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STUDIA PALEOMAGNETYCZNE SKAŁ POLSKICH
II. GÓRNY KARBON I DOLNY PERM SUDETÓW

(16 fig., 6 tab.)

Palaeomagnetic Studies of Polish Rocks
II. The Upper Carboniferous and Lower Permian of the Sudetes

(16 Figs., 6 tabs.)

STRESZCZENIE

Opracowanie zawiera wyniki pomiarów kierunku naturalnego magnetyzmu szczątkowego w górnokarbońskich i dolnopermskich skałach magmowych intruzyjnych i wylewnych oraz w przeobrażonych osadach tego wieku, występujących w depresjach śródsudeckiej i północnosudeckiej. Stwierdzono ponadto, że niektóre skały opisywane dotychczas pod nazwą „melafirów" są najprawdopodobniej zmetasomatyzowanymi skałami osadowymi, na co wskazują relikty struktur sedymentacyjnych.

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A b s t r a c t. The mean directions of magnetization determined from the examination of Lower Permian volcanics and Upper Carboniferous volcanics and intrusives from the Sudetic region of Poland (Lower Silesia) were 196 —4 (virtual pole position 175E 43N) and 196 —12 (174E 43N) respectively. Detailed descriptions of the sampling sites are given and reasons adduced for considering the alteration of the Carboniferous igneous rocks to be of Carboniferous rather than of Permian age.

It was found that certain of the rocks previously identified as „melaphyres" were metasomatised sediments on the basis of retained sedimentary structures. This however was not observed in some cases where their origin remain doubtful.

INTRODUCTION

The present paper is a continuation of the palaeomagnetic study of Polish rocks begun in 1961, and extends the survey of Permian rocks from the Kraków area (B i r k e n m a j e r and N a i r n, 1964) to the

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Sudetic basin (Figure 1). In all, some 32 sites were visited (see Figures 2 and 3), and if this number is small, the major outcrops are nevertheless represented. The work complements the purely palaeomagnetic study on the Permian rocks in the Czech part of the Sudetic basin (B u c h a et

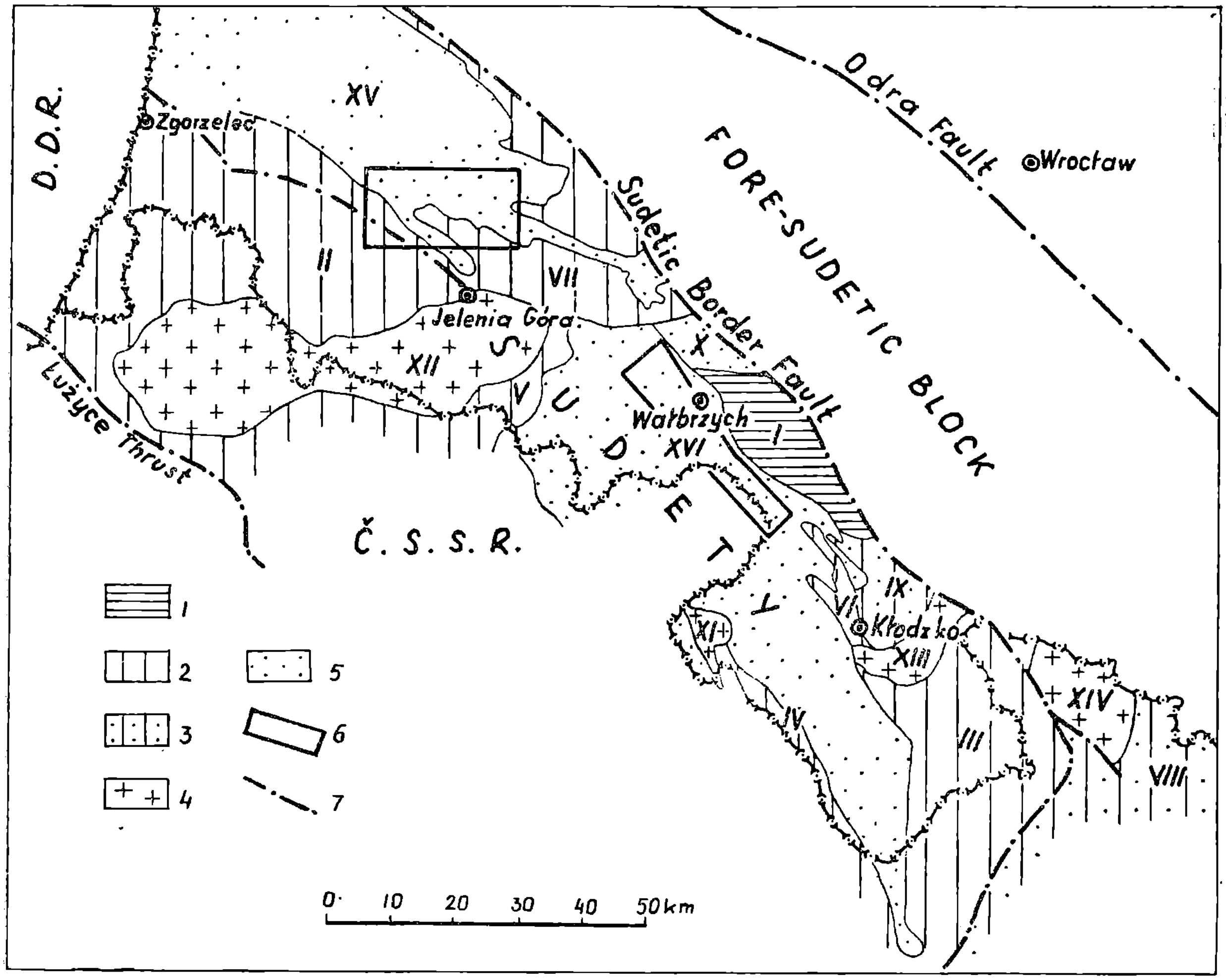


Fig. 1. Główne elementy strukturalne Sudetów (budowę geologiczną bloku przedsudeckiego pominięto). 1 — skały archaiczne; 2 — skały prekambryjskie i staropaleozoiczne; 3 — skały paleozoiczne; 4 — granitoidy waryscyjskie; 5 — skały młodopaleozoiczne i mezozoiczne; 6 — obszary pobrania prób; 7 — główne dyslokacje; I — blok gnejsowy Gór Sowich; II — blok Karkonoszy—Gór Izerskich; III — kompleks metamorficzny Lądka-Śnieżnika; IV — kompleks metamorficzny Gór Bystrzyckich i Gór Orlickich; V — kompleks metamorficzny wschodnich Karkonoszy; VI — kompleks metamorficzny kłodzki; VII — kaledonidy Gór Kaczawskich; VIII — struktura wschodniosudecka; IX — struktura Barda; X — depresja Świebodzic; XI — granitoidy Kudowej; XII — granitoidy Karkonoszy; XIII — intruzja kłodzko-złotostocka; XIV — granitoidy Žulovej; XV — depresja północnosudecka; XVI — depresja śródsudecka

Fig. 1. Main structural elements of the Sudetes mountains (exclusive of the geological structure in the Fore-Sudetic Block, NE of the Sudetic Border Fault). 1 — Archaean rocks; 2 — Pre-Cambrian and older Palaeozoic rocks; 3 — Palaeozoic rocks; 4 — Variscan granitoids; 5 — Late Palaeozoic and Mesozoic rocks; 6 — Sampled areas; 7 — Main dislocations; I — Gneiss block of the Góry Sowie mts.; II — Karkonosze—Góry Izerskie block; III — Metamorphic complex of Lądek—Śnieżnik; IV — Metamorphic complex of Góry Bystrzyckie and Góry Orlickie; V — Metamorphic complex of E Karkonosze mts.; VI — Metamorphic complex of Kłodzko; VII — Caledonides of the Góry Kaczawskie; VIII — East Sudetic region; IX — Bardo region; X — Świebodzice depression; XI — Granitoids of Kudowa; XII — Granitoids of Karkonosze; XIII — Kłodzko-Złoty Stok intrusion; XIV — Žulova granitoids; XV — North Sudetic Depression; XVI — Inner Sudetic Depression

al., 1964). Certain Carboniferous rocks are included, and a comparison of these measurements together with results from the Czech part of the basin have been compared with the results from rocks of the same age on the Bohemian Massif (Birkenmajer, Krs, Nairn, 1968). The authors are deeply indebted to the Director of the Lower Silesian branch of the Geological Survey, Dr L. Sawicki, for facilities readily made available.

OUTLINE OF GEOLOGY

a) Upper Carboniferous and Lower Permian of the Inner Sudetic Depression

The Inner Sudetic Depression (or Basin) has an elongated synclinal form. It is bordered by crystalline massifs save only in the south-west where there is tectonic contact with the Permian to Mesozoic fill of the Hronov Graben. The south-east and north-west margins of the Depression are formed by the crystalline rocks of the Góry Orlickie, Góry Bystrzyckie and Kłodzko massifs, and the Karkonosze-Góry Izerskie massifs respectively. The north-east flank is formed by the Caledonides of the Góry Kaczawskie and the gneiss of the Góry Sowie mountains (Figs. 1, 2).

The Inner Sudetic Depression is a Variscan structure, accentuated by bordering faults which generally parallel the Elbe line and which were reactivated in younger geological times. Tertiary orogenic movements resulted in a dominantly Saxonian type tectonic structure.

Since the Visean, and possibly even within the Tournaisian, the Depression was an area of deposition in which accumulated locally derived, predominantly fresh-water sediments, throughout the Upper Carboniferous to Permian into Lower Triassic (Bunter) times. The youngest sediments found, excluding Quaternary and some problematic (?Tertiary) deposits, are marine Upper Cretaceous beds. The Inner Sudetic Basin was initiated as a result of late Bretonic movements, and according to the conclusions of recent studies (cf. Dziedzic, 1966; Augustyniak and Grocholski, 1967), was not influenced by movements of the Sudetic Phase. The Erzgebirge and Asturic phases were important and repeated earth movements assigned to the latter occurred at intervals from Westphalian B times through the Stephanian. Further distinctive movements during the Lower Permian (Rotliegende) are assigned to the Saalic Phase.

The more important stages in the tectonic history of the basin were accompanied by volcanic activity, the earliest but not very marked activity occurred in Lower Carboniferous: Tournaisian-Visean (A. K. Teisseyre, 1966). Important volcanism accompanied the Asturic movements, but the greatest volcanic activity occurred in the Middle Rotliegende.

The tectonic instability of the area is reflected in the character of the deposits, most formations begin with a coarse often conglomeratic unit and there is marked lithological variation both laterally and vertically. There are in consequence many difficulties in stratigraphic correlation. Table 1 presents the currently accepted correlation for the Polish and Czech parts of the basin (Augustyniak, Grocholski, 1967; Holub, 1961; Tásler, 1966) compared against the older established successions found in Brinkmann (1954) and Dorn (1966).

Table 1

Stratigraphic column of the Upper Carboniferous and Lower Permian deposits in the Inner Sudetic Depression after Augustyniak and Grocholski (1967) and Tásler (1966). The older columns of Brinkmann (1954) and Dorn (1966) are given for comparison

		Dorn 1966	Brinkmann 1954	POLISH (NE) PART Augustyniak, Grocholski 1967		CZECH (SW) PART Tásler 1966	
Saxonian				III Cycle {Fanglomerates of Radków and Mieroszów}		Trutnov Fm.	U. Rotliegende
Autunian	U.	L. Rotliegende	L. Rotliegende	II Cycle {"Walchia" Sh. / Volcanic comp. / "Building" Ss.}		Broumov Fm.	M. Rotliegende
Autunian	L	L. Rotliegende	L. Rotliegende	I Cycle {U. Anthracosia Sh. / Conglomerates}		Chvaleč Fm. {Bečkov Mb. / Vernéřovice Mb.}	L. Rotliegende
Stephanian	C	No C division given	Radowenz Beds	Ludwikowice Fm {L. Anthracosia Sh. / Sandstone / Conglomerate}		hiatus	
Stephanian	B	Radowenz Beds	Hexenstein Beds	Ludwikowice Fm		Odolov Fm. Jívka Mb. {Radvanice Coals / Žaltman Arkose}	
Stephanian	A	Hexenstein Arkose / Idastall Beds	Idastall Beds	Glinik Fm.		Odolov Fm. Svatoňovice Mb. Z. Nejedlý Coals	
Westphalian	D	Schadowitz Beds	Schadowitz Beds	Glinik Fm.		? hiatus	
Westphalian	C	Zdiarek Beds	Schadowitz Beds	Glinik Fm. / Volcanic activity		Žacléř Fm. Upper Mb.	
Westphalian	B	Schatzlar Beds	Schatzlar Beds	Žacléř Fm		Žacléř Fm. Middle Mb. / Lower Mb	
Westphalian	A	Weisstein Beds	Weisstein Beds	Biały Kamień Fm.	Nowa Ruda Fm	Biały Kamień Fm.	
Namurian	C	Waldenburg Beds	Weisstein Beds	Biały Kamień Fm.	Nowa Ruda Fm	Biały Kamień Fm.	
Namurian	B	Waldenburg Beds	hiatus	hiatus	Nowa Ruda Fm	hiatus	
Namurian	A	Waldenburg Beds	hiatus / Waldenburg Beds	Wałbrzych Fm	Nowa Ruda Fm ↓	hiatus	

The Upper Carboniferous stratigraphic schemes are based on macrofloras, supplemented by information from the microflora. The lowest unit the Wałbrzych Formation, up to 325 m thick, is developed in two local basins (the Wałbrzych and Wolibórz basins). The basal part, mainly siltstones and claystones, represents a gradual transition from the underlying Visean beds. Higher in the sequence a quartz conglomerate horizon occurs which pass upwards into siltstones and claystones with numerous coal seams. The conglomerate is the base of a new sedimentary cycle which, according to Dziedzic (1966), is related to climatic change. The age of the Wałbrzych Formation is Namurian A.

The Biały Kamień Formation, represented by coarse clastics, is transgressive, and separated from the Wałbrzych Formation by a local unconformity. The formation is best developed in the northern part of the Inner Sudetic Depression, where it reaches a maximum thickness of 350 m. In the south-eastern part of the Depression, the Biały Kamień

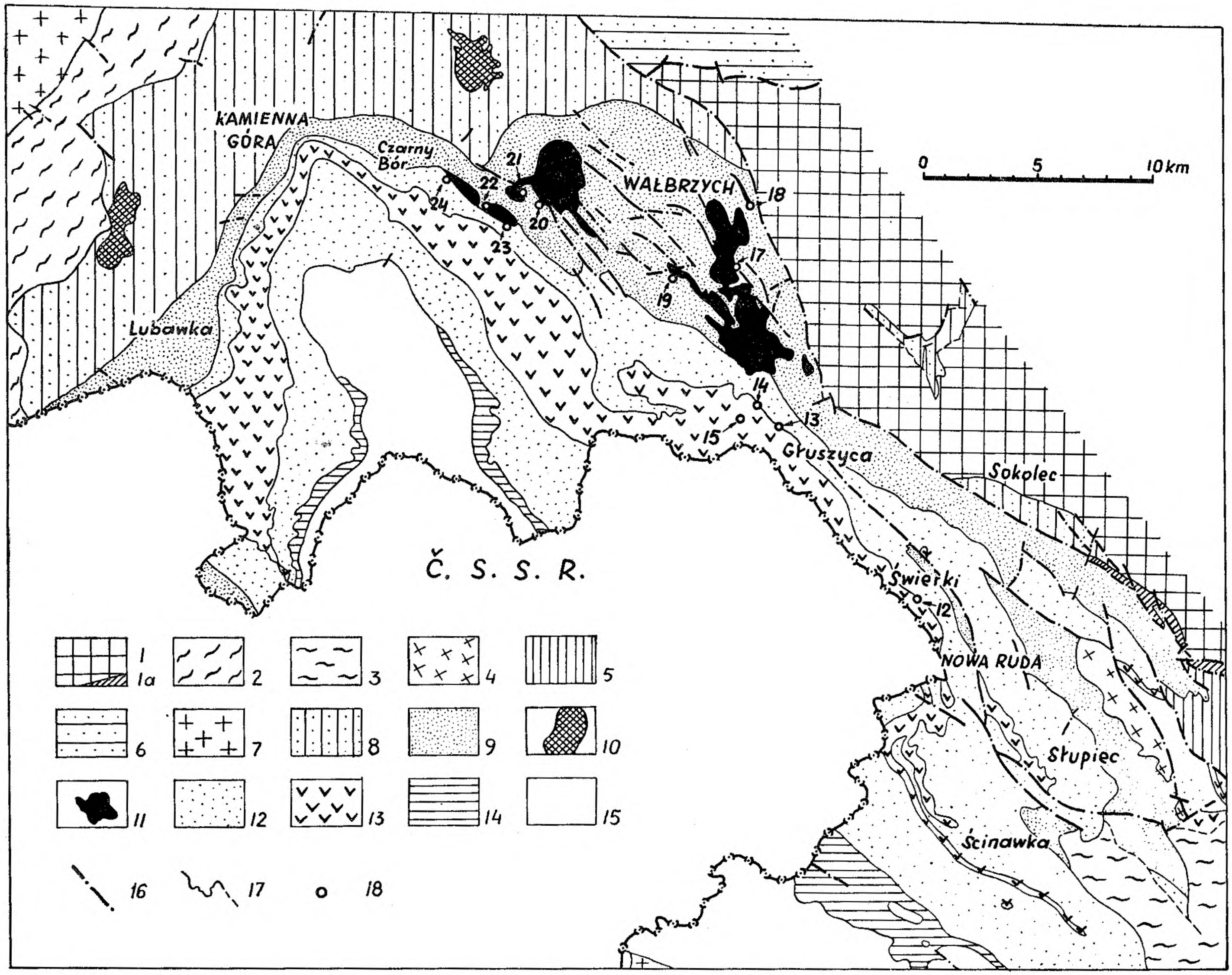


Fig. 2. Szkic geologiczny polskiej części depresji śródsudeckiej. 1 — gnejsy Gór Sowich, prekambr; 1 a — mylonity i kataklazyty; 2 — kompleks metamorficzny wschodnich Karkonoszy; 3 — kompleks metamorficzny kłodzki; 4 — gabra i diabazy wału kłodzkiego; 5 — osady paleozoiczne struktury bardzkiej; 6 — osady górnodewońskie i dolnokarbońskie depresji Świebodzic; 7 — granitoidy Karkonoszy i Kudowy; 8 — osady dolnokarbońskie; 9 — osady górnokarbońskie, 10 — młodopaleozoiczne skały wulkaniczne nie określonego bliżej wieku (karbon lub dolny perm); 11 — skały wulkaniczne górnokarbońskie (głównie porfiry); 12 — osady dolnopermskie (czerwony spągowiec); 13 — skały wulkaniczne dolnopermskie (melafiry, porfiry, tufy itd.); 14 — osady górnopermskie (cechsztyn); 15 — osady mezozoiczne (trias i kreda); 16 — uskoki stwierdzone i przypuszczalne; 18 — miejsca pobrania prób (liczby jak w tab. 5). Skały kenozoiczne pominięto

Fig. 2. Geological sketch map of the Polish part of the Inner Sudetic Depression. 1 — Gneisses of the Góry Sowie, Pre-Cambrian; 1 a — Mylonites and cataclasites; 2 — Metamorphic complex of the eastern Karkonosze mts.; 3 — Metamorphic complex of Kłodzko; 4 — Gabbros and diabases of the Kłodzko Ridge; 5 — Palaeozoic sediments of the Bardo region; 6 — Upper Devonian and Lower Carboniferous sediments of the Świebodzice Depression; 7 — Granitoids of Karkonosze and Kudowa; 8 — Lower Carboniferous sediments; 9 — Upper Carboniferous sediments; 10 — Late Palaeozoic volcanites of unknown age (Carboniferous or Lower Permian); 11 — Upper Carboniferous volcanites (mainly porphyries); 12 — Lower Permian (Rotliegende) sediments; 13 Lower Permian volcanites (melaphyres, porphyries, tuffs etc.); 14 — Upper Permian (Zechstein) sediments; 15 — Mesozoic (Triassic and Cretaceous) sediments; 16 — Faults recognized and supposed; 17 — Geological bouandaries recognized and supposed; 18 — Sampling localities (site numbers refer to Tab. 5). Post-Mesozoic rocks not marked

Formation in its type development is lacking, but some authors regard as its equivalent the Nowa Ruda Formation, a sequence of sedimentary breccias and regoliths, passing upwards into kaolinitic shales and siderite-bearing siltstones. According to Dziedzic (1966), deposition of the Nowa Ruda Formation began in the Lower Carboniferous. A Namurian C to lower Westphalian A age is generally accepted for the Biały Kamień Formation.

The Biały Kamień Formation gradually passes upwards to the Žacléř Formation. In north-eastern part of the Depression the age of the Žacléř Formation (up to 900 m thick) is regarded as Westphalian A and B, while in the south-western part of the Depression it also includes Westphalian C. The lower part of the formation consists mainly of sandstones and siltstones with coal seams. In the upper part of the formation sandstones and conglomerates dominate.

On the north-eastern flank of the Inner Sudetic Depression the Glinik Formation, 100—600 m thick, formerly known as the „Ottweiler Schichten", is transgressive over the Žacléř, and locally over the Wałbrzych Formation. It has a Westphalian C — Lower Stephanian age (Grocholski, 1965) and with a succession of conglomerates and sandstones alternating with red siltstones is lithologically distinct from the underlying Žacléř Formation.

Three sedimentary cycles can be recognized in the Westphalian beds corresponding roughly to the Westphalian A, B, and C. The middle (Westphalian B) and upper (Westphalian C) cycles begin with conglomerates, the latter being particularly well developed over the whole of the Inner Sudetic Depression. Volcanic material is present in the middle and upper cycles in the south-western (Czech) part of the basin, but only in the upper cycle (Glinik Formation) in the Polish part of the Depression. The maximum volcanic activity occurred in Westphalian C (Holub, 1961).

The Glinik Formation is overlain by conglomerates passing upwards into sandstones, which in turn give way to siltstones and claystones, formerly known as the „first sedimentary cycle of the Rotliegende". The argillaceous horizon, known as the „1st Anthracosia shale horizon", contains spore assemblages typical for the Stephanian, as well fresh-water pelecypod *Anthraconaia prolifera* (Wat.) of the same age (T. Górecka and K. Augustyniak, pers. comm.). This formation, younger than the Glinik Formation and older than the Rotliegende proper, has been renamed the Ludwikowice Formation (Augustyniak, Grocholski, 1967).

In the southern part of the Inner Sudetic Depression a break in deposition is recognized at the boundary of Westphalian C and D. The Stephanian is represented by the Odolov Formation, which is subdivided into the lower Svatoňovice Member, and the upper Jívka Member. Both members begin with coarse sandstones, occasionally even conglomerates, and differ from the underlying Žacléř Formation. These differences have been attributed to climatic change and to the appearance of new sources of clastic material as the result of Asturic movements, although tectonic instability alone seems an adequate cause.

The Svatoňovice Member represents the Westphalian D and Lower Stephanian, on the basis of palaeobotanic studies of the coals from Z. Nejedly pit. The Radvanice coals of the Jívka Member are compared on floral grounds with the Kounov coals of Central Bohemia, and represent the Stephanian B and part of Stephanian C. A sedimentary break with erosion of the top part of the Jívka Member has been recognized in the uppermost part of the Stephanian (T á s l e r, 1966).

The Rotliegende of the Polish part of the Intra Sudetic Depression is up to 1,800 m thick and shows the characteristics of cyclic molasse sedimentation (D z i e d z i c, 1961). It is separated by an unconformity from the underlying Carboniferous. The sedimentary cycles usually start with conglomerates (fanglomerates) and grade upwards into sandstones and shales. Three cycles have been recognized, and assigned to the Lower, Middle, and Upper Rotliegende respectively. A complex of effusive acid and basic volcanics appear at the close of the second cycle (D z i e d z i c, 1961; K o z ł o w s k i, 1963). Prior to the recognition of the Ludwikowice Formation, this was regarded as the third cycle.

Two stratigraphic members, both starting with conglomerates and grading upwards into finer deposits with limestone horizons are recognized in the Czech part of the Inner Sudetic Depression. The lower Vernéřovice Member contains a thin coal seam with „*Walchia*". The upper Bečkov Member contains a limestone horizon near the top. Both members belong to the Lower Rotliegende. The Middle Rotliegende is represented by the Broumov Formation which contains tuffs and lava sheets of porphyry and melaphyre. The Trutnov Formation represents the Upper Rotliegendes. In the Polish part of the Depression its equivalents are the fanglomerates of Radków and Mieroszów.

b) Upper Carboniferous and Lower Permian of the North Sudetic Depression

The sediments in the North Sudetic Depression rest on a substratum of epimetamorphic schists of the Góry Kaczawskie mountains, West Sudetes (Figures 1, 3). The borders of the Depression are mainly tectonic, and its prolongation to the north west is concealed under Cenozoic sediments. The older formations of the Depression are Upper Carboniferous (S part) and Rotliegende (N part), the younger formations being represented by the Zechstein, the Bunter, the Muschelkalk and Upper Cretaceous deposits.

The Upper Carboniferous deposits are poorly known from scanty outcrops and from boreholes. The Westphalian B, more than 100 m thick, recognized only in boreholes in an area close to the Polish-German frontiers (Nysa Łużycka river), is represented by siltstones with sandstone and conglomerate intercalations and by porphyry lavas and tuffs (H i r s c h m a n n, 1959). The lack of the Westphalian C deposits is apparently the result of Asturic uplift. The Westphalian D and Stephanian sequence, up to 300 m thick (M i l e w i c z, G ó r e c k a, 1965), starts with regolithic breccias overlain by alternating conglomerates, arkosic sandstones, and generally brown-red and grey siltstones and claystones (M i l e w i c z, 1967). Four sedimentary cycles have been recognized here, and these can be correlated with the cycles found in the Central Bohemian Upper Carboniferous. Porphyry sills probably Stephanian in age occur in the deposits of the upper cycle.

The Permian is represented by continental deposits of the Rotliegende and by the predominantly marine Zechstein. The Rotliegende deposits are especially well known in the eastern part of the Depression.

Here three sedimentary cycles may be recognized (Milewicz, 1966) in a succession 500—1000 m thick. The first cycle, of 170—340 m, consists mainly of fine sandstones and siltstones, coarser beds being infrequent and thin. The second cycle, 200—400 m thick, is lithologically more variable: with sandstones dominating over siltstones, and with conglomerates infrequent in the lower part of the cycle, but more common in its upper part. The eruptive complex attributed to the second cycle is represented by porphyries and porphyry tuffs in the eastern part of the Depression and by melaphyres and melaphyre tuffs in the central part of the Depression. A break in sedimentation and erosion of the underlying deposits is recognized at the base of the third cycle, the result of the Saalic uplift. The third cycle, 200—500 m thick, consists almost entirely of fine conglomerates (fanglomerates), grading upwards into coarse sandstones.

LOWER PERMIAN VOLCANIC AND SEDIMENTARY ROCKS OF THE NORTH SUDETIC DEPRESSION

Description of Localities

Płóczki Górne
(Fig. 4a, Tab. 5: Sites 1—3)

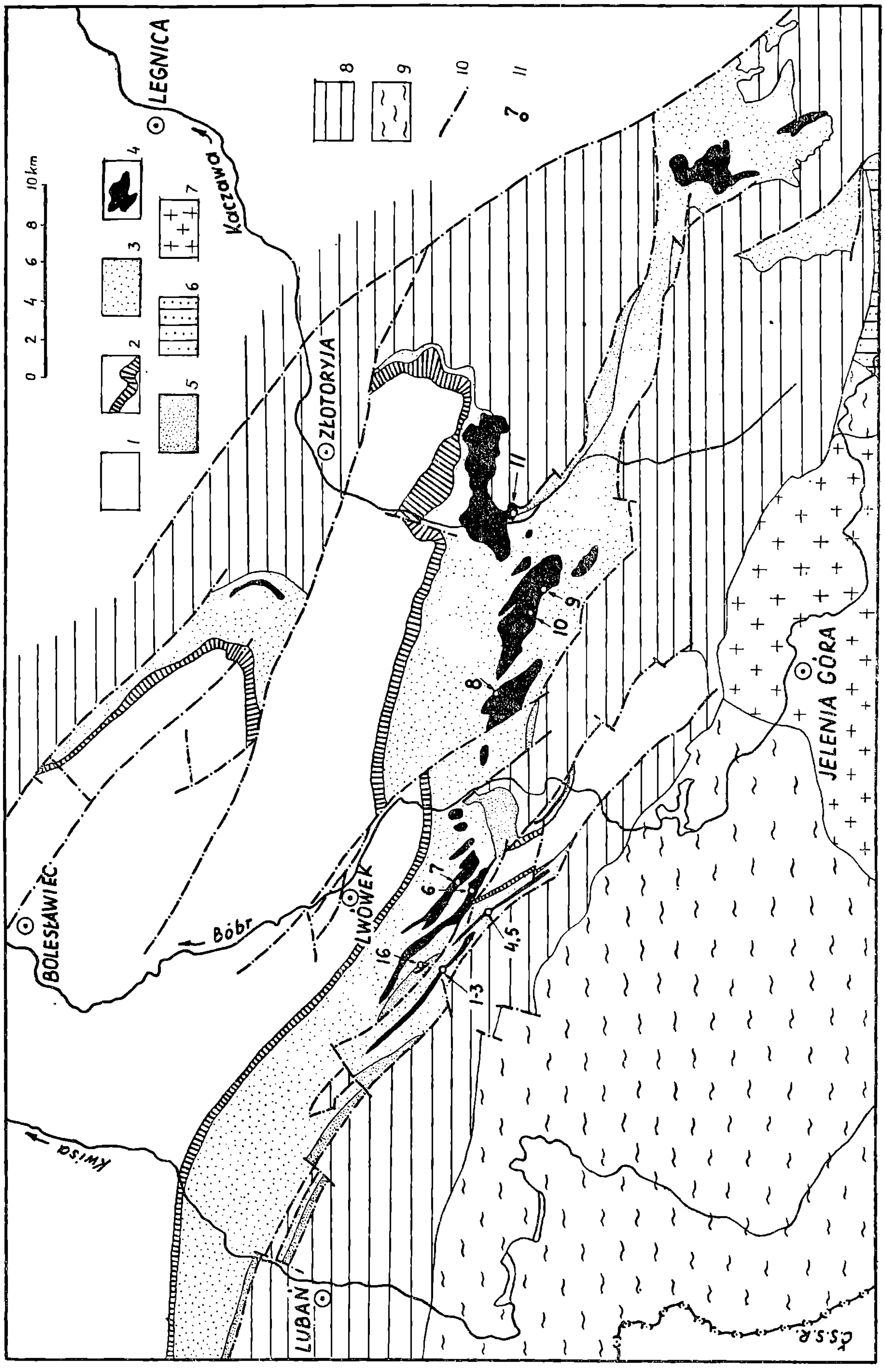
Three melaphyre lava flows are exposed at Płóczki Górne in the Wleń Graben. The lower part of the lava flows consists of basal breccia 1—3 m in thickness. It is made up of fragments and blocks of vesicular and amygdaloidal red melaphyre, and of red sandstone blocks up to 1 m in diameter. The main lava flow above the breccia is 15—18 m thick and consists of red-brown, massive, transversally jointed melaphyre in the lower part, and vesicular and amygdaloidal melaphyre in the upper 3—5 m.

Below the first flow there occur red sandstones and quartz conglomerates of the Rotliegende, dipping 95° NNE 30°. The dip of the lava flows is conformable with the dip of the underlying sediments.

The oriented samples were collected from the massive melaphyre of the first and second flows and from the vesicular region in the upper part of the third flow.

Pławna Górna
(Fig. 4b, Tab. 5: Sites 4, 5)

The exposures at Pławna Górna also belong to the Wleń Graben. In a railroad cutting three melaphyre flows dipping ENE are displaced by a fault. The first flow is poorly exposed with only its upper part accessible. In appearance it is a violet-red massive melaphyre passing upwards into amygdaloidal melaphyre. The second flow, about 27 m thick, dips about 45° towards the ENE. It has a basal breccia about 10 m thick in which are blocks of violet-red vesicular and amygdaloidal melaphyre, 0.1—1.5 m in diameter, as well as fragments of brick-red sandstones and quartz pebbles, 2—5 cm in diameter. Upon this rests massive violet-red melaphyre. It is traversed by joints, both parallel and transverse to the basal plane, as well as by calcite veins. The top part of the flow, 4 m thick, to the NE of the fault, dips 170° ENE 30°. It has a similar colour and is vesicular and amygdaloidal. The third lava flow more than 26 m thick, again has a basal breccia, 0.5—2 m thick, consisting of fragments of violet-red amygdaloidal melaphyre blocks, 0.3—1 m in diameter, above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which there is some 17 m of massive melaphyre, similar in colour to the bottom breccia, with thermal joints parallel and transverse to the flow bottom. The top 7 m of the flow is vesicular and amygdaloidal melaphyre.

Oriented samples were collected from the massive zone in the second and third flows.

Pławna Średnia
(Fig. 4c, Tab. 5: Site 6)

The exposures at Pławna Średnia lie in the Lwówek Graben. Two melaphyre lava flows are recognized in an outcrop at the right bank of the Srebrna river, NE of the church. The first flow is represented by the upper 2 m of a green melaphyre. The second flow has a basal breccia 4—5 m thick, consisting of blocks 0.1—1 m in diameter of vesicular and amygdaloidal melaphyre, violet, violet-red in colour, and of red sandstone blocks 5—10 cm in diameter. The massive violet-red, brown, or green melaphyre of which 10 m is exposed, dips 130° SW 30°. It shows brecciation and jasper-like veins in the lower part, and is more massive in the upper part.

The samples for palaeomagnetic measurements were taken from the massive zone of the second lava flow.

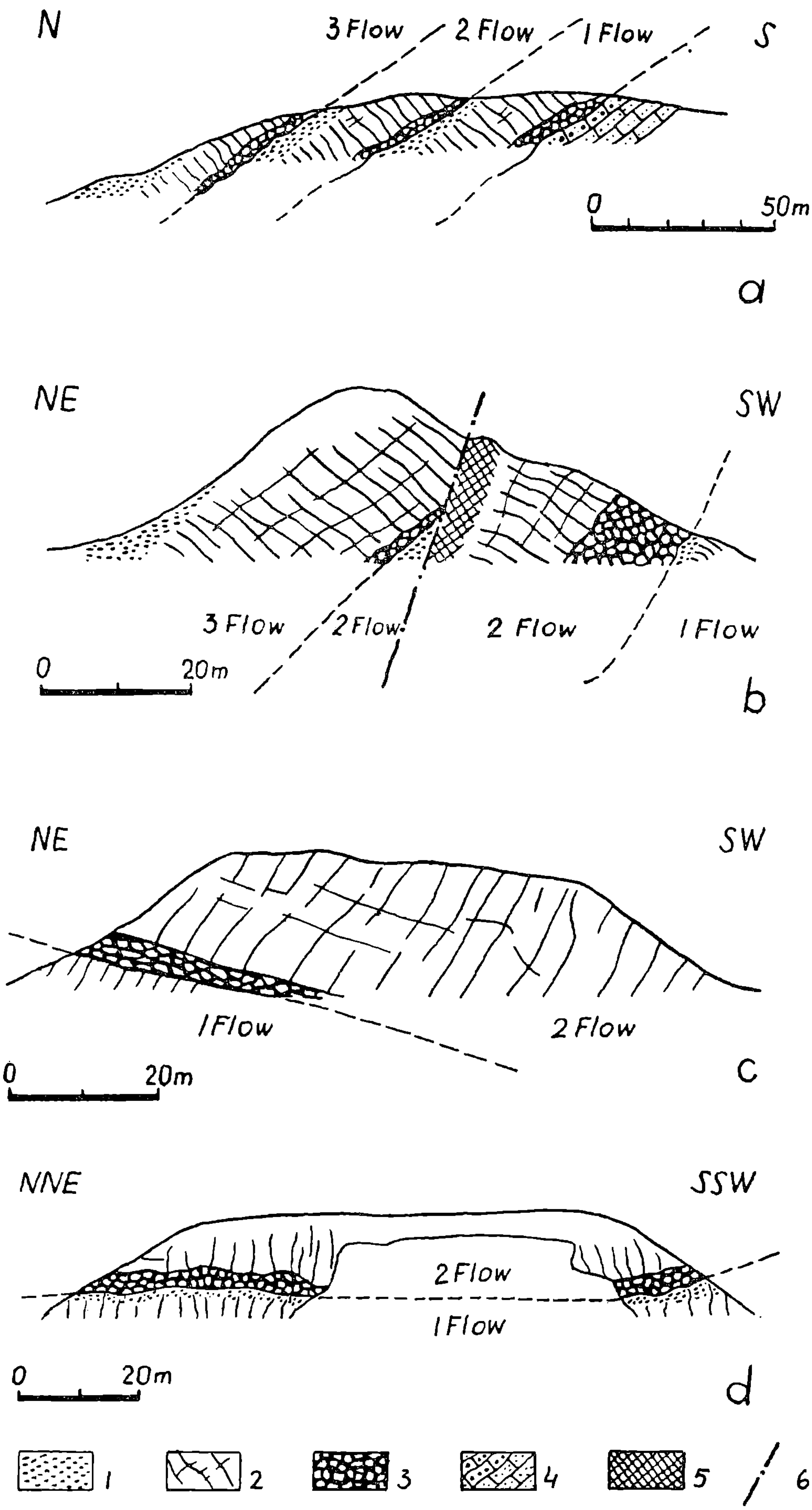
Pławna Dolna-I
(Fig. 4d)

Near a railway cutting, W of point 301 m, two melaphyre lava flows crop out. Of the lower flow only the upper 2—3 m is exposed. It is composed of weathered massive violet-red melaphyre, which passes into vesicular and amygdaloidal melaphyre. The second flow has a 3—5 m basal breccia consisting of vesicular and amygdaloidal melaphyre blocks passing up into massive weathered melaphyre of which 10 m is exposed. The lava flows lie in a syncline, as indicated by opposite dips of the contact surface of the flows: 80° SSE 8° in the northern, and 60° NW 10° in the southern part of the outcrop.

Samples were collected from the upper part of the first flow. The results are omitted from Table 5 because of the exceedingly scattered nature of the results. This may be an effect of strong weathering.

Fig. 3. Struktura geologiczna Gór Kaczawskich (depresja północnosudecka). 1 — osady kredowe i triasowe; 2 — osady górnopermskie (cechsztyńskie); 3 — osady dolnopermskie (czerwony spągowiec); 4 — skały wulkaniczne dolnopermskie (stanowiska 1—11) i górnokarbońskie ? (stanowisko 16); 5 — osady górnokarbońskie (westfal D-stefan); 6 — osady dolnokarbońskie (w depresji śródsudeckiej); 7 — waryscyjski granit Karkonoszy; 8 — kompleks metamorficzny Gór Kaczawskich (starszy paleozoik-prekambr); 9 — kompleks metamorficzny Gór Izerskich (prekambr); 10 — główne dyslokacje; 11 — miejsca pobrania prób (liczby jak w tab. 5) Skały kenozoiczne pominięto

Fig. 3. Geological structure of the Góry Kaczawskie (North Sudetic Depression). 1 — Cretaceous and Triassic sediments; 2 — Upper Permian (Zechstein) sediments; 3 — Lower Permian (Rotliegende) sediments; 4 — Lower Permian (Sites 1—11) and ?Upper Carboniferous (Site 16) volcanic rocks; 5 — Upper Carboniferous (Westphalian D — Stephanian) sediments; 6 — Lower Carboniferous sediments (Inner Sudetic Depression); 7 — Variscan granite of Karkonosze; 8 — Metamorphic complex of the Góry Kaczawskie (older Palaeozoic — Pre-Cambrian); 9 — Metamorphic complex of the Góry Izerskie (Pre-Cambrian); 10 — Main dislocations; 11 — Sampling localities (site numbers correspond to Tab. 5). Post-Mesozoic rocks not marked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Pławna Dolna-II
(Tab. 5: Site 7)

In an outcrop near the railway station at Pławna Dolna there occur rocks regarded by Milewicz (1965) as belonging to the „third melaphyre complex" of the Rotliegende. We found here fine-grained sandstones with mica, indurated by iron oxides, sometimes forming a hard, massive rock, superficially resembling melaphyre. It seems probable that ferric oxide solutions that indurated the sandstone were related to post--magmatic solutions. The altered sandstones dip 90° N 15°.

Between Marczów and Zadole east of Pławna Dolna the same „third melaphyre complex" of Milewicz is poorly exposed and represented by fine-grained sandstones of similar type as those at Pławna Dolna-II. No samples were taken for palaeomagnetic measurements.

Similar rocks crop out also at Gorczyca, on the right bank of the Bóbr river in the eastern part of the Lwówek Graben. The samples taken from grey or variegated hard siltstones dipping 20° WNW 30° gave negative results.

Bełczyna
(Fig. 5a, Tab. 5: Site 8)

Two melaphyre lava flows are exposed in a road cutting between Bełczyna and Wleń, W of Bełczyna. The lower flow has the usual basal breccia, 0.5—1.5 m in thickness, succeeded by about 9—10 m of massive, then vesicular and amygdaloidal melaphyre in succession. The second flow is represented by a 1 m basal breccia only.

The substratum of the first flow is represented by hard, cleaved sandstones, red and violet-red dipping 90° N 45°, resembling those of Pławna Dolna-II. The lava flows are tilted in the same direction as the sandstones.

The samples were collected from the first flow, from both the lower, massive melaphyre zone and the upper vesicular part.

Sokołowiec
(Fig. 5b, Tab. 5: Site 9)

The exposure in an old quarry face 8—10 m high exposes rocks of the Rotliegende. Hard, grey or greenish fine-grained sandstones appear in the lower part of the exposure. They are irregularly jointed, and show traces of large-scale cross bedding. The sandstones contain some mica and carbonized plant detritus, and small bioglyphs may be encountered on bed surfaces. The dip of the rocks is 20° WNW 10°. In the upper part of the exposure the sandstones are harder still, they are bluish, weathering to yellowish colour. Bedding disappears and a vertical joint

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Fig. 4. Schematyczne profile geologiczne odsłonięć dolnopermskich law melafirowych w depresji północnosudeckiej (skala przybliżona): a — Płóczki Górne; b — Pławna Górna; c — Pławna Średnia; d — Pławna Dolna I; 1 — melafir gąbczasty i migdałowcowy; 2 — melafir masywny; 3 — brekcja spągowa; 4 — piaskowce i zlepieńce (czerwony spągowiec); 5 — melafir zbrekcjowany tektonicznie; 6 — uskok

Fig. 4. Schematic geological sections of the Lower Permian (Rotliegende) melaphyre lava flows of the North Sudetic Depression (scale approximate): a — Płóczki Górne; b — Pławna Górna; c — Pławna Średnia; d — Pławna Dolna I; 1 — Vesicular and amygdaloidal melaphyre; 2 — Massive melaphyre; 3 — Bottom breccia; 4 — Sandstones and conglomerates (Rotliegende); 5 — Tectonically brecciated melaphyre; 6 — Fault

system is developed which resembles that of the melaphyre lava flows. It seems possible that the sandstone may have formed the substratum of the melaphyre lava flow exposed nearby (see Rawka mount), and was altered by ferruginous solutions connected with volcanic activity.

The samples for palaeomagnetic work were taken from the upper part of the exposure.

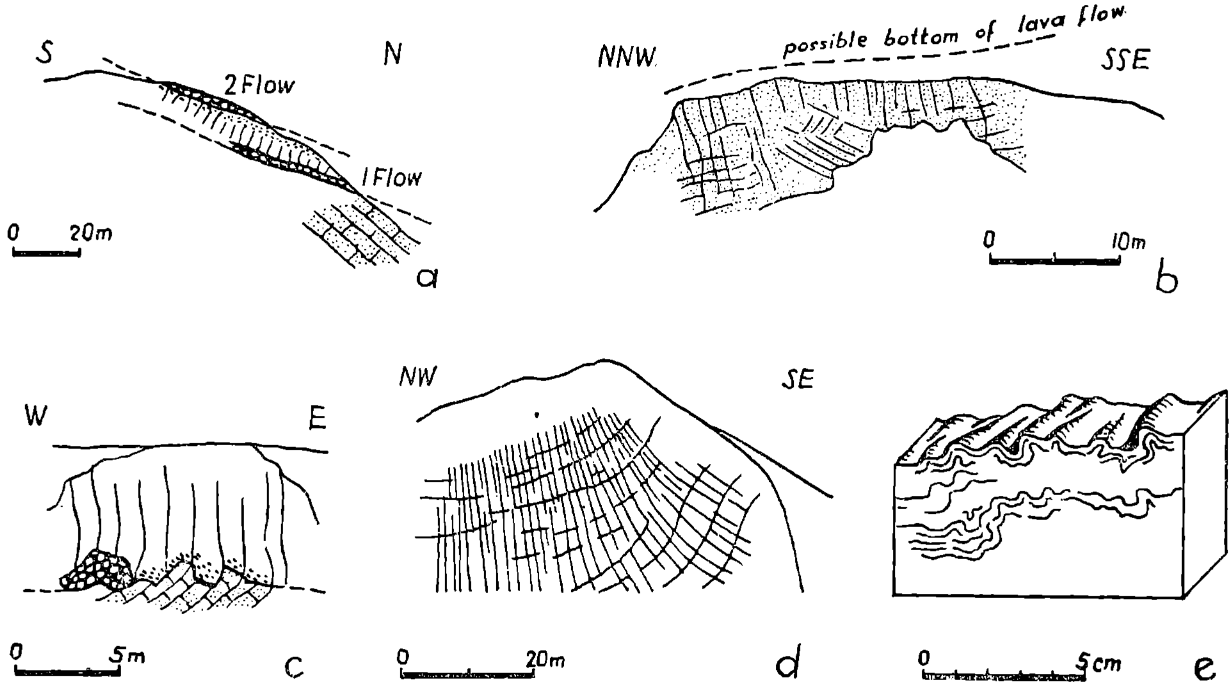


Fig. 5. Schematyczne profile geologiczne odsłonięć dolnopermskich law melafirowych, zmienionych osadów i wylewnego porfiru w depresji północnosudeckiej (skala przybliżona): a — Bełczyna; b — Sokołowiec; c — góra Rawka (Rząśnik); d — Wielisław Złotoryjski (porfir); e — Wielisław Złotoryjski, struktury fluidalne w porfirze. (Objaśnienia oznaczeń do fig. 5 a—c — jak na fig. 4)

Fig. 5. Schematic geological sections of the Lower Permian (Rotliegende) melaphyre lava flows, altered sediments and effusive porphyry of the North Sudetic Depression (scale approximate): a — Bełczyna; b — Sokołowiec; c — Rawka mt. (Rząśnik); d — Wielisław Złotoryjski (porphyry); e — Wielisław Złotoryjski, detail of flow structures in the porphyry. (For explanations to Figs. 5 a—c — see Fig. 4)

Rawka Mount (Rząśnik)
(Fig. 5c, Tab. 5: Site 10)

At Rawka mount (427 m), near Rząśnik village, samples were collected from green amygdaloidal and vesicular melaphyre exposed in the old, western, quarry. In the old, eastern, quarry the contact zone of melaphyre flow and the underlying Rotliegende sediments (Fig. 5c) is exposed. The sandstone is of the same type as that at Sokołowiec, i. e., altered black or bluish sandstone, dipping 70° NW 20°. The lava flow only locally begins with a basal breccia (up to 2 m thick), and the main body is represented by massive reddish or greenish melaphyre. When the massive melaphyre comes directly into contact with the underlying sandstone, it becomes vesicular.

Wielisław Złotoryjski
(Figs. 5d, e, Tab. 5: Site 11)

In a big old quarry situated at the right bank of the Kaczawa river close to Wielisław Złotoryjski, an extrusive porphyry has columnar jointing arranged in a fan-like form, normal to the surfaces of successive lava flows. Thin zones of vesicular porphyry, sometimes only 5—20 cm thick, are present in the top parts of the individual lava flows, and fine fluidal lava folds are visible (Fig. 5e). The overturn of the folds indicates the direction of lava motion towards the N or NNW (azimuths 345°, 330°, 320°, 0°). Occasionally larger flow structures appear, with fold amplitudes up to 0.5—1 m.

Oriented samples were collected in the central, and lower part of the quarry.

Remarks

The melaphyre lava flows belong to a single effusive complex. This is consistent with the palaeomagnetic measurements (Tab. 5). Locally they may split into subordinate complexes separated by clastic sediments as shown by Milewicz (1965, Fig. 1). The maximum number of lava flows at a single outcrop never exceeds three. The flows vary in thickness from 11 to 27 m, with the lowest lava flows usually thinner than the upper ones. Nearly all the lava flows have a basal breccia made up of vesicular and amygdaloidal melaphyre blocks often with an admixture of Rotliegende sandstone fragments. The higher part of the flows usually consist of massive columnar jointed melaphyre, with the joints mostly

Table 2

D and I values for the Lower Permian melaphyre and porphyry lavas and altered sediments of the North Sudetic Depression (cf. Tab. 5)

		Site No.	D	I
Płóczki Górne	1 Flow	1	196	−18
	2 Flow	2	196	−14
	3 Flow	3	206	−7
Pławna Górna	(1 Flow)	—	—	—
	2 Flow	4	193	−36
	3 Flow	5	200	—29
Pławna Średnia	(1 Flow)	—	—	—
	2 Flow	6	196	−25
Bełczyna	1 Flow	8	214	−6
	(2 Flow)	—	—	—
Mt. Rawka	1 Flow	10	200	+4
Pławna Dolna-II	sediment	7	180	+10
Sokołowiec	sediment	9	199	+0.5
Wielisław Złotoryjski	porphyry	11	200	+28

transverse, but occasionally also parallel to the surface of the flow. The top part of the flow is usually represented by vesicular and amygdaloidal melaphyre, originally a scoriaceous lava. The structure of the lava flows strongly resembles that recognized in the Lower Permian melaphyre lavas of the Kraków District (B i r k e n m a j e r, N a i r n, 1964). The presence of scoriaceous lava in most cases immediately below the basal breccia of the successive flow points to short-time intervals between the subsequent flows, when neither stronger erosion, nor clastic sedimentation intervened. As a result, conformable lava sheets were formed.

The lowest lava flow in most cases rests conformably upon the sandstones and conglomerates of the Rotliegende. Only locally the top surface of the underlying clastics shows signs of bottom erosion caused by moving lava.

The sandstones of Rotliegende underlying the lava flows sometimes show alteration zones up to 10 m thick, presumably caused by infiltrating iron oxide solutions, where the sandstones are indurated, their original red colouration being changed to grey, blue or black. Further alteration

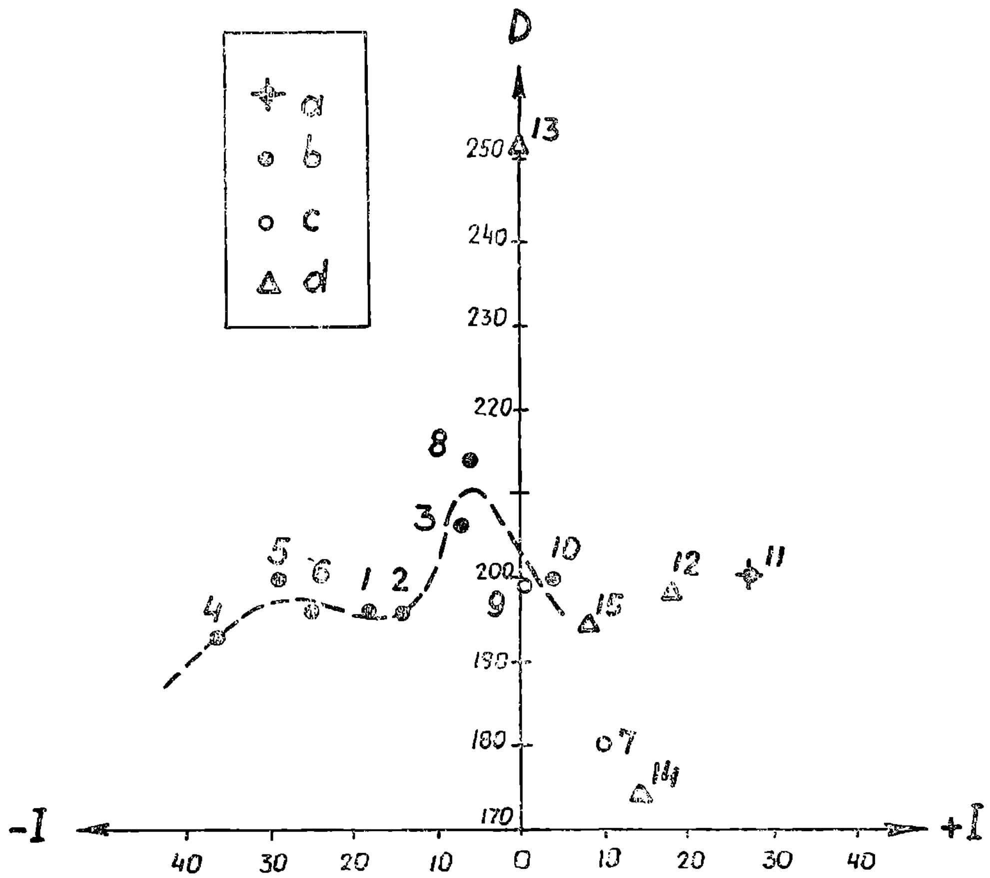


Fig. 6. Zmiany w deklinacji i inklinacji magnetycznej w czasie dolnego permu, w oparciu o pomiary magnetyzmu szczątkowego skał depresji północnosudeckiej i następstwo zjawisk wulkanicznych depresji śródsudeckiej (por. tab. 4). Liczby oznaczają miejsca pobrania prób (por. tab. 5). a — porfir; b — melafir; c — przeobrażone skały osadowe (a—c — depresja północnosudecka); d — „melafir" (doleryt, spilit itd.) i porfir w depresji śródsudeckiej

Fig. 6. Sequential changes in declination and inclination during the Lower Permian, based on measurements on rocks from the North Sudetic Depression, and the volcanic succession of the Inner Sudetic Depression (cf. Tab. 4). Site numbers as in Tab. 5. a — Porphyry; b — Melaphyre; c — Altered sediment (a—c — North Sudetic Depression); d — „Melaphyre" (dolerite, spilite etc.) and porphyry, Inner Sudetic Depression

results in the acquisition of a system of jointing much resembling that of the transverse jointing in the melaphyre lava flows. It seems probable that the above alterations post-dated the lava effusions. These altered rocks bear a striking resemblance to the buchites described by Spry and Solomon (1964).

Similar altered clastic rocks at Pławna Dolna-II, Marczów-Zadole and Gorczyca are regarded as younger than the effusive complex dealt with in the present paper.

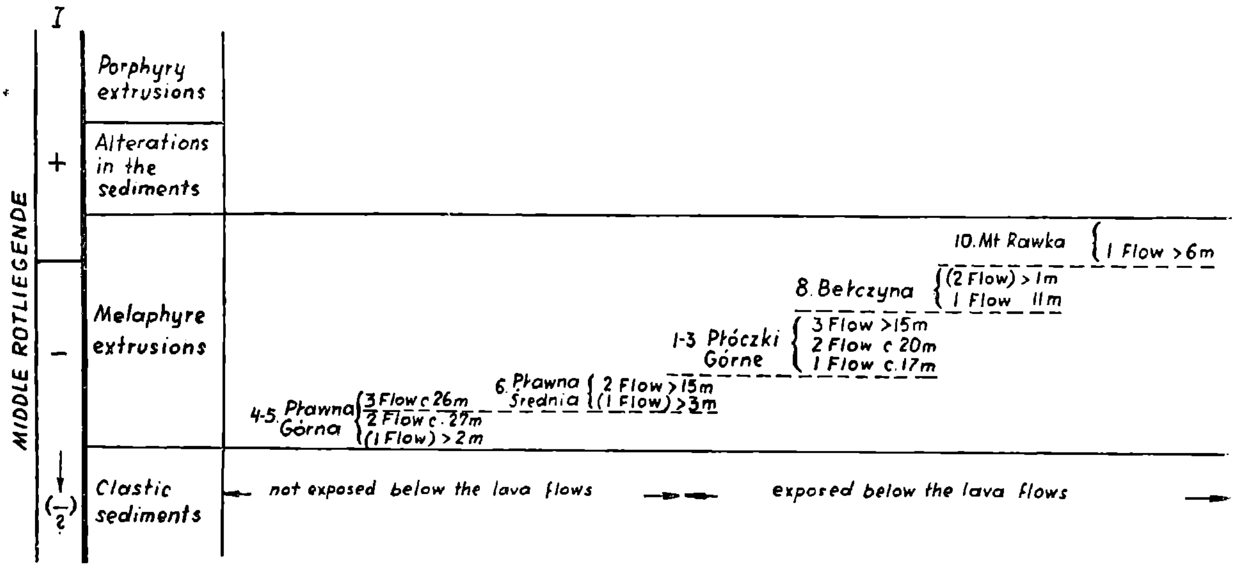
The acid volcanism represented by porphyry extrusions at Wielisław Złotoryjski seems to be younger than melaphyre extrusions, and coeval with the thermal alterations of the sandstones.

Figure 6 shows grouping of Lower Permian sites of the North Sudetic Depression in apparent stratigraphic order. The melaphyre lavas have declinations between 193° and 214° with progressively lower inclination values, whilst the altered sediments of Rotliegende have declinations delimited by D = 180° and 199°. There is considerable variation in the inclination values, the flows in general with negative inclinations and the sediments and the porphyry with positive values.

Taking into account the succession of melaphyre lavas as based on the combination of stratigraphic and palaeomagnetic data (Tabs. 2, 4), and the geographical position of the lava flow sites of the North Sudetic Depression, it appears that the oldest melaphyre extrusions are in the southwest part of the Depression (Fig. 3, Tab. 3), at Pławna Górna (Sites 4, 5), a minimum three flows. The centres of effusion then migrated

Table 3

Supposed stratigraphical succession of Lower Permian melaphyre lava flows of the North Sudetic Depression



farther N (NE) to Pławna Średnia (Site 6) — minimum two lava flows, and reappeared in the southwest zone at Płóczki Górne (Sites 1—3) — three lava flows. The youngest melaphyre lavas were extruded in the central part of the Depression at Bełczyna (Site 8), two lava flows, and at Rawka mt. (Site 10), one (?) lava flow. The strongest volcanic activity was centered in the southwest part of the North Sudetic Depression, where altogether six lava flows have been recognized (Pławna Górna + Płóczki Górne), the lava flows are here thickest (up to 27 m), with the total thickness of the lava sheet exceeding 100 m. This may point to the proximity of a deep fracture in the substratum that served as the feeder for the melaphyre lava-sheet volcanoes.

LOWER PERMIAN VOLCANIC AND SEDIMENTARY ROCKS OF THE INNER SUDETIC DEPRESSION

Description of Localities

Świerki-I

(Figs. 7a, b, 8 a—c, Tab. 5: Site 12)

In the new quarry at Świerki peculiar Lower Permian rocks determined as melaphyres (Kozłowski, 1958) or as quartz dolerites and spilites (Dziedzicowa, 1958) crop out. Kozłowski regarded them to be extrusive melaphyre lavas which strongly disturbed plastic clays (now shales) of the Rotliegende, so that baked sediments arranged in diapir-like structures often came to the contact with top surface of the lava body. Part of the lava then cooled under a thin cover of the displaced bottom sediments, and gave rise to the formation of „subvolcanic bodies" (Kozłowski, 1963).

According to our observations the rocks have obvious differences when compared with the extrusive melaphyres of the North Sudetic Depression. Neither bottom breccias nor scoriaceous top parts of the lavas, so characteristic of the melaphyres of the North Sudetic Depression, are present within the „melaphyres" at Świerki. The rocks superficially closely resemble those dealt with as the altered sandstones in the North Sudetic Depression.

The „melaphyre" at Świerki-I is quarried at five exploitation levels. At the first level there is a fine-grained black, greenish and bluish rock with vertical jointing, superficially resembling a fine-grained altered sandstone (it is the quartz dolerite, Dziedzicowa 1958). Similar rocks at the IInd, IIIrd and IVth exploitation levels correspond to quartz dolerite and, in the upper part of the quarry, to the spilite of Dziedzicowa, and to melaphyre of Kozłowski (1958). The rocks are here fine-grained, greenish, sometimes reddish and bluish in colour, with vertical jointing, as at the Ist exploitation level. Immediately upon the „spilite" of the Vth exploitation level there appear (Figure 8a) thermally altered (baked) reddish and whitish shales and, farther from the contact, unaltered red and violet shales of the Middle Rotliegende. It should be noted that the basal jointing planes within the quartz dolerite at IIIrd exploitation level (20° WNW 30—35°) are arranged in a way similar to that of the bedding planes of the „Bausandstein" underlying the „extrusive" rock, where Kozłowski (op. cit.) measured 160° WSW 15° dips.

Oriented samples were collected from the IInd (quartz dolerite), the IIIrd (quartz dolerite), and IVth (spilite) exploitation levels.

In the old quarry at Świerki-I (Fig. 7a, b), the bottom contact of the melaphyre (quartz dolerite) is exposed with the sedimentary substratum formed by thermally altered purple or variegated shales with yellow limonitic spots (Fig. 8c). The shales are traversed by vertical joints in the upper part close to the contact with the dolerite; the joints disappear quickly downwards. The contact surface of shales and dolerite dips 55° NW 12°. The „dolerite", which superficially resembles metasomatic sandstones, shows relics of sedimentary current bedding and load casting in the lower part.

In a higher part of the exposure in the old quarry at Świerki-I we see the top surface of the rock („spilite") dipping ca. 45° towards SW. Just above the „spilite" there occurs a thin band (0.5—1 cm) of thermally altered violet, black and whitish shale, while unaltered bright red Middle Rotliegende clay shales and clays with marl concretions appear higher still.

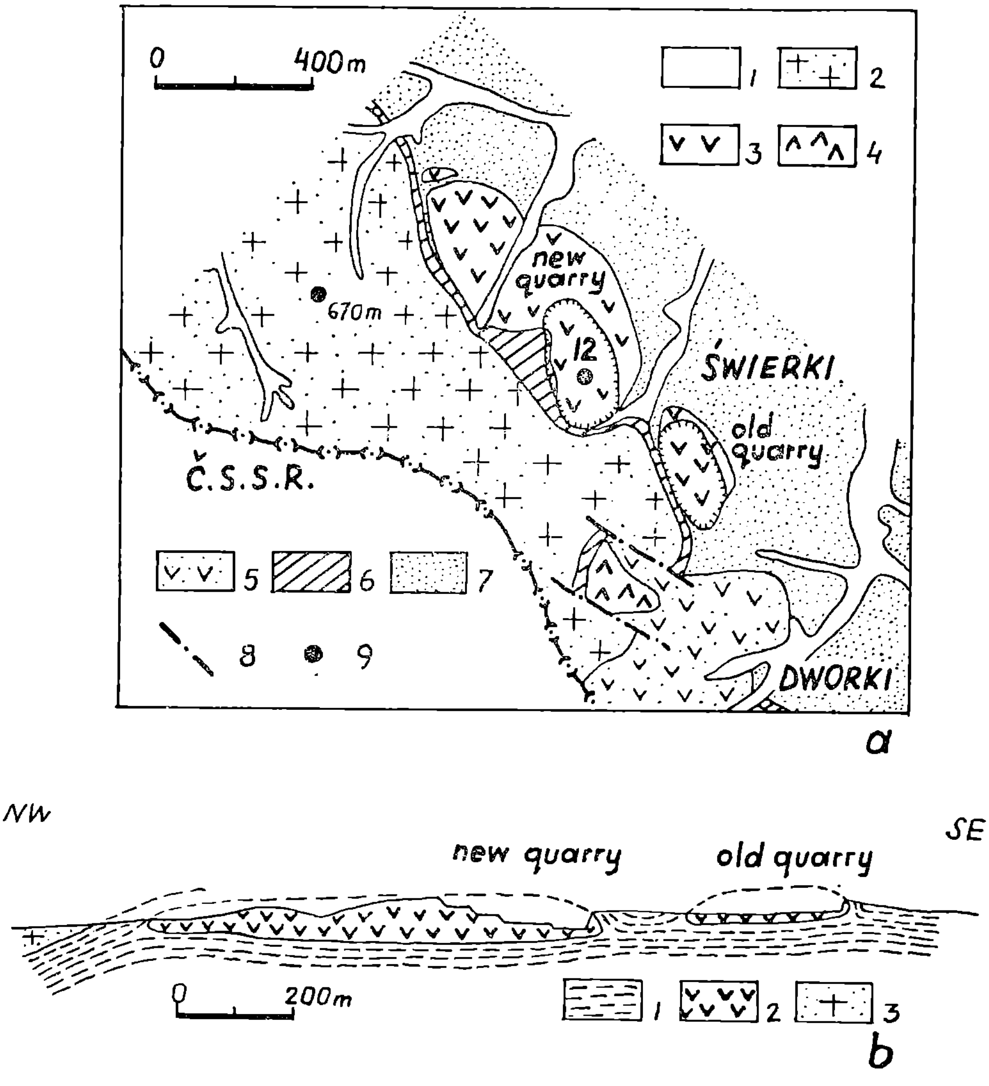


Fig. 7. a. Odsłonięcia skał dolnopermskich w Świerkach — depresja śródsudecka (budowa geologiczna uproszczona według Kozłowskiego, 1958, tabl. III). 1 — osady napływowe; 2 — porowaty porfir kwarcowy; 3 — doleryt-spilit itd. (skały intruzyjno-metasomatyczne, „melafirowe"); 4 — melafir wylewny; 5 — tuf melafirowy; 6 — łupki; 7 — piaskowiec „budowlany": piaskowce i łupki (2—7 — czerwony spągowiec); 8 — uskoki; 9 — miejsca pobrania próbek

b. Przekrój geologiczny przez „melafir" (doleryt kwarcowy-spilit itd.) w Świerkach-I (według Kozłowskiego, 1958, fig. 12, zmodyfikowane). 1 — łupki; 2 — intruzyjno-metasomatyczne ciała „melafirowe"; 3 — porowaty porfir kwarcowy

Fig. 7. a. Lower Permian sites at Świerki, Inner Sudetic Depression (geological features after Kozłowski, 1958, Pl. III, simplified). 1 — Alluvial deposits; 2 — Porous quartz porphyry; 3 — Dolerite-spilite etc. (intrusive-metasomatic „melaphyre" rocks); 4 — Effusive melaphyre; 5 — Melaphyre tuff; 5 — Shales; 7 — „Bausandstein": sandstones and shales (2—7 — Rotliegende); 8 — Faults; 9 — Sampling localities

b. Geological cross-section of „melaphyre" (quartz dolerite-spilite etc.) at Świerki-I (after Kozłowski, 1958, Fig. 12, modified). 1 — Shales; 2 — Intrusive-metasomatic bodies of „melaphyre"; 3 — Porous quartz porphyry

The melaphyre rocks in question (dolerites and spilites) represent intrusions rather than extrusions; part of them could result from metasomatic alterations of some clastic sediments (cross-bedded arkoses) of

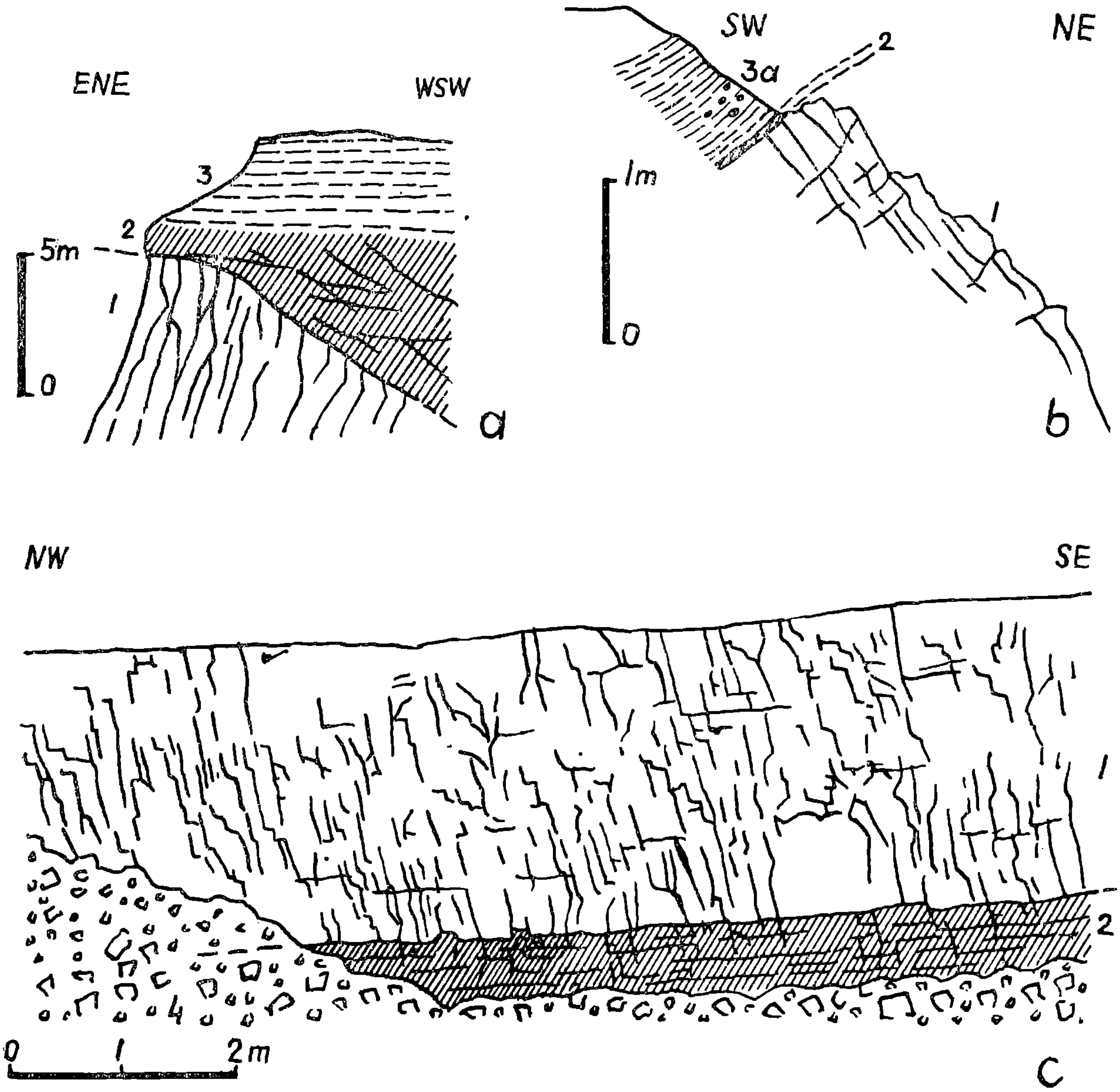


Fig. 8. a. Intruzyjny kontakt stropowy spilitu z łupkami dolnopermskimi w Świerkach-I (nowy kamieniołom) — depresja śródsudecka

b. Intruzyjny kontakt stropowy spilitu z osadami dolnopermskimi w Świerkach-I (stary kamieniołom) — depresja śródsudecka

c. Intruzyjny kontakt spągowy dolerytu kwarcowego z osadami dolnopermskimi w Świerkach-I (stary kamieniołom) — depresja śródsudecka

Objaśnienia oznaczeń: 1 — doleryt-spilit; 2 — przeobrażone łupki; 3 — niezmienione łupki (3a — z konkrecjami marglistymi); 4 — usypisko

Fig. 8. a. Intrusive top contact of the spilite with the Lower Permian shales. Świerki-I (new quarry), Inner Sudetic Depression

b. Intrusive top contact of spilite with the Lower Permian sediments. Świerki-I (old quarry), Inner Sudetic Depression

c. Intrusive bottom contact of quartz dolerite with the Lower Permian sediments. Świerki-I (old quarry), Inner Sudetic Depression

Explanations: 1 — Dolerite-spilite; 2 — Altered shales; 3 — Unaltered shales (3a — with marl concretions); 4 — Scree the Middle Rotliegende, the metasomatizing solutions being related to Lower Permian volcanic activity. The intrusive character of the rocks (sills or laccoliths) is corroborated by the presence of thermal contacts with both the underlying and overlying sediments. The lack of typical lava structures, i. e. bottom breccias, scoriaceous top surfaces, fluidal structures, etc., preclude the possibility of lava sheets.

Świerki-II

W of Świerki village (near point 670 m a.s.l. — Fig. 7 a) a porous porphyry (Upper porous porphyry, IInd eruptive cycle of Kozłowski, 1958) is poorly exposed. It forms small cliffs, slightly disturbed by down-slope gravity movements. No reliable measurements were obtained from the oriented samples collected.

A further locality of „porous porphyry" was recognized by Kozłowski at Krajanów. Here tuff-like rocks composed of fragments of weathered porphyry, of sandstone and red siliceous shales (contact shales ?), usually angular, sometimes subrounded, cemented by a matrix resembling reworked porphyry are exposed. These rocks show the presence of current bedding (azimuth 325°, dips of foresets 40°). Part of the rock, more resembling weathered porphyry, forms a lens, but seems to be simply a more strongly cemented tuff-like rock. The lens shows the presence of joints resembling thermal joints, while some parts of the rock are vesicular. The voids however are the result of the weathering out of clastic fragments, and show an orientation parallel to foreset laminae (dipping NW 40°, azimuths 310—320°), i.e. in the same direction as at the previous site. Typical pyroclastic material is lacking, and the „porphyry", regarded by the authors as water-laid reworked volcanic deposit, is underlain by a „melaphyre" analogous to that from Świerki-I („melaphyre of Krajanów" of Kozłowski, 1958).

A typical quartz porphyry was found between Krajanów and Dworki, but could not be sampled because of inadequate exposures.

At Dworki fragments of a typical effusive melaphyre, red or violet-red, strongly resembling the melaphyres of the North Sudetic Depression, were found as a weathering cover („melaphyre of Dworki" of Kozłowski, 1958, Pl. III). According to Dziedzicowa (1958) the rock belongs to the basalt group.

Głuszyca Górna
(Figs. 9a, b, Tab. 5: Site 13)

In a working quarry at Głuszyca Górna there occur rocks determined by Kozłowski (1958) as melaphyres (rhyobasalts — Kozłowski, 1963), which lithologically resemble the quartz dolerites of Świerki-I (old and new quarries). The rocks form two sill-like horizons separated by shales which dip 130° SW 30°. The shales are thermally altered (baked) at the contact with the lower „melaphyre". According to Kozłowski (1958, p. 25) porous and amygdaloidal structures were present in the top part of the upper melaphyre. The small and scattered voids found, however, occur not in the melaphyre, but in the altered shales, and may have been formed by the dissolving out of marly concretions (see — old quarry at Świerki-I).

The melaphyre resembles metasomatized sandstones (as at Świerki-I), its geological form is that of a sill, and not a lava flow. The samples for

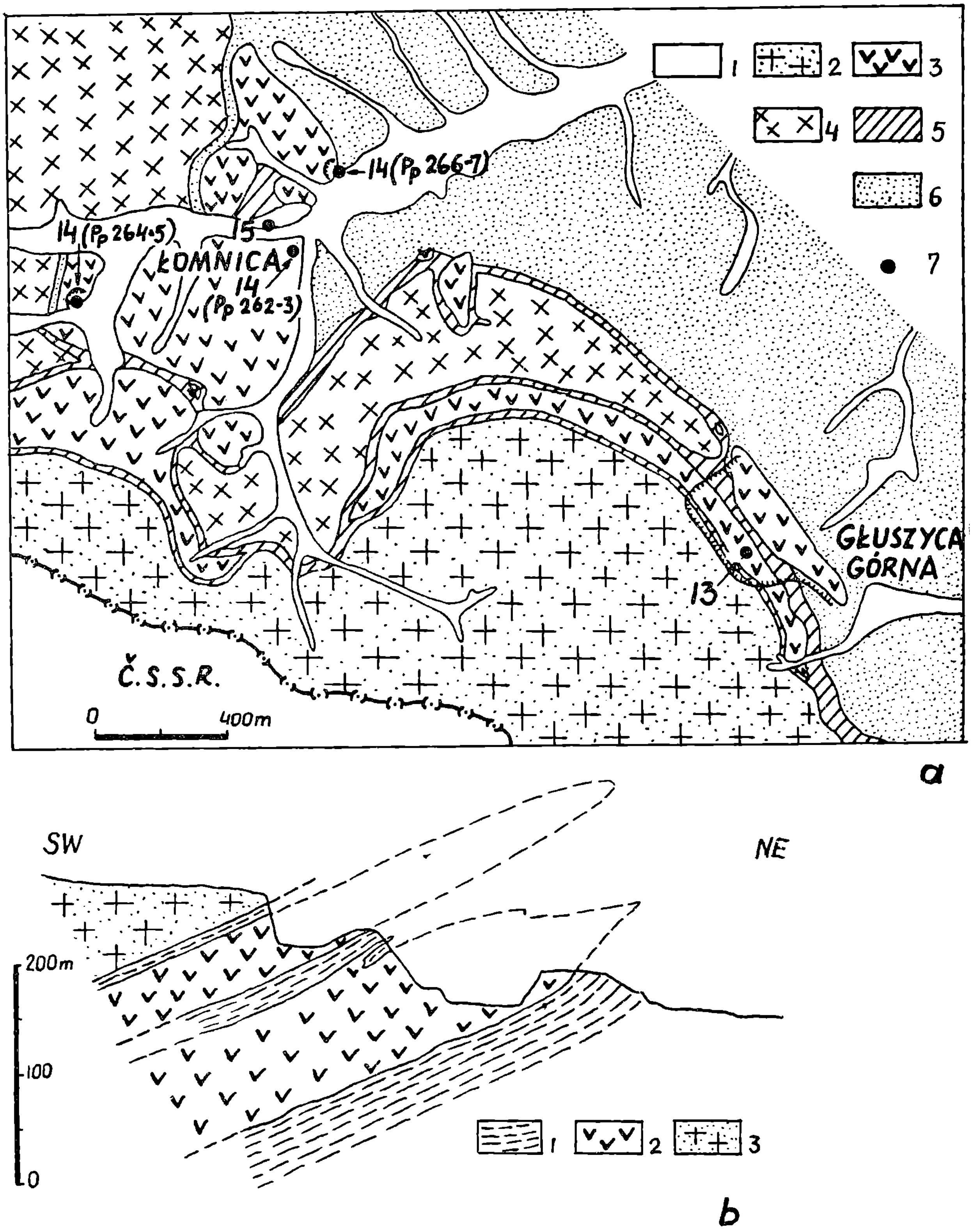


Fig. 9. a. Odsłonięcia skał dolnopermskich w Głuszycy Górnej i Łomnicy — depresja śródsudecka (budowa geologiczna uproszczona według Kozłowskiego 1958, tabl. II). 1 — osady napływowe; 2 — porowaty porfir kwarcowy i tuf porfirowy; 3 — „melafir" (prawdopodobnie intruzyjno-metasomatyczny doleryt); 4 — zbity porfir skaleniowo-kwarcowy (intruzja ryolitowa); 5 — łupki; 6 — piaskowiec „budowlany": piaskowce i łupki (2—5 — czerwony spągowiec); 7 — miejsca pobrania próbek

b. Przekrój geologiczny przez „melafir" w Głuszycy Górnej (według Kozłowskiego, 1958, fig. 9, nieco zmodyfikowane). 1 — łupki (z tufem melafirowym); 2 — intruzja „melafirowa"; 3 — porowaty porfir kwarcowy palaeomagnetic measurements were taken from the upper melaphyre at the IIIrd exploitation level.

Łomnica-I
(Fig. 9a, Tab. 5: Site 14)

The „melaphyre of Łomnica" is regarded by Kozłowski (1958) as the stratigraphic equivalent of the „melaphyre" from Świerki-I. The rock in question, intermediate between trachyandesite and rhyobasalt (rhyodacite), according to Kozłowski (1958, 1963), occupies a lower position in the stratigraphic sequence than the melaphyre of Głuszyca Górna.

The first exposure shows rocks analogous to those from Świerki-I and Głuszyca Górna. It is only near the top of a small hill at Łomnica, that some porous rocks resembling effusive melaphyre were found under weathering cover.

The second outcrop (quarry No. 3 of Kozłowski, 1958, Pl. II) represents a big exposure of a rock („melaphyre") analogous to those of Świerki-I and Głuszyca Górna. The melaphyre is 10-12 m thick and is underlain by horizontal violet-red and red shales of the Middle Rotliegende. The shales penetrate vertical joint fissures from below. Another shale caps the melaphyre.

The last quarry (quarry No. 2 of Kozłowski, 1958, Pl. II) shows the presence of a dark fine-grained rock of the same character as above („melaphyre"). The contact of the „melaphyre" and the underlying Middle Rotliegende sediments dips 150° SW 65°. The sediments are altered dark shales with an intercalation of altered sandstone (glassy melaphyre of Kozłowski, op. cit.) in which relics of sedimentary structures: slump bedding and cross bedding occur. Green, unaltered shales appear farther from the contact.

Łomnica-II
(Fig. 9a, Tab. 5: Site 15)

In the centre of the village Łomnica there occur rocks determined by Kozłowski (1958, Pl. II) as „compact feldspar-quartz porphyry" (leucorhyolite, according to Nożanka, 1958; alkali rhyolite, according to Nowakowski, 1961).

Remarks

Tab. 4 shows the succession of Lower Permian volcanic events of the Inner Sudetic Depression (vicinity of Świerki and Głuszyca) after Kozłowski (1958, modified in 1963). The above scheme needs a revision in some respects. It seems that only a part of the rocks hitherto described as the melaphyres is of effusive character. The rest (i. e. quartz

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Fig. 9. a. Lower Permian sites at Głuszyca Górna and Łomnica, Inner Sudetic Depression (geological features after Kozłowski, 1958, Pl. II, simplified). 1 — Alluvial deposits; 2 — Porous quartz porphyry and porphyry tuff; 3 — „Melaphyre" (probably intrusive-metasomatic dolerite); 4 — Compact feldspar-quartz porphyry (rhyolite intrusion); 5 — Shales; 6 — „Bausandstein": sandstones and shales (2—5 Rotliegende); 7 — Sampling localities

b. Geological cross-section of „melaphyre" at Głuszyca Górna (after Kozłowski, 1958, Fig. 9, slightly modified). 1 — Shales (with melaphyre tuff); 2 — „Melaphyre" intrusion; 3 — Porous quartz porphyry dolerites, spilites, etc.) seem to be metasomatic rocks which originated due to a deep transformation of some clastic sediments of the Middle Rotliegende by magmatic solutions and/or by intruding magma. The geological form of the latter resembles more the sills and the laccoliths than the lava flows.

According to Dziedzicowa (1958) the melaphyres from Świerki are differentiated into zones each passing gradually into another (op. cit.,

Table 4

Lower Permian volcanic succession of the Inner Sudetic Depression, the area of Głuszyca and Świerki (after Kozłowski, 1958, 1963)

		Głuszyca	Świerki
Middle Rotliegende	IInd volcanic cycle	porous quartz porphyry	
		porphyry tuff and shale III	
		melaphyre of Głuszyca	melaphyre of Dworki
		melaphyre tuff of Dworki and shale II	
	Ist volcanic cycle	compact quartz-feldspar porphyry	porous porphyry of Krajanów
		shale I	
		melaphyre of Łomnica and Rybnica	melaphyre of Świerki and Krajanów
	„Bausandstein"		

Fig. 1). The centre of the „melaphyre sheet" is formed by spilites, passing downwards into quartz metadolerites, then into quartz dolerites and „border facies". From the centre of the „sheet" upwards, the spilites pass immediately into the „border facies". Such geological relations are unknown in the effusive melaphyres of the North Sudetic Depression or from the Kraków District. With respect to the Intra Sudetic Depression the petrological differentiation of the „melaphyres" could speak in favour of their metasomatic and/or intrusive character.

Some other doubts are raised as to a part of the rocks determined by Kozłowski (op. cit.) as porphyries. E.g. at Krajanów they are pseudo-tuffs formed from reworked and partly decomposed porphyries and other Lower Permian rocks (sediments) by running water.

The „melaphyre" rocks under discussion (possibly metasomatic and/or intrusive — see above) from the exposures at Świerki-I (Site 12), Głuszyca Górna (Site 13), Łomnica-I (Site 14), as well as the porphyries at Łomnica-II (Site 15), show grouping in a sector between D = 174 and 251 and I = +0 and +28 (Fig. 6). Most of these sites (excluding Site 13) therefore give similar directions to the altered sediments of the North Sudetic Depression, differing somewhat from the effusive melaphyres of that area.

UPPER CARBONIFEROUS (?) VOLCANIC ROCKS OF THE NORTH SUDETIC DEPRESSION

Description of Localities

Płóczki Górne
(Fig. 10, Tab. 5: Site 16)

Two porphyry sills intruded in the Upper Carboniferous deposits are exposed in a field road cutting at Płóczki Górne. The lowermost part of the section shows grey, sometimes reddish arkoses dipping 160° NE 25°. The bottom contact of the first sill is not exposed. The sill, about 8 m thick, is a weathered, light red, pink or whitish porphyry. Baked, greenish, siltstones and shales about 1 m thick appear between the first and the second sills. The second (upper) sill, about 7 m thick, is a cherry-red porphyry with numerous xenoliths of green shale 1—3 mm in diameter.

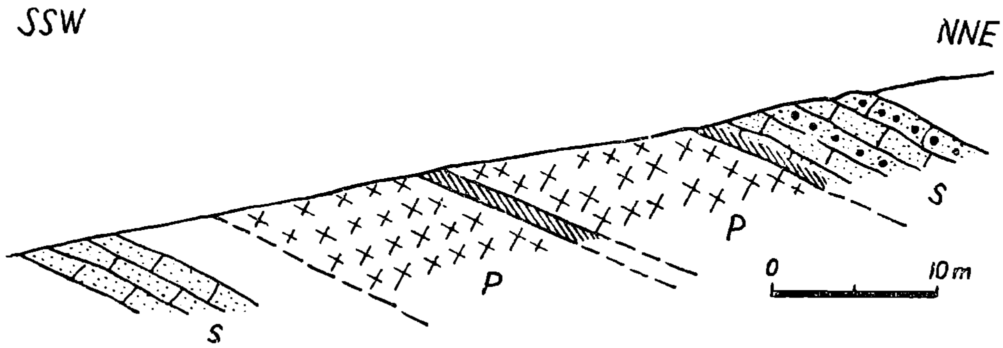

Fig. 10. Dwa sille porfirowe wieku powestfalskiego w Płóczkach Górnych (depresja północnosudecka). p — porfir; s — osady górnokarbońskie (arkozy, zlepieńce, łupki itd.); osady spieczone kontaktowo oznaczono skośnym kreskowaniem

Fig. 10. Two porphyry sills of post-Westphalian age, at Płóczki Górne, North Sudetic Depression. p — Porphyry; s — Upper Carboniferous sediments (arkoses, conglomerates, shales, etc.); baked sediments — obliquely hatched

The porphyry sometimes shows amygdaloidal structure superficially resembling melaphyre, and is finely jointed 2—3 cm parallel to the contact with sediments. Medium and fine conglomerates and coarse and fine grained arkose sandstones, reddish, grey and variegated, occur above the second sill. The fragmental material consists of quartz, gneiss and phyllite. The sediments dip 150° NE 20°. Baked red shales and siltstones form a thin zone (5—10 cm) at the contact with the porphyry.

Oriented samples for palaeomagnetic investigations were taken from the upper sill.

Remarks

The age of the sills is post-Westphalian, probably older than the Lower Permian effusive melaphyres. The direction of magnetization of the upper sill resembles those of both the Lower Permian melaphyre lavas of the North Sudetic Depression, and the Upper Carboniferous volcanites of the Wałbrzych area (Inner Sudetic Depression).

UPPER CARBONIFEROUS VOLCANIC ROCKS OF THE INNER SUDETIC DEPRESSION

Description of Localities

Kamieńsk Wałbrzyski
(Tab. 5: Site 17)

An interesting porphyry intrusion (neck) is exposed in an old quarry at Kamieńsk Wałbrzyski opposite the railway station. The porphyry cuts through the deposits of the Westphalian B (Žacléř Formation) which dip 15—20° towards SW. The Westphalian B/C age is accepted for the porphyry, as fragments of analogous rock have been found reworked in the Westphalian C deposits. The porphyry neck dips steeply towards the south. It consists of concentric bands of alternating felsite and fine crystalline porphyry. The outer part of the neck shows flow structure with the phenocrysts parallel to the neck skin. Cylindrical, radial and basal joint systems can also be observed. As a result, the porphyry splits into blocks resembling concretions. At the core the presence of rings recalling Liesegang rings can be seen. Between the blocks („concretions") which show the increase in silica content, there occur desilicified parts of the porphyry of violet colouration, resembling tuffs. The least altered porphyry is found in the central part of the neck.

It seems possible that successive rings (cylinders) of the porphyry have been added in a centrifugal direction.

As the central zone appeared least altered, oriented samples were collected from this zone.

Rusinowa
(Tab. 5: Site 18)

A felsite porphyry sill is exposed in an old quarry at Rusinowa, near the road to Wałbrzych. It is intruded into the Wałbrzych Formation (Namurian A), represented here by arenaceous shales with mica, and separated from the porphyry by a thin magmatic breccia. The age of the porphyry is believed to be higher Westphalian, by analogy with other intrusions of the area.

Barbarka Mount
(Figs. 11 a—c, Tab. 5: Site 19)

The northern slope of Barbarka mount, south of the railway station Wałbrzych Główny, is built of the Žacléř Formation (higher part of Westphalian B) with a coal seam (Ernestine-Amalia coal seam, i.e. coal seam No. 1 in the Polish standard), dipping 145° SW 25°. The porphyry is exposed in an old quarry near the summit of the hill. This is a typical effusive felsite porphyry showing distinct flow structures (Figs. 11 a—c) such as flow folds recumbent to the NE indicating flow in this direction (azimuths 20°, 60°). Big xenoliths of unaltered conglomerates form either lenses conformable with the flow folds of the lava, or lenticular intercalations between flat lying bands of porphyry. These geological relations indicate contemporaneity of the lava extrusions with the formation of conglomerates of this part of the Žacléř or Glinik Formation.

The sedimentary cover of the porphyry is represented by the Glinik Formation (Westphalian C), the latter showing the presence of reworked porphyry of the same type. Thus the age of the porphyry at Barbarka mount is well determined as the Westphalian B/C (Grocholski, 1965).

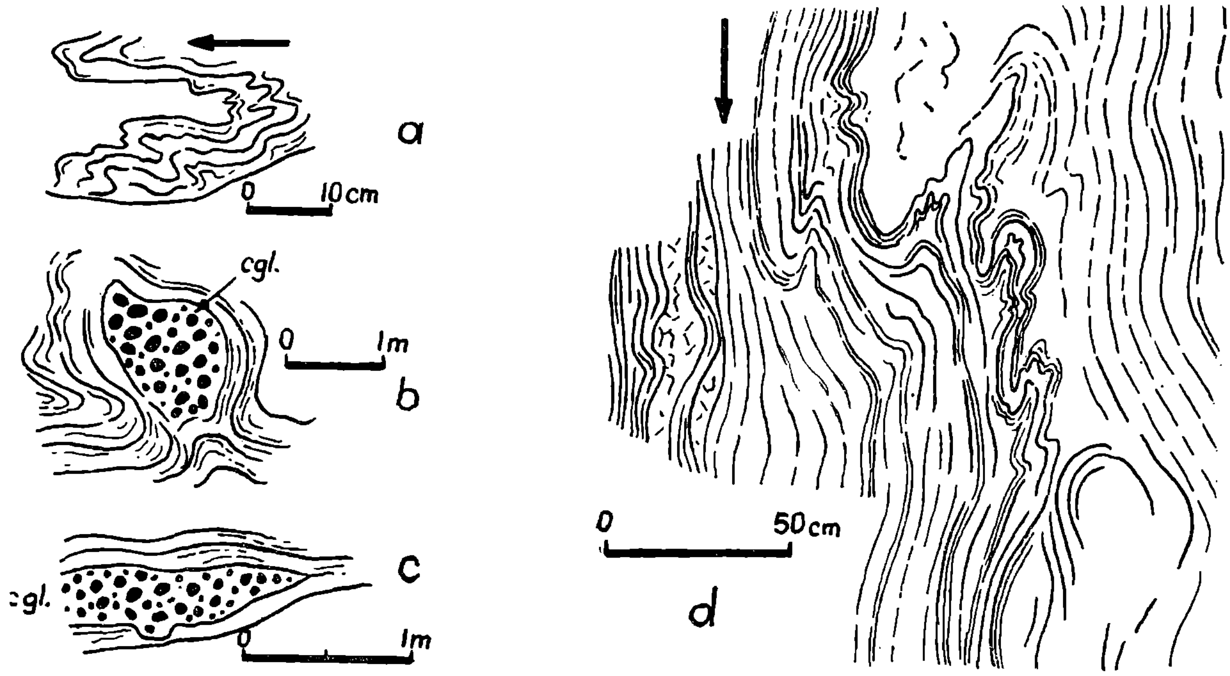

Fig. 11. a—c. Struktury fluidalne w wylewnym porfirze (westfal B/C) na górze Barbarka w depresji śródsudeckiej. d. Struktury fluidalne w wylewnym porfirze (górny westfal) w Starym Lesieńcu, w depresji śródsudeckiej. Cgl — zlepieniec; strzałki wskazują kierunek płynięcia lawy porfirowej

Fig. 11. a—c. Fluidal structures in effusive porphyry (Westphalian B/C) at Barbarka mt., Inner Sudetic Depression. d. Fluidal structures in effusive porphyry (Upper Westphalian) at Stary Lesieniec, Inner Sudetic Depression. Cgl — Conglomerate; Arrows indicate directions of lava motion

Boguszów
(Tab. 5: Site 20)

The exposure of felsite porphyry in an old quarry at Boguszów belongs to the Chełmiec porphyry laccolith. The porphyry intruded into the Wałbrzych Formation. The regional dip of the sediments (Dathe and Berg, 1926) at Szczawno is 15° towards the S. Local dips of the Wałbrzych Formation are often much steeper close to the laccolith, and conformable with the dome of the intrusion, consequent upon the lifting the sedimentary roof by intruding magma.

Three systems of joints are recognizable in the outcrop, similar to those of the porphyry laccolith at Zalas near Kraków (cf. Dżułyński, 1955; Birkenmajer, Nairn, 1964): radial joints (every 0.1—0.3 m), marginal joints, conformable with the roof of the laccolith (every 0.5—1.5 m), and conical joints, corresponding to inverse cone surfaces with the confluence apex situated inside the laccolith (every 2—4 m). Some barite veins occur in the porphyry, their directions being parallel to the Kuźnice Fault.

The porphyry lacks fluidal structures. Both feldspar phenocrysts and the matrix show some kaolinization. The age of the porphyry is accepted as Westphalian B/C (Grocholski, 1965) on general considerations.

Mniszek
(Tab. 5: Site 21)

In an old quarry on Mniszek hill (NE part of the hill) near Gorce, a greenish felsite porphyry in which a complicated thermal joint pattern belonging to two main systems is found. The first joint system cuts the rock every 20—30 cm, and dips 45—50° towards N or NE (azimuths 0—60°), the second is visible every 1—3 cm, dips 60—70° towards SE (azimuths 140—160°). The latter system tends to change its direction, becoming centrifugal (conical). It seems possible that the intrusion has a phacolithic character and is conformable with the crest of the Jabłów Anticline.

Local dips of the Upper Carboniferous strata in the vicinity of hill Mniszek are 60° SE 20° (Dathe, Berg, 1926). A Westphalian age of the intrusion is accepted (Grocholski, 1965).

Gorce
(Tab. 5: Site 22)

In a working quarry at Gorce (S part of the village) a pink, dark grey or dark green (reddish weathering) felsite porphyry with numerous feldspar phenocrysts crops out. Fluidal structures are here absent, and the main joint system resembles columnar jointing. The other joint system normal or at oblique angles to the columns, dips 105° SW 40°, which resembles the regional dip of the Upper Carboniferous sediments in the surroundings of Gorce (see Dathe, Berg, 1926): SW 45—50°.

The geological form of the porphyry is not quite clear. It is either an intrusion with eroded sedimentary top, or — more probably — a deeper part of a thick lava flow. The latter possibility is suggested by the presence of columnar jointing.

The reworked porphyry of this type was found in the Lower Permian „Bausandstein" ($ru_2\delta$ of Berg, 1938). If, as it seems likely, the rock is a lava flow the porphyry must be younger than Westphalian B and older than Lower Permian. In the area of Gorce the Lower Permian sediments rest directly upon Westphalian B deposits.

Stary Lesieniec
(Fig. 11 d, Tab. 5: Site 23)

An effusive felsite porphyry is present in an old quarry at Stary Lesieniec, near the road. It shows a characteristic banding of alternating pink and violet porphyry. Well developed fluid structures are visible here and there, indicating the movement of the lava towards SW and W (azimuths: 200°, 210°, 270°). The general tilt of the lava flows, as determined from fluidal lamination, is 175° WSW 50° in the quarry and 150° SW 45° to the west of the quarry.

The age of the porphyry is Upper Westphalian (Grocholski, 1965).

Czarny Bór
(Tab. 5: Site 24)

An effusive green porphyry is exposed at Czarny Bór, along the south west slope of the hill. The porphyry shows the presence of columns steeply dipping towards the N, traversed by basal joints which dip 85° SSE 30°. The thickness of the lava flow at the outcrop is about 20 m. The age of the porphyry is younger than Westphalian B and older than the Lower Rotliegende (Kuseler Schichten, ru_1c — see Berg, 1938).

Niedźwiadki

At Niedźwiadki near Wałbrzych, in an old quarry near the road, rocks determined by Dathe and Berg (1926) as the melaphyre crop out.

Here brecciated, strongly altered fine-grained yellowish, greenish or rusty sandstones crop out. They partially resemble „melaphyres" of the area of Świerki-I, Łomnica and Głuszyca Górna. Here and there pseudo-amygdales of fragments of indeterminable rocks. The sandstones form layers 0.1—2 m thick, separated by red shales 1—5 cm thick. The whole complex dips 30° NW 35°.

The relation of the altered sandstones and shales to the porphyries in the neighbourhood is not clear. They could represent a big xenolith in a volcanic vent breccia. The age of the altered sediments is unknown: but a higher Westphalian date is assigned to them.

No confidence can be assigned to the results from the altered sandstones (D = 220.5, I = +2.0, α = 44.8, K = 33.2, sampling 2/3, R = 1.970, demagnetizing field = 85 oe.) because of the high dispersion of the results and the small sample size.

Trójgarb

The mount Trójgarb is built of an irregularly jointed pink felsite porphyry intrusion. The intrusion is younger than the Lower or Middle Visean and its age may range between the Upper Carboniferous and the Lower Permian (H. Teisseyre, 1952). The regional dip of the surrounding Culm amounts to 85° SSE 30° (Zimmermann, 1914). The samples for palaeomagnetic measurements were taken in an old quarry, about 300 m NE of the summit of the mountain. They gave the following results: D = 193, I = +41, sampling 2/3, α = 83.4, K = 3.3, R = 2.391, demagnetizing field = 85 oe. These results are not significant because of high values for α.

Owiecznik

On Owiecznik hill (between Boguszów and Sobięcin) an olivine kersantite neck, younger than the Wałbrzych Formation (Namurian A) crops out in an old quarry. The Wałbrzych Formation dips 45° SE 30° (Dathe, Berg, 1926). The joints in the kersantite are directed 170° ENE 30° and 60° NW 75°. The results of palaeomagnetic measurements are: D = 210, I = +10, sampling 3/4, α = 46.2, K = 8.2, R = 2.756, demagnetizing field = 170 oe. The results are not significant because of high value for α.

Remarks

Of the eight sites 17—24 included in Tab. 5, the four sites represent intrusive porphyries, the rest are effusive porphyries. Their stratigraphic age, best determined for the lava flow of Barbarka mount (site 19), is Westphalian B/C (Grocholski, 1962, 1965), i.e. it corresponds to the Asturic Phase. The intrusive porphyries are partly volcanic vents or plugs (e.g. Kamieńsk Wałbrzyski, Site 17) forming feeder veins, and partly they are subvolcanic bodies (e.g. Chełmiec laccolith, Boguszów, Site 20) showing no direct connection with surface volcanism.

The palaeomagnetic aspect of the porphyries is less uniform than that of Lower Permian melaphyre lavas, North Sudetic Depression, and shows larger dispersions of values for declination and inclination. A number of sites here had to be excluded because of the very scattered results, showing up as very high values of α.

The results from porphyry lavas (Sites 19, 22, 23, 24) show a greater scatter than those from the porphyry intrusion. In the case of the lava

Table 5

Palaeomagnetic results, Upper Carboniferous and Lower Permian of the Sudetes.
A — Lower Permian sites (1—15); B — Upper Carboniferous sites (16—24)

SAMPLING DATA

Direction of magnetization: D — declination; I — inclination
J — Intensity of magnetization J×10^{-4} e.m.u./c.c.
F_{oe} — Demagnetizing field
a/b — Number of samples used/number of samples collected

STATISTICAL DATA

R — Length of vector mean
X — Susceptibility ×10^{-4}
α — Confidence
K — Dispersion
Q — Coefficient

Site and rock type	D	I	J	F_{oe}	a/b	R	α	K	X	Q
A.										
1. Płóczki Górne, melaphyre, 1st flow	196	—18	23.9	170	5/5	4.949	8.66	79.0	2.4	22.1
2. Płóczki Górne, melaphyre, 2nd flow	196	—14	43.7	215	5/5	4.992	3.45	491.7	4.0	24.3
3. Płóczki Górne, melaphyre, 3rd flow	206	— 7	2.6	170	3/5	2.927	23.94	27.6	7.9	0.73
4. Pławna Górna, melaphyre, 2nd flow	193	—36	9.6	85	5/5	4.893	12.70	37.3	14.1	1.51
5. Pławna Górna, melaphyre, 3rd flow	200	—29	6.0	170	4/5	3.972	8.94	106.5	4.7	2.84
6. Pławna Średnia, melaphyre, 2nd flow	196	—25	0.8	85	3/4	2.999	3.17	1517.0	0.2	0.89
7. Pławna Dolna-II, altered sandstone	180	+10	2.0	340	2/4	1.994	19.55	165.3	5.0	0.89
8. Bełczyna, melaphyre, 1st flow	214	— 6	40.1	85	4/6	3.957	11.10	69.6	0.3	290.0
9. Sokołowiec, altered sandstone	199	+ 0.5	5.1	0	4/4	3.912	15.93	34.2	17.8	0.64
10. Rawka Mt., melaphyre, 1st flow	200	+ 4	11.1	85	3/5	2.972	14.78	70.6	4.7	5.25
11. Wielisław Złotoryjski, effusive porphyry	200	+28	0.13	255	2/5	1.997	12.99	372.0	0.05	5.77

12. Świerki-I, „melaphyre”	198	+18	0.03	85	4/6	3.899	17.16	29.6	7.1	0.01
13. Głuszyca Górna, „melaphyre”	251	+ 0	0.25	0	3/4	2.970	15.21	66.7	0.18	3.08
14. Łomnica-I, „melaphyre”	174	+14	0.05	170	6/6	5.228	28.49	6.5	0.05	2.22
15. Łomnica-II, intrusive porphyry	194	+ 8	0.13	0	6/6	5.894	9.86	47.1	0.05	5.77
Mean Direction (excluding 13)	196	— 4	—	—	—	13.121	10.7	14.8	—	—
Ancient Pole	175 E	43 N								
B.										
16. Płóczki Górne, porphyry sill	196	— 2	0.13	170	4/5	3.932	13.93	44.4	0.09	3.04
17. Kamieńsk Wałbrzyski, porphyry neck	169	— 4	0.46	0	5/6	4.779	18.49	18.1	0.18	5.70
18. Rusinowa, porphyry sill	214	—15	0.16	255	3/5	2.922	24.82	25.7	0.04	8.90
19. Barbarka Mt., effusive porphyry	182	—46	0.08	255	6/6	5.854	11.59	34.4	0.09	1 98
20. Boguszów, porphyry laccolith	194	— 3	0.02	85	4/5	3.987	6.10	228.2	0.08	0.55
21. Mniszek, porphyry intrusion (?phacolith)	184	—21	0.04	0	4/5	3.876	19.07	24.2	0.12	0.74
22. Gorce, porphyry (effusive?)	198	+10	0.07	255	4/5	3.984	6.65	191.9	0.11	1.41
23. Stary Lesieniec, effusive porphyry	254	—64	0.14	0	5/6	4.798	17.64	19.76	0.65	0.48
24. Czarny Bór, effusive porphyry	205	—13	0.40	255	3/5	2.994	6.69	340.8	0.15	5.9
Mean Direction (excluding 23)	196	—12	—	—	—	7.599	13.6	17.4	—	—
Ancient Pole	174 E	43 N								

flows the greater scatter may be in part the result of some pre-existing tilt of the Upper Carboniferous landscape and lava-flow morphology, both very difficult — if not impossible — to determine. It is also possible that the internal deformations (flow structures) in viscous porphyric lavas could have resulted in movement after the primary magnetization was acquired.

PALAEOMAGNETIC MEASUREMENTS

Methods

The methods and techniques followed are essentially those described in the earlier papers (Birkenmajer, Nairn, 1964, 1965). From

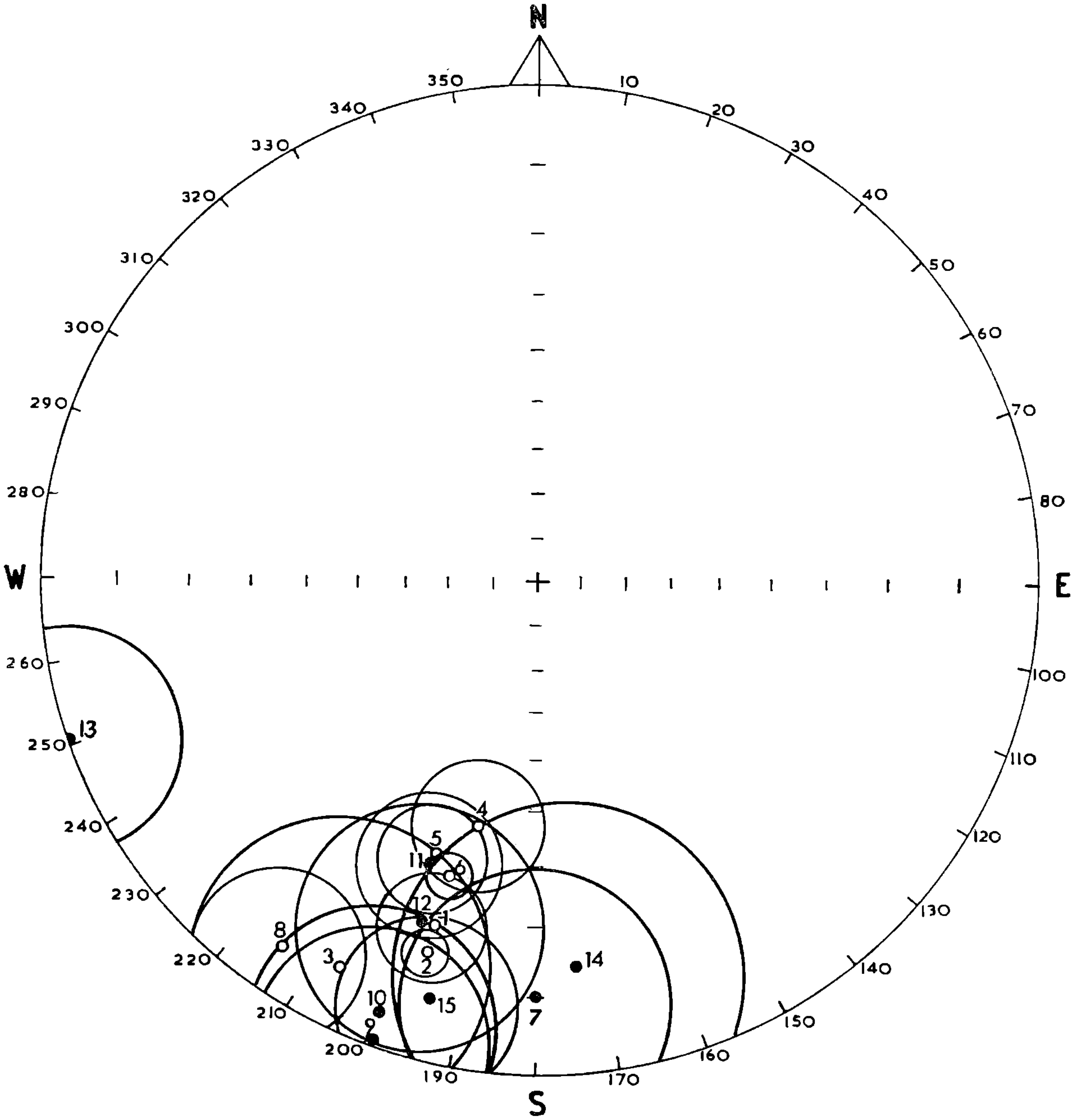

Fig. 12. Średnie lokalne kierunki magnetyzacji (z zaznaczonymi kołami ufnośoi) próbek dolnopermskich. Uwzględniono poprawkę na upad warstw. Numery punktów pobrania próbek — jak w tab. 2, 5

Fig. 12. Site mean directions of magnetization with circles of confidence for Lower Permian samples. A correction has been made for geological dip. Site numbers correspond to tabs. 2, 5

each site up to six oriented blocks were collected spread as widely as possible over the available outcrops. In general quarries were preferred as sampling sites though in some cases samples had also to be collected from natural outcrops. The distribution of the sites is indicated in the geological sketch maps Figs. 1—3.

A single core was cut from each sample and the directions of remanence measured using either a short period, or a highly sensitive astatic magnetometer. All were subjected to progressive demagnetization in alternating fields of up 340 gauss. The direction of magnetization at that stage of demagnetization at which the dispersion of results was at a minimum, was adopted as indicating the direction of the geomagnetic field in which the rocks acquired their magnetization.

Susceptibility was measured in low fields, of the order of 2 gauss, in a susceptibility bridge designed by Collinson, Molyneux and Stone (1963). Thermo-magnetic curves were obtained from an automatically recording Chevallier balance.

As will be clear from the sampling data summarised in Tabs. 5 and 6 though few of the samples failed to respond to demagnetization treatment, many of them possessed such low intensities of magnetization that the high sensitivity magnetometer had to be used. There is a fairly clear division on the basis of intensity of magnetization, the lavas having an intensity one or even two orders of magnitude greater than the intrusions. This feature was also recorded in the Kraków Permian study (Birkenmajer, Nairn, 1964). The mean directions of magnetizations are illustrated in Figs. 12 and 13, depicting the Lower Permian and Upper Carboniferous respectively. Typical demagnetization curves are given in Fig. 15.

Directions of Magnetization

The geological evidence of Lower Permian and Upper Carboniferous ages for the lava flows is clear, the stratigraphical position of some of the intrusions is not so clear.

Table 6

Mean directions of magnetization and virtual pole positions

	D	I	α	K	ancient pole
Lower Silesia, Lower Permian	196	−4	10.7	14.8	175E 43N
Lower Silesia, Upper Carboniferous	196	−12	13.6	17.4	174E 43N
Kraków District, Lower Permian lavas [1]	204.9	−19.5	8.1	41.5	164E 45N
Inner Sudetic Basin, Czechoslovakian part, Lower Permian sediments [2]	205.2	−9.2	4.7	21.3	162.1E 39.5N

[1] Data from Birkenmajer, Nairn (1964).
[2] Data from Bucha, Chlupačová, Krs, Větrovská, Nairn (1964).

A virtual pole position for the Lower Permian lavas and sediments was calculated and is listed with other pole positions for comparison (Tab. 6).

The virtual pole position, in fact, agrees well with other computations and lies with the tight grouping of Permian virtual poles (Nairn, 1960, 1964) known from many places in northern Europe. The virtual pole position for the Upper Carboniferous intrusions was calculated in two ways, on the assumption that the intrusion preceded tilting as recorded from the dip of the enclosing beds and on the basis that the rocks were intruded into inclined strata. The directions of magnetization in these two cases are illustrated in Figs. 13, 14, and as can be seen from

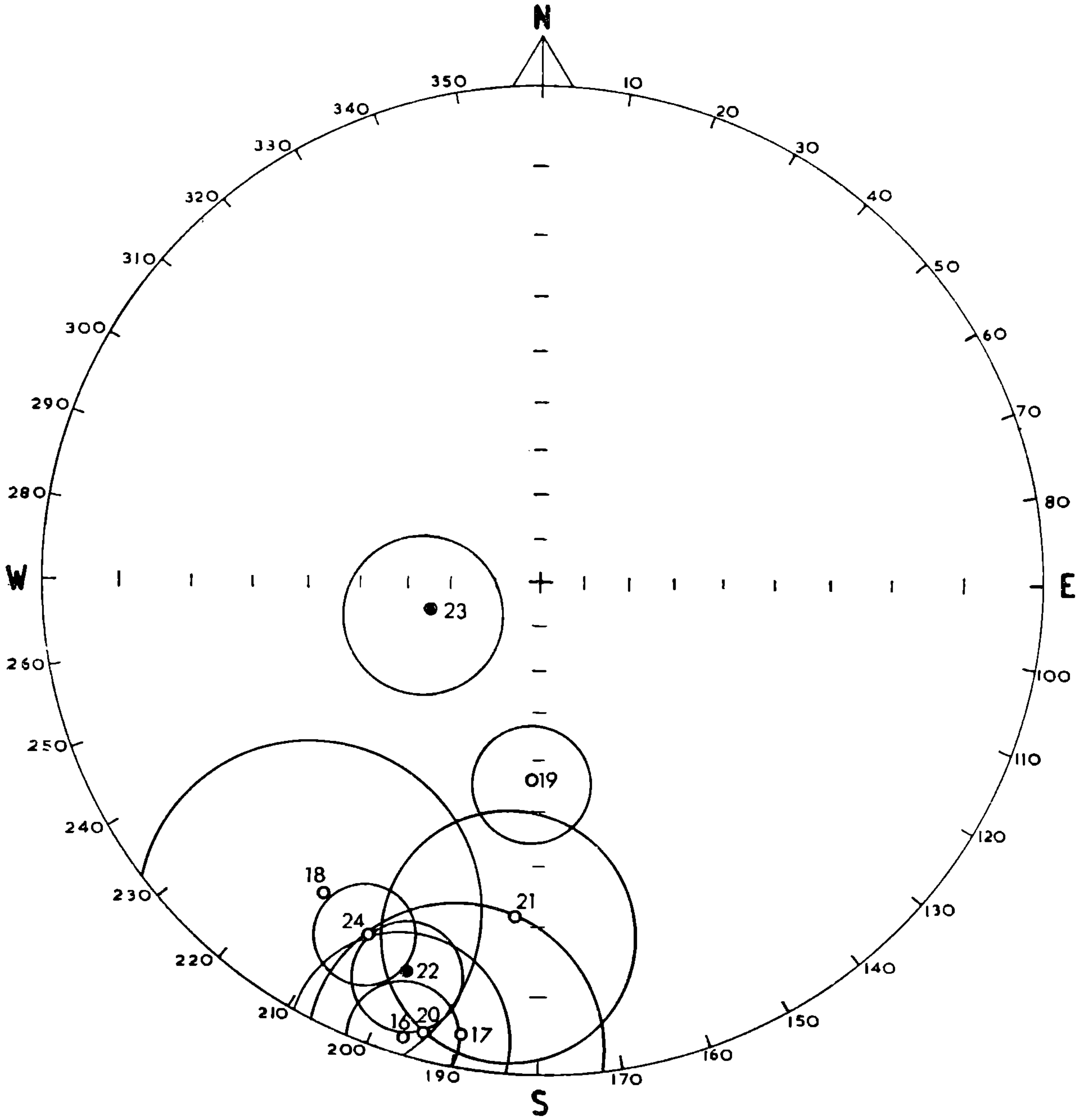

Fig. 13. Średnie lokalne kierunki magnetyzacji (z zaznaczonymi kołami ufności) skał górnokarbońskich. Uwzględniono poprawkę na upad skał osadowych w sąsiedztwie. Numery punktów pobrania próbek — jak w tab. 5

Fig. 13. Site mean direction of magnetization with circles of confidence for Upper Carboniferous rocks. Measurements made with respect to the enclosing sedimentary beds. Site numbers correspond to tab. 5

the figures, the scatter and confidence limits of the mean are much improved by assuming that intrusion preceded tilting. The direction of magnetization is closely similar to the Lower Permian lavas and the virtual poles. Thus whilst no conclusion may be drawn from the direction of magnetization about the age of the rocks, it seems probable that intrusion preceded tilting, and that the field of the time was substantially the same as that pertaining during Lower Permian times. The geological evidence is also less than conclusive in the absence of radiometric dating, and in this paper the views of G r o c h o l s k i (1965) are followed. The situation is analogous to that found in the case of the Great Whin Sill (C r e e r, I r v i n g, N a i r n, 1959) and two associated dykes (C o l l i n-

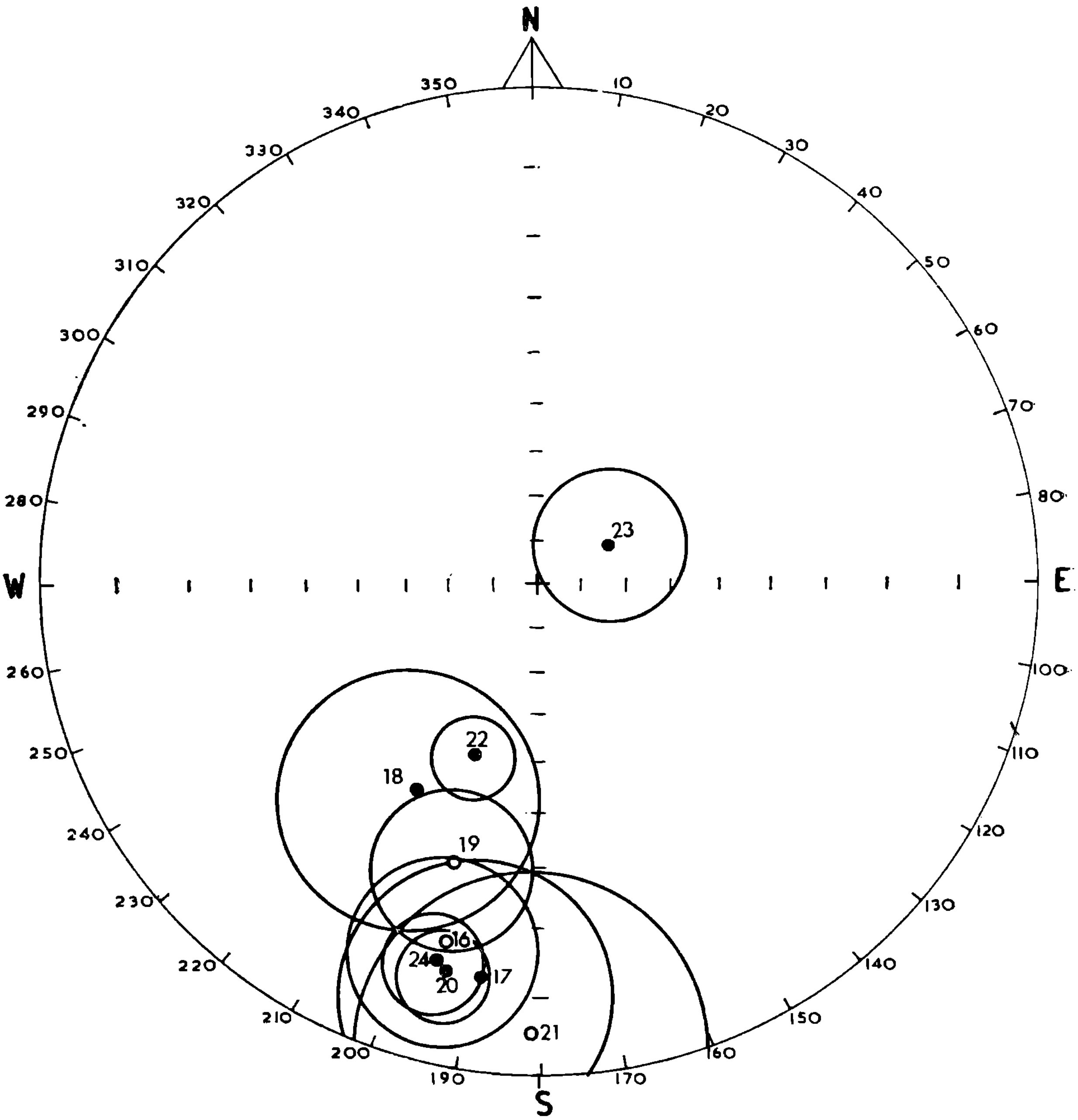

Fig. 14. Średnie lokalne kierunki magnetyzacji (z zaznaczonymi kołami ufności) skał górnokarbońskich, bez uwzględnienia poprawki na upad skał osadowych w sąsiedztwie. Numery punktów pobrania próbek — jak w tab. 5

Fig. 14. Site mean directions of magnetization with circles of confidence for Upper Carboniferous rocks. Measurements made with respect to the present horizontal. Site numbers correspond to tab. 5

son, Nairn, 1960). The age of the former is now known to be 295 m.y. (Fitch and Miller, 1964).

The directions of magnetization of the Upper Carboniferous intrusions are also similar to the Lower Permian, and to the Stephanian results found elsewhere in Europe in the Saar and Massif Central (Nairn, 1960). They are also essentially identical with measurements carried out on Carboniferous sediments in the Czech part of the basin (Birkenmajer, Krs, Nairn, 1968).

INTERPRETATION OF PALAEOMAGNETIC MEASUREMENTS

The Upper Carboniferous igneous rocks are extensively altered, some even kaolinitized. Haematite has been recognized in the sections, commonly as a decomposition product of mafic minerals, occasionally in the form of veinlets. Since the haematite appears to be one of the principal carriers of remanence, the time at which it was formed is of considerable importance. The alteration is generally regarded as autometamorphism and hence of Upper Carboniferous age rather than Permian. The overlying beds show little trace of extensive alteration, whilst on the nearby Bohemian Platform similarly altered igneous rocks are found and sedimentary kaolinites occur in the Stephanian. Subsequent reheating save by burial is unlikely. Only at Boguszów (Site 20) there is evidence of slight hydrothermal activity which produced barite veins. These veins cut the porphyry but the heating effect is not regarded very great.

The balance of evidence thus favours an Upper Carboniferous date for the alteration, though the magnetization probably does not represent the local geomagnetic field at the time of origin of the rocks but rather an unspecified time during which alteration occurred. Recent work (Walker, 1967) has shown that alteration may continue for a considerable time even after burial of the rock.

It follows from the above that the directions of magnetization record the geomagnetic field at some period in the Upper Carboniferous, possibly as low as Westphalian B-C, of the region. It has previously been noted (see above) that the directions of magnetization and the virtual pole position calculated from them, are in accord with those from rocks of a similar age in other parts of Europe. The present result (Fig. 13), however, is from rocks whose age cannot be very different from the Upper Carboniferous sedimentary rocks the results from which are reported in Creer, Irving and Runcorn (1957) or from some of the igneous rocks described by Everitt and Belshé (1960). The ages of some of the latter are known from the work of Fitch and Miller (1964). Everitt and Belshé (1960) attribute their result to the resultant of an original Carboniferous direction upon which a Permian direction has been imprinted. However, in the absence of magnetic cleaning of much of the material involved, it is not certain whether a secondary effect is involved or whether there is a real difference.

The N.R.M. (natural remanent magnetization) of the Lower Permian lavas is ten to a hundred times greater than that found in the Upper Carboniferous igneous rocks, extrusive or intrusive, the same is true of their relative susceptibilities. This difference is related to differences in the ferromagnetic mineral content (see Fig. 16), in the Permian lavas magnetite or a titanomagnetite occurs whilst in the Carboniferous igneous

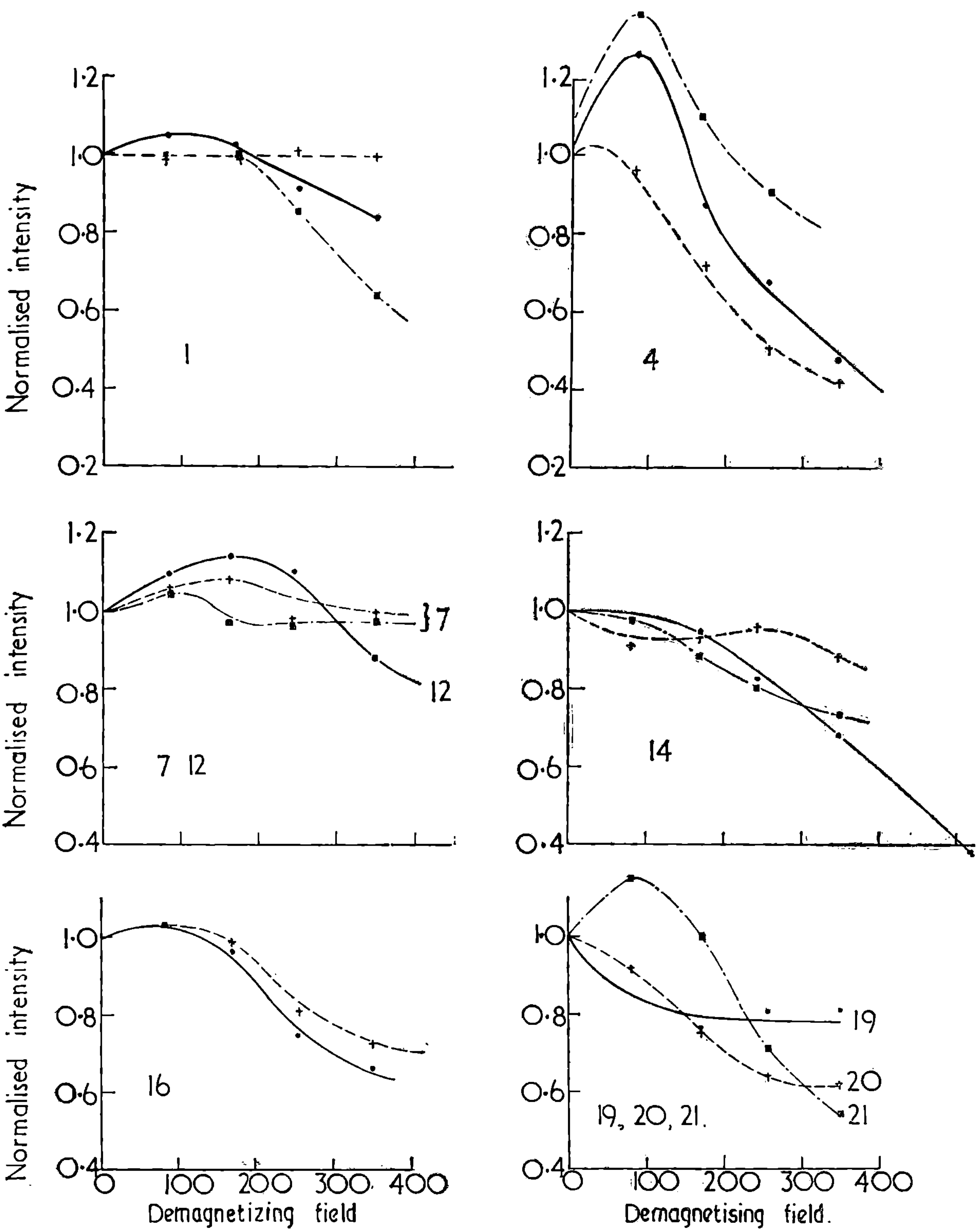

Fig. 15. Typowe krzywe odmagnesowywania próbek w polach zmiennych. Zmienność lokalna podana w kilku przykładach na różnych próbkach pobranych w tym samym odsłonięciu (np. stanowiska 1, 4, 14). Numery punktów pobrania próbek — jak w tab. 5

Fig. 15. Typical curves of demagnetization in alternating fields. Some measure of the variability per site is given by reproducing demagnetization curves from several samples at the same site (e. g. Sites 1, 4, 14). Site numbers correspond to Tab. 5

rocks the mineral is haematite. The metasomatic Lower Permian sediments of the North Sudetic Depression, hitherto regarded as melaphyres also possess the same low intensity and susceptibility as the Upper Carboniferous rocks.

CONCLUSIONS

a) Lithological

In contrast to the Permian melaphyres the Carboniferous igneous rocks were all considerably altered, to the extent that the remanent magnetization was due to secondarily produced haematite. In order to interpret the significance of the Carboniferous rocks, it is necessary to know when this alteration occurred. The current geological view (Grocholski, 1965) is that the alteration largely autometamorphism and consequently dates from near the time of formation, and that the process of formation of haematite may even have begun prior to complete consolidation (J. Kornaś, personal communication). It is also possible that subsequent subaerial weathering also played a part, for on the

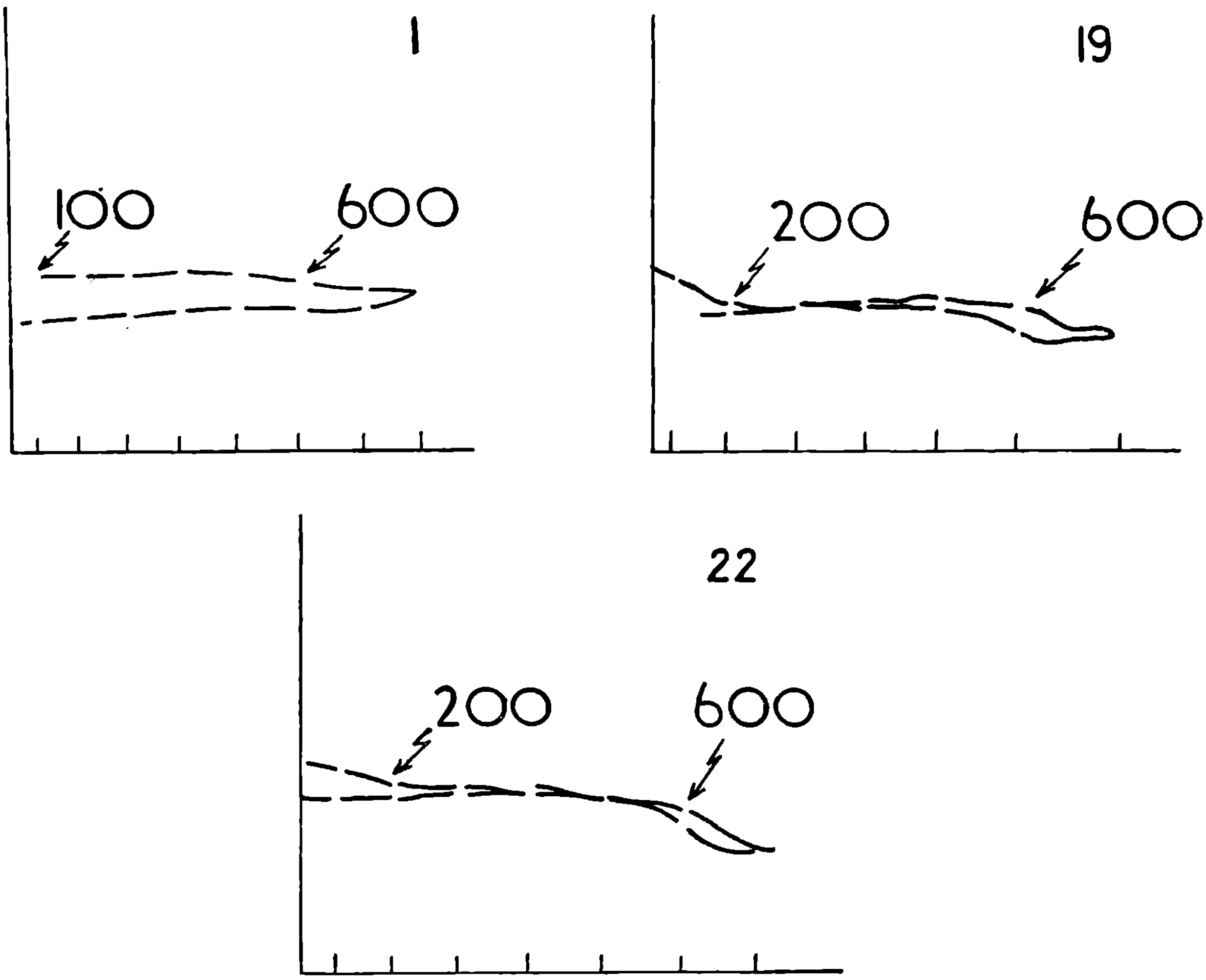

Fig. 16 a

Fig. 16 a, b. Typowe krzywe otrzymane z automatycznej wagi skręceń Chevalliera — odrysy z klisz fotograficznych. Numery punktów pobrania próbek — jak w tab. 5

Fig. 16 a, b. Typical Chevallier balance thermo-magnetic records, copied from photographic plates. Site numbers correspond to Tab. 5

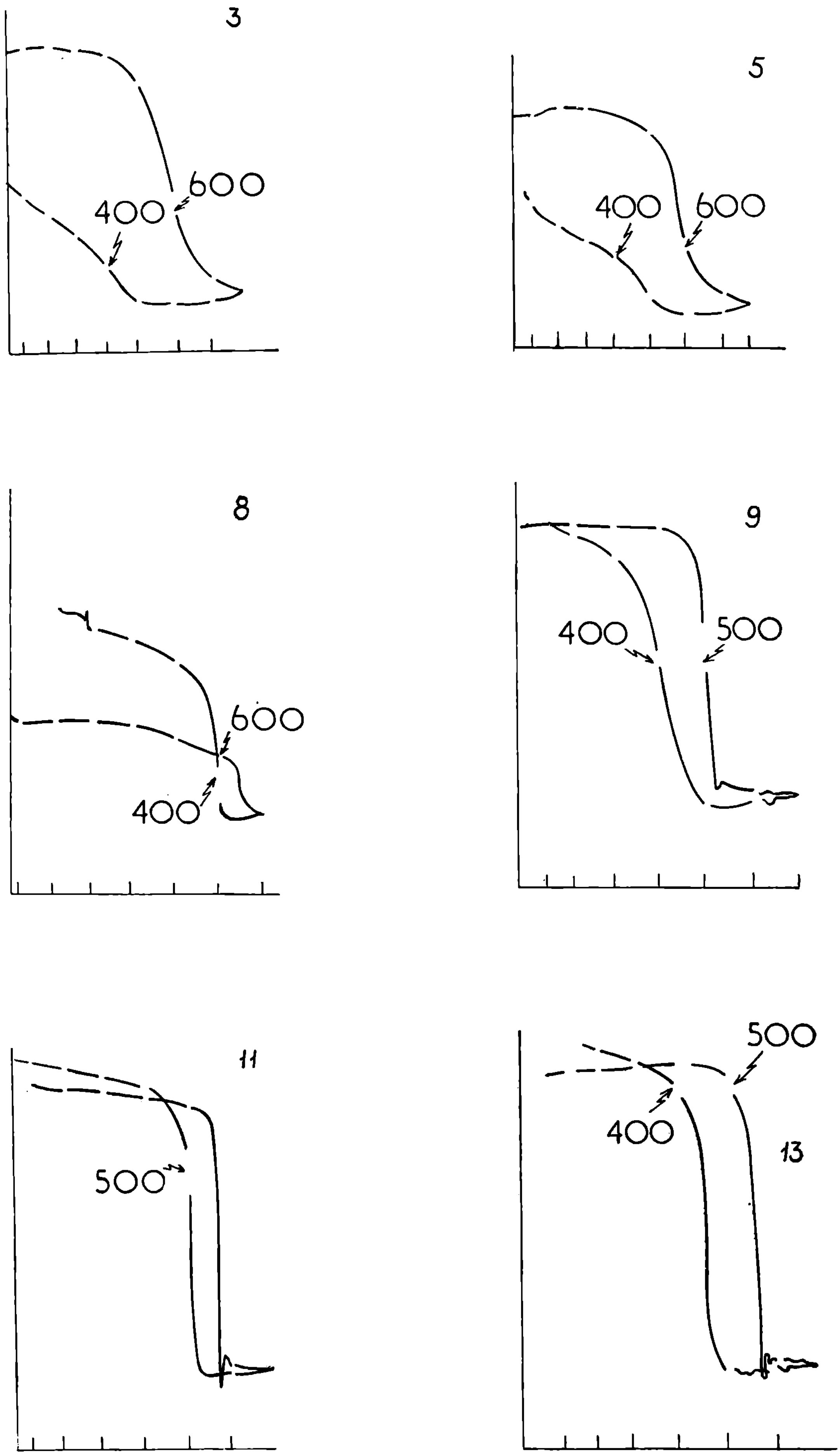

Fig. 16 b

Bohemian Platform kaolin deposits and weathered lavas are known. A Permian deep weathering seems unlikely in view of the relatively unaltered nature of the Permian lavas, and the unaltered intervening beds.

During the process of collecting, a number of sites in rocks described as melaphyres of Lower Permian age, by Kozłowski (1958, 1963) and Milewicz (1965), and occasionally associated with rocks described as spilites and dolerites were visited. In some cases these appear to represent metasomatized sediments (? buchites), for in them relict sedimentary structures were still recognizable. Details of these observations are to be found under the site descriptions, but as detailed work was not carried out on these rocks no general conclusions can be reached.

b) Palaeomagnetic

The results from the Lower Permian melaphyres agree reasonably well with the results previously reported from around Kraków (Birkenmajer, Nairn, 1964). The directions of magnetization of the Carboniferous rocks are similar, and are believed to represent the geomagnetic field of late Carboniferous times in the Sudetes. They show very good agreement with measurements made on sedimentary rocks in the Czech part of the Sudetes (Birkenmajer, Krs, Nairn, 1968) and suggest that the geomagnetic field as far back as Westphalian B-C did not differ essentially from that of the Permian.

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