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Anomalous paleomagnetic declinations of Karpatian and Badenian rocks, Southern Slovakia

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Abstract. The declination of the remanent magnetic polarization (RMP) of the Sečianky Member, Modrý Kameň Formation, Karpatian in age, and the Hrušov Member, Vinica Formation, Badenian in age, display clockwise (CW) rotation, which is an anomaly in the relation to the recent knowledge concerning the RMP of the contemporaneous rocks of Southern Slovakia and Northern Hungary. The volcano-tectonic activity of the Šahy-Lysec Zone would be the cause of the CW rotation. The biostratigraphic age of the studied rocks and the character of the RMP make it possible to correlate the Sečianky Member (Karpatian) with the chron C5Cr (17.7 - 17.2 Ma) and the Hrušov Member (Middle Badenian) with the older normal event of the chron C5Bn (15.15 - 15.03 Ma).

Key words: paleomagnetism, CW rotation, Karpatian, Badenian

Introduction

During the 90ties of the 20th century the paleomagnetic properties of the South-Slovakian and North-Hungarian Cenozoic rocks have been studied (Orlický et al., 1995; Márton et al., 1995, 1996; Márton and Márton, 1996). One of the most important results of that study was the finding that the declinations of the remanent magnetic polarisation (RMP) of the Lower Miocene rocks in the mentioned area display 80° counterclockwise (CCW) rotation. In the Northern Hungary two pulses of the rotation have been distinguished. The first rotation of about 50° CCW took place during the Ottnangian, while the latter and younger rotation of about 30° CCW took place during the Early Badenian (Márton and Fodor, 1995; Márton and Márton, 1996). Paleomagnetic measurements of Šiator Andesite and thermally altered sandstone of the Fiľakovo Formation, Eggenburgian in age, support such discrimination. The Šiator Andesite intrusion is evidently contemporaneous with neighbouring Karanč Andesite intrusion radiometrically dated to 15.1 Ma (Balog, 1984), the numeric age indicats the Middle Badenian. Declination of the Šiator Andesite is identical with that of recent Earth magnetic field, thus it was not rotated. The thermal effect of the andesite intrusion on the host rocks – the sandstone of Fiľakovo Formation caused the loss of original RMP and the acquisition of a new one, identical with RMP of the andesite intrusion (Orlický et al., 1995).

To specify the time and extent of the Miocene rotations of the Southern Slovakia, a paleomagnetic investigation of rocks coming from two sites has been performed (Fig. 1): the deposits of the Sečianky Member, Modrý Kameň Formation (Karpatian stage) and the tuffaceous claystones of the Hrušov Member, Vinica Formation (Middle Badenian).

Methodology

Paleomagnetic measurements were performed in the Paleomagnetic Laboratory of the Geophysical Institute SAS in Modra – Piesky. Thermal demagnetization was applied using a MAVACS demagnetization equipment. Magnetic polarization was measured with JR5 spinner magnetometer. Demagnetization was carried out in increment of 50°C starting at laboratory temperature up to 620°C. Magnetic volume susceptibility was measured after each step of demagnetization with Kappa bridge KLY3. All instruments are products of the AGICO comp. Brno, Czech Republic.

Demagnetization graphs were constructed for the analysis of results for each sample, namely normalized curves of thermal dependence of the remanent magnetic polarization and magnetic bulk susceptibility (KAPPA), as well as the Zijderveld diagrams of XY and XZ components of the RMP. The RMP directions were also plotted in double stereographic projections, one for RMP direction in situ, and the second one in position after bedding correction. This correction is necessary because original singenetic magnetic polarization was fixed in rock during sedimentation and clivage process, it means in a horizontal position.

Illustrations of the demagnetization graphs are in Figs. 2, 3 and 4. Fig 2 presents the demagnetization course of samples with work labels 1A and 3 from the locality Dolné Príbelce. It can be seen on the demagnetization curves of remanent magnetic polarization (marked as J) and magnetic volume susceptibility (marked as K) that magnetic cleaning is smooth up to 300°C. Mineralogical change which is indicated by rapid rising of magnetic volume susceptibility (curve K) occurs after this temperature. Also the value of RMP is rising after the same temperature (curve J). The rock, where the carrier

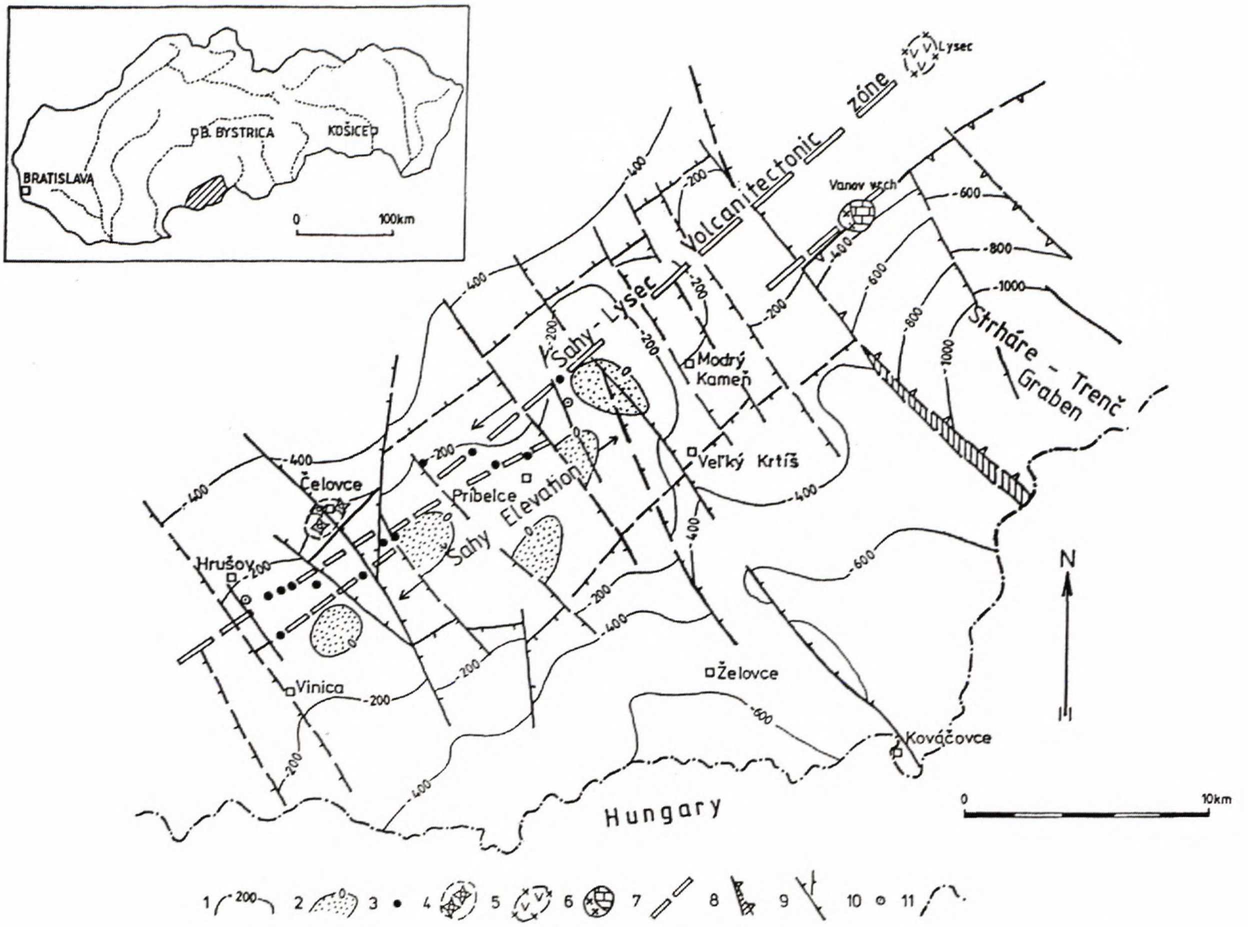

Fig. 1. Šahy-Lysec Volcanotectonic Zone with numerous andesite extrusions, Badenian in age, directed by perpendicular faults of NNW direction. The sampling sites are pointed.

of magnetism is a small amount of titanomagnetite (Curie temperature up to 300°C) with the admixture of some sulfide, has usually such behaviour (McElhinny and McFadden 2000). Stereographic projections of the paleodirections indicate, that magnetic polarization changes during the demagnetization from a normal direction in the natural state to the reversed one after 200°C. This reversed polarization is probably original in the rock. This is indicated also by the Zijderveld diagrams. Component analysis showed that there are three components of NRM in the rock (Fig. 3). The reversed paleodirections which remained in rock after demagnetization by the temperature of 250°C, were taken as a characteristic direction for the statistical processing of the Dolné Príbelce samples.

Similar analysis of demagnetization graphs was performed on samples from locality Hrušov. The characteristic course of demagnetization is presented in graphs of Fig. 4. Here the rock has only one carrier of magnetism, which is magnetite. Demagnetization is very smooth, there are no mineralogical changes (normal) and remaining after magnetic cleaning by heating to 300°C was taken for statistical processing.

The paleodirections for both localities were calculated using Fisher's statistics (McElhiny and McFadden 2000). The final paleodirections are presented in Figs. 5, 6 and Tab. 1.

Paleomagnetic sampling and results

The Dolné Príbelce site

The samples for measurements were taken in a gorge NE of the village Dolné Príbelce. The tin bedded calcareous friable siltstone – claystone of the Sečianky Member, Modrý Kameň Formation, was sampled. The Karpatian age of the Sečianky Member has been established mainly on the basis of the foraminiferal assemblage containing beside others the taxa typical for the Karpatian stage Uvigerina tarchanensis, G. bulloides, G. concina (Kantorová in Vass et a. 1979; in Vass and Elečko eds. 1992). The assemblage of the calcareous nanoplankton consists the taxa of NN4 zone including the index taxa Helicosphaera ampliaperta (Lehotayová in Vass et al., 1979).

The characteristic remanence of the sampled rock is reversed (partially overprinted?). The mean value of the declination (7 measurements) is of 184° and inclination of -29°. The dispersion of data is relatively large α_{95} = 17° (Fig. 5, Tab. 1). The declination indicates no rotation with respect to stable Europe.

The Hrušov site

The samples were taken from a deep gorge at the southern margin of Hrušov village. The site is a strato-

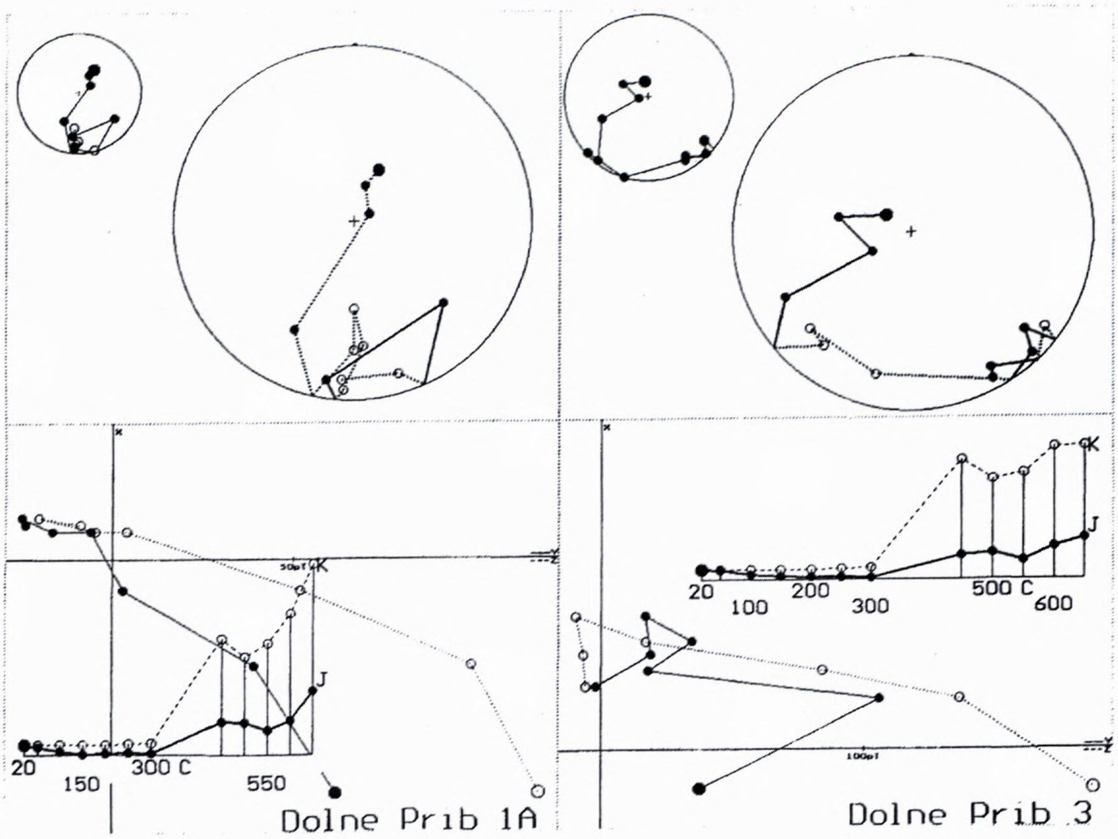

Fig. 2. Demagnetizing graphs of thermal demagnetization of sedimentary rocks from the locality Dolné Príbelce (Karpatian in age) samples 1A and 3. Upper part of picture – streoprojections of directions of remanent magnetic polarization (smaller circle – directions in situ, larger one – directions in position after bedding correction) after each demagnetizing step, the biggest point means start of demagnetization. The full dots – normal direction, open dots – reversed direction of magnetic polarization. Lower part of picture – thermal dependence of remanent magnetic polarization (curve J) and magnetic volume susceptibility (curve K); Zijderveld diagrams of the XY and XZ components of remanent magnetic polarization (Krs 1969).

type locality for the Hrušov Member (Vass et al. in press, Vass, 2002) occuring at the top the Vinica Formation. The sampled rocks are tuffitic andesite claystone and siltstone containing small non sculptured shells of *Amussium denudatum* (Vass in Vass et al., 1979), the foramaniferal assemblage including the planktonic taxa *Globigerinoides bulloides*, and calcareous nanoplankton including the taxa *Sphenolithus heteromorphus*. Its presence together with the absence of the taxa *Helicosphearea ampliaperta indicates* the nanoplanctonic zone NN5 (Lehotayová in Vass et al. 1979; Holcová in Vass et al. in press). The numeric age of the zone NN5 of 15.4 - 14.2 Ma (Berggren et al., 1995) corresponding in the numeric time-table of the Paratetys Neogene to the Middle-Late Badenian (Vass et al., 1987). Based on the biostratigraphically proven Early to Early Middle Badenian age we suppose that the Hrušov Member topping the Vinica Formation is Middle Badenian in age (Vass et al. in press). Because the RMP of the Member is normal it is possible to correlate the Hrušov Member with the oldest normal event of the chron C5Bn having numeric age of 15.15 - 15.03 Ma (Berggren et al., 1995).

The mean value of the declination (5 measurements) is 23° and mean inclination is 66°. The measured directions are consistent, the dispersion is small $\alpha_{95} = 3°$. The declination indicates a small CW rotation with respect to the stable Europe (Fig. 6, Tab. 1)

Discussion

As we have mentioned already in the introduction, in Northern Hungary and in Southern Slovakia the total Miocene rotation is about 80° CCW. Two pulses of rotation were discriminated. The younger one, of about 30°CCW, took place in Early Badenian. We had assumed to define a similar rotation by paleomagnetic measurements of the Sečianky Member, Karpatian in age in the Ipeľská kotlina .We also had assumed, that the declination of the Hrušov Member (Middle Badenian) would be a Stable European one as it is the case at the Middle Badenian Šiator Andesite (Orlický et al. 1995). The paleomagnetic measurements did not confirm our assumptions. So we shall try to explain the discrepancy between assumptions and results of measurements.

The investigated sites are situated either in the close neighbourhood of the Šahy – Lysec Volcanotectonic Zone (Dolné Príbelce) or directly inside the zone (Hrušov, see Fig. 1). The intensive volcanic activity of the zone took place during Badenian. The extrusive volcanic centers of Vinica, Opava and Lysec formations belong to the volcanotectonic zone. The volcanism was accompanied by tectonic activity manifested mostly in faults of NNW direction. The majority of those faults originated during the Badenian and their genetic connection with

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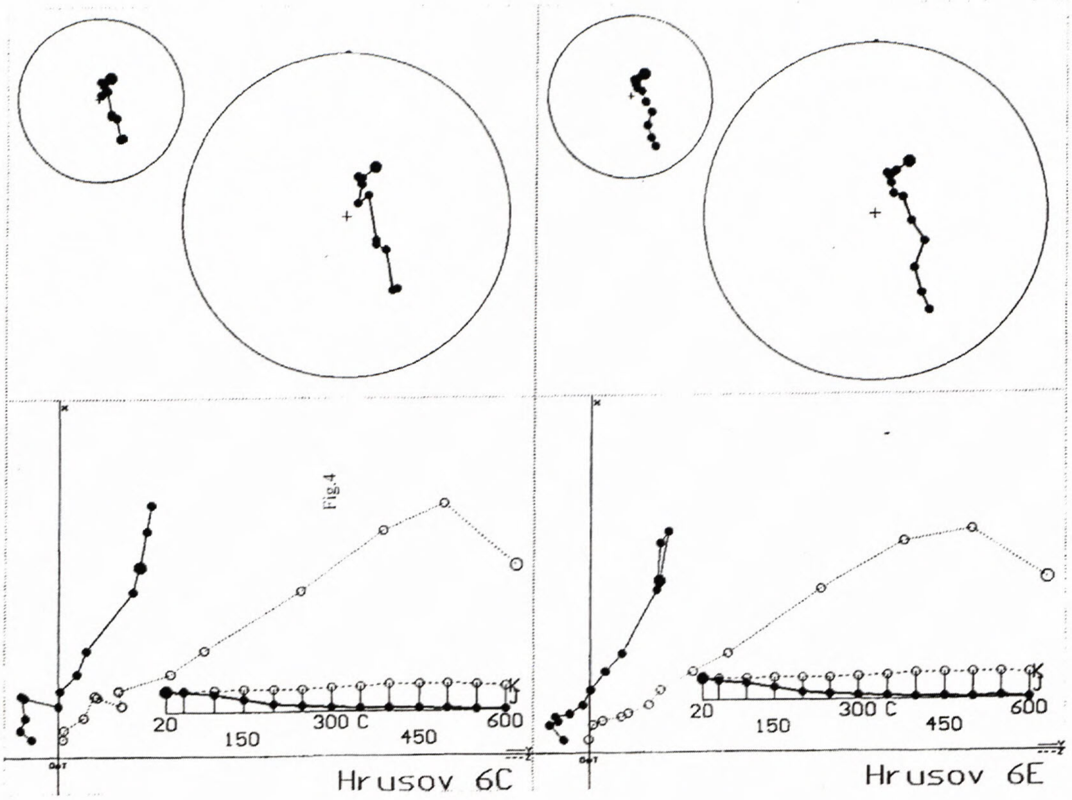

Fig. 3. Demagnetizing graphs of thermal demagnetization of tuffitic claystones from the locality Hrušov (Middle Badenian in age) samples 6C and 6E (for explanation see the Fig. 2).

volcanism is manifested in the fact, that volcanic centers are situated at the intersection of the NNW and NE trending faults. Several faults of NNW direction are strike – slip faults. One of them runs along the gorge where the stratotype profile of Hrušov Member is found – the paleomagnetically studied site (Fig.7). Another one runs along the eastern margin of Dolné Príbelce village, close to the sampled site (Fig. 8). Both faults are dextral strike-slips and may generate CW block rotation (Terres and Sylvester, 1981; Sengör in Allen and Allen, 1992 a.o.). So the dextral strike-slip on the NNW faults generated by volcanic activity could have been the cause of the local CW rotations in the area of the Šahy – Lysec Volcano-tectonic Zone and in their close neighbourhood.

The angle of the CW rotation is determined by the vector of RMP declination of the Hrušov Member having the value of 23° (Fig. 8). Probably it is the rotation vector of a block rotated inside of the Šahy – Lysec Volcano-tectonic Zone.

The local rotation connected with Badenian volcanic activity was preceded the regional CCW rotation of the Early Badenian. Present vector of the RMP declination 184° (= 4° CW) of the Sečianky Member deposits have got a backward rotation aprox. 23° (which is the rotation of Hrušov Member), so the regional CCW rotation during Early Badenian has had the vector aprox. 19° (Fig. 7, variant A). Is it not encluded, that the Early Badenian CCW rotation in the area studied was about 30° CCW (the same as the rotation measured by Márton and Márton, 1996 on the Karpathian rocks at the southern foothills of the Bükk Mts., Hungary) than the younger Badenian Badenian local CW rotation of the block at Dolné Príbelce was larger: about 34° CW (Fig. 7, variant B).

Another problem, that the paleomagnetic study of both sites helps to solve is the correlation of the studied rocks with the magnetostratigraphic Neogene scale and the precision of their numeric age. Coming from the Karpatian stage numeric age 17.5 - 16.5 Ma (Vass et al. 1987), then during the Karpatian the reversed polarisation was dominant. The chron of such polarisation C5Cr having numeric age 17.2 - 16.7 Ma (Berggren et al., 1995). During this chron the Sečianky Member came to existence because their RMP is reverse. The upper part of Karpatian stage corresponds to lower part of the chron C5Cn of normal magnetic polarity. The upper part of the Karpatian in Ipeľská kotlina Depression, but also in the whole Southern Slovakia and Northern Hungary area is missing being removed by a post – Karpatian and pre – Badenian erosion (Vass et al., 1979; Vass and Šucha, 1994).

The age of the Vinica Formation topped by the Hrušov Member is Early – Middle Badenian (Vass et al. in press). The Hrušov Member likely originated in late Middle Badenian. The late Middle Badenian and early Late Badenian correspond to the chron of normal magnetic polarity C5Bn having the numeric age 15.5 - 14.8 Ma (Berggren et al., 1995). The older normal event of the chron (15.15 - 15.03 Ma) is likely the time-period of the Hrušov Member coming to existence (Vass l. c.), (Fig. 9).

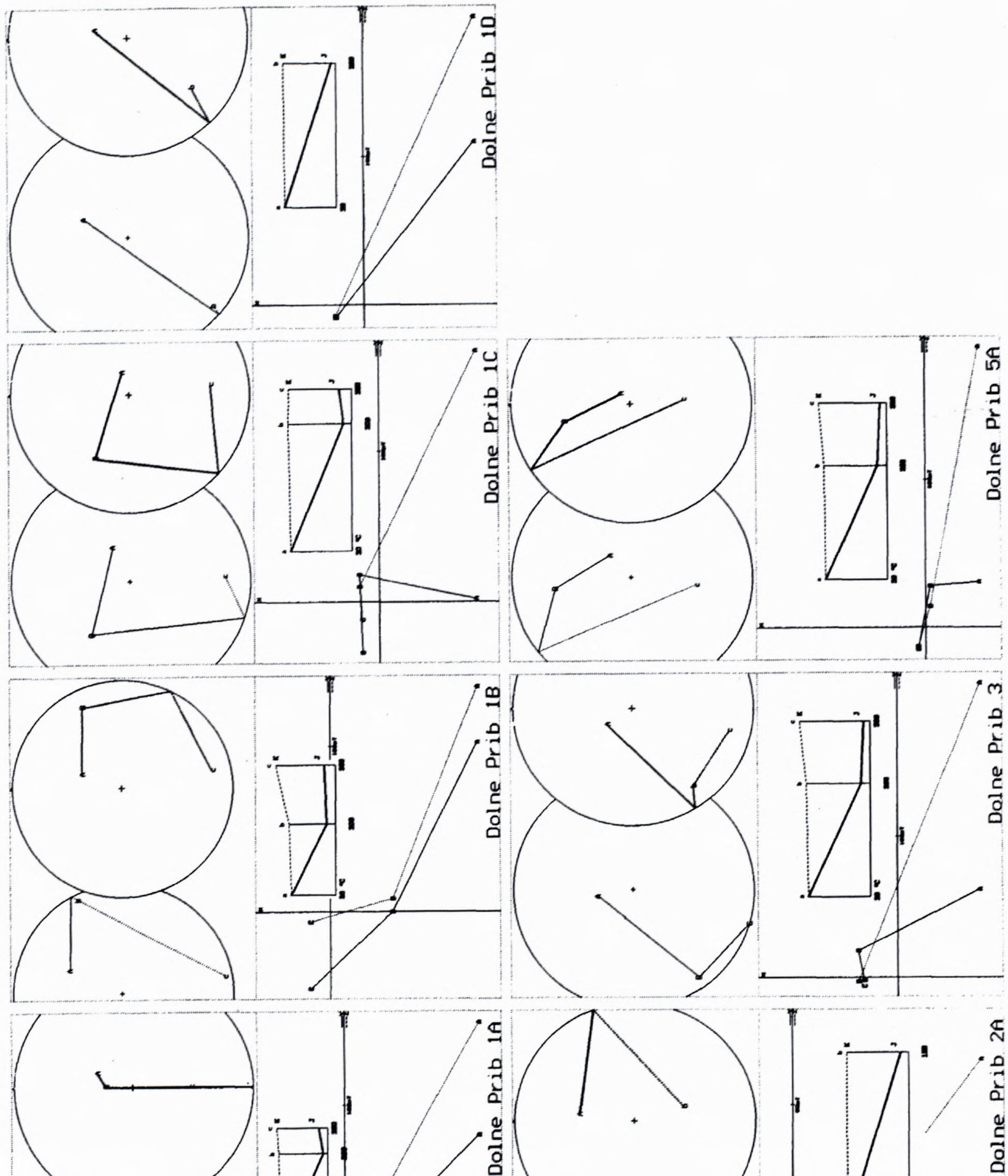

Fig. 4. Demagnetizing graphs of thermal demagnetization of 7 samples from sedimentary rocks from the locality Dolné Príbelce (Karpatian) – three components of remanence (for explanation see the Fig. 2).

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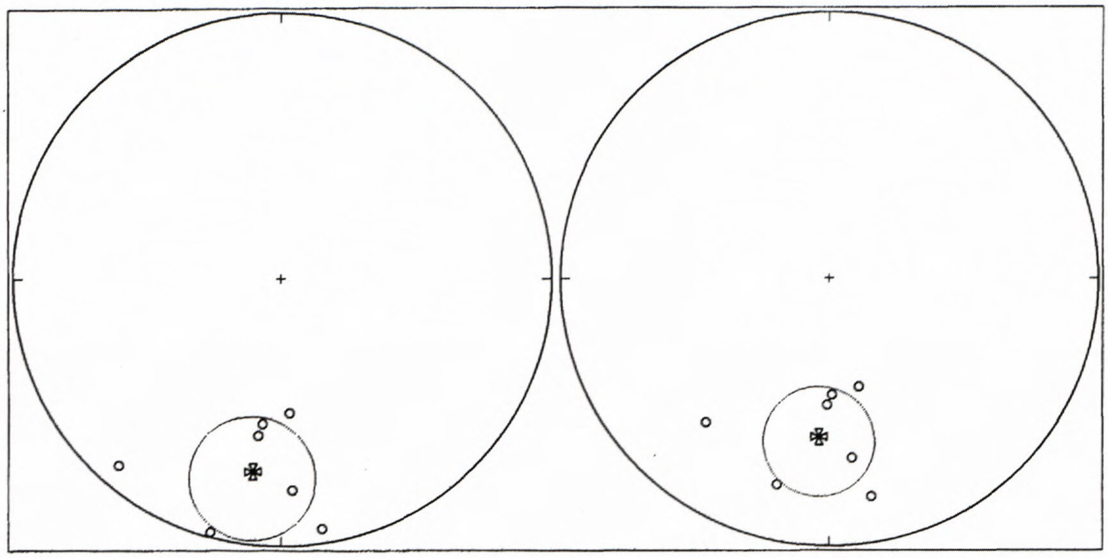


Fig. 5. Stereographic projection of the paleodirections and main direction of 7 samples from sedimentary rocks of the locality Dolné Príbelce. Left circle - paleodirections in situ, right circle – paleodirection in position after bedding correction. Main direction is marked by Malta cross (full for the normal, open for reversed paleodirection); circle around main direction marks cone of probability of 95%.

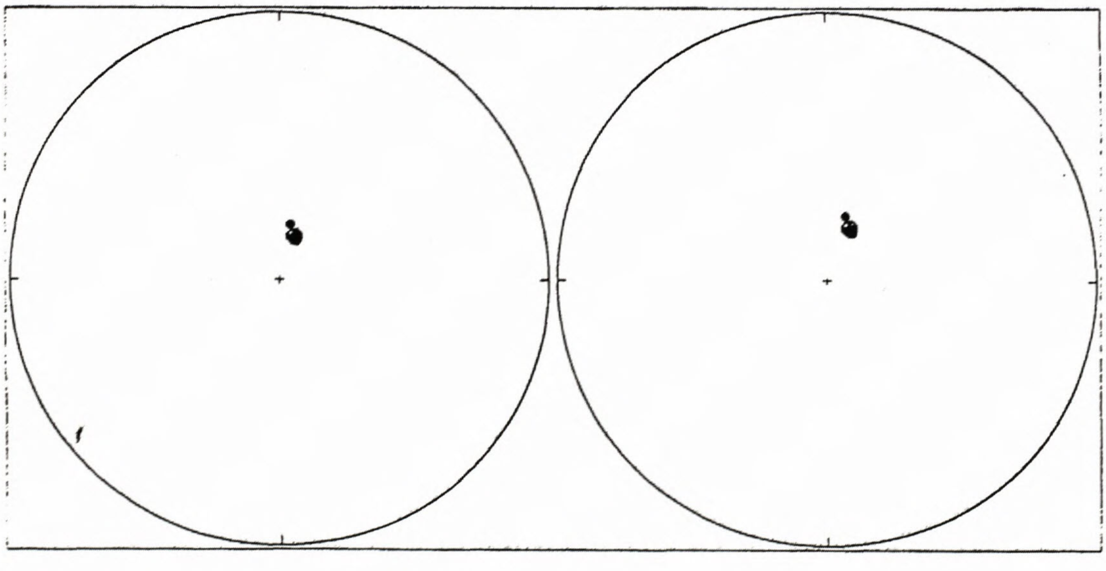


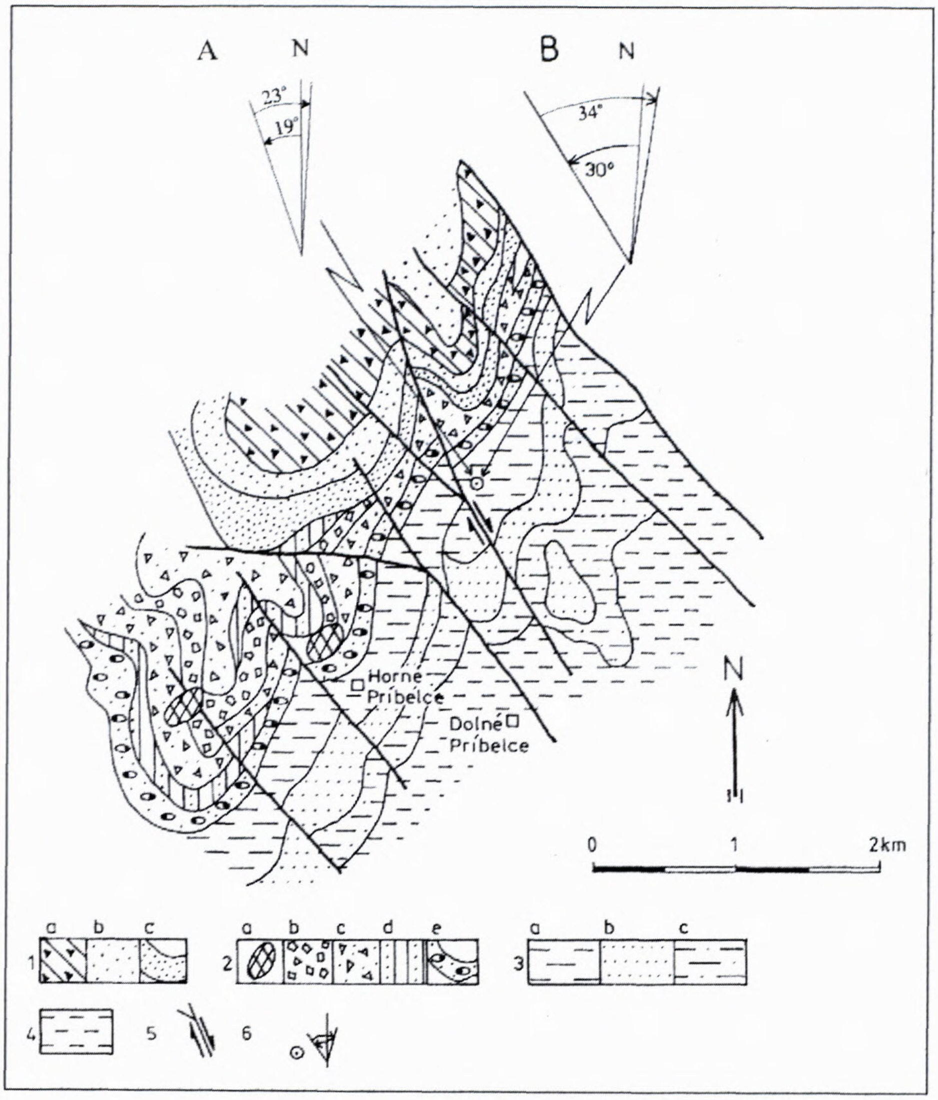
Fig. 6. Stereographic projections and main direction from 5 samples of tuttitic claystones from locality Hrušov (for explanation see the Fig. 5).

Table 1 Paleomagnetic results

Locality	Lithology	Age		BBC				ABC					
			N	D°	I°	k	α_{95}	D°	I°	k	α_{95}	J [nT]	K .10^{-6} uSI
Dolné Príbelce	calc. friable silstone-claystone	Karpatian	7	194	-18	9	21	184	-29	9	21	0.008	107
Hrušov	tuffitic andesite, claystone - silt-stone	Middle Badenian	5	17	71	660	3	23	66	66	3	17.8	6390

N – number of rock samples; D°, I° – paleomagnetic mean declination, inclination; BBC before bedding correction; ABC – after bedding correction; k – statistical precission parameter; α_{95} – half angel of confidence at the 95 % level (Fisher, 1953); J [nT] – mean value of remannent magnetic polarization; K.10^{-6} u.SI – mean value of magnetic volume susceptibility.

Fig. 7. Schematic geologic map of the village Dolné Príbelce surroundings with the sampling site of the Sečianky Member (Karpatian). See the dextral strike-slip and interpretation of CCW versus CW rotations



Conclusions

Paleomagnetic results of the Sečianky Member of the Modrý Kameň Formation, Karpatian in age, and the Hrušov Member of Vinica Formation, Middle Badenian in age, are not consistent with results of coeval rocks of Northern Hungary, as well as Southern Slovakia. While the declinations in Karpatian rocks in Northern Hungary display CCW rotation of 30° and Middle Badenian rocks in the same area have declination close to the recent geomagnetic field, the declinations of investigated rocks in the area of Šahy-Lysec Volcanotectonic Zone display no rotation or CW rotation with respect to stable Europe.

A probable cause of the CW rotation (with respect to the general, CCW rotated declinations) is the tectonic activity of the Šahy-Lysec Zone, where numerous faults of NNW direction had been generated. Some of them were strike-slips. One of such faults runs through village Hrušov and another runs close to eastern border of village Dolné Príbelce, thus not far from the sampled sites. The mentioned faults are dextral strike-slips and the dextral strike-slip has probably generated local CW rotation of some blocks. In the case of the Sečianky Member the first rotation must have been CCW taking place during Early Badenian. The second rotation was in opposite sense – clockwise.

Since the studied rocks are relative well dated biostratigraphically, we tried to correlate them with the Neogene magnetostratigraphic scale. The Sečianky Member, Karpatian in age, having reversed RHP, may be correlated with the chron C5Cr with numeric age 17.2 - 16.7 Ma.

Hrušov Member, Middle Badenian in age, having normal RMP, may be correlated with the older normal event of the chron C5Bn with numeric age of 15.15 - 15.03 Ma.

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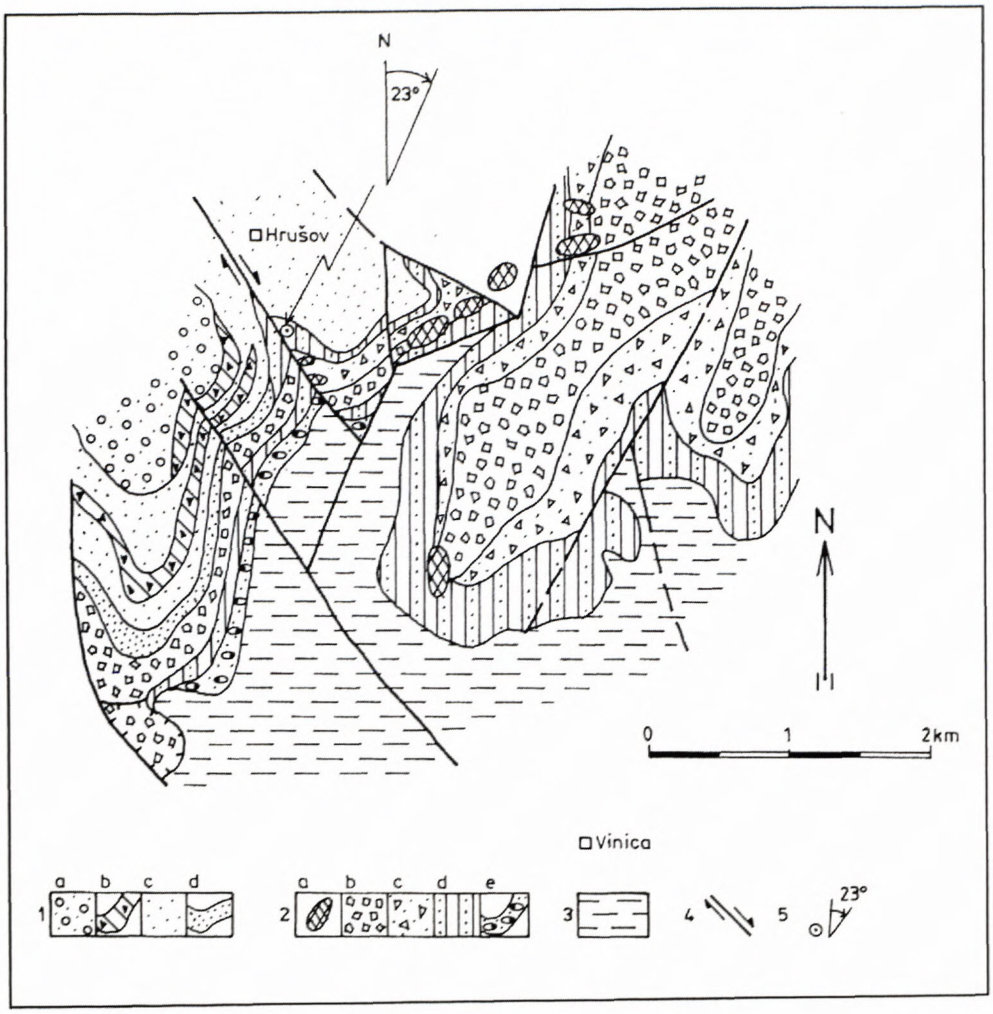

Fig. 8. Schematic geologic map of village Hrušov surrounding with the sampling site of the Hrušov Member (Middle Badenian). See the dextral strike-slip and imagination of CW rotation.

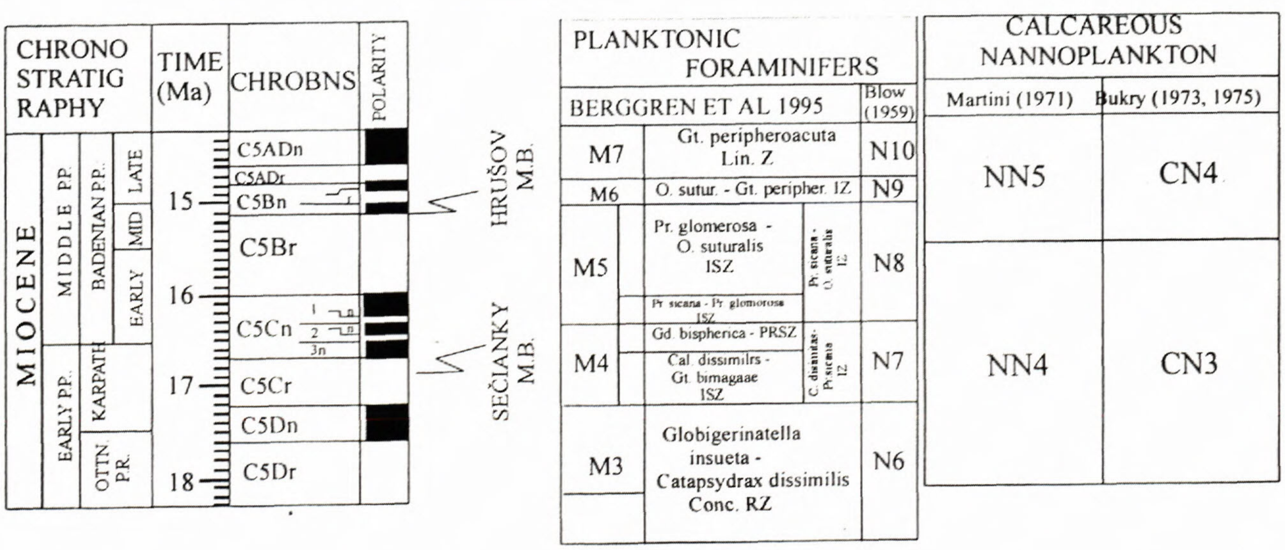

Fig. 9. Position of Sečianky Member (Karpatian) and Hrušov Member (Middle Badenian) in the Miocene stratigraphic time-scales (the correlation scheme of Berggren et al. 1995 was used).

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