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Geological structure of the Trzebnica Hills in the light of new investigation

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Over 100-m elevation of Cainozoic sediments (mostly of Tertiary age) in the Trzebnica Hills was the effect of tectonic movement of rock masses within the Fore-Sudetic Monocline. Differences in heights are considerably high and locally reach 70 m. Glaciotectonic deformations during consecutive glaciations additionally contributed to substantial complication of inner structure. The main stage of glaciotectonic deformations as well as tectonic uplifting took place in the time of the Sanian Glaciation. Only one (and the same) glacial horizon covers the surface of the Trzebnica Hills and their southern foreland. It is a common idea that in the Silesian Lowland the glacial horizon represents a ground moraine of the Odranian Glaciation. Underlying sandy-gravely sediments should be connected with deglaciation period of this glaciation.

INTRODUCTION

The Trzebnica Hills (previously known as the Góry Kocie Mts.) are a part of the Trzebnica Ridge extending over 250 km from the Nysa Łużycka River in the west to the Ostrzeszów Hills in the east. The ridge is markedly visible in morphology of the Fore-Sudetic area. When determining the extent of continental glaciations, this fact was (among other arguments) used to support the interpretation of this unit as the frontal moraine connected — in respect of its origin — with the Wartanian Stadial (P. Woldstedt, 1925, 1932, 1935). This idea was later developed by F. Berger (1937) who recognized the Trzebnica Ridge as the frontal push moraine of this stadial.

Discussion on the origin of the Trzebnica Hills dates back to the beginning of the XX century. Ideas of advocates of tectonics in deep bedrock dominated first (W. Czajka, 1931; F. Frech, 1901, 1904, 1913, 1915; E. Meister, 1935; O. Tietze, 1910, 1915). The main argument for tectonic origin of the Trzebnica Hills was their orientation parallel to the Sudetic Marginal Fault. The matter in question was later discussed by other researchers who represented an option of glacial tectonics (F. Berger, 1937; S. Dyjor, 1993; S. Dyjor, T. Kuszell, 1975; C. Pachucki, 1952; M. Schwarzbach, 1942 — among others).

The paper presents the results of the authors study on main topics of geological structure of eastern part of the Trzebnica Hills and their southern foreland (Fig. 1). A major part of field observations was collected in the course of a mapping project conducted by the author for the Trzebnica sheet of *Detailed Geological Map of Poland* to the scale of 1:50 000 in the years 1980–1983 (J. Winnicki, 1990*b*). Further data was collected due to co-operation with the Archaeological Department of Wrocław University, when researchers of this centre conducted an emergency excavation mission on the Trzebnica 2 site situated in the brick-yard at Winna Góra Mt. in Trzebnica (the mission was in part financially supported by the research project KBN No. 101559101 and in part — by the municipality and commune of Trzebnica). Remains of the Lower Palaeolithic settlement were unearthed on this site (J. M. Burdukiewicz, 1990, 1994; J. M. Burdukiewicz, J. Winnicki, 1988).

Lithological criteria were employed to establish stratigraphic division of Quaternary sediments in southwestern Poland, and such approach resulted from the lack of uniformly documented organogenic interglacial sediments of Middle Pleistocene age (S. Szczepankiewicz, 1989). It is common in geological mapping that number of Pleistocene glaciations is being established on the basis of ground moraine horizons

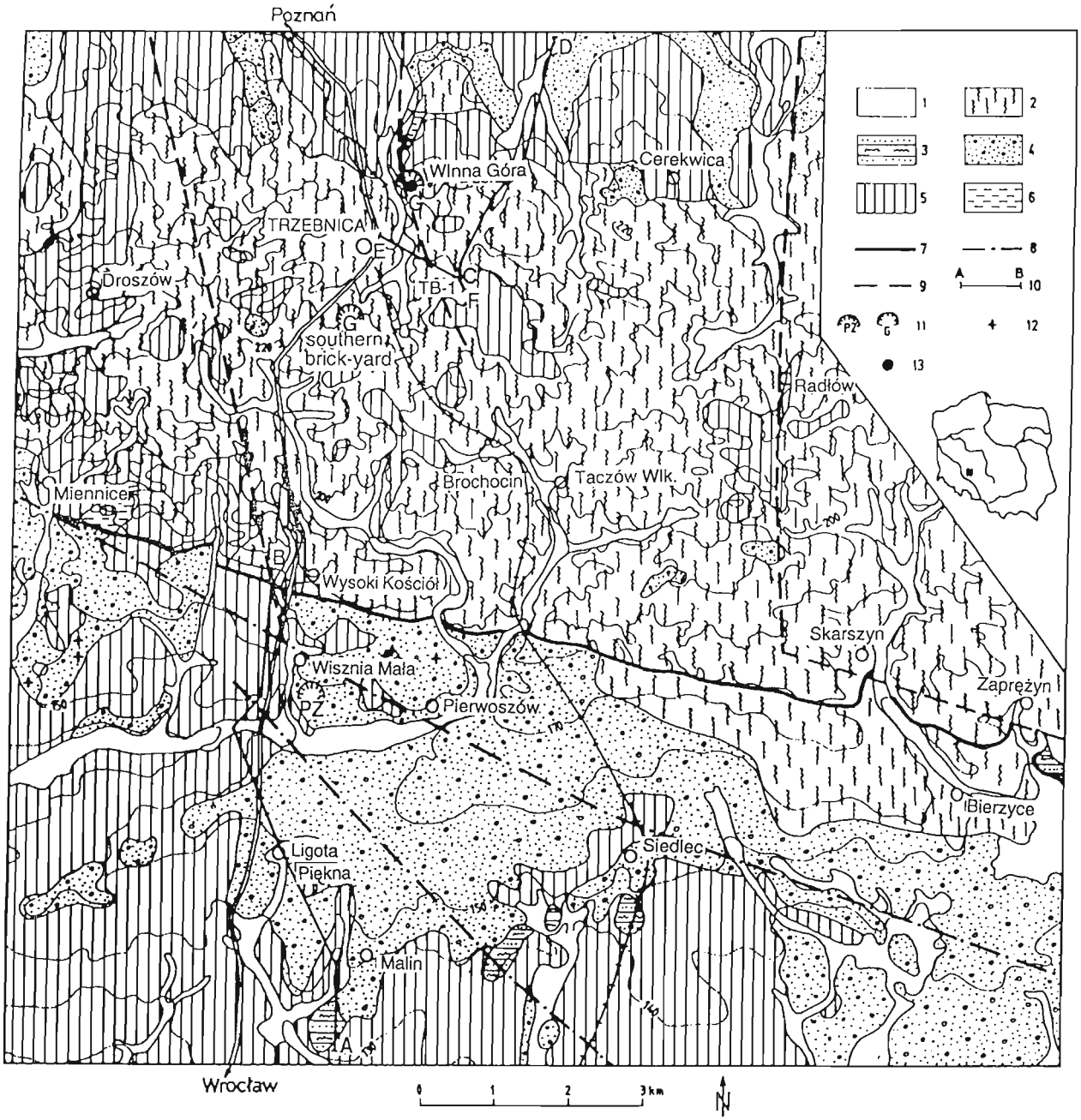

Fig. 1. Geological map of central part of Trzebnica Hills (simplified)

Holocene: 1 — sands and muds of valley beds; Vistulian Glaciation: 2 — loesses and loess-like formation; Odranian Glaciation: 3 — muds, sands with gravel in kames and kame terraces, 4 — fluvioglacial sands and gravels, 5 — glacial tills; Upper Miocene: 6 — clays of Poznań Series; 7 — southern edge of Trzebnica Hills; 8 — photolineaments confirmed by gravimetric survey; 9 — photolineaments interpreted on satellite and radar images; 10 — lines of geological cross-sections; 11 — workings discussed in text: PŻ — sandstones — gravel-pits, G — clay-pits; 12 — erratics; 13 — archaeological site (Trzebnica 2); TB-1 — test borchole

Mapa geologiczna środkowej części Wzgórz Trzebnickich (uproszczona)

Holocen: 1 — piaski i namuły den dolinnych; zlodowacenie wisły: 2 — lessy i utwory lessopodobne; zlodowacenie odry: 3 — mułki, piaski, piaski ze żwirami kemów i tarasów kemowych, 4 — piaski i żwiry wodnolodowcowe, 5 — gliny zwałowe; miocen górny: 6 — iły serii poznańskiej; 7 — południowa krawędź Wzgórz Trzebnickich; 8 — fotolineamenty potwierdzone grawimetrią; 9 — fotolineamenty zinterpretowane na zdjęciach satelitarnych i radarowych; 10 — linie przekrojów geologicznych; 11 — wyrobiska omawiane w tekście: PŻ — piaskowce — żwirownie, G — glinianki; 12 — głazy narzutowe; 13 — stanowisko archeologiczne Trzebnica 2; TB-1 — otwór badawczy

distinguished with respect to lithostratigraphic study of grain-size distribution, lime content, composition of heavy minerals, and pertrography of gravels as well. Groups of characteristic features were distinguished as a result of such the study; consequently, three glacial horizons were identified, then correlated with the area of the Trzebnica Hills as well as their southern foreland.

A test hole designated TB-1 (RPBP.III.35) was drilled to verify accepted scheme of stratigraphy of Pleistocene sediments within a buried valley in Trzebnica.

GEOLOGICAL STRUCTURE OF SOUTHERN FORELAND OF THE TRZEBNICA HILLS

The area south of the Trzebnica Hills is incorporated in the northern part of the Silesian Lowland, which is known as the Oleśnica Plain. Its extent is consistent with the extent of buried valley of the pre-Odra River, where average thickness of Quaternary sediments is in the range of 40–45 m while its maximum is over 70 m. Before the World War II, the area under consideration was in respective literature referred to as the Wrocław Depression.

Based on laboratory analyses of samples collected from boreholes drilled for mapping needs (Fig. 2), three horizons of glacial tills separated by ice-dammed lacustrine deposits or fluvioglacial deposits were distinguished (J. Czerwonka, 1984; J. Winnicki, 1990*b*) (Fig. 3). Many places are known in the Silesian Lowland where all glacial tills form one uniform morainic complex of thickness reaching 73 m as in the vicinity of Oława. Two lower till horizons, both dark grey and strongly compressed, with weathering rinds at the top of each one, were assigned to the Nidanian and Sanian Glaciations. The upper horizon composed of glacial till brown and yellow-brown in colour, was assigned to the Odranian Glaciation. It should be noted here that M. Schwarzbach (1942) connected the upper moraine with the Solavian Glaciation while the lower two — with the Elsterian Glaciation. Glacial till in the region of Miennice and Wysoki Kościół, that was assigned to the Odranian Glaciation, expands from the Oleśnica Plain to the area of the Trzebnica Hills (Fig. 3).

Sandy-gravely covers lying in the proximity of southern edge of the Trzebnica Hills (Fig. 1) make a characteristic element of geological structure of the area under consideration. Since the time when the Trzebnica Hills were interpreted as the frontal moraine of the Wartanian Glaciation, the sandy-gravely covers were defined as marginal forms (glacial outwash) developed during this glaciation (D. Krzyszkowski, 1993; E. Meister, 1935; C. Pachucki, 1952; M. Schwarzbach, 1942).

The so-called Siedlec Outwash is the most characteristic example of such morphological forms. Its exposure in a gravel-pit at Wisznia Mała can be used to trace its geological structure (Pl. I, Fig. 11). Horizontal beds are visible here; they are composed of predominantly fine-grained sands, sands with gravel, sometimes sandy muds — of total thickness reaching 7 m. The increased content of gravely material is observed towards the top. The gravely material is accompanied by scarce balls of both Tertiary clays and glacial till as well as individual pebbles up to 30 cm in size. Sediment in the sandy beds is most often stratified horizontally; an oblique bedding is seen in places. A diagram of cross bedding shows that directions of transport of material were strongly differentiated. A slight domination of palaeotransport from eastern

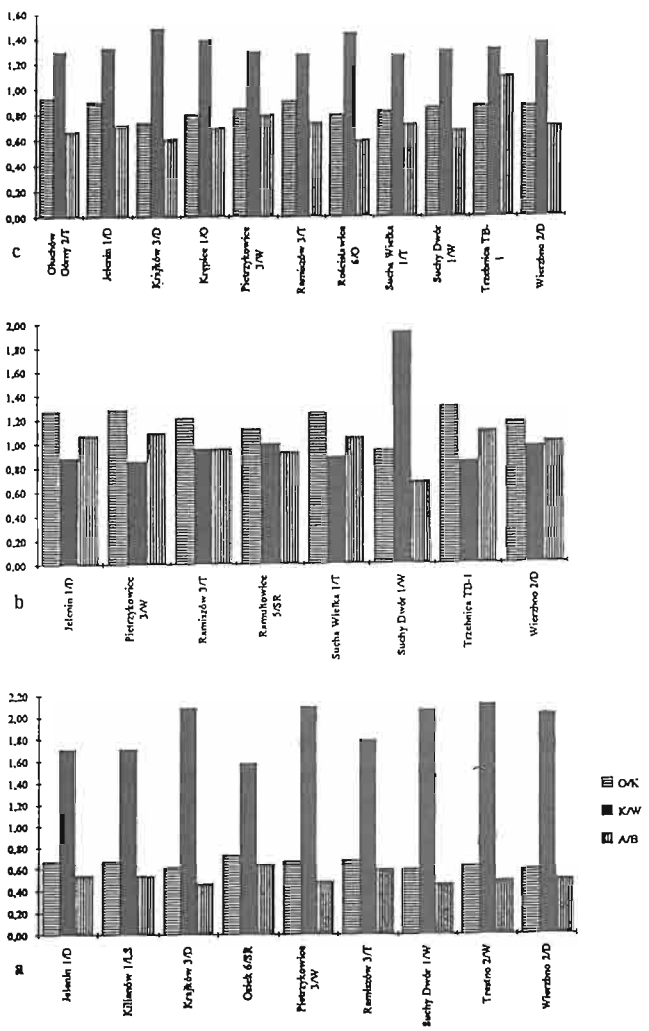

Fig. 2. Petrographic coefficients of three glacial till horizons within Trzebnica Hills and Silesian Lowland: **a** — Nidanian Glaciation, **b** — Sanian Glaciation, **c** — Odranian Glaciation

Wskaźniki petrograficzne trzech poziomów glin zwałowych ze Wzgórz Trzebnickich i Niziny Śląskiej: **a** — zlodowacenie nidy, **b** — zlodowacenie sanu, **c** — zlodowacenie odry

sector is seen over transport from northern and southern directions (Fig. 4). Thin covers of structureless sands and gravels, with individual erratics over 1 m in size, can be observed in some local culminations on the surface of the so-called Siedlec Outwash (Pl. II, Fig. 13).

The morphological form that was previously known as the so-called Siedlec Outwash is of the shape of a wide fan, with its peak situated near Malina, approx. 5 km southwards from the edge of the Trzebnica Hills (Fig. 1). The extent of this form is delimited by edges (escarps) made up of glacial till deposited during the Odranian Glaciation. These edges developed sharply in the land relief near the peak of the alleged fan (Fig. 1). From the southeastern side they are associated with small kame mounds built up of muds and muddy sands. If one accepts that the form under discussion is a real outwash, then its shape suggests that the material was fed from the south. Trying to explain the occurrence of ablation cover with

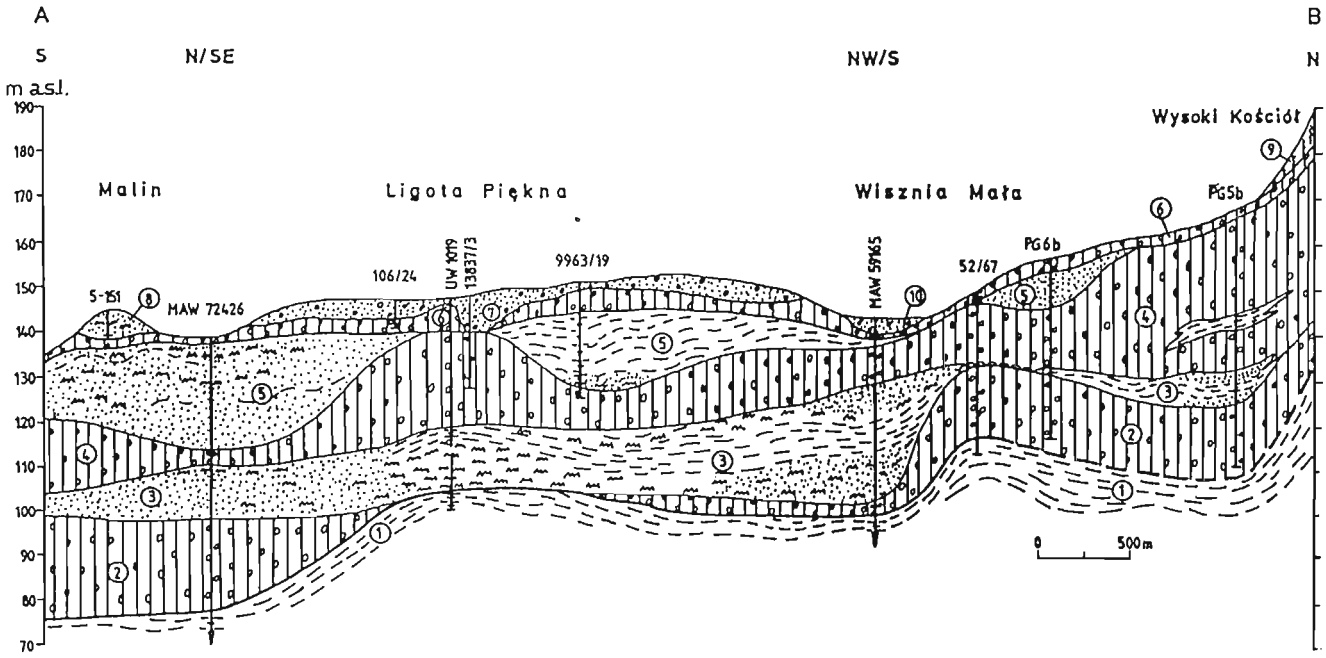

Fig. 3. Cross-sections A–B through southern foreland of Trzebnica Hills (location shown in Fig. 1)

Upper Miocene: 1 — clays of Poznań Series; Nidanian Glaciation: 2 — tills, locally with ice pavement in the top; Sanian Glaciation: 3 — clays, muds, and ice-dammed lacustrine sands, 4 — glacial tills; Odranian Glaciation: 5 — clays, sands, ice-dammed lacustine muddy sands, 6 — glacial tills, 7 — fluvioglacial sands and gravels, 8 — kame sands and muds; Vistulian Glaciation: 9 — loesses; Holocene: 10 — fluvial sands with admixture of gravel

Przekrój A–B południowego przedpola Wzgórz Trzebnickich (lokalizacja na fig. 1)

Miocen górny: 1 — iły serii poznańskiej; zlodowacenie nidy: 2 — gliny zwałowe, lokalnie z brukiem morenowym w stropie; zlodowacenie sanu: 3 — iły, mułki i piaski zastoiskowe, 4 — gliny zwałowe; zlodowacenie odry: 5 — iły, piaski, piaski mułkowate zastoiskowe, 6 — gliny zwałowe, 7 — piaski i żwiry wodnolodowcowe, 8 — piaski i mułki kemów; zlodowacenie wisły: 9 — lessy; holocen: 10 — piaski z domieszką żwirów rzeczne

erratics on the surface of the so-called outwashes in the southern foreland of the Trzebnica Hills, C. Pachucki (1952) considered them as traces of oscillation of ice-sheet edge during the Wartanian Glaciation. Such was the conclusion from the accepted idea that the Trzebnica Hills constitute the frontal moraine of that glaciation. Owing to such an idea, the author has modified the extent of the Wartanian ice-sheet by shifting its limit slightly southwards from the Trzebnica Hills.

The sandy-gravely covers at the foot of the Trzebnica Hills reach the elevation of 175 m a.s.l. They are extended along the southern edge of the Trzebnica Hills from Oborniki Śląskie to the Ostrzeszów Hills where the elevation of sand filling is as high as 200 m a.s.l. Individual erratics are being found everywhere on the sandy-gravely covers. Different morphological forms of similar geological structure (mounds, ridges, etc.), occurring in the region situated further south from the Ostrzeszów Hills and the Trzebnica Hills (the Oleśnica Plain up to the proximity of Opole), are associated with numerous depressions without drainage.

Data cited here uniformly suggest that the sandy-gravely covers in the area under consideration developed during deglaciation of the ice-sheet which overpassed the Trzebnica Hills and extended further southwards. Since evidences of the presence of the Wartanian ice-sheet are missing in that area, a conclusion should be drawn that the melting-related forms developed in crevasses or on dead-ice during the deglaciation of the Odranian ice-sheet.

GEOLOGICAL STRUCTURE OF THE TRZEBNICA HILLS

SOUTHERN EDGE

There is a sharp edge distinctly evidenced in the morphology, that separates the Trzebnica Hills from their southern foreland (Figs. 1 and 3). In the area between Miennice and Wysoki Kościół the edge is covered with glacial till that extends from the slopes to the foreland area. Flamy Clays of Tertiary age are cropping out in some places on the land surface (Fig. 1). In the area east of Nowy Kościół the edge is built up of sandy-gravely fluvioglacial sediments, strongly ferruginous at their top, that crop out from under a loess cover. A new outcrop near Zaprężyn provide an evidence that their

thickness is over 10 m (Pl. II, Fig. 14). Sandy muds of horizontal lamination are seen at the foot of a northern wall at this outcrop. They are grading upwards into muddy sands of horizontal stratification; the muddy sands contain occasional grains of grits and balls of brown glacial tilt. A 5-m series of fine-grained sands with gravel occurs near the top, under a loess layer with fossil soils, also 5 m thick. Predominantly, material in particular beds is of flat stratification; occasionally an oblique and cross stratification is also visible. The beds exhibit a slight slope northwards.

From consideration on lithological development of sediments and the altitude of their occurrence (approx. 160 m a.s.l.) a conclusion can be drawn that the edge discussed so far and the neighbouring so-called Siedlec Outwash were formed at the same time and under similar conditions. In the area of Zaprężyn the sediments discussed above are deposited in such a form that can be defined as a came terrace connected with the close of the Odranian Glaciation.

TRZEBNICA HILLS

A complicated inner structure is a characteristic feature of the Trzebnica Hills. Tertiary and partly Quaternary components of this structure are disturbed. They are discordantly overlain by younger Quaternary sediments of glacial origin that have been assigned by the majority of geologists to the Wartanian Glaciation (S. Dyjor, 1993; E. Meister, 1935; C. Pachucki, 1952; M. Schwarzbach, 1942 — among others).

Geological structure of the topmost portion of the Trzebnica Hills was best recognized in two brick-yards: a southern and a northern one (the latter on the western slope of Winna Góra Mt.). Two morainic horizons have been found in the working of a brick-yard situated in the southern part of Trzebnica, near the Wrocław road; the lower one has been assigned to the Middle-Polish Glaciation (the Elsterian Glaciation) while the upper — to the Odranian Glaciation (the Saalian one) (E. Meister, 1935; C. Pachucki, 1952; M. Schwarzbach, 1942).

Similar geological structure was observed in the southern working of the brick-yard situated on the western slope of Winna Góra Mt., where archaeological and geological investigations were carried out in the years 1983–1994 (Figs. 1 and 5). A residuum of glacial till was found in the southern wall of the working; the residuum is 2 m thick, it overlies Tertiary clays, and is composed of ice pavement with erratics reaching 1.5 m in size (Pl. I, Fig. 12). Most of crystalline rocks are very effectively weathered. A concentration of Lower Palaeolithic artefacts with remains of forest and steppe fauna was found at the base of this horizon (J. M. Burdukiewicz, 1990, 1994; M. Pakiet *et al.*, 1993). Former ideas linked the origin of this residuum with the Mazovian Interglacial (J. Winnicki, 1990*b*); however, against the background of current state of investigation it is not excluded that the residuum was formed earlier (in the time of Malopolanian Interglacial?). Overlying formation is composed of silt; its thickness is over 6 m (Z. Śnieszko, 1995).

Essentially different is geological profile of the northern wall (Fig. 6) of the southern working in the brick-yard on

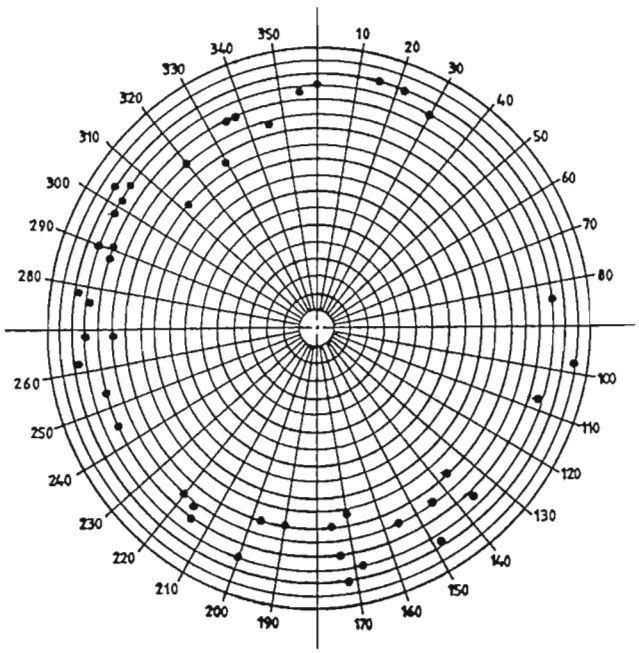

Fig. 4. Diagram showing scatter of results of cross bedding measurements in fluvioglacial sandy-gravely sediments in region of Wisznia Mała (so-called Siedlec Outwash)

Diagram rozrzutu pomiarów warstwowania przekątnego piaszczysto-żwirowych osadów wodnolodowcowych w rejonie Wiszni Małej (tzw. sandr siedlecki)

Winna Góra Mt. Its lower part incorporates clays of the Poznań Series and overlying (though preserved in fragments only) white quartzic sands belonging to the Gozdnica Series. The Neogene formation is covered with a layer of clayey glacial till (with lignites), which is chocolate brown on the wall surface and dark grey in deeper portions of the working wall. Greater boulders (approx. 0.5 m in size) near the contact with Tertiary clays form a local sort of pavement (J. Winnicki, 1990*a*). Till does not make a continuous horizon, and in places its thickness can reach 2 m. Morainic sediments of similar development (Fig. 6) were previously observed in an old outcrop in the brick-yard on Winna Góra Mt. (F. Frech, 1913; W. Walczak, 1951). The bottom of this till is the place where Lower Palaeolithic artefacts were discover; they were exactly the same as those in the southern wall (J. M. Burdukiewicz, 1990, 1994). A thick series of yellow and yellow-brown fine-grained sands and muddy sands as well as muds is observed above the lower till horizon; the series is glaciotectonically deformed. Infrequent are lenses of vari-grained sands with grits. Previously, a description was made of interbedding of varved clayey muds occurring at the bottom of upper morainic horizon in the part of eastern wall (J. Winnicki, 1990*b*). A profile of northern wall (Fig. 6) is completed with sand-rich glacial till, yellow-brown in appearance, up to 7 m thick. This till contains frequent gravels and boulders as well as sandy-gravely lenses and interbeddings.

Different methods were employed to investigate the morainic horizons in southern working of brick-yard on Winna Góra Mt. Due to sediment effectively weathered, petro-

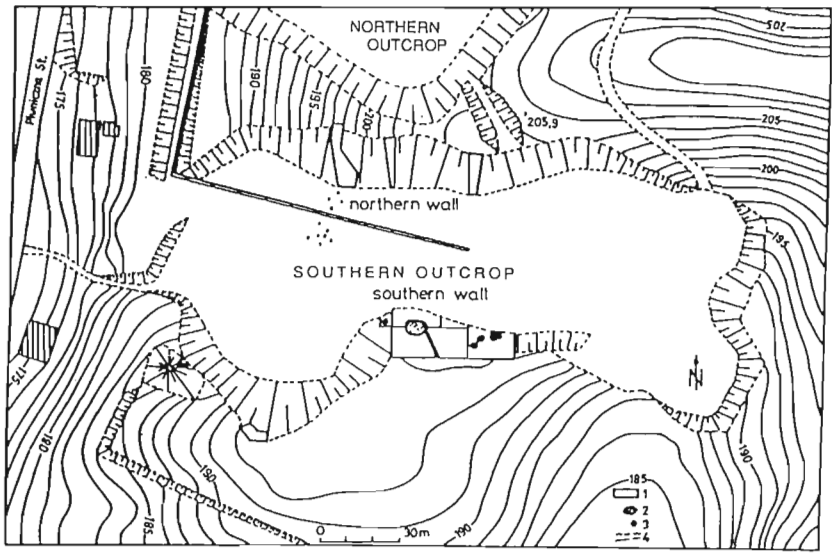

Fig. 5. Gencral layout of brick-yard on Winna Góra Mt. in Trzebinia
1 — limits of archaeological excavations; 2 — concentration of artefacts and remnants of fossil fauna; 3 — individual artefacts; 4 — cross-cuts

Plan sytuacyjny cegielni na Winnej Górze w Trzebnicy
1 — granice wykopów archeologicznych; 2 — skupienia artefaktów i szczątków fauny kopalnej; 3 — pojedyncze artefakty; 4 — przekopy

graphic analysis of 5–10 mm fraction brought insufficient results (J. Czerwonka, 1988). On the other hand, when applying a Lüttig method, results of petrographic analysis of 20–60 mm fraction occured to be representative (J. M. Burdukiewicz, K. -D. Meyer, 1991). The method confirmed stratigraphic differentiation of morainic horizons, with the lower horizon in the northern wall (Fig. 6) together with morainic residuum in the southern wall (Pl. I, Fig. 12) corresponding to the Elsterian Glaciation (the South-Polish Glaciation) while the upper moraine — to the Drenthe Stadial of the Saalian Glaciation (the Odranian Glaciation). This way of investigation has confirmed previous assessments that formations of the Wartanian Glaciation are lacking even on the northern (proximal) slopes of the Trzebnica Hills and that the highest morainic horizon was formed during the Odranian Glaciation.

GLACIAL FORMATIONS AND THEIR RELATION TO DEFORMATIONS

Since the time when the Trzebnica Ridge was interpreted as the frontal push moraine of the Wartanian Glaciation (F. Berger, 1937), a question was still vivid to find arguments for this concept. Despite some reservations, E. Meister (1935) connected with that glaciation the sediments almost 4 m thick, composed of sands with gravel, gravels with large boulders, and glacial till — with the latter occurring discordantly on the Tertiary and Quaternary in the region of Taczów Wielki, Brochocin, Radłów, and Droszów. In his cartographic work entitled "Blatt Wiese" (Wisznia Mała) on the scale of 1:25 000, E. Meister called them "the sediments of undetermined age". He assigned two morainic horizons in the southern brick-yard in Trzebnica (Fig. 1) to the South-Polish (Elsterian) and Odranian (the Saalian) Glaciations as it seemed to him that the two were disturbed jointly with the Tertiary formation. The issue of glacial till participating in this deformations can be better explain on the basis of detailed observations in two outcrops situated side by side in the brick-yard on Winna Góra Mt. in Trzebnica.

The southern working of this brick-yard (Fig. 5) was used to extract the Flamy Clays of the Poznań Series dipping southwards. Tertiary clays and sands of the Gozdnica Series in the northern working were dipping northwards. Accordingly, there is an elevation of sub-Quaternary substratum, that is covered with two morainic horizons. Profiles compiled by F. Frech (1913) clearly show that both upper and lower glacial tills in the northern working overlie the Tertiary formation in a discordant way.

This discordance cannot be seen on the northern wall of the nearby working, which is perpendicular to F. Frech's profile lines (1913). Also, this fact explains troubles in interpretation of geological structure of sediments in the brick-yard situated in the southern part of Trzebnica, for which the W–S cross-sections were plotted perpendicular to directions of deformation (E. Meister, 1935; M. Schwarzbach, 1942).

From analysis of geological observations in the brick-yard on Winna Góra Mt. (F. Frech, 1913; W. Walczak, 1951, 1970) as well as on wall profiles in the brick-yard in the southern

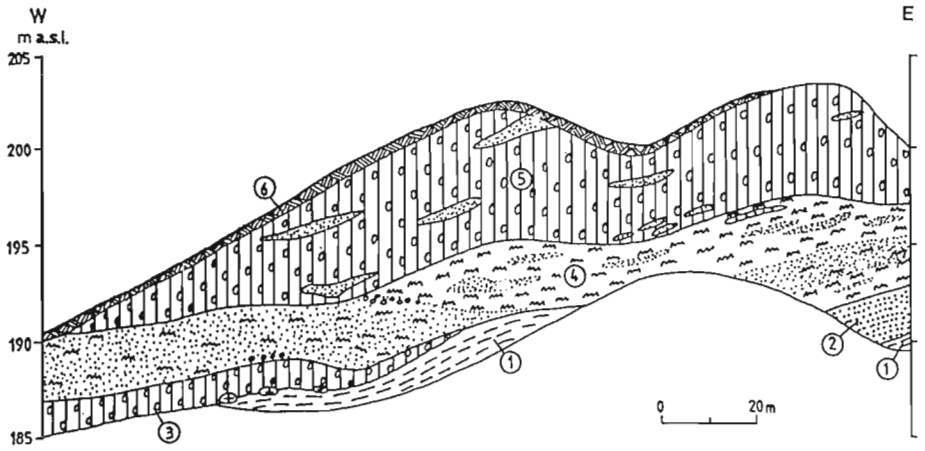

Fig. 6. Profile of northern wall of southern working in brick-yard on Winna Góra Mt. in Trzebnica
Upper Miocene: 1 — clays of Poznań Series; Pliocene: 2 — quartzic sands of Gozdnica Series; Sanian Glaciation: 3 — glacial tills; Odranian Glaciation: 4 — muddy sands, muds, locally clayey varved muds, 5 — glacial tills; Holocene: 6 — soil

Profil ściany północnej cegielni na Winnej Górze w Trzebnicy (wyrobisko południowe)
Miocen górny: 1 — iły serii poznańskiej; pliocen: 2 — piaski kwarcowe serii Gozdnicy; zlodowacenie sanu: 3 — gliny zwałowe; zlodowacenie odry: 4 — piaski mułkowate, mułki, lokalnie ilaste mułki warwowe, 5 — gliny zwałowe; holocen: 6 — gleba

part of Trzebnica (E. Meister, 1935; C. Pachucki, 1952; M. Schwarzbach, 1942) further conclusion can be drawn that the deformation of Tertiary sediments took place prior to the sedimentation of two upper morainic horizons that only repeat morphologically the Neogene surfaces (Figs. 6 and 7).

Observations were made in the two brick-yards in Trzebnica that glacial tills adjust themselves to positive forms in their substratum; this phenomenon is simply explained as the effect of static load exerted on this substratum by the ice-sheet in the time of the Odranian Glaciation. Similar phenomena are also observed in the Ostrzeszów Hills area (J. Winnicki, 1996).

Reservations as to Wartanian age of the Trzebnica Ridge were expressed by T. Bartkowski (1967), S. Dyjor (1993), and W. Walczak (1970) among others. Based on geological and geomorphologic data the authors mentioned here assumed that the Trzebnica Ridge was formed prior to this glaciation.

A mapping project carried out on the Trzebnica Hills showed that near-surface geology over entire area under discussion consisted in upper morainic horizon (glacial till in combination with glacial sands and gravel) lying discordantly on disturbed older formations of the Tertiary and Quaternary. This is particularly visible on northern slopes of the Trzebnica Hills, that are predominantly covered with these morainic formations (Fig. 9). The morainic horizon under discussion does not end at the southern edge of the Trzebnica Hills but extends further southwards to the Oleśnica Plain. Laboratory analyses indicate that the highest morainic horizon in both the Trzebnica Hills and the Silesian Lowland is characterized by the same values of petrographic coefficients (Fig. 2).

BURIED VALLEY IN TRZEBNICA

Thickness of Quaternary formation reaches its maximum in buried valleys which is documented by boreholes penetrating the northern and southern slopes of the hills in the region of Trzebnica, Cerekwica, Sucha Wielka, and Skarszyn. Thickness of Pleistocene sediments in the buried valley in Trzebnica can be as great as 123 m.

Only 2-km valley tract in Trzebnica was recognized by drilling (Fig. 10). Three horizons of glacial tills were encountered there, with the lowermost horizon of fragmentary occurrence only. Two lower morainic horizons are separated by a series of fluvial sediments up to 45 m thick. Its composition includes muddy and fine-grained sands, locally with grit. Sandy muds containing numerous, well preserved tree trunks and fragments, were found at the bottom of fluvial sediments. Among them recognized were macroscopic remains of ash (*Fraxinus excelsior*), elm (*Ulmus* sp.), and poplar (*Populus* sp.), all belonging to thermophilous plants (W. Pyszyński, J. Winnicki, 1990; W. Pyszyński *et al.*, 1991). One of boreholes encountered an accumulation of foliage; no identification was made with respect to their species. Similar series of fluvial sediments with numerous (though indeterminable) tree species has been recognized in the test-cartographic 1T borehole at Sucha Wielka (J. Winnicki, 1990*b*).

In the TB-1 borehole in Trzebnica, intercalations of muds with large amount of plant debris were encountered in ice-dammed lacustrine sediments occurring at the top of fluvial series. Based on palynological analysis it was only possible to define that cool climate, characteristic for the beginning or

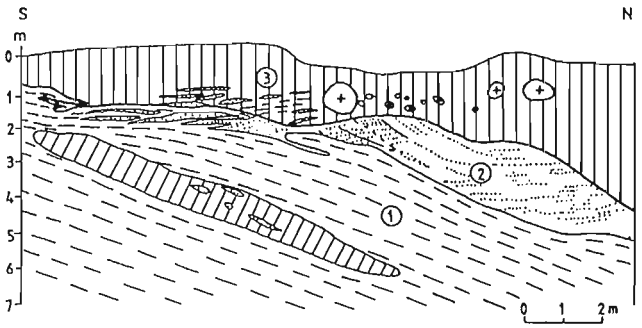

Fig. 7. Profile of western wall of northern working in brick-yard on Winna Góra Mt. in Trzebnica (after F. Frech, 1913)

Upper Miocene: 1 — clays of Poznań Series, with detached block of glacial till; Pliocene: 2 — quartzic sands of Gozdnica Series; Odranian Glaciation: 3 — brown glacial till with erratics and pebbles

Profil ściany zachodniej cegielni na Winnej Górze w Trzebnicy (wyrobisko północne) (według F. Frecha, 1913)

Miocen górny: 1 — iły serii poznańskiej z porwakiem gliny zwałowej; pliocen: 2 — piaski kwarcowe serii Gozdnicy; zlodowacenie odry: 3 — brunatna glina zwałowa z głazami i otoczakami

Complicated geological structure of both the Trzebnica Hills and the Trzebnica Ridge as the whole was a factor challenging different interpretations of their origin to emerge. Deformed in the Trzebnica Hills are mostly Tertiary sediments being components of some lithostratigraphic members. They are represented by monotonous clays and muds of the Poznań Series with the Flamy Clays at the top. Locally preserved are overlying white quartzic sands of the Gozdnica Series. The oldest Tertiary member includes a formation with the thin brown coal seams at its top, that in the Lower Silesian area is known as the "Henryk" Seam. Age of this bed encountered in boreholes penetrating the Trzebnica Hills was defined as Upper Tortonian (A. Sadowska, 1984).

Pleistocene sediments taking part in deformations are met occasionally (Fig. 7), mostly below ground level (F. Frech, 1913; E. Meister, 1935; J. Winnicki, 1990*b*). A situation was encountered in the region of Oborniki Śląskie, in which Quaternary sands and gravels overlain by Tertiary clays have been found at a depth over 100 m (M. Różycki, 1957).

The origin and extent of Cainozoic sediments are subject to many polemics. Troubles in interpretation of these deformations result from the fact that many researchers extent surface observations to deeper parts of the Trzebnica Hills, which is groundless in the light of limited number of observations. The deformations of Cainozoic sediments were most often documented in brick-yard workings in Trzebnica (F. Frech, 1913; E. Meister, 1935; C. Pachucki, 1952; M. Schwarzbach, 1942). These deformations of scale and fold character were of distinct southern vergence (Figs. 7 and 8) and their axes were of E–W orientation. Glaciotectonic origin of these deformations is unquestionable. As concluded from field observations, apart from forms connected with dynamic influence of ice-sheet — of frequent appearance are deformations of squeeze character, the origin of which can be connected with static impact of ice-sheet on the substratum (J. Winnicki, 1990*b*).

It is probable that several generations of glaciotectonic deformations exist here and that they developed during consecutive glaciations (S. Dyjor, 1993). Data acquired within the Ostrzeszów Hills area indicates the most intensive glaciotectonic processes taking place during transgression of the

the decline of interstadial or interglacial (T. Kuszell, 1991) prevailed at the time of deposition of sediments discussed. The ice-dammed lacustrine sediments developed as muds, muddy sands, and fine-grained sands separates the middle glacial till horizon from the upper till layer. Based on laboratory determinations of petrographic coefficients (O/K — 1.30, KW — 0.85, and A/B — 1.1), the middle glacial till and glacial sands from the TB-1 were assigned to the Sanian Glaciation; as to the upper morainic horizon, characterized by the petrographic coefficients of O/K — 0.87, KW — 1.32, and A/B — 0.71), it was assigned to the Odranian Glaciation (Fig. 2). More detailed description of laboratory analyses has been presented in a separate work by J. Winnicki (1992).

Beyond zones of buried valleys, thickness of Quaternary cover over the Trzebnica Hills is relatively small. There are many places, particularly within elevations, where Tertiary sediments (mostly clays of the Poznań Series) are exposed immediately on ground level.

GENERAL REMARKS ON THE ORIGIN OF THE TRZEBNICA HILLS

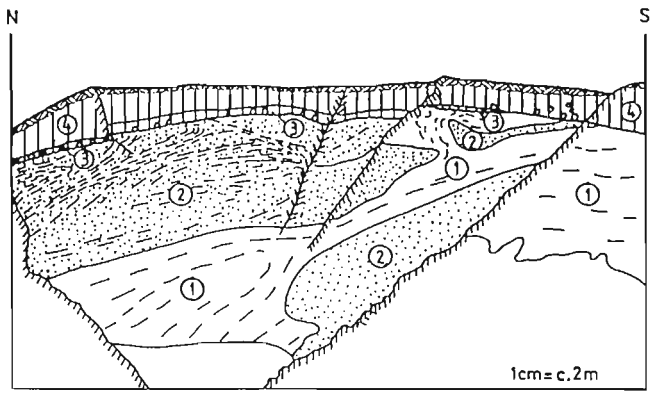

Fig. 8. Profile of eastern wall of northern working in brick-yard on Winna Góra Mt. in Trzebnica (a drawing of photograph after F. Frech, 1913)

Upper Miocene: 1 — clays of Poznań Series; Pliocene: 2 — quartzic sands of Gozdnica Series; Sanian Glaciation: 3 — glacial tills, chocolate brown; Odranian Glaciation: 4 — glacial tills, brown

Profil ściany wschodniej cegielni na Winnej Górze w Trzebnicy (wyrobisko północne) (rysunek fotografii według F. Frecha, 1913)

Miocen górny: 1 — iły serii poznańskiej; pliocen: 2 — piaski kwarcowe serii Gozdnicy; zlodowacenie sanu: 3 — gliny zwałowe barwy czekoladowej; zlodowacenie odry: 4 — gliny zwałowe brunatne

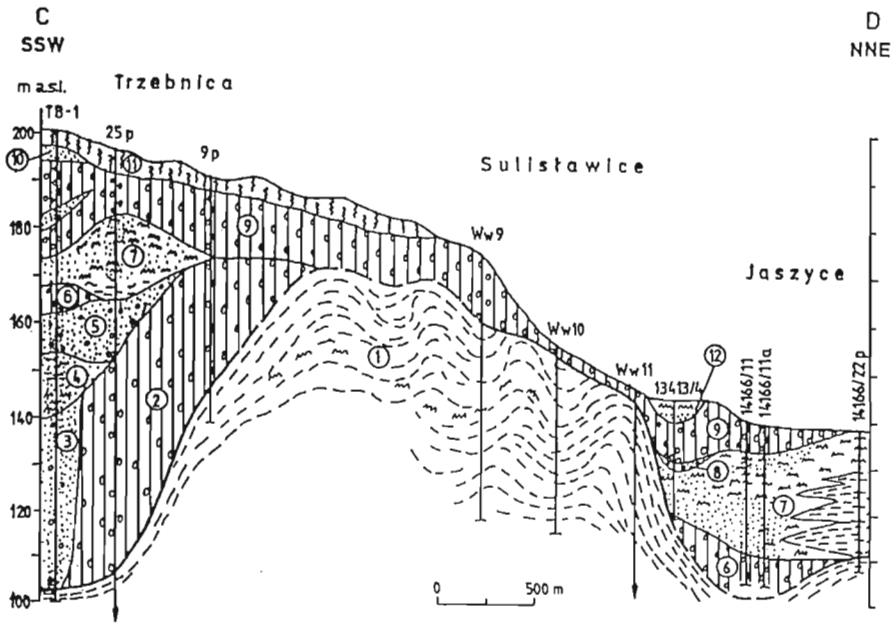

Fig. 9. Cross-section C–D through northern slope of Trzebnica Hills (location shown in Fig. 1)

Upper Miocene: 1 — clays and muds of Poznań Series; Nidanian Glaciation: 2 — glacial tills; Malopolanian Interglacial: 3 — fluvial sands with addition of gravel, with tree fragments at the bottom; Sanian Glaciation: 4 — muddy sands and ice-dammed lacustrine muds, 5 — fluvioglacial sands with gravel, 6 — glacial tills; Odranian Glaciation: 7 — muds, muddy sands, and ice-dammed lacustrine clays, 8 — fluvioglacial sands with gravel, 9 — glacial tills, 10 — fluvioglacial sands with gravel; Vistulian Glaciation: 11 — loesses; Holocene: 12 — muds and fluvial sands

Przekrój C–D północnego skłonu Wzgórz Trzebnickich (lokalizacja na fig. 1)

Miocen górny: 1 — iły i mułki serii poznańskiej; zlodowacenie nidy: 2 — gliny zwałowe; interglacjał małopolski: 3 — piaski z domieszką żwirów, w spągu z ułamkami drewna, rzeczne; zlodowacenie sanu: 4 — piaski mułkowate i mułki zastoiskowe, 5 — piaski ze żwirem wodnolodowcowe, 6 — gliny zwałowe; zlodowacenie odry: 7 — mułki, piaski mułkowate i iły zastoiskowe, 8 — piaski ze żwirem wodnolodowcowe, 9 — gliny zwałowe, 10 — piaski ze żwirem wodnolodowcowe; zlodowacenie wisły: 11 — lessy; holocen: 12 — namuły i piaski rzeczne

Sanian ice-sheet (A. Markiewicz, J. Winnicki, 1997). Despite K. Rotnicki's view (1967), glacial tills discordantly overlying glaciotectonically deformed Tertiary and Quaternary formations were found in some outcrops (J. Winnicki, 1996). Laboratory examination of these morainic sediments provided evidence that they were correlable with tills of the Sanian Glaciation in the Silesian Lowland (T. Dobosz, 1994).

It is natural that the majority of observations are limited to a shallow zone near the ground level. At present it is difficult to establish what forces caused a vertical displacement of thick Tertiary series within the Trzebnica Hills. Tertiary sediments are met up to the altitude of about 240 m a.s.l. — nearly 120 m higher than in the neighbouring area of the Środa Śląska Plateau.

As concluded from the test-cartographic boreholes, brown coal in the "Henryk" Seam occurs at different altitudes. In the 2T borehole near Głuchów Górny in the vicinity of the southern edge of the Trzebnica Hills, this bed was encountered at a depth of 200 m equivalent to about 35 m a.s.l. On the other hand, in the 1T borehole at Sucha Wielka (the northern slopes) it occurs at 20 m b.s.l.; respective difference in height is considerable and can reach as much as 55 m.

It is impossible at the current state of investigation to uniformly define kind of deformation of Cainozoic formation within the Trzebnica Hills. On the one hand it is caused by the presence of continuous cover of loesses and silty deposits of the Vistulian Glaciation; on the other hand there is insufficient number of boreholes in the central part of the Trzebnica Hills that penetrate the Cainozoic to its very bottom. Due to some disturbances in measurements, seismic survey conducted by the Oil Exploration, Cracow and Geophysical Prospecting, Warsaw occurred to be ineffective in recognizing the morphology of the top of the Fore-Sudetic Monocline.

For the advocates of tectonic origin of the Trzebnica Hills, the character of the southern edge of this morphologic form is the fundamental argument for their concept (W. Czajka, 1931; E. Meister, 1935). Its straight-line course, 18 km long and parallel to the Sudetic Marginal Fault, was expected to indicate the presence of dislocation in deep bedrock, along which vertical movements might have taken place. This concept was in part confirmed by M. Graniczny (1980) who — making use of satellite and radar images — delimited several lineaments in the area considered (Fig. 1). Some of them were confirmed by gravimetric anomalies (M. Graniczny, 1980).

Interesting data on the origin of the Trzebnica Ridge was acquired in the area of the Ostrzeszów Hills (J. Winnicki, 1996; A. Markiewicz, J. Winnicki, 1997). Boreholes and geophysical survey provided evidence on the presence of elongated horsts built up of Upper Triassic rocks. They are situated below the highest culminations of the Ostrzeszów Hills, thus repeating the course of morphological axis. They are elevated to 120–160 m above the top of the Fore-Sudetic

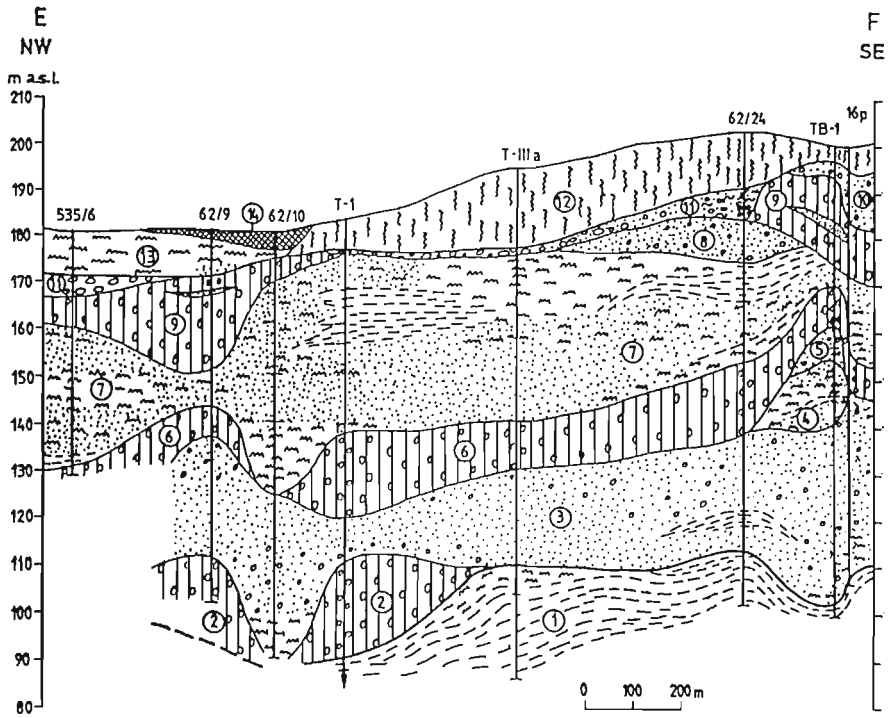

Fig. 10. Longitudinal cross-section E–F through a part of buried valley in Trzebnica (location shown in Fig. 1)

Upper Miocene: 1 — clays and muds of Poznań Series; Nidanian Glaciation: 2 — glacial tills; Malopolanian Interglacial; 3 — sands, sands with admixture of gravel, muds and fluvial clays with tree fragments at the bottom; Sanian Glaciation: 4 — muddy sands, muds, and ice-dammed lacustrine clays, 5 — fluvioglacial sands with gravel, 6 — glacial tills; Odranian Glaciation: 7 — muds, muddy sands, and ice-dammed lacustrine clays, 8 — fluvioglacial sands with gravel, 9 — glacial tills, 10 — fluvioglacial sands with gravel; Eemian Interglacial(?): 11 — gravels and pebbles (pavements), locally sandy and loamy; Vistulian Glaciation: 12 — loesses; Holocene: 13 — muds and fluvial sands, 14 — fills

Przekrój podłużny E–F części kopalnej doliny w Trzebnicy (lokalizacja na fig. 1)

Miocen górny: 1 — iły i mułki serii poznańskiej; zlodowacenie nidy: 2 — gliny zwałowe; interglacjał małopolski: 3 — piaski, piaski z domieszką żwirów, mułki i iły rzeczne z ułamkami drewna w spągu; zlodowacenie sanu: 4 — piaski mułkowate, mułki i iły zastoiskowe, 5 — piaski ze żwirem wodnolodowcowe, 6 — gliny zwałowe; zlodowacenie odry: 7 — mułki, piaski mułkowate, piaski i iły zastoiskowe, 8 — piaski ze żwirem wodnolodowcowe, 9 — gliny zwałowe, 10 — piaski ze żwirem wodnolodowcowe; interglacjał eemski(?): 11 — żwiry i otoczaki (bruki) lokalnie zapiaszczone i zaglinione; zlodowacenie wisły: 12 — lessy; holocen: 13 — namuły i piaski rzeczne, 14 — nasypy

Monocline in the Odolanów Valley. Tectonic movements of Cainozoic basement were taking place during the Sanian Glaciation and can partly be linked with the movements of the Mazovian Phase in the Polish Lowlands (M. D. Baraniecka, 1975). As a result, further deformation of already deformed (slighty earlier) Cainozoic sediments followed. Tectonic engagement of these sediments is expressed by, among others, a local change in orientation of the deformations from NNE–SSW to W–E. Apart from this, sediments of the oldest Tertiary (brown coals, coal clays, Ostrzeszów Quartzites of Middle Miocene age) can be found on the ground level in the axis of the Ostrzeszów Hills. Detailed description of geological structure of the Ostrzeszów Hills along with their tectogenesis has been presented in A. Markiewicz and J. Winnicki's work (1997).

It is likely that similar processes were also taking place within the Trzebnica Hills. It is not exluded that narrow horst structures (whose width within the Ostrzeszów Hills does not exceed 700–800 m) can appear in the basement of the Trzebnica Hills. This can be indicated by data acquired in deep exploration boreholes for natural gas, drilled mainly on the northern slopes of the Trzebnica Hills. Differences in height of the top of the Fore-Sudetic Monocline in nearby Czeszów 12 and Czeszów 13 boreholes can be as much as 70 m (the top encountered at 30.5 and 98.0 m b.s.l. in particular boreholes, respectively). In extreme cases the top of the Upper Triassic sediments in the Twardogóra 1 borehole lies at the altitude of 14.0 m b.s.l. while in the Prusice 2 borehole — at 145.5 m b.s.l.

CONCLUSIONS

Based on results of geological investigation of field and laboratory character with different methods employed, a conclusion can be drawn that actual view on the stratigraphy of Quaternary sediments (of the Wartanian Glaciation) and the origin of the Trzebnica Hills should be subject to modification.

In the light of data acquired, the Trzebnica Hills can no longer be interpreted as the frontal moraine of the Wartanian Glaciation. The ground level, both on the northern and southern slopes, is covered with one morainic horizon which extends further into the area of the Oleśnica Plain — where it is assigned by all of the researchers to ground moraine of the Odranian Glaciation. There is a great similarity in results of granulometric-petrographic analysis of these sediments in areas of the Trzebnica Hills and those situated further south; for that reason there is no basis to assign the sediments under consideration to different glaciations, once to the Wartanian Glaciation and other time — to the Odranian Glaciation.

Of great importance for the advocates of the presence of the Wartanian ice-sheet within the Trzebnica Hills are the so-called outwashes — distinguished in the southern foreland of the Trzebnica Hills. As demonstrated above, sandy-gravely covers of this type cannot be interpreted as true outwash forms; they should be connected with the time of areal deglaciation during the Odranian Glaciation. The presence of large boulders on the sandy-gravely covers indicates that their sedimentation was taking place in the zone of dead-ice melting over considerable area of southern foreland of the Trzebnica Hills and the Ostrzeszów Hills as well. This is additionally evidenced by no-flow depressions within these covers as well as individual kame mounds lying in their proximity. One can admittedly assume that in line with idea of V. Milthers (1936) the Wartanian ice-sheet extended further south. This author drew the limit of this glaciation along a line connecting Mużaków, Żary, Żagań, Szprotawa, Legnica, Wrocław, and Kluczbork — as such the idea was motivated by the extent of brown Baltic porphyries. This view cannot be confirmed morphologically — which was already noticed by M. Schwarzbach (1942). A latest study of grit composition using a Lüttig method indicates that the upper glacial till on the northern slopes of the Trzebnica Hills is genetically connected with the Odranian Glaciation (J. M. Burdukiewicz, K. D. Meyer, 1991).

Observations in the Trzebnica Hills and other parts of the Trzebnica Ridge (the Ostrzeszów Hills) showed that main processes to deform the Cainozoic sediments were taking place during the Sanian Glaciation. Two generations of deformations of different origin can be observed within the Ostrzeszów Hills area. Transgression of ice-sheet was the time of domination of glaciotectonic processes; recession was that time when intensification of tectonic movements in deeper bedrock followed. The latter resulted in the formation of horsts of relative height over 120 m and in further complication of former glaciotectonic deformations. Glacial tills of the Odranian Glaciation (the Saalian one) and the Sanian Glaciation (the Elsterian one) lie discordantly on former sediments.

The author represents the view that the process leading to formation of the Trzebnica Hills was a complex one. Tectonic movements in deep basement elevated the Cainozoic sediments — and glaciotectonic processes taking place during consecutive glaciation (particularly the Sanian one) contributed to considerable complication of geological structure.

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BUDOWA GEOLOGICZNA WZGÓRZ TRZEBNICKICH W ŚWIETLE NOWYCH BADAŃ

Streszczenie

Przedstawiono poglądy na genezę i stratygrafię osadów kenozoicznych Wzgórz Trzebnickich. Nowe dane uzyskano podczas prac kartograficznych (J. Winnicki, 1990*b*) i archeologiczno-geologicznych na stanowisku Trzebnica 2, gdzie zostały znalezione najstarsze w Polsce artefakty (J. M. Burdukiewicz, 1990, 1994).

Od czasów F. Bergera (1937) Wał Trzebnicki, w skład którego wchodzą Wzgórza Trzebnickie, ciągle uchodzi za spiętrzoną morenę czołową, tzw. Warthestadium. Teoria genezy glacitektonicznej tej jednostki geologicznej zastąpiła wcześniejsze koncepcje tektoniczne (m. in. W. Czajka, 1931; F. Frech, 1901, 1904, 1913, 1915; O. Tietze, 1910, 1915). Zgodnie z nią utwory górnego trzeciorzędu zostały wyniesione ponad 100 m nad leżące w sąsiedztwie wysoczyzny neogeńskie dzięki naciskom lądolodu zlodowacenia warty. Zdaniem F. Bergera (1937) i późniejszych autorów potwierdzeniem tej teorii miały być obserwacje z odsłonięć i otworów wiertniczych. Chodziło tu o przypowierzchniowe deformacje osadów kenozoicznych, które miały charakter łusek, fałdów, wyciśnięć itp. o wergencji południowej. Jak wynika z nowych danych geofizycznych i głębokich otworów, na obszarze Wzgórz Ostrzeszowskich za wypiętrzenie utworów kenozoicznych są odpowiedzialne podłużne zręby zbudowane ze skał triasu górnego. Podobne formy tektoniczne najprawdopodobniej występują również w centralnej części Wzgórz Trzebnickich, na co wskazują dane z głębokich otworów wiertniczych wykonanych na ich północnych zboczach. Deniwelacje stropu monokliny przedsudeckiej dochodzą tutaj lokalnie do 70 m.

Jednym z zasadniczych problemów budowy geologicznej Wzgórz Trzebnickich jest wiek najwyższego poziomu morenowego, zaliczanego do zlodowacenia warty (E. Meister, 1935; C. Pachucki, 1952; M. Schwarzbach, 1942). Stwierdzono jednak, że górne gliny zwałowe ze Wzgórz Trzebnickich (w rejonie Wysokiego Kościoła i Miennic) przechodzą na obszar Równiny Oleśnickiej, tworząc tam morenę denną zaliczaną z kolei do zlodowacenia odry (E. Meister, 1935; M. Schwarzbach, 1942). Prace kartograficzne i wyniki analiz laboratoryjnych nie dały podstaw do wydzielania na obszarze Wzgórz Trzebnickich osadów zlodowacenia warty (J. Winnicki, 1990*b*). Znalazło to potwierdzenie (Fig. 3) w wiarygodnych statystycznie wynikach analiz petrograficznych tych glin (J. Czerwonka, 1984). Wykonane niezależnie od tego analizy petrograficzne górnego poziomu glin w cegielni na Winnej Górze metodą Lüttiga (J. M. Burdukiewicz, K.-D. Meyer, 1991) wykazały jednoznacznie, że pochodzą one ze zlodowacenia odry. Jednym z dowodów na obecność zlodowacenia warty na Wzgórzach Trzebnickich miały być tzw. sandry z ich południowego przedpola. Jak wykazano, pokrywy piaszczysto-żwirowe na znacznym obszarze Równiny Oleśnickiej nie są formami marginalnymi typu sandrowego i należy je wiązać z etapem deglacjacji zlodowacenia odry.

Obserwacje z obszaru Wzgórz Ostrzeszowskich i Trzebnickich wskazują, że wypiętrzenie tektoniczne osadów kenozoicznych i ich glacitektonika miały miejsce podczas zlodowacenia sanu. Wskazuje na to obecność glin zwałowych tego okresu leżących dyskordantnie na zaburzonych strukturach. Zaburzenia glacitektoniczne podczas zlodowacenia odry przyczyniały się do dodatkowej komplikacji budowy wewnętrznej niżej leżących osadów.

EXPLANATIONS OF PLATES

PLATE I

Fig. 11. Outcrop at Wisznia Mała — fluvioglacial formation in eastern wall
Odkrywka w Wiszni Małej — utwory wodnolodowcowe ściany wschodniej

Fig. 12. Ice pavement exposed archaeological excavation at the bottom of southern wall of working in brick-yard on Winna Góra Mt. in Trzebnica
Bruk morenowy odsłonięty podczas badań archeologicznych w spągu ściany południowej nowej odkrywki cegielni na Winnej Górze w Trzebnicy

PLATE II

Fig. 13. Erratic in culmination of fluvioglacial sediments (of so-called Siedlec Outwash) in region of Pierwoszowo
Głaz narzutowy w kulminacji osadów wodnolodowcowych (tzw. sandru siedleckiego) w rejonie Pierwoszowa

Fig. 14. Horizontally bedded sands and gravels in kame terrace in southern edge of Trzebnica Hills near Zapryn
Horyzontalnie warstwowane piaski i żwiry tarasu kemowego w krawędzi południowej Wzgórz Trzebnickich koło Zapryna

Fig. 11

Fig. 12

Fig. 13

Fig. 14