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Klonów Beds (uppermost Silurian–?lowermost Devonian) and the problem of Caledonian deformations in the Holy Cross Mts.

Zbigniew KOWALCZEWSKI, Krzysztof JAWOROWSKI, Maria KULETA

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This paper presents the results of sedimentological, petrographical, stratigraphical and tectonic studies of the Klonów Beds from the Silurian/Devonian boundary interval in the Holy Cross Mts. They have been found in boreholes Klonów 1 and Klonów 2. Alluvial fan, braid plain and braid delta deposits have been recognized and characterized. A facies model has been constructed for the Klonów Beds which interfinger with Miedziana Góra Conglomerates and Bostów Beds. The occurrence of two marine basins, separated by an uplifted area located in the present-day Pasmo Główne Range, has been evidenced. A detailed lithological description of the cored sedimentary and pyroclastic deposits is given. Mineral composition of greywackes and arenites were analysed allowing determination of the geotectonic character of source areas. The source area for the Klonów and Bostów Beds were different zones of a recycled orogen whereas for the Barcza Beds — mainly a continental block. Palynological studies indicate that the Klonów Beds were deposited during the Pridoli and may correspond to the earliest Gedinnian. The studied rocks have been considered exhibit fault-fold tectonics. Geological processes, which took place at the decline of the Caledonian epoch at the boundary of the Kielce and Łysogóry Regions in the Holy Cross Mts., are described. A problem of molasses representing the decline of the Lower Palaeozoic sedimentary-diastrophic cycle is also discussed. It has been evidenced that the Kielce and Łysogóry units had become integrated into the single Holy Cross orogen during the Late Silurian — before the Klonów Beds were deposited, probably during the Ardennian tectonic movements.

Zbigniew Kowalczewski, Maria Kuleta, Świętokrzyskie Mts. Branch, Polish Geological Institute, Zgoda 21, 25-953 Kielce, Poland; Krzysztof Jaworowski, Polish Geological Institute, Rakowiecka 4, 00-975 Warszawa, Poland *(received: 28.08.1998; accepted: 09.11.1998).*

Key words: Klonów Beds, Upper Silurian–Lower Devonian, sedimentology, petrography, stratigraphy, Caledonian deformations, the Holy Cross Mountains.

INTRODUCTION

Geological processes which took place in the Holy Cross Mts. at the turn of the Silurian, particularly at the boundary between the Kielce and Łysogóry Regions, are a subject of much interest, especially due to: (1) a peculiar position of this area (Fig. 1) located adjacent to the edge of the East European Craton, (2) its close relation to the Caledonian, Variscan and Alpine orogens, and (3) its position within the Trans-European Suture Zone. It should be ultimately determined, where, in the basement, the SW edge of the East European Craton runs: whether this is expressed near the surface by a fault zone from the middle part of the Kamienna River — as it was claimed earlier (*vide* Z. Kowalczewski, 1981), or by the major Holy Cross Fault (HCF) — as it has been suggested in recent papers (R. Dadlez *et al.*, 1994).

The Łysogóry Unit, which is probably situated on a downwarped and downfaulted edge of the East European Craton, either might have been thrusting over the craton during the earliest Palaeozoic, or has been forming in that place from the Cambrian until Carboniferous. Therefore, the unit is either a part of the strongly folded Małopolska Caledonides (J. Znosko, 1996; R. Dadlez *et al.*, 1994) or an element of a platform cover which was tectonically reactivated during the Variscan tectonic movements (W. Pożaryski *et al.*, 1992*a*, *b*). A hypothesis of the Łysogóry monocline arises from the latter interpretation (W. Mizerski, 1979, 1995).

The attempts to reconstruct geological evolution of the Holy Cross Mts. and adjacent areas basing upon the tectonics

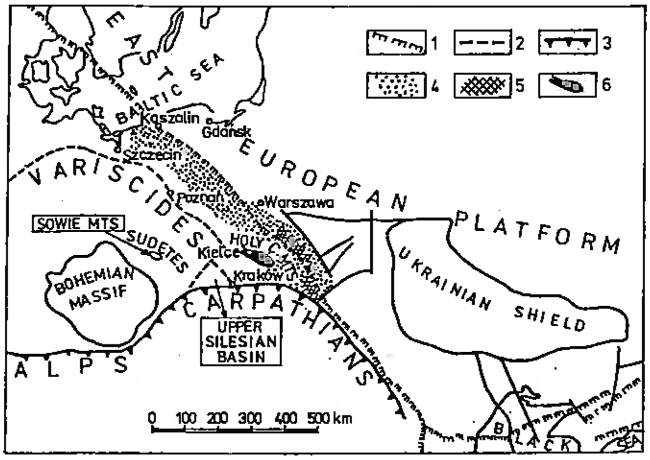

Fig. 1. Position of the Holy Cross Mts. and adjacent areas against the background of major Central and East European tectonic units (after A. Guterch *et al.*, 1984, simplified)

1 — Teisseyre-Tornquist lineament; 2 —Variscan orogen front; 3 — Carpathian orogen front; 4 — zone of a thickened earth's crust; 5 — deep crust anomaly zone; 6 — Holy Cross Mts.

Pozycja Gór Świętokrzyskich i obszarów przyległych na tle wielkich jednostek tektonicznych Europy Środkowo-Wschodniej (według A. Gutercha i in., 1984, w uproszczeniu)

1 — lineament Teisseyre'a-Tornquista; 2 — czoło górotworu waryscyjskiego; 3 — czoło górotworu karpackiego; 4 — strefa o pogrubionej skorupie ziemskiej; 5 — strefa anomalii w głębi skorupy ziemskiej; 6 — Góry Świętokrzyskie

of terranes (W. Pożaryski *et al.*, 1992*a, b*), are of a preliminary, working character. They are ahead of regional comparative studies on the successive Palaeozoic formations.

An exciting idea of two terranes in the Holy Cross Mts. area: the Małopolska (Kielce) Terrane and the Łysogóry one, separated by the HCF, is based both on differences in geological structure between these two regions (W. Pożaryski *et al.*, 1992*a, b*), and on palaeomagnetic data (M. Lewandowski, 1993, 1994, 1996; J. Nawrocki, 1995). However, this opinion requires a verification, using various methods of modern geology. Difficulties in confirmation of this hypothesis by lithofacies analysis of Palaeozoic deposits, make geologists consider also other possibilities to solve problems of regional tectonics. Therefore, a question is posed whether there existed only a single Holy Cross Terrane or if there were any terranes at all at the passive Lublin edge of the East European Craton (R. Dadlez *et al.*, 1994).

A relationship between Late and Early Palaeozoic deposits in the Łysogóry Region is also under discussion. Predominant is the opinion that in the northern part of the Holy Cross Mts., at a broad boundary interval between the Silurian and Devonian, there occurs a sedimentary continuity and thus a tectonic concordance (H. Łobanowski, 1971, 1981, 1990; H. Tomczyk, 1962, 1968*a, b*, 1974; E. Tomczykowa, H. Tomczyk, 1981). Z. Kowalczewski (1975; Z. Kowalczewski *et al.*, 1976) and J. Znosko (1996) are of a different opinion. They emphasize the occurrence of unconformities either at a contact between the Devonian and its basement, or within Lower Devonian strata in elevated zones (Łysogóry Fold, Bronkowice Anticline).

Major difficulties also arise while determining sequences and timing of deposition at the turn of the Silurian in the Łysogóry Region of the Holy Cross Mts. (*cf.* Figs. 4 and 5).

The Kielce Beds, distinguished by J. Malec (1993) basing upon the Gruchawka section (shales with subordinate and thin greywacke intercalations), according to L. Teller (J. Malec, 1993) are of the Pridoli age, whereas according to E. Tomczykowa (1993) — of early Ludlow age. J. Malec (1993, 1994, 1996) at first considered them to have the Pridoli, and later — Ludlow age.

The Klonów Beds are considered to be Gedinnian and/or Pridoli (J. Czarnocki, 1936, 1938; K. Pawłowska, 1961; M. Pajchlowa, 1962; E. Tomczykowa, H. Tomczyk, 1981; J. Malec *et al.*, 1990; J. Malec, 1993; Z. Kowalczewski, E. Turnau, 1997).

The Bostów Beds, according to E. Tomczykowa (1962, 1975, 1988) and E. Tomczykowa and H. Tomczyk (1979, 1981), were deposited in the northern part of the Holy Cross Mts. during Gedinnian and lower Siegenian times. E. Turnau (1986; E. Turnau, L. Jakubowska, 1989; Z. Kowalczewski, E. Turnau, 1997) have constrained their age to the early Gedinnian. We also still do not know when the Miedziana Góra Conglomerates were deposited: prior to deposition of the Klonów Beds (K. Pawłowska, 1961), at the same time (M. Pajchlowa, 1962), or after (P. Filonowicz, 1971; Z. Kowalczewski, 1968; J. Malec, 1993)?

The Barcza Beds were considered to be of the late Siegenian age (M. Pajchlowa, 1962; E. Tomczykowa, H. Tomczyk, 1981; H. Łobanowski, 1971, 1981, 1990; Z. Kowalczewski, 1971, 1994). Recently, due to a corrected age of the Bostów Beds, a question has arisen whether the sedimentation of the overlying strata started earlier, e.g. in the earliest Siegenian or even at the end of the Gedinnian.

Mutual relations and character of sediments which were deposited at the Silurian/Devonian boundary have not been studied in details, as yet. Were they formed in continental, e.g. fluvial environments (H. Łobanowski, 1990), marine conditions (J. Malec, 1993) or perhaps in both environments? This question chiefly refers to the Klonów Beds and Miedziana Góra Conglomerates.

The Klonów Beds from the Łysogóry Region are the subject of the investigations presented here (Fig. 2). Of all sedimentary formations from the Silurian/Devonian boundary of Małopolska, they have been recognized most poorly. Their lithological section in the stratotype area has not been precisely studied and attributes of this informal lithostratigraphic unit have not been univocally determined. Reddish or cherry-coloured packages of greywackes and shales from the top of the Rzepin Series or variegated complexes from the bottom of the Barcza Beds were at times considered to represent the Klonów Beds.

The authors are convinced that the Klonów Beds are the key to a recognition of geological events which took place at the decline of the Lower Palaeozoic sedimentary-diastrophic cycle, i.e. at the turn of the Silurian. Two fully cored boreholes drilled at Klonów village (western part of the Łysogóry Region) in the seventies by the Polish Geological Institute have

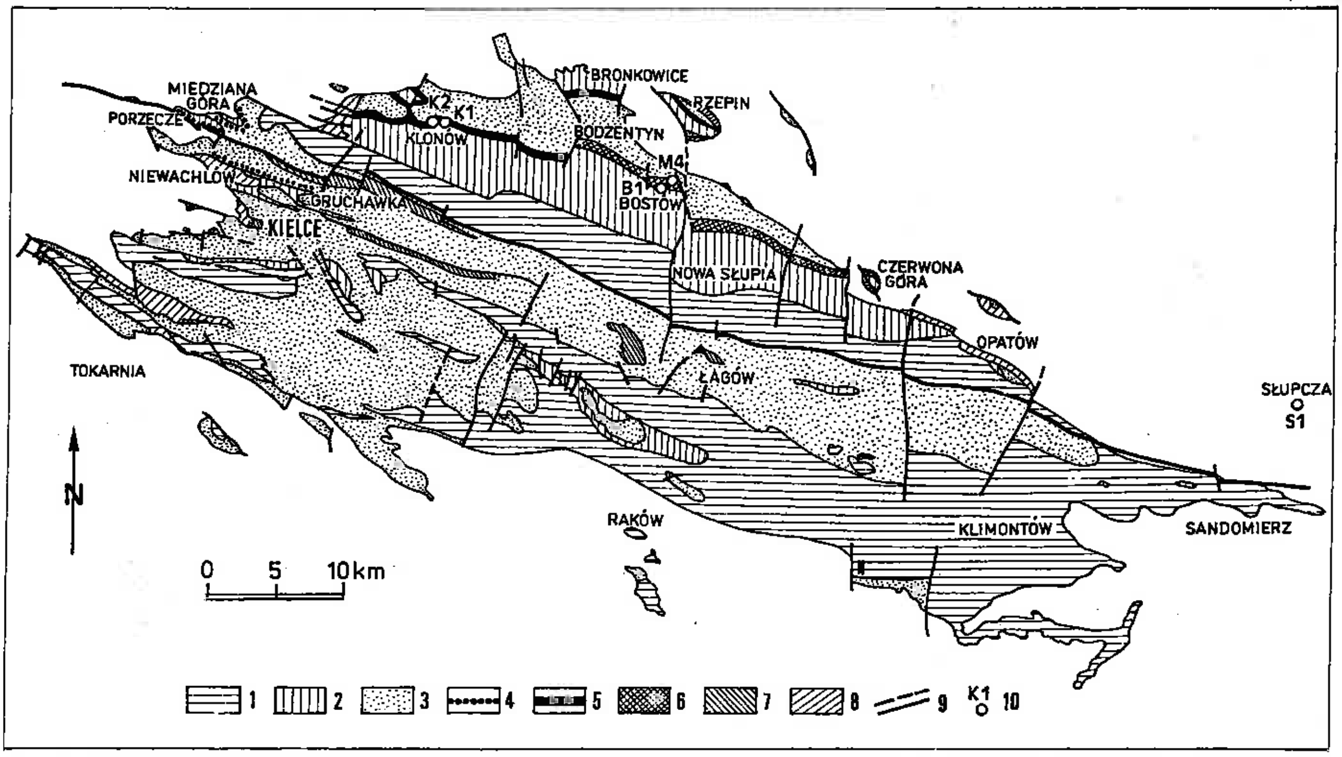

Fig. 2. Geologic sketch-map ot the Holy Cross Palaeozoic showing outcrops of the Miedziana Góra Conglomerates, Klonów Beds and Bostów Beds
1 — Cambrian; 2 — Ordovician and Silurian; 3 — Devonian; 4 — Miedziana Góra Conglomerates; 5 — Klonów Beds; 6 — Bostów Beds; 7 — Lower Carboniferous; 8 — Permian; 9 — faults and thrusts; 10 — boreholes: K1 — Klonów 1, K2 — Klonów 2, B1 — Bostów 1, M4 — Modrzewie 4, S1 — Słupcza 1

Szkic geologiczny paleozoiku świętokrzyskiego z zaznaczonymi wychodniami zlepieńców miedzianogórskich, warstw klonowskich i warstw bostowskich
1 — kambr; 2 — ordowik i sylur; 3 — dewon; 4 — zlepieńce miedzianogórskie; 5 — warstwy klonowskie; 6 — warstwy bostowskie; 7 — karbon dolny; 8 — perm; 9 — uskoki i nasunięcia; 10 — otwory wiertnicze (objaśnienia symboli — patrz podpis angielski)

enabled to study these events. Borehole Klonów 1 attained a depth of 80 m, whereas Klonów 2 — 100 m. The cores are stored at the archives of the Świętokrzyskie Mts. Branch of the Polish Geological Institute in Kielce.

Studies of the Klonów Beds were initiated by Z. Kowalczewski from the Świętokrzyskie Mts. Branch of the PGI in Kielce. He has described herein a local and regional historical context. Sedimentological investigations have been conducted by K. Jaworowski from the Polish Geological Institute in Warsaw. They are supported by the petrographical analysis carried out by M. Kuleta from the Świętokrzyskie Mts. Branch of the PGI. Microfossils have been determined by E. Turnau from the Polish Academy of Sciences in Cracow. The results of these investigations are summarized by Z. Kowalczewski and K. Jaworowski.

EVOLUTION OF VIEWS ON GEOLOGY OF THE KLONÓW BEDS

The Klonów Beds were informally established as a lithostratigraphic unit within the Lower Devonian sequence by J. Czarnocki (1936). They are composed of distinctive grey-cherry "platy sandstones" with intercalations of tuffaceous sandstones, quartzites and variegated shales. The stratotype area are Klonów village environs and the southern slopes of the Klonów Belt (Figs. 2, 3). J. Czarnocki (1936) recognized them in this region also within the Miedziana Góra, Bronkowice and Wydrzyszów folds as well as in the western part of the Kielce–Łagów Synclinorium within the Niewachlów fold. He estimated their thickness at about 200 m.

The Klonów Beds, like their counterparts in Western Europe "...are expressed by a continental facies, marking an onset of the proper Old Red [Sandstone]..." (J. Czarnocki, 1936). The Klonów sandstones are situated within the Klonów Belt and NE of it, overlying the **Rzepin Beds** with a sedimentary continuity. Near Miedziana Góra and Niewachlów, J. Czarnocki (1936) placed them above the **Miedziana Góra Conglomerates** which represent a near-shore, shallow-marine facies. He did not describe the contact between these two complexes, but it may be inferred that he considered it to be tectonically concordant.

The Klonów Beds are everywhere overlain by the **Barcza Beds — Placoderm Sandstones** of the Holy Cross Old Red Sandstone (J. Czarnocki, 1936). The contact between the Klonów Beds and Placoderm Sandstones is thought to be penacordant — with a stratigraphical gap comprising the

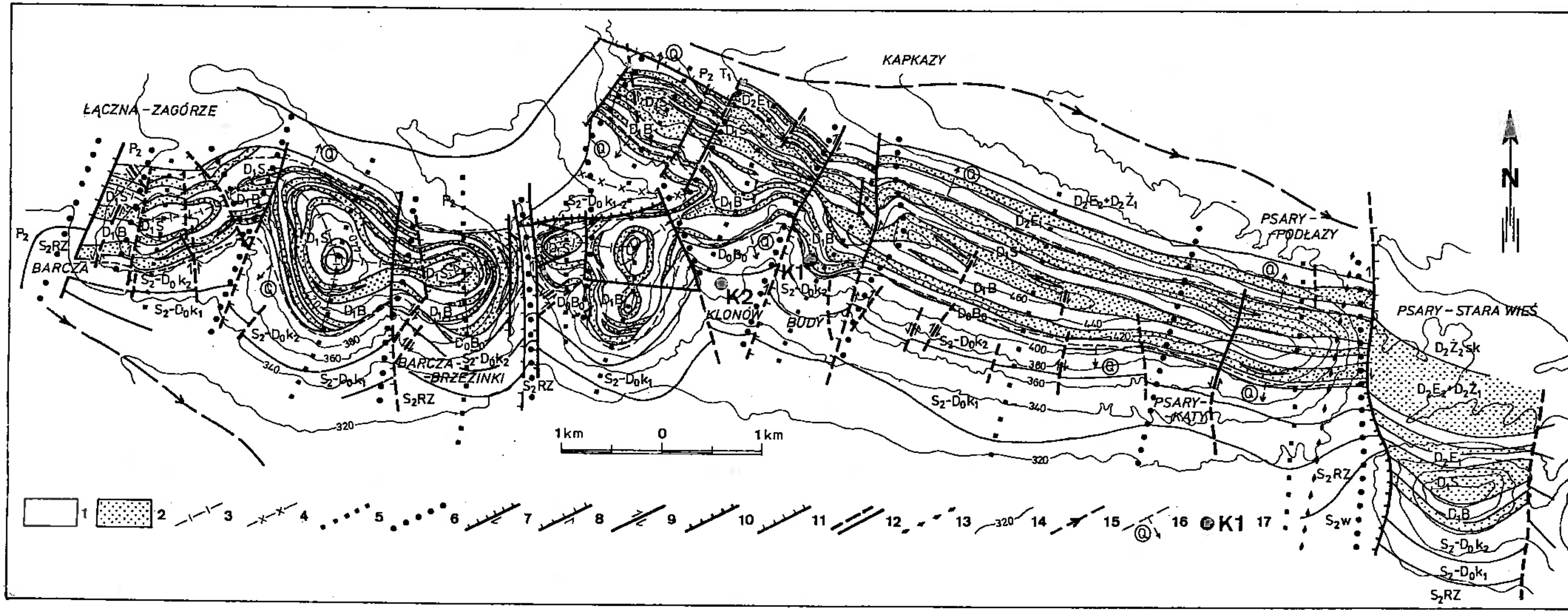

Fig. 3. Geological-tectonic map of the Klonów environs (after Z. Kowalczewski *et al.*, 1989)

1 — rocks of low relative resistivity — claystones and siltstones; 2 — rocks of high relative resistivity — compact quartz sandstones, quartzite sandstones; 3 — synclinal axes; 4 — anticlinal axes; 5 — transverse depressions; 6 — transverse elevations; 7 — oblique-reverse-slip faults; 8 — oblique-normal-slip faults; 9 — strike-slip faults; 10 — reverse faults; 11 — normal faults; 12 — evidenced and supposed faults; 13 — diabasic intrusion; 14 — isohypses (every 10 m); 15 — rivers — local erosion base level; 16 — approximate extent of Quaternary deposits on slopes; 17 — boreholes Klonów 1 and 2; S_2w — Upper Silurian, Wydrzyszów Beds; S_2RZ — Upper Silurian, Rzepin Beds; S_2-D_0k_1 — Upper Silurian–Lower Devonian, Lower Klonów Beds; S_2-D_0k_2 — Upper Silurian–Lower Devonian, Upper Klonów Beds; S_2-D_0k_{1-2} — Upper Silurian–Lower Devonian, Klonów Beds (undivided); D_0B_0 — Lower Devonian, Gedinnian, Bostów Beds; D_1B — Lower Devonian, Siegenian + lower Emsian, Barcza Beds; D_1S — Lower Devonian, upper Emsian, *Spirifer* Beds; D_2E_1 — Middle Devonian, lower Eifelian, Grzegorzowice Beds; D_2E_2 + $D_2Ż_1$ — Middle Devonian, upper Eifelian + lower Givetian; $D_2Ż_2sk$ — Middle Devonian, Givetian, Skały Beds; P_2 — Zechstein, variegated series; P_2-T_1 — Upper Permian + Lower Triassic, variegated series

Mapa geologiczno-tektoniczna okolic Klonowa (według Z. Kowalczewskiego i in., 1989)

1 — skały o małej oporności względnej — iłowce i mułowce; 2 — skały o dużej oporności względnej — piaskowce kwarcowe zwięzłe i piaskowce kwarcytowe; 3 — osie synklin; 4 — osie antyklin; 5 — depresje transwersalne; 6 — elewacje transwersalne; 7 — uskoki nasuwczo-przesuwcze; 8 — uskoki zrzutowo-przesuwcze; 9 — uskoki przesuwcze; 10 — uskoki odwrócone nasuwcze; 11 — uskoki normalne zrzutowe; 12 — uskoki pewne i przypuszczalne; 13 — intruzja diabazowa; 14 — izohipsy (cięcie co 10 m); 15 — rzeki — lokalna baza erozyjna; 16 — przybliżony zasięg osadów czwartorzędowych na stokach; 17 — otwory wiertnicze Klonów 1 i 2; S_2w — sylur górny, warstwy wydrzyszowskie; S_2RZ — sylur górny, warstwy rzepińskie; S_2-D_0k_1 — sylur górny–dewon dolny, warstwy klonowskie dolne; S_2-D_0k_2 — sylur górny–dewon dolny, warstwy klonowskie górne; S_2-D_0k_{1-2} — sylur górny–dewon dolny, warstwy klonowskie nierozdzielone; D_0B_0 — dewon dolny, żedyn, warstwy bostowskie; D_1B — dewon dolny, zigen + ems niższy, warstwy barczańskie; D_1S — dewon dolny, ems wyższy, warstwy spiriferowe; D_2E_1 — dewon środkowy, eifel dolny, warstwy grzegorzowickie; D_2E_2 + $D_2Ż_1$ — dewon środkowy, eifel górny + żywet dolny; $D_2Ż_2sk$ — dewon środkowy, żywet, warstwy skalskie; P_2 — cechsztyn, seria pstra; P_2-T_1 — perm górny + trias dolny, seria pstra

Siegenian stage. The Klonów sandstones, which are lacking any fossils within the stratotype area were considered by J. Czarnocki (1936) to be of the late Gedinnian age, whereas the underlying Miedziana Góra Conglomerates — of early Gedinnian age. The overlying Barcza Beds are, according to that author, of the early Emsian age.

In the later paper, after the central (Bostów) and eastern (Czerwona Góra) part of the Łysogóry Region had been recognized, J. Czarnocki (1950), basing upon the Rzepin Beds, distinguished a regional stratigraphical stage — the Rzepin stage[1], representing the Middle and Upper Silurian. At its top, he distinguished the Bostów Horizon composed of the **Bostów Beds** with a marine fauna. In the cited paper he did not discuss any geological problems of the Klonów Beds — he included them into the Upper Rzepin Beds. According to such an approach they would be of the late Ludlow age. In the borehole Słupcza 1 located near Sandomierz, K. Pawłowska (1954, 1961) distinguished the Słupcza Beds — the Old Red sandy-silty facies of considerable thicknesses with fish remains of *Cephalaspis* and *Pteraspis*. She correlated this unit to the Klonów Beds whereas the overlying sandy siltstones and ferruginous claystones (around 50 m thick) with marine ostracods (*Beyrichia* sp., *Leperditia* sp., *Poloniella* aff. *symmetrica* Halle, *Bollia* sp., *Eridoconcha* sp.) were included into the Bostów Beds. K. Pawłowska (1961) placed the Klonów and Słupcza Beds within the Gedinnian, above the Miedziana Góra Conglomerates and below the Bostów Beds.

The age and succession of the deposits at the Silurian/Devonian boundary were also analyzed by E. Tomczykowa and H. Tomczyk as well as M. Pajchlowa. At first they (E. Tomczykowa, 1959; H. Tomczyk, 1960; M. Pajchlowa, 1959) unanimously declared that the Bostów Beds are of the Late Silurian age and older than the Klonów Beds. Later, E. Tomczykowa (1962, 1969) and H. Tomczyk (1968*a, b*) evidenced the Gedinnian age of the Bostów Beds using key fossils. Nevertheless, they still maintained their opinion that these strata are older than the Klonów Beds, because in borehole Bostów 1, the Upper Rzepin Beds are underlying the Bostów Beds with sedimentary continuity.

After continuous deposition at the Silurian–Devonian transition had been recognized in boreholes Ciepielów IG 1 and Lisów 1, drilled in the Radom Elevation, E. Tomczykowa and H. Tomczyk (1979, 1981) admitted that the Bostów Beds in the Holy Cross Mts. represent the whole Gedinnian and lower Siegenian (regional stratigraphic stages: Bostów and Ciepielów). They also strengthened their opinion on the position of the Klonów Beds, because their time equivalent — the Czarnolas Series — overlies the Sycyna Series which in turn corresponds to the Bostów Beds (L. Miłaczewski, 1981).

P. Filonowicz (1962, 1963, 1965, 1968, 1969, 1971, 1973, 1978) who mapped the Holy Cross Palaeozoic deposits expressed a different opinion on the position of the Klonów Beds. He thought that, in the western and central part of the Łysogóry Region, they overlie the Rzepin Beds, underlying the Bostów Beds. He suspected their occurrence even south of Bostów (P. Filonowicz, 1963, 1968). Such a view was questioned by H. Tomczyk *et al.* (1977), whereas Z. Kowalczewski, who mapped in details a borderland area between the Łysogóry Old Red and Bodzentyn Syncline (Fig. 3), shared the opinion of P. Filonowicz (Z. Kowalczewski, 1975; Z. Kowalczewski *et al.*, 1989).

According to P. Filonowicz, the Klonów Beds underlie — and not overlie as it was claimed by J. Czarnocki (1936) and K. Pawłowska (1961) — the Miedziana Góra Conglomerates in the northwestern part of the Kielce Region. P. Filonowicz (1978) is of the opinion that sediments analogous to the Klonów Beds also occur within the Dyminy–Klimontów Anticlinorium, in the centre of the Kielce Region, near Ciosowa, Trzemoszna and Bilcza. This view is not shared by other geologists.

M. Pajchlowa (1962, 1968) was first to assume that the Klonów and Słupcza Beds from the western and eastern parts of the Łysogóry Region are of the same age as the Gedinnian Bostów Beds from the centre of this area. The Klonów Beds represent the Old Red facies, whereas the Bostów siltstones — a shallow-marine one. She was also inclined to ascribe the Gedinnian age to the Miedziana Góra Conglomerates. At first, J. Malec (1993) was also close to that idea and M. Szulczewski (1994, 1995) accords with this opinion, as well.

In recent years, the knowledge on the Klonów Beds has been increased. Even the name "Klonów Formation" has been introduced, although requirements for its formal description has not been fulfilled yet. H. Łobanowski (1981, 1990) found within the basal part of the Klonów Beds, brachiopods of the genus *Rhynchonella* and crinoids (along with fish remains *Pteraspis* sp., bivalves and psilophytes), and near their top he noted the occurrence of the bivalves *Miodolopsis ekpempusa* Fuchs. That author and after him also E. Stupnicka (1989) are of the opinion that in the Łysogóry Region, the Klonów Beds were deposited during the Gedinnian–lower Siegenian.

Z. Kowalczewski constantly maintained the hypothesis of the Late Silurian–Early Devonian (Pridoli–Gedinnian) age of these rocks. He subdivided the Klonów Beds, basing upon both geophysical data and core investigations from boreholes Klonów 1 and 2, into two members (Z. Kowalczewski *et al.*, 1989). The **Lower Klonów Beds** consist of polymictic sandstones and siltstones, usually greywacky, frequently laminated, showing fissility, variegated in colour, with intercalations of tuffaceous sandstones, tuffs, conglomerates and sedimentary breccias. The matrix contains many scattered clasts of claystones, siltstones and sandstones. The **Upper Klonów Beds** are composed of similar lithologic types, but differ mainly in the occurrence of coarse-grained intercalations with laminated sandstones appearing only sporadically.

The Klonów sandstones represent, according to H. Łobanowski (1990), chiefly alluvial floodplain deposits. Short-lived marine transgressions are responsible, in his opinion, for the appearance of bioturbated sediments and shallow-marine macrofauna (brachiopods, bivalves). J. Malec (1996) declares

[1]The idea of a regional stratigraphical stage: the "Rzepin" stage — within the Upper Silurian, and a "Bostów" horizon or stage — within the Lower Devonian, was later followed and developed by E. Tomczykowa and H. Tomczyk (1970, 1979, 1980, 1981). H. Łobanowski (1971) attempted to create other regional stages basing on the Klonów, Barcza and Zagórze Beds. Later he abandoned this idea (H. Łobanowski, 1981).

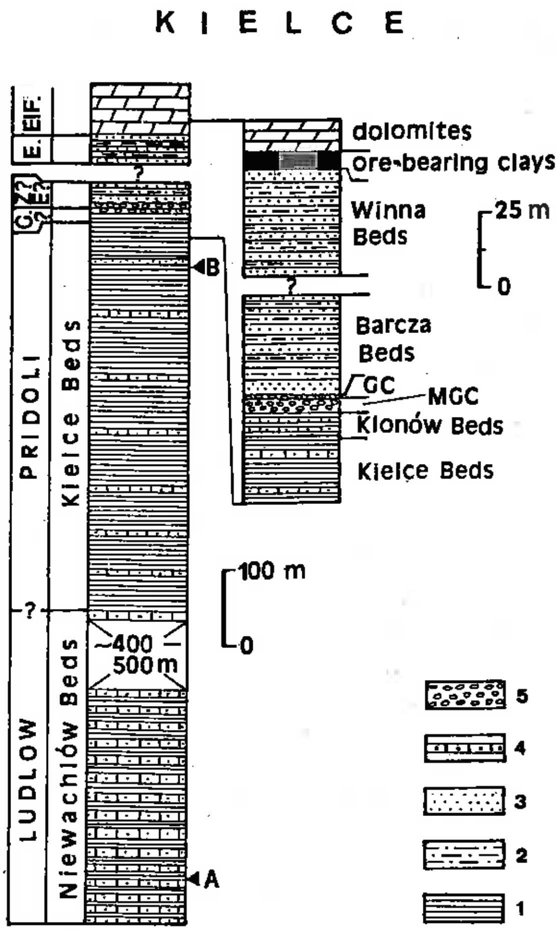

Fig. 4. Composite lithological log of the Upper Silurian and Lower Devonian deposits from NW part of Kielce (after J. Malec, 1993)

1 — claystones, 2 — siltstones, 3 — sandstones, 4 — greywacke sandstones, 5 — conglomerates; A — *scanicus* Zone graptolites; B — *Monograptus transgrediens* Perner graptolites; MGC — Miedziana Góra Conglomerate; GC — Gruchawka Conglomerate; G? — Gedinnian?; Z?–E? — Siegenian? Emsian?; E. — Emsian; EIF. — Eifelian

Zbiorczy profil litologiczny osadów górnego syluru i niższego dewonu z NW części Kielc (według J. Malca, 1993)

1 — iłowce, 2 — mułowce, 3 — piaskowce, 4 — piaskowce szarogłazowe, 5 — zlepieńce; A — lokalizacja graptolitów poziomu *scanicus*; B — lokalizacja graptolitów *Monograptus transgrediens* Perner; MGC — zlepieniec miedzianogórski; GC — zlepieniec z Gruchawki; G? — żedyn?; Z?–E? — zigen? ems?; E. — ems; EIF. — eifel

himself in favour of exclusively marine environment: deeper in their lower part, and shallower or brackish at the near-top interval in the western part of the Łysogóry Region.

Views on the origin of the Miedziana Góra Conglomerates have been also changing. These conglomerates were considered to represent either regressive deposits terminating sedimentation of a shrinking marine basin (H. Tomczyk, 1962, 1974) or transgressive sediments initiating the Devonian sedimentary cycle (Z. Kowalczewski, 1968, 1971). J. Malec (1993, 1994) thinks that their origin is related to a submarine fan development. Their subaerial origin was suggested by E. Stupnicka (1995). She considered them to be talus fans forming at the foots of steep slopes or scarps. An alluvial origin of the conglomerates deposited by rivers discharging material from the south, from the Kielce Region (Z. Kotański, 1959; M. Tarnowska, 1988; M. Szulczewski, 1994, 1995) was also discussed. Most of geologists are of the opinion that the pebbles composing the Miedziana Góra Conglomerates come mainly from Cambrian rocks eroded in the Pasmo Główne Range (J. Czarnocki, 1936; Z. Kowalczewski, 1968, 1971; P. Filonowicz, 1973; J. Malec, 1993, 1994).

J. Malec's investigations (1993, 1994) of the Gruchawka field section exposed in Kielce (Fig. 4) have evidenced that the Miedziana Góra Conglomerates *sensu* J. Czarnocki (1936) are not uniform. Their lower, main part is older and overlies with sedimentary continuity the Klonów Beds. Sandstones and conglomerates interfinger with each other at least at a near-contact zone (Fig. 5). The older deposits are defined according to J. Malec (1993), as the Miedziana Góra Conglomerates. They are unconformably overlain with a stratigraphical gap by the younger **Gruchawka Conglomerates**, related to Barcza Beds and displaying a smaller thickness (J. Malec, 1993, 1994). These two conglomerate units do not differ from each other in their lithology, therefore some difficulties arise with their correct mapping in the field.

The Klonów and Barcza Beds from Gruchawka have not yielded any fossils. Their age has been determined using both stratigraphical data from the lower part of the exposed section and general regional observations. According to L. Teller (*vide* J. Malec, 1993), the Kielce Beds underlying the Klonów sandstones are Pridoli whereas according to E. Tomczykowa (1993) — late Ludlow in age. In the former case the Klonów Beds may be considered to have the Pridoli or Pridoli–early Ludlow age, whereas in the latter — late Ludlow, late Ludlow–Pridoli or late Ludlow–Pridoli–early Gedinnian age. J. Malec (1993) first supported the L. Teller's opinion who found the key Pridoli graptolite *Monograptus transgrediens* Perner in the Kielce Beds. Later on, J. Malec concluded that their age is older basing on the opinion of E. Tomczykowa supported by trilobite studies. In the latter case, the Miedziana Góra Conglomerates, considered recently to be late Ludlow in age, have also become older (J. Malec, 1996).

We do not share the last-mentioned views because they question the identity of both the rocks which are believed to represent the Klonów Beds, and the conglomerates correlated with the Miedziana Góra ones in the vicinity of Kielce and Niewachlów. The Kielce Beds, according to them, would not be any longer a time and lithofacies equivalent to the Rzepin Beds in the Łysogóry Region. They would be considered older then they really are.

GENERAL DATA ON INVESTIGATED SECTIONS

The boreholes Klonów 1 and 2 are located at Klonów village about 15 km NE of Kielce city. Both boreholes have been drilled on the southern slope of Bukowa Góra: Klonów 1 in its upper part, and Klonów 2 slightly lower (Fig. 3). They are situated in the western part of the Łysogóry Region on the southern limb of the Bodzentyn Syncline common with the Łysogóry Fold (Fig. 2). The boreholes have been drilled in the

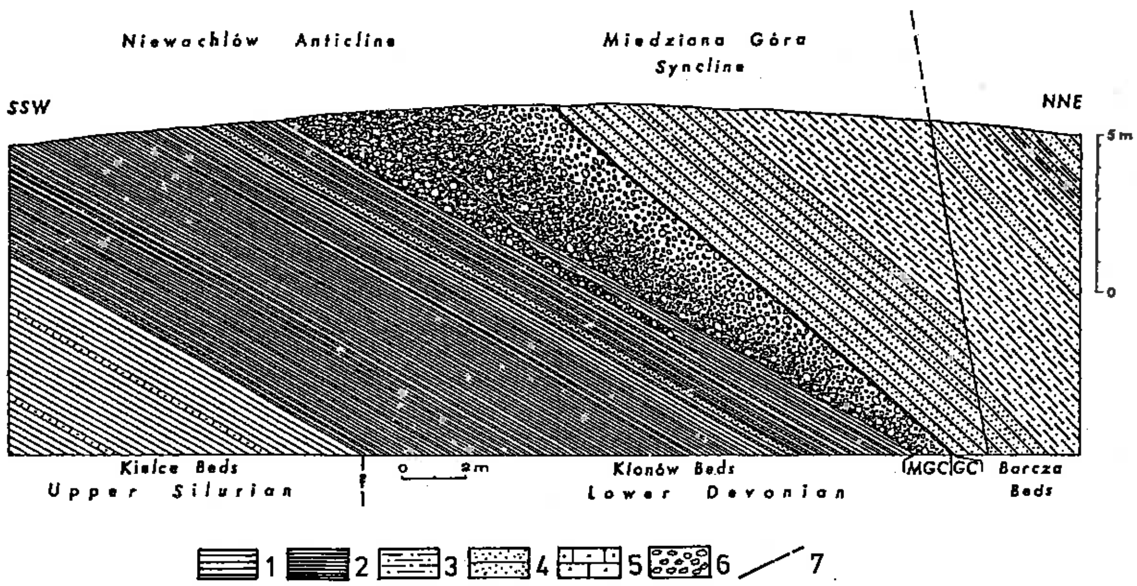

Fig. 5. Section of the Silurian/Devonian contact zone from Kielce — Gruchawka (after J. Malec, 1993)
1 — claystones; 2 — cherry claystones; 3 — siltstones; 4 — sandstones; 5 — greywacke sandstones; 6 — conglomerates; 7 — faults; MGC — Miedziana Góra Conglomerate; GC — Gruchawka Conglomerate

Profil strefy kontaktowej syluru z dewonem w Kielcach — Gruchawce (według J. Malca, 1993)
1 — iłowce; 2 — iłowce wiśniowe; 3 — mułowce; 4 — piaskowce; 5 — piaskowce szarogłazowe; 6 — zlepieńce; 7 — uskoki; MGC — zlepieniec miedzianogórski; GC — zlepieniec z Gruchawki

stratotype area of the Klonów Beds. In the northwestern part of the borderland zone between both above structural units, the lower-order Barcza Syncline and Klonów Anticline developed. Borehole Klonów 2 has been situated near a periclinal closure of the Klonów Anticline. In each of the boreholes, a different interval of the Klonów Beds has been recognized: the upper part — in the borehole Klonów 1, and the lower one — in the borehole Klonów 2 (Fig. 6). Borehole Klonów 1 pierced the Barcza Beds (depth 1.8–12.8 m), the Bostów Beds (depth 12.8–17.75 m) and finally the Upper (17.75–54.0 m) and Lower Klonów Beds (54.0–80.0 m).[2] Borehole Klonów 2 encountered only the Lower Klonów Beds, which have not been pierced down to a total depth of 100 m.

The Barcza Beds are clearly bipartite in borehole Klonów 1. The upper package from a depth of 1.8–5.3 m is largely composed of compact quartzite sandstones with hematite concentrations in the matrix. The lower package, occurring at a depth of 5.3–12.8 m, consists of cherry, yellowish, celadon and grey siltstones and massive claystones. The lower package is a typical fragment of the variegated complex, whereas the upper one represents a part of the sandstone complex *sensu* M. Tarnowska (1967, 1976). The Barcza Beds are separated from the Bostów Beds by a reverse fault.

[2] The boundary between the Upper and Lower Klonów Beds was initially drawn in borehole Klonów 2 at a depth of 12.35 m — at the top of the first intraformational conglomeratic layer in this section (Z. Kowalczewski, E. Turnau, 1997). Now, after petrographical-sedimentological investigations, this boundary has been shifted several scores of metres up the section. In borehole Klonów 1, it is drawn at a depth of 54.0 m, at the top of the distinct diamictite layer.

Previously, the Bostów Beds were not distinguished in the borehole Klonów 1. Bioturbated sediments of a marine origin were included into the Klonów Beds. This opinion was verified when the sedimentological analysis showed that, at Klonów, the underlying rocks were deposited in continental environment.

SEDIMENTOLOGICAL ANALYSIS AND ITS GEOLOGICAL IMPLICATIONS

Sedimentological investigations are based upon the analysis of cores from the boreholes Klonów 1 and 2 (Fig. 7). The boreholes revealed different parts of the Klonów Beds. Those parts are separated by a small break and jointly make up a section embracing deposits about 170 m thick. For the sake of simplicity the whole section recognized in the two boreholes will be here-after called "the section Klonów 1 and 2". The characteristics of facies distinguished within the section Klonów 1 and 2 is based upon their macroscopic features. The latter enable the recognition of the discussed facies owing to observations carried out directly in the field. Therefore, the wackes occurring within the Klonów Beds, have been described just as dirty sandstones. A detailed description of these rocks (largely lithic quartz greywackes and occasionally quartz arenites) is given in the chapter devoted to petrography.

The two different regions, which have been distinguished within the Holy Cross Mts. since a long time: the Łysogóry

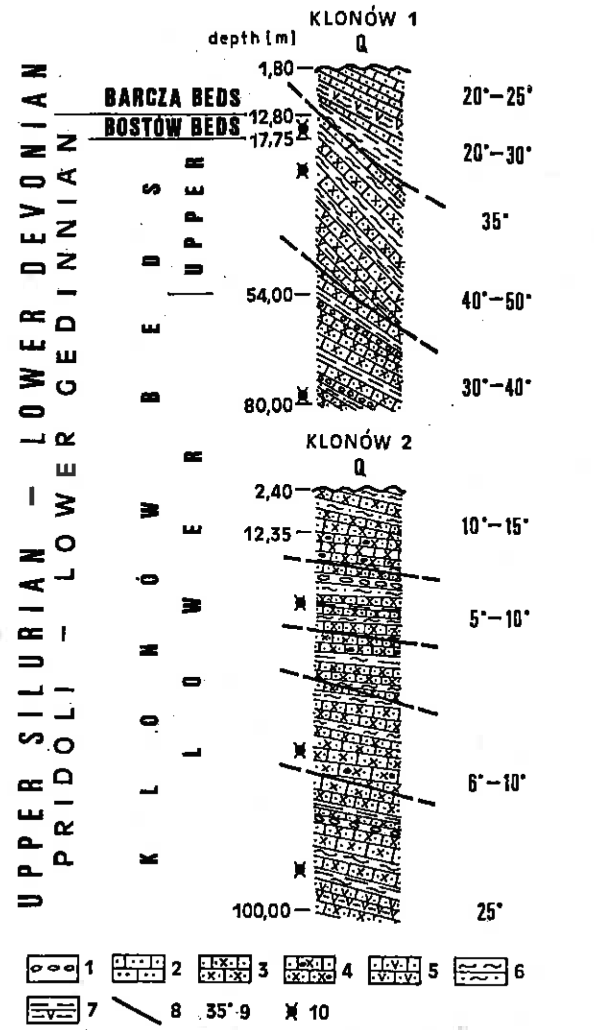

Fig. 6. Stratigraphic-tectonic sections of boreholes Klonów 1 and 2
1 — conglomerates; 2 — sandstones; 3 — greywacke sandstones; 4 — greywacke sandstones with claystone and siltstone clasts; 5 — tuffaceous sandstones; 6 — siltstones and sandy siltstones; 7 — claystones and tuffaceous claystones; 8 — faults; 9 — dip of strata; 10 — microflora samples

Profile stratygraficzno-tektoniczne skał z otworów Klonów 1 i 2
1 — zlepieńce; 2 — piaskowce; 3 — piaskowce szarogłazowe; 4 — piaskowce szarogłazowe z okruchami iłowców i mułowców; 5 — piaskowce tufitowe; 6 — mułowce i mułowce piaszczyste; 7 — iłowce i iłowce tufitowe; 8 — uskoki; 9 — upady warstw; 10 — próbki z mikroflorą

and Kielce Regions, are understood as either structural or palaeogeographic units. In the first case, a boundary between them is drawn along the Holy Cross Fault. In the second case, this boundary is not in line with that fault (*cf.* J. Czarnocki, 1936), and its position have changed in time. In order to avoid any ambiguities, when mentioning these regions from a tectonic point of view — the terms of "Kielce Unit" and "Łysogóry Unit" will be in use. In a case of palaeogeographic considerations — the terms of "Kielce area" and "Łysogóry area", will be applied respectively.

FACIES DESCRIPTION

Gd — DIAMICTITES
(Pl. I, Figs. 1–4)

These are breccias, gravels and red-cherry muddy conglomerates, brownish or greenish in places. Poorly sorted gravel-sized clasts of fine-grained sandstones and mudstones occur within a clay-mud-sand matrix. Sandstones occurring as coarse clasts of the facies **Gd** strikingly resemble sandstones from other facies. Sediments of facies **Gd** show a grain-supported or, rarely, matrix-supported fabric. They exhibit neither orientation nor segregation of the clasts. The maximum clast size is up to 8 cm, occasionally greater. Clasts are either angular or subrounded, usually elongated, although, in a case of smaller clasts (up to 1 cm), more or less spherical. Strata composed of facies **Gd** range in thickness between a dozen or so centimetres up to over 2 m.

These deposits were deposited by sediment gravity flows, immobilized due to intergranular friction or/and cohesion. In the first case (grain-supported diamictites), mud slurry was supporting clasts remaining in contact, and lubricating them thus reducing friction. In the second case (matrix-supported diamictites), the clasts were floating in a mud slurry due to its buoyancy and cohesiveness. These processes occur under both subaerial and subaqueous conditions.

Gif — INTRAFORMATIONAL CONGLOMERATES
(Pl. II, Figs. 1, 2)

Conglomerates are composed of mudstone and claystone intraclasts occurring in a silty or sandy matrix. Intraclasts, usually flat, are approximately horizontally arranged. Their maximum size is up to 2–5 cm. Sediments of facies **Gif** largely show a matrix-supported fabric, although a grain-supported one is also fairly frequent. Red, cherry, grey and greenish intraclasts often occur within the same conglomerate bed. The matrix is usually red or cherry in colour. Facies **Gif** occurs in a form of thin beds not exceeding a dozen or so centimetres in thickness. The conglomerates of facies **Gif** originated due to deposition from traction carpet of high energy flows. Quite large mudstone intraclasts are indicative of a short transport.

Sm — MASSIVE SANDSTONES
(Pl. II, Figs. 3, 4)

These are very fine-grained dirty sandstones, red-cherry in colour, with fairly frequent, scattered small mudstone intraclasts (of size from 2 mm up to a teen of millimetres), usually flat and displaying roughly horizontal orientation. The sandstones show in places indistinct horizontal lamination. Thicknesses of beds composed of facies **Sm** are variable and range from about a dozen centimetres up to 10 m. Most frequently they amount to 2–3 m.

Occasionally recorded indistinct horizontal lamination and orientation of mudstone clasts indicate that some sediments of facies **Sm** were deposited under upper flow regime. Lack of distinct internal structures may be indicative of very rapid deposition from flowing waters. A massive appearance of sandstones may have also resulted from gravity grain flows, or secondarily — due to fluidization of sandy material.

Sh — HORIZONTALLY LAMINATED SANDSTONES
(Pl. III, Figs. 1, 2)

It is composed of very fine-grained dirty sandstones, showing horizontal lamination with parting lineation. Two subfacies can be distinguished: a dominant one, red in colour — **Shr** (Pl. III, Fig. 1), and a grey one — **Shg** (Pl. III, Fig. 2). Apart from horizontal lamination a small-scale cross-bedding, mud flasers, and occasionally minute mudstone and claystone intraclasts can be observed within red and cherry sandstones of subfacies **Shr** (Pl. III, Fig. 3). Horizontal lamination is particularly distinct within grey sandstones of subfacies **Shg**. Subfacies **Shr** most frequently occur as 1–5 m-thick beds. A thickness of the single bed representing subfacies **Shg** is about 2 m (borehole Klonów 1).

Sandstones of facies **Sh** originated due to deposition from traction carpet under upper flow regime. In the case of subfacies **Shr**, the deposition sometimes took place under lower flow regime (small-scale cross-bedding). Clay flasers point to sedimentation from suspension during a considerable drop in flow velocity. Sandstones of facies **Sh**, which show thin platy parting, were previously considered to have been especially characteristic of the Klonów Beds (J. Czarnocki, 1936).

Slc — LARGE-SCALE CROSS-BEDDED SANDSTONES
(Pl. II, Fig 5; Pl. III, Fig. 4)

These are very fine-grained dirty sandstones, red-cherry in colour. Large-scale cross-bedding, characteristic of this facies, is frequently accentuated by the presence of small, well-rounded mudstone intraclasts, which rest on surfaces of cross laminae. It has been impossible to recognize univocally the shapes of sets of cross laminae in the core material studied. They seem to be tabular. Horizontal lamination and small-scale cross-bedding can occasionally be observed.

Thicknesses of beds consisting of facies **Slc** are variable and attain up to a few tens of centimetres. Sandstones of facies **Slc** originated due to deposition from traction carpet under lower flow regime.

Sfr — SANDSTONES WITH MUD FLASERS AND SMALL-SCALE CROSS-BEDDING
(Pl. IV, Fig. 1)

The facies is composed of light grey, greenish sandstones and grey sandy mudstones. Sediments of this facies also appear in the lower part of the Barcza Beds (borehole Klonów 1) being red and green in colour. The sandstones exhibit flaser-bedding, small-scale cross-bedding and indistinct horizontal lamination.

Thicknesses of beds composed of facies **Sfr** range from about a dozen centimetres up to 2 m. Sandstones of facies **Sfr** originated due to deposition from traction carpet under lower flow regime and from suspension (mud flasers) while flow velocity was decreasing.

Sbt — BIOTURBATED SANDSTONES
(Pl. IV, Fig 2)

These are very fine-grained sandstones, grey-green in colour, very intensely bioturbated. Traces of primary flaser-bedding are visible. Facies **Sbt** has only been recognized as about 2 m-thick layer, in the upper part of the Bostów Beds (cored in the borehole Klonów 1).

Sediments of the facies were initially deposited under conditions resembling those in which facies **Sfr** was formed. Later, as a result of long-lasting decrease in sedimentation rate, the sediments were colonized by numerous organisms whose activities destroyed their primary structure.

Fm — MASSIVE FINE-GRAINED DEPOSITS
(Pl. IV, Figs. 3–5)

Mudstones and claystones, most frequently lacking any sedimentary structures which are usually indistinct and rare, if any. Within this facies, two subfacies can be distinguished: red-coloured subfacies **Fmr** (Pl. IV, Fig. 3) and grey-coloured subfacies **Fmg** (Pl. IV, Fig. 4).

Subfacies **Fmr** is composed of massive red or cherry, occasionally variegated (red-brown-greenish) mudstones, and claystones with small-scale cross-bedding, horizontal lamination of lower flow-regime and — sporadically — with lenticular bedding and mud cracks.

Subfacies **Fmg** consists of grey, in places grey-green, massive mudstones and claystones, with small-scale cross-bedding and horizontal lamination (the latter is slightly more frequent here then within subfacies **Fmr**). Horizontal lamination occurs among others in thin tuffite intercalations (Pl. IV, Fig. 5). Within the sediments of subfacies **Fmg**, microflora has been found. Thicknesses of beds consisting of subfacies **Fmr** from the Klonów Beds ranges up to 2.5 m. Within the Barcza Beds, an exceptionally thick (over 8 m) variegated bed of this subfacies has been noted. Beds of subfacies **Fmg** reach up to 4.5 m in thickness. Very rare symptoms of traction currents indicate that sediments of facies **Fm** (subfacies **Fmr** and **Fmg**) were deposited from suspension in stagnant waters or weak currents.

SEDIMENTARY ENVIRONMENTS OF THE KLONÓW BEDS

PREVIOUS VIEWS

The Klonów Beds were previously considered to represent continental deposits of the Old Red Sandstone facies (J.

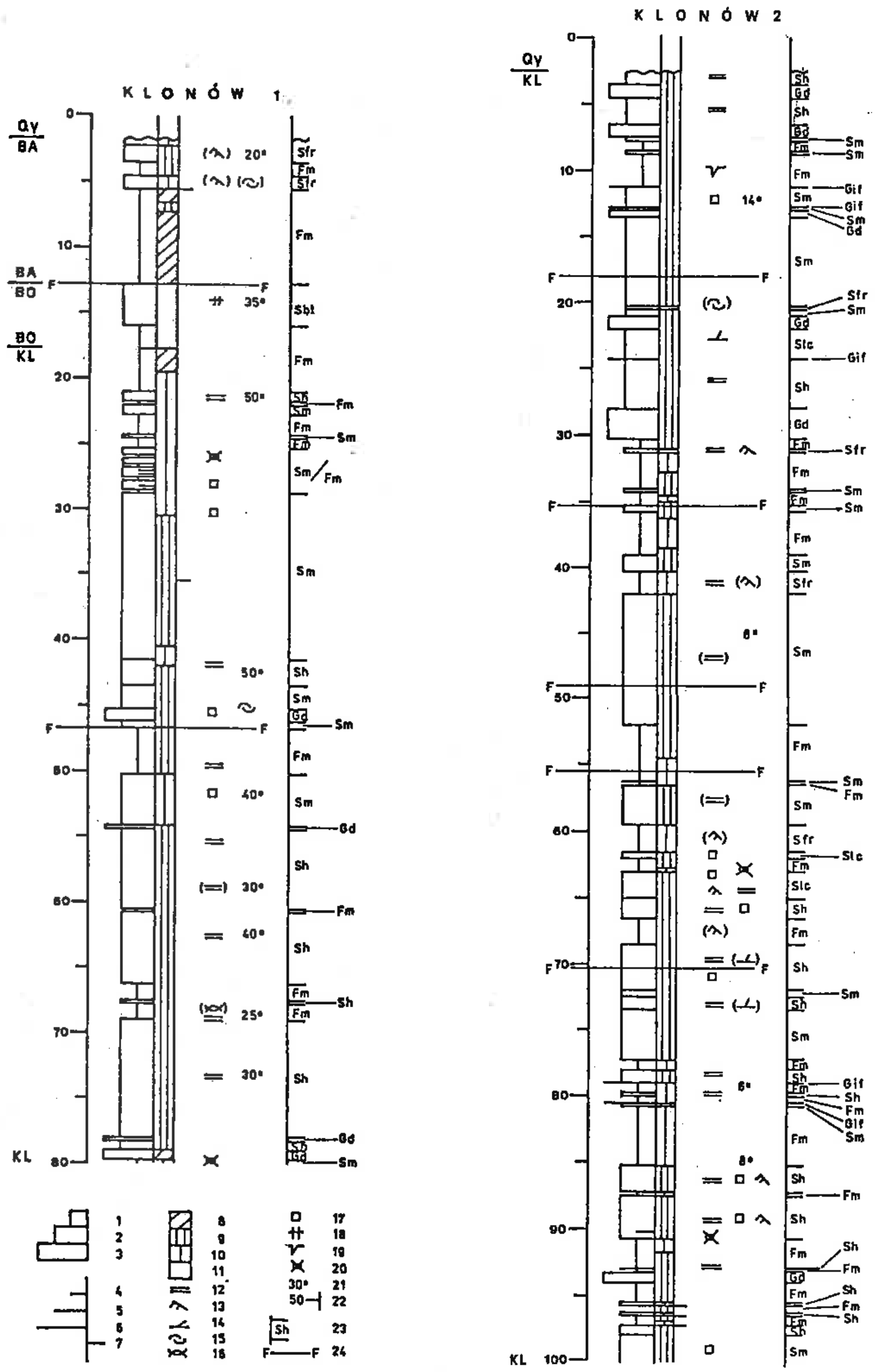

Fig. 7. Facies log of boreholes Klonów 1 and 2

L i t h o l o g y : 1 — claystones, siltstones, 2 — sandstones, 3 — conglomerates; t h i n i n t e r c a l a t i o n s : 4 — claystones, mudstones, 5 — sandstones, 6 — conglomerates, 7 — tuffites; c o l o u r : 8 — variegated, 9 — red and dark red, 10 — grey, 11 — grey-greenish; s e d i m e n t a r y s t r u c t u r e s : 12 — horizontal lamination, 13 — small-scale cross-bedding, 14 — large-scale cross-bedding, 15 — mud fläsers, 16 — lenticular bedding, 17 — siltstone intraclasts, 18 — bioturbation, 19 — mud cracks (indistinct structures in brackets); o t h e r s : 20 — microflora remains, 21 — dip of strata, 22 — depth in metres, 23 — vertical range of facies (for explanations see the text, also compare Plates I–IV), 24 — faults; Qy — Quaternary; BA — Barcza Beds; BO — Bostów Beds; KL — Klonów Beds

Czarnocki, 1936, 1950; K. Pawłowska, 1961; M. Pajchlowa, 1962, 1968; H. Łobanowski, 1971; E. Tomczykowa, H. Tomczyk, 1981). J. Czarnocki (1936) related them to a lagoonal environment. According to H. Łobanowski (1990), the Klonów Beds are widely spread floodplain deposits. That author points to the presence within the Klonów Beds, of three intercalations containing a marine fauna which are indicative of marine ingressions (*cf.* M. Szulczewski, 1994). J. Malec (1993) is of the opinion that the Klonów Beds, recognized in the Kielce Region (western part of the Holy Cross Mts.), at least in their major part represent shallow-marine deposits. However, he emphasizes that he has not found neither microspores nor faunal remains in those sediments. Within the Klonów 1 and 2 section of the Łysogóry Region, E. Turnau (Z. Kowalczewski, E. Turnau, 1997) has found acritarchs in grey massive mudstones and claystones (subfacies **Fmg**). They are indicative of a marine environment. The Miedziana Góra Conglomerates, interfingering with the Klonów Beds and occurring within both the Kielce and Łysogóry Units (J. Czarnocki, 1936), should be considered, according to J. Malec (1993), to represent submarine fan deposits.

THE PRESENT AUTHORS' VIEW

GENERAL INTERPRETATION

The above-described facies recognized within the Klonów 1 and 2 section, allow to list characteristic features of the Klonów Beds. They are as follows:

— presence of gravelly deposits accumulated due to gravity flows (facies **Gd**);

— presence of gravelly deposits, with an intraformational conglomerate characteristics, related to deposition from flowing waters under upper flow regime (facies **Gif**);

— presence of sandy deposits related to deposition from flowing waters under upper flow regime (facies **Sm** and **Sh**);

— presence of sandy deposits related to deposition from flowing waters under lower flow regime (facies **Slc** and **Sfr**);

— presence of massive fine-grained deposits accumulated mainly in stagnant waters sometimes agitated by weak currents (subfacies **Fmr** and **Fmg**);

— lack of any organic remains in gravelly facies (**G**) and sandy facies (**S**);

— high degree of sediment oxidation, expressed by dominating cherry, red and variegated colours (Pl. I–IV);

— mineralogical and textural immaturity of sandy facies (**S**), represented mainly by dirty sandstones, i.e. wackes, largely lithic;

— reccurrence of the above-listed facies, indicative of their interfingering.

The occurrence of the above-mentioned features leads to a conclusion that most probably the Klonów Beds recognized in the Klonów 1 and 2 section were deposited in an alluvial fan environment passing into braid plain. However, this interpretation requires taking into account the following facts:

— previously mentioned, and evidenced by H. Łobanowski (1990), presence within the Klonów Beds of three intercalations containing a marine fauna;

— presence of acritarchs in some samples from grey mudstones (subfacies **Fmg**), within the section studied, which would be indicative of a marine environment (Z. Kowalczewski, E. Turnau, 1997).

These facts do not disprove the above-presented interpretation, but enable its development. The Klonów Beds recognized in the Klonów 1 and 2 section may be considered to represent not only alluvial fan and braid plain deposits but also braid delta sediments. The latter developed due to a progradation of alluvial fans and a braid plain into a shallow-marine basin. The undoubtedly marine sediments of the Bostów Beds (i.a. facies **Sbt**), recognized in the upper part of the Klonów 1 section, interfinger with the Klonów Beds. As their lateral equivalent, the Bostów Beds were accumulated in shallow-marine waters, but more distant from the coast (*cf.* J. Malec, 1993; Z. Kowalczewski, 1994; M. Szulczewski, 1994, 1995).

Alluvial fan deposits are very frequent under arid and semiarid climates, with repeated fluctuations in river water flows and a considerable supply of much vari-grained, loose material. Its abundance can be related to intense uplift movements which affected source areas. The most favourable environments for a development of alluvial fans and braid plains are poorly vegetated land areas. This fact is an additional argument supporting the presented interpretation as at the turn of the Silurian continental vegetation was poor.

DETAILED INTERPRETATION AND FACIES MODEL

A facies model corresponding to the above-proposed interpretation is illustrated in Fig. 8. It shows that facies **Gd** is considered to have been accumulated in the proximal parts of alluvial fans, close to source areas. It is typical that the clasts composing facies **Gd** consist of sandstones occurring in other facies. This means that the early cemented sandy deposits on fan surfaces, owing to strong erosion and weathering, produced much debris, which was set into motion during gravity flows. These gravity flows were related to periodical heavy rainfalls. The latter gave rise to braided streams. Their channels incised into older sediments of both fans and a braid plain. Pavement deposits of facies **Gif** were accumulated within some of these channels. Channel bar sediments are largely represented by facies **Slc**. Moreover, sandy sediments of other facies may have been deposited within braid channels. Beside

Profile facjalne otworów Klonów 1 i 2

L i t o l o g i a : 1 — iłowce, mułowce, 2 — piaskowce, 3 — zlepieńce; c i e n k i e p r z e w a r s t w i e n i a : 4 — iłowców i mułowców, 5 — piaskowców, 6 — zlepieńców, 7 — tufitów; b a r w a o s a d ó w : 8 — pstra, 9 — czerwona i ciemnoczerwona, 10 — szara, 11 — szarozielonawa; s t r u k t u r y s e d y m e n t a c y j n e : 12 — laminacja pozioma, 13 — warstwowanie przekątne małej skali, 14 — warstwowanie przekątne dużej skali, 15 — smugi mułowców i iłowców, 16 — warstwowanie soczewkowe, 17 — intraklasty mułowców, 18 — bioturbacje, 19 — szczeliny błotne (w nawiasach struktury niewyraźne); i n n e : 20 — szczątki mikroflory, 21 — upady warstw, 22 — głębokość w metrach, 23 — pionowy zasięg facji (objaśnienia symboli w tekście, porównaj także tabl. I–IV), 24 — uskoki; Qy — czwartorzęd; BA — warstwy barczańskie; BO — warstwy bostowskie; KL — warstwy klonowskie

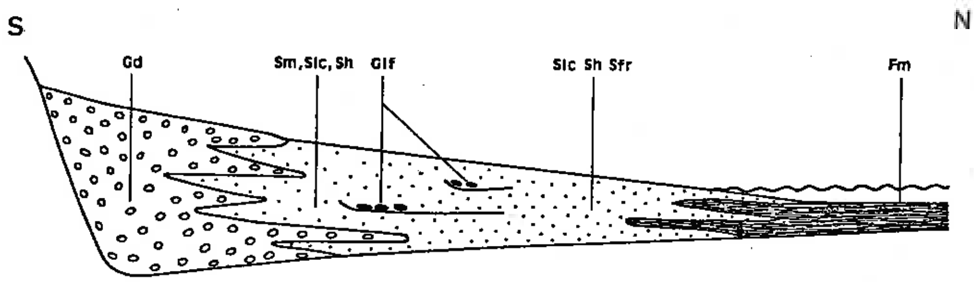

Fig. 8. Facies model of the Klonów Beds recognized in boreholes Klonów 1 and 2 (for explanations see the text)
Model facjalny warstw klonowskich w profilach Klonów 1 i 2 (objaśnienia w tekście)

channel deposits, widely spread sand covers of facies **Sm** and **Sh** developed within the braid plain. Sediments of facies **Sh**, particularly frequent in the section studied (Fig. 7), were deposited from sheet-floods. Sandy deposits of braided streams and sheet-floods (and sometimes coarse-grained gravity flow sediments) while transported into shallow-marine waters, produced a braid delta. They interfingered, within this delta, with sediments of facies **Fm** which are here interpreted as deposits of a stagnant, shallow-marine basin. In marginal part of the basin, and distal parts of braid deltas as well, sandy sediments of facies **Sfr** were accumulated together with sediments of facies **Fm**. The former were related to weak currents. Sediments of subfacies **Fmr**, due to the presence of mud cracks (very rare), may be related to the shallowest, near-shore zone of the basin.

PALAEOGEOGRAPHIC IMPLICATIONS

Sediments of the section Klonów 1 and 2 were deposited in a foreland of the uplifted area which stretched in a zone now formed by northern part of the Łysogóry Fold. A comparison of the Klonów Beds from the Klonów Anticline with sediments believed to be their eqivalents in the Niewachlów Fold and Miedziana Góra Syncline (*cf.* J. Czarnocki, 1936; Z. Kowalczewski, 1968, 1971, 1994; J. Malec, 1993), leads to a conclusion that they were formed in two different areas with different depositional environments. The Klonów depositional area, located farther to the north, was dominated by the above-described depositional conditions. In the southern, Niewachlów–Miedziana Góra depositional area, the Klonów Beds were not deposited in a submarine fan as J. Malec (1993) suggested, but rather in fan deltas, i.e. in alluvial fans prograding directly into a shallow sea — presumably lagoon, as it was supposed by J. Czarnocki (1936). The Miedziana Góra Conglomerate resulted from deposition in fan deltas. According to J. Czarnocki (1936), Z. Kowalczewski (1966, 1968, 1971) and recently J. Malec (1993), a coarse-grained material of this conglomerate, in which Middle Cambrian quartzite pebbles have been found, was transported from the north, and strictly speaking from the western part of the present-day Łysogóry Unit. Z. Kotański (1959), M. Tarnowska (1988) and M. Szulczewski (1994) are of the opinion that it came from the south, i.e. from the Kielce area, strongly uplifted at the turn of the Silurian.

The above-presented remarks seem to indicate that the Klonów Beds, and interfingering conglomerates, were accumulated in two different basins separated by an uplifted area situated in the place now formed by the Łysogóry Unit (Pasmo Główne Range). According to this idea, towards the north, we are passing from the Kielce source area of clastic material, through Niewáchlów–Miedziana Góra basin to the Łysogóry source area and then to the Klonów basin (Fig. 9).

The Niewachlów–Miedziana Góra basin was a relatively shallow sea (bay?) with steep coasts, into which — from both: the south, i.e. from the Kielce area, and north, i.e. from the Łysogóry area — coarse-grained alluvial fans prograded, forming fan deltas represented by the Miedziana Góra Conglomerate. The Klonów basin spread north of the Łysogóry source area, embracing a zone of gently sloping alluvial fans passing north and northeastwards into braid plains and braid deltas, and farther off into a vast, shallow sea. In its waters, slightly farther off-shore, lateral equivalents of the Klonów Beds i.e. the Bostów Beds were deposited.

PALAEOTECTONIC IMPLICATIONS

The Klonów Beds from the Łysogóry area, interpreted for a long time (J. Czarnocki, 1936) as a counterpart of the Old Red facies, belong to red bed facies association (*cf.* R. Gradziński *et al.*, 1976). Similar deposits are characteristic of periods dominated by continental conditions which follow great orogenies. Sedimentary cover of the epi-Caledonian platform begins with the Old Red Sandstone facies.

J. Znosko (1970, 1974) is of the opinion that the Old Red deposits of the lowermost Devonian, occurring in the Holy Cross Mts., represent the younger Caledonian molasse. The older molasse, according to that author, is represented by the Silurian Niewachlów Greywackes with tuffogenous deposits. J. Malec (1993) considers the Klonów Beds together with the Miedziana Góra Conglomerate within the Niewachlów Fold, to be the older Caledonian molasse. The younger molasse is represented, according to J. Malec (1993), by Gruchawka Conglomerate (separated — in his opinion — from the Miedziana Góra Conglomerate by a distinct erosional gap) and the Barcza Formation unconformably overlying the Miedziana Góra Conglomerate, Klonów and Barcza Beds.

An exceptionally important in considerations on whether the Klonów Beds and Miedziana Góra Conglomerate are of a molasse character or not, is the fact that there exists sedimentary continuity between them and the uppermost Silurian deposits, in both: the Łysogóry Region where they overlie the Pridoli Rzepin Beds and in the Kielce Region where they rest upon the Kielce Beds of the same age. In both these regions, the lower part of the presumed Holy Cross Caledonian molasse, represented by the Klonów Beds, conformably and with sedimentary continuity overlies the greywacke-shaly flysch deposits which are Ludlow–Pridoli in age (the Niewachlów and Kielce Beds in the Kielce area, Wydryszów Beds and Rzepin Beds in the Łysogóry area).

According to the most commonly accepted definition by S. Dżułyński and A. J. Smith (1964), the term flysch refers to "...a syn-orogenic formation which is largely composed of one essential type of facies, laid down below the wave-base". According to those authors: "...molasse is syn-orogenic and partly also post-orogenic a multifacies formation laid-down generally in shallow water, marine and non-marine environment in piedmont and intramontane basins." Therefore, from a purely descriptive point of view, the Klonów Beds, as a whole, correspond to the definition of molasse. Besides other features, this is in agreement with the presence of tuffaceous intercalations in facies **Fmg** (Pl. IV, Fig. 5).

Let us remind, according to the theory of geosyncline and development of thrust-fold belt cycles, that flysch deposits are accumulated during the infilling of geosynclinal troughs before the main orogenic phase transforming the majority of geosynclinal system into a mountain range with a synchronous development of a foredeep. Molasse is deposited after the main orogenic phase in both the foredeeps and intramontane grabens. This is a classical approach. However, the problem emerges, as a molasse-type facies may occur within a flysch suite, and a flysch-type facies may appear within a molasse sequence (S. Dżułyński, A. J. Smith, 1964; L. R. Contescu, 1964). This fact was one of the reasons why unsuccessful attempts to abandon the terms flysch and molasse have been made. It seems that in the Lower Palaeozoic of the Holy Cross Mts., we have a good example of a molasse-type facies appearing above a flysch-type formation. The example is provided by the Upper Silurian Kielce Beds (J. Malec, 1993), containing greywacke beds with wave ripplemarks.

In general, the Klonów Beds overlying with sedimentary continuity the Silurian flysch of the Holy Cross Mts. may be classified as paramolasse (*sensu* L. R. Contescu, 1964), i.e. early molasse which had been formed in a geosynclinal basin before the main orogenic phase took place. Continuing this interpretation, the Barcza Beds (and Gruchawka Conglomerate) separated from the Klonów Beds with erosional unconformity, should be considered as the late, Caledonian ortomolasse of the Holy Cross Mts.

We do admit that another interpretation is not out of question. The red beds facies association of the final stage of a tectonic cycle may occur in a direct relationship with fold-thrust belts or without such a relation i.e. within a craton (e.g. red continental formation of a stable platform *sensu* W. J. Chain, 1974). In the first case, during deposition of the Klonów Beds, the Kielce and Łysogóry source areas of clastic material would have been rising intrageoanticlines of Caledonian geosyncline while in the second case these areas would have been elongated tectonic blocks (horsts) developed in the areas of older than Early Caledonian consolidation. Uplift of such blocks, separated by basins-tectonic grabens may be accompanied by formation of flysch- and then of molasse-type deposits.

A system of horsts and tectonic grabens may have formed at the turn of the Silurian in the border zone between the Kielce and Łysogóry Units. The reasons why they came into existence should be explained, according to R. Dadlez *et al.* (1994), by a collision of the proximal Małopolska Terrane with the Łysogóry fragment of a passive margin (miogeosyncline) of the East European Craton, or by a collision of the presumed Małopolska and Łysogóry Terranes (W. Pożaryski, 1990).

Comparing the facies model (Fig. 8) with the section Klonów 1 and 2 (Fig. 7), it may be stated that in the upper part of the Klonów Beds, there is a significant increase of sediments related to braid plain or braid delta, and stagnant water deposits. This results from the fact that uplift movements of source areas of clastic material decreased with an increasing distance from their erosional front. This process was accompanied by a widening marine basin in which deposition of the Bostów Beds took place. That was followed by marine transgression in which the Barcza Formation deposits, recognized among others in the upper part of the Klonów 1 and 2 section (Fig. 7), were accumulated. The Barcza Formation constitutes a sedimentary cover complex being the first evidence of the ultimate coalescence of the Kielce and Łysogóry Units into a single platform area.

RESULTS OF PETROGRAPHICAL ANALYSES

Petrographical features of sediments from the section Klonów 1 and 2 have been determined basing upon microscope studies of 98 thin sections. They are supplemented by chemical analyses of three samples and X-ray diffraction analyses of two samples. Planimetric analyses of grains and cements of sandy deposits have been made for 41 samples. Features of sandstone fabric also have been studied in order to determine the maximum and most frequent quartz grain-size, its shape, roundness and orientation.

Classification of sandstones is based upon the nomenclature by R. L. Dott, modified by F. J. Pettijohn *et al.* (1973) and by K. Jaworowski (1987). Names of the remaining terrigenous and pyroclastic rocks are given after the classifications of K. Jaworowski (1987), and W. Ryka and A. Maliszewska (1991).

Petrographical composition of sandstone framework was analysed using the Gazzi-Dickinson method (W. R. Dickinson *et al.*, 1983), in order to determine a provenance of detrital material and geotectonic position of source areas. The following abbreviations of grain components have been applied: *Qm* — monocrystalline quartz, *Qp* — polycrystalline quartz, *Q* —

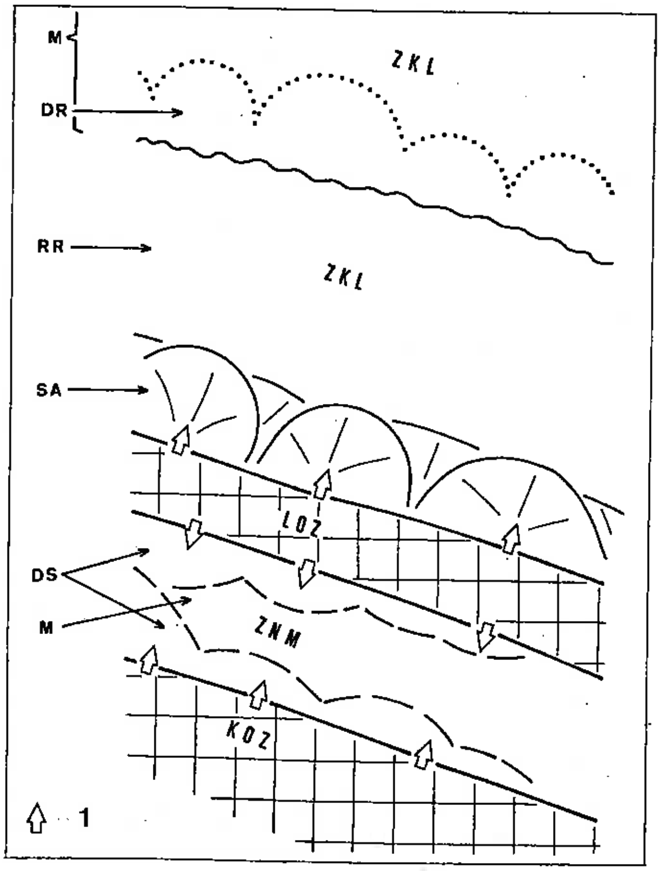

Fig. 9. Palaeogeographic sketch-map illustrating deposition of the Klonów Beds

KOZ — Kielce source area; LOZ — Łysogóry source area; ZNM — Niewachlów–Miedziana Góra basin; ZKL — Klonów basin; DS — fan deltas; SA — alluvial fans; RR — braid plain; DR — braid deltas; M — sea; 1 — arrows indicate main directions of clastic material transport

Szkic paleogeograficzny depozycji warstw klonowskich

KOZ — kielecki obszar źródłowy; LOZ — łysogórski obszar źródłowy; ZNM — zbiornik niewachlowsko-miedzianogórski; ZKL — zbiornik klonowski; DS — delty stożkowe; SA — stożki aluwialne; RR — równina roztokowa; DR — delty roztokowe; M — morze; 1 — strzałki wskazują główne kierunki dostawy materiału okruchowego

Qm+Qp, *K* — potassium feldspar, *P* — plagioclase, *F* — *P+K*, *Lv* — volcanic rocks, *Ls* — sedimentary rocks, *Lm* — metamorphic rocks, *Lf* — ferruginous rocks, *L* — *Lv+Ls+Lm+Lf*, *Lt* — *L+Qp*, *M* — micas, *Hm* —heavy minerals.

PETROGRAPHICAL DESCRIPTION

The lithologic section Klonów 1 and 2 is largely composed of mineralogically and texturally immature sandstones — corresponding in their composition first of all to lithic greywackes, more rarely to sublithic arenites, and sporadically to quartz arenites. Mudstones occur in smaller amounts; conglomerates and tuffites are rare.

A variability of petrographical features: lithologic succession, framework and cement composition of sandstones, proportions of these components, categories of roundness and sorting; all these parameters characterize the lithostratigraphic units distinguished within the section. Some of these features also accentuate attributes of the recognized sedimentary facies (Figs. 7, 10).

Individual types of sediments will be described collectively for the whole section Klonów 1 and 2 with reference to characteristic features of the distinguished lithostratigraphic units and facies.

GREYWACKES AND ARENITES

These are largely red-brown and brownish-grey rocks — lithic greywackes and sublithic arenites, more rarely light-coloured, grey-beige, fine-grained, occasionally medium-grained lithic and quartz arenites, well and moderately sorted.

The main components of their framework are quartz grains and clasts of sedimentary and volcanic rocks. Micas, alkaline feldspars and fragments of metamorphic rocks are less abundant. Heavy minerals and glauconite are accessory. The rocks are cemented by muddy-ferruginous matrix and quartz and carbonate cement. Content of individual components and their petrographical features are shown in Fig. 10 and Pl. V–VIII.

Quartz (*Q*) is usually monocrystalline (*Qm*). There is a considerable number of grains with deep corrosional embayments indicative of volcanic source (Pl. VII, Fig. 3), whereas very angular and strongly elongated quartz grains with concave surfaces suggest pyroclastic origin. Such grains occur only in the Klonów Beds. Polycrystalline quartz (*Qp*) is represented by single grains in a dozen of samples. In the whole section, elongated grains are more abundant than spherical ones. Subrounded grains are more frequent than rounded ones, although the proportion is reversed in a few samples. Here, a textural inversion is also marked (according to R. L. Folk — 1.6) which may be indicative of a mixing of sediments from various sedimentary environments under high energy conditions (facies **Sm**). Subrounded grains prevail upon angular and rounded ones (Fig. 10) in the Lower Klonów Beds (facies **Sh**, **Sm**).

Lithoclasts (*L*) represent three genetic groups: volcanic (*Lv*), sedimentary (*Ls*) and metamorphic (*Lm*). The most abundant are sedimentary clasts (*Ls*); clayey and siliciclastic rocks, occurring here as fragments of claystones, siltstones and sediments of a mixed cleyey-silty composition. Fragments of very fine-grained quartz arenites are more scarce while greywackes appear sporadically. Ferruginous clasts composed of iron oxides and hydroxides, frequently with a pelitic and argillaceous admixture, have also been included into the group of sedimentary clasts (*Lf*). They occur in a form of irregular fragments and concentrations or poorly rounded grains which may have originated from weathering crusts. The latter import a brownish colour on the Upper Klonów Beds.

Volcaniclasts (*Lv*) which are lacking only in the Barcza Beds (facies **Sfr**), are largely represented by variably rounded fragments of volcanic glass with microcrystalline felsitic structure, composed of quartz-feldspar microlithes and frequently impregnated by iron oxides. In some of them, a porphyric fabric may be recognized, and in this case there occur small ferruginous and chlorite pseudomorphs after dark minerals, and clayey ones after feldspars. Fragments of volcanics, showing a trachytic structure, occur sporadically. Few feldspar-chlorite or feldspar-ferruginous-argillaceous fragments with traces of an intersertal structure may represent diabases. Grains composed of a mixture of clay minerals and microcrystalline quartz-feldspar concentrations have been considered a product of partly devitrificated volcanic glass (Pl. VIII, Figs. 1–3).

Rare fragments of metamorphic rocks (*Lm*), quartz and quartz-micaceous shales, have been identified in merely a few samples.

Feldspars (*F*) occur in small percentage throughout the whole section. They are represented by kaolinized alkaline feldspars and, very rarely, by albite-twinned plagioclase. Their grains show irregular and blurred outlines, poorly contrasting against the groundmass.

Micas (*M*) occur throughout the whole section without displaying any particular variability in their distribution. They have been noted in most samples but the highest percentage is recorded in fine-grained greywackes, where they are enriched in individual laminae (facies **Sh**). Most frequently this is biotite, being subjected to chloritization and decolouration, accompanied by iron oxides formation.

Heavy minerals (*Hm*) appear accessory throughout the whole section. They are also considerably enriched in certain laminae in fine-grained sediments (facies **Sh**). Most frequently this is zircon accompanied by tourmaline and opaque minerals. A typical accessory component is also glauconite. In the Klonów Beds it occurs in a form of reworked and weathered grains. This allows to ascribe glauconite to epiclastic material. Variability of the cement composition in the section is reflected in a more or less predominant content of chlorite in greywackes and sublithic arenites. Chlorite is a dominant matrix component in the Upper Klonów Beds.

The analysis of framework composition in various types of sandstones, calculated using *Q, F, L* parameters, well reflects a subdivision of this section into four units (Fig. 10; Pl. V–VIII, Fig. A). The average values are as follows:

— in the Barcza Beds, where only quartz arenites occur — $Q_{94.2}F_{1.2}L_{4.6}$ (facies **Sfr**),

— in the Bostów Beds composed of lithic greywackes — $Q_{76.2}F_{3.0}L_{20.8}$ (facies **Sbt**),

— in the Upper Klonów Beds, represented by lithic greywackes and fine- and medium-grained lithic arenites — $Q_{66.9}F_{2.3}L_{30.8}$ (facies **Sm**),

— in the Lower Klonów Beds, where fine-grained lithic greywackes occur — $Q_{57.9}F_{3.5}L_{38.6}$ (facies **Sm** and **Sh**).

The composition calculated using *Qm, F, Lt* parameter, only slightly differs from the above given values due to a minimum content of polycrystalline quartz grains.

Proportions of unstable lithoclasts *Lv, Lm, Ls+Lf* show a strong vertical variability. The respective values are as follows: in the Barcza Beds — $Lm_{19.6}Lv_{0.0}Ls{+}Lf_{80.4}$; in the Bostów Beds — $Lm_{0.0}Lv_{56.3}Ls{+}Lf_{43.7}$; in the Upper Klonów Beds — $Lm_{3.00}Lv_{36.3}Ls{+}Lf_{60.7}$; in the Lower Klonów Beds — $Lm_{1.3}Lv_{26.0}Ls{+}Lf_{72.7}$.

SILTSTONES AND CLAYSTONES

These are red-brown, brownish and grey rocks (facies **Fm**). In the studied section both claystones and "pure" siltstones have been found, as well as a full range of transitional varieties between these end-members. Siltstones usually interfinger with lithic greywackes. In siltstones, compared with greywackes, a content of quartz increases with a decreasing percentage of unstable components, particularly fragments of claystones. Quartz-lithoclastic components of siltstones are distributed irregularly or they are enriched in laminae interlaminated by argillaceous material.

Siderite is a typical accessory component in claystones. It occurs as scattered, single, globular forms resembling framboidal concentrations of pyrite. The major component of siltstones and claystones is a mixture of illite, hydromicas with abundant iron oxides — in the Lower Klonów Beds, and of illite and chlorite — in the Upper Klonów and Bostów Beds (Fig. 10; Pl. IX, Figs. 1–4).

CONGLOMERATES

These are poorly sorted rocks of grain-supported or matrix-supported fabric, composed of lithoclasts of fine-grained sandstones which correspond in their composition to lithic greywackes and siltstones (facies **Gd**). These clasts, with respect to petrographical features of their components, are very similar to sediments forming the lower parts of the section studied. They have a muddy-sandy matrix of a composition similar to that of the clasts, in parts enriched in strongly ferruginous rock fragments which may represent weathering crusts. Thin conglomeratic intercalations, showing features of intraformational deposits (facies **Gif**), occur within the section, in particular in the Lower Klonów Beds. They are composed of small, commonly irregular fragments of mudstones derived from eroded neighbouring deposits.

TUFFITES

In the borehole sections Klonów 1 (depth interval 41.15–51.5 m) and Klonów 2 (depth interval 94.9–97.2 m), they compose a series of laminae and intercalations, up to 5 cm thick. These are grey and grey-green in colour, and thinly laminated deposits which disintegrate in a few seconds when treated with water. Size distribution of pyroclastic grains usually correspond to a fine sand fraction, which allows them to be distinguished as sandy tuffites. Pyroclastic material is largely represented by fragments of partly devitrificated volcanic glass of irregular, wedge-shaped and Y-shaped outlines, as well as by rare quartz grains also exhibiting peculiar shapes. Rock fragments with a relict-ashy structure preserved, and locally visible fibrous microstructure, have also been ascribed to pyroclastic components. They may be poorly defined and, together with terrigenous clay minerals, they constitute a background of better preserved grains. Pyroclastic grains are also represented by thick mica flakes and commonly noted zircons. Proportions of pyroclastic to epiclastic material are

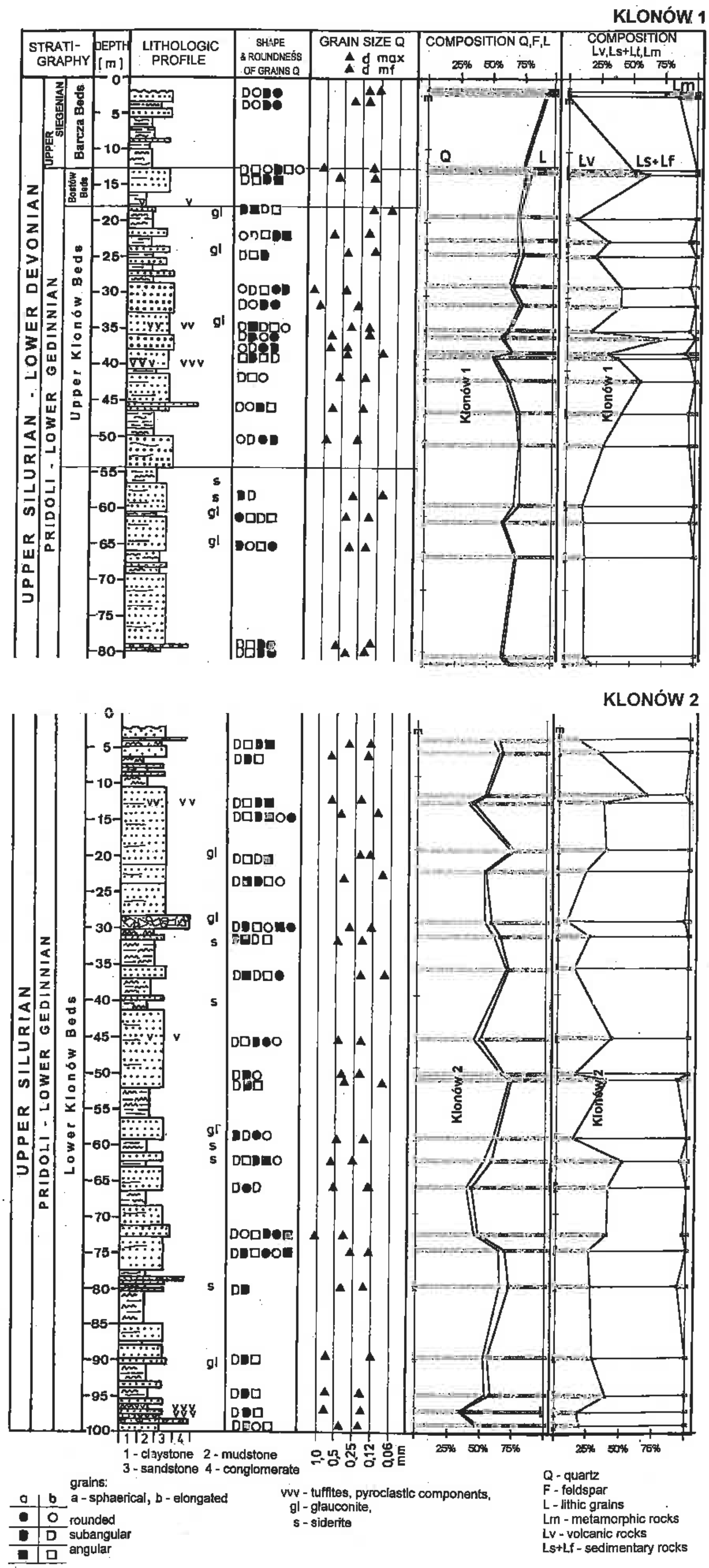

Fig. 10. Lithological-petrographical sections of boreholes Klonów 1 and 2

Profil litologiczno-petrograficzny otworów Klonów 1 i 2 variable and difficult to determine precisely, however, they are always in excess of the boundary amount for tuffites, i.e. 25% (Pl. X, Figs. 1–4).

A microlithic, quartzose and quartz-feldspathic composition of devitrificated glass, the presence of quartz grains exhibiting peculiar shapes, as well as the occurrence of zircon, suggest an acid or acid-neutral type of the volcanism.

Epiclastic material in the tuffites is the same as in the lithic greywackes, i.e. largely quartz grains of a fine sand and silt fraction, showing various categories of roundness. There are also partly reworked glass fragments similar to those found in pyroclasts, fragments of claystones and mudstones, micas, feldspars, matrix and, occasionally, carbonate cement. Microscopic studies of the Klonów Beds and lower part of the Bostów Beds have revealed thin sandstone and siltstone laminae considerably enriched in the above-listed pyroclastic material (Fig. 10).

X-ray identification of clay components has given the following results: in the Klonów tuffite (depth 41.15 m) mixed-layer minerals illite/smectite (I/S), containing 90% of illite, illite (I), kaolinite (K) and chlorite (Ch); in the Klonów 2 tuffite (depth 97.15 m) only mixed-layer minerals illite/smectite (I/S), containing 65% of illite.

SOURCE AREA OF CLASTIC MATERIAL

The analyses of greywackes and arenites in the section Klonów 1 and 2 show that the source area was an uplifted orogen with complex lithologies. The latter included largely siliciclastic sedimentary rocks: sandstones, siltstones, greywackes and claystones, as well as acid volcanic rocks. The area showed tectonic activity during the sedimentation, which is evidenced by tuffite intercalations within the Klonów Beds. Lava products of this volcanism may have enriched the greywackes in fragments of volcanic glass and quartz grains with deep corrosive embayments. Acid or acid-neutral character of the volcanism, both of the Late Silurian age and older one, is also evidenced by fragments of pyroclastic quartz and quartz or quartz-feldspar composition of devitrificated glass.

Low mineral and textural maturity of the Klonów and Bostów Beds along with facies-genetic features of sediments, confirm rapid erosion and short transport from uplifted older deposits located in an immediate proximity to the sedimentary basin. Quantitative data on the composition of sandstones clearly show an increasing upwards percentage and roundness of detrital quartz, with decreasing proportion of lithoclasts. There has also been noted a relative increase in volcanic clasts content compared with sedimentary ones, starting from the Lower Klonów Beds up to the Bostów Beds. These features may be related to both a change in a sedimentary environment in the uppermost part of this section, and erosion as well as redeposition of progressively older rocks of lithologies increasingly dominated by mature quartz arenites.

A geotectonic position of the source areas has been determined basing upon the interpretation of triangular diagrams constructed by W. R. Dickinson *et al.* (1983) and R. V. Ingersoll and C. A. Suczek (1979). In the *QFL* triangle, with its corners representing quartz (*Q*), feldspars (*F*) and lithoclasts (*L*), the sandstone samples collected from the whole section are located within the area of a recycled orogen. A similar situation is in the case of the Klonów and Bostów Beds for the areas of the *QmFLt* diagram. In the case of the Barcza Beds, their source area is located within a continental block (Pl. V–VIII, Figs. B, C). In the triangles, with corners labelled as *Lm, Lv, Ls+Lf*, the studied samples occupy various areas. In the case of the Barcza Beds, these are parts referred to as the structural suture zone. The Bostów Beds greywackes occupy the magmatic arc area. The Klonów Beds greywackes and arenites occupy 2 areas: of the magmatic arc and suture zone. The Lower Klonów Beds greywackes are markedly shifted towards the structural suture zone, when compared with the Upper Klonów Beds ones (Pl. V–VIII, Fig. E).

STRATIGRAPHICAL INVESTIGATIONS

The studied Klonów 1 and 2 sections are completely lacking any macrofossils. They have been investigated palynologically by E. Turnau (Z. Kowalczewski, E. Turnau, 1997). In the samples studied, she has found microfloral assemblages characterized by the presence of similar spores throughout the whole section. Moreover, a great number of spiny cryptospores as well as smooth and mammiform tetrads and diads has occurred in the samples.

The Bostów Beds from borehole Klonów 1 have yielded the following spores:

— depth 13.0 m: *Synorisporites* cf. *verrucatus* Richardson et Ioannides, *Ambitisporites dilutus* (Hoffmaister) Richardson et Lister, *Aneurospora* sp., tetrads no phytoplankton;

— depth 14.1 m: *Synorisporites* cf. *verrucatus* Richardson et Ioannides, *Tholiosporites chulus* (Cramer) Mc Gregor, *Ambitisporites dilutus* (Hoffmaister) Richardson et Lister, *Leiotriletes, Ratusotriletes*, tetrads, acritarchs and sphaeromorphs;

— depth 15.3 m: *Archaeozonotriletes divellomedium* Chibrikova, *Synorisporites* sp., *Ambitisporites dilutus* (Hoffmaister) Richardson et Lister, *Emphanisporites* cf. *protophanus*, diads, tetrads, acritarchs and sporomorphs.

These spore assemblages contain taxons introduced in the Silurian and ranging up to the lowermost Devonian. No species characteristic of the Gedinnian *micronatus–newportensis* Zone, and recognized at the top of the Bostów Beds in borehole Modrzewie 4 near Bostów, have been found. Sediments from Klonów 1 are probably older than those from the upper part of the Bostów Beds. Their age falls between the latest Silurian–earliest Gedinnian. The rocks containing marine phytoplankton were deposited in a marine environment. Microplankton is among others represented by *Cymatiogallea stelligera* Górka and *Tasmanites* cf. *balticus* Eisenack. These species are known from the Tremadoc of the Holy Cross Mts., and in Klonów they comprise redeposited assemblage.

Microflora has also been found in the Klonów Beds: in borehole Klonów 1 at depths of 25.8 and 79.75 m, in borehole Klonów 2 at depths of 29.2, 62.68 and 90.85 m. All the samples contained similar assemblages characterized by the presence of the following spores: *Ambitisporites dilutus* (Hoffmaister) Richardson et Lister, *A. avitus* Hoffmaister, *Tholiosporites chulus* (Cramer) Mc Gregor var. *nanus* Richardson et Lister and cryptospores *Laevolancis divellomedium* (Chibrikova) Burgess et Richardson. At a depth of 25.8 m, *Emphanisporites rotatus* Mc Gregor has been found. In the sample from borehole Klonów 2 (depth 62.68 m), spores *Cymbosporites* sp. have been encountered. According to E. Turnau, the occurrence of these taxons suggests that the sediments are not older than the *tripapillatus*–spicula Zone corresponding to the Pridoli. Therefore, the Klonów sandstones represent the Pridoli and, maybe, lowermost Gedinnian.

When discussing the age of the Klonów Beds, we should also consider the age of underlying Rzepin and Kielce Beds, overlying Barcza Beds, as well as that of coeval (at least in part) rocks — the Miedziana Góra Conglomerates and Bostów Beds.

The Upper Rzepin Beds were deposited in the Łysogóry Region during the Pridoli (L. Teller, 1995)–Podlasian according to E. Tomczykowa and H. Tomczyk (1981) nomenclature. In the opinion of the present authors, in the Kielce Region, their stratigraphical equivalents are the Kielce Beds, described by J. Malec (1993) from Gruchawka. A reliability of L. Teller's opinion (mentioned above) is high because the guide graptolites (*Monograptus transgrediens* Perner) found in Gruchawka, identify the Late Silurian age of these rocks most precisely, as yet. The timing based upon trilobites well known from the Ludlow of North America (E. Tomczykowa, 1993), seems to be less precise. The Pridoli age of the Kielce and Rzepin Beds also constrains the age of the overlying Klonów Beds in both Holy Cross regions. Everywhere they represent the uppermost Pridoli and presumably lowermost Gedinnian.

Considerably less clear picture appears in case of presumed late Ludlow age of the Kielce Beds. Under such an assumption the Klonów Beds and Miedziana Góra Conglomerates overlying them with sedimentary continuity, may be of late Ludlow, Pridoli, early Gedinnian age or possibly of different age in various areas. This is best illustrated by the problems which J. Malec (1993, 1996) has experienced trying to determine their age, after accepting the opinion of E. Tomczykowa (1993).

The Miedziana Góra Conglomerates, developed on both sides of the main Holy Cross Fault at the borderland between the Kielce and Łysogóry Regions, are strictly connected with the Klonów Beds, also in respect of the timing of deposition. They were accumulated at the same time i.e. at the end of the Pridoli and beginning of the Gedinnian.

A comprehensive discussion on the age of the Bostów Beds goes far beyond the scope of this paper. The present authors share the opinion of E. Turnau (1986; E. Turnau, L. Jakubowska, 1989; Z. Kowalczewski, E. Turnau, 1997) who suggests that they are most likely of the early Gedinnian age. On the other hand, E. Tomczykowa claims that the youngest packages of the Bostów Beds from the vicinity of Bostów (borehole Modrzewie 4) correspond to the upper Gedinnian. However, it cannot be excluded that they are already equivalents of the lowermost Gedinnian (*vide* Z. Kowalczewski, 1975).

The Barcza Beds, which overlie the Bostów Beds at Klonów, are most likely late Siegenian in age (H. Łobanowski, 1981, 1990). In borehole Modrzewie 4 (depth 30.0–59.55 m) located near Bostów, bivalves have been found (Z. Kowalczewski, 1975) in variegated deposits occurring 29–53 m above the basal contact. H. Łobanowski described them as *Modiolus antiquus* (Goldfuss), *Modiomorpha westfalica*? (Beushausen) and *Palaeoneila* cf. *beushauseni* Kegel. These fossils occurred, according to that author, in the Siegenian and Emsian marine deposits of the Ardennes–Rhenish Province. From borehole Modrzewie 4, E. Turnau has determined the following microflora: *Apiculiretusispora* cf. *brandti* Streel *sensu* Riegel, *Dibolisporites eifaliensis* (Lanninger) Mc Gregor, as well as *Acinosporites obnubilus* Turnau, *Perotrilites subitus* (Arkhangelskaya) Turnau, and *Oculatisporites mirandus* Arkhangelskaya. Ranges of these species are undefined and, as yet, they have been noted from around the boundary of the Siegenian and Emsian of Lithuania as well as from the vicinity of Pionki in Poland (Z. Kowalczewski, E. Turnau, 1997).

Within the basal Lower Devonian interval at Klonów the upper Gedinnian and lower Siegenian deposits are most likely lacking. It seems that the initial sedimentary gap and relevant stratigraphical hiatus occurring here, were increased by a slightly later, post–Devonian fault.

TECTONIC OBSERVATIONS

Somewhat different tectonic position of two investigated boreholes (see above) have led to certain differences in continuous and discontinuous deformation style in each of them (Fig. 6). Dips of strata measured in the Barcza Beds from borehole Klonów 1 are, on average, as follows: in the upper package of quartzitic sandstones — 20–23°, in the basal complex of variegated mudstones — 30°. Near the boundary fault they reach up to 70°.

The siltstones and sandstones of the Bostów Beds dip at about 35°. Below, within the Klonów Beds, dips range between 25–50°, and in exceptional cases they attain 70°. They seem to be greater in the inter-fault zone (up to 46.8 m) reaching 40–50°, and smaller in the lower part of the borehole — about 30–40° (Fig. 6).

Rocks from borehole Klonów 1 are disrupted by two faults of a small throw, probably reverse faults. One of them developed at the contact between the Barcza and Bostów Beds at a depth of about 10.8–12.8 m, the other one — slightly above the contact between the Upper and Lower Klonów Beds at a depth of about 46.8–48.4 m (Fig. 6).

Rocks from borehole Klonów 2 are, in general, less inclined compared with those from borehole Klonów 1, usually at about 5–15°, and in exceptional cases near the fault — up to 25°. In the upper part of this section, average dips are of 10–14°, whereas below — 5–10°. These observations show that borehole Klonów 2 was drilled closer to the hinge zone of the fold.

The Upper Klonów Beds recognized in borehole Klonów 2 are disrupted by several faults, probably of an interstratal

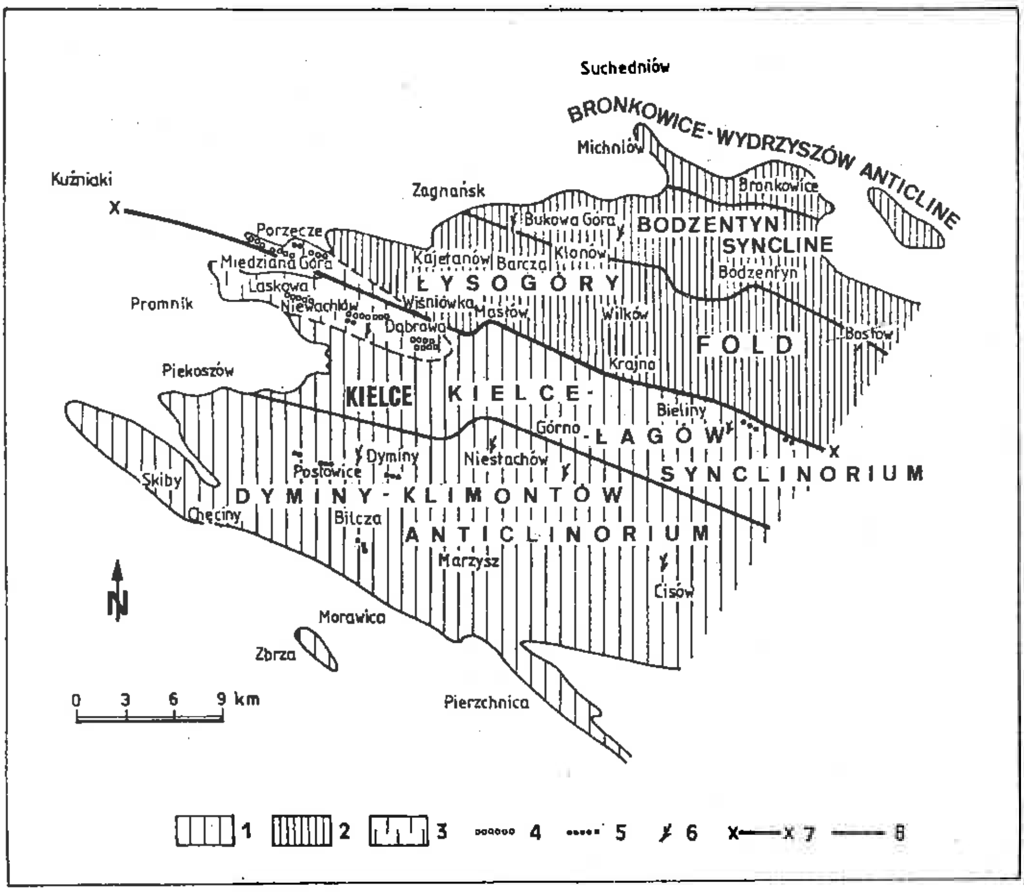

Fig. 11. Miedziana Góra Conglomerates distribution against the background of major tectonic elements, western part of the Holy Cross Mts. Palaeozoic (after J. Czarnocki, 1936, modified)

1 — Kielce Unit; 2 — Łysogóry Unit; 3 — extent of the Miedziana Góra Conglomerate; 4 — Miedziana Góra Conglomerate; 5 — Bieliny Conglomerate; 6 — Lower Devonian flora; 7 — Holy Cross Fault; 8 — assumed boundaries of major tectonic elements

Obszar występowania zlepieńców miedzianogórskich na tle głównych elementów tektonicznych zachodniej części paleozoiku Gór Świętokrzyskich (według J. Czarnockiego, 1936, zmodyfikowany)

1 — jednostka kielecka; 2 — jednostka łysogórska; 3 — obszar zasięgu zlepieńca miedzianogórskiego; 4 — zlepieniec miedzianogórski; 5 — zlepieniec bieliński; 6 — flora dolnodewońska; 7 — dyslokacja świętokrzyska; 8 — granice umowne głównych elementów tektonicznych

décollement character (Fig. 6). These have been recognized at depths of: 18.35–19.40, 35.0–35.90, 47.6–49.0, around 53.0 and 69.0–70.3 m.

The contact between the Barcza and Bostów Beds, disrupted at Klonów, most likely conceals a stratigraphical gap comprising the upper Gedinnian and lower Siegenian (which was mentioned above), and maybe it also conceals a small tectonic unconformity of about 5–8° (Z. Kowalczewski *et al.*, 1989).

Generally the rocks from borehole Klonów 1 are more steeply inclined and show slightly higher plastic deformations, whereas those recognized in borehole Klonów 2 are more intensely faulted.

Rocks from boreholes Klonów 1 and 2, judging by direct observations, show rigid deformations. No folds or boudinage have been noted in either section. They are even lacking drag folds in mudstone packages. Average dips of the strata in these two boreholes range between 5 and 35°. Higher values have only been recorded at near-fault zones. These observations indicate that the studied strata were deformed at relatively small depths. Tectonics of the Klonów Beds at Klonów appears to be of a fault-block character.

KEY PROBLEMS OF REGIONAL GEOLOGY IN THE LIGHT OF PRESENT INVESTIGATIONS

The above-presented results of investigations allow the authors for putting forward the following conclusions, partly hypotheses of regional significance.

The two major tectonic units of the Holy Cross Mts., the Kielce and Łysogóry units formed the single Holy Cross orogen during the Late Silurian. This had taken place before the Miedziana Góra Conglomerates, Klonów Beds and Bostów Beds were deposited, maybe due to either a collision of the Małopolska Terrane with the Łysogóry segment of a passive margin of the East European Craton (R. Dadlez *et al.*, 1994) or a collision between the presumed Małopolska and

Łysogóry Terranes (W. Pożaryski, 1990). The Miedziana Góra Conglomerates and Klonów Beds were deposited on both sides of the Holy Cross Fault, i.e. in both Kielce and Łysogóry Regions (Figs. 9, 10). Petrographical analyses of the Klonów Beds show that their source area was a reactivated orogen where rocks, related to a volcanic arc and structural suture, were subjected to erosion.

These conclusions are not surprising for the advocates of a hypothesis on the Caledonian orogen having been formed during two phases: the Early Caledonian one (Sandomierz), and Late Caledonian one (J. Znosko, 1974, 1983; Z. Kowalczewski, 1981; Z. Kowalczewski, Z. Migaszewski, 1993; R. Dadlez *et al.*, 1994). The strong Ordovician–Silurian volcanism in the southern peripheries of the Holy Cross Mts. has been recognized for a long time (R. Chlebowski, 1971, 1978; Z. Kowalczewski, 1974; T. Przybyłowicz, E. Stupnicka, 1989, 1991). T. Przybyłowicz and E. Stupnicka (*op. cit.*) have recently interpreted the existence of an active magmatic zone with explosive volcanoes during the late Ludlow in the Kielce Region. Macroscopic observations and petrographical analyses indicate that sedimentation of the Klonów Beds was also accompanied by a strong rhyolite or rhyolite-dacite volcanism. Tuffite and tuffaceous sandstone intercalations occur throughout the whole section. Pyroclastic detritus, although found in lesser amounts, also appears in other rock types of the Klonów Beds.

The source area occupied, in the light of sedimentological studies (Fig. 9), the area of the present-day Łysogóry Fold, in particular the Pasmo Główne Range. No acid or neutral volcanic rocks have been found in this area, as yet. When searching, in the future, for presumed traces of the Early Palaeozoic magmatic arc here, it is necessary to reach the basement of the overthrusted Łysogóry Cambrian rocks. It comprises magnetically unsusceptible rocks of higher density gravity. We do not know if there are also acid volcanites amongst them.

Discussing the source area of volcanic detritus, we must also bear in mind that many clasts of this type were redeposited and come from the eroded upper Ludlow greywacke-tuffogenous formation, which was eroded soon after it had been deposited, i.e. during the Pridoli.

Having rejected the provenance of sedimentary and volcanic rocks from the area located south of the Łysogóry Region, one will question as well the assignment to the Klonów Beds of sandstones and siltstones, accumulated in the local Niewachlów–Miedziana Góra basin. Thus, one will also question the existence of the above-mentioned basin — a marine bay, at the turn of the Silurian. For many reasons, this opinion is less probable at present.

Considering the problem where the structural suture zone was located in the Holy Cross Mts., geologists pay their attention first of all to the Holy Cross Fault. The opinion that it is a tectonic suture, may be accepted within the framework of both hypotheses: (1) the Małopolska Terrane amalgamated with the East European Craton, and (2) the two terranes (Małopolska–Kielce and Łysogóry) coalesced. Geological observations and results of geophysical researches excluded the existence of subduction zone during Palaeozoic in proximity of the Holy Cross Fault.

Magnitude of the pre-Pridoli (Ardennian?) movements recorded along the boundary between the Kielce and Łysogóry Regions, considerably increased westwards. This is well evidenced by, among others, an increasing thickness of the Miedziana Góra Conglomerates, in this direction. In the vicinity of Kielce they are a few metres thick only (J. Malec, 1993), in Miedziana Góra — about 40 m (J. Czarnocki, 1936), and in Porzecze — over 120 m (Z. Kowalczewski, 1979). Forming tectonic horsts and grabens (or half-horsts and half-grabens?) exhibit more and more pronounced relief westwards. Above remnant lagoons and bays, steep hills and scarps emerged above coastal braid plains and water surface (Porzecze, Ławeczno, Miedziana Góra, Wiśniówka). They were composed of hard Palaeozoic rocks (Fig. 9) which quickly weathered under a hot and arid climate, and detrital material — rapidly transported downslope — was deposited as alluvial fans and fan deltas (Fig. 8).

In the most strongly uplifted areas, erosion rapidly exposed Tremadoc–Cambrian rocks. This is evidenced by both quartzite pebbles of the Łysogóry Cambrian within the Miedziana Góra Conglomerates and Tremadoc acritarchs redeposited into the Klonów Beds.

A palaeogeographic sketch-map of the Klonów Beds and coeval deposits (Fig. 9) illustrates two eroded zones: the first one in the Łysogóry Region — the Pasmo Główne Range area, and the second in the Kielce Region — the Zagórz–Dyminy–Posłowice Belt. The former is composed of the Łysogóry Fold, horst-like framed by longitudinal faults (LOZ). The latter is made up of peripherial folds of the Dyminy–Klimontów Anticlinorium (KOZ). A depression zone located between the source areas was marked at the decline of the Silurian as a tectonic graben which was forming on a foundation of the Lower Palaeozoic Kielce–Łagów Synclinorium. A relic marine bay of this zone was not directly connected with the greater Klonów basin developed north of the Pasmo Główne Range (Fig. 9).

Sandy-silty facies of the latter basin (ZKL) were passing farther north and north-east towards the present-day Bodzentyn Syncline, into dark grey sandy and muddy rocks with sideritic intercalations, which are characteristic of the Bostów Beds. The presence of the Klonów sandstones in limbs of the Bronkowice and Wydrzyszów Anticlines (J. Czarnocki, 1936; P. Filonowicz, 1968, 1969) suggest a northern extent of the Klonów–Bodzentyn basin in that very area (Fig. 2). This is further supported by the occurrence of the Miedziana Góra-type conglomerates at the base of the Lower Devonian complex within the southern limb of the Bronkowice Anticline, that was evidenced by E. Mariańczyk (1973). A suspicion, justified after all, that those conglomerates are equivalents of the Gruchawka Conglomerates, rather than Miedziana Góra Conglomerates *sensu* J. Malec (1993), does not change a fundamental significance of above-mentioned fact. The uplifted Bronkowice–Wydrzyszów area was characterized by similar geological conditions as in the Wiśniówka and Miedziana Góra regions, at the decline of the Silurian and beginning of the Devonian.

A tectonic pattern exhibited by the Early Palaeozoic–Gedinnian cores of anticlines in the Łysogóry Region (J. Znosko, 1996), reveals features typical of the Holy Cross Caledonides.

They manifested themselves more and more strongly southwards, in so much that in the Pasmo Główne Range — Łysogóry Fold, they attain an expression identical to that in the Dyminy–Posłowice Belt of the Kielce Region (Z. Kowalczewski *et al.*, 1976; H. Żakowa, Z. Kowalczewski, 1978; J. Znosko, 1996).

We believe that the Klonów basin (ZKL at Fig. 9) also developed on an older, lowered tectonic element — the Bodzentyn Syncline. This basin ultimately declined as late as in the late Gedinnian–early Siegenian, when uplifting pulses related to the Erian movements increased in the Holy Cross area. Those were followed by conditions favourable for a widespread development of the variegated sandy-silty Old Red Sandstone facies with flora and placoderms throughout the Holy Cross Mts.

A marine transgression which later gradually spread over the area, as late as during the late Emsian resulted in deposition of the Zagórze Formation, i.e. the *Spirifer* Sandstones (H. Łobanowski, 1971, 1981, 1990).

The Klonów Beds, Miedziana Góra Conglomerates and Bostów Beds together with the overlying Devonian-Carboniferous rocks of the area were subjected to tectonic movements during the Late Palaeozoic. The analysis of the Klonów rocks convinces us that these deformations were of a fault-block character (Fig. 5). Nevertheless, the Variscan movements considerably obliterated the record of older deformations in anticlinal zones, and imposed their own deformation style, easily perceptible in synclinal zones.

The Miedziana Góra Conglomerates, Klonów and Bostów Beds had been deposited at the turn of the Silurian (the end of the Early Palaeozoic sedimentary-diastrophic cycle), after the onset of the strong Ardennian(?) tectonic movements, but before their final phase. Their accumulation was closely accompanied by an intense rhyolite-dacite volcanism. The Miedziana Góra Conglomerates and Klonów Beds represent the older Holy Cross Old Red Sandstone corresponding to the older Caledonian molasse. It was deposited at both the boundary area between the northern and southern regions of the Holy Cross Mts., and in the Łysogóry area uplifted at that time. The younger Holy Cross Old Red Sandstone corresponding to the late Caledonian orthomolasse and represented by the Barcza Beds, started to be deposited as late as after the Erian pulses which terminated marine sedimentation of the Bostów Beds and stopped deposition of their equivalents — the Klonów Beds — in declining isolated basins. In the areas subjected to a slow but continuous downwarping only single major succession of the Old Red deposits occurs. The authors suspect that this might have just been the case of the Słupcza region near Sandomierz.

The above-described conditions of Late Silurian and earliest Devonian sedimentation and structural evolution in the Holy Cross Mts. were responsible for the fact that the post-Caledonian unconformity in the Klonów Belt — in the southern limb of the Bodzentyn Anticline is insignificant, nowhere exceeding 8–10°. However, the Caledonian movements are expressed here in a very strong development of the thick (400–600 m) Old Red Sandstone complex exhibiting a typical young molasse character.

FINAL REMARKS

The studies of rocks drilled near Klonów have yielded rich data on lithology, sedimentary environments, stratigraphy and tectonics of the Klonów Beds. They throw an additional light on geological processes which took place in the Holy Cross Mts. at the decline of the Caledonian epoch, when the Early Palaeozoic sedimentary-diastrophic cycle came to its end. This paper is another step towards a detailed recognition of sediments from the boundary of the Silurian and Devonian in the Holy Cross Mts. In the future, when all exposures of sandstones and siltstones, which are now believed to represent the Klonów Beds, will have been verified, an extensive comparative study of the Miedziana Góra Conglomerates and Bostów Beds with the real Klonów Beds, will have to be carried out. Such a regional study will complete the picture which is preliminarily outlined in this paper.

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WARSTWY KLONOWSKIE (NAJWYŻSZY SYLUR–?NAJNIŻSZY DEWON) A PROBLEM DEFORMACJI KALEDOŃSKICH W GÓRACH ŚWIĘTOKRZYSKICH

Streszczenie

Procesy geologiczne, zachodzące u schyłku epoki kaledońskiej (przełom syluru i dewonu) w Górach Świętokrzyskich, na pograniczu regionów łysogórskiego i kieleckiego, budzą zainteresowanie z powodu szczególnej pozycji, jaką zajmuje ten obszar w obrazie strukturalnym Europy (fig. 1). Określa ją sąsiedztwo kratonu wschodnioeuropejskiego (platformy prewendyjskiej) oraz bliski związek tektoniczny z górotworami: kaledońskim, waryscyjskim i alpejskim. Krawędź SW kratonu wschodnioeuropejskiego ukrytą głęboko w podłożu może odwzorowywać przy powierzchni główna dyslokacja świętokrzyska (R. Dadlez i in., 1994), która dzieli jednostkę kielecką od łysogórskiej. Jednostka łysogórska jest częścią składową kaledonidów małopolskich (J. Znosko, 1996; R. Dadlez i in., 1994) lub elementem pokrywy platformowej zregenerowanej podczas ruchów waryscyjskich (W. Pożaryski i in., 1992*a*, *b*).

Idea dwóch terranów z Gór Świętokrzyskich: małopolskiego (kieleckiego) i łysogórskiego (W. Pożaryski i in., 1992*a*, *b*; M. Lewandowski, 1993,

1994, 1996) wymaga weryfikacji. Analiza litofacjalna i tektoniczna osadów paleozoicznych zaważy na ostatecznym jej wyniku.

W artykule podano wyniki badań sedymentologicznych, petrograficznych, stratygraficznych i tektonicznych warstw klonowskich z pogranicza syluru i dewonu świętokrzyskiego (fig. 2) nawierconych w regionie łysogórskim w obszarze stratotypowym (fig. 3) w otworach Klonów 1 (głęb. 80 m) i Klonów 2 (głęb. 100 m). W otworze Klonów 1 (fig. 6) pod warstwami barczańskimi (głęb. 1,8–12,8 m) odwiercano najpierw warstwy bostowskie (12,8–17,75 m), a następnie warstwy klonowskie górne (17,75–54,0 m) i dolne (54,0–80,0 m). W otworze Klonów 2 wiercono wyłącznie w warstwach klonowskich dolnych, których nie przebito do 100 m.

Warstwy klonowskie, nieformalną jednostkę litostratygraficzną zdominowaną przez lądowej genezy piaskowce i łupki pstre z wkładkami piaskowców tufitowych (początek oldredu), wyróżnił w Paśmie Klonowskim J. Czarnocki (1936). Uznał je za górnożedyńskie, młodsze od zlepieńców miedzianogórskich (dolny żedyn), a starsze od warstw barczańskich (piaskowców plakodermowych emsu dolnego).

J. Czarnocki (1950) wydzielił również w stropie ludlowskich warstw rzepińskich (piętra rzepińskiego) warstwy bostowskie (poziom bostowski).

Warstwy ze Słupczy kreowała i skorelowała z warstwami klonowskimi K. Pawłowska (1954, 1961). Lokowała je w profilu żedynu ponad zlepieńcami miedzianogórskimi, a pod warstwami bostowskimi. Wiek osadów i ich następstwo w profilu geologicznym pogranicza syluru i dewonu oraz litologię studiowali również: M. Pajchlowa (1959, 1962, 1968), E. i H. Tomczykowie (1959–1993), P. Filonowicz (1962–1978), Z. Kowalczewski (1966–1997), H. Łobanowski (1971, 1981, 1990), M. Szulczewski (1994, 1995), J. Malec (1993, 1994, 1996), E. Stupnicka we współpracy z T. Przybyłowicz (1989–1995) i inni.

Dotychczas nie udało się ustalić jednoznacznie czasu powstania warstw klonowskich. Ich wiek określany różnie przez poszczególnych badaczy mieści się w przedziale górny ludlow–zigen.

Nie wyjaśniono też w pełni wzajemnych relacji między warstwami klonowskimi a zlepieńcami miedzianogórskimi i warstwami bostowskimi. Warstwy klonowskie mogą być zarówno starsze, jak i równowiekowe czy młodsze od zlepieńców miedzianogórskich i warstw bostowskich. Interesujące nas skały jako pierwsza uznała za równowiekowe, żedyńskie, M. Pajchlowa (1962, 1968). Piaskowce klonowskie reprezentują według niej facje oldredu, natomiast mułowce bostowskie fację płytkowodną zanikającego zbiornika morskiego.

Badania J. Malca (1993, 1994) nad profilem górnego syluru i niższego dewonu odsłoniętego w Kielcach na Gruchawce (fig. 4) dowiodły, że zlepieńce miedzianogórskie *sensu* J. Czarnocki (1936) nie są jednorodne. Starsza i większa ich część wiąże się sedymentacyjnie z warstwami klonowskimi (fig. 5), natomiast młodsza leżąca na niej niezgodnie i z luką sedymentacyjną, o małej miąższości — z warstwami barczańskimi (fig. 5). Zlepieńce miedzianogórskie, według J. Malca (1993, 1994), odpowiadają części starszej, natomiast zlepieńce z Gruchawki — młodszej.

W warstwach klonowskich na Gruchawce nie znaleziono fauny. Ich wiek określa się na podstawie skamieniałości znajdowanych w warstwach kieleckich leżących poniżej oraz uogólnionych spostrzeżeń regionalnych. L. Teller ze stropu tych warstw oznaczył przewodni dla przydolu *Monograptus transgrediens* Perner (*vide* J. Malec, 1993), zaś E. Tomczykowa (1993) trylobity znane z ludlowu górnego Ameryki Północnej. Na temat wieku tych skał J. Malec (1993, 1994, 1996) najpierw podzielał opinię L. Tellera, a później E. Tomczykowej.

Obserwacje sedymentologiczne oparto na analizie rdzeni z otworów Klonów 1 i 2 (fig. 7). Wyróżniono następujące facje: **Gd — diamiktyty** (tabl. I, fig. 1–4), **Gif — zlepieńce intraformacyjne** (tabl. II, fig. 1 i 2), **Sm — piaskowce masywne** (tabl. II, fig. 3 i 4), **Sh — piaskowce z laminacją poziomą** (tabl. III, fig. 1 i 2), **Slc — piaskowce z warstwowaniem przekątnym w dużej skali** (tabl. II, fig. 5; tabl. III, fig. 4); **Sfr — piaskowce ze smugami mułowcowymi i warstwowaniem przekątnym w małej skali** (tabl. IV, fig. 1), **Sbt — piaskowce zbioturbowane** (tabl. IV, fig. 2), **Fm — masywne skały drobnoziarniste** (tabl. IV, fig.3–5).

Jak wynika z modelu facjalnego (fig. 8), warstwy klonowskie w profilu otworów Klonów 1 i 2 powstały w środowisku stożków aluwialnych, równi roztokowej i delt roztokowych utworzonych na skutek wkraczania stożków aluwialnych i równi roztokowej do płytkowodnego zbiornika morskiego. Rozpoznane w górnej części profilu otworu Klonów 1 niewątpliwie morskie osady warstw bostowskich (m.in. facja **Sbt**) zazębiają się z warstwami klonowskimi.

Osady warstw klonowskich powstawały w dwóch odrębnych zbiornikach przedzielonych obszarem wyniesionym, znajdującym się w miejscu dzisiejszego Pasma Głównego. Z południa ku północy przechodzimy więc kolejno od kieleckiego obszaru źródłowego materiału okruchowego przez zbiornik niewachlowsko-miedzianogórski do łysogórskiego obszaru źródłowego, a następnie do zbiornika klonowskiego (fig. 9). Do zbiornika niewachlowsko-miedzianogórskiego, zarówno z południa — z obszaru kieleckiego, jak i z północy — z obszaru łysogórskiego wkraczały gruboziarniste stożki aluwialne tworząc delty stożkowe (zlepieniec miedzianogórski).

Z opisowego punktu widzenia warstwy klonowskie w pełni odpowiadają definicji molasy. Można je sklasyfikować jako paramolasę (*sensu* L. R. Contescu, 1964), tj. **molasę wczesną** powstałą w zbiorniku geosynklinalnym przed główną fazą górotwórczą. Formację barczańską (wraz ze zlepieńcem z Gruchawki), oddzieloną od warstw klonowskich niezgodnością erozyjną, należałoby wówczas uznać za późną, kaledońską **ortomolasę** Gór Świętokrzyskich.

Analiza petrograficzna osadów wskazuje, że piaskowce tworzące profil Klonów 1 i 2 wykazują niską dojrzałość mineralogiczną i teksturalną i odpowiadają składem szarowakom litycznym, rzadziej arenitom sublitycznym i sporadycznie arenitom kwarcowym. Z piaskowcami współwystępują mułowce i iłowce, a także zlepieńce i tufity (fig. 10; tabl. V–X). Dla określenia pochodzenia materiału detrytycznego i pozycji tektonicznej obszarów źródłowych metodą Gazzi-Dickinsona (W. R. Dickinson i in., 1983) analizowano skład petrograficzny szkieletu ziarnowego piaskowców. Wyniki badań wskazują, że obszarem źródłowym był orogen zbudowany ze skał osadowych — piaskowców, mułowców, szarogłazów i iłowców, a także kwaśnych skał wulkanicznych. Wkładki tufitów w obrębie warstw klonowskich świadczą też o towarzyszącej sedymentacji **aktywności wulkanicznej** obszarów źródłowych. Pozycja tektoniczna określona z trójkątnych diagramów *QFL* wskazuje na reaktywowany orogen jako źródło materiału klastycznego, natomiast z trójkąta, w którego narożach występują okruchy skał *Lm, Lv, Ls+Lf*, wynika, że był to łuk magmatyczny przechodzący w strefę **szwu strukturalnego** (tabl. V–VIII).

W próbkach skał z otworów Klonów 1 i 2 przebadanych palinologicznie przez E. Turnau (*vide* Z. Kowalczewski, E. Turnau, 1997) rozpoznane zostały zespoły spor świadczące o tym, że osady nie są starsze od zony *tripapillatus-spicula* obejmującej przydol. Brak w nich gatunków charakterystycznych dla żedyńskiej zony *micronatus-newportensis*, które znaleziono w stropie warstw bostowskich w otworze Modrzewie 4 pod Bostowem. **Piaskowce klonowskie reprezentują więc przydol i być może najniższy żedyn.**

Opisywane otwory znajdują się w strefie granicznej skiby łysogórskiej i synkliny bodzentyńskiej (fig. 11). Otwór Klonów 1 leży na wspólnym skrzydle tych dwóch jednostek tektonicznych (fig. 3), a otwór Klonów 2 — na skrzydle antykliny klonowskiej, bliżej strefy jej peryklinalnego zamknięcia. Nieco inna pozycja tektoniczna obu otworów warunkuje pewne różnice w obrazie deformacji plastycznych i nieciągłych w każdym z nich.

W otworze Klonów 1 upady wynoszą: w warstwach barczańskich 20–30°, w warstwach bostowskich ok. 35°, a w warstwach klonowskich 25–50°, i wzrastają w strefach przyuskokowych. Przy uskoku granicznym dzielącym warstwy barczańskie od warstw bostowskich dochodzą do 70°.

Skały z otworu Klonów 2 są wychylone z poziomu mniej, aniżeli z Klonowa 1 — w granicach 5–15°, wyjątkowo przy uskoku do 25° (fig. 6). Otwór Klonów 2 nawiercał warstwy położone bliżej przegubowej części fałdu.

Profile skał z obu otworów zaburzają uskoki: w Klonowie 1 — dwa, w Klonowie 2 — cztery. Nie ustalono wielkości przemieszczenia skał w strefie tych uskoków inicjowanych przez zluźnienia międzywarstwowe. Jeden z nich, o charakterze nasuwczym, zaburza w Klonowie 1 kontakt warstw barczańskich z bostowskimi. Kontakt ten kryje w sobie najprawdopodobniej lukę stratygraficzną obejmującą żedyn górny i niższy zigen, a niewykluczone, że maskuje niewielką niezgodność tektoniczną rzędu 5–8° (Z. Kowalczewski i in., 1989)

Tektonika warstw klonowskich w Klonowie przedstawia się jako **uskokowo-fałdowa**. Obserwacje sugerują, że odkształcenie badanych warstw zachodziło na niezbyt dużej głębokości.

Dwie główne jednostki tektoniczne północno-zachodniej Małopolski: kielecka i łysogórska zespoliły się w sylurze górnym w jeden górotwór świętokrzyski. Stało się to przed depozycją zlepieńców miedzianogórskich, warstw klonowskich i warstw bostowskich, prawdopodobnie w czasie ruchów ardeńskich. Być może na skutek kolizji terranu małopolskiego (kieleckiego) z łysogórskim segmentem pasywnej krawędzi kratonu wschodnioeuropejskiego (R. Dadlez i in., 1994) lub też zderzenia domniemanych terranów: małopolskiego i łysogórskiego (W. Pożaryski, 1990). Zlepieńce miedzianogórskie i warstwy klonowskie tworzyły się po obu stronach głównej dyslokacji świętokrzyskiej, zarówno w regionie łysogórskim, jak i kieleckim (fig. 9, 10). Analiza petrograficzna wskazuje, że obszarem źródłowym dla detrytusu z warstw klonowskich był regenerowany orogen, w obrębie którego erozji podlegały skały z łuku wysp wulkanicznych oraz ze strefy szwu strukturalnego. Warstwy barczańskie alimentował głównie blok kontynentalny.

Wnioski te nie zaskakują zwolenników tezy o górotworze kaledońskim formowanym w dwóch etapach: starokaledońskim (sandomierskim) i młodokaledońskim (J. Znosko, 1974, 1983; Z. Kowalczewski i in., 1976; R. Dadlez i in., 1994). Silny wulkanizm ordowicko-sylurski na S peryferiach Gór Świętokrzyskich rozpoznawano już od dawna (R. Chlebowski, 1971, 1978; Z. Kowalczewski i in., 1976). Ostatnio mówi się o istnieniu w regionie kieleckim w wyższym ludlowie aktywnej strefy magmowej z wulkanami eksplozywnymi (T. Przybyłowicz, E. Stupnicka, 1991). Intensywny wulkanizm ryolitowy czy ryolitowo-dacytowy towarzyszył też sedymentacji warstw klonowskich. Dyskutując o obszarze źródłowym dla detrytusu wulkanicznego, pamiętajmy, że wiele tych klastów było redeponowanych i pochodzi z niszczenia formacji szarogłazowo-tufogenicznej ludlowu górnego — osadów zerodowanych niedługo po ich powstaniu, bo już w przydolu.

Pogląd, że główna dyslokacja świętokrzyska ma charakter szwu tektonicznego, można przyjąć zarówno na gruncie hipotezy o zespoleniu terranu małopolskiego z kratonem Europy Wschodniej, jak i hipotezy przyjmującej połączenie dwóch terranów: małopolskiego (kieleckiego) i łysogórskiego. Obserwacje geologiczne i wyniki badań geofizycznych wykluczają istnienie strefy subdukcji w paleozoiku w sąsiedztwie głównej dyslokacji świętokrzyskiej.

Natężenie ruchów przedprzydolskich — ardeńskich analizowanych wzdłuż pogranicza regionów kieleckiego i łysogórskiego wzrastało ku zachodowi. W tym kierunku rośnie miąższość zlepieńców miedzianogórskich: w Miedzianej Górze wynosi ok. 40 m, w Porzeczu powyżej 120 m (J. Czarnocki, 1936; Z. Kowalczewski, 1979). Powstające wówczas zręby i rowy (czy półzręby i półrowy?) tektoniczne miały ku W coraz to ostrzejszy relief. W obszarach najsilniej wyniesionych (np. oznaczonym LOZ na fig. 9) erozja szybko odsłoniła skały kambryjsko-tremadockie, które w klimacie gorącym i suchym intensywnie wietrzały. Materiał okruchowy masowo przemieszczany w dół zboczy usypał u ich podstawy stożki aluwialne i delty stożkowe.

Zarówno zbiornik klonowski (ZKL na fig. 9), jak niewachlowsko-miedzianogórski (ZNM na fig. 9), które powstały na starszych, obniżonych elementach tektonicznych zanikły dopiero w wyższym żedynie–niższym zigenie, kiedy nasiliły się w obszarze świętokrzyskim pulsacje wznoszące związane z ruchami eryjskimi.

W Paśmie Klonowskim, w południowym skrzydle synkliny bodzentyńskiej, niezgodność pokaledońska mieści się zwykle w granicach błędu pomiarowego i nigdzie nie przekracza 8–10°. Jednakże ruchy kaledońskie wyraziły się tutaj bardzo mocno rozwojem miąższego (400–600 m) kompleksu oldredowego o charakterze typowej molasy. Zlepieńce miedzianogórskie i warstwy klonowskie reprezentują starszy oldred świętokrzyski, tj. starszą molasę kaledońską. Młodszy oldred świętokrzyski, czyli późną ortomolasę kaledońską, reprezentują warstwy barczańskie utworzone już po pulsacjach eryjskich, które zamknęły sedymentację morską warstw bostowskich i zarazem przerwały depozycję warstw klonowskich.

Na wschodzie obszaru świętokrzyskiego (rejon Słupczy k. Sandomierza) w terenach powoli, ale długotrwale obniżanych, występuje prawdopodobnie jedna wielka sukcesja osadów oldredowych.

Obraz tektoniki (J. Znosko, 1996) i jego rozwój czytelny w staropaleozoiczno-żedyńskich jądrach jednostek antyklinalnych w regionie łysogórskim ujawnia cechy typowe dla kaledoniku świętokrzyskiego. Manifestują się one ku S coraz silniej: w Paśmie Głównym — w skibie łysogórskiej osiągają charakter identyczny jak w Paśmie Dymińsko-Posłowickim regionu kieleckiego (Z. Kowalczewski i in., 1976; H. Żakowa, Z. Kowalczewski, 1978; J. Znosko, 1996).

EXPLANATIONS OF PLATES

PLATE I

Fig. 1. Facies **Gd** — diamictite of grain-supported fabric. Clasts of sandstones in sandy-muddy matrix are visible. Klonów 1, depth 78.0 m

Facja **Gd** — diamiktyt o zwartym szkielecie ziarnowym. Widoczne okruchy piaskowców w piaszczysto-mułowcowej masie wypełniającej. Klonów 1, głęb. 78,0 m

Fig. 2. Facies **Gd** — diamictite of grain-supported fabric. Clasts of sandstones in muddy-sandy matrix are visible. Klonów 1, depth 45.7 m

Facja **Gd** — diamiktyt o zwartym szkielecie ziarnowym. Widoczne okruchy piaskowców w mułowcowo-piaszczystej masie wypełniającej. Klonów 1, głęb. 45,7 m

Fig. 3. Facies **Gd** — diamictite of matrix-supported fabric (in places grain-supported). Clasts of sandstones in muddy matrix can be seen. Some of the clasts are subvertically oriented. Klonów 2, depth 21.9 m

Facja **Gd** — diamiktyt o rozproszonym (miejscami zwartym) szkielecie ziarnowym. Widoczne okruchy piaskowców w mułowcowej masie wypełniającej. Niektóre okruchy zorientowane subwertykalnie. Klonów 2, głęb. 21,9 m

Fig. 4. The same specimen as in Fig. 3, turned by 90°

Ten sam okaz co na Fig. 3 obrócony o ok. 90°

PLATE II

Fig. 1. Facies **Gif** — intraformational conglomerate, composed of flat-lying mudstone intraclasts. Klonów 2, depth 78.7 m

Facja **Gif** — zlepieniec intraformacyjny złożony z płasko leżących intraklastów mułowców. Klonów 2, głęb. 78,7 m

Fig. 2. Facies **Gif** — intraformational conglomerate, composed of flat-lying mudstone intraclasts of different colours (grey and cherry). Klonów 2, depth 24.1 m

Facja **Gif** — zlepieniec intraformacyjny złożony z płasko leżących intraklastów mułowców o różnej barwie (wiśniowych i szarych). Klonów 2, głęb. 24,1 m

Fig. 3. Facies **Sm** — massive, muddy sandstone with scattered siltstone intraclasts showing horizontal orientation. Klonów 2, depth 98.1 m

Facja **Sm** — piaskowiec masywny z rozproszonymi intraklastami mułowców wykazującymi orientację poziomą. Klonów 2, głęb. 98,1 m

Fig. 4. Facies **Sm** — massive, muddy sandstone. Small mudstone intraclast, horizontally oriented is visible in upper part. Klonów 2, depth 72.2 m

Facja **Sm** — piaskowiec masywny, mułowcowy. W górnej części zdjęcia widoczny drobny intraklast mułowcowy zorientowany poziomo. Klonów 2, głęb. 72,2 m

Fig. 5. Facies **Slc** — sandstone with large-scale cross-bedding. Indistinct horizontal lamination in upper part. Klonów 2, depth 22.9 m

Facja **Slc** — piaskowiec z warstwowaniem przekątnym dużej skali. W górnej części zdjęcia niewyraźna laminacja pozioma. Klonów 2, głęb. 22,9 m

PLATE III

Fig. 1. Facies **Sh** — horizontally laminated sandstone, red in colour (subfacies **Shr**). Klonów 1, depth 69.9 m

Facja **Sh** — piaskowiec z laminacją poziomą, czerwony (subfacja **Shr**). Klonów 1, głęb. 69,9 m

Fig. 2. Facies **Sh** — horizontally laminated sandstone, grey in colour (subfacies **Shg**). Characteristic thin platy parting related to primary current lineation can be seen. Klonów 1, depth 41.8 m

Facja **Sh** — piaskowiec z laminacją poziomą, szary (subfacja **Shg**). Widoczna charakterystyczna oddzielność płytkowa związana z lineacją oddzielnościową. Klonów 1, głęb. 41,8 m

Fig. 3. Facies **Sh** (subfacies **Shr**) — sandstone with small-scale cross-bedding. Klonów 2, depth 86.4 m

Facja Sh (subfacja **Shr**) — piaskowiec z warstwowaniem przekątnym małej skali. Klonów 2, głęb. 86,4 m

Fig. 4. Facies **Slc** — sandstone with large-scale cross-bedding. Minute siltstone intraclasts resting upon surfaces of cross laminae are visible. Klonów 2, depth 64.6 m

Facja **Slc** — piaskowiec z warstwowaniem przekątnym dużej skali. Widoczne drobne intraklasty mułowców leżące na powierzchniach lamin przekątnych. Klonów 2, głęb. 64,6 m

PLATE IV

Fig. 1. Facies **Sfr** — sandstone with mud flasers and small-scale cross-bedding. Klonów 2, depth 31.1 m

Facja **Sfr** — piaskowiec ze smugami mułowcowymi i warstwowaniem przekątnym małej skali. Klonów 2, głęb. 31,1 m

Fig. 2. Facies **Sbt** — bioturbated sandstone. Klonów 1, depth 13.0 m (Notice: facies **Sbt** has been found in the upper part of the Bostów Beds only)

Facja **Sbt** — piaskowiec zbioturbowany. Klonów 1, głęb. 13,0 m (Uwaga: fację **Sbt** stwierdzono wyłącznie w górnej części warstw bostowskich)

Fig. 3. Facies **Fm** — massive, red claystone (subfacies **Fmr**). Klonów 2, depth 53.7 m

Facja **Fm** — iłowiec masywny, czerwony (subfacja **Fmr**). Klonów 2, głęb. 53,7 m

Fig. 4. Facies **Fm** — massive, grey claystone (subfacies **Fmg**). Klonów 2, depth 55.6 m

Facja **Fm** — iłowiec masywny, szary (subfacja **Fmg**). Klonów 2, głęb. 55,6 m

Fig. 5. Facies **Fm** — thin tuffite intercalation in claystones. Horizontal lamination is seen. Klonów 2, depth 97.2 m

Facja **Fm** — cienkie przewarstwienie tufitu w iłowcach. Widoczna laminacja pozioma. Klonów 2, głęb. 97,2 m

PLATE V

Fig. 1. Fine-grained quartz arenite. Klonów 1, depth 1.8 m, crossed nicols

Arenit kwarcowy drobnoziarnisty. Klonów 1, głęb. 1,8 m, nikole skrzyżowane

Fig. 2. Fine-grained sublithic arenite. Klonów 1, depth 2.5 m, crossed nicols

Arenit sublityczny drobnoziarnisty. Klonów 1, głęb. 2,5 m, nikole skrzyżowane

Fig. A. Percentage contribution of grain components in sandstones (for abbreviation explanations see the text)

Udziały procentowe składników ziarnowych piaskowców (objaśnienia symboli w tekście)

Fig. B. Classification diagram of sandstones (after R. M. Dott, modified by F. J. Pettijohn *et al.*, 1973 and K. Jaworowski, 1987)

Diagram klasyfikacyjny piaskowców (według R. M. Dotta, zmodyfikowany przez F. J. Pettijohna i in., 1973 i K. Jaworowskiego, 1987)

Figs. C, D, E. Genetic diagrams of source areas of detrital components (C, D — after W. R. Dickinson *et al.*, 1983; E — after R. V. Ingersoll, C. A. Suczek, 1979)

Diagramy genetyczne obszarów źródłowych składników detrytycznych (C, D — według W. R. Dickinsona i in., 1983; E — według R. V. Ingersolla, C. A. Suczka, 1979)

PLATE VI

Fig. 1. Fine-grained lithic greywacke. Klonów 1, depth 12.8 m, crossed nicols

Szarowaka lityczna, drobnoziarnista. Klonów 1, głęb. 12,8 m, nikole skrzyżowane

Fig. 2. Fine-grained lithic greywacke. Klonów 1, depth 13.1 m, crossed nicols

Szarowaka lityczna, drobnoziarnista. Klonów 1, głęb. 13,1 m, nikole skrzyżowane

Figs. A–E. For explanations see Plate V

Objaśnienia na tabl. V

PLATE VII

Fig. 1. Fine-grained lithic greywacke. Klonów 1, depth 31.2 m, crossed nicols

Szarowaka lityczna, drobnoziarnista. Klonów 1, głęb. 31,2 m, nikole skrzyżowane

Fig. 2. Medium-grained lithic arenite, variously rounded grains. Klonów 1, depth 37.65 m, crossed nicols

Arenit lityczny średnioziarnisty o zróżnicowanym obtoczeniu ziarn. Klonów 1, głęb. 37,65 m, nikole skrzyżowane

Fig. 3. Medium-grained lithic arenite with a contribution of volcaniclastic quartz with deep corrosive embayments, fragments of partly devitrificated glass and claystones. Klonów 1, depth 37.65 m, crossed nicols

Arenit lityczny średnioziarnisty, w składzie udział wulkanoklastycznego kwarcu z głębokimi zatokami korozyjnymi, okruchy częściowo zdewitryfikowanego szkliwa i fragmenty iłowców. Klonów 1, głęb. 37,65 m, nikole skrzyżowane

Figs. A–E. For explanations see Plate V

Objaśnienia na tabl. V

PLATE VIII

Figs. 1–3. Fine-grained lithic greywacke. Klonów 2, depths 6.35, 12.5 and 95.4 m, respectively; crossed nicols

Szarowaki lityczne drobnoziarniste. Klonów 2, głęb. odpowiednio 6,35, 12,5 and 95,4 m; nikole skrzyżowane

Figs. A–E. For explanations see Plate V

Objaśnienia na tabl. V

PLATE IX

Figs. 1, 3, 4. Siltstones passing into lithic greywackes laminated with claystone. Klonów 1, depth 24.1 m, Klonów 1, depth 79.4 m, Klonów 2, depth 62.75 m, respectively; crossed nicols

Mułowce z przejściami do szarowak litycznych laminowane iłowcem. Odpowiednio: Klonów 1, głęb. 24,1 m, Klonów 1, głęb. 79,4 m, Klonów 2, głęb. 62,75 m; nikole skrzyżowane

Fig. 2. Claystone with globular siderite. Klonów 1, depth 55.35 m, crossed nicols

Iłowiec z kuleczkowymi formami występowania syderytu. Klonów 1, głęb. 55,35 m, nikole skrzyżowane

PLATE X

Figs. 1–4. Tuffites. Pyroclastic components of characteristic shapes — wedge-shaped and irregular glass and quartz fragments, as well as thick biotite flakes, can be seen. Klonów 1, depth 41.15 m, Klonów 1, depth 41.5 m, Klonów 2, depth 96.5 m, Klonów 2, depth 97.15 m, respectively; crossed nicols

Tufity. Widoczne składniki piroklastyczne o charakterystycznych kształtach: klinowate i nieforemne fragmenty szkliwa i kwarcu oraz grube blaszki biotytu. Odpowiednio: Klonów 1, głęb. 41,15 m, Klonów 1, głęb. 41,5 m, Klonów 2, głęb. 96,5 m, Klonów 2, głęb. 97,15 m; nikole skrzyżowane

Photos in Plates I–IV have been taken by M. Krzyżanowski from the Photography Laboratory of the Polish Geological Institute in Warsaw. Photos in Plates V–X have been taken by M. Kuleta from the Świętokrzyskie Mts. Branch of the PGI in Kielce

Zdjęcia do tabl. I–IV wykonał M. Krzyżanowski z Pracowni Fotograficznej PIG w Warszawie, a zdjęcia do tabl. V–X wykonała M. Kuleta z Oddziału Świętokrzyskiego PIG w Kielcach

Geol. Quart., 1998, **42** (4)

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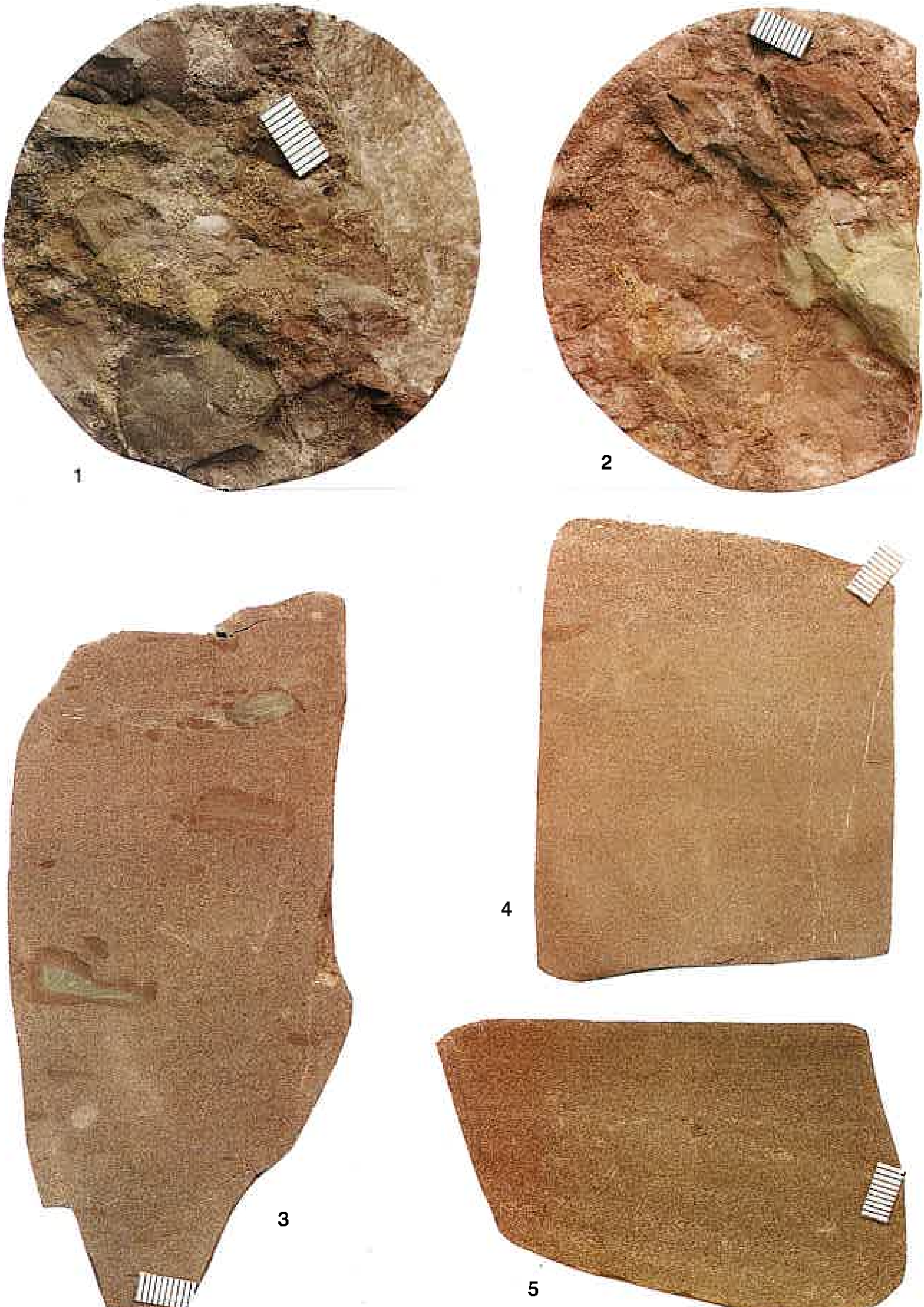
Zbigniew KOWALCZEWSKI, Krzysztof JAWOROWSKI, Maria KULETA — Klonów Beds (uppermost Silurian–?lowermost Devonian) and the problems of Caledonian deformations in the Holy Cross Mts.



Zbigniew KOWALCZEWSKI, Krzysztof JAWOROWSKI, Maria KULETA — Klonów Beds (uppermost Silurian–?lowermost Devonian) and the problems of Caledonian deformations in the Holy Cross Mts.

Zbigniew KOWALCZEWSKI, Krzysztof JAWOROWSKI, Maria KULETA — Klonów Beds (uppermost Silurian–?lowermost Devonian) and the problems of Caledonian deformations in the Holy Cross Mts.

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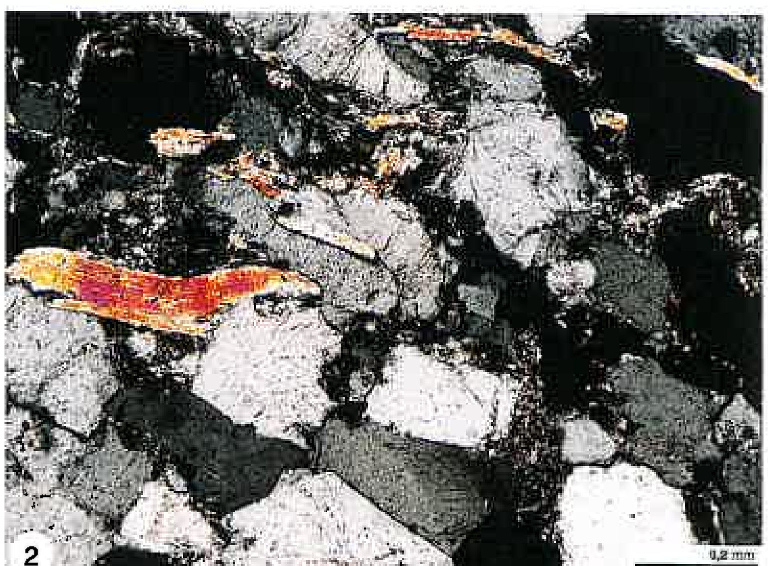
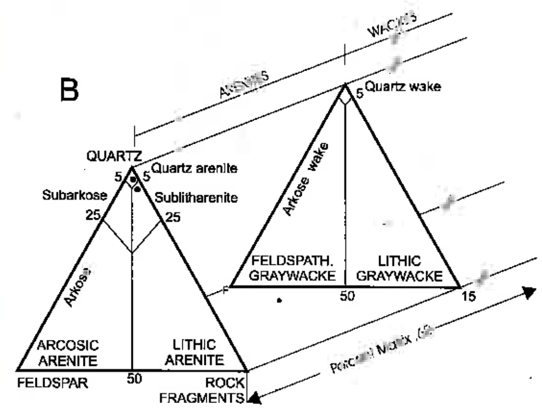
Zbigniew KOWALCZEWSKI, Krzysztof JAWOROWSKI, Maria KULETA — Klonów Beds (uppermost Silurian–?lowermost Devonian) and the problems of Caledonian deformations in the Holy Cross Mts.

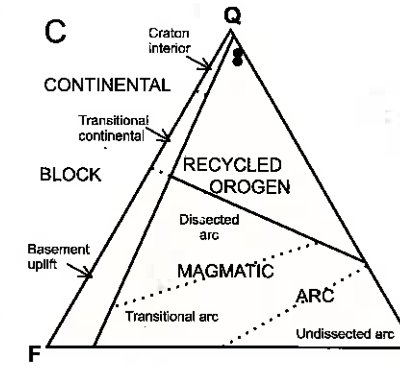


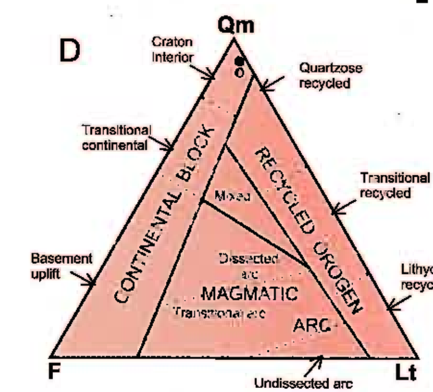
BARCZA BEDS

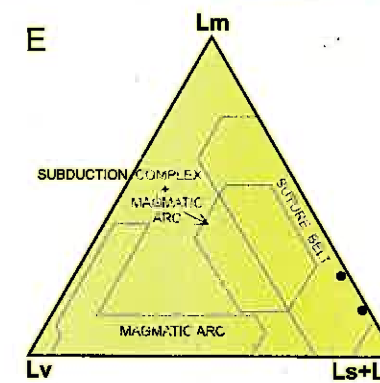
A

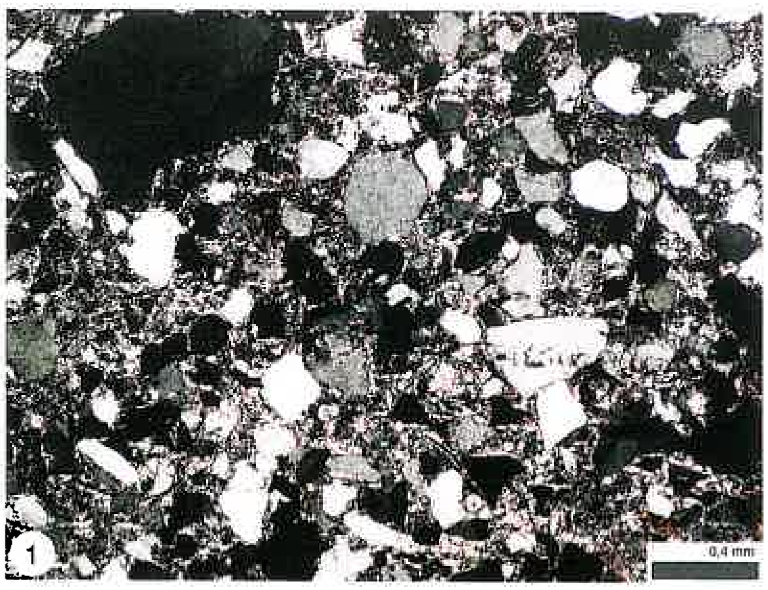
No	Q	F	L	Qm	F	Lt	Lm	Lv	Ls+Lf
1	96.0%	0.8%	3.2%	94.4%	0.8%	4.8%	25.0%	0.0%	75.0%
2	92.4%	1.7%	5.9%	89.1%	1.7%	9.2%	14.3%	0.0%	85.7%
avg	94.2%	1.2%	4.6%	91.7%	1.3%	7.0%	19.6%	0.0%	80.4%

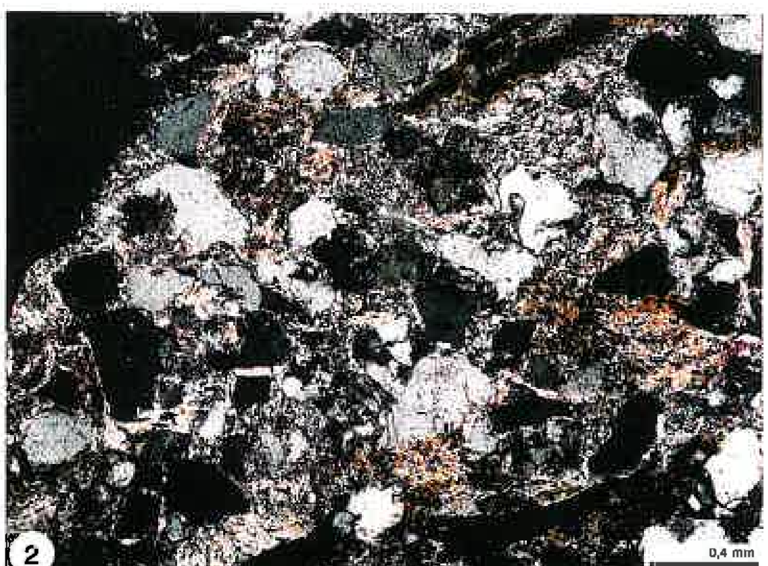








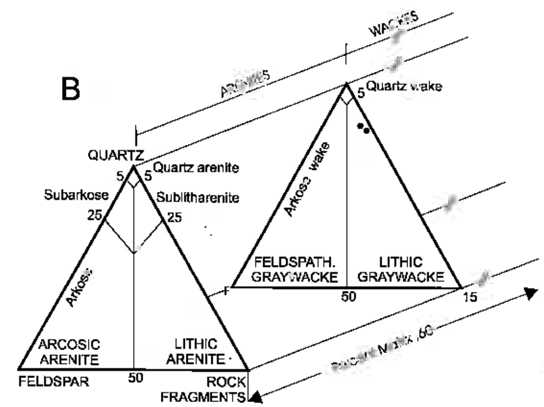


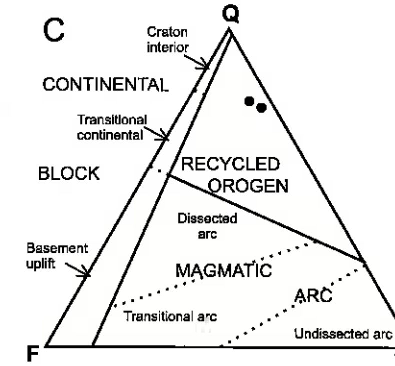


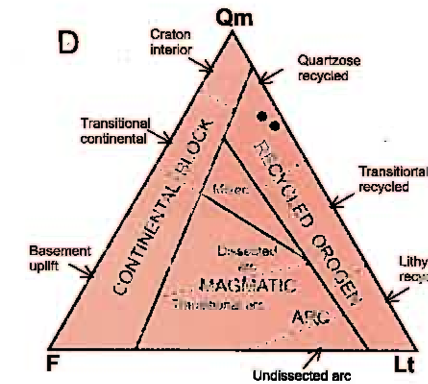
BOSTÓW BEDS

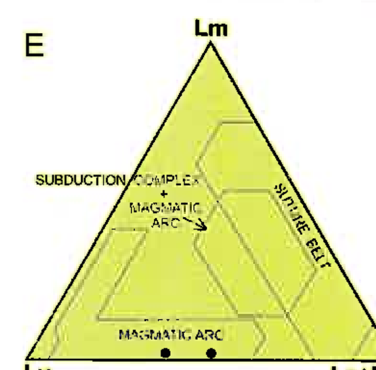
A

No	Q	F	L	Qm	F	Lt	Lm	Lv	Ls+Lf
3	74.6%	1.5%	23.9%	75.1%	1.5%	23.4%	0.0%	50.0%	50.0%
4	77.8%	4.4%	17.6%	77.8%	[illegible]	17.8%	0.0%	62.5%	37.5%
avg	76.2%	3.0%	20.8%	[illegible]	3.0%	21.6%	0.0%	56.3%	43.7%

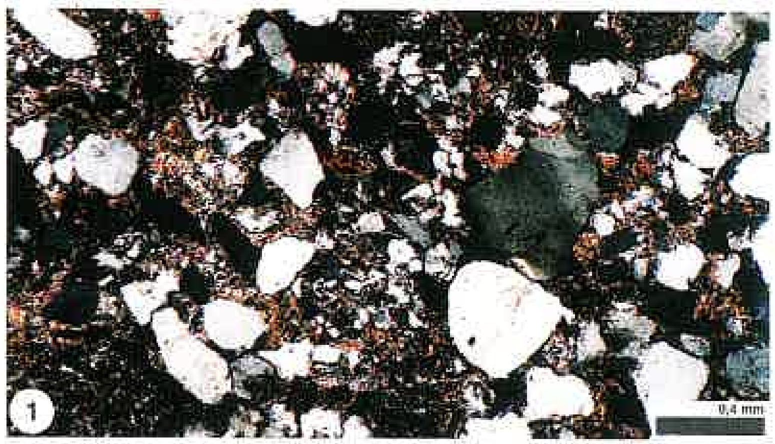








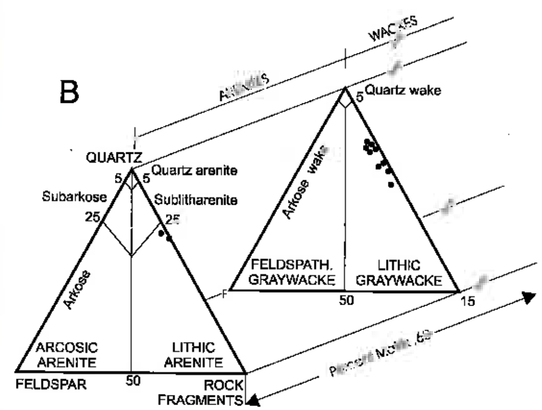
UPPER KLONÓW BEDS



A

No	Q	F	L	Qm	F	Lt	Lm	Lv	Ls+Lf
5	70.8%	2.1%	27.1%	70.8%	2.1%	27.1%	0.0%	7.7%	92.3%
6	71.4%	3.9%	24.7%	68.8%	3.9%	27.3%	5.3%	31.6%	63.1%
7	72.4%	3.4%	24.2%	69.0%	3.4%	27.6%	0.0%	21.4%	78.6%
8	64.9%	2.7%	32.4%	63.5%	2.7%	33.8%	4.2%	41.7%	54.1%
9	73.2%	2.8%	24.0%	70.4%	2.8%	26.8%	0.0%	41.2%	58.8%
10	64.6%	1.5%	33.9%	63.1%	1.5%	35.4%	4.5%	18.2%	77.3%
11	58.5%	1.9%	39.6%	58.5%	1.9%	39.6%	0.0%	76.2%	23.8%
12	67.9%	0.0%	32.1%	65.4%	0.0%	34.6%	7.7%	30.8%	61.5%
13	52.0%	2.0%	46.0%	50.0%	2.0%	48.0%	4.9%	39.1%	56.0%
14	62.3%	3.3%	34.4%	60.7%	3.3%	36.0%	0.0%	57.1%	42.9%
15	71.2%	2.8%	26.0%	71.2%	2.7%	26.1%	5.3%	42.1%	52.6%
16	73.5%	1.2%	25.3%	71.1%	1.2%	27.7%	4.6%	28.6%	66.6%
avg	66.9%	2.3%	30.8%	65.2%	2.3%	32.5%	3.0%	36.3%	60.7%

B



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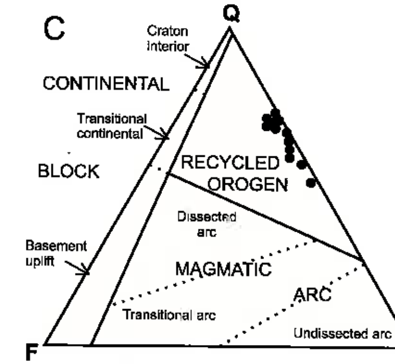

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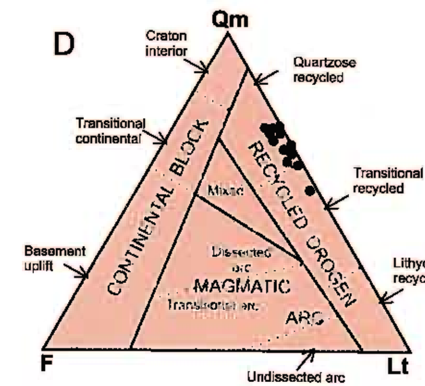

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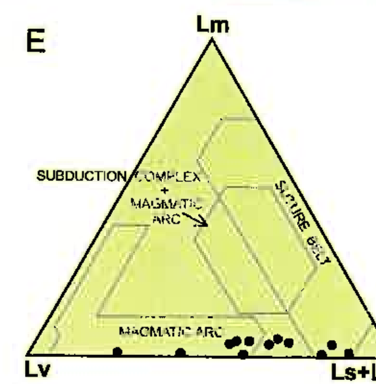

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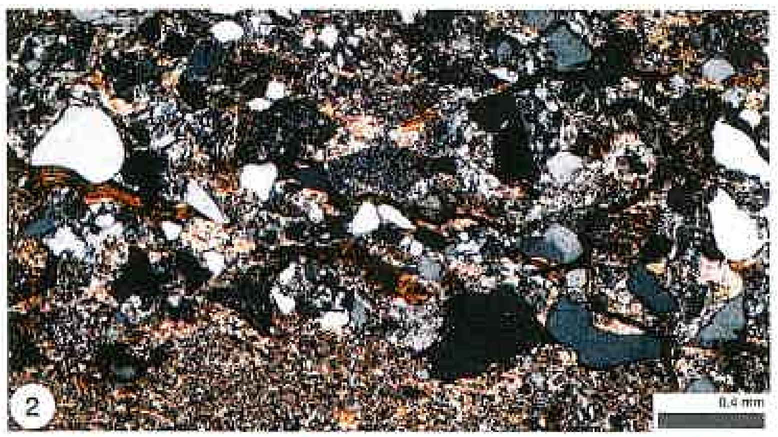
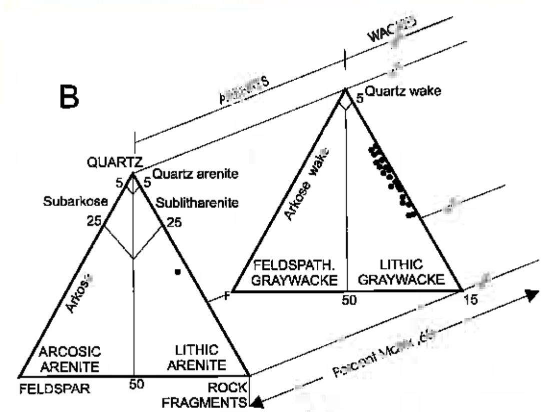


LOWER KLONÓW BEDS

A

No	Q	F	L	Qm	F	Lt	Lm	Lv	Ls+Lf
17	69.8%	4.6%	25.4%	[illegible]	[illegible]	[illegible]	0.0%	12.5%	87.5%
18	60.7%	1.3%	38.0%	[illegible]	[illegible]	[illegible]	3.3%	13.3%	83.4%
19	71.1%	1.3%	27.6%	[illegible]	[illegible]	[illegible]	0.0%	14.3%	85.7%
20	60.7%	1.8%	37.5%	[illegible]	[illegible]	[illegible]	0.0%	14.3%	35.7%
21	65.1%	3.2%	31.7%	[illegible]	[illegible]	[illegible]	0.0%	20.0%	80.0%
22	58.1%	4.8%	37.1%	[illegible]	[illegible]	[illegible]	0.0%	13.0%	87.0%
23	62.8%	2.9%	34.3%	[illegible]	[illegible]	[illegible]	0.0%	29.2%	70.8%
24	51.7%	1.7%	46.6%	[illegible]	1.7%	[illegible]	3.7%	66.7%	29.6%
25	38.8%	4.5%	56.7%	[illegible]	[illegible]	[illegible]	0.0%	34.2%	65.8%
26	72.7%	2.3%	25.0%	72.7%	2.3%	[illegible]	0.0%	36.4%	63.6%
27	51.5%	1.4%	47.1%	51.5%	1.4%	[illegible]	0.0%	21.2%	75.8%
28	52.0%	5.5%	42.5%	[illegible]	5.5%	[illegible]	3.2%	6.5%	90.3%
29	59.3%	5.1%	35.6%	[illegible]	5.1%	[illegible]	0.0%	23.8%	76.2%
30	69.1%	1.8%	29.1%	69.1%	1.8%	[illegible]	0.0%	12.5%	87.5%
31	43.8%	5.3%	50.9%	43.8%	[illegible]	[illegible]	0.0%	41.4%	58.6%
32	65.2%	2.9%	31.9%	[illegible]	2.9%	[illegible]	0.0%	13.6%	86.4%
33	71.5%	2.0%	26.5%	[illegible]	2.0%	26.5%	7.7%	38.5%	53.8%
34	59.4%	3.1%	37.5%	[illegible]	[illegible]	[illegible]	0.0%	12.5%	87.5%
35	52.0%	6.3%	41.7%	52.0%	[illegible]	41.7%	5.0%	50.0%	45.0%
36	38.8%	4.1%	57.1%	[illegible]	[illegible]	57.1%	0.0%	39.3%	60.7%
37	44.9%	2.9%	52.2%	[illegible]	2.9%	52.2%	2.8%	38.9%	58.3%
38	64.0%	4.7%	31.3%	[illegible]	4.7%	31.3%	0.0%	25.0%	75.0%
39	64.8%	7.4%	27.8%	64.8%	7.4%	27.8%	6.7%	26.7%	66.6%
40	52.4%	3.2%	44.4%	52.4%	[illegible]	44.4%	0.0%	28.6%	71.4%
41	46.0%	3.2%	50.8%	46.0%	3.2%	50.8%	0.0%	18.8%	81.2%
avg	57.9%	3.5%	38.6%	[illegible]	[illegible]	[illegible]	1.5%	25.0%	73.7%

B



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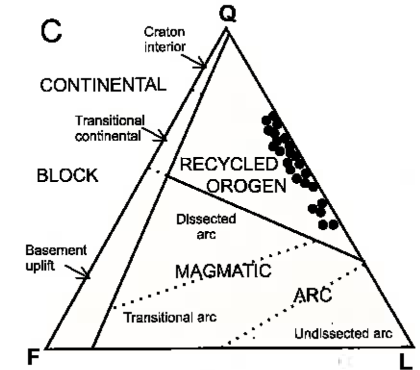

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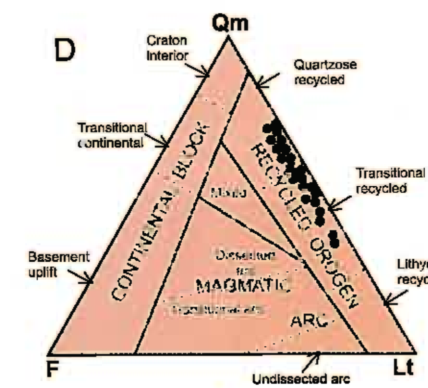

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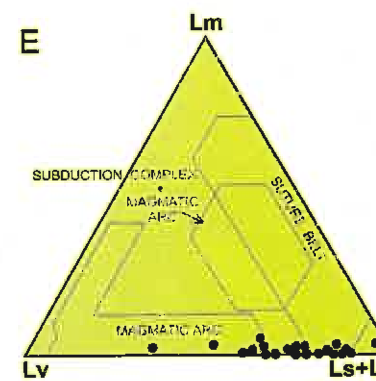
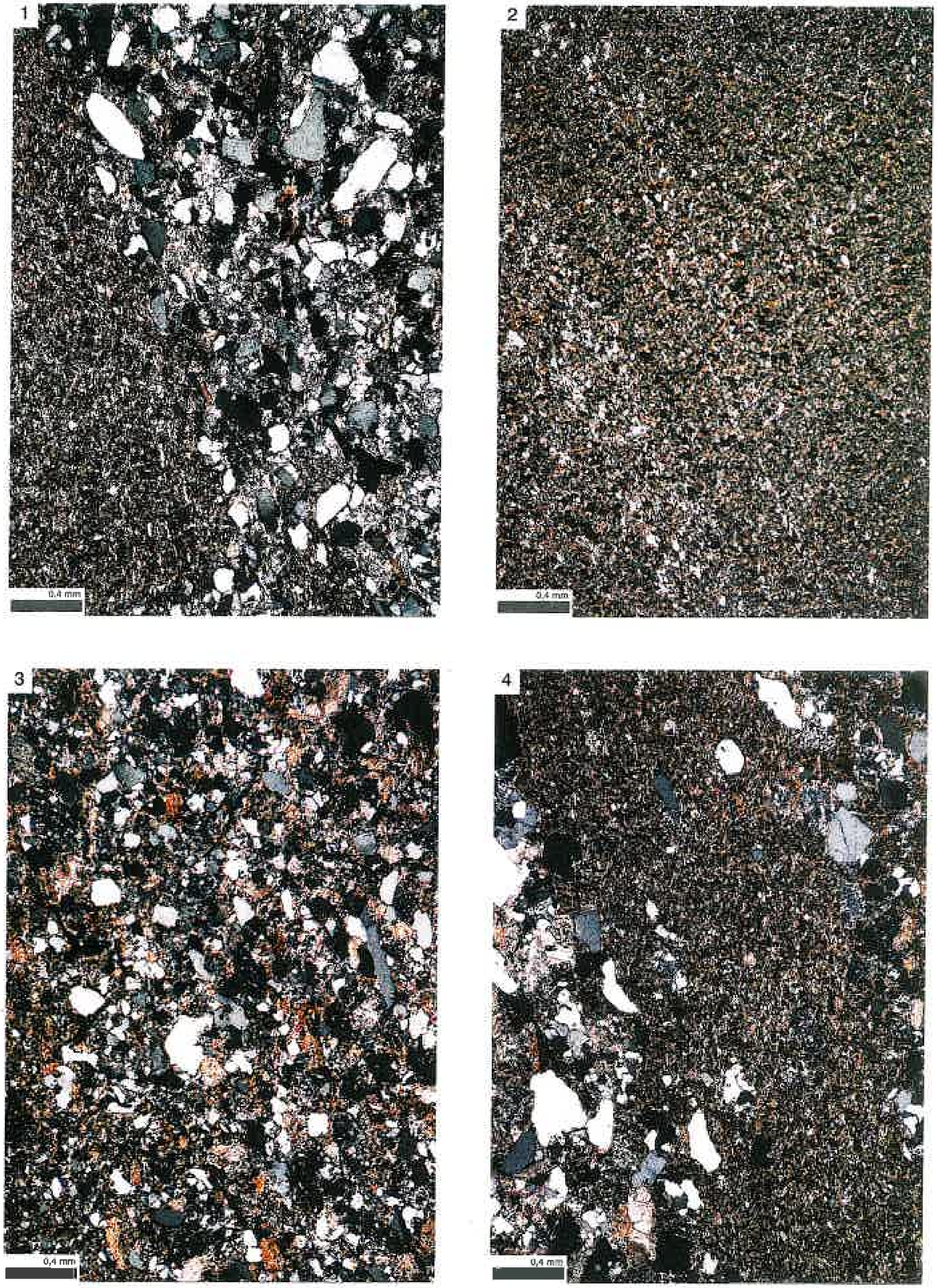


Geol. Quart., 1998, **42**(4)



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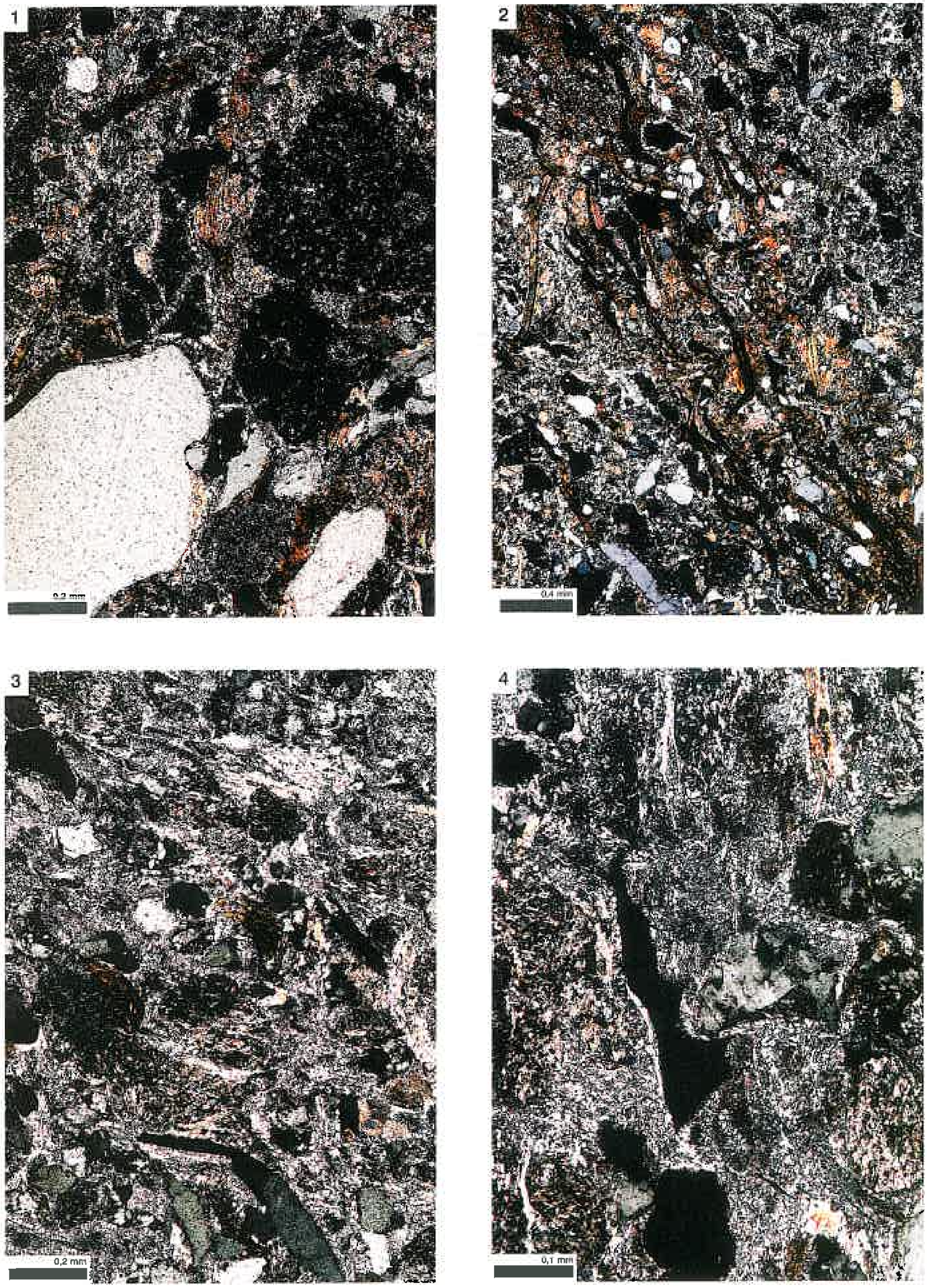

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