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Depositional and tectonic controls on Early Badenian clastic sedimentation in the Sandomierz–Tarnobrzeg area (Baranów Beds, northern Carpathian Foredeep)

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The distribution, sedimentary environment and tectonic evolution of the Lower Badenian clastic deposits (Baranów Beds) in the area between Sandomierz and Tarnobrzeg are described. These deposits represent two facies: transitional marine, continental and open marine. The morphology and microtextures of quartz grains from the Świniary sand-pit indicate changing sedimentary environments in the upper part of the Baranów Beds: from a marine shore-influenced zone gradually through to deeper conditions. The thickness distribution of these deposits shows the influence of a nearby fault zone.

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Key words: Carpathian Foredeep, Baranów Beds, clastic deposits, quartz grain microtextures, sedimentary environment.

INTRODUCTION

The aim of this paper is to determine the distribution, and environment of sedimentation of, and the tectonic control on, the Lower Badenian clastic deposits of the northern Carpathian Foredeep between Sandomierz and Tarnobrzeg within a context of research to date. These deposits, known as the Baranów Beds, are developed as sandstones and quartz sands with intercalations of siltstones, lithothamnium limestones and subordinate clays with brown coal. Here, the Baranów Beds are regarded as a lithostratigraphic unit within the Lower Badenian of the southern and eastern part of the Carpathian Foredeep, which accumulated in the marginal part of the basin. They correspond to the Skawina and Przemyśl Beds of the inner basin (N. Oszczypko, 1996).

The paper deals with the Sandomierz Basin between Sandomierz and Tarnobrzeg (Figs. 1, 2), and combines field observations in the few existing outcrops with descriptions of 150 cores stored in the Central Geological Archive of the Polish Geological Institute in Warsaw.

PREVIOUS STUDIES

The term Baranów Beds was used for the first time in the second half of the last century in connection with deposits cropping out in sections along the Złota Lipa River in the vicinity of Tarnopol (Ukraine). The Baranów Beds were defined by V. Hilber (1882), who included within them clayey-sandy beds with glauconite, from several centimetres to a metre thick, with a typical fauna of the pectinid *Chlamys scissa*, transgressively overlying older sediments in the region of Podole, and overlain by gypsum beds. A. M. Łomnicki (1897), W. Teisseyre (1900), W. Friedberg (1910, 1933), K. Kowalewski (1929) and J. Czarnocki (1935) studied the stratigraphy and distribution of the deposits. They interpreted the Baranów Beds as a shallow water, transgressive sandy facies.

In the Sandomierz–Tarnobrzeg region, deposits corresponding to the Baranów Beds were described initially by K. Kowalewski (1929) in a paper dealing with the stratigraphy of the Krakowiec Clays. This author regarded the deposits cropping out at Świniary as shallow water Tertiary deposits

Fig. 1. Location of the area investigated

1 — Palaeozoic; 2 — Mesozoic; Tertiary–Miocene: 3 — Badenian, 4–6 — Sarmatian: 4 — Krakowiec Clays, 5 — carbonate-detrital deposits, 6 — reef limestones

of the Nida Trough. He stated the age of the series as Upper Tortonian. The quartz sands were determined as sands with *Pecten scissus* within the sub-*Ervilia* Beds, laterally equivalent with the Baranów Beds of Podole.

Further papers on the stratigraphic position and environment of sedimentation of the Badenian clastic deposits as well as their industrial importance as glass-sands appeared after World War II. These ineluded papers by K. Kowalewski (1950, 1957*a*, *b*, 1958), S. Pawłowski (1956, 1957), W. Krach (1956, 1962), E. Łuczkowska (1963, 1964), R. Ney (1966), R. Ney *et al.* (1974), A. Radwański (1973), K. Pawłowska (1985, 1994) and K. Kenig, A. Wysocka (1996).

GEOLOGICAL SETTING

Miocene basement. The area investigated covers the northern, marginal part of the Carpathian Foredeep in the Sandomierz–Tarnobrzeg region (Fig. 1). Precambrian and Cambrian deposits, mainly shales, siltstones and claystones occur as a basement to the Miocene deposits. The Badenian sea advanced over a land area which was largely a peneplain, though basal conglomerates including much reworked Cambrian material are well developed south of Świniary, indicating erosion of a sizeable landmass. The deposits dip at about 1° to the south-east (Figs. 3A, C) and a marked increase in thickness adjacent to a fault (Fig. 3B) argues for tectonic downwarping during sedimentation (see below).

North-west of Tarnobrzeg, Miocene deposits have been removed due to uplift of the Cambrian deposits in the core of the Klimontów Anticlinorium. In this area Miocene deposits are present only as local erosional outliers near Nawodzice and Jurkowice.

Miocene deposits. In the area investigated Badenian as well as Sarmatian deposits occur. A lithostratigraphic seheme for the Tarnobrzeg region has been constructed from core data (Fig. 4). Clastic deposits of Lower Badenian age are characterized by a basal conglomerate composed of reworked fragments of Cambrian siltstone and claystone, resting directly on the Cambrian basement and included within the Baranów Beds. Locally the lower part of the clastic deposits contains clayey intercalations with lignite. The upper part in turn is developed as partly lithified quartz sands.

In the Sandomierz–Tarnobrzeg region a thin (max. 5 cm) sandy-marly layer, occasionally sandy-clayey with abundant

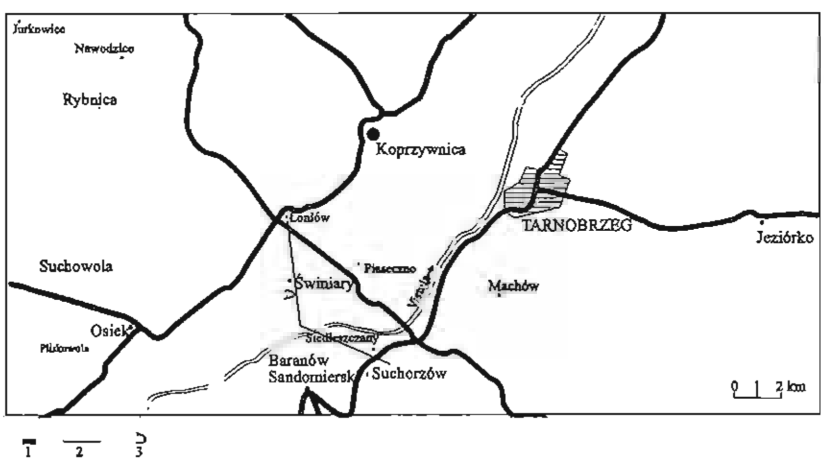

Fig. 2. Location of places mentioned in the text

1 — roads, 2 — section line, 3 — outcrops

fossils, including *Ervilia pusilla* and *Modiola hoernesi*, occurs in the upper part of the sandy deposits. Chemically precipitated deposits of the Chemical Series (Fig. 4) lie directly above. Gypsum was deposited in the offshore part of the basin. In the area investigated the thickest gypsum and sulphur-bearing limestones occur around Osiek, Baranów Sandomierski, Machów and Jeziórko. Areas closer to the marginal zone of the basin are characterized by poorly sulphurous dark clays, marly clays and breccia-type limestones.

The upper Badenian deposits comprise marls and marly limestones with a characteristic pectinid fauna, known as the *Spiralis-Pecten* Beds. Sarmatian clays, namely the *Syndesmya* and Unfossiliferous Beds, occur above these.

This lithostratigraphy is based on the scheme of K. Kowalewski (1957*a*), modified by S. Pawłowski *et al.* (1985).

Lithology of the Baranów Beds. The Baranów Beds are characterized by a bipartite development (Figs. 4, 5). The lower part, accumulated only within larger depressions of the basement, is developed as sandy-silty or clayey deposits with intercalations of lignite, abundant plant detritus, occasionally with an abundance of the molluscs *Limnocardium* sp., *Potamides* sp., *Cerithium* sp., *Cardium* sp., *Helix* sp. and *Natica* sp., together indicating brackish conditions. The deposits represent a near-shore marsh facies, transitional between continental and marine conditions (S. Pawłowski *et al.*, 1985; K. Pawłowska, 1994).

Sandy deposits laid down in an open marine environment occur above. These are lithologically variable, particularly in the marginal part of the basin. They include fine- and medium-grained quartz sands, cemented to a variable degree by calcite and silica. In the western and northwestern part of the area investigated a considerable admixture of lithothamnium detritus occurs in these sandy deposits, occasionally as lithothamnium conglomerates. The algal material is derived from the erosion of lithothamnium limestones on local basement highs. The proportion of algal detritus varies, presumably due to variable rates of erosion of the lithothamnium limestones. The Baranów Beds contain also an admixture of glauconite and include the bivalves: *Amussium denudatum, Chlamys scissa, Ch. koheni, Ostrea cochlear, Venus multilamelata,* and microfauna: *Uvigerina costai, Orbulina suturalis, Heterostegina costata, Amphistegina lessonii* (K. Pawłowska, 1994). The Baranów Beds fine towards the central parts of the basin, where they are developed as sandy and clayey silts. Biostratigraphically, the Baranów Beds are restricted to the NN5 Zone (A. S. Andreeva-Grigorovich, 1994).

Extent and thickness distribution of the Baranów Beds. In the area between Sandomierz and Tarnobrzeg the northern limit of the Lower Badenian clastic deposits more or less coincides with the western margin of the Vistula Valley. The only exception is in the area west of Świniary and Łoniów, where these deposits occur in the Kielce–Sandomierz Upland. In this area the northernmost occurrence lies in the vicinity of Nawodzice, where erosional remnants of these deposits are preserved. Over the area investigated the northern limit of the Baranów Beds is erosional.

The thickness of the Baranów Beds is variable (Figs. 3B, 5), with two well-defined, NW–SE aligned areas of thicker accumulation. The first of these, near Suchowola, is oval and

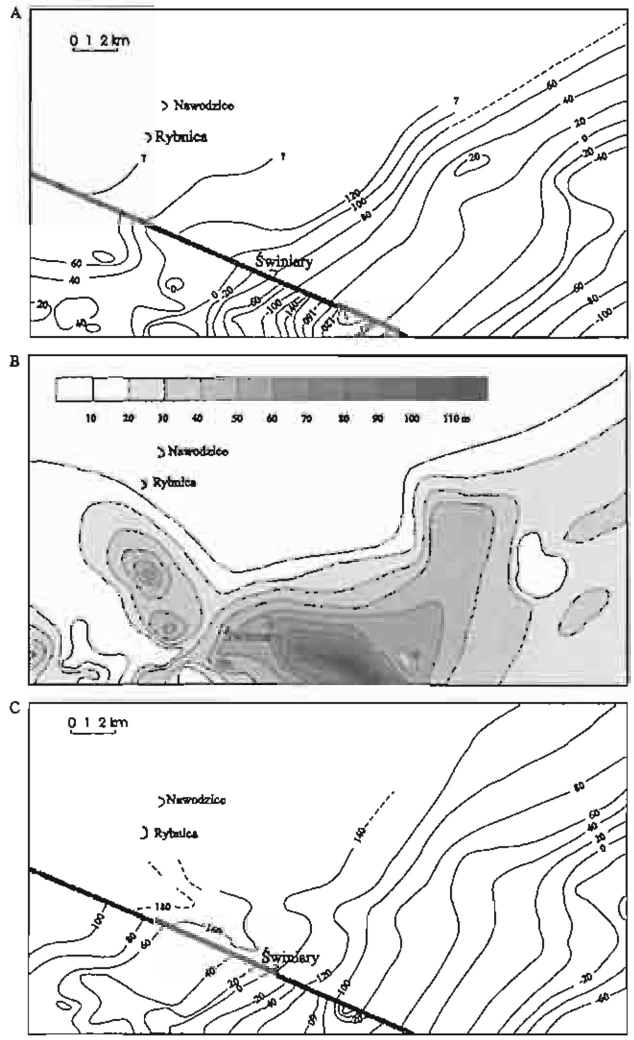

Fig. 3. Range and thickness distribution of the Baranów Beds: A — contours on the base of the unit (relative to sea level), B — thickness contours, C — contours on the top of the unit (relative to sea level)

the thickness of clastic deposits reaches 60 m. Within it, the lowermost part of the Baranów Beds include fine-clastic sediments with intercalations of lignite. In the region of Baranów Sandomierski, the thickness of sediments reaches 114 m (Fig. 5). To the north-west, the thickness of sandy deposits decreases to 30 m in the region of Piaseczno and Pliskowola, and continues to thin northwards, reaching 0.70 m at their present northern limit.

The top surface of the Baranów Beds (Fig. 3C) is even and dips gently to the east and south-east. The overlying Chemical Series, *Pecten-Spiralis* Beds and the Sarmatian *Syndesmya* and Unfossiliferous Beds reach a thickness at 229.50 m in the region of Baranów Sandomierski, and thin northwards to merely a few metres. Occasionally, in the region of Świniary and Łoniów (Fig. 5), Quaternary deposits directly overly the Baranów Beds, and they are exposed at the surface in the region of Rybnica and Nawodzice.

Tectonics. The shape of the basement to the Baranów Beds suggests the presence of a NW–SE fault (Fig. 3A). The

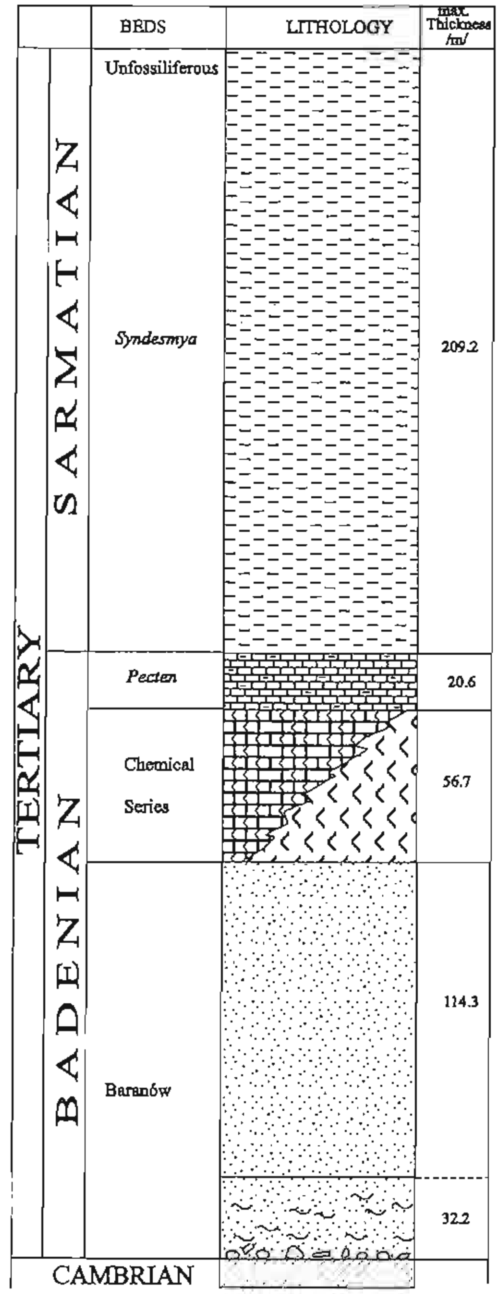

Fig. 4. Synthetic lithostratigraphic profile of the Sandomierz–Tarnobrzeg region

For explanations see Fig. 5

axis of the thickest accumulation parallels the fault strike, suggesting that the fault zone underwent subsidence during the accumulation of the Badenian deposits. The origin of the fault, however, relates to tectonic movements affecting the basin during the Sarmatian. The post-Badenian age of the fault can also be deduced from the morphology of the top surface of the Baranów Beds (Fig. 3C). The fault caused a mutual displacement of Badenian age sediments, the northeastern block undergoing relative uplift. The throw of the fault is variable, the smallest throw occurring in the northwestern part of the area near Wiązownica, the largest in turn near Suchorzów, where the displacement exceeds 200 m (Fig. 5).

In the area between Chmielnik and Rozwadów B. Kubica (1992) recognized graben-horst structures connected with post-Badenian tectonic movements, linked with the rejuvenation of lateral NW–SE dislocations of the Cimmerian and Laramide phases. The fault described here is a normal hinge fault, the strike of which is in line with the fault between the Tarnobrzeg horst and the Staszów–Baranów block, recognized by B. Kubica (1992) in the northern part of the Carpathian Foredeep (Fig. 6).

THE BARANÓW BEDS AT ŚWINIARY

Lower Badenian clastic deposits crop out within the Opatówka River valley in Męczennice and Słaboszewice and to the west of Tarnobrzeg in the area between Nawodzice and Świniary. In the area investigated the best described exposures included Nawodzice, Rybnica and Świniary (K. Kowalewski, 1929, 1950; S. Pawłowski, 1956, 1957, 1965; M. Błaszak, 1965; W. Bałuk, A. Radwański, 1968; A. Radwański, 1973; K. Kenig, A. Wysocka, 1996).

Sands and quartz sandstones of the Baranów Beds were still available for investigation a few years ago in the abandoned glass-sand pit, in Świniary (Łoniów district), about 4 km north of Baranów Sandomierski. The lowermost part of this unit as well as its contact with the basement were not exposed in the area.

The pit face at Świniary (Fig. 7) was oriented WNW–ESE, and its central and eastern part were mined out. Investigations carried out in the 60's and 70's focussed on the western part of the sand-pit, which was unavailable for further investigation in the early 90's. Here, the oyster *Pycnodonta leopolitana*, pectens and other bivalves, the echinoid *Psammechinus* sp., the asteroid *Astropecten* sp., as well as the cirripede *Verruca* sp. were present. Frequent oyster, bryozoan and serpulid conglomerates were also noted in the quarry, as well as single burrows of *Ophiomorpha nodosa*. The serpulid and oyster conglomerates were redeposited, and occurred with cross-stratified deposits in the upper part of the section. These observations were made by A. Radwański (1973) in a paper outlining the Miocene sea transgression on the southeastern and eastern slopes of the Holy Cross Mountains.

The present author carried out field observations in the vicinity of Świniary between 1994 and 1995 (K. Kenig, A. Wysocka, 1996). The western sections discussed above had become obscured. Sections in the eastern part of the pit had been opened, but were deteriorating. Exploitation has now ceased and recultivation is taking place.

In the Świniary sand-pit (Pl. I, Fig. 1) the highest part of the quartz sand unit, 3–4 m in thickness, was visible (Fig. 7). It was typically structureless, though sporadic bioturbation horizons and single borrows of *Ophiomorpha nodosa* were present. No beds of reworked echinoid fragments were present. Rare accumulations of oyster and pecten shells (Pl. I, Fig. 5), serpulids, bryozoan thalli, single foraminifers and rare

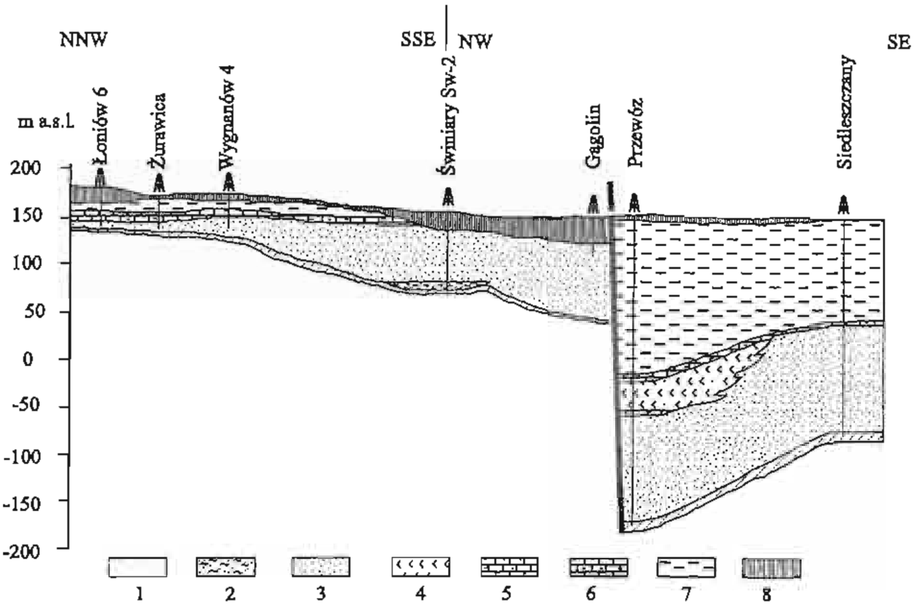

Fig. 5. Geological section between Łoniów and Siedleszczany

1 — Cambrian basement; 2–6 — Badenian: 2 — sandy-silty deposits with lignite (lower part of the Baranów Beds), 3 — quartz sands (upper part of the Baranów Beds), 4 — gypsum of the Chemical Series, 5 — sulphur-bearing limestones of the Chemical Series, 6 — marly limestones (the *Pecten* Beds); 7 — Sarmatian, clayey deposits (the *Syndesmya* and Unfossiliferous Beds); 8 — Quaternary

fragments of echinoid and asteroid tests were present. The oysters, serpulids and bryozoans appeared in a form of reworked conglomerates. Skeletal elements generally occurred as layers of crushed detritus within the sands. They had undergone considerable decalcification — most being very fragile. In the eastern part of the exposure (Fig. 7) units with tabular cross-bedding were present (Pl. I, Fig. 4). The quartz sands contain several horizons of calcite concretions, either bed-like or cylinder-shaped, most frequent in the western and central part of the outcrop (Pl. I, Fig. 3). The eastern part of the section showed only sporadic poorly lithified spherical zones, up to 3 cm in diameter, with a calcite-ferruginous cement. The sands were directly overlain by a 2 cm thick layer of cream-coloured marls with an abundance of crushed *Ervilia* shells (Pl. I, Fig. 2). The transition between the sands and this bed was sharp, with slightly more clay within the top part of the sands. The upper part of the section was largely obscured, but comprised a 4–5 m thick unit of grey and brown layered marly clays and marls, characterized by a high $CaCO_3$ and smectite content. K. Kowalewski (1929) distinguished the Chemical Series and *Pecten* Beds as well as the Sarmatian *Syndesmya* and Unfossiliferous Beds within this unit. The section was topped by a 2 m thick layer of Quaternary tills.

Quartz sands sampled had a uniform granulometric composition and lacked distinct changes in grain-size parameters such as the mean grain size *Mz* and the sorting coefficient (R. L. Folk, W. C. Ward, 1957). The mean grain size varied from 2.25 to 2.50 Ø, the sands thus being fine-grained; the sorting coefficient varied from 0.30 to 0.68, showing values typical for well to very well sorted deposits. The mineral content of sands from the outcrop was also uniform. Apart from quartz, small amounts of heavy mineral grains, muscovite, feldspar and barite were found. The fraction above 0.25 mm comprises a max. of 10% of the sediment and is composed of an organic detritus, quartz grains and calcite- and barite-cemented aggregates of quartz grains, reaching 1.25 mm in diameter. X-ray analyses have shown that both calcite and quartz is present within fractions smaller than 0.63 mm.

Because quartz surface textures are related to the environment of sedimentation, and to diagenesis, quartz sands from Świniary were studied using on SEM (K. Kenig, A. Wysocka, 1996).

In the lower part of the section the quartz grains possess surface features pointing to short transport from source, together abundant polished grains displaying v-shaped subaqueous pits (Pl. II, Figs. 1, 2), typical of a high-energy shore environment (D. H. Krinsley, J. C. Doornkamp, 1973; K. Rywocka-Kenig, 1993). Arc shaped incisions of different size are also present. In general, the quartz grains were "clean", with a predominance of mechanical features due to transportation, while post-sedimentation textures were less frequent. Grains suggesting shorter transport occur in the lower part of the section. They can be traced to intensely eroded areas, most probably within the Cambrian sandstones of the Klimontów Anticlinorium, which is situated north of Świniary.

The upper part of the sand unit also suggest a basin with shore zone influence, in which sharp-edged grains typical of short transport prevail, without signs of distinct erosion. There is, however, an increase in chemical features, involving the chemical "destruction" of the grain surface, observed under the binocular microscope as an increase in the proportion of frosted grains to polished grains. At magnifications of x 200

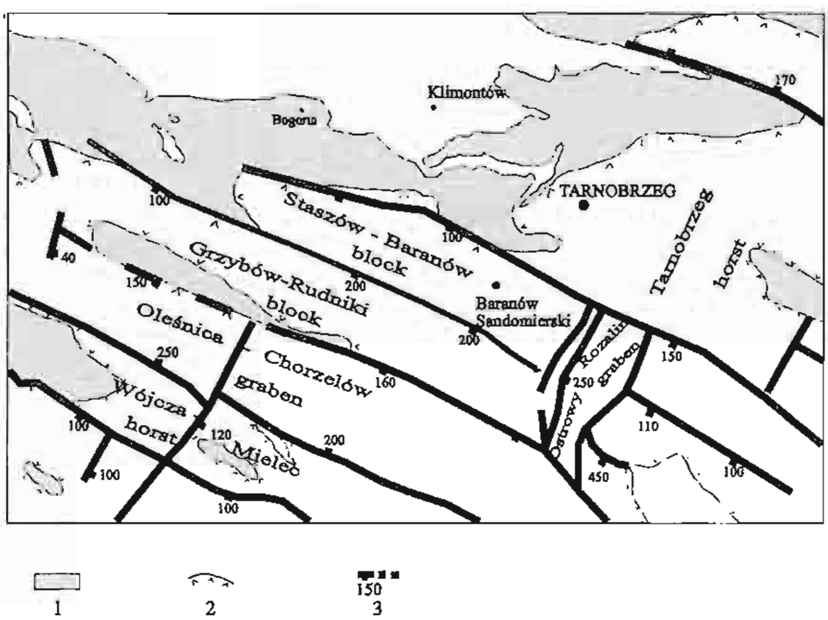

Fig. 6. Sketch of Miocene tectonic units (after B. Kubica, 1992)

1 — areas devoid of sulphates, 2 — extent of sulphates, 3 — faults confirmed and inferred, and magnitude of their displacements

v-shaped subaqueous pits appear (Pl. II, Figs. 3, 4), suggesting a high-energy shore environment. These are often accompanied by rectilinear cracks and arc shaped incisions of variable intensity. Some grains show local aluminosilicate overgrowths, resulting in a frosted effect visible at low magnifications.

The topmost sands from the section reveal a smaller proportion of rounded grains with polished surfaces, and with arc shaped subaqueous pits. Instead, partly rounded grains prevail. Fractured grains are also present. Both types of grains are characterized by frosted surfaces. Traces of surface etching are evident on fractured grains. On the surfaces of grains with a variable degree of frosting frequent traces of dissolution and precipitation (Pl. II, Figs. 5, 6) are present. Even very smooth conchoidal fractures start to be covered with precipitated silica dust. Etch marks are either in line with crystallographic directions or are irregular. The increase of frosted grains in samples from the topmost part of the sands points to an increase in chemical processes.

This trend in quartz grain surface features indicates changes in the environment of sedimentation of the uppermost part of the Baranów Beds: from a high-energy environment with a distinct shoreline influence characterized by stable physical-chemical conditions, slightly aggressive to quartz grains, gradually to an environment further from shore and more aggressive to quartz grains. These changes were probably linked with warming of the water, deepening of the basin and/or increase of the quantity of free silica in the sea water.

Cementation. Calcite-cemented quartz sandstones occurring within sands in the form of cemented patches and layers were also investigated. In order to compare the grain surface features and to determine the granulometric properties, sandstone samples were etched in 2nHCl. Cemented layers and lenses are typically present in a structureless, fine- and very fine-grained deposit. Grains with mean grain size M_z from 2.25 to 2.50 Ø and very good sorting — sorting coefficient between 0.23 and 0.42 — prevail. Skeletal organic remains are rare and unevenly distributed within the cement-bodies. They are represented mainly by oyster and pectinid shells, their content being variable, from horizons totally lacking them, to lithified oyster and serpulid conglomerates.

Apart from quartz, these sandstones contain rare (less than 1%) grains of heavy minerals, feldspars and micas. The quartz grains within the cemented-bodies are angular or poorly rounded and grain surface textures domaintly reflect chemical overprint. Rare mechanically produced features are typical of a shore zone. Inspection of thin sections reveals a lack of contacts or single quartz grain contacts. The grain outlines indicate a strong corrosion (Pl. III, Figs. 1, 2). A low-magnesium calcite cement predominates, while barite and silica may also occur as a cement. The low content of magnesium (from 0.05 to 0.30%) and particularly strontium (from 25 to 61 ppm) in the cement unequivocally points to fresh or mixed pore waters saturating the sediment during diagenesis. The intensity of sparite cementation and co-eval quartz grain dissolution was variable. The cemented sands are locally poorly lithified ($\rho < 1.80$ g/cm^3). However, cement-bodies with a bulk density between 2.06 and 2.46 g/cm^3 predominate, representing strongly and very strongly lithified rocks (J. Rutkowski, 1976), the $CaCO_3$ content varying from 7 to 50%. The cementation by calcite and barite and the synchronous quartz dissolution took place after the disappearance of the marine conditions. Therefore all observed cements are epigenetic, taking place from the Pliocene till present, when skeletal

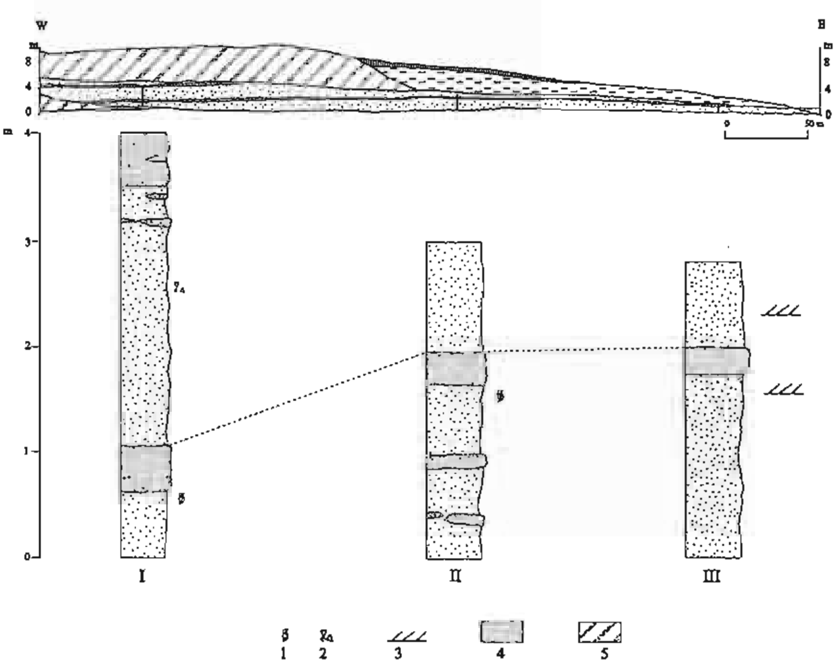

Fig. 7. Schematic view of the section at Świniary (in 1995); selected profiles (I–III) of sandy deposits in Świniary

1 — accumulation of oyster and pectinid shells, 2 — organic detritus, 3 — cross-bedding, 4 — calcite concretions, 5 — talus; for other explanations see Fig. 5

calcareous material dissolved, quartz grains were etched and calcium carbonate locally precipitated. It is thought that the processes were most intense during the Pliocene, in view of the prevailing warm climate and tectonic movements in the Holy Cross Mountains area (G. Czapowski 1976).

CONCLUSIONS

The thickness distribution of the Baranów Beds in the area investigated shows the influence of a nearby fault-zone. The final phase a fault movement is connected with the Sarmatian rejuvenation of NW–SE oriented linear dislocations of Cimmerian and Laramide age.

The Baranów Beds in the area investigated represent two facies. The lower of these represents a marshy shoreline transitional between marine and continental sedimentation. The upper facies represents an open marine environment of clastic sedimentation.

The quartz sands observed accumulated in a shallow marine environment below wave-base. Despite a general lack of diversity in granulometric composition and mineral composition, quartz grain surface morphologies enabled recognition of changes in environmental conditions within this part of the Baranów Beds: from a high-energy environment, directly linked with the shore zone, to a decreasing shoreline influence, probably due to a deepening of the basin.

By comparison with descriptions by A. Radwański (1973) of currently obscured levels at Świniary, the part of the sand-pit investigated probably corresponds to a deeper environment, distant from the shore. Accumulation of the sediment took place below wave-base, the clastic material being transported from the north.

All the cementation observed at Świniary is epigenetic, originating starting from the Pliocene.

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WPŁYW PROCESÓW SEDYMENTACYJNYCH I TEKTONICZNYCH NA POWSTAWANIE UTWORÓW OKRUCHOWYCH WE WCZESNYM BADENIE NA OBSZARZE SANDOMIERSKO-TARNOBRZESKIM (WARSTWY BARANOWSKIE, N CZĘŚĆ ZAPADLISKA PRZEDKARPACKIEGO)

Streszczenie

Celem pracy jest określenie zasięgu występowania, środowiska sedymentacji oraz ewolucji tektonicznej dolnobadeńskich utworów klastycznych oraz przedstawienie dotychczasowych wiadomości na ich temat. Utwory te określane mianem warstw baranowskich wykształcone są jako piaskowce i piaski kwarcowe z wkładkami mułowców, wapieni litotamniowych oraz podrzędnie iłów z węglem brunatnym.

W podłożu utworów mioceńskich na obszarze badań, w północnej, brzeżnej części zapadliska przedkarpackiego występują utwory eokambryjskie oraz kambryjskie, przede wszystkim łupki, mułowce i iłowce. Ukształtowanie powierzchni, na którą wkraczała transgresja morza badeńskiego, było zróżnicowane. Świadczy o tym występowanie zlepieńców w spągu warstw baranowskich, w profilach wielu otworów wiertniczych. Składają się one głównie z porwaków mułowców i iłowców kambryjskich. Dowodem zróżnicowania rzeźby podłoża i występowania w nim obniżeń jest również obecność w spągu utworów badeńskich iłów i piasków ilastych z węglem brunatnym. Wyższa część utworów klastycznych wykształcona jest natomiast jako piaski kwarcowe, częściowo zlityfikowane.

Warstwy baranowskie na obszarze badań reprezentują dwie facje. Część niższa powstawała w brzeżnej, bagiennej części zbiornika, przejściowej pomiędzy środowiskiem morskim a lądowym. Część wyższa reprezentuje otwartomorskie środowisko sedymentacji terygenicznej. Dostępne obserwacjom piaski kwarcowe, z wyższej części warstw baranowskich, gromadziły się w środowisku morskim, w płytkowodnej strefie, poniżej podstawy falowania. Pomimo braku zróżnicowania uziarnienia oraz składu mineralnego w profilu badanych osadów, na podstawie cech powierzchni ziarn kwarcu, stwierdzono zmiany warunków sedymentacji w obrębie tej części warstw baranowskich. Od środowiska wysokoenergetycznego, wyraźnie związanego ze strefą brzegową, do zaniku wpływu środowiska brzegowego, co związane jest najprawdopodobniej z pogłębieniem zbiornika.

W porównaniu do opisów A. Radwańskiego (1973) dotyczących nieistniejącej części odsłonięcia w Świniarach, obecnie odsłonięta część złoża piasków wydaje się przedstawiać nieco głębsze środowisko, bardziej oddalone od brzegu. Zdaniem autorki akumulacja osadu odbywała się poniżej podstawy falowania, a materiał klastyczny i organodetrytyczny przynoszony był z północy. Wszystkie obserwowane w Świniarach formy cementacji są

epigenetyczne. Powstawały w wyniku procesów diagenetycznych zachodzących w osadzie od pliocenu po dzień dzisiejszy.

Na obszarze sandomiersko-tarnobrzeskim w stropie osadów piaszczystych lokalnie występuje cienka (max. 5 cm) warstewka piaszczysto-marglista, rzadziej piaszczysto-ilasta z masowym nagromadzeniem fauny, wśród której dominują *Ervilia pusilla* i *Modiola hoernesi*. Ponad nią stwierdzono osady chemiczne, a także margle oraz wapienie margliste z charakterystyczne pekteny wyróżniane jako warstwy pektenowo-spirialisowe. Powyżej nich znajdują się iły sarmackie, zarówno warstwy syndesmyowe, jak i bezskamielinowe.

Na całym analizowanym obszarze północny zasięg warstw baranowskich ma charakter erozyjny, a ich miąższość jest zmienna. Powierzchnia stropowa warstw baranowskich jest wyrównana i łagodnie nachylona na wschód i południowy wschód. Miejscami, w rejonie Świniar i Łoniowa, bezpośrednio nad serią piaszczystą występują osady czwartorzędowe lub seria ta odsłania się na powierzchni terenu w rejonie Nawodzic i Rybnicy.

Analiza ukształtowania i głębokości występowania podłoża warstw baranowskich pozwala na stwierdzenie istnienia uskoku o kierunku NW–SE. Powstanie uskoku należy wiązać z ruchami tektonicznymi mającymi miejsce na obszarze zapadliska w sarmacie. Powstanie uskoku spowodowało wzajemne przemieszczenie utworów badeńskich, skrzydło północno-wschodnie uległo względnemu podniesieniu, południowo-zachodnie zaś obniżeniu.

EXPLANATIONS OF PLATES

PLATE I

Fig. 1. General view of the Świniary section

Fig. 2. Contact of quartz sands with overlying deposits, the arrow points to the *Ervilia* bed; scale bar = 0.1 m

Fig. 3. Cross-bedded sands with cemented levels; scale bar = 0.1 m

Fig. 4. Tabular cross-bedding and tangential cross-bedding in the eastern part of the section; scale bar = 0.1 m

Fig. 5. Sand layer with an accumulation of oyster shells and their fragments (profile II from Fig.7); scale bar = 0.1 m

PLATE II

Micromorphology of quartz grains (samples from profile I from Fig. 7)

Fig. 1. Fractured rounded grain, polished

Fig. 2. Fragment of grain from Fig. 1, with large v-shaped pits and arc shaped incisions

Fig. 3. Partly rounded grain, rather smooth surface

Fig. 4. Fragment of grain from Fig. 3, with numerous, large v-shaped pits typical of high-energy shore environments

Fig. 5. Partly rounded grain, frosted

Fig. 6. Fragment of grain from Fig. 5, with surface modified by dissolution and silica precipitation

PLATE III

Thin sections of calcite cemented sandstone

Fig. 1. Lack of contacts between quartz grains, grain outlines strongly affected

Fig. 2. Lack of contacts between quartz grains, calcite sparite cement. Syntaxial cement on echinoid spines

Geol. Quart., 1999, 43 (4)

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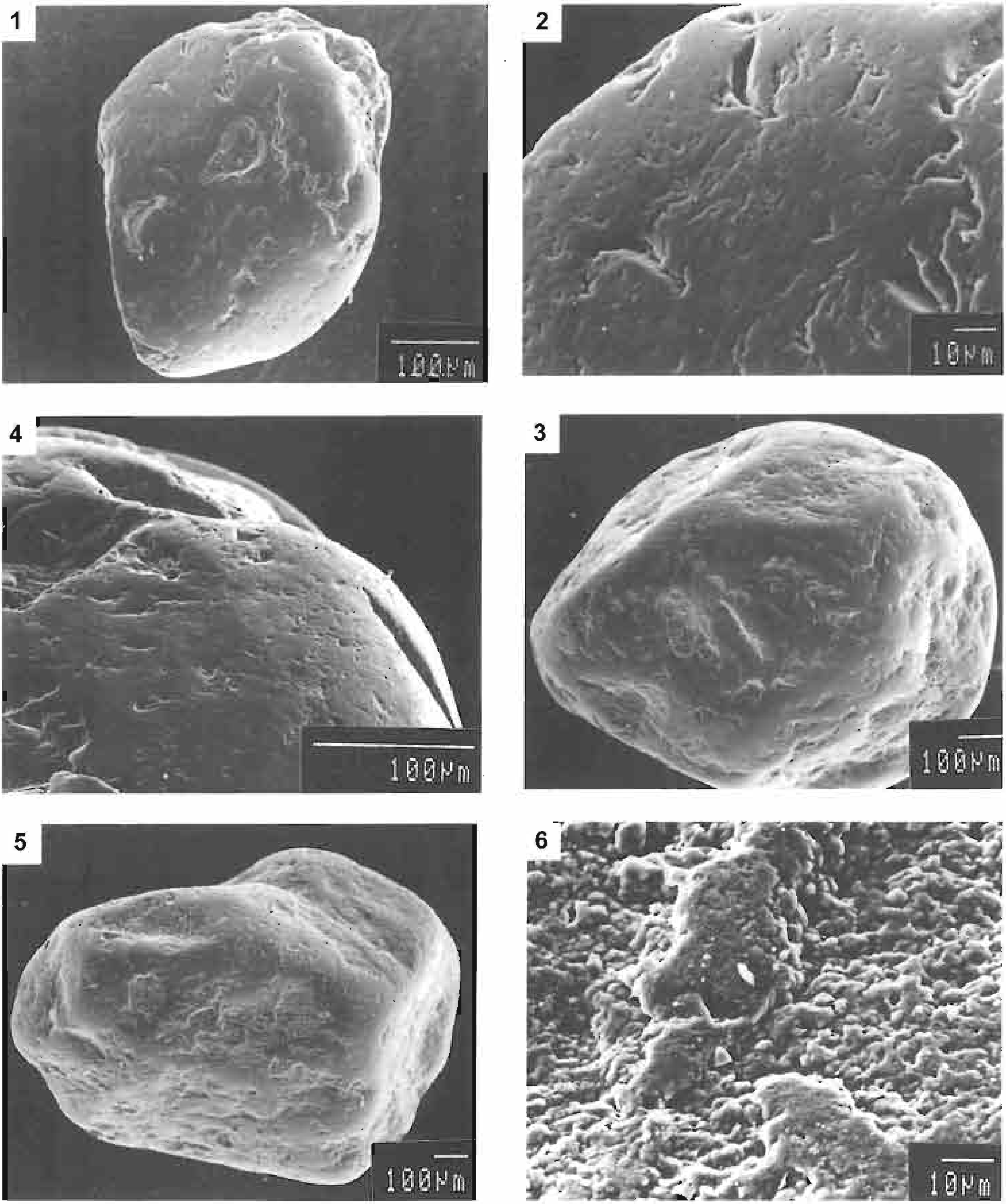

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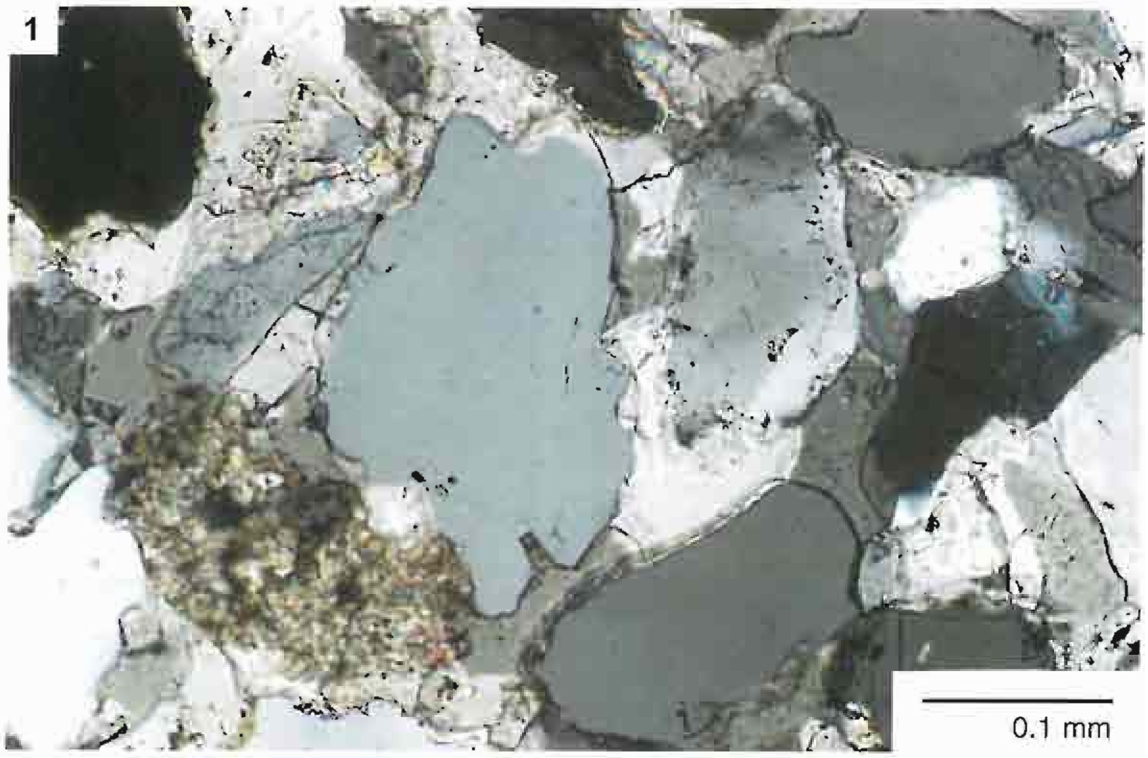

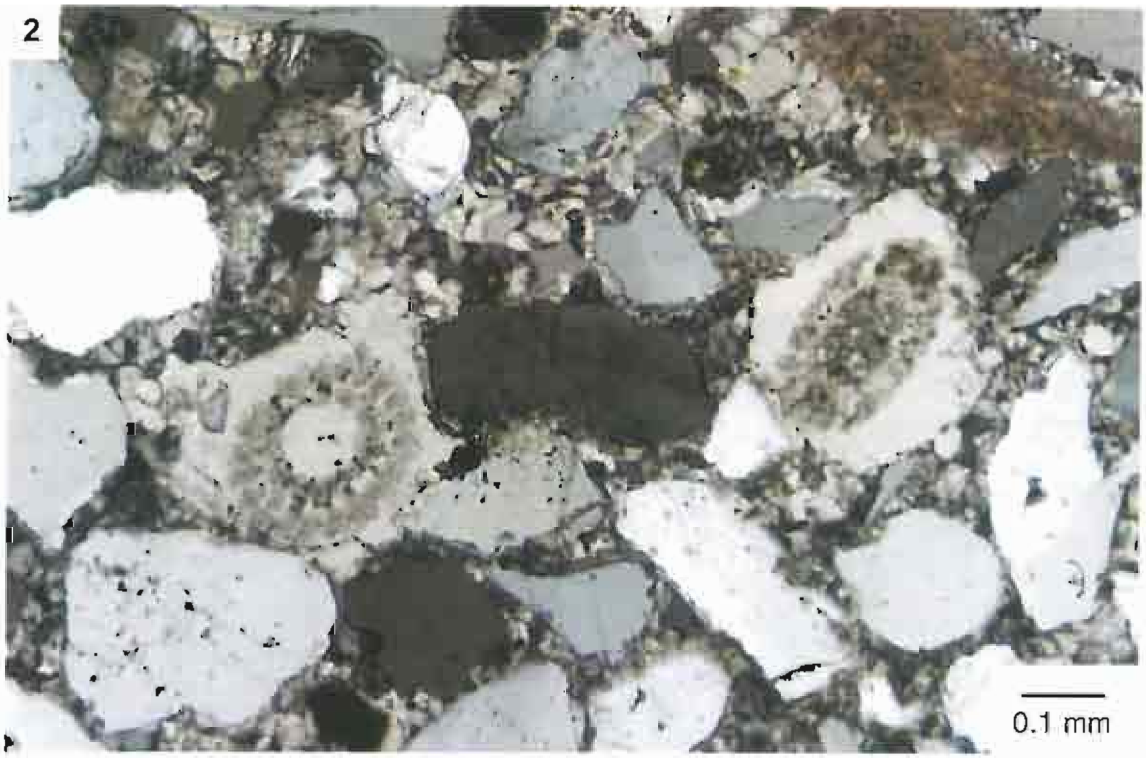

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