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PALAEOMAGNETISM OF IGNEOUS ROCKS FROM THE VELENCE HILLS AND MECSEK MOUNTAINS

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Granitoids are known to outcrop in Hungary in the Velence Hills (part of the Transdanubian Central Range) and in the Mecsek Mountains. Both are dated radiometrically. The minimum age for the Velence granite is 280 Ma (K/Ar method); the granitization in the Mecsek Mountains is limited to the 365–334 Ma interval by U/Pb, whole rock Rb/Sr and K/Ar methods.

Palaeomagnetic analysis has revealed the complex nature of the natural remanence (NRM) in both areas.

Comparison between the components of the complex NRM observed in the granitoids and the characteristic remanences of later intruded and extruded igneous rocks in the respective areas has shown that the periods of renewed igneous activity play an important role in the formation of overprint magnetization.

In the Velence Hills the Tertiary andesite volcanism extensively remagnetized the granite. The andesite volcanism (about 30 Ma, K/Ar method) is represented palaeomagnetically by the site-means for 8 andesite and the locality means of one diabase and 7 completely remagnetized granite outcrops ($D = 151°$ $I = -45°$ $k = 22$ $\alpha_{95} = 8.4°$). This direction permits one to conclude that the 30–35° counter-clockwise rotation of the Transdanubian Central Range relative to Africa and stable Europe known till now as post-Mesozoic is in fact younger than 30 Ma.

At five localities in the Velence Hills the granite seems to preserve a remanence different from both the Earth's present field direction and the field about 30 Ma ago (on average $D = 144°$ $I = +30°$ $k = 49$ $\alpha_{95} = 11.1°$). This direction may be interpreted as Carboniferous.

The distribution of the completely and partically remagnetized granite in relation to the eruption centre of the andesite is irregular suggesting that the remagnetization was caused by the chemical influence of the postmagmatic solutions and that the degree of alteration depends on the porosity of the granite.

The youngest igneous activity is about 20 Ma old (K/Ar method) in the Mecsek Mountains. For lack of outcrops the volcanism is represented palaeomagnetically by three sites from a single laccolith of a few square kilometers in the horizontal dimension ($D = 59°$ $I = 65°$ $k = 36$ $\alpha_{95} = 22.2°$, the statistics are based on the number of sites).

Products of the Cretaceous alkali volcanism are widespread in the different parts of the Mecsek Mountains. The palaeomagnetic direction for the Mórágy Ridge ($D = 94°$ $I = 57°$ $k = 28$ $\alpha_{95} = 9.3°$) is based on 8 site means for alkali volcanism and 2 locality means for completely remagnetized granite aplite; the direction for the Eastern Mecsek is $D = 79°$ $I = 54°$ $k = 7$ $\alpha_{95} = 27.2°$ before tilt correction, $D = 47°$ $I = 56°$ $k = 5$ $\alpha_{95} = 33.6°$ after tilt correction, based on 6 site means.

In view of the good quality of the palaeomagnetic direction obtained for the Carboniferous granitoids (Mórágy Ridge: $D = 189°$ $I = 18°$ $k = 36$ $\alpha_{95} = 11.4°$, based on 1 serpentinite and 5 granitoid localities), and directions determined for Permian, Triassic and late Jurassic sediments from the Western and Eastern Mecsek respectively, a significant counter-clockwise rotation must have taken place in the Cretaceous followed by a large clockwise rotation presumably in the late Tertiary.

The results of the present study confirm the past relative rotations between the NW and SE tectonic units of Transdanubia indicated by earlier palaeomagnetic studies; they suggest that the tectonic units of the present Pannonian Basin must have been involved in important large-scale

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movements in the late Tertiary; finally the newly obtained palaeomagnetic directions imply that SE Transdanubia moved in a complex manner during the Cretaceous and after, and that the observed declination rotations may equally be interpreted as the movements of an originally northern or originally southern Tethyan unit.

Keywords: palaeomagnetism, complex magnetization, igneous rocks, relative rotations, Hungary

1. Introduction

Evaluation of geological and geophysical observations has led to the conclusion that the Mid-Pannonian Mobile Belt separates two entirely different tectonic units [Szádeczky–Kardoss 1972, 1973, Géczy 1973a, 1973b, Szepesházy 1975, 1977, Channel and Horváth 1976, Horváth et al. 1977, Vörös 1977, Márton and Márton 1978, 1980, Wein 1978, Channell et al. 1979, Balla 1982]. Based on the fauna and the facies, the NW unit seems likely to be derived from the southern margin, the SE unit from the northern margin of the Tethys.

Palaeomagnetic evidence for NW and SE Hungary being different tectonic units was first published in 1978 [Márton and Márton 1978]. The African affinity of Jurassic poles for the NW unit and the European affinity of Mesozoic poles for the SE unit appeared to support the idea that the tectonic units of Hungary originated at different margins of the Tethys.

As a result of systematic palaeomagnetic studies on Mesozoic rocks from the Transdanubian Central Range independent proof was obtained for its southern Tethyan origin: the "Mesozoic loop" shown by the apparent polar wander curve (APW) for the Transdanubian Central Range reflects similar relative movements in the Mesozoic with respect to the magnetic pole as the African APW. The APW for the Transdanubian Central Range however, revealed a very important movement of the area, which is the post-Mesozoic 30–35° counter-clockwise rotation with respect to both Africa and stable Europe [Márton and Márton 1981, 1983]. This conclusion is very important for more than one reason. First of all it is a hard fact which cannot be disregarded in any plate tectonic reconstruction; secondly, it supports the model put forward by VandenBerg [1979] which questioned the persistence of the African Promontory [Channel et al. 1979] up to recent times; relative movement between the African Promontory and Africa was proved later, first for autochtonous Istria then for Gargano [Márton and Veljovic 1983, VandenBerg 1983]; thirdly, the post-Mesozoic rotation implies that the horizontal displacements must have been large in the Tertiary, i.e. the final collision between Africa and stable Europe is younger than Cretaceous.

Although it became clear from the Mesozoic APW for the Transdanubian Central Range that the large counter-clockwise rotation is post-Mesozoic, observations on younger rocks were needed to date the rotation more precisely.

The old end of the APW for the Transdanubian Central Range became interesting, too, mainly for the correlation of the Palaeozoic within the Alpine

Belt (IGCP project 5). The Velence granite hills – penetrated by Tertiary andesite – seemed to be an area ideally suited to both ends.

Palaeomagnetic results for the tectonic unit SE of the Mid-Pannonian Belt have accumulated at a slow rate. Apart from the early works by Kotásek et al. [1969], Márton and Márton [1969a, 1969b, 1970], Dagley and Ade-Hall [1970], palaeomagnetic results were published for the Villány Hills by Márton and Márton in 1978. Both the Permian from the Mecsek Mts [Kotásek et al. 1969] and the Mesozoic from the Villány Hills [Márton and Márton 1978]

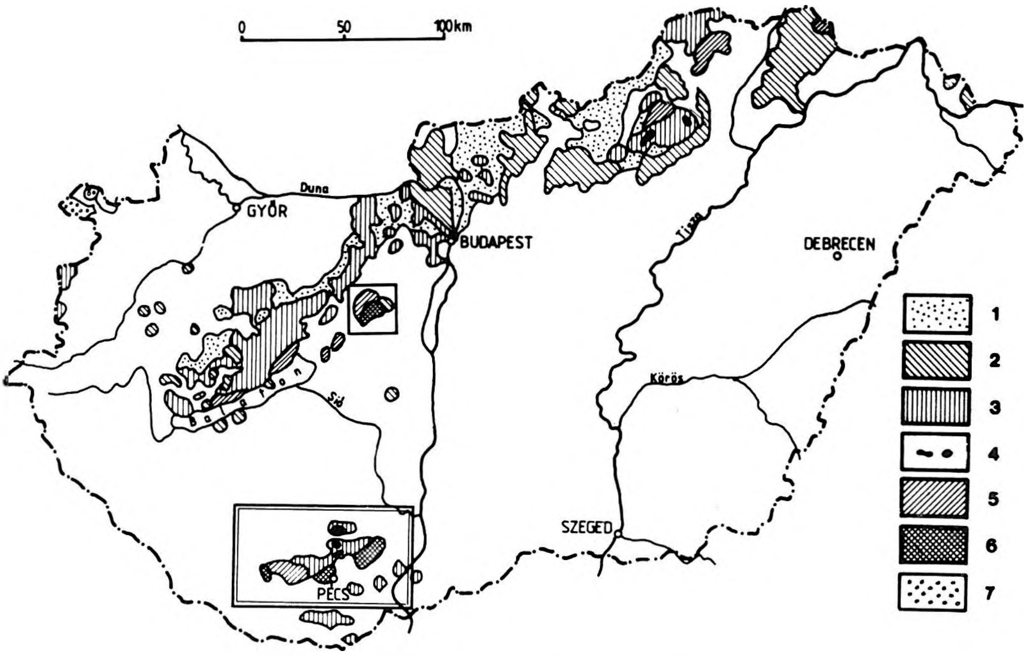


Fig. 1. Simplified geological map of Hungary showing the sampling areas of the recent study
1 — Palaeogene sediments; 2 — Tertiary volcanic rocks; 3 — Mesozoic sediments; 4 — Mesozoic eruptive rocks; 5 — Palaeozoic sediments; 6 — Palaeozoic granitoids; 7 — gneiss and crystalline schists. Single frame: Velence Hills; double frame: Mecsek Mountains

1. ábra. Magyarország egyszerűsített földtani térképe a jelen paleomágneses tanulmány mintavételi területeivel
1 — paleogén üledékes kőzetek; 2 — harmadkori vulkáni kőzetek; 3 — mezozoos üledékes kőzetek; 4 — mezozoos eruptív kőzetek; 5 — paleozoos üledékes kőzetek; 6 — paleozoos granitoidok; 7 — gneisz és kristályos palák. Szimpla keret: Velencei-hegység; dupla keret: Mecsek hegység

Рис. 1. Схематическая геологическая карта Венгрии с обозначением районов отбора проб при проведенных исследованиях
1 — палеогеновые отложения; 2 — третичные вулканические породы; 3 — мезозойские отложения; 4 — мезозойские магматические породы; 5 — палеозойские отложения; 6 — палеозойские гранитоиды; 7 — гнейсы и кристаллические сланцы. В простой рамке: Веленцейские горы; в двойной рамке: Мечекские горы

yielded uniformly "stable European" directions. For the Cretaceous, the between-site scatter was large. Dagley and Ade-Hall simply disregarded the "anomalous" results, Márton and Márton attributed the scatter to local tectonics.

For the next study in SE Transdanubia a relatively undisturbed area, the Mórágy Ridge, was selected where metamorphic rocks, granitoids and alkali magmatites crop out *(Fig. 1)*. At the start of the palaeomagnetic analysis, the age of the ultrametamorphism was debated. It was generally accepted, however, that the granitization ended in the Carboniferous, i.e. the study of the Mórágy granitoids provided an opportunity to obtain Carboniferous directions that compare in age with the Velence granites.

Prior to the first directions determined on Hungarian granitoids [MÁRTON 1979, 1980], very few results have been reported on intrusive granites and none on migmatites, for the granitoids were not easy to work with. The standard laboratory processing of the seventies failed to yield meaningful results. The standard itself had to be changed in order to isolate the components of a complex natural remanence.

2. Palaeomagnetic standard in the 70s

The generally accepted procedure in the 70s for palaeomagnetic investigation may be characterized in the following way. Either hand samples or drill cores were oriented using the Sun or a magnetic compass. The remanent magnetization was measured in the natural state, then selected specimens — pilot specimens — were subjected either to alternating field (AF) (mainly igneous rocks) or thermal (sediments) demagnetization to prove the stability of the remanence and remove less resistant components. Based on the behaviour of the pilot samples a single demagnetization step was chosen and the whole collection cleaned at that step.

Criteria for reliable palaeomagnetic results were first formulated in the 60s [IRVING 1964]. A palaeomagnetic direction was accepted when
- it was based on a minimum of 6 independently oriented samples
- the author thought that his result was indicative of the Earth's field direction at the time of the rock formation
- the circle of confidence, α_{95} [FISHER 1953], was less than 25°
- for older than Tertiary rocks the direction departed significantly from the present local field direction or the stability of the magnetization was proved by laboratory cleaning
- the age of the rock was known to the precision of a geological period.

IRVING, himself, emphasized that these were minimum criteria and he had not intended to imply that "the results which satisfy them necessarily give the direction of the geomagnetic field at the time of formation of the rocks in question" [IRVING 1964, p. 102].

McElhinny [1973] modified Irving's criteria by requiring 8 independently oriented samples together with a laboratory stability test in each case. Concering the age, for Precambrian rocks he accepted only the results of isotope age determinations.

3. Method applied to the Hungarian granitoids

The method of obtaining meaningful palaeomagnetic directions for granitoids that could be interpreted in geological terms emerged from the laboratory analysis of the magnetization of the Mecsek granitoids. It is important, however, first to point out why and how the analysis was done, for it may promote the better understanding of the palaeomagnetic results described in Sections 6 and 7.

Initially the standard method was applied to the granitoids. When AF cleaning was unsuccessful for most sample groups, all sister-specimens were subjected to detailed thermal demagnetization. The reason for rejecting the pilot method, or rather the treatment of all samples as pilots, was the very varied behaviour of the samples on both AF and thermal demagnetization.

The detailed demagnetization of each specimen revealed the complex nature of the magnetization. The separation of the components was helped by the method of subtracted vectors [Hoffman and Day 1978] though it could not be used in its original form. The components of the remanence in the Mecsek granitoids did not obey the rules required by the method, except the one aligned with the present field, which was removed at a very early stage of cleaning. Two components, significantly different from the present local field direction, were more resistant. The components were first identified in samples where one of them dominated over the whole blocking spectrum above 300 °C as characteristic magnetization. In a number of samples however, the NRM was complex: the direction of the removed magnetization alternated between two directions. In samples with complex magnetization one of the components was weakly magnetic but resistant on termal cleaning; the other, more intensive and less resistant. The more intensive component unblocked in a narrow 50–100 °C interval, always below the Curie point of the magnetite.

In samples with complex remanence above 300 °C the more intensive component (component I) was identified as removed remanence during the intensity fall on the assumption that the subtracted vector was only insignificantly biased towards the direction of the weak component. The weak component (component II) survived the intensity fall as a single-component magnetization [Márton 1980].

After the separation of the components it became evident that the non-uniform directions often observed within a single granitoid locality were meaningful from the tectonic point of view. The direction of component II corresponds to those of the later intruded alkali volcanics. Component I is interpreted as Carboniferous magnetization. The partial or complete remagnetization of the granitoids during the Cretaceous volcanism may be the consequence of regionally elevated temperature or of the chemical changes brought about by hydrothermal solutions or both.

Complete remagnetization may not be recognized by component analysis, i.e. a secondary remanence may be mistaken for a primary direction. Based on experience gained with the Hungarian granitoids it is recommended that not only the complexity of the remanence of samples be investigated but also the complex magnetic history of a certain area.

4. Proposed palaeomagnetic standard for the 80s

Today the complete demagnetization and analysis of the whole blocking or coercivity spectrum is gaining ground as a routine procedure since more and more researchers realize that it is only a single magnetic component that can be interpreted in any terms.

Briden and Duff in 1981 published the first and so far the only system of classifying palaeomagnetic directions that is not simply an enumeration of rejection criteria. In 1983, at the meeting of the Palaeomagnetic Team of IGCP project 5 in Budapest, I suggested the use of a modified version, which I later improved and supplemented with rejection criteria *(Fig. 2)*.

The rejection criteria of Fig. 2 serve to eliminate the poorest palaeomagnetic directions. The definition of a site is taken from Tarling [1983. p. 76], viz. "A volume of material that can be considered to have been magnetized at the same time, e.g. sediments from the same stratigraphic level or thin lavas or dykes".

The criteria for classification of *group I* are self-explanatory: they characterize the quality of the laboratory investigation.

Group II criteria need some explanation. The tectonic correction is usually best known for sediments, although in strongly deformed areas it may be a problem (plunging fold axis combined with high dip angle). For igneous rocks either no tectonic correction is applied (e.g. migmatites or large intrusive bodies) or the correction is estimated by the position of the enclosing sediments. For metasediments the plane of the original bedding provides guidance but the measured remanence direction of a metamorphic rock is usually not easy to correct for post-magnetization movements.

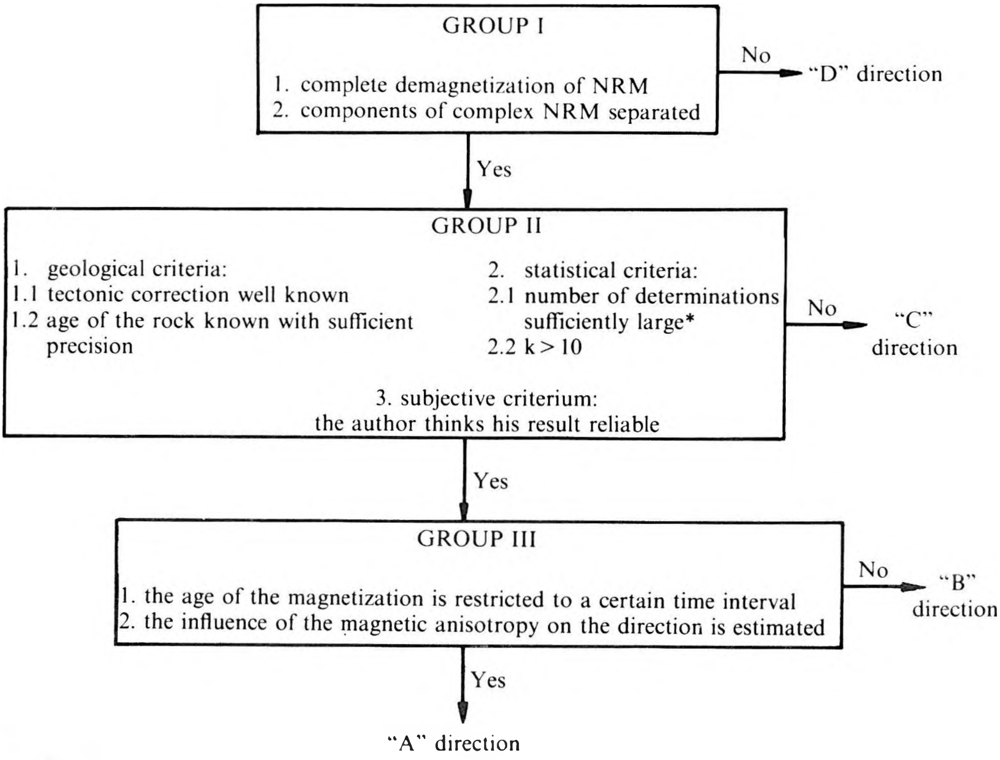
The age of the rock should be known with a precision suited to the problem. For instance, a loose age assignment, like a period, is sufficient when the apparent polar wandering is slow and only large relative movements are studied. On the other hand, ages should be known to stages when, for instance, Mesozoic movements are traced within the Mediterranean area.

The number of samples has always been regarded important in a palaeomagnetic work but no distinction has been made between results representing a point reading of the magnetic field and those averaging out the secular variation. My suggestion is that the number of samples, sites, localities should

REJECTION CRITERIA

- no laboratory cleaning
- less than 3 sites
- $k < 5$
- age is not known to an era
- reappraisal found the direction incorrect

CRITERIA FOR CLASSIFICATION
Full documentation is required



*II.2.1

extrusive rocks: (point readings of the magnetic field)	6 independent igneous bodies, minimum 3 samples per body
large intrusions or metamorphic rocks	6 different parts sampled, minimum 3 samples per place
sedimentary rocks	16 samples from minimum 6 different strata

Fig. 2. Chart for the classification of palaeomagnetic directions to be interpreted in terms of tectonics

2. ábra. A tektonikai értelmezésben felhasználni kívánt paleomágneses irányok osztályozása

Рис. 2. Классификация палеомагнитных направлений для целей тектонической интерпретации depend on the rock type (Fig. 2). Moreover, the statistical parameter, k [Fisher 1953], which characterizes the scatter, should be given equal weight with the number of samples, sites, localities. The statistical parameter k is increased only when better quality results are used for statistical evaluation, i.e. in a way independent of the number of determinations (sites, samples), while α_{95} [Fisher 1953], which was earlier used, may be improved by increasing the number of determinations.

The subjective criterion belonging to the group II criteria is called so for lack of better terminology. In fact it is the summary of the judgement of a specialist dealing with a certain material based on observations that cannot be systematized. Examples could be that the normal and reversed directions within an age group are 180° apart (applicable only when both polarities are present), or the high stability of the magnetization may indicate the old age of the NRM, but equally possibly the secondary, chemical origin of the magnetization.

Group III criteria are very hard to satisfy. In general, the age of the magnetization for folded sediments may best be restricted between the age of folding and the stratigraphic age; going a step further we may say that if the magnetization was sufficiently stable to survive a folding process, it should be a primary magnetization.

The influence of magnetic anisotropy on the direction of the remanence may be estimated on theoretical grounds or by laboratory experiments. It is generally agreed, however, that below 5 percent of anisotropy, the influence is less than the measuring error [Irving 1964, McElhinny 1973].

The system of criteria summarized in Fig. 2 may seem to be too rigorous even in the mid 80s. It has, however, a great advantage over any simple rejection system: it permits one to rely on a palaeomagnetic result to an extent dependent on the quality of a direction. With the help of these criteria, the better established directions may be given more weight in any kind of interpretation.

5. Geology of the Velence Hills and the Mecsek Mountains

The quality of a palaeomagnetic determination is influenced by geological factors (Fig. 2, group II: geological criteria). Moreover, the laboratory work and the interpretation of the magnetic signal may be helped by information concerning the formation, homogeneity, and secondary alteration of the studied rocks. In this section the geological observations relevant to palaeomagnetism will, therefore, briefly be discussed.

The Velence granite is a high level intrusion, homogeneous and well differentiated [Jantsky 1957, Buda 1969, Pantó 1980]; The Mecsek granite is of anatectic origin, very varied in composition and texture [Buda 1969, Jantsky 1977, Pantó 1980].

The Velence granite is surrounded by phyllite. The regional metamorphism predates the intrusion. The phyllite enveloping the granite is thought to belong to the metamorphic series of the Balaton Highlands, and these include diabase outcropping on Gécsi Hill and cored at Székesfehérvár. The phyllite suffered weak contact metamorphism but was more altered chemically by magmatic fluids.

The contact of the Velence granite intrusion with the phyllite is tectonic. Only the northern part of the intrusion is on the surface, the southern part is covered [JANTSKY 1957].

The Mecsek granitoids in the Mórágy Ridge have no sharp contact with the neighbouring amphibolites. The northern rim of the Mórágy Ridge consists of rocks metamorphosed to a lesser degree (between greenschist and amphibolite facies), with peridotites, originally serpentinite [GHONEIM and SZEDERKÉNYI 1979].

Judging from geological observations the Velence granite is of late Carboniferous age. The intrusion is dated geologically by the Visean age of the phyllite, which has been altered by the postmagmatic fluids of the granite and the appearance of turmalin-bearing aplite and schist in the Permian conglomerate, respectively [JANTSKY 1957]. Dating by K/Ar gives 280–290 Ma [BALOGH et al. 1983]. The intrusion of the main granite body was followed by the formation of granite-, granite-porphyry-, and aplite dykes [JANTSKY 1957].

The age of the Mecsek granitoids is debated. Based on analogies and earlier determined but later revised Rb/Sr ages the migmatization was though to be of Precambrian age: 1000–1200 Ma [JANTSKY 1977]. Jantsky suggested that a second metamorphic event of a lower grade followed the ultrametamorphism between 520 and 700 Ma. Recently isotope ages were determined by different methods. Whole rock Rb/Sr [SVINGOR and KOVÁCH 1981], K/Ar [BALOGH et al. 1983], and U/Pb [BALOGH et al. 1983] dates all point to Carboniferous granitization. The oldest age is given by the U/Pb method: 365 ± 8 Ma, which is probably the age of the migmatitic process, while the end of the granitization may be marked by the K/Ar age measured on biotites which is 334 ± 11 Ma.

It is generally agreed that the granite dykes and aplites intruded the migmatites in the Carboniferous.

Post-Carboniferous andesite volcanism has been known for a long time in the Velence granite area. SCHRÉTER and MAURITZ [1952] found evidence for late Eocene age since they observed andesite tuff intercalated with fossiliferous late Eocene sediments in the northern foreground of the Velence Hills. A slightly younger age, about 30 Ma, is indicated by the lavas (K/Ar isotope age: 30 Ma, BALOGH, pers. comm.). Recently the products of an extreme alkali magmatism have been recognized in the Transdanubian Central Range. One monchiquite dyke belonging to this volcanism crops out at the western part of the Velence Hills [HORVÁTH, pers. comm.). The K/Ar age is about 60 Ma [BALOGH, pers. comm.].

In the Mecsek Mts. Permian rhyolite volcanism (Rb/Sr age 222 ± 45 Ma, KOVÁCH 1973), Triassic and Jurassic andesite volcanism [SZEDERKÉNYI, pers. comm.], Cretaceous alkali volcanism and Neogene andesite volcanism (K/Ar age: 20–21 Ma, ÁRVA-SOÓS and RAVASZ 1978) are known. Of the four, the products of the Cretaceous alkali volcanism are widespread in the Mórágy

Ridge. Earlier, the alkali volcanism was dated with fossils as Valanginian–Hauterivian [Vadász 1960]. More recent observations indicate that the volcanism lasted longer: it started in the late Jurassic and reached its maximum intensity in the early Cretaceous with basaltic composition (the products of this volcanism were subjected to low-grade metamorphism, Szilágyi 1979), while the lava bodies that are devoid of any sign of metamorphism and/or cut through folded structures must have intruded after the Austrian orogeny, i.e. in the late Cretaceous [Némedi Varga 1983].

6. Palaeomagnetism of the igneous rocks from the Velence Hills

6.1 Sampling

Sampling sites for the different rocks of the Velence Hills are presented in *Fig. 3*.

Sampling of the andesite and the monchiquite

Two dykes were drilled at the western end of Sukoró village (sites 1 and 2), one at the eastern end (site 3). North of the same village three sites (4–6) were sampled. Site 7, was cored at the north end of Sukoró, site 8 in the Nadap granite quarry. The single outcrop of the monchiquite that was found (site 30) is close to Pákozd.

Sampling of the granite and its metamorphic envelope

The main granite intrusion and the dykes (granite, granite porphyry, aplite) were tested at 16 points: some are close to the andesite outcrops, such as three granite porphyries at Sukoró (locality 9: pinkish grey; 13: dark red; 17: reddish-brown in colour), a quarry with fine-grained grey granite (locality 21), a fluorite bearing pink granite (locality 22), a red granite and a pink aplite on Gécsi Hill (localities 10 and 11), an autometamorphosed white-grey granite (locality 25). Localities 14 and 15, at the village Kisfaludpuszta (dark red granite porphyry and pink aplite, respectively); locality 18, close to Székesfehérvár (Aranybulla quarry: grey granite dyke) and localities 19 and 20 at Pátka (reddish-brown and grey granite porphyries, respectively) are situated far from the known andesite outcrops, at the western margin of the Velence Hills. Localities 16, 23 and 24 (medium grained pinkish granite, grey granite porphyry dyke and a medium grained pink granite respectively are still within a reasonable distance from the eastern part of the Velence Hills where the andesite is thought to have erupted.

Phyllites that were subjected to moderate contact metamorphism were collected at the northern rim of the granite intrusion (localities 26–29), and the single outcrop of the diabase (12), belonging to the metamorphic envelope of the granite, was drilled at Gécsi Hill.

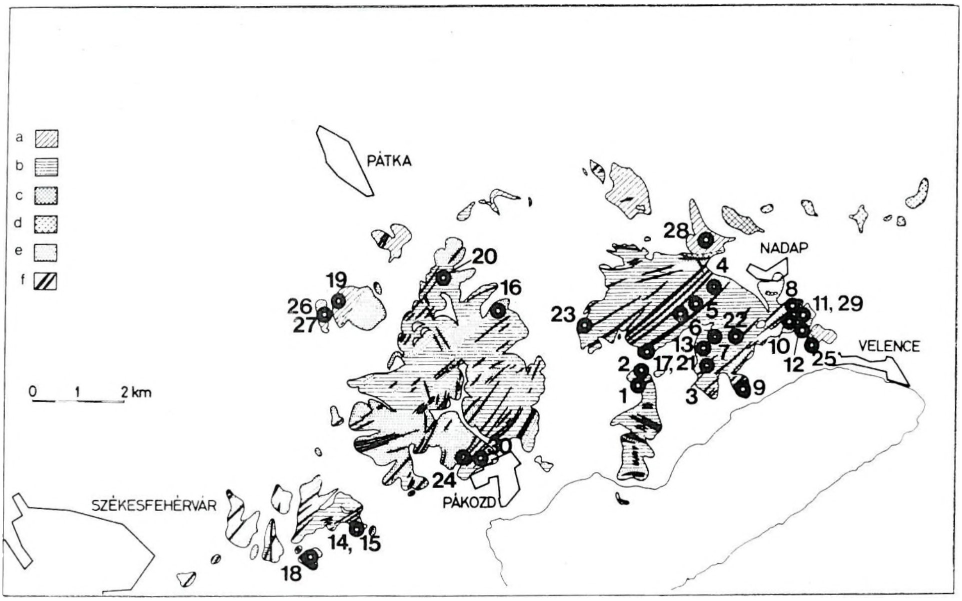


Fig. 3. Geological sketch map of the Velence Hills with the palaeomagnetic sampling sites and localities
a — schist; b — the main granite intrusion; c — andesite; d — hydrothermally altered andesite; e — altered granite; f — granite porphyry and aplite dykes; 1–8 — sampling sites for the andesite; 9–11 and 13–25 — sampling localities for the granite; 12 and 26–29 — sampling localities for the metamorphic envelope of the granite

3. ábra. A Velencei-hegység vázlatos földtani térképe a paleomágneses mintavételi helyekkel
a — pala; b — gránit; c — andezit; d — hidrotermálisan bontott andezit; e — mállott gránit; f — gránitporfir- és aplittelérek; 1–8 — mintavételi helyek andezitben; 9–11 és 13–25 — mintavételi helyek gránitban; 12 és 26–29 — mintavételi helyek a gránit metamorf burkában

Рис. 3. Схематическая геологическая карта Веленцейских гор с точками отбора проб на палеомагнитные определения
а — сланцы; b — граниты; с — андезиты; d — гидротермально измененные андезиты; е — измененные граниты; f — дайки гранитпорфиров и аплитов; 1–8 — точки отбора проб из андезитов; 9–11 и 13–25 — точки отбора проб из гранитов; 12 и 26–29 — точки отбора проб из метаморфического чехла гранитов

6.2 Laboratory treatment

The NRM of the magnetically oriented samples was measured with JR–4 spinners, the magnetic susceptibility on a KLY–1 susceptibility bridge. One specimen per sample was subjected to stepwise cleaning. The andesite was demagnetized progressively in AF field (the demagnetizers used were a Schonstedt GSD–1 and an AF demagnetizer built at the Technical University of Budapest). In addition, all sister samples from site 6 were subjected to stepwise thermal demagnetization to check on the carriers of the magnetization since the specimens showed uncommonly resistant behaviour for a magnetite (the expected carrier of the NRM in basalts and andesites). The monchiquite was cleaned thermally.

Two sister specimens were demagnetized from each granite and metamorphic sample: one by progressive heating and cooling in a field-free space, the other either by progressive AF or by heating at one or more temperatures depending on the behaviour of the stepwise heated sister specimen. During thermal cleaning the possible change in magnetic mineralogy was monitored by measuring the magnetic susceptibility at each heating step.

6.3 Results

Andesites (Fig. 3, sites 1–8)

Most of the andesite specimens cleaned readily in AF. Either the secondary magnetization (acquired in the Earth's present magnetic field) was insignificant (e.g. site 3) or was practically removed at an early stage of the cleaning *(Figs. 4/a* and *5/a)*. Thermal cleaning, where applied, was less efficient and of course more time-consuming than AF cleaning *(Fig. 4/a)*. Nevertheless, it was worth doing for it revealed that the natural remanence was carried by three different magnetic minerals:

a) maghemite (decrease in susceptibility between 250 and 525 °C accompanied by a marked change in direction of the NRM),

b) magnetite (slight change in susceptibility combined with a sudden decrease in the intensity of the NRM between 525 and 550 °C), *(Fig. 4/b)*

c) haematite (part of the NRM survives at 585 °C).

Moreover, analysis of the NRM showed that the secondary magnetization along the present field resided in maghemite while the magnetite and the haematite reflected the same field direction—away from the present local field (in Fig. 4/a both D and I decrease towards the origin as a straight line, from 525 °C onwards).

Рис. 4. Веленцейские горы. Поведение естественной остаточной намагниченности при размагничивании. Диаграмма наклонение (I) — склонение (D)

a) Андезиты, точка № 6: поведение выборочных проб при размагничивании переменным током и при термальном размагничивании, соответственно. 1 единица = $8 \cdot 10^{-2}$ А/м Точки: термальное размагничивание, ступени чистки (1–10): естественная намагниченность, 100, 200, 250, 300, 400, 480, 525, 550, 580 °C. Кружки: размагничивание переменным током, ступени чистки (1–8): естественная намагниченность, 0,02, 0,03, 0,04, 0,05, 0,06, 0,1, 0,12 тесла

b) Мончикиты, точка № 30: изменение естественной остаточной намагниченности при термальном размагничивании. 1 единица = $1{,}6 \cdot 10^{-1}$ А/м

⇨

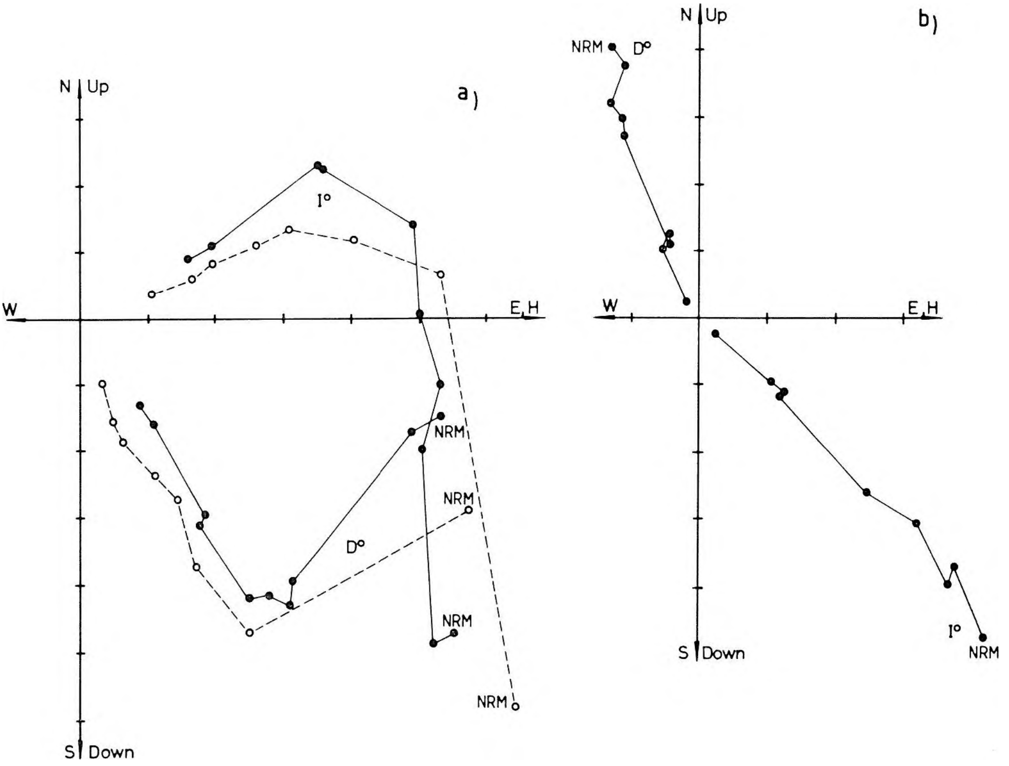


Fig. 4. Velence Hills. Behaviour of the NRM on demagnetization. Declination (*D*) and inclination (*I*) plots

a) Andesite, site 6: change in NRM of sister specimens on AF and thermal demagnetization, respectively. 1 unit = $8 \cdot 10^{-2}$ A/m

Dots: thermal demagnetization, cleaning steps (1–10): NRM, 100, 200, 250, 300, 400, 480, 525, 550, 580 °C. Circles: AF demagnetization, cleaning steps (1–8): NRM, 0.02, 0.03, 0.04, 0.05, 0.06, 0.1, 0.12 Tesla

b) Monchiquite, site 30: change in NRM on thermal demagnetization. 1 unit = $1.6 \cdot 10^{-1}$ A/m

4. ábra. Velencei-hegység. Az NRM viselkedése lemágnesezéskor. Deklináció (*D*) és inklináció (*I*) ábra

a) Andezit, 6. mintavételi hely: az NRM viselkedése váltóterű és termális lemágnesezéskor. 1 egység = $8 \cdot 10^{-2}$ A/m

Pontok: termolemágnesezés, tisztítási lépések (1–10): NRM, 100, 200, 250, 300, 400, 480, 525, 550, 580 °C. Körök: váltóterű lemágnesezés, tisztítási lépések (1–8): NRM, 0,02, 0,03, 0,04, 0,05, 0,06, 0,1, 0,12 Tesla

b) Monchiquit, 30. mintavételi hely: az NRM viselkedése termális lemágnesezéskor. 1 egység = $1{,}6 \cdot 10^{-1}$ A/m

As a result of cleaning, all the studied andesite dykes (all the known outcrops were sampled) yielded statistically well defined directions (in *Table I* k: large, α_{95}: small). The overall mean based on 8 sites is:

$$D = 144° \quad I = -44° \quad k = 14 \quad \alpha_{95} = 15.1°$$

Monchiquite (Fig. 3, site 30)

All 10 cores, collected at a single outcrop, were subjected to cleaning by stepwise heating after 0.01 T AF. Maghemite and magnetite were recognized in the samples, both being magnetized along the same field direction. As seen in *Fig. 5/b* the maghemite started to convert to a stable mineral phase from 350 °C on, but the direction remained unchanged. Cleaning above 500 °C resulted in a good grouping of the directions:

$$D = 334° \quad I = 43° \quad k = 33 \quad \alpha_{95} = 8.5°$$

based on 10 cores.

Granites and metamorphic envelope (Fig. 3, localities 9–25)

The overprint component along the present local field is not as conspicuous as in the andesites. It can be detected, however, as removed magnetization below a maximum of 500 °C *(Fig. 6)*. Characteristic magnetization may be defined for most of the granites and for the diabase but they fall into two groups.

In the first group (localities 9–16) even complete demagnetization *(Fig. 7)* fails to reveal any direction different from that of the present local field or from that of the andesites (*Fig. 8, Table II* polarity is indifferent to direction). The overprint due to recent remagnetization is easily removed. The characteristic magnetization is similar to the characteristic remanent magnetization (ChRM) of the andesites. It is interpreted therefore as secondary remanence acquired during the andesite volcanism. It is interesting to note that complete remagnetization is not dependent on the magnetic mineralogy: haematite *(Fig. 9/a)* as well as magnetite *(Fig. 9/b)* may be the carrier of the secondary remanence.

The fully remagnetized andesites are treated as representatives of the Earth's magnetic field direction at the time of the andesite volcanism. Thus the mean at the time of the andesite volcanism may be estimated from the directions for both andesites and remagnetized older rocks:

$$D = 151° \quad I = -45° \quad k = 22 \quad \alpha_{95} = 8.4°$$

The direction, based on 8 andesite sites and 7 granite and 1 diabase localities, is a better approximation to the average direction of the Earth's magnetic field than the mean based on the 8 andesite dykes.

The second group of granites (localities 21–25) allows the identification of a magnetic direction different from both the direction of the present field and that of the field at about 30 Ma ago. The dominant carrier of the ChRM in this group seems to be magnetite, but minor haematite may also be detected.

Sampling sites, codes refer to Fig. 3	After AF cleaning								Before cleaning			
	N	$\bar{D}^\circ$	$\bar{I}^\circ$	k	α_{95}°	$\bar{I}_n$	$\bar{\kappa}$	$\bar{Q}_n$	$\bar{D}^\circ$	$\bar{I}^\circ$	k	α_{95}°
1. W of Sukoró	4	146	−49	129	8.1	$12 \cdot 10^{-4}$	$31 \cdot 10^{-4}$	0.8	158	−54	52	12.9
2. W of Sukoró	3	147	−48	81	13.8				122	−50	4	50.6
3. Sukoró, E side	9	144	−33	85	5.6	$14 \cdot 10^{-4}$	$3 \cdot 10^{-4}$	7.8	140	−26	70	6.2
4. Meleg Hill, S slope	4	155	−33	101	19.2	$2 \cdot 10^{-4}$	$21 \cdot 10^{-4}$	0.2	306	−36	4	53.8
5. N of Sukoró	3	163	−37	79	14.0	$5 \cdot 10^{-4}$	$34 \cdot 10^{-4}$	0.3	132	5	8	45.4
6. N of Sukoró	5	144	−22	42	11.9				107	42	13	22.5
7. Sukoró, N side	4	169	−44	16	23.3	$4 \cdot 10^{-4}$	$32 \cdot 10^{-4}$	0.2	54	64	20	21.3
8. Nadap, granite quarry	8	155	−62	25	11.2	$4 \cdot 10^{-4}$	$36 \cdot 10^{-4}$	0.2	8	77	4	37.4

Table. I. Velence Hills, andesite dykes. Palaeomagnetic results. N — number of samples; D° and I° — mean declination and inclination; k, α_{95} — statistical parameters commonly used in palaeomagnetism [Fisher 1953]; $\bar{I}_n$ — mean intensity of magnetization, $\bar{\kappa}$ — mean magnetic susceptibility, both in CGS units; $\bar{Q}_n$ — mean Koenigsberger ratio

I. táblázat. Velencei-hegység, andezit telérek. Paleomágneses eredmények. N — minták száma; D° és I° — közepes deklináció és inklináció; k, α_{95} — a paleomágnességben általában használt statisztikus paraméterek [Fisher 1953]; $\bar{I}_n$ — a remanens mágnesezettség átlagos intenzitása; $\bar{\kappa}$ — közepes mágneses szuszceptibilitás, mindkettő CGS egységben; $\bar{Q}_n$ — Koenigsberger viszonyszám

Табл. I. Веленцейские горы, дайки андезитов. Палеомагнитные данные. Условные обозначения: N — количество проб: D°, I° — средние склонение и наклонение: k, α_{95} — статистические параметры, обычно используемые в палеомагнетизме [Fisher 1953]; $\bar{I}_n$ — средняя интенсивность намагниченности; $\bar{\kappa}$ — средняя магнитная восприимчивость, обе — в единицах CGS: Q_n — среднее значение параметра Кёнигсбергера

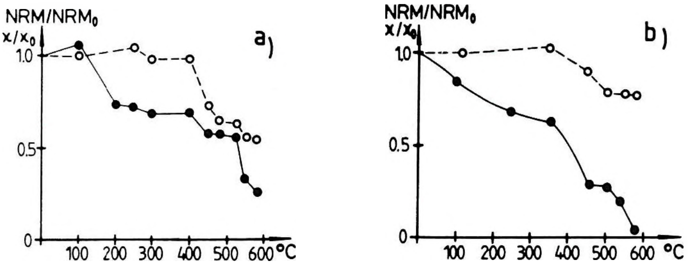


Fig. 5. Velence Hills. Normalized intensity (dots) and susceptibility (circles) curves for thermally demagnetized specimens

a) Andesite, site 6

b) Monchiquite, site 30

5. ábra. Velencei-hegység. A kezdeti értékkel normált intenzitás (pontok) és szuszceptibilitás (körök) görbék a hőmérséklet függvényében

a) Andezit, 6. mintavételi hely

b) Monchiquit, 30. mintavételi hely

Рис. 5. Веленцейские горы. Кривые нормализованной интернсивности (точки) и восприимчивости (кружки) проб после термической чистки

а) Андезиты, точка № 6

b) Мончикиты, точка № 30

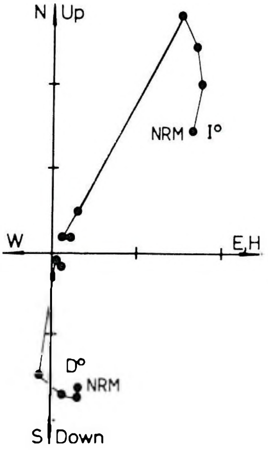


Fig. 7. Velence Hills. Granite aplite, locality 10. Declination–inclination plot showing the behaviour of the NRM on thermal demagnetization. 1 unit: $4 \cdot 10^{-4}$ A/m. Cleaning steps: NRM, 100, 200, 300, 500, 550, 575 °C

7. ábra. Velencei-hegység. Gránit aplit. 10. mintavételi hely. Deklináció–inklináció ábra, amely az NRM viselkedését mutatja termolemágnesezésre. 1 egység: $4 \cdot 10^{-4}$ A/m. Tisztítási lépések: NRM, 100, 200, 300, 500, 550, 575 °C

Рис. 7. Веленцейские горы. Гранит-аплиты, точка № 10. Диаграмма наклонение–склонение, показывающая поведение естественной остаточной намагниченности при термическом размагничивании. 1 единица = $4 \cdot 10^{-4}$ А/м. Ступени чистки: естественная намагниченность, 100, 200, 300, 500, 550, 575 °C

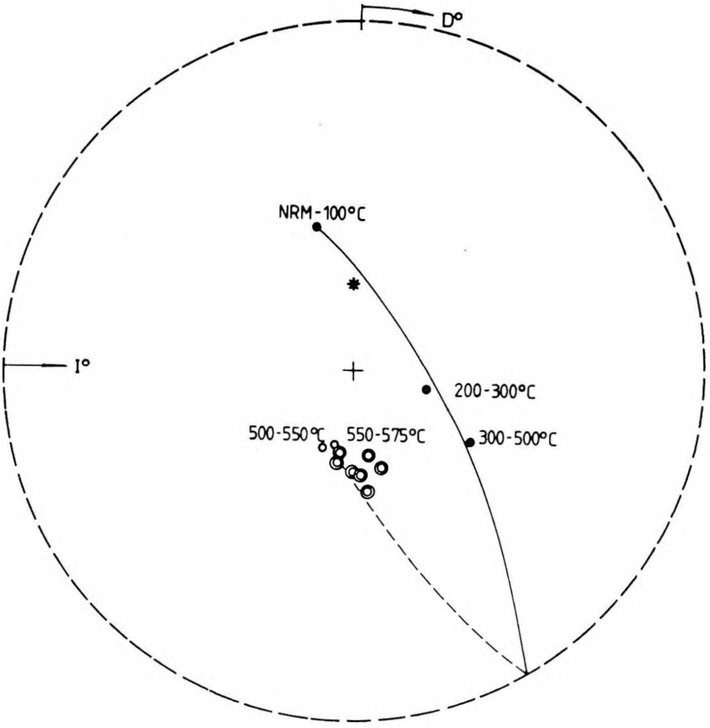


Fig. 6. Velence Hills. Granite aplite, locality 10. Directions of the measured (double circles) and the removed (dots and circles) remanence at and between the temperatures indicated on the plot. Stereographic projection. Solid symbols: positive inclination, hollow symbols: negative inclination. Asterisk: direction of the present local magnetic field

6. ábra. Velencei-hegység. Gránit aplit, 10. mintavételi hely. A mért (kettős körök) és az eltávolított (pontok és körök) remanens mágnesezettség iránya az ábrán jelzett hőmérsékleteken. Szögtartó vetület. Teli jelek: pozitív inklináció, üres jelek: negatív inklináció. Csillag: a mai helyi mágneses tér iránya

Рис. 6. Веленцейские горы. Гранит-аплиты, точка № 10. Направления измеренной (двойные кружки) и удаленной (точки и кружки) остаточной намагниченности при температурах, фигурирующих на диаграмме, и между ними. Стереографическая проекция. Залитые знаки: положительные наклонения, полые знаки: отрицательные наклонения. Звездочка: направление современного магнитного поля в районе отбора проб

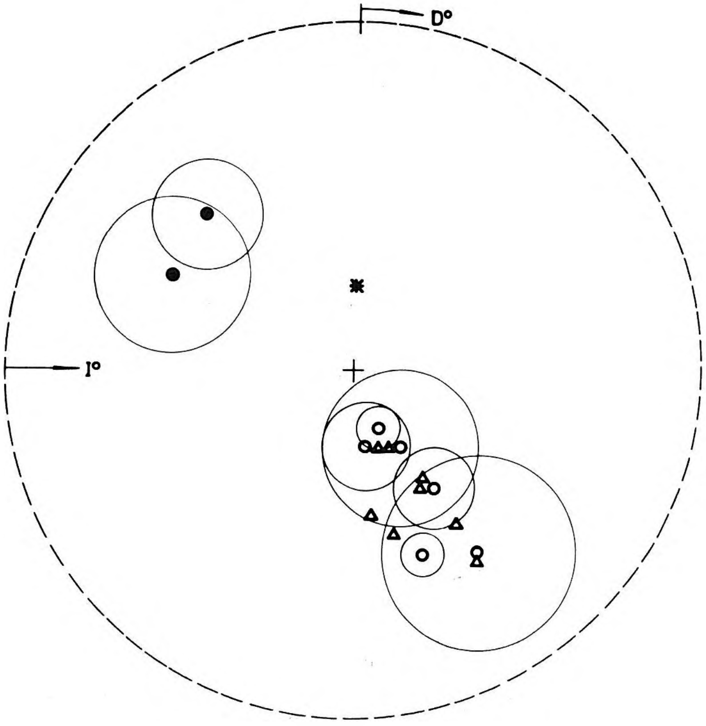


Fig. 8. Velence Hills. Andesites (triangles) and completely remagnetized granites (small circles). Site and locality means. Stereographic plot. Solid symbols: positive inclination, hollow symbols: negative inclination. For the remagnetized granites the confidence circles are shown, too (α_{95}). The present local magnetic field direction is indicated by the asterisk

8. ábra. Velencei-hegység. Andezitek (háromszög) és teljesen átmágnesezett gránitok (kis körök). Mintavételi helyek középiránya szögtartó vetületen. Teli jelek: pozitív inklináció, üres jelek: negatív inklináció. Az átmágnesezett gránitok középirányával együtt a konfidenciakörök (α_{95}) is láthatók. A jelenlegi helyi mágneses tér irányát csillag jelzi

Рис. 8. Веленцейские горы. Андезиты (треугольники) и полностью перемагниченные граниты (малые кружки). Средние по точкам. Стереографическая проекция. Залитые знаки: положительные наклонения, полые знаки: отрицательные наклонения. Для перемагниченных гранитов показан также круг доверия (α_{95}). Современное магнитное поле в районе отмечено звездочкой

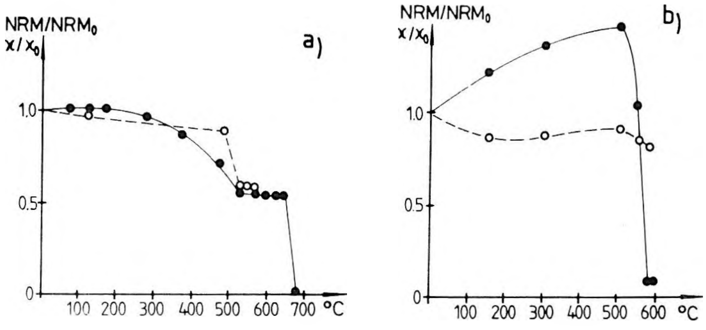


Fig. 9. Velence Hills. Normalized NRM (dots) and susceptibility (circles) versus temperature curves
a) completely remagnetized red granite, b) completely remagnetized granite aplite

9. ábra. Velencei-hegység. Az NRM (pontok) és a szuszceptibilitás (körök) kezdeti értékkel normált értékei a hőmérséklet függvényében
a) teljesen átmágnesezett vörös gránit, b) teljesen átmágnesezett gránit aplit

Рис. 9. Веленцейские горы. Кривые зависимости нормализованной естественной остаточной намагниченности (точки) и магнитной восприимчивости (кружки) от температуры a) полностью перемагниченные красные граниты и b) полностью перемагниченные гранит-аплиты

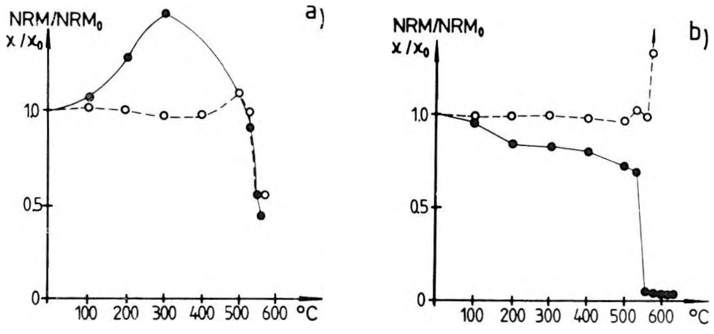


Fig. 10. Velence Hills. Normalized NRM (dots) and susceptibility (circles) versus temperature curves
a) grey granite — locality 21; b) pink granite — locality 24

10. ábra. Velencei-hegység. Az NRM (pontok) és a szuszceptibilitás (körök) kezdeti értékkel normált értékei a hőmérséklet függvényében
a) szürke gránit — 21. mintavételi hely; b) rózsaszín gránit — 24. mintavételi hely

Рис. 10. Веленцейские горы. Кривые зависимости нормализованной естественной остаточной намагниченности (точки) и магнитной восприимчивости (кружки) от температуры
a) серые граниты — точка № 21; b) розовые граниты — точка 24

Sampling localities, codes refer to Fig. 3	N	$\bar{D}^\circ$	$\bar{I}^\circ$	k	α_{95}°	Cleaning	$\bar{\kappa} \cdot 10^{-6}$	$\bar{I}_n \cdot 10^{-6}$
9. Sukoró, granite porphyry dyke	13	158	−30	59	5.4	thermal > 500 °C	12	82
10. Gécsi Hill, granite aplite	7	155	−69	94	6.9	thermal > 500 °C	5	146
11. Gécsi Hill, red granite	5	168	−65	27	14.9	thermal > 550 °C	11	130
12. Gécsi Hill, diabase	6	148	−60	6	24.6	AF 0.18 T	228	1840
13. Sukoró, red granite porphyry dyke	4	144	−24	14	25.3	thermal > 525 °C	8	3
14. Kisfaludpuszta, red granite porphyry dyke	5	316	+26	34	13.3	thermal > 500 °C	40	61
15. Kisfaludpuszta, granite aplite	5	299	+29	17	19.0	AF 0.03–0.05 T	3	3
16. Ságimajor, granite	7	144	−44	26	12.0	AF 0.03 T	25	11

Table. II. Velence Hills, remagnetized granites. Palaeomagnetic results. Symbols as in Table I

II. táblázat. Velencei-hegység, átmágnesezett gránitok. Paleomágneses eredmények. Jelölések mint az I. táblázatban

Табл. II. Веленцейские горы, перемагниченные граниты. Палеомагнитные данные. Условние обозначения — как в табл. I

Sampling localities, codes refer to Fig. 3	N	$\bar{D}^\circ$	$\bar{I}^\circ$	k	α_{95}°	$\bar{I}_n$	$\bar{\kappa}$
21. Sukoró–Rigó Hill quarry, granite	9	152	35	10	16.9	$9.7 \cdot 10^{-7}$	$1.42 \cdot 10^{-5}$
22. Sukoró–Olasz quarry, granite	13	143	31	9	15.6	$12.8 \cdot 10^{-7}$	$1.08 \cdot 10^{-5}$
23. N of Sukoró, granite porphyry dyke	5	153	29	33	14.3	$6.4 \cdot 10^{-7}$	$2.52 \cdot 10^{-5}$
24. Pákozd–Karácsony Hill quarry, granite	7	140	39	11	19.0	$1.8 \cdot 10^{-7}$	$0.81 \cdot 10^{-5}$
25. Sukoró–Retezi quarry, granite	8	132	16	6	25.9	$29.6 \cdot 10^{-7}$	$0.71 \cdot 10^{-5}$

Table. III. Velence Hills, granites. Palaeomagnetic results. Symbols as in Table I

III. táblázat. Velencei-hegység, gránitok. Paleomágneses eredmények. Jelölések mint az I. táblázatban

Табл. III. Веленцейские горы, граниты. Палеомагнитные данные. Условные обозначения — как в табл. I

Maghemite is not evidenced magnetically in the specimens belonging to this group *(Fig. 10/a)* except for locality 24 *(Fig. 10/b)*. Although overprint components are present, thermal cleaning removes them efficiently *(Fig. 11)*.

The locality means after min. 500 °C cleaning are shown in *Table III* and *Fig. 12*. The overall mean based on 5 localities is:

$$D = 144^\circ \quad I = +30^\circ \quad k = 49 \quad \alpha_{95} = 11.1^\circ$$

The granites from localities 17–20 and all the phyllites failed to yield characteristic magnetizations.

The irregular distributions of the completely remagnetized granite localities and of those with different direction suggest that the remagnetization was caused by the chemical influence of the hydrothermal solutions and that the degree of alteration must have been dependent on the porosity of the granit.

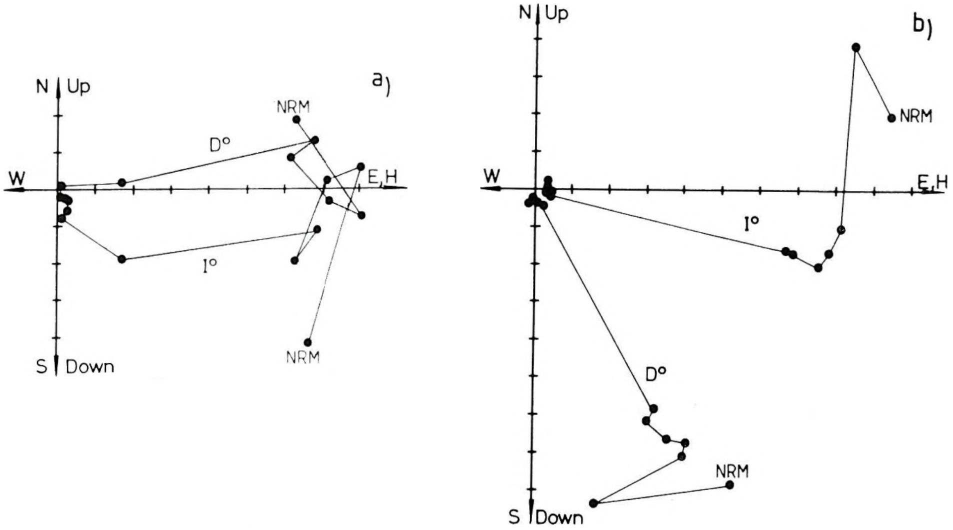


Fig. 11. Velence Hills. Change of the NRM on thermal demagnetization. Declination (*D*) — inclination (*I*) plots. 1 unit = 8 · 10⁻⁴ A/m
a) Grey granite porphyry, locality 23: cleaning steps are NRM, 100, 200, 300, 400, 500, 525, 535, 545 °C
b) Grey granite, locality 21: cleaning steps are NRM, 100, 200, 300, 400, 500, 525, 560, 575, 585, 600, 625 °C

11. ábra. Velencei-hegység. Az NRM változása termolemágnesezésre. Deklináció–inklináció ábra. 1 egység: 8 · 10⁻⁴ A/m
a) Szürke gránit porfir, 23. mintavételi hely, tisztítási lépések: NRM, 100, 200, 300, 400, 500, 525, 535, 545 °C
b) Szürke gránit, 21. mintavételi hely, tisztítási lépések: NRM, 100, 200, 300, 400, 500, 525, 560, 575, 585, 600, 625 °C

Рис. 11. Веленцейские горы. Изменение естественной остаточной намагниченности при термической чистке. Диаграмма склонение (*D*) — наклонение (*I*). 1 единица = 8 · 10⁻⁴ А/м.
а) серые гранит-порфиры, точка № 23: ступени чистки: естественная намагниченность, 100, 200, 300, 400, 500, 525, 535, 545 °C; (серые граниты, точка № 21: ступени чистки: естественная намагниченность, 100, 200, 300, 400, 525, 560, 575, 585, 600, 625 °C

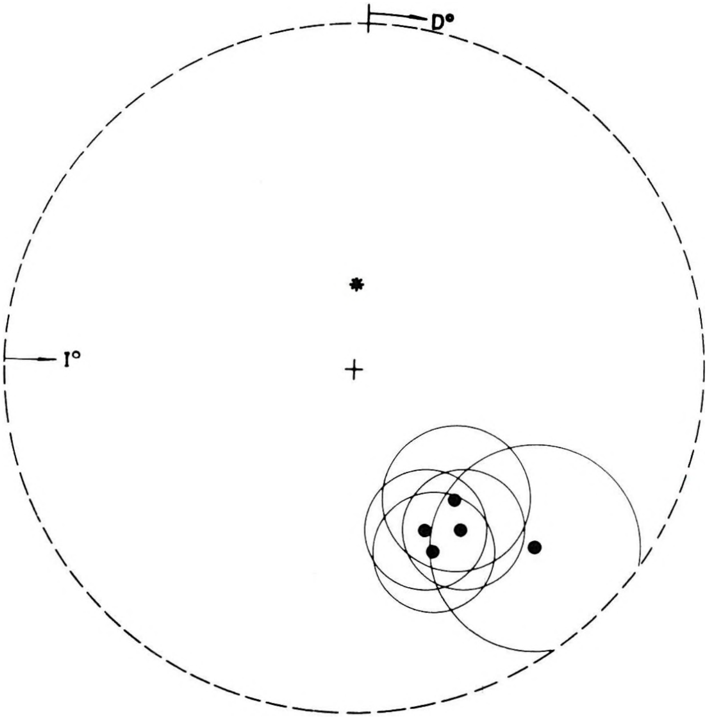


Fig. 12. Velence Hills. Locality means with α_{95} of the granites with independent characteristic magnetization. Stereographic plot. Positive inclinations. Asterisk represents the present local magnetic field direction

12. ábra. Velencei-hegység. Gránitok önálló mágnesezettséggel. A mintavételi helyek középiránya α_{95}-el. Szögtartó vetület, pozitív inklinációk. A csillag a mai helyi földmágneses tér irányát jelzi

Рис. 12. Веленцейские горы. Средние по точкам с α_{95} для гранитов с независимой характерной намагниченностью. Стереографическая проекция. Положительные наклонения. Звездочкой отмечено направление современного магнитного поля в районе

7. Palaeomagnetism of the igneous rocks from the Mecsek Mountains

As was mentioned in section 1, early works on the Cretaceous alkali basalts and related rocks in the Mecsek Mountains [Márton and Márton 1969, 1970, 1971; Dagley and Ade-Hall 1970] preceded the modern analysis of the complex magnetization of the granitoids [Márton 1980]. *Table IV* summarizes the results obtained by different authors and compares the corresponding directions.

I								II						
N	$D°$	$I°$	$D°_c$	$I°_c$	k	$\alpha°_{95}$	Sampling sites, codes refer to Fig. 13	N	$D°$	$I°$	$D°_c$	$I°_c$	k	$\alpha°_{95}$
6	205	−73	158	−52	50	10	17. Jánosipuszta, alkali basalt lava agglomerate	8	236	−75	157	−46	40	9
4	228	−60	180	−53	60	12	18. Márévár valley, alkali basalt lava	10	222	−67	167	−34	169	4
5	299	−39	256	−56	36	13	19. Hosszúhetény, alkali basalt still	6	299	−53	242	−49	15	6
10	82	+62	–	–	112	4	23. Komló, andesite	18	21	+63	–	–	288	2
6*	31	+58	35	+10	15	18	20. Kövestető, phonolite	8	50	+72	20	+34	8	6
5			unstable				Zengővárkony, alkali basalt	8**	9	+68	316	+54	31	10
							pillow lava	8**	345	+70	307	+48	135	5
9			unstable				Márévár valley, alkali basalt lava	8	347	+77	312	+37	28	11
			no sample				Jánosipuszta, alkali basalt lava	8	328	+59	322	+15	237	4
			no sample				Jánosipuszta, alkali basalt lava	8	353	+67	331	+25	27	11
			no sample				Márévár valley, alkali basalt lava	8	347	+88	312	+37	28	11
8	216	−46	274	−64	17	14	22. Máza, phonolite				no sample			

Table. IV. Mecsek Mountains. Compilation of palaeomagnetic results on igneous rocks published before 1975

N — number of determinations on which the statistics is based; $D°$ and $I°$ — declinations and inclination before; $D°_c$ and $I°_c$ — after tilt correction, k and α_{95} — Fisher's precision parameter and the radius of circle of confidence. * result obtained after 1975; ** two groups probably from the same lava flow; I — published in MÁRTON and SZALAY-MÁRTON 1969a; II — published in DAGLEY and ADE-HALL 1970

IV. táblázat. Mecsek hegység. Az 1975 előtt publikált paleomágneses eredmények összefoglalása N — a statisztikai paraméterek becsléséhez figyelembe vett minták száma; $D°$ és $I°$ valamint $D°_c$ és $I°_c$ — deklináció és inklináció tektonikai korrekció előtt, illetve után; k és α_{95} — Fisher pontossági paraméter és a konfidenciakör sugara; * 1975 utáni eredmény; ** a két csoport valószínűleg ugyanabból a lávaárból származik; I — lásd MÁRTON és SZALAY-MÁRTON 1969a; II — lásd DAGLEY és ADE-HALL 1970

Табл. IV.. Мечекские горы. Сводка палеомагнитных данных, опубликованных до 1975 г. по магматическим породам. Условные обозначения: N — количество определений, на которых основана статистика: $D°$ и $I°$ — склонение и наклонение до поправки за наклонное залегание: $D°_c$ и $I°_c$ — то же, после введения поправки за наклонное залегание: k и α_{95} — параметр точности Фишера и радиус круга доверия: * результат, полученный после 1975 г.: ** две группы, вероятно, с одного и того же лавового потока: I — опубликовано в MÁRTON and SZALAY-MÁRTON 1969a: II — opublikovano в DAGLEY and ADE-HALL 1970

The directions shown in Table IV are the results of similar field and laboratory procedures: in the field, magnetic orientation, in the laboratory, AF cleaning was the standard. The Komló andesite is an exception: this was oriented by means of a Sun compass by the British team. The mean directions determined by both teams for the same sites (except Komló) are similar. Nevertheless, the published mean poles for the Cretaceous are very different:

$\Phi = 62°$ $\Lambda = 265°$ (Dagley and Ade-Hall)
$\Phi = 82°$ $\Lambda = 160°$ (Márton and Márton)

respectively. The disagreement is due to the different data base and the different method of interpretation.

First of all, not all sites were sampled by both teams. Secondly, the Hungarian team based the site means on stable samples only, and on one direction per sample. The British team improved the statistics by taking the directions measured at two consecutive cleaning steps on the same specimen as independent observations (!), and with the help of a computer, selected two consecutive cleaning steps for each specimen by testing every possible combination of the directions for a site until the best grouping was achieved. Thirdly, the British team based the overall mean on all site means, no matter how large within-site scatter (and of course the scatter was underestimated) but rejected a statistically very well defined site mean (Hosszúhetény) thinking that the direction was anomalous. Local tectonic correction posed a problem for both teams. According to the geological model of the 60s, the alkali volcanism predated the mid-Cretaceous folding in view of which the obtained magnetic directions had to be tilt-corrected. By doing so the scatter was not reduced—as was remarked on by the British team. The Hungarian team interpreted their results—acceptable even by modern standards—in terms of local tectonics.

Although the difference in the final result was realized by the authors themselves and by others [e.g. McElhinny 1973], the problem was not touched upon again, until the first results on the Cretaceous were obtained from the Mórágy Ridge [Márton 1980].

7.1 Sampling

Sampling sites for the different rocks of the Mecsek Mountains are presented in *Fig. 13*.

Sampling of the granitoids

From the Mórágy Ridge diatexite, nebulite and porphyroblastic granite were collected at locality 1, diatexite and nebulite at locality 2, diatexite and porphyroblastic granite were sampled at localities 4, 5, and 8. Aplites intersecting the migmatites (localities 7 and 8), and a single serpentinite occurence at Ófalu (locality 6) were studied too, this last by Dunkl et al. [1982].

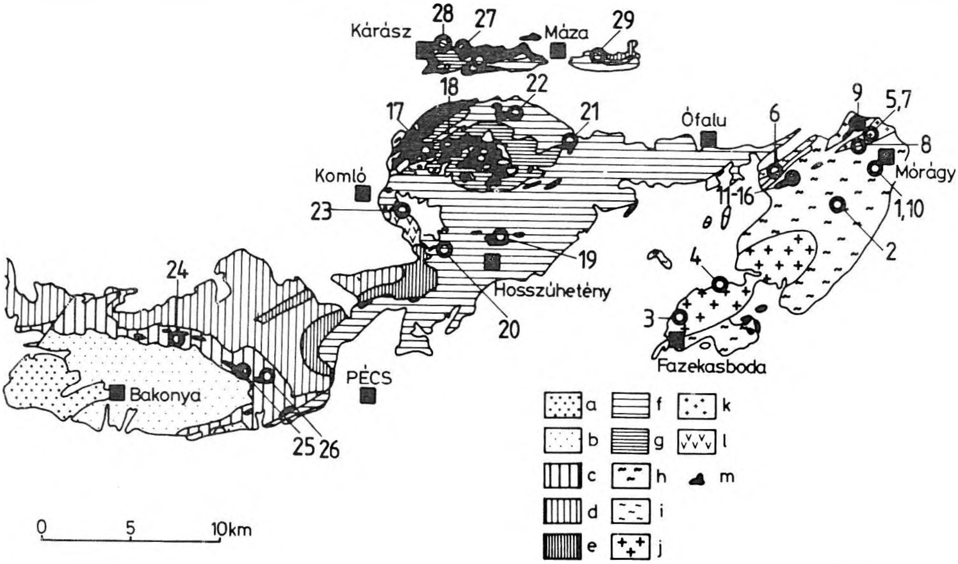


Fig. 13. Geological map of the Mecsek Mountains with the palaeomagnetic sampling sites and localities. Sediments: a — Early Permian; b — Middle and Late Permian; c — Early Triassic; d — Middle Triassic; e — Late Triassic; f — Early and Middle Jurassic; g — Late Jurassic. Metamorphic and igneous rocks: h–k — Palaeozoic: h — migmatite; i — mica schist; j — porphyroblastic granite; k — fine-grained granite. l — Miocene andesite; m — Cretaceous alkali basalts. Sampling localities: 1–5 — granites of migmatitic origin; 6 — serpentinite; 7–8 — aplite; 9–16 — dykes, products of the Cretaceous alkali volcanism in the Mórágy Ridge; 17–22 — lava flows and dykes, products of the Cretaceous alkali volcanism in the Eastern Mecsek; 23 — Miocene andesite; 24–26 — dykes, products of the Cretaceous alkali volcanism in the Western Mecsek; 27–29 — lava flows, dykes and small intrusion, products of the Cretaceous alkali volcanism in the Northern Nappe

13. ábra. A Mecsek hegység földtani térképe a paleomágneses mintavételi helyekkel. Üledékes kőzetek: a — alsó perm; b — középső és felső perm; c — alsó triász; d — középső triász; e — felső triász; f — alsó és középső jura; g — felső jura. Metamorf és magmás kőzetek: h–k — paleozoos: h — migmatit; i — csillámpala; j — porfiroblasztos gránit; k — finomszemű gránit; l — miocén andezit; m — kréta alkáli bazalt. Mintavételi helyek: 1–5 — migmatitos gránitok; 6 — szerpentinit; 7–8 — aplit; 9–16 — kréta alkáli vulkanizmus termékei a Mórágyi Rög területén; 17–22 — a kréta alkáli vulkanizmus termékei a Keleti Mecsekben; 23 — miocén andezit; 24–26 — a kréta alkáli vulkanizmus termékei a Nyugati Mecsekben; 27–29 — a kréta alkáli vulkanizmus termékei az Északi Pikkelyben

Рис. 13. Геологическая карта Мечекских гор с точками отбора палеомагнитных проб Осадочные породы: a — нижняя пермь; b — средняя и верхняя пермь; c — нижний триас; d — средний триас; e — верхний триас; f — нижняя—средняя юра; g — верхняя юра; метаморфические и магматические породы: h–k — палеозойские: h — мигматиты; i — слюдяные сланцы; j — порфиробластовые граниты; k — тонкозернистые граниты; l — третичные андезиты; m — меловые щелочные базальты. Точки отбора проб: 1–5 — граниты мигматитового происхождения; 6 — серпентиниты; 7–8 — аплиты; 9–16 — дайки — продукты мелового щелочного вулканизма в Морадьском блоке; 17–22 — лавовые потоки и дайки — продукты мелового щелочного вулканизма в восточной части Мечекских гор; 23 — третичные андезиты; 24–26 — дайки — продукты мелового щелочного вулканизма в западной части Мечекских гор; 27–29 — лавовые потоки, дайки и мелкие интрузивы — продукты мелового щелочного вулканизма в Северной чешуе

Sampling of the Cretaceous volcanites

Bostonite was collected at sites 9 and 10, trachite at sites 12 and 14, alkali basalt at sites 11 and 13. White and red calcite veins probably connected with the alkali volcanism were sampled at sites 15 and 16 respectively. Sites 11–16 were sampled and processed by Dunkl et al. [1982].

An alkali basalt dyke was collected at site 21 and site 19 was resampled by Sun compass orientation. Phonolite was cored at locality 20.

Alkali basalt dykes were drilled at sites 24–26.

Locality 27 supplied samples both from a lava flow and cutting dykes. One more lava flow was drilled at site 28, and a dyke at 29.

Sampling of the Komló andesite laccolith

One site was sampled from the big quarry near Komló. Orientation was again done by a magnetic compass.

7.2 Laboratory treatment after 1975

The same instruments were used for processing the rocks collected after 1975 from the Mórágy Ridge and other parts of the Mecsek Mountains as for the rocks from the Velence Hills. In addition, an electromagnet capable of creating a maximum field of 0.7 T DC was used for experiments with the isothermal remanence (IRM).

One specimen per sample of the granitoids was AF cleaned, a sister specimen was thermally demagnetized in many steps. The serpentinite was subjected to thermal cleaning only. The possible change in magnetic mineralogy on heating was judged by comparing the spectrum of the isothermal remanent magnetization of the heated and the AF cleaned sister specimens, respectively.

The NRM of the Cretaceous and younger volcanics was treated with AF or thermal demagnetizers or a combination of both (first with AF, then thermal cleaning). Mineralogical change was monitored by susceptibility measurements after each heating step.

The anisotropy of the susceptibility was determined for some of the localities with a DIGICO instrument at the University of Newcastle upon Tyne and with a KLY 1 susceptibility bridge in Budapest.

7.3. Results

Granitoids and serpentinite (Fig. 13, localities 1–8)

The NRM directions exhibited a large scatter before cleaning, except for locality 2. AF cleaning had either no effect on the scatter or even increased it because of the instability of the NRM on AF treatment.

Thermal and AF demagnetization revealed similar characteristic remanences for locality 2 *(Fig. 14)*. Thermal cleaning permitted the isolation of characteristic remanences for localities 7 and 8 *(Fig. 15)*, but these ChRM-s were different from the ChRM of locality 2. The ChRM for locality 2 (for further discussion we call it direction I) was similar to the Permian direction for the Western Mecsek [Kotasek et al. 1969] whereas those for localities 7 and 8 (direction II) to some of the Cretaceous directions for the Eastern Mecsek [Márton and Márton 1969, Dagley and Ade-Hall 1970].

Directions I and II were combined in a complex manner at the other localities. Detailed thermal demagnetization and analysis of both measured and removed remanence at every heating step resulted in the separation of the components. At the same time, the non-uniform direction of the ChRM at some localities became meaningful.

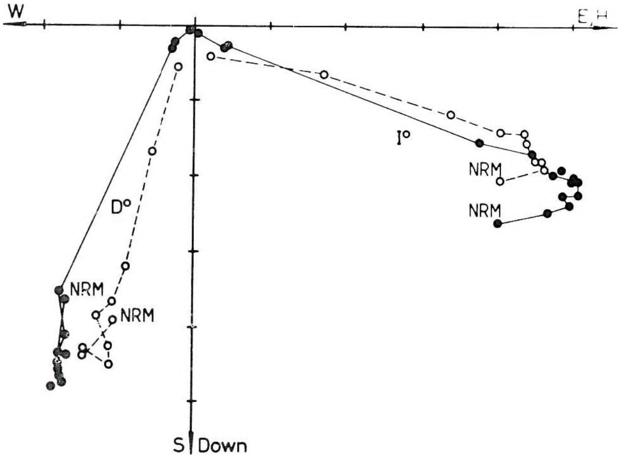


Fig. 14. Mecsek Mountains. Agmatite, locality 2. Behaviour of sister specimens on AF (circles) and thermal (dots) demagnetization. Declination–inclination plot. 1 unit = 8 · 10^{-2} A/m. Cleaning steps, thermal demagnetization: NRM, 100, 150, 200, 250, 300, 350, 400, 450, 500, 550, 575, 625, 650 °C; AF demagnetization: NRM, 0.005, 0.01, 0.015, 0.02, 0.025, 0.03, 0.04, 0.07, 0.1 Tesla

14. ábra. Mecsek hegység. Agmatit, 2. mintavételi hely. Egy mintából kivágott próbák viselkedése váltóterű (pontok) és termo (körök) lemágnesezésre. Deklináció–inklináció ábra. 1 egység: 8 · 10^{-2} A/m. Tisztítási lépések, termolemágnesezés: NRM, 100, 150, 200, 250, 300, 350, 400, 450, 500, 550, 575, 625, 650 °C; váltóterű lemágnesezés: NRM, 0,005, 0,01, 0,015, 0,02, 0,025, 0,03, 0,04, 0,07, 0,1 Tesla

Рис. 14. Мечекские горы. Агматиты, точка № 2. Поведение выборочных проб при размагничивании переменным током (кружки) и термическом размагничивании (точки). Диаграмма наклонение–склонение. 1 единица = 8 · 10^{-2} А/м. Ступени термической чистки: естественная намагниченность, 100, 150, 200, 250, 300, 350, 400, 450, 500, 550, 575, 625, 650 °С. Ступени при чистке переменным током: естественная намагниченность, 0,005, 0,01, 0,015, 0,02, 0,025, 0,03, 0,04, 0,07, 0,1 тесла

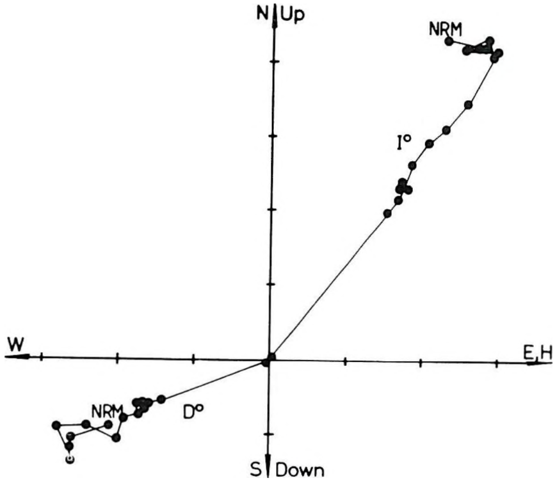


Fig. 15. Mecsek Mountains. Granite aplite, locality 7. Behaviour of the NRM on thermal demagnetization. Declination–inclination plot. 1 unit = $2 \cdot 10^{-3}$ A/m. Cleaning steps: NRM, 100, 150, 200, 250, 300, 350, 400, 450, 500, 550, 575, 600, 625, 650, 675, 700 °C

15. ábra. Mecsek hegység. Gránit aplit, 7. mintavételi hely. Az NRM viselkedése termolemágnesezésre. Deklináció–inklináció ábra. 1 egység: $2 \cdot 10^{-3}$ A/m. Tisztítási lépések: NRM, 100, 150, 200, 250, 300, 350, 400, 450, 500, 550, 575, 600, 625, 650, 675, 700 °C

Рис. 15. Мечекские горы. Гранит-аплиты, точка № 7. Поведение естественной остаточной намагниченности при термическом размагничивании. Диаграмма склонение–наклонение. 1 единица = $2 \cdot 10^{-3}$ А/м. Ступени чистки: естественная намагниченность, 100, 150, 200, 250, 300, 350, 400, 450, 500, 550, 575, 600, 625, 650, 675, 700 °C

Both components were observed as subtracted vectors below 300 °C, except in samples where only direction II was present: I found that the granitoids rich in mafics, such as diatexite and nebulite, and the serpentinite possessed a characteristic remanence parallel to direction I, which was isolated above 300 °C. This direction was sometimes carried by a single low blocking mineral *(Fig. 16)*, sometimes by two, a low and a high-blocking mineral *(Fig. 17)*. The high blocking mineral must be haematite, the low blocking either magnetite or oxidized magnetite *(Fig. 18)*. In a few porphyroblastic granite samples only direction II could be observed; in others, both components. In the latter samples, direction I unblocks in a narrow temperature range below the Curie point of the magnetite, while the surviving direction II usually behaves in a moderately unstable manner. Direction I for the samples with composite remanence was calculated as a subtracted vector between two cleaning steps, before and after the intensity fall, on the assumption that direction II with much lower intensity could not influence significantly direction I. The high resistance but low intensity of direction II in the migmatites points to haematite as the carrier. Because of its diretion *(Fig. 19)*, which is similar to some earlier observed Cretaceous directions from the Eastern Mecsek and to the overall mean of Cretaceous alkali

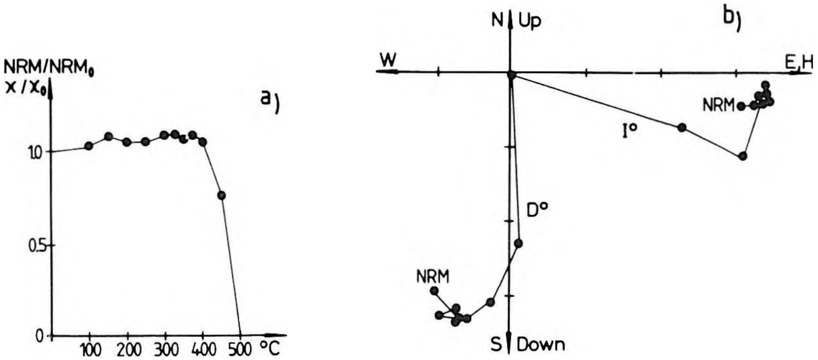


Fig. 16. Mecsek Mountains. Diatexite, locality 1. Behaviour of the NRM on thermal demagnetization

a) Normalized intensity as a function of temperature showing that the NRM disappears at 500 °C

b) Inclination–declination plot. Cleaning steps correspond to those of 16/a. 1 unit = $2 \cdot 10^{-4}$ A/m

16. ábra. Mecsek hegység. Diatexit, 1. mintavételi hely. Az NRM viselkedése termolemágnesezésre

a) A kezdeti értékkel normált intenzitás a hőmérséklet függvényében, amely azt mutatja, hogy az NRM 500 °C-on eltűnik

b) Inklináció–deklináció ábra. A tisztítási lépések megfelelnek az a) ábráénak. 1 egység: $2 \cdot 10^{-4}$ A/m

Рис. 16. Мечекские горы. Диатекситы, точка № 1. Поведение естественной остаточной намагниченности при термическом размагничивании

a) Нормализованная интенсивность как функция температуры; естественная намагниченность исчезает при 500 °C

b) Диаграмма наклонение–склонение. Ступени чистки соответствуют таковым на рис. 16/a. 1 единица = $2 \cdot 10^{-4}$ А/м

rocks from the Mórágy Ridge (see next section), it is clearly a secondary magnetization. It seems very likely, therefore, that direction II resides in the pink feldspars of the migmatites, where the haematite exsolved during the alkali volcanism. Direction I may be the old, Carboniferous direction with the following overall mean:

$$D = 189° \quad I = 18° \quad k = 36 \quad \alpha_{95} = 11.4°$$

based on the 5 granitoid and 1 serpentinite localities of *Table V*. Direction II is either superimposed on direction I, or it is only the remanence observed, depending on the original magnetic mineralogy. Its acquisition is more likely due to the regionally elevated but lower than 300 °C temperature during the alkali basalt volcanism than to the chemical influence of magmatic solutions.

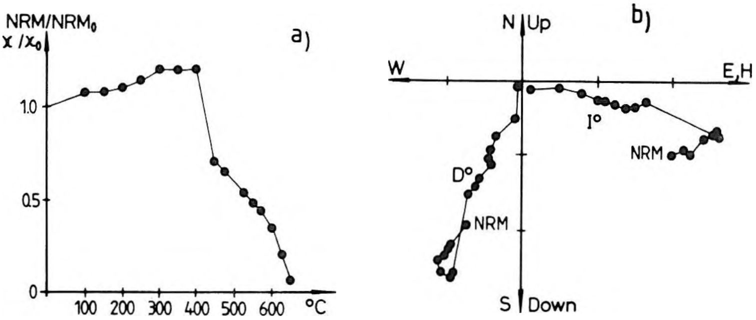


Fig. 17. Mecsek Mountains. Diatexite, locality 1. Behaviour of the NRM on thermal demagnetization

a) Normalized intensity as a function of temperature distinctly showing two magnetic phases,

b) Inclination–declination plot. Cleaning steps correspond to those of 17/a.

1 unit = $2 \cdot 10^{-3}$ A/m

17. ábra. Mecsek hegység. Diatexit, 1. mintavételi hely. Az NRM viselkedése termolemágnesezésre

a) A normalizált intenzitás a hőmérséklet függvényében két mágneses fázist mutat

b) Deklináció–inklináció ábra. Tisztítási lépések megfelelnek az a) ábráénak.

1 egység: $2 \cdot 10^{-3}$ A/m

Рис. 17. Мечекские горы. Диатекситы, точка № 1. Поведение естественной остаточной намагниченности при термическом размагничивании

a) Нормализованная интенсивность как функция температуры; ясно видно присутствие двух магнитных фаз

b) Диаграмма наклонение–склонение. Ступени чистки соответствуют таковым на рис. 17/a. 1 единица = $2 \cdot 10^{-3}$ А/м

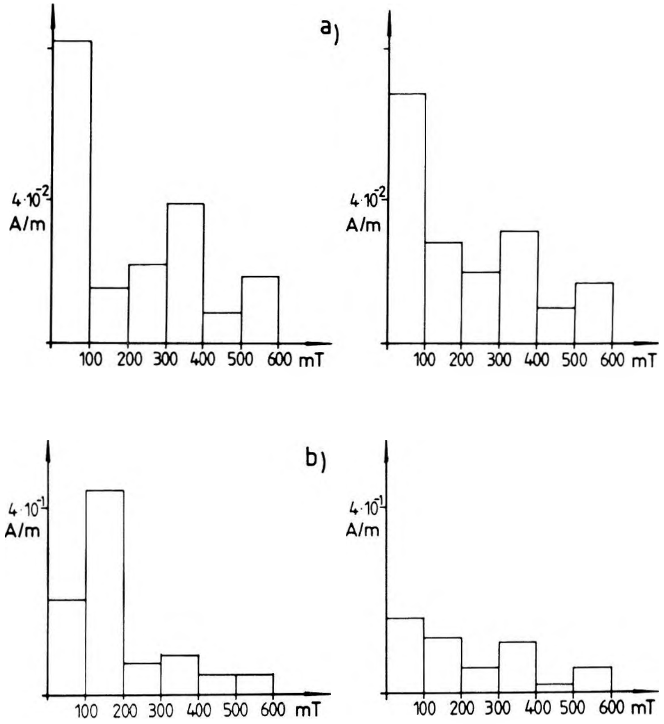


Fig. 18. Mecsek Mountains. Granitoids, locality 1. Isothermal remanence (IRM) acquisition of sister specimens before (left-hand side) and after heating to 500 °C (right-hand side)
a) Little change in the low-blocking phase on heating points to magnetite
b) Considerable reduction in the low-blocking phase points to oxidized magnetite as the carrier

18. ábra. Mecsek hegység. Granitoidok, 1. mintavételi hely. Izotermális remanens mágnesezettség felvétele ugyanabból a mintából kivágott kezeletlen próbán és egy másikon 500 °C-ra történt melegítés után
a) Melegítésre a kis terekben telítődő fázisban csak kis változás észlelhető (magnetitre utal)
b) Melegítésre a kis terekben telítődő fázis átalakul (maghemitre utal)

Рис. 18. Мечекские горы. Граниты, точка № 1. Запись изотермальной остаточной намагниченности по двум образцам из одной и той же пробы, один (слева) без термообработки, другой (справа) с предварительным нагревом до 500 °С
а) при нагревании наблюдается незначительное изменение в фазе, насыщающейся в полях малой интенсивности (указывает на магнетит)
b) при нагревании наблюдается превращение фазы, насыщающейся в полях малой интенсивности (указывает на маггемит)

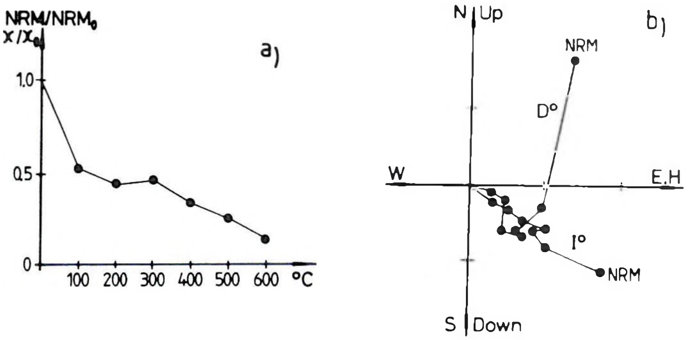


Fig. 19. Mecsek Mountains. Porphyroblastic granite, locality 1. Behaviour of the NRM on thermal demagnetization
a) Normalized intensity as a function of temperature
b) Declination–inclination plot. 1 unit = $8 \cdot 10^{-4}$ A/m.
Cleaning steps correspond to those of 19/a

19. ábra. Mecsek hegység. Porfiroblasztos gránit, 1. mintavételi hely. Az NRM viselkedése termolemágnesezésre
a) Normalizált intenzitás a hőmérséklet függvényében
b) Deklináció–inklináció ábra. 1 egység: $8 \cdot 10^{-4}$ A/m. A tisztítási lépések megfelelnek az a) ábráénak

Рис. 19. Мечекские горы. Порфиробластовые граниты, точка № 1. Поведение естественной остаточной намагниченности при термическом размагничивании.
a) нормализованная интенсивность как функция температуры,
b) диаграмма наклонение–склонение. 1. единица = $8 \cdot 10^{-4}$ A/м. Ступени чистки соответствуют таковым на рис. 19/a

Cretaceous alkali rocks

a) Mórágy Ridge

Compared with the NRM of the migmatites, the remanence of the alkali rocks is very simple *(Fig. 20)*. The directions after cleaning depart from the present field direction. Normal and reversed polarities lie 180° apart. The overall mean direction based on 8 sites is:

$D = 93°$ $I = 60°$ $k = 27$ $\alpha_{95} = 10.8°$

The mean direction will not change by adding the two granite aplite localities to the Cretaceous sites (Table V, localities 7 and 8). This procedure is permitted regardless of the mechanism of the aquisition of the NRM in the aplites, which may be similar to the way the porphyroblastic granites acquired direction II, or may be different, e. g. thermoremanent magnetization. This latter mechanism could explain better the high intensity of direction II in the aplites (Fig. 15), but it would imply that the aplites are of Cretaceous age, thus contradicting the isotope ages.

Locality		N	D°	I°	k	α_{95}°	Cleaning
Older than Mesozoic rocks							
1. Mórágy, quarry	diatexite, nebulite, porphyroblastic granite	11	182	14	28	8.8	300–550 °C
2. Üveghuta, quarry	diatexite, nebulite	7	188	15	26	12.1	450 °C
3. Lochmalom, quarry	diatexite, porphyroblastic granite	4	190	30	12	27.2	300–550 °C
4. Erdősmecske, quarry	porphyroblastic granite	5	199	20	8	25.8	300 °C
5. Mórágy, railway station (quarry I.)	porphyroblastic granite	5	194	−2	14	21.0	300–550 °C
6. Ófalu, outcrop	serpentinite	8	183	31	11	21.5	400 °C
7. Mórágy, railway station (quarry I.)	aplite	5	99	40	19	18.3	400–600 °C
8. Mórágy, railway station (quarry II.)	aplite	5	92	51	25	15.8	400 °C
Mesozoic rocks							
9. Mórágy, railway station (quarry III.)	bostonite	6	261	−56	11	21.4	0.04 Tesla
10. Mórágy, quarry	bostonite	3	114	43	43	19.1	600 °C
11. Ófalu, outcrop	alkali basalt	3	38	65	71	14.8	400 °C
12. Ófalu, outcrop	alkali basalt trachite	4	106	75	104	9.0	300 °C
13. Ófalu, outcrop	alkali basalt	3	109	61	9	33.3	400 °C
14. Ófalu, outcrop	trachite	3	113	61	8	29.6	300 °C
15. Ófalu, outcrop	white calcite vein	4	93	53	21	20.3	400 °C
16. Ófalu, outcrop	red calcite vein	5	80	52	45	11.6	300–400 °C
Mean values for older than Mesozoic magnetizations (1–6)		6	189	18	36	11.4	
Mean values for younger than Palaeozoic magnetization (7–16)		10	94	57	28	9.3	

Table. V. Mórágy Ridge. Palaeomagnetic results. Symbols as in Table I

V. táblázat. Mórágyi Rög. Paleomágneses eredmények. Jelölések mint az I. táblázatban

Табл. V. Морадьская Глыба. Палеомагнитные данные. Условные обозначения — как в табл. I

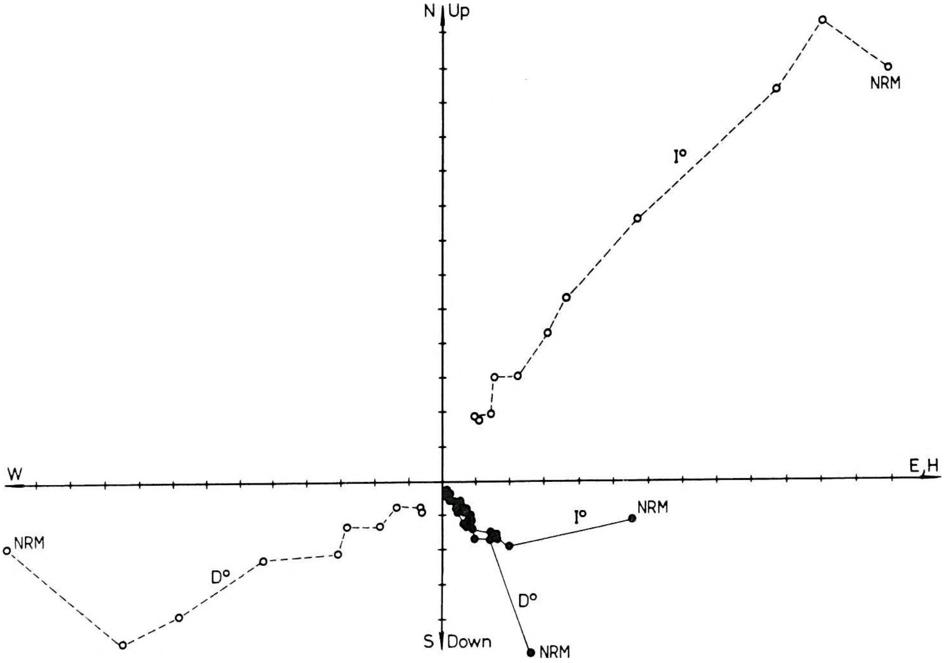


Fig. 20. Mecsek Mountains. Bostonites. Localities 9. (circles) and 10. (dots). Behaviour of the NRM on thermal and combined AF and thermal demagnetization. Declination–inclination plot. 1 unit = 8 · 10^{-4} A/m. The characteristic remanences of the two samples are of similar direction, but opposite polarity. Cleaning steps: locality 9: NRM, 0.01, 0.02, 0.03, 0.04, 0.05, 0.06, 0.07, 0.08, 0.09, 0.1 Tesla; locality 10: NRM, 0.1 Tesla, 100, 150, 200, 250, 300, 350, 375, 400, 425, 450, 475, 500, 550, 600, 650 °C

20. ábra. Mecsek hegység. Bosztonitok. 9. (körök) és 10. (pontok) mintavételi hely. Az NRM viselkedése termo és kombinált váltóterű- és termolemágnesezésre. Deklináció–inklináció ábra. 1 egység: 8 · 10^{-4} A/m. A két minta jellemző mágnesezettségének iránya hasonló, de ellentétes polaritású. Tisztítási lépések: 9. mintavételi hely: NRM, 0,01, 0,02, 0,03, 0,04, 0,05, 0,06, 0,07, 0,08, 0,09, 0,1 Tesla; 10. mintavételi hely: NRM, 0,1 Tesla 100, 150, 200, 250, 300, 350, 375, 400, 425, 450, 475, 500, 550, 600, 650 °C

Рис. 20. Мечекские горы. Бостониты. Точки № 9. (кружки) и № 10 (точки). Поведение естественной остаточной намагниченности при термическом и комбинированном (термическое + переменным полем) размагничивании. Диаграмма склонение–наклонение. 1 единица = 8 · 10^{-4} А/м. Характерное направление остаточной намагниченности обеих проб сходно по по направлению, но противоположно по полярности. Ступени чистки: по точке № 9: естественная намагниченность, 0,01, 0,02, 0,03, 0,04, 0,05, 0,06, 0,07, 0,08, 0,09, 0,1 тесла;
по точке № 10: естественная намагниченность, 0,1 тесла, 100, 150, 200, 250, 300, 350, 375, 400, 425, 450, 475, 500, 550, 600, 650 °C

The mean direction based on both Cretaceous alkali rocks and granite aplites; i. e. 8 sites and 2 localities, is:

$D = 94°$ $I = 57°$ $k = 28$ $\alpha_{95} = 9.3°$

b) Eastern Mecsek (localities 17–23)

Cleaning by AF or combined AF and thermal demagnetization *(Fig. 21)* revealed the characteristic magnetization. The "anomalous" direction for locality 19 (Fig. 13) has been confirmed: partly because orientation by the Sun or by magnetic compass makes no difference (the average difference is less than 1°),

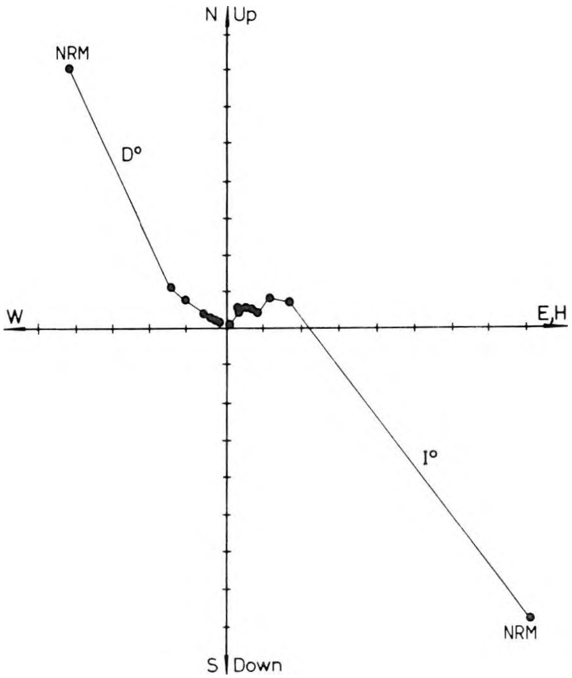


Fig. 21. Mecsek Mountains. Alkali basalt, locality 19. Behaviour of the NRM on combined AF and thermal demagnetization. Declination–inclination plot. 1 unit = $8 \cdot 10^{-1}$ A/m. Cleaning steps: NRM, 0.02, 0.03, 0.04, 0.07, 0.1 Tesla, 525, 550, 575, 600, 625, 650, 676 °C. For technical reasons, not all cleaning steps are shown in the figure

21. ábra. Mecsek hegység. Alkáli bazalt, 19. mintavételi hely. Az NRM viselkedése kombinált váltóterű- és termolemágnesezésre. Deklináció–inklináció ábra. 1 egység: $8 \cdot 10^{-1}$ A/m. Tisztítási lépések: NRM, 0,02, 0,03, 0,04, 0,07, 0,1 Tesla, 525, 550, 575, 600, 625, 650, 675 °C. Technikai okokból csak néhány tisztítási lépést ábrázoltunk

Рис. 21. Мечекские горы. Щелочные базальты, точка № 19. Поведение естественной остаточной намагниченности при комбинированном (переменным полем + термическое) размагничивании. Диаграмма склонение–наклонение. 1 единица = $8 \cdot 10^{-1}$ А/м. Ступени чистки: естественная намагниченность, 0,02, 0,03, 0,04, 0,07, 0,1 тесла, 525, 550, 575, 600, 625, 650, 675 °C. По техническим причинам, на рис. показаны не все ступени чистки partly because the mean directions based on three different collections of samples from the same dyke are very similar (Tables IV and VI).

When calculating the overall mean for the Eastern Mecsek, the results of the new determinations are used. If no new determination is available, directions published by MÁRTON and MÁRTON [1969] are preferred. For 6 sites *(Table VI)* the overall mean is:

$D = 79°$ $I = 54°$ $k = 7$ $\alpha_{95} = 27.2°$

Having applied the tilt corrections *(Table VII)* the mean direction and the statistical parameters change to:

$D = 47°$ $I = 56°$ $k = 5$ $\alpha_{95} = 33.6°$

In both cases the scatter is large. A way to obtain a better defined direction for the Eastern Mecsek would perhaps be to divide the directions into two groups in accordance with the estimated age. Sites 17 and 18 (Fig. 13) very likely belong to the early Cretaceous group, since these lava flows are intercalated with early Cretaceous sediments. Unfortunately, very little geological information is available about the rest, except for locality 20 which can be considered late Cretaceous [NÉMEDI VARGA 1983].

Nevertheless, both the corrected and uncorrected mean directions are similar to the mean Cretaceous direction for the Mórágy Ridge. Since α_{95} is large for the Eastern Mecsek, the difference in declination is not significant.

c) Western Mecsek (localities 24–26)

Full demagnetization was achieved either by AF or combined AF and thermal cleaning *(Fig. 22)*. The uncorrected directions of the ChRM for sites 24 and 26 are close to the present field direction whereas for site 25 it is significantly different. Tectonic correction increases the scatter. The results do not permit one to quantify the declination rotation *(Table VIII)*. It is possible, however, to see a trend towards clockwise rotation, both from the uncorrected and corrected directions *(Fig. 23)*.

d) Northern Nappe (localities 27–29)

Laboratory processing of the samples supplied very good demagnetization curves *(Figs. 24–26)*. In spite of the careful and apparently successful cleaning, the results are very poor. Although the specimens appeared to have single component ChRM, the origin is questionable. For instance, locality 27 is not likely to carry primary magnetization for two reasons: One is that both normal and reversed samples are present in one of the narrow dykes, which is assumed to have cooled very fast; the second is that the scatter is rather large and the distribution of the directions implies that the overprint is not completely removed *(Fig. 27)*. Site 28, on the other hand, is a failure in the statistical sense: k in Table VIII is too low to be acceptable for a small igneous body with strongly magnetized samples.

In conclusion, the alkali basalts from the Northern Nappe are not suitable for tectonic evaluation. It seems unlikely that the study of a large number of localities could results in a more optimistic summary for the area is very strongly tectonized and, in consequence, remagnetized.

Sampling sites, codes refer to Fig. 13	Rock type	N	D°	I°	k	α°_{95}	D°_c	I°_c	Cleaning
* 17. Jánosipuszta, outcrop	alkali basalt lava agglomerate	6	205	−73	50	9.6	158	−52	0.03 Tesla
* 18. Márévár valley, outcrop	alkali basalt lava	4	228	−60	60	12.0	180	−53	0.05 Tesla
* 19. Hosszúhetény, quarry	alkali basalt dyke	5	299	−39	36	12.8	256	−56	0.03 Tesla
** 19. Hosszúhetény, quarry		4	306	−39	38	15.2	276	−43	0.04 Tesla
** 20. Kövestető, quarry	phonolite sill	6	31	+58	15	18.2	35	+10	0.03 Tesla
** 21. Óbánya, outcrop	alkali basalt dyke	2	283	−15	–	–	285	−40	0.04 Tesla
* 22. Máza, outcrops	teschenite, dykes	8	261	−46	17	13.9	274	−66	0.03 Tesla
* 23. Komló, quarry	andesite laccolith	10	82	+62	112	4.2	–	–	0.05 Tesla
** 23. Komló, quarry		5	71	+64	179	5.7	104	+71	0.05 Tesla

Table. VI. Eastern Mecsek, magmatic rocks. Paleomagnetic results. Symbols as in Table IV, except * MÁRTON and SZALAY-MÁRTON 1969b; ** results obtained after 1975

VI. táblázat. Keleti-Mecsek, magmatitok. Paleomágneses eredmények összefoglalása. Jelölések mint a IV. táblázatban, kivéve * MÁRTON és SZALAY-MÁRTON 1969b; ** 1975 utáni eredmények

Табл. VI. Восточная часть Мечекских гор, магматические породы. Условные обозначения — как в Табл. IV, за исключением * MÁRTON and SZALAY-MÁRTON 1969b; ** результаты, полученные после 1975 г.

Locality code numbers refer to Fig. 13	Tilt correction
9–11	no tilt correction, since the sampling sites are situated within the migmatite area of the Mórágy Ridge, with no folding
17*	135/35
18*	310/30
19**	16/33
20**	50/25
21**	276/25
22***	180/40
23**	180/15
24**	330/48
25**	10/25
26**	76/36
27****	350/80 overturned?
29**	346/45

Tilt corrections are taken to be the same as the position of the enclosing sediments and were provided by the following geologists: * Bilik I. ** Szabó Cs. *** Viczián I. **** Balla Z.

Table VII. Local tilt correction applied to the Cretaceous volcanics and the Komló andesite (dip azimuth/dip angle)

VII. táblázat. A kréta vulkanitok és a komlói andezit paleomágneses irányát módosító tektonikai korrekciók (dőlésirány/dőlésszög)

Табл. VII. Поправки за наклонное залегание, применявшиеся в случае меловых вулканитов и андезитов из Комло (азимуты и углы падений)

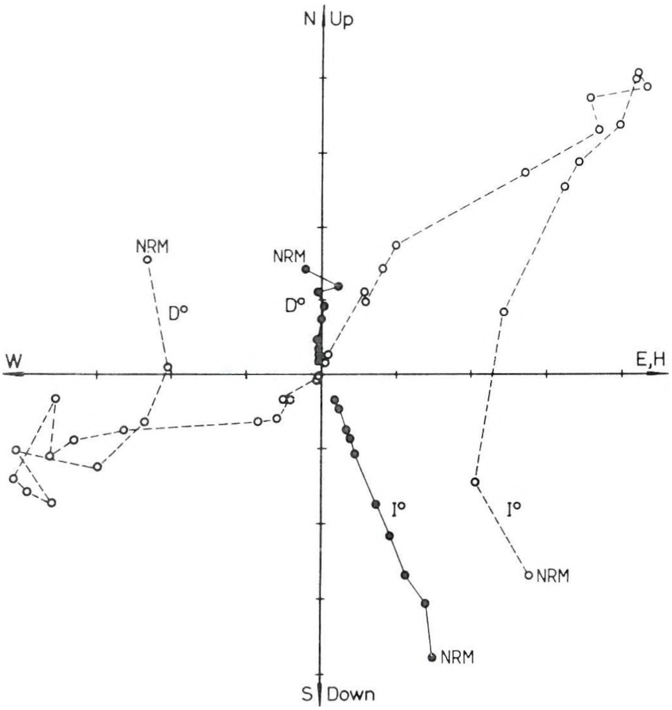


Fig. 22. Mecsek Mountains. Alkali basalts, localitites 25 (circles) and 26 (dots). Behaviour of the NRM on AF and combined AF and thermal demagnetization. Declination–inclination plot. 1 unit = 8 · 10^{-1} A/m. Cleaning steps: locality 25: NRM, 0.01, 0.02, 0.03, 0.04, 0.05, 0.06, 0.07, 0.08, 0.1 Tesla, 400, 500, 525, 550, 575, 585, 625, 675 °C; locality 26: NRM, 0.01, 0.02, 0.03, 0.04, 0.05, 0.06, 0.07, 0.08, 0.09 Tesla

22. ábra. Mecsek hegység. Alkáli bazaltok, 25. (körök) és 26. (pontok) mintavételi hely. Az NRM viselkedése váltóterű valamint kombinált váltóterű és termolemágnesezésre. Deklináció–inklináció ábra. 1 egység: 8 · 10^{-1} A/m. Tisztítási lépések: 25. mintavételi hely: NRM, 0,01, 0,02, 0,03, 0,04, 0,05, 0,06, 0,07, 0,08, 0,1 Tesla, 400, 500, 525, 550, 575, 585, 625, 675 °C; 26. mintavételi hely: NRM, 0,01, 0,02, 0,03, 0,04, 0,05, 0,06, 0,07, 0,08, 0,09 Tesla

Рис. 22. Мечекские горы. Щелочные базальты, точки № 25 (кружки) и № 26 (точки). Поведение естественной остаточной намагниченности при комбинированном (переменным полем + термическое) размагничивании. Диаграмма склонение–наклонение. 1 единица = 8 · 10^{-1} А/м. Ступени чистки: по точке 25: естественная намагниченность, 0,01, 0,02, 0,03, 0,04, 0,05, 0,06, 0,07, 0,08, 0,1 тесла, 400, 500, 525, 550, 575, 585, 625, 675 °C; по точке 26: естественная намагниченность: 0,01, 0,02, 0,03, 0,04, 0,05, 0,06, 0,07, 0,08, 0,09 тесла

Sampling sites and localities codes refer to Fig. 13	Rock type	N	D°	I°	k	α°_{95}	D°_c	I°_c	Cleaning
				Western Mecsek					
24. Szentkút, outcrop	alkali basalt dyke	7	23	67	80	6.8	351	26	0.05 Tesla
25. Petőc brook, outcrop	alkali basalt dyke	2	244	−38	–	–	234	−22	0.03 Tesla
26. Gégenkút, outcrop	alkali basalt dyke	4	345	66	245	5.9	40	48	0.08 Tesla
				Northern Nappe					
27. Vékény, outcrop	alkali basalt lava flow and dykes	16	176	−52	10	12.3	–	–	525–70 °C
28. Kárász, quarry	alkali basalt	6	149	−14	5	34.8	–	–	525–90 °C
29. Váralja, outcrop	alkali basalt dyke	2	249	−31	–	–	211	−31	0.04 Tesla

Table. VIII. Western Mecsek and the Northern Nappe, alkali basalts. Palaeomagnetic results. Symbols as in Table IV

VIII. táblázat. Nyugati-Mecsek és Északi Pikkely, alkáli bazaltok. Paleomágneses eredmények. Jelölések mint a IV. táblázatban

Табл. VIII. Западная часть Мечекских гор и Северная чешуя, щелочные базальты. Палеомагнитные данные. Условные обозначения — как в табл. IV

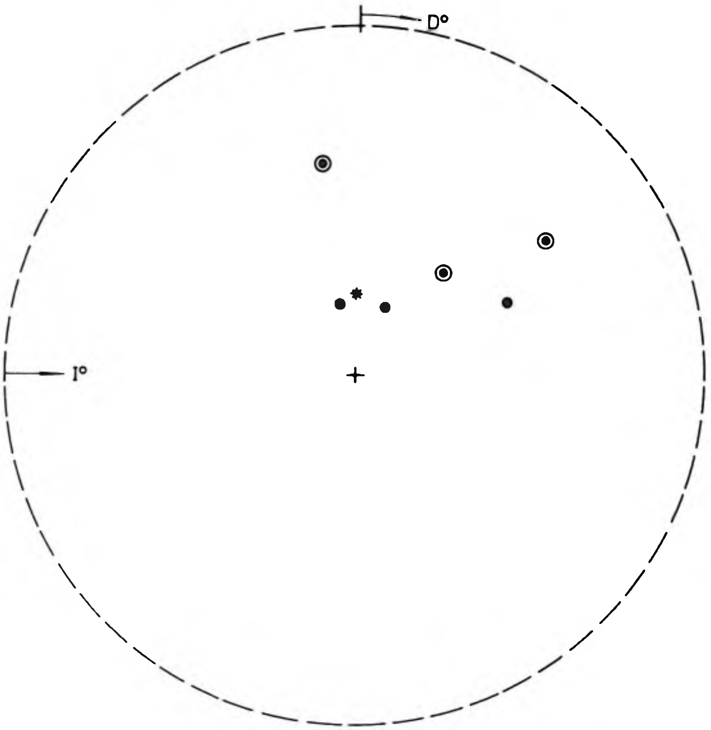


Fig. 23. Western Mecsek. Site means before and after (double symbols) tilt correction. Stereographic projection, inclinations are positive. Asterisk represents the present local magnetic field direction

23. ábra. Nyugati Mecsek. A mintavételi helyekre meghatározott középirányok tektonikai korrekció előtt és után (kettős jelek). Szögtartó vetület, pozitív inklinációk. A csillag a mai helyi földmágneses tér irányát jelzi

Рис. 23. Западная часть Мечекских гор. Средние по точкам до и после (двойные знаки) поправки на залегание. Стереографическая проекция, положительные наклонения. Звездочкой отмечено направление магнитного поля в районе

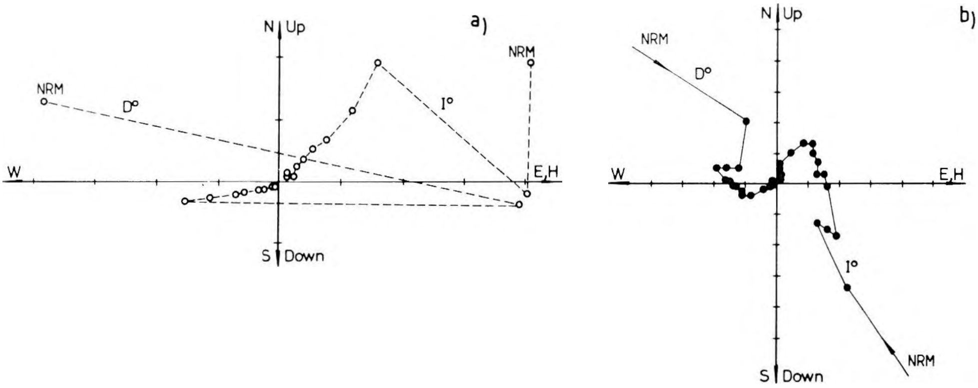


Fig. 24. Northern Nappe, alkali basalts. Behaviour of the NRM on demagnetization. Declination–inclination plot

a) Site 29, AF demagnetization, 1 unit = $8 \cdot 10^{-1}$ A/m. Cleaning steps: NRM, 0.01, 0.02, 0.03, 0.04, 0.05, 0.06, 0.07, 0.08, 0.09, 0.1 Tesla

b) Site without a code number, thermal demagnetization, 1 unit = $8 \cdot 10^{-2}$ A/m. Cleaning steps: NRM–590 °C in 18 steps. The directions of the characteristic remanences are similar though the samples come from different sites

24. ábra. Északi Pikkely, alkáli bazaltok. Az NRM viselkedése lemágnesezésre. Deklináció–inklináció ábra

a) 29. mintavételi hely, az NRM viselkedése váltóterű lemágnesezésre, 1 egység: $8 \cdot 10^{-1}$ A/m. Tisztítási lépések: NRM, 0,01, 0,02, 0,03, 0,04, 0,05, 0,06, 0,07, 0,08, 0,09, 0,1 Tesla

b) Kód nélküli mintavételi hely, az NRM viselkedése termolemágnesezésre, 1 egység: $8 \cdot 10^{-2}$ A/m.

Tisztítási lépések: NRM-től 590 °C-ig 18 lépésben. A jellemző mágnesezettség irányai hasonlók, habár a minták különböző helyről származnak

Рис. 24. Северная чешуя, щелочные базальты. Поведение естественной остаточной намагниченности при размагничивании. Диаграмма склонение–наклонение

a) Точка № 29, размагничивание переменным полем, 1 единица = $8 \cdot 10^{-1}$ А/м. Ступени чистки: естественная намагниченность, 0,01, 0,02, 0,03, 0,04, 0,05, 0,06, 0,07, 0,08, 0,09, 0,1 тесла

b) точка без номера, термическое размагничивание, 1 единица = $8 \cdot 10^{-2}$ А/м. Ступени чистки: естественная намагниченность – 590 °C в 18 ступенях. Направления характерной остаточной намагниченности сходны, хотя пробы взяты в разных точках

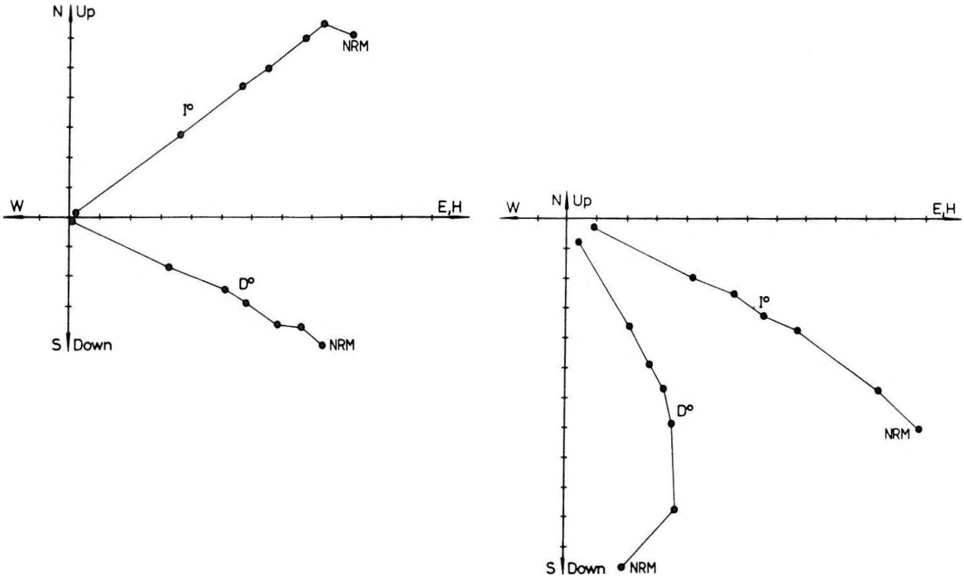


Fig. 25. Northern Nappe. Alkali basalt, site 28. Behaviour of the NRM on thermal demagnetization. Declination–inclination plots for two samples from the same site. 1 unit = $8 \cdot 10^{-4}$ A/m. Cleaning steps: NRM, 525, 550, 560, 570, 580, 590 °C. The directions of the characteristic remanences are different though the samples come from the same site

25. ábra. Északi Pikkely. Alkáli bazalt, 28. mintavételi hely. Az NRM viselkedése termolemágnesezésre. Deklináció–inklináció ábra, amelyen két minta látható. 1 egység: $8 \cdot 10^{-4}$ A/m. Tisztítási lépések: NRM, 525, 550, 560, 570, 580, 590 °C. A jellemző mágnesezettség irányai különbözők, habár a minták ugyanarról a helyről származnak

Рис. 25. Северная чешуя. Щелочные базальты, точка № 28. Поведение естественной остаточной намагниченности при термическом размагничиванни. Диаграмма склонение–наклонение для двух образцов с той же самой точки. 1 единица = $8 \cdot 10^{-4}$ А/м Ступени чистки: естественная намагниченность, 525, 550, 560, 570, 580, 590 °С. Направления характерной остаточной намагниченности различны, хотя образцы взяты с одной и той же точки

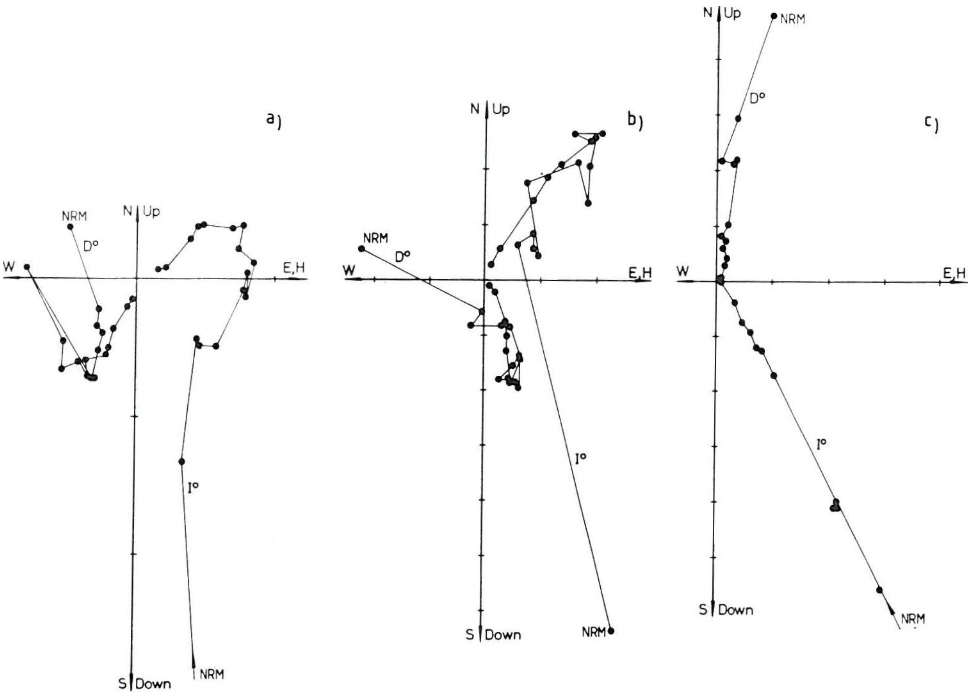


Fig. 26. Northern Nappe. Alkali basalt, locality 27. Behaviour of the NRM on combined AF and thermal demagnetization observed on samples from a lava flow (a) and dykes intruding the lava flow (b and c). Declination–inclination plots. 1 unit = $8 \cdot 10^{-1}$ A/m.
Cleaning steps: NRM, 0.005, 0.01 Tesla,
100, 150, 200, 250, 300, 350, 400, 450, 500, 525, 550, 560, 570, 580, 590 °C.
Note that the direction of the characteristic remanence in the lava flow is similar to those in Fig. 24 but the direction for the dykes is close to that of the present day field, both with normal (c) and reversed (b) polarities

26. ábra. Északi Pikkely. Alkáli bazalt, 27. mintavételi hely. Az NRM viselkedése kombinált váltóterű- és termolemágnesezésre a lávaárból származó mintákon (a) és a lávaárba benyomuló telérekből származó mintákon (b és c). Deklináció–inklináció ábrák. 1 egység: $8 \cdot 10^{-1}$ A/m.
Tisztítási lépések: NRM, 0,005, 0,01 Tesla,
100, 150, 200, 250, 300, 350, 400, 450, 500, 525, 550, 560, 570, 580, 590 °C.
A lávaárból származó minta jellemző mágnesezettségének iránya hasonló a 24. ábrán bemutatott mintákéhoz, a teléreké viszont közel van a mai tér irányához normál (c) illetve fordított (b) polaritással

Рис. 26. Северная чешуя. Щелочные базальты, точка № 27. Поведение естественной остаточной намагниченности при комбинированном (переменным полем и термическом) размагничивании образцов из лавового потока (a) и прорывающих его дайках (b и c). Диаграммы склонение–наклонение. 1 единица = $8 \cdot 10^{-1}$ А/м. Ступени чистки: естественная намагниченность, 0,005, 0,01 тесла, 100, 150, 200, 250, 300, 350, 400, 450, 500, 525, 550, 560, 570, 580, 590 °C.
Можно заметить, что направление характерной остаточной намагниченности лавового потока сходно с таковым на рис. 24, но направления характерной остаточной намагниченности даек близки к современному полю как при нормальной (c), так и при обратной (b) полярности

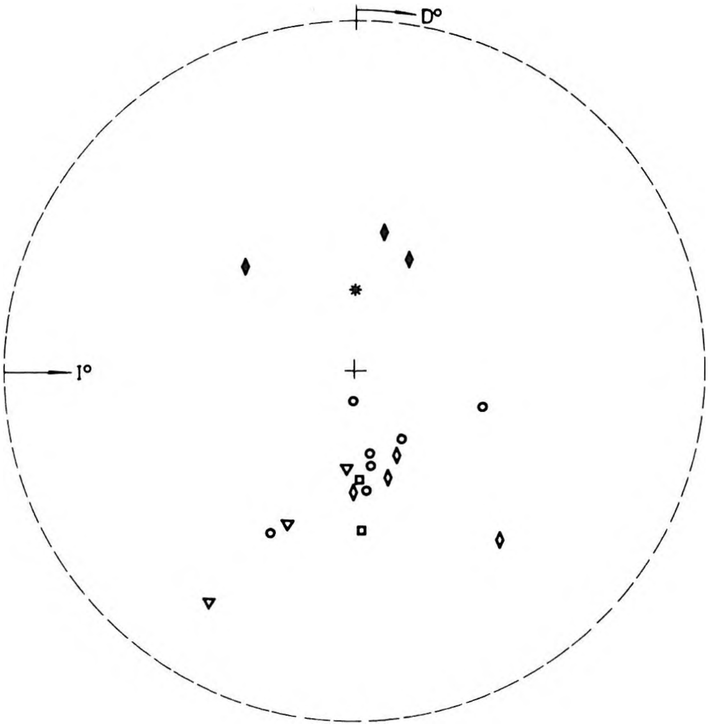


Fig. 27. Northern Nappe. Directions of the characteristic remanences for samples from a lava flow (triangle) and dykes intruding the lava flow (dyke 1 circle, dyke 2 square, dyke 3 diamond). Stereographic projection. Solid symbols: positive inclination, hollow symbols: negative inclination. Asterisk represents the present local magnetic field direction

27. ábra. Északi Pikkely. A jellemző mágnesezettség irányai egy lávaárból (háromszögek) és a lávaárba benyomuló telérekből (1. telér: körök, 2. telér: négyzetek, 3. telér: rombuszok). Szögtartó vetület. Teli jelek: pozitív inklináció, üres jelek: negatív inklináció. A csillag a jelenlegi földmágneses tér irányát jelzi

Рис. 27. Северная чешуя. Направления характерной остаточной намагниченности образцов из лавового потока (треугольник) и из прорывающих его даек (дайка № 1 — кружок, дайка № 2 — квадрат; дайка № 3 — ромб). Стереографическая проекция. Залитые знаки: положительные наклонения, полые знаки: отрицательные наклонения. Звездочкой отмечено направление современного магнитного поля в районе

Tertiary andesite laccolith at Komló (site 23)

As a result of combined AF and thermal demagnetization, well defined characteristic magnetization was found *(Fig. 28)*. The mean direction for the recently studied site is very close to what was found by MÁRTON and MÁRTON, earlier [1969] but both are different from the direction determined by DAGLEY and ADE-HALL [1970]. Since the samples from the Komló laccolith are remarkably stable (the only carrier seems to be haematite), all three independent determinations are used for calculating a mean direction for the laccolith:

$D = 59°$ $I = 65°$ $k = 32$ $\alpha_{95} = 22.2°$

8. Classification of the palaeomagnetic results of the present study

In this section the reliability of the palaeomagnetic directions determined for the igneous rocks from the Velence Hills and the Mecsek Mountains will be estimated using the rejection and classification criteria of Fig. 2. The result is summarized in *Table IX* where the groups of palaeomagnetic directions are represented by the following codes:

MRC: Mórágy Ridge, Carboniferous granitoids
VHC: Velence Hills, Carboniferous granitoids
MRK: Mórágy Ridge, Cretaceous alkali rocks
EMK: Eastern Mecsek, Cretaceous alkali rocks
WMK: Western Mecsek, Cretaceous alkali rocks
NMK: Northern Nappe, Cretaceous alkali rocks
VH60: Velence Hills, monchiquite, 60 Ma
VH30: Velence Hills, andesites, 30 Ma
EM21: Eastern Mecsek, andesite, 21 Ma

As seen from Table IX, WMK, NMK, VH60 are rejected: the first two because of the high within and between site scatter, while VH60 is only a single site. All the rest pass not only the rejection criteria but classification criteria group I as well (for details, see Section 6 and 7).

VHC is a "C" direction because the characteristic magnetization may be constructed geometrically from the present field direction and the direction of the Earth's magnetic field during the andesite volcanism (the author is suspicious about the result in spite of the demagnetization behaviour of the samples, suggesting single-component ChRM).

EMK exhibits large between-site scatter both before and after tilt correction ($k < 10$), EM21 is based on less than 6 sites, i.e. neither of them satisfies criteria II. 2, thus both are classified as "C" directions.

MRC, MRK and VH30 are good from the viewpoint of statistics (Sections 6 and 7) as well as of geology (age well established, tilt correction not necessary, for small-scale tectonic movements are not evidenced). In addition to the tabulated requirements, the reliability is enhanced by observations such as the significant departure of the directions from the present field direction, the

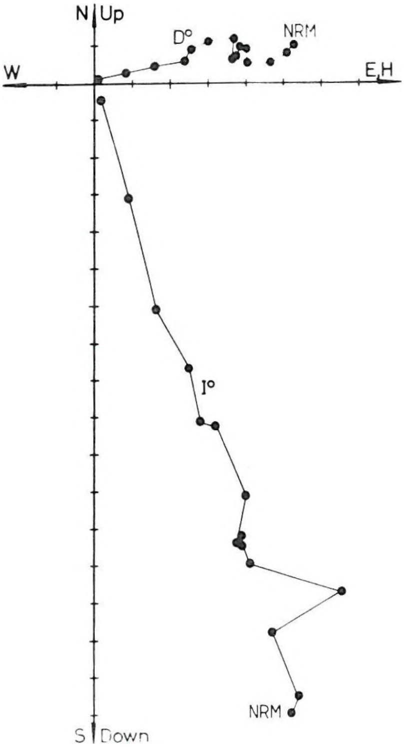


Fig. 28. Andesite laccolith, Komló, site 23. Behaviour of the NRM on combined AF and thermal demagnetization. Declination–inclination plot. 1 unit = $8 \cdot 10^{-1}$ A/m. Cleaning steps: NRM, 0.01, 0.02, 0.04, 0.06, 0.08, 0.1 Tesla, 500, 550, 575, 585, 600, 630, 675 °C

28. ábra. Andezit lakkolit, Komló, 23. mintavételi hely. Az NRM viselkedése kombinált váltóterű- és termolemágnesezésre. Deklináció–inklináció ábra. 1 egység: $8 \cdot 10^{-1}$ A/m. Tisztítási lépések: NRM, 0,01, 0,02, 0,04, 0,06, 0,08, 0,1 Tesla, 500, 550, 575, 585, 600, 630, 675 °C

Рис. 28. Андезитовый лакколит, Комло, точка № 23. Поведение естественной остаточной намагниченности при комбинированном (переменным полем + термическое) размагничивании. Диаграмма склонение–наклонение. 1 единица = $8 \cdot 10^{-1}$ А/м. Ступени чистки: естественная намагниченность, 0,01, 0,02, 0,04 0,06, 0,08, 0,1 тесла, 500, 550, 575, 585, 600, 630, 675 °C

presence of both polarities (about 180° apart), and the different petrology and texture of the rocks giving the same ChRM.

The degree of the magnetic susceptibility anisotropy $\kappa_{max}/\kappa_{min}$ was estimated for the igneous rocks from the Velence Hills and the granitoids from the Mórágy Ridge on the basis of susceptibility measurements in three mutually perpendicular directions. Standard anisotropy measurements were made on most samples from MRK, EMK, WMK, NMK, EM21 using a KLY–1 susceptibility bridge and a DIGICO susceptibility meter (this latter at the University of Newcastle upon Tyne). The results show that on average the degree of anisotropy is below 5 per cent (practically no deviation expected) except for site 20, Fig. 13 (7 per cent). The maximum degree measured for a sample is 27 per cent (site 10, Fig. 13). This sample was heated to 700 °C and cooled to room temperature in a controlled field. The observed deflection from the direction of the applied field was 6°, 4° and 0° on repeated heatings in three perpendicular directions, i.e. it did not exceed the expected deviation [McElhinny 1973]. The assumed minor influence of the anisotropy on the remanence directions becomes even more insignificant at site level because of the large scatter in the principal susceptibility directions within a single site (e.g. sites 5, 8, 9, 19, 20, 24, 26 in Fig. 13).

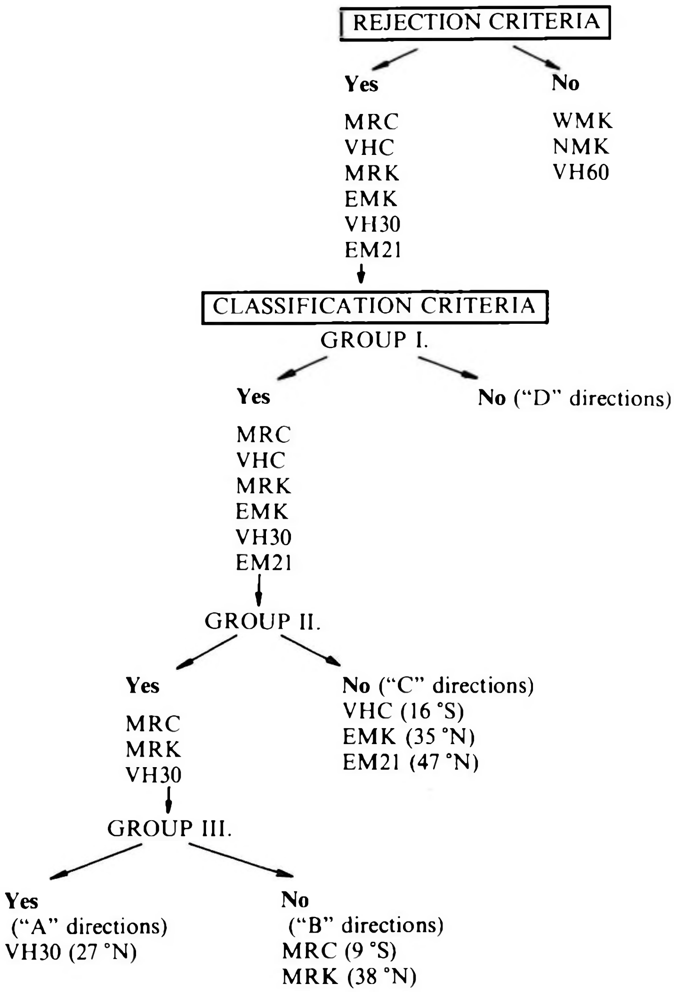


Table. IX. Classification of the palaeomagnetic directions observed on igneous rocks from the Velence Hills and the Mecsek Mountains using the rejection and classification criteria of Fig. 2

IX. táblázat. A Velencei-hegység és a Mecsek hegység magmás kőzetein meghatározott paleomágneses irányok osztályozása a 2. ábra kritériumainak megfelelően

Табл. IX. Классификация палеомагнитных направлений, полученных по магматическим породам Веленцейский и Мечекских гор с использованием критериев рис. 2

It is concluded, therefore, that the anisotropy of the magnetic susceptibility seems to play but an insignificant role for all groups of palaeomagnetic directions, including the ones to be further examined for the age of magnetization (MRC, MRK, VH30). The magnetizations of MRC and MRK may be primary, but proof is lacking. MRC and MRK are, therefore, "B" directions. The age of the magnetization of VH30, on the other hand, may be restricted to a narrow time interval, between the K/Ar isotope age of 30 Ma and the practical termination of the large-scale tectonic movement in the Pannonian Basin – probably not later than 15 Ma ago. Therefore VH30 is classified as "A" direction.

9. Tectonic interpretation

9.1 Tectonic significance of the palaeomagnetic directions for the Velence Hills and the Mecsek Mountains

The palaeomagnetic direction to be interpreted in terms of tectonics is characterized by an inclination-declination pair. On the assumption that the geomagnetic field has always been dominantly an axial geocentric dipole field, the inclination may simply be related to the palaeolatitude, where the rock was magnetized. In this model the declination is always and everywhere zero (the secular variation is averaged out). Palaeodeclinations, therefore, reflect post-magnetization rotations, while the inclination refers to the original latitude and is not influenced by post-magnetization movements.

Palaeomagnetic directions for distant points may be compared with the help of palaeomagnetic poles. The palaeomagnetic pole is calculated from the local declination and inclination on the basis of the axial geocentric dipole model of the Earth's magnetic field. Different palaeomagnetic pole positions for the same age indicate relative movements between the respective points. Agreement means either no displacement or coinciding magnetic and rotation poles.

From the viewpoint of tectonic interpretation the model in which the results are interpreted is as important as the quality of a palaeomagnetic result. The axial geocentric dipole model is the only one so far utilized in practice. Recently it was shown by P. Márton [Márton 1986] that although it is indeed the best approximation to the structure of the geomagnetic field from the Jurassic onwards, an excentric dipole field fits better the observations in the Triassic and the Permian. Older magnetic fields were not studied because of the insufficient number of suitable palaeomagnetic results. By applying the geocentric dipole model instead of a more sophisticated one, we certainly introduce an error in the interpretation of the Permian and Triassic results and perhaps in the Carboniferous, as well. Nevertheless, for the purpose of the present tectonic evaluation the simple axial geocentric dipole model is sufficiently precise: partly because there is no information about the exact structure of the

Carboniferous magnetic field, partly because the Palaeozoic palaeomagnetic results in general are moderately reliable.

Palaeolatitudes

Both the Velence and Mecsek granitoids must have acquired the magnetization at low southern latitudes (Table IX, VHC and MRC). Since the Carboniferous, a significant northward shift can be observed: the Mecsek Mountains moved to 35–38 °N by the Cretaceous, the Velence Hills to 27 °N by 30 Ma. The Mecsek Mountains seem to have reached the present latitude by 21 Ma. The change in latitude need not necessarily have been monotonous: for instance the shift of the Transdanubian Central Range was sometimes even southward directed [Márton and Márton 1985]. The palaeolatitudes in Table IX are useful as a means of placing both the Velence Hills and the Mecsek Mountains at approximately correct latitudes, but neither their precision nor our knowledge of the Carboniferous magnetic field allows us to decide whether or not the two areas moved independently.

Rotations

Even though the general trend of the latitudinal movement is the same for both areas, the rotations must have been significantly different since the respective palaeomagnetic declinations for the Velence Hills and the Mecsek Mountains are different and, consequently, the poles occupy different parts on the globe *(Fig. 29)*. This observation gives further support to those tectonic models that permit the relative movement — including very young relative movements — between the Transdanubian Central Range (represented by the Velence Hills in the present study) and Southeast Transdanubia (represented by the Mecsek Mountains).

The palaeodeclination determined for the time of the andesite volcanism in the Velence Hills is counter-clockwise rotated by 30°. It means that the Transdanubian Central Range underwent a significant rotation after the magnetization of the andesites. An even larger young rotation, but in the opposite sense, is indicated by the Cretaceous and younger igneous rocks from the Mecsek Mountains.

The rotations shown by the older rocks cannot be interpreted without keeping in mind the influence of subsequent rotations, i.e. each declination should be interpreted in the light of the later movements. On the other hand, young rotations are better established when shown by rocks of different ages.

Due to the favourable distribution in time and space of the palaeomagnetic results from the Transdanubian Central Range, the new determinations are not isolated but may be interpreted in context with the Mesozoic directions. The Mesozoic poles for the Transdanubian Central Range form a loop similar to the so called African loop (*Fig. 30*). The two loops may be brought into coincidence by rotating the Mesozoic poles for the Transdanubian Central Range clockwise around a local rotation pole by about 35° [Márton and Márton 1983]. The same rotation is sufficient to restore the Carboniferous and

Fig. 29. Palaeomagnetic poles for the igneous rocks from the Velence Hills and the Mecsek Mountains. 1 — Mecsek Mountains, Early Carboniferous ("B" direction); 2 — Velence Hills, Late Carboniferous ("C" direction); 3 — Velence Hills, 30 Ma ("A" direction); 4 — Mórágy Ridge, Cretaceous ("B" direction); 5 — Eastern Mecsek, Cretaceous, uncorrected for tilts ("C" direction); 6 — Eastern Mecsek, Cretaceous, corrected for tilts ("C" direction); 7 — Eastern Mecsek, andesite, uncorrected for tilt ("C" direction); 8 — Eastern Mecsek, andesite, corrected for tilt ("C" direction)

29. ábra. A Velencei-hegység és a Mecsek hegység magmás kőzeteire meghatározott paleomágneses pólusok. 1 — Mecsek hegység, alsó karbon ("B" irány); 2 — Velencei-hegység, felső karbon ("C" irány); 3 — Velencei-hegység, 30 millió év ("A" irány); 4 — Mórágyi Rög, kréta ("B" irány); 5 — Keleti Mecsek, kréta, tektonikai korrekció előtt ("C" irány); 6 — Keleti Mecsek, kréta, tektonikai korrekció után ("C" irány); 7 — Keleti Mecsek, andezit, tektonikai korrekció nélkül ("C" irány); 8 — Keleti Mecsek, andezit, tektonikai korrekció után ("C" irány)

Рис. 29. Палеомагнитные полюса магматических пород Веленцейских и Мечекских гор. 1 — Мечекские горы, ранний карбон (направление категории „B"); 2 — Веленцейские горы, поздний карбон (направление категории "C"); 3 — Веленцейские горы, 30 млн. лет (направление категории "A"); 4 — Морадьский блок, мел (направление категории "B"); 5 — восточная часть Мечекских гор, мел, без поправки за наклонное залегание (направление категории "C"); 6 — восточная часть Мечекских гор, мел, с поправкой за наклонной залегание (направление категории "C"); 7 — восточная часть Мечекских гор, андезиты, без поправки за наклонное залегание (направление категории "C"); 8 — восточная часть Мечекских гор, андезиты, с поправкой за наклонное залегание (направление "C")

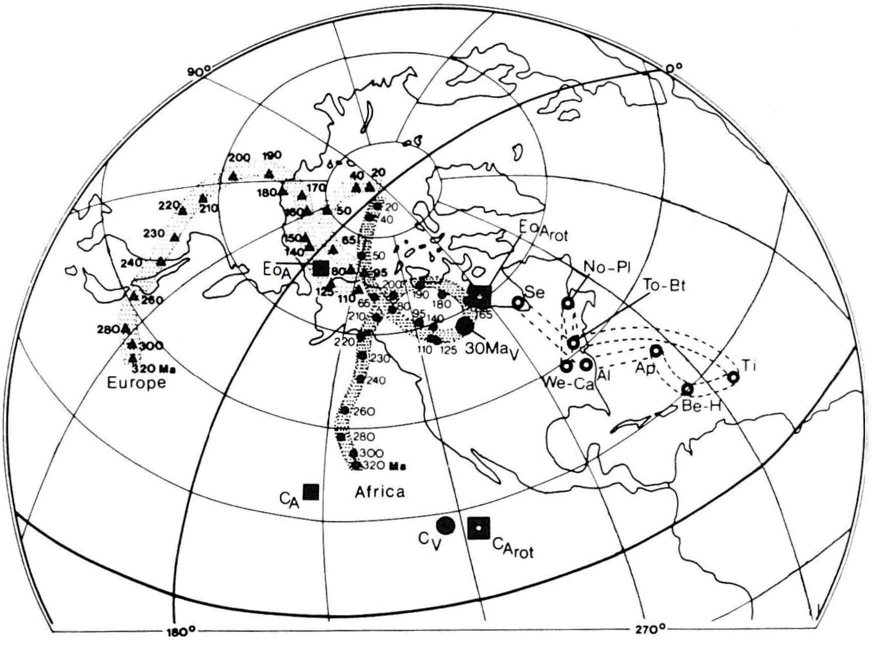


Fig. 30. Comparison between the palaeomagnetic poles for the Transdanubian Central Range and those for Africa and stable Europe. The apparent polar wander curves for Africa and stable Europe are derived from the smoothed North American apparent polar wander curve [Irving 1977] using the rotation poles for the opening of the Atlantic [Sclater et al. 1977]. Direct determinations for Africa [Brook 1981] are transferred to the coordinate system of the Transdanubian Central Range applying a single counter-clockwise rotation of 35° around a local rotation pole

C_A — Carboniferous palaeomagnetic pole for Africa, $C_{A_{rot}}$ — the same rotated; Eo_A — Eocene palaeomagnetic pole for Africa, $Eo_{A_{rot}}$ — the same rotated; C_V — Velence Hills, Carboniferous palaeomagnetic pole; 30 Ma_V — Velence Hills, 30 Ma palaeomagnetic pole. Mesozoic palaeomagnetic poles for the Transdanubian Central Range: We–Ca — Werfenian–Carnian, No–Pl — Norian–Pliensbachian; To–Bt — Toarcian–Bathonian; Ti — Tithonian; Be–H — Berriasian–Hauterivian; Ap — Aptian; Al — Albian; Se — Senonian

30. ábra. A Dunántúli-középhegység, Afrika és stabil Európa paleomágneses pólusainak összehasonlítása. Afrika és stabil Európa látszólagos pólusvándorlási görbéjét a simított észak-amerikai látszólagos pólusvándorlási görbéből [Irving 1977] az Atlanti-óceán felnyílására meghatározott rotációk segítségével [Sclater et al. 1977] származtattuk. Az Afrikára ismert közvetlen meghatározásokat [Brook 1981] a Dunántúli-középhegység koordináta-rendszerére egy helyi tengely körüli 35°-os, óramutató járásával ellentétes elfordulás feltételezésével számítottuk át

C_A — afrikai karbon paleomágneses pólus; $C_{A_{rot}}$ — ugyanaz, elforgatva; Eo_A — afrikai eocén paleomágneses pólus; $Eo_{A_{rot}}$ — ugyanaz elforgatva; C_V — Velencei-hegység, karbon paleomágneses pólus; 30 Ma_V — Velencei-hegység, 30 millió éves paleomágneses pólus. A Dunántúli-középhegység mezozoos paleomágneses pólusai: We–Ca — werfeni–karni; No–Pl — nóri–pliensbachi; To–Bt — toarci–bath; Ti — titom; Be–H — berriázi–hauterivi; Ap — apti; Al — albai; Se — szenon the 30 Ma old positions (from Africa we have an Eocene and a late Carboniferous pole for comparison). It follows that the Transdanubian Central Range must have been part of the African plate at the time of the andesite volcanism, and the 30–35° counter-clockwise rotation with respect to Africa (and to stable Europe as well) postdates the andesite volcanism in the Velence Hills. The relative positions of the Carboniferous poles suggest that the Velence Hills have been part of the Palaeozoic sequence underlying the Mesozoic of the Transdanubian Central Range since the Carboniferous.

Prior to the recognition of the young clockwise rotation, the palaeomagnetic poles from Southeast Transdanubia were interpreted as poles akin to the stable European ones [Kotásek et al. 1969, Márton and Márton 1978]. Unpublished results by the author for the Triassic and the Tithonian–Berriasian from the Western and Eastern Mecsek respectively, fit the trend suggested by the published results. As is clear from *Fig. 31* the pattern suddenly changes with the alkali volcanites. The clockwise rotation is large as indicated by rocks from the Mórágy Ridge and the Eastern Mecsek. It seems very likely, however, that the whole of Southeast Transdanubia was subjected to similar rotations otherwise the similar trend of the palaeomagnetic poles from the Carboniferous through the Tithonian–Berriasian is not easy to explain since these poles were determined for different parts of Southeast Transdanubia (Carboniferous: Mórágy Ridge; Permian and Triassic: Western Mecsek; Tithonian–Berriasian: Eastern Mecsek; Mesozoic in general: Villány Hills).

The correct position of SE Transdanubia prior to the clockwise rotation is not easy to reconstruct. In any reconstruction, however, the younger than Tithonian–Berriasian declination should be rotated back to zero. In this way the Berriasian and older declinations will become counter-clockwise rotated. The similarity of the observed Berriasian and older poles for SE Transdanubia to the stable European poles, therefore, must not be interpreted as proof of the stable European origin. If SE Transdanubia was once part of the northern margin of the Tethys, as is assumed for reasons of facies and fauna, it must have decoupled from stable Europe at the time of the alkali volcanism (rifting).

Рис. 30. Сопоставление палеомагнитных полюсов Задунайского Среднегорья с таковыми Африки и стабильной Европы. Кривые кажущегося блуждания полюсов для Африки и стабильной Европы получены из сглаженной кривой кажущегося блуждания полюсов для Северной Америки [Irving 1977] с использованием полюсов поворота для раскрытия Атлантики [Sclater ет ал. 1977]. Прямые определения для Африки [Brook 1981] переведены в координатную систему Задунайского Среднегорья с использованием простого поворота против часовой стрелки на 35° вокруг местного полюса. C_A — палеомагнитный полюс для карбона Африки; $C_{A rot}$ — то же, повернутый; Eo_A — палеомагнитный полюс для эоцена Африки; $Eo_{A rot}$ — то же, повернутый; C_V — Веленцейские горы, палеомагнитный полюс для карбона; 30 Ma_V — Веленцейские горы, палеомагнитный полюс для 30 млн. лет. Мезозойские палеомагнитные полюся для Задунайского Среднегорья: We–Ca — верфенско—карнийское время; No–Pl — норийско–плинсбахское время; To–Bt — тоарско–батское время; Ti — титонской век; Be–H — берриасско–готеривское время; Ap – аптский век; Al — альбский век; Se —

Alternatively, SE Transdanubia could have moved in coordination with Africa (counter-clockwise rotated declinations are characteristic of the African plate) with the decoupling being marked by the post-Cretaceous clockwise rotation.

9.2 Connection to other parts of the Mediterranean region

In the last decade many studies have been undertaken in the Mediterranean. Palaeomagnetism has contributed considerably to a better understanding of the geodynamic history, especially in those countries where efforts were concentrated on certain areas, like in Italy, Hungary, Austria and over the last few years Yugoslavia and Greece.

Earlier, palaeomagnetic directions were considered useful for testing existing regional tectonic models. The discovery of important relative rotations with the palaeomagnetic method, e.g. the Tertiary counter-clockwise rotation of Italy south of the Po basin by VANDENBERG and WONDERS [1976], that of the Transdanubian Central Range by MÁRTON and MÁRTON [1981], have proved, however, that palaeomagnetism is a powerful method for detecting past movements. We have arrived at a stage when the number, the quality, and the distribution of the palaeomagnetic observations — both in space and time — permit a synthesis of the palaeomagnetic results [MÁRTON 1984, 1985].

Based on the declination, the Velence Hills, as part of the Transdanubian Central Range, belong to a large unit characterized by counter-clockwise rotations relative to the present orientation *(Fig. 32)*. The declinations within this region are not uniform: the angle of the rotation differs depending on age and, to a lesser extent, on the location. The available observations suggest that this unit was part of the African plate until some time in the Tertiary. Its decoupling from Africa is evidenced by an additional counter-clockwise rotation which definitely post-dates the Eocene in Umbria [VANDENBERG et al. 1978], the early Oligocene in Piedmont [VANDENBERG 1979], and the 30 Ma in the Transdanubian Central Range (present paper). This extra rotation was shown to be about 20 Ma old in Sardinia [EDEL 1979], and to be younger than Eocene in the eastern part of the outer West Carpathians [KRS et al. 1982].

Southeast Transdanubia may have shared the Tertiary movements of certain parts of Greece: Epiros: post-Eocene clockwise rotation [HORNER and FREEMAN 1983, KISSEL et al. 1985], Chalkidiki [KONDOPOULOU 1985], the Soviet Outer East Carpathians: post-Cretaceous clockwise rotation [BAZHENOV and BURTMAN 1980], East-Serbia: post Cretaceous clockwise rotation [STEFANOVIC and VELJOVIC 1972]. Unfortunately, little is known about the older directions from the same parts, except Epiros, where the pattern of rotations is similar to that of the Mecsek Mountains *(Fig. 33)*.

It would be an oversimplification to conclude that the indications of similar rotations in the southeastern segment of the Central Mediterranean necessarily mean a rigid connection between the different parts. On the other hand, these observations of similar rotations should encourage further studies to help us to recognize those areas that indeed belonged together for shorter or longer periods during the development of the Tethys.

Fig. 31. Palaeomagnetic poles for Southeast Transdanubia compared with average poles for stable Europe. The age of the poles for stable Europe [Morel and Irving 1981]: 1 — 260–279 Ma; 2 — 240–259 Ma; 3 — 220–239 Ma; 4 — 200–219 Ma; 5 — 180–199 Ma; 6 — 160–179 Ma; 7 — 125 Ma; 8 — 80 Ma; 9 — 50 Ma; 10 — 20 Ma; C — Carboniferous pole for the Mórágy Ridge; P — Permian pole for the Western Mecsek; Tr — Triassic pole for the Western Mecsek; Ju — Late Jurassic–Berriasian pole for the Eastern Mecsek; M — average Mesozoic pole (mainly Jurassic) for the Villány Hills; a–e — Cretaceous – 21 Ma old poles for the Mórágy Ridge and the Eastern Mecsek

31. ábra. Délkelet-Dunántúl paleomágneses pólusainak összehasonlítása stabil európai átlagpólusokkal a következő időszakokra: 1 — 260–279; 2 — 240–259; 3 — 220–239; 4 — 200–219; 5 — 180–199; 6 — 160–179; 7 — 125; 8 — 80; 9 — 50; 10 — 20 millió éves pólusok [Morel és Irving 1981]; C — Mórágyi Rög, karbon pólus; P — Nyugati-Mecsek, permi pólus; Tr — Nyugati-Mecsek, triász pólus; Ju — Keleti-Mecsek, felső jura–berriázi pólus; M — Villányi-hegység, mezozoos, főleg jura pólus; a–e — kréta – 21 milió éves pólusok a Mórágyi Rögre és a Keleti-Mecsekre

Рис. 31. Палеомагнитные полюса Юговосточной Задунайщины в сопоставлении со средними полюсами стабильной Европы. Возраста полюсов стабильной Европы [Morel–Irving 1981]: 1 — 260–279 млн. лет; 2 — 240–259 млн. лет; 3 — 220–239 млн. лет; 4 — 200–219 млн. лет; 5 — 180–199 млн. лет; 6 — 160–179 млн. лет; 7 — 125 млн. лет; 8 — 80 млн. лет; 9 — 50 млн. лет; 10 — 20 млн. лет; С — полюс для карбона Морадьского блока; Р — пермский полюс для западной части Мечекских гор; Tr — триасовый полюс для западной части Мечекских гор; Ju — позднеюрско–берриасский полюс для восточной части Мечекских гор; М — средний полюс для мезозоя (в основном, для юры) Вилланьских гор; a–e — полюса возрастом от мела до 21 млн. лет для восточной части Мечекских гор и Морадьского блока

Fig. 33. Comparison between the poles in the "C" unit of Fig. 32., from areas where clockwise rotation was observed. C, P, Tr, Ju, M, a–e: for key, see Fig. 31. Palaeomagnetic poles for Greece: 1 — Epiros, Eocene; 2 — Epiros, Cretaceous; 3 — Epiros, Jurassic [HORNER 1983, HORNER and FREEMAN 1983]; 4 — Epiros, Eocene [KISSEL et al. 1985]; 5 — Chalkidiki, Eocene–Oligocene [KONDOPOULOU 1985]; 6 — for the East Carpathians, Late Cretaceous [BAZHENOV and BURTMAN 1980]; 7 — for Eastern Serbia, Late Cretaceous [STEFANOVIC and VELJOVIC 1972]

33. ábra. A 32. ábrán látható „C" egység azon területeiről származó paleomágneses pólusok összehasonlítása, ahol óramutató járásával egyező irányú deklináció rotációt is megfigyeltek. Jelölések: C, P, Tr, Ju, M, a–e: mint a 31. ábrán. Görögországra meghatározott paleomágneses pólusok: 1 — Epiros, eocén; 2 — Epiros, kréta; 3 — Epiros, jura [HORNER 1983, HORNER és FREEMAN 1983]; 4 — Epiros, eocén [KISSEL et al. 1985]; 5 — Chalkidiki, eocén–oligocén [KONDOPOULOU 1985]; 6 — Keleti-Kárpátok, felső kréta [BAZSENOV és BURTMAN 1980]; 7 — Kelet-Szerbia, felső kréta [STEFANOVIC és VELJOVIC 1972]

Рис. 33. Сопоставление полюсов из единицы «С» на рис. 32 из районов, где наблюдался поворот о часовой стрелке. С, Р. Tr, Ju, M, a–e: см. на рис. 31. Палеомагнитные полюса из Греции: 1 — Эпейрос, эоцен; 2 — Эпейрос, мел; 3 — Эпейрос, юра [HORNER 1983; HORNER, FREEMAN 1983], 4 — Эпейрос, эоцен [KISSEL et al. 1985], 5 — Халкидики, эоцен–олигоцен [KONDOPOULOU 1985], 6 — Советские Карпаты, верхний мел [BAZHENOV, BURTMAN 1980], 7 — Восточная Сербия, верхний мел [STEFANOVIC, VELJOVIC 1972]

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A VELENCEI-HEGYSÉG ÉS A MECSEK HEGYSÉG MAGMÁS KŐZETEINEK PALEOMÁGNESESSÉGE

MÁRTONNÉ SZALAY Emő

Felszini granitoid előfordulások a Velencei-hegységből és a Mecsek hegységből ismertek. A Velencei-hegység intruzív gránitjának izotóp kora minimum 280 millió év (K/Ar módszer). A Mecsek hegységben a gránitosodás folyamatát U/Pb, teljes kőzeten meghatározott Rb/Sr és K/Ar izotóp korok 365 és 334 millió év közé korlátozzák.

Mindkét gránitterületen előfordulnak fiatalabb magmás kőzetek is. Ezek közül a felszínen több feltárásban hozzáférhető a kb. 30 millió éves andezit a Velencei-hegységben (K/Ar kor), a kb. 20 millió éves andezit (K/Ar kor) és a főtömegben valószínűleg kréta alkáli magmatitok a Mecsek hegységben.

A granitoidokon évekkel ezelőtt megkezdett kisérleti jellegű mérések már felfedték, hogy mágnesezettségük összetett. Módszertani szempontból erőpróbát jelentett az összetett mágnesezettség komponensekre bontása, majd a különböző mágneses komponensek korának becslése. Ez utóbbi csak a granitoidoknál fiatalabb magmás kőzetek rendszeres vizsgálata után történhetett meg, amelyet az a felismerés tett szükségessé, hogy az idősebb kőzetek fiatal magmás folyamatokban részlegesen vagy teljesen átmágneseződhetnek.

A többkomponensű természetes remanens mágnesezettség laboratóriumi elemzése, majd a komponensek pontosságának és bizonyos időhöz rögzíthetőségének vizsgálata nyomán olyan kritériumrendszer kristályosodott ki, amely alkalmas általában a paleomágneses meghatározások megbízhatóságának becslésére. Bizonyos minimális követelményeknek eleget tevő paleomágneses irányokat további négy kategóriába sorolhatunk minőségük szerint.

"A" irányt meglepően ritkán lehet találni, mert ebben az esetben bizonyítani kell, hogy a jó minőségű irány ismert korú mágneses teret képvisel, azaz egy idős kőzetben a mágnesezettség felvételének korát szűkebb határok közé lehet szorítani, mint a kőzet sztratigráfiai vagy izotóp kora és a jelen.

"B" irány esetén az iránymeghatározás pontossága egyenértékű egy "A" irányával, de a mágnesezettség kora nem bizonyított.

A "C" irány gyengébb minőségű, vagy statisztikai szempontból vagy azért, mert a kőzet kora és/vagy települése nem elég pontosan ismert.

"A"–"C" irányok csak olyanok lehetnek, ahol a természetes remanens mágnesezettség (NRM) egykomponensű volta bizonyított, illetve összetett remanencia esetén a komponenseket szétválasztottuk. Olyankor, amikor a stabilitás bizonyított valamilyen laboratóriumi módszerrel, de nem biztos, hogy egykomponensű a mágnesezettség (bár nem kizárt), "D" irányról beszélhetünk. Ezt tektonikai értelmezésre csak nagy óvatossággal lehet használni.

A Velencei-hegységből és a Mecsek hegységből származó minták mágnesezettségét részletesen és a természetes remanens mágnesezettség eltűnéséig elemeztük a laboratóriumban (váltóterű tisztitással vagy hőkezeléssel, illetve a kettő kombinációjával). A laboratóriumi vizsgálat eredményét a 2. ábrán látható kritériumrendszer szerint minősítettük. Az eredmények az alábbiak szerint foglalhatók össze.

A Velencei-hegységben a harmadkori andezit erőteljesen átmágnesezte a gránitot. Az andezitvulkanizmus idejére jellemző paleomágneses irány "A" kategóriájú ($D = 151°$ $I = -45°$ $k = 22$ $\alpha^{\circ}_{95} = 8{,}4°$, ez az irány 8 andezit feltárásra, 7 teljesen átmágnesezett gránitra és 1 diabáz feltárásra meghatározott középirányok középiránya). Tektonikai szempontból azt jelenti, hogy a Dunántúli-középhegység Afrikához és természetesen egyúttal stabil Európához viszonyított, az óramutató járásával ellentétes 30–35°-os elfordulása fiatalabb 30 millió évnél.

A teljesen átmágnesezett gránitok mellett öt mintavételi helyről sikerült olyan remanenciát elkülöníteni, amelyek iránya mind a jelenlegi tér irányától, mind az andezitvulkanizmus idejére meghatározott paleomágneses iránytól különbözik ($D = 144°$ $I = +30°$ $k = 49$ $\alpha^{\circ}_{95} = 11{,}1°$, "C" irány). Kora lehet karbon, mert inklinációja kis déli szélességen történt mágneseződésre utal; deklinációja jól illeszkedik ahhoz a rotációs képhez, amelyet a mezozoos és fiatalabb kőzetek határoznak meg a Dunántúli-középhegységre.

Az andezitvulkanizmus idején teljesen és alig átmágnesezett gránitok térbeli eloszlása az andezitkitörés központjához képest, amelyet a hegység keleti részén feltételeznek, szabálytalan. Az átmágneseződés valószínűleg utómagmás oldatok kémiai hatásának a következménye és erőssége függ a gránit porozitásától.

A Mecsekben a legfiatalabb magmás tevékenység, az andezitvulkanizmus kb. 20 millió éves (K/Ar kor). Paleomágnesesen ezt a kort a komlói andezit lakkolit három különböző helyéről vett minták képviselik ($D = 59°$ $I = 65°$ $k = 36$ $\alpha^{\circ}_{95} = 22{,}2°$, a statisztika alapját a mintavételi helyek száma képezi! Az irány "C" kategóriájú). Irányuk a Mecsek hegységnek az andezit mágneseződése utáni, óramutató járásával egyező irányú elfordulását jelzi. Maga az óramutató járásával egyirányú elfordulás azonban nemcsak a komlói andezit paleomágneses irányán jelentkezik, hanem a korábbi alkáli vulkanizmus termékein is.

A Mórágyi Rög alkáli vulkanitjain és két teljesen átmágneseződött gránit aplit teléren sikerült "B" irányt meghatározni ($D = 94°$ $I = 57°$ $k = 28$ $\alpha^{\circ}_{95} = 9{,}3°$). A keleti Mecsek alkáli vulkanizmusát csak "C" irány jellemzi, vagy a tektonikai korrekciók vagy a korok pontos ismerete hiányában ($D = 79°$ $I = 54°$ $k = 7$ $\alpha^{\circ}_{95} = 33{,}6°$ tektonikai korrekció után, 6 mintavételi hely középirányának középiránya).

A Mórágyi Rög karbon granitoidjainak paleomágneses iránya: $D = 189°$ $I = 18°$ $k = 36$ $\alpha^{\circ}_{95} = 11{,}4°$ "B" irány (6 mintavételi hely középiránya). A karbonra kapott és a permi, triász és felső jura üledékes kőzetekre ismert paleoirányokhoz képest a fiatalabbak az óramutató járásával egyező irányban jelentősen elfordultak. Ez a kép arra utal, hogy a kréta folyamán a Mecsek hegység az óramutató járásával ellentétesen fordult el, majd később, valószínűleg a felső harmadkorban jelentős, az óramutató járásával egyirányú rotációt végzett.

Fenti eredmények megerősítik, hogy a Pannon területnek a Dunántúlon a felszínen levő ÉNy-i és DK-i egysége a földtörténeti múltban egymástól független mozgásokat végzett; azt jelzik, hogy jeelntős mozgásokkal kell számolnunk a felső harmadkorban is. Végül az újonnan meghatározott paleomágneses irányok arra utalnak, hogy a DK-i egység bonyolult mozgásokat végzett és az eddig ismert deklináció rotációk alapján nem lehet eldönteni, hogy a DK-i egység a Tethys északi vagy déli pereméhez tartozott-e.

ПАЛЕОМАГНЕТИЗМ МАГМАТИЧЕСКИХ ПОРОД ВЕЛЕНЦЕЙСКИХ И МЕЧЕКСКИХ ГОР

Эмё МАРТОН

Выходы гранитов на поверхность известны в горах Веленце (40 км к ЮЗ от Будапешта) и Мечек (150 км к ЮЮЗ от Будапешта). Изотопный возраст интрузивных гранитов гор Веленце составляет минимум 280 млн. лет по данным калий–аргоновых определений. Процесс гранитизации в горах Мечек, по данным ураново–свинцовых определений и по рубидиево–стронциевым и калий–аргоновым изотопным возрастам, полученным по породе, имел место в интервале времени 365–334 млн. лет.

В обоих районах развития гранитов встречаются и более молодые магматические породы. Из них на поверхности в ряде обнажений доступны андезиты с возрастом около 30 млн. лет (калий–аргоновый возраст) в горах Веленце, а также андезиты с возрастом около 20 млн. лет (калий–аргоновый возраст) и щелочные магматические породы, в своей основной массе имеющие, вероятно, меловой возраст, в горах Мечек.

Опытными измерениями, начатыми несколько лет тому назад, было выявлено, что на магниченность гранитоидов является сложной, многокомпонентной. С методической точки зрения потребовалось немало усилий, чтобы разложить эту сложную намагниченность на компоненты, а затем оценить возраста обособленных компонент. Последнее стало возможным лишь вслед за систематическим изучением магматических пород моложе гранитоидов, что было вызвано тем открытием, что более древние магматические породы могли быть перемагничены частично или полностью во время более молодых магматических процессов.

Вслед за лабораторным анализом многокомпонентной естественной остаточной намагниченности, а затем исследованием точности отдельных компонент и возможности их привязки к определенным временным интервалам создана система критериев оценки надежности палеомагнитных определений вообще. Палеомагнитные направления, удовлетворяющие некоторым минимальным требованиям, можно по их качеству отнести к одной из четырех нижеследующих категорий:

Направления категории "A" встречаются удивительно редко, поскольку в этом случае необходимо доказать, что данное направление высокого качества характеризует магнитное поле известного возраста, то-есть имеется возможность уточнить время намагничивания какой-нибудь древней породы в пределах интервала, началом которого является стратиграфический или изотопный возраст породы, а концом – настоящий момент.

В случае направлений категории "B" точность определения палеомагнитных направлений такова же, как и в случае категории "A", но возраст намагниченности не доказан.

Направление категории "C" имеет более низкое качество либо с точки зрения статистических параметров, либо из-за того, что возраст и/или условия залегания породы известны с недостаточной точностью.

Палеомагнитные направления могут быть отнесены к категориям "A"–"C" в том случае, если либо доказана однокомпонентная природа естественной остаточной намагниченности, либо, в случае сложной остаточной намагниченности, удалось разделить компоненты. В тех случаях, когда стабильность доказана каким-либо лабораторным методом, но нет уверенности в том, что намагниченность является однокомпонентной (хотя этого нельзя и исключить), направления могут быть отнесены только к категории "D". В тектонических интерпретациях они могут использоваться лишь с большой осторожностью.

Намагниченность проб из гор Веленце и из гор Мечек нами была исследована весьма детально, вплоть до исчезновения естественной остаточной намагниченности (чисткой переменным током или термообработкой или же их комбинацией). Результаты лабораторных исследований были оценены по системе критериев, приводимой на рис. 2. Результаты могут быть обобщены нижеследующим образом.

В горах Веленце граниты были интенсивно перемагничены третичными андезитами. Палеомагнитное направление, характерное для времени проявления андезитового вулканизма ($D = 151°$, $I = -45°$, $k = 22$, $\alpha_{95}^{\circ} = 8{,}4°$, это направление представляет собой среднее из средних направлений по 8 обнажениям андезитов, 7 обнажениям полностью перемагниченных гранитов и 1 обнажению диабазов), относится к категории "A". С точко зрения тектонических интерпретаций это означает, что поворот Задунайского Среднегорья на 30–35° против часовой стрелки по отношению к Африке и в то же время, естественно, и по отношению к Европе произошло менее, чем 30 млн. лет назад.

Наряду с полностью перемагниченными гранитами в пяти точках опробования удалось выделить такую остаточную намагниченность, направление которой отличается как от направления современного поля, так и от палеомагнитного направления, определенного для времени андезитового вулканизма ($D = 144°$, $I = +30°$, $k = 49$, $\alpha_{95}^{\circ} = 11{,}1°$; направление категории "C"). Оно может быть каменноугольного возраста, поскольку наклонение указывает на намагничивание на низких южных широтах; склонение соответствует ротационной картине, определяемой для Задунайского Среднегорья по мезозойскими и более молодыми породами.

Пространственное распределение гранитов, полностью или еле перемагниченных во время андезитового вулканизма, по отношению к центру извержения андезитов, предполагаемому в восточной части гор Веленце, является нерегулярным. Перемагничивание, вероятно, вызвано химическим воздействием постмагматических растворов, и его интенсивность зависит от пористости гранитов.

В горах Мечек наиболее молодая магматическая деятельность: андезитовый вулканизм – имела место примерно 20 млн. лет назад (калий-аргоновый возраст). В палеомагнитном отношении этот возраст представлен пробами, взятыми в трех разных участках андезитового лакколита в Комло ($D = 59°$, $I = 65°$, $k = 36$, $\alpha_{95}^{\circ} = 22{,}2°$; основа статистики – количество участков отбора проб; направление категории "C"). Этим направлением отмечается поворот гор Мечек по часовой стрелке после намагничивания андезитов. Сам по себе поворот по часовой стрелке, однако, проявляется не только в палеомагнитном направлении андезитов Комло, но также и в продуктах более раннего щелочного вулканизма.

На щелочных вулканитах и на семи полностью перемагниченных дайках гранит-аплитов Морадьской глыбы удалось определить направление категории "B" ($D = 94°$, $I = 57°$, $k = 28$, $\alpha_{95}^{\circ} = 9{,}3°$). Щелочной вулканизм восточной части гор Мечек характеризуется направлением только категории "C" вследствие неточности знания либо тектонических поправок, либо возраста ($D = 79°$, $I = 54°$, $k = 7$, $\alpha_{95}^{\circ} = 33{,}6°$ после тектонических поправок, среднее из средних направлений 6 пунктов отбора проб).

Палеомагнитное направление гранитоидов каменноугольного возраста Морадьской глыбы – $D = 189°$, $I = 18°$, $k = 36$, $\alpha_{95}^{\circ} = 11{,}4°$, категории "B" (среднее из 6 пунктов отбора проб). По отношению к полученным для карбона и известным для перми, триаса и верхней юры по осадочным породам палеонаправлений более молодые направления повернуты по часовой стрелке на значительный угол. Эта картина свидетельствует о том, что в мелу горы Мечек были повернуты против часовой стрелки, затем позже, вероятно, в позднетретичное время участвовали в значительном повороте по часовой стрелке.

Приводимые результаты подтверждают, что северозападная и юговосточная части Паннонского региона, выходящие на поверхность в Задунайщине, в геологическом прошлом участвовали в не зависимых друг от друга движениях; они отмечают, что необходимо считаться со значительными движениями и в позднетретичное время. Наконец, вновь определенные палеомагнитные направления указывают на то, что юговосточная единица участвовала в сложных движениях и что по познанным до сих пор поворотам склонений нельзя решить, относилась ли юговосточная единица к северной или к южной окраине Тетиса.

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ANALYSIS OF THE ANTI-CLOCKWISE ROTATION OF THE MECSEK MOUNTAINS (SOUTHWEST HUNGARY) IN THE CRETACEOUS: INTERPRETATION OF PALAEOMAGNETIC DATA IN THE LIGHT OF THE GEOLOGY

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Geological material available in the literature is analysed to show that there is no basis for supposing some Cretaceous volcanites in the Mecsek Mountains to be younger than the orogeny. On the other hand, some subvolcanic bodies are really younger than the prevailing mass of surface volcanites and it is reasonable to assume that the Mecsekian Cretaceous volcanism lasted till the Senonian although post-Barremian Cretaceous complexes are absent due to erosion.

Palaeomagnetic data can be interpreted in terms of two rotations one of which occured in the Cretaceous in the anti-clockwise sense, the other took place in the Miocene in the clockwise sense. These rotations mutually compensate each other so that pre-Cretaceous formations manifest almost no rotation relative to Europe. Based on geological data and kinematic considerations the first rotation can be fixed in the Albian–Cenomanian time span. This timing and the degree of rotation exclude location of the Mecsek on the African plate.

The first, anti-clockwise rotation led to the decoupling of the Mecsek from Europe and to the opening of the Inner Carpathian basin between them. The Lower Cretaceous alkali basalt volcanism both in the Mecsek and in the Moravo–Silesian Beskids can be related to rifting in the initial stages of the opening. The second, clockwise rotation led to the closing of the same basin.

Keywords: albitization, alkali basalts, Cretaceous, metamorphism, orogeny, palaeomagnetism, phonolites, rotation, Tethys, volcanism

1. Introduction

The Cretaceous volcanites of the Mecsek Mountains *(Fig. 1)* differ in composition. Besides the dominant alkali diabases [PANTÓ 1961, VICZIÁN 1966, BILIK 1974, SZILÁGYI 1979, BÓNA et al. 1983] also called trachydolerites [MAURITZ 1913, SZÉKY-FUX 1952] or alkali basalts [BILIK 1966], also more acid rocks, viz. trachytes and alkali trachytes [MAURITZ 1958, BILIK 1974] or keratophyres and quartz keratophyres [SZILÁGYI 1979], as well as phonolites [MAURITZ 1913, 1925, SZÉKY-FUX 1952, VICZIÁN 1970, 1971] and basic differentiates of essexite, camptonite and teschenite type [MAURITZ 1913, VICZIÁN 1971] occur. Since the first detailed description [MAURITZ 1913], all petrographers [MAURITZ 1925, SZÉKY-FUX 1952, PANTÓ 1961, VICZIÁN 1970] have regarded the whole rock association to be uniform in the genetic sense.

Among the magmatites both surface volcanites and subvolcanic rocks (in sills, dykes, etc.) occur. Surface volcanites comprise two complexes: a pure

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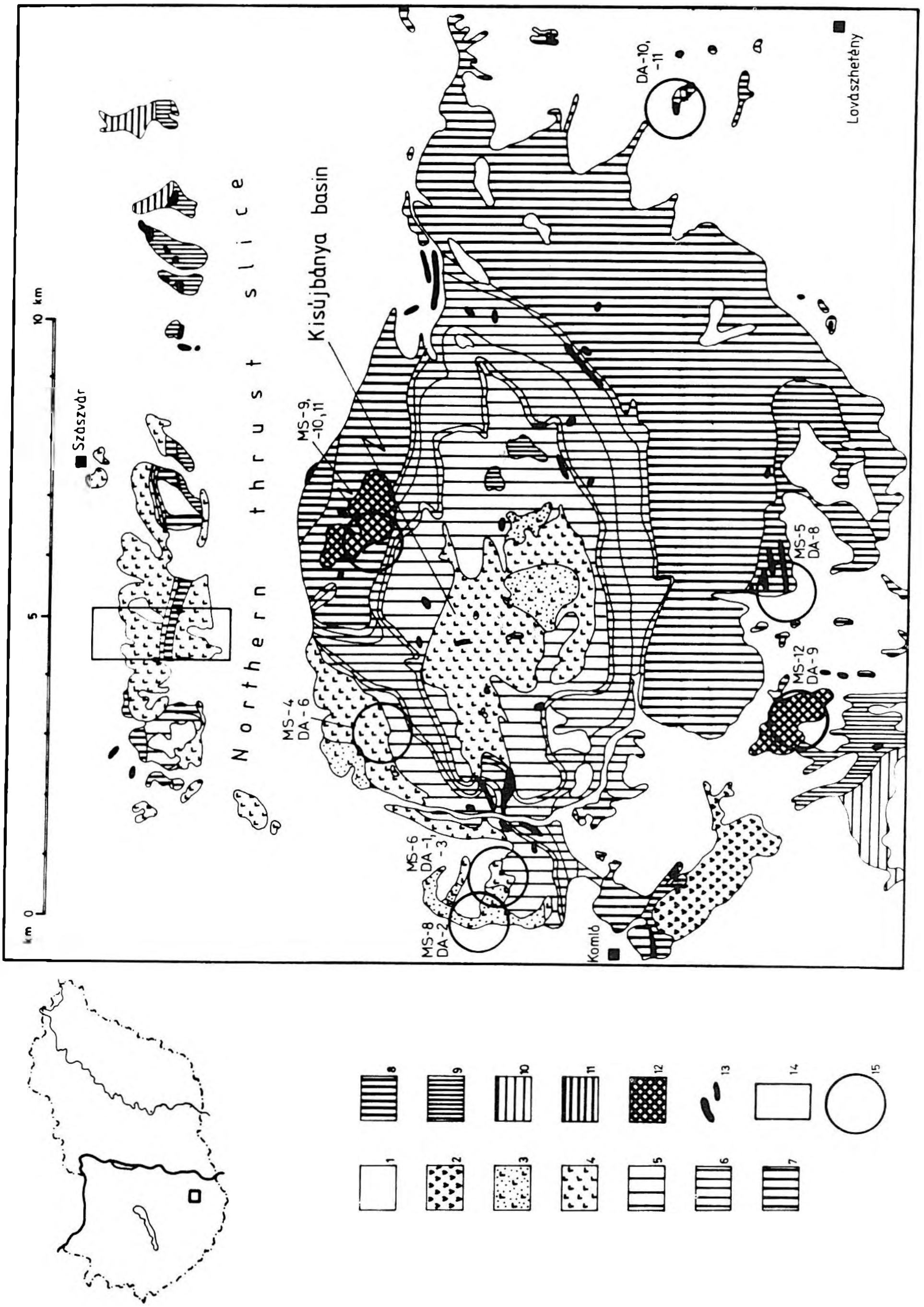
km 0
5
10 km
Szászvár
Northern thrust slice
Kisújbánya basin
MS-9, -10,11
MS-4 DA-6
MS-6 DA-1, -3
MS-8 DA-2
Komló
MS-5 DA-8
MS-12 DA-9
DA-10, -11
Lovászhetény
1
2
3
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volcanic one below and a volcano-sedimentary one immediately above it. The youngest sediments underlying the volcanic complex are of Berriasian age [Vadász 1960] and already contain volcanic material [Pantó 1961, Wein 1961] as do various levels of the Upper Jurassic sequence [Nagy 1967]. The volcanic complex was placed into the Valanginian stage while the volcano-sedimentary complex was considered to belong to Late Valanginian to Hauterivian [Wein 1961, 1967, Földi et al. 1977], Hauterivian [Nagy et al. 1978] or Hauterivian to Barremian [Bilik 1974, Bilik et al. 1978]. The volcanism may thus have already started in the Late Jurassic, the main paroxysm having taken place in the Valanginian and the volcanism continuing during the Hauterivian and, possibly, Barremian.

The first idea on the change of volcanites in time was epxressed by Wein [1961]: in his stratigraphic column, lavas are followed by dykes and then by phonolites. Later [Wein 1967] he supposed that the volcanites become more and more acidic in time. According to the stratigraphical scheme elaborated during the 1 : 10 000 geological mapping [Bilik 1974, Hámor et al. 1974, Földi et al. 1977, Bilik et al. 1978, Nagy et al. 1978] magmatism occured in several phases, and the complete differentiation sequence including most of the subvolcanic rocks arose during the second phase related to the beginning or middle of the Valanginian.

Fig. 1. Geological map of the eastern Mecsek Mountains (simplified after Vadász 1935)
1–2 — Cenozoic: 1 — sediments, 2 — Lower Miocene andesite; 3–13 — Mesozoic: 3–4 — Lower Cretaceous (Valanginian–Hauterivian): 3 — volcano-sedimentary complex, 4 — volcanic complex: 5–9 — Jurassic sediments: 5 — Tithonian, 6 — Upper Lias to Callovian, 7 — Middle Lias; 8–9 — Lower Lias: 8 — marine complex, 9 — coal-bearing complex; 10–11 — Triassic sediments: 10 — Rhaetian, 11 — Middle Triassic; 12–13 — Cretaceous subvolcanic bodies: 12 — phonolite, 13 — alkali diabase; 14 — frame of Fig. 11; 15 — palaeomagnetic sampling sites with codes

1. ábra. A Keleti Mecsek földtani térképe (Vadász 1935 nyomán, egyszerűsítve)
1–2 — kainozoikum: 1 — üledékek, 2 — alsó miocén andezit; 3–13 — mezozoikum: 3–4 — alsó kréta (valangini–hauterivi): 3 — vulkáni–üledékes összlet, 4 — vulkáni összlet; 5–9 — jura üledékek: 5 — titon, 6 — felső liász–kallóvi, 7 — középső liász; 8–9 — alsó liász: 8 — tengeri összlet, 9 — kőszéntelepes összlet; 10–11 — triász üledékek: 10 — rhaeti, 11 — középső triász; 12–13 — kréta szubvulkáni testek: 12 — fonolit, 13 — alkáli diabáz; 14 — a 11. ábra kerete; 15 — paleomágneses mintavételi hely és jele

Рис. 1. Геологическая карта восточной части Мечекских гор [по Vadász 1935, упрощена]
1–2 — кайнозой: 1 — осадочные породы, 2 — нижнемиоценовые андезиты; 3–13 — мезозой: 3–4 — нижний мел (валанжин–готерив): 3 — вулканогенно-осадочная толща, 4 — вулканогенная толща; 5–9 — юрские отложения: 5 — титонские, 6 — верхнелейасово–келловейские, 7 — среднелейасовые, 8–9 — нижнелейасовые: 8 — морская толща, 9 — угленосная толща; 10–11 — триасовые отложения: 10 — рэтские, 11 — среднетриасовые; 12–13 — меловые субвулканические тела: 12 — фонолитов, 13 — щелочных диабазов; 14 — рамка рис. 11; 15 — точка отбора палеомагнитных проб с ее обозначением

Editor's note: the "Northern thrust slice" is the same tectonic unit called in the former paper "Northern Nappe"

According to Vadász [1960], Wein [1961] and Pantó [1961] the volcanic complex covers an erosional surface of Upper Jurassic to Berriasian sediments. Based on this, Wein [1961, 1967] supposed uplift and folding (doming) after the beginning of the volcanism and before the accumulation of the volcanic complex (Hils phase of the Neocimmerian orogeny). He assumed, however, that the principal folding occured after the termination of the magmatism. During the 1 : 10 000 geological mapping this picture was modified; it was supposed that the volcanism was interrupted by several compressive phases although it occured in extensive phases and that the principal folding took place after the volcanism hat ended [Bilik et al. 1978].

Némedi Varga [1963] assumed that the Kövestető phonolite intruded after the principal folding although the intrusive body suffered later compressive dislocations. Viczián [1971] criticized this concept but the author of the work ignored this criticism and in a subsequent article [Némedi Varga 1971] also regarded some alkali diabase dykes to be younger than the folding. Szilágyi [1979] supported this concept explaining alterations of dyke rocks by metamorphism and linking the metamorphism with the orogeny and supposing that fresh rocks were formed after the metamorphism and folding. Némedi Varga [1971, 1983a] has called attention to the fact that palaeomagnetic declinations [Márton and Szalay-Márton 1969] of Lower Cretaceous diabase lavas from Márévár Valley (belonging mostly to the Valanginian volcanic complex and partly to the Hauterivian volcanosedimentary complex) significantly differ from those for the subvolcanic phonolites of the Somlyó Hill that are regarded as Late Cretaceous.

After tilt corrections, palaeomagnetic pole directions *(Table I)* form two groups: the first with declination close to the present one and the second with declination significantly different from it. Mean values of tilt-corrected directions for locality groups (all treated as normal)

	N	D_c°	I_c°	k	α°_{95}
Group I	8	341.6	41.7	25	11.3
Group II	3	76.4	55.5	33	21.7

Table I. Summary and re-evaluation of palaeomagnetic data for the Mecsekian Cretaceous volcanites. MS = Márton and Szalay-Márton 1969; DA = Dagley and Ade-Hall 1970 n = number of samples, D° = palaeomagnetic declination, I° = palaeomagnetic inclination, k = Fisher's precision parameter, α°_{95} = angle of confidence, φ° = dip azimuth, δ° = dip angle

I. táblázat. A mecseki kréta vulkanitokra vonatkozó paleomágneses adatok összesítése és újraértékelése. MS = Márton and Szalay-Márton 1969; DA = Dagley and Ade-Hall 1970 n = a minták száma, D° = paleomágneses elhajlás, I° = paleomágneses lehajlás, k = a Fisher-féle pontossági paraméter, α°_{95} = konfidenciakör, φ° = dőlésirány, δ° = dőlésszög

Табл. I. Сводка и переинтерпретация палеомагнитных данных по меловым вулканитам Мечекских гор. MS = Márton and Szalay-Márton 1969; DA = Dagley and Ade-Hall 1970 n = количество образцов, D° = палеомагнитное склонение, I° = палеомагнитное наклонение, k = параметр кучности Фишера, α°_{95} = угол доверия, φ° = азимут падения, δ° = угол падения

	Locality	Reference	Code	Rock Name	Age	Rock position	Direct measurement results					Tectonic position				Tilt-corrected directions				Mean values for localities with two sets of measurements	
												referred		this work		referred		this work			
							n	D°	I°	k	α°_{95}	φ°	δ°	φ°	δ°	D°_c	I°_c	D°_c	I°_c	D°_m	I°_m
GROUP I	Márévár Valley	MS DA	3 4	trachydolerite dolerite	– Val.	dyke sill	4 10	350.4 74.7	51.5 57.0	27 5	18.0 24	– 310	– 51	– 316	– 52	350.0 354.4	51.5 50.2	– 359.7	– 46.3	–	–
	Márévár Valley	MS DA	4 6	trachydolerite basalt	– Val.	lava lav	4 10	227.7 222.0	– 60.1 – 67.2	60 169	12.0 4	305 310	30 51	322 322	22 22	182.0 165.7	– 54.1 – 34.4	196.1 185.1	– 52.2 – 56.1	190.9	– 54.3
	Márévár Valley	DA	7	alkali basalt	Haut.	lava	8	347.1	87.7	28	11	310	51	317	30	311.7	37.2	319.2	58.0	–	–
	Márévár Valley	DA	5	–	Val.	lava	12	187.5	28.9	1.4	68	310	51	–	–	226.0	42.0	–	–	–	–
	Jánosi Great Valley	MS DA	6 1	trachydolerite alkali diabase	– Val.	lava lava	6 8	205.4 235.5	– 73.3 – 74.8	50 40	9.6 9	310 315	30 45	334 334	32 32	158.0 156.7	– 51.5 – 45.9	172.8 179.5	– 45.6 – 52.9	175.9	– 49.3
	Jánosi Great Valley	DA	3	alkali daibase	Haut.	lava	8	352.9	66.6	27	11	315	45	334	32	330.7	25.3	343.1	35.4	–	–
	Jánosi Puszta	MS DA	8 2	trachydolerite alkali diabase	– Haut.	aggl. lava	– 8	– 327.9	– 59.3	– 237	– 4	135 315	35 45	– 334	– 32	– 321.8	– 14.8	– 330.5	– 27.4	–	–
	Dezső Rezső Valley	DA	10	alkali diabase	Val.	lava	8	9.4	69.7	31	10	280	30	304	32	316.3	54.1	331.0	46.0	–	–
	Dezső Rezső Valley	DA	11	alkali diabase	Val.	lava	8	345.2	70.8	135	5	280	30	320	40	306.8	48.5	329.5	32.2	–	–
GROUP II	Hosszúhetény Quarry	MS DA	5 8	trachydolerite dolerite	– Val.	dyke sill	5 6	298.7 298.8	– 39.1 – 53.5	36 15	12.8 6	345 5	40 42	352 352	32 32	255.5 241.6	– 56.0 – 49.4	267.4 247.4	– 51.3 – 60.5	258.6	– 56.3
	Kövestető Quarry	MS DA	12 9	phonolite phonolite	– Val.	lava intr.	– 8	– 50.2	– 71.8	– 8	– 6	40 5⁺	48 42⁺	– 75	– 30	– 20.5	– 34.0	– 64.7	– 42.9	–	–
	Máza Valleyhead	MS MS MS	9 10 11	teschenite phonolite phonolite	– – –	– lava dyke	3 2 } 8 3	216.1	– 45.9	17	13.9	180	40	180	40	274.0	– 64.5	274.3	– 65.7	–	–

⁺ Not published, reconstructed from the tilt-corrected direction

Initially, it was supposed (MÁRTON and SZALAY-MÁRTON 1969, 1970] that pole directions for the second group reflect local tectonic rotations around vertical axes. Later, in consequence of palaeomagnetic investigations of crystalline rocks in the southeastern Mecsek Mountains it became clear that pole directions for the Cretaceous volcanites and older sedimentary rocks manifest double rotation of the whole Mecsek–Villány area [MÁRTON 1980] one before and the other after the volcanism.

The second, clockwise rotation was through a large angle, and after its compensation the pole direction for the Permian [KOTÁSEK et al. 1969] and Mesozoic [MÁRTON-SZALAY and MÁRTON 1978] sediments which are close to the stable European ones in their present position, became significantly different from the European pole directions thereby contradicting the European origin of South Transdanubia [MÁRTON 1984a, 1984b]. Two different explanations for the origin of the earlier anti-clockwise rotation have appeared. MÁRTON [1984a, 1984b] emphasized that it was close to the rotation of the African plate and, therefore, the Mecsek–Villány domain might have been located on the African plate till the second rotation. BALLA [1984b, 1985] regarded this coincidence to be accidental and supposed that the first rotation had been connected with decoupling of the Mecsek–Villány domain from the Euopean plate.

The Komló andesite (Lower Miocene [ÁRVA-SÓS and RAVASZ 1978, PORDÁN 1983, SÜTŐ-SZENTAI 1983]) also suffered the second rotation therefore the latter must have occured in the Miocene. Its kinematics have been studied in detail [BALLA 1984c]. At the same time, the kinematics of the first rotation have remained unclear. The goal of this work is to confront geological and palaeomagnetic data in relation to this rotation.

The main question to be examined is the age of the rotation. Since the Cretaceous volcanites partly suffered this rotation and partly not, it is very important to have a real idea of the geological data with regard to the timing of the volcanites. The simplest approach seemed to be to consider the volcanites with the palaeomagnetically detectable first rotation (i.e. with no rotation relative to the present pole because of mutual compensation of two rotations) to be Lower Cretaceous in age and the volcanites without the first rotation (i.e. with only clockwise rotation relative to the present pole) to be Late Cretaceous in age [NÉMEDI VARGA 1971]. The real question is, however, whether Late Cretaceous volcanites do exist in the Mecsek or not.

2. On the Cretaceous volcanism postdating the folding and metamorphism

Late Cretaceous volcanites have been distinguished [NÉMEDI VARGA 1963, 1971, SZILÁGYI 1979] by supposing that they are younger than both the folding and the metamorphism. There are no doubts on the folding of the Mesozoic complexes of the Mecsek Mountains but as for the metamorphism, the picture is not so simple.

2.1 Metamorphism of Cretaceous volcanites

Metamorphism of Cretaceous volcanites was assumed to have occured [Szilágyi 1979] based on re-examinations of alteration of dyke rocks described by Mauritz [1913]. With regard to the mineralogy and petrography of altered rocks, Szilágyi [1979] stated nothing new; he does, however, mention siderite and leucoxene in altered rocks and zoisite instead of epidote. The only important difference as opposed to Mauritz's description concerns analcite and albite: whereas Mauritz [1913] described albite as a primary and analcite as a secondary mineral, Szilágyi [1979] emphasized the albitization of the analcite. His view is that analcite occurs in the same interstitial position between feldspar laths as in Mauritz's description. This is a typical case when it is very difficult to decide whether analcite is of primary or secondary origin [Deer et al. 1963].

This question is, however, very important because analcite is also abundant in phonolites [Mauritz 1913, Viczián 1971] which were regarded as Late Cretaceous [Némedi Varga 1963] and post-metamorphic [Némedi Varga 1983a]. In phonolites, analcite can only be of magmatic or hydrothermal origin and, obviously, the same is true for similar analcite in 'metamorphic' volcanites. On the other hand, albite is the most important 'metamorphic' mineral in Szilágyi's opinion; it could not, therefore, be older than analcite. However, no facts have been presented to support albitization of analcite.

As for Szilágyi's other evidence of the metamorphism: the temperature estimations for the plagioclase (400–510 °C) [Szilágyi 1979] are completely inconsistent with the zeolite facies metamorphism supposed, the presence of relics of basic plagioclase in altered rocks does not prove metamorphism, the same being true for the asymmetric alteration of the sill studied. The last evidence would be the exclusion of outer sources for sodium. In this respect Szilágyi puts forward two considerations: the first being that spilitization is impossible in subvolcanic conditions. This is, however, not correct since the seawater filling pores in terrigenous sediments is sufficient to produce spilitization of subvolcanic intrusions. Szilágyi's second argument is that the sodium content is constant across the only sill studied in this relation. According to Némedi Varga [1971], however, the 2–5 m thick sills and dykes are completely altered whereas in the 5–20 m thick bodies the alteration is restricted to 2–3 m thick rims. This pattern clearly manifests an outer source of alteration agents, and it is quite obvious that there is no reason for any changes in the sill studied by Szilágyi since it is only 2.7 m thick. This means that none of the arguments for the metamorphism is convincing.

It is of interest at this point to review data on country rocks. Two series of investigation of coalification processes have been carried out. On the basis of volatile studies Némedi Varga [1967] and Nagy [1971] concluded that the correlation of the volatile content with the depth is too weak; thus, changes in volatile content cannot be related to differences in the burial depth, but to orogenic processes. On the other hand, Vető [1978] and Laczó [1983] established clear dependence of vitrinite reflection on the stratigraphic depth and related coalification to the burial processes. In spite of contradictions between two groups of data, both of them are in agreement when determining coalification temperatures to have a maximum of 120–130 °C, which is too low speak about metamorphism of magmatic rocks.

2.2 Relationships between the volcanism and folding

We have seen that alternation of volcanism and compressive dislocations in time has been accepted by most people. In Némedi Varga's concept [1963, 1971, 1983a, 1983b] the new element is that this view was extended to the principal folding as well and, accordingly, part of the volcanites was considered Late Cretaceous. As long as the tectonic qualification of the Mecsekian Cretaceous volcanites remained ambiguous (e.g. 'miogeosynclinal' [Viczián 1970]) and alternation of compressive and extensive phases was considered as the essence of the tectonic development, this concept seemed to be quite reasonable. Since then, however, with the assumption of the genetic connection of the Mecsekian volcanites with ophiolites [Szepesházy 1977] the above idea has already become unacceptable. After outlining the rift origin [Balla 1982, Bilik 1983] it became incomprehensible how the periodic compression could be consistent with the alkali diabase magmatism of permanent character.

Re-examining the argumentation of Wein [1961, 1967] and Bilik et al. [1978] for the periodic compression in the light of the above theoretical considerations, it became clear that there can be only one argument, i.e. that of periodic erosion. It must be clear that an explanation of erosion in terms of compressive tectonics is not necessarily true and that never and nowhere have synvolcanic folds been outlined in the Mecsek Mountains. On the other hand, rifting processes always and everywhere are accompanied by block tectonism, so periodic erosion is quite explainable in this framework.

The concept of Némedi Varga [1963, 1971], however, cannot be rejected on purely theoretical grounds and it needs a comprehensive analysis. According to him, alkali diabase and phonolite bodies occur in three different positions within the coal-bearing complex as follows:

1) in sills — this is the dominant type with bodies which follow folded structures;

2) in dykes intruding into the country rocks;

3) in 'fissure fillings' — as thick bodies occurring where tectonic dislocations are strong.

Рис. 2. Колонки буровых скважин, вскрывших фонолиты на Кёвештетё (по Némedi Varga 1963, с изменениями), скоррелированные по кровле угленосной толщи. Положение скважин см. на рис. 3 и 4

1 — рэтский ярус; 2–4 — нижний лейас: 2 — геттангско–синемюрский ярус, угленосная толща, 3 — нижнелотарингсий подъярус, толща перекрывающих песчаников, 4 — верхнелотарингский подъярус, толща перекрывающих мергелей; 5 — нижнаяя часть среднего лейаса, толща пятнистых известковистых мергелей; 6–7 — мел: 6 — щелочные диабазы, 7 — фонолиты; 8 — гельветский ярус (миоцен); 9 – антропоген; 10 — разрывное нарушение; 11 — комлойская скважина, 12 — хоссухетеньская скважина

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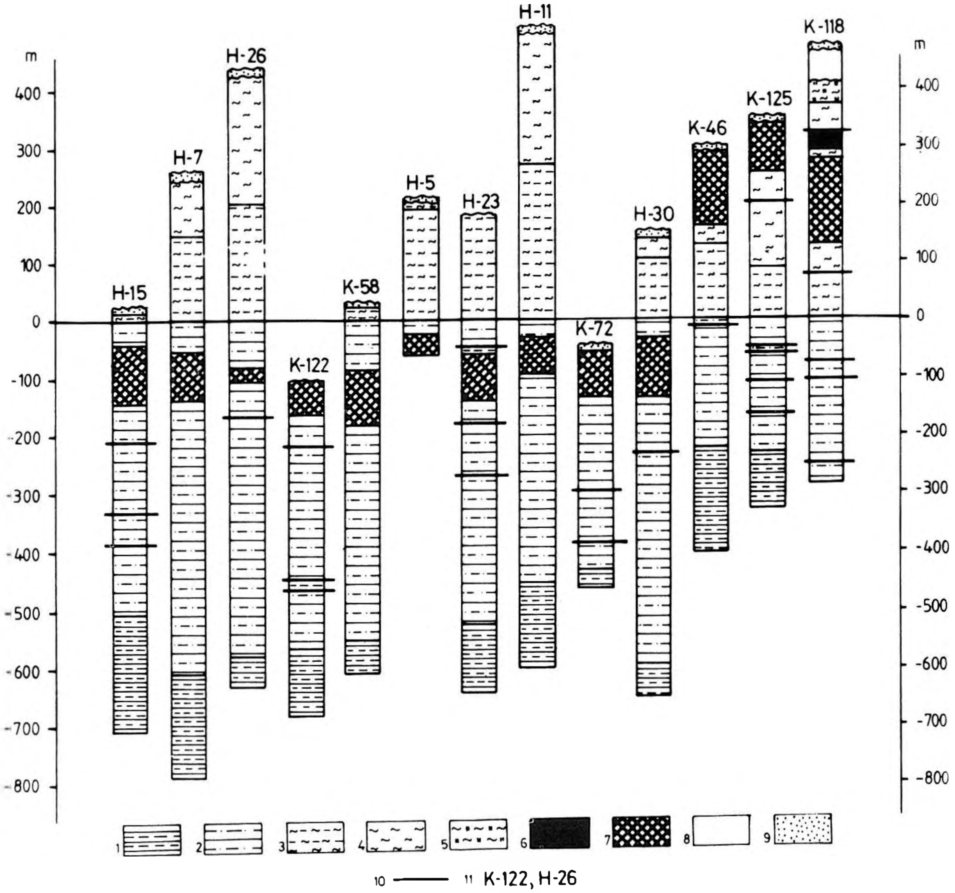

Fig. 2. Stratigraphic columns of the boreholes penetrating the Kövestető phonolite correlated along the top of the coal-bearing complex (modified after NÉMEDI VARGA 1963). For locations, see Figs. 3 and 4

1 — Rhaetian; 2–4 — Lower Lias; 2 — Hettangian–Sinemurian, coal-bearing complex, 3 — Lower Lotharingian, overlying sandstone complex, 4 — Upper Lothariangian, overlying marl complex; 5 — Middle Lias, lower part, spotty calcareous marl complex; 6–7 — Cretaceous: 6 — alkali diabase, 7 — phonolite; 8 — Helvetian; 9 — Quaternary; 10 — fault; 11 — boreholes in the Komló and Hosszúhetény areas

2. ábra. A kövestetői fonolitot feltáró mélyfúrások rétegsorai (NÉMEDI VARGA 1963 nyomán, módositva) a kőszéntelepes összlet fedővonala mentén párhuzamositva. Helyüket l. a 3. és 4. ábrán

1 — rhaeti; 2–4 — alsó triász: 2 — hettangi–szinemuri, kőszéntelepes összlet, 3 — alsó lotharingiai, fedőhomokkő összlet, 4 — felső lotharingiai, fedőmárga összlet; 5 — középső liász alsó része, foltos mészmárga összlet; 6–7 — kréta: 6 — alkáli diabáz, 7 — fonolit; 8 — helvéti; 9 — kvarter; 10 — törés; 11 — komlói és hosszúhetényi mélyfúrások

The sill position itself does not give any information on the succession of the folding and the intrusion since, according to Némedi Varga [1971], the Komló andesite which intruded after the principal folding in all tectonic concepts forms a sill. Similarly, the singificance of 'fissure fillings' is unclear: intrusions may preferably have taken place in tectonized sites but also the dislocations themselves could be concentrated around and within rigid magmatic bodies during the folding.

No careful structural analysis has been carried out to decide what is the case with sills and 'fissure fillings'. Moreover, there are problems concerning the term 'fissure filling'. Némedi Varga [1963, 1971, 1983a] has considered the Kövestető phonolite body to be an example of 'fissure fillings' transversal relative to the fold axis while according to his own data this body is in the same stratigraphic position in most boreholes *(Fig. 2)*. It could be qualified as a 'transversal fissure filling' based on the geological map *(Fig. 3)* but contour maps for the top and bottom surfaces of the phonolite body *(Fig. 4)*, the horizontal sections *(Fig. 5)* and the vertical sections in the dip direction *(Fig. 6/A* and *C)* prove the sill character of the body [Viczián 1971]. As another example of 'fissure fillings' Némedi Varga [1983a] has only named the Somlyó phonolite body which is — according to Vadász [1935] — a sill. Additionally, Némedi Varga has mentioned a geological section from the Kossuth colliery in which post-tectonic dykes are shown, his reference ['Lipi oral comm. 1977', see in Némedi Varga 1983a] is hardly a reasonable substitute for a publication of the section. Our view, therefore, is that no material on the post-tectonic intrusions has been presented.

In this relationship the only doubt remains with the northwestern part of the Kövestető phonolite body. Based on the geological map *(Fig. 3)* and the vertical sections along the strike *(Fig. 6/B, D* and *E)* one could conclude that the phonolite body is in a discordant position here. Although Viczián [1971] linked this discordance with the process of the intrusion *(Fig. 7)*, the question is, however, whether this discordance exists or not. Only borehole columns *(Fig. 2)* can be considered as concrete facts and they clearly show that the phonolite really is in a higher position in the northwest but the point is that this position is stratigraphically constant, manifesting a stratigraphic jump not stratigraphic shift of the body. In other words, borehole data demonstrate a pre-intrusion fault but not pre-intrusion bending (folding). The map *(Fig. 3)* and the sections *(Fig. 6/B* and *D)* are products of interpretation, and it is quite

Рис. 3. Геологическая карта окрестностей фонолитового тела на Кёвештетё со снятием четвертичных отложений (по Némedi Varga 1963, с изменениями)
1 — рэтский ярус; 2–4 — нижний лейас: 2 — геттангско-синемюрский ярус, угленосная толща, 3 – нижнелотарингский подъярус, толща перекрывающих песчаников, 4 — верхнелотарингский подъярус, толща перекрывающих мергелей; 5–6 — средний лейас: 5 — нижняя часть, толща пятнистых известковистых мергелей, 6 — верхняя часть; 7–8 — мел: 7 – щелочные диабазы, 8 — фонолиты; 9 — гельветский ярус (миоцен); 10 — геологические разрезы рис. 6; 11 — ось антиклинали; 12 — сброс; 13 — взброс; 14 — скважина; 15 — горная выработка; 16 — участок структурных наблюдений (см. рис. 8)

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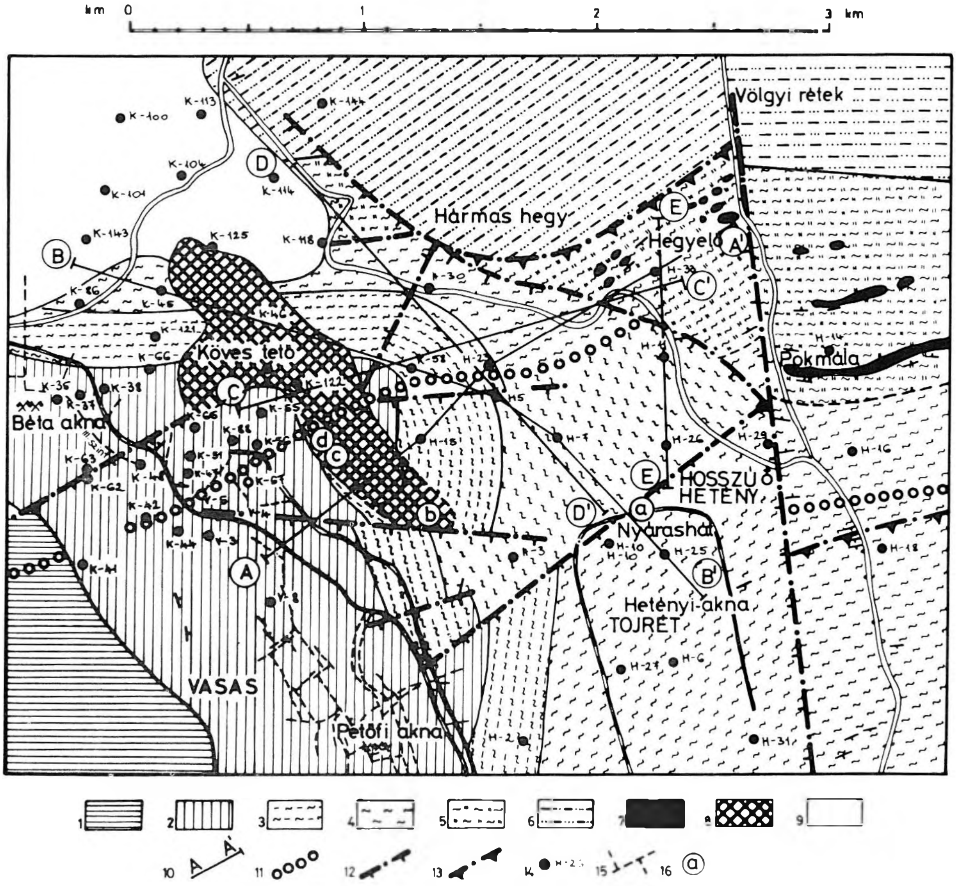


Fig. 3. Uncovered geological sketch of the Kövestető phonolite area (modified after NÉMEDI VARGA 1963)
1 — Rhaetian; 2–4 — Lower Lias; 2 — Hettangian–Sinemurian, coal-bearing complex, 3 — Lower Lotharingian, overlying sandstone complex, 4 — Upper Lotharingian, overlying marl complex; 5–6 Middle Lias; 5 — lower part, spotty calcareous marl complex, 6 — upper part; 7–8 — Cretaceous; 7 — alkali diabase, 8 — phonolite; 9 — Helvetian; 10 — geological cross-sections of Fig. 6; 11 — axis of anticline; 12 — normal fault; 13 — reverse fault; 14 — borehole; 15 — gallery; 16 — site of structural observations (see Fig. 8)

3. ábra. A kövestetői fonolitterület fedetlen földtani térképe (NÉMEDI VARGA 1963 nyomán, módosítva)
1 — rhaeti; 2–4 — alsó liász; 2 — hettangi–szinemuri, kőszéntelepes összlet, 3 — alsó lotharingiai, fedőhomokkő összlet, 4 — felső lotharingiai, fedőmárga összlet; 5–6 — középső liász; 5 — alsó rész, foltos mészmárga összlet, 6 — felső rész; 7–8 — kréta; 7 — alkáli diabáz, 8 — fonolit; 9 — helvéti; 10 — a 6. ábra földtani szelvényei; 11 — antiklinális tengelye; 12 — vetődés; 13 — feltolódás; 14 — mélyfúrás; 15 — bányavágat; 16 — szerkezetföldtani megfigyelések helye (l. a 8. ábrán)

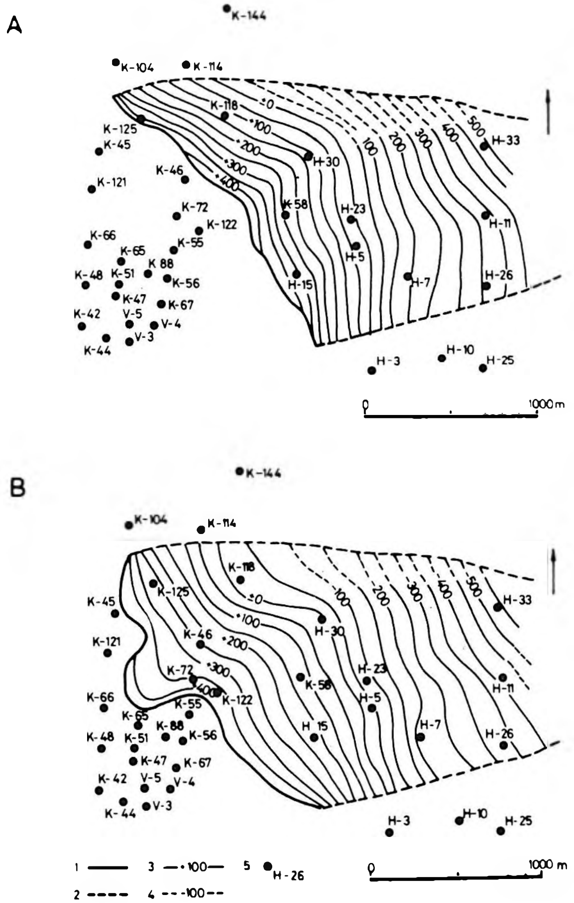


Fig. 4. Contour maps of the Kövestető phonolite body (after Némedi Varga 1963)
A) Contour lines of the top surface
B) Contour lines of the bottom surface
1 — boundary of outcrop; 2 — line of pinch-out; 3 — contour line constructed; 4 — contour line inferred; 5 — prospecting borehole

4. ábra. A kövestetői fonolittest szintvonalas térképei (Némedi Varga 1963 nyomán)
A) Fedőszintvonalak
B) Feküszintvonalak
1 — kibúvási vonal; 2 — kiékelődési vonal; 3 — szerkesztett szintvonal; 4 — feltételezett szintvonal; 5 — kutatófúrás

Рис. 4. **Карты фонолитового тела Кёвештетё в изолиниях (по Némedi Varga 1963)**
А) Изолинии кровли
В) Изолинии почвы
1 — линия выхода на поверхность; 2 — линия выклинивания; 3 — отстроенная изолиния; 4 — предполагаемая изолиния; 5 — скважина

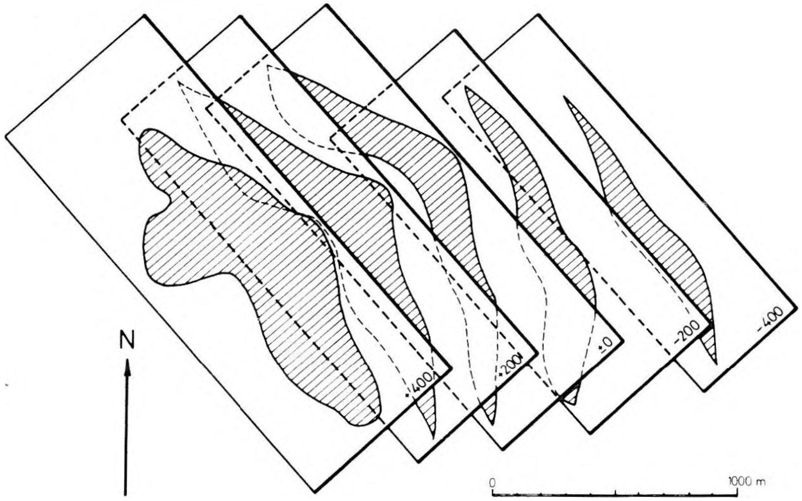


Fig. 5. Horizontal sections of the Kövestető phonolite body [after Némedi Varga 1963]

5. ábra. A kövestetői fonolittest vízszintes metszetei [Némedi Varga 1963 nyomán]

Рис. 5. Горизонтальные сечения фонолитового тела Кёвештетё [по Némedi Varga 1963]

probable that they could be constructed with the fault mentioned above without any stratigraphic shifting, i.e. without any discordance of the phonolite body.

Consequently, when taking only definite facts from Némedi Varga's [1963] publication one can outline a clear picture with a concordant phonolite intrusion after a fault but before the folding. This picture is consistent with the fact that along both contacts of the phonolite body sediments are tectonically disturbed [Némedi Varga 1963]. Proof is given in another way, viz. that most of the tensional fissures filled by hydrophonolite are near-vertical and parallel with the fold axis.

Finally, some words on the measurements of the joints *(Fig. 8)*. When rejecting second- and third-order maxima, each diagram displays three principal joint sets: one along the stratification plane and two perpendicular to it *(Fig. 9)*. Country sediments on the southern limb of the anticline and phonolite quarries display similar joint patterns relative to the fold axis and, accordingly, reflect the same strain pattern. Joint sets in the southeastern phonolite outcrop manifest tilting towards the east or southeast but the causes are not clear (local second-order dislocations, gliding on the present slope, something else?). Similarity in joint patterns for the phonolite and country sediments — in agreement with the fold structures — leaves no place for speculations on the post-tectonic intrusion of the phonolite.

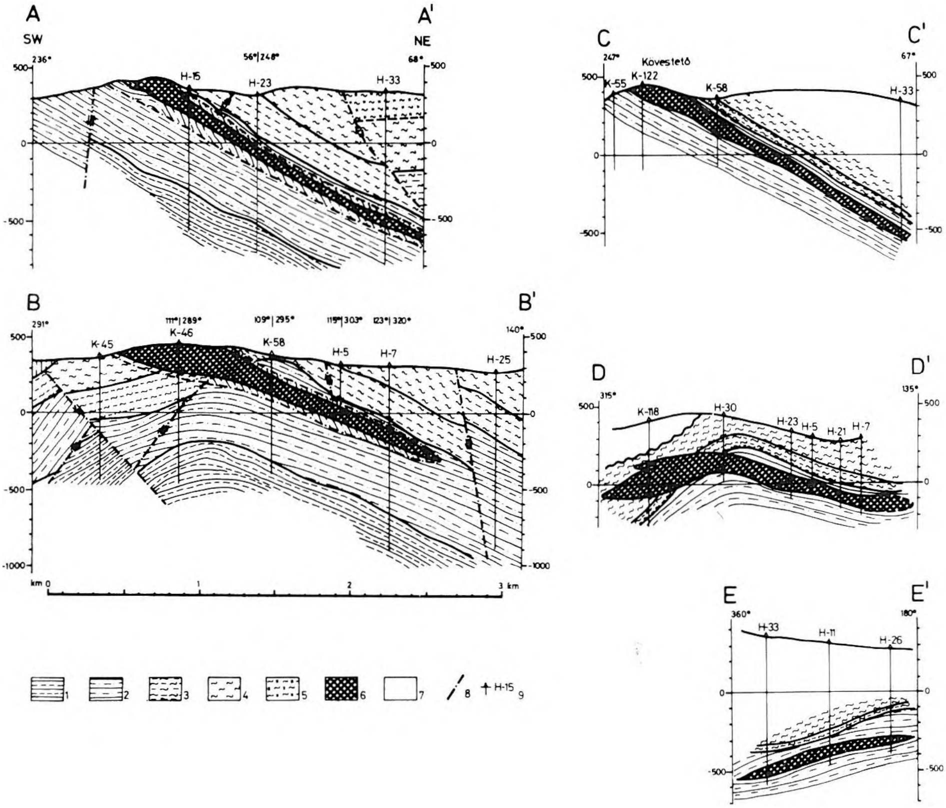


Fig. 6. Geological sections across the Kövestető phonolite area (A–A' and B–B' after Némedi Varga 1963, and C–C', D–D' and E–E' after Viczián 1971)
1 — Upper Triassic, Rhaetian stage; 2–4 — Lower Lias: 2 — Hettangian and Sinemurian stages (coal measures), 3 — Lotharingian stage, lower part (overlying sandstone suite), 4 — Lotharingian stage, upper part (overlying marl suite); 5 — Middle Lias, lower part (spotted calcareous marl suite); 6 — Cretaceous phonolite; 7 — Miocene sediments; 8 — fracture; 9 — propecting borehole

6. ábra. Földtani szelvények a kövestetői fonolitterületen át (A–A' és B–B' Némedi Varga 1963, C–C', D–D' és E–E' Viczián 1971 nyomán)
1 — felső triász, raeti emelet; 2–4 — alsó liász: 2 — hettangi–szinemuri emelet (kőszéntelepes csoport), 3 — lotharingiai emelet, alsó tagozat (fedőhomokkő csoport), 4 — lotharingiai emelet, felső tagozat (fedőmárga csoport); 5 — középső liász, alsó tagozat (foltos mészmárga csoport); 6 — kréta fonolit; 7 — miocén üledék; 8 — törés; 9 — kutatófúrás

Рис. 6. Геологические разрезы через фонолитовое тело Кёвештетё (А–А' и В–В' по Némedi Varga 1963, С–С', D–D' и Е–Е' по Viczián 1971)
1 — верхний триас, рэтский ярус; 2–4 — нижний лейас: 2 — геттангско–синемюрский ярус (угленосная толща), 3 — нижнелотарингский подъярус (толща перекрывающих песчаников), 4 — верхнелотарингский подъярус (толща перекрывающих мергелей); 5 — нижняя часть среднего лейаса: (толща пятнистых известковистых мергелей); 6 — меловые фонолиты; 7 — миоценовые отложения; 8 — разрывное нарушение; 9 — разведочная скважина

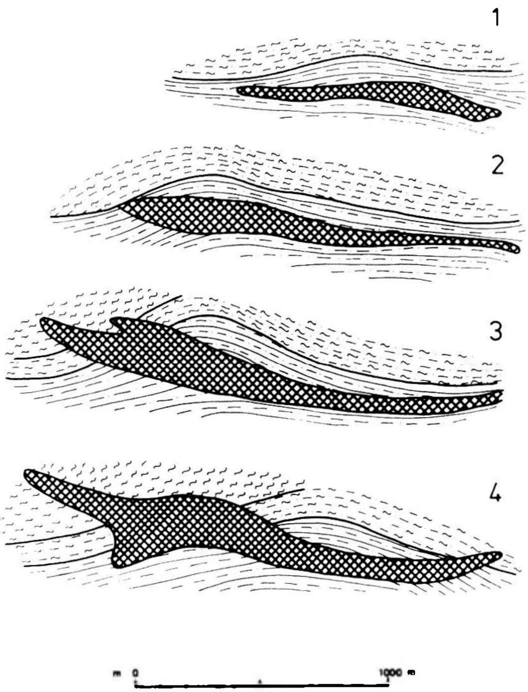


Fig. 7. Schematic sections in strike direction to illustrate stages of intrusion of the Kövestető phonolite body (after Viczián 1971). For legend, see Fig. 6

7. ábra. A kövestetői fonolittest benyomulásának egyes szakaszait illusztráló vázlatos csapásmenti szelvények (Viczián 1971 nyomán). Jelmagyarázat a 6. ábrán

Рис. 7. Схематические разрезы по простиранию, иллюстрирующие последовательные стадии внедрения фонолитов Кёвештетё (по Viczián 1971). Условные обозначения см. на рис. 6

Summarizing, we can state that any intrusion of some Cretaceous magmatites after the folding is improbable theoretically, and from the practical point of view cannot be supported by data. Facts used in this connection either prove folding after the intrusion and not vice versa, or at least do not contradict it.

2.3 Summary

Analysis of data on the metamorphism and structure [Némedi Varga 1963, 1971, 1983a, Szilágyi 1979] has revealed the absence of any basis for assuming post-tectonic magmatism and syn-tectonic metamorphism. This conclusion accords both with the concepts of other scientists on the uniformity of the magmatism and with its general character, i.e. rift origin. On the other hand, the age relationships of subvolcanic and volcanic rocks as well as the timing of the termination of the magmatism need further analysis.

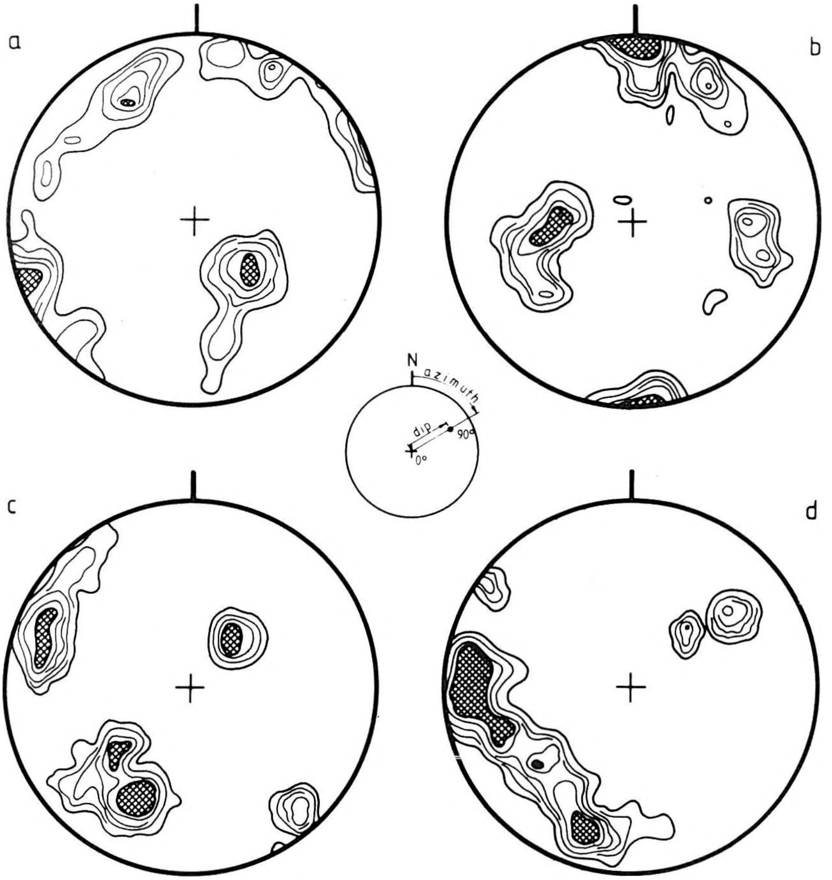


Fig. 8. Upper hemisphere equal-area projections showing the distribution of joints of the Kövestető phonolite area (after Némedi Varga 1963)
a) overlying marl, 150 measurements; b) phonolite, southeastern outcrop, 100 measurements; c) phonolite, active quarry, 100 measurements; d) phonolite, abandoned quarry, 100 measurements. For locations, see Fig. 3. Density contour lines — 0, 1, 2, 3, 4, 6%

8. ábra. A kövestetői fonolitterület kőzetrés-eloszlási diagramjai: (Némedi Varga 1963 nyomán); területtartó vetületek a felső félgömbről
a) fedőmárga, 150 mérés; b) fonolit, DK-i kibúvás, 100 mérés; c) fonolit, működő kőfejtő, 100 mérés; d) fonolit, felhagyott kőfejtő, 100 mérés. Helyüket lásd a 3. ábrán. Izovonalak — 0, 1, 2, 3, 4, 6%.

Рис. 8. Распределение трещин в районе Кёвештетё (по Némedi Varga 1963), проекция на сетку Шмидта с верхней полусферы
а) перекрывающие мергели, 150 замеров; b) фонолиты, юговосточный выход, 100 замеров; c) фонолиты, действующий карьер, 100 замеров; d) фонолиты, заброшенный карьер, 100 замеров. Положение участков см. на рис. 3. Изолинии: 0, 1, 2, 3, 4, 6%

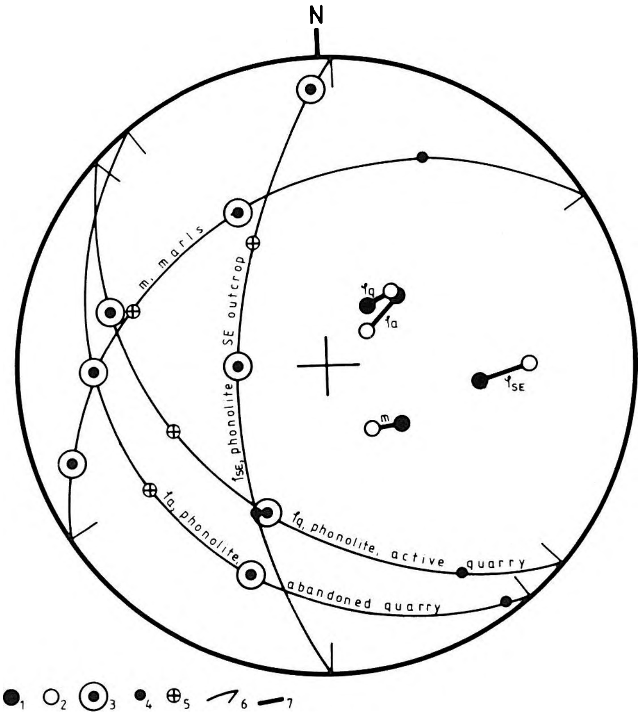


Fig. 9. Summary of principal joint sets of the Kövestető area. Upper hemisphere equal-angle projection showing results of re-evaluation of Némedi Varga's [1963] measurements
1–5 — poles of planes: 1 — joint set interpreted as stratification, 2 — plane normal to both shear planes, 3 — joint set interpreted as a shear plane, 4 — bisectrix plane in the acute angle of the shear planes, 5 — same in the obtuse angle; 6 — trace (great circle) of the plane normal to both shear planes; 7 — link between the poles of the stratification and of the great circle (symbol 6)

9. ábra. A kövestetői fő kőzetrés-nyalábok összesítése. Némedi Varga [1963] méréseinek újraértékelési eredményeit bemutató szögtartó vetület a felső félgömbről
1–5 — síkok pólusai: 1 — rétegződésként értelmezett kőzetrés-nyaláb, 2 — mindkét nyírási síkra merőleges sík, 3 — nyírási síkként értelmezett kőzetrés-nyaláb, 4 — szögfelező sík a nyírási síkok által bezárt hegyesszögben, 5 — u.az a tompaszögben; 6 — a mindkét nyírási síkra merőleges sík nyomvonala (főkör); 7 — az összetartozó rétegződés és főkör (6. jel) pólusait összekötő egyenes

Рис. 9. Сводка главных систем трещин района Кёвештетё, проекция на сетку Вульфа с верхней полусферы. Переинтерпретация результатов замеров Némedi Varga [1963].
1–5 — полюса плоскостей: 1 — система трещин, сопоставляемая со слоистостью, 2 — плоскость, нормальная к обеим системам сколов, 3 — система трещин, интерпретируемая как скол, 4 — плоскость-биссектриса в остром углу сколовых плоскостей, 5 — то же в тупом углу; 6 — след (большой круг) плоскости, нормальной к обоим сколам; 7 — отрезок, соединяющий полюса слоистости и большого круга (знак 6)

3. Timing of subvolcanic intrusions and of the termination of the magmatism

We have seen that volcanism still lasted in the Hauterivian and, probably, also in the Barremian – at least in places. Because there is no horizon within the Mecsekian Lower Cretaceous which is free of synchronous volcanic material, the timing of the termination of the volcanism is, strictly speaking, uncertain. Based on the general tendency of Lower Cretaceous sequences *(Fig. 10)*, i.e. concentration of volcanic material in the lower part (volcanic complex phases I–II) and its dilution with sediments in higher parts (volcano-sedimentary complex, phases III–VI), it is usually believed [Wein 1961, 1967, Pantó 1961, Bilik 1974] that the last observable volcanogenic horizons are close in time to the termination of the volcanism. This may be true but not necessarily.

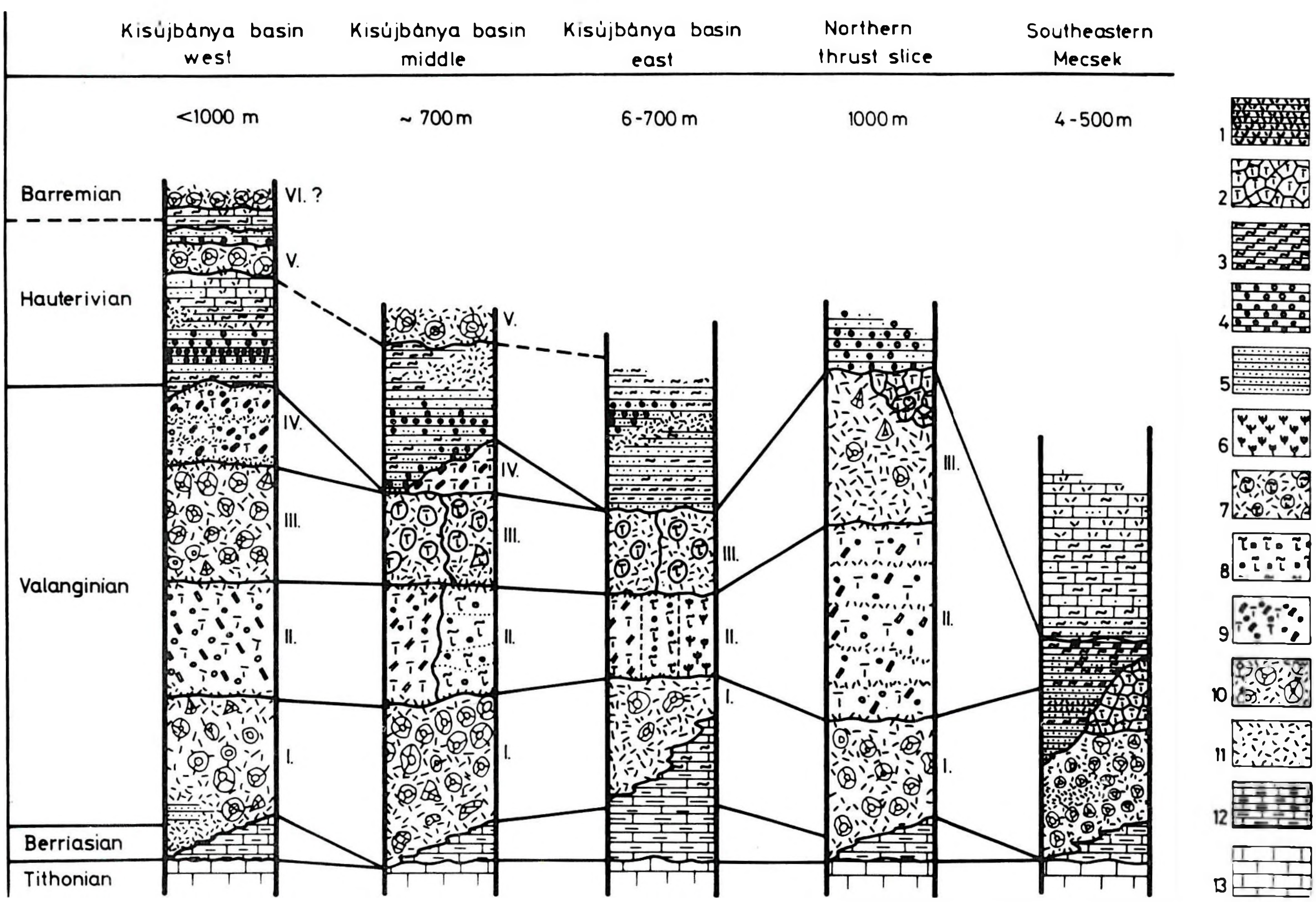
In the so-called 'Northern thrust slice' (see Fig. 1) within the thick volcanic complex of postulated Valanginian age marl strips abundant with forams are observable *(Fig. 11)*. Formerly, forams were regarded to be of Cenomanian age [Majzon 1961, Sidó 1961] but determinations on new samples carried out by Kovács-Bodrogi (pers. comm.) have revealed that all marls belong to Lower and Middle Turonian. The southern half of the thick marl strip is strongly tectonized but its northern contact may be of stratigraphic origin. Independently of this, the thin strip in the northern part of the volcanite outcrop consisting of cracked marls is, possibly, in the normal stratigraphic position. If this is true, the volcanism continued into the Turonian.

In any case, Turonian sediments of pelagic type seem to be inconsistent with the idea that in the post-Hauterivian Cretaceous the Mecsek area was

Fig. 10. Idealized stratigraphic columns for Lower Cretaceous formations of the eastern Mecsek Mountains (after Bilik 1974)
1 — stratified hyaloclastite; 2 — in situ lava breccia; 3 — marl; 4 — conglomerate; 5 — sandstone; 6 — phonolite; 7 — alkali trachyte pillow lava; 8 — alkali trachyte massive lava; 9 — alkali diabase massive lava; 10 — alkali diabase pillow lava; 11 — alkali diabase hyaloclastite; 12 — argillaceous limestone; 13 — limestone;
I–VI — phases of the volcanic activity ⇨

10. ábra. A Keleti Mecsek alsó kréta képződményeinek elvi rétegoszlopai (Bilik 1974 nyomán)
1 — rétegzett hialoklasztit; 2 — helyben képződött lávabreccsa; 3 — márga; 4 — konglomerátum; 5 — homokkő; 6 — fonolit; 7 — alkáli trachit párnaláva; 8 — alkáli trachit tömeges láva; 9 — alkáli diabáz tömeges láva; 10 — alkáli diabáz párnaláva; 11 — alkáli diabáz hialoklasztit; 12 — agyagos mészkő; 13 — mészkő; I–VI — a vulkáni működés fázisai ⇨

Рис. 10. Сводные стратиграфические колонки нижнемеловых образований восточной части Мечекских гор (по Bilik 1974)
1 — слоистые гиалокластиты; 2 — лавобрекчии, возникшие на месте; 3 — мергели; 4 — конгломераты; 5 — песчаники; 6 — фонолиты; 7 — подушечные лавы щелочных трахитов; 8 — массивные лавы щелочных трахитов; 9 — массивные лавы щелочных диабазов; 10 — подушечные лавы щелочных диабазов; 11 — гиалокластиты щелочных диабазов; 12 — глинистые известняки; 13 — известняки;
I–VI — фазы вулканической активности ⇨


Kisújbánya basin west
Kisújbánya basin middle
Kisújbánya basin east
Northern thrust slice
Southeastern Mecsek
<1000 m
~ 700 m
6-700 m
1000 m
4-500 m
Barremian
Hauterivian
Valanginian
Berriasian
Tithonian
VI. ?
V.
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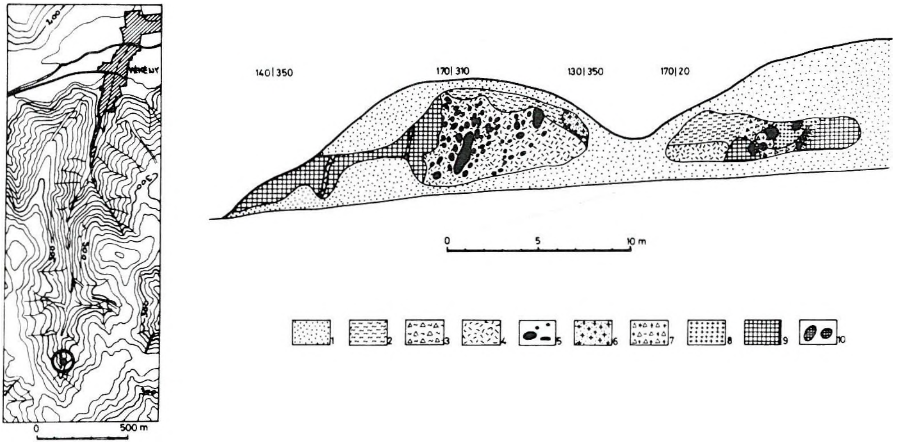


Fig. 11. The marl exposure near Vékény in spring 1982 (for location see Fig. 1)
1 — debris; 2 — red clay (weathering product of marls); 3 — red clay with limestone blocks (tectonic breccia); 4 — cracked and weathered (argillaceous) red marl; 5 — fresh red marl (in blocks); 6 — sandy conglomerate of basaltic composition; 7 — cracked breccia of basaltic composition with limestone and marl blocks (tectonic breccia); 8 — cracked basalt (agglomerate?); 9 — brecciated basalt (agglomerate?); 10 — basalt in blocks; ⊙ — location of the exposure

11. ábra. A Vékény melletti márgafeltárás 1982 tavaszán (helyzetét l. az 1. ábrán)
1 — lejtőtörmelék; 2 — vörös agyag (a marga máll̇ási terméke); 3 — vörös agyag mészkőtömbökkel (tektonikus breccsa); 4 — töredezett és mállott (agyagos) vörös márga; 5 — üde vörös márga (tömbökben); 6 — bazaltos összetételű homokos konglomerátum; 7 — bazaltos összetételű töredezett breccsa mészkő- és márga-tömbökkel (tektonikus breccsa); 8 — töredezett bazalt (agglomerátum?); 9 — breccsás bazalt (agglomerátum?); 10 — bazalt tömbökben; ⊙ — a feltárás helye

Рис. 11. Выход мергелей близ с. Векень весной 1982 г. (положение см. на рис. 1)
1 — делювий; 2 — красные глины (продукты выветривания мергелей); 3 — красные глины с обломками известняков (тектонические брекчии); 4 — трещиноватые и выветрелые (глинистые) красные мергели; 5 — свежие красные мергели (в глыбах); 6 — песчанистые конгломераты базальтового состава; 7 — трещиноватые брекчии базальтового состава с обломками известняков и мергелей (тектонические брекчии); 8 — трещиноватые базальты (агломераты?); 9 — брекчированные базальты (агломераты?); 10 — базальты в глыбах; ⊙ — положение выхода

uplifted. On the other hand, boreholes discovered all horizons of the Cretaceous in the basement of the Pannonian basin east and northeast of the Mecsek. Although basaltic rocks are widespread [Juhász and Vass 1974, Szepesházy 1977, Balla 1982] Cretaceous sediments are usually free of synchronous volcanic material [Bérczy-Makk 1985, Szentgyörgyi 1984a, 1984b] independently of their stratigraphic position. This could mean that the volcanism took place here in deeper water, almost with no explosions, therefore the alkali basalt volcanism was generally not recorded in synchronous sediments. Volcano-sedimentary complexes are known on the western periphery of the Apuseni Mountains (Romania, Upper Senonian) and in Vojvodina (Yugoslavia, Upper

Turonian to Senonian) but they are related to subaerial volcanism in the Apuseni—Sredna-Gora magmatic belt [Szentgyörgyi 1984b]. This means that the upper age limit of the Mecsekian volcanism cannot be established when using stratigraphic data only.

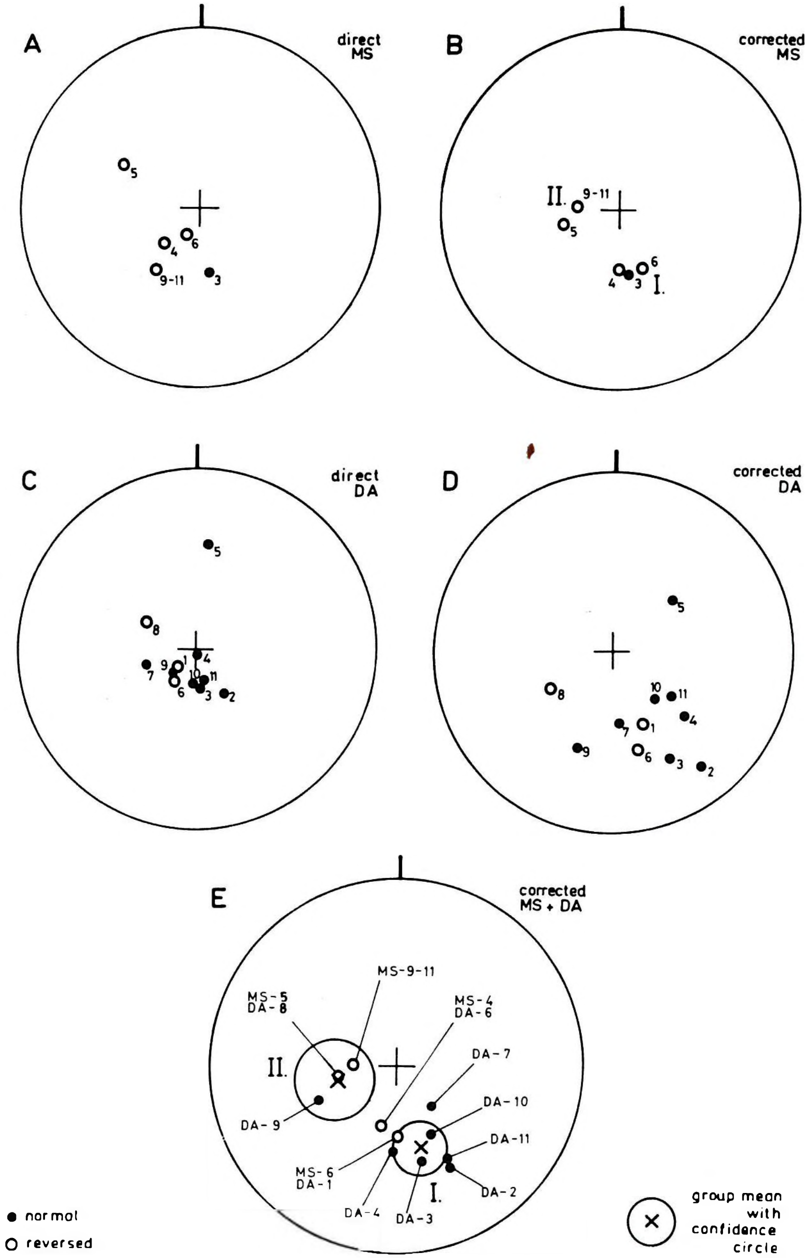
In the Danube–Tisza interfluve, erosional disconformities have been established at the base of the Upper Cenomanian and of the Upper Senonian but Albian–Cenomanian and Turonian–Senonian concordances also are observable and the interrelations between the Turonian and Cenomanian are unknown [Szentgyörgyi 1984b]. This means that tectonic criteria manifest at least local movements within the Late Cretaceous but they do not allow one to determine more accurately the age of the first significant folding in the Mecsek Mountains which could stop the alkali basaltic volcanism.

As for the subvolcanic bodies, their relationships with the surface volcanites are highly speculative. Until now, no special investigations of this problem have been carried out. Moreover, subvolcanic and effusive bodies have not been mapped seperately and existing geological maps display rock types with no qualification of their geological position (effusive, extrusive, intrusive, etc.). In a situation like this the correlation of subvolcanic intrusions including phonolites, teschenites, etc., with the second phase of the Valanginian volcanism (Fig. 10) can be regarded as a hypothesis only. Accordingly, the age of subvolcanic intrusions within the time span of volcanic activity is unknown. If significant stratigraphic intervals containing volcanites have disappeared due to erosion, at least some of the subvolcanic bodies — as products of the terminating volcanic activity — preserved in deeper stratigraphic levels must be younger than the remaining volcanites, and vice versa. Independent evidence for a younger age of some subvolcanic bodies would exhibit much longer duration of the magmatism than is usually believed.

Summarizing, the termination of the volcanism in the Mecsek Mountains cannot be fixed within the Turonian–Senonian time span. Since most of the stratified volcanites are, probably of Valanginian or Hauterivian age, much younger ones may occur among the subvolcanic bodies. The latter must all be older than the folding of uncertain age. Based on this conclusion we can start discussing palaeomagnetic data.

4. Palaeomagnetic data and the age of the first rotation

There are two groups of palaeomagnetic data on Cretaceous volcanites of the Mecsek Mountains (Table I), one published by Márton and Szalay-Márton [1969] the other by Dagley and Ade-Hall [1970]. Tilt correction led to an increase in the between-site scatter *(Fig. 12)*. so that Dagley and Ade-Hall suggested that the magnetization might be of post-tilting (i.e. post-folding age). Except for the andesites in the southwest there is no sign of young magmatism in the area. The thermal history of the sediments shows maximum heating at


A
direct MS
5
4
6
9-11
3
B
corrected MS
II.
9-11
5
4
3
6
I.
C
direct DA
5
8
9
1
4
7
10
11
6
3
2
D
corrected DA
5
8
10
11
4
7
1
9
6
3
2
E
corrected MS + DA
MS-9-11
MS-5
DA-8
MS-4
DA-6
II.
DA-7
DA-10
DA-9
DA-11
MS-6
DA-1
DA-2
I.
DA-4
DA-3
● normal
O reversed
group mean with confidence circle

the end of the sedimentation [Vető 1978], i.e. in Early or Middle Cretaceous. Thus, no geological reasons exist for regional re-magnetization after the folding.

Hungarian data (Fig. 12/B) display two groups after tilt correction: the first of them ($D = 349°$, $I = 52°$) corresponds to pole directions obtained from Upper Jurassic to Lower Cretaceous sediments of the Mecsek Mountains and Villány Hills *(Table II, Fig. 13)*; the second group ($D = 84°$, $I = 61°$) corresponds to pole directions of the Komló andesite of Early Miocene age ($D = 82°$, $I = 62°$) [Márton and Szalay-Márton 1969].

The British team, however, obtained an irregular picture after tilt correction (Fig. 12/D). When comparing their values for the tilt correction (Table I) with those used by the Hungarian team one can see systematically higher angles for dips and also different azimuths.

It is understable that while direct measurements agree rather well the corrected values give quite different results. That is why we checked each value for tilt correction in 1 : 10 000 geological maps and redetermined palaeomagnetic directions with new values for tilt corrections (Table I). Most of the pole directions (Fig. 12/E) belong to the first group [sensu Márton and Szalay-Márton 1969, 1970] displaying $D = 342°$, $I = 42°$. Only three sills belong to the second group: the Kövestető phonolite, the Somlyó ('Máza Valleyhead') phonolite and the Hosszúhetény alkali diabase. One could express doubts on the reality of the second group because of the limited amount of bodies. But completely independent measurements on alkali diabase dykes and remagnetized aplites within crystalline rocks of the Mórágy area southeast of the Mecsek Mountains yielded similar directions (mean of 10 sites: $D = 94°$, $I = 57°$ [Márton 1984a]; individual results for most of the localities remained unpublished). This is the basis for distinguishing between the two rotations *(Fig. 14)*.

Fig. 12. Palaeomagnetic directions for the Mecsekian Cretaceous volcanites all treated as normal. Upper hemisphere equal-angle projections
A–B — Márton and Szalay-Márton 1969 (MS): A — direct measurements, B — tilt-corrected directions; C–D — Dagley and Ade-Hall 1970 (DA): C — direct measurements, D — tilt-corrected directions; E — directions with newly estimated tilt-corrections (for code numbers and directions, see Table I)

12. ábra. A mecseki kréta vulkanitok paleomágneses irányai, valamennyit normálisként kezelve. Szögtartó vetületek a felső félgömbről
A–B — Márton és Szalay-Márton 1969 (MS): A — mért irányok, B — dőléssel korrigált irányok; C–D — Dagley és Ade-Hall 1970 (DA): C — mért irányok; D — dőléssel korrigált irányok; E — az újonnan meghatározott dőlésértékekkel korrigált irányok (a sorszámokat és irányokat lásd az I. táblázatban)

Рис. 12. Палеомагнитные направления для меловых вулканитов Мечекских гор, нанесенные как нормальные. Проекция на сетку Вульфа с верхней полусферы
A–B — по Márton and Szalay-Márton 1969 (MS): A — измеренные направления, B — направления с поправкой за наклонное залегание; C–D по Dagley and Ade-Hall 1970 (DA): C — измеренные направления, D — направления с поправкой за наклонное залегание; E — направления со вновь определенной поправкой за наклонное залегание (обозначения и направления см. в табл. I)

Area	Locality	Age	Rock	Direct measurement results					Tectonic position				Tilt-corrected directions						
									referred		reconstr.		for sites		for areas				
				n	$D°$	$I°$	k	$\alpha_{95}°$	$\varphi°$	$\delta°$	$\varphi°$	$\delta°$	$D_c°$	$I_c°$	$D_m°$	$I_m°$	k	$\alpha_{95}°$	N
MECSEK	Magyaregregy	Tithonian – Berriasian	grey limestone	6	28	53	8	24.6	–	–	297	40	348	39	10	42	13	26.7	4
	Magyaregregy			7	98	48	7	24.5	–	–	310	40	32	68					
	Magyaregregy			3	27	13	19	29.1	–	–	277	33	17	22					
	Zobák			9	5	2	5	25.9	–	–	155	40	13	37					
VILLÁNY	Máriagyüd	Upper Jurassic	red limestone	6	5.6	35.7	91	7.0	164.3	25.5	–	–	18.7	58.4	17.9	59.5	99	9.3	4
	Harkány		pink limestone	5	2.7	26.6	64	9.6	171.3	31.0	–	–	10.2	56.6					
	Harsány		grey limestone	5	11.0	0.3	31	14.0	180.0	72.1	–	–	33.6	68.8					
	Beremend	Lower Cretaceous	grey limestone	5	23.4	51.7	55	10.4	270.6	10.7	–	–	14.9	53.2					

Table II. Palaeomagnetic data for the South Transdanubian Upper Jurassic and Lower Cretaceous sedimentary rocks (Mecsek Mountains = Márton E. pers. comm.; Villány Hills = MÁRTON-SZALAY and MÁRTON 1978)

n = number of samples, N = number of sites, $D°$ = palaeomagnetic declination, $I°$ = palaeomagnetic inclination, k = Fisher's precision parameter, $\alpha_{95}°$ = angle of confidence,
$\varphi°$ = dip azimuth, $\delta°$ = dip angle

II. táblázat. A dél-dunántúli felső jura és alsó kréta üledékes kőzetekre vonatkozó paleomágneses adatok. (Mecsek: MÁRTON E. szóbeli közlés; Villányi-hegység: MÁRTON-SZALAY and MÁRTON 1978)

n = a minták száma, N = a mintavételi pontok száma, $D°$ = paleomágneses elhajlás, $I°$ = paleomágneses lehajlás, k = a Fisher-féle pontossági paraméter, $\alpha_{95}°$ = konfidenciakör, $\varphi°$ = dőlésirány, $\delta°$ = dőlésszög

Табл. II. Палеомагнитные данные по верхнеюрским и нижнемеловым отложениям Южной Задунайщины (Мечекские горы: по Márton E., устн. сообщ; Вилланьские горы: по MÁRTON-SZALAY and MÁRTON 1978)

n = количество образцов, N = количество точек, $D°$ = палеомагнитное склонение, $I°$ = палеомагнитное наклонение, k = параметр кучности Фишера, $\alpha_{95}°$ = угол доверия, $\varphi°$ = азимут падения, $\delta°$ = угол падения

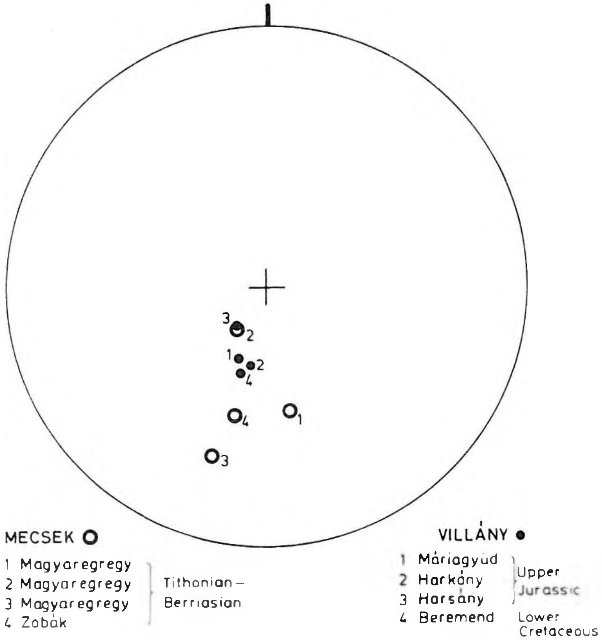


Fig. 13. Palaeomagnetic directions for the South Transdanubian Upper Jurassic and Lower Cretaceous sediments (see Table II). An upper hemisphere equal-angle projection

13. ábra. A dél-dunántúli felső jura és alsó kréta üledékek paleomágneses irányai (lásd. a II. táblázatban). Szögtartó vetület a felső félgömbről

Рис. 13. Палеомагнитные направления южно-задунайских верхнеюрских и нижнемеловых отложений (см. табл. II). Проекция на сетку Вульфа с верхней полусферы

Age limitation for the first, anti-clockwise rotation are as follows. The youngest sediments displaying pre-rotational pole directions (first group) are the Beremend grey limestones (Table II) placed into Barremian–Aptian [Vadász 1960], Aptian [Majzon 1966] or Lower Albian [Fülöp 1966]. According to Fülöp [1966] the presence of *Orbitolina beremendensis* and absence of *Orbitolina lenticularis* is the basis for the qualification as Albian. The first species has been newly described from this quarry by Méhes [see in Fülöp 1966]. Later he has found that *O. beremendensis* is the same as *O. minuta* which is known from Upper Aptian and Lower Albian strata, and limestones of the Beremend quarry are of Late Aptian age [Méhes, pers. comm.]. Consequently, the lower age limit of the rotation must be placed within the Late Aptian. In agreement with this statement, all Mecsekian lavas of Hauterivian and Valanginian age exhibit the same pole direction. Accordingly, the first rotation must have taken place in post-Aptian time.

Only subvolcanic rocks are post-rotational. Solely the fact that the second group arose after the tilt correction proves that these rocks were intruded before

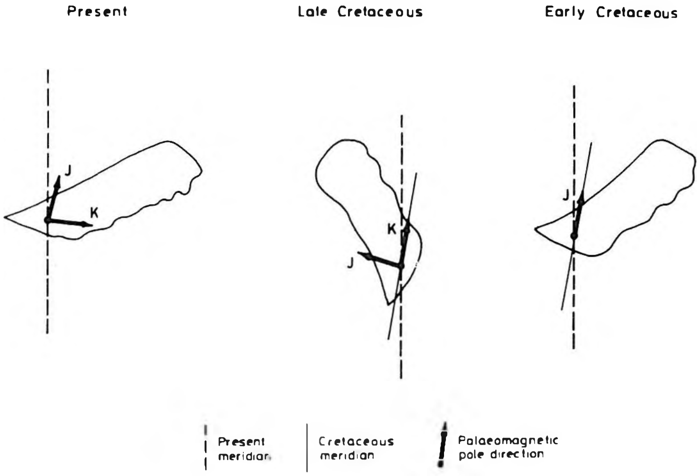


Fig. 14. Three positions of the South Pannonian domain with the Late Jurassic to Early Cretaceous (J) and Middle Cretaceous (K) palaeomagnetic directions. J = 14° (present mean direction for sedimentary rocks of the Mecsek Mountanins and Villány Hills, see Table II. and Fig. 13), K = 94° (present mean direction for the Cretaceous dykes and remagnetized aplites within crystalline rocks of the Mórágy area: Márton 1984a), Cretaceous meridian = 7° [Krs 1979]

14. ábra. A Dél-Pannon egység három helyzete a felső jura–alsó kréta (J) és a középső kréta (K) paleomágneses irányokkal. J = 14° (a mecseki és villányi üledékes kőzetek mai középiránya, l. a II. táblázatot és a 13. ábrát), K = 94° (a mórágyi kristályos kőzetekben települő kréta telérek és átmágnesezett aplitok mai középiránya: Márton 1984a), kréta délkör = 7° [Krs 1979]

Рис. 14. Три положения Южно-Паннонской единицы с позднеюрско–раннемеловым (J) и среднемеловым (K) палеомагнитными направлениями. J = 14 ° (современное среднее направление для осадочных пород Мечекских и Вилланъских гор см. б табл. II и рис. 13) K = 94° (современное среднее направление меловых даек и перемагниченных аплитов среди кристаллических пород Морадьского блока: Márton 1984a), меловой меридиан = 7° [Krs 1979]

the folding. The same conclusion has been reached by the analysis of geological data in Section 2.

The upper age limit for the first rotation can be determined when using a kinematic model for the second rotation [Balla 1984c] and some geological considerations. In our opinion, in the situation before the second rotation the Apuseni—Sredna-Gora ('banatite') magmatic belt was straight *(Fig. 15)*. Since the magmatism commenced here in the Cenomanian [Antonijević et al. 1974, Russo-Săndulescu and Berza 1979] or Turonian [Cioflica and Vlad 1973, Čanović and Kemenci 1975] the situation presented in Fig. 15 must already have existed at that time. Accordingly, the time span for the first rotation has to be restricted to the Albian–Cenomanian, i.e. to the 110–95 Ma interval. Such timing completely excludes location of the Mecsek on the African plate [cf. Márton 1984a, 1984b] since pieces of the latter, e.g. the Transdanubian Central Range [Márton and Márton 1983], manifest only about 10° rotation between

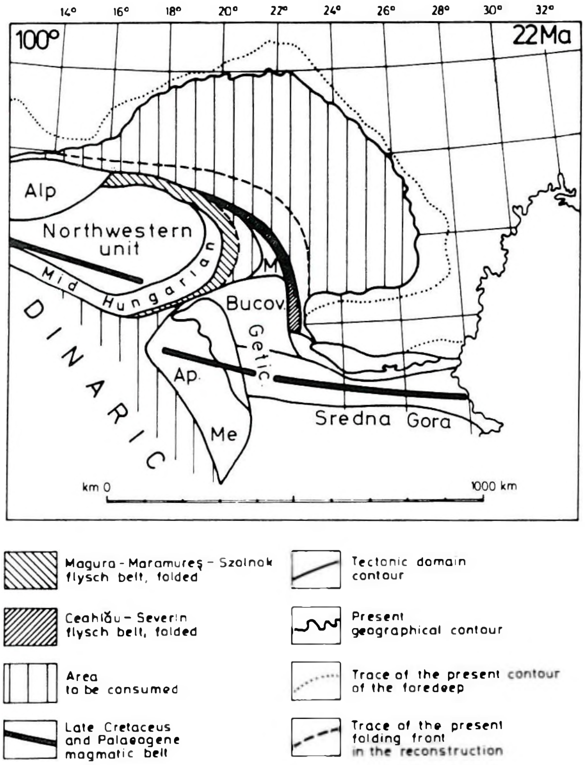


Fig. 15. Tectonic sketch and the Upper Cretaceous to Palaeogene magmatic belts of the Carpatho–Balkan region in the Early Miocene reconstruction (after Balla 1984c)
Magmatic belts (solid lines): within the Northwestern unit — Peri-Adriatic–North-Pannonian (Late Eocene to Early Oligocene); within the southeastern unit — Apuseni–Sredna-Gora (Late Cretaceous to Early Palaeocene). Alp. = Alpine domain, Ap. = Apuseni, Me. = Mecsek, Bucov. = Bucovinian domain, Getic = Getic + Danubian domains, M = Maramureş spur

15. ábra. A Kárpát–Balkán régió tektonikai vázlata és felső kréta–paleogén magmás övei az alsó miocén rekonstrukcióban (Balla 1984c nyomán)
Magmás övek (vastag vonalak): az ÉNy-i egységen belül — Periadriai–Észak-Pannon (felső eocén–alsó oligocén); a DK-i egységen belül — Apuseni–Szredna-Gora (felső kréta–alsó paleocén). Alp. = Alpi egység, Ap. = Erdélyi-középhegység, Me. = Mecsek, Bucov. = Bukovinai egység, Getic = Géta + Dunai egység, M = Máramarosi sarkantyú

Рис. 15. Тектоническая схема и позднемелово–палеогеновые магматические пояса Карпато–Балканского региона в раннемиоценовой реконструкии (по Balla 1984c)
Магматические пояса (жирные линии): в пределах Северозападной единицы – Периадриатически–Северопаннонский (поздний эоцен–ранний олигоцен); в пределах Юговосточной единицы — Апусенско–Среднегорский (поздний мел–ранний палеоцен). Alp. = Альпийская единица, Ap. = Апусенская единица, Me. = Мечекская единица, Bucov. = Буковинская единица, Getic = Гетская + Дунайская единицы, M = Марамурешские шпоры

the Valanginian and Aptian and only about 35° anti-clockwise rotation between the Aptian and Campanian–Maestrichtian *(Table III)*.

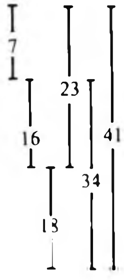
Summarizing, palaeomagnetic data for the Mecsekian volcanites manifest large anti-clockwise rotation which must have occured within the Albian–Cenomanian time span. Indirectly, it means that the subvolcanic bodies sampled are younger than Aptian although they are, obviously, older than the folding. The timing and the angle of the rotation are inconsistent with the location of Southeast Transdanubia on the African plate. The last question to be examined is the geological frame of the rotation.

5. Geological frame of the rotation

Previously, it was supposed [BALLA 1982] that the Mecsekian Valanginian–Hauterivian volcanism occured in connection with rifting in early stages of the decoupling of the South Pannonian (Mecsek–Apuseni) domain from Europe. This process resulted in the opening of a basin of at least partly mafic crust by the Albian or Cenomanian. Sediments of this Inner Carpathian basin now form the Szolnok–Maramureş flysch belt of accretionary prism type [BALLA 1982]. On the opposite — European — margin of this basin, teschenites in the Moravo–Silesian Beskids [MAHMOOD 1973] mark early (Hauterivian–Barremian) rifting phases of the same opening [BALLA 1984a] (VICZIÁN [1971] was the first to call attention to the petrological similarity between the Silesian teschenites and the Mecsekian Cretaceous volcanites). The Inner Carpathian basin as a bay on the southern margin of Europe existed until the beginning of the Neogene and was closed during the clockwise rotation of the South Pannonian domain in the Miocene [BALLA 1984c, 1985, 1986a, 1986b].

The above analysis has revealed a possibility to relate the first, anti-clockwise rotation of the South Pannonian domain to its decoupling from Europe and to confirm that this decoupling took place, indeed, in the Albian–Cenomanian and that former conclusions have remained valid. Accordingly, we suppose the following succession of events:

1. In the initial situation (Late Jurassic) the Mecsek domain was close to the Moravo–Silesian Beskids somewhere in what is now the Danube–Rába lowland. They were situated on the southern margin of the European continent. The Beskids were in a position rotated by about 70–75° clockwise ($D=294°$, $I=62°$ [KRS 1981]) relative to their present position (mean Cretaceous meridian for the area of their probable location: 6–7° [KRS 1979]). The rotation of the Mecsek is negligible although they could be situated north of their present position.
2. During the Valanginian–Aptian, rifting of the European margin was in progress with no significant rotation of neighbouring domains and, probably, with insignificant extension but with strong alkali basalt volcanism in both the Beskids and Mecsek areas.
3. In the Albian–Cenomanian, the rift was opened and the South Pan-

Age	Locality	Rock	Direct measurement results					Tectonic position		Tilt-corrected directions							Horizontal angle of the rotation
										for sites		for age intervals					
			n	D°	I°	k	α°_{95}	φ°	δ°	D°_c	I°_c	D°_m	I°_m	k	α°_{95}	N	
Berr.	Sümeg	grey limestone	56	312	−42	6	13.7	294	105	277	31	277	31	–	–	1	
Val. – Haut.	Lábatlan	grey marl	10	299	45	25	9.9	235	12	290	39	277	41	31	46.6	2	
	Borzavár II	grey limestone	8	258	40	42	8.8	172	7	263	42						
Apt.	Borzavár I	grey limestone	6	271	42	52	9.4	12	5	275	43	284	46	132	10.8	3	
	Borzavár II		11	290	42	39	7.4	70	7	294	47						
	Vértessomlyó		7	289	27	–	16.0	124	21	285	47						
Alb.	Úrkút	grey limestone	8	309	60	13	15.8	308	30	308	30	300	38	71	14.8	3	
	Olaszfalu		9	297	25	12	15.8	106	20	300	44						
	Jásd		22	284	47	12	11.5	339	11	292	40						
Camp.– Maas.	Halimba	red marl	10	305	58	–	11.0	340	10	312	50	318	53	203	6.5	4	
	Magyarpolány	grey marl	5	314	72	–	14.0	325	12	320	52						
	Bakonyjákó		8	347	59	29	10.4	260	11	330	57						
	Tapolcafő		11	145	−57	31	8.4	250	8	133	−54						

Note: The tilt-corrected direction for the Berriasian is of low accuracy because of unusually large angle of the correction (overturned)

Table III. Summary of palaeomagnetic data on the Cretaceous rotation of a piece of Africa (Transdanubian Central Range: MÁRTON and MÁRTON 1983)

n = number of samples, N = number of sites, D° = palaeomagnetic declination, I° = palaeomagnetic inclination, k = Fisher's precision parameter, α°_{95} = angle of confidence, φ° = dip azimuth, δ° = dip angle

III. táblázat. Az Afrika egy darabjának (Dunántúli-középhegység: MÁRTON and MÁRTON 1983) kréta elfordulására vonatkozó paleomágneses adatok összesítése

n = a minták száma, N = a mintavételi pontok száma, D° = paleomágneses elhajlás, I° = paleomágneses lehajlás, k = a Fisher-féle pontossági paraméter, α°_{95} = konfidenciakör, φ° = dőlésirány, δ° = dőlésszög

Табл. III. Сводка палеомагнитных данных по меловому повороту кусочка Африки (Задунайского Среднегорья: MÁRTON and MÁRTON 1983)

n = количество образцов, N = количество точек, D° = палеомагнитное склонение, I° = палеомагнитное наклонение, k = параметр кучности Фишера, α°_{95} = угол доверия, φ° = азимут падения, δ° = угол падения nonian domain was decoupled from Europe being rotated anti-clockwise by about 75–90° according to palaeomagnetic data, or more (by about 100°) according to our kinematic model [Balla 1984c]. Since the magmatism could have lasted during the rotation and have stopped synchronously with it, the sampled bodies were probably formed before the end of the rotation. The angle difference, therefore, cannot be considered as a contradiction.

4. Beginning with the Turonian, the South Pannonian domain was integral with the Bucovinian and Getic domains. They had all become integral with Europe by the end of the Eocene although during the Senonian and Early Palaeogene they were probably not far from it depending on the magnitude of compression of the Balkanids during this time interval.

5. In the Miocene, the western part of this area, i.e. the South Pannonian and the South and East Carpathian domains, suffered compression and turning towards the north and northeast with large clockwise rotation but without interrupting direct connections with Europe [Balla 1984c, 1985, 1986a, 1986b]. At the same time, the Moravio–Silesian Beskids were rotated in the opposite, anti-clockwise direction together with the North Pannonian domain [Balla 1984c] and suffered additional rotation in the same direction due to detachment from their European basement and formed the present nappe structure [Krs et al. 1979].

Summarizing, the first rotation of the South Pannonian domain was connected with the opening of the Inner Carpathian basin [sensu Balla 1982], its second rotation was due to the closing of the same basin. The similarity in the positions of the South Pannonian domain before the first and after the second rotation demonstrates the close position of the poles of rotation. Their determination would be possible in the frame of a widespread kinematic analysis but this is beyond the scope of this work.

6. Conclusions

The principal problems with the Mecsekian Cretaceous volcanites arise partly from the absence of the upper part of the sequence due to erosion and partly from the limited knowledge on the relationships between the subvolcanic and volcanic formations. As for the palaeomagnetic data, these are insufficient to enable us to reconstruct continuous temporal change of the pole directions. In this work we have tried to compensate for the insufficiency of data by taking into account various considerations and speculations.

Some of our conclusions only support those made by previous investigators: the forming of all magmatic bodies before the folding, longer duration of the magmatism than can be directly deduced from stratigraphic data, anti-clockwise rotation of the area in the Cretaceous. Other conclusions throw new light upon the interrelations between the magmatism and palaeomagnetic rotation. The main conclusion is that the Mecsek had been integral with Europe until the Early Cretaceous — as is known from palaeobiogeographical data

[Géczy 1973a, 1973b, Vörös 1977, 1984] — and was decoupled from Europe by means of anti-clockwise rotation in the Albian–Cenomanian. This conclusion emphasizes the importance of the kinematic causes of such rotational decoupling and this problem can be solved only by means of a wide-ranging analysis.

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A MECSEK HEGYSÉG KRÉTA IDŐSZAKI (ÓRAMUTATÓ JÁRÁSÁVAL ELLENTÉTES) ELFORDULÁSÁNAK ELEMZÉSE: PALEOMÁGNESES ADATOK ÉRTELMEZÉSE A FÖLDTANI ISMERETEK TÜKRÉBEN

BALLA Zoltán

A tanulmány a Mecsek hegységre vonatkozó eddigi földtani eredmények elemzésével rámutat arra, hogy a Mecsekben nincs alapja az orogenezisnél fiatalabb kréta korú vulkanitok feltételezésének. Ugyanakkor egyes szubvulkáni testek valóban fiatalabbak a felszíni vulkanitok nagy részénél, s okunk van feltételezni, hogy a mecseki kréta vulkánosság a szenonig tartott, bár a barréminél fiatalabb kréta összleteket az erózió elpusztította.

A paleomágneses adatokat két rotáció feltételezésével értelmezzük, amelyek közül az első a krétában történt és az óramutató járásával ellentétes irányú volt, míg a második a miocénban játszódott le az óramutató járásával egyező irányban. Ezek kölcsönösen kompenzálják egymást, úgyhogy a krétánál idősebb képződmények gyakorlatilag nem mutatnak elfordulást Európához viszonyítva. Földtani adatok és kinematikai megfontolások alapján az első elfordulás az albai–cenománi időszakra rögzíthető. Ez a kor és az elfordulás szöge kizárja annak lehetőségét, hogy a Mecsek az afrikai lemez részeként fordult volna el.

Az első, óramutató-járással ellentétes elfordulás vezetett a Mecseknek Európáról való leválásához és ezzel a belső-kárpáti medence felnyílásához. Az alsó kréta alkáli bazalt vulkánosság mind a Mecsekben, mind a Morva–Sziléziai Beszkidekben e felnyílás kezdeti szakaszait jelző riftesedéshez kapcsolható. A második, óramutató-járással egyező elfordulás e medence bezáródását eredményezte.

АНАЛИЗ ПОВОРОТА МЕЧЕКСКИХ ГОР (ЮГО-ЗАПАД ВЕНГРИИ) В МЕЛУ ПРОТИВ ЧАСОВОЙ СТРЕЛКИ: ИНТЕРПРЕТАЦИЯ ПАЛЕОМАГНИТНЫХ ДАННЫХ В СВЕТЕ ГЕОЛОГИЧЕСКИХ ЗНАНИЙ

Золтан БАЛЛА

Путем анализа опубликованных геологических материалов делается вывод о том, что нет оснований для предположения существования в Мечекских горах меловых вулканических пород моложе орогенеза. В то же время отдельные субвулканические тела действительно моложе преобладающей массы вулканических образований, и есть основания предполагать, что меловой вулканизм Мечекских гор продолжался до сенона, хотя вулканические толщи моложе барремского века уничтожены эрозией.

Палеомагнитные данные интерпретируются на основе представления о двух поворотах, один из которых имел место в мелу в направлении против часовой стрелки, а второй – в миоцене, по часовой стрелке. Эти повороты взаимно скомпенсировали друг друга, так что домеловые образования не проявляют поворота по отношению к Европе. На основе геологических данных и кинематических соображений первый поворот может быть отнесен к альбско-сеноманскому времени. Этот возраст совместно с углом поворота исключает возможность того, что Мечек поворачивался в качестве части Африканской плиты.

Первый поворот против часовой стрелки привел к отщеплению Мечекской единицы от Европы и тем самым – к раскрытию Внутрикарпатского бассейна. Нижнемеловой щелочно-базальтовый вулканизм как в Мечекских горах, так и в Мораво–Силезских Бескидах может быть связан с рифтообразованием, отмечающим начальные стадии этого раскрытия. Второй поворот по часовой стрелке привел к закрытию того же бассейна.

BOOK REVIEW

Intrinsic Geodesy by ANTONIO MARUSSI
Translated by W. I. Reilly.
Springer-Verlag Berlin Heidelberg New York Tokyo
1985. 7 figures. XVII + 219 pages.
ISBN 3-540-15133-8

The volume is a collection of papers presented by the late A. Marussi in the period of 1950–1984. This is the first time that many of the papers are published in English translation.

The papers are edited into seven chapters, appendix by the translator and bibliography.

To present the contents of the first six chapters here are the most authentic words of the author; written in the introductory remarks of the book.

"The first chapter, entitled *Fundamentals of Intrinsic Geodesy* comprises a set of papers in which the foundations of Intrinsic Geodesy are given, making use of the natural observable coordinates latitude, longitude, and geopotential for which the fundamental metric tensor, the coefficients of connection, and the structure of the coordinate lines and surfaces are given.

The so-called first fundamental problem of Geodesy, of transfering the coordinates from one given point to another, is solved in three-dimensional space.

Application of the methods of intrinsic geodesy is also made to the study of the microgravitational field (the tidal field) of a satellite, or of a spacecraft in inertial motion, including the derivation of Ricci's coefficients of rotation which connect the eigenvectors of the tensor surfaces describing the field.

The second chapter, entitled *Structure of the Gravity Field and Laplace's Equation,* comprises two papers dealing with the curvature and torsion of the gravity field and a generalization of the famous Dalby's theorem which expresses, in an absolute form, Laplace's equation.

In the third chapter, entitled *Principles of Intrinsic Geodesy Applied to the Normal Reference Field,* the general equations established previously are applied to the case of the reference field endowed with rotational symmetry, e.g., Somigliana's ellipsoidal field. In this case the integrability conditions furnish the equations for the continuation of the field in space starting from the values assigned on the boundary surface.

The first fundamental problem of Geodesy for the transfer of the geographical coordinates and the potential along a given curve is solved. The fundamental parameters for the ellipsoidal field are computed.

In the fourth chapter, entitled *Mapping of the Actual Gravity Field onto the Normal Reference Field,* the correspondence between points of the surface of the Earth and the surface of an ellipsoid is generalized in three dimensions by establishing a one-to-one correspondence between points of the actual gravity field and points of the normal ellipsoidal reference field, assuming that the centre of mass of the Earth coincides with the centre of figure of the ellipsoidal field.

A procedure for the adjustment of geodetic networks in the three-dimensional ellipsoidal model space is also given which generalises the method of variation of coordinates as used in the adjustment of bidimensional networks applying conformal representations.

One paper is devoted to the problem of conformal representations in the three-dimensional space. It is shown that it is impossible to introduce in conformal space a system of orthogonal coordinates having the tranforms of the equipotential surfaces as one of the families of coordinate surfaces.

In the fifth chapter, entitled *Mapping Between Surfaces*, the mapping problem is approached from the local point of view by assuming that the quadratic form determining the modulus of deformation is assigned. The various types of representations are classified accordingly and the alterations induced in the curvatures are determined.

Some integral properties of the comformal representations relating the variation of the integral curvature with the flux of the gradient of the logarithm of the modulus of deformation are given.

In the sixth chapter, entitled *Propagation of a Light Path in Continuous Isotropic Refracting Media*, the geometric laws of propagation of a light ray in a continuous isotropic refracting medium are compared with the properties of conformal mapping in three dimensions."

The seventh chapter contains a posthumous work entitled *The Motion of a Free Particle and of a Spherical Pendulum in the Microgravitational Field of a Gravitationally Stabilized Satellite in Circular Orbit in a Central Field*, co-authored by C. Chiaruttini.

The volume is a remarkable cross section of the scientific contribution of Prof. A. Marussi to modern theoretical Geodesy. He initiated the treatment of the Earth's gravitational field by modern differential geometry. His thinking was motivated by his mathematical training and his practical work as a surveyor and engineer. Ha wanted to deal always with observed quantities having physical reality and wanted to use them as direct as possible avoiding any reductions based on simplifying hypothetical assumptions which falsify the results of the operations.

The book, partly due to the professional translation, is an excellent treatment of the fundamentals of Intrinsic Geodesy and gives an insight to the evolution of modern geodesy. It is a very useful study for specialists and students of geodesy and related fields alike.

Zoltán Szabó

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