Multiple remagnetizations in the Devonian carbonates in the northwestern part of the Kielce region (Holy Cross Mts., southern part)

Givetian dolomites from Laskowa and Frasnian limestones from Kostomloty (NW part of the Kielce region, Holy Cross Mts., southern part) were the subject of palaeomagnetic study. Post-folding age of characteristic remanent magnetization was confirmed at Kostomloty and two new Late Carboniferous and Early Permian components were revealed that had not been described in the previous palaeomagnetic studies. The two components of magnetization in Laskowa dolomites are also most probably (fold test has not been applied) of Late Carboniferous-Early Permian age. Their acquisition was slightly shifted in time in relation to those of Kostomloty limestones. The age of remagnetization is estimated as 315–275±10 Ma. Thermoviscous burial magnetization can not be unambiguously identified. A link between multicomponent remagnetization and Late Variscan ore mineralization is tentatively suggested. All palaeomagnetic poles from the investigated area are matched with the reference European apparent polar wander path after ±4.6° counter-clockwise intra-block rotation. This implies that the area was affected by Early Permian or later tectonic movements which modified the direction of the Late Carboniferous fold structures.

INTRODUCTION

Palaeomagnetic studies of Devonian and Carboniferous carbonate rocks were carried on by M. Lewandowski (1981, 1985). The author established, that the fold structures in the Holy Cross Mts. originated mainly during Variscan diastrophic cycle and the palaeomagnetic poles of characteristic components of magnetization roughly coincide with the apparent polar wander path (APWP) for Eurasia. However, the progress of analytical methods in palaeomagnetism and accumulation of new data (M. Lewandowski, 1993; J. Nawrocki, 1993) during last decade caused that some informations and conclusions presented in the older papers should be reinterpreted.
One of the problems was the mechanism and age of remagnetization of the Frasnian limestones cropping out at the “Kostomłoty” quarry. The Kostomłoty limestones revealed very consistent post-folding magnetization (M. Lewandowski, 1981). The palaeomagnetic pole (DS6) corresponded well with the inferred palaeomagnetic pole position for European Platform for 350 Ma (M. Lewandowski, 1993). This time of remanence acquisition (Tournaisian/Viséan boundary) was obviously too early, because the main Variscan unconformity in the Holy Cross Mts. occurs above the Upper Viséan, i.e. not earlier than 333 Ma and there is no geological evidences for the onset of folding already in Tournaisian. M. Lewandowski (1981, 1985) did not consider the possible mechanisms of remagnetization. According to Z. Belka (1990) the carbonate rocks in the Kostomłoty area reveal one of the highest CAI values in the Holy Cross Mts. Thus it would be possible that the Kostomłoty limestones acquired their remanence due to a thermal event of magnitude 150–200°C, related to burial and higher than contemporary heat flow regime during the Variscan orogeny (Z. Belka, op. cit). However, preliminary palaeomagnetic data from equally heated rocks (CAI = 3–3.5) in the neighbouring “Laskowa” and “Mogiiki” quarries (J. Grabowski et al., 1994) revealed well defined characteristic components which significantly deviate from the DS6 direction of M. Lewandowski (1993) from Kostomłoty (the results were presented at the EUROPROBE meeting at Kielce, 1994, at the poster session). Therefore the urgent need emerged to solve the following problems:

1. What is the real age of magnetization of the Kostomłoty limestones?
2. How was the thermal event recorded by palaeomagnetism and what were the other possible origins of remagnetization?

In this study the revision of palaeomagnetism of Kostomłoty limestones, and new data from Laskowa dolomites are presented.

GEOLOGICAL SETTING AND SAMPLING

The Holy Cross Mts. is the horst of Palaeozoic rocks emerging from below the Mesozoic cover. The area was uplifted and exposed mainly due to vertical movements at the end of Cretaceous and in the Miocene (J. Kutek, J. Glazek, 1972). Palaeozoic core consists of two distinct tectono-stratigraphic units (the northern — Łysogóry region and the southern — Kielce region; Fig. 1), separated by a major Holy Cross Fault (for details see M. Szulczewski, 1977; E. Stupnicka, 1992).

Middle-Upper Devonian carbonate rocks in the southern region of the Holy Cross Mts. are the part of a syn-Variscan structural unit. The Emsian clastic sedimentation started after tectonic movements, uplift and erosion in the Late Silurian/Early Devonian. Afterwards a carbonate platform developed with variable littoral, reef and basinal facies (M. Szulczewski, 1977). The epigenetic dolomitization phenomena also took place (M. Narkiewicz, 1991). In the Early Carboniferous pelagic sediments prevailed, in the Late Viséan they were replaced by thick clastic deposits. After the Viséan the region was folded and uplifted. Flat lying or gently dipping Permian conglomerates covered the Palaeozoic structure.

The sampled localities are situated in the northwestern part of the Kielce region (Fig. 1). They belong to the westernmost termination of the great Kielce–Łagów Synclinorium, just south from the Holy Cross Fault. This is the area of most prominent fold structures
Multiple remagnetizations in the Devonian carbonates...

Fig. 1. Geological sketch of the investigated area (after S. Salwa, 1995, modified): A — general position of the Holy Cross Mts. (HCM), B — tectonic division of the Palaeozoic core of the HCM (little box indicates the area pictured in Fig. 1C), C — geological sketch map of the Kostomłoty Hills

developed during the Variscan movements (i.e. Kostomłoty) and the highest degree of thermal alteration (CAI = 3–3.5). In the western part of the Kielce–Łagów Synclinorium the occurrence of ore minerals (zinc, lead and copper compounds) are known. The mineral deposits were exploited in XV–XIX centuries. According to Z. Rubinowski (1971) there were two main phases of mineralization. The older “Variscan” was terminated before the deposition of Upper Permian conglomerates started. The younger phase is regarded as post-Triassic related to syn-Alpine tectonic events (Z. Rubinowski, op. cit.). The region is cut by NW–SE trending faults which disturb the WNW–ESE facing Variscan tectonic structures and down-thrust the Palaeozoic rocks to the west, where they disappear under the Mesozoic cover.
**Table 1**

Description of sampled localities

<table>
<thead>
<tr>
<th>Locality</th>
<th>Lithology</th>
<th>Tectonic position*</th>
<th>Number of samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kostomloty</td>
<td>dark limestones</td>
<td>16/52, 6/12, 145/15, 190/22, 10/70</td>
<td>8</td>
</tr>
<tr>
<td>Laskowa</td>
<td>dark dolomites (epigenetic)</td>
<td>355/40</td>
<td>10</td>
</tr>
</tbody>
</table>

* strike/bedding dip

**LABORATORY METHODS**

Natural remanent magnetization (NRM) was measured by means of the JR-5 spinner magnetometer. The rock specimens were thermally demagnetized with the MMTD oven. Alternating field (AF) demagnetization was carried out using a device produced at the Institute of Geophysics, Polish Academy of Sciences. Characteristic directions were calculated mainly using the principal component analysis (J. Kirschvink, 1980), but other methods (stable end vector, differential vectors) were also applied. Magnetic susceptibility was monitored with KLY-2 bridge. Magnetic minerals were identified with thermomagnetic analysis. It consisted of thermal demagnetization in nonmagnetic space of isothermal remanence (IRM) acquired in the field of about 0.1 T (the first curve in appropriate Figs. 3a and 4a). Then the sample was cooled, magnetized and demagnetized again (the second curve in the Figs. 3a and 4a). This method gives values of blocking temperatures of magnetic minerals and shows what new minerals originate in the rock due to its heating in the air (J. Kruczyk et al., 1995).

**CONSTRUCTION OF THE REFERENCE APWP**

Reference European APWP for Devonian-Permian periods was constructed using mean palaeopoles calculated by R. Van der Voo (1993, tab. 5.1) and calibrated according to A. R. Palmer’s (1983) time scale. The calculation and smoothing of the path was done with the GMAP for Windows program (T. H. Torsvik, M. A. Smethurst, 1994), with smoothing parameter 100. The obtained reference curve, together with the data is shown in Figure 2. The relatively large error of the curve is observed within its Early Devonian-Middle Carboniferous segment, while the Late Carboniferous-Triassic segment is better defined. The dating of characteristic components was performed by comparing the palaeomagnetic pole with estimated age of calibrated segment of the APWP. The age estimation error should be about 10 Ma for Late Carboniferous-Early Triassic directions but it amounts to 35 Ma for Middle Devonian-Middle Carboniferous components.
Thermomagnetic analyses revealed that the magnetic minerals had maximum blocking temperature 500–550°C (Figs. 3a, 4a), which was tentatively interpreted as characteristic for magnetite, although these temperatures are lower than the Curie temperatures for that mineral. It can not be excluded, that another magnetic minerals such as pyrrhotite and maghemite could also contribute to the NRM. However, there was no reliable method at authors disposal to identify these minerals. Obviously goethite and hematite do not occur in the investigated rocks, because kinks at the Curie temperatures characteristic for these minerals (100–200°C for goethite and 680°C for hematite) are not observed at the thermomagnetic curves. During thermal treatment secondary magnetite originate, as can be seen from the shape of the second heating curves and large increase of the IRM intensity after the first heating (Figs. 3a, 4a).
Magnetic susceptibility amounts to $100-160 \cdot 10^{-6}$ SI units at Kostomłoty and Laskowa. The mineralogy of investigated carbonates differs between localities in some details, because the production of secondary magnetite, as inferred from the increase of magnetic
Multiple remagnetizations in the Devonian carbonates...

Fig. 4. Rock magnetic properties of the Laskowa dolomites
a — thermomagnetic analysis, b — changes of magnetic susceptibility \( k \) during thermal demagnetization; other explanations as in Fig. 3

Własności petromagnetyczne dolomitów z Laskowej
a — analiza termomagnetyczna, b — zmiany podatności magnetycznej \( k \) podczas rozmagnesowania termicznego; pozostałe objaśnienia jak na fig. 3

susceptibility in Kostomłoty limestones, is observed already at 375°C, while in Laskowa it occurs between 450 and 500°C (Figs. 3b, 4b). A peculiar feature is a dramatic decrease of magnetic susceptibility in the temperature range 250–425°C in many specimens from Laskowa. That could be attributed to goethite dehydration (J. Kruczyk et al., 1995), however, in the investigated carbonates that mineral apparently does not occur. Another
Geographical position. Fitted lines of sample: koc1 5°

**Sample koc1 005**

<table>
<thead>
<tr>
<th>RANGE</th>
<th>D</th>
<th>I</th>
<th>INT</th>
<th>A.S.D</th>
</tr>
</thead>
<tbody>
<tr>
<td>60 TO 525</td>
<td>211.3</td>
<td>13.8</td>
<td>.082</td>
<td>9.4</td>
</tr>
</tbody>
</table>

Geographical position. Fitted lines of sample: koc1 5°

**Sample koc1 005**

<table>
<thead>
<tr>
<th>RANGE</th>
<th>D</th>
<th>I</th>
<th>INT</th>
<th>A.S.D</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 TO 350</td>
<td>213.3</td>
<td>3.6</td>
<td>.027</td>
<td>6.1</td>
</tr>
</tbody>
</table>
Multiple remagnetizations in the Devonian carbonates...

explanation of this phenomenon could be a conversion of maghemite to hematite. That process occurs at temperature above 350°C (F. D. Stacey, S. K. Banerjee, 1974) and may result in decrease of magnetic susceptibility: the spontaneous magnetization of maghemite is about 100 times greater than that of hematite (F. D. Stacey, S. K. Banerjee, op. cit.). If the occurrence of maghemite as a natural magnetic carrier in the investigated carbonates could be proved, it would be of great importance for interpretation of characteristic magnetizations. Maghemite is always a secondary mineral originating by slow oxidation of magnetite in temperature 150–250°C (F. D. Stacey, S. K. Banerjee, op. cit.). However, it cannot be excluded that maghemite in our samples originated in the laboratory during thermal demagnetization.

DEMMAGNETIZATION RESULTS

KOSTOMŁOTY

The NRM intensities range from 5.03 to 20.3 · 10⁻⁴ A/m. Thermal and alternating field demagnetization methods were applied. The best results were obtained using combined both methods: up to 50 mT with AF and then thermally up to 350–370°C (Fig. 5). A very soft, randomly oriented component was removed between 0 and 5 mT. This is probably a viscous component of no further significance. Afterwards a KS1 component emerged, which was demagnetized mostly in the ranges of 5–50 mT and 250–300°C. After demagnetization to 50 mT usually 20–30% of the initial NRM intensity was left, what indicated the presence of other high coercivity components. Indeed, thermal demagnetization revealed two other components: KS2 and KS3 of blocking temperatures 200–350°C and above 350°C, respectively. All three components are post-folding because the cluster of characteristic direction is much better before unfolding of the beds (Tab. 2, 3). The values of the k parameter are

Fig. 5. Demagnetization of the Kostomłoty limestone (before tectonic correction): a — alternating field demagnetization, b — further thermal demagnetization of the same specimen

1 — stereographic projection of the demagnetization path: black (open) symbols — lower (upper) hemisphere directions, bigger symbol — NRM direction; 2 — intensity decay curve: Inrm — the intensity of the NRM, Mrm — the intensity of the remanent magnetization after thermal treatment; 3 — orthogonal projection (Zijderveld diagram): x, y, z — planes of projection, bigger symbols — the NRM components, one unit is 10⁻⁴ A/m; RANGE — temperature or alternating field interval of calculated line, D — declination, I — inclination, INT — intensity (x10⁻² A/m), A.S.D. — angular standard deviation of the best fitted line

Rozmagnesowanie wapieni z Kostomłotów (układ przed korekcją tektoniczną): a — rozmagnesowanie polem zmiennym, b — dalsze rozmagnesowanie termiczne tej samej próbki co w a)

1 — projekcja stereograficzna ścieżki rozmagnesowania; symbole pełne (puste) — projekcja na dolną (górna) półsfere, symbol większy — kierunek naturalnej pozostałości magnetycznej (NRM); 2 — krzywa spadku natężenia podczas rozmagnesowania: Inrm — natężenie NRM, Mrm — natężenie pozostałości magnetycznej po wygrzaniu; 3 — projekcja ortogonalna (diagram Zijdervelda): x, y, z — płaszczyzny projekcji, symbole większe — składowe NRM, jedna jednostka na osi — 10⁻⁴ A/m; RANGE — przedział temperatury lub zmiennego pola magnetycznego dla wyróżnionej linii (kierunku), D — deklinacja, I — inklinacja, INT — natężenie (x10⁻² A/m), A.S.D. — kątowe odchylenie standardowe linii najlepszego dopasowania
Table 2

Characteristic directions from the Kostomłoty limestones (Frasnian), before tectonic correction

<table>
<thead>
<tr>
<th>Component</th>
<th>$D$</th>
<th>$I$</th>
<th>$\alpha_{95}$</th>
<th>$k$</th>
<th>Pole</th>
<th>$n/N$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>lat. S</td>
<td>long. E</td>
</tr>
<tr>
<td>KS1</td>
<td>220</td>
<td>8</td>
<td>4.2</td>
<td>42.1</td>
<td>-25</td>
<td>336</td>
</tr>
<tr>
<td>KS2</td>
<td>219</td>
<td>-8</td>
<td>3.3</td>
<td>65.2</td>
<td>-33</td>
<td>333</td>
</tr>
<tr>
<td>KS3</td>
<td>216</td>
<td>-24</td>
<td>5.1</td>
<td>26.3</td>
<td>-42</td>
<td>331</td>
</tr>
</tbody>
</table>

$D, I$—declination and inclination of palaeomagnetic direction, $\alpha_{95}, k$—Fisher statistics parameters, $n/N$—number of specimens/samples used for the calculation of the mean direction.

Table 3

Characteristic directions from the Kostomłoty limestones (Frasnian), after tectonic correction

<table>
<thead>
<tr>
<th>Component</th>
<th>$D$</th>
<th>$I$</th>
<th>$\alpha_{95}$</th>
<th>$k$</th>
<th>Pole</th>
<th>$n/N$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>lat. S</td>
<td>long. E</td>
</tr>
<tr>
<td>KOS1</td>
<td>227</td>
<td>22</td>
<td>12.0</td>
<td>5.9</td>
<td>-16</td>
<td>333</td>
</tr>
<tr>
<td>KOS2</td>
<td>224</td>
<td>7</td>
<td>11.4</td>
<td>6.3</td>
<td>-24</td>
<td>332</td>
</tr>
<tr>
<td>KOS3</td>
<td>219</td>
<td>-10</td>
<td>11.7</td>
<td>5.8</td>
<td>-34</td>
<td>332</td>
</tr>
</tbody>
</table>

Explanations as in Table 2

4–10 times higher before tectonic correction, thus the simple fold test of M. W. McElhinny (1973) is sufficient for establishing the age of remanence.

It should be noted that thermal demagnetization alone does not enable to separate the KS1 and KS2 components. These components have overlapping blocking temperature spectra but different coercivities. Combined alternating field and thermal cleaning is needed for identification of all components.

LASKOWA

Most of the NRM intensities range between 1 and $5.51 \cdot 10^{-3}$ A/m. Thermal demagnetization was applied to bulk of collection (Fig. 6). Single specimens were demagnetized using AF or combined method. These methods, however, did not lead to good separation of characteristic components, as in the previous locality. Usually about 10% of the initial NRM intensity was left after demagnetization up to 50 mT.

The soft, viscous component is removed between 20 and 300°C. The LS1 component (Tab. 4, 5) occurs in most of samples and it constitutes the main part of the NRM. It is demagnetized between 250 and 400°C. The LS2 component, almost anti-parallel to the LS1, reveals the blocking temperature spectrum 400–500°C.
Although the sampling localities were not very distant from each other (1 km only) and they belong to the same tectonic structure (southern limb of the Miedziana Góra Syncline), considerable variety of characteristic directions is observed.

Post-folding age of remanence could be established at Kostomłoty because only there a fold test could be performed. The KS1 component is identical to the DS6 component of M. Lewandowski (1993) and its pole is situated exactly on the reference APWP near an inferred date 350 Ma (Fig. 7a). Palaeopoles KS2 and KS3 lie to the NW from the Permian sector of the European APWP. Their age must be of Early Permian, because inclination of KS2 and KS3 components corresponds to the expected Early Permian inclination of the area. After counter-clockwise rotation of $13\pm 4.6^\circ$ around a vertical axis situated in the sampling locality, the KS2 and KS3 components are matched with the reference path with
Table 4

Characteristic directions from the Laskowa dolomites (Givetian), before tectonic correction

<table>
<thead>
<tr>
<th>Component</th>
<th>$D$</th>
<th>$I$</th>
<th>$\alpha_{95}$</th>
<th>$k$</th>
<th>Pole</th>
<th>n/N</th>
</tr>
</thead>
<tbody>
<tr>
<td>LS1</td>
<td>213</td>
<td>-10</td>
<td>4.4</td>
<td>39.5</td>
<td>-36</td>
<td>338</td>
</tr>
<tr>
<td>LS2</td>
<td>34</td>
<td>16</td>
<td>5.0</td>
<td>42.9</td>
<td>-36</td>
<td>335</td>
</tr>
</tbody>
</table>

Explanations as in Table 2

Table 5

Characteristic directions from the Laskowa dolomites (Givetian), after tectonic correction

<table>
<thead>
<tr>
<th>Component</th>
<th>$D$</th>
<th>$I$</th>
<th>$\alpha_{95}$</th>
<th>$k$</th>
<th>Pole</th>
<th>n/N</th>
</tr>
</thead>
<tbody>
<tr>
<td>LS1</td>
<td>216</td>
<td>19</td>
<td>4.3</td>
<td>40.4</td>
<td>-22</td>
<td>342</td>
</tr>
<tr>
<td>LS2</td>
<td>34</td>
<td>-14</td>
<td>5.3</td>
<td>39.1</td>
<td>-25</td>
<td>343</td>
</tr>
</tbody>
</table>

Explanations as in Table 2

the inferred dates 305 and 275 Ma, respectively (Fig. 7c). The same rotation applied to the KS1 pole matches it with the 316 Ma pole of the reference curve (Namurian/Westphalian boundary).

The age of magnetization at Laskowa has to be established by comparison with the reference APWP only. Poles LS1 and LS2 after tectonic correction falls near the date 336 Ma (Fig. 7b). However, it must be born in mind that they should be subjected to rotation around the vertical axis, the same as was applied to the post-folding Kostomloty poles. It is authors presumption that the rock formations in Laskowa did not stay fixed while rotation was taking place 1 km to the east at Kostomloty. After that rotation the pre-folding LS1 and LS2 poles would be situated well outside the reference curve. One could argue that the Devonian-Middle Carboniferous segment of the European APWP is poorly defined (see Fig. 2) and the pre-folding age of LS1 and LS2 cannot be totally rejected. However, post-folding age of these components seems more probable. Before tectonic correction the poles are situated between the post-folding KS2 and KS3 poles (Fig. 7a) and the counter-clockwise rotation of 13° around the vertical axis matches them with the Early Permian segment of the reference curve (Fig. 7c) at 300 (LS1) and 285 Ma (LS2). They become also very similar to a pole of the A direction of J. Nawrocki (1993) obtained from remagnetized carbonates in the Cracow region and synchronous with intrusions of Lower Permian volcanites in the area.
Fig. 7. Palaeomagnetic poles obtained in this study at the background of the reference APWP for Europe (ages in Ma): a — all poles before tectonic correction, b — poles KS1–KS3 before tectonic correction, poles LS1, LS2, after tectonic correction, c — all poles before tectonic correction, rotated 13° counter-clockwise around the local vertical axis.

Note the good agreement of the post-folding poles with the Late Carboniferous/Permian segment of the reference APWP.

Bieguny palaeomagnetyczne opisane w artykule na tle pozornej wędrówki paleobieguna dla Europy (wiek w milionach lat): a — wszystkie bieguny przed korekcją tektoniczną, b — bieguny KS1–KS3 przed korekcją tektoniczną, bieguny LS1 i LS2 po korekcji tektonicznej, c — wszystkie bieguny przed korekcją tektoniczną, zrotowane o 13° przeciwnie do ruchu wskazówek zegara wokół lokalnej osi pionowej.

Zwraca uwagę dobra zgodność biegunów pośfaldowych z późnokarbońsko-permskim odcinkiem krzywej referencyjnej.

**GEOLOGICAL IMPLICATIONS**

The studied Middle-Upper Devonian dolomites and limestones revealed secondary magnetizations of post-folding (Late Carboniferous/Early Permian) age in Kostomłoty and
The remagnetization phenomena were distributed in time and space. Thermoviscous magnetization that should originate during Variscan burial and uplift event (Z. Belka, 1990) can not be unambiguously identified because several secondary components are superposed. Chemical remagnetization should also be postulated, related to Pb–Zn–Cu mineralization events, hydrocarbons migration or magnetite authigenesis due to migration of meteoric waters (C. McCabe, R. D. Elmore, 1989; R. D. Elmore et al., 1993). Determining of the mechanism of remagnetization requires more detailed mineralogic and rock magnetic investigations. A causal link between remagnetization and ore mineralization could be tentatively suggested in the light of recent report of S. Salwa (1995). According to this author the Kostomłoty quarry is a “type locality” of occurrence of Variscan calcite mineralization related to hydrothermal copper-polymetallic formation. Indeed he mentions paragenesis of calcite with pyrite, marcasite, quartz, copper sulphides, barite, dolomite, zinc and lead sulphides (S. Salwa, op. cit.) It is possible that the same mineralized fluids caused magnetite authigenesis. Z. Rubinowski (1971) accounts for relation of ore magnetization to lamprophyre intrusions in the Kielce region. Similarity of palaeomagnetic poles from Kostomłoty (KS2) and Laskowa (LS1 and LS2) to A pole of J. Nawrocki (1993) could indicate that these remagnetizations were synchronous with the Lower Permian intrusions of volcanites in the Cracow region. Thus the origin of remagnetization in Kostomłoty and Laskowa could be different than that occurring in North American mid-continent, where remagnetization is related to a Zn–Pb–Ba Mississippi-type ore formation and migration of mineralized brines (C. M. Bethke, S. Marshak, 1990).

Late Carboniferous/Early Permian directions from Kostomłoty and Laskowa are rotated and 13 ± 4.6° counter-clockwise rotation is needed to match them with expected “European” directions. A tectonic rotation responsible for that discrepancy might have taken place in the Mesozoic, for example during the syn-Alpine uplift of the Palaeozoic core. Examples of tectonic deformations of that age are common in the western part of the Holy Cross Mts.: no more than 5 km to the west from Kostomłoty (Chelmce Anticline) a Palaeozoic rocks crop out with fault contacts from beneath the rocks of Mesozoic cover (J. Czarnocki, 1938). Recently J. Kutek (1995) postulated that the Holy Cross Fault acted in the Jurassic and Cretaceous as a strike-slip fault. Thus some rotational movements in its close vicinity are not unlikely. Restoration of Laskowa and Kostomłoty fold structures to its Early Permian position results in changing of present WNW–ESE tectonic trends to W–E. It is still not possible to establish if the rotation was of local or regional character. Available palaeomagnetic data from the Permian of the Holy Cross Mts. (listed in the paper of M. Lewandowski, 1993) are scarce and its accuracy is too low (α95 = 15–20°) to use them for evaluating subtle tectonic rotation. It is interesting that recently J. Kruczyk et al. (1995) described similar amount of rotation (15° clockwise) from the Jurassic rocks of the Mesozoic cover, south from the Palaeozoic core of the Holy Cross Mts., and estimated its age as Oligocene-Miocene.

CONCLUSIONS

1. Middle–Upper Devonian carbonate rocks from the NW part of the Kielce region (Kostomłoty and Laskowa) reveal post-folding magnetizations of Late Carboniferous/Early
Multiple remagnetizations in the Devonian carbonates...

Permian age (ca. 315–275 Ma). Magnetite seems to be the main magnetic carrier but the presence of maghemite or pyrrhotite is also possible.

2. A tectonic rotation (13±4.6° clockwise) in the Kostomloty and Laskowa area took place after Early Permian.

3. Late Carboniferous/Early Permian secondary components could be thermoviscous as well as chemical remagnetizations. The latter are possibly related to copper-polymetallic ore mineralization.

Acknowledgements. The authors wish to thank Prof. M. Szulczewski and Dr. S. Skompski (both Institute of Geology, Warsaw University) for helpful discussion and field guidance.

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REFERENCES


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ZŁOŻONE PRZEMAGNESOWANIE WĘGLANOWYCH SKŁA DWONU
W NW CZĘŚCI REGIONU KIELECKiego GÓR ŚWIĘтокrzYSKICH

Streszczenie

Przedmiotem analizy paleomagnetycznej były skały węglanowe środkowego i górnego dewonu z południowo-zachodniej części regionu kieleckiego Gór Świętokrzyskich. Oprobowano skały z kamieniołomu „Laskowa” (dolomity żywna) i „Kostomłoty” (wapienie francu). W wapieniach kostołockich potwierdzono istnienie pofaladowego przemagnesowania wieku późnokarbońskiego (składowa KS1). Stwierdzono też obecność dwóch młodszych składowych namagnesowania (KS2, KS3) wieku późny karbon-wczesny perm, które nie były opisywane w poprzednich pracach paleomagnetycznych. W kamieniołomie „Laskowa” nie przeprowadzono testu fałdowego, jednak kierunki charakterystyczne uzyskane z dolomitów żywnych (składowe LS1 i LS2) są podobne (choć nie identyczne) do otrzymanych w Kostomłotach. Można z dużym prawdopodobieństwem przyjąć, że są to również pofaladowe przemagnesowania wieku późny karbon-wczesny perm. Mechanizm przemagnesowania pozostaje niejasny. Najprawdopodobniej niektóre ze składowych są związane z półnowarczyjskim wydarzeniem termicznym, które spowodowało przeobrażenie materiału organicznego w konodontach — wskaznik zmian barwy konodontów wskazuje na podgrzanie skal do 150–200°C. Wydarzenie to jest wśród geologów interpretowane jako efekt pogrzebania skala dewońskich pod nakładem karbonu i zwiększającego wypływu ciepła podczas orogenezy warszyckiej. Jednak zgodnie z takim modelem, jednolite przemagnesowanie powinno występować w skalach regionalnej. Tymczasem w kamieniołomach odległych od siebie zaledwie o jeden kilometr występuje kilka różnych przemagnesowań utrwalonych między 315 i 275±10 mln lat. Nie negując możliwości, że niektóre z nich mogły utrwałać się w wyniku pogrzebania i wypiętnienia Gór Świętokrzyskich w późnym paleozoiku, należy rozpatrzeć też inne możliwe przyczyny przemagnesowania. Jedną z nich mogła być cyrkulacja roztworów hydrotermalnych, które doprowadziły do powstania złoże miedzi (formacja miedziowo-polimetaliżyczna) eksploatowanych m. in. w pobliskiej Miedzianej Górze. Wiek tej mineralizacji oceniany jest właśnie jako późnowarczyjski, wcześniejszy od sedimentacji permskiej złeśnicza zygmunckowskiego. W kamienioło-
mie „Kostomloty” opisano niedawno przejawy mineralizacji kalcytowej w paragenezie z pirytem, markasytem, kwarcem, siarczkami miedzi, cynku i ołowiu oraz barytem.

Bieguny paleomagnetyczne z Łaskowej i Kostomłotów leżą systematycznie na NW od odpowiedniego odcinka referencyjnej krzywej pozornej wędrówki paleobieguna dla Europy. Niezgodność ta znika po rotacji wokół osi pionowej przechodzącej przez miejsca pobrania próbek, o 13±4,6° przeciwnie do ruchu wskazówek zegara. Możliwa rotacja tektoniczna odpowiedzialna za tę niezgodność mogła mieć miejsce we wczesnym permie lub później. Świadczy to, że ruchy tektoniczne po głównej (sudeckiej) fazie orogenicznej modyfikowały geometrię struktur fałdowych również na obszarze trzonu paleozoicznego Gór Świętokrzyskich.