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Stanisław BURLIGA

Implications for early basin dynamics of the Mid-Polish Trough from deformational structures within salt deposits in central Poland

In the weakly strained portions of the Kłodawa salt diapir, small scale tectonic structures developed in early stages of the diapir evolution are preserved. These are sheath folds and faults developed during gravity gliding in still horizontally layered rocks. They indicate bulk tectonic transport towards the east-towards the centre of a subsiding depression. The latter was controlled by faulting in the basement, related to NE–SW extension within the Mid-Polish Trough. The small scale structures, thus, provide evidence for the early basin dynamics.

INTRODUCTION

The structural recognition of the Mid-Polish Trough (MPT) and its evolution is dominantly based on geophysical investigations. They included deep seismic profiling (refraction and wide-angle reflection methods) which revealed the crustal structure of this area (A. Guterch *et al.*, 1985, 1986) and more detailed, shallower profiling (reflection method) of the Permian-Mesozoic cover. The latter were promoted by hydrocarbon prospecting, therefore they were additionally completed with drill logs and cores, which provide the most direct information on lithology and stratigraphy of the sedimentary infill of the trough.

Because of a thick cover of Cenozoic deposits and a very few outcrops of the pre-Cenozoic sediments, no other methods of investigation have been applied. Those rare occurrences of older rocks are basically related to salt structures (salt pillows, ridges and diapirs) buckling in places the Mesozoic sequences (e.g. the Zalesie Structure, where Jurassic limestones are exposed) or piercing through it (e.g. Inowrocław, Wapno, Kłodawa salt diapirs). The diapirs consist of Zechstein evaporites and terrigeneous rocks, thus, they offer an insight into the almost oldest rocks in the sedimentary record within MPT. They

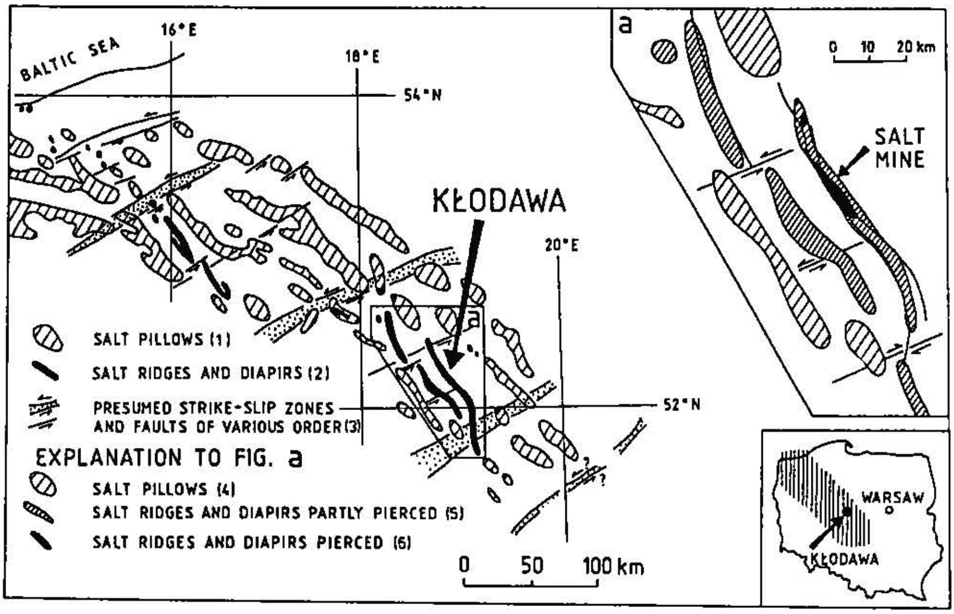

Fig. 1. General tectonic features of the Mid-Polish Trough (based on R. Dadlez, 1994) and location of the study area

Ogólne cechy tektoniczne bruzdy śródpolskiej (na podstawie R. Dadleza, 1994) i położenie obszaru badań

1, 4 — poduszki solne; 2 — grzbiety i diapiry solne; 3 — przypuszczalne strefy i uskoki przesuwcze różnej rangi; 5 — grzbiety i diapiry solne częściowo przebite; 6 — grzbiety i diapiry solne przebite

also experienced the longest deformational path, which obviously was controlled by overall tectonics in the basin. Exceptional rheological properties of evaporites allowed the development and preservation of abundant tectonic structures within the Zechstein deposits, which provide evidence for different stages in the diapir evolution and, consequently, in the evolution of the basin. Despite numerous mine excavations existing in some of the diapirs (of which only one — the Kłodawa salt diapir — is accessible for observation at present) this excellent opportunity has not been used so far. The diapirs were studied as structural features themselves (J. Poborski, 1955; Z. Werner *et al.*, 1960; R. Tarka, 1992) but no attempt was made at correlation of the observations within the diapirs with those obtained by the geophysical methods for MPT in general. In other words, the diapirs were analysed independently of the basin within which the rocks constituting them were both deposited and subsequently deformed and emplaced into their present position.

Observations made by the author in a salt mine located within the Kłodawa salt diapir indicate that tectonic structures developed in early stages of the evaporite sequence deformation are also preserved in it. An attempt at analysis of these structures and implications for the early basin dynamics resulting from their shape and presence is the main objective of this paper.

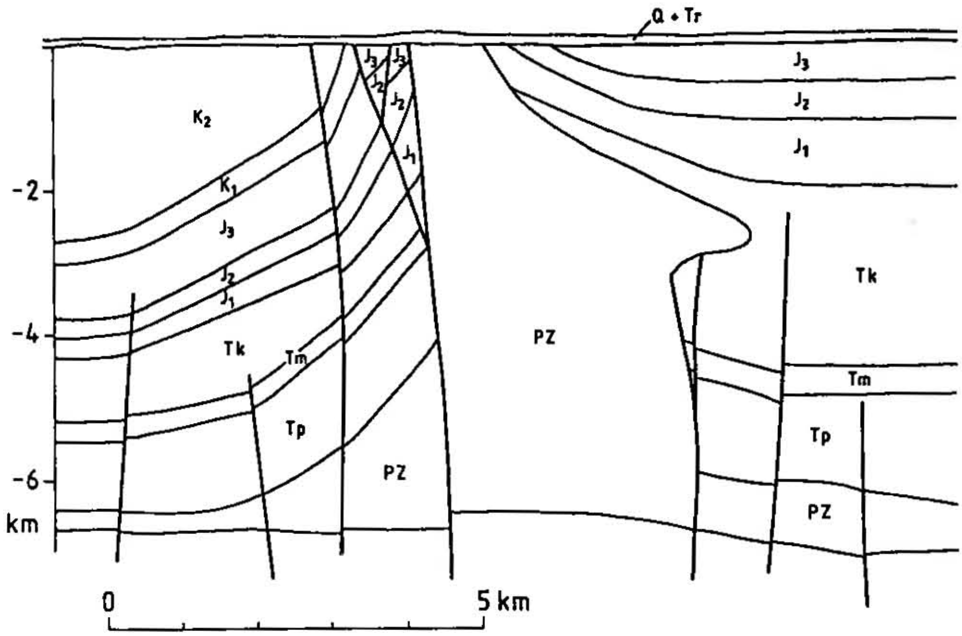

Fig. 2. Simplified cross-section of the Kłodawa salt diapir, showing prominent difference in the thickness of Triassic deposits (after R. Dadlez and S. Marek, unpublished)

PZ — Zechstein, Tp — Buntsandstein, Tm — Muschelkalk, Tk — Keuper, J_1 — Lower Jurassic, J_2 — Middle Jurassic, J_3 — Upper Jurassic, K_1 — Lower Cretaceous, K_2 — Upper Cretaceous, Q+Tr — Quaternary and Tertiary

Uproszczony przekrój przez wysad solny Kłodawy ukazujący zmianę zróżnicowania miąższości osadów triasu (według R. Dadleza i S. Marka, niepublikowany)

PZ — cechsztyn, Tp — pstry piaskowiec, Tm — wapień muszlowy, Tk — kajper, J_1 — jura dolna, J_2 — jura środkowa, J_3 — jura górna, K_1 — kreda dolna, K_2 — kreda górna, Q +Tr — czwartorzęd i trzeciorzęd

GEOLOGICAL SETTING

The Mid-Polish Trough was a zone of almost uninterrupted sedimentation since the Permian until the Late Cretaceous, resulting in several kilometre thick accumulation of deposits in its axial part. The foundation of this basin is strictly connected with regional tectonic events at the Trans-European Suture Zone (TESZ) — the boundary zone between the Precambrian and Palaeozoic Platforms of Europe (A. Berthelsen, 1993). This zone is characterised by numerous fractures at crustal scale, trending parallel to the East European Platform (EEP) margin (A. Guterch *et al.*, 1985, 1986, 1994). According to some authors, these fractures are a response to rifting and crustal extension or, in part, to densification of the lower crust prevailing in that area in the Palaeozoic and Mesozoic, which lead to relatively constant subsidence, enabling continuous sedimentation until the Late Cretaceous (W. Pożaryski, 1975; R. A. Stephenson *et al.*, 1993, 1995). The stages in its evolution were summarised by R. Dadlez and J. Pokorski (1993) .

The most prominent salt structure within MPT is the Izbica Kujawska–Kłodawa–Łęczyca salt ridge (Fig. 1). The ridge is about 60 km long and only about 2 km wide in the upper

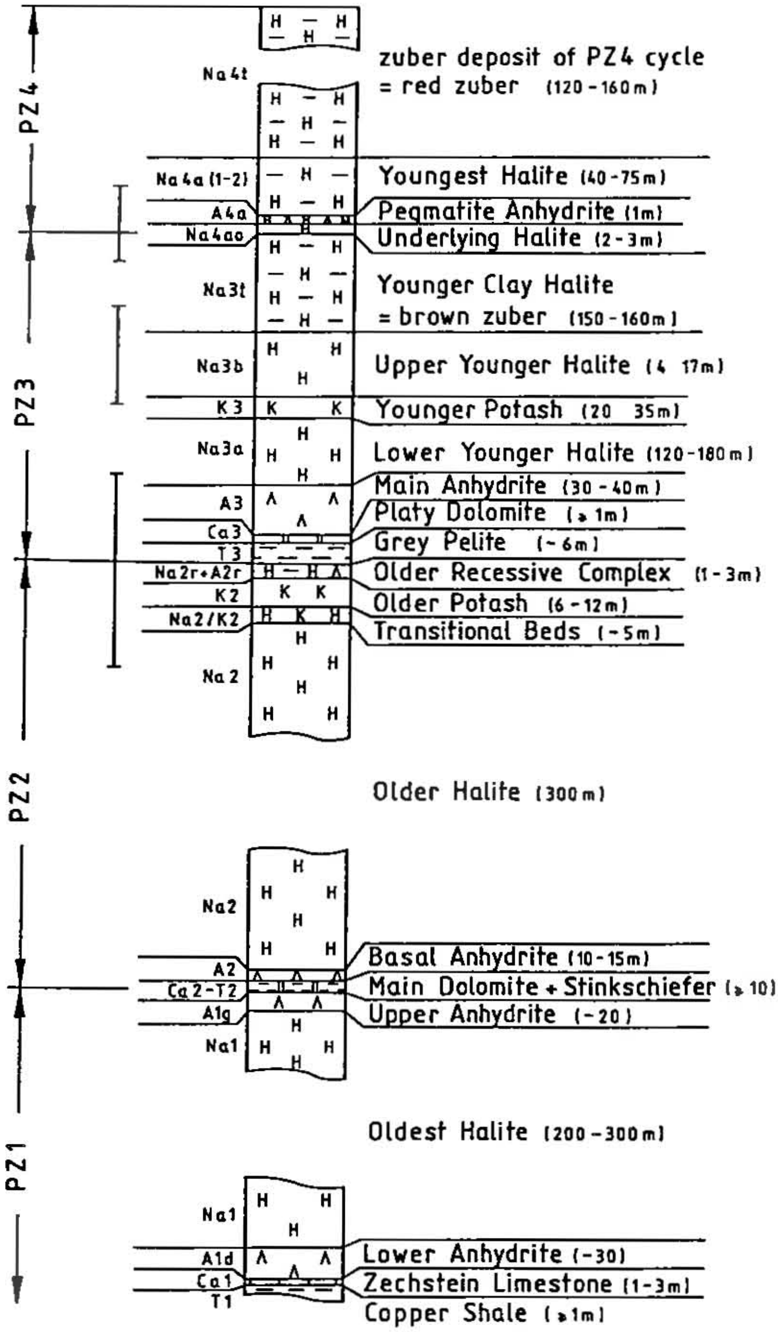

Fig. 3. Stratigraphic column of Zechstein deposits in the Kłodawa salt diapir (after W. Charysz, 1973, modified)
Profil stratygraficzny osadów cechsztynu w wysadzie solnym Kłodawy (według W. Charysza, 1973, zmodyfikowany)

part and, alike other salt structures in that area, it is extremely elongated in the NW–SE direction, being parallel to the boundaries of MPT and to the EEP margin. As seen on Figure 1, similar trend have also some faults presumably existing in the pre-Permian basement (R. Dadlez, 1994). The middle, about 30 km long sector of the ridge pierces through the Mesozoic cover and this part is referred to as the Kłodawa salt diapir (Z. Werner *et al.*, 1960). It rises from the depth of more than 6000 m up to several tens of metres below the surface (Fig. 2). The Mesozoic sequences around the diapir are generally flat-lying and only close to it the beds are distinctly buckled upwards and pierced through by Zechstein rocks (Fig. 2). There is a clear difference in the thickness of the Mesozoic deposits on both sides of the diapir. East of this structure the thicknesses are remarkably higher than on the western side. This in particular concerns the thicknesses of the Upper Triassic units, which on the eastern side are more than twice as thick as on its western side. The latter observation and palaeoisopach maps for the Triassic units (S. Marek, 1988; A. Szyperko-Teller, W. Moryc, 1988; I. Gajewska, 1988*a*, *b*; Z. Deczkowski, M. Franczyk, 1988) imply increasing rate of sedimentation east of the diapir, related to the development of the Kutno and Krośniewice Depressions. These depressions, according to the above-mentioned authors, were a response to strong subsidence operating in that area. The borders of the depressions were fault controlled and one of the faults must have coincided with the present position of the Izbica Kujawska–Kłodawa–Łęczyca salt ridge, as this structure separates areas of distinctly different thicknesses of the Triassic deposits.

The Kłodawa salt diapir is built of Zechstein evaporites and terrigeneous rocks. Their stratigraphy was described in detail by W. Charysz (1973), hence it will not be considered here and only a lithostratigraphic column after this author is shown (Fig. 3). Internal structure of the diapir was studied and described by J. Poborski (J. Poborski, 1955; Z. Werner *et al.*, 1960) and his interpretation of the diapir architecture is generally accepted until now (Fig. 4). One should, however, bear in mind the limitation to this interpretation, which result from the fact that salt mine excavations are mainly located in the eastern part of the diapir, they do not exceed the depth of 750 m below the surface and that the deeper portion of this structure was investigated only by a few boreholes.

The beds are generally steeply dipping (70–90°) and striking parallel to the diapir boundaries, i.e. SE–NW. Normal stratigraphic arrangement of beds is also maintained in large portions of the structure, but repetition of some horizons do locally occur. Occasionally, some units from the lithostratigraphic column may be missing, which is due to different rheology. Although evaporites are among the least competent rocks, the individual lithological varieties constituting the diapir (Fig. 3) have contrasting competence. The most competent are dolomite, anhydrite and shales while the least competent are potassium salts and rock salt. Any admixture of clay or anhydrite within the rock salt increases its competence in relation to pure rock salt. This lithological variation and dependence on the rheological properties of rocks caused that the strain distribution throughout the diapir varies and is localised dominantly within thick pure rock salt and potassium salts units. Other, competent elements are passively carried as rafts within the most strained rocks (S. Burliga, 1996). Therefore, the rocks may contain even synsedimentary structures preserved within them in little altered, "frozen" form. These least strained portions of the diapir will be considered further in the paper, as they should provide reliable evidence for the nature

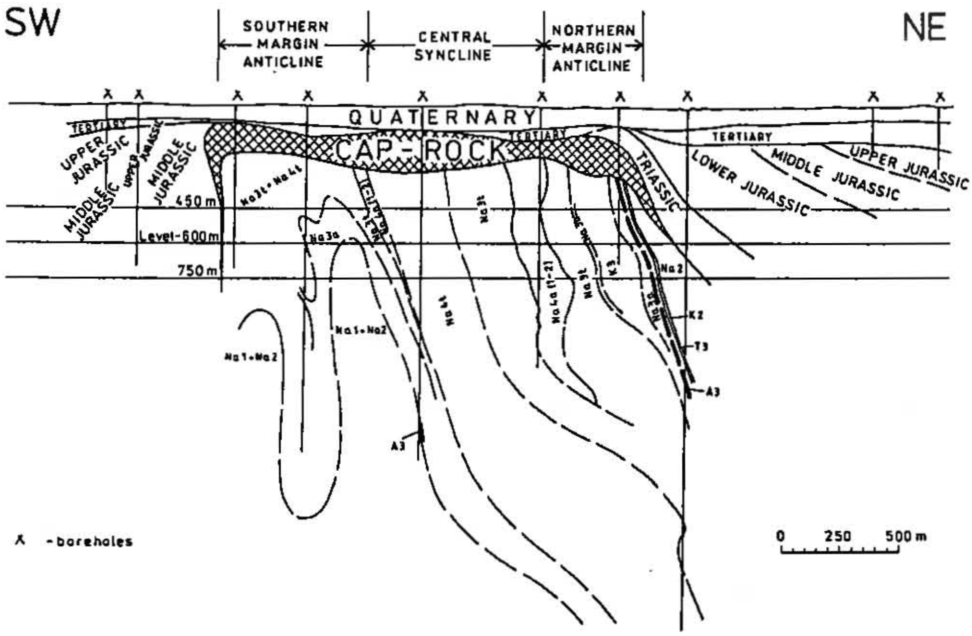

Fig. 4. Geological cross-section across the upper part of the Kłodawa salt diapir (based on Z. Werner *et al.*, 1960 and modified by mine geologists)

Explanations as in Fig. 3

Przekrój geologiczny przez górną część wysadu solnego Kłodawy (na podstawie Z. Wernera i in., 1960, i zmodyfikowany przez geologów kopalnianych)

Objaśnienia jak na fig. 3

of the earliest deformations affecting the Zechstein sequence. A big advantage to this study is that the original position of the deformed rocks is known (horizontally bedded deposits).

TECTONIC STRUCTURES WITHIN THE DIAPIR

The analysis of tectonic structures was carried out at 3 mine levels: 450, 600, 750 (Fig. 4) throughout the diapir. Due to dimensions of the mine galleries it was focused on small scale structures, which were mapped and measured up where possible. For the purpose of this study only those horizons were selected, which have clear stratigraphic position, are not intensely strained and within which the tectonic structures do not exhibit complex deformational history. The above requirements are the best met within the bottom and top horizons of the K3 Younger Potash unit. In fact, this unit is composed of rock salt layers alternating with thin potassium salts, clayey salt, anhydrite or shale layers. The latter are thicker and more abundant closer to the boundaries with the Na3a Lower Younger Halite and Na3b Upper Younger Halite. Only within the middle part of this unit increased thickness of potassium salts layers is observed. There the rocks are extremely strained and more competent layers (rock salt, clayey salt) are even completely distorted. The intensity of deformation decreases visibly towards the bottom and top of the unit. It is important to notify that the transition to the Na3b Upper Younger Halite and Na3t Younger Clayey Halite is gradual. Within this transitional zone several horizons of desiccation polygons are preserved (S. Burliga, 1995).

From a variety of tectonic structures developed within the layered rocks (folds, faults, boudines, fractures, veins, etc.) the most important implications on the nature of the early deformation are provided by peculiar folds and faults.

FOLDS

Rock salt layers in the upper and lower part of the K3 Upper Potash unit are generally 10–40 cm thick, and they are separated by thin, up to 5 cm thick, layers of potassium salts. The rock salt may contain anhydrite or clays, either dispersed within it or concentrated in laminae. Because the majority of mine galleries follows the strike of beds or are slightly oblique to it, such a cross-section through the beds is most often observable. In that cross-section folds occurring within the rock salt layers have relatively constant geometry. They appear as isoclinal folds with their limbs and axial planes being parallel/subparallel to the bedding and the fold interlimb angle close to 0° (Pl. I, Fig. 7). Thickness of limbs is similar, although occasionally the stratigraphically lower limb can be thinner. Layer thickness is distinctly increased within the fold hinges and there the stratigraphically lower part of the hinge zone is also thicker. In the scale of the mine galleries the folds seem to affect singular beds or only a few of them; the surrounding beds remain undisturbed. While layers incorporated in folds are close to each other in the limbs, in the hinge zones they are considerably pulled apart. The space between them is filled with potassium salts in the form of saddle reefs (Pl. I, Fig. 8). These folds represent class 1C folds in the isogonal fold classification of J. G. Ramsay (J. G. Ramsay, M. I. Huber, 1987). Similar geometry have the second order folds (Pl. I, Fig. 7). The angle of dip of the axial planes and limbs is very steep (70–90°) and it is determined by the dip of the bedding. Their fold axes in the analysed cross-section also plunge steeply (45–70°) but the axial plunge direction varies significantly. Even in neighbouring anticline and syncline the direction of axis plunge may be opposite. This variation is, however, limited to two main directions, i.e. NW and SE, which correspond to the strike direction of beds (the strike of beds changes from the dominant direction in large scale folds within the ridge and so do the directions of fold axis plunge). That apparently intriguing situation is easy to explain when looking at a cross-section perpendicular to the bedding. There the folds have a closed outcrop pattern — a pattern of extremely elongated ellipses (Pl. II, Fig. 9). The folds should be, thus, classified as sheath folds. Their axes cannot be measured directly. From the spatial orientation of fold axes measured in oblique cross-section results that the plunges directions of the sheath fold axes are steeper than the observed ones, more approaching the direction of the dip line of the beds.

All the above features indicate that the beds were initially folded by the flexural-slip folding and consequently were progressively modified into the sheath folds. What is

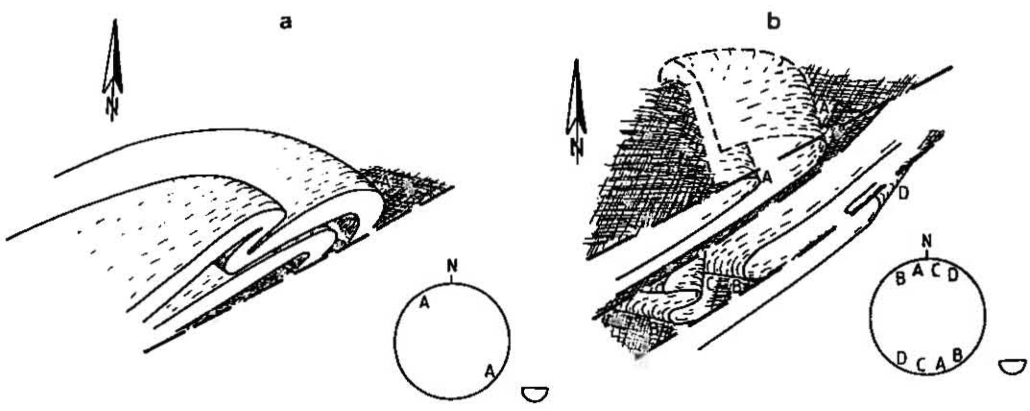

Fig. 5. Schematic interpretation of folds: a (Pl. I, Fig. 7) and b (Pl. I, Fig. 8) and orientation of fold axes after rotation of beds to horizontal position

Schematyczna interpretacja fałdów: a (tabl. I, fig. 7) and b (tabl. I, fig. 8) oraz orientacja osi fałdów po rotacji warstw do położenia poziomego

characteristic, most often anticlinal arrangement of beds within those sheath folds is preserved. Besides bedding, no lineation or foliation is visible with naked eye.

FAULTS

Folds occurring in the K3 Younger Potash unit are often truncated by faults. The fault planes likewise the axial planes and fold limbs are generally parallel to the bedding planes. Because of that, the faults are visible only in those places, where the fold hinges are present. Usually they displace one of the fold limbs, commonly the stratigraphically upper one. The fault surface truncates the folds just behind the hinge zone. There are no striations or other small scale structures indicative of transport direction on them. The displacement surfaces occur within potassium salts horizons.

DISCUSSION

The structures characterised in the previous chapter are interpreted as early tectonic structures. Their most striking features are the fold axial planes, limbs and fault planes concordant with the bedding planes, the fold interlimb angle close to 0°, intriguing asymmetry of the second order folds and the thickness variation in hinge zones (Pl. I, Figs. 7 and 8). All these features are typical of folds related to gravity gliding and this is the most likely mechanism for their formation. In consequence, they had to deform in still horizontally layered rocks, as at the present position they would have to glide upwards. But this interpretation may meet some objections, which require discussion. Two major of them concern the possibility of preservation of such structures within the diapir and the possibility of such a folding mechanism in rock salt.

First of them was already partly addressed. The rocks constituting the diapir have different rheological characteristics. The competence contrast between them may be very high. This factor causes that strain is unequally distributed throughout the diapir and individual lithological varieties are strained with variable intensity. The areas of high strain were basically accommodated by the least competent potassium salts and pure rock salt units and the tectonic transport was also localised within them (S. Burliga, 1996). Some portions of rocks between those highly strained horizons might escape much of the overall deformation. This is proved by the presence of synsedimentary desiccation polygons, occurring in several continuous horizons throughout the diapir. The origin of these structures was attributed to different mechanisms (A. Garlicki, 1991; R.Tarka, 1989) but comparing them to the structures observable on modern deserts (R. Cooke *et al.*, 1993), they posess all typical features of modern desiccation polygons (S. Burliga, 1995). If synsedimentary structures are preserved in the diapir, thus, the presence of the early tectonic structures is also likely.

Mechanism of salt deformation is still not fully understood. According to commonly accepted model of F. Trusheim (1960), the basic mechanism leading to salt structure formation is the salt flow on a slightly inclined surface. Whatever is its nature, the movement is triggered by the gravity forces, coupled with forces exerted by loading with the overlying strata, acting on a thick unit of rock salt. These forces make the salt beds to move first downslope and then, due to density unstable arrangement, upwards. Because of contrasting competence of beds in the Zechstein sequence, the response of different rocks to the salt flow varies. The more competent rocks become fractured, boudinaged and numerous décollement structures develop within the less competent horizons.

Examples of salt flow and tectonic structures related to it are described by C. J. Talbot (C. J. Talbot, 1979; C. J. Talbot, M. P. A. Jackson, 1987) from modern namakiers, i.e. salt glaciers. The salt within the namakiers flows only due to gravity. During its movement abundant folds are formed, with geometry very similar to those observed in the Kłodawa salt diapir. Slides developed in the salt glaciers also have similar characteristics and spatial relation to the folds. It is impossible to distinguish the movement direction and the only indication for it is the inclination of the slope. The minor differences between the structures in the salt glaciers and in the diapir may result from different composition of these structures. The namakiers are composed mainly of rock salt and in the diapir it is interbedded with other rocks. The structures are additionally observable at different scale.

Provided that the above reasoning is justified, the sheath folds preserved within the Kłodawa salt diapir have a valuable significance in determination of the bulk tectonic transport direction, mechanism of the earliest deformation of the evaporite sequences and of the regional conditions prevailing within the basin. This analysis should be, however considered at original arrangement of beds, i.e. at horizontally layered rocks.

Figure 5 presents schematic interpretation of folds showed in Pl. I, Figs. 7 and 8. The sheath fold geometry is assumed for them. The orientation of fold axes is also schematically shown in the lower hemisphere projection, after rotation of beds to horizontal plane. In both cases the transport direction is generally towards E–NE. It seems unreasonable to determine this direction more precisely, as the possibility of an error in measurements and rotation is too big. Such a transport direction is indicated by all early tectonic structures throughout the diapir, which additionally confirms that those structures had to develop before the

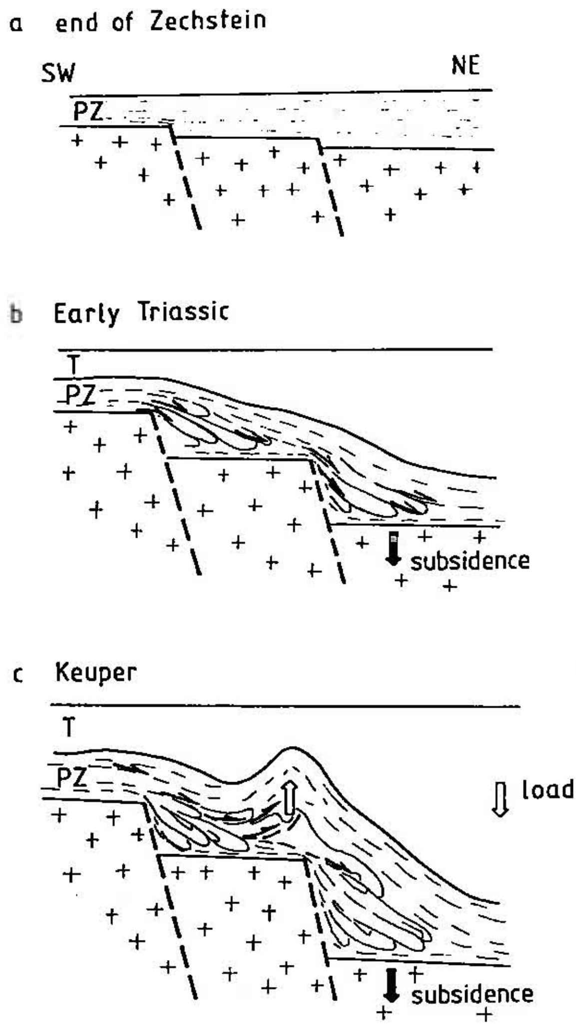

Fig. 6. Schematic interpretation of early diapir development in the Kłodawa area; see the text for details
Schematyczna interpretacja wczesnego rozwoju wysadu solnego Kłodawy; szczegóły w tekście

upward movement started. The latter lead to development of more variably oriented structures.

A question arises concerning the time of this movement. Looking at the palaeoisopach and palaeotectonic maps for the Permian and Triassic, it is clearly visible that the region of the present diapir was an area of extremely huge accumulation of deposits (J. Pokorski, 1988; R. Wagner, 1988; A. Szyperko-Teller, W. Moryc, 1988; I. Gajewska, 1988*a, b*; Z. Deczkowski, M. Franczyk, 1988). According to these authors it was linked with strong subsidence, which was especially pronounced east of the diapir, within the Kutno and

Krośniewice Depressions. These depressions exhibited their presence by increased deposit thickness already in the Middle Buntsandstein (A. Szyperko-Teller, W. Moryc, 1988). Thus, in this time the inclination of the Zechstein bed surfaces towards the east appeared. Additionally, those sequences were already covered by several hundred metres of Lower Triassic deposits, which must have exerted pressure on the underlying strata. Sharp boundaries of the depressions suggest that they were fault bounded, and, consequently, that the basement in this region was not stable. The latter might be the overall triggering mechanism for the salt movement. The eastward direction of movement must have dominated until the Late Keuper, because only in that period a more differential basin morphology is visible on the palaeoisopach maps (I. Gajewska, 1988*b*). The variation in morphology can be attributed to the beginning of the upward salt movement, buckling the overlying strata.

MODEL FOR THE EARLY DEVELOPMENT OF THE KŁODAWA SALT DIAPIR

A schematic interpretation of the above regional events is illustrated in Fig. 6. Figure 6a illustrates the palaeotectonic situation in the Kłodawa region inherited after the Zechstein. A thick sequence of evaporites filled morphological depressions in the basement. Their development was controlled by faults existing in the basement, which is indicated by very high rate of subsidence in this area (R. Wagner, 1995). Therefore, sedimentation of the Lower Buntsandstein started in the morphologically levelled basin (A. Szyperko-Teller, W. Moryc, 1988). It is possible that the first salt movements were already initiated in the subsiding Zechstein basin.

In Figure 6b (Early Triassic-Middle Buntsandstein?) the depression east of Kłodawa was reactivated, most probably due to general NE–SW extension and rifting within MPT, which reactivated the fault zones in the basement. It caused a strong increase of the rate of subsidence within the depression and, in consequence, the inclination of the Zechstein beds and salt flow towards the axis of the subsiding basin, i.e. towards the east. The rock salt beds were folded and faulted due to the gravity gliding, leading to thicker accumulation of the evaporites close to the fault escarpment. The more competent beds were passively carried within the flowing rock salt. As the subsidence continued, the thickness of the Zechstein beds and of the overlying strata became big enough to make the evaporites move upward, due to a prominent density unstable arrangement and still active fault zone (Fig. 6c, Keuper). The diapir started to rise above the fault zone, which mechanically was the weakest.

The proposed scheme of the gravity gliding is likely, because the beds preserved their stratigraphical order and synsedimentary structures in large portions of the diapir, even in spite of more than 7 km transport. The Izbica Kujawska–Kłodawa–Łęczyca salt ridge was, thus, fault controlled and its shape follows a fault existing in the basement. Other elongated salt structures within MPT most probably have similar relations to the basement faults. The implications resulting from the small scale structures preserved within the diapir are in agreement with those obtained by geophysical investigations in MPT in general. However, they provide another evidence for extensional faulting in the basement and subsidence during the early stages of the MPT evolution. The above conclusions are also in agreement with observations in other parts of the European Zechstein Basin as e.g. in the Central North Sea area, where similar dependence of salt structures on the basement faults is observed (P. G. Buchanan *et al.*, 1996; S. A. Stewart, 1996).

CONCLUSIONS

Tectonic structures preserved within the weakly strained portions of the Kłodawa salt diapir indicate that deformation of the evaporite sequences started in still horizontally layered rocks. It basically affected rock salt units, which became folded into sheath folds and faulted in response to the gravity gliding. Their presence suggests that, in the time of their development, the Zechstein sequences had to become slightly inclined to enable gliding. The bulk tectonic transport indicated by these early structures is towards the east/north-east, i.e. towards the axis of a subsiding depression, which was developing east of Kłodawa since the Middle Buntsandstein. The latter was related to extensional faulting in the basement (NE–SW extension). In the Keuper the diapir started to rise over a fault bordering the depression. This was due to a huge, gravity gliding driven accumulation of salts close to the fault and a pressure exerted by the overlying strata. The small scale tectonic structures preserved within the Kłodawa salt diapir confirm the observations and conclusions on the MPT development in the Triassic, obtained by the geophysical methods and boreholes. They also indicate how big is the potential of evaporites in recording the tectonic events in the region.

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Instytut Geologii
Uniwersytetu im. Adama Mickiewicza
Poznań, ul. Maków Polnych 16
e-mail: burliga@hum.amu.edu.pl
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Stanisław BURLIGA

DYNAMIKA BRUZDY ŚRÓDPOLSKIEJ WE WCZESNYM STADIUM ROZWOJU NA PODSTAWIE STRUKTUR DEFORMACYJNYCH W OSADACH SOLNYCH CENTRALNEJ POLSKI

Streszczenie

Badania przeprowadzone w wysadzie solnym Kłodawy wykazały obecność drobnych struktur tektonicznych, dokumentujących najwcześniejszy etap deformacji sekwencji ewaporatowej. Zachowały się one szczególnie w mało odkształconych obszarach wysadu, w których występują także struktury synsedymentacyjne (horyzonty szczelin z wysychania). Są to fałdy futerałowe i uskoki powstałe podczas grawitacyjnego płynięcia i ześlizgiwania się ławic solnych. Skały mniej podatne od czystej soli kamiennej i soli potasowych były biernie transportowane w ich obrębie, co umożliwiło zachowanie pierwotnego układu stratygraficznego w wielu miejscach wysadu. Struktury tektoniczne w obrębie wycinka wysadu objętego robotami górniczymi wskazują na generalny kierunek transportu tektonicznego ku E i NE. Obserwacja ta pozostaje w zgodzie z danymi uzyskanymi metodami geofizycznymi i za pomocą wierceń, które wykazują istnienie w triasie silnie pogrążającego się basenu na wschód od Kłodawy. Basen ten miał założenia tektoniczne. Jego intensywna subsydencja wiązana jest z reaktywacją uskoków w podłożu, wywołaną NE–SW ekstensją w bruździe śródpolskiej.

Nachylenie podłoża powodowane reaktywacją normalnych uskoków w rejonie Kłodawy (środkowy pstry piaskowiec?) i nacisk wywierany przez gromadzące się osady triasu wywołały grawitacyjne spływanie soli w kierunku pogrążającego się basenu. Prowadziło to do zwiększania miąższości utworów solnych w rejonie uskoku, a w efekcie do pogłębiania gęstościowo niestatecznego układu i wymuszenia ruchu soli ku górze (kajper?). Zachowane w skałach solnych wysadu kłodawskiego drobne struktury tektoniczne dokumentują zatem aktywność tektoniczną bruzdy śródpolskiej we wczesnym etapie jej rozwoju.

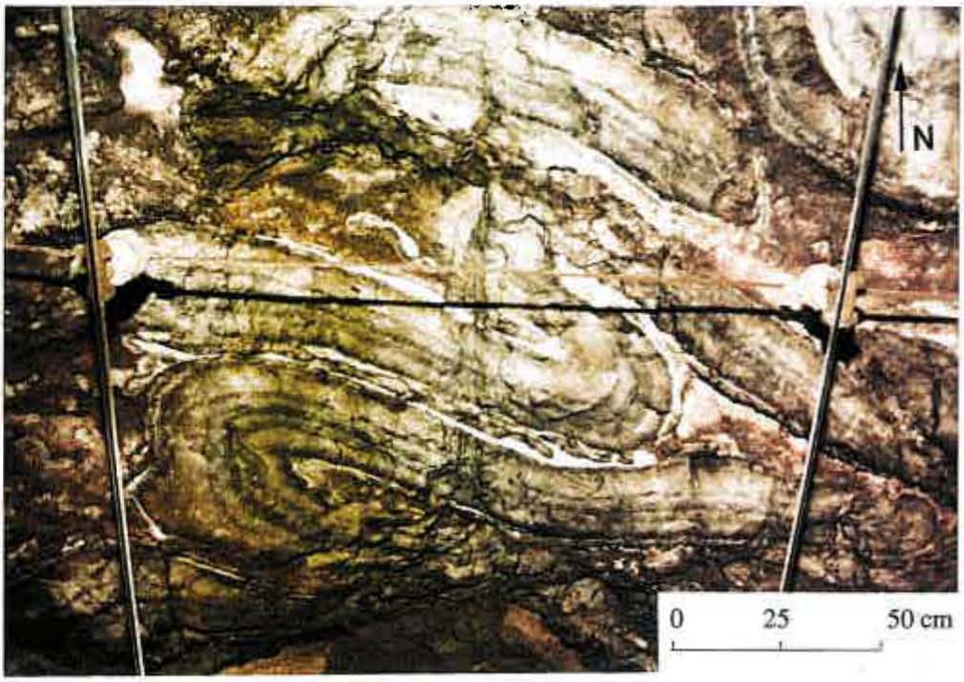

Fig. 7

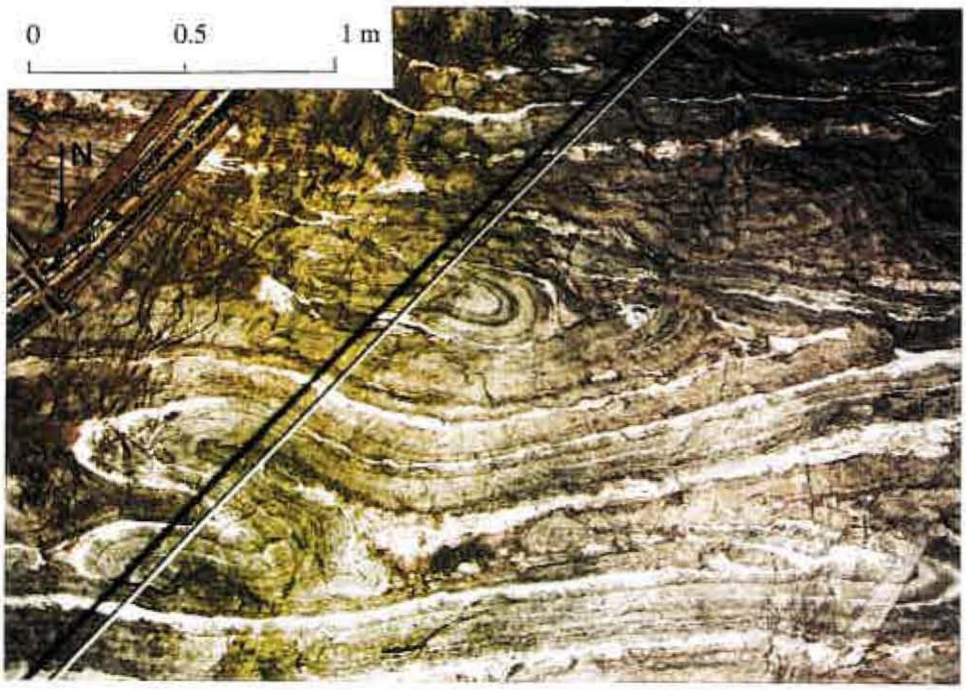

Fig. 8

Stanisław BURLIGA — Implication for early basin dynamics of the Mid-Polish Trough from deformational structures within salt deposits in central Poland

PLATE I

Figs. 7, 8. Early sheath folds and faults preserved within the Kłodawa salt diapir (cross-section subparallel to the fold axes); roof of a mine gallery; normal stratigraphic arrangement of beds; level 600, K3 Younger Potash unit

Fałdy futerałowe i uskoki powstałe we wczesnym etapie deformacji zachowane w wysadzie solnym Kłodawy (przekrój prawie równoległy do osi fałdów); strop chodnika kopalnianego; orientacja warstw zgodna z porządkiem stratygraficznym; poziom 600; młodsza sól potasowa K3

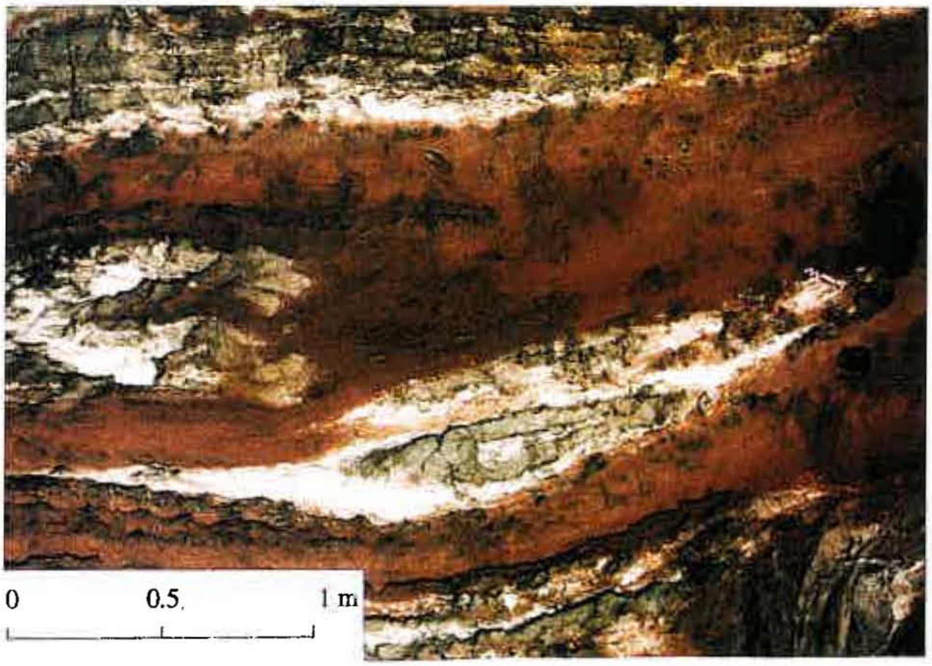

Fig. 9

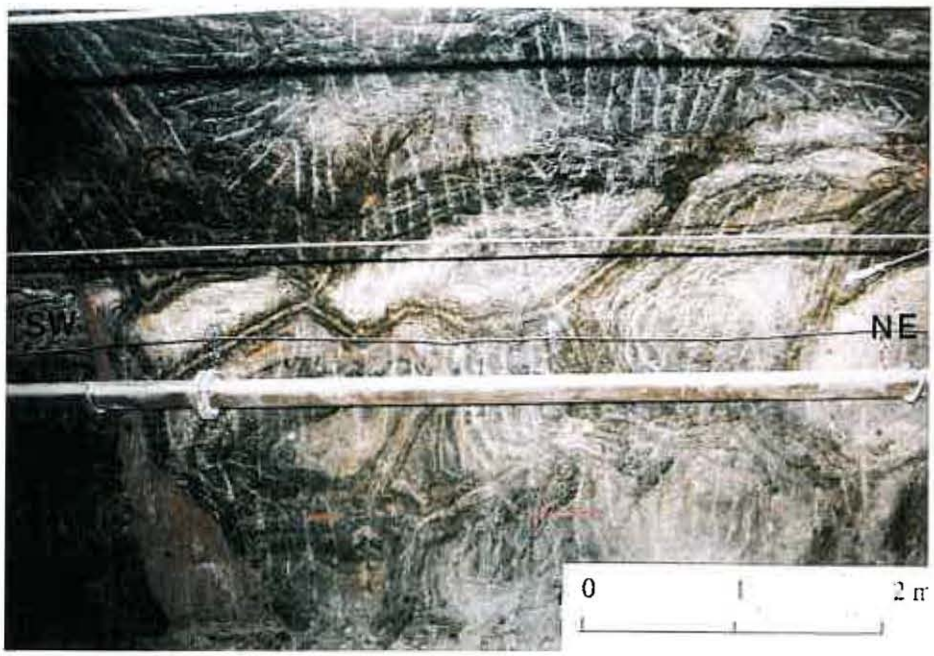

Fig. 10

Stanisław BURLIGA — Implication for early basin dynamics of the Mid-Polish Trough from deformational structures within salt deposits in central Poland

PLATE II

Fig. 9. Sheath fold geometry in a perpendicular cross-section to the fold axis; note the closed, elliptical outcrop pattern; wall of a mine gallery; normal stratigraphic arrangement of beds; level 600, K3 Younger Potash unit

Geometria fałdu futerałowego w przekroju prostopadłym do osi fałdu; widoczna zamknięta, eliptyczna forma odsłonięcia; ściana chodnika kopalnianego; orientacja warstw zgodna z porządkiem stratygraficznym; poziom 600; młodsza sól potasowa K3

Fig. 10. Desiccation polygons in a cross section parallel to the bedding; level 750, transitional horizons to Na3t Younger Clay Halite

Poligony z wysychania w przekroju równoległym do uławicenia; poziom 750; utwory przejściowe do zubra brunatnego Na3t