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South-western boundary of the Mid-Polish Trough — new seismic data from the Oświno–Człopa Zone (NW Poland)

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The Mid-Polish Swell (MPS), uplifted in the latest Cretaceous–earliest Tertiary at the site of the earlier Permian–Mesozoic Mid-Polish Trough (MPT), is adjoined to the south-west by a chain of salt diapirs which are probably underlain by a system of late Variscan deep faults in the pre-Zechstein basement. The Mesozoic reactivation of this system is responsible for the rapid thickness increase towards the axis of the MPT. Consequently, it may be regarded as the southwestern boundary of the MPT. During the phase of inversion, this system caused the mobilization of the Zechstein salt, the formation of the chain of diapirs and also (indirectly) the uplift of the regional unit of the MPS.

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Key words: Zechstein-Mesozoic, Mid-Polish Trough, Pomerania, tectonics, thickness changes.

INTRODUCTION

A new seismic reflection survey made by the CALENERGY company in northwestern Poland in 1998 comprises more than twenty SW–NE profiles, spaced on average 2–4 km apart, and intersected by a few NW–SE profiles. The total length of these profiles is about 800 km, and they cover a quadrangle 75 km long and 25–30 km wide. Two earlier regional seismic profiles made by the Polish Oil and Gas Company are also located here. The research area lies on both sides of the boundary between two first-order units of the Permian-Mesozoic platform cover in Pomerania (northwestern Poland): the Mid-Polish Swell (MPS) to the north-east and the Szczecin Trough (ST) to the south-west. The former (MPS) originated at the place of a regional unit called the Mid-Polish Trough (MPT), an elongated centre of subsidence active from the Permian to the early Late Cretaceous. This unit was uplifted in the latest Cretaceous to earliest Tertiary to form the MPS. It was intensely eroded, and this results in the occurrence of the Lower Jurassic (or locally even Triassic) rocks at the sub-Cenozoic surface. The latter (ST) remained depressed and was filled with an almost complete Mesozoic sequence, including thick Upper Cretaceous deposits. At some distance from the MPS slope a characteristic chain of salt diapirs occurs within the ST.

This paper is not aimed at a comprehensive tectonic interpretation of the area. My intention is, on the background of the excellent seismic data, the best such in this part of the Polish Lowlands:

— to outline the principal structural features of the area;

— to define what new data were achieved and what was known earlier;

— to constrain on this basis the interesting and controversial topic of the southwestern boundary of the Mid-Polish Trough.

The present study is illustrated by:

— a table of Jurassic–Lower Cretaceous thicknesses in boreholes;

— three maps showing the relief on the Zechstein base, the Muschelkalk top and the Upper Cretaceous base together with the sub-Cenozoic subcrops (Figs. 1–3) as well as a tectonic sketch (Fig. 4).

—selected segments of the seismic time sections with geological interpretations (Figs. 5–8).

PREVIOUS WORK

The area was investigated by seismic regional survey in the 1960's to early 1980's. The latest profiles performed by the Pol-

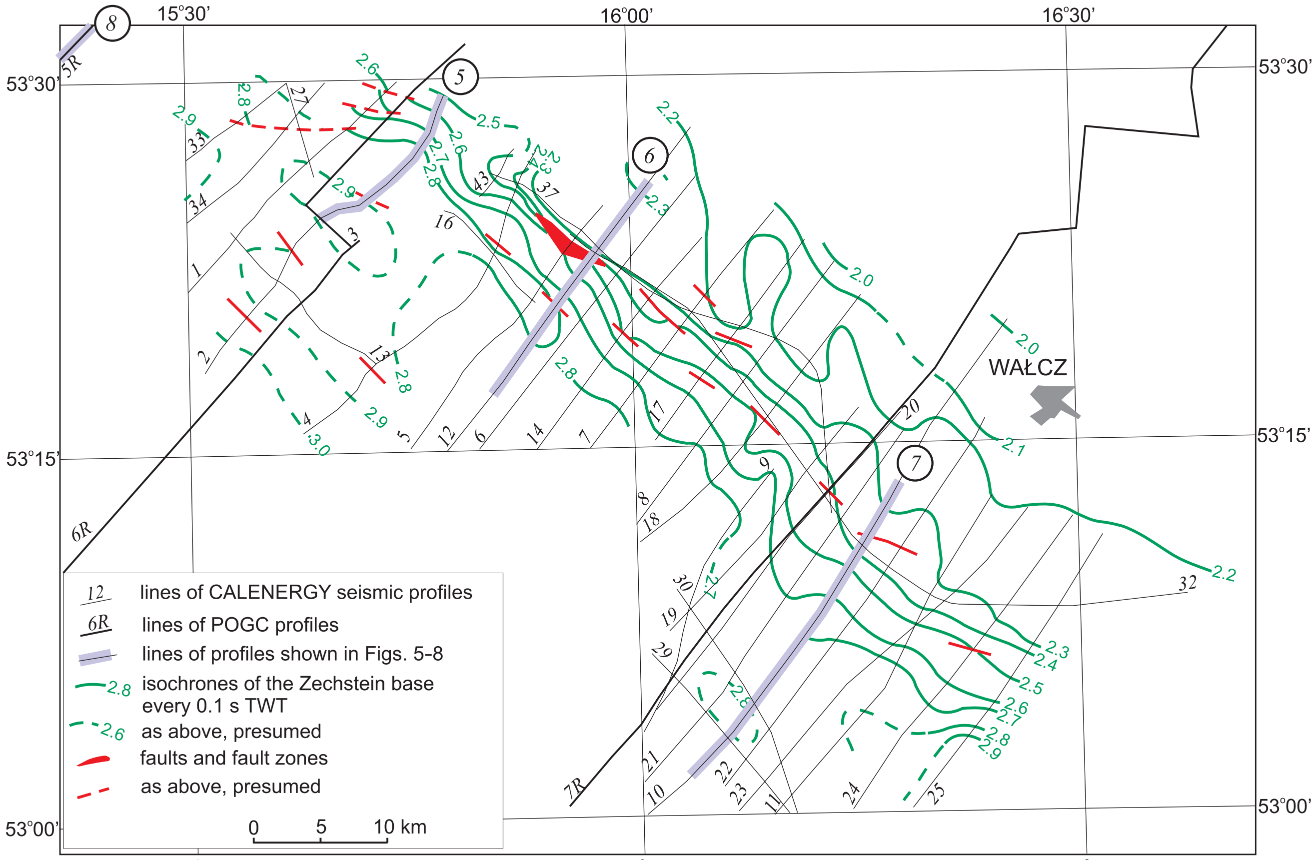

Fig. 1. Time map of the Zechstein base

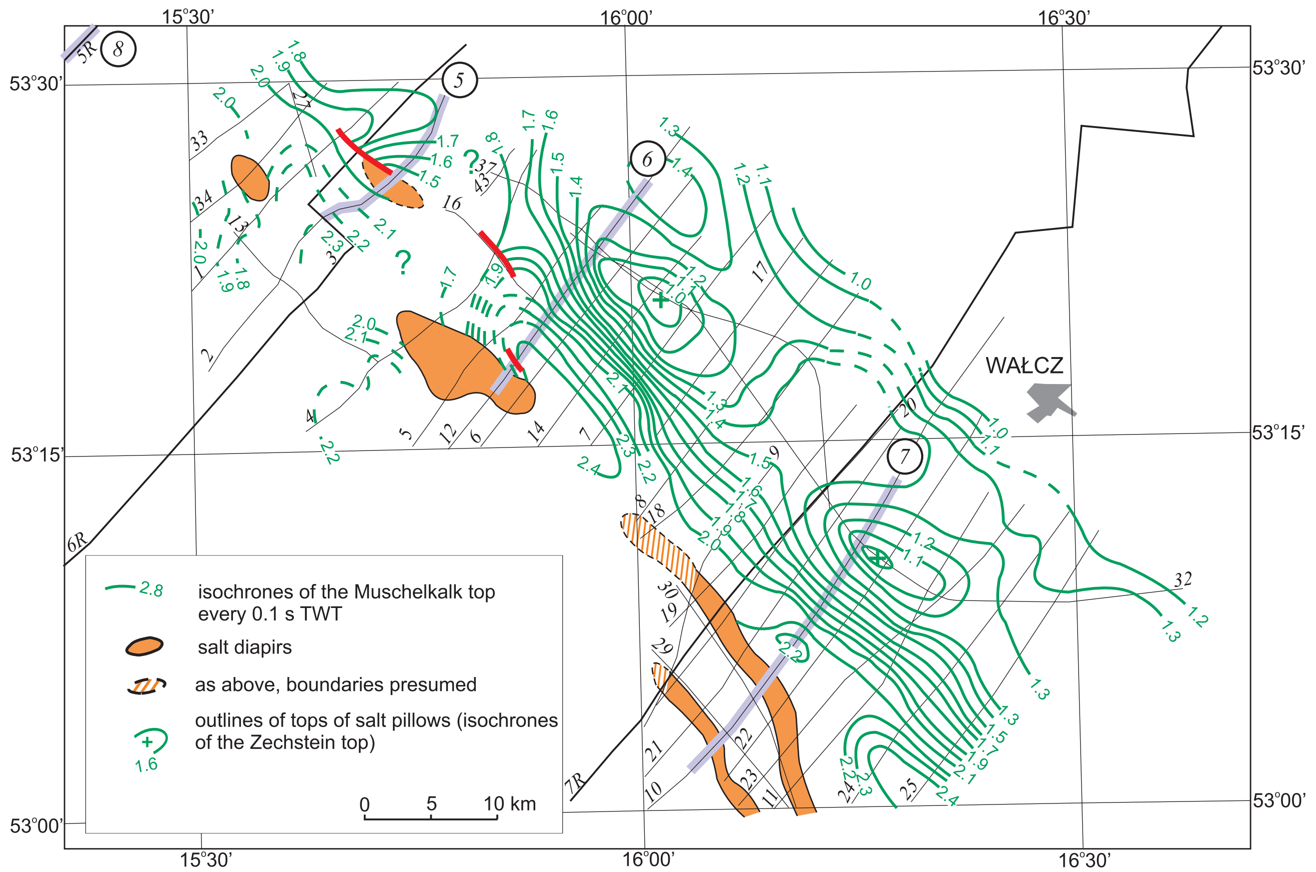

Fig. 2. Time map of the Muschelkalk top

For other explanations see Figure 1

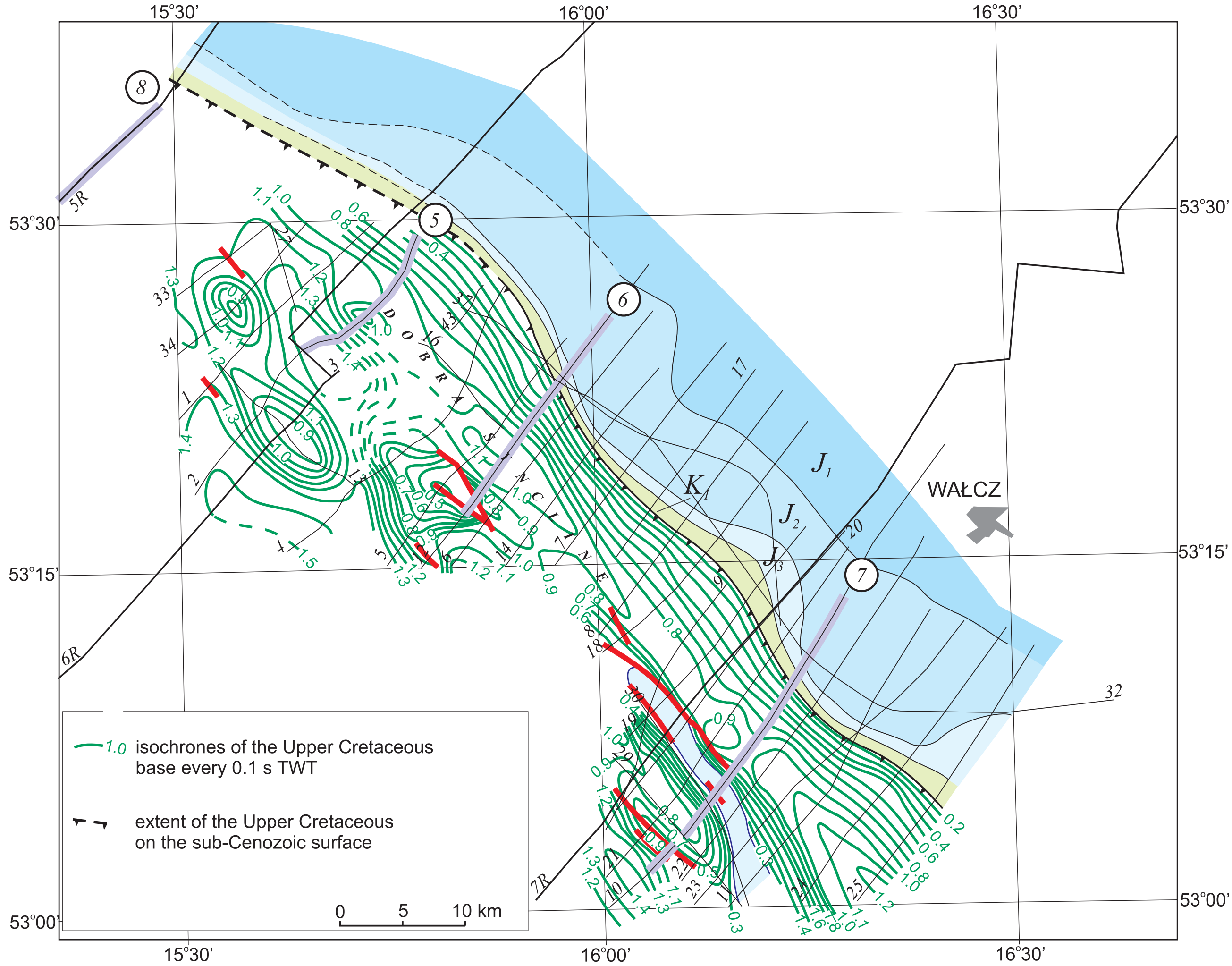

Fig. 3. Time map of the Upper Cretaceous base and sub-Cenozoic map

For other explanation see Figure 1

ish Oil and Gas Company (POGC) date back to the late 1970's and early 1980's. The quality of those data was not exceptionally good. Moreover, as those studies were planned separately for investigation of each first order unit (MPS and ST), the profiles were not always mutually connected because the network of profiles was mostly terminated at the boundary betweeen the two units. The CALENERGY survey is characterized by much better quality and is located astride this boundary.

The results of this stage of investigations were first reported in two synthetic publications (Jaskowiak-Schoeneich, 1979; Raczyńska, 1987) in which I wrote the tectonic chapters. The area was later also portrayed within the context of the entire Polish Lowlands on a tectonic map (Dadlez, 1998) and on Mesozoic thickness maps (Dadlez, 2003). The regional seismic profiles (5R, 6R and 7R — Figs. 1–4) have been geologically interpreted and figured by Dadlez (2001), labelled there as profiles no. 5–7. During this stage of research most of the local structures, among others the salt diapirs, (Grzęzno, Ińsko, Drawno, Człopa and Dzwonowo) had already been recognized. The names of these structures are maintained in the present paper with one change: instead of the Trzcianka North salt pillow the term Mirosławiec salt pillow is introduced. Particular attention was paid to a linear zone of these diapirs accompanying the MPS from the south-west, and to a probable fault system that had caused the growth of these diapirs. This zone was also a place of rapid thickness increase (especially of Jurassic strata) towards the north-east, i.e. towards the MPT. It was suggested then that this system represents the southwestern boundary of the MPT.

Recently Krzywiec (2000, 2002*a*, *b*) — referring to the Oświno Anticline, located at the northwestern boundary of the area — put forward an idea that the "master fault", equivalent to the MPT boundary, is situated not below the diapirs but farther to the NE below the slope of the MPS. For details of his arguments and my counterarguments see later in the discussion chapter.

The CALENERGY investigations confirmed the existence of these diapirs and allowed also to detail their outlines and to correct the sub-Cenozic boundaries on the slope of the MPS. A new salt diapir (the Studnica diapir) has been discovered.

QUALITY OF SEISMIC DATA

Due to the attenuating influence of the Zechstein salt on seismic waves, there are no data from below the Zechstein, as in other areas of the MPT. In some places only short indistinct reflections occur, coming probably from the Rotliegend volcanics.

In the Zechstein–Mesozoic strata the quality of seismic data is variable. In the north-east — on the slope of the MPS and in

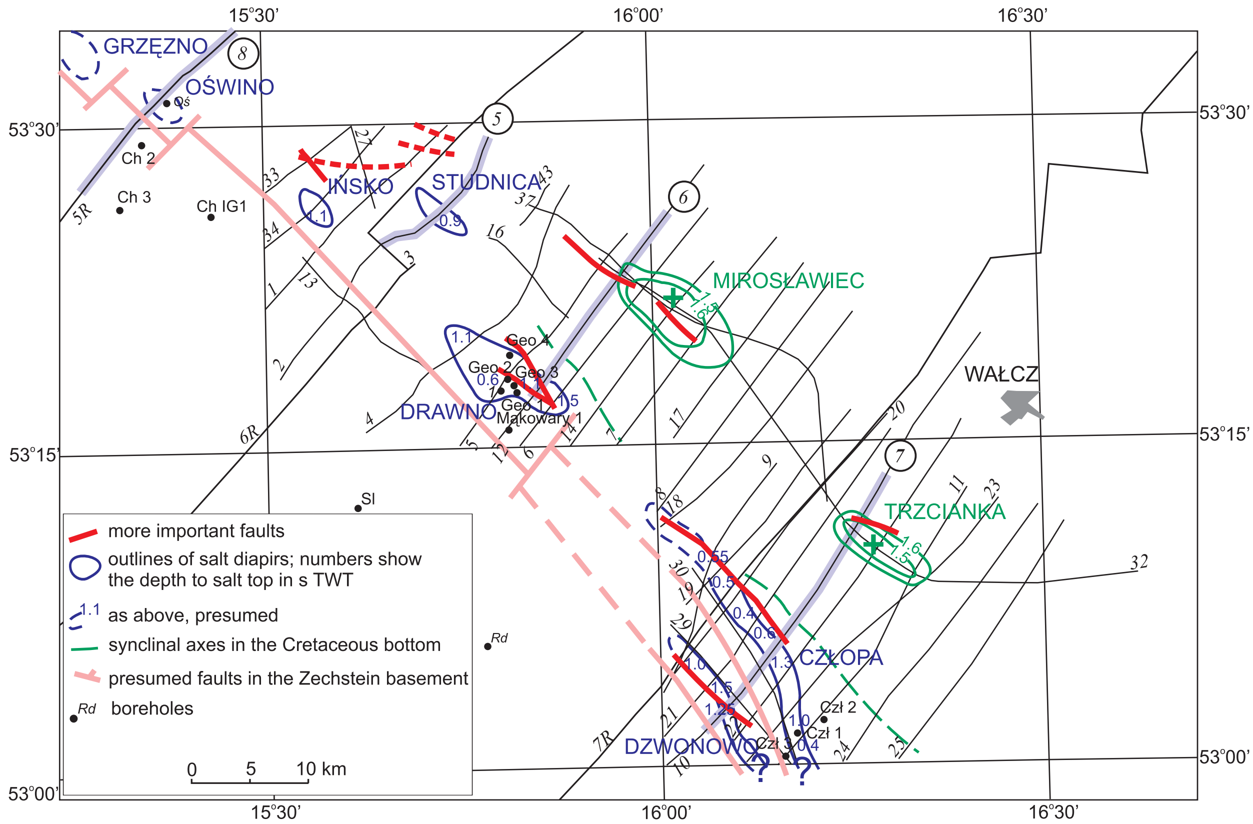

Fig. 4. Tectonic sketch

For other explanations see Figure 1

adjoining Dobra Syncline (Fig. 3) — it is excellent (Figs. 5–7). The cluster of reflectors from the Zechstein Main Dolomite to the Zechstein Limestone series is recognizable, so the Zechstein base is easy to define. Higher up in the sequence one can see: the reflectors from the Zechstein top; the most distinct horizon within the Triassic (Muschelkalk) as well as — less certainly — the top of the Triassic. In addition, subordinate reflectors are observed: within the Zechstein, from the Main Anhydrite; below the Muschelkalk, from the Rhoetian dolomites; below the top of the Triassic from the Schilfsandstein. Above the Triassic the reflectors from two main shaly series of the Lower Jurassic (Łobez Beds and Ciechocinek Beds) are locally recorded, as well as the cluster of reflectors from the lowermost part of the marine shales of the Middle Jurassic. The thickness of the Upper Jurassic and Lower Cretaceous is so small that these series are indivisible. Within the Upper Cretaceous two clusters of reflections are noted, the lower one from the top of the Turonian shales and the upper one from unidentified younger rocks (Santonian? Campanian?). The base of Cenozoic is easily visible.

In the southwestern part of the area the quality of data is distinctly worse. The salt diapirs of the Oświno-Człopa structural trend are seismically structureless with a chaotic pattern of reflectors and are overlain by strongly faulted Mesozoic strata, difficult as regards stratigraphic identification and correlation. Farther to the south-west the Zechs-

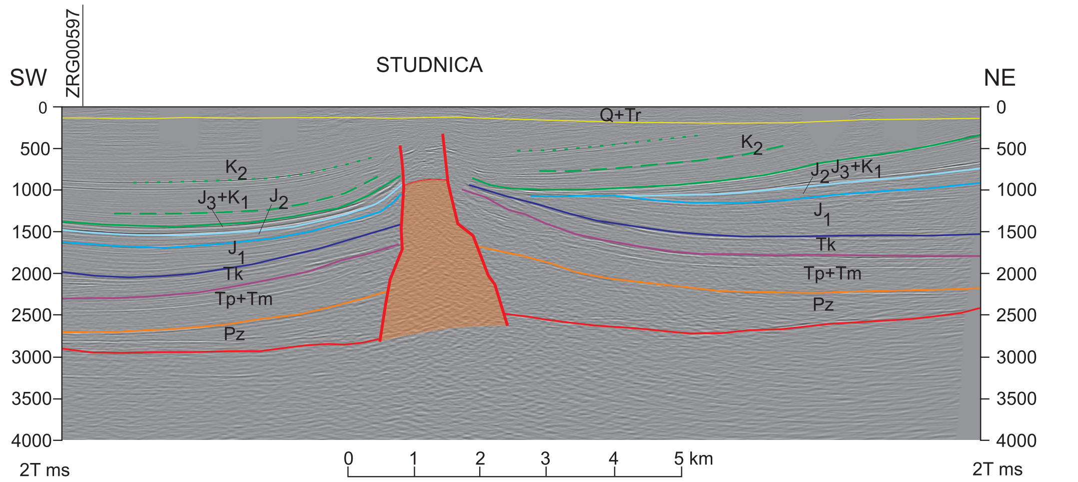

Fig. 5. Cross-section no. 5

Pz — Zechstein, Tp + Tm — Bunter and Muschelkalk, Tk — Keuper, J_1 — Lower Jurassic, J_2 — Middle Jurassic, $J_3 + K_1$ — Upper Jurassic and Lower Cretaceous, K_2 — Upper Cretaceous, Q + Tr — Cenozoic; for location see Figures 1–4

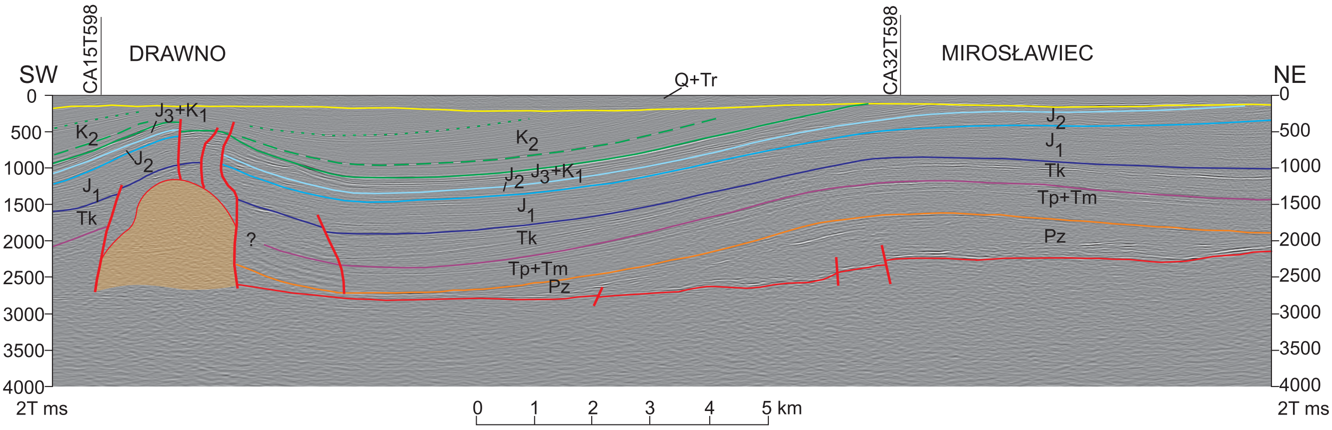

Fig. 6. Cross-section no. 6

For location see Figures 1–4; abbreviations as in Figure 5

tein reflectors are disrupted or disappear completely. The Mesozoic reflectors are also discontinuous except for the Upper Cretaceous and, at some places, the Middle and Upper Jurassic. On a single profile (Fig. 7) the picture is somewhat better but the correlation still remains difficult.

An additional difficulty in interpretation is the *ca*. 10 km distance between the CA 02 and CA 04 profiles. (Figs. 1–4) which results in correlation difficulties and uncertainties between the northwestern part of the area and its remaining portion.

Borehole data that could help in geological interpretation are scarce in the area (Figs. 1 and 4). The only deep borehole (Piła IG 1), lying beyond the area on the territory of the MPS, but connected by the CA 32 profile, allows the identification of seismic reflectors up to the Lower Jurassic only, because of deep erosion in the area of the MPS. Other boreholes are located in the vicinities of salt diapirs (Drawno and Człopa) and represent therefore only local conditions. South-west of the area, some boreholes were drilled (Chociwel, Suliszewo and Radęcin) which enable the reconstruction of the Mesozoic sequence in its southwestern part.

The presentation of time versions of seismic sections in this paper is disadvantage because a detailed thickness interpretation is impossible — it is obvious that the same time intervals at different depths are not equivalent to the same thicknesses.

RESULTS OF SEISMIC INVESTIGATIONS

ZECHSTEIN BASE

This is well recorded in the north-east where it descends southwestwards from 2000 ms TWT to 2800 ms TWT (Fig. 1). This corresponds to the lowering of this surface from *ca*. 3500 m below the MPS to *ca*. 5000 m and more below the ST. The Zechstein base — particularly in the zone of its strongest inclination — is cut by short longitudinal faults of minor displacement (e.g. Fig. 7) except for the CA 05 profile (Fig. 1) where a more distinct fault zone was found.

MESOZOIC

The fact that below the MPS the thicknesses of the Mesozoic successions are significantly greater than south-west of it has long been known from borehole results. This was part of the evidence that the MPS originated at the place of an earlier sedimentary trough called the Mid-Polish Trough (MPT). The seismic survey reported here shows this feature convincingly for the first time (earlier results were sometimes not conclusive). This feature is visible on all profiles (Figs. 5–7). Particularly interesting is the CA 10 profile (Fig. 7) where one can compare the thickness south-west of the Dzwonowo diapir (in the ST) with that north-east of the Czlopa diapir (on the slope of the MPS). While in the former area the distance from the Cretaceous base to the top of Zechstein is 1000 ms TWT, in the latter area it increases to 1600 ms TWT. As we know that the thickness changes in the Muschelkalk are rather small and in the Keuper they depend mainly on salt displacement, the greatest thickness increases are connected with the Bunter and Jurassic successions — the main stages of the MPT formation.

Farther to the north-east, upslope of the MPS, observations of the thickness changes are limited because of the erosion of higher parts of the Mesozoic including the Middle Jurassic. However, the thickness increase of the Lower Jurassic towards the MPS axis is visible (e.g. Fig. 7 — from 400 to 600 ms TWT). These numbers are indirectly confirmed by data from the Chociwel 3, Suliszewo 1 and Radęcin 1 boreholes (Table 1) where the thickness of the Jurassic to Lower Cretaceous amounts to 500–600 m., as well as from the Mąkowary borehole, located just SW of the Drawno diapir (*ca*. 600 m). Thus the entire SW part of the area is characterized by a 500–600 m. thickness of this interval, while below the MPS slope it exceeds 1000 m. Comparison of the Muschelkalk top (Fig. 2) with the Zechstein base (Fig. 1) shows clearly the influence of salt mobilization (oval anticlines above the monoclinal pattern).

SALT STRUCTURES

As in many salt basins (including the Polish Basin) there are two categories of salt structures in the area in question. The first,

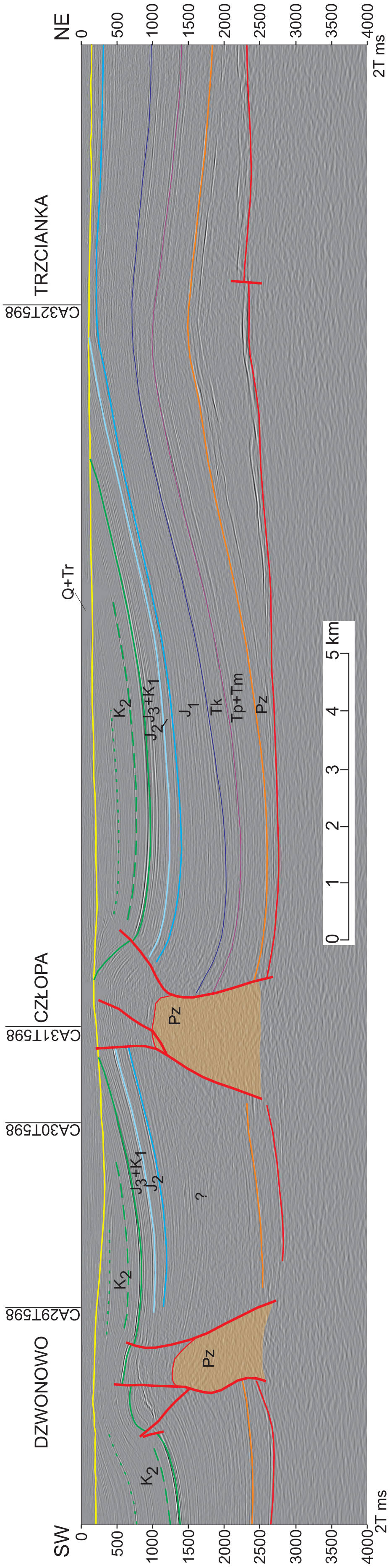

Fig. 7. Cross-section no. 7

For location see Figures 1–4; abbreviations as in Figure 5

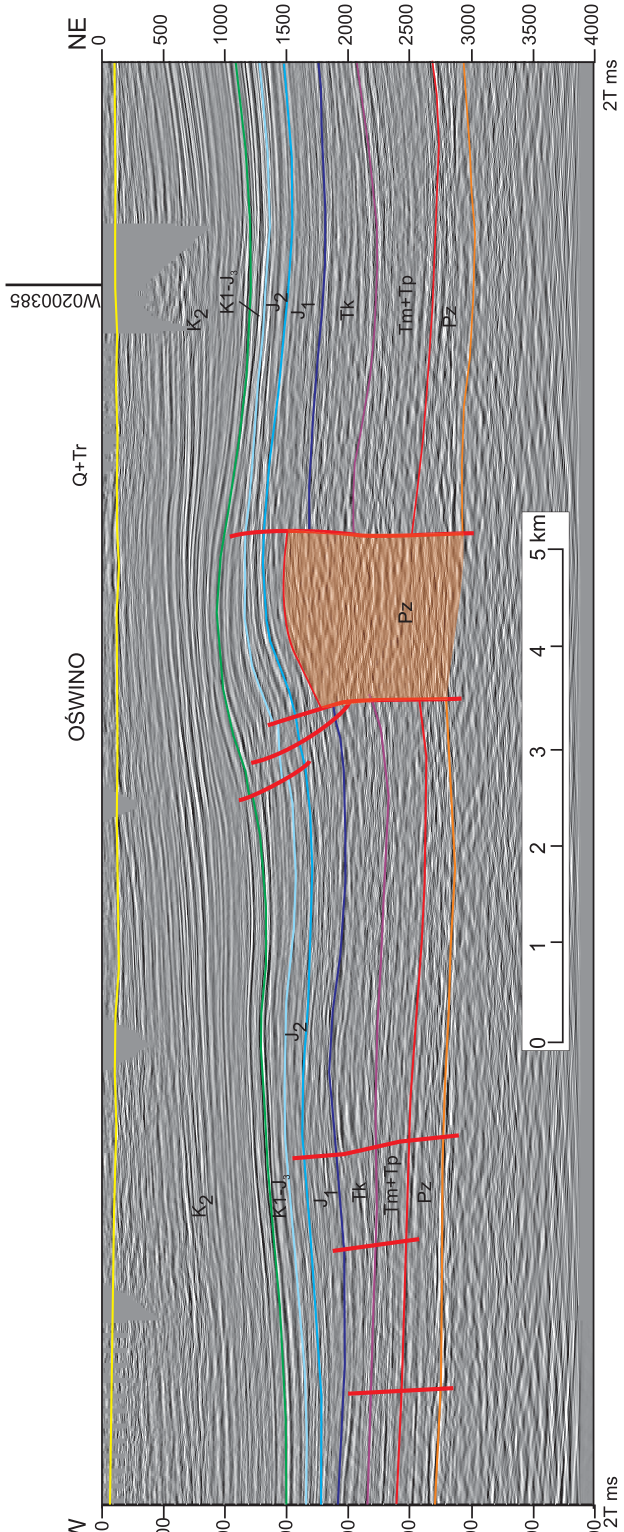

Fig. 8. Cross-section no. 8

For location see Figures 1–4; abbreviations as in Figure 5

located generally nearer the basin margins, are salt pillows, where the salt swells up, but does not pierce through the overlying strata. The second, located in the basin centre, are salt diapirs where the overburden is pierced by salt. In our area the first category was ascertained in the marginal zone of the MPS: there are two salt pillows — Trzcianka in the SE and Mirosławiec in the NW (Fig. 4). Their outlines are well recorded on the map of the Muschelkalk top (Fig. 2) where the tops of both anticlines rise up to 1000 ms TWT while in synclines adjoining from the north-west the values are 1300–1400 ms TWT. The opposite slope of both anticlines (equivalent to the slope of the MPS) is steeper, so that in the Dobra Syncline isolines of 2300–2400 ms TWT occur. The influence of both salt pillows is also visible on the pre-Cenozoic solid map (Fig. 3) as bends in the Jurassic subcrops on the MPS slope.

A minor thickness decrease of the Upper Triassic above the tops of these salt pillows (e.g. Fig. 6) indicates their activity during the Late Triassic. This process — characteristic of the first phase of salt movements in the Polish Basin — is observed also in more central parts of the basin where, however, thickness decreases are greater and are connected with intra-Late Triassic erosional gaps. Further stages of growth of these salt pillows is not known because the younger parts of the sequence have been removed by erosion. However, judging from the evolution of other areas, the next stage of intense salt movement was in the Late Cretaceous. Some cross-sections (e.g. Fig. 6) suggest minor activity in the Early Jurassic.

Several salt diapirs occur in the area (Figs. 2 and 4). They are aligned NW–SE, from Grzęzno through Oświno, Ińsko and Drawno to Człopa. Two diapirs (Studnica and Dzwonowo) accompany this main trend from NE and SW, respectively. The breakthrough of salt in Grzęzno, Drawno and Człopa has been confirmed by boreholes, the remaining diapirs being recorded by seismic survey only. The top of the salt in the first and last of these localities rises up to 1300–1500 m b.s.l. while below the synclines adjoining from the NE it descends to *ca.* 4000–5000 m.

A convergent pattern in the Upper Cretaceous reflectors above the salt diapirs (e.g. Fig. 6) suggests their growth during this period. The overburden is strongly faulted, so it is difficult to interpret the stratigraphy in boreholes. This is exemplified by sections at Człopa (Table 1) where the thickness changes in the Lower Cretaceous, and in the Upper and Middle Jurassic, seemingly opposite to the regional trend, are in fact an artefact of faults cutting the sequences (Table 1). The data from Grzęzno and Drawno point unanimously to a post-Turonian pre-Late Santonian stratigraphic gap (Leszczyński, 2002), defining one of the Late Cretaceous stages of salt movement. The pillow stage of the evolution is difficult to reconstruct. The Jurassic thickness changes in the neighbourhood of the Studnica and Oświno diapirs (Figs. 5 and 8) may account for this stage. By contrast with these local diapiric structures there is no evidence in seismic data for uplift of the regional unit of the MPS, at least before the Coniacian. The reflector connected with the Turonian top does not converge with the Upper Cretaceous base. A lack of convergence is also characteristic of the Turonian and Santonian? reflectors, but in this case the observations are limited due to erosion on the MPS slope.

Table 1

Thicknesses of stratigraphic units in boreholes (in metres)

Borehole	Lower Cretaceous	Upper Jurassic	Middle Jurassic	Lower Jurassic
Chociwel 1	20	199	86	not pierced
Chociwel 2	13	140	75	612
Chociwel 3	10	82	93	350
Suliszewo 1	9	102	86	285
Radęcin 1	16	124	88	357
Mąkowary 1	33	184	88	314
Oświno IG 1	239	416	192	not pierced
Człopa 3	348	643	89(2)	154
Człopa 2	85	497(1)	130	948

1 — two reverse faults within the sequence; 2 — normal fault at the lower boundary

CENOZOIC

The base of Cenozoic is surprisingly well recorded by comparison with earlier seismic data. It is particularly clear in those segments where the Cenozoic lies upon the inclined Mesozoic beds. A local small thickness decrease above salt diapirs (e.g. Fig. 7) and above the MPS against the ST (e.g. Fig. 6) is evidence of insignificant mobility of both the regional and local structures during this youngest stage of evolution.

DISCUSSION

The origin of the Oświno anticline is used here as a starting point for discussion. Though it lies beyond the area in question, it belongs to a characteristic array of anticlines accompanying the MPS from the south-west. Therefore the question of its origin has an influence on understanding the tectonics of the entire area. Seismic data on the 6R profile, crossing this structure, are ambiguous and allow various interpretations (comp. fig. 8 with fig. 4 in Krzywiec 2002*b*)

I have long considered the Oświno structure as one of a chain of salt diapirs (Dadlez in Jaskowiak-Schoeneich, 1979). Krzywiec (2000, 2002*a*) initiated discussion and later dedicated a separate paper to this topic (Krzywiec, 2002*b*). He suggested that the Oświno structure developed above an earlier normal, second-order fault coupled with a first-order master fault lying to the NE both originated during MPT formation with downfaulted northeastern walls. During regional inversion of the trough the fault was rejuvenated as a reverse fault which brought about the development of the peri-fault Oświno Anticline without any salt movement. Quoting Krzywiec (2002*b*, p. 340), the Oświno–Chociwel area comprises an "...imbricated fan of blind reverse faults (thrusts) and related fault propagation folds".

However, I maintain my earlier view that the Oświno Anticline is underlain by a salt diapir. New data has supported this opinion, showing clearly the diapiric character of the entire anticlinal trend. My reasoning is based on the following arguments.

1. In the first phase of seismic investigations in the area (in the late 1960's) a trend of oval structures (recorded at that time in the younger Mesozoic strata only) was found in the north-eastern part of the ST (Grzęzno, Oświno, Ińsko, Drawno and Człopa anticlines). The boreholes made subsequently revealed that three of these structures (Grzęzno, Drawno and Człopa) are built over salt diapirs. The Oświno Anticline is a part of this trend situated between the Grzęzno and Drawno diapirs. The seismic pattern in it is chaotic as in the remaining structures in-

vestigated by the recent seismic survey, and the boundaries between their anticlinal cores and their aureoles, characterized by a bedded pattern of reflectors, are also similar. The salt cores of all these anticlines are evident. Thus, there is no reason to attribute a different origin to any one of these five structures. Krzywiec (2002*b*) allowed salt diapirism in the Drawno and Człopa anticlines (SE of Oświno), but overlooked the fact that, NW of Oświno, a diapir was also confirmed at Grzęzno. According to his idea the Oświno Anticline would be the single exception to this general pattern.

The solution proposed here does not exclude that there is a fault (or rather faults) below all the diapirs (presumably below their southwestern limbs) and that they influenced both the Mesozoic thickness increase towards the NE during the evolution of the MPT and the subsequent formation of diapirs during the inversion phase. I had put forward this view earlier (Dadlez, in Jaskowiak-Schoeneich, 1979). It was thought then that there is a NW–SE trending system of deep faults, cut by smaller SW–NE trending faults (Fig. 4) which was inherited from the earlier late Variscan normal to strike-slip system (Dadlez, 1994). During the Mesozoic this marked the southwestern edge of the MPT and during its inversion it caused periodic salt movement as well as — indirectly — the uplift of the MPS. The best evidence of the particular activity of this fault (or faults) is the fact that salt diapirs are located in opposition to the regional pattern mentioned above i.e. nearer to the basin margin than are the salt pillows. Inversion processes may have first mobilized the fault (and diapirs) and subsequently caused uplift of the MPS.

2. Krzywiec suggested that a "master fault" (more precisely: a master basement normal fault) played a significant role in the tectonic evolution of the area and marked the boundary of the MPT. However, in new seismic data (as elsewhere in the MPT area) there is no evidence for regional faults in the Zechstein basement at all, and particularly in the place indicated by Krzywiec (2002*b*, fig. 4), below the slope of the MPS. There is also no evidence for a rapid thickness increase of the Zechstein at his master faults (2002*b*, fig. 5). One could presume that minor faults observed at the Zechstein base in CALENERGY data (e.g. Fig. 6) are posthumous effects of the activity of such a fault. However, across these small faults no rapid thickness changes neither in the Zechstein nor in the cover are noted along the entire MPS slope (and such changes should be the main evidence for the influence of a fault); the northeasternward thickness increase is gradual. These small faults are rather an effect of normal faulting during the uplift of the MPS. On the contrary, rapid thickness changes are very probable across the belt of salt diapirs, and this is perhaps a place for location of a master fault. In this case the presumed faults near Chociwel would be second-order faults.

3. After Krzywiec (2002*b*) the Oświno Anticline lies nearer to the hypothetical master fault than the other structures and therefore its origin is different. This argument is doubtful. If the presumed master fault is located somewhere beneath the MPS slope, the distance to the Oświno structure is comparable or even greater (13 km versus 10 km in the case of Grzęzno and Człopa) than in the case of the remaining structures.

4. Generally, it seems that Krzywiec overestimated the role of regional compression during the Zechstein/Mesozoic structural stage. He suggested, inter alia that lateral stress exerted by the uplifting MPS caused the compression in the Oświno–Chociwel area. He writes that "morphological gradient and increased pressure of overburden rocks directed towards the south-west ... most probably significantly contributed to Late Cretaceous reactivation..." which was "...due to compression caused by uplift of the axial part of the MPT" (Krzywiec, 2002*b*, p. 343). In this context he referred to tectonic environments entirely different from the intracontinental environment in which the MPS formed. He mentioned passive margins and foreland fold-and-thrust belts. In the case of such comparison, analysis of data on the morphological gradients and on rheological properties of the deformed rocks involved seems necessary. Moreover, the MPS should uplift simultaneously with, or even earlier than, the local structures. However, the seismic data, as noted above, suggest rather the earlier mobility of the salt diapirs (from the beginning of the Late Cretaceous) than of the MPS; the latter started to rise not earlier than in the Santonian.

I do not deny the existence of local compression during the inversion of the area discussed. However, it seems to be only one of several deformational agents, acting parallel and simultaneously in the entire MPT. During the period of inversion (latest Cretaceous and earliest Tertiary) a complicated stress pattern existed in the area of the entire European peninsula, lying between the continuously spreading North Atlantic realm and the oceanic spaces of the Tethyan realm with its incipient closure. Over the whole area, horizontal tensional (transtensional) and compressional (transpressional) stresses acted in tandem with vertical movements induced by transformations in the crystalline crust (probably with predominance of the latter movements). The best evidence of such a situation is the coexistence of normal and reverse faults (as is confirmed by seismic data as well as by borehole sections), with minor participation of strike-slip displacements. If compression prevailed, the reverse faults would play a more decisive role than observed in the seismic and borehole data.

CONCLUSIONS

1. The chain of salt diapirs accompanying the main body of the MPS from the SW is underlain by a system of sub-Zechstein faults.

2. The Mesozoic reactivation of this system is responsible for a rapid thickness increase towards the axis of the MPT. Consequently it may be regarded as a boundary of the MPT.

3. During the phase of inversion this system caused, from the beginning of the Late Cretaceous, the mobilization of Zechstein salt and the formation of this chain of diapirs. Its continuous activity accounts also indirectly for the uplift of the regional unit of the MPS

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REFERENCES

DADLEZ R. ed. (1998) — Tectonic map of the Zechstein-Mesozoic complex in the Polish Lowlands 1:500.000. Państw. Inst. Geol. Warszawa.

DADLEZ R. (1994) — Strike-slip movements in the Polish Lowlands. Geol. Quart., **38** (2): 307–318.

DADLEZ R. (2001) — Mid-Polish Trough — geological cross-sections 1:200.000. Państw. Inst. Geol.

DADLEZ R. (2003) — Mesozoic thickness pattern in the Mid-Polish Trough. Geol. Quart., **47** (3): 223–240.

JASKOWIAK-SCHOENEICH M. ed. (1979) — Geological structure of the Szczecin Trough and Gorzów Block (in Polish with English summary). Prace Inst. Geol., **96**.

KRZYWIEC P. (2000) — On mechanisms of the Mid-Polish Trough inversion — results of seismic data interpretation (in Polish with English summary). Biul. Państw. Inst. Geol., **393**: 135–166.

KRZYWIEC P. (2002*a*) — Decoupled vs. coupled evolution of the Mid-Polish Trough — role of salt during extension and inversion. Am. Assoc. Petr. Geol. Amnn. Meeting, **97**.

KRZYWIEC P. (2002*b*) — The Oświno structure (NW Mid-Polish Trough) — salt diapir or inversion-related compressional structure? Geol. Quart., **46** (3): 337–346.

LESZCZYŃSKI K. (2002) — Late Cretaceous inversion and salt tectonics in the Koszalin–Chojnice and Drawno–Człopa–Szamotuły zones, Pomeranian sector of the Moid-polish Trough. Geol. Quart, **46** (3): 347–362.

RACZYŃSKA A. ed. (1987) — Geological structure of the Pomeranina Swell and its substratum (in Polish with English summary). Prace Inst. Geol., **119**.