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THE DEVONIAN PALEOMAGNETIC POLE FOR THE SOUTHERN PART OF THE RUSSIAN PLATFORM (DONETS BASIN) AND ITS GEODYNAMIC IMPLICATION

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Abstract: Detailed paleomagnetic studies of Middle-Upper Devonian sedimentary and volcanic rocks from the zone of the junction of the Donbass with the Near-Azov block of the Ukrainian Shield have detected the following main components of natural remanent magnetization: B-metachronic component (R-polarity) whose nature is secondary on the basis of the data of statistical tests (before and after tectonic correction) and magnetic-mineralogical studies: A1 and A2-synchronous (N and R-polarity) is interpreted as having been acquired during deposition. The southern paleomagnetic pole calculated from mean directions the B-component (Lat. = –36°, Long. = 338°, dp = 6.6°, dm =3.4°) agrees well with the paleomagnetic poles of Permian sediments of the Donets Basin. The paleopoles calculated from A1 (Middle Devonian) and A2 (Upper Devonian) components have the following coordinates: A1 (Lat. = 13°, Long. = 289°, dp = 9.8°, dm = 4.9°) and A2 (Lat. = –3.7°, Long. = 359°, dp = 4.7°, dm = 2.3°). The significant deviation of paleopoles A1 and A2 from the Eifel-Famenian segment of APWP for Baltica may reflect the effect of the local tectonic rotation of the block enclosing the rocks studied.

Key words: Middle-Upper Devonian rocks, magnetization components, paleomagnetic poles.

Introduction

In recent years—new confident data on the position of paleomagnetic poles in the Devonian have been obtained for the East-European platform (EEP). EEP sediments in normal sections show clearly enough the pole positions in the Early Devonian (Smethurst & Khramov 1992; Orlova 1992; Mikhailova et al. 1994). Less clear are the poles of Middle and especially the Late Devonian since they are similar to Permian ones. This is illustrated by synthetized curves of APWP set up for the Baltic region (Torsvik et al. 1992; Lewandowski 1993) which the autors consider to be a great part of the East-European platform. According to these curves, the paleomagnetic pole was shifted in the Devonian from an equatorial latitude (Early Devonian) to the latitude of the Permian-Carboniferous poles (Late Devonian).

The present paper aimes to elucidate the results of paleomagnetic studies of the clearly stratified Middle-Upper Devonian sediments from the Donbass-Near-Azov-block junction zone of the Ukrainian Shield, including studies of their tectonic aspects.

Geology

The Eufelian-Famenian sedimentary-volcanic rocks of the Donets Basin are a continuous succession of four formations (upwards): Nikolaevskaya (Middle Devonian), Antonovskaya (Middle-Upper Devonian), Dolginskaya and Razdolnenskaya (Upper Devonian) (Aizenverg & Lagutin 1974) with normal stratigraphic boundaries and subhorizontal occurrence. Together with overlaying Carboniferous sediments this mass forms the so-called southern stepped monocline of the Donbass dipping northward at an angle to 10–20° (Fig. 1c,d). Lithologically, the Middle and Upper Devonian sediments are gravelites, differently composed and grained sandstones, argillites, volcanic tuffs (Fig. 1b). In the middle part a mass of differently composed effusives occurs. Their age is estimated at 387–360 Ma.

Methods of sampling and laboratory studies

Within the territory considered of sedimentary and volcanic rocks — one in the area of Nikolaevka village — 10 partial sections and another in the area of Razdolnoe village — 2 partial sections (Fig. 1b,c) were studied. The tested thickness of the former and the latter sections is 384 m and 232 m respectively. The oriented samples were taken at 1-5 m intervals along the section. The sedimentary and the majority of the volcanic rocks were oriented in the bedding plane and for the some effusives an arbitrary plane which was then referred to a horizontal one. In general, the sampling was made by a conventional method. Each section horizon is represented by a thin sample from which at least eight 2 × 2 × 2 cm cubes were then sawn up for further studies. The stratigraphic succession of the samples is shown on the lithologic columns of the partial sections (Fig. 1c). Measuring of natural remanent magnetization (NRM) and magnetic susceptibility were performed with astalic magnetometers MA-21, LAM-2 and with JR-3, KLY-1 devices.

The following laboratory tests were employed to determine the stability as well as the origin of the NRM: alternating field (AF) demagnetization with steps at 2.5, 7.5, 10, 16 mT up to 200 mT and thermal demagnetization (T) with

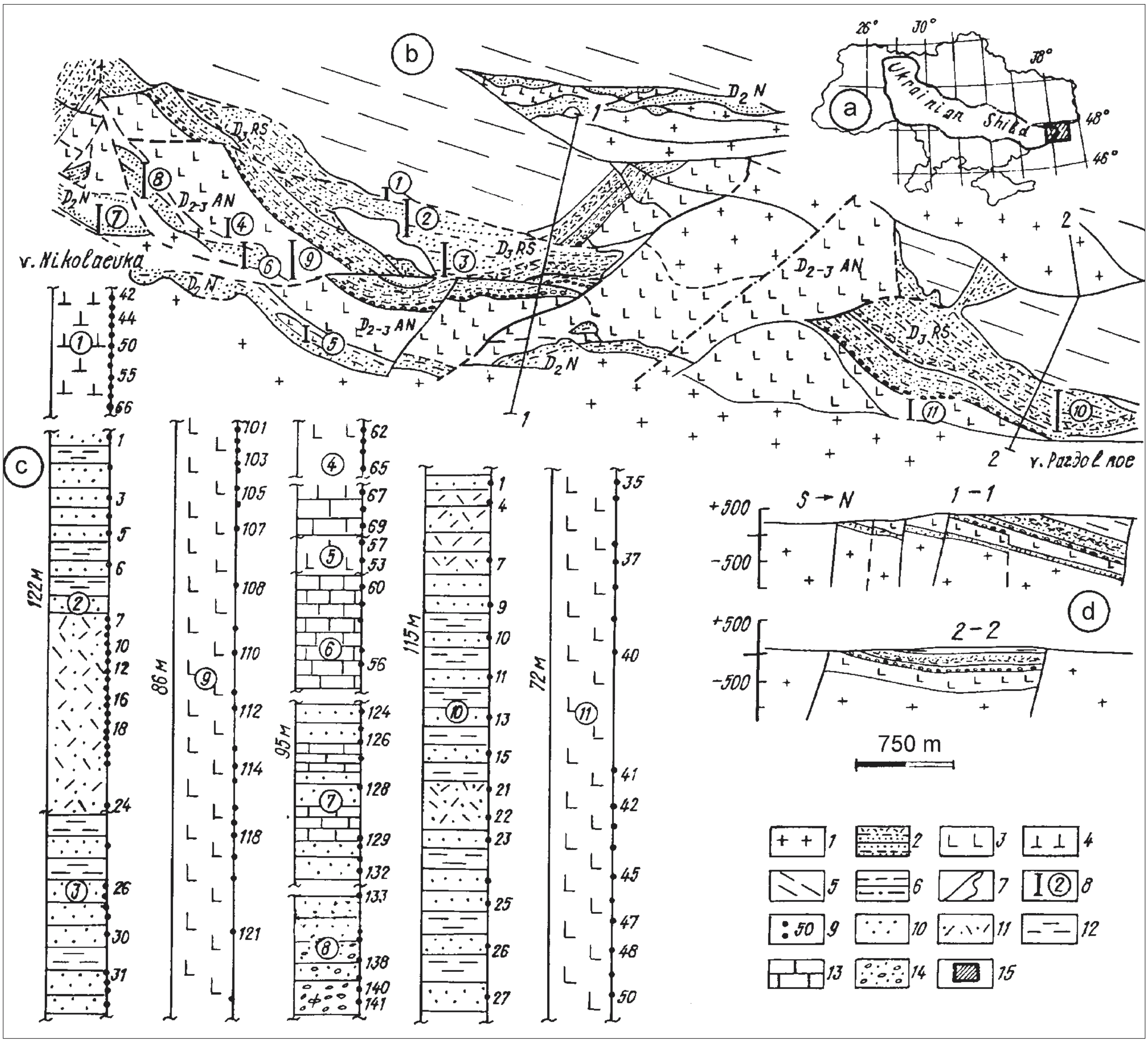

Fig. 1. The geological map of the paleomagnetic sampling area, showing the location of the sites of Middle-Upper Devonian sedimentary and volcanic rocks in the Donets Basin with US joint zone. 1 — Precambrian granites; 2 — Upper-Middle Devonian sedimentary-volcanic rocks; 3 — Middle Devonian volcanic; 4 — Upper Devonian volcanics; 5 — Carbonate sedimentary units; 6 — faults; 7 — Late Paleozoic intrusions; 8 — sampling sites (sections): 9 — the points reflecting the stratigraphic order of sampling and the sample numbers (the investigated thickness shown on the right side the partial sections); 10 — sandstones; 11 — volcanic tuffs; 12 — argillites; 13 — limestones; 14 — gravel; 15 — map; 1–1, 2–2 — cross sections lines. Numbers inside of a circle: 1, 2, 3, 10 — Razdolnenskaya Formation (D3 RS); 9,11 — Antonovskaya Formation (D-2-3 AN); 4–8 — Nikolaevskaya Formation (D2 N).

steps of 50–100 °C up to 700 °C in field-free space; determination of partial thermo-remanent magnetization (PTRM), Curie temperature (Tc), acid leaching HCl. Chemical leaching of the secondary magnetic minerals was performed on the cube samples with the special shaped cross-sections. These cross-sections allowed enlargement of the surface of the sample for more effective leaching by HCl acid. The duration of the sample exposure in acid was different and it depended on rock porosity and composition of ferrimagnetic mineral (the minimal-exposure was 24 h and the maximal one 220 h). After each leaching cycle the cubes were extracted from acid, washed with water, dried and measured. The chemical leaching was continued till the separation of magnetization component with stable orientation. This procedure was frequently combined with T-demagnetization. In some cases the samples were first demagnetized by AF to 10 mT or exposed to acid during 24 h and then tested by thermal method. The method for determination of original NRM based on a comparison of the spectrum of isothermal remanent magnetization (IRM) curves was devised by Cholpo (1977, pers. com.). The NRM directions remaining after each demagnetization step were analysed using the Zijderveld ortagonal vector projections. The magnetic minerals were identified by both the rock magnetic and microscopic methods. Laboratory works were carried out by the instruments and apparatus of the Institute of Geophysics of the UAS.

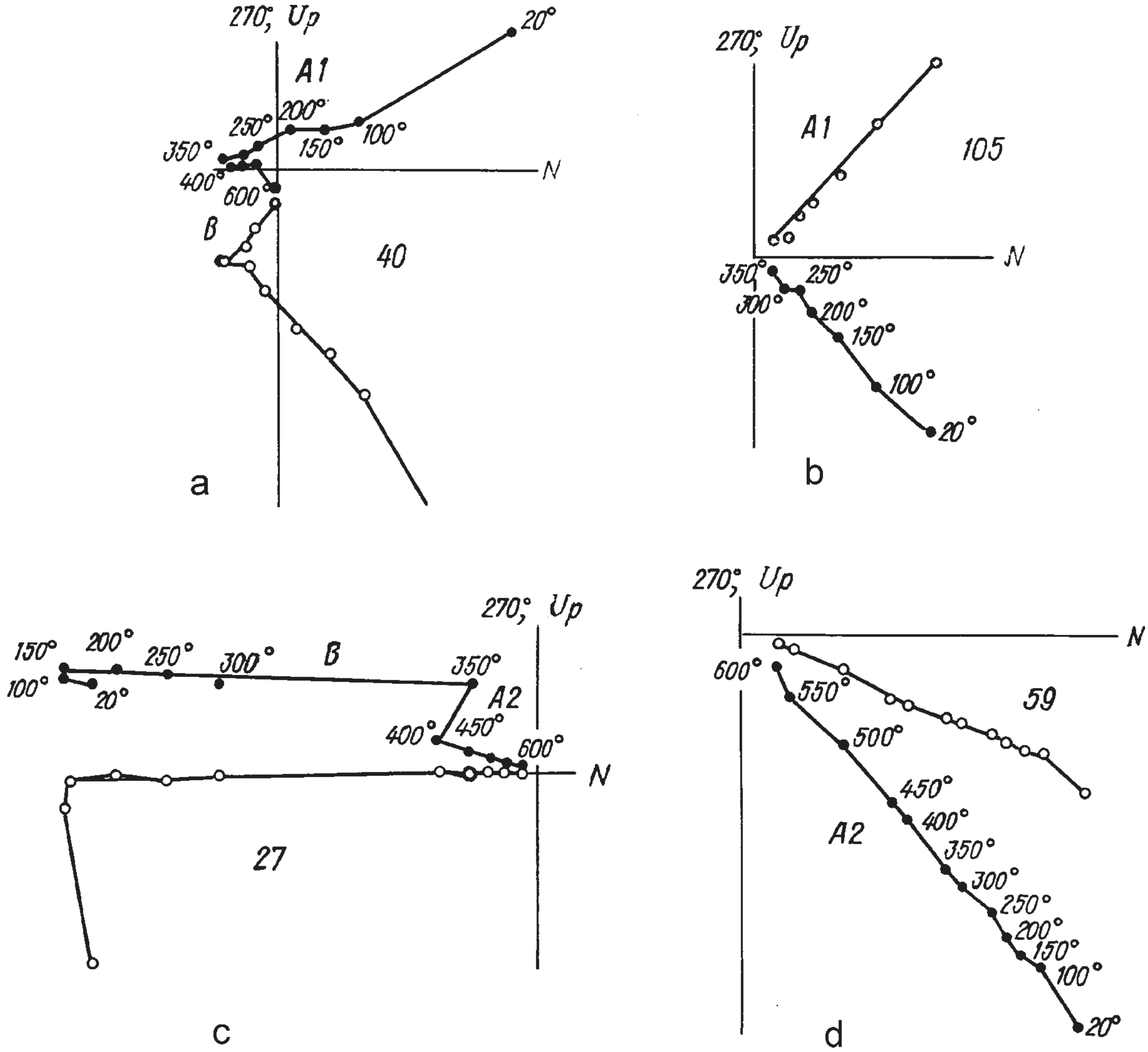

Fig. 2. Progressive T-demagnetization diagrams of A1, A2 — andesite from the Antovskaya Formation sampled near village of Razdolnoe, B — basalt (v. Nikolaevka) from the Razdolnenskaya Formation. Open (closed) symbols represent projections of the end points of NRM vectors on the vertical (horizontal) planes.

Results

The magnetic properties of the sedimentary and volcanic rocks were described in a previous study (Orlova 1992; Mikhailova et al. 1994).

Combined laboratory studies show inhomogeneity of the NRM composition of the rocks studied. Together with the one-component magnetization generally marked in effusives (Fig. 2, samples 105, 59), the great majority of the rocks studied has polycomponent NRM structure consisting of two or more components of different orientation (Fig. 2, samples 40, 27).

The complicated NRM composition is shown by magnetic-mineralogical analysis to be due to the concentration and proportion of ferrimagnetic minerals of different generation in rocks. These are firstly primary homogeneous magnetites, titanomagnetite, synchronous in time with rock formation which were presented as relicts of mostly greatly changed grains in effusives and their detritus in sediment and secondary maghemite, titanomaghemite and hematite of oxides which appeared both at the pre-lithification stage and during diagenesis and finally, iron hydroxides formed in hypergenic conditions. Together with multi-domain titanomagnetite and fine-dispersed hematite they cause low-coercive including viscous magnetization.

The results of the component analysis have allowed suggestion of the following interpretation:

1. Soft component oriented with present geomagnetic field. It is generally destroyed by alternating magnetic field to 20 mT, heating to 100–150 °C and sometimes to 250° or exposure to concentrated HCl acid for 24 h. As this component does not carry information on the ancient geomagnetic field it has not been considered here.

2. B-component (R-polarity) that is hard in effusive rocks (AF = 70 mT, T = 500-600 °C) and relatively soft in the sediments (AF = 5-200 mT, T = 20-300 °C) practically exists in all rocks of the studied sections. The tectonic correction for the tilt angle of the thickness (Fig. 4a-c) showing the change of the Fisher parameters k and α_{95} clearly indi-

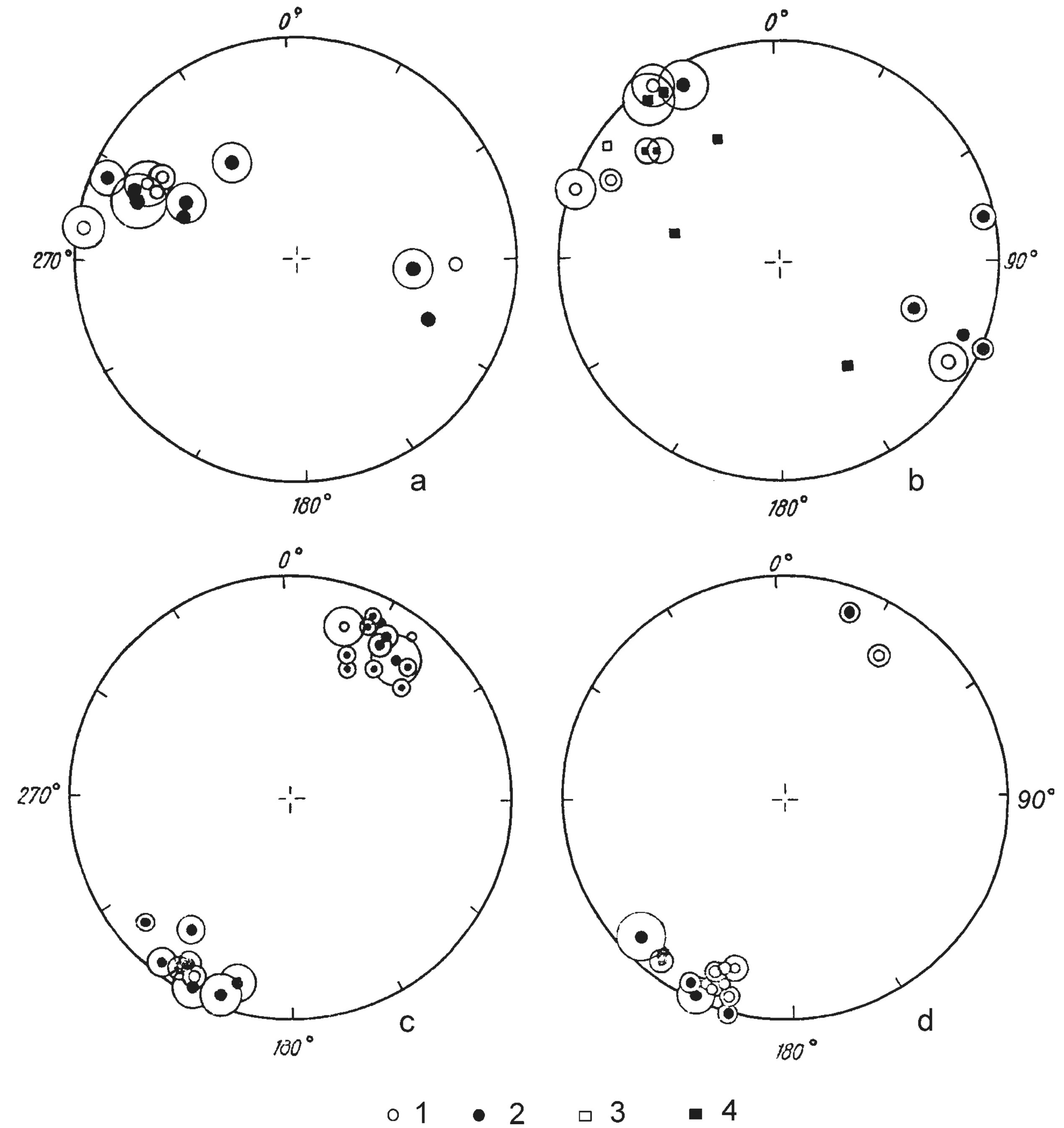

Fig. 3. The mean directions of characteristic magnetizations A1 and A2 with the circles of 95 % confidence: a — the mean directions of component A1 of the Nikolaevskaya and b — Antonovskaya Formations (1, 2 — from sections near village of Nikolaevka, 3, 4 — sections near v. Razdolnoe), c — the mean directions of component A2 of Razdolnenskaya Formation from sections near v. Nikolaevka, d — from sections near v. Razdolnoe.

cates the secondary post-fold nature of this component, which agrees with the data of magneto-mineralogical studies of rocks. The mean direction of the B-component of all sections studied D = 225°, I = −18°, coincides well with the direction of synchronous magnetization of Permian sediments of the Donets Basin (Chramov 1992 in Orlova 1992).

3. The hard component A1(R and N-polarity) exists in NRM of some effusives and in sediments as a single component, but in most cases together with the B-component. In the sediments it is distinguished in the 20–500° or 350–600 °C and in volcanites in 20–450° or 20–700 °C temperature range (Fig. 3a,b). As seen from this figure the A1-component orientation does not notably differ in the formations of the Nikolaevskaya and Antonovskaya Formations (Middle Devonian age). The mean direction of the A1 component is D = 294°, I = 4° for rocks of the Nikolaevskaya Formation in the section near village of Nikolaevka. Similar A1-component directions are seen for volcanites of the Antonovskaya Forma-

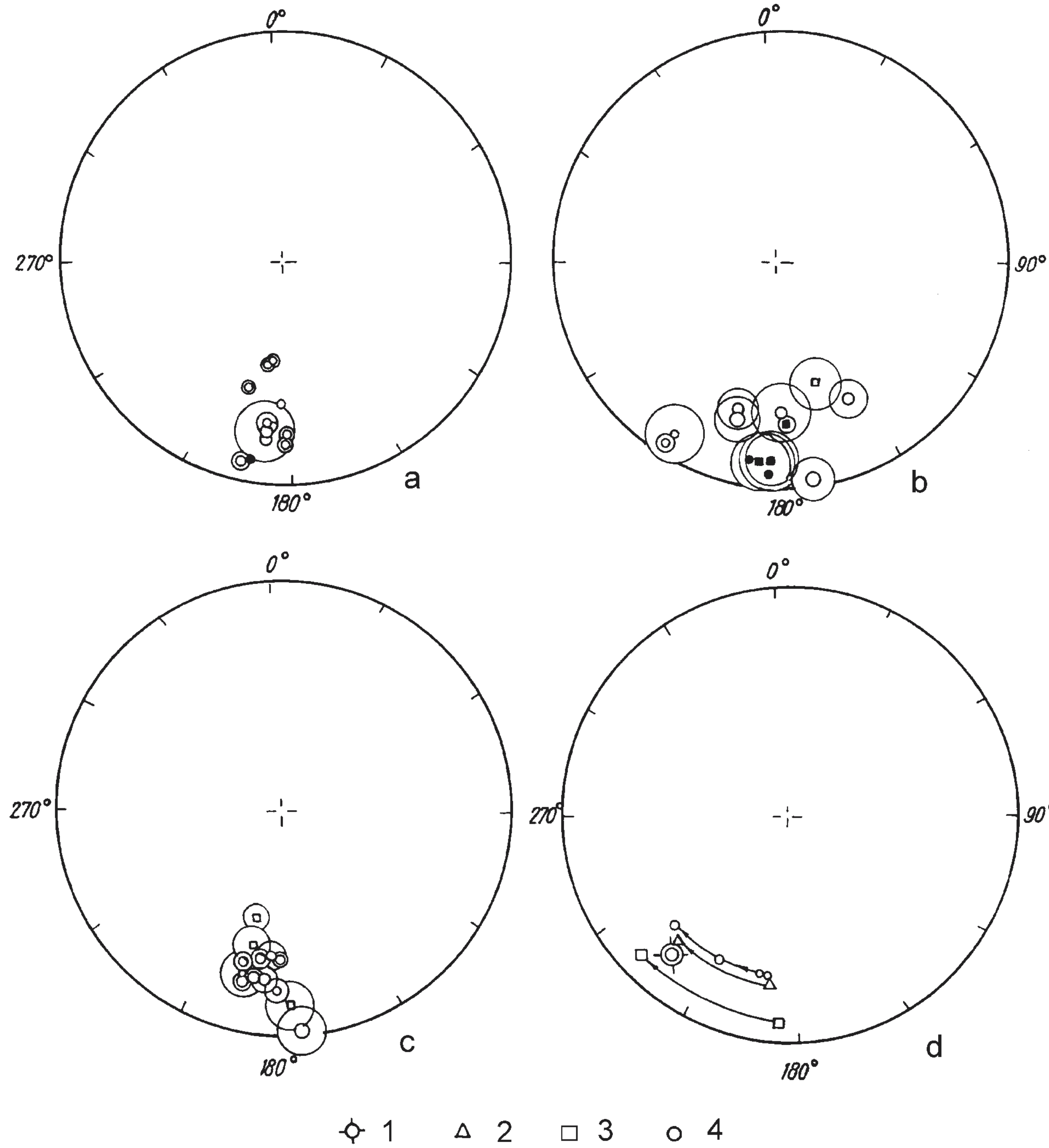

Fig. 4. Tilt corrected characteristic mean directions of samples with the B-component show with the circles of 95 % confidens: a — the Nikolaevskaya Formation, b — the Antonovskaya Formation, c — the Razdolnenskaya Formation, d — mean directions of the B-components from the sections a, b, c corrected respecting the present day bed thicness; 1 — mean direction, 2 — the Nikolaevskaya Formation, 3 — the Antonovskaya Formation, 4 — the Razdolnenskaya Formation.

tion both in village of Nikolaevka section and near village of Razdolnoye (Fig. 3a,b). Magneto-mineralogical data clearly show the A1-component to be synchronous with the formation of rocks of Eufelian-Givetian age in the study region. The mean directions calculated for rocks of all sections of this age (Nikolaevskaya and Antonovskaya Formations) have coordinates Dm = 292°, Im = –5°.

4. The hard component A2 (R and N-polarity) of Razdolnenskaya Formation (Upper Devonian age) oriented also with a slight difference in directions both in near village of Nikolaevka and near village of Razdolnoe sections, but notably differs from A1-component in declination (Fig. 3c,d). The mean direction of the A2-component Dm = 210° and Im = –3° roughly coincides with the Famenian geomagnetic field direction for Baltica.

The A1 and A2 components are due to primary ferrimagnetics of the first generation and are synchronous with the rock formation moment, i.e. with the Devonian period. The

Table 1: Mean paleomagnetic directions and pole position for Middle-Devonian sedimentary and volcanic rocks determined in this study, Donets Basin.

Age of the characteristic magnetization components	D degree	I degree	α_{95} degree	k	n	The southern pole			
						Lat. degree	Long. degree	δ_p degree	δ_m degree
Middle Devonian (Eifel-Givetian) (A1-component)	292	-5	9.81	10.7	19°	12.7	289	9.84	4.94
Late Devonian (Famenian) (A2-component)	210	-3	4.66	25.1	36°	-37	359	4.66	2.33
Permian (B-component)	225	-18	6.34	12.9	38°	-36	338	6.58	3.42

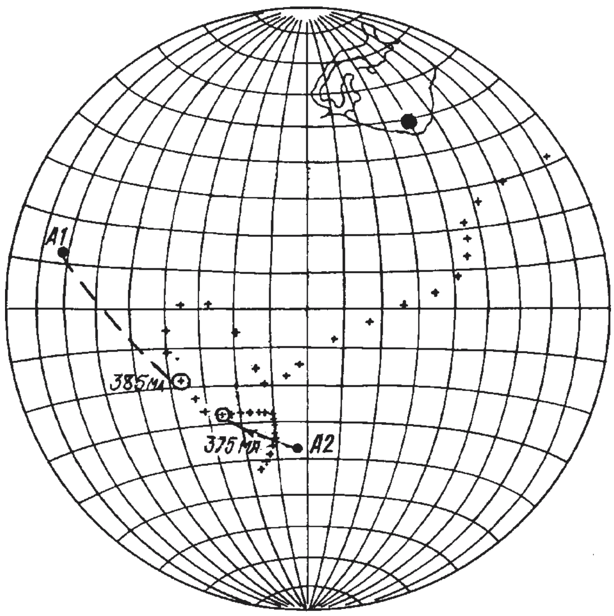

Fig. 5. Comparison of the paleopoles A1 and A2 with APWP for Baltica (Lewandowski 1993). The poles rotated around the Eulerian pole located at the point 50N/39E. Such a rotation places the A1 and A2 poles at the Eifel-Vizean part (points 385 MA and 374 MA, respectively) of APWP.

B-component is a superimposed one and reflects the rock maghemitization and hematization time.

Discusion

From the statistically averaged orientations of the A1, A2 and B-components the paleomagnetic poles have been calculated (Table 1). Their comparison with a synthesized curve of APWP in the Phanerozoic for the Baltic region (Fig. 5) shows an agreement of the B-component pole with that of the curve and the proximity of the A2 pole to it, though the curve segment age does not completely correspond with Famenian age of the rocks studied. At the same time the result obtained, gives reason to consider the high-latitude position of the Upper Devonian pole to be a feature of the Devonian geomagnetic field, which agrees with the present viewpoint on this problem (Torsvic et al. 1992; Lewandowski 1993) but it is not the result of remagnetization of Devonian rocks by the Permian field as was postulated earlier.

The significant north-westwards (A1-paleopole) and south-eastwards (A2-poleopole) deviation from the Eifel-Famenian segment of APWP for Baltica may be attributed to the clockwise rotation of the area in question by about 34° during the Middle Devonian and 17° in the anti-clockwise direction during the Upper Devonian. This interpretation does not contradict the geological insight into the Dnieper-Donets paleorift formation, i.e. at the rift's formation moving apart of blocks with rotation was of great importance as well as the earth's crust *becoming less concentrated* because of extension (Chekunov 1994).

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