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THE TECTONIC SETTING OF THE OPHIOLITES IN THE BÜKK MOUNTAINS (NORTH HUNGARY)

(Figs. 1—19, Photo 1—17)

Abstract: The largest ophiolitic region in the Internal West Carpathians locates in the SW part of the Bükk Mountains. The turbiditic series of Szarvaskö probably has generated in a continental rift and the ophiolitic magma has extruded and intruded laterally from the opening fissures of the oceanic rift near here. In the Darnó-hegy stratigraphic sequence the normal oceanic lithosphere is overlain by hemipelagic and pelagic sediments. Both series in overturned position form tectonic nappes of complicated structure lying on the crystalline limestones and epicontinental sediments as it follows from drilling data.

Резюме: Крупнейшая область развития офиолитов во внутренних Западных Карпатах лежит в СЗ части гор Бюкк. Турбидитные толщи Сарвашкё образовались, вероятно, в континентальном рифте, и магма офиолитов изливалась и внедрялась латерально из трещин океанского рифта, открывающихся вблизи. В стратиграфической последовательности горы Дарно нормальная океанская литосфера перекрыта гемипелагическими и пелагическими осадками. По данным бурения обе серии в опрокинутом положении образуют тектонические покровы сложной структуры, надвинутые на кристаллические известняки и эпиконтинентальные осадки.

Introduction

The largest ophiolite complex in Hungary is found in the southwestern part of the Bükk Mountains (Fig. 1). In the last decade the attention has been focussed largely upon the tectonic interpretation of these Mesozoic formations as if they have belonged to oceanic lithosphere. The lates comprehensive geological summary of the area was compiled by Lengyel (1957) more than twenty years ago. Since then only interpreted results have been available, and very few detailed field-work has been made. Most of these interpretations do not include the field data which could support their conclusions.

It has seemed necessary to analyse the facts and ideas as well as collect new field evidences for the proper evaluation of the regional structural setting of this formation. On the western part of the area three deep stratigraphic diamond drill holes have provided valuable informations, while at Szarvaskő a new surface geological mapping has been carried out.

1. Review of previous data

Data of previous investigators will be reviewed according to three aspects: age, tectonic character and tectonic position of the igneous rocks.

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1.1. Age relationships

The sediments associated with the ophiolites have been initially considered as Carboniferous (S c h r é t e r, 1913, 1914, 1943). Later works by B a l o g h (1950) have concluded Middle Triassic Ladinan age. S c h r é t e r (1913, 1914) has attributed intrusive character for the mafic igneous rocks. S z e n t p é t e r y (1923) has recognised their partly effusive origin. This opinion has later been supported by further investigations (S c h r é t e r, 1943; S z e n t p é t e r y, 1953; L e n g y e l, 1957, K i s s, 1958).

For a long time there had been a general understanding that the mafic effusives have been deposited on the eroded surface of the folded sediments (S z e n t p é t e r y, 1923, 1953; L e n g y e l, 1957; P a n t ó, 1961). These opinions were in accordance with the field observations on the intrusive contacts of some of the igneous rocks (P á l f y, 1910; S z e n t p é t e r y, 1923; V e n d l, 1939; S z e n t p é t e r y, 1943, 1953; K i s v a r s á n y i, 1953; L e n g y e l, 1957) and has been fit into the earlier regional considerations about the Cretaceous age of the igneouos formation (S c h r é t e r, 1923; P a n t ó—F ö l d v á r y n é, 1950; K i s s, 1958; P a n t ó, 1961).

Fig. 1. Schematized geological map of the Mesozoic igneous rocks of the Bükk Mountains (after [B a l o g h, 1964]).

Legend: 1 — Devonian, Lower Carboniferous sediments, 2 — Middle and Upper Carboniferous sediments, 3 — Lower and Upper Permian sediments, 4 — Triassic sediments, 5 — Middle Anisian porphyry and tuffs, 6 — Upper Ladinian — Karnian diabase, quartz-porphyry and tuffs, 7 — Cretaceous diabase, spilite, gabbro, peridotite, 8 — Cenozoic sediments and volcanic rocks, 9 — Fold axes, a — anticlines, b — synclines. Note: considerably simplified version, a part of the original map.

The Triassis age of the basic igneous rocks has been initially proposed by Mezősi (1950), based on the petrochemical comparisons between the rocks of Szarvaskő and Lillafüred (Eastern Bükk) area. His evidences, however, were inconclusive since despite of certain overlaps on his diagrams (Figs 2—5), the chemical compositions of the rocks suites shows apparent differences. Possibly, this is why there have been almost no references to his concept in later works. Using these data Middle Triassic age has been also suggested by Balogh (1964), proposing that further evidences should have yet to be found for the submarine origin and pillow lava character for the effusives.

By the early sixties a controversial image has been developed concerning the geological build-up of the area. Most petrologists (Szentpétery, 1953; Lengyel, 1957; Kiss, 1958) have recorded typical effusive rocks with

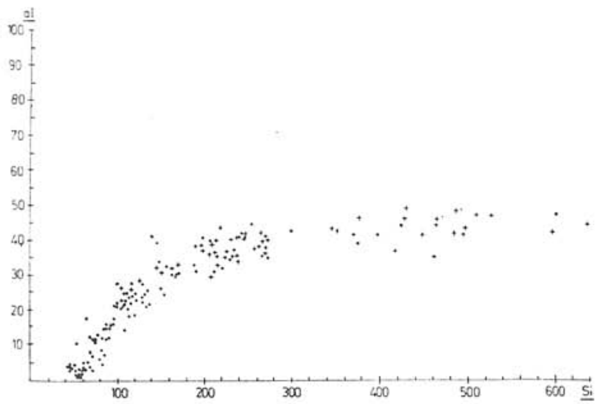


Fig. 2. *al* - *si* diagram of the igneous rocks around Szarvaskő and Lillafüred (Mezősi, 1950, Fig. 1). dots — Szarvaskő, crosses — Lillafüred.

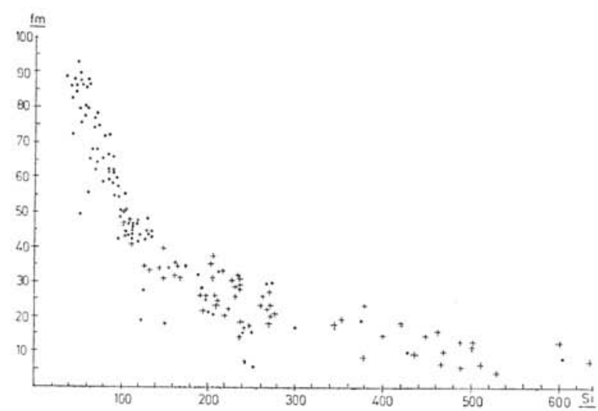


Fig. 3. *fm* — *si* diagram of the igneous rocks around Szarvaskő and Lillafüred (Mezősi, 1950, Fig. 2.). See legend in Fig. 2.

vitreous and flowage textures, spherical jointing. These have been associated exclusively with Ladinian sediments. However, their age has been considered as Cretaceous. One of the first investigators who called attention to this contradiction was B a l o g h (1964), who emphasized that in order to keep the assumption on the Cretaceous age of these igneous rocks one should reject the presence of any effusives among them.

The contradiction has been finally solved by the investigations of F ö l d e s s y (1975) who recorded the presence of typical pillow-lavas, hyaloclastites, i.e. submarine effusives alternating with sediments in the Darnó-hegy. He suggested close age relationship of the sediments and associated volcanic rocks. K o z u r and M o c k (1977) have provided evidences for the pillow lava character of the effusives at Szarvaskő, and also they have determined Upper Triassic Middle Karnian stage for the limestones co-existing with effusives according the presence of Condonts.

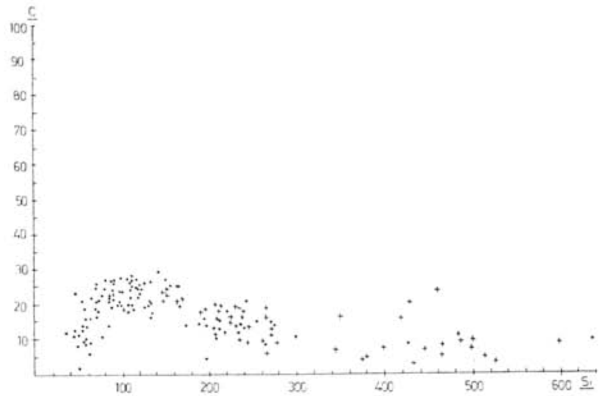


Fig. 4. *e* — *si* diagram of the igneous rocks around Szarvaskő and Lillafüred (M e z ő s i, 1950, Fig. 3.). See legend in Fig. 2.

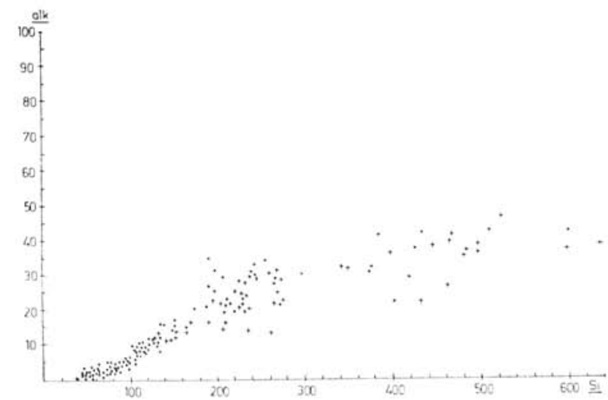


Fig. 5. *alk* — *si* diagram of the igneous rocks around Szarvaskő and Lillafüred (M e z ő s i, 1950, Fig. 4.). See legend in Fig. 2.

1.2 Tectonic charater

Pantó and Földváryné Vogel (1950) have sugested orogenic initial magmatic character and ophiolite origin for the Darnóhegy and Szarvaskő igneous formations. Later Pantó (1961) has reviewed them as products of characteristic geosynclinal igneous activity, though did not explain the reasons of this conceptual change. Zelenka (1973, 1975) has classified them as initial eruptives of mantle-origin.

Ophiolitic nature of these magmatites has been proposed by Onuoha (1977a, 1977b) who considered them as remnants of oceanic lithosphere. According geochemical and petrochemical data he established their relationship with tholeites and defined them as typical oceanic rather than island-arc tholeites (Figs. 6—10).

1.3. Tectonic position

The early opinions being held by several authors (Lengyel, 1957; Pantó, 1961; Balogh, 1964; Zelenka, 1973, 1975) suggested that the seemingly belt-like setting of the basic igneous rocks reflects that fracture-pattern, which has also been served as eruptive channel for the effusives. Szádeczky—Kardoss (1974, 1976a, 1976b) has given an alternative explanation. He concluded the basic igneous rocks as obducted remnants and the fault zones as sutures, along which the once existed oceanic lithosphere had disappeared and suggested that there is no genetic relationship between these faults and the centres of eruptions. This opinion has been adopted by Onuoha (1977a, 1977b), who also proposed the possibility of a tectonic

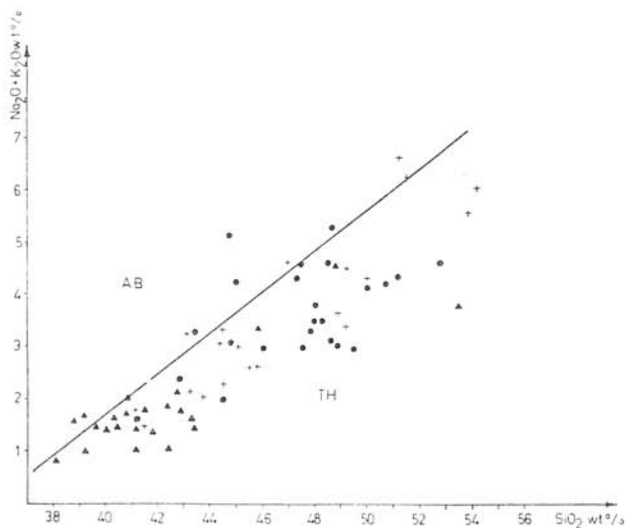


Fig. 6. Na_2O + K_2O — SiO_2 diagram of the igneous rocks at Szarvaskő and Darnóhegy (Onuoha, 1977, Fig. 3.).
AB — alkali basalt series, TH — tholeitic series; o = diabase and effusives, + = gabbro, ▲ = ultrabasic rocks.

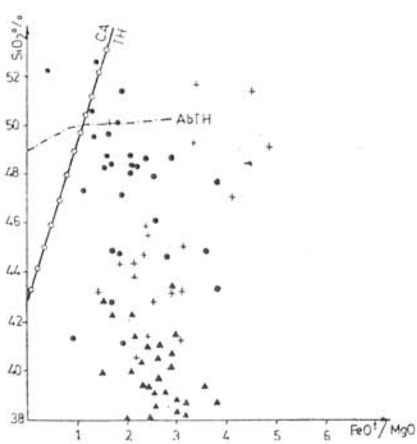


Fig. 7. SiO_2 — $[FeO + Fe_2O_3]/MgO$ diagram of the igneous rocks at Szarvaskő and Darnó-hegy (O n u o h a, 1977b, Fig. 4.).

Ca — calc-alkaline series, TH — tholeitic series, AbTH — abyssal tholeites; c = diabase and effusives, + = gabbro, ▲ = ultrabasic rocks.

window. S z e p e s h á z y (1979) holds similar opinion. W e i n (1978) suggested autochthonous or para-autochthonous setting.

1.4. Summarisation

Concerning the *age* the field data from Darnó-hegy (F ö l d e s s y, 1975) are good evidences for the contemporaneity of effusives and sediments. The same is yet to be proved at Szarvaskő pretending that age of the volcanics depends on the palaeontological age of the contemporaneous sediments. The stratigraphical relationships of the igneous rocks and the limetones with Conodonts (K o z u r and M o c k, 1977) had also to be cleared.

As far as *tectonic character* is concerned we accepted O n u o h a's data (1977b) about the oceanic tholeite character of the effusives. His conclusions however do not give relevant explanation about the lack of radiolarites and cherts around Szarvaskő, where the gabbro and peridotites have intruded into a thick shale series.

In *tectonic position* S z á d e c z k y — K a r d o s s' opinions (1974, 1976a, 1976b) have been accepted. He stated that the belt-like pattern of the igneous rocks is related to younger deformations and not to eruptive channels. This conclusion needed further support of additional field evidences. The question allochthonous or autochthonous nature of the ophiolite complex has been left open.

2. Recent investigations

The determination of the exact stratigraphic relationships has seemed to be the most useful key in solving the problems. Available data indicated the complexity and steeply dipping position of the ophiolites. Since further subdivision of the series could not have been made on palaentological basis, the normal or overturned position of the sequence was determined only by lithological features, like shape of pillows, cross cuttting relationships in turbidites, shales and silt-stones, as well as cross-bedded sandstones.

2.2. Darnó-hegy area

At Darnó-hegy the ophiolite complex outcrops in a 4—5 km long NNE—SSW trending zone of 2—3 km width (Fig. 11.). Poor exposure prevents the investigation of the complete sequence on the surface. Besides pillow lavas, intrusive diabases, radiolarites, shales and limestones have been recorded during the surface mapping (K i s s, 1958, F ö l d e s s y, 1975), deformed by dense thrust pattern and shear systems.

Three 1200 m deep stratigraphic holes have been drilled here during 1977—1979. Our recent study does not include re-mapping, these drilling informations have been exclusively used. The complexity of structure had been reflected in the frequent occurence of thick tectonic breccias in the individual logs, therefore we had to encounter several separated tectonic units. This fact had created new difficulties in defining the original stratigraphic sequence.

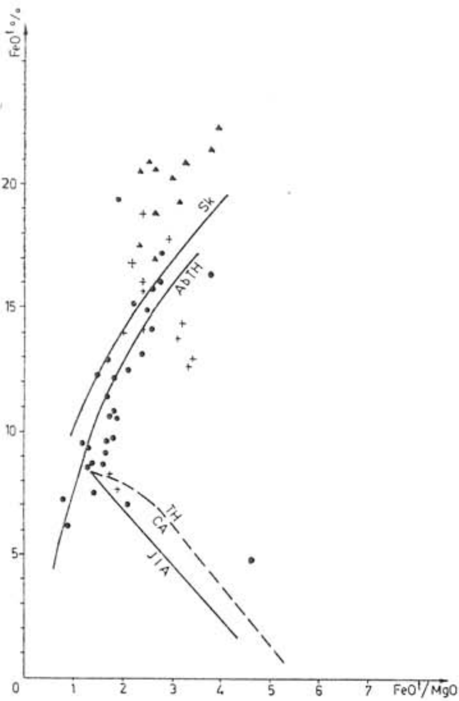


Fig. 8 FeO + Fe_2O_3 — (FeO + Fe_2O_3)/ /MgO diagram of the igneous rocks at Szarvaskő and Darnó-hegy (O n u o h a, 1977b, Fig. 5).
Sk — Skaergaard intrusion, AbTH — abyssal tholeites TH — Tholeitic series, CA — calc-alkaline series, JIA — Japanese island arc; o = diabase and effusives, + = gabbro, ▲ = ultrabasic rocks.

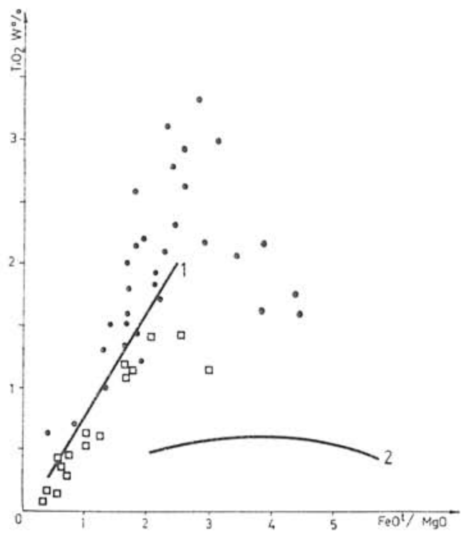


Fig. 9. TiO_2 — (FeO + Fe_2O_3)/MgO diagram of the igneous rocks at Szarvaskő and Darnó-hegy (O n u o h a, 1977b, Fig. 6).
1 — low K_2O tholeites from Tonga, Fiji; 2 — basalt from DSDP 37 station; • = diabase, gabbro and peridotite from the Darnó-hegy—Szarvaskő complex, □ = dolerite, gabbro and peridotite from Kizil Hatay ophiolite complex, Turkey.

In our work used the proven methods applied for the reconstructions of several Alpine and Carpathian nappe systems. The main elements of these methods are as follows:

a) Diagnosis — i.e. the determination of the palaeogeographical character of the individual tectonic units.

b) Synthesis — the reconstruction of these established relationships in the framework of certain geological regularities.

c) Reconstruction — the positioning of the different units in the generalised palaeogeographical pattern after the necessary corrections has been made.

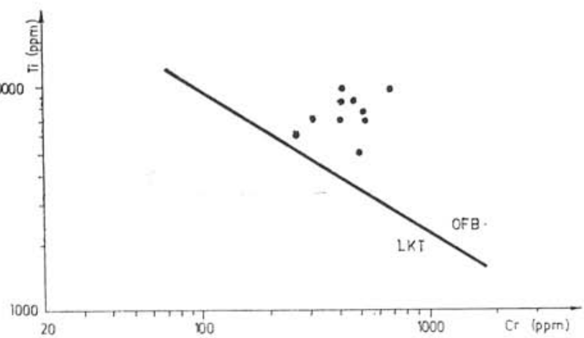


Fig. 10. Ti — Cr diagram of the igneous rocks at Szarvaskő and Darnó-hegy (O n u a h a, 1977b, Fig. 7.).
OFB — ocean floor basalt, LKT-low-K tholeites, island arc series

In the drill hole logs at Darnó-hegy the following rock-types, lithologies have been distinguished during the *diagnosis:*

1. Intrusive diabase, diabase-porphyry, gabbro-diabase, fine-grained gabbro, and related effusive diabases, spilite, dominantly in greenish-grey colours.

2. Effusive diabases, motly spilite pillow lavas (Photos 1—3) with alternating greenish grey to reddish brown colours.

3. Siltstones and shales with varying red and grey colours, composed of terrigenous components (quartz, feldspar, muscovite), showing underwater slumping and flame structures (Photos 4—6).

4. Radiolarites, cherts, biomicrite-limestones, volcanic tuffs, massive amygdaloidal spilite and shale in alternating sequence. The dominant colours are reddish-violet to yellowish red (Photo 7).

5. Planctonogenic biomicrite limestone and calcareous shales (marls) with flame- and slump structures, graded bedding. Light to dark grey colours (Photos 8—11).

6. Sandstone, siltstone, shale, marl and limestone, dolomite, anhydrite in alternating series. Undisturbed bedding, with pale grey, green to black colours (the latter are intensely carbonaceous varieties) (Photos 12—13).

7. Intensely folded steeply dipping marble and crystalline limestones, white to pale grey.

The rocks of Type 1 and 2 outcrop on the surface too, these are the spilites which are analogies of present-day ocean floor tholeites according to O n u-

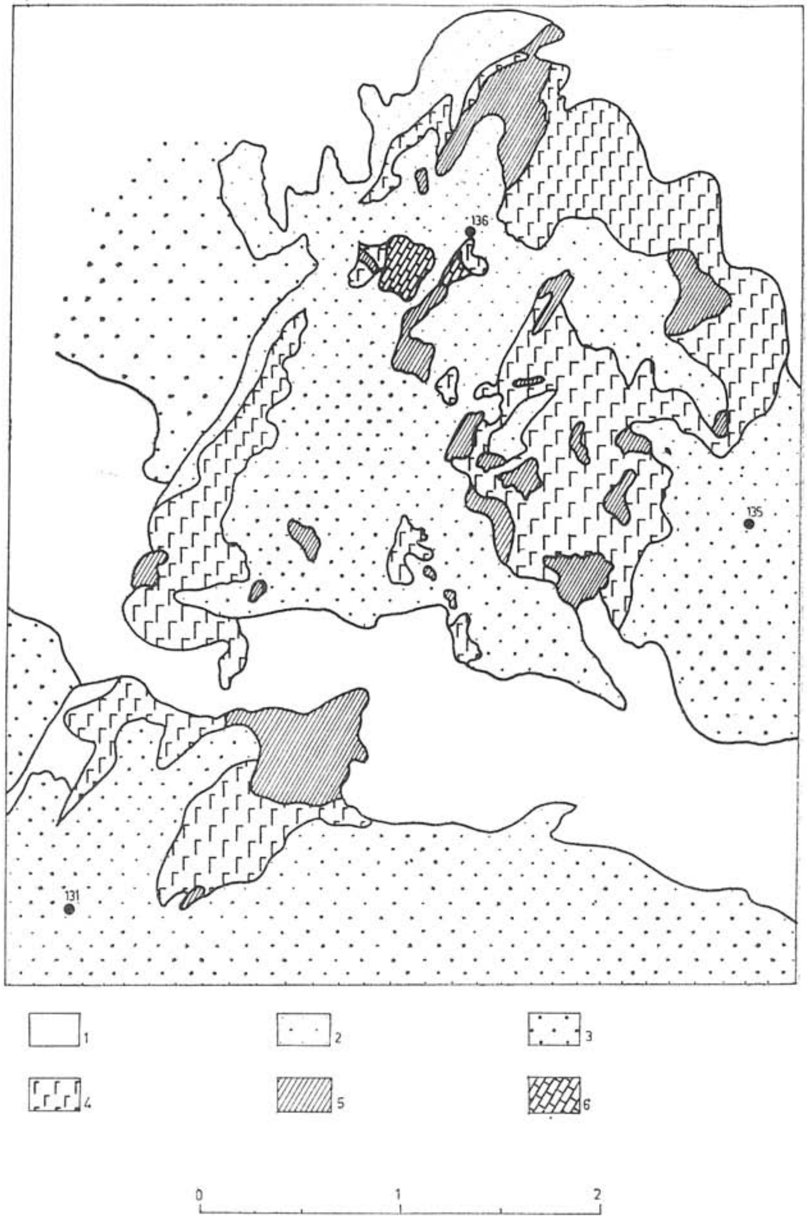


Fig. 11. Geological map of the Darnó-hegy (F ö l d e s s y, 1975, Fig. 1.).
Legend: 1 — Quaternary sediments, 2 — Miocene sediments and volcanic rocks, 3 — Oligocene sediments, 4 — Diabase and spilite, 5 — Shales and cherts, 6 — Limestone.
Fig. 12.

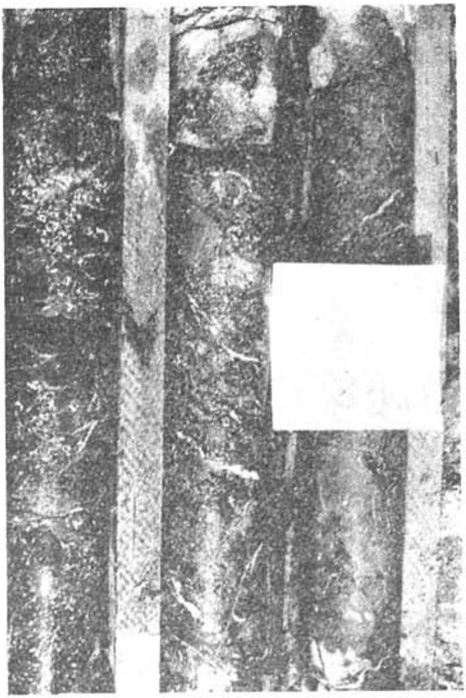
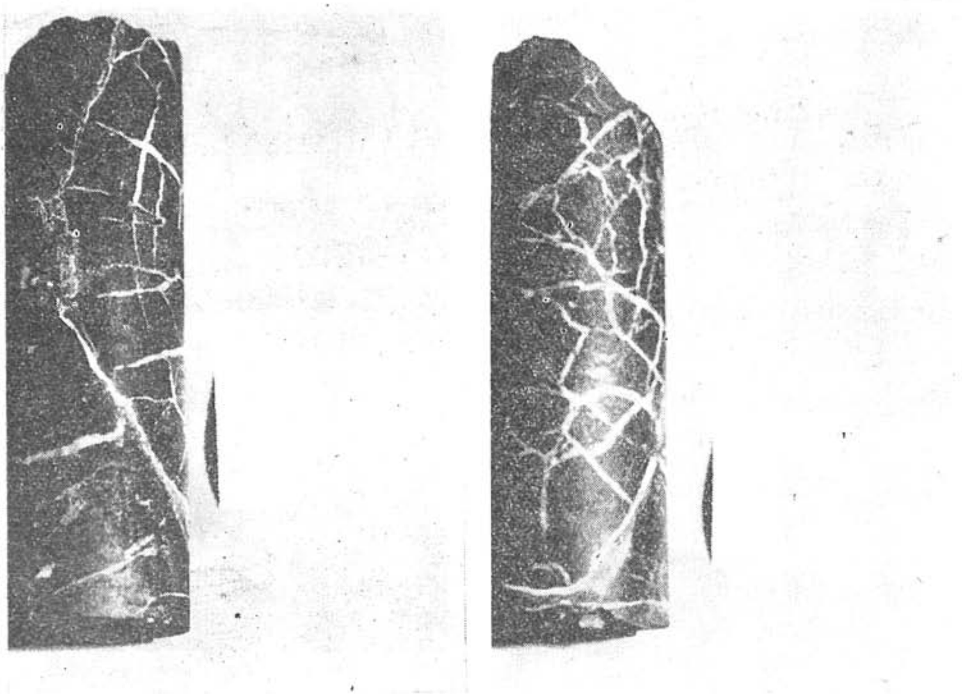


Photo 1. Diabase, reddish and greenish, partly breccia-like, amygdaloidal; the bore hole No. 136, 285 m.

oha (Figs 6—10). The radiolarites and associated rocks (Type 4) are typical pelagic ones, while the limestone-shale group (Type 5) is typical semipelagic (Murdmaa 1979b) analogous. The terrigenous sediments of Type 3 have been deposited by slumping or gravitational sliding, while those as Type 5, partly those associated with limestones are turbidites.

The rocks of Type 5 and 7 are distinctly different from the above mentioned groups. In the sections of drill holes these are situated beneath the Type 1—5 rocks, separated from them by tectonic breccias. Therefore it is suggested that the ophiolite-turbidite complex is in allochthonous position overlying the shelf sediment as tectonic nappe. These shelf sediment as being not related to the ophiolite complexes are not included in our further discussions.

The *synthesis* of facts for the Type 1—5 rocks has led to one important conclusion: the sequence shows typical oceanic character, with Type 1—2 rocks as crust, and Type 3—5 rocks as sedimentary cover. In reality, however, disregarding certain alternations and overlaps is found that the positions of the different rock types are reversed, i.e. Type 3—5 formations are in lower, Type 1—2 rocks are on upper topographic position. This apparent contradiction can be eliminated by assuming overturned setting for these sequences. The fact that overthrusting has occured is sufficiently proven by the lithological structures (cross bedding, graded bedding, convolute bedding) as well as depositional characters of pillows — Photo 14). We therefore suggest



Photos 2.—3. Pillow in the drill sample; the bore hole No 131. 2 — cross-section; 3 — view of the same sample from „within".

a primary stratigraphic sequence from basic instrusives upwards through effusives and pelagic sediments to semi-pelagic sediments.

In the *reconstruction* the mutual relationships of the different lithologies have to be considered:

a) The effusive diabases and spilites of Type 1 and 2 show similarities hence gradual transition between these two types can be assumed.

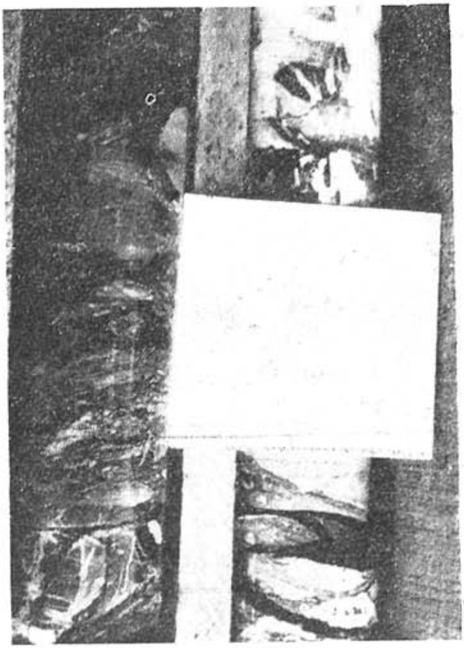
b) Only carbonate-free red and grey terrigenous sediments (Type 3) have been found in indisturbed stratigraphic contract with effusive spilites (Type 2) in form of frequently alternating strata.

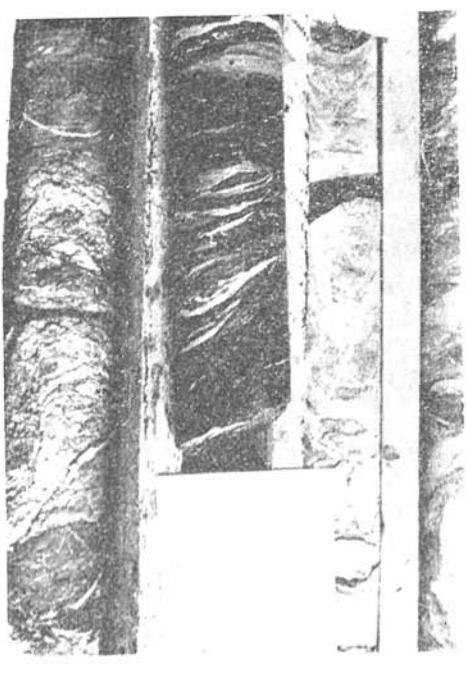
c) There is a gradual change from the red and grey coloured terrigenous sediments (Type 3) towards the pelagic ones (Type 4).

d) Only very specific variaties of spilites and diabases have been associated with pelagic sediments (Type 4). These are not known from other parts of the sequence. At least a part of them occure in detrital from in the sediments (Photo 7).

e) The tuffaceous intercalations in the pelagic sediments can be considered as analogous of the dubious tephra layers in the recent oceanic floor sediments (M u r d m a a, 1979a).

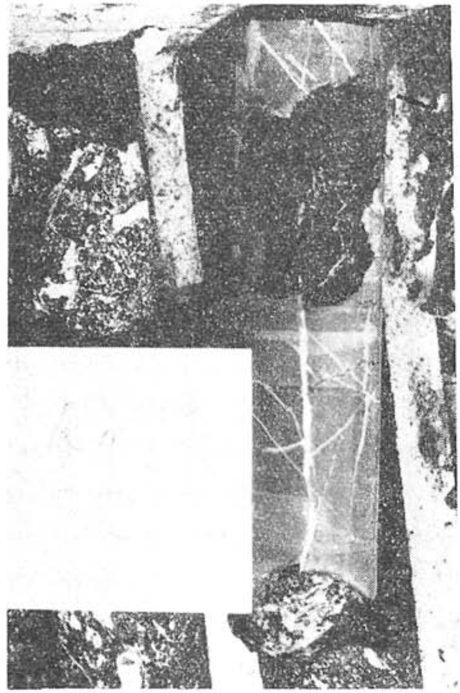
f) There is no trace of any volcanogenic material in the calcareous-origilacceous semi-pelagic sediments (Type 5). These rocks are in tectonic contact





Photos 4.—6. Siltstone—shale, red and grey, with traces of sliding and disturbance; the bore hole No. 136. Note: the drill samples are turned into their primary stratigraphic position (the arrows show the direction towards the drill bottom). 4—5 — 347,3 m, views from different sides; 6 — 345,1 m.

Photo 7. Red biomicrite limestone (in photo light, with white veins) in the massive red amygdaloidal diabase and with a fragment of the same diabase. The bore hole No. 136, 370,4 m.



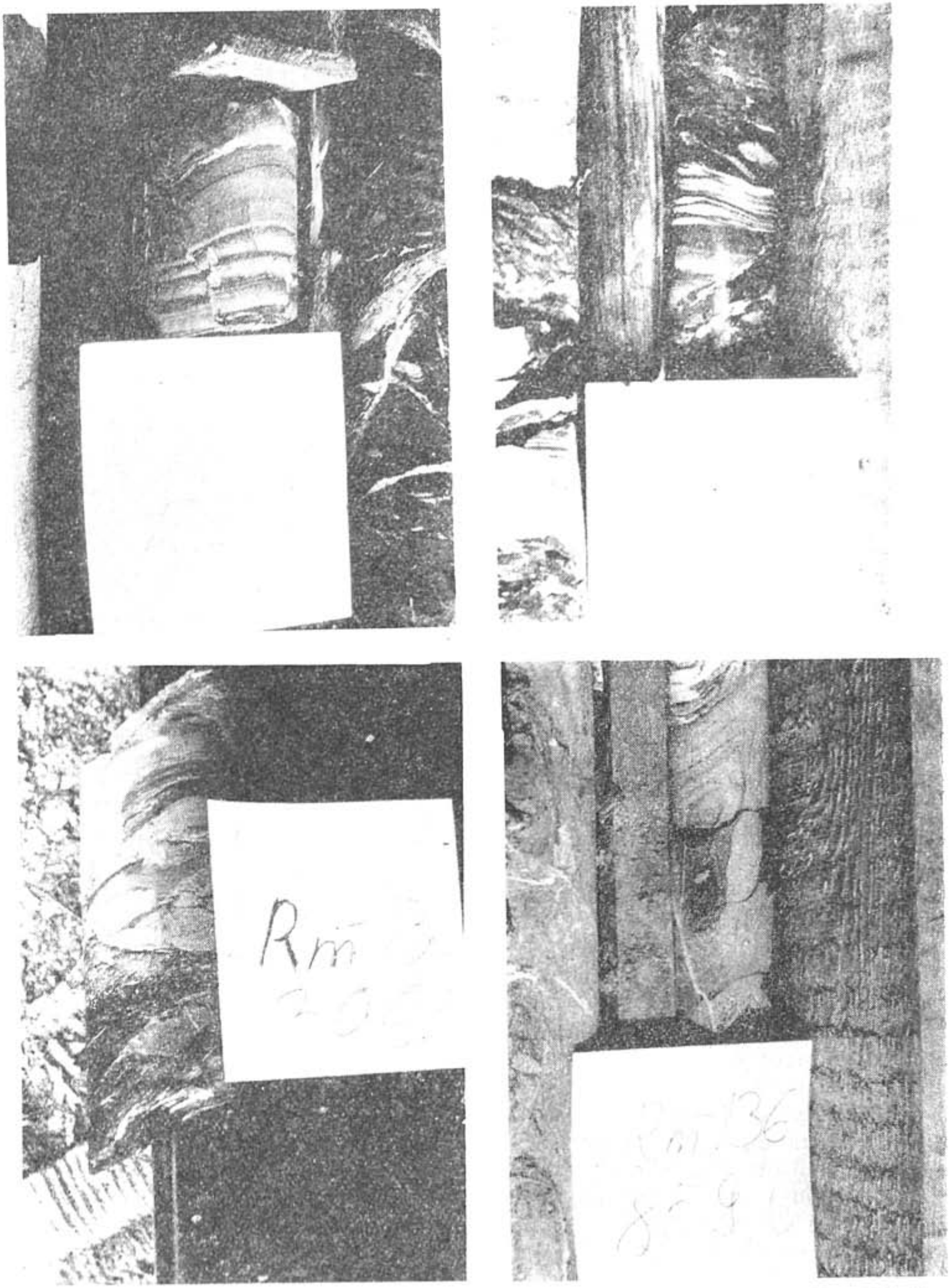
with every other types. Certain lithologies are common with either the $CaCO_3$ free terrigenous sediments (Type 3) or especially with the pelagic sediments (Type 4). This fact allows the assumption of a primary gradation in the pelagic to semi-pelagic change in the character of sedimentation.

These considerations leave little doubt about the primary sequence of the oceanic formation at the Darnó-hegyous (Fig. 13). The sequence is differeng from a standard ophiolite profile only in the alternation of effusives and terrigenous sediments between the upper pelagic and lower igneous (diabase-spilite) formations.

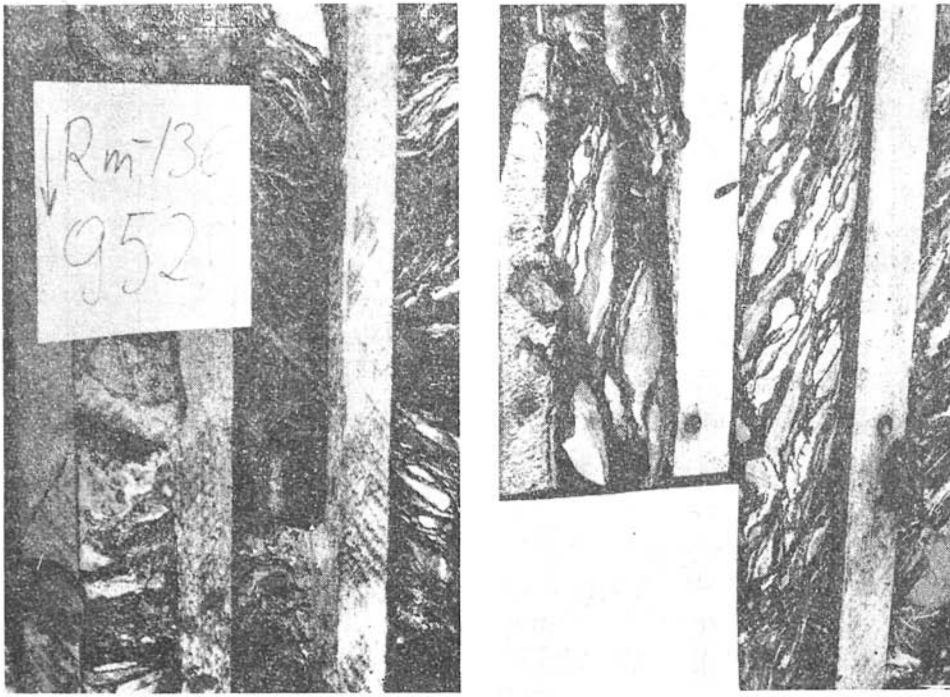
Now it is possible to summarise the conslusions concerning the *geodynamic situation of the genesis* of ophiolite-turbidite complex at the Darnó-hegy:

1) The alternation of effusive diabases (i.e. equivalent with spreading tholeites) and the terrigenous sediments produced by gravity sliding indicates accumulation of the continental detritus on the area of generating oceanic lithosphere during the period of normal spreading. While this phenomena is highly improbable in the case of a middle-oceanic ridge, it is a reasonable realistic situation in the initial period of spreading when the width of the newly formed lithosphere did not exceed few hundred kilometers.

2) The appearance of pelagic sediments on the top of effusives and continental slope sediments reflect the shifting of the area into the abyssal plain, with water-depth of about 4—4,5 km, according the presence of radiolarites. While the subsidence is a direct consequence of continual spreading, the increased distance from the adjacent cotinental slope can not be explained this way. The discontinuation of the terrigenous material transport should



Photos 8.—11. Grey calcareous — argillaceous turbidite; the bore hole No. 136. For notes see photos 4—6. 8 — 575,0 m; 9 — 554,0 m; 10 — 396,0 m; 11 — 859,0 m (with a convolute fold).



Photos 12.—13. Epicontinental Upper Palaeozoic — Lower Mesozoic. Sandy silty argillaceous sediments; strong marks of plastic flow can be seen in these photos. The bore hole No. 136. Note: the drill samples are shown in their original position (the arrows show the direction towards the drill bottom). 12 — 952,0 m; 13 — 957,0 m.

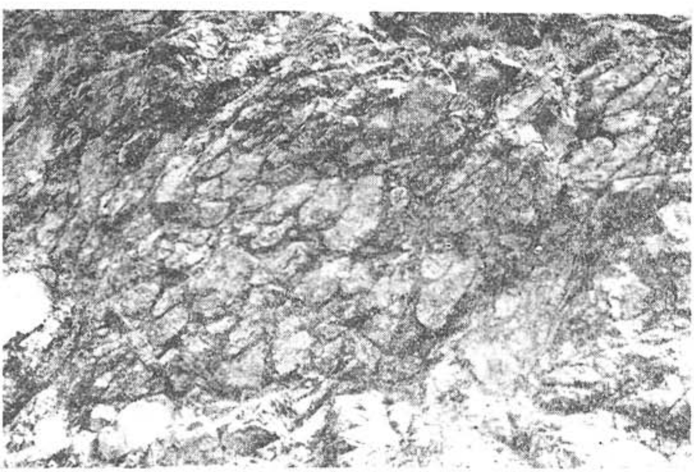


Photo 14. The „Nagyrézoldal" exposure at the basis of the Southern flank of the Darnóhegy. Pillow lava in overturned bedding. The plane of this exposure has a NNW-SSE direction (from left to right).

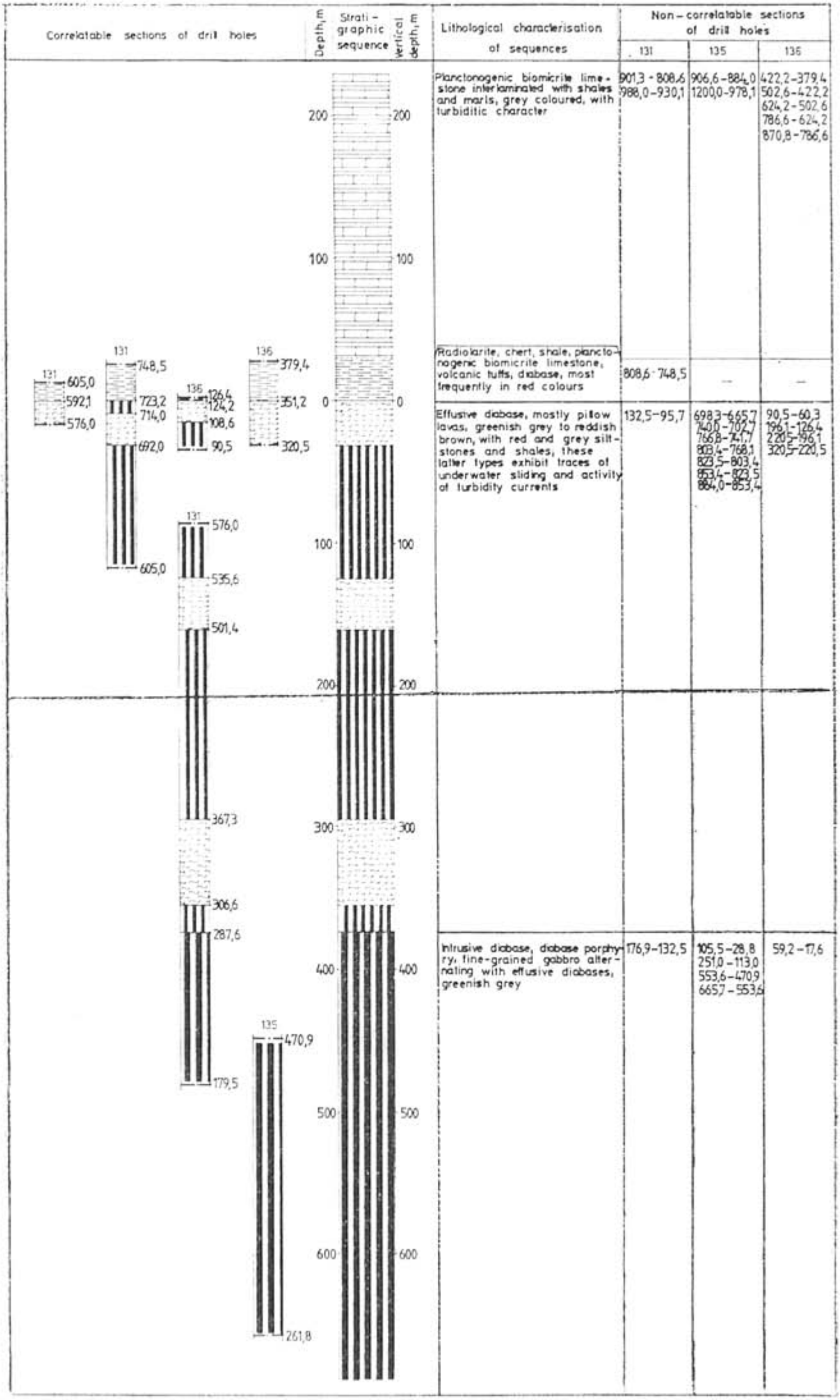


Fig. 12. Schematized logs of the stratigraphic bore holes in Darnó-hegy.

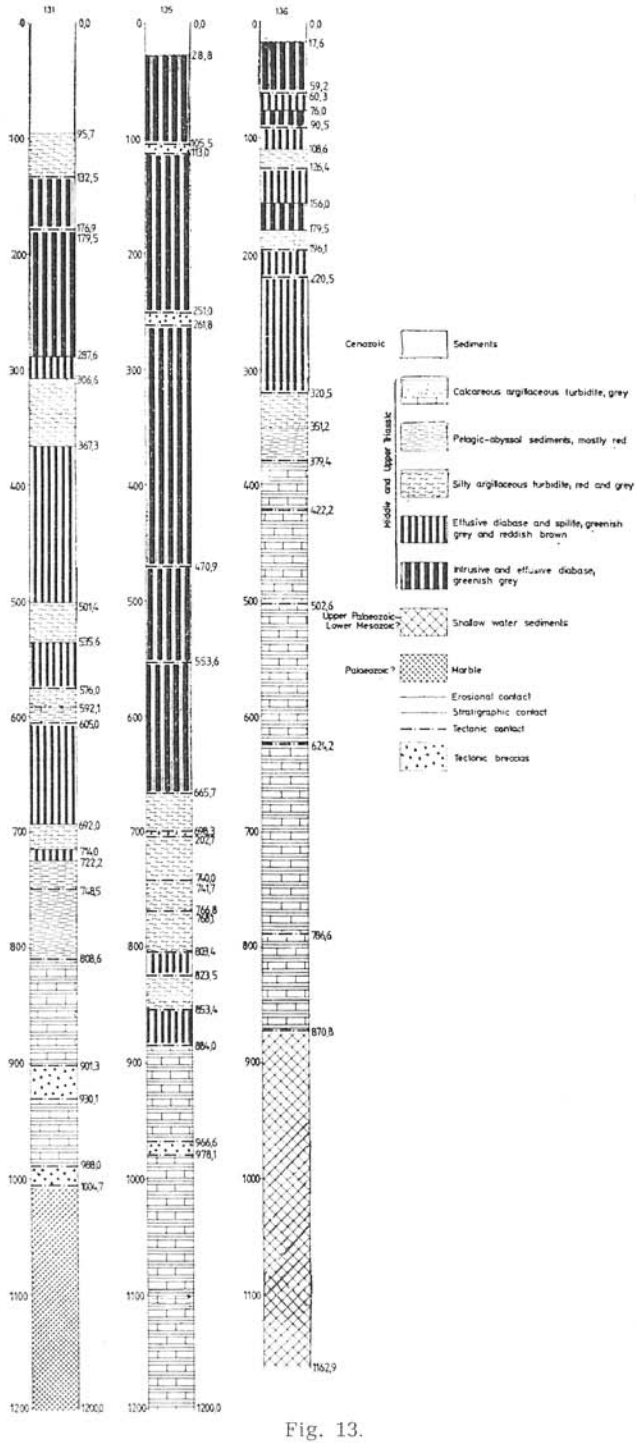

131
135
136
Cenozoic
Sediments
Middle and Upper Triassic
Calcareous argillaceous turbidite, grey
Pelagic-abyssal sediments, mostly red
Silty argillaceous turbidite, red and grey
Effusive diabase and spilite, greenish grey and reddish brown
Intrusive and effusive diabase, greenish grey
Upper Palaeozoic–Lower Mesozoic?
Shallow water sediments
Palaeozoic?
Marble
Erosional contact
Stratigraphic contact
Tectonic contact
Tectonic breccias

Fig. 13.

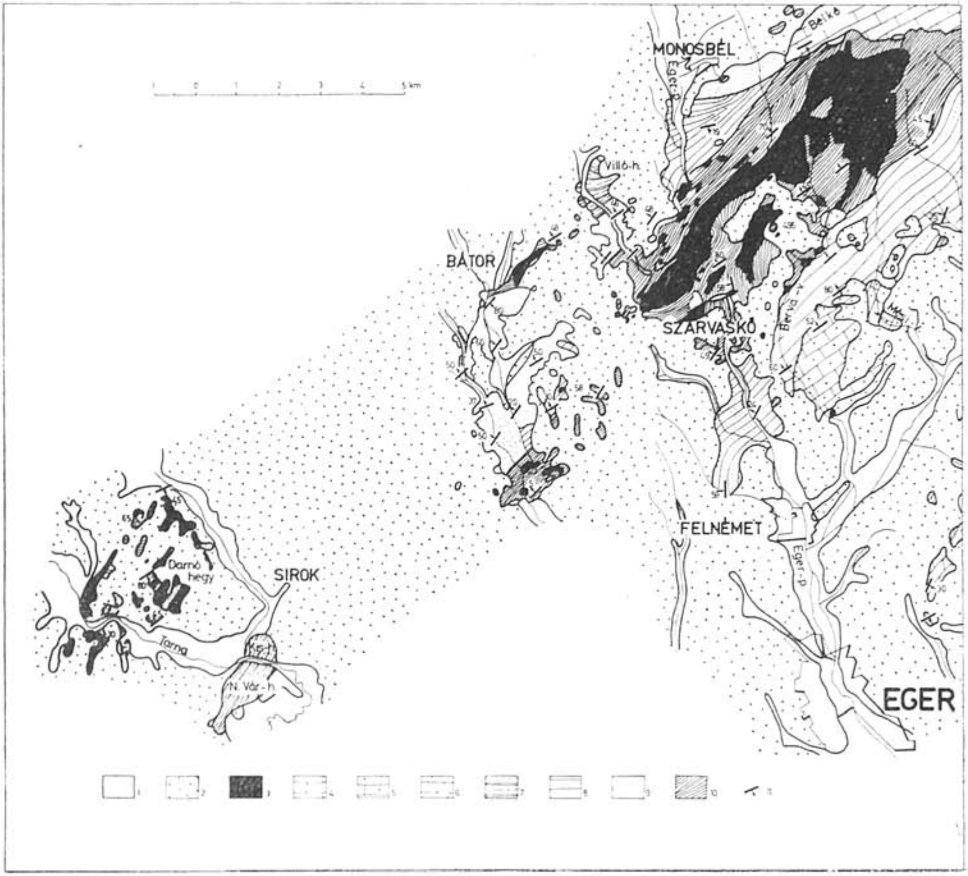


Fig. 14. Geological map of the Szarvaskő area (Scheréter, 1943).
Legend: 1 — Holocene alluvium, 2 — Pleistocene and Tertiary sediments and volcanics, 3 — Cretaceous diabase, gabbro, peridotite, 4 — 6 Middle Triassic: 4 — light grey and white laminated limestone, 5 — esino-marmolata type white limestone, 6 — Wengenian: dark grey cherty limestone, 7 — 9 Lower Triassic 7 — mostly dolomite and limestone with subordinate shales, 8 — mostly shales, with subordinate limestone intercalations, 9 — cherts, 10 — Upper Carboniferous, shale and sandstone. *Notes:* this figure is a part of the original map.

Fig. 13. The reconstructed primary stratigraphic sequence of the ophiolite-turbidite complex of the Darnó-hegy. For legend see Fig. 12.

Notes: 1. On top of the correlatable sections of drill holes there are the numbers of the holes, on the right the original depths of the sections are given. 2. Couples of numbers for the non-correlatable sections refer to real depth intervals along the vertical drill axis.

be due, in the given case, to a weakening or termination of the material transport downward the continental slope. Reasonable explanations need more investigations on regional scale.

3) Similarly, the re-appearance of turbidites in the sequence can be best explained by the increased rate of terrigenous material transport from the shelves. The lack of radiolarites, and generally speaking the cherts can be attributed to a certain decrease of water depth or the subsiding carbonate compensation level due to the rearrangement of oceanic currents. In any case the pelagic and/or semi-pelagic sedimentation indicates the persistency of oceanic environment.

2.2. Szarvaskő area

The ophiolite complex outcrops in a 10 km long and 3 km wide NE—SW trending belt in the northern part of the southwestern flanks of the Bükk Mountains. Here the formation is also poorly exposed, but the gorge of the Eger River provide a full section of the ophiolitic complex and its country rocks too (Fig. 1). The initial mappings in the area allowed a stratigraphic subdivision of this profile into three groups: the northern and the southern limestone shale group, and the middle sandstone-shale group with the associated diabase, gabbro and peridotite (Fig. 14). Later this concept had been neglected (B a l o g h, 1964), but it has again verified during our recent field work and as such, it serves as base for our further discussions.

The general setting is similar to that of the Darnó-hegy: steep monoclinal dip to NW, with frequent overthrusts, shear zones. In creating our model we followed the same way as in the case of the Darnó-hegy.

During the *diagnosis,* following rock types have been distinguished in the geological profile (Fig. 15).

1) Limestone with laminated, frequently schistose texture, with chert nodules, grey coloured. It is interlaminated with brown to dark grey shale, showing frequent spotty or banded coloration. The shale presents traces of sliding and convolute bedding. In the thicker pelitic layers olistholite rich horizons have been recorded with fragments of limestone, red sandstone and quartz-conglomerates.

2) Shale similar to the former type, but completely free of $CaCO_3$, without any limestone intercalations. Limestone olistholites, lenses of chert do occur.

3) Grey, dark grey shale with occasional chert lenses, usually without any marks of an obvious stratification and free of characteristic primary texture.

4) Grey, brown shale with red and green varieties, finely interbedded with grey to greenish grey siltstone and fine grained sandstone. These intercalations reflect certain rhythmicity with tilted laminated bedding.

5) Fine to very fine grained sandstone in massive poorly bedded form, frequently alternated with siltstone and shale, exhibiting graded bedding. Its material is purely terrigenous (quartz, feldspar, muscovite), with no traces of volcanogenic material. Carbonaceous remnants of fossilised plant fragments and thin laminae of coal (1—2 mm) are not uncommon.

6) Diabase and spilite, greenish grey, amygdaloidal, with pillow structure.

7) Massive effusive diabase.

8) Intrusive looking diabase and gabbro-diabase.

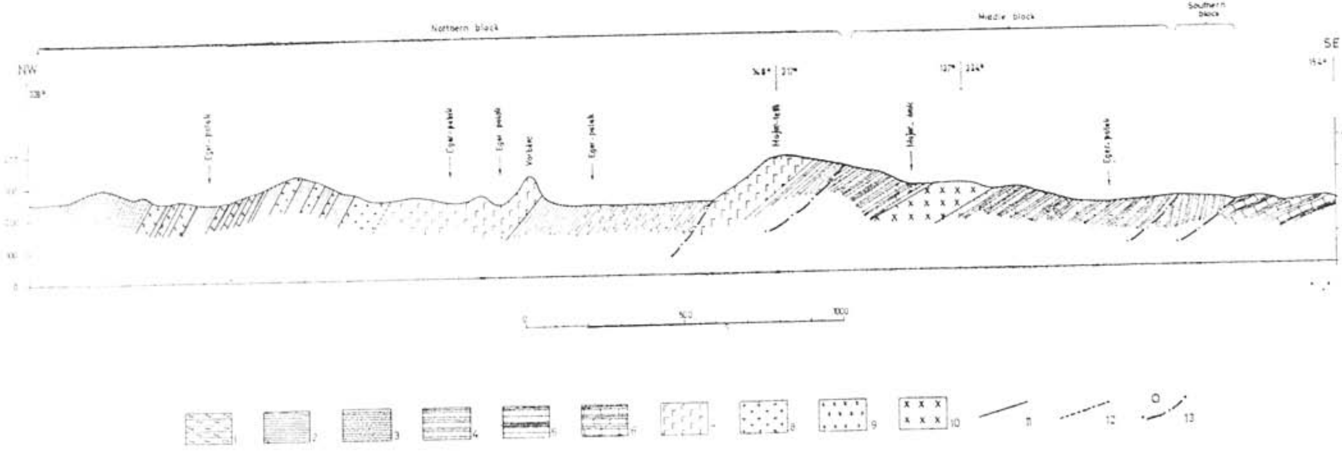


Fig. 15. The profile of the ophiolite-turbidite complex along the gorge of the Eger river.
Legend: 1 — light coloured shales with turbiditic textures and limestone olistholites, 2 — dark grey shale, 3 — shale, siltstone and fine-grained sandstone, finely bedded, with shale dominance, 4 — shale, siltstone, fine-grained sandstone, finely bedded, with sandstone dominance in several places, 5 — massive fine grained sandstone with siltstone and shale intercalations, 6 — limestone — shale series, 7 — diabase — pillow lavas, 8 — effusive looking massive diabase, 9 — intrusive diabase and gabbro-diabase, 10 — differentiated gabbro with peridotite bands, 11 — normal stratigraphic or intrusive contact, 12 — contact of uncertain localisation or sense, 13 — overthrust.

Photo 15. Cliff exposure in the upper part of the Western flank of the „Várbércszurdok" gorge West from Szarvaskő. Pillow lava in overturned bedding. The exposure has a NW—SE orientation (from left to right).

9) Layered fine grained gabbro with medium grained interlayers.

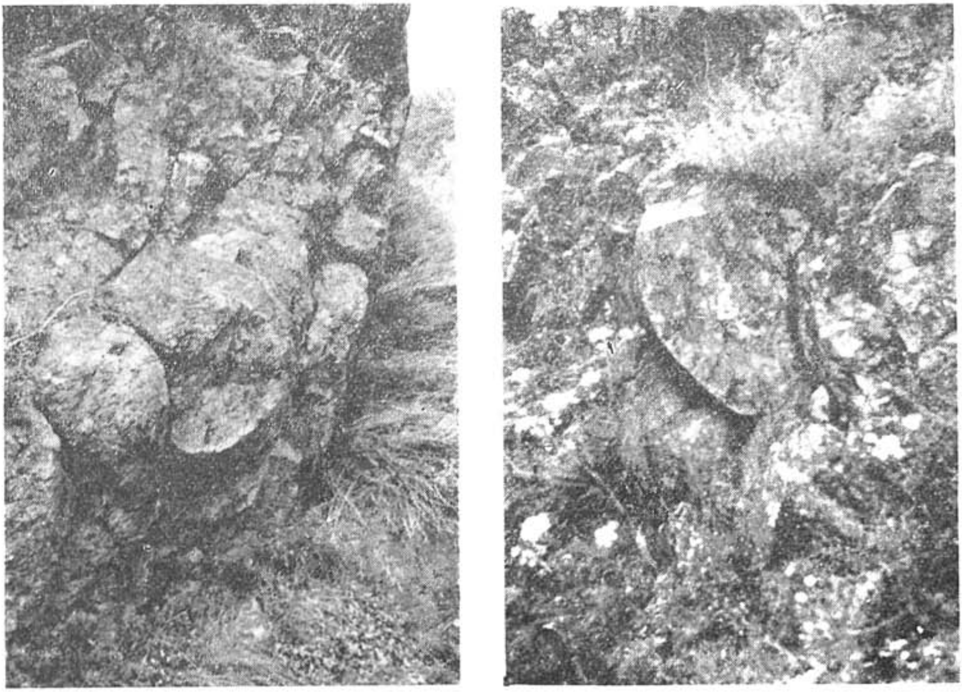
10) Gabbro, eight medium and coarse grained melanocratic (peridotite) and leucocratic (albite-quartzite) extremities in form of layers and bands. The peridotite forms small (several ten meters) lenses in gabbro with gradational contacts.

The limestone-shale (Type 1) can be considered as semi-pelagic according to its textural character and lack of macrofauna. This assumption is supported by the presence of cherts. The shales of Type 1 and 2 show turbidite character. This is even more apparent in the coarse and fine grained sediments of Type 4 and 5. The diabase and gabbro are analogous of ocean floor tholeites.

In the *synthesis* one can draw the conclusions that the characteristic components of the upper horizons of oceanic lithosphere are associated with terrigenous turbidites, and these are overlain by the pelitic carbonate sequence of the sempi-pelagic sediments.

In the *reconstruction* of the primary stratigraphic sequence one must keep in mind both the shape of the spilite pillows (Photos 15—17) and the graded bedding and other disturbant textures in sediments indicate overturned position for the whole sequence. The boundaries of the different types are not exposed, so only circumstancial evidences are available in determining the features of the undisturbed units.

The main faults however could have been traced in even the homogeneous strata according the regular variations in the positions of bedding planes



Photos 16.—17. Separate pillows in overturned position in the cliffs on top of the Western flank of the „Várbérc-szurdok" gorge West from Szarvaskő. 16 — a view from South, 17 — a view from North-East.

(Fig. 16). On this base the sandstone-shale group, which also includes the diabase and gabbro, is subdividable into three blocks: the northern, the middle and the southern one. Multiple alternation of igneous rocks and sediments has been observed in the northern block (Fig. 15). If we investigate them individually, the following regularities can be observed upwards in the original stratigraphy (from NW to SE, i.e. downwards in the present position):

a) In the igneous parts the differentiated fine-grained gabbro (Type 9) is replaced by gabbro-diabase and intrusive diabase (Type 8), then massive effusive diabase (Type 7), finally pillow lavas (Type 6).

b) In the sedimentary pile sandstones and siltstones, shales (Type 4) are followed by grey to dark grey shales (Type 3), then lighter coloured clay-shales (Type 2).

In this context the pillow and massive diabases (Type 6 and 7) are interbedded into the dark shales (Type 3), while the intrusive diabases, gabbro-diabase and gabbro (type 8 and 9) into the fine-grained sandstone-siltstone pelitic series (Type 4). These associations are persistent over the whole strike length of the outcropped formations. Therefore we believe the sequence to be primary in the northern block as a whole.

Repetition is assumed only in the case of the second pillow lava horizon, for two reasons: first, a Type 2 light coloured shale is observed between the two effusive horizons; this is replaced by a darker variety (Type 3) in both sides, secondly, the thicknesses of intercalated shales and effusives show abrupt change along strike indicating the existence of a longitudinal fault.

According the lithological variation in the northern block, it can be suggested, that the rocks of the other two blocks are in deeper position in the stratigraphy, among the sediments the sandstones (Type 5) are either the most abundant (in the southern block) or in signifcant proportion (middle block). The igneous rocks are represented here by differentiated visually holocrystalline gabbro (Type 10). The variation in the intensity and width of contact metamorphic aureolas show similar pattern. The gabbro-diabase (Type 8) exhibits only 0.5—1 m thick zones of hornfelses. In the case of fine-grained gabbro (Type 9) 8—10 m thick zones of hornfels are associated with spotted shales. The highly differentiated gabbro (Type 10) is contacted against hornfelses as well as biotitic, garnetiferous cordierite-sillimanite schists, over more than ten meters.

Based on these facts a fairly reasonable outline can be given for the primary stratigraphic sequence of the formations at the Szarvaskő area (Fig. 17). It differs from a standard ophiolite series in that different elements of the oceanic lithosphere are dismembered within a terrigenous turbidite series. There is no doubt however about the contemporaneity of the various igneous rock types since all type of gradational changes from differentiated peridotites to pillow lavas could be traced in one profile. This uniformity indicates temporal connection between the intrusives and effusives. The effusives also give the relative age relationships compared to the sediments with their position in the stratigraphic sequence. It can also be stated that sedimentation has been continuous after the igneous activity had ceased in the area, but its character had changed to carbonatic-pelitic (Type 1).

The *geodynamic situation of the formation* of ophiolite turbidite complex around Szarvaskő can be reconstructed as follows:

1) The normal sequence of the oceanic lithosphere components reflects the development of igneous activity in an advanced stage of continental rifting. However, the presence of terrigenous sedimentary underlayers point to the continental origin of that block of crust, which has been the site of the sedimentary accumulation. This controversy can be eliminated by assuming a situation where pillow lava horizons mark the process of initial spreading along a continental rift in the neighbouring region. The sediments beneath the effusives have been deposited in a subsiding and spreading continental rift in marine environment. The magma has extruded and intruded laterally from the opening fissures of the oceanic rift. The sediments overlying the effusives have already deposited at the base of the newly formed continental slope.

2) The lack of the pelagic sediments (radiolarite etc.) pretending it is not due to recently unknown tectonic displacements, fits well into the above-described model.

3) The introduction of carbonatic-pelitic semi-pelagic sedimentation reflects a decrease in the rate of accumulation of terrigenous material from the shelf. The considerable thicknesses of sediments indicate the persistency of oceanic conditions. According this reconstruction the changing in the structural cha-

racter of the rift from continental to oceanic took place probably in the Lower Karnian stage, or even earlier, in the Middle Triassic period.

2.3. Comparison between the two areas

Two main questions have been discussed concerning the ophiolites of Darnó-hegy and Szarvaskő: their primary structural setting and their present tectonic position.

The *primary structural setting* involves the geodynamic processes of formations of different lithologies. This is essentially similar in both areas. The ophiolites have generated on constructive lithospheric plate margin. There is a difference in their position relative to the boundaries of oceanic and continental lithospheric plates. At Szarvaskő the ophiolites have formed immediately at the base of the continental slope at the time of birth of the oceanic lithosphere. The Darnó-hegy ophiolites have formed in a more matured stage of oceanic lithosphere generation in several hundred kilometers distance from the continental slope.

If these two areas were in the same belt perpendicular to the axis of spreading, the Darnó-hegy ophiolites should be the younger ones. Encounting a few cm/year as rate of spreading, the difference in age could be estimated to several million years.

In the Eastern Bükk Mountains at Lillafüred—Diósgyőr (near to Miskolc) Middle—Upper Triassic diabases, porphyries and quartz porphyries are known in a shelf type carbonate sedimentary sequence. In general these are analogous of those bimodale series related to continental rift zones. These formations, along with the ophiolites at the southwestern parts of the Bükk Mountains can be related to he same process of evolution, though they have formed in a different environment.

In this case the three different areas of Triassic igneous activity in the Bükk Mountains could be merged into a single model and considered as subsequent stages of the same evolution history: purely continental rift (Lillafüred—Miskolc), the change of the continental rift to oceanic (Szarvaskő), and relatively immatured oceanic rift (Darnó-hegy). To what extent this reconstruction reflects a real situation for a given period of time is not determinable at present due to discrepancies in the available data for the respective ages of the formations.

Fig. 16. Schematized geological map of Szarvaskő (Compiled by Balla Z. and Havas L. 1979).

Legende: 1 — 5 Middle and Upper Triassic: 1 — sandstone, siltstone and shale series, 2 — diabase pillow lavas, effusive looking diabase, 3 — intrusive diabase and gabbro-diabase, 4 — gabbro with occasional peridotite bands, 5 — limestone-shale series, Middle Karnian age in its lowermost (?) parts; 6 — Middle-Upper Triassic (?) uncertain chert-shale sequence, 7 — Middle-Upper Triassic (?) epicontinental series „Fennsiki mészkő" = „Highland limestone", 8 — Mappable contact aureola, 9 — Normal stratigraphic or intrusive boundary, 10 — Cross-faults — horizontal displacements (?), a — observed, b — assumed, 11 — Longitudinal overthrust, a — observed, b — assumed, 12 — Uncertain contact, a — observed, b — assumed, 13 — Contours of mapped or exposed area.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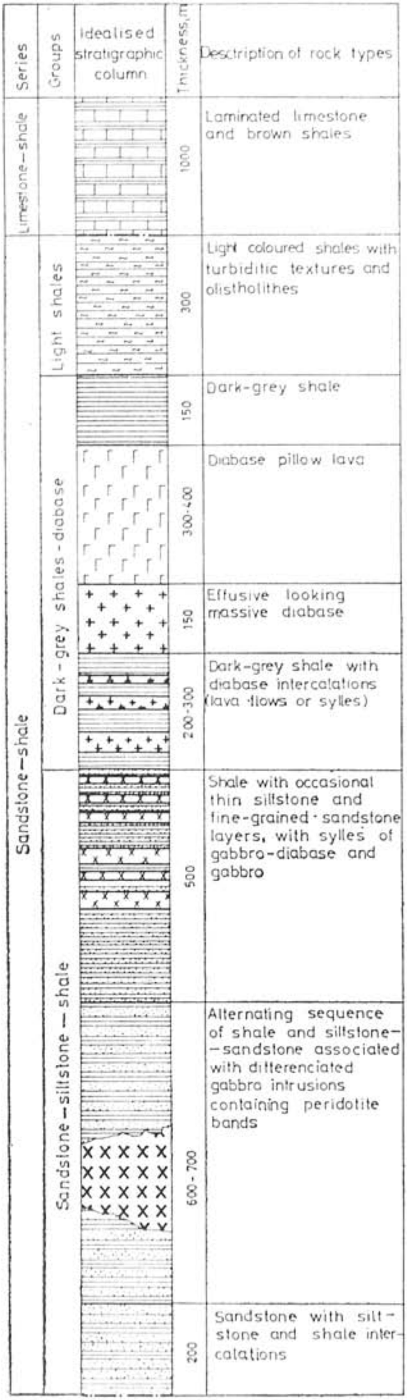

Fig. 17. Idealised primary stratigraphic sequence of the ophiolite-turbidite complex at Szarvaskő.

The *secondary structural setting* i.e. the present geological position is determined mainly by two factors, the formation of a tectonic nappe in an earlier stage and the subsequent block tectonics. The most important fact is the overturned position of the ophiolites in both areas. These therefore should be regarded as allochthonous in form of nappe. The basement adjacent to the overlying nappe is known only from the bore-holes in Darnó-hegy: these are epi-continental sediments. As a consequence the magnitude of horizontal displacement should be in the order of at least 80—100 km.

The considerable extent of the displacement is also indicated by the relatively short distance (about 10 km) between the two genetically different formations of the Darnó-hegy and Szarvaskő (Fig. 18). The Mesozoic nappes had been dismembered by Cenozoic faults into separate blocks, which had been covered by Tertiary sediments. This creates great difficulties in tracing the extent of these nappes.

2.4 *Final remarks*

Our considerations for the tectonic position and stratigraphic sequence in both areas seem to be reasonably well established and would need only small modifications in the future. Nevertheless several questions have been remained unsolved concerning the structural setting of the formations:

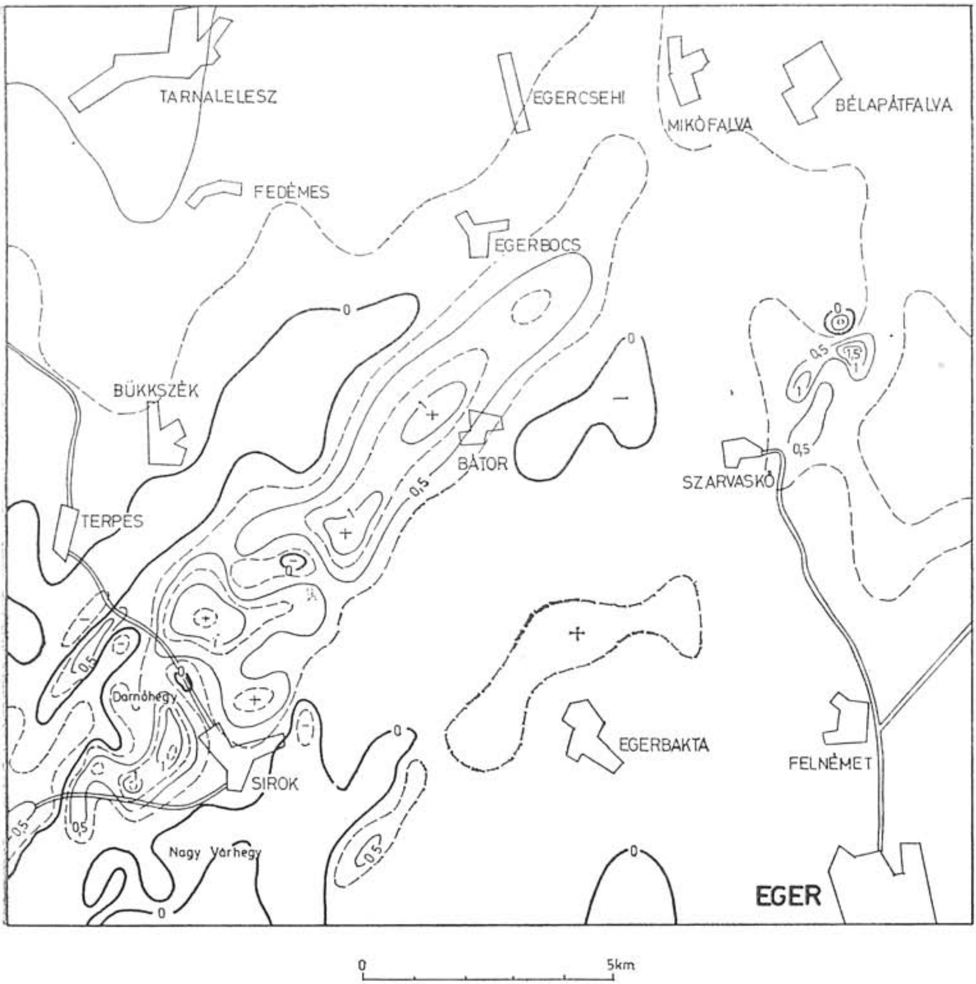

Fig. 18. Airborne magnetic $\triangle T$ map of the Southwestern Bükk Mountains. Flight altitude 50 m.

a) There is no direct evidence for even the approximate contemporaneity of the formations of the two areas. Here we simply adapted B a l o g h's opinion (1964).

b) There are no data for petrochemical and geochemical similarities of the Darnó-hegy and Szarvaskő ophiolites. This aspect needs further investigations.

c) The oceanic tholeite analogy is solely based on O n u o h a's (1977b) study, which is less reasonable as far as geological aspects are concerned (Fig. 19).

Until these problems are not solved several points of our model should serve only as a working hypothesis.

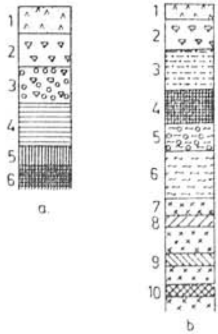

Fig. 19. The schematic sequence of the Darnó-hegy and Szarvaskő ophiolitic complex by Onuoha (1977b, Fig. 2.). *Legend:* a — Idealized composite section of the ophiolites near Darnó-hegy, 1 — radiolarite beds and tuffs, 2 — spilitic pillow lavas, 3 — brecciated pillow lavas, 4 — sill-like spilitic diabases, 5 — diabase dyke complex, 6 — gabbro-diabase. b — Idealized composite section of the ophiolites at the Várbérc gorge near Szarvaskő: 1 — marine sediments, radiolarites, 2 — pillow lavas, 3 — diabase sheets with minor dykes, 4 — gabbro-diabase, 5 — quartz diorite, 6 — gabbro, 7 — peridotite, 8 — hornblendite, 9 — pyroxenite, 10 — wehrlite.

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