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THE DITRĂU ALKALINE INTRUSIVE COMPLEX AND ITS GEOLOGICAL ENVIRONMENT

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THE DITRAU ALKALINE INTRUSIVE COMPLEX AND ITS GEOLOGICAL ENVIRONMENT

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Introduction.

The ***Ditrau Alkaline Intrusive Complex*** (DAIC) occurs in the southern part of the „East Carpathian crystalline zone", near the towns Gheorgheni, Lazarea and Ditrau (Fig.1). Since the 19-th century it has been described in the geological literature as the „Ditrau alkaline massif" or „Ditro massif". Due to its peculiar lithologic constitution, numerous mineralogical and petrographical investigations were performed on the Ditrau massif; several specific rock names were introduced, such as *„ditroite"* (ZIRKEL, 1866: a biotite-bearing variety of nepheline syenite with cancrinite, primary calcite and sodalite along fractures), *„orotvite"* (STRECKEISEN, 1934, 1938: a variety of nepheline bearing diorite) and *„ditro-essexite"* (STRECKEISEN, 1952, 1954, 1960: a comprehensive term for plutonic rocks of essexitic and theralitic chemistry).

The DAIC cut the metamorphic rocks of the East Carpathians near the Neogene volcanic arc of the Harghita - Calimani Mts. Andesitic pyroclastics and basalt-andesitic lava flows from these volcanoes unconformably overlay parts of the DAIC. The Ditrau massif is also covered by sedimentary lacustrine deposits which separated the volcanic arc from the East Carpathian landmass during the upper Pliocene and lower Quaternary.

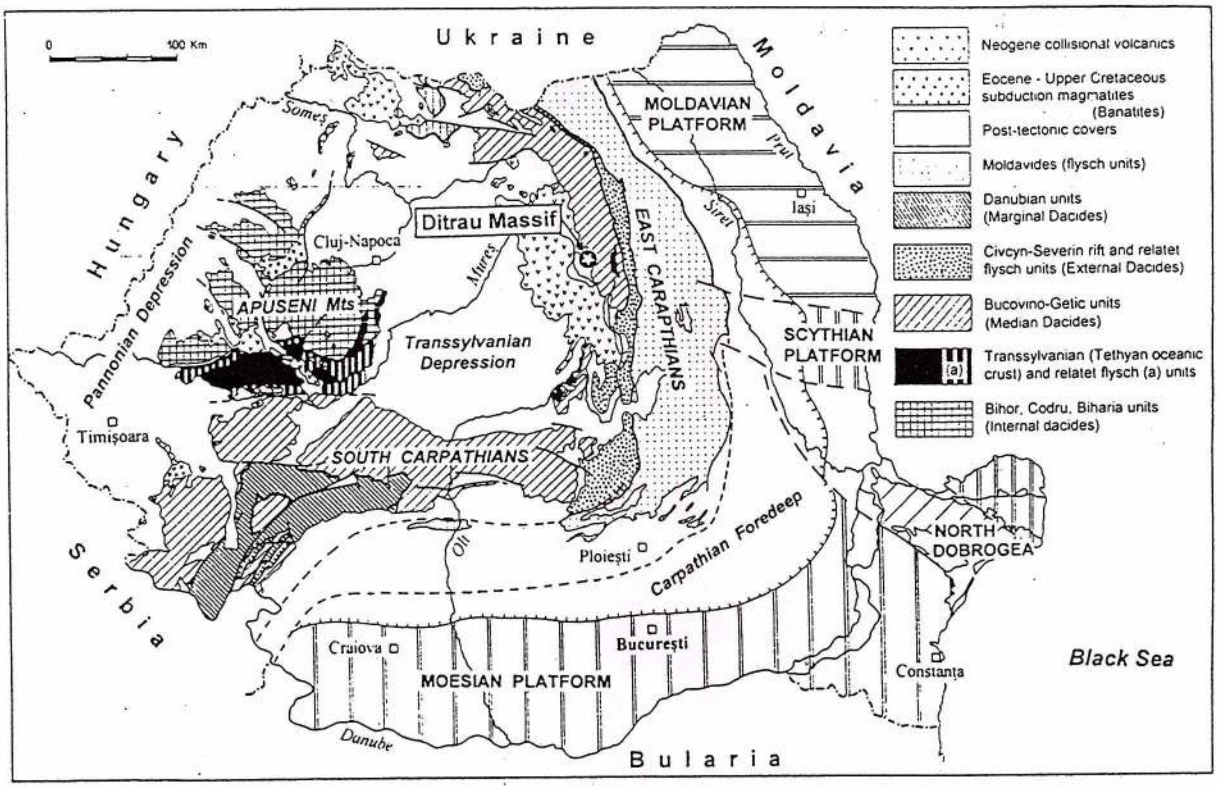


Fig.1 Position of the DAIC in the structural framework of the Carpathians (acc. to Sandulescu, 1984).

Metamorphic rocks of the Bucovinian Nappe (uppermost alpine unit including metamorphic rocks) occur over a large area surrounding the DAIC (Fig.2). This metamorphics were involved in several nappe structures that are cut by the DAIC and were welded by its contact aureoles. Since the DAIC was shown by radiometric data (BAGDASARIAN, 1972; STRECKEISEN & HUNZIKER, 1974; KRÄUTNER et al., 1976, MÎNZATU et al., 1981, unpubl.data) to be of Jurassic age, the Ditrau massif was considered to be a stitching intrusion proving the Variscan stacking of the afore mentioned nappes (BALINTONI, 1981; MURESAN, 1983).

Geological setting.

The East Carpathians are a geomorphologic segment in the European Alpine mountain belt that roughly corresponds to a relative young tectonic setting and acquired its present form during the Miocene collision.

The East Carpathians represent a segment of the Alpine shear-nappe pile, about 200 km long, which formed on the European continental margin during Cretaceous-Eocene shortening. In the Neogene collisional stage, this segment escaped between the South-Transsylvanian and the Szolnok - North Transsylvanian strike-slip faults and was shifted eastwards by transpression over more than 100 km (Fig.2).

In the Alpine structural framework of the East Carpathians the following main tectonic units may be distinguished from the west towards the east, respectively from higher towards lower tectonostratigraphic positions (acc. to SANDULESCU, 1984) (Figs.2, 3):

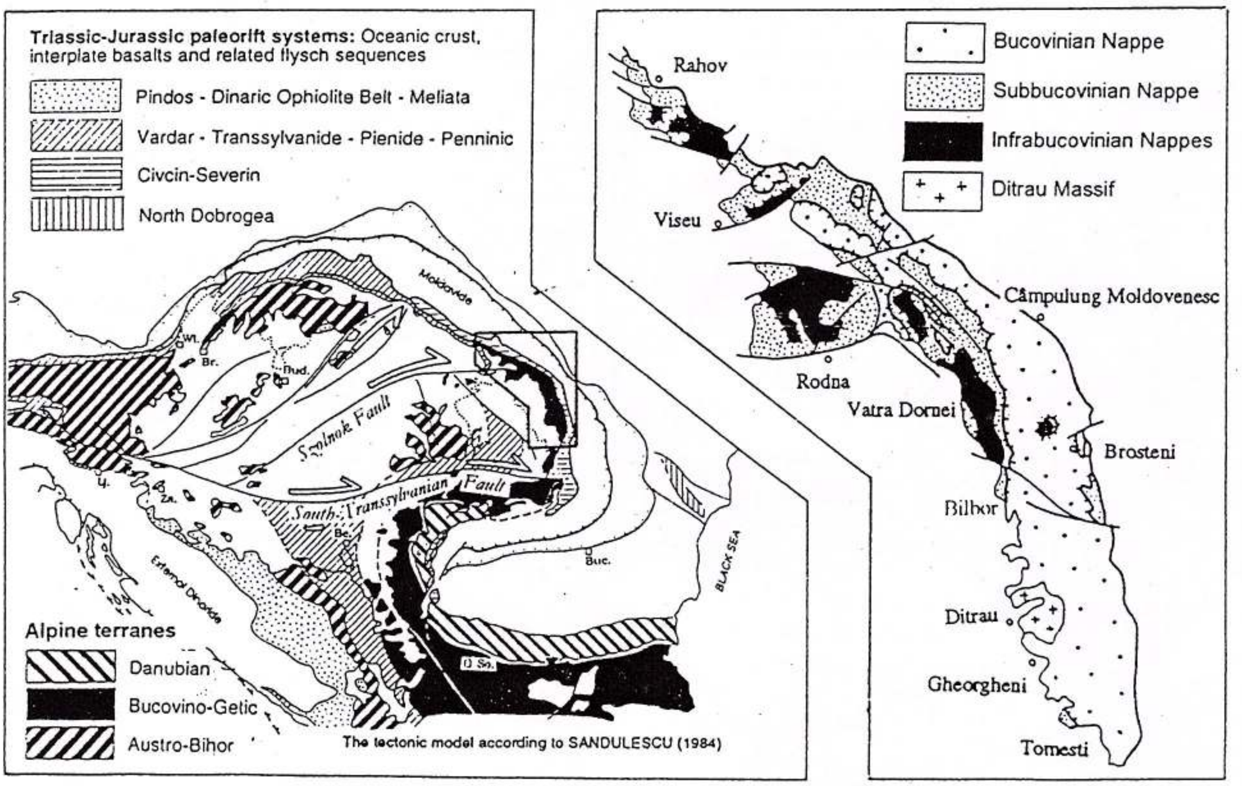


Fig.2 Left: Main Alpine terranes of the Carpathians and adjacent areas.
Right: Detail with the Bucovinian Nappes of the East Carpathians and the position of the DAIC.

1. *Transsylvanian nappes (Transsylvanides)* - fragments of obducted Tethyan oceanic crust and their sedimentary cover (T_2-J). Overstep sequences are Vracono-Cenomanian in age.

2. *Bucovinian nappes (Median Dacides)* - stacked fragments of the Variscan and Pre-Variscan basement from the southern European continental margin and its sedimentary cover (T-K_1). The *Bucovinian, Subbucovinian* and *Infrabucovinian nappes* were distinguished as the main Alpine tectonic units. They are characterized by different facial development of their sedimentary covers. The Bucovinian nappes were stacked at the end of the Lower Cretaceous, as they include Barremian-Aptian sediments and the overstep sequences started with the Vracono-Cenomanian.

3. *External Dacides* - fragments of the Jurassic - Lower Cretaceous Civcin-Severin intra-continental rift system, including intraplate basalts with incipient alpine LT/HP metamorphism (SANDULESCU et al. 1981) and related flysch deposits („Black flysch“ and Sinaia flysch).

4. *Moldavides* - Upper Cretaceous - Miocene flysch sequences and Lower Miocene - Sarmatian molasse deposits derived from an intracontinental trough, interposed between the Peri-Moldovian rise (continental crust east of the Civcin-Severin rift, exposed in the Danubian units of the South Carpathians) and the Moldavian platform. Main deformational stages were in the Burdigalian, Badenian and Sarmatian.

5. *Moldavian platform* - Alpine-undeformed part of the European continental plate, including Precambrian of the Ukrainian Shield, bordered by Caledonian and Variscan fold belts and covered by Mesozoic and Neozoic sediments.

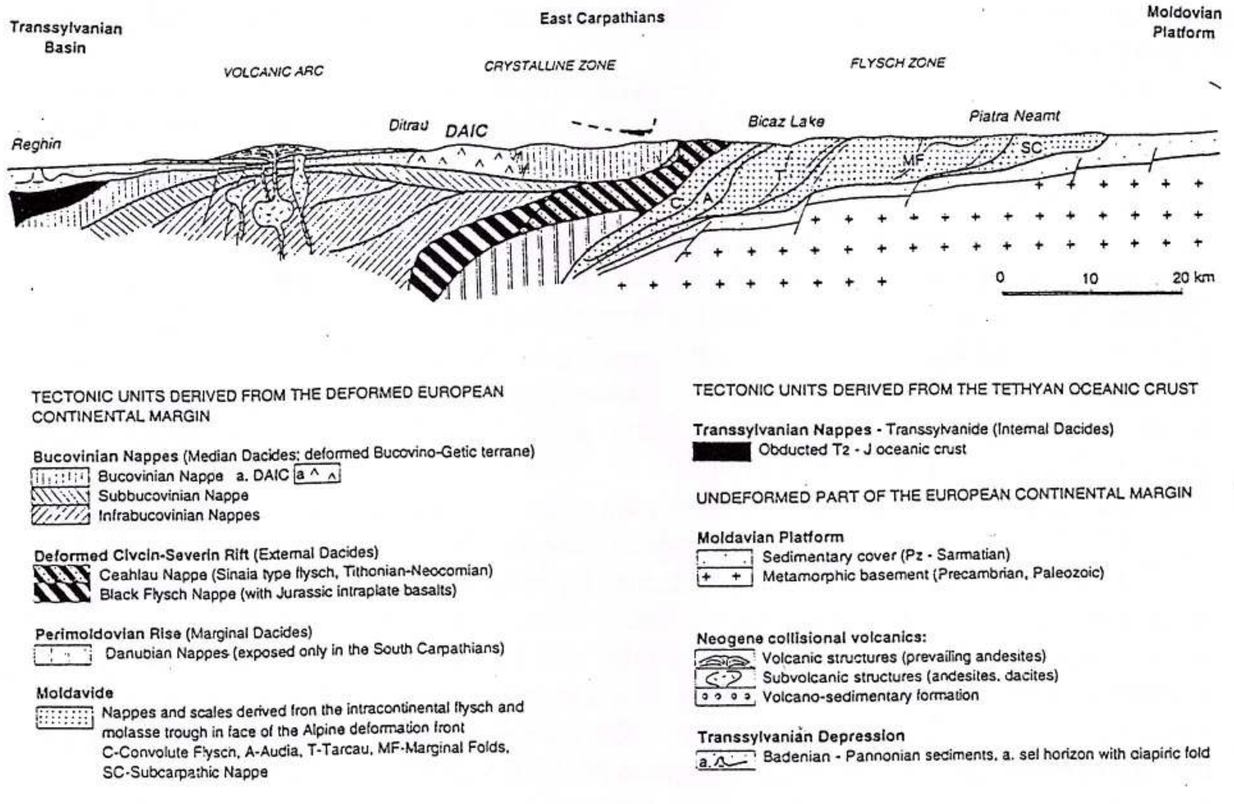


Fig.3. Schematic cross-section through the East Carpathians between Reghin, Ditrau and Piatra Neamt. (Moldavides and Moldovian Platform after M.Sandulescu, 1984)

Pre-DAIC evolution

The DAIC belongs to the Bucovino-Getic terrane of the Carpathians (Figs.2,4), placed between the Tethyan oceanic crust and the Civcin-Severin rift (KRÄUTNER, 1994, 1996). Here the Alpine evolution commenced with the Lower-Triassic transgression, largely extended on a Variscan basement that was nearly peneplaned during the Permian. This transgression marks the beginning of the Alpine extensional stage which produced the oceanic crust of the Tethys. During the Triassic, the Bucovinian part of the Bucovino-Getic terrane evolved as a carbonatic platform on the southern margin of Paleo-Europe. This carbonatic platform emerged at the end of Triassic and in the Lower Lias. A second extensional phase is marked by the Lias transgression which was more extensive, also covering continental areas in the east of the Triassic carbonatic platform deposits (eastern Infrabucovinian area and Danubian units) (Fig.4). In contrast to the Triassic, mainly detrital epicontinental deposits formed during the Lias (Gresten facies), which locally include coal deposits (Holbav, Cristian).

DAIC emplacement

The DAIC is related to the extensional phase of Alpine evolution, in which Tethyan spreading was active since Middle Triassic and the southern European continental margin was split off by the Civcin-Severin rifting system in Jurassic. Palinspastic reconstitutions suggest that the DAIC was placed on the south-western Bucovinian (European) continental border, near the passive contact with the Tethyan oceanic crust, whereas the Lias alkaline magmatites of Holbav were situated near the Civcin-Severin rift (Fig.4), as suggested by their Infrabucovinian position (SANDULESCU, 1984).

The DAIC emplacement developed polyphasically, as clearly indicated by cross-cutting relationships between constituent rocks. Three main intrusion stages were recognised, lasting for about 90 Ma.:

1) The emplacement started in Carnian with *gabbro-dioritic* rocks which give ^{40}Ar-^{39}Ar and K-Ar ages of 231-227 Ma (DALLMEYER et al., 1996, PÁL MOLNAR & ÁRVA-SÓS, 1995). The ascending mantle derived magma carried mantle xenoliths and may be explained by mantle plum activity that predates an incipient Jurassic rifting on the western margin of the Bucovinian continental margin (DALLMEYER et al., 1996).
2) In a second stage, during Upper Norian (216-212 Ma ago), a *syenitic crustal magma* intruded in dominated dynamic conditions. It produced various hybridisation of the former gabbro-dioritic rock association by both, mixing in subsolidus stage and metasomatic phenomena. By assimilation of quartz rich metamorphic country rocks from relatively high crustal levels, the syenitic parental magma evolved locally to granitic composition (STRECKEISEN & HUNZIKER, 1974).
3) The DAIC emplacement ended by a third main phase which produced *nepheline syenites*. The intrusion was dated in the Callovian-Oxfordian by K-Ar ages of 160-154 Ma (STRECKEISEN & HUNZIKER, 1974). It may be correlated with the Jurassic extensional stage which produced the separation of the Bucovino-Getic terrane from the European margin (represented by the Danubian terrane and by the Peri-Moldovian rise) by rift dispersion. Thus the DAIC emplacement ends subsequent to the Lias alkaline volcanism which was active further south (Holbav), on the eastern margin of the Bucovinian terrane, near the opening Civcin-Severin rifting system (SANDULESCU et al., 1986)

- By available K-Ar data the cooling of the DAIC may be approximated between 155-135 Ma, thus till Berriasian-Valanginian. In this stage developed early and late post-magmatic alterations including nepheline and feldspar substitution by sodalite, cancrinite, muscovite

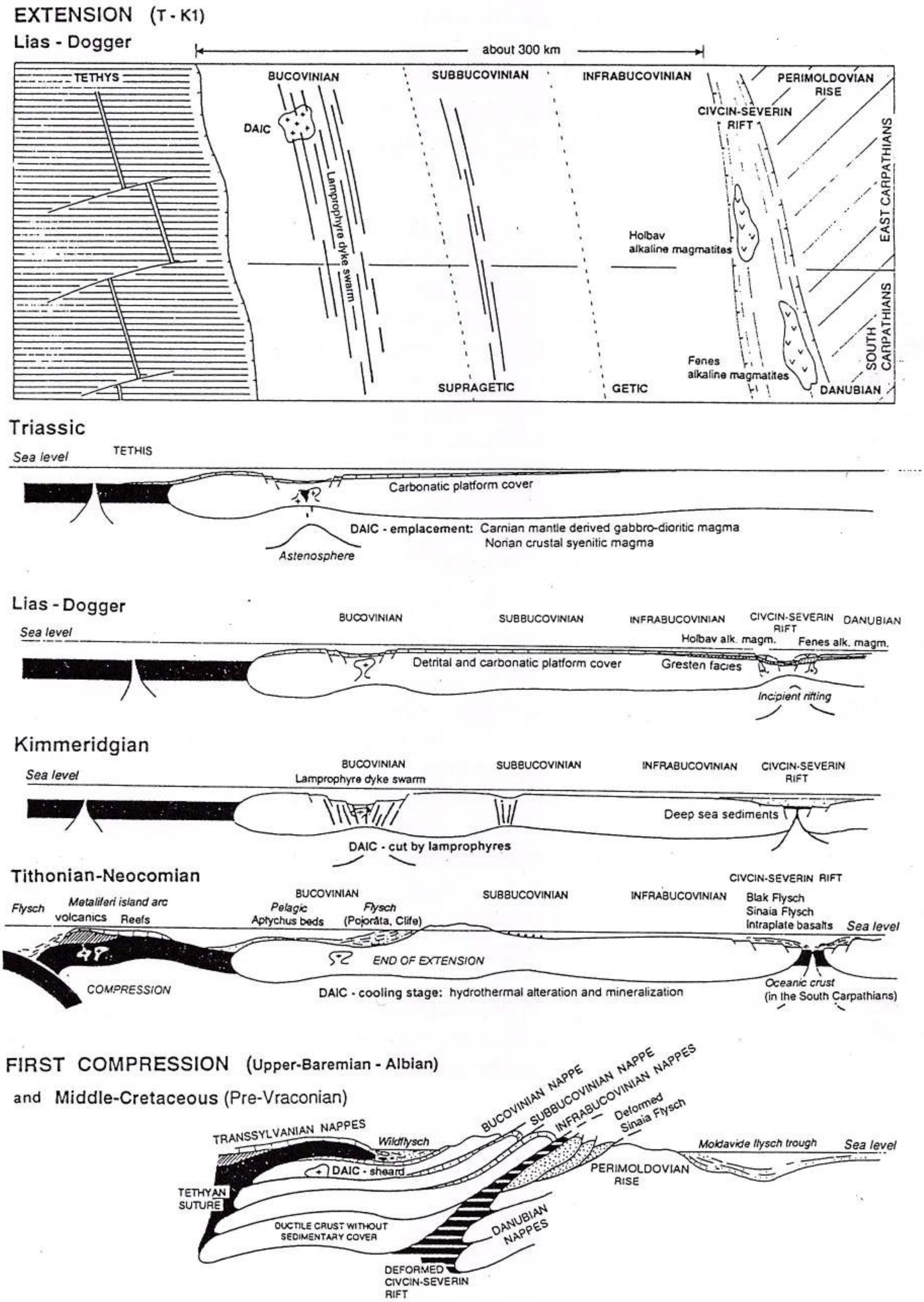


Fig.4. Reconstruction of Alpine evolution in the East Carpathians showing the geological environment of DAIC emplacement and its subsequent history. Schematic representation, not to scale. (Sedimentary facies according to Sandulescu, 1984, 1990)

(liebneritization), as well as mineralization. The relatively long cooling period of about 20 Ma suggests a relative deep crustal position of the DAIC till the end of Valanginian.

- During Barremian and Aptian uplifting installed due to incipient crustal shorting predating the main Meso-Cretaceous nappe tectonic. This is indicated by wildflysch development on the eastern margin of the Bucovinian terrane, accompanying initiation of shear-napping and obduction of oceanic slabs from the Tethys (Transsylvanide nappes, SANDULESCU, 1984). By this event the DAIC was raised above the isotherm of about 300°C and the Ar loss from the system was definitively closed. Thus usually K-Ar ages younger than 110 Ma were not recorded on DAIC rocks.

Subsequent to the emplacement, the DAIC, as well as the metamorphic basement of the East Carpathians and to some extend also the Triassic and Lias sedimentary covers, were crossed by a swarm of post-Lias lamprophyre (mainly camptonites) and alkali gabbroic dykes. These dykes extend for about 300 km (including the Fagaras Mts. of the South Carpathians) roughly parallel to the Civcin-Severin rift and the Tethyan margin. The dyke swarm probably follows a system of transcrustal extensional faults (Fig.4) which marked an incipient splitting zone along the European continental margin during Dogger time. This extensional zone ceased its evolution in the Upper Jurassic, after the lamprophyre-dyke emplacement. The fact that this splitting zone did not evolve to a spreading system with oceanic crust could be correlated with the first compressional phase in the Tethys, east of the Bucovinian terrane. An intra-oceanic subduction started there in the Jurassic (pre-Malm), marked in the Transsylvanides of the Drocea Mts. by calc-alkaline island arc volcanics and granitoid intrusions of about 128.6 ± 1 Ma (SAVU et al. 1986).

Post-DAIC evolution

In the Middle Cretaceous and in later tectonic phases the metamorphic basement of the East Carpathians and its Mesozoic sedimentary cover were sheared and thickened by nappe stacking (Bucovinian nappes) as well as by obducted segments of Tethyan oceanic crust (Transsylvanian nappes) (Fig.3). The Pre-Cretaceous emplacement of the DAIC invoke its uprooting by Alpine nappe transport. The DAIC is probably cut at a depth of about 1800-2000 m by the Bucovinian shear zone and thus overlays the Subbucovinian nappe by a tectonic unconformity (Fig.3). Drillholes in the DAIC until depths of 1200 m have not intersected the Subbucovinian Nappe. South and north of Gheorgheni, however, this nappe is exposed in the tectonic windows near Tomesti and Bilbor (Fig. 2).

Subsequent to the Alpine napping the DAIC and the surrounding metamorphics were successively cut and fragmented by several fault systems. In the Pliocene the Ditrau Massif already was partly eroded and exposed near to the present extend, as indicated by the cover of Dacian-Romanian andesitic pyroclastics.

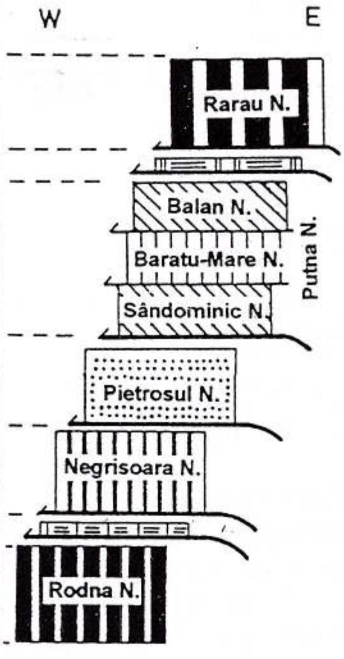
Pre-Alpine tectonostratigraphy of the Bucovinian nappe in the central East Carpathians.

The *Bucovinian nappe* consists of a pre-Alpine metamorphic basement and a Mesozoic (T-K_1) sedimentary cover. The metamorphic basement rocks are represented by different sequences and lithologic associations (table 1) which have been observed in tectonic relationships only. They form a pile of Variscan nappes as represented in table 1.

Table 1

Pre-alpine tectonostratigraphy and main lithologic units of the Bucovinian nappe

Lithologic units	Tectonic units
Rarau Formation (Bretila Group), *PC* Haghimas Granitoids, *PC*	1. Rarau Nappe (includes scales or a discrete nappe of Haghimas Granitoids)
Balaj mylonitic rocks	2. Balaj unit
Tulghes Group (formations Tg1-Tg4), *C* Baratu sequence (Tg3-Tg4) Balan sequence (Tg3-Tg4) Sândominic sequence (Tg3-Tg4)	3a. Balan Nappe 3b. Baratu-Mare Nappe 3c. Sândominic Nappe 3a-c were previously separated as Putna Nappe
Pietrosul Porphyroids	4. Pietrosul Nappe (previously included in the Pietrosul Bistritei Nappe)
Negrisoara Formation, *PC ?*	5. Negrisoara Nappe (previously included in the Pietrosul Bistritei Nappe)
Izvorul Mures mylonitic rocks	6. Izvorul Mures unit
Rebra Group, *PC*	7. Rodna Nappe



The nappe structure of the Bucovinian metamorphic basement has been recognized by detailed lithostratigraphic mapping and was confirmed by a relatively large number of drillholes. The main arguments for this nappe structure lie in the fact that the lithologic units shown in tab. 1 clearly overlay each other unconformably and Precambrian metamorphics partly overlay Cambrian rocks. The contacts are marked by shear zones with mylonites and phyllonites, which obliquely cut the internal lithostratigraphic structure of the units. Variscan stacking of these tectonic units is indicated by the following arguments:

- The contact between the tectonic units 1 and 3 (table 1) is transgressively covered by Triassic sediments (e.g. east of the Rarau Mts.).
- Excluding units 1 and 6 the entire pile of nappes is cut by the 230-154 Ma old DAIC and welded by its thermal contact aureola. Biotites from hornfelses gives K-Ar ages of 157-149 Ma (STRECKEISN & HUNZIKER, 1974; MÎNZATU et al.,1981, unpubl.data).
- Variscan retrogressive overprinting may be observed near the contacts between the tectonic units, giving a range of late-Variscan K-Ar ages.

A similar sequence of Variscan nappes may be observed in the *Subbucovinian Nappe* of the northern East Carpathians (BALINTONI, 1984; KRÄUTNER et al., 1991). In the *Infrabucovinian Nappes* such a pile of Variscan nappes is not exposed, but drillholes in the Bistrita Mts. (Barnar valley), have intersected Tulghes type rocks below the Bretila sequence of the Arsita-Barnarului tectonic window at a depth of 930-1100 m. Therefore, equivalents of the Variscan Rarau and Putna nappes could be expected also in Infrabucovinian position.

Palinspastic reconstructions of the pre-Alpine nappe structure in the continental crust prior to the Triassic transgression (Fig. 5) suggest that the Variscan nappes moved from the east towards the west, i.e. in the opposite direction to Alpine nappe transport. This conclusion is supported by westward directed vergencis of the Variscan deformation in the Silurian, Devonian and Lower-Carboniferous metamorphics exposed in the Infrabucovinian units of the Rodna tectonic window (KRÄUTNER & KRÄUTNER, 1970, Fig. 5).

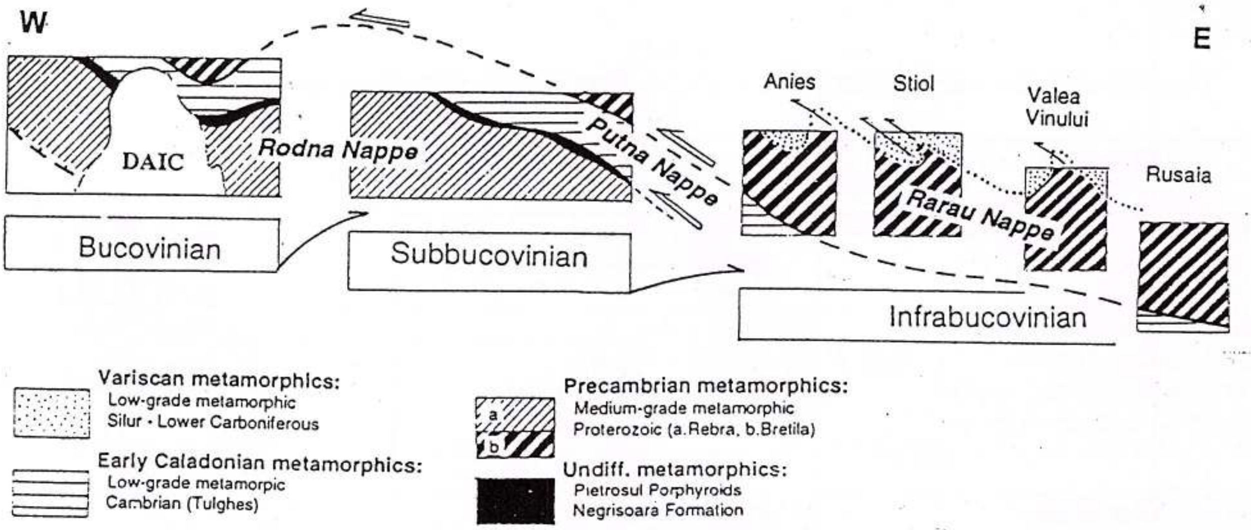


Fig.5. Position of the DAIC in a schematic reconstruction of the Variscan nappe structure in the pre-Triassic basement of the East Carpathians.

Rarau Nappe. This tectonic unit is placed on the top of the Variscan nappe sequence. It consists of Bretila-type MT/MP gneisses and Haghimas Granitoids, separated from the underlying tectonic units by an about 100-200 m thick tectonic sheet of greenschist facies mylonites and low-grade overprinted rocks. These retrogressive rocks grade towards Bretila-gneisses in which no mineralogical or textural overprinting may be observed. K-Ar data of these rocks (POP et al., 1974; KRÄUTNER et al., 1976), clearly show a rejuvenation trend towards Variscan ages (Fig.6). Locally, in the retrogressive rocks crenulation of the mylonitic foliation may be observed as well as small idiomorphic spessartine-rich garnet crystals, randomly disseminated. This post-deformational mineral growth could be related with the late Variscan thermal pike observed also in other tectonic units (e.g. Tulghes Group of the Putna Nappe; low-grade metamorphic Paleozoic and its retrogressively overprintet gneissic basement exposed in the Infrabucovinian units of the Rodna and Rusaia tectonic windows, KRÄUTNER, 1991, KRÄUTNER et al., 1992).

Usually the Haghimas Granitoids are included in the Rarau Nappe, but tectonic contacts with the surrounding Bretila gneisses prevail. These contacts are marked by greenschist facies phyllonites and mylonites and are covered by Triassic sediments. In the Hagota - Corbu area granitoids clearly overlie Bretila rocks in a subhorizontal position. Therefore it seems that the Haghimas Granitoids are either involved in tectonic scales of the Rarau Nappe, or form a discrete Variscan tectonic unit.

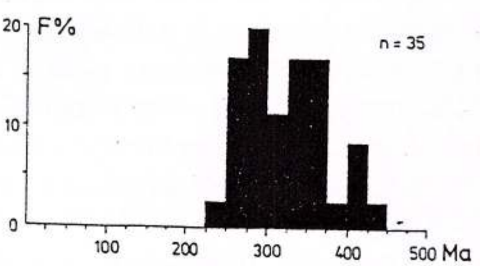


Fig.6 K-Ar ages of Bretila rocks from the Rarau Nappe (data from KRÄUTNER et al., 1976)

Balaj mylonite zone. Between the Bretila Group of the Rarau Nappe and the Tulghes Group of the Baratu-Mare and Balan nappes, mylonitic rocks and massive quartzites are interposed. These rocks were assigned to a distinct lithologic unit, as no petrographic resemblance with mylonites derived from

Bretila or Tulghes rocks may be recognized. They undervent a greenschist facies metamorphism which locally reached the biotite-*in* isograde. The massive quartzites are fine-gained mostly homogeneously recrystallized rocks. Their metamorphic (mylonitic) foliation is marked only by small biotite crystals.

Baratu-Mare, Balan and Sândominic nappes. In the Bucovinian Nappe, as well as in the Subbucovinian Nappe, the Tulghes Group is tectonically interposed between the Rarau Nappe and different tectonic units represented by Pietrosul Porphyroids, Negrisoara Formation and Rebra Group (Fig.5). In the past, this tectonic sheet of Tulghes rocks was assigned to a single nappe named *Putna Nappe*. Detailed lithostratigraphic mapping in the last years and about fifty drillholes have shown that the•Tulghes Group of the „Putna Nappe" was involved in complicate thrust systems of both, Variscan and Alpine age. Alpine scales my be recognized by interposed Mesozoic sediments, whereas Variscan units are welded by the thermal contact aureole of the DAIC. The Variscan tectonic imbrications are indicated by: a) older parts overlying younger parts of the lithostratigraphic sequence, b) unconformable shear-cutting of different lithologic units and c) interposed mylonitic zones. Thus in the central part of the East Carpathians three main Variscan tectonic sheets were distinguished, named *Baratu-Mare, Balan* and *Sândominic nappes*. Alternatively these tectonic units may be considered as tectonic scales of the Putna Nappe.

Between Gheorgheni and Sândominic the *Sândominic unit* is widely exposed and underlies the less extensive Baratu-Mare and Balan units. South of Tulghes it forms the Sumuleu tectonic window and was intersected by most of the drillholes in the Putna valley (fig. 7). The *Baratu-Mare unit* occurs in the Tulghes tectonic halfwindow and in a small band east of the DAIC. The *Balan unit* is exposed in a narrow zone between Balan and Hagota overlying both, the Baratu-Mare and Sândominic units.

South of Balan these Variscan nappes were deformed and overturned together with the Mesozoic sedimentary cover of the Bucovinian Nappe. In the eastern part of the crystalline zone, near the flysch units (Damuc - Lunca de Jos area), the Variscan Baratu-Mare and Sândominic Nappes are involved in frontal scales of the Alpine Bucovinian Nappe (e.g. Damuc scale).

Pietrosul Nappe. Below the nappes constituted of Tulghes type rocks, Pietrosul Porphyroids occur as tectonic lenses. They are intensively overprinted by Variscan greenschist facies metamorphism and mylonitization. Unaffected rocks were preserved only in central parts of relatively thick tectonic lenses. Initially these rocks, together with the Negrisoara Formation, were assigned to the „Pietrosul-Bistritei Nappe" (BALINTONI & GHEUCA, 1977). As only mylonitic shear contacts may be observed between the Pietrosul Porphyroids and the Negrisoara Formation, we assigned the Pietrosul Porphyroids to a distinct tectonic unit.

Negrisoara Nappe. The Negrisoara Formation forms a discrete nappe, interposed between underlying Rebra type rocks and overlying Pietrosul Porphyroids or Tulghes sequences. As afore mentioned, initially the Negrisoara Formation was included together with the Pietrosul Porphyroids in the „Pietrosul-Bistritei Nappe" (BALINTONI & GHEUCA, 1977). Rocks of the Negrisoara Nappe were intensively affected by Variscan dynamic and low-grade metamorphic overprint.

Izvorul-Mures mylonite zone. Foliated dark mylonites and black or brownish massive quartzites are tectonically interposed between the Negrisoara and Rebra sequences east of Izvorul-Mures and in the Voslabeni valley. These rocks have no lithologic resemblance with mylonites formed on the surrounding rock associations. It is suspected that the Izvorul-Mures mylonites derived from a distinct sequence of metamorphic rocks, probably of Paleozoic age (MURESAN, 1973). This assumption is supported by the restrictive outcrop area of these rocks.

Rodna Nappe. In the East Carpathians the Rebra Group forms the lowermost tectonic unit of the Variscan nappe pile. At the base it is cut by the Alpine Bucovinian and Subbucovinian shear planes. In the South Carpathians an equivalent of the Rodna Nappe overlies the Paleozoic metamorphics of the Poiana Rusca Mts. by a Variscan overthrust. Thus it seems justified to assign the Rebra Group of the East Carpathians to a Variscan nappe (Rodna Nappe) and not to a Variscan autochthonous.

Basement sequences of the Bucovinian nappe

Stratigraphy

Although only few radiometric and palynological data are available, the consensus among Romanian geologists is that the lithologic units of the Bucovinian nappe from the central part of the East Carpathians may be assigned to the Cambrian and the Precambrian as shown in table 2.

Table 2

Ages assigned to the lithologic sequences of the main metamorphic basement units of the Bucovinian nappe in the central part of the East Carpathians

Age		*Lithologic unit*		*Abbreviation*
CAMBRIAN		Tulghes Group		Tg
PROTEROZOIC	*UPPER ?*	Pietrosul Porphyroids Negrisoara Formation		PP Ne
	MIDDLE ?	CARPIAN SUPERGROUP	Rebra Group Bretila group	Rb Br

Tulghes Group. Low grade metamorphics are assigned to this lithostratigraphic unit. Palynological data (ILIESCU et al., 1983), zircon U-Pb ages (560-640 Ma, BOIKO et al., 1975) and common Pb-Pb ages (540-600 Ma, VÎJDEA, ANASTASE, 1975, unbubl. data) constrain the age of sedimentation and contemporaneous volcanism to the *Lower-Cambrian*, with possible transition to the *Upper-Cambrian* and *Lower-Ordovician*. K-Ar ages of 470 Ma suggest an Early-Caledonian metamorphism, although most of the recorded K-Ar and Rb-Sr data show Variscan regenerations (POP et al. 1974, KRÄUTNER et al., 1976;). A Variscan LT/LP overprint is indicated also by dephengitisation of K-white mica (KRÄUTNER et al., 1975) and by partial mineral reorganization with new growth of chlorite, sericite, quartz and rutile (BALINTONI & CHITIMUS 1973, KRÄUTNER et al.,1992).

Bretila and Rebra Groups. Polymetamorphic rocks of initial MT/MP grade are assigned to these lithologic units. They are considered to represent parts of the lower and respectively upper part of the Carpian sequence (KRÄUTNER, 1988). A *Proterozoic* age is assumed for the first main metamorphism of these Groups due to isolated maximal K-Ar ages of 650-700 Ma and interpretative K-Ar isochron ages of about 850 Ma (KRÄUTNER et al. 1976). Most of the recorded K-Ar data indicate Variscan and Alpine overprints. Rb-Sr isochron ages also show different younging, e.g. 330±35 Ma in Bretila gneisses of the Bucovinian nappe (GOROHOV et al., 1967) and 514±8 Ma in Bretila rocks of the Infrabucovinian nappe (Tisa tectonic window, (GOROHOV & LECHENKOV, 1982). On syngenetic Pb-Zn ores of the Rebra Group (Valea-Blaznei ore deposit) common Pb-Pb ages of 800 Ma were obtained (VÎJDEA, unpubl data). As regards geological relationships, between the Cambrian Tulghes Group and the Bretila-Rebra sequences only tectonic contacts may be observed. In the northern East Carpathians (Rodna and Bistrita Mts.), however low grade metamorphic Silurian schists (Repedea and Rusaia Groups) overlay the Bretila gneisses by a stratigraphic unconformity (KRÄUTNER, 1972, 1991).

Negrisoara Formation and Pietrosul Porphyroids. No age constraints exist for these lithologic units. Conventionally they were assigned to the upper Proterozoic, as they show Variscan retrogressive overprints and their lithologic constitution is different from both the Paleozoic and Carpian sequences.

Lithology and lithostratigraphy.

Tulghes Group.

The stratotype of the Tulghes Group consists of four formations (Tg1 - Tg4). It was described in the Bistrita Mts. between Pojorâta and Brosteni, where the most complete sequence is exposed, but also only tectonic contacts are known at the base and at the top. In the central part of the East Carpathians the two lower lithostratigraphic units (Tg1, Tg2) were sheared and only the upper part of the sequence (Tg3 - Tg4) is exposed. This formations occur in three discrete tectonic units: Sândominic, Baratu-Mare and Balan (table 1).

Approximately the same lithostratigraphic sequence may be observed in the Balan, Baratu-Mare and Sândominic Nappes. Detailed mapping and careful drill-core logging revealed some difference in the primary sedimentary lithologic constitution of these tectonic units. This is the reason for the use of different names for some equivalent lithostratigraphic units. Details of the lithostratigraphic sequences in the Sândominic, Baratu-Mare and Balan Nappes are given in Figs. 10, 11,12. A lithostratigraphic correlation is shown in Fig.8.

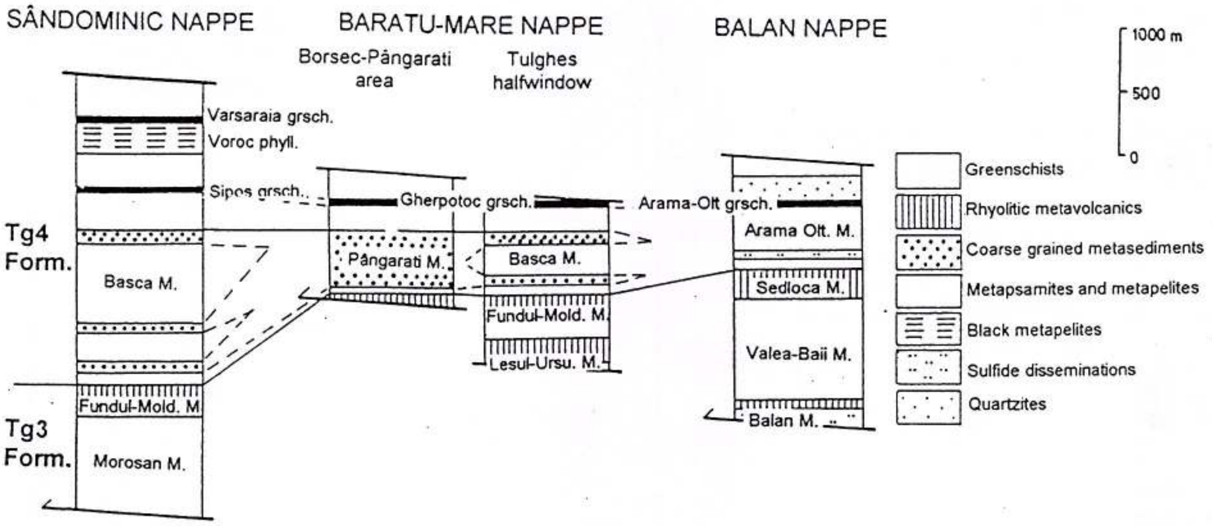


Fig.8 Correlation of lithostratigraphic sequences of the Tulghes Group exposed in the Variscan Sândominic, Baratu-Mare and Balan nappes.

Formation Tg3 (volcano-sedimentary) consists mainly of rhyolitic metavolcanics alternating with metadetrital rocks (sericite-chlorite schists, quartz-sericite schists, quartzites, albite-porphyroblast schists) originating from both terrigenous and volcanic sources (metasediments and metaepiclastites). The metavolcanics are dominantly of alkali-feldspar rhyolitic composition (Fig.9). According to their lithostratigraphic position, seven main extrusion phases could be recognized in the Tulghes stratotype. In the Bucovinian nappe of the Central East Carpathians and around the DAIC products of only the Balan, Lesul-Ursului, Fundul-Moldovei (Sedloca) and Prasca phases were preserved. Related to the Balan and Lesul-

Ursului phases, massive and disseminated sulfide ores of Kuroko type, are mined at Balan and have been drilled at Baratu-Mare (Figs. 11, 12). The Fundul-Moldovei phase was followed by pyrite and chalcopyrite disseminations only in the Balan Nappe.

Differences between the sequences exposed in the mentioned tectonic units consist mostly of a peculiar development of the Fundul-Moldovei Member in the Balan Nappe. Here metabasites of irregular shape are associated with the acid metavolcanics and meta-epiclastics (Sedloca Member). These occurences of basic rocks could represent a feeder zone for the basic volcanisme of the Tg4-Formation. An other difference appears in

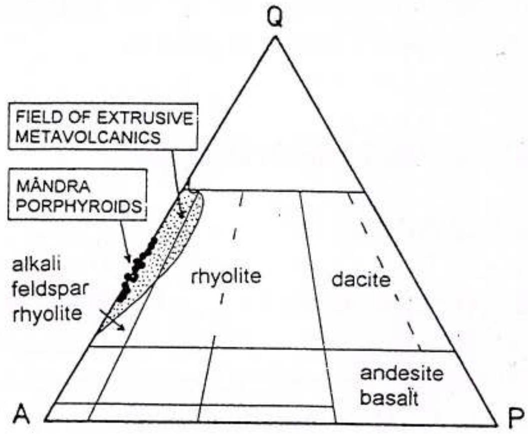


Fig.9 Q-A-P plot (LE MAÎTRE et al., 1989) of Tulghes rhyolitic metavolcanics.

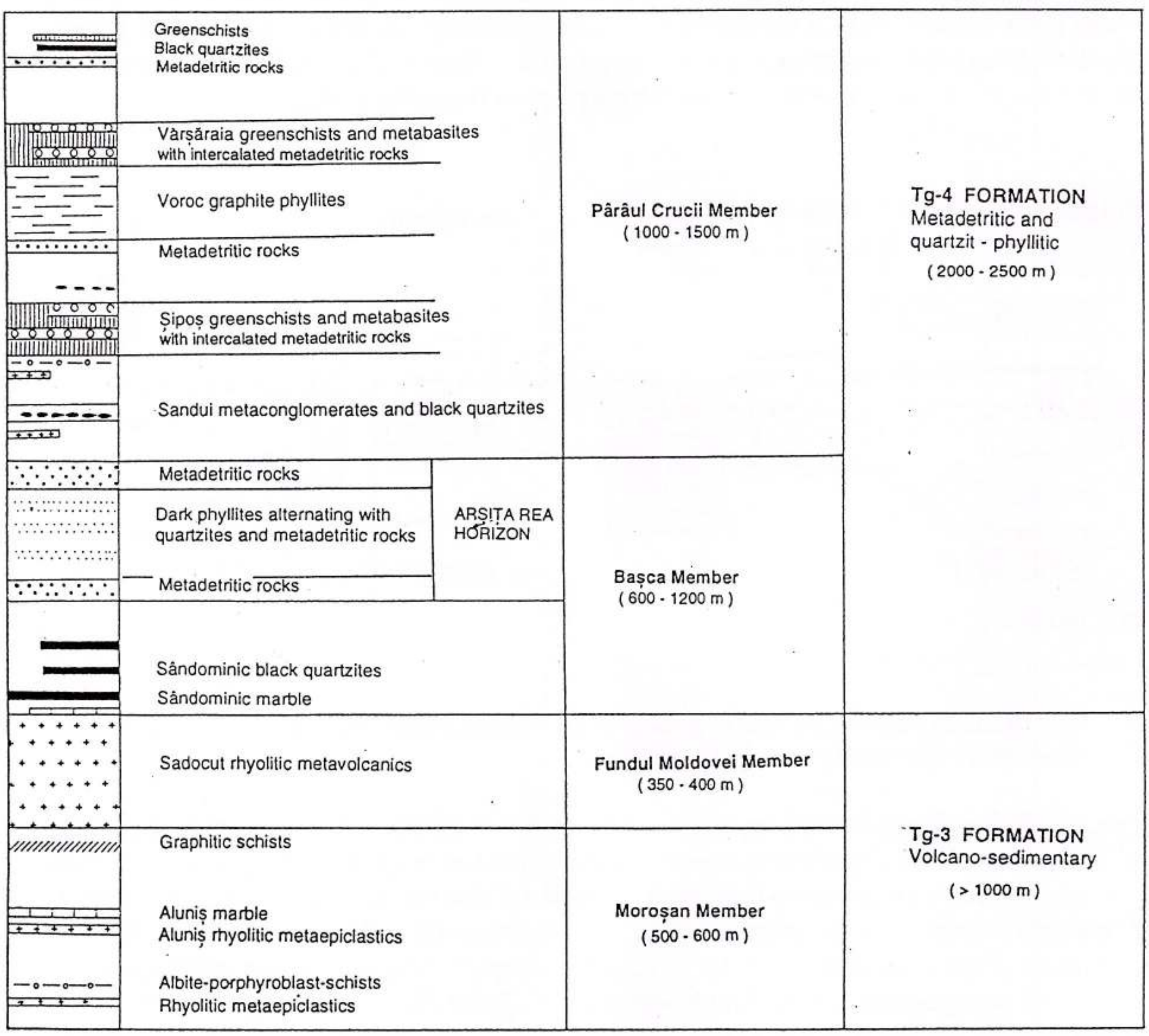


Fig.10 Lithostratigraphic sequence of the Tulghes Group in the Sândominic Nappe (not to scale)

the Morosan Member which is definitely thicker in the Sândominic Nappe. Here a lithostratigraphic marker developed (Alunis Horizon) constituted of rhyolitic metavolcanics and limestones (Fig.10).

Formation Tg4 (blastodetritic, quartz-phyllitic) consists of phyllitic rocks alternating with quartzites, metagreywackes („metadetrital rocks"), metaconglomerates, black quartzites (metalydites) and albite-porphyroblast schists. At some levels metatuffs and lava flows of basaltic composition (Sipos and Varsaraia greenschists in the Sândominic Nappe, Parâul Crucii - Gherpotok greenschists in the Baratu-Mare Nappe, Arama-Oltului greenschists in the Balan Nappe) and intrusive rocks of gabbroic composition (Sipos, Varsaraia and Mogos-Bük metabasites in the Sândominic Nappe) are intercalated (Figs. 10,11). Rhyolitic metatuffs and epiclastites occur subordinately. Subvolcanic bodies assigned to the last rhyolitic phase (Mândra Porphyroids) are extensively exposed in the Baratu-Mare tectonic unit. Products of basic and acid extrusive phases occur in alternating lithostratigraphic positions indicating a bimodal character of the late volcanic phases of the Tulghes Group.

Differences between the sequences exposed in the three Variscan tectonic units consists essentially in the variable amount or in the thickness of some specific rock types. Thus the Pângarati Member represents a local increase of Arsita-Rea metadetrital rocks in the Baratu-Mare Nappe (Fig. 11). In the Sândominic Nappe occur maximal amounts of metabasites and Pârâul-Crucii greenschist (Varsaraia and Sipos greenschists). as well as of metalyditic rocks.

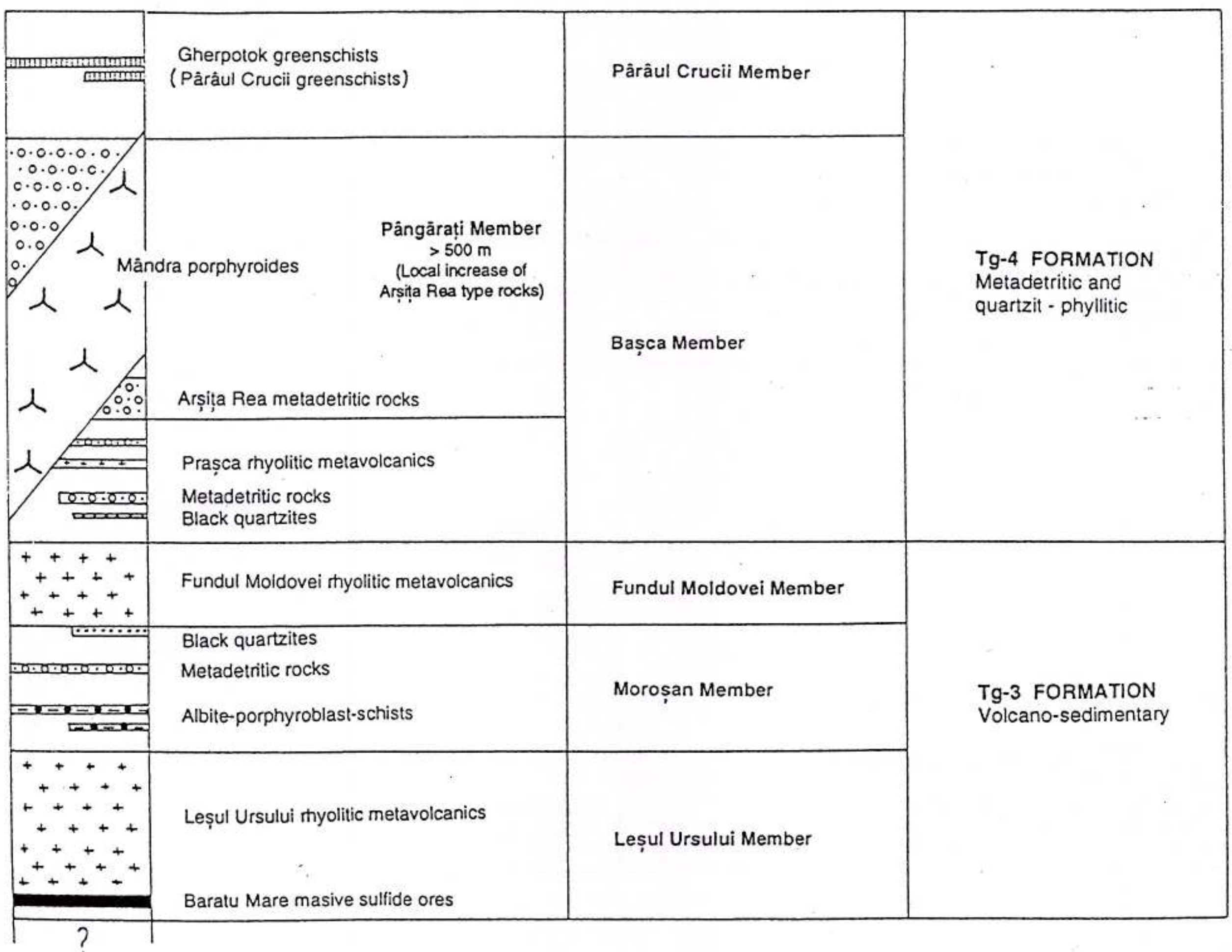


Fig. 11. Lithostratigraphic sequence of the Tulghes Group in the Baratu-Mare Nappe (not to scale).

(Sândominic black quartzites) and detrital black quartzites, which locally are associated with dark metaconglomerates (Sandui metaconglomerate, MUREŞAN & MUREŞAN, 1972).

At the present erosion level the largest part of the DAIC is enveloped by the Tg4 Formation of the Sândominic Nappe.

The main metamorphism of the Tulghes Group is assigned to an Early-Caledonian (probably Sardic) event. It developed under LT/MP conditions (Barrovian type greenschist facies). This is indicated by geobarometric date based on b_o-values of the K-white micas (KRÄUTNER et al., 1975) and by the following mineral parageneses:
Chlorite ± biotite + albite + muscovite + quartz + calcite ± spessartine (in pelitic and psamitic rocks),
chlorite ± biotite +actinolite + albite + epidote + calcite (in basic rocks),
calcite + quartz (in carbonatic rocks),
orthoclase + albite (replacing high temperature Na-K feldspar in acid volcanic rocks),
rutile (replacing primary ilmenite).

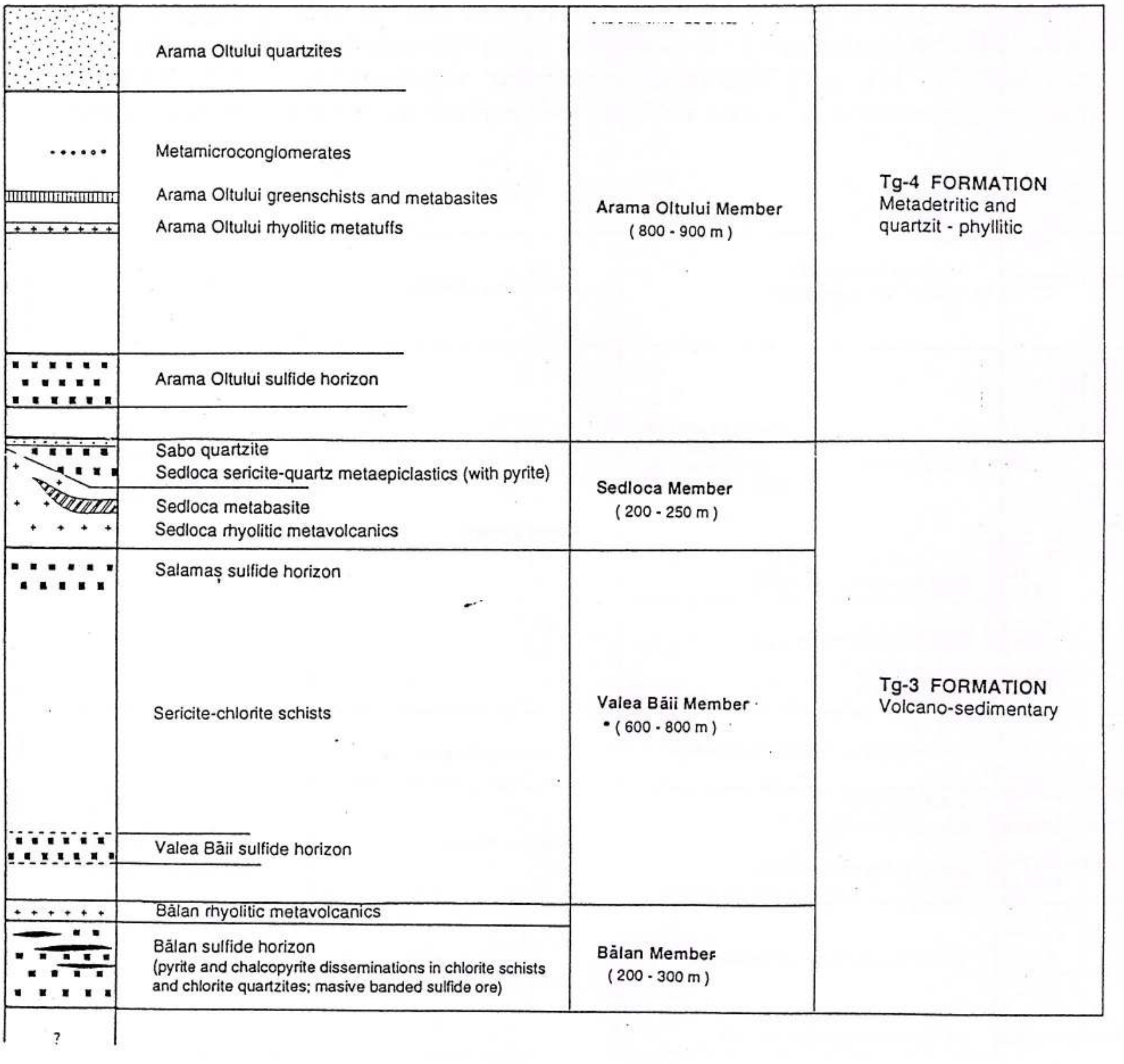


Fig. 12. Lithostratigraphic sequence of the Tulghes Group in the Balan Nappe (not to scale).

Later metamorphic overprints are due to the Variscan event and to Alpine tectogenesis.

The Variscan mineral and textural overprinting was not penetrative over the entire Tulghes Group. It resulted from both heating in static condition and from dynamic retrogressive overprinting in zones of ductile shearing and Variscan nappe transport. Static heating is indicated by random idiomorphic growth of

Stilpnomelane, muscovite, biotite, spessartine-rich almandine and albite

Variscan overprinting is also indicated by rejuvenation of radiometric K-Ar and Rb-Sr ages. The dynamic Alpine overprint produced semiductile low-temperature mylonitization near the shear planes of the Bucovinian Nappe and of its frontal scales.

Bretila Group

A relatively small part of the Bretila sequence (Rarau Formation) is preserved in the Rarau Nappe of the Bucovinian realm. In the Central East Carpathians it was described by STRECKEISEN (1931) as „Haghimas-Kristallin". The Rarau Formation may be an equivalent of the mainly gneissic association of the Lespedea Formation from the stratotype of the Bretila Group exposed in the Infrabucovinian Nappes of the Rodna Mts. Paragneisses and augengneisses prevail. Locally bands of micaschist, 1-20 meters in thickness, and thin amphibolite layers are intercalated. South of the Putna Valley, MURESAN (sheets Damuc, Sândominic and Tulghes of the national geological map 1: 50 000) separated the Rarau Formation into two lithostratigraphic units using a horizon of white leptinitic gneisses associated with augengneisses (Naghiag gneiss) as a marker-level.

The main metamorphism of the Bretila Group is assigned to a Precambrian event. It developed under MT/MP conditions as indicated by migmatization and by some occurences of kyanite, staurolite and almandine bearing rocks. At least two deformational phases developed in this garnet-amphibolite facies stage.

Variscan dynamic overprinting at the greenschist facies may be observed in zones some hundreds of meters in size, passing gradually towards ductile mylonites on the shear plane of the Rarau Nappe. Main mineralogical changes are replacement of biotite, garnet, hornblende by chlorite and of plagioclase by white micas (sericite). Locally, in these retrograded rocks a subsequent growth of small idiomorphic garnet crystals may be observed. This could correspond to the same Variscan thermal climax that produced the afore mentioned late random growth of idiomorphic minerals in rocks of the Tulghes Group.

The alpine tectogenesis produced low-temperature dynamic metamorphism by shearing and brittle deformation of local extent.

Haghimas Granitoids

A large part of the Rarau Nappe in the Central Eat Carpathians is formed of granitoids described as Haghimas Granitoids (MURESAN & MURESAN, 1980). ATANASIU (1929) considered these rocks as post-metamorphic intrusions in the Tulghes Group producing in their thermal aureola the higher-grade metamorphics presently assigned to the Bretila Group.

According to STRECKEISEN (1931) the granitoids intruded the metamorphics of the Bretila Group producing a late metamorphism. BANCILA (1941) also suggests a syn-metamorphic emplacement for explaining gneissic structures observed in the granitic and dioritic rocks. Later the Haghimas Granitoids were considered as migmatites and anatexites related to the Bretila Group (STRECKEISEN, 1940, 1968; IANOVICI et al., 1968). According to MURESAN & MURESAN (1980) the Haghimas granitoids were affected by the metamorphism of the Bretila Group and therefore their premetamorphic intrusion was presumed. Retrogressive, prevailing dynamo-metamorphic overprint was recognized by STAN (1990-1992, unpubl. data).

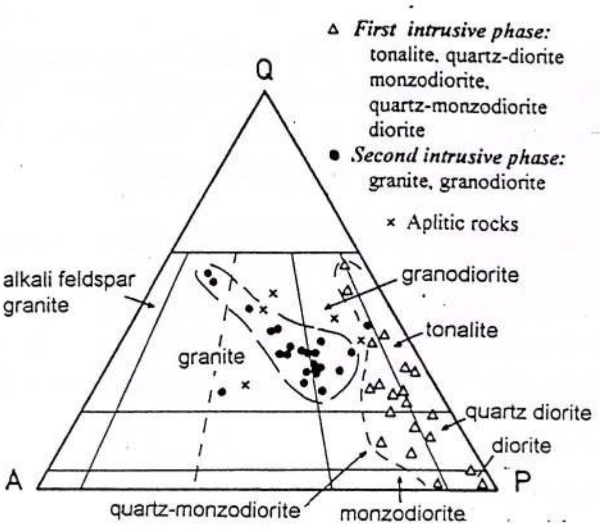


Fig.13 Q-A-P plot (LE MAÎTRE et al., 1989) of Haghimas Granitoids (data from MURESAN & MURESAN, 1980).

The Haghimas granitoids are represented by a large variety of granitic, granodioritic and dioritic rocks of calc-alkaline character. Clear cross-cutting relationships indicate a first intrusion stage including diorites, quartz-diorites, tonalites and quartz-monzodiorites, followed by a second stage represented by granitic and granodioritic rocks (Fig.13). Both rock associations are crosscut by felsic dykes (for details see MURESAN & MURESAN, 1980, STAN 1990-1992, unpubl. data).

Between Haghimas Granitoids and the surrounding Bretila rocks usually tectonic contacts were observed. Greenschist facies mylonitization and phyllonites frequently developed at these contacts (STAN, 1990-1992, unbubl. data). Around the Tulghes tectonic halfwindow, south of the Putna Valley, detailed mapping indicates that the granitoids lie in a subhorizontal position over Bretila rocks. Therefore it may be assumed that the Haghimas Granitoids, at least partly, overthrust Bretila gneisses and belong to a scale of the Rarau Nappe or to another Variscan nappe.

Rebra Group

Rebra type rocks occur exclusively in the Rodna Nappe. They are exposed in the tectonic window at Borsec, north of Bilbor and in the area between Voslabeni and Sândominic, south of Gheorgheni. Here they were described by STRECKEISEN (1952) as „Magas Series". Later this rock sequence was assigned to the Rebra Group by lithostratigraphic correlation (BERCIA et al., 1976) and its equivalence with the Fagaras Group of the South Carpathians has been recognized (KRÄUTNER, 1980).

The stratotype of the Rebra Group is exposed in the Subbucovinian Nappe of the Rodna Mts. It includes three lithostratigraphic units (Rb1 - Rb3) from which the lowermost (Rb1) may be considered transitional to the lower Carpian sequence (Bretila Group in the East Carpathians, Cumpana Group in the South Carpathians). In the central part of the East Carpathians, the Rebra Group is exposed only in the Bucovinian Nappe. Its lower part (Rb1) does not occur, as the Bucovinian shear plane lies inside the Rb2-Formation.

Voslabeni Formation (Rb2) (carbonatic formation). It consists of a sequence of calcite-marbles and dolomite-marbles, some hundreds of meters thick, with intercalations of micaschists, amphibolites and quartzites.

Ineu Formation (Rb3) (quartz-micaschist formation). The lower part is formed of micaschists with some intercalations of amphibolites, limestones and graphite-quartzites. In the upper part some meter-thick bands of quartzites and quartz-rich paragneisses are intercalated in garnet-micaschists and quartz rich micaschists.

Polymetamorphism is evident for the Rebra rocks but no constraints for the timing of the different events are currently available. The two oldest metamorphic events are assigned to the Precambrian. The first event probably was common with the oldest Bretila metamorphism and developed under MT/MP conditions, as indicated by mineral parageneses with:

kyanite + staurolite + almandine + biotite + muscovite + plagioclase + quartz (in pelitic rocks),
hornblende + almandine + plagioclase ± biotite (in amphibolites),
dolomite + calcite + tremolite + quartz (in carbonatic rocks).

The second event produced MT/LP mineral parageneses (BALINTONI & GHEUCA, 1977), due to a thermal climax in static conditions. These mineral associations were observed only in the Bucovinian Nappe whereas in the Subbucovinian realm parageneses of the first event prevail. The newly formed minerals include:

andalusite (replacing staurolite),
cordierite,
sillimanite (replacing biotite),
diopside (in carbonatic rocks).

Variscan overprint is a third metamorphic event recognized in Rebra rocks, prevailing in zones of sheraring and nappe transport. It develops regressively by replacement of garnet and biotite by chlorite, of hornblende by chlorite ± actinolite, of andalusite and cordierite by sericite and of plagioclase by sericite or albite + calcite + epidote.

The Alpine tectogenesis produced dynamic low-temperature metamorphism around alpine shear planes. In the northern part of the East Carpathians, Alpine K-Ar ages were recorded in Rebra rocks which show no retrograde overprinting. It is assumed that these ages correspond to cooling after uplifting by the Mesocretaceous nappe transport of deep seated parts without sedimentary cover (KRÄUTNER et al., 1976).

Negrisoara Formation

In the Bucovinian Nappe of the Central East Carpathians, a monotonous sequence of biotite-paragneisses and muscovite schists with thin layers of feldspar quartzites is assigned to the Negrisoara Formation. It is exposed around Borsec, Gheorgheni and Izvorul-Mures. This lithologic unit (with a rather different petrographic constitution) was delineated in the northern East Carpathians (BALINTONI & GHEUCA, 1977) as a lithologic constituent of the Pietrosul-Bistritei Nappe. As the other constituent of this nappe, the Pietrosul Porphyroid, forms a distinct nappe unit, we here use the term *Negrisoara Nappe* for the Variscan tectonic unit including the Negrisoara Formation. A penetrative retrogressive metamorphism is largely extended near the tectonic planes of this nappe.

Pietrosul Porphyroids

In the East Carpathians Pietrosul Porphyroids occur only in tectonic slides. As no primary relationships with other metamorphic units are known we assign this peculiar lithologic unit to the *Pietrosul Nappe.*

The Pietrosul Porphyroids, initially described by SAVU & MASTACAN (1952), are represented by metadacites and metaporphyric granodiorites (Fig.14) with well preserved porphyric structures. Relict phenocrysts of magmatic corroded quartz and plagioclase (recrystallized as albite) may be recognized. The quartz phenocrysts frequently show a peculiar violet-blue colour due to inclusions (exsolution) of fine rutile needles. The recrystallized groundmass is affected by a penetrative schistosity marked by abundant biotite. According to BALINTONI & GHEUCA (1977) the primary metamorphism developed under similar conditions as in the Negrisoara Formation. Variscan overprinting may be recognized preferentially near the shear planes at the base and top of the tectonic slides. It is represented by chloritization of biotite, albitization of the plagioclase, recrystallization of quartz and a structural reorganization by a new schistosity.

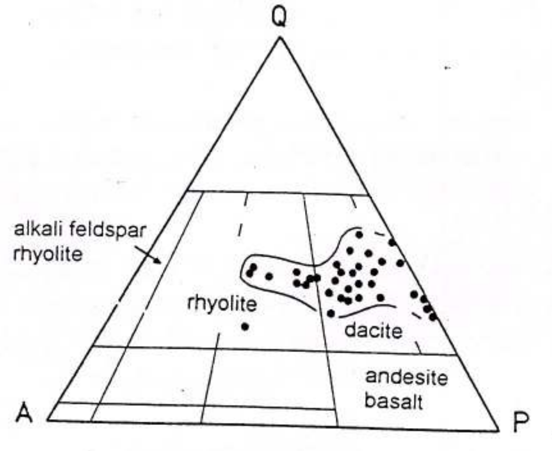


Fig.14 Q-A-P plot (LE MAÎTRE et al., 1989) of Pietrosul Porphyroids (metadacites).

No genetic relationships exist with the Cambrian volcanism of the Tulghes Group. The Pietrosul Porphyroids occur in a discrete tectonic unit and show distinctive petrographic features, different from the rhyolitic porphyroids of the Tulghes Group (Mândra Porphyroids). According to their contrasting zircon typology the Pietrosul and Mândra Porphyroids evolved in different geotectonic settings (KRÄUTNER et al., 1993). Zircon crystals of the Pietrosul Porphyroids developed at relatively low temperature (700-800° C) in an Al-rich environment suggesting an anatectic origin. Contrary, zircons of the Mândra Porphyroids evolved at higher temperature (750-850° C) in an alkali-dominated environment which marks, according to PUPIN (1980) and PUPIN &TURCO (1981) the alkaline and calc-alkaline magmatic series of mantle origin.

Ditrau Alkaline Intrusive Complex

Due to the peculiar lithological and structural constitution of the Ditrau massif, investigations lead to various petrogenetical interpretations. Briefly the chronological succession of the main concepts may be listed as follows:

1. Magmatic origin
a) Assimilation of limestones (Daly's theory) by a basic calc-alkaline magma gave an alkali-gabbroic magma which developed by fractional crystallisation to alkali-syenitic and nepheline syenitic magmas: A. STRECKEISEN (1931, 1934), A. FÖLDVARY (1946).
b) Magmatic differentiation by fractional crystallisation and gravitational accumulation: V. IANOVICI (1933, 1938).
2.Two opposite concepts: migmatc-metasomatic versus magmatic and magmatic-metasomatic
a) Migmatic cover of an anatectic diapir, migmatic metasomatism: A. CODARCEA, M. DESSILA-CODARCEA, V. IANOVICI (1957, 1958)
b) Magmatic differentiation with successive magma emplacements, magmatic metasomatism: A. STRECKEISEN (1960).
3. Ring structure: A. STRECKEISEN (1954), D: ZINCENCO (1978)
4. Different successive magmatic intrusions:
a) Successive emplacement of gabbro-dioritic magmas (1), syenitic magmas (2), nepheline syenitic magmas (3), followed by hydrothermal alteration: A. STRECKEISEN & J. C. HUNZIKER (1974).
b) Successive intrusion and mixing of two different magma types - a basic subcrustal magma (1) and an alkaline crustal magma (2): N. ATANASIU & E. CONSTANTINESCU (1978).
c) Three successive intrusive phases, represented by the basic-ultrabasic complex (1), marginal red-syenite complex of sialic character (2), central white syenite complex with simatic geochemical signature (3): G. JAKAB (1982, 1986).
5. Actual state: parental rocks and hybrid rocks
a) Magmatic mixing in subsolidus stage of an alkali-basaltic parental magma with a crustal contaminated syenitic magma. Later intrusion of a nepheline syenitic and a crustal granitic magma: G. BINDEA (1994); V. MOROGAN, B. J. C. UPTON, G. BINDEA (1994).
b) Intrusion sequence in the Middle Triassic extensional stage (^{40}Ar-^{39}Ar = 231-227 Ma), due to mantle plum activity predating Jurassic rifting: R. D. DALLMEYER, H. G. KRÄUTNER, F. NEUBAUER (1996).
c) Three main intrusion phases during the Triassic extensional stage and the Jurassic-rifting stage. 1) Gabbro-dioritic intrusion (231-227 Ma, Ladinian-Carnian) caring mantle xenoliths, 2) syenitic intrusion (216-212 Ma, Norian) giving syenites and hybrid dioritic-monzonitic rocks by mixing with previous magmatic products and granitic rocks by contamination with quartz rich metamorphics, 3) nepheline syenitic intrusion (161-155 Ma, Callovian-Oxfordian) giving nepheline syenites and hybrid basic foid rocks („ditro essexite“) by partial substitution of previous gabbro-dioritic rocks. During the cooling stage (till 135/115 Ma) developed late- and post-magmatic alteration and mineralization: H. G. KRÄUTNER, G. BINDEA (1996, this contribution).

Detailed petrographical descriptions were given by STRECKEISEN (1952, 1974), IANOVICI (1933), CODARCEA et al. (1958), IANOVICI et al (1968), ANASTASIU et al. (1978, 1983), PÁL-MOLNÁR (1992, 1994), geochemical data by STRECKEISEN (1954), IANOVICI et al.(1958), JAKAB (1982, 1986), MOROGAN et al. (1994), structural analyses by ANASTASIU et al. (1980, 1984, 1985), geochronological data by BAGDASARIAN 1972), STRECKEISEN & HUNZIKER (1974), MÎNZATU et al. ((1981), PÁL-MONÁR & ÁRVA-SÓS (1995), DALLMEYER et al. (1996) and geophysical data by GHON et al. (1973), BOTEZATU & CALOTA (1979).

Table 3

Main types of „parental“ and hybrid DAIC-rocks

classified according to intrusion phases, magmatic mixing, late- and post-magmatic alteration and „rock complexes“ separated on the attached map of BINDEA et al.

(„Parental“ rocks in shaded boxes)

A **Mantle xenoliths**	**B** **Gabbro-dioritic intrusion**	**C** **Syenitic intrusion**	**D** **Nepheline syenitic intrusion**	**X** **Metam. country rocks**	**E** **Late&post-magmatic alteration**	
A Olivine pyroxenite	AB Pyroxene-hornblendite Hornblendite	AC Biotite-hornblendite Biotitite				**A**
	B Gabbro-diorite	BC *Foliated and massive rocks:* Diorite Monzodiorite Monzonite Syenite	BD „Ditro essexite“			**B**
		C *massive and foliated rocks:* Syenite (Biotite-syenite) **Dyke & Vein:** Microsyenite Bostonite Aplite		CX Quartzsyenite Granite Alkali-feldspar granite **Dyke & Vein:** Aplite		**C**
			D Nepheline-syenite Pegmatoid nepheline syenite **Dyke & vein:** Tinguaite		DE Cancrinite-, sodalite-nepheline syenite Liebneritized-nepheline syenite	**D**
					E Mineralization	**E**

- Complex of olivine bearing ultramafic rocks
- Hornblendite syenite complex
- Monzonite-syenite complex
- Complex of granitic rocks
- Complex of nepheline syenites
- Complex of muscovitized syenites

The Jolotca complex includes rocks of the classes A, AB, B and BC, while the Gudut complex consists mainly of BD type rocks:

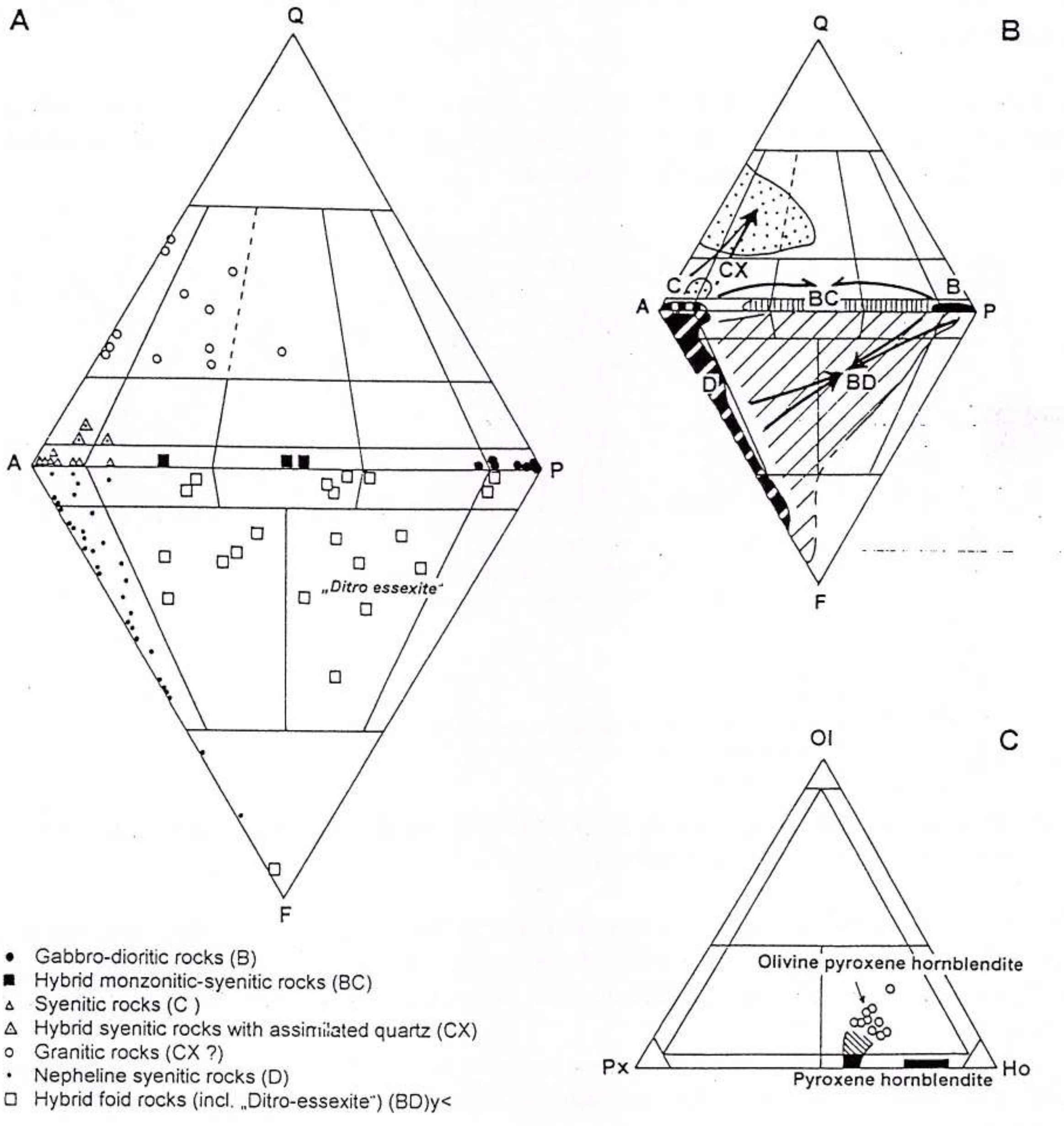


Fig.15 DAIC-rocks in the normative petrographical classification diagrams of LE MAITRE et al. (1989).

A. Q-A-P-F plot of the main DAIC rocks (data from BINDEA and ANASTASIU & CONSTANTINESCU, 1978)

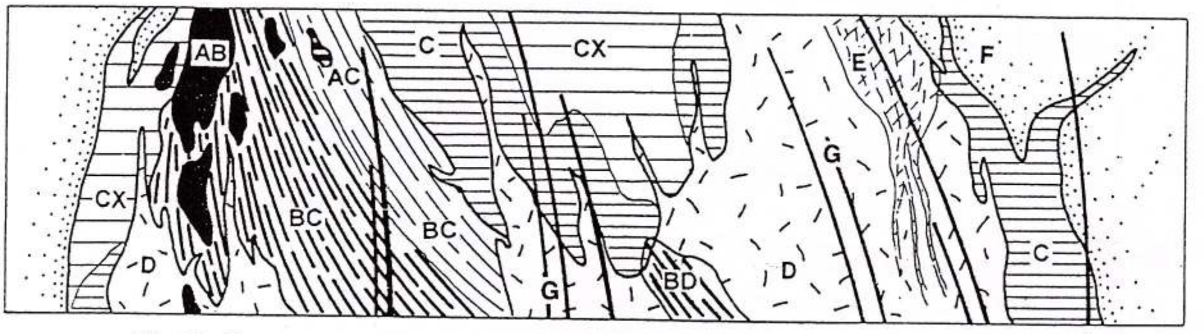
B. Q-A-P-F diagram with fields of the main „parental" rock classes(B, C, D) and the inbetween position of the hybrid rock classes (BC, BD, BX) (notations acc. to Table 3)

C. Plot of hornblendites and olivine pyroxene hornblendites in the Ol-Px-Ho triangle (data from BINDEA and PÁL MOLNÁR, 1992)

The mineralogical constitution of the main DAIC rocks is shown in QAPF and Ol-Px-Ho diagrams of Fig.15. Rock classes A, D, CX, DE (Table 3) are massive varieties, while the other classes consists of both massive and foliated rocks. Foliated varieties prevail in classes C, BC and BD.

There is clear structural, mineralogical and geochemical evidence supporting a multistage development of the magmatic history in the DAIC and a hybrid character of a large part of its petrographic constituents.

Macro-structural arguments are based on both, sharp cross-cutting relationships and gradual transition between some of the main lithologic units. These relationships are schematically shown in Fig.16. They may be listed as followed:



AB, AC Hornblendite (transformed mantle xenoliths)
BC Gabbroic and prevailing foliated diorite-monzonitic (heavy lines) and monzonite-syenitic (thin lines) rocks
BD „Ditro-essexite"
C Syenite
CX Granite, quartz syenite
D Nepheline syenite
E Muscovitized (liebneritized) nepheline syenite and syenite
F Thermal contact aureole
G Lamprophyre dykes

Fig. 16 Intrusion relationships between the main DAIC rock associations (schematic representation). (Notations A-E according to classification in table 3)

1) Pyroxene hornblendites and hornblendites are included in gabbro-dioritic and syenitic rocks as lense shaped bodies (xenoliths), from few cm to hundred metre ore more in size. Usually contacts to enclosing gabbro-dioritic rocks are transitional from mineralogical-petrographical point of view.

2) There are a continuous gradual transition between hornblendite, gabbro, diorite , monzo-diorite, monzonite to syenite. Consequently in the field no petrographic limits may be recognized ore mapped.

3) Continuous gradual transition also occur between syenites, quartz syenites, quartz-monzonites and granites.

4) Xenoliths of metamorphic country rocks and hornfelses, variable in size, are included in syenitic and granitic rocks.

5) Hornblendites are included and veined by granitic rocks.

6) Syenites intrude gabbro-dioritic rocks as well as monzonite-syenitic transitional types.

7) Nepheline syenites and pegmatoid nepheline syenites cut hornblendites, gabbro-diorites and transitional rock types to syenite, as well as syenites and granites.

8) Tinguaite veins and dykes cut nepheline syenites and rocks listed at pt.7.

9) Lamprophyre veins and dykes cut all DAIC -rocks. They are not restricted to the Ditrau massif as they intruded the metamorphic basement of the whole East Carpathian chain.

10) Veinlets and replacement by sodalite and cancrinite occur over the entire Ditrau massif. They prevail in nepheline syenites, but were observed also in tinguaites (STRECKEISEN & HUNZIKER, 1974).

11) Hydrothermal alteration (liebneritization) is restricted to some areas in the western and north-western part of the massif (Fig. 20)

Micro-structural arguments are based on microscope investigation of relationships between different successive mineral generations:

12) Accumulations of xenomorphic quartz crystals and single large exotic quartz crystals with preserved metamorphic shear fabric, included among magmatic fine-grained isometric feldspar aggregates. This structures strongly suggest assimilation from country rocks (STRECKEISEN & HUNZIKER, 1974).
13) Two different plagioclase types in the same rock. Albite (0-3 An) in cogenetic association with microcline and oligoclase (14-25 An) in paragenetic association wit hornblende (Mg-hastingsite) and titanite.
14) Basic plagioclase overgrown by rims of albitic plagioclase.
15) Pyroxene and olivine inclusions in large hornblende, biotite and plagioclase crystals of hornblenditic rocks.

Geochemical arguments refer to different signatures for some lithologic associations:
16) Rocks of the syenitic and of the nepheline syenitic associations differ by contrasting U and Th concentrations (GHON et al, 1973, JAKAB, 1986).
17) REE and other trace elements distribution is different in zircon crystals of syenites and nepheline syenites (JAKAB, 1986).
18) According to JAKAB (1986) different Rb/Sr ratio, Ba and REE patterns suggest that the nepheline syenitic magma resulted from residual melting, while the syenites are palingenetic products. According to MOROGAN et al. (1994) the first Ditrau magmas derived from a highly fractionated alkali basalt parental magma, while the nepheline syenite magma had a different parent.
19) Incompatible elements of syeno-diorites suggest contamination with the nepheline syenite magma (MOROGAN et al., 1994).

Geophysical arguments refer to magnetic properties of the basic rock associations:
20) The Jolotca complex give clear aeromagnetic anomalies, even wen covered by young sediments, while the Gudut complex shows no magnetic pecularity (Fig.19).

Age of the DAIC

A Jurassic age of the Ditrau massif was supposed about sixty years ago by IANOVICI (1938), but proves became available only since first K-Ar ages were recorded on DAIC rocks (BAGDASARIAN, 1972) (Table 4). More precisely the nepheline syenites, tinguaites and the contact aureole were dated at 160-150 Ma by STRECKEISEN & HUNZIKER (1974) and MÎNZATU et al. (1981). Recently Triassic K-Ar ages of 237-216 (PÁL-MOLNÁRM & AVA-SÓS, 1995) and ^{40}Ar-^{39}Ar ages of 231-227 Ma (DALLMEYER et al., 1996) were recorded on hornblendites and grabbros of the Jolotca and Gudut complexes (Table 4). This data require a new geologic interpretation of older data and of the DAIC emplacement history.

On the basis of all available data (Table 4) and considering overlapping age intervals (Fig.17), the following dating of the main intrusion phases and post magmatic evolution is proposed:

231-227 Ma *(≈230 Ma)* **= B, AB (Carnian)**
Emplacement of gabbro-dioritic magma (B) caring mantle xenoliths transformed to hornblendites. Therefore hornblende ages from xenoliths were accommodated to the gabbro emplacement (231-217 Ma overlapping ages of hornblende from gabbro and hornblendite, Fig.18).

Table 4

K-Ar ages obtined on the main rock types of the DAIC

Rock type	K-Ar age (in Ma)
A Hornblendite	**237** (P), **234** (P), **226** (P), **216** (P), 169 (B), ***168 (P)***, ***162 (P)***, *161 (P)*, ***134 (M)***
A1 Hornblendite (lense in foliated diorites)	189 (B)
A2 Hornblendite (lense in foliated syenites)	154 (B), 152 (B)
Biotitite (in syenites)	***161 (M)***
Gabbro-diorite	*255 (P)*, **218** (P), **208** (P), **176** (P), ***149 (M)***, *138 (P)*, *137 (P)*
C1 Syenite	*182 (P)*, ***139 (M)***, 136 (M), ***134 (M)***, 131 (M), 122 (B), ***117 (M)***, 115 (B), 115 (B), ***113 (M)***, *113 (P)*, 112 (M), ***107 (P)***, ***102 (P)***
Pegmatitic syenite	134 (B)
C2 Granite	***217 (P)***, ***213 (P)***, ***206 (P)***, *146 (P)*, *142 (P)*, *139 (P)*, 118 (B)
D Nepheline syenite	154 (B), ***153 (S)***, ***151 (S)***, 150 (M), *116 (M)*
E Nepheline syenite with sodalite veins and Nepheline syenite with cancrinite Liebneritized nepheline syenite	*232 (P)*, ***182 (P)***, *147 (P)*, *147 (M)*, ***136 (M)***, ***126 (M)***, ***119 (M)*** *81 (M)*
F Thermal contact aureole: hornfelses	***175 (M)***, 172 (M), ***157 (M)***, ***150 (S)***, ***142 (M)***, 138 (M), ***120 (M)***
G Tinguaite	172 (M), 161 (S), 159 (M), 156 (S)

Abbreviations for sample notation: **237** hornblende; ***161*** = biotite; 150 = nepheline; *161* = feldspar; 189 = whole rock.
B = Bagdasarian (1972); S = Streckeisen & Hunziker (1974); M = Mînzatu et al. (1981); Pál-Molnár & Árva-Sós (1995).

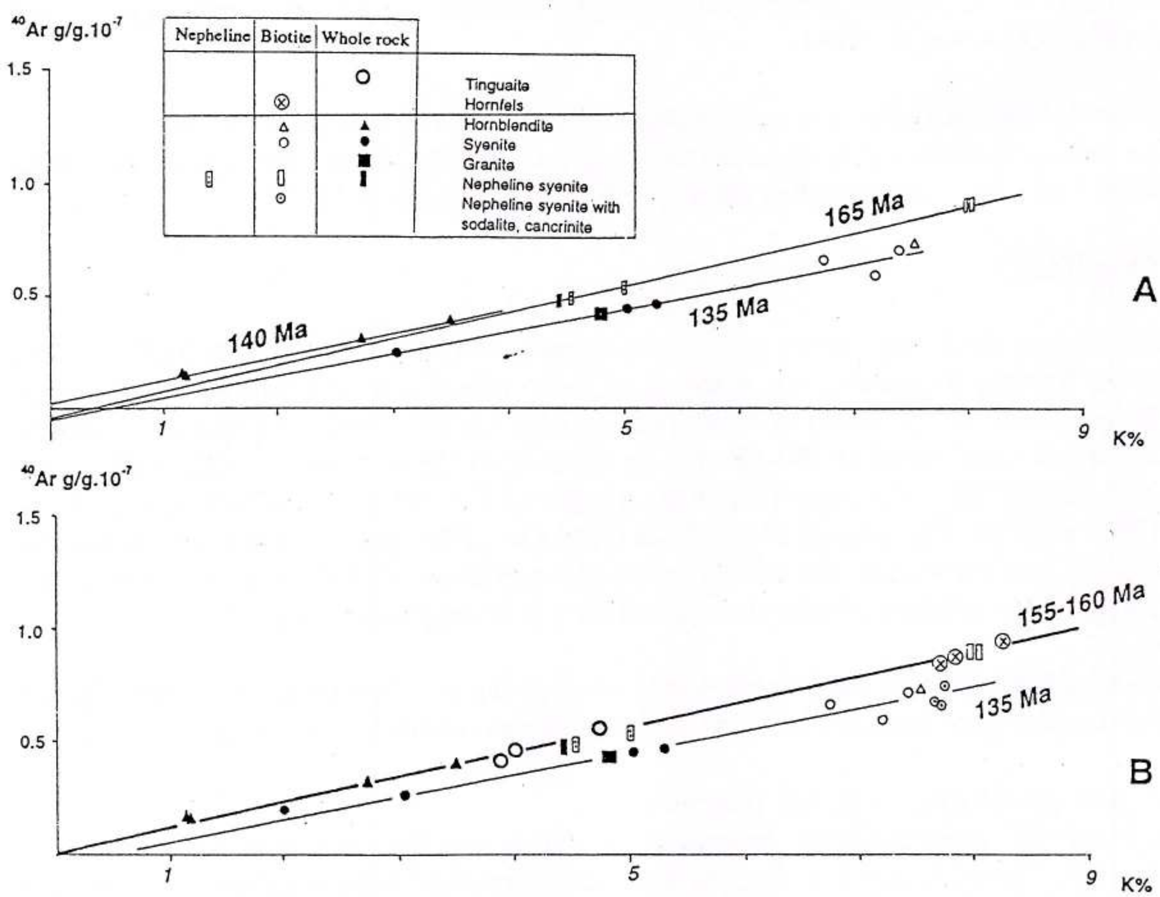


Fig.17. K-Ar isochrones for different associations of DAIC rocks.

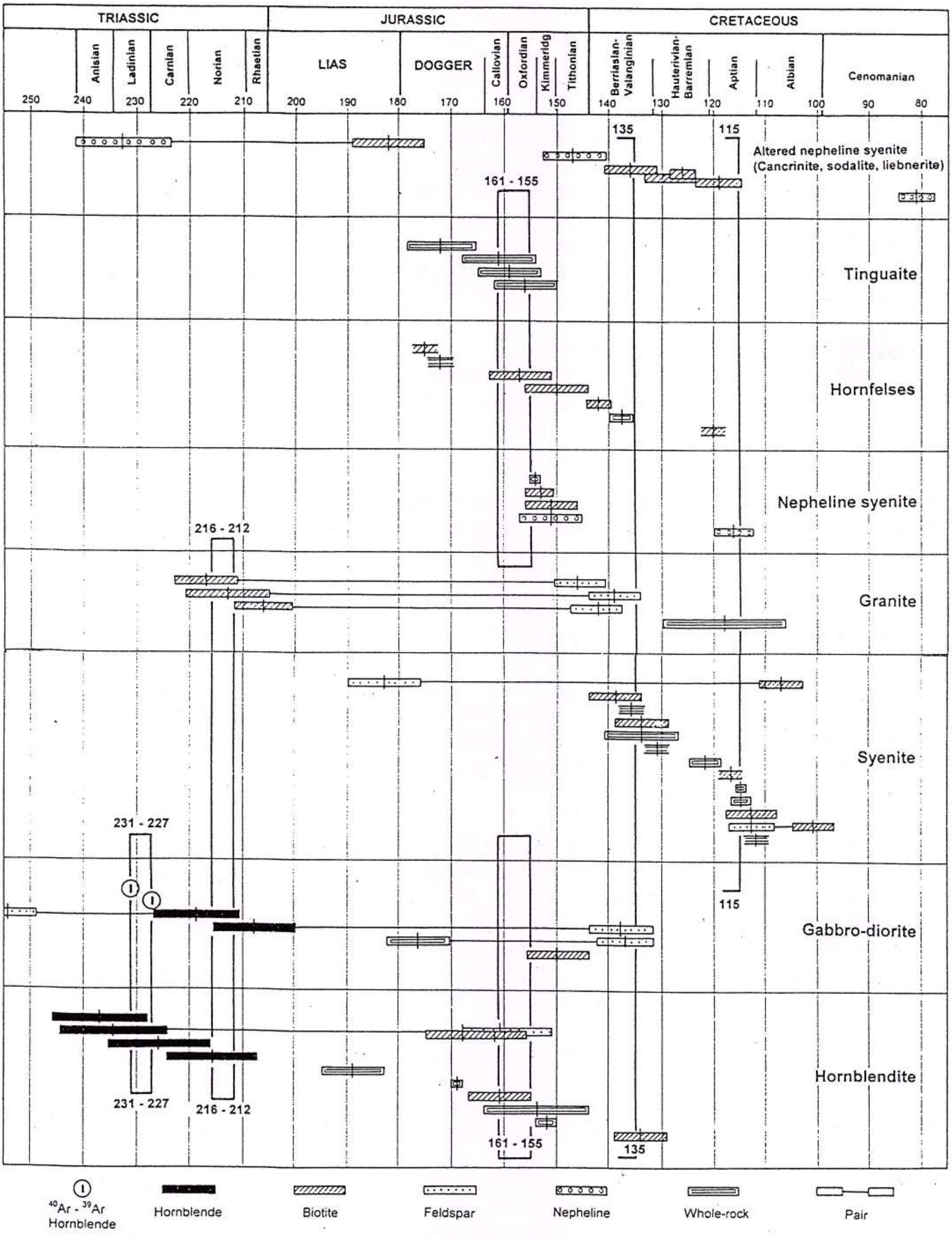


Fig.18 Distribution of K-Ar ages in different DAIC rock associations and their overlapping age intervals. (Mesozoic time scale acc. to GRADSTEIN et al., 1994)

216-212 Ma *(≈215 Ma)* **= C, BC (Upper Norian)**
Emplacement of syenitic (C) magma producing the monzonite-syenite rock association (BC) by hybridisation of previous gabbro-dioritic rocks. By assimilation of quartz-rich metamorphics granitic rocks formed (212-216 Ma overlapping biotite ages from granites, Fig.18).

161-155 Ma *(≈160 Ma)* **= D, BD (Callovian-Oxfordian)**
Emplaccment of nepheline syenites (D) producing hybridisation and metasomatic changes in previously formed DAIC rocks, e. g. formation of „Ditro-essexites", (BD) (overlapping of biotite ages in nepheline syenites and accommodated biotite ages in gabbro and hornblendite, 161-155 Ma). This timing is proved by overlapping 161-155 Ma whole-rock ages recorded in tinguaites which closed the nepheline syenitic intrusion, as well as by overlapping biotite ages from hornfelses (Fig.18).

155-135 Ma (Kimmeridgian-Berriasian)
Long lasting cooling period at deep crustal levels, indicated by a sequence of continuously decreasing biotite, feldspar and whole rock ages (155-135 Ma) from most of the DAIC rocks (Fig.18).

115 Ma (Aptian)
Definitive closing of the system for Ar-loss, due to tectonic uplifting of the Bucovinian basement, including the Ditrau massif. End of late hydrothermal alteration and mineralization. 115 Ma are youngest overlapping K-Ar ages (Fig.18).

Proposed history of the DAIC emplacement

The following history of DAIC emplacement is proposed, having in mind results of previous investigators, the afore mentioned 20-point arguments for polyphase intrusions and timing of magmatic activities by radiometric ages. The suggested scenario fits all available information on the DAIC and on the actual state in regional geology (A-G correspond with notations in Table 3 and Figs.15, 16)

1. A mantle derived gabbroic magma (B) raised up 230 Ma ago (Carnian), due to mantle plum activity related to a Middle Triassic extensional stage on the western passive margin of the Bucovino-Getic terrane (DALLMEYER et al. 1996). The ascending magma carried from the depth ultramafic mantle xenoliths, represented by olivine bearing pyroxenites (A). The xenoliths are accommodated to crustal conditions by metasomatic changes with the gabbroic magma and partial hydratation. Thus an „amphibolization" was performed and the rocks were partially or completely transformed in hornblendites (AB).

2. A second main intrusion stage is marked by the emplacement of a crustal syenitic magma (C), 215 Ma ago (Upper Norian). A deep crustal intrusion level may be assumed as foliated syenitic rocks formed and hybridisation with previous gabbroic rocks was produced in a nearly subsolidus stage. A suite of foliated, grading to massive, dioritic, monzodioritic and monzonitic rocks formed (BC). Assimilation of crustal quartz rich rocks (metamorphic quartzites of the Tulges Group) gave gradual transitions to quartz monzonites and quartz syenites (CX). For the granitic DAIC rocks formed in this stage, two interpretation may by envisaged: a) Progressive Si-enrichment by larger country rock assimilation at the intrusion level (IANIVICI, 1933, STRECKEISEN & HUNZIKER, 1974), b) crustal contamination at deeper crustal levels, giving a granitic magma. The ascending granitic magma transported hornblenditic and gabbroic rocks from their deeper crustal position to higher levels. Aplitic rocks in the DAIC support this interpretation.

3. A nepheline syenite intrusion (D) 160 Ma ago (Callovian-Oxfordian) represent the third main magmatic event. It formed a central „stock", but penetrated laterally to marginal parts of the massif and veined all previously formed DAIC rocks. In late stages it developed locally to pegmatoid facies. The nepheline syenite event ended by late tinguaite veins.

4. A long cooling period, lasting for about 20-25 Ma, till 135 Ma ago (Berriasian), supports the assumption of a deep crustal intrusion level. Late- and post-magmatic metasomatic and hydrothermal alterations produced peculiar varieties of nepheline syenites with cancrinite and sodalite („ditroit").

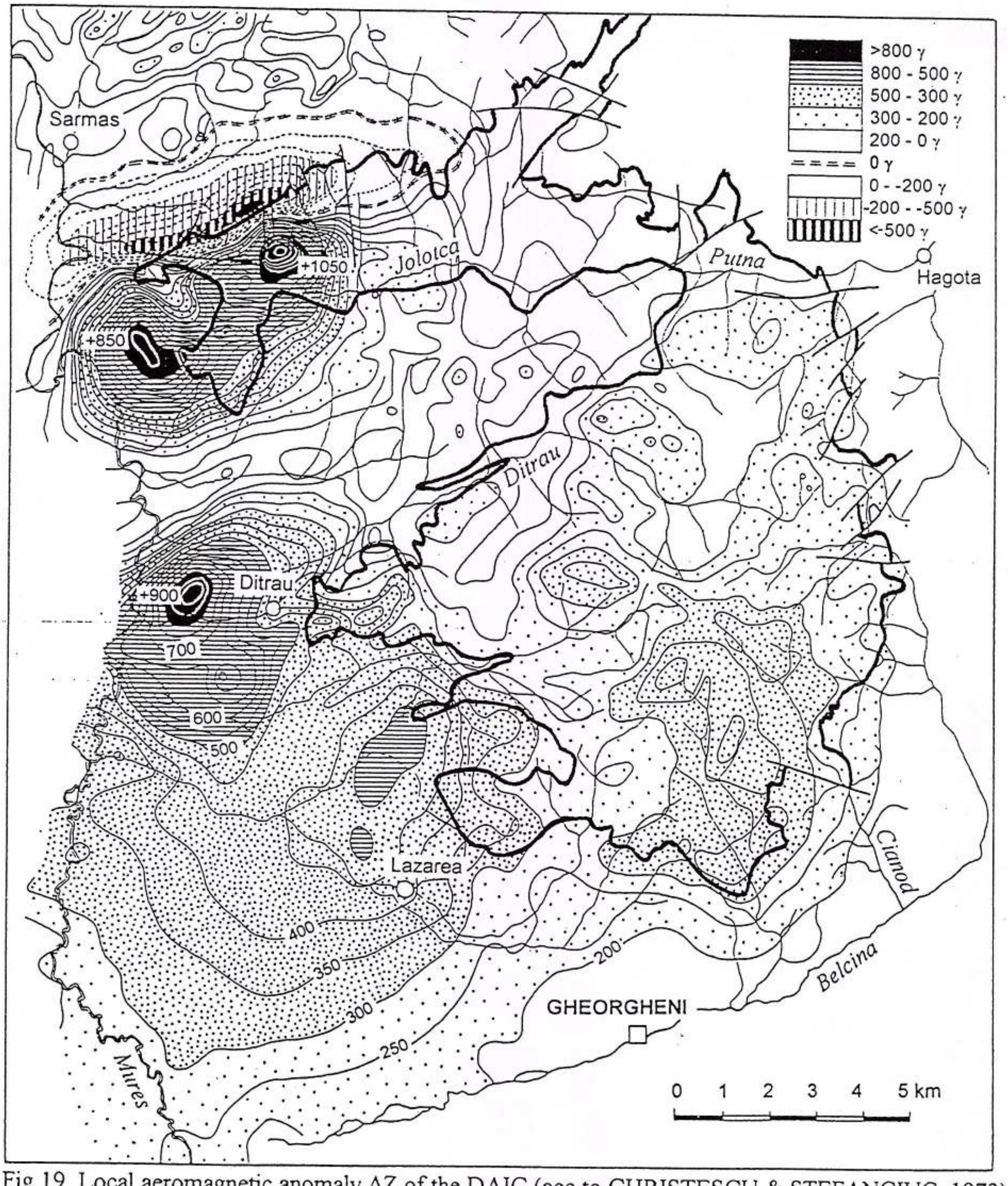
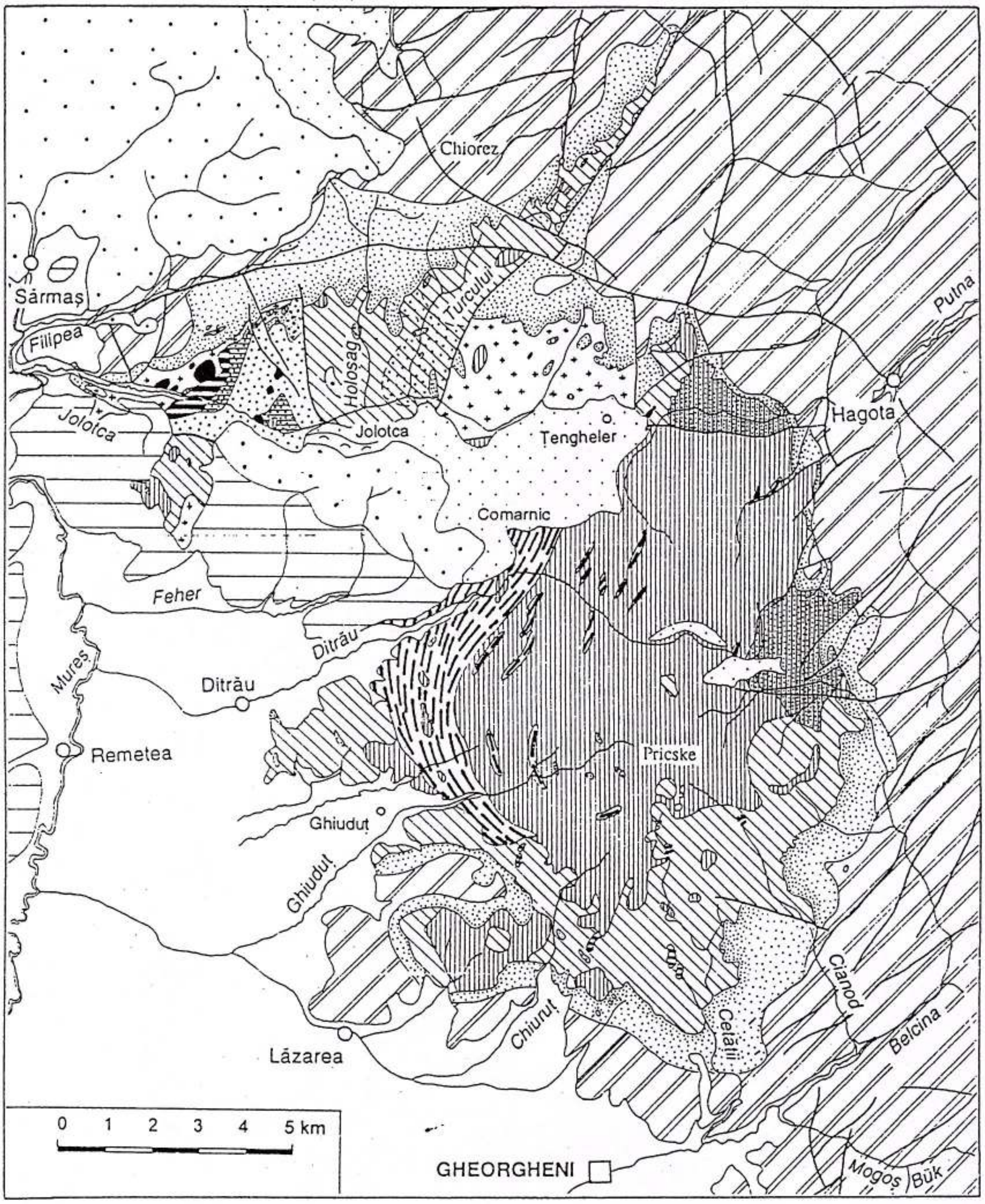


Fig.19 Local aeromagnetic anomaly ΔZ of the DAIC (acc.to CHRISTESCU & STEFANCIUC, 1973)

Fig.20

H.G. KRÄUTNER, G. BINDEA **GEOLOGICAL MAP OF THE DITRAU MASSIF**

(Data from BINDEA G., RUNCEANU M., ROBU I., ROBU L. (1994); ANASTASIU N., CONSTANTINESCU E. (1979); STRECKEISEN A. (1974)



Holocene

Pleistocene sedimentary deposits

a b Pliocene andesitic pyroclastics (a) and volcano-sedimentary formation (b)

Pre-Alpine metamorphites

DAIC

Mantle xenolith derived rocks
Hornblendite, pyroxene hornblendite (AB)

Gabbro-diorites and derived hybrid rocks
Jolotca complex (AB)
Gabbro, diorite

Monzodiorite

Monzonite

Syenite

Giudut complex (AD)
„Ditro essexite"

Syenites and derived hybrid rocks
Syenite, alkali feldspar syenite (C)

Monzonite, quartz monzonite (CX)

Granite, alkali feldspar granite (CX ?)

Nepheline syenitic rocks (D)
Nepheline syenite,
nepheline bearing alkali feldspar syenite

Altered syenitic rocks
Muscovitized (liebneritized) nepheline syenites and syenites

Thermal contact aureole
Hornfelses

5. Uplifting of the Bucovinian continental crust including the Ditrau massif lasted till 115 Ma ago (Aptian), covering an other period of about 20 Ma. In this period The DAIC was raised above the 300°C isotherm and Ar loss was definitively stopped. It may be assumed that postmagmatic hydrothermal alteration (liebneritization) and mineralization developed in this time. Aptian uplifting of the DAIC is proved by regional geological development. Upper Barremian-Aptian wildflysch including ophiolite olistolites formed on the western margin of the Bucovinian terrane, indicating obduction of oceanic slabs from the Tethys and crustal thickening by incipient nappe staking, that predates the main Meso Cretaceous shortening (tectogenesis).

References

ANASTASIU N., CONSTANTINESCU E. (1978) - Les feldspaths potassiques du massif alcalin de Ditrau. (in Romanian) *D. S. Inst. Geol. Geofiz.*, ***LXIV*, *1*, *13-36. Bucuresti.***

ANASTASIU N., CONSTANTINESCU E. (1980) - Structure du massif alcaline de Ditrau. *Anal. Univ. Bucuresti,* ***XXIX*,** *3-22, Bucuresti.*

ANASTASIU N., CONSTANTINESCU E., GARBASEVSKI N., JAKAB G. (1983) - Petrografia si petrogeneza rocilor filoniene din masivul alcalin de la Ditrau. *St. cerc. geol., geofiz.. geogr., seria Geologie,* ***28*,** *17-23, Bucuresti.*

ANASTASIU N., CONSTANTINESCU E. (1984) - Contributions à la connaissance pétrologique et structurale du massif alcalin de Ditrau - Implications métallogénetiques. *Anal. Univ. Bucuresti,* ***XXXIII*,** *43-49, Bucuresti.*

ANASTASIU N., CONSTANTINESCU E., JAKAB G., GARBASEVSKI N. (1985) - Structural control of vein setting in the alkaline massif of Ditrau. *Anal. Univ. Bucuresti,* ***XXXIV*,** *15-22, Bucuresti.*

ATANASIU I. (1929) - Etudes géologiques dans les anvirons de Tulghes, district Neamtu. *An. Inst. Geol. Rom.,XIII, 165-508, Bucuresti.*

BAGDASARIAN G.P. (1972) - Despre vîrsta absoluta a unor roci eruptive si metamorfice din masivul Ditrau si Muntii Banatului din Romania. *St. cerc.geol., geofiz.. geogr., seria Geologie,* ***17/1*,** *13-21, Bucuresti.*

BALINTONI I., CHITIMUS V. (1973) - Prezenta paramorfozelor de rutil dupa brookit in cristalinul seriei de Tulghes (Carpatii Orientali). *St. cerc. geol., geofiz., geogr.. seria Geologie,* ***18/2*.** *329-334, Bucuresti.*

BALINTONI I., GHEUCA I. (1977) - Metamorfism progresiv, metamorfism regresiv si tectonica in regiunea Zugreni-Barnar (Carpatii Orientali). *D. S. Inst. Geol. Geof..* ***LXIII/5***.*11-38. Bucuresti.*

BALINTONI I. (1981) - The importance of the Ditrau alkaline massif emplacement moment for the dating of the basement overthrusts in the East Carpathians. *Rev. roum.géol., géophys., géogr., serie Géologie,* ***25*,** *89-94, Bucuresti.*

BALINTONI I. (1984) - Structure of the right side of the Bistrita river between Ciocanesti and Vatra Dornei (Carpathes Orientales). *D. S. Inst. Geol. Geofiz.,* ***LXVIII/5***,*5-21, Bucuresti.*

BANCILA I. (1941) - Étude géologique dans les monts Haghimas-Ciuc (Carpathes Orientales). *An. Inst. Geol. Rom.,* ***XXI*,** *1-118, Bucuresti.*

BERCIA I., KRÄUTNER H.G., MURESAN M. (1976) - Pre-Mesozoic metamorphites of the East Carpathians. *An. Inst. Geol. Geofiz.,* ***50*,** *37-70, Bucuresti.*

BOIKO K. A., BARTNITKII E. N., ELISEEVA G. D., KAZANTEVA A. I., LEVKOVSKAIA N. I., OVSICENKO V. D., TERET G. E. (1975) - Results of the first investigation on zirkon geochronology of the crystalline basement in the Soviet Carpathians (in Russian). *Geol. Journ. AN USSR, 35/2, 112-116, Kiew.*

CODARCEA A., DESSILA-CODARCEA M, IANOVICI V. (1958) - Structure géologique du massif des roches alcalines de Ditrau. *Rev. Geol. Geogr. Acad.R.P.Roumanie,* ***2*, *1*,** *1-135. Bucuresti.*

DALLMEYER R. D., KRÄUTNER H G., NEUBAUER F. (1986) - Middle - Late Triassic $^{40}Ar/^{39}Ar$ hornblende ages for intrusion of the Ditrau alkaline massif, Romania: Implications for Alpine rifting in the Carpathian orogen. *(subitted to Sschw. Min. Petr. Mitt.)*

FÖLDVARI A. (1946) - Age and contact-metamorphic effects of the nepheline syenite stock of Ditró (Transsylvania) (in Hungarian). *Besz. Magy. All. Földt. Int., **VIII, 1-2**, 11-32, Budapest.*

GOHN E., ISVOREANU I, SCURTU S., HEREDEA N. (1973) - Investigations aéroradiométriquesdans le massif de Ditrau et dans les formations adjacentes (in Romanian) *St. Cerc. Geol. Geofiz. Geogr., seria Geologie, **11, 1**, 3-11, Bucuresti.*

GOROHOV I. M., RUDAKOV G. G., VARSHAVSKAIA E. S., MOROZOVA I. M. (1967) - Geohronological investigation of the metamorphic rocks from the Civcin Massif by K-Ar and Rb-Sr isochrons (in Russian). *In: Voprosi datirovki geologiceskich abrazovanii i osnovnich parod, Izdat. Nauka.*

GOROHOV I. M., LEVCHENKOV O. L. (1982) - In connection with the article by A.K.Boiko „The interpretation of radiometric dating of ancient formations of the Ukrainian Carpathians" (in Russian). *Geol. Jour., **42/3**, 138-141, Kiew.*

GRADSTEIN F. M., AGTERBERG F. P., OGG J. G., HARDENBOL J., VEEN P. van, THIERRY J., HUANG Z. (1994) - A Mesozoic time scale. *Jour. Geophys. Research, **99, B12**, 24,051-24,074.*

IANOVICI V., RADULESCU D., RADULESCU I., SANDULESCU M. (1968) - Crystalline Mesozoic complexes and volcanism in the East Carpathians (central sector). *Int. Geol. Congr., XXIII sess. Prague 1968, Guide to excursion 47 AC Romania, 52 pp., Bucuresti.*

ILIESCU V., KRÄUTNER H. G., KRÄUTNER FL., HANN H. (1983) - New palynological proofs on the Cambrian age of the Tulghes Group (East Carpathians): *An. Inst. Geol. Geofiz., **59**, 7-17, Bucuresti.*

JAKAB G. (1982) - Studiu mineralogic si geochimic al mineralizatilor metalifere dintre dintre Voslabeni si Corbu. (Teza de doctorat). *Univ. „Al. I. Cuza", Iasi.*

JAKAB G. (1986) - Geochemical data on the different origin of two phases of syenitic intrusion in the Ditrau alkaline massif. *D. S. Inst. Geol. Geofiz., **70-71, 1**, 363-372, Bucuresti.*

KRÄUTNER H. G., KRÄUTNER F. (1970) - Les formations cristallines du versant septentrional du massif Rodna. *D. S. Inst. Geol., **LV, 1**, 173-196, Bucuresti.*

KRÄUTNER H. G. (1972) - Hercynische Regionalretromorphose im präkambrischen Kristallin der Ostkarpaten. *Rev. roum. géol., géophys., géogr., serie Géologie, **16/2**, 121-129. Bucuresti.*

KRÄUTNER H. G., SASSI F. P., ZIRPOLI G., ZULIAN T. (1975) - The pressure characters of the pre-Alpine metamorphisms in the East Carpathians (Romania). *N. Jb. Min., Abh., **125/3**, 278-296, Stuttgart.*

KRÄUTNER H. G., KRÄUTNER FL., TANASESCU A., NEACSU V. (1976) - Interpretation des âges radiometriques K-Ar pour les roches métamorphiques régénérées. Un exemple - les Carpathes Orientales. *An. Inst. Geol. Geofiz., **50**, 167-229, Bucuresti.*

KRÄUTNER H.G. (1980) - Lithostratigraphic correlation of Precambrian in the Romanian Carpathians. *An .Inst. Geol. Geophys.,**LVII**, 292-296, Bucuresti.*

KRÄUTNER H. G. (1988) - Interregional correlations. *In "Precambrian in younger fold belts: European Variscides, the Carpathians and Balkan" eds. V.Zoubek, J.Cogné, D.Kozhoukharov, H.G.Kräutner, 853-862, John Wiley & Sons.*

KRÄUTNER H. G., SZASZ L., KRÄUTNER FL., BINDEA G., MUNTEANU M., ION J.(1991) - Sheet Cosna of the geological map of Romania 1:50 000 (preprint). *Inst. Geol. Geofiz., Bucuresti.*

KRÄUTNER H.G. (1991) - Stratigraphic, metamorphic and deformational unconformity between the Variscan and Precambrian metamorphics of the East Carpathians. *Mineralia Slovaca, **23**, 421-429, Alfa Bratislava.*

KRÄUTNER H. G., BINDEA G., VOICU G., RUNCEANU M., MUNTEANU M., LUPULESCU M., LUPULESCU A., VAIDA M. (1992) - The metamorphic rocks of the Gîrbova massif (in romanian). *Rom. Journ. Petrology, **75**, 161-181, Bucuresti.*

KRÄUTNER H. G., ROBU L., ROBU I., BINDEA G. (1993) - Zircon typology in porphyroids of the East Carpathians. *Rom. Journ. Mineralogy, **76 / 1**, 103-108, Bucuresti.*

KRÄUTNER H. G. (1994) - Pre-Alpine terranes in the Romanian Carpathians. *Rom. Journ Petrology, **75,supl.1**, 31-32, Bucuresti.*

KRÄUTNER H. G. (1996) - Terrane descriptions: Eastern Carpathians. *(in press)*

LE MAÎTRE R.W.(edt.) (1989) - A classification of igneous rocks and glossary of terms. *193 pp., Blackwell Sci. Publ., Oxford.*

MÎNZATU S., VÂJDEA E., ROMANESU O., IOSIPCENCO N. (1981) -K-Ar ages of the Ditrau massif (internal report in Romanian) *Unpubl., IGG, Bucuresti*

MOROGAN V., UPTON B. G. J., BINDEA G. (1994) - Petrogenesisof the Ditrau complex, East Transylvania, Romania. *Abstr. Min. Symp. Pisa. Italy.*

MURESAN G., MURESAN M. (1972) - Sur la présence des conglomérates métamorphisés dans la série de Tulghes (Carpates Orientales) (in Romanian, Franch summary) *D.S. Inst.Geol., LVIII, 1, 243-256, Bucuresti.*

MURESAN M. (1973) - Izvorul-Mures Series - a new Paleozoic series in the East Carpathians (in romanian). *D. S. Inst. Geol., LIX/4, 65-70, Bucuresti.*

MURESAN M., MURESAN G. (1980) - Granitoides associées au Précambrien métamorphique des Carpathes Orientales. *An. Inst. Geol. Geofiz., LVII, 367-402, Bucuresti.*

MURESAN M (1983) - Relations entre le massif alcalin de Ditrau et les nappes de charriage des Carpathes Orientales. *An. Inst. Geol. Geofiz., LX, 159-167, Bucuresti.*

PÁL-MOLNÁR E. (1992) - Petrographical characteristics of Ditrò (Orotva) hornblendites. Eastern Carpathians, Transylvania (Romania): A preliminary description. *Acta Min. Petr. Szeged, XXXIII, 67-80, Szeged.*

PÁL-MOLNÁR E. (1994) - Petrographical characteristics of Ditró (Orotva) diorites, Eastern Carpathians, Transsylvania (Romania) *Acta Min. Petr. Szeged, XXXV, 95-109, Szeged.*

PÁL-MOLNÁR E., ÁRVA-SÓS E. (1995) - K/Ar radiometric dating on rocks from the northern part of the Ditró syenite massif and its petrogenetic implications. *Acta Min. Petr. Szeged. XXXVI, 101-116, Szeged.*

POP G., AILENEI G., CRISTEA I., SOROIU M., POESCU G. (1974) - Evolution of the metamorphic belt in the Romanian East Carpathians as revealed by K-Ar dating. *Rev. roum. géol., géophys., géogr., serie Géologie, 18, 141-148, Bucuresti.*

PUPIN J. P. (1980) - Zircon and granite petrology. *Contr.Mineral. Petrol., 73, 207-220, Berlin.*

PUPIN J. P., TURCO G. (1981) - Le zircon, minéral commun significatif des roches endogènes et exogènes. *Bull. Minéral., 104, 723-731, Paris.*

SANDULESCU M., KRÄUTNER H. G., BALINTONI I., RUSSO-SANDULESCU D., MICU M. (1981) - The structure of the East carpathians (Moldavia-Maramures area). *Guidebook ser., Inst. Geol. Geofiz., 92p., Bucuresti.*

SANDULESCU M. (1984) - Geotectonica Romaniei. *Edit. teh., 336p., Bucuresti.*

SANDULESCU M., RUSSO-SANDULESCU D., UDRESCU C., MEDESAN A. (1986) - Position structurale, pétrologie et ambiance géotectonique des magmatites Mésozoiques de Tara Bîrsei. *D. S. Inst. Geol. Geofiz., 70-71, 5, 197-221, Bucuresti.*

SANDULESCU M. (1990) - Paleogeography of the Romanian Carpathians and Foreland. *In: Evolution of the Northern Margin of Tethys, vol.III, Pt 1, (edited by M.Rakús, J. Decourt, A.E.M.Nairn), Mém.Soc.Géol.France.Nouvelle serie No.154, (III,Pt.1), 91-100, Paris.*

SAVU H., VÂJDEA E., ROMANESCU O. (1986) - The radiometric age (K-Ar) and the origine of the Savarsin granitoid massif and of other late Kimmerian intrusions from the Mures zone. *D. S. Inst. Geol. Geofiz., 70-71/1, 419-429, Bucuresti.*

SAVUL M., MASTACAN GH. (1952) - Contributii la cunoasterea gnaiselor porfiroide din Carpatii Orientali. *Acad. RSR, Bul. st. (sectia bio.-agr.-geol.-geogr.), IV/2, 427-439, Bucuresti.*

STRECKEISEN A. (1931) - Über das Nephelinsyenitmassiv von Ditro (Rumänien). *N. Jb. Miner. Geol. Pal., Beilage Band 64, Abt.A, (Brauns-Festband), 615-628.*

STRECKEISEN A. (1934) - Zur Differentiation im Nephelinsyenit-Massiv von Ditro (Rumänien). *Bul. Lab. Miner. Univ. Bucuresti, 1, 3-9, Bucuresti*

STRECKEISEN A. (1938) - Das Nephelinsyenit-Massiv von Ditro in Rumänien als Beispiel einer kombinierten Differentiation und Assimilation. *Verh. Schweiz. Naturf. Ges.,1938, 159-161.*

STRECKEISEN A. (1940) - Über Migmatite im Kristallin der Ostkarpathen. *Schw. Min. Petr. Mitt., 20, 299- 302.*

STRECKEISEN A. (1952, 1954) - Das Nephelinsyenit-Massiv von Ditro (Siebenbürgen).
Teil I. *Schweiz. Min. Petr. Mitt., 32,(1952), 251-309,*
Teil II. *Schweiz. Min. Petr. Mitt., 34, (1954), 336-409.*

STRECKEISEN A. (1960) - On the structure and origine of the nepheline-syenite complex of Ditro (Transsylvania, Romania). *21th Int. Geol. Congr.*, ***Part 13****, 228-238,*

STRECKEISEN A., HUNZIKER J. C. (1974) - On the origine and age of the nepheline-syenite massif of Ditro (Transsylvania, Romania). *Schweiz. Min. Petr. Mitt.*, ***54/1****, 59-77,*

VÂJDEA E., ANASTASE S. (1975) - Absolute dating by the method of common lead of some deposits connected with the crystalline massifs of the East Carpathians (Romania). *Proc.10th Congr. Carpatho-Balk. Geol. Assoc.*, ***IV****, 253-260, Bratislava.*

ZIRKEL F. (1886) - Lehrbuch der Petrographie.(vol. I). *Marcus, 607p., Bonn.*

APENDIX

Concepts on the Ditrau Alkaline Intrusive Complex
and
Ditrau Maps

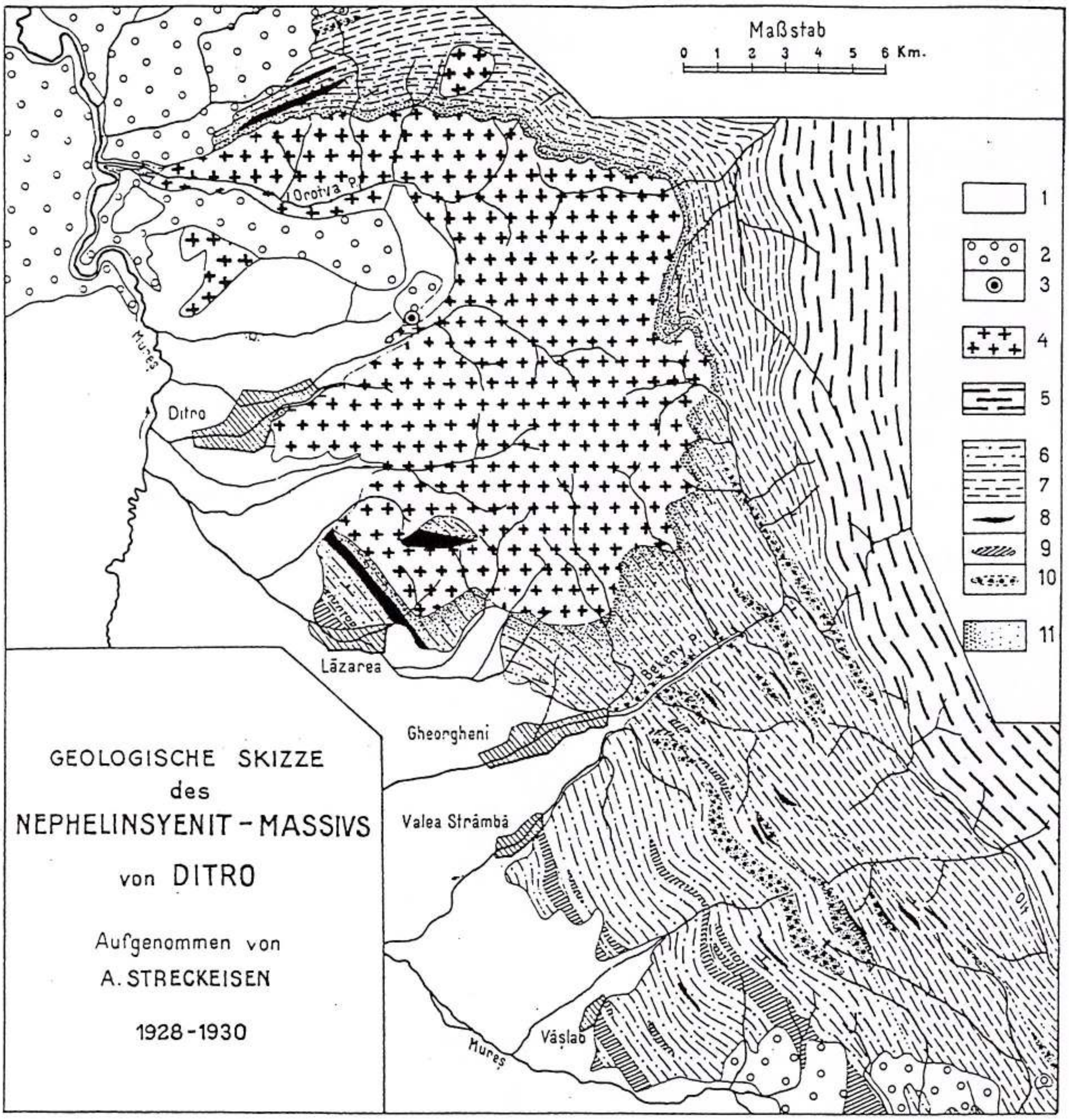
ALONG TIME !

1. Magmatic origin

a. Assimilation of limestones (Daly's theory) by a basic calc-alkaline magma gave an alkali-gabbroic magma which developed by fractional crystallisation to alkali-syenitic and nepheline syenitic magmas: ***A. STRECKEISEN (1931, 1934), A. FÖLDVARY (1946).***

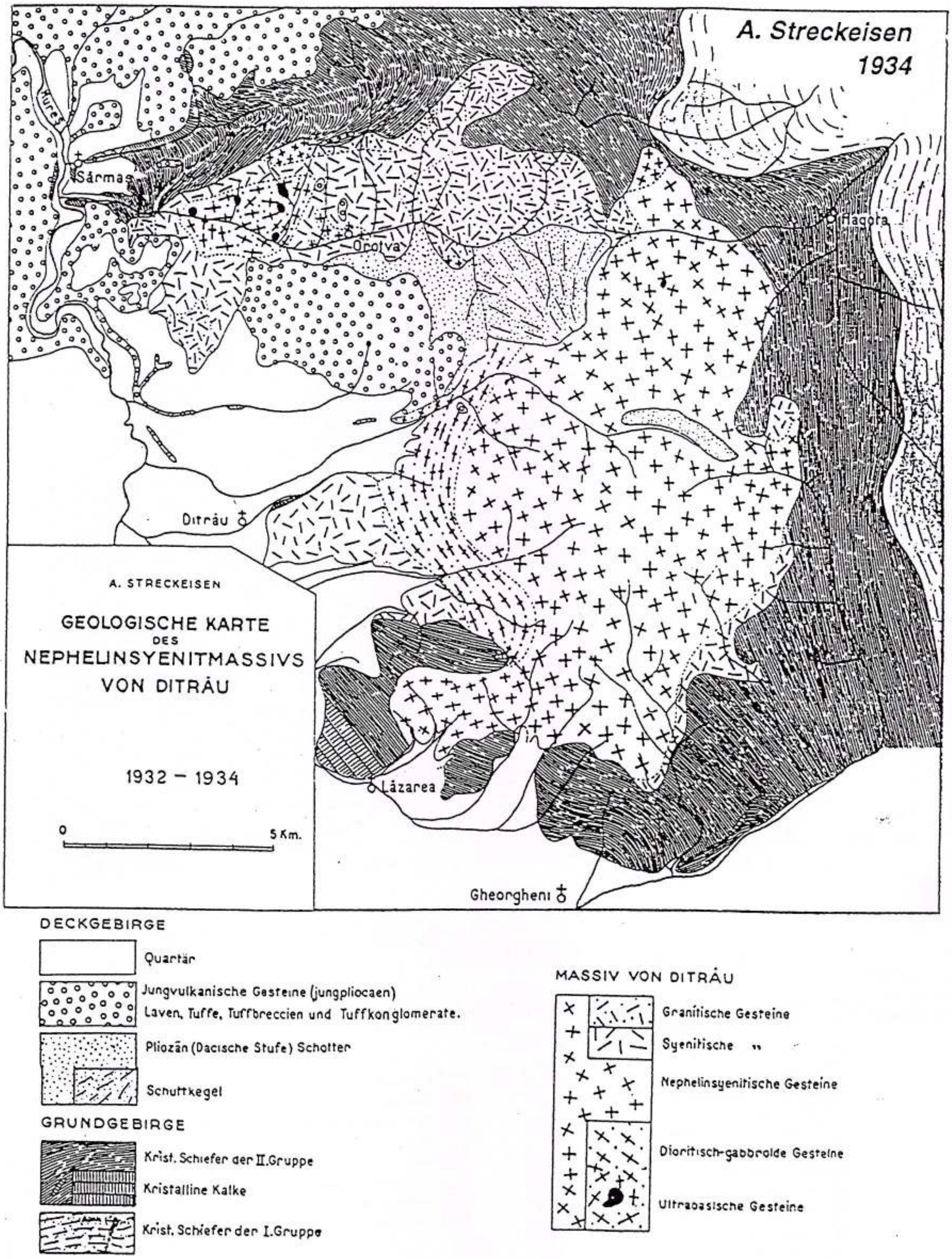
A. Streckeisen
1931

Brauns-Festband (N. Jahrb. f. Min. etc. Beil.-Bd. 64. Abt. A).



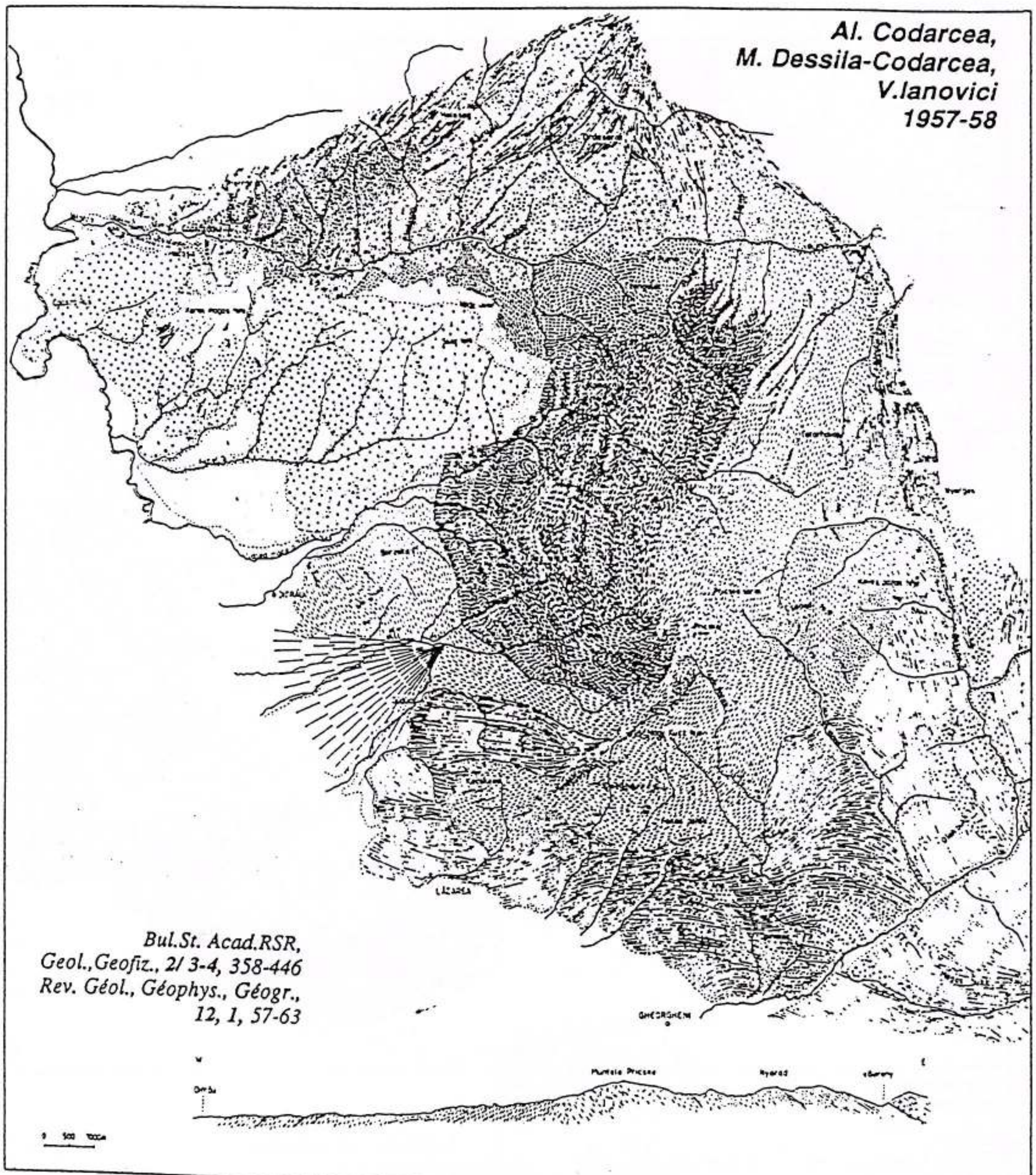
Legende zur geologischen Skizze.
Quartäre und pliocäne Schotter und Alluvionen. (1).
Jungvulkanische Gesteine: Tuffe und Tuffkonglomerate (2).
Basalt von Ditro (3).
Nephelinsyenitmassiv (4); sein Kontakthof (11).
Kristalline Schiefer:
Hăghimaşer Kristallin (5).
Giurgeuer Kristallin (6—10): Biotitführende Phyllite (6). Gewöhnliche Phyllite (7). Schwarze Quarzite und Graphitschiefer (8). Kristalline Kalke (9). Porphyrogene Gesteine (10).

b. Magmatic differentiation by fractional crystallisation and gravitational accumulation: ***V. IANOVICI (1933, 1938).***

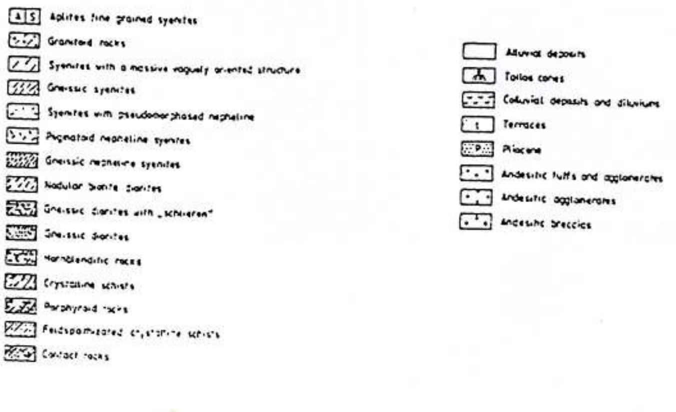


2. Two opposite concepts: migmatic-metasomatic versus magmatic

a. Migmatic cover of an anatectic diapir;
migmatic metasomatism: ***A. CODARCEA, M. DESSILA-CODARCEA, V. IANOVICI (1957, 1958)***



GEOLOGICAL MAP OF THE DITRĂU ALKALINE MASSIF



b. Magmatic differentiation with successive magma emplacements; *magmatic metasomatism:* ***A. STRECKEISEN (1960).***

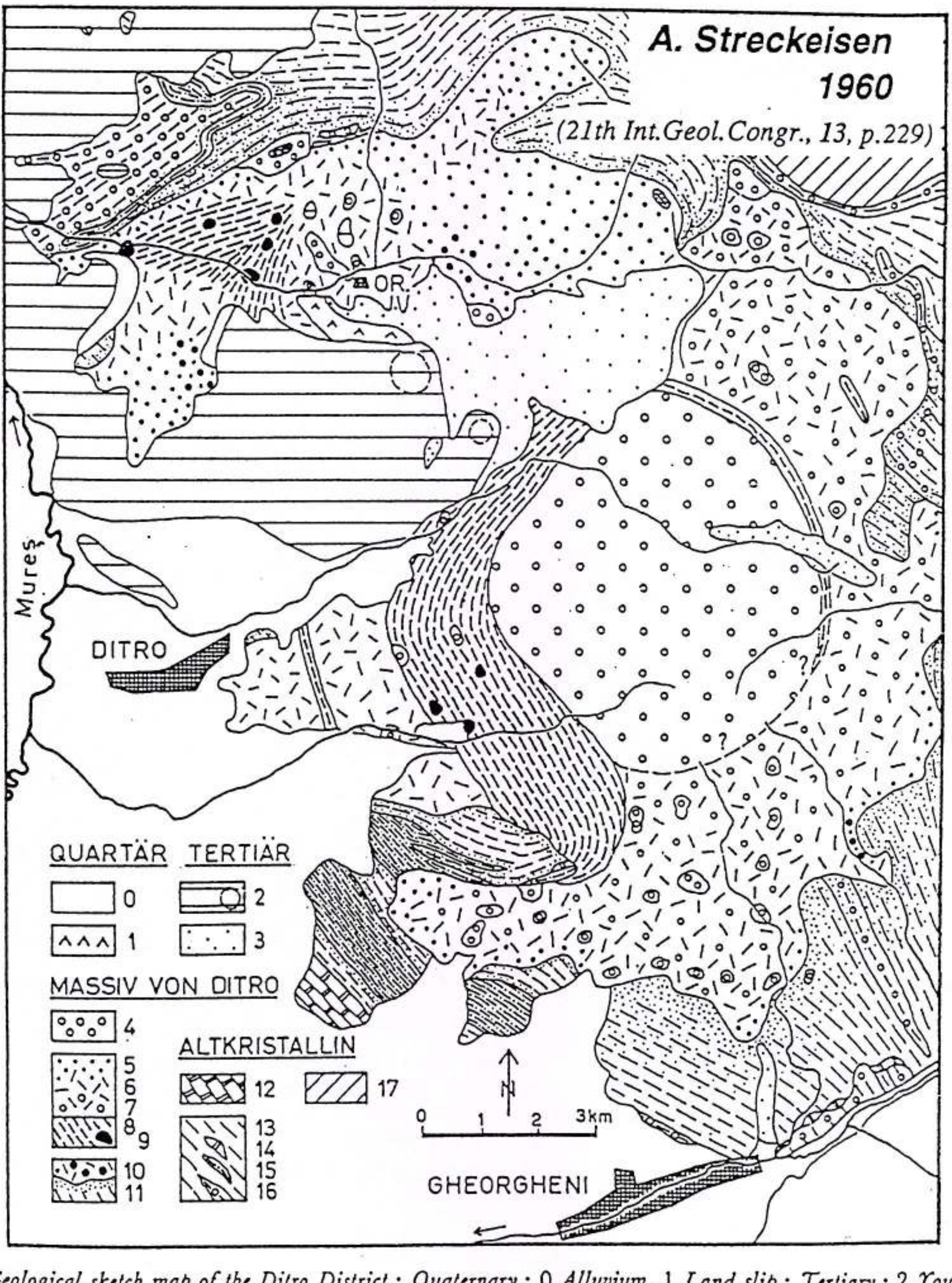


FIG. 1.—*Geological sketch map of the Ditro District: Quaternary:* 0 *Alluvium,* 1 *Land slip; Tertiary:* 2 *Young volcanic lavas, tuffs and agglomerates (with vent),* 3 *Pliocene; Ditro Igneous Complex:* 4 *Younger nepheline-syenite,* 5 *Alkali-granite,* 6 *Alkali-syenite,* 7 *Older nepheline-syenite,* 8 *Ditro-essexite,* 9 *Ultrabasite,* 10 *Xenoliths in the eruptive rocks,* 11 *Contact aureole; pre-Permian metamorphics:* 12 *Crystalline limestones and dolomites (of the mesozonal series),* 13–16 *Epizonal series* (13 *phyllites,* 14 *crystalline limestones,* 15 *black quartzites and graphitic schists,* 16 *metamorphic porphyrogene and tuffogene rocks),* 17 *High-grade metamorphic series (migmatites). OR=Orotva*

3. Ring structure:

A. STRECKEISEN (1954)

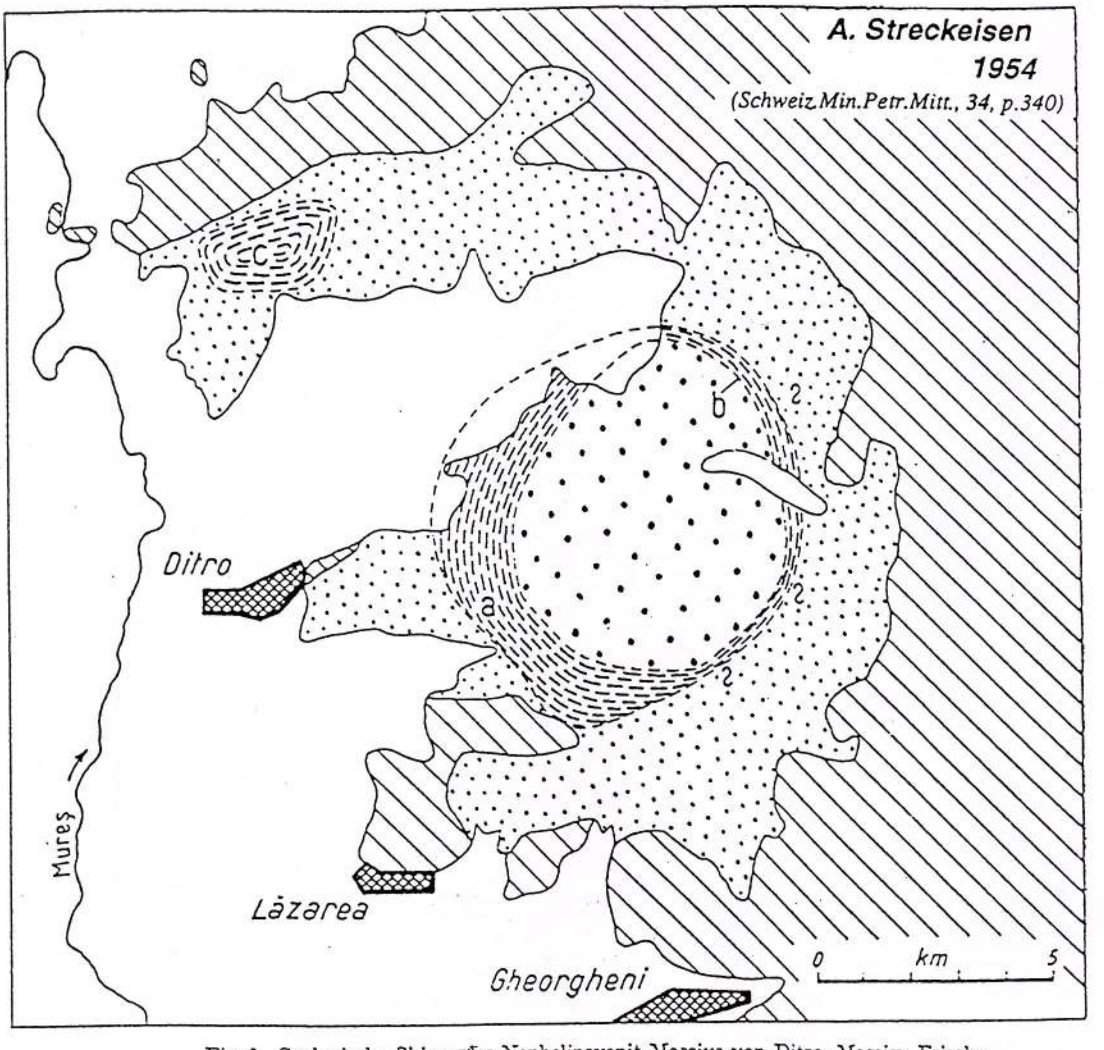
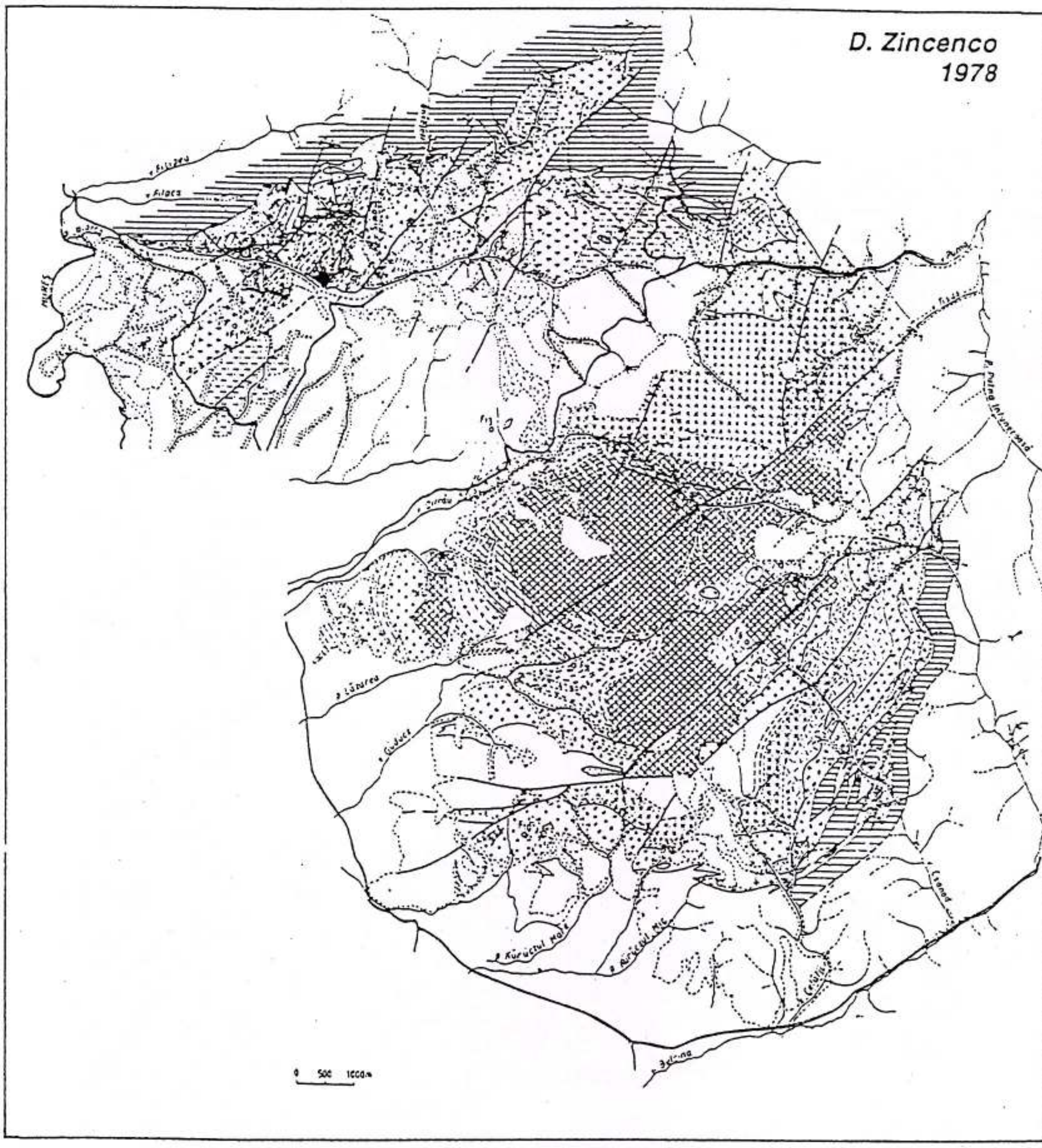


Fig. 1. Geologische Skizze des Nephelinsyenit-Massivs von Ditro. Massiv: Frische weisse Nephelinsyenite des Zentrums Piricske-Ujhavas (grob punktiert); Ditro-Essexite (gestrichelt); rötliche Nephelinsyenite, Alkalisyenite und Alkaligranite (fein punktiert). Altkristallin (gestrichelt). Weiss gelassen sind die das Massiv bedeckenden jüngeren Bildungen (jungvulkanische Gesteine, pliozäne und pleistozäne Ablagerungen).

a Güdücz-Zone, b Kecske rész, c Unt. Orotva-Tal.

D: ZINCENCO (1978)



GEOLOGICAL MAP OF THE DITRĂU ALCALINE MASSIF

DITRAU MASSIF (Jurasic 1-2)

MARGINAL RING

- Granitic rocks (contact facies)
- Granitic rocks
- Quartz - syenite
- Monzonite (oriented texture)
- Syenite (massiv texture)
- Liebneritized - sienite
- Diorite and monzonite (oriented texture)

JOLOTCA COMPLEX

- Diorite and hornblendite (oriented texture)
- Hornblendite and diorite with veins (massiv texture)
- Clinopiroxen hornblendite

CENTRAL STOCK

- Nephelin syenite (contact facies)
- Nephelin syenite (massiv facies)
- Nephelin syenite (oriented texture)

GŪOŪCZ COMPLEX

- Nephelin syenite, nephelin diorite, maphic rocks
- Nephelin syenite (oriented texture)
- Nephelin diorite
- Maphic and ultramaphic rocks with veims

THERMAL CONTACT AUREOLE

- Hormfelses
- Fault
- Stratigraphic unconformity
- Geological limite
- Limite of complexes

4. Different successive magmatic intrusions:

a. Successive emplacement of gabbro-dioritic magmas (1), syenitic magmas (2), nepheline syenitic magmas (3) followed by hydrothermal alteration:
A. STRECKEISEN & J. C. HUNZIKER (1974).

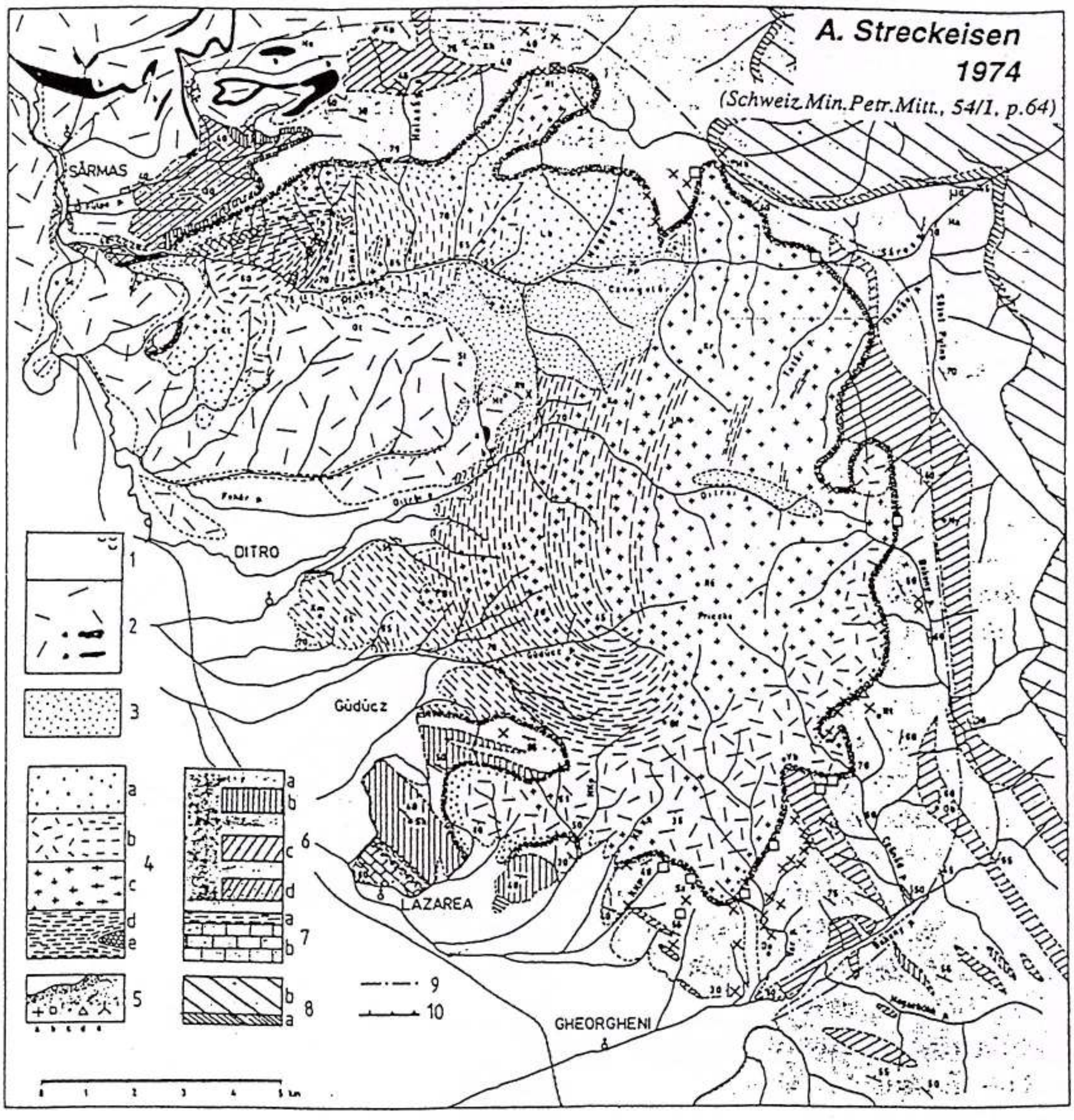
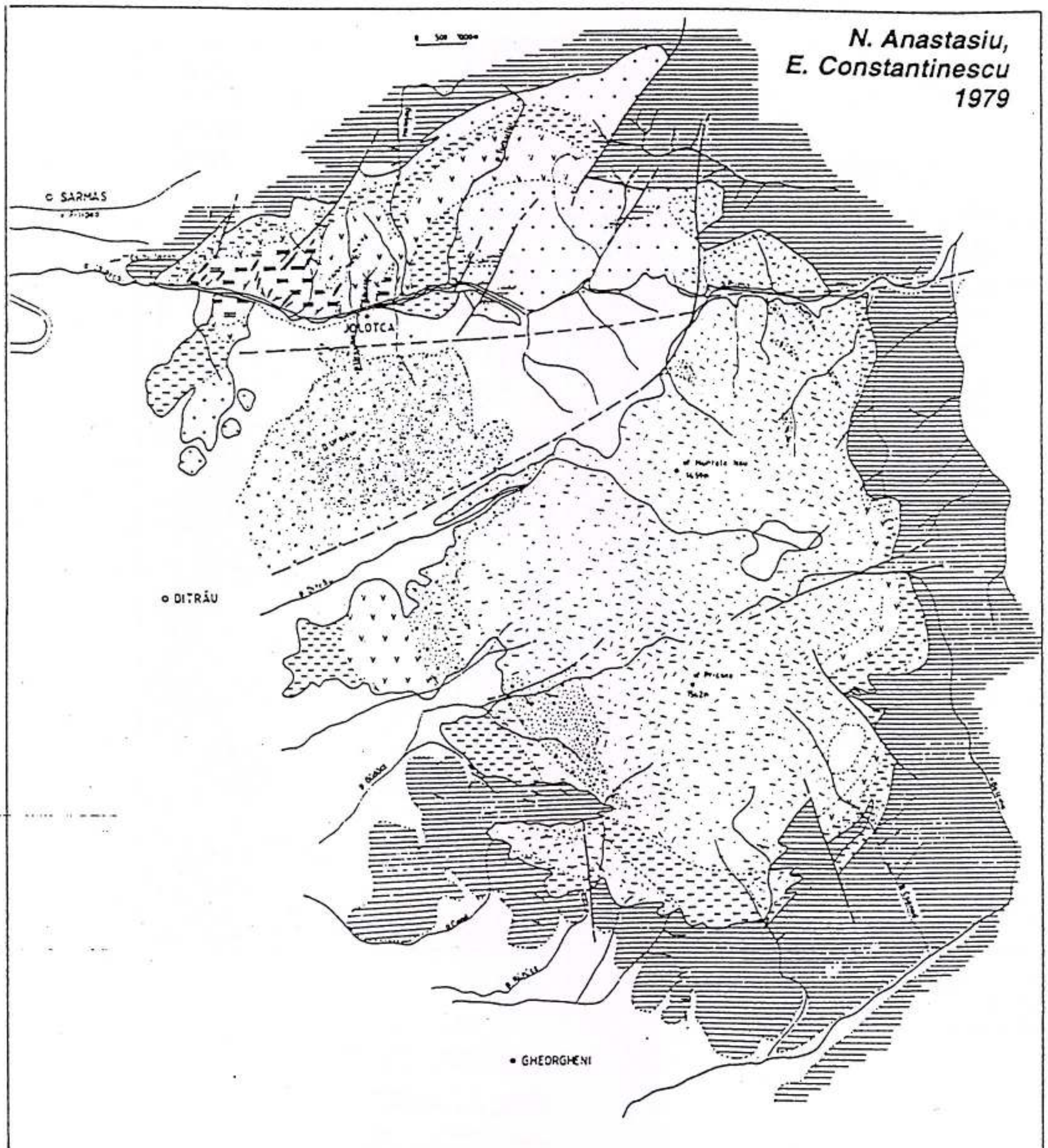


Fig. 2. Geological sketch map of the massif of Ditro and its surroundings, according to the mapping done by A. Streckeisen 1928–1935 and the maps presented by CODARCEA et al. (1958).

1 Quaternary deposits. 2 Pyroclastics and Volcanic-sedimentary complex; a) Andesite, b) Basaltic andesite. 3 Gravels and torrential deposits (Upper Pliocene or Lower Pleistocene). 4 Massif of Ditro: a) Granitoid rocks, b) Syenites, c) Nepheline syenites, d) Dioritic rocks (Ditro-essexites), e) Hornblendites. 5 Thermal contact aureole; contact minerals: a) andalusite, b) corindon, c) spinel, d) alkali amphibole, e) chloritoid. 6 Epizonal series (Tulgheş series): a) Phyllites, b) Black quartzites and graphitic schists, c) Metamorphosed porphyritic and tuffaceous rocks, d) Metamorphosed tuffaceous series of Sârmaş. 7 Mesozonal series (Bistriţa-Bârnar series): a) Micaschists, b) Crystalline limestones and dolomites. 8 High-grade metamorphic series (Rarău gneiss series): a) Flaser and augen gneisses of Rarău type, b) Garnet micaschists, migmatites and anatexites. 9 Outer limit of contact aureole. 10 Thrust plane of the Rărau gneiss nappe.

b. Successive intrusion and mixing of two different magma types - a basic subcrustal magma (1) and an alkaline crustal magma (2): ***N: ATANASIU & E. CONSTANTINESCU (1978)***.

c. Three successive intrusive phases, represented by the basic-ultrabasic complex (1), marginal red-syenite complex of sialic character, central white syenite complex with simatic geochemical signature: ***G. JAKAB (1982, 1986)***.



GEOLOGICAL MAP OF THE DITRĂU ALKALINE MASSIF
(N. ANASTASIU, E. CONSTANTINESCU, 1979)

ROCKS OF THE MASSIF

ULTRAMAPHICS AND MAPHICS COMPLEX
- Hornblendite, hornblendite + biotite, hornblendite + pyroxene

DIORITICS COMPLEX
- Leucodiorite, diorite, meladiorite

SYENITES AND MONZONITES COMPLEX
- Monzodiorite, monzonite
- Syenite, alkali feldspar syenite

COMPLEX OF THE FOIDIC ROCKS
- Foid syenite, foid monzonite, foid monzosyenite
- Essexite

GRANITIC COMPLEX
- Granite, alkali feldspar granite

- Rebra-Barnar and Tulgheş series

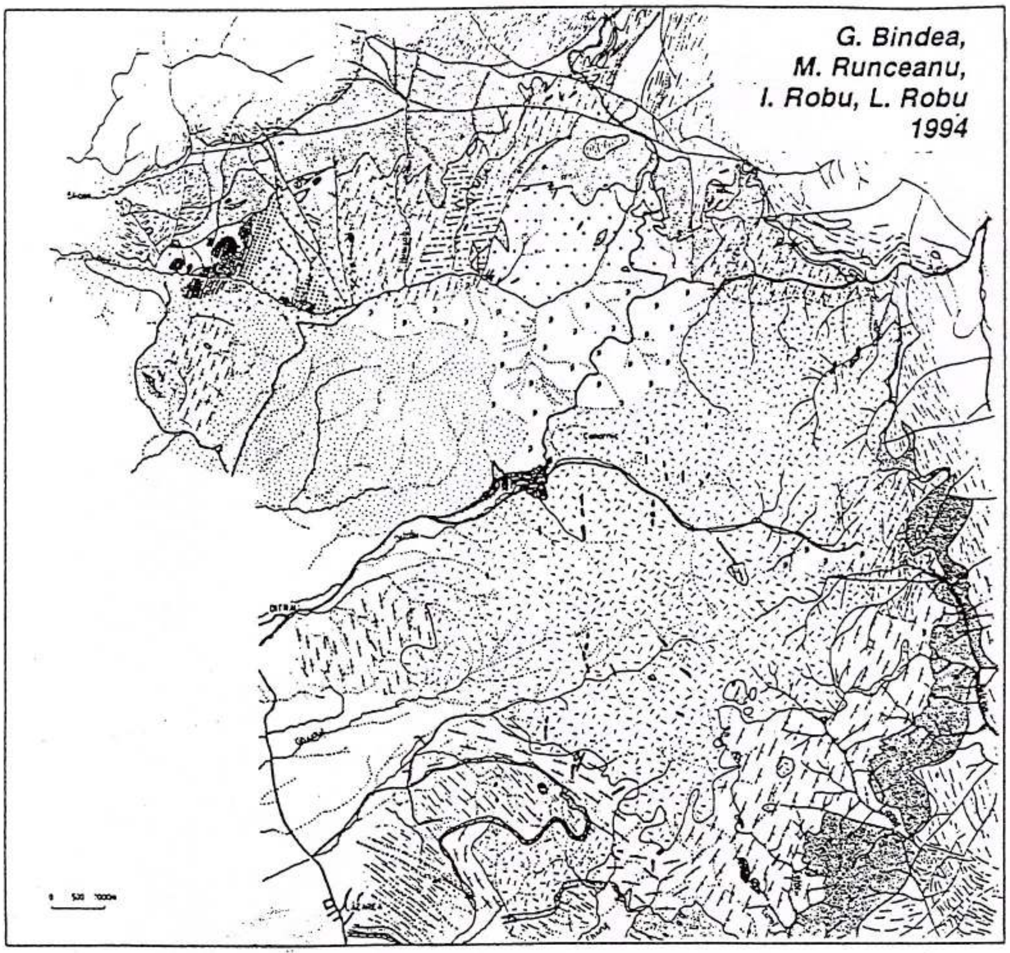
THERMAL CONTACT AUREOLE
- Hornfelses with biotite, corderite, andalusite

COVER
- Neogen magmatism
- Alluvial deposits
- Fault
- Geological limite of the Massif

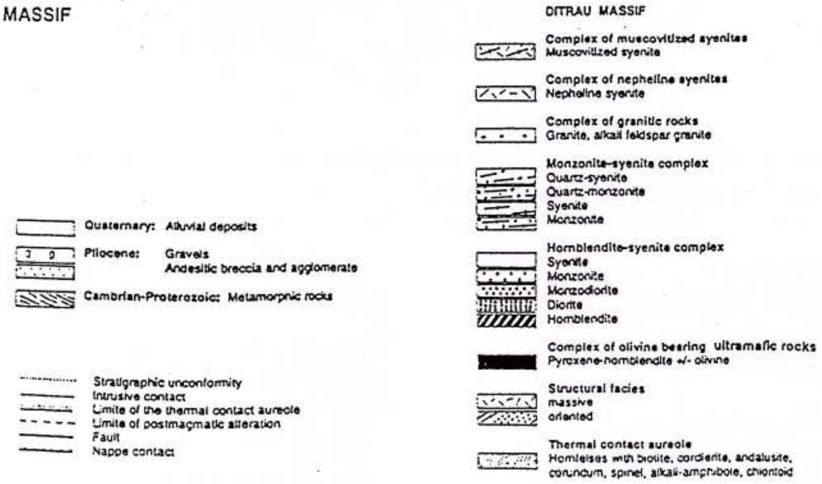
5. Actual state: parental rocks and hybrid rocks

a. Magmatic mixing in subsolidus stage of an alkali-basaltic parental magma with a crustal contaminated syenitic magma. Later intrusion of a nepheline syenitic and a crustal granitic magma: ***G. BINDEA (1994); V: MOROGAN, B. J. C. UPTON; G. BINDEA, (1994)***.

b. Intrusion sequence in the Middle Triassic extensional stage (^{40}Ar-^{39}Ar = 231-227 Ma), due to mantle plum activity predating Jurassic rifting: ***R. D. DALLMEYER, H. G. KRÄUTNER, F. NEUBAUER (1996)***.

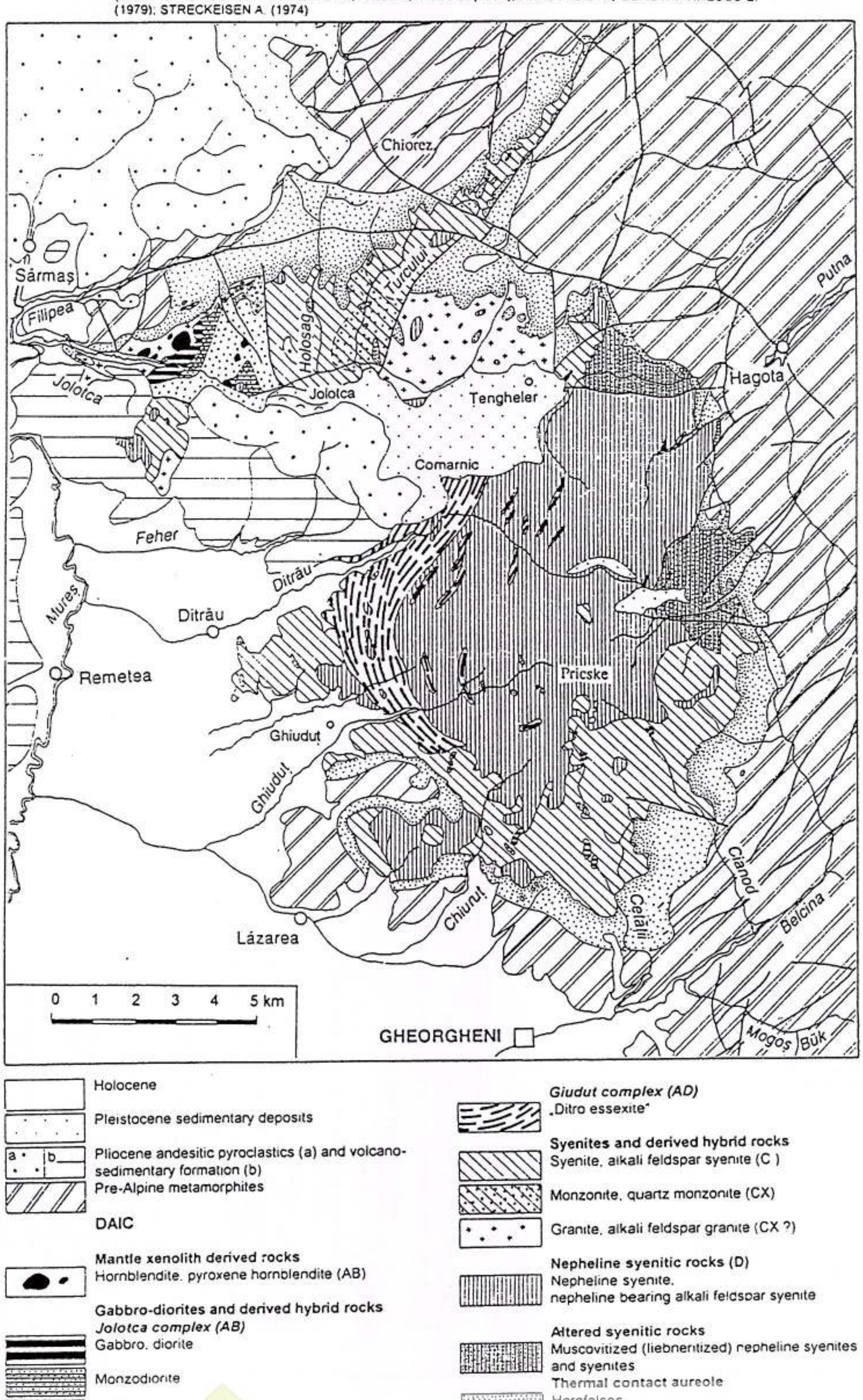


GEOLOGICAL MAP
OF THE
DITRAU MASSIF



c. Three main intrusion phases during the Triassic extensional stage and the Jurassic-rifting stage. 1) Gabbro-dioritic intrusion (231-227 Ma, Ladinian-Carnian) caring mantle xenoliths, 2) syenitic intrusion (216-212 Ma, Norian) giving syenites and hybrid dioritic-monzonitic rocks by mixing with previous magmatic products and granitic rocks by contamination with quartz rich metamorphics, 3) nepheline syenitic intrusion (161-155 Ma, Callovian-Oxfordian) giving nepheline syenites and hybrid basic foid rocks („ditro essexite") by partial substitution of previous gabbro-dioritic rocks. During the cooling stage (till 135/115 Ma) developed late- and post-magmatic alteration and mineralization: ***H. G. KRÄUTNER, G. BINDEA (1996, this contribution)***.

H.G. KRÄUTNER, G. BINDEA GEOLOGICAL MAP OF THE DITRAU MASSIF
(Data from BINDEA G., RUNCEANU M., ROBU I., ROBU L. (1994); ANASTASIU N., CONSTANTINESCU E. (1979); STRECKEISEN A. (1974)



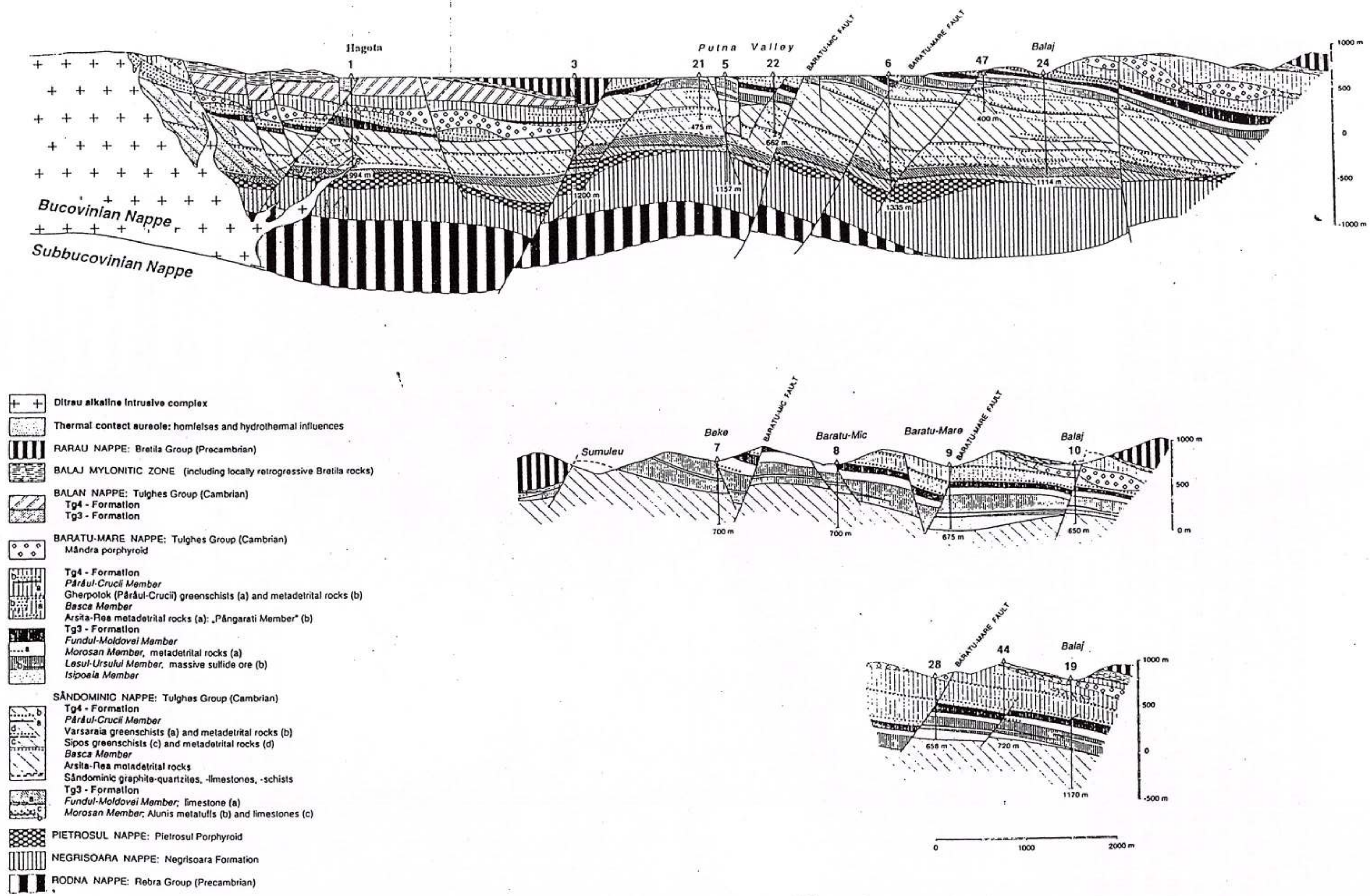


Fig. 7. Geological cross-sections east of the Ditrau Massif (Hagota - Baratu-Mare - Tulghes)