVEILLE (L 7, L 19, but also in V6); the last species needs to be underlined by its rising much earlier than generally accepted. The top of the Balearis zone is also marked by the first record of *Paraspiticeras pachycyclum* (UHLIG) (V7/3).

In the upper part of the "Pseudothurmannia" zone various species of *Anahamulina: A.* cf. *hoheneggeri* (UHLIG), *A.* ex gr. *subcincta* (UHLIG) were recorded (in L 19 and in L 19 and V8/1 respectively), beside *Crioceratites thiollierei* ASTIER (V8/1; 3+25/5-8), *Acrioceras* ex gr. *tabarelli* (ASTIER) (V8/1), *Paraspiticeras guerrinianum* (D'ORBIGNY) (V8/1) and also, *Psilotissotia* sp. (L 20; 3+25/3-4) and *P. favrei* (OOSTER) (3+25/4).

The beds next to the *Pseudothurmannia* bearing ones offered also *Crioceratites thiollierei* (3+25/5; 3+25/8), then the first Leptoceratoidinae: *Eoleptoceras parvulum* (UHLIG) (3+25/9), *Leptoceras* cf. *brunneri* (OOSTER) (still existing in Lower Barremian, here in 3+25/14), beside *Psilotissotia favrei* (V8/4, the layer 65+6 m), *P. mazylea* (COQUAND) (3+25/9) and numerous desmoceratidae still specifically unidentified, except *Abritusites neumayri* (HAUG) (3+25/8); in the same interval, the first representatives of the genus *Pseudocrioceratites* EGOJAN were also recognised (V8/4).

Spitidiscus oosteri [the thin ribbed variant of the *S. hugii* (OOSTER)- *S oosteri* (SARASIN & SCHÖNDELMAYER) group] was identified at several meters above the top of *Pseudothurmannia* (3+25/14).

The dinoflagellate cysts succession in the beds near the Hauterivian-Barremian boundary (Antonescu, Avram, 1980) displays a very

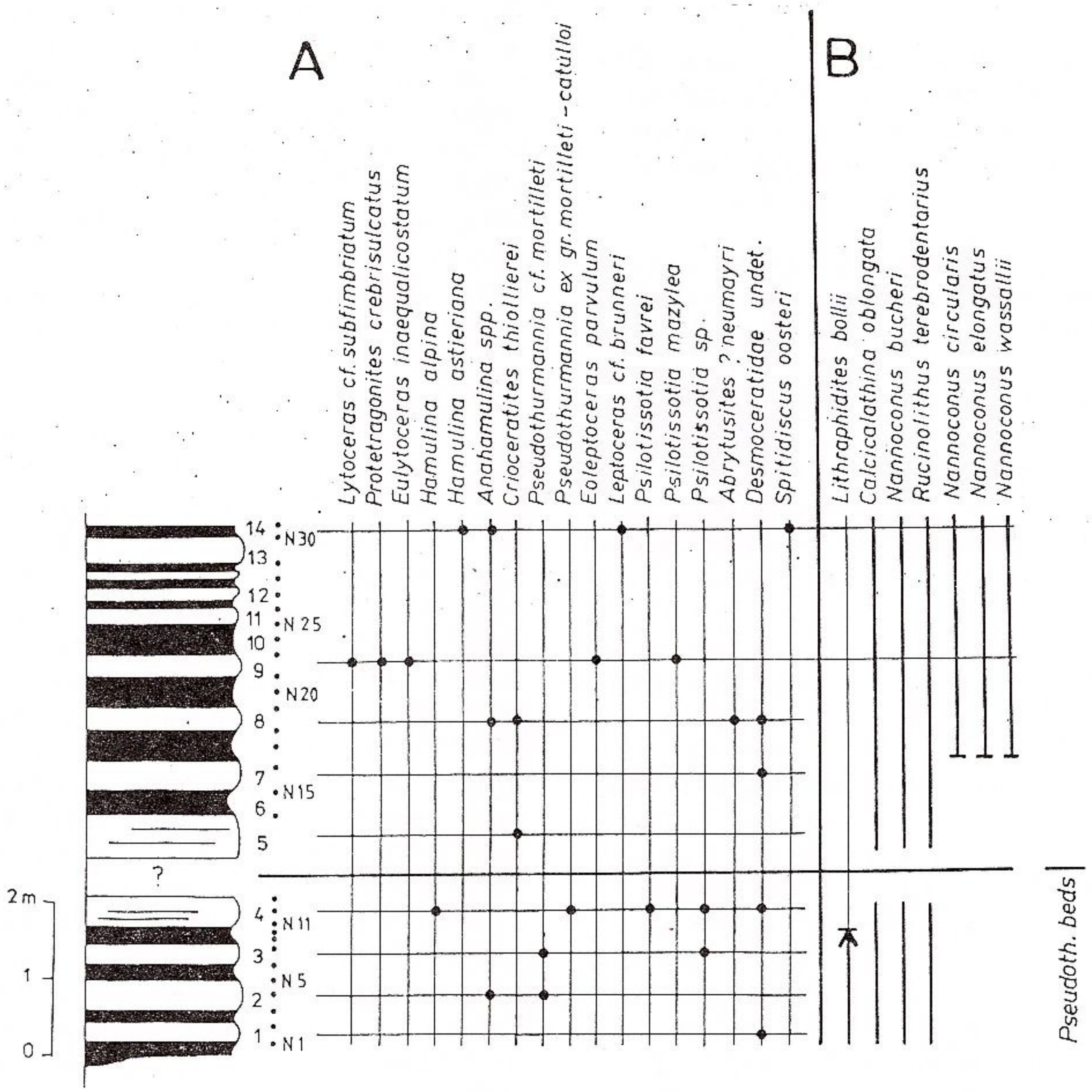

Fig. 4 - The ammonite and nannofossil Uppermost Hauterivian and Lowermost Barremian assemblages in the site 3+25.

important evolutionary step in the interval V7/1-V7/3, just below the first *Pseudothurmannia* and in the same layer with *Paraspiticeras pachycyclum*, where no changes in lithologies are observed: several species such as *Spiniferites ramosus* (EHRENB.) MANTELL, *Dingodinium albertii* SARJEANT, *Baltisphaeridium* sp. B. ex HABIB (1971), *Meiourogoniaulax stoveri* MILLIOUD are spectacularly larger developed, some of them such as *Oligosphaeridium complex* (WHITE) DAVEY & WILL., become rare, and *Cassiculosphaeridia magna* DAVEY, *Gonyaulacysta* cf. *diutina* DUXBURY, *Muderongia* cf. *tomaszo-*

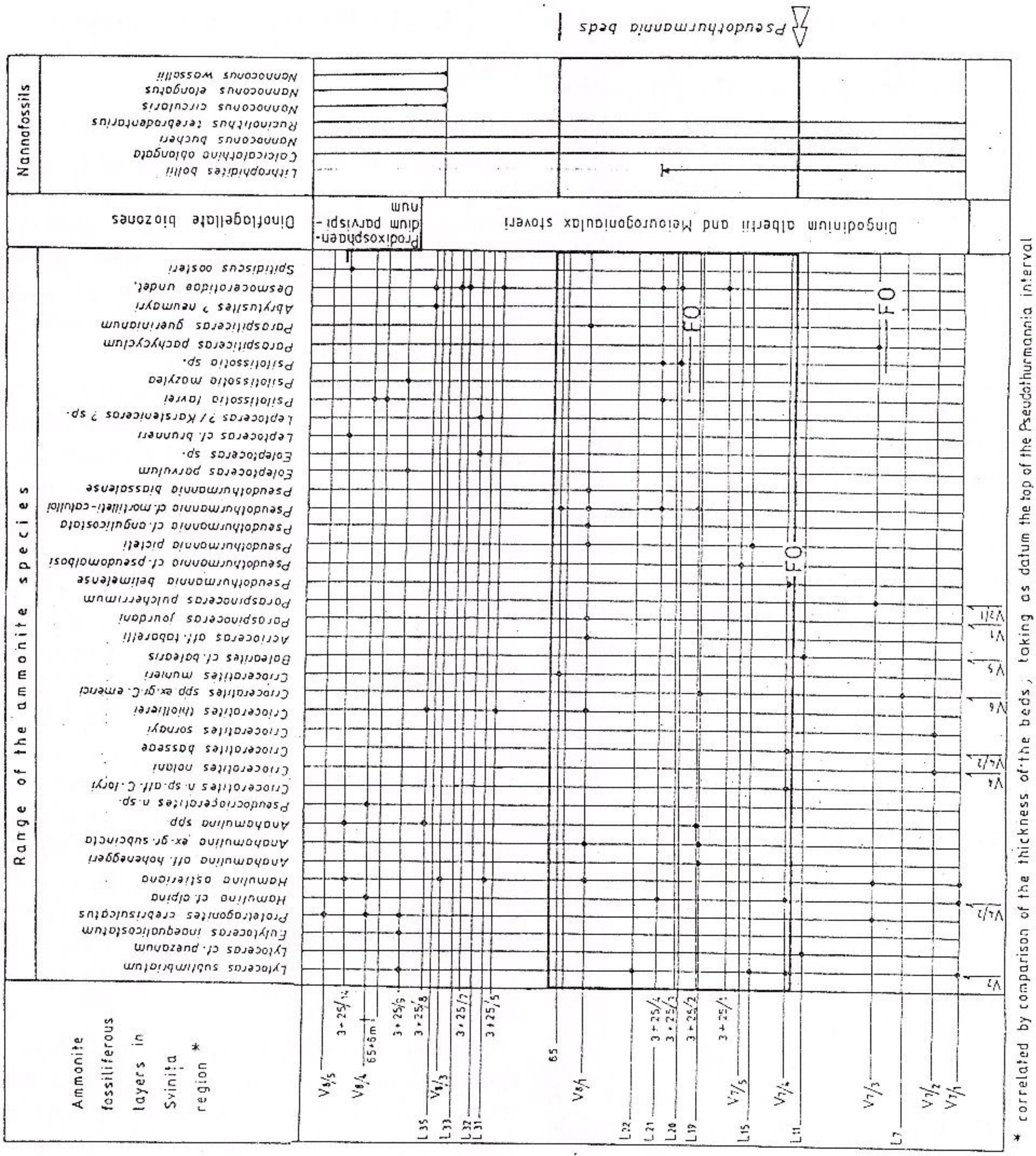

Fig. 5 – Comparative biostratigraphic (ammonite, dinoflagellate and nannofossil) data at the Hauterivian-Barremian boundary in the Sviniţa region (FO=first occurrence). The arrow on the right of the figure notes the Hauterivian-Barremian boundary as proposed in the paper.

wensis ALBERTI, *Phoberocysta neocomica* (GOCHT) MILLIOUD, *Tapeinosphaeridium* cf. *granulatum* IOANN., STAVR. & DOWNIE disappear, while some others such as *Odontochitina operculata* (WETZEL) DEFLANDRE & COOKSON are recorded for the first time (Fig. 3). Another step in dinoflagellate evolution is registered in layer V8/5, some 6 m above the top of the Pseudothurmannia beds, where the biozone with *Dingodinium albertii* and *Meiourogoniaulax stoveri* is repalced by the biozone with *Prolixosphaeridium parvispinum* (DEFLANDRE) DAVEY, DOWNIE, SARJEANT & WILL., also characterised by the range-end of the species *Pseudoceratium pelliferum* GOCHT and *Muderongia* cf. *mcwhaei* COOK-

SON & EISENACK. Thus, only the base of the former biozone seems to be significant in comparison with the evolution of the ammonite assemblages.

The nannofossil assemblages of the same succession are, as shown by the sections L and 3+25, mainly characterised by the extinction of *Lithraphidites bollii* THIERSTEIN (in sample N 11; between layers 3+25/3 and 3+25/4; and also in sample N 98, i. e. in layer L 21), and the first occurrence of *Nannoconus circularis* DERSE & ACHERITEGUY, *N. elongatus* BRÖNNIMANN and *N. vassallii* BRÖNNIMANN (in sample N 18, immediately below layer 3+25/5; in sample N 128, i. e. in layer L 35); several other nannofossil species were recognised in all the samples here (most of them not presented in the text-figures), all crossing the boundary: *Assipetra infracretacea* (THIERSTEIN) ROTH, *Axopodorhabdus dietzmannii* (REINHARDT) WIND & WISE, *Biscutum constans* (GORKA) BLACK, in Black & Barnes (1959), *Calcicalathina oblongata* (WORSLEY) THIERSTEIN, *Conusphaera rothii* (THIERSTEIN) JAKUBOWSKI, *C. mexicana mexicana* TREJO, *Cretarhabdus angustiforatus* (BLACK) BUKRY, *Cyclagelosphaera margerelii* NOËL, *Diazomatolithus lehmannii* NOËL, *Grantarhabdus meddii* BLACK, *Haqius circumradiatus* (STOVER) ROTH, *Lithraphidites carniolensis* DEFLANDRE, *Micrantholithus obtusus* STRADNER, *Nannoconus bucheri* BRÖNNIMANN, *N. golbosus* BRÖNN., *N. kamptneri* BRÖNN., *N. minutus* BRÖNN., *N. steinmannii steinmannii* KAMPTNER, *Perissocyclus plethotretus* (WIND & CEPEK & CRUX, *Rucinolithus terebrodentarius* APPLEGATE et al. in Covington & Wise (1987), *Vekshinella stradneri* ROOD et al., *Watznaueria barnesae* (BLACK) PERCH-NIELSEN, *W. britannica* (STRADNER) REINHARDT.

3. The Hauterivian-Barremian boundary

The constant development of the Pseudothurmannia beds along the Tethyan domain leads us to consider them as a very representative, undividable marker at the boundary.

As for the appurtenance of these beds to the Hauterivian or to the Barremian stage, two main points of view have been mostly discussed until now:

1) that considering the boundary at the base of Pseudothurmannia beds, indirectly asserted by Coquand (1862) in his original definition on the Barremian stage, much before the proposition of the Hauterivian stage, by Renevier (1874) (see also Busnardo, 1965 and Lapeyre, Thomel, 1974) and argued or only adopted by Haug (1927)[1], Luppov, Drushtchits (1958), Drushtchits, Kudrjavcew (1960), Breskovski (1973), Avram (1976), Patrulius, Avram (1976), Avram (1983), Vašiček et al. (1983);

2) that considering the boundary above the beds with *Pseudothurmannia*, solution introduced by Kilian (1895) and by Paquier (1895)[1] and adopted by Lory (1898), Paquier (1900)[1], Kilian (1907), Debelmas, Thieuloy (1965), Busnardo (1965), Mandov (1976), Kakabadze (1983, 1989), etc. and confirmed by Hoedemaeker et al. (1993).

The above described succession of the ammonite assemblages in Svinița region, very near to that previously presented by Avram (1983) argues for considering the boundary below the beds with *Pseudothurmannia*, on the ground of the presence in, or immediately under these beds of the first Hemihoplitidae (*Pseudothurmannia*), Cheloniceratinae (*Paraspiticeras*) and Pulchelliidae (*Psilotissotia*), all these groups being very important for the Barremian stage biostratigraphy. Moreover, except the ammonite zonation based on Pulchelliidae (Vermeulen, 1974), the other

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[1] Took over from Lapeyre, Thomel (1974)

markers of the whole Lower Barremian belong to the family Holcodiscidae, a taxon risen in the lowermost Hauterivian (or even in Valanginian, by *Jeanthieuloyites*) and with the typical Barremian representatives (especially referring to the genera *Holcodiscus* and *Astieridiscus*) developed some meters above the top of the Pseudothurmannia beds; or, like in *Crioceratites emerici*, they rise clearly below the beds with *Pseudothurmannia*.

The same conclusion is reached by the study of the dinoflagellate cysts from the same rock-sequences, where the step between the biozone with *Oligosphaeridium complex* and *Druggidinium deflandrei* is replaced by the biozone with *Dingodinium albertii* and *Meiourogoniaulax stoveri* very near the layer of the first occurrence of *Paraspiticeras* and some 4 m lower than the base of Pseudothurmannia beds (Antonescu, Avram, 1980). On the other hand, while the species *Subtilisphaera perlucida* (ALBERTI) JAIN & MILLEPIED is in Spain characteristic of the interval between the upper part of the Balearis zone and the top of the Hugii zone (Hoedemaeker, Leereveld, 1995), in the Sviniţa region it was recognised only in the Upper Barremian.

The nannofossil assemblages, which offered a ground to correlate with one another the sections here studied by the extinction of *Lithraphidites bollii* and rising-level of *Nannoconus circularis, N. elongatus* and *N. wassallii*, could not offer any relevant data correlable to the evolution of the ammonites.

4. Conclusions

The Sviniţa region is the only area in Romania favourable to the study of the Hauterivian-Barremian boundary, by its richness in fossils and well exposed rock-sequences at this level. There, the Pseudothurmannia beds are better characterised by *P. picteti* than by *P. angulicostata* and, although it could be divided into two subzones, it is obviously the best marker (as a body) at the Hauterivian-Barremian boundary. Its appurtenance to the Barremian stage could be a better solution than it is now accepted, in accordance with the first definition of the Barremian stage (Coquand, 1861), on the ground of the rising in its interval or immediately below the first Cheloniceratinae *(Paraspiticeras)*, the first Hemihoplitidae *(Pseudothurmannia)* and the first Pulchelliidae *(Psilotissotia)*, all of these families/subfamilies being well represented in Barremian; on the contrary, the family Holcodiscidae, which offered the first markers of the Lower Barremian as accepted by Hoedemaeker et al. (1993) is mainly developed in Hauterivian.

The appurtenance of the Pseudothurmannia beds to the Barremian is also supported by the change in dinoflagellate assemblage, from the biozone with *Oligosphaeridium complex* and *Druggidinium deflandrei* to the biozone with *Dingodinium albertii* and *Meiourogoniaulax stoveri* in almost the same layer with the first *Paraspiticeras*.

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SUBSURFACE SANTONIAN–MAASTRICHTIAN DEPOSITS IN NORTH–EASTERN SOUTH DOBROGEA (ROMANIA)

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Key words: Biostratigraphy. New lithostratigraphic units. Santonian-Maastrichtian interval. Foraminifers. Nannoplankton. Charophyta. Moesian Platform.

Abstract: The litho- and biostratigraphic studies (based on foraminifers, calcareous nannoplankton, charophytes) of some deposits intercepted by drillings in the north-east part of South Dobrogea offer new data on the Senonian succession within the sedimentary cover of the Moesian Platform in this area. They show that the Senonian deposits exted stratigraphycally higher than it has been generally thought till now and include two different Maastrichtian facies: a continental-lacustrine facies rich in charophytes (Lower Maastrichtian) and a marine facies (Lower Maastrichtian-Upper Maastrichtian or only Upper Maastrichtian), with strongly diachronous boundary between them. These facies are described as two new lithostratigraphic units, Nazarcea Formation and Nisipari Formation, respectively. In the north-eastern part of South Dobrogea, a new unconformity is outlined in the base of the Maastrichtian following a hiatus which corresponds to the upper part of the Upper Campanian (Globotruncanita calcarata Interval Zone). The first intercorrelated biozonation is made now for the South Dobrogea Senonian deposits on the basis of foraminifera and nannoplankton. An assemblage of Maastrichtian charophytes with *Septorella brachycera, Porochara malladae, Microchara parazensis* was also pointed out.

1. Introduction

Litho- and biostratigraphic studies (foraminifers, Ion; calcareous nannoplankton, Melinte; charophyte, Iva) have been made on certain deposits intercepted by several drillings (6, 7, 8, 9, 10, 12-of "IFLGS"), located in the north-eastern part of South Dobrogea (Fig. 1), respectively within the area called Nisipari Valley-Nazarcea, in the north-east of Carasu Valley. The results of our research supplied new data concerning the stratigraphy and distribution of the Senonian deposits belonging to the sedimentary cover of the South Dobrogea area of the Moesian Platform. These new data, published by us in this paper, have been presented for the first time in a preliminary form (Iva et al., 1990) on the occassion of the International Symposium, Bucharest 1990, for Project 245 and Project 262 of the International Geological Correlation Program.

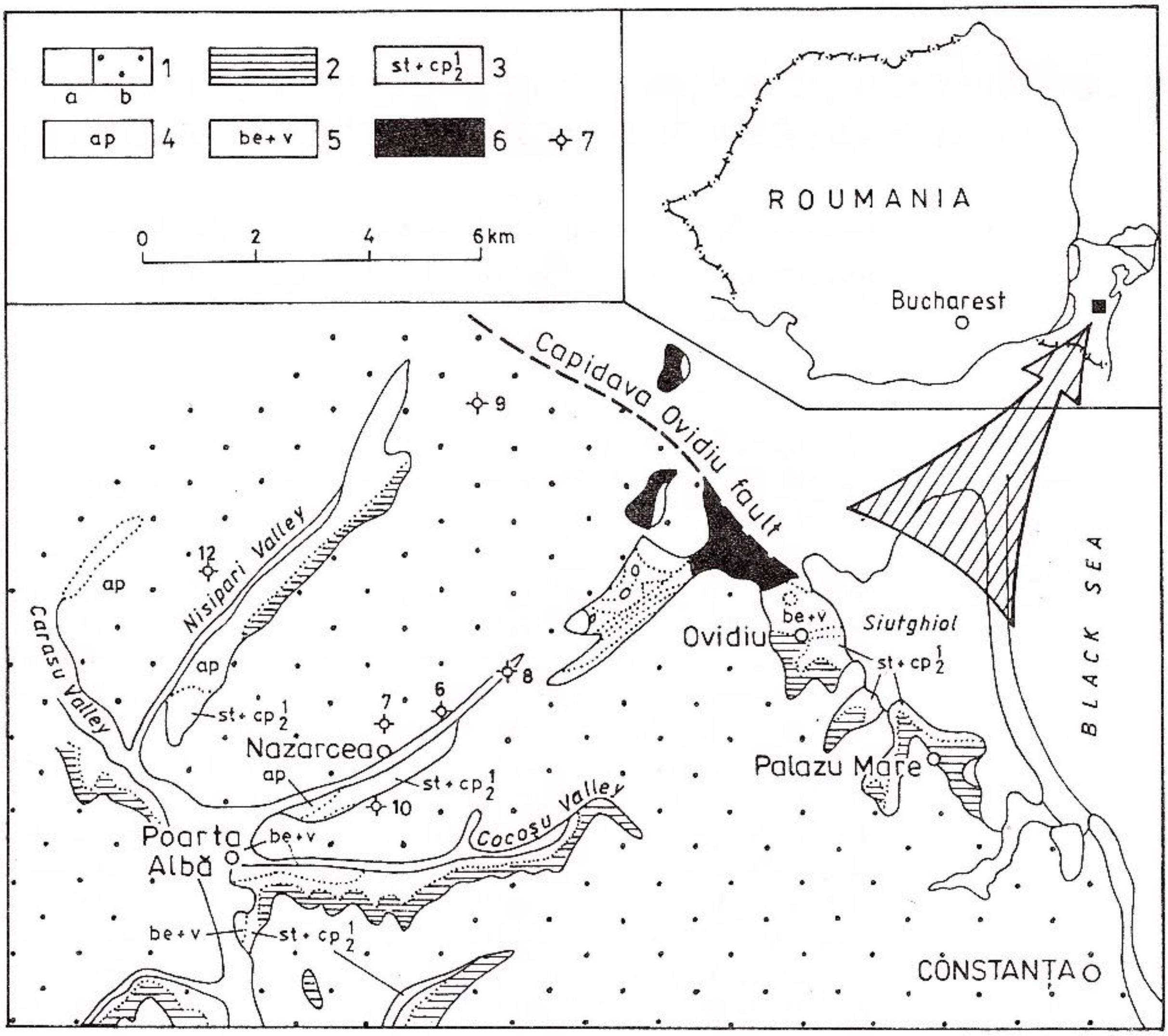

Fig. 1 - The simplified geological map of the Nisipari Valley-Nazarcea area, South Dobrogea (acc. to Avram et al., 1988), with placement of drillings. 1, Quaternary: a, alluvial deposits; b, loess; 2, Post Cretaceous deposits; 3, Murfatlar Formation (st+cp2^1 = Santonian-basal Upper Campanian); 4, Gherghina Formation (ap = Aptian); 5, Cernavodă Formation (be+v = Berriasian+Valanginian); 6, Pre-Cretaceous deposits; 7, Drillings.

It has been established that the Senonian succession of this area includes not only Santonian-Upper Campanian p.p. deposits, as it has been admitted in recent works (Neagu, 1987; Avram et al., 1988) on the basis of surface data, but also Maastrichtian deposits represented by the Lower Maastrichtian deposits in continental-lacustrine facies, followed (and substituted) by the Lower Maastrichtian-Upper Maastrichtian up to only Upper Maastrichtian deposits in marine facies (Fig. 2). So far, the Maastrichtian in continental-lacustrine facies has been unknown within the sedimentary cover of the South Dobrogea area of the Moesian Platform and the presence of the Maastrichtian in marine facies has not been admitted (Avram et al., 1988) due to the lack of paleontological data. Or, at the most, it was admitted as a possibility in certain areas (Macovei & Atanasiu, 1934; Chiriac et al., 1977),

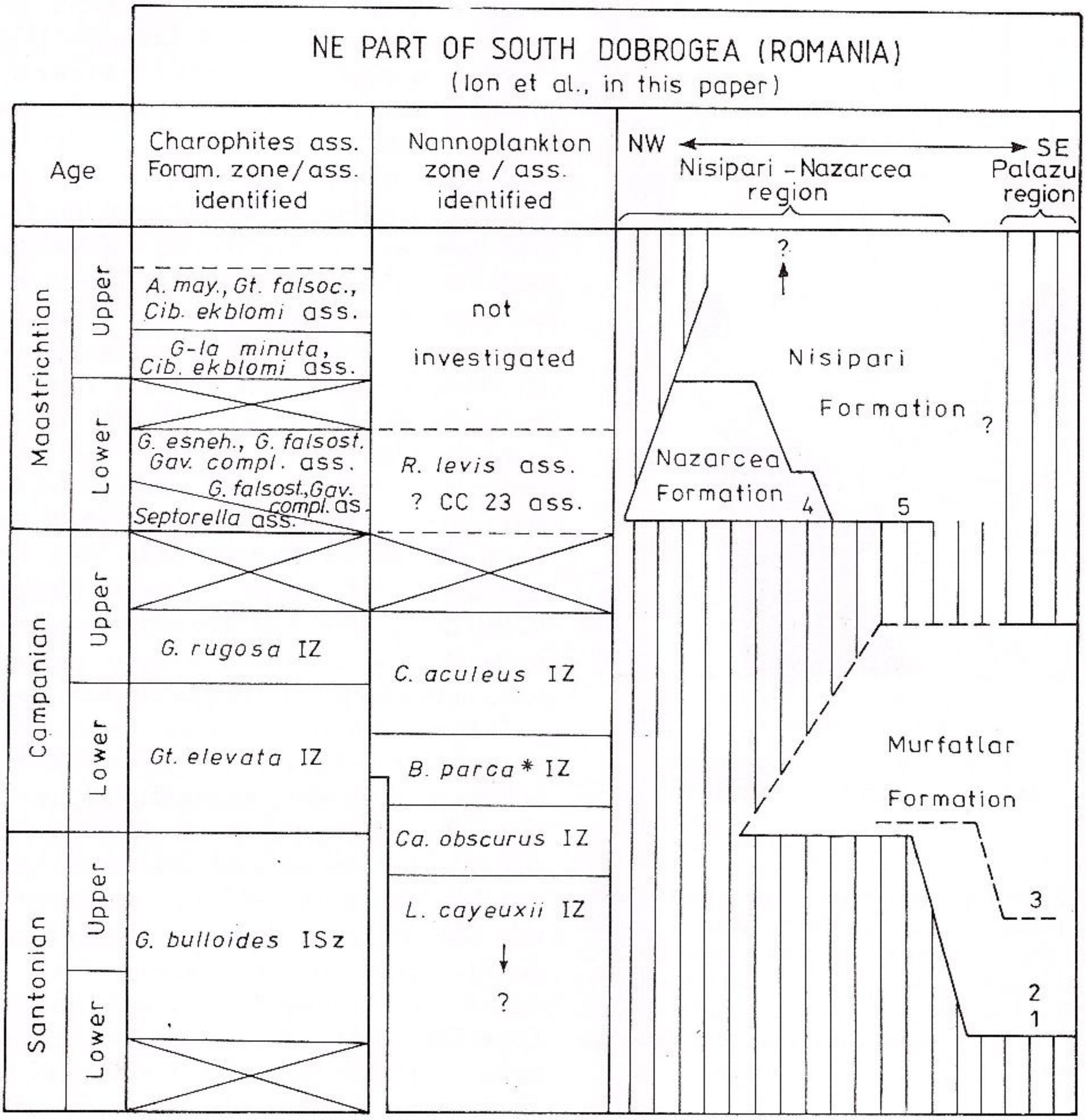

Fig. 2 - The bio- and stratigraphy of the Santonian-Maastrichtian deposits from NE part of South Dobrogea (Romania). 1-3, Murfatlar Formation (acc. to the outcropping and drilling data): 1, basal conglomerate; 2, sandstones or sands to glauconitic quartzose chalks; 3, massive white chalk with cherts and sometimes glauconitic; 4, Nazarcea Formation (known till now only in drillings), whitish and mottled marls and clays, with carophytes; 5, Nisipari Formation (known till now only in drillings), chalky clays or marls to limestones or chalky, sometimes glauconitic limestones, locally chalky sands or soft sandstones. Observation: 1-3, according to the outcropping data, Avram et al., 1988, and drilling data, Iva et al., 1990, Ion et al. in this paper; 4-5, according to the drilling data, Iva et al., 1990, Ion et al. in this paper. A. may.= *Abathomphalus mayaroensis*; Gt. falsoc.= *Globotruncanita falsocalcarata*; Cib.= *Cibicides*; G-la= *Globotruncanella*; G.esneh.= *Globotruncana esnehensis*; G.fals.= *Globotruncana falsostuarti*; Gav.compl.= *Gavelinella complanata*; G.= *Globotruncana*; Gt.= *Globotruncanita*; R.= *Reinhardtites*; C.= *Ceratolithoides*; B.= *Broinsonia*; Ca.= *Calculites*; L.= *Lucianorhabdus*; ass.= assemblage; IZ=Interval Zone; ISz=Interval Subzone.

* *Aspidolithus parcus constrictus*

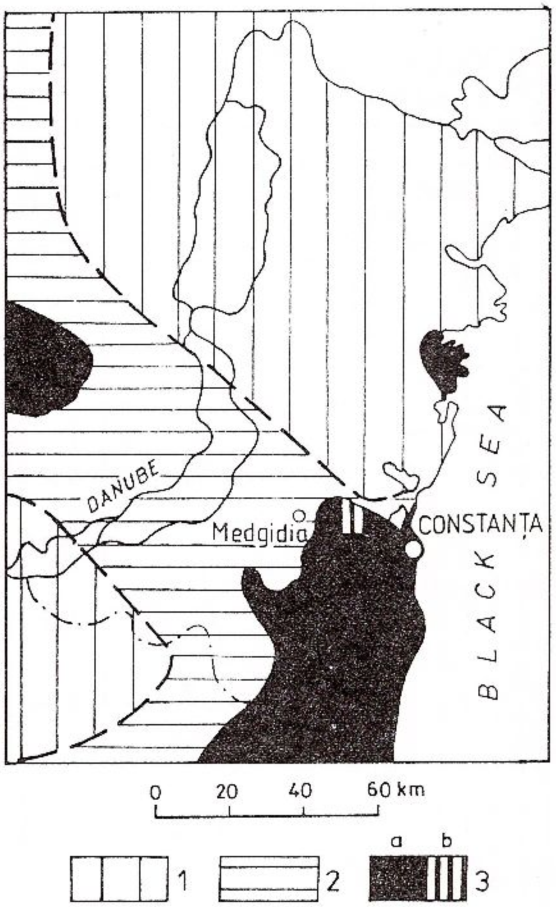

Fig. 3 - Paleogeographic sketch map of South Dobrogea during the Santonian-Maastrichtian. 1, denudation area (continental domain with varied relief); 2-3, sedimentation area with (2) erosional zones, (3 a) preserved Santonian-Maastrichtian marine deposits and (3 b) Lower Maastrichtian continental-lacustrine deposits.

i.g. from outcrops in the Ovidiu area and in boreholes in the Eforie area, the Maastrichtian continuous chalky deposits on the Campanian chalk.

We now conclude that at least within the study area situated north-east of the Carasu Valley, in the Senonian succession there is a sedimentary break which corresponds to the upper part of the Upper Campanian (approximately corresponding of the Globotruncanita calcarata Zone), besides the Coniacian-basal Santonian break as it was known from previous research works.

The drilling data proved that within the north-eastern part of South Dobrogea (Fig. 3) the area which preserves the Senonian deposits is much more extended (up to 1–2 km south of Capidava-Ovidiu fault) as compared to the one admitted till now. It has been proved that within the area between the Nisipari Valley and the Nazarcea locality (drilling perimeter 6, 7, 9, 12; Fig. 1), there was a paleorise. Within this area (Fig. 4) on the substratum consisting of Barremian-Aptian or Tithonian-Valanginian deposits, there directly lie the Lower Maastrichtian ones in continental-lacustrine facies only. The depth where these ones come into contact with the substratum is relatively small. It grows towards the western extremity of the area, but especially to the northern extremity (drilling 9) and in the latter case, where the succession of the Maastrichtian becomes thicker and contains in this upper part marine deposits, too.

The subsurface Santonian-Maastrichtian succession of the Nisipari Valley-Nazarcea area belongs to a marginal sedimentation area of the Dobrogean sector of the Moesian epicontinental realm, situated close to the Central Dobrogea main rise. This succession is thin (22–110 m of which the Maastrichtian deposits 20–75 m), with unconformity, in shallow-water marine facies and locally (in Lower Maastrichtian) in continental-lacustrine facies. At the beginning the marine facies is sandy, sandstone-like, glauconitic, then predominantly carbonate, with limestones, chalks, marls, and sometimes with glauconite or cherts; it contains echinids, brachiopods, inoceramids, belemnites, benthonic and planktonic foraminifers, calcareous nannoplankton. The continental-lacustrine facies is marly and clayey, striped with charophytes.

The stratigraphic correlations with other areas (e.g. East Bulgarian part of the Moesian Platform) and some paleogeographic observations will be made by us in an other work.

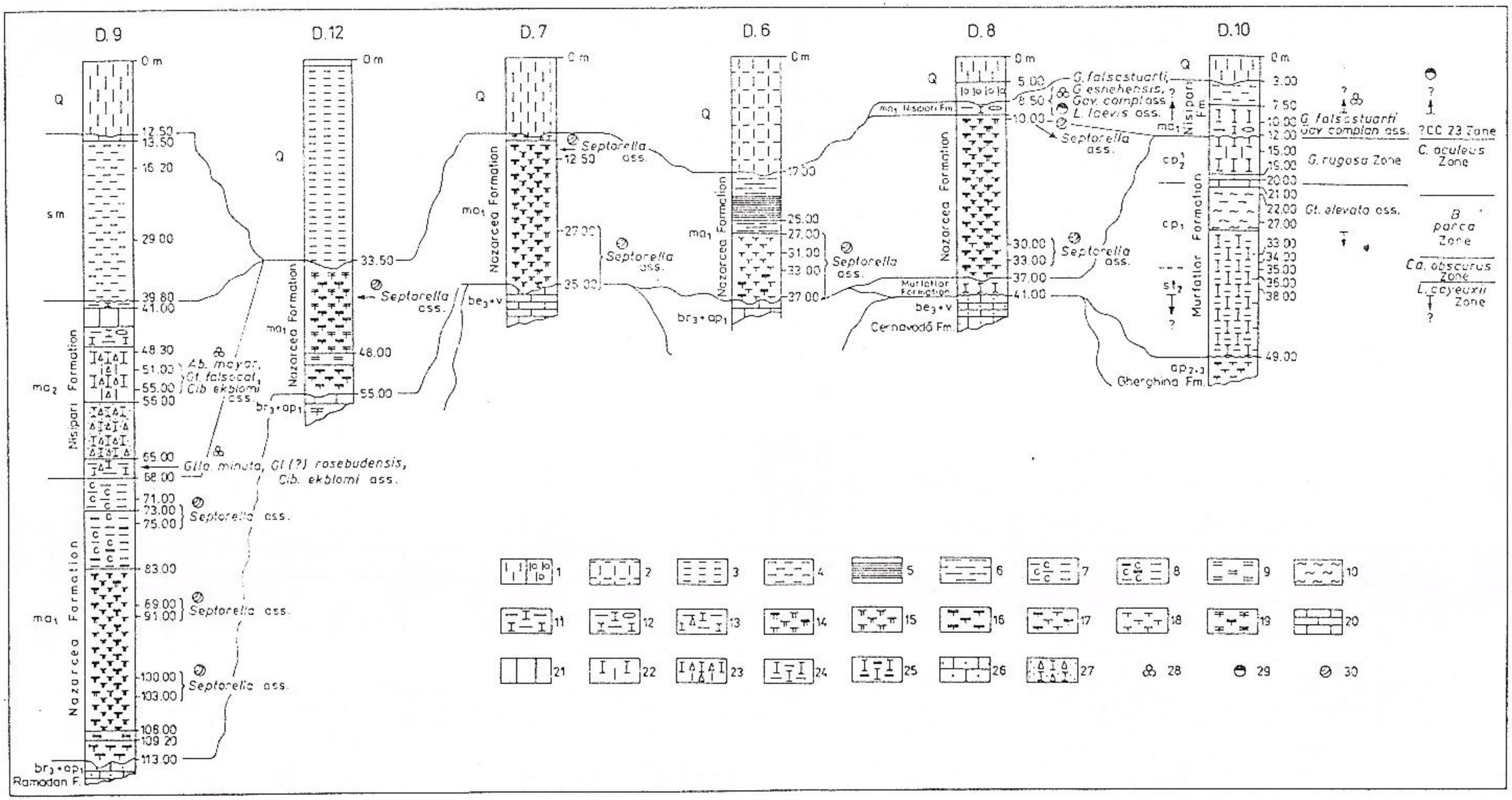

Fig. 4 - The Santonian-Maastrichtian deposits in drillings of the Nisipari Valley-Nazarcea area. 1, loess and loess with limestone lithoclasts; 2, loess and loessoid clays; 3, clays; 4, gray plastic clays; 5, gray-black clays; 6, gray-whitish fissile kaolinitic clays; 7, gray-whitish kaolinitic clays; 8, whitish and mottled (yellow and red) kaolinitic clays; 9, gray-greenish clays; 10, yellowish friable clays; 11, chalky marls and clays; 12, chalky marls and clays with limestone lithoclasts; 13, chalky marls and clays with glauconite; 14, whitish and mottled (yellow and red) marls; 15, whitish marls; 16, red marls; 17, gray marls with reddish colour in alteration; 18, gray-yellowish marls; 19, gray-greenish and reddish marls; 20, whitish and soft limestones, sometimes with gray-blackish separation; 21, whitish massive limestones; 22, whitish massive chalky limestones; 23, glauconitic chalky limestones; 24, gray-whitish argillaceous chalky; 25, gray-whitish argillaceous chalky with reddish and brownish alteration zones; 26, calcarenites; 27, chalky sands with glauconite; 28, planktonic foraminifers; 29, calcareous nannoplankton; 30, charophytes.

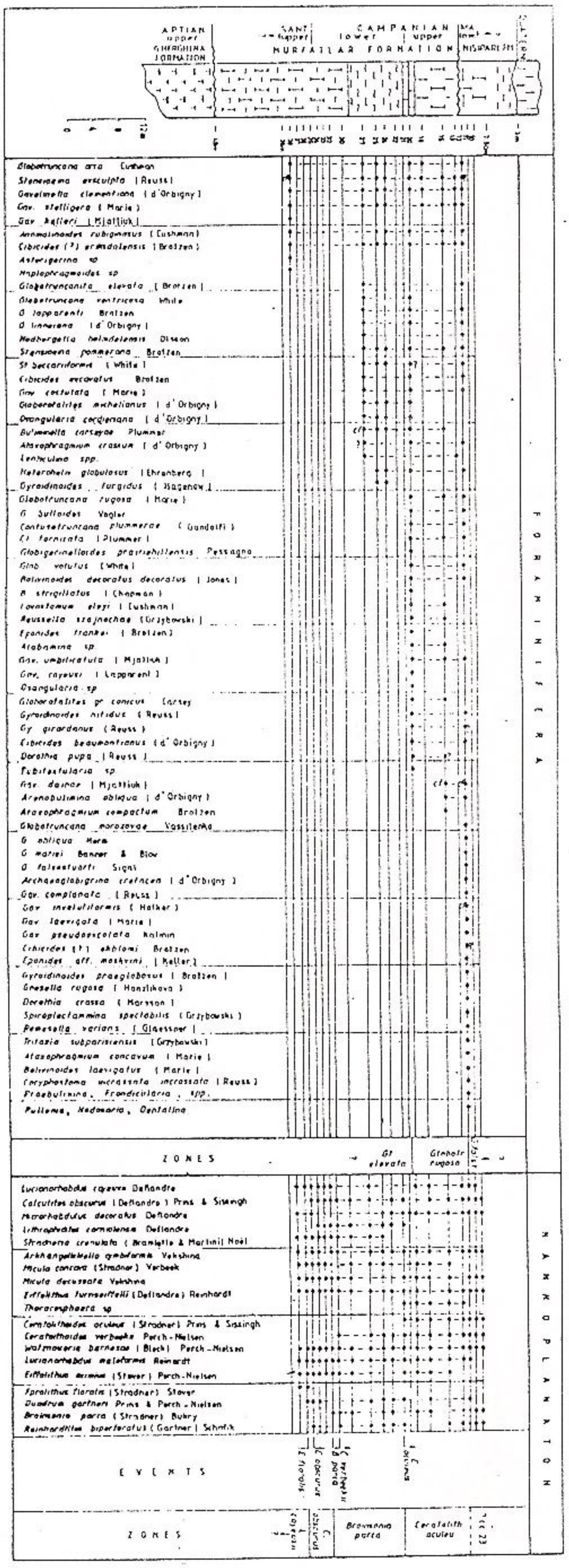

Fig. 5 – Biostratigraphy (foraminifers, calcareous nannoplankton) of the Upper Santonian-Lower Maastrichtian deposits (Murfatlar Formation and Nisipari Formation) in drilling 10.

2. Santonian-Maastrichtian stratigraphy

2.1. *Murfatlar Formation* (Santonian-lowermost Upper Campanian)

The Murfatlar Formation was defined (Avram, Szasz & Drăgănescu in Ghenea et al., 1984; Avram et al., 1988) in outcrops in the north-eastern part of South Dobrogea. When we began the core study, it was known that the Santonian-lowermost Upper Campanian succession of Murfatlar Formation is maximum 45 m thick, transgressively lies on Jurasic, Lower or Mid-Cretaceous deposits and is overlain transgressively by Lower Eocene to Quaternary deposits.

The Murfatlar Formation intercepted by drillings (8,9,10; Fig. 4) within the Nisipari Valley-Nazarcea area offered us a new stratigraphic element: as least in the north of the Carasu Valley, the earliest strata of this formation – after a hiatus which corresponds to the uppermost Upper Campanian – are Lower Maastrichtian deposits, at the beginning in a continental-lacustrine facies and then in marine facies, or only in marine facies (drilling 10).

Other details that should be mentioned are: the Murfatlar Formation intercepted by drillings varies in thickness (4 m in drilling 8; 40 m in drilling 10), has a varied substratum (Middle- Upper Aptian, Tithonic ?-Valanginian in age) that can be found at different depths, which proves its belonging to a paleorelief.

By the description of the Murfatlar Formation, on the basis of the surface data, three stratigraphic subdivisions are mentioned (Fig. 2):

(1) basal conglomerate or conglomeratic sanstone (0–80 cm thick), sometimes with chalky-glauconitic matrix, usually with many reworked fauna; (2) sandstone and quartzose-glauconitic-chalky sands up to glauconitic-quartzose chalks, usually massive, with many echinids (1–4 m thick); (3) massive white, sometimes glauconitic chalk with cherts (20-30 m), with inoceramids, echinids, brachiopods, belemnites, siliceous sponges, foraminifers. The first two subdivisions have been assigned (according to Macovei, 1911; Macovei & Atanasiu, 1934; Chiriac, 1956) to the Santonian, the third one (Neagu, 1987; Avram et al., 1988) to the Upper Santonian-Lower Campanian with the possibility of being extended in certain areas in the base of the Upper Campanian.

The Murfatlar Formation intercepted by two drillings, 8 and 10, is represented (Figs. 4, 5) only by the last subdivision. In drilling 8 it is thin (4 m), and consists only of white massive chalk. In drilling 10 it is thick (40 m) and made up of the following stratigraphic succession (Fig. 5):

- *Grey-whitish argillaceous chalk*, with reddish mottled zones (20 m thick, 49 m-29 m depth interval). For the lower part of this sequence we have no paleontological data, but by correlation with surface data, we assigned it to the Upper Santonian. The upper part of the sequence belongs to the Upper Santonian-Lower Campanian. It first contains the assemblage of *Lucianorhabdus cayeuxii* nannoplankton zone and the foraminiferal assemblage with *Globotruncana arca* (CUSHMAN), *Gavelinella kelleri* (MJATLIUK), *G. stelligera* (MARIE), *G. clementiana* (D'ORBIGNY); then follows the assemblage of the *Calculites obscurus* nannoplakton zone and finaly the *Broinsonia parca*[1] nannoplankton zone.

- *Yellowish friable clays* (8 m thick, 29 m–21 m depth interval) uppermost Lower Campanian in age. Most of them contain the planktonic foraminiferal assemblage with *Globotruncanita elevata* (BROTZEN), *Globotruncana ventricosa* WHITE, *Heterohelix globulosus* (EHRENBERG), of the upper part of the Globotruncanita elevata Zone, together with the nannofossils of Broinsonia parca[2] Zone, followed by the debut of the Ceratolithoides aculeus Zone. Together with these they contain the benthonic foraminiferal assemblage with

Table 1

Distribution of Charophytes in the Maastrichtian cores from drillings 6, 7, 8, 9, 12	d6					d7			d8			d9				d12
	core from depth interval:															
Septorella sp.					x								x			
S. brachycera GRAMBAST		x	x	x		x	x	x	x	x	x	x	x		x	x
S. brachycera GRAM. n. comb.	x		x	x							x			x		
Porochara malladae (BATALLER) FEIST			x								x					
Microchara parazensis MASSIEUX, REY VILLATE			x								x					
Lamprothamnium altanulaensis (KARC. & ZIEM.) n. comb. Kark. Ziem. 1981			x								x					
Atopochara ulanensis KVANSEP-ROM.			x							x	x					
A. trivolvis-triquetra (PECK) GRAM.			x	x	x					x	x		x			
A. trivolvis PECK			x	x									x			
Atopochara sp.						x	x	x								
A. restricta GRAMBAST-FESSARD			x								x		x			
Amblyochara agathae KARC. & ZIEMB.			x								x					
Saportanalla nana KARC. & ZIEMB.			x								x					
Mesochara orientalis KARC. & ZIEMB.			x								x					
Pseudoglobator furcadei GRAMBAST			x								x					
P.paucibracteatus MARTIN-CLOSAS & GRAMBAST-FESSARD		x	x								x					
Pseudoglobator sp.		x	x								x					
Nodosoclavator adnatus MARTIN-CLOSAS & GRAMBAST-FESSARD		x	x	x	x			x	x		x		x			
N. nudus GRAMBAST				x								x	x			
Clypeator europaeus MADLER			x	x					x		x		x			
Perimneste horrida GRAMBAST													x			
P. micrandra GRAMBAST-FESSARD										x			x			
P.micrandra ancora MARTIN-CLOSAS & GRAMBAST-FESSARD													x			
Clavator harrisi PECK					x								x			

Stensioeina pommerana BROTZEN, *S. beccariiformis* (WHITE), *Gavelinella clementiana* (D'ORBIGNY), *Osangularia cordieriana* BROTZEN.

- *Fine-grained glauconitic limestones* (2 m, 21 m-19.50 m depth interval) where we find the debut of the planktonic foraminiferal assemblage of the Globotruncana rugosa Zone, marking the beginning of Upper Campanian. The assemblage of the Ceratolithoides aculeus Zone is continued within this sequence, and the levels with *Globotruncana* *rugosa* assemblage equally contain the benthonic foraminiferal assemblage with *Reussella szaynokae* (GRZYBOWSKI), *Eponides frankei* BROTZEN, *Bolivinoides decoratus decoratus* (JONES), *B. strigillatus* (CUSHMAN), *Loxostomus eleyi* (CUSHMAN).

- *Whitish, massive chalky limestones* (8 m thick, 19.50 m–12 m depth interval), Upper Campanian in age. They contain the planktonic foraminiferal assemblage of the Globotruncana rugosa Zone, the same characteristic benthonic foraminiferal assemblage as that of the underlying deposits, and the nannofossils of the Ceratolithoides aculeus Zone.

Therefore the paleontological data resulting from this drilling certify the Upper Santonian-earliest Upper Campanian age for the last subdivision of the Murfatlar Formation, confirming the age as it was known from previous studies in the surface succession, and proving once more, without any doubt, the presence of the lowermost Upper Campanian deposits, too.

2.2. Nazarcea Formation (Lower Maastrichtian)

For the Lower Maastrichtian succession in continental-lacustrine facies, recently discovered (Iva et al., 1990) and known till now only in drillings in the Nisipari Valley-Nazarcea area we introduce (Iva, Ion & Melinte) in this paper the name Nazarcea Formation (Figs. 1, 4). Its type succession is provided by the cores of the drillings 8 and 9, the first one to 2 km east of the Nazarcea locality, which gave its name to this formation. It has been equally found in drillings 6, 7 and 12.

The Nazarcea Formation lies on a paleorelief. Its lower limit has been intercepted at different depths (beginning with 35 m to 55 m, but also at 113 m) and it is given by the contact with deposits of different ages (Tithonian-Berriasian-Valanginian, in drilling 7; Barremian-Lower Aptian, in drillings 6, 9, 12; Senonian of Murfatlar Formation, in drilling 8). It is overlain in stratigraphic continuity by the Maastrichtian strata of the Nisipari Formation.

The Nazarcea Formation (Fig. 4) is variable in thickness (between 20 and 45 m), with the following lithostratigraphic cumulated succession: - it begins with an interval of reddish marls (4-6 m thick; drillings 9, 12) or gray-yellowish marls (6 m thick; drilling 6); - then follow fine greenish marls (2 m thick; drillings 9, 12); - withish and mottled (yellow-red) marls (12-28 m thick; drillings 7, 8, 9, 12); - finally, there is an interval of grayish, sometimes kaolinic clays (16 m thick; drilling 9), or gray-blackish, sometimes mottled (yellow and red) clays, and gray fissile kaolinic clays (10 m thick; drilling 6).

Generally, it is a clayey marly banded succession, quite rich in charophytes. It contains (Tab. 1) a characteristic assemblage of charophytes, with *Septorella brachycera* GRAMBAST,
Porochara malladae (BATALLER) FEIST, *Microchara parazensis* MASSIEUX, REY & VILLATTE, all these species being known in the Maastrichtian in southern France and northern Spain (Massieux et al., 1979, 1987).

The charophytes assemblage contains also some other species from the Late Cretaceous, such as *Atopochara ulanensis* KYANSEP-ROMASCHKINA and *Lamprothamnium altanulaensis* (KARCZEWSKA & ZIEMBINSKA) nova comb. Karczewska & Ziembinska 1981, mentioned in Mongolia in the Nemegt Formation from the Gobi Desert (Karczewska & Ziembinska, 1981). It includes also other species known in the Lower Cretaceous, that are frequently present also (Iva, 1990) in the Upper Barremian-Aptian (Ramadan and Gherghina Formations) continental-lacustrine deposits of South Dobrogea: *Nodosoclavator adnatus* MARTIN-CLOSAS & GRAMBAST-FESSARD, *Pseudoglabator furcadei* GRAMBAST, *P. paucibracteatus* MARTIN-CLOSAS & GRAMBAST-FESSARD, *Clypeator europaeus* MADLER, *Atopochara trivolvis* (PECK), *A. restricta* GRAMBAST-FESSARD, *A. trivolvis-*

Table 2

Distribution of Foraminifers in the Maastrichtian cores from drillings 8 and 9	d8	d9	
	the core from depth interval		
	8m	66m	51m
1	2	3	4
Gansserina wiedenmayeri (GANDOLFI)	x		
Plummerita hantkeninoides (BRONNIMANN	x		x
Globotruncana falsostuarti SIGAL	x		
G. esnehensis NAKKADY	x		
G. aegyptiaca NAKKADY	x		x
G. insignis GANDOLFI	x		
G. orientalis EL NAGGAR	x		
G. arca CUSHMAN	x		x
G. rugosa MARIE	x		x
G. morozovae VASSILENKO	x		
G. rosetta CUSHMAN	x		
G. ventricosa WHITE	x		
G. bulloides VOGLER	x		
G. lapparenti BROTZEN	x		x
G. linneiana (D'ORBIGNY)	x		x
G. obliqua HERM	x		
G. (?) spinea KIKOINA	x		
Rugotruncana sucircumnodifer (GANDOLFI)	x		
Globotruncanita elevata (BROTZEN)	x		
Gt. stuartiformis (DALBIEZ)	x		
Gt. falsocalcarata KERDANY & ABDEL.			x
Contusotruncana fornicata (PLUMMER)	x		
Ct. plummerae (GANDOLFI)	x		
Ct. nothi (BRONNIMANN & BROWN)	x		
Archaeoglobigerina cretacea (D'ORBIGNY)	x		
Heterohelix globulosus (EHRENBERG)	x		
Ht. semicostatus (CUSHMAN)	x		
Gublerina ornatissima (CUSHMAN)	x		
Globigerinelloides multispinus (LALICKER)	x		
Gl. volutus (WHITE)	x		
Gl. prairiehillensis PESSAGNO	x		
Gl. (?) gr. *rosebudensis* SMITH & PESSAGNO		x	
Abathomphalus mayaroensis (BOLLI)			x
Rugoglobigerina rugosa (PLUMMER)			x
R. rotundata BRONNIMANN			x
R. hexacamerata BRONNIMANN			cfx
Hedbergella monmouthensis (OLSSON)			x
Globotruncanella minuta CARON & GONZALES DONOSO		cfx	x
Gavelinella stelaria (VASSILENKO)	cfx		?x
Gav. complanata (REUSS)	x	x	x
Gav. stelligera (MARIE)	x	x	
Gav. costulata (MARIE)	x	x	x

Table 2 (continued)

1	2	3	4
Gav. clementiana (d'Orbigny)	x		
Gav. umbilicatula (Mjatliuk)	x	x	x
Gav. midwayensis (Plummer)		x	x
Gav. laevigata (Marie)	x		x
Gav. cayeuxi (Lapparent)			x
Gav. involutiformis (Hofker)			cfx
Gav. pertusa (Marsson)			cfx
Stensioeina beccariiformis (White)	x	x	x
St. pommerana Brotzen	x		
St. exsculpta (Reuss)	x		
Gyroidinoides nitidus (Reuss)	x		
Gy. turgidus (Hagenow)	x		
Cibicides excavatus Brotzen	x		
Cibicides (?) eriksdalensis (Brotzen)		x	x
Cibicides (?) ekblomi Brotzen		cfx	cfx
Cibicidoides spiropunctatus Gall. & Morrey		x	
Cib. (?) voltzianus (d'Orbigny)		x	
Cib. (?) bembix (Marsson)			x
Globorotalites spineus (Cushman)		cfx	cfx
Glob. michelianus (d'Orbigny)	x		
Globorotalites spp.	x	x	x
Nutalinella sp., *Patellina* sp.			x
Praebulimina reussi (Morrow)	x		
Pr. ovulum (Reuss)	?x		
Buliminella pusilla (Brotzen)	x		
Eouvigerina americana Cushman	x		
Elipsoidella spp., *Lagena* spp.	x		
Lenticulina spp.	x	x	x
Quadrimorphina allomorphinoides (Reuss)	x		
Bolivinoides decoratus decoratus (Jones)	x		
em B. decoratus giganteus Hilt. & Koch	x		
B. laevigatus (Marie)	x		
B. strigillatus (Chapman)	x		
Verneuillina ornata (Cushman)	x		
Gaudryna cretacea (Karrer)	x		
Tritaxia tripleura (Reuss)	x		
Tritaxia spp.	x		
Ataxophragmium crassum (d'Orbigny)	x		
A. concavum (Marie)	x		
Arenobulimina obliqua (d'Orbigny)	x	x	
Ar. obesa (Reuss)		x	
Ar. pseudodorbigny Marie		x	
Egerellina spp.	x		
E. braevis (d'Orbigny)	x		
Dorothia spp.	x		
Do. pupa (Reuss)	x		
Goesella rugosa (Hanzlikova)	x		
Reusella szaynochae (Grzybowski)	x		
Spiroplectammina spp.	x		

triquetra (PECK) GRAMBAST, etc.

The data available till now, i.e. the association of charophytes as well as the fact that it is overlain by the uppermost Lower Maastrichtian or Upper Maastrichtian levels of the marine Nisipari Formation, indicate that the Nazarcea Formation is Lower Maastrichtian pro parte or Lower Maastrichtian in age. The boundary between these two formations is heterochronous.

2.3. *Nisipari Formation* (Lower Maastrichtian

-Upper Maastrichtian to Upper Maastrichtian only

For the Maastrichtian-Upper Maastrichtian to only the Upper Maastrichtian succession in marine facies, recently discovered (Iva et al., 1990) in drillings in the Nisipari Valley-Nazarcea area, and known so far only in drillings, we give (Ion, Iva & Melinte) in this paper the name Nisipari Formation.

This Maastrichtian marine succession has been intercepted (Figs. 1, 4) in drillings 8, 9 and 10. Within the area situated between the Nisipari Valley and the Nazarcea locality, it did not exist (in drillings 6, 7, 12), within this area the Lower Maastrichtian continental-lacustrine formation is directly overlain by the Quaternary deposits.

The succession from drilling 9 is the type succession for this formation. The name of this formation is the same as that of the place where the drilling was located, at 4,7 km north of the Nisipari Valley.

Drillings 8 and 9 are important, too as they offered us the contact of this formation with the Nazarcea Formation as well as cores containing assemblages of foraminifers and nannoplankton in order to establish the age of its base.

The Nisipari Formation overlies conformably the Nazarcea Formation or unconformably other deposits, and is unconformable overlain either by Quaternary or Sarmatian deposits.

Its thickness varies between 2-28 m. It consists of epineritic to infraneritic epicontinental marine deposits. Within the limits of the already studied succession, we can state that this formation contains sands, soft chalky sandstones, chalky, marls or clays up to chalky limestones and limestones. The lower part of the formation sometimes is glauconitic, and the marls or clays from its terminal and basal part include white limestones fragments.

In drilling 9, the Nisipari Formation has, from bottom to top, the following characteristics (Fig. 4; Tab. 2):

- *Chalky marls and clays*, with glauconotic and coprolite levels (3 m thick, 68 m-65 m depth interval) contain (at 66 m depth) a lowermost Upper Maastrichtian foraminiferal assemblage with *Cibicides* (?) *ekblomi* (BROTZEN), *Gavelinella midwayensis* (PLUMMER), *G. complanata* (REUSS) and *Globotruncanella minuta* CARON & GONZALES DONOSO.
- *Friable chalky glauconotic sands/ sandstones* (10 m thick, 65 m - 56 m depth interval).
- *Whitish, massive chalky limestones* (8-9 m thick, 56 m - 48 m depth interval), with glauconite and fragments of the inoceramids, and with (in the 55-51 m depth interval) an uppermost Upper Maastrichtian foraminiferal assemblage with *Abathomphalus mayaroensis* (BOLLI), *Globotruncanita falsocalcarata* KERDANY & ABDELSALAM, *Cibicides* (?) *ekblomi*, *Gavelinella midwayensis*, *G. complanata*.
- *Chalky marls and clays with limestone lithoclasts* (4 m thick, 48 m - 44 m depth interval).
- *Whitish massive limestones* (3 m thick, 44 m - 41 m depth interval).
- *Whitish friable chalky clays* (1 m thick, 41 m - 39.80 m depth interval).

In drilling 8, the Nisipari Formation (only 2 m thick) consists of gray-yellowish marls with limestone pebbles. It contains (Tab. 2) a Lower Maastrichtian planktonic foraminiferal assemblage with *Globotruncana falsostuarti*

SIGAL, *G. esnehensis* NAKKADY, *Gansserina wiedenmayeri* (GANDOLFI) (of the upper part of Globotruncanita stuarti/Globotruncana falsostuarti Zone) and an assemblage of *Reinhardtites levis* nannoplankton zone as well as a benthonic foraminiferal assemblage with *Gavelinella complanata* (REUSS), *G. laevigata* (MARIE), *Stensioeina pommerana* BROTZEN, *Bolivinoides decoratus giganteus* HILT. & KOCH. The nannoplankton assemblage of R. levis Zone contains: *Reinhardtites levis* PRINS & SISSINGH, *Prediscosphaera microrhabdulina* PERCH-NIELSEN, *P. cretacea* (ARKHANGELSKY) GARNER, *P. grandis* PERCH-NIELSEN, *Calculites obscurus* (DEFLANDRE) PRINS & SISSINGH, *Arkhangelskiella cymbiformis* VEKSHINA, *Lucianorhabdus cayeuxii* DEFLANDRE, *Microrhabdulus decoratus* DEFLANDRE, *Rhagodiscus angustus* (STRADNER) RUNHARDT, *Micula decussata* VEKSHINA, *Ceratolithoides aculeus* (STRADNER) PRINS & SISSINGH, *Chiastozygus platyrhetus* HILL, *Lithraphidites carniolensis* DEFLANDRE, *Eiffelithus turriseiffelii* (DEFLANDRE) REINHARDT, *Braarudosphaera bigelowii* (GRAN & BRAARUD) DEFLANDRE, *Acuturris scotus* (RISATTI) WIND & WISE.

In drilling 10 (Fig. 5), this formation begins with an interval (4 m thick, 12 m-7.50 m depth interval) of gray chalky marls and clays with lithoclasts, followed by whitish, massive chalky limestones; then fallow gray marls and clays (4 m thick, 7,50 m - 3 m depth interval). The basal interval, Lower Maastrichtian in age, containning a planktonic foraminiferal assemblage with *Globotruncana falsostuarti* SIGAL, *Heterohelix globulosus* (EHRENBERG) concomitantly with *Gavelinella complanata* (REUSS), *G. laevigata* (MARIE), *Stensioeina pommerana* BROTZEN, *Remesella varians* (GLAESSNER) and other benthonic foraminifers, and with a nannofossil assemblage, probably pertaining to the Tranolithus phacelosus Zone (CC 23). For the terminal interval there are no palentological data available.

The foraminiferal and nannofossil assemblages (Figs. 2, 4; Tab. 2) identified in drillings 9, 8 and 10 in the Nisipari Formation prove that this begins in the lower part of the Upper Maastrichtian or in the Lower Maastrichtian and continues in the uppermost Upper Maastrichtian. Its lower boundary is heterochronous, the marine Nisipari Formation substituting the continental-lacustrine Nazarcea Formation.

3. Biostratigraphic remarks

3.1. Foraminifera and calcareous nannoplankton

The Senonian succession in marine facies yielded by cores from the north-eastern part of South Dobrogea presents the following biostratigraphic characteristics with respect to foraminifera and calcareous nannoplankton (Figs. 4, 5):

The Upper Santonian (in the Murfatlar Formation) is characterized by the nannoplankton assemblage of the Lucianorhabdus cayeuxii Zone and the debut of the Calculites obscurus Zone. A foraminiferal assemblage with *Globotruncana arca, Gavelinella kelleri, G. stelligera and G. clementiana* is in co-occurrence with *L. cayeuxii* nannofossil assemblage.

The Lower Campanian (in the Murfatlar Formation) is represented in the first part only by the nannoplankton of the C. obscurus Zone and of the lower part of Broinsonia parca Zone. Then fallows a foraminiferal assemblage with *Globotruncanita elevata* and *Globotruncana ventricosa*, the upper part of the Gt. elevata Zone respectively, together with the nannoplakton assemblage of the upper part of the B. parca[3] Zone, followed by the one which marks the debut of *Ceratolithoides aculeus* nannoplankton zone. For the uppermost Lower Campanian we notice also the presence of a benthonic foraminiferal assemblage with *Stensioeina pommerana, S. beccariiformis, Osangularia cordieriana, Ataxophrag-*

mium crassum and with abundently *Gavelinella stelligera, G. clementiana* and *Globorotalites michelianus.*

The lowermost Upper Campanian (in the Murfatlar Formation) is characterized by the continuation of the *C. aculeus* nannoplankton Zone. As for benthonic foraminifera, we notice the presence of the assemblage with *Reussella szajnochae, Eponides frankei, Bolivinoides decoratus decoratus* and *Osangularia cordieriana.*

The Lower Maastrichtian (in the Nisipari Formation) is characterized by a foraminiferal assemblage with *Globotruncana falsostuarti, Heterohelix globulosus, Gavelinella complanata, G. laevigata, G. involutiformis, Remessella varians, Stensioeina pommerana*, together with a nannoplankton assemblage, probably of the Tranolithus phacelosus Zone; there follows a foraminiferal assemblage with *Globotruncana falsostuarti, G. aegyptiaca, G. esnehensis, Gansserina wiedenmayeri, Heterohekix globulosus, Gavelinella complanata, G. laevigata, Stensioeina pommerana, Bolivinoides decoratus giganteus*, together with a characteristic nannoplankton assemblage of the Reinhardtites levis Zone. Concerning the planktonic foraminifer taxa the former Lower Maastrichtian foraminiferal assemblage belongs to the lower part of the Globotruncanita stuarti/Globotruncana falsostuarti Zone, and the latter to the upper part of this zone.

The lowermost Upper Maastrichtian (in the Nisipari Formation) is represented by a foraminiferal assemblage with *Cibicides* (?) *ekblomi, Gavelinella complanata, G. midwayensis, Globotruncanella minuta.* The uppermost Upper Maastrichtian is represented by the same benthonic foraminiferal taxa but in co-occurrence with a planktonic foraminiferal assemblage - with *Abathomphalus mayaroensis* and *Globotruncanita falsocalcarata* - of the Abathomphalus mayaroensis Subzone (lower part of the A. mayaroensis Zone).

In relation to the above-mentioned biostratigraphic data, we specify that concerning the planktonic foraminifera we accepted the same biozonal scale (Ion in Ion & Szasz, 1994) as that from the Romanian East and South Carpathians areas. Globotruncanita elevata Zone (according to definition Ion, 1983), Globotruncana rugosa Zone (acc. def. Ion, 1993) and Abathomphalus mayaroensis Zone (acc. def. Bellier et al., 1983) belong to the category of the Interval-zone (it represents the interval between the first occurrence of one index species and the first occurrence of another index species); the Globotruncanita stuarti/Globotruncana falsostuarti Zone (acc. def. Sigal, 1977) is a Partial range-zone (the interval with zonal marker, between the last occurrence of one index taxon and the first occurrence of another index taxon acc. to definition); the A. mayaroensis Subzone (acc. def. Bronnimann, 1952) is a Total range-subzone.

In the cores of the Nisipari Valley-Nazarcea area, the planktonic foraminiferal assemblages within the Upper Santonian sequence of the Murfatlar Formation, are not well represented. They are better known in the outcrops of the northern part of South Dobrogea (Neagu, 1987; Neagu in Avram et al., 1988), where they are represented by the assemblage with "*Dicarinella concavata carinata* and *Globotruncana bulloides*". From our point of view, this assemblage belongs to the G. bulloides Subzone. The assemblage of this subzone has been identified (Ion in Szasz & Ion, 1988) also within the levels of *Echinocorys vulgaris*, Santonian in age, of the Murfatlar Formation which is preserved in the south of Sinoe Lake in Central Dobrogea.

The G. bulloides Interval Subzone (acc. def. Ion, 1983, as a zone, revised by Ion in Ion & Szasz, 1994, as a subzone), according to planktonic foraminiferal zonation for Dobrogea and South and East Carpathians areas (Ion in Ion & Szasz, 1994) is Lower Santonian p.p. - Upper Santonian in age. According to this zonation it represents the upper part of the Dicarinella asymetrica Interval Zone (acc. def. Wonders, 1979), that in the above two areas is Middle Coniacian-Santonian in age by direct calibration using the ammonites and inoceramids faunas.

For the Lower Campanian, Globotruncanita elevata Zone is better outlined in the outcrops in South Dobrogea (Neagu, 1987; Neagu in Avram et al., 1988). But for the lower part of the Upper Campanian the cores (from drilling 8) provided a more complete characterization from the point of view of planktonic foraminifera as compared with the outcrop data. It should be mentioned that the Globotruncana rugosa Zone which we use in order to characterize the lower part of the Upper Campanian, probably is not equivalent in age to the G. ventricosa Zone used in previous studies by Neagu (Neagu, 1987; Neagu in Avram et al., 1988). It seems that the first occurrences of *G.rugosa* and *G. ventricosa* are not synchronous. We mark the lower part of Upper Campanian by the G. rugosa Zone, since this species is constantly identified at this level in the Carpathian area.

On the occasion of this work we make, from the point of view of the nannoplankton content, a first characterization of the Senonian of South Dobrogea. With respect to the identified or utilized nannoplankton zones we make certain remarks.

- Lucianorhabdus cayeuxii Zone. *Author*: Sissingh (1977). *Age*: Upper Santonian. *Definition*: interval from first occurrence of *Lucianorhabdus cayeuxii* to first occurrence of *Calculites obscurus*. *Remarks*: only the upper limit of this zone could be observed by us; the presence of *L. cayeuxii*, corroborated with that of *Eprolithus floralis* determined us to place the nannoplankton assemblage identified in the lower part of the Murfatlar Formation (with foraminiferal assemblage of uppermost Upper Santonian) to the Lucianorhabdus cayeuxii Zone.

- Calculites obscurus Zone. *Author*: Sissingh (1977). *Age*: upper part of the Upper Santonian-basal part of the Lower Campanian. *Remarks*: the lower limit of this zone is marked by the first occurrence of *Calculites obscurus*, corroborated with the last occurrence of *Eprolithus floralis*; the upper limit is marked by the first occurrence of *Broinsonia parca*[4].

- Broinsonia parca[5] Zone. *Author*: Verbeek (1976). *Age*: Lower Campanian p.p. *Remarks*: the lower limit is marked by the first occurrence of *Broinsonia parca*[6], the upper limit by the first occurrence of *Ceratolithoides aculeus*.

We preferred Verbeek's zone since the *Marthasterites furcatus* has not been identified, a species used by Sissingh to separate the Aspidolithus parcus and the Calculites ovalis zones. It is interesting to note the presence in South Dobrogea of *Ceratolithoides verbeekii* quite close to the first occurrence of *Broinsonia parca*[7], therefore quite near the lower boundary of B. parca Zone. According to Perch-Nielsen (1979), *Ceratolithoides verbeekii* appears in CC 18b Zone, in the middle part of Lower Campanian, while our studies indicated its presence already since the basal Lower Campanian.

- Ceratolithoides aculeus Zone. *Author*: Cepek & Hay (1969). *Age*: lower part of Lower Campanian-Upper Campanian. *Remarks*: in South Dobrogea, this zone begins in the strata with planktonic foraminifera of the Globotruncanita elevata Zone, and continues in the strata with Globotruncana rugosa Zone.

- Reinhardtites levis Zone. *Author*: Sissingh (1977). *Age*: Lower Maastrichtian. *Remarks*: to this zone has been assigned the nannofossil assemblage identified in the strata (of the basal part of the Nisipari Formation) with the planktonic foraminiferal assemblage of the Gt. stuarti/G. falsostuarti Zone. This nannofossil assemblage contains *Reinhardtites levis* which has its last occurrence within the R. levis Zone, as well as *Prediscosphaera grandis* and *P. microrhabdulina*, ranging since the Lower Maastrichtian.

3.2. Charophytes

With regard to the "Lower Cretaceous" charophytes genera and species identified in the Nazarcea Formation, together with the Maastrichtian and Upper Cretaceous charophytes species, it is worth noting some observations. In South Dobrogea these "Lower Cretaceous" taxa are present not only in the Lower Cretaceous continental-lacustrine deposits, but also in the Maastrichtian ones, frequently and in an excellent state of preservation. Nevertheless, the same taxa are known only from the Lower Cretaceous, both in France (Mojon, 1988) and Spain (Martin-Closas, 1986). It is possible that the Dobrogean taxa be reworked or in situ. It is possible (?) therefore that these/part of these taxa have a larger range, as in South Dobrogea, where the Lower Cretaceous continental-lacustrine facies were locally not suddenly interrupted by the definitive return of the Upper Cretaceous marine facies as in France and Spain.

$^{1-7}$, *Broinsonia parca = Aspidolithus parcus constrictus*

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Plate I

Fig. 1 — *Globotruncana falsostuarti* SIGAL (x 75), drilling 8, 8 m depth, Lower Maastrichtian (Globotruncanita stuarti/Globotruncana falsostuarti Zone).

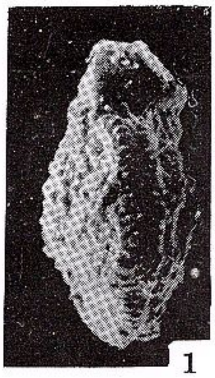
Fig. 2 — *Globotruncanita elevata* (BROTZEN) (x 75), drilling 10, 27 m depth, Lower Campanian (Globotruncanita elevata Zone).

Figs. 3-5 — *Globotruncana arca* (CUSHMAN) (3,5, x 75; 4, x 60), drilling 8, 8 m depth, Lower Maastrichtian (Gt. stuarti/G. falsostuarti Zone).

Figs. 6, 7, 8 — *Globotruncana rugosa* (MARIE) (x 75), drilling 10, 15 m depth, Upper Campanian (Globotruncana rugosa Zone).

Figs. 9, 10, 11 — *Globotruncana rugosa* (MARIE), (9, 11, x 80; 10, x 60), drilling 8, 8 m depth, Lower Maastrichtian (Gt.stuarti/G. falsostuarti Zone).

Figs. 12, 13, 14, 15 — *Globotruncana bulloides* VOGLER (x 45), drilling 8, 8 m depth, Lower Maastrichtian (Gt. stuarti/G. falsostuarti Zone).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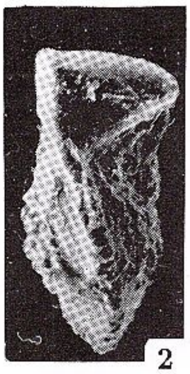
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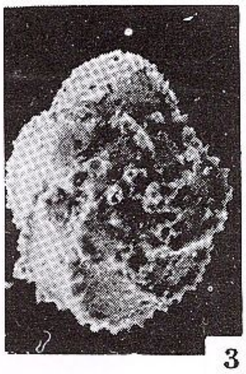
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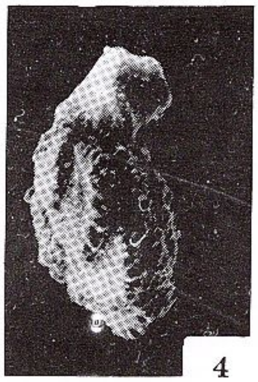
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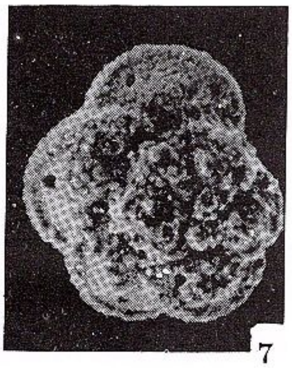
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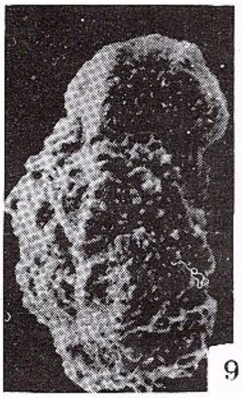
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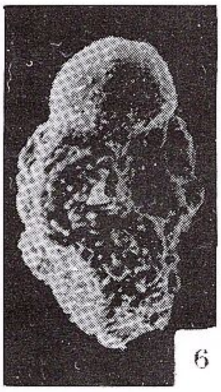
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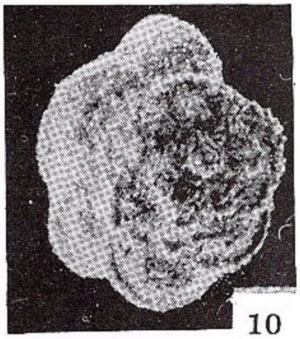
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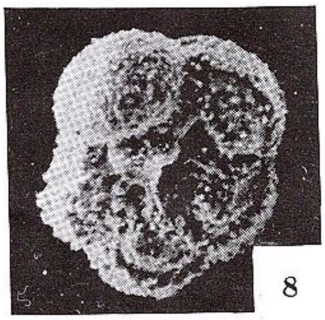
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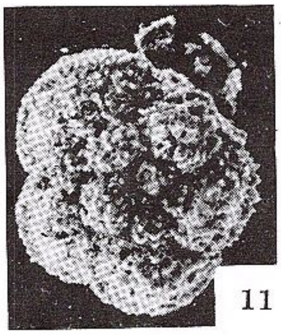
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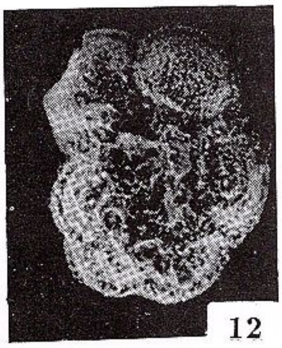
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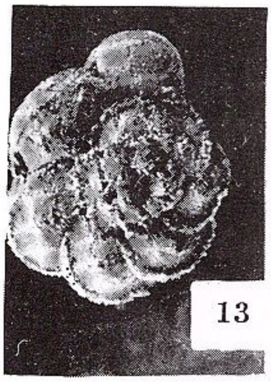
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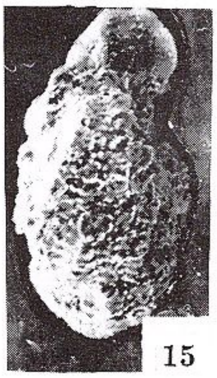
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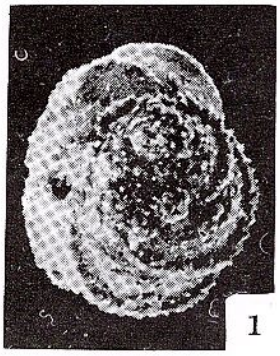
Plate II

Figs. 1-8 — *Globotruncana morozovae* VASSILENKO (x 65), drilling 8, 8 m depth, Lower Maastrichtian (Gt. stuarti/G. falsostuarti Zone).

Figs. 9-13 — *Contusotruncana fornicata* (PLUMMER) (x 45), drilling 8, 8 m depth, Lower Maastrichtian (Gt. stuarti/G. falsostuarti Zone).

Figs. 14-16 — *Contusotruncana plummerae* (GANDOLFI) (x 65), drilling 8, 8 m depth, Lower Maastrichtian (Gt. stuarti/G. falsostuarti Zone).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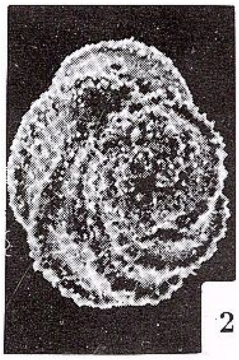
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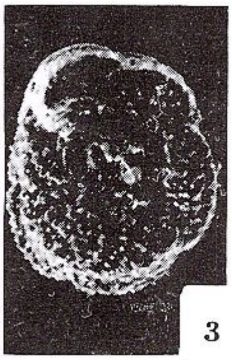
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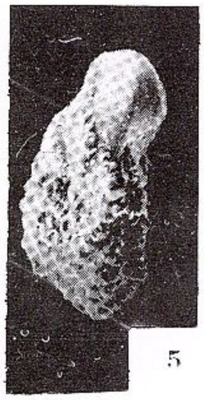
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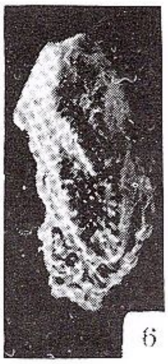
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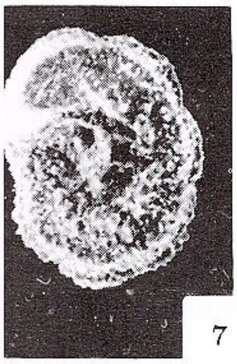
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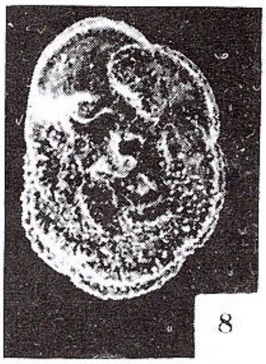
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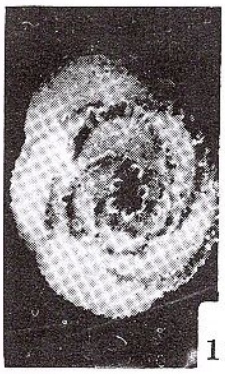
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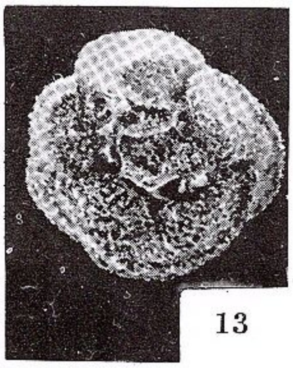
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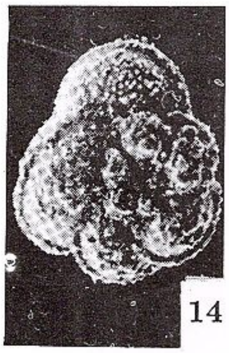
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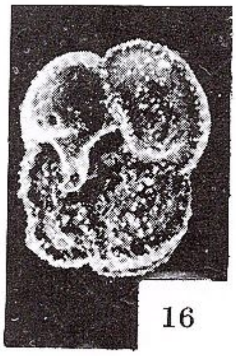
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Plate III

Figs. 1-4 — *Globotruncana orientalis* El Naggar.

Fig. 5 — *Globotruncana esnehensis* Nakkady.

Fig. 6 — *Globotruncana (?) spinea* Kikoina.

Figs. 7, 8 — *Globotruncana aegyptiaca* Nakkady.

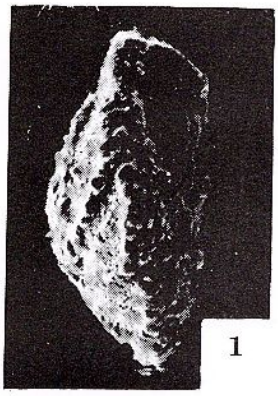
Fig. 9 — *Globotruncanita elevata* (Brotzen).

Figs. 10, 11 — *Archaeoglobigerina cretacea* (d'Orbighy).

Fig. 12 — *Globotruncana arca* (Cushman).

Figs. 13-16 — *Rugotruncana subcircumnodifer* (Gandolfi).

(all figures x 70, drilling 8, 8 m depth, Lower Maastrichtian, Gt. stuarti/ G. falsostuarti Zone)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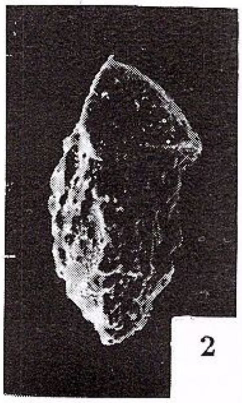
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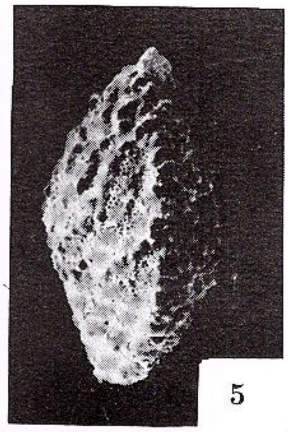
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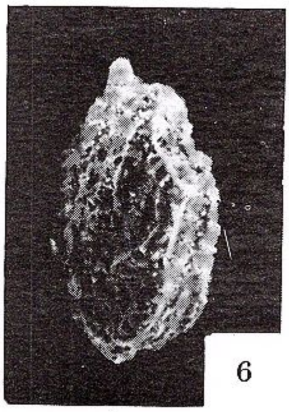
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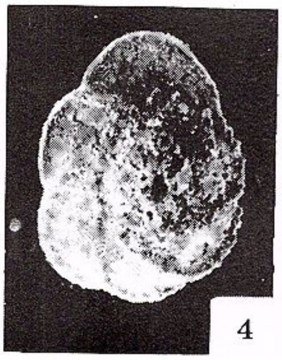
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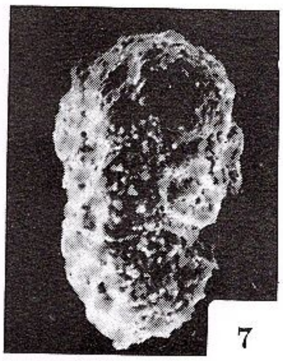
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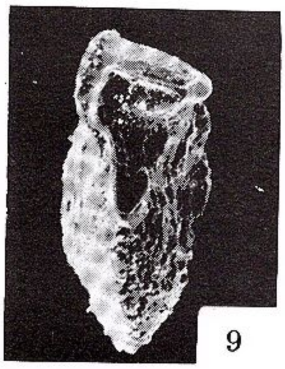
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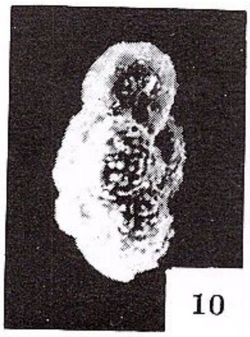
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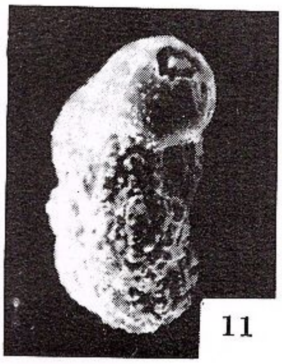
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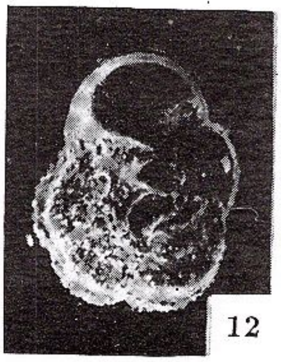
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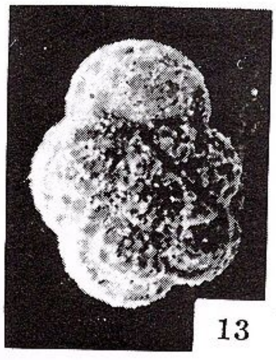
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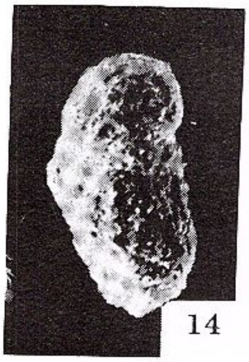
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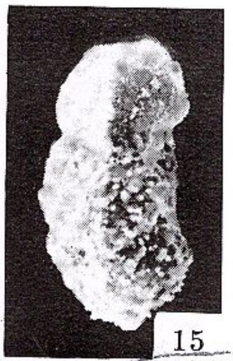
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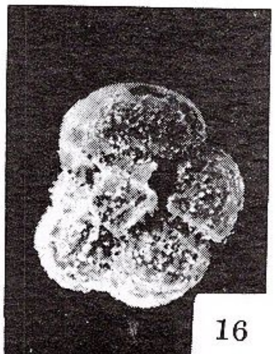
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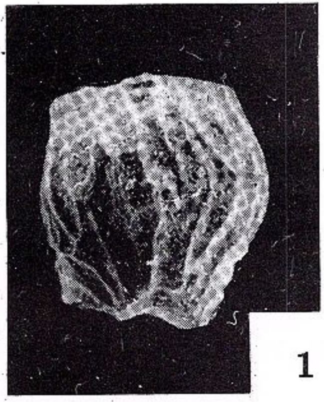
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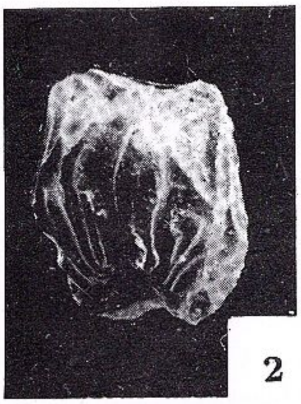
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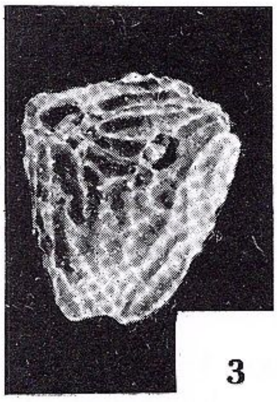
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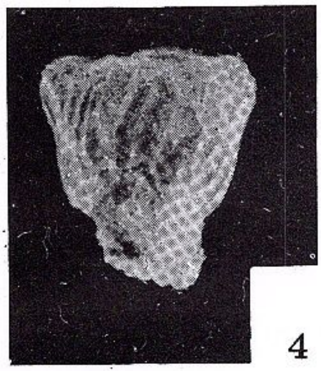
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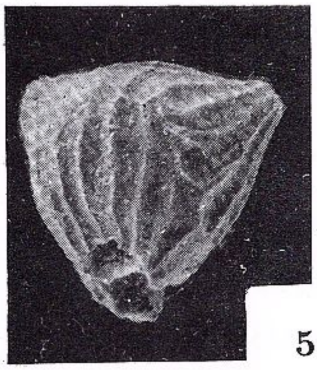
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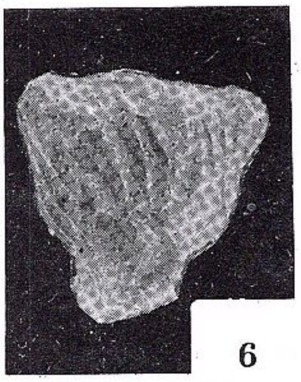
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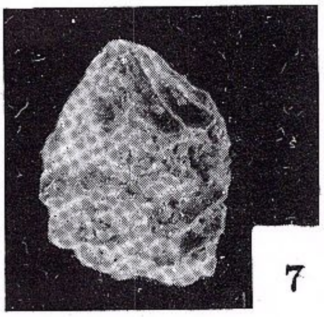
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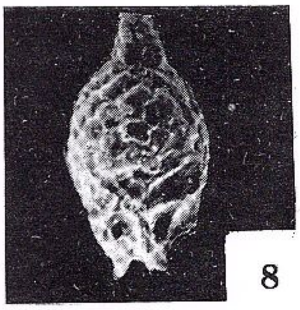
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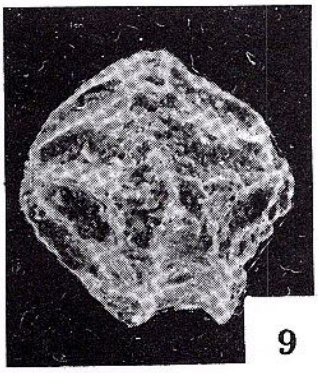
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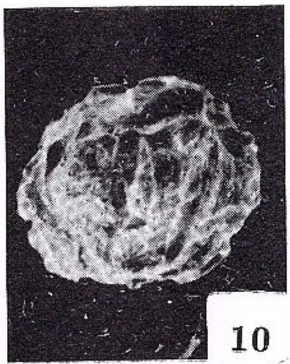
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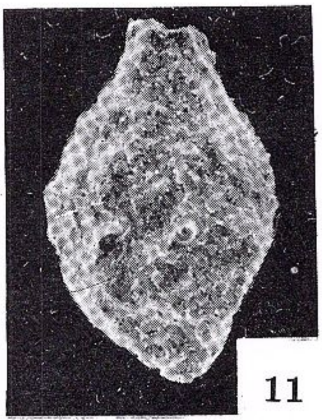
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Plate V

Figs. 1–4 — *Septorella brachycera* GRAMBAST nova comb. (1, x 65; 2, x 20; 3, x 24; 4, x 32), drilling 6, 31–32 m depth, Maastrichtian.

Fig. 5 — *Atopochara trivolvis* (PECK) (x 32), drilling 6, 31–32 m depth, Maastrichtian.

Fig. 6 — *Amblyochara agathae* KARCZEWSKA & ZIEMBINSKA (x 75), drilling 6, 31–32 m depth, Maastrichtian.

Fig. 7 — *Mesochara orientalis* KARCZEWSKA & ZIEMBINSKA (x 41), drilling 8, 33–35 m depth, Maastrichtian.

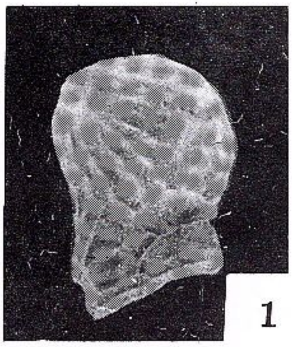
Fig. 8 — *Lamprothamnium altanulaensis* (KARCZEWSKA & ZIEMBINSKA) nova comb. Karczewska & Ziembinska 1981 (x 40), drilling 8, 33–35 m depth, Maastrichtian.

Fig. 9 — *Microchara parazensis* MASSIEUX, REY & VILLATTE (x 81), drilling 8, 33–35 m depth, Maastrichtian.

Fig. 10 — *Saportanella nana* KARCZEWSKA & ZIEMBINSKA (x 52), drilling 8, 33–35 m depth, Maastrichtian.

Fig. 11 — *Atopochara ulanensis* KYANSEP-ROMASCHKINA (x 45), drilling 8, 33–35 m depth, Maastrichtian.

Fig. 12 — *Porochara malladae* (BATALLER) FEIST (x 52), drilling 8, 33-35 m depth, Maastrichtian.



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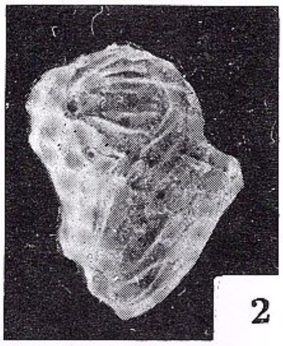

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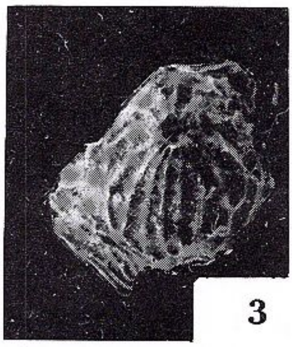

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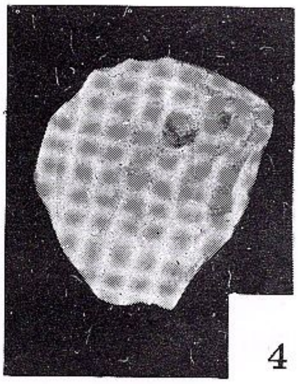

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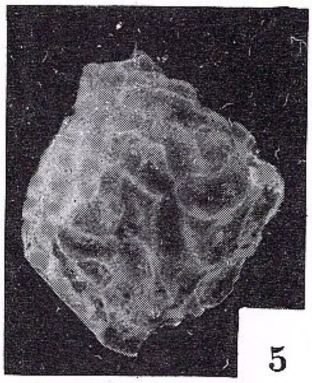

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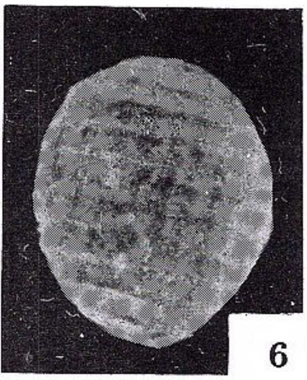

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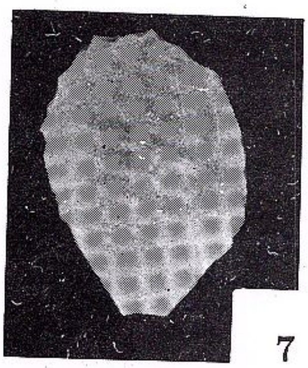

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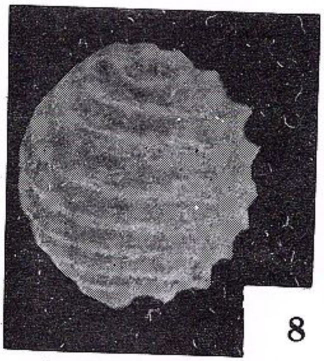

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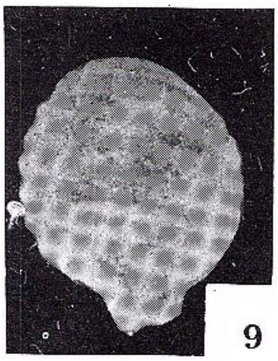

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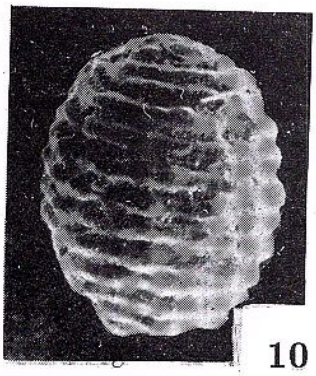

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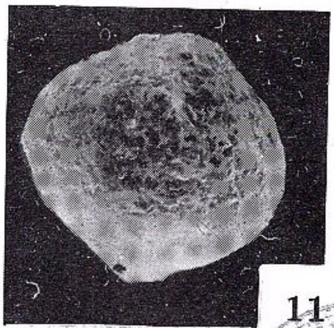

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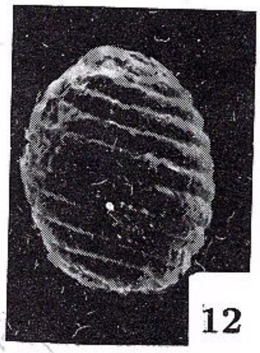

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Plate VI

Fig. 1 — *Braarudosphaera bigelowii* (GRAN & BRAARUD) DEFLANDRE (LM x 200; x-nichols), drilling 10, Upper Campanian.

Figs. 2, 3, 4 — *Prediscosphaera intercisa* (DEFLANDRE) SCHUMENKO (LM x 1800; 2, 3, x nichols; 4, Ph), drilling 10, Upper Campanian.

Fig. 5 — *Stradneria crenulata* (BRANIETTE & MARTINI) NOËL (LM x 1200, x-nichols), drilling 10, Upper Santonian.

Fig. 6 — *Micula decussata* VEKSHINA (LM x 2200, x-nichols), drilling 8, Lower Maastrichtian.

Figs. 7, 8 — *Cribrosphaerella ehrenbergi* (ARKHANGELSKY) DEFLANDRE, *Eiffelithus* sp. r (LM x 2200; 7, x nichols; 8, Ph), drilling 10, Upper Campanian.

Fig. 9 — *Ceratolithoides verbeekii* PERCH-NIELSEN (LM x 2000, x-nichols), drilling 10, Upper Campanian.

Fig. 10 — *Ceratolithoides aculeus* (STRADNER) PRINS & SISSINGH (LM x 2000, x-nochols), drilling 10, Upper Campanian.

Fig. 11 — *Lucianorhabdus maleformis* REINHARDT (LM x 2000, x-nichols), drilling 10, Upper Santonian.

Figs. 12, 13 — *Lucianorhabdus cayeuxii* DEFLANDRE (LM x 2000; 12, Ph; 13, x-nichols), drilling 8, Lower Maastrichtian.

Fig. 14 — *Microrhabdulus decoratus* DEFLANDRE (LM x 2200, x-nichols), drilling 10, Lower Campanian.

Figs. 15, 16 — *Micula decussata* VEKSHINA, *Micula concava* (STRADNER) VERBEEK (LM x 2200; 15, x-nichols; 16, Ph), drilling 8, Lower Maastrichtian.

Fig. 17 — *Prediscosphaera cretacea* (ARKHANGELSKY) GARTNER (LM x 2200, x-nichols), drilling 10, Upper Santonian.


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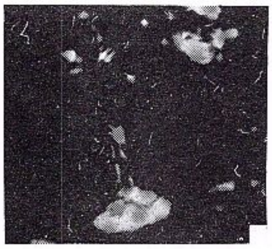
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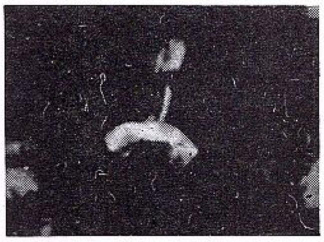
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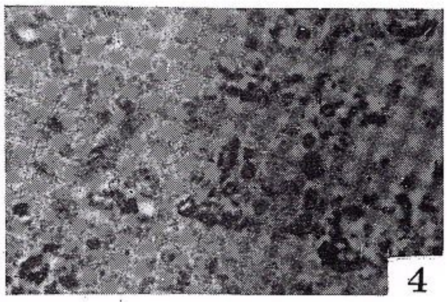
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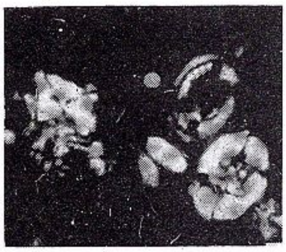
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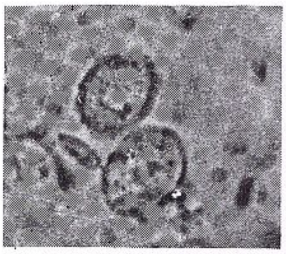
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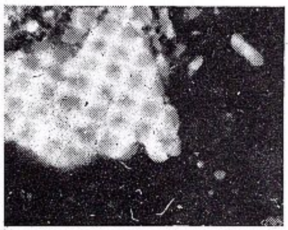
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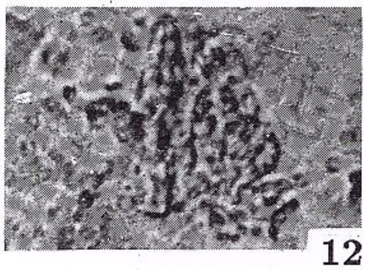
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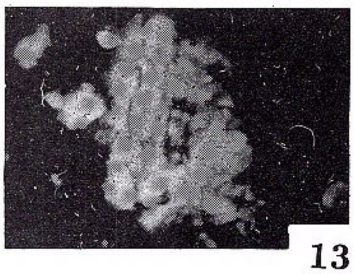
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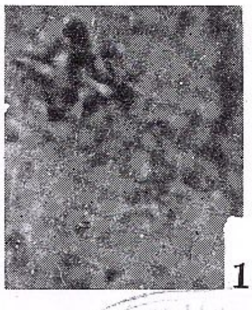
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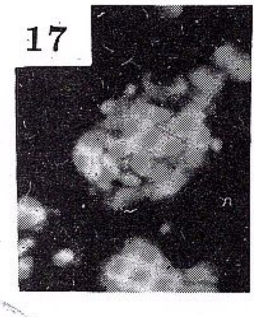
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Rom. J. Stratigraphy, 77, 4, p. 65–83, Bucureşti, 1998

TENTATIVE FOR AN INTEGRATED STANDARD BIOSTRATIGRAPHY - ON THE BASIS OF MACROFAUNA, PLANKTONIC FORAMINIFERA, CALCAREOUS NANNOPLANKTON, DINOFLAGELLATES, POLLEN - FOR THE UPPER CRETACEOUS DEPOSITS FROM ROMANIA

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Key words: Upper Cretaceous. Romania. Ammonites. Inocerams. Planktonic foraminifera. Nannoplankton. Dinoflagellates. Pollen. Biozonation.

The paper presents the first attempt to achieve, for the Upper Cretaceous deposits from Romania, the intercorrelated standard biozonal scales on the basis of ammonites, inocerams (L.S.), planktonic foraminifera (J.I.), calcareous nannoplankton (M.C.M.), dinoflagellates and microspores-pollen (E.A.). They are the results of our researches regarding the intercorrelated biostratigraphy, first on the basis of planktonic foraminifera-microflora (Antonescu et al., 1978; Ion et al., 1994) and of the macrofauna-planktonic foraminifera (Ion, 1983, 1993; Ion et Szasz, 1989, 1994; Szasz et Ion, 1984, 1988, 1991) then on the basis of the macrofauna-planktonic foraminifera-microflora (Ion et al., 1987) together, in the last time, with the calcareous nannoplankton (Szasz et al., 1992, 1994, 1995; Ion et al., 1996). The results concerning the intercorrelated biostratigraphy on the basis of all these six fossil groups are unpublished; the principal data will be presented now, in this paper.

The data/the biostratigraphic key sections come from the Upper Cretaceous deposits of the South and East Carpathians, North Dobrogea (Babadag Basin) and South Dobrogea (by outcrops and by boreholes). In the case of the Carpathians domains the data come mainly from the deposits of the Median Dacides major structural unit, preserved in the Haţeg Basin, Sebeş Basin, the Vânturariţa-Cozia area, the Dâmbovicioara-Ţara Bârsei area, Vlădeni area, Perşani Mts.; only for some stratigraphical intervals the data come also from the Outer Dacides (for Vraconian-Lower Cenomanian: Icoveşti-Bădeni area) or from the Moldavides (for the Campanian-Maastrichtian: Largu, Găineşti-Suha Mare, Oanţu Valley, Lepşa Valley area).

It is to note that for the Cenomanian-Coniacian intercorrelated biostratigraphy the ortho-chronology has been assigned by ammonits and/or inoceramid faunas while for the Santonian-Maastrichtian, excepting some few intervales, it has been assigned by planktonic foraminifera.

Figures 1-4 present the intercorrelated biozonal scales – on the basis of the above mentioned fossil groups – established/proposed by us for the Upper Cretaceous from Romania and their correlation with the ammonite, inoceramid and/or planktonic foraminifera stan-

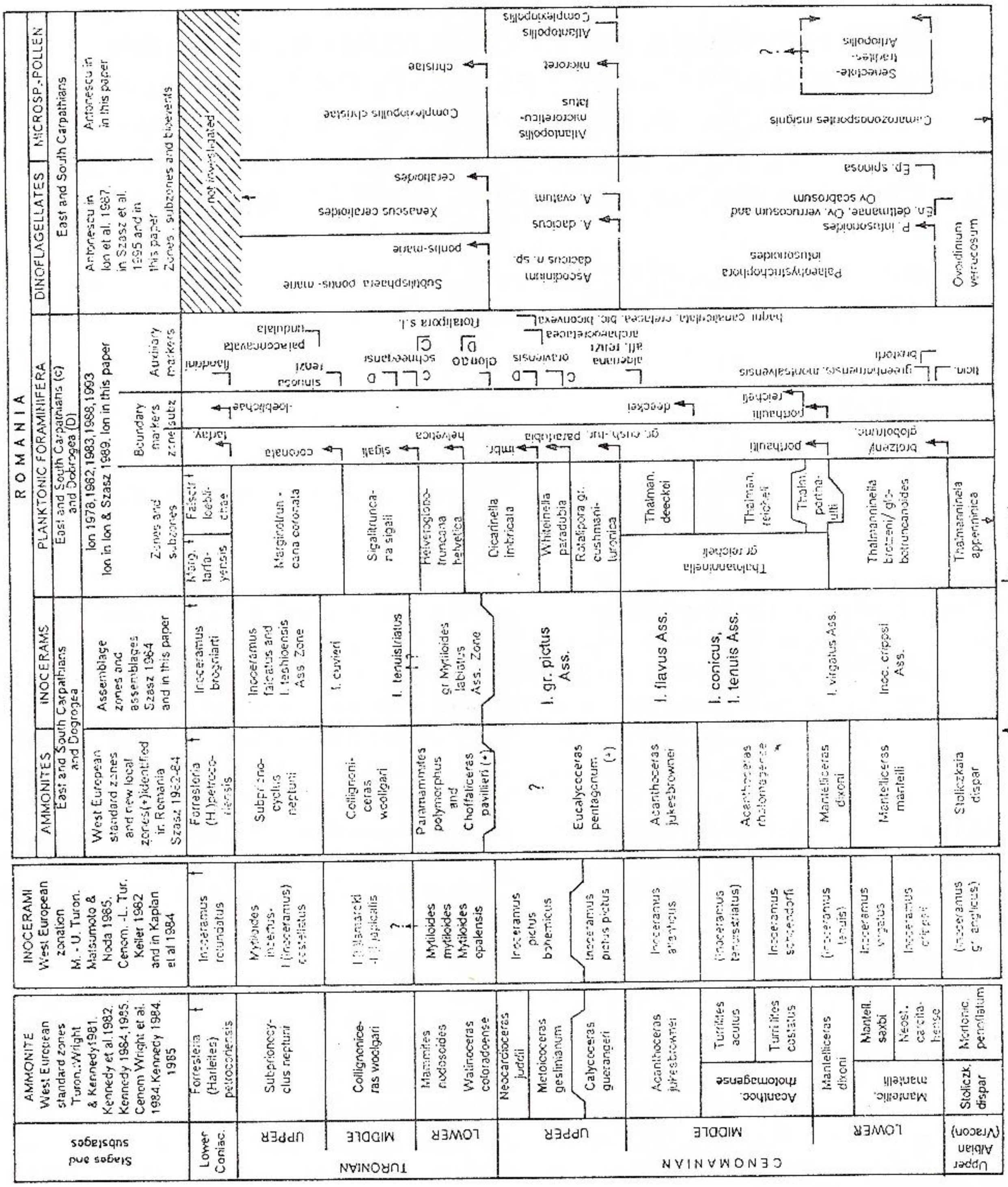

Fig. 1 – Cenomanian-Turonian intercorrelated biostratigraphy in Romania on the basis of ammonite, inoceramid, planktonic foraminifera, dinoflagellates, microspores-pollen.
Boundary marker bioevents for zones and subzones: 1, First occurrence; 2, Last occurrence. Auxiliary bioevents: 3, First occurrence; 4, Last occurrence.

dard biostratigraphic scales for the Tethys. For the biozonal scales for Romania have been graphically presented the principal marker bioevents (the first occurrence= FO or the last occurrence= LO of some taxons) which define the zones or subzones (marking their lower and upper boundaries) as well as the auxiliar bioevents which are important in order to establish the characteristic assemblage/ assemblages of the biostratigraphic units. It is to note that the term Interval Zone is taken in the sense of the International Stratigraphic Guide (1979).

As shown in Appendix I-IV for each fossil group the new biostratigraphic units are presented, defined by us on the basis of the data from Romania as well as those only emended by us.

It is to note that detalied regional studies made in the world concerning the Upper Cretaceous biostratigraphy have demonstrated that the "global standard biozonal scheme" cannot be applied on a worldwide basis because of the existence of paleobiogeographic provinces and transitional province, latitudinally controlled.

As a result of these controls is the diachronic distribution recorded for some stratigraphic index species. So, only regional/local biostratigraphic scales should offer the good criteria in establishing the geological age in the respective region.

At the same time these regional/local scales show the regional biostratigraphic characteristic as well as some global or common characteristic with those known in the other zonal scales from the Tethys, offering criteria for the regional and global correlations.

Consequently, especially in the last times, the biostratigraphical researches take into account the possibility of some regional or even local biostratigraphical scales. The last international projects, i.g. the IUGS Projects, deal also with these themes. The present work corresponds to this purpose. The data of the biostratigraphic schemes elaborated by us for Romania have argued also the conclusions that the mechanical utilisation of the standard or of the other regional biozonal schemes known in the world yield a mistaken estimate of the geological ages at least for some intervals.

AMMONITE AND INOCERAMID ZONATION IN THE UPPER CRETACEOUS

No ammonite or inoceramid zonation could be made for the Santonian-Maastrichtian in Romania, for this interval the macrofauna has generally been reported as few and isolated occurrences (Figures 3 and 4).

For the Cenomanian-Coniacian (Figures 1, 2 and 5) an ammonite zonal scale (Szasz, 1982, 1986 b, c; Szasz in Szasz & Ion, 1984, 1988, in Ion & Szasz, 1994; Szasz in this paper) has been proposed. It contains mostly the zones of the West European standard schemes proposed by Wright & Kennedy (1981), Kennedy et al. (1983), Kennedy (1984, 1985, 1986), but also the following new zones separated and defined by us on the basis of the data from Romania:

– Eucalycoceras pentagonum Zone. Age: lower part of the Upper Cenomanian. Author: Szasz in Pop & Szasz 1973 with emend. Szasz 1976, 1983. Definition: the lower boundary is marked by the FO of *E. pentagonum*. The upper boundary has not been established yet, the strata of the Upper Cenomanian (according to planktonic foraminifera) which follow above being devoid of the ammonite fauna. Remarks: this zone is an equivalent to the Ca-

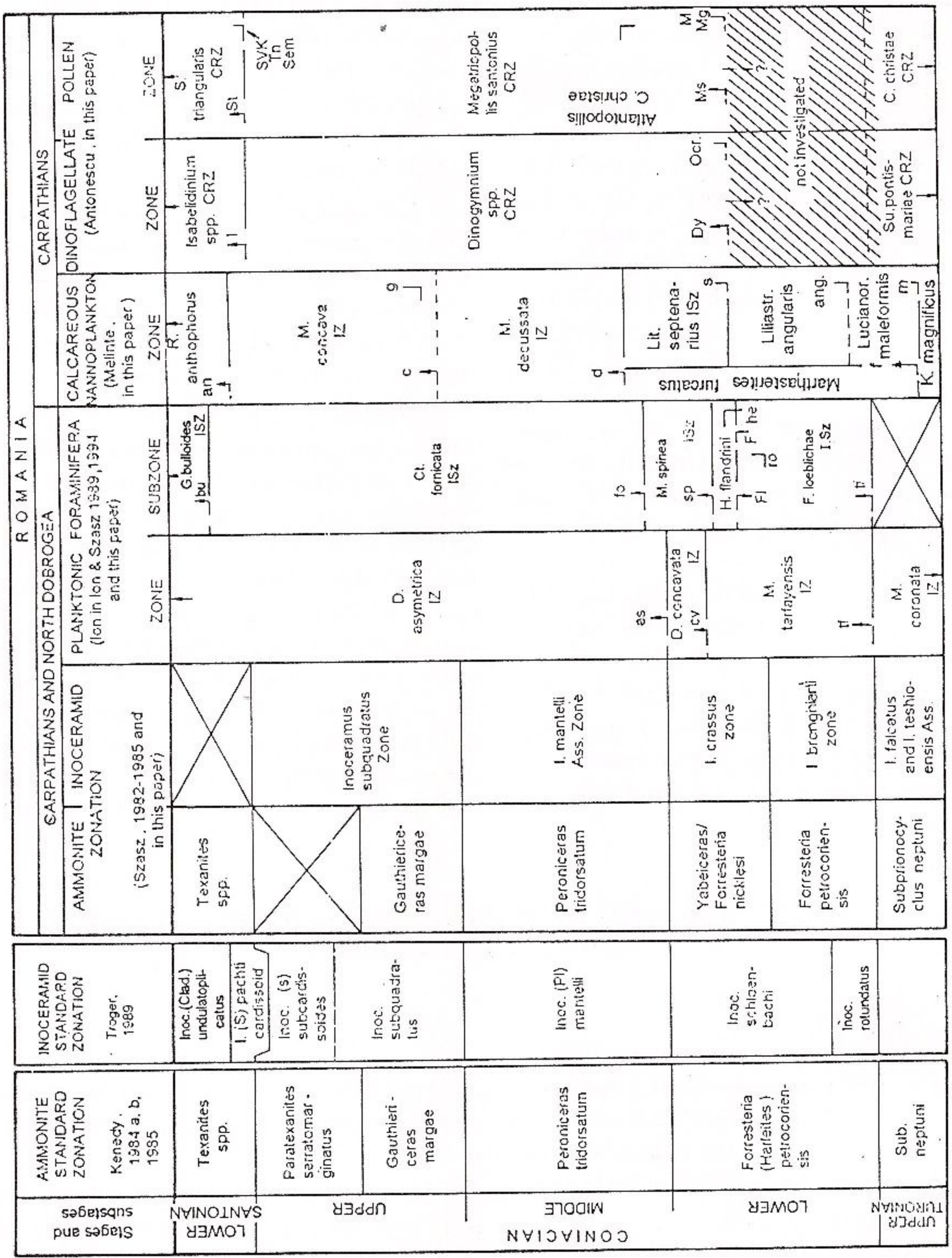

Fig. 2 – Coniacian intercorrelated biostratigraphy in Romania on the basis of ammonites, inoceramid, planktonic foraminifera, calcareous nannoplankton, dinoflagellates and pollen.

lycoceras guerangeri Zone and the lower part of the Metoicoceras geslinianum Zone of the West European standard ammonite scale.

– Paramammites polymorphus and Choffaticeras pavillieri Assemblage Zone. Age: Lower Turonian. Author: Szasz, 1986 b. Definition: the interval from the FO of *P. polymorphus* closely followed by the FO of *Ch. pavillieri*, to the FO of *Kammerunoceras* cf. *turoniense*. Remarks: within the base of this zone, concomitantly with the FO *C. pavillieri*, appear also the FO *Kammerunoceras inequicostatus, Spatites (Jeanrogericeras) reveliereanum, S. (J.) toroiagensis, Pachydesmoceras denisonianum, Fagesia peroni, F.* sp. aff. *teovestiensis, Baculites* aff. *undulatus, Baculites* sp., *Mammites* sp., *Choffaticeras* aff. *quaasi, Watinoceras* sp. In the upper part of the zone, *Cibolaites* cf. *molensari* and *Kammerunoceras* sp. have the FO too.

– Forresteria (Harleites) petrocoriensis Zone. Age: lower part of the Lower Coniacian. Author: Kennedy, 1984, but with emended definition by Szasz in Szasz & Ion, 1984 and Szasz in this paper. Definition: the interval from the FO of *F. (H.) petrocoriensis* to the FO of *Yabeiceras* genus or/and *Forresteria (Harleites) nicklesi*. Remarks: at the lower boundary of the zone, *Barroisiceras haberfellneri* has the FO too.

– Yabeiceras/Forresteria (Harleites) nicklesi Zone. Age: upper part of the Lower Coniacian. Author: originally defined by Szasz (in Szasz & Ion, 1984) as Yabeiceras Zone and recently renamed by Szasz in Szasz et al., 1993 (unpublished) and in this paper as Yabeiceras/F. (H.) nicklesi Zone. Definition: interval from the FO of *Yabeiceras* genus or/and of *F. (H.) nicklesi* to the FO of the species of *Peroniceras* sensu stricto represented by *P. tridorsatum* and *P. (Zuluiceras) bajuvaricum*. Remarks: this zone is devoid of *Barroisiceras haberfellneri, Forresteria petrocoriensis* and the species of *Peroniceras* sensu stricto. In North Dobrogea, its lower boundary is marked by the FO of *Yabeiceras orientale* and within this zone *Nowakites macoveii* and *Pseudokosmaticeras* sp. occur for the first time too. In the Carpathians, the lower boundary of the zone is marked by the FO of *F. (H.) nicklesi*; the assemblage of its lower part contains also the FO of *Peroniceras (Zuluiceras) isamberti*, while the assemblage of its upper part includes also the FO of *Nowakites tallawignesi, Tissotioides haplophyllus, Nowakites lemarchandi, N. carezi, Pseudokosmaticeras* sp. aff. *brandti, Eupachydiscus sayni. Neocrioceras (Schlueterella) kossmati, Scaphites kieslingswaldensis* and *Gaudryceras* aff. *mite* are common species for the Carpathians and North Dobrogea.

Concerning the Cenomanian-Coniacian inoceramid zonation in Romania, for the Cenomanian some isolated inoceramid faunas are known (Figure 1), but for the Turonian-Coniacian (Figures 1, 2 and 5) a succession with Assemblages, Assemblage Zones and Zones (Szasz in Szasz & Ion, 1984, 1988; Szasz in Ion & Szasz, 1994; Szasz, 1986; Szasz in this paper) has been established. For the Middle-Upper Coniacian they are in concordance with Troger's (1984) zonation, while the Lower Coniacian is represented by the following zones known in Walaszczyk's (1992) zonation and recently identified by us in Romania (Szasz in this paper):

– Inoceramus brongniarti Zone. Age: lower part of the Lower Coniacian [co-occurs with the F. (H.) petrocoriensis Zone]. Author: Walaszczyk, 1992. Definition: interval from the FO of *I. brongniarti* to the FO of *Inoceramus .crassus*. Remarks: *Mytiloides incertus* has the FO at the lower boundary of the zone and *Inoceramus deformis* at its upper boundary. In the zonation established by Walaszczyk, the I. brongniarti Zone is upper Lower Coniacian in age.

- Inoceramus crassus Zone. Age: upper part of the Lower Coniacian [co-occurs with Yabeiceras /F.(H.) nicklesi Zone]. Author: Walaszczyk 1992, but with the emended definition by Szasz in this paper. Definition:

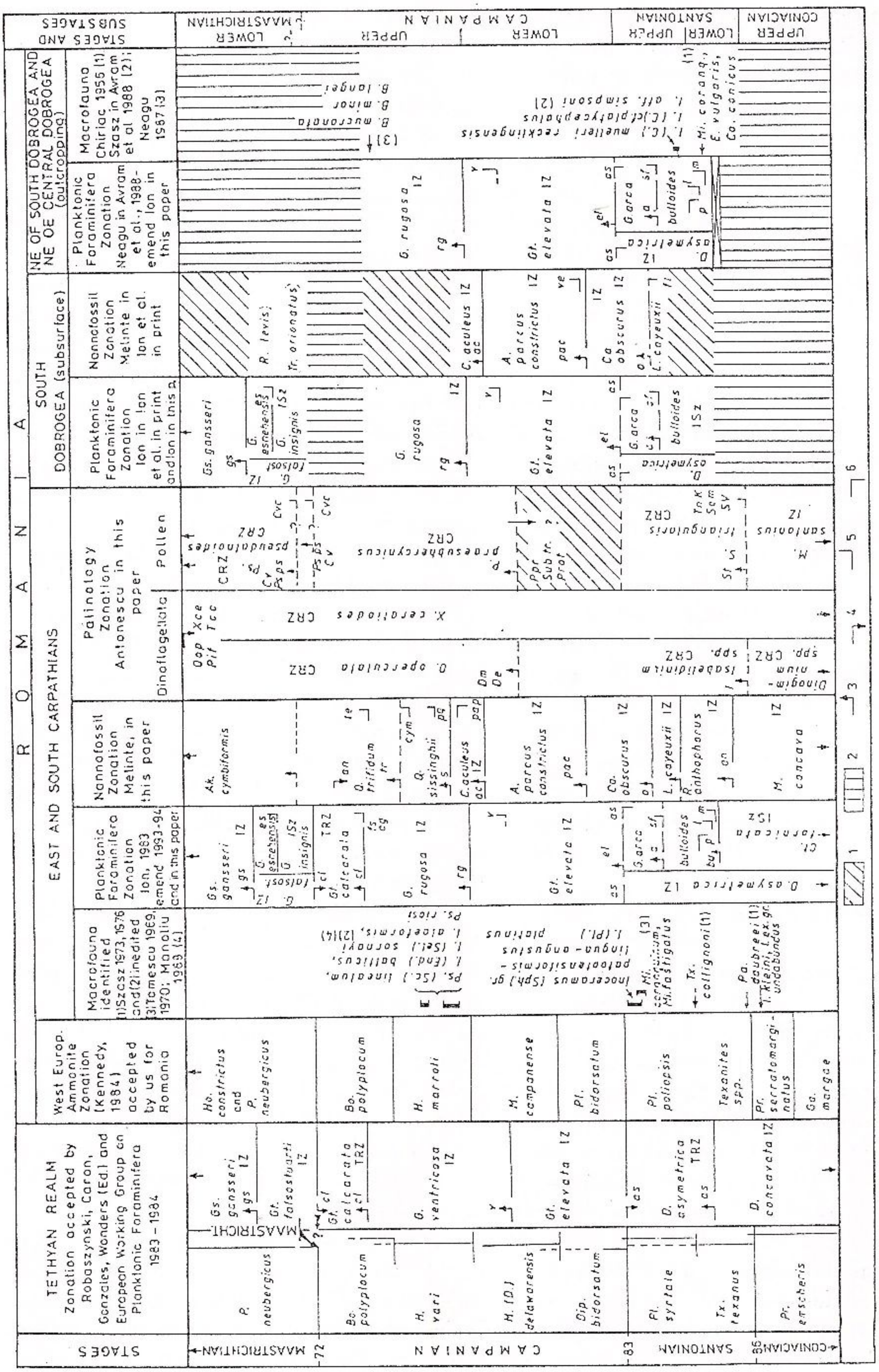

Fig. 3 – Santonian-Campanian intercorrelated biostratigraphy in Romania on the basis of macrofauna, planktonic foraminifera, calcareous nannoplankton, dinoflagellates and pollen (Legend of signed and key to fossils see Fig. 2)

interval from the FO of *I. crassus* to the FO *Inoceramus mantelli.* Remarks: at the lower boundary of the zone, *I. deformis* has the FO too. In the Walaszczyk zonation, *I. deformis* has the FO before of *I. crassus* and the I. crassus Zone is Middle Coniacian in age and has the upper boundary marked by the FO of *Inoceramus involutus.*

PLANKTONIC FORAMINIFERA ZONATION IN THE UPPER CRETACEOUS

The planktonic foraminifera standard zonation (Figures 1-5) proposed by us for the Upper Cretaceous from Romania are results of our works: J. Săndulescu, 1969, Ion 1978, 1983, and Ion in Szasz & Ion, 1984 - but with emend. and new zones and subzones by Ion in Ion & Szasz, 1989 and 1994, Ion, 1993, as well as Ion in Ion et al. 1996 and Ion in this paper. It contains some bio-stratigraphic units from the other zonal scales of the Tethys but also the following emended and new biostratigraphic units established on the basis of the data from Romania. It is to note that because some Coniacian-Santonian facies in Romania are devoid of *Dicarinella concavata* and *D. asymetrica*, an alternative zonation with six new subzones has been elaborated for use in facies with or without "concavates".

- Thalmanninella brotzeni/Th. globotruncanoides Interval Zone. Age: terminal Upper Albian (terminal part of the Vraconian respectively)-Lower Cenomanian pro parte. Author: J. Săndulescu, 1969. Definition: interval from the FO of *Th. brotzeni* or/and *Th. globotruncanoides* to the FO of *Thalmanninella porthaulti.* Remarks: this zone originally has been defined by J. Săndulescu, 1969, with the upper boundary marked by the FO of *Rotalipora (Thalmanninella) reicheli*-not typical form, which subsequently has been grouped by J. Ion, 1983, as *Th. portaulti* n.sp., as the first species of the *reicheli* spectrum. In the lower part of the zone, in the basal Lower Cenomanian, *Thalmanninella greenhornensis* and *Rotalipora montsalvensis* have the FO; towards the upper part of the zone, several new species of *Thalmanninella* have the FO (see Ion, 1983), among which is *Th. oresti* directly ancestral to the *Th. porthaulti*; the terminal part of the zone contains abundant *Rotalipora montsalvensis* (Acme Subzone) and the FO of *R. thomei.*

- Thalmanninella gr. reicheli Interval Zone. Age: terminal Lower Cenomanian-Middle Cenomanian. Author: Ion, 1978 (1977). Definition: interval from the FO of *Thalmanninella porthaulti* to the FO of Rotalipora cushmani-turonica group (of *R. cushmani, R. turonica, R. turonica expansa* respectively). Remarks: originally defined by Ion, 1978 (1977) with the lower boundary marked by the FO of *Rotalipora reicheli*-not typical form, subsequently grouped as *Th. porthaulti* n.sp. Ion, 1983. Within the lower part of the zone, *Th. reicheli* has the FO; within the upper part of the zone, *Th. deeckei* has the FO and near its upper boundary *Dicarinella algeriana* and *Marginotruncana* aff. *renzi* - convex form, as the first *Dicarinella* and *Marginotruncana* specimens have the FO.

- Thalmanninella porthaulti Interval Subzone. Age: terminal Lower Cenomanian. Author: Ion, 1978 (1977). Definition: interval from the FO of *Th. porthaulti* to the FO of *Thalmanninella reicheli.* Remarks: this subzone, originally has been defined by Ion, 1978 (1977), as "Rotalipora reicheli non typique" Subzone; subsequently it has been renamed, by Ion, 1983, Th. porthaulti Subzone, by synonymy *R. reicheli*-non typique= *Th. porthaulti* n.sp. Ion, 1983. This zone may be synonymous with Cn 2b (with *Rotalipora* aff.

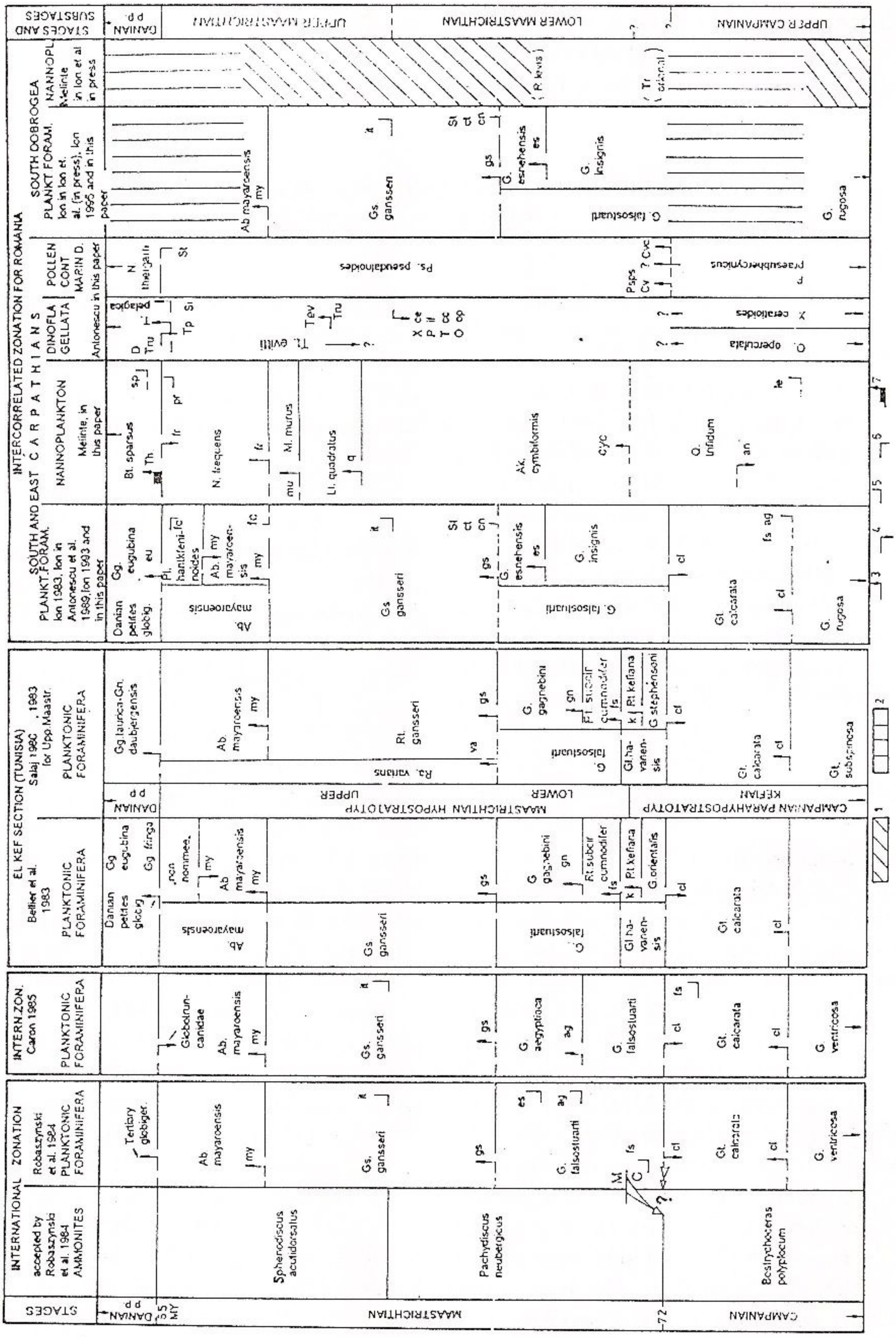

Fig. 4 – Maastrichtian intercorrelated biostratigraphy in Romania on the basis of planktonic foraminifera, calcareous nannoplankton, dinoflagellates and pollen. (Legend of signs and key to fossils see Fig. 2).

reicheli) Zone defined by Portault (1974) from uppermost Lower Cenomanian from East France.

– Thalmanninella reicheli Interval Subzone. Age: lower part of the Middle Cenomanian. Author: Bolli, 1957, has introduced the "Rotalipora reicheli Zone", but the definition used by us for it in the present paper is the one given by Ion, 1978 (1977). Definition: interval from the FO of *Th. reicheli* to the FO of *Thalmanninella deeckei*. Remarks: the "Subzone R. reicheli-tipique" separated by Ion 1978= by synonymy with Th. reicheli Subzone, Ion 1983.

– Thalmanninella deeckei Interval Subzone. Age: upper part of the Middle Cenomanian. Author: Sigal, 1966, has introduced the Rotalipora (Thalmanninella) deeckei Zone, but the definition used by us for it in the present paper is the one given by Ion, 1978 (1977). Definition: interval from the FO of Th. deeckei to the FO of *Rotalipora cushmani turonica* group (respectively of *R. cushmani, R. turonica* and *R. turonica expansa*).

– Rotalipora gr. cushmani-turonica Interval Zone. Age: lower part of the Upper Cenomanian. Author: Ion, 1978 (1977). Definition: interval from the FO of *Rotalipora* gr. *cushmani-turonica* (*R. cushmani, R. turonica, R. turonica expansa* respectively) to the FO of *Whiteinella paradubia*. Remarks: at the lower boundary of this zone, *Thalmanninella appenninica* has the LO and *Pseudorotalipora* genus (represented by *Ps. praemontsalvensis*) has the FO. Within relative middle part of the zone, *W. aumalensis* and probably *W. baltica* have the FO. In the terminal part, have the FO *W. kingi*, then *W. inornata* and *Marginotruncana renzi* (convex form) followed by the FO of *Helvetoglobotruncana (?) praehelvetica, W. aprica* (not= *W. archaeocretacea*) and angular-lobate morphs of *Rotalipora* sensu lato (e.g. *Th.* aff. *Th. micheli* and *Th.* aff. *Th. marchigiana* in Ion 1983, *R. convoluta* in Ion 1978).

– Whiteinella paradubia Interval Zone. Age: upper part of the Upper Cenomanian. Author: Ion, 1978 (1977) with emend of definition by Ion in Szasz & Ion, 1988 (fide pl. II) and of the rank by Ion in Ion & Szasz, 1989 and Ion, 1993. Definition: interval from the FO of *W. paradubia* to the FO of *Dicarinella imbricata*. Remarks: it is to note that originally this zone has been defined as Hedbergella paradubia Subzone (Ion, 1978) with the upper boundary marked by the FO of *D. imbricata* or *Archaeoglobigerina cretacea*. At the upper boundary of the W. paradubia Zone, *Dicarinella hagni, D. canaliculata, D. biconvexa biconvexa* and *Archaeoglobigerina cretacea* have the FO too. Within this zone, in the Carpathians have the FO the specimens of *Praeglobotruncana* gr. *oraviensis* and in the Carpathians and North Dobrogea the specimens of *Whiteinella archaeocretacea*.

– Dicarinella imbricata Interval Zone. Age: terminal Upper Cenomanian-basal part of the Lower Turonian. Author: Salaj & Samuel, 1966, but with the definition specified by Ion, 1978 (1977) for the D. imbricata Subzone and then, Ion in Szasz & Ion (pl. II) as zone. Remarks: at the lower boundary of the zone, *D. hagni (=D. indica), D. canaliculata, D. biconvexa biconvexa* and *Archaeoglobigerina cretacea* have the FO too. Within its middle part (probably at the Cenomanian-Turonian boundary), *Marginotruncana elenae* (direct ancestral form of *M. paraconcavata*) passes the FO and, only in North Dobrogea, in its basal part, specimens of *Praeglobotruncana* gr. *oraviensis* appear. In the lowermost part of Lower Turonian of this Zone, in the Carpathians probably, *D. biconvexa gigantea* has the FO. In the Carpathians and North Dobrogea, *Rotalipora* sensu lato (*Th. reicheli, R. cushmani, R. turonica*) persists in entire D. imbricata Zone.

– Marginotruncana coronata Interval Zone. Age: terminal Middle Turonian-Upper Turonian. Author: Douglas, 1969 the first named this zone, but the definition used by us for it in the present paper is the one given by Ion, 1982 for M. coronata Subzone and then, Ion,

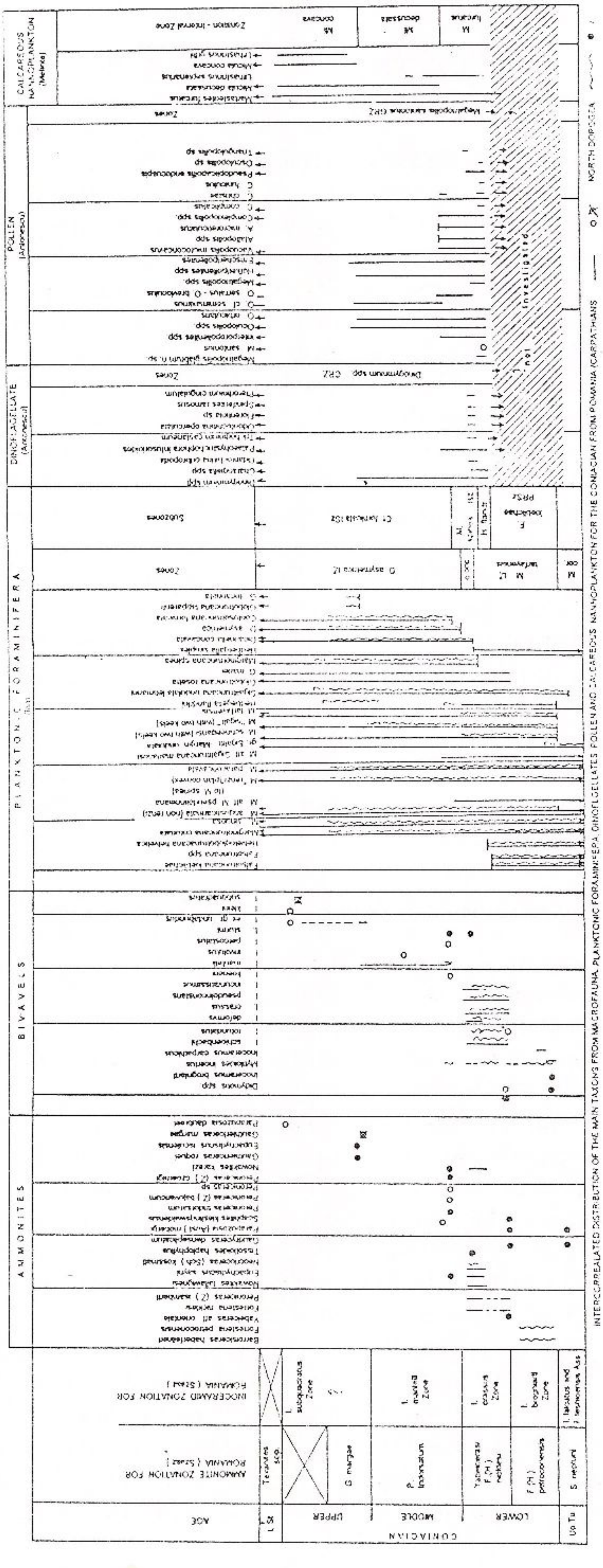

Fig. 5 – Intercorrelated zonation and distribution of the main zones from macrofauna, planktonic foraminifera, dinoflagellates, pollen and calcareous nannoplankton in the Coniacian from Romania. 1, in East and South Carpathians; 2, in North Dobrogea.

1993 as zone. Definition: interval from the FO of *M. coronata* to the FO of *Marginotruncana tarfayensis.* Remarks: at the lower boundary of this Zone, in the Carpathians and North Dobrogea have the FO *Marginotruncana sinuosa* and *M. "renzi" planconvex* and in the Carpathians has the FO *Marginotruncana angusticarinata* and transited specimens from *Marginotruncana elenae* to *M. paraconcavata*; in the first Upper Turonian levels, in both domains appear gr. *Sigalitruncana-Marginotruncana undulata undulata, M. paraconcavata Marginotruncana* aff. *Sigalitruncana marianosi, M.* aff. *M. angusticarinata* (with the very involute chambers on the spiral side), *M.* aff. *M. pseudolinneiana* (with the spiral side in *Globotruncana obliqua*-type forms) and *M.* aff. *M. pseudolinneiana* (angular-lobate in outline) which marks the transition to the *M. spinea.* In the Carpathians and North Dobrogea, *Helvetoglobotruncana helvetica* persists in entire M. coronata Zone.

– Marginotruncana tarfayensis Interval Zone. Age: Lower Coniacian pro parte (without its uppermost part). Author: Ion, 1982 (1979) as subzone, Ion in Ion & Szasz, 1989 and Ion, 1993, as zone. Definition: interval from the FO of *M. tarfayensis* to the FO of *Dicarinella concavata.* Remarks: at the lower boundary of this zone in the Carpathians and North Dobrogea appear specimens of *Marginotruncana scheneegansi* and *M. "sigali"* with two carenas, and at least in the Carpathians *Hedbergella flandrini* appears. In the upper part of this zone (in the interval with Yabeiceras/Forresteria (H.) nicklesi ammonite zone), *Globotruncana rosetta* and *G. mariei* appear. In both domains, in the terminal part of the M. tarfayensis Zone, the *Falsotruncana* genus and then *H. helvetica* species have the LO, and near its upper boundary *M. spinea* appears.

– Falsotruncana loeblichae Interval Subzone. Age: lower and middle part of the Lower Coniacian. Author: Ion, in this paper. Definition: interval from the FO of *Marginotruncana tarfayensis* to the LO of *Falsotruncana loeblichae.* Remarks: at the lower boundary of this subzone, *Hedbergella flandrini* at least in the Carpathians, *Marginotruncana angusticarinata* in North Dobrogea and the specimens of *M. schneegansi* and *M."sigali"*-with two carenas in both domains, have its FO too. In the uppermost part of the subzone, *Globotruncana rosetta* and *G. mariei* have the FO. In both domains *Helvetoglobotruncana helvetica* persists in entire subzone and at its upper boundary *Falsotruncana* genus has the LO.The assemblage of this subzone, forming the lower part of the M. tarfayensis Zone, is characterized by the co-occurrence of *M. tarfayensis, M. flandrini, Falsotruncana, H. helvetica* and intermediate specimens from *M. pseudolinneiana* to *M. spinea.*

– Hedbergella flandrini Interval Subzone. Age: middle part of the Lower Coniacian. Author: Ion in this paper. Definition: interval from the LO of *Falsotruncana loeblichae* to the FO of *Marginotruncana spinea.* Remarks: within the lower part of this subzone, in the Carpathians and North Dobrogea, *Helvetoglobotruncana helvetica* has the LO. The assemblage of this subzone is characterized by co-occurrence of *M. tarfayensis, H. flandrini, Globotruncana rosetta, G. mariei*, the last *H. helvetica*, intermediate specimens from *M. pseudolinneiana* to *M. spinea*, the absence of *Falsotruncana* genus.

– Marginotruncana spinea Interval Subzone. Age: uppermost part of the Lower Coniacian-lowermost Middle Coniacian. Author: Ion in Ion & Szasz, 1994. Definition: interval from the FO of *M. spinea* to the FO of *Contusotruncana fornicata.* Remarks: in the facies with "cocavates", *Dicarinella concavata* has the FO in the basal part (uppermost Lower Coniacian in age) of this subzone (little above its lower boundary) and in its terminal part (lowermost Middle Coniacian in age) *D. asymetrica* has the FO.

– Contusotruncana fornicata Interval Subzone. Age: the greatest part of the Middle Coniacian-lower part of the Lower Santonian. Author: Bolli, 1957, the first has separated and introduced the name "Globotruncana fornicata" Zone (by synonymy= *Ct. fornicata*), but the definition of Contusotruncana fornicata Subzone used by us in the present paper is the one given by Ion in Ion & Szasz, 1994. Definition: interval from the FO of *Ct. fornicata* to the FO of *Globotruncana bulloides.*

– Globotruncana bulloides Interval Subzone. Age: Lower Santonian pro parte-Upper Santonian pro parte. Author: Pessagno, 1967, the first who has separated and introduced the name G. bulloides Assemblage Zone, but the G. bulloides Subzone separated by us in the present paper has the definition given by Ion in Ion et al., 1996, and in this paper. Remarks: at the lower boundary of this subzone, *Dicarinella biconvexa biconvexa* and *D. jekeliana* have the LO; in its lowermost part, *Globotruncana linneiana* followed by *Contusotruncana manaurensis* have the FO; from the middle part, marking the Lower-Upper Santonian boundary, the species *Marginotruncana paraconcavata* has the LO; at its upper boundary, *Globotruncanita stuartiformis* has the FO too.

– Globotruncana arca Interval Subzone. Age: upper part of the Upper Santonian. Author: the name G. arca Zone has been introduced by Dalbiez, 1955, for a Lower Maastrichtian Zone and subsequently it has been used also for some Campanian or Upper Santonian zones. But the G. arca Subzone separated by us has a new definition introduced by Ion in Ion et al., 1996 and in this paper. Definition: interval from the FO of *G. arca* to the FO of *Globotruncanita elevata.* Remarks: at the lower boundary of this subzone, in the Carpathians and Dobrogea, *Globotruncanita stuartiformis* has the FO followed by the FO of *Globotruncana orientalis*; at its upper boundary, *Decarinella asymetrica* and *D. biconvexa gigantea* have the LO.

– Globotruncanita elevata Interval Zone. Age: Lower Campanian. Author: Dalbiez, 1955, the first who has separated and introduced the name "Zone elevata", but the definition used by us for it is the one given by Ion, 1983. Definition: interval from the FO of *Gt. elevata* to the FO of *Globotruncana rugosa.* Remarks: in both domains, at the lower boundary of this zone, *Dicarinella asymetrica* and *D. biconvexa gigantea* have the LO and within its uppermost part, *Globotruncana ventricosa* has the FO.

– Globotruncana rugosa Interval Zone. Age: lower part of the Upper Campanian. Author: Salaj & Samuel, 1966, the first who have separated and introduced the name G. rugosa Zone, but the definition used by us is the one given by Ion, 1983. Definition: interval from the FO of *G. rugosa* to the FO of *Globotruncanita calcarata.*

-Globotruncana insignis Interval Subzone. Age: terminal part of the Upper Campanian (?)-lower part of the Lower Maastrichtian. It starts in the terminal Upper Campanian if the Campanian-Maastrichtian boundary will be situated within the G. falsostuarti Zone. Author: Ion in Ion et al., 1996 (unpublished) and Ion in this paper. Definition: interval from the LO of *Globotruncanita calcarata* to the FO of *Globotruncana esnehensis.* Remarks: in the basal part of the subzone, *Plummerita hantkeninoides* and *Globotruncana lamellosa* SIGAL have the FO. From the Globotruncanita calcarata Zone persist *Globotruncana falsostuarti* and *G. aegyptiaca.*

-Globotruncana esnehensis Interval Subzone. Age: median part of the Lower Maastrichtian. Author: Ion in Ion et al., 1996 (unpublished) and Ion in this paper. Definition: interval from the FO of *G. esnehensis* to the FO of *Gansserina gansseri.*

-Plummerita hantkeninoides Interval Subzone. Age: terminal part of the Upper Maastrichtian. Author: Bellier et al., 1983, defined and named the "non nommee" subzone, renamed by Ion in Antonescu et al., 1989, Ion, 1993, as "Plummerita hantkeninoides"

Subzone. Definition: interval from the LO of *Abathomphalus mayaroensis* to the FO of the basal Danian "petites globigerines". Remarks: within the upper part of this subzone, *Globotruncanita falsocalcarata* has the LO. Consequently this subzone includes an assemblage with *Gt. falsocalcarata* and *Pl. hantkeninoides*, followed by an assemblage with *Pl. hantkeninoides*. The latter, in the first part, contains also several *Globotruncanidae* and *Heterohelicidae, Globigerinelloides* and rare specimens of *G. arca, G. falsostuarti, Gs. gansseri, Globotruncanella paschadae.*

CALCAREOUS NANNOPLANKTON ZONES IN THE UPPER CRETACEOUS

From the point of view of the intercorrelated biostratigraphy the study concerning the calcareous nannoplankton have been undertaken only in the Coniacian Carpathian deposits (Melinte in Szasz et al., 1993; unpublished), and in the Santonian-Maastrichtian Carpathian and Dobrogean deposits (Melinte in Szasz et al., 1994 and in Ion et al., 1996; unpublished). The nannoplankton zones established for Romania (Figs. 2-5) come mainly from the zonal scale proposed by Sissingh (1977) and Verbeek (1977) and some from the West Carpathian scale (Svabenicka, 1993), but the following zones are emended or are new zones separated and defined by us:

– Micula decussata Interval Zone. Age: the greatest part of Middle Coniacian-basal Upper Coniacian. Author: Manivit, 1971, definition emended by Melinte in Szasz et al., 1994, unpublished and Melinte in this paper. Definition: interval from the FO of *M. decussata* to the FO of *Micula concava.*

– Calculites obscurus Interval Zone. Age: uppermost part of the Upper Santonian-lowermost part of the Lower Campanian. Author: Sissingh, 1977, definition emended by Melinte in Ion et al., 1996 and Melinte in this paper. Definition: interval from the FO of *C. obscurus* to the FO of *Aspidolithus parcus constrictus.*

– Arkhangelskiella cymbiformis Interval Zone. Age: upper part of the Lower Maastrichtian-lowermost part of Upper Maastrichtian. Author: Sissingh, 1977, definition emended by Melinte in Ion et al., 1996 (unpublished) and Melinte in this paper. Definition: interval from the FO of *A. cymbiformis cymbiformis* to the FO of *Lithraphidites quadratus.*

DINOFLAGELLATE AND POLLEN ZONATION IN THE UPPER CRETACEOUS

The dinoflagellate and pollen zonal schemes proposed by us for the Upper Cretaceous Carpathian areas from Romania are achieved by us (Antonescu in Szasz et al., 1995, in Ion et al., 1996 a, b) and contain completely new zones. The microflora zonation has been initially elaborated by us on the basis of dinoflagellates together with pollen (Antonescu in Antonescu & Alexandrescu, 1982, in Ion et al., 1985, 1987, 1994).

The zonation on the base of dinoflagellate contains:

– Ovoidinium verrucosum Total Range Zone. Age: uppermost Upper Albian (=Vraconian). Author: Antonescu in this paper. Definition: interval of total range of *O. verrucosum*. Remarks: this zone represents the total range of *Endoceratium dettmanae* too. Also at the upper boundary of this zone *Ovoidinium scabrosum* has the LO.

– Palaeohystrichophora infusorioides Concurrent Range Zone. Age: Lower and Middle Cenomanian. Author: Antonescu in Ion et al., 1987 (unpublished) and Antonescu in this paper. Definition: interval from the FO of *P. infusorioides* to the FO of *Ascodinium dacicus* n.sp.. Remarks: At the lower boundary of this zone, *Ovoidinium verrucosum, O. scabrosum* and *Endoceratum dettmaniae* have the LO and *Epelidosphaeridia spinosa* has the FO. At the upper boundary, *Ascodinium ovatum* has the FO too.

– Ascodinium dacicus Concurrent Range Zone. Age: Upper Cenomanian but the age of the top of the zone is insufficiently argued. Author: Antonescu in this paper. Definition: interval from the FO of *A. dacicus* n.sp. to the FO of *Subtilisphaera pontis-marie*. Remarks: at its lower boundary *Ascodinium ovatum* has the FO too.

– Subtilisphaera pontis-marie Concurrent Range Zone. Age: Turonian, but the age of the lower boundary is insuficiently argued. Author: Antonescu in this paper. Definition: interval from the FO of *S. pontis-marie* to the FO of *Dinogymnium* genus.

– Xenascus ceratioides Concurrent Range Zone or Assemblage Zone. Age: Turonian-Lower Maastrichtian. Author: Antonescu in this paper. Definition: interval from the FO of *X. ceratioides* to the LO of *X. ceratioides, P. infusorioides, Odontochitina operculata, Trichodinium castaneum*. Remarks: in the upper part of the zone (upper part of the Lower Campanian) a lot of species of *Chatangiella* and *Isabelidinium* appear. This zone characterizes the open sea facies.

– Dinogymnium sp. Concurrent Range Zone. Age: Coniacian. Author: Antonescu in Szasz et al., 1995 (unpublished) and Antonescu in this paper. Definition: interval from the FO of *Dinogymnium* to the FO of *Chatangiella*. Remarks: within this zone, *Odontochitina cribropoda* has the FO and persist from Turonian the species *P. infusorioides, Trichodinium castaneum, Odontochitina operculata, Florentinia* sp., *Spiniferites ramosus, Pterodinium cingulatum*.

–Isabelidinium sp. Concurrent Range Zone. Age: Santonian-(?) Lower Campanian pro parte. Author: Antonescu in Ion et al., 1996 and in this paper. Definition: interval from the FO of *Isabelidinium* genus (represented by *I. cooksoni* species) to the FO of *Dinogymnium euclaense* and *D. majus*.

– Odontochitina operculata Concurrent Range Zone. Age: upper part of the Lower Campanian-Lower Maastrichtian. Author: Antonescu in Ion et al., 1996 and Antonescu in this paper. Definition: interval from the FO of *Dinogymnium euclaense* and *D. majus* to the LO of *O. operculata* as well as of the other species as *X. ceratioides, P. infusorioides, Tr. castaneum*. Remarks: this zone characterizes the shelf marine facies.

– Trithirodinium evittii Concurrent Range Zone. Age: Lower Maastrichtian pro parte (upper part only?)-Upper Maastrichtian. Author: Antonescu in Ion et al., 1996. Definition: interval from the FO of *Tr. evittii* to the FO of *Thalassiphora pelagica*. Remarks: at the lower boundary *Triblastula utinensis* has the FO too, followed by the successive FO of *Alterbidinium minus-Manumiella raijac-Alterbidinium acutulum* group, *Palaeoperidinium pyrophorum, Cerodinium striatum, C.* aff. *speciosum, Cerodinium sp.* A (=new species), *Hystrichosphaeropsis ovum, Palaeocystodinium golzowense, Cannosphaeropsis utinensis* and possible *Phanerodinium cayeuxii*. At the upper boundary, *Senoniasphaera inornata* has the FO too.

– Thalassiphora pelagica Concurrent Range Zone. Age: terminal Upper Maastrichtian-

Danian pro parte. Author: originally defined by Antonescu in Ion et al., 1985, as *Senoniasphaera inornata* and *Thalasiphora pelagica*, and recently renamed by Antonescu in Ion et al., 1996 and Antonescu in this paper. Definition: interval from the FO of *Th. pelagica* to the FO of *Carpatella cornuta*. Remarks: at the lower boundary of this zone, *Senoniasphaera inornata* has the FO and at the upper boundary the species *Alisocysta circumtabulata* and *Duosphaeridium rugosum* have the FO too. Within this zone, in the terminal part of Maastrichtian, the species *Palaeocystodinium australinum* and *Spiniferites cornutus* have the FO while *Dinogymnium* genus and *Triblastula utinensis* have the LO.

The zonation on the basis of pollen contains:

- Camarozonosporites insignis Concurrent Range Zone. Age: Upper Albian-Middle Cenomanian. Author: Antonescu in this paper. Definition: interval from the FO of *C. insignis* to the FO of *Atlantopollis microreticulatus*.

- Senectotetradites-Artiopollis Total Range Subzone. Age: Lower Cenomanian, but the age of the upper boundary of this zone is insufficiently argued. Author: Antonescu in this paper. Definition: interval of total extension of Senectotetradites-Artiopollis genera. Remarks: this subzone characterizes the littoral marine facies.

- Atlantopollis microreticulatus Concurrent Range Zone. Age: Upper Cenomanian, but the age of the upper boundary is insuficiently argued. Author: Antonescu in this paper. Definition: interval from the FO of *A. microreticulatus* to the FO of *Complexiopollis christae*. Remarks: at the lower boundary of this zone, have the FO *Complexiopollis* and *Atlantopollis* genera.

- Complexiopollis christae Concurrent Range Zone. Age: Turonian, but the upper boundary is insufficiently argued. Author: Antonescu, in this paper. Definition: interval from the FO of *C. christae* to the FO of *Megatriopollis santonius*. Remarks: at the upper boundary of this zone, *Megatriopollis* genus and *M. glabrum* n.sp. have the FO too.

- Megatriopollis santonius Concurrent Range Zone. Age: Coniacian, but the levels of the lower part of the Lower Coniacian [Forresteria (Harleites) petrocoriensis Zone] have not been studied yet concerning the microflora. Author: Antonescu in this paper. Definition: interval from the FO of *M. santonius* to the FO of *Suemeghipollis triangularis*. Remarks: at the lower boundary of this zone have the FO of *Megatriopollis* genus represented by the species *M. santonius* and *M. glabrum*; at the upper boundary have the FO of *Suemeghipollis, Verruoculopollis* and *Krutzschiopollis* genera, *Trudopollis* sp. cf. *T. nonperfectus* and *Semioculopollis medius* species.

- Suemeghipollis triangularis Concurrent Range Zone. Age: Santonian, but this zone could extend up to the uppermost Coniacian and to the Lower Campanian pro parte. Author: Antonescu in Ion et al., 1996 and in this paper. Definition: interval from the FO of *S. triangularis* and *Verruculopollis* genus (with the species *V. pflugii, V. tschudyii, V. skarbyae*) to the FO of *Pseudopapilopollis praesubhercynicus* and of *Trioporopollenites* (with *T. robustus* species), *Subtriporopollenites* (with *S. constans* species) and *Proteacidites* genera. Remarks: at the lower boundary of the zone, *Suemeghipollis* and *Krutzschioppollis* genera and *Trudopollis nonperfectus, Semioculopollis medius* species have the FO.

- Psedopapilopollis praesubhercynicus Concurrent Range Zone. Age: upper part of the Lower Campanian-lowermost Lower Maastrichtian. Author: Antonescu in Ion et al., 1996 and in this paper. Definition: interval from the FO of *Pseudopapilopollis praesubhercynicus* and of *Triporopollenites* (with *T. robustus* species), *Subtriporopollenites* (with *S. constans* species) and *Proteacidites* genera to the FO of *Pseudotrudopollis pseudalnoides* and of *Convexiopollis* genus. Remarks: at the upper boundary of this zone *Convexiopollis con-*

vexigerminalis has the FO.

– Pseudotrudopollis pseudalnoides Concurrent Range Zone. Age: Lower Maastrichtian pro parte-Upper Maastrichtian. Author: Antonescu in Ion et al., 1996 (unpublished) and in this paper. Definition interval from the FO of *Ps. pseudalnoides* and of *Convexiopollis* genus to the FO of *Nudopollis endangulatus* and *N. thiergarti.* Remarks: at the lower boundary of the zone, the *Convexiopollis* genus with *Convexiopollis* sp., *C. rotundatus*, *C. convexigerminalis* species has the FO.

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Legend of signs for Figures 2–4. 1, Not biostratigraphically investigated; 2, Hiatus; Boundary marker bioevents for zones and subzones, 3 - first occurrence, 4 - last occurrence, 7 - "boom", Auxiliary bioevents, 5 - first occurrence, 6, last occurrence.

Key to fossils for Figures 2–4. **Macrofauna**: B, *Belemnitella*; Bo, *Bostrychoceras*; Co, *Conulus*; Di, *Diplacmoceras*; Ga, *Gauthiericeras*; H, *Hoplitoplacenticeras*; Ho, *Holcoscaphites*; E, *Echinocorys*; I, *Inoceramus*; M (D), *Menabites (Delawarella)*; Mi, *Micraster*; P, *Pachydiscus*; Pa, *Parapuzosia*; Pl, *Placenticeras*; Pr, *Paratexanites*; Px, *Pseudoxybeloceras*; Tx, *Texanites*. **Planktonic foraminifera**: Ab, *Abathomphalus*; my, *Ab. mayaroensis*; Ct, *Contusotruncana*; ct, *Ct. contusa*; fo, *Ct. fornicata*; m, *Ct. manaurensis*; D, *Dicarinella*; as, *D. asymetrica*; bb, *D. biconvexa biconvexa*; bg, *D. biconvexa gigantea*; cv, *D. concavata*; F, *Falsotruncana*; Fl, *F. loeblichae*; G, *Globotruncana*; a, *G. arca*; ag, *G. aegyptiaca*; bu, *G. bulloides*; es, *G. esnehensis*; fs, *G. falsostuarti*; gn, *G. gagnebini*; l, *G. linneiana*; ro, *G. rosetta*; rg, *G. rugosa*; v, *G. ventricosa*; Gg, *Globigerina*; eu, *Gg. eugubina*; Gl, *Globotruncanella*; Gn, *Globoconusa*; Gs, *Gansserina*; gs, *Gs. gansseri*; Gt, *Globotruncanita*; cl, *Gt. calcarata*; cn, *Gt. conica*; el, *Gt. elevata*; fc, *Gt. falsocalcarata*; sf, *Gt. stuartiformis*; st, *Gt. stuarti*; H, *Hedbergella*; fl, *H. flandrini*; he, *Helvetoglobotruncana helvetica*; M, *Marginotruncana*; p, *M. paraconcavata*; sp, *M. spinea*; tf, *M. tarfayensis*; Pl, *Plummerita*; Ra, *Racemiguembelina*; va, *Ra. varians*; Rt, *Rugotruncana kefiana*; **Dinoflagellates**: Dy, *Dinogymnium*; De, *D. euclaense*; Dm, *D. majus*; I, *Isabelidinium*; Oo, *Oculopollis orbicularis*; O, *Odontochitina*; Ocr, *O. cribropoda*; Oop, *O. operculata*; Pif, *Palaeohystrichophora infusorioides*; Su, *Subtilisphaera*; Si, *Senoniasphaera inornata*; T, *Talassiphora*; Tp, *T. pelagica*; Tc, *Trichodinium castaneum*; Tt, *Trithirodinium*; Tev, *T. evittii*; Tru, *Triblastula utinensis*; X, *Xenascus*; Xce, *X. ceratioides*. **Pollen**: C, *Complexiopollis*; Cv, *Convexiopollis*; Cvc., *Cv. convexigerminallis*; K, *Krtzschiopollis*; M, *Megatriopollis*; Ms, *M. santonius*; Mg, *M. glabrum*; P, *Pseudopapilopollis*; Prp, *P. praesubhercynicus*; Po, *Pompechjoidaepollenites*; Prot, *Proteacidites*; Ps, *Pseudotrudopollis*; Psps, *Ps. pseudalnoides*; S, *Suemeghipollis*; St, *S. triangularis*; Sem, *Semioculopollis medius*; Sub, *Subtriporopollenites*; Tn, *Trudopollis* cf. *nonperfectus*; Tr, *Triporopollenites*. **Calcareous nannoplankton**: A, *Aspidolithus*; pac, *A. parcus constrictus*; pap, *A. parcus parcus*; Ak, *Arkhangelskiella*; cyc, *Ak. cymbiformis cymbiformis*; cym, *Ak. cymbiformis minor*; Bt, *Biantholithus*; sp, *Bt. sparsus*; Ca, *Calculites*; o, *Ca. obscurus*; fl, *Eprolithus floralis*; g, *Lithastrinus grillii*; se, *L. septenarius*; L, *Lucianorhabdus*; cy, *L. cayeuxii*; Lt, *Lithraphidites*; pq, *Lt. praequadratus*; q, *Lt. quadratus*; M, *Micula*; d, *M. decussata*; mu, *M. murus*; pr, *M. prinsii*; Ma, *Marthasterites*; f, *Ma. furcatus*; N, *Nephrolithus*; fr, *N. frequens*; Q, *Quadrum*; s, *Q. sissinghii*; tr, *Q. trifidum*; R, *Reinhardtites*; an, *R. anthophorus*; le, *R. levis*; Tr, *Tranolithus*; ve, *Ceratolithoides verbeekii*.

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PREMISES OF TEPHROLOGICAL INVESTIGATION OF THE QUATERNARY IN ROMANIA

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Key words: Tephrochronology. Quaternary. Romania.

Abstract: Although favourable premises do exist, systematic tephrochronologic and tephrostratigraphic approaches in the geological research of the Quaternary in Romania have not yet been carried out. These premises include both Quaternary explosive volcanism which supplied widespread tephra marker horizons, and coeval Quaternary deposits prone to record such volcanic events, occurring in Romania or at more distant sources. Quaternary volcanic activity occurs in two areas, both located in the southern part of the East Carpathians. One of these had generated silicic plinian ash-fall tephra from the twin-cratered volcanic center of Ciomadul and presumed other vents, recognized as primary and reworked ash layers in the neighbouring areas, including Quaternary intramountain basins. These tephras probably covered much larger areas and are recorded within loess sequences in more distant places. Upper Pliocene to Pleistocene basaltic volcanism in the Perşani Mts supplied phreatomagmatic tephras spread over limited surfaces, with only local stratigraphic value. Possible tephra-recording Quaternary deposits include Pleistocene loess with widespread occurrences in Romania (Moesian Platform, Dobrogea, eastern part of the Pannonian Basin) and upper Pleistocene to Holocene pit-bogs in several areas, two of which being located in craterial depressions. Although the presence of volcanic material was pointed out in some loess sequences it was not an up-to-date subject of any tephrological investigation.

Introduction

Tephrology has little tradition in Romania. Although Neogene tephra layers widely occur, they have very sparsely been approached from tephrostratigraphic viewpoint and no modern tephrological study has been performed. In order to unravel the gas-bearing dome structure pattern of the Transylvanian Basin, the Lower Badenian "Dej tuff" has largely been used in exploring works as marker horizon (Vancea, 1960). The thickest of all the Neogene tephras, the "Dej tuff", drapes the basin as a whole and it has been subjected to only local petrographical investigations (i.e. Mârza, 1965, 1974;

Mârza, Chintăoan, 1975) and recently to local tephrological approaches (Seghedi, Szakács, 1991).

Occurrences of Quaternary tephras have been pointed out in several papers dealing with Quaternary stratigraphy, but no systematic investigation has yet been achieved on them.

Since tephrology has been proved as a powerful tool in Quaternary researches, the present paper intends to examine the premises for such investigations in Romania.

Favourable premises for tephrostratigraphy in Quaternary terrains include coeval explosive volcanic activity and suitable tephra-recording deposits. Both are present in Romania.

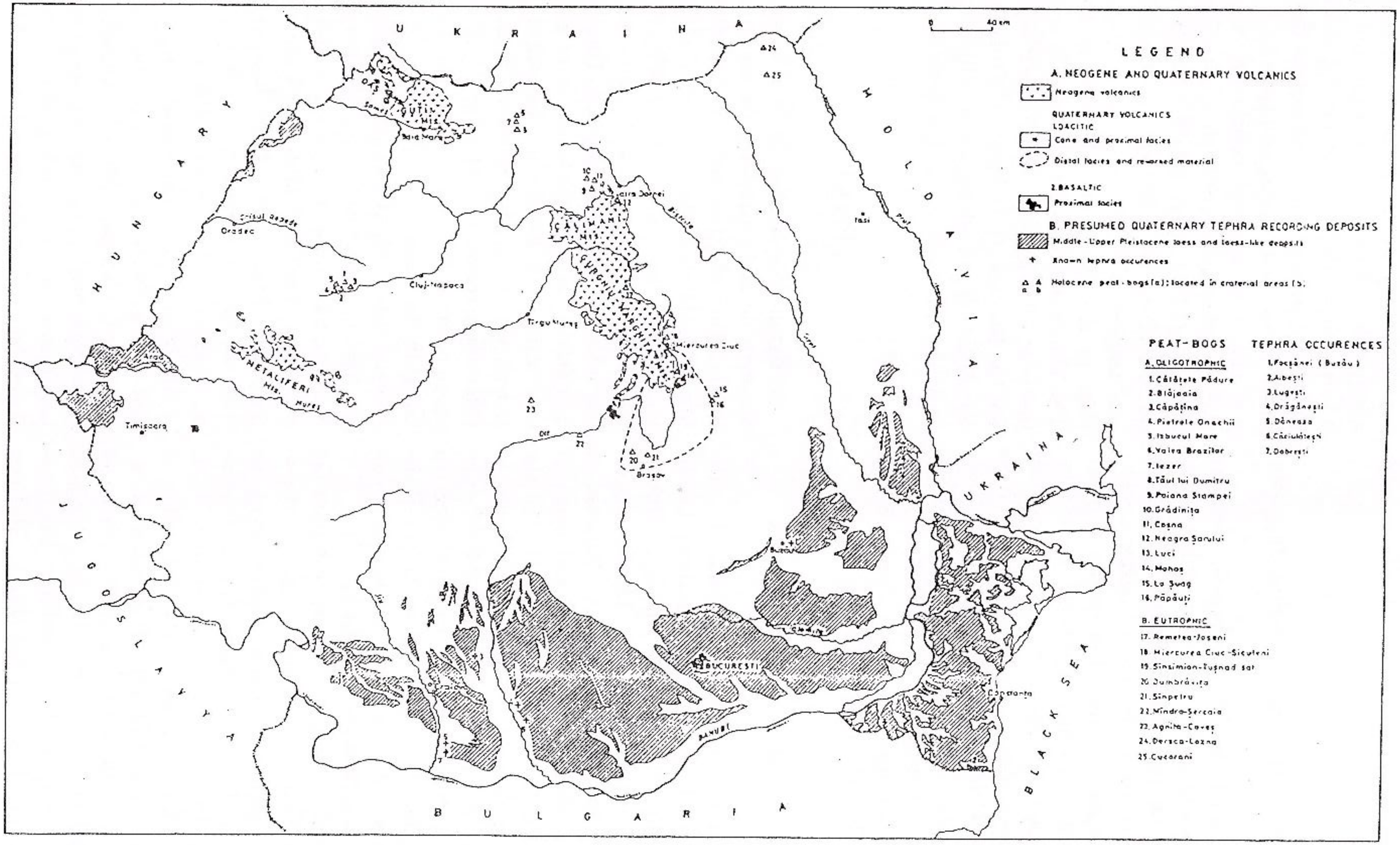
Quaternary explosive volcanism

Volcanic activity in the well-known Neogene volcanic chain of the East Carpathians (Călimani, Gurghiu and Harghita Mts) started in the Upper Miocene and lasted, at its southern end, until Pleistocene (Rădulescu et al., 1973; Peltz et al., 1987; Szakács et al., 1993). At the chain terminus the prevailing calc-alkaline character of the volcanics turns into high-K calc-alkaline and shoshonitic one (Seghedi et al., 1987).

Exposive volcanism occurs only in the dacitic Ciomadul Massif where a twin-cratered pyroclastic cone has been built (Rădulescu, 1973; Szakács, Seghedi, 1990). The edifice is complicated by numerous subsequent dome-generating vents. Explosive activity consists of plinian or sub-plinian pumice and ash-fall followed by pyroclastic flows and base-surge activity (Szakacs, Seghedi, 1990). Several K-Ar datings (850 k.a., Casta, 1980, 0.56 and 0.22 Ma, Szakács et al., in press) point to the Pleistocene age of these eruptions, though recent data (10,700 years by ^{14}C) suggest a much younger age of the last explosive eruption in Ciomadul (Juvigné et al., 1994). Their tephras have been encountered in the neighbouring areas. Pumice-bearing coarse tephras have been spread toward west and found in the Cormoş river basin. Fine-grained tephras (ash-fall tuffs) occur northward in the adjacent Lower Ciuc Basin, southward in the Olt valley terraces at Micfalău and southeastward in the Caşin Basin (Bandrabur, Codarcea, 1975). In the Braşov Depression reworked Ciomadul tephras are known (Casta, 1980; Teulade, 1989). Although a much farther dispersal area may be reasonably presumed for the Ciomadul plinian tephra, no well documented proof in this respect is yet available. In distal areas only one thin (several mm) tephra layer found in a sequence near Paks (Hungary) has been tentatively assigned to an origin from South Harghita Mts (Kriván, 1958), but more recent investigations found it as coming from a Rhine graben volcanic source (Juvign@ et al., 1991). Due to its peculiar composition (Teulade, 1989) and its presumed large dispersal, the Ciomadul tephra might be a good regional marker horizon in the Pleistocene of Romania and adjacent areas as well.

In the nearby Perşani Mts, another Quaternary volcanic area, including tephra deposits, is known. Alkaline basaltic explosive-effusive volcanic activity occurred here during the Upper Pliocene and Pleistocene (Preda, 1940; Mihăilă et al., 1972; Mihăilă, Peltz, 1978). K-Ar ages range between 2,25-0,35 Ma. (Casta, 1980; Mihăilă, Kreutzer, 1981; Ghenea et al., 1981). Several volcanic centers evolved in two main eruptive stages. Both started with strong hydromagmatic activity (phreatic and phreatomagmatic eruptions) leading to base-surge and ash-fall deposits and ended with lava flows or scoria cone-building strombolian activity (Seghedi, Szakács, 1990). Although pyroclastics have been mapped only in a limited area around volcanic centers, a somewhat broader dispersal area would be presumed. However, due to the type of explosive activity and assumed limited dispersal, the tephrostratigraphic value of these tephras might be only a local one. Other occurrences of basaltic volcanics like those described in western Romania (Mateescu, 1937) are mostly effusive,

OCCURENCES OF YOUNG VOLCANIC ROCKS AND POSSIBLE QUATERNARY TEPHRA RECORDING DEPOSITS IN ROMANIA



the explosive activity being only of strombolian type.

Quaternary tephra-recording deposits

Fine-grained distal tephra is easily removed unless it is quickly buried. Thus tephra record is uneven on land and subaqueous environment. It is more effective in marine and lacustrine deposits. Land surfaces may also provide tephra preserving conditions. Loess is especially prone to retain tephra. Widespread Pleistocene tephras have been found in loess record in Central Europe (Juvigné et al., 1991). Peat bogs have recorded more recent, Upper Pleistocene to Holocene tephras, as proved for instance in the French Massif Central (Gewelt, Juvigné, 1988).

Loess and loess-like deposits

Loess and reworked loess (loess-like) deposits cover large areas in Southern Romania, including the Moesian Platform, Dobrogea and Southern Moldova. Limited occurrences are also found in western Romania on both sides of the Mureş valley and north of Oradea (Fig.). According to the Map of the Quaternary deposits of Romania (Ghenea et al., 1971), they have been assigned to Middle-Upper Pleistocene in the western Moesian Platform and Dobrogea and to Upper Pleistocene in western Romania, Eastern Moesian Platform and Southern Moldova.

In several outcrops well exposed tephra occurrences have been found related to these deposits. Tephra outcrops cluster along the Olt valley at Lugeşti, Drăgăneşti and Dăneasa (Liteanu, 1953; Liteanu, Bandrabur, 1957; Ghenea, 1967) and along the Jiu valley at Căciulăteşti and Dobreşti (Bandrabur et al., 1963) (Fig.). Another two isolated occurrences are located at Focşani near Buzău (Pricăjan, 1961) and at Albeşti in Southern Dobrogea (Ghenea, unpublished data) (Fig.). All these tephras mostly consist of more or less altered glassy ash and pumice fragments and display a surprisingly uniform thickness of about 0.50 m. Their petrographic features as described in the mentioned papers, and their bulk chemical character are not conclusive either for their primary nature or their origin. Ghenea's attempt (1967) to correlate them is highly questionable. He considers the Lugeşti tuff, interbedded with pre-loess sand, gravel and clay, as the oldest one (Lower Pleistocene). The Dăneasa tuff is interbedded in loess deposits and it is assigned to Middle Pleistocene. For the Drăgăneşti, Dobreşti, Căciulăteşti and Focşănei tuffs, all related to loess-like deposits, an Upper Pleistocene age has been assumed.

Peat-bogs

A significant number of peat-bogs, both oligotrophic and eutrophic, are known in Romania. They are clustered mainly in the Gilău Massif (Călăţele-Pădure, Blăjoaia, Căpăţâna, Pietrele Onachii), Maramureş (Valea Brazilor, Iezer, Tăul lui Dumitru) and the East Carpathians (La Suag, Păpăuţi, Dumbrăviţa, Sâmpetru). Several peat-bogs have also been encountered in Northern Moldova (Dersca-Lozna, Cucorani) and Southern Transylvania (Mândra-Sercaia, Coveş) (Fig.). A number of them occur with in or near the Călimani-Gurghiu-Harghita volcanic chain (Poiana Stampei, Grădiniţa, Coşna, Neagra Şarului, Remetea-Joseni, Miercurea Ciuc-Siculeni, Sânsimion-Tuşnad-sat). At least two peat-bogs (Luci and Mohoş) fill craterial depressions (Fig.). Peat-bogs have benefited from specialised research mainly from palaeobotanical point of view (Pop, 1960).

Although in some places peat is well exposed and it is extracted for valorisation (in Gilău and North Călimani Mts, for instance), detailed compositional investigations of the peat-bog deposits are still lacking and consequently no evidence of tephra record is yet known in

Romanian peat-bogs.

Conclusions

In Romania both Pleistocene explosive volcanism and contemporary potential tephra-recording sediments - loess and loess-like deposits - occur providing favourable premises for promoting Quaternary tephrostratigraphy. Romanian peat-bogs may have been suitable tephra traps for far-originating large Holocene eruptions located in Central and Southern Europe and consequently they might supply valuable information for large scale stratigraphic correlations in the Holocene.

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NEW OBSERVATIONS ON THE THICKNESS OF THE QUATERNARY FORMATIONS FROM THE EASTERN ROMANIAN PLAIN (SLOBOZIA – ŢĂNDĂREI SECTOR)

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Key words: Romanian. Quaternary. Pleistocene. Holocene. Alluvia. Bivalves. Gastropods. Taxa. Deposit age.

Abstract: Taking into account the upper boundary of the Middle Romanian (85-140 m) and the faunal remains reported in the sediments above these depths, it is considered that the Pliocene-Quaternary boundary should be placed at depth smaller than that proposed by Liteanu (1961). This boundary is established also depending on the sedimentation zone, which was affected or not by neotectonic movements. The stratigraphic volumes, related to the Middle and Upper Pleistocene, have been also reconsidered. The formations situated between the depth of 25-60 m were assigned to the Middle and Upper Pleistocene, while the remainder of the sediments up to the depth of 85-140 m were assigned to the Lower Pleistocene.

The investigations for the elaboration of the Ţăndărei hydrogeological map led to the observations which will be further presented.

The data provided by recent drillings increased the degree of knowledge of the Neogene and Quaternary stages.

Within the Neogene succession molasse deposits were identified, which are assigned to the Upper Badenian, Middle Sarmatian, Lower Meotian, Upper Pontian, Dacian and Middle Romanian (Papaianopol, 1993).

The existence of the Badenian and Meotian could be established on very short intervals and in a few boreholes, the other stages being identified in all the wells and through much greater thicknesses.

The Romanian was identified in all the drillings carried out within the following intervals: borehole 99 Slobozia (125-180 m depth), borehole 158 T. Vladimirescu (85-115 m depth), borehole 142 Mărculeşti (87-140 m depth), borehole 151 Perişoru (75-108 m depth), borehole 130 Strachina (82-182 m depth), borehole 131 Ţăndărei (139-198 m depth), borehole 132 Ţăndărei (94-190 m depth) and borehole 182 Kogălniceanu (94-190 m depth).

On the whole it is represented in the lower part by lutites, locally with thin lignite and sand interbeds, sands with rare gravels in the upper sequence. It should be mentioned, however, that this distribution may be different, there existing situations when arenites prevail throughout the interval or alternate with lutites.

In most boreholes the Upper Dacian is directly overlain by bivalves and gastropods, among which the sculptured unionids (g. *Rugunio, Cuneopsidea* and *Rytia*) play the most important role. The taxa encountered are: *Rugunio moldavensis* (M. HOERNES), *Tytia slovonica* (M. HOERNES), *Cuneopsidea beryrichi* NEUMAYER, *C. sculpta* (BRUSINA), *C. trumata* (LUBENESCU et NICOLESCU), *Subcopotomida herjei* (PORUMBARU), *Pristinunio pristinus* (BIELZ), *Viviparus bifarcinatus* (BIELZ), *V. stricturatus* (NEUMAYER), *V. craiovensis* TOURNOUER, *Melanopsis (M.) rumana* TOURNOUER etc., that attest the presence of the Middle Romanian (Pelendavian) (Papaianopol, 1993).

One of the most debated problems connected with the Quaternary formations in the geological and hydrogeological papers on the geology of the Eastern Romanian Plain is the thickness of these sediments. Thus Liteanu (1961), analysing the data from the Balta Albă and Făurei boreholes and adopting the criterion used by Wenz (1942), according to which the Quaternary gastropods are characterized by a larger size that the Pliocene ones, places the lower boundary of the Quaternary round the thickness of 500 m.

Taking into account the results provided by some boreholes on a segment of the Eastern Romanian Plain as well as the microfauna encountered in the borehole drilled in the Lanurile locality, I placed the Pliocene-Quaternary boundary somewhat higher, at the depth of 300 m (Mihăilă, 1992).

The data furnished by the boreholes for coal (Papaianopol, 1993) indicated that the paleontologically dated upper boundary of the Middle Romanian formations can be placed round the depth of 80-140 m (Mărculeşti 87 m, Strachina 82 m, Ţăndărei 140 m, Slobozia 125 m, Perişoru 75 m, M. Kogălniceanu 94 m, T. Vladimirescu 81 m etc.).

For the territory included on the Ţăndărei sheet the lithofacial study of the formations overlying the Middle Romanian, crossed by boreholes, indicates the existence of some sedimentation zones with different functions for the Quaternary. Thus the boreholes drilled in the western half of the territory crossed an alternation of clays, sandy clays, argillaceous sands, sands and more rarely gravels below the depth of 20-25 m. This situation is generally maintained up to the depth of about 60-70 m, below it the lithofacies becoming prevailingly coarse (gravels and boulders) up to the depth of 85-125 m.

The extension, thickness and vertical distribution of the alternations of beds at the upper part (25-60 m) changes radically northeastwards (Platoneşti-Ţăndărei), where the existence of some coarse alluvia is pointed out from the depth of 30 m.

The analysis of some data provided by the drillings carried out farther north of the investigated area (Mihai Bravu - M. Kogălniceanu) indicates that these would reach the depth of 140-170 m and, according to Ghenea et al., 1990, might represent the Middle-Upper Pleistocene interval.

By the investigation of these boreholes from the east (outside the zone), these coarse alluvia could be observed to the flood plain of the Danube River. The existence of these alluvial deposits in the present zone of the Danube River supports the existence of an older course of the river in the present region of the valley.

As regards the age of the deposits at the upper part of the Middle Romanian, some observations are to be found in the paper of Papaianopol et al. (1992), who mention the presence in a borehole drilled at Vlădeni (east of the region investigated in this paper), between the depth of 40-50 m, of the following taxa: *Unio (U.) pictorum pseudorumanu* TSCHAPALYGA, *Dreissena polymorpha* PALLAS, *D. fluviatilis* PALLAS, *D. marina* PALLAS, *Litogliphus* aff. *noticoides* PFEIFER, *Limnocythem laculenta* MONDELATUM, *Omnicythen* *propinque tuberculata* OLTEANU, *Darvinella stivensoni* BRODY et ROBERTSON.

The quoted fauna indicates only the environment of its deposition and by no means its appurtenance to a certain subdivision of the Quaternary, but the above-mentioned forms are surely younger than those from the Romanian. The dating of some coarse deposits from the Brăila zone seems more interesting, remnants of *Praemegaceros ventricomis* DOWKINS, *Equs (E.)* cf. *mosbachiensis* v. REICHMAN being found there, on the basis of which they were assigned to the Middle Pleistocene (Feru et al., 1977).

In conclusion, taking into account the upper boundary of the Middle Romanian, the above-mentioned faunal indications, and the regional relationships, it can be stated that the Pliocene- Quaternary boundary is placed at smaller depths than those proposed by Liteanu (1961) or Ghenea et al. (1990), depending, of course, on the sedimentation zone, which was affected or not by neotectonic movements.

In this sense, the stratigraphic volumes related to the Middle and Upper Pleistocene should be also reconsidered. Thus the formations situated at depths ranging between 25-60 m could be assigned to the Middle and Upper Pleistocene, while the rest of the sediments up to the depths of 85-140 m might represent the Lower Pleistocene.

This conclusion is supported also by the fact that the data provided by the drillings and outcrops revealed the regressive character of the Upper Romanian. This was pointed out only in the Subcarpathian Zone and doubtfully somewhat lower.

This is the reason why in my opinion, this substage is lacking in the Slobozia-Ţăndărei zone, and the Middle Romanian is overlain by the Lower Pleistocene.

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