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PALEOMAGNETIC INVESTIGATIONS ON LATE CRETACEOUS - CENOZOIC SEDIMENTS FROM THE NW PART OF THE PANNONIAN BASIN

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Abstract: The article presents results of paleomagnetic investigation of the NW part of the Pannonian Basin. More than 170 independently oriented sedimentary samples from 10 localities from Hungarian and Slovak side were subjected to the AF and thermal demagnetization. They were sandstones, siltstones, marls and limestones and their age is late Cretaceous - late Miocene. The results gave counterclockwise rotation with angles of declination between an important common component to the Cenozoic movements affect ing the present NW part of the Pannonian Basin.

Key words: paleomagnetic direction, Cenozoic movements.

Introduction

The area we studied is situated within the North Pannonian Block (bordered by the Outer Western Carpathians in the north and the Mid-Pannonian mobile belt in the south) in the vicinity of the Bohemian Massif, close to the Eastern Alps-Western Carpathians junction, on both, West and East sides of the Danube Basin (Fig. 1).

The NW part of the Pannonian Basin was the subject of paleomagnetic investigations from the sixties on. The first results were obtained on mid-late Cenozoic volcanics (Pagáč 1970; Márton & Márton 1971; Andó et al. 1977; Balla & Márton 1978; Krs et al. 1979; Orlický et al. 1982). These studies, although primarily aimed at the behaviour of the Earth's magnetic field in the geological past, contain important information concerning the tectonic history of our study area. Namely, that the significant horizontal movements had ended before the calc-alcaline volcanism started (Márton E. 1981).

Unfortunately, the subsequent studies did not proceed back in time methodically, but having left out a considerable time interval, dealt with Paleozoic (Krs et al. 1982) or Mesozoic (Márton & Márton 1981) rocks.

However, it became clear soon that the North Pannonian Block must have been subjected to important horizontal movements also in the Cenozoic. The evidence for such movements was provided by paleomagnetism, which indicated that the Transdanubian Range continued its rotation in the Cenozoic (Márton & Márton 1983; Márton E. 1984, 1986).

North of the Northern Pannonian unit, in the Outer Western Carpathians, paleomagnetic evidence was obtained for counterclockwise rotation matching that of the Transdanubian Range on both Cretaceous (Krs et al. 1982) and Eocene (Krs et al. 1982, 1991) sediments.

Between the Outer Western Carpathians and the Transdanubian Range paleomagnetic work was not initiated on the post-Paleozoic until recently, when the analysis of microtectonic fea-

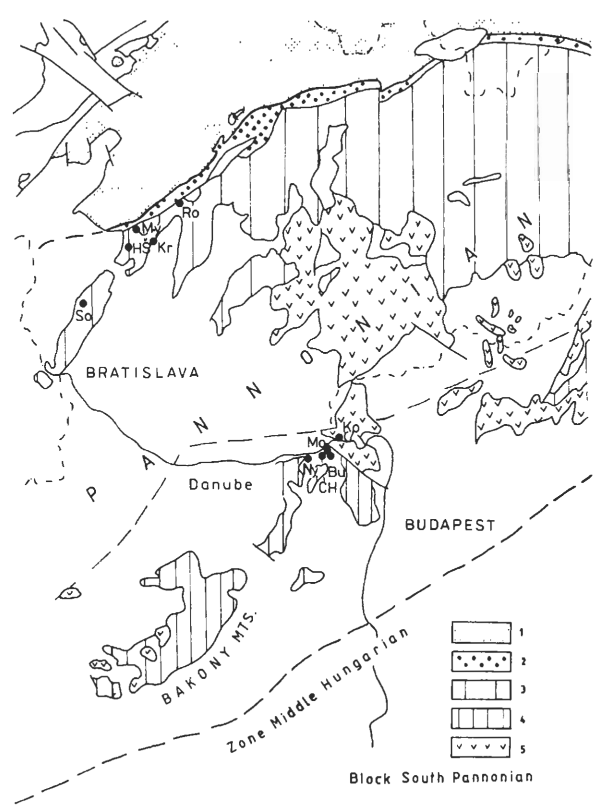

Fig. 1. Paleomagnetic sampling localities (1 - 10).
Key to the geology: 1 - Flysch-zone; 2 - Pieniny Clippen Belt; 3 - Inner Western Carpathians; 4 - Bakony and Bükk Mts.; 5 - Neogene volcanics. Locality: Ro - Roh motel; My - Myjava; Kr - Krajné; HS - Horný Štverník; So - Sološnica; Ko - Kováčov; Mo - Esztergom Monteverdi ut.; Bu - Esztergom Basa ut.; CH - Esztergom Castle Hill; Ny - Nyergesújfalu.

tures lead to the recognition of the importance of Cenozoic tectonics (Kováč et al. 1989; Marko et al. 1991).

According to the microtectonic studies, the critical interval for tectonic movements in the Inner Western Carpathians must have been the early-mid Miocene. Thus the first samples for paleomagnetic study were collected from the youngest stratigraphic horizon, still showing evidence for important strike-slip motion.

In the Malé Karpaty Mts., where the investigation started in 1985, 8 localities were sampled. Four of the localities yielded statistically well-defined paleomagnetic directions as a result of AF cleaning (Túnyi & Kováč 1991). Sampling was extented in the meantime to the Brezovské Karpaty Mts. as far as the Pieniny Clippen Belt. On the eastern side of the Danube Basin one locality (Kováčov) was sampled in the south and one in the north (Podmanínska pahorkatina Mts.).

By combining microtectonic and paleomagnetic information it was concluded that paleomagnetically indicated declination rotations and the orientation of the stress field were related.

Close relationship between Cenozoic paleomagnetic declination rotations and the orientation of the stress field was also suggested to explain paleomagnetic and microtectonic observations at the southern margin of the Bükk Mts. (Márton E. 1990). Surprisingly, the timing of the rotations in the Bükk Mts. and in the Malé/Brezovské Karpaty Mts. were also in harmony.

A Slovak-Hungarian joint project in the field of paleomagnetism started in 1991 with the aim of investigating the possibility of coordinated movement of the two areas. In order to ensure the highest degree of compatibility, cooperation was close during all stages of the paleomagnetic investigation.

Sampling and laboratory experiments

We collected more than 170 independently oriented sedimentary samples at 10 localities (Fig. 1). Most of them were drilled and oriented independently in the field. However, hand samples were also taken and drilled in the laboratory. Half of the collection comes from Slovak, the other from the Hungarian side.

The age of the sediments (sandstone, siltstone, marl, limestone) is late Cretateous - late Miocene.

The natural remanence (NRM) of sister specimens of a smaller pilot collection was measured in the laboratory of ELGI in Budapest and in Bratislava GFI. Then each laboratory subjected one specimen per sample to detailed thermal (ELGI) or AF demagnetization (GFI). These experiments showed that certains of the localities were unsuitable for tectonic evaluation.

Those with good magnetic signal were revisited and additional samples collected with the aim of improving the precision of the paleomagnetic locality mean directions.

Results

It is well known that the remanent magnetization of sediments, especially clastic sediments, is sensitive to secondary alteration. The magnetic signal of depositional origin may be modified or completely reworked by early to late diagenetic processes as well as processes connected to tectonic events, exposure etc.

Since the rocks exposed in the study area mostly clastics, it is not surprising that a considerable proportion of the collection did not yield tectonically valuable result, despite of the very careful selection of samples in the field and exhausting laboratory processing. This chapter will concisely present the most important types of paleomagnetic behaviour, for succesful as well as for unsuccesful localities.

The Eocene flysch from Nyergesújfalu is an example of rocks with complex remanence. Each sample possesses a NRM which is fairly stable or moderately unstable on thermal demagnetization (Fig. 2).

However, the individually well behaved NRMs do not allow to characterize the locality by a mean paleomagnetic direction.

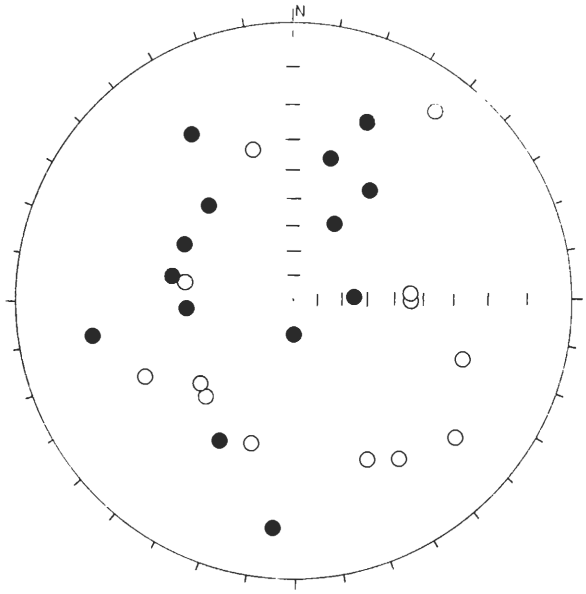

Fig. 2. Nergesújfalu. Eocene flysch. Thermally cleaned NRM directions. Stereographic projection. Positive inclinations: dots, negative inclinations: circles.

Due to the large within-locality scatter (Fig. 3), exhibited by both siltstone and sandstone samples, the locality is not suitable for tectonic evaluation.

The NRM at Solośnica (Eocene limestone) is also composite. Nevertheless, thermal cleaning has the power to separate the components (Fig. 4). The majority of the samples define a mean paleomagnetic direction with reasonably good statistical parameters (Fig. 5).

Occasionally the overprint magnetization is of very different stabiliy in different samples at the same locality. For instance, at Esztergom, Castle Hill secondary magnetization is the only detectable NRM in some specimens, while in others it is easily removable (Fig. 6). The characteristic magnetizations of the samples define two groups: one close to the actual field direction, an other far away from it. Three samples out of twenty-six fall in neither: these preserve the composite nature of the NRM during demagnetization (Fig. 7). Rejecting the latters, mean paleomagnetic directions can be estimated for the two groups separately. However, the one coinciding with the actual field direction cannot be interpreted in terms of tectonics.

The NRM of the samples from Kováčov (siltstone) define a mean paleomagnetic direction close to the actual field with excellent statistics.

AF demagnetization hardly influeces this position. Thermal demagnetization, however, destroyes the consistency: With increasing temperature, the mean direction moves away from the actual field towards CCW rotated direction (reversed polarity), but the increasing scatter prevents the definition of a characteristic ancient magnetization (Fig. 8.).

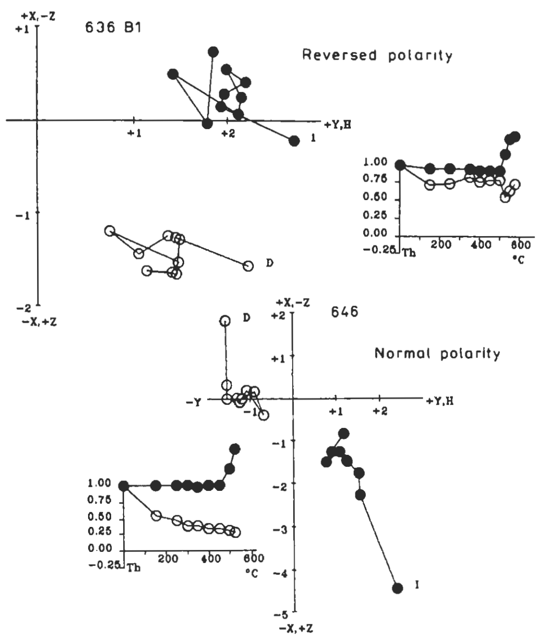

Fig. 3. Nyergesújfalu. Eocene flysch. Typical demagnetization behaviour. Modified Zijderveld diagrams (D and I curves) and susceptibility (dots)/intensity (circles) versus temperature plots.

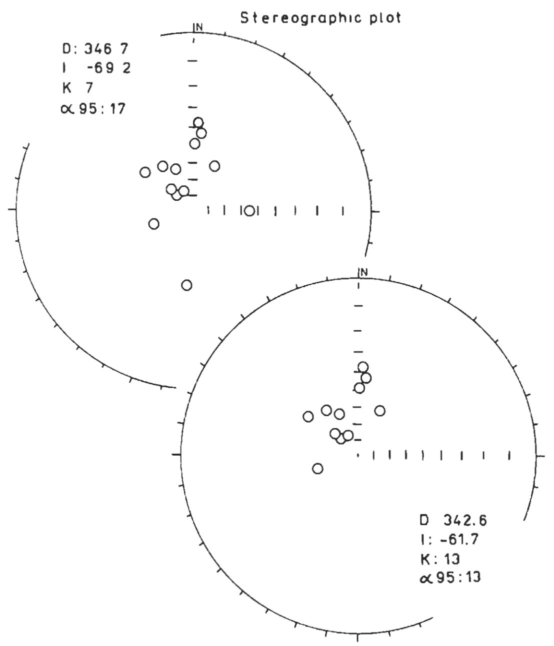

Fig. 5. Sološnica. Eocene limestone. Termally cleaned NRM directions on stereographic projection. All inclinations are negative. Top left: all directions with locality mean declination (D), inclination (I) and statistical parameters; bottom right: the same after rejecting two directions situated far from the cluster.

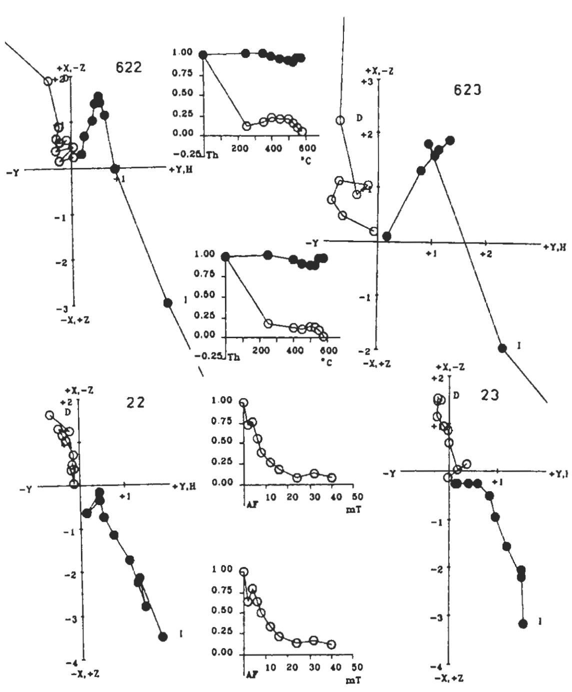

Fig. 4. Sološnica. Eocene limestone. Typical demagnetization behaviour. Top left and right: thermal cleaning, modified Zijderveld diagrams. Intensity (circles) drops at low temperatures (middle, from top to bottom: first and second) while susceptibility (dots) remains fairly stable; AF demagnetization fails to separate the two components of NRM, although intensity versus demagnetizing field curves (in the middle of the diagram, third and fourth) exhibit a behaviour similar to the thermal characteristics.

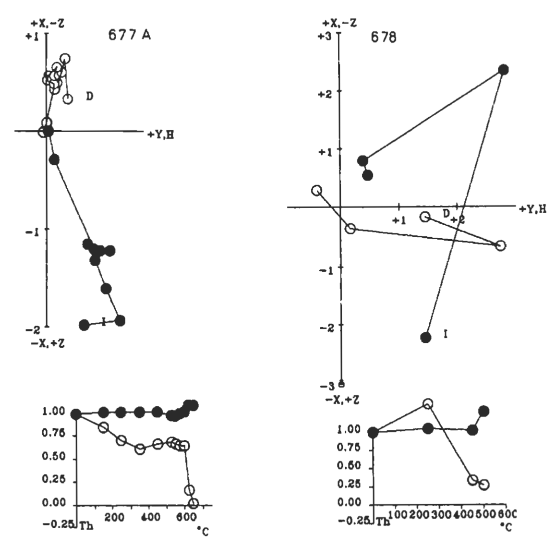

Fig. 6. Esztergom, Castle Hill. Oligocene siltstone. Typical demagnetization diagrams. 677A: secondary magnetization; 678: primary magnetization, partially overprinted. Below the modified Zijderveld diagrams shoving declination (D) and inclination (I) trends susceptibility (dots)/intensity (circles) versus temperature plots are shown.

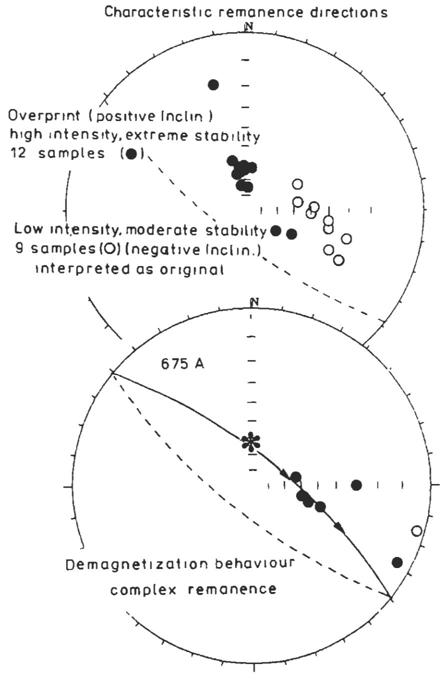

Fig. 7. Esztergom, Castle Hill. Thermally cleaned NRM directions on stereographic projection. Dots: positive; circles: negative inclinations. Top: all directions at the optimal cleaning step; bottom: sample 675A at different cleaning steps. The latter shows how the NRM direction moves along a great circle containing the actual field direction (asterisk), never reaching stable end point.

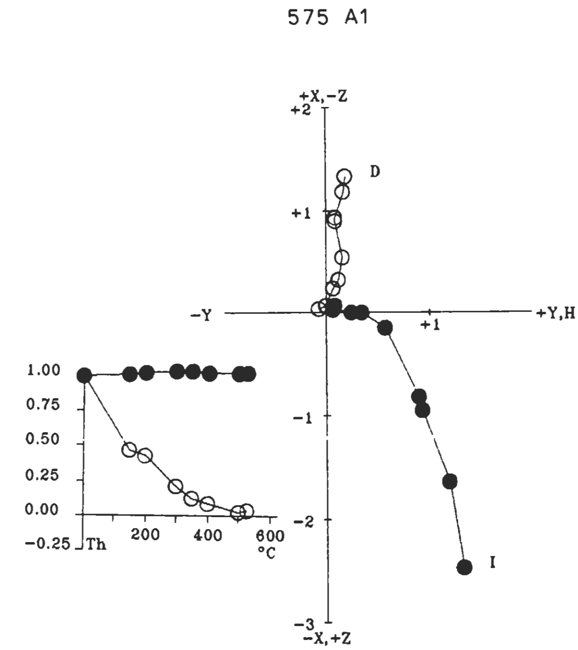

Fig. 9. Roh motel (near Stará Turá). Eocene flysch. Typical demagnetization behaviour on modified Zijderveld (D and I) and susceptibility (dos)/intensity (circles) versus temperature diagrams.

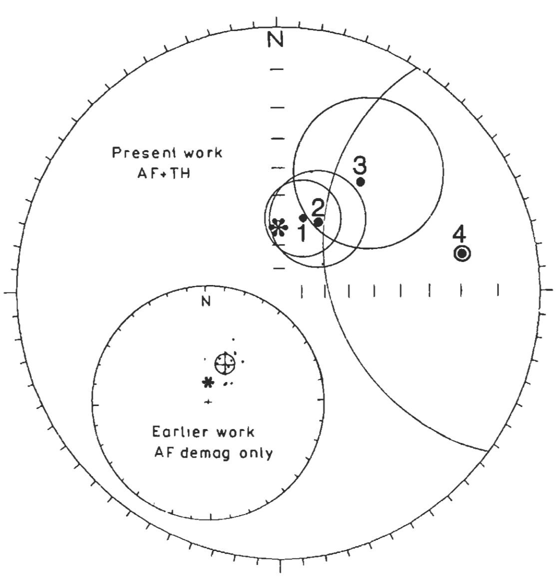

Fig. 8. Kováčov (near Štúrovo). Ottnangian siltstone. Present work: mean direction of 8 samples on successive demagnetization (1: NRM; 2: AF 10 *mT*; 3: TH 250 °*C*; 4: TH 450 °*C*; 1-3: positive; 4: negative inclination) with $\alpha 95$ increasing on demagnetization. Earlier work: directions NRM after AF demagnetization (dots) and mean direction (cross) with $\alpha 95$, asterixs show the direction of the actual field.

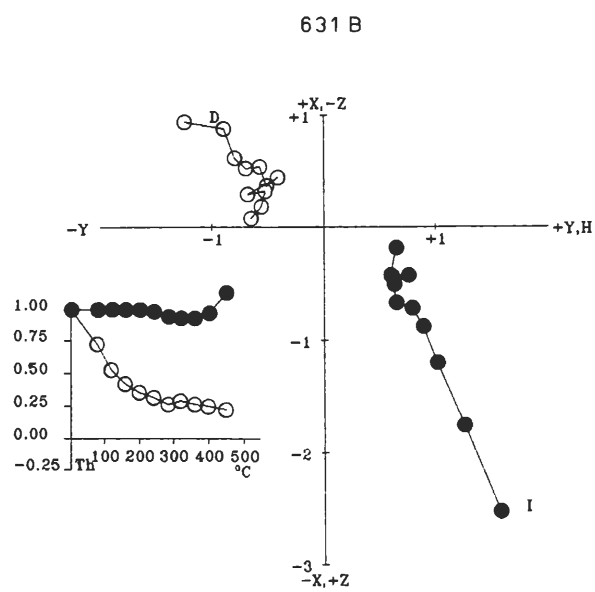

Fig. 10. Esztergom, Basa u. Oligocene marl. Typical demagnetization behaviour on modified Zijderveld (D and I) and susceptibility (dots)/intensity (circles) versus temperature diagrams.

Overprint caused less problem when the ancient remanence had normal polarity (Figs. 9, 10), although the change in direction is clearly seen on progressive demagnetization.

To summarize the results, we accept as tectonically significant those yielding statistically reasonably well defined mean paleomagnetic direction, as a result of thermal cleaning. The paleomagnetic mean direction must also lie at a significant distance from the direction of the actual field, before tilt correction is applied (Tab. 1).

Table 1: Summary of tectonically significant paleomagnetic results.

Sampling locality:	N/N	Dec Dec_{corr}	Inc Inc_{corr}	k	α95
Sološnica:	11/15	343 106	-62 -66	13	13
ROH Motel: *	6/6	21	6 250	29 21	13
Esztergom, Castle Hill:	9/25	99 113	-43 -33	24	11
Esztergom, Basa utca:	10/10	303 315	38 49	44	7

Key: N/N_o: number of used/collected samples. Dec, Inc: declinations, inclination before tilt correction. Dec_{corr}, Inc_{corr}: declination, inclination after tilt correction. k, $_{95}$: statistical parameters of the mean paleomagnetic directions.

* - corrected for overturned position.

Discusion and conclusions

After tilt correction, the paleomagnetic directions of the succesful localities exhibit counterclockwise rotation (two with normal, two with reversed polarity). The angle of declination rotation is high, between 50 and 110 degrees (Fig. 11).

Despite of the large distance, different tectonic setting, the locality mean directions of rocks of similar ages suggest that there must have been an important common component to the Cenozoic movements affecting the present NW part of the Pannonian Basin.

The overall declination rotation of the study area seems to be larger than that of the SW part of the North Pannonian Block. It matches better the magnitude of the post Oligocene net CCW declination of the Mátra-Bükk area (Fig. 12).

In the light of the large CCW rotation of Cenozoic age, the equally large declination rotation observed on Permian rocks in the Choč Nappe (Muška & Vozár 1978) might have to be reinterpreted as counterclockwise rotation. Since the Permian paleomagnetic directions have extremely shallow inclinations it is a matter of subjective decesion whether the sense of rotation is regarded as CW (as the authors of the paleomagnetic directions did) or CCW. However, once the second possibility is accepted. Cenozoic movements alone can account for the declination deviation observed on the Permian. Thus nappe displacement during the Mesozoic as the mechanism causing rotation, will become subordinate compared to mid-late Cenozoic tectonism.

Concerning the details, it would be early, especially in the light of the inclination scatter, to suggest that the existing declination differences between localities are tectonically significant. Our strategy for the future is laid down so that the problem of differential movements within each area of the studied region could be better approached.

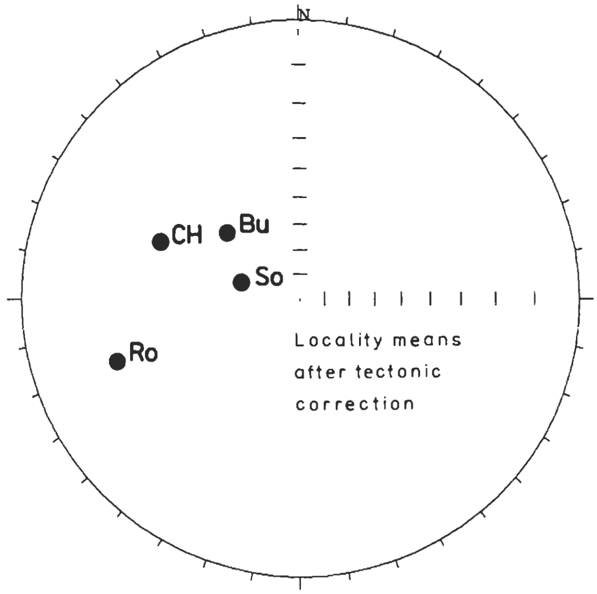

Fig. 11. Mean paleomagnetic directions, after cleaning and tilt correction.
1 - Esztergom, Castle Hill (CH), Oligocene; 2 - Esztergom, Basa u. (Bu), Oligocene; 3 - Sološnica (So), Eocene; 4 - Roh motel (Ro), Eocene. Stereographic projection, inclinations are positive.

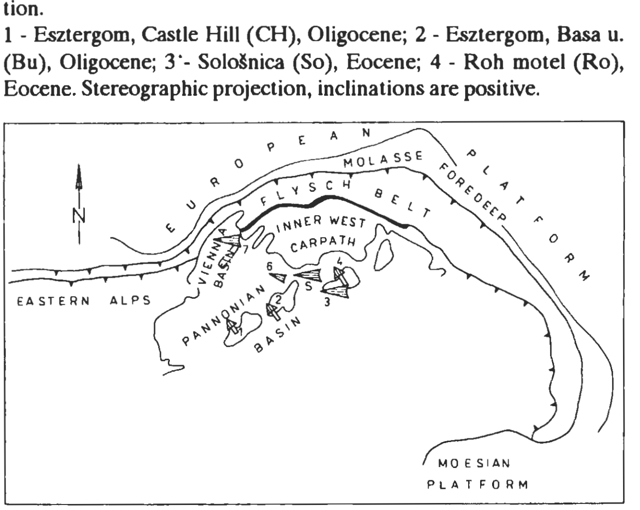

Fig. 12. Orientation of paleomagnetic declinations in the Bakony (1 and 2), the Bükk (3 and 4) Mts. in the northen margin of the Mátra (5), at Esztergom (6) and in the Malé/Brezovské Karpaty Mts. (7). Age of the studied rocks: 1-2 - late Cretaceous (1) and Eocene - Oligocene (2); 3-4 - Paleogene + early Miocene (3) and mid-late Miocene (4); 5 - early Miocene; 6 - Oligocene; 7 - Eocene.

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