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On geological structure of the Ostrzeszów Hills

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Specific tectonic structure of sub-Cainozoic substratum played a decisive part in the origin of glaciotectonic deformations in the region of Ostrzeszów; the substratum is complicated here by the occurrence of proven horsts that are manifested by, among others, the occurrence of the oldest members of the Tertiary or even the Triassic — exposed on the land surface.

The position of the Odolanów Valley within block-type dislocation zones as well as a region of littoral sedimentation of Zechstein salt deposits contributed to the appearance of different cover structures with essential participation of halotectonic dislocations due to consecutive epeirogenic movements.

When young-Alpine movements affected the area, horsts (of NE–SW orientation) were formed in the axis of the present Ostrzeszów Hills; sedimentation which was taking place in the Poznań Basin situated in the southeastern part of the Fore-Sudetic Monocline was subject to differentiation with respect to these horsts. The horsts were reactivated and even considerably uplifted (though on a local scale) in the time of Pleistocene glaciotectonic deformations.

Apart from essential participation of water and differentiated compaction, shallow positive structures of stiff substratum within Cainozoic sediments in the south and a deep valley of the pre-Barycz River of tectonic setting in the north were the main factors that under subglacial conditions stimulated the development of shearing planes. This process resulted in the origin of many glaciotectonic structures within the Ostrzeszów Hills.

INTRODUCTION

The Ostrzeszów Hills situated at the southeastern end of the Wielkopolska Lowland are the easternmost part of the Trzebnica Ridge; the latter is clearly evidenced in Quaternary morphostructure of the Fore-Sudetic area. The Ostrzeszów Hills form the highest part of the ridge, with altitudes reaching 284.0 m above sea level at hill Kobyla Góra, 278.5 m a.s.l. in region of Mostki, and 278.0 m a.s.l. at hill Góra Bałczyna. The area extending westwards and north-westwards of the Ostrzeszów Hills is the Odolanów Valley — which is a part of the Milicz–Głogów Depression, with its bottom at the level of approx. 120 m a.s.l.

The Ostrzeszów Hills were for long a subject of interest of those geologists and geographers whose concern was the hills geological structure, and in particular — their origin. Tectonic concept of origin dominated first (W. Czajka, 1931; F. Frech, 1901, 1904, 1913, 1915; J. Gołąb, 1931, 1951; O. Tietze, 1910, 1915). However, the lack of weighty arguments was the reason for emerging a glacial tectonic idea, with its adherents represented by K. Rotnicki (1960, 1967) and S. Połtowicz (1961).

Investigations conducted so far were limited to geological observations of outcrops and relatively abundant in number, but shallow boreholes penetrating only the Cainozoic in the frame of exploration for mineral raw materials.

Exploration for and extraction of natural gas from the Odolanów Valley (scores of deep wells) and a number of exploration holes for brown coal carried out by the Geological Institute, Warsaw in the 1970's allowed for more complete representation of the geological structure of the region under consideration down to the horizon of Zechstein evaporites (inclusive). Moreover, the application of remote sensing method and geophysical data made it possible to analyse structurally the Permo–Mesozoic and Cainozoic cover. Based on this, and making additional use of the latest results of mapping within the Ostrzeszów sheet area of the *Detailed Geological Map of Poland* on the scale of 1:50 000 (J. Winnicki, in preparation *a*), the current state of knowledge

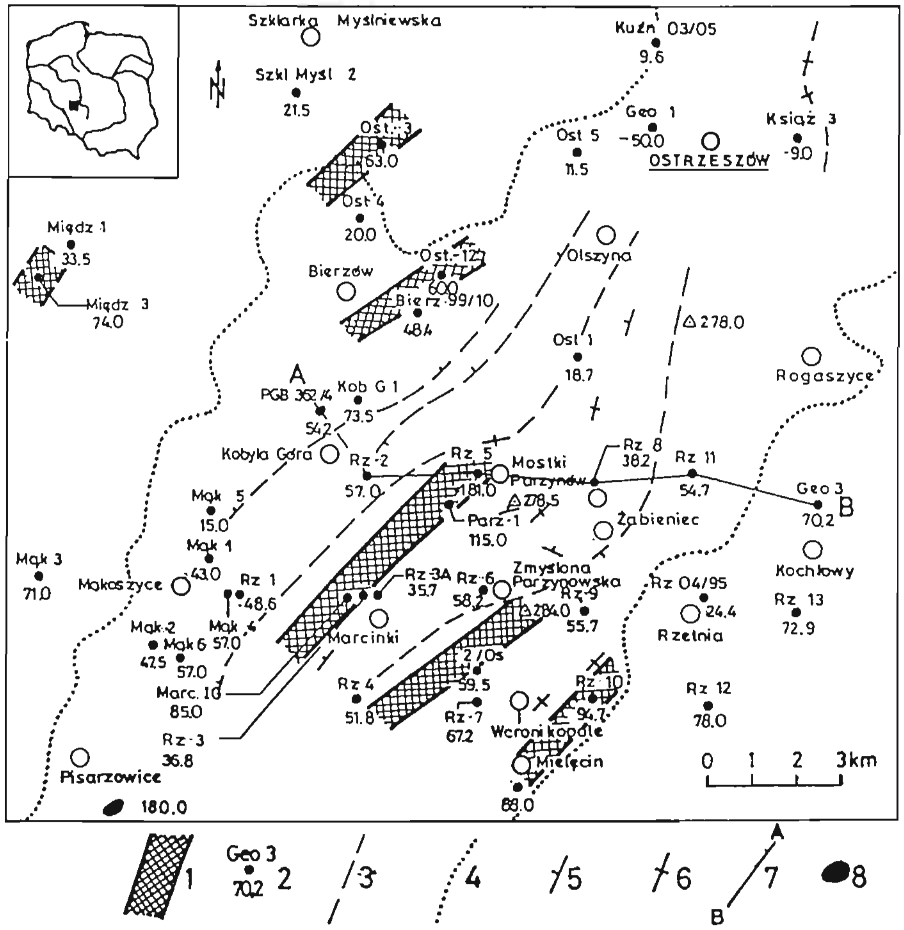


Fig. 1. Structural map of top of the Fore-Sudetic Monocline in the southern part of the Ostrzeszów Hills

1 — horsts; 2 — boreholes, with their numbers and altitude of top of the Fore-Sudetic Monocline indicated; 3 — orientation of more important glaciotectonic deformations; 4 — extent of surface occurrence of Cainozoic sediments deformations within the Ostrzeszów Hills; 5 — dip of most important glaciotectonic structures; 6 — axes of synclines and anticlines; 7 — geological cross-section; 8 — outcrop of Upper Triassic formation

Mapa strukturalna stropu monokliny przedsudeckiej południowej części Wzgórz Ostrzeszowskich

1 — zręby; 2 — otwory wiertnicze z nazwą i rzędną stropu monokliny przedsudeckiej; 3 — orientacja ważniejszych zaburzeń glacitektonicznych; 4 — zasięg występowania na powierzchni zaburzeń osadów kenozoicznych we Wzgórzach Ostrzeszowskich; 5 — pomiary upadu ważniejszych struktur glacitektonicznych; 6 — osie synklin i antyklin; 7 — linia przekroju geologicznego; 8 — wychodnia utworów triasu górnego

could be compiled on lithostratigraphic development of Cainozoic sediments, their glaciotectonic deformations, as wells as the structural framework of the Permo–Mesozoic substratum. The analysis of geological structure allowed for modified formulation of tectogenesis of the Ostrzeszów Hills and adjacent area; this was based on considerable influence exerted by the tectonic setting of the sub-Cainozoic substratum. The possibility of such treatment of the question is evidenced by proven Triassic horsts existing in the axis of the Ostrzeszów Hills (Figs. 1 and 2).

Tectonic movements that had an important bearing on differentiation of sedimentation within the Cainozoic sediments and their later deformations in the Odolanów Valley and the Ostrzeszów Hills were provoked by transregional endogenic processes that started in the Neogene. It is likely that halotectonic movements in the horizon of Zechstein chlorides were taking a considerable part in these processes (A. Markiewicz, in preparation). The authors are of the opinion that young-Alpine setting was rejuvenated through reactivation of cover structures due to the load exerted by ice-sheets in the Middle Pleistocene; this had an important bearing on the origin of the Ostrzeszów Hills.

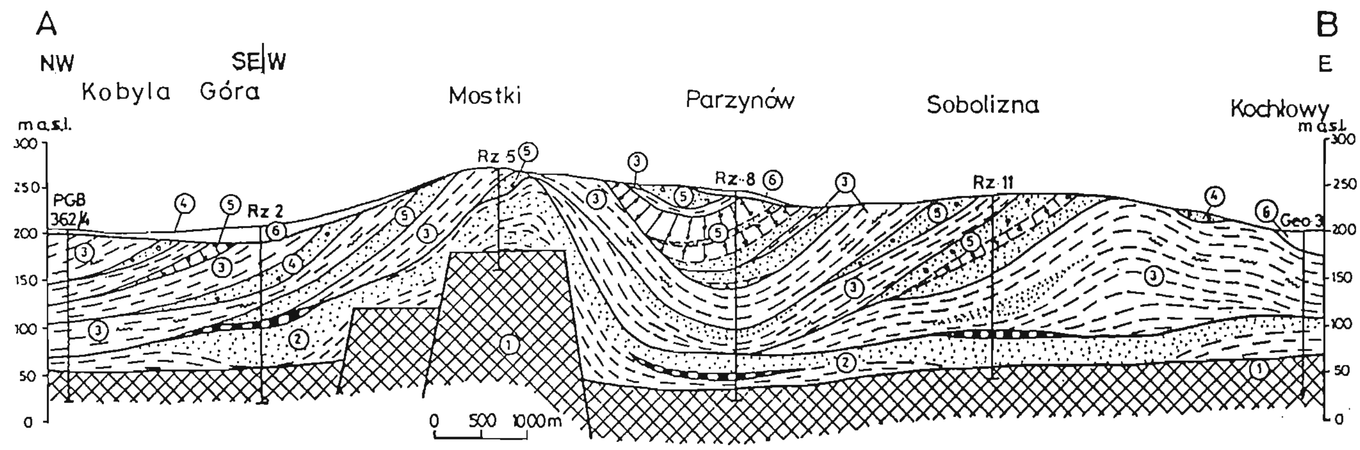


Fig. 2. Schematic geological cross-section through the Ostrzeszów Hills

1 — Upper Triassic: siltstones and claystones, secondary clays; 2 — Middle Miocene: sands, sands with gravels, so-called Ostrzeszów Quartzites, clays, brown coal; 3 — Upper Miocene: clays, silts, and sands; 4 — Pliocene: sands and gravels of Gozdnica Series; 5 — Middle-Polish Glaciations (mostly the Nidanian Glaciation): tills, fluvioglacial sands and gravels; 6 — Quaternary formations lying discordantly on disturbed substratum

Schematyczny przekrój geologiczny przez Wzgórza Ostrzeszowskie

1 — trias górny: mułowce i iłowce, podrzędnie iły; 2 — miocen środkowy: piaski i piaski ze żwirem z ławicami tzw. kwarcytów ostrzeszowskich, iły, węgle brunatne; 3 — miocen górny: iły, mułki i piaski; 4 — pliocen: piaski i żwiry serii Gozdnicy; 5 — zlodowacenia południowopolskie (głównie zlodowacenie nidy): gliny zwałowe, piaski i żwiry wodnolodowcowe; 6 — utwory czwartorzędowe leżące niezgodnie na zaburzonym podłożu

GEOLOGICAL STRUCTURE OF CAINOZOIC FORMATION

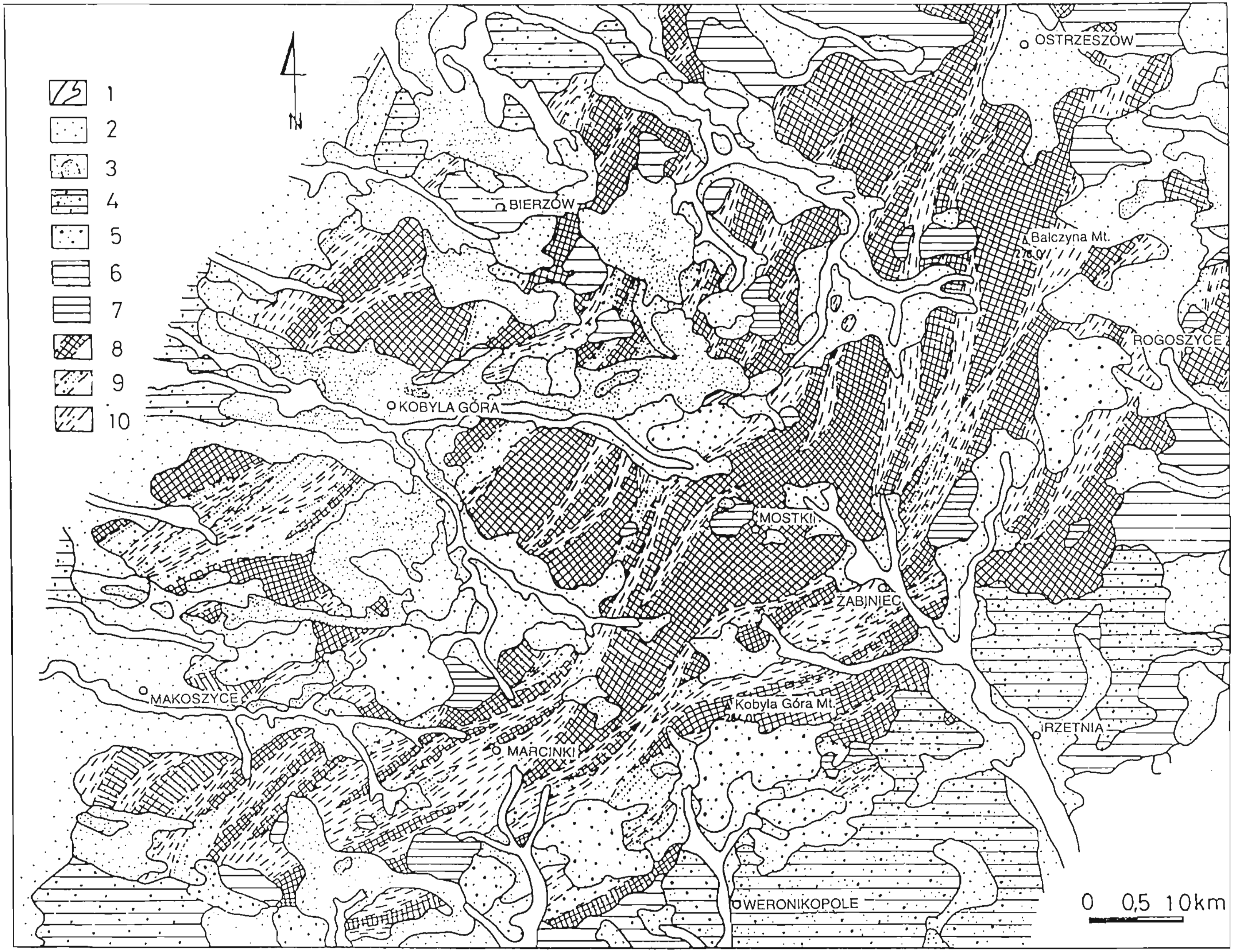
The Tertiary and Quaternary formations occurring in the Ostrzeszów Hills are strongly deformed and take part in both continuous and discontinuous tectonic deformations. Stratigraphic inversions are frequent; they consist in overlying a younger formation by an older one. Such is the case of the Rzetnia 3A borehole at Marcinki, where glacial till has been encountered at the depth of 147.5 m under overlying Neogene formation over 80 m thick. It is the deepest proven occurrence of Pleistocene sediments participating in such deformations. Detailed description of deformations of Quaternary and Tertiary sediments is contained in works by J. Gołąb (1931, 1951), S. Połtowicz (1961), and K. Rotnicki (1960, 1967).

A generalized image of surficial geology and style of deformations within the Cainozoic sediments in the Ostrzeszów Hills are shown in Figure 3.

Results of mapping evidenced that exposures of Tertiary and Quaternary members are met on the land surface, with all members different from each other with respect to their origin and stratigraphy. Width of exposures is several to dozen or so metres, which makes it impossible to plot them on the map (Fig. 3); accordingly, the map shows only complexes dominated either by the Tertiary or Quaternary sediments. Furthermore, cases were frequently observed when outcrops (of Miocene clays, for instance) were wedging out and replaced by glacial till (for example). This is why geological cross-sections compiled by S. Połtowicz (1961) and based on numerous shallow boreholes present only approximate style of the structure of Ostrzeszów Hills fragments. Such was the opinion of K. Rotnicki (1967) on this issue. Furthermore, a serious question emerged whether the glacial till and fluvioglacial sediments occurring on slopes of the Ostrzeszów Hills participate in disturbations or are overlying them discontinuously.

STRATIGRAPHY AND LITHOLOGY OF CAINOZOIC SEDIMENTS

The structural Cainozoic formation of the region of Ostrzeszów incorporates sediments of the Middle and Upper Miocene, Pliocene, and Quaternary. Characteristics of the oldest Tertiary members is based, first of all, on J. Gołąb's (1951) observations. A series of white and grey quartzic sands commences the Neogene profile; sands are locally enriched with brown coal dust and sometimes contain thin brown coal seams, most frequently they are underlain with clays interbedded with sand-gravel mixture or gravels. The series also contains layers of sand and gravel, strongly impregnated by silica. They reach a thickness of 3 m and are called the Ostrzeszów Quartzites. With respect to its lithology, the series under discussion shows very close similarity to the Gozdnica Series of Pliocene age; however, the latter is free of brown coal enrichment. Exact stratigraphic position of this series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ROGOSZYCE
KOBYLA GÓRA
MOSTKI
ŻABJNIEC
MAKOSZYCE
Kobyla Góra Mt.
MARCINKI
IRZETNIA
WERONIKOPOLE
0 0,5 10km

remains unknown; it can be either a member of the Middle-Polish Beds or Adamów Beds as well.

Overlying clays are grey or grey-bluish, sometimes olive-green, or chocolate brown, with streaks and lenses of brown coal, coal clay, and quartzic sands. Age of coal sampled in the Ostrzeszów 3 borehole was defined as Upper Badenian (K. Skawińska, 1989). The said formation has been assigned to the Middle-Polish Beds and the Lower Poznań Beds.

Sediments of the oldest Tertiary on the surface of the Ostrzeszów Hills were found only in their central part. Before the World War II the so-called Ostrzeszów Quartzites were mined in adits and excavations in region of Olszyna, Mostki, Zmyślona Parzynowska, and at hill Kobyla Góra. Earlier, an attempt was made to mine brown coal in the region of Olszyna (J. Gołąb, 1951).

Green and blue clays with sandy and muddy interbeddings of Upper Poznań Beds, with a horizon of Flamy Clays at their top have been included in the Upper Miocene. Frequently, they can be found on the entire surface of the Ostrzeszów Hills.

White sands and gravels of fluvial origin known as the Gozdnica Series terminate the Neogene profile. They can be correlated with the III and IV complex of this series in the Fore-Sudetic area, where its sedimentation was most likely ceased in the Older Pleistocene (J. Wojewoda *et al.*, 1995).

The Quaternary formation in the study area occurs in two positions: jointly with the Tertiary it builds up different tectonic structures or overlie them discordantly. Grey and dark grey glacial till, frequently strongly weathered, most likely deposited during the Nidanian Glaciation, and fluvioglacial sands and gravels (Fig. 1), and sometimes ice-dammed lake sediments participate in glaciotectonic deformations. Residual sediments are occasionally met; they also participate in the deformations (Fig. 2). A sandy and gravelly layer, 8 m thick, is observed in the exposure near Żabieniec; the layer contains numerous iron concentrations and pebbles and boulders of effectively weathered crystalline rocks. Together with adjoining formations, the sand layer is dipping north-westwardly at an angle of about 45°. As to origin of residual sediments, it can be linked with the Malopolanian Interglacial.

Granulometric-petrographic analyses of bronze-brown and chocolate brown glacial till (T. Dobosz, 1991) covering discordantly the deformations and appearing in the form of not large lobes (Pl. I, Fig. 10) have made it possible to

Table 1

Petrographic coefficients and limenes of tills lying discordantly on disturbances

Locality	O/K	K/W	A/B	Limenes [%]
Weronikopole	1.61	0.68	1.29	9.8
Rzetnia	1.42	0.77	1.15	6.8
Rogaszyce	1.39	0.78	1.19	8.7
Olszyna	1.44	0.74	1.27	8.3

establish age of Pleistocene sediments taking part in the deformations and the deformations themselves.

Glacial till of similar parameters, occurring within the Silesian Lowland, has been assigned to the Sanian Glaciation (J. Czerwonka, 1984). It is not excluded that fluvioglacial and ice-dammed lake sediments from the time of transgression of the Sanian Glaciation ice-sheet, initially deposited in this area and disturbed later in the Ostrzeszów Hills were also incorporated in the deformations.

The disturbed Cainozoic sediments discussed hitherto are discordantly overlain not only by glacial till of the Odranian Glaciation but also a formation of the Odranian Glaciation (J. Winnicki, in preparation *a*). Wide-spread exposures of glacial till of the latter were also found on slopes of the Ostrzeszów Hills in region of Bierzów, Ostrzeszów, Rogaszyce, Kochłowy, and Weronikopole. Up to altitude of about 200 m a.s.l. they are associated with a continuous fluvioglacial layer; it is positioned at the slope-foot and is morphologically clearly visible at the eastern and southeastern edge of the Ostrzeszów Hills. Other fluvioglacial layer, but situated at a higher altitude between 200 and 225 m a.s.l. evidences morphologically its occurrence in the region of Rzetnia (Pl. II, Fig. 11). Exposures of rock series belonging to the Odranian Glaciation and discussed so far are shown in Figure 3.

The formation of the Wartanian Glaciation was found neither here nor in the Trzebnica Hills (J. Czerwonka, 1984; J. Winnicki, 1990, 1992). Field observations supported by laboratory examinations uniformly demonstrated that the eastern part of the Trzebnica Ridge is of similar geological structure.

Fig. 3. General geological map of central part of the Ostrzeszów Hills

Holocene: 1 — river valley sediments; North-Polish Glaciation: 2 — slope wash, 3 — eolian sands and eolian sands in dunes; Odranian Glaciation: 4 — sands with fluvioglacial gravels, 5 — sands and gravels of crevasse-like accumulation, 6 — tills; Sanian Glaciation: 7 — tills; 8 — undivided Pliocene sediments (mostly of Nidanian Glaciation), secondary Neogene formation; 9 — sands and gravels of Gozdnica Series, secondary sediments of Pleistocene, and Upper and Middle Miocene; 10 — clays and silts of Upper Miocene, secondary formations of Pliocene, Gozdnica Series, and Middle Miocene

Mapa geologiczna centralnej części Wzgórz Ostrzeszowskich (zgeneralizowana)

Holocen: 1 — osady dolin rzecznych; zlodowacenie północnopolskie: 2 — osady deluwialne, 3 — piaski eoliczne i piaski eoliczne w wydmach; zlodowacenie odry: 4 — piaski ze żwirem wodnolodowcowe, 5 — piaski i żwiry akumulacji szczelinowej, 6 — gliny zwałowe; zlodowacenie sanu: 7 — gliny zwałowe; 8 — utwory nierozdzielone plejstocenu (głównie zlodowacenia nidy), podrzędnie neogenu; 9 — piaski i żwiry serii Gozdnicy, podrzędnie osady plejstocenu, miocenu górnego i środkowego; 10 — iły i mułki miocenu górnego, podrzędnie plejstocenu, serii Gozdnicy i miocenu środkowego

ZONES OF DEFORMATION OF CAINOZOIC SEDIMENTS IN THE OSTRZESZÓW HILLS AREA

Based on geological observations, three deformation zones can be distinguished within the Ostrzeszów Hills; they differ from each other in respect of style of deformation of Cainozoic sediments. All are of similar orientation, consistent with the direction of morphological axis of the hills. This fact was earlier strongly expressed by J. Gołąb (1931, 1951), S. Połtowicz (1961), and K. Rotnicki (1967).

The first zone (the proximal one) incorporates the western and southwestern slopes of the Ostrzeszów Hills. Scale structures dipping monoclinally towards the Odolanów Valley are dominant here (Fig. 2). Frequently visible is a vertical position of these structures. Detailed description of these discontinuous deformations has been given by K. Rotnicki (1960, 1967); this author expressed the view that the entire Ostrzeszów Hills are the monoclinal scale structure.

The middle zone (the transient one) in the central part of the Ostrzeszów Hills represents the most complicated inner structure. Making use of interpretation of geological cross-sections based on numerous exploration boreholes (for mineral raw materials), S. Połtowicz (1961) distinguished, apart from discontinuous structures, also anticlines (probably detached from their roots) overthrusted on the foreland as well as anticlines having their connection with bedrock. He was also of the opinion that degree of complication of inner structure should be decreasing with depth — accordingly, these forms should become more regular downwards. However, due to the lack of materials the S. Połtowicz's point of view could not be confirmed. Many observations from this zone were made available by J. Gołąb (1951), whose main concern was directed to the so-called Ostrzeszów Quartzites and associated formations. This author was of the opinion that sediments of the oldest members of the Tertiary were most often making up both synclines and anticlines. He also drew attention to the fact of local change in direction of these structures from SSW–NNE to SW–NE, and even to direction running evenly with a parallel of latitude. The J. Gołąb's observations were in part confirmed when conducting the field study.

The third zone (the distal one) incorporates the eastern and southeastern slopes of the Ostrzeszów Hills, where the Cainozoic sediments were noted in the anticlines and synclines in the region of Rogaszyce, Rzetnia, and Weronikopole. Discontinuous deformations in the form of scales are sporadic here. In the anticline near Weronikopole the formations that take part in the deformations include the Gozdnica Series, glacial till, and fluvioglacial sands (Pl. I, Fig. 9). The core of anticline contains the Flamy Clays of the Upper Poznań Beds. There is an agreement between the SSW–NNE orientation of mesostructures of asymmetric and overturned fold types and the direction of anticlinal axis (Pl. I, Fig. 9; Pl. II, Fig. 12); this fact suggests that the deformations were most likely formed simultaneously. Their width is in excess of 100 m.

Z. R. Olewicz (1961) presented the description of glaciotectonic deformations of Cainozoic sediments in region of Kalisz, at the extension of the Ostrzeszów Hills; their origin is connected with the time of the South-Polish Glaciation. However, both the synclines and anticlines making up Neogene formations of N–S direction and buried by the Quaternary sediments do not manifest themselves in the present-day morphology.

CONFIGURATION OF SUB-CAINOZOIC SURFACE

Along its segment from the Żary Upland to the Twardogóra Hills, the Trzebnica Ridge runs from NW to SE, parallel to the Marginal Sudetic Fault. The Ostrzeszów Hills being the last element of this unit are of SSW–NNE direction. Despite this fact, the German researchers (W. Czajka, 1931; F. Frech, 1901, 1904, 1913, 1915; O. Tietze, 1910, 1915) assumed that a horst deep-seated in the bedrock was responsible for the uplifting of Cainozoic sediments.

Both drilling and geophysical data from early period of exploration for natural gas indicated explicitly that the top of monocline is relatively flat and dips gently north-eastwards (Fig. 4). To those advocated to the idea of glaciotectonic origin of the Ostrzeszów Hills (S. Połtowicz, 1961; K. Rotnicki, 1960, 1967), this provided an important argument for the lack of relation between relief of older substratum and commonly observed deformations of Cainozoic sediments. Only for the Mielęcino region S. Połtowicz (1961) assumed that the change in the course of deformation zone from NW–SE to SSW–NNE was partly influenced by the edge of so-called Ostrzeszów reservoir which could be an erosional depression in the top of the Fore-Sudetic Monocline.

Based on new data acquired from drilling for brown coal and geophysical survey as well (S. Mżyk, 1992), a new image was obtain along the geological cross-section compiled for the Ostrzeszów sheet — showing quite different representation of top of the Fore-Sudetic Monocline (Fig. 1).

The occurrence of oblong horsts consistent in respect of their orientation with morphological axis of the Ostrzeszów Hills (NW–SE) has been noted in the region of Szklarka Myślniewska, Bierzów, and Mostki, and near the summit of Kobyla Góra Mt. Best documented is the horst between Mostki and Marcinki (Figs. 1 and 2). A top of sediments of Upper Triassic in the Rzetnia 5 borehole was encountered at 181.0 m a.s.l., in the Parzynów 1 — at 115.0 m a.s.l., and in the Marcinki IG 1 — at 85 m a.s.l. Moreover, when mapping the area of the Kępno sheet (on-going activity) of the *Detailed Geological Map of Poland* to the scale of 1:50 000, red-brown clays of Rhaetian age were encountered on land surface, at the altitude of about 180 m a.s.l., at the extention of this horst to the region of Pisarzowice (Fig. 1)(J. Winnicki, in preparation *b*). Height of remaining horsts is considerably lower.

In the Odolanów Valley, lying in the northern foreland of the Ostrzeszów Hills, the top of the Fore-Sudetic Monocline occurs at the average interval between 0 and 20 m a.s.l. Thus, differences in heights of the monocline top between the Odolanów Valley and the Ostrzeszów Hills is of the order of 160–180 m. Similar difference in height (162.3 m) is observed between the Rzetnia 5 and Ostrzeszów 1 boreholes within the Ostrzeszów Hills themselves (Figs. 1 and 2).

As interpreted from drilling and geophysical data, the horsts have sharp edges and they are not wider than 750–800 m. Siltstones and claystones of Upper Triassic (Keuper and Rhaetian) that build up the horsts are firm at the top, very often shaly; Rhaetian clays that are met here are slickensided and in principle, of not large thickness. In several boreholes the Lower Jurassic sediments were encountered; most often they developed in the form of fine-grained sandstones, with thin interbeddings of conglomerates, claystones, and siltstones.

GEOLOGICAL STRUCTURE OF SUB-CAINOZOIC SUBSTRATUM

In the region of Ostrzeszów the Cainozoic sediments lie discordantly on sedimentary cover of the east Permo–Mesozoic part of the Fore-Sudetic Monocline. A deeper substratum of the cover is made up of several tectonic blocks with folded formations of the Lower Carboniferous and Lower Namurian, both participating in rock assembly of southwestern zone of the Variscides (J. Oberc, 1972). The area under discussion lies between southwestern slope of the Wolsztyn Ridge and extended Oleśnica–Kępno Plateau. Differentiation of morphology of this Variscan surface had an important bearing on the character and thickness of Rotliegend (Saxonian) sediments being just only 50–100 m thick. Of similar considerable influence upon sedimentation of first lithostratigraphic horizons of Zechstein evaporites (Zechstein Limestone and Lower Anhydrite of Werra Cyclothem) was the morphology of Lower Permian surface.

Tectonics of sedimentary cover of the Permo–Mesozoic monocline developed during the Cimmerian and Laramide Phases as well as in the Tertiary. As a result of these large-scale deformations, drape structures of different types were formed in the discussed area (J. Sokołowski, 1974).

The occurrence in the structural plan the top of the Zechstein Limestone and Rotliegend of a number of elevated forms favoured the making of structural traps for natural gas which at present is being extracted from the Odolanów Valley.

Main discontinuities in the region of Ostrzeszów are of the character of tectonic fractures and intra-crustal discontinuities whose roots are extending downwards to a lower lithosphere and constitute a tectonic boundary of quasiautonomic structural blocks of upper order (M. Bal *et al.*, 1970).

Results of exploration and documentary works for oil and natural gas conducted in the region of Ostrzeszów as well as remote sensing survey (M. Graniczny, 1991) provide evidences on a complex disjunctive structure of the Permo–Mesozoic cover being of block character (Fig. 5). This was influenced by the superimposition of several tectonic directions including the WSW–ENE, NNW–SSE, NNE–SSW, and NE–SW ones and the secondary NW–SE one.

Faults of WSW–ENE direction are of the Variscan setting. They were rejuvenated in the Cimmerian and Laramide Phases and during the early Tertiary movements. On the basis of remote sensing this dislocation system has been interpreted as a superphotolineament of Tachov–Pinsk (M. Graniczny, 1991).

Faults running evenly with a parallel of latitude within the area under consideration includes the Sulmierzyce Dislocation Zone which has a character of antithetic graben with preserved Jurassic and partly Cretaceous formations, with the latter separating the lowered zone of Krotoszyn–Sulmierzyce from the elevated zone of Bogdaj–Tarchały.

Faults of NNW–SSE direction in the western part of the discussed area between Milicz and Oleśnica are incorporated in great dislocation zone of Poznań–Oleśnica which evidenced its activity already in the Lower Permian (P. Karnkowski, 1980). It is composed of several parallel dislocations of "step" type, that decline, in general, to the east. This faults form tectonic grabens of block-wedge structure; their origin is connected with several phases starting from the Upper Keuper to the Quaternary (W. Grocholski, 1991). Moreover, the same tectonic direction includes the Parzynów–Uciechów Dislocation of overthrust character which is indicated by data from the Uciechów 2 and Uciechów 3, Garki 3 and Garki 4 boreholes. Overthrusting the western block on the eastern one and extinguishing in the Oldest Halite Horizon, this structure was induced to originate by salt tectonics. Vertical amplitude of this overthrust in the Buntsandstein formation is about 300 m. There is no reflection of this dislocation in the lower members of the Zechstein and Buntsandstein. Analogous dislocation structures are the tectonic grabens of NW–SE direction in the gas field at Wierzchowice.

Faults of NNE–SSW direction form the Tertiary tectonic grabens. These directions of local pivotal character separate and displace the anticlinal elevations (which is the case of the Bogdaj–Uciechów field and Henrykowice as well). On the other hand, faults of NE–SW trend that are recorded on seismic sections form tectonic grabens such as those in the Triassic formation in the Brzostowo field where their amplitude is of the order of 50–100 m. Among other, also the Świeca–Wysocko Dislocation has been assigned to these tectonic zones (Fig. 5); this dislocation is composed of two pivotal faults situated at a distance of about 1 km from one another and forms a graben the amplitude of which — counted at the top surface of the Middle Buntsandstein — can be as great as 200 m.

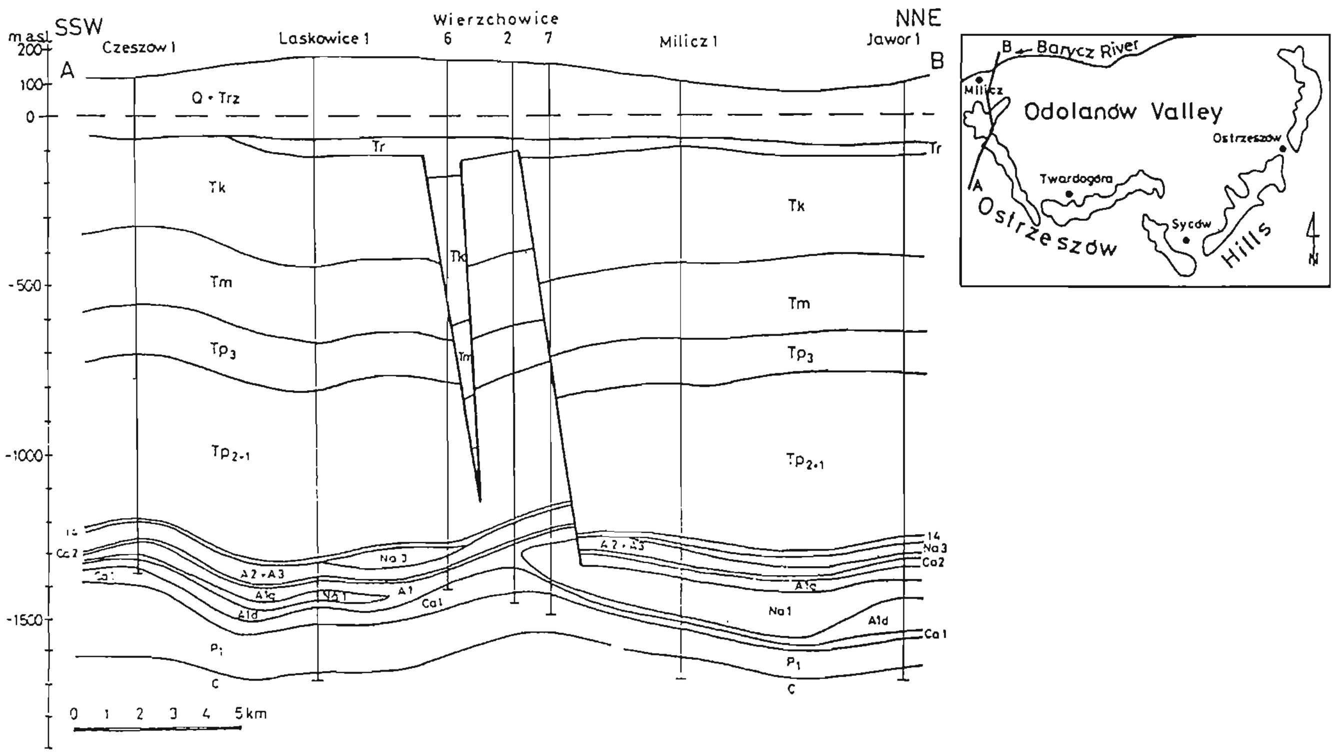

Fig. 4. Geological cross-section through Czeszów 1–Jawor 1 boreholes (after A. Malarczyk and J. Żurawik, 1973)

Q + Trz — Quaternary and Tertiary; Tr — Rhaetic; Tk — Keuper; Tm — Muschelkalk; Tp_3 — Upper Bundsandstein (Roethian); Tp_{2+1} — Middle and Lower Bundsandstein; I4 — transitional claystones; Na3 — Zechstein Salts; A, A1, A1d, A1g, A2, A3 — anhydrites; Ca2 — Main Dolomite; Ca1 — Zechstein Limestone; P_1 — Rotliegend; C — Carboniferous

Przekrój geologiczny Czeszów 1–Jawor 1 (według A. Malarczyka i J. Żurawika, 1973)

Q + Trz — czwartorzęd i trzeciorzęd; Tr — retyk; Tk — kajper; Tm — wapień muszlowy; Tp_3 — pstry piaskowiec górny (ret); Tp_{2+1} — pstry piaskowiec środkowy i dolny; I4 — iłowce przejściowe; Na3 — sole cechsztyńskie; A, A1, A1d, A1g, A2, A3 — anhydryty; Ca2 — dolomit główny; Ca1 — wapień podstawowy; P_1 — czerwony spągowiec; C — karbon

The discontinuity of faults in the Triassic formation and the lack of their reflection in formation underlying the Oldest Halite is commonly observed in natural gas fields in the region of Ostrzeszów (Fig. 4). Such a situation is caused by post-sedimentary and disharmonic deformations of chloride sediments on the plan of the Permo–Triassic overburden being subject to dislocation in a block-like mood. This is connected with the fact that salt layers were markedly extinguishing stresses, thus compensating the Cimmerian, Laramide, and younger movements. Due to such a situation, three distinct structural stages can be distinguished in the post-Variscan cover:

— the Lower Permian stage comprising a group of formations from the Rotliegend to Lower Anhydrite of Werra Cyclothem (inclusive),

— the Cimmerian–Laramide stage comprising the Triassic and upper parts of Zechstein formation,

— the Cainozoic formation.

With respect to its geological structure, the Ostrzeszów Monocline can be assigned to fold-block structures — whose origin is connected with interference of the Variscan and Alpine directions (J. Sokołowski, 1974). A serious part in them is played by compaction structures and anticlinal structures situated overburied Variscan ridges, as well as halotectonic structures that formed as a result of younger movements of the cover.

Narrow depressional zones superimposed on grabens of direction close to SW–NE were formed in periods of tensional stresses during the Old-Cimmerian Phase. On the other hand, dominant in the Jurassic and Cretaceous was the NW–SE direction of subsidence; this direction is reflected in the form of grabens that are filled with sediments of Keuper, sometimes Rhaetian or even Liassic, of increased thickness.

The Laramide uplifting of the monocline as the whole caused, among others, dipping of strata at an angle of 3–4° towards NE; then, the removal of sediments followed in the Lower Tertiary, that left untouched younger formations including the Cretaceous in zones formerly visibly depressed and in grabens. Furthermore, these movements caused a belt-like arrangement of subsurface exposures of strata in the Tertiary substratum, with dominant gravity faults of WNW–ESE trend and reverse faults of NW–SE orientation.

The rejuvenation of older faults in the Fore-Sudetic Monocline, that happened in the Tertiary, consisted in activation

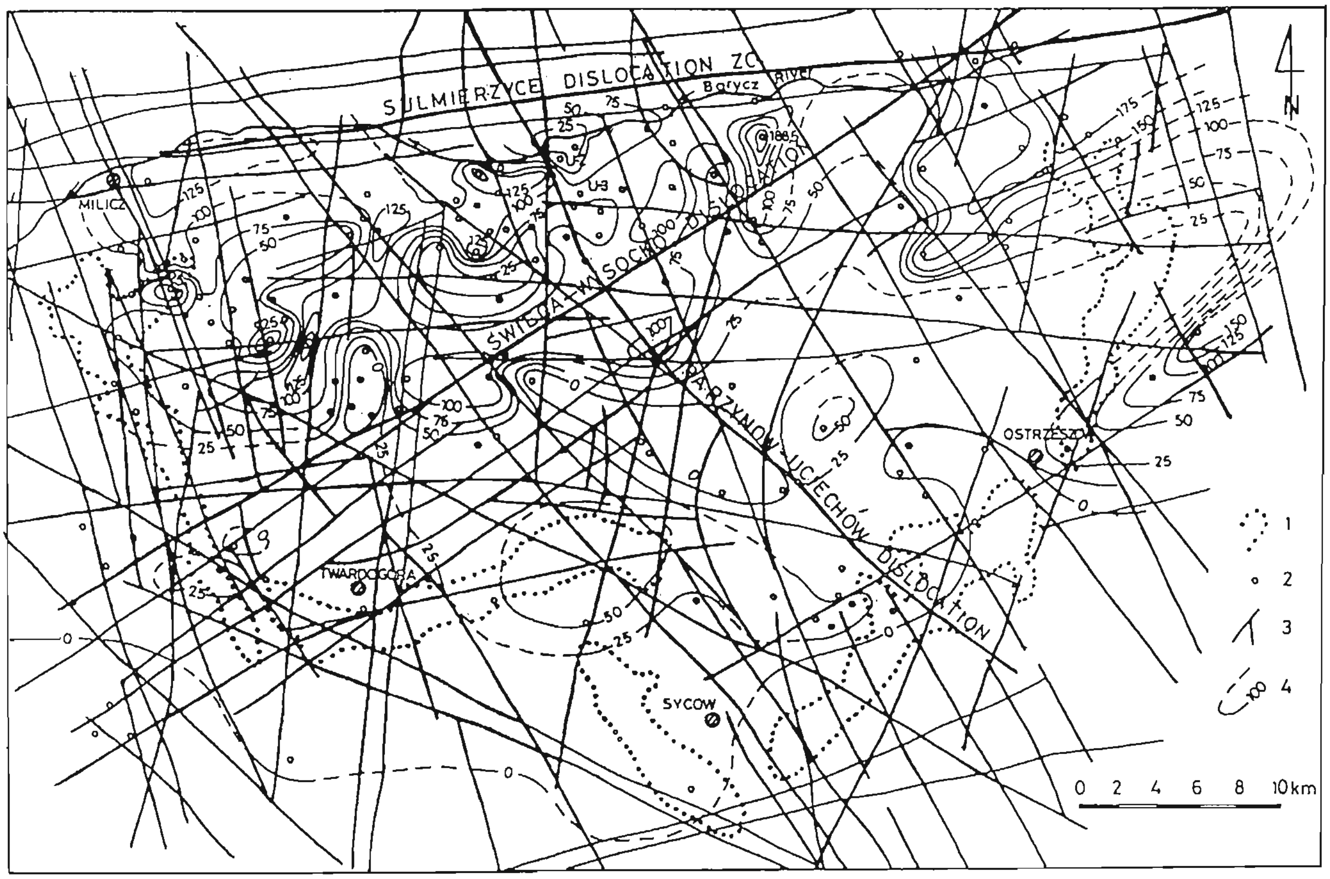

Fig. 5. Map of total thickness of Zechstein salt formations (Na1 + Na3) against the background of tectonic lines in the region of Ostrzeszów (after A. Markiewicz)
1 — zones of glaciotectonically pushed and deformed Neogene and Pleistocene sediments; 2 — gas wells; 3 — faults interpreted from both remote sensing and geophysical data; 4 — isopach of total thickness of salts of PZ1 + PZ3 Cyclothems

Mapa sumarycznych miąższości cechsztyńskich utworów solnych (Na1 + Na3) na tle linii tektonicznych — rejon Ostrzeszowa (według A. Markiewicza)
1 — strefy wyciśniętych i zaburzonych glacitektonicznie osadów neogenu i plejstocenu; 2 — otwory gazowe; 3 — uskoki wyinterpretowane z danych teledetekcyjnych i geofizycznych; 4 — izopachyta sumarycznej miąższości soli cyklotemu PZ1 + PZ3

and block movements along the NE–SW direction first, then along the NW–SE to WNW–ESE directions. Thus, an important influence was exerted on intensity and facial differentiation as well as on the southern and eastern extent of the deposition of sediments in particular substages of the Tertiary reservoir (S. Dyjor, 1978).

A number of oval and ellipsoidal structures (not shown in Fig. 5) have been detected in a remote sensing image of considered area (J. Bażyński, J. Sokołowski, 1976). Their origin can be attributed to neotectonic uplifting of Triassic blocks in the sub-Cainozoic horizon, at essential share in this process of halotectonic movements of Zechstein chlorides (A. Markiewicz, in preparation).

STRUCTURAL DEVELOPMENT OF SALT DEPOSITS

In the eastern part of the Fore-Sudetic Monocline the Zechstein is represented by sediments of all of the cyclothems; however, locally they can be partly reduced. No doubt, the sedimentation of these evaporites was influenced, apart from differentiation of post-Variscan substratum, by the existence of a barrier zone that developed on a morphological escarp; this escarp was controlled by step-like displacements that were taking place in the dislocation zone of Jelenia Góra–Wrocław–Piotrków Trybunalski–Brześć running evenly with a parallel of latitude (J. Sokołowski *et al.*, 1984).

A belt of relatively shallow lagoonal and back barier sea of variable morphology of its bottom, running on the southern side of a line connecting Żmigród and Ostrzeszów was the environment where sediments developed in facies characteristic to sublittoral and shallow-neritic environments (J. Sokołowski, 1967). This area is characterized by increased

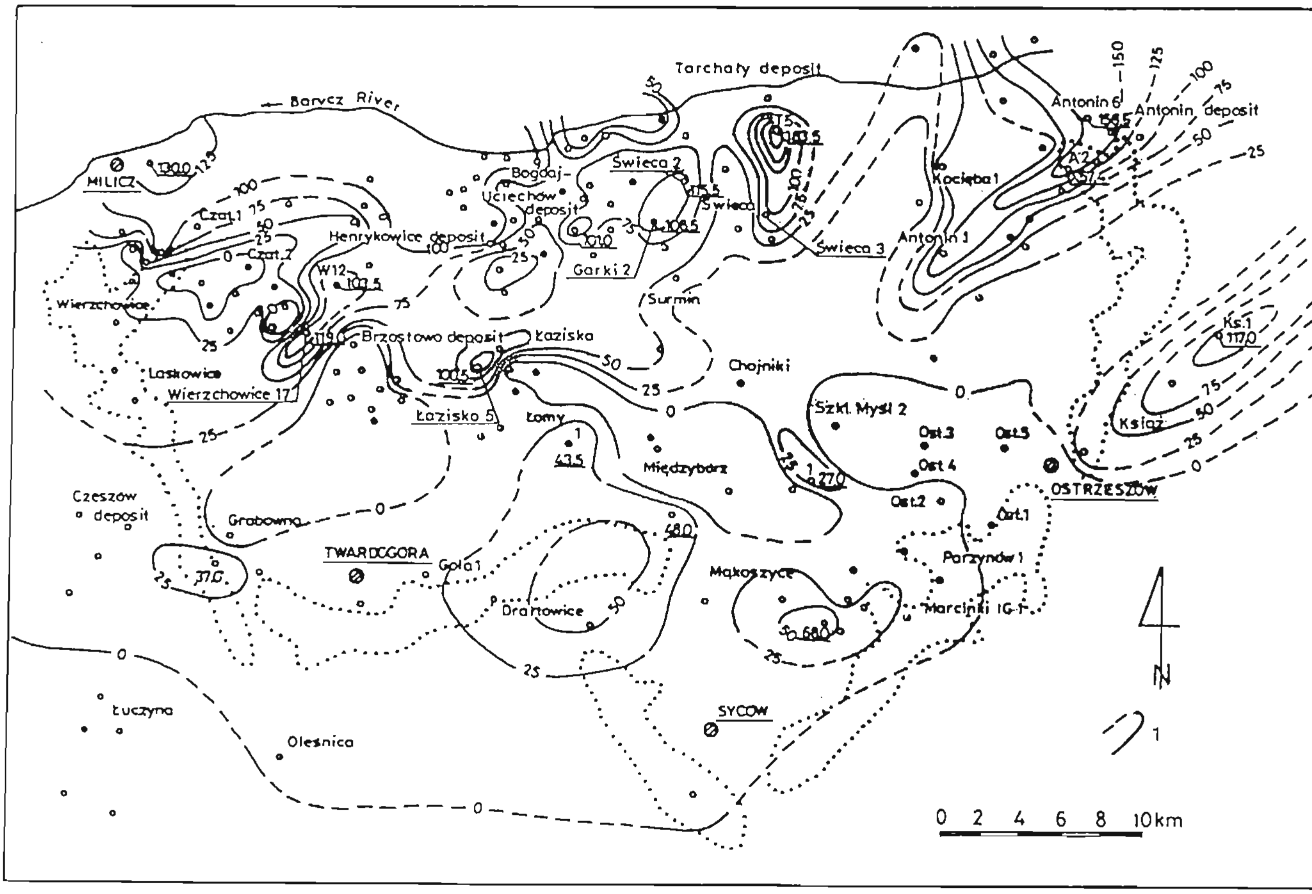

Fig. 6. Isopach map of the Oldest Halite Na1 — region of Ostrzeszów (after A. Markiewicz)
1 — isopach of salt formation Na1; for remaining explanations see Fig. 5

Mapa izopachytowa najstarszej soli kamiennej Na1 — region Ostrzeszowa (według A. Markiewicza)
1 — izopachyta utworów solnych Na1; pozostałe objaśnienia jak na fig. 5

thickness of Zechstein Limestone and anhydrite and by decreased thickness of rock salts, particularly those in the Werra Cyclothem.

For the occurrence of Zechstein chloride sediments, the Ostrzeszów region constitutes a littoral zone with the southernmost extent of the Oldest Halite (Na1) and the extent of the remaining cyclothems shifted to the north. J. Zwierzycki (1951) was the first to suggest the likely occurrence of rock salt in this part of Poland. This suggestion was entirely confirmed in the course of consecutive exploration for oil and gas.

A comprehensive monograph of Zechstein anhydrites and salts in the Fore-Sudetic Monocline, with the region of Ostrzeszów also discussed, has been prepared by T. Peryt *et al.* (1992).

The Oldest Halite (Na1) of the Werra (PZ1) Cyclothem. As revealed by drilling, their thickness is at present differentiated and ranging from 0 to 183.5 m in the Tarchały 5 borehole (Fig. 6). As the boreholes in the northeastern part of field at Antonin have not penetrated the salt body to its very bottom, it is difficult to determine its extent and size in the littoral part of evaporative basin. In general, a distinct increase of thickness of the Oldest Halite (Na1) can be observed along a NE–SW line connecting the Antonin 6 (158.5 m), Antonin 2 (157.5 m), and Antonin 1 (121.0 m) boreholes. Salt is lacking in the region of Szklarka Myślniewska 2 borehole which together with other boreholes such as the Ostrzeszów 1, Ostrzeszów 3, Ostrzeszów 4, and Ostrzeszów 5 documents a deep salt-free bay in the proximity of Ostrzeszów.

Not large salt pillows occur westwards of the salt swell within the Antonin field; they were encountered in the following boreholes: Świeca 5 (99.5 m), Tarchały 5 (183.5 m), Garki 2 (108.5 m), Świeca 2 (116.5 m), Łazisko 5 (100.5 m), Wierzchowice 12 (103.5 m), and Wierzchowice 17 (119.0 m).

A wide belt extending along the line of Syców–Twardogóra–Milicz allows for observation of characteristic diversity in thickness of the oldest chloride sediments (Fig. 6). Not large isolated salt-free zones are noted here; such a situation exists, for instance, in the region of Międzybórz (along a WNW–ESE line), and in fields at Brzostowo and Wierzchowice. Moreover, the Lower Anhydrite (A_d) and Upper Anhydrite (A_g) were found in the gas wells installed in these zones; frequent-

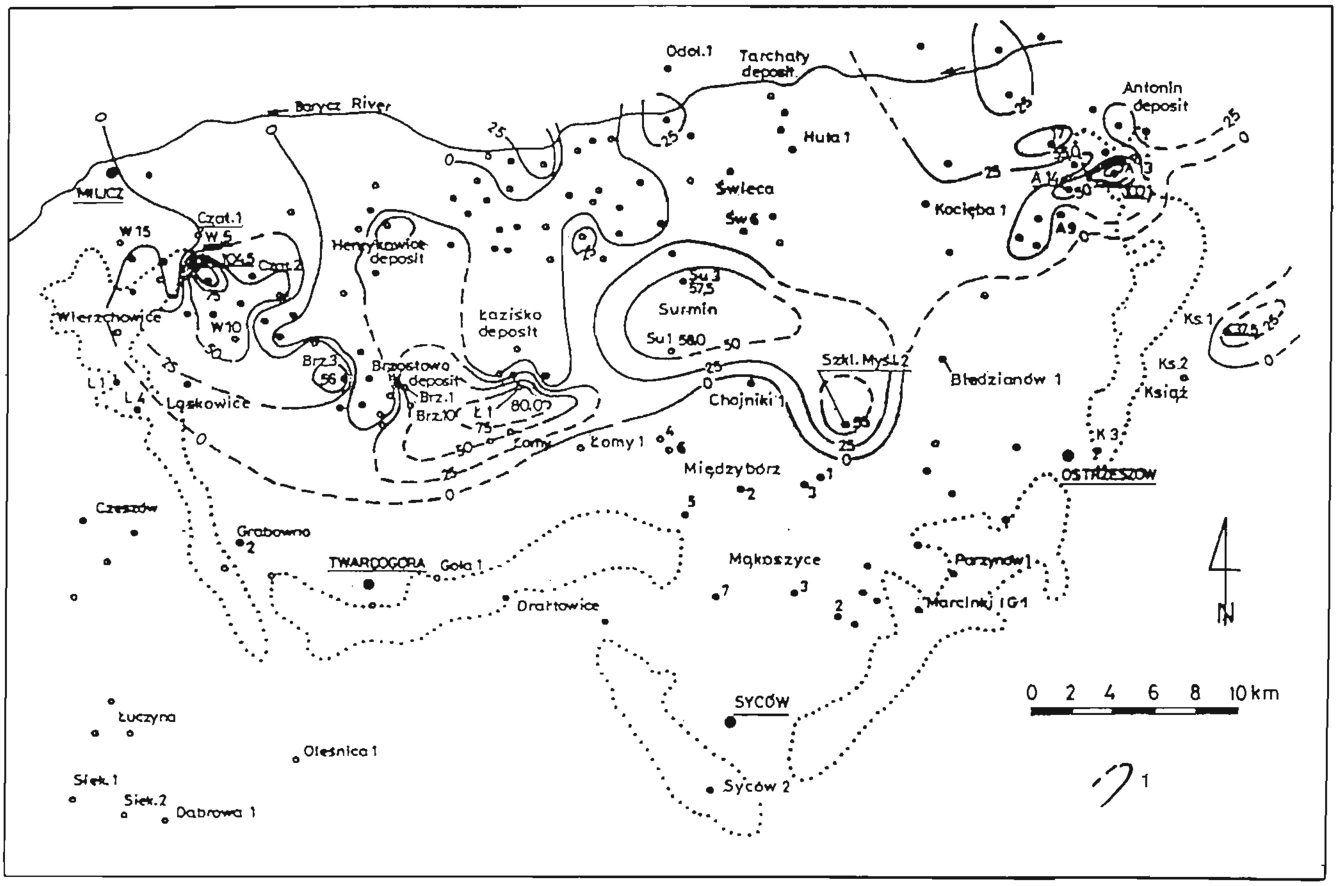

Fig. 7. Isopach map of the Younger Halite Na3 — region of Ostrzeszów (after A. Markiewicz)
1 — izopach of salt formation Na3; for remaining explanation see Fig. 5

Mapa izopachytowa młodszej soli kamiennej Na3 — rejon Ostrzeszowa (według A. Markiewicza)
1 — izopachyta utworów solnych Na3; pozostałe objaśnienia jak na fig. 5

ly, the anhydrites are separated by an anhydritic-clayey breccia.

Therefore, some regularity can be observed in the structural image of salts in the Na1 horizon, consisting in immediate neighbourhood of salt-free regions with salt pillows or salt swells surrounding the salt-free regions in the east and west, and sometimes also in the south.

The Older Halite (Na2) of the Stassfurt (PZ2) Cyclothem. These sediments are lacking over dominant part of the area under consideration. These salts were encountered on a local scale only in the following boreholes: Topola 1, Przygodzice 1, Antonin 9, and Antonin 14; salt thickness in all boreholes cited does not exceed 15 m.

The Na2 salts are underlain by 4.5 m thick series of Screening Anhydrite (A_g) (K. Słupczyński, 1979).

The Younger Halite (Na3) of the Leine (PZ3) Cyclothem. These sediments developed in the form of rock salt layer several metres thick, containing interbeddings of red clays and siltstones. They appear northwards of a line running through a number of boreholes such as: Bledzianów 1, Międzybórz 1, Międzybórz 4, Łomy 1, Grabowno 2, Laskowice 4, Laskowice 1, and Wierzchowice 15 (Fig. 7). Thickness of the Na3 salts is, in dominant number of cases, in the range of 9 to 86 m. To the west — in the Antonin field, and to the north — in the Wierzchowice field (Fig. 7), thickness of the Na3 salts is considerably greater (Fig. 7).

A distinct salt swell has been noted in the Antonin field; it is of NE–SW orientation and is documented in a group of boreholes designated Antonin 13 (100 m), Antonin 14 (71 m), and Antonin 17; on the other hand a salt pillow (104.5 m thick) was encountered in the Wierzchowice 5. A series of salt crests can be observed between these two culminations at extreme locations; the salt crest occur arranged along irregular bend running from the west eastwards through the line of boreholes: Wierzchowice 10 (53 m), Brzostowo 3 (55 m), Brzostowo 10 (65 m), and Brzostowo 1 (67.5 m), Łazisko 1 (80 m), and Szklarka Myślniewska 2 (55 m).

The littoral zone of increased thickness of the Younger Halite (Na3) borders in the north on the digital bifurcation of the salt-free zone in the region of gas fields at Garki, Bogdaj–Uciechów, Łazisko, Henrykowice, and Brzostowo.

A great diversity at not large distances (of the order of 1.5 km) is observed in the image of isopach development of the Younger Halite (Na3); such a situation occurs along the

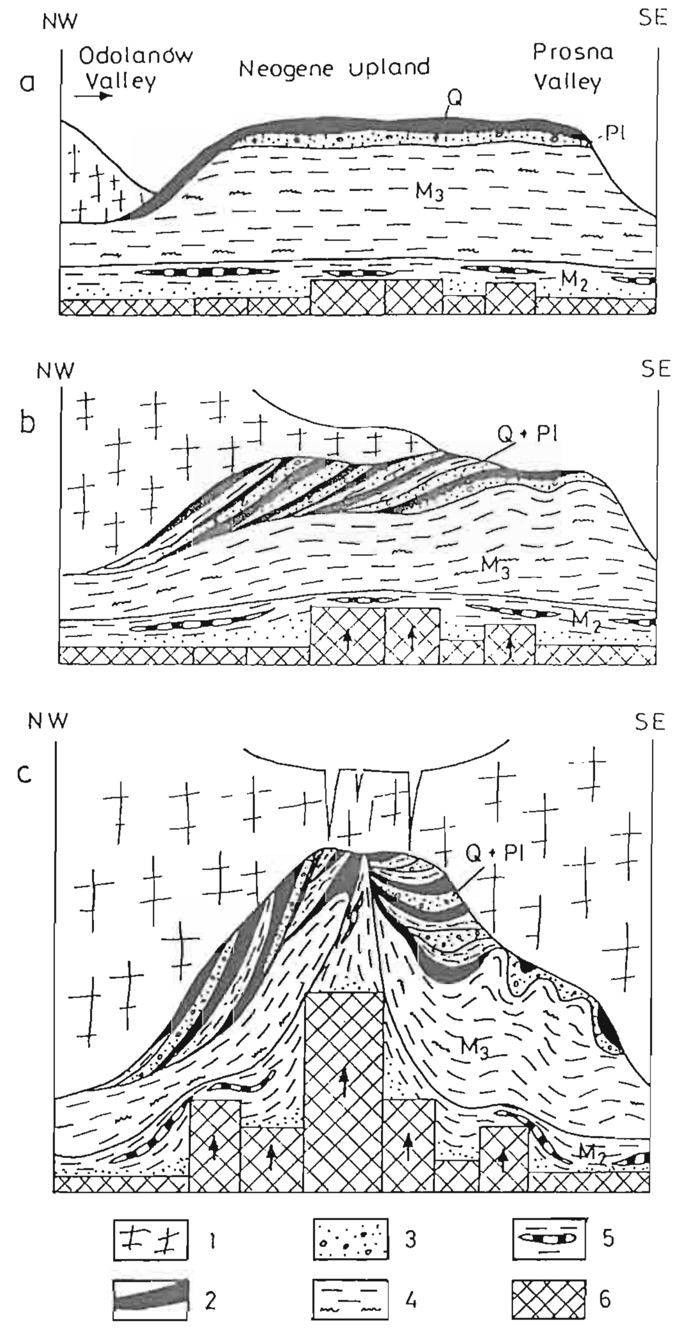

Fig. 8. Hypothetical sequence of tectonic processes in the region of Ostrzeszów Hills: a — stage of ice-sheet transgression to the area of Odolanów Valley; b — stage of advanced transgression of ice-sheet; c — stage of deglaciation

Pleistocene: 1 — continental ice-sheet, 2 — sediments predominantly of Nidanian Glaciation; Pliocene–Older Pleistocene: 3 — sands and gravels of Gozdnica Series; Upper Miocene: 4 — clays and silts; Middle Miocene: 5 — clays intercalated with brown coal and sands; Triassic and Jurassic: 6 — claystones, siltstones, secondary clays and silts

Hipotetyczne następstwo procesów tektonicznych w rejonie Wzgórz Ostrzeszowskich: a — etap transgresji lądolodu na obszar Kotliny Odolanowskiej, b — etap pogłębionej transgresji lądolodu, c — etap deglacjacji lądolodu

Plejstocen: 1 — lądolód, 2 — osady głównie zlodowacenia nidy; pliocen–starszy plejstocen: 3 — piaski i żwiry serii Gozdnicy; miocen górny: 4 — iły i mułki; miocen środkowy: 5 — iły z wkładkami węgla brunatnego i piasków; trias i jura: 6 — iłowce, mułowce, podrzędnie iły i mułki

WNW–ESE direction between the Antonin 10 and Antonin 14 boreholes (26 and 100 m, respectively), and along the N–S direction between the Antonin 2 and Antonin 14 (0.5 and 71 m of salt, respectively). It should be noted that tectonic zones of NE–SW trend, decisive for such anomalous diversified thickness run in both cases between the boreholes indicated.

The Youngest Halite (Na4) of the Aller (PZ4) Cyclothem occur only locally in the Odolanów Valley where they reach a thickness of 30 m in the Antonin field and 80 m in the field at Łaziska.

Thus, the analysis of development of Zechstein salt deposits in the region of Ostrzeszów points to a distinct differentiation of salt thickness, particularly in the Werra and Leine Cyclothems. The salt bodies form swells, pillows, and crests oriented consistently with the tectonic lines creating tectonic blocks in the overburden (Fig. 5). The salt bodies are elongated in the NE–SW and NNE–SSW directions in the eastern part while a distinct change in the arrangement of salt bodies is observed to the east of the Parzynów–Uciechów Dislocation; the change consists in the appearance of irregular forms the origin of which was under the influence of activation of NW–SE, WNW–ESE, NNE–SSW, and NNW–SSE tectonic directions.

Tops of particular salt layers are morphologically diversified, which is mainly dependent on thickness of these sediments. Predominantly, elevations of salt top surfaces correspond to increased thickness, and *vice versa.* This is consistent with J. Sokołowski's (1967) and A. Markiewicz's (1995) observations; both researchers noted that halotectonic displacement of Zechstein salts had took place in the southwestern part of the Fore-Sudetic Monocline. Similar secondary tectonic deformations of salt deposits in the region of Ostrzeszów can be concluded from the following observations:

1. A sedimentary-facial analysis (T. Peryt *et al.*, 1992) does not provide a sufficient explanation to such serious differentiation in thickness of the Zechstein chloride sediments.

2. Neither reflection nor continuation of faults in the Triassic exists in the formation underlying the Oldest Halite. This is connected with an accord between both the elongation and shape of Zechstein salt bodies and the course of faults making up the blocks of the Permo–Mesozoic overburden.

3. Granoblastic and fusiform overfoldings of salt packages along with the occurrence of hair-salt are observed in cores of salt sediments; all these phenomena are generated as a result of strong linear recrystallization caused by the influence of additional tectonic stresses. Furthermore, thin sections show distinct crack systems, accentuated cleavage, and elongated crystals whose edges have recrystallized character (T. Peryt *et al.*, 1992).

The foregoing observations indicate that the present tectonic position of Zechstein salts in the southwestern part of the Fore-Sudetic Monocline results both from their original sedimentary position and their halotectonic displacement resulting from specific mechanical properties of chloride sediments as the rocks particularly sensitive to plastic deformations and translation under the influence of additional stresses.

There is no doubt that the halotectonic movements compensated the epeirogenetic movements within the Permo–Mesozoic cover, that were taking place on the turn of the Jurassic and Cretaceous first, then on the turn of the Cretaceous and Tertiary, and in the Younger Tertiary as well. One can assume that the process of halotectonic displacements was also taking place during the Pleistocene. These tectonic movements can be connected with the compensation in the lithosphere within the foreland of continental ice-sheets disturbing the glacioisostatic balance, as well as with processes resulting from irregular load exerted on deeper bedrock in the ice-sheet frontal zone (A. Markiewicz, in preparation).

CONCLUSIONS

Localization of the Odolanów Valley and Ostrzeszów Hill arch within the dislocation zones of block structures (whose development was essentially influenced by the halotectonic movements of the Zechstein chloride sediments)(Figs. 4 and 5) is of particular importance for the reconstruction of the entirety of factors stimulating the origin of deep glaciotectonic deformations in the area under consideration.

Development of glaciotectonics in this area was favoured by diversified geological structure of the Neogene upland with positive structures of stiff substratum (horsts), as well as the presence (more to the south) of the pre-Barycz Valley with its setting of tectonic character (Fig. 5).

Young-Alpine block movements (of the Styrian Phases?) along with the local uplifting of horsts had an important bearing on sedimentation of Tertiary formation making up the upland.

The upland was built up of the Middle Miocene formation of the Upper Poznań Beds and the Gozdnica Series (the III and IV complexes after J. Wojewoda's division), and additional glacial and fluvioglacial sediments of the Nidanian Glaciation (Fig. 8a).

In the buried valley of the pre-Barycz and its escarpments (in the Odolanów Valley area) the series of ice-dammed lake deposits and fluvioglacial ones — connected with the transgression of the Sanian ice-sheet — were probably deposited on the older Pleistocene formations. The Sanian Glaciation was that time when main glaciotectonic processes (Fig. 8b) and the tectonic ones — those that formed the Ostrzeszów Hills (Fig. 8c) — were taking place.

Results of lithostratigraphic analyses of Quaternary sediments and reports of antecedent gorges in the Trzebnica Hills (J. A. Czerwonka *et al.*, 1991) provide evidence of periodic movements of alternating uplifting and lowering character. Moreover, these movements are indirectly evidenced by some Triassic horsts (having their tops at the altitude of 180 m a.s.l.), that in the undisturbed areas adjacent to the Trzebnica Ridge protrude in a distinct way over the Neogene surface. The region of Środa Śląska with the Neogene surface at 140–145 m a.s.l. is given here as the example of the case.

It is obvious then that the Pleistocene tectonic processes were initiated by those movements that associated the deflection of the lithosphere due to isostatic balance being disturbed by transgressing Scandinavian ice-sheet. These movements could reactivate the cover structures in the sub-Cainozoic substratum; the halotectonic movements could also be of considerable part.

The block movements of deeper substratum transmitted by the Cainozoic complex differentiated stresses being active at the bottom of approaching ice-sheet swelling in mass in the Odolanów Valley (a transition zone — after K. Brodzikowski, 1982). A contribution to this process was made by additional compaction of variable intensity and making flexible the sediments in shallow substratum due to action of water. All of these forced tangential stresses in the ice-sheet to be active and, according to W. Jaroszewski's (1991) hipothesis, contributed to cylindrical shear in the sedimentary substratum to come into being. This process was favoured by the occurrence of anisotropic surfaces in the diversified Cainozoic complex with positive structures of horst type already pronounced (Fig. 8b). This resulted in decollementing, displacing, then overthrusting of Cainozoic sediments strata — which took place on proximal slopes of positive structures of sub-Cainozoic surfaces in the form of wedging scales. Furthermore, continuous deformations originated at the same time within their further zones; at present, they are visible on their distal sides.

The most important structure-forming stage took place in the time of deglaciation (Fig. 8c). Diversified gravitational effect of disintegrating ice-sheet could influence the regeneration of block movements in their bedrock; this included the uplifting of horsts towards land surface in zones of axial segments of the hills unaffected by load. Process of ice-sheet disintegration was probably followed by a considerable share of increased amount of heat that was migrating upward along the activated faults. A zonal influence was exerted by dead-ice blocks formed in such a way; due to such zonal influence the extrusion folds were formed in the shallow Cainozoic substratum between the dead-ice blocks. This was also a stimulus for diapir-like squeezing of Tertiary sediments of Middle Miocene in age, thus for additional complication of glaciotectonic structures.

In the time of Middle-Polish Glaciations the Ostrzeszów Hills already dominated in morphology of this part of Wielkopolska (T. Bartkowski, 1967).

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UWAGI O BUDOWIE GEOLOGICZNEJ WZGÓRZ OSTRZESZOWSKICH

Streszczenie

Wzgórza Ostrzeszowskie wchodzące w skład wschodniej części Wału Trzebnickiego charakteryzują się skomplikowaną budową wewnętrzną (fig. 1–3). Prowadzone ostatnio na tym obszarze prace geologiczne przyniosły wiele interesujących obserwacji co do wykształcenia litologiczno-stratygraficznego osadów kenozoicznych, genezy ich deformacji oraz wpływu na nie tektoniki głębszego podłoża po ewaporaty cechsztyńskie włącznie. Takie szerokie spojrzenie pozwoliło na wyciągnięcie nowych przesłanek dotyczących genezy Wzgórz Ostrzeszowskich.

W deformacjach glacitektonicznych tego rejonu biorą udział osady trzeciorzędowe i czwartorzędowe. Trzeciorzęd reprezentowany jest przez ilaste utwory miocenu środkowego z węglami brunatnymi i tzw. kwarcytami ostrzeszowskimi miocenu górnego oraz charakterystyczne piaski i żwiry serii Gozdnicy (tabl. I, fig. 10; tabl. II, Fig. 12) ze schyłku trzeciorzędu i ze starszego plejstocenu.

Wśród osadów czwartorzędowych w deformacjach spotyka się przede wszystkim utwory wodnolodowcowe i glacjalne zlodowacenia nidy (tabl. I, fig. 9) oraz przypuszczalnie utwory wodnolodowcowe i zastoiskowe fazy anaglacjalnej zlodowacenia sanu.

Na zaburzeniach leżą dyskordantnie gliny zwałowe zlodowacenia sanu (tabl. I, fig. 10), co świadczy, że największe deformacje glacitektoniczne Wzgórz Ostrzeszowskich powstały najprawdopodobniej podczas tegoż zlodowacenia. Ponadto, niezgodnie zalega również seria osadów glacjalnych i wodnolodowcowych zlodowacenia odry (tabl. II, fig. 11), którą obserwuje się głównie na skłonach tychże wzgórz (fig. 2).

Podobnie jak na obszarze Wzgórz Trzebnickich i Twardogórskich na omawianym obszarze nie znaleziono osadów zlodowacenia warty.

Najnowsze wyniki prac kartograficznych oparte na danych otworowych i geofizycznych udokumentowały w podłożu wzgórz horsty zbudowane z utworów triasu górnego. Przebieg tych pozytywnych struktur, o wysokości dochodzącej do 180 m n.p.m., jest zgodny z orientacją osi morfologicznej Wzgórz Ostrzeszowskich (NE–SW) oraz makrostruktur glacitektonicznych w ich obrębie (fig. 1).

Analiza petrograficzna osadów trzeciorzędowych świadczy, że w osi obecnych wzgórz musiał istnieć próg różnicujący sedymentację górnych ogniw trzeciorzędu (J. A. Czerwonka, 1995, inf. ustna). Można z tego wnosić, że proces wynoszenia horstów z podłoża triasowego należy przypisywać początkom faz styryjskich(?).

Analiza strukturalna cechsztyńskich osadów solnych (fig. 5–7) oraz wyniki profilowań geofizycznych w rejonie gazowych złóż Kotliny Odolanowskiej wskazują na istotny udział procesów halotektonicznych w kształtowaniu struktur pokrywowych w nadkładzie permo-mezozoicznym.

Plejstoceńskie procesy kompensacji glacizostatycznej na dalekim przedpolu, jak również bezpośrednie, zróżnicowane oddziaływanie statyczne lądolodów na blokowo zdyslokowane permo-mezozoiczne podłoże, mogły wpływać na reaktywację struktur pokrywowych (fig. 8).

Głęboka dolina pra-Baryczy o założeniach tektonicznych, jak również występujące na południu pozytywne struktury triasowe w obrębie wysoczyzny neogeńskiej, przy istotnym udziale wody oraz kompakcji zróżnicowanych anizotropowo osadów kenozoicznych, były głównymi czynnikami wpływającymi na inicjowanie procesów glacitektonicznych w rejonie obecnej Kotliny Odolanowskiej (fig. 8a). W warunkach subglacjalnych, w płytkim podłożu osadowym tworzyły się cylindryczne powierzchnie ścięciowe przeradzające się w poślizg „poziomy" zgodny z powierzchniami anizotropowymi. W konsekwencji prowadziło to do powstania deformacji glacitektonicznych z udziałem utworów kenozoicznych, m.in. powszechnych struktur łuskowych po proksymalnej stronie wzgórz oraz licznych struktur fałdowych na ich południowym zapleczu (fig. 8b; tabl. I, fig. 9; tabl. II, fig. 12).

Cienienie pokrywy lodowej podczas deglacjacji mogło wpłynąć na odrodzenie ruchów blokowych w podłożu i wynoszenie zrębów ku powierzchni w osiowych, nieobciążonych partiach wzgórz (fig. 8c). Bryły martwego lodu oddziaływując grawitacyjnie na osady płytkiego podłoża powodowały powstawanie fałdów wyporowych w strefach pomiędzy nimi. Prowadziło to również do wyciskania diapirowego trzeciorzędowych osadów środkowego miocenu i dodatkowej komplikacji struktur glacitektonicznych.

Do powstania głównych założeń morfostruktury obecnych Wzgórz Ostrzeszowskich doszło podczas zlodowacenia sanu.

EXPLANATIONS OF PLATES

PLATE I

Fig. 9. Tills (1) and fluvioglacial sands (2) of Middle-Polish Glaciations in overturned folds within western limb of anticline; a southern wall of gravel-pit at Weronikopole

Gliny zwałowe (1) i piaski wodnolodowcowe (2) zlodowaceń południowopolskich w fałdach obalonych na zachodnim skrzydle antykliny; ściana południowa żwirowni w Weronikopolu

Fig. 10. Tills of Sanian Glaciation, overlying discordantly sands and gravels of Gozdnica Series dipping towards WNW; a western wall of gravel-pit at Rzetnia

Gliny zwałowe zlodowacenia sanu zalegające dyskordantnie na zapadających ku WNW piaskach i żwirach serii Gozdnicy; ściana zachodnia żwirowni w Rzetni

PLATE II

Fig. 11. Sands and gravels of upper fluvioglacial horizon of Odranian Glaciation overlying older fluvioglacial formation; a southern wall of gravel-pit near Rzetnia

Piaski i żwiry zlodowacenia odry wyższego poziomu wodnolodowcowego w żwirowni koło Rzetni na starszych utworach fluwioglacjalnych; ściana południowa żwirowni koło Rzetni

Fig. 12. Overturned fold in zone of anticlinal turn; a western wall of gravel-pit at Weronikopole

Fałd obalony w strefie przegubu antyklinalnego; ściana północna żwirowni w Weronikopolu

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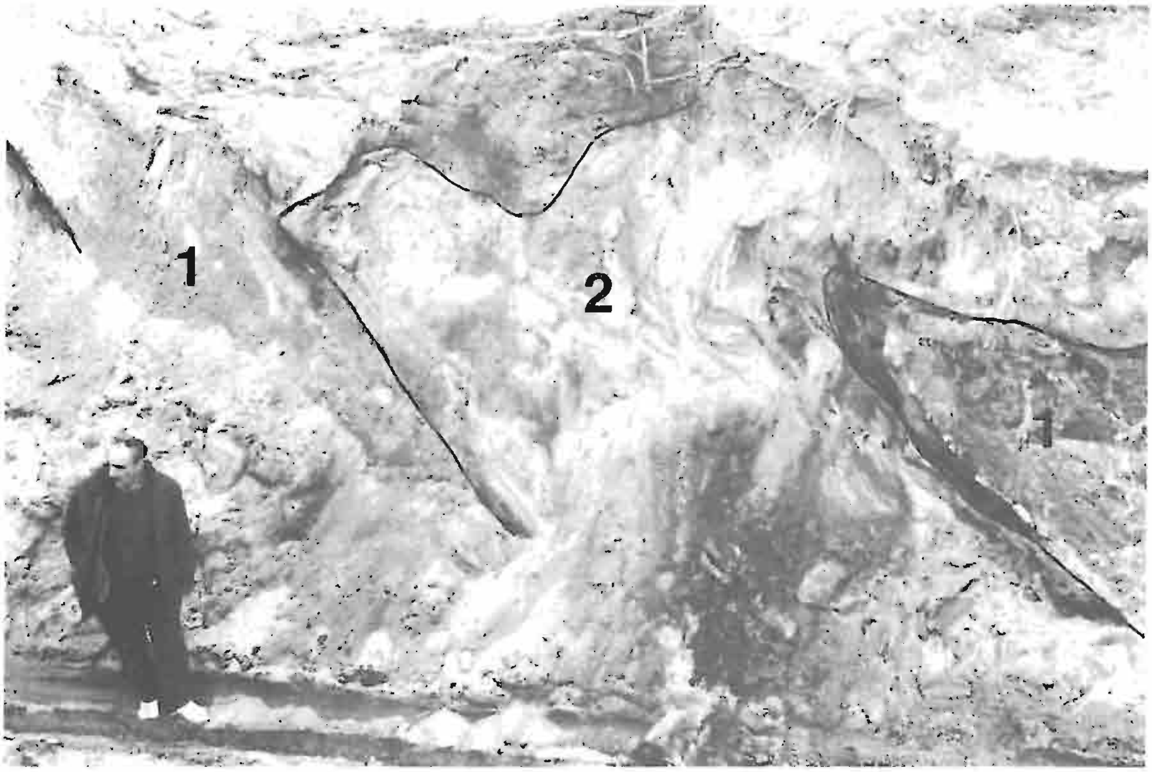

Fig. 9

Fig. 10

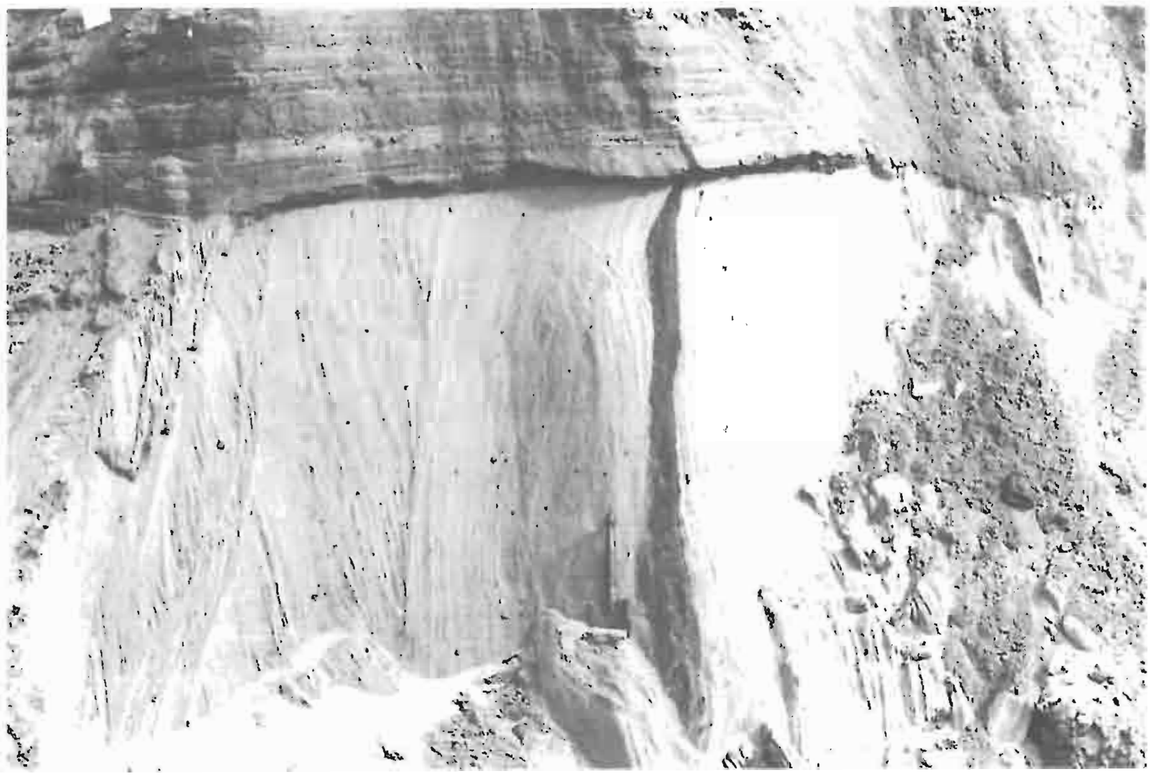

Fig. 11

Fig. 12

Andrzej MARKIEWICZ, Jarosław WINNICKI — On geological structure of the Ostrzeszów Hills