ROCZNIK POLSKIEGO TOWARZYSTWA GEOLOGICZNEGO
ANNALES DE LA SOCIÉTÉ GÉOLOGIQUE DE POLOGNE

Tom (Volume) XXXVIII — 1968 Zeszyt (Fascicule) 4 Kraków 1968

KRZYSZTOF BIRKENMAJER [1], ALAN E. M. NAIRN [2]

STUDIA PALEOMAGNETYCZNE SKAŁ POLSKICH

III. NEOGEŃSKIE SKAŁY OGNIOWE PIENIN

(8 fig., 4 tab.)

Palaeomagnetic Studies of Polish Rocks

III. Neogene Igneous Rocks of the Pieniny Mountains, Carpathians

(8 Figs., 4 Tabs.)

STRESZCZENIE

Opracowanie zawiera wyniki pomiarów kierunku naturalnego magnetyzmu szczątkowego w neogeńskich skałach ogniowych Pienin. Orientowane próby do badań laboratoryjnych pobrano z ponad trzydziestu stanowisk. Pomiary elementów magnetyzmu szczątkowego dały dobre wyniki jedynie w przypadku dajek andezytowych góry Wżar koło Czorsztyna, które wykazały kierunek namagnesowania szczątkowego odwrotny w stosunku do obecnego pola magnetycznego Ziemi. W andezytach okolic Szczawnicy i Szlachtowej, które są uważane za starsze od andezytów Wżaru, stwierdzono kierunek namagnesowania szczątkowego zarówno normalny, jak i odwrócony.

Próbna korelacja paleomagnetyczna andezytów Wżaru z mioceńskimi skałami ogniowymi Słowacji wskazuje, że dajki andezytowe pierwszej generacji na Wżarze mogą odpowiadać andezytom pierwszej fazy (dolny torton) centralnosłowackiej prowincji wulkanicznej, dajki zaś andezytowe drugiej generacji na Wżarze — starszym andezytom drugiej fazy (granica tortonu i sarmatu) tej prowincji wulkanicznej.

*

* *

A b s t r a c t. Oriented samples were collected from about thirty sites in the Pieniny Mountains, Carpathians. Routine measurements and stability tests indicated consistent results from the andesite dykes exposed on Wżar mount only. Only reversed magnetization was recorded. A tentative correlation of the results with the igneous rocks of Slovakia would equate the Wżar intrusions with the first phase and lower part of the second phase andesites of the Central Slovakian province. From the sites in the region of Szczawnica and Szlachtowa there is an indication of both normal and reversed directions of magnetization in andesites older than those found on Wżar mount.

[1] Laboratory of Geology, Polish Academy of Sciences, Kraków, ul. Senacka 3.
[2] Department of Geology, Case Western Reserve University, Cleveland (Ohio).

INTRODUCTION

The present paper is a further contribution to the palaeomagnetic study of Polish rocks begun in 1961 (Birkenmajer, Nairn, 1964, 1965; Birkenmajer, Krs, Nairn, 1968; Birkenmajer, Grocholski, Milewicz, Nairn, 1968). The present report details the palaeomagnetic study of the Neogene volcanics, andesites and basalt of the Pieniny Mountains, in the Polish Carpathians (Fig. 1). Although about thirty sites were visited, only those on Wżar mount gave positive results. Andesites east of Czorsztyn at Szczawnica (2 sites), on Jarmuta mount (4 sites) and on Krupianka mount (1 site), and the basalt at Biała Woda were sampled without obtaining any consistent results.

The main conclusions from the study of the Wżar andesites were reported at the VIIth Congress of the Carpathian-Balkanian Association of Geologists, in Sofia (Birkenmajer, Nairn, 1965).

OUTLINE OF GEOLOGY (WŻAR MOUNT)

The igneous rocks of the Wżar mount near Czorsztyn are for the most part amphibole-augite andesites (Małkowski, 1958). According to Birkenmajer (1961, 1962) they belong to two generations of dyke intrusions. The first generation is represented by a series of sub-parallel dykes which change in strike from E-W on the eastern slopes of the hill, to ENE-WSW near the crest, and to ESE-WNW on the western flanks (see Fig. 2). The dykes are found mainly in the Lower Palaeogene core of an anticline in the Magura Flysch (Fig. 3). There is slight contact metamorphism. According to Birkenmajer (1963) the dykes dip towards the core of the anticline as if following tension joints developed during folding and prior to the intrusions. Their age is not known with any certitude but on regional geological grounds Birkenmajer (1960, 1962) suggested an early Miocene age (close to the Savian phase). However, a Middle Miocene age cannot be excluded (Birkenmajer, Nairn, 1965). Their intrusion appears to be synchronous with a series of NW-SE faults.

The second generation dykes cut the first generation dykes approximately at right angles following generally the line of faults which displace the first generation dykes. The older dykes are thermally altered by the younger intrusions and there are zones of brecciation sometimes found following the contacts of the second generation dykes in which fragments of the first generation andesites and altered sedimentary rocks are found. The age of the second generation dykes on regional geological grounds is Lower Miocene (Birkenmajer 1960, 1962) but again a Middle Miocene (Tortonian) age cannot be ruled out.

The general geological picture of Wżar mount was generally confirmed by the magnetometric survey of Małoszewski (1961, 1963), who assumed, however, the dips of the first generation dykes opposite to those indicated by Birkenmajer (1963). Several authors, Morozewicz, Małkowski and Michalik (cf. Małkowski, 1958; Birkenmajer, 1962), considered the major part of the Wżar andesites as forming a laccolith, as does Kozłowski (1961 a, b, 1965) whose opinions of the geological structure differ markedly from Birkenmajer and Małoszewski.

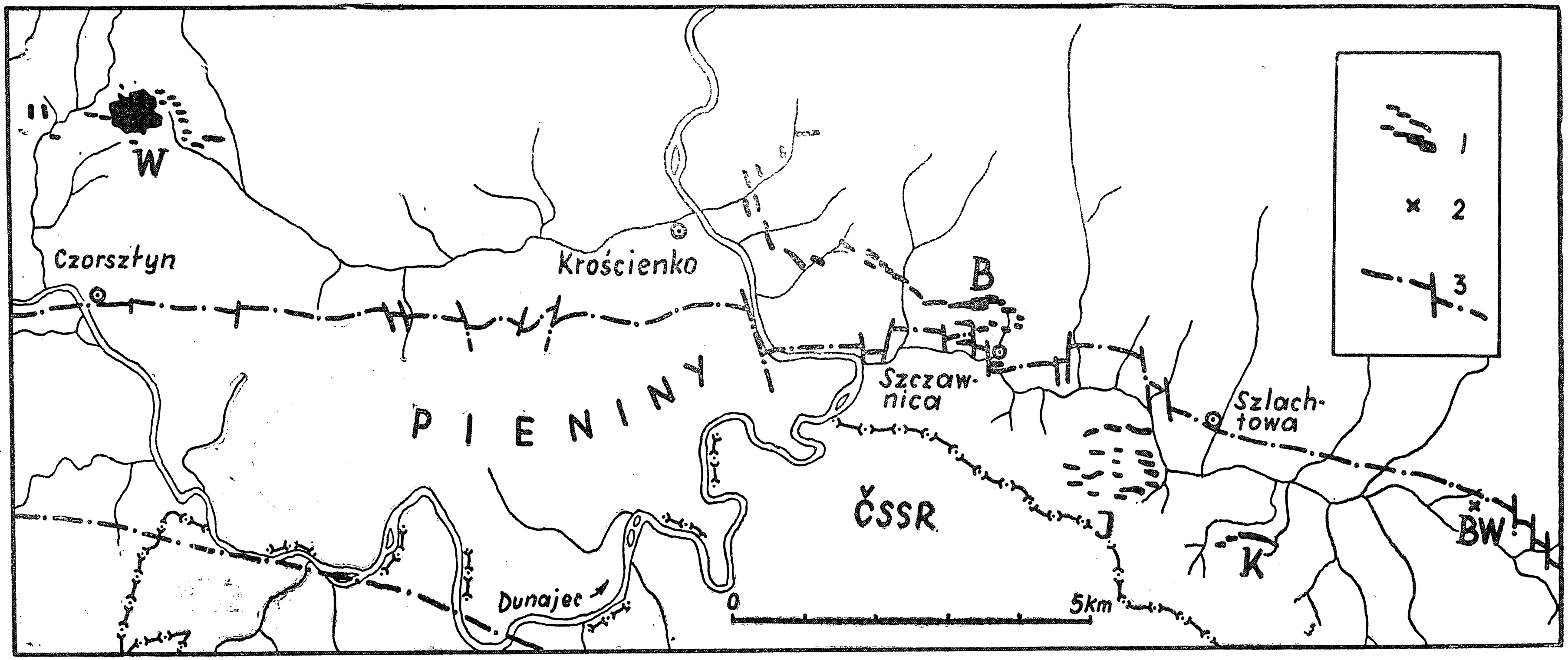


Fig. 1. Występowanie neogeńskich skał wulkanicznych w Pieninach. 1 — andezyt; 2 — bazalt; 3 — południowe i północne tektoniczne ograniczenie pienińskiego pasa skałkowego; B — góra Bryjarka; BW — Biała Woda; J — góra Jarmuta; K — góra Krupianka; W — góra Wżar

Fig. 1. Distribution of the Neogene igneous rocks in the Pieniny Mountains. 1 — Andesite; 2 — Basalt; 3 — Southern and northern tectonic borders of the Pieniny Klippen Belt; B — Bryjarka mt.; BW — Biała Woda; J — Jarmuta mt.; K — Krupianka mt.; W — Wżar mt.

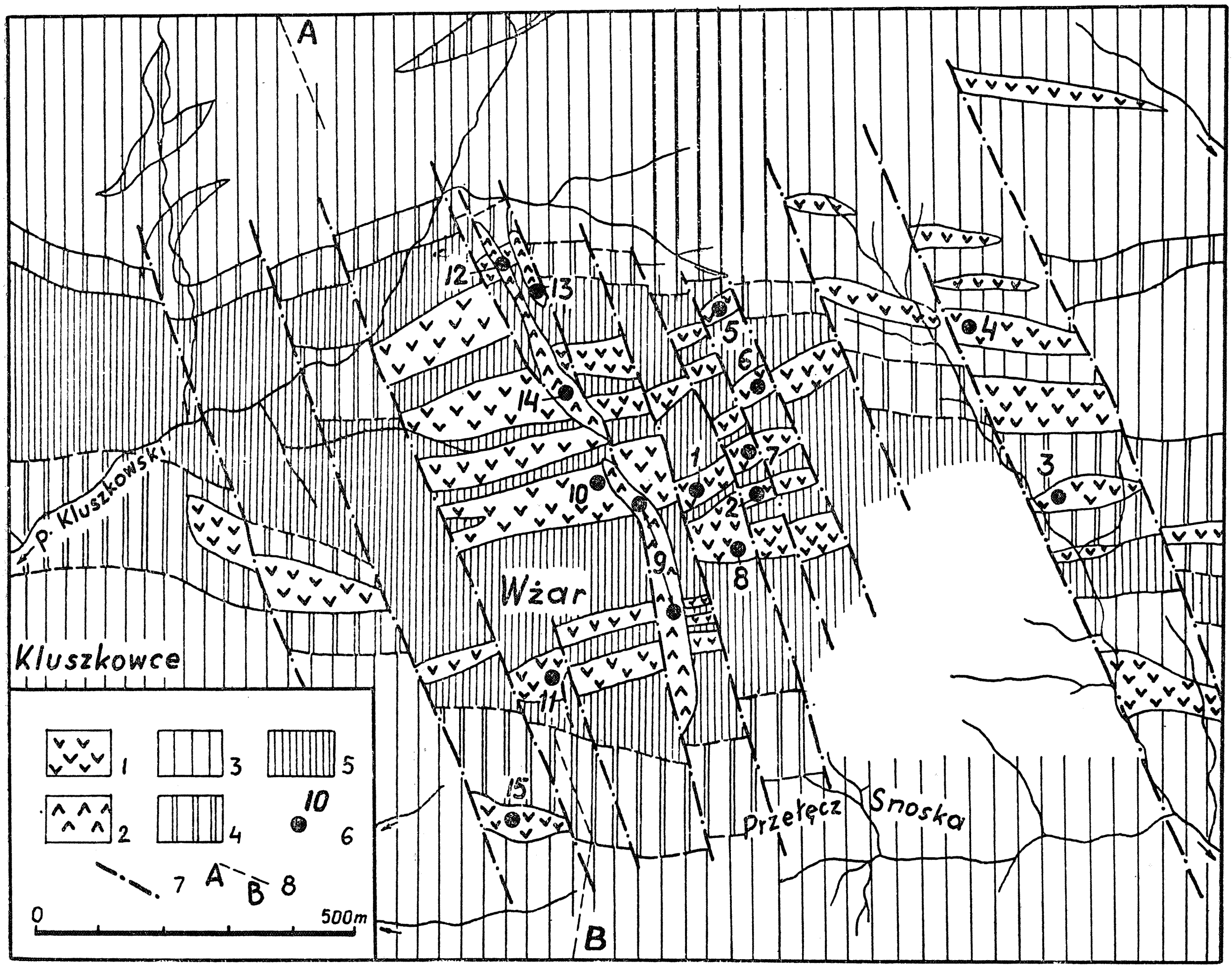
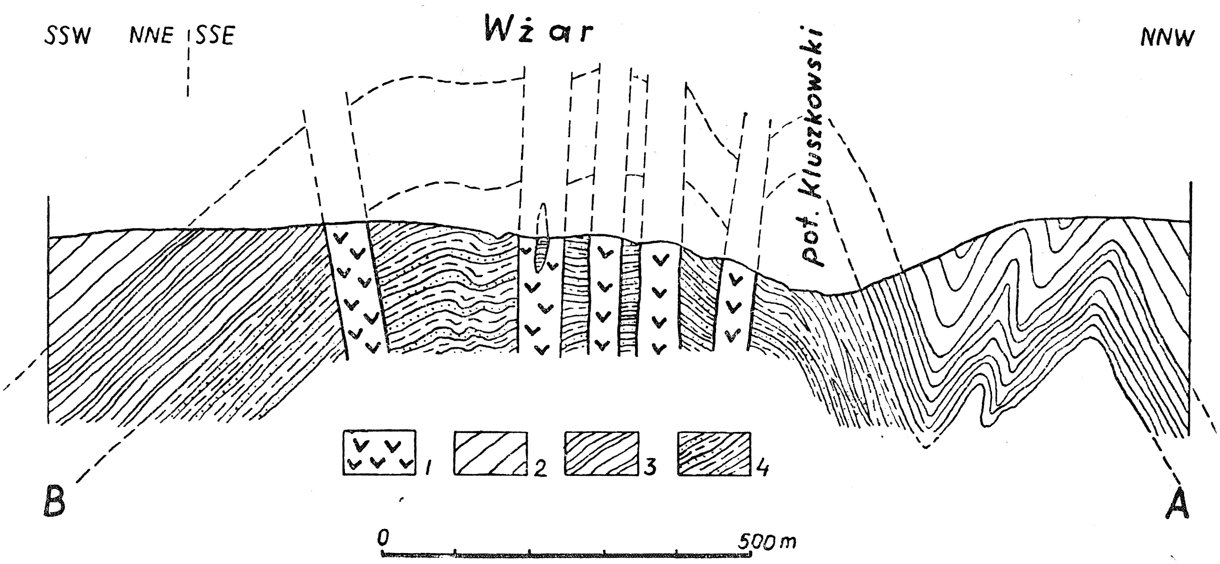


Fig. 2. Lokalizacja miejsc pobrania prób do badań paleomagnetycznych na górze Wżar koło Czorsztyna. Budowa geologiczna według Birkenmajera (1962), uproszczona. 1 — andezyty pierwszej generacji; 2 — andezyty drugiej generacji; 3 — piaskowiec magurski (środkowy eocen); 4 — warstwy podmagurskie (dolny eocen); 5 — warstwy kluszkowskie (dolny eocen-paleocen); 6 — miejsca pobrania prób; 7 — uskoki; 8 — linia przekroju geologicznego przedstawionego na fig. 3. Brekcje andezytowo-osadowe i strefy zmian termicznych w skałach osadowych nie zostały zaznaczone

Fig. 2. Location of dyke sampling sites on the Wżar mount near Czorsztyn. The geological map is modified from Birkenmajer (1962). 1 — First generation andesites; 2 — Second generation andesites; 3 — Magura sandstone (Middle Eocene); 4 — sub-Magura beds (Lower Eocene); 5 — Kluszkowce beds (Lower Eocene-Paleocene); 6 — Sampling sites; 7 — Faults; 8 — Line of cross-section illustrated in Fig. 3. Andesite-sedimentary breccias and zones of thermal alteration of sediments not indicated



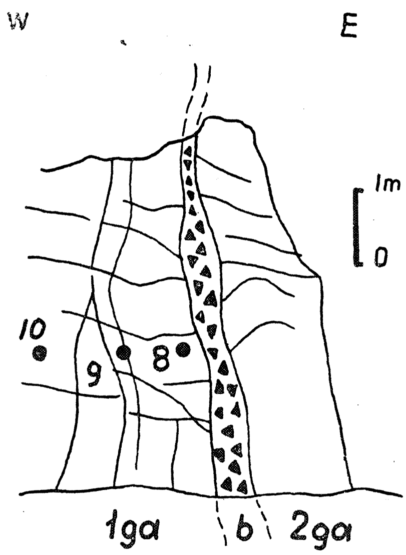


Fig. 4. Kontakt dwóch dajek andezytowych na górze Wżar. 1ga — andezyt pierwszej generacji (stanowisko 9); 2ga — andezyt drugiej generacji (stanowisko 10); 6 — brekcja andezytowa

Fig. 4. Contact of two andesite dykes at the Wżar mount. 1ga — First generation andesite (Site 9); 2ga — Second generation andesite (Site 10); 6 — Andesite breccia

PALAEOMAGNETIC INVESTIGATION

1) Direction of Magnetization

As the techniques used are standard and have been frequently described, for example by Birkenmajer and Nairn (1964) and Nairn (1966) no more than an outline will be given here. Oriented blocks were collected from both natural outcrops and quarries. The number of samples per site varied according to the nature and size of the outcrops, in the earlier collection (1961), rather few were taken but in the later collection (1963) attempts were made to collect six samples per site. Sampling information is given in Table 1. Cylinders 2.5 cm in diameter and length were cut from the field blocks. Multiple measurements were made initially on the 1961 collection to obtain a sample mean which was then used to obtain a site mean. With larger sample numbers however, only a single core was measured per sample without perceptible loss in accuracy (see Doell, Cox, 1963). All measurements of declination and inclination were made under a short period astatic magnetometer with a sensitivity of about 1×10^{-5} emu/cc. All cores were subjected to progressive demagnetization in alternating fields as a standard technique. This tests stability and also serves to remove secondary components of magnetization („magnetic cleaning"). The fields used in general did not exceed 340 oe, although in a few cases demagnetization was carried up to 850 oe. Typical demagnetization curves are

Fig. 3. Przekrój geologiczny góry Wżar (według Birkenmajera, 1963), 1 — andezyty pierwszej generacji; 2 — piaskowiec magurski (środkowy eocen); 3 — warstwy podmagurskie (dolny eocen); 4 — warstwy kluszkowskie (dolny eocen--paleocen). Brekcje andezytowo-osadowe i strefy zmian termicznych w skałach osadowych nie zostały zaznaczone

Fig. 3. Geological cross-section of the Wżar mount (after Birkenmajer, 1963). 1 — First generation andesites; 2 — Magura sandstone (Middle Eocene); 3 — sub--Magura beds (Lower Eocene); 4 — Kluszkowce beds (Lower Eocene-Paleocene). Andesite-sedimentary breccias and zones of thermal alteration of sediments not indicated

Table 1

Site mean directions of magnetization and statistics of the Wżar andesite dykes

Site No	Dyke generation	Mean		Sampling[1]	Confidence[2]	Scatter[3]	Vector[4]	Demagnetization Field	log mean intensity of magnetization x10^{-4}gauss			
		Declination D	Inclination I	a/b	α	K	R	oe	J NRM	S.D.[5]	J demagnetiz.	S.D.
1	First	123.8	—77.5	2/3	11.0	517	1.998	170	1.93	0.44	1.32	0.38
2	First	144.8	—81 6	2/3	43.4	35	1.972	85	1.43	0.08	1.39	0.08
3	First	195.8	—39.0	2/5	16.8	65	1.940	85	0.41	0.76	0.42	0.05
4	First	233.5	—42.8	3/4	14.3	76	2.974	255	1.12	0.13	0.62	0.17
5	First	191.9	—67.2	4/4	7.8	140	3.979	85	1.53	0.41	0.74	0.07
6	First	302.0	—76.9	5/5	17.2	21	4.808	170	1.24	0.06	1.07	0.08
7	First	123.4	—78.7	4/4	9.5	95	3.968	170	1.57	0.10	1.38	0.10
8	First	214.6	—77.8	3/4	7.5	271	2.993	85	1.04	0.05	0.93	0.10
9	Second	215.6	—75.8	5/7	11.2	48	4.916	85	0.75	0.38	0.83	0.32
10	First (contact margin of 9)	199.1	—76.9	2/3	9.0	775	1.999	0	1.31	0.42	1.31	0.42
11	First	228.3	— 73.6	2/3	25.1	101	1.990	127	0.65	0.10	0.64	0.04
12	Second	197.2	—80.9	5/6	10.4	55	4.927	85	0.74	0.23	0.75	0.19
13	Second	183.7	—71.0	5/6	9.3	69	4.942	85	0.76	0.22	0.71	0.18
14	Second	173.7	—66.0	5/6	8.9	78	4.948	0	0.65	0.23	0.65	0.23
15	First	145.0	—45.7	3/3	49.8	7	2.722	85	—	—	—	—

1 Sampling: a) number of samples used in computation; b) number of samples collected.
2 Radius at the circle of confidence in degrees.
3 Scatter K computed from Fisher's statistics.
4 Length of the vector mean.
5 Intensity and standard deviation both given in logarithmic form.

shown in Fig. 6. The site mean at each demagnetization stage was computed using an electronic computer with a programme devised by Dr. L. Molyneaux. The direction of magnetization at the stage at which the scatter was a minimum was adopted as that best representing the original magnetization. Where this was the N.R.M. stage the condition was imposed that the mean direction should not alter significantly during demagnetization.

All the relevant data is summarised in Table 1, and illustrated in Fig. 5, from which it can be seen that the first and second generation andesite dykes cannot be separated on the basis of their directions of magnetization. Inspection of Table 1 also indicates the large circles of confidence about the mean values and some would normally be excluded as unsatisfactory. That this is partly due to the small sample size is

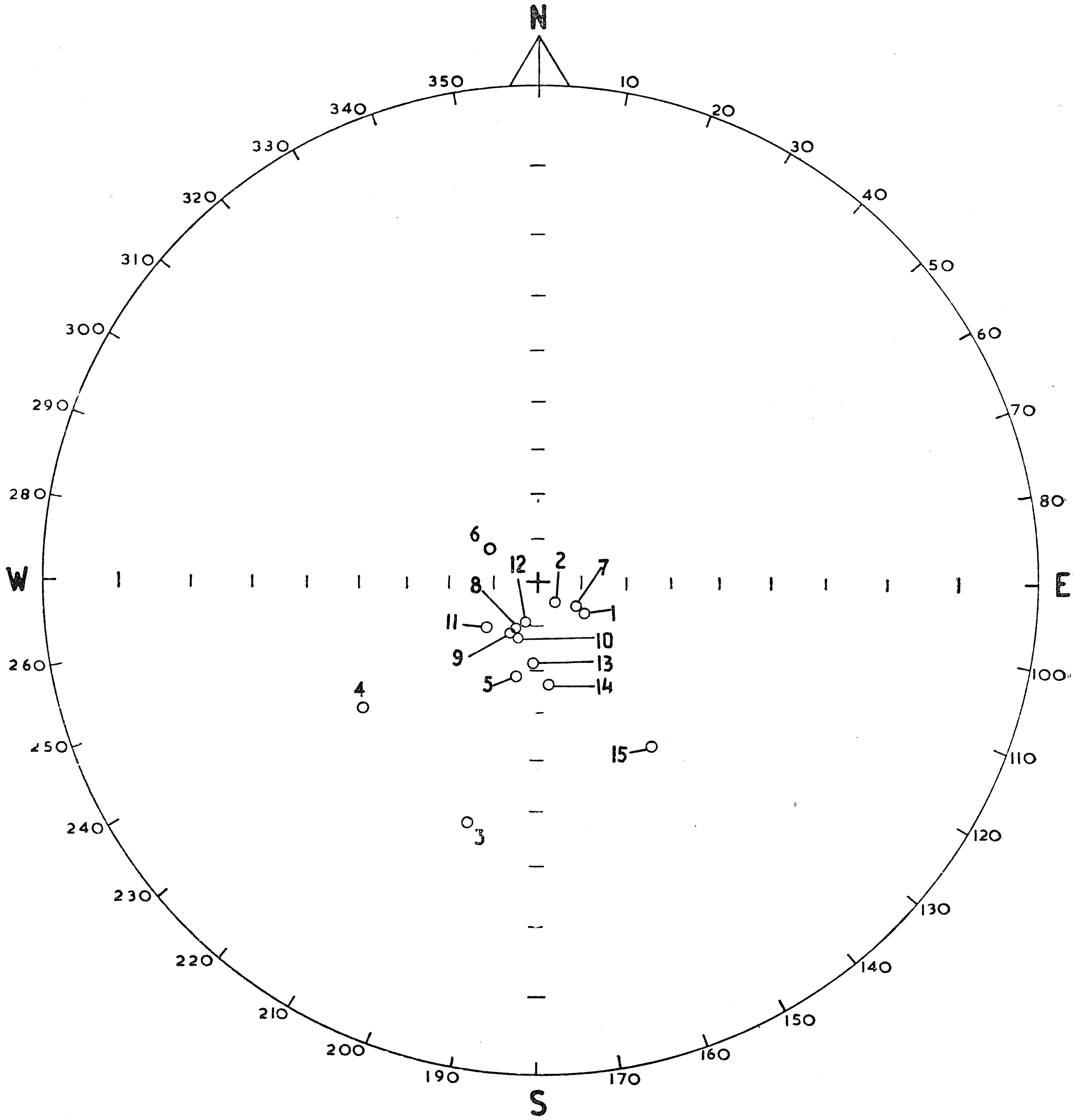


Fig. 5. Stereogram kierunków magnetyzacji andezytów góry Wżar. Liczby odpowiadają stanowiskom wymienionym w tabeli 1

Fig. 5. Stereogram showing the direction of magnetization of the Wżar mount andesites. Numbers correspond to sites in Table 1

evidenced by the smaller values found when more samples were collected. Nevertheless it remains true that the confidence limits are large when compared to many other results. The reason for this is not clear. For completeness all the measurements are given.

2) Intensity of Magnetization

The intensity of magnetization was generally low and even within a site, values were scattered. It can be seen from the inspection of Table 1 that even at the stage of minimum scatter in the directions of remanence the intensity values remain dispersed. This can also be seen in the behaviour of demagnetization curves from different samples from the same site (see Fig. 6). The dispersion of the intensity can be illustrated by showing the cumulative distribution of intensity values, using all the sample values (not site mean values). Fig. 7 shows that this dispersion both at the N.R.M. stage and the intensity at the stage of minimum scatter of directions follows very closely a log normal distribution. The near parallel condition of the two curves implies that the ratio of primary to secondary magnetization is about the same independent of the magnitude of the magnetization.

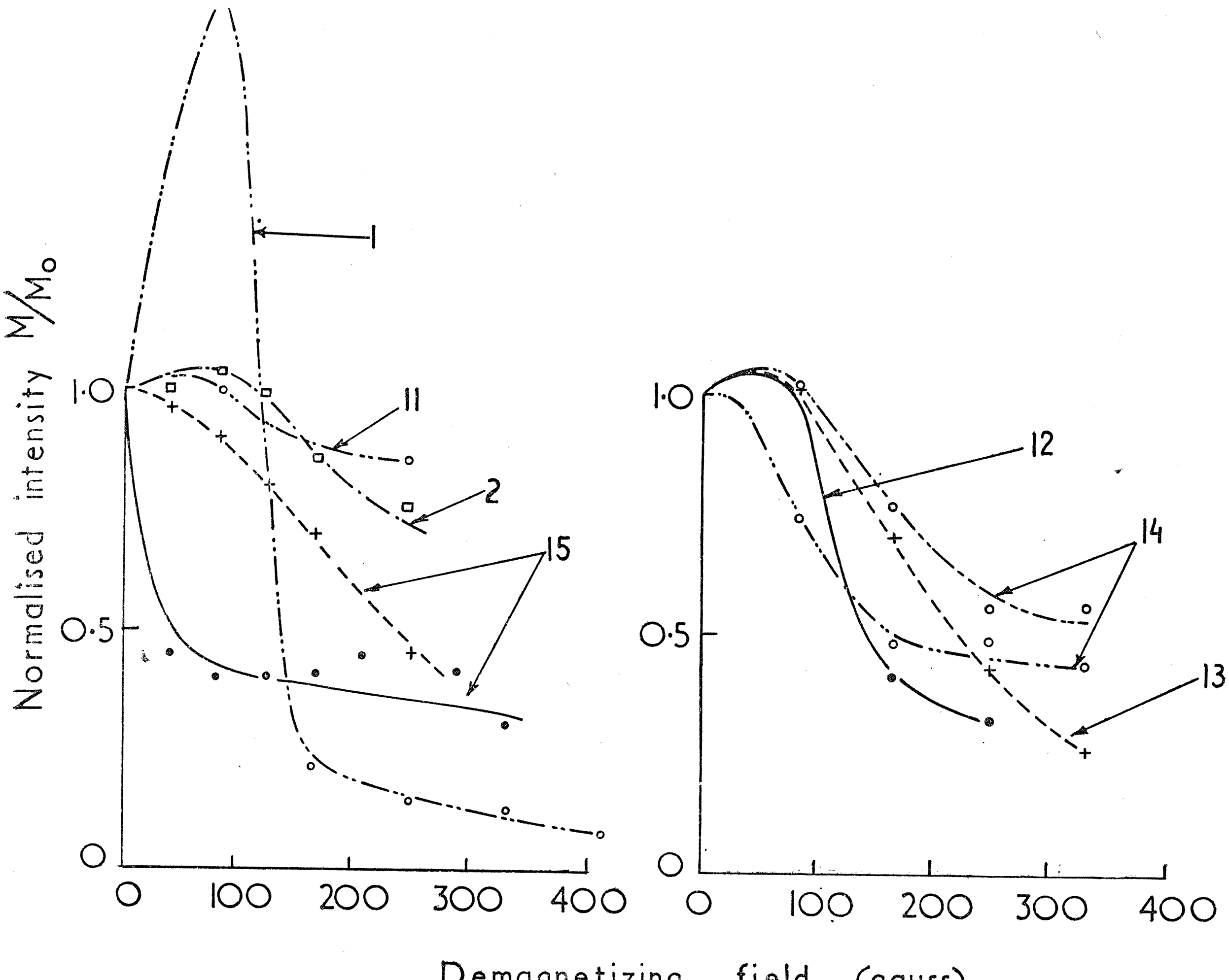


Fig. 6. Typowe krzywe odmagnesowywania próbek w polach zmiennych. Zmienność lokalna podana w kilku przykładach na różnych próbkach pobranych w tym samym odsłonięciu (np. stanowiska 14, 15). Numery punktów pobrania próbek — jak w tabeli 1

Fig. 6. Typical curves of demagnetization in alternating fields. Some measure of variability per site is given by reproducing demagnetization curves for several samples at the same site (e.g. Sites 14, 15). Site numbers correspond to Table 1

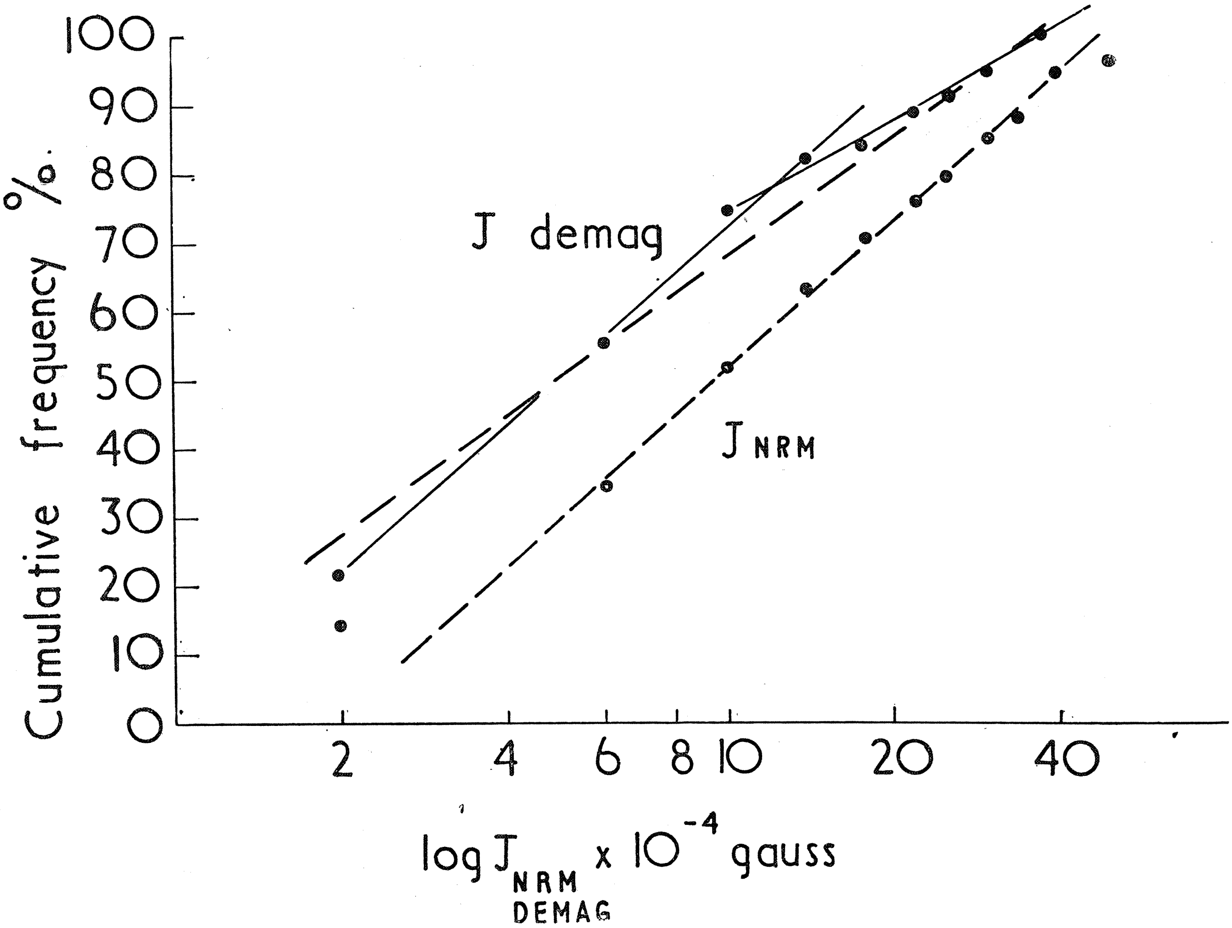


Fig. 7. Wykres natężenia pola magnetycznego (naturalny magnetyzm szczątkowy NRM i po odmagnesowywaniu) andezytów góry Wżar w postaci krzywych log normalnych

Fig. 7. Graph of distribution of intensity (NRM and after demagnetization) of magnetization of the Wżar mount andesites as log normal curves

DISCUSSION OF RESULTS

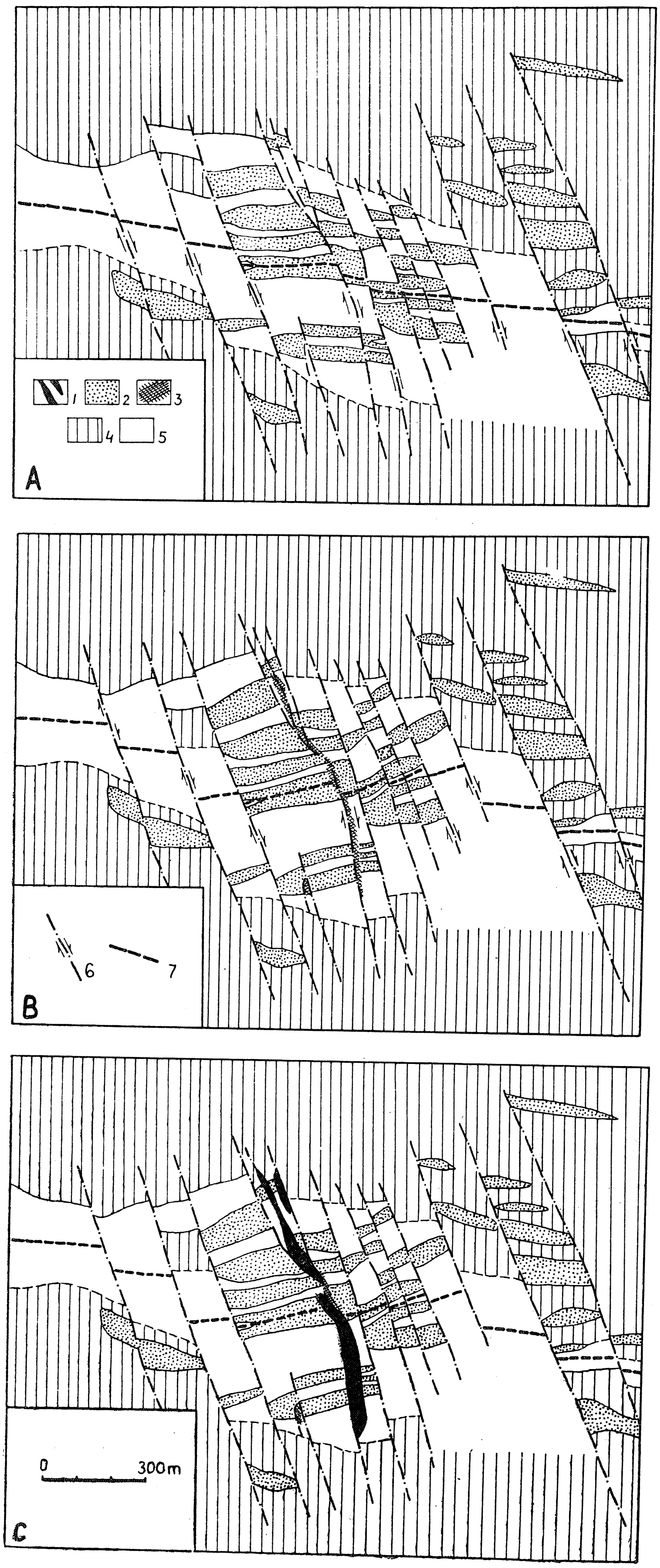
1) Dyke Trend

There is a change in trend of the first generation dykes, which could be the result of the accumulation of small movements of slices between pairs of faults. This is illustrated diagrammatically in Fig. 8. Because of the scatter between the site mean directions and the small number of sites between any pair of faults the magnetic declinations measured cannot contribute to the problem. The improvement on computing an overall mean direction brought about by assuming a 20° rotation is minimal (see Tab. 2).

Table 2

Overall site mean of the first generation andesites of the Wżar mount

	D	I	α	K
Assuming no rotation	191.5	—73.2	9.4	17.5
Assuming 20° rotation	200.6	—72.6	9.1	18.6


1
2
3
4
5
A
6
7
B
0
300m
C

2) Magnetic Inclination

There is a very large variation in the value of the magnetic inclinations recorded amounting to some 40°. As the intrusion of the second generation dykes is the last geologically significant event, the average declination value of about 74° may be regarded as a standard of comparison. If this is done, then an apparent correlation can be seen between the inclination value and geographic position (the large confidence limits of most sites preclude definite statements). The largest departures are found on the lower slopes of the hill, in the central region values are in general close to the adopted standard. Thus, although palaeomagnetism can contribute nothing to the tectonic argument involving rotation between pairs of faults, the inclination values do suggest that the blocks between faults may have tilted independently, and not necessarily always in the same sense, some to the north-west, others to the south-east. The combination of both tectonic and inclination arguments is then to suggest rotation about an inclined axis.

3) Age of the Intrusions

The local geological evidence for the age of the intrusions based upon the work of Birkenmajer (1960, 1962) which leads to the suggestion of a Lower or Middle Miocene age, has already been summarised. In a broader sense, the change in trend of the first generation dykes is tectonic and thus related to the last stages of the Carpathian orogenic activity. In the External Carpathian zone this activity is placed within the Tortonian (cf. Książkiewicz, 1963), which therefore is tentatively regarded as the most probable age for the Wżar dykes.

It is now possible to attempt to relate the sign of magnetization to a sequence established in the andesites and rhyolites of the Central and East Slovakian volcanic provinces which Nairn (1966, 1967) attempted to correlate with results from Japan, New Zealand and France. The reversed magnetization of the Wżar dykes suggests correlation with

←

Fig. 8. Rekonstrukcja ewolucji strukturalnej góry Wżar. A — stadium przed rotacją, andezyty pierwszej generacji posiadają kierunki W-E; B — rotacja andezytów pierwszej generacji w centralnej partii góry Wżar jako efekt sumowania się małych przesunięć wzdłuż prawoskrętnych uskoków i tworzenie się brekcji andezytowo-osadowych, przede wszystkim wzdłuż głównej strefy rozłamu; C — stadium po rotacji (stadium obecne). Andezyty drugiej generacji intrudowane wzdłuż strefy głównego rozłamu.

Objaśnienia: 1 — andezyty drugiej generacji; 2 — andezyty pierwszej generacji; 3 — brekcja andezytowo-osadowa; 4 — piaskowiec magurski (środkowy eocen) i warstwy podmagurskie (dolny eocen) na skrzydłach antykliny Wżaru; 5 — warstwy kluszkowskie (dolny eocen-paleocen) w jądrze antykliny Wżaru; 6 — uskoki; 7 — przybliżony przebieg osi antyklinalnej

Fig. 8. Reconstruction of structural evolution of the Wżar mount. A — Pre-rotation stage, the first generation andesite dykes trending W-E; B — Rotation of first generation andesite dykes in the central part of Wżar mount due to accumulation of small movement along dextral faults, and formation of andesite-sedimentary breccias mainly along the major fracture zone; C — Post-rotation stage (the present stage) with the second generation andesite dykes intruded along the major fracture zone.

Explanations: 1 — Second generation andesites; 2 — First generation andesites; 3 — Andesite-sedimentary breccia; 4 — Magura sandstone (Middle Eocene) and sub-Magura beds (Lower Eocene) on the limbs of the Wżar mount anticline; 5 — Kluszkowce beds (Lower Eocene-Paleocene) in the core of the Wżar mount anticline; 6 — Faults; 7 — Approximate course of the anticlinal axis first and lower second phase andesites of the Central Slovakian province. However, all the Tortonian rocks save those in the highest Tortonian--lowest Sarmatian are reversely magnetized, and until more detailed sampling can be carried out, the possibility that this is an artefact of the sampling cannot be eliminated. The correlation is given in Table 3.

Table 3

Tentative age and palaeomagnetic correlation of the Pieniny Mountains andesites with the igneous rocks of the Central and East Slovakian Provinces

Age		Central Slovakia		East Slovakia	Pieniny Mountains, Poland
Sarmatian	Upper		R−	2nd phase andesites	
	Middle	Final phase andesites 3rd phase rhyolites	N+ + − − − −	1st phase andesites	
	Lower	3rd phase andesites intrusives 2nd phase andesites	R − − + + +N + + −R−	2nd phase rhyolites Introductory phase andesites	
Tortonian	Upper				2nd generation amphibole-augite andesites
	Middle	2nd phase rhyolites			
	Lower	1st phase andesites	−R−		1st generation amphibole--augite andesites

The geological aspects of the correlations in Slovakia follow Kuthan (1948, 1964). The palaeomagnetic zonation is from Nairn (1967).

4) Measurements on Igneous Rocks between Krościenko and Biała Woda

East of the Wżar mount there are numerous andesite dykes outcropping between Krościenko and Biała Woda (Fig. 1). Between Krościenko and Szczawnica all the andesites examined proved to be too badly weathered or too poorly exposed for sampling. At Szczawnica on the Bryjarka mount and in the Grajcarek stream, and near Szlachtowa on mounts Jarmuta and Krupianka samples were collected at several sites in amphibole andesite or amphibole-augite andesite which appeared fresh. A small isolated outcrop of olivine basalt was sampled at Biała Woda.

All of these samples were weakly magnetized and upon demagnetization did not produce consistent results. As minimum information it appeared that two Jarmuta sites were reversely magnetized and three (on Jarmuta, Grajcarek and Bryjarka) were normally magnetized (Tab. 4).

Table 4

Palaeomagnetic aspect of igneous rocks between Szczawnica and Biała Woda

Site/rock type	D	I	α	K	R	Demagn. field oe	Sampling
Szczawnica, Bryjarka: amphibole andesite	320.3	+5.1	53.9	6.3	2.683	170	2/5
Szczawnica, Grajcarek stream: amphibole andesite	306.5	+43.2	32.3	15.6	2.872	85	3/4
Jarmuta (Malinów quarry), Site 1: amphibole andesite	284.8	−71.4	75.8	13.1	1.924	255	2/4
Jarmuta (Pod Bukami), Site 2: amphibole andesite	55.9	+73.0	—	—	—	—	1/4
Jarmuta (SE slope), Site 3: amphibole andesite	all too weak or inhomogenous for measurement						
Jarmuta (Pałkowski Potok), Site 4: amphibole-augite andesite	two samples gave no readings, other two only NRM at D = ca 240 and I = −45						
Biała Woda: olivine basalt	two samples gave no readings, one sample only NRM measureable						

According to the work of Małkowski (1958) the amphibole andesites are the oldest phase of magmatic activity in the Pieniny Mountains. Confirmation of this view was obtained by Kardymowicz (1952) who found xenoliths resembling the amphibole andesites within the amphibole-augite andesites of mount Wżar. Their petrological character indicates they cooled at greater depths than the Wżar andesites and their implacement geologically is regarded as contemporaneous with the end of the Savian phase (lowest Miocene or uppermost Oligocene — cf. Birkenmajer, 1958, 1960). This is consistent with the known occurrence of rocks of both normal and reversed magnetization within the Burdigalian.

WYKAZ LITERATURY

REFERENCES

Birkenmajer K. (1958), Nowe dane o geologii skał magmowych okolic Szczawnicy (New contributions to the geology of magnetic rocks of the Szczawnica area, within the Pieniny Klippen-belt). *Pr. Muz. Ziemi*, 1, 89—103, Warszawa.

Birkenmajer K. (1960), Geology of the Pieniny Klippen Belt of Poland (A review of latest researches). *Jb. Geol. Bundesanst.*, 103, 1—36, Wien.

Birkenmajer K. (1961), Uwagi o formie geologicznej andezytów góry Wżar koło Czorsztyna (Remarks on the geological form of the Mt. Wżar andesites near Czorsztyn — in Polish). *Spraw. Komis. Oddz. PAN, Kom. Nauk Geol.*, VII—XII, 1960. Kraków.

Birkenmajer K. (1962), Forma geologiczna andezytów Wżaru (Remarks on the geological form of the Mt. Wżar andesites, Pieniny Mts., Carpathians). *Acta geol. pol.*, 12, 201—213, Warszawa.

Birkenmajer K. (1963), Mapa geologiczna pienińskiego pasa skałkowego w skali 1 : 10 000. Ark. Czorsztyn (Detailed geological map of the Pieniny Klippen Belt of Poland, 1 : 10,000. Sheet Czorsztyn). *Inst. Geol.* Warszawa.

Birkenmajer K., Grocholski A., Milewicz J., Nairn A. E. M. (1968), Palaeomagnetic studies of Polish rocks. II. The Upper Carboniferous and Lower Permian of the Sudetes. *Rocz. Pol. Tow. Geol.* (*Ann. Soc. Géol. Pol.*), 38 (4), Kraków.

Birkenmajer K., Krs M., Nairn A. E. M. (1968), A palaeomagnetic study of Upper Carboniferous rocks from the Inner Sudetic Basin and the Bohemian Massif. *Bull. Geol. Soc. Am.*, 79 (5), 589—608.

Birkenmajer K., Nairn A. E. M. (1964), Palaeomagnetic studies of Polish rocks. I. The Permian igneous rocks of the Kraków District and some other results from the Holy Cross Mountains. *Rocz. Pol. Tow. Geol.* (*Ann. Soc. Géol. Pol.*), 34 (1—2), 225—244. Kraków.

Birkenmajer K., Nairn A. E. M. (1965), Palaeomagnetic investigations applied to the Neogene andesites of the Pieniny Mts., Polish Carpathians. *Carpatho-Balkan Geol. Ass.*, VII Congr. Sofia, Sept. 1965. *Reports*, Pt. VI: 187—190. Sofia.

Doell R. R., Cox A. (1963), The accuracy of the paleomagnetic method as evaluated from historic Hawaiian lava flows. *J. Geophys. Res.*, 68, 1997—2009.

Kardymowicz I. (1952), Enklawy w andezytach okolic Pienin (Inclusions in the andesites of the Pieniny neighbourhood). *Acta geol. pol.*, 2 (4), 452—476. Warszawa.

Kozłowski S. (1961a), Forma geologiczna i cios andezytów Wżaru koło Czorsztyna (Geological form and jointing of andesites of mt. Wżar near Czorsztyn — in Polish). *Spraw. Komis. Oddz. PAN, Kom. Nauk Geol.*, VII—XII, 1960, Kraków.

Kozłowski S. (1961 b), Budowa petrograficzna andezytów z góry Wżar (Petrography of the mt. Wżar andesites — in Polish). *Spraw. Komis. Oddz. PAN, Kom. Nauk Geol.*, VII—XII, 1960. Kraków.

Kozłowski S. (1965), Andezyty Wżaru (Andesites of the Mt. Wżar). *Rocz. Pol. Tow Geol.* (*Ann. Soc. Géol. Pologne*), 35 (3), 357—359, 408. Kraków.

Książkiewicz M. (1963), Évolution structurale des Carpathes Polonaises. *Livre à la mém. Prof. P. Fallot*, 2. *Soc. Géol. France*: 529—562. Paris 1960—1963.

Kuthan M. (1948), Unduláčný vulkanizmus karpatského orogenu a vulkanologické studie v severnej časti Prešovských hôr. *Pr. Š.G.Ú.*, 17. Bratislava.

Kuthan M. (1964), Vysvetlivky k prehladnej geologickej mape ČSSR 1 : 200.000, list Zborov-Košíce, 35—38. *Geofond.* Bratislava.

Małkowski S. (1958), Przejawy wulkanizmu w dziejach geologicznych okolic Pienin (Volcanic processes in the geologic history of the Pieniny Mts. area). *Pr. Muz. Ziemi*, 1, 11—55. Warszawa.

Małoszewski S. (1961), Tektonika andezytów góry Wżar i okolic w świetle wyników badań magnetycznych (Tectonics of the andesites of the mt. Wżar and its vicinity based on magnetometric survey — in Polish). *Spraw. Komis. Oddz. PAN, Kom. Nauk Geol.*, VII—XII, 1960. Kraków.

Małoszewski S. (1963), Mikrotektonika góry Wżar i jej okolic na podstawie magnetycznych badań prospekcyjnych (Microtectonics of the Wżar Mountain and of its vicinity in the light of magnetometric research works). *Prz. geol.*, 7 (124), Warszawa.

Nairn A. E. M. (1966), Palaeomagnetic investigations of the Tertiary and Quaternary igneous rocks. II. A palaeomagnetic study of the Central Slovakian province. *Geofys. Sbor. ČSAV*, 252, 359—431. Praha.

Nairn A. E. M. (1967), Palaeomagnetic investigations of the Tertiary and Quaternary igneous rocks. III. A palaeomagnetic study of the East Slovakian province. *Geol. Rdsch.*, 56, 408—419. Stuttgart.