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Sedimentation and tectonics of the Upper Proterozoic-Lower Cambrian deposits of the southern Małopolska Massif (SE Poland)

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In the latest Precambrian and Early Cambrian, turbidity currents and cohesive flows transported pebbles, sand and mud into a deep water in south-east Poland, this sediment probably being sourced from Gondwana. Abundant detrital albite grains suggest volcanism during sedimentation. Pebbles in conglomerate interbeds are polymict and include rock fragments showing greenschist facies regional metamorphism in the source area. The Precambrian surface in the marginal part of the Carpathians lies at 2000–5000 m b.s.l., whereas farther south, around Kuźmina it reaches 7000 m. Still farther south (Krosno–Sanok–Baligród) geophysical evidence suggests it lies at about 17–20 km depth.

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INTRODUCTION

Basement rocks of the Carpathian Foreland were recognized in 1954 in the Gorliczyna 2 borehole, located around 35 km NE of Rzeszów. They comprise strongly folded and weakly metamorphosed claystones and siltstones, lying unconformably beneath Miocene deposits. Initially, Wdowiarz (1954) suggested a Silurian or Cambrian, or perhaps older age. Samsonowicz (1955, 1956) considered them to be Precambrian (Riphean), as did subsequent authors (Karnkowski and Głowacki, 1961; Głowacki and Karnkowski, 1963; Głowacki *et al.*, 1963; Łydka and Siedlecki, 1963; Obuchowicz, 1963; Parachoniak, 1963; Stemulak and Jawor, 1963; Pożaryski and Tomczyk, 1968; Jawor, 1970; Kicuła and Wieser, 1970; Heflik and Konior, 1971, 1974; Jurkiewicz, 1973, 1975; Łydka, 1973; Konior, 1974, 1978; Kowalczewski, 1979; Heflik, 1982), and they were also considered to represent the Upper Sinian (Znosko, 1965; Jaworowski *et al.*, 1967; Jurkiewicz and Kowalczewski, 1968), Vendian (Kowalczewski, 1979, 1981*a*; Kowalski, 1983) or Precambrian-Cambrian (Kowalczewski, 1981*b*, 1990, 1994; Wieser, 1967, 1989, in: Wdowiarz *et al.*, 1974; Pożaryski *et al.*, 1981). Acritarchs found by Vidal (in: Pożaryski *et al.*, 1981) indicated an Early Cambrian age. Based on this, similar deposits drilled in the Ryszkowa Wola 3a borehole (about 50 km NE of Rzeszów) have also been considered to be Early Cambrian (*Holmia* Cambrian).

Early Cambrian acritarchs in lithologically similar deposits have also been recently found in boreholes in the NW part of the Ryszkowa Wola Horst (Dziadzio and Jachowicz, 1996). No acritarchs have been noted so far from such deposits located to the south (Jarosław–Przemyśl area), though it has been suggested that "*Sub-Holmia* and older rocks" may be exposed in this area (Pożaryski *et al.*, 1981). Rocks occurring south of the Ryszkowa Wola Horst were considered by Moryc (1985) to be Precambrian. Assuming the presence of a sedimentary succession ranging from the uppermost Proterozoic through Lower Cambrian, such *Sub-Holmia* Beds and Precambrian rocks may also occur south of the Ryszkowa Wola Horst, as suggested also by Precambrian acritarchs recognized in the vicinity of Tarnów (Zalasowa 1 borehole) (Moryc and Jachowicz, in press).

The age of claystones and siltstones which represent the Precambrian in the southern part of the Carpathian Foreland is unknown, isotopic studies to date being inconclusive (Burchart, 1971). In the Polish part of the "non-metamorphosed

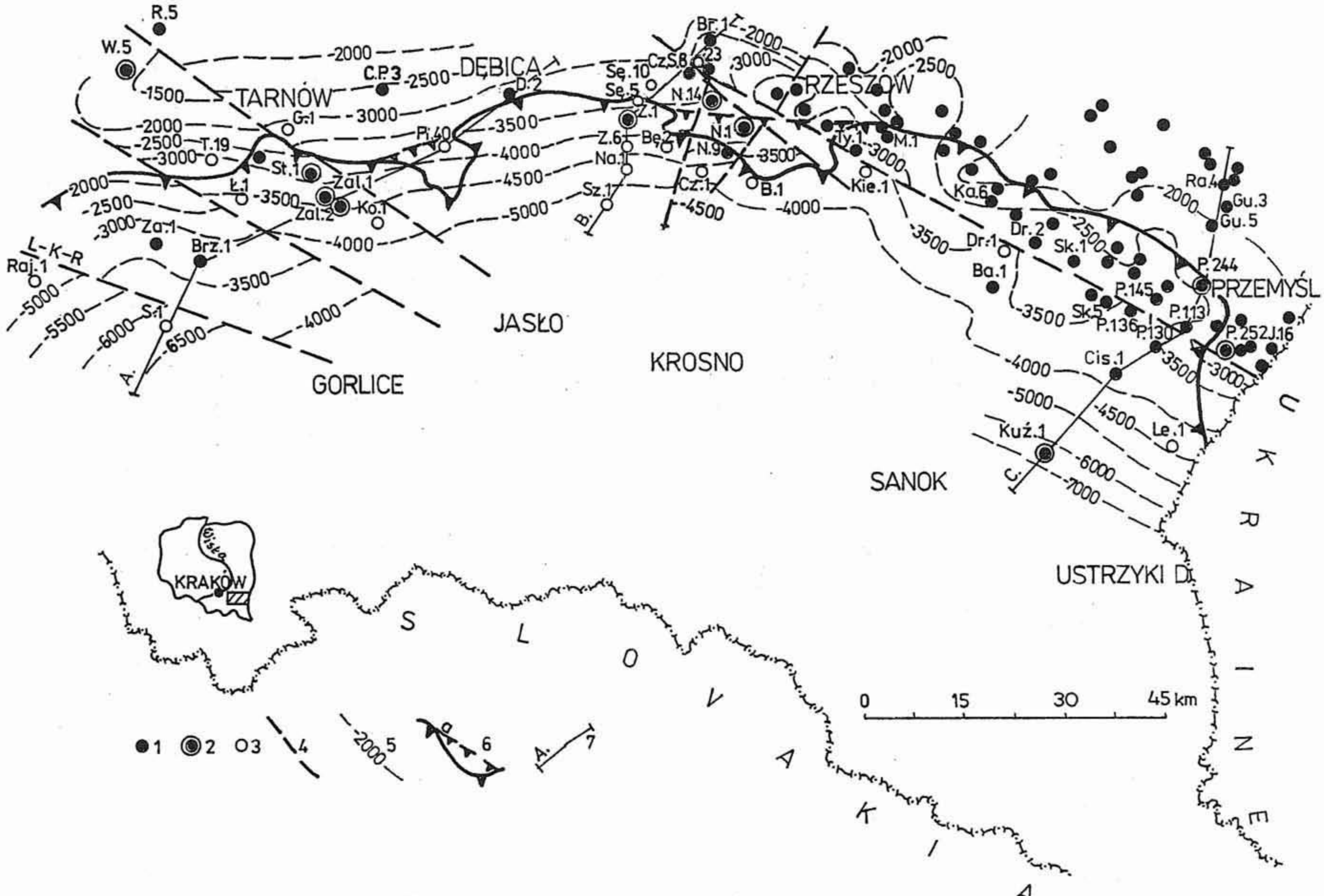


Fig. 1. Structure of the basement surface in the Tarnów–Przemyśl region of the Carpathians

1 — key boreholes with recorded Precambrian; 2 — boreholes with Precambrian deposits analysed petrographically; 3 — key boreholes with no Precambrian deposits reached; 4 — major faults (L-K-R — presumable eastern continuation of the Lubliniec–Kraków–Rajbrot fault zone); 5 — isobaths of the erosional surface of the top Precambrian; 6 — Carpathian thrust front (a — pre-Miocene); 7 — geological cross-section lines; boreholes: Ba — Babica IG, Ba — Bachórzec, Bę — Będzienica, Br — Bratkowice, Brz — Brzozowa, Cis — Cisowa IG, C.P. — Czarna Pilzno; Cz.S. — Czarna Sędziszowska, Cz — Czudec, D — Dębica, Dr — Drohobyczka, Gu — Gubernia, G — Gumniska, J — Jaksmanice, Ka — Kańczuga, Kie — Kielnarowa, Ko — Kowalowy, Kuź — Kuźmina, Le — Leszczyny, Ł — Łowczów, M — Malawa, Na — Nawsie, N — Nosówka, Pi — Pilzno, P — Przemyśl, R — Radłów, Ra — Radymno, Raj — Rajbrot, Sę — Sędziszów, S — Siekierczyna IG, Sk — Skopów, St — Stawiska, Sz — Szufnarowa, T — Tarnów, Ty — Tyczyn, W — Waryś, Z — Zagórzyce, Za — Zakliczyn, Zal — Zalasowa

Precambrian" (Heflik and Konior, 1971, 1974; Heflik, 1982) east and north-east of the Rzeszotary high, isotopic measurements were made on material from 4 boreholes (Siedlecki *et al.*, 1966). Recalculations by Burchart (1971) of material from the Nieczajna 3 borehole suggests an age of 600 Ma. This corresponds, according to the time scales by Odin (1982) and Harland *et al.* (1989), to the Late Proterozoic (Vendian). Rocks from the Puszcza (P-2) borehole yielded an age of 523 Ma, corresponding either to the Early Cambrian (Odin, 1982) or to the Middle Cambrian(?) (Harland *et al.*, 1989). Deposits from the Mędrzechów 1 borehole yielded an age, after recalculation by Burchart (*op. cit.*), of 434 Ma, corresponding to the Early Silurian. As the weakly metamorphosed mudrocks from the Mędrzechów 1 borehole are overlain by Ordovician (Arenig) deposits, this date must be wrong.

It is clear that the age of the mudrock deposits in the Carpathian Foreland basement requires further investigation. Regional assessment of these deposits require petrographic and structural data as well. Recently, in the vicinity of Tarnów (Zalasowa), two conglomerate horizons have been found for the first time within these pelitic sediments, and are currently under study.

LITHOLOGY AND DEPOSITIONAL ENVIRONMENTS

The oldest deposits of the consolidated basement of the Małopolska Massif comprise poorly metamorphosed claystones and siltstones with interbeds of conglomerates and sandstones showing variable levels of diagenetic changes. The pelites usually show ribbon textures, are compact and very poorly calcareous. They are frequently variegated in red and green, densely jointed with single pyrite inclusions or concentrations, and thin calcite veins. Thin to thick interbeds of grey siltstone and greywacke sandstone and locally coarse-grained conglomerates and greywackes — as at Zalasowa near Tarnów — are intercalated with the pelitic material. The rocks are usually strongly folded and frequently show abundant slickensides.

Many publications describe the uppermost parts of these rocks, below which most drilling stopped. Their total thickness is still unknown. The thickest section yet recognized in the northern part of the Carpathian Foreland was recorded in the Opatkowice 1 borehole (Kicuła and Wieser, 1970). There, the apparent thickness of unpierced deposits exceeds 1310 m. In the southern part of the Carpathian Foreland, the most complete section is represented in the Zalasowa 1 borehole (740 m — Fig. 2).

The Precambrian basement drilled in different parts of the Carpathian Foreland usually shows steep stratal dips up to 90° reflecting folds and/or thrust slices. Hence, it is difficult to estimates their true thickness. Previous estimate suggested thicknesses of > 8500 m (Tokarski, 1962), 1000 m (Kowalczewski, 1981*b*) or 3000–4000 m (Znosko, 1983). Thicknesses of analogous deposits in Central Dobrogea, Romania, are estimated at about 5000 m (Kräutner and Savu, 1978; Sandulescu, 1984). Samples described herein were collected from boreholes drilled in the southern part of the Carpathian Foreland. They are thought to be roughly coeval with the Precambrian rocks proved in the northern zone (Zalasowa). 90 samples were collected (Fig. 2) for mineralogical-petrographic studies from 10 boreholes drilled between Tarnów–Rzeszów and Przemyśl (Figs. 1, 2A, B). They represent pelitic (claystones and siltstones) and coarse-grained deposits (sandstones, greywackes, conglomerates).

TARNÓW REGION

Samples from boreholes Zalasowa 1, Zalasowa 2, Stawiska 1 and Waryś 5 (Fig. 2A) were examined using microscopic and X-ray methods. For sandstones the classification by Dott modified by Pettijohn *et al.* (1972) was employed. The Zalasowa 1 borehole recorded a 740 m-thick succession at well depths 3695–4435 m, overlain by Jurassic deposits (Dogger). Its upper part (3695–4182 m) is represented by variegated red, green, grey and brown slates and siltstones, which are locally sandy. The claystones are compact and are diagenetically altered. In places they contain thin intercalations of grey, compact and fractured sandstones and greywackes with calcite veins. Locally, dispersed crystals and concentrations of pyrite occur in muddy strata. Compact siltstone layers within mudstones represent turbidite bases. Stratal dips are low, predominantly 2–5°, indicating that the drilled thickness approximates the true thickness.

Similar claystone-siltstone deposits were recorded in the boreholes Stawiska 1 (98 m-thick) and Waryś 5 (220 m). Unlike the Zalasowa 1 borehole, they show steep dips ranging from 35 to 75° (Fig. 2A). Petrographically, there are a number of common features. The pelites are composed of fine-grained detrital albite and quartz, authigenic chlorite passing into brown biotite, and calcite cement. Siltier rocks from the borehole are laminated and contain albite, quartz, microcline and muscovite. Chlorite in porphyroblasts shows optical features of penninite and occurs as a subordinate component. The rocks are locally fractured into a tectonic breccia of cm-scale angular and elongated fragments. Coarsely crystalline calcite fills fractures and cements the breccia. In the core interval of 1972–1976 m, silty mudstones show synsedimentary flow structures.

Table 1 shows the mineral composition of pelites from boreholes Waryś 5 and Zalasowa 1 compared with analogous rocks from the western part of the Małopolska area.

The Zalasowa 1 borehole penetrated older Precambrian rocks. An upper unit of variegated polymict conglomerates with pebbles 1 to 5 cm in diameter occurs at depths of 4182–4225 m (Fig. 2). These conglomerates are accompanied by mostly thin pelitic interbeds as well as by lithic arkosic greywackes (in particular within a second, lower conglomerate unit occurring at depths of 4352–4410 m). Smaller pebbles of rocks similar to those from the conglomeratic intervals have been found in both mudstones (also from depths of 4410–4435 m) and greywackes. The two units contain detrital material petrographically variable and of different transformation grade (Pl. I, Figs. 1, 2; Pl. II, Fig. 1). This deversity is demonstrated, among others, by microcline clasts, 2–4 cm in diameter, without traces of alteration, co-occurring with large, angular albite grains sericitized to a considerable extent. There are also garnet a few millimetres in diameter with no trace of secondary alteration.

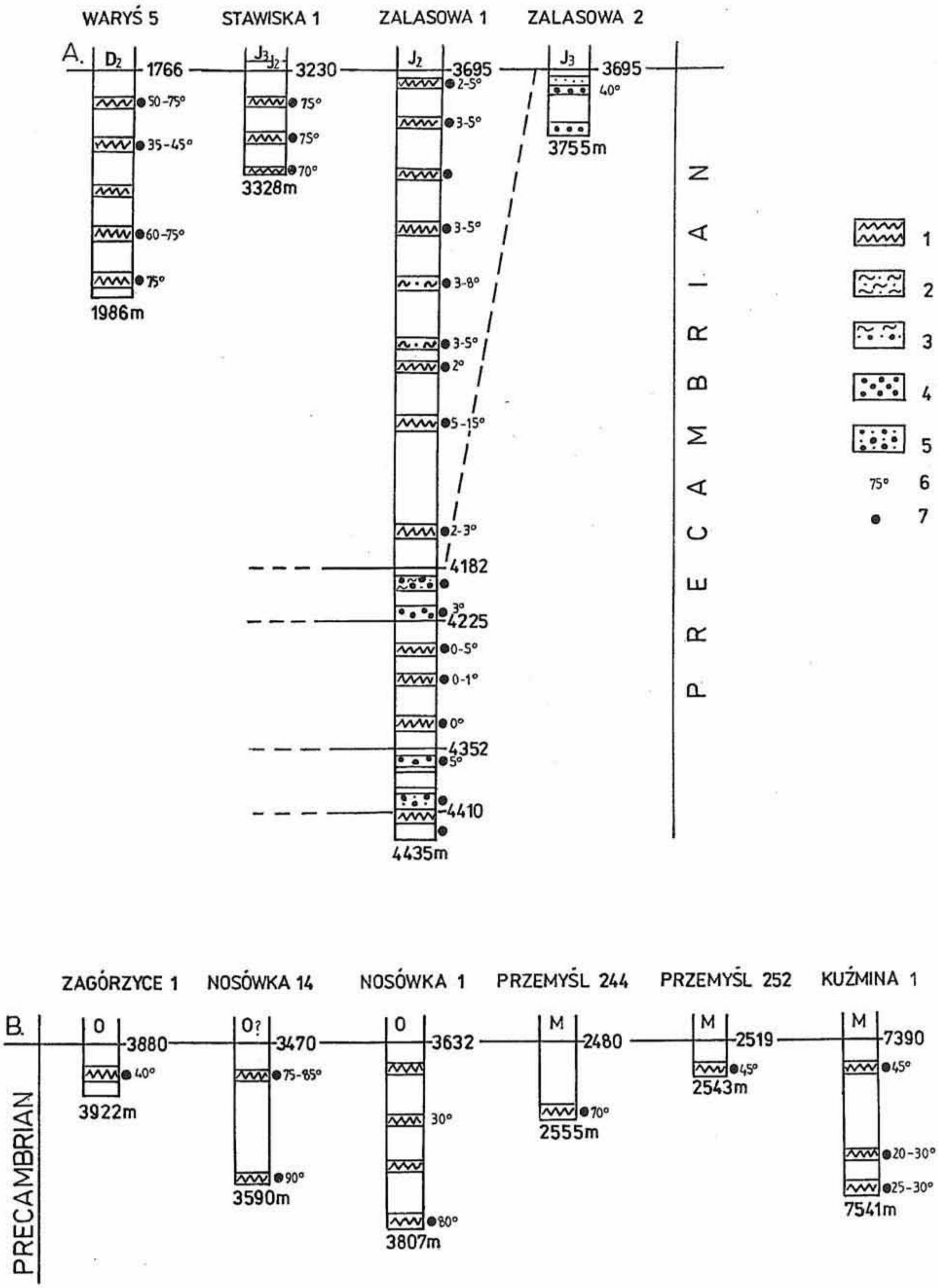


Fig. 2. Correlation of Precambrian deposits from selected boreholes; Tarnów region (**A**), Rzeszów and Przemyśl region (**B**)

1 — claystones with strong diagenetic alterations; 2 — siltstones with strong diagenetic alterations; 3 — pelites with interbeds of compact sandstones; 4 — polymict conglomerates; 5 — greywacke conglomerates and sandstones; 6 — stratal dips; 7 — petrographical samples; M — Miocene; J_3 — Upper Jurassic; J_2 — Middle Jurassic; D_2 — Middle Devonian; O — Ordovician

Table 1

Mineral composition of pelitic rocks and matrix of Precambrian deposits

Component	Slates				Conglomerates matrix
	Waryś 5 1840 m	Zalasowa 1 4132 m	Puszcza 2 1144.8–1147.8 m	Mrzygłód 1 256 m	Zalasowa 1 4190 m
Quartz	30	33	26	27	30
Albite	48	45	25	16	48
Microcline	7	4	trace	11	14
Chlorite	3	2	17	16	1
Sericite	12	16	17	23	7
Pyrite+Fe and Ti oxides	trace	trace	3	6	trace
Carbonates	trace	trace	11	trace	trace

Larger clasts, several centimetres in diameter, include fragments of magmatic, metamorphic and sedimentary rocks.

Gabbro pebbles, with augite and labradorite, and of ophitic structure show no trace of secondary alteration. There are also pebbles of albite metabasites with epidotized plagioclases as well as large epidote and chlorite porphyroblasts. Granitoid pebbles displaying graphic texture, in which idiomorphic and bipyramidal quartz grains with identical optic orientations are included in microcline crystals, occur together with material derived from erosion of basic magmatic rocks. Microcline pegmatite pebbles are sporadic. Volcanic pebbles include spherolitic variolites composed of albite and chlorite. Microophitic dolerites and fragments of chloritized metabasite with epidote porphyroblasts have also been found. Trachyte and rhyolite pebbles are unmetamorphosed and composed of feldspar and quartz grains embedded in a felsitic groundmass. Some of the trachytes are cut by ptygmatic veins of microcrystalline quartz and albite. Some dacite pebbles contain polysynthetically twinned albite grains to 1 mm in diameter. The volcanic pebbles include rocks which underwent both cataclasis in the source area and metamorphism under greenschist facies conditions; their brittle fractures are filled with coarsely crystalline epidote and quartz.

Metamorphic rocks are represented by fragments of coarsely crystalline albite-microcline orthogneisses locally cut by thin quartz veins; fragments of augen gneisses with albite porphyroblasts rich in sericite and epidote inclusions are also observed.

Paragneiss pebbles with quartz and albite laminae, as well as fragments of quartz-albite paragneisses with chlorites and epidote occasionally reach 25 mm in diameter. Fragments of albite-epidote-quartz schists belong to rather rarely occurring constituents of coarse-grained sediments. These schists similarly as quartzitic phyllites and thinly laminated quartz-muscovite schists are characterized by microfold structures, and occasionally contain large muscovite porphyroblasts.

Sedimentary rock fragments include abundant arenite pebbles, as well as intraclasts of lithic greywackes and tuffite pebbles. The conglomerates frequently show gradational transitions into lithic greywackes or arkosic greywackes. Their matrix is compositionally similar to the interbedded arenites and siltstones (Tab. 1). Detrital material composing the matrix is very poorly rounded, fractures are filled with coarsely crystalline calcite which corrodes detrital feldspars.

These conglomerate units are separated (depth 4225–4352 m) and underlain (depth 4410–4435 m) by mudstones (Fig. 2A).

The deposits from the Zalasowa 1 borehole represent turbidites dominated by thinly laminated claystones and siltstones, and interbedded with lithic arkosic greywackes and polymict conglomerates.

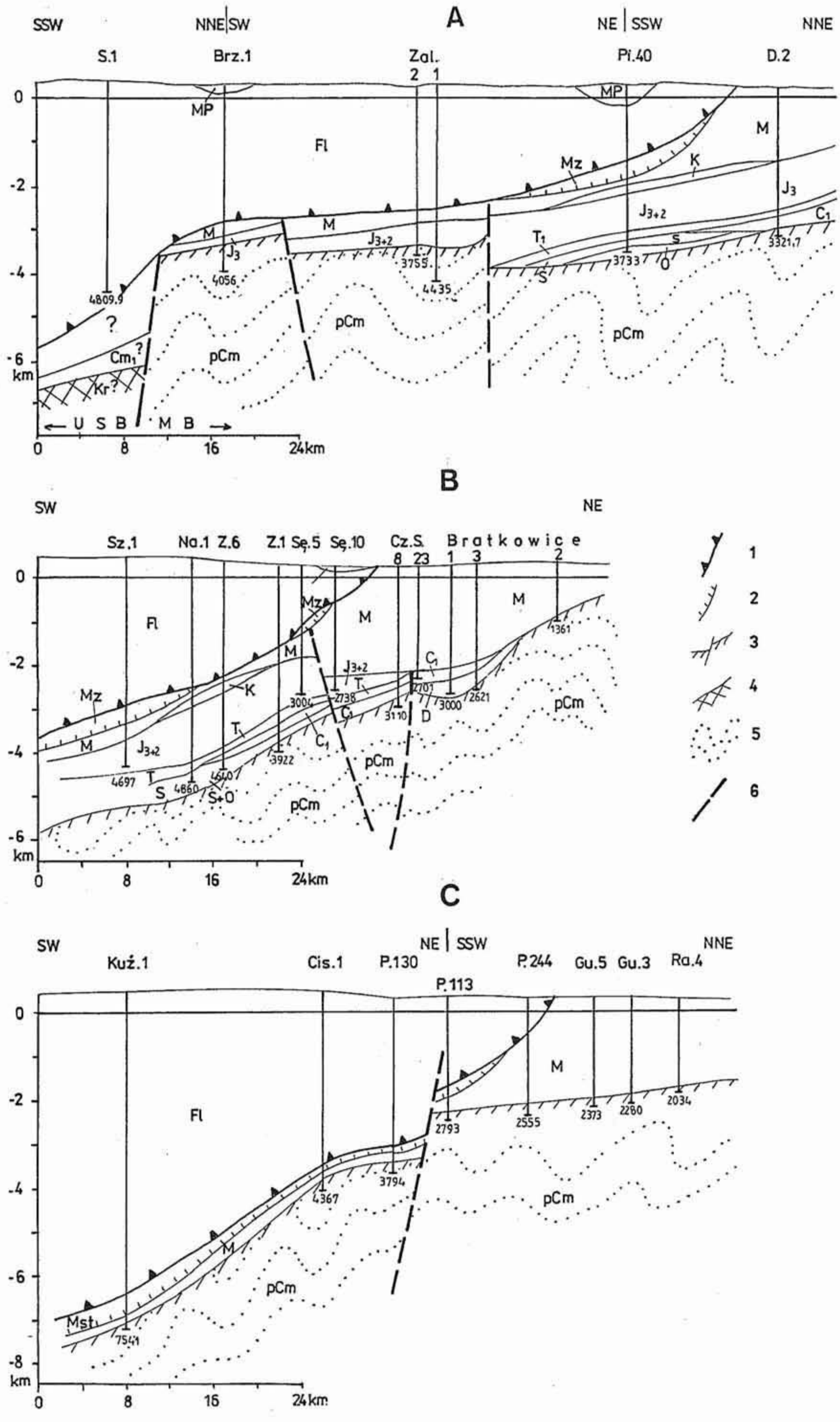
Similar deposits have also been drilled below the Upper Jurassic carbonates in the borehole Zalasowa 2. These are conglomerates and greywackes with, in their upper part, a mudstone interbed dipping at about 40°.

In the Stawiska 1 and Zalasowa 1 boreholes these deposits have yielded acritarchs indicating a Precambrian age (Moryc and Jachowicz, in press).

RZESZÓW–PRZEMYŚL REGION

Many boreholes drilled over this area (Fig. 1) have encountered pelites considered to be of Precambrian age. In the boreholes Zagórzyce 1, Nosówka 1 and Nosówka 14, around Rzeszów, these Precambrian pelites occur below Ordovician deposits. The Precambrian mudstones and siltstones are green, grey and red in colour, frequently colour-banded, fractured and cut by numerous thin calcite veins. These deposits show steep dips of strata, locally (e.g. Nosówka 14) up to 90°(Fig. 2B).

The rocks have undergone diagenetic and low-grade metamorphic alterations. The highest grade pelitic deposits were drilled near Przemyśl (Fig. 2B). Chlorite-sericite slates with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porphyroblasts of green pleochroic chlorite locally passing into brownish-green biotite have been found in cores from the Przemyśl 252 (Pl. II, Fig. 2) and Przemyśl 254 boreholes. Such deposits were earlier described by Wieser (1967 and in: Wdowiarz *et al.*, 1974) from the Cisowa IG 1 borehole and Wieser (1989) from the Kuźmina 1 borehole and assigned by him to a quartz-albite-muscovite-chlorite subfacies. Wieser (1989) recorded bioturbation in these sediments and noted that these rocks show a level of metamorphism similar to that observed in analogous deposits from Cisowa, Kańczuga and Opatkowice.

Pelites from the Kuźmina 1 borehole contain small chlorite xenoblasts displaying optical properties of penninite, in places with biotite intergrowths. Locally, the pelites are laminated; the laminae being a few to several tens of millimetres thick. Light laminae are enriched in detrital quartz and albite. The dark ones are enriched in micro-aggregates of iron oxides. Occasionally, within a fine-grained quartz-albite groundmass, green chlorite grains are arranged according to the oriented structure of rock. Local, cross-cutting veins are filled with quartz and subordinate chlorite.

In summary, the following conclusions can be drawn:

Sedimentation in a pelagic environment took place over this area in the Late Precambrian and Early Cambrian. The subordinate interbeds of coarse-grained sediments were deposited at that time. These rocks have undergone various diagenetic alterations and low-grade regional metamorphism, reflecting progressive burial and then tectonism.

Early diagenetic processes include illitization and progressive sericitization of detrital feldspars and — probably — of volcanic glass. The preponderant detrital albites might suggest volcanism, presumably pyroclastic, during sedimentation. Coeval and subsequent quartz and chlorite crystallization partly took place in response to tectonism.

Pebbles in the coarse-grained interbeds suggest lithologically diverse source areas where the rocks underwent regional metamorphism of epidote-amphibolite and greenschist facies. Rocks composing pebbles of conglomerates have not been known from the basement of the Carpathian Foredeep (Małopolska Massif) so far. These source areas probably lay within Gondwana.

TECTONICS

The analysed Precambrian deposits were found in boreholes located in the southern part of the Małopolska Massif. This structural element can be traced westwards to the Lubliniec–Myszków–Kraków belt (Brochwicz-Lewiński *et al.*, 1983; Pożaryski, 1990; Buła, 1994; Buła and Jachowicz, 1996), SE to the Bochnia–Zakliczyn area (Jachowicz and Moryc, 1995; Moryc and Jachowicz, in press) and farther east across Poland to the eastern state border. This massif is separated from the Upper Silesian Block, located in the south-west, by the Lubliniec–Kraków–Rajbrot fault zone.

The southeastern continuation of the fault zone separating these two massifs has been documented as far as the Rajbrot area (Jachowicz and Moryc, 1995) with a completely different development of Lower Palaeozoic deposits on either side of the zone. There are clues to the probable course of the fault zone yet farther east. The top of Precambrian deposits in the Zakliczyn 1 and Brzozowa 1 boreholes (Fig. 1), still within the Małopolska Massif, is at the same level as at Zalasowa, at around 3400 m b.s.l. Boreholes at Rajbrot to the south (Fig. 1) (Jachowicz and Moryc, *op. cit.*) revealed epicontinental Lower Cambrian deposits, suggesting a location on the Upper Silesian Block. These deposits extend to a depth of at least –4560 m and presumably overlie a crystalline basement. About 22 km SE of the Rajbrot boreholes, the Siekierczyna IG 1 borehole (Fig. 1) reached a depth of nearly 4810 m (4425 m b.s.l.), without reaching the base of the Carpathian flysch deposits (Fig. 3A). This borehole occurs within the SE continuation of the Rajbrot region, and should encounter similar geology. Hence, once below the flysch, Miocene, Mesozoic and Palaeozoic deposits (including the Cambrian epicontinental deposits), totalling some 2 km in thickness, should also occur beneath Siekierczyna. Thus, the top of the assumed crystalline basement may descend from about –5000 m down to –6500 m between Rajbrot and Siekierczyna (Fig. 1), being approximately 2000–3000 m lower than the top of the Precambrian pelites of the Zakliczyn–Brzozowa Block. Such a considerable difference in the depths to the crystalline basement top between these two blocks (Fig. 3A) suggests separation by a fault zone, which is probably a SE continuation of the Lubliniec–Kraków–Rajbrot fault zone (Fig. 1). It is impossible to trace this zone farther at present. Its trend may be affected by basement tectonics e.g. the transversal Wysowa–Jasło fault (see Żytko, 1997 and Ryłko and Tomaś, 1998).

The Precambrian basement rocks of the Małopolska Massif (Fig. 1) were strongly folded (Fig. 3) and perhaps also thrusted.

Consolidated deposits in the Carpathian Foreland are represented — at least in part — by Proterozoic rocks. This is evidenced by the above-mentioned presence of acritarch microflora. Deposits similar in lithology, also exhibiting identical alterations, occur farther to the north in the Carpathian Foreland as far as about the Ryszkowa Wola Horst (e.g. in boreholes:

Fig. 3. Geological cross-section across the Carpathians and their basement; Siekierczyna–Pilzno–Dębica region (**A**), Szufnarowa–Bratkowice region (**B**), Kuźmina–Przemyśl–Radymno region (**C**); see Fig. 1 for a location

1 — Carpathian thrust front; 2 — Zgłobice Unit (Mz) or Stebnik (Mst) thrust front; 3 — top surface of Precambrian deposits (in Małopolska Massif); 4 — presumed top surface of crystalline rocks (probable SE continuation of the Upper Silesian Block); 5 — folded and faulted Precambrian deposits (simplified sketch); 6 — major faults; Fl — Carpathian flysch; MP — transgressive Miocene overlying flysch (i.a. "embayments" of Pilzno, Brzozowa and Rzeszów); Mz — Miocene of the Zgłobice Unit; Mst — Miocene of the Stebnik Unit; M — autochthonous Miocene; K — Cretaceous; J_{3+2} — Upper and Middle Jurassic; T — Triassic; C_1 — Lower Carboniferous; D — Devonian; S — Silurian; O — Ordovician; Cm_1 — Lower Cambrian (presumable); Kr? — probable crystalline rocks — Precambrian; pCm — pelites — Precambrian; USB — Upper Silesian Block; MB — Małopolska Massif; for symbols of boreholes see Fig. 1

R. W. 3a, Jeżowe 3, Łętownia 1, Rudka 7, Dobra 4, Piskorowice 2). They contain there Early Cambrian acritarchs of the *Holmia* Zone (Pożaryski *et al.*, 1981; Dziadzio and Jachowicz, 1996). The same lithology is known from many boreholes drilled in the area between the Carpathians and Ryszkowa Wola Horst. We may thus infer that a continuous succession of deposits, representing intermediate members between the uppermost Precambrian and *Holmia* Zone Cambrian, occurs in this area. This opinion is in conformity with an idea expressed in the study by Pożaryski *et al.* (1981).

This deformation post-dated the Early Cambrian (see above) and pre-dated Upper Cambrian and possible Middle Cambrian rocks differring from the pelitic Late Precambrian/Early Cambrian succession in lithology and fauna (Tomczyk, 1962, 1963; Pożaryski and Tomczyk, 1968; Dziadzio and Jachowicz, 1996) and in showing consistent low dips in an absence of metamorphism. These contrasts indirectly indicate the presence of an unconformity between the two rock successions, folding taking place due to Late Cadomian (Early Caledonian?) orogenic movements in the Middle Cambrian (Pożaryski *et al.*, 1981; Brochwicz-Lewiński *et al.*, 1983; Znosko, 1983; Pożaryski, 1990; Kowalczewski, 1990, 1994).

In some boreholes (e.g. Zalasowa 1) the discussed deposits show low dips of strata and even rest horizontally. This may be explained by the location of the boreholes in synclinal axes or anticlinal crests (Fig. 3A).

Faults in the Precambrian basement (Figs. 1, 3) include some showing Miocene movements probably representing rejuvenation of older tectonic lineaments.

The present-day Precambrian-Early Cambrian surface reflects tectonic and erosional events which took place after the Alpine orogeny. This surface (Figs. 1, 3) descends towards the south from a depth of –2000 m in the marginal zone of the Carpathians down to –5000 m in the Szufnarowa area and to about –6500 m in the presumed prolongation of the Silesian Block in the Siekierczyna region. Its lowest directly recorded position — at a depth of about –7000 m — is seen in boreholes in the Kuźmina region. Geophysical data (e.g. Pożaryski, 1970; Ślączka, 1975; Karnkowski, 1977*a*, *b*; Ryłko and Tomaś, 1995, 1998; Żytko, 1997) indicate that farther south, in the Krosno–Sanok–Baligród region, this surface descends to about 12 km or even 17–20 km (Żytko, *op. cit.*).

The top surface of the consolidated Precambrian deposits is additionally disturbed by a series of faults, into a pattern of smaller and larger tectonic blocks. Figure 1 shows only some of the most important faults (see also Fig. 3). They reveal a series of horsts (Zakliczyn–Brzozowa Block), tectonic grabens locally of "scissors" type (Waryś–Zalasowa) and monoclines (Dębica–Kuźmina). The monoclinal tectonic block locally controlled Palaeozoic and Mesozoic sedimentation by movement on its northern bounding fault. In the Polish part of the Carpathian Foredeep this fault zone extends from the state border with the Ukraine, between boreholes Przemyśl 113 and Przemyśl 130 (Figs. 1, 3C), westwards between boreholes Drohobyczka 1 and Drohobyczka 2, and between boreholes Tyczyn 1 and Kielnarowa 1. West of Rzeszów it trends between Bratkowice and Czarna Sędziszowska (Fig. 3B) and then near Mielec, and north of Busko it continues into the Miechów Trough. This fault zone was rejuvenated several times and influenced erosion of suprajacent deposits and the top of the Precambrian surface between the Dębica–Kuźmina monoclinal block and the hanging Bratkowice–Przemyśl Block to the north (Figs. 1, 3B, C). The course of this fault zone coincides with the erosional extent of Lower Palaeozoic (lacking in the north) and Devonian (lacking in the southern block) deposits and with lateral thickness changes in the Mesozoic (Moryc, 1992, 1996). Later, post-Laramide erosion resulted in a truncation of block margins which largely reduced differences in depth of the surface on either side of the fault zone.

CONCLUSIONS

1. Interbeds of sandstone, greywacke and conglomerate occur within the pelites that make up the basement of the Małopolska Massif.

2. Sedimentation took place from turbidity currents and submarine cohesive flows (conglomerates).

3. The conglomerates are composed of clasts of igneous, metamorphic and sedimentary rocks which are so far unknown from the Carpathian Foredeep (Małopolska Massif).

4. These clasts were probably sourced from Gondwana.

5. The basement deposits comprise a Late Proterozoic to Early Cambrian succession.

6. The deposits were folded during Late Cadomian (Early Caledonian?) orogenic movements of Middle Cambrian age.

7. This basement to the Carpathian Foreland descends southwards from about 2000–5000 m b.s.l. down to 7000 m south of Przemyśl (Kuźmina) and to 17–20 km depth yet farther south.

8. The basement of the Małopolska Massif is transected by a series of faults dividing this area into smaller tectonic blocks.

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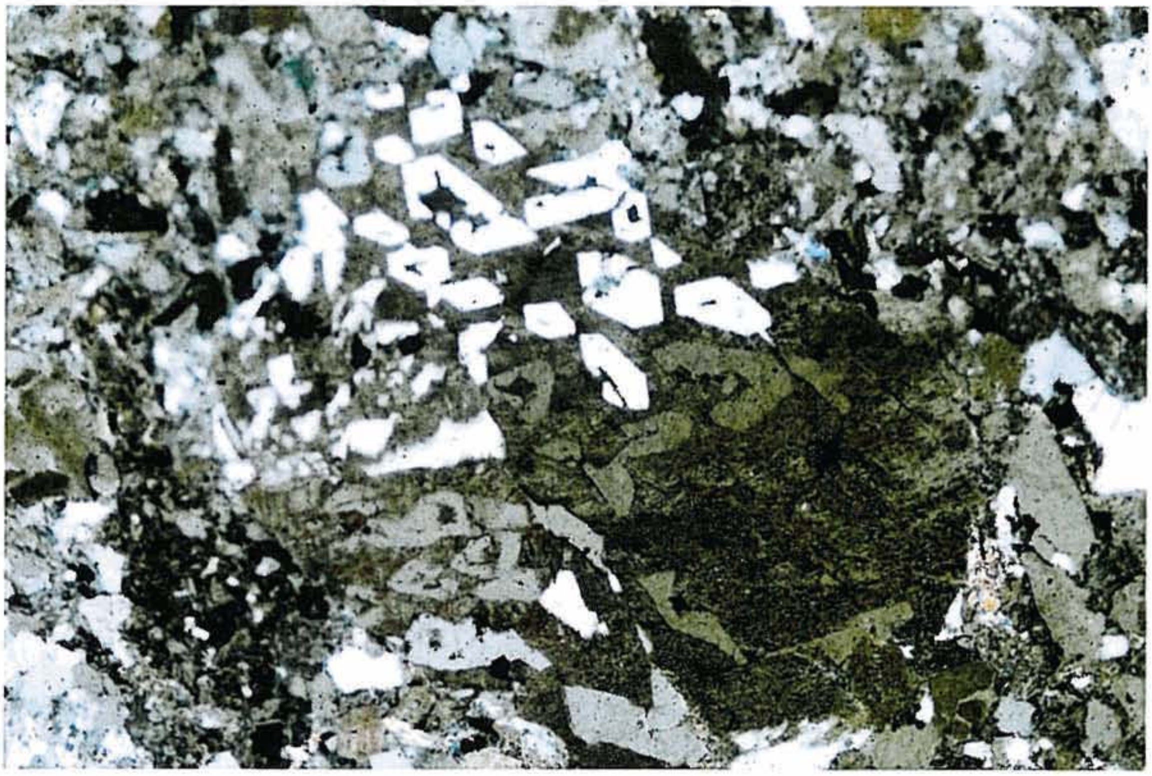

1. Conglomerate from the Zalasowa 1 borehole, depth 4360–4369 m. Pebble of micropegmatite granite. Feldspars with intergrowths of bipyramidal, idiomorphic quartz; x 100, crossed polars

2. Conglomerate from the Zalasowa 1 borehole, depth 4360–4369 m. Metabasite pebble with large epidote crystaloblast crossed by numerous quartz veins; x 100, crossed polars

1. Conglomerate from the Zalasowa 1 borehole, depth 4360–4369 m. In upper part — quartz-feldspar matrix with green chlorite; in lower part — volcanite pebble with large, idiomorphic plagioclase crystal penetrated by brown hydrated iron oxides; x 100, crossed polars

2. Pelite with chlorite porphyroblasts. Borehole Przemyśl 252, depth 2539–2543 m; x 100, crossed polars