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STUDIA PALEOMAGNETYCZNE SKAŁ POLSKICH
IV. KENOZOICZNE BAZALTY DOLNEGO ŚLĄSKA

(5 fig., 7 tab.)

Palaeomagnetic Studies of Polish Rocks
IV. Cenozoic Basalts of Lower Silesia

(*5 Figs., 7 Tabs.*)

STRESZCZENIE

Przeprowadzono badania magnetyzmu szczątkowego skał bazaltowych Dolnego Śląska, z których najstarsze są wieku oligoceńskiego, najmłodsze zaś prawdopodobnie plejstoceńskiego. Stwierdzono występowanie skał bazaltowych o namagnesowaniu szczątkowym zarówno normalnym, jak i odwróconym, które odpowiadają kilku epokom paleomagnetycznym ery kenozoicznej. Trudności w dokładnym określeniu wieku względnego i niemal zupełny brak datowań wieku bezwzględnego bazaltów dolnośląskich utrudnia ustalenie generalnej sukcesji zjawisk wulkanicznych i kierunków migracji wulkanizmu trzeciorzędowego w tym obszarze. Stosunkowo dokładnie datowane najstarsze (oligoceńskie) bazalty okolic Jawora można było porównać metodą paleomagnetyczną z bazaltami Łużyc (NRD), które wydają się nieco młodsze. Natomiast w okolicy Lądka Zdroju, gdzie bazalty uważane są za bardzo młode (plioceńskie lub plejstoceńskie), dane paleomagnetyczne sugerują, że wylewy lawy mogły tutaj być młodsze niż 0,69 miliona lat. Bliższe analizy sukcesji zjawisk wulkanicznych na podstawie danych geologicznych i paleomagnetycznych zostały przeprowadzone dla okolic Jawora, Lubania, Niemodlina i Lądka Zdroju.

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Abstract: The investigation of the Tertiary to Recent volcanic rocks of Lower Silesia, which range in age from Oligocene to possibly a Pleistocene age, indicates the presence of several zones of normal and reversely magnetized rocks. Unfortunately in the absence of detailed radiometric studies, the palaeomagnetic investigation can contribute little to the study of the sequence of reversals in the sign of magnetization. Suggested tentative correlation of the rocks of the Jawor

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area with those of eastern Germany is made. In the region of Lądek Zdrój it is also clear that the normal magnetization found in conjunction with the geological evidence suggests that the volcanics found there may be younger than 0.69 m.y.

Although the broad geophysical conclusions are disappointing, the palaeomagnetic data are interest in the tentative geological correlation on a local scale, of the volcanic episodes. The geological-palaeomagnetic implications of the inter-relationships of the volcanic rocks are discussed for the regions around Jawor, Lubań, Niemodlin, and Lądek Zdrój.

INTRODUCTION

The present paper is a final contribution to the palaeomagnetic studies of Polish rocks begun in 1961 (Birkenmajer, Nairn, 1964, 1965, 1968, 1969; Birkenmajer, Krs, Nairn, 1968; Birkenmajer, Grocholski, Milewicz, Nairn, 1968). The present report details the geological application of the palaeomagnetic study of the Cenozoic basaltic rocks of Lower Silesia. Oriented samples from sixty mine sites in the Lower Silesian basalts were collected for palaeomagnetic work between the summer of 1962 and spring of 1965. The sites were widely distributed (Fig. 2). The main palaeomagnetic results are reported separately in a preliminary form (Birkenmajer, Nairn, 1969). Here we will discuss the palaeomagnetic data against a wider geological background, where possible trying to establish the succession and relative age of volcanic activity.

Sincere thanks are due to Drs. J. Milewicz, J. Szałamacha and L. Wójcik of the Lower Silesian Branch of the Geological Survey of Poland, and in particular to its director Dr L. Sawicki for their generous aid in the field.

OUTLINE OF GEOLOGY

a. General Remarks

The Cenozoic basalts of Lower Silesia form the eastern extremity of the Central European volcanic province, i.e. Bohemo-Silesian belt. Igneous rocks belonging to this belt stretch from Doupovské Hory in the west through the region of Teplice, Ústí and Dečín in North Bohemia and the Lausitz area of Germany into Poland (Fig. 1). Further to the southwest, the trend is continued by another belt of alkali rocks, extending as far as the Rhine valley (Hegau and Keiserstuhl).

In Poland outcrops are most abundant in the vicinity of Lubań and Zgorzelec, between Lwówek Śląski and Jawor, and between Gryfów Śląski and Świeradów. More scattered outcrops are found around Strzegom, Niemcza, Strzelin and Lądek, with more isolated occurrences between Strzelin, Strzelce Opolskie and Głubczyce (Fig. 2). The total number of individual volcanic units, both basalts and basaltic tuffs, in Lower Silesia lies between 200 and 300, of which less than one fifth are lava flows (cf. Wojno, Pentlakowa, Szarras, 1951; Smulikowski, 1960; Birkenmajer, 1967; Śliwa, 1967). Most of the outcrops are to be found on 1 : 25,000 geological maps published by the German authors prior to World War II. Although short descriptions are found in the explanatory texts, detailed observations were seldom

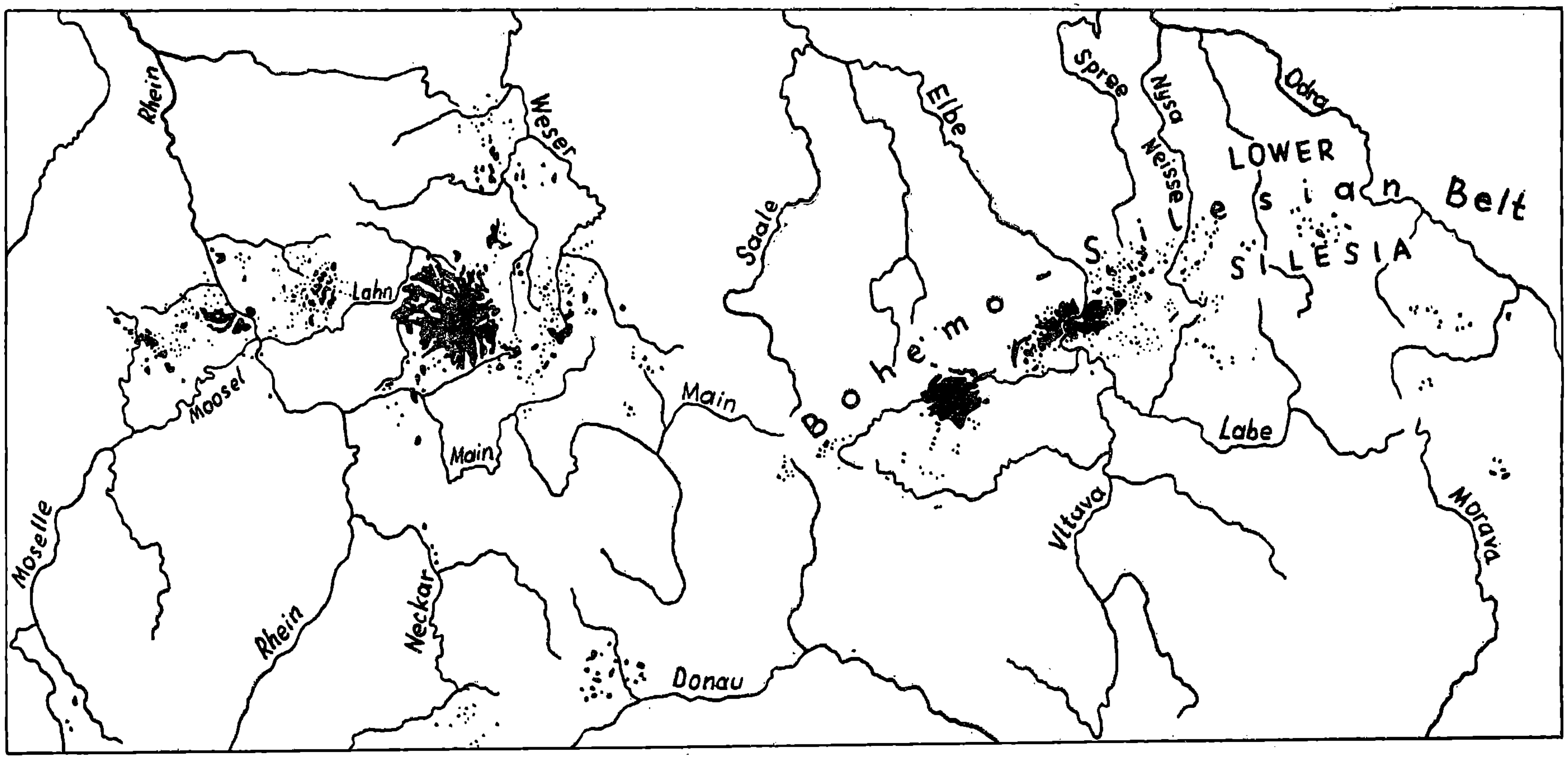

Fig. 1. Pozycja dolnośląskich skał bazaltowych na tle centralnoeuropejskiej prowincji wulkanicznej (według Kopecký'ego, 1966, uproszczone)

Fig. 1. Position of the Lower Silesian basaltic rocks within the Central European volcanic province (after Kopecký, 1966, simplified)

published (e.g. Möhl, 1875; Krusch, 1895; Berg, 1930; Berger, 1932; Ebert, 1937, 1939). Of more recent date is the synthesis of field and laboratory data of 135 exposures of basalts by T. Wojno, Z. Pentlakowa and S. Szarras (1951).

The geological forms of the Lower Silesian basalts have been discussed and illustrated recently in a number of papers (e.g. Jerzmański, 1956, 1961, 1965; Kozłowski, 1960; Kozłowski, Parachoniak, 1960; Birkenmajer, 1966, 1967; Śliwa, 1967).

b. Petrology

T. Wojno and Z. Pentlakowa (op. cit.) classified the Lower Silesian Cenozoic volcanics as plagioclase basalts (trachybasalts), plagioclase-nepheline basalts, nepheline basalts and pyroxene basalts (limburgites), with additional local varieties. K. Smulikowski (1960) divided these rocks into basalts, basanites, tephrites, nephelinites, limburgites, basanitoids and tephritoids, with additional local varieties (e.g. trachyphonolites). Other recent petrological investigations include those of J. Jerzmański (1956, 1961, 1965), H. Pendias and S. Maciejewski (1959), S. Kozłowski and W. Parachoniak (1960), L. Chodyniecka (1967) and J. Jerzmański and S. Maciejewski (1968).

The petrological classification adopted in the present paper follows chiefly that of K. Smulikowski (1960), the main reference being to the work by T. Wojno and Z. Pentlakowa (Wojno, Pentlakowa, Szarras, 1951).

The basaltic rocks under consideration show porphyritic textures. The phenocrysts are mainly olivine and augite, the second phase minerals being microlites of augite, feldspars, feldspathoids, iron oxides, apatite and glass. Phenocrysts of amphibole and, sometimes, of rhombic pyroxenes are less frequent. The latter may represent residua of xenoliths of foreign rocks dissolved by basalt magma.

Olivine phenocrysts are usually euhedral prisms with pyramidal endings; frequently they show traces of magmatic corrosion. They are often hydrothermally altered to form minerals of serpentine group (antigorite, bowlingite, iddingsite). Amphibole phenocrysts are prismatic, sometimes twinned. Zonal and hourglass augites most commonly show diopsidic cores. Amphibole phenocrysts belong to lamprobolites.

The second phase minerals are represented by light and dark minerals. The former are basic plagioclase (labrador), nepheline and silica-poor glass. Alkali feldspars and analcite are rare, while secondary minerals of zeolite group common. Dark minerals of the second phase are augite, iron oxide, apatite, sometimes also biotite.

The xenoliths found in basaltic rocks may sometimes reach up to several metres in diameter. They often show traces of alteration by magma, stronger in volcanic vents than in the lava sheets. Some xenoliths show the presence of secondary spinel and cordierite indicating according to I. Kardymowicz (1967) a comparatively high temperature of the lavas.

The silica content in mafic rock varieties represents about 37 per cent by weight, in rocks with feldspathoids 38—43%, and in basalts sensu stricto 43—49%. Most rocks contain from 10 to 13 per cent of Al_2O_3 and about 12% of iron oxides in which Fe^{+++} exceeds Fe^{++}. The mean content of MgO is about 10%, of CaO 13%, of Na_2O 3.5% and of K_2O 1%. The deviations from the mean are sometimes considerable (up to 2% for MgO).

The mean content of trace elements in basaltic lavas is 1.71% TiO_2 and 0.20% MnO by weight, and 280 Ni, 25 Co, 240 V, 330 Cr, 80 Cu in p.p.m.

The leucocratic rocks are richer in silica, alumina and alkalies, and poorer in divalent elements.

About 3/4 of the total number of the rocks analysed are deficient in silica according to Johannsen-Niggli-Smulikowski's scheme (see Jerzmański, Maciejewski, 1968, Fig. 2) based on all published analyses (cf. Pendias, Maciejewski, 1959; Pendias, 1961; Kozłowski, Parachoniak, 1960). About 50 per cent of the analysed rocks fall within the trachybasanite-trachytephrite field, and not within the basanite-tephrite field as would appear from microscopic examination. The rest of rocks are basanites (about 22%), trachybasanites (about 20%), basalts *sensu stricto* (about 5%), alkali trachytes (1%) and plagiphonolites (1%).

c. Age Relationships

In common with the rest of the Bohemo-Silesian subprovince, and with the rest of western Europe, the Tertiary to Recent igneous activity in Lower Silesia was closely related to young crustal movements. In western Poland these movements principally involved vertical block movements of the Sudetes mountains. Basaltic rocks occur on both the uplifted Sudetic horst and on the downthrown Sudetic foreland. As a result of prolonged erosion during the Tertiary and Quaternary times only relics of formerly more extensive volcanic material mostly in the form of plugs, vents and dykes, remain on the uplifted horst. Lava flows such as found near Złotoryja and Lądek Zdrój are comparatively rare. As might be anticipated, preservation is better in the downthrown area northeast of the Sudetic boundary fault, where in addition to lava flows, volcanic cones and calderas can be recognized.

In the absence of a detailed programme of radiometric dating, and the general paucity of stratigraphic data, it is at present very difficult, if possible at all, to reconstruct the succession of volcanic events for the whole Lower Silesian subprovince. There are nevertheless a number of control points which enable the time of the vulcanicity to be defined.

In the vicinity of Męcinka, west of Jawor, the trachyandesite flow overlies Upper Eocene sediments, and is covered by Upper Oligocene according to palaeobotanic work (Jerzmański, 1961, 1965). This is consistent with the He age determinations of W. D. Urry (1936) which gave values of 29 ± 2 and 34 ± 2 m.y. for the flow. South of Męcinka samples of the Basaltowa columnar basalt plug gave W. D. Urry 36 ± 2 m.y.

Nephelinite and basalt lava flows overlie the lignite-bearing Miocene sediments especially in the area of Lubań. Between the flows are red clays, the result of contemporary weathering of the flows (cf. Kozłowski, Parachoniak, 1960; Birkenmajer, 1967). As the red colouration of the sediments is characteristic rather of the Pliocene sediments (cf. Mazur, 1967), part of the nephelinite flows of the Lubań area could eventually be regarded as Pliocene. The Miocene sediments are cut by basalt and basanite sills found near Leśna and Gryfów Śląski. The youngest volcanic activity in this area is represented by volcanic vents filled with breccia with fragments of red clay (Gryfów Śląski) which cut the sills. If the red clays were the results of Pliocene weathering, the vents and sills would be of a higher Pliocene or even Pleistocene age.

Near Lądek Zdrój a basanite lava rests on the Pliocene fluvial gravel of the Biała Lądecka river (cf. W a l c z a k, 1957), suggesting a Pliocene or Pleistocene age for the lava (B e r g e r, 1932; S m u l i k o w s k i, 1960).

Near Szklary south of Strzelin, according to the recent investigation of J. W r o ń s k i (1968), a basalt lava sheet overlies Pliocene fresh-water clayey-sandy deposits. The tuff breccias which partly cut and partly overlie the basalt sheet are still younger. The breccias contain fragments of the underlying Pliocene clays and interfinger with Pleistocene sediments. An analysis of palaeogeomorphology of the area indicates the existence of very young crustal movements responsible for the volcanic activity which died out at least in Mid-Pleistocene times.

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The volcanic activity therefore began in Lower or Middle Oligocene times, at about 36 ± 2 m.y., reached a maximum during the Miocene, finally dying out either in late Pliocene or Middle Pleistocene. It is not possible to say at this stage whether the maximum of volcanic activity occurred at the same as the maximum in northern Bohemia (Lower Aquitanian to Burdigalian — K o p e c k ý, 1966) or whether it was somewhat later.

In the Bohemo-Silesian belt, volcanic activity gradually moved from the centre towards the margins of the volcanic area, the intensity, as well as petrographic diversity of the volcanic products gradually increasing in the initial and decreasing in later phases (K o p e c k ý, 1966). This is also generally valid for the Lower Silesian subprovince. Here the oldest (Lower or Middle Oligocene and younger) and most diversified volcanic products (trachyandesites, trachybasanites, basanites, basalts, nephelinites etc.) are centred in the area of Jawor and Złotoryja. In marginal areas to the west, between Gryfów Śląski, Lubań and Zgorzelec (nephelinites, basalts, basanites: Miocene and possibly Pliocene), and to the east, near Lądek (basanites: Pliocene or early Pleistocene), the volcanic products are younger and less diversified.

d. Volcanic Forms

The lava flows are generally in the form of flat lying basaltic sheets dissected by erosion and form gentle hills and plateaux. They occur especially between Lubań and Leśna, between Złotoryja, Legnickie Pole and Jawor, east of Niemcza, south of Niemodlin and near Lądek. The hill slopes are often softer sedimentary beds of the lignite-bearing formation in which pyroclastic layers are interbedded (between Lubań and Leśna). The lava sheets may exceed 100 m in thickness although the original scoriaceous surface of the sheets is seldom preserved. Columnar jointing is common, with individual columns often over a dozen metres in length, and with column thicknesses of 0.5 to 1.5 m, sometimes even to 3 m. Although less regular than those developed in plugs and vents, they can be observed to be vertical or nearly vertical, normal to the cooling surface.

More common than flows are the plugs and vents. In some cases they may be associated with lava flows, and can be recognized as different units within a single strato volcano. They may be round, elliptical or irregular in cross-section. Some are located along dislocations parallel or transverse to the Sudetic boundary fault between Jawor and Złotoryja. They are usually characterized by a system of well developed columnar jointing mostly vertical in the upper part but spreading fan-wise in the lower parts towards laterally distributed cooling surfaces. Feeder veins or dykes cutting the plugs have horizontally disposed joints. In the case of multiple events different columnar patterns may develop within a single vent or plug.

Volcanic cones as such are nowhere found, but it is possible to discern relicts of them, often with a fill of lava or of tuff breccias and agglomerates. In some stratified cones lava flows alternating with tuff and breccia horizons are found, e.g. near Gracze (Birkenmajer, 1966, 1967).

In addition dykes and sills showing no direct relationship to any of the volcanic forms described also occur. Where the sills intrude almost unconsolidated sediments as at Gryfów Śląski (Wieża) intense synintrusive tectonics are observed.

e. Description of Localities

Site 1: Męcinka E

Trachyandesite, upper part of the lava flow, north face of the quarry. Age: Middle or Lower Oligocene according to palaeobotanical dating of the underlying and overlying sediments (Jerzmański, 1956, 1961, 1965). Absolute age by He method: 34 ± 2 and 29 ± 2 m.y. (Urry, 1936).

Site 2: Męcinka W

Trachyandesite, lava flow, working quarry. The same lava flow as at Site 1. Age: as a Site 1 (op. cit.).

Site 3: Winnica

Trachyandesite plug with columnar jointing in the lower part and with well developed „Bankung" in the upper part of the exposure (old quarry), hill south of Site 1. Possibly feeder vein of the trachyandesite lava flows of Męcinka (Sites 1, 2), Chróślica (Site 34), Słup (Site 36) and Żarek (Site 37) — see Fig. 3, then probably Lower or Middle Oligocene in age. For geological descriptions see Jerzmański (1956, 1965) and Birkenmajer (1967).

Site 4: Rataj

Basalt plug (plagioclase basalt according to Wojno and Pentlakowa, 1951) with radial and concentric jointing, old quarry (Jerzmański, 1956, 1961, 1965; Birkenmajer, 1966, Fig. 4, 1967, Fig. 18). Country rocks represented by Cambro-Silurian of the Góry Kaczawskie mountains. Age: Tertiary (without closer determination).

Site 5: Grodziec

Nephelinite cone (nepheline basalt according to Wojno and Pentlakowa, 1951) of the castle hill (cf. Birkenmajer, 1967). Vertical columnar jointing visible near the top of the hill (where the samples were taken), scoriaceous nephelinite lava at the slopes of the hill. Substratum formed by Lower Triassic (Bunter) sediments. Age: Tertiary (without closer determination).

Site 6: Pielgrzymka

Big basalt plug (plagioclase basalt or trachybasalt according to Wojno and Pentlakowa, 1951), with columnar jointing (Birkenmajer, 1967, Fig. 22). Samples taken in the NW and SE parts of the working quarry. The plug is situated at a fault separating the Cenomanian and the Lower Triassic (Bunter) sandstones. Age: Tertiary (without closer determination).

Site 7: Wilcza Góra

Basanite plug (plagioclase-nepheline basalt or nepheline basanite according to Wojno and Pentlakowa, 1951), with two systems of columnar jointing (Birkenmajer, 1967, Fig. 19). Working quarry west of Złotoryja. Country rocks formed of the Turonian sediments of the North Sudetic depression. Age: Tertiary (without closer determination).

Site 8: Kozia Góra

Pyroxene basalt with glass according to Wojno and Pentlakowa (1951) — ankaratrite (?). Plug with two systems of columnar jointing (Birkenmajer, 1966, Fig. 3, 1967, Fig. 20). Working quarry southeast of Złotoryja. Country rocks represented by Turonian sediments of the North Sudetic depression. Age: Tertiary (without closer determination).

Site 9: Strzegom I

Basalt plug (plagioclase basalt or trachybasalt according to Wojno and Pentlakowa, 1951) with platy jointing. Hill with a cross named Krzyżowa Góra (Kreuzberg on German maps). Country rocks formed by Variscan granite. Age: Tertiary (without closer determination).

Site 10: Strzegom II

Basalt plug (plagioclase basalt or trachybasalt according to Wojno and Pentlakowa, 1951) with columnar, irregular or platy jointing. Hill west of Site 9 (Georgen Berg on German maps). Country rocks formed by Variscan granite. Age: Tertiary (without closer determination).

Site 11: Strzegom III

Basalt plug (plagioclase basalt or trachybasalt according to Wojno and Pentlakowa, 1951) with columnar and platy jointing (Birkenmajer, 1967, Fig. 14). Working quarry (Breite Berg on German maps), close to the Sites 9 and 10. Country rocks formed by Variscan granite. Age: Tertiary (without closer determination).

Site 12: Sichów

Basanite plug (plagioclase-nepheline basalt with glass according to Wojno and Pentlakowa, 1951) with well developed columnar jointing (Birkenmajer, 1967, Fig. 15), exposed in an old quarry. Intruded along the Sudetic boundary fault and along another, W-E fault crossing the Cambro-Silurian of the Góry Kaczawskie mountains (Jerzmański, 1956, Fig. 1, 1965, Fig. 2). Age: Tertiary (without closer determination).

Site 13: Bazaltowa

Trachybasanite (plagioclase basalt or trachybasalt according to Wojno and Pentlakowa, 1951) plug with well developed vertical columns exposed in a working quarry (Breitenberg on German maps). Country rocks formed by Cambro-Silurian of the Góry Kaczawskie mountains (Jerzmański, 1956, Fig. 1, 1965, Fig. 2). Absolute age determination by He method: 36 ±2 m.y. (Urry, 1936).

Site 14: Owcza Góra

Small basalt plug (plagioclase basalt or trachybasalt according to Wojno and Pentlakowa, 1951) with fine columnar jointing (Birkenmajer, 1967, Fig. 17), exposed in an old quarry on a small hill (Schäferberg on German maps). Country rocks represented by Cambro-Silurian of the Góry Kaczawskie mountains. Age: Tertiary (without closer determination).

Site 15: Czartowska Skała

Nephelinite plug (nepheline basalt and nepheline basalt with glass according to Wojno and Pentlakowa, 1951) with very well developed system of columns typical of plugs (Birkenmajer, 1966, Fig. 2, 1967, Fig. 16; Śliwa, 1967, Fig. 5A). Exposed in old quarries on a prominent hill (Spitzberg on German maps). Country rocks represented by Cambro-Silurian of the Góry Kaczawskie mountains. Age: Tertiary (without closer determination).

Site 16: Krzeniów I

Basalt (plagioclase basalt or trachybasalt according to Wojno and Pentlakowa, 1951), intruded in cross-bedded Lower Triassic (Bunter) sandstones. Shallow part of plug exposed in an old quarry on a hill (Geiers Berg on German maps), where both horizontally columnar basalt and tuff agglomerates are visible (Birkenmajer, 1967, Fig. 21 A—C). Age: Tertiary (without closer determination).

Site 17: Krzeniów II

Plagioclase basalt with glass (according to Wojno and Pentlakowa, 1951) — basanitoid (?), forming small plug with fine columnar jointing, surrounded by tuff agglomerate. Well exposed in an old quarry on a hill (Putz Berg on German maps) — see K. Birkenmajer (1967, Fig. 21 D—E). Country rocks represented by Lower Triassic (Bunter) sediments. Age: Tertiary (without closer determination).

Site 18: Krzeniów III

Nephelinite plug exposed in a big working quarry (Kahle Berg on German maps) with well developed columnar jointing arranged in a system typical of plugs. Plug crossed by a younger basaltic vein horizontally jointed, associated with tuff breccia containing xenoliths of Cretaceous sandstones (cf. Birkenmajer, 1967). Country rocks represented by Cretaceous sediments. Age: Tertiary (without closer determination).

Site 19: Leopoldówka

Small limburgite plug (pyroxene basalt or limburgite according to Wojno and Pentlakowa, 1951) exposed on a small hill below a chapel (Leopoldskapelle on German maps), south of Gryfów Śląski. The country rocks represented by gneisses of the Góry Izerskie mountains. Age: Tertiary (without closer determination).

Site 20: Lubań I

Nephelinite lava flow (plagioclase-nepheline basalt or nepheline basanite according to Wojno and Pentlakowa, 1951) exposed in an old quarry at Lubań—Kamienna Góra, with well developed vertical columns (Birkenmajer, 1967, Fig. 3). Substratum formed by fresh-water Miocene sediments. Age: Miocene (or younger).

Site 21: Lubań II

Nephelinite lava flow with thick vertical columns exposed in a working quarry at Bukowiec (Bukowa Góra) hill near Lubań (cf. Kozłowski, Parachoniak, 1960; Birkenmajer, 1967). Substratum known from boreholes is represented by red clays and weathered basalt conglomerates overlying Miocene sands and gravels (Kozłowski, Parachoniak, 1960). Age: Pliocene (?) — see Sites 23, 24.

Site 22: Lubań III

Nephelinite plug with columnar jointing arranged in a system characteristic of plugs. Exposure on a small hill in woods south of Site 21 („Pagórek Liściasty" of Kozłowski and Parachoniak, 1960). Country rocks represented by fresh-water Miocene sediments. Age: Miocene (or younger).

Site 23: Zaręba Górna I

Nephelinite lava flow (upper flow) exposed in a big quarry (Kozłowski, Parachoniak, 1960; Birkenmajer, 1967). Substratum formed by Miocene sands and gravels, locally also by tuffs, volcanic breccias and red clays, the latter overlying the lower flow (Site 24). As red colouration of the Tertiary sediments in the area of Lubań and Zgorzelec seems characteristic for Pliocene clays (cf. Mazur, 1967), this age is probable.

Site 24: Zaręba Górna II

Nephelinite lava flow (lower flow). Locality and geological relations as above. Age: Pliocene (?).

Site 25: Wieża

Basanite complex sill intrusion (Birkenmajer, 1967, Fig. 40) exposed in a working quarry south of Gryfów Śląski. Sills separated by almost unconsolidated fresh-water Pliocene (?) sediments (clays, clays with coal seams, gravels) intensely disturbed by intrusions. Sill complex crossed by volcanic vents filled with basanite blocks cemented by tuff and lava, with red clay xenoliths. Age: as red clays could correspond to Pliocene (see Sites 23, 24) a Pliocene age of the sills and vents is highly probable.

Site 26: Lądek Zdrój

Basanite lava flow (plagioclase-nepheline basalt or nepheline basanite according to Wojno and Pentlakowa, 1951) exposed in a working quarry (Grauer Stein on German maps). Substratum formed by Pliocene terrace gravels of the Biała Lądecka river, containing blocks of basanite (Berger, 1932; Walczak, 1957). Age: Pliocene or early Pleistocene.

Site 27: Lutynia I

Pyroxene basalt with glass (Wojno and Pentlakowa, 1951) exposed in a working quarry at Szwedzkie Szańce (Festung on German maps). Geological form: plug in mica schists (Śliwa, 1967, Fig. 5 B). Age: Pliocene or early Pleistocene (?).

Site 28: Lutynia II

Basanite (plagioclase-nepheline basalt or nepheline basanite according to Wojno and Pentlakowa, 1951), exposed in an old quarry in

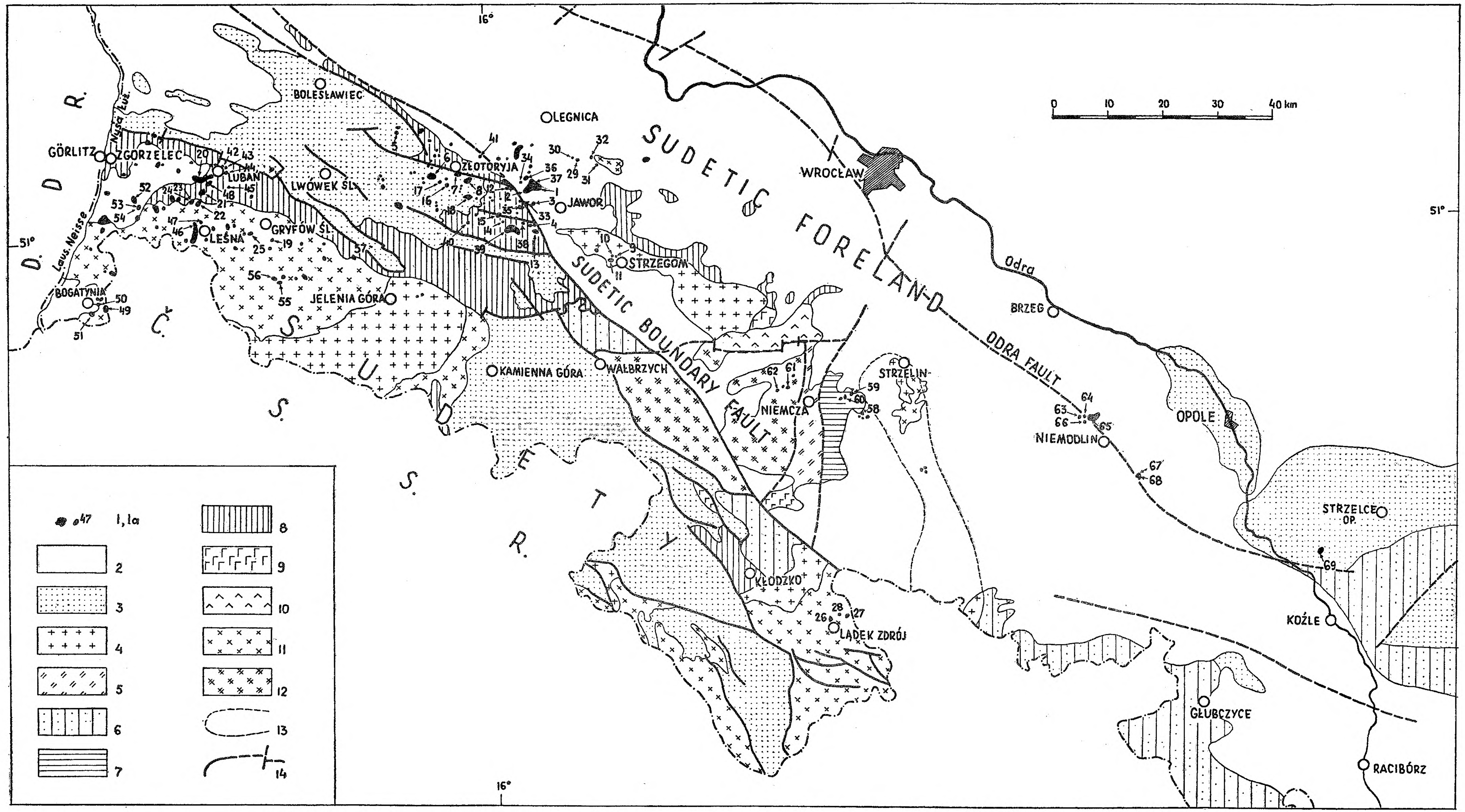

Fig. 2. Lokalizacja punktów pobrania prób do badań paleomagnetycznych ze skał bazaltowych Dolnego Śląska, na tle budowy geologicznej regionu. 1 — skały bazaltowe (trzeciorzęd, częściowo czwartorzęd); 1a — miejsca pobrania prób do badań paleomagnetycznych, liczby odnoszą się do tabeli 1; 2 — osady neogenu; 3 — młodszy paleozoik i mezozoik (depresja śródsudecka, depresja północnosudecka, trias górnośląski, kreda opolska); 4 — granitoidy waryscyjskie; 5 — strefa Niemczy (utwory karbońskie i przedkarbońskie); 6 — dewon — karbon dolny (depresja Świebodzic, struktura bardzka, dewon i kulm wschodniosudecki); 7 — serie okrywy granitu strzelińskiego (przypuszczalnie dewon); 8 — kambrosylur (starszy paleozoik sudecki i przedsudecki); 9 — gabro (starszy paleozoik — prekambr); 10 — serpentynity (starszy paleozoik — prekambr); 11 — gnejsy łupki łyszczykowe, granity i granodioryty (starszy paleozoik — prekambr); 12 — gnejsy Sowich Gór (archaik); 13 — przypuszczalny zasięg występowania granitu; 14 — dyslokacje

Fig. 2. Localization of sampling sites in basaltic rocks of Lower Silesia. 1 — Basaltic rocks (Tertiary, partly Quaternary); 1a — Rocks sampled for palaeomagnetic investigation, numbers refer to sites as listed in Table 1; 2 — Neogene deposits; 3 — Younger Palaeozoic and Mesozoic (Inner Sudetic Depression, North Sudetic Depression, Upper Silesian Triassic and Opole Cretaceous); 4 — Variscan granitoids; 5 — Niemcza Zone (Carboniferous and older rocks); 6 — Devonian — Lower Carboniferous (Świebodzice Depression, Bardo Structure, Devonian and Culm of East Sudetic Zone); 7 — Metamorphic mantle of the Strzelin Granite (possibly Devonian); 8 — Cambro-Silurian (Sudetic and Fore-Sudetic older Palaeozoic); 9 — Gabbro (Older Palaeozoic — Pre-Cambrian); 10 — Serpentinites (Older Palaeozoic — Pre-Cambrian); 11 — Gneisses and mica schists, granite and granodiorite (Older Palaeozoic — Pre-Cambrian); 12 — Gneisses of the Sowie Góry mountains (Archaean); 13 — Probable extent of granitic intrusions; 14 — Major dislocations

woods (Überscharberg on German maps). Geological form unknown. Age: Pliocene or early Pleistocene (?).

Site 29: Lubień I

Plagioclase basalt or trachybasalt (according to Wojno and Pentlakowa, 1951) lava flow, possibly equivalent to trachyandesite lava flows of the vicinity of Jawor (Sites 1, 2, 34, 36, 37). Exposure in an old quarry shows thick vertical columns. Substratum: Tertiary (?). Age: Tertiary (Lower or Middle Oligocene as at Męcinka ?).

Site 29a: Lubień II

Plagioclase basalt (trachybasalt), prolongation of lava sheet from Site 29. Exposure in a small working quarry. Substratum: Tertiary (?). Age: Tertiary (Lower or Middle Oligocene as at Męcinka ?).

Site 30: Pawłowice

Plagioclase basalt with glass (Wojno, Pentlakowa, 1951) — basanitoid (?), with well developed vertical columns strongly weathered in the upper part (cf. Birkenmajer, 1967, Fig. 23). Exposure in an old quarry. Country rocks: Tertiary (?). Age: Tertiary (without closer determination).

Site 31: Mikołajowice I

Basalt plug (plagioclase basalt or trachybasalt according to Wojno and Pentlakowa, 1951) with well developed system of columnar jointing, exposed in a working quarry (Steinberg on German maps). Columns strongly weathered in the upper part (Birkenmajer, 1966, Pl. II a, b). Country rocks represented by Pre-Cambrian paragneisses. Age: Tertiary (without closer determination).

Site 32: Mikołajowice II

Nephelinite lava flow (nepheline basalt according to Wojno and Pentlakowa, 1951) with irregular columnar jointing, exposed in small old quarries on a hill (Rothe Berg on German maps), northwest of Mikołajowice. The lava is covered by red weathering clays considered to be Miocene (Tietze, 1912), but their Pliocene age cannot be excluded (see Sites 23, 24). Age: Miocene (?).

Site 33: Męcinka S

Small basalt (plagioclase basalt) plug (Jerzmański, 1956, Fig. 3) exposed in an old quarry. Country rocks represented by Cambro-Silurian of the Góry Kaczawskie mountains. Age: Tertiary (without closer determination).

Site 34: Chróślica N

Trachyandesite lava flow exposed in an old quarry. Prolongation of lava sheet from Męcinka E and W, Słup and Żarek (Sites 1, 2, 36, 37), hence Lower or Middle Oligocene in age (Jerzmański, 1956, 1961, 1965).

Site 35: Górzec

Basalt plug (plagioclase basalt or trachybasalt according to Wojno and Pentlakowa, 1951) with columnar and platy jointing. Exposure in an old quarry on a hill (Hessberg on German maps). Country rocks represented by schists and quartzites (Cambro-Silurian) of the Góry Kaczawskie mountains. Age: Tertiary (without closer determination).

Site 36: Słup

Trachyandesite lava flow, prolongation of lava sheet from Sites 1, 2, 34, 37. Exposure in an old quarry east of the church shows curvilinear columns traversed by platy jointing. Age: Lower or Middle Oligocene, as at Męcinka (cf. Jerzmański, 1956, 1961, 1965).

Site 37: Żarek

Trachyandesite lava flow, prolongation of lava sheet from Sites 1, 2, 34, 36 (cf. Jerzmański, 1956, 1961, 1965). Exposure in an old quarry shows irregular inclined columns of the flow pierced by a vent filled with tuff agglomerate and vesicular basalt (Birkenmajer, 1967, Fig. 11). Age: Lower or Middle Oligocene (as at Męcinka).

Site 38: Myślinów

Basalt plug situated along the same W—E trending fault as the one at Rataj (Site 4). Exposure on a hill (Geisterberg on German maps) south of the road. Country rocks represented by Cambro-Silurian of the Góry Kaczawskie mountains. Age: Tertiary (without closer determination).

Site 39: Muchów

Trachybasanite plug (plagioclase basalt or trachybasalt according to Wojno and Pentlakowa, 1951) exposed in an old quarry on the southwest slope of a hill (cf. Jerzmański, 1956, Fig. 1: Mszana-Obłoga). Well developed columns arranged in a system typical of plugs. Country rocks represented by Cambro-Silurian of the Góry Kaczawskie mountains. Age: Tertiary (without closer determination).

Site 40: Rzeszówek

Nephelinite plug (nepheline basalt according to Wojno and Pentlakowa, 1951) exposed in an old quarry on a hill (Heerenberg on German maps), east of Świerzawa. Two systems of columnar jointing similar to those of Kozia Góra (Site 8). Country rocks represented by Cambro-Silurian of the Góry Kaczawskie mountains. Age: Tertiary (without closer determination).

Site 41: Kozów

Nephelinite lava flow (nepheline basalt with glass according to Wojno and Pentlakowa, 1951). Exposure in a working quarry NE of Złotoryja (left bank of the Kaczawa river) shows thick vertical columns (Birkenmajer, 1967, Fig. 9). Substratum formed by Tertiary deposits. Age: Tertiary (without closer determination).

Site 42: Uniegoszcz I

Nephelinite lava flow (nepheline basalt with glass according to Wojno and Pentlakowa, 1951) exposed in an old quarry near the road from Lwówek to Lubań (Birkenmajer, 1967, Fig. 26). Substratum probably formed by Miocene sediments. Age: Miocene.

Site 43: Uniegoszcz II

Nephelinite plug (nepheline basalt according to Wojno and Pentlakowa, 1951) with well developed columnar jointing arranged in a system typical of plugs, piercing the nephelinite lava of Site 42, surrounded by tuffs and pyroclastic conglomerates (Birkenmajer, 1967, Fig. 26). Age: Miocene (or younger).

Site 44: Uniegoszcz III

Nephelinite plug (nepheline basalt with glass according to Wojno and Pentlakowa, 1951). Big artificial exposure south of the working quarry (Ostróżek hill), south of Sites 42 and 43, shows the presence of two generations of columnar nephelinite (Birkenmajer, 1967, Fig. 27). Samples taken from the first generation nephelinite. Country rocks represented by Miocene sediments. Age: Miocene (or younger).

Site 45: Jałowiec

Nephelinite plug (nepheline basalt according to Wojno and Pen-(Birkenmajer, 1967, Fig. 28). Exposure in a working quarry south of Site 44. Country rocks represented by Cambro-Silurian gneisses and schists of the Góry Kaczawskie mountains: Age: Tertiary (without closer determination).

Site 46: Leśna I

Basalt lava flow with columnar jointing exposed in a working quarry at the top of a hill west of Leśna. Substratum formed by Miocene clays containing intercalations of pyroclastic material (Birkenmajer, 1967, Fig. 8), intruded with basalt sills (plagioclase basalt or trachybasalt according to Wojno and Pentlakowa, 1951). Age: Miocene (or younger).

Site 47: Leśna II

Basalt plug (plagioclase basalt or trachybasalt according to Wojno and Pentlakowa, 1951), exposed on a hill (342 m a.s.l. — „Stożek Perkuna" of Kozłowski, 1960), east of Site 46, showing two generations of well developed fine columnar jointing (Birkenmajer, 1967, Fig. 29). Samples taken from the first generation basalt in the old western quarry. Country rocks represented by Miocene sediments. Age: Miocene (or younger).

Site 48: Księginki

Nephelinite lava flow with curvilinear columnar jointing (Birkenmajer, 1967, Fig. 4) exposed in a big working quarry south of Lubań. Samples taken from the upper exploitation level (upper lava flow). Substratum of the lava flow formed by pyroclastic conglomerates overlying two more nephelinite lava sheets, also separated with pyroclastic conglomerates, sometimes also with red clays, and resting upon Miocene fresh-water sediments, as known from boreholes (Kozłowski, Parachoniak, 1960). Age: Pliocene (?).

Site 49: Markocice

Trachyandesite (according to Smulikowski, 1960) with irregular columnar jointing (possibly lava flow) exposed in a big working quarry close to the Polish-Czechoslovakian frontier, east of Bogatynia. Country rocks represented by metamorphic complex (Pre-Cambrian) of the Karkonosze — Góry Izerskie block. Age: Tertiary (without closer determination).

Site 50: Bogatynia

Hornblende basanite (according to Smulikowski, 1960) exposed in a small old quarry on a hill (315 m a.s.l.) east of Bogatynia (east of the hill with basalt exposures). Possibly lava flow. Country rocks represented by metamorphic complex (Pre-Cambrian) of the Karkonosze — Góry Izerskie block. Age: Tertiary (without closer determination).

Site 51: Opolno Zdrój

Trachyphonolite (according to Smulikowski, 1960) plug exposed in an old quarry on a hill (289 m a.s.l.) east of the health resort. Arrangement of columnar jointing typical of plugs (Birkenmajer, 1967, Fig. 31). Country rocks represented by metamorphic complex (Pre-Cambrian) of the Karkonosze — Góry Izerskie block. Age: Tertiary (without closer determination).

Site 52: Sulików

Exposures of basaltic rocks visible in a big western working quarry and in an old eastern quarry near the main road from Lubań to Sulików. Wojno and Pentlakowa (1951) distinguished here three main types of rocks characteristic for different parts of the quarries: nepheline basalt with or without glass, nepheline basalt, and plagioclase basalt with glass. The nephelinite with irregular curvilinear columnar jointing exposed in the working quarry (west of the hill top) represents a lava flow. In the eastern part of this quarry, and in the western part of the old quarry, the platy jointed nephelinite belongs to the outer zone of the plug (feeder vein of the nephelinite lava flow), while basanitoid rocks (in the easternmost part of the old quarry) are supposed to form the inner part of the same plug (cf. Birkenmajer, 1967). Our samples refer to the platy jointed nephelinite plug of the old quarry. The substratum of the flow and country rocks of the plug are represented on the west by Miocene sediments, on the NW and N by Eo-Cambrian greywackes, and on the NE, E and S by Eo-Cambrian granodiorites. Age: Miocene (or younger).

Site 53: Mała Wieś Górna I

Small nephelinite plug (nepheline basalt with glass according to Wojno and Pentlakowa, 1951) exposed in an old quarry near the main road, with well developed fine columnar jointing (Birkenmajer, 1966, Fig. 5, 1967, Fig. 20). Country rocks represented by Miocene sediments. Age: Miocene (or younger).

Site 54: Mała Wieś Górna II

Plagioclase basalt with glass (according to Wojno and Pentlakowa, 1951 — basanitoid ?). Exposure in an old quarry on the right slope of the Czerwona Woda river valley shows columnar jointing arranged in a system typical of plugs. Younger volcanic phase represented by tuff conglomerates with volcanic bombs (Birkenmajer, 1967). Country rocks represented by Miocene sediments. Age: Miocene (or younger).

Site 55: Proszowa I

Nephelinite plug (nepheline basalt according to Wojno and Pentlakowa, 1951) with platy and columnar jointing, exposed in a big quarry (Kahle Berg on German maps). Country rocks represented by metamorphic complex (Lower Palaeozoic — Pre-Cambrian) of the Góry Izerskie mountains. Age: Tertiary (without closer determination).

Site 56: Proszowa II

Nephelinite plug (nepheline basalt of Wojno and Pentlakowa, 1951: Rębiszów) with columnar or platy jointing, exposed in an old quarry near the road from Gierczyn to Rębiszów. Country rocks represented by metamorphic complex (Pre-Cambrian) of the Góry Izerskie mountains. Age: Tertiary (without closer determination).

Site 57: Pilchowice

Nephelinite plug with well developed columnar jointing typical of plugs. Exposure in a big working quarry (Schlossberg on German maps) where besides nephelinite (nepheline basalt and nepheline basalt with glass of Wojno and Pentlakowa, 1951) there occurs also limburgite (op. cit.). Samples taken from the nephelinite plug. Plug situated on the boundary of metamorphic complex (Pre-Cambrian) of the Góry

Izerskie mountains and the Cambro-Silurian of the Góry Kaczawskie mountains. Age: Tertiary (without closer determination).

Site 58: Targowica

Plagioclase basalt or trachybasalt (according to Wojno and Pentlakowa, 1951) lava flow exposed in a working quarry. Sampled in the reddened east face, not far above the contact with tuff. Substratum formed probably by Tertiary sediments. Age: Tertiary (without closer determination).

Site 59: Kowalskie-Żelowice I

Nephelinite (nepheline basalt of Wojno and Pentlakowa, 1951) lava flow with vertical columns, exposed in the eastern quarry at Kowalskie-Żelowice. Sampled close to the bottom of the flow. Substratum represented by metamorphic mantle (probably Devonian) of the Variscan Strzelin granite. Age: Tertiary (without closer determination).

Site 60: Kowalskie-Żelowice II

Nephelinite plug (nepheline basalt of Wojno and Pentlakowa, 1951) with columnar jointing, exposed in the western quarry at Kowalskie-Żelowice. Substratum formed by metamorphic mantle (probably Devonian) of the Variscan Strzegom granite. Age: Tertiary (without closer determination).

Site 61: Gilów I

Basalt (plagioclase basalt of Wojno and Pentlakowa, 1951), platy jointed, exposed in a quarry (Butterberg on German maps). Sampled above the red-baked floor of the quarry. Geological form unknown: lava flow (?). Substratum represented by Archaean gneisses of the Sowie Góry mountains. Age: Tertiary (without closer determination).

Site 62: Gilów II

Basalt (plagioclase basalt of Wojno and Pentlakowa, 1951) vent fill or shallow part of cone (Birkenmajer, 1967, Figs. 32, 33) with regular columnar jointing in the inner zone and irregular (platy or columnar) jointing in the outer zone. Tuff breccias with gneiss fragments exposed in the working quarry (Stachelberg on German maps) at the contact with the Archaean gneisses of the Sowie Góry mountains. Age: Tertiary (without closer determination).

Site 63: Radoszowice

Nephelinite plug (nepheline basalt according to Wojno and Pentlakowa, 1951) with columnar or platy jointing arranged in a system typical of plugs (Birkenmajer, 1966, Figs. 9, 11, 1967, Figs. 35, 38). Exposure in an old quarry southeast of Radoszowice shows besides nephelinite also the presence of weathered tuffs with fragments of altered Cretaceous marls. Country rocks represented by argillaceous sediments marked as Miocene on geological maps (Cretaceous according to Doc. Dr. S. W. Alexandrowicz — pers. comm.). Age: Tertiary (without closer determination).

Site 64: Gracze I

Basanite plug (plagioclase-nepheline basalt with glass of Wojno and Pentlakowa, 1951) with platy and columnar jointing arranged in a system typical of plugs (Birkenmajer, 1966, Figs. 9, 11, 1967, Figs. 35, 38). Exposure in an old quarry (called „Ameryka") south of Gracze (east of Site 63) shows besides basanite also the presence of black shales and clays marked as Miocene on geological maps (Cretaceous according to Doc. Dr. S. W. Alexandrowicz — pers. comm.). Age: Tertiary (without closer determination).

Site 65: Gracze II

Basanite (plagioclase-nepheline basalt with glass according to Wojno and Pentlakowa, 1951), vent fill of the crater, with well developed columnar jointing. The stratified cone surrounding the basanite is built of lava flows, massive and columnar in the lower part and scoriaceous in the upper part, alternating with tuff breccias containing fragments of baked Cretaceous marls. Other tuff breccias with abundant xenoliths of baked Cretaceous marls fill the small vents of the last volcanic phase at the boundary of strato cone and the plug (Birkenmajer, 1966, Figs. 9—11, 1967, Figs. 35, 37, 38). Exposure in a big working quarry. Substratum formed by Cretaceous (and Miocene ?) sediments. Age: Tertiary (without closer determination).

Site 66: Rutki

Basalt plug (plagioclase basalt according to Wojno and Pentlakowa, 1951) exposed in an old quarry south of Site 64. Sampled along the north face from the platy jointed basalt of the feeder vein (plug) and from the columnar basalt of the lava flow connected with the plug (Birkenmajer, 1967, Figs. 35, 36), just above the contact with baked Cretaceous marls. Country rocks represented by dark shales and clays marked as Miocene on geological maps (Cretaceous according to Doc. Dr. S. W. Alexandrowicz — pers. comm.). Age: Tertiary (without closer determination).

Site 67: Ligota Tułowicka I

Basanite lava flow (plagioclase-nepheline basalt of Wojno and Pentlakowa, 1951) with irregular columnar jointing, exposed in an old quarry (Birkenmajer, 1967, Fig. 12). According to geological maps the substratum is formed by Miocene sediments. Age: Tertiary (without closer determination).

Site 68: Ligota Tułowicka II

Nephelinite lava flow (nepheline basalt with glass according to Wojno and Pentlakowa, 1951), with vertical curvilinear columnar jointing. Exposed in a working quarry west of Site 67. According to geological maps the substratum is formed by Miocene sediments. Age: Tertiary (without closer determination).

Site 69: Góra Św. Anny

Nephelinite (nepheline basalt of Wojno and Pentlakowa, 1951; nephelinite of Chodyniecka, 1967), vent fill of crater or caldera (Birkenmajer, 1967, Fig. 39), with columnar jointing. Samples taken from a big old quarry south of the monastery, close to the contact with Triassic sediments. To the north of the town the nephelinite contacts also with Cenomanian sands. Age: Tertiary (without closer determination).

SITE MEAN DIRECTIONS OF MAGNETIZATION OF THE LOWER SILESIAN BASALTS

Table 1

Site No.	Litho-logy	Volca-nic form	Age	Magnetiza-tion		Sam-pling a b	Con-fi-dence ∝	C.S.D. C.S.E. K	Vec-tor R	Demag. field	Log Mean Intensity & Sr.bev. x 10^{-4} cm		Log Mean Suscept. x 10^{-4} cm	
				D	I						NRM	demag.	x	S.D.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. Męcinka E	trachy-ande-site	lava flow	Lower or Middle Oligocene 34 ± 2 and 29 ± 2 m.y. /He dating/	154.7	-56.6	4-4	8.1	129.1	3.977	170	1.77 0.74	1.04 0.47	1.42	0.84
2. Męcinka W	trachy-ande-site	lava flow	Lower or Middle Oligocene	171.2	-53.9	4-5	4.3	465.4	3.994	255	1.41 0.97	1.24 0.77	1.38	0.65
3. Winnica	trachy-ande-site	plug	Lower or Middle Oligocene ?	177.2	-53.4	6-6	3.3	402.1	5.988	85	1.07 0.77	1.11 0.66	1.49	0.59
4. Rataj	basalt	plug	Tertiary	334.5	+70.3	6-6	11.1	37.4	5.867	85	1.74 1.36	1.57 1.25	1.29	0.96
5. Grodziec	nephe-linite	cone	Tertiary	12.3	+30.5	4-5	5.5	279.0	3.989	170	1.12 0.46	0.90 0.36	1.47	0.88
6. Pielgrzymka	basalt	plug	Tertiary	177.2	-77.8	6-6	10.0	45.5	5.890	85	1.87 1.41	1.61 1.33	1.05	0.77
7. Wilcza Góra	basanite	plug	Tertiary	131.7	-85.9	6-6	7.1	89.0	5.944	85	1.19 0.77	1.07 0.36	1.44	1.14
8. Kozia Góra	pyroxene basalt with glass /ankara-trite ?/	plug	Tertiary	351.9	-26.7	5-5	6.8	129.1	4.969	85	1.30 0.67	1.18 0.73	1.32	0.70
9. Strzegom I	basalt	plug	Tertiary	285.8	-83.8	6-6	4.3	247.0	5.980	255				
10. Strzegom II	basalt	plug	Tertiary	285.8	-85.6	6-6	5.2	169.7	5.971	170				
11. Strzegom III	basalt	plug	Tertiary	142.1	-84.1	6-6	8.2	68.2	5.927	255				
12. Sichów	basanite	plug	Tertiary	248.5	+75.8	6-6	6.2	116.3	5.957	85				
13. Bazaltowa	trachy-basa-nite	plug	36 ± 2 m.y. /He dating/	159.7	-63.7	6-6	7.1	90.0	5.945	170				

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
14. Owcza Góra	basalt	plug	Tertiary	187.6	-59.8	6-6	4.5	224.8	5.978	85				
15. Czartowska Skała	nephelinite	plug	Tertiary	17.6	+73.7	6-6	4.2	261.6	5.981	85				
16. Krzeniów I	basalt	plug	Tertiary	12.3	+71.4	5-6	5.3	208.2	4.981	85				
17. Krzeniów II	plagioclase basalt with glass /basanitoid ?/	plug	Tertiary	132.7	-51.8	6-6	32.3	5.3	5.050	340				
18. Krzeniów III	nephelinite	plug	Tertiary	no conf.		-	-	-	-	-	-	-	-	-
19. Leopoldówka	limburgite	plug	Tertiary	14.4	+72.2	6-6	7.3	85.7	5.942	85				
20. Lubań I	nephelinite	lava flow	Miocene or younger	195.8	+20.1	4-6	25.7	13.8	3.783	85				
21. Lubań II	nephelinite	lava flow	Pliocene ?	no conf.		-	-	-	-	-	-	-	-	-
22. Lubań III	nephelinite	plug	Miocene or younger	102.5	+53.1	6-6	12.2	31.1	5.839	340				
23. Zaręba Górna I	nephelinite	lava flow /upper flow/	Pliocene ?	176.4	-51.3	6-6	9.9	46.8	5.893	85				
24. Zaręba Górna II	nephelinite	lower lava flow	Pliocene ?	159.8	-46.3	6-6	17.7	15.3	5.673	85				
25. Wieża	basanite	complex sill intrusion	Pliocene or younger ?	348.3	+65.7	6-8	5.1	177.0	5.972	0				
26. Lądek Zdrój	basanite	lava flow	Pliocene or early Pleistocene	3.6	+66.6	7-7	4.3	5.8 2.2	6.969	85	1.52 0.15	1.37 0.08	1.19	0.13
27. Lutynia I	pyroxene basalt with glass	plug	Pliocene or early Pleistocene ?	352.8	+65.3	6-7	4.0	4.9 2.0	5.982	0	1.83 0.34	1.83 0.34	1.36	0.09

1	2	3	4	5	6	7	8	9		10	11	12		13		14	15
28. Lutynia II	basanite	?	Pliocene or early Pleistocene ?	356.1	+65.4	7-7	4.2	5.7	2.2	6.970	85	1.59	0.15	1.41	0.19	1.70	0.38
29, 29a. Lubień I Lubień II	plagioclase basalt /trachybasalt/	lava flow	Lower or Middle Oligocene ?	25.9	+60.5	8-8	3.1	4.6	1.6	7.978	170	1.50	0.05	1.39	0.08	1.45	0.47
30. Pawłowice	plagioclase basalt with glass /basanitoid ?/	plug	Tertiary	333.3	+71.9	6-6	16.7	19.7	8.1	5.706	85	1.22	0.11	0.99	0.15	1.54	0.29
31. Mikołajowice I	basalt	plug	Tertiary	322.4	+81.0	5-6	6.1	6.4	2.9	4.975	85	1.33	0.18	1.10	0.16	1.76	0.46
32. Mikołajowice II	nephelinite	lava flow	Miocene ?	202.0	-47.0	7-7	11.7	15.4	5.8	6.783	85	1.09	0.12	0.84	0.14	1.67	0.23
33. Męcinka S	basalt	plug	Tertiary	358.1	+13.9	6-6	14.4	17.1	7.0	5.778	0	1.25	0.13	1.25	0.13	1.48	0.22
34. Chróślica N	trachyandesite	lava flow	Lower or Middle Oligocene	no result		0-5	-	-	-	-	-	1.04	0.12	-	-	1.52	0.25
35. Górzec	basalt	plug	Tertiary	106.0	-43.4	6-6	no conf.	61.2	25.0	3.370	170	1.95	0.50	1.10	0.16	1.89	0.34
36. Słup	trachyandesite	lava flow	Lower or Middle Oligocene	129.1	-86.6	6-6	9.6	11.5	4.7	5.899	85	0.79	0.15	0.76	0.16	1.72	0.39
37. Żarek	trachyandesite	lava flow	Lower or Middle Oligocene	161.7	-50.9	6-6	9.1	10.9	4.4	5.910	170	1.34	0.13	1.02	0.10	1.56	0.12
38. Myślinów	basalt	plug	Tertiary	179.1	-64.2	5-6	12.2	12.8	5.7	4.901	170	1.89	0.40	1.46	0.30	1.86	0.45
39. Muchów	trachybasanite	plug	Tertiary	189.6	-54.4	6-7	3.2	3.9	1.6	5.989	85	1.39	0.11	1.23	0.05	1.42	0.02
40. Rzeszówek	nephelinite	plug	Tertiary	146.5	-46.7	5-6	no conf.	40.9	18.3	4.014	85	1.18	0.16	1.27	0.08	1.73	0.03
41. Kozów	nephelinite	lava flow	Tertiary	346.1	+75.8	6-6	6.3	7.6	3.1	5.957	170	1.42	0.27	0.83	0.12	1.83	0.02

1	2	3	4	5	6	7	8	9		10	11	12		13		14	15
42. Uniegoszcz I	nephelinite	lava flow	Miocene	164.4	+26.6	6-6	no conf.	44.9	18.3	4.527	170	1.33	0.42	0.64	0.08	1.70	0.05
43. Uniegoszcz II	nephelinite	plug	Miocene	169.3	-15.4	5-6	no conf.	34.7	15.5	4.283	170	1.32	0.22	0.89	0.22	1.66	0.12
44. Uniegoszcz III (Ostróżek)	nephelinite	plug	Miocene	176.3	-74.1	6-6	9.1	10.9	4.4	5.910	85	1.43	0.15	1.42	0.13	1.96	0.14
45. Jałowiec	nephelinite	plug	Miocene	170.0	-73.1	6-6	10.0	12.0	4.9	5.891	85	1.24	0.21	1.33	0.05	2.11	0.01
46. Leśna I	basalt	lava flow	Miocene or younger	161.4	-56.5	6-6	4.2	5.1	2.1	5.980	85	1.60	0.10	1.45	0.13	1.63	0.51
47. Leśna II	basalt	plug	Miocene or younger	352.4	-52.5	5-6	9.4	9.9	4.4	4.940	255	1.65	0.11	1.21	0.11	1.40	0.22
48. Księginki	nephelinite	lava flow	Pliocene ?	no result		0-7	-	-	-	-	-	0.77	0.16	-	-	1.87	0.08
49. Markocice	trachyandesite	lava flow ?	Tertiary	78.1	+48.9	5-6	no conf.	40.5	18.1	4.034	85	1.09	0.21	0.67	0.10	1.92	0.04
50. Bogatynia	hornblende basanite	lava flow ?	Tertiary	18.3	+63.1	5-6	17.3	17.9	8.0	4.805	85	1.60	0.12	1.12	0.06	1.96	0.04
51. Opolno Zdrój	trachyphonolite	plug	Tertiary	315.0	+37.6	8-8	no conf.	47.3	16.7	5.732	85	0.34	0.13	0.25	0.03	1.82	0.03
52. Sulików	nephelinite	plug	Miocene or younger	167.8	-69.2	7-7	3.0	4.0	1.5	6.985	85	1.27	0.07	1.35	0.07	2.09	0.03
53. Mała Wieś Górna I	nephelinite	plug	Miocene or younger	208.3	-56.2	6-6	2.6	3.2	1.3	5.992	85	1.61	0.06	1.60	0.03	1.66	0.12
54. Mała Wieś Górna II	plagioclase basalt with glass /basanitoid ?/	plug	Miocene or younger	6.5	+72.0	6-6	9.4	11.2	4.6	5.904	85	1.41	0.12	1.35	0.10	1.71	0.37
55. Proszowa I	nephelinite	plug	Tertiary	236.6	-76.4	6-6	9.6	11.6	4.7	5.899	85	1.37	0.09	0.98	0.19	2.11	0.01

1	2	3	4	5	6	7	8	9		10	11	12		13		14	15
56. Proszowa II	nephelinite	plug	Tertiary	222.3	-63.7	5-6	14.6	15.2	6.8	4.859	85	1.26	0.12	1.11	0.11	2.08	0.02
57. Pilchowice	nephelinite	plug	Tertiary	306.6	+71.1	3-7	12.6	8.2	4.7	2.979	255	1.14	0.07	0.94	0.06	1.72	0.56
58. Targowica	plagioclase basalt /trachybasalt/	lava flow	Tertiary	196.1	-60.4	6-6	8.2	9.8	4.0	5.927	255	1.62	0.24	1.44	0.31	1.33	0.10
59. Kowalskie-Żelowice I	nephelinite	lava flow	Tertiary	215.8	-44.5	6-6	8.6	10.4	4.2	5.912	85	1.35	0.32	1.30	0.22	1.43	0.30
60. Kowalskie-Żelowice II	nephelinite	plug	Tertiary	218.3	-53.6	6-6	7.0	8.5	3.5	5.946	0	1.10	0.05	1.10	0.05	1.29	0.12
61. Gilów I	basalt	lava flow ?	Tertiary	150.4	-67.9	4-6	17.6	15.3	7.6	3.894	255	2.18	0.49	0.83	0.14	1.45	0.37
62. Gilów II	basalt	vent or lower part of cone	Tertiary	184.7	-72.0	6-6	11.0	13.1	5.4	5.869	0	1.24	0.17	1.24	0.17	1.51	0.42
63. Radoszowice	nephelinite	plug	Tertiary	45.9	+49.2	6-6	no conf.	25.8	10.5	5.580	85	0.47	0.14	0.42	0.13	1.62	0.48
64. Gracze I	basanite	plug	Tertiary	47.9	+53.0	3-6	11.1	7.3	4.2	2.984	170	0.92	0.08	0.40	0.12	1.76	0.33
65. Gracze II	basanite	vent fill of crater	Tertiary	31.6	+54.7	6-6	4.9	6.0	2.4	5.973	85	1.34	0.21	1.22	0.22	1.79	0.04
66. Rutki	basalt	plug	Tertiary	25.8	+49.2	6-6	6.3	7.6	3.1	5.956	85	1.10	0.07	0.71	0.13	1.71	0.05
67. Ligota Tułowicka I	basanite	lava flow	Tertiary	179.3	-44.7	5-6	7.3	17.7	3.5	4.964	85	1.24	0.30	1.26	0.28	1.93	0.04
68. Ligota Tułowicka II	nephelinite	lava flow	Tertiary	173.6	-44.0	6-6	6.3	7.6	3.1	5.957	0	1.22	0.14	1.22	0.14	1.69	0.20
69 Góra Św. Anny	nephelinite	vent fill of crater or caldera	Tertiary	213.2	-54.1	6-6	5.3	6.6	2.7	5.967	0	1.50	0.14	1.50	0.14	1.02	0.17

APPLICATION OF PALAEOMAGNETIC DATA TO GEOLOGICAL INTERPRETATION

In the succeeding sections an attempt will be made to discuss the geological implications of the results of the palaeomagnetic measurements carried out on the volcanic rocks. As the details of the geophysical aspect of the study have appeared elsewhere (Birkenmajer, Nairn, 1969), these will not be repeated here. It is only necessary to remark that the directions of magnetization recorded in the various tables are the mean directions obtained from collections of six or more samples per site after magnetic cleaning had ensured the removal of secondary components of magnetization. The directions are believed to represent the directions of the geomagnetic field pertaining at the time of emplacement at the site of volcanic emplacement. The confidence values given represent an estimate of the reliability of the mean value.

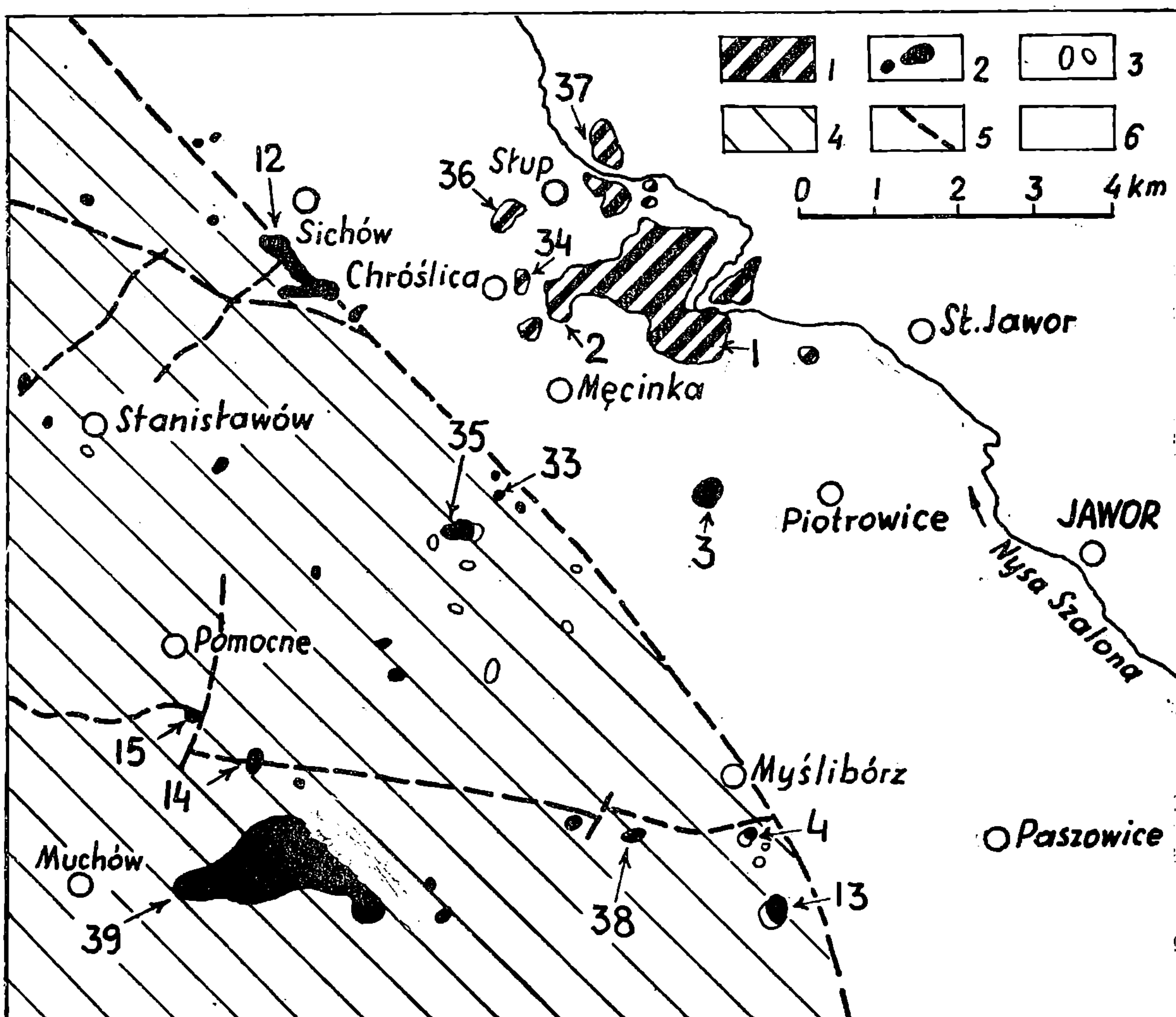

Fig. 3. Lokalizacja punktów pobrania prób do badań paleomagnetycznych w skałach bazaltowych okolic Jawora. Liczby odnoszą się do tabeli 1. 1 — pokrywy lawowe; 2 — czopy wulkaniczne; 3 — tufy i konglomeraty tufowe; 4 — kambrosylur Gór Kaczawskich; 5 — uskoki; 6 — pokrywa czwartorzędowa

Fig. 3. Basaltic sampling sites in the area of Lubań, numbers refer to sites as listed in Tab. 1. 1 — Lava flows; 2 — Plugs; 3 — Tuffs and tuff conglomerates; 4 — Cambro-Silurian of the Góry Kaczawskie mountains; 5 — Faults; 6 — Quaternary cover

1. Area of Jawor

In the area of Jawor the Tertiary volcanics occur on two tectonic units separated by the Sudetic boundary fault (Fig. 3). To the northeast of the fault, on the downthrown block, there occur trachyandesite lava flows (Sites 1, 2, 34, 36, 37) being parts of one large sheet of a Lower or Middle Oligocene age, as proved by palynological investigations of the underlying and overlying sediments (Jerzmański, 1956, 1961, 1965). The absolute age determination by He method gave to W. D. Urry (1936) 34 ± 2 and 29 ± 2 m.y. (Site 1). All the sites (Nos. 1, 2, 36, 37) are reversely magnetized (Tabs. 1, 2) consistent with the similarity in geological age.

Table 2

Site mean directions of magnetization for selected sites in the area of Jawor

Site No.	Magnetization		Lithology	Volcanic form	Age by geological dating	Age by He dating
	D	I				
1	154.7	—56.6	trachy-andesite	lava flow	Lower or Middle Oligocene	34±2 m.y. 29±2 m.y.
2	171.2	—53.2	„	„	„	—
34	—	—	„	„	„	—
36	129.1	—86.6	„	„	„	—
37	161.7	—50.9	„	„	„	—
3	177.2	—53.4	„	plug	—	—
13	159.7	—63.7	trachy-basanite	„	—	36±2 m.y.
39	189.6	—54.4	„	„	—	—
14	187.6	—59.8	basalt	„	—	—
4	334.5	+70.3	„	„	—	—
12	248.5	+75.8	basanite	„	—	—
33	358.1	+13.9	basalt	,	—	—
15	17.6	+73.7	nephelinite	„	—	—

The trachyandesite plug (Site 3) on the downthrown block which has the same sign of magnetization as the lava flow may be a feeder vein of the neighbouring lava sheet.

Two trachybasanite plugs (Sites 13, 39) were sampled on the uplifted block of the Góry Kaczawskie mountains, the former one dated by He method (U r r y, op. cit.) to be 36 ± 2 m.y. As both the petrologic character of the plugs (Site 3: trachyandesite, Sites 13, 39: trachybasanite) and the palaeomagnetic data are similar, we can consider them as roughly coeval with the trachyandesite lava. This is confirmed by He dating of one of the plugs.

Using a tentative scheme of palaeomagnetic zoning of the Oligocene times as presented by A. E. M. N a i r n and H. V o l l s t ä d t (1967, Tab. 2) we can place the trachyandesite-trachybasanite volcanic phase of the Jawor area in the following scheme (Tab. 3):

T a b l e 3

Tentative palaeomagnetic zones of Oligocene (after N a i r n and V o l l s t ä d t, 1967) and the position of trachyandesite-trachybasanite phase of volcanic activity, area of Jawor

Oligocene	Stampian	Chattian	U	N	
				....	
			M	R	
			L	———	Lausitz volcanics (Germany)
		Rupelian		N	
	Sannoisian			R	Trachyandesite-trachybasanite phase, Jawor area, 29 to 36 ± 2 m.y.

Of the rest of plugs of the Jawor area selected in Tab. 2, one (Site 14) is a reversely magnetized basalt, with values of declination and inclination very similar to the trachyandesite-trachybasanite phase, three others are normally magnetized basalts (Sites 4, 14, 33) and basanite (Site 12), and one — normally magnetized nephelinite (Site 15). It is possible, but by no means certain, that they correspond to the Chattian Lausitz volcanics of Germany (N a i r n, V o l l s t ä d t, op. cit.), but Miocene ages cannot be ruled out. These plugs are located either along the Sudetic boundary fault (Site 12) or along W-E faults crossing the uplifted block of the Góry Kaczawskie mountains (Sites 4, 14, 15, 33, partly also Site 12). As these W-E faults were already used by trachybasanite plugs (Site 13: 36 ± 2 m.y., and Site 39), the supposed succession of magmatic phases: trachyandesite and trachybasanite → basanite → basalt → nephelinite, seems probable.

2. A r e a o f L u b a ń

In the area of Lubań an important locality is that at Uniegoszcz I, II (Sites 42, 43) where a normally magnetized nephelinite flow (Site 42) is crossed by a reversely magnetized nephelinite plug (Site 43). As the substratum of the lava flow is formed by Miocene sediments, a Miocene age of the nephelinites is very probable. The N/R change in magnetization could therefore correspond either to N_5/R_4 (Helvetian) or to N_4/R_3 (Tortonian-Pontian) palaeomagnetic zones (cf. N a i r n, 1966, Tab. 10) —

see Tab. 4. As the palaeomagnetic reversal sequence in the middle and lower parts of the Miocene has not been studied in detail the suggestions made here are very tentative.

South of Site 43 (nephelinite plug) two more nephelinite plugs (Sites 44 and 45) situated along the same NNW-SSE line (possibly a fault) are also reversely magnetized and show the same values of declination and inclination as the plug of Site 43 (Tab. 5). This may indicate their similar age.

The nephelinite lava flows south of Lubań are either normally magnetized (Site 20) or reversely magnetized (Sites 23 and 24). The nephelinite lavas of Sites 23 and 24 (exposures in the same quarry) are separated by red clays, weathering products of the lower nephelinite flow (cf. Kozłowski, Parachoniak, 1960; Birkenmajer, 1967). It should be noted that the red colouration of the sediments in the area of Zgorzelec and Lubań is characteristic for the Pliocene and not the Miocene clays (cf. Mazur, 1967). If we accepted the Pliocene age for the red clays separating the successive nephelinite lavas, then this nephelinite phase (Sites 23, 24) could correspond to R_2 (Gilbert epoch: boundary of Plaisancian and Astian) palaeomagnetic zone (see Tab. 4).

The relation of the remaining basaltic rocks south of Lubań (Fig. 4) to the ones discussed above is unknown. The nephelinite plug of Site 22 (Tab. 5) is normally magnetized, hence it could not serve as a feeder vein for the neighbouring nephelinite lavas of Sites 23 and 24 which

Table 4

Tentative scheme of Neogene and Quaternary palaeomagnetic zones
(after Nairn, 1966, Tab. 10, simplified)

Quaternary	Holocene		N_1 Brunhes epoch 0.69±0.05 m.y.
	Pleistocene 2.5 m.y.		R_1 Matuyama epoch 2.5±0.2 m.y.
Pliocene	Astian		N_2 Gauss epoch 3.4±0.1 m.y.
	Plaisancian 13 m.y.		R_2 Gilbert epoch
			N_3
Miocene	Pontian		R_3
	Vindobonian	Tortonian	N_4 Štiavnica-Kremnica epoch
		Helvetian	R_4
	Burdigalian 25 or 26 m.y.		N_5
			R_5
			N_6

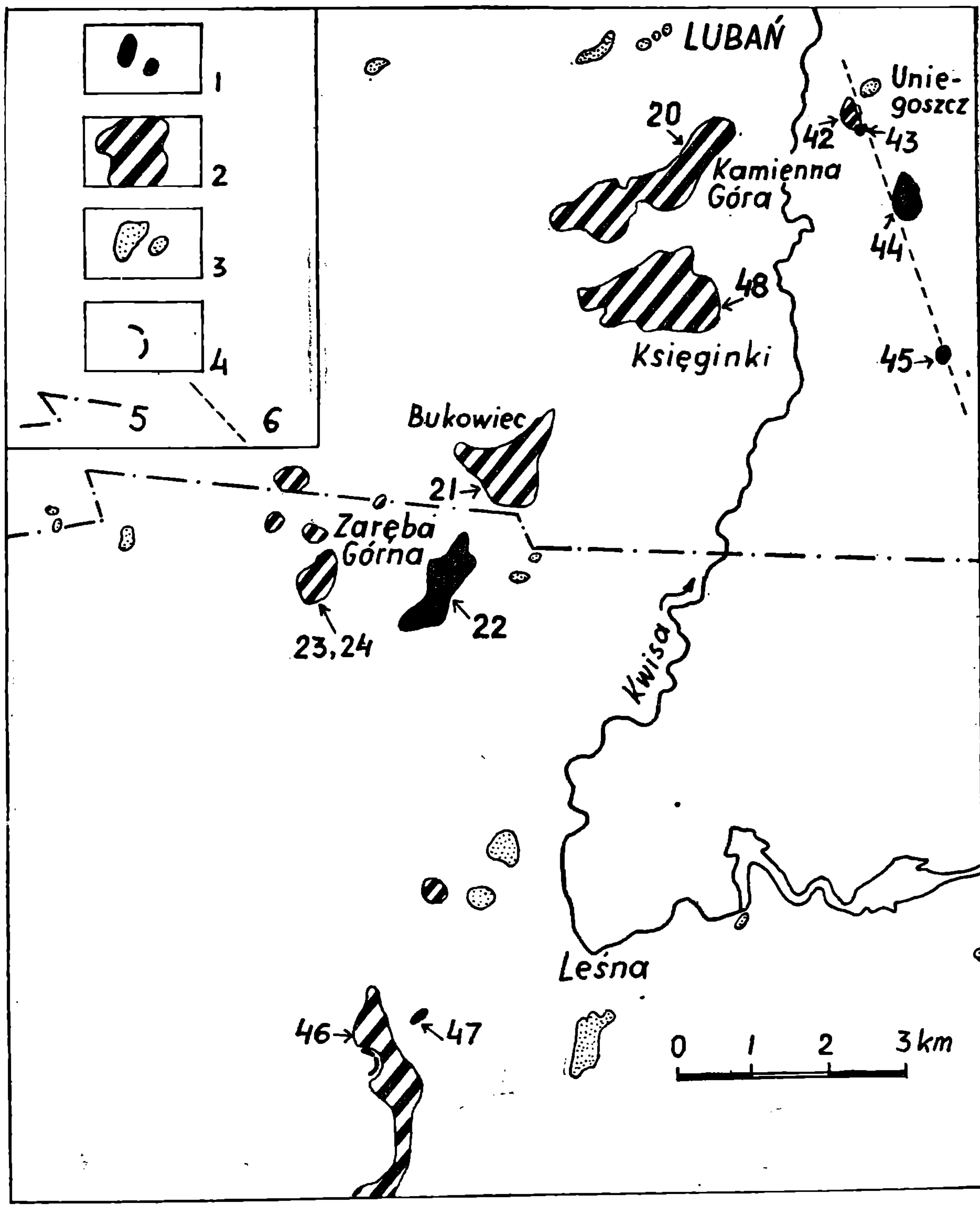

Fig. 4. Lokalizacja punktów pobrania prób do badań paleomagnetycznych w skałach bazaltowych okolic Lubania. Liczby odnoszą się do tabeli 1. 1 — czopy wulkaniczne; 2 — pokrywy lawowe; 3 — skały bazaltowe o nieustalonej formie geologicznej; 4 — sille; 5 — granica między strefą gnejsów Gór Izerskich i kambrosylurem Gór Kaczawskich; 6 — przypuszczalny uskok na linii występowania czopów nefelinitu

Fig. 4. Basaltic sampling sites in the area of Lubań, numbers refer to sites as listed in Tab. 1. 1 — Plugs; 2 — Lava flows; 3 — Basaltic rocks, geological form unknown; 4 — Sills; 5 — Boundary between the gneisses of the Góry Izerskie mountains and the Cabro-Silurian of the Kaczawskie Góry mountains; 6 — Supposed fault along the line of occurrence of nephelinite plugs

are reversely magnetized. The nephelinite lava flow of Kamienna Góra (Site 20) is normally magnetized, as is the one at Uniegoszcz (Site 42) and could be part of the same lava sheet. Table 5 shows the palaeomagnetic aspect of the three nephelinite phases of the Lubań area (Miocene and Pliocene ?) as generally similar.

As well as nephelinites, basalts also occur in the area south of Lubań (Fig. 4: Leśna). The basalt plug of Site 47 is normally magnetized, while the neighbouring basalt lava flow (Site 46) is reversely magnetized. This indicates that these basalts belong to different volcanic phases. In the case the basalt plug would be connected with basalt sills intruded below the basalt lava sheet (at Site 46), and younger than the flow, the R/N succession of basalts would be probable. It remains uncertain whether this R/N change would correspond to N_6/R_5 zones of Lower Miocene (cf. Tab. 4) or is still younger.

Table 5

Site mean directions of magnetization and supposed succession of nephelinites of the Lubań area

Site No.	Magnetization		Lithology	Volcanic		Supposed age
	D	I		form	phase	
23	176.4	—51.3	nephelinite	upper lava flow	III	Pliocene ? (R)
24	159.8	—46.3	„	lower lava flow		
45	170.0	—73.1	„	plug	II	Miocene? (R)
44	176.3	—74.1	„	plug		
43	169.3	—15.4	„	plug		
42	164.4	+26.6	„	lava flow	I	Miocene? (N)
20	195.8	+20.1	„	lava flow		

3. Area of Niemodlin

In the vicinity of Gracze (Fig. 5) the succession of volcanic events (Birkenmajer, 1967) shows that the nephelinite lava of the Gracze volcano is older than the basanite fill of the crater. Unfortunately, we have no palaeomagnetic data from the nephelinite lava. All the plugs of this area show normal magnetization despite the fact that they consist either of nephelinite (Site 63), of basanite (Sites 64, 65) or of basalt (Site 66). The similarity of palaeomagnetic results is consistent with the suggestion based on geological grounds that they belonged to the same palaeomagnetic zone.

The volcanoes of Gracze (Sites 63—66) are situated along a NW-SE trending Odra fault. Farther to the southeast two more localities of

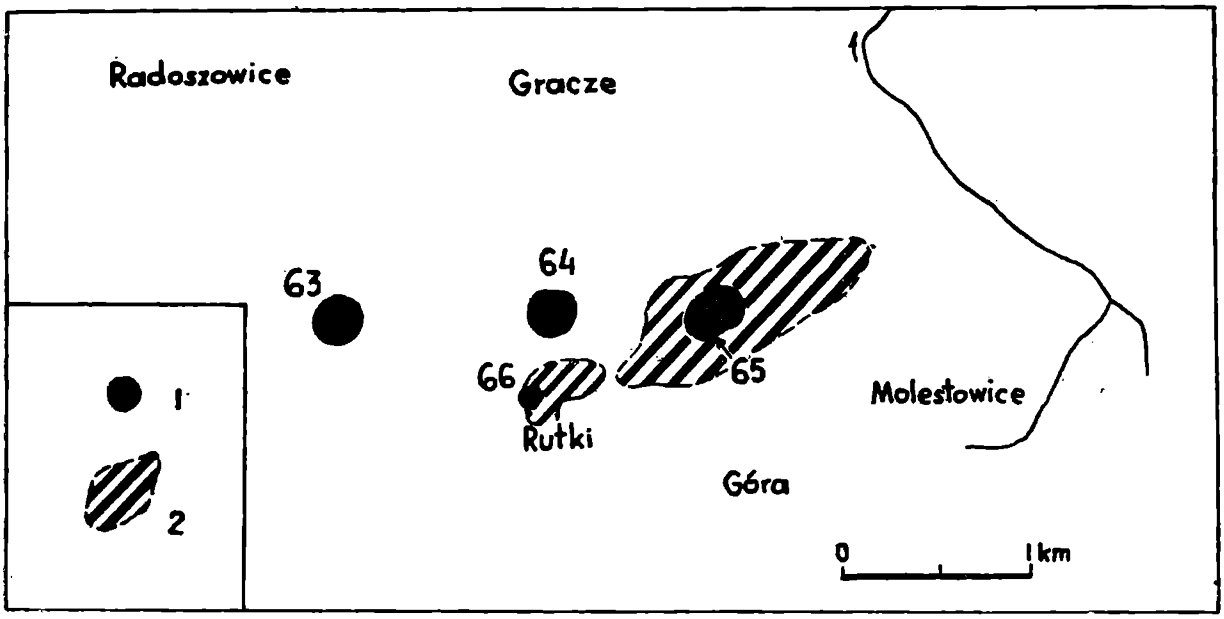

Fig. 5. Lokalizacja punktów pobrania prób do badań paleomagnetycznych w skałach bazaltowych okolic Graczy. Liczby odnoszą się do tabeli 1. 1 — czopy wulkaniczne; 2 — pokrywy lawowe

Fig. 5. Basaltic sampling sites in the area of Gracze, numbers refer to sites as listed in Tab. 1. 1 — Plugs; 2 — Lava flows

Table 6

Site mean directions of magnetization for the sites near Niemodlin

Site No.	Magnetization		Lithology	Volcanic form	
	D	I			
66	25.8	+49.2	basalt	plug	Gracze volcanoes
65	31.6	+54.7	basanite	vent fill of crater	
64	47.9	+53.0	basanite	plug	
63	45.9	+49.2	nephelinite	plug	
67	179.3	−44.7	basanite	lava flow	Ligota Tułowicka lavas
68	173.6	−44.0	nephelinite	lava flow	

basanite and nephelinite lavas (Sites 67, 68: Ligota Tułowicka) also coincide with this fault. The lavas are here reversely magnetized, therefore belonging to a different palaeomagnetic zone than that of the Gracze volcanoes (Tab. 6).

4. Area of Lądek Zdrój

In the area of Lądek Zdrój (Fig. 2) a very important locality is represented by Site 26 which is a basanite flow of a Pliocene or Lower Pleistocene age (Berger, 1932; Walczak, 1957). As the basanite is normally magnetized it would correspond to the N_1 Brunhes epoch (0.69 m.y.) of the early Pleistocene (cf. Tab. 4). Also two other localities in the vicinity of Lądek Zdrój (Sites 27 and 28: Lutynia) would belong to the same epoch (Tab. 7).

Table 7

Site mean directions of magnetization for the sites near Lądek Zdrój

Site No.	Magnetization		Lithology	Volcanic form	Age
	D	I			
26	3.6	+66.6	basanite	lava flow	Pliocene or Lower Pleistocene
27	352.8	+65.3	pyroxene basalt with glass	plug	Pliocene or Lower Pleistocene?
28	356.1	+65.4	basanite	?	Pliocene or Lower Pleistocene?

CONCLUSIONS

In the preceeding discussion an attempt has been made to refine the dating of the various volcanic events in Lower Silesia, using the data from palaeomagnetism. On a regional scale very little of significance can be said since the basic age data are too imprecise. Tentatively the volcanics of the Jawor area have been related to the volcanic events in eastern Germany (Lausitz volcanics). On a more local basis, it is possible on occasion to use the sign of magnetization observed as a consistency test of geological prediction even if the test is not wholly conclusive. It does appear, however, that variety of petrological type is no criterion of a long time span — for apparently within the same magnetic epoch different lithologies may occur, and conversely the same lithology, even in a restricted area, may be represented palaeomagnetically by the occurrence of a site of normal and/or reversed magnetization.

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