Panaiotu, C., 1998. Paleomagnetic constrains on the geodynamic history of Romania, In: D. Ioane (editor): Monograph of Southern Carpathians, Reports on Geodesy, No 7(37),

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Paleomagnetic constrains on the geodynamic history of Romania

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Introduction

Paleomagnetic measurements, when they are based on adequate laboratory treatment and on statistically significant number of samples and sites, can give a reliable record of the ancient geomagnetic field at the site of rock formation. The basic hypothesis that the geomagnetic field was, on average, that of an axial and geocentric dipole permits the paleomagnetist to interpret his results in terms of paleolatitude of the sampling site and its location with respect to the paleomeridians. When paleomagnetic directions from a possibly displaced or rotated block are compared with those from a neighbouring craton, the declination difference between an expected or reference direction and an observed direction indicate the amount of rotation, whereas the paleolatitude difference indicates north-south displacement.

Paleomagnetic data provide the best, often the only, means for measuring rotations on vertical axes (e.g. Jackson and McKenzie, 1989; Garfunkel, 1989). Physical and mathematical arguments show that the observed movement on faults within a wide zone of continental deformation does not in general determine the rotation rate of the rigid block bounded by faults. Only if an *a priori* model for the deformation is assumed can the fault movements be related to observations of paleomagnetic rotations. Even when such a model is valid, the faulting determines the block rotations relative to the boundaries of the zone, whereas the paleomagnetic data measure the rotation with respect to the Earth's rotation axis. Since geological, geodetic, seismic, and paleomagnetic measurements tend to sample complementary aspects of the deformation field, we need an integrated observation program to find the answer at the question whether deformation of continents is more accurately describe by the motion of a few small rigid plates or by quasi-continuous flow.

In this paper, I will review the most important paleomagnetic results from the Romania territory. Then a discussion of paleomagnetic constrains on the Cainozoic geodynamic history will follow. The paleomagnetic data will be presented together with a review of the geological structural data (Maţenco, 1997) to support a future integrated model of tectonic evolution of Carpatho-Pannonian area.

Review of Romanian paleomagnetic data

Jurassic

Little work has been done on Jurassic rocks in Romania up to now. Only recent two paleomagnetic directions were reported from Oxfordian red limestone from Piatra Craiului and Kimmeridgian pink limestones from Bucegi (Hambach et al., 1996). These new data show a paleolatitude during Middle - Late Jurassic of around 18°-20° N and an important clockwise rotation.

Upper Cretaceous

Magmatic rocks

The banatites were sampled extensively in the Apuseni Mountains, Poiana Ruscă Mountains, Hațeg Basin and Banat area (Pătraşcu et al., 1990, 1992, 1995). Recent K-Ar data (Downes et al., 1995; Pécskay, pers. com., 1997) show that the magmatic rocks from the Mureş Valley, considered by Pătraşcu et al. (1994) as Paleogene in age, are in fact of Maastrichtian age. These data were combined with previous paleomagnetic directions and a new mean direction for the banatites, based on 56 sites, was computed: Declination=81° Inclination = 47° Paleolatitude = 27°N. The new data set has a positive reversal and fold test, so the mean direction is characteristic for the whole banatitic province sampled for paleomagnetism.

Sedimentary rocks

Preliminary paleomagnetic results were reported from the Upper Cretaceous deposits from the South Carpathians: Maastrichtian marls from Prahova Valley (Bazhenov et al., 1993; Zweigel, 1998, in press) and sandstones from Olt Valley (Panaiotu et al., 1998, in press). All the results have large eastward declination: 50° to 90°.

Eocene

Recent paleomagnetic results from Transylvanian Basin (Panaiotu et al., 1997) were obtained from Ypresian carbonate rocks (north-western part) and siliciclastic rocks (south-eastern part) and from the Lutetian minettes (north-western part). Ypresian sandstones were sampled also in the Argeş Valley in the Southern Carpathians. All the sites passed a positive fold test for the inclination (mean inclination = 43° ± 7°). The declination range from 85°-70° for the Transylvanian data to 106° for the Eocene from Argeş Valley.

Other Paleogene-Neogene results are reported from the external parts of East Carpathians (Zweigel, 1998, in press). They show different amplitudes of clockwise rotations in the nappes system from this area. Since they are based on only a few sites that are not geographically distributed inside the nappes, these results will be omitted from the further analysis.

Neogene

Transylvanian tuff

The Badenian tuff was sampled in great detail in Pâglişa quarry (north-western part of the basin). The mean direction is Dec=30° Inc=60°. It is possible that the age of the acquisition of the primary magnetisation to be delayed with respect to the biostratigraphic age: NN5 biozone.

Volcanic rocks - Apuseni Mountains

First results from this area were presented by Pătraşcu et al. (1994) and Panaiotu et al. (1995). These results show that the declinations spread from 80° to the north. The correlation of this pattern with the K-Ar age of the volcanism (Roşu et al., 1997) was difficult since at that moment only a few sites were sampled both for paleomagnetism and K-Ar data. A recent study (Panaiotu et al., in press) show that the paleomagnetic data can be grouped according to the K-Ar ages and paleomagnetic declination as follow: a) mean age = 14.2 Ma, mean declination = 61°; b) mean age = 13.0 Ma , mean declination = 28°. The rest of the paleomagnetic data suggest that younger ages (7 - 11 Ma) has a mean declination pointing to the north. The inclination is always around 60°.

Volcanic rocks - Eastern Carpathians

Previous published paleomagnetic results (Pătraşcu, 1976, Pătraşcu, 1993) were reinterpreted according to new K-Ar data (Pécskay et al., 1995). The data were separated in 5 groups: 1) Seini formation (Sarmatian age, Dec=344° Inc=57°); 2) Oaş-Igniş-Tibleş (11-9 Ma, Pannonian age, Dec=5° Inc=63°); 4) Gurghiu (6.5 - 8.5 Ma, Pannonian-Pontian, Dec=359° Inc=62°); 5) Northern Harghita (4 - 6.5 Ma, Dec=7° Inc=61°).

<u>Late Pliocene -Quaternary</u>

Paleomagnetic results from Late Pliocene - Quaternary rocks were obtained from basalts from Perşani Mountains (Hambach et al., 1994, Pătraşcu et al., 1995, mean direction:Dec=7° Inc=61°) and the shoshonitic rocks from the Apuseni Mountains (Uroiu Hill, 1.6 Ma, mean direction: Dec=180° Inc=-48°).

<u>Remagnetization problem</u>

Several studies (Surmont et al.., 1990, Hambach et al., 1996, Panaiotu et al., 1997) reported large remagnetization of the sampled Mesozoic rocks. In all the situations these remagnetizations has high inclination values around 60° and large eastern declination (60° to 125°). According to the inclination the age of the acquisition must be post Eocene, but before the starting of the clockwise rotation.

Interpretation of paleomagnetic data in terms of kinematic evolution

The inclination data and the northward drift

According to the geocentric axial dipole hypothesis, inclination data are connected with the paleolatitude of the sampling area during the magnetisation. In Fig. 1 the paleolatitudes obtained for the Jurassic rocks from Piatra Craiului and Bucegi Mountains, for the Upper Cretaceous magmatic rocks from the Apuseni Mountains, Poiana Ruscă, Haţeg Basin and Banat area and for the Neogene volcanics rocks from the Apuseni Mountains and East Carpathians are represented. In order to give a quantitative estimate of the latitudinal drift with respect to the stable Africa and Europe, the expected paleolatitudes with 95% confidence limits are also plotted. These paleolatitudes were computed in the hypothesis of a rigid connection of the studied area in the present day position with one of the two major plates in the last 200 Ma. It is obviously that the sampled areas from Transylvanian Basin and Southern Carpathians were to the south of Europe at lest until post Eocene. Only the paleolatitudes from the Miocene volcanics are closed to the present day position. This implies a northward drift of the studied area to the north during Oligocene - Lower Miocene to reach the present day position with respect to Europe. According to the Debiche and Watson' method (1995) the latitudinal movement of Transylvanian Basin with respect to Africa is not significant statistical during Eocene. So the northward drift of Transylvanian basin has the same order of magnitude likes the drift to the north of Africa with respect to Europe. The results from the Transdanubian Central Range and North Pannonian Paleogene Basin (Mauritsch and Márton, 1995; Márton and Márton, 1996) show for Tertiary shallower paleolatitudes that those expected in the African reference frame. These data were interpreted like an abrupt northward shift of these areas during Ottnangian (Burdigalian). More data are needed from Transylvanian Basin to cover the interval Eocene - Miocene to check if this sudden drift to the north is also characteristic for the Tertiary evolution of Transylvanian Basin.

The declination data and block rotations

To interpret the data in term of block rotation the measured declinations from Transylvanian Basin were plotted against the expected declination in the European reference frame (Fig. 2). In the same figure, the declination data from Transdanubian Central Range and North Pannonian Paleogene Basin (Mauritsch and Márton, 1995; Márton and Márton, 1996; Márton and Pécskay, 1997) were represented. Several conclusions can be drawn from this figure: 1) most of the clockwise rotation of the Transylvanian Basin, around 55° with respect to Europe, took place very fast during Late Badenian-Early Sarmatian. In that moment the northward drift of the Transylvanian Basin was finished (Fig. 1); 2) a similar fast rotation rate was also recorded in the Northern Pannonian Basin, but this counterclockwise rotation was finished during Badenian. Part of this rotation (around 40°-60°) took place probably during the northward drift (Márton and Márton, 1996); 3) most of the counterclockwise rotation of the Transdanubian Central Range took place also post Eocene.

To correlate the paleomagnetic data from the Carpatho-Pannonian area with the structural data, the horizontal component of the mean paleomagnetic directions were plotted on the structural maps with the deformation structure of Maţenco (1997). According to the structural data these maps are divided in 4 deformation intervals: Paleogene - Early Miocene (Fig. 3), Late Burdigalian/Karpathian - Badenian (Fig. 4), Sarmatian (Fig. 5), Late Sarmatian-Meotian (Fig. 6). The general correlation of the deformations recorded in the Carpathian and Intra-Carpathian units during Tertiary is after Maţenco (1997). Paleomagnetic data for the north-eastern part of the area are from Márton and Márton (1989), Márton and Mauritsch (1990), Krs et al. (1991), Krs et al. (1993), Márton et al. (1996), Tuny and Márton (1996).

The main conclusions of this correlation are:

1. From the point view of paleomagnetic data, the Carpatho-Pannonian region can be separated in two domains with different senses of rotation during Tertiary. Large areas from these domains have not only an identical sense of rotation but also the same amplitude of post Eocene rotation. According to Westaway (1990) this kind of organisation style of paleomagnetic directions in large domains reflect the movement of the blocks in the brittle layer of the crust in response to the viscous torque acting on their base from the underlying plastic deformation of the lithosphere. Local deviations from the general pattern probably reflect changes in the vertical vorticity of the viscous flow of the lithosphere or the response to the frictional torque acting at the margins of the blocks. The main boundary between the two large domains is along the Mid Hungarian Line and North Transylvanian Fault. On the Romanian territory the clockwise rotation is well sustain by paleomagnetic data for the Transylvanian Basin and internal parts of the South Carpathians. Preliminary paleomagnetic results suggest that this rotation affected also the southern border of the South Carpathians.
2. During the Tertiary northward drift of the area, only 20° of clockwise rotation took place between Eocene and Middle Miocene and there is no rotation between Maastrichtian and Eocene.
3. Most of the clockwise rotation of the central part of the Transylvanian Basin took place during Late Badenian - Early Sarmatian. The age of the rotation in the S-E corner of basin is clear post-Eocene and taking into account the inclination of remagnetizations probably post-Paleogene. So, it is probably contemporaneous with the rotation of the central part of the basin. This rotation took place after the cessation of counterclockwise rotation of the North Pannonian Paleogene Basin. Contemporaneous counterclockwise rotations are recorded only in the Sarmatian volcanic areas from Zemplen and Igniş Mountains (Fig. 5)

   During Late Badenian, the Pannonian area was characterised by a major stretching phase, leading to the eastward escape of the basin. A system of NW-SE normal faults developed in the Pannonian Basin and the Apuseni Mountains (Fig. 4). The development of this faults system was probably the answer of the brittle upper crust to accommodate the rotation imposed by the continuum deformation of the lower crust and mantle lithosphere. It must be point out that present direction of this faults system corresponds to the position of the faults when the rotation was finished. It is quite probably that the faults also rotate to accommodate the distributed deformation (e.g. Jackson and McKenzie, 1989). In the Outer Romania Carpathians the Sarmatian tectonic episode was characterised by large scale eastward motion of the inner East Carpathians and South Carpathians, causing differential contraction and uplift, accompanied by the disruption of the roll-back process in the East Carpathians and right-lateral shearing along a roughly E-W trending corridor between the South Carpathians and the Moesian Platform. The most advanced East Carpathians nappes reached the East European block in the central sectors and this probably produced the cessation of the rotation.

Such a fast clockwise rotation (20°/Ma to 30°/Ma) was probably the answer of the upper plate to a very rapid migration to the east of the slab's hinge (Dvorkin et al., 1993). This retreating was probably accelerated by the slab breakoff (Wortel and Spakman, 1992).

4. After Late Sarmatian, the paleomagnetic data show the absence of significant rotation. It must be point out that all the data come only from volcanics rocks and that the paleomagnetic directions indicate the absence of rotation after the emplacement of studied volcanic rocks. So present paleomagnetic data did not exclude the presence of rotations on the eastern border of Transylvanian Basin after Late Sarmatian. A good example in that sense is the result from the volcanic rocks (10.5 Ma, 2 sites) and the remagnetised Mesozoic alkaline rocks from the Ditrău Mountains (Fig. 6). The mean paleomagnetic direction has a declination around 90° indicating a large clockwise rotation that is not present in paleomagnetic data from younger rocks of the Călimani Mountains and the Gurghiu Mountains. More paleomagnetic sites are need from the Ditrău Mountains to decide if this results indicate a fast and ample clockwise rotation during Pannonian time. Rotations in the SE part of the East Carpathians are not unexpected since the structural analyses indicate the ESE advancement of this part during latest Miocene. The northern segments of the East Carpathians remained blocked, while in this transition zone the roll-back process continued, and is still presently recorded in the seismically active Vrancea area. The paleomagnetic data from the Northern Harghita Mountains and the Perşani Mountains don't support significant rotations in the transition zone in the last 5 Ma. From geological point of view, the late Sarmatian marks the beginning of the common evolution of the Outer Carpathians and the Intra-Carpathians units and this aspect is probably reflected in the absence of important rotation.

REFERENCES:

Bazhenov, M.L., Burtman, V.S. and Săndulescu, M., 1993. Paleomagnetism of the Upper Cretaceous rocks and its bearing to the origin of the Romanian Carpathian arc. Rom. J. Tect & Reg. Geol, 75, 9-14.

Debiche, M. G. and Watson, G. S., 1995. Confidence limits and bias correction for estimating angles between directions with applications to paleomagnetism. J.G.R., 100, B12, 24405-24429.

Downes, H., Vaselli, O., Seghedi, I., Ingram, G., Rex, D., Coradossi, N., Pécskay, Z. and Pinarelli, L., 1995. Geochemistry of late Cretaceous-early Tertiary magmatism in Poiana Ruscă (Romania). Acta Vulcanologica, 7, 209-217.

Dvorkin, J., Nur., A., Mavko, G. and Ben-Avraham, Z., 1993. Narrow subducting slabs and the origin of the back-arc basins. Tectonophysics, 227, 63-79.

Garfunkel, Z., 1989. Regional deformation by block translation and rotation. In C. Kissel and C. Laj (eds): Paleomagnetic rotations and Continental deformation. Kluwer Academic Publishers, 181-208.

Hambach, U., Orleanu, M., Rogenhagen, J. and Schnepp, E., 1994. Paleomagnetism of Pleistocene volcanics from the Perşani Mountains, East Carpathians (Romania). Rom. Journ. of Tectonics and Regional Geology, 75 (Abstract volume), 20-22.

Hambach, U., Panaiotu, C. and Panaiotu, C. E., 1996. Gondwana origin of the Tisza-Dacia unit? Arguments from paleomagnetism. PANCARDI Workshop 1996 (abstract), Mitt. Ges. Geol. Berbaustud. Osterr. 41, Wien 1996, 101-148.

Jackson, J. and McKenzie, D., 1989. Relation between seismicity and paleomagnetic rotations in zones of distributed continental deformation. In: C. Kissel and C. Laj (eds), Paleomagnetic rotations and continental deformations, Kluwer Academic Publishers, 33-42.

Krs, M., Krsova, M., Chvojka, R. and Potfaj, M., 1991. Paleomagnetic investigation of the flysch belt in the Orava region, Măgura unit, Czechoslovak Western Carpathians. Geol. prace, Spr., 92, 135-151.

Krs, M., Krsova, M., Pruner, P., Chvojka, R. and Potfaj, M., 1993. Paleomagnetic investigation in the Biele Karpaty Mts. unit, Flysch Belt of the Western Carpathians. Geologica Carpathica, 45, 1, 35-43.

Márton, E. and Márton, P., 1989. A compilation of paleomagnetic results from Hungary. Geophys. Trans., 35 (1-2), 117-133.

Márton, E. and Márton, P., 1996. Large scale rotations in North Hungary during Neogene as indicated by paleomagnetic data. In A. Morris and D. H. Tarling (eds.): Paleomagnetism and tectonics of the Mediterranean Region. Geol. Soc. Special Pub., 105, 153-173.

Márton, E. and Mauritsch, H., 1990. Structural applications and discussion of a paleomagnetic post-Palaeozoic database for the Central Mediterranean. P.E.P.I., 62, 45-59.

Márton, E. and Pécskay, Z., 1997. Correlation and dating of the Miocene ignimbritic volcanics in the Bückk foreland, Hungary: complex evolution of paleomagnetic and K-Ar data. PANCARDI workshop 1997 (abstract), Przeglad Geologiczny, 45 (10), 1090-1091.

Márton, E., Vass, D. and Tuny, I., 1996. Rotation of the south Slovak Paleogene and Lower Miocene rocks indicated by paleomagnetic data. Geologica Carpathica, 47, 1, 31-41.

Maţenco, L., 1997. Tectonic evolution of the Outer Romanian Carpathians: constrains from kinematic analysis and flexural modelling. PhD. Thesis, Vrije Universiteit, Amsterdam, pp. 155., 5

Mauritsch, H. J. and Márton, E., 1995. Escape models of the Alpine-Carpathian-Pannonian region in the light of paleomagnetic observations. Terra Nova, 7, 44-50.

Panaiotu, C., Hossu, A., Balintoni, I., Zweigel, P. and Panaiotu C. E., 1997. Preliminary paleomagnetic results from sedimentary rocks of Transylvanian Basin. Pancardi workshop 1997 (abstract), Przeglad Geologiczny, 45, 10, 1096.

Panaiotu, C., Pătraşcu, S. and Panaiotu, C. E., 1995. Paleomagnetism of Neogene magmatic rocks from the Apuseni Mountains (Romania). (abstract) Annales Geophysicae, supplement I to vol. 13, C77.

Pătraşcu, S., 1976. Paleomagnetic study of some Neogene eruptive formations in the Călimani-Gurghiu-Harghita (Romania). Rev. Roum. Geol. Geophys. Geogr. Ser. Geophys., 20, 51-63.

Pătraşcu, S., 1993. Paleomagnetic study of some Neogene magmatic rocks from the Oaş-Igniş-Văratec-Tibleş Mountains (Romania). Geophys. J. Int., 113, 215-224.
Pătraşcu, S., Bleahu, M. and Panaiotu, C., 1990. Tectonic implication of paleomagnetic research into Upper Cretaceous magmatic rocks in the Apuseni Mountains, Romania. Tectonophysics, 180, 309-322.
Pătraşcu, S., Bleahu, M., Panaiotu, C. and Panaiotu, C., E., 1992. The paleomagnetism of the Upper Cretaceous magmatic rocks in the Banat area of South Carpathians: tectonic implications. Tectonophysics, 213, 341-352.
Pătraşcu, S., Panaiotu, C. and Voinea, S., 1995. New areas with characteristic remanent magnetisation of banatites from the Apuseni Mountains (Romania). Rom. Journ. Phys., 40, 953-959.
Pătraşcu, S., Panaiotu, C., Şeclăman, M. and Panaiotu, C. E., 1994. Timing of rotational motion of Apuseni Mountains (Romania): paleomagnetic data from Tertiary magmatic rocks. Tectonophysics, 233, 163-176.
Pécskay, Z., Edelstein, O., Seghedi, I., Szakacs, A., Kovacs, M., Crihan, M. and Bernard, A., 1995. K-Ar dating of Neogene-Quaternary calc-alkaline volcanic rocks in Romania. Acta Vulcanologica, 7, 53-61.
Roşu, R., Pécskay, Z., Stefan, A., Popescu, G., Panaiotu, C. and Panaiotu, C. E., 1997. The evolution of the Neogene volcanism in the Apuseni Mountains (Romania): constrains from new K-Ar data. Geologica Carpathica, 48, 6, 1-7.
Surmont, J., Săndulescu, M. and Bordea, S., 1990. Mise en evidence d'une reaimantation fini cretacee des series mesozoiques de l'unite de Bihor (Monts Apuseni, Roumanie) et de sa rotation horaire ulterieure. C. R. Acad. Sci. Paris, 310, II, 213-219.
Tuny, I. and Márton, E., 1996. Indications for large Tertiary rotation in the Carpathian-Northern Pannonian region outside the North Hungarian Paleogene Basin. Geologica Carpathica, 47, 1, 43-49.
Westaway, R., 1990. Block rotation in western Turkey and elsewhere. Theoretical models., J.G.R., vol. 95., B12, 19885-19901
Wortel, M. J. R. and Spakman, W., 1992. Structure and dynamics of subducted lithosphere in the Mediterranean region. Proc. Kon. Ned. Akad. v. Wetensch, 95 (3), 325-347.

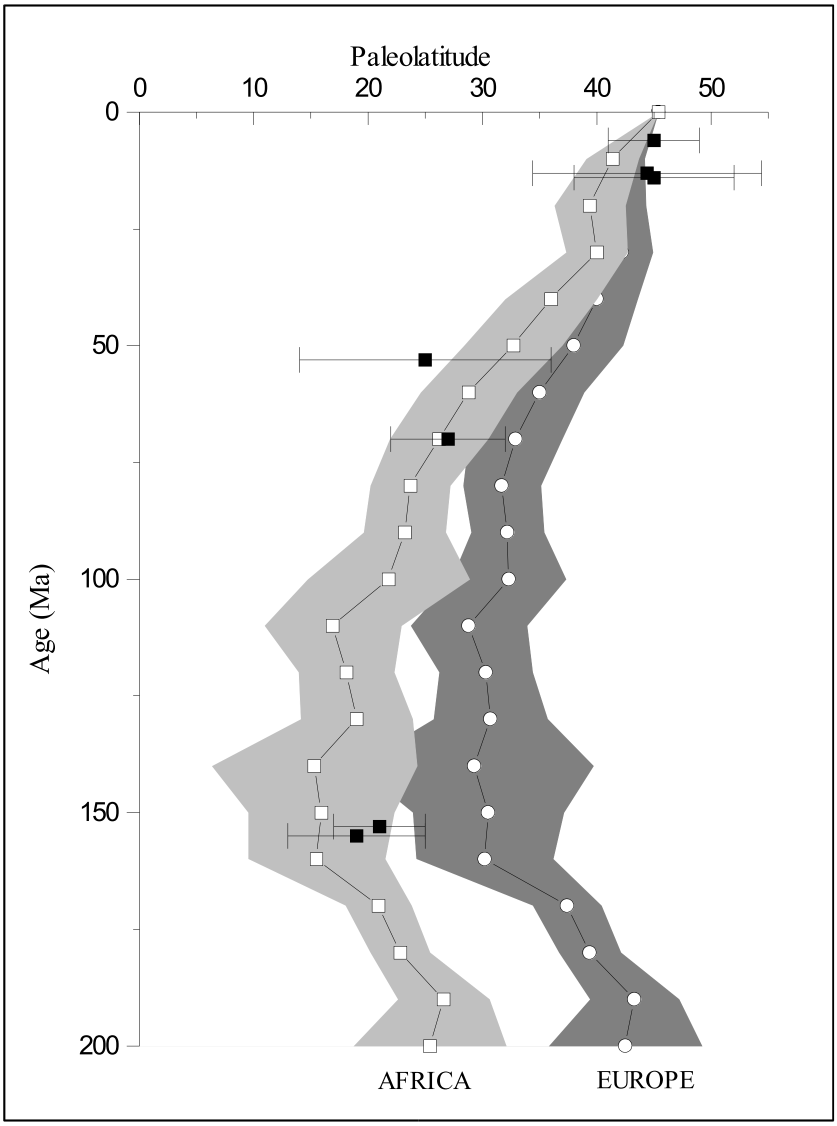

Fig. 1. Measured paleolatitudes for Transylvanian Basin and South Carpathians and their 95% confidence limits (solid circles). Expected paleolatitudes with 95% confidence limits calculated from: the African Apparent Polar Wander Paths (open circle and light grey confidence limits) and the European Apparent Polar Wander Paths (open squares and dark grey confidence limits).

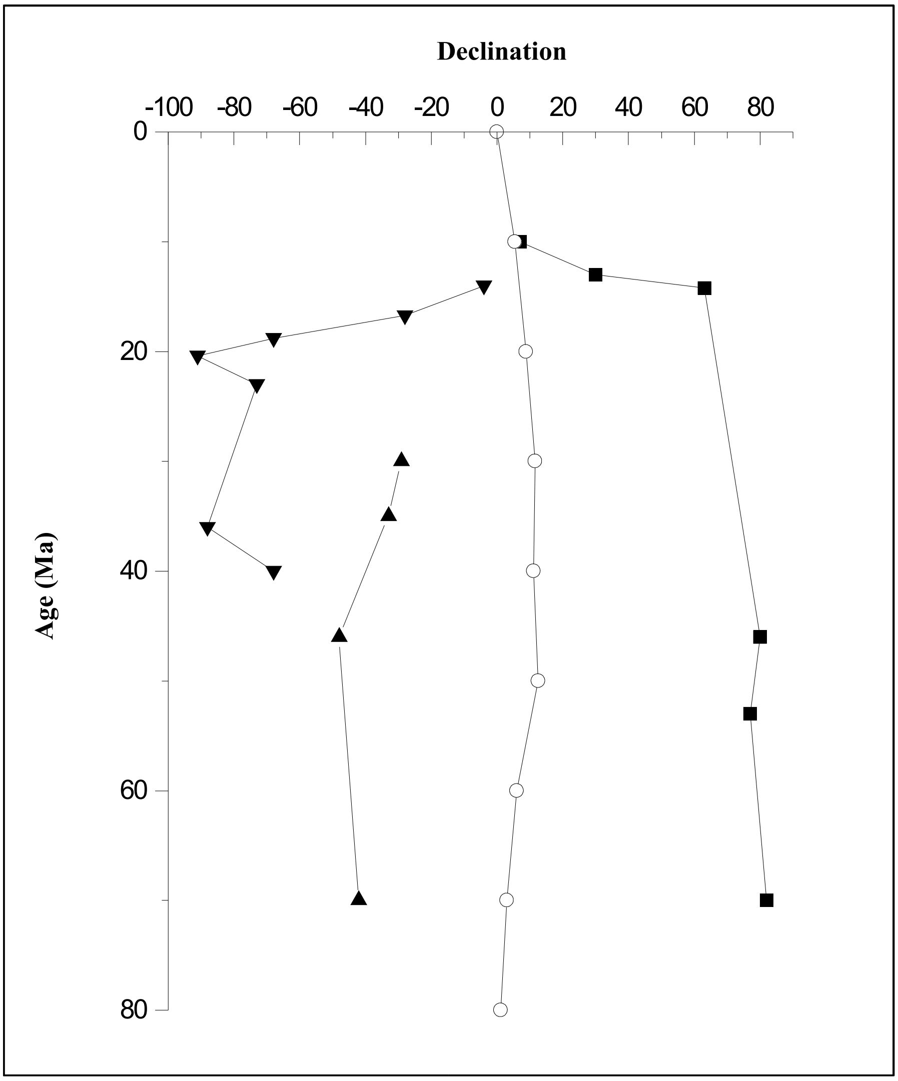

Fig. 2. Timing of rotation events in the Transylvanian Basin (solid squares), the Transdanubian Central Range Domain (solid triangles) and North Pannonian Paleogene Basin (solid inverse triangle). Open circles represent expected declinations calculated from the European Apparent Polar Wander Path.

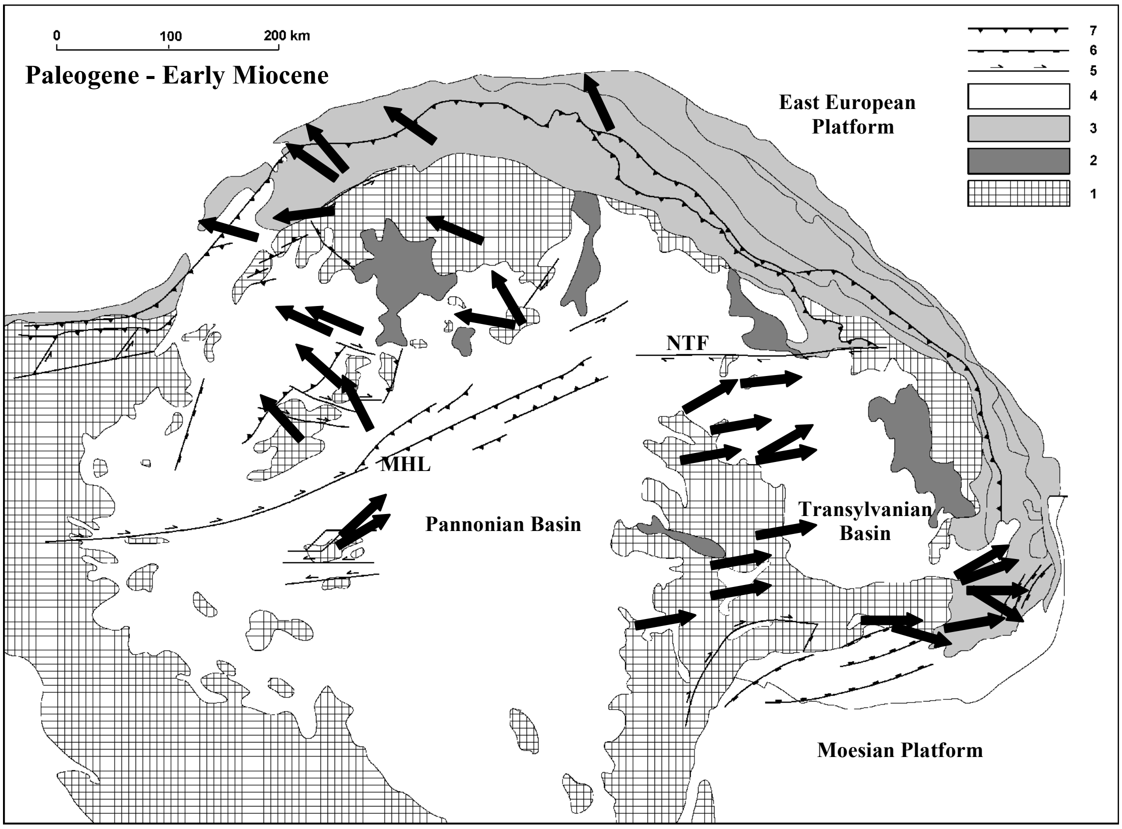

Fig. 3. Distribution of horizontal component of Upper Cretaceous - Lower Miocene paleomagnetic directions (black arrows) in Carpatho-Pannonian area. Regional map with schematic deformation structures active during Paleogene - Early Miocene after Maţenco (1997). Symbols: 1=Inner basement; 2=Neogene volcanics; 3=Thin-skinned belt; 4=Autochthonous foreland and intra/inter-montane depressions; 5=Dextral/sinistral fault; 6=Normal fault; 7=Thrust fault; MHL=Midd Hungarian Lineament; NTF=North Transylvanian Fault.

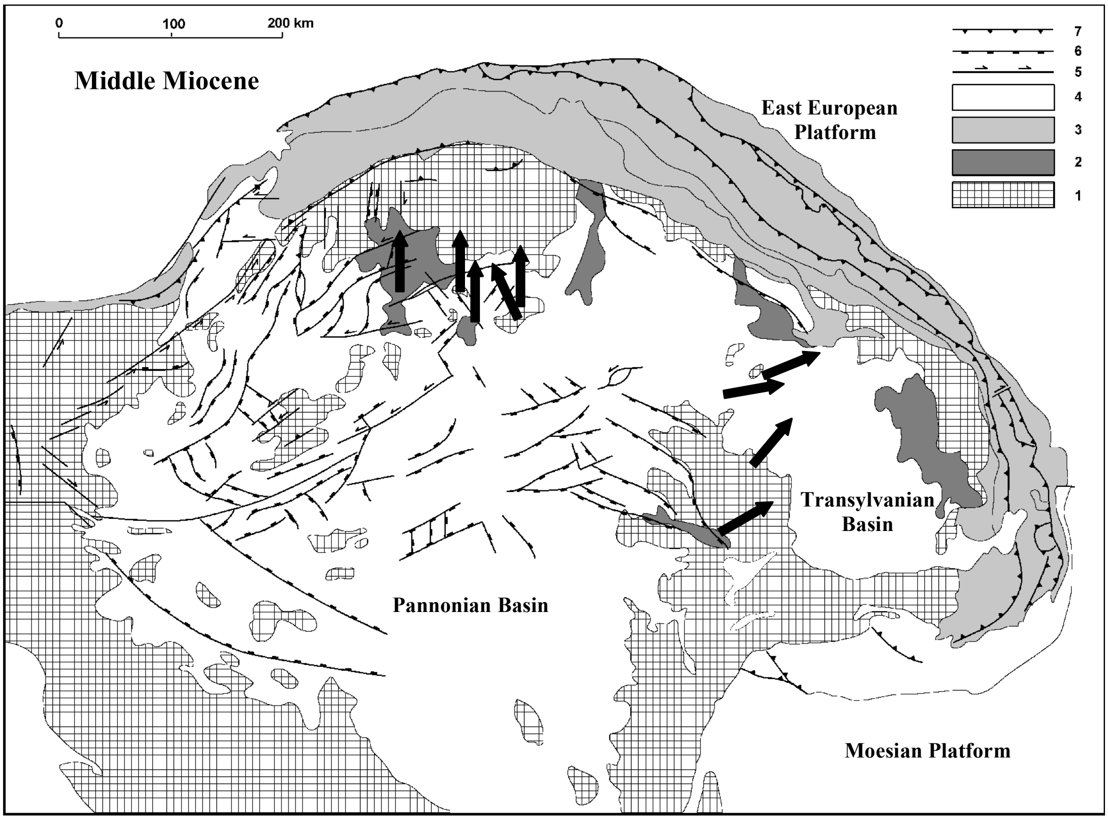

Fig. 4. Distribution of horizontal component of Middle Miocene paleomagnetic directions (black arrows) in Carpatho-Pannonian area. Regional map with schematic deformation structures active during Middle Miocene (Late Burdigalian/Karpathian - Badenian) after Mațenco (1997). Figure conventions as in Fig. 3.

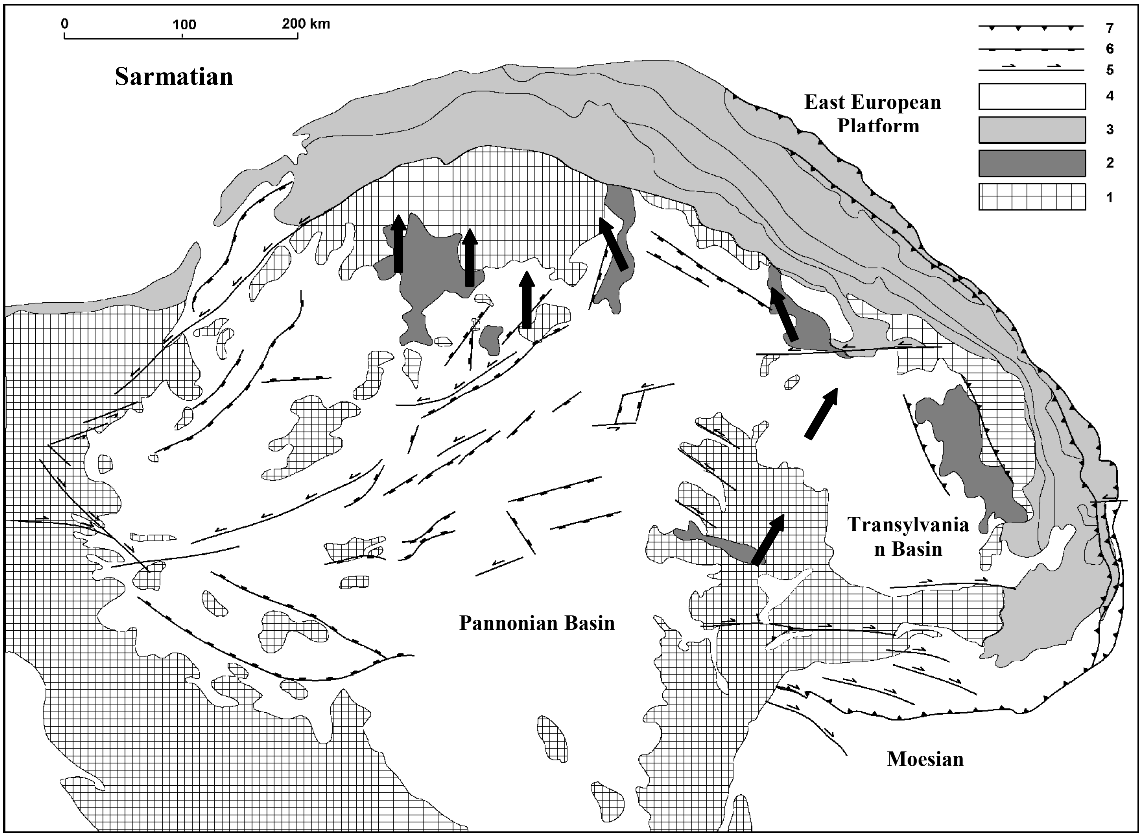

Fig. 5. Distribution of horizontal component of Sarmatian paleomagnetic directions (black arrows) in Carpatho-Pannonian area. Regional map with schematic deformation structures active during Sarmatian after Mațenco (1997). Figure conventions as in Fig. 3.

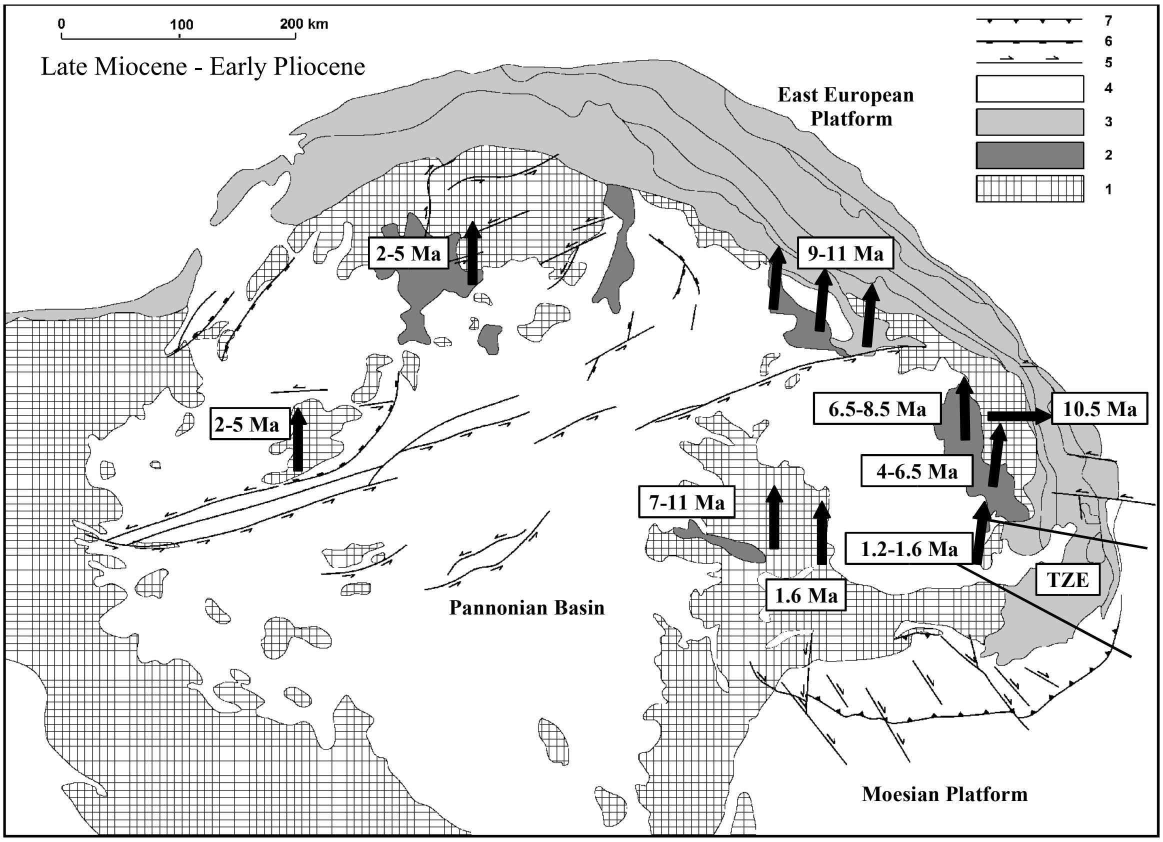

Fig. 6. Distribution of horizontal component of Late Sarmatian - Quaternary paleomagnetic directions (black arrows) in Carpatho-Pannonian area. Regional map with schematic deformation structures active during Late Miocene - Early Pliocene after Mațenco (1997). Figure conventions as in Fig. 3; TZE=Transition zone ESE-ward escape.