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STUDIA PALEOMAGNETYCZNE SKAŁ POLSKICH

I. PERMSKIE SKAŁY OGNIOWE OBSZARU KRAKOWSKIEGO I PEWNE WYNIKI Z GÓR ŚWIĘTOKRZYSKICH

(Fig. 9)

Palaeomagnetic Studies of Polish Rocks

I. The Permian Igneous Rocks of the Kraków District and Some Results from the Holy Cross Mountains

(Figs. 1—9, Tabs. 1—3)

STRESZCZENIE

Opracowanie zawiera wyniki pomiarów kierunku naturalnego magnetyzmu szczątkowego w skałach wieku permskiego, triasowego i prawdopodobnie karbońskiego. W permskich skałach ogniowych obszaru krakowskiego został stwierdzony stały magnetyzm szczątkowy, gdy w osadowych skałach pstrego piaskowca w Górach Świętokrzyskich stwierdzono magnetyzm szczątkowy zmienny. Wykonano również pewną ilość oznaczeń temperatur punktu Curie badanych skał ogniowych. Przeprowadzona jest dyskusja wyników na tle stosunków geologicznych badanych skał.

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A b s t r a c t. The results of the measurements of the direction of natural remanent magnetism in rocks of Permian, Triassic, and possibly Carboniferous age are reported. A stable magnetization was found in the Permian rocks of the Kraków district, whilst the Triassic Buntsandstein of the Kielce area, and the possibly Carboniferous igneous rocks from Bardo (Holy Cross Mts.) were unstably magnetized. A limited number of Curie point temperatures were measured using an automatically recording Chevallier balance. The significance of these results in their geological context is discussed.

INTRODUCTION

Since the development and availability of sensitive magnetometers capable of measuring the directions of natural remanent magnetism in rocks, a magnetism which is characteristically of very low intensity (as low, or lower than 10^{-7} e.m.u./c.c. in some sedimentary rocks), investigations have spread rapidly and widely. A considerable volume of data now exists which has been summarized by C o x and D o e l l (1960) and which can be found in a series of tables published by I r v i n g (1960, 1961). Of more particular interest here are the summary of European results in N a i r n (1960).

In the summer of 1961 the authors began collections of Polish rocks with the collection of orientated samples of Permian igneous rocks, mostly lavas, from the vicinity of Kraków, and also of Triassic Buntsandstein and the possibly Carboniferous intrusion of Bardo in the Holy Cross Mountains. These results are here recorded.

It is not intended to discuss here the general problems of origin of magnetization and method of measurement. For information of this kind the reader is referred to survey papers by Cox and Doell (1960), Collinson and Nairn (1960), and by Runcorn (1956).

FIELD SAMPLING

In general it has been found advisable to collect rocks from quarries or deep road cuttings whenever and wherever possible for by this means the effects of weathering and of lightning may be avoided. Inevitably, however, it is also necessary to collect from surface outcrops.

In collecting orientated samples of sedimentary rocks, it was usual to obtain at least three from different horizons spaced through the exposed outcrop thickness. As the number of samples must obviously depend upon local conditions no set number can be given, but rather, as a generalization, about one sample every 2 to 3 metres may be taken. Each is regarded as representing a single instant in time, and a sample mean is calculated from up to four measurements per sample.

In the case of igneous rocks extrusive or intrusive, the length of time taken for all points at any given outcrop to have cooled through the Curie point temperature of the ferromagnetic mineral or minerals involved, is so short in comparison with the period of secular variation, that the magnetization at that point may be regarded as a single instant. As such it must obviously be effected by secular variation. Consequently site mean directions are used based on measurements on up to six samples per site.

Orientation is measured by use of a geological compass corrected for local secular variation — only in a very few cases is the local magnetic anomaly or the permanent magnetism of the rock of sufficient intensity to affect the accuracy of the compass. The strike of the bedding plane of sedimentary rock samples is found by use of small spirit level. In the case of igneous rocks it was usually more convenient to measure the dip and strike of any plane or joint surface and make a correction in the laboratory based on observation of the dip and strike of the enclosing sedimentary rocks.

LABORATORY MEASUREMENTS AND ANALYSIS

Each orientated sedimentary sample represents a different unit bounded above and below by bedding planes. Consequently each must represent a different interval of time; however with the variation in grain size and the general absence of information on rates of deposition, it is not possible to state how long an interval is represented within the sample. It was, therefore, assumed that each sample approximated to a single „instant" of time, and a mean was obtained using up to four 2.5 cm discs 1 cm in thickness cut from one or two cylinders. The direction of natural remanent magnetism was measured using a sensitive magnetometer of the type described by Collinson *et al.* (1957). The computation of the directions and intensity of magnetization were carried out on a high speed electronic computer using a programme devised by Dr. L. Molyneux.

From each igneous sample up to four cores were cut, but more usually only a single core from each was used without perceptible loss in accuracy. Site means were then computed. All igneous rocks were subjected to A.C. demagnetization in fields of increasing magnitude as a test of stability and as a means of removing secondary components of magnetization.

In general, demagnetizing field stages of 75, 150, and 250 oe, produced in a coil by 50 cycle mains current tuned by a bank of condensers to obviate harmonics, were used. Smooth field reduction was obtained by withdrawing from an electrolyte tower one electrode by means of a small electric motor driving a pulley with a conical thread. The specimen, mounted in field free space (to less than 50γ), was rotated about two axes within the demagnetizing coil.

The Curie point temperature and thermo-magnetic curves were obtained for a number of samples by using an automatically recording Chevallier balance, in which a small specimen of a few grams weight rested on a torsion arm within a furnace in an asymmetrical magnetic field (up to 1650 oe maximum) of an electro-magnet. The change in magnetic properties with heating is reflected in the movement of the torsion arm, the balance deflection falling to zero at the Curie point. Typical curves from the Rudno lavas are illustrated in Fig. 7.

Mean directions of magnetization using sample means (sediments) or site means (igneous rocks) and the computation of ancient pole positions were carried out on an electronic computer using programmes devised by Dr. L. Molyneux. The statistic devised by Fisher (1953) was used to obtain the mean, α, the semi-angle of the cone of confidence about the mean, and K a parameter which is a measure of dispersion. The formulae for the calculation of the confidence limit of the mean and K are given below:

$$\cos \alpha = 1 - \frac{N-R}{R}\left\{\left(\frac{1}{P}\right)^{\frac{1}{N-1}} - 1\right\}$$

$$K = \frac{N-1}{N-R}$$

Where N is the number of measurements used;
P the probability level required (usually 95%);
R the vector mean of N measurements;
α is the semi-angle of the cone of confidence;
K is a measure of scatter.

This statistic is used almost without exception in rock magnetism, and discussion centres mainly around the choice of N, here the sample mean for sedimentary and the site mean for igneous rocks. In the case of demagnetized igneous rocks, the direction adopted as best representing the true original site magnetization was that at which the K value was a maximum (i.e. scatter a minimum).

DISCUSSION OF RESULTS

1. Permian Igneous Rocks of the Kraków District

The igneous rocks of the Kraków district (Fig. 1) belong to late--Variscian magmatic cycle. The oldest are porphyry tuffs and blocks of porphyry contained in slump breccias of the uppermost Visean marine sediments of Orlej (cf. Dżułyński 1952; Czarniecki & Łydka 1958). The lava is of rhyolitic type.

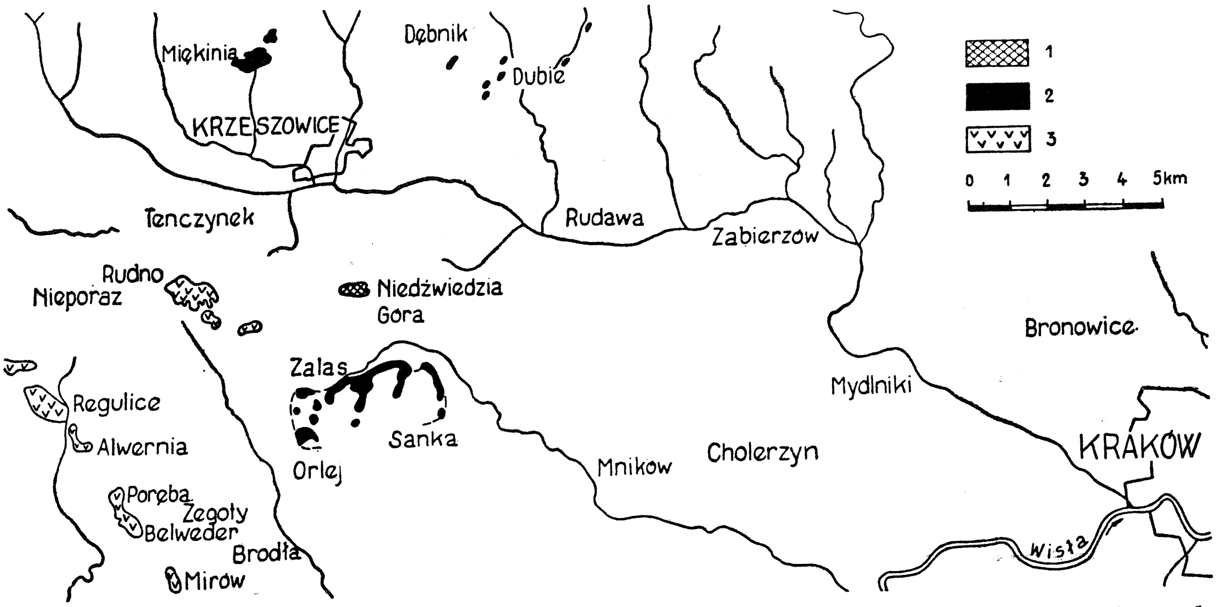

Fig. 1. Schematyczna mapa najważniejszych późnopaleozoicznych skał ogniowych obszaru krakowskiego. 1 — diabazy; 2 — porfiry; 3 — melafiry

Fig. 1. Schematic map of most important late Palaeozoic igneous rocks of the Kraków district. 1 — Diabase; 2 — Porphyry; 3 — Melaphyre

A group of small quartz porphyry sills, dykes etc. crossing Devonian and Lower Carboniferous carbonate rocks of the Dębnik Anticline are related to the Upper Carboniferous Asturic phase (Kozłowski 1955). A similar age is also suggested (Kozłowski 1955, p. 83) for a porphyry laccolith of Zalas-Głuchówki (Orlej) which intruded into uppermost Visean-Namurian marine deposits (Dżułyński 1955) though a Lower Permian age cannot be excluded (cf. Siedlecki 1952, 1954).

A Lower Permian age is established for extrusive quartz porphyry at Miękinia which rests upon either Namurian beds or upon the Lower Permian Myślachowice Conglomerate (cf. Siedlecki 1956, p. 454). Petrologically the porphyries vary from dacites to rhyodacites (cf. Czarniecki & Łydka 1958).

A number of diabase (hypersthene-quartz diabase) sills have been found in bore holes (cf. Siedlecki 1954) within Upper Carboniferous sediments. The only known outcrop of this rock is at Niedźwiedzia Góra. These diabases are also referred to Asturic phase (cf. Siedlecki 1951, 1952), but a Lower Permian age cannot be excluded.

The melaphyres are all extrusive rocks (lava flows) of an undoubted lower Permian age as they are younger than, or partly coeval with, the Lower Permian Myślachowice Conglomerate (cf. Birkenmajer 1952; Siedlecki 1951, 1952; Siedlecki & Żabiński 1953). Mineralogically they correspond to augite andesites and related rocks. The melaphyre lavas are largely grouped along two lines which partly correspond to late-Variscian (Saalic) faults bordering the so-called Nieporaz-Brodła Graben stretching NW-SE (cf. Siedlecki & Żabiński 1953). Along the south-western fault there occurred linear eruptions which produced melaphyre lava flows of Mirów, Belweder (Poręba Żegoty), Alwernia, Regulice, and along the north-eastern fault lavas were extruded between Rudno and Zalas.

The youngest are Lower Permian porphyry- and melaphyre tuffs and tuffites, partly pseudo-tuffs, the latter formed from weathered porphyries and melaphyres mostly during the Lower but possibly also during the Upper Permian (cf. Siedlecki 1951, 1952, 1954; Siedlecki & Żabiński 1953).

Notwithstanding differences in mineral composition and geological form, the chemical character of the igneous rocks of the Kraków district is very similar (cf. Rozen 1909; Broder 1931). Diabases and melaphyres are more basic than the porphyries, all are comagmatic. The rocks in question were subjected to alteration, which can be partly attributed to late-magmatic solutions rich in K_2O which caused calification of both porphyries and melaphyres (cf. Siedlecki 1954) although these phenomena have also been explained by a special type of weathering (Rozen 1909). Opinions have also been expressed (Bolewski 1939) that the rocks rich in K_2O („potash trachytes") are products of independent lava extrusions. These opinions are not supported by geological evidence.

Miękinia

At Miękinia there occurs a Lower Permian red quartz porphyry lava flow about 60 m thick. It rests in part upon the Namurian marine deposits and partly upon the Lower Permian Myślachowice Conglomerates (including red clays), the latter found by Zajączkowski (cf. Siedlecki 1956, p. 454). The porphyry is covered by Lower Triassic in some places or by Quaternary deposits in others. The lava flow is believed to be horizontal.

The two sites examined, described below as Miękinia 1 and Miękinia 2, were separated by a small valley cutting through porphyry, which exposed Namurian shales. Miękinia 1 is an old (northern) quarry where samples (P_p48-53) were collected from the upper part of the lava flow which shows well developed thick columnar jointing. Miękinia 2 is a new (southern) quarry where samples (P_p54-57) were collected from the lower part of the lava flow (lower exploitation level) which shows well developed thin platy jointing, about 10—12 m above the bottom of the flow as determined by bore holes evidence.

Regulice

At Regulice there occur two Lower Permian melaphyre flows exposed in a big (eastern) quarry near the railway station (Fig. 2). The first lava flow (Regulice 1) is about 40 m thick. It begins with a thin basal breccia of melaphyre resting immediately upon arkose sandstones resembling the Karniowice Sandstones (Upper Stephanian ?) well exposed in the eastern part of the eastern quarry. The contact plane dips 170° ENE 10°. Further west the bottom breccia almost disappears and the horizontally jointed melaphyre rests on a thin conglomerate of the Myślachowice Conglomerate (Lower Permian) type, underlain by sandstones similar to the Karniowice Sandstone (cf. Siedlecki 1951, 1952). Farther up from the contact the melaphyre becomes massive with vertical or oblique joint planes (samples P_p80-83); still higher vesicles and amygdales appear which become more and more frequent in the upper part of the flow (samples P_p76-79).

Of the upper flow (Regulice 2) only the lower part (2—3 m thick) is exposed in the eastern quarry. This flow also begins with thin melaphyre breccia tilted 0° E 15°, followed by massive, vertically jointed melaphyre (samples P_p84, 85) and is covered by Quaternary deposits.

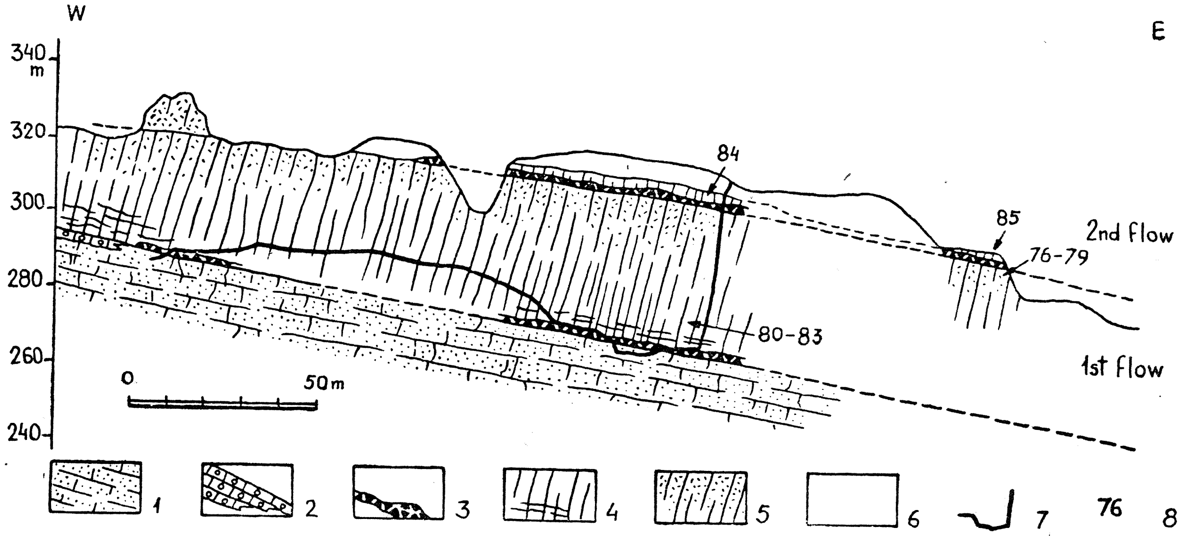

Fig. 2. Schematyczny przekrój przez wylew melafirowy w Regulicach (łom wschodni). 1 — piaskowce karniowickie; 2 — zlepieńce myślachowickie; 3 — podstawowa brekcja melafirowa; 4 — masywny melafir; 5 — melafir porowaty i migdałowcowy; 6 — osady czwartorzędowe i hałdy; 7 — granica łomów; 8 — numery próbek

Fig. 2. Schematic cross-section of melaphyre flows at Regulice (eastern quarry). 1 — Karniowice Sandstone; 2 — Myślachowice Conglomerate; 3 — Melaphyre basal breccia; 4 — Massive jointed melaphyre; 5 — Vesicular and amygdaloidal melaphyre; 6 — Quaternary deposits and dump heaps; 7 — Limits of the quarries; 8 — Number of sample

Further west there occur masses of amygdaloidal and vesicular melaphyre which may be considered as belonging to the second flow. There the melaphyre is covered by Lower Triassic sediments.

Rudno

At Rudno 5 melaphyre flows crop out. We sampled the rocks exposed in small quarries west of Tenczynek Castle (Fig. 3). All the flows though differing in thickness have the following common features: basal melaphyre (or melaphyre-sedimentary) breccia, massive vertically jointed melaphyre in the middle and vesicular, or amygdaloidal melaphyre in the upper part (Fig. 4). All the samples mentioned below were taken from the middle, massive, part of melaphyre flows.

The first flow (Rudno 1) represented by samples P_p86-90 is at least 12 m thick. The base, not exposed in the quarry, is exposed further east, S of the castle (cf. Birkenmajer 1952; Siedlecki 1951), where below the melaphyre the Myślachowice Conglomerate is found. The flow seems horizontal.

The second flow (Rudno 2) represented by samples P_p91-94 is about 12 m thick; the melaphyre breccia at the bottom is here approximately 4 m thick.

The third flow (Rudno 3) 6—8 m thick is poorly exposed, with a basal breccia of 2—3 m in thickness. No samples were collected.

The fourth flow (Rudno 4) represented by samples P_p95-98 is 10—12 m thick. Its basal breccia fills the uneven surface of the 3rd flow, evidently an erosion surface; thus its thickness varies from 4 to 6 m.

The fifth and last flow (Rudno 5) represented by samples P_p99-102 is over 5 m thick. Its basal breccia is 1.5 m thick. The upper vesicular part has been removed by erosion.

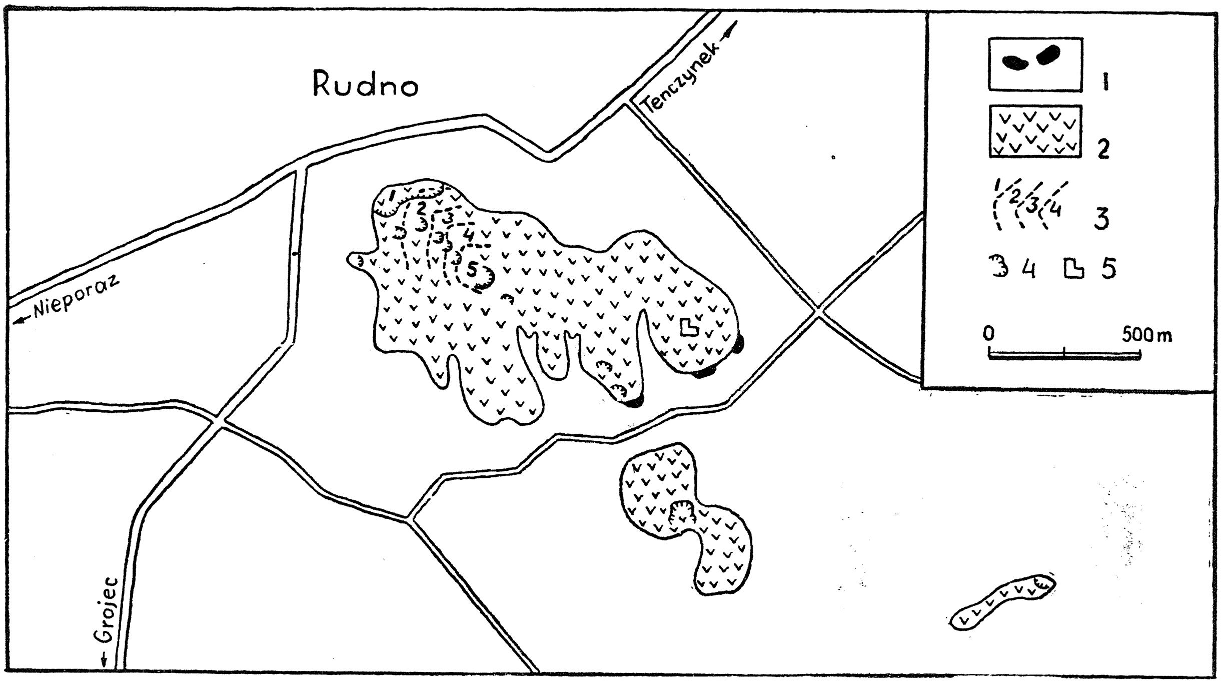

Fig. 3. Odsłonięcie melafiru w Rudnie. 1 — zlepieńce myślachowickie; 2 — melafir; 3 — kolejne wylewy lawowe; 4 — kamieniołomy; 5 — zamek w Tenczynku

Fig. 3. Outcrops of melaphyre at Rudno. 1 — Myślachowice Conglomerate; 2 — Melaphyre; 3 — Successive lava flows; 4 — Quarries; 5 — Tenczynek Castle

B e l w e d e r

At Belweder near Poręba Żegoty there occurs only one Lower Permian melaphyre lava flow tilted 110° NNE 15°. Its bottom breccia and contact with the Kwaczała Arkose (Middle Stephanian) were well exposed some time ago (cf. B i r k e n m a j e r 1952). The minimum thickness of the flow may be established as 15 m (of this 1—2 m is represented by the basal breccia). The melaphyre is covered by Quaternary deposits. The samples (P_p72-75) were taken from massive, vertically or obliquely jointed melaphyre exposed in the quarry.

O r l e j a n d Z a l a s

The outcrops of quartz porhyry at Orlej (Głuchówki) and at Zalas belong to one laccolith which is some 100 m thick (cf. D ż u ł y ń s k i 1955). The porphyry is intruded into uppermost Visean-Namurian sediments (cf. D ż u ł y ń s k i o.c.; C z a r n i e c k i 1955) and hence is of post-Namurian age. It is not clear whether the porphyry was intruded during the Upper Carboniferous or during the Lower Permian (S i e d l e c k i 1952). However, K o z ł o w s k i (1955, p. 83) is inclined to believe that it is related to the Asturic phase.

At Zalas samples (P_p64-67) were taken from the first quarry to the east of the road leading from Zalas to Sanka (see G r a d z i ń s k i 1960, p. 120, No. 42). The rock is here mostly greenish, but reddish if slightly altered.

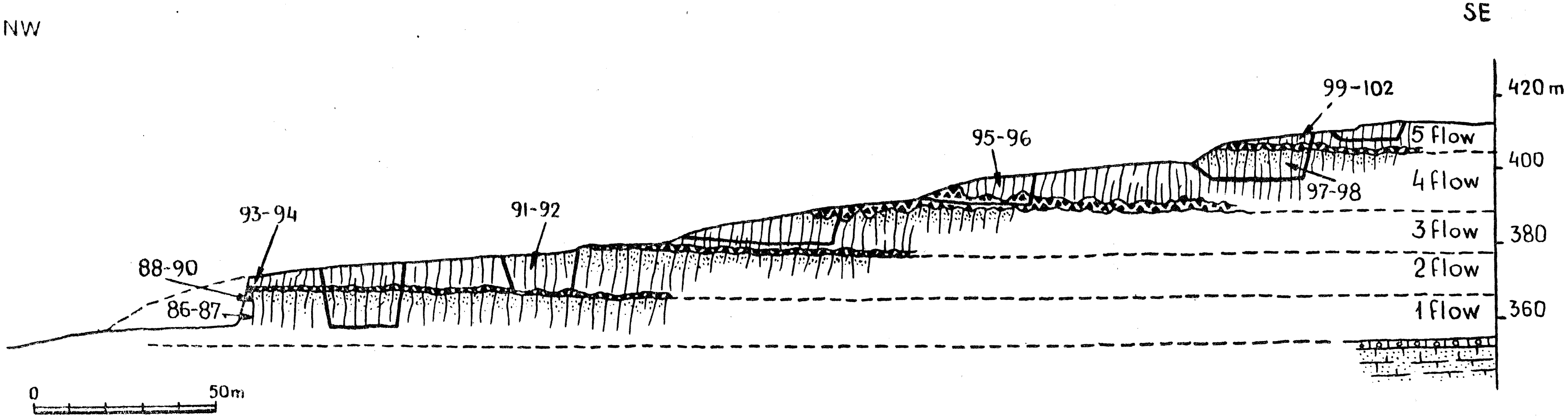

Fig. 4. Schematyczny przekrój przez wylew melafirowy na zachód od zamku w Tenczynku. Objaśnienia jak na fig. 2

Fig. 4. Schematic cross-section of melaphyre flows at Rudno west of the Tenczynek Castle. For explanations see Fig. 2

At Orlej the samples (P_p68–71) were taken from greenish and reddish porphyry exposed in the southern part of the quarry, about 50 m from the contact with thermally altered Carboniferous sediments.

In general the rocks mentioned above were stably magnetized (Tab. 1) though of low intensity of magnetization, for demagnetization in A.C. fields never significantly altered the direction of magnetization in the majority of cases (typical demagnetization curves are shown in Fig. 6). It made very little difference whether the site mean was based on sample means of four measurements or upon single measurements and the latter method was consequently generally applied.

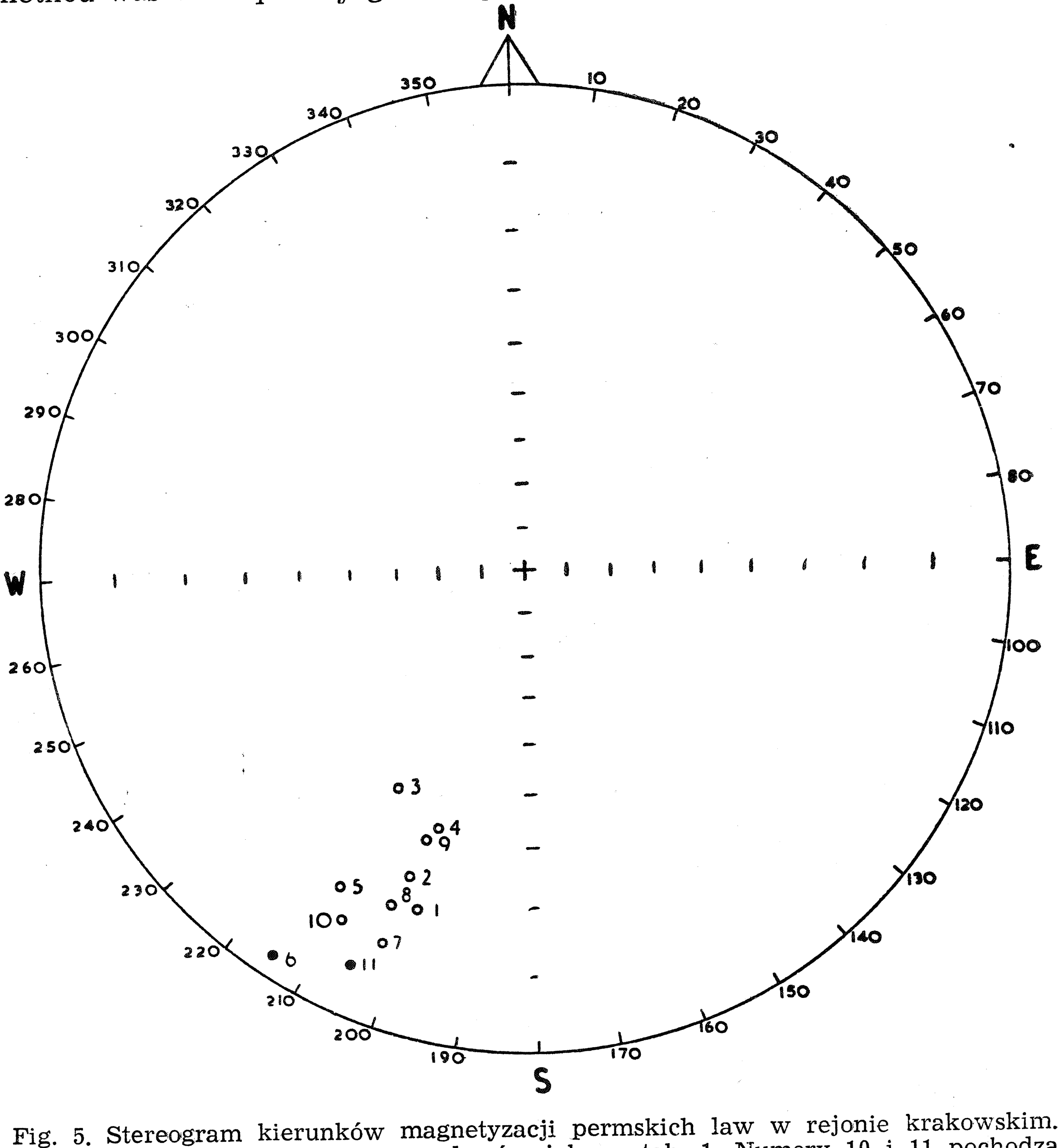

Fig. 5. Stereogram kierunków magnetyzacji permskich law w rejonie krakowskim. Numery odpowiadają numerom wylewów jak na tab. 1. Numery 10 i 11 pochodzą z intruzywnego lakkolitu w Orleju i Zalasie

Fig. 5. Stereogram showing the direction of magnetization of Permian lavas from the Kraków district. The numbers correspond to the numbers of flows as in Tab. 1. Note that 10 and 11 are from an intrusive laccolith sampled at Orlej and Zalas respectively

Table 1

Permian Volcanics, Kraków District

Site	Mean Declination	Mean Inclination	α	K	N	R	Demagnetization Field
1. Miękinia 1	198.7	−17.4	9.2	53.9	6	5.907	170 oe
2. Miękinia 2	201.5	−21.8	4.6	393.3	4	3.992	0
3. Regulice Flow 1	211.1	−34.7	8.4	52.9	7	6.887	85 oe
4. Regulice Flow 2	200	−31	—	—	1	—	85 oe (a)
5. Rudno Flow 1	211.5	−15.6	14.6	28.4	5	4.859	0
6. Rudno Flow 2	214.2	+ 2.7	26.4	13.1	4	3.771	0
7. Rudno Flow 4	202.1	−11.2	15.3	37.0	4	3.919	85 oe
8. Rudno Flow 5	203.0	−16.6	9.4	97.3	4	3.969	85 oe
9. Belweder	201.3	−28.5	31.8	63.7	2	1.984	255 oe
10. Orlej	208.7	−11.6	91.3	9.8	2	1.898	170 oe (b)
11. Zalas	204.9	+ 6.5	53.8	23.8	2	1.958	0 (c)
Overall mean							
excluding (b) (c)	204.9	−19.5	8.1	41.5	9	8.807	
including (b) (c)	205.2	−16.4	7.9	34.5	11	10.710	

(a) only one sample, results from same demagnetizing field for Regulice flow 1 quoted.
(b) of four samples, two gave no reading, remaining two samples only gave result in a field of 170 oe.

At only one site (Orlej) were some samples too weakly magnetized for measurement (two out the four collected), the remaining two only gave a measurement in a field of 170 oe. The mean, as in the case of the Zalas samples, despite the very large circle of confidence agreed very well with the mean of the remainder (excluding the Zalas samples). This distinction of the Zalas and Orlej sites in an intrusive laccolithic body, separates them from all the remaining sites which were in lava flows and indicates some marked difference in their ferromagnetic mineral

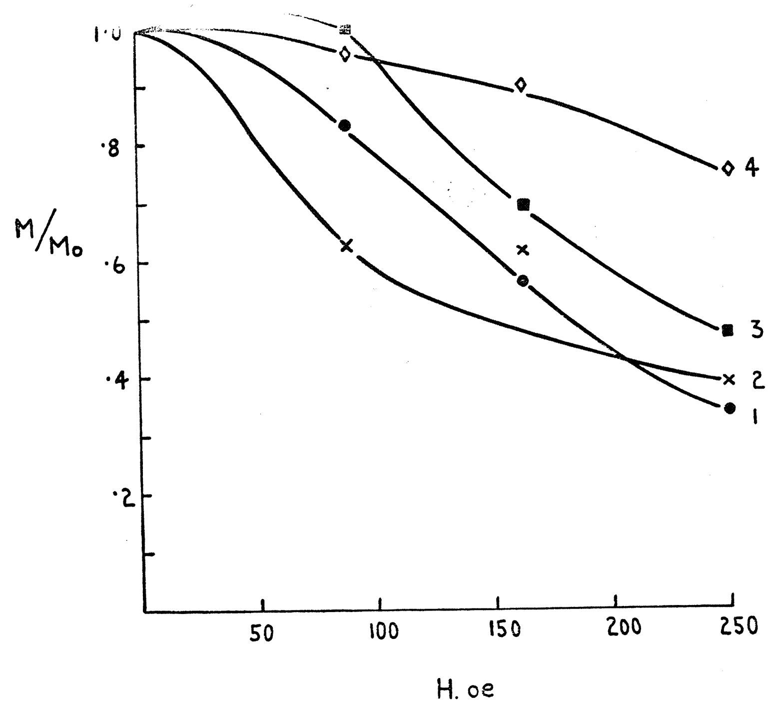

Fig. 6. Znormalizowane krzywe demagnetyzacji law z Rudna i Regulic (melafiry), pola zmienne do 250 oe. 1 — Regulice, wylew 1; 2 — Rudno, wylew 5; 3 — Rudno, wylew 4; 4 — Rudno, wylew 5; 2 i 4 są krzywymi z próbek pobranych w tym samym miejscu

Fig. 6. Normalized demagnetization curves of Rudno and Regulice lavas (melaphyre), alternating fields up to 250 oe. The curves are numbered as follows. 1 — Regulice, flow 1; 2 — Rudno, flow 5; 3 — Rudno, flow 4; 4 — Rudno, flow 5; 2 and 4 are curves from different samples collected at the same site

content. That some difference exists is borne out by measurements on the Chevallier balance. Thermo-magnetic curves did not reveal the presence of a second magnetic phase in any of the lavas examined. Typical curves, tracings of photographic records, shown in Fig. 7 indicate a Curie point close to that of magnetite. Three of the curves in Fig. 8, however, do indicate the presence of a material with a Curie point of about 350 °C, a material which would appear to be destroyed by heating since it does not reappear in the cooling curve, in addition to magnetite. Two of the curves (a, b) came from samples collected at Zalas, the other two (c, d) were obtained from Orlej samples.

Overall site means have been calculated (see Tab. 1) including and excluding the two results (Zalas and Orlej), and from these means the position of the ancient pole has been calculated [1]. It is felt that the better

[1] Mineralogical analysis would be interesting to see whether ilmenite showing exsolution was present in the Zalas and Orlej samples.

representation of the ancient Permian pole excludes the Zalas and Orlej results. The ancient pole so obtained fits in remarkably well with other determination made in western Europe (see N a i r n 1960).

Individual flow directions are plotted in Fig. 5 in which the distribution appears somewhat elongate although representing measurements which are magnetically stable from the A.C. point of view. The omission

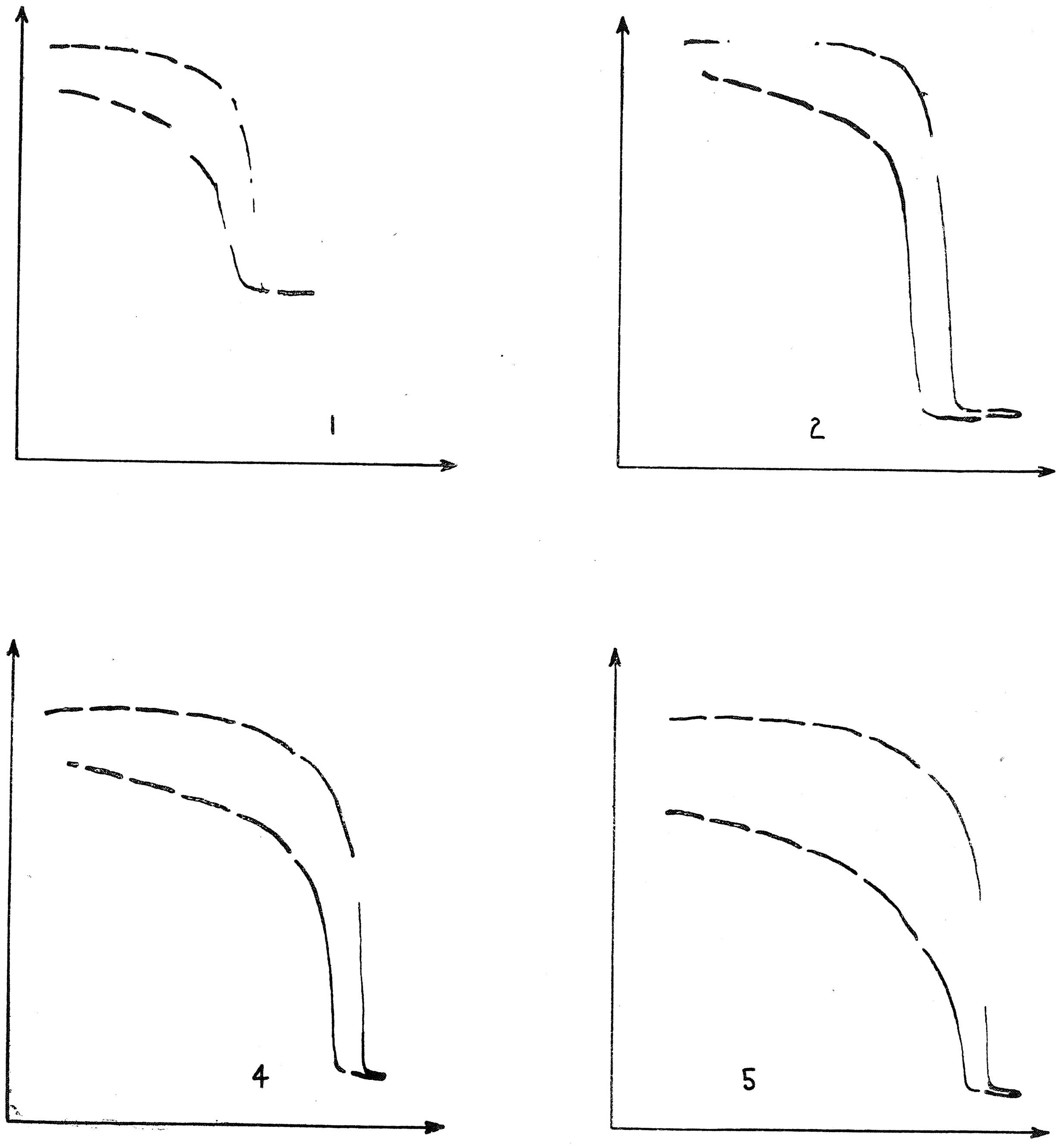

Fig. 7. Krzywe termo-magnetyczne otrzymane z automatycznej wagi skręceń z wylewów lawowych (melafirów) z Rudna. Wylewy ponumerowane jak na tab. 1. Gwałtowny spadek intensywności zachodzi w punkcie Curie. Na osi pionowej wyznaczono intensywność, na osi poziomej temperaturę. Przerwy w przebiegu krzywej występują w odstępach 100°, krzywa górna jest krzywą ogrzewania, dolna — oziębiania

Fig. 7. Thermo-magnetic curves obtained from an automatic torsion balance of lava flows (melaphyre) from Rudno. The flows are numbered as in Tab. 1. The sharp fall in intensity occurs at the Curie point. Arbitrary axes are drawn for convenience: intensity — vertically, temperature — horizontally. Breaks in the trace occur at 100° C intervals, the upper curve being the heating curve, the lower the cooling curve

of the Zalas and Orlej results from the calculations can be justified on the basis of their very large circles of confidence.

Niedźwiedzia Góra

Within the same area, three samples (P_p58-60) were collected from a single diabase sill intruded into Upper Carboniferous rocks at Nie-

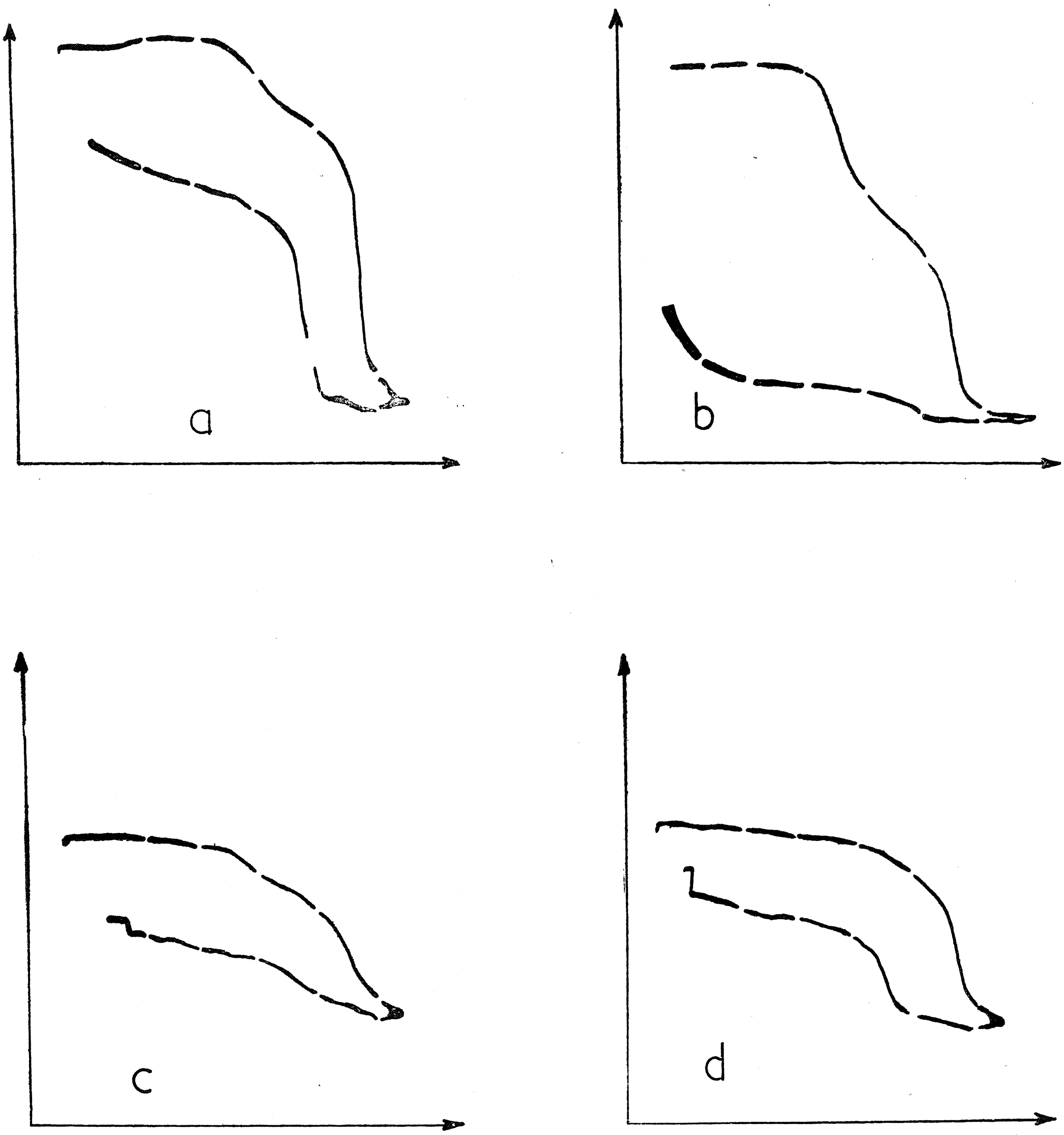

Fig. 8. Krzywe z próbek pobranych z lakkolitu porfirowego. a, b — Zalas; c, d — Orlej, inne oznaczenia jak na fig. 7

Fig. 8. Curves from porphyry laccolith samples. a, b — Two samples from Zalas; c, d — Two samples from Orlej. For other explanations see Fig. 7

dźwiedzia Góra (western part of the quarry), and itself believed to be of Upper Carboniferous age (cf. Siedlecki 1951, 1952), related to Asturic phase. Two samples (P_p61, 62) were also obtained of the lower contact [1],

[1] Below the sill there occur Upper Carboniferous sandstones and arkoses. The contact plane exposed in the western part of the quarry dips 120—135° SW 21—30°.

and these together with A.C. demagnetization establish with reasonable certainty the magnetic stability of rock in question.

The study of the rock raises several problems: whether, in the absence of the upper contact, it is a genuine still or a possible lava flow, or whether intrusion or extrusion post-dated or pre-dated tilting. A case could also be made for a Permian age of the rock which is not different in chemical composition from the Permian extrusives (melaphyres) of the district.

In the absence of precise information as to the attitude in which the rock cooled, directions and pole positions have been computed with respect to the present bedding and with respect to the horizontal (see Tab. 2).

Table 2

Diabase of Niedźwiedzia Góra, Kraków District

	Mean Declination	Mean Inclination	a	K	N	R	Ancient Pole
Computed with respect to bedding	212.0	+ 8.0	10	59.6	5	4.9329	28.9N 162.9E
Computed with respect to horizontal	212.5	— 15.8					40.1N 155.9E

It is not possible to draw any definite conclusion from the above data, for the rock from our initial considerations must be considered as affected by secular variation. If intruded or extruded and then tilted a Carboniferous age is possible; if intruded into tilted beds, then a Permian age is equally possible.

2. Palaeozoic Igneous Rocks from Bardo, Holy Cross Mts.

Measurements were attempted on four of five samples (P_p124-128) collected near the outlet of Prągowiec creek from natural outcrops of an augite- and spilite diabase dyke intruded subparallel to the contact of the Lower and Middle Ludlow [1]. Two, of what appeared fresh material came from near the upper (southern) contact, and the remainder from a poorer outcrop some 10 m distant, near the lower (northern) contact. Two samples were not measurable; whilst the remaining two gave measurements of reasonable internal consistency, there was little agreement between samples. Demagnetization in alternating fields up to 250 oe does not produce any better agreement, consequently no further work was carried out on this material. It is possible that with good exposures and fresh material, satisfactory results might be obtained.

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[1] There are no direct evidences of the age of the diabase. At any rate it is younger than Middle Ludlow. On comparisons with analogous rocks in the Holy Cross Mts., where the phases of tectonic deformations are dated more precisely a Carboniferous age (Sudetic phase?) is suggested (cf. Ryka 1957, 1958).

3. Triassic Buntsandstein from the Holy Cross Mts.

Five sites were visited of which three were quarries and two were road cuttings.

Gałęzice

The samples were collected from the Lower Buntsandstein (cf. Czarnocki 1938) exposed in a small quarry east of hill 312 m a.s.l. (samples

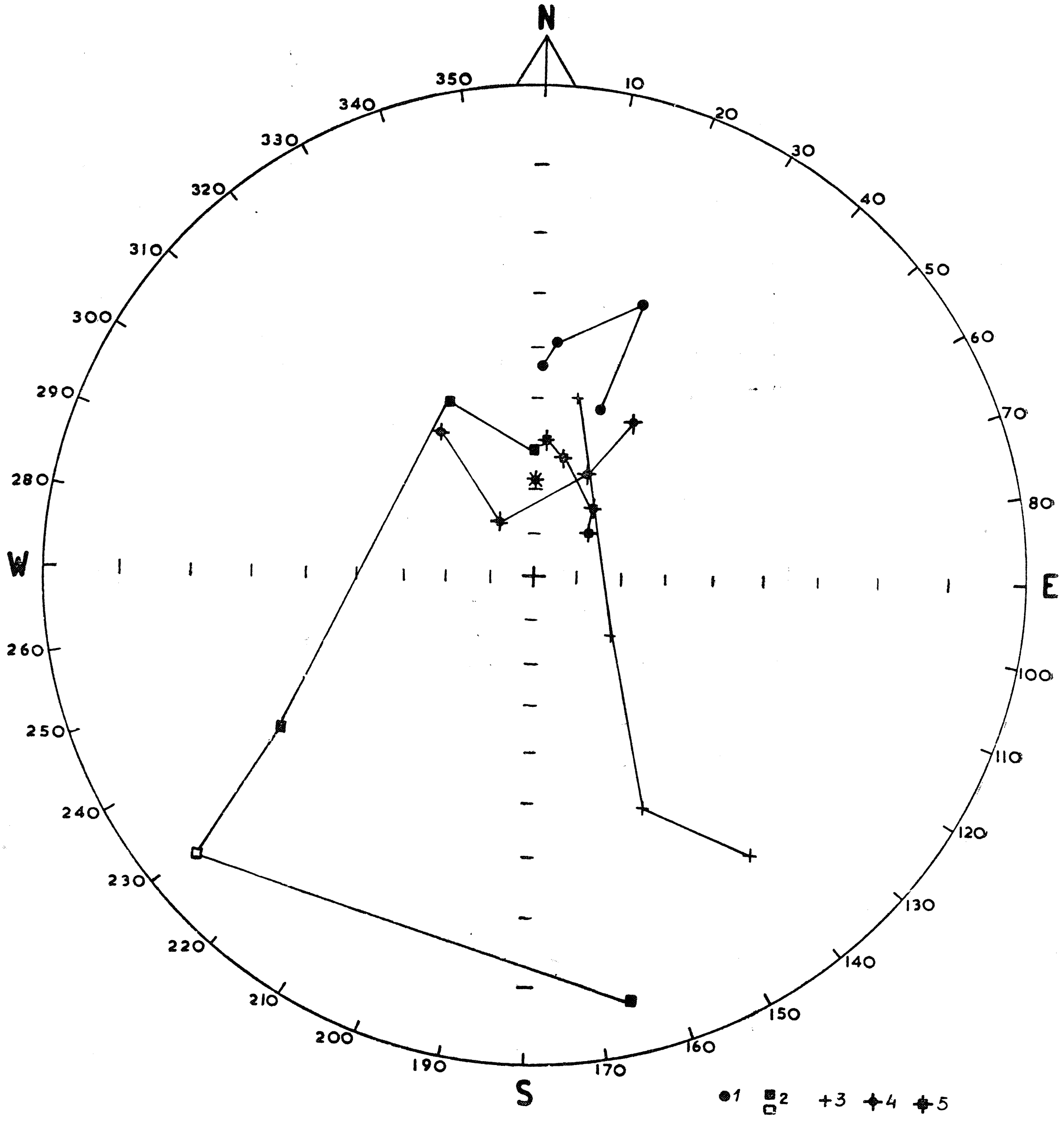

Fig. 9. Stereogram kierunków magnetyzacji pstrego piaskowca z Gór Świętokrzyskich. Próbki z tych samych miejsc zostały połączone razem. Wszystkie próbki z wyjątkiem jednej są normalnie namagnetyzowane. 1 — Gałęzice; 2 — Jaworznia; 3 — Występa; 4 — Tumlin; 5 — Wykień

Fig. 9. Stereogram showing the directions of magnetization of Triassic Buntsandstein samples from the Holly Cross Mountains. Samples from the same site are linked together. Note all samples with a single exception are normally magnetized and are indicated by solid symbols. The present dipole field is indicated by an asterisk. The sites are as follows: 1 — Gałęzice; 2 — Jaworznia; 3 — Występa; 4 — Tumlin; 5 — Wykień

Buntsandstein of

Site	Sample No.	Intensity of magnetization x 10^{-6}	Mean Declination	Mean Inclination
Gałęzice	108	12.165 ± 2.77	20.9	+ 39.8
	109	37.925 ± 7.13	0.9	+ 43.8
	110	8.623 ± 1.88	3.9	+ 38.9
	111	10.323 ± 1.63	20.7	+ 28.6
	site mean		12.1	+ 38.1
Jaworznia	103	1.770 ± 0.30	358.2	+ 61.3
	104	1.175 ± 0.24	237.9	+ 28.4
	105	2.178 ± 0.60	333.5	+ 47.4
	106	6.240 ± 0.88	229.0	− 6.5
	107	8.99 ± 0.11	165.7	+ 6.7
	site mean		237.6	+ 51.3
Występa	112	1.890 ± 2.317	12.5	+ 49.4
	113	2.385 ± 2.147	141.7	+ 18.5
	114	1.038 ± 0.459	153.7	+ 34.8
	115	0.627 ± 0.229	127.2	+ 69.2
	site mean		127.6	+ 56.1
Tumlin	116	0.808 ± 0.382	328.9	+ 74.1
	117	0.965 ± 0.492	326.9	+ 51.2
	118	1.365 ± 0.167	27.9	+ 62.7
	119	1.298 ± 0.283	31.7	+ 49.3
	site mean		2.4	+ 63.1
Wykień	120	1.748 ± 0.557	3.0	+ 59.1
	121	1.308 ± 0.755	51.2	+ 74.3
	122	1.690 ± 0.373	40.1	+ 70.7
	123	1.858 ± 0.771	12.8	+ 61.6
	site mean		21.7	+ 67.6

Table 3

the Kielce District

α	K	N	R	Ancient Pole	
6.0	238.8	4	3.9874		
4.6	393.2	4	3.9924		
13.2	49.4	4	3.9393		
16.1	59.6	3	2.9665		
12.1	58.6	4	3.9488	58.9N	178.8E
				58.9S	1.2W
14.5	41.3	4	3.9274		
50.6	4.3	4	3.2964		
48.8	4.5	4	3.3349		
—	—	2	—		
13.8	81.4	3	2.9754		
76.2	2	5	2.9704	7.2N	25.2W
				7.2S	154.8E
99.9	1.8	4	2.3754		
64.4	3.0	4	3.0043		
53.9	3.9	4	3.2276		
176.7	1.8	3	1.9041		
59.3	3.4	4	3.1115	9N	61E
				9S	118.9W
26.0	13.4	4	3.7767		
81.4	2.3	4	2.6733		
30.2	10.2	4	3.7058		
52.0	4.1	4	3.2678		
24.5	15	4	3.800	83.4N	174N
				83.4S	6E
26.2	13.3	4	3.7743		
101.7	1.8	4	2.3507		
19.2	23.9	4	3.8743		
36.7	7.2	4	3.5855		
12.8	52.6	4	3.9429	76.3N	104.6E
				76.3S	75.4W

P_R108,109), and from a road cutting in the western part of the hill (samples P_R110, 111). Dip of the beds ± 30° NNE.

J a w o r z n i a

The samples (P_R103-107) were collected from the Lower Buntsandstein (cf. C z a r n o c k i o.c.) in the western part of the quarry near point 313.0 m a.s.l., 1—5 m above the contact with the Givetian limestones. Mean strike and dip of the Buntsandstein: 95° NNE 20°.

W y s t ę p a

The samples (P_R112-115) were collected from the Lower Middle Buntsandstein (cf. C z a r n o c k i o.c.) in a road cutting, about 500 m NW of the main road (Kielce—Radom). The strike and dip of ripple-marked sandstones were 65° NW 4°.

T u m l i n

The samples (P_R116-119) were collected from the Lower Middle Buntsandstein (cf. C z a r n o c k i o.c.) in an old (eastern) quarry. Mean strike and dip of cross-bedded sandstones: 95° NNE 21°.

W y k i e ń

The samples (P_R120-123) were collected from Lower Middle Buntsandstein (cf. C z a r n o c k i o.c.) in a working quarry at Wykień (Ćmińsk), SW of Tumlin. Mean strike and dip of cross bedded sandstones: 80° NNW 15°.

The rock in general was a fine grained reddish sandstone; only in the Jaworznia quarry, immediately above the Devonian unconformity did it prove possible to obtain deep red coloured siltstones.

As can be seen from the accompanying stereogram (Fig. 9), the results are in general clustered around the dipole field (cf. Tab. 3). The presence of occasional samples in the south-west quadrant suggests that some at least of the samples may have been initially of reversed magnetization.

At only one site, the one showing also the best grouping was the mean intensity of magnetization greater than 3×10^{-6} e.m.u./c.c. On the basis of the observed scatter and the low intensity of magnetization, these rocks were concluded to be unsuitable for the investigation of the direction of the ancient magnetic field, and no further work was carried out of them.

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