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Sedimentation of Middle Miocene marine complex from the area near Tarnobrzeg (north-central part of the Carpathian Foredeep)

The complex of Upper Badenian-Sarmatian deposits, overlying the sulphur-bearing evaporites in the area southwestward from Tarnobrzeg (north-central part of the Carpathian Foredeep) was deposited within an open marine deep basin, with dominant deposition of pelitic material from suspension and some activity of traction/turbidity currents. Two transgressive-regressive cycles (lower cycle dated as Upper Badenian and upper cycle as Sarmatian) were distinguished, reflecting the general pattern of evolution of the Carpathian Foredeep at that time. The transition between both cycles occurred in the same basin conditions (basin depth and deposition style were unchanged) except that the transgression of the upper cycle was registered as an increase in water salinity and the occurrence of new faunal elements but decline of older ones.

INTRODUCTION

The complex of Middle Miocene marine deposits in the Carpathian Foredeep, overlying the evaporitic deposits of the Middle Badenian (Wielician substage), is very homogeneous and developed mainly as pelitic deposits; few papers have considered its sedimentology. Most of studies refer to its general characteristics, description of macro- and microfossils and defining its stratigraphic position (W. Krach, 1962, 1967, 1971; K. Kowalewski, 1958, 1966; E. Łuczkowska, 1964; E. Odrzywolska-Bieńkowa, 1966; W. Parachoniak, 1962; S. Pawłowski, 1965; S. Szafran, 1980). Some authors regarded these deposits as an open marine pelitic facies (W. Krach, 1973; S. Pawłowski *et al.*, 1985; A. Radwański, 1973); others as shelf sediments with widely prograding prodelta deposits with distributary channel facies in the area between the Wisła and San rivers up to the Carpathian margin (P. Karnkowski, 1978, 1989; T. Piątkowski, 1973); still others distinguished systems of lagoons, barriers and fan deltas, developed at the southern margin of the foredeep (P. Krzywiec, 1993). The most

Fig. 1. Studied area and geology of the Carpathian Foredeep near Tarnobrzeg (after A. Gąsiewicz, 1989, changed)
1 — extent of Miocene deposits, 2 — extent of Miocene sulphates, 3 — native sulphur deposits, 4 — Carpathian margin, 5 — major dislocations, 6 — area studied
Zarys geologii zapadliska przedkarpackiego w rejonie Tarnobrzega (według A. Gąsiewicza, 1989, zmienione)
1 — zasięg osadów miocenu, 2 — zasięg siarczanów mioceńskich, 3 — złoża siarki rodzimej, 4 — brzeg Karpat, 5 — większe dyslokacje, 6 — obszar badań

comprehensive image of facies distribution of these deposits was shown in 1974 (R. Ney *et al.*, 1974) but from that time new data obtained from cores and seismic studies (P. Karnkowski, 1994; E. Gaździcka, 1994; J. Paruch-Kulczycka, 1994) supplemented and/or changed our view of the geology and stratigraphy of this Upper Badenian-Sarmatian complex.

This paper presents the detailed geological characteristics and a reconstruction of the origin of this complex from a small area in the northern-central part of the Carpathian Foredeep, southwest of Tarnobrzeg (Fig. 1), and it compares the development pattern observed there with the tendencies of evolution of the Fore-Carpathian basin during the Upper Badenian-Sarmatian period.

GEOLOGICAL PATTERN

The marine pelitic sediments, occurring in most of the Carpathian Foredeep above the evaporitic series of Middle Badenian age (Wielician substage — see G. Czapowski, 1994; B. Kubica, 1994) with native sulphur and rock salt deposits, consist of two main lithological units: the *Pecten* Beds and the Krakowiec Clays (K. Kowalewski, 1966; W. Krach, 1967, 1971; R. Ney *et al.*, 1974; S. Pawłowski *et al.*, 1985). The *Pecten* Beds and lower part of the Krakowiec Clays are dated as Upper Badenian (Kosovian substage — A. Papp *et al.*, 1978) and their thickness varies in the foredeep from several to over 1000 m (Fig. 2). However, in the studied area it changes between 20 to over 60 m. The Krakowiec Clays, regarded as a facies unit, is subdivided — based on fossils — into two subunits: the *Syndesmya* (= Abra) Beds and the *Serpula-Ctenophora* Beds. The lower part of the *Syndesmya* Beds belongs to the Kosovian substage based on foraminifers (E. Odrzywolska-Bieńkowa, 1966; J. Szczechurowa, 1982) and the upper part, together with the *Serpula-Ctenophora* Beds, are dated as the Lower-Middle Sarmatian stage (Volhynian substage — A. Papp *et al.*, 1974). The thickness of these Sarmatian series varies within the Carpathian Foredeep from several to over 2400 m (Fig. 3). In the studied area it changes from about 200 to over 800 m in its southeastern part. The average total thickness of the post-evaporitic marine complex in the discussed area is estimated at about 530 m.

The sedimentological analysis of this complex is based on the preserved cores of two boreholes: Gwoździec P10 and Poręby Dębskie P12, located in the Alfredówka – Gwoździec area, southeast of Tarnobrzeg (Fig. 4A). Due to variable preservation of these cores some samples, illustrating lithology and faunal assemblages of this complex (Pl. I, Figs. 6–8), were taken from other profiles near Tarnobrzeg and Osiek (the collection of S. Pawłowski and K. Pawłowska).

The analysed series overlies the lithologically diffentiated evaporitic horizon of the Wielician age (A. Gąsiewicz, 1989) consisting of limestones, sulphur-bearing limestones and sulphates (Fig. 4A). In the northwestern and southern parts of area this horizon is cutting by two faults, the southern one has thrown down the evaporites over 200 m (Fig. 4A, B).

CHARACTERISTICS OF THE MIDDLE MIOCENE COMPLEX

THE *PECTEN* BEDS

This unit, from 2 to over 33 m thick, is distinguished by frequent occurrences of *Pecten* shells and developed mainly as grey and grey-green carbonate siltstones and marls, structureless or rarely horizontally laminated. Locally fine sandy as well as limestone or marly limestone intercalations are noticed (Fig. 5). In the section several tuffite and bentonitic tuffite interbeds, 2–20 mm thick (Fig. 5, borehole Poręby Dębskie P12), are present. Such tuffite and bentonite laminae/layers within this unit are common in the whole foredeep (E. Fijałkowska, J. Fijałkowski, 1966; W. Parachoniak, 1962) and are assumed to be correlative horizons. In the studied area they are very thin and occur irregularly which eliminated their use as the marker beds.

The *Pecten* Beds contain numerous fossils, dispersed or concentrated locally in the form of shell beds (Pl. I, Fig. 6). Among pectens the most common are *Chlamys elini* Ziszczenko

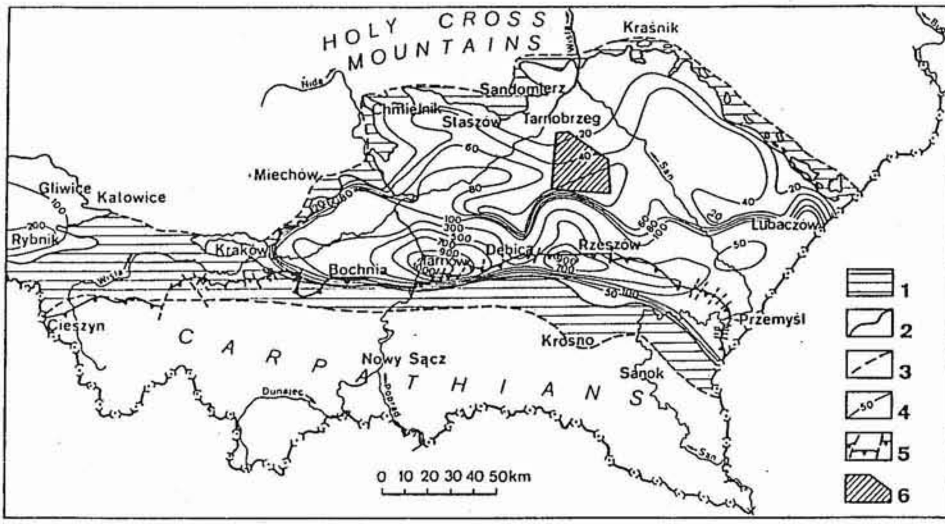

Fig. 2. Thickness map of the Upper Badenian (Kosovian) deposits in the Carpathian Foredeep (after R. Ney *et al.*, 1974, simplified)
1 — area with eroded Kosovian deposits, 2 — recent extent of Kosovian deposits, 3 — primary extent of Kosovian deposits, 4 — isopachytes of primary deposit thickness, 5 — Carpathian margin and related dislocations, 6 — area studied
Mapa miąższościowa utworów górnego badenu (kosowu) w zapadlisku przedkarpackim (według R. Neya i in., 1974, uproszczona)
1 — obszar, na którym osady kosowu zostały zerodowane, 2 — obecny zasięg osadów kosowu, 3 — pierwotny zasięg osadów kosowu, 4 — izopachyty osadów przed erozją, 5 — współczesny brzeg Karpat i dyslokacje, 6 — obszar badań

and *Ch. neumayeri* Hilber; other bivalves include the genera *Nucula, Corbula, Thracia, Syndesmya* (= Abra), *Ostrea, Venus* and *Crania.* Other fossils are represented by fish otolithes and scales, fragments of sea urchins (plates and spines), crabs, bryozoans and abundant foraminifers with index forms for the Kosovian substage: *Neobulimina longa* Wengliński and *Hanzawaia crassiseptata* (= *Cibicides crassiseptatus* Łuczkowska) (E. Łuczkowska, 1964; E. Odrzywolska-Bieńkowa, 1966; R. Ney *et al.*, 1974; A. Papp *et al.*, 1978). Also common are gastropods, worm tubes (*Serpula* and *Vermetus*) and bioturbation as well as fine plant remains and pyrite concentrations. Locally numerous pteropods of the genus *Spirialis* are observed as well as fine clay rollers (Fig. 5, borehole Gwoździec P10).

THE KRAKOWIEC CLAYS

THE *SYNDESMYA* BEDS

The lower part of the Krakowiec Clays is distinguished as the *Syndesmya* (= Abra) Beds due to numerous shells of the bivalve *Syndesmya* (= Abra) *reflexa* Eichwald (Pl. I, Fig. 7) and a lack of pectens. In the studied area these deposits are 33–50 m thick and in their lower part contain more carbonates. The fossil assemblage consists of bivalves and gastropods

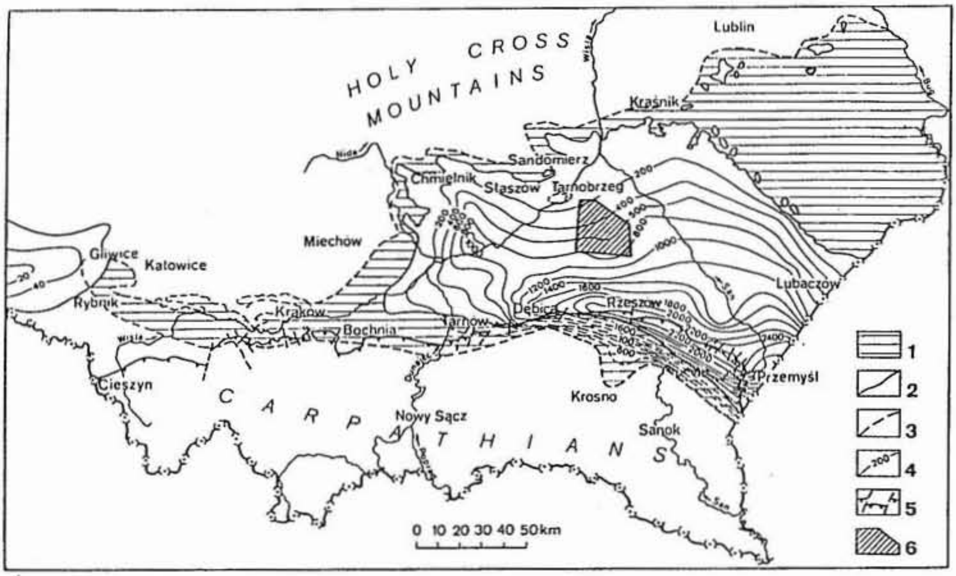

Fig. 3. Thickness map of the Sarmatian deposits in the Carpathian Foredeep (after R. Ney *et al.*, 1974, simplified) 1 — area with eroded Sarmatian deposits, 2 — recent extent of Sarmatian deposits, 3 — primary extent of Sarmatian deposits; other explanations as in Fig. 2

Mapa miaższościowa utworów sarmatu w zapadlisku przedkarpackim (według R. Neya i in., 1974, uproszczona) 1 — obszar na którym osady sarmatu zostały zerodowane, 2 — obecny zasięg osadów sarmatu, 3 — pierwotny zasięg osadów sarmatu; pozostałe objaśnienia jak na fig. 2

dominated by the genera *Syndesmya* (= Abra), *Ervilia, Mohrensternia* and *Hydrobia* (R. Ney *et al.*, 1974; A. Papp *et al.*, 1974, 1978; S. Pawłowski *et al.*, 1985). In the lower part of this unit were frequently found foraminifers *Hanzawaia crassiseptata* Łuczkowska that document its Upper Badenian age but upward occurred abundant *Anomalinoides dividens* Łuczkowska (an equivalent of *Anomalinoides badenensis* d'Orbigny— see R. Ney *et al.*, 1974) as well as *Quinqueloculina sarmatica* Karrer, the index foraminifers for the Lower Sarmatian (E. Łuczkowska, 1964; R. Ney *et al.*, 1974; A. Papp *et al.*, 1974; S. Pawłowski *et al.*, 1985).

Generally, in the whole profile of the Krakowiec Clays was observed the gradual lowering of faunal diversity resulted from decrease of number of genera and flourishing of some species (*op. cit.*).

THE *SERPULA-CTENOPHORA* BEDS

This unit is very impoverished in fauna and only rare foraminifers, representing the *Elphidium hauerinum* Zone, were noticed (S. Pawłowski *et al.*, 1985). Some *Serpula* tubes, fish scales and remains/traces of planktonic *Ctenophora* as well as plant remains have been found (*op. cit.*). This is the thickest part of the Krakowiec Clays, and its thickness quickly increases southward from over 200 to over 490 m.

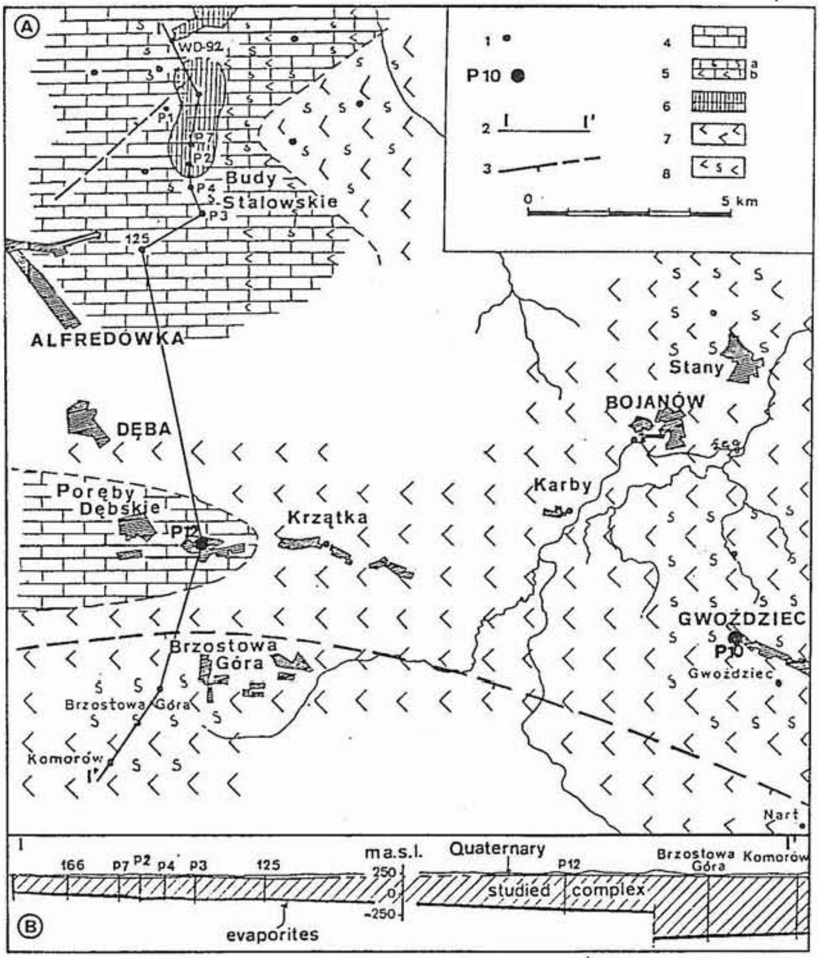

Fig. 4: A. Lithofacies of Middle Badenian chemical deposits in area studied (after A. Gąsiewicz, 1989, changed)
1 — borehole (P10 — borehole studied), 2 — geological section (Fig. 4B), 3 — dislocations, 4 — gangue limestone, 5 — sulphur-bearing limestone (a) and limestone with sulphate intergrowths (b), 6 — economic sulphur concentrations, 7 — sulphates, 8 — sulphates with sulphur traces
B. Geological section (after A. Gąsiewicz, 1989, changed)
Dashed part — discussed deposits
A. Litofacje środkowobadeńskich osadów chemicznych na obszarze badań (według A. Gąsiewicza, 1989, zmienione)
1 — otwór wiertniczy (P10 — otwór zbadany), 2 — przekrój geologiczny (fig. 4B), 3 — uskoki, 4 — wapienie płonne, 5 — wapienie siarkonośne (a) i wapienie z przerostami siarczanów (b), 6 — przemysłowe koncentracje siarki rodzimej, 7 — siarczany, 8 — siarczany śladowo osiarkowane
B. Przekrój geologiczny (według A. Gąsiewicza, 1989, zmienione)
Obszar zakreskowany — osady dyskutowane

In the profile of the Krakowiec Clays (Fig. 5) are observed rare, 3–20 mm thick tuffite and bentonitic tuffite layers (Pl. I, Fig. 8) and dispersed tuffite matter, similar to that in the Sarmatian sequence from the foredeep and the Holy Cross Mts. margin (E. Fijałkowska, J.

Fijałkowski, 1966; R. Ney *at al.*, 1974; J. Rutkowski, 1973, 1976). Due to their irregular occurrence they cannot be correlated.

LITHOLOGY

The Krakowiec Clays complex consists mainly of grey, beige and greenish claystones, clay-siltstones and siltstones with higher muscovite content (Fig. 5). The subordinate lithologies are quartz sands and sandstones, grey in colour, fine or coarse, well sorted, with silt admixture and high muscovite content. They are from one millimetre up to several decimetres thick. The beds of poorly sorted, various grained psammites, with a gravel fraction, are very rare but relatively thick, from several centimetres up to 11 m (Fig. 5; borehole Gwoździec P10).

The pebbles (size 2–13 mm) consist of well rounded, well sorted fragments of quartzites, quartzitic sandstones, marls, limestones, lydites and claystone fragments (Pl. I, Fig. 9). Also single pebbles of quartz and quartzite occur locally within siltstones.

All rocks are calcareous, and the source of carbonates were fossil remains. Also, fine pyrite aggregates and cubes as well as plant fragments are common. Iron concretions are quite rare, a millimetre in size, and consitst mainly of pyrite. In the lower part of the Krakowiec Clays are found small clay rollers several millimetres in size (Fig. 5, borehole Poręby Dębskie P12), indicating the events of erosion and redeposition of semicoherent bottom sediment.

STRUCTURES

Most of the rock is structureless or is characterized by fine, more or less distinct, horizontal bedding (Pl. I, Fig. 8), consisting of millimetre thick silty laminae, separated by thicker clay laminae/beds. In the case of a regular occurrence of such fine laminae these sequences are regarded as rhythmites.

Horizontal lamination and lenticular bedding are typical for clay-siltstones and siltstones. Within some sandy lenses were observed fine cross-bedding that suggest they are buried ripples. In the thicker sandy intercalations, sand and sandstone beds the sets of ripples were visible, up to 5 mm high. Psammites are characterized by structureless units with dispersed pebbles, horizontal lamination and ripple bedding. Sporadically, normal graded bedding was observed (Fig. 5, borehole Gwoździec P10).

Locally, fine erosion scours and surfaces were detected at the bottom of sandy interbeds. Load structures were also located there. Fine dessication crack systems are very rare contrary to the common tectonic fractures (Fig. 5).

Bioturbation, located mainly in the lower part of profile, is developed as fine vertical corridors/tubes and indicates — assuming a very low accumulation rate for pelitic sediments — relatively deep bottom penetration by organisms due to quick development of anoxic conditions at the bottom and faunal decline.

All described sedimentary structures indicated the mechnisms and conditions of accumulation. Horizontal lamination of rhythmite type could reflect size variations of suspended material, resulting from storm waves, transporting coarse sediment from the shore zone or could be an effect of deposition from distal, diluted turbidity currents. Thick series of structureless coarse psammites with fine gravels, and siltstone beds with dispersed pebbles, were accumulated by a main stream of turbidity currents. The erosion scours, ripple bedding, buried ripple sets, fine cross-bedding and clay rollers indicate periodic action of traction currents from storm waves and/or density currents.

The concentrations of fossil remains, sometimes of coquina character, as well as bioturbation horizons documented intensive benthic faunal development during periods of low accumulation. Relatively quick increase of anoxic conditions due to a weak water exchange and high organic matter supply with suspended material caused almost total decline of benthic organisms, leaving such faunal death horizons.

DEPOSITIONAL ENVIRONMENT AND CYCLES

The described features of the *Pecten* Beds and Krakowiec Clays from the studied area allowed reconstruction of the general characteristics of their environment of deposition. These deposits accumulated within an open basin, over several tens of metres deep, with prevailing deposition from suspension and rare bottom current action. Sometimes, probably due to storm surges, the rip currents supplied more coarse material and plant remains from basin margins. The basin bottom was affected by turbidity currents, flowing down from the slopes and carrying "clouds" of clastics left on the bottom as structureless beds of psammites with gravels. Limited water circulation within this basin and high content of suspended organic matter favoured the development of anoxic conditions on the bottom and seasonal benthic decline. The point data of boron content confirmed the marine character of this basin (values mainly between 170 and 330 ppm — compare with data of standard boron content in various environments by A. Pasieczna, 1983) but some events of lowered salinity, evidenced by boron values of 90–105 ppm, were noticed and related with higher river water input and limited of water exchange with the open Tethys Ocean.

The evolution of the whole Upper Badenian-Sarmatian series in the studied area could be sudivided into two, transgressive-regressive cycles, starting with a new transgression or general water exchange and finishing with basin desalting due to increased river input and limited connection with the open sea.

The first cycle comprises the deposit series from the depth intervals: 195–533 m for the borehole Gwoździec P10 and 223–481 m for Poręby Dębskie P12 (Fig. 5), including the *Pecten* Beds and the lower part of *Syndesmya* Beds.

The marly *Pecten* Beds, containg a rich macro- and microfauna typical for the open sea, indicate the general marine transgression onto evaporites of the dessicated older, Middle Badenian basin. This transgression resulted from the tectonic rebuilding of the Carpathian Foredeep at the end of Middle Badenian (Z. Krysiak, 1986; T. Osmólski, 1972; R. Ney *et al.*, 1974; S. Pawłowski *et al.*, 1985), involving differential subsidence within the foredeep and creating local hiatuses and discordances. The transgression development produced facies uniformity within large parts of the basin and covered the evaporitic horizon with marly deposits (the evidences of transgression in the evaporites are still discussed (B. Kubica, 1992; S. Pawłowski *et al.*, 1985).

Some volcanic activity at the basin margins, related to the above mentioned tectonic movements, was reflected by frequent tuffite intercalations at the profile bottom. Quiet, constant accumulation from suspension interplayed with the events of rapid deposition from turbidity currents, transporting coarse material from basin slopes. Some of these currents

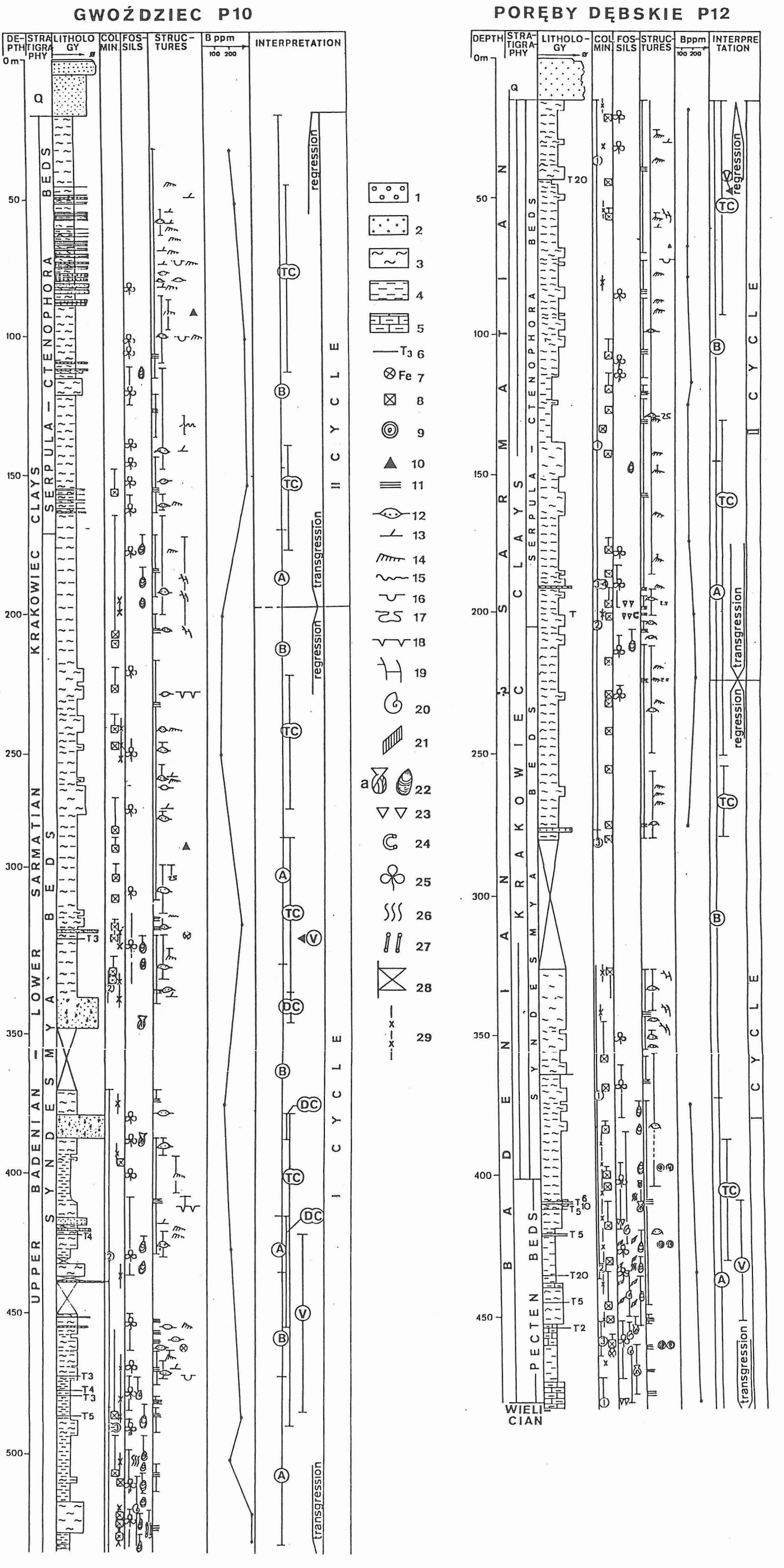

Fig. 5. Sedimentological profiles of Upper Miocene deposits from the Gwoździec P10 and Poręby Dębskie P12 boreholes

1 — gravel, 2 — sand/sandstone, 3 — silt/siltstone, 4 — clay/claystone, 5 — marl, 6 — tuffite (thickness in mm), 7 — iron concretion, 8 — pyrite aggregate, 9 — clay roller, 10 — normal graded bedding, 11 — horizontal lamination (R — rhythmites), 12 — lenticular bedding, 13 — cross-bedding, 14 — ripple bedding, 15 — erosional surface, 16 — erosional scour, 17 — load, 18 — syneresis crack, 19 — tectonic fracture, 20 — microfossils, 21 — gastropods, 22 — bivalves (a — pectens), 23 — fish scales, 24 — *Serpula* tubes, 25 — plant remains, 26 — bioturbations, 27 — *Chondrites*, 28 — core lack, 29 — carbonates; A — marine basin with benthic macrofauna, B — marine basin with anoxic bottom, TC — traction current activity, DC — density current activity, V — volcanic activity, T — dispersed tuffite, Q — Quaternary deposits; colours: 1 — grey, 2 — beige-grey, 3 — green, 4 — brown

Profile sedymentologiczne osadów górnego miocenu w otworach wiertniczych Gwoździec P10 i Poręby Dębskie P12

1 — żwir, 2 — piasek/piaskowiec, 3 — muł/mułowiec, 4 — ił/iłowiec, 5 — margiel, 6 — tufit (grubość warstw w mm), 7 — konkrecje żelaziste, 8 — skupienia pirytu, 9 — toczeńce ilaste, 10 — warstwowanie gradacyjne normalne, 11 — laminacja pozioma (R — rytmity), 12 — warstwowanie soczewkowe, 13 — warstwowanie skośne, 14 — warstwowanie zmarszczkowe, 15 — powierzchnie erozyjne, 16 — rozmycia erozyjne, 17 — pogrązy, 18 — szczeliny synerezyjne, 19 — spękania tektoniczne, 20 — mikroskamieniałości, 21 — ślimaki, 22 — małże (a — pekteny), 23 — łuski ryb, 24 — rurki serpul, 25 — szczątki roślin, 26 — bioturbacje, 27 — struktury typu *Chondrites*, 28 — brak rdzenia, 29 — węglany; A — basen morski z makrofauną bentoniczną, B — basen z przydenną strefą anoksyczną, TC — działalność prądów trakcyjnych, DC — działalność prądów zawiesinowych, V — aktywność wulkaniczna, T — tufit rozproszony; Q — czwartorzęd; kolory: 1 — szary, 2 — beżowo-szary, 3 — zielony, 4 — brunatny

were induced by seismic shakes, common with tectonic displacements and other ones by sediment overload on the inclined basin slope. These currents and related traction currents supplied more oxidized waters from basin margins and locally stopped the development of anoxic conditions at the bottom, favouring benthic faunal renewal (the borehole Gwoździec P10, Fig. 5). In places, where such currents were absent or very weak, the benthos gradually died off (borehole Poręby Dębskie P12, Fig. 5). The basin, being of marine character at the beginning, was slowly desalted due to increased river input and limited connections with the ocean (evidenced by boron content decrease — Fig. 5). This evolution corresponds with the development of the Carpathian Foredeep during Upper Badenian (R. Ney *et al.*, 1974; A. Papp *et al.*, 1978; J. Szczechurowa, 1982). At the beginning of the Kosovian substage the new transgression, coming from the southeastern marine Paratethys basins, transformed the dessicated evaporitic basin into a new marine one, dominated by clastic deposition. The further phases of Carpathian tectonic movements (the late leitha phase — Z. Krysiak, 1986) crossed these marine connections at the end of the Kosovian and induced the more brackish conditions.

The second sedimentary cycle includes the deposits from the overlying Quaternary cover to the depth 197–233 m (see — borehole profiles, Fig. 5). It consists of the upper part of the *Syndesmya* Beds and the *Serpula-Ctenophora* Beds.

The basin character (depth, deposition style) was the same as observed in the earlier cycle. Some supply of coarse material from land was indicated during the deposition of this cycle but, except for some evidence of weak traction currents, there were no sediments of turbidity currents due to more distant basin margins. The volcanic events were very uncommon, and they only rarely registered as fine tuffite intercalations (borehole Poręby Dębskie P12, Fig. 5). The fauna was depleted in species and at the end of the cycle the macrofauna mostly declined (*Serpula-Ctenophora* Beds). After an initial salinity increase (see variations of boron content, Fig. 5) a gradual decrease occurred; suggesting continuous basin desalting and prevalence of more brackish conditions.

This second cycle in the studied area reflected the sedimentation pattern in this part of the foredeep during the Sarmatian stage (R. Ney *et al.*, 1974; A. Papp *et al.*, 1974; J. Szczechurowa, 1982). At the beginning of the Sarmatian the foredeep area was flooded by fresh marine waters from the southeastern basins of the Paratethys, carrying the new faunal assemblages. This transgression was not registered as a different deposit type in the basin center where the older sedimentation style was inherited and the depth and material character remained unchanged. Only the salinity increased at the beginning and the new fauna occurred. On the basin margins the transgressive-regressive deposits could develop and preserve marginal clastic Sarmatian deposits (G. Czapowski, 1984; G. Czapowski, B. Studencka, 1990; P. Karnkowski, 1978, 1989; S. Pawłowski, 1965; A. Radwański, 1973; J. Rutkowski, 1976). In the upper part of the Sarmatian the basin became more brackish due the foredeep narrowing as a result of the last phases of folding movements in the Carpathians (Z. Krysiak, 1986; R. Ney *et al.*, 1974) and increased river input.

CONCLUSIONS

The Upper Badenian-Sarmatian clastic complex, overlying the sulphur-bearing evaporites in the area southeast of Tarnobrzeg (northern-central part of the Carpathian Foredeep) was deposited within an open marine basin, with dominant accumulation from suspension and the events of turbidity/traction current action. Varied water circulation resulted in the development of changes in anoxic/oxidized conditions at the basin bottom and related flourishing and decline of benthic fauna. The intensive tectonic movements on the basin margins was documented both by volcanic activity (pyroclastic intercalations) and development of turbidites.

This complex was subdivided into two transgressive-regressive cycles, starting with a marine transgression and finishing with a lowering of basin salinity due to changes in basin morphology and increased river input. The lower cycle corresponds to the Upper Badenian (Kosovian substage) and the upper one to the Sarmatian stage. The transition between cycles occurred within the same depth conditions and it was indicated in described part of the foredeep by an increase of salinity and a change in faunal composition (new genera and species occurred). Both cycles reflected the general pattern of evolution of the Carpathian Foredeep at that time and confirm tendencies in variations of faunal assemblages. It seems necessary to continue similar studies on this complex in the other areas of the foredeep and to test whether these cycles are correlable within whole basin.

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Grzegorz CZAPOWSKI

SEDYMENTACJA KOMPLEKSU MORSKICH OSADÓW ŚRODKOWEGO MIOCENU Z REJONU TARNOBRZEGA (PÓŁNOCNO-ŚRODKOWA CZĘŚĆ ZAPADLISKA PRZEDKARPACKIEGO)

Streszczenie

Utwory środkowego miocenu (górny baden-dolny sarmat), występujące w rejonie Dęby – Gwoździca (otwory wiertnicze Gwoździec P10 i Poręby Dębskie P12) na SE od Tarnobrzega nad środkowobadeńską serią ewaporatów, tworzą dość monotonną serię marglisto-ilastą, podrzędnie zapiaszczoną, o miąższości ponad 530 m. Różne zespoły faunistyczne i niewielkie różnice litologiczne pozwalają podzielić całą serię na kilka ogniw lito-biostratygraficznych: warstwy pektenowe, warstwy syndesmyowe (z Abra), warstwy z *Serpula* i *Ctenophora* (warstwy bezskamielinowe) (S. Pawłowski i in., 1985). Dwa ostatnie ogniwa nazywane są potocznie warstwami bądź iłami krakowieckimi.

Badania sedymentologiczne zachowanych rdzeni wiertniczych pozwoliły odtworzyć środowisko powstania i historię depozycji tych utworów. Osady nadewaporatowe powstały w otwartym, dość głębokim zbiorniku morskim, zdominowanym przez sedymentację zawiesinową, ze słabymi prądami przydennymi. Dzięki nim okresowo do zbiornika docierał grubszy materiał skalny (pakiety piaszczyste z warstwowaniem zmarszczkowym i drobnoskalowym skośnym) i liczne szczątki roślinne. Chmury prądów zawiesinowych, spływających ze stoków basenu, pozostawiały tu ławice bezteksturalnych psamitów ze zróżnicowanym litologicznie materiałem żwirowym. Generalnie niewielka ruchliwość wód i znaczne ilości materii organicznej, dostarczane z zawiesiną, sprzyjały zarówno okresowemu rozkwitowi bentosu (warstwowe i soczewkowe nagromadzenia fauny, bioturbacje), jak i rozwojowi warunków redukcyjnych przy dnie (partie profilu bez fauny, skupienia pirytu) i w konsekwencji — okresowemu wymieraniu organizmów. Punktowe badania zawartości boru potwierdzają generalnie morski charakter basenu (zawartość przeważnie od 170 do 330 ppm) z momentami wysłodzeń (90–105 ppm), związanych z większym dopływem wód lądowych i ograniczeniem połączeń z innymi basenami Paratetydy.

W omawianym kompleksie osadów wyróżniono dwa cykle depozycyjne, transgresywno-regresywne. Cykl pierwszy obejmuje warstwy pektenowe oraz dolną część warstw syndesmyowych i odpowiada generalnie podpiętru kosow. Początkowo zaznacza się w nim aktywność wulkaniczna obramowania basenu (tzw. faza leitha ruchów alpejskich — A. Papp i in., 1978), wyrażająca się licznymi przewarstwieniami tufitów. Spokojną akumulację z zawiesiny przerywały epizody raptownej depozycji z prądów zawiesinowych, zainicjowane przez wstrząsy tektoniczne, towarzyszące wulkanizmowi. Prądy te i powiązane z nimi silniejsze prądy trakcyjne dostarczały bardziej utlenionych wód z płytszych partii basenu i hamowały lokalnie rozwój warunków redukcyjnych przy dnie, co sprzyjało rozkwitowi bentosu. W strefach o nikłej cyrkulacji wód wymiana gazowa nie następowała i bentos stopniowo wymierał. Cały zbiornik, początkowo wybitnie morski (pekteny), stopniowo wysładzał się (malejąca zawartość boru) zapewne wskutek ograniczenia połączeń z basenami Paratetydy (ruchy tektoniczne w Karpatach z końcem kosowu, schyłek fazy leitha — Z. Krysiak, 1986).

Drugi cykl depozycyjny obejmuje górną część warstw syndesmyowych oraz warstwy z *Serpula* i *Ctenophora* i datowany jest na dolny sarmat. Wpływ lądu zaznaczył się dostawą grubszego materiału, lecz oprócz działalności słabych prądów trakcyjnych brak wyraźnych śladów prądów zawiesinowych. Wynikało to zapewne z większego oddalenia stoków basenu. Zjawiska wulkaniczne były sporadyczne (rzadkie tufity). Nastąpiło zubożenie gatunkowe fauny, zaś pod koniec cyklu makrofauna niemal zanikła (warstwy bezskamielinowe). Po początkowym

wzroście zasolenia nastąpił stopniowy jego spadek (zmiany zawartości boru), wynikający z wysłodzenia. Cykl ten odzwierciedla rozwój sedymentacji w osiowej partii zapadliska przedkarpackiego w dolnym sarmacie, gdy na obszar starszego zbiornika górnobadeńskiego napłynęły świeże wody ze wschodniej Paratetydy, wnosząc nowe zespoły fauny, natomiast nie zmieniając generalnie charakteru sedymentacji i batymetrii zbiornika. W wyższym sarmacie, w miarę zawężania obszaru basenu w zapadlisku i przesuwania jego osi ku N i NE (ruchy tektoniczne w Karpatach — Z. Krysiak, 1986; R. Ney i in., 1974), następowało stopniowe wysładzanie całego zbiornika.

PLATE I

Fig. 6. Claystone with *Pecten* shell imprints, dark points are pyrite aggregates; *Pecten* Beds, Upper Badenian, borehole Łęg3 near Osiek (southern border of the Holy Cross Mts.), depth 177.75 m

Iłowiec z odciskami muszli pektenów, ciemne punkty — skupienia pirytu; warstwy pektenowe, górny baden, otwór wiertniczy Łęg3 koło Osieka, głęb. 177,75 m

Fig. 7. Claystone with abundant foraminifers (fine nodules), large *Syndesmya* (= Abra) shell imprints (arrows) and dark pyrite aggregates (p); *Syndesmya* Beds, Sarmatian, borehole P7 near Budy Stalowskie, depth 235 m

Iłowiec z licznymi otwornicami (drobne gruzełki), dużymi odciskami muszli *Syndesmya* (= Abra) (strzałki) i ciemnymi skupieniami pirytu (p); warstwy syndesmyowe, sarmat, otwór wiertniczy P7 koło Bud Stalowskich, głęb. 235 m

Fig. 8. Tuffite (T) interbed within horizontally laminated claystone; Krakowiec Clays, Sarmatian, borehole A12 near Tarnobrzeg, depth 95.25 m

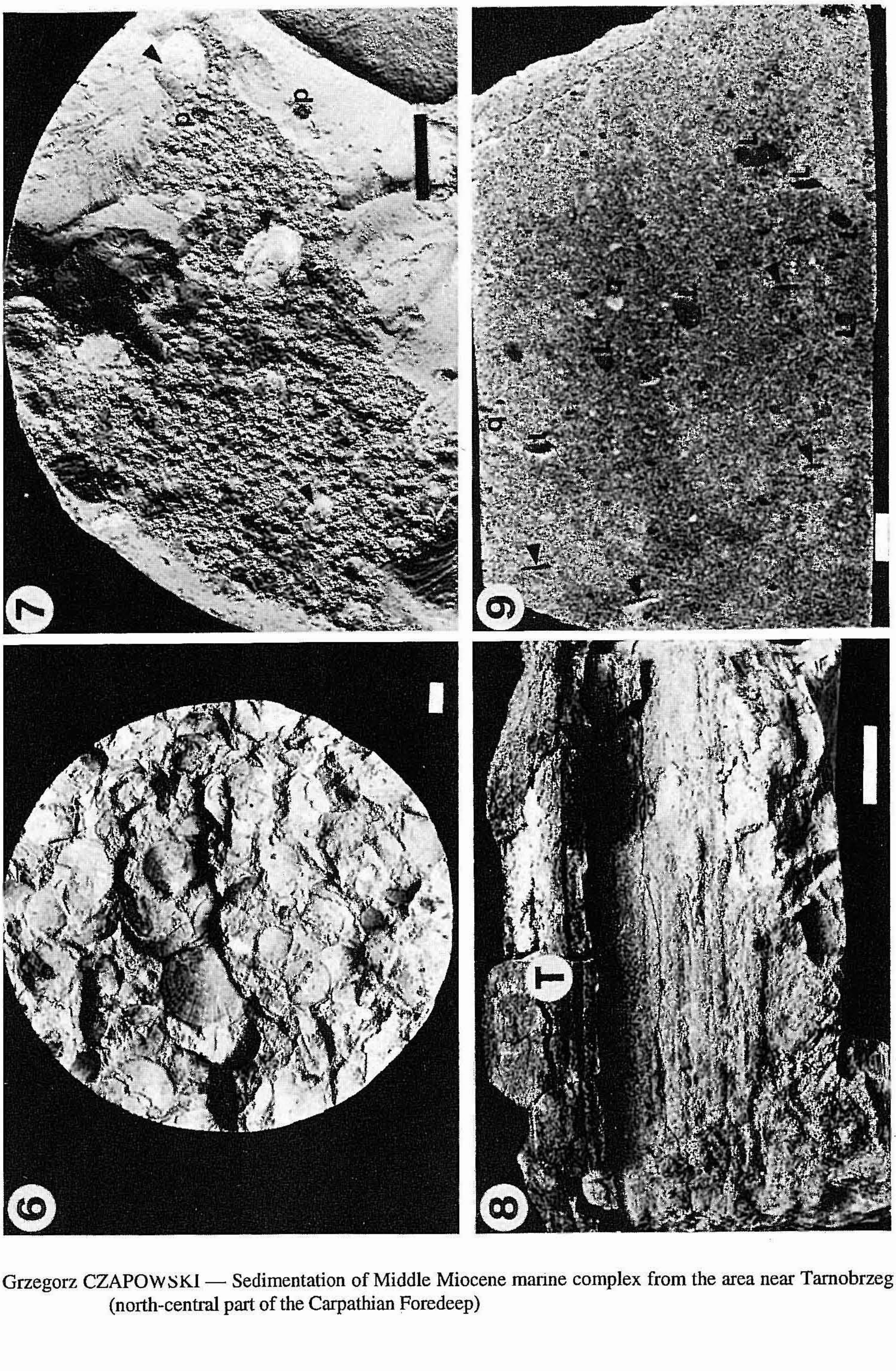
Przewarstwienie tufitu (T) w obrębie poziomo laminowanego iłowca; iły krakowieckie, sarmat, otwór wiertniczy A12 koło Tarnobrzega, głęb. 95,25 m

Fig. 9. Medium-coarse sandstone with fine quartz (q), limestone (L) pebbles and claystone flakes (arrows); *Syndesmya* Beds, Sarmatian, borehole Gwoździec P10, depth 438.25 m

Średnio-gruboziarnisty piaskowiec z drobnymi otoczakami kwarcu (q), wapieni (L) oraz okruchami iłowca (strzałki); warstwy syndesmyowe, sarmat, otwór wiertniczy Gwoździec P10, głęb. 438,25 m

Bar length — 1 cm

Skala na zdjęciach odpowiada 1 cm



Grzegorz CZAPOWSKI — Sedimentation of Middle Miocene marine complex from the area near Tarnobrzeg (north-central part of the Carpathian Foredeep)