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Jerzy NAWROCKI

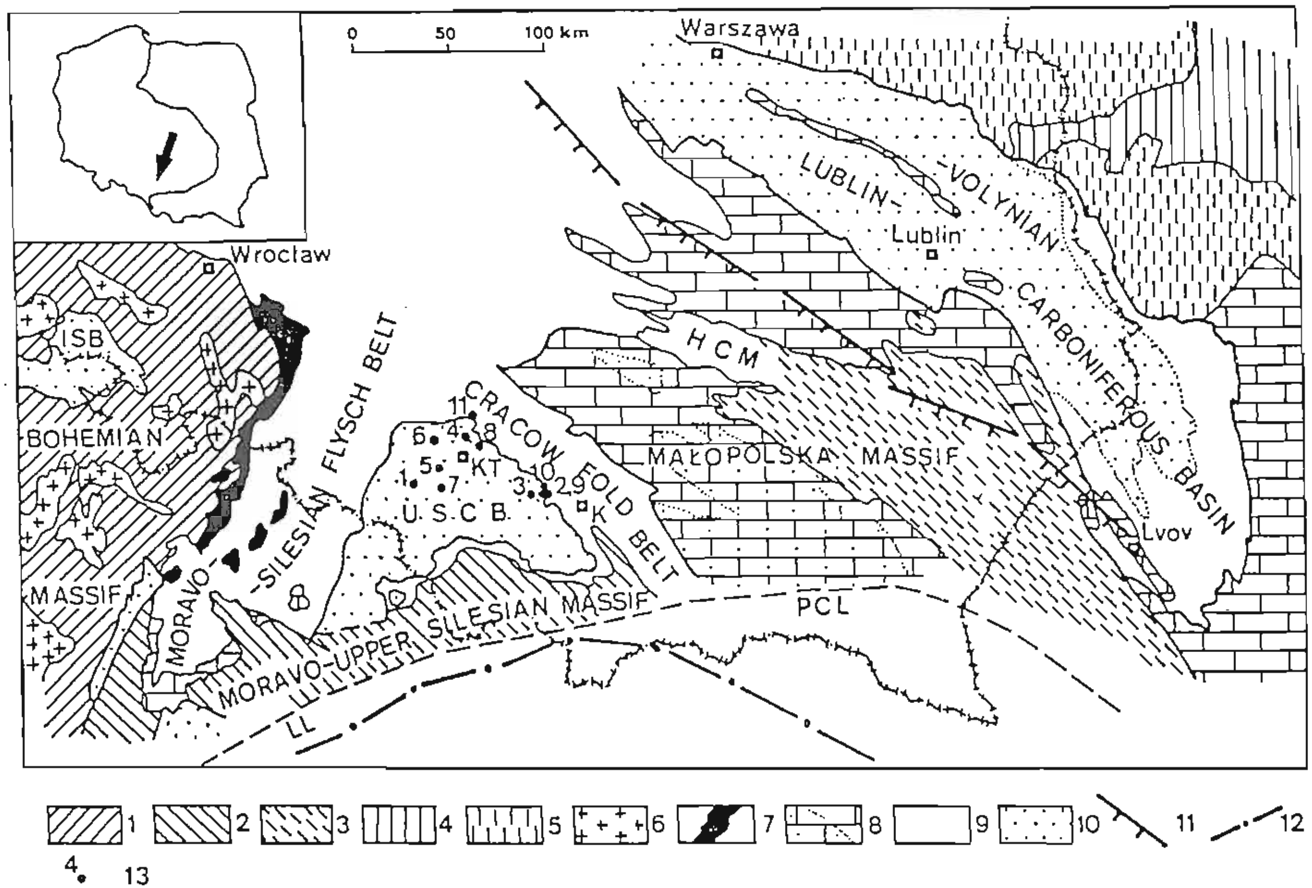
The Devonian–Carboniferous platform paleomagnetic directions from the Silesian-Cracow area and their importance for Variscan paleotectonic reconstructions

Paleomagnetic investigations of the Givetian–Upper Carboniferous sediments from the Silesian-Cracow area (S Poland) were carried out. They revealed a near-primary Givetian–Frasnian remanence with the paleomagnetic pole at lat. 5°S, long. 311°E, dp/dm 2.3°/4.4°, N = 16 samples (normal polarity). Two secondary components were also isolated. The first (lat. 26°S, long. 327°E dp/dm 0.8°/2.9°, N = 3 locality, reversed polarity) was probably acquired in Early Carboniferous time. The second one was connected with a strong Permian remagnetization. These poles fit well to the APW path of the "Old Red Continent". In the Upper Carboniferous clastic coal-bearing sediments from the Upper Silesian Coal Basin three components were obtained, but only one (lat. 39°S, long. 351°E, dp/dm 1.7°/3.2°, N = 3 locality, reversed polarity) was accepted as realistic. The conclusion was drawn that the investigated area was jojned to the "Old Red Continent" at least since the Givetian.

INTRODUCTION

Several years of paleomagnetic investigations have not provided enough data to understand the pre-Permian tectonic history of the Variscan Europe. The paleomagnetic data does not usually fit well with the geological facts (P. Matte, 1991). On the other hand many different tectonic models for the Variscides exists (e.g. J. P. N. Badham, 1982; W. Franke, 1989; J. Neugebauer, 1989; P. Matte et al., 1990; P. Matte, 1991).

In this paper an answer to the question — what is the age of consolidation of the area between the Sudetes and the SW edge of the East-European Platform (EEP), will be sought.


0 50 100 km
Warszawa
Lublin
LUBLIN-VOLYNIAN CARBONIFEROUS BASIN
Lvov
HCM
MAŁOPOLSKA MASSIF
CRACOW FOLD BELT
KT
K
U.S.C.B.
PCL
LL
MORAVO-UPPER SILESIAN MASSIF
MORAVO-SILESIAN FLYSCH BELT
Wrocław
ISB
BOHEMIAN MASSIF
1 2 3 4 5 6 7 8 9 10 11 12
13

GEOLOGICAL SETTING

The Upper Silesian Coal Basin (USCB) developed in the northern corner of the Moravo-Upper Silesian Massif during the Carboniferous time. The Precambrian crystalline basement of the Moravo-Upper Silesian Massif is covered by the Lower Cambrian red and grey sandstones (S. Orłowski, 1975). These sandstones are covered by Devonian and Carboniferous sediments (A. Kotas, 1985). Between the USCB and the Bohemian Massif a zone of Visean flysch exists (Fig. 1). In the western part of the Moravo-Upper Silesian Massif the Visean flysch is thrusted over the Westphalian sediments of the USCB (S. Bukowy, 1984). This thrusting was probably synchronous with the thrusting of the Bohemian Massif over the Moravo-Silesian Massif (P. Matte et al., 1990). A major part of the USCB is situated within the area now occupied by the Carpathian Foredeep, and its southernmost parts — even beneath Outer Carpathian nappes (A. Kotas, 1985).

The NE boundary of the USCB is delineated by the Cracow Fold Belt with Variscan or earlier plutonic bodies (K. Jarmołowicz-Szulc, 1985). In this area the Devonian and Lower Carboniferous rocks outcrop in the vicinity of Krzeszowice (K. Bogacz, 1980) and in some quarries near Olkusz, Siewierz and Zawiercie (S. Śliwiński, 1964).

According to most authors, the Devonian rocks of the areas enclosed between the Sudetes and the edge of the EEP form the epi-Caledonian platform (e.g. J. Znosko,

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Fig. 1. Regional setting of the Upper Silesian Coal Basin (after A. Kotas, 1985; slightly modified)

1 — crystalline basement of the Bohemian Massif; 2 — crystalline basement of the Moravo-Upper Silesian Massif; 3 — Lower Paleozoic formations of the Małopolska Massif; 4 — Precambrian formations of the East-European Platform (EEP); 5 — Lower Paleozoic formations of the EEP; 6 — major Variscan plutonic bodies; 7 — Devonian deep-sea formations; 8 — Devonian epicontinental formations (mainly carbonates, dotted: also Carboniferous carbonates and greywackes); 9 — Carboniferous marine, clastic formations (Variscan flysch, greywackes and early molasse); 10 — Carboniferous clastic, coal-bearing formations (Variscan molasse); 11 — SW limit of the EEP; 12 — Peri-Pieniny Lineament (northern limit of the Inner-Carpathian Block); 13 — sampling localites (1 — Czerwionka, 2 — Dubie, 3 — Filipowice, 4 — Grodków, 5 — Kochłowice, 6 — Kozłowa Góra, 7 — Mikołów, 8 — Sarnów, 9 — Racławka, 10 — Dębnik, 11 — Podleśna); ISB — Inner-Sudetic Basin; HCM — Holy Cross Mts.; USCB — Upper Silesian Coal Basin; LL — Lednice Line; PCL — Peri-Carpathian Line; K — Cracow; KT — Katowice

Położenie górnośląskiego basenu węglowego (według A. Kotasa, 1985; nieznacznie zmodyfikowane)

1 — fundament krystaliczny Masywu Czeskiego; 2 — fundament krystaliczny masywu morawsko-górnośląskiego; 3 — dolnopaleozoiczne formacje masywu małopolskiego; 4 — prekambryjskie formacje platformy wschodnioeuropejskiej (EEP); 5 — dolnopaleozoiczne formacje EEP; 6 — większe waryscyjskie ciała plutoniczne; 7 — dewońskie formacje głębokomorskie; 8 — dewońskie formacje epikontynentalne (głównie węglany, kropkowane: także karbońskie węglany i szarogłazy); 9 — morskie, klastyczne formacje karbońskie (flisz waryscyjski, szarogłazy i wczesna molasa); 10 — karbońskie, klastyczne formacje węglonośne (molasa waryscyjska); 11 — SW krawędź EEP; 12 — lineament peripieniński (północna granica bloku wewnątrzkarpackiego); 13 — opróbowane odsłonięcia (numeracja odsłonięć w podpisie angielskim); ISB — basen wewnątrzsudecki; HCM — Góry Świętokrzyskie; USCB — górnośląski basen węglowy; LL — linia Lednic; PCL — linia perikarpacka; K — Kraków; KT — Katowice

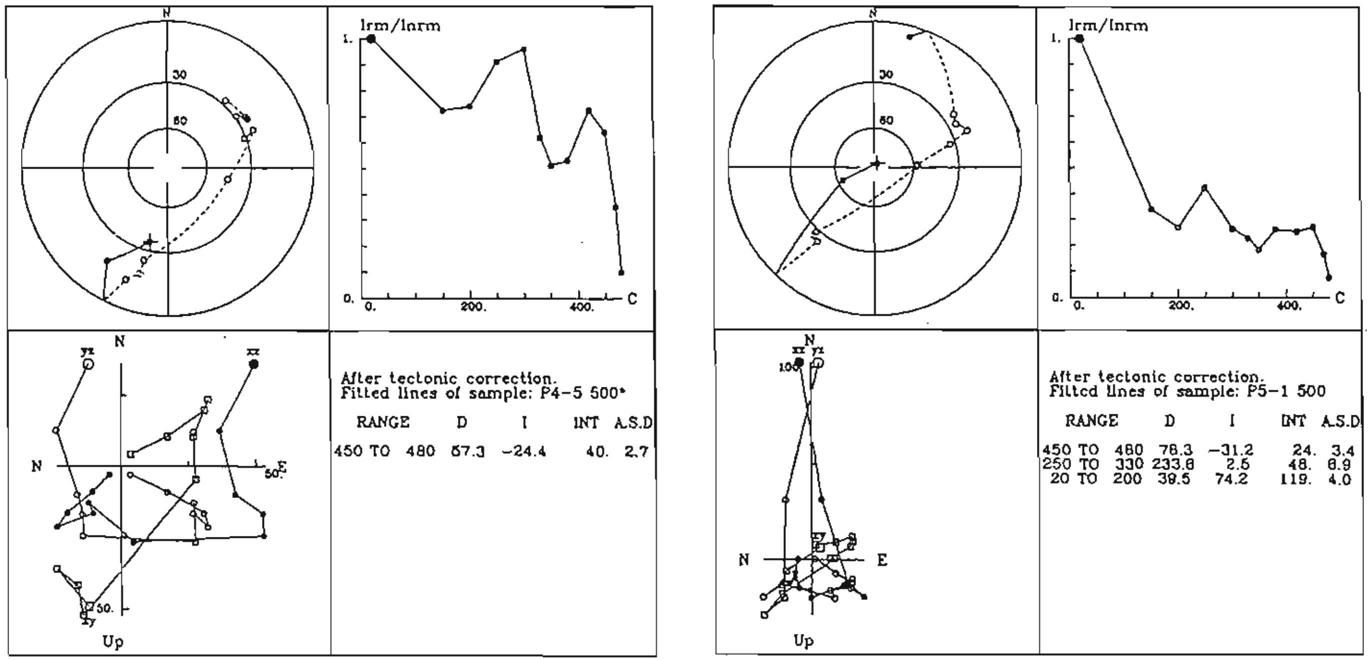

Fig. 2. Examples of thermal demagnetization (polar projection, intensity decay curve, orthogonal plot, table of characteristic components) of two specimens from Podleśna quarry

Open (solid) symbols on the stereonet — upper (lower) hemisphere directions; crossed symbol — *NRM* direction; *Irm* — the intensity of the remanent magnetization after thermal treatment; *Inrm* — the intensity of the *NRM*; the bigger symbols on the orthogonal plot — *NRM* components; *x, y, z* denote the planes of the projection; the units on the axes are 10^{-5} Am^{-1}; RANGE — the temperature interval of the calculated line (direction); *D* — declination; *I* — inclination; *INT* — intensity (in 10^{-5} Am^{-1}), *A. S. D.* — angular standard deviation of the best fitted line; the direction are presented in the geographical position of the rock's formation

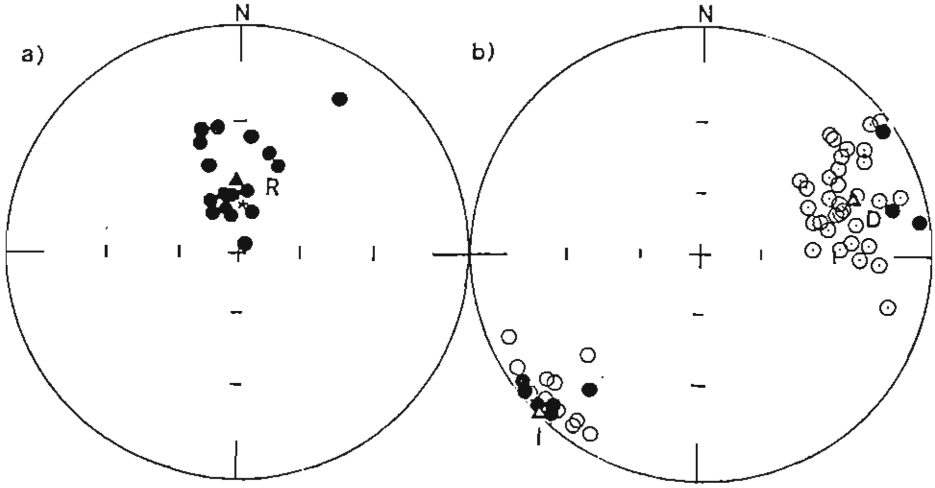

Fig. 3. Stereographic projections of characteristic components R (a), I and D (b) from Podleśna quarry

Open (closed) symbols — upward (downward) pointing magnetization; direction of the local, present-day geomagnetic vector is marked by starlet; the mean directions are marked by triangle

Projekcje stereograficzne składowych charakterystycznych R (a), I i D (b) z kamieniołomu Podleśna

Symbole puste (zamalowane) — kierunki z ujemną (dodatnią) inklinacją; gwiazdką zaznaczono kierunek współczesnego wektora geomagnetycznego, trójkątem — kierunki średnie

1970; J. Krokowski, 1980). However, a Variscan age of consolidation of these areas has also been assumed (e.g. E. Stupnicka, 1992; W. Brochwicz-Lewiński et al., 1986).

SAMPLING AND LABORATORY METHODS

A total number of 220 hand samples was taken from eleven localites (Fig. 1). The Givetian dolomites and limestones from the Dębnik, Dubie and Podleśna quarries, and the Famennian–Tournaisian limestones from the Racławka valley (M. Narkie-

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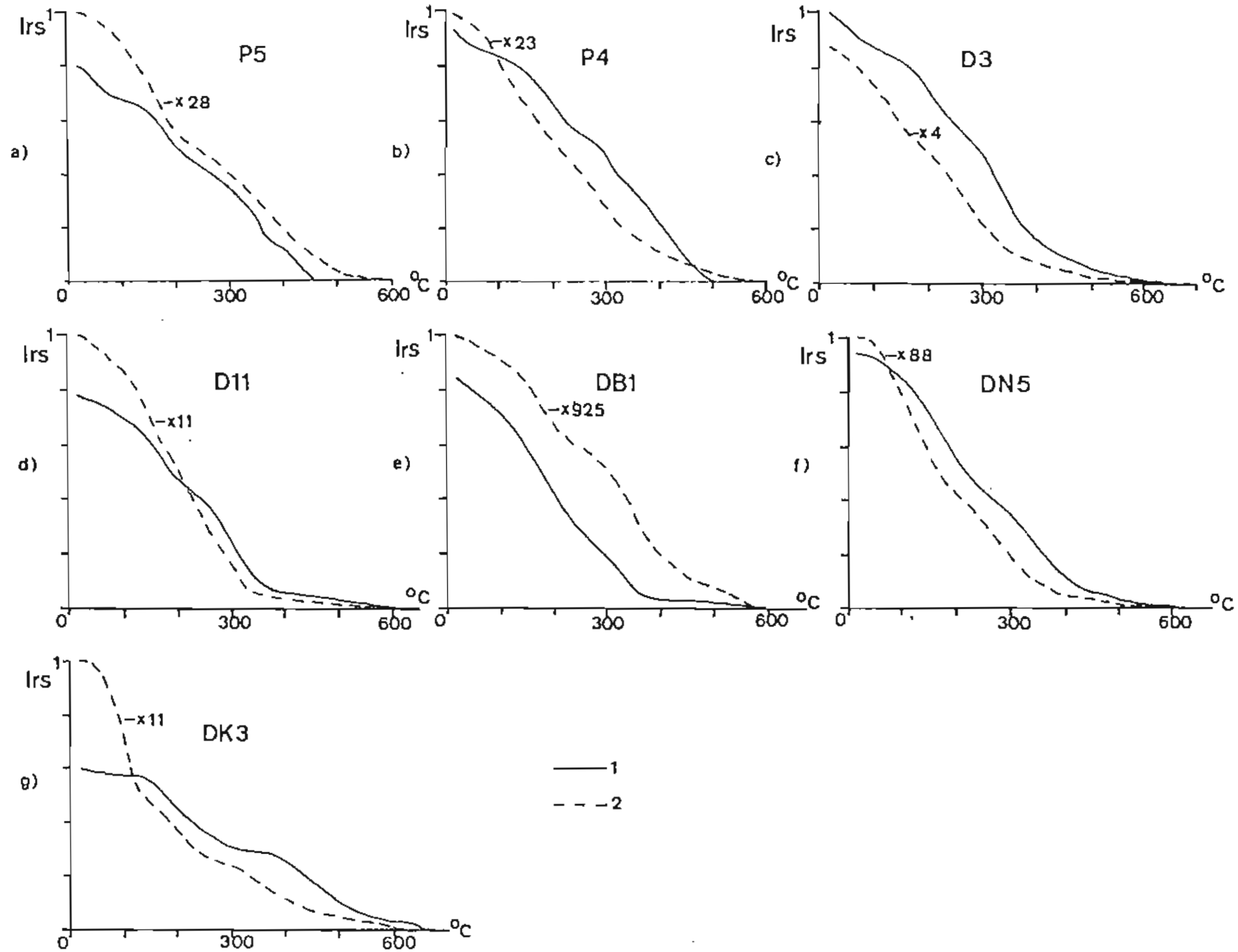
Przykłady termicznego rozmagnesowania (projekcja biegunowa ścieżki rozmagnesowania, krzywa spadku natężenia, diagram ortogonalny, tabela z kierunkiem charakterystycznym) dwóch próbek z kamieniołomu Podleśna

Symbole puste (zamalowane) na siatce stereograficznej — kierunki na górnej (dolnej) półsferze; symbol przekreślony — kierunek *NRM*; *Irm* — natężenie pozostałości magnetycznej po wygrzaniu; *Inrm* — natężenie *NRM*; największe symbole na diagramie ortogonalnym — składowe *NRM*; *x, y, z* wskazują płaszczyzny projekcji; jednostki na osiach w 10^{-5} Am^{-1}; RANGE — przedział temperatury dla liczonej linii (kierunku); *D* — deklinacja; *I* — inklinacja; *INT* — natężenie (w 10^{-5} Am^{-1}); *A. S. D.* — kątowe odchylenie standardowe linii najlepszego dopasowania; kierunek dowiązany jest do geograficznej pozycji badanych formacji skalnych



a) P5 x28
b) P4 x23
c) D3 x4
d) D11 x11
e) DB1 x925
f) DN5 x88
g) DK3 x11
Irs
1
0
300
600
°C
1
2

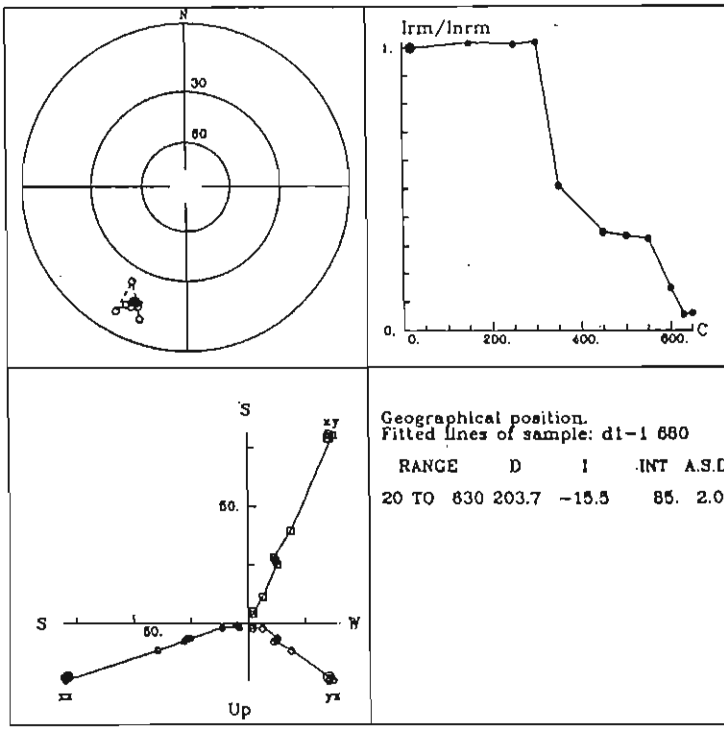


Fig. 5. Dubie new quarry; results of thermal demagnetization of the specimen with the direction A

Explanations see Fig. 2

Nowy kamieniołom w Dubiu; rezultaty rozmagnesowania termicznego próbek z kierunkiem A

Objaśnienia na fig. 2

wicz, G. Racki, 1984, 1987) were sampled. The Namurian–Lower Westphalian clastic sediments were sampled on the USCB area in seven brick-yards.

The natural remanent magnetization (*NRM*) intensities were measured by *JR-4* and *JR-5* spinner magnetometers. Thermal and alternating magnetic field (AF) demagnetizations were carried out means of a non-magnetic furnace and a tumbling

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Fig. 4. Examples of intensity decay curves of saturation remanence during heating of Givetian dolomites from Podleśna (a, b) and Dubie (c, d), Givetian limestones from Dębnik (e, f), and Famenian (Tournaisian) limestones from Racławka valley (g)

Heating: 1 — first, 2 — second

Przykłady krzywych spadku natężenia pozostałości magnetycznej nasycenia z biegiem grzania dolomitów żywetu z Podleśnej (a, b) i Dubia (c, d), wapieni żywetu z Dębnika (e, f) oraz fameńskich (turnejskich) wapieni z doliny Racławki (g)

Grzanie: 1 — pierwsze, 2 — drugie

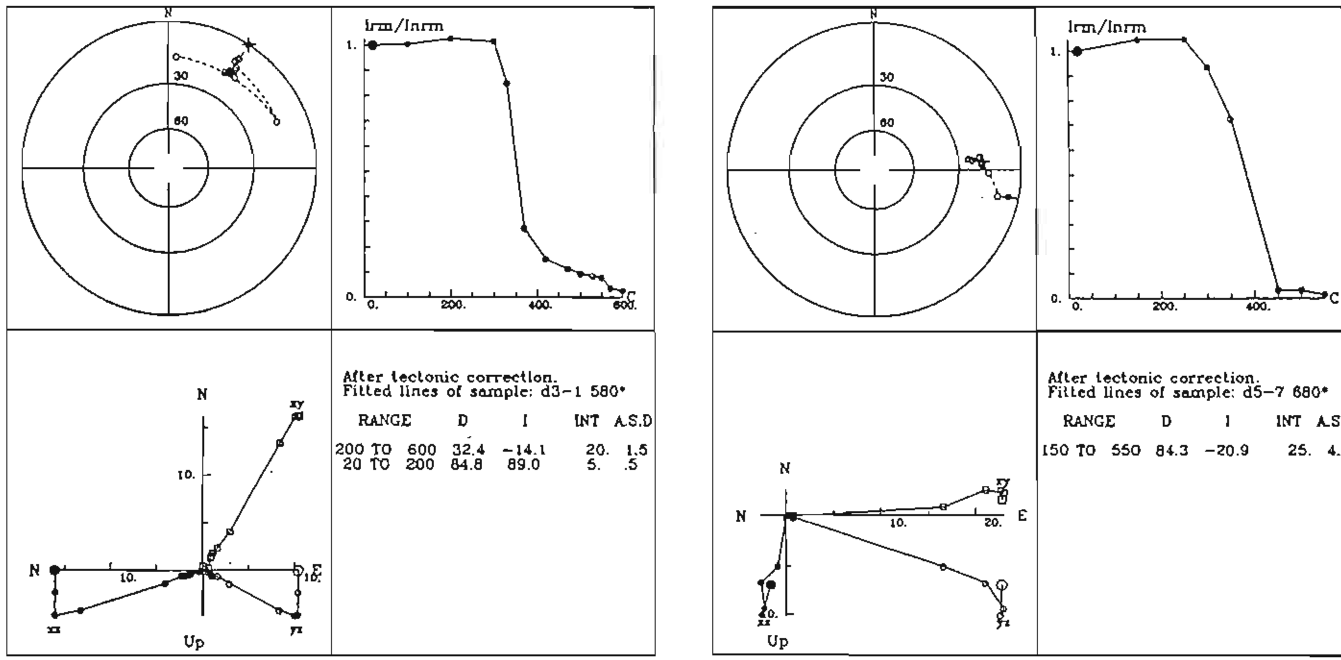


Fig. 6. Dubie quarries; results of thermal demagnetizations of the specimens with the directions D1(sample d3–1) and D2 (sample d5–7)
Explanations see Fig. 2

Kamieniołomy w Dubiu; rezultaty rozmagnesowania termicznego próbek z kierunkami D1 (próbka d3–1) i D2 (próbka d5–7)
Objaśnienia na fig. 2

Table 1

Paleomagnetic directions from Podleśna quarry (19.3E, 50.5N)

Cat.	Lev.	*Dh*	*Ih*	α_{95}	*K*	*VGP*	*Do*	*Io*	α_{95}	*K*	*VGP*	*Tb* [°C]	Pol.
D	n=36	66.3	1.2	5.5	19.6	15N 128E	68.8	–19.1	5.4	20.3	5N 132E	470–500	N
	N=16	66.7	0.9	4.5	67.2	15N 127E	69.6	–19.2	4.2	76.6	5N 131E		
	S=3	66.2	0.9	7.1	297.1	15N 128E	69.4	–19.4	7.6	263.5	5N 132E		
I	n=17	227.7	–26.9	5.3	46.0	37N 135E	225.8	–2.9	5.3	45.8	27N 145E	420	R
	N=7	229.2	–26.1	6.6	84.3	36N 134E	227.3	–2.2	7.2	71.8	27N 144E		
R	n=17	357.1	54.2	9.8	14.1	73N 6E	6.1	29.3	10.5	12.6	55N 29E	250	N
	N=7	356.2	54.4	13.5	20.5	73N 4E	5.3	30.2	14.2	18.8	55N 28E		

Cat. — category of paleodirection; Lev. — levels of statystical analysis (n — specimens, N — samples, S — sites); *Dh*, *Ih* — declination and inclination before bedding correction; *Do*, *Io* — declination and inclination after bedding correction; α_{95}, K — parameters of Fisher statistic; *VGP* — coordinates of the virtual geographic north pole; *Tb* — maximum blocking temperatures; Pol. — polarity paleodirection (N — normal, R — reverse)

Table 2

Paleomagnetic directions from Dubie (19.7E, 50.2N)

Locality	Cat.	Lev.	*Dh*	*Ih*	α_{95}	*K*	*VGP*	*Do*	*Io*	α_{95}	*K*	*VGP*	*Tb*	Pol.
Dubie new quarry	A	$n=46$	209.1	–15.2	3.1	48.7	41N 160E	211.1	–8.2	3.3	41.8	37N 160E	650	R
		$N=9$	208.2	–15.1	5.9	73.7	41N 160E	210.2	–7.1	6.1	70.3	37N 161E		
	D1	$n=8$	35.1	–27.3	7.1	64.2	18N 163E	36.2	–12.4	7.1	64.1	26N 160E	600	N
		$N=4$	36.1	–27.2	7.2	165.3	18N 163E	37.2	–12.6	7.3	159.8	25N 159E		
Dubie old quarry	A	$n=28$	207.3	–16.2	2.9	91.8	42N 162E	208.1	–7.3	2.7	103:1	38N 163E	630	R
		$N=10$	207.1	–16.0	4.3	125.5	42N 162E	208.0	–7.2	4.0	150.2	38N 163E		
	D2	$n=10$	88.3	–4.4	5.6	75.5	1S 113E	86.4	–17.1	5.9	68.5	5S 117E	450	N
		$N=4$	87.8	–4.6	4.8	258.1	1S 113E	87.4	–17.5	4.5	294.2	5S 117E		
Zbrza valley	A	$n=28$	198.2	–14.2	4.3	40.8	44N 169E	200.1	–9.8	4.1	44.5	41N 169E	600	R
		$N=7$	202.1	–15.9	7.1	73.8	43N 168E	204.2	–10.8	6.3	91.6	41N 167E		

Explanations see Tab. 1

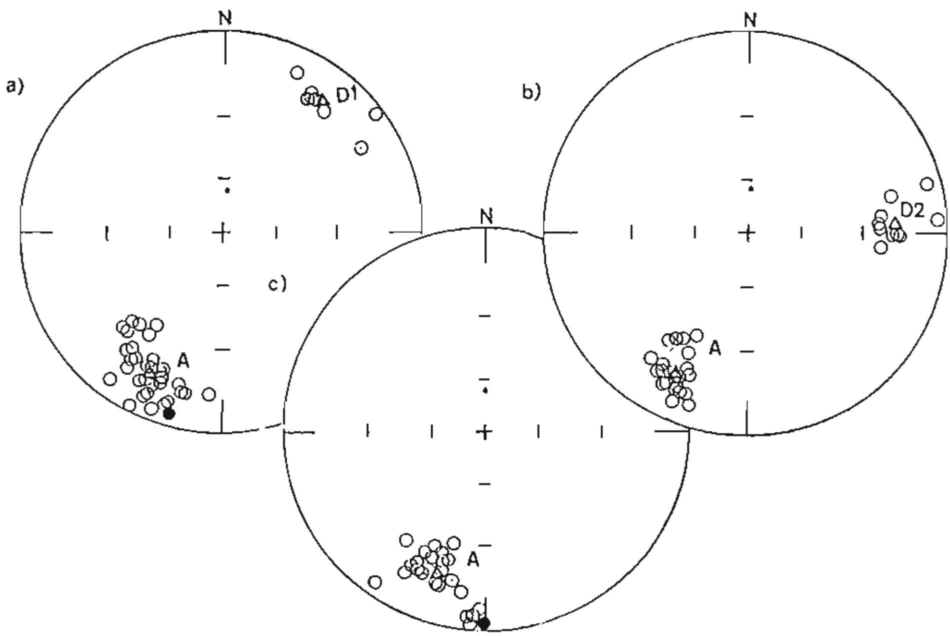


Fig. 7. Stereographic projections of characteristic components A, D1 and D2 from Dubie new (a) and old (b) quarries, and Zbrza valley (c)

Explanations see Fig. 3

Projekcje stereograficzne składowych charakterystycznych A, D1 i D2 z nowego (a) i starego (b) kamieniołomu w Dubiu oraz z doliny Zbrzy (c)

Objaśnienia na fig. 3

demagnetizer with permaloy screens. The magnetic susceptibility was measured by a kappabridge *KLY-2*.

In many samples of Carboniferous clastic rocks at temperatures of 300–400°C a great increase of magnetic susceptibility was observed. In these cases thermal demagnetization was applied at first (up to 300°C) and later the AF method was used. For statistical calculations a computer program by J. L. Kirschvink (1980) was used. Line fit was accepted as representative for the *NRM* component if maximum angular deviation was less than 10°. The mean direction from each investigated locality was considered as reliable if its fisherian parameters (K and α_{95}) were good enough (R. Van der Voo, 1990). If the sum of coincidence cones radius (α_{95}) was less than the distance between the two analysed directions its label was the same (e.g. A, I).

In order to identify the carriers of the *NRM* thermomagnetic analysis was carried out. Additionally some polished sections and the results of X-ray analysis were also studied.

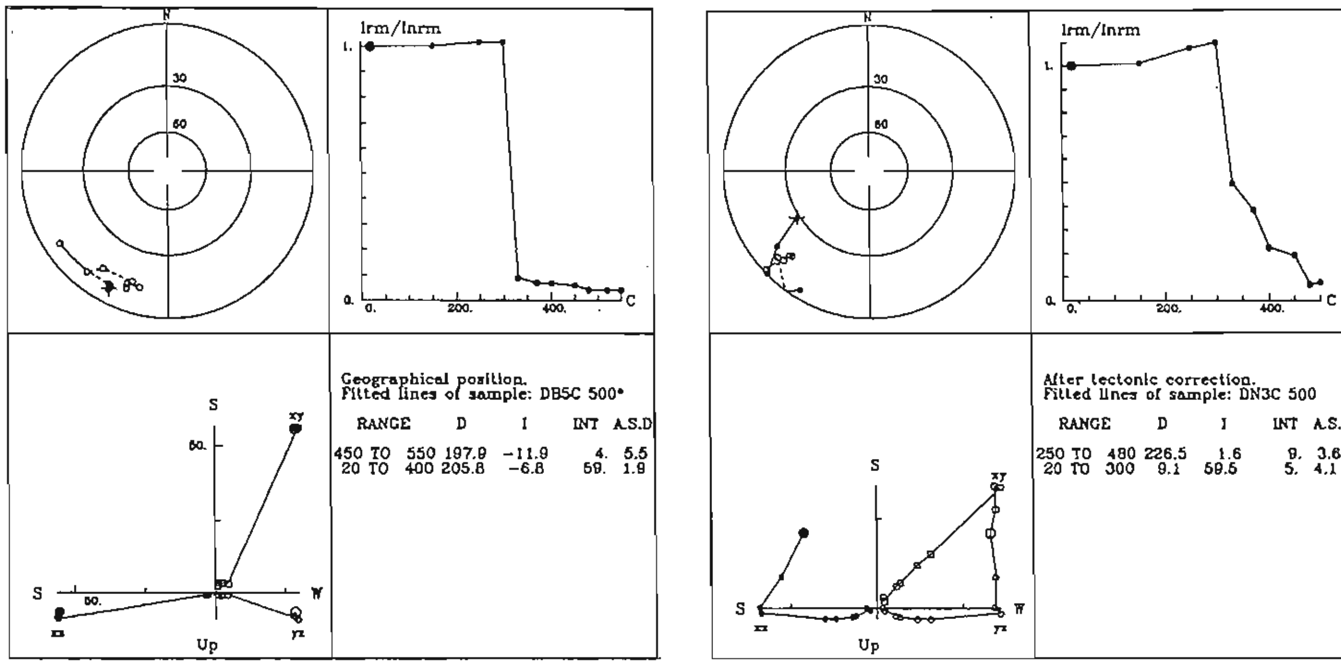


Fig. 8. Dębnik quarries; results of thermal demagnetizations of the specimens with the directions A (DB5C) and I (DN3C)
Explanations see Fig. 2

Kamieniołomy w Dębniku; rezultaty rozmagnesowania termicznego próbek z kierunkami A (DB5C) i I (DN3C)
Objaśnienia na fig. 2

Table 3

Paleomagnetic directions from Dębnik (19.7E, 50.3N)

Locality	Cat.	Lev.	*Dh*	*Ih*	α_{95}	*K*	*VGP*	*Do*	*Io*	α_{95}	*K*	*VGP*	*Tb*	Pol.
Dębnik new quarry	A	n=19 N=8	207.7 207.0	–15.0 –15.0	4.8 6.2	49.0 80.5	41N 162E 42N 163E	205.7 206.0	–7.9 –7.6	4.3 5.0	61.1 122.5	40N 166E 39N 166E	480–600	R
	I	n=15 N=7	224.4 224.5	–2.7 –2.3	6.9 10.5	31.6 34.0	28N 147E 28N 147E	224.1 224.0	1.3 1.6	6.5 9.8	35.2 39.1	27N 148E 27N 148E	330–480	R
	R	n=16 N=6	8.4 12.4	75.6 75.6	5.7 9.0	42.2 56.4	77N 36E 76N 43E	348.5 346.8	63.4 63.6	5.1 6.6	53.3 102.8	81N 320W 80N 314W	300	N
Dębnik old quarry	A	n=13 N=6	204.9 204.7	–12.3 –12.7	2.2 3.3	361.8 420.3	41N 166E 42N 166E	201.5 202.0	–9.3 –9.7	2.3 2.5	335.6 707.5	41N 171E 41N 170E	450–550	R

Explanations see Tab. 1

Table 4

Paleomagnetic directions from Racławka valley (19.7E, 50.2N)

Cat.	Lev.	*Dh*	*Ih*	α_{95}	*K*	*VGP*	*Do*	*Io*	α_{95}	*K*	*VGP*	*Tb*	Pol.
I	n=20 N=8 S=2	224.3 224.1 223.6	–16.4 –16.2 –16.9	6.4 5.0 –	26.8 122.4 –	34N 143E 35N 143E 35N 143E	226.3 226.1 225.9	4.9 4.6 3.7	6.5 5.2 –	26.5 114.4 –	24N 147E 24N 147E 25N 147E	480	R
R	n=11 N=4	351.1 345.1	72.5 72.1	18.5 24.3	7.1 15.1	80N 345W 78N 330W	55.8 53.5	58.8 60.3	18.6 24.2	6.9 15.1	50N 116E 52N 117E	250	N

Explanations see Tab. 1

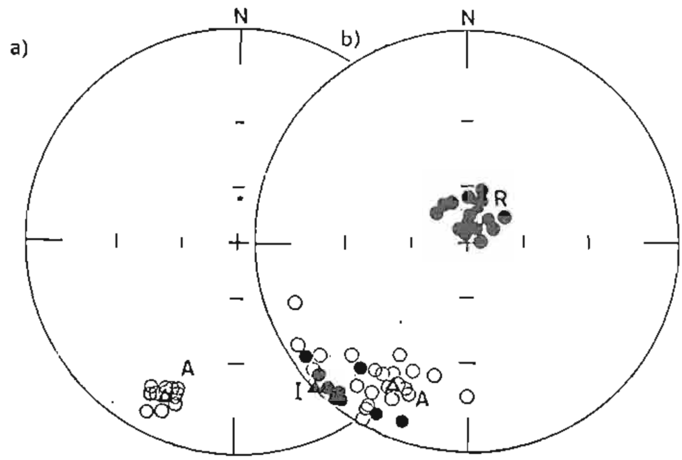


Fig. 9. Stereographic projections of characteristic components A, I and R from Dębnik old (a) and new (b) quarries

Explanations see Fig. 3

Projekcje stereograficzne składowych charakterystycznych A, I i R ze starego (a) i nowego (b) kamieniołomu w Dębniku

Objaśnienia na fig. 3

PALEOMAGNETIC RESULTS

GIVETIAN DOLOMITES FROM PODLEŚNA QUARRY

In the dolomites which were sampled in three walls of Podleśna quarry three directions were isolated. Figure 2 shows the typical results of demagnetization experiments. The low stability component (Fig. 3a, Tab. 1) has a direction (R) approximately parallel to the local present-day direction of the Earth's field. Therefore it can be presumed that this component is connected with a viscous remanent magnetization of comparatively young age. The direction I with intermediate maximum unblocking temperature (about 420°C) and shallow inclination is located in the third quarter of the sphere (Fig. 3b). In the major part of the investigated samples there also occurs a direction with blocking temperatures of 470–500°C. This most distinct component has negative inclination and declination in the first quarter of the sphere (Fig. 3b, direction D). The thermomagnetic curves (Fig. 4a, b) show that the magnetite is probably the main carrier in the rock investigated.

GIVETIAN DOLOMITES FROM DUBIE

These rocks were sampled in three outcrops situated in the old and new quarry, and in the Zbrza valley. Almost all samples contain only one component with maxi-

Table 5

Paleomagnetic directions from the Upper Silesian Coal Basin (Upper Carboniferous clastic sediments)

Cat.	Lev.	*Dh*	*Ih*	α_{95}	*K*	*VGP*	*Do*	*Io*	α_{95}	*K*	*VGP*	*Tb*	Pol.
A1	N=4 n=50	202.0	−1.1	5.7	259.5	37N 171E	202.5	1.9	14.3	41.8	35N 171E	300, >430	R
	N=3 n=35	201.1	0.7	6.0	428.5	37N 172E	201.3	−4.0	5.5	494.8	39N 171E		
B	N=4 n=31	252.0	−4.0	8.8	110.1	13N 122E	252.2	2.5	9.1	102.1	10N 124E	300, >430	R?
C	N=5 n=39	139.8	3.2	10.7	51.9	28S 81E	140.8	−1.0	7.6	101.0	30S 80E	380	N, R

Explanations see Tab. 1

Table 6

Summary statistic for the directions I and A

Cat.	Lev.	*Dh*	*Ih*	α_{95}	*K*	*VGP*	*Do*	*Io*	α_{95}	*K*	*VGP*
1	N=3	225.7	−26.0	18.6	44.4	33N 142E	225.7	1.4	5.5	495.6	26N 147E
A	N=5	205.8	−15.0	2.5	965.5	42N 164E	206.0	−8.5	3.4	504.1	39N 165E

N — number of localities; for other explanations see Tab. 1

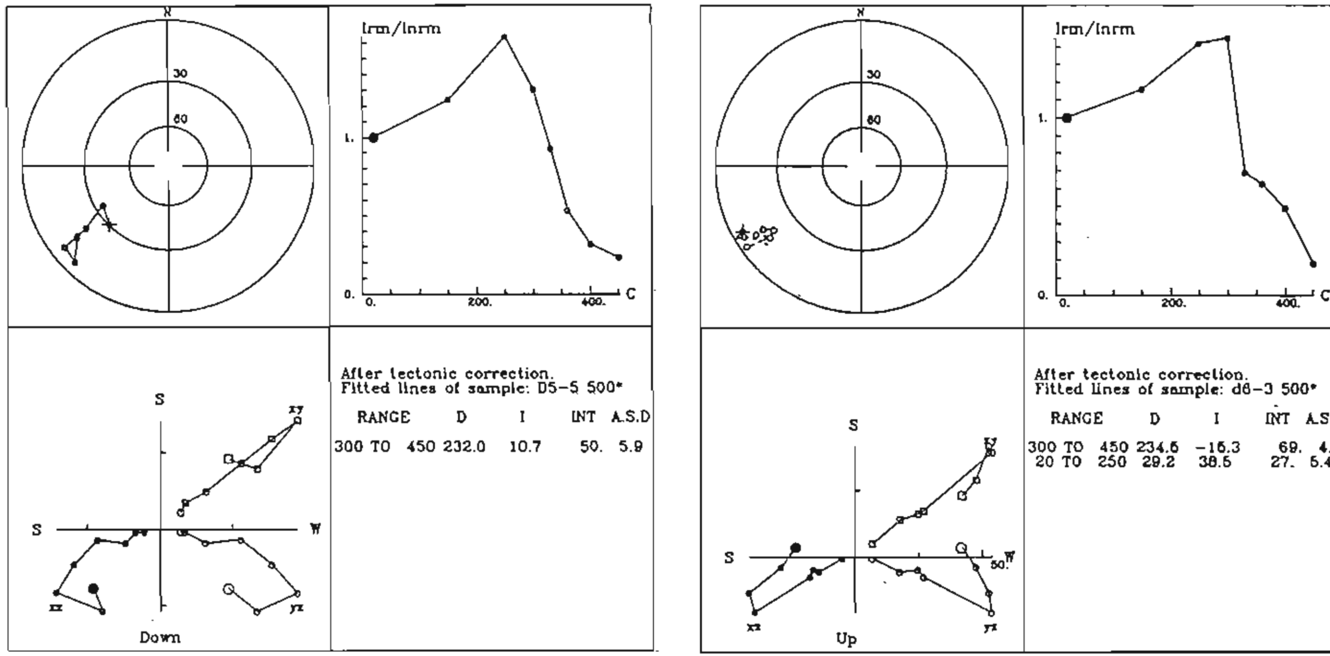


Fig. 10. Racławka valley; results of thermal demagnetizations of the specimens with the directions *R* and *I*
Explanations see Fig. 2
Dolina Racławki; rezultaty rozmagnesowań termicznych próbek z kierunkami *R* i *I*
Objaśnienia na fig. 2

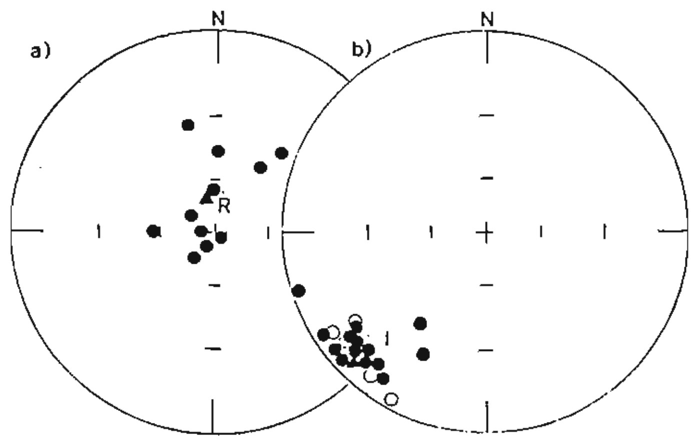


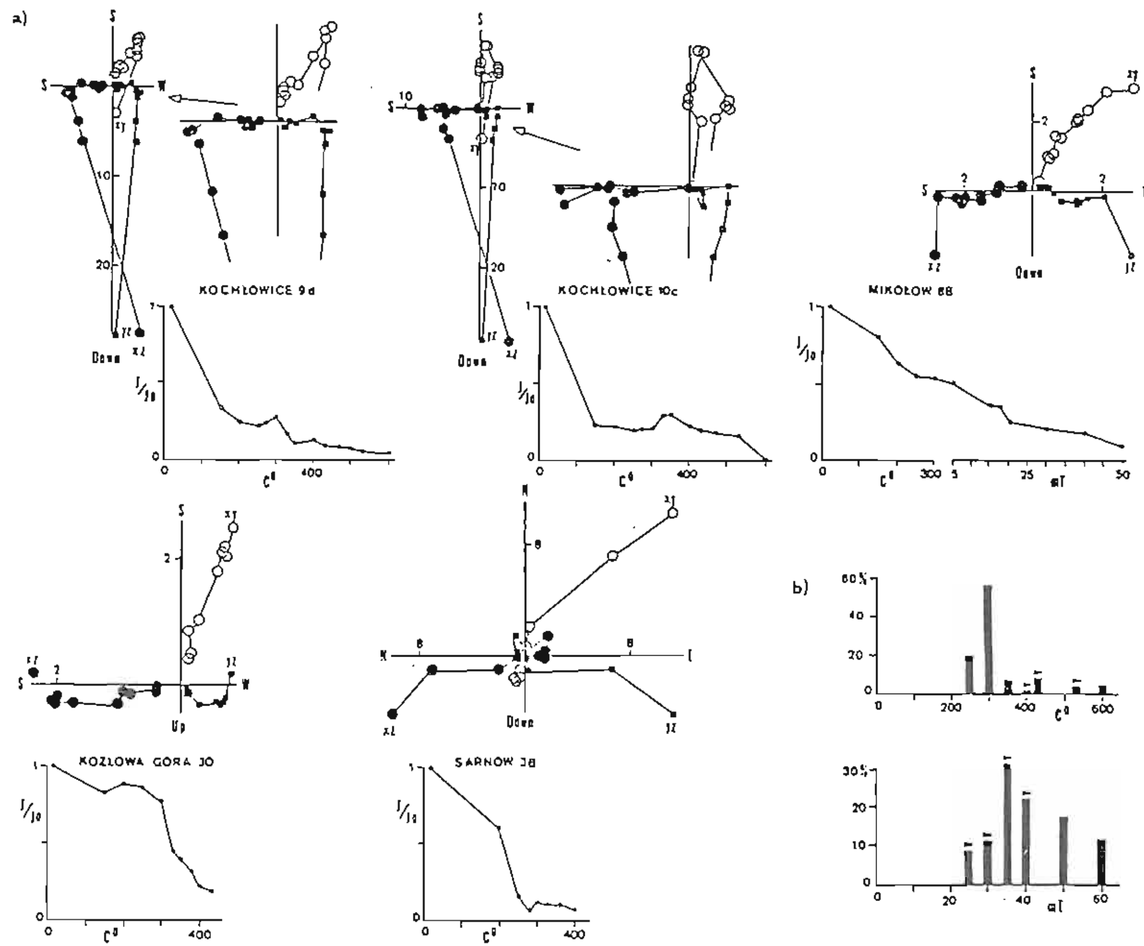
Fig. 11. Stereographic projections of characteristic components R (a) and I (b) from Racławka valley
Explanations see Fig. 3
Projekcje stereograficzne składowych charakterystycznych R (a) i I (b) z doliny Racławki
Objaśnienia na fig. 3

mum blocking temperatures reaching 650°C (Fig. 5). However, most of the *NRM* intensities decrease at a temperature of 300–400°C (Fig. 4c, d). During AF demagnetization of a heated sample (up to 300°C) its *NRM* intensity only decreased by about 10% at fields up to 105 mT. The high value of coercivity indicates that the main carrier of magnetization is hematite. The characteristic direction for these samples are very well defined (Tab. 2, direction A). Distinctly different components (Fig. 6) were obtained only in two sites. They have very good internal homogeneity of characteristic directions at each site, but their position on the sphere is slightly different (Fig. 7, Tab. 2, directions D1 and D2).

GIVETIAN LIMESTONES FROM DĘBNIK

The paleomagnetic characteristic of the Givetian limestones from Dębnik old quarry is similar to the one from Dubie. They also have a very well defined component (Fig. 8, Tab. 3, direction A) based on the same high coercivity magnetic carrier.

In the samples from Dębnik new quarry the structure of magnetization is much more complicated. Their intensities of *NRM* are over two times lower than the intensities of the samples from Dębnik old quarry. During demagnetization three characteristic components were isolated. The low stability component has direction parallel to the present local field direction (Fig. 9, Tab. 3, direction R). The component with intermediate stability (Figs. 8, 9, Tab. 3, direction I) is obtained at temperatures of 330–480°C. In the major part of the samples a direction A also occurs (Fig. 9, Tab. 3).


a)
KOCHŁOWICE 9d
KOCHŁOWICE 10c
MIKOŁOW 68
KOZŁOWA GORA 30
SARNOW 38
b)
J/J0
C°
mT
Down
Up
xy
yz
xz
S
W
N
E
60%
30%

FAMENNIAN-TOURNAISIAN LIMESTONES FROM RACŁAWKA VALLEY

Two characteristic directions were separated from these very weakly magnetized limestones. The *NRM* intensities were not higher than 0.1 mA/m. The low stability component is removed at temperatures up to 300°C. Above this temperature only one component with blocking values of about 480°C occurs (Figs. 10, 11, Tab. 4, direction I). The low values of coercivity indicate that magnetite is probably the main carrier in these rocks.

NAMURIAN-LOWER WESTPHALIAN CLASTIC SEDIMENTS

In the clastic sediments of Namurian and Lower Westphalian age (138 samples) three directions (A1, B, C; Tab. 5) were isolated. These directions have similar, equatorial inclination. Typical orthogonal projections, the maximum unblocking temperatures and amplitude of demagnetizing field for each category are presented in the Figures 12, 13 and 14 respectively. The direction C of mixed polarity (Fig. 15c, d) is characterized by low values of coercivity (15 mT) and blocking temperatures in the range of 350–470°C.

The directions A1 and B have higher coercivity and usually lower blocking temperatures than the direction C. Because of the similar range of these parameters their separation was based mainly on a density analysis (M. Lewandowski, 1992*a*; Fig. 16). The results of observation of polished sections and thermomagnetic analyses (Fig. 17) indicate that magnetite and probably maghemite are the main carriers of the *NRM* in the rocks investigated. In samples with a direction C grains of titanomagnetite were observed by means of a scaning microscope.

INTERPRETATION OF ISOLATED CHARACTERISTIC DIRECTIONS

THE DIRECTIONS FROM DEVONIAN-LOWER CARBONIFEROUS ROCKS

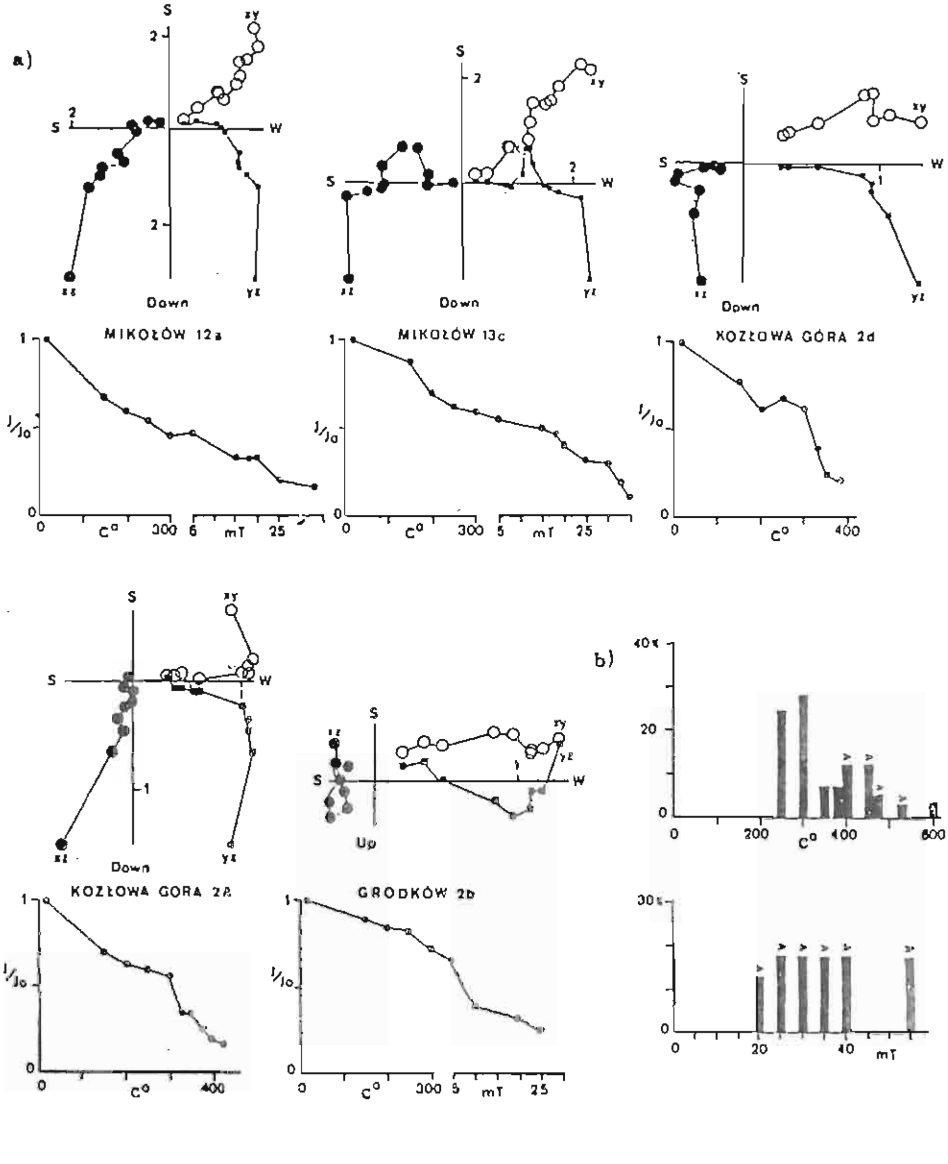
The directon D isolated in Podleśna was acquired before deformation of the Givetian dolomites. These rocks were most probably deformed in the Asturian Phase (see S. Śliwiński, 1964). The inclination of the uncorrected direction was in fact about

Fig. 12. Typical orthogonal projections and demagnetization curves of specimens with the direction A1 from the Namurian and Lower Westphalian sediments (a) and the maximum unblocking temperature and coercivity diagrams (b)

> — the highest temperature and field appled during demagnetization; the blocking values are most probably higher; other explanations in Fig. 2

Typowe projekcje ortogonalne i krzywe rozmagnesowania próbek z osadów namuru i dolnego westfalu, które zawierały kierunek A1 (a) i diagramy maksymalnych koercji i temperatur odblokowujących (b)

> — najwyższa temperatura lub pole zastosowane podczas rozmagnesowania; wartości blokujące są tutaj najprawdopodobniej wyższe; pozostałe objaśnienia na fig. 2


a)
MIKOŁÓW 12a
MIKOŁÓW 13c
KOZŁOWA GÓRA 2d
KOZŁOWA GÓRA 2A
GRODKÓW 2b
Down
Up
xy
yz
xz
S
W
J/Jo
C°
mT
b)
40%
20
0
200
400
600
30%
20
40

15° lower because the overlying Triassic rocks are inclined of about 15° towards NE. In the Late Carboniferous such direction with normal polarity is not acceptable on this area. The direction D may be connected with the process of early dolomitization of the reef limestones. On the apparent polar wander (APW) paths for "stable" Europe it is situated exactly on the area of the Givetian–Frasnian paleopoles (Fig. 18).

Similar directions (D1, D2) with negative inclination and declination in the first quarter of the hemisphere were separated in two sites of Dubie (Fig. 7). However they have poor statistical representation. The dispersion of their declination may be connected with the local, very complicated tectonics (J. Krokowski, 1980).

The direction I which was isolated in Dębnik, Podleśna and the Racławka valley (Figs. 3, 9, 11) was been acquired before deformation of the rock investigated. Before tectonic correction this direction has negative inclination similar to the Permian characteristic inclination for "stable" Europe. However its declination is over 20° different. Due to occurrence of the directions A and A1 such rotation is excluded in Permian time. Moreover, the fisherian parameters for average I direction are distinctly better after tectonic correction (Tab. 6). On the APW path the poles obtained from this category of paleodirection are situated on the area of the Visean poles (Fig. 18). The secondary origin of the direction I is probably connected with the Early Carboniferous thermal or chemical event.

The direction A which occurs in the Givetian dolomites and limestones from Dubie and Dębnik is nearly the same as the direction of K. Birkenmajer and A. E. M. Nairn (1964) from the Lower Permian volcanites, outcropping in the vicinity of the area investigated. The strong Permian remagnetization of these rocks is connected with the Permian volcanism. A big subvolcanic body occurs in the floor of the Givetian rocks which build the Dębnik Anticline (W. Zajączkowski, 1964).

THE DIRECTIONS FROM THE UPPER CARBONIFEROUS COAL-BEARING CLASTIC SEDIMENTS

In the preliminary paleomagnetic works the directions B and C were accepted as real, recording dextral rotation of the USCB or even the whole Variscan Belt during Late Carboniferous (J. Nawrocki, 1991, 1992). Further investigations of the Upper Carboniferous rocks did not confirm that interpretation. The direction C occurs also in the Westphalian rocks of the Lublin Coal Basin (Fig. 19). In this area, belonging to the EEP its occurrence is improbable. It can not be tectonically interpreted. What was

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Fig. 13. Typical orthogonal projections and demagnetization curves of specimens with the direction B from the Namurian and Lower Westphalian sediments (a) and the maximum unblocking temperature and coercivity diagrams (b)

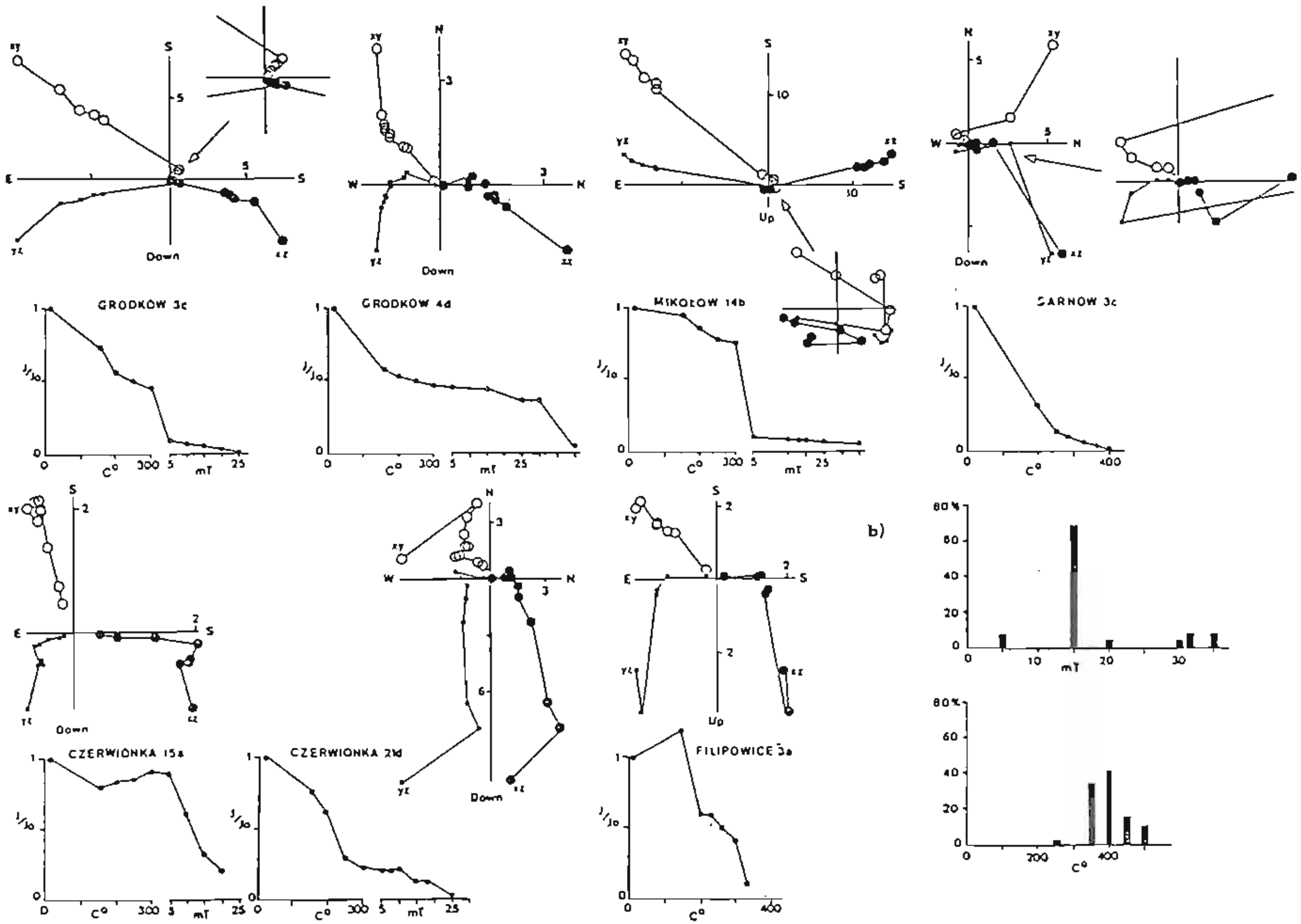
Explanations see Figs. 2 and 12

Typowe projekcje prostokątne i krzywe rozmagnesowania próbek z osadów namuru i dolnego westfalu, które zawierały kierunek B (a) i diagramy maksymalnych koercji i temperatur odblokowujących (b)

Objaśnienia na fig. 2 i 12

a)

b)


GRODKOW 3c
GRODKOW 4d
MIKOŁOW 14b
SARNOW 3c
CZERWIONKA 15a
CZERWIONKA 21d
FILIPOWICE 3a
Down
Up
mT
C°
80 %

the mechanism recording the direction C? This component might have originated during a Carboniferous reversal as a result of thermoviscous reorientation of direction in the multidomain magnetite. Result of laboratory experiments seems to confirm the thermoviscous origin of the direction C (Fig. 19). Partially demagnetized (up to 20–30 mT) specimens that initially contained the direction C were heated at a temperature of 80°C from 1 to 5 hours. After heating the specimens were left at room temperature. Throughout this time, the specimens were oriented according to the present magnetic north direction. The blocking temperature of the obtained thermoviscous component depends on the time of the treatment of the magnetic external field. The maximum blocking temperature reached 270°C after heating for 5 hours and leaving for 4 months.

In three specimens of the same sample from Mikołów three different directions are present with equatorial inclination and low coercivity (Fig. 20). Two nearly opposite directions convergent with the Carboniferous directions of "stable" Europe occur here together with direction C. Such a fact seems to confirm a non-dipolar origin of the direction C.

The direction B has a flattened maximum of density unlike the direction A1 (Fig. 16). Because of this its reliability is doubtful. The very distinct direction A1 is the same as the Upper Carboniferous characteristic directions for "stable" Europe (J. D. A. Piper, 1987). However it is difficult to prove if it is of primary origin. If we omit the distinctly postdeformational direction from Kozlowa Góra, we obtain similar fisherian parameters after and before tectonic correction (Tab. 5). The polarity test seems to be necessary in this case.

PALEOTECTONIC AND PALEOGEOGRAPHIC IMPLICATIONS

The paleomagnetic poles described in this paper fit well to the APW path of the EEP (M. A. Smethurst, A. N. Khramov, 1992; Fig. 18). This fact supports the hypothesis that, at least since the Givetian, no major movements of the Moravo-Upper Silesian Massif in relation to the EEP have occurred. It is obvious that the Małopolska Massif was behaving similarly because of the tectonic framework of these areas. There is no geological and paleomagnetic evidence for the Early Devonian time of tectonic

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Fig. 14. Typical orthogonal projections and demagnetization curves of specimens with the direction C from the Namurian and Lower Westphalian sediments (a) and the maximum unblocking temperature and coercivity diagrams (b)

Explanations see Fig. 2

Typowe projekcje ortogonalne i krzywe rozmagnesowania próbek z osadów namuru i dolnego westfalu, które zawierały kierunek C (a) i diagramy maksymalnych koercji i temperatur odblokowujących (b)

Objaśnienia na fig. 2

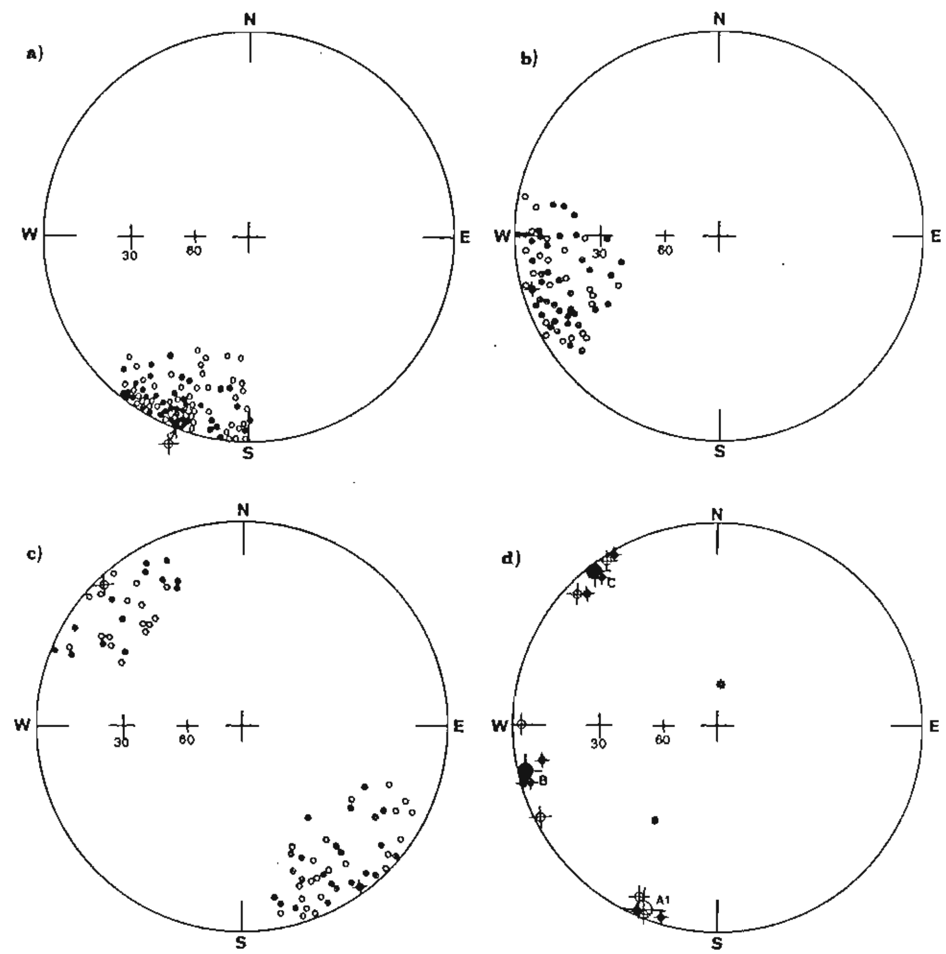


Fig. 15. Characteristic directions A1 (a), B (b), C (c) and mean directions for the localites (d) from the Upper Silesian Coal Basin

Small crossed circles — mean directions; big crossed circles — mean directions for the whole investigated area

Kierunki charakterystyczne A1 (a), B (b), C (e) oraz średnie kierunki dla odsłonięć (d) skał z górnośląskiego basenu węglowego

Małe kółka przekreślone — kierunki średnie; duże kółka przekreślone — kierunki średnie na poziomie odsłonięć dla całego obszaru

consolidation in the area studied. The reliability of the paleomagnetic direction from the Lower Devonian sandstones of the Holy Cross Mts. (M. Lewandowski, 1991) is not sufficiently high because of the low value of the fisherian parameter $K = 7$. Moreover its nearly equatorial inclination differs from the Early Devonian characteristic inclination of the Western Ukraine (M. A. Smethrust, A. N. Khramov, 1992)

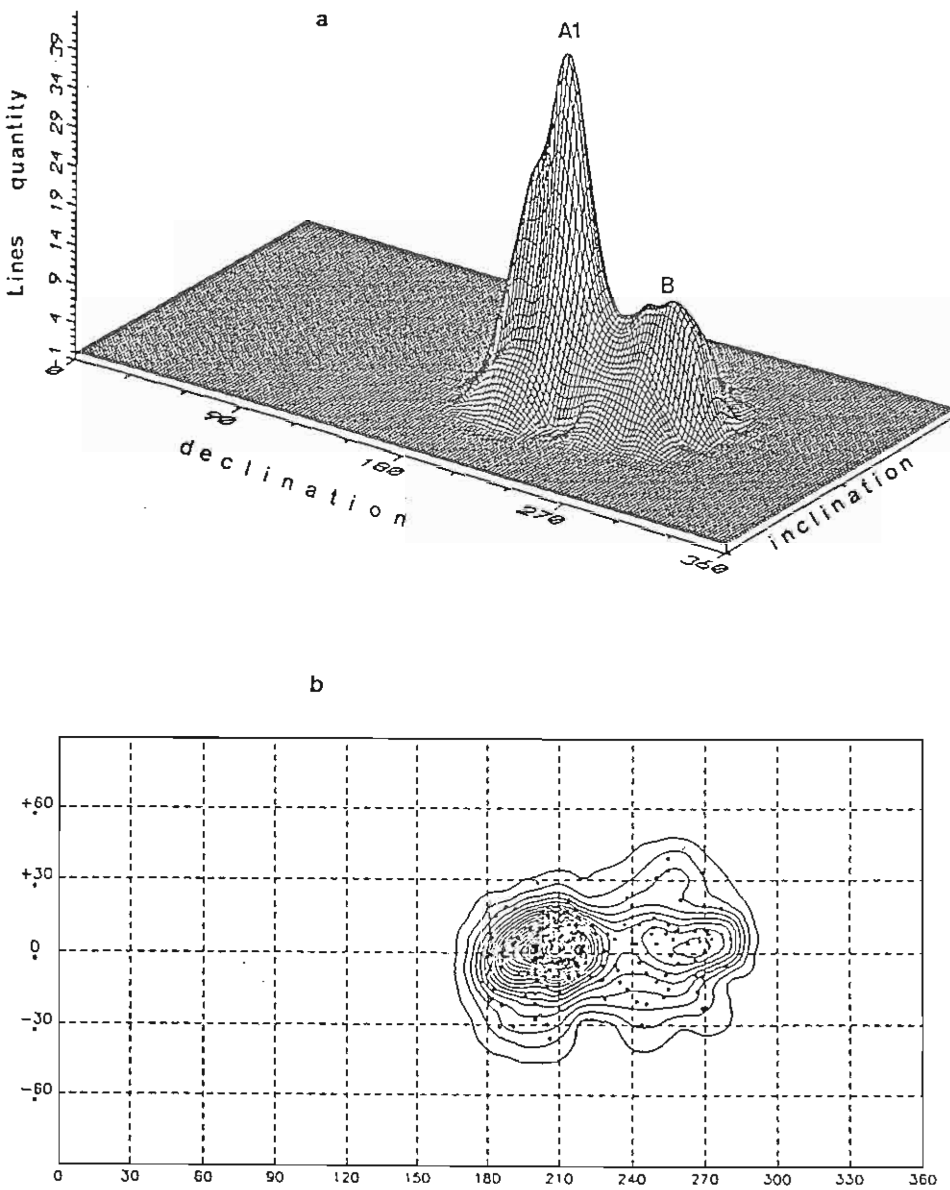
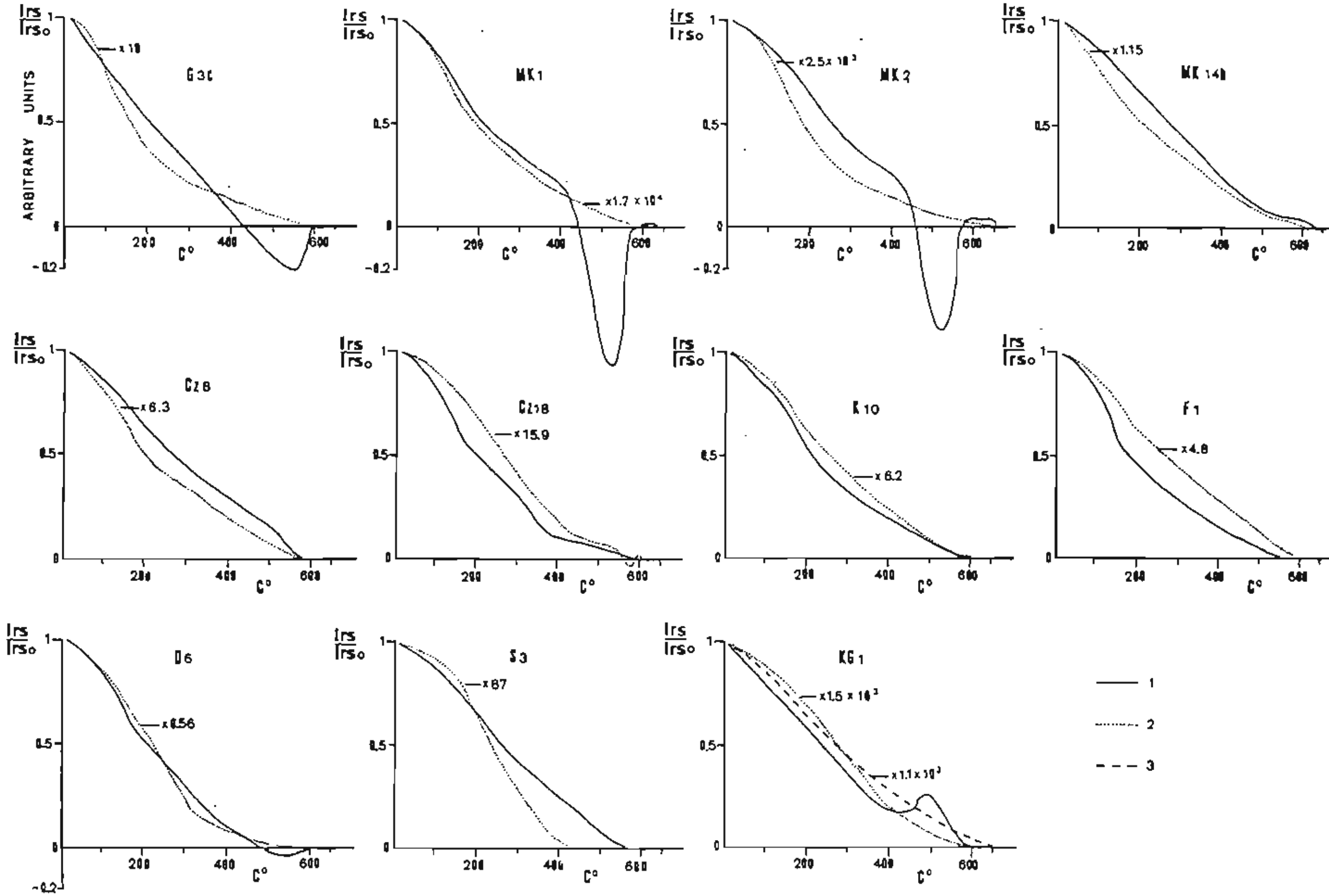


Fig. 16. Separation of characteristic directions A1 and B from the Namurian–Lower Westphalian sediments by means of SURFER plot package (see M. Lewandowski, 1992*a*); a — perspective view, b — density diagram

Separacja kierunków charakterystycznych A1 i B, występujących w osadach namuru i dolnego westfalu, za pomocą programu graficznego SURFER (patrz M. Lewandowski, 1992*a*); a — rzut perspektywiczny, b — diagram gęstości


Irs/Irso
ARBITRARY UNITS
G3c
x10
MK1
x1.7 x 10^4
MK2
x2.5 x 10^3
MK14b
x1.15
Cz8
x6.3
Cz18
x15.9
K10
x6.2
F1
x4.8
D6
x0.56
S3
x67
KG1
x1.5 x 10^3
x1.1 x 10^3
C°
1
2
3

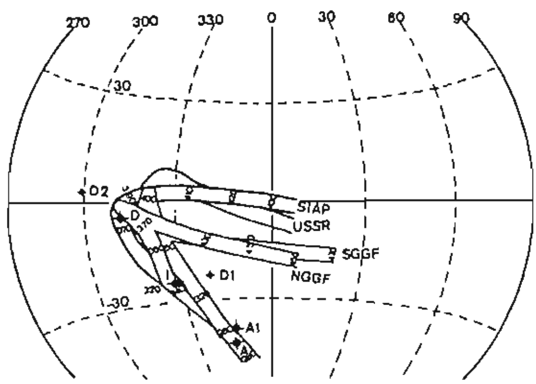


Fig. 18. The paleomagnetic poles from the Silesian–Cracow area on the background of reference south APW paths for Great Britain drawn by T. H. Torsvik et al. (*fide* M. A. Smethurst and A. N. Khramov, 1992), and for the East-European Platform (*op. cit.*)

Small symbol — the poles with poor statistic (D1, D2); SIAP — south of Iapetus suture: SGGF — south of the Great Glen Fault; NGGF — north of the Great Glen Fault; USSR — the East-European Platform; ages in My

Bieguny paleomagnetyczne z obszaru śląsko-krakowskiego na tle referencyjnych ścieżek pozornej wędrówki paleobieguna dla Wielkiej Brytanii, zestawionych przez T. H. Torsvika i in. (*fide* M. A. Smethurst, A. N. Khramov, 1992), oraz dla platformy wschodnioeuropejskiej (*op. cit.*)

Małe kółka — bieguny słabo reprezentowane statystycznie (D1, D2); SIAP — obszar położony na południe od szwu Iapetus; SGGF — obszar położony na południe od wielkiego uskoku Glen; NGGF — obszar położony na północ od wielkiego uskoku Glen; USSR — platforma wschodnioeuropejska; wiek w milionach lat

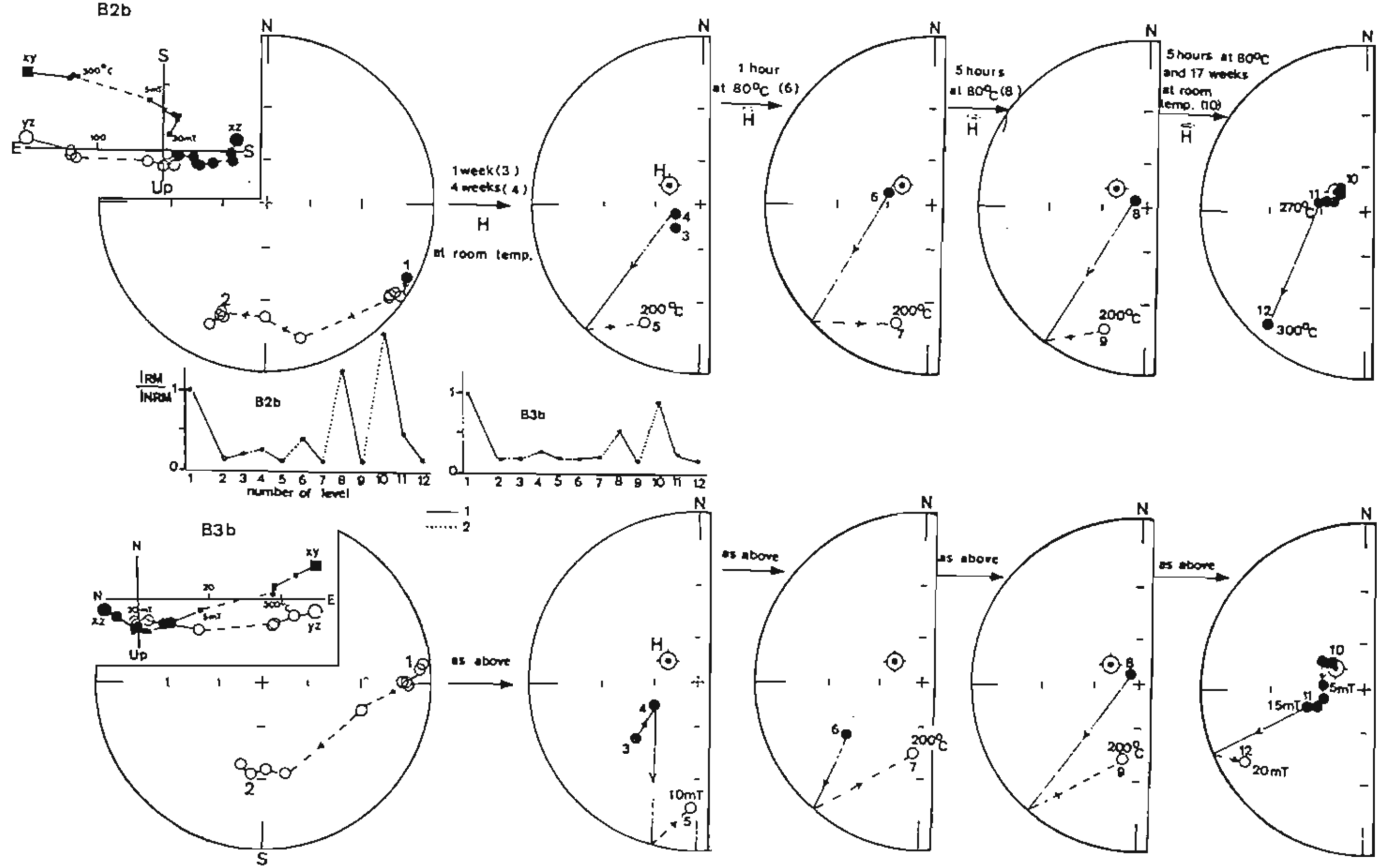
of about 40°, and from the inclination obtained in this paper of 28°. It is difficult to accept that the Małopolska Massif was, at that time situated at nearly equatorial, north paleolatitudes (see M. A. Smethurst, 1992). Such fact and results presented in this paper are in disagreement with the hypothesis about large clockwise rotation of the Małopolska Massif during the Variscan time (M. Lewandowski, 1992*b*)

Fig. 17. Examples of intensity decay curves of saturation remanence during heating of Namurian–Lower Westphalian clastic rocks from the Upper Silesian Coal Basin

Heating: 1 — first, 2 — second, 3 — third

Przykłady krzywych spadku natężeń namagnesowania nasycenia z biegiem wygrzewania namurskich i dolnowestfalskich skał klastycznych z górnośląskiego basenu węglowego

Grzanie: 1 — pierwsze, 2 — drugie, 3 — trzecie


B2b
xy
300°C
5mT
30mT
yz
xz
100
E
S
Up
N
1
2
1week (3)
4 weeks (4)
H
at room temp.
H
4
3
200°C
5
1 hour
at 80°C (6)
H
6
200°C
7
5 hours
at 80°C (8)
H
8
200°C
9
5 hours at 80°C
and 17 weeks
at room
temp. (10)
H
10
11
270°C
12
300°C
IRM
INRM
B2b
number of level
B3b
1
2
B3b
N
xy
20
E
xz
30mT
5mT
300°C
yz
Up
as above
S
H
4
3
10mT
5
as above
6
200°C
7
as above
8
200°C
9
as above
10
5mT
11
15mT
12
20mT

The tectonic consolidation of the areas enclosed between the Sudetes and the edge of the EEP and their accretion[1] with the EEP most probably took place in the Silurian (see e.g. R. Dadlez, 1982; J. Znosko, 1984; W. Franke, 1989; W. Pożaryski, 1991). The Moravo-Upper Silesian Massif, containing a Pan-African basement, probably formed part of Gondwana during Early Paleozoic time. After rifting it moved near the EEP edge in Late Caledonian time. It is difficult to prove without Ordovician and Silurian paleomagnetic data if this massif was a part of the Avalonia microcontinent or if it behaved as an independent tectonic unit. According to T. H. Torsvik et al. (1991) Avalonia rifted away from Gondwana late in the Early Ordovician (Arenig) and later collided with Baltica and Laurentia, ultimately forming Euramerica by Late Silurian–-Early Devonian times.

The Late Variscan deformations of the areas lying between the Sudetes and the edge of the EEP are most probably connected with the translation of the Bohemian Massif over the Moravo-Upper Silesian in a NE direction (see P. Matte et al., 1990). These deformations are associated with the zones of old sutures and strike-slip faults. However, the horizontal component of summary translation of the basement could not be greater than an error of paleomagnetic data.

CONCLUSION

At least since the Late Givetian, the paleogeographic position of the Moravo--Upper Silesian and Małopolska Massifs in relation to the EEP have not changed significantly.

The consolidation of these areas most probably took place in the Silurian. Such a point of view was presented by some Polish geologists.

Some Carboniferous clastic rocks revealed non-dipolar components, probably of thermoviscous origin, that cannot be tectonically interpreted.

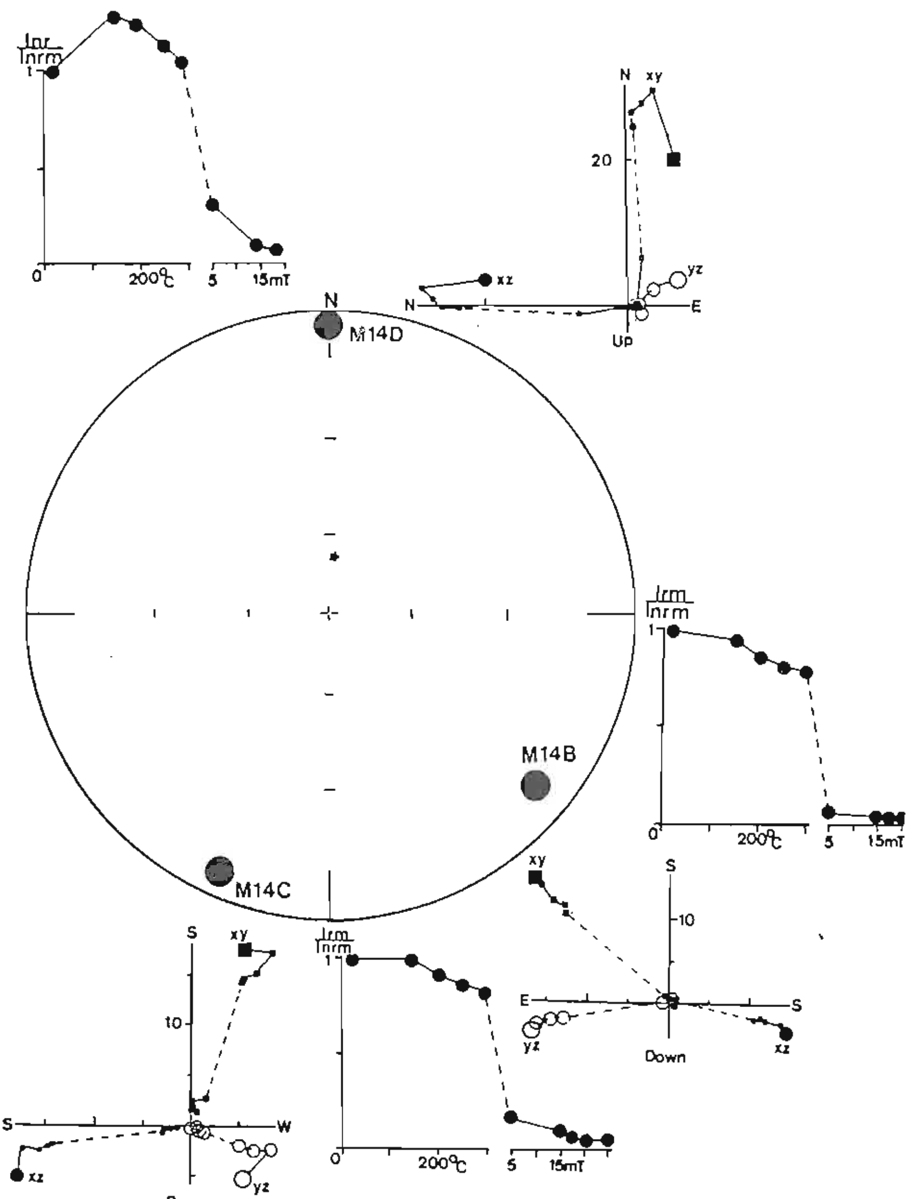
[1]These areas were affected in some places by the Variscan movements. Because of this the word "amalgamation" is maybe better in this place.

Fig. 19. Specimens from the Lower Westphalian clastic rocks of the Lublin Coal Basin (locality Bogdanka); orthogonal diagrams, intensity decay curves and polar projections of obtained directions; results of viscous and thermoviscous magnetizations in present-day magnetic field are presented on the series of stereonets

1 — demagnetization, 2 — magnetization

Próbki ze skał klastycznych dolnego westfalu z lubelskiego basenu węglowego (odsłonięcie Bagdanka); diagramy ortogonalne, krzywe spadku natężeń oraz projekcja sferyczna otrzymanych kierunków; wyniki lepkiego i termolepkiego namagnesowania w kierunku współczesnego pola geomagnetycznego są prezentowane na szeregu siatek stereograficznych

1 — rozmagnesowanie, 2 — magnesowanie



Irr/Inrm
200°C
5
15mT
N
xy
20
xz
yz
E
Up
M14D
M14B
M14C
S
10
W
Down

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Zakład Geofizyki
Państwowego Instytutu Geologicznego
Warszawa, ul. Rakowiecka 4
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Fig. 20. Specimens from the same sample M14 of the Early Westphalian sediments (locality Mikołów, S part of the Upper Silesian Coal Basin); stereonet with the characteristic directions, intensity decay curves and orthogonal plots

Próbki z tej samej próby M14, pochodzącej z osadów wczesnego westfalu (odsłonięcie Mikołów, południowa część górnośląskiego basenu węglowego); siatka stereograficzna z kierunkami charakterystycznymi, krzywe spadku natężeń namagnesowania oraz diagramy ortogonalne

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Jerzy NAWROCKI

DEWOŃSKO-KARBOŃSKIE PLATFORMOWE KIERUNKI PALEOMAGNETYCZNE Z OBSZARU ŚLĄSKO-KRAKOWSKIEGO I ICH ZNACZENIE DLA WARYSCYJSKICH REKONSTRUKCJI PALEOTEKTONICZNYCH

Streszczenie

Przedmiotem analizy paleomagnetycznej były węglanowe skały dewonu oraz klastyczne osady namuru i dolnego westfalu z obszaru śląsko-krakowskiego. W dolomitach żywieckich wyodrębiono pierwotną lub wczesnodiagenetyczną składową namagnesowania o następujących parametrach bieguna paleomagnetycznego: długość geograficzna $\lambda = 311°E$, szerokość geograficzna $\phi = 5°S$, $N = 16$ próbek, polarność normalna. W skałach tych oraz w wapieniach famenu wydzielono ponadto dwie wtórne składowe. Pierwsza z nich ($\lambda = 327°E$, $\phi = 26°S$, $N = 22$, polarność odwrotna) utrwaliła się najprawdopodobniej we wczesnym karbonie, natomiast drugą należy wiązać z silnym permskim przemagnesowaniem. W skałach górnego karbonu wydzielono trzy kierunki charakterystyczne. Jednak tylko jeden z nich został uznany za dipolowy, przydatny do interpretacji tektonicznych ($\lambda = 351°E$, $\phi = 39°S$, $N = 50$, polarność odwrotna). Otrzymane bieguny leżą dokładnie na ścieżce pozornej wędrówki bieguna paleomagnetycznego, charakterystycznej dla Europy platformowej. Opierając się na tym fakcie, możemy stwierdzić, że od żywetu badany obszar nie zmienił zasadniczo pozycji w stosunku do platformy wschodnioeuropejskiej.

Zasadniczy etap konsolidacji tektonicznej obszaru położonego między Sudetami a krawędzią platformy miał miejsce najprawdopodobniej w sylurze. Taki wiek konsolidacji był i jest przyjmowany przez znaczną część geologów.