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Late Paleozoic geodynamics of the Małopolska Massif in the light of new paleomagnetic data for the southern Holy Cross Mountains

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ABSTRACT:

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Paleomagnetic studies of Devonian carbonate rocks in the southern Holy Cross Mountains have been conducted, the general aim being to verify the occurrence of hypothetical pre-Variscan rotations of the Małopolska Massif as well as to examine time-relationships between remagnetizations and successive stages in tectonic deformations. The paleomagnetic analysis confirms the presence of the three components of characteristic remnant magnetization. Two magnetite-bearing components display reversed (component A) and normal (component B) polarity. The third component (C) is recorded on hematite and shows reversed polarity. Component B is of synfolding origin and has been recorded during the Visean, whereas components A and C are of postfolding origin and represent Early Permian and Permo-Triassic overprints. These results confirm the stable position of the Małopolska Massif with respect to the East European craton, at least since the Visean. Results of fold tests imply that the earliest phases of Variscan deformation can be dated most probably as Visean, while formation of the main Variscan fold structures was completed during the Early Permian. It is also documented that representative Variscan folds did not significantly change their geometry during Maastrichtian-Paleocene reactivation.

Key words: Holy Cross Mountains, Małopolska Massif, Paleomagnetism, Paleogeography.

INTRODUCTION

The territory of Poland is intersected by one of the most important tectonic discontinuities of the European Continent, the Trans European Suture Zone (TESZ), which constitutes the transitional zone between the Precambrian East European Craton (EEC) and the Paleozoic mobile belts of central and western Europe (Text-fig. 1). The TESZ comprises distinct terranes whose detailed Paleozoic drift history and amalgamation time remain a matter of controversy to this day. A detailed study of TESZ evolution is hampered by the fact that through most of its extent it is covered by a thick Mesozoic overburden/sediments. Exposures of Paleozoic rocks do occur, however, in the Holy Cross Mountains (HCM) which makes this area especially important to our understanding of regional geotectonic evolution.

The Paleozoic of the HCM (Text-fig. 2) can be subdivided into a southern and northern regions (SHCM and NHCM, respectively), separated by the Holy Cross Fault (HCF). The SHCM and NHCM regions are characterized by different tectonic and stratigraphic structures (CZARNOCKI 1957), which is

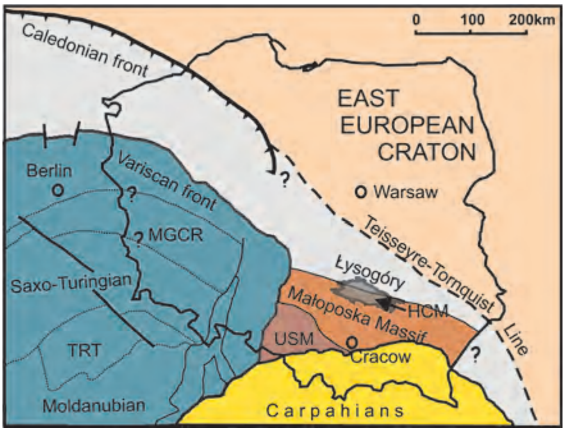

Fig. 1. Tectonic map of Poland (modified after Bełka & *al.* 1992); HCM – Holy Cross Mountains; MGCR – Mid-German Crystalline High, TRT – Tepla-Barrandian Terrane

commonly interpreted to be the result of paleogeographic separation (Pożaryski 1991). The SHCM belongs to the northern part of the Małopolska Massif (MM; see Text-fig. 1), which constitutes an individual crustal block interpreted as a tectonostratigraphic terrane derived from Gondwana (Bełka & *al.* 2000, 2002; Winchester & *al.* 2002).

More controversy has arisen over the date of MM accretion onto the EEC. Some authors are of the opinion that amalgamation occurred during the Caledonian or even Variscan orogenies (Pożaryski 1991; Stupnicka 1992; Lewandowski 1993; Dadlez & *al.* 1994; Unrug & *al.* 1999). However, in most recent studies a Cambrian date is postulated for the final accretion of MM (Bełka & *al.* 2000; Winchester & *al.* 2002; Nawrocki & Poprawa 2006).

Paleomagnetic data from the SHCM provide strong evidence in support of interpretations of a pre-Silurian date for the amalgamation of MM and EEC (Nawrocki 2000; Schatz & *al.* 2006). However, these data conflict with some previous paleomagnetic results obtained from younger rocks. Within Emsian clastic sediments, Lewandowski (1993) reported the occurrence of primary magnetization indicative of significant clockwise rotations. Consequently, that author concluded that MM had undergone large-scale tectonic transport along the southwesterly edge of Baltica some time during the Emsian/Carboniferous interval. Much smaller, albeit still significant, clockwise rotations have been traced by studies of Devonian carbonates as well (Lewandowski 1981, 1999; Grabowski & Nawrocki 1996, 2001). However, those data have been obtained mostly from the northwesternmost part of the SHCM which was affected by relatively intensive Maastrichtian-Paleocene deformations (Lamarche 1999). It is also worth noting that local clockwise rotations have also been observed in the NHCM (Grabowski & Nawrocki 2001).

The above-mentioned Devonian carbonates from the SHCM display a complex structure of natural remanent magnetization (NRM) which calls for a more detailed discussion. The NRM comprises two compo-

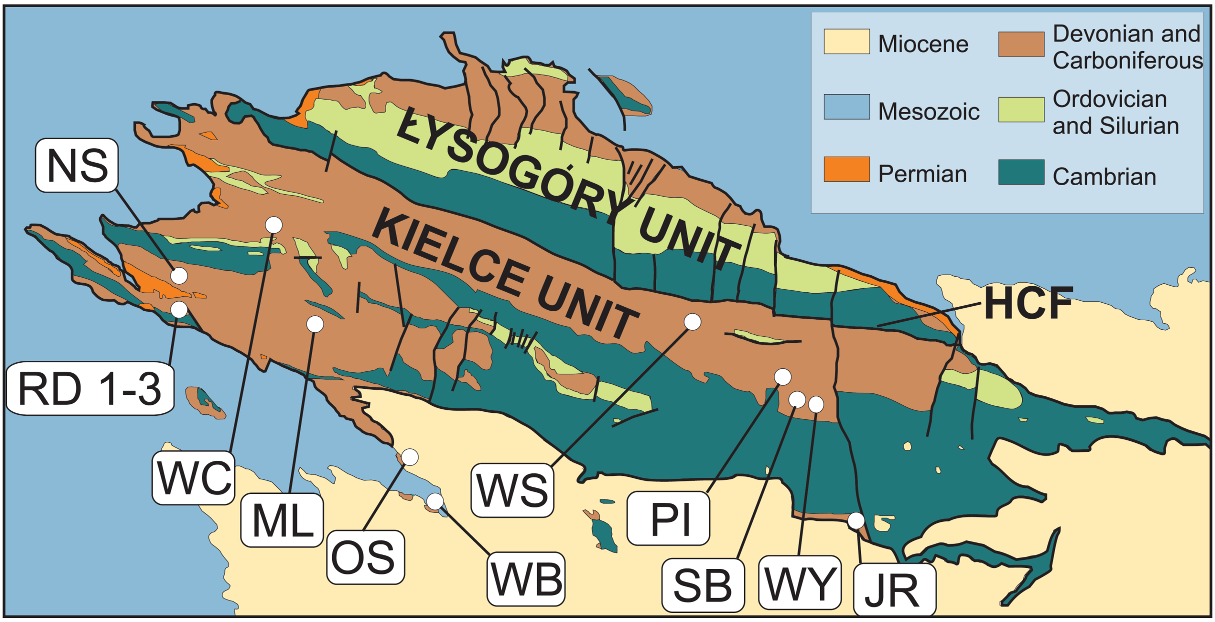

Fig. 2. Geological map of the Holy Cross Mountains (after Czarnocki 1938) showing location of paleomagnetic sampling sites; HCF – Holy Cross Fault

nents of middle to high unblocking temperatures (A and B components in ZWING's [2003] terminology), together with one high-temperature component representing late Permian overprint (the C component in ZWING's [2003] terminology). The A component is characterized by reversed polarity and is of postfolding origin (GRABOWSKI & NAWROCKI 2001; ZWING 2003; GRABOWSKI & *al.* 2006). Its direction shows differences between individual sites commonly displaying small clockwise rotations and variable inclination. On the other hand, the B component reveals normal polarity (GRABOWSKI & NAWROCKI 1996; SZANIAWSKI 1997; ZWING 2003; GRABOWSKI & *al.* 2006), is of synfolding age (ZWING 2003) and shows horizontal inclinations.

For both A and B components, the controversy arose from inconsistency of fold test results and remagnetization time deduced from inclinations (ZWING 2003). It is also difficult to explain the commonly observed small-scale rotations of the A component. It is worth noting here that fold tests presented so far have been performed within the small, second-order folds that in fact belong to individual limbs of kilometre-scale fold structures and as such require a special procedure of unfolding.

The present study was carried out in Devonian carbonates of the SHCM in order to determine the exact date of remagnetization episodes and to verify the occurrence of hypothetical rotations. The research focused on the B component, because previously acquired data suggested that this represented the oldest episode of remagnetization. The aims of the present study are threefold:

Determination of time-relationships between remanence acquisition and Variscan deformations. Fold tests within representative map scale folds.
Paleolatitude dating of A and B components with an aim to determine the paleomagnetic timeframe for Variscan deformations in the SHCM.
Test the hypothesis of Devonian and post-Devonian rotations of the MM.

GEOLOGICAL SETTING

Paleomagnetic studies have been carried out in Devonian carbonates of the SHCM where carbonate sedimentation started during the Eifelian and continued into the Middle and Late Devonian, reflecting the development and progressive drowning of a carbonate platform (see RACKI 1993; SZULCZEWSKI 2006). By the Early Carboniferous, carbonates had been gradually replaced by deep-water shelly sediments followed by clayey-sandy sediments of late Visean age, the latter representing the youngest Carboniferous deposit in the area. Resting discordantly on the above-mentioned sediments are Upper Permian strata which determine the general timeframe of Variscan deformations.

The Upper Paleozoic carbonates of the SHCM underwent multi-stage tectonic deformations which need to be considered in paleomagnetic investigations. Firstly, these rocks were subject to intensive synsedimentary deformations (see SZULCZEWSKI 1989; LAMARCHE 1999; RACKI & NARKIEWICZ 2000). Spectacular examples of synsedimentary slumps and breccias have been described from e.g. the Kowala quarry and a nearby railroad cutting (SZULCZEWSKI 1971; LAMARCHE & *al.* 2003). The main tectonic activity occurred when the HCM constituted the foreland of the Variscan orogen (JAWOROWSKI 2002; MAZUR & *al.* 2006). At that time, the Paleozoic rocks were affected by N-S to NNE-SSW shortening and folding (see CZARNOCKI 1957; LAMARCHE & *al.* 2002). Several authors have noted the multi-stage character of Variscan deformations, suggestive of an early episode of N-S compression (LAMARCHE & *al.* 1999) and late Variscan block tectonics associated with localized folding (KONON 2006).

The latest phase of tectonic activity occurred during Maastrichtian-Paleocene uplift (KUTEK & GŁAZEK 1972) and was characterized by mostly brittle deformations which were intensified in the contact zone of the Paleozoic substrate and the Mesozoic cover (see LAMARCHE & *al.* 2002, 2003).

SAMPLING AND LABORATORY METHODS

In the present study, special care was taken to select the best possible sample locations in order to realize the scientific goals and in due consideration of the local tectonic framework. Principally, those areas in the SHCM which preserve the possibly best record of the B component were preferred. Therefore, the north-westernmost area of the SHCM, together with the environs of the HCF, both characterized by pervasive Permian remagnetization (i.e., the A component) which covers the older magnetic remanence (GRABOWSKI & *al.* 2006), were excluded from sampling. In addition, areas affected by intensive Maastrichtian-Paleocene deformations were not considered, since the interference of two deformation phases makes it difficult to perform accurate tectonic correction.

The total number of sampled sites was 13. Some of these sites are located in quarries and natural exposures for which detailed stratigraphic interpretations and locality data are available (see RACKI 1993); JB – Jurkowice-Budy, NS – Sitkówka-Kostrzewa, ML – Marzysz, SB – Sobiekurów, and WC – Wietrznia). Other sampling sites are located within well-known active quarries: OS – Osiny, PI – Piskrzyn, RA – Radkowice, WB – Wierzbie, WS – Wszachów, and WY – Wymysłów. Sampling was done in various areas of the SHCM, including its central and eastern parts which were omitted in most previous studies. In this way, the results obtained are representative of the entire SHCM. With regard to the appropriate fold test, each sampling site was located within a separate limb of the kilometre-scale Variscan folds. Small-scale fold structures belonging to limbs of larger folds were avoided, because such would complicate tilt correction.

At each sampling site, six to seven hand samples of common bedding orientation were collected. Samples were subsequently drilled in the laboratory to give standard specimens of 24 mm diameter. Preliminary identification of the magnetic minerals was done by thermomagnetic analysis (KĄDZIAŁKO-HOFMOKL & KRUCZYK 1976), in which a saturated sample (3T) was continuously heated in a zero magnetic field in a furnace combined with spinner magnetometer. The NRM analysis was performed applying a 2G SQUID cryogenic magnetometer and Magnetic Measurements MM-1 furnace. The magnetic susceptibility was monitored after subsequent steps of thermal cleaning using the KLY-3 bridge.

For calculation of paleomagnetic directions, both principal component analysis (PCA; see KIRSCHWINK 1980) and great circles method (HALLS 1978) were employed. Software by LEWANDOWSKI & *al.* (1997) and CHADIMA & HROUDA (2006) was also utilized. Final paleomagnetic directions for specific components were determined as an average of site mean directions. The site mean directions were calculated as a mean of hand sample directions, while every sample direction was determined as a mean of specimen directions obtained by PCA. The fold test analysis was carried out applying parameter estimation formulation (WATSON & ENKIN 1993) using ENKIN's (1994) program.

PALEOMAGNETIC RESULTS

In most cases, thermomagnetic curves reveal (Text-fig. 3 – blue curve) the presence of magnetite which manifests itself by progressive decrease of the magnetic signal with maximum unblocking temperatures (Tub) in the 500-510°C range (LOWRIE & HELLER 1982). Only at the RA3 site and in some specimens from the WC site does the high Tub of about 660°C imply the occurrence of hematite (Text-fig. 3 – red curve). These hematite-bearing rocks can also be distinguished by their characteristic reddish colour. The outcome presented here is in line with previous studies that have reported the magnetite and hematite magnetic carrier of Devonian carbonates (e.g., SZANIAWSKI 1997; ZWING 2003; GRABOWSKI & *al.* 2006).

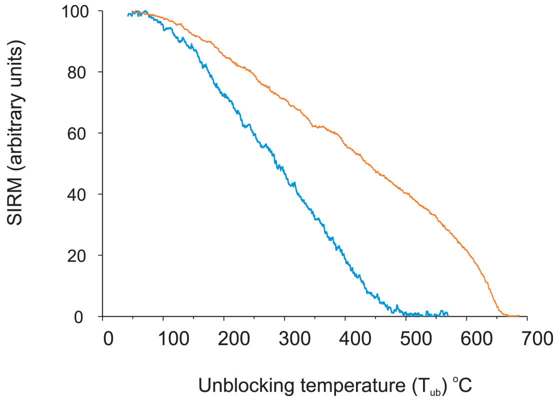

Fig. 3. Typical result of thermomagnetic analysis of carbonate rocks studied (blue curve). Example of thermomagnetic analysis of reddish carbonates from site WC (red curve); SIRM – saturation isothermal magnetization

The NRM shows a relatively low initial intensity, ranging typically between 0.1 and 10 mA/m. Multicomponent structure of the NRM was effectively separated only by thermal cleaning since the alternating field method (AF) failed, due to the overlapping coercivity spectra. At the lowest temperatures of demagnetization, all samples display soft, recently directed component demagnetized up to the 200-250°C. Subsequently, at higher temperatures of magnetic cleaning, various structures of the NRM were observed.

The simplest pattern of the magnetic record was documented at sites ML, NS, RA2 and RA3 where, after elimination of the soft component, only one component of the characteristic remanent magnetisation (ChRM) occurs. This component (B) is characterized by Tub in the 350-450°C range (Text-fig. 4a), NE-directed declination and shallow negative inclination (after tectonic correction). Directions for the B component at the above-mentioned sites were easily determined applying the PCA method (Table 1).

At most other sites, the magnetite record proved more complex because, in addition to the B component, there also is the other, A component, which is distinguished by Tub of 250-400°C, SE-directed declination and shallow negative inclination (prior to tectonic correction). Co-occurrence of the recently directed soft component followed by the reversed-po-

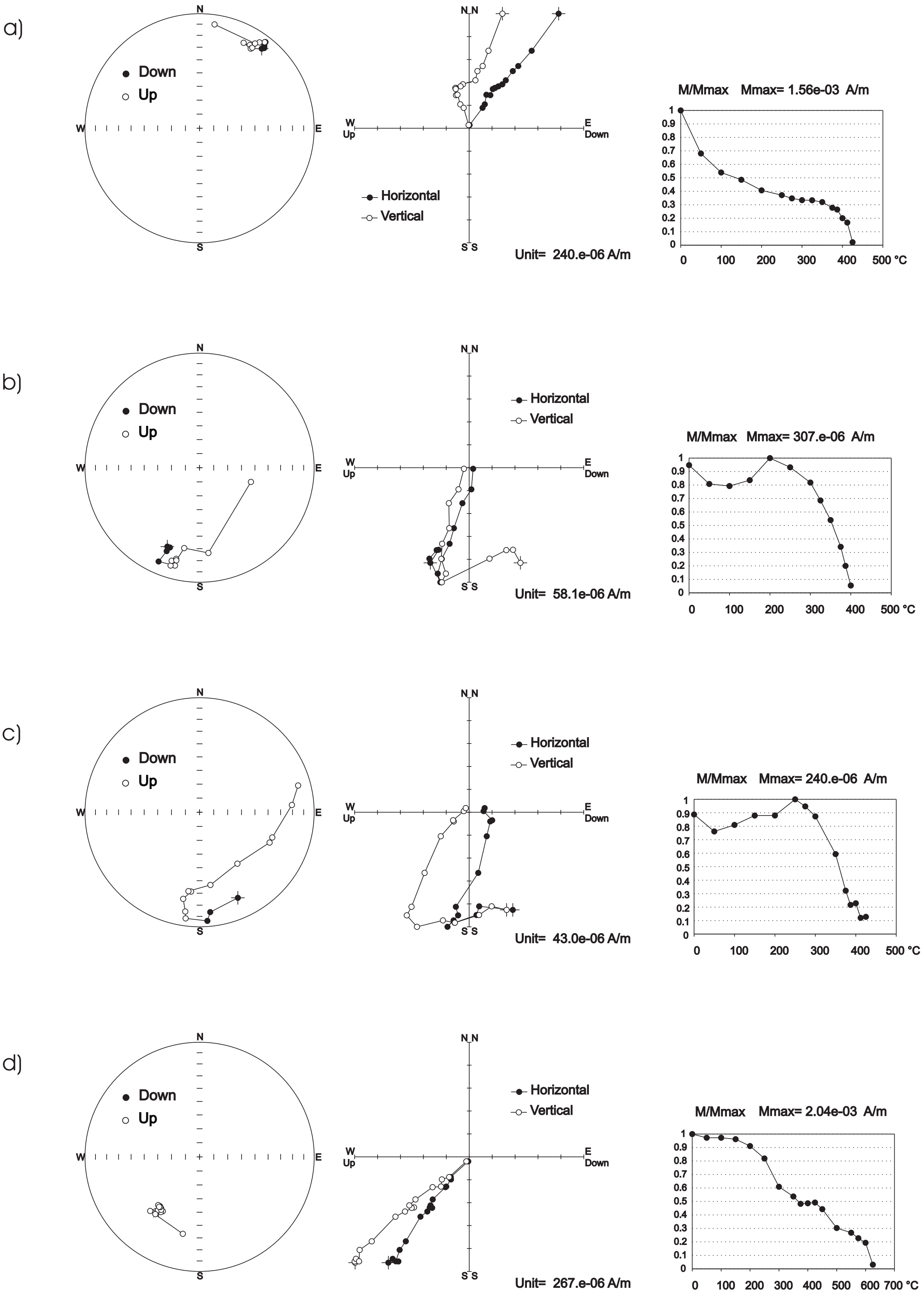

Fig. 4. Thermal demagnetization results of four representative specimens: (a) – after tectonic correction, (b, c, d) – *in situ* position

			A component				B component				AB GREAT CIRCLE
Site	**age**	**Dir/dip**	**D/I**	**k**	**α**	**N_1/n_1**	**D_c/I_c**	**k**	**α**	**N_1/n_1**	**D_{gc}/I_{gc}**
JB	Givetian	40/3	-		-	-	42/-6	292	4	6/12	-
NS	Frasnian	173/65	-		-	-	34/-2	33	11	7/12	-
ML	Givetian	200/10	-		-	-	33/-1	47	11	5/7	-
PI	Givetian	12/45	204/-13	21	21	4/7	–		–	-	202/66
RA 2	Givetian	353/84	-		-	-	28/-11	58	7	8/14	–
RA 3	Givetian	2/85	-		-	-	39/-16	59	8	7/11	-
SB	Frasnian	148/14	191/-16	104	5	9/17	-		–	-	111/44
WC	Frasnian	39/39	-		-	-	38/-21	82	9	5/13	306/9
WS	Givetian	60/25	203/-14	207	5	6/20	-		–	-	136/44
WY	Givetian	217/14	196/-18	62	8	7/8	–		–	-	116/19
			Average direction (4 sites) com. A, *in situ* position: **198.5/-15.5** k=164.4 α=7.2				Average direction (6 sites) com. B, 87% of unfolding: **35.6/-9.6** k=130.6 α=5.9				Results of HALLS's (1978) procedure: comp. **A** (*in situ*) **206.1/-14.4** comp. **B** (87% of unfolding) **37.3/-13.6**

Table 1. Paleomagnetic results. Dir/dip – tectonic orientation of strata, D/I – declination and inclination of site mean before tectonic correction, k, α – statistical parameters of site mean (sample level), N_1/n_1 ć number of samples/specimens used in calculations, D_c/I_c – declination and inclination of site mean after tectonic correction, D_{gc}/I_{gc} – orientation of the normal to the site mean great circle between the A and B components

larity A component and normal-polarity B component results in a spectacular demagnetization behaviour (Text-fig. 4b, c). At first, the magnetic vector migrates from recent directions towards intermediate A and B position accompanied by a decrease, in turn followed by an increase of the magnetic intensity. Then, after demagnetization of the soft component, the magnetic vector moves along the great circle between the A and B components. Strongly overlapping spectra of blocking temperatures and frequent thermochemical alteration at temperatures over 400°C meant that direct calculation of remanence directions (PCA) was not always possible. The A component was determined at sites SB, PI, WS and WY, the B component at sites

JB, ML, NS, RA2, RA3 and WC. For sites PI, SB, WC, WS and WY, great circles between the A and B components were determined (Table 1).

Within hematite-bearing rocks there is another ChRM component, C, which is characterized by high Tub (620°C), SW-declination and negative inclination. Its direction was determined at site RA1 (D = 220, I = -33, k = 40, α = 15, N = 4, n = 9), whereas at site WC, the occurrence of the C component was recognized only in a few hand samples. The structure of NRM described here is akin to that recorded by ZWING (2003). It is also worth noting that two of the sites studied (OS and WB) display very low values of NRM intensity as well as the occurrence of only the soft, recent component.

FOLD TEST AND RELATIVE AGE OF MAGNETIZATION

Determination of site mean directions (summarized in Table 1) allows fold tests to be carried out by applying the parameter estimation formulation procedure (WATSON & ENKIN 1993). The results of fold test for the B component show a maximum for k at 87% of unfolding with a 95% level of confidence between 81% and 94% of unfolding (Text-fig. 5). Results presented here indicate a synfolding origin for the B component since the 95% confidence interval does not include the 100% of unfolding. However, considering the proximity of the maximum k value to the prefolding position, the synfolding origin of the B component is not absolutely certain. Therefore, the author concludes that the B component was most probably acquired during the very early stages of deformation or prior to folding. Alternatively, results for the A component reveal its post-folding genesis since the maximum value of k was observed at –7% of unfolding and a 95% confidence level in the range of –24% to 9% includes the 0% of unfolding (Text-fig. 5).

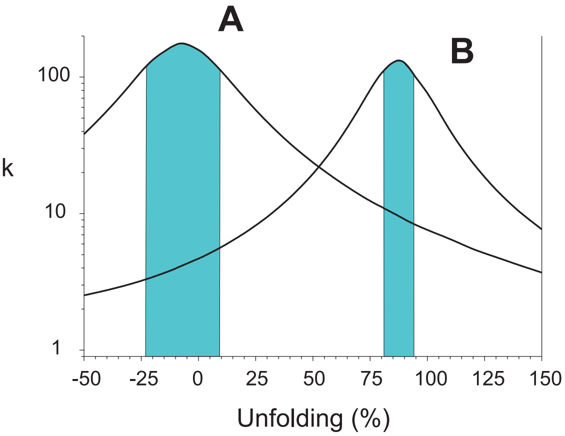

Fig. 5. Fold test results for the A and B components. Colour bars represent 95% confidence level, k – Fisherian precision parameter

Fold test results were used for calculation of average directions giving: D = 35.6, I = -9.6, k = 130.6, α = 5.9 (6 sites, 87% of unfolding) for the B component and D = 198.5 , I = -15.5 , k = 164.4, α = 7.2 (4 sites, *in situ* position) for the A component (Table 1). Paleomagnetic directions were also determined, utilizing the great circles between the A and B components. Firstly, the mean great circle for each individual site was calculated (Table 1). Then, all site mean great circles were evaluated applying HALLS's (1978) procedure after 0% and 87% of unfolding (Text-fig. 6). The paleomagnetic directions thus obtained (206.1/-14.4 for the A component and 37.3/-13.6 for the B component) are comparable to those derived from the PCA (Table 1). This is a strong argument in support of the reliability of results presented here.

The age of the A and C components was estimated by comparing paleolatitudes with the reference paleolatitude plot for the stable part of the continent (after TORSVIK & *al.* 1992, 1996). Paleolatitude data (Text-fig. 7) indicate an age of about 271-283 Ma (Early Permian) for the A component and around 222-274 Ma (i.e. early Late Triassic to Middle Permian) for the C component.

Paleolatitude data for the B component are considered to be inconclusive because the paleolatitude value is almost consistent with the reference curve during an extended time interval. There are, however, other data which allow to determine its age. The B component is of secondary origin, as described by ZWING (2003), who documented chemical remagnetization related to burial diagenesis of smectites. The age of the B component could be estimated as Visean, keeping in mind the position of its virtual geomagnetic pole (VGP) on the apparent polar wander path (APWP) for Baltica (Text-fig. 8). The Visean age of the B component also corresponds to its synfolding origin and normal polarity, it predating the onset of the Kiaman reversed polarity superchrone, ~312 Ma after GRADSTEIN & *al.* 2004).

GEODYNAMIC IMPLICATIONS AND DISCUSSION

VGPs of the A, B and C components are shown in Text-fig. 8. The VGP of the oldest component B is situated on the Visean segment of the apparent polar wander path (APWP) for Baltica (reference data after

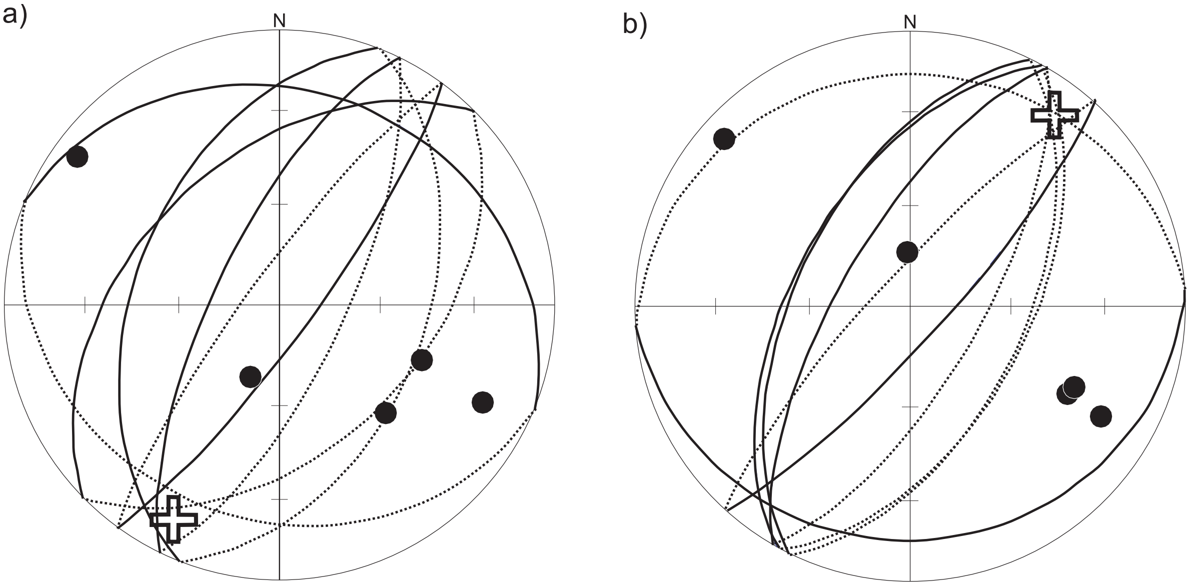

Fig. 6. Great circles analysis: (a) – results for the A component (0% of unfolding), (b) – results for the B component (87% of unfolding). Points represent normal to the site mean great circle, crosses show average characteristic directions calculated using HALLS's (1978) method

TORSVIK & *al*. 1992, 1996). The acquisition time of the early synfolding B component correlates with Visean deposits of the SHCM which record carbonate debris flows into a deep sedimentary basin, followed by basin shallowing associated with sedimentation of clayey-sandy deposits (SKOMPSKI 2006). This implies that such a sequence of geological events coincided with the very early stages of Variscan deformations or, most probably, just predated them.

The author suggests that the direction of the B component obtained by ZWING (2003) from the Kowala railroad cutting is not valid in view of the fact that the applied tectonic correction did not take into account that the studied second-order fold structures

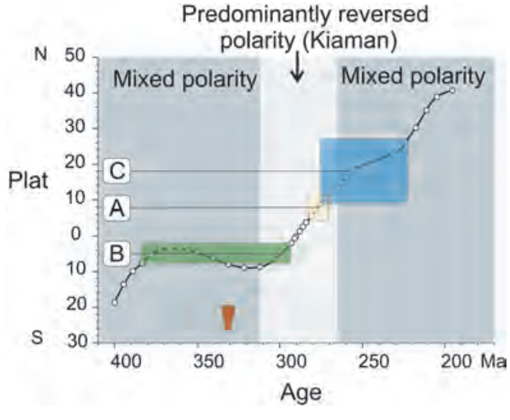

Fig. 7. Variation of paleolatitude during the Phanerozoic, calculated for HCM co-ordinates from the APWP for Baltica (calculated from data by TORSVIK & *al*. 1992, 1996) with paleolatitudes (horizontal lines) for the A, B and C components obtained in the present study. Horizontal bars represent error estimates for paleolatitude, defined as 2 × dp value (dp – semi-axis of the 95 % confidence ellipse along the great-circle path from site to pole). The solid triangle shows the age of the youngest Carboniferous deposits outcropping in the southern Holy Cross Mountains

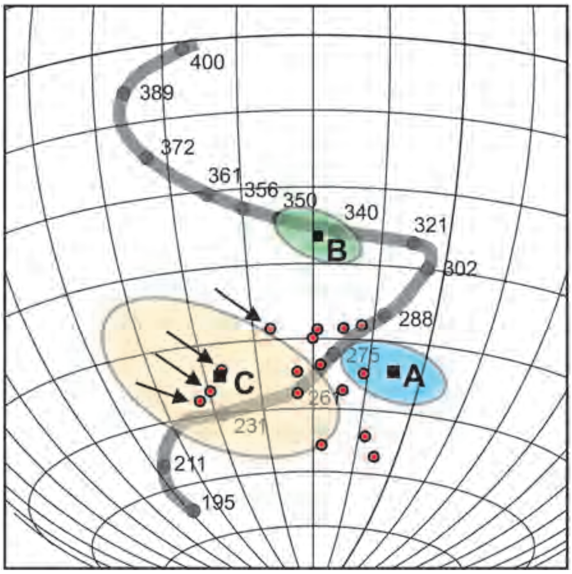

Fig. 8. Virtual geomagnetic poles of the A, B and C components with 95% confidence cones (blue, green and yellow, respectively) shown against a background of the apparent polar wander paths (grey line) for Baltica (southern pole). Red dots represent the Permian reference poles (after TORSVIK & *al*. 1992), arrows denote poles derived from Arendal diabases and Ytteroy dyke (see text for explanations)

belong to the southern limb of the map-scale Gałęzice syncline. This section also records intensive synsedimentary deformations which may have an impact on fold test results. Moreover, the Kowala railroad cutting does not appear to be representative of the SHCM, since strata in this area represent a deviant E-W to SW-NE tectonic trend which is most probably the result of local faulting.

In the present study, the most important outcome obtained for the B component is that its direction does not show any rotations with regard to the reference APWP (Text-fig. 8). This implies that the SHCM, and thus the entire MM, occupied a stable position with respect to the EEC at least since the Visean. This conclusion is in line with data suggesting an Early Palaeozoic date for the MM accretion (e.g. BEŁKA & *al*. 2000).

The VGP of the A component is situated very close to the 278 Ma segment of the APWP. The small counter-clockwise deviation (about 8°) of this pole could be explained as a result of statistical errors in the A pole and APWP determination. However, this rotation appears to be significant keeping in mind the common rotations of Permian VGPs observed in the HCM (LEWANDOWSKI 1993; GRABOWSKI & *al*. 2006), in the Kraków area (NAWROCKI & *al*. 2005) and in the Sudetes (NAWROCKI 1998; JELEŃSKA & *al*. 2003). Such a position of VGPs derived from the area situated southwest of the TESZ has been interpreted to be the result of small-scale counter-clockwise rotations during the Permian (NAWROCKI 1998; JELEŃSKA & *al*. 2003; NAWROCKI & *al*. 2005; GRABOWSKI & *al*. 2006) or during Alpine deformations (LEWANDOWSKI 1993).

The author proposes an alternative explanation of these data, assuming an inaccuracy in APWP determination. The Permian APWP is defined as a mean of relatively distant VGPs (TORSVIK & *al*. 1992; Text-fig. 8). The VGP of the A component corresponds to most reference Permian VGPs. There is, however, a population of SW-located reference VGPs which displace the Permian segment of the APWP curve westwards (Arendal diabases, Ytteroy dyke; HALVORSEN 1972; TORSVIK & *al*. 1989). It is suggested here that the latter population is not representative and thus the VGPs from MM, the Upper Silesian Massif and the Sudetes match reference VGPs from the EEC.

The direction of the A component separated by ZWING (2003), together with other results from the westernmost parts of the SHCM (e.g., LEWANDOWSKI 1981; GRABOWSKI & NAWROCKI 1996), reveals a different, clockwise sense of rotations. The author suggests that such rotations have a local character only. This could be linked to locally more intensive Maastrichtian-Paleocene deformations of the westernmost edge of the Paleozoic. The author also puts forward that rotations observed within the NHCM (GRABOWSKI & NAWROCKI 2001) result from only local block tectonics as well.

The above-mentioned A component results of ZWING (2003) at Śluchowice quarry reveal the same negative result of fold test as the one obtained in the present study but differs in the value of inclination. This could be seen to be the result of improper unfolding procedure which failed to consider that the studied metre-scale folds belong to the vertical southern limb of the map-scale Niewachlów Anticline. The author suggests that such a vertical limb of the main fold was slightly tilted during Maastrichtian-Paleocene reactivation, which changed the inclination results but did not influence the fold test performed within metre-scale Variscan structures.

The present study was carried out within representative folds all over the SHCM. The results indicate that the A component of Early Permian age postdates the main map-scale folds in the SHCM and constitutes the time limit of the main Variscan deformations. This also indicates that the Maastrichtian-Paleocene reactivation did not influence the general shape of Variscan structures in the internal portions of the Paleozoic substrate.

The results for the C component are in line with previous data (SZANIAWSKI 1997; ZWING 2003) and confirm the absence of extensive rotations and important changes in the geometry of Variscan fold structures during Maastrichtian-Paleocene reactivation. All observations also substantiate the model of remagnetization triggered by oxidizing, meteoric fluids that penetrated carbonate rocks during an episode of Permo-Triassic karstification (SZANIAWSKI 1997; ZWING 2003).

GEODYNAMIC CONCLUSIONS

The Małopolska Massif has not changed its position with respect to the EEC at least since the Visean.

The early phases of Variscan folding already started during the Visean, whereas the main Variscan fold structures were completed in early Permian times.

Representative kilometre-scale Variscan folds in the SHCM did not significantly change their geometry during Maastrichtian-Paleocene reactivation.

It is suggested that the westernmost Paleozoic of the SHCM was subject to more intensive Maastrichtian-Paleocene deformations than the internal portions studied.

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