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Palaeomagnetic constraints for Variscan mobilism of the Upper Silesian and Małopolska Massifs, southern Poland

Palaeomagnetic results from the NE part of the Upper Silesian Massif (USM) have been interpreted as evidence for the final amalgamation of this block with Baltica by the Givetian (J. Nawrocki, 1993*a,b*). This paper aims to indicate, however, that closer analysis of palaeomagnetic results reported by J. Nawrocki has shown their applicability to a wide scope of mobilistic interpretations. It will be substantiated that palaeopole D (5°S/313°E) obtained for the Givetian dolostones of the Siewierz area can not represent the Givetian palaeopole for Baltica (by extrapolation — for the Old Red Continent — ORC), as was postulated by J. Nawrocki (1993*a,b*), because this conclusion results in confusing Middle Devonian palaeogeographic configuration of ORC, in which Eifelian-Givetian oolite and evaporites of Laurentia would be deposited in palaeolatitudes over 50°S. It will also be presented that juxtaposition of pole D with the current palaeomagnetic data for the Middle-Late Devonian poles of ORC reveals ca. 30° misfit, pole D being shifted to the NW. This implies clockwise rotation of USM in Variscan times. Taking into account that pole D is similar to the palaeopoles of the Early Carboniferous reported from some Variscan blocks of Western Europe, approximately the same acquisition time is suggested for the corresponding natural remanent magnetization (NRM). An origin of this and other intermediate/hard components of NRM are tentatively attributed to a conjectural, pulsative epigenetic mineralization during the time spanning from the Tournaisian to the Bashkirian (360–305 Ma). Finally, the inadequacy of palaeopole D for disproving the hypothesis of strike-slip displacement of Małopolska Block along the SW margin of Baltica in Devonian time will be shown.

INTRODUCTION

Geological development of the present-day SW forefield of the East European Platform (EEP) in Variscan time is still insufficiently understood. The poor exposure and incompleteness of Palaeozoic formations, scarcity of seismic profiling, as well as paucity of drilling in the area between Sudetes and EEP give a chance for the appearance of a variety of geotectonic ideas. Only during the past decade have different concepts been put forward,

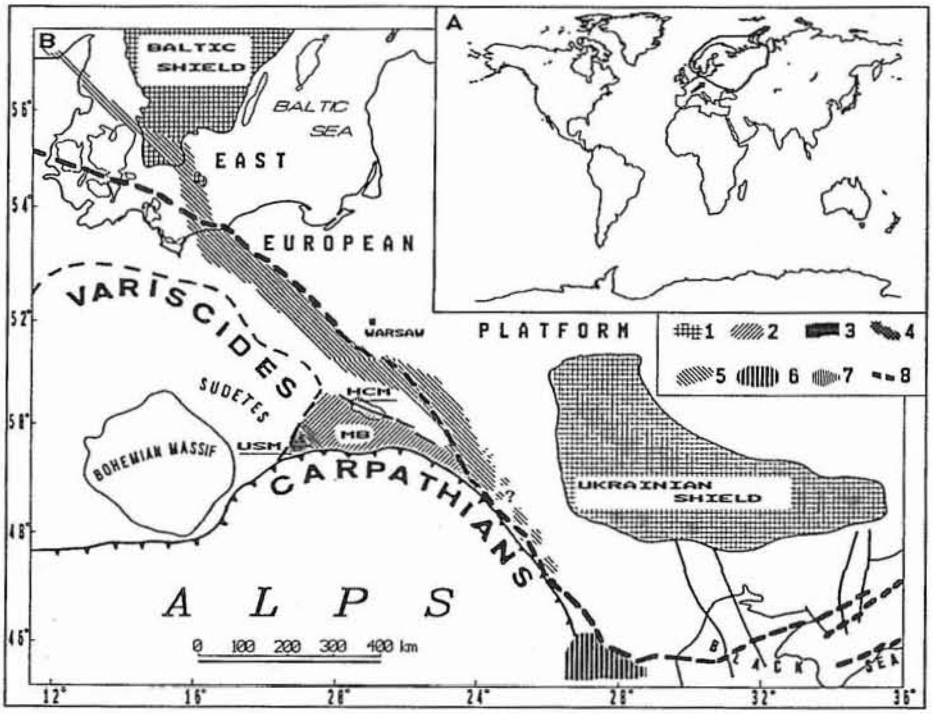


Fig. 1. A. Geographical positioning of the Upper Silesian Massif (USM); B. The USM against the main structural units of the region

1 — Precambrian shields, 2 — Małopolska Block (MB), 3 — USM, 4 — Caledonian orogen of Cracovides, 5 — Tornquist zone (in NW Poland coincides with Trans-European Suture Zone), 6 — inferred pre-Variscan position of MB, 7 — Łysogóry region of the Holy Cross Mts. (HCM), 8 — south-western edge of the East European Platform

A. Ogólna pozycja geograficzna masywu górnośląskiego (USM). B. Pozycja USM na tle głównych jednostek strukturalnych regionu

1 — tarcze prekambryjskie, 2 — blok małopolski (MB), 3 — masyw górnośląski, 4 — kaledoński orogen krakowidów, 5 — strefa Tornquista (na obszarze NW Polski zgodna ze strefą szwu transeuropejskiego), 6 — przypuszczalna przedwaryscyjska pozycja bloku małopolskiego, 7 — region łysogórski Gór Świętokrzyskich (HCM), oddzielony od bloku małopolskiego dyslokacją świętokrzyską, 8 — południowo-zachodnia krawędź platformy wschodnioeuropejskiej

but none of them could be definitively disproved or verified. Pertinent literature is available in the recently published papers by M. Lewandowski (1993), M. Moczydłowska (1993), J. Nawrocki (1993*a,b*), W. Pożaryski, H. Tomczyk (1993).

Recently, J. Nawrocki (1993*a,b*) has presented new palaeomagnetic data from the Givetian dolostones and Namurian/Westphalian clastics of the Upper Silesian Coal Basin (USCB), which is a part of the Upper Silesian Massif (USM, see Fig.1). His study of the Givetian dolostones yielded a stable, normal-polarity pre-folding component D. Since the resulting pole falls into a Devonian segment of the apparent polar wander path (APWP) for

Baltica, J. Nawrocki (1993*a,b*) has drawn a conclusion on the relative stability of the USM and Baltica from the Givetian onwards.

The aim of this paper is to point out several aspects of palaeomagnetic analysis that considerably influence the eventual interpretation but were not taken into account by J. Nawrocki (1993*a,b*). Contrary to the Author's conclusion, it will be demonstrated that the data evidence, in fact, a significant geotectonic mobilism of USM in Devonian-Carboniferous time.

As a side note, I would like to emphasize that I did not suggest anything to J. Nawrocki while he was writing his paper, although it could be inferred so from his acknowledgments (J. Nawrocki, 1993*a*).

DISCUSSION

TIME ERROR

The essential question in palaeomagnetic research concerns the time of acquisition of components of the natural remanent magnetization (NRM). The potential time error stretches from the age of the rock to the present, unless palaeomagnetic tests prove otherwise. In the Givetian (377±3 Ma)[1] dolomites of NE margin of the USCB the pre-folding age of a characteristic component of NRM (CHRM) has been determined (J. Nawrocki, 1993*a,b*). Since the age of tectonic deformation is estimated to be of syn-Asturian age (ca. 290 Ma), it implies that the time error of determination of the age of the CHRM comprises some 90 Ma. However, because of the normal polarity of component D, it had to be acquired before the reversed-polarity Kiaman epoch, the beginning of which can be estimated as ca. 305 Ma (based on the global palaeomagnetic data set as listed by R. Van der Voo, 1993). Hence, the real time error amount is ca. 72±3 Ma.

THE ORIGIN OF NRM

There are two sets of indirect evidence (available from the data presented by J. Nawrocki, 1993*a,b*) that may indicate the possible origin of CHRM: assemblage of magnetic carriers and statistical features of the palaeomagnetic record.

ORIGIN OF MAGNETIC CARRIERS

Acquisition of NRM is inseparably connected with the presence of magnetic carriers. In the case of sedimentary rocks, if their syndepositional origin (e.g. detrital, chemical, or extraterrestrial) has been proven, then magnetization has the potential to be of primary origin. According to J. Nawrocki (1993*a*), the acquisition of the magnetite-related component D may be connected with the process of early dolomitization of the reef limestones. It might have happened indeed, if dolomitization was associated with chemical precipitation of magnetite. Dolomitization, however, is not a precondition, since secondary magnetite

[1]Palmers's time scale (A. R. Palmer, 1983) will be used througout this paper.

may originate in limestones or dolomites due to much later diagenetic processes. A vast literature reports a significant gap between the age of carbonates and the time of acquisition of a chemical remanent magnetization residing in fine-grained diagenetic magnetite (e.g. C. R. Scotese *et al.*, 1982; M. W. Wisniowiecki *et al.*, 1983; C. McCabe *et al.*, 1983; C. McCabe *et al.*, 1984; V. Bachtadse *et al.*, 1987; D. Suk *et al.*, 1990, 1993*a*; R. Van der Voo, 1993). Recently, D. Suk *et al.* (1993*b*) argued that the presence of hydrocarbons promoted formation of authigenic magnetite responsible for the Late Palaeozoic remagnetization of the Upper Ordovician limestones of the Michigan Basin.

Pervasiveness of secondary overprints in Palaeozoic carbonates both in Europe (T. H. Torsvik *et al.*, 1990) and North America (C. McCabe, R. D. Elmore, 1989) makes it a rule, so that an early diagenetic (or primary) magnetization is exceptionally postulated (e.g. C. McCabe *et al.*, 1985; D. Suk *et al.*, 1992). In these rare cases, the near-or primary magnetization is inferred from dissimilarity of the corresponding palaeopole to the poles of younger age (T. H. Torsvik, A. Trench, 1991*a*; A. Trench, T. H. Torsvik, 1991), but this sort of evidence is not present in the case of the dolomites from the USCB (see discussion in the next chapter). A convincing argument for syn-depositional (or early diagenetic) magnetization is the presence of reversals along the stratigraphic column (T. H. Torsvik, A. Trench, 1991*b*; D. Suk *et al.*, 1992) — another argument that is lacking in Nawrocki's data. According to C. McCabe *et al.* (1989), titaniferous iron oxide grains are the only direct evidence for a possible magnetic carrier of the primary magnetization in carbonates. This piece of evidence (although still not sufficient — see D. Suk *et al.*, 1992) in favour of primary magnetization is also absent in dolomites of the Siewierz area.

Another indirect argument for the secondary origin of CHRM in dolostones of the Silesian-Cracow area is the coexistence of magnetite and sulphides, the latter including magnetic pyrrhotite (max. unblocking temperature ca. 320–330°C, see J. Nawrocki, 1993*a*, Fig. 4). According to D. Suk *et al.* (1992), the sulphide-magnetite assotiation is believed to be characteristic of remagnetized carbonates in the northeastern USA, while unremagnetized rocks contain a sulphide-hematite composition.

Studies on the mode of acquisition of the remanent magnetization in carbonates have become a separate branch of palaeomagnetism in the recent years (e.g. R. Freeman, 1986; H. Pan *et al.*, 1990; D. Suk *et al.*, 1992). Actually, SEM and scanning transmission electron microscope analysis, accompanied by hysteresis measurements of magnetic extracts are required in order to reveal the shape and domain structure of magnetic carriers in Palaeozoic carbonates. These investigations provide a firm foundation for the reliability of the palaeomagnetic record, with statistical parameters having important, yet auxiliary meaning.

Such analyses were not made in studies by J. Nawrocki (1993*a,b*), thus, according to present-day knowledge, a preassumption of diagenetic origin of magnetite in dolomites of the Siewierz Anticline should be given preference. This implies a low probability for the CHRM to be of primary origin, a near-primary time of precipitation of magnetite not, however, being excluded.

HIGH PRECISION OF THE PALAEOMAGNETIC RECORD

J. Nawrocki (1993*a,b*) put the highest attention on the reliability of the palaeomagnetic data, regarding the statistical parameters and positive fold test as the most important criteria of the seven-grade reliability scale (R. Van der Voo, 1990). However, these criteria do not necessarily mean that magnetization is primary, since the fold test constraints only the upper age limit of magnetization (see the first chapter), while statistics restrict the area of uncertainty of the palaeopole position. The latter, expressed by very good values of the fisherian parameter *k*, points to well-ordered magnetic domains and is characteristic of fine-grained magnetic bodies. It is also often met in some red beds or remagnetized sedimentary rocks. In limestones that are carrying primary (i.e. detrital) magnetization (DRM), one should expect rather poorly grouped directions, due to inaccurate alignment of magnetic grains in the environment of deposition. Even if post-depositional processes might have improved the accuracy of the palaeomagnetic record, such strong grouping of individual directions as presented by J. Nawrocki (1993*a*, Fig. 3) suggest secondary alignment of magnetic domains (cf. M. A. Smethurst, A. N. Khramov, 1992).

To all appearances, therefore, the primary origin of the D related component, as suggested by J. Nawrocki (1993*a,b*), is doubtful. The more probable explanation is epigenetic mineralization, caused by Fe-bearing brines that were potentially active during the time spanned from the Givetian up to the Bashkirian (377–305±3 Ma). The swathe-like palaeopole distribution (Fig. 2) suggests two general pulses of mineralization: older (poles B, D2, D) and younger (poles of population I and D1), the later one also inferred by J. Nawrocki (1993*b*). N. D. Opdyke *et al.* (1992) have shown that reversals occurred on average every 1–2 Ma during pre-Kiaman period of the Carboniferous. If remagnetization was indeed related to mineralized fluid migration at this time (see later discussion), it would give some insight into the permeability of carbonate rocks and physico-chemical kinematics of the processes involved, given that pole D related magnetization is of unimodal (normal) polarity.

THE AGE OF MAGNETIZATION

The basic argument of J. Nawrocki (1993*a,b*) for the Givetian age of palaeopole D is its compatibility with the Givetian-Frasnian poles for Baltica. However, no palaeomagnetic poles obtained from the Middle-Late Devonian (380–363 Ma) rocks of Baltica are similar to pole D (cf. T. H. Torsvik *et al.*, 1990, 1992; R. Van der Voo, 1990, 1993).

In fact, J. Nawrocki has compared pole D (5°S/312°E) with the **estimated** Givetian sector of the apparent polar wander path (APWP) for the British Isles (after T. H. Torsvik *et al.*, 1990) and Baltica (after M. A. Smethurst, A. N. Khramov, 1992; see also T. H. Torsvik *et al.*, 1992). In both cases, the time calibration has been made by cubic splines interpolation between the Lower Devonian poles of Britain and Baltica and the one Lower Carboniferous pole from Spitsbergen. In the cubic splines procedure, however, the definition of time intervals between the palaeomagnetic poles involved depends both on the subjectively established smoothing parameter (varying from 1 to 10 000) and the selections of key poles. In the case of the British Isles, a specific selection of smoothing parameters and key poles has led to a significant discrepancy between APWP's time intervals and palaeopole ages. It is enough to say that none of the Middle-Upper Devonian poles of Britain fall on the 370 Ma sector of APWP, being removed by some 20° eastward (see T. H. Torsvik *et al.*, Fig. 3 and Tables 1–3). Another example of the contrast between the cubic splines calibrated APWP for Baltica and the mean ages derived from the palaeomagnetic data is depicted in M. Lewandowski (1993, Fig. 19), where the time difference for the interpolated ages of the

APWP for Baltica and the mean palaeopole ages reaches 20 Ma. That is why APWPs, when sliced into mathematically-defined time intervals, are dangerous for palaeomagnetic dating; the factual palaeomagnetic dataset should be use for this purpose instead (cf. R. Van der Voo, 1993, p.77).

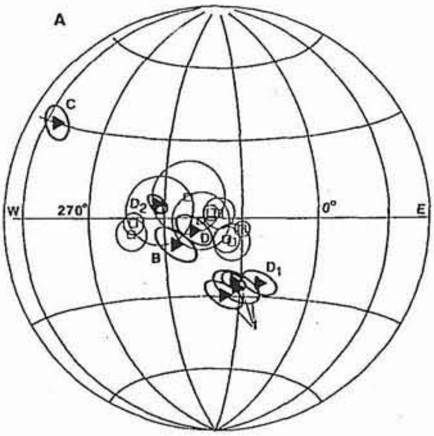
If, therefore, palaeopole D is compared with the currently existing poles for Europe, it becomes evident (Fig. 2a) that it fits to the Silurian/Devonian poles of Great Britain (T. H. Torsvik *et al.*, 1991; J. E. T. Channel *et al.*, 1992) or to the one Early Devonian pole from Spitsbergen and to the two Eifelian (384 Ma) poles of the south Urals (Fig. 2b). It should be born in mind, however, that the latter poles are obtained from an ophiolite complex that represents a rotated, allochthonous unit (K. S. Burakov *et al.*, 1984), hence it can not be considered representative for Baltica (cf. T. H. Torsvik *et al.*, 1992), as was tentatively suggested by M. A. Smethurst and A. N. Khramov (1992).

Apart from the Early Devonian poles, pole D has its counterparts in the younger, namely Namurian-Westphalian poles (Fig. 2c), obtained for some Variscan massifs of Europe (so-called palaeopoles B, see J. B. Edel, 1987; J. B. Edel, F. Wickert, 1991). Hence, reliability criterion 7 (dissimilarity of the considered pole to younger poles) is not met in this case, although J. Nawrocki (1993*b*) states otherwise.

The bulk of palaeomagnetic data from "stable" (i.e. pre-Variscan) Europe indicates that the poles obtained from the Middle-Upper Devonian rocks of "stable" Europe differ from the D pole by some 30° of arc and cluster around the grand-mean pole 330°E/26°S (T. H. Torsvik *et al.*, 1990; R. Van der Voo, 1990, 1993). The problem whether these poles or pole D represent the true Middle Devonian palaeofield, may be clarified by a test, employing a comparision of the implied palaeogeographic situation of ORC with climatically sensitive Middle Devonian lithofacies data (see later disscusion).

The position of the Devonian-Permian poles for ORC, are listed by R. Van der Voo (1990, 1993, Table 5.7). They are also shown in the Figure 3, contrasted with the position of pole D. As in the case of poles from Baltica, pole D also matches pre-Middle Devonian poles, being identical with the uppermost Silurian/lowermost Devonian age (406±8 Ma, 3°S/315°E, N=19). Middle and Late Devonian poles are definitively situated some 30° southeast of pole D. Notable is the proximity of the mean Lower/Middle Devonian pole for ORC (388±9 Ma, 22°S/328°E, N=10) to the pole obtained for the Emsian (390±4 Ma) sandstones of Bukowa Mt. (24°S/322°E, Holy Cross Mts., Łysogóry region; see M. Lewandowski *et al.*, 1987), that seems to confirm structural coherence of the northern unit of the Holy Cross Mts. (HCM) with Baltica from the Devonian onwards (see M. Lewandowski, 1993 for comprehensive discussion). The approximate position of the Givetian/Frasnian (372±6 Ma, 27°S/329°E, N=14) palaeopole for ORC remains in agreement with estimations by T. H. Torsvik *et al.* (1990), who tentatively place the Givetian/Frasnian segment of Baltica and Spitsbergen in the area 20°S/330°E (*op.cit.*, Fig.6).

In conclusion, the dating of pole D made by J. Nawrocki (1993*a,b*) was erroneous, since the palaeomagnetic time-scale involved was artificially obtained. The true Middle Devonian geomagnetic axis for ORC is situated some 30°SE from pole D. The hypothesis about the Givetian (or Givetian/Frasnian) age of pole D has a much stronger alternative, founded on similarity with the real (not hypothetical) palaeomagnetic poles of Namurian-Westphalian age of Europe (cf. J. B. Edel, 1987; J. B. Edel, F. Wickert, 1991).



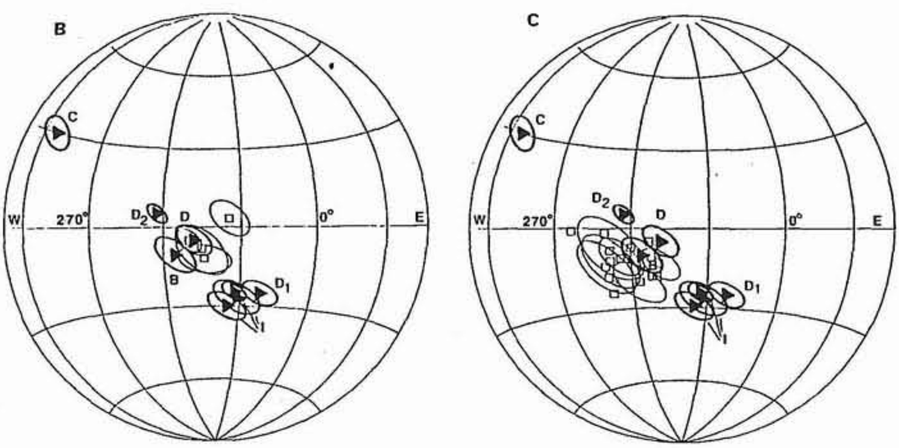


Fig. 2. Palaeopoles from USCB (triangles) against Devonian and Carboniferous poles of Europe (quadrangles) A — Great Britain (Silurian/Devonian, 412±20 Ma; T. H. Torsvik *et al.*, 1991), B — Baltica (Lower Devonian, 390±6 Ma; M. Lewandowski, 1993), C — poles of various Variscan blocks (Namurian-Westphalian, 315±18Ma; J. B. Edel, 1987; J. B. Edel, F. Wickert, 1991); Schmidt projection; grid 30°

Paleobieguny USCB (trójkąty) na tle dewońskich i karbońskich biegunów europejskich (kwadraty) A — Wielka Brytania (sylur/dewon, 412±20 mln lat; T. H. Torsvik i in., 1991), B — Baltika (dolny dewon, ok.390±6 mln lat; M. Lewandowski, 1993), C — różne masywy waryscyjskie (namur-westfal, 315±18 mln lat; J. B. Edel, 1987; J. B. Edel, F. Wickert, 1991); projekcja Schmidta; podziałka co 30°

RELATIVE POSITION OF USM AND BALTICA VS. PALAEOMAGNETIC DATA

Being impressed by the positive fold test, very good statistical data, and apparent agreement of palaeopole D with the supposed Givetian/Frasnian sector of APWP for Baltica, J. Nawrocki (1993*a,b*) assented that the structural identity of USM and Baltica since Middle/Upper Devonian time was proved. Consequently, he had to reject his older

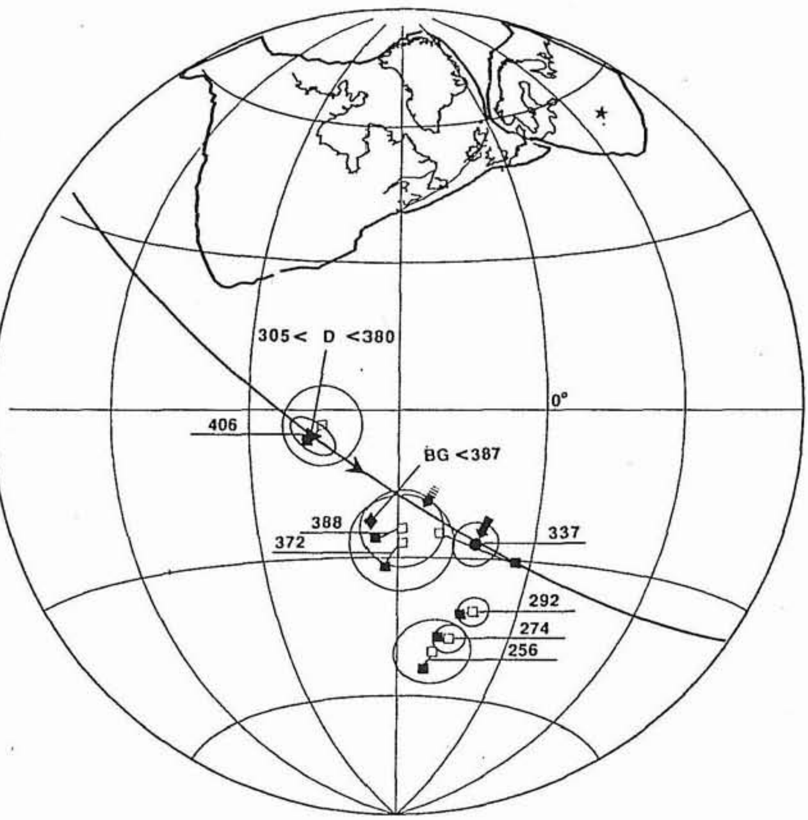


Fig. 3. Devonian-Permian mean palaeomagnetic poles (squares) for Baltica (open) and Laurentia (full) in the European coordinates after E. C. Bullard's reconstruction (see text)

The mean 337 Ma pole derived from the combined dataset of both continents is shown as a full dot; this and remaining poles from Baltica are shown with their A95 circles of confidence; coeval poles are linked, the ages in Ma are given; D pole (after J. Nawrocki, 1993*b*) is shown as a full triangle with its α_{95} oval of confidence (the potential time of the CHRM acquisition is shown), pole from the Emsian of Góra Bukowa Mt. (northern HCM, M. Lewandowski *et al.*, 1987) — full rhomb (the lower age limit for CHRM acquisition is shown by the pole label — BG); star depicts the Eulerian pole of rotation, while the Eulerian equator is shown by a bold line (direction of rotation of the pole D towards the Middle Devonian-Late Carboniferous poles for ORC is shown); amount of rotation depends on the real age of pole D and may vary from ca. 30 to 45° for the Givetian age (dashed arrow) and Visean/Namurian age (bold arrow); Schmidt projection; grid every 30°

Dewońsko-permskie średnie bieguny paleomagnetyczne (kwadraty) dla Baltiki (puste) i kratonu północnoamerykaskiego (pełne) we współrzędnych europejskich po rekonstrukcji ORC według E. C. Bullarda i in. (patrz tekst)

Bieguny dla średniego wieku 337 mln lat z obu kontynentów zostały uśrednione (duża kropka); ten biegun oraz pozostałe bieguny dla Baltiki pokazane wraz z ich kołami ufności A95; równowiekowe bieguny dla obu kontynentów są połączone, wiek każdej pary podany w milionach lat; biegun D (według J. Nawrockiego, 1993*b*) z możliwym zakresem wieku — pełny trójkąt z owalem ufności α_{95}, biegun z emsu Góry Bukowej (północne Góry Świętokrzyskie, M. Lewandowski i in., 1987) — pełny romb (dolna granica wieku przy symbolu próby — BG); eulerowski biegun rotacji — gwiazdka, równik eulerowski — gruba linia (strzałka pokazuje zwrot rotacji bieguna D w kierunku środkowodewońskich-górnokarbońskich biegunów dla ORC); wielkość rotacji bieguna D zależy od wieku namagnesowania dolomitów okolic Siewierza i wynosi od ok. 30° dla żywetu (strzałka przerywana) do ok. 45° dla wizenu/namuru (strzałka pełna); projekcja Schmidta; siatka co 30°

data, that formerly gave mobilistic interpretations (i.e. poles C and B, see J. Nawrocki, 1992*a,b*).

I will not discuss the method that J. Nawrocki (1993*a*) has used to prove the nondipole origin of the C component. According to my knowledge, it is impossible to judge the structure of the geomagnetic field from only one site on the Earth. Even if the assumption of the nondipole origin of the C component is correct, the acquisition of the component had to be long enough to record perfectly antipodal directions (see J. Nawrocki, 1993*a*, Fig. 15c). In such a case, there are no reasons to reject the C remanence related palaeopole, since long-term nondipole components are believed to show axial symmetry (D. A. Schneider, D. V. Kent, 1990).

The next, so-called B pole, has also been rejected (J. Nawrocki, 1993*a*) using an enigmatic (i.e. not described so far in literature) "flattened maximum of density" criterion (J. Nawrocki, 1993*a*, Fig. 16). In this case, however, a dull peak in density of the B directions is exclusively due to a smaller number of orientations compared to the juxtaposed population A1, both populations being more than sufficient in number of directions in order to regard them as reliable. Moreover, the precision parameter *k* has a better (bigger) value than the most reliable D palaeopole (J. Nawrocki, 1993*a*). Accounting for similarity to Carboniferous poles of Variscan Europe (Fig. 2c), the B directions (poles) of the Namurian-Westphalian successions of USCB should be considered real.

Also important is that, even if the validity of poles C and B is disproved, the relative stability of USCB (USM) with reference to Baltica is not guaranteed by the position of pole D alone. It is because pole D lies on the Eulerian equator (like the Middle Devonian-Late Carboniferous poles for ORC do), drawn around the Eulerian pole situated in the central part of Baltica (see Fig. 3). Theoretically therefore, pole D can be a rotated pole of any age within the time error limit, Givetian age included. Hence the J. Nawrocki's (1993*a,b*) main conclusion concerning lack of major movements between EEP and USM is, at best, only one of many other possibilities. As will be indicated in the next section, there is little probability that the Givetian pole for ORC is situated in the vicinity of pole D because of the implied ORC palaeogeography.

CONFIGURATION OF THE OLD RED CONTINENT IN THE MIDDLE DEVONIAN

The Old Red Continent resulted from the Silurian collision of Laurentia, Baltica, and Avalonia. ORC assembly is best resolved according to E. C. Bullard and colleagues fit (see R. Van der Voo, 1990) and the configuration of this palaeocontinent has recently been depicted by T. H. Torsvik *et al.* (1993). The same reconstruction is used in this paper.

Let us now assume that palaeopole D from USM represents the Givetian geomagnetic field of ORC, as was postulated by J. Nawrocki (1993*a,b*). Consequently, we can reconstruct ORC according to pole D and, subsequently, compare the obtained configuration with palaeoclimatic zonation.

Such a reconstruction is presented in Figure 4a and is juxtaposed with an alternative ORC configuration (Fig. 4b), made according to the mean Givetian pole (27°S/331°E, 372±6 Ma, European coordinates, see R. Van der Voo, 1993). It may be seen from Figure 4 that the reconstruction according to R. Van der Voo's pole is more compatible with Middle Devonian (Eifelian-Givetian) palaeoclimatic sensitive facies pattern distribution (see dis-

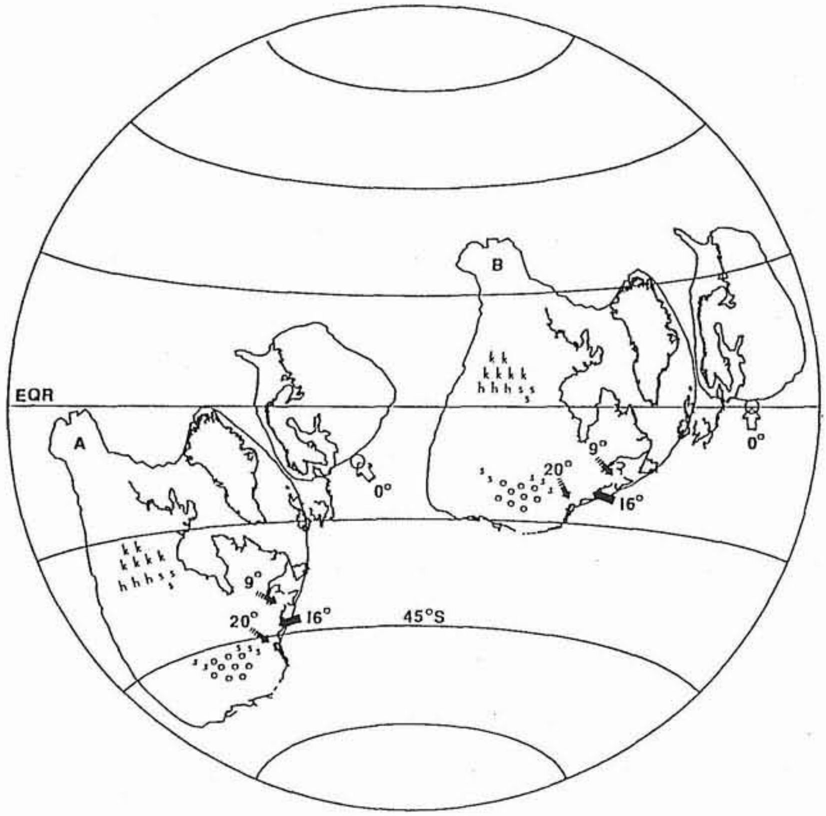


Fig. 4. ORC reconstruction according to: A — D palaeopole of J. Nawrocki (1993*b*), B — R. Van der Voo (1993, Tab. 8.1)

Warm climate facies distribution in the Eifelian-Givetian is schematically redrawn from B. J. Witzke (1990); o — carbonate oolites, s — sulphate evaporates, h — halite, k — potash salts; arrows with numbers indicate places and palaeolatitudes determined for Laurentia (arrows: dashed — after D. V. Kent, R. Van der Voo, 1990, bold — after J. D. Miller, D. V. Kent, 1986); equatorial inclination obtained for the uppermost Eifelian sandstones from Góra Bukowa Mt. is shown by an empty arrow (circle denotes the position of Łysogóry region, northern Holy Cross Mts.); note concordance of warm facies occurrences and palaeomagnetically determined paleolatitudes with reconstruction B, and their apparent disagreement in configuration A according to pole D, if Givetian/Frasnian age is assumed; palaeolatitudes every 22.5°; EQR — equator; Schmidt projection

Rekonstrukcja ORC według: A — bieguna D (J. Nawrocki, 1993*b*), B — R. Van der Voo (1993, tab. 8.1)

o — oolity wapienne, s — gipsy i anhydryty, h — halit, k — sole potasowe (rozkład facji dla eiflu-żywetu według B. J. Witzkego, 1990); liczby przy strzałkach pokazują wartość lokalnej paleoszerokości w górnym dewonie (strzałki przerywane — D. V. Kent, R. Van der Voo, 1990, strzałka pełna — J. D. Miller, D. V. Kent, 1986); pusta strzaka pokazuje zerową inklinację, stwierdzoną w piaskowcach najwyższego emsu Góry Bukowej z regionu łysogórskiego Gór Świętokrzyskich (kółko); rekonstrukcja według R. Van der Voo pozostaje w zgodzie ze wskaźnikami paleoklimatycznymi; położenie ORC według J. Nawrockiego (1993*a*) jest sprzeczne z rozkładem klimatycznie czułych facji i z danymi paleomagnetycznymi dla Laurencji; paleoszerokości co 22.5°; EQR — równik; projekcja Schmidta cussion in B. J. Witzke, 1990). On the other hand, the configuration obtained with J. Nawrocki's concept situates Eifelian-Givetian oolite, anhydrite and gypsum of the Laurentian midcontinent at palaeolatitudes which are definitely too high (50 to 55°). A specific consequence of this solution is that the equator runs through Baltica, but does not cut across the Laurentian craton. Such a model has not been proposed so far for the Middle-Late Devonian continental configurations.

Moreover, palaeomagnetically determined palaeolatitudes of different regions of Laurentia (J. D. Miller, D. V. Kent, 1986; D. V. Kent, R. Van der Voo, 1990) remain in disagreement with the configuration implied by palaeopole D (Fig. 4a), but are otherwise in agreement with the alternative arrangement (Fig. 4b). Also, palaeolatitude derived from the uppermost Eifelian sandstones (Łysogóry Unit, Holy Cross Mts., see M. Lewandowski *et al.*, 1987), is in keeping with the reconstruction according to the data by the American authors.

Alternatively, one may consider the possibility that the reconstruction of ORC by T. H. Torsvik *et al.* (1993) is incorrect and Baltica should be positioned according to pole D (as in the Fig. 4a), while the orientation of Laurentia should be governed by the data from the American craton (as in the Fig. 4b). This, however, gives rise to a new problem, since in such a configuration North Scandinavia is juxtaposed with either the Anglo-Brabant Massif or with the SE margin of Laurentia (i.e. Northern Ireland and Scotland), in the latter case Avalonia being apart of Laurentia. Such a scenario contradicts our present-day knowledge of the Middle-Late Devonian continental configuration (cf. C. R. Scotese, W. S. McKerrow, 1990), but if true then the importance of the palaeomagnetic data from the Siewierz platform have indeed not been overestimated.

Summarizing, palaeopole D can not represent the Givetian palaeomagnetic pole of ORC due to the conflict arising between ORC palaeogeography and Middle Devonian palaeoclimatic zonation. Consequently, Middle Devonian time calibration of the APWP for Great Britain, as presented by T. H. Torsvik *et al.* (1990) and recalled by J. Nawrocki (1993*a*), can not be representative for ORC, unless Avalonia was unstable (i.e. rotated clockwise) with reference to Laurussia (i.e. Laurentia and Baltica) in post-Givetian time. On the other hand, reconstruction according to the mean Givetian pole as given by R. Van der Voo (1993) is compatible with palaeoclimatic facies distribution.

MOBILISTIC INTERPRETATION OF THE PALAEOPOLE FROM THE SIEWIERZ ANTICLINE

Accepting the pole by R. Van der Voo (1993) as the pole of reference for the Givetian of ORC, let us consider the geotectonic implications, resulting from the position of pole D (J. Nawrocki, 1993*a,b*). According to its time error limit, the age of pole D may span from the Givetian to the Bashkirian. Depending on the time calibration of pole D, the tectonic consequences are of different scale and meaning, but anticlockwise rotation of pole D on the order of 30–40° is required in any case. If pole D is of Givetian age, then ca. 10° gap of palaeolatitude additionally emerges between the present-day SW margin of Baltica (equatorial latitude, see Fig. 4) and USM (palaeolatitude ca. 10°S, as calculated from the inclination given by J. Nawrocki, 1993*b*). Although not significant for the angular errors involved, such a difference speaks against Givetian age of pole D, since there is no evidence for 1000 km of shortening between Baltica and USM in post-Givetian time.

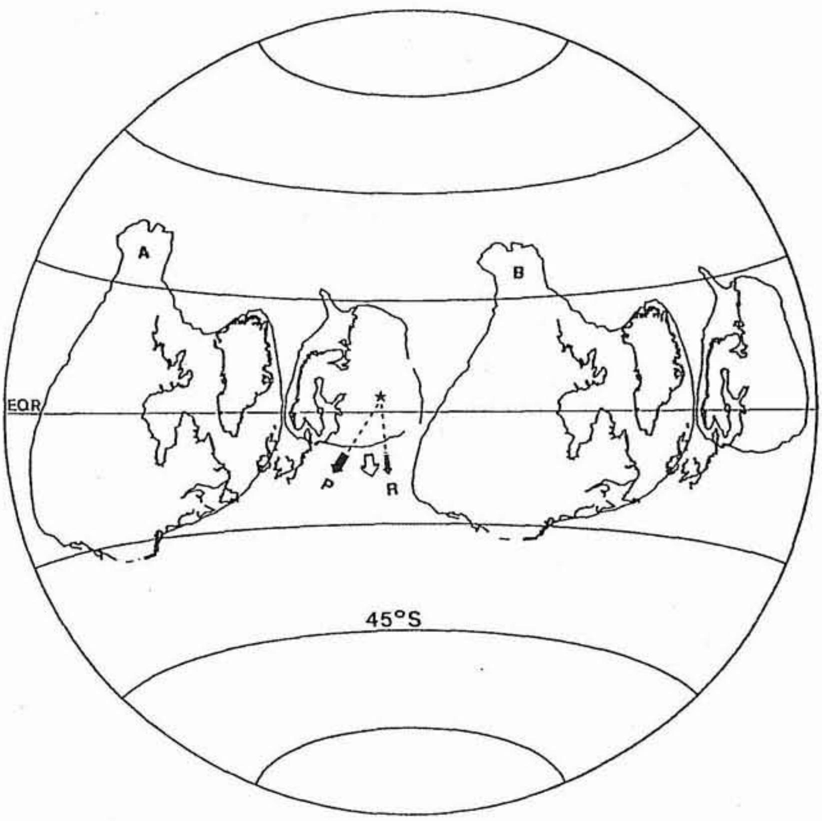


Fig. 5. Visean/Namurian reconstruction of ORC: A — according to pole D, rotated anticlockwise by 40° (see text), B — according to the pole of age 337±28 Ma for the North American craton (R. Van der Voo, 1993, Tab. 8.1) Both reconstructions are compatible, provided that USM (present-day orientation shown by a bold arrow P) is rotated around a best-fitted Eulerian pole (star) by ca. 40° and occupies position according to dashed arrow R; arbitrarily chosen solution for additional intra-block vertical axis rotation (see text) is shown by an empty arrow; palaeolatitudes every 22.5°; EQR — equator; Schmidt projection

Wizeńsko-namurska rekonstrukcja ORC dla: A — zrotowanego o 40° przeciwnie do ruchu wskazówek zegara bieguna D (patrz tekst), B — bieguna wieku 337±28 mln lat dla kratonu północnoamerykańskiego (R. Van der Voo, 1993, Tab. 8.1)

Obie rekonstrukcje są przystające, jednak USM (jego dzisiejsza orientacja pokazana jest pełną strzałką P) jest zrotowany o ok. 40° względem najlepiej dopasowanego bieguna Eulera (gwiazdka) do pozycji i orientacji wskazanej przez kreskowaną strzałkę R; pustą strzałką pokazano arbitralnie przyjęte rozwiązanie, wynikłe ze złożenia dwóch rotacji (patrz tekst); paleoszerokości co 22.5°; EQR — równik; projekcja Schmidta

However, Carboniferous (Tournaisian-Bashkirian, 360–305 Ma) age of the D component may be reasonably assumed. As an exemple of the geotectonic consequences for USM, let us consider the possibility that pole D is of Visean/Namurian age and that the grand-mean pole at 337 Ma (see Fig. 3) is representative for the Visean/Namurian of ORC. Accepting a minimum distance movement criterion, let pole D match with the 337 Ma pole. This requires a counter-clockwise rotation of pole D by ca. 45° around the best fitted Eulerian pole (48°N/36°E, Central Baltica). Such rotation implies translation the of USM Block along the southwest margin of Baltica (actually Teisseyre-Tornquist Line) to the southeast for a distance of several hundred kilometres (from P to R, see Fig. 5).

Comparison of palaeogeographic reconstructions of ORC made according to the rotated pole D (Fig. 5a) and to the 337 Ma pole for ORC (Fig. 5b) reveals their identity. Hence, pole D **may be** of Namurian age, providing that USM is sinistrally offset to the east along the same parallel of latitude.

In fact, this solution sets only the boundary condition for the maximum translation of USM in post-Givetian time. It is important to realize that within the limit of error, a similar match of the poles will be obtained as an effect of intra-block, vertical-axis rotation by the same angle, or by any combination of both types of rotations. The eventual solution depends on geological constraints; in any case, USM had to be subjected to dextral shear-coupling during Early Carboniferous time. Taking into account that the extremely mobilistic concepts that involved closure of the vast oceanic domains between USM and EEP in the Late Carboniferous (e.g. J. Nawrocki, 1992*a,b*) did not meet any criticism from the geological community, it seems that the geological evidence is not too rigorous in this case.

For a suitable model of geotectonic development for the central segment of the Variscides that agrees well with the palaeomagnetic data for USCB, the reader is kindly referred to the paper by J. F. Dewey (1982). In accordance with this model is the concept of impingment of USM against more westerly situated terranes, as implied by the mobilistic interpretation presented in this study. The S-shaped structural plan of the Variscides in their eastern termination may be, therefore, causally related with such westward indentation of USM (combined with clockwise rotation ?).

MOBILISM OF MAŁOPOLSKA BLOCK AND PALAEOMAGNETIC DATA FROM USCB

According to J. Nawrocki (1993*a,b*) his palaeomagnetic evidence for the structural unity of USM with Baltica makes the concept of large-scale strike-slip displacement of the Małopolska Block (MB, see M. Lewandowski, 1992,1993) not very probable due to the close structural relationship between MB and USM. As it has been substantiated in the previous paragraphs, it is quite the other way round and the data from the USM confirm rather than deny the Variscan mobilism of the blocks adjacent to the SW boundary of Baltica.

However, J. Nawrocki (1993*a,b*) presents several other arguments against the mobilism of MB. Some of them are factual (such as low precision of the mean characteristic direction from the Lower Devonian sandstones of the Kielce region, or a big difference in inclination between the southern Holy Cross Mts. — S-HCM — and Ukrainian formations), while others emerge either from Author's prejudices ("It is difficult to accept that Małopolska Massif was, at that time at nearly equatorial, north palaeolatitudes...", J. Nawrocki, 1993*a*), or from his premature conviction that the stability of USM with respect to Baltica from the Givetian onwards is being proved (e.g. a short time span for strike-slip translation of MB).

Considering his factual arguments, I agree with J. Nawrocki (1993*a*) that precision parameter *k* for the CHRM of the Lower Devonian sandstones (M. Lewandowski, 1991) is low. However, we differ in the interpretation of this detail: while J. Nawrocki (1993*a*) sees

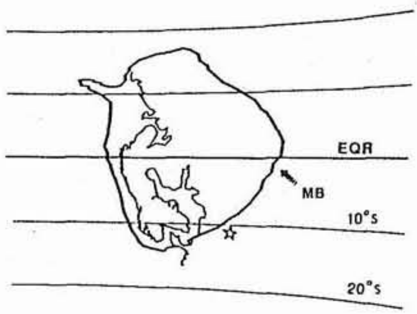


Fig. 6. Emsian reconstruction for Baltica (390±4 Ma), according to the pole 384 Ma from APWP for Baltica (see M. Lewandowski, 1993, Fig. 19), that corresponds to 395 Ma (Early Emsian) for ORC, according to R. Van der Voo (1990,1993)

An arrow points to the supposed position of the Małopolska Block (MB), inferred from the equatorial inclination, obtained for the Lower Devonian sandstones of the southern Holy Cross Mts. (see M. Lewandowski, 1991); present-day position of MB is shown by a star; EQR — equator; Schmidt projection

Położenie Baltiki w emsie (390±4 mln lat), zrekonstruowane według bieguna 384 mln lat z krzywej APWP dla Baltiki (patrz M. Lewandowski, 1993, fig. 19), co odpowiada ca. 395 mln lat (dolny ems) dla ORC według R. Van der Voo (1990, 1993)

Strzałka pokazuje przypuszczalną pozycję bloku małopolskiego (MB), zgodnie z równikową inklinacją NRM piaskowców dolnego dewonu regionu kieleckiego Gór Świętokrzyskich (M. Lewandowski, 1991); dzisiejsza pozycja MB pokazana gwiazdką; EQR — równik; projekcja Schmidta

only a low reliability of the palaeomagnetic record, I see a low precision of the CHRM mean (at the specimens level) as a immanent feature of a detrital remanent magnetization (cf. R. Løvlie *et al.*, 1984; M. Jeleńska, M. Lewandowski, 1986; M. A. Smethurst, A. N. Khramov, 1992). Many CMRMs, obtained from detrital rocks, are considered to be sufficiently reliable, in spite of a k value even less then 10 (see R. Van der Voo, 1993 and his tables of the global palaeomagnetic dataset). Mixed polarity observed in the rocks under discussion enhanced the probability of early depositional remanence acquisition.

With respect to dissimilarity of the inclinations between the Emsian (390±4 Ma) sandstones of S-HCM and the Old Red Sandstones of Ukraine (404±10 Ma), the potential time gap between both formations may reach ca. 25 Ma. This is quite enough time for northward drifting Baltica to record differently inclined palaeomagnetic vectors, even if the MB was situated in its present-day position.

However, the Emsian reconstruction of Baltica (Fig. 6) results in equatorial palaeomagnetic inclination obtained for the Emsian sandstones of S-HCM which requires its positioning at the present-day SE corner of Baltica (see M. Lewandowski, 1993, Fig. 23), thus making the presence of the difference in inclinations between Ukraine and S-HCM indispensable.

I do not see a problem in the time span required for the strike-slip translation of the MB, either. According to the tectonic scenario by M. Lewandowski (1993), in the post-Emsian time MB acted alike continental sliver, that was cut off from the Dobrudgean-Crimean part of Baltica by a transcurrent fault and subsequently translated along the edge of Baltica on the distance ca. 1000 km to its present-day place. Assuming that the movement, understood as the rotation of MB around Eulerian pole located in the Central Baltica, was accomplished as early as the end of the Givetian (or it was at its decline), there were still some 15 Ma for the relative block translation. This means ca. 3 cm/a of velocity (in opposite directions along a strike-slip fault) for both Baltica and MB. This falls within the normal speed limit for present plate motion, otherwise being 5–7 times smaller than the postulated velocity for the Gondwana plate during the Devonian (I. G. Meert *et al.*, 1993). Similarly to the case of USM (see previous chapter), other solutions, employing intra-block vertical-axis rotations, are also possible, although they are less probable, according for the present-day geological knowledge from HCM (see M. Lewandowski, 1993).

Finally, one may conclude that palaeomagnetic poles as presented by J. Nawrocki (1993*a,b*) can not deny the mobilism of MB, even if pole D did represent the Givetian palaeofield for ORC. On the contrary, if USM and MB formed a consolidated entity since the Caledonian orogeny, as J. Nawrocki (1993*a, b*) argues, then palaeomagnetic data from USM may be considered the next palaeomagnetic proofs for MB mobility in Devonian-Carboniferous time.

CONCLUSIONS

Palaeomagnetic results from USCB were originally interpreted as evidence for relative stability of this block with respect to ORC since the Givetian (J. Nawrocki, 1993*a,b*). This interpretation relied on similarity of palaeopole D and the Middle Devonian segment of APWP for Great Britain (the intrinsic part of ORC in this time) as determined by cubic splines. It has been indicated that the conclusion drawn by J. Nawrocki (1993*a,b*) leads, however, to contradiction between ORC palaeogeography and the distribution of palaeoclimatic indicators. The controversy is resolved if pole D is compared with the current palaeomagnetic dataset for ORC. Such comparison reveals northwestward shift of the pole D by 30 to 45° from potentially coeval palaeopoles, which implies the equivalent dextral rotation of USCB with reference to ORC in post-Givetian time.

High precision of the palaeomagnetic record in dolostones of USCB, as well as the presence of pyrrhotite and magnetite as magnetic carriers and the lack of magnetic reversals in the otherwise spatially distributed sites, suggest secondary origin of the characteristic NRM component. Given the unimodal polarity of the D directions, the remagnetization could be caused by a short-lived chemical phenomenon, e.g. mineralization of the dolostones during syn-Variscan tectonic movements. The swathe-type palaeopole distribution, obtained by J. Nawrocki (1993*a*), can be explained by pulsative hydrothermal activity while the USM Block was rotating clockwise, Eulerian pole situated in the central part of Baltica. Such a scenario is compatible with the model of geotectonic development of the Variscides, as presented by J. F. Dewey (1982).

In conclusion, the palaeomagnetic results from USCB (J. Nawrocki, 1993*a,b*) speak more in favour of a dynamic, mobilistic development of the present-day SW forefield of

EEP in Variscan time than a stationary platform evolution of this area from the Givetian onwards.

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PALEOMAGNETYCZNE OGRANICZENIA MOBILIZMU WARYSCYJSKIEGO MASYWU GÓRNOŚLĄSKIEGO I MAŁOPOLSKIEGO

Streszczenie

Bliższa analiza danych paleomagnetycznych, uzyskanych z dewońsko-karbońskich formacji masywu śląskiego (USM, J. Nawrocki, 1993*a,b*) wykazała, że postulowana przez tego autora jedność strukturalna USM z kontynentem Old Redu (ORC) już od żywetu nie znajduje potwierdzenia w przedstawionych wynikach. Datowanie paleomagnetyczne bieguna D, stanowiące podstawę tezy J. Nawrockiego (1993*a,b*), zostało oparte na fałszywej przesłance, że interwały czasu na wygładzonej metodą splinów krzywej wędrówki bieguna są zawsze zgodne z położeniem równoczasowych biegunów paleomagnetycznych.

Wykazano, że biegun D nie może być reprezentatywny dla żywetu ORC, gdyż takie twierdzenie prowadzi do sprzeczności pomiędzy żywecką pozycją paleogeograficzną ORC, a rozkadem klimatycznie czułych litofacji.

Niektóre cechy zapisu paleomagnetycznego (wysoka zbieżność kierunków, jednakowa polarność, pasowy rozkad biegunów) oraz częsta w przemagnesowanych formacjach węglanowych asocjacja pirotyn-magnetyt sugerują wtórną genezę składowych NRM w dolomitach okolic Siewierza. Składowe te (oznaczone symbolami D i I, patrz J. Nawrocki 1993*a*) mogły utrwalić się wskutek pulsacyjnej mineralizacji epigenetycznej dolomitów, w czasie zgodnej z ruchem wskazówek zegara waryscyjskiej rotacji USM.

Porównanie bieguna D z paleobiegunami dla ORC wykazuje, że jest on odchylony od nich w kierunku NW, przy czym odchylenie wynosi ok. 30° w stosunku do paleobiegunów otrzymanych dla skał żywetu oraz ok. 45° względem paleobiegunów dla skał dolnego karbonu. Wynikająca z tego faktu rekonstrukcja kinematyki waryscyjskiej bloków dzisiejszego przedpola platformy wschodnioeuropejskiej wymaga uwzględnienia prawoskrętnej rotacji USM, w ogólnym rozwiązaniu podobnej do rotacji bloku małopolskiego (M. Lewandowski, 1993).

Wielkość tej rotacji zależy od wieku bieguna D, który zawierać się może w granicach żywet-baszkirian, przy czym karboński wiek tego bieguna wydaje się być bardziej prawdopodobny. W ogólności, taki ruch USM mieści się w koncepcji rozwoju geotektonicznego waryscydów, przedstawionej przez J. F. Deweya (1982).