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TRANSGRESSIVE URGONIAN SEQUENCE WITH BLACK "PEBBLES" FROM THE VILLÁNY MOUNTAINS, HUNGARY

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The Urgonian Lower Cretaceous sequence explored in the Nagyharsányhegy quarry in a thickness of 200 m is reviewed. Based on the thin section investigations carried out in the lower 70 m section of the four units of member rank 9 facies types are discussed. Based on the poorish fauna and of the macroscopic characteristics the changes of salinity oscillating between the freshwater and marine conditions are determined. The interpretation of formation of the frequent black limestone breccia considered as an element of the Lofer-cycle is dealt with in detail. Starting from macroscopic characteristics (texture, structure, fauna) the paleogeographic reconstruction of the area is carried out. In this respect the existence of an external and of an internal lagoon were determined. It is emphasized that the investigations in progress have stressed the remarkable difference between this occurrence and the base strata of the neighbouring outcrops (Hauterivian and Albian, respectively).

Keywords: Villány Mountains, carbonate sedimentology, Urgonian facies, Lofer-cycle, Valanginian-Albian microfossil

Geological setting

The Nagyharsány Limestone Formation developed in the structural zone of the Villány Mountains has a special position among the varied Urgonian formations of different age of Hungary (Fig. 1). The formation that can be traced by boreholes beneath the Tertiary formations as far as the Királyerdő in Transylvania with some breaks (Patrulius, D., 1976; Fülöp, J., 1966) overlies the youngermost incomplete Jurassic sequence, i.e. the superthick Kimmeridgian to Lower Tithonian shallow marine limestone by erosional unconformity (Fülöp, J., 1966) and the similar Lower Cretaceous limestone in the Danube-Tisza Interfluve (Bérczi-Makk, A., 1987). Between the underlying strata and the Urgonian limestone bauxite is found both in the Villány

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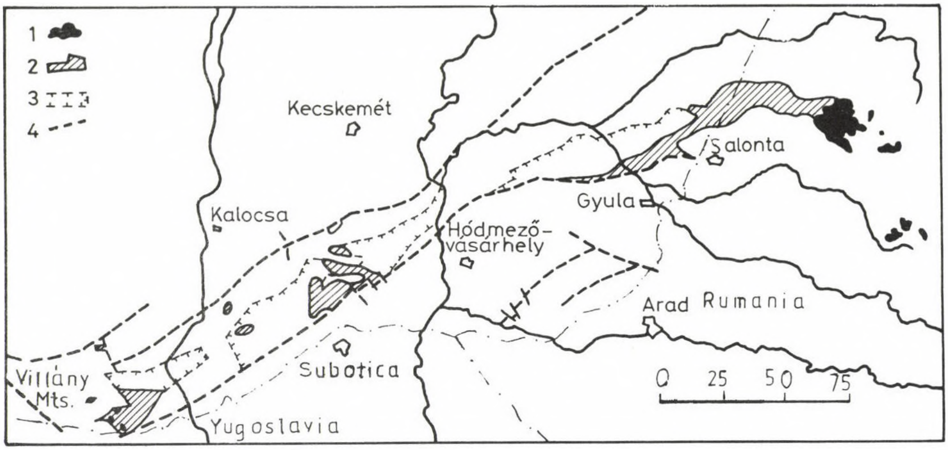


Fig. 1. Extension of Urgonian formations in the Villány zone. (Used maps: Fülöp, J. and Dank, V., 1987; Bérczi–Makk, A., 1987). 1. Urgonian limestone on the surface; 2. evidenced Urgonian limestone below the surface; 3. possible subsurface extension of the Urgonian limestone; 4. main tectonic lines

Mountains and in the Királyerdő, here in several horizons (Dragastan et al., 1986). As to the considerations so far in the overlying strata of the formation of originally presumably also changing thickness (from several tens of meters to several hundreds of meters) silty marl is found with unconformity both in the Villány Mountains (Fülöp, J., 1966) and in the Királyerdő (Bleahu, M. et al., 1981): this is called Bisse Marl Formation in the Villány Mountains and Ecléja Marl Formation in the Királyerdő. The age of the former was put to Lower-Middle Albian, that of the latter to Upper Aptian. In harmony with the results of hydrocarbon exploration wells drilled in the Danube–Tisza Interfluve a gradual transition can be probabilized between the two formations.

In the Villány Mountains of imbrication structure the Nagyharsány Limestone Formation is known only in the two outernmost imbrications, i.e. from that of Tenkes and of Villány (Fig. 2). The youngermost formation of the intermediate three imbrications is of Oxfordian age (Fülöp, J., 1966). The Cretaceous sequence of the two imbrications shows conspicuous differences. The Urgonian limestone with rudists and orbitolines in the Tenkes imbrication is 30 m thick and of Albian age is overlain with sharp boundary but with conformity by the Bisse Marl (Fülöp, J., 1966) while in the karstic cavities of the Barremian–Albian limestone of several hundred

Fig. 2. Structural sketch and Cretaceous formations of the Villány Mountains. (Used maps: Fülöp, I., 1966; Nagy, E., 1976.) 1. Bisse Marl Formation; 2. Nagyharsány Limestone Formation; 3. Harsányhegy Bauxite Formation; 4. Jurassic formations; 5. Triassic formations; 6. Paleozoic and metamorphic formations; 7. Mesozoic formations on the surface; 8. overthrust (imbrication); 9. fault

meter thickness and of varied structure of the Villány imbrication bauxitic clay is found (Császár, G., Farkas, L., 1982). In this paper some results on the unique sequence of the Nagyharsány quarry belonging to the latter imbrication will be reported first of all from paleoenvironmental and sedimentological points of view.

Cretaceous sequence of the Nagyharsány quarry

The Cretaceous sequence of the quarry was qualified first by Rakusz, Gy. (1937) as "reef limestone of Urgonian facies". He and J. Noszky (1957) divided the sequence into two, Fülöp, J. (1966) into three units. In case of the lower two units the division on macroscopic and microscopic bases shows remarkable differences (Fülöp, J., 1966). As to my observations and based on the macroscopic features the sequence of the quarry can be divided into four greater units (Fig. 3). The lower unit of about 70 m thickness consists of thick-banked usually macrofauna-poor apharenitic limestone that is characterized by the repeated occurrence of black, rarely grey or greyish-

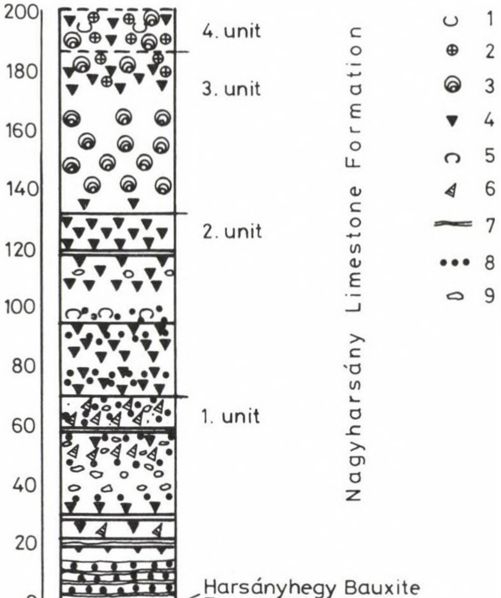


Fig. 3. Idealized Cretaceous sequence of Nagyharsány quarry. 1. Orbitolina; 2. coral colony; 3. Stromatopora and Chaetetopsis; 4. rudists; 5. Chondrodonta; 6. gastropods; 7. fenestral structure; 8. "black" limestone breccia; 9. marl and lime-marl lenses

white limestones breccias, by the frequent occurrence of algal-laminar of fenetral structure, by the tendency of upward decreasing quantities of thin variegated clay, marl and lime-marl as well as by globular calcite-lenses of 1 to 2 cm in diameter filled usually by pale-green, yellow or violet apharenitic, sometimes clayey limestones.

The second, about 62 m thick middle unit is represented by medium-grey very thick-bedded or massive limestone with abundant rudist and with upward decreasing proportions of black limestone clasts.

The approximately 54 m thick third unit is characterized by the small-sized bioherms of reef-building organisms (Stromatoporoids (?) and corals), but in its tectonically very complicated (brecciated) upper part contains solely large-sized rudists in certain blocks. In other blocks both the mollusc shells and the above-mentioned reef-building organisms can be found.

The banks of the uppermost 15 m thick unit can be characterized by moderate frequence of Orbitolinae, occasionally by coral and chaetetopsis colonies.

Lower member

Concerning the about 200 m thick Cretaceous limestone sequence of the Harsányhegy exhaustive thin section investigations were carried out only on the samples from the smaller lower part (i.e. from the first member). Fortunately, the phenomena that have initiated to write this paper, are concentrated in this part of the section. Thus, the comprehensive review below deals only with this section.

The uneven surface of the Upper Jurassic Szársomlyó Limestone Formation is conformable overlain apparently with conformity (occasionally with the intercalation of the Harsányhegy Bauxite Formation) by the Cretaceous limestone the lower unit of which can be lithologically divided into three subunits (Fig. 4).

The limestone of the lowermost subunit including the strata No. 2 to No. 23 of the section is usually light-grey but often variegated (greyish-brown, violaceous-grey, violaceous-red, yellowish-violet, ochre-yellow). The varied color is characteristic of the more or less clayey intercalations. The thickness of limestone banks varies between 30 and 350 cm. At the contact of the beds the green to red color clay-marl and marl intercalations of 5 to

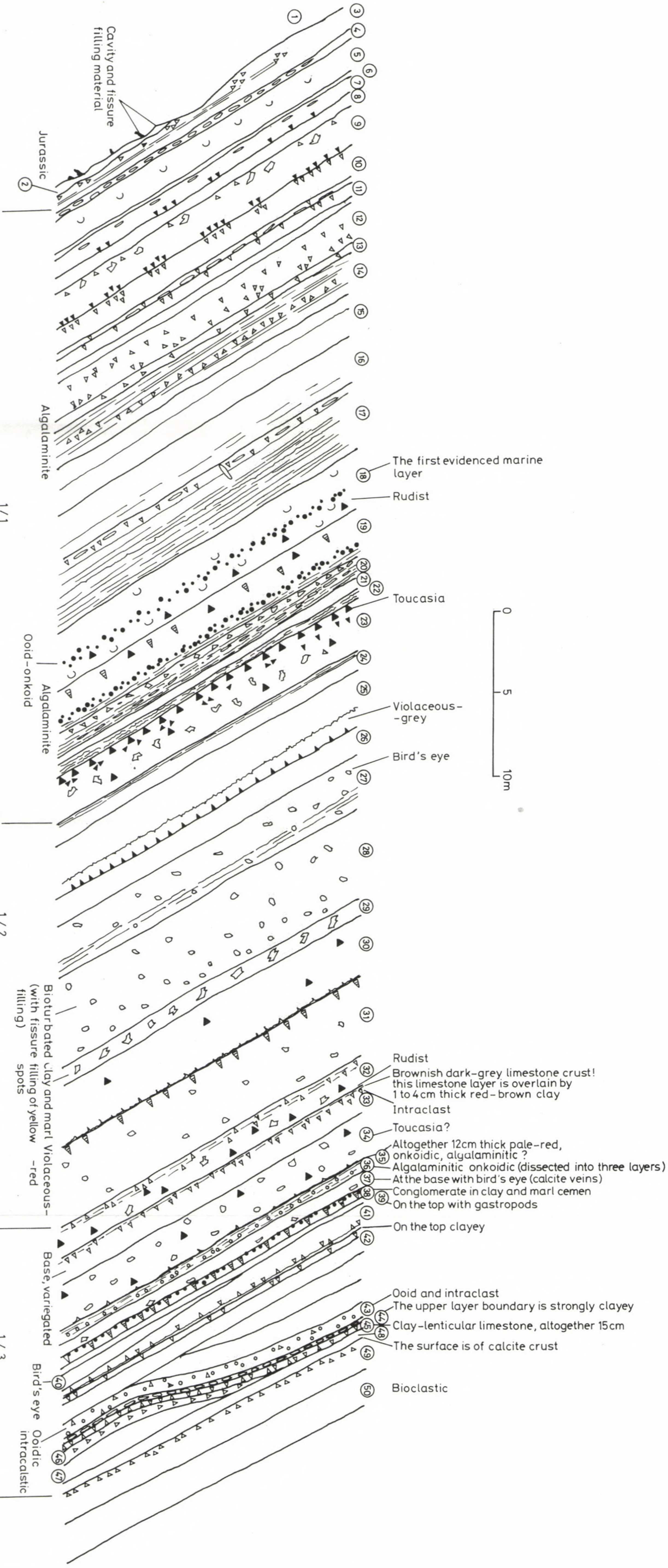
10, rarely 20 to 30 cm in thickness are frequent. These may occur sometimes in form of lenses (layers No. 5, 7, 10, 17 and 20). The variegated clay-marl with limestone nodules is rare (layer No. 4). The presence of Lofer-cycle of irregular rhythm is most characteristic of this subunit. The most frequent element is the 20 to 230 cm thick observable fenestral or algal-laminitic structure. The other diagnostic character is the brownish-grey or black, usually angular, rarely slightly rounded limestone clasts with a size of several millimetres to 40 cm (layer No. 20). Without referring to the color the existence of breccias was reported already by Fülöp, J. (1966). The detrital grains occur in certain layers as disseminations within a small interval, in other cases accumulated as lenses. Breccia grains are concentrated around -- usually above -- but seldom only below the uneven bedding plane. In exceptional case, however, these may occur as disseminated grains within the layer, as well. The limestone variety containing the intraclasts of ooidic encrustation representing genetic conditions different from those of the apharenitic limestone is an exceptional phenomenon and occurs only in layers No. 18 and 19. The 1 to 5 cm large randomly occurring lenticular strucure of calcite crust and of rounded or irregular shape can be observed mainly in the upper part of the subunit, the internal part of which is filled by occasionally slightly clayey limestone or lime-marl that is similar to the host rock but the color is pale-grey, violaceous of yellow shaded. This type of infilling occurs sometimes as spots without calcite crust.

The stylolitic structure subparallel with the stratification is rare. Similar phenomenon can be observed in layers No. 20 and 22. Here the variegated (violaceous and yellowish-shaded) limestone is interlaced by clay- film structures.

As layer boundary and often within the layer it can be observed that the color becomes faded upwards, then along a weakly uneven but sharp boundary dark-grey color occurs (e.g. layer No. 8). Rarely inverse change of color can also be observed. (The phenomenon is more frequent than demonstrated since in case of several very thick limestone strata the sharp color-boundary was drawn as layer boundary.)

The subunit is very poor in macrofauna, only four strata contained pelecypods, these are usually small rudists of relatively thin shell and two strata (No. 19 and 22) contained gastropods.

In thin section the texture of the subunit is characterized by the subordinate, usually 10% quantity of allochemical components. Among these


Cavity and fissure filling material
Jurassic
Algalaminite
1/1
Ooid-onkoid
Algalaminite
1/2
Bioturbated clay and marl Violaceous-red (with fissure filling of yellow spots)
Base, variegated
1/3
Bird's eye
Ooidic intracalstic
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
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44
45
46
47
48
49
50
The first evidenced marine layer
Rudist
Toucasia
Violaceous--grey
Bird's eye
0
5
10m
Rudist
Brownish dark-grey limestone crust! this limestone layer is overlain by 1 to 4cm thick red-brown clay
Intraclast
Toucasia?
Altogether 12cm thick pale-red, onkoidic, algalaminitic ?
Algalaminitic onkoidic (dissected into three layers)
At the base with bird's eye (calcite veins)
Conglomerate in clay and marl cemen
On the top with gastropods
On the top clayey
Ooid and intraclast
The upper layer boundary is strongly clayey
Clay-lenticular limestone, altogether 15cm
The surface is of calcite crust
Bioclastic

Fig. 4.

the biogenic grains usually of non-detrital origin predominate. The maximal frequency of the allochemical components does not reach 60% and exceeds 50% only in four cases (based on 101 thin-sections). The frequency of pellets and of intraclasts exceeds that of the biogenic components only in five (No. 5, 7, 15, 23 and 47) and in two samples (No. 36 and 37), respectively. The maximal values are as follows: biogenic components 40%, pellets 25% and intraclasts 40%. Consequently, the frequency of the matrix and of the cementing material is of primordial significance. It is characteristic of the common appearance of the micritic matrix that only one thin section showed micritic matrix below 2%. Its average frequency varies between 60 and 70%, in extreme cases may be as high as 98% (sample No. 20). The microsparitic cement reached 2% only in every second or third samples (this value being the lower limit of demonstration) and its maximal quantity was only 21% (layer No. 15). The sparitic cement shows less frequency, but its proportion when occurring is higher. Its maximal value was found in layer No. 19, this proved to be 40%. The frequency changes of the sparitic and microsparitic cement follow the quantity changes of the allochemical components, first of all of intraclasts and pellets. The common occurrence of "cavity-filling sparite" that fills the desiccation cracks is worthy of mention. Its average frequency varies between 5 and 10%, the maximal value being 36%. Nevertheless, the extreme frequency values coincide only to 50% with the macroscopically identified fenestral structures. This may be probably traced back to the large sampling intervals.

Summing up the textural featurs, according to the Folk-categories the bioclastic micrite and the biomicrite, respectively, are the most frequent texture types. As rare exceptions intramicrite, pelbiomicrosparite and biosparite also occur. These correspond essentially to mudstone and wackestone; packstone is rare and in the whole lower unit only one grainstone was found.

The frequency of fossils is changing throughout the section and shows different features. The change of shape or size of certain groups allows to trace facies changes. Nevertheless, due to the loose sampling the results obtained from thin sections may reflect only a part of the true changes. Thus, the changes of the fauna will be discussed by subunits and will not be parallelized with the facies changes.

The most common elements of the poorish fauna are the foraminifera, the frequency changes of which seem to be irregular. Usually these are of calcareous forms among which Miliolidae predominate. These are small, their tests are thin, but medium or relatively large sized forms also occur (layers 7/b, 15, 19/a and 21). It is worthy of mention that the large-sized forms occur always together with a more abundant faunal assemblage. The total quantity of foraminifera shows an increasing upwards tendency. On the contrary, ostracods show minimum quantities in the upper part (in the layers No. 15--19 these could not be practically evidenced). Mollusc shells are subordinate and occasional, only the layer No. 22 is worthy of mention due to its extreme high (4) frequency value. It is surprising that rudist shell fragments could be identified only in the layer No. 23/a.

The occurrence of other fossils is more incidental. The Chara oogoniums and stems are the exception that occur in the layers No. 3--10.

The second subunit (layers 24—31) is characterized by thick, moreover very thick banks (90 to 480 cm) and by subordinate amounts of pelitic intercalations and by the subordinate variegated color. The pelitic intercalation above the layer No. 30 shows desiccation cracks. The two characteristic elements, the fenestral structure and the intrabreccia of the Lofer-cycle are practically missing. The latter is restricted only to two layers (No. 25 and 29). The fade-grey, off-yellow or off-red marl, lime-marl or limestone lenses of irregular shape and 1 to 3 cm size are common features that seem to be infillings.

The macrofauna content is poorish: close to the base of the layer No. 30 some small rudist shells while in the reddish-brown micronodular clay-marl and marl at the base of layer No. 31 many tiny gastropods can be recognized.

The texture in thin sections is uniform: it is of bioclastic micrite and biomicrite type, and only the frequency of biogenic components and occasionally the change of cavity-filling sparite are worthy of mention. At the same time, in spite of the poorly developed state of Lofer-cycle the maximum quantity of cavity-filling sparite falls to this section (layer No. 30/b: 36%).

The fauna content of the subunit is more poorish than in case of the previous subunit, though in thin sections the ostracods are more frequent and more common, while foreminifera display smaller total amounts and consists mostly of small-sized Miliolidae. Only gastropods show greater frequency in addition to the ostracods. Chara fragments are known from one layer and green algae (Salpingoporella) is known from two layers (sample No. 5).

The third subunit (layers No. 32—48) is thinner-banked and platy, respectively (12 to 240 cm). The occurrence of two elements of the Lofer-cycle is characteristic, especially that of black or dark-grey intraclasts (layers No. 32, 33, 36, 38, 40, 42, 43, 45 and 46). Fenestral structure can be recognized in layers No. 35, 36 and 37. It is a speciality of these strata that the dark-grey algal laminite forming the breccia grains could be studied in situ on a surface of several square metres at the top of layer No. 32. This material can be observed as breccia at the base of layer No. 33. This subunit is the most intensely intrabrecciated section of the sequence where clasts of several tens of cm also occur. Clast grains are occasionally rounded like gravels and often occur imbedded in variegated, reddish-brown, greenish-yellow, blueish-green cementing material. The coarse detrital strata overlie usually unevenly eroded surfaces, the upper layer boundary, however, may also be uneven. Both phenomena can be observed in case of layer No. 38 where above the conglomerate and in lateral directions, respectively limestone of reddish color of varying shade is found instead of it, with large amount of gastropods filled by calcite. In case of clayey layer boundaries fissures penetrating into the underlying bed to several cm or dm can often be observed and these can be interpreted as desiccation cracks. The pastel marl lenses are considerably less frequent than in case of the former subunit and are restricted to the base of this subunit.

The relatively frequent macrofossil content is concentrated in the lower part of the subunit. Rudists occur in layers No. 32 and 34, while the en-mass occurrence of gastropods is characteristic of the layer No. 38.

The texture in thin section shows the greatest variability in this subunit. The matrix is here also always micritic but among the allochemical components not only the amounts of biogenic components are remarkable, but pellets and intraclasts are also frequent.

The subunit is characterized by relatively increased amounts of microfauna. The increase is mostly due to that of the total foraminifer quantity, more strictly to Miliolidae. Among these the medium or large sized forms also occur (samples 40, 41, 47/a and 47/b). Ostracods display decreasing upwards frequency and gastropods are concentrated in the layers No. 34—37.

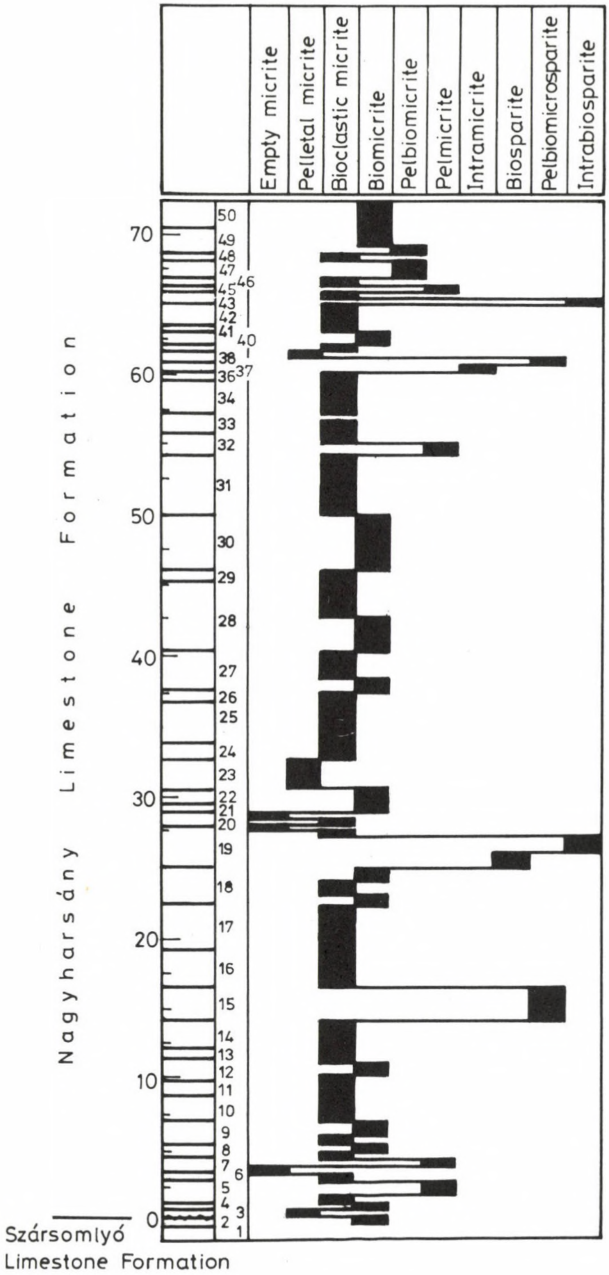

Fig. 5. Changes of texture types in thin sections of lower member of the Nagyharsány Limestone

Texture types of the lower member

(Figs 5 and 6)

In thin sections from the studied profile ten kinds of texture could be distinguished, seven of these proved to be of micritic matrix.

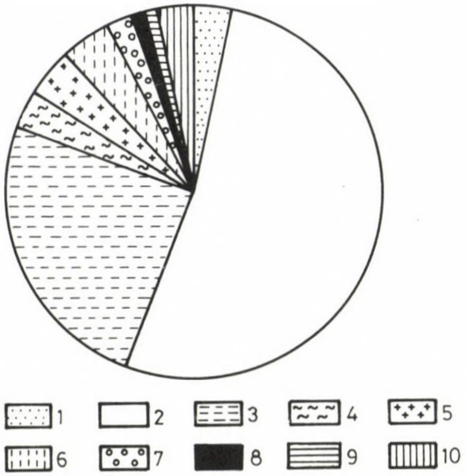

Fig. 6. Texture types in thin sections of the lower member of the Nagyharsány quarry. 1. Empty micrite; 2. bioclastic micrite; 3. biomicrite; 4. pelletal micrite; 5. pelmicrite; 6. pelbiomicrite; 7. intramicrite; 8. pelbiomicrosparite; 9. biosparite; 10. intrabiosparite

Empty micrite

This texture type that contains allochemical components in an amount less than 1% is subordinate in the studied section, i.e. less than 3%. Allochems consist of biogenic grains without exception. Ostracods with thin shells are common, in one sample Miliolina sp. of thin wall, in two samples agglutinated forms could be detected. It is conspicuous that Charadeae are missing in these samples!

Bioclastic micrite

More than half of the samples can be assigned to this type. The most common allochemical component is the biogenic grains (1 to 10%) that can be qualified as clast (e.g. mollusc shells, Chara-stems or ostracods) only in a few cases. Other components reach the amount that can be percentually expressed only about in one-third of the thin sections (this value is always less than that of the bioclasts); intraclasts occur only sporadically. The terrigeneous non-carbonate detritus shows values that cannot be expressed in percent though some quartz grains could be identified in one-third of the samples.

The usually ranged shrinkage pores, i.e. the bird's eye structure is characteristic of the texture and its amounts are as high as 10 to 20%, and in these structures the pore filling of oriented joint and of different crystallization degree proved to be often two generations. The true algal laminar structure, however, is rather rare (sample No. 32).

Though among the biogenic components elements referring to rather different paleoenvironments are found, their quantities, however, are subordinate. Ostracods as well as calcareous beuthonic foraminifera are the most frequent fossil these could be determined in more than 80% of the samples. In the group of calcareous forams Miliolidae predominate showing small size and thin wall. Only one sample contained Miliona sp. of medium size while the tiny forms, together with the ostracods of thin shell are relatively frequent. This is true especially when Chara fossils also occur.

The frequency of arenaceous foraminifera is less (in less than 60% of the samples) and it is less also within the individual samples. Their occurrence is in a good anti-correlation with that of the Chara-types. The investigations of Kovács—Bodrogi I. verified the presence of the genera: Dorothia, Erlandia?, Tritaxia, Marssonella, Novaleria, Arenobulimina.

Other biogenic elements: fragments of pelecypod shells are relatively frequent, while in case of the gastropods usually the embryonal forms can be detected. The blueish-green algae, the calcareous algae belonging to the Dasycladales (being assigned mainly to the genus Salpingoporella) or its fine-ground detritus are rare. It is characteristic that the two groups are in anti-correlation. Characeae are of similar frequency, their occurrence is restricted practically to the lowermost ten strata. Cadosina is occasional and the Echinoidea fragments were found only in one sample, and this is the case with other calcareous algae, holothuroidean elements and sponge spicules.

Pelletal-micrite

Samples containing pellets of 2 to 10% belong to this textural type, the number of these samples is only three. Due to this rarity, no reliable characterization can be given. Pellets are accompanied by intraclasts of remarkable quantity (3%) only in one sample, and no terrigeneous detritus could be detected. The shrinkage pores with two generations of filling is also characteristic and in one sample stromatolitic structure was also identified.

Its fauna is very poorish, the only constant element being the calcareous benthic foraminifera, these are here small or very tiny.

Other fossils, as ostracods, Cadosina, arenaceous benthic foraminifera, microgastropods and Chara sp. are occasional and rare.

Biomicrite

About one fifth of the samples of the studied sequence belong to this texture type and within this group two fundamentally differing microfacies types can be distinguished. The foraminiferal (biomicrite) facies is more frequent, and here the calcareous and arenaceous foraminifera display nearly the same proportion. It is worthy of note that among the calcareous forms Miliolidae predominate while among the arenaceous forms Kovács—Bodrogi, I. determined Textularidae and Arenobulimina div. sp. though in the uppermost strata she found Choffatella decipiens and Sabaudia minuta, too. The ostracod and mollusc shell fragments is common here, similarly to the previous texture types. The frequencies of Cadosina (8 of 15 samples) and of Dasycladacea algae(7 of 15 samples) have considerably increased (occasionally their frequency value is as high as 3), thus these have become the characteristic elements of the foraminiferal biomicrite. The pellet is also a common texture forming component and intraclasts occur in several samples.

Characeae biomicrite constitutes the other microfacies type where the fragments of the demoniating fossils have a relative frequency mostly of 3. Ostracods are common accompanying elements. It is worthy of mention that no forams could be detected. In this microfacies both the intraclasts and the pellets are missing.

Pelmicrite

This texture type shows a proportion of 5%. Among the allochemical components pellet predominates, its quantity 10% at least, the quantities of other components do not reach 10% by groups. The intraclasts of several percentages are characteristic accompanying elements, further occasionally encrusted grains also occur. The fauna content is conspicuously poorish, though essentially the same elements occur as in the former texture types but with less frequency. Only Cadosina shows somewhat higher relative frequency. Small cavities with calcite filling occur also here.

Pelbiomicrite

In this texture type about 5% of the samples is found, in addition to the biogenic components (20 to 35%) and to the pellet content (15 to 25%) some percentage (max. 5%) intraclasts can also be detected. In thin section the intraclasts visible to naked eye can be hardly detected. Among the biogenic components the foraminifera predominate, among which the calcareous and agglutinated forms show roughly the same proportion. In two samples relatively large-sized Miliolidae could also be recognized. The other elements are of subordinate frequency, occasionally green algae, bluish-green algae and ostracods occur.

Intramicrite

This texture type was observed only in two thin sections. In these considerable intraclast content could be verified in addition to the low pellet content. Intraclasts can be only with uncertainity separated from the matrix (often without sharp boundary) indicating the totally unconsolidated character of the matter during the formation of the intraclasts. The separation of the sparry cement and the shrinkage pore filling proved to be troublesome, too.

The fossil content is poorish, some samples contain remarkable quantities of blueish-green algae and gastropods.

Pelbiomicrosparite

Only the pelbiomicrosparite texture represents the group of texture types of microsparry matrix and only one sample was qualified to this group. The assignment is uncertain since in addition to 20% microsparry cement the sample contains 20% sparite and 7% micrite. In addition to these components some intraclasts can also be observed. Among the biogenic components foraminifera predominate. The arenaceous benthic forms are most frequent but the occurrence of large-sized Miliolidae is worthy of mention. Cadosina is also frequent but the speciality of this sequence is the occurrence of thick-shell mollusc fragments.

Biosparite

Two types could be separated from the texture group of sparry cement and these occur only in three samples. The only sample assigned to the biosparry texture type contains 25% sparry cement, 15% microsparry and 15% micritic matrix. Recrystallization is remarkable and cavity-filling sparite can also be recognized. Among the allochemical components 21% is the amount of biogenic elements, in addition small amounts of pellets and intraclasts are also found. The relatively high bioclast content includes an assemblage that is more varied than usual. Calcareous foraminifera are most frequent (among these also the large-sized Miliolicae), the arenoceous foraminifera are also remarkable as well as the mollusc shells, the blue-green algae, Cayeuxia and Cadosian. Rarely ostracods, echiderm fragments and gastropods also occur.

Intrabiosparite

This texture type is also rare (three samples) and the classification may be also doubtful since in addition to the sparry cement of 15 to 40%, 0 to 32% micrite is found. The intraclasts content varies between 12 and 20%, bicolast between 20 and 35% while the pellet content is 6 to 10%. Some of the intraclasts have onkoidic encrustation.

The fossil content is varied and changes from sample to sample. The elements of the two foraminifer groups are most frequent, but Cayeuxia is characteristic, occasionally predominating, sometimes Dasycladales is frequent. The other elements are as usual.

Changes of salinity

(Figs 7 and 8)

To follow the changes of salinity in the geohistory is a rather uncertain procedure. Though there are a lot of methods undoubtedly the fossils have a leading role in spite of the fact that these could have undergone considerable changes in their environmental requirements during phylogenetic history. Figs 7 and 8 were constructed mainly on the basis of the microfauna, microflora and macrofauna. It was a special trouble that in the whole of the particularly studied lower unit the macro and microfossils are rather poorish.

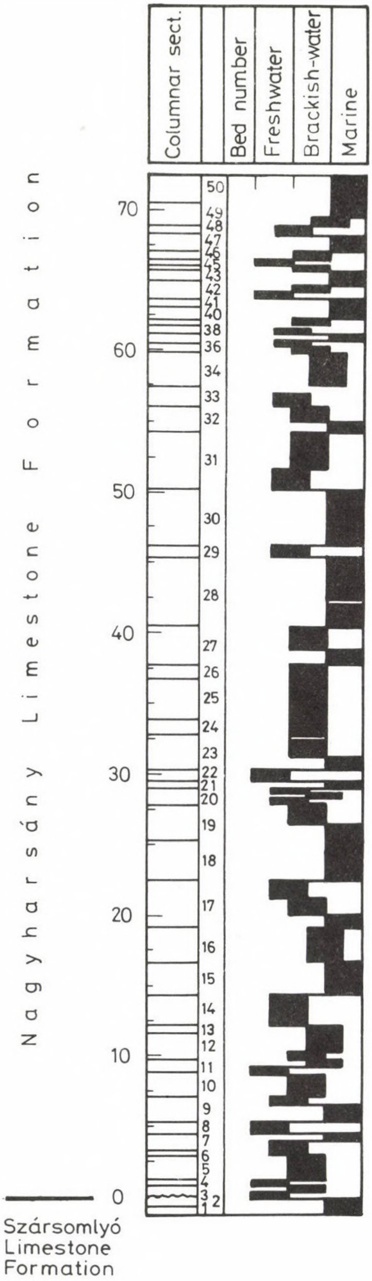

Fig. 7. Facies changes of the lower member of the Nagyharsány Limestone in the Nagyharsány quarry

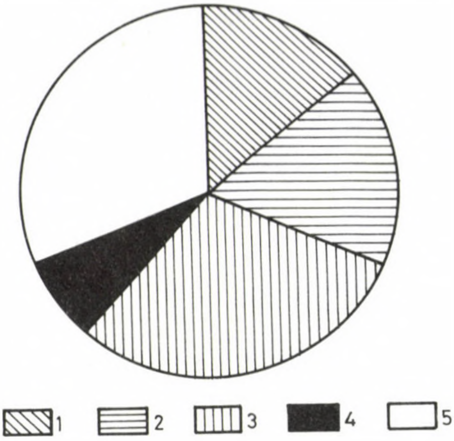

Fig. 8. Facies distribution of the lower member of the Nagyharsány Limestone in the Nagyharsány quarry. 1. Fresh-water; 2. fresh-water – brackish; 3. brackish water; 4. brackish water – marine; 5. marine

Fresh-water facies

The most characteristic feature of this facies is the fossil assemblage poor in species; Chara-types as facies guides with relative frequency value of 1 to 3. In addition to different Chara oogoniums the stem relics are also frequent, among others specimens resembling to Munieria are found. Chara are accompanied always by ostracods of same frequency. The total lack of fossils that would indicate marine facies can be interpreted as evidence of this facies. The only one echinoderm fragment found in one sample is interpreted as an extraneous element. In lack of positive evidence (Chara types) some samples were assigned to this facies that though containing fossils do not include elements referring to marine origin. In addition to the ostracods these are as follows: gastropods, mollusc shell fragments, occasionally blueish-green algae. The 14 samples assigned to this facies occur sporadically in the sequence but the major part of the samples that contain positive elements of great number is concentrated in the lower four meters of the sequence.

Fresh-water – brackish? water facies

This term was applied to 16 samples in which in addition to the permanently occurring ostracods minimal quantity of calcareous benthic foraminifera in particular tiny Miliolidae of usually thin wall are found. Occasionally mollusc shell fragments, sometimes gastropods or blueish-green algae also occur. Nevertheless, all the fossils relating to marine facies are lacking, among others the arenaceous benthic foraminifera. Further, two samples were assigned to this facies in which Chara-types could be identified in addition to the forms above but together with Cadosina. The latter ones probably got this facies as extraneous elements.

Samples belonging to this facies occur mostly in the middle third of the lower unit of the section.

Brackish facies

This was applied to 28 samples in which the calcareous benthic foraminifera are found with a frequency of at least 2 or with these or without arenaceous forms occur. Miliolidae predominate among the calcareous forms and are represented usually by tiny form often of thin wall. The arenaceous forms are also tiny. Among these Kovács—Bodrogi, I.determined the following forms: *Arenobulimina meltae* Kov., *Debarina hahounerensis urgoniana* Arn.—Vann., Glomospirella sp., *Marssonella praeoxycona* Moull., Marsonella sp., Novalesia sp., Nautiloculina sp., Textularidae sp., Dorothia sp., *Sabaudia minute* (Hofker), *Charenthia cuvillieri* Neu., *Choffatella decipiens* Schl., Debarina sp., Erlandia? conradi Arn.—Vann., Gaudryina sp., Orbitolinidae, Pseudocyclammina sp.

With a few exceptions the ostracods are common, the minimal amount of shell fragments and gastropods (mostly microgastropods) are also frequent. Cadosina and the blueish-green algae are occasional. When classifying, it was an important aspect that in addition to foraminifera no other fossils relating to marine facies were found in the given samples. The two samples are worthy of note in which in addition to the calcareous foraminifera the Characeae relics were found with a frequency value of 2, and with calcareous and agglutinated foraminifera those with a frequency value of 1 were found. In these cases Characeae were considered to be extraneous.

The samples assigned to the brackish-water facies are unambiguously concentrated in the upper part of the section.

Brackish water-marine facies

The samples that display poorish fossil contents and in which both the arenaceous and the calcareous foraminifera showed relative frequencies of 1 to 3 are assigned to this facies. Accessory elements are the ostracods, occasionally blueish-green algae, pelecypod shells or gastropods, and the common occurrence of Dasycladales or Cadosina can be interpreted as marine elements. It is conspicuous that most of these samples derive from the lower third of the section.

Marine facies

This is most widespread facies of the unit investigated and involves about one third of all samples. The fossil content is most abundant here. Foraminifera are common without exception and with great frequency and the taxon number is highest here. Among the calcareous benthic foraminifera the medium to large-sized Miliolidae are also frequent. Kovács—Bodrogi, I. determined the forms below: Bolivinopsis rhopaloides Arn.—Vann., small- and medium-sized Miliolina, Nezzazatinella macovei Neagu, Nummoloculina heimi Bonet, Pfendrina globosa Foury, Quinqueloculina robusta Neagu, Spirillina minima Shcacko, Trocholina cf. friburgensis (Guill. et Reich). Trocholina sp.

Ostracods, pelecypod shell fragments and Cadosina are also common but with lower frequency values. The individuals of gastropods and Dasycladaceae (mainly Slapingoporella) can be systematically observed. The echinoderm fragments are rare but show the highest frequency value here. Other fossils like blueish-green algae,Globochaeta, Bouenia, Bacinella and holothuroideans are rare and occasional. Uncertain radiolarians and Colomiella seem to be found only in one sample.

It can be considered to be characteristic of this facies that mollusc shells are often corroded due to the activity of corroding organisms and are micritized, respectively. This latter phenomenon can be observed also in case of Miliolidae.

Relationship between rock color, black breccia and paleoenvironment

The change of rock color was discussed in detail when introducing the sequence thus here the relationship between change of color and the environment will be dealt with. The rock is grey as a whole and shows its shades from greenish to brownish. The change of the grey color is twofold: within a layer bordered by clayey of hard ground surface may be gradual and sharp. The gradual change has two varieties again. In one case the darker, usually brownish shade becomes pale upwards, then usually along a surface broken by smaller unevennesses the dark-grey color occurs again by a sharp change. The light-grey rock variety is usually of fine bioclastic or pelletal-intraclastic texture while the dark-grey variety is poorer in allochemical components. It is a rare phenomenon that in the darker grey matrix tiny rock grains of paler color are found.

In the other case the change of color is reversed, i.e. the grey color becomes darker and transits into brownish-grey or blackish-grey. In these rarely stromatolitic lamination can also be observed (layer No. 38; Photo). In this latter case in the light-grey overlying bed the darker coloured rock varieties are found as fragments. This is the case at the base of the Cretaceous sequence.

The sharp change of color is usually accompanied with surface unevennesses, sometimes with clasts that refer to erosion of certain extent.

It can also be often observed that among the clasts there are more darker varieties than the color of the underlying bed. It is also frequent, that no shade difference can be detected between the over and underlying beds and the thin clayey surfaces are overlain by strata with dark-grey or black clasts.

These phenomena can be explained as follows. Due to the water level changes that can be traced back to different reasons the major part of the sedimentation area (in our case the marginal zone) rises above the water level. Nevertheless in the depressions the water remains and in isolated supratidal lakes the continuously generating limestone becomes dark-grey or black. The rock occurs as clasts when the quiet shallow water being reductive due to the plant material becomes desiccated and becomes disintegrated and at the time of water inundation the breccia grains are redeposited. In case of more considerable energy the grains can be transported to several tens occasionally to hundred meter distance. Thus, the grains may get areas without remarkable material change (intra-layer breccia) indicating a continuous sedimentation. Nevertheless, the case is more frequent when breccia grains are deposited over the clayey bedding planes and this indicates that in the course of repeated inundation or preceding this material input took place from the flat continental area.

The sudden occurrence and gradual fading of strongly reductive lime-mud can be explained in a more troublesome way. The phenomenon presumes that isolation of the recently undeterminable part of the sedimentation area, i.e. the sudden formation of isolated lagoon followed within a very short time and was gradually eliminated either by slow destroying of the barrier or by an eustatic water level rise. The only trouble is that the breccia formation that is necessarily accompanying these changes of environment is subordinate and occasional.

Shape and size of the "black pebbles"

Only the breccia grains have been mentioned above reflecting the fact that usually these are found. Nevertheless, in addition to the angular hardly moved grains rounded varieties with slurred contours are also found, occasionally together with the angular ones. The angular grains are in situ or hardly moved clasts of the desiccating lime-mud showing the initial stage of consolidation. The grains of nearly isometric shape and of several mm size occurring almost solely at the basis of the dark-coloured cycles belong to this group. In case of the in situ breccia grains that can be traced back to desiccation the elongated forms, i.e. having a longitudinal axis exceeding several times the thickness are also frequent. In the profile, however, mostly the subisometric, angular and subangular grains are characteristic. In addition to these the forms rounded more or less in one side but angular in the other are also found and this roundness refers to weak movements and further disintegration at about the end of transport.

Rounded pebbles and cobbles are rare but occur in the sequence. The finest example is found in layer No. 38 where imbedded in the variegated clayey matrix clasts of 1–2 cm to several tens of cm in diameter, of elongated shape and of changing roundness (Photo) are found. Their size considerably exceeds the thickness of the dark-grey and mainly black isolated lagoonal sediments. Accordingly, among the pebbles and cobbles the light-grey limestone variety often of fenestral structure is frequent. To generate this phenomenon not only a medium energy higher than usually was needed but a movement mechanism differing from those above. The generation of shallow water breccias is explained by the getting of the subaerial region and by desiccation, but their generation needs short but intense wave motion (storm), occasionally earthquake and current of certain extent. This condition could exist in every year when the water lashed by storms remobilized the dried material of the higher situated or farther-lying areas. It is conspicuous that the surfaces below breccias are unevenly eroded but no sign refers to the formation of channels. The composition of pebbles refers to erosion highly exceeding the measure of desiccation, while the shape refers rolling wave motion that allows to presume the relative stabilization of storms and the abrasive erosion. When the storms dropped in the removing and quiet water the pelites flowing in from the subaerial areas filled the interstices among the clasts.

Sedimentary cycles

The rhythmicity of the sequence is expressed by the lithological setting, i.e. by the intercalation of terrestrial pelites. This is seen in the rhythmic changes of the darker and lighter grey color (by 1 to 2 m) and by the changes of salinity described only as a general character due to the lack of thin sections of enough number. Everybody may presume that the three phenomena are in close relationship with one another but these cannot be deduced from one another. Between the change of salinity and the drying periods only a loose relationship can be presumed just due to the frequent inundation by fresh-water, that is between two drying periods the extreme fluctuation of salinity of complete cycle or several part-cycle can be probabilized. The similar relationship exists between the drying periods and the redox rhythms, i..e between two drying periods numerous redox rhythms may occur. The relationship between salinity changes and redox rhythms may be theoretically either very close or very loose. Our example is probably closer to the latter since reductive environment may occur either under fresh water or under hypersaline conditions. In lack of the systematic analysis of the redox rhythm of our case the given relationship can only be presumed.

In addition to the variegated clay intercalations the drying is evidenced by other facts. Most conspicuous evidences are the considerable desiccation cracks that often accompany the variegated clay surfaces. The fenestral structures that are common in the sequence and often show high frequency, i.e. the shrinkage pores filled by colorless calcite refer also to drying. In addition to these, greater cavities with calcite crust referring to vadose origin can also be observed.

Paleogeographic reconstruction

In the Villány zone, at the beginning of the Lower Cretaceous sedimentation a large undissected or hardly dissected flat erosion surface was generated that could be characteristic especially in the region of the Nagyharsány imbrication. Thus, the sea transgressing from the south rarely generated wave-cut notches and this is why the basal conglomerate is partly missing. In the flat surface, in a broad region a fresh-water or brackish water sedimentation zone developed that extended over several hundreds of meters where the change of several tens of cm of the sea level produced the elimination of sea water and the complete drying, as well. A lake system of two different characters could be generated extending over greater areas at the time of lower, and to minor areas at the time of higher water levels. In the areas with fresh-water supply the inundation was "constant" while in the regions without water supply and without water movement a reductive environment was formed in the lakes and thus a progressively blackening lime-mud was deposited. After the complete drying of lakes the sediment desiccated and at the time of the subsequent inundation accompanied probably with storms the hard lime-mud lamellae were redeposited or even transported. The long-lasting storms may result in rounded clasts and the formation of conglomerate. Due to the rains accompanying the storms pelites containing a few fine quartz grains were transported into the lakes from the gently sloping terrestrial background.

It is a phenomenon similar to blackening that occurs repeatedly in the marginal zone of changing width and rising to the surface or bordered by subaquatic dam (Fig. 9), when the darker grey and lighter grey lime-muds alternate. The change follows suddenly with some overshadowing to both directions while a reverse change can be gradual (see the description earlier) as well. The sharp change is often accompanied by the occurrence of black breccia relating to the close relationship of the two phenomena.

In the usually fairly well separated brackish water marginal zone small amounts of blueish-green algae and gastropods could be observed, in addition to the ostracods. A similar assemblage together with foraminifera populated the internal zone of the inner lagoon, this being supplemented with green algae in the central part of the lagoon. Rudists occurred in the external zone of the inner lagoon. In the ratch reef zone separating the inner and outer lagoons Chaetetopsis, Stromatopora, single and branching coral colonies existed the tiny clasts of which together with the molluscs accumulated in gentle slope and fore reef. Orbitolinae existed first of all in the outer lagoon and in the fore reef. The presumption of the outer lagoon is verified by the weakly agitated water characteristic throughout

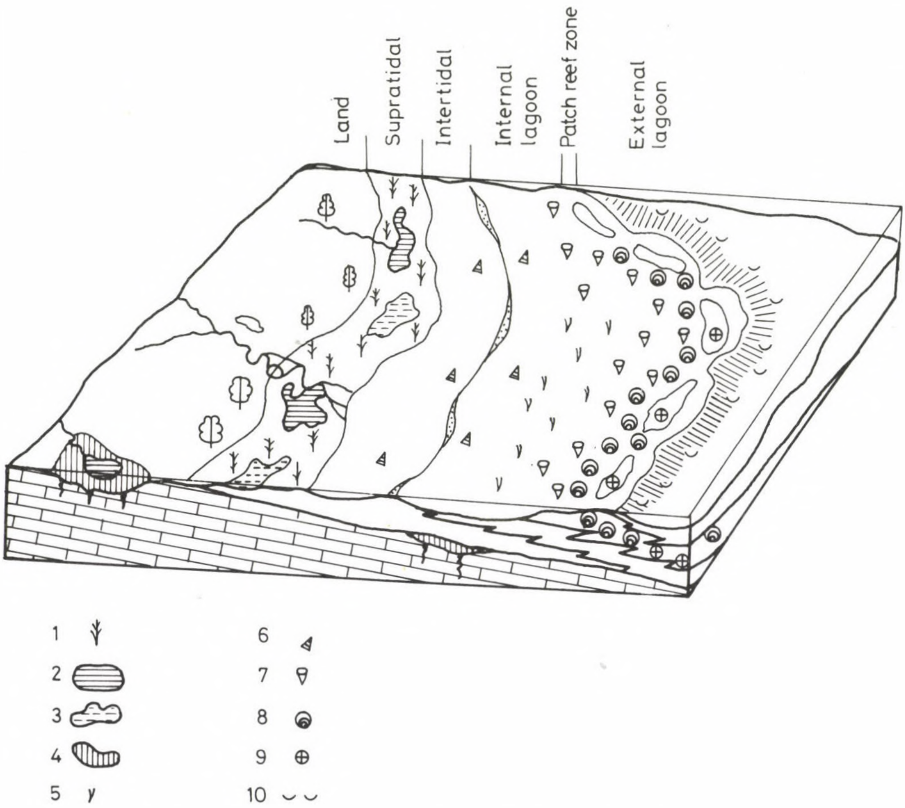

Fig. 9. Sedimentation environment types of the Nagyharsány Limestone Formation based on the strata column of the Nagyharsány quarry. 1. Grass-like marshy vegetation; 3. lake with water supply; 3. drying lakes (sources of black breccia); 4. bauxite lense; 5. Dasycladaceae; 6. gastropods; 7. rudists; 8. Chaetetopsis; 9. corals; 10. Orbitolina

the whole sequence and by the Beremend quarry representing the upper part of the sequence that is sediments and also of lagoonal formation.

In the area of the Tenkes imbrication that existed northwards max. to several tens of kilometers, the scene of sedimentation could be somewhat smaller and steeper, since here the sedimentation (without fresh-water and brackish water sediments) started later, according to Fülöp, J. (1966) in the Albian.

Age of the formation

The recent investigations did not promote to eliminate the contradiction of the ages of Urgonian sediments in the Tenkes and Nagyharsány imbrications since the age of the 200 m thick sequence of the Nagyharsány quarry can be unambiguously determined, neither. In the samples deriving from the Nagyharsány-1 borehole Juhász, M. determined a spore and pollen assemblage characteristic of the Lower Albian. The same was found as a result of the spore and pollen studies of Bóna, J. and of the nannoplankton studies of Gál, M. Recently, Schlagintweit, F. determined *Orbitolina* (Mesorbitolina) *texana* and *O.* (Mesorbitolina) *subconcave* species, and concluded Upper Aptian age (oral communication) not excluding the possibility of Lowermost Albian, in spite of the fact that these surficial samples derive from a horizon higher by several tens of meters. Kovács--Bodrogi, I. recognized *Salpingoporella aff. annulata alga* in sample No. 9 of the surficial profile and on this basis she presumed the sedimentation to start in the Hauterivian. So, the time scissors of Tenkes and Nagyharsány seem to be wider and not narrower. Taking these results as preliminaries I did not consider to be exact when calculating the duration of rhythms consisting of the alternation of darker and lighter grey color though this could promote the explanation of these rhythmic changes.

Conclusions

- The Nagyarsány Limestone Formation can be divided into four lithological units (members) in the profile of the Nagyharsány quarry:
  - a) limestone with varied pelite intercalations, poor in micro and macrofossils but abundant in fenestral structures that can be subdivided into three subunits on lithological bases;
  - b) thick-bedded and massive limestone with rudists;
  - c) limestone with Chaetetopsis, stromatoporoids and corals; and
  - d) limestone with Orbitolina and dispersed rudists.
- It is stated that the lower member have cyclic structure with elements characteristic of the Lofer-cycle, further the rhythmicity consisting of the systematic alternation of darker and lighter grey color is also a characteristic feature.
- Thin section investigations carried out on the lower unit revealed a

poorish fauna in general and predominating micritic matrix (among these empty micritic ones). The microsparry and sparry cement as texture type has a proportion of max. 18%.

- In the lower member in harmony with the facies determinations based first of all on fossils the certainly marine facies samples represent about 38%. The proportion of brackish samples is 30%, that of the fresh-water samples 14% while the rest cannot be classified exactly.
- The paleogeographic reconstruction based on the results first of all of the Nagyharsány quarry provides explanation to the mode of formation of the three characteristic elements of the Lofer-cycle, i.e. black breccia, fenestral structures and algallaminite.
- Based on the textural and facies characteristics the reconstruction reveals the existence of an outer and of an inner lagoon and states that the sequence of the Nagyharsány quarry is restricted to the marginal zone and inner lagoon and in case of some samples to the internal zone of the outer lagoon.
- Investigations carried out so far approach to some accuracy considering the upper limit of the sequence of the Nagyharsány quarry. Accordingly, the profile extends to the top of the Upper Aptian and to the basis of the Lower Albian. The data of Dasycladaceae referring to the start of sedimentation relate to Hauterivian and this makes troubles in the solution of contradiction of formation of the Urgonian limestone (Hauterivian and Albian) in the Tenkes and Nagyharsány imbrications.

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TRIASSIC FORMATIONS OF THE AGGTELEK-RUDABÁNYA MOUNTAINS (NORTHEASTERN HUNGARY)

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The Triassic lithostratigraphic classification elaborated in the course of the recently completed geological reambulation of Aggtelek–Rudabánya Mountains is presented, according to tectonofacial classification. Out of the 24 formations characterized here only shortly, 13 will be described here first.

Keywords: Triassic, Aggtelek–Rudabánya: N-Hungary, lithostratigraphy, tectonofacial classification

1. Introduction

Prior to our recent investigations, the Triassic stratigraphy of the Aggtelek and Rudabánya Mountains was comprehended by Balogh (1940, 1943, 1948a, b, 1950, 1953a, b) and by Balogh, K. and Pantó, G. (1952). The first classification into formations according to the knowledge of that time are found in the works of Balogh, K. (1973, 1974) and of Alföldi, L.–Balogh, K. et al. (1975).

The introduction of the modern investigations that allow the fine-stratigraphic classification (microfacies, Conodonta, Dasycladacea, Sphinctozoa and later radiolarians) was initiated by Balogh, K. in 1973 and these investigations resulted in the sudden improvement of the knowledge of Triassic formations in the two mountains. In the first phase of investigations the stratigraphic built-up of the Alsóhegy Triassic area was largely cleared (Kovács, S. 1977, 1979), while in the Rudabánya area it was just proved that formations overlying the Steinalm Limestone and comprehended previously into the Ladinian (just because of the lack of modern methods listed above) range, in fact, from the Pelsonian to the Sevatian; even, the

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presence of Jurassic was supposed (Balogh, K.–Kovács, S. 1977; Balogh, K. 1982; Kovács, S. 1983). This is why the Triassic correlation table of Balogh, K. (1980, 1981) and the Triassic table of the "Lithostratigraphic formations of Hungary" (Császár, G.–Haas, J. 1983) include only the Aggtelek Mountains and the Rudabánya Mts. was omitted because of the initial stage of this new stratigraphic subdivision. Within the frame of the geological mapping carried out between 1979 and 1985 in a scale of 1:10 000 (Less, Gy. 1981; Don, Gy. et al. 1981; 1982; Grill, J. et al. 1984) and of the National Key-Section Programme a detailed, bed-by-bed investigation of numerous artificial outcrops and boreholes was possible. The Triassic lithostratigraphic classification discussed below is the result of this work. In order to avoid the introduction of distinct formations for each exposure and borehole of the Rudabánya Mountains showing extremely varied Triassic lithology, when creating the formation units we tried to define these in a sense as wide as possible, at which, however, the hazard of mingling of characteristically different lithologies and facies could be still excluded. The stratigraphic table published here (Fig. 1) is found in somewhat different form in the work of Grill, J. et al. (1984) and in the English report of the Hungarian Triassic Subcommission (References) but the formations are not described there in detail. The more particular description of the lithostratigraphic units as well as the data will be published in "The geological monography of the Aggtelek–Rudabánya Mountains".

Formations will be discussed according to tectofacies units, disregarding the Lower Triassic formations and the Gutenstein and Steinalm Formations among which no considerable differences exist between the different tectofacies units (or are known only in part, e.g. in case of the Szőlősardó Facies). Nevertheless, before discussing the lithostratigraphy, the tectofacies units serving as a frame of the discussion have to be shortly reviewed.

2. Triassic tectofacies units of the Aggtelek-Rudabánya Mountains

The differentiation of Triassic of the Aggtelek–Rudabánya Mountains started during the Anisian by the appearance of formations of pelagic basinal facies related to beginning of rifting. In the course of rifting the following facial units[1] were separated that differ most sharply in their Ladinian formations:

2.1 Silicicum

- Aggtelek Facies: The building up of carbonate platforms together with occasional occurrence of intrashelf basinal facies continued up to the Upper Carnian. The site of sedimentation subsided only in the Upper Carnian while that of the other facies units already in the Anisian.
- Szőlősardó Facies: Slope facies with frequent resedimentation phenomena (intra-conglomerates, allodapic limestones). This corresponds to the shelf-slope.
- Bódva Facies: Pelagic, often condensated basinal facies predominantly with red or reddish carbonate sediments, with thin shale intercalations of similar colour. Its deepest parts deposited below the carbonate compensation level (part of the Szárhegy Siliceous Shale). Resedimentation phenomena are frequent here, too.

2.2 Meliaticum (Hungarian part)

- Bódvarákó Facies[2]: Partly euxine basinal facies with dark grey to black carbonate and clayey sedimentation. In the overlier of the Gutenstein Dolomite the Steinalm Limestone and Dolomite does not occur.
- Tornakápolna Facies: Oceanic crust (ultramafics, gabbro, basalt) with red radiolarite sediments.

2.3 Tornaicum

- Torna Facies: Grey pelagic basinal facies, the resedimentation features are usually missing. The rocks of the Tornaikum endured anchi- and epizonal metamorphism (Árkai, 1982; Árkai and Kovács, 1986).

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[1] At the same time these characterize also subsequently formed tectonic units, this is why these can be called "tectofacies" in harmony with the Alpine practice.

[2] In order to introduce the complete facies sequence the Deresk (Držkovce) Facies being fitted between the Bódva and Tornakápolna Facies has to be mentioned, too, that does not occur in Hungarian areas: this is a sequence consisting predominantly of pelagic red radiolarite overlying the Anisian carbonate platform facies (Steinalm Limestone) and deposited on thinned continental crust. The Meliata key-section belongs also to this group presuming the continuity of the sequence disturbed by faults.

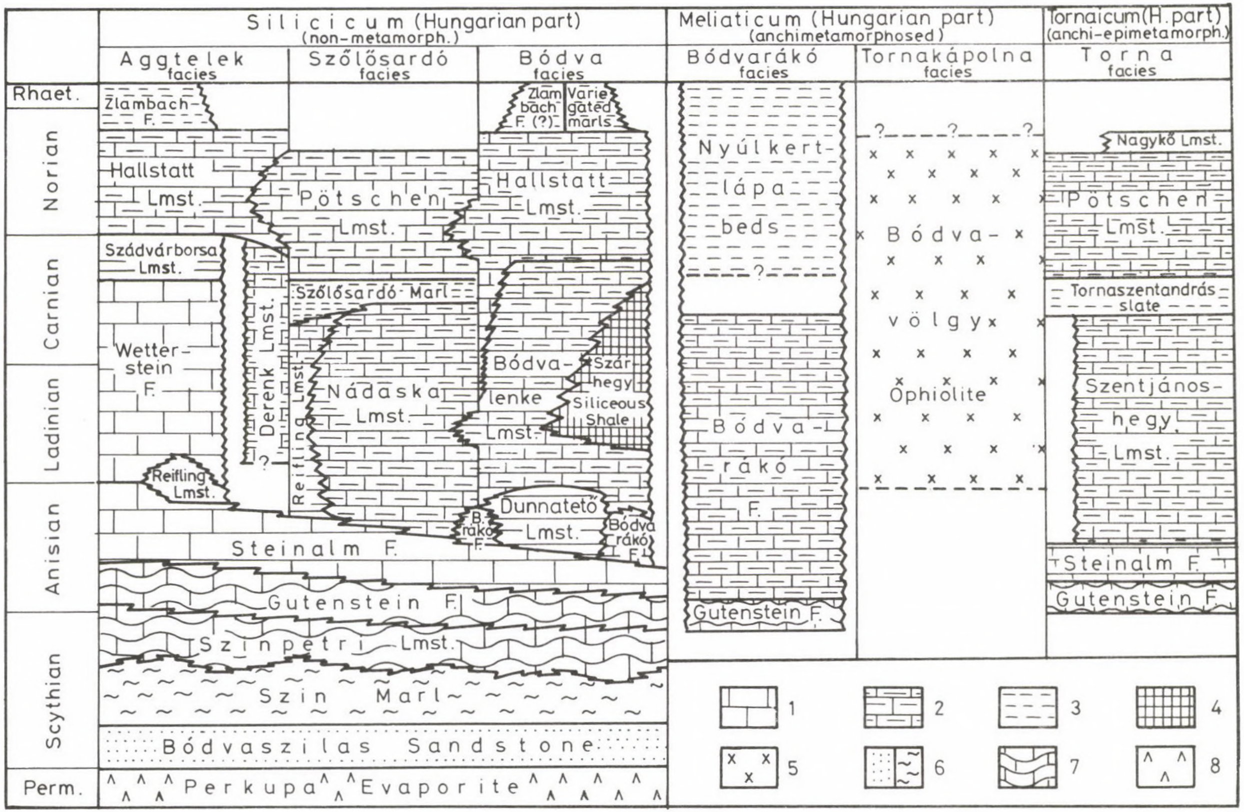


Fig. 1. Triassic formations of the Aggtelek—Rudabánya Mts. 1. Carbonate platform facies; 2. pelagic basinal facies; 3. basinal detrital facies (marly-argillaceous); 4. Radiolarite; 5. ophiolite; 6. shallow marine detrital and marly facies; 7. restricted lagoonal carbonate facies; 8. evaporite

3. Pre-rift formations

3.1 Lower Triassic

The terms "Werfenian", "Seisian" and "Campilian" generally used previously in the international Triassic stratigraphy are not accepted today as official chronostratigraphic units due to their restricted regional applicability (cf. Zapfe, H. 1983), but only as lithostratigraphic terms. Thus in our region the further usage of terms "Seis Beds" and "Campil Beds" used previously in lithostratigraphic sense but bearing definite chronostratigraphic connotation has to be abandoned due to the entirely different lithology of the South Alpine "Membro di Suisi" and "Membro di Campil". (Lithologically, the "Membro di Campil" of that area corresponds to our "Seis Beds" while our "Campil Beds" except their upper part are similar just to the "Membro di Suisi").

3.1.1 Bódvaszilas Sandstone Formation

The formation overlying the Upper Permian Perkupa Evaporite Formation and called previously as "Seis Beds" is built up by alternation of purplish-red, occasionally greenish-grey sandstone, siltstone and shale. Sandstone and siltstone alternate often within the same bed, i.e. as microlayers. The bed surfaces often display ripple marks or wrinkle marks. In sand waves cross bedding can also be observed. The rich macrofauna (pelecypods) becomes abundant on the micaceous upper bedding planes of sandstone beds. The detritus consists predominantly of quartz, feldspar and muscovite. The cement is siliceous or clayey, sometimes calcareous. Its thickness is 200 to 300 m.

Sedimentary facies: shallow-subtidal – intratidal, partly restricted, flat coastal sediment. The conglomerate lenses of the Kavicsos Hill at Bódvaszilas may be tidal channel fillings.

Type locality: Perkupa, key-section at the so-called upper church (AR-16).

Middle to Upper Griesbachian on the basis of Claraia clarai (Emmrich) without other Claraiae from the rich pelecypod fauna; its uppermost part, however, ranges into the Dienerian because of the appearance of Claraia aurita (Hauer).

3.1.2 Szin Marl Formation

The formation corresponding to the former "Campil Beds" (except the uppermost part of that) is built up by alternation of greyish-green, grey, sometimes reddish-brown, in weathered state brownish-yellow marl, schistose clay-marl and calcareous marl; in the lower part with light brownish-grey sandy limestone banks, in the middle part with red-brown sandstone and siltstone interbeddings. Worm traces and trace fossils (Rhizocorallium) are frequent on the upper bedding planes of the marl beds. Sand waves may occur but are less frequent than in the Bódvaszilas Sandstone. The thickness is 300 to 400 m. The main microfacies types of the carbonatic beds are as follows:

Oosparite; grainstone
Marl-microsparite; mudstone
Intra-microsparite; packstone-grainstone (biogenic components: foraminifers, echinoderm fragments)
Microsparite; mudstone.

Sedimentary facies: open subtidal (shallower and deeper) sediment with varying terrigeneous material influx.

Type locality: Szin village, quarry in front of the lower mill (AR-14). Other significant exposures: along the Perkupa—Varbóc road and in the Gazsi-creek valley west of the Perkupa anhydrite mine.

Age: It probably includes the major part of the Dienerian, Smithian and Spathian substages, but the only fossil known so far that could be suitable to more exact subdivision is the Tirolites cassianus (Quenstedt) (Spathian). Other characteristic macrofaunal elements are Dinarites sp., Naticella costata (Muenster), Turbo rectecostatus (Hauer), Costatoria costata (Zenk.), Eumorphotis telleri (Bittner), Gervilleia costata (Schloth.), Entolium discites (Schloth.). In its foraminifer fauna two characteristic biofacies can be distinguished (Bérczi—Makk, A. 1981): a probably deeper Scythian Rectocornuspira biofacies (with Rectocornuspira kalhori), and a higher Scythian Glomospirella biofacies (with Meandrospira pusilla).

3.1.2.1 Miklóshegy Limestone Member

Purplish-red or greenish-grey ooidic limestone often with black pelecypod-lumachelles. It occurs at the base of the Szin Marl Formation, overlying directly the Bódvaszilas Sandstone Formation. Thickness: varying, max. cca. 50 m.

Type locality: Miklós Hill, west of Bódvaszilas.

3.1.2.2 Véghegy Sandstone Member

Brown, occasionally red or grey, usually calcareous sandstone, subordinately siltstone, occurring in the middle horizon of the Szin Marl. It develops from the Lower Szin Marl by bed alternation and shows transition towards the Upper Szin Marl with bed alternation. The red variety is lithologically very similar to the Bódvaszilas Sandstone.

3.1.3 Szinpetri Limestone Formation

A limestone sequence with decreasing detrital matter, corresponding to the former uppermost "Campil Beds". It is divided into two members: the Szinpetri Limestone s.s. and the Jósvafő Limestone.

The typical Szinpetri Limestone is a grey, platy, vermicular limestone, the characteristic thin-nodular to knobby structure is dissected by thin greenish, in weathered state yellowish marl intercalations. In certain bedding planes, in addition to the vermicular features, Gervilleia pelecypods occur in great masses; Rhizocorallium is also frequent. This facies is called "Wurstlkalk" in the Alps. Its thickness is 100 to 150 m. The main microfacies types are: marl-mudstone; intramicrosparite, intrabiomicrosparite, microsparite.

Sedimentary facies: subtidal, restricted lagoon facies with decreasing terrigeneous material influx and with abundant inbenthos of low diversity (consisting mostly of worms).

Type locality: along the road between Szinpetri and Jósvafő, close to the western end of Szinpetri.

Age: Uppermost Scythian, without the possibility of more exact classification. The main faunal elements are: Costatoria costata (Zenk.), Entolium discites (Schloth.), Gervilleia modiola (Frech), Myophora laevigata (Hieth.), Velopecten albertii (Goldf.), sporadically with poorly preserved ammonoids. Its foraminifer fauna is characterized by a Meandrospira biofacies with the following forms: Meandrospira pusilla Ho, Glomospirella elbursorum (Broenn. et al.), G. sinensis Ho, Spirorbis phlyctaena (Broenn. et Zan.).

The Lower Triassic of Rudabánya differs from that of the Jósva-völgy by the immediate transition of the Szin Marl into the Gutenstein Dolomite; the Szinpetri Limestone is missing there. The transition is marked by the appearance of dolomite beds in the marl (Szentpétery, I. 1983 and personal communication).

3.1.3.1 Jósvafő Limestone Member

It is a dark-grey, banked, vermicular limestone. It differs from the Szinpetri Limestone in its banked structure and in the lack of terrigeneous material. The thicker banks are vermicular (subtidal cycles), the thinner ones are banded-laminated (tidal cycles). Its thickness is 50 to 100 m. Microfacies types:

homogeneous microsparite; mudstone
intramicrosparite; wackestone

Sedimentary facies: subtidal-intertidal restricted lagoon facies with rich inbenthos of low diversity (consisting only of worms).

Type locality: along the road between Szinpetri and Jósvafő, in the northern side of the road, closer to Jósvafő. In the Jósvafő environs it is found on the surface in a larger area.

Age: because of the poor fossil content it cannot be exactly classified: Uppermost Scythian, but may reach the Lower Anisian, too.

3.2 Middle Triassic

3.2.1 Gutenstein Formation

It consists of the alternation of dark-grey or black, thin-bedded to banked bituminous limestone with white (occasionally brownish-red) calcite veins and of grey, stratified bituminous dolomite with thin (1 to 2 cm) grey marl intercalations. The friable marl layers do not occur in the natural exposures of the mountains. The laminated-banded feature of the dolomite beds can be observed also only in cave exposures. Limestone predominates in the Aggtelek and dolomite in the Rudabánya Mountains. The thickness of the formation is about 250 m. The predominating microfacies of the limestone beds is homogeneous microsparite, mudstone. In addition to the obviously recrystallized texture rare foraminifers and intraclasts preserved only in the uppermost part of the formation.

Sedimentary facies: restricted euxinic lagoon facies of low energy level, with tidal and subtidal cycles. The vermicular inbenthos characteristic of the Szinpetri Limestone is completely lacking.

Local type locality: the artificial entrance section of the Baradla cave at Jósvafő, until the eastern wall of the Giant's Hall (Borka, Zs. 1982).

Age: Based on its stratigraphic position it belongs to the Lower Anisian but it cannot be excluded (especially in the Bódva facies region) that it begins already in the Uppermost Scythian. The overall poorness in fossils does not allow a more exact chronology. The poor foraminifer fauna known from the upper part of the formation – *Glomospira* cf. *densa* Pantić, *Trochammina almtalensis* Koehn-Zaninetti, *Endothyranella wirzi* (Koehn-Zaninetti), *Haplophragmella inflata* Zaninetti et Broennimann (det. Bérczi-Makk, A.) is also unsuitable to an exact chronological classification.

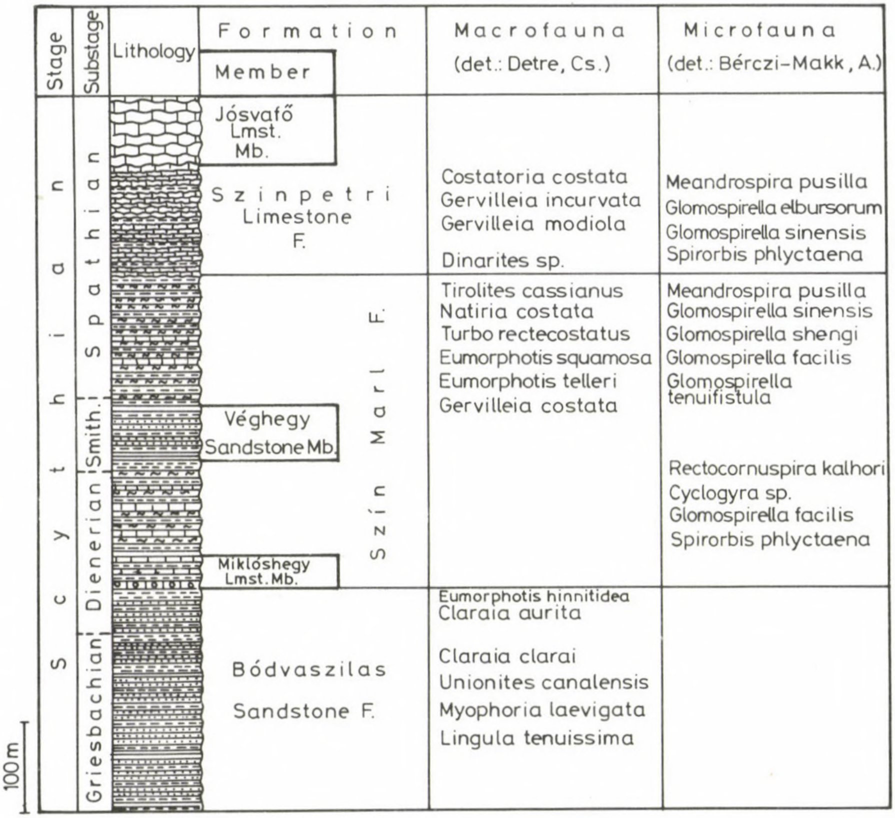


Fig. 2. Lower Triassic faunas of the Aggtelek–Rudabánya Mts. (Based on the determinations made by Detre, Cs. and Bérczi-Makk, A.)

3.2.2 Steinalm Formation

The Gutenstein Limestone and Dolomite are usually overlain by white, greyish-white, sometimes purplish-grey/purplish-red or purplish-black, bedded saccharoidal dolomite, that transits upwards into limestone. The typical Steinalm Limestone is white, greyish-white or light-grey with banked/thick-banked structure and with alternation of tidal laminated and subtidal bioclastic cycles. In the latter ones dasycladaceans occur in great masses in certain horizons. Nevertheless, brownish-white dolomites, as in the eastern end of Alsóhegy, may occur in form of irregular patches up to the top of the Steinalm Limestone. Its thickness is varying, usually 200 to 400 m, but in the Bódvarákó facies it is missing. The main microfacies types are:

Tidal homogeneous loferite: banded biopelsparite, biopelmicrosparite; grainstone.

Subtidal bioclastic limestone: bio-orthosparite with algal fragments; grainstone;

Dasycladacean bio-orthosparite; grainstone.

Oncoidic bio-orthosparite; grainstone.

Sedimentary facies: as against the Gutenstein Limestone it is an open, well oxigenated lagoon facies. Dolomites are late diagenetic.

Age: from the Upper Lower Anisian to the Upper Anisian. Except the Aggtelek facies the formation of the Steinalm carbonate platform usually ended in the Middle Anisian. The Dasycladacean zones of the Steinalm Limestone are shown in Figs 3a.

4. Syn-rift formations

4.1 Aggtelek Facies

4.1.1 Wetterstein Formation

4.1.1.1 Wetterstein Reef Facies

Light-grey massive limestone of uneven fracture. On rock surfaces weathered in soil the prepared tests of reef-building organisms, i.e. calcareous sponges, corals, hydrozoans, are seen in great amounts. It often contains mostly rhythmically precipitated stromatactis structures of several cm size, consisting of grey drusy calcite, that fills the interstices preserved in the original reef framework or within the reef detritus and were not filled by sediments. Within the reef limestone the reef-detritus facies predominates, the reef-core facies that built up originally patch reefs is subordinate, practically it is buried by its own detritus. Microfacies types of the reef-core: framestone, boundstone, bindstone. Those of the reef

Stage	Sub-stage	Zone	Dasycladacean zones
Anisian	Illiryan	IV.	Diplopora annulatissima
		III.	Diplopora annulatissima, Teutloporella peniculiformis, Physoporella dissita, Ph. varicans – Oligoporella pilosa
		II.	Teutloporella peniculiformis,
	Pelsonian		Physoporella pauciforata-Oligoporella pilosa
		I.	Physoporella pauciforata-Oligoporella pilosa
			Diplopora hexaster

Fig. 3a. Dasycladacean zones of the Anisian stage in the Aggtelek–Rudabánya Mts. (Piros, O., 1986)

detritus strongly broken by the wave activity are: bio-orthosparite (bioclastite) – grainstone; this deposited partly in the interstices of the solid reef-core, partly in the coarser reef detritus.

In the Aggtelek Mountains reef facies of two different ages can be distinguished, and their reef-biocoenoses also differ from each other:

a) Upper Anisian – Lower Ladinian reefs: between Jósvafő and Aggtelek, further in the northern slope of the Kecső-valley and in the borehole Szin-2 between 767.5 and 974.8 m. In the reef biocoenosis the calcareous sponges do not predominate above the other reef-builders and this is the difference from the type b; the reef-dwellers, however, are frequent (first of all crinoids and brachiopods; see also in Scholz, G. 1972). Its calcisponge fauna not yet described in details also differs from that of type b. The reef facies of Jósvafő–Aggtelek that is divided into several patch reefs contains a horizon with Diplopora annulatissima in its middle part (at 4400 m from the Aggtelek entrance of the Baradla-cave; det. by Bystricky,

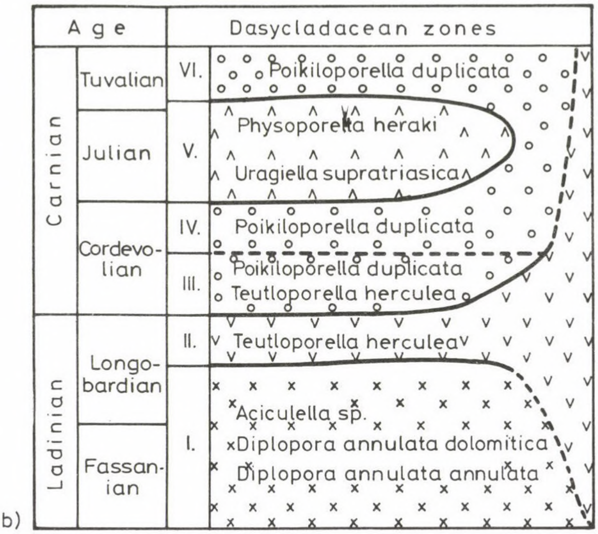


Fig. 3b. Dasycladacean zones of the Ladinian and Carnian stages in the Aggtelek-Rudabánya Mts. (Piros, O., 1986)

J. and this refers to the fact that the lower part is of Anisian age, i.e. contemporaneous with the upper part of the Steinalm Limestone, while its upper part is of Ladinian age and may be contemporaneous with the lowermost part of the Wetterstein Limestone of lagoonal facies. The continuity of reef evolution is the reason why this Steinalm-Wetterstein reef facies is discussed here.

b) Reefs of Upper Ladinian (?) — Carnian age: This is a reef facies occurring in the southern slope of the Alsóhegy and in the southern part of its plateau. Among the reef-building organisms calcareous sponges (especially inozoans) predominate. Its abundant Sphinctozoa fauna (Kovács, S., 1979) is the same as that of the North Alpine Wetterstein Limestone. The thickness of both facies is several hundred meters, at least.

4.1.1.2 Wetterstein Lagoon Facies

It is a light-grey (sometimes dark-grey in certain horizons), thick-banked limestone. The same tidal and subtidal cycles representing the B and C members of the Lofer cyclothems, build up it as the lagoon facies of the Steinalm Limestone. Its microfacies types are also the same but here the codiacean-solenoporacean bioorthosparite-intrabioorthosparite; grainstone is frequent, too.

Age: Lower Ladinian (Fassnian) – Lower Upper Carnian (Tuvalian). (The Dasycladacea-zones of the Wetterstein Limestone are shown in Table II/b). The Ladinian Wetterstein Limestone occurs in greater extension in the Aggtelek environs and in the range lying south of the Ménes-valley (Szelcepuszta), while the Carnian limestone occurs in the Alsóhegy plateau and in its western continuation.

The total thickness of the Wetterstein lagoon facies considerably exceeds 1000 m.

4.1.1.3 Wetterstein Dolomite Member

Within the Wetterstein Formation large dolomite masses occur north of Jósvafő–Aggtelek that are mappable separately and can be distinguished as a distinct member. The microfacies of the dirty-grey to brownish-grey, saccharoidal dolomite interwoven with the lagoonal limestone is homogeneous dolosparite-dolomicrosparite, in which no traces of the original texture and of fossils can be found. Its formation can be interpreted as late diagenetic dolomitization of the reef masses (Piros, O., 1986).

4.1.2 Szádvárborsa (Silická Brezová) Limestone Formation

Pink, grey or red, usually crinoidal, often ooidic limestone containing brachiopods and ammonits. Characteristic microfacies are: crinoidal biosparite and biomicrosparite; grainstone and oointrasparite; grainstone.

Sedimentary facies: platform/basin transitional facies.

Type-section: Szádvárborsa (Silická Brezová), southern slope of the Dét-Hill (Mišík, M.–Borza, K., 1976, pp. 9–12). (Unit stratotype). In Hungarian territory it preserved on the Alsóhegy plateau, in the depressions of the Wetterstein carbonate platform and in its fissure fillings.

Age: Tuvalian (except its lowermost and uppermost part); at the Alsóhegy this is proved by the occurrence of Gondolella nodosa carpathica Mock.

4.1.3 Derenk Limestone Formation

It is a banked-thick-banked or unstratified, syndiagenetically brecciated limestone. The original sediment consisting of predominantly reddish-grey or brownish-grey, often red, grey, sometimes brown micritic or fine-crystalline limestone is penetrated by thick, grey, coarse-crystalline (drusy) calcite veins and irregular fillings that also penetrate one another in several generations. The grey drusy calcite constitutes often the major part of the rock and the original sediment occurs in it only in forms of coloured relics. Its thickness is about 30 to 50 m; its contact with its stratigraphic underlying strata is everywhere tectonic or is unexplored. This formation was called previously as the "syndiagenetically brecciated limestone" member of the Hallstatt Limestone (Kovács, S., 1977, 1979).

Sedimentary facies: Basinal sediment affected by repeated cracking in more or less compact state, in several generations. Cracking could presumably be connected to the extension tectonics inducing the Upper Carnian subsidence of the Wetterstein carbonate platform.

Type-section: Key-section No. AR-2 at the southern foot of an unnamed hill close to the northwestern side of Szádvár. Its range extends from Derenk in the southern foreground of the Alsóhegy carbonate platform mass to the northern environs of Komjáti.

Age: Lower Ladinian (Gondolella trammeri interval zone) — Lower Upper Carnian (Gondolella polygnathiformis interval zone).

4.1.3.1 "Kastélykert Limestone"

The rocks of basinal facies explored mainly in the western environs of the Kastélykert of Tornanádaska are discussed as a non-official lithostratigraphic unit within the Derenk Limestone Formation. They were called previously as "Ladinian Hallstatt Limestone" (Kovács, S., 1977, 1979).

The material consists of reddish-grey — purplish-greyish-red as well as brownish-grey, finecrystalline, banked-thick-banked limestone of uneven fracture, with fist-to-head sized red chert nodules in the upper part of the sequence.

Microfacies types:

Pelmicrosparite; packstone
Pelbiomicrosparite; wackestone
Filament biomicrosparite; wackestone.

Because of its isolated tectonic position its under- and overlying strata, and in lack of measurable dip data its thickness cannot be determined.

Sedimentary facies: below restricted, upwards gradually deepening and ever more pelagic basinal facies. To discuss it within the Derenk Limestone Formation is proved by the fact that it can be explained as a non-typical variety of this formation that did not undergo the syndiagenetic brecciation.

Age: it contains a poor Lower Ladinian conodont fauna: Gondolella constricta Mosher et Clark, Gondolella excelsa (Mosher), Gondolella trammeri Kozur, Gondolella transita Kozur et Mosher, Gladigondolella tethydis (Huckr.). The possibility that it transits into the Upper Anisian and into the Upper Ladinian, respectively, cannot be excluded.

4.1.4 Hallstatt Limestone Formation

In the pelagic basinal facies zone extending from Szádvárborsa (Silická Brezová) eastward up to Tornanádaska and being sometimes interrupted the formations below constitute the "Hallstätter Buntfazies" (in sense of Krystyn, L. and Schöllnberger, W., 1972) here:

a) "Kastélykert Limestone" (Ladinian)
b) Derenk Limestone (Fassanian – Lower Tuvalian)
c) Lower "Massiger Hellkalk" A (Tuvalian)
d) Lower "Massiger Hellkalk" B (Lacian)
e) Hangendrotkalk (Alaunian – Lower Sevatian)
f) Upper "Massiger Hellkalk" (Sevatian)

The "Kastélykert Limestone" and the Derenk Limestone (discussed under the Derenk Limestone Formation) are heteropic facies of the North Alpine "Grauvioletter Bankkalk" and Roter Bankkalk in the Alsóhegy Hallstatt facies region. The lithologies of the Lower "Massiger Hellkalk" and of the "Hangendrotkalk" are completely the same as their North Alpine analogues (Kovács, S., 1977, 1979). They overlie the Szádvárborsa Limestone in the basin facies zone west of Derenk, but overlie the Derenk Limestone east of Derenk. The units to be dealt with below and marked by c-f can be considered as members of the Hallstatt Limestone Formation s.s.

4.1.4.1 Lower "Massiger Hellkalk" A

Brownish-grey, light brownish-grey (occasionally with red shadow), light-grey, whitish-grey, fine-crystalline banked or thick-banked limestone of conchoidal-splintery fracture. It is an atypical variety of the "Massiger Hellkalk". Characteristic microfacies: pelbiomicrosparite and microsparitic pelbiomicrite; it may contain intraclasts, too. It differs from the typical "Massiger Hellkalk" in its overlier by the macroscopic fine-crystalline character, respectively by the finer fracture and the predominating pink color of that. In its microfacies the difference is represented by the coarser groundmass (microsparite) and occasional pellet- and intraclast content.

Local type-section: in the lower part of the section above the Vecsem-spring (Kovács, S., 1977).

Age: Tuvalian-2-3 (Gondolella nodosa taxon-range zone).

4.1.4.2 Lower "Massiger Hellkalk" B

It is the typical variety of the "Massiger Hellkalk": pink, greyish-, purplish- or reddish pink, pinkish-grey, occasionally whitish-grey or light-grey, typically aphanitic, banked or thick-banked limestone with conchoidal-splintery fracture. Sometimes it may contain brownish-grey, red or reddish-brown chert. Characteristic microfacies: radiolarian, occasionally filament biomicrite; wackestone. Due to its very fine homogeneous micrite it differs from all the other basin-facies of the Aggtelek-Rudabánya Mountains. Macroscopically only the Dunnatető Limestone is similar to it.

Local type-section: middle-upper part of the section above the Vecsem-spring (Kovács, S., 1977).

Age: Lacian (Metapolygnathus primitius taxon-range zone — Gondolella hallstattensis interval zone).

4.1.4.3 "Hangendrotkalk"

It is a light-red, red, dark-red, fine-crystalline bedded or banked limestone of conchoidal-splintery fracture, sometime with nodular or flaser bedding. Occasionally it contains fawn-coloured interbeddings. Rarely coquina-interbeddings may also occur in form of 1-2 dm thick, grey crystalline limestone lenses. Its microfacies is microsparitic biomicrite; wackestone, with more diverse biogenic components than in case of "Massiger Hellkalk A": filaments, echinoderms, ostracods, radiolarians and pellets.

Local type-section: Kecskés-oldal, northwest of Derenk.

Age: Alaunian — Lower Sevatian (Gondolella steinbergensis intervallum zone — Metapolygnathus bidentatus taxon-range zone).

4.1.4.4 Upper "Massiger Hellkalk"

Pinkish-grey — pinkish-white limestone in the overlier of the "Hangendrotkalk" and resembling in its appearance to the Lower "Massiger Hellkalk A" Member.

Type-section: Haragistya, key-section AR-1.

Age: based on its stratigraphic position Sevatian.

4.1.5 Zlambach Formation

Brownish-grey, platy marl overlying the "Upper Massiger Hellkalk" Member of the Hallstatt Limestone, with grey marly limestone interbeddings and with their slided(?) blocks.

Local type-section: Haragistya key-section (AR-1), between 26.4 and 59.7 m; in the Hungarian territory it outcrops only here.

Age: Upper Sevatian — Rhaetian, but in Hungary only the Upper Sevatian is biostratigraphically evidenced. The ammonoid fauna of the Haragistya key-section (Cladiscites? sp., Clionites ares Mojs., Clionites cf. pseudonodosus Kutassy, Clionites? sp., Megaphyllites insectus Mojs.; det. Detre, Cs.) and the foraminifers (Variostoma crassum Kristan-Tollmann, Trochammina alpina Kristan-Tollmann; det. Oravecz-Scheffer, A.) characterize the lower, Sevatian part ("Cochloceras-Mergel") of the north Alpine Zlambach Beds.

4.2 Szőlősardó Facies

4.2.1 Bódvarákó Formation

In the Szőlősardó facies region the formation is represented in the borehole Szőlősardó-1 between 465.35 and 435.10 m (in a real thickness of about 20 m) by cherty dolomarl, that is grey in the lower part with a 0.5 m thick greenish-grey rhyodacite-tuffite interbedding, and is blackish-grey in its upper part with cherty siltstone, claystone, marl and limestone (Balogh, K. — Kovács, S., 1981), and in the borehole Rudabánya-690 between 638.8 and 642.4 m by medium-grey, micaceous silty dolomarl and dolomite (Szentpétery, I., 1983).

Age: Lower(?) — Middle Anisian; based on conodonts in the Sza-1 borehole (the occurrence of Gondolella regalis Mosher of problematic taxonomic position) and on its stratigraphic position in the Rb-690 borehole.

Though the formation occurs in both boreholes between the Steinalm Limestone and Dolomite and the Nádaska Limestone, in the borehole Sza-1 it cannot be excluded that the parts of the borehole below and above 435.10 belong to separate tectonic units since the boundary of the Bódvarákó and Nádaska Formations coincides with that of a coring interval.

4.2.2 Nádaska Limestone Formation

It is a fine-crystalline or aphanitic, thin-banked, banked or thick-banked, varicoloured limestone of conchoidal-splintery fracture. Its colour changes between red and grey: greyish-red, reddish- pinkish- brownish- or drabbish-grey, sometimes violaceous-grey, occasionally with greenish shadow, but may be medium-grey, light-grey and red, as well. Bedding planes are even. Other diagnostic features: the frequent stromatactis and protointraclastic structures. The thickness is changing: at the eastern edge of the Alsóhegy about 40, in the borehole Sza-1 about 120 m. Its most frequent microfacies types (in the Sza-1 borehole) are:

Filament biomicrite — microsparitic biomicrite; wackestone
Filament microsparitic pelbiomicrite; wackestone
Radiolarian-filament biomicrite — microsparitic biomicrite; wackestone
Pelecypod biosparite (coquina); grainstone

Sedimentary facies: pelagic slope sediment deposited below the wave base. The irregular stromatactis-structures, the intraformational breccias and conglomerates are related to sediment sliding and sediment flows. The protointraclastic structure can be traced back to initial sediment flows and bottom currents.

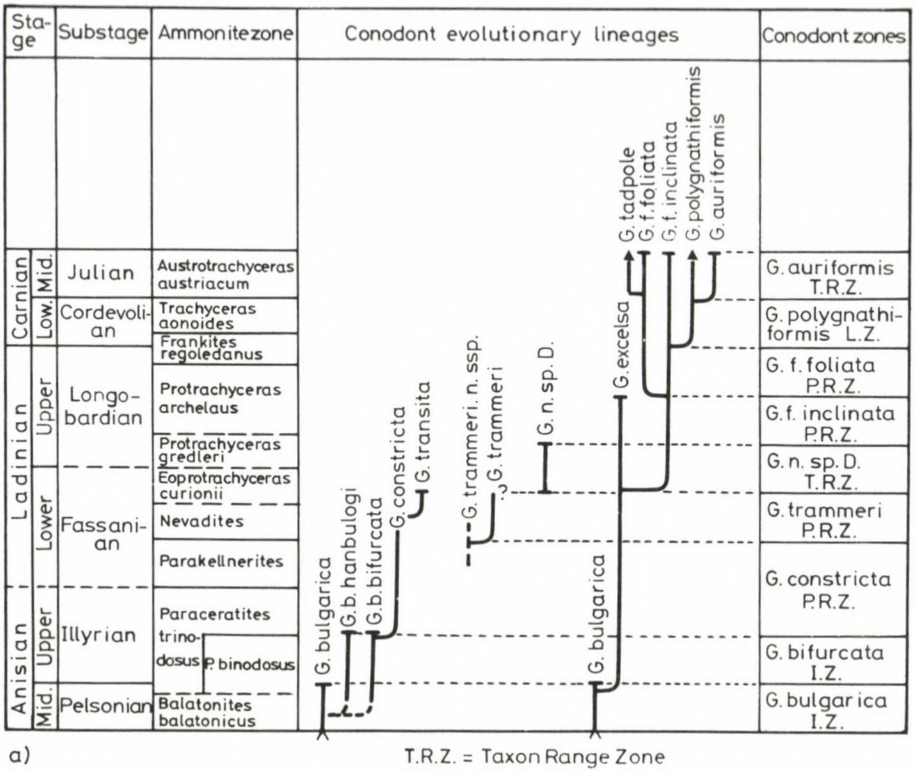
Type-section: Alsóhegy-I section at the eastern edge of the Alsóhegy (stratotype); Sza-1 borehole (parastratotype). Extension: in the Hungarian part in the two scales of the eastern end of Alsóhegy Mt. and in the southern vicinity of Szőlősardó, as well as in the borehole Rb-690.

Age: its maximal range is from the Middle Anisian to the Middle Carnian (from the Gondolella bulgarica interval zone to the Gondolella auriformis taxon-range zone). The conodont biostratigraphy of the Nádaska Limestone is seen in Fig. 4a.

4.2.3 Reifling Limestone Formation

4.2.3.1 Cherty Reifling Limestone ("Reiflinger Knollenkalk")

Grey to dark-grey, fine-crystalline thin to medium bedded limestone of uneven-splintery fracture, with brownish-grey, dark-grey chert nodules, lenses and layers. Bedding planes are often undulatory with yellowish-brown clay coatings. Its thickness cannot be determined in lack of a complete section. Microfacies: radiolarian pelbiomicrite; wackestone, and radiolarian-ostracod pelbiomicrite; wackestone.



T.R.Z. = Taxon Range Zone
P.R.Z. = Partial Range Zone
L.Z. = Lineage Zone
I.Z. = Interval Zone
C.R.Z. = Concurrent Range Zone

Fig. 4a. Conodont biostratigraphy of the Nádaska Limestone Formation (Kovács, S., 1983)

Sedimentary facies: pelagic basinal facies with rich inbenthos.

Local type-section: eastern end of the Alsóhegy Mt. at the top of the upper scale (in the overlier of the Nádaska Limestone). It occurs also in the Rudabánya-690 borehole (Szentpétery, I., 1983; here it is of nodular structure also within the beds) and at the eastern slope of Szárhegy, northwest of Martonyi.

Age: at the eastern edge of Alsóhegy Lower Carnian (with Gondolella polygnathiformis) while in the two other outcrops Ladinian – Lower Carnian.

4.2.3.2 Banked Reifling Limestone ("Reiflinger Bankkalk")

Medium-grey, sometimes dark-grey, fine-crystalline, banked, occasionally thick-banked limestone of uneven-splintery fracture. The bedding planes are even with thin yellowish-brown clay coatings. It does not contain chert. Microfacies: intrabiopelmicrosparite; packstone, sometimes containing clasts of platform origin. Its thickness cannot be determined in lack of a complete section.

Sedimentary facies: basinal facies near the platform. It occurs only in the two scales of the eastern end of Alsóhegy Mt.

Age: based on its interfingering with the Nádaska Limestone Upper Anisian to Lower Carnian, biostratigraphically, however only the Upper Ladinian – Lower Carnian age is proved (Neospathodus tatricus Zawidzka, Gondolella polygnathiformis Bud. et Stef.).

4.2.4 Szőlősardó Marl Formation

Medium-grey to dark-grey, compact locally silty clay-marl and spotty marl of conchoidal fracture with grey to dark-grey fine-crystalline, mostly cherty limestone and calcareous marl intercalations of conchoidal-splintery fracture. Pyrite grains and thin lenses, as well as small bivalves and Halobia-like imprint-fragments are frequent in the marl and calcareous marl. Resedimentation phenomena, i.e. undulatory microbedding, gradation, intraformational breccias, are also characteristic of the formation. Thickness: in the Sza-1 borehole about 80 m. The main microfacies types of the limestone intercalations are:

Radiolarian-filament biomicrite; wackestone-packstone
Radiolarian biomicrite; wackestone-packstone
Pelbiomicrite; wackestone
Crinoidal-filament biomicrite; packstone (rudite).

Sedimentary facies: typical slope sediment representing the "Raibl event".The pyrite content of the marls and clay-marls relates to reductive conditions and rapid sedimentation rate.

Type-section: Sza-1 borehole, between 177.10 and 66.33 m (Balogh, K. –Kovács, S., 1981). Other occurrences: Rb-382 (Balogh, K., 1976) and Rb-690 (Szentpétery, I., 1983) boreholes.

Age: Middle Carnian (Julian) to lowermost Upper Carnian (Tuvalian) but may reach also the upper Lower Carnian (Cordevolian). Conodont biostratigraphy: Gladigndolella malayensis malayensis interval zone and Gon-

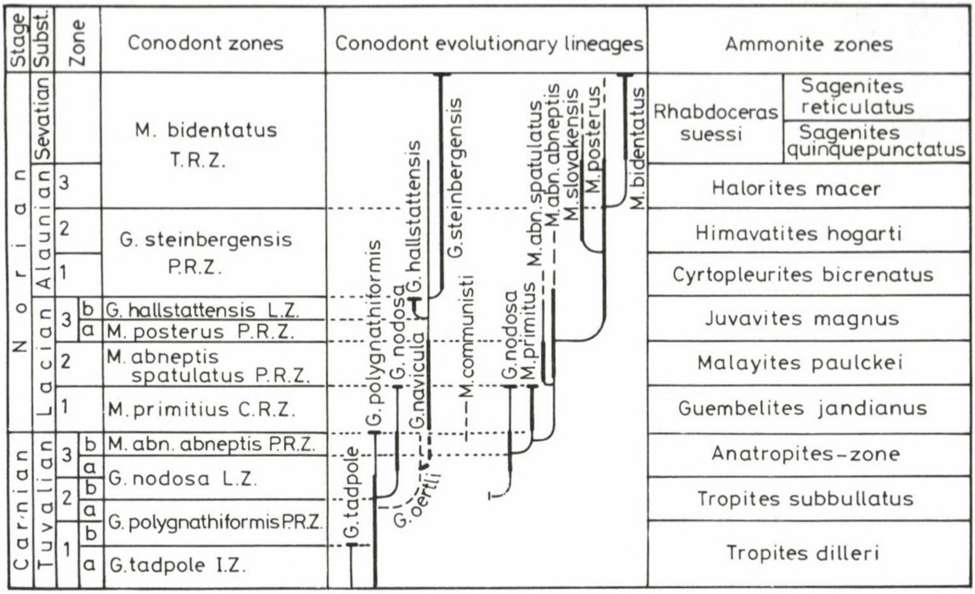


Fig. 4b. Conodont zones of the Upper Carnian and Norian stages (Kovács, S., 1985; modified after Krystyn, L., 1980 and Kozur, H. 1980)

dolella tadpole interval zone. Macrofauna (Balogh, K.–Kovács, S., 1981): Austrotrachyceras? sp., Sirenites sp., Sirenites ex gr. senticosus (Dittmar), as well as Halobia rugosa Mojs.

4.2.5 Pötschen Limestone Formation

The typical variety is grey, aphanitic or fine-crystalline, bedded or thin-banked limestone of conchoidal-splintery fracture with brownish-grey or dark-grey chert nodules, lenses and layers. Bedding planes are undulatory with yellow clay coatings, but yellowish-brown-yellowish-red marl interbeddings of several mm to max 10 cm thickness are also frequent. Thicker banks are split into internal beds along undulatory surfaces. It contains Halobia-lumachelles in certain horizons. In its lower, chert-free part intraconglomerate and allodapic crinoidal limestone interbeddings often occur (Balogh, K. – Kovács, S., 1981); the latter are found also in the certy parts.

Its thickness is about 90 m. The main microfacies types are:

Radiolarian biomicrite; wackestone

Radiolarian–filament biomicrite and microsparitic biomicrite; wackestone
Pelletal coquina packstone
Crinoidal–filament biomicrite and microsparitic biomicrite; wackestone

Sedimentary facies: pelagic basinal facies. Its lower part containing intraconglomerates and crinoidal, allodapic limestone interbeddings was deposited on an unstable slope.

Local type-section: Szőlősardó-1 borehole, between 66.34 and 4.60 m (Carnian) and the northern slope of the Lepényke Hill at Szőlősardó (Norian). Less typical varieties occur at the southern foothill of Alsóhegy Mt. above Komjáti, and at Szádvár.

Age: Upper Carnian (Tuvalian-1/a, Gondolella tadpole intervallum zone) – Lower Norian (Lacian-3, Metapolygnathus posterus intervallum zone). At Szádvár the non-typical part gets also the Lowermost Middle Norian (Gondolella steinbergensis intervallum zone). Balogh, K. (1976) described Lower Norian forms (Lacian-1) from the Halobia-lumachelles: Halobia austriaca Mojs., Halobia charlyana Mojs., Halobia styrica (Mojs.).

4.3 Bódva Facies

4.3.1 Bódvarákó Formation

One (partly euxinic) kind of the first basinal facies overlying the Steinalm Formation. Its main occurrences: Bódvalenke-2 borehole between 129.0 and 146.4 m, in the underlier of the Bódvalenke Limestone, where it is represented by a darker-grey silty marl with a thinner limestone interbedding. In the borehole Varbóc-1/2 (Telekes-valley, side-valley No. 8) that did not explore the Mesozoic under- and overlying beds, between 26.2 and 66.1 m it is represented by a thin- to well-bedded, dark blueish-grey limestone alternating with a dark-grey to black chert, with the interbeddings of purplish-grey, grey and fawn-coloured siltstone laminae. The chert and siltstone are usually graded, sometime the limestone,too. In the latter borehole its Pelsonian age is probabilized by the fragments of Gondolella cf. bulgarica.

4.3.2 Dunnatető Limestone Formation

The other (pelagic) kind of the first basinal facies overlying the Steialm Formation.

Typical variety: predominantly pink or whitish-grey, occasionally pinkish-grey, pinkish-white, fawn-coloured or grey, typically aphanitic, banked to thick-banked limestone of conchoidal-splintery fracture. Its thickness is from 1–2 m to more than 100 m. Characteristic microfacies are: micrite and microsparitic micrite; mudstone. The few biogenic components are represented by radiolarians, filaments, echinoderm fragments and ostracods. Macroscopically it closely resembles of the "Massiger Hellkalk" Member of the Upper Triassic Hallstatt Limestone Formation.

Type-section: at the southern-southwestern margin of the Dunnatető. Other significant occurrences: the southwestern slope of Dunnatető, the western slope of the western peak of Szárhegy and the borehole Varbóc-4 (in the side-valley No. 8 of the Telekes-valley). It often forms fissure fillings in the Steinalm Limestone.

Age: Pelsonian – Illyrian (from the Gondolella bulgarica interval zone to the Gondolella constricta interval zone).

In broader sense other pelagic limestones directly overlying the Steinalm Limestone are assigned to this formation, too, e.g. the part of the section No. 6 of the Telekes-valley ending with purplish-red nodular limestone or the purplish-red ammonitic limestone on the eastern peak of Szárhegy.

4.3.3 Bódvalenke Limestone Formation

The typical variety consists of the alternation of well- or thin-bedded reddish-pink or purplish-red, fine-crystalline to aphanitic limestone and of white to light-grey, coarse-crystalline filament limestone (coquina), with purplish-red shale intercalations of 1–2 mm to 1–2 cm thickness and with red chert lenses, sometimes with nodules ro layers. The characteristic microfacies of the fine-crystalline to aphanitic limestone is radiolarian–filament biomicrite or microsparitic biomicrite; wackestone; that of the coarse-crystalline limestone is filament biosparite (coquina); grainstone. Based on the distribution of filaments (juvenile pelagic bivalves) gradation can be often observed in this latter. The lithology can considerably change even within short distances (i.e. within a few hundred meters) and several non-typical varieties exist. The thickness is varying, usually several ten meters.

Sedimentary facies: this sediment deposited in the zone of intense carbonate dissolution under conditions of the interactions of deep-water lithification – carbonate dissolution – non-sedimentation. The purplish-red shale intercalations refer to the interruptions of carbonate deposition, the light crystalline filament limestone ("coquina") beds represent carbonate turbidites.

Type-section: Bódvalenke village, the exposure beneath the road bend at the northwestern edge of the village (stratotype), and in the Bódvalenke-2 borehole (lower boundary-stratotype). Other, often non-typical occurrences: in the northwestern side-valleys of the Telekes-valley, in the northwestern side of Dunnatető and in the western side of the Csipkéshegy, at the Szárhegy, in some couloirs in the southern and eastern side of Esztramos, in the Slovakian part of the mountains in the Žarnov environs and in several boreholes, e.g. Szendrő-4, Varbóc-4 etc.

Age: changing from section to section, from the Illyrian to the Lower Tuvalian (from the Gondolella constricta interval zone to the G. polygnathiformis interval zone).

4.3.4 Szárhegy Radiolarite Formation

The typical variety is the greenish-yellow to yellowish-green, occasionally yellowish-brown laminated radiolarite often with dark-grey to black coloured bands. Purplish-red and dark-grey-black varieties may also occur. The radiolarite laminae are often separated by thin (mm to cm size) shale intercalations. Bedding planes display sometimes Daonella (Halobia) shell imprints. Characteristic microfacies: a) carbonatic variety: silicified radiolarian-filament biomicrosparite; wackstone-packstone; b) carbonate-free variety: radiolarian biomicrosparite; packstone-wackestone. The latter one is more clayey and rich in sericite lamellae. Its thickness is about 30 m.

Type-section: Szárhegy, key-section of the eastern peak. Extension: southern slope of the eastern and middle peaks, in small area it extends over the southeastern slope of the western peak.

The sequence of the former manganese exploring gallery in the valley-head of the northwestern sidevalley No. 8 of the Telekes-valley can be assigned to this formation: 6 m thick laminated reddish-brown, pink, occasionally white, thin bedded chert, at the margins of beds with pink porous radiolarite, and with light greenish-grey lime-free clay intercalations, then in 1.5 m thickness brown radiolarite alternating with greenish-yellowish-brownish lime-free clay.

Sedimentary facies: the carbonate-bearing variety derives from about the carbonate compensational level, the carbonate-free one (in the top part of the Szárhegy-East section and in the manganese exploring gallery mentioned) deposited below that.

Age: based on its stratigraphic position in the type-region the age is Ladinian-Carnian. In the section of the manganese exploring gallery in the Telekes-valley Upper Fassanian radiolarians (Triassocampe scalaris Dumitrica, Kozur et Mostler) and conodont fragments (Gondolella sp.) were found (Kozur, H. oral communication).

4.3.5 Hallstatt Limestone Formation

In the Bódva facies the Hallstatt Limestone is mostly disturbed by slump and sediment flow structures (as in the environs of Bódvalenke and of the Lászi Spring). The Norian light "Massiger Hellkalk" and the red "Hangendrotkalk" merged and got mixed already in plastic lime mud stage and cannot be mapped separately. Nevertheless, in other localities (e.g. in the Mész-valley and in the borehole Szalonna-5 west of the Szárhegy, in the borehole Szendrő-4 and in the northwestern side-valleys of the Telekes-valley) the sedimentary structure of the Hallstatt Limestone is undisturbed, the two aforementioned members are not mixed. The Norian age of the limestones is evidence by the same conodonts that are found in the Aggtelek facies.

The Rudabánya-658 borehole (about 1 km from the gorge of the Telekes-valley) and the Perkupa-74 borehole (at the Csipke's-hill) explored white, aphanitic, nodular, red cherty limestone with red clay interbedding among the nodules, the age of which is Upper to Middle Norian on the basis of the occurrence of Gondolella steinbergensis Mosher. (Limestone of similar lithology of Ladinian age occurs as a variety of the Bódvalenke Limestone.)

4.3.5.1 Lászi Spring Member

In the environs of the Lászi spring not only Norian but also Upper Ladinian – Middle Carnian variegated limestones of sediment flowage structure developed by the mixing of light and red lime-mud occur. Therefore this Upper Ladinian–Norian brecciated Hallstatt Limestone is considered as a distinct member. Its age is proved by the Gondolella foliata inclinata Kovács, Gondolella polygnathiformis Bud. et Stef., Gondolella cf. trammeri Kozur and Gladigondolella malayensis malayensis Nogami, while that of the Norian ones by Gondolella steinbergensis (Mosher), Metapolygnathus bidentatus (Mosher) and M. posterus (Kozur et Mostler).

4.3.6 Zlambach Formation

Only uncertain data are available on the occurrence of the Zamblach Beds within the Bódva facies. In the borehole Szalonna-5 (southwestern side of the western top of Szárhegy), between the "Hangendrotkalk" member of the Hallstatt Limestone and the certain Jurassic dark-grey schistose mudstone and siltstone (37.10—44.80 m) green to greenish-grey — dark-grey mudstone and siltstone are found with tectonically undisturbed contact and with grey limestone olistoliths emplaced still in plastic stage; this may correspond probably to the Zlambach Formation. In the borehole Szendrő-4 marked out and documented by Grill, J. it is lacking and the uneven surface of the grey micritic limestone, containing Gondolella steinbergensis and overlying the "Hangendrotkalk" between 85.70 and 81.30 m, is directly overlain by the Jurassic black shale.

The "variegated marl" sequence explored in the ravine of the northwestern side-valley No. 8 of the Telekes-valley may correspond to the Zlambach Formation horizon (alternation of green and purplish-red marl, limestone and schistose calcareous mudstone representing the oldest unit of the Telekes Valley Group). In one purplish-red limestone olistolith Gondolella steinbergensis (Mosher) was found.

4.4 Bódvarákó Facies

4.4.1 Bódvarákó Formation

It consists of the alternation of medium to dark-grey, well-bedded limestone and of black chert layers, rarely lenses. The average thickness of limestone beds is 10 cm, that of the chert layers is 5 cm. Bedding planes are uneven, undulatory. Between the beds locally 1 to 15 mm thick black clay and siltstone bands are found. The Steinalm Formation is missing and the sequence overlies directly the Gutenstein Dolomite. The real thickness is 40 m in the borehole Bódvarákó-5 and 5 m of this is represented by the chert-free limestone constituting the transition towards the Gutenstein Formation. Its microfacies is radiolarian and filament biosparite and biomicrosparite; wackestone.

Sedimentary facies: euxine deep-water basinal facies (black colour, bacteriopyrite).

Type-section: in the abandoned quarry, 1 km of Bódvarákó in the right side of the Nyúlkertvölgy creek, below the service road leading to the Esztramos quarry (key section AR-19).

Age: from the Lower(?) – Middle Anisian (*Gondolella* cf. *bulgarica* from the borehole Bódvarákó-5 between 116.65 and 116.70 m; Kozur, H., oral communication) to the Upper Ladinian (*Gondolella foliata inclinata* Kovács from the upper part of the surface key-section) but may reach the Lower Carnian, as well.

"Nyúlkertlápa Beds"

It is an about 80 m thick greenish-grey – grey – black shale and marl sequence overlying the Bódvarákó Formation, with grey limestone olistoliths of two kinds of texture (fine- and medium-crystalline) in its upper part. Because of its uncertain age and of its only one occurrence it is considered as an unofficial lithostratigraphic unit.

The microfacies of the fine-crystalline limestones is radiolarian biomicrosparite; wackestone.

Age: Upper Triassic(?), but it cannot be excluded, that the sequence belongs to the Jurassic, overlying the Bódvarákó Formation with a considerable sedimentary gap. No conodonts were found in the limestone olistoliths even having investigated more 20 samples.

4.5 Tornakápolna Facies

4.5.1 Bódvavölgy Ophiolite Formation

Dismembered ophiolite sequence, the slabs of which are mélange-like tectonically reworked into Upper Permian evaporites at the base of the units of the Silicicum. The ophiolitic rock association contains the types below (Réti, Zs., 1985):

Serpentinite. This is the most common rock type. Its anhydrous formula and certain relict minerals indicate a parental rock of most likely lherzolitic composition and of upper mantle origin.

Albite gabbro and albite diabase. Completely spilitized coarse-grained gabbro and finer-grained diabase containing mostly low-albites, secondary amphibole, actinolite, epidote and chlorite as well as ilmenomagnetite.

Metabasalt. Highly spilitized greyish-green effusive rocks, occasionally coloured by dark-red hematite. Pillow-basalts are the most frequent rocks but massive varieties and hyaloclastite flows are also abundant. The cores of pillows and massive basalts are of subophiolitic or intersertal texture, while the selvages are characterized by vitroclastic or variolitic texture, the hyaloclastic flows mostly by vitroclastic texture.

Radiolarite. Red radiolarite and clay intercalations of a few cm to a few m thickness are found in the pillow basalt sequence or fill the inter-pillow voids.

The geochemistry of metabasalts refers to ocean floor thoeliitic origin.

The radiometric age determinations on albite gabbro relate to the Middle to Upper Triassic age of these rocks (219 ± 15 Ma on the average of seven measurements, see Árva-Sós, E. et al., 1987) while in the borehole Tornakápolna-3 in one inter-pillow radiolarian clay intercalation Upper Fassanian radiolarians were found (Kozur, H.-Réti, Zs., 1986).

It is to be noted that the age datum of 233 ± 10 Ma determined on biotite is considered by Árva-Sós, E. et al. (1987) as the best approximation of the time of emplacement of the gabbro intrusion.

The most significant occurrences of these ophiolitic rocks can be found in the boreholes Tornakápolna-3, Szögliget-4, Szin-1 and Komjáti-11 and above all in the Perkupa anhydrite mine.

4.6 Torna Facies

4.6.1 Szentjánoshegy Limestone Formation

Grey, locally drabbish or reddish-pinkish, fine-crystalline banked limestone with brownish or reddish bands. The bands of metamorphic origin (lineation) are parallel with the banks. It does not contain chert. Its thickness is 20 to 25 m in the Hidvégardó environs. The original microfacies of the coloured (drab, reddish-pink) limestones that can be partly recognized is radiolarian (subordinately filament) biomicrosparite; wackestone, rarely mudstone or packstone. The microfacies of the recrystallized varieties is euqigranular (rarely inequigranular) hypidiotopic-xenotopic metasparite with a crystal size of 40-50 µm. In the grey limestones the amounts of filaments (and occasionally of crinoids) become abundant, the original microfacies is filament (subordinately radiolarian) biomicrosparite and biosparite, respectively (wackestone, packstone or grainstone). The recrystallized form is inequigranular xenotopic metasparite with a crystal size of 50-100 µm.

Sedimentary facies: pelagic basinal facies deposited on a fairly even bottom (lack of resedimentation phenomena).

Type-section. the borehole Hidvégardó-3, between 45.9 and 64.4 m (unit stratotype).

Age: Upper Anisian (Gondolella constricta interval zone) – Uppermost Ladinian (Gondolella foliata foliata interval zone), but may reach into the Lower Carnian, too (though no conodonts ofthat age were found in the top part).

The Esztramos sequence showing some differences to this picture is discussed within the Szentjánoshegy Limestone Formation:

Here the metamorphic Steinalm Limestone is overlain in a thickness of about 70 m by Pelsonian to Lower Longobardian grey, banded, banked limestone (with brownish and drabbish bands and interbeddings), and yellowish-white to brownish-white schistose finer-coarser crystalline limestone. The Pelsonian age is evidenced by Gondolella bulgarica (Bud. et Stef.) and Gladigondolella malayensis budurovi Kovács et Kozur while Gondolella foliata inclinata Kovács relates to the Longobardian. This part of the sequence can be correlated in broader sence with the Szentjánoshegy Limestone.

In its overlier, in a thickness of about 70 m (upwards to the Tornaszentandrás Shale) a bone-white, schistose banked limestone is found often with purplish-red and brownish-grey chert lenses and nodules, in its upper part with brown finer-crystalline platy limestone intercalations. This sequence is devoid of fauna; based on its stratigraphic position its age should be Upper Longobardian to Cordevolian. Because of its occurrence only in one section it is not regarded as an independent official lithostratigraphic unit.

4.6.2 Tornaszentandrás Shale Formation

It is a black shale (sometimes silty) consisting of 2 to 10 mm thick lamellae of more or less even joint surfaces and being yellowish-brown weathered and lamellarly disintegrating on its surface. Locally it is slightly carbonatic, rarely transversely schistose. The only, 50 cm thick dark-grey coarse-crystalline limestone intercalation is found in the Nagy-Rednek-valley of Martonyi. Its total thickness is 30 to 50 m in the Hidvégardó area, the apparent thickness is about 50 m on the southern side of the Esztramos and about 100 m in the Martonyi–Tornaszentandrás area.

Type-section: the borehole Hidvégardó-3, between 69.4 and 96.7 m (unit-stratotype); surficial type-exposure: Tornaszentandrás, at the end of the court of the house Kossuth street 18.

Sedimentary facies: fine-detrital basinal facies representing the "Raibl event", deposited on an even bottom under reductive conditions.

Age: based on its stratigraphic position Middle Carnian in general, but may include part of the Lower and Upper Carnian, as well. The limestone intercalation in the Nagy-Rednek-valley mentioned above contains Lower to Middle Carnian conodonts (Gladigondolella malayensis malayensis Nogami, Gondolella foliata inclinata Kovács, Gondolella foliata foliata Bud. et Stef., Gondolella polygnathiformis Bud. et Stef.).

4.6.3 Pötschen Limestone Formation

It is a grey, thin-banked – bedded – thin-bedded fine to small crystalline, cherty limestone. The brownish-grey chert nodules, lenses and layers alternate with the limestone and the chert amount often exceeds that of the limestone. Its thickness is about 55–60 m at Hidvégardó, between Martonyi and Tornaszentandrás 150 m at least. Its original microfacies is the same as that of the non-metamorphic variety (see the Szőlősardó Facies), but its texture is oriented. The texture of the completely recrystallized varieties (mainly between Martonyi and Tornaszentandrás) is homogeneous oriented metasparite.

Its sedimentary facies differs from the typical Pötschen Limestone of Szőlősardó, being free of resedimentation phenomena.

Age: Upper Carnian (Tuvalian-1/b–2/a, Gondolella polygnathiformis interval zone) – Lower Norian (Lacian-3, Metapolygnathus posteurs interval zone).

4.6.4 Nagykő Limestone Formation

It is a yellowish-brown, yellowish-white, purplish-pink, sometimes purplish-red, small-crystalline, well-bedded limestone locally with red chert nodules. The known thickness is 20 to 30 m. Its texture is homogeneous oriented sparite, sometimes with faint filaments and crinoid fragments and frequently with authigenic quartz crystals of 25 to 50 μm size.

Sedimentary facies: similarly to the underlying Pötschen Limestone basin sediment but at the time of deposition with considerably reduced carbonate production and presumably with increasing terrigeneous detrital influx.

Type-section: Hidvégardó, western slope of Nagykő (lower boundary-stratotype).

Age: based on its poor conodont fauna (it contains only *Gondolella steinbergensis* Mosher) and on its stratigraphic position Middle–Upper(?) Norian.

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INVESTIGATION OF CALPIONELLIDS FROM THE MECSEK MOUNTAINS (SOUTH HUNGARY) - 2

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This work aims at the continuation of describing the new calpionellid taxa published in Acta Geol. Acad. Sci. Hung. Vol. 29, 1—2 (1986). Here 3 new genera and 55 new species are described, the remaining part will be published later. The taxon descriptions being restricted to the most significant features and to be published serve as a possibility to process and correlate the calpionellid-containing sections. Photos (Plate I—IV) show only the holotypes, the dimensions of which are found in Table I in micrometers. Finally, the new provisional table ('88HM-2) of the Calpionellidea zonation of the Mecsek Mountains (HM = Hungary, Mecsek) is published in which the occurring taxa mark the zone boundaries (Table II).

Keywords: Upper Jurassic, Lower Cretaceous, Jurassic/Cretaceous boundary, Calpionellid biostratigraphy, new taxa

New taxa

Sopianella nov. gen.

Type species: Sopianella longa n.sp.

Derivatio nominis: after the Latin name of the closest town (Pécs = Sopianae).

Description: small-medium sized elongated forms with a lorica narrowing in the aboral part, with slightly developed shoulder and with straight or slightly bending collar.

Sopianella longa n.sp. (Code: Sl, Regist. No. MP-1).

Derivatio nominis: reference to the long (longus) lorica.

Holotype: Sample No. 85-53/60, Plate I. Fig. 1; Table I/1. Photo 88/3/2.

Locus typicus: Magyaregregy. Stratum typicum: Berriasian.

Description: Medium-sized form of thin wall. The lorica is widest at the shoulder, from here to the lower one-third slightly, from there considerably thins. The aboral end is slightly rounded. The shoulder is

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Table I

No.	Code	Length	Width	Oral
1.	Sl	60	41	26
2.	Smi	42	31	18
3.	Ccc	61	41	25
4.	Ccp	34	31	16
5.	Bg	62	40	24
6.	Bl	60	47	29
7.	Lsa	68	38	25
8.	Lsc	57	38	27
9.	Lsm	75	38	25
10.	Lsd	68	39	28
11.	Lssl	60	42	30
12.	Cha	66	52	35
13.	Cpua	33	33	18
14.	Tbc	80	54	43
15.	Tgc	66	44	30
16.	Tcc	72	48	34
17.	Tic	70	48	36
18.	Tpbc	76	62	46
19.	Tlc	108	56	44
20.	Tlac	106	62	48
21.	Ttuc	100	61	40
22.	Tcoc	92	60	44
23.	Tpl	160	52	38
24.	Cpsobes	81	59	44
25.	Cpsshlo	56	31	21
26.	Cpspuo	62	31	22
27.	Cpsfuso	65	43	29
28.	Cpspvfuso	52	35	22
29.	Cpspovo	65	43	28
30.	Cpsbovo	55	38	24
31.	Cpsovo	72	41	30
32.	Cpaheplo	74	40	29
33.	Cpsplo	74	39	29
34.	Cpsgplo	88	40	28
35.	Cpsrplo	87	47	30
36.	Cpsgovo	89	46	30
37.	Cpspvbo	52	38	29
38.	Cpsbo	78	40	30
39.	Cpscubo	87	41	27
40.	Cpscompo	79	40	27
41.	Cpstho	96	43	29
42.	Cpsbello	88	43	28
43.	Cpsveno	93	46	30
44.	Cpsgracilo	100	42	30
45.	Cpspromo	108	37	28
46.	Cpsvinco	98	50	30
47.	Cpsginlo	110	58	32
48.	Cpscoho	98	38	22
49.	Cpsho	92	40	30
50.	Cpspvho	80	36	25
51.	Cpslho	86	40	30
52.	Cpsteho	91	37	29
53.	Cpsbho	80	40	25
54.	Cpspaho	85	35	23
55.	Cpstuho	96	37	25

slightly sloped, the collar is of medium-size and straight. The oral opening is medium-sized.

Sopianella minuta n.sp. (Code: Sm Regist. No. MP-2).

Derivatio nominis: reference to the small size (= minutus).

Holotype: Sample No. 85-53/60, Plate I, Fig. 2; Table I/2, Photo 88/3/3.

Locus typicus: Magyaregregy. Stratum typicum: Berriasian.

Description: small-sized form with thin wall. Its lorica is widest below the shoulder, to the lower one-fifth it becomes slightly, from there strongly pointed. The aboral end is slightly rounded, the shoulder is undeveloped with arched transition. The collar is rudimentary, straight, the oral opening is small-to-medium sized.

Crassicalpionella nov. gen.

Type species: Crassicalpionella conica n.sp.

Derivatio nominis: Reference to the kinship with the genus Calpionella and association with the relatively thicker (= crassus) wall.

Description: small-to-medium sized, elongated forms of relatively thick wall, with medium-developed shoulder and straight collar.

Crassicalpionella conica n.sp. (Code: Ccc Regist. No. MP-3).

Derivatio nominis: on the conic (= conicus) shape of the lorica.

Holotype: Sample No. 85-53/56, Plate I, Fig. 3; Table I/3, Photo 88/3/1.

Locus typicus: Magyaregregy. Stratum typicum: Berriasian.

Description: Medium-sized elongated form with thick walls in the shoulders. Lorica is widest at the shoulder, downwards becomes conically narrow, the aboral end is rounded. The shoulder is slightly sloped, the collar is medium-developed and thin as compared to the wall of lorica and is straight. The oral opening is small-to-medium sized.

Crassicalpionella pusilla n.sp. (Code: Ccp Regist. No. MP-4).

Derivatio nominis: reference to the very small (= pusillus) size.

Holotype: Sample No. 85-53/73, Plate I, Fig. 4; Table I/4, Photo 88/4/33.

Locus typicus. Magyaregregy. Stratum typicum: Berriasian.

Description: very small-sized form with thick wall. Lorica is widest at the shoulder, from there it slightly thins in a short part then becomes narrow with a strong bend almost to the apical aboral end. The shoulder is strongly sloped, the collar is weakly developed and straight. The oral opening is small-medium sized.

Baranella nov. gen.

Type species: Baranella gracilis n. sp.

Derivatio nominis: after the name of the administrative unit (Baranya county) including most of the Calpionellidea localities of the Mecsek Mountains.

Description: small-medium sized elongated forms with very underdeveloped shoulder and with straight collar.

Baranella gracilis n. sp. (Code: Bg Regist. No. MP-5).

Derivatio nominis: reference to the slim (= gracilis) form.

Holotype: Sample No. 85-53/68, Plate I, Fig. 5; Table I/5. Photo 88/3/6.

Locus typicus: Magyaregregy. Stratum typicum: Berriasian.

Description: Medium-sized, strongly elongated elliptic form. Lorica is widest just above its middle line and mildly bends both towards the oral and towards the aboral parts. The aboral end is slightly rounded. The shoulder is strongly sloped, hardly detectable. The collar is developed and straight.

Baranella laxa n. sp. (Code: Bl Regist. No. MP-6).

Derivatio nominis: reference to the wide (= laxus) oral opening.

Holotype: Sample No. 85-53/60, Plate I, Fig. 6; Table I/6. Photo 88/4/32.

Locus typicus. Magyaregregy. Stratum typicum. Berriasian.

Description: Medium-sized slightly elongated oval form with thick wall. Lorica has its maximum width just above the middle line and becomes narrow towards both ends with a continuous bend. The aboral end is strongly rounded. The shoulder strongly sloped, the collar is undeveloped and straight. The oral opening is wide.

Lorenziellopsis nov. gen.

Type species: Lorenziellopsis arcuata n. sp.

Derivatio nominis: in honour of Th. Lorenz and reference to the relationship with the genus Lorenziella.

Description: Small-sized elongated forms with apical aboral end. Collar is very undeveloped, its wall is thinner than that of the lorica and adjoins the lorica with a mild bend, towards the oral opening it becomes slightly bulging then slightly bends out.

Lorenziellopsis arcuata n. sp. (Code: Lsa Regist. No. MP-7).

Derivatio nominis: reference to the bended shape (= arcuatus) of the lorica.

Holotype: Sample No. 63-39/49, Plate I, Fig. 7; Table I/7, Photo 88/4/18.

Table II

Age				ROMA STANDARD ZONES	Sümeg subzones			'88HM-2 Zone	
								No.	Index foss.
CRETACEOUS	NEOCOMIAN	VALANGINIAN		CALPIONELLITES		E	22-19	54.	Ct. darderi
				CALPIONELLOPSIS	oblonga	D3	18	53.	Pc. murgeanui
							17	52.	T. perlonga
								51.	T. turgicarpathica
								50.	T. perbrevicarpathica
								49.	T. brevicarpathica
								48.	Ls. arcuata
								47.	L. hungarica
		RYAZANIAN	BERRIASIAN			D2	16	46.	Cps. tumohastoblonga
								45.	Cps. hastoblonga
								44.	Cps. conohastoblonga
							15	43.	Cps. conoblonga
								42.	Cps. pusilloblonga
								41.	Cps. oblonga
								40.	Cps. venoblonga
								39.	Cps. humiloblonga
							14	38.	Cps. acutoblonga
					simplex	D1	13	37.	Cps. planoblonga
								36.	Cps. crassoblonga
							12	35.	Cps. protoblonga
								34.	Cps. brevoblonga
								33.	Cps. oblosimplex
								32.	Cps. breviclaroblonga
								31.	Cps. brevisimplex
							11	30.	Cps. procerosimplex
							10	29.	Cps. simplex
				CALPIONELLA		C	9	28.	Lt. venustus
							8	27.	C. latalpina
								26.	C. elliptica
JURASSIC	MALM	VOLGIAN				B	7	25.	C. globalpina
								24.	C. parvelliptica
							6	23.	C. grandalpina
							5	22.	C. brevelliptica
								21.	S. longa
								20.	T. carpathica
								19.	Cc. conica
								18.	R. cadischiana
							4	17.	C. parvalpina
								16.	T. doliformis
								15.	T. inornata
								14.	Cr. colomi
								13.	C. alpina
			L.TITH.	CRASSICOLLARIA	intermedia	A3	3	12.	Cr. massutiniana
								11.	Cr. brevis
								10.	C. longalpina
						A2	2	9.	T. gracilicarpathica
								8.	Cr. parvula
								7.	T. crassicarpathica
								6.	Cr. intermedia
					remanei	A1	1	5.	Cr. latintermedia
								4.	T. remanei
			M.TITH.					3.	Pt. andrusovi
								2.	Ch. boneti
								1.	Ch. dobeni

Locus typicus: Hosszúhetény. Stratum typicum: Valanginian.

Description: small-medium sized elongated form with a wall thicker than the average. Lorica has its maximal width in the subcollar region, from here gently bends with slow narrowing to the lower one-third, from there with stronger narrowing. The aboral end is almost apicular. The collar is extraordinarily undeveloped, after an inward bulging small bend it slightly bends out, in about 70°. The oral opening is narrow.

Lorenziellopsis compactilis n. sp. (Code Lsc Regist. No. MP-8).

Derivatio nominis: reference to the stubby (= compactilis) lorica.

Holotype: Sample No. 85-54-2/71, Plate I, Fig. 8; Table I/8, Photo 88/3/32.

Locus typicus: Magyaregregy. Stratum typcium: Valanginian.

Description: small-medium sized slightly elongated form with thin wall. Lorica has its maximal width below the collar, from here the walls run quasi-parallel to the lower third then with a sudden break these get the aboral end with a strong bend. The collar is of medium size and becomes thin. After an inward bulging fine bend it bends out at about 60°. The oral opening is medium-sized.

Lorenziellopsis mucronata n. sp. (Code: Lsm, Regist No. MP-9).

Derivatio nominis: reference to the spiked (= mucronatus) lorica.

Holotype: Sample No. 85-54-2/62, Plate I, Fig. 9; Table I/9, Photo 88/3/29.

Locus typicus: Magyaregregy. Stratum typicum: Valanginian.

Description: Small-medium sized strongly elongated form with thicker wall than the average. Lorica has its maximal width at the upper seventh, upwards slightly, downwards slightly bending becomes continuously narrower to the apical aboral end. Collar is very undeveloped, hardly detectable. The oral opening is narrow.

Lorenziellopsis dilatata n. sp. (Code: Lsd Regist. No. MP-10).

Derivatio nominis: reference to the elongated (= dilatatus) lorica.

Holotype: Sample No. 85-54/83, Plate I, Fig. 10; Table I/10, Photo 88/4/2.

Locus typicus: Magyaregregy. Stratum typicum: Valanginian.

Description: small-medium sized elongated form with thin wall. Lorica has its maximal width at its upper third from where becomes narrow towards its both ends with a continuous bend. The aboral end is almost apical. The collar is undeveloped, on the left it bends out from the lorica wall at about 45^{0} with an inward bulging bend, on the right it is slightly broken at the bend. The oral opening is narrow.

Lorenziellopsis suplata n. sp. (Code: Lsl Regist. No. MP-11).

Derivatio nominis: Reference to the upper (= superior) part of the lorica is wider (= latus).

Holotype: Sample No. 85-54-2/87, Plate I, Fig. 11; Table I/11, Photo 88/4/6.

Locus typicus: Magyaregregy. Stratum typicum: Valanginian.

Description: small-medium sized slightly elongated form with thicker wall than the average. Lorica has its maximal width at the suboral part, from here to the lower third slowly then suddenly becomes narrow just to the apical aboral end. The collar is extraordinarily undeveloped, hardly detectable. The oral opening is medium-sized.

Calpionella hebalpina n. sp. (Code: Cha Regist. No. MP-12).

Derivatio nominis: reference to the relationships with the species C. alpina and to the blunt (= hebes) aboral end.

Holotype: Sample No. 85-53/79, Plate I, Fig. 12; Table I/12, Photo 88/3/8.

Locus typicus: Magyaregregy. Stratum typicum: Berriasian.

Description: Large-medium sized slightly elongated form. The wall thins out at the aboral end. Lorica has its maximal width at the shoulder, then becomes narrow by a mild bend, the aboral end is bluntly rounded. The shoulder is definitive, the collar is developed bulging out in its central part. The oral opening is wide.

Calpionella pusillalpina n. sp. (Code: Cpua Regist. No. MP-13).

Derivatio nominis: reference to the relationship with the species C. alpina and to the tiny (pusillus) shape.

Holotype: Sample No. 85-53/73, Plate I, Fig. 13; Table I/13, Photo 88/3/7.

Locus typicus: Magyaregregy. Stratum typicum: Berriasian.

Description: very small-sized, almost isometric form of moderately thick wall. Lorica has its maximal width at the shoulder, then becomes narrow first with a mild then with a stronger bend to the almost apical aboral end. The shoulder is rather sloped, the collar is undeveloped and straight. The oral opening is medium-wide.

Tintinnopsella gracilicarpathica n. sp. (Code: Tgc Regist No. J. 10844).

Derivatio nominis: reference to the relationship with the species T. carpathica and to the shape (= gracilis).

Holotype: Sample No. 67-1/8, Plate I, Fig. 15; Table I/15, Photo 84/32/33.

Locus typicus: Magyaregregy, Stratum typicum: Berriasian.

Description: small-sized form with thin wall and with medium-sized oral opening. Lorica has its maximal width at the upper third, the aboral end is almost apical, slightly rounded. The collar adjoints the lorica without break by a mild bend and bends out at about 45°, and is medium-developed.

Tintinnopsella crassicarpathica n. sp. (Code: Tcc Regist. No. J. 10843).

Derivatio nominis: reference to the relationship with the species T. carpathica and to the considerable wall thickness as compared to the small size (= crassus = thick).

Holotype: Sample No. Pv-V. 23, Plate I, Fig. 16; Table I/16, Photo 84/20/21.

Locus typicus: Pécsvárad. Stratum typicum: Berriasian.

Description: small-sized form with considerably thick wall as compared to its size, with medium-sized oral opening. Lorica has its maximal width at the central line, the aboral end is almost apical. The collar adjoins the lorica with the break and bends out by about 45°.

Tintinnopsella isocarpathica n. sp. (Code: Tic Regist. No. J. 10845).

Derivatio nominis: reference to the isometric habit and to the relationship with the species T. carpathica.

Holotype: Sample No. 67-1/24a, Plate I, Fig. 17; Table I/17, Photo 84/22/15.

Locus typicus: Magyaregregy. Stratum typicum: Berriasian.

Description: small-medium sized slightly elongated form with medium-sized oral opening. Lorica has its maximal width at the upper fourth, to the lower third slightly, from there suddenly becomes narrow. The aboral end is apical. The collar adjoining the narrowing lorica bends out at the oral opening by about a rectangle, then at its ends it bends upwards.

Tintinnopsella brevicarpathica n. sp. (Code: Tbc Regist. No. MP-14).

Derivatio nominis: reference to the relationship with the species T. carpathica and to the short (= brevis) lorica.

Holotype: Sample No. 85-54-2/62, Plate I, Fig. 14; Table I/14, Photo 88/3/26.

Locus typicus: Magyaregregy. Stratum typicum: Valanginian.

Description: Large-medium sized hardly elongated shield-shaped form of medium thick wall. Lorica has its maximal width somewhat below the central line, it becomes narrow only to insignificant extent towards the oral opening and transits into the almost apical aboral end with an unbroken bend. The collar is medium-developed, after small thickening bends out only slightly from the horizontal line at its end. The oral opening is wide.

Tintinnopsella perbrevicarpathica n. sp. (Code) Tpbc Regist. No. MP-15).

Derivatio nominis: Reference to the relationship with the species T. carpathica and to the very short (= perbrevis) lorica.

Holotype: Sample No. 85-54-2/62, Plate I, Fig. 18; Table I/18, Photo 88/3/25.

Locus typicus: Magyaregregy. Stratum typicum: Valanginian.

Description: Large-medium sized isometric form with slightly thick wall that thins out at the aboral end. Lorica has its maximal width just below the central line, becomes slightly narrow towards the oral opening and inclines to the wide and slightly rounded aboral end with a strong bend. The collar is developed, after initial thickening bends out horizontally then in the right collar it bends upwards in a short section. The oral opening is very wide.

Tintinnopsella longocarpathica n. sp. (Code: Tlc Regist. No. J. 10838).

Derivatio nominis: reference to the transitional character between the species T. longa and T. carpathica.

Holotype: Sample No. Tb-2/41, Plate II, Fig. 1; Table I/19, Photo 84/33/6.

Locus typicus: Magyaregregy. Stratum typcium: Berriasian.

Description: medium-large sized elongated form with relatively large oral opening. Lorica has its maximal width at about the central line this hardly exceeds the size of the oral opening. The lorica becomes only slightly narrow upwards, downwards the narrowing is slow to the lower fourth, from there this is sudden. The aboral end is apical and shows the commencement of caudal apophysis. The collar is medium-developed and bends upward by about 35°.

Tintinnopsella laticarpathica n. sp. (Code: Tlac Regist. No. J. 10841).

Derivatio nominis: reference to the relationship with the species T. carpathica and to the wide (= latus) lorica.

Holotype: Sample No. Tb-2/18, Plate II, Fig. 2; Table I/20, Photo 84/33/2.

Locus typicus: Magyaregregy. Stratum typicum: Berriasian.

Description: Large-sized elongated form with relatively large oral opening. Lorica has its maximal width at about its lower third, from here becomes narrow slightly to the oral opening and strongly but continuously to the aboral end. The aboral end is rounded. The collar is medium-developed, the right one stands horizontally, its end bends slightly upward, the left bend slightly down.

Tintinnopsella turgicarpathica n. sp. (Code: Ttuc Regist. No. MP-16).

Derivatio nominis: reference to the relationship with the species T. carpathica and to the "blown-up" (= turgidus) lorica.

Holotype: Sample No. 85-54-2/62, Plate II, Fig. 3; Table I/21, Photo 88/4/28.

Locus typicus: Magyaregregy. Stratum typicum: Valanginian.

Description: large-sized elongated form with thick wall. Lorica has its maximal width below the central line, becomes gradually and rather strongly narrow towards the oral opening, the aboral end is widely rounded, thus showing the form of a ballon. The collar is developed, asymmetric, the left one bends up by a mild bend after slight thickening, the right points outwards and begins with a double fracture and stands somewhat deeper than the other. The oral opening is relatively narrow.

Tintinnopsella collcarpathica n. sp. (Code: Tcoc Regist No. J. 10842).

Derivatio nominis: reference to the relationship with the species T. carpathica and to the conspicuously developed state of the collar (= collar).

Holotype: Sample No. Sz-Ir/1, Plate II, Fig. 4; Table I/22, Photo 84/33/14.

Locus typicus: Mázaszászvár. Stratum typicum: Valanginian.

Description: medium-large sized elongated form with relatively small-sized oral opening. Lorica has its maximal width at about the central line, from here the walls run with a nice bend towards the oral opening and aboral end. The aboral end is almost apical, very slightly rounded. The collar is extremely developed, it is about one sixth of the lorica length, bends out and up at about 35^{o}, its end bends slightly up.

Tintinnopsella perlonga n. sp. (Code: Tpl Regist. No. J. 10840).

Derivatio nominis: reference to the relationship with the species T. longa and to the very long (= perlongus) habit.

Holotype: Sample No. Szv. Ir/1, Plate II, Fig. 5; Table I/23, Photo 84/33/10.

Locus typicus: Mázaszászvár. Stratum typicum: Valanginian.

Description: very large-sized highly elongated form Lorica walls are parallel from the oral opening to the lower fifth, from here these form as an arc the aboral end. The collar is developed, commences almost horizontally, then bends up by a mild arc.

Calpionellopsis obesisimplex n. sp. (Code: Cpsobes Regist. No. MP-17).

Derivatio nominis: reference to the relationship with the species C. simplex and to the thick habit (= obesitas).

Holotype: Sample No. 85-54/36, Plate II, Fig. 6; Table I/24, Photo 88/3/12.

Locus typicus: Magyaregregy. Stratum typicum: Berriasian.

Description: Large-sized, elongated oval form. Lorica has its maximal width at the central line, from here becomes narrow towards both ends by a mild bend. The aboral end is rounded. The lorica walls incline inwards at the ends, from inside are arcuate-grooved. The superimposed collars sit in the grooves and are medium-developed and of the same orientation as the lorica walls. The oral opening is medium-sized.

Calpionellopsis semihumioblonga n. sp. (Code: Cpsshlo Regist. No. MP-18).

Derivatio nominis: reference to the very close relationship with the species C. humioblonga.

Holotype: Sample No. 85-54/48, Plate II, Fig. 7; Table I/25. Photo 88/3/19.

Locus typicus: Magyaregregy. Stratum typicum: Berriasian.

Description: very small-sized, slightly elongated form. The wall thickest at the middle third, elsewhere it is thin. Lorica has its maximal width at the slightly rounded aboral end with a strong bend. Towards the oral opening the walls almost converge. No collar can be observed, the oral opening is narrow.

Calpionellopsis pusilloblonga n. sp. (Code: Cpspuo Rigst. No. MP-19).

Derivatio nominis: reference ot the relationship with the species C. oblonga and to the tiny (= pusillus) habit.

Holotype: Sample No. 85-54/53, Plate II, Fig. 8; Table I/26, Photo 88/3/23.

Locus typicus: Magyaregregy. Stratum typicum: Berriasian.

Description: very small-sized elongate form. Lorica has its maximal width at the lower two-fifth, from here it suddenly becomes narrow to the apical aboral end. Towards the oral opening the walls almost straight but slightly converge. No collar can be observed, the oral opening is narrow.

Calpionellopsis fusoblonga n. sp. (Code: Cpsfuso Regist. No. MP-20).

Derivatio nominis: reference to the relationship with the species C. oblonga and to the spindle-shaped (= fusiformis) lorica.

Holotype: Sample No. 85-54-2/27, Plate II, Fig. 9; Table I/27, Photo 87/12/18.

Locus typicus: Magyaregregy. Stratum typicum: Berriasian.

Description: small-medium sized slightly elongated form with somewhat thicker walls. Lorica has its maximal width at the central line from where it becomes gradually narrow towards both ends by the same incline. The aboral end is almost apical, very slightly rounded. Towards the oral opening the lorica wall thins inside, the underdeveloped superimposed collar occurs as a departing form of it. The oral opening is narrow.

Calpionellopsis parvifusoblonga n. sp. (Code: Cpspvfuso Regist. No. MP-21).

Derivatio nominis: reference to the relationship with the species C. oblonga and to the tiny (= parvus) and spindle-shaped (fusformis) lorica.

Holotype: Sample No. Pv-V. 51, Plate II, Fig. 10; Table I/28, Photo 88/4/19.

Locus typicus: Pécsvárad. Stratum typicum: Berriasian.

Description: small-sized slightly elongated form with thick walls. Lorica has its maximal width at the central line, from here becomes narrow towards both ends by the same bend. The aboral end is almost apical, very slightly rounded. The lorica wall thickness inside at its upper third but towards the oral opening becomes suddenly thin. No collar can be observed. The oral opening is narrow.

Calpionellopsis perovoblonga n. sp. (Code: Cpspovo Regist. No. MP-22).

Derivatio nominis: reference to the relationship with the speices C. oblonga and to the strong oval form of the lorica.

Holotype: Sample No. 85-54-2/46, Plate II, Fig. 11; Table I/29, Photo 88/3/17.

Locus typicus: Magyaregregy. Stratum typicum: Berriasian.

Description: small-medium sized, slightly elongated form with thick walls. Lorica has its maximal width at the central line, from here it becomes narrow towards its both ends by the same and strong bend. The aboral end is slightly rounded, here the wall becomes thin. In the continuation of the lorica-wall a weak superimposed collar can be observed. The oral opening is narrow.

Calpionellopsis breviovoblonga n. sp. (Code: Cpsbovo Regist. No. MP-23).

Derivatio nominis: reference to the relationship with the species C. oblonga and to the oval and short (= brevis) lorica.

Holotype: Sample No. 85-54-2/52, Plate III, Fig. 6; Table I/30, Photo 88/3/22.

Locus typicus: Magyaregregy. Stratum typicum: Berriasian.

Description: small-medium sized slightly elongated form with thick walls. Lorica has its maximal width at the central line, from here it becomes narrow slightly towards the oral opening and by a strong bend towards the aboral end. The aboral end is rounded and thins out. It has a weak superimposed collar. The oral opening is rather wide.

Calpionellopsis ovoblonga n. sp. (Code: Cpsovo Regist. No. MP-24).

Derivatio nominis: reference to the relationship with the species C. oblonga and to the oval shape of the lorica.

Holotype: Sample No. 85-54-2/36, Plate III, Fig. 2; Table I/31, Photo 88/3/11.

Locus typicus: Magyaregregy. Stratum typicum: Berriasian.

Description: medium-sized elongated form. Lorica has its maximal width at the central line, from here it becomes narrow by a mild bend towards both ends. The aboral end is widely rounded. No collar can be observed. The oral opening is medium-sized.

Calpionellopsis hebeplanoblonga n. sp. (Code: Cpsheplo Regist. No. MP-25).

Derivatio nominis: reference to the relationship with the species C. oblonga and to the blunt (= hebes) and flat (= planus) lorica.

Holotype: Sample No. 85-54-2/41, Plate III, Fig. 3; Table I/32, Photo 87/13/26.

Locus typicus: Magyaregregy. Stratum typicum: Berriasian.

Description: medium-sized elongated form. Lorica has its maximal width at the upper third, from here the walls slightly converge with mild bend towards the oral opening, towards the aboral end these run first with mild, then with progressively stronger bend. The aboral end is bluntly rounded and thins out. The existence of collar is uncertain. The oral opening is medium-sized.

Calpionellopsis planoblonga n. sp. (Code: Cpsplo Regist. No. MP-26).

Derivatio nominis: reference to the relationship with the species C. oblonga and to the flat lower part (= planus) of the lorica.

Holotype: Sample No. 85-54-2/45, Plate III, Fig. 4; Table I/33, Photo 88/3/16.

Locus typicus: Magyaregregy. Stratum typicum: Berriasian.

Description: medium-sized elongated form. Lorica has its maximal width at the central line, from here the walls run straight and slightly converge, towards the slightly rounded aboral end become strongly narrow. The existence of the collar is uncertain, only the pale spot in the right refers to it. The oral opening is medium-sized.

Calpionellopsis grandiplanoblonga n. sp. (Code: Cpsgplo Regist. No. MP-27).

Derivatio nominis: reference to the relationship with the species C. oblonga and to the large (= grandis) and flat (= planus) lorica.

Holotype: Sample No. Pv-V. 2009, Plate III, Fig. 5; Table I/34, Photo 88/4/20.

Locus typicus: Pécsvárad. Stratum typicum: Berriasian.

Description: large-medium sized elongated form with somewhat thick wall. Lorica has its maximal width somewhat above its central line, from here the walls slightly converge towards the oral opening, towards the slightly rounded, almost apical aboral end these become gradually narrow. Uncertain superimposed collar can be observed. The oral opening is narrow.

Calpionellopsis robustoplanoblonga n. sp. (Code: Cpsrplo Regist. No. MP-28).

Derivatio nominis: reference to the relationship with the species C. oblonga, to the robust (= robustus) habit and to the flat (= planus) lower part of the lorica.

Holotype: Sample No. 85-54-2/86, Plate III, Fig. 11; Table I/35, Photo 88/4/5.

Locus typicus: Magyaregregy. Stratum typicum: Berriasian=Valanginian.

Description: large-medium sized elongated form with thick wall. Lorica has its maximal width at the central line. Walls slightly converge towards the oral opening. Towards the slightly rounded aboral end these run with gradual narrowing. The superimposed collar can hardly be seen. The oral opening is rather narrow.

Calpionellopsis grandovoblonga n. sp. (Code: Cpsgovo Regist. No. MP-29).

Derivatio nominis: reference to the relationship with the species C. oblonga, to the large (= grandis) habit and to the oval shape of the lorica.

Holotype: Sample No. 85-54-2/60, Plate III, Fig. 1; Table I/36, Photo 88/3/24.

Locus typicus: Magyaregregy. Stratum typicum: Berriasian.

Description: large-medium sized elongated form with somewhat thick walls. Lorica has its maximal width somewhat below its central line, from here it becomes narrow, towards the oral opening with weaker towards the aboral end with stronger bend. The aboral end is slightly rounded. At the oral end the lorica wall becomes thin both in- and outside. The oral opening is rather narrow.

Calpionellopsis parvibrevoblonga n. sp. (Code: Cpspvbo Regist. No. Mp-30).

Derivatio nominis: reference to the relationship with the species C. oblonga, to the small (= parvus) habit and short (= brevis) lorica.

Holotype: Sample No. 85-54-2/52, Plate III, Fig. 8; Table I/37, Photo 88/3/21.

Locus typicus: Magyaregregy. Stratum typicum: Berriasian.

Description: small-sized isometric form. Lorica has its maximal width in the central line, slightly converges towards the oral opening and transits to the slightly rounded aboral end with definitive bend. The lorica wall is cut at its end, in the groove a superimposed collar cen be seen. The oral opening is medium-sized.

Calpionellopsis brevoblonga n. sp. (Code: Cpsbo Regist. No. MP-31).

Derivatio nominis: reference to the relationship with the species C. oblonga and to the relatively short (= brevis) lorica.

Holotype: Sample No. 85-54-2/39, Plate III, Fig. 7; Table I/38, Photo 88/3/13.

Locus typicus: Magyaregregy. Stratum typicum: Berriasian.

Description: large-medium sized elongated form. The wall is medium-thick but thins out at the slightly rounded aboral end. Lorica has its maximal width at its lower tow-fifth, walls slightly converge towards the oral opening running with straight lines. In the wall continuation underdeveloped superimposed collar is found. The oral opening is rather narrow.

Calpionellopsis cuspibrevoblonga n. sp. (Code: Cpscubo Regist. No. MP-32).

Derivatio nominis: reference to the relationship with the species C. oblonga, to the pointed (= cuspidatus) and short (= brevis) lorica.

Holotype: Sample No. 85-54-2/40, Plate III, Fig. 12; Table I/39, Photo 88/3/14.

Locus typicus: Magyaregregy. Stratum typicum: Berriasian.

Description: small-medium sized, slightly elongated form. Lorica has its maximal width at its central line, from here slightly converges towards the oral opening, towards the aboral end becomes slightly narrow to the lower third, from here becomes narrow with a definite bend. The lower fourth of the wall is thinned out, its upper third thickened. At the left wall a superimposed collar can be presumed. The oral opening is medium-sized.

Calpionellopsis compoblonga n. sp. (Code: Cpscompo Regist. No. MP-33).

Derivatio nominis: reference to the relationship with the species C. oblonga and to the stubby (= compactilis) habit.

Holotype: Sample NO. 85-54/83, Plate III, Fig. 9; Table I/40, Photo 88/4/29.

Locus typicus: Magyaregregy. Stratum typicum: Berriasian-Valanginian.

Description: small-medium sized, slightly elongated form with very thick wall. The lorica walls are subparallel to the lower two-fifth, from here run with a mild bend to the almost apical aboral end. The wall-end is cut inward, in the groove a small superimposed collar is found. The oral opening is medium-sized.

Calpionellopsis tholoblonga n. sp. (Code: Cpstho Regist. No. MP-34).

Derivatio nominis: reference to the relationship whit the species C. oblonga and to the dome (= tholus) shaped form of the aboral region.

Holotype: Sample No. 85-54/26, Plate III, Fig. 10; Table I/41, Photo 88/4/30.

Locus typicus: Magyaregregy. Stratum typicum: Berriasian.

Description: medium-sized elongated form. The wall gradually thickens downwards, the lower part of the lorica is filled with sparic calcite. Lorica has its maximal width somewhat below its central line, and becomes hardly narrower towards the oral opening. The aboral end is rounded like an elongated dome-shape. No collar can be observed. The oral opening is narrow.

Calpionellopsis belloblonga n. sp. (Code: Cpsbello Regist. No. MP-35).

Derivatio nominis: reference to the relationship with the species C. oblonga and to the beautiful (= bellus) appearance of the lorica.

Holotype: Sample No. 67-1/133, Plate III, Fig. 13; Table I/42, Photo 88/4/15.

Locus typicus: Magyaregregy. Stratum typicum: Berriasian.

Description: medium-sized elongated form. Lorica has its maximal width at its lower third. Walls strongly converge towards the oral opening, and after strong inclination run with a continuous bend towards the slightly rounded aboral end. As continuation of the walls small superimposed collars can be seen. The oral opening is narrow.

Calpionellopsis venoblonga n. sp. (Code: Cpsveno Regist. No. MP-36).

Derivatio nominis: reference to the relationship with the species C. oblonga and to the gracious (= venustus) lorica.

Holotype: Sample No. 85-54/45, Plate III, Fig. 14; Table I/43, Photo 88/3/15.

Locus typicus: Magyaregregy. Stratum typicum: Berriasian.

Description: large-medium sized elongated form. Walls are somewhat thicker than the average, at the aboral end, however, strongly thin out. Lorica has its maximal width below its lower third, walls slightly converge towards the oral opening, downwards adjoin the slightly rounded aboral end with mild bend. The wall ends of the lorica are grooved inward, here is the small superimposed collar. The oral opening is medium-sized.

Calpionellopsis graciloblonga n. sp. (Code: Cpsgracilo Regist. No. MP-37).

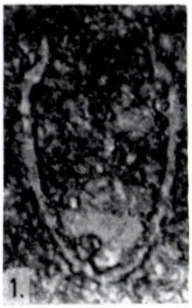
Derivatio nominis: reference ot the relationship with the species C. oblonga and to the slim (= gracilis) habit.

Holotype: Sample No. 63-39/39, Plate IV, Fig. 1; Table I/44, Photo 88/4/16.

Locus typicus: Hosszúhetény. Stratum typicum: Berriasian.

Description: large-medium sized strongly elongated form. The wall strongly thins out at the aboral end. Lorica has its maximal width above its lower fourth. Walls converge slightly towards the oral opening, downwards taking a conic shape with a sudden inclination adjoin the very slightly rounded aboral end with a mild bend. No collar can be seen. The oral opening is narrow.

Plate I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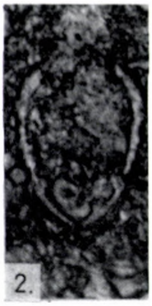
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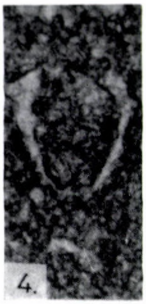
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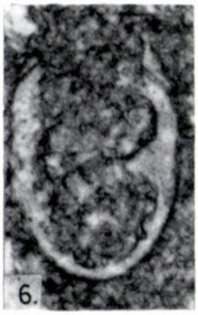
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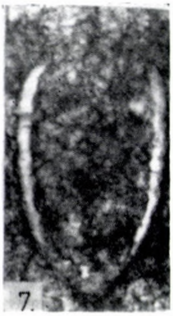
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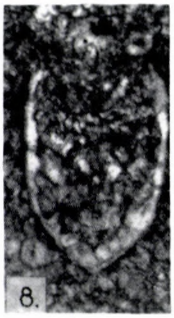
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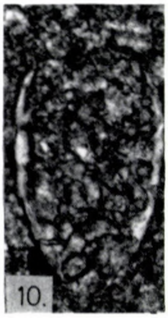
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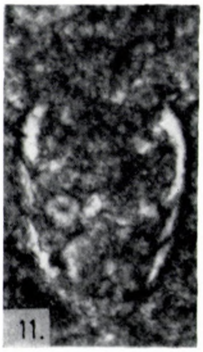
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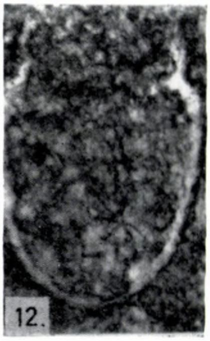
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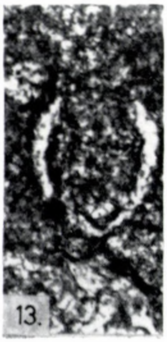
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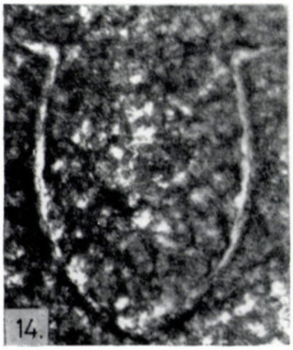
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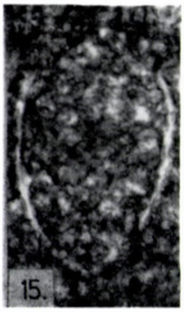
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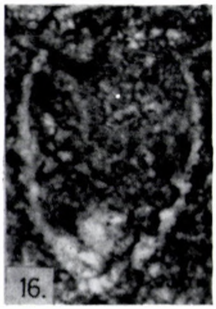
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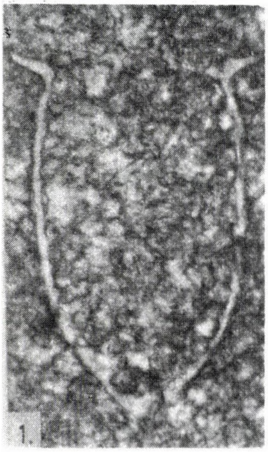
Plate II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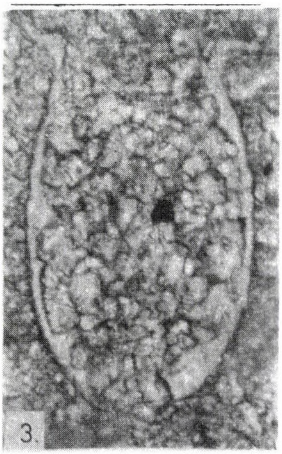
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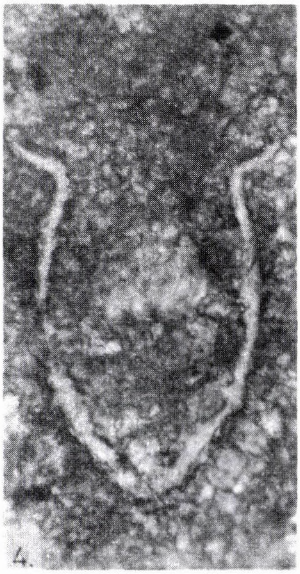
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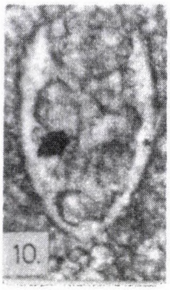
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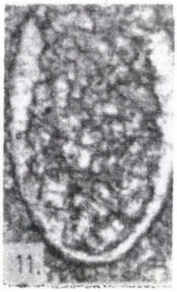
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Plate III


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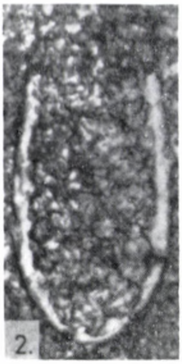
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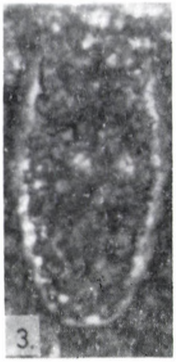
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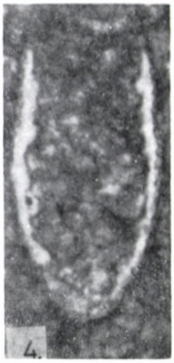
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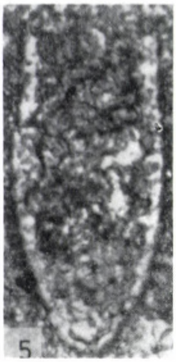
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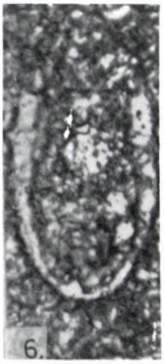
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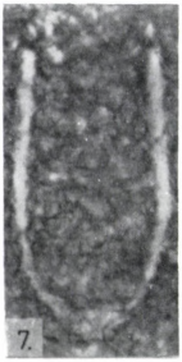
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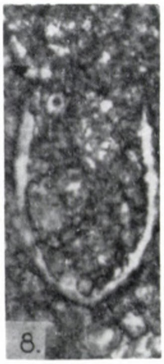
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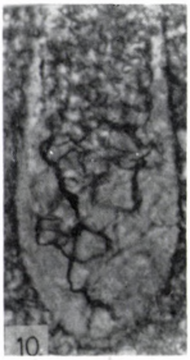
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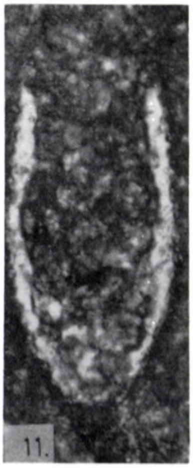
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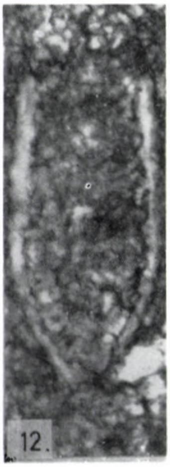
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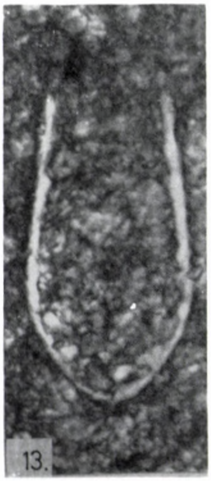
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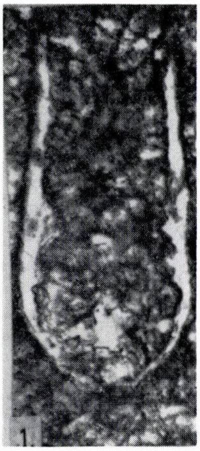
Plate IV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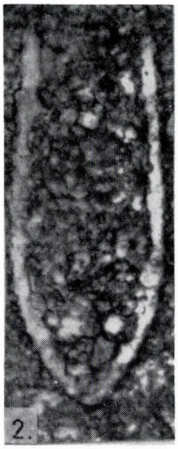
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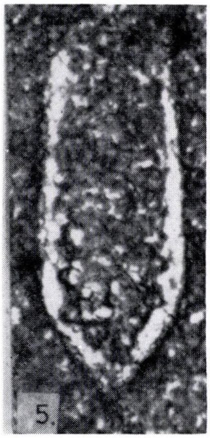
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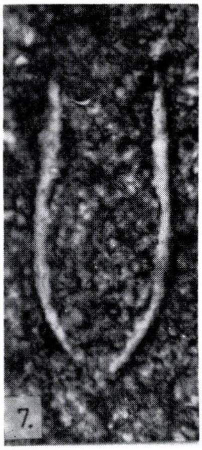
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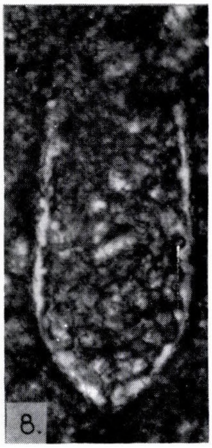
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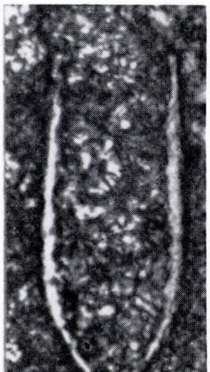
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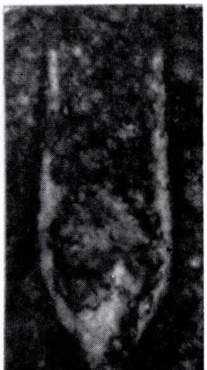
12.

Plate I

1. Sopianella longa n. sp. b.
2. Sopianella minuta n. sp. b.
3. Crassicalpionella conica n. sp. b.
4. Crassicalpionella pusilla n. sp. b.
5. Baranella gracilis n. sp. b.
6. Baranella laxa n. sp. b.
7. Lorenziellopsis arcuata n. sp. v.
8. Lorenziellopsis compactilis n. sp. b-v.
9. Lorenziellopsis mucronata n. sp. v.
10. Lorenziellopsis dilatata n. sp. b-v.
11. Lorenziellopsis suplata n. sp. b-v.
12. Calpionella hebalpina n. sp. b.
13. Calpionella pusillalpina n. sp. b.
15. Tintinnopsella brevicarpathica n. sp. v.
15. Tintinnopsella gracilicarpathica n. sp. b.
16. Tintinnopsella crassicarpathica n. sp. b.
17. Tintinnopsella isocarpathica n. sp. b.
18. Tintinnopsella perbrevicarpathica n. sp. v.

Plate II

1. Tintinnopsella longocarpathica n. sp. b.
2. Tintinnopsella laticarpathica n. sp. b.
3. Tintinnopsella turgicarpathica n. sp. v.
4. Tintinnopsella collcarpathica n. sp. v.
5. Tintinnopsella perlonga n. sp. v.
6. Calpionellopsis obesisimplex n. sp. b.
7. Calpionellopsis semihumiloblonga n. sp. b.
8. Calpionellopsis pusilloblonga n. sp. b.
9. Calpionellopsis fusoblonga n. sp. b.
10. Calpionellopsis parvifusoblonga n. sp. b.
11. Calpionellopsis perovoblonga n. sp. b.

Plate III

1. Calpionellopsis grandovoblonga n. sp. b.
2. Calpionellopsis ovoblonga n. sp. b.
3. Calpionellopsis hebeplanoblonga n. sp. b.
4. Calpionellopsis planoblonga n. sp. b.
5. Calpionellopsis grandiplanoblonga n. sp. b.
6. Calpionellopsis breviovoblonga n. sp. b.
7. Calpionellopsis brevoblonga n. sp. b.
8. Calpionellopsis parvibrevoblonga n. sp. b.
9. Calpionellopsis compoblonga n. sp. b-v.
10. Calpionellopsis tholobolonga n. sp. b.
11. Calpionellopsis robustoplanoblonga n. sp. b-v.
12. Calpionellopsis cuspibrevoblonga n. sp. b.
13. Calpionellopsis belloblonga n. sp. b.
14. CAlpionellopsis venoblonga n. sp. b.

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b: Berriasian; V: Valanginian

Plate IV

1. Calpionellopsis graciloblonga n. sp. b.
2. Calpionellopsis promoblonga n. sp. b-v.
3. Calpionellopsis vincoblonga n. sp. b.
4. Calpionellopsis grandilatoblonga n. sp. b.
5. Calpionellopsis conohastoblonga n. sp. b-v.
6. Calpionellopsis hastoblonga n. sp. v.
7. Calpionellopsis parvihastoblonga n. sp. b-v.
8. Calpionellopsis latihastoblonga n. sp. b-v.
9. Calpionellopsis tenuhastoblonga n. sp. b-v.
10. Calpionellopsis brevihastoblonga n. sp. b-v.
11. Calpionellopsis peracutihastoblonga n. sp. v.
12. Calpionellopsis tumohastoblonga n. sp. b-v.

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b: Berriasian; v: Valanginian

Calpionellopsis promoblonga n. sp. (Code: Cpspromo Regist. No. MP-38).

Derivatio nominis: reference to the relationship with the species C. oblonga and to the strongly elongated (= promissus) lorica.

Holotype: Sample No. 85-54/72, Plate IV, Fig. 2; Table I/45, Photo 88/3/9.

Locus typicus: Magyaregregy. Stratum typicum: Berriasian-Valanginian.

Description: large-sized strongly elongated form with slightly thick wall. Lorica has its maximal width at its lower third, walls slightly converge towards the oral opening, downwards adjoin the almost apical aboral end with a continuous bend. No collar can be seen. The oral opening is narrow.

Calpionellopsis vincoblonga n. sp. (Code: Cpsvinco Regist. No. MP-39).

Derivatio nominis: reference to the relationship with the species C. oblonga and to the loop- (= vinculum) like shape of the lorica.

Holotype: Sample No. 85-54-2/50, Plate IV, Fig. 3; Table I/46, Photo 88/3/20.

Locus typicus: Magyaregregy. Stratum typicum: Berriasian.

Description: large-sized elongated form. Lorica has its maximal width at its lower third. After a transition of mild bend the walls converge. The aboral end terminates with a continuous bend like a loop. A very pale superimposed collar can be seen. The oral opening is narrow.

Calpionellopsis grandilatoblonga n. sp. (Code: Cpsginlo Regist. No. MP-40).

Derivatio nominis: reference to the relationship with the species C. oblonga, to the large (= grandis) habit and to the wide lower part (= inferior latus).

Holotype: Sample No. 63-39/41, Plate IV, Fig. 4; Table I/47, Photo 88/4/10.

Locus typicus: Hosszúhetény. Stratum typicum: Berriasian.

Description: large-sized elongated form. Lorica has its maximal width at its lower fifth. Walls considerably converge towards the oral opening, downwards these form the widely-flatly rounded aboral end with sudden inclination. In the right wall an underdeveloped superimposed collar can be seen. The oral opening is narrow.

Calpionellopsis conohastoblonga n. sp. (Code: Cpscoho Regist. No. MP-41).

Derivatio nominis: reference to the relationship with the species C. oblonga, to the conic (= conicus) and lanciform (= hasta) lorica.

Holotype: Sample No. 85-54-2/74, Plate IV, Fig. 5; Table I/48, Photo 88/3/35.

Locus typicus: Magyaregregy. Stratum typicum: Berriasian-Valanginian.

Description: medium-sized elongated form. Lorica has its maximal width at its lower third, from here upwards very slightly converges. Walls run towards the apical aboral end first with mild bend and meet in a straight-line cone. No collar can be observed. The oral opening is narrow.

Calpionellopsis hastoblonga n. sp. (Code: Cpsho Regist. No. MP-42).

Derivatio nominis: reference to the relationship with the species C. oblonga and to the lanciform (= hasta) lorica.

Holotype: Sample No. 85-54-2/62, Plate IV, Fig. 6; Table I/49, Photo 88/3/30.

Locus typicus: Magyaregregy. Stratum typicum: Valanginian.

Description: large-medium sized elongated form. Lorica has its maximal width at its lower third, from here becomes narrow by an elongated bend to the almost completely apical aboral end. Walls slightly converge upwards. At the oral opening the walls thin out from inside, in a small section. A very pale superimposed collar can be observed. The oral opening is narrow.

Calpionellopsis parvihastoblonga n. sp. (Code: Cpspvho Regist. No. MP-43).

Derivatio nominis: reference to the relationship with the species C. oblonga, to the small (= parvus) habit and lanciform (= hasta) shape of the lorica.

Holotype: Sample No. 85-54-2/84, Plate IV, Fig. 7; Table I/50, Photo 88/4/3.

Locus typicus: Magyaregregy. Stratum typicum: Berriasian-Valanginian.

Description: small-medium sized elongated form. Lorica has its maximal width at its lower third, walls slightly converge towards the oral opening, in their upper fifth slightly thicken from inside. The transition towards the almost apical aboral end is of elongated bend. The superimposed collar can be weakly seen. The oral opening is narrow.

Calpionellopsis latihastoblonga n. sp. (Code: Cpslho Regist. No. MP-44).

Derivatio nominis: reference to the relationship with the species C. oblonga, to the wide (= latus) and lanciform (= hasta) shape of the lorica.

Holotype: Sample No. 85-54-2/86, Plate IV, Fig. 8; Table I/51, Photo 88/4/4.

Locus typicus: Magyaregregy. Stratum typicum: Berriasian-Valangianian.

Description: medium-sized elongated form. Lorica has its maximal width at its lower fourth, from here it becomes narrow by a mild bend to the almost apical aboral end. Walls slightly converge upwards, aş their continuation a pale superimposed collar occurs. The oral opening is medium-sized.

Calpionellopsis tenuhastoblonga n. sp. (Code: Cpsteho Regist. No. MP-45).

Derivatio nominis: reference to the relationship with the species C. oblonga, to the thin (= tenuis) and lanciform (= hasta) lorica.

Holotype: Sample No. 85-54-2/73, Plate IV, Fig. 9; Table I/52, Photo 88/3/34.

Locus typicus: Magyaregregy. Stratum typicum: Berriasian-Valanginian.

Description: medium-sized strongly elongated form. Lorica walls run parallel to its lower third, from here continue by an elongated bend to the almost apical aboral end. In the continuation of the lorica wall a very pale superimposed collar can be seen. The wall thins from inside at its upper seventh. The oral opening is narrow.

Calpionellopsis brevihastoblonga n. sp. (Code: Cpsbho Regist No. MP-46).

Derivatio nominis: reference to the relationship with the species C. oblonga, to the short (= brevis) and lanciform (= hasta) lorica.

Holotype: Sample No. 85-54-2/72, Plate IV, Fig. 10; Table I/53, Photo 88/3/33.

Locus typicus: Magyaregregy. Stratum typicum: Valanginian.

Description: small-medium sized slightly elongated form. Lorica has its maximal width somewhat below its central line, upwards it slightly converges, inclines to the apical aboral end with a mild bend. No collar can be seen. The oral opening is medium-sized.

Calpionellopsis peracutihastoblonga n. sp. (Code: Cpspaho Regist. No. MP-47).

Derivatio nominis: reference to the relationship with the species C. oblonga, to the very pointed (= peracutus) and lanciform (= hasta) lorica.

Holotype: Sample No. 85-54-2/62, Plate IV, Fig. 11; Table I/54, Photo 88/3/31.

Locus typicus: Magyaregregy. Stratum typicum: Valanginian.

Description: small-medium sized elongated form. Lorica has its maximal width at its central line, walls converge upwards and run towards the almost apical aboral end with a mild bend, i. e. conically. No collar can be seen. The oral opening is narrow.

Calpionellopsis tumohastoblonga n. sp. (Code: Cpstuho Regist No. MP-48).

Derivatio nominis: reference to the relationship with the species C. oblonga, to the bump (= tumor) or the aboral end and to the lanciform (= hasta) lorica.

Holotype: Sample No. Pv-V. 2010, Plate IV, Fig. 12; Table I/55, Photo 88/4/21.

Locus typicus: Pécsvárad. Stratum typicum: Berriasian-Valanginian.

Description: medium-sized elongated gracile form. Lorica has its maximal width at its lower third. Walls slightly converge towards the oral opening, downwards after a mild inclination meet in acute angle and at about one-tenth of the form meet in a smaller bump. No collar can be seen. The oral opening is narrow.

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MICRITINOIDEA NOV. FORMA SUPERFAM.: ROCK-FORMING HYPOTHETIC MICROFOSSIL GROUP FROM THE UPPER JURASSIC – LOWER CRETACEOUS FORMATIONS OF SOUTH HUNGARY

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The major part of the allochemical constituents and of the micritic matrix of the intraclastic-ooidic-pelletic microlithofacies is considered and relics generated by formerly existed organisms and suggestion is made to the paleontological processing and treatment as biofacies of the microfacies. Together with the description of forma taxa and forma system is demonstrated including the most characteristic 22 forma species assigned to 18 forma genera, 12 forma subfamiliae, 4 forma familiae and 1 forma superfamilia. It is emphasized that micritins are most widespread microfossils of the earth's history. The main presumptions concerning the micritins are summarized in a short working hypothesis.

Keywords: Upper Jurassic, Lower Cretaceous, pelagic microfacies, allochems, micrite, Microfossilia inc. sed., new taxa

Introduction

Between 1969 and 1971 I participated in the exploration for ornamental stones carried out by the Hungarian Geological Survey in the Villány Mountains. In the course of microscopic studies of several hundred thin sections deriving from the 300 m thick Upper Jurassic Szársomlyó Limestone Formation I described the formations to have ooidic-pseudo-ooidic texture, in harmony with the concept of that time. I dealt with these formations again in 1984 when I made a description of one exposure of these rocks for the excursion guide to the Moscow Geological Congress. Here I applied the terms pellet and intraclast, in addition to those mentioned above. At the same time I recognized that the role of organic relics in this microfacies is much more significant then believed so far. Thus, as an indication I mentioned the characteristic features of sessile forams and of bioturbation.

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In 1986 I was commissioned to carry out microfacies and micropaleontological investigations on the Upper Jurassic material of the Bóly-1 borehole drilled in the northern foreground of the Villány Mountains. In the course of processing I had to realize that these formations of complicated texture cannot be interpreted solely as inorganic lithofacies. Si I recognized that not only the role of living organisms predominates over the inorganic components but vica versa: practically all components are relics of living organisms and the abiogenic elements are only secondary, so their occurrence is curiosity except that of the sparite.

This working hypothesis served as a basis to the further work and I was convinced that almost all pellets, pseudo-ooids, ooids and intraclasts are peculiar relics of formerly lived organisms. Regarding the fact that the relics consist mostly of micrite, I found it to be prectical to take this feature as a basis when demoniating this group and to speak about Micritinae, all the more so since I believed the rock matrix to be of the same origin.

This paper aims at to give an impulse to the investigations of this view of the formations of this type. The description of several characteristic taxa serve also this aim.

MICROFOSSILIA INCERTAE SEDIS

MICRITINOIDEA nov. forma superfamilia (Fig. 1)

Type genus: Micritina nov. forma genus

Diagnosis: The material partly or totally fine-grained calcium carbonate (micrite), from the globular to the absolutely irregular in shape, relics varying from the simplest to the most complicated ones with "chambers" of different size and shape.

Micritinidae nov. forma familia

Type genus: Micritina nov. forma genus.

Diagnosis: Micritic forms with globular to irregular shape with "chambers" of different size and shape.

Micritininae nov. forma subfamilia

Type genus: Micritina nov. forma genus

Diagnosis: Micrite substance, isometric to irregular in shape, simple forms, with "chambers" of different size and shape.

Micritina nov. forma genus

Type species: M. vulgaris n. f. sp.

Derivatio nominis: reference to the material of the relics consisting of micrite.

Diagnosis: Micritic, medium to large sized, more or less isometric forms with chambers of different size and shape.

Table I

No.	Code	Length µm	Width µm
1.	Mv	640	440
2.	Gp	260	260
3.	Ge	160	120
4.	Oc	660	560
5.	Pms	20	16
6.	Cmf	320	360
7.	Cmg	320	320
8.	Crmi	350	240
9.	Crmc	640	80
10.	Crms	300	160
11.	Cic	1.400	1.040
12.	Amc	800	500
13.	Comc	1.160	800
14.	Adc	740	400
15.	Imt	2.500	400
16.	Nc	600	300
17.	Mmqu	1.200	500
18.	Ace	740	1.000
19.	Conggo	8.000	5.000
20.	Perp	3.000	1.000
21.	Palb	1.240	600
22.	Pana	2.900	1.750

Micritina vulgaris n. f. sp. (Code: Mv, Reg.: No. MP-49).

Derivatio nominis: reference to the form being of the most common characteristics of the group (vulgaris = common).
Holotype: Sample No. Borehole D-I. 4264 m/b. Plate I, Fig. 1, Table I/1.
Locus typicus: Doboz (Békés County, South-Hungary).
Stratum typicum: : Valanginian-Hauterivian.
Description: Medium-sized isometric relics. Its contour varies from the mildly arched to the angular shape but is certainly rounded also at the angles. In its upper quarter (Photo 1) two slightly oval chambers of remarkable size can be seen. Further, 6-7 very small point-like chambers can be observed.

Globomicritininae nov. forma subfamilia

Type genus: Globomicritina nov. forma genus.
Diagnosis: Micritic, simple forms with spherical or subspherical shape and with small to medium sized round chambers.

Globomicritina nov. forma gen.

Type species: G. pulla n. f. sp.
Derivatio nominis: reference to the rounded (= globosus) shape.
Diagnosis: Micritic spherical forms with small and medium sized round chambers.

Globomicritina pulla n. forma sp. (Code: Gp, Reg.: No. MP-50).

Derivatio nominis: reference to the dark shade of the form (pullus = dirty-black).

Holotype: Sample No. Borehole B-1. 1238 m, Plate I, Fig. 2, Table I/2.
Locus typicus: Baranya County (South-Hungary).
Stratum typicum: Lower Tithonian.
Description: Small-sized spherical forms. The slightly visible lighter spots could be chambers.

Globomicritina erodens n. f. sp. (Code: Ge, Reg.: No. MP-51).

Derivatio nominis: reference to the fact that the forma species dissolves the biogenic limestone lamellae (erodens = eroding).
Holotype: Sample Borehole B-1, 1216 m, Plate I, Fig. 2, Table I/3.
Locus typicus: Bóly (Baranya County, South-Hungary).
Stratum typicum: Lower Tithonian.
Description: very small-sized, subspherical-oval form that intrudes into the limestone lamellae. No chambers can be seen.

Oomicritina nov. forma gen.

Type species: O. concentricellata n. f. sp.
Derivatio nominis: reference to the ooid-like shape of the forms.
Diagnosis: Micritic spherical or subspherical forms of concentric structure, with small round or slightly elongated chambers.

Oomicritina concentricellata nov. forma sp. (Code: Oc, Reg.: No. MP-52).

Derivatio nominis: reference to the concentric position of the chambers.
Holotype: Sample No. Borehole D-I. 4261.7 m, Plate I, Fig. 4, Table I/4.
Locus typicus: Doboz (Békés County, Southeast Hungary).
Stratum typicum: ? Valanginian-Hauterivian.
Description: Small-sized spherical formation the internal structure of which displays ooid under microscope section. It consists concentrically of about five layers, without central core, three lighter walls can be relatively well recognized between the strata. In the internmost surface free of wall 3–4 chambers can be seen, in the middle wall one, in the outer wall 2 to 3, in the outernmost layer the trace of one small chamber can be detected.

Pellmicritina nov. forma gen.

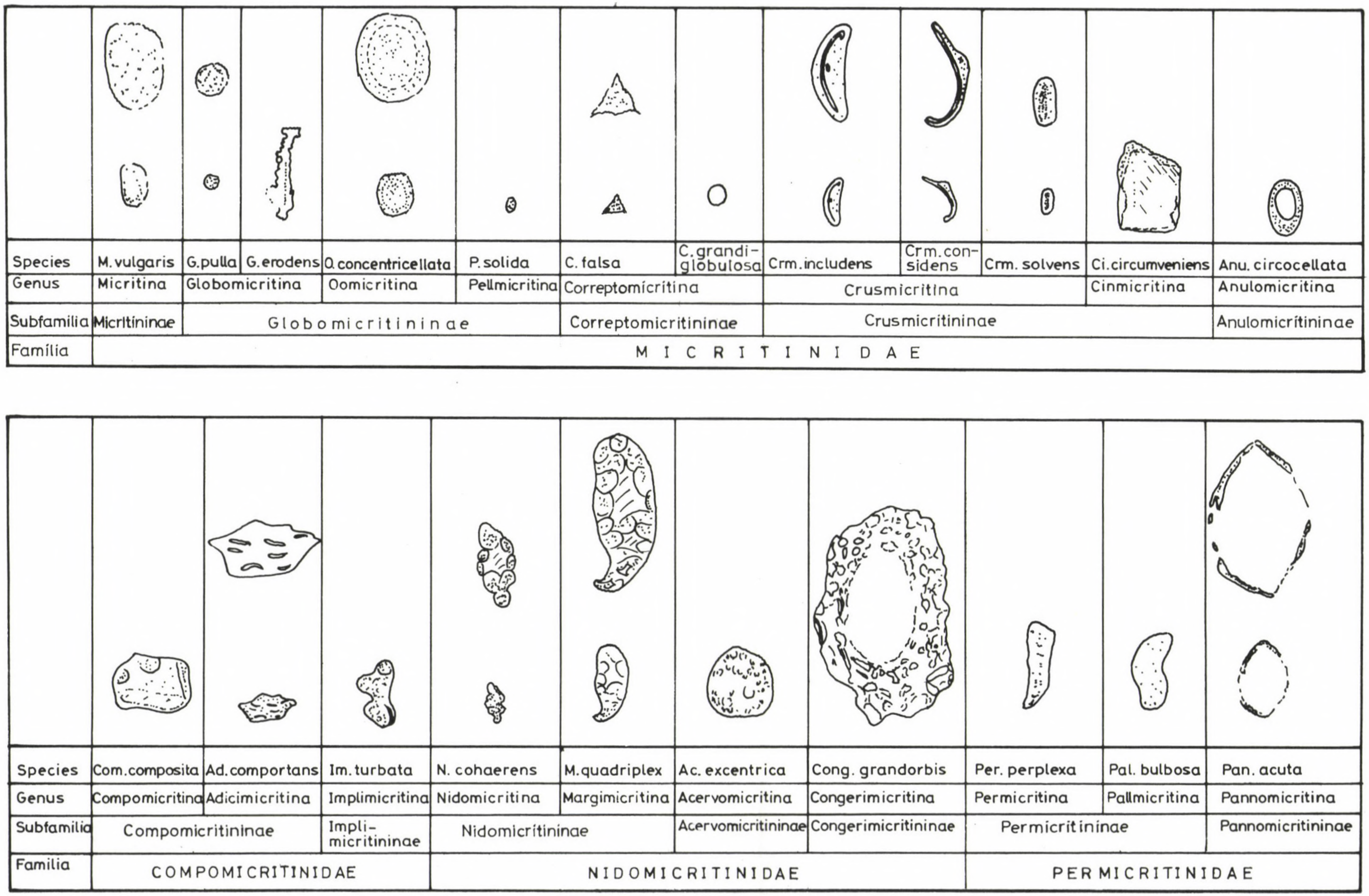
Type species: P. solida n. f. sp.
Derivatio nominis: reference to the pellet-like appearance.
Diagnosis: Micritic, subspherical or slightly elongated very small forms without surely identifiable chambers.

Pellmicritina solida n. forma sp. (Code: Pms, Reg.: No. Mp-53).

Derivatio nominis: reference to the massive (= solidus) state of the form.
Holotype: Sample No. Borehole B-1, 1249 m, Plate III, Fig. 7, Table I/5.
Locus typicus: Bóly (Baranya County , South-Hungary).
Stratum typicum: Lower Tithonian.
Description: Very small-sized, subspherical, slightly elongated form. No chamber can be seen.

Correptomicritininae nov. forma subfamilia

Type genus: Correptomicritina nov. forma genus
Diagnosis: Micritic simple forms with small-tomedium sized chambers. These developed in the internal part or hollow of another fossil and took its shape (pseudomorphosa). Their chambers are small-to-medium sized, usually rounded.



Species	M. vulgaris	G. pulla	G. erodens	O. concentricellata	P. solida	C. falsa	C. grandiglobulosa	Crm. includens	Crm. considens	Crm. solvens	Ci. circumveniens	Anu. circocellata
Genus	Micritina	Globomicritina		Oomicritina	Pellmicritina	Correptomicritina		Crusmicritina			Cinmicritina	Anulomicritina
Subfamilia	Micritininae	Globomicritininae				Correptomicritininae		Crusmicritininae				Anulomicritininae
Família	MICRITINIDAE											

Species	Com. composita	Ad. comportans	Im. turbata	N. cohaerens	M. quadriplex	Ac. excentrica	Cong. grandorbis	Per. perplexa	Pal. bulbosa	Pan. acuta
Genus	Compomicritina	Adicimicritina	Implimicritina	Nidomicritina	Margimicritina	Acervomicritina	Congerimicritina	Permicritina	Pallmicritina	Pannomicritina
Subfamilia	Compomicritininae		Implimicritininae	Nidomicritininae		Acervomicritininae	Congerimicritininae	Permicritininae		Pannomicritininae
Familia	COMPOMICRITINIDAE			NIDOMICRITINIDAE				PERMICRITINIDAE		

Fig. 1. Taxonomic review of the forma superfamilia MICRITINOIDEA

Correptomicritina nov. forma gen.

Type species: C. falsa n. f sp.
Derivatio nominis: reference to the fact that the form is found in the shell or hollow of an other fossil, i. e. gets into it (= correptus).
Diagnosis: Micritic forms that take the shape of the "host" shell or hollow of an other fossil. Chambers are small-to-medium sized and are usually rounded.

Correptomicritina falsa n. forma sp. (Code: Cmf, Reg.: No. MP-54).

Derivatio nominis: reference to the false (= falsus) shape of the form.
Holotype: Sample No. Borehole B-1, 1293 m, Plate I, Figs 4–5, Table I/6.
Locus typicus: Bóly (Baranya County, South-Hungary).
Stratum typicum: Lower Tithonian.
Description: Small-sized form that developed within a radiolarian shell and partly around it, as a pseudomorpho of it. The traces of 5 to 6 chambers can be seen (Fig. 5).

Correptomicritina grandiglobulosa n. f. sp. (Code: Cmg, Reg.: No. MP-55).

Derivatio nominis: reference to the large globular appearance.
Holotype: Sample No. Borehole B-1, 1220 m, Plate III, Fig. 8, Table I/7.
Locus typicus: Bóly (Baranya County, South-Hungary).
Stratum typicum: Lower Tithonian.
Description: Among micritines it is small-to-medium sized, but among the globular forms it belongs to the large-sized ones. Originally the form could be a foraminifer test and this was dissolved or replaced by micrite by the organisms generated the micritines.

Crusmicritininae nov. forma subfamilia

Type genus: Crusmicritina nov. f. gen.
Diagnosis: Micritic simple forms, their shape being determined by the fossil that these micritine-generating organisms encrust, surround or fill. These have small-to-medium sized globular or oval chambers.

Crusmicritina nov. forma gen.

Type species: C. includens n. f. sp.
Derivatio nominis: reference to the fact that the forms belonging to this forma genus encrust (= crusta) other fossils.
Diagnosis: Micritic forms that encrust or fill fossil shells. The chambers are small-to-medium sized, globular or oval.

Crusmicritina includens n. f. sp. (Code: Crmi, Reg.: No. MP-56).

Derivatio nominis: reference to the fact that the form includes (= includo) and extraneous fossil.
Holotype: Sample No. Borehole B-1, 1252 m, Plate IV, Fig. 1, Table I/8.
Locus typicus: Bóly (Baranya County, South-Hugnary).
Stratum typicum: Lower Tithonian.
Description: Small-sized forms species that developed around and ostracod shell so that in the concave side its thickness is three times greater than in the convex side. At about the middle of the concave side a medium-sized oval chamber is situated.

Crusmicritina considens n. forma sp. (Code: Crmc, Reg.: No. MP-57).

Derivatio nominis: reference to the fact that the form settles on the shell of an extraneous fossil (settle on = considens).
Holotype: Sample No. Borehole B-1, 1249 m, Plate IV, Fig. 2, Table I/9.
Locus typicus: Bóly (Baranya County, South-Hungary).
Stratum typicum: Lower Tithonian.
Description: Small-sized, strongly elongated form that grew on the convex side of an ostracod half-shell. The holotype forms a very thin but uniformly thick crust in the 2/3 of its length, in 1/3 length it upwards to fourfold thickness, here 3–4 point-like chambers are seen. (In the concave side of the shell an individual of an other species is found.)

Crusmicritina solvesn n. forma sp. (Code: Crms, Reg.: No. MP-58).

Derivatio nominis: reference to the fact that the form dissolves the fossil included by it (dissolve = solvens).
Holotype: Sample No. Borehole B-1, 1238 m, Plate III, Fig. 9, Table I/10.
Locus typicus: Bóly (Baranya County, South Hungary).
Stratum typicum: Lower Tithonian.
Description: Small-sized elliptic form that got its shape by surrounding a fragment of a foreign fossil. (In the photo the calcitic fragment is mostly "dissolved" by the micritine, only the remnant of it dissolved to jagged-shape can be seen.) Chambers cannot be unambiguously identified.

Cinmicritina nov. forma gen.

Type species: C. circumveniens n. f. sp.
Derivation nominis: reference to the fact that the forms belonging to this groups surround (= cingens) other fossils.
Diagnosis: Micritic forms that surround the major pieces of other fossils as a relatively thin crust. Chambers are small-sized, globular or oval.

Cinmicritina circumveniens n. f. sp. (Code: Cic, Reg.: No. MP-59).

Derivatio nominis: reference to the fact that the form entwines (= circumveniens) an other fossil.
Holotype: Sample No. Borehole D-1, 4261.7 m, Plate I, Fig. 6, Table I/11.
Locus typicus: Doboz (Békés County, Southeast Hungary).
Stratum typicum: ? Valanginian – Hauterivian.
Description: The relict surrounds rather large shell fragment that is probably an echinoderm lamella and probably dissolved it, too. (The oval chambers in the left lower part can be only conditionally assigned to this individual.)

Anulomicritininae nov. forma subfamilia

Type genus: Anulomicritina nov. forma genus.
Diagnosis: micritic forms showing ring-shape in section, with small-to-medium sized round chambers.

Anulomicritina nov. forma genus

Type species: A. circocellata n. f. sp.
Derivatio nominis: reference to the ring-shaped form of its section (= anulatus).
Diagnosis: Medium-sized micritic forms showing ring-shape in secitons, with small-to-medium sized round chambers.

Anulomicritina circocellata n. forma sp. (Code: Amc, Reg.: No. MP-60).

Derivatio nominis: reference to the circular arrangement (= circulus) of the chambers (= cella).
Holotype: Sample No. Borehole D-I. 4262 m/a, Plate IV, Fig. 3, Table I/12.
Locus typicus: Doboz (Békés County, Southeast Hungary).
Stratum typicum: ? Valanginian – Hauterivian.
Description: Medium-sized, in section ring-shaped form. The width of the ring is about the half of that of the inner core, in one end it becomes thick, in its medium-line 7 to 8 small round chambers can be seen.

Compomicritinidae nov. forma familia

Type genus: Compomicritina nov. forma gen.
Diagnosis: Mostly micritic forms with varied shape, the forms are complex and are built up by the fragments of other micritines and foreign fossils; chambers are of different size and dimensions.

Compomicritininae nov. forma subfamilia

Type genus: Compomicritina nov. forma gen.
Diagnosis: Consist mostly of micrite; mostly isometric forms composed of shell fragments of other micritines and of foreign fossils; chambers are of different size and dimensions.

Compomicritina nov. forma gen.

Type species: C. composita n. f. sp.
Derivatio nominis: reference to the complex (= compositus) state of the form.
Diagnosis: Consists mostly of micrite; the complex forms are small-to-medium sized and built up by the shell fragments of other micritines and reraly by the fragments of foreign fossils; chambers are of different size and dimensions.

Compomicritina composita n. forma sp. (Code: Comc, Reg.: No. MP-61).

Derivatio nominis: reference to the complex (= compositus) state of the form.
Holotype: Sample No. Borehole B-1, 1249 m, Plate I, Fig. 7, Table I/13.
Locus typicus: Bóly (Baranya County, South-Hungary).
Stratum typicum: Lower Tithonian.
Description: Medium-to-large sized, slightly elongated form of irregular circumference, including mostly Globomicritinae. (In the holotype Crusmicritina and Cinmicritina surrounding presumably lime lamella of echiderm origin are also found.) The trace of chambers can be hardly seen in the specimen.

Adicimicritina nov. forma genus.

Type speices: A. comportans n. f. sp.
Derivatio nominis: reference to the fact that the forms belonging to this genus incorporta (= adicio) other fossils.
Diagnosis: Micritic, small-to-medium sized, mostly isometric forms incorporating the shells of fossils of similar origin and size, with small-sized chambers of different shape.

Adicimicritina comportans n. forma sp. (Code: Adc, Reg.: No. MP-62).

Derivatio nominis: reference to the fact that the form collects (= comportans) the shell fragments of other fossils.
Holotype: Sample No. Vill. 13/7, Plate IV, Fig. 4, Table I/14.
Locus typicus: Nagyharsány (Baranya County, South-Hungary).
Stratum typicum: Oxfordian.
Description: Medium-to-large sized, subisometric form with incorporated ostracod shells and Crusmicritinae.

Implimicritininae nov. forma subfamilia

Type genus: Implimicritina nov. forma gen.
Diagnosis: Intricately complex forms of irregular shape, consisting mostly of micrite, with chambers of different size and dimensions.

Implimicritina nov. forma gen.

Type species: I. turbata n. f. sp.
Derivatio nominis: reference to the intricate (= implicatus) built-up.
Diagnosis: Medium-to-very large forms of irregular shape and mostly of micritic matter, with chambers of different size and dimensions.

Implimicritina turbata n. f. sp. (Code: Imt, Reg.: No. MP-63).

Derivatio nominis: reference to the confused (= turbatus) built-up.
Holotype: Sample No. Borehole D-I. 4261.7 m, Plate III, Fig. 1, Table I/15.
Locus typicus: Doboz (Békés County, Southeast Hungary).
Stratum typicum: ? Valanginian – Hauterivian.
Description: Medium-to-large sized intricately complex form of very irregular shape. (The holotype incorporates Oomicritina, Crusmicritina, Pellmicritinae and shell fragments of other fossils.) No chambers can be identified.

Nidomicritinidae nov. forma familia

Type genus: Nidomicritina nov. forma gen.
Diagnosis: Medium-to-very large forms composed of micritines, with circular or oval section, in their internal parts with polygonal or irregular-shaped sparic fields (that could take in the organism instead of chambers).

Nidomicritininae nov. forma subfamilia

Type genus: Nidomicritina nov. forma gen.
Diagnosis: Medium-sized isometric or slightly elongated forms composed unilinearly mostly of globular micritines, with polygonal sparitic field in their internal part.

Nidomicritina nov. forma gen.

Type species: N. cohaerens n. f. sp.
Derivatio nominis: reference to the production of the form, i. e. like a nest (= nidus).
Diagnosis: Nest-like forms composed unilinearly of globular micritines in which the globules are rarely substituted by other fossils or fragments. Their section is isometric or slightly elongated oval (this mean occasionally the sections through the minor or major axes of a rotation ellipsoid), with polygonae sparitic field in their internal part.

Nidomicritina cohaerens n. forma sp. (Code: Nc, Reg.: No. MP-64).

Derivatio nominis: reference to the fact that the elements of the form are sticking together (= cohaerens).
Holotype: Sample No. Vill-13/7, Plate III, Fig. 10, Plate V, Fig. 1, Table I/16.
Locus typicus: Nagyharsány (Baranya County, South-Hungary).
Stratum typicum: Oxfordian.
Description: Medium-sized, in section oval "nest" in which unilinearly sticking Globomicritina individuals are found. In the internal part, in the space free of globules a polygon of arched side is found filled by sparite.

Margimicritina nov. forma gen.

Type species. M. quadruplex n. f. sp.
Derivatio nominis: reference to the framed (= marginatus) state of the forms.
Diagnosis: Simple or complex forms composed unilinearly of mostly globular micritines. The section of the "nest" is isometric, oval or elongated and is mounted by a thin, compact, dark micrite strip. The "nest-core" is a sparitic polygonal field.

Margimicritina quadruplex n. forma sp. (Code: Mmqu, Reg.: No. MP-65).

Derivatio nominis: reference to the fourfold (= quadruplex) state of the "nest".
Holotype: Sample No. Vill-13/7, Plate III, Fig. 2, Table I/17.
Locus typicus: Nagyharsány (Baranya County, South-Hungary).
Stratum typicum: Oxfordian.
Description: Large-to-medium sized, in section suboval, elongated complex "nest", built up even in the section by 20 Globomicritina. Globules are covered from outside by a uniform strip ("pellicle"). Within this four small "nests" separated from one another by Globomicritina individuals and pellicle are found that are polygonal and are filled by sparite. (The uniform external coat refers to the stages of evolution of an individual of the specimen.)

Acervomicritininae nov. forma subfamilia

Type genus: Acervomicritina nov. forma gen.
Diagnosis: Forms with agglomerate-like "nests" consisting mostly of globular micritines. (The organism(s) could reside in the agglomerate optionally, this may be reflected by the unbroken sparitic fields.)

Acervomicritina nov. forma gen.

Type species: A. excentrica n. f. sp.
Derivatio nominis: reference to the fact that the forms belonging to this genus are of "agglomerate-nest" forms built up nearly by the same elements (acervus = homogeneous agglomerate).
Diagnosis: Medium-to-large sized, in section globular and oval "nest-like" forms composed like agglomerates of globular micritines. From outside the "agglomerate-nests" are coated by a thin pellicle consisting of micrite more compact and darker than its environs.

Acervomicritina excentrica n. forma sp. (Code: Ace, Reg.: No. MP-66).

Derivatio nominis: reference to the excentric arrangement of the sparitic filling.

Holotype: Sample No. Borehole B-1, 1236 m, Plate I, Fig. 8, Table I/18.
Locus typicus: Bóly (Baranya County, South-Hungary).
Stratum typicum: Lower Tithonian.
Description: Medium-to-large sized round "nest" composed of globular micritines like an agglomerate, surrounded by a pellicle consisting of micrite more compact and darker than its environs. In the "agglomerate-nest" an excentrically large sparitic field is found that exceed a qarter of the section area and is spotted with small micritines. (This could be the residence of the organisms.)

Congerimicritininae nov. forma subfamilia

Type genus: Congerimicritina nov. forma gen.
Diagnosis: Very large-sized "nest"-bearing forms composed like an agglomerate of different micritines.

Congerimicritina nov. foma gen.

Type species: C. gandorbis n. f. sp.
Derivatio nominis: reference to the fact that the forms belonging to this genus are agglomerate-like, built up by different elements (congeries = inhomogeneous agglomerate).
Diagnosis: "Agglomerate-nest" like forms occurring in section as rings, built up by different micritines.

Congerimicritina grandorbis n. forma sp. (Code: Conggo, Reg.: No. MP-67).

Derivatio nominis: reference to the large size (= grandis) and to the ring-shape (= orbis).
Holotype: Sample No. Borehole B-I, 1249 m, Plate II, Fig. 1, Table I/19.
Locus typicus: Bóly (Baranya County, South-Hungary).
Stratum typicum: Lower Tithonian.
Description: Very large-sized "nest" composed like an agglomerate of different micritines and displaying an oval ring in section. The ring consists mostly of the representatives of the genera Micritina and Crusmicritina, with 1 to 2 Nidomicritina. Similarly to the matrix, the internal side of the ring contains en masse predominantly Pellmicritinae and subordinately Globomicritinae. The internal part of the ring does not contain sparitiv field, but the ring itself contains this at several places (this could provide as a shelter for the organism, occasionally simultaneously for several individuals).

Permicritinidae nov. forma familia

Type genus: Permicritina nov. forma genus
Diagnosis: Forms showing uncertain outline and possessing "nests" with micritic or micritinic frame, containing small-sized micritines.

Permicritininae nov. forma subfamilia

Type genus: Permicritina nov. forma gen.
Diagnosis: Elongated forms with micritic rims, containing small-sized micritines of uncertain outlines in section.

Permicritina nov. forma gen.

Type species: P. longa n. f. sp.
Derivatio nominis: reference to the hardly recognizable enigmatic (= perplaxus) state of the forms that merge into the matrix.

Diagnosis: Medium-to-large sized elongated forms of slightly irregular shape, surrounded by a thin dark micrite rim and containing small-sized micritines of uncertain outline in section.

Permicritina perplexa n. f. sp. (Code: Perp, Reg.: No. MP-68).

Derivatio nominis: reference to the hardly recognizable "enigmatic" (= perplexus) state of the form that merges into the matrix.
Holotype: Sample No. Borehole B-1, 1250 m, Plate III, Fig. 5, Table I/20.
Locus typicus: Bóly (Baranya County, South-Hungary).
Stratum typicum: Lower Tithonian.
Description: Large-sized strongly elongated form mounted by thin, dark, compact micritic material. The built-up of tis internal part is the same as that of the matrix and consists mostly of small micritines, of biomicrite deriving from presumably disintegrated micritines and of small amount of psarite. No traces of caves suitable to involve chambers or protoplasm could be identified.

Pallmicritina nov. forma gen.

Type species: P. bulbosa n. f. sp.
Derivatio nominis: reference to the fact that the forms belonging to this genus have in their internal part micritines and other elements of indistinct (= pallidus) outline.
Diagnosis: Forms of irregular outline, in the marginal parts mounted by more compact micrite and containing in their internal part indistinctly dissolved micritines. Chambers cannot be identified, the sporadic sparite spotes are insignificant.

Pallmicritina bulbose n. forma sp. (Code: Palb, Reg.: No. MP-69).

Derivatio nominis: reference ot the shape of the holotype (potato seed = bulbus).
Holotype: Sample No. Borehole D-I, 4274.3 m, Plate III, Fig. 6, Table I/21.
Locus typicus: Doboz (Békéscounty, Southeast Hungary).
Stratum typicum: ? Valanginian — Hauterivian.
Description: Medium-to-large sized elongated form of irregular and rounded outline that comes out of its environs by the more compact and darker micrite of the marginal part which shows gradual transition inwards. Micritines of the internal part are of indistinct outline, seem to be dissolved, do not contact each other and th einterstices between them are filled by sparite. In the section no chambers or other configuration can be detected.

Pannomicritininae nov. forma subfamilia

Type genus: Pannomicritina nov. forma gen.
Diagnosis: Medium-to-large sized forms of changing shape and thickness, the circular or oval outlines of which consist of interwoven micritines in section. As compared to the whole form, this micritine fram is thin.

Pannomicritina nov. forma gen.

Type species: P. acuta n. f. sp.
Derivatio nominis: reference to the extremely irregularly thick, "ragged" (= pannosus) appearance of the micritine band mounting the forms.
Diagnosis: Is the same as in case of the subfamilia Pannomicritininae.

Pannomicritina acuta n. forma sp. (Code: Pana, Reg.: No. MP-70).

Derivatio nominis: reference to the tapering (= acutus) of one end of the holotype.
Holotype: Sample No. Borehole D-I, 4370 m, Plate III, Fig. 3, Table I/22.
Locus typicus: Doboz (Békés County, Southeast Hungary).
Stratum typicum: ? Valanginian — Hauterivian.
Description: Large-sized oval form tapering at its end. In section it is mounted by a collar consisting of elongated micritines, the collar becomes sometimes very thin or is broken. Within the mount predominantly Pellmicritinae, subordinately Globomicritinae are found, similarly to the matrix. Chambers cannot be identified.

Working hypothesis to study the micritines

1) The major part of the micritine-generating organisms could be creatures that in the course of the earth's history have become suitable to excrete microgranulated micrite.

2) The biomicrite excreting capacity allowed the building of elements of solid material that are suitable to fossilization.

3) This "building" could be a successful evolutionary step since in major part of their lifetime this could serve as a shelter from their enemies. This shelter served also for the only adhering forms since these could also avoid the whirling adn suction effects of their predators and could resist to the drifting caused by water currents.

4) As a peculiar feature of habit of a part of the micritine-generating organisms it can be presumed that were able to leave their "houses" and in a part of their life took an unfixed habit. One type of this habit could be the removal of the organism to "house" surface in order to continue the "house-building". The other type of this habit could be activity when the organism leaved its "house" and removed considerably from it as compared to its dimensions in order to take foods or to "purchase" materials for "house-building".

5) The "house" could be of special function when served only to the resistance against the currents, i. e. served as a ballast and promoted the adherence. This habit could be most characteristic of the organisms generated the micritines.

6) The mode of "house-building" had been a "tradition", thus it is specific and taxonomically a significant element, and indispensable for classification.

7) The dependence on the environment of the micritine form is un-

ambiguous only in case of pseudomorphs (Correptomicritina falsa), in case of Cinmicritinae and e.g. of Crusmicritinae is less significant. The shape of the "house" varies from the practically ideal sphere to the absolutely irregular shape, in spite of this, however, the number of possible varieties is not too large since the spectrum of the regular forms is rather narrow. Metazoans, protozoans, algae, bacteria or inorganic processes could contribute to their building.

8) To build-up the micritine "house", this needed lime-material that could derive from the following sources:

- seawater, from which the organism excreted the $CaCO_3$ (together with $MgCO_3$; and this could explain the fact that the Mg-content of the micritinic rocks is usually higher than that of the Calpinella-bearing limestones),
- calcareous shells of other organisms that the micritine-generating organisms collect, involve, encrust, corrode, dissolve and excrete again in form of micrite,
- other micritines,
- the biomicrite formed from micritines.

In the course of diagenesis the micritine individuals may lose their independency and may be cemented as biomicrite. Referring to this origin, this can be termed as micritinite.

9) In lithofacies the micritines behave as grains:

- as a result of submarine resedimentation a wide spectrum of micritinic mixtures can develop, micritines and micritinite may occur in facies that are unfamiliar for them;
- the large-scale redeposition of micritines of different size may display graded stratification, the Globomicritinae and Pellmicritinae generated formerly together may be separated in bands.

10) Micritines are fossils of greatest extension in space and time of the earth's history. The major part of the localities of their occurrence is characterized by the abundant proliferation of their individuals where there cover, involve, encrust etc. all the environs, even form their basement, as well. Most of these forms are shallow marine but may be abundant in the shallow-bathyal region, some of their types could be generated even in greater depths. Their stratigraphic value cannot be determined, maybe these will be suitable to biostratigraphic analysis only after determining several hundred species. Their distribution in a profile is demonstrated in Fig. 2.

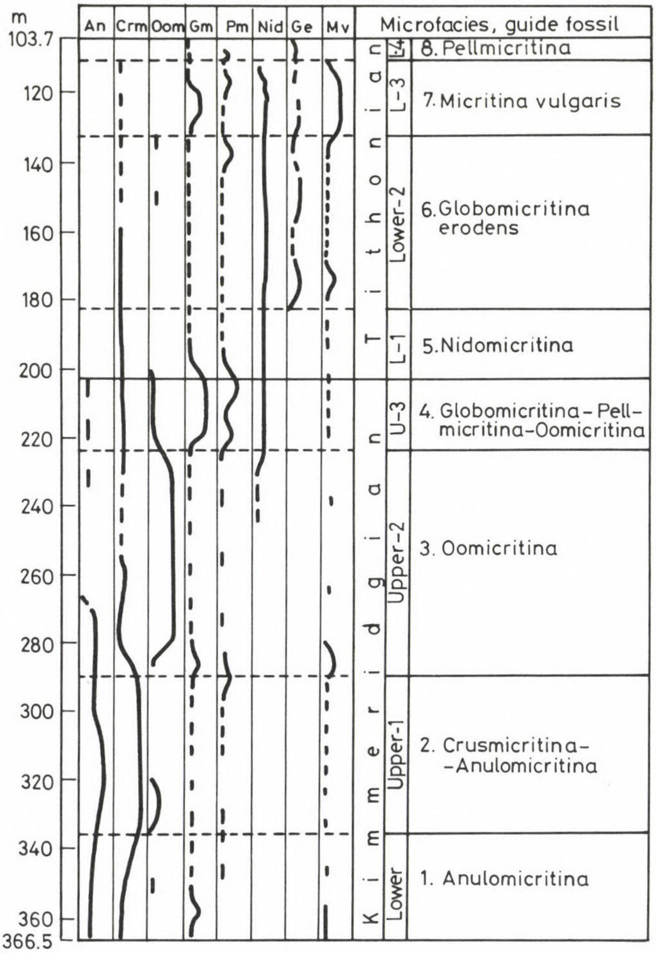


Fig. 2. Distribution of Micritinae in the sequence of the borehole Villány-8

Contradictions between the observations referring to the living origin and the inorganic derivation of micritines

1) Unfortunately, I could not know the original rock corresponding to the "lithoclasts" of the Szársomlyó Limestone Formation. At the same time, these components do not resemble the true intraclasts of resedimented limestones of similar age but of deeper facies of the Mecsek Mountains (South-Hungary).

2) The micritine forms of characteristic outline are consequent in spite of their irregular state and have no sharp corners or long straight sides. In their rims no cut, rounded fossils or other components are found.

3) If these were intraclasts these would have been generated in the foreshore. In such a medium the friable fossils would have been reworked (e.g. Globochaete of the substrate or the gracile Lombardia). At the same time, in the foreshore these fossils are a priori unfamiliar, similarly to the radiolarians and Cadosina.

4) The globular components of 15 µm size (tiny Globomicritinae) could not have rolled, thus could not have rounded and grown. In this facies the large-sized globules as the ooids of true ooliths or pisolites are missing. (Here the relatively large globules were radiolarians or foraminifer tests that transformed into micritines.)

5) The allochemical components of this region could not be generated in the foreshore section since in this case the "nests" and "agglomerate-nests" would have disintegrated.

6) It is a biogenic character that the material of the "intraclasts" is the same as the material of the encrustations.

7) Biomicrites developed from micritines (= micritinite) are never totally even since either the micritine individuals or their fragments would stand out of it due to their differing compactness.

8) The relict dissolved to a jagged shape observed in Crusmicritina solvens can be hardly imagined to be generated in an abiogenic way. The same is valid of the jagged lime lamellae produced by Globomicritina erodens that are too frequent as to treat these as lusu naturae.

9) In case of Cinmicritina circumveniens the megacrystalline calcite lamellae of echinoderms are transformed into micrite from outside inwards. Under inorganic conditions this process can hardly proceed since micrite can be better solved than the echinoderm skeletal elements usually preserved in the interlayer clays.

10) The encrustation of the friable several micrometer thick Globochaete substrate cannot be imagined in an inorganic manner since it would either break off or would be buried instead of the slow lime accumulation. The biogenic variety is more familiar: it was encrusted rapidly and without damage by the organism generating the Crusmicritina includens (Fig. 3).

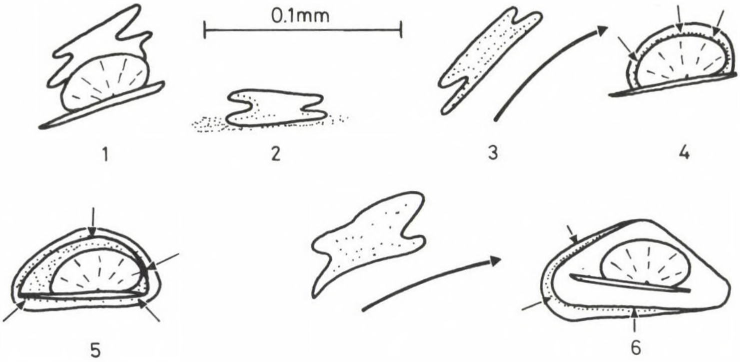


Fig. 3. Presumed way of building up of Crusmicritina considens: it resides on a tiny substrate Globochaete oospore (1). Secreting from the seawater and/or collecting from the basement (2, 3) it begins to encrust the Globochaete (4). Completely coats it (5), if the "house" is too large, builds it in parts (6)

(11) In the holotype of Crusmicritina considens the protuberance with tiny chamber refers to living organism.

12) The presence of frequently observable chambers supports the animal being of the forms.

13) The large individuals of Implimicritinae of complicated structure and shape could not be generated either by rolling or by other inorganic manner.

14) The globules forming the "nest" of Nidomicritinae could not be accumulated without the activity of living organisms, especially within a field of differing grain size. This is a zoogenic character.

15) The coat of the four units of Margimicritina and the join coat are very similar, this is a zoogenic character, too, together with the accumulation.

16) The selective accumulation of the elements of Congerimicritina grandorbis can be imagined only with the activity of animal organisms.

17) Inorganic processes could not have generated such a complicated and varied formation assemblage.

Other features of micritines

1) The superfamilia Micritinoidea is a fossil category, the characterization of the relics belonging to this superfamilia can be only hypothetic. The available relics named here micritines are the material relics of the activity of living organisms. Certain part of these can be regarded as "house" or "nest" or "burrow", the major part, however, proved to be only a "ballast" by means of which the animal having adhered could avoid drifting or predation (i.e. guarded itself against abriptation and predation).

2) The overwhelming majority of micritine relics is not internal casts, the "houses", "nests" and adhering bases are pigmented, microgranulated calcites excreted by living organisms, similarly to the shell of the species Cadosina Fusca WANNER.

3) The shape of micritines is presumably not affected by hereditary biological factors. The organisms generating these forms hardly possess the shape of their "buildings" in their genes, if at all the simplest globular or spherical shape, but possess the compulsion for secretion and commutation. It is plausible that the overwhelming majority of micritines is generated so that the living organisms transofrm some kind of detritus. E.g. the tiny, elongate-oval Pellmicritinae coul have transformed from powder-fine disintegrated calcitic shell fragments. "House-building" can be combined with sedimentation and other exogenic factors, e.g. inorganic, bacteriogenic of algogenic lime secretion. It is also probable the most of the large-sized Micritina vulgaris were originally fossil fragments (e.g. echinoderm) or multielemental Compomicritina, and were transformed and homogenized into M. vulgaris, respectively.

4) Certain animals, presumably the metazoans create their nests by the collection and conglutination of the elements. Out of the forms of small size numerous specimen may transform into M. vulgaris, e.g. the Nidomicritina decays or leaves its "nest" and the organisms generating the M. vulgaris of commutation capability enter the "nest".

5) Certain organisms generating the micritines when fixed to their "house" (= domuncula) or "nest" (= nidus) or to their adhesion basis could catch the falling or streaming food, under quiet aquatic conditions having left their "house" could pick it.

6) Other organisms generating the micritines, e.g. those producing the Correptomicritina occupy the tests of other organisms, e.g. of radiolarians or foraminifers, often the cells and pores of calcareous algae and as fossils occur as pseudomorphs. I believe I recognized these types in photoplates of publications in Permian Mizzia, Jurassic Clypeina, Cretaceous Acicularia and Eocene Gryphoporella etc. I observed a peculiar phenomenon in the thin sections of Barremian-Aptian limestones of the Mecsek Mountains where in certain radiolarian shells foraminifer tests are found. I believe this pertractation to be made by animal organisms.

7) The Globomicritina erodens could develop by corroding the lime lamellae. The frequent and peculiar unilinear arrangement of its individuals may derive from their activity,i.e. these start to corrode the shell elements where originally pores existed.

8) In the crusmicritinal microbiofacies constituted by the encrusting and upgrowing forms often nearly all grains are encrusted. The Crusmicritina considens grows not only onto shell fragments but also onto other micritines. In this microfacies the phenomenon rarely occurs that the larger shells remain unencrusted indicating the lack of Cinmicritinae. The organism generating the Crusmicritina solvesn dissolves the included calcitic shell fragments; when the dissolution ends without traces, the form becomes usually unidentifiable.

9) A part of the small forms similar to Pellmicritinae ("pelloids") may be the indigestible remains ejected by the protoplasm of protozoans. The larger ones could be metazoan coproliths.

10) By all means, the micritine relics are in some kind of unity. Out of the features the most common is the most significant, i.e. these were generated by living organisms, the evolution is valid of which. Thus, their relics are specific, this provokes the paleontological analysis that is associated with the application of the binomial nomenclature.

Micrite — biomicrite — micritinite

- I denominate biomicrite the micrite generated, predominantly by living organisms.
- I denominate micritinite the special kind of biomicrite that is the fossil appearance of calcite secreted by micritines generating organisms.

- Micritinite as litho-matrix is composed predominantly of micritine relics, by means mostly of elidative homogenization.
- The biomicrite of micritinite the living organism generating the micritines:
  - secrets directly from seawater (= secretio),
  - transforms from megacrystalline calcite (= commutatio),
  - discharges as digestion relics (= excretio),
  - builts in itself from other micritine relics or from micritinite (drugging in = raptatio).
- The micritine generating organisms transform only relics or grains consisting of megacrystalline calcite, do not dissolve the micritinic ones, e.g. the micritines and foraminifers with biomicritic test. (Presumably, the latter ones if not secreted themselves the biomicrite of their test, then collected the material for their test from micritinite, only if these were not composed of megacrystalline calcite that was transformed into biomicrite by the micritine generating organisms.)
- The filling of micritine "chambers" is sparitic or rarely chemimicritic. The presumably sticky biomicrite could not roll as the sand grains, thus it could not fill immediately e.g. the chambers or the shell of a fossil. The regular tiny white spots appearing from the micritinite fields may be the traces of former chambers.
- The distinction between chemimicrite and micritinite is problematic by means of simple tools. In first approximation:
  - chemomicrites are more grey, their grains are more isometric, more angular and larger,
  - micritinites are rather brown, their grains are "hooked" or arched and smaller.

Some faciological problems of the Szársomlyó Limestone Formation

- The allochemical components of the Formation derive solely from micritines and these are here in rock-forming amounts.
- In this microfacies practically only the sparitic material is chemogenic, all the other components are biogenic partly as shell and test fragments of other fossils, partly as micritine relics and partly as biomicritic matrix or micritinite deriving from the disintegration of the latter.
- Where the organisms generating the Correptomicritnae lived, these gave

the radiolarians micritic filling. These are the characteristic "dark radiolarites" that are remarkable in the Oxfordian section of the Formation.

- This litho- and biofacies is free of fine grains, of the graciel tests and shells, i.e. of all the things that can be drifted by the slightly streaming water. On the contrary, the foraminifers or micritine generating organisms with heavier "house" or fixed state, the larger-heavier shell fragments are preserved, out of the lighter ones only those that are encrusted by micritines.
- The organic matter content of the initially sticky biomicrite can be decomposed, thus micrite is able to be mobilized and may be washed out from the sediments or can be separated by means of resedimentation. Getting farther from the grains (i.e. from the micritines) the micrite may contribute to the formation of limestones of the abyssal-bathyal regions.
- The sediments of the Szársomlyó Limestone Formation could be generated in a foreshore-free environment with weak currents in which the very light elements, e.g. the protoplasm of monoplastids, could have been transported away but not the large-sized bioclasts and micritines. The depth of formation can be put to the shallow-bathyal region, this is characteristic of the lower part of the sequence, upwards a shallow marine environment has to be presumed.

Extension of micritines

As to the literature, micritines are probably the most common often rock-forming relics of the earth's history showing wide extension in space and time. Regarding the fact that thousands of publications deal with these and their demonstration by photos is also frequent, here only one work will be cited, i.e. the work of Barattolo, F. and Pugliese, A. published in 1987 and entitled "Il Mesosoico dell' Isola di Capri":

- Tav. 26. fig. 1: Aalenian. Pellmicritina and Compomicritina predominate, Oomicritina is also characteristic, some of these is included by Compomicritina. Some Micritina vulgaris are also seen. Micritines "swim" in white sparite far of one another. Sparite cannot be of micrite origin, since micritines are intact and recrystallization would damage these. It is more probable that the interstices among micritinites was originally filled by the organic matter deriging from the organisms generating

Plate I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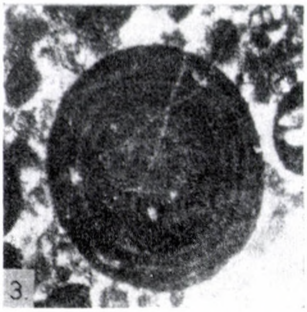
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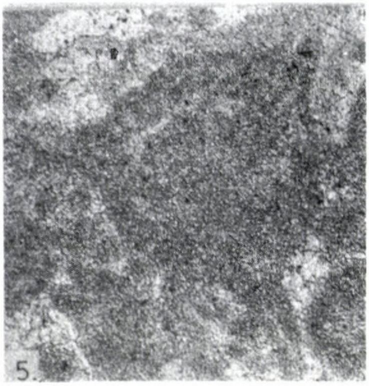
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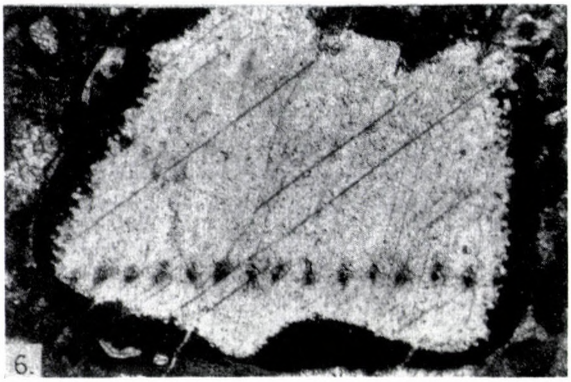
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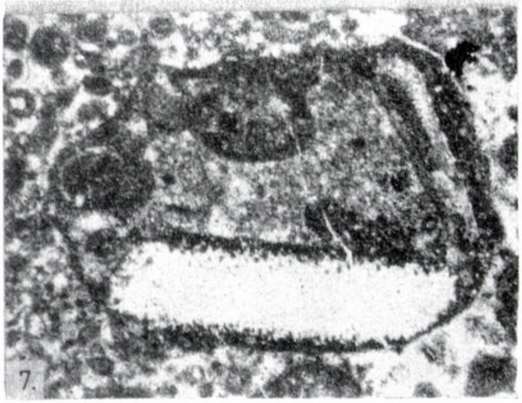
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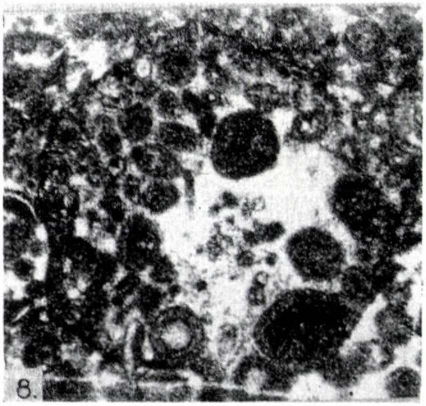
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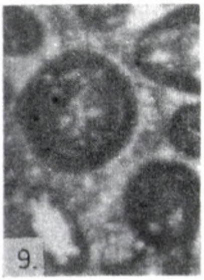
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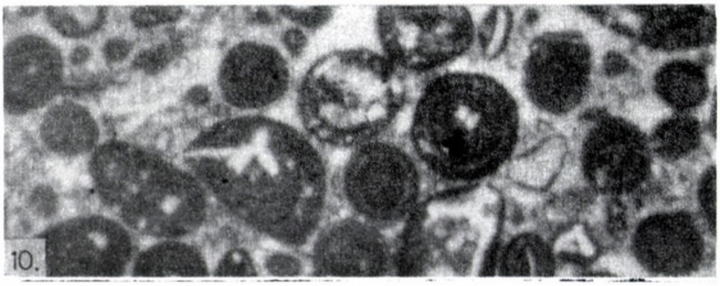
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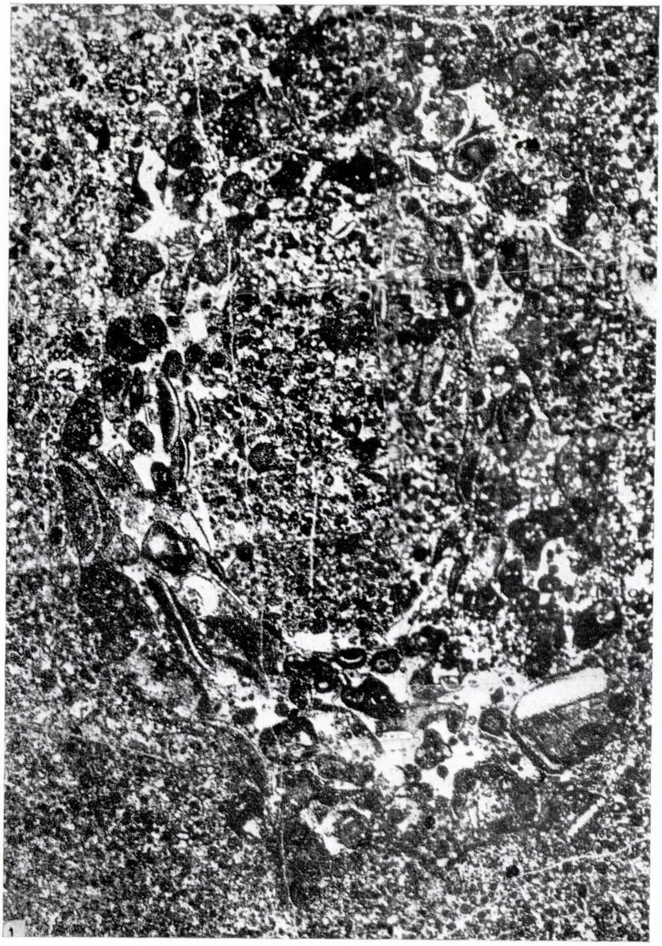

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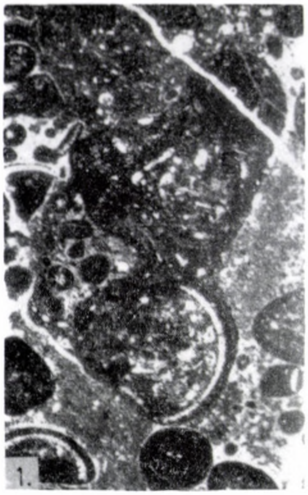
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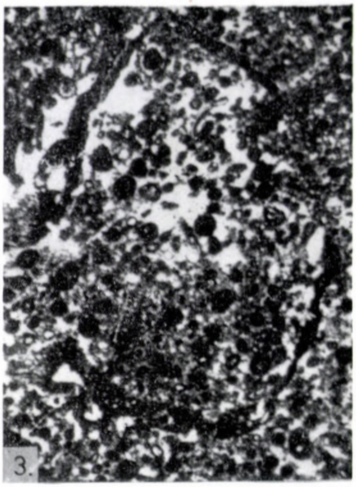
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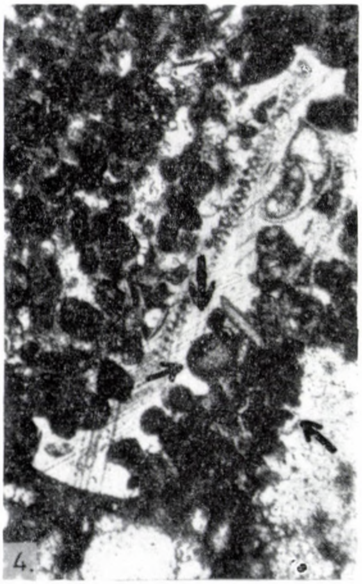
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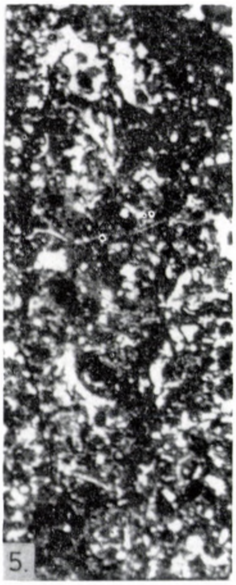
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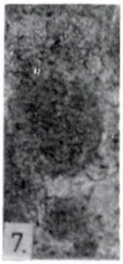
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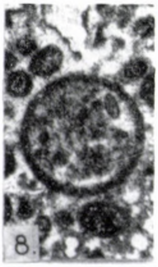
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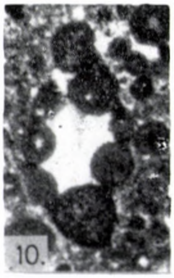
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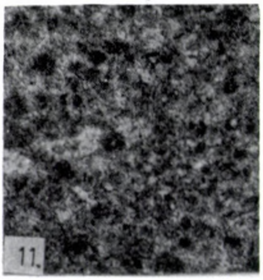
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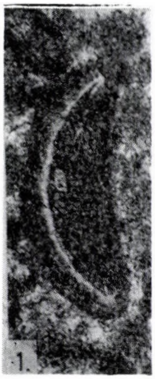

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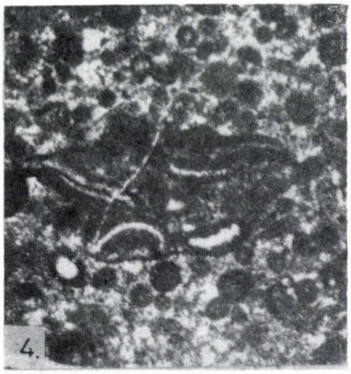

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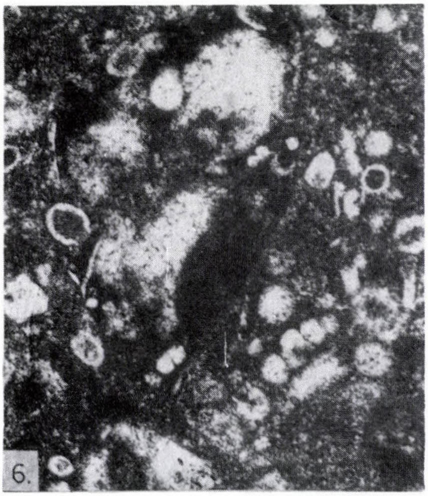

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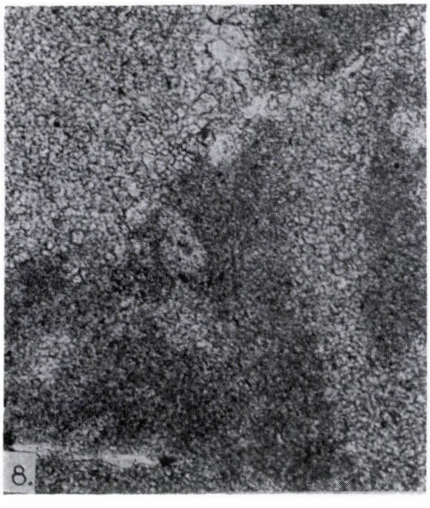

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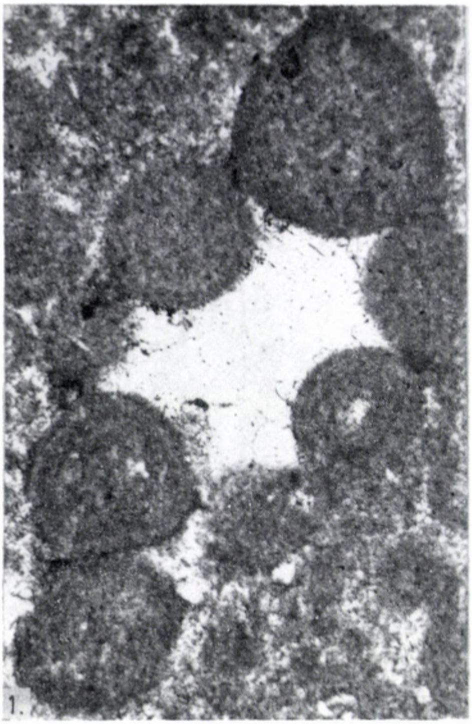
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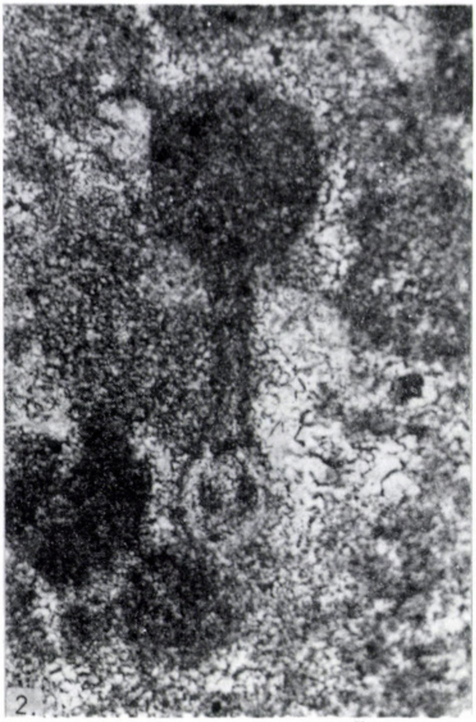
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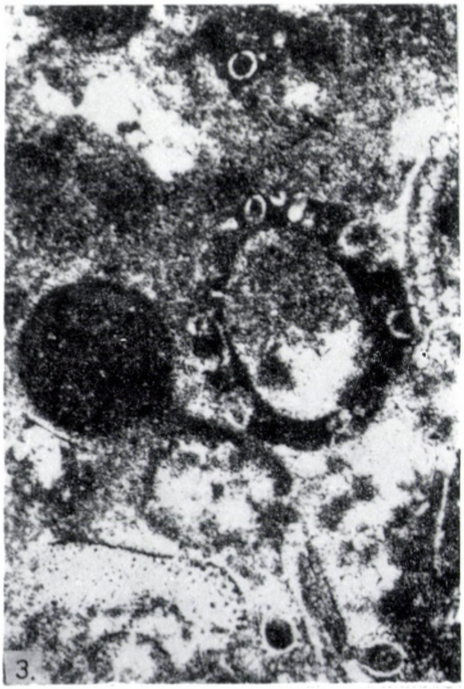
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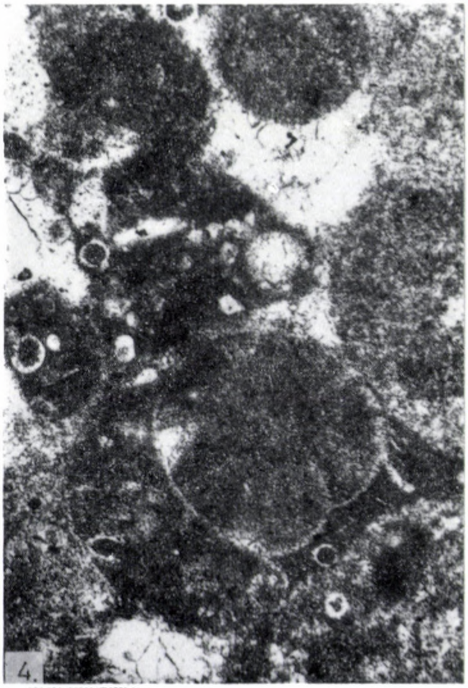
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Plate VI


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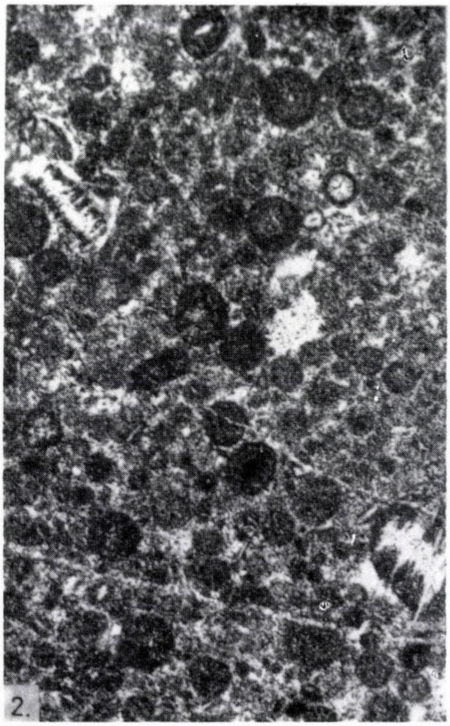
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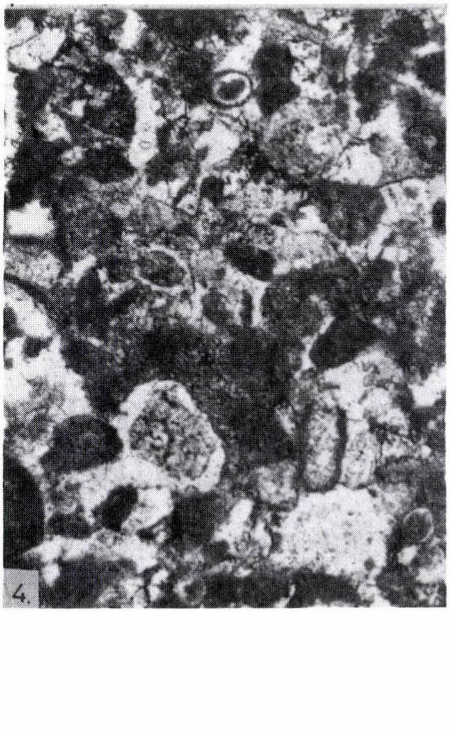
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Plate I

1. *Micritina vulgaris* n. sp. – holotype.
2. *Globomicritina pulla* n. sp. – holotype.
3. *Oomicritina concentricellata* n. sp. – holotype.
4. *Correptomicritina falsa* n. sp. – holotype.
5. Ibid.
6. *Cinmicritina circumveniens* n. sp. – holotype.
7. *Compomicritina composita* n. sp. – holotype.
8. *Acervomicritina excentrica* n. sp. – holotype.

9–10. *Oomicritinic subfacies.* – Lower Tithonian. Nagyharsány.

Fig. 1–4, 6–8: x50. 5: x125. 9–10: x32

Plate II

1. *Congerimicritina grandorbis* n. sp. – holotype. x20

Plate III

1. *Implimicritina turbata* n. sp. – holotype.
2. *Margimicritina quadruplex* n. sp. – holotype.
3. *Pannomicritina acuta.* n. sp. – holotype.
4. *Globomicritina erodens* n. sp. – holotype (signed with an arrow).
5. *Permicritina perplexa* n. sp. – holotype.
6. *Pallmicritina bulbosa* n. sp. – holotype.
7. *Pellmicritina solida* n. sp. – holotype.
8. *Correptomicritina grandiglobulosa* n. sp. – holotype.
9. *Crusmicritina solvens* n. sp. – holotype.
10. *Nidomicritina cohaerens* n. sp. – holotype.
11. Pellmicritinic microbiofacies. – Lower Tithonian. Bóly, Borehole B-1.

Fig. 1,3,5: x20. 2,4,6,8–11: x50. 7: x650

Plate IV

1. *Crusmicritina includens* n. sp. – holotype.
2. *Crusmicritina considens* n. sp. – holotype.
3. *Anulomicritina circocellata* n. sp. – holotype.
4. *Adicimicritina comportans* n. sp. – holotype.

5-7. *Micritines involving calpionellids.* – Lower Berriasian. Hosszúhetény, Borehole Hh-LXII.

8. B: biomicrite (micritinite), C: chemomicrite – Lower Tithonian. Bóly, Borehole B-1.

Fig. 1: x125. 2–4: x50. 5,7: x250. 6: x100. 8: x325

Plate V

1. *Nidomicritina cohaerens* n. sp. – holotype.
2. Correptomicritina filling Radiolaria and Calpionella. – Lower Berriasian. Hosszúhetény, Borehole Hh-LXII.

3. Correptomicritina filling a radiolarian and Anulomicritina involving calpionellids. — Lower Berriasian. Hosszúhetény, Borehole Hh-LXII.
4. Micritines involving calpionellids. — Lower Berriasian. Hosszúhetény, Borehole Hh-LXII.

Fig. 1: x165. 2: x250. 3—4: x100

Plate VI

1. Micritinic microbiofacies. Mv: Miritina vulgaris, Crmc: Crusmicritina considens, Crmi: Crusmicritina includens, Pms: Pellmicritina solida. — ?Valanginian-Hauterivian. Doboz, Borehole D-I.
2. Micritinic microbiofacies. Gp: Globomicritina pulla, Pms: Pellmicritina solida, Crms: Crusmicritina solvens. — Oxfordian. Nagyharsány.

3—4. Micritinic microbiofacies. M: Micritina div. sp., Am: Anulomicritina sp. — Lower Berriasian. Pécsvárad.

Fig. 1—2: x50. 3—4: x75

the micritines that decomposed and removed as a fluid and was gradually substituted by sparite.

- Tav. 26. fig. 2: Aalenian. Pellmicritina predominates, in addition a few Micritina vulgaris can be seen. In the field extending from the right lower corner to the centre the micritines are compacted as a micritic matrix (= micritinite) in which the outlines of certain individuals can be recognized.
- Tav. 27. fig. 1: Aalenian. Pellmicritina predominates, in addition to it Oomicritina, Crusmicritina includens and Micritina vulgaris can be seen. Sparitization seems to be after micrite, since micritines are often broken.
- Tav. 27. fig. 2: Bathonian. Oomicritina predominates, in addition to it Comptomicritinae and some Globomicritina and Pellmicritina can be seen. In the Oomicritina in the right lower corner the tiny round chambers being situated round the core can be fairly well recognized.
- Tav. 30. fig. 2: Bathonian. Compomicritinae predominate, some of them contains Oomicritina. At about the centre of the picture a tiny Compomicritina composita is seen, onto the upper end of which a Crusmicritina considens is found.
- Tav. 21.: Middle-Upper Liassic. The Crusmicritina considens grew onto Palaeodasycladus but not on the Solenopora. The formation is presumably partly or totally resedimented, the two floral elements deposited not in the same syncline.

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SEDIMENTOLOGICAL AND FACIOLOGICAL CHARACTERISTICS OF THE SENONIAN PELAGIC FORMATIONS OF THE HUNGARIAN PLAIN

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Based on the data of hydrocarbon exploration wells the Senonian formations are known in two sedimentary belts in the region of the Great Hungarian Plain (Alföld). In the middle part of the Great Hungarian Plain the Senonian formations of northern facies belt consist mainly of red, pelagic marl and calcareous marl of rich foraminifer content. The petrologically homogeneous formations are known in a narrow zone of SW—NE, and faciologically are similar to the formations of the Carpathian Klippen Belt of similar age (Puhov-type marl). The reddish-brown marl and calcareous marl sediments are of Campanian and Maastrichtian stages. The Senonian sediments known from the central part of the Great Hungarian Plain connect with Upper Cretaceous formations Klippen Belt across the formations of the same age and facies of the Transcarpathian and Máramaros zones.

Keywords: Senonian sedimentary cycle, lithology, pelagic formation, subsurface geology, Great Hungarian Plain (Alföld)

In the middle part of the Hungarian Plain, south of the "Central Hungarian Megatectonic Zone" Senonian formations were penetrated by the hydrocarbon exploratory wells along two nearly parallel zones. From the aspect of superposition and sedimentology the Upper Cretaceous formations of both belts represent an independent sedimentary cycle. The Senonian sequences starting everywhere transgressively with basal coarse-grained sediments are connected with their underlying and overlying strata with hiatus combined with unconformity. The sequences of the two belts extend over the Campanian and Maastrichtian stages. In the belts the lateral connections are proved by borehole data but the relationship and the paleogeographical connection of the two sedimentological zones are unknown so far (Fig. 1).

In the southern zone the mainly detrital Senonian sequences of max. 1000 m thickness are built up by the alternation of sandstone and siltstone

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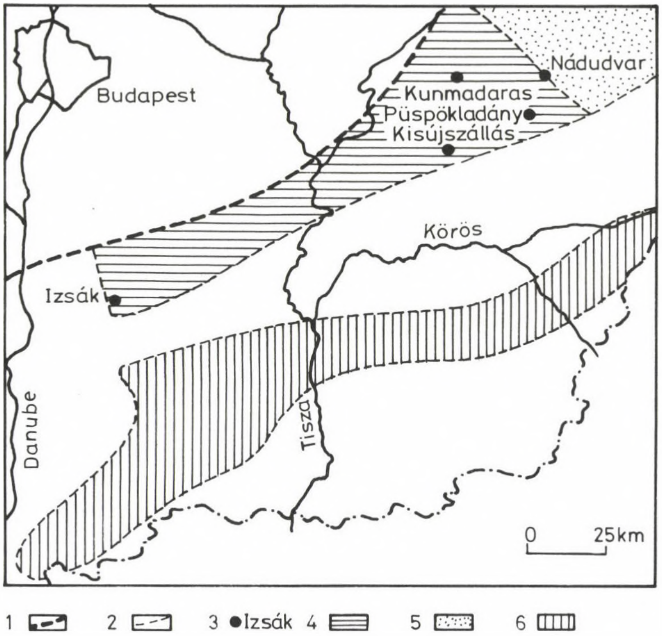

Fig. 1. Extension of Senonian formations in Hungarian Plain. 1. "Middle Hungarian Megatectonic Zone"; 2. border of facies belt; 3. occurrence of pelagic Senonian facies in boreholes; 4. pelagic marly sediments; 5. flysch-like sediments; 6. epicontinental carbonatic and terrigeneous sediments

layers. In the western and northeastern margins of the zone the sequences can be lithologically divided into three parts. The sequences are built up by conglomerate (Szank Formation), marl (Csikéria Formation) and bioclastic limestone (Bácsalmás Formation). These latter deposits represent the middle shelf sediments, while the terrigeneous formations represent the outer shelf and slope sediments, respectively.

In the middle part of Hungarian Plain the lithofacies of the Senonian deposits are essentially different from the above mentioned ones. Northward to the Izsák, Szolnok, Kisújszállás, Püspökladány, Nádudvar line as far as the "Central Hungarian Megatectonic Zone" in a narrow belt lithologically and faciologically essentially homogeneous Upper Cretaceous sediments are known, which consist of pelagic calcareous marl and marl with some limestone intercalations.

The underlying formations and the basal strata of the pelagic sequences are known only in some places, the basal strata being represented by polymict basal conglomerate. The Senonian formations are overlain by strata of various stratigraphic positions (Paleogene, Miocene or Pannonian). This belt is bordered tectonically now. Northeastwards the zone contacts terrigeneous flysch-like formation of Upper Cretaceous age by tectonically sharp facies boundary.

The lithostratigraphically uniform sediments are found in the Izsák Formation (K. Szentgyörgyi, 1982, 1983, 1985). The formations were investigated lithologically, faciologically and paleontologically and reported by L. Körössy (1959, 1977), V. Dank (1963, 1965), Á. Juhász et al. (1982), Á. Juhász–Mrs. B. Csongrádi (1969), L. Majzon (1961, 1966), M. Sidó (1969), K. Szepesházy (1973), E. Dudich et al. (1979) and J. Kőváry.

Extention, thickness, lithological features

The pelagic Senonian sediments are known in the pre-Tertiary basement along a belt of 150 km length and 25–50 km width. On the basis of considerable petrological and paleontological similarities, the rocks of this formation can be fairly well correlated even in distant sequences. In the region unexplored by boreholes the presence of this formation can be deduced on the basis of fragments included by younger sediments (Fig. 1). The sequences were explored in a thickness of 75–407 m. The underlying strata usually were not reached by drillings. The surface of the formation is an erosion surface. The extention of the hiatus is unknown.

The underlying strata of pelagic sediments are transgressive basal conglomerates (borehole Izsák-1, Püspökladány-5, Kisújszállás-NE-2). Carbonatic and in various degree pelitic (argillaceous) sediments follow onto this, with sharp boundary and lithological change. The lower and major parts of the sequences are red or reddish-brown. Only the layer subsequent to the basal conglomerate and the uppermost part of the series consist of grey coloured rocks. The change of colour can be observed within the thickness of some ten cm. Alternation of colours cannot be detected.

88% of the formation is built up by calcareous marl and marl with predominance of calcareous marl. The amount of the silty shale (this forms the layers settled above the reddish-brown calcareous marl) is 4%. The quantity of the siltstone (between the basal conglomerate and pelitic-carbonatic sediments) is 4%. 4% of the penetrated rocks is mudstone-type limestone of micritic texture (as intercalations in calcareous marl). The average carbonate content of the rocks is 69% with 2–10% dolomite content. Stratification cannot be observed in the sequences, sections of various carbonate content are developed continuously without sharp boundary. Fine- or coarse-grained terrigeneous intercalations are not found. The rocks are compact and as the carbonate content increase, the rocks become brittle.

In this case the texture becomes brecciated as a result of subsequent tectonic effects. Due to the subsequent stress the marls of greater argillite content become foliated and finally fractured. All of these are postsedimentation phenomena proceeding after lithification.

The carbonate content of the rocks decreases gradually upwards in the sequences and the disperse fine graine clast content (argillite, silt) increases gradually from place to place to various extent. The mineral composition of the fabric is shown in Fig. 2.

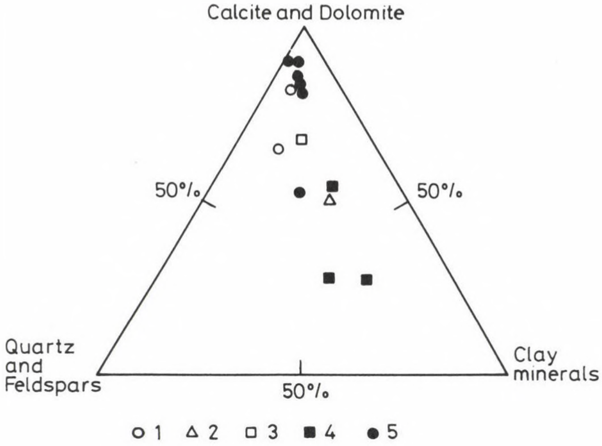

Fig. 2. Mineral composition of pelagic sediments. 1. Kunmadaras-8. borehole; 2. Kunmadaras-3. borehole; 3. Kisújszállás-NE-2. borehole; 4. Nádudvar-SE-3. borehole; 5. Izsák-1. borehole

At the time of deposition the texture of sediments might be primarily of mudstone – wackestone type. Now, as a result of physical and chemical processes of diagenesis the primary texture can be observed only in calcareous marl and marl of less carbonate content. Significant parts of the calcareous marl and limestone interbeddings are recrystallized to a considerable degree. The texture is mainly biomicrite – pelbiomicrite, the texture of limestone sections is biosparite. The determination of the original texture is more difficult in some sections due to diagenetic alterations and leaching. From the point of view of investigation of sedimentary processes important data could be obtained by the key-section of the borehole Izsák-1 drilled in the southwestern part of the zone (Fig. 1). In this sequence two stages of development could be unambiguously established.

The first stage is represented by a carbonate cycle. The carbonate content increases gradually, then decreases (Fig. 3). In the middle part of cycle limestone was deposited practically without fine-grained non-carbonate detritus. Based on the lack of dolomite it can be assumed, that the dolomite occurring at the base of the cycle and then in some layers was formed syngenetically. The end of this carbonate cycle is marked by the decrease in the carbonate content and by the increase of the amount of fine-grained components (argillaceous marl). At the beginning of the subsequent cycle increasing carbonate content can be detected again, but only the initial part of the sequence can be examined because of the postgenetic erosion (Fig. 3).

In other sequences the temporal succession of sedimentation cannot be followed in such details because of insufficient sampling. Nevertheless, the spatial changes and variance of sedimentary characters within the deposition environment can be established inductively. In the facies belt the carbonate content of rocks decrease gradually from SW to NE (the predominating calcareous marl is succeeded by marl). Limestone layers are known in the southwestern part only. The amount of the fine-grained terrigeneous detritus increases gradually similarly (Fig. 4). The dispersed argillite and silt content increase, too. In the northeastern part of the belt the scattered fine-grained muscovite fragments are characteristic elements of the texture. In the southwestern part the quartz content is less than 10% in the rocks. Illite, chlorite, kaolinite and feldspars can be found only in traces. The quantity of calcite varies between 75 and 90%, the amount of dolomite is 4–11%. The mineral composition of the northeastern part of similar position is as follows: quartz 8–20%, feldspars 1–6%, illite 2–20%, chlorite 1–12%, kaolinite 3–13%. The calcite content varies between 40 and 63%, that of dolomite between 2 and 10%. For this reason, it is obvious that in the southwestern part of the belt carbonatic sedimentation took place while greater amount of fine grained, dispersed, terrigeneous material was transported into the northeastern part.

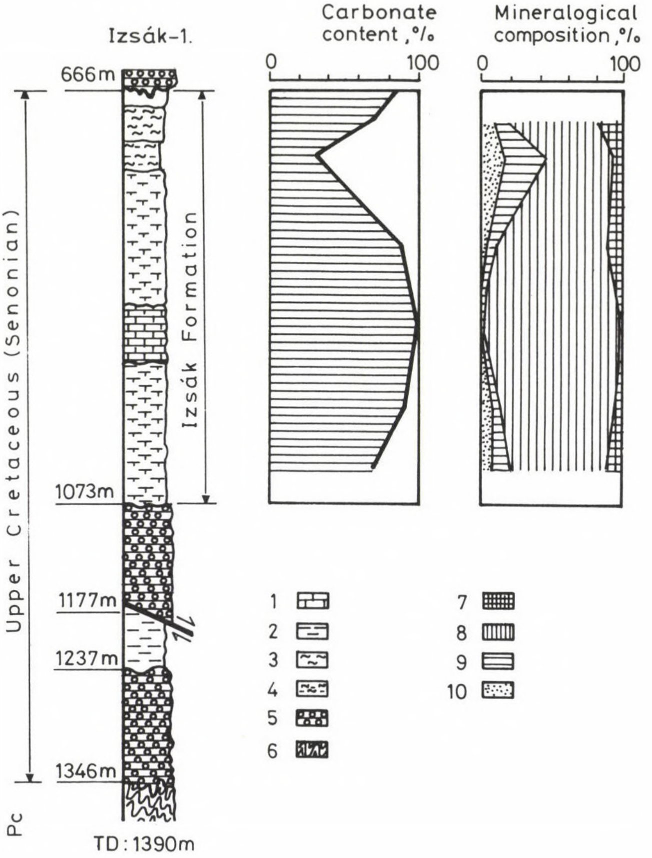

Fig. 3. Lithological sequence of the Senonian in the Izsák-1 borehole.
1. Limestone; 2. reddish-brown calcareous marl; 3. marl; 4. argillaceous marl; 5. conglomerate; 6. metamorphic rock; 7. dolomite; 8. calcite; 9. clay minerals; 10. quartz

In spite of the far-lying boreholes the transition of sedimentation can be recognized in the two region. The fine-grained terrigeneous influx found in the northeastern part can be brought probably into direct causal connection with the development of mainly detrital Senonian formation known from the northeastern continuation of this belt. The upper part of the sequences consist of grey silty argillaceous marl or marl (where it is remained in spite of erosion). This formation could spread commonly and its development can be related to new depositional conditions.

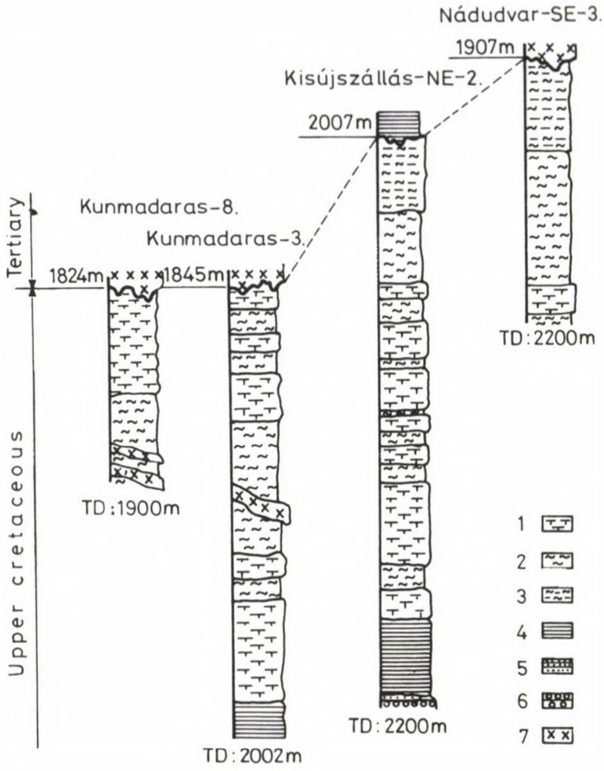

Fig. 4. Lithological sequences of the pelagic Senonian in the northeastern part of the facies belt. 1. Reddish-brown calcareous marl; 2. marl (lower part reddish-brown, upper part grey); 3. argillaceous marl/shale; 4. siltstone; 5. sandstone; 6. conglomerate; 7. Miocene volcanic rocks (partly dykes)

Depositional environment, facies

The above mentioned fine-grained, carbonatic sediments deposited out of the shelf, on the area of open-marine basin. This is proved by the facts as follows:

a) Fine-grained sediment with limited amount of non-carbonate grains, fragments, full lack of detrital strata;

b) Sedimentary features relating to the near-shore shallow water sedimentation are absent;

c) Microbiofacies consisting of planktonic foraminifers in the majority of cases (Globotruncanidae species, Pithonella species, etc.). Molluscs are practically absent.

Major part of the rocks is oxidized, the oxidation degree varying between 0.6–1.0 on the Burri-scale. Oxidation took place without interruption, extreme low values are unknown. Both bottom currents in deep marine and low sedimentation rate contributed probably to the oxidation process.

The diagenesis started immediately after the deposition and the texture became chalk-type. Because of the significant and quick compaction there was a drastic decrease in porosity. The water was squeezed fast from the pore-space so in the deeper layers the texture was not affected by the diagenesis. The pelagic foraminifers accumulated in great quantities in sediments and considerable dissolution cannot be observed on the tests. On the basis of the texture and microbifacies these sediments deposited over the CCD. The depth of water could not be more than 2.5–3.0 km, but more probable, that it was less. So the pelagic – hemipelagic character of sediments is due to the great distance from the coasts. The sporadic occurrence of the benthonic foraminifer assemblage is also against the supposition of water depth of several thousand meters. The characteristic concomitants of the deep marine sedimentation (manganese nodules, hardground surface, condensated sequences, etc.) are also absent or cannot be recognized.

Paleogeography, chronostratigraphy

Based on the lack of the lateral facies transition towards the shallow water it is probable that the pelagic Senonian formation in the middle part of the Great Hungarian Plain, bounded now tectonically, accumulated in a non-separated basin. Most likely this basin was connected southeastwards directly with a nearly parallel basin containing slope – and self-origin sediments. According to the biostratigraphic data in this facies belt the Senonian sedimentation started in the Campanian.

At that time rapid transgression began and continued without interruption until the Campanian–Maastrichtian boundary. At the beginning of the Maastrichtian the sedimentation rate decreased temporarily and the influx of the fine-grained detritus increased simultaneously. This increase was of greater degree in the northeastern and of smaller degree in the southwestern part of the sedimentation area. The pelagic sedimentation continued in the Maastrichtian, but the deposition of silty marl, argillaceous or silty calcareous marl and argillaceous marl and marl predominated instead of the accumulation of reddishbrown, oxidized carbonate sediments. In the northeastern part of the basin the late Maastrichtian sedimentation can be proved paleontologically, too (Globotruncana mayaroensis Zone).

Formations and events from the end of the sedimentary cycle are unknown since the late Senonian strata eroded in the Paleogene. As a consequence of the compression and of the tectonic movements in the Late-Tertiary the formation of Senonian facies belt overthrusted. The present foliated, brecciated features of these rocks are the result of these tectonic processes.

Acknowledgement

This report is a part of the research work done for National Scientific Research Foundation (OTKA) in the topic of "Investigation of Mesozoic key-sections of Hungary and their correlation with Alpine—Carpathian—Dinaric realm". Author thanks for the management of the Central Geological Office and of János Haas, leader of this project for his support.

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COMPLEX GEOLOGICAL INVESTIGATION OF LAKE BALATON (HUNGARY) AND ITS RESULTS

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Lake Balaton and its surroundings have been studied in several phases since the turn of the century. During past decades, eutrophication and filling-up have continued at an exponential rate. A new phase of study started in 1981 aimed at a better understanding of the thickness and properties of the recent sediments and the reconstruction of the geological history of the lake, as a preview for its future state. Seventeen boreholes up to 90 m depth were put down in the eastern part of the Lake between 1981 and 1986. 370 km seismoacoustic and echographic profiles were recorded in 1987.

The results can be summarized as follows:

1. The Holocene sediments comprise of clayey silt, silt and sand. Lumasella and peat occur in some cores near the base. This date, by ^{14}C-dating is 10—12 tyrs. BP. A few cm-thick layer of polygenetic pebbles covers the Pannonian basement. These vary in size and have been weathered, and are derived from the northern shore. The Holocene sediments show downward consolidation trend from liquid into stiff mud. No sample could be collected from the upper 50 cms. DTA and X-ray analyses indicate that the lacustrine sediments are carbonate (40—80%), and quartz, muskovite, clorite and clay minerals (illite, montmorillonite) in decreasing abundance. Carbonates include mostly the magnesium calcite, calcite and dolomite. Magnesium calcite diminishes towards lower sediment contact. Organic carbon contents are not a function of depth. Natural sulphur was found in extracts, from 2.5—3.5 m depth intervals. Ostracods and pollens are most useful for the geological history of the lake. Palynological results indicate the lake has been existing since 12 000 yrs BP.

2. Isopach map of the loose mud and seismostratigraphical — tectonic map of the basement, have been compiled both on scale 1:50 000. On the basis of the thickness map the mud is generally 5 m thick. There are elevations in the basement with 1—1.5 m thick mud, while in subsidences it may reach the 8 m. By applying radiocarbon and palynological dating, the speed of mud accumulation could be calculated as 0.4—0.6 mm/yr. As for the basement, on the basis of seismic time section 7 zones and within 2 zones five layers were appointed and its depiction accompanied with tectonic elements is the seismostratigraphic — tectonic map of the basement. The selected zones and layers are partly lithologically differing and on the other hand their conditions of deposition are also different. Geological identification of the zones and layers on the basis of the

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already existing and planned boreholes, is the task of the near-future.

Keywords: Hungary, Lake Balaton, lake sedimentology, seismo-acoustical logging, seismostratigraphic-tectonic map

Introduction

Lake Balaton is the largest lake of Central Europe, one of the most valuable and important recreation zones. That is why the lake and its neighbourhood has been studied since the beginning of this century in several phases.

— The complex investigation of the area under the direction of L. Lóczy Sr. was started at the end of the 19th century and lasted till about 1913. As a result a monograph series of 32 volumes and two maps (scale: 1:75 000) were published. Also in the course of this work 17 boreholes were put down in the lake (Lóczy, L. 1919, and Fig. 1). Simultaneously, between 1894 and 1895, the first detailed isobath map was prepared by the Hydrographical Institute, then these measurements were repeated in 1929—1930, with special respect to the mud accumulation of the Keszthely Bay.

— In 1948, and then between 1962 and 1965, boreholes for chronological studies and characteristics of the lacustrine sediments were put down (altogether 21 boreholes). The work has been done under the direction of B. Zólyomi and K. Szesztay, respectively. Some papers were written or published on the subject (Zólyomi, B. 1962, 1987; Szesztay, K., 1966). During this period, in 1955—1956, using supersonic sounding, a new isobath map of the Lake Balaton was accomplished by the VITUKI

— Since 1965 the Hungarian Geological Institute has been conducting complex geological investigations in the Balaton region. Mapping on scale 1:10 000, and 1:50 000 was completed in the last years (Raincsák—Kosári, Zs., T. Cserny, 1984). Since 1981 a project for investigation of the recent lacustrine sediments has been under way (Cserny, T. 1987b). Simultaneously, between 1970—1976, mapping of the mud on the surface of the bottom of the lake on scale 1:50 000 was carried out by the Balaton Lymnological Institute of the Hungarian Academy of Sciences (Máté, F., 1987). In 1969—1972 G. Müller took samples by piston corer and studied them sedimentologically (Müller, G. 1970, 1978; Wagner, F., 1978). In 1984 the VITUKI, for comparing the former bottom surveys, with the present ones applied an Atlasz-Echolog

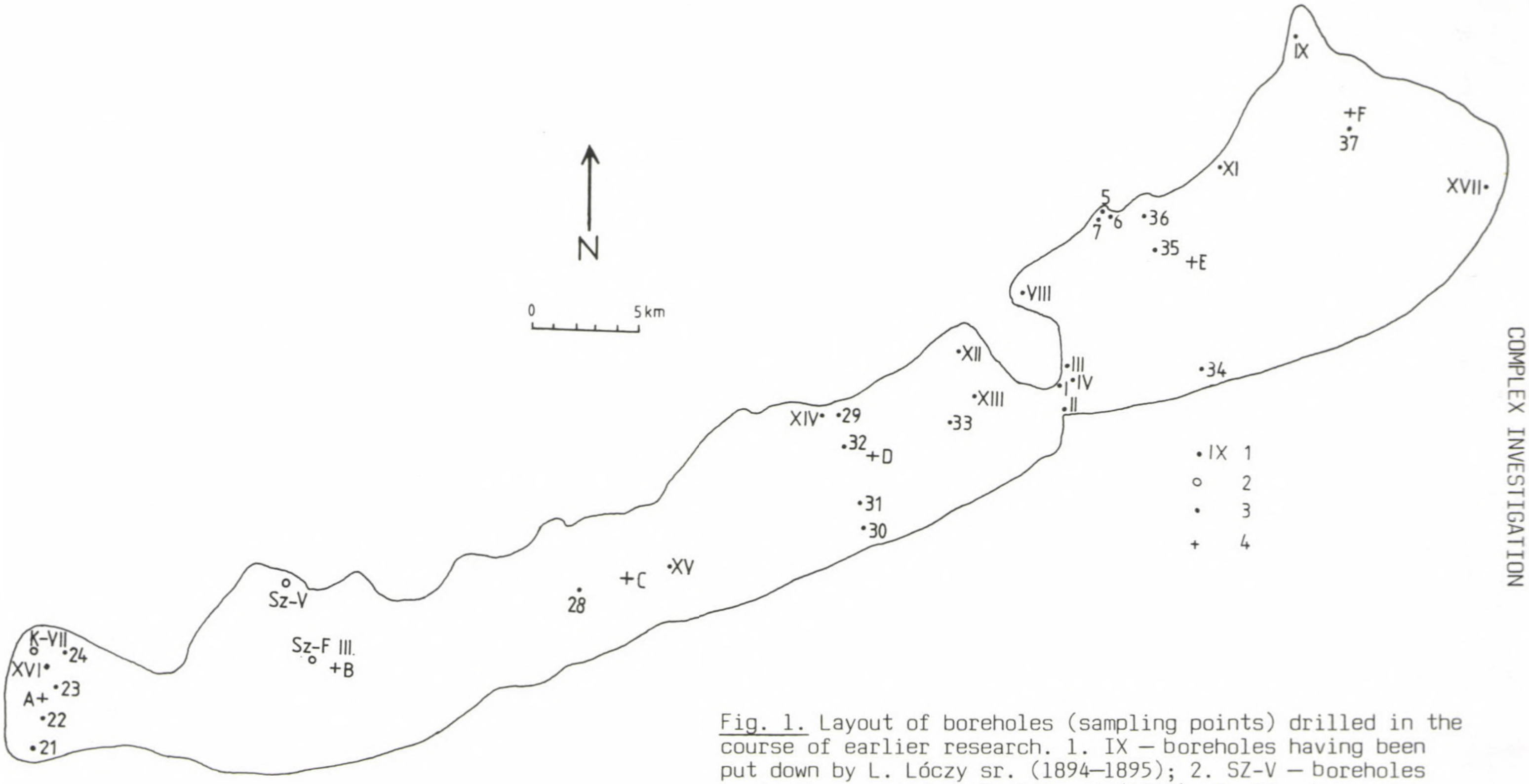


Fig. 1. Layout of boreholes (sampling points) drilled in the course of earlier research. 1. IX – boreholes having been put down by L. Lóczy sr. (1894–1895); 2. SZ-V – boreholes having been put down B. Zólyomi (1948); 3. 36 – boreholes made by VITUKI (1964–1965); 4. A – samplings of G. Müller (1972)

supersonic sounder, and performed a high accuracy bottom survey on scale: 1:25 000 (Bauer, J., A. Sárdi, 1984).

Actuogeological investigation of the Lake Balaton

During the past decades eutrophication and non-desirable filling-up has been continuously going on at an exponential rate. The final aim of the investigations started in 1981, is to obtain a better knowledge of the mud — thickness, sediment properties and the reconstruction of the geological history of the lake, offering a forecast for its future state.

Two stages of the present work have been already finished (Fig. 2):

— 17 boreholes were put down in the eastern part of the Lake between 1981—86.

— Seismoacoustic and echographic geophysical profile was prepared for the Lake in 1987, and isopach and seismostratigraphic-tectonic maps have been compiled in 1988 (Figs 4, 5).

Results of the first stage of actuo-geological investigations of the Balaton region

Boreholes were performed by applying rotary and percussion drill, 50—105 mm in diameter. The intact cores, were transported to the laboratory in 2 m long plastic core-pipes. Here the pipes were cut by rotary saw, and then the core was halved.Afterwards the macroscopic description and photodocumentation of the cores and treatment with aldoform, half of the samples was hermetically sealed, and the other half was sampled according to a previously determined plan, in 10—50 cm stages. In the laboratory the following parameters could be determined: physical properties, grain distribution, water content, gravimetric density, density, limits and indices of consistence, mineralogy (DTA and X-ray spectroscopy), organic geochemistry (bitumen content and organic coal), palaeontology (malacology, palynology, diathom, and ostracods) and in certain cases radioactive dating. Laboratory results for each borehole are shown on a combined version of the given geological section (Fig. 3).

Six of the 17 boreholes totally penetrated the Holocene lacustrine sediments and stopped in the underlying Lower Pannonian formations. The

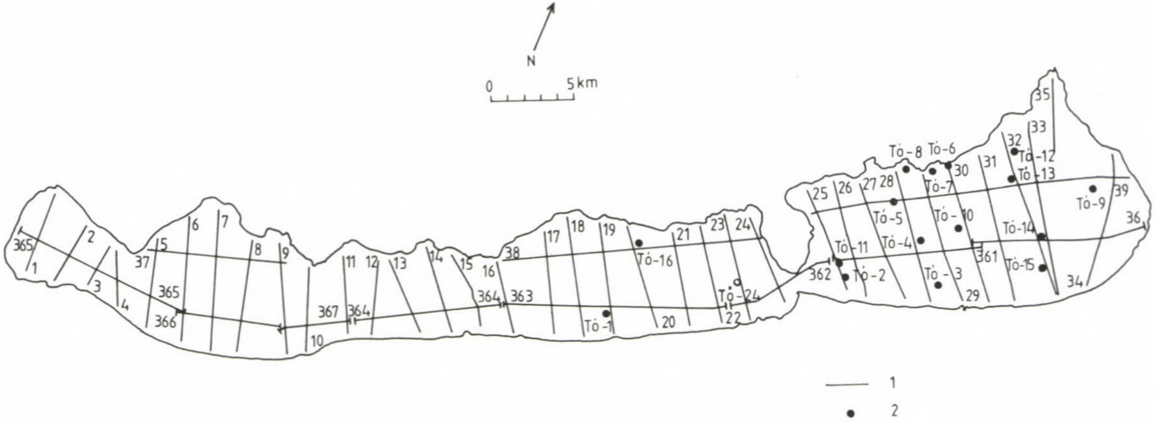


Fig. 2. Layout of boreholes and geophysical logs made within the frame of the actuogeological project. 1. 12 – Route and number of geophysical logs; 2. Tó-24 – layout of boreholes in the area of the lake with complex laboratory analysis

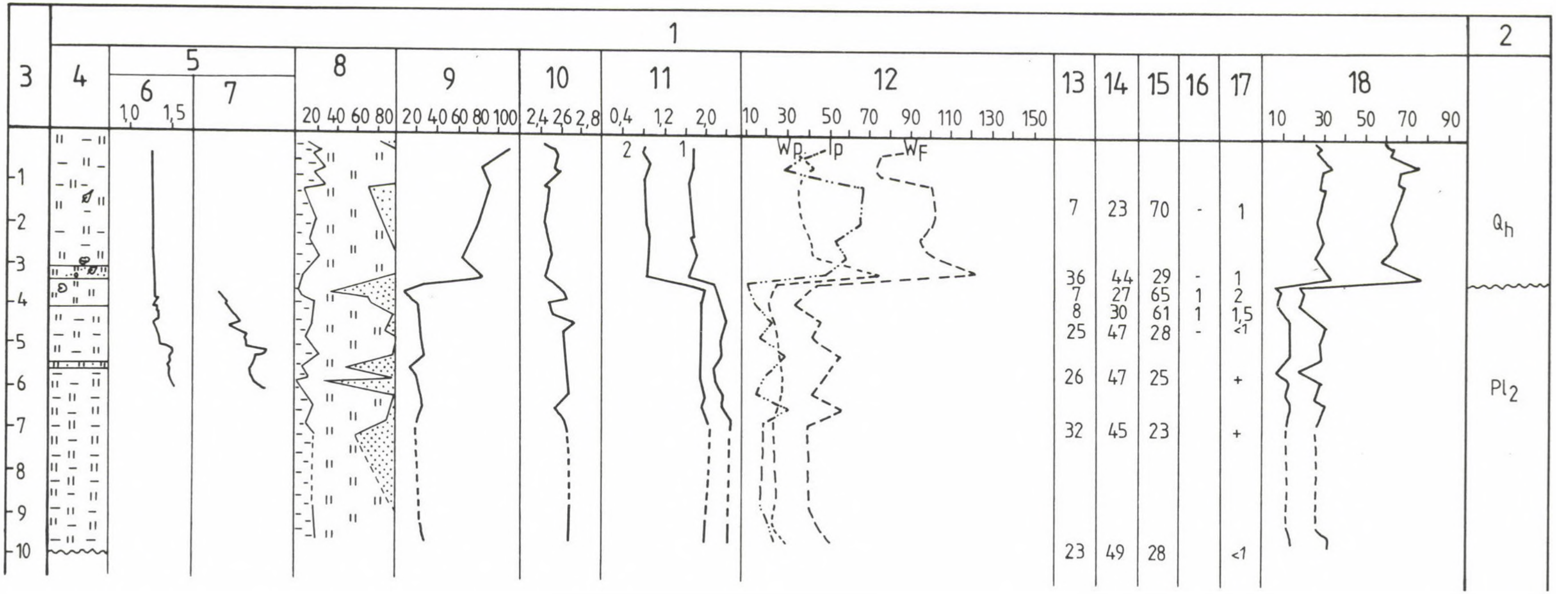


Fig. 3. Complex geological section of borehole Tó-24. 1. Soil mechanical tests; 2. age; 3 m; 4. geological column.; 5. in situ; 6. electron probe; 7. dynamic probe; 8. granulometric distribution %; 9. water content %; 10. density (g/cm^3); 11. body density (g/cm^3) (natural state: 1, dried state: 2); 12. plasticity; 13. detrital minerals; 14. clay minerals; 15. carbonate; 16. goethite, pirite; 17. organic matters; 18. carbonate content (Scheibler)

Holocene sediments consist of clayey silt, silt and sandy silt. In some boreholes, near the bottom strifes with lumasella and peat can be found. The age of the latter, is 10–12 yrs BP, determined by ^{14}C radioactive dating (Hertelendi, E., 1987), i.e. it indicates the very end of the Pleistocene. At the boundary of the lacustrine sediments and the underlying Pannonian formations a few cm thick layer consisting of weathered pebbles of different diameter derived from the north, can be also found.

At the bottom of Lake Balaton the Holocene sediments gradually transform from the liquid mud into stiff rock. From the upper (max. 0.5 m) suspension no samples could be collected.

DTA and X-ray analyses indicate that the lacustrine sediments are of basically carbonate type (40–80%), and according to frequency order quartz, muscovite, clorite, and clay minerals (illite, montmorillonite) also occur. Among the carbonates the most frequent is magnesium calcite; calcite and dolomite to a smaller extent can also be found. Magnesium-calcite appearance rate decreases towards gradually greater depths, and it disappears at the lake-bottom boundary. Analyses of the water solvent ions of the samples, depending on depth may indicate several maximums and minimums. These changes can be indicated by climatic changes (Cserny, T., 1987a).

Results of the analysis for bitumen contents cannot be accepted as a rule in the function of the depths. From 2.5–3.5 depth interval of the cores native sulphur solution was to be found. This process can be explained by the intensive activity of the resulphating bacteria (redoxi-processes) (Bruckner–Wein, A., 1988). As part of the paleontological investigations and determinations for Ostracods, Diatoms and items of palynological character provided sufficient data for the evolutionary history and ecology of the Lake. Summarizing the above statements, we can say that all the above pollen zones (Firbas, 1949) can be indicated, accordingly the lake must have been present some 12 000 years ago (Miháltz–Faragó, M., 1982; Bodor, E.,1987; Nagy–Bodor, E., 1988).

Results of the second stage of the investigations of the Lake

The geophysical measurements were carried out, based on Cuban-Hungarian bilateral agreement, by applying seismoacustic and echographic geophyiscal methods (Corrada, R. et al., 1987; Cserny, T. et al., 1989;

Cserny, T., R. Corrada in press). Problems to be solved were the following:

1. Determination of the full thickness of the lacustrine sediments, and that of the loose colloidal mud layer in the lake along the profile network.

2. Determination of the optimum locality of further drillings. By applying seismoacoustical (sparker) method, complemented with echoprobe continuous logging was carried out in sections deeper than 2 m of the Lake Balaton covered with water. The sections, along the longitudinal axis of the lake are placed in spaces of 4 km, while the horizontal sections positioned perpendicularly to the former one are spaced at 2 km intervals within the total section length of 370 km. The sparker measurements were performed with the Canadian-made instrument Hidrosond-A, while echosounding was carried out by using the Soviet-made Echolot PEC-3 instrument. The measurement accuracy of both of the instruments is within 0.5 m. Exact geodetic location of the ship's position was obtained in two ways:

– from the shore, using theodolite, by way of intersection

– from the ship by using sextant.

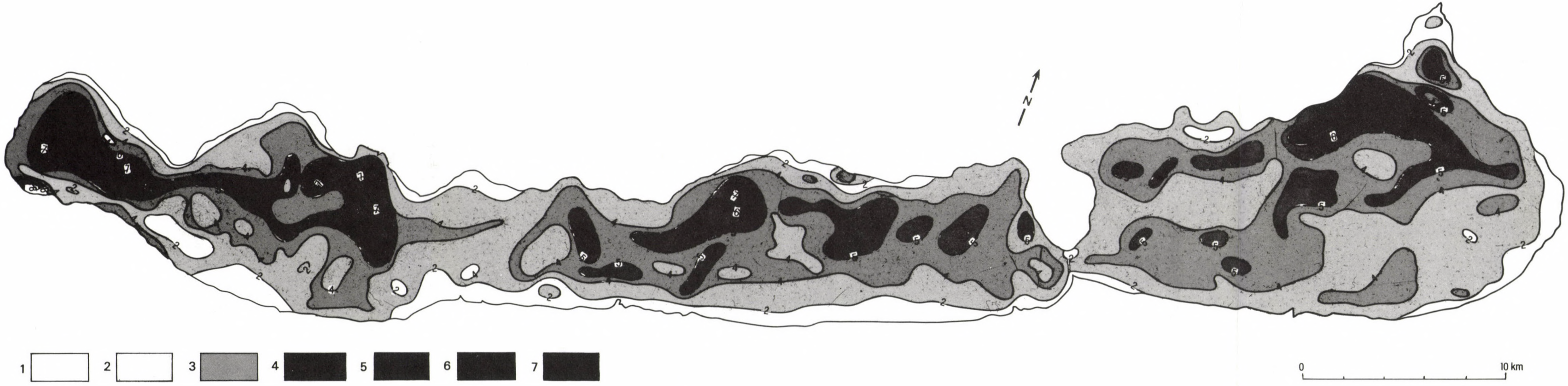
By means of computerized processing of field data the wave velocity in the different layers was determined by applying empirical methods. These were the following: water 1450 m/sec, loose sediments 1611 m/sec, basement 2000 m/sec.

As results of interpretation and evaluation the following maps have been prepared: "Seismostratigraphic-tectonic map of the basement of Lake Balaton", and the "Isopach map of the loose mud of the Lake", both on scale 1:50 000.

As a result of the echosounding and seismoacoustic investigations we could obtain useful information concerning the surface of the lake and its solid basement, and the thickness of the loose Quaternary sediments. As an addition to the plotted mud-thickness map (Fig. 4) the following remarks should be considered:

The pre-Quaternary surface is extremely varied. At certain places there are outcrops of 3–4 m heights, here the thickness of the mud is only 0–1.5 m, while in recesses of 4–5 m depth it may reach 7.5 m. At a distance of 1–2 km from the southern and northern shore drift terraces may be observed in the basement, with heights of 1.5–4.0 m.

Average thickness of the Quaternary mud is 5.0 m. East of the Tihany peninsula the maximum thickness of the mud is 6 m. West of the



<u>Fig. 4.</u> Isopach map of loose mud of the Lake Balaton (Compiled by Cserny, T. and V. Ramos)

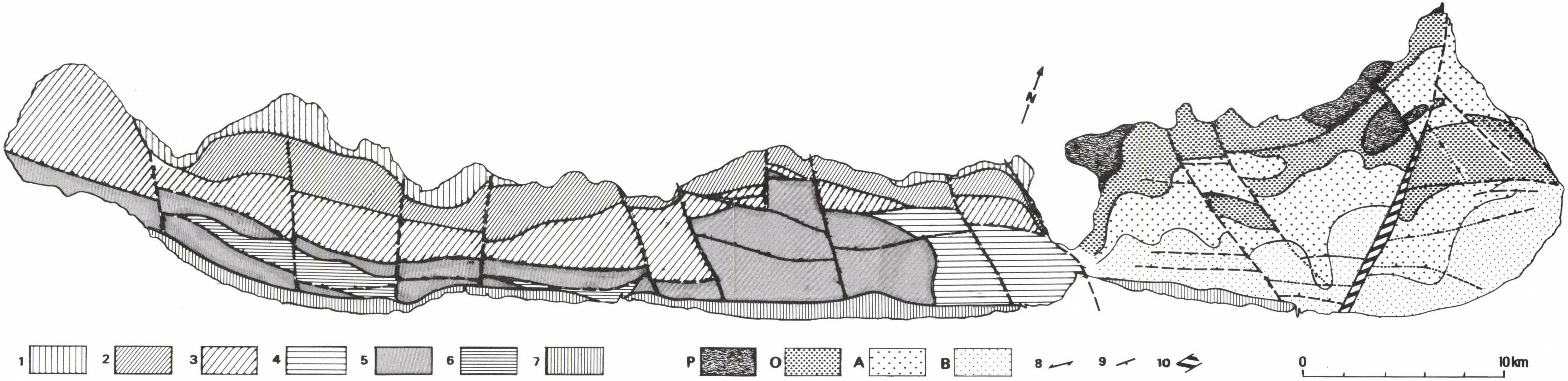


Fig. 5. Seismostratigraphic-tectonic map of the basement of Lake (Compiled by Cserny, T. with assistences Corrada, R., Ramos, V., Csilling, L.)
Legend: 1, 2, 3,... 7: zones; B,A,O,P: layers; ↗ :transcurrent fault; ⊥ :vertical (normal) fault

peninsula up to the Badacsony–Fonyód line maximum thickness of the mud is 5.0 m. In the Szigliget bay maximum thickness is 7.0 m, while it is 8.0 m in the Keszthely bay.. The maximum mud thickness of the Lake: 10 m, can be observed near the mouth of the Zala river, in a "V" shaped valley incut. The sedimentation velocity can be determined with the knowledge of sediment thickness (by geophysical profiles and boreholes) and the duration of deposition (by radiocarbon and palynological dating). Considering the initial diagenesis of the sediments this value in the older Holocene is 0.1–0.3 mm/years, while in the younger Holocene it is 0.6–0.8 mm/years. Plotting of the seismostratigraphic-tectonic map of the basement of the Lake (Fig. 5) has contributed not only to our knowledge concerning the evolution of the Lake but it is a methodological novelty in itself. That is why, in case of the above sections, we shall go into details concerning the geophyiscal sources and their possible geological interpretations.

During our work the differences of the physical properties of the formations constituting the bottom of the lake were taken into consideration which also influence the propagation of the seismic and acoustic waves. All these factors, for obtaining geological information have proved to be useful, i.e. they facilitated the selection of 7 zones in the basement and within 2 zones six layers, and also their cartographic representation, respectively.

Characteristic features of the appointed zones and layers

Zone 1: It could be separated in the sections W of the Tihany Peninsula, near to the N shore of Lake Balaton. Geophysical description: under the mud-layer of small thickness (the shore is near), a certain scattering of the acoustic energy is present that results in multiple but temporary wave-reflection on the seismogram.

Based on the shoreline and near-shore bottom boreholes it may be supposed that cemented debris is present in the basement that diffuses the energy and makes the obtaining of information from deeper ranges impossible.

Zone 2: It is located between the Tihany Peninsula and the W border of the Szigliget Bay, in the southward continuation of Zone 1. The records indicate a general decrease in the amplitude. Between the loose mud and the basement the boundary is not sharp but the transition is gradual since the contrast between the two layers is small, under the boundary surface the signal intensity is low, and above 20 m/sec it disappears. According to the few available archival boreholes the basement consists of silt with a very few sand and clay content: its grain composition is similar to that of today's mud of Lake Balaton but may be a bit more compact.

Zone 3: To Révfülöp from Tihany it occurs only in spots, and then westwards its extension is greater, southward of Zone 2, frequently with gradual transition. Even in case of mud-thickness of 4–5 m, reflexion waves indicate a 3–4 m thick compact formation. There is a horizontally deposited layer in the zone, and due to its presence we can obtain a perfectly continuous signal of great amplitude consisting of two strong phases by which it could be separated from all the other zones.

From data obtained from some of the boreholes we can conclude that the basement consists of clayey silt and clay accompanied by silt.

Zone 4: The area ranges W of the Tihany Peninsula till the region in front of the village Balatonakali. Zone 4 differs from the three former ones since this, under the loose mud, offers several signals, i.e. contains several layers. Towards N it is generally in tectonic contact with Zone 3. The Zone's lower boundary is represented by a slightly uneven surface giving a markedly strong signal (Q layer). Above this often undistinguishable layers (P, O, A, B) are to be found the transition among which is probably continuous. Thickness of these so-called "covering layers" may reach even 30 m. Based on the upper 6 m part of the borehole deepened in the bottom of Zone 4 the layer is compact, clayey silt.

Zone 5: W of the Balatonakali region the basement of the southern part of the Lake and the Siófok subbasin belong to this zone. Practically it is the same as the former one, it starts in the N where the layers of Zone 3 begin dipping towards S–SE. A lower boundary surface can be clearly distinguished that may appear in three forms. It is marked with "P" in the Siófok subbasin, with "Q" in the area between the Révfülöp region and the Tihany Peninsula, and with "T" in the Fonyód area. According to the knowledge of the sequences of boreholes put down in the lakeshore as well as of the geology of the shore line "Q" is to be identified with Miocene limestone, "P" with solid rock older than Pannonian, and "T" with basalt-tuff by chance. The difference between Zone 4 and 5 is that above one of the above mentioned "marker horizons" the layers (P, O, A, B) can be clearly distinguished in case of Zone 5.

Geophysical interpretation of the seismic horizons of the layers within the zone:

The wave reflected from the surface of "P" is generally of great amplitude and can be detected in 3 or 4 phases. Amplitude of the wave reflected by the seismic horizon of "O" is smaller but its frequency is higher than that of "P", and 2–3 continuous phases can be observed. Thickness of this sequence ranges between 0–20 m. Considering the slight reflection of the sequence signs from the inner part of the layer, it may be supposed that the "O" layer is lithologically more homogeneous than the others.

The upper horizon of "A" layer is continuous with a signal consisting generally of 3–4 phases and its frequency is lower as compared to that of horizon "O". In the internal section of "A" several interrupted signals characteristic also of the upper horizon but of smaller amplitude could be observed. It means that within this layer further stratification may occur, i.e. "A" is lithologically more heterogeneous and horizontally rather varied. Upper horizon of layer "B" is eroded. It can be found only in the southern part of the lake where Q, P, O and A are deeper seated. The "B" itself can be characterized by a wave phase that has the same frequency as that of "A" but is of greater amplitude, and is present in the total thickness of the layer as a continuous line. The "B" layer is the most microstratified and offers only little horizontal variability.

Zone 6: It can be found in the southern part of the Szigliget Bay and in the basin in front of the village Boglárlelle in a comparatively narrow strip. Its seismogram is very similar to that of Zone 3 though the signals may be reflected from harder rocks than in the previous case. Almost in the total time-span multiple wave reflection may be observed on the siesmograms, the signal is intensive and is of high frequency, that is why no information could be gathered from greater depths.

This zone from the N is always bordered by Zone 5, while from the S by Zones 5 and 7, respectively. In this zone no borehole has been deepened in the bottom but based on the seismograms this zone consists of the horizontally deposited layers of Zone 5 dipping towards S or SE.

Zone 7: Along the southern shore of the lake, with minor interruptions (Keszthely Basin, Szántód area), it appears in a 500–1500 m wide strip. It is characterized by signals of great amplitude with two well determinable phases. Multiple signals on the registers prevent us to obtain information concerning the layers that are to be found deeper. According to results obtained from near-shore boreholes under the mud of minimum thickness redeposited fine-grain sand is present here, deposited in water and that is why it is rather compact.

Tectonic features

In the basement of Lake Balaton faults and fracture zones can be observed. When selecting the fractures and determining their exact localities the following geophysical features were taken into consideration:

– the information loss, the disappearance of the seismic horizons in a well determinable strip;

– interruption of the continuity of the seismic boundaries;

– change of the reflection time signals of the same layer boundaries as compared to a given plain, or point;

– increase or decrease of the observed reflection time.

Observation of the above geophysical features made possible the differentiation of the horizontal (transcurrent fault or strike-slip) and vertical (normal) faults. In case of horizontal slips the extension of the disturbed zone was taken as the basis with a limit value of 150 m. In case of vertical faults the position of the blocks as related to each other was considered. A greater than 10 m dislocation was considered extensive vertical fault.

The sinistral strike strip along the western shore of the Tihany Peninsula divides the basement of the Lake, and two subbasins were formed.

In the eastern subbasin the longitudinal faults seem to be dilatational (secondary, i.e. normal) ones that often disappear along the track. They, however, seldom cut across geological boundaries. Transverse faults can be observed in two directions: NNW–SSE and approximately N–S. The sharpest N–S fault of the subbasin can be traced in the younger loose sediments and can be classified as dextral strike. Its probably conjugate, so-called Riedel, shear is the NNW–SSE sinistral system (Hancock, P.L., 1985).

In the western subbasin several normal faults of small and one fault of great amplitude, and also transcurrent faults were appointed. The NNW–SSE fault zone at cca. the middle of the western subbasin seems also to be a sinistral strike. It may be assumed that the conjugate shears of two directions emerged in the very same field of force. Activity of the faults is also proved by the earthquake mechanisms observed in the region (Berhida, Balatonfűzfő, 1987, 1989).

In the second phase of this survey, considering the above results, further boreholes are planned to be put down. The tasks are (1) complex geological investigation of the Holocene sediments in the central and W basins of the lake, and (2) the geological identification of the layers and zones of the basement that are determined by microacoustic methods. Completion of these investigations makes possible to learn the geological history of the lake, the Holocene climatic and lacustrine ecological conditions, and the determination of the sites for dredging in order to lessen the eutrophication of the lake.

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THE AGE OF METAMORPHISM OF THE EAST ALPINE TYPE BASEMENT, LITTLE PLAIN, W-HUNGARY: K-AR DATING OF K-WHITE MICAS FROM VERY LOW- AND LOW-GRADE METAMORPHIC ROCKS

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The K—Ar isotopic dating of the metamorphic evenst that affected the very low- and low-grade rocks of the Little Plain basement was carried out using illite/muscovite-rich $< 2\ \mu m$ grain size fractions of representative samples characterized previously by microstructural, textural, mineral paragenetic, illite crystallinity, b_0-geobarometric, and coal rank measurements (Árkai et al., 1987).

The metamorphic age of the mainly anchizonal Nemeskolta—Takácsi Zone which belongs to the Transdanubian Midmountains Unit proved to be Hercynian (Sudetian, 311—329 Ma) and agrees with the former (indirect) geological deductions based mainly on lithologic analogies with the Early Paleozoic of the Balaton Highland area (Lelkes—Felvári, 1978).

On the other hand, partial resetting of the K—Ar ages was observed in the mainly epizonal rocks of the Mihályi Ridge and its environment, which — based on the lithostratigraphic correlation of Fülöp (1980) and partly Balázs (1975) — was correlated with the Graz Paleozoic of the Upper Austroalpine Nappe System. Several hypotheses were set up to understand these age values strongly scattering between 116 and 203 Ma. Evaluating the available data, Hercynian epizonal (greenschist facies) metamorphism overprinted by an Alpine (Cretaceous) thermal ($\sim < 200^{\circ}C$) event with or without minor recrystallization seems to be the most probable explanation. This hypothesis is concordant with the recent tectonometamorphic evolution model of the Graz Paleozoic (Frank, 1983).

All of these K—Ar ages differ significantly from those of the low-temperature, polyphase metamorphic rocks of the Kőszeg—Rechnitz Mountains obtained by Balogh et al. (1983). Thus, the eastern continuation of the Mesozoic of the Penninic Window in the surface of the Little Plain basement seems to be very unlikely.

Keywords: Isotope geochronology, K—Ar dating, illite/muscovite, anchizone, epizone, low-temperature metamorphism, Little Plain, Hungary

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Introduction, previous data

The metamorphic basement of the Little Plain, a marginal part of the Pannonian Neogene Basin System, represents an important link between the Eastern Alps and the Pannonian Basin. Although the Eastern Alps terminate by young faults near to the Austrian/Hungarian border, the different units of the Austroalpine Nappe System can be traced under the surface up to the Rába Lineament. Northwest of the Rába Lineament the Penninic Window of the Kőszeg—Rechnitz Mountains and their environment form the lowermost tectonic unit (Fig. 1) with polyphase (plurifacial) Eo- and Mesoalpine glaucophane and greenschist facies metamorphism. The Lower Austroalpine Nappe System is built up by pre-Hercynian, Hercynian and Alpine, mostly amphibolite, partly greenschist facies polymetamorphic complexes which outcrop in the Sopron Mountains and in the so-called Fertőrákos Crystalline Islands.

Based on lithostratigraphic analogies and geographic connections, the formations located between the Répce and Rába Lines (called Mihályi Ridge and its environment in the present paper) were correlated with the Hercynian very low- and low-grade Graz Paleozoic of the Upper Austropalpine Nappe System, while the basement rocks southeast of the Rába Line with the Paleozoic of the Transdanubian Midmountains Unit (Fülöp, 1980; partly Balázs, 1975). For a more detailed review of the lithostratigraphic classification of these formations made by Fülöp and Balázs, see Árkai et al. (1987). The Rába Lineament represents one of the northeastern continuations of the bifurcated Periadriatic (Insubric) Lineament along which the Transdanubian Midmountains Unit was displaced from its original position by several hundred kilometres to ENE, thus escaping the Alpine orogenic and metamorphic effects ("continental escape", see Kázmér and Kovács, 1985). According to Haas (1987) the present position of this unit can be interpreted by a more complicated series of processes.

Based on the lithostratigraphic subdivisions of Fülöp (1980) and Balázs (1975) a detailed metamorphic petrological investigation of the low-temperature metamorphic rocks of the Little Plain basement was carried out by Árkai et al. (1987). Using microstructural, textural, illite crystallinity, b_0-geobarometric and coal rank data, the incipient metamorphic basement was subdivided into two groups:

I) In the eastern part of the basement (Nemeskolta—Takácsi Zone) which belongs to the Transdanubian Midmountains Unit, low pressure (high thermal gradient), anchizonal ($\sim$ 250—300 ^{0}C) regional metamoprhism was

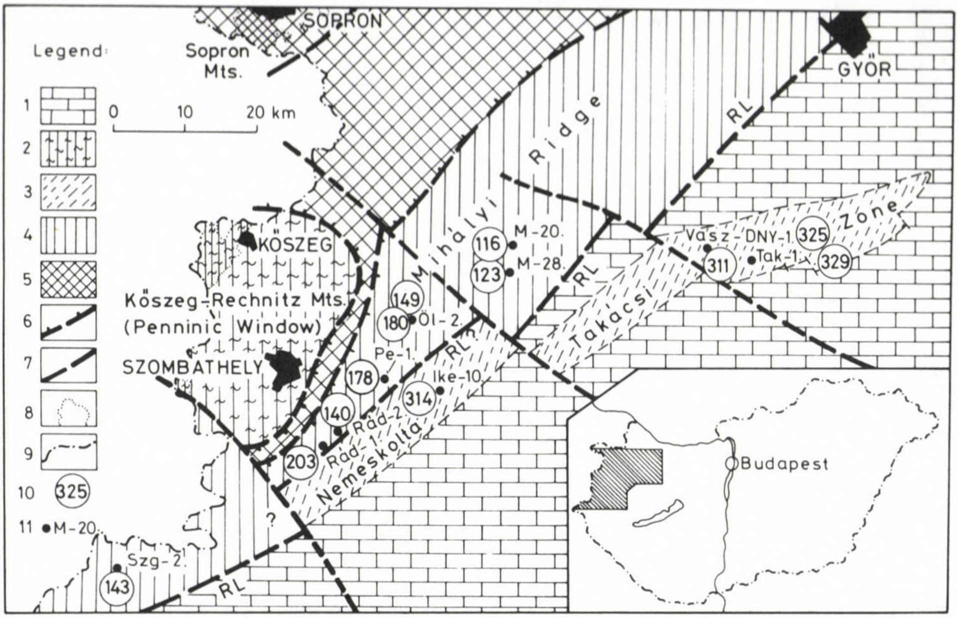

Fig. 1. Geological and metamorphic petrological map sketch of the Little Plain after Fülöp et al. (1985) and Árkai et al. (1987), strongly simplified. 1. Non-metamorphic Mesozoic and Late Paleozoic; 2. Penninic Mesozoic with Alpine plurifacial metamorphism; 3. very low grade (mostly anchizonal) Paleozoic; 4. low-grade (mostly epizonal) Paleozoic; 5. polymetamorphic (pre-Hercynian + Hercynian + Alpine), mainly medium-grade rocks; 6. overthrust; 7. fault; 8. boundary of outcrop; 9. state border; 10. K–Ar age of white K-mica (< 2 μm Ø); 11. borehole; RL – Rába Lineament

proved. This complex is composed of carbonate-poor or -free clastic (psammitic, silty, pelitic) sediments with basic and acidic volcanic intercalations. According to Balázs (1975) the possible primary age is Silurian. This complex should not be correlated with the Graz Paleozoic, but proved to be very similar to the Ordovician–Silurian clastic series of the Balaton Highland (Fülöp, 1980, Árkai et al., 1987). (For characterization of the Hercynian metamorphic rocks of the Balaton Highland see Lelkes–Felvári (1978) as well as Árkai and Lelkes–Felvári (1987)).

Geological evidence of the Hercynian metamorphic age of the Nemeskolta–Takácsi Zone was demonstrated by Balázs (1971, 1975), who described erosional unconformity which separates the underlying anchimetamorphic slate from the non-metamorphic Permian and Triassic in the northern foredeep of the Bakony Mountains (bore No. Tét-2). On the other hand, neither biostratigraphic nor isotopic data exist on the ages of the sedimentation and on the metamorphism, respectively.

II) The basement of the Mihályi Ridge and its environment (Graz Paleozoic) was subjected to a high thermal gradient, low (cca. 2–3 kbar) pressure, maximally epizonal (~ greenschist facies quartz-albite-muscovite-chlorite subfacies, cca. 350–400 ^{0}C) regional dynamothermal metamorphism. This complex corresponds to the Devonian(?) formations of Balázs (1971, 1975). The recent results confirmed the earlier statements of Balázs on the lithological conditions: the complex is built up predominantly by pelitic, silty, subordinately by psammitic sediments with varying carbonate content; pure carbonatic sediments and basic-intermediate volcanoclastic intercalations.

No direct biostratigraphic or isotopic data are available on the primary (sedimentary, magmatic) or metamorphic ages. Based on East Alpine analogies, Hercynian metamorphism seems to be the most probable, but the possibility of Alpine (Cretaceous) metamorphism (overprint) should not be excluded either (see Flügel, 1980; Frank, 1983).

Interpreting the recent petrological results, the occurrence of rock types belonging to the Penninic Unit on the surface of the Little Plain basement is not likely, but in lack of appropriate age data it cannot be surely excluded.

Balogh et al. (1983) determined several K-Ar ages on minerals of the Kőszeg–Rechnitz Mountains. The ages fall in the range from about 35 Ma to 15 Ma, unaltered muscovites being the oldest and chloritized biotites and a whole rock sample giving the younger ages. These age values are typical for the Penninic Window (e.g. Wagner et al., 1977).

It is obvious from the short review above that the metamorphic age(s) of the two main low-temperature metamorphic units of the Little Plain is (are) not proved exactly. In case of the Nemeskolta–Takácsi Zone (Transdanubian Midmountains Unit) the Hercynian metamorphic age is probable, while the age-relationships are totally uncertain in case of the Mihályi Ridge (Graz Paleozoic). The preclusion of the occurrence of Penninic Unit in the basement of the Little Plain needs also further evidence.

Thus, the aim of the present paper is to determine the metamorphic ages in the two segments of the Little Plain, and to compare these with those of the Penninic Window. These data may contribute to the better understanding of the geological (tectonic and metamorphic) evolution of this transitional area.

The investigated samples derived from hydrocarbon exploratory boreholes. The metamorphic petrological investigation of the area was formerly supported by the Oil and Gas Mining Enterprise (Nagykanizsa). A more detailed description of the results and their genetic interpretation can be found in Árkai (1985) and Árkai et al. (1987).

K-Ar dating of illite/muscovite and its use for determining sedimentation, diagenetic and low-temperature metamorphic ages: a short review

The first K-Ar studies on clay minerals (Hurley et al., 1961; Bailey et al., 1962; Hower et al., 1963) revealed that illites are usually unsuitable for dating the age of sedimentation. The main obstacle is the presence of detrital grains which preserve partly their radiogenic argon content during transport and redeposition and which cannot be separated from the authogenic minerals. Ages obtained on finer grains are mostly younger what might be explained either by continuous and increasing argon loss from the finer grains and/or by the enrichment of newly formed minerals in them. New investigations (Bonhomme, 1987) indicate that under a certain temperature full resetting of the K-Ar system requires a complete change of the mineralogy and the size fraction of 0.1—0.5 μm is most suitable for dating events of diagenetic type if restructuration is properly evidenced. In lack of recrystallization even the smallest grain size fraction may not give the correct age of mineral formation.

Due to the difficulties of interpretation the use of illites for dating stratigraphic events is very limited. On the other hand, it has increasing importance in dating very low- and low-grade metamorphic events (e.g. Hunziker et al., 1986) and in studying chronologic problems of hydrocarbon migration (e.g. Lee et al., 1985).

Harper (1970) suggested the use of whole rock samples of slates and phyllites for dating of their metamorphism. In plurifacial (polyphase) or polymetamorphic terraines, however, radiogenic argon from an earlier phase can be liberated during a later event and subsequently can be incorporated in newly formed phases or trapped in fluid inclusions.

This is why the use of mineral fraction (first of all illite/muscovite) has been preferred (Hunziker, 1979). In case of illite/muscovite the disturbing effect of the inherited (detrital) K-white mica can be eliminated either by the use of acid to intermediate metatuffs containing metamorphic sericite (see for example Ahrendt et al., 1978), or by using the fine grain size fraction of slates and phyllites possibly devoid of detritic muscovite (Frank and Stettler, 1979; Clauer and Kröner, 1979; Bonhomme et al., 1980, Hunziker, 1986; Hunziker et al., 1986; Reuter, 1987).

The possibilities for studying metamorphism by isotopic dating have been greatly improved by the introduction of the concept of blocking temperature (Dodson, 1973) and its determination for the main rock forming minerals by (among others) Wagner et al. (1977) and Harrison and McDougall (1982).

Blocking temperature of 260±30°C has been estimated for illites of <2 μm by Hunziker et al. (1986). Since recrystallization may occur at lower temperature, unequivocal interpretation of K-Ar data requires a manysided study of mineral fractions like executed e.g. by Hunziker et al. (1986). Unfortunately, the lack of similar facilities prevented the authors of this work from exploiting all the possibilites of radiometric dating of illites, but it is felt that the decision of some important questions concerning the tectonometamorphic evolution of this region justifies our attempts.

It seems to be obvious that in case of a mineral such as illite/muscovite which may form also below the blocking temperature, the age of metamorphic climax (crystallization) can be obtained instead of the cooling (blocking) ages of minerals formed in higher grade rocks. There are two main factors which make the interpretation of the apparent K-Ar ages of very low-grade rocks of fine-detritic origin more complicated. One of them is the effect of detrital muscovite the amount of which is obviously decreasing (consequently, the apparent ages are lowered) with decreasing grain size. However, the effect of detrital white mica can be traced even in high temperature anchizonal conditions also in the fractions of <2 μm (Árkai, 1983; Reuter, 1987 etc). For example, Reuter (1987) have got acceptable K-Ar results only in the fraction <0.63 μm in case of upper anchizonal metapelites. On the other hand, the small grain size may cause severe problems for the retention of radiogenic daughter products, as there is an exponential function between the grain size and the characteristics of diffusion (Hunziker, 1987).

Thus, in most cases the <2 μm fractions are used for K-Ar dating after applying careful preparatory techniques and a thorough mineralogic investigation. In common conditions neither the small grain size nor the different acid leaching cause significant change in K-Ar ages (Hunziker et al., 1986).

It is a general tendency that during the diagenetic – very low-grade metamorphic evolution of pelitic rocks K-Ar ages of illite/muscovite are continuously lowered from the age of detritus (or from the age of sedimentation) to the age of metamorphic event (Hunziker et al., 1986). Mineralogically, this process is characterized by the continuous change from illite/smectite mixed layer clay mineral through illite (fine grained dioctahedral mica-type clay mineral with K-deficiency and incorporated smectite layers and H_2O) up to the metamorphic muscovite (phengite), the small ($<100\ \mu m$) grained variants of which are named as sericite. This process is characterized by the gradual decrease of H_2O and increase of K content, by the increase of the $2M_1/1Md$ ratio, the increase of grain size, and is reflected in the illite crystallinity parameters.

Summarizing the available literature data it can be concluded that in case of anchizonal and epizonal (ca. 200–400 °C temperature) rocks reliable data can be obtained by K-Ar dating of the illite/muscovite-rich fractions with grain size $<2\ \mu m$. It is natural that because of different problems of separation, "pure" (monomineralic) fractions cannot be obtained generally. In practice, these fractions are mixtures of dominant illite/muscovite with smaller (generally minor) amounts of chlorite and/or quartz and other (trace) minerals (see also Hunziker et al., 1986).

Although the K-Ar method has been widely used for the determination of metamorphic ages of low-temperature rocks in the last, nearly twenty years, this is the first report on the application of this method for trying to solve age problems of such terrains in Hungary.

Methods

As it was mentioned before, K-Ar dating of the illite/muscovite-rich $<2\ \mu m$ fraction was preceded by detailed petrographic investigations, namely, by

— macroscopic and microscopic characterization of the samples with special regard to the identification of "inherited" (detrital) micas as well as to the microstructural and textural features (cleavage type, orientation, overgrowth etc.);

XRD analyses of whole rock, acid (3% HCl) insoluble residue and their $<2\ \mu m$ fraction samples in order to determine (a) the qualitative and semiquantitative mineral composition, and combining the XRD technique with microscopic observations, to distinguish the metamorphic and postmetamorphic (hydrothermal) mineral assemblages; (b) the metamorphic grade ($\sim$temperature) indicating illite crystallinity parameters (IC $^{\circ}2\theta$) after the method of Kübler (1968, 1975), calibrating the zone boundaries with the help of standard rock slab set kindly provided by professor Kübler; (c) the pressure indicating K-white mica b_0 parameters according to the method (and limitations) of Sassi (1972), Guidotti and Sassi (1976, 1986).

The XRD work was carried out on a Philips PW-1730 type diffractometer with the following recording conditions: CuK_{α} radiation, 45 kV, 35 mA, proportional counter, graphite monochromator, divergency and detector slits: 1^0, goniometer speeds: 2^0/min and $1/2^0$/min, time constant: 2 sec, registration paper speed: 2 cm/min.

— Measurements of vitrinite reflectance (carried out by Z.A. Horváth, Laboratory for Geochemical Research, Hungarian Academy of Sciences) by means of a Reichert Zetopan-Pol microscope using the reflectance glass prism series of the Bituminous Coal Research Inc. as reference standards, in oil immersion, at a wavelength of 548 nm.

The techniques mentioned above as well as the problems connected with the interpretation of the anchizone and its correlation with mineral facies are outlined in detail in former publications (Árkai, 1983, 1987; Árkai et al., 1987; Árkai and Lelkes-Felvári, 1987; Árkai and Tóth, 1983).

K-Ar dating was performed in the Institute of Nuclear Research of the Hungarian Academy of Sciences with instruments constructed in this institute. Samples were degassed by high frequency induction heating, argon was cleaned with the usual method applying zeolite, cold traps and furnaces with Ti sponge and CuO. ^{38}Ar was introduced with a gas pipette.

A magnetic mass spectrometer of 150 mm radius and 90^0 deflection was used in static regime for Ar isotopic ratio measurement.

Prior to K determination the samples were digested by $HF+H_2SO_4+HClO_4$ acids and dissolved thereafter in HCl. Na buffer and Li internal standards were added and K content was measured with a flame emission photometer of OE-85 type produced by OMSZÖV, Hungary.

Interlaboratory standards of Asia 1/63 (Soviet) and GL-0 were used for control and calibration of Ar and K determinations.

Construction and parameters of instruments, the applied methods have been described in detail by Balogh (1985). Results on interlaboratory standards have been published by Odin et al. (1982), too.

A furnace with resistance heating inserted in the argon extraction line was used for stepwise degassing of the samples. During calibration the furnace temperature was measured with a thermocouple as a function of the input power. In the course of degassing only the input power was measured.

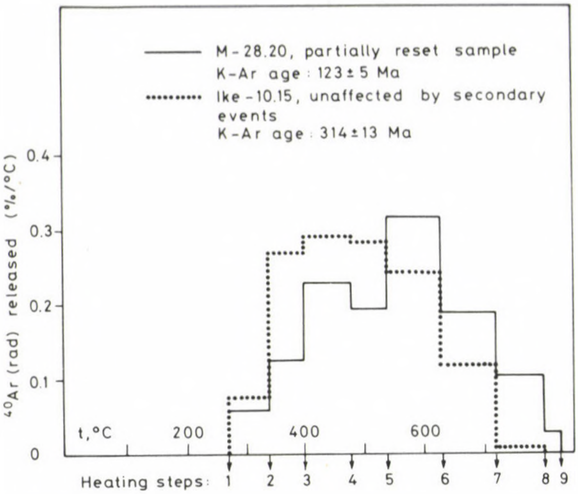

Fig. 2. Argon release spectra of illite/muscovite rich <2 μm grain size fractions

Therefore the error of temperatures shown in Fig. 2 is estimated as ±50°C, but the reproducibility of heating step temperatures during measurement of the two samples is certainly better.

In the first step of degassing ^{38}Ar spike was used for the determination of the liberated radiogenic ^{40}Ar content. In the following steps ^{40}Ar (rad) quantity was deduced only from the peak heights. Summarizing the amount of ^{40}Ar(rad) liberated in the individual steps the total ^{40}Ar(rad) content has been obtained and it is indicated in parenthesis in Table 3. The agreement with the values measured during K-Ar dating is acceptable and shows the stability of the instruments. Heating at a given temperature lasted for 40 minutes and the sample was not cooled between the successive steps.

Results

K-Ar isotopic measurements were carried out on the <2 μm (and in two cases on 0.6–2 μm and <0.6 μm) grain size fractions of core samples representing the two, slightly different very low- and low-grade metamorphic units of the Little Plain basement. The list of the samples investigated containing also the location, depth interval and the rock type can be found in Table I.

Table I

Representative rock samples from the basement of the Little Plain subjected to K-Ar dating

village	bore	core sample	depth (m)	rock type
1. Nemeskolta–Takácsi Zone (Transdanubian Midmountains Unit): mostly anchizonal rocks				
Ikervár	Ike-10.	15.	1750 – 1753	slate
Takácsi	Tak-1.	19.	1428.5 – 1431	sideritic slate
Takácsi	Tak-1.	21.	1442.5 – 1444.5	slate
Vaszar	Vasz-DNY-1.	3.	1893.5 – 1896.5	metasandstone
2. Mihályi Ridge and its southwestern continuation (Graz Paleozoic, Upper Austroalpine Nappe System): mostly epizonal, partly anchizonal rocks				
Szentgotthárd	Szg-2.	2.	981 – 984	slate (silty)
Egyházasrádóc	Rád-1.	9	2938 – 2942	slate (banded, clayey, silty)
Egyházasrádóc	Rád-2.	5.	2948 – 2950	slate (banded, clayey, silty)
Pecöl	Pe-1.	20.	2330.5 – 2332.5	neutral(?) metatuff
Ölbő	Öl-2.	16.	1821 – 1824	carbonate phyllite
Ölbő	Öl-2.	17.	1834 – 1836	brecciated dolomite schist with phyllite bands
Mihályi	M-28.	20.	2947.5 – 2949.5	carbonate phyllite
Mihályi	M-20.	7.	1504.5 – 1506.5	carbonatic metasandstone with phyllite bands

Table II contains the mineral composition as well as the illite crystallinity, -b_0 and coal rank data of these samples.

K-Ar isotopic compositions, the calculated age values and their standard deviations measured on the illite/muscovite-rich fractions are listed in Table III, together with the mineral composition and illite crystallinity data of the given fractions.

It must be emphasized, however, that both the illite crystallinity and the b_0-geobarometric methods are statistical ones. Thus, no direct conclusions can be drawn from the IC and b_0 data of Table II for the metamorphic grade and pressure conditions. The conclusions reported in the

Table II

Mineral composition, illite crystallinity, -b_o and vitrinite reflectance data of the whole rock samples listed in Table I

Sample	mineral composition (weight %)*														illite - - muscovite crystallinity ($IC^o 2\theta$) Kübler-index		b_o (Å)	vitrinite reflectance (%)		
	quartz	plagioclase (albite)	K-feldspar	illite- -muscovite	paragonite	chlorite	kaolinite	calcite	dolomite	ankerite	siderite	hematite	pyrite	rutile	2^o/min goniometer speed	$1/2^o$/min goniometer speed		R_{max}	R_{random}	R_{min}
1. Nemeskolta–Takácsi Zone (Transdanubian Midmountains Unit)																				
Ike-10.15.	23	11	-	28	-	38	-	-	-	-	-	-	tr	tr	0.394	0.364	8.988	n.m.	3.910	n.m.
Tak-1.19.	43	6	-	11	-	7	14	-	-	-	19	-	tr	tr	0.221	0.188	9.002	n.m.	5.558	n.m.
Tak-1.21.	13	17	-	31	-	38	-	-	-	-	tr	-	1	tr	0.256	0.199	9.012			
Vasz-DNY-1.3.	40	29	-	16	-	-	3	-	tr	-	12	-	-	-	0.267	0.222	9.026	5.668	5.328	5.095
2. Mihályi Ridge and its environment (Upper Austroalpine Nappe System)																				
Szg.2.2.	25	17	-	16	-	42	-	-	-	-	-	-	-	tr	0.213	0.181	9.018	5.647	3.930	1.841
Rád-1.9.	24	31	-	14	-	29	-	1	-	-	-	-	1	-	0.275	0.205	8.997	n.m.	n.m.	n.m.
Rád-2.5.	28	29	-	16	-	22	-	-	3	-	-	-	1	1	0.286	0.202	9.004	n.m.	n.m.	n.m.
Pe-1.20.	33	40	-	24	-	-	-	1	-	-	-	2	-	-	0.236	0.201	9.048	n.m.	n.m.	n.m.
Öl-2.16.	30	tr	2	40	-	-	4	11	3	-	10	-	-	-	0.267	0.219	9.007	n.m.	n.m.	n.m.
Öl-2.17.	12	-	-	13	-	2	1	2	70	-	-	-	-	tr	0.280	0.194	9.023	autochtonous graphite		
M-28.20.	17	-	-	44	7	1	-	-	-	31	-	-	-	-	0.297**	0.232**	8.986	-"-		
M-20.7.	45	3	-	9	-	-	3	23	-	9	8	-	-	tr	0.259	0.183	8.989	-"-		

* — calculated by XRD method

tr — traces

n.m. — not measurable

** — broadened by paragonite

Boundaries of the anchizone: IC(2^o/min): 0.25–0.37 $^o 2\theta$; IC($1/2^o$/min): 0.20 – 0.30 $^o 2\theta$;

R_{random} = 5.0 – 3.0 %; R_{max} = 6.0 – 3.5%

Table III

K-Ar isotopic compositions, apparent ages, mineral composition and illite crystallinity data

Sample	<2 μm Ø fractions					mineral composition							illite crystallinity Kübler-index, IC $^{o}2\theta$	
	K,weight%	^{40}Ar(rad), ccSTP/g	^{40}Ar(rad), rel.%	Age,Ma**	standard deviation	illite-sericite	paragonite	chlorite	kaolinite	quartz	albite	rutile	2^{o}/min	$1/2^{o}$/min
1. Nemeskolta-Takácsi Zone (Transdanubian Midmountains Unit)														
Ike-10.15.	5.07	6.745×10^{-5} (6.691×10^{-5})	81	314 ±	13	+	-	+	-	o	-	-	0.427	0.385
Tak-1.19.	4.14	5.707×10^{-5}	75	325 ±	13	+	-	x	x	o	-	o	0.216	0.173
Tak-1.21.	7.29	1.023×10^{-4}	91	329 ±	13	+	-	x	-	-	-	o	0.246	0.216
Vasz-DNY-1.3.	5.34	7.037×10^{-5}	86	311 ±	13	+	-	-	x	o	o	o	0.290	0.254
2. Mihályi Ridge and its environment (Upper Austroalpine Nappe System)														
Szg-2.2.	4.56	2.629×10^{-5}	60	143 ±	6	+	-	+	-	o	o	o	0.245	0.187
Rád-1.9.	3.48	2.910×10^{-5}	72	203 ±	8	+	-	+	-	o	o	-	0.307	0.236
Rád-2.5.	5.34	3.013×10^{-5}	76	140 ±	6	+	-	+	-	o	o	o	0.322	0.259
Pe-1.20.	5.84	4.250×10^{-5}	65	178 ±	7	+	-	-	-	o	o	o	0.357	0.339
Öl-2.16	7.04	4.251×10^{-5}	94	149 ±	6	+	-	o	o	o	-	-	0.249	0.189
Öl-2.17.	7.73	5.687×10^{-5}	96	180 ±	7	+	x	o	o	o	-	o	0.298	0.241
M-28.20.	4.67	2.300×10^{-5} (2.148×10^{-5})	65	123 ±	5	+	x	o	-	-	-	-	0.336	0.252
M-20.7.	4.28	1.999×10^{-5}	72	116 ±	5	+	o	o	x	o	-	o	0.289*	0.221*
0.6 — 2 μm Ø fractions:														
Ike-10.15.	4.17	6.260×10^{-5}	97	348 ±	13									
Rád-2.5.	5.03	3.078×10^{-5}	86	151 ±	6									
<0.6 μm Ø fractions:														
Ike-10.15.	5.80	7.429×10^{-5}	97	302 ±	12									
Rád-2.5.	6.21	2.621×10^{-5}	80	106 ±	5									

+ abundant
x subordinate
o traces
- missing

Boundaries: of the anchizone: IC(2^{o}/min) = 0.28 — 0.44 $^{o}2\theta$; IC($1/2^{o}$/min) = 0.25 — 0.42 $^{o}2\theta$

* — broadened by paragonite

** — ages calculated with atomic constants suggested by Steiger and Jäger (1977) previous part of this paper have been based on statistical evaluation of more than fifty samples and were collated with other (microstructural, textural, mineral paragenetic) criteria (see Árkai et al., 1987).

Discussion

Evaluating the K-Ar ages together with the available mineralogic and petrologic data, the following conclusions can be drawn on the age realations of the basement of the Little Plain.

1. In the case of the Nemeskolta–Takácsi Zone belonging to the Transdanubian Midmountains Unit practically identical values (311–329 Ma) were obtained. These results indicate Hercynian metamorphic event, and are in agreement with other, indirect parameters, namely with the high thermal gradient (low-pressure type) of the metamorphism which is characteristic of the Hercynian tectometamorphic regime in the Eastern Alps and Carpatho–Pannonian area, as well as with the geological conclusions made by Balázs (1975) for the given area (see the first chapter of this paper).

The average of the data (~320 Ma) corresponds fairly well to the Sudetian phase of the Hercynian orogeny. This metamorphic age seems to be concordant also with the genetic interpretation of the Paleozoic formations located along Lake Balaton, forming the southern boundary of the Transdanubian Midmountains Unit (Lelkes–Felvári, 1978, 1987 (the latter in Árkai and Lelkes–Felvári, 1987)). The possible connection of the Early Paleozoic zones ranging along the northern and southern margins of the Transdanubian Midmountains Unit (Bakony Mts.) was already supposed by Oravecz (1964). According to Lelkes–Felvári, Lower Carboniferous (Visean) sequence (Szabadbattyán Limestone Formation) was also subjected to Hercynian anchizonal regional metamorphism, while the Permian and Mesozoic formations separated by erosional unconformity from the metamorphic Paleozoic suffered only weak (diagenetic) transformations (see also Árkai and Viczián, 1975).

In two samples (cores Tak-1.19 and Vasz-DNY-1.3) the considerable amounts of kaolinite + siderite indicate postmetamorphic, hydrothermal alteration (Árkai et al., 1987). It can be stated that the possible heat and/or chemical effects of this (presumably younger, Cenozoic?) acitivity possibly being of moderate ($\sim < 250^{0}$C) temperature character did not influence observably the isotopic composition of the fractions $<2\,\mu$m.

Minor amounts of albite does not make any harm in the age (sample Vasz-DNY-1.3).

In case of the <2 µm fractions of the given samples (the metamorphism of which could be in the upper anchizone, near the anchi-/epizone boundary) no differences caused by the eventually different detritic mica content can be detected.

On the contrary, systematic changes in age values of different grain size fractions of a given sample can be detected (sample Ike-10.1, see Table III). The coarser (0.6–2 µm) fraction gives higher (348±13 Ma), the finer (<0.6 µm) fraction lower (302±12 Ma) values, while for the whole <2 µm fraction (containing both parts) an intermediate (314±13 Ma) age was obtained.

This tendency can be interpreted with one or with the combinations of the following reasons:

– the amount of the detritic white mica is decreasing with decreasing grain size;

– the blocking temperature of the illite/muscovite decreases with decreasing grain size. Thus, the age differences would represent an extremely low cooling (uplift) rate;

– the possibility of radiogenic argon loss from finer grains is greater than from coarser grains;

– the smaller grains of illite react more sensitively to the possible younger heat effects than the larger ones.

2. Contrasting with the well defined Hercynian metamorphic age of the Transdanubian Midmountains Unit, the K-Ar ages of the partly anchizonal, mostly epizonal (greenschist facies, chlorite zone) rock fractions of the Mihályi Ridge and its environment (Graz Paleozoic, Upper Austroalpine Nappe System) are strongly scattering between 116 and 203 Ma). This scattering suggests that these values should be "mixed" ages not representing real geologic events. Trying to explain the possible geological causes of the partial resetting of the K-Ar isotopic systems in the fractions <2 µm several hypotheses can be set up:

(i) the partial resetting may be the result of a younger (Cenozoic?) moderate temperature hydrothermal activity. The mineral association kaolinite + siderite may represent the sign of such an activity. As the age values of the samples presumably affected by hydrotherms (116–180 Ma) do not differ significantly from those (e.g. 123–203 Ma) which were measured on samples containing only metamorphic assemblages, this factor can be presumably excluded.

(ii) Minor feldspar (albite) contents detected in certain samples may contribute to the resetting (and capture) of radiogenic isotopes, resulting anomalous age values. For there is also a wide overlap between the ages of albite-bearing separates (140–203 Ma) and those of feldspar-free fractions (116–180 Ma), this assumption seems to be unrealistic. Estimating the ratio of K content of the illite and albite in the samples and excluding the possibility of albite ages older than Hercynian it can be seen that even the possible greatest scatter of albite ages is insufficient to cause the observed range of K-Ar ages. Thus, this possibility can be fully excluded.

(iii) The age values in question are scattering between the ages of a Hercynian and an Alpine (Eoalpine, Cretaceous) event. Thus, the large dispersion of the data can be interpreted by partial resetting of the Hercynian illite/muscovite during an Alpine phase with or without significant recrystallization. This model is in agreement with the tectonometamorphic evolution of the Graz Paleozoic outlined by Frank (1983). However, it should be emphasized that the temperature of the presumed Alpine event must have been much lower (ca. 200 °C or below) than the temperature of the Hercynian regional metamorphism (~350–400 °C). Otherwise a total Ar resetting should have been reached during the Alpine event. (According to Hunziker (1986) a total Ar resetting can be extrapolated in case of $<2\ \mu m$ fraction at a temperature of 260 ± 20 °C during 10 ± 5 Ma.

In case of different grain size fractions (sample Rád-2.5, see Tabel III) similar tendency can be observed among the age values as in case of sample Ike-10.15 (the causes may be also the same as in the former case, see point (1)).

Argon release spectra were recorded for sample Ike-10.15 which is unaffected and for sample M-28.20 which is (at least partially) reset by Alpine event. Release spectra are shown in Fig. 2. Since the distance of heating steps was not uniform the percentage of libertaed ^{40}Ar(rad) over 1 °C temperature increase has been plotted against the temperature. Similar spectra may be constructed from the $^{40}Ar/^{39}Ar$ data of Dallmeyer (in Hunziker et al., 1986) with the main difference that in case of our samples Ar is liberated in a wider temperature range, what is attributed to the difference in the size of mineral fractions being always $<0.6\ \mu m$ in Dallmeyer's experiments and $<2\ \mu m$ in our case.

According to Fig. 2 a part of ^{40}Ar(rad) releases from the (partially) resetted sample M-28.20 at higher temperature. This may be explained by the presence of a mineral phase which accomodates Ar with greater binding energy. This is likely caused by the higher (epizonal) temperature of metamorphism of this sample.

At lower temperature steps greater portion of ^{40}Ar(rad) is released from the unaffected sample Ike-10.15. This may be attributed only to the differences in mineralogy if during the second (Alpine) event sample M-28.20 had been completely reset. If resetting was only partial, the observed effect can be explained also by the missing of weakly bound Ar from sample M-28.20. Since secondary effects liberate Ar preferentially from the finest mineral fraction, partial loss is usually manifested by the difference of K-Ar ages measured on the different grain size fractions.

Summarizing the results it must be stressed that

1) in the southeastern part of the Little Plain basement (in the Nemeskolta–Takácsi Zone belonging to the Transdanubian Midmountains Unit) Hercynian (Sudetian, 320 Ma) age of the high thermal gradient, very low-grade regional metamorphism can be proved, and all subsequent thermal events of various origin leading to the restructuration of finest illite/muscovite grains may be excluded;

2) in the Mihályi Ridge and its environment belonging to the Upper Austroalpine Nappe System (Graz Paleozoic) the apparent K-Ar isotopic ages are scattering between 116 and 203 M.a. These "mixed" ages do not represent real geologic events. Out of the different possibilities, the partial resetting of the illite/muscovite can be reasonably explained by an Alpine (Cretaceous) retrograde ($\sim< 200^{0}$C) event, partially overprinting the Hercynian metamorphism. This model is in good agreement with the tectonometamorphic evolution of the Graz Paleozoic outlined by Frank (1983).

3) Finally, it must be emphasized that the K-Ar isotopic data support our former conclusion (Árkai et al., 1987), namely there are no traces of the eastern continuation of the Penninic Window in the surface of the metamorphic basement in the Little Plain. The average of the K-Ar ages determined by Balogh et al. (1983) on muscovites of different rock types of the Penninic Window of the Kőszeg–Rechnitz Mountains is about 35 Ma and is strongly differing from the present values getting for the Little Plain basement.

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A NEW OCCURRENCE OF LAMPROPHYRE IN THE BUDA MOUNTAINS, HUNGARY

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In 1987 speleologists found magmatic rocks in a limestone quarry at Remetehegy. Detailed mineralogical and petrological examination revealed a dyke rock with panidiomorphic texture, containing 65.7 vol% pyroxene. Optical and geochemical investigation of the components indicate that a part of the pyroxenes is made of enstatite and Cr-diopside. The mechanically twinned olivines are more rich in MgO, than the euhedral ones. Mica appears as high-Ti phlogopite and as extremely high-BaO biotite. Opaque minerals are mostly Ti-magnetites, the feldspars are sanidines. The magmatite contains phlogopite-bearing, altered ultramafic xenoliths.

The rock belongs to the Upper Cretaceous lamprophyric-carbonatitic-picritic association, also suggested by its 64 Ma radiometric age.

Keywords: Lamprophyre, Upper Cretaceous, Buda Mountains

Introduction

In 1987 a lamprophyre dyke was found in a cave and in a limestone quarry at Máriaremete. It belongs to the Upper Cretaceous lamprophyric-carbonatitic-picritic association of northeastern Transdanubia (Kubovics et al., 1981; Kubovics, 1983; Szabó, 1984; Kubovics, 1985; Kubovics et al., 1985; Szabó, 1985; Kubovics—Szabó, 1987; Kubovics et al., 1987; Horváth et al., 1983; Horváth—Ódor, 1984).

Petrography

The Dachstein Limestone quarry in the NE side of Remetehegy contains a 1—3 m thick, strongly weathered, reddish brown basalt-like rock body. The dyke shows a curved shape: below the Quarternary debris its extension was traced by a Geiger—Müller counter (Fig. 1). It is ca. 3 m wide.

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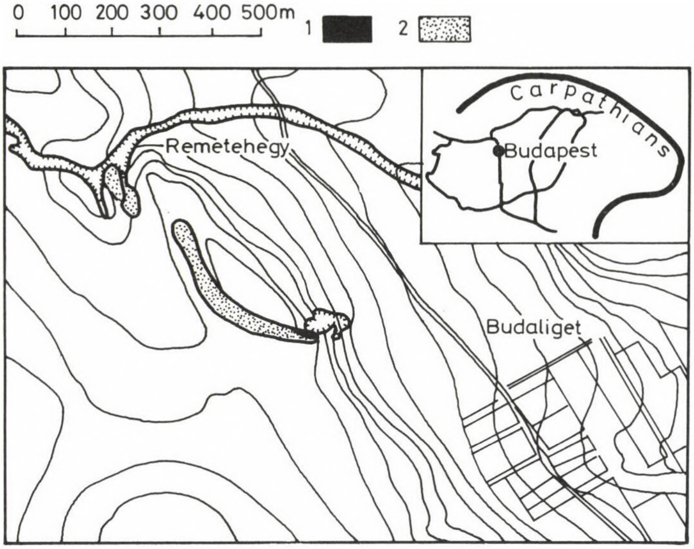

Fig. 1. Occurrence of the Remetehegy dyke rock

On the nearby Nagykopasz-hegy rocks belonging to the lamprophyric-carbonatitic-picritic association of NE Transdanubia were detected (Wéber, 1962), and mapped by geophysical methods (Dudko, 1984). The dyke discussed here may show relations to this swarm.

The studied rock body at the Remetehegy quarry is mostly reddish brown, friable. It is almost totally altered, limonitic, clay mineralized, with spherical jointing and contains some decimetre-sized, hard, dark grey, unaltered "fragments". There are several, grey or greenish white xenoliths of 10–20 cm diameter, too, (Plate I, Photo 1). Some of the xenoliths contain large amount of pale, light brown mica of 1–2 mm size and some opaque minerals; the other components cannot be identified due to strong clay mineralization.

Microscopic examination of the apparently fresh, grey "fragments" of the dyke revealed a panidiomorphic texture. Phenocrysts are olivines and pyroxenes, while microphenocrysts are pyroxenes, opaque minerals, and mica. The groundmass consists of feldspars, carbonate minerals, acicular apatite, glass, and fine-grained material unidentifiable under the microscope. The average proportion of olivine is 11.3 vol%; part of these are euhedral, while the rest are anhedral and display mechanical twinning. The average amount of the pyroxenes is 65.7 vol%; the grains are strongly zoned. Irregular orthopyroxene (enstatite) and clinopyroxene (Cr-diopside) xenocrysts with different optical properties were observed in the centre of several pyroxene grains (Plate I, Photo 2). The xenocrysts are surrounded by an augitic frame, followed by a strongly zoned, Ti-augitic rim of violet tint. The mica scales (2.7 vol%) are concentrated around the opaque minerals of Ti-magnetitic composition (4.0 vol%), and are biotites determined after their strong pleochroism (α, β = reddish brown, γ = light brown). The slightly altered samples contain larger amount (5.6–7.0 vol%) of mica of somewhat larger size than the fresh specimens, and their pleochroism is considerably weaker. This may suggest phlogopitic composition. Feldspars occur in not more than 5.0 vol%; the optical characters suggest sanidine.

Microprobe analyses

Analyes were made by JXA-50A microprobe using 15 kV, beam current of 25 nA; kaersutite, biotite, clinopyroxene, albite, and orthoclase were used as standards, and MAGIC program for correction. Minerals were checked for homogeneity at five or more points.

Olivin

Table I contains the analytical data of fresh rock olivines. The difference between euhedral phenocrysts and mechanically twinned xenocrysts is the somewhat larger mg-value of the latter group.

Comparing the analytical results of the phenocrysts with those of the Alcsútdoboz-2 lamprophyre (Kubovics and Szabó, 1987) and the Nógrád–Gömör alkali basalts (Árgyelán, 1987) we have found no significant differences between them; the higher Al_2O_3 content of the AD-2 olivine can be mentioned only. The high mg-value of the examined samples corresponds to those of primitive upper mantle melts (0.87–0.90, after Frey et al., 1978).

Pyroxene

Centres of most of the clinopyroxenes are formed by enstatite and Cr-diopside (Table II), and are considered as xenocrysts. Their almost equal mg-values ($\sim$ 90) and low Al_2O_3 contents suggest, that these grains are relicts of disintegrated upper mantle xenoliths. The relatively high

Table I

Composition of olivines

	1	2	3	4
SiO_2	39.8	40.2	38.9	40.2
Al_2O_3	nd	nd	0.28	0.04
FeO_t	11.9	10.4	12.4	11.6
MnO	0.14	0.17	0.14	0.18
NiO	0.30	0.25	0.20	na
MgO	46.8	47.9	47.4	47.7
CaO	0.10	0.03	0.19	0.23
$\sum$	99.04	98.95	99.51	99.95
mg-value	87.5	89.2	87.2	88.0

nd = not detected; na = not analyzed; FeO_t = total iron as FeO

1. Phenocryst (Remetehegy)
2. Xenocryst (Remetehegy)
3. Ad-2 lamprophyre (average, Kubovics—Szabó, 1987)
4. Nógrád—Gömör alkaline basalt (average, Árgyelán, 1987)

proportion of these components significantly distorts the modal composition of the dyke rock. Similar pyroxenes from ultramafic xenoliths of low Al_2O_3 lamprophyres were described by Szabó (1984) and Kubovics et al. (1985). These minerals clearly differ from the analogous components of alkali basalts from the Balaton Highland (Embey—Isztin, 1977; Kubovics et al., 1985) and from the Nógrád—Gömör region (Jánosi, 1984; Kubovics et al., 1985; Hovorka and Fejdi, 1982). The above mentioned xenocrysts are surrounded by a transitional zone of low TiO_2 and FeO_t, and of relatively high SiO_2, MgO, and Na_2O contents (Table II), which form the cores of enstatite- and Cr-diopside-free pyroxenes. One half of the total Al-content is enough to fill all tetrahedral positions besides Si. It indicates the occurrence of a larger amount of jadeite +$CaAlAlSiO_6$ molecules. Aoki and Kushiro (1968), Aoki (1971) and Borley et al. (1971) consider these clinopyroxenes as phases crystallized under 15—20 kbar. The pyroxene type called Al-augite after Wilshire and Shervais (1975) is cognate with the embedding rock (Irving, 1974; Wilkinson, 1975; Wass, 1979).

Most of the pyroxenes are characterized by Al_2O_3-, TiO_2-, FeO_t- and CaO-rich and SiO_2-and MgO-poor rims. The change from the Al-augite towards

Table II

Compositions of pyroxenes (Remetehegy)

	Enstatite core		Cr-diopside core		Al-augite mantle		Ti-salite rim
SiO_2	54.5	54.6	53.6	53.4	51.8	51.6	44.5
TiO_2	0.07	0.03	0.20	0.19	0.61	0.59	2.29
Al_2O_3	1.26	1.83	2.11	2.23	4.70	4.06	8.50
Cr_2O_3	0.16	0.29	0.66	0.86	0.58	0.13	nd
FeO_t	8.00	6.57	3.03	2.62	4.55	5.18	7.70
MnO	0.18	0.17	0.10	0.11	0.07	0.15	0.11
MgO	34.9	35.2	16.0	16.4	14.2	15.5	11.3
CaO	0.53	0.38	22.1	22.6	22.7	21.1	23.5
Na_2O	na	na	1.47	1.33	0.65	0.78	0.56
	99.60	99.77	99.27	99.74	99.86	99.09	98.46

nd = not detected; na = not analyzed; FeO_t = total iron as FeO

Fe_2O_3					–	–	4.02
FeO					4.55	5.18	4.08

Si	1.913	1.912	1.966	1.950	1.902	1.907	1.705
Al^{IV}	0.052	0.076	0.034	0.050	0.098	0.093	0.295
Al^{VI}			0.057	0.046	0.105	0.084	0.089
Ti	0.002	0.001	0.006	0.005	0.017	0.016	0.066
Cr	0.004	0.008	0.019	0.025	0.017	0.004	–
Fe^{3+}					–	–	0.166
Fe^{2+}	0.234	0.192	0.093	0.080	0.140	0.160	0.131
Mn	0.005	0.005	0.003	0.003	0.002	0.005	0.004
Mg	1.826	1.837	0.875	0.893	0.775	0.854	0.645
Ca	0.020	0.014	0.869	0.884	0.893	0.836	0.965
Na			0.105	0.094	0.046	0.056	0.042
mg-value	88.6	90.5	90.4	91.8	84.7	84.2	65.7

Table II (cont.)

	Al-augite mantle		Ti-salite rim
$CaTiAl_2O_6$	1.7	1.6	6.0
$CaCrAlSiO_6$	1.7	0.4	-
$NaAlSi_2O_6$	4.6	5.5	3.8
$CaAlAlSiO_6$	4.8	4.6	4.3
$CaFe^{3+}AlSiO_6$	-	-	14.1
$NaFe^{3+}Si_2O_6$	-	-	-
$CaSiO_3$	41.0	37.9	31.4
$MgSiO_3$	39.1	42.1	29.1
$(Fe^{2+} + Mn)SiO_3$	7.1	7.9	11.3

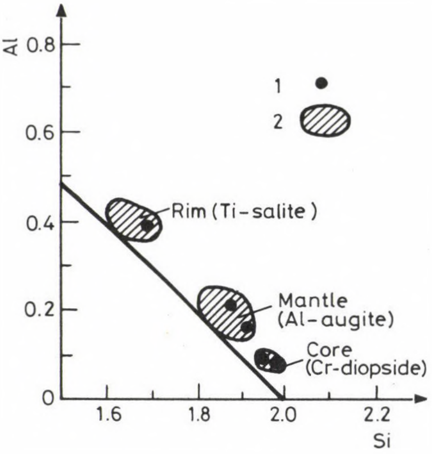

Fig. 2. Si vs. Al in clinopyroxenes. 1. Remetehegy magmatite; 2. Ad-2 lamprophyre (average, Kubovics-Szabó, 1987)

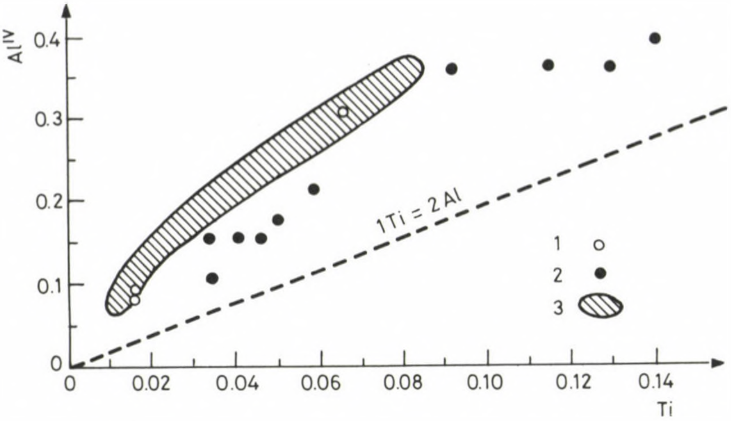

Fig. 3. Ti vs. Al^{IV} in clinopyroxenes. 1. Remetehegy magmatite; 2. Ad-2 lamprophyre (Kubovics-Szabó, 1987); 3. Yogo lamprophyre (Meyer-Mitchell, 1988)

its rim is shown by the Al ⟶ Si substitution (Fig. 2), like in the pyroxenes of the Alcsútdoboz-2 lamprophyres (Kubovics and Szabó, 1987). Since the decrease of SiO_2 content due to progressing crystallization requires increasing occupation of tetrahedral coordinations by Al, the role of Ti and Fe^{3+} grows among the cations filling the octahedral positions. The ratio of the latter ones was determined by Papike's (1974) method (Table II). Figure 3 displays the above mentioned Ti-Al^{IV} relationship. Our data considerable differ from the 1Ti:2Al line and from the pyroxenes of the AD-2 lamprophyres, and are located in the field of the Yogo lamprophyre (Meyer and Mitchell, 1987). This indicates that here the significance of the $CaTiAl_2O_6$ molecule is less than that of the $CaAlAlSiO_6$ molecule, and of the $CaFe^{3+}AlSiO_6$ molecule in the rim.

Points of the clinopyroxene cores are located in the alkali lamprophyre (AL) field containing also the ultramafic lamprophyres (UML) (Rock, 1987), lying immediately at the points of the AD-2 lamprophyre. The rim is separated due to its lower mg-value, indicating a considerable Fe ⟶ Mg substitution in the octahedral positions (Fig. 4).

Table III

Composition of micas (Remetehegy)

	Ultramafic micas		Groundmass micas		
			Phlogopite		Biotite
SiO_2	39.7	39.2	36.4	34.7	32.0
TiO_2	1.21	2.47	6.08	7.72	6.50
Al_2O_3	15.4	16.3	18.0	16.7	15.0
Cr_2O_3	0.89	0.64	0.97	0.13	nd
FeO_t	4.64	4.66	4.36	7.52	21.2
MnO	nd	nd	nd	0.05	0.22
MgO	22.8	23.5	19.4	17.5	7.90
CaO	0.26	0.28	0.05	0.09	0.38
BaO	0.12	0.10	1.61	1.91	6.30
Na_2O	0.58	0.06	0.47	0.54	0.73
K_2O	8.63	2.15	9.20	9.02	6.20
	94.23	89.35	96.54	95.88	96.43

nd = not detected; FeO_t = total iron as FeO

Si	5.680		5.183	5.081	5.119
Al^{IV}	2.320		2.817	2.883	2.829
Fe^{IV}	-		-	0.036	0.052
	8.000		8.000	8.000	8.000
Al^{VI}	0.278		0.205	-	-
Fe^{VI}	0.555		0.519	0.885	2.784
Ti	0.130		0.651	0.850	0.782
Cr	0.101		0.100	0.015	-
Mn	-		-	0.006	0.030
Mg	4.862		4.117	3.819	1.883
	5.926		5.592	5.575	5.479
Ca	0.040		0.008	0.014	0.065
Ba	0.007		0.090	0.110	0.395
Na	0.161		0.130	0.153	0.226
K	1.575		1.671	1.685	1.265
	1.783		1.899	1.962	1.828
mg-value	89.8		88.8	80.6	39.9

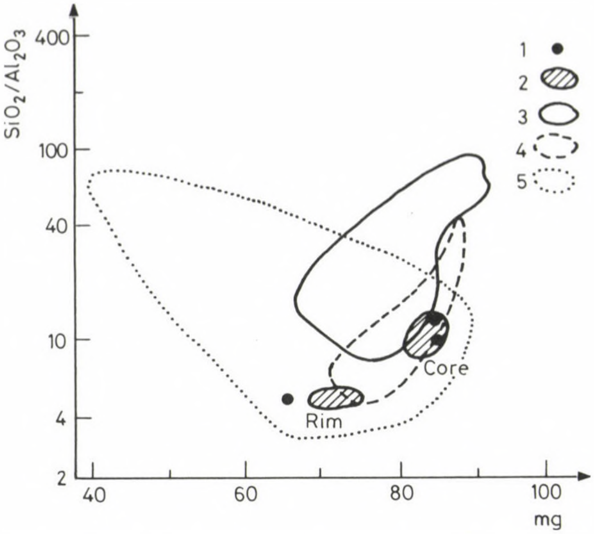

Fig. 4. mg-value vs. SiO_2/Al_2O_3 in clinopyroxenes. 1. Remetehegy magmatite; 2. Ad-2 lamprophyre; 3. calc-alkaline lamprophyres; 4. ultramafic lamprophyres; 5. alkaline lamprophyres (3→5. Rock, 1987)

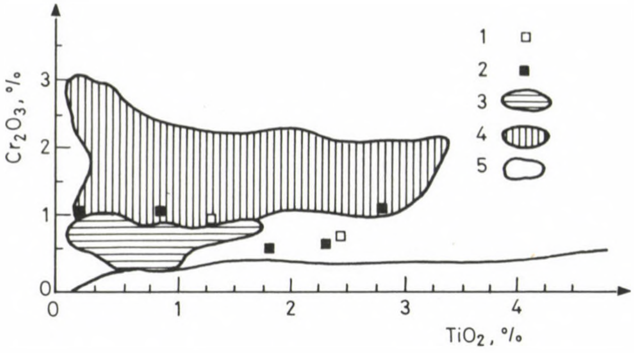

Fig. 5. TiO_2 vs. Cr_2O_3 in phlogopites. 1. Remetehegy magmatite, ultramafic xenoliths; 2. Ad-2 lamprophyre, ultramafic xenoliths; 3. primary micas; 4. secondary micas; 5. MARID+glimmerite

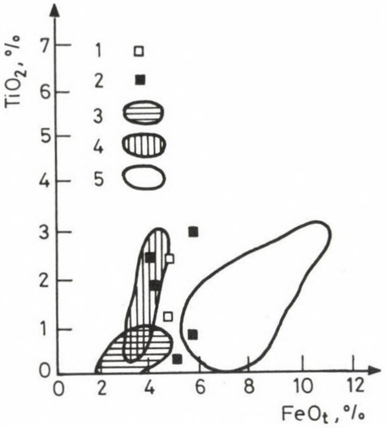

Fig. 6. FeO$_t$ vs. TiO$_2$ in phlogopites. (Symbols as in Fig. 5)

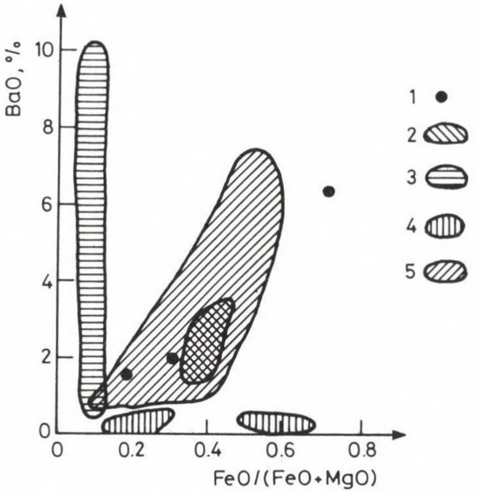

Fig. 7. BaO vs. FeO/(FeO+MgO) in micas. 1. Remetehegy magmatite; 2. Ad-2 lamprophyre (Kubovics-Szabó, 1987); 3. carbonatite; 4. kimberlite; 5. leucite bearing lavas; (3-5. Gaspar-Wylley, 1982)

Mica

Table III contains the composition data of representative specimens of micas showing strong and weak pleochroism, and of the grains from two ultramafic xenoliths (Plate I, Photo 1).

The above mentioned alteration of xenoliths is displayed by the alkali loss of micas (Table III). Both micas from the ultramafic xenoliths are of phlogopitic composition (as shown by their optical behaviour, as well) based in their less mobile main elements. Considering the analytical data of Carswell (1975), Dawson and Smith (1977), Delaney et al. (1980) and others these are secondary micas and are in close genetic correlation with the micas of the metasomatized ultramafic xenoliths of the AD-2 lamprophyre (Figs 5, 6) (Kubovics et al., 1988).

The magmatite embedding the xenoliths contains two kinds of mica, as shown by their pleochroism. Two of the examined grains are phlogopites and one is biotite (Table III).

Fe is required to fill all tetrahedral positions in the biotite and in one of the phlogopites. It indicates Si-poor micas. Substitution in the octahedral positions in phlogopites and biotites occurs simultaneously by the model of Forbes and Flower (1974):

$$2Mg_{VI} \rightleftharpoons Ti_{VI} + \square_{VI} \cdot$$

and Robert (1976):

$$Mg_{VI} + 2Si_{IV} \rightleftharpoons Ti_{VI} + 2Al_{IV}$$

The simultaneous appearance of the two kinds of substitution was shown by Arima and Edgar (1981) in phlogopites of kimberlites and carbonatites; they also appeared in the micas of the AD-2 lamprophyres (Kubovics and Szabó, 1987). While the BaO content of phlogopites below 2 wt% does not exceed the BaO content of lamprophyre micas of Rock (1987) and of the AD-2 lamprophyre, the 6.3 wt% for biotites is a very high value (Fig. 8). Phlogopite points appear in the leucite-bearing lava field (Gaspar and Wyllie, 1982) together with those of the AD-2 lamprophyre. The biotite is very near to that of Thompson (1977), which corroborates the coincidence of his and our opinions. Ba is enriched in biotite, because it is the last precipitate. Ba cannot enter the lattice of other minerals earlier due to its low concentration.

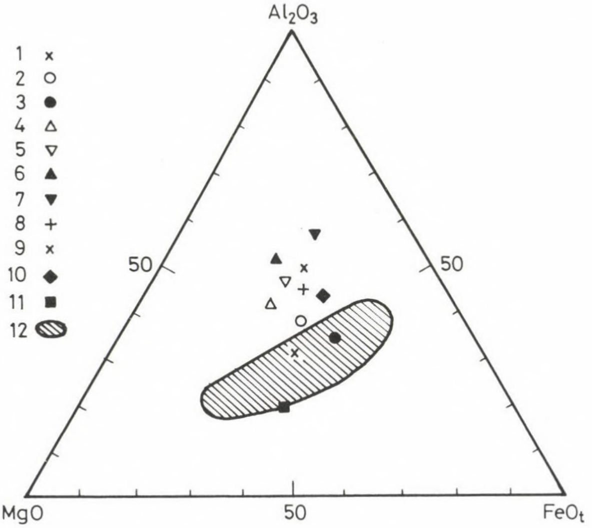

Fig. 8. MgO-FeO_t-Al_2O_3 plots for different alkali basic rocks. 1. Remetehegy magmatite; 2. Ad-2 lamprophyre (Kubovics-Szabó, 1987); 3. Bő-1 lamprophyre (Kubovics-Szabó, 1987); 4. Bondoróhegy; 5. Szigliget; 6. Bárna-Nagykő; 7. Medves (4-7. Jugovics, 1976); 8. "Alkali basalt" (Hovorka et al., 1983); 9. calc-alkaline lamprophyres; 10. alkaline lamprophyres (9-11. Rock, 1987); 11. ultramafic lamprophyres; 12. alnöit (Rock, 1986)

Petrochemical calculations

Table IV shows the chemical composition, normative mineral components and some petrochemical parameters of the most fresh rock, which contains 11.3 vol% groundmass. Data for comparison are Hungarian rocks containing upper mantle xenoliths. Average values of AD-2 borehole dykes of the Upper Cretaceous lamprophyric-carbonatitic-picritic association (Kubovics, 1983; Kubovics and Szabó, 1987), and the Neogene–Quaternary alkali basalts of Bondoróhegy and Szigliget from the Balaton Highlands, and the Medves and Nagykő at Bárna from the Nógrád–Gömör region are shown (Jugovics, 1976).

In Fig. 3 the examined magmatite appears near the alnöite together with the AD-2 lamprophyre average due to its low Al content and is definitely separated form the Neogene–Quaternary alkali basalt points. It confirms the ultramafic lamprophyric (alnöitic) character of the lamprophyric-carbonatitic-picritic association of Hungary.

The Remetehegy magmatite shows conspicuously low normative ortho-

Table IV

Mean major element compositions and CIPW norms and some petrochemical indices of different alkaline basic rocks (Hungary

	1	2	3	4	5	6
SiO_2	41.74	38.80	45.39	45.95	45.29	47.10
TiO_2	0.93	1.39	1.16	1.72	2.22	1.47
Al_2O_3	9.11	9.98	14.83	15.52	17.33	18.52
Fe_2O_3	6.59	5.47	4.66	2.76	3.13	3.85
FeO	4.12	4.34	5.57	6.47	6.67	5.26
MnO	0.13	0.13	0.15	0.18	0.15	0.14
MgO	10.59	8.39	11.48	9.03	7.05	5.77
CaO	15.08	13.17	8.19	9.08	9.76	9.39
Na_2O	2.18	3.08	3.51	3.05	4.31	4.43
K_2O	1.56	2.17	1.70	1.91	2.59	2.17
H_2O^-	1.6	1.97	0.99	0.72	0.54	0.48
H_2O^+	3.0	4.02	1.44	2.49	0.58	1.22
CO_2	1.6	6.67	0.27	0.93	0.23	0.08
P_2O_5	1.17	0.59	0.85	0.41	0.25	0.25
	99.40	100.17	100.41	100.22	100.10	100.13
q	-	-	-	-	-	-
or	9.2	12.8	10.0	11.3	15.3	12.8
ab	8.4	25.3	21.2	22.0	7.5	17.3
an	10.5	7.0	19.7	23.0	20.3	24.2
ne	5.5	0.4	4.6	2.1	15.7	10.9
di	36.4	8.0	10.8	10.8	20.1	16.2
ol	7.2	13.1	19.4	17.5	10.2	7.9
mt	9.6	7.9	6.8	4.0	4.5	5.6
il	1.8	2.6	3.2	3.3	4.2	2.8
ap	2.8	1.4	2.0	1.0	0.6	0.6
cc	3.6	15.2	0.6	2.1	0.5	0.2
D.I.	23.0	38.5	35.8	35.3	38.5	41.1
S.I.	42.3	35.8	42.6	38.9	29.2	26.8
mg	82.1	77.1	78.6	71.3	65.3	66.2

1. Remetehegy magmatite; 2. Ad-2 lamprophyre (13 samples, Kubovics—Szabó, 1987); 3. Bondoróhegy alkali basalt (4 samples, Jugovics, 1976); 4. Szigliget alkali basalt (4 samples, Jugovics, 1976); 5. Bárna—Nagykő alkali basalt (2 samples, Jugovics 1976); 6. Medves alkali basalt (8 samples, Jugovics, 1976)

clase, albite and anortite contents as compared either to the Alcsútdoboz lamprophyre or to the Neogene—Quaternary alkali basalts (Table IV). The extremely high normative diopside and low olivine contents correspond to the modal mineralogical composition. The Remetehegy magmatite and the Alcsútdoboz lamprophyre are both characterized by higher normative magnetite and lower ilmenite contents than the representatives of the Neogene—Quaternary alkali basalts.

The Remetehegy sample displays an extremely high mg-value (Table IV) that is characteristic of undifferentiated, primitive melts. It is corroborated by the high S. I. (42.3) and lowest D. I. (23.0) values. The latter may be even lower, because the upper mantle xenocrysts may further lower this value.

The AD-2 lamprophyre and the Bondoróhegy and Szigliget alkali basalts differ from the Remetehegy magmatite in their slightly lower mg- and S. I. values, i.e. these formations derive from a primitive, less differentiated magma. On the other hand, the alkali basalt of the two Nógrád—Gömör localities derive from a differentiated melt and form a separate group according to their petrochemical characters. It is shown by their higher normative nepheline and relatively low olivine contents, too.

REE analyses

The REE analytical data (Table V) unambiguously determine the genetic relationships of the Remetehegy magmatite. The light rare earths display a minor, but definite enrichment as compared to the AD-2 lamprophyre suggestive of ultramafic lamprophyre averages (Rock, 1987), while heavy rare earths(together with the AD-2 lamprophyre) occur in lower amounts than the averages of Rock (1987). The total REE content is 593.25 ppm, falling within the 26.1—1033 ppm lamprophyre interval (Cullers and Graf, 1982), being close to the average values of ultramafic lamprophyres (Rock, 1987). The extremely high $(La/Lu)_{cn}$ ratio (1033) far exceeds the values of used for materials comparison and can be fitted into the extremely wide carbonatite interval (7.1—1240) only.

The chondrite normalized light REE patterns (Fig. 9) are located in the lamprophyre field (Cullers and Graf, 1982), slightly above the averages of the AD-2 lamprophyre and of the ultramafic lamprophyres (Rock, 1987), but parallel with it. On the contrary, the heavy rare earths are separated

Table V

Rare earth element compositions of the Remetehegy magmatite and of different lamprophyres

	1	2	3	4
La	155	122	83	151
Ce	278	230	151	256
Nd	135	129	64	131
Sm	19	17	20	20
Eu	3.6	3.2	5	4.7
Tb	0.9	0.6	1.8	1.7
Yb	1.6	1.5	2.3	2.5
Lu	0.15	0.17	0.4	0.3
REE	593.25	503.47	327.5	567.2
La/Lu_{cn}	1033	717	208	503

1. Remetehegy magmatite (average); 3. Ad-2 lamprophyre average); 3. Alkali lamprophyre (average, Rock, 1987); 4. Ultramafic lamprophyre (average, Rock, 1987)

from the published data together with the AD-2 average and are located in the kimberlite field (Cullers and Graf, 1982).

The lamprophyric and kimberlitic character of the Remetehegy magmatite is proven by the Sm-La/Y plot (Fig. 10): the points are located in the common field of minette (including the field of ultramafic lamprophyre) and kimberlite, together with the genetically closely related AD-2 lamprophyre points.

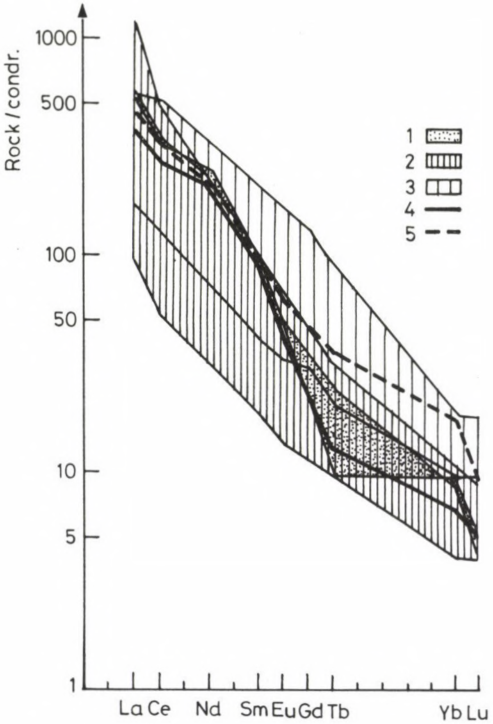

Fig. 9. REE distributions normalized to the chondrites of Nakamura (1974). 1. Remetehegy magmatite; 2. Ad-2 lamprophyre (Kubovics-Szabó, 1987); 3. ultramafic lamprophyres (Rock, 1987); 4. lamprophyre (Cullers-Graf, 1982); 5. kimberlite (Cullers-Graf, 1982)

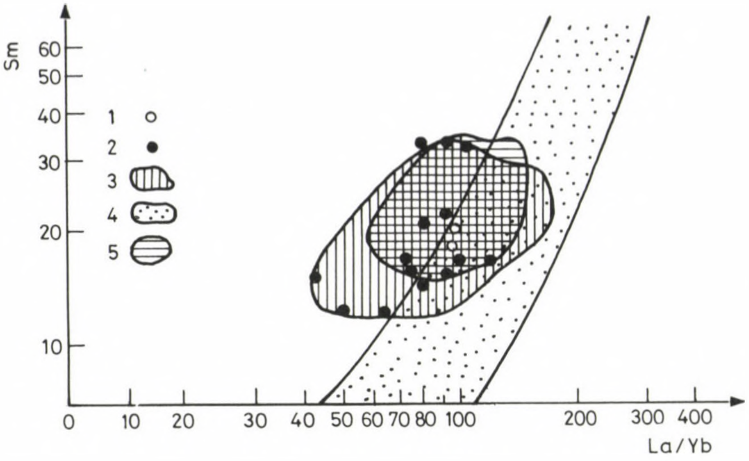

Fig. 10. Sm vs. La/Yb in lamprophyres and kimberlites. 1. Remetehegy magmatite; 2. Ad-2 lamprophyre (Kubovics-Szabó, 1987); 3. ultramafic lamprophyres (Rock, 1987); 4. kimberlite (Nixon et al., 1980); 5. minette (Rock, 1987)

Conclusions

The Remetehegy magmatite belongs to the lamprophyric-carbonatitic-picritic association of NE Transdanubia. This relation is supported by the large amount of mafic components, by their geochemical characters, by the REE distribution, and by the phlogopite-rich xenoliths, like the metasomatized upper mantle xenoliths of the Alcsútdoboz-2 lamprophyre. The 61.5–67.0 Ma K/Ar age (determined by Balogh K., in Institute of Nuclear Research of the Hung. Acad. Sci.) indicates the same; this datum serves for orientation only due to the strong alteration of the rock.

Most probably a similar rock was examined by A. Embey-Isztin et al., reported on the meeting of the Hungarian Geological Society in 1988.

The enstatite and Cr-diopside cores in the pyroxenes of the magmatite and the twin-lammellar olivine with higher MgO content derived from the upper mantle and are relics of a peridotite disintegrated to its mineral components.

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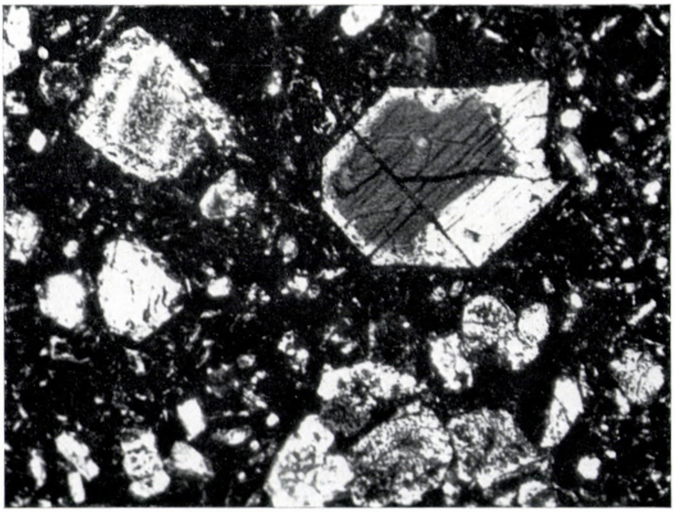
Plate I

1.

Plate II



2.

Plate I

Photo 1. Altered ultramafic xenoliths in lamprophyric dyke, at Remetehegy

Photo 2. Anhedral orthopyroxene (enstatite) core surrounded by augitic rim, in the Remetehegy magmatite. +N, M = 44x

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MINERALOGY AND PETROLOGY OF WESTERN HUNGARIAN METAMAGMATITES AND THEIR CONNECTIONS TO THE EASTERN ALPS

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Besides titanite-crossitite several kinds of chloritite and talc-serpentinite are found in the Hungarian part of the Vashegy (Eisenberg) group of the Kőszeg-Rechnitz Penninic window. The original rock of the titanite-chloritite was pyroxenite of high ilmenite content, being in close genetic relationship with the source rock of titanite-crossitite. Ti-poor chloritite was produced probably by Mg-containing solutions.

Talc-serpentinite was produced directly from a lherzolitic peridotite, as shown by the texture; the alteration of serpentinite to talc was subordinate.

Petrochemical calculations proved that the metaultramafics with high Ti and Fe contents of the Vashegy region, in the Möltern, Bernstein and Rechnitz windows are of igneous origin, produced by "reverse differentiation" caused by partial melting of the mantle.

Keywords: Metamagmatites, Eastern-Alps, Western Hungary, reverse differentiation

Introduction

There are basalts, basalt tuffs, gabbros and ultramafics in the upper part of the Jurassic—Createceous pelitic sequence (Pahr, 1971; Schönlaub, 1973) of the Vashegy group in the Kőszeg—Rechnitz Mts. The Penninic mafic-ultramafic metamagmatites form large bodies in Burgenland (Schmidt, 1950; Pahr, 1960; Evren, 1972; Tollmann, 1979; Koller and Pahr, 1980), and occur as minor ones in Hungary near Felsőcsatár, Bozsok and Velem (Fig. 1). (Benda, 1929; Varrók, 1955; Vendel and Kisházi, 1967; Kotsis, 1982, 1986; Kubovics, 1983).

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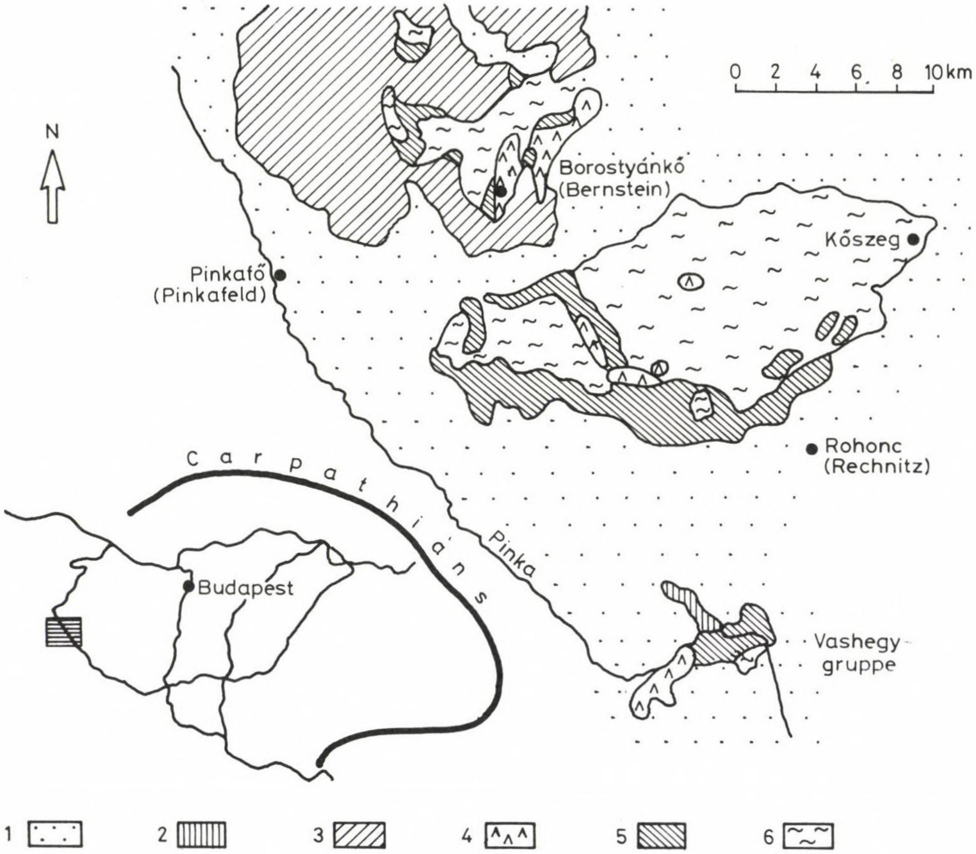

Fig. 1. Geological map of the eastern part of the Penninicum (after Koller-Pahr, 1980). 1. Tertiary (in general); 2. Upper Austro-Alpine; 3. Lower Austro-Alpine. Penninicum: 4. serpentinite; 5. greenschist, metagabbro; 6. metasediments

The sediments and the enclosed magmatic rocks suffered greenschist facies Alpine metamorphism, although Evren (1972) supposed also albite-epidote-amphibolite, and amphibolite facies metamorphism, too. There is abundant greenschist at the Vashegy, originated mostly from calc-alkaline mafic pyroclastics (Kubovics, 1983; Kotsis, 1986). Alkali amphibole- and titanite-containing crossitite also occur derived from metabasites-metaultrabasites (Kubovics, 1983) or from metagabbros (Koller and Pahr, 1980). Amphiboles of the latter group were investigated by Lelkes-Felvári (1982). Besides these rocks chloritite, serpentinite, talc-schist are found in this region. Their origin is discussed in the present paper.

Petrogenesis

Varrók (1955), and Kotsis (1982) considered the minor bodies of serpentinite, chlorite schist (chloritite), and talc-schist at Vashegy as "tectonic" and "hydrothermal" Mg-metasomatic products altered from "diabase" or gabbro. However, serpentinite and talc cannot derive from high-Al rocks. Feldspars are altered to stable albite and epidote under greenshcist facies conditions; these minerals are unknown in the above mentioned rocks. Chlorite is table, too. Alumina can be hardly mobilized in this facies. These contradictions were eliminated by Vendel and Kisházi (1967), who derived serpentinite from ultramafic rocks. The chlorite around the serpentinite bodies could have been formed from serpentinite by absorbing alumina. Locally the serpentinite is ilmenite-rich (Varrók, 1955), indicating alteration from high-Ti tholeiitic ferroultramafics or melagabbro. The original variability of the magmatites is shown by the highly different mineral composition of the chlorite schist (titanite-chloritite, chloritite). The almost alkali-free titanite-chloritite is made of titanite and prochlorite, while other chloritite varieties contain several percents of magnetite, ilmenite, and/or apatite (Fig. 2). The original material that altered to titanite-chloritite was probably pyroxenite of low silica and high ilmenite content, formed by differentiation from basic melt. Chloritisation of mafic components (pyroxenes) yielded SiO_2 and CaO. These (mostly large amounts of silica) were released from the system which resulted in the relative increase of concentration of the above mentioned oxides (Table I). Part of the SiO_2 and CaO reacted with ilmenite in a H_2O-containing environment, producing large amount of titanite:

$$FeTiO_3 + SiO_2 + CaO \longrightarrow CaTiSiO_5 + FeO \quad .$$

Part of the FeO entered the newly formed chlorite — producing prochlorite or Fe-prochlorite —, partly it was oxidized and precipitated as magnetite.

This process led to the overgrowth of the original magnetite crystals and to the appearance of new, fine grained magnetite agglomerations. The varied titanite was formed by different processes. The large "leukoxene" containing ilmenite relics are considered as alteration product of ilmenite. The large titanite crystals are missing from some rock varieties; their site is occupied by fine-grained agglomerations (Plate I/1). Rarely the titanite crystals are scattered or arranged in a banded

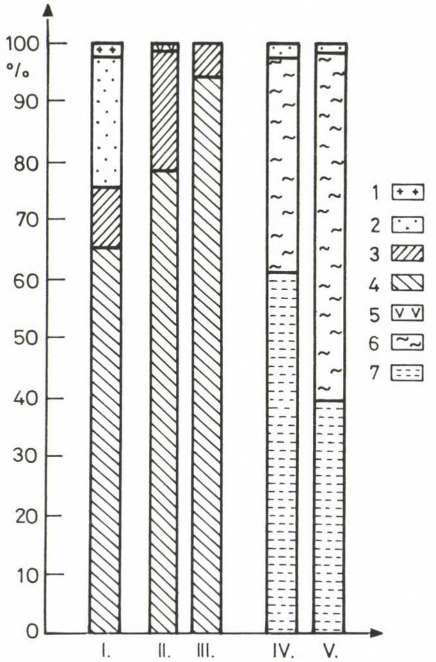

Fig. 2. Mineralogical composition of some West Hungarian (Vashegy-Eisenberg) metamorphites. 1. ilmenite; 2. magnetite; 3. titanite; 4. chlorite; 5. apatite; 6. talc; 7. serpentine. I. Chloritite; II—III. Titanite-chloritite; IV-V. Talc-serpentinite

pattern. These micrometre-sized titanite crystals contain TiO_2 and are free of primary mafic components (clinopyroxene). The habit and arrangement of titanite may indicate the process and intensity of metamorphism. The strongest metamorphism is indicated by few, large, twinned titanites. If there is only a subordinate amount of "leukoxene" (i.e. only a minor part of ilmenite altered to titanite) the chlorite displays much lighter colour, and is of lower FeO content. This indicates that the ilmenite is altered to titanite under somewhat higher P—T conditions than the chloritization of mafic silicates proceeded. The process is influenced by fluid composition and the amount of CaO and SiO_2.

Titanite-chloritite contains about 10 vol.% apatite arranged in bands. This large amount of phosphor and titanite may derive from metamorphites and partly from pegmatitic rocks.

Chloritite containing the same silica ratio as titanite-chloritite (Table I) bears little TiO_2 and CaO, but much Al_2O_3 and MgO. The extremely

Table I

Main major element compositions of different orthometamorphites from the Vashegy (Eisenberg) group and Borostyánkő (Bernstein) Unit

	1	2	3	4	5	6	7	8	9	10	11
SiO_2	27.14	29.68	30.09	33.07	34.25	30.75	32.04	29.49	31.50	47.94	43.05
TiO_2	10.16	11.67	7.17	0.17	0.1	1.20	1.92	3.93	1.17	0.15	0.1
Al_2O_3	10.52	13.83	9.48	18.16	15.74	19.00	18.28	15.43	17.38	1.88	1.82
Fe_2O_3	13.04	3.61	1.80	1.61	2.17	4.01	3.64	0.1	3.12	2.78	5.44
FeO	12.72	14.4	15.87	4.36	3.18	12.40	8.47	12.7	9.03	5.29	2.37
MnO	0.15	0.30	0.11	0.22	0.16	0.15	0.19	0.39	0.22	0.10	0.1
MgO	11.25	11.97	12.06	29.16	30.03	22.00	21.61	20.63	23.07	31.88	33.63
CaO	8.00	6.47	8.82	0.27	1.22	1.00	2.44	4.99	1.57	0.20	0.58
Na_2O	0.10	0.05	0.04	0.08	0.1	0.04	0.05	0.19	0.05	0.03	0.1
K_2O	0.05	0.05	0.07	0.1	0.1	0.02	0.06	0.19	0.05	0.05	0.1
P_2O_5	0.10	0.17	4.78	0.01	0.01	0.02	0.11	2.45	0.07	1.25	0.01
$-H_2O$	0.38	0.2	0.30	-	-	0.26	0.15	0.5	0.7	0.70	-
CO_2	1.3			0.3	0.4	1.7					0.6
$+H_2O$	4.93	8.38	8.82	12.1	12.1	7.88	11.59	10.50	12.40	7.09	11.90
	99.84	100.78	99.41	99.61	99.56	100.43	100.50	100.59	100.33	99.34	99.80

1–3. Titanite – chloritite, Felsőcsatár; 4–5. Chlorite-schist, Bernstein; 6. Chloritite, Felsőcsatár; 7. Chloritite, Wappendorf; 8–9. Chloritite, Bernstein; 10. Talc-serpentine schist, Felsőcsatár; 11. Serpentinite, Bernstein high amount of MgO may be the result of Mg-containing solutions (it may be corroborated by the 3–4% dolomite content of chloritite). These fluids might have solved the titanite formed during former metamorphic processes, and transported its components (CaO, TiO_2). This strong and long metamorphic/metasomatic process is clearly shown by the grain size of chloritite larger than average and by the homogeneous distribution of the few titanites (Plate I/2). This process is responsible for the high-Mg clinochlore, as component of the metamorphite instead of the prochlorite (Fe-prochlorite). The chemical composition of chloritite is similar to that of some chlorite-schist varieties from the Bernstein Mts (Table I).

In the Kőszeg–Rechnitz Mts. and in the Vashegy group there is clinochlore chlorite-schist displaying fine-grained, strongly schistose texture with less titanite as frequent rock bodies besides titanite-chloritite with magnetite porphyroblasts. Its chemical composition (Table I 4–5. columns), especially the relatively high Al_2O_3 content were probably formed from a magmatite (Al-basalt?) containing much neutral-basic feldspars. The high-Al_2O_3, iron-free clinochlore is an alteration product of basic plagioclase (montmorillonite→smectite-chlorite → mixed-layer chlorite). Talc was not formed from the above mentioned chlorite, despite the earlier hypotheses. The silica content of the high-Al_2O_3 chlorite is aboute 30%. As regards the formation of Al_2O_3-free talc containing more than 60% SiO_2 the chemical composition had to be changed – even in the tetrahedral coordination lattice points – in a way, which is possible only under extreme conditions. Besides silicates of the greenschist facies including chlorites it bears Al_2O_3 as main component, which is indicated by the lack of newly formed alumina containing minerals.

Several authors have studied the minor serpentinite bodies and serpentinite varieties of the Kőszeg–Rechnitz Mts (Varrók, 1955; Vendel and Kisházi, 1967; Kotsis, 1965, 1977). However, the present paper discusses the massive, dark or light green serpentinite of ultramafic origin, found near the crossitite (Kubovics, 1983) at Vashegy (Fig. 1). Its main components are antigorite, lizardite, and talc, the oxide is fine-grained anhedral magnetite (Fig. 2). Although we did not find relic minerals, the outline of the antigorite-lizardite-talc agglomerates and the distribution of magnetite grains clearly show the primary olivine (Plate I/3). Therefore, the serpentinite was formed from olivine-bearing ultramafics, possibly from lherzolite.

The considerable amount of secondary magnetite indicates high

Fe content of the primary minerals (olivine, pyroxene), and the igneous origin of the ultramafic rock (metabasite). The main components of the rock (antigorite, lizardite), and the secondary magnetite were produced by metamorphic processes according to the following equations:

$$12(Mg,Fe)_2SiO_4 + 12H_2O + O_2 \longrightarrow 3Mg_6(Si_4O_{10})(OH)_8 + 2FeFe_2O_4 \qquad (1)$$

The amount of secondary magnetite as well as the chemical composition of the associated rocks indicate that the Mg : Fe ratio of the original mafic component was about 3:1. If the FeO content is higher, the alteration process yields free SiO_2. It may result the frequent alteration of serpentine minerals to talc and the local silicification of serpentinite. Serpentinite formation needs SiO_2 or silica solutions under low-Fe conditions. If the Mg : Fe ratio is 4:1 in the olivine, the following process takes place:

$$15(Mg_{1.6}Fe_{0.4})SiO_4 + SiO_2 + 16H_2O + O_2 \longrightarrow 4Mg_6(Si_4O_{10})(OH)_8 + 2FeFe_2O_4 \qquad (2)$$

Serpentinite contains usually a large, but variable amount of talc. Talc surrounds the serpentine aggregates, i.e. it was formed during subsequent metamorphism (Plate I/3).

The Felsőcsatár talc (talc-schist) appears at the rim, rarely in the centre of serpentinite bodies (Varrók, 1955; Vendel and Kisházi, 1968). The talc is associated by silica minerals (e.g. chalcedony) or carbonates. It clearly indicates that most of the talc was formed from ultramafic serpentinite, in contrast with the opinions of Varrók, 1955; Kotsis, 1965, 1982. The process is the following:

$$Mg_6(Si_4O_{10})(OH)_8 + 4SiO_2 \longrightarrow 2Mg_3(Si_4O_{10})(OH)_2 + 2H_2O \qquad (3a)$$

It means that high-Fe olivine may promote talc formation, but the reaction needs somewhat higher temperature than needed for serpentinization. Talc is formed from serpentine minerals due to CO_2-containing solutions under relatively low temperatures, dependent on the partial pressure of CO_2, according to the following equations:

$$Mg_6(Si_4O_{10})(OH)_8 + 3CO_2 \longrightarrow Mg_3(Si_4O_{10})(OH)_2 + 3MgCO_3 + 3H_2O \quad (3b)$$

Dolomite is formed besides talc by Ca-hydrogencarbonate solutions:

$$Mg_6(Si_4O_{10})(OH)_8 + 3Ca(HCO_3)_2 \longrightarrow Mg_3(Si_4O_{10})(OH)_2 + 3CaMg(CO_3)_2 + 6H_2O \quad (3c)$$

The three basic types of talc formation are discussed by Deer et al., 1962; Turner and Verhoogen, 1960; Wellman, 1942; Vendel and Kisházi, 1967. The Vashegy talc is locally silicified or occurs together with dolomite or magnetite, indicating that alteration to talc was made by silica-containing solutions, containing variable amount of Ca-hydrogencarbonate. The predominant alteration of talc from serpentinite is corroborated by the subsequent alteration of serpentine minerals, and the texture relationships of the two minerals (Plate I/3).

Part of the talc-bearing serpentinites are neither silicified nor carbonatized, and the serpentinites do not contain carbonate or silicate minerals. In these cases the outlines of the former pyroxene altered to talc can be observed besides the serpentinized former olivine.

This proves, that most of the talc was formed directly from Mg-Fe-pyroxene (Plate I/4). The process is the following:

$$12(Mg_{1.5}FeO_{0.5})Si_2O_6 + 6H_2O + O_2 \longrightarrow 6Mg_3(Si_4O_{10})(OH)_2 + 2FeFe_2O_4 \quad (4a)$$

If the proportion of iron(II) is higher in the original pyroxene (indicated by the extremely high FeO content of these metaultrabasites), the alteration is associated by the release of SiO_2. This promotes olivine (or orthopyroxene) to alter to talc.

The orthopyroxene – under low partial CO_2 pressure, and under less than 500^0C temperature – can alter to serpentine directly, especially if the Fe^{2+} proportion is lower than in the euqation.

$$3Mg_2Si_2O_6 + 4H_2O \longrightarrow Mg_6(Si_4O_{10})(OH)_8 + 2SiO_2 \quad (4b)$$

However, in cases 4/a and 4/b the new minerals have larger volume than the original ones; i.e. this process acts under low pressure, possibly under higher temperature, especially under hydrothermal conditions.

Plate I/1

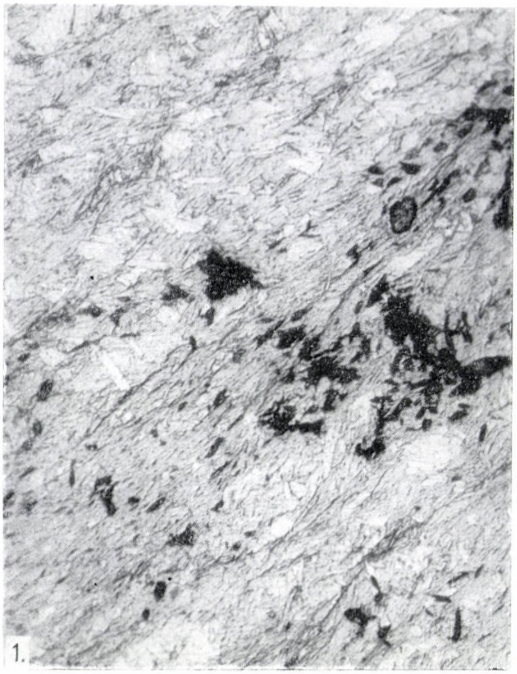

Plate I/2

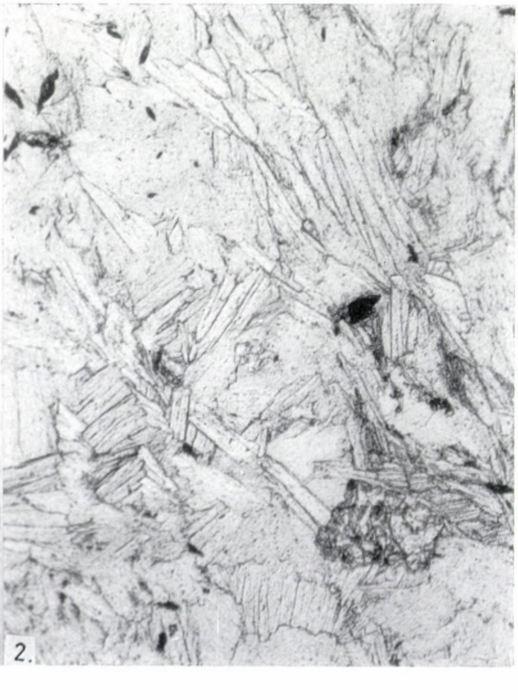

Plate I/3

Plate I/4

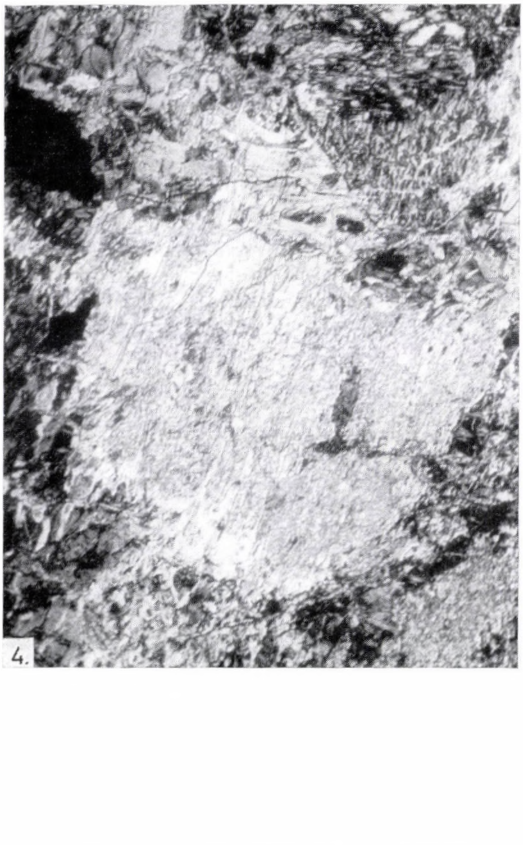

Plate I

Fig. 1. Titanite-chloritite, Felsőcsatár (FV-19), 1N, M=110X

Fig. 2. Relatively coarse-grained apatite-bearing chloritite, Felsőcsatár (FV-18); +N, M=110X

Fig. 3. Talc-bearing serpentinite, serpentine agglomeration after olivine (the fine-grained talc surrounds serpentine indicating the contours of the former olivine); Felsőcsatár, (FV-13); +N, M=110X

Fig. 4. Talc-bearing serpentinite. Talc agglomerate after pyroxene. Felsőcsatár (FV-13); +N, M=70X

Serpentine and talc formation means volume reduction only if we consider the volume needs of H_2O or solutions in the left side of equations 1, 2, 3/b, 3/c. It means that "solution" temperature and pH_2O play important role in the formation of the two minerals. CO_2 and pCO_2 supports further alteration of serpentine and talc and magnesite formation from it. The alteration temperature is influenced by the chemical composition of the "solution".

Conclusions

Recent investigations (Kubovics, 1983; Koller and Pahr, 1980; Koller, 1980; Koller and Wiesender, 1981) indicate that Mesozoic igneous rocks – similar to those of the Vashegy region in Hungary – appear in other windows of the Penninic tectonic zone (Möltern, Bernstein, Rechnitz). There are no significant differences among greenschist varieties in their mineralogy, petrology and geochemistry (Kubovics, 1983; Kotsis, 1987). The titanite-crossitite of Vashegy (Kubovics, 1983) and the FeO_t- and TiO_2-containing metaultramafics (discussed in the present paper) show close genetical relationships with ophicalcites and metagabbros (Koller and Pahr, 1980) from Burgenland. These metamorphites are of igneous origin, in contrast with the Penninic ophiolites (Koller and Pahr, 1980) of the Rechnitz and Bernstein windows. The increase of the TiO_2-content with growing basicity and FeO_t together with the high concentrations of both components corroborate this suggestion.

The plots (Figs 3, 4, 5) clearly show that the discussed metaultramafics were produced by "reverse differentiation", like the ultramafics at Szarvaskő (Bükk) (Kubovics, 1984). Although the FeO_t/MgO ratio usually decreases during metamorphism due to the decrease of the FeO-content, these metamorphites belong certainly to the tholeiitic series (Fig. 3). But there are very important differences in the compositions of typical ophiolites (Coleman, 1977; Menzies–Allen, 1974) (e.g. Othris, Troodos) and the rocks discussed in the present paper (Figs 4, 5) due to genetical circumstances. We suggest, that the melt of Penninic metamagmatites is a melting product of upper mantle silicates with extremely high iron content.

The sudden decrease of pressure and temperature made by rapid, but minor spreading promoted the partial melting of Ti- and Fe-rich silicates, and primary and secondary enrichment of FeO and TiO_2.

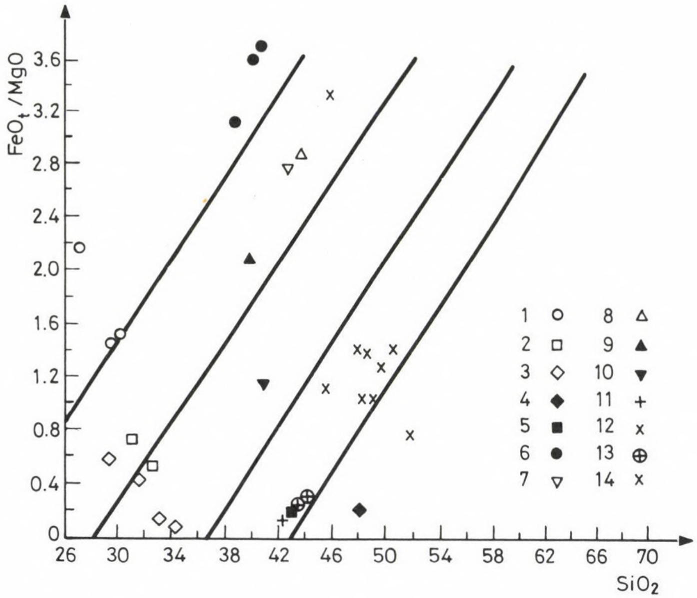

Fig. 3. FeO$_t$/MgO-SiO$_2$ diagram of different metamorphic rocks. 1. titanite-chloritite (Vashegy–Eisenberg group); 2. chloritite (Vashegy–Eisenberg group); 3. chloritite (Bernstein unit); 4. serpentinite (Vashegy–Eisenberg group); 5. serpentinite (Bernstein unit); 6. titanite-crossitite (Vashegy–Eisenberg group, Kubovics, 1983); 7. metagabbro (Koller, 1978); 8. diallage-hornblendite (Bükkium, Szentpétery, 1953); 9. hornblendite (Bükkium, Szentpétery, 1953); 10. hornblendite (Ditró, Transsylvania, Szentpétery, 1953); 11. harzburgite (Othris, Menzies-Allen, 1974); 12. lherzolite (Othris, Menzies-Allen, 1974); 13. harzburgite (Troodos, Menzies-Allen, 1974); 14. greenschist (Penninicum)

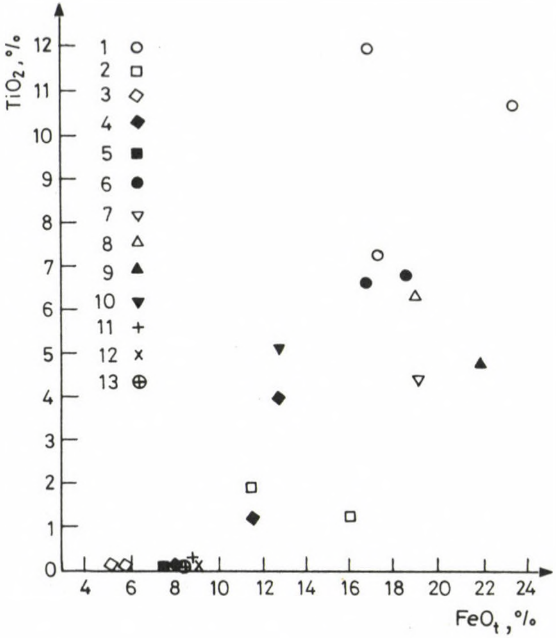

Fig. 4. TiO_2–FeO_t diagram of different metamorphic rocks. (Symbols as in Fig. 3)

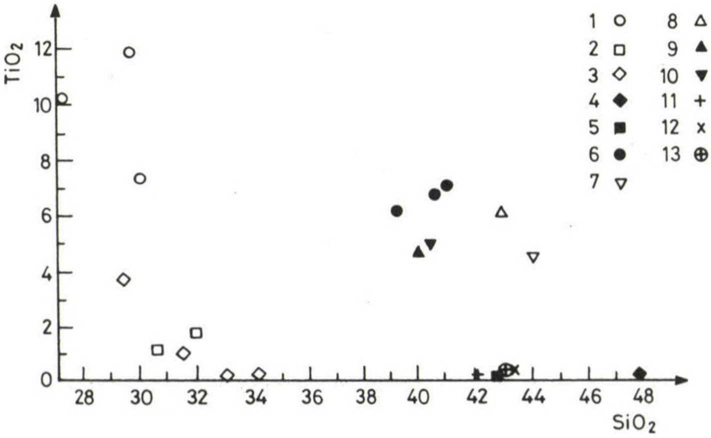

Fig. 5. TiO_2–SiO_2 diagram of different metamorphic rocks. (Symbols as in Fig. 3)

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PALEOVOLCANIC STRUCTURES IN THE NORTH-TOKAJ MOUNTAINS INTERPRETED ON THE BASIS OF SATELLITE IMAGERY AND AERIAL PHOTOGRAPHY

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In the LANDSAT TM false coloured satellite photograph a few Miocene (Sarmatian) volcanic eruption centers can be recognized in the northern empart of the Tokaj Mountains. Based on lower taken aerial photographs information of the satellite photographs was corrected. In the area of Kéked—Telkibánya—Hollóháza a few paleovolcanic eruption centers can be recognized. During the detailed geological reambulations and field trips four eruption centers could be identified. In the course of examinations morphological, petrological and tectonic information were used.

Keywords: Paleovolcanic structures, satellite imagery, aeral photography, Tokaj Mountains

1. Telkibánya

A rhyolite-tuff volcano is situated North-West of the village.

Morphology: Two and three tuff rings can be found in 270° part of a circle with a radius of 1.5 km. The caldera of the eruption center is 250 m, and an inner cone in the eastern side of the center can be recognized. There are harder stones than tuffs accompanied by lines of bushes in thin zones perpendicular to and parallel with the tuff rings.

Petrology: The material of the tuff rings is a stratified, well sorted, multi cyclic fine and coarse grained, pumiceous rhyolite tuff with perlite-, rhyolite lapillis. A rough pumiceous welded rhyolite tuff is superpositioned on the tag of the second tuff ring. In addition to the tuffs in the central caldera flow, vesicular rhyolite, andesite, and volcanic neck breccia clasts can be found. The tuff volcano contains 0.1—0.5 m thick hydroquartzite dykes of concentric and radial structure. Close to these 0.5 m thick

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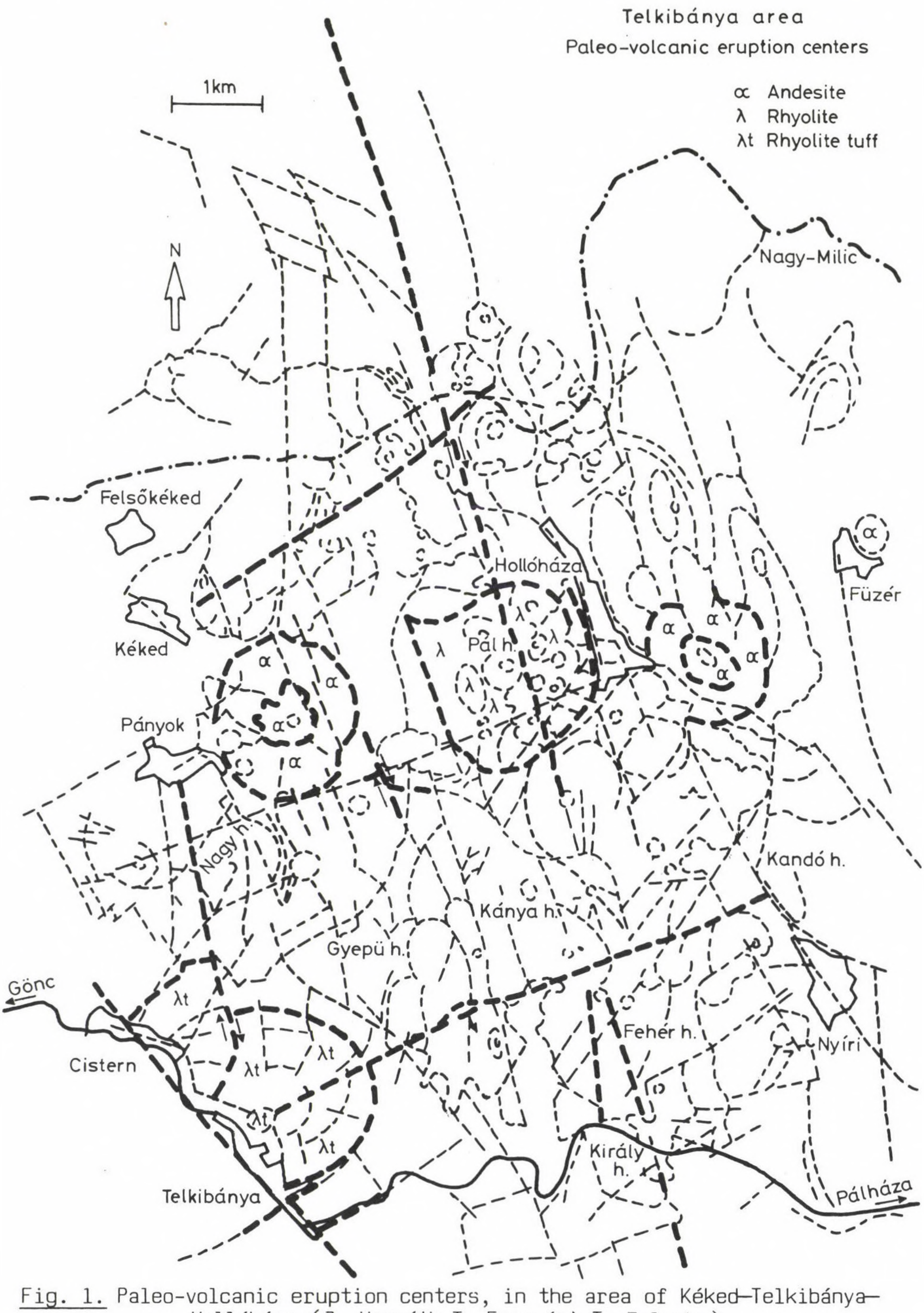

Fig. 1. Paleo-volcanic eruption centers, in the area of Kéked–Telkibánya–Hollóháza (J. Horváth–T. Fegyvári–T. Zelenka)

Fig. 2. Satellite imagery of the area of Kéked–Telkibánya–Hollóháza (Landsat TM 5.)

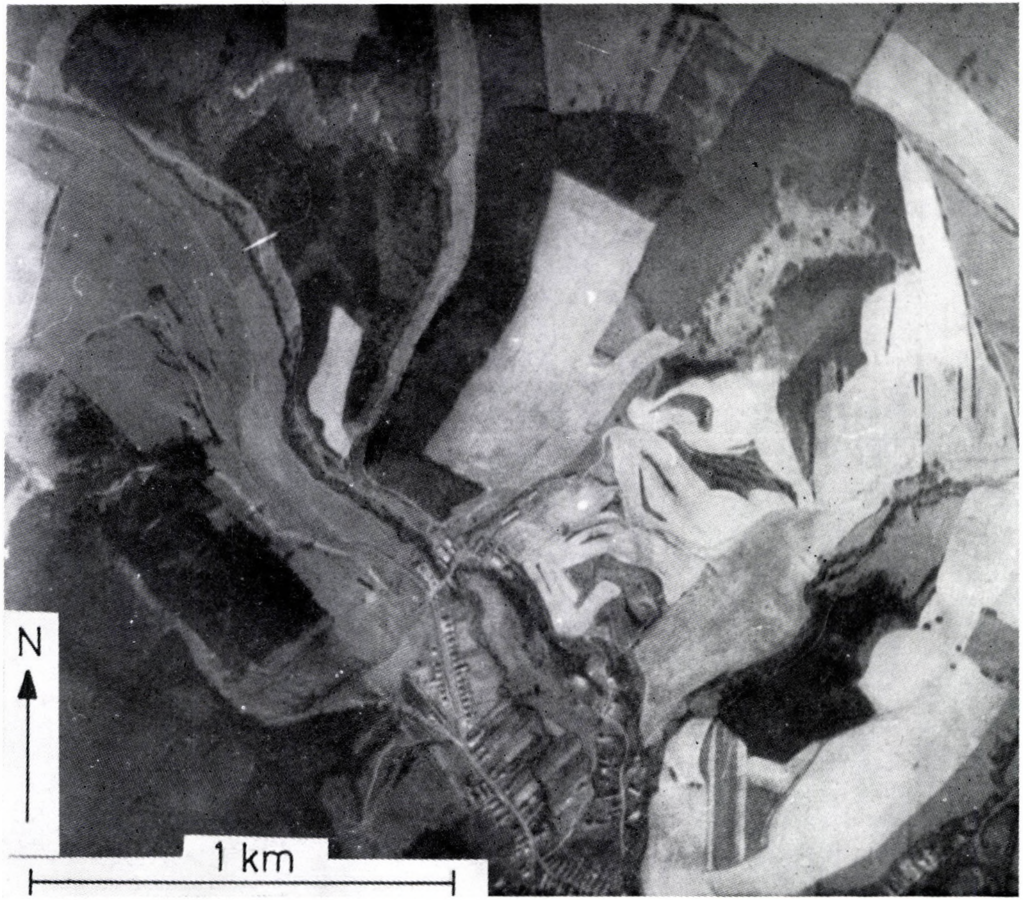

Fig. 4. Aerial photography of the rhyolite tuff volcano in the NW of Telkibánya

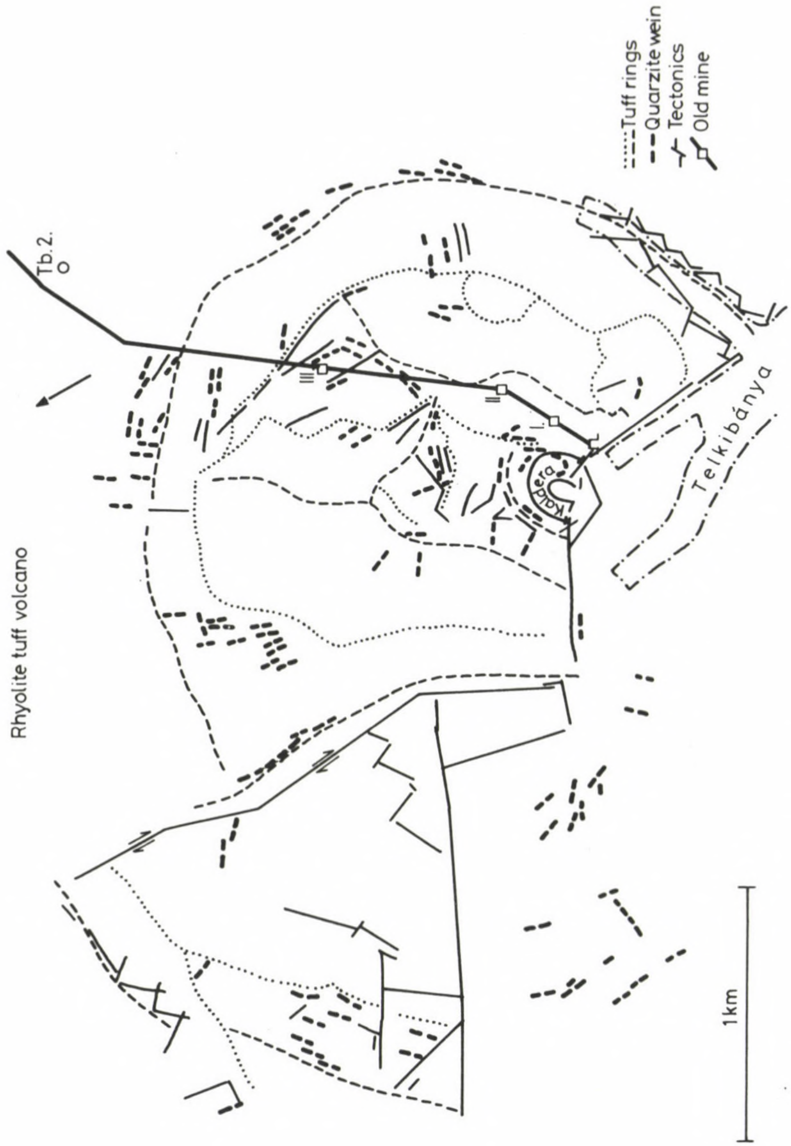

Fig. 3. Rhyolite tuff volcano in the NW of Telkibánya (J. Horváth–T.Fegyvári, T. Zelenka)

breccia with siliceous cementing material is found. Quartzite consists mainly of opal, chalcedony, and in some parts geyser cones surrounded by limnic quartzite zones with aquatic plant remnants can be found.

Tectonics: Structural displacements are along and across the rings. The western side of the ring was moved northwards by about 600 m.

2. Késed–Pányok

An andesite volcano is situated between these two villages, in the area of Lápishegy–Nagysátor.

Morphology: There is a whole circle, slightly open to the west, with a diameter of 1.75 km. There is an inner circle in its centre with a diameter of about 0.5 km. Ribs can be recognized in the outer side of the external ring.

Petrology: The extinct volcano consists mainly of pyroxene andesite, the underlying bed of which is andesite tuff. The andesite in the eastern side of the external ring is superpositioned on potassium-trachyte. The andesite of the external ring is lamellar and generally dips towards the eruption center. In the valley a hydrothermally altered quartz-veined propilitized pyroxene andesite surrounds the inner ring. The shape of the eruption center is oval with a diameter of 300–350 m and it consists of intact pyroxene andesite.

Tectonics: It has no characteristic tectonics.

3. Hollóháza-Májushegy

In this area an andesite volcano is situated.

Morphology: There is an external circle, with a diameter of nearly 2 km. A spike-shaped structure is intruded into the ring from the north. The diameter of the inner ring is 0.5 km, in the centre of which there is an eruption center with diameter of 100 m.

Petrology: The andesite volcano is superpositioned on Miocene clay, rhyolite tuff, and rhyolite. The inner ring consists mainly of amygdaloidal pyroxene andesite with breccia. In the centre and in other parts of the ring 200x100 m intact pyroxene andesite necks can be seen in the lamellar andesite. In the margin of the ring dips towards the centre. Red and green quartzite with ore traces, referring to hydrothermal activity can also be found.

Tectonics: The former volcanic area is intersected by a younger NW-SE structural line.

4. Hollóháza, Pálhegy, Ökörhegy

In this area a few small rhyolitic volcanic cones are situated.

Morphology: The central rhyolite cones of the Pálhegy, and 5–7 small independent-rhyolite cones east of it, can be recognized in a 2 km wide zone. The shape of these small cones is straight, oval or circular, and their size varies between 100 and 500 m.

Petrology: The cones consist of compact, lamellar rhyolite, with vesicular facies in the margins.

Tectonics: A large NW-SE structural line runs between the cones, along which in a length of about 6 km several rhyolite volcanoes can be recognized.

The geological structure of the rhyolite tuff volcano of Telkibánya

Morphology: Two and three tuff ring volcanoes can be found in 270° part of a circle with a radius of 1.5 km. First we recognized there with the help of aerial photos, and then during the field trips we verified our hypothesis.

The diameter of the central caldera of the tuff ring is 250 m. In the eastern side of it a 50 m wide inner cone can be recognized. The wall of the caldera is steep (approximately 40%). The horseshoe-shaped caldera is open to the South-West.

One internal and one external caldera tuff ring can be unambiguously reconstructed. Another external ring may have existed (on the western side), but it could not be proved unambiguously because its recognition is trouble some due to subsequent volcanic and tectonic movements.

The inner sides of tuff rings are steep, while the outer sides are flat, slightly crooked. In the area of the tuff rings harder stones than tuff can be found in concentric and radial thin strips, generally accompanied by lines of bushes.

Petrology: The main material of the tuff rings is white, unconsolidated, fine to coarse grained pumice rhyolite tuff with perlite- and rhyolite lapillis. The material seems to be sorted, it is probably the result of several eruptions and accumulated partly in water.

A hard and coarse pumice welded rhyolite tuff is superpositioned on the top of the second tuff ring, usually with remnants of winnowed and demolished pumice. Besides the two kinds of tuff, flowing vesicular rhyolite and andesite clast as well as neck breccia clast can be found in the area of the central caldera. The tuff volcano is permeated by 0.1–0.5 m wide hydroquartzite veins of radial and concentric structure. Besides these max. 0.5 m wide breccia of siliceous cementing material can be found. Their material derive mainly from the wall rock. The quartzite is grey-green and white, massive, sometimes slightly banded, and it consists mainly of opal-chalcedony. In some places small geyser cones are on the veins, which formed local limnoquartzite pits, with water-plant fossils. In the quartzite cinnabar referring to telethermal formation can be found.

Perlite blocks penetrate into the southeastern side of the external ring of the tuff volcano (Telkibánya-village). 2–5 m sized perlite sand benches are superpositioned among the flat dip tuff beds ($70/10^{0}$, $125/25^{0}$, $300/20^{0}$) next to the eruption centre. There are andesite tuff and andesite tuffite with fauna on the eastern side of the volcano. These may be the products of this volcano.

Tectonics: Structural displacements along and across the rings of the tuff volcano can be seen. These tend to show an echelon form, with repeating intersection of two structural lines, crossing each other.

In the south-western side the tuff volcano is cut by the stream bed of Ósva. The valley was generated by the fault tectonics of north-south and northwest-southeast fissures. The western external ring of the tuff volcano and the stream bed of Ósva were moved away northwards by about 600 m by the fault tectonics of fissures of N-S and NW-SE direction. This net slip was generated at the time of intrusion of the andesite of Pányoki Nagyhegy. The sketch map of the tuff volcano, made on the basis of aerial photos and controlled by field trips, is found in the Fig. 3.

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HYALOCLASTICS IN THE VALANGINIAN MARL OF LÁBATLAN-ÖRDÖGGÁT

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The material of sandy intercalations of the Valanginian Bersek Marl Formation were derived from the older Mesozoic strata in the southern-south-eastern foreground of the Cretaceous sea. Having studied the core samples of the Lábatlan-Ördöggát area the presence of volcanic material in the intercalations of the Valanginian marl could be determined. The presence of the altered volcanic glass of huge quantity, the hydratation altered state of the porphyric components, its replacement phenomena by calcite, the fragments and the spheroidal phenomena of the granular calcite as well as the geochemical data refer to redeposited hyaloclastics produced by submarine volcanism.

Keywords: Hyaloclastics, Valanginian, submarine volcanism

Introduction

The thin sandstone interbeddings of the Valanginian Bersek Marl Formation serving as raw material of cement production were previously interpreted as a result of different wave motion, on the basis of the marly detritus at the base of the strata. Recently, the redeposited-turbidite flow character of the Lower Cretaceous of the Gerecse Mountains has been already mentioned (Császár, G.–Haas, J., 1984).

Core samples of the boreholes L-14, L-15, L-22 and L-115 were studied out of the boreholes traversing the Valanginian Marl of the Lábatlan-Ördöggát region (Figs 1 and 2). Layer wedgings and lenticular and branching "sandstone" strata could be observed that seemed to be extraneous concerning their shape and material and sometimes showed sharp contours towards the marl (Plate I, 1-2-3). Their material obviously differs from that of the marl. At the edges contacting the marl an altered zone can be

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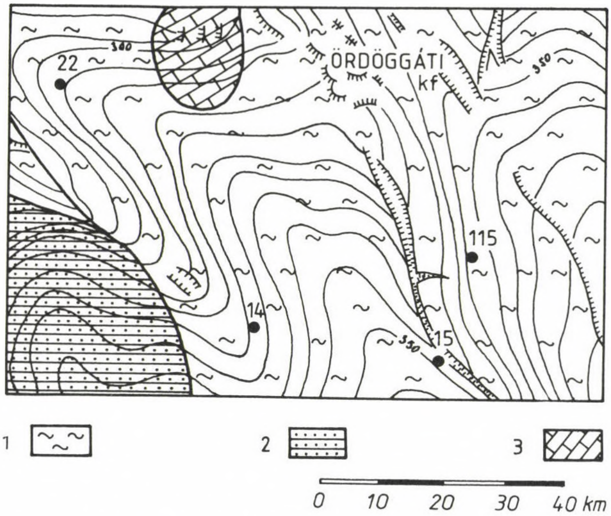


Fig. 1. Uncovered geological map of the Lábatlan-Ördöggát area (after the report of the Surveying and Soil Investigating Enterprise), with the boreholes studied. 1. Cretaceous marl; 2. Cretaceous sandstone; 3. Jurassic nodular ammonitic limestone

frequently observed while the central part of the lense is relatively intact (Plate I, 2). The grains of this material type occurring in these interbeddings can be found in fine-stratified form in the marl but these strata are often separated from the interbeddings of altered coat by a sharp contour and these do not form continuous transition towards the marl.

In harmony with the data of earlier geological references (Vadász, 1960) the detrital material in the Cretaceous sequence of the Transdanubian Midmountains derive from the older Mesozoic strata of the southern-southeastern foreground of the Cretaceous sea. Nevertheless, in the detritus of the Cretaceous sequence of the Mecsek Mountains volcanic material could be observed in addition to other types of detritus.

In the grain size fraction of less than 1 mm of the sandy interbeddings of the Valanginian marl of the Gerecse Mountains formerly only slightly rounded quartz and many chert grains were determined. The local green color of the interbeddings was attributed to the glauconite content. The detailed sedimentological investigations of Fülöp, J. (1958) did not prove the glauconite contents of the reddish and greyish-green so-called glauconitic marly sandstone of the Lábatlan Sandstone Formation of Hauterivian-Barremian age.

In the course of our investigations X-ray and DTA records were also

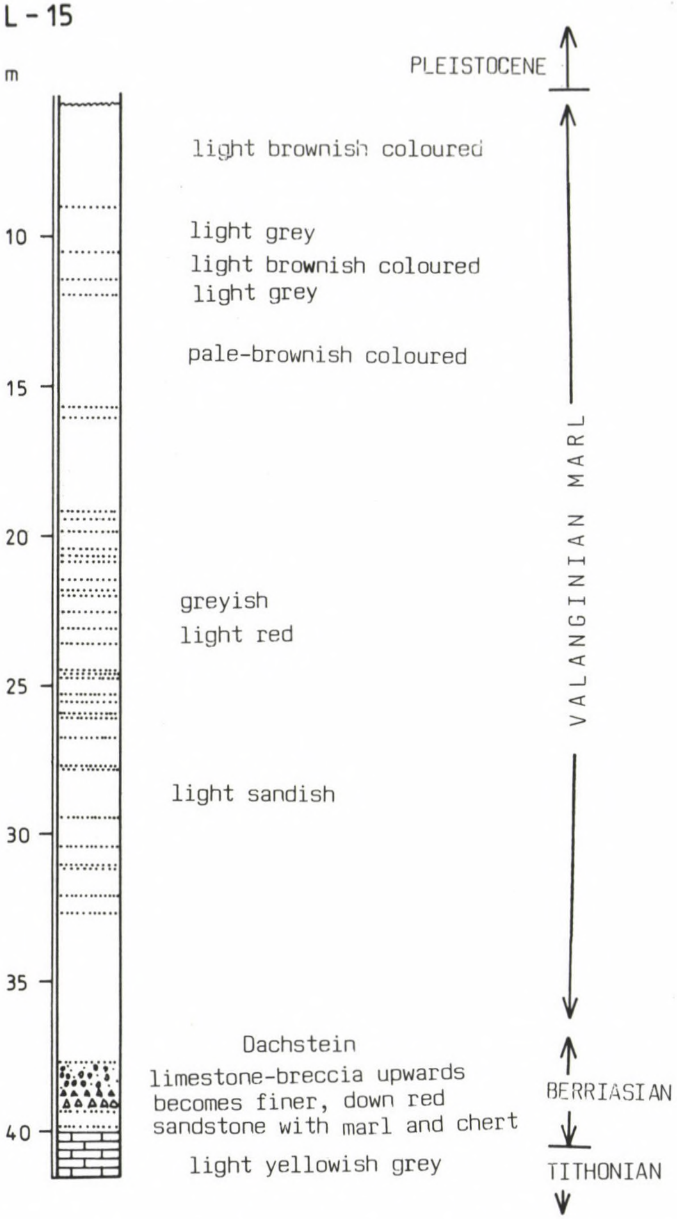


Fig. 2. The Valanginian marl of Lábatlan, with marking the coarser-grained interbeddings in the L-15 borehole (after the field records of Fülöp, J.)

made, but no glauconite could be determined in the Valanginian Bersek Marl. Having studied the thin sections of the sequence it was proved that the main part of the detrital material of the sandy interbeddings consists of the fresh and altered components of mafic volcanic material and of altered volcanic glass. The varied character of this formation is due to the ratio of the volcanic material to the carbonate content, to its grain size and distribution pattern in the carbonate material and to the structural changes developed in the course of interaction of the two substances.

Forms of joint occurrence of the carbonatic groundmass and of the volcanic material

The character and the traces of most intense interaction of the two substances can be observed in the microtextural picture of the coarse-grained intercalation found at 19.8 m of the borehole L-15. The yellowish-green to greenish-brown altered volcanic glass contacts the surrounding carbonate material by a limonitic reaction edge (Plate II, 1 and 2). The crystallization of the molten $CaCO_3$ often disintegrates the material of the volcanic glass that contains mosaic-likely the crystalline calcite material (Plate II, 3). Rounded probably diabase fragments containing acicular plagioclase laths also occur (Plate II, 4). In case of a part of the detrital grains cold-contact without reaction edge can be observed. The calcite material of the formation recrystallized only close to the volcanogenic material. Thus, the intermediary material consists of recrystallized calcite surrounding the volcanics and of fine-crystalline calcite farther of the volcanics. This type approaches best the requirements of the in-situ hyaloclastite. In most of interbeddings the non-recrystallized fine-crystalline calcite is disintegrated but displays an areal predominance as compared to the recrystallized calcite. The turbidite-like mixture of the oxidized les coarse-grained volcanic material and of the fine-crystalline calcite is characteristic of the limonitic sandy marl strata of the sequence. Carbonate recrystallization due to thermal effects cannot be observed here. In the foliated banked grey marl the very fine detritus (about 0.01 mm) is characteristic; it occurs in the non-recrystallized fine-crystalline calcite matrix in unoxidized and sparsely dispersed state and is of mixed origin.

Occurrence of the basic volcanic glass

The material of the greenish-brown rock glass of 0.1–0.5 mm diameter completely transformed into the radial-fibrous mixture of chlorite-montmorillonite of dark-grey interference colour. In the glass material concentric (Plate III/1) or parallel(Plate IV/1, 2), sometimes occasional main cooling cracks and adjoining secondary thinner cooling cracks are found (Plate III/2).

In case of the grains of 0.06–0.1 mm no cooling cracks can be observed, these contain occasionally some transverse cracks. Nevertheless, the well-defined mobilization elementary sequence and the rhythmic crystallization generated during the deposition conditions are characteristic (Plate III/3, 4). In case of the given grain size the phenomenon generated in rock glasses by vapour pressure and proved by experiments (Pesty, L. personal communication) is to be mentioned.

It is most probable that these small-sized volcanic glass fragments solidified immediately, just after getting the lime-mud and the complete cooling ended due to the vapour pressure of the environment. In harmony with the laws of thermodynamics the generation of the crystalline phasis realized in a step-by-step way. The contaminating ions that cannot enter the lattice are expelled (main the iron) and these consitute the mobilization elementary sequence subsequent to the zonel crystallization. A typical evidence of this process is the marginal chlorite zone consisting of parallel fibres perpendicular of the surface (Plate III/3, 4).

Porphyric components and their alterations

In the thin section of the coarse-grained interbedding in a depth of 19.8 m of the borehole L-15 purple isotropic grains are found in the material of the basic rock glass clasts (Plate IV/1, 2). Their occurrence is not frequent in the sequence but their mineral and trace element compositions may have genetic value concerning the volcanic material. According to the emission spectrographic data, in presence of the mineral the Cr-content and not the Ti-content increase. Thus, these may be Al-chromite grains of abyssal origin. The phenomenon of replacement can also be observed. The augite and plagioclase of the volcanic material are replaced by calcite. The calcium and magnesium taken up previously by the volcanic material but that cannot enter the early crystallizing minerals precipitate in form of calcite (dolomite) and partially replace the earlier crystallized minerals (Plate IV/3, 4).

The precipitated plagioclases display hydratation phenomena. The spot-like clay mineralization and chloritization of the sometimes idiomorphic plagioclases are frequent phenomena (Plate V/1, 2). Radial-fibrous areas occur within the porphyric components (Plate V/3, 4). The fact that the clay mineralization of the plagioclases is of restricted measure refers to low heat reserves of the lavas here. It cooled rapidly before the hydratation phenomena could progressively proceed.

Spheroidal phenomena

The spheroidal phenomena are not so frequent and not so conspicuous as experienced in the sequences produced by submarine volcanism in general, but occur. Spheroidal volcanic fragments (Plate VI/1, 2, 3) as well as the spheroid-formation and spheroidal recrystallization of the fine-crystalline calcite can be observed in the contact zone of the volcanic material and of the fine-crystalline calcite (Plate VI/4).

Mineralogical-petrological and geochemical results

The results of X-ray diffractometric analyses are found in Table I. It is seen that considerable amounts of montmorillonite (3 or 27%) and chlorite could be detected.

In the formation only small amounts of detrital heavy minerals are found, only Al-chromite occurs in greater amounts. This is represented by splints of sharp edges, fragments, sometimes by octahedra. Occasionally some strongly rounded garnets also occur. Augite related to the volcanic material is also frequent. Tremolite-actinolite as heavy minerals generated by contact effect are the most characteristic ones.

About 80% of the heavy and light fractions consists of detritus with iron hydroxide. In the light fraction the idiomorphic plagioclases of altered internal structure are frequent.

The Cr-content of the coarse-grained interbeddings is mostly higher by one line intensity grade than in the marl. In 19.8 m of the L-15 borehole it is 1600 ppm that is evidenced by the presence of purple Al-chromite of deep origin relating to abyssal mafic-ultramafic rocks. The average trace element content found in the boreholes is shown in Table II.

Table I

Results of X-ray diffractometric analyses (minerals in %)

Lábatlan	montmorillonite	illite	kaolinite	chlorite	quartz	plagioclase	calcite
L-14 27.6 m	27	6		8	8	11	40
L-15 26.6 m	20			7	14	13	46
L-22 35.6 m	12	11		10	15	9	43
L-22 45.0 m	3	10		6	10	4	67
L-22 72.0 m	4	9		6	9	3	69
L-22 74.0 m	20	9	9		16	6	40
L-22 80.0 m	15	8	6		11	8	52
L-22 83.5 m	13				11	2	74
L-22 88.5 m	31	9	5		12	8	35
L-22 89.0 m	8	10	5		8	7	42

Analyst: Mrs. Juhász, Mrs. Peiker, I. Viczián; X-ray Laboratory of the Hungarian Geological Survey

Table II

Average trace element values in ppm in the sequence of the Bersek Valanginian Marl (Lábatlan)

	Sedimentary averages after Vinogradov ppm	Average values of trace elements in ppm			
		L-22 27	L-115 30	L-14 12	L-15 9
B	100	11.4	17.6	32.8	37.2
Sr	450	459.2	666.7	377.8	365.0
Ba	800	214.4	108.3	212.5	365.5
Ga	30	20.4	10.0	25.5	15.0
Pb	20	28.6	10.2	33.8	24.5
Zn	100	81.8	198.0	95.0	115.5
Cu	57	86.7	58.8	195.1	155.5
Ni	95	87.8	189.7	165.0	83.7
Co	20	34.0	23.8	51.7	34.8
Mn	670	1096.2	816.7	883.3	933.3
Cr	100	101.2	129.5	157.5	309.5
V	130	56.0	81.8	83.3	47.2

Analyst: Gy. Muraközy; Geological Research Team at the Dept. of Geology; Eötvös Loránd University; Budapest

In harmony with the data, the Ni-content of the sample from the borehole L-115 containing highest values of thalassophile elements is the highest and this relates not to volcanic material of terrestrial origin but rather to submarine volcanism. Probably the boreholes L-15 and L-115 lie closest to the locality of the volcanic eruption.

Comparison was made between the samples taken from Lower Cretaceous sequence of the Mecsek Mountains containing basic alkali diabase volcanic members of remarkable thickness and the Valanginian marl found in the Lábatlan boreholes concerning the concentration values of their chemical components. The relationship of the elements versus the Si-content was illustrated in diagrams.

It is fairly well demonstrated in the figures that the range of the Valaginian marl of the Lábatlan boreholes is separated in case of all elements from the range observed in the Mecsek Mountains but it is also characteristic that the ranges displaying not so remarkable overlapping (that changes by elements) practically keep on with each other. The range of the separately marked hyaloclastics of the Mecsek Mountains is a consequent continuation of the range of the Valanginian marl of Lábatlan towards the diabase rocks (Figs 3–8).

The dispersion of elements as a function of the silicon content is different in the different rock composition ranges and this provides further data.

The FeO and TiO_2 ranges of the Valanginian marl of Lábatlan fall towards the lower concentrations as compared to the Mecsek diabases of same silica concentrations (Figs 3–4). The area of the two ranges only contact each other. The range of hyaloclastics of the Mecsek Mountains, similarly though less than the Valanginian marl is lower in case of the two elements. This element distribution evidences the fact that Fe^{2+} and Ti^{4+} are related to minerals of high specific gravity (mainly to magnetite and ilmenite) that are partly missing in the hyaloclastics of Lábatlan.

In case of alumina the overlap and area of dispersion are of transitional character (Fig. 5).

The similarity is greatest in the overlapping and area of dispersion in case of the MgO and Fe_2O_3 (Figs 6–7). The iron hydroxide precipitating close to the volcanic crater is transported far by the water flows and is distributed evenly in the loose sediment. Mg^{2+} is transported partly in dissolved state, partly by the lamellar chlorites.

Concerning the CaO-contents, the range of the Valanginian marl of

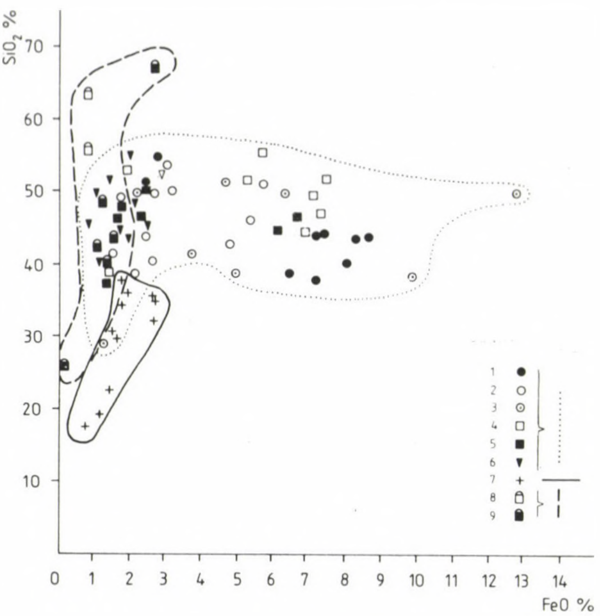


Fig. 3. FeO vs. SiO_2 in percent comparing the Lower Cretaceous of the Mecsek Mountains and the Valanginian marl of Lábatlan. 1. Komló I; 2. Komló II; 3. Komló III; 4. Márévár-valley; 5. Jánosi-puszta; 6. Magyaregregy (1-6: Lower Cretaceous diabase of the Mecsek Mountains); 7. Lábatlan, Valanginian hyaloclastite-bearing marl; 8. hyaloclastite, Márévár-valley; 9. hyaloclastite; Jánosi-puszta (8-9: Lower Cretaceous hyaloclastite of the Mecsek Mountains). Data from the Mecsek Mountains were used after the Ph.D theses of Bilik, I. (1979)

Lábatlan is the straight continuation of the Lower Cretaceous formations of the Mecsek Mountains towards the higher CaO-concentrations (Figs 8a, 8b).

The results and comparison of the chemical analyses support our statement that the coarse-grained interbeddings of the Valanginian marl of Lábatlan are interpreted as marginal hyaloclastics.

Formation possibilities of the sequence

The submarine erosion close to the marginal part of the submarine lava eruption is the most probable possibility for the formation of the coarse-grained interbeddings of cm to max. dm size found in the Bersek Marl sequence of Valanginian age traversed by the Lábatlan boreholes. That is, in most cases redeposited hyaloclastics are in question. This is proved by the small thickness of the strata, by the sparse presence of spheroids and

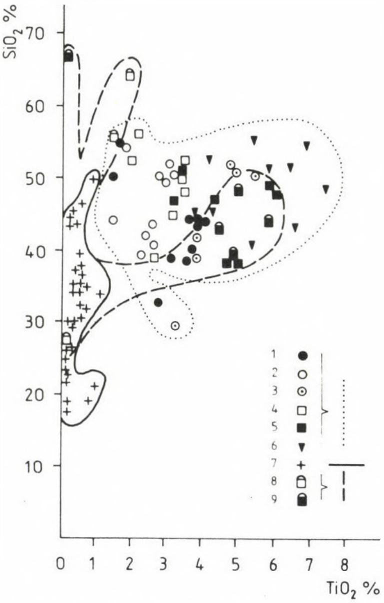


Fig. 4. TiO$_2$ vs. SiO$_2$ in percent comparing the Lower Cretaceous of the Mecsek Mountains and the Valanginian marl of Lábatlan. For explanation see Fig. 3

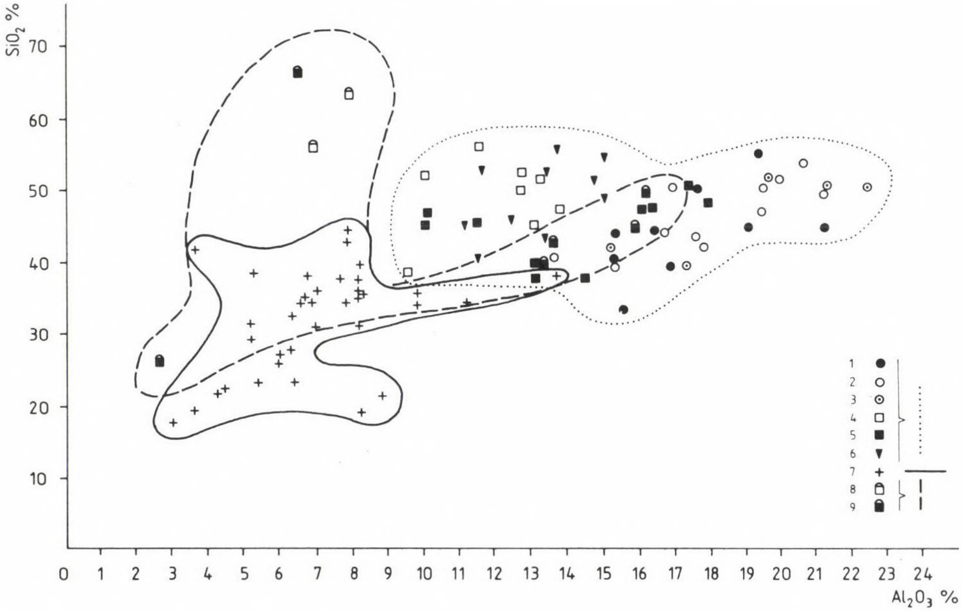
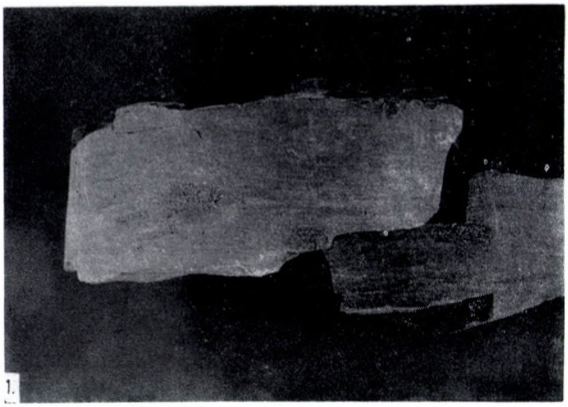


Fig. 5. Alumina vs. silica in percent comparing the Lower Cretaceous of the Mecsek Mountains and the Valanginian marl of Lábatlan

Plate I



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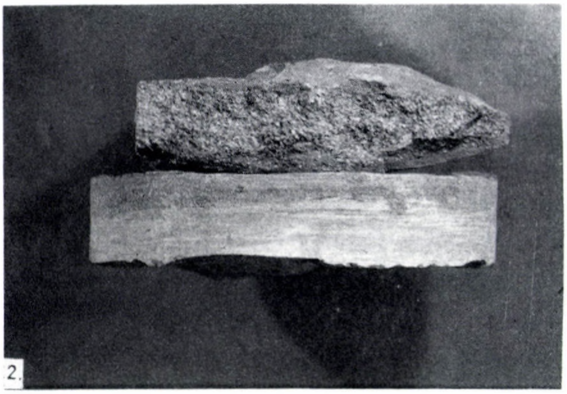

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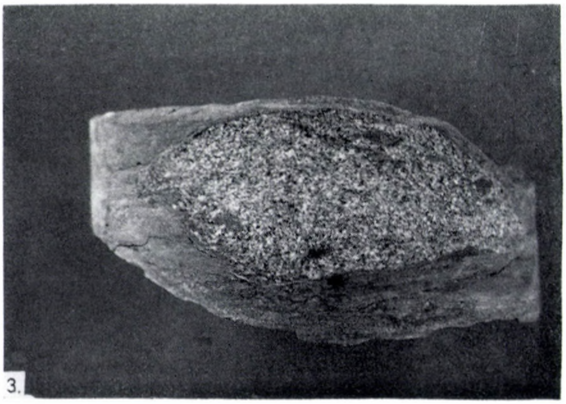

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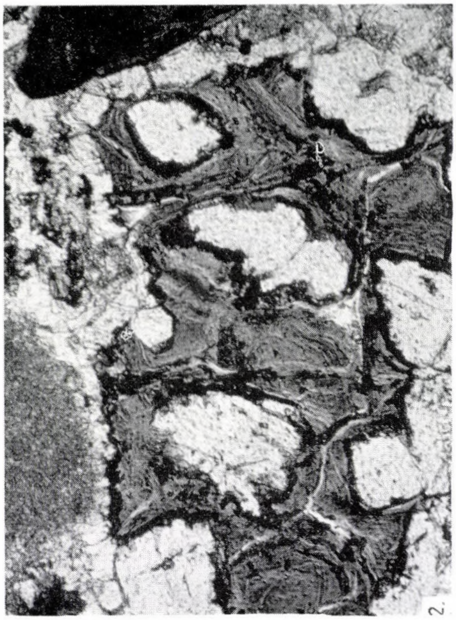
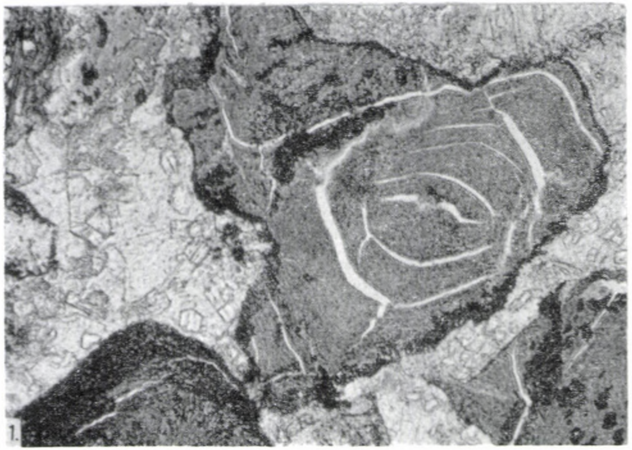


Plate III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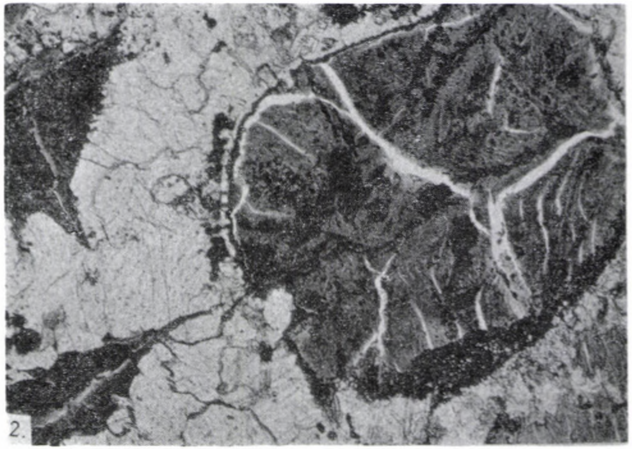
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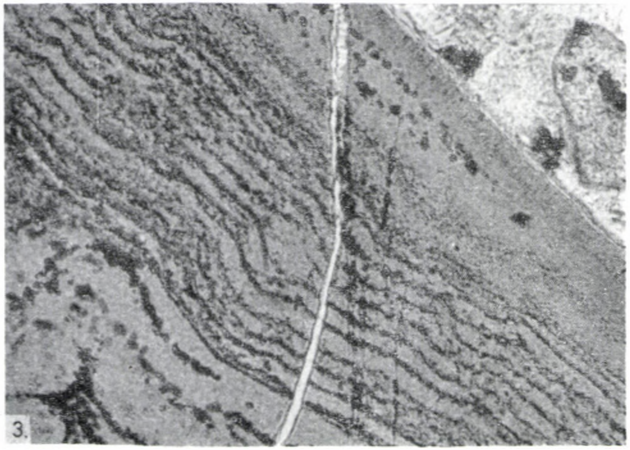
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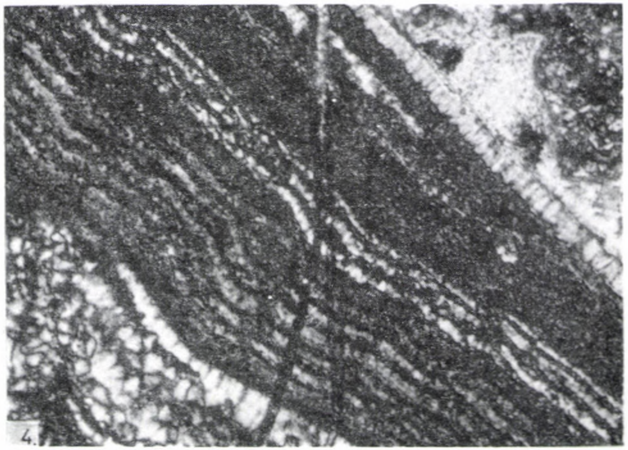
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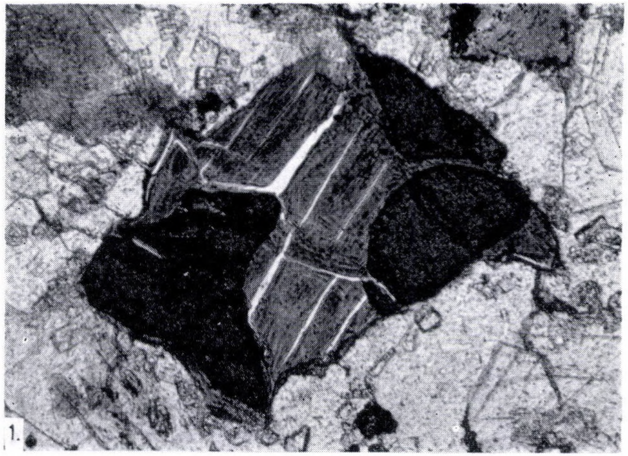
Plate IV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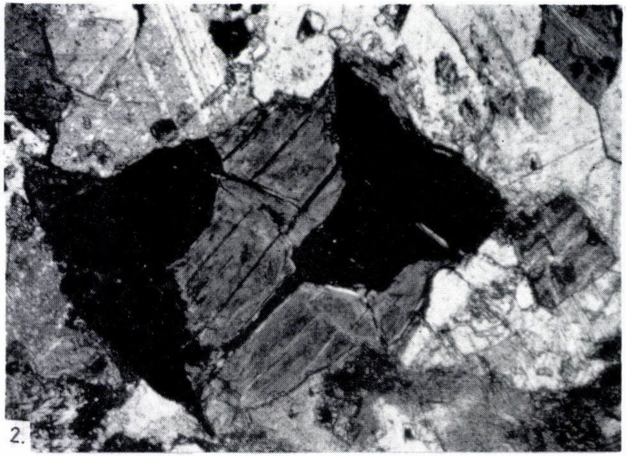
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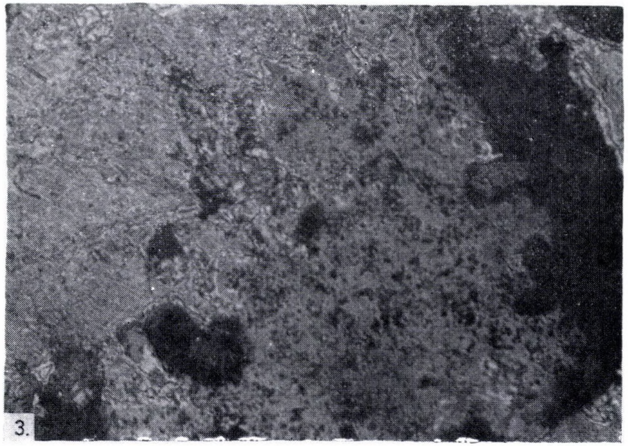
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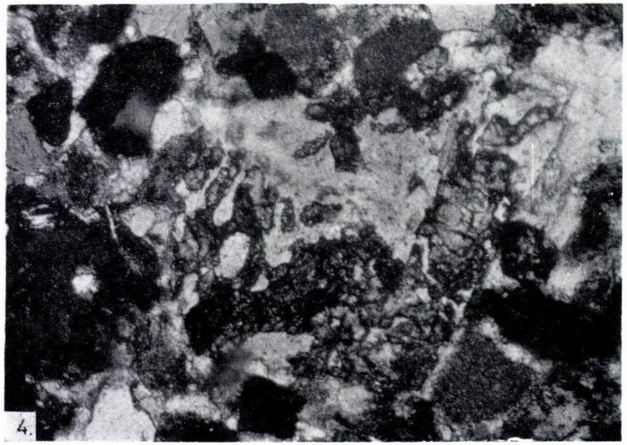
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Plate V


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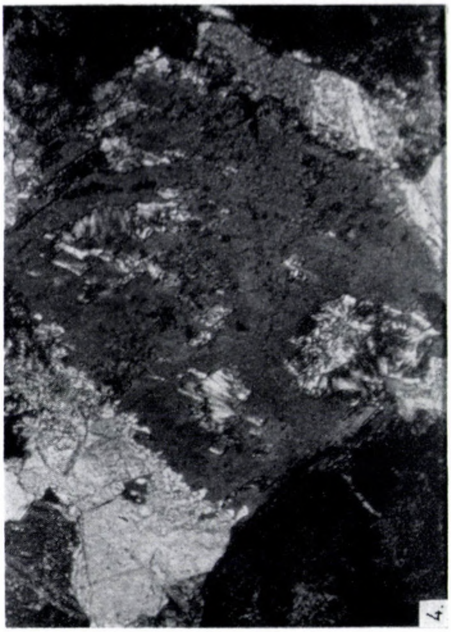
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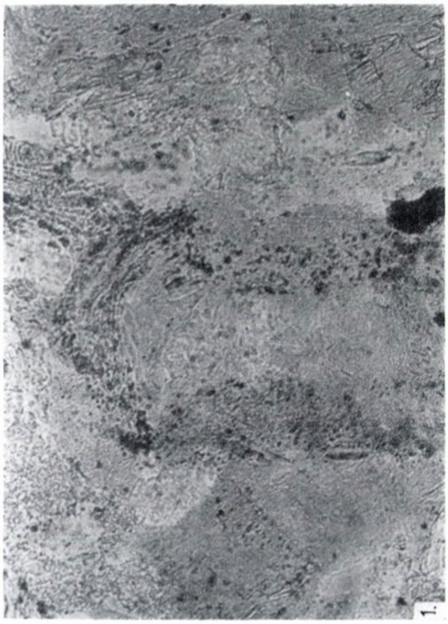
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Plate VI

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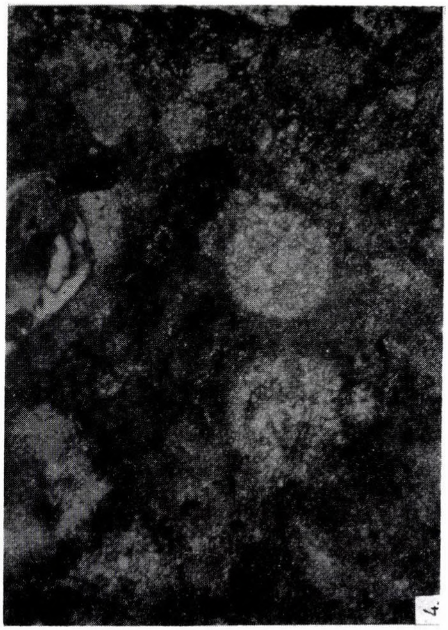

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Plate I

1. Coarse-grained hyaloclastite blocks imbedded in the Valanginian marl. L-15 borehole, core sample from 16.1 m
2. Coarse-grained hyaloclastite lense in the Valanginian marl. L-15 borehole, core sample from 19.8 m
3. Coarse-grained redeposited hyaloclastite interbedding with plastically reworked marl pieces. L-15 borehole, core sample from 35.3 m

Plate II

1. Altered limonitized volcanic glass, with fissure filling branches in the recrystallized carbonate matrix and with cooling cracks. L-15 borehole, core sample from 19.8 m, M = 160X
2. Altered volcanic glass, it contacts the carbonate matric with a limonitic reaction edge, the surrounded carbonate material is not dissolved. L-15 borehole, core sample from 19.8 m, M = 240X
3. The crystallizing carbonate material disintegrates the volcanic matter. L-15 borehole, core sample from 19.8 m, +N, M = 420X
4. Rounded diabase fragment with lamellar-acicular plagioclases. L-15 borehole, core sample from 19.8 m, M = 80X

Plate III

1. Altered volcanic glass with thin limonitic reaction rim and with concentric cooling cracks. L-15 borehole, core sample from 19.8 m, M = 240X
2. Altered volcanic glass with thin limonitic reaction rim and with random primary and secondary cooling cracks. L-15 borehole, core sample from 19.8 m, M = 120X
3. Volcanic glass detritus altered by rhythmic crystallization, with mobilization element series. L-15 borehole, core sample from 19.8 m, M = 300X
4. The same as under 3, but +N

Plate IV

1. Altered volcanic glass with cooling cracks; it contains purple Al-chromite. L-15 borehole, core sample from 19.8 m, M = 300X
2. The same as under 1, but +N
3. Replacement phenomenon: Calcite replaces the earlier crystallized plagioclase. L-14 borehole, core sample from 35.7 m, +N, M = 300X

Plate V

1. Idiomorphic plagioclase of partly altered internal structure, with inclusions following the edges and generated by vapour pressure. L-14 borehole, core sample from 29.6 m, M = 160X
2. Idiomorphic zoned plagioclase of partly altered internal structure. L-22 borehole, core sample from 90.7 m, +N, M = 180X
3. The same as under 1, but +N
4. Replacement phenomenon and the internal alteration of plagioclase plate due to vapour pressure, in the same grain. Clay mineral pockets with radial structure. L-14 borehole, core sample from 35.4 m, +N, M = 240X

Plate VI

1. Spherolite structure in volcanic detritus. L-22 borehole, core sample from 82.5 m, M = 300X
2. The same as under 1, but +N
3. Volcanic detritus with spherolitic structure in the carbonate matrix. L-14 borehole, core sample from 35.0 m, M = 300X
4. Spherolitized carbonate matrix with plagioclase fragments. L-14 borehole, core sample from 39.9 m, M = 300X

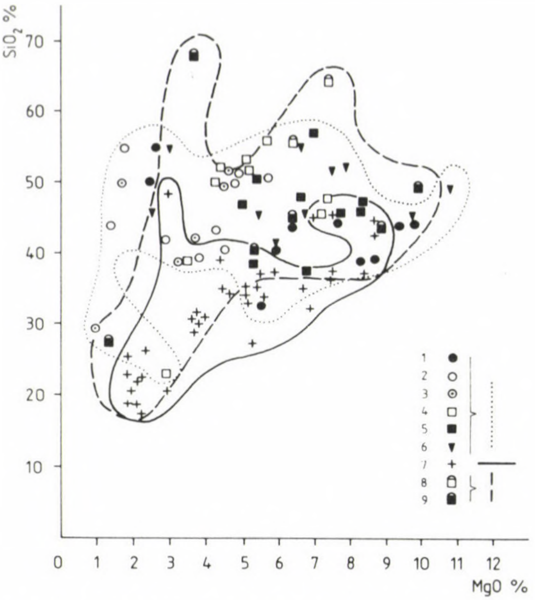

Fig. 6. MgO vs. silica in percent comparing the Lower Cretaceous of the Mecsek Mountains and the Valanginian marl of Lábatlan

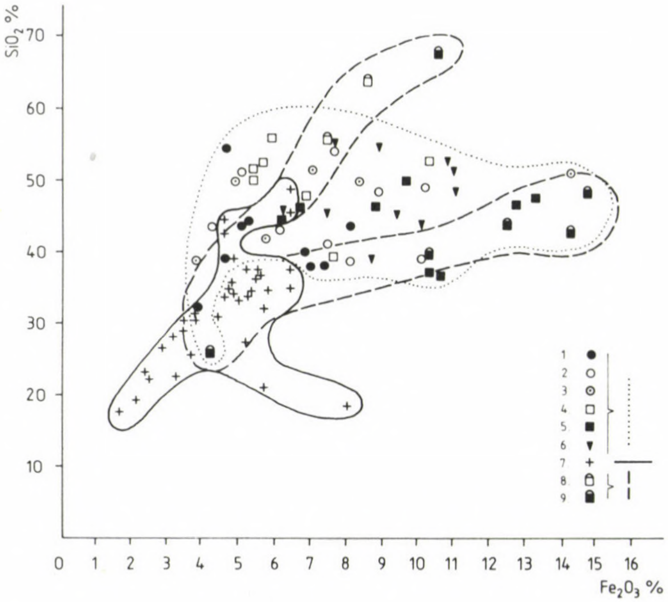

Fig. 7. Fe$_2$O$_3$ vs. silica in percent comparing the Lower Cretaceous of the Mecsek Mountains and the Valanginian marl of Lábatlan

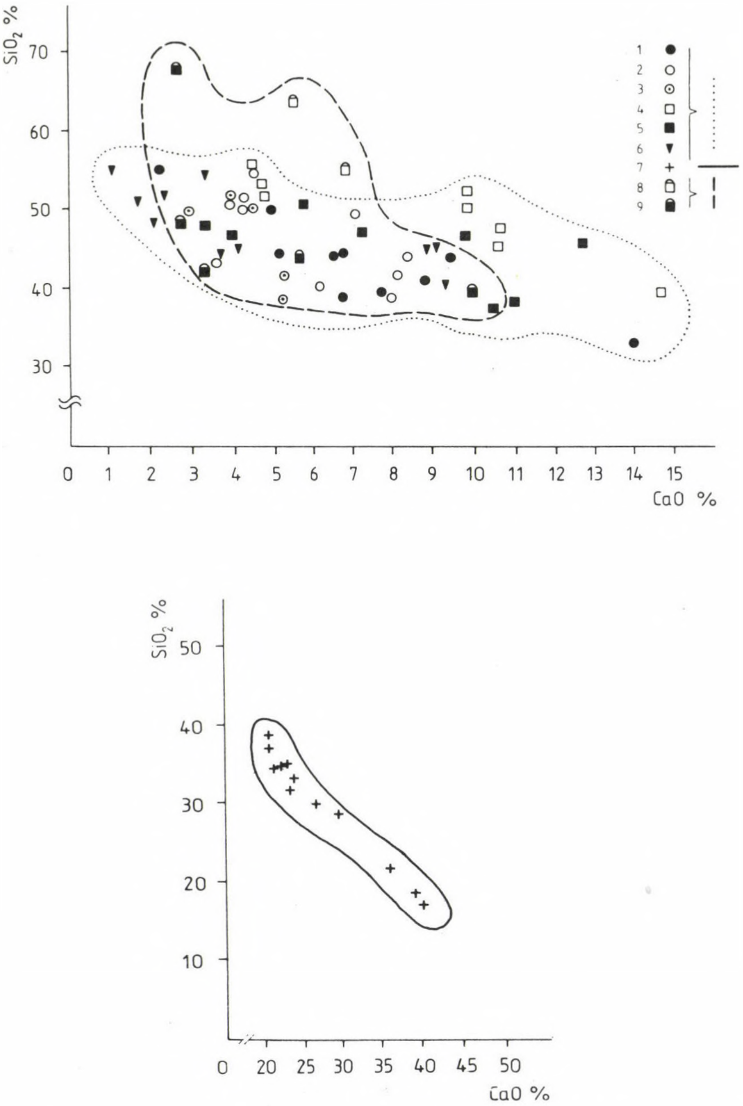

Fig. 8. a-b. CaO vs. silica in percent comparing the Lower Cretaceous of the Mecsek Mountains and the Valanginian marl of Lábatlan

by the often reaction-rim-free cold contact of the fragments and porphyric components with the surrounding rocks.

Calcite formation at the expense of porphyric components as well as the presence of calcite-bearing pockets presume a thermal effect that occasionally dissolved the carbonate material.

Bilik, I. (1979) in his Ph.D. theses mentioned similar grains found in the sedimentary sequence containing Lower Cretaceous volcanics in the Mecsek Mountains and which may derive from the erosion of the surface of a submarine height built up by a submarine eruption series and which are interbedded in the carbonate sequence.

North of Hungary in Slovakia is known the picritic type, in the Hron-valley, among the alkali mafics and ultramafics found in the NE-SW megatectonic zone (Kubovics, I., 1985).

Based on stratigraphic and micromineralogical investigations (Decker, K. et al., 1987) first of all paleogeographic relation can be supposed between the Lower Cretaceous sequence of the Gerecse Mountains and the Austrian North-Alpine Rossfeld-strata. The volcanic matter content, however, nas not been studied comparatively yet, this is planned to be carried out in the next years.

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USE OF WELL-LOGS IN BASIN ANALYSIS

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Basin analysis, an exploration method which follows the process of hydrocarbon genesis with the help of reconstruction of the events in time and space, searches for the answer to the question of perspectivity. On the basis of reconstruction theory the entire process of hydrocarbon genesis can only be followed by the co-ordinated work of the different exploring professional branches such as geology, seismics, well logging and geochemistry. Analysis and processing of well-logs help to answer different questions of the reconstruction of basin evolution. By using the data calculated from well-logs together with other test results, the potential source rocks, their location in space, the possible directions and paths of hydrocarbon migration and the expected accumulation places can be determined.

This paper provides a short review on the calculation method of the parameters from well-logs, way of using, the results obtained so far, and on some conclusions drawn from the results.

Keywords: Well-log, basin-analysis, hydrocarbon prospection

1. Introduction

Hydrocarbon reservoirs for exploration are expected to be in more and more difficult geological conditions, so beside finding structures, uses of other indirect research methods are also needed.

The research method following the process of hydrocarbon genesis, taking use of geological geochemical, hydrodynamic and thermodynamic data, by building up relations among subprocesses, and with the help of reconstruction of the processes both in time and space, looks for the answer to the question of perspectivity.

Differentiation of lithogenetic units in Neogene formations makes more precise the geological model of perspective hydrocarbon exploration. Seismic correlation of the units results in depth and thickness map series on pelitic and psammitic complexes and makes possible the regional identification of source rocks and formations allowing migration.

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The core-analysis, the continuous petrophysical parameters from well-log data, the analysis of the pore pressure are results to be used in the exploration with reconstruction aspect.

On the basis of the reconstruction concept, the whole process of the hydrocarbon genesis can be explored only by the coordinated work of geology, seismics, borehole geophysics and geochemistry.

Analyzing and processing the well-logs and other data enable us to answer different questions of the reconstruction of basin evolution:

— The lithogenetic differentation of sequences on the basis of lithological trend analysis makes more precise geological model of genetic reconstruction.

— Continuous temperature measurements and analysis of data measured at bottomhole, help to reconstruct recent' temperature conditions and temperature history of the basin.

— History of compaction and subsidence can be determined by using porosity vs. depth relations derived from well-logs.

— Pore pressure curves can be used to make up geological-technical projects, to describe the hydrodynamic conditions and to construct pressure maps.

— From the data of subsidence history, former depth and thickness maps can be constructed, and by their help, paleo-pore pressure logs can be computed from pore-pressure logs.

— Having paleo-pore pressure values, the former hydrodynamic conditions and the development of pressure barriers can be reconstructed.

Using the above mentioned data and other test results, potential source rocks and their location in space can be determined. Possible directions and pathways of hydrocarbon migration and the expected places of accumulation can also be marked.

2. Plots of lithological trend curves and determining lithogenetic units

The basis of plotting lithological trend curves is the fact that, the chosen rock types can be selected and grouped reliably by the well log analysis.

A Tertiary formation in the Pannonian basin consists of pelitic (shale, marl, siltstone and their mixture), psammitic (sand and sandstone), constituents and subordinately gravel (conglomerate, sandy gravel) rocks.

Analyzing the logs, two groups of rocks can be separated: pelitic and psammitic.

The pelitic and psammitic formations can be separated by the primary characteristics on the well-logs (micrjudge, spontaneous potential, gamma ray, borehole diameter, etc.) as well as the formation parameters (shale content, total porosity, effective porosity).

Interpretation and presentation of data are based on the fact that the filling of basins subsided at different degrees in space and time, took place according to certain rules.The essential change in basin evolution is the consequence of the basic changes of paleo-geography, so it is reflected in lithological changes.

Such interpretation and presentation processes are used that stress the essential, trend-like feature of the change, following the process of sedimentation (Fig. 1).

On the basis of trend curves, the intervals of the same trend — so-called lithogenetic units — can be marked (Fig. 2).

Following the lithological trend intervals in horizontal direction, the lithogenetic units can be identified (Fig. 3). Between distant boreholes, seismiclogs can be used to follow the trend intervals.

3. Calculation methods of porosity logs from different available well-logs

Physical properties of rocks affect the genetic processes. The parameters which can be obtained from well-logs, are most suitable to the petrophysical—physical characterization of Neogene sedimentary complexes filling the basins (Great Plain, Hungary).

Well-logs provide continuous information from the entire length of the borehole: as against to other measuring methods which can be considered station-like ones, e.g.: measurements carried out on core samples etc. So it is advisable to use the information from well-logs in largest extent possible. In order to make hydrocarbon prognosis for the Great Hungarian Plain basins and to solve the reconstructional problems, methods to determine the porosity values from different available well-logs for pelitic and psammitic formations — for the longest possible intervals — and their graphic presentation were elaborated.

To make the porosity logs from well-logs, it should be taken into

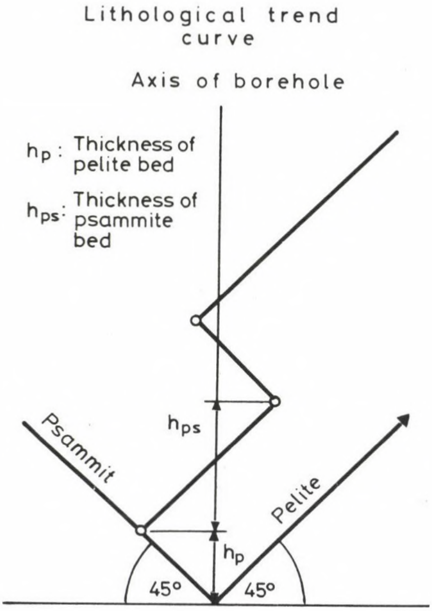

Fig. 1. Presentation principle of the lithological trend curve

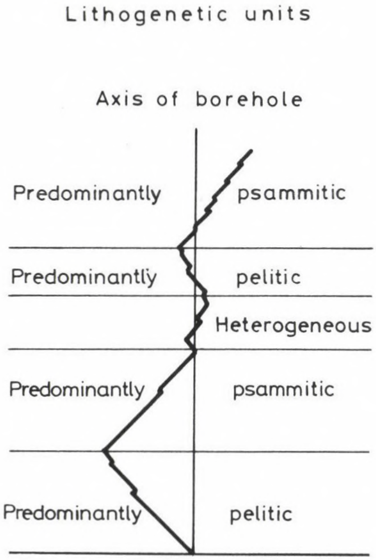

Fig. 2. Marking the lithogenetic units on trend curves

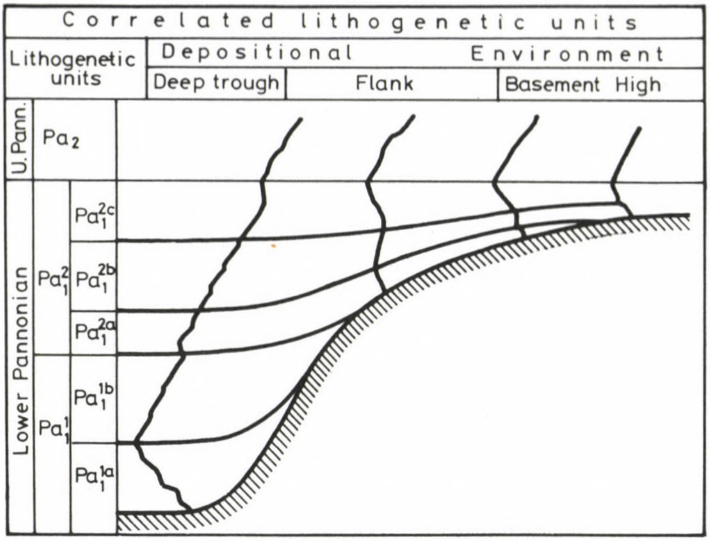

Fig. 3. Correlated lithogenetic units along an idealized basin profile

consideration that different intervals of boreholes are logged in different degrees. The upper layers considered nonproductive (from the point of view of hydrocarbon contents) are logged only in minimum degree, for informative purposes. Logging suit to be run along the reservoir intervals corresponds to the available logs at the time of drilling. After checking the available logs, it is evident that the estimation of porosity for the longest possible intervals of the borehole can first be made by using resistivity logs. Obviously, when other porosity logs were measured these were used to calculation of porosity.

By using a computer program, written for porosity calculation, there is a possibility of computation and presentation of total porosity (FI), effective porosity (FIE) and shale content (VSH).

The relation between depth and porosity is plotted on a semi-log paper versus depth – separately for shale and sand layers – considering that normal compaction is described by an exponential function. An exponential function (which is linear on the logarithmic porosity scale) is suited to the calculated data range of porosity. The porosity vs. depth relation of the shale and sand layers in a Great Plain borehole, is shown in Fig. 4, where:

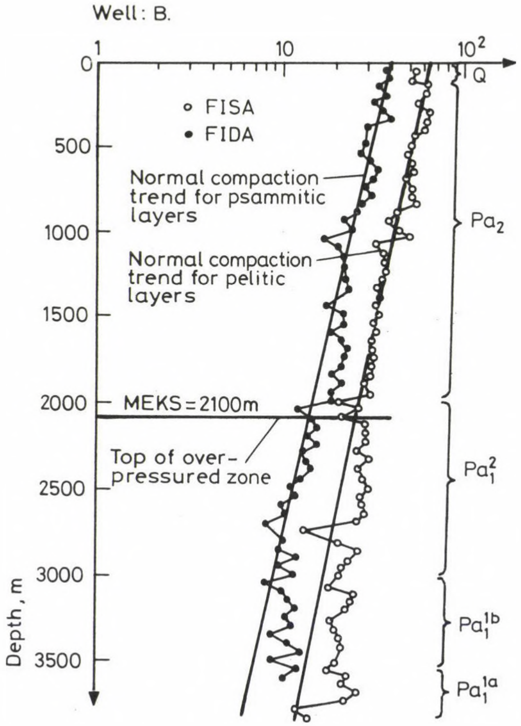

Fig. 4. Porosity vs. depth relation for pelitic and psammitic layers in well "B"

FISA – the total shale porosity,

FIDA – the effective sand porosity.

To check the porosity results calculated from resistivity logs and to compare these with those obtained from the porosity well-logs, data from two boreholes were processed by the log evaluating program package of the Energy Systems program, on a VAX-11/780 computer. Pelitic porosities, calculated from the porosity well-logs measured in the well "B", versus depth are shown in Fig. 5, where:

FISAAT – porosity of pelitic layers calculated from acoustic logs

FISADE – porosity of pelitic layers calculated from density logs.

On the basis of comparison and analysis of the results calculated from porosity and resistivity logs, conclusions listed below can be made:

– comparing the pelitic porosities calculated from acoustic travel time and density logs (Fig. 5) with the porosities (Fig. 4) coming from

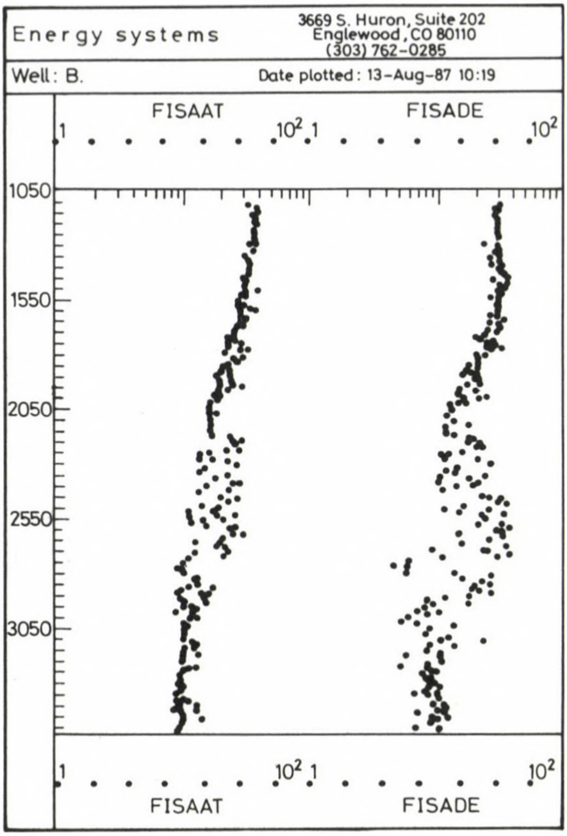

Fig. 5. Pelitic porosity vs. depth relationship derived from porosity logs in well "B"

resistivity logs, it can be stated that their shape is quite similar, the isolation depth is at about 2100 m, and there is a depletion on each logs between 2750–2800 m,

– normal compaction trend can be established on porosity logs, i.e. the intervals of hydrostatic and overpressured zones can be marked,

– porosity values obtained from resistivity logs, are similar to those calculated from porosity well-logs over 3000 m, but below this depth these give higher values.

Summarizing the above mentioned facts, it can be stated that the trends derived from resistivity logs are suitable to find undercompacted

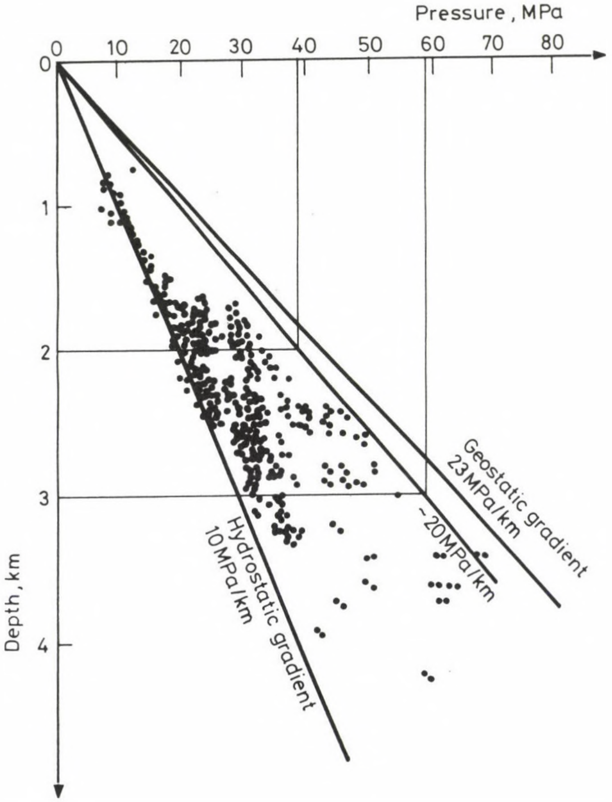

Fig. 6. Distribution of pressure data vs. depth coming from hydrocarbon exploratory boreholes in the Great Plain

zones but using porosity well-logs results in more accurate and reliable porosity values.

4. Determination of pore-pressure for shale and sand layers

In the process of deposition, the increasing overburden generates a hydraulic gradient while it compacts the matrix of rock and reduces the porosity. In the case of normal compaction, the change of shale porosity vs. depth is regular and there is usually a linear relationship between the logarithm of porosity and the depth of layers. In the case of restricted (non equilibrium) compaction, the pore fluids bear one part of overburden because of the restricted filtration of pore-fluids. Anomalously high porosity values represent the high pore-pressures, so-called overpressures.

Distribution and values of overpressure are shown by the pressure values measured during completion operation (Fig. 6).

When determining the pore-pressures, the starting point is that the "causes of Great Plain overpressures can be conducted back to the effect of geostatic weight following the isolation", i.e. in possession of the recent porosities and the normal compaction trend, the values of pore-pressures can be estimated by the following equation:

$$PFI = PGRH \times MEE + PGRBU \times (ME - MEE),$$

where:

PFI – pore-pressure
ME – recent depth of the layer
MEE – depth of isolation
PGRH – hydrostatic pressure gradient
PGRBU – geostatic pressure gradient

If aquathermal effect also existed besides the restricted compaction, then the sum of geostatic and aquathermal pressure gradient must be taken into consideration.

From the calculated values, the pore-pressure profile of each well can be plotted on the desired depth scale, separately for pelitic and psammitic layers.

The porosity profile, calculated for both types of rocks has the following importance:

- the profile of the pelitic and psammitic porosity or the profile of pore pressure have often the same shape,
- so it gives help to establish the normal compaction trend of pelite, in sandy intervals and that of psammite in shaly intervals,
- the determination of overpressure is more reliable when the normal compaction trend is confirmed by the data derived for both types of rock,
- in the upper intervals of the boreholes, the calculated data indicate slightly overpressured shale layers besides the hydrostatic sand beds.

5. Determination and presentation of the subsidence history, on the basis of reconstructed original thicknesses

The possibility of subsidence history reconstruction is based on the principle that the solid material volume of rocks has not changed after deposition. Since the thickness of layers is determined by their solid material content and porosity, therefore once the compaction trend (change of porosity vs. depth) of shales and sands is determined, then knowing the depth (ME), the solid material content (VSZ) and the shale content (VSH), the actual thickness (HL) of almost homogeneous layers of shale-sand sequences can be reconstructed.

This reconstruction cannot be made for shales and sands separately because these layers overlapped each other, and due to this fact subsided into a greater depth and consequently did not suffer changes in porosity and thickness independently.

Calculation of subsidence history is made so that the sand-shale sequences are divided into layers and calculating their former thicknesses, the former bottom depth of each lithogenetic unit is determined. Since only the original and former thicknesses of each lithogenetic unit are needed, the thickness calculations are made only in cases, where the upper layer of

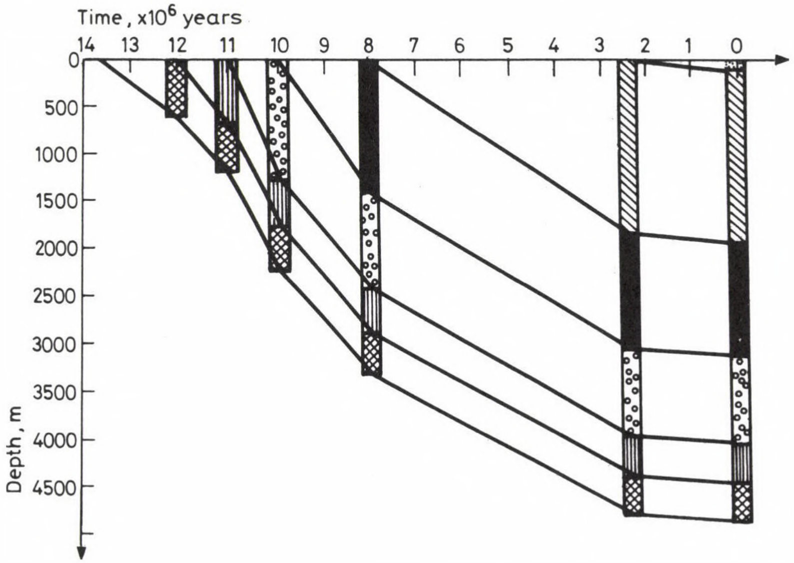

Fig. 7. Presentation of subsidence history

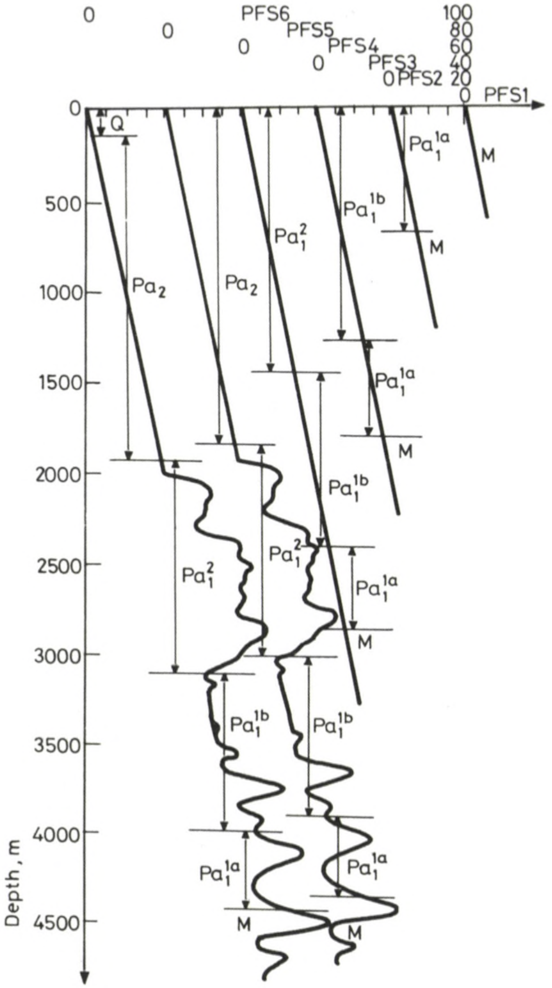

Fig. 8. Pore- and paleo-pore pressure of shale layers

the considered lithogenetic unit was on the surface. Reconstructing the subsidence history, it must be taken into consideration that a layer reaching its isolation depth, did not compacted further and its thickness did not changed. Results are presented in such a way that bottom depths are plotted on the depth-scale against time defined by each lithogenetic unit and so the changes in thickness developed during subsidence of each complex can be followed (Fig. 7).

6. Determination of the paleo-pore pressure

Determining the subsidence history, the former depths of layers within the lithogenetic units are known. In possession of the former pore pressure, so-called paleo-pore pressure, it is possible to determine the former depth, the isolation depth of the layer and the normal compaction trend.

Paleo-pore pressure is calculated for the same time-points as for the thicknesses of layers during the reconstruction of subsidence history. If the layer was at greater depth than the isolation depth in the questionable time-point, then the recent porosity, and if the former depth was less than the isolation depth then the porosity determined by the normal compaction trend is adjusted to the former depth. The technique of the pore pressure determination described in the 4. paragraph is used to the porosity data range obtained in this way, and paleo-pore pressure profiles, being related to the sequences and corresponding to the lithogenetic units are obtained. This profiles are figured separately for pelites (Fig. 8) and psammites. In the figure, the curve on the left side shows the recent pore pressures of the layers and the other curves — from left to right — show the paleo-pore pressures entering in the past as lithogenetic units. (Signs: A, Pa_2, Pa_1^2, Pa_1^{1b}, Pa_1^{1a}, M show lithogenetic units of the Great Plain Neogene sedimentary sequence.)

Summarizing, it can be stated that the method reconstructing formation and development of Neogene sedimentary basin and formation, migration and accumulation process of hydrocarbons, can be a useful tool in hydrocarbon exploration. The parameters which can be derived from well-logs, can considerably contribute to this.

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BERYLLIUM AND SOME OTHER RARE ELEMENT CONTENTS OF ACID VOLCANICS (TUFFS) AND METAMORPHITES IN HUNGARY

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Following a literature study of the American "beryllium tuffs" geologically similar formations in Hungary were sampled and investigated. The trace element survey of more than 300 samples of rhyolite tuffs and acidic metamorphites, etc. has shown Be concentrations near clark values, except in the Bükkszentkereszt anomaly. The significant Be enrichment (near to the concentrations of the Be ores in Utah) in the phosphatic rhyolite tuff at Bükkszentkereszt, formerly explored by the Mecsek Ore Company was studied in detail.

The Bükkszentkereszt Be-enrichment shows a similar mineral paragenesis, and is considered to be of similar origin as the Utah deposits. Both occurrences were formed by hydrothermal solutions in strongly faulted zones, and are associated with a minor enrichment of U, F, Mn, and in some places Li, and chalcophile elements (Ag, Pb, Zn, Sn).

The ages of the Utah and Bükk formations are different, the Hungarian one being the older. Be occurs in fluorite and opal in the American deposits, and in collomorphous fluor-apatite at Bükkszentkereszt. The US deposits are the most important non-pegmatitic Be-occurrences of the world, while the Bükkszentkereszt locality is considered as an indication as yet. Further studies of the Bükk locality, however may yield significant results.

Keywords: Be-enrichment, collomorphous fluor-apatite, rhyolite-tuff, Bükkszentkereszt, Hungary

A significant amount of world beryllium resources is found in the "beryllium tuff" deposits of Spor Mountains (Utah, USA), discovered in 1959 (Griffits, W.R., 1964). The beryllium mineral of these Miocene tuffites, the bertrandite was identified by Staaz, M.H. and Griffits, W.R. (1961). In the years subsequent to the discovery detailed results on the geology, mineralogy, petrology, geochemistry and economic geology of the deposits were obtained (Montoya, J.W.–Havens, R.–Bridges, D.W., 1962; Cohenour, R.E., 1963a;

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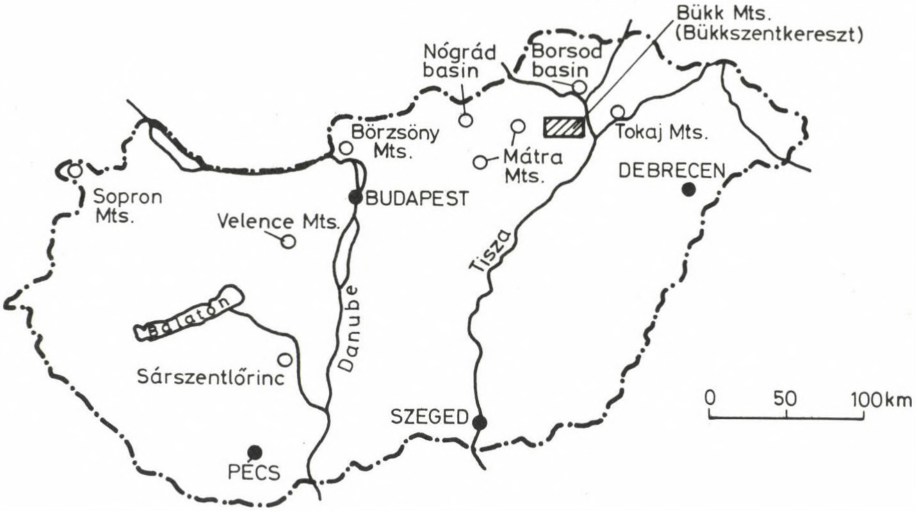

Fig. 1. Location of sampling in the acid volcanic and metamorphic formations in Hungary

Cohenour, R.E., 1963b; Govorov, I.N.–Stunzhas, A.A., 1963; Griffits, W.R.–Rader, L.F., 1963; Staaz, M.H., 1963; Williams, N.C., 1963; Montoya, J.W.–Bauer, G.S.–Wilson, S.R., 1964; Shawe, D.R.–Mountjoy, W.–Duke, W., 1964; Staaz, M.H.–Carr, W.J., 1964; Park, G.M., 1968; Shawe, D.R., 1968; Lindsey, D.A.–Ganow, H.–Mountjoy, W., 1973). These studies provided solid foundations for the discoveries of similar beryllium deposits in Arizona, New Mexico, and Nevada (Shawe, D.R., 1966; Shawe, D.R., 1972).

The geochemical knowledge obtained during our participation in the Rare Metals Research Program (1965–1970) coordinated and governed by the Hungarian Geological Institute, and particularly by Mária Kliburszky-Vogl, and a thorough literature study of Be-rich rhyolite tuffs of the USA resulted in commencing a Project to investigate the Be, and some other rare element distribution of Hungarian acid volcanic and metamorphic formations (Fig. 1). To clarify similarities, differences, and analogies as a first step a detailed study of Hungarian and foreign papers, and reports of the National Rare Metals Research Program (Csalagovits, I.–Víg-Fejes, M., 1969; Földvári-Vogl, M., 1970, 1971; Kubovics, I.–Andó, J.–Póka, T.–Rózsavölgyi, J., 1973; Nagy, B., 1967a, 1967b, 1971, 1972, 1980; Ódor, L., 1971; Vető, I., 1971) was carried out. In addition to a large number of Hungarian samples some Be-enriched rhyolite tuffs from the Spor Mts. USA were analyzed by several methods for comparisons. Results were summarized in a detailed report (Kubovics, I.—Nagy, B.—Nagy-Balogh, J.—Puskás, Z.—Gál-Sólymos, K., 1987).

Reference spectral analyses were carried out on all samples studied. Quantitative spectral analyses and atomic absorption control measurements were made on the samples containing Be above the detection limit i.e. 4 ppm (Nagy-Balogh, J.—Hoffmann, L., 1988). F and P contents of the samples containing more than average Be were also determined.

In the course of our survey no significant Be enrichment was found except the known anomaly region at Bükkszentkereszt village, Bükk Mts, NE-Hungary. The crystalline schists in the Sopron Mts (Easternmost Alps) contain Be less than the clark value (5 ppm). The Miocene zeolitic rhyolite tuff of Mád and the pumice tuff of Bodrogszegi (Tokaj Mts) showed concentrations close to the clark values. Samples from the Velence Mts displayed lower values than measured during the Rare Metals Research Program (15 ppm), i.e. below the clark for the acidic rocks (5 ppm). Samples from the Börzsöny Mts showed values below the clark value, while the acidic rocks of the Mátra Mts had values near to the clark. The so-called lower rhyolite tuff (Lower Miocene) of Nógrád Basin, the Sárszentlőrinc rhyolite tuff and the mixed tuff of the Borsod Basin contain scattered Be traces only.

A significant Be-enrichment was confirmed solely in the collomorphous fluor-apatitic phosphate rocks localized as fracture fillings in the mylonitic zones of the weakly metamorphosed rhyolite tuff ("quartz porphyry tuff") at Bükkszentkereszt, explored in the early 1970s by geologists of the Mecsek Ore Company. Since these phosphatic rock samples of Bükkszentkereszt show Be concentrations near to those of rhyolite tuffs mined as Be-ores in the USA, the further detailed investigations were centred here.*

The Be- and U-enriched phosphatic formation at Bükkszentkereszt has been reported by J. Vincze in the book of S. Koch (1985): Magyarország ásványai (Minerals of Hungary).

The Be-enrichment of Bükkszentkereszt is connected to an Upper Ladinian (Middle Triassic) rhyolite tuff, which suffered complex metamorphic,

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*The help of J. Vincze and I. Elek (Mecsek Ore Company), supplying us with rock and powdered samples from boreholes and trenches, is sincerely acknowledged.

deformation and metasomatic processes. The alteration processes raised difficulties in the precise determination of the source material. Beside the acidic pyroclastics forming most of the Ladinian formation, there are also fine grained, aleuritic components, indicating that at least part of the original rock was tuffite. This rock suffered weak metamorphism first, associated with the formation of fissure fillings made of quartz and alkali-feldspars and containing rare chlorite and titanite. These fissures were strongly deformed, folded and sheared indicating a subsequent deformation metamorphism (phyllonitisation, cataclasis). It was followed by hydrothermal-metasomatic alteration, producing pyrite, hydromicas, then phosphate minerals (almost exclusively collomorphous fluor-apatite). The latter one was precipitated mainly in the random fracture systems of cataclasites (Fig. 2).

More or less collomorphous apatite appeared in the compact, unfragmented regions, e.g. older fissure fillings, too. Here the tiny (micrometres to tens of micrometres in size), optically amorphous, light greenish-grey — rarely brownish-grey — collomorphous apatite grains follow either cleavage planes or the older fissure fillings; they are predominantly concentrated either in the feldspar-containing or in the sericite-rich regions (Fig. 3).

The fracture-filling collomorphous apatite usually superseded the former mafic components, and formed encrustations on cataclasites. The phosphate-encrusted cavities (10—100 μm in diameter) bear 10x2 μm euhedral, prismatic fluor-apatite crystals on their walls (Fig. 4). The grain size of the equant, or radial fluor-apatite crystals ranges from submicroscopic to 20 μm.

The principal constituent of the phosphatic rock is spherulitic apatite, it contains, however, collomorphous or fine grained Mn- and Fe-oxide-minerals, radial dufrenite ($Fe^{2+}_3Fe^{3+}_6\ [(OH)_3 \cdot PO_4]_4$; Fig. 5), and an intergrowth of submicroscopic Mn-oxide and radial-fan-like apatite crystals either, all in an inhomogeneous distribution.

Table I contains the average trace element contents obtained from the spectral analyses, and calculated for each formation. Beryllium displays three times the clark values in the rhyolite tuff, and much higher enrichment in the phosphate rock, where the average concentration is 421 ppm.

Detailed trace element investigations of the Be-bearing rhyolite tuff and the phosphate rock (Table II) show that Be-enrichment is in close relationship with the phosphate minerals. Chalcophile and some other ele-

Table I

Average trace element contents in rock samples from Bükkszentkereszt

rock types	number of samples	ppm										
		Ag	As	B	Ba	Be	Co	Cr	Cu	Ga	Mo	Mn
limestone	5	<1	<160	<10	<100	<4	<10	l.c.	20	<10	<10	700
quartzite	4	<1	<160	5	<100	2	<10	<10	9	5	<10	80
rhyolite	42	0.15	<160	119	<100	4.5	<10	6	23	15	<10	210
rhyolite tuff	33	0.17	<160	64	74	16	<10	5	10	15	1.7	163
phosphatic rock	3	17	167	47	270	421	<10	35	120	35	13	6857
total	87											

		ppm										W%
		Ni	Pb	Sb	Sn	Sr	Ti	Tl	V	Zn	Li	P_2O_5
limestone	5	<10	<10	<60	<40	326	268	l.c.	<10	<100	<300	<0.1
quartzite	4	<10	12	<60	<40	100	125	<10	<10	<100	<300	<0.1
rhyolite	42	4	10	<60	39	38	346	5.1	<10	31	<300	<0.1
rhyolite tuff	33	3	20	<60	29	28	435	3	3	25	<300	2.1
phosphatic rock	3	9	367	35	40	587	346	12	<10	l.c.	625	27
total	87											

l.c. = line coincidence

Table II

Trace element and P_2O_5 contents of Be-rich samples from Bükkszentkereszt

sample number	rock types	ppm														
		Ag	As	B	Ba	Be	Cd	Co	Cr	Cu	Ga	La	Mo	Mn	Nb	Ni
189	phosphatic rock	1	160	16	400	550	-	<10	-	100	-	50	6	1%	-	<10
190	phosphatic rock	<1	250	25	250	350	-	<10	-	160	<10	40	25	1%	<16	16
199	rhyolite tuff	1	-	60	160	169	-	-	10	25	25	40	10	160	16	-
202	rhyolite tuff	-	-	160	-	87	-	-	10	25	16	40	-	400	16	10
202/s	yellow encrustation on sample	-	-	160	100	150	-	-	40	25	60	40	-	600	40	-
202/f	white encrustation on sample	40	-	100	160	363	-	-	60	100	60	40	-	600	60	-

		ppm										W%	
		Pb	Sb	Sc	Sn	Sr	Ti	Tl	Zn	Zr	Y	Li	F	P_2O_5
189	phosphatic rock	40	-	<6	40	600	<100	10	l.c.	40	200	<300	0.98	36.3
190	phosphatic rock	60	60	<6	40	1000	<100	20	l.c.	160	100	1600	0.84	30
199	rhyolite tuff	100	-	<6	40	160	400	10	-	40	16	<300	0.39	14.6
202	rhyolite tuff	60	-	<6	40	-	600	<10	100	50	10	<300	0.099	2.5
202/s	yellow encrustation on sample	400	-	-	40	-	600	<10	250	400	60	<300		6
202/f	white encrustation on sample	1000	-	-	40	160	600	<10	600	400	160	<300		16

l.c. = line coincidence

Fig. 2

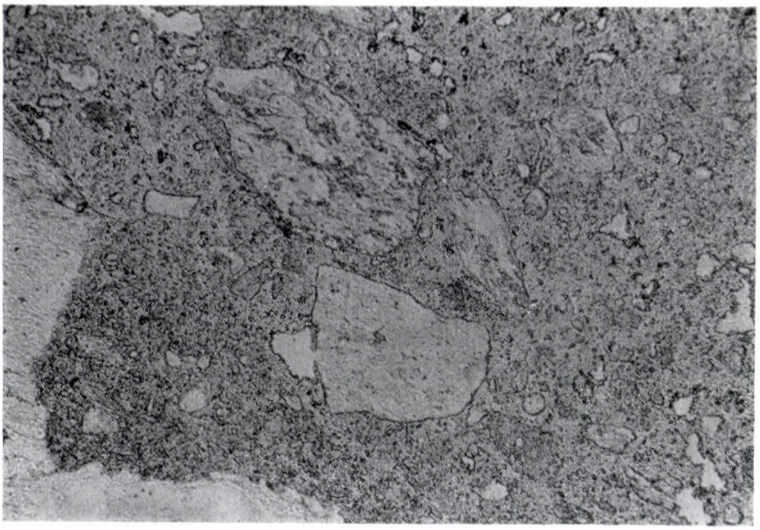

Fig. 3

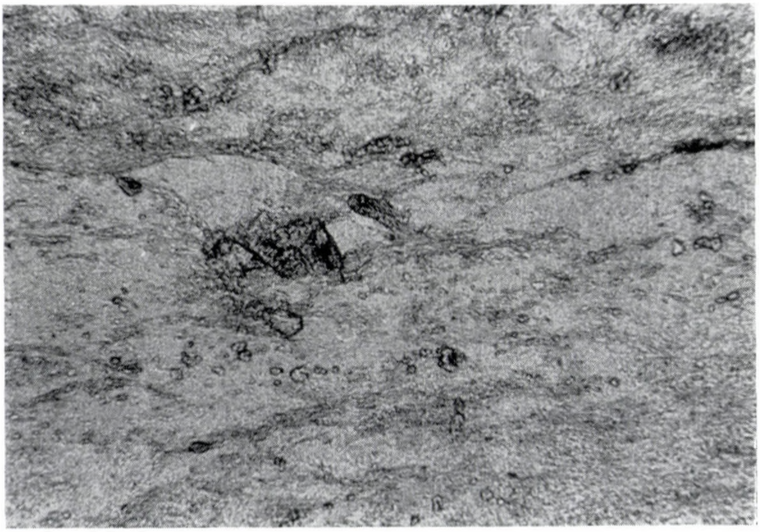

Fig. 2. Rhyolite tuff fragments in collomorphous fluor-apatite. Magnification: 67X, plane-polarized light.

Fig. 3. Fine-grained collomorphous fluor-apatite in a compact metamorphosed rhyolite tuff. Magnification: 167X, plane-polarized light

Fig. 4

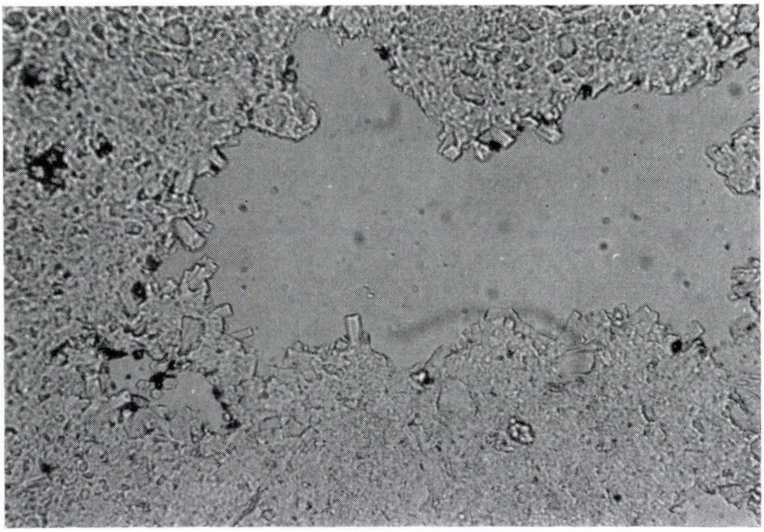

Fig. 5

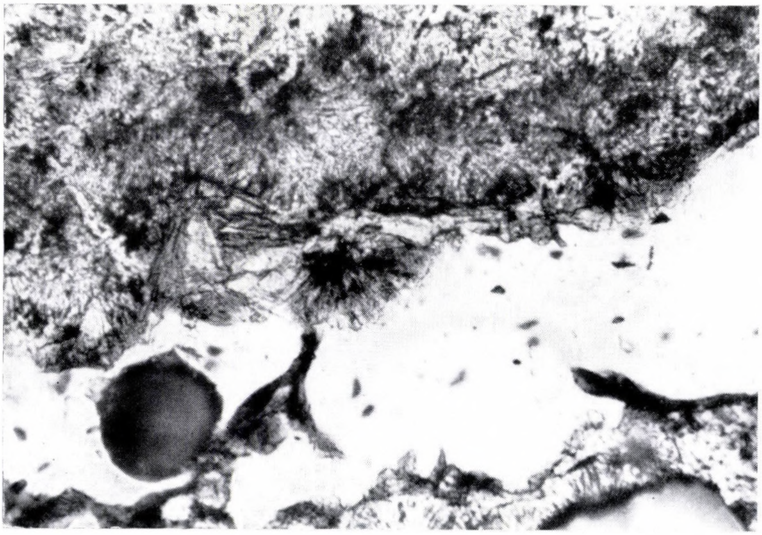

Fig. 4. Upgrown apatite crystals in the cavities of massive collomorphous phosphatic rock. Magnification: 418X, plane-polarized light

Fig. 5. Dufrenite on fissure walls of phosphatic rock. Magnification: 418X, plane-polarized light

ments are enriched together with beryllium in the phosphatic formations indicating a predominant hydrothermal origin (Table I).

The massive phosphate rock contains some dufrenite, and minor amounts of quartz, sericite, and calcite beside fluor-apatite, as shown by X-ray diffraction. DTA analysis has shown the presence of 0.6% zeolite (mordenite, clinoptilolite). The P_2O_5 content of the rock richest in phosphate minerals is 36.3%, while the concentration of Be is 550 ppm. Laser microanalysis has shown that Be is enriched in the collomorphous fluor-apatite and in the apatite-Mn-oxide intergrowths fraction and is homogeneously distributed. Mn, Ti,Fe, Y, Zr, and the chalcophile elements (Ag, Cu, Zn, Pb, As), however, display inhomogeneous distribution, clearly indicating their occurrence in trace minerals. The presence of Zr and Y may indicate primary Zr-minerals.

Geochemical analyses proved a close correlation between P_2O_5 and Be-contents of rhyolite tuff. Correlation relationships among the elements enriched in the massive phosphate rock are shown in Table III. The correlation calculations are based on the data of Table II, and on radioactive element concentrations supplied by the Mecsek Ore Company.

Table III

Correlation between elements enriched in massive phosphatic rock

	Be	P_2O_5	U	Mn	Y	F
Be	-	0.89	0.96	0.77	0.95	0.96
P_2O_5	0.89	-	0.79	0.93	0.73	0.99
U	0.96	0.79	-	0.74	0.95	0.87
Mn	0.77	0.93	0.74	-	0.61	0.94
Y	0.95	0.73	0.95	0.61	-	0.91
F	0.96	0.99	0.87	0.94	0.91	-

Light microscopy of the rocks provided evidences for the location of the collomorphous fluor-apatite within brecciated zones of the rhyolite tuff, and along cleavage planes indicating a metasomatic influence contemporaneous with brecciation. P, Be, and U, Th, REE (determined by the Mecsek Ore Company) are considered as evidences for an alkali granitic or alkali syenitic magma source.

Brecciation along (deep) faults provided paths for hydrothermal solutions ascending from the intrusion. However, metasomatic features indicate that these might have been closed towards the surface during the phosphate precipitation. Beryllium might have ascended as fluoride; decreasing temperature, increasing pH and emplacement of fluor in collomorphous apatite contributed to its precipitation, too.

Distribution and concentration of the mentioned trace elements indicate that Be and P of the Bükkszentkereszt rhyolite tuff were derived from an alkali magma or alkali magmatite, being products of lateral secretion in the latter case. This hypothesis is supported by the Neogene, mostly intermediate and acidic occasionally egirine-bearing alkaline volcanic rocks found in boreholes around the Bükk Mts., and investigated by B. Mauritz and V. Tolnay (1953). Further studies, including radiometric measurements, will help to solve this problem.

Comparative geology, petrology and geochemistry of the Be-bearing rocks from Bükkszentkereszt and Utah yielded the following results; Both regions are underlain by carbonate rocks: Devonian in Utah, Triassic in the Bükk. Be-enrichment is found in rhyolite tuffs, being Miocene in Utah, while the Bükkszentkereszt Be- and P-enrichment was formed in Middle Triassic pyroclastics.

Be-enrichments are located in tectonically preformed, brecciated zones and are of relatively minor extent in both regions. The highest Be-concentrations are in silica-fluorite concretions in the Utah deposits, and in massive collomorphous fluor-apatite at Bükkszentkereszt. The Bükk apatite-bearing rhyolite tuff is characterized by common enrichment of U, Be, F, and Mn, associated with some chalcophile elements, among others Pb, Ag, Zn, Sn, etc. Fluorine occurs in fluorite in the Utah samples, and in fluor-apatite at Bükkszentkereszt. Microprobe analysis have shown 3.6% average F concentration in apatite.

Several genetic similarities were also found. The Be and associated U, F, and Mn enrichments, K-metasomatism, zeolitization and formation of clay minerals were produced by hydrothermal solutions in both regions.

The mineral paragenesis is partly the same in both areas: quartz varieties, Mn-oxide minerals, zeolites, K-feldspar, and clay minerals occur in both formations. Be is included in fluorite and opal in the Utah deposits, and in fluor-apatite at Bükkszentkereszt. A submicroscopic Be mineral, bertrandite was determined by X-ray diffraction from the ore-concentrate by US experts. Whereas Be displays near homogeneous distribution in the collomorphous fluor-apatite of Bükkszentkereszt, bertrandite was determined by the geologists of the Mecsek Ore Company. Probably this mineral is submicroscopically disseminated in the phosphate minerals, and the tiny Si-enrichments (inclusions) in the phosphate-rich regions determined by electron microprobe analysis are contained in the bertrandite. However, it can be connected to phsophate, i.e. beryllonite, as well, corroborated by the significant correlation between Be and P.

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BORNITE FROM RUDABÁNYA: AN ELECTRON DIFFRACTION STUDY

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Sulfide samples from Rudabánya were investigated by ore microscopy and selected area electron diffraction. The present paper is a mineralogical study of the bornite in the samples. Four polymorphs of bornite have been identified. The possible crystallization temperatures of the bornite polymorphs and the effect of the Ar ion beam thinning preparation method is discussed.

Keywords: Bornite, polymorphism, Rudabánya, electron diffraction.

Introduction

The relationship between minerals in the Cu-S and Cu-Fe-S systems has been the subject of numerous investigations, but there are still several problems which are not well understood. Two main types of copper (iron) sulfide structures are distinguished: one with a cubic close-packed array, the other with a hexagonal close-packed array of sulfur atoms. Chalcocite (Cu_2S) and djurleite ($Cu_{1,96}S$) were reported to belong to the first type (Evans, 1979), digenite (Cu_9S_5) and bornite (Cu_5FeS_4) to the other type, respectively (Morimoto and Kullerud, 1966).

Several polymorphs are known to exist in the bornite-digenite series, all based upon an anti-fluorite type subcell with a_0=5.5 Å (Fig. 1). Metal atoms occupy the tetrahedral sites of the cubic close-packed sulfur framework. Some of the tetrahedral voids are empty or partially filled, and the vacancies can form vacancy-rich and vacancy-poor clusters (Pierce and Buseck, 1978). Occupancy of the metal atom positions and ordering of the vacancy-rich clusters result in the formation of a number of superstructures with different unit cell sizes. The polymorphs are named as multiples of the a-dimension of the cubic subcell (e.g. 2a4a2a: low bornite, lalala=la: high bornite) (Fig. 2). The existence of the la, 2a, 3a, 4a, 5a, 6a, 2a4a2a,

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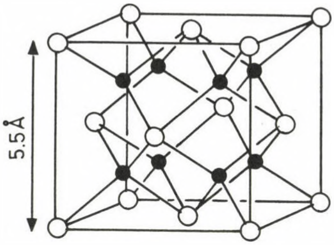

Fig. 1. The bornite subcell. Filled circle: Cu, Fe, open circle: S

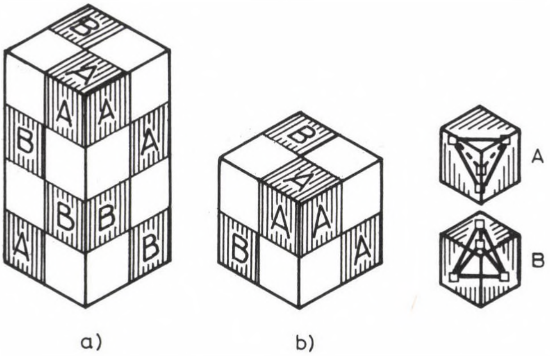

Fig. 2. The structure of (a) low-bornite (2a4a2a), (b) 2a bornite. White cubes: subcells with all metal sites filled. Hatched cubes: subcells with four vacancies and four filled sites. Vacancies can occur in one of two orientations (A and B). (Pierce and Buseck, 1978)

1a1a2a and Na (N is a non-integral value) superstructures was confirmed by Pierce and Buseck (1978). Mixtures of two ordered phases produce the non-rational Na phase (Conde et al., 1978).

The stability of the many structural forms depends upon composition and temperature. On heating to 228°C the low-temperature tetragonal bornite (2a4a2a) inverts to the cubic 1a form. The 2a bornite develops on rapid cooling of the high-temperature 1a polymorph, it is stable above 170°C

(Kostov and Minčeva-Stefanova (1981)). Quenching of compounds with intermediate compositions along the bornite-digenite join may result in the formation of the metastable polymorphs 2a, 3a, 4a, 5a, 6a and Na (Morimoto and Kullerud, 1966).

Experimental

Samples from Rudabánya, Andrássy-II mine were provided by S. Szakáll. Sulfide minerals occur within the metasomatised carbonate (ankerite) matrix. The two main phases of the sulfide mineral association are chalcopyrite and bornite. Bornite has a characteristic violet and dark green color. Pyrite and a very small amount of chalcocite are also present in the samples.

The samples were examined in polished section and in transmission electron microscope. Two different preparation methods were applied for TEM investigations: 1. The mineral grains were crushed under chloroform and mounted on a carbon-coated specimen grid. 2. The ion beam thinning method was applied: the specimens were ground to 30 μm thickness and thinned by argon gas in a double-beam ion thinning apparatus. The two different preparation methods provided different TEM results: more structural variations of bornite were found in the ion beam thinned specimens than in the crushed ones. This can be explained in two different ways: 1. The mineral has transformed during thinning, i.e. additional polytypes have formed. 2. The additional structural variations observed in the ion beam thinned specimens were also present in the crushed material, but only the selective thinning effect of the ion beams could throw light on them. In this paper we shall try to establish the correctness of any of the above variations.

Investigations were carried out at 100 kV accelerating voltage with a JEOL JEM 100U electron microscope fitted with a double-tilting goniometer stage.

Ore microscopy

The investigated specimens seem to be of the same type of material which was described by Koch et al. (1950) from the Andrássy-II mine. The oldest mineral of the assemblage is the pyrite, its grains are rounded, fractured. Sometimes the pyrite grains contain isotropic bornite inclusions.

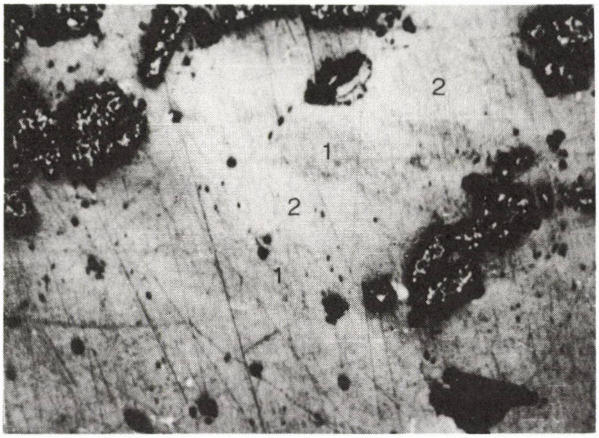

Fig. 3. Dark bands of isotropic bornite (1) in light, anisotropic bornite (2). Magnification: 150X

The most abundant sulfide minerals – bornite and chalcopyrite – seem to be syngenetic with each other. Bornite is predominantly light pink and anisotropic, but darker bands of isotropic material can be observed in it (Fig. 3). The youngest member of the sulfide mineral assemblage is the chalcocite at the rims of the bornite grains. In spite of the careful study idaite (described by Koch (1966)) was not found.

Electron diffraction

Mainly the bornite [110] zone axis was chosen as the direction of the incident electron beam. The strong reflections of the diffraction patterns relate to the sulfur close-packed matrix, the weaker superlattice spots reveal the arrangement of metal atoms.

Figures 4 and 5 were taken from specimens prepared by crushing. Only sublattice spots appear in Fig. 4, this crystallite has obviously the high-temperature 1a bornite structure. (The vacancies are disordered in the structure.) Fig. 5 is the diffraction pattern of the 2a polymorph. The distances between subcell spots are halved by weaker superstructure spots, indicating that the unit cell edges are twice as long as the subcell edges. This pattern seems to be the most characteristic of the bornite samples prepared by crushing.

Fig. 4. la bornite, [110] projection

Fig. 5. 2a bornite, [110] projection

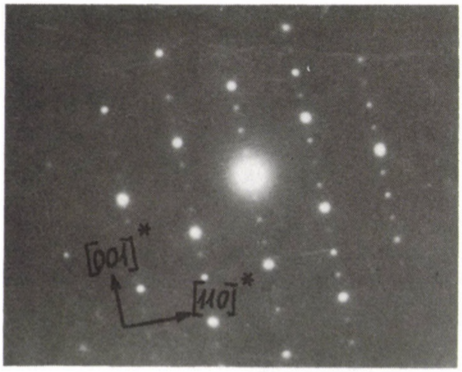

Fig. 6. la1a2a bornite, [110] projection

Fig. 7. la1a2a bornite, viewed from the a axis

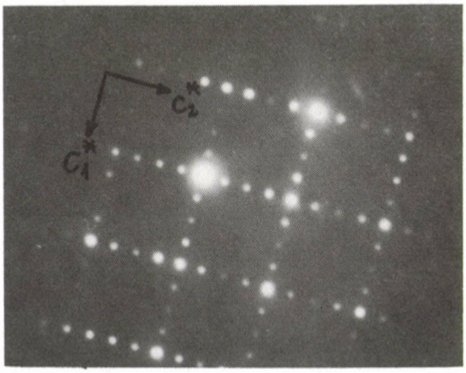

Fig. 8. Oriented intergrowth of two la1a2a bornite crystals. [100] projection

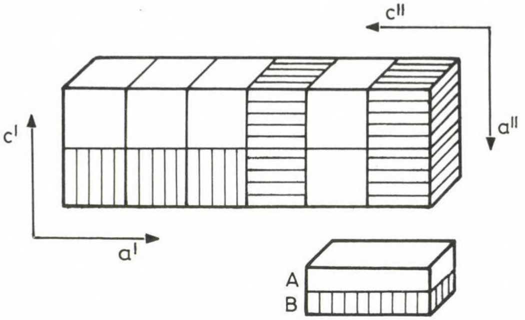

Fig. 9. A possible interpretation of Fig. 8. A: metal-rich layer, B: metal-poor layer

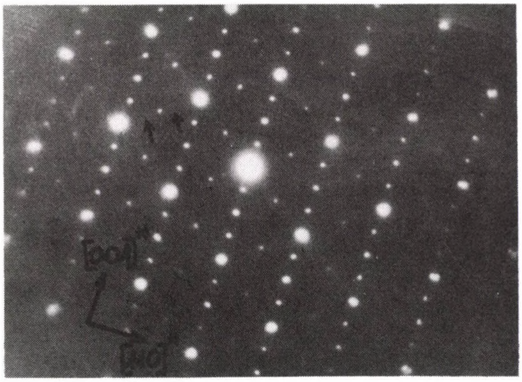

Fig. 10. A mixture of the 1a1a2a, 2a and 3a bornite polymorphs

The following diffraction patterns were recorded from the ion beam thinned specimens. The most abundant phase in these samples has the unit cell dimensions 1a1a2a. The same crystal fragment can be seen in Fig. 6 and 7, but in two different orientations. Superstructuring occurs only in the [001] direction in both patterns. This means that the metal atoms are ordered in metal-rich and metal-poor layers, which alternate along the [001] direction. A diffraction pattern of an intergrowth of two 1a1a2a crystals can be seen in Fig. 8. The structural interpretation of this pattern is shown in Fig. 9.

The diffraction pattern in Fig. 10 is a very specific one, it was found only twice in the course of investigation. It consists of the patterns of three different structural variations. The electron beams diffracted from the 2a, 1a1a2a and 3a polymorphs contribute to this pattern. The distance between sulfur matrix spots is divided into three equal parts by the weak 3a superlattice reflections (marked by arrows) along the two [111] directions. The inhomogeneity of the bornite is well characterized by this diffraction pattern: three different polymorphs occur together within an area of one μm in diameter.

Discussion

The comparison of the results of TEM and optical investigations helps to answer the question concerning the effect of ion beam thinning. On the basis of the diffraction patterns the only anisotropic bornite polymorph found in the sample has the 1a1a2a structure. It seems that this structural variation corresponds to the light pink, anisotropic bornite observed in polished section.As the 1a1a2a bornite was found only in ion beam thinned samples, the true distribution of the sulfide minerals in the sample is probably better revealed by this preparation method than by crushing. Therefore, it seems that the sulfide minerals have not transformed during thinning.

Yund and Kullerud (1966) reported that the bornite-pyrite assemblage is stable only above 228°C. This means that the bornite inclusions found in pyrite must have formed above 228°C, so these are of the 1a type.

The dark pink bands of isotropic bornite seem to have the 2a structure, the light pink, anisotropic bornite matrix is probably the 1a1a2a variation. The 2a bornite develops at about 170°C (Kostov and Minčeva-Stefanova, 1982). The anisotropism and the cation order suggest that the 1a1a2a structure must be a lower temperature form, close to the low-temperature (2a4a2a) bornite.

The 3a phase occurs probably only in the boundary region between the 2a and 1a1a2a phases, as it was not found separately (Fig. 10).

Conclusions

The 1a, 2a, 1a1a2a and 3a polymorphs of bornite were found in the samples. The 1a bornite occurs in a small amount, very likely as inclusions in pyrite. The most abundant phases have the 1a1a2a and the 2a structures. The boundary region between the latter phases probably exhibits a strong variation of several polymorphs (for example the 3a phase) in the range of unit cell sizes, below the limit of resolution of selected area electron diffraction.

Possible succession of the sulfide minerals: 1. pyrite-1a bornite ($>228^{0}$C), 2. chalcopyrite-2a bornite-1a1a2a bornite ($\sim170^{0}$C), 3. chalcocite (at a significantly lower temperature).

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BONITY INVESTIGATIONS BASED ON THE NATURAL CHARACTERISTICS OF MINERAL RAW MATERIAL LOCALITIES

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A methodological case study based solely on the natural characteristics instead of the traditional evaluation of economic geology has been compiled.

Altogether 15 variants of three coal localities were studied. The natural characteristics to be taken into account are: depth, calorific value, relative sulfur content, thickness, quantity, water hazard, gas hazard.

The calculation of bonity functions obtained in the course of non-linear correlation is carried out by the softwarer DBASE 3 +. The data base used is the MÉRLEG system of the National Mineral Resource Register.

Keywords: Economic geology, evaluation, correlation, non-linear functions, coal deposits, data base, Hungary

The determination of absolute and relative value of potential mineral resource bases explored by geological surveying has been a research task of primordial significance for decades. Concerning this topic numerous methodological studies, directives and instructions can be mentioned but the solutions have been always bound to decision junction points where the human subjectivity may a priori decide the fate of the locality in question.

A comparative method was developed respecting the traditional methods but avoiding the economic traps that can be hardly defined, and in this method the subjective elements can be unambiguously neglected.

The evaluations below based on the data base of the National Mineral Resources Register are solely of comparative character. The basis of comparison is a natural parameter, i.e. a natural feature that can be effectively measured in all cases.

Our methodological suggestion includes the parameters below:

- weighted depth (m)
- geological thickness (m)

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- exploitable calorific value (MJ/kg)
- relative sulfur content (g sulfur/MJ)
- geological resources (million tons)
- water hazard
- hazard of gas or coal-dust outburst.

As a first step of the algorithm the variants listed above were put to the same numeric level. In harmony with the method used in factor analysis all the variants (in the following variables) were reduced to the same interval and within the interval to the same grid value. The difference between the minimal and maximal depth limit is 1200 m, and presuming subdivision by 50 m this results in 24 "bonity" steps. In case of the other variables the same value was accepted, thus all really measurable factors were converted to this value.

All the values presumed to be of elementary bonity have an absolute advantageous (24) and an absolute disadvantageous (0) extreme values. The interpolation between the two values can be carried out either by linear approximation or by an empirically generated function. In favour of greater reliability this latter method was used. In Fig. 1 the shape of the functions is demonstrated.

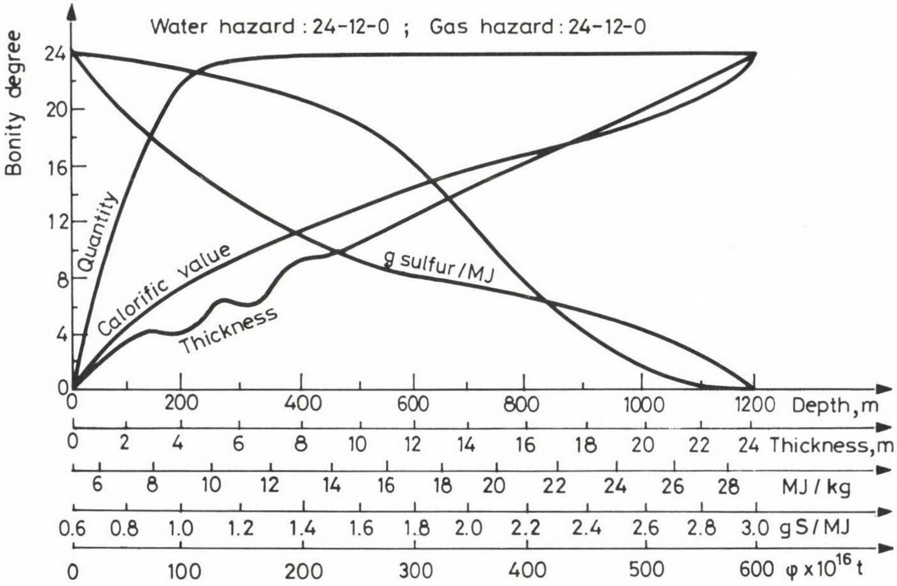

Fig. 1. Bonity values of localities as a function of different natural parameters

It is easy to understand that the effect of each natural factors are not linear in most of the cases. The role of depth becomes determinative unambiguously below 400 to 600 m. In case of small thicknesses the cost-increasing effect of the geological thickness observed in the nature is obvious but the role of possible limits of mono- and multislicing cannot be neglected either. Over certain thickness limits (e.g. in case of opencast mining) the bonity degree does not increase. The shape of the curve will least differ from the linear in case of the calorific value though the traditional users may prefer certain sections.

As a new natural parameter the real consideration of the combustible sulfur content that is highly polluting the environment is suggested. The term "real" denotes the joint consideration of calorific value and sulfur content so that the sulfur quantity in gram is calculated for 1 MJ calorific value.

The quantity of the calculated geological resource is fundamental when determing the economic value of the locality. At the same time, this has also an upper limit bound to the realities. According to the amortization period, about 30 years and roughly 100 million tons determine the maximal quantity to be needed.

The effect of water, gas and coal-dust outburst hazards on the bonity degree of the locality is treated partly qualitatively but this also promotes the comparison. Actually, here also the 24-step scale is applied but due to the generality of the information the steps 0-1-12-23-24 will be applied.

In harmony with the method above the bonity degree of the studied locality may vary between 0 and 168 (7 x 24). Four of the seven parameters are predominant so if any of these has a value of zero, the complex bonity factor cannot be greater than zero. The four parameters: depth, calorific value, thickness and quantity.

Calculations were carried out by digitizing the functions and subsequently the non-linear correlation of each sections was performed. The table truly reflects the calculation and the evaluation of the results. The software is based on DBASE 3 + and was made by László Drótos (Hungarian Geological Survey). Different variants can be interpreted essentially as different localities. The practical value of the non-manipulated results is indicated by the fact that based on the known natural parameters the Dubicsány locality seems to be optimal solution of the near-future. Some variants of Máza and Váralja show somewhat more advantageous picture than

Table I

Elementary and complex bonity values of three Hungarian mineral resource localities

Locality		MÁZA					VÁRALJA						AJKA II			DUBICSÁNY
variant*		A	AO	B	C	D	A	AO	B	C	D	report	A	B	C	REPORT
depth (m)**		798	848	796	639	646	702	743	597	570	582	613	600	602	726	190
	B	7.9	5.6	8.0	15.5	14.3	12	10.2	16.1	16.5	16.3	14.8	16	16	10.8	23
calorific value (KJ/kg		12.8	15.4	14.0	17.1	17.0	11.5	14.7	13.2	14.4	17.2	8.9	13.1	12.7	16.2	10.9
	B	11.2	13.3	12.2	14.6	14.5	10.0	12.8	11.4	14.8	14.6	7.3	11.3	11.0	13.8	9.3
sulfur g/MJ		1.32	1.17	1.43	1.23	1.25	1.21	1.03	1.18	0.96	1.00	1.63	1.67	1.65	1.95	2.46
	B	12.2	14.0	10.8	11.2	13.0	13.5	15.9	13.7	16.9	16.3	8.9	8.6	8.8	7.7	5.0
thickness (m)		2.84	3.41	3.97	4.89	5.31	1.71	2.15	2.22	3.04	3.46	7.70	7.24	6.22	1.80	3.95
	B	4.0	4.0	4.1	5.2	6.2	2.60	3.20	3.40	3.90	4.00	8.80	7.90	6.10	2.90	4.0
quantity 0 6 t		701	552	501	92	80	236	159	141	33	23	235	120	94	1	93.0
	B	24	24	24	21.6	19	23.9	23.7	23.2	8.70	7.20	23.9	23	10.6	-	21.6
water hazard		-	-	-	-	-	-	-	-	-	-	+	+	+	+	-
	B	23	23	23	23	23	23	23	23	23	23	0	0	0	0	12
gas hazard		+	+	+	+	+	+	+	+	+	+	-	-	-	-	-
	B	0	0	0	0	0	0	0	0	0	0	23	23	23	23	23
Σ	B	82.3	83.9	82.1	91.1	90.0	85	88.8	90.8	85.3	80.8	86.7	89.8	86.6	0	97.9

*quantitative variant related to different "Cut off" values; **"B" = elementary bonity value expected. This is not astonishing, since the locality possesses the advantageous natural conditions, only consideration conditions that adapt themselves better to the locality have to be applied.

Realities are evidenced by the moderate results obtained to the Ajka locality. The perspectivity of this locality can be evidenced with difficulties.

We know that the comparisons carried out solely on the basis of natural parameters do not include the value-increasing effect of the investments done so far. Of course, the decisions cannot ignore these data but our investigations aimed only at the study of natural parameters.

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NEW TASKS OF RAW MATERIAL PROSPECTING FOR THE CEMENT INDUSTRY

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The new methods aiming at the improvement of the efficiency of exploration for cement industrial raw materials are described. The Bélapátfalva locality is analyzed on the basis of geological and technological profile. By means of variograms and correlation relations of the raw material parameters it is expected that max. 1% deviation can be achieved in case of raw flour quality extrapolations.

Keywords: Raw material prospecting, cement industry

Recently, the national cement consumption and-parallel with this the cement production have became reduced. The demand for special cements (e.g. S 54, S 100) has increased. Factories therefore try to realize an extension of choice and to produce more kinds of cement, and this needs raw materials of different quality compared with those used so far. At present the factories acquire the cement – industrial sand raw material of high SiO_2-content – exceeding 70% – from hardly known stocks with buying. For ensuring a safe raw material basis prospecting is going on in the area of the cement factories of Hejőcsaba and Bélapátfalva. Although the demand of sand-raw material is only a few million tons, the unfavourable environmental conditions, further the strict quality requirements cause serious difficulties. The prospecting and the engineering preliminary works are made more difficult by the fact that a cement industrial raw material differing from the previous type is in question. This makes some revaluation of the necessary methods, a few more important elements of which will be shown by the example of Bélapátfalva.

For the choice of the most economic raw material catching variant it is generally expedient to survey and look for all possibilities. Therefore our investigations were extended at first to a region lying 50 km of the factories. On the basis of information and in situ survey the sand

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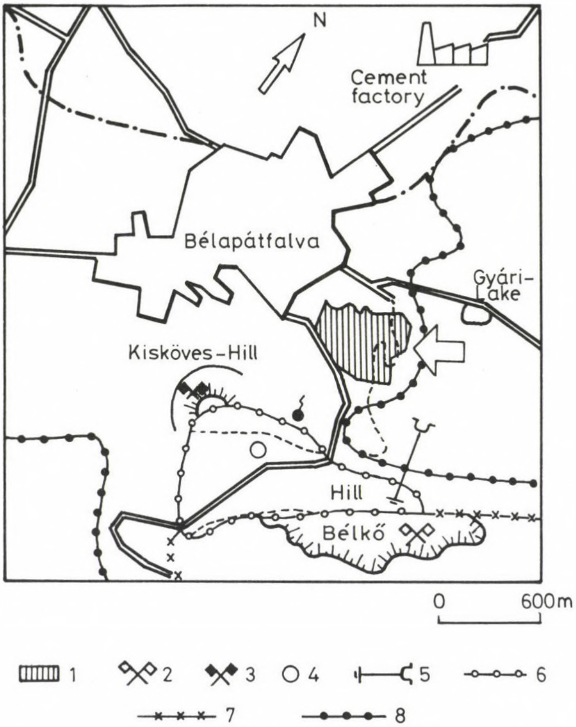


Fig. 1. Obtention of cement industrial sand raw material in the area of Bélapátfalva. 1. Explored cement industrial sand locality (Pusztaszőlő); 2. cement-industrial limestone-mine; 3. marl-mine; 4. well for gaining carst water; 5. carst-opening; 6. planned primary- and 7. secondary-hydrogeological protecting object-limit; 8. boundary of the Bükk National Park

mining, mining and industrial hillocks and geological conditions of the area were considered. Anyhow in all cases the sand occurrences in the neighbourhood of cement industrial plants seem to be most suitable. The full utilization of these, however, is often limited by the built-up situation, the protection of environment, earth, water, forest and minerals etc. In case of Bélapátfalva the village, the Bükk national park and the near position of the planned hydrogeological protecting objects of the surrounding water catchments, the road network of the factory cause problems (Fig. 1).

The marking out and detailed knowledge about the cement-industrial sand-raw material occurrence of natural position are preliminary planning tasks connected to prospecting. Information can be obtained through geophysical and drilling prospecting, material investigation of great number and in several directions for founding the preparation of mining operations and the cement technology. In many cases the first valuation of the results were surprising. Formations qualified as sand on the basis of geophysical methods and macroscopic processing of the sample-material gained from boreholes could not have been considered to be cement-industrial sand-raw material because of their low SiO_2-content. This made necessary to create a new rock-nomenclature adjusted to the cement-technology and following the chemical composition. The denomination of rocks can be characterized by the estimation of the $CaCO_3$-content – of the quartz sand – (total SiO_2 %-value decreased by the SiO_2 % bound in clay materials) and clay-content (Fig. 2).

The comparison of the rock physical parameters and the characterization of the raw material with the above chemical valuation can render an assistance among others for the direction of prospecting and by the quality nearly oriented organization of the later mining operations.

Besides the usual cement-industrial raw materials the appearance of the new silicate-component in the field of qualifications requires solutions different from those used so far. As it is generally known, our cement factories produce the raw flour mostly with using limestone-clay raw material and as a correcting material pyrite cinder by mixing on the basis of a receipt. In the present case the sand presents itself as a further raw material. With the common consideration of these, further on besides the raw flour modules bound generally with limit values the optimal model of adjustability taking into account a minimal dosage of pyrite cinder had to be elaborated. The computer-process diagram of this is shown in Fig. 3. Its applicability is unambiguously justified by our prospecting practice.

As an important part of the preliminary planning work the investigation of inner structure of the occurrence can be considered. The knowledge of this may multiply the value of research information. In advance to the information about the applied structural analyses it has be known that the chlamys sand-series in the area of Bélapátfalva being the subject of prospecting is the initial member of the Miocene formations. It consists of the variation of river bank sand, sandstone and clay-marl and goes over with a macroscopically hardly traceable transition towards the covering layer, into the clay-marl series. It is probable to find a qualitative orientation in it in NW-SE direction and perpendicular of this because of genetic reasons. This picture is made further complicated by the strongly tectonized state of the area. The general inclination of the rocks in the SE-direction can be indicated, as well as the often strong disintegration of these along faults. For the analysis of law-like regularities appearing as

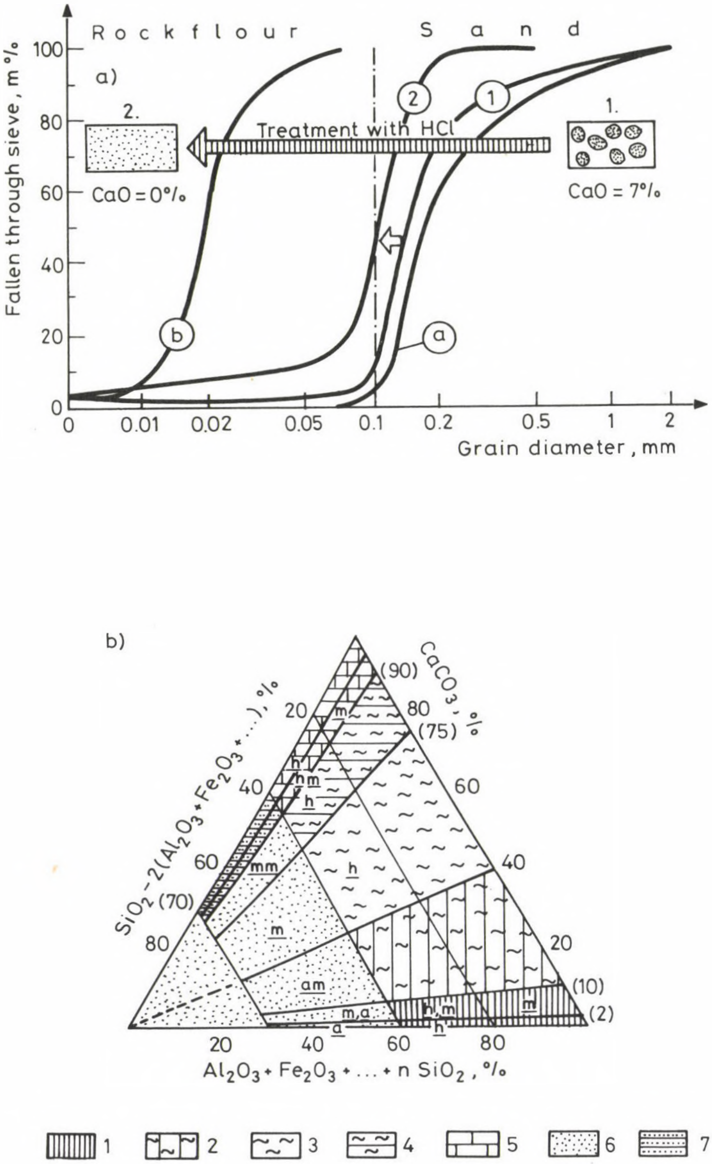
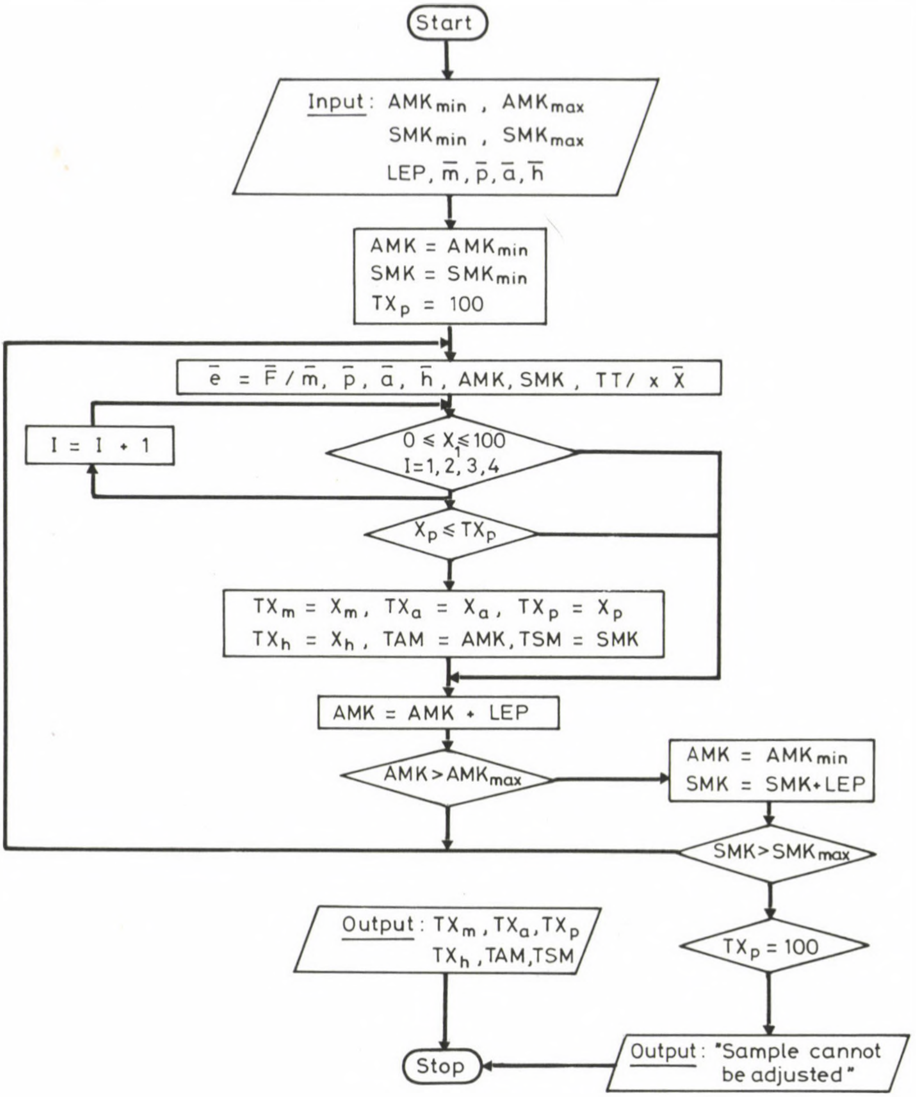


Fig. 2. Rock-nomenclature from the point of view of the cement industry. A — Grain distribution of sand raw material (Bélapátfalva, Pusztaszőlő): 1. natural-; 2. CaCO$_3$-free-state; a — on the effect of handling with HCl disappearing range, b — appearing range. B — Triangular diagram of rock denomination: 1. clay; 2. clay-marl; 3. marl; 4. lime-marl; 5. limestone; 6. sand; 7. sandstone; m — marly, h — sandy, a — clayey, am — clay-marly and mm — lime-marly indicator



AMK	1.	$\overline{m}$	4.	$\overline{p}$	7.
SMK	2.	$\overline{a}$	5.	$\overline{X}$	8.
TT	3.	$\overline{h}$	6.	LEP	9.

Fig. 3. Computer-process diagram of raw material qualification taking into consideration the composition-calculation (in case of 4 components). 1. Aluminate- and 2. silicate-module of raw mixture; 3. its saturation-factor; 4. chemical composition of limestone-, 5. clay-, 6. sand- and 7. pyrite-cinder; 8. percentual proportion of components in the raw mixture; 9. step distance

a result of the common effect of these, geostatistical methods were applied. In the units corresponding to mining exploitation cuts of 10 m with the chemical parameters variograms were produced. The empiric variograms reflect an anisotropy in space. An effect-distance of 70 m in the NW-SE direction, 100 m perpendicularly of this and 30 m vertically presents itself (Fig. 4A). The occurrence can be characterized statistically ap-

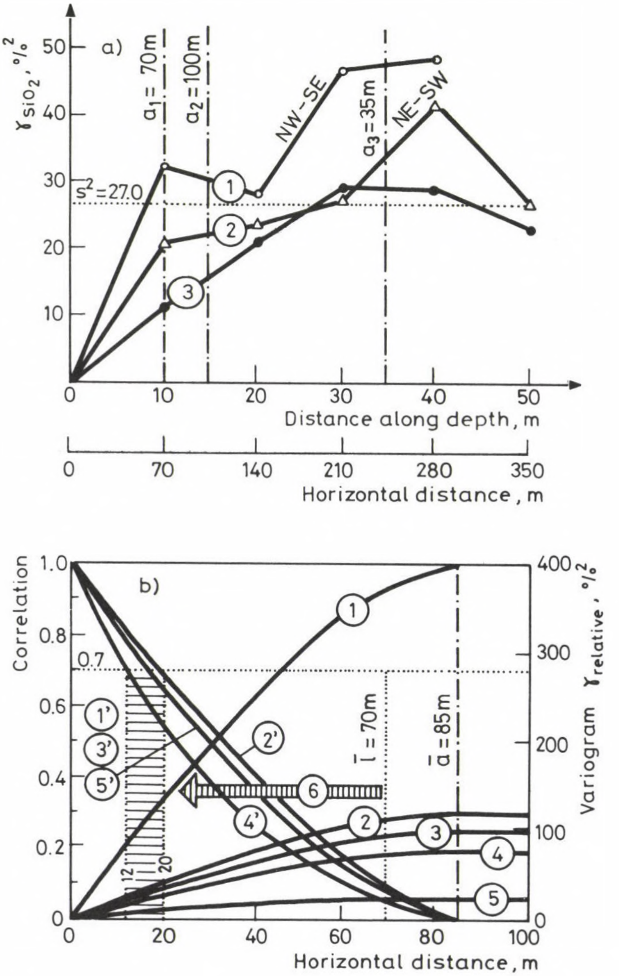


Fig. 4. Structural analysis (Bélapátfalva, Pusztaszőlő). A — SiO_2 (%) variograms along direction; 1, 2. in horizontal; 3. and in vertical direction, a_1, a_2, a_3 — effect distances along direction. B — Modelled variogram- and correlation-relations of chemical parameters: 1-1' — MgO%-, 2-2' — Na_2O+K_2O%-, 3-3' — AM-, 4-4' — SiO_2%-, 5-5' — SM variogram and correlation curve, $\bar{a}$ — limit distance, $\bar{l}$ — network distance of drilling, 6 — network-densifying of drilling

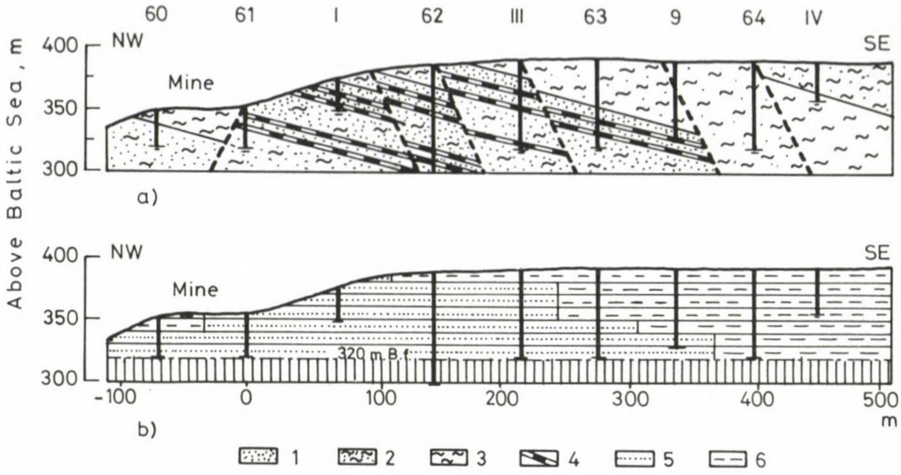


Fig. 5. Geological and technological profile. A — Geological profile: 1. sand; 2. marly sand; sandy clay-marl; 3. clay-marl; 4. sandstone. B — Technological profile (on the basis of mine-exploitation profiles of 10 m each); 5. cement industrial sand-; 6. clay-raw material

proximately by these dimensions and can be built practically from homogeneous units. The exploration of the space-contact of the units of same quality may have great advantages. An indication of this is not delivered directly by the geological picture. To follow the arrangement of quality we found suitable to investigate the space-distribution of the raw material which can be adjusted in its cement technological conditions as sand (Fig. 5). On the basis of the arrangement of sand so characterized in the qualitative profiles as well as of the position of its mostly with clay raw material covered surface, the tectonic lines being probabilized on geological basis could be made more exact. At the same time, a base point could be acquired also for the magnitudes of the faults (Fig. 6). On the basis of these units restored and limited with structural lines have shown a statistically good coincidence with the results of the variograms. Now taken into consideration, the tectonized state appearing in the single mining exploitation profile and reflecting various faulting the sand and clay can be separated from each other with a great exactitude and their arrangement can be adjusted to the orientation of the quality parameters (Fig. 6B). As a consequence of the geologically complicated situation of the area it was more explored by drilling than usual. On the basis of different correlations this exploration will not ensure an acceptable local estimation (Fig. 4B). In spite of all of these the above valuation renders acceptable results according to our opinion. It must be mentioned that without similar analyses the space-interpolation methods (e.g. kriging) applied generary in trade practice cannot supply acceptable results. The above methods multiply the efficiency of application of the prospecting results

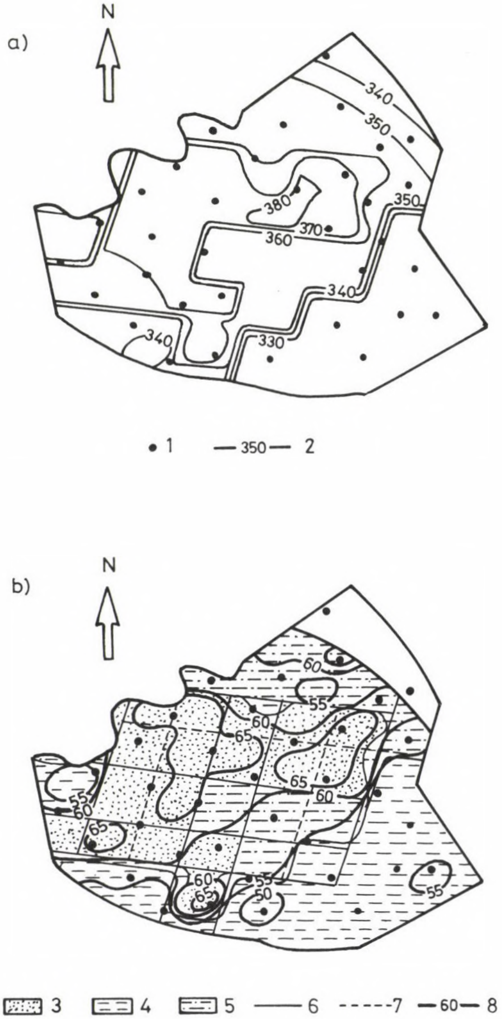


Fig. 6. Evaluation preparing raw material utilization. A — Sand raw material surface map: 1. drilling; 2. level line of surface (m above Baltic sea). B — SiO$_2$% map of mining exploitation profile (350–360 m above Baltic sea); 3. cement industrial sand-; 4. clay; 5. mixed (3+4)-raw material; 6. indicated-; 7. supposed-fault (360 m above Baltic sea); 8. isometric line of SiO$_2$%

of exploration. Besides the given prospected situation their application ensures greater reliability and exactitude than usual. It renders a direct information for the qualitatively oriented control of mining operations adjusted to the cement industrial expectations and gives an assistance to ensure the maximally 1% deviation admissible in the raw flour. The development of methods is in progress, in form of simulation models by means of which we wish to supply even more correct basic data for the cement technological planning.

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TASKS AND PROBLEMS OF THE ENGINEERING GEOLOGICAL MAPPING OF SETTLEMENTS WITH CELLARS

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Settlements with subsurface cellar systems are highly endangered due to the increased load and to the decreased load capacity of the cellar ceiling. The engineering geological mapping of the towns and settlements of this type, e.g. Szentendre, Szekszárd, Eger, Pécs and especially Nagymaros where the hydroelectric power plant in planned may provide useful information on the geotechnical, geomorphological and hydrological conditions of the areas in question. The map variants may serve as a basis for technical and economic experts for their decisions concerning urban and are regulations.

Keywords: Engineering geological mapping geotechnics, settlements with cellars

Introduction

As a consequence of the urban development of recent decades the stability of the cellar- and cave-systems developed in the course of historic times decreased rapidly, creating a real danger situation. The planned elimination of state of caves and cellars endangering life- and fortune-safety required the preparation of the engineering geological map-series in a stressed way.

So with the planned elimination of cellar problems concerning the towns Eger and Pécs, the engineering geological mapping has started and continued since the beginning of the eighties with the engineering geological mapping of Szentendre, Szekszárd, later on Nagymaros, Noszvaj, Novaj, Ostoros, Budafok in the XXIInd district of Budapest and from 1988 of Paks.

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Taking the geological, soil mechanical and hydrological exploration of the given settlement as a basis and having made the exploration corresponding to the scale of mapping, on the basis of the previously prepared program schedule approved by the Central Geological Office the engineering geological map-series have been made on sheets covering the administration area of the settlement. The engineering geological map-series summarizes the earlier and new data and because of their construction on each other an extensive knowledge is ensured about the mapped areas. The complex processing like this enlightens the area-utilization and settlement decisions, the reconstruction activity, the planning of area regulation and development and in case of investments it becomes a cost sparing factor. It was the task of the building geological mapping made parallel with the precise surveying and eliminating works to supply such data for the cellar works. The usefulness of the engineering geological mapping works, however, cannot be limited only to the cellar subject because it takes into consideration also the perspective development concepts of the town, so mapping gives useful information for the whole town that is advantageous for the users in long term planning.

General tasks and problems of the engineering geological mapping

The engineering geological conditions and according to these the problems of the mapped areas are determined basically by two components: the geological structure and the anthropogenic effects together. Because the cellars are essentially connected to viticulture at the hilly landscape, their location can be observed mostly on the range, the side or the back of hills. According to this, the geological conditions are complicated and require a more detailed exploration. Because of the flange situation the rock material is cut by cracks and faults, the block form and separation is not rare either. With the development and extension of settlements also such undercellared areas became built up in the urban way which were before only loosely built up and therefore they do not have greater load-bearing capacity. Also the anthropogenic effects increased and influence the unfavourable geological conditions in the harmful direction. Out of these effects the dynamical effects increasing with an order of magnitude, the rock soaking effect of water coming from flows from public utilities and drying of sewage, the lack of systematical maintenance of slopes and

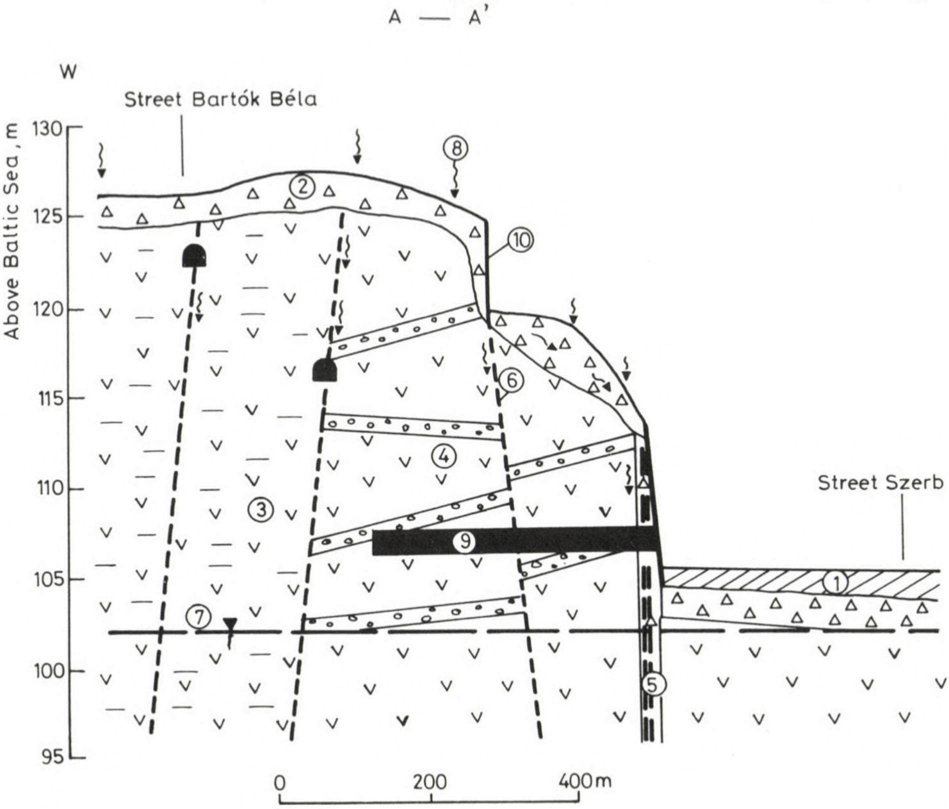

Fig. 1. Characteristic engineering geological profile of Szentendre-Szamárhegy. 1. Upfill; 2. slope detritus; 3. Miocene clayey tuffite; 4. Miocene tuffaceous sand, sandstone; 5. fault, broken zone; 6. important fracture; 7. average water level; 8. surface water-infiltration; 9. cellar; 10. supporting wall

loosely built supporting walls are the most important ones. The different problems are connected with one another because e.g. the loosing up subsequent to the collapse of the ceilings of cellars may reach the foundation plane of buildings and the ground surface and may cause building damages and road collapses. The deterioration of supporting walls may cause the movement of slopes and as a result of the movement of slopes the damages of supporting walls and buildings can be followed.

The considerable part of stability problems is caused by the deterioration of the rock material. In Szentendre the material of cellars dug in tuff and sandy tuffite is weathered on effect of water (Fig. 1) and as a consequence of this its load-bearing capacity decreases essentially, maybe to 25—30% of the original strength.

In Szekszárd and Nagymaros the cellars were excavated in loess where the most important stability problem is caused, in addition to the considerable increase of the dynamical effect, by the unsuitable drainage of the surface water. On the flange of the cellar-lines and loess deep ways, due to the effect of water rush down, vertical separation planes coming from the structure of loess are formed which can develop further block-collapses. This is especially characteristic of the entrance section of cellars (Fig. 2) and in an unfavourable case this may cause the collapse of this part of the cellar.

It follows from the stability problems that the engineering geological processing and depiction of the areas is a very complex task. One can group the data to be processed according to the following themes:

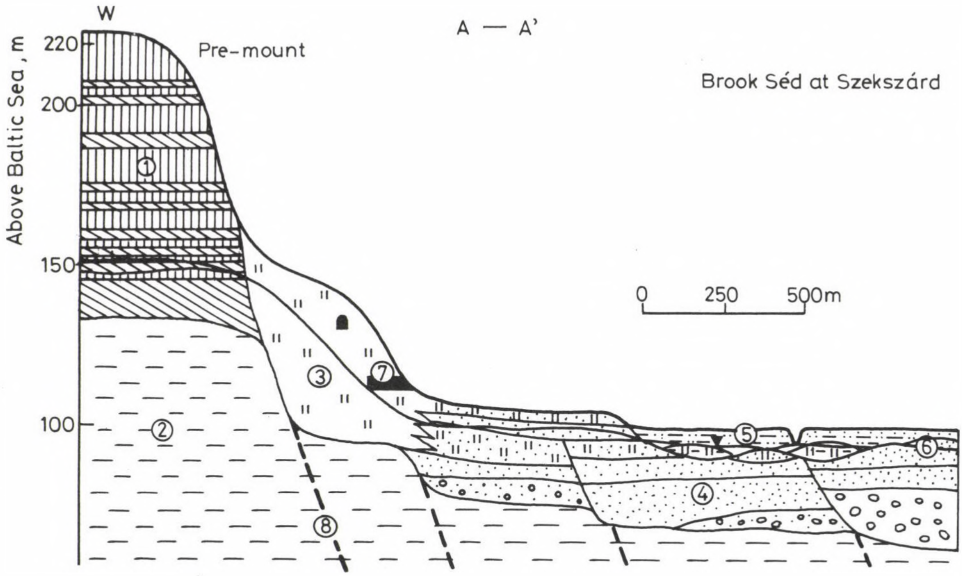

Fig. 2. Characteristic engineering geological profile on the flange of the hill-line in Szekszárd. 1. Undisturbed loess layers with clayey layers; 2. Upper Pannonian clay; 3. overheaped loess; 4. Danube sediments; 5. sediments of little flows; 6. average groundwater level; 7. cellars on the hill-flange; 8. supposed fault, fracture

- geological, geomorphological knowledge,
- geotechnical, petrophysical knowledge,
- knowledge concerning the water near the surface.

This data-heap was depicted according to each theme on a separate map. So the geological, geomorphological knowledge on geological observation-, covered geological-, uncovered geological- and geomorphological maps; the geotechnical and petrophysical knowledge on drilling point- and foundation-maps; data concerning the near surface waters on hydrogeological observation map and different variants of water level maps will be shown. Using up these map variants thematic maps showing the engineering geological specialities of the given area in a complex way will be drawn. A type of this is e.g. the engineering geological synthetizing map which puts the geological, geomorphological, hydrogeological, hydrochemical, soil mechanical and foundation conditions from the point of view of the users into categories, enlightening by this the task of the not specialist users.

To help the work of environmental protection the environment sensitivity map is prepared, on which among others one can see the area especially sensitive to erosion, the groundwater area near the surface sensitive to pollution, the areas to be protected of the water bases etc. For special use of the council the urban development potential map is drawn where the engineering geological prognostics of the building up possibilities are given.

The principles of the map documentation are already fully developed, but according to the special conditions and interference requirements of the single settlements engineering geological map-variants are prepared.

Engineering geological mapping of Szentendre

The engineering geological mapping of the town started in 1981 in a scale of 1:4000 (Fig. 3) on seven map-sheets. On a single map-sheet the area to be mapped is 2.88 km^2, the full area extends to 20.16 km^2. Mapping has started with the preparation of a cadastre for springs and dug wells and continued with a data collection concerning soil mechanics and geology. As a result the layer-series of about 500 soil mechanical boreholes were processed; 80 engineering geological mapping boreholes and 31 groundwater level observing wells were made (960 m). After the material-tests continuously the following map-series were prepared: in 1987: 3. Izbég, 4. Pismány,

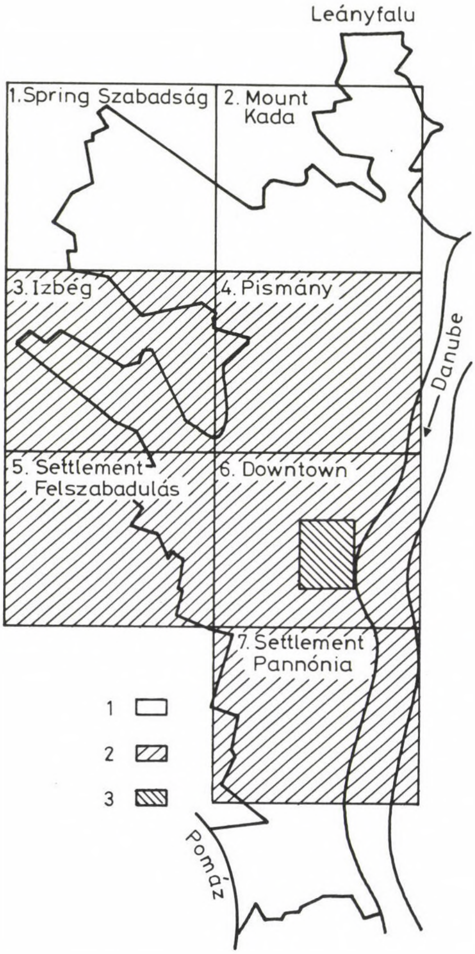

Fig. 3. Profile-sectioning of the engineering geological mapping of Szentendre. 1. Eng. geological map-series ready in 1988; 2. eng. geological map-series ready between 1982 and 1987; 3. downtown, mount Szamár, map-section, scale 1:500

5. residential district "Felszabadulás", 6. Downtown, 7. Pannónia-settlement. For 1988 the preparation of the following map-series is planned: 1. Szabadság-spring, 2. Kada-mount, as well as on the basis of water level observations of the whole mapping area carried out so far the estimated maximal groundwater level maps.

A characteristic part of "Szamárhegy" having cellar problems and its engineering geological profile are shown in Figs 1 and 4.

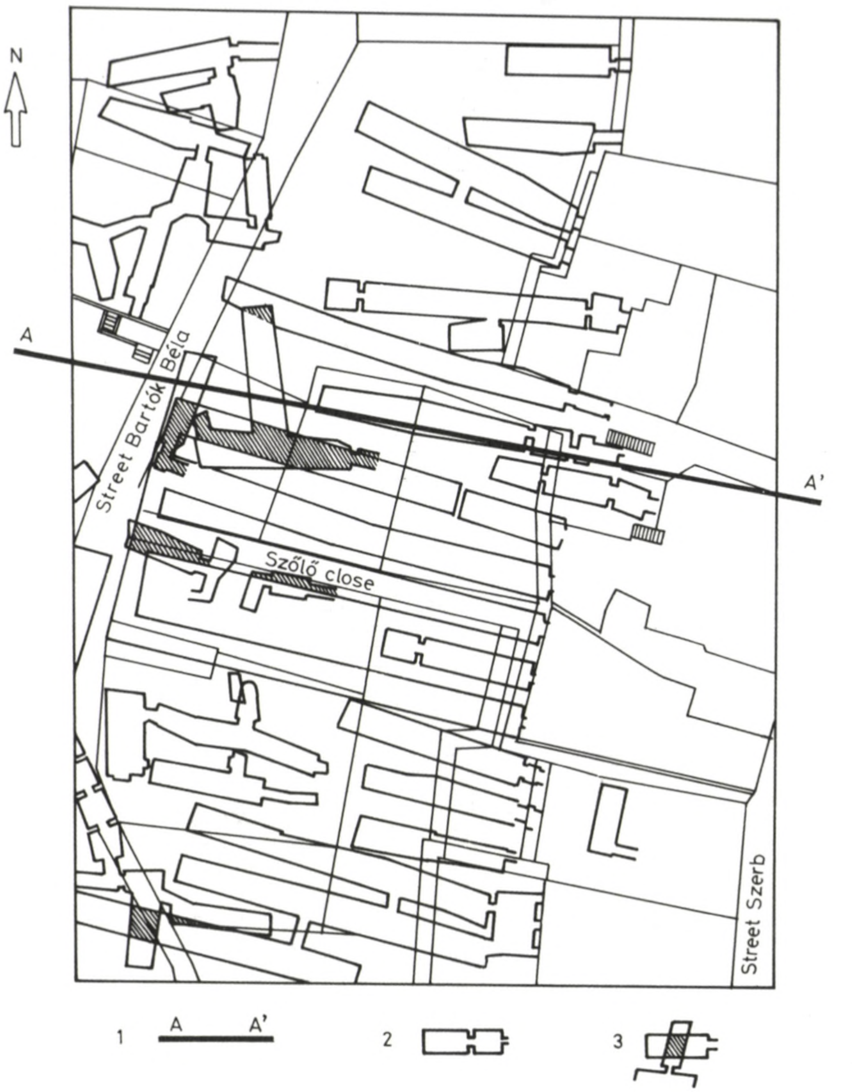

Fig. 4. Map about the cellar-system of mount Szamár in Szentendre, scale: 1:500. 1. Direction of eng. geological profile; 2. cellar, cellar-system; 3. cellars located above each other

Engineering geological mapping of Szekszárd

The engineering geological mapping of the town started in 1981 in the scale of 1:4000 (Fig. 5) on 8 map-sheets. The area of one map-sheet is 3 km^2, the whole area is 24 km^2. The process of mapping was the same as the mapping in Szentendre, in the course of the soil mechanical data collection the material of about 800 boreholes were processed, 29 mapping boreholes and 59 groundwater level observing wells (2413 m) were drilled. The engineering geological map-variants made until now are: 6. Bakta, 4. downtown, 1. mount Bottyán, and in 1988 the following map-sheets will be prepared: 5. "Vásártér", 6. "Szőlőhegy".

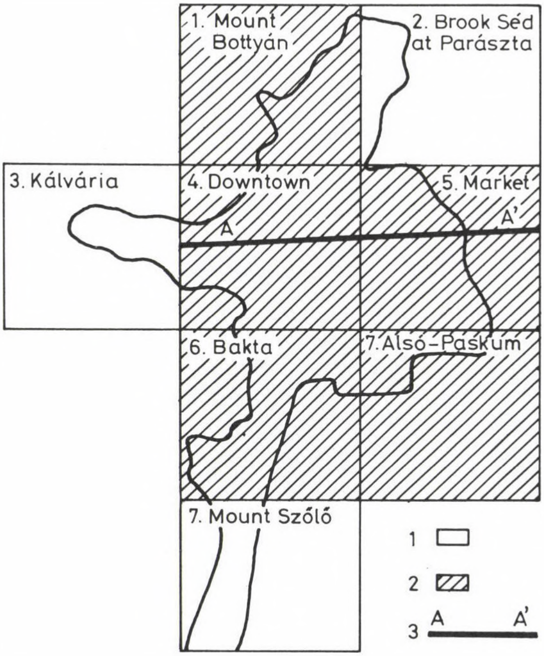

Fig. 5. Profile-sectioning of the engineering geological mapping of Szekszárd. 1. Eng. geological map-series ready between 1989 and 1990; 2. eng. geological map-series made ready between 1986 and 1988; 3. direction of hydrogeological profile

Engineering geological mapping of Noszvaj

The engineering geological mapping of the village started in 1986 with the preparation of topographic base-maps and continued in 1987 with a geological, engineering geological, and hydrogeological data collection. For 1988 the geological exploration of the Northern 1:4000 profile is planned (Fig. 6) in a depth of 10–15 m and in a total length of 125 m.

The engineering geological determination of state of the cellars is made difficult by the fact that a part of these is used as a flat yet. One part of the cellars is excavated in Oligocene clay-marl these are not lined and collapse. An other part of the cellars was cut into rhyolite-tuff, the state of which is deteriorated by water flowing away from sewage-driers (Fig. 7).

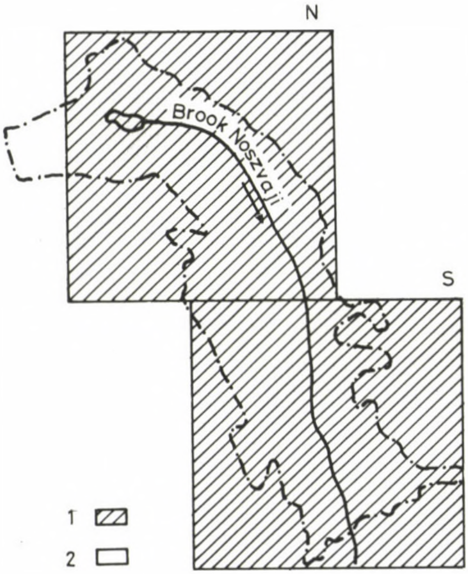

Fig. 6. Profile-sectioning of the engineering geological mapping of Noszvaj. 1. Map-profile, scale 1:4.000; 2. map-profile, scale 1:10.000

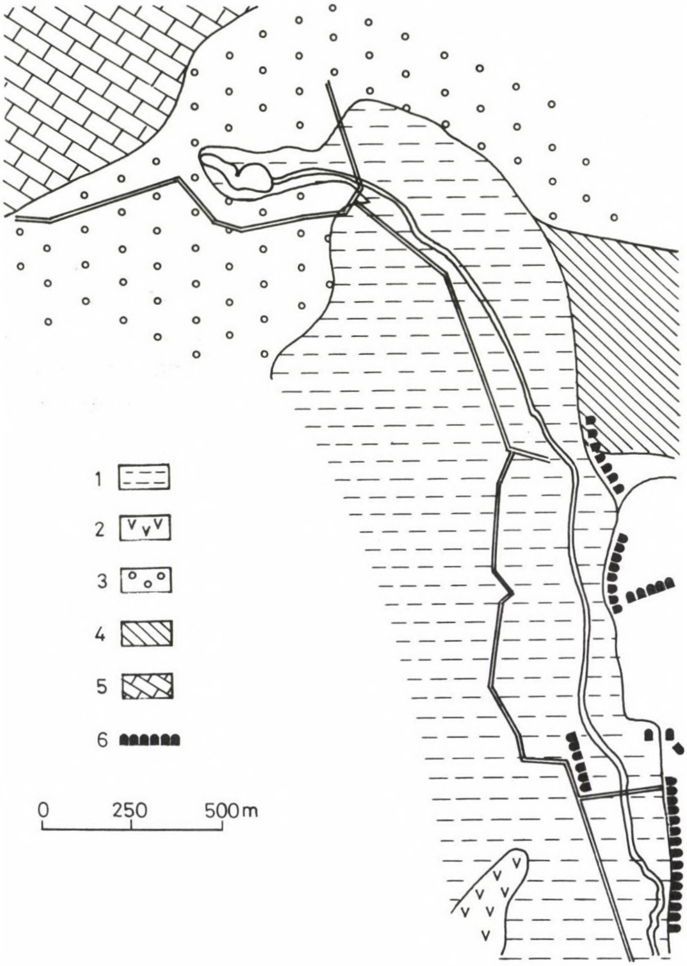

Fig. 7. Covered geological map of Noszvaj. 1. Holocene–Pleistocene silty clay, clay; 2. Miocene rhyodacite tuff; 3. Miocene clayey gravel, conglomerate; 4. Oligocene clay, sand; 5. Eocene limestone with nummulits; 6. cellar-line

Engineering geological mapping of Nagymaros

The engineering geological mapping of the great village started at the same time as that one of Noszvaj. Similarly to that one of Noszvaj the exploration works of one map-sheet No. 2 became ready (150 m, Fig. 8). In the course of data collection 260 soil mechanical borings were collected; using these data the documentation, covered and uncovered geological, as

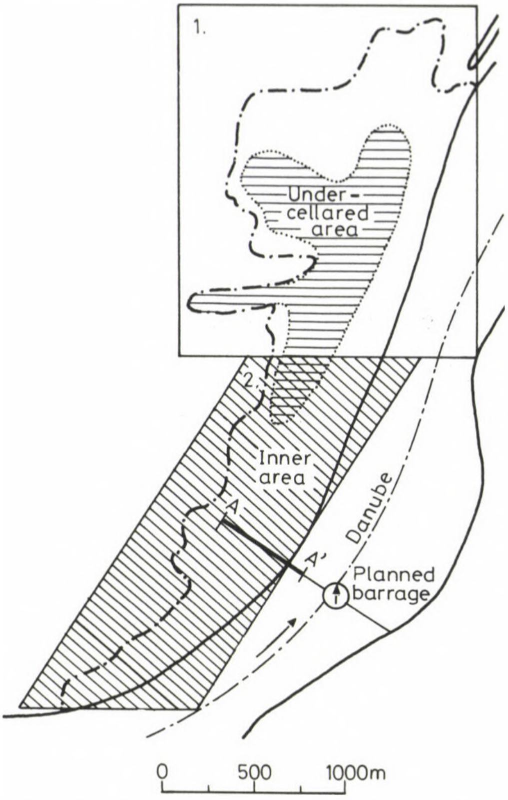

Fig. 8. Profile-sectioning of the engineering geological mapping of Nagymaros

well as the hydrogeological observation maps of the profile No. 2 were prepared.

The importance of mapping is stressed by the fact that the barrage under construction will be located in the area of the settlement (Fig. 9).

The cellars are located mostly in the Northern sheet No. 1 in loess. The great highway traffic and its increasing dynamical effect resp. starting with the construction of the barrage will have presumably a harmful effect on the consistence of the cellars.

The engineering geological mapping of the villages Novaj and Ostoros started in 1987 with the exploration works (350 m). For 1988 the preparation of the observation and geological maps is planned.

Having prepared the engineering geological mapping in the scale of

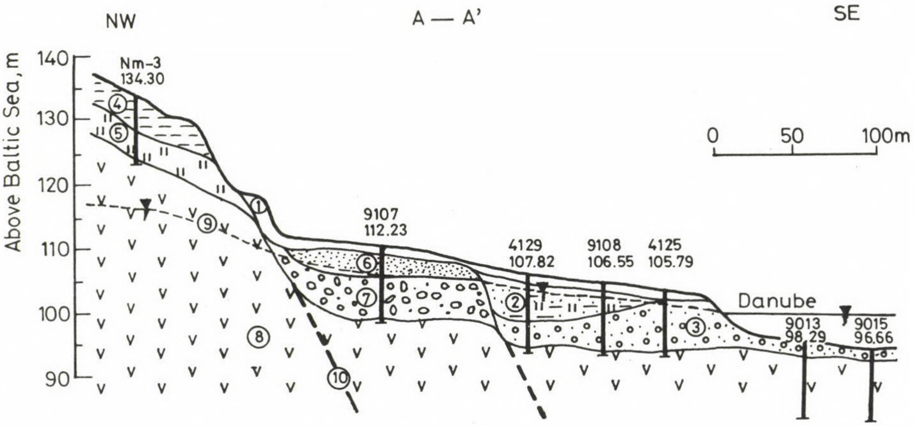

Fig. 9. Engineering geological profile designed along the planned barrage of Nagymaros. 1. Rockflour, overheaped loess; 2. clay, silty rockflour; 3. sandy gravel, gravelly sand; 4. clay with slope detritus; 5. loess with slope detritus; 6. sand; 7. terrace-gravel; 8. Miocene andesite, andesite tuff and agglomerate; 9. average groundwater level; 10. supposed fault, fracture

1:4000 the maps will be over-designed to the scale of 1:10 000 and afterwards will be the press-publications prepared.

Summary

In the course of the engineering geological mapping different map-variants are prepared which render an assistance to technical projecting, settlement development, reconstruction and other purposes. Its engineering geological and building hydrological applicability includes a wide range. The published data, conclusions and the designed map-variants can be utilized by technical and economic experts dealing with urban regulation and area regulation, by contractors and companies etc. More founded and economic decisions and plans can be prepared in the knowledge of the engineering geological map-series.

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A clear, careful and unequivocal formulation of the papers, lucidity of style and the use of uniform nomenclature adopted in Hungary are basic requirements. It is convenient to subdivide the text of the papers into sections under subheadings.

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The paper complete with abstract, figures, captions, tables and bibliography should not exceed 25 pages (25 double-spaced lines with a 3 cm margin on both sides).

The first page should include:

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Acta Geologica Hungarica, Vol. 32/3-4, pp. 269-324 (1989)

REVIEW OF THE GEOLOGY OF THE s.l. PANNONIAN FORMATIONS OF HUNGARY

Á. JÁMBOR

Hungarian Geological Survey, Budapest

The geological features of the (sensu lato) Pannonian stage involving a part of the Upper Miocene and the Pliocene and representing the relatively monotonous sequence of the Central Paratethys between the Sarmatian and the Pleistocene characterized first by inland sea, subsequently by lacustrine-terrestrial sedimentary sequence due to the filling effect of delta systems prograding from the north, are discussed. This sequence of Hungary is of greatest mass and extension among the geological formations and bear primordial significance from the aspects of raw material prospecting and production, as well. The concept, temporal position, Hungarian extension (75.000 km^2), the grade of exploration, the thickness conditions, the lower and upper boundaries, rock types and their frequency and proportion in the sequence, the mineral compositions of the rocks, the lithostratigraphic classification, the biostratigraphic classification system (molluscs, ostracods, vertebrates, microplankton etc.) as well as the chronostratigraphic data of the Pannonian (s.l.) formations are dealt with.

A comprehensive discussion is given on the tectonic features of the formations, on the occurrence of volcanics, on the history of evolution of the sequence and on the paleogeographical conditions, as well.

Finally, the significance and genetic conditions of related and various mineral resources (water, thermal water, hydrocarbons, lignite, non-metallic materials e.g. bentonite, alginite, kaolinite, diatomite, chalk, building materials) are summarized.

Keywords: Pannonian Basin, Upper Miocene, Pliocene, stratigraphy, paleogeography, mineralogical-petrological built-up, tectonics, volcanism, history of evolution, mineral raw materials.

Introduction

Among the natural sciences the geology has the most national characteristics. This is valid especially of the Pannonian formations that extend over more than the half of one country. Here are the thickest formations and the majority of its mass.

Experts have dealt with the research of the Pannonian formations since about 150 years, and the Hungarian geologists proved to be the first

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ones to recognize the significance of this sequence. In spite of this, first of all the explorations of the last three decades and the applied up-to-date exploration means (boreholes, up-to-date analytical methods, reflection seismics) assured the comprehensive knowledge of the Hungarian Pannonian sequence.

Applying the given possibilities and the manysided sponsorship of G. Hámor (General Manager of the Hungarian Geological Survey), in this work the basic features of the Pannonian sequence of Hungary are to be introduced.

To prepare nowadays a review of this type is verified first of all by the increasing demands of the society for mineral resources since the Pannonian sequence contains the greatest reserves of potable water of the country, the major part of the petroleum and gas reserves, the lignite reserves, the industrial sand masses, the greatest bentonite deposits and the manysided alginite raw material and the brick industry is also bound to these formations. The long-term possibilities of raw material prospecting and utilization can be determined only on the basis of the high-quality elaboration of the geological picture. Further, the rapidly increasing stresses of the coexistence of the society and its environment require the periodical drawing of such a picture.

To solve this task, of course, it highly exceeds the possibilities and capabilities of one expert. In addition to me and to my close coworkers, numerous specialists of the Hungarian Geological Survey and numerous experts of different firms have taken part in this work (National Petroleum and Gas Industrial Trust, Petroleum and Gas Mining Company, Geophysical Exploration Company, National Geological Exploration and Drilling Company, Mecsek Ore Mining Company, GEOS Ltd. among different companies, the Eötvös Loránd Geophysical Institute, the Hungarian Hydrocarbon Exploration and Development Company, the Scientific Research Institute for Water Researches, the Institute of Nuclear Research, the Geographical Research Institute, the Institute of Mining Development among different institutions, and the Eötvös Loránd University, the József Attila University, the Technical University of Heavy Industry of Miskolc among the universities).

During the last 20 years a more or less systematic fruitful cooperation has developed among the experts dealing with the Pannonian formations. In spite of this there are and till the geological explorations exist will be debates and professional conflicts in a lot of geological problems.

Since the publication of the Pannonian monography marked by the name of F. Bartha (Bartha et al. 1971), the explorations on the geology of the Pannonian formations during the last 20 years provided a lot of general results which could not be produced by the neighbouring countries (Yugoslavia, Rumania, Czechoslovakia, Austria, Soviet Union). In the following first of all the new results are to be introduced.

Knowledge level

The first steps to be familiar with the Pannonian formations were taken in the first half of the 19th century (Partsch, 1835). Based on the uncommon and characteristic fossils these strata were called "Congeria stage". Their wide extension and relatively monotonous sequences (grey clay, sand, occasionally gravel and freshwater limestone) became obvious in the course of the first geological mapping of 1:144 000 scale of the country (between 1850 and 1900). The term Pannonian derives from L. Roth (1879) who suggested to apply this term to the sequence between the Sarmatian and Pleistocene on the basis of Congeria found also in older Miocene formations by Böckh (1876) and of the individual and characteristic features of this formation assemblage.

Due to the use of this term, to the deviation from the international terms Miocene and Pliocene, and to the overlap of uncertain measure there have been troubles but no better term has been found so far.

At about the end of the first mapping period the drilling of boreholes for water started (Halaváts, 1896), which in spite of their rudimentary techniques proved the thickness of more than 200 m of the Pannonian sequence in lowlands.

In the course of the first mapping phase Fuchs (1870), Halaváts (1886, 1903), Koch (1873), Lőrenthey (1900-1906) and Vitális (1908) elaborated the bases of mollusc stratigraphy though as a result of hard debates and the processing of fossils of ostracods (Méhes, 1907, 1908) and of vertebrates (Kormos, 1911, 1914; Kadič, 1911) also started.

The knowledge of the true complete picture of the Pannonian formations was improved by the processing of the hydrocarbon (Schmidt, 1939; Papp, 1939; Barnabás and Strausz, 1947) and lignite (Schréter, 1929, 1952; Vigh, 1939; Jaskó, 1948) exploratory bores, mainly between the two world wars, and the reambulatory mapping of the lowland areas (Strausz, 1941; Vigh, 1939; Schréter, 1952, Vadász, 1935; Szentes, 1943) in scales of 1:25 000 and 1:75 000 also contributed to have more data on these formations.

The industrial development and related mineral raw material prospecting started in 1950 and in the period up to the end of the eighties more than 7000 hydrocarbon exploratory well with well logging and of periodic coring, several ten thousand browncoal, bauxite, uranium and sand exploratory coreholes, and several hundred thousand hydrological wells of periodic coring explored the Pannonian formations (Fig. 1). In addition to these the Hungarian Geological Survey has continued the mapping activities in the mountainous areas (1:10 000 and 1:25 000 scales) and in the lowlands (1:100 000 scale) that covered the whole area of the country, and drilled several hundred coreholes, the so-called mapping and key boreholes located always in geologically significant points. The data obtained from these boreholes, as well as the sedimentological, mineralogical-petrological, biostratigraphic (molluscs, ostracods, microplankton, nannoplankton, spore-pollen, diatoms, trace fossils), geochemical, organic geochemical, paleomagnetic and K-Ar data together with the industrial exploration data allowed to create a reliable picture on the Pannonian formations.

In the exploration of deep basins the modern seismic reflection profiles of several thousand kilometres total length have been of primordial significance in addition to boreholes.

To process the borehole sequences (the cores) a logic system was elaborated in 1962-1963. The essence of this system is very simple: exact rock definition practice, the consistent and systematic observation and description of basic rock properties in the field aiming at three indirect items: 1. when reading the rock description the rock should appear for the reader; 2. based on the description the rock facies should be determinable; 3. the sequence described and drawn should be unambiguously transformed.

The exploration tasks of the past 40 years have been carried out by several dozens of experts. Their effect on one another has been traditional. In every year 20-70 papers were published concerning the Pannonian and the lectures amounted roughly to the same number. In these lectures the exchange of opinions has been intense. Since the beginning of the sixties the international relations have become more frequent, then systematic.

Geological characteristics of the Pannonian formations

1. The concept of the time interval Pannonian. In sense of the formulation of L. Roth in 1879 the concept of the Pannonian stage is expedient to be used for the time of formation between the Sarmatian and Pleistocene in the Carpathian basin and it has been a constraint for me to use the term "Pannonian sensu lato". In 1975, at the Neogene Conference

at Bratislava the colleagues dealing with these formations in the neighbouring countries decided to interprete the originally Lower Pannonian as Pannonian stage.

The former Upper Pannonian substage was divided into Pontian, Dacian and Romanian stages. Nevertheless, the major part of the Hungarian geologists did not accept the viewpoint concerning the dismembering of the Pannonian stage. To maintain our opinion was governed not by the superabundance of nationality but by the geological considerations below: when denoting the geohistoric time units in our Earth one ought to accept only one stage system accepted and suggested by the International Geological Congress, since in other case confusion hindering the progress will develop.

When determining the concept of stages only one decisive aspect has to exist: the date of their lower and upper boundaries. Of course, it is necessary to bind the stage boundaries to some geohistoric event that can be observed in the section. These boundaries, however, have to be searched for first of all by chronostratigraphic methods in the section being in a basin of different history of evolution.

Recently, by means of the chronostratigraphic methods the possibilities are provided to determine the dates of boundaries of the Pannonian sequence, i.e. of the Pannonian stage and to correlated with an internationally accepted stage system. This type of classification, however, does not exist for the Neogene though the use of the term "Mediterranean" stage becomes ever more widespread.

Instead of using the local, regional stage terms, the lithostratigraphic units should be denominated and in this respect all countries are allowed to insist on her own term, without restrictions.

If our neighbours insist on their national Neogene regional stage system, I would suggest and have suggested new terms that better fit the history of evolution of the Pannonian formations: instead of Lower Pannonian the "Kunságian" and instead of Upper Pannonian the "Balatonian", since the internationally accepted rules do not allow the derivation of fraction terms with attributes "lower" and "upper".

There is no denying that when suggesting this idea I was influenced both by the areal and the quantitative distribution of the Pannonian s.l. formations; their major part is found in Hungary since except the mountainous areas these are common and in knowing these formations we have overtaken our neighbours.

Though the basic principle of priority argues in favour of accepting the stage terminology based on the terrestrial (Vertebrate) biostratigraphy - the repeated suggestion of M. Kretzoi - for the experts dealing with the inland sea intrabasinal sequences of 100 to 4500 m thickness the correlations with the thin formations determined usually in cave fillings cannot be accepted. It is expedient to apply certain members of this terrestrial stage system only to denominate the terrestrial formations consisting mainly of cave fillings.

Nevertheless, the everyday practice will use the Lower and Upper Pannonian terms, and as lithostratigraphic unit the Lower and Upper Pannonian sequence in Hungary presuming that we want to understand each other.

The final solution in this respect will be provided by an internationally accepted stage system for the Neogene and by the correlation with this system.

It is to be emphasized, however, that the formation of the Lower and Upper Pannonian sequences extends over different time intervals in different sections, thus the use of their term for stages is incorrect since these cover lithostratigraphic and not temporal concepts. This is why in harmony with the standpoint of the Hungarian Committee on Stratigraphy I suggest the terms Peremartonian (Lower Pannonian) and Transdanubian (Upper Pannonian formations) Main Group. In the internationally accepted stage scale to be determined the positions of these terms have to be fixed.

2. Lower boundary of the Pannonian formations. In this problem a common consent seems to be reached.

At the time of the formation of the Sarmatian-Pannonian boundary the sedimentation was continuous in the depressional areas of the basement of inland sea basin of that time (Á. Szalay, K. Szentgyörgyi, 1979). These areas are practically the same nowadays as the areas of intrabasinal and mountain-marginal depressions, in which essentially pelitic sedimentation proceeded.

This sedimentation produced the lamellar marl sequence of the Zala Formation of Transdanubia where in favourable case the age boundary can be marked by thin rhyolite crystal tuff intercalations, further in the marginal sequences rich in fossils by the drastic change of the living world, i.e. the appearance of Limnocardium praeponticum and its predominance (M. Korpás-Hódi), by the complete change of the ostracod (M. Széles, A. Szuromi-Korecz) and foraminifer (I. Korecz-Laky) fauna and of

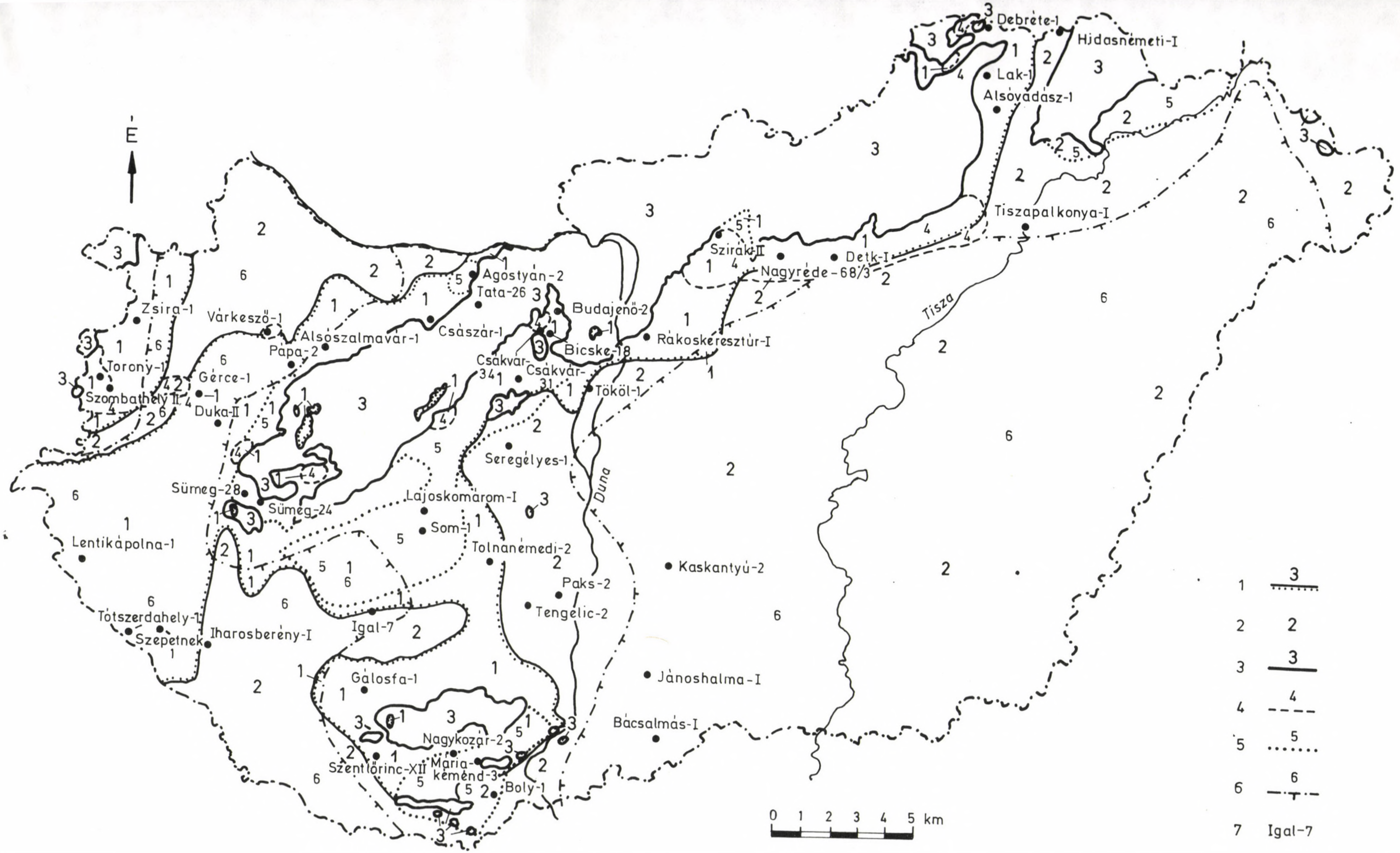


Fig. 1. Map of exploration of Pannonian formations in Hungary. 1. extension of the smaller-greater surface exposures of Pannonian formations (regions with geological maps of 1:100 000 to 1:10 000 scales); 2. Pannonian formations covered by Quaternary sequences thicker than 10 to 20 m; 3. surface extension of the formations older than Pannonian; 4. Pannonian regions explored densely by raw material exploratory coreholes; 5. Pannonian regions explored sporadically by raw material exploratory boreholes; 6. Pannonian regions explored by very deep hydrocarbon and medium-deep hydrological exploratory wells; 7. geological key-boreholes with particular laboratory analyses

the microflora of organic skelet (M. Sütő-Szentai) (In: Á. Jámbor, M. Korpás-Hódi, M. Széles, M. Sütő-Szentai, 1985 and 1987).

These types of sequences were found in the Zala Basin, in the southern foreground of the Transdanubian Mid-Mountains (Lajoskomárom-1 and Budajenő-2 boreholes), in the depressions of the basin area north of the Mecsek Mountains (Tengelic-2 borehole), in the southern foreground of the Mecsek Mountains (Martonfa-1 and Nagykozár-2 boreholes).

No particular paleontological analyses have been carried out in the thick intrabasinal sequences. In the Great Plain, in the depressional areas the Sarmatian-Pannonian boundary is unexplored by coreholes.

In the western part of the Zagyva Trench, above the Sarmatian-Pannonian boundary turbiditic-olistholithic alternating (Szirák-2 borehole), in the Hernád Valley close to the Sarmatian-Pannonian boundary freshwater (fluviatile-lacustrine) unbroken sequence with acid pyroclastic intercalations developed. In the Hernád Valley no difference exists between the sediments of the two stages. According to the analyses of E. Nagy-Bodor the proper temporal place is proved by the change of palynoflora observed in the facies stratotype section of the borehole Lajoskomárom-1.

In formerly uplifted areas that are recently also heighs almost without exception, the appearance of geological sections can be expected being characterized by alternating Sarmatian and Lower Pannonian strata developed on the slopes under continuous inundation but incomplete due to erosion and mud-slides, and by strata at their foots characterized by alternating pelitic-fine sandy layers including occasionally mixed fossil assemblage (Paks-2 borehole).

In the top parts of the formerly uplifted areas usually Lower Pannonian sequences being incomplete from below were formed. Here the inland sea sedimentation is evidenced to proceed in three phases: in the Middle and Upper Lower Pannonian and in the Lower Upper Pannonian; in this respect the results of Kőrössy (1968), Szalay and Szentgyörgyi (1979), Pogácsás and Völgyi(1982) and Jámbor (1980) have to be mentioned.

In the foregoing sentence the ambiguous use of the term Pannonian is no accident. These parts denote lithostratigraphic units thus the contemporaneity or discontemporaneity of the three prograding phases, as well as the measure of this has been undetermined so far.

Accordingly, in these heighs Lower Pannonian sequence being incomplete from below have to be taken into account. Their structure is simple. These start with thin gravel or gravelly sand basal layer (that forms only a negligible part of the total thickness of the whole Lower Pannonian sequence) and are overlain by monotonous inland sea pelitic sequences.

Such sequences are known in the Sopron Mountains, in the southern, western and northwestern margin of the Mecsek Mountains, in the southern, eastern and northern foreground of the Villány Mountains, above the South-Baranya blocks, in many localities of the marginal areas in the Transdanubian Mid-Mountains, and rarely in the southern foreground of the Mátra and Bükk Mountains and in the southwestern foreground of the Tokaj Hills. These are also frequent in intrabasinal uplifted areas, e.g. Mihályi, Algyő, the Battonya high block, the Mezősas heigh, Iharosberény etc. In harmony with the results of Szalay and Szentgyörgyi their extension in lithostratigraphic sense is common on the intrabasinal heighs.

The Lower Pannonian sequences are incomplete from below also in the frequent case when these overlie the Sarmatian ooidic limestone sequences apparently with continuous sedimentation. It is known that in three profiles lying rather far from one another (the boreholes Zalaszentlászló-1, Tihany-62 and Kaskantyú-2) the Limnocardium praeponticum (M. Korpás-Hódi) the Amplocypris-Hungarocypris (M. Széles) zones, further the whole of the Pleurozonaria ultima zone in the Mecsek Mountains and the lower part of the Spiniferites bentori zone (M. Sütő-Szentai) are missing. Their absence can be interpreted by single subaquatic sediment erosion and by the alternation of short sedimentation and long erosion phases above the uplifted hard surfaces.

Without particular biostratigraphic investigations it is troublesome to determine whether these sequences are complete or incomplete from below, since the incomplete sequences "try" to demonstrate their completeness by their petrographic formations, i.e. their lower part consists also in these cases of lime-marl or at least at the cover of more calcareous pelite strata. Moreover, similarly to the phenomenon recognized in the Zsámbék Basin, in the lowermost horizon of the Lower Pannonian rhyolite tuff and bentonite strata of millimetre-to-centimetre thickness are also intercalated (boreholes Tihany-2, Bácsalmás-1, Nagykozár-2).

If the Pannonian pelite sequence above the Sarmatian sequence starts with gravel or sand layer, the incompleteness from below can be evidenced.

The Sarmatian sequences consisting of pure pelitic or of the alternation of mixed (grey pelite, sand, limestone) strata and the overlying grey pelitic Lower Pannonian sequences are unbroken and of complete formation. Nevertheless, special cases may occur also in this region, e.g. washing, redeposition, lack or excess caused by mud-slides, Sarmatian and Pannonian layer alternation (south-western part of the Zsámbék Basin), "conglomerate" basal layer at the base of the Lower Pannonian consisting of intraformational clay pebbles (Paks-2 borehole).

In the southeastern foreground of the Transdanubian Mid-Mountains, in the Csákvár Basin, in the Várpalota Basin, in the Balatonfő environs and in the Cserehát the variegated clayey Sarmatian strata are overlain by similar variegated clayey Pannonian strata. In these sequences of the Transdanubian Mid-Mountains, due to the frequent occurrence of fauna-bearing strata it is easier to mark though not without troubles the Sarmatian-Pannonian boundary, but in the Cserehát it is more troublesome due to the lack of these. Here it is expedient to take the base of uppermost rhyolite tuff of Radócz (1969) though based on the borehole Hidasnémeti-1 the top of Sarmatian or the basis of the Lower Pannonian lies in a somewhat deeper horizon.

The repeated evidence of assigning the uppermost rhyolite tuff, and of the underlying thin crystal tuff strata to the Lower Pannonian disturbed the classification of the Tokaj Hill volcanism into the Badenian-Sarmatian (G. Pantó, 1968). The thickness of the uppermost rhyolite tuff gradually increases from the Borsod Basin through the Cserehát towards the Tokaj Hills. Its pumice abundance and the extreme dimensions (several decimetres) of its pumice bombs and rolls are characteristic features of the rhyolite tuff initiating the uppermost volcanic cycle of the Tokaj Hills classified earlier as Upper Sarmatian.

Thus, the assignment of the Erdőbénye diatomite (Hajós, 1959) and of the flora deriving from the Meggyaszó volcanosediments (Pálfalvi, 1962) to the Lower Pannonian was also evidenced by the comparison of Neogene palynological profiles of the boreholes of Hidasnémeti-1 and Lajoskomárom-1 (E. Nagy-Bodor).

Consequently, the youngest volcanic cycle of the Tokaj Hills is of Lower Pannonian age, as indicated also by the radiometric analyses of Széky-Fux (1980) and of her co-workers, first of all K. Balogh and it is expedient to draw the Sarmatian-Lower Pannonian boundary at the base of the formations belonging to the youngest volcanic cycle.

On the contrary, I have to rectify the Lower Pannonian classification of the andesite pyroclastics, gravel, tuff-sand and tuffaceous clay sequence of wide extension in the Borsod Basin (Jámbor, 1985) that was based on the radiometric measurement results of K. Balogh and on the oral communication (Pálfalvi, 1962) concerning the macroflora. Based on the lithological and microplankton profile of the Nyékládháza-1 borehole the Sarmatian-Lower Pannonian boundary lies unambiguously above the andesite pyroclastic sequence.

The apparently unbroken Sarmatian — Lower Pannonian sequence explored in the profile of the Máriakéménd-3 borehole lying in the margin of the blocks between the Mórágy and Villány Mountains has to be evaluated as a special southern formation. Here, in the Pannonian sequence two several decimeter thick ooidic limestone intercalations are found and due to the lack of the lowermost Lower Pannonian biostratigraphic horizons the apparently unbroken sequence between the hard surface developed above the uniform Sarmatian ooidic coarse limestone sequence and the initial marl layer of the Pannonian can be qualified as pennaccordant layer. Due to the uplifted position here considerable sedimentation gaps or posterior erosion periods can be presumed between the strata. Ooidic limestone intercalations in the Lower Pannonian sequence were referred from East Serbia by Stevanovič (1959).

Since in Hungary the sedimentation was unbroken between the Sarmatian and Lower Pannonian sequences in many areas and since the fauna of Sarmatian strata of the Carpathian and Vienna basins prove the presence of the Volhynian and Lower Bessarabian (Gaál, 1911; Schréter, 1941; Boda, 1971; Bohn-Havas, 1983) it is doubtless that exactly undeterminable part of the Hungarian Lower Pannonian formations can be correlated with the younger sequences of the South-Russian Sarmatian, i.e. these cannot be assigned to the Pliocene but are of Miocene age.

3. The upper boundary of the Pannonian formations is a double litho- and chronostratigraphic concept. This denotes, on the one hand, the upper boundary of the Pannonian s.l., thus that of the Pliocene stage, and the lithostratigraphic surface of the Pannonian and Quaternary formations, on the other.

As to the standpoint mentioned under point 1 the upper boundary of the Pannonian s.l. stage coincides with the lower boundary of the Pleistocene. The question is the same: does an internationally accepted Pliocene-Pleistocene boundary exist? Of course, it does not exist so far. As to the attitude of the expert group of the Mediterranean and North Atlantic (from Canada and the United States) deriving from 1984, the Pliocene ended at 1.8 Ma and above this boundary the Pleistocene follows.

At the same time, based on the comparison of the basin filling sequences (Franyó, 1978) and of the measurement results of the paleomagnetic profiles in the southeastern Great Plain, A. Rónai (in: H.B.S. Cook-J.M. Hall-A. Rónai, 1981) marked this boundary at 2.4 Ma in one of the deepest depressions of the Great Plain (Békés Basin) where above the Pliocene (Upper Pannonian) predominantly blueish-grey sequence the proportion of the flood-plain, lacustrine variegated sediments becomes prevalent and the biostratigraphic data also do not contradict to assign these strata to the Quaternary.

Both competent standpoints seem to be acceptable for everyday practice since in Hungary only a few formations developed in the questionable period of 600 000 years and these occur usually in the former deep depressions, i.e. Southeastern Great Plain, Jászság Depression, a part of the Danube-Tisza Interfluve, the Szigetvár-Nagyatád region and the Hanság Depression(?). The age of these sequences will be debated for a long time since their lithostratigraphic position is characterized by their different deposition. In Southeastern Great Plain, in the Jászság and Hanság depressions there is a continuous relation between the Pannonian and the variegated sequence of uncertain age, while in the other areas the Pannonian starts with initial cycle after the preceding erosion. Their biostratigraphy is uncertain due to the rarity of fossils, their chronostratigraphy is questionable due to the difficulty and expensiveness of paleomagnetic measurements and the rarity of formations suitable for K-Ar measurements (the only formation is the Bár basalt) is responsible for the uncertainties.

In the other major part of Hungary, above different horizons of the Pannonian sequence the Pliocene formations of different age follow by unconformity, with initial cycles due to the morphological differentiation produced by the preceding considerable tectonic movements and to the erosion of locally several hundred meters. As to the general rule of their deposition the higher uplifted position the older formations show, the younger Pleistocene basin and the older terrace formation overlie them. We do not posses enough data to draw the uncovered surface map of the Pannonian sequence and the bottom-view map of the Quaternary sequence. Data concerning these knowledges are summarized in Table I.

4. In Hungary the Pannonian formations are found country-wide, only the Paleo-Mesozoic block mountains and the northern part of the Paleogene basin are not covered by Pannonian formations. Consequently, these for-

Table I

Overview of the terminal Pannonian and directly overlying Pleistocene formations

Areal units	Formations recently closing the Pannonian sequence	Mode of deposition of the Quaternary cover	Formation of the Quaternary cover
Transdanubian Hills	Tihany, rarely Torony Formation	unconform	Late Pleistocene loess, rarely Early Pleistocene variegated clay and terrace sediments
Western frontier Hills and their environs	Torony, rarely Hanság Formation, in the Sopron MTS also older Pannonian formations	unconform	Late Pleistocene alluvium and loess, Early Pleistocene terrace, red-clay and slope debris
Kemeneshát	Torony, Tihany, Tapolca and Pula Formations	unconform	Early Pleistocene (uplifted) fluviatile basin series
SW-Transdanubia (Drava-Mura region)	Torony and Hanság Formations	unconform	Early Pleistocene fluviatile basin series, red- and variegated-clay
Győr Basin	Torony and Hanság Formations	unconform	Early Pleistocene fluviatile basin series
Transdanubian Mid-Mountains and the Mecsek environs	Tihany, Somló, Kálla, Tapolca, Szák, Kisbér, Sárvár, Csákvár-Csór and Ősi Formations	unconform	Late Pleistocene loess and alluvial fan, Pleistocene terrace- and slope debris series
SE-Transdanubian basin regions	Tihany, Somló, Kálla, Kisbér, Szák and Dráva Formations	unconform	Early Pleistocene variegated and red-clay series
Southern and Central Danube-Tisza Interfluve	Great Plain Formation	unconform	Pleistocene Danube series
Csepel Island environs	Hanság Formation	unconform	Pleistocene Danube series
Gödöllő-Ceglédbercel Hills	Bükkalja and Great Plain Formations	unconform	Late Pleistocene loess, Early Pleistocene red- and variegated clay series
Southern marginal areas of the Northern Mid-Mountains	Bükkalja and Great Plain Formations	unconform	Early Pleistocene variegated and red-clay series, Pleistocene alluvial fans
Uplifted parts of the Northern Mid-Mountains	Edelény, Szák, Kálla and Cserehát Formations	unconform	Late Pleistocene loess, Pleistocene terrace and slope detritus sediments
Basin marginal parts of the Great Plain	Bükkalja, Tihany and Great Plain Formations	unconform	Early Pleistocene fluviatile gravel, sand and variegated clay series
Depressions of the Great Plain	Great Plain and Bükkalja Formations	unconform, conf. continuous	Early Pleistocene variegated clay series

mations are found in more than three-quarters of the country (cca. 75 000 km^2), usually covered by Pleistocene formations as indicated above. Due to the early and intra-Pleistocene tectonic movements and to the subsequent erosion its surface outcrops are found in the piedmonts and in the Transdanubian hills. This picture is coloured by the basalt volcanics belonging to the Transdanubian Main Group. The most characteristic forms are the monadnocks rising above Pannonian sediments in the Balaton Highland, in the southern shore of Balaton and in the western margin of the Little Plain (Lóczy sen., 1913), while in the Northern Mid-Mountains mainly strongly eroded volcanic remnants occur in Oligocene and Early Miocene environs (Balogh, 1966).

Nevertheless, the extension of the Pannonian formations is not uniform. Due to the transgressive character of the whole sequence the Peremarton Main Group extends over a smaller area. Its sediments are lacking in several areas, e.g. southeastern foreland of the Kőszeg Mts., a part of the northwestern foreland of the Mecsek Mts., the South-Baranya crystalline ridge, the southeastern foreland of the Velence Hills, the Balatonfő, the Sárszentmiklós high block, the Bugyi-Örkény ridge, the Dánszentmiklós environs, the northern part of Hegyhát (Tolnanémedi environs), the Kaposfő environs, the Göböljáráspuszta-Etyek high block and above the Tarpa-Beregdaróc volcanics. In the basin margins, however, depending on the measure of uplift the formations of the Peremarton Main Group extend farther on the foothills than those of the Transdanubian Main Group. This, however, is due to subsequent erosion processes.

5. In spite of the small extension of the basin the thickness of Pannonian formations is remarkably great, the maximal value is as high as 5000 m, the average being 1200 m but considerably changing. Moving off the margin of the block mountains the thickness increases either rapidly or slowly and beneath the hardly dissected basin surface crest, ridges, trenches and depressions of different dimensions vary the thickness values (Fig. 2).

The thickest sequences are found in the deep depressions in the southeastern part of the Great Plain: Makó trench (4600 m), Békés depression (4100 m), Derecske depression (4000 m), but remarkably thick Pannonian sequences are found in the Jászság depression (3200 m), Győr basin (3700 m), Zala basin (3500 m), Dráva basin (3500 m) (Table II).

The essentially same character of tectonic processes during the deposition of the Pannonian sequence is unambiguously marked by the simi-

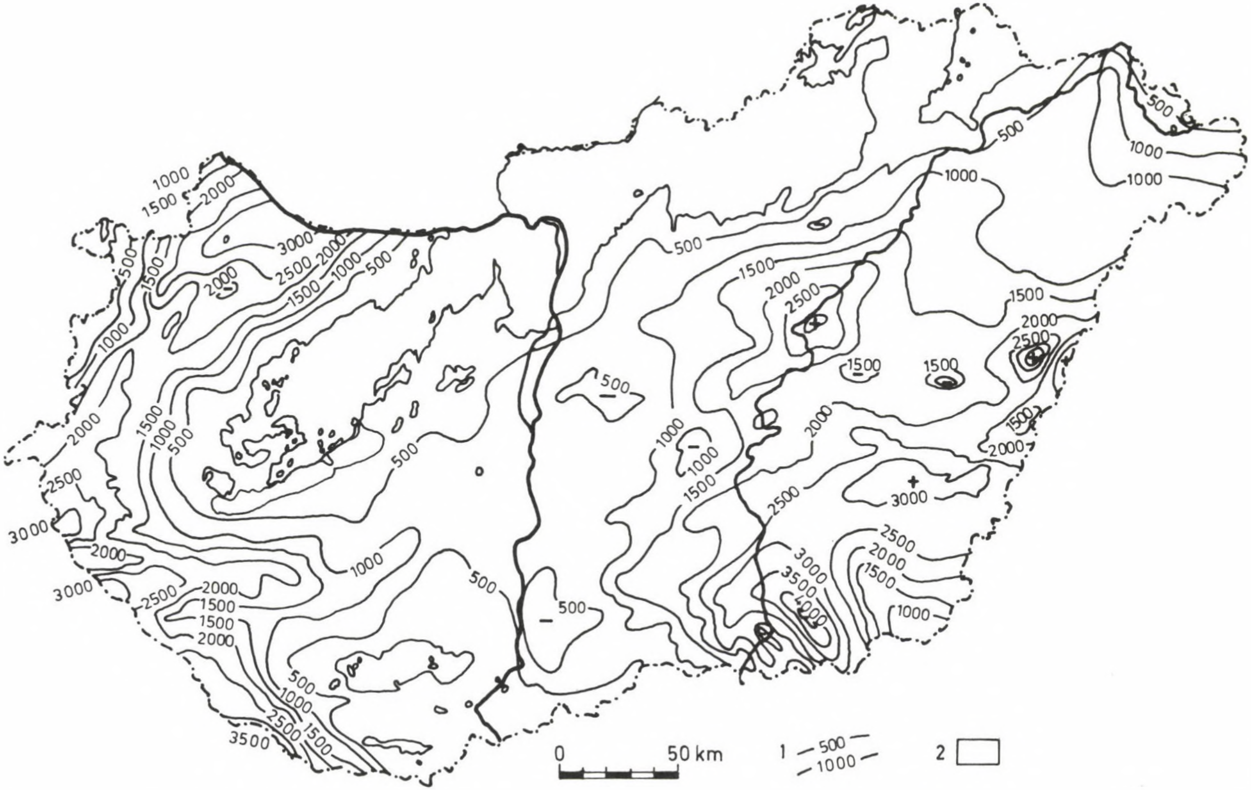


Fig. 2. Thickness of the Pannonian s.l. formations of Hungary. 1. Thickness of Pannonian formation in meters; 2. extension of the formations older than Pannonian without the Quaternary formations

Table II

Areal distribution of the thickest Pannonian sequences

Area units	Pannonian total	Peremarton Main Group	Transdanubian Main Group
Győr Basin	3700	1200	2500
Zala Basin	3400	1700	1700
Dráva Basin	3500	2000	1500
Jászság Basin	3200	1900	1300
Makó Trench	4600	2800	1800
Békés Depression	4100	2000	2100
Derecske Depression	4000	2500	1500

larity of thickest regions of the Peremarton and Transdanubian Main Groups (Table II).

The remarkable intrabasinal heighs are also the same during the formation of the two main groups except the Igal and Algyő ones. This is illustrated by Table III.

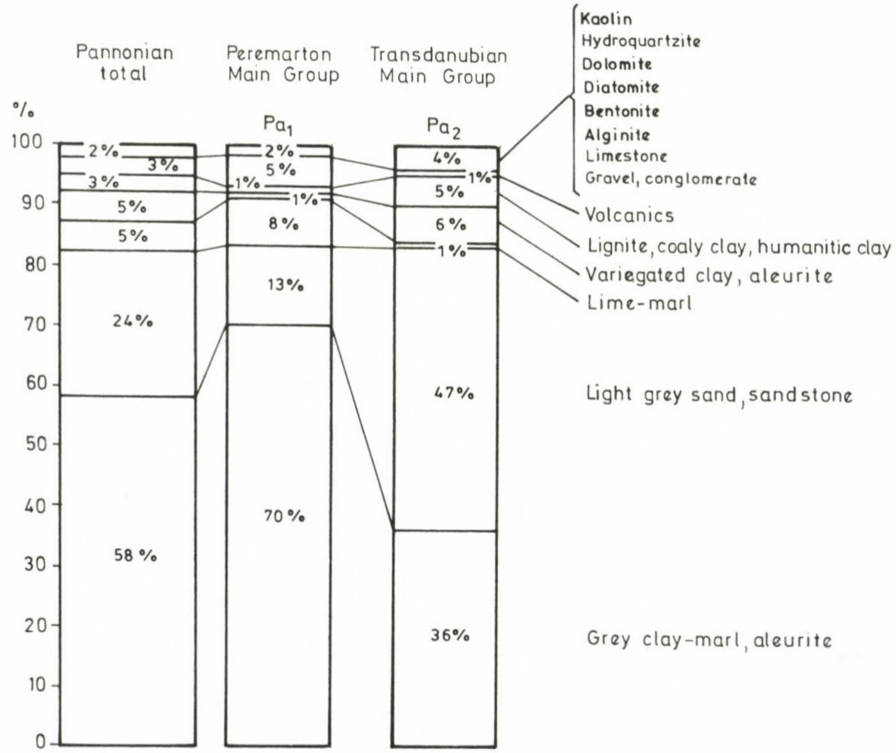


Fig. 3. Frequency distribution (Vol. percent) of the main rock types of the Pannonian formations

Table III

Significant intrabasinal heighs and thickness of their Pannonian cover

	Total	Peremarton Main Group	Transdanubian Main Group
Lovászi	1600	1000	600
Budafa	1400	900	500
Igal	800	100	700
Sárszentmiklós	0-200	0-100	0-100
Bugyi-Sári-Örkény	200	0-100	100
Dánszentmiklós	350	—	350
Kecskemét	700-800	300	400-500
Sükösd	100-300	100-200	100
Tompa-Madaras	100-200	100-200	100
Algyő	2100	600	1500
Kismarja	800-900	200-300	600
Mezősas	1200	500	700
Battonya	700-900	300-400	400-500

6. In first approximation the formation of the Pannonian sequence is rather monotonous but this unambiguously corresponds to the formation of the Pannonian sequence in the late postorogenic sedimentation phase. In the Peremarton Main Group and in the intrabasinal areas the rocks display less diversity while in the Transdanubian Main Groups and in the marginal areas the rock types are more diverse. The distribution of the sequence of round 95 000 km^3 volume according to rock types is presented in Table and Fig. 3, based mostly on estimated, in case of the sand-pelite rock quantities on calculated data from several dozens of coreholes.

To facilitate the overview, in Table 4 only fourteen units are incorporated. Nevertheless, the Pannonian sequence is much more varied. The 85 rock types distinguished so far fairly well reflects the facies abundance of the Pannonian main group though the number of types can be multiplied when taking into account the changes in grain size composition (aleuritic sand, clay-marly aleurite, aleuritic lime-marl, gravelly sand etc.), the differences in shadows, in the fauna content, in the rock texture and structure. The frequency distribution of these parameters, however, can be only relatively presented due to the lack of strata sequences of suitable quantity (Table V).

The partition of basic rock groups by main groups reveals first of all the most significant facts of the history of evolution. The areal differences delineate the boundaries of the paleogeographic units.

7. The mineral composition of the sedimentary Pannonian formations

Table IV

Distribution of the Pannonian formations according to the main rock types, in volume percent

Main rock types	Pannonian total	Peremarton Main Group	Transdanubian Main Group
1. Grey clay-marl and aleurite	58	70	36
2. Light-grey sand and sandstone	24	13	47
3. Dark- and light-grey lime-marl, marl	5	8	1
4. Variegated (yellow, brown, red, green, grey) clay, aleurite	5	1	6
5. Lignite, coaly clay, huminitic clay, aleurite	3	1	5
6. Volcanics (rhyolite, dacite, trachyte, basalt, andesite) and their pyroclastics	3	5	1
7. Gravel, conglomerate	1	<1	<1
8. Limestone	<1	<1	<1
9. Alginite	<1	<1	<1
10. Bentonite	<1	<1	<1
11. Diatomite	<1	<1	<1
12. Dolomite	<1	-	<1
13. Hydroquartzite	<1	<1	<1
14. Kaolin	<1	<1	-

is simple. The allogenic components are predominating, the authigenic ones are also characteristic.

The allogenic minerals of pelitic rocks are as follows according to their frequency sequence: clay minerals (illite, chlorite, smectite, montmorillonite, kaolinite), quartz, feldspar, muscovite, chlorite, biotite (Viczián, 1971) and the heavy minerals. In certain rock types the interrelated frequency of micas may change and may precede the feldspars (Fig. 4).

The clay mineral composition of pelitic sediments deposited in intrabasinal areas is rather uniformized: the predominance of illite and

Table V

Basic rock types of the Pannonian formations and their relative significance in the sequence

Main rock types	Transdanubian Main Group	Peremarton Main Group
Clay-marl		
Common grey clay-marl	VF 4	VF 4
Clay-marly lumachelle	VR 1	VR 1
Mollusc-bearing clay-marl	F 3	F 3
Ostracod-bearing clay-marl	R 2	F 3
Clay-marl with leaf-remnants	R 2	VR 1
Clay-marl rich in sponge spicules	- 0	VR 1
Clay-marl with Arenicols	F 3	- 0
Aleurite with Pectinaria	F 3	F 3
Sand		
Common grey sand	VF 4	F 3
Yellow limonitic spotty sand	F 3	R 2
Biotite-rich sand	VR 1	- 0
Feldspar-rich sand	R 2	R 2
Kaolinitic-feldsparic sand	R 2	- 0
Mica-rich (muscovite, chlorite, biotite) sand	F 3	- 0
Quartz sand	R 2	R 2
Sandstone quartzite	VR 1	- 0
Molluscan sand	R 2	R 2
Lime-marl		
Light-grey lime-marl	R 2	F 3
Pale, coffee-tinted lime-marl	- 0	VF 4
Dark-grey lime-marl	- 0	F 3
Dirty-white lime-marl	- 0	R 2
Dark-grey laminated marl	- 0	R 2
Molluscan lime-marl	R 2	F 3
Ostracod-bearing lime-marl	- 0	F 3
Pisoidic molluscan lime-marl	R 2	- 0
Variegated Clay		
Grey clay with leaf remnants	R 2	R 2
Grey-greyish green clay	F 3	F 3
Yellow-brown variegated clay	F 3	R 2
Yellow, green, brown variegated clay	F 3	R 2
Grey, yellow, brown clay with violet spots	VR 1	- 0
Red, brownish-red clay	R 2	- 0
Lignite		
Xylitic lignite with branch and trunk remnants	R 2	- 0
Lignite of foliated microlenticular structure	F 3	R 2
Bright brown-coal	R 2	- 0
Clayey lignite	F 3	VR 1
Clay rich in plant fragments	F 3	R 2
Huminite-pelite-rich clay	F 3	R 2

Table V (cont.)

Main rock types	Transdanubian Main Group	Peremarton Main Group
Dark-grey clay	F 3	R 2
Grey clay	F 3	R 2
Grey clay with root remnants	R 2	VR 1
Volcanics		
Pumice-rich rhyodacite tuff	- 0	R 2
Crystal-rich ryhodacite tuff	- 0	R 2
Bentonitic rhyodacite tuff	- 0	R 2
Kaolinic rhyodacite tuff	- 0	VR 1
Grey, massive subporphyric basalt	F 3	F 3
Violet subporphyric basalt	VR 1	- 0
Coccolithic basalt	R 2	R 2
Slaggy basalt	R 2	- 0
Alveolar basalt	R 2	R 2
Unstratified basalt breccia	R 2	R 2
Stratified basalt tuff and breccia	F 3	R 2
Cross-bedded basalt tuff	F 3	- 0
Basalt tuff sand	VR 1	- 0
Dark-grey subporphyric andesite	- 0	R 2
Andesitic breccia and tuff	- 0	R 2
Gravel		
Pearl-gravel	R 2	R 2
Limonitic pearl-gravel	R 2	- 0
Pyritic pearl-gravel	- 0	R 2
Coarse gravel with exotic material	R 2	R 2
Dolomite pearl-gravel	R 2	- 0
Gravel with variegated caly	- 0	R 2
Limestone		
Massive fresh-water limestone	F 3	- 0
Macroporous freshwater limestone	R 2	- 0
Molluscan freshwater limestone	F 3	R 2
Lime-mud	VR 1	- 0
Ooidic limestone	- 0	VR 1
White, coarse-crystalline fissure-filling limestone	VR 1	- 0
Alginite		
Lamellar greenish green alginite	R 2	R 2
Massive alginite	VR 1	- 0
"Sole"-type alginite	VR 1	- 0
Pale-red lamellar alginite	VR 1	- 0
Bentonite		
Grey bentonite	F 3	R 2
Red bentonite	VR 1	- 0
Brown, yellow, green, variegated bentonite with limestone concretions	R 2	- 0
Black huminitic bentonite with bone fragments	VR 1	- 0
Grey slightly altered bentonite	R 2	- 0

Table V (cont.)

Main rock type	Transdanubian Main Group	Peremarton Main Group
Dolomite		
Green cryptocrystalline dolomite	R 2	- 0
Brownish-grey microcrystalline dolomite	VR 1	- 0
Grey aleuritic-clayey dolomite	R 2	- 0
White, siliceous-calcareous dolomite (geysirite)	VR 1	- 0
Hydroquartzite		
Grey translucent hydroquartzite	- 0	R 2
Dirty-white porous calcareous flint (geysirite)	VR 1	- 0
Diatomite		
White foliated diatomite	- 0	VR 1
Dirty-white clayey diatomite	- 0	VR 1
Diatomite, lamellar clay-marl	- 0	VR 1
Number of types occurring of the 85 rock types	66	53
Number of frequent and very frequent types	22	12
Number of rare and very rare types	44	41

(Legend: - = no occurrence; VR = very rare; R = rare, F = frequent; VF = very frequent; -=0, VR=1, R=2, F=3, VF=4

chlorite is characteristic. Downwards in the basinal sequences the proportion of swelling clay minerals is regularly decreasing (Viczián, 1971).

In the special facies of the basal formations of the marginal areas other clay minerals, e.g. montmorillonite, kaolinite prevail. These will not be dealt with here, the work of Viczián is cited.

Disregarding the common lack of clay minerals in sandy rocks, in these formations the allogenic minerals are the same as in the coarser fraction of the pelitic rocks, i.e. quartz prevails, further feldspar, muscovite, chlorite, biotite and the heavy minerals follow in frequency order.

In certain parts of the marginal hollows the repeated drying of the sandy material, and as a consequence the repeated change first of all of biogenic acid and basic medium as well as the repeated redeposition resulted in the dissolution and grinding of pyrite and carbonates, subsequently those of biotite, chlorite, feldspars and muscovite and this is why quartz sand strata of 92 to 96 grain percent developed in several

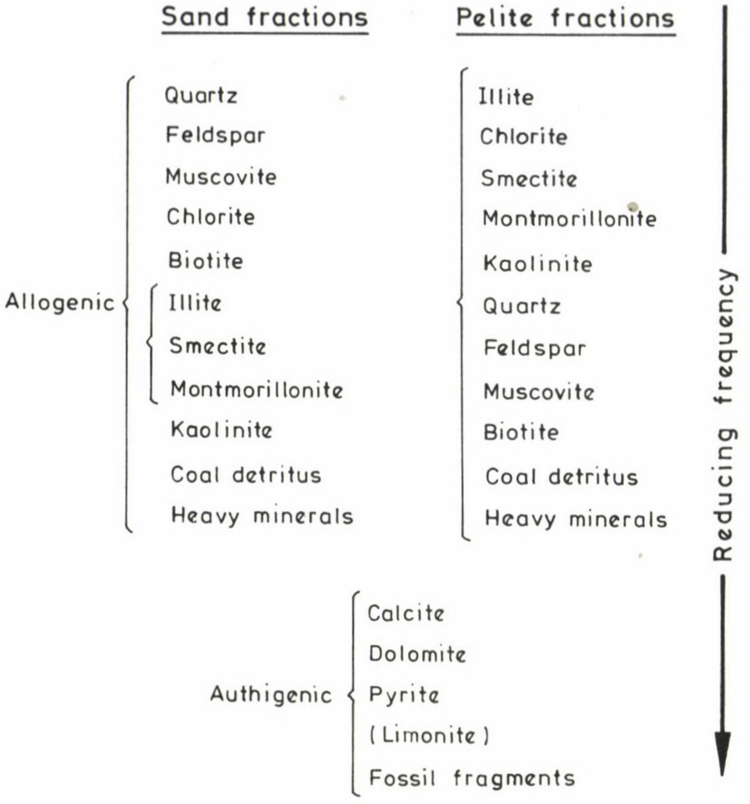


Fig. 4. Mineral composition of Pannonian sedimentary rocks

stratigraphic horizons. These pure quartz sand strata are separated from the intrabasinal grey polymict strata of common composition by a limonite-rich zone.

The authigenic minerals are the same in both rock groups. Calcite is of greatest importance, then dolomite, pyrite and limonite follow and finally the occasionally accumulating pelite-size huminite (below 0.1 mm) is assigned to these minerals, too. Rarely aragonite as shell material of molluscs and ostracods, and in special facies the ferroan and manganiferous calcite also occur.

The role of carbonate minerals is similarly important in both rock groups. In the lower part of the Pannonian sequence the $CaCO_3$ content is as high as 40%, the proportion of dolomite is negligable (only several percent). In the middle part both carbonate minerals amount to about

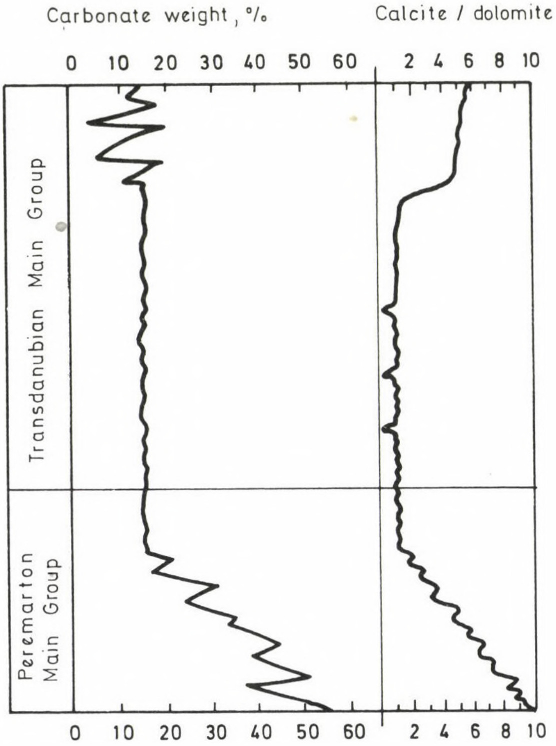


Fig. 5. Average carbonate content profile of the Pannonian formations

10-10%. In the upper part the proportion of $CaCO_3$ increases again, here a part of the strata, however, is completely carbonate-free (Fig. 5).

The regularities of areal frequency distribution of carbonate minerals could be cleared only on a rough level. In the vicinity of mountains rich in carbonate rocks the calcite and dolomite content of the Pannonian profiles is usually higher, but this relation is rather loose being considerably affected by the thickness of the sequences. In the thick sequences of the Great Plain the $CaCO_3$ and dolomite contents are less, probably due to the time-determined carbonate precipitating ability of the plankton.

Pyrite is the biogeochemically formed early and latediagenetic mineral of the grey pelitic rocks. It is found in a quantity below one percent practically in all strata and is present also in the grey sand. In both rock types it forms spherules or euhedral crystals. Their more particular characterization is found in T. Hámor (1988).

Limonite is characteristic of the variegated formations occurring in the marginal areas (Ősi and Edelény Formations, Kabhegy Member), and of the 0.5 to 20 m thick weathering zone below the Quaternary formations. In the variegated formations it occurs as yellow, brown and very rarely red early-diagenetically developed finely dispersed colouring material. In the weathering zone below the Quaternary it occurs also in finely dispersed form but only in yellow and brown shadows that prograde downwards in the sand rocks. Rarely thin (1 to 20 mm) hard, sandy-aleuritic limonite crusts and lenses also developed. Here limonite was produced unambiguously by oxidation weathering processes first of all from pyrite, occasionally from biotite or chlorite. In the variegated formations a part of limonite is allogenic, the other part of it, however, was produced by the late-diagenetic weathering of the early-diagenetic pyrite.

The huminite pelite material occurs as colouring substance first of all in the carbonate-free pelitic rocks in swampy sedimentation areas, usually amounting to 1-2%. Its origin can be interpreted as the redeposition of the tiny plant-detrital material produced by periodical drying of swamp forests by rainfalls into deep-swampy areas. The organic geochemical studies of A. Bruckner-Wein and I. Vető are in harmony with this conclusion, i.e. these pelitic rock types contain remarkable quantities of bitumoids. Obviously, the plant parts rich in resinite are resistant to periodical drying and redeposition and these are rich in bitumoids.

The presentation of the mineral composition of all the 85 rock types is impossible here and is not justified. The minerals of clastic rock types were essentially dealt with, the terms of biogenic and chemical sediments follow from their denomination and distinction.

In the field of heavy minerals no remarkable progress has been achieved in the past 13 years. In the course of former studies in the Transdanubian Mid-Mountains the predominance of minerals of metamorphic origin as well as the Little Plain (Alpine) and Great Plain (Carpathian) heavy mineral provinces could be identified. In the classification of this latter area remarkable results were achieved by B. Molnár (1965) but a lot of tasks, e.g. the determination of the source areas are to be solved here, in the Little Plain, in North-Hungary and in South-Transdanubia, as well.

In the micromineralogical literature of Hungary it has been a frequent and summary statement that the allogenic material of the Pannonian formations derives from metamorphic and igneous provenance areas. Taking into account the quantities of the Pannonian and Quaternary formations, i.e. 95 000 km^3 and cca. 10 000 km^3 and looking at the geological map of the Carpathian Basin and of its environs, this statement cannot be accepted. The overwhelming majority of allogenic material of the Pannonian sequence derives from the erosion of older sedimentary sequences: Alpine-Carpathian flysch, Paleogene and older Neogene molasse formations. My statement is verified by the presence of mature disperse vitrinite matter found everywhere in the Pannonian sequence by I. Laczó (In: Laczó-Jámbor, 1988). Most of the igneous and metamorphic heavy minerals got the Pannonian sequence as a result of secondary, moreover Tertiary sedimentary processes.

8. Stratigraphy of the Pannonian formations. The development of stratigraphy can be considered as the most important result produced by geology in the past two centuries. This is why all the field geologists have to contribute to the development of stratigraphy. The stratigraphy of Pannonian formations reached the third phase of development. The first phase includes the recognition of Congeria-bearing strata, the second one is represented by the classification on the basis of changes in the Mollusc fauna. The third phase is characterized not only by the manysidedness of biostratigraphic classification and by the application of the stratigraphic trialism (litho-, chrono- and biostratigraphy together) but also by the acceptance of lithostratigraphy as a starting basis.

8.1 Biostratigraphy

8.1.1 Molluscs. Similarly to other Cenozoic sedimentary formations, in the classification of the Pannonian sequence the Mollusc fauna, in particular predominantly the Congeria, and partly the Limnocardium and Melanopsis species prevailed for about hundred years (1870-1970). In the elaboration of the Pannonian stratigraphy of Hungary based on molluscs and on their guide fossils, respectively, the works of K. Partsch, S. Brusina, K. Gorjanovič-Kramberger, Th. Fuchs, A. Koch, Gy. Halaváts, I. Lőrenthey, I. Vitális, L. Strausz, F. Bartha, M. Széles and M. Korpás-Hódi have to be mentioned; these works have marked the guideline of possibilities and conceptual evolution. The most up-to-date Mollusc stratigraphic concept being in harmony with the facts is presented in the compilation of M. Korpás-Hódi (Fig. 6). It is seen that though the faunal sequence is usually the same in each profile but the correlation is usually not temporal but means only facies identity especially in case of the Upper Pannonian fauna. Nevertheless, for stratigraphic purposes these faunae are suitable due to their high frequency though a temporal "slipping" of one or two million years may occur even in case of the same faunal assemblage.

More severe problems occur in the nearly freshwater formations of the marginal Lower Pannonian sequences (Öskü, Cserehát, Komjáti Basins) where mostly Upper Pannonian (swampy) Mollusc fauna is found, usually without the "guide" Lower Pannonian Congeria and Limnocardium species. The classification of these into their right position is possible only when "cathing" favourable inland sea intercalations.

8.1.2 In the historic sequence the Vertebrate faunae follow in the application of fossils in the Pannonian stratigraphy. The study of this fauna has begun several decades later than that of the Molluscs.

The rich and well-preserved Vertebrate faunae consisting solely of one bone and not of a skeleton could not and will not be suitable as tools for solving the everyday tasks of stratigraphy in spite of their particular state of knowledge (T. Kormos, O. Kadic, Gy. Leidenfrost, R. Schubert, I. Gaál, M. Mottl, M. Kretzoi, D. Jánossy, L. Kordos). The reasons are as follows: a) the really rich faunae are rare and disregarding a few exceptions (Baltavár, Gödöllő) these were found in caves (Csákvár, Polgárdi, Sümeg, Osztramos etc.) thus their lithostratigraphic position cannot be provided; b) the determination of the sporadic finds deriving from inland sea sediments, that of their biostratigraphic position has led to contradictions in the comparison with the evolutionary facts of Mollusc- and lithostratigraphy which can be removed only by conclusions concerning the unreliability of Vertebrate faunae; c) to accept generally the vertebrate-based stratigraphy it is deteriorated by forcing a special stage system. Though the proposition of certain stages bears occasionally temporal priority, this argument is not enough today and the characterization of required quality of the stratotypes can be hardly achieved in the cave sequences or in the profile of several meter thickness of the locality of a Vertebrate find that can be hardly or cannot be correlated by means of other methods.

Based on literature data and on his own experiences L. Kordos compiled the vertebrate stratigraphic column of Fig. 6.

8.1.3 The study and elaboration of the rich Ostracod assemblage of the Pannonian s.l. formations were initiated by Hungarian researchers (Gy. Méhes, B. Zalányi). Their activity has been continued by A. Pokorny (in Czechoslovakia), A. Sokač and N. Krstič (in Yugoslavia) and by. R. Jiriček (in Slovakia). Based on their results a particular stratigraphic classification was developed concerning the Yugoslavian and Slovakian Pannonian formations. This, however, could not be fully adapted in Hungary. In harmony with the studies of M. Széles (In: J. Halmai-Á.Jámbor-L.Ravasz-Baranyi-I. Vető, 1982) five biozones can be marked by the Ostracod features. When comparing these with the zonation based on other fossil assemblages, however, it can be stated that this means also a characteristic facial-stratigraphic classification.

Based on the observations of Korecz (1985) and on some data of M. Széles it seems so that in the Middle(?) and upper part of the Upper Pannonian, above the uppermost "Candona" member of the former zonation, the freshwater Ostracod assemblage described from West-European Pleistocene also occurs.

8.1.4 Though the most novel method is the classification on the basis of microplankton of organic skeleton, in the past years its application has become important first of all due to the great extension of the fossils. Being initiated by J. Bóna the zonation shown in Fig. 6 was developed by M. Sütő-Szentai which proved to be successful first of all in case of thin, i.e. up to 1500 m thick Pannonian strata. Being a plankton-benthos assemblage in question it could be expected that the boundaries of the assemblages would mark time-identical horizons. Having compared these, however, with the Mollusc and Ostracod zonations and with the chronostratigraphic data these proved to be also facies dependent. Another problem is that the sequences formed within the basin and probably in deeper water contain fossil-poor and fossil-free horizons, the phenomenon being uninterpreted so far. The faster sedimentation and in greater depths the epigenetic alterations may also decimate them.

8.1.5 The fossil assemblages discussed above allow the classification of the whole Pannonian s.l. sequence, other fossils, e.g. Bryozoa (Lőrenthey, 1905), Thecamoeba (Kőváry, 1985), Foraminifera (Korecz-Laky, 1985) and Nannoplankton (Bóna, 1985) occurred essentially only in the Lower Pannonian. Practically the same is the situation in case of Diatoma and sponge spicules (Hajós, 1985) since these are found recently (?) only in the crater lake filling alginites representing a negligible part of the Upper Pannonian sequence.

8.1.6 Similarly to the microplankton of organic skeleton, the trace fossils are characteristic also of the strata deposited in shallow water. These are usually suitable to mark three or four horizons, their recognition promotes first of all the rapid stratigraphic orientation in the field (Jámbor, 1987).

8.1.7 The stratigraphic possibilities of spores and pollen are not used to the full though in the column of Fig. 6 four horizons were distinguished by E. Nagy on the basis of changes of the microflora remnants. These, however, are highly facies dependent. Researchers used to classify the swampy microflora into the Upper Pannonian. It is my opinion that the elaboration of a more detailed and more reliable classification is disturbed by the abundance of the remnants. Due to the great number of facies dependent remnants, the spore and pollen remnants of aerial origin and fallen in the whole surface of the Pannonian inland sea and reflecting the climate governed evolution of the vegetation cannot be separated. Theoretically, however, these may serve as an ideal basis for chronostratigraphic classification.

8.1.8 When taking into account the biostratigraphic classification system of the Pannonian formations, the following general statements can be made:

In the lowermost horizon the small limnocardian Mollusc fauna developed from the Sarmatian Congeria species, the species-poor (Hungarocypris, Amplocypris) but individual-rich Ostracod fauna consisting of "giants" as well as the assemblage indicating the marine origin of the former eastern Paratethys but suggesting the divergent unique "Pannonian" evolution (Foraminifers: Trochammina, Miliammina, acicular bryozoans, nannoplankton: Noelorhabdus, Bekelithella; microplankton: Pleurozonaria (Mecsekia) ultima). This assemblage is characteristic of the unbroken (without subaquatic erosion) Pannonian parts of the Sarmatian-Pannonian profiles, in 1/5 to 1/10 proportion of the Lower Pannonian phase. The development of this fossil assemblage can be interpreted first of all by the studies of Szuromi-Korecz on the Zala (laminated marl) Formation, by the lithological formations, by the predominance of the summer hypersaline, winter nearly freshwater inland sea biotopes caused by the Late Sarmatian special climate and finally by the drastic decrease of salinity of the Pannonian inland sea.

In the subsequent biostratigraphic horizon the following assemblages flourished: Molluscs (Limnocardium, Melanopsis), Ostracods, Thecamoeba, Triaxon silicisponges of the Pannonian brackish water, and the nannoplankton, Dinoflagellata and Diatoma microplankton. Here the Foraminifers, the bryozoans and Pleurozonaria are absent. This fossil assemblage is characteristic of 4/5 to 8/10 part of the Lower Pannonian profile. Here the stability of the Lower Pannonian paleogeographic conditions (practically constant salinity, uniform climatic conditions) can be unambiguously stated, disregarding the areas reflecting occasionally fluviatile effects.

The third biostratigraphic horizon is marked by the spectacular forced evolution of the Pannonian brackish Mollusc and Ostracod faunae. In the early Upper Pannonian relatively or as a whole more freshwater flew into the inland sea, its water became gradually limnic. The brackish Pannonian fauna assemblage and the Dinoflagellata microflora were gradually replaced by freshwater assemblages. The Upper Pannonian sequences are characterized by Dreissena auricularis, Congeria balatonica, C. rhomboidea, Prosodacna vutskitsi, Viviparus, Unio-rich molluscs, by the Ostracod fauna without Cyprideis pannonica and by the Dinoflagellata-Zygnemataceae microplankton flora.

In the youngest horizon of the Upper Pannonian the freshwater-terrestrial Mollusc and Ostracod fauna and the microflora with Mougeotia became prevalent that can be hardly or cannot be distinguished from the Quaternary ones. To assign this phase to the Upper Pannonian is verified by the facts that it belongs to this period from the lithostratigraphic aspect, the Lower Pleistocene sequence is of different formation and it was deposited usually after a preceding erosion.

Consequently, the fossil assemblage of the Pannonian sequence is suitable for the relatively detailed biostratigraphic classification and to the determination of the relative position of a Pannonian formation being in any basin part, with the required accuracy. Nevertheless, it is unsuitable to the correlation with the formations out of the Pannonian-brackish paleogeographic unit even if there exists an international decision that the Sarmatian-Pannonian boundary coincides with the boundary between the Lower and Upper Bessarabian in the eastern Paratethys. It is my opinion that by means of biostratigraphic data neither this nor the younger correlations can be unambiguously proved due to the temporal displacement possibilities of the separated evolution of the fauna and microflora.

8.2 Lithostratigraphy

The stratigraphic practice of Europe paid only little attention to lithostratigraphy in the past 50 years. In the last century a part of mapping geologists recognized to certain extent the significance distinguishing between the formation assemblages but the large-scale development of paleontology suggested the impression that it is enough to determine the biostratigraphic horizon of the studied layer or strata since this will unambiguously provide also the chronostratigraphic position, and this is the case even nowadays according to several experts.

As a result of the Hungarian application of the stratigraphic principles initiated by J. Fülöp et al. (1975) on the basis of the activity of H.D. Hedberg (1976), the lithostratigraphic denomination and position determination of all hungarian geological formations has been though for the most part subsequently carried out since 1971. Moreover, most of the experts have accepted that the true stratigraphic picture can be developed by the joint application of the three (litho-, bio- and chronostratigraphic) stratigraphic methods. It is not enough to determine the biostratigraphic position of certain fossil assemblages or to assign the chronostratigraphic data of certain rock to the geological time scale, but the geological exploration practice needs first of all the drawing of boundaries of the formation assemblages (formations, members etc.) and the identification of their mode of bedding, of their interrelations, independently of other stratigraphic facts. These bedding basic principles are as follows: a) what of the formations lies above or below; b) their dip is either the same or different; c) their relation is characterized by continuous transition, by sedimentary gap or by gap and unconformity; d) their maturity is either the same or considerably different.

I presented the lithostratigraphic units of the Pannonian s.l. formations in the Hungarian Geological Society in 1980. The compilation of that time (Fig. 7) has been improved. Due to the manysided critics of the Leadership of the Hungarian Committee on Stratigraphy, to the comparison with the Miocene and Pleistocene tables, further to the publication of the data from the Great Plain (Gajdos-Pap-Somfai-Völgyi, 1983) some modifications that did not changed the essence were carried out.

Like the first variety, this classification follows the picture of formation of the Pannonian s.l. sequence and can be divided into two great parts. Their terms are Peremarton and Transdanubian Main Groups instead of the terms Lower Pannonian and Upper Pannonian Formation Group. The lower one marks the predominantly pelitic, the upper one the thin-bedded sandy-pelitic sequence. The lower limemarl sequence (Tótkomlós, Dorozsma, Vásárhely, Belezna, Zala and Lenti Formations) develops from the Sarmatian with continuous transition. In case of sedimentary gap or outranging beddings its bottom is characterized by basal conglomerate or sandstone (Békés, Lovászi and Mihályi Formations).

The position within the Sarmatian of the lower boundary of the Zala

Marl Formation and the close relationship between the Ősi Formation and the Sarmatian Gyulafirátót Formation is especially worthy of mention.

In addition to the sedimentary formations, in the Danube-Tisza Interfluve the Kecel Basalt (Pap, 1983), in the Little Plain the Pásztor Trachyte, in the southeastern foreland of the Transdanubian Mid-Mountains the Zsámbék Marl (with rhyolite tuff bands), in Northeast Hungary the Cserehát or Tokaj Volcanite Formation overlapping the Sarmatian can be distinguished.

The transgressive character was strongest at about the middle of the Peremarton Main Group. In the basin centres sandy sequences (Szolnok and Tófej Formations), in the marginal parts aleurite (Csór Formation) and quartz-sand - pearl gravel (Zámor and Kisbér Formations) developed. The intramountain basins are characterized by the Csákvár Claymarl Formation with diatomite intercalation, by the Imárhegy Aleurite Formation with sponge spickles and abundant organic matter (in the Kapolcs-Nagyvázsony basin), by the Strázsahegy Limestone Member lying in the lower part of the Lower Pannonian of the Zsámbék Basin, in the Bódva-Hernád Interfluve by the Edelény Variegated Clay Formation in the Taktaköz and Bodrogköz, in the latter sand, coaly clay and lignite intercalations are also known. In the northwestern foreland of the Transdanubian Mid-Mountains as well as in the northern and eastern environs of the Villány Mountains the upper part of the Peremarton Main Group is represented by homogeneous clay-marl, by the Szák Formation.

In the basin centres and mostly in the marginal parts the Transdanubian Main Group is tripartite. In its lower and upper part swampy intercalation cannot or can be hardly observed, in its middle part, however, these are characteristic and usually frequent.

The lower part starts with relatively thick sand in many places, i.e. in the areas of formerly uplifted position (Törtel and Újfalu Sandstone Formation). In the marginal parts quartz sand and pearl gravel (Kállai Formation) are known. The inland sea facies of fauna-rich clay-marl-sand formation replacing the former ones in the marginal parts is assigned to the Somló Formation.

The Tihany, Zagyva and Rábaköz Formations are different local terms of the thin-bedded inland sea-lacustrine-swampy-fluviatile facies unit. The predominantly variegated clay sequence of the uppermost facies unit (Great Plain and Hanság Formations) is poor in lignite intercalations and contains freshwater-terrestrial fauna and in harmony with the studies

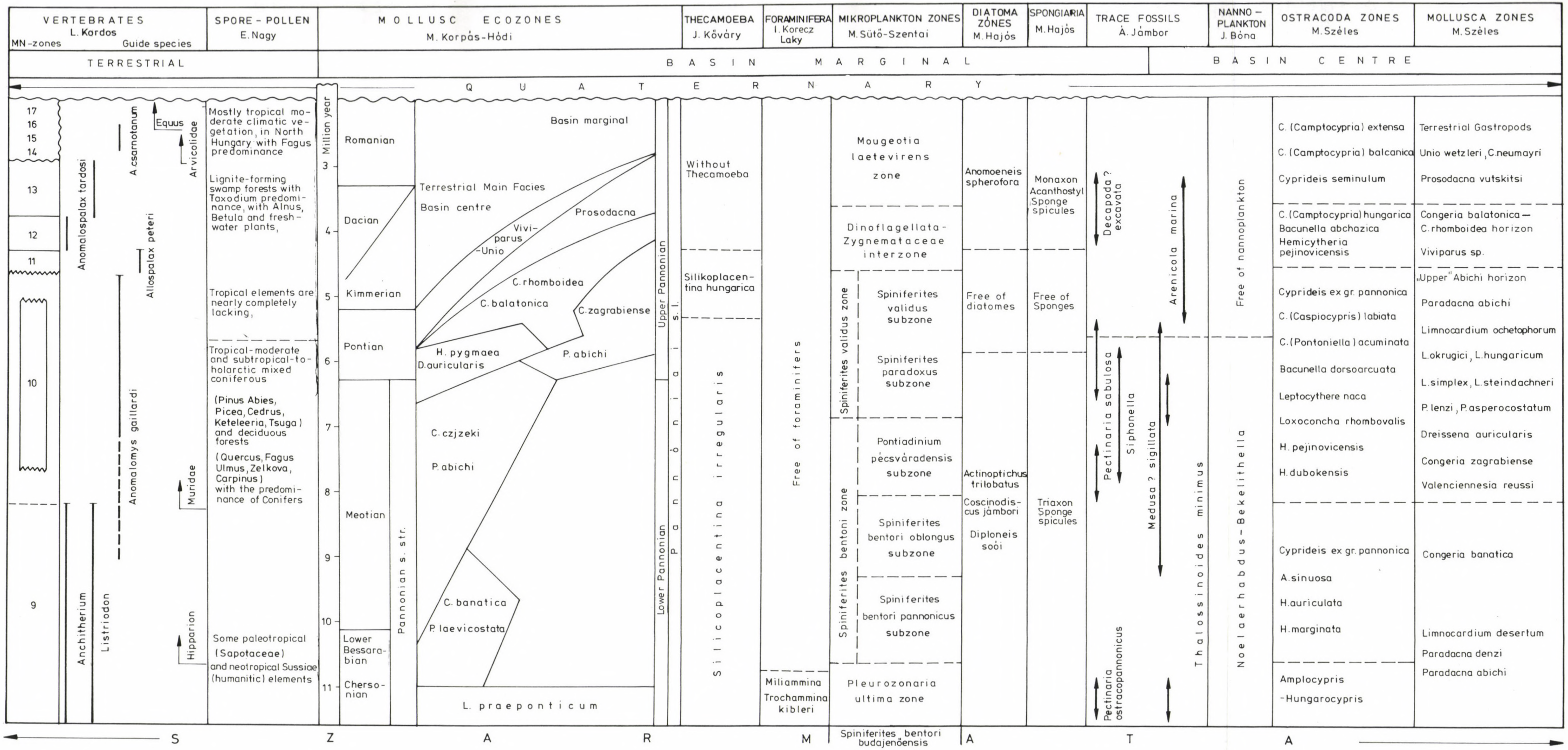


Fig. 6. Biostratigraphic classification of the Pannonian sequence

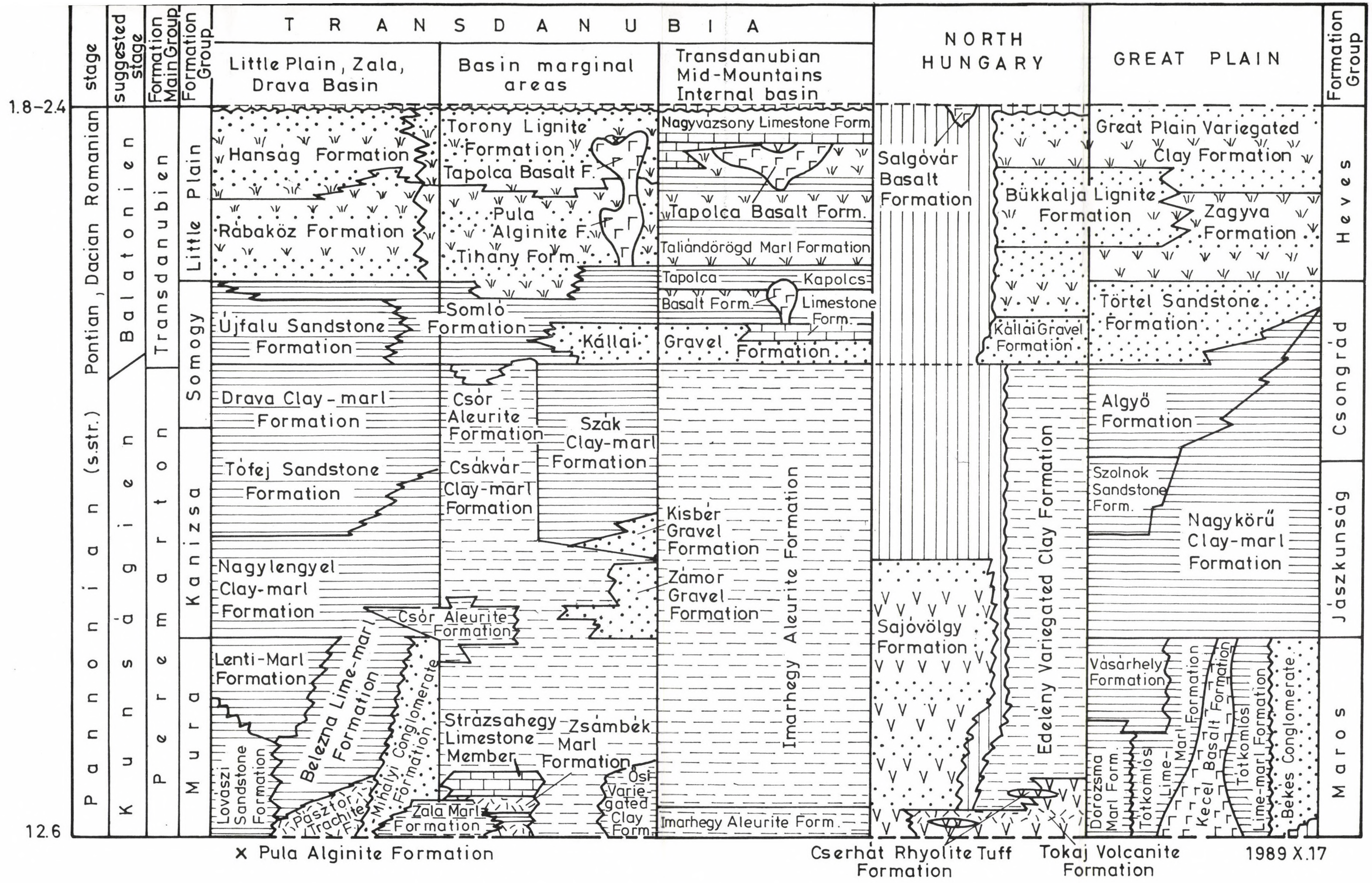


Fig. 7. Lithostratigraphic classification of the Pannonian formations

of Horváth (1962) a flora being considerably poorer than in the Torony Formation. The Torony Formation is older than these and rich in lignite beds, its extension, however, is restricted only to West-Hungary.

The past three years eyewitnessed new results in the classification of the Transdanubian Main Group. It has become clear that the Tihany Formation (i.e. the oscillation horizon of Bartha, 1959) is older than the Torony and Bükkalja Lignite Formations, and that systematically occurring variegated clay sequence of favourable basement morphological position in its upper part can be fairly well-correlated with the drying period of the Messinian stage, after the seismic studies of Pogácsás et al. (1987) and after the paleomagnetic studies. In the lower part of the Transdanubian Main Group the thin dolomite intercalations of great extension in Central and Western Transdanubia (Sorkikápolna Member) can be interpreted by periodically slighter evaporation and Na-carbonatic hypersalinity of the inland sea water.

The internal basins of the Transdanubian Mid-Mountains are rich in facies. Above the Kállai Formation first freshwater limestone (Kapolcs Formation), then freshwater marl and thin-bedded clay-marl - sand strata intercalated by swampy strata follow (Taliándörögd Formation) and the sequence is closed by freshwater limestone (Nagyvázsony Formation). The former sequence is dissected by repeated basalt eruptions (Tapolca Formation) associated with red bentonite intercalations (Kabhegy Member). The maar crater basins of the basalt tuff are filled by lamellar alginite and bentonite (Pula Formation).

In the Oligocene-- Lower-to-Middle Miocene Nógrád basin strongly eroded basalt tuff, lava and subvolcanic dykes (dykes, volcanic truncations) are known that extend into the Pleistocene, too, according to K-Ar data (Balogh et al., 1987), that are not associated by Pannonian sediments (Salgóvár Formation).

The establishers of the system (in the Great Plain: Gajdos-Pap-Somfai-Völgyi, 1983; in Transdanubia: Bardócz-Mészáros-Németh) assigned the genetically interrelated formations of the basin areas into four groups. In the Table these, of course, also found.

8.3 Chemostratigraphy

The core samples of boreholes were analyzed systematically, i.e. by strata and at least by every 5 meters, for the cold and hot hydrochloric acid soluble carbonate content(M. Partényi-Lechner). Based on the carbonate profiles of the more or less complete 15 Pannonian profiles the Pannonian sequence can be divided into three characteristic carbonate horizons that can be fairly well-correlated with one another, but the two boundaries can be correlated neither with the lithostratigraphic nor with the biostratigraphic boundaries without contradictions. The lowermost horizons is characterized by high calcite and low dolomite contents and the calcite quantity gradually decreases upward. This is the initial phase from the Sarmatian. The middle horizon is the phase of the predominance of the Pannonian inland sea in which calcite and dolomite are in equilibrium at a relatively low level while the third phase represents the filling of the Pannonian inland sea. Here the calcite content increases again, the dolomite content remains low but their quantities are strongly fluctuating (Fig. 5).

8.4 Chronostratigraphy

The chronostratigraphic position of the Pannonian sequence was studied by two methods so far. In the southwestern part of the Transdanubian Mid-Mountains it has been successful to determine the 3 to 5 million years K/Ar ages of basalt lavas belonging to the Middle Upper Pannonian of litho- and biostratigraphically fixed position (Balogh, 1980). The measurement data (above 20) were not free of contradictions since in the southern part of the Little Plain in the boreholes of the Várkesző environs similarly values of 3 to 4 million years were measured though these are younger both from the biostratigraphic (in the Balaton Highland these derive from the Congeria balatonica, in the Little Plain from the Unio wetzleri horizons) and from the evolutionary aspects (theoretically in the Little Plain this true inland sea state had to be longer in time). Based on these data in the Balaton Highland the boundary between the Lower and Upper Pannonian was dated to 5.5 million years, i.e. it was essentially correlated with the Mediterranean Miocene-Pliocene boundary (Balogh-Jámbor, 1985).

The age of basalts in the Danube-Tisza Interfluve lying in or below the Congeria partschi horizon proved to be round 10 million years, the well-preserved (black) biotite of the rhyolite tuff from the Congeria banatica horizon (Nagykozár-2 borehole) deriving from shallow depth (263.67-263.70 m) yielded 11.6 million years. Comparing this value with the 13.7 million years obtained for the Galgavölgy (upper) rhyolite tuff (Hámor et al., 1982) lying in the middle of the Lower Sarmatian, the age of lower boundary of the Pannonian can be probabilized between 11 and 12 million years (11.5 million years). This seems to correlate with the data of Pannonian paleomagnetic profiles measured so far (Kaskantyu-2, Tiszapalkonya-I) of the ages of Hungarian Neogene volcanics and with the biostratigraphic data.

The age of the upper boundary of the Pannonian sequence is unknown recently. In Transdanubia the K/Ar age of the basalts in the Unio wetzleri horizon proved to be 3-5 million years, the age of the basic rock (as to Ravasz-Baranyai it is humillite) lying in the Bár Lower Pleistocene red clay is round 2 million years (Balogh et al., 1982), but in Transdanubia unbroken, i.e. erosion-less Pannonian-Pleistocene profile is not known.

Though the paleomagnetic profiles of Vésztő and Dévaványa described by Rónai (In: Cook - Hall - Rónai, 1979) did not reach the strata overlying the Upper Pannonian layers with brackish fauna, as to the complex reambulation (Pogácsás et al., 1987) the Dévaványa-1 borehole traversed the Great Plain Formation and got the Zagyva Formation. The lower boundary of the former proved to be 4.2 million years, the upper one to 2.4 million years. At the same time this is the lower boundary of the Great Plain sequence of Pleistocene type, which seems to continue in this profile without break though with cycle initiating member above the Great Plain Formation.

The age of upper boundary of the sequence of traditionally Pannonian type (grey inland sea) cannot be fixed at 4.2 million years (an age of more than 5 million years can be read for the top of the Bükkalja and Zagyva Formations) since above, i.e. at the lower boundary of the Great Plain Formation in the profiles of the Kaskantyú and Tiszapalkonya boreholes considerable sedimentary gap can be probabilized on sedimentological and paleomagnetic bases, consequently remarkable amount (more than 100 m) could be eroded from the "traditional" Pannonian sequence before the deposition of the Great Plain Formation. In the Dévaványa profile the Great Plain Formation overlies the "traditional" sequence probably without interruption though with initial cycle, but the age of the "traditional" Pannonian sequence cannot be read off the paleomagnetic profile. The problem could be solved so when by means of paleomagnetic method at least one profile could be investigated in a basin area where it is sure that the Great Plain Formation conformly overlies the Zagyva (or Bükkalja) Formation.

In the profiles of the two boreholes (Kaskantyú-2 and Tiszapalkonya-I) traversing the Pannonian s.l. sequence and measured by paleomagnetic method (though the former was located on an uplifted structure, the latter in a depression), the lithostratigraphic boundary between the Lower and Upper Pannonian could be fixed in both cases at 8.9 million years in the paleomagnetic profiles. In the Lower Pannonian phase of the two boreholes (Peremarton Main Group) the biostratigraphic and chronostratigraphic boundaries run essentially parallel with each other, i.e. the former ones proved to be also time boundaries. Nevertheless, in their Upper Pannonian phase (Transdanubian Main Group) these boundaries are not parallel, i.e. these are not time but facies boundaries as stated by Korpás-Hódi (1985) on the basis of paleogeographical considerations.

The traces of eolian activity are found in the paleomagnetically studied Kaskantyú-2 and Tiszapalkonya-I profiles as well as in the sequences of the close Jánoshalma and Bácsalmás boreholes in the sequences younger than 2.4 million years. When comparing this with the Lower Pleistocene red clay sequence of the Tengelic-2 borehole (and with the strong eolian effects on the intercalated sand layers), further with the round 2 million years age of the Bár basalt within the same red clay sequence as well as with the paleogeographic consideration that the eolian activity extend over large areas, the bottom of red clays of the marginal parts can be probabilized as 2.4 million years.

It is to be noted that in harmony with the K/Ar data obtained for the basalts of the South Bakony Mountains the 5.5-6.0 million years for the Lower/Upper Pannonian boundary and the 8.9 million years for this boundary in the paleomagnetic profiles of the Great Plain display a considerable difference of round 3 million years. The paleomagnetic profiles of the studied boreholes were correlated with the sedimentary sequence on the basis of two radiometric K/Ar data, i.e. of the basalt in the Kiha-Ny-3 borehole (Meszéna, 1978) and of the rhyolite tuff of the Nagykozár-2 borehole. The former is related to the Kaskantyú sequence by modern seismic profiles, the latter is bound to the Lower Pannonian strata of both boreholes by the essentially time-boundary fauna of Congeria banatica. This difference is worthy of meditation since a difference of opposite direction ought to be obtained for the Lower/Upper Pannonian boundary of the Great Plain and of the Southern Bakony Mountains because within the basin the "deep-water" ("Lower Pannonian") facies conditions had to exist for longer times than in the marginal areas. Similar contradiction was observed between the K/Ar data of basalts in the Southern Bakony Mountains and in the Little Plain. These contradictions have not been eliminated so far.

The paleomagnetic profiles of the Kaskantyú and Tiszapalkonya boreholes were coupled in 1986-87 by means of seismic profiles (Pogácsás et al., 1989) and were correlated also with the Vésztő and Dévaványa boreholes. By means of this system it was successful to reevaluate the paleomagnetic position of the lower part of the Dévaványa-Vésztő profiles on the one hand, so that all the existing data were correlated in the Great Plain, and by means of seismic profiles the whole of the Pannonian sequence filling the Great Plain basin could be divided into 10 horizons by nine fairly well traceable chronostratigraphic levels. In the course of the subsequent studies this can be used both in the comparison of stratigraphic methods and in the hydrocarbon exploration, as well.

Pogácsás et al. (1989) when starting from the profile of the Tiszapalkonya borehole northward studied whether on the basis of seismic measurements the sea level changes of Vail can be determined in the Pannonian sequence or not. They got positive results. They fixed the position of three intrasequential sedimentary gaps in the Upper Pannonian and the "opening" of these northwards, i.e. they proved that in this apparently uninterrupted sequence internal erosion and stagnancy existed. It was successful to correlate these with the Vail's horizons by means of paleomagnetic connection and interpretation.

The gap between 7.9 and 7.6 million years occurred most markedly and this coincides with the start of the variegated clayey sedimentation (Palkonya Member) of narrow sense between the double lignite-bearing sequence, i.e. the water table decrease of the inland sea seems to be evidenced from this side, too. The second regression horizon involves the time interval between 5.7 and 6.8 million years and denotes the top of the previous variegated clay horizon and the lower section of the Messinian "salinity crisis". The interpreted age of the third horizon falls between 4.4 and 5.3 million years.

Some words have to be mentioned about the results obtained by the correlation of well logs. The marker system elaborated by D. Marinović in Vojvodina and applied also in Croatia was adapted to the Great Plain region by Gajdos (1972). Several regional profiles were prepared but these displayed severe chronostratigraphic problems: in the southern part of the Great Plain the markers running deep in the basin rose close to the surface in the northern part and this could not be verified by other stratigraphic (biostratigraphic, seismostratigraphic) methods and the comparison has not been carried out so far.

The Committee on Paratethys has forced the general use of the stage system accepted in 1975 in Bratislava. At the Neogene Congress held at Budapest in 1985 D. Vass presented the time boundaries of the Pannonian

s. str. (Lower Pannonian) and based on eastern Paratethyan data of the Pontian, Dacian and Romanian stages, as well. In possession of more suitable paleomagnetic profiles the correlation with these can be solved. In it questionable, however, that is the use of these necessary and expedient in the Pannonian Basin? These can be traced only by paleomagnetic profiles and from the related seismic profiles, i.e. it is expensive and troublesome. We need, however, a stratigraphy that can be used also by common methods. This is why I do not suggest their use and believe that valuable work within the Carpathian Basin is hopeless by using these methods.

9. The structure of the Pannonian formations is characterized by relative tranquillity: most of them are of horizontal bedding. The dip of strata hardly exceeds 5^{0} though in southern margin of the Mecsek Mountains and in the eastern margin of the Bükk Mountains Pannonian strata of vertical position are also found in the tectonic zones. The dip of strata of the Peremarton Main Group is usually steeper than that of the Transdanubian Main Group.

The closer are the strata to the dissected surface of the basement of the Pannonian formations, the steeper is their dip. The strata conform with the basement dip from the basement highs towards the depressions. The decisive significance of this phenomenon was recognized by L. Szebényi already in 1955. The number of structures related to Pannonian formations is several dozens in Hungary, their length varies between 5 and 10 km, in extreme case 35 km, their width is 1-2 km. The greatest ones are found in Mihályi, Lovászi, Budafa, Görgeteg-Babócsa, Inke, Igal, Algyő, Battonya, Endrőd, Hajdúszoboszló and Kismarja-Mezősas. The differences of compaction between the thicker sequences above depressions and the thinner ones overlying the top of the structures are responsible for their formation. In the Carpathian Basin the nearly general morphotectonic phenomenon characteristic of Pleistocene times increased the uplifted character of structures, i.e. in the uplifted areas along the rejuvenated marginal faults the uplifted parts were rising, the subsiding parts were subsiding.

The whole of the Transdanubian Mid-Mountains was tilted southeastwards and was uplifted by 150-200 metres while its northwestern background was considerably subsiding. The fault systems developed in this manner could be identified by borehole measurements (Kókay, 1956; Jaskó, 1988; Jámbor, 1980) in the southeastern foreland and mainly by geophysical measurements in the northwestern part. Similar uplift but of greater measure took place also in the Northern Mid-Mountains (Börzsöny, Cserhát, Mátra, Bükk and Tokaj Mountains).

The Mecsek Mountains was also considerably uplifted and the northern and southern overthrusts cut also the Pannonian formations.

Young marginal faults were revealed by bauxite exploration drillings in the northern and southern foreland of the Villány Mountains, too.

The rejuvenation of certain large transversal faults after the Pannonian could be identified in the Transdanubian Mid-Mountains (western side of the Keszthely Mountains, the Mór trench, the northeastern side of the Velence Hills, the area between the Buda Hills and Zsámbék Basin, the western side of the Mátra and the eastern side of the Bükk Mountains).

By means of detailed studies fault displacements of several ten meters or exceeding 100 m could also be identified in the densely drilled Transdanubian and Great Plain hydrocarbon trapping structures of uplifted position (Völgyi, 1956; Szalánczy, 1948; Gajdos-Pap, 1977). Based on the correlation studies of well logs of the Pannonian sequences Gajdos and Pap stated that greater young faults are found in localities where considerable differences exist in the basement morphology.

In the generation of the two greatest covered Transdanubian structures (Budafa, Lovászi) the folding resulted in by compressional stresses could play also important role (Kőrössy, 1965).

Recently first of all seismic reflection measurements serve to explore the structure of the Pannonian formations. These proved the marginal faults of the uplifted structures, determined the downward ceasing fault systems, the flower structures (Pogácsás and Pogány, 1988) developed in depressions as a result of horizontal displacements, and revealed several young fault elements, among others that is known to be the longest: the horizontal displacement zone connecting the Kapos-line with Kismarja. The method and the measured profiles include further possibilities, the development and demonstration by maps, however, are the tasks of the future.

10. History and paleogeography of the Pannonian formations. In the Carpathian Basin the Pannonian age represents the last evolutionary phase of the adjoining of the southern Eurasian plate to the continent. Subsequently to the inland sea stagnation during the Late Sarmatian, in the Pannonian large-scale subsidence followed. At the beginning the inland sea sedimentation accelerated under spectacularly changing conditions as compared to the Sarmatian, while in the second part of this age the whole basin was characterized by the delta filling prograding from the north and associated with decelerating subsidence.

In addition to the rapid subsidence of the basement the volcanism occurring in many localities and in several horizons during the Pannonian also indicated the changes proceeding in the crust and mantle of the Carpathian Basin.

Based on the main evolutionary events and on their grouping proceeding during the Pannonian five main phases can be distinguished from down upwards (Fig. 8):

1. Sarmatian -Lower Pannonian transition,
2. the phase of the first Lower Pannonian transgression,
3. the stable phase of the Lower Pannonian,
4. the initial phase of filling,
5. the terminal phase of filling.

10.1 The most important event of the Sarmatian-Lower Pannonian transition proved to be the tectonic event (Rhodanian-1) outside the Hungarian part of the Pannonian Basin as a result of which the aquatic relation was eliminated or became very restricted towards the Pontian Basin. Parallel with the tectonic events the erosion area was also uplifted producing the considerable increase of the amount of annual precipitation. The summer hot and dry, winter mild rainy climate was replaced by a moderate rainy climate. The seasonal change of salinity of the sea water was responsible for the development of Pannonian-brackish fauna from the Sarmatian-type assemblage. As a result the salinity of the inland sea became lower, the annual mean temperature decreased but the seasonal fluctuations of temperature were less characteristic. At that time the dimensions of the inland sea did not exceed those of the Late Sarmatian but the Sarmatian variegated clay - sand - gravel, coastal coarse limestone, intrabasinal clay-marl - sand facies conditions were replaced by terrestrial variegated clay - sand - gravel, near-shore lime-marl - clay-marl, intrabasinal laminated clay-marl facies sequence while the shallow water depth remained essentially unchanged.

As an indication of the afore-mentioned remote tectonic event the oldest Pannonian volcanic explosion proceeded: the dissemination of rhyodacite crystal tuff (Fig. 9) from the Tokaj Hills reached the area of Transdanubia, as well. To trace this volcanic activity in the Great Plain is hindered by the scarse coreholes. In the Little Plain basin the trachyte volcanism started in the Sarmatian (Pásztori) extended into the lower part of the Pannonian, as well.

In the southeastern foreland of the Transdanubian Mid-Mountains the Csákvár lagoon system, in its southeastern part the Kapolcs-Nagyvázsony

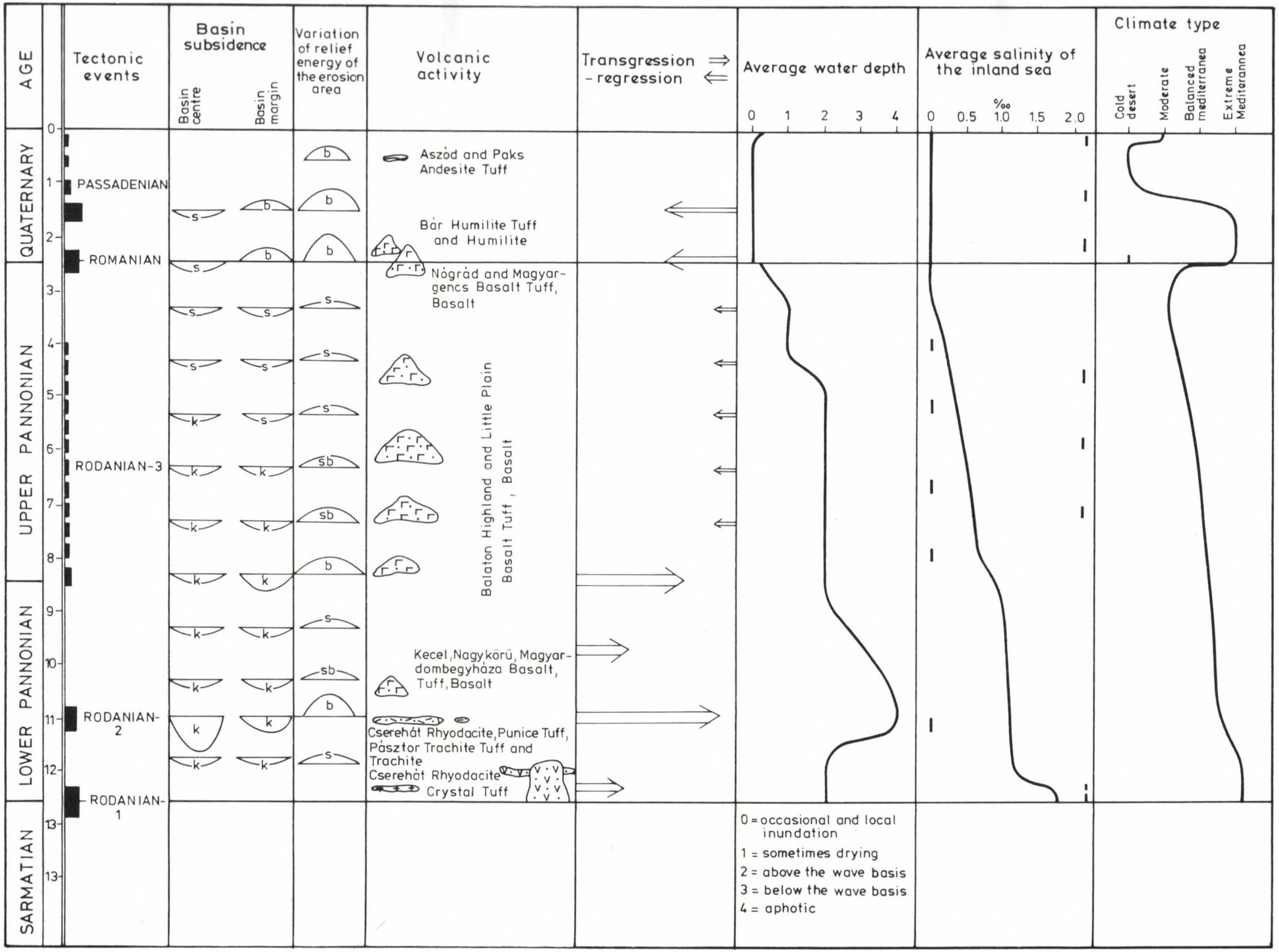
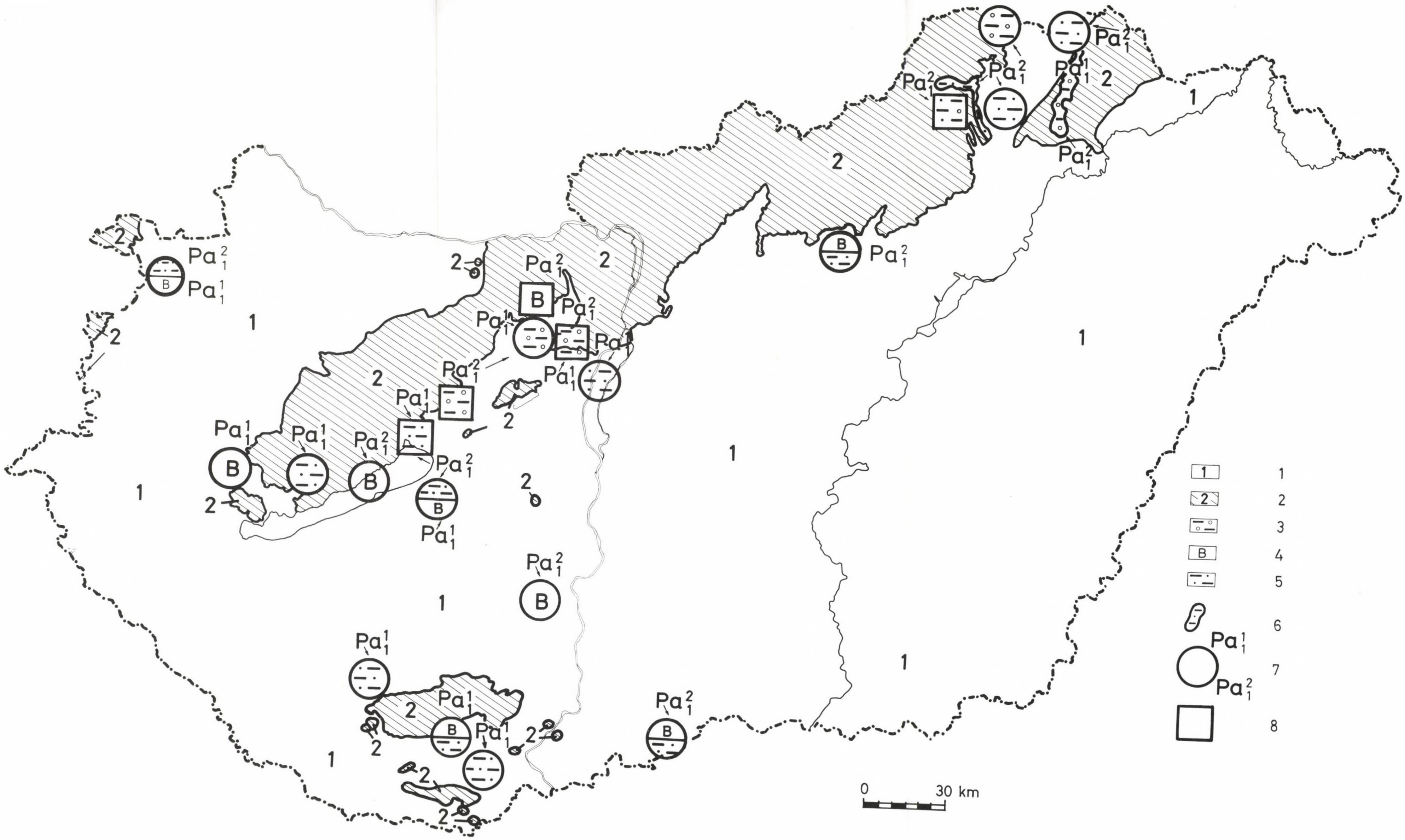


Fig. 8. Main phases of evolution of the Pannonian s.l. and of the Quaternary



<u>Fig. 9.</u> Localities of Lower Pannonian rhyodacites. 1. Surface extension of Pannonian and Quaternary formations; 2. surface extension of the formations older than Pannonian; 3. rhyodacite tuffite; 4. bentonite; 5. rhyodacite tuff; 6. surface outcrop; 7. occurrence in horizon, - occurrence observed in certain boreholes, - occurrence in horizon; 7. occurrence observed in several boreholes

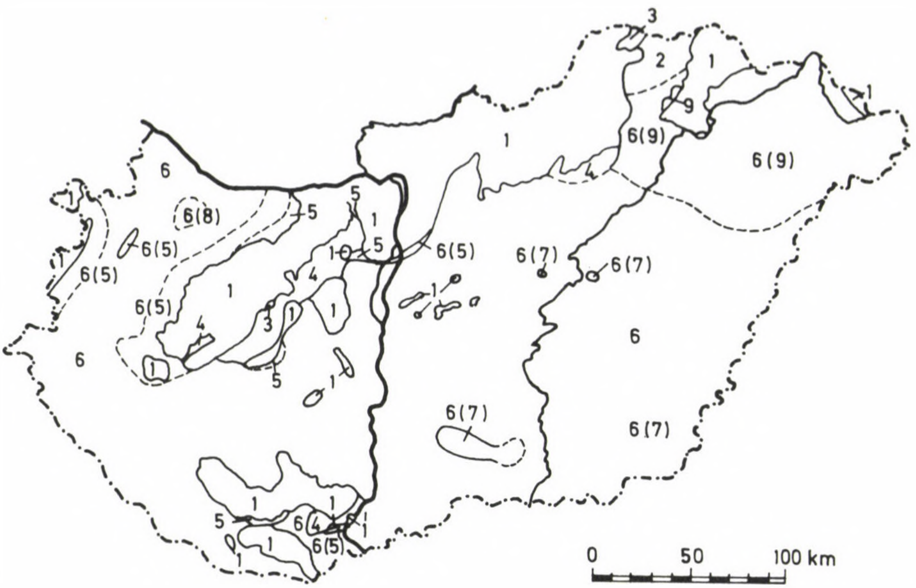


Fig. 10. Paleogeographic sketch of the Lower Pannonian formations. 1. terrestrial erosional area consisting of former older formations; 2. areas with fluviatile, flood-plain and lacustrine sedimentation; 3. areas with swampy and lacustrine sedimentation; 4. areas with brackish, inland sea, coastal, lagoonal sedimentation; 5. areas with brackish inland sea abrasional-coastal sedimentation; 6. areas with brackish inland sea pelagic sedimentation; 7. basalt volcanics; 8. trachyte volcanics; 9. rhyolite and dacite volcanics

intramontane basin developed. Both persisted in the whole Lower Pannonian and were characterized by diatome-rich sedimentation of decreased velocity. Simultaneously, in the marginal and internal depressions of the Tokaj Hills special volcanosediments (hydroquartzite, bentonite, kaolin, diatomite and their mixtures) were deposited.

10.2 A subsequent Pannonian tectonic phase (my term is Rhodanian-2) produced the rapid differentiated subsidence of the basement, the small-scale uplift of the erosion areas, the process of the first large-scale Lower Pannonian transgressions and the formation of the first delta sedimentation system. The terrestrial and delta-plain parts of the latter (Cserehát, eastern foreland of the Bakony Mountains) were rather underdeveloped while in the recent deep depressions (Makó-Hódmezővásárhely trench, Békés depression, Derecske-trench and their broader environs) the foreland formation of delta slopes prevailed in large areas (Fig. 10).

In the inundated areas (and the major part of the intrabasinal highs was of this type) the transgressions formed thin abraisonal gravel facies (Mihályi and Pinnye structures, marginal areas in the Mecsek Mountains, Tapolca Basin, Balatonfő etc.).

This phase is characterized also by strong volcanic activity. The products of the youngest volcanic cycle of the Tokaj Hills, the pumice-rich rhyolite tuff with pumice rolls developed throughout the Cserehát as well as the related dacite and andesite masses can be assigned to this phase. In the Danube-Tisza Interfluve (Kiskunhalas, Kecel, Ruzsa, Bordány, Sándorfalva and in the environs of Nagykörű north of Szolnok) remarkable basalt volcanism occurred (Cserepes-Meszéna, 1978; Pap, 1983; Tanács-Ravasz, 1984). In the Mecsek environs (Nagykozár-2 borehole) and in the southern Great Plain (Bácsalmás-I borehole) thin dispersed rhyolite tuffs deposited in this phase are also known that can be related to the rhyolite explosion in the Tokaj Hills.

This evolutionary phase is characterized essentially by the same climate and by similar oligohaline Pannonian-brackish living world.

10.3 The third evolutionary phase was the most quiet one of the Pannonian age. The subsidence of the basement and the transgression continued (Sopron Mountains, northwestern foreland of the Transdanubian Mid-Mountains) and the extension of the Pannonian inland sea became the greatest. The surrounding provenance areas were slowly eroded, the climate remained warm and rainy, the pelitic oligohaline sublittoral sedimentation prevailed. The volcanic activity had a pause.

10.4 The initial phase of filling was characterized by the relatively slowing of basin subsidence, by the tectonic rise of the erosion areas and by the predominance of the humid warm - dry warm climatic periods. In sedimentation the extension of the subaquatic, later subaerial deltas prograding from the north (Bérczi-Phillips, 1985), and the progress of formation of the shallow water, undulatory, trace fossil rich sand clay-marl facies proceeded. Along the margins of block mountains rising in the Hungarian part of the Pannonian Basin considerable transgression followed forming characteristic abrasional (pearl gravels) and lagoonal (quartz sand, freshwater limestone) facies. In the more or less isolated basins (Csákvár, Kapolcs-Nagyvázsony, Vérteskozma) and basin parts the swampy freshwater strata (lignite, huminitic clay, clay) have already occurred. The salinity of the inland sea decreased in general, but due to the dry periods sodium-carbonatic hypersaline small basin developed from time to time with dolomite formation. Contemporaneously with the large-scale subsidence of the Little Plain basin the Na-alkali basalt volcanism

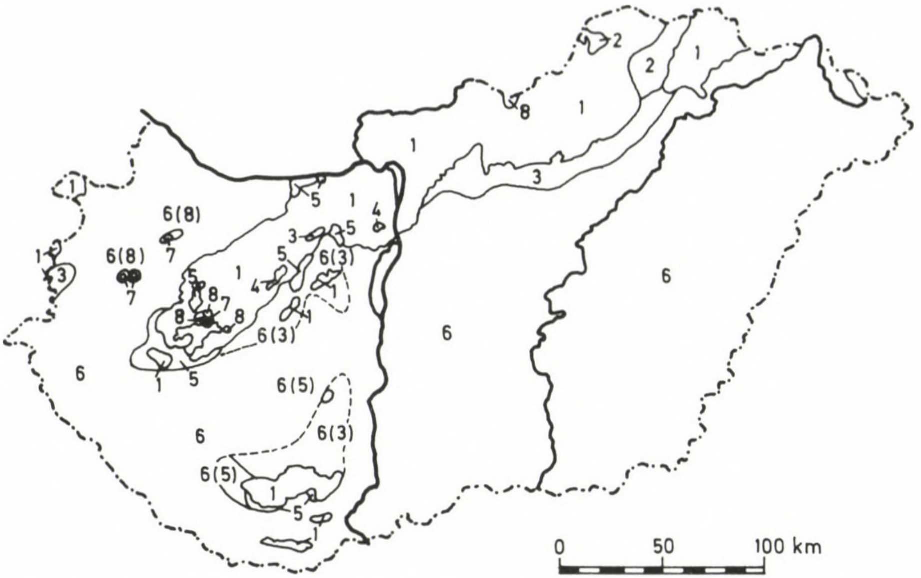


Fig. 11. Paleogeographic sketch of the Upper Pannonian formations. 1. terrestrial erosional areas consisting of former older formations; 2. areas with fluviatile and flood-plain - lacustrine sedimentation; 3. areas with swampy and lacustrine sedimentation; 4. areas with inland sea coastal brackish and freshwater lagoonal sedimentation; 5. areas with brackish inland sea abrasional-coastal sedimentation; 6. areas with brackish inland sea shallow water delta sedimentation; 7. areas with eutrophic lacustrine sedimentation; 7. basalt volcanics.

started in the southwestern part of the Bakony Mountains (Fig. 11).

10.5 In the terminal phase of filling of the Pannonian Basin in the whole of the sedimentation area the delta plain facies became predominant and the strata deposited under subaquatic conditions were replaced more frequently and in ever greater areas by the terrestrial yellow-brown-grey-variegated strata of narrow sense. In the former ones sand, clay-marl, huminitic clay, lignite, in the latter one the alteration of sand and variegated clay strata is characteristic. The water of the depositional basins became ever more limnic, climatologically the dry periods were ever more frequent.

In the marginal areas of block mountains that inclined to be karstified, rather large basins with freshwater limestone sedimentation developed in the environs of large karst wells (Nagyvázsony, Várpalota-Guttamási, Szabadsághegy). The Na-alkali basalt volcanism continued in three or four phases in the southeastern Bakony Mountains and in the Little Plain and started in the Nógrád area, too. In the two latter areas the volcanic activity continued also during the Lower Pleistocene. The most characteristic products of volcanism are the maar tuff rings and crater basins in the Little Plain and in the southern Bakony Mountains that were filled by special volcano-sedimentary deposits (alginite, bentonite, see Jámbor-Solti, 1975).

The Pannonian sedimentation was broken by a drastic tectonic phase (Romanian). As a result of this not only the erosion areas were uplifted again but the strong rise of the sedimentary sequence of the basin that did not extend to certain regions (Makó-Hódmezővásárhely trench, Békés and Jászság depression) also proceeded probably around 2.4 million years. Extreme climatic changes followed. This period was characterized hot dry summer, first by humid warm, then cooling humid winter, that is usually assigned to the Upper Pliocene or Pleistocene by the experts.

11. Mineral resources of the Pannonian formations

Though there is an increased effort to know the geological environment of the society exceeding the manysided short-term raw material focussed exploration, recently it is expected of the geologist to explore and know the immediately utilizable geological formations. I do not elude this question so I give a short comprehension of the related exploration results. Occurrences are found in the map series edited by Csiky-Erdélyi-Jámbor-Kárpáti-Radó and Kőrössy (1987).

11.1 Drinking water. The Upper Pannonian formations and within these first of all the strata of the Transdanubian Main Group store the major part of the drinking water reserves of the country. In this respect only the Quaternary sequence play similar important role but the surface pollution of increasing measure endangers this latter one.

The Pannonian sequence possesses usually moderate bases from the aspect of drinking water explorations. The near-surface (0 to 500 m) strata are sand strata, that are loose, usually fine-grained and of considerable porosity. This is less favourable from the aspect of well preparation. On the other hand, the waters are of good quality, rarely of medium quality, locally with sodium carbonate (northern Great Plain) or ferrous or gas-bearing (Central and Southern Great Plain).

In the marginal areas of the mountains the coarser strata with gravel formations of the Peremarton or of the Transdanubian Main Groups are very advantageous formations from the aspect of water exploitation.

In general it can be stated that the water supply of the villages and town settled above the Pannonian formations is solely technical, i.e.

economic problem since the water production is possible from these formations.

11.2 Thermal water. In the basin areas the depths of which is more than 1000 m thermal water can be explored almost in all regions of Hungary. The construction and operation of wells with suitable water quantity, water temperature and less scale-forming material, however, need remarkable investment costs. As a general rule it can be stated that temperature increases downward more rapidly above uplifted basement structures than in depression areas. The dissolved material content of waters is increased by depth and temperature together.

11.3 Hydrocarbons. 60% of the petroleum and gas reserves being primordial significance from the aspects of national economy are reservoired in the Pannonian (mainly in the Transdanubian Main Group) sandstones, between 1000 and 2500 m. The exploration of most arches being the classical areas of exploration seem to be practically ended, the exploration of hidden traps is the task of future though this will need more time and financial background, i.e. will be more expensive. Nevertheless, the country is not in the position to give up these resources since it is cheaper than to import this indispensable energy resource.

11.4 Carbon dioxide. The Mihályi deposit found in the course of hydrocarbon exploration (Papp, 1935) contains CO_2 gas of high purity and this has served as a basis of considerably industry. Explorations carried out in the environment since 1935 multiplied these reserves, thus the supply of the Répcelak works is assured for long terms. The progressed development of this type of industry is restricted by the low level of demands.

11.5 Lignite. In the formations constituting the middle part of the Transdanubian Main Group and the lower part of the Peremarton Main Group (Tihany, Bükkalja, Torony, and Edelény Formations, respectively) lignite intercalations are known on a country scale. Lignite seams of industrial thickness (more than 0.8 m) developed first of all in southern forelands of the Bükkalja, further of the Torony and Edelény Formations. In the forelands of the Mátra, Bükk and Cserhát Mountains, in the southern foothill of the Kőszeg-Rohonc Mountains SW of Szombathely Upper Pannonian, in the Komjáti, Szendrő, Abod and Öskű intramontane basins Lower Pannonian lignite deposits are known. These are paralic multi-seam sequences except the Öskű Formation.

Mining operations are in progress in the foothills of the Mátra and

Bükk Mountains in opencast mines, nearly solely for power plant utilization.

As to the recent evaluation only the resources of the Upper Pannonian occurrences can be economically exploited. The lignite reserves of altogether several billion tons mean considerable proportion of the country's energy reserves though the environmental aspects, e.g. the sulfur and fly ash emission per produced heat quantity, the used land area, water reserves etc., has repeatedly changed the value of them.

11.6 Quartz sand, sandstone, quartzite. In the marginal areas of the mountains the lagoonal Lower and Upper Pannonian quartz sand occurrences are known for more than 100 years in the environs of Fehérvárcsurgó, Zámoly, Kővágóörs, Diósd, Bicske, Szomód, Pusztazámor, Kán, Gorica, Mályi and Alsótelekes (Szatmári, 1971, Vecsernyés, 1966). The Fehérvárcsurgó deposit seems to be most economically exploitable one and it succeeded to settle here industry for processing the glass sand.

The reserves of the Kővágóörs, Diósd, Bicske and Pusztazámor occurrences have been used as backing sand, recently being the basic material of tile production for BRAMAC tiles.

In the Kállai Basin and Mór trench the sandstone-quartzite occurrences are found in the marginal parts facing the mountains. Due to their high silica content these are suitable for ferrosilicon production. Their mining in the Balaton Highlands is a heavy environmental problem.

11.7 Feldspar-bearing sand was explored in the marginal parts of the Mórágy Mountains in the past years (Tomka Gy.) and started its mining at Pécsvárad. The material of the deposit belonging to the Kállai Formation is used for porcelain production by the Zsolnay factory.

11.8 Alginite (oil shale), bentonite. Based on the explorations at Pula (Bakony Mountains) started 15 years ago (Jámbor-Solti, 1975), in the Kemeneshát first at Gérce, then at Várkesző (Bence-Jámbor-Partényi, 1979), recently at Egyházaskesző (Solti, 1988) Upper Pannonian alginite filling basalt tuff craters, at the two latter localities basalt bentonite were discovered.

The alginite reserve is estimated recently to 150, the bentonite reserve to 30 million tons.

The wide investigations proved first of all the utility of alginite for soil melioration and production increase (Solti, 1987). Their utilization shows recently a restricted progress.

The applicability of bentonite for drilling, civil and water engineering, cleaning and carrier purposes has also been proved.

In the Kemeneshát there is the possibility to explore further bentonite and alginite beds.

In harmony with the facts described in the chapter dealing with stratigraphy, most of the bentonites of the Tokaj Hills belongs to the Lower Pannonian. As to the studies of Mátyás (1985) their formation is related to the limnic basins developed within the volcanic mountains and at their marginal parts, respectively. The possibilities of successful explorations are given here, too.

11.9 Kaolin. Lower Pannonian kaolin deposits of industrial value are known solely in the Tokaj Hills. Here the considerable occurrences developed partly as a result of the postvolcanic alteration of acid Badenian, Sarmatian and Lower Pannonian volcanic tuffs, partly by their erosion and accumulation in limnic basins. The intense mining and exploration of kaolin has been in progress.

11.10 Zeolite. In the course of epigenic alteration the acid volcanic glass produces zeolite minerals: mordenite, heulandite, clinoptilolite etc. In the Tokaj Hills a part of the uppermost rhyolite tuff contains zeolite of considerable quantity. The exploration, processing and manysided utilization have been managed by E. Mátyás for years with the assistance of Ilkey-Perlaky, E.

11.11 Alunite. In the Tokaj Hills as a result of the interaction of sulfatic hydrotherms ascending in the course of postvolcanic activity and of the volcanic tuffs alunite-rich zones, in the limnic basins alunitic clay strata were formed. The geological and technological exploration of alunite directed by E. Ilkey-Perlaky is now in progress.

11.12 Pyrite accumulation in the Pannonian sequence is known in the southwestern, western and northern foreland of the Keszthely Mountains. In the Upper Pannonian pelitic rocks the crystalline pyrite occurs in form of smaller-greater nodules while in gravels as cementing material. The hydrothermal-sedimentogenic occurrence of pyrite related to basalt volcanism is of indicative value in spite of its gold content (Tóth, 1972).

11.13 Quartzite. In the Tokaj Hills the terminal layer of the Lower Pannonian limnic basins is represented by the mostly grey to dirty-white hydroquartzite which can be used by the chemical industry due to its high silica content. Its exploration and production are integral parts of the non-metalliferous industry in the Tokaj Hills.

11.14 Diatomite. This type of raw material occurs also within the

Lower Pannonian formations. Its deposit of industrial value is found in the Tokaj Hills (Erdőbénye) and the possibilities for development are given here, as well. This diatomite and clayey diatomite strata are found also in the Csákvár Basin (Jámbor, 1971). Indications were recognized in the Bogács environs by Gy. Radócz (in: Hajós-Radócz, 1971). The microflora of the three occurrences was processed by Hajós (1959, 1971, 1971).

11.15 Lime-mud occurrence is known in the Kapolcs-Nagyvázsony Basin, close to Kapolcs. Here the several meters thick Hydrobia(?) lumachelle facies of the Upper Pannonian Kapolcs Limestone Formation altered to snow-white lime-mud. Its exploration and utilization have not started yet, being explored only by two bauxite exploration wells.

11.16 Building industrial raw materials. The Pannonian moistly plastic clay-marly aleurites are used for the most part. Brick, building brick and tile are produced from the Lower Pannonian (Sopron, Kisbér, Bakonyszentlászló, Csót, Tata, Bátaszék, Mályi etc.) and Upper Pannonian (Tab, Balatonszentgyörgy, Bátaszék, Kőröshegy, Székesfehérvár, Szerecseny, Győrszentmárton, Kőbánya, Hatvan etc.) materials.

The Tófej and Magyarszombatfa Upper Pannonian clay occurrences close to Nagykanizsa is of special quality and suitable to facing stones and other ceramics. Both occurrences serve industrial purposes.

In the Budaörs side of Szabadsághegy the Upper Pannonian "Buda earth" is known at least for a century. Relatively small amounts are exploited for painter bricks. This is one of the traditional raw materials for decoration.

In the areas of near-surface occurrences of Pannonian formations practically close to each village sand has been explored and exploited for bricklayer and mortar purposes.

Pearl gravel occurrences are related to the Lower and first of all to the Upper Pannonian quartz sand formations and represent their marginal basal formations. Usually their periodical mining has been in progress in the Balaton Highland (Lesenceistvánd, Kékkút), in the northwestern margin of the Vértes and in the southern margin of the Buda Mountains (Pusztazámor). Its pure quartz variety is used for well building, park building and concrete production, the limonitic varieties were used for covering platforms, the dolomitic varieties for park building. Its significance was severely restricted by the development of Danube gravel production.

Among building stones the basalt is worthy of mention. Its mining of economic measures developed first of all in the environs of the Tapolca

Basin. Smaller basalt quarries are in operation also in Nógrád county.

It is used nearly solely for road and railway building in form of breakstone of different size. Mining has no raw material troubles so far though the environmental aspects force the production back to the Keszthely Mountains (Uzsa, Sümegprága).

The lava rocks of the third volcanic cycle of the tokaj Hills belonging to the Lower Pannonian (dacite, andesite) are exploited from several smaller-greater quarries.

In the last century and at the beginning of our century the basalt tuff has been a favourized brick stone, and was used for basements, palisades profile stones (columns, stairs, portals and burial stones) though it is moderately frost resistant. Quarries were found in the Little Plain in the Kemeneshát (Várkesző, Egyházaskesző, Sitke, Gérce, Kemenesmagasi. Kissomlyó, Ság), in the Balaton Highland (Pula, Királykő, Taliándörögd). Remarkable resources of this stone are available but the prevalence of brick and concrete also for countrymen practically eliminated its application.

The freshwater limestone of Nagyvázsony, Várpalota, Kapolcs and Szabadsághegy was used for similar purposes but their fate has become similar to that of the basalt tuffs.

In the Héviz environs (Karmacs, Alsópáhok) the mining of the Upper Pannonian laminated basal sandstone (in popular expression "pite"-stone) is flourishing. The not too attractive (brownish-greyish yellow) laminated frost resistant rock is used for basements, palisades, columns and park building. In the past 20 years this occurred in Transdanubia in exacting building operations.

Its mining is assured for decades by the reserves but it has no other locality since it is closely bound to the Late Pannonian hydrothermal activity along the Héviz main fault.

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VERY LATE HOLOCENE OVERBANK SEDIMENTATION AND ^{14}C AGES OF BURIED SOILS IN THE ROUGE RIVER BASIN, SOUTH-CENTRAL ONTARIO

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Ground soils formed in the Rouge River 2 m terrace system (Highland Surface; Mahaney and Sanmugadas, 1986) often contain buried pedons resulting from burial by overbank sedimentation during late winter/early spring flooding. In late February, 1985, sudden thawing produced rapid melting and breakup of river ice in the Rouge River Basin of South-Central Ontario, as well as in several nearby drainages. Large river-ice dams produced water levels >2 m higher than normal, and high enough to flood large tracts of the 2 m terrace system (Highland Surface) with sufficient velocity to deposit 3 ± 1 cm of fresh silty sediment. Underlying buried soils yield radiocarbon dates to within the last century (carbonates removed), and to within the last few hundred years (with carbonate). Because the soils formed in the Highland Surface are thin, poorly developed Regosols (compared with better developed Brunisols in the higher terraces (at 8 and 15 m), there must be considerable difference in age of several thousand years between the 2 m and the 8-15 m pair of terraces. The absence of buried soils below a depth of 1 m suggests, either that overbank processes are sufficiently powerful to occasionally remove all accumulated overbank deposits to a depth of 1 ± 0.5 m, or that stream competence has slowly increased over the last few hundred years. Radiocarbon age determinations of buried soils is hampered by biogeochemical contamination and high carbonate content; the former can be detected by microbial enumeration and the latter by chemical pretreatment.

Keywords: Sedimentation, buried soils, ^{14}C age-determination, Holocene, overbank-depositions.

Introduction

Numerous ground soils in the lower terrace system (floodplain; 2 m surface of Mahaney and Sanmugadas, 1986) in South-Central Ontario drainages overlie buried soils at shallow depths ($\pm$ 0.5 m). These buried soils are difficult to date with precision because roots penetrate from the ground soils into the buried profiles, and ground water sometimes

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invades the lower buried units. During late February, 1985, a sudden thaw produced rapid river-ice breakup and dammed numerous parts of the Rouge River and Little Rouge Creek (Fig. 1), just inside the Pickering township boundary in South-Central Ontario. Damming and subsequent flooding occurred within 48 hours and with sufficient force to transport large (2 m x 2 m x 0.3 m) blocks of ice onto interfluve surfaces. The flooding process deposited 3.0 ± 1.0 cm of fresh unweathered silty and sandy sediment onto the existing A horizons of thin soils on the 2 m terrace (floodplain). In this paper we discuss the flooding event, nature of the sediment transported and deposited, its relation to underlying older sediments of late-Holocene age, and the problems inherent in dating these buried soils.

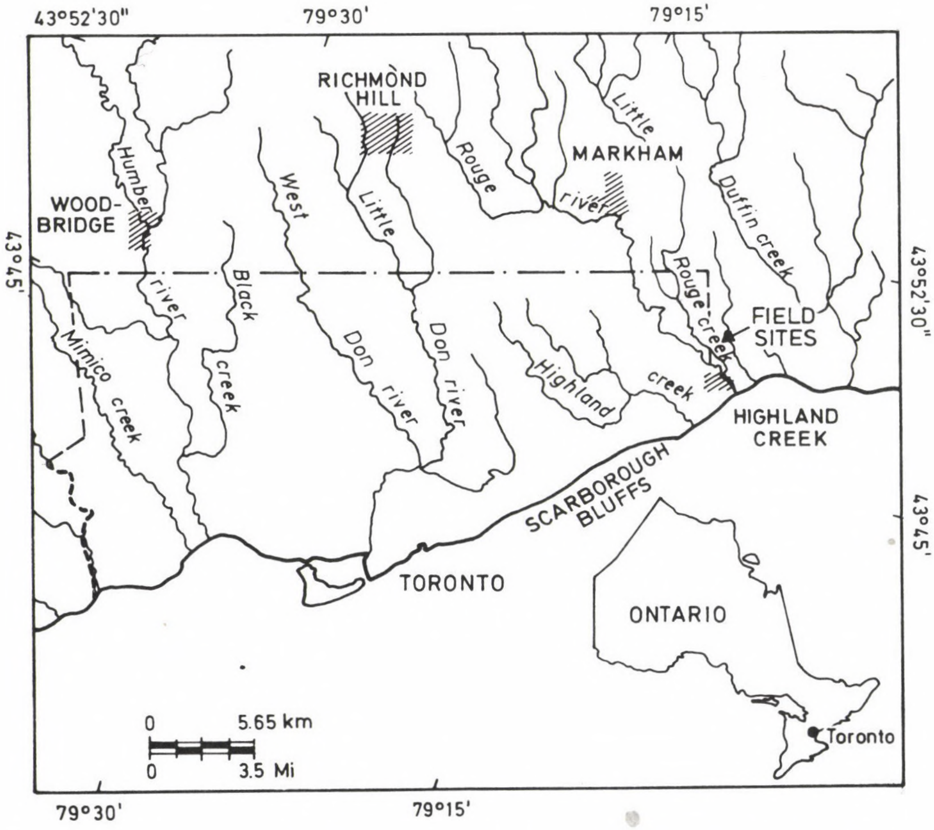

Fig. 1. Location of the study area in Little Rouge Creek and Rouge River Basins, South-Central Ontario

Methods

The study sites were selected on representative parts of the Highland Surface (2 m terrace tract) (Mahaney and Sanmugadas, 1986) along Little Rouge Creek near its confluence with the Rouge River (Fig. 1). Soil and sediment samples were collected from each horizon described in the field (following the nomenclature of the Canada Soil Survey Committee (1977), and Birkeland, 1984). Particle size analysis follows Folk (1968) and Soil Survey Staff (1951) and was performed on the <2 mm fractions; coarse grain sizes (>63 μm) were determined by dry sieving, whereas fine-grained sizes (<63 μm) were calculated by sedimentation following procedures established by Bouyoucos (1962) and Day (1965). Chemical analyses of the <2 mm fractions include pH on a 1:1 paste, total organic nitrogen by the Kjeldahl method (Bremner, 1965), cation exchange capacity and extractable cations with 1N NH_4OAc (Peech, et al., 1947; and Schollenberger and Simon, 1945). Organic carbon was determined by the Walkley and Black (1934) method. Iron was extracted with sodium dithionitecitrate (Fe_d) according to procedures established by Mehra and Jackson (1960). Calcium carbonate was determined by acid neutralization.

The mineralogy of the <2 μm grain size fraction was determined by agitating samples with a cell dismembrator and pretreating with H_2O_2. Clay was centrifuged onto ceramic tiles, air dried, and X-rayed following procedures established by Jackson (1956) and Whittig (1965).

The samples collected for radiocarbon dating were air dried on aluminum foil and dated within 45 days. One sample suite was dated without pretreatment, a second sample suite was leached with HCl to remove $CaCO_3$ and washed with distilled H_2O.

The soil samples were collected for microbial analysis as subsamples of those taken for chemical and particle size determinations. No less than 1000 g was collected in sterile bags from each profile. Following exposure of the soil and just prior to collection, each horizon was cut back to provide an uncontaminated sampling face. Subsamples were collected and placed in sterile scintillation vials.

Several routine methods were employed to obtain estimates of the numbers and species of fungi and bacteria. For fungi a solid extract medium (SEA) was used that was prepared from the surface mineral horizon of a clay loam. The extract was prepared by autoclaving 1000 g of crushed air-dried soil with 1000 ml tap water for 15 min at 15 lb pressure, followed by cold storage until clear. The filtered extract was then made up to 1000 ml, and the following were added: 0.2 kg K_2HPO_4, 1.0 g glucose, 3.3 ml of 1% rose bengal, and 15 g Sigma agar. The pH was reduced to 6.0 with 10% lactic acid following sterilization. For bacteria, standard Difco nutrient agar was employed supplemented by 1.0 g tryptone l^{-1}.

Soil samples to be processed were air-dried aseptically, homogenized in a mortar and pestle, and processed in sterile tap water. The pour plate method was employed for routine counting procedures. Triplicate plates were prepared for each dilution, usually 1×10^{-2} to 1×10^{-4}, and samples were incubated at 16 ^{0}C for 7 days prior to counting. Confidence limits were estimated, except in cases where zero values were obtained in one of the plates.

Field Area

The Rouge River Drainage Basin contains a number of higher terrace tracts at 8 and 15 m above the existing water level that were presumably formed as a result of downcutting episodes in the later Pleistocene and early Holocene. For the most part these terraces are discontinuous surfaces cut into older Pleistocene deposits and surfaced with lag gravels and aeolian sediments, that depending on relative age, are weathered to variable depths (Mahaney and Sanmugadas, 1986). In all, these older terraces total less than 20 percent of the drainage area; the remaining 80 percent of surface area is at or close to the 2 m level - the Highland Surface. The difference in soil development in these three surfaces provides some evidence of relative age (Mahaney and Sanmugadas, 1986). Even though it must have taken considerable time to form this broad expanse of lowland surface, the ground and buried soils formed in it are always thin Entisols (Ah/C or Ahb/Cbox profiles). Unlike the older terraces the younger system contains weathered and unweathered sediments that coarsen upwards, suggesting either overall increased stream competence over the last few centuries, or periodic flooding, perhaps as a result of large scale ice damming after late winter and spring thawing episodes.

The climate in the study area is humid continental with a cool summer and no dry season (Brown, 1968). The mean temperature ranges from 20 ^{0}C in July to -7 ^{0}C in January with extremes of 40 ^{0}C in July and -34 ^{0}C in February. The mean annual frost-free period lasts for about 150 days from mid-May to early October. However, minimum frost-free periods have been recorded as short as 100 days, with a maximum of 173 days (Mahaney and Ermuth, 1974). The mean annual precipitation is 850 mm.

Vegetation on the low terrace system consists predominantly of willow (Salix nigra Marsh. with some Salix fragilis L.), some aspen (Populus tremuloides Michx.) and alder (Alnus rugosa (Du/Roi) Spreng.).

Results and Discussion

Flooding Process

Two transects were established within several hours of the flooding event and deposition of cover sediments on the low terrace surface (Fig. 2). Sediment samples were collected at stations 2 m apart in an open area and in a forested zone. During the initial ice-breakup stage the river rose by 1 m, and the ice divided first into rather large sections (Fig. 3), and later into smaller pieces that could be rafted onto the river bank. After creasting and flooding over the 2 m interfluves, large blocks of ice, together with dirty and sandy silt cover sediments, littered the stream banks and terrace surface (Fig. 4). Some of these

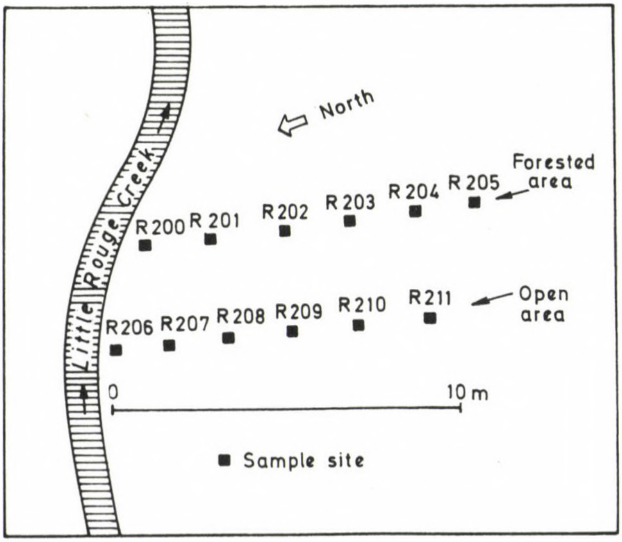

Fig. 2. Transects from which samples were collected in a wooded zone (R200-R205) and in an open area (R206-R211)

Fig. 3. Initial river ice break up and rise of Little Rouge Creek to within 1 m of the terrace surface (late February, 1985)

Fig. 4. Post-flood stage with river ice rafted on the 2 m terrace surface

Fig. 5. Large ice blocks and tree impact damage near site R200, Little Rouge Creek

Fig. 6. River ice rafted onto wooded area near site R204, Little Rouge Creek

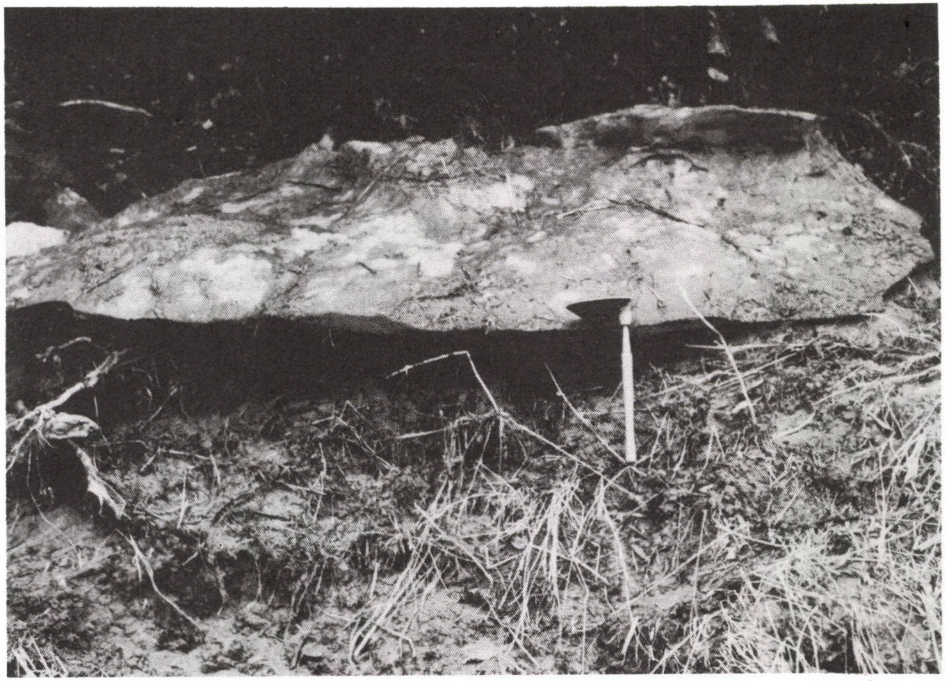

Fig. 7. Large block of river ice and fresh cover sediment in April, 1985, in shaded position

Fig. 8. Detritus including cover sediment, a log, pieces of woody growth, and dead roots

Fig. 9. Little Rouge Creek in May, 1985, after the flood with water level 2 m below the terrace surface

blocks were sufficiently large to cause significant damage to tree bark (Fig. 5). For the most part, ice was rafted to considerable distances away from the creek (± 15 m) and most ice blocks had to thaw out before sediment samples could be collected (Fig. 6). In protected situations, away from the sun, blocks of ice remained until early May before finally melting away (Fig. 7). Accompanying the river ice, a considerable amount of debris, including driftwood and uprooted vegetation, was deposited as a "mat" of material together with silty sediments (Fig. 8). Towards the end of May, 1985, all the ice had melted out and Little Rouge Creek dropped to its normal level, approximately 2 m below the Highland Surface (Fig. 9).

Cover Sediments

The transects shown in Fig. 2 were established to collect representative samples - 6 in an open area, and 6 in a forested zone. The particle size distributions from these two transects were analyzed to determine information about the flow regime that emplaced the cover sediments. All sediments collected were either silt or sandy silt (Fig. 10). Calculations of mean phi values from particle size curves (Table I) show somewhat different trends for the samples in the two transects. In the R200-205 transect (forest zone) the sample nearest the stream contained finer sized sediments, becoming somewhat coarser at R201 and R202, and then becoming finer again (e.g. R203-205). Perhaps, this trend is the result of trees acting as barriers which caused variable water velocities. In the open area, a somewhat different trend is apparent from the samples collected. R206 yields a coarse texture which fines inland towards R211 (which contains the finest grain sizes and very similar to R203-205).

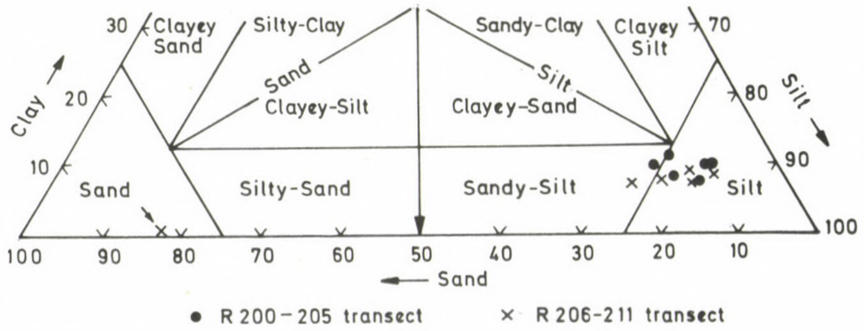

Fig. 10. Textural classification of cover sediments in transects R200-205 and R206-211, Little Rouge Creek

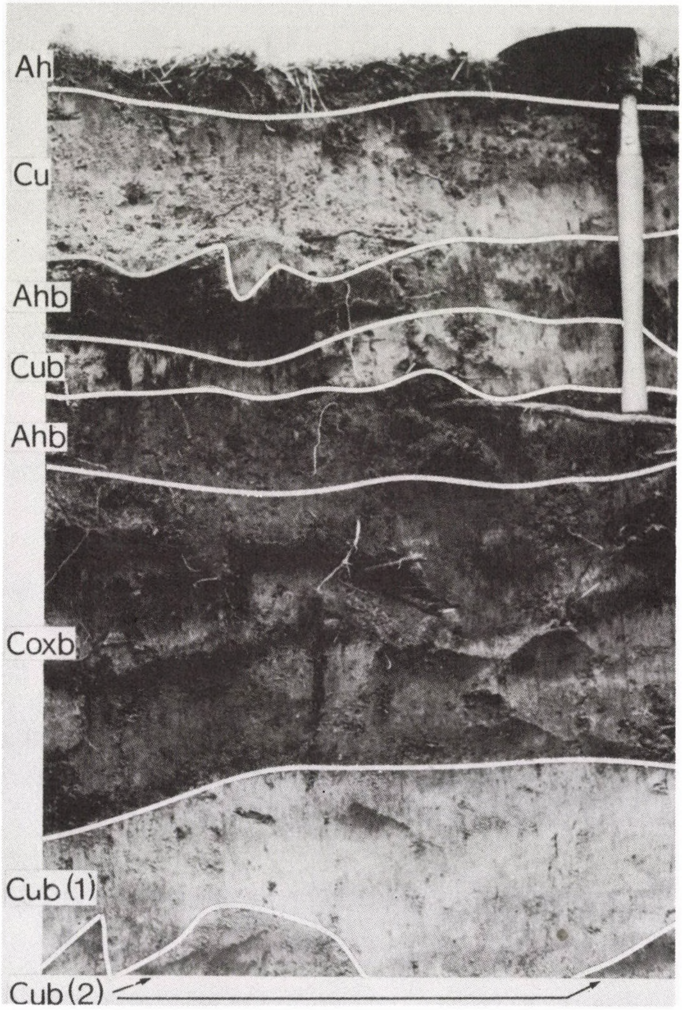

Fig. 11. Ground and buried soils in Rouge River Drainage basin showing horizons dated by radiocarbon and from which samples were taken for microbial analyses. The ground soil (Ah/Cu) and upper buried soil (Ahb/Cub) extend to the top of the shovel handle. The lower Ahb/Coxb/Cub(1) sequence extends to the bottom of the photograph. Note that horizon boundaries are clear and distinct indicating little time for leaching effects to occur

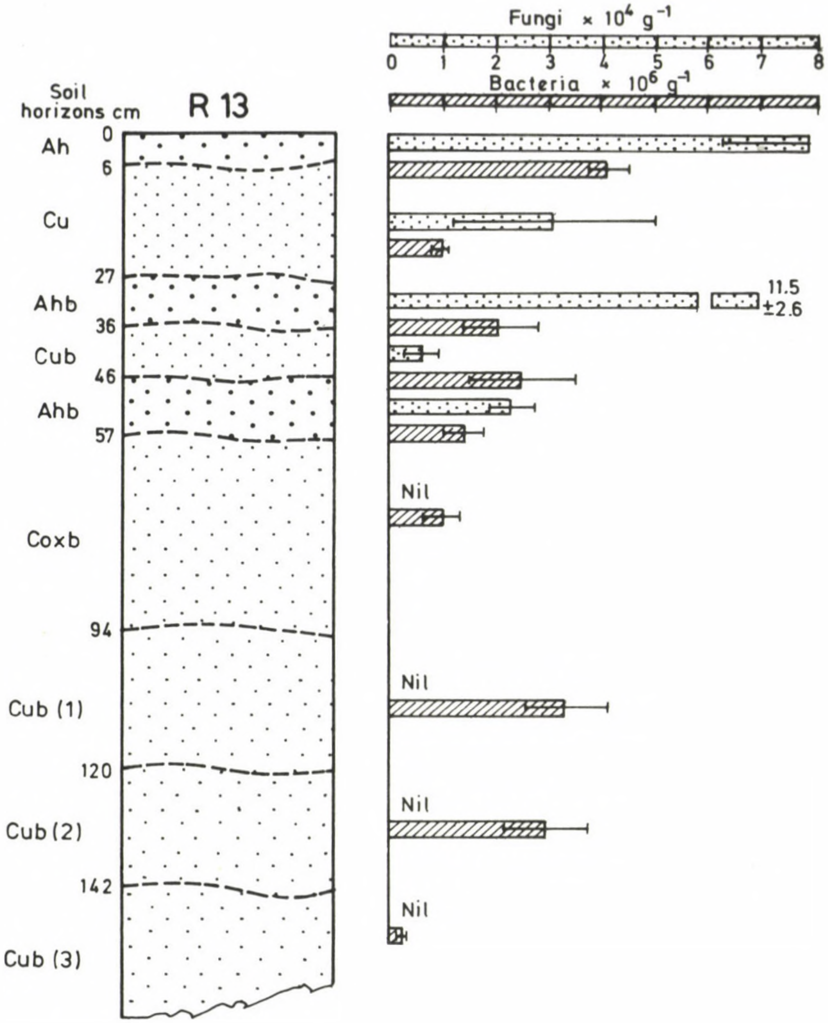

Fig. 12. Microbial distribution in the Rouge River ground and buried soil sequence. Counts for fungi are 10^4 per g. Standard deviations for counts in each horizon are shown with horizontal bars or with numerical expression if the count was unusually high

Without any obstruction, water leaving the main drainage channel appears to have emplaced sandy sediments first, followed by deposition of finer-grained sediments of ever increasing distances from the river bank. While a larger sampling network would be required to prove the validity of these relationships, the two transects provide a convenient suite of samples of representative cover sediments for comparison with underlying buried soils. In all, these cover sediments are slightly finer than the sandy silt and clayey sand that dominate in the lower units (Figs 11, 12).

Mineralogy

Samples in the $< 2\ \mu m$ fraction collected from the two transects were subjected to analyses by XRD to determine their primary and secondary mineral composition. The presence of moderate amounts of quartz, feldspar and calcite suggests that most material is derived from fresh unweathered Pleistocene deposits in the upstream area. This relationship is reinforced by the dominance of illite and illite-smectite with small amounts of chlorite and vermiculite in the clay mineral suites, which are the major clay minerals in unweathered glacial and nonglacial sediments (Mahaney, 1985; Mahaney and Sanmugadas, 1986).

Dating Problems

Radiocarbon dating of soils and alluvial overbank flood deposits is vexed by many problems among which the multiplicity and chemical complexity of the source material (the organic matter) occupy a prominent position. In addition, there are additional possible sources of error that can be introduced after the initial deposition of the primary organic matter. At least some of these problems are also relevant to the dating of relatively thin peat deposits that are subject to root penetration and groundwater percolation.

Research during the past 10 to 20 years has identified probably most of the problems concerning radiocarbon dating of soils and provided at least partial solutions for dealing with some of these problems through improved understanding of pedogenic processes related to the accumulation of soil organic matter. However, the need for additional information on this subject matter is clearly evident in many published reports (Ellis and Matthews, 1984; Polach and Costin, 1971; Scharpenseel, 1971; Stuckenrath et al., 1979).

As pointed out by Geyh et al. (1983), the organic matter in a soil is a mixture of an unknown number of compounds of unknown chemical composition, concentration, and age.

The accumulation of plant remains (stems, leaves, roots, etc.) in soil produces a continuous supply of fresh organic matter which ten undergoes a series of chemical and biological processes of degradation (Gilet-Blein et al., 1980).

Grant-Taylor (1972) concluded that "... organic soils can range from the extreme of completely altered material to the other extreme that occurs in a wet swamp where aerobic soil processes are suppressed and only a limited amount of degradation and resynthesis occurs", and in the same study it was also pointed out that "the problem of solution-borne contamination of carbonaceous materials is one of the most important faced in obtaining radiocarbon ages" of soils.

The general topic of contamination and potential sources of error in age determination have received particular attention in studies related to radiocarbon dating of soils. Grant-Taylor (1972) summarized the contamination processes that can affect the carbon isotope composition of a soil.

1) Penetration of roots, and parts of fallen trees which are later incorporated in the soil.

2) Soil biota incorporating fresh carbon either directly derived from the air or by biochemical alteration of dead plant tissue.

3) Downward percolation of soluble organic compounds into an older soil.

4) Rejuvenation of a buried soil or peat when it is reexposed by erosion and once again becomes the site of active soil development.

These and other possible contamination processes can affect the age of soil organic matter to various extents under different environmental circumstances. However, the effect of contamination on the radiocarbon age of soil will increase as the difference in age of the admixture of materials (contaminant and host) increases. It is also important to consider whether the contaminant is younger or older than the host. For example, as pointed out by Grant-Taylor (1972) "... contamination by dead carbon must be very massive before it has significant effects on a modern carbon sample, e.g. 50% addition of dead carbon to a "modern" (1950) sample would give an appearance of about 3400 years, while the inverse mixture appears to be about 9200 years old".

In order to eliminate or at least reduce the effects of contamination, several methods have been developed for pretreatment of samples. Most commonly used are the alkali and acid pretreatments that presumably remove the solution-borne contaminants. Some researchers prefer charcoal as the best and most reliable material for dating of soils. However, charcoal is also subject to redeposition and its physical and chemical properties make it susceptible to solution-borne contamination that may be difficult to remove.

The final evaluation of soil radiocarbon dates must be made on the basis of careful consideration of all potentially useful evidence including both pedological and geological information, as well as the environmental history of the study site. As pointed out by Geyh et al. (1971) "the inevitable conclusion is that blind confidence in ^{14}C dates of soils is mostly not justified even if contamination is thought to be absent" and, furthermore, that "... the ^{14}C age of the organic matter of soils will invariably differ from the mean age and lie between the latter and the time of completion of soil formation".

The burning of fossil fuels (introduction of "dead" carbon re. ^{14}C) and the atmospheric testing of nuclear weapons (the "bomb effect" which about doubled the atmospheric ^{14}C concentration) are relatively recent contamination sources (in addition to the demonstrated natural variations of atmospheric radiocarbon activity) that further complicate radiocarbon dating of soils that still interact with the atmospheric carbon source (Terasmae, 1984).

The description of ground and buried soil profiles in the Highland Surface yielded buried A horizons over Cbox horizons that were thin and showed only slight chemical alteration, or Cu horizons (S. Birkeland, 1984; Hodson, 1976; for parent material designations) of fresh and unweathered sediment. Because the ground and buried soils (Fig. 10) were so similar in particle size characteristics, and formed shallow profiles (Mahaney and Sanmugadas, 1986), with little chemical alteration, we considered them to be rather young, perhaps a few hundred years old at most. To test these age relationships we radiocarbon dated the upper and lower A horizons in a representative profile, first with the carbonate in the sample, and later with the carbonate removed. The results are given in Table II.

As expected, the radiocarbon ages of the buried horizons with carbonate are significantly greater when compared with ages from organic material with carbonate removed. Moreover, the dates vary somewhat between sections A and B which are less than 1 m apart, but in similar stratigraphic positions within the buried profiles. The dates with carbonate

Table I

Mean phi[*] values for samples in the R200-R211 transect in Little Rouge Creek

Station	Mean phi
R200	5.8
R201	5.1
R202	5.0
R203	5.4
R204	5.3
R205	5.3
R206	2.8
R207	4.9
R208	5.1
R209	5.3
R210	5.3
R211	5.4

[*] Mean phi values were calculated from the Σ of the 25th, 50th and 75th percentile values for each particle size distribution.

Table II

Radiocarbon dates of two buried paleosols[a] formed in the Rouge River Basin 2 m terrace (Highland Surface)

Site	Section	Horizon	Depth (cm)	Age[b] (with carbonate)	Lab No.	Age (Carbonate Removed)	Lab No.
R13	A	Ahb1	26-33	2500±80	BGS-1069	20±70	BGS-1068
		Ahb2	41-55	2260±80	BGS-1071	50±70	BGS-1070
	B	Ahb1	27-36	4000±80	BGS-1073	100±80	BGS-1072
		Ahb2	46-57	1930±80	BGS-1075	0±70	BGS-1074

[a] for relative position in the profile see Fig. 10

[b] ^{14}C yrs B.P.

- not dated

Table III

Selected chemical properties of ground and buried soils in the 2 m terrace, Rouge River Drainage Basin, South-Central Ontario

Site	Horizon	Depth (cm)	pH	Ca	Mg	Na	K	Organic Carbon %	Nitrogen %	$CaCO_3$ (%)	Fe_2O_3 (%)
				(meq/100 gms)							
2 m Terrace	A1	0-6	7.0	7.13	0.39	0.07	0.21	2.54	0.172	26.4	0.20
	Cu	6-27	7.3	3.88	0.19	0.10	0.05	0.27	0.025	21.3	0.13
	Ahb	27-36	7.2	7.50	0.31	0.07	0.07	1.79	0.161	50.5	0.23
	Cub	36-46	7.3	6.25	0.23	0.05	0.04	0.60	0.056	26.8	0.20
	Ahb	46-57	7.3	8.75	0.27	0.07	0.05	1.45	0.144	22.5	0.21
	Coxb	57-94	7.4	4.88	0.25	0.13	0.05	0.46	0.055	32.8	0.21
	Cub(1)	94-120	7.5	6.00	0.23	0.23	0.05	0.31	0.030	33.0	0.19
	Cub(2)	120-142	7.5	6.75	0.25	0.26	0.05	0.38	0.033	33.3	0.23
	Cub(3)	142+	7.6	6.90	0.26	0.27	0.05	0.25	0.028	31.5	0.24

removed appear compatible with the amount of chemical weathering apparent in the profiles (Fig. 10) and presumably yield valid ages. Because the samples are so close to the surface, we considered that they might be subject to biogeochemical contamination which would produce some discrepancy between ^{14}C age and true age. To test this hypothesis we analyzed the ground and buried soils for key chemical parameters to determine if contamination could be detected. As shown in Table III, pH increases with depth suggesting little in the way of H^+ ion movement downwards in the superposed profiles. The ratio of extractable Ca/Mg is nearly uniform with depth and supports the interpretation of little downward translocation of carbon. Extractable Na appears lower in the upper buried soil and ground soil, which may result either from leaching, or possibly from differences in the mineralogy of the detrital sediments. The distributions for organic carbon and nitrogen show increases in each buried Ahb horizon, but with significantly lower amounts in the intervening Cu and Cub horizons. These trends suggest some contamination may have occurred as a result of root activity. The percentage of $CaCO_3$ in the profile is relatively uniform with depth, with the exception of the upper Ahb horizon, which yielded higher values. From the field description there appears to be little secondary $CaCO_3$ in the profile, which suggests that carbonate is derived mainly from detrital sediments rich in calcite. Thus the data appear somewhat equivocal in terms of proving biogeochemical contamination.

Microbial Distributions

To further test the hypothesis that some contamination may have occurred we counted the bacteria and fungi in the ground and buried soils (Fig. 12) to determine if their distribution might prove useful in eliciting information on contamination. In a similar study on Mount Kenya, paleosols of variable age were sampled for their microbial components (Mahaney and Boyer, 1986). In these Mount Kenya paleosols, we identified three distinct trends: a sequential decline in numbers with depth; disjunct distributions where fungi and/or bacteria disappear at specific depths and then reappear; and bimodal distributions with fluctuating peaks. In the Rouge River profile both bacteria and fungi exhibited fluctuating peaks. For fungi, the secondary peak in the Ahb is strongly suggestive of the presence of sufficient unprocessed organic matter to support growth of these aerobic organisms. Their apparent visual identity with the common species of the Ah horizon supports the interpretation that it is not a specialized substrate. Bacteria also increase in numbers in the Ahb-Cub profiles. While it is not feasible to identify the bacterial species we have no reason to assume they are in any way distinguished from those in the horizons above. We suspect from this that there is some vertical displacement of microorganisms in these soils.

While the lower horizons in Fig. 12 did not yield fungi, they did yield bacteria in sufficiently large numbers to suggest that ground water influx might be contributory (Fig. 12). If ground water is responsible for the increase in bacteria in the Cub(1) and Cub(2) horizons, its fluctuations may be indicated by the lower microbial counts in the Coxb horizon above.

Paleoenvironmental Significance

The data discussed herein suggest that major drainage basins are periodically subjected to flooding and overbank sedimentation sufficient to bury pre-existing soils, perhaps two or three times each century. Some of these events may have sufficient power to completely remove pre-existing soil cover, setting the stage for depositon of new unweathered and unconsolidated parent materials. Given the more advanced stage of weathering on older terraces in the Rouge River sequence (Mahaney and Sanmugadas, 1986), this seems to be the only plausible hypothesis for explaining why soils in the 2 m terrace system are so thin and poorly altered.

Conclusions

Periodic flooding of the low terrace system in the Rouge River Basin is of sufficient magnitude to emplace surface cover sediments, burying pre-existing soils, on a frequency of three times over the last century. Because there is an absence of older buried soils in this lower terrace system, we believe there must have been an expanding cycle of high-magnitude flooding events that periodically eroded pre-existing neoformed sediments and soils. Such events might be linked with hurricanes, or unusually large build ups of river ice and sudden thaw, which is the case under discussion here. While there is equivocal chemical evidence favoring geobiochemical contamination of the buried Ahb horizons in the sequence, the microbial distribution data support the hypothesis that some limited contamination has occurred and continues to occur. Differences between the radiocarbon ages of one group of samples with carbonate and another with carbonate removed, suggest that only samples with carbonate removed are likely candidates for revealing close correspondence between true age and ^{14}C age.

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A TRIVARIATE DISTINCTION BETWEEN RIVER AND BEACH ENVIRONMENTS OF ANCIENT SEDIMENTARY ROCKS – A NEW APPROACH

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Grain size parameters have been determined for 81 samples of quartzarenites collected from Ajra, Madilge and Nesri basins by using the thin section method. The data so obtained has been plotted on a triangular diagram considering the values of Mean size ($M_z\phi$), Standard deviation (σ_I) and Skewness (SK_I). The fields of beach and river environments have been delineated on such a diagram and the validity of line of delineation has been tested by considering 13 test samples collected from different locality as reported in the literature. It has been shown that 3 grain size parameters effect a better separation than the traditional bivariant ones. It is suggested that the new trivariate diagram can be applied to hard compact ancient sedimentary rocks as well as to the modern sediments, in the context of ascertaining the beach and river environments.

Keywords: Sedimentary rocks, grains size parameters determination, trivariant diagram for characterization of the environment.

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Introduction

Friedman (1961, 1967), Moiola and Weiser (1968), Solohub (1970) and others have delineated the different environments by considering two grain size parameters at a time and constructing bivariate diagrams. The fields delineated by the several workers are primarily for the loose sediments, the different grain size parameters being determined by the method of sieve analysis. Sahu (1964) has suggested 4 discriminatory functions by considering all the four grain size parameters but has not put forth any classificatory diagrams.

The method of sieve analysis is not found suitable to hard indurated and compact sedimentary rocks that are found to compose the different sedimentary basins, because during the process of disaggregation of the grains of such rocks, the original shapes and especially the sizes are likely to get affected. The ancient sedimentary and metasedimentary rocks are also subjected to metamorphic recrystallisation and the deformative forces that had enacted in the geological past. These episodes are likely to affect the original shapes and sizes of the constituent grains composing the metasedimentary rocks. Therefore the bivariate diagrams suggested by the earlier workers may not indicate the true environment of depositon because the fields delineated by them are primarily meant for the loose modern sediments. In view of the discussions given above, thin section method of determination of the grain size parameters is found more suitable to the hard, compact, indurated and even metamorphosed sedimentary rocks.

Trivariate approach

Eighty-one samples of quartzarenites collected from Ajra, Madilge and Nesri basins (which forms the westernmost part of the main Kaladgi basin) have been subjected to the thin section method of determination of grain size. From the values of mean size obtained, those of standard deviation, skewness and kurtosis have been calculated. In most of the bivariate plots, values of mean size, standard deviation and skewness have been commonly considered. Therefore in the present trivariate diagram also, the said 3 parameters have been utilised. The environment of sedimentation whether river or beach has been initially established on the bivariate diagrams of Friedman (1961, 1967) and Moiola and Weiser (1968). The fields so obtained have been tentatively utilised in the delineation of the two fields in the trivariate diagram.

Skewness has both positive and negative numerical values and it has been held by the sedimentologists that the 'River' sediments have higher values of positive skewness, while those of 'Beach' sediments have higher values of negative skewness. In order to test this hypothesis, the 81 samples under study have been grouped into 4 categories as mentioned below:

1. Samples belonging to positively skewed river environment,
2. Samples belonging to negatively skewed river environment,
3. Samples belonging to positively skewed beach environment,
4. Samples belonging to negatively skewed beach environment.

The values of mean size, standard deviation and skewness (Positive or Negative) have been calculated and plotted and the results are presented in Fig. 1.

Discussion

In order to locate the position of the line delineating the fields of river and beach, average values of the 4 categories of skewness as noted above have been considered. To test the accuracy of the line of demarcation shown in Fig. 1, the results obtained on bivariate plots on the line of Friedman and Moiola et al. and the new trivariate plot for the 81 samples under study, together with 13 test samples collected from the literature have been given in Table I. Study of Table I reveals that:

1. The environment of sedimentation obtained on the bivariate and trivariate plots are almost identical for the loose sediments (Sl. Nos 2, 7, 8 of Table I).

2. A considerable discrepancy exists between the environments obtained on the bivariate and trivariate plottings for the hard, compact rocks.

(a) Thus according to bivariate plots for the hard compact rocks of Friedman, Jaisalmer samples (Sl. No. 5) are beach, whereas according to Moiola they are all river samples.

(b) Samples from Pachhapur (Sl. No. 12) get classified as river according to Friedman, but these become all beach according to Moiola et al.

Table I

Environments predicted by Bivariant and Trivariant Parameters

Sl No.	Location/Source	Number of samples analysed	Environment predicted from Friedman (1961) Bivariate plot			Environment predicted from Moiola et al. (1968) Bivariate plot			Environment predicted by new Trivariate plot (Average)		
			River		Beach	River		Beach	River		Beach
1	Ajra, Madilge and Nesri basins. Bhimsen, K. (1989)	81	59	4	18	60	-	21	35	3	43
2	Loose sediments of Polem Beach, Goa. Naik, et al. (1987)	40	20	-	20	20	-	20	-	-	40
3	Upper Vindhyan Sand stones. Ramasamy (1984)	5	3	-	2	4	-	1	-	-	5 Av.
4	Gokak quartzites. Hedge, V.R. (1986)	6	1	-	5	6	-	-	-	-	6 Av.
5	Jurassic sandstones of Jaisalmer formation, Mahender et al. (1989)	22	1	-	21	20	-	2	-	-	20 Av.
6	Bhima sandstones. Akthar et al. (1977)	7	7	-	-	3	-	4	-	-	7 Av.
7	Kali river sediments. Chavadi, V.C. et al. (1989)	13	12	-	1	13	-	-	13 Av.	-	-
8	Manimala river sediments. Nair, A.M. et al. (1985)	10	10	-	-	10	-	-	10 Av.	-	-
9	Manoli quartzarenites. Pujar (1989)	25	5	-	20	-	-	-	9	-	16
10	Gondwana sediments. Ramanamurthy (1985)	16	16	-	-	15	-	1	16 Av.	-	-
11	Barakar Sandstones. Zahid Khan, A. (1984)	17	17	-	-	17	-	-	17 Av.	-	-

Table I (cont.)

Sl No.	Location/Source	Number of samples analysed	Environment predicted from Friedman (1961) Bivariate plot			Environment predicted from Moiola et al. (1968) Bivariate plot			Environment predicted by new Trivariate plot (Average)		
			River		Beach	River		Beach	River		Beach
12	Pachhapur-Manoli area quartzarenites. Parthsarathy et al. (1977)	8	8	-	-	1	-	7	8 Av.	-	-
13	Pachmarhi sandstones. Saxena, S.K. (1966)	15	12	-	3	8	-	7	-	-	15 Av.
14	Mudakavi-Lakhmapur. Quartzarenites. Hedge. G.V. (1986)	9	-	-	9	-	-	9	-	-	9 Av.

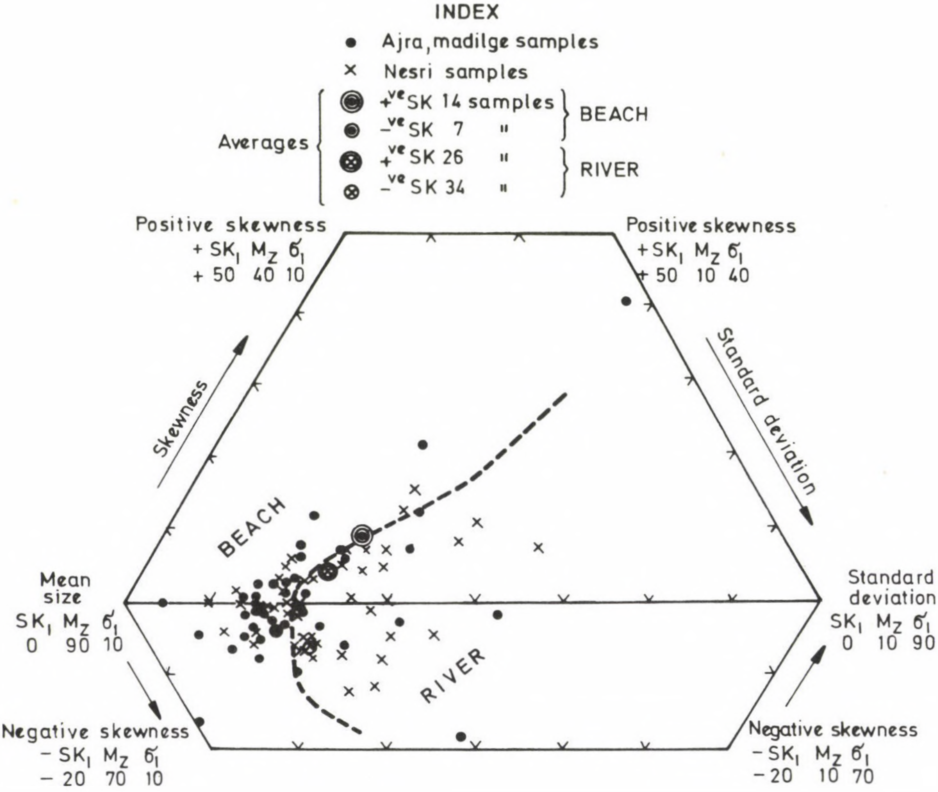

Fig. 1. Ajra, Madilce and Nesri quartzarenites. Plot of mean size, standard deviation and skewness for 81 samples of quarzarenites from Ajra, Madilce and Nesri basins

(c) Pachmarhi sandstones (Sl. No. 13) get categorized dominantly as river environment according to Friedman, but according to Moiola et al., both river and beach environments are observed to be equally indicated. Such a behaviour is also observed for the Bhima sandstones (Sl. No. 6 of Table I).

The above noted behaviour is possibly due to the consideration of only 2 grain size parameters in the bivariate diagrams. In order to test the points as noted above, average values of Mean size, Standard deviation and skewness (positive and negative) of the 13 test samples along with the average values obtained for the 81 samples under consideration are plotted and the results are presented in Fig. 2. Study of this figure immediately indicates that the test samples get correctly categorized thereby confirming the validity of the new line of demarcation shown in Fig. 2.

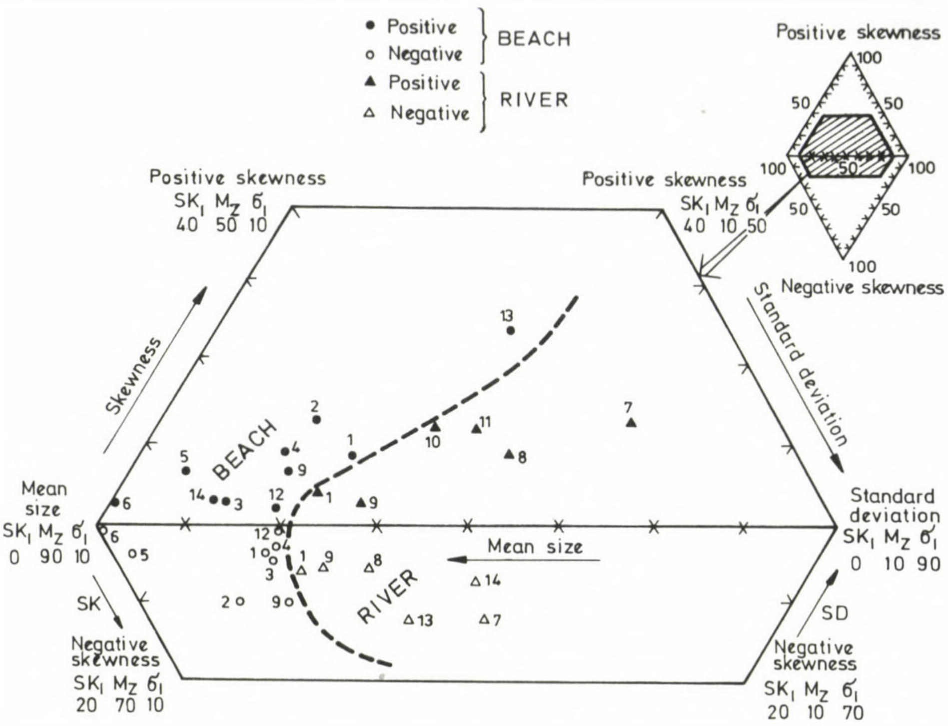

Fig. 2. Beach sediments of Polem Beach, Goa. Conforming the line of demarcation between River-Beach environments for loose/consolidated sediments

Conclusions

From the foregoing account, following conclusions may be drawn:

1. 3 grain size parameters effect a better demarcation between the fields of river and beach.

2. The trivariant diagram is useful in establishing the environment of river and beach for the hard compact indurated ancient sediments, unlike the bivariant one which are applicable to the loose sediments alone.

3. Even on the new trivariant diagram, a mixed environment is possible, the reason being that the ancient sediments are vulnerable to the effects of metamorphism, deformative forces, with the provenance being sedimentary and nonsedimentary rocks. A similar view is held by Solohub et al. (1970).

4. The new line of demarcation is concave towards the vertex of standard deviation and is located closer to that of mean size. Therefore the beach sediments are more fine grained and better sorted than those of river sediments.

5. With higher values of standard deviation but lower values (Positive or Negative) of skewness, the environment is of river. The sediments will, therefore, be ill sorted in character.

6. With higher numerical values of mean size together with the lower values (positive or negative) of skewness, the environment is of beach. The sediments, therefore, will be fine grained.

7. When the value of mean size and standard deviation are moderate, then the environment may be beach or river. Under this situation it is suggested that the higher values of positive skewness (Fine skewed) indicate a beach environment, while higher values of negative skewness (Coarse skewed) a river environment is indicated.

8. It is also suggested that a mixed environment is obtainable for the ancient sediments, owing to superimposition of the effects of metamorphism, deformative forces and the like on the grain size of the metasedimentary rocks.

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