acta
geologica
polonica

Vol. 29, No. 4 Warszawa 1979

HENRYK ŁOBANOWSKI & TERESA PRZYBYŁOWICZ

Tidal flat and flood-plain deposits in the Lower Devonian of the western Lublin Uplands (after the boreholes Pionki *1* and Pionki *4*)

ABSTRACT: Facies analysis of the Lower Devonian deposits recorded in the boreholes Pionki *1* and Pionki *4* located in the western Lublin Uplands, between the Holy Cross Mts and the southwestern margin of the East-European platform, permits a recognition of marine, tidal-flat, and flood-plain environments. The accumulated clastic material derived from the East-European platform.

INTRODUCTION

The Lower Devonian strata of Poland are known from outcrops in the Holy Cross Mts and the Sudetes, and deep boreholes pierced mostly in southern Poland. Among the most interesting areas for investigation of the Lower Devonian of Poland are the Lublin Uplands extending between the Holy Cross Mts and Bug river, adjacent in the north to the southwestern margin of the East-European platform (Fig. 1). The Devonian of that area was investigated by several students, which has resulted e.g. in a comprehensive and multi-faceted work by Miłaczewski (1975) that summarizes up the results of a long research by that author and his collaborators. The paper by Miłaczewski (1975) deals with all but a few problems posed by the whole section of the Devonian and hence, leaves some points mentioned but unexplained.

The present paper is aimed to consider the stratigraphy, lithology, and selected sedimentological aspects of the Lower Devonian deposits of the northwestern Lublin Uplands (Figs 1—2) where the series attains its maximum thickness. Two deep boreholes were pierced in that area called by Żelichowski (1972) as the Radom—Kraśnik rise, namely the boreholes Ciepielów *IG-1* and Pionki *4*. The former borehole passed through continental and marine Devonian deposits underlying the Jurassic ones, and reached the Silurian (Pajchlowa 1964, Miłaczewski 1974). In the other borehole, the Triassic has been found to be underlain by carbonates of the

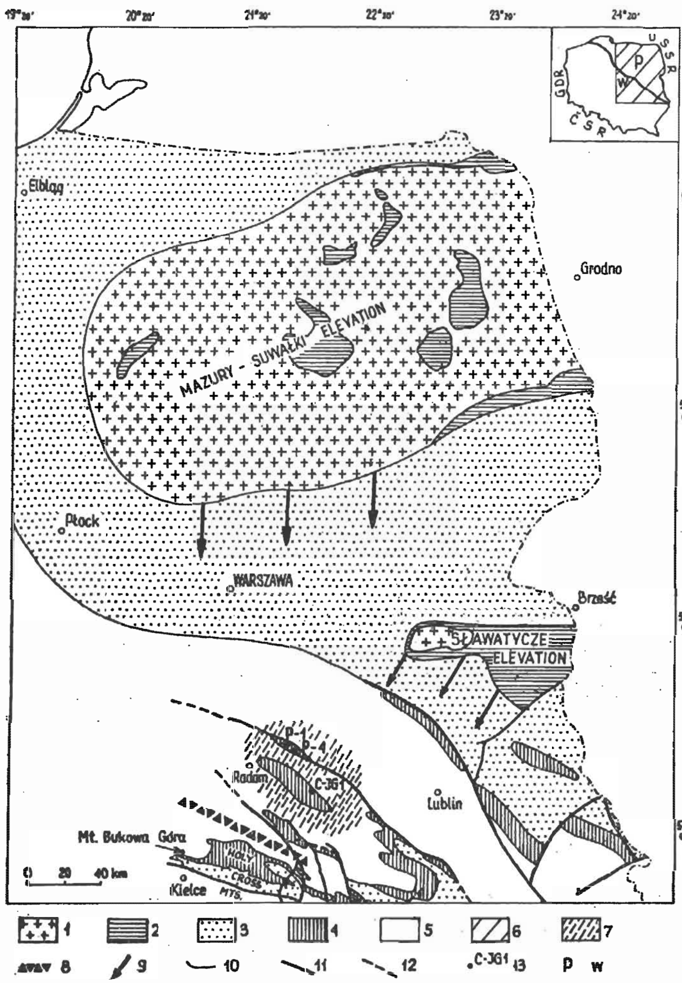


Fig. 1. Simplified, solid geologic map of the northeastern Poland showing Devonian and older sediments (compiled on the basis of Devonian map *in*: Znosko & Pajchlowa, Geological Atlas of Poland, 1968)

1 — Archaic and Proterozoic granitoids, *2* — basalts, tuffs and terrigenic rocks (Pre-Cambrian), *3* —terrygenic and partly carbonate rocks of the Cambrian, Ordovician and Silurian, *4* — Lower Devonian terrygenic rocks, *5* — Middle to Upper Devonian rocks predominantly carbonate, *6* — location of the map fragment within the boundaries of Poland, *7* — western part of the Lublin region dealt with in the paper, *8* — inferred position of a morphologic barrier separating during the Lower Devonian times two sedimentary basins: West Lublin and Łysa Góra (northern part of the Holy Cross Mts), *9* — main transport directions of clastic material in the Lower Devonian toward the sedimentary basin in the western part of the Lublin region with suggestion of the source areas, *10* — erosive boundaries separating the particular series — according to recent geophysical and borehole data; *11* and *12* — proved (*11*) and inferred (*12*) trend of important faults and flexures; *13* — boreholes dealt with in the paper; *P* — East-European Platform, *W* — Warszawa

Frasnian, Givetian, and possibly Late Eifelian age; the carbonates are underlain by the Upper Siegenian to Eifelian continental terrigenous deposits overlying in turn sediments bearing a marine fauna of Early Siegenian and possibly Late Gedinnian age. Continental deposits of unknown age have been recorded to underlie the Triassic strata in the neighboring borehole Pionki *1* (Figs 1—2). The data supplied by the borehole Ciepielów *IG-1* were studied in detail by staff geologists of the Geological Institute, Warsaw (Niemczycka 1974). Stratigraphy and lithology of the Devonian strata recorded in the borehole Pionki *4* are presented in an unpublished paper by Łobanowski (1967) commisioned by the Bureau of Geological Documentation and Design, Warsaw. Selected problems in stratigraphy and lithology of those strata were also discussed by Łobanowski (1976) within the framework of the research programme Geodynamics of Poland undertaken by the Institute of Geological Sciences of the Polish Academy of Sciences. The Devonian found in the borehole Pionki *1* has thus far not been studied.

The present authors are indebted to the Director of the Oil Mining Survey "Geonafta" in Warsaw for making available the borehole cores. Docent Wiesław Bednarczyk, Director of the Laboratory of Stratigraphy of the Institute of Geological Sciences, is gratefully acknowledged for discussion of several topics considered in this paper and critical reading of the manuscript. Thanks are also due to Docent A. Nowakowski, Institute of Geochemistry, Mineralogy, and Petrography of the Warsaw University, for his valuable comments on the part of the text dealing with lithology.

The present work was carried over within the framework of the MR problem "*Geodynamics of Poland*"

STRATIGRAPHY

In the borehole Pionki *1* (Figs 1—2), 409.0 m thick, continental Devonian deposits underlying the Triassic have been recorded at the depth interval 1396.0 to 1805.0 m. These are mottled siltstones with minor amounts of claystones and fine-grained sandstones. The core covers 101.0 m in thickness, which makes up 24.7% of the set thickness. The mottled, bedded, deposits lacking any sedimentary structures are non-fossiliferous which makes obviously impossible their biostratigraphic analysis.

In the borehole Pionki *4*, Frasnian down to Upper? Gedinnian deposits have been recorded at the depth interval 1378.5 to 3036.4 m (i.e. 1657.9 m in thickness, without dip reduction taken into account). The Lower Devonian deposits with a marine fauna cover the depth interval 2770.0 to 3036.4 m (i.e. 266.4 m in thickness); they are of Early Siegenian and possibly Late Gedinian age. They are overlain by continental sediments assigned to the Upper Siegenian, Emsian, and at least Lower Eifelian, recorded at the depth interval 1800.0 to 2770.0 m (i.e. 970.0 m in total thickness). Marine carbonate rocks of Frasnian, Givetian, and possibly Late Eifelian age have been found at the depth interval 1378.0 to 1765.0 m (i.e. 387.0 m in thickness). The core taken from the Lower Devonian including the continental Eifelian deposits covers merely 11% of the total thickness of the set, which makes indeed difficult both stratigraphic and sedimentologic analyses. The core efficiency is 59.4% in the neighboring borehole Ciepielów *IG-1* (Fig. 2) in the Lower Devonian Series attaining there a considerable thickness and resembling closely the coeval rocks recognized in the borehole Pionki *4* (Miłaczewski 1974). The Devonian is clearly tripartite in lithology in the borehole Pionki *4*, which permits their biostratigraphic zonation and easy lithostratigraphic identification. The carbonate deposits at the

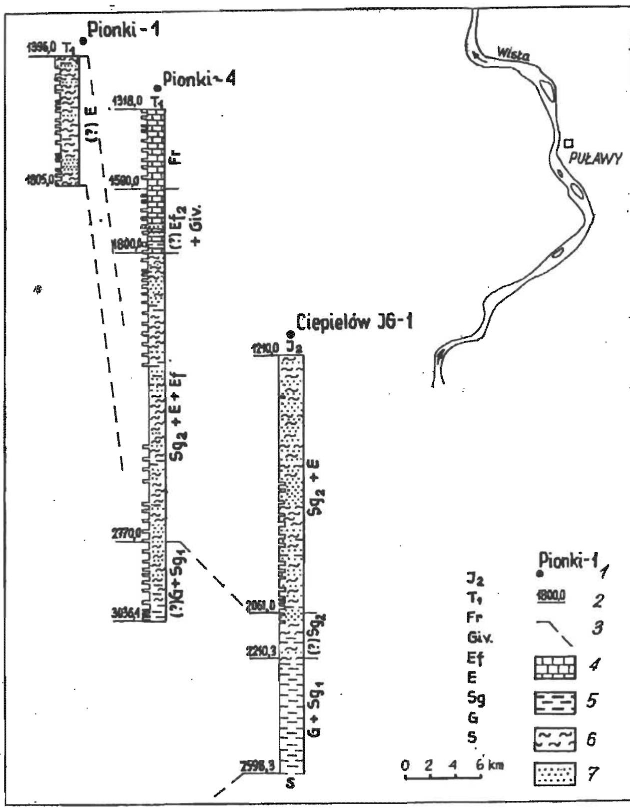


Fig. 2. Topographic location of boreholes and stratigraphy and correlation of the pierced Devonian sediments

1 — location of boreholes, *2* — depth in meters, *3* — correlation lines for sediments of the same age, *4* — carbonates, *5* — claystones, *6* — siltstones, *7* — sandstones
J_2 — Middle Jurassic sediments, T_1 — Lower Triassic sediments, *F* — Frasnian, *Giv* — Givetian, *Ef* — Eifelian, *E* — Emsian, *Sg* — Siegenian, *G* — Gedinnian, *S* — Silurian

top of the system are limestones and dolomites with a marine fauna. The underlying continental deposits are represented mostly by grey and mottled siltstones with minor amounts of claystones and fine-grained sandstones. The lowest portion of the system comprises dark siltstones and claystones intercalated with limestones, with a marine fauna (Figs 2, 8). This apparent lithofacies succession permits an application of the lithostratigraphic subdivision proposed by Miłaczewski (1975). For the moment, however the present authors follow merely the chronostratigraphic attributions because the study by Miłaczewski remains thus far in press.

The data supplied by the borehole Ciepielów *IG-1* were analysed by several authors who published separately (Krassowska & Kulczycki 1963; Hajłasz 1968; Jakubowska 1968) and thereafter jointly (Niemczycka 1974) reports on the Upper Silurian and Lower Devonian macro- and microfossils, stratigraphy, facies development, and paleogeography. Their stratigraphic scheme is to be considered as a standard also for the equivalent strata of the borehole Pionki *4*. In the latter borehole, the Lower to partly Middle Devonian set of sedimentary rocks lacking any marine fossils shows a continuous transition to both the underlying and overlying sets comprising each a marine fauna. The dark claystones intercalated with limestones and passing upwards into siltstones (depth interval 3036.4 to 2770.0 m), with a bivalve-brachiopod fauna in the limestones, are analogous in lithology to the deposits recorded in the borehole Ciepielów *IG-1* at the depth interval 2598.3 to 2210.3 m. Accordingly to Dr. E. Tomczykowa (oral communication), the bivalve-brachiopod fauna resembles that one yielded by the top portion of the considered set of the section Ciepielów *IG-1*. Tomczykowa (1974) and Tomczyk (1974) attributed that lithological set to the Gedinnian to Siegenian. In both the boreholes (cf. Miłaczewski 1974), the dark claystones are replaced upwards with siltstones intercalated at the top with sandstones. In addition to minute bivalves, there are also fragmented eurypterid carapaces. There are no marine fossils at the depth of 2770.0 m in the borehole Pionki *4*. The transitional deposits found in the borehole Ciepielów *IG-1* at the depth interval 2210.3 to 2061.0 m (Fig. 2) have been assigned to the Upper Siegenian (Tomczykowa 1974, Tomczyk 1974). In the borehole Pionki *4*, the transitional deposits occur at the depth interval 2770.0 to 1800.0 m and are overlain by grey siltstones intercalated with sandstones, sometimes with plant detritus but never with marine fossils. Analogous but mottled in color deposits have been recorded at the depth interval 1396.0 to 1805.0 m in the borehole Pionki *1*, and at the depth interval 2061.0 to 1210.0 m in the borehole Ciepielów *IG-1*. Fin spines assigned to *Machaeracanthus* sp. and *Porolepis* sp. have been found in the latter borehole at the depth of 1415.7—1413.2 m (Krassowska & Kulczycki 1963). Accordingly to Kulczycki (op. cit.), the fin spines of the former placoderm are conspecific with their congeners collected from the Emsian sandstones of Daleszyce region, southern Holy Cross Mts. On this basis, Miłaczewski (1974) attributed the upper part of the Devonian deposits found in the borehole Ciepielów *IG-1* to the Emsian, and the whole lithological set lacking any marine fossils to the Upper Siegenian to Emsian (Fig. 2). In the borehole Pionki *4*, the considered deposits with no marine fossils are overlain (beginning with the depth of 1800.0 m) by siltstones and sandstones intercalated with limestones. The latter deposits yielded a brachiopod fauna including *Uncinulus coronatus* (Kayser) (Pl. 1, Figs. 1a—e), *Euryspirifer supraspecious* (Lotze) (Pl. 1, Figs 2a—b; Pl. 2, Figs 2a—d), *Euryspirifer*? sp. (Pl. 2, Fig. 1), and *Eoreticularia aviceps* (Kayser) (Pl. 2, Fig. 3). *U. coronatus* and *E. aviceps* were already reported from Poland. Biernat (1966) recorded them in the Lower Givetian of the Łysogóry region, Holy Cross Mts. In the Rheinische Schiefergebirge (Eifel Mts), these fossils were commonly noted in the Upper Eifelian to Lower Givetian.

The species *Euryspirifer supraspeciosus* (Lotze) has thus far not been recorded in Poland. Solle (1953) considered it as an important guide fossil for the Upper Eifelian to Lower Givetian of the Rhenische Schiefergebirge. In turn, it occurs exclusively in the Couvinian, and especially in its uppermost portion in the Belgian Ardennes (Vandercammen 1963).

Any unequivocal conclusion on the date of the beginning of the Middle Devonian ingression in the Lublin Uplands cannot be drawn from the above discussion. Neither *Uncinulus coronatus*, nor *Eoreticularia aviceps* has thus far been recorded in the Eifelian of the Holy Cross Mts. *Euryspirifer supraspeciosus* occurs in the Belgian Ardennes exclusively in the Couvinian (Vandercammen 1963) but in the Rheinische Schiefergebirge it was also noted in the Lower Givetian (Solle 1953), which suggests that east of the latter area the species may persist at least up to the Lower Givetian. In fact, this is the case of *Eoreticularia aviceps* restricted to the Upper Eifelian in the Rheinische Schiefergebirge but persistent up to the Lower Givetian in the Holy Cross Mts, and up to the Upper Givetian east of Moscow (Biernat 1966, Ljashenko 1959). To summarize up the above discussion, the present authors are of the opinion that the Middle Devonian ingression started in the western Lublin Uplands in the Early Givetian or at most in the latest Eifelian (Fig. 3). Thus, the ingression started in the investigated area much later than in the Łysogóry region of the Holy Cross Mts (Łobanowski 1971).

CORRELATION

A part of the Lower Devonian strata found in the borehole Pionki *4* can be correlated with analogous deposits recorded in the boreholes Pionki *1* and especially Ciepielów *IG-1*. Because of the sedimentary continuity between the Silurian and Lower Devonian strata in the latter borehole, as well as because of their well known paleontology and stratigraphy (Miłaczewski 1974, Tomczykowa 1974, Tomczyk 1974), the section Ciepielów *IG-1* is to be regarded as the type section for the western Lublin Uplands. Unfortunately, there are no uppermost Lower to Middle Devonian strata in that borehole. This gap can be filled up with the strata found in the borehole Pionki *4*. An attempt to correlate both the sections is presented in Figs 2 and 3. The chronostratigraphic subdivision and nomenclature follow those applied by Tomczykowa & Tomczyk (1979) to the Lower Paleozoic of the southwestern slope of the East-European platform. The present authors are of the opinion that the lowermost set of marine deposits recorded in the borehole Pionki *4* is time and facies equivalent to the Ciepielovian Stage and possibly also the uppermost Bostovian Stage of the borehole Ciepielów *IG-1*. Following Miłaczewski (1974), the authors assign the continental deposits of the borehole Pionki *4*, equivalent to the analogous lithological set found in the borehole Ciepielów *IG-1*, to the Upper Siegenian to Emsian. The deposits transitional from the lower marine ones to the overlying continental sediments (at the depth interval 2210.3 to 2061.0 m in the borehole Ciepielów *IG-1*) are non-fossiliferous and hence, their chronostratigraphic position can hardly be unequivocally recognized. As shown by the compendium of paleontological data (Tomczyk 1974, Tab. 2, p. 92), there are no unequivocal criteria for its time attribution. Its lower part may be equivalent to the uppermost part of the Lower Ciepielovian Stage (Lower Siegenian), and its upper part may be equivalent to the Upper Ciepielovian Stage (Upper Siegenian). One may claim

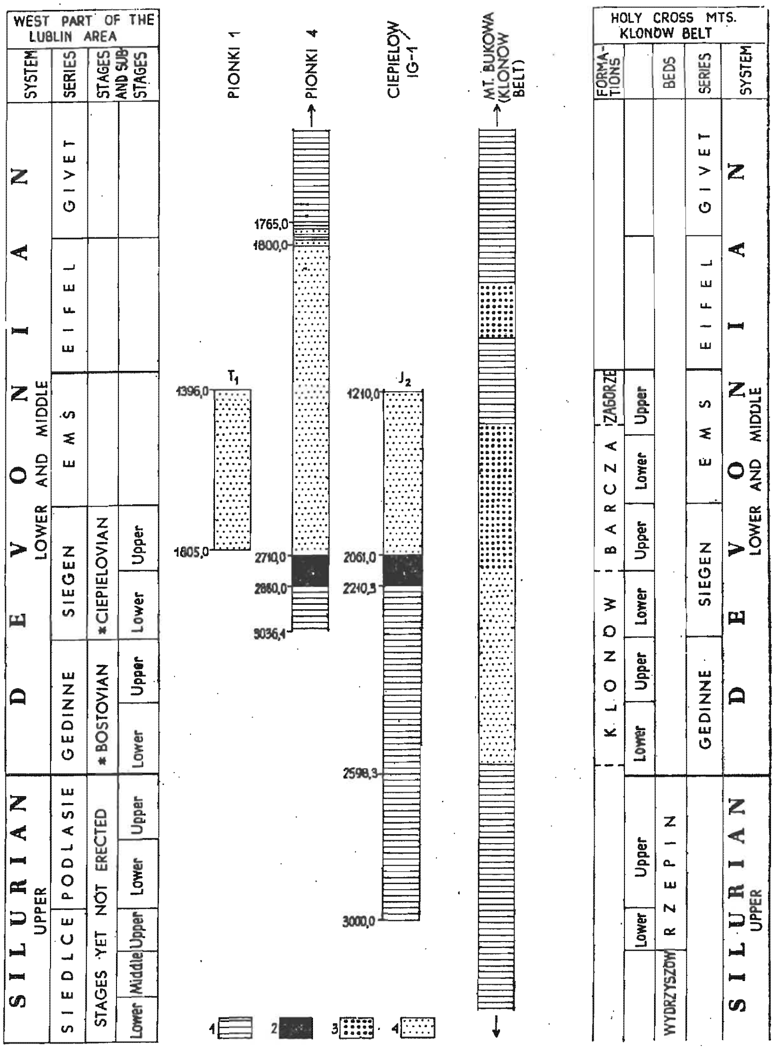


Fig. 3. Facies correlation of the Silurian—Devonian sediments in the western part of the Lublin region with a profile of the same age at Bukowa Góra (the Klonów Belt, Łysa Góra region of the Holy Cross Mts)

Subdivision of the Silurian after Tomczykowa & Tomczyk (1979) and oral information by H. Tomczyk. Regional stages are marked with asterisks. Parts of profiles not marked on drawing are pointed by arrows. Thickness not to scale

1 — **Marine sediments: Silurian and Lower Devonian — terrigenic; Middle Devonian — carbonate-terrigenic; *2* — tidal flat sediments, *3* — continental alluvial fine- to medium-grained sediments, *4* — continental fine grained alluvial sediments**

that for the purposes of regional correlation over the western Lublin Uplands, the Lower Devonian fossiliferous marine deposits are to be regarded as of Gedinnian to Early Siegenian age, while the continental ones as of Late Siegenian, through Emsian to Eifelian age (Fig. 3).

A correlation of the Lower Devonian to Eifelian strata of the western Lublin Uplands with their time equivalents found in the northwestern Klonów Range, Łysogóry region, Holy Cross Mts, is presented in Fig. 3. The senior author is of the opinion that the substages introduced by him in an earlier paper (Łobanowski 1971) for the Lower Devonian lithostratigraphic units in the latter area are actually of formation rank. Therefore, the units called previously as substages are referred to as formations in Fig. 3.

DESCRIPTION OF THE FOSSILS

Family **Uncinulidae** Rzhonsnickaja, 1956
Genus *UNCINULUS* Bayle, 1878
Uncinulus coronatus (Kayser, 1871)
(Pl. 1, Fig. 1a—e)

1871. *Rhynchonella coronata*; E. Kayser, p. 512, Pl. 9, Fig. 5.
1904. *Rhynchonella coronata* Kayser; D. Sobolev, p. 94, Pl. 9, Fig. 23.
1941. *Uncinulus coronatus* (Kayser); H. Schmidt, p. 24, Pl. 2, Fig. 24; Pl. 4, Fig. 73; Pl. 6, Fig. 18.
1966. *Uncinulus coronatus* (Kayser, 1871); G. Biernat, p. 86—88, Pl. 19, Figs 27—29; Text-fig. 28.

Locality: borehole Pionki *4*, depth of 1765.2 to 1759.3 m.
Material: a single shell.
Dimensions (in mm):

length	width	convexity	sulcus width
14.0	19.0	9.5	8.5

Description. — Shell triangular-oval in outline. Dorsal valve attains its maximum convexity in the anterior part where it forms a distinct fold. Ventral valve convex in its beak part, concave in the anterior part where a wide sulcus appears delimited on both sides by well developed wings.

Ornamentation. — Shell covered entirely with 20 radial, sharp-crested costae. The sulcus and fold show each 5 alternately located costae.

Remarks. — A comparison of a single specimen to numerous and often dissimilar ones illustrated by previous authors (cf. Schmidt 1941, Pl. 2, Fig. 24, and Biernat 1966, Pl. 19, Figs 27—29) is possible only in fairly vague morphological terms. A single specimen does not allow to recognize the whole range of intraspecific variability in subordinate morphological features. The general characteristics of the investigated specimen, that is the shell outline, dimensions, and number of costae, are close to the mean figures for the species as presented in descriptions and illustrations referred to in the synonymy.

Occurence. — Middle Devonian of Europe. In Germany (Rheinische Schiefergebirge, Eifel Mts), the species was recorded in the uppermost Eifelian (Junkenberg—Schichten, "*Ostiolatus*" Horizon). In Poland, it occurs in the Lower Givetian of the Łysogóry region, Holy Cross Mts.

Family **Delthyrididae** Waagen, 1883
Genus *EURYSPIRIFER* Wedekind in Salomon, 1926
Euryspirifer supraspeciosus (F. Lotze, 1928)
(Pl. 1, Fig. 2a—b)

1928. *Spirifer supraspeciosus*; F. Lotze, p. 87, Pl. 2, Figs 5—7.
1953. *Hysterolites (Acrospirifer) supraspeciosus* (Lotze 1928); G. Solle, p. 133, Pl. 16, Figs 228—233; Pl. 17, Figs 234—243; Pl. 18, Figs 244—249.

1963. *Euryspirifer supraspeciosus* (F. Lotze, 1928); A. Vandercammen, p. 87, Pl. IX, Figs 1—11.
Locality: borehole Pionki *4*, depth of 1796.0 to 1795.6 m and 1765.2 to 1759.3 m.
Material: two ventral valves, one of them incomplete.
Dimensions (in mm):

	length	width	convexity
Pl. 2, Fig. 2a—c	12	ca 44	11
Pl. 1, Fig. 2a—b	13	ca 30	11

Description. — Shell elongate rhomboidal in outline. Ventral valve moderately convex, domed in its beak part. Cardinal margin long; sulcus V-shaped, deep, and fairly narrow, distinct all over the valve in length. Sulcus tongue short, triangular in outline. Costae distinct, sharp-crested, 5 to 6 per half the valve in number. Beak minute, sharp, turned towards the commissural plane. Area low and concave. One of the specimens (Pl. 2, Fig. 2a—c) bears fairly long and narrow wings ended with an elongate, narrow auricle.

Remarks. — The external morphology of the investigated specimens is identical or very close to the characteristics of the species *Euryspirifer supraspeciosus* (F. Lotze, 1928) described in most detail by Solle (1953). The scarcity of material at the present authors' disposal makes impossible any comparison of the investigated two valves with representatives of several subspecies recognized by Solle (1953).

Occurrence. — The considered species appears as an important guide fossil for the lower Middle Devonian of the Belgian Ardennes and the Rheinische Schiefergebirge. In the Ardennes, it is restricted to the Couvinian, most commonly to its upper part (Vandercammen 1963). In the Rheinische Schiefergebirge, the nominal subspecies occurs both in the Upper Eifelian and in the Lower Givetian; three other subspecies erected by Solle (1953) occur exclusively at the top of the Eifelian. The species has thus far not been reported from Poland.

Euryspirifer? sp.
(Pl. 2, Fig. 1)

Locality: borehole Pionki *4*, depth of 1765.2 to 1759.3 m.
Material: half a ventral valve.
Dimensions: ca 40 mm in width.

Description. — Shell transversally elongate, semicircular in outline. Wing semicircular, ended with an elongate, spine-like auricle. Auricle length attains half the shell width. Costae prominent, thick, with tapering crests. There are 4 costae per half the valve. Sulcus narrow.

Remarks. — The poor preservation state makes impossible any more precise identification of the investigated specimen. Its most characteristic features are: long auricle, and merely 4 thick costae per half the valve. The morphological characteristics of the specimen and its comparison to various representatives of the genus *Euryspirifer* presented by Solle (1953) suggest that it may actually belong to that genus.

Family **Reticulariidae** Waagen, 1883
Genus *EORETICULARIA* Nalivkin, 1924
Eoreticularia aviceps (Kayser, 1871)
Pl. 2, Fig. 3)

1871. *Spirifer aviceps;* E. Kayser, p. 578, Pl. 11, Fig. 4.
1966. *Eoreticularia aviceps* (Kayser, 1871); G. Biernat, p. 128, Pl. 30, Figs 1—12; Text-figs 45—46.
Locality: borehole Pionki *4*, depth of 1763.2 to 1762.2 m.
Material: a single ventral valve.
Dimensions (in mm):

length	width
ca 11	ca 18

Remarks. — The valve shape, dimensions, and ornamentation resemble those typical of the species as presented in a comprehensive description and illustrations by Biernat (1966).

Occurrence. — The type material was collected in the Upper Eifelian of the Rheinische Schiefergebirge (Freilingen Beds). In Poland, it occurs in the Lower Givetian of the Łysogóry region, Holy Cross Mts. However, it persists up to the Upper Givetian in the European part of the Soviet Union, east of Moscow (Ljashenko 1959).

LITHOLOGY

The Lower to lower Middle Devonian deposits found in the boreholes Pionki *4* and Pionki *1* were subject to a lithological analysis. Both macro- and microscopic characteristics of the deposits were investigated. Sedimentological analysis was also performed. The results are presented in table form (Table 1) and supplemented with photographs (Pls 3—17). To facilitate an adequate sample location by the reader in the investigated borehole sections, the sample numbering used in the course of the logging process is here applied.

MACROSCOPIC CHARACTERISTICS OF THE DEPOSITS

A detailed lithological sequence found in the Devonian of the borehole Pionki *4* was established by the senior author (Łobanowski 1967) for the purposes outlined by The Oil Mining Survey "Geonafta" in Warsaw. The same author studied in 1975 the core derived from the borehole Pionki *1*.

The general lithological characteristics of the Devonian deposits found in the section Pionki *4*, more complete than the other one, are as follows:

The bottom portion of the sequence (depth interval 3036.4 to 2770.0 m) comprises dark claystones intercalated with limestones and passing upwards into siltstones. There are no sandstones. This lithological set attains 266.4 m in thickness, while the core covers merely 34.7 m in thickness. The deposits contain marine fossils.

This lowermost lithological set is overlain with a sedimentary continuity by 970.0 m thick (depth interval 2770.0 to 1800.0 m) siltstones and sandstones of continental origin. The available core covers 103.0 m of the set thickness, with 82.0 m (79.6%) represented by siltstones and minor amounts of claystones, and the remaining 21.0 m (20.4%) represented by sandstones. In the borehole Pionki *1*, the equivalent continental deposits occur at the depth interval 1805.0 to 1396.0 m (409.0 m in thickness); 84.0 m (83.2%) of the available 101.0 m long core are represented by siltstones, and the remaining 17.0 m (16.8%) by sandstones. In both the boreholes, the continental deposits are predominantly grey to mottled in color; there are aquamarine-grey, aquamarine-cherrish, cherrish, and grey siltstones, and light-grey sandstones. The siltstones include dolomitic concretions.

Beginning with the depth of 1920.0 m, the lithology changes gradually in the borehole Pionki *4*. At first, grey-yellowish sandstones with carbonized plant detritus become dominant; these are still continental deposits. Higher in the section, beginning with the depth of 1800.0 m, sandstones with carbonate intercalations appear overlain in turn by pure carbonate deposits with an abundant marine fauna (Fig. 8). A similar lithological sequence was reported from the borehole Ciepielów *IG-1* by Miłaczewski (1974). In the latter section, the deposits transitional from marine to continental ones (depth interval 2210.3 to 2061.0 m) included mostly siltstones and claystones (86.6%) with sandstones occurring but subordinately (13.4%). The overlying set of continental deposits (depth interval 2061.0 to 1210.0 m) comprises mostly siltstones and claystones (66%) but with considerable amounts of sandstones (34%).

The above presented data show that the thick terrigenous Lower Devonian deposits consist in the study area mostly of fine-grained material; they are dominated by siltstones and claystones with fine-grained sandstones present in minor amounts, and conglomerates lacking at all.

MICROSCOPIC ANALYSIS

The grain-size-distribution of quartz has been determined for 13 thin sections (200 measurements per thin section) of the sandstones. The histograms for six most characteristic thin sections are presented in Fig. 4. As indicated by the grain-size-distributions, the basic fractions are represented by very fine sand and coarse silt. The Eifelian sandstones (Fig. 4, sample 30) include medium, fine, and very fine sandy fractions, with the fine-grained sand as the predominant one (cf. Pettijohn et al. 1972, Tab. 3-2, Gradziński & al. 1976, Tab. 3—1). As judged from the histograms, the deposits are moderately sorted, with the Eifelian sandstones sorted a little better than the older ones.

There is no variation in composition and structure of the detritic material but the proportions of various components vary in the section (Tab. 1, Fig. 5). The sandstones recorded at the bottom of the section are fine-grained, psammitic in structure, with slight addition of the aleuritic fraction. The modal grain size is 0.1, mm but the grains range sometimes up to 0.2 mm in size. In turn, the sandstones found at the top of the investigated section (samples 29 and 30) are well sorted, with grains ranging from 0.2 to 0.3 mm in size, without any addition of aleuritic fraction. In general, the detritic material is sharp--edged but at the top of the section, the grains show sometimes rounded angles. Most commonly, the sandstones show a parallel banding structure reinforced also by the orientation of flaky minerals clustered usually in bands, and in some samples by band-like accumulations of clay material. The rocks are to be recognized for quartz sandstones dominated by monocrystallic quartz showing a straight to (rarely) wavy extinction of light. The quartz makes up 52 to 82% of the rock in volume. Sometimes, micaceous inclusions or other microlitic dark mineral appear in quartz grains. All the other rock components occur in variable amounts in the section. Feldspars account for 3.3 to 13.2% of the rock volume. The most common are potassium feldspars dominated by microcline with a characteristic twin network (Pl. 3, Figs 1—2). They are associated with plagioclases in form of albitic twins of albite or oligoclase (Pl. 4, Figs 1—2). The plagioclases are less common than the potassium feldspars and account for 1.3 to 5.8% of the rock volume. Most feldspar grains are pure and fresh, only a few ones (both plagioclases and potassium feldspars) are opaque and a little brownish. Micas are represented by muscovite and biotite in form of long flakes and somewhat thicker patches. The flakes are commonly wavy to twisted, arranged usually in bands reinforcing the laminar nature of the rocks (Pl. 5, Figs 1—2). Biotite patches are sometimes intergrown with muscovite (Pl. 5, Fig. 2). The flakes are greater than the quartz and feldspar grains in dimensions, as a rule. The modal diameter of mica flakes ranges from 0.2 to 0.3 mm, but it ranges up to 0.4—0.5 mm at the top of the section. Some flakes range up to 0.8 to 1.0 mm and sporadically even up to 1.4 mm in diameter. Muscovite flakes are usually fresh; rarely, fine-scaled varieties appear. Most biotite flakes are also fresh but a few ones are bleached and with a decreased birefringency. Minute accumulations of iron oxides appear sometimes at the cleavage planes. The biotite shows a pleochroism (mostly green to

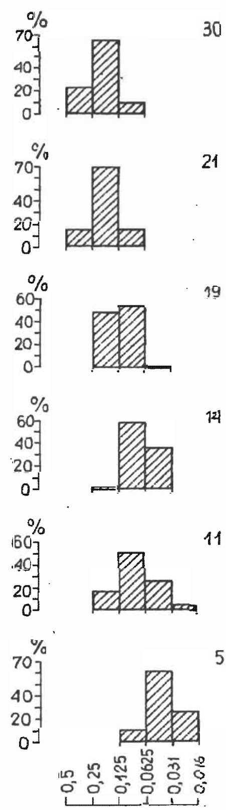


Fig. 4
Histograms of grain composition of Devonian sandstones in the Pionki 4 borehole. Numbers 5—30 designate the sample numbers (compare with Figs 5 and 8)

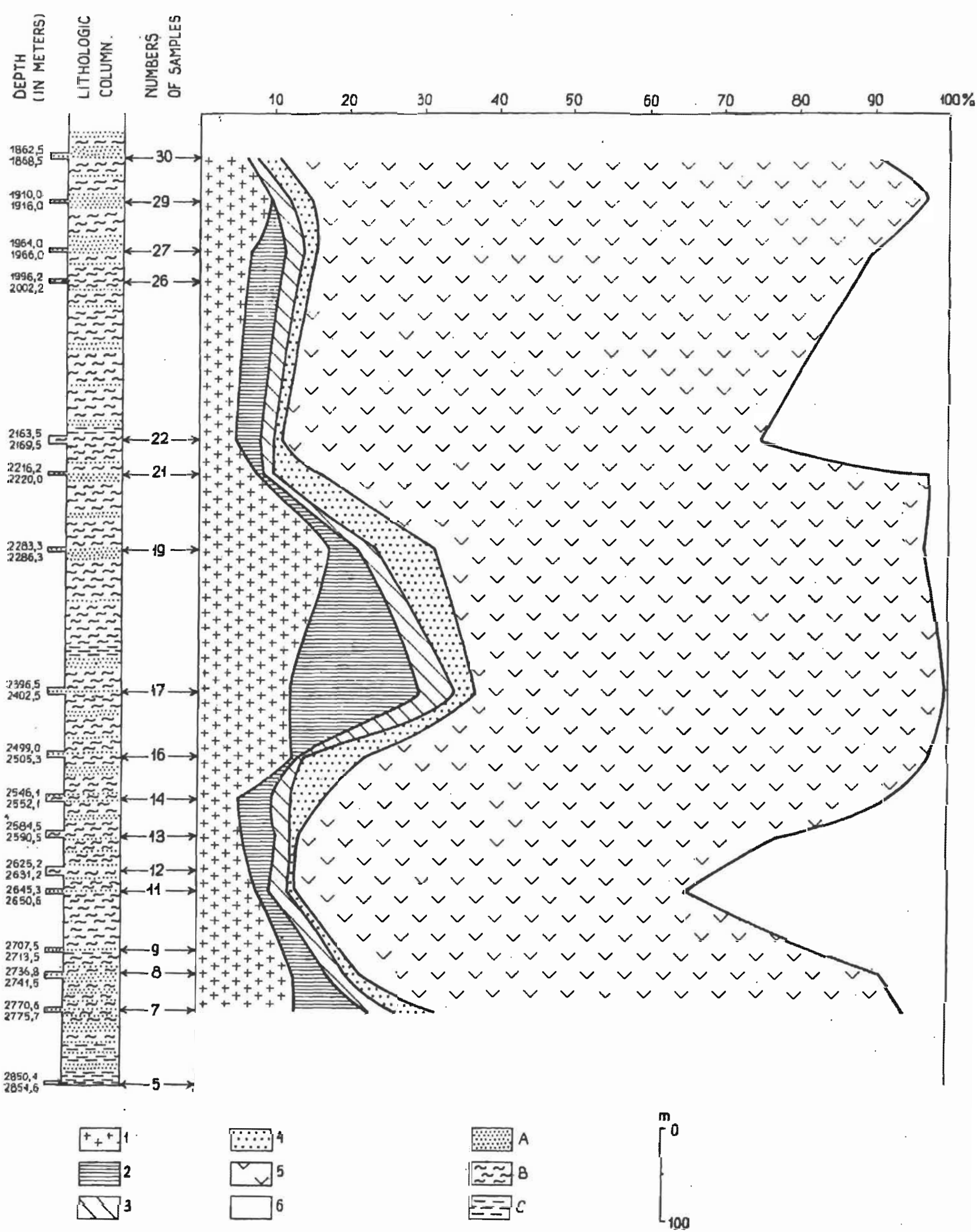
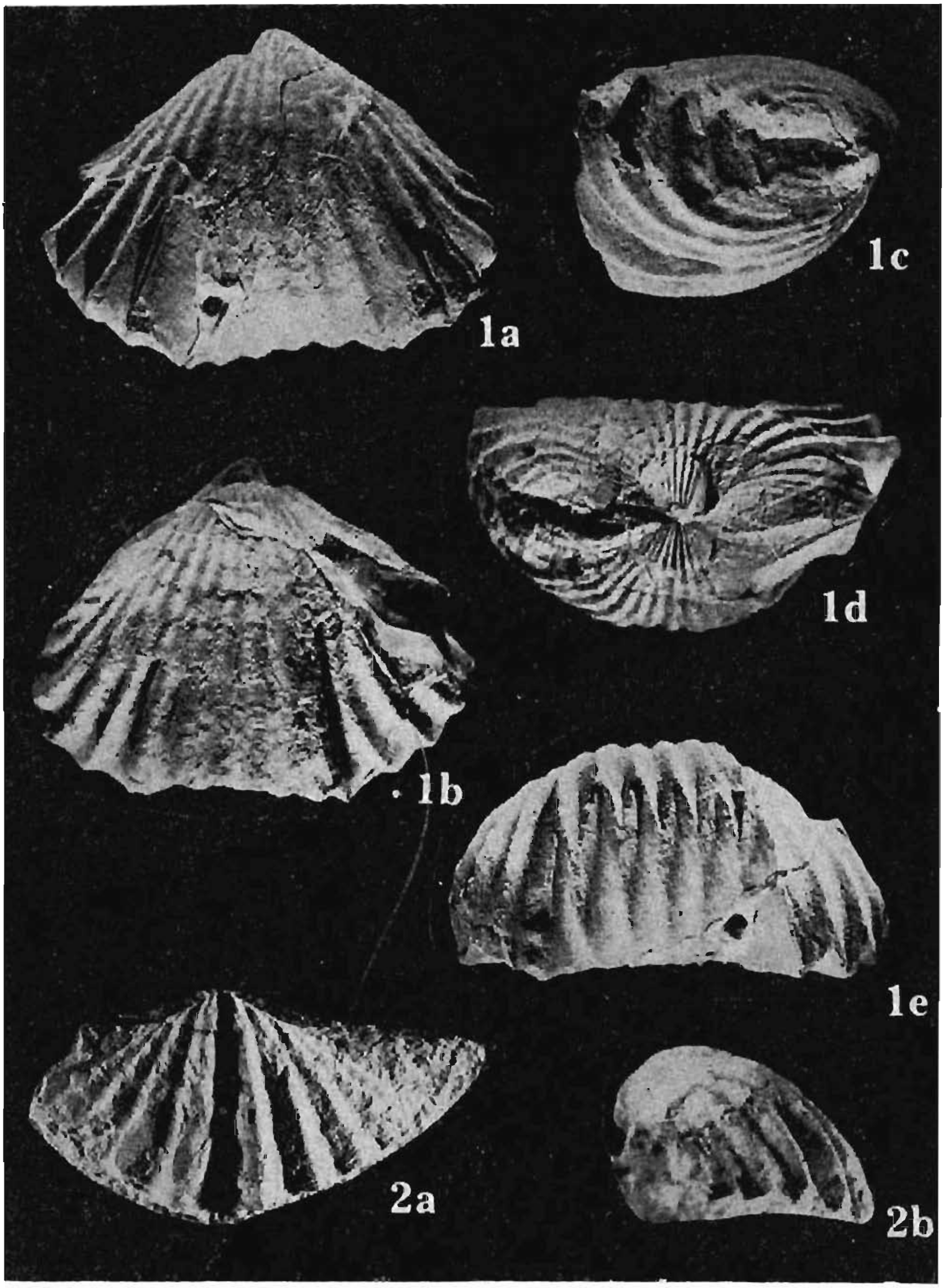


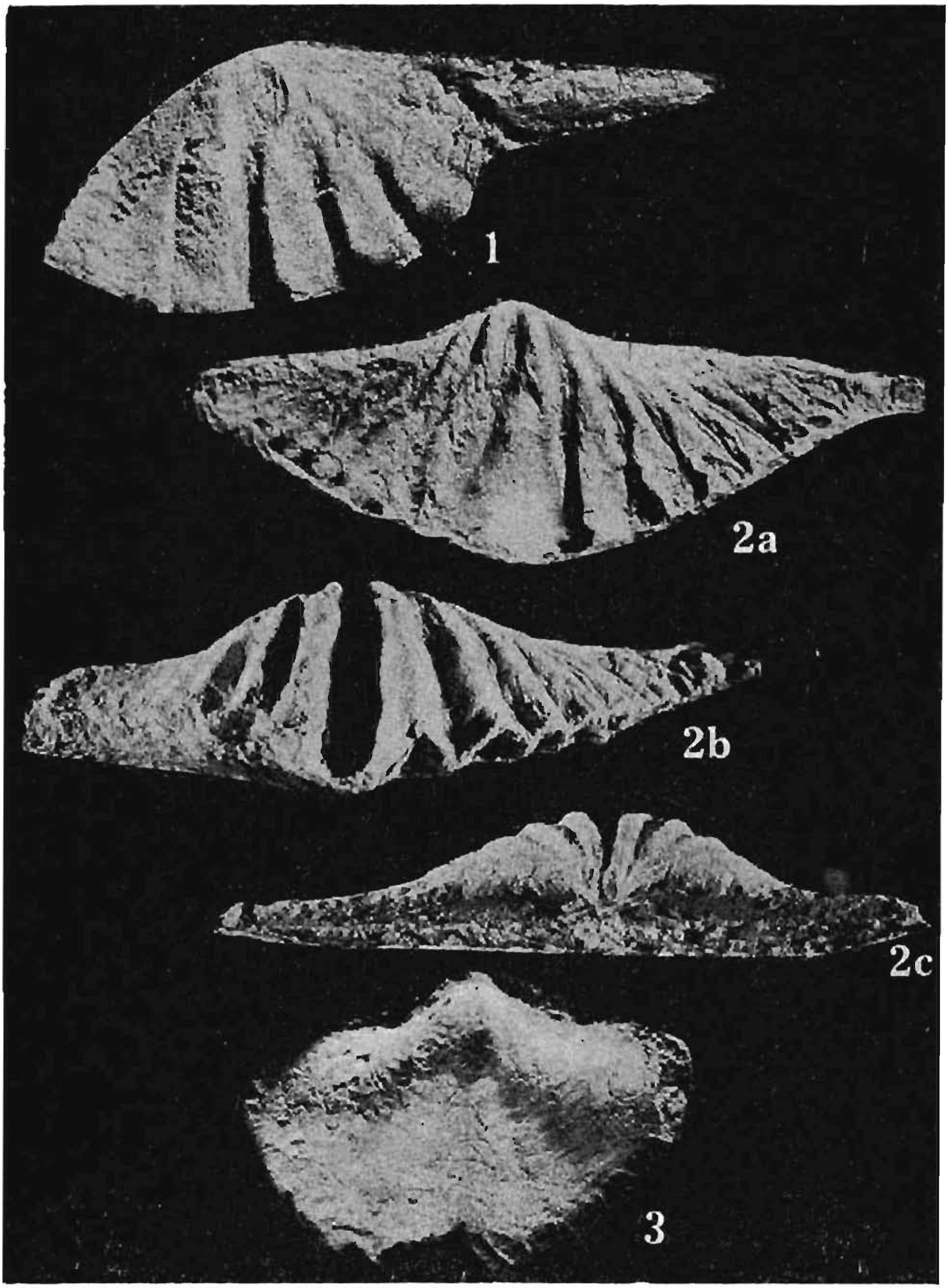
Fig. 5. Mineral composition of the Devonian sandstones from the Pionki 4 borehole (in volume percents)

1 — feldspars, *2* — biotite and flaky chlorite, *3* — muscovite, *4* — clay and siliceous clasts, *5* — quartz; *6* — other components such as: accessory minerals, non transparent minerals, clayey cement, carbonates. Symbols of rocks in profile: *A* — sandstone, *B* — siltstone, *C* — claystone.

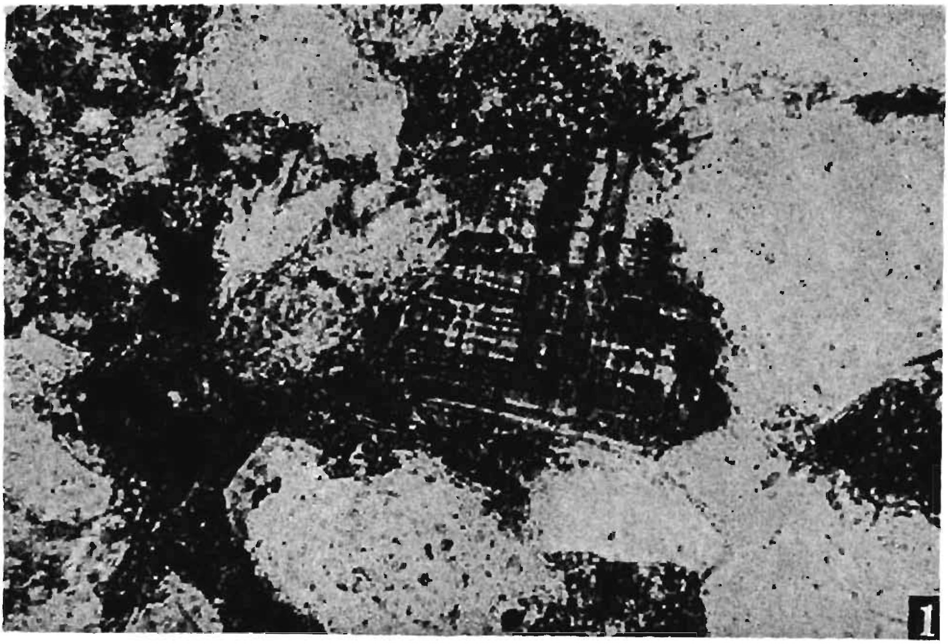


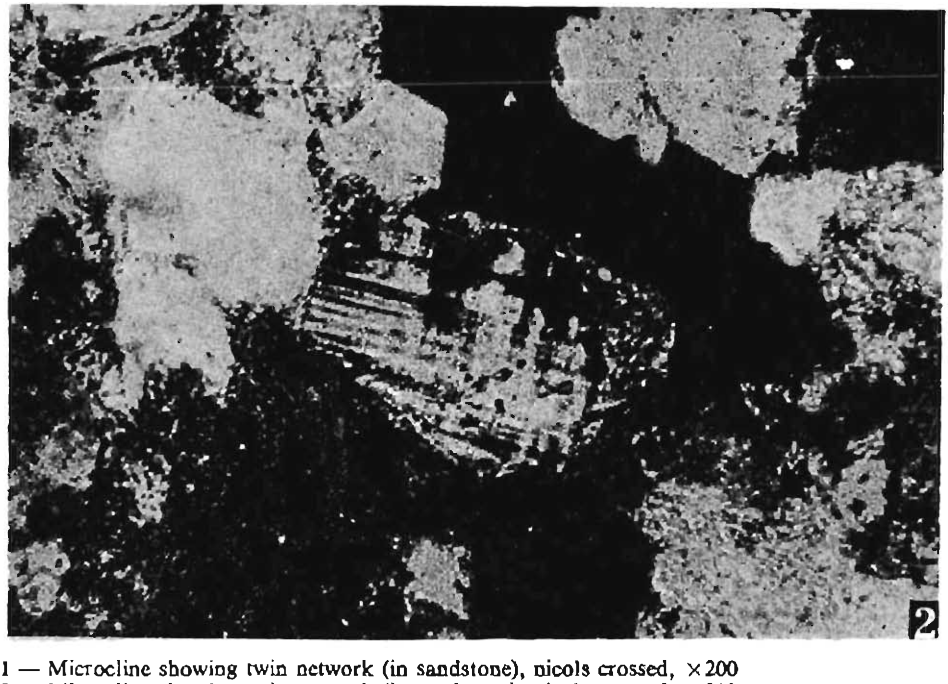
1a—e — *Uncinulus coronatus* (Kayser, 1871); shell in five different positions, Pionki *4* borehole, depth 1765.2—1759.3 m, ×4

2a—b — *Euryspirifer supraspeciosus* (F. Lotze, 1928); *a* ventral shell, top view, ×2.3; *b* same shell, side view, ×2.3; Pionki *4*, 1765.2—1759.3 m

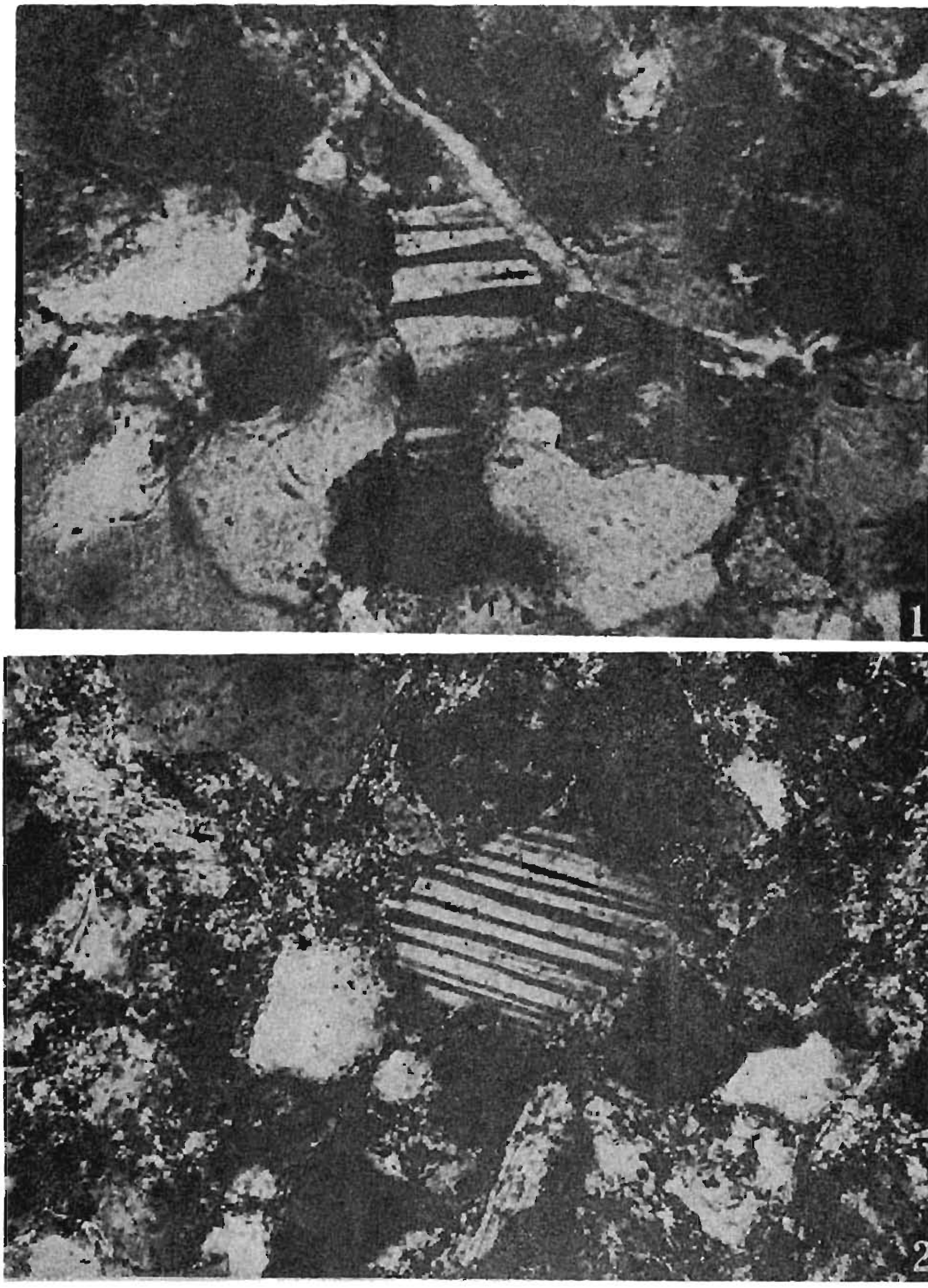


1 — *Euryspirifer*? sp.; *a* fragment of ventral shell, ×4, Pionki *4*, 1765.2—1759.3 m
2a—c — *Euryspirifer supraspeciosus* (F. Lotze, 1928); *a* ventral shell, top view, ×2.7; *b* same shell, view of anterior part, ×2.7; *c* same shell, view of posterior part, ×2.5; Pionki *4*, 1796.0—1795.6 m
3 — *Eoreticularia aviceps* (Kayser, 1871); ventral shell, top view, ×4, Pionki *4*, 1763.2—1762.2 m

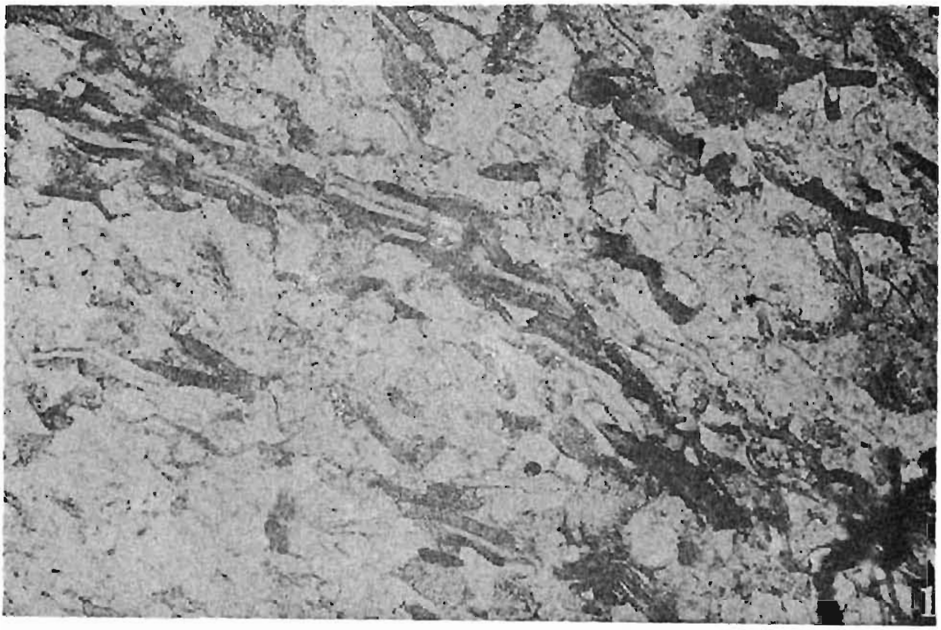


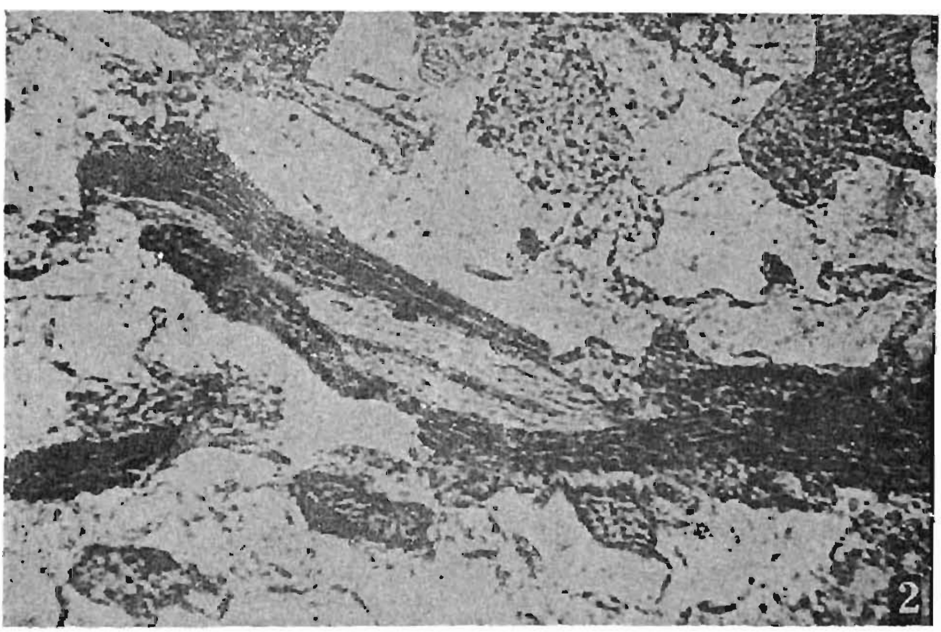


1 — Microcline showing twin network (in sandstone), nicols crossed, ×200
2 — Microcline showing twin network (in sandstone), nicols crossed, ×200
Pionki *4*, sample 27, depth 1966.0—1964.0 m



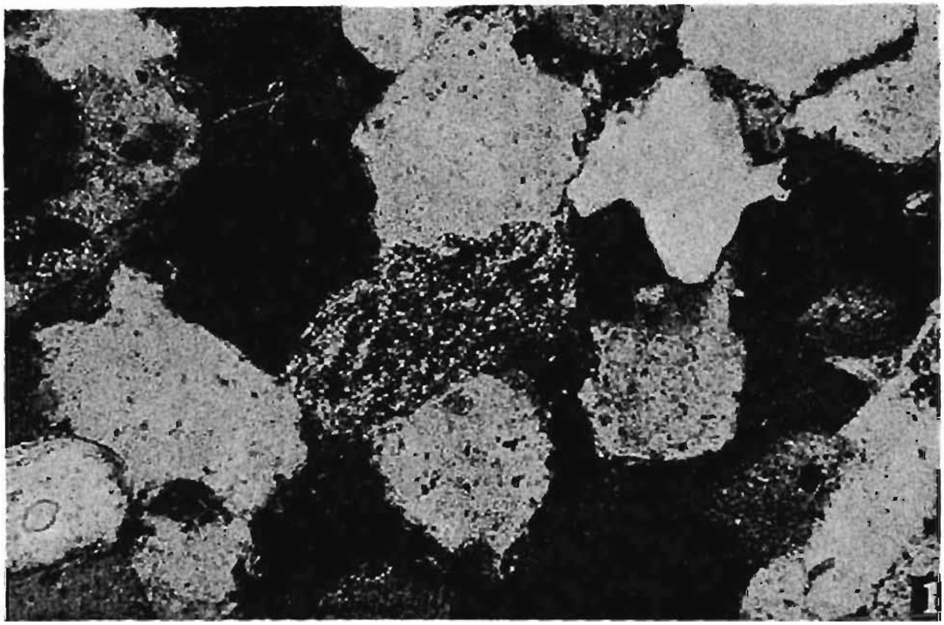
1 — Albite twinned plagioclases (in sandstone), nicols crossed, ×200, Pionki *4*, sample 7, 2775.7—2770.6 m
2 — Albite twinned plagioclases in siltstone with clayey matrix, nicols crossed, ×200 Pionki *4*, sample 26, 2002.2—1996.2 m

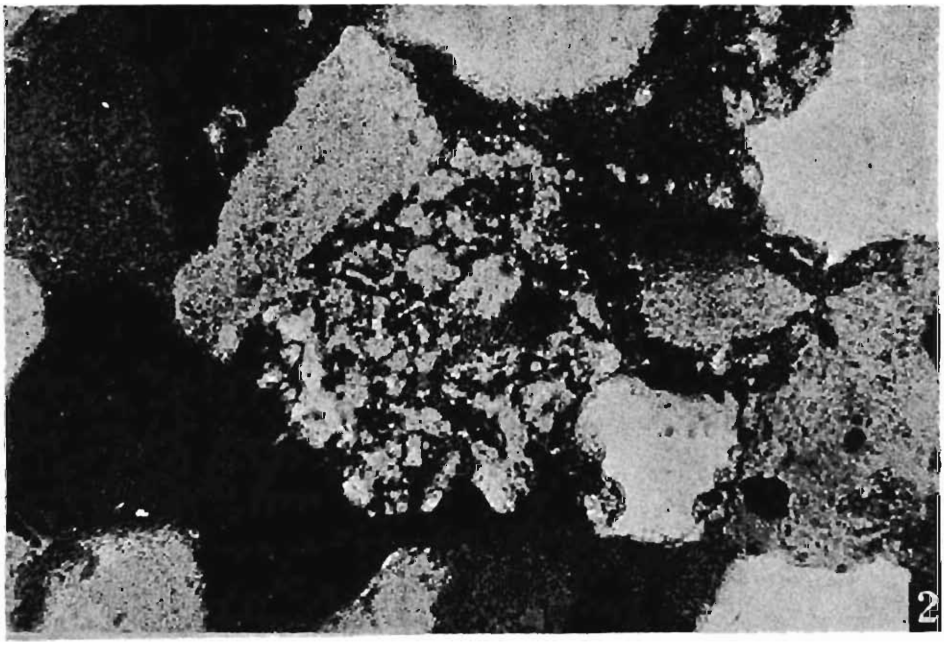




1 — Flakes of streak oriented micas: biotite and muscovite (in sandstone), nicols parallel, ×50
Pionki *4*, sample 17, 2438.3—2432.3 m

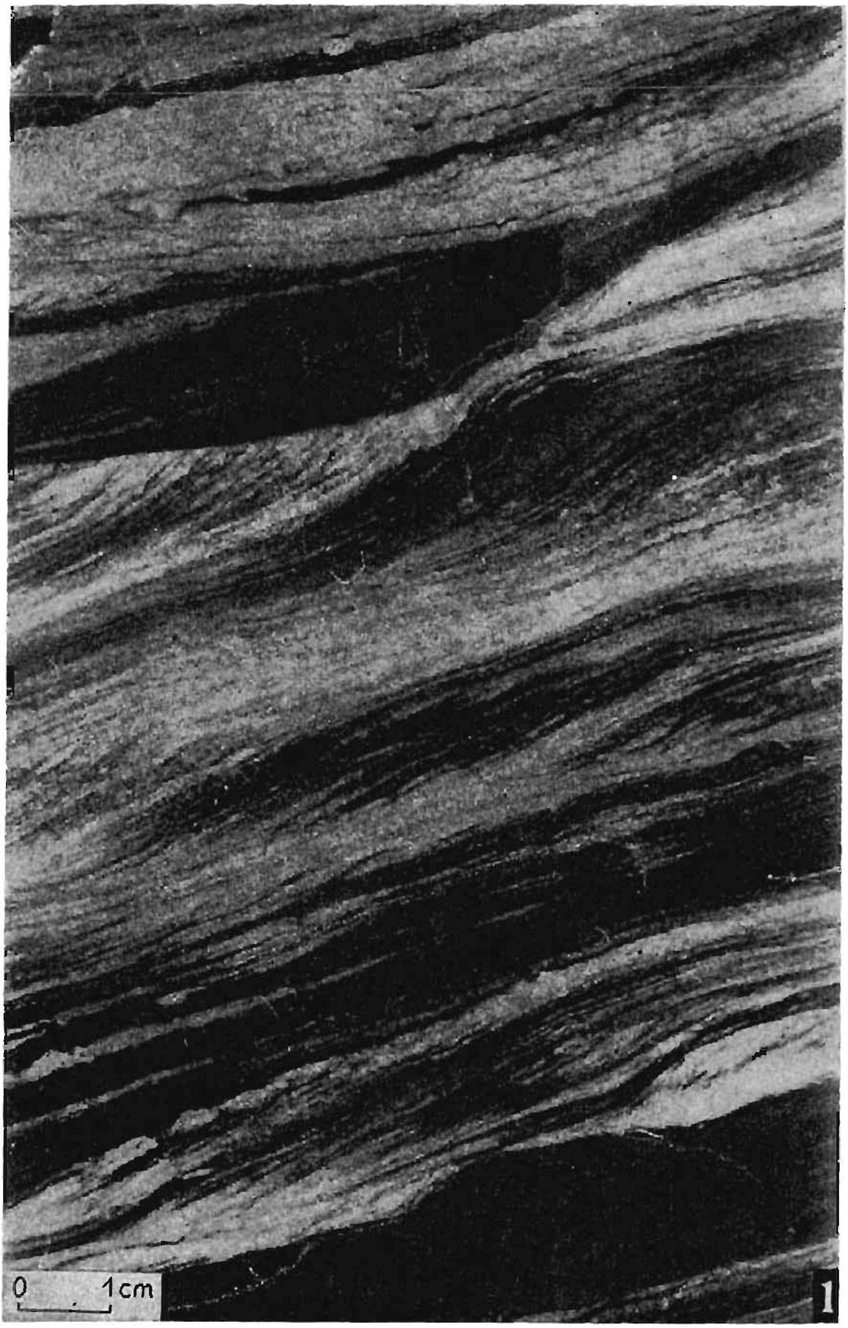
2 — Biotite intergrown by muscovite (in sandstone), nicols parallel, ×160, Pionki *4*, sample 17, 2438.3—2432.3 m





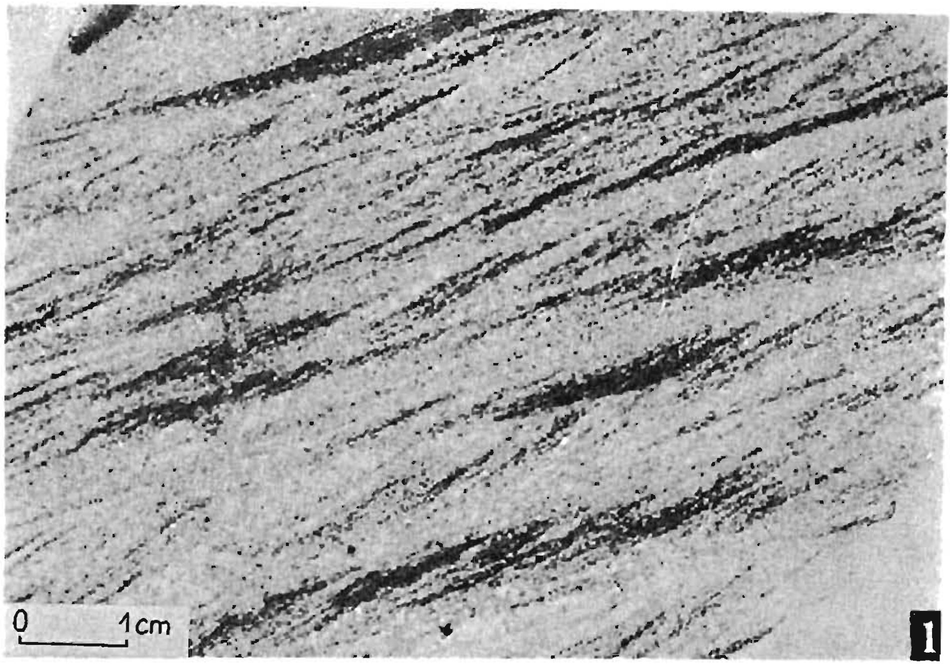
— Clayey-illite fragment in sandstone, nicols crossed, × 150, Pionki *4*, sample 29, 1916.0—1910,0 m
— Siliceous fragment in sandstone, nicols crossed, × 150, Pionki *4*, sample 21, 2220.0—2216.0 m

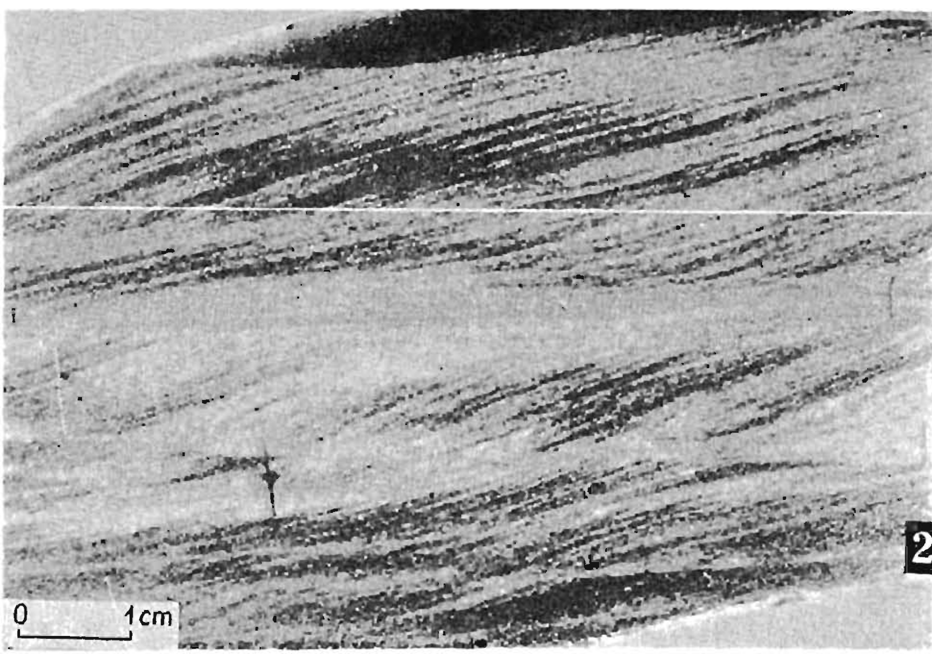
1 — A fragment of core showing siltstone of composite bedding. At bottom delicate parallel bedding, discontinuous, higher up (at right) passing into delicate cross bedding of small scale, then wavy flaser bedding. At top indistinct parallel bedding, discontinuous. Section parallel to current direction. Pionki *4*, sample 4, depth 2882.1—2876.1 m



1 — A fragment of core showing siltstone of composite bedding. At bottom dark siltstone of washed surface is overlain by siltstone of sinusoidal ripple lamination (type S), which then passes into parallel bedding (in dark siltstone). Higher up parallel bedding is replaced again by sinusoidal ripple lamination. In the top part of core erosional furrow infilled with dark siltstone of delicate parallel bedding. At top discontinuous parallel bedding, slightly wavy with fine bioturbation structures. Section parallel to current direction.

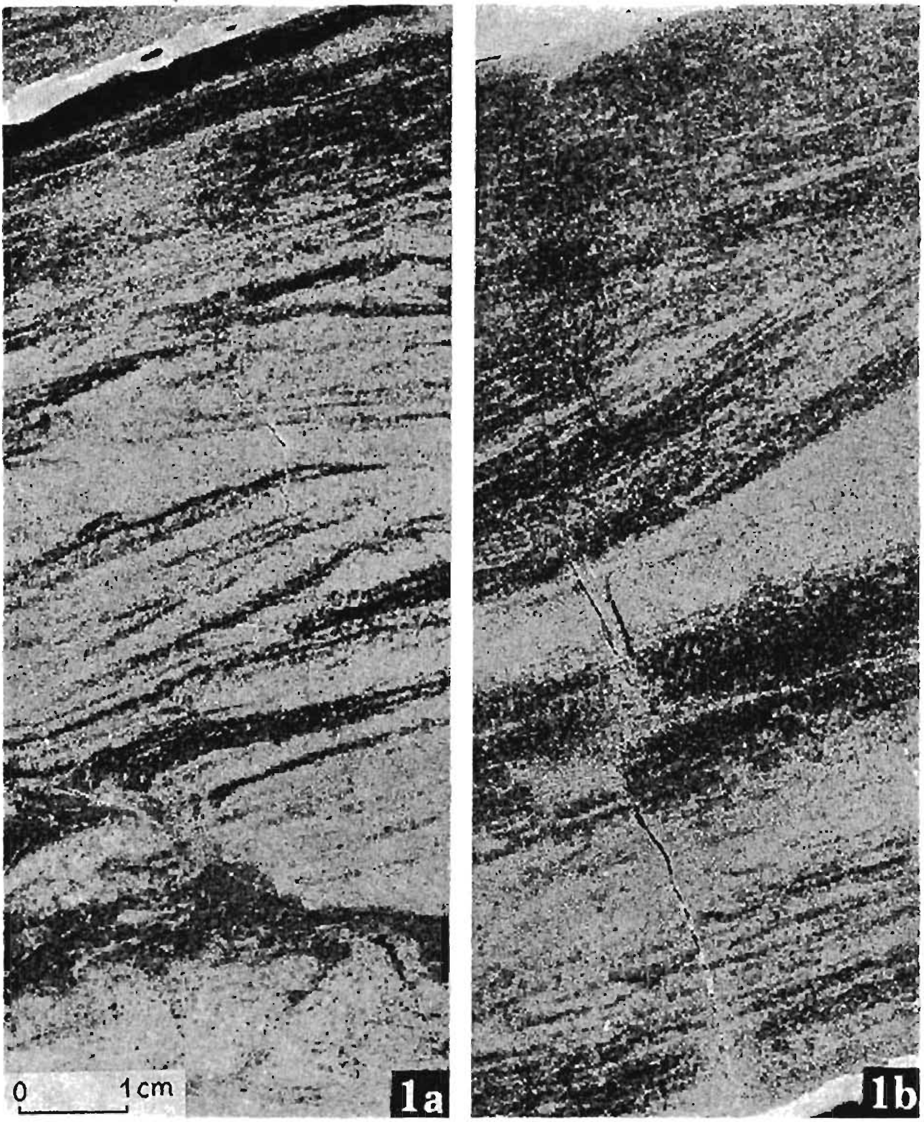
Pionki *4*, sample 7, 2775.7—2770.6 m



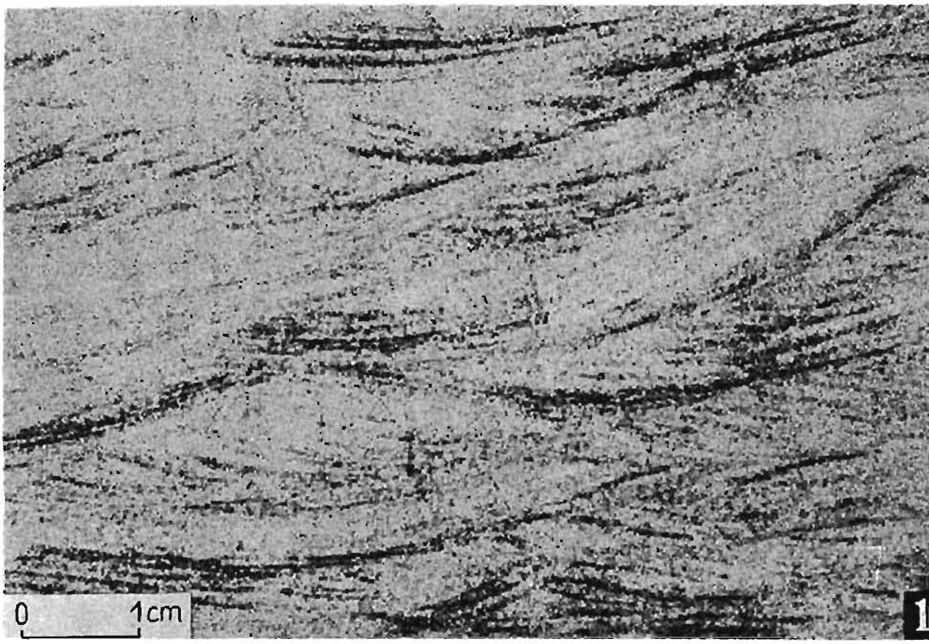


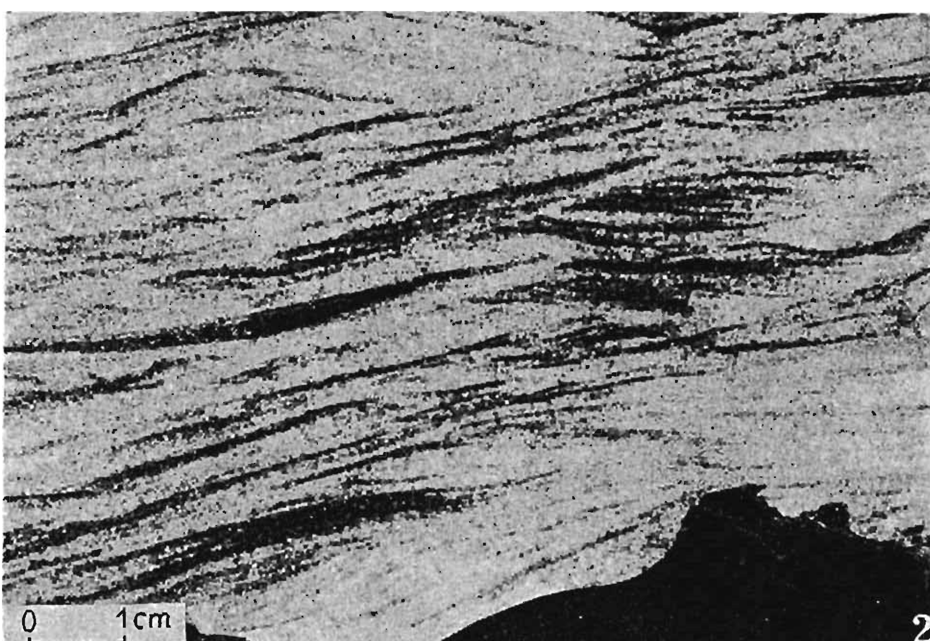
1 — Ripple drift cross lamination, type *A*. Section parallel to current direction. Pionki *1*, 1757.0—1751.0 m

2 — Ripple drift cross lamination, type *B*. Outwash surface with siltstone layer of very delicate parallel bedding in the center of specimen. Section parallel to current direction. Pionki *4*, sample 9, 2713.5—2707.5 m



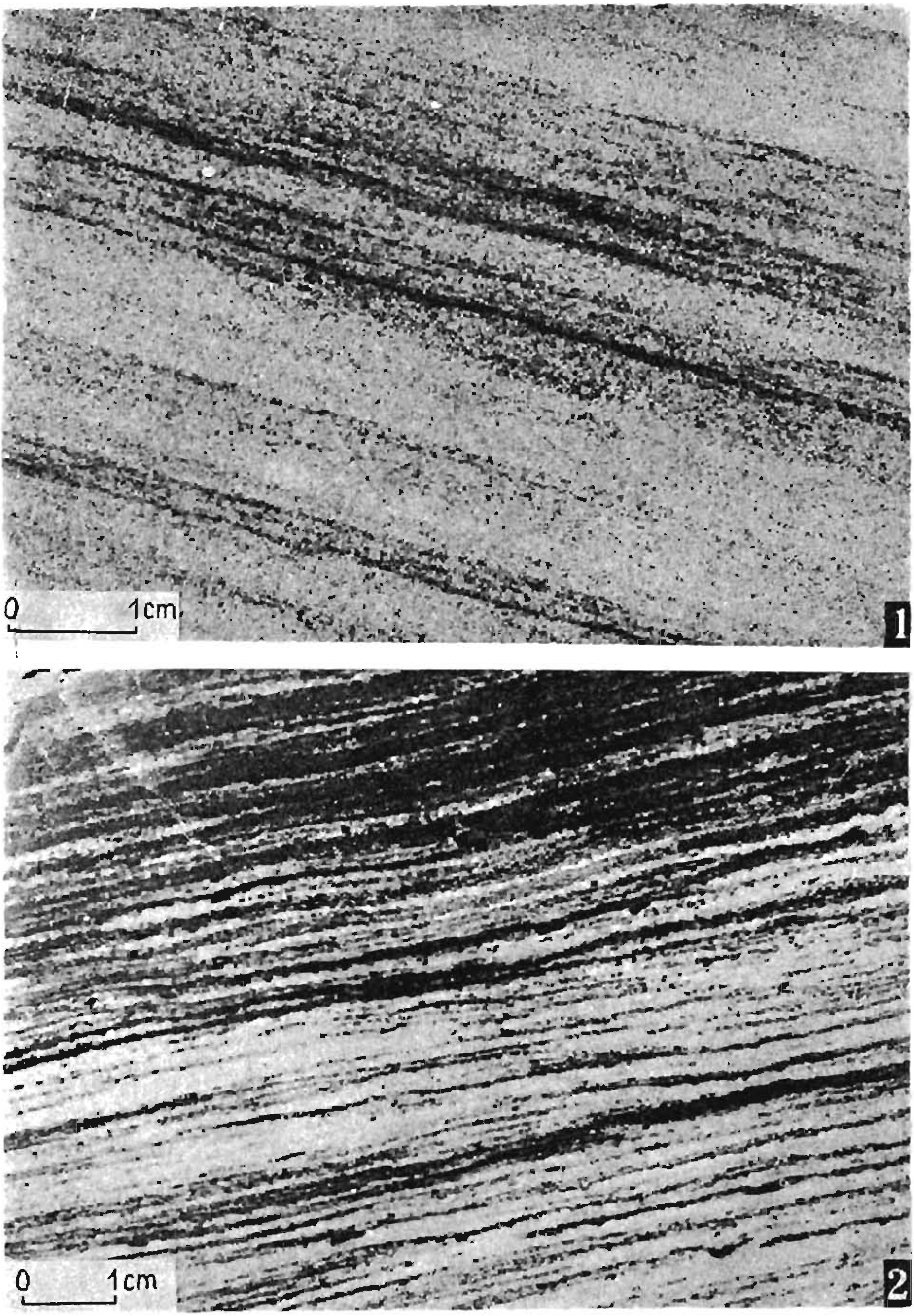
A fragment of core with siltstone of composite beeding
1a — bottom of a core fragment, 1b — top part of the same fragment. *1a* — dark siltstone of wavy flaser bedding passing into siltstone of delicate parallel bedding overlies outwashed surface of light siltstone. Above a siltstone layer (Fig. *1b* bottom) of flaser bedding. In the center over the outwashed surface of light siltstone there is a siltstone layer of delicate parallel bedding, discontinuous. Section parallel to current direction
Pionki *1*, 1596.1—1590.0 m





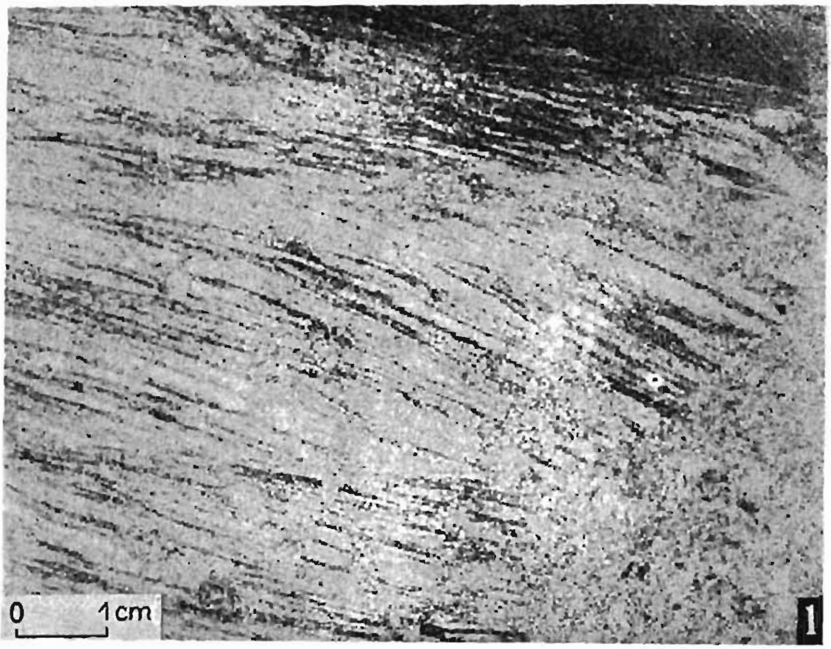
1 — A fragment of core showing siltstone of delicate parallel bedding. Pionki *4*, sample 17, 2438.3—2432.3 m

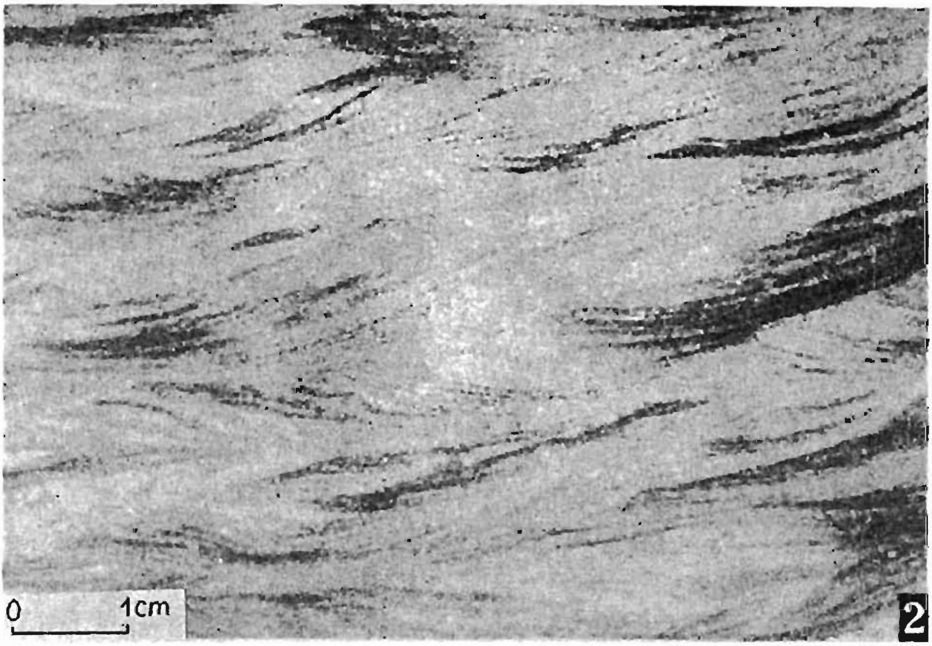
2 — Fragment of core showing rock of parallel bedding. At bottom fine-grained light sandstone laminated with dark siltstone, toward the top dark siltstone with laminae of light finegrained sandstone. Pionki *4*, sample 8, 2741.5—2736.8 m.



1 — Trough cross bedding in light siltstone. Section perpendicular to current direction. Pionki *4*, sample 9, 2713.5—2707.5 m

2 — Flaser bedding with isolated claystone lenses in light siltstone resting on outwashed surface of dark claystone. Section perpendicular to current direction. Pionki *4*, sample 6, 2809.6—2806.3 m

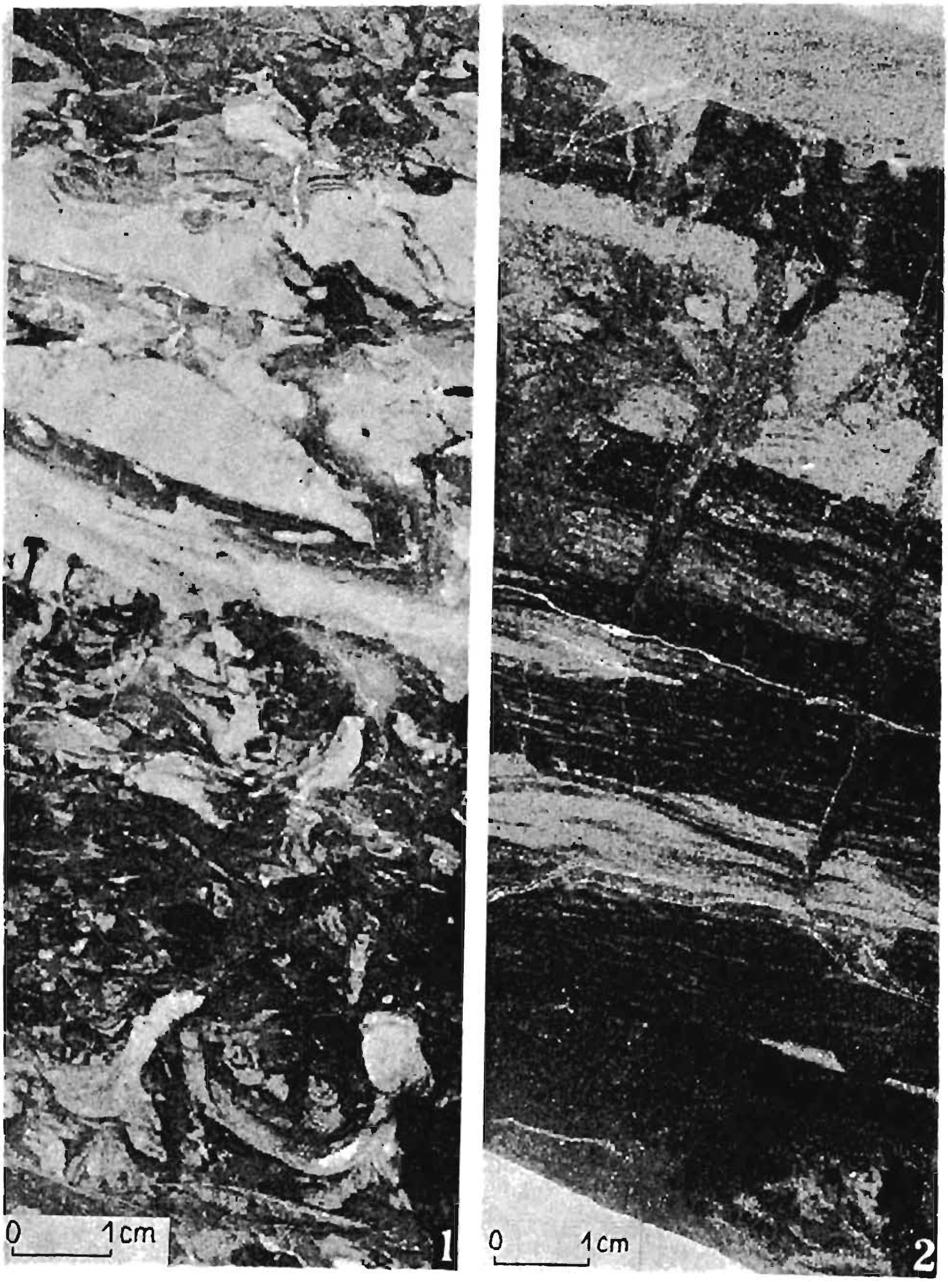




1 — Clastic dykes of various size in siltstone of tabular cross bedding. Section parallel to current direction. Pionki *4*, sample 17, 2402.5—2396.5 m

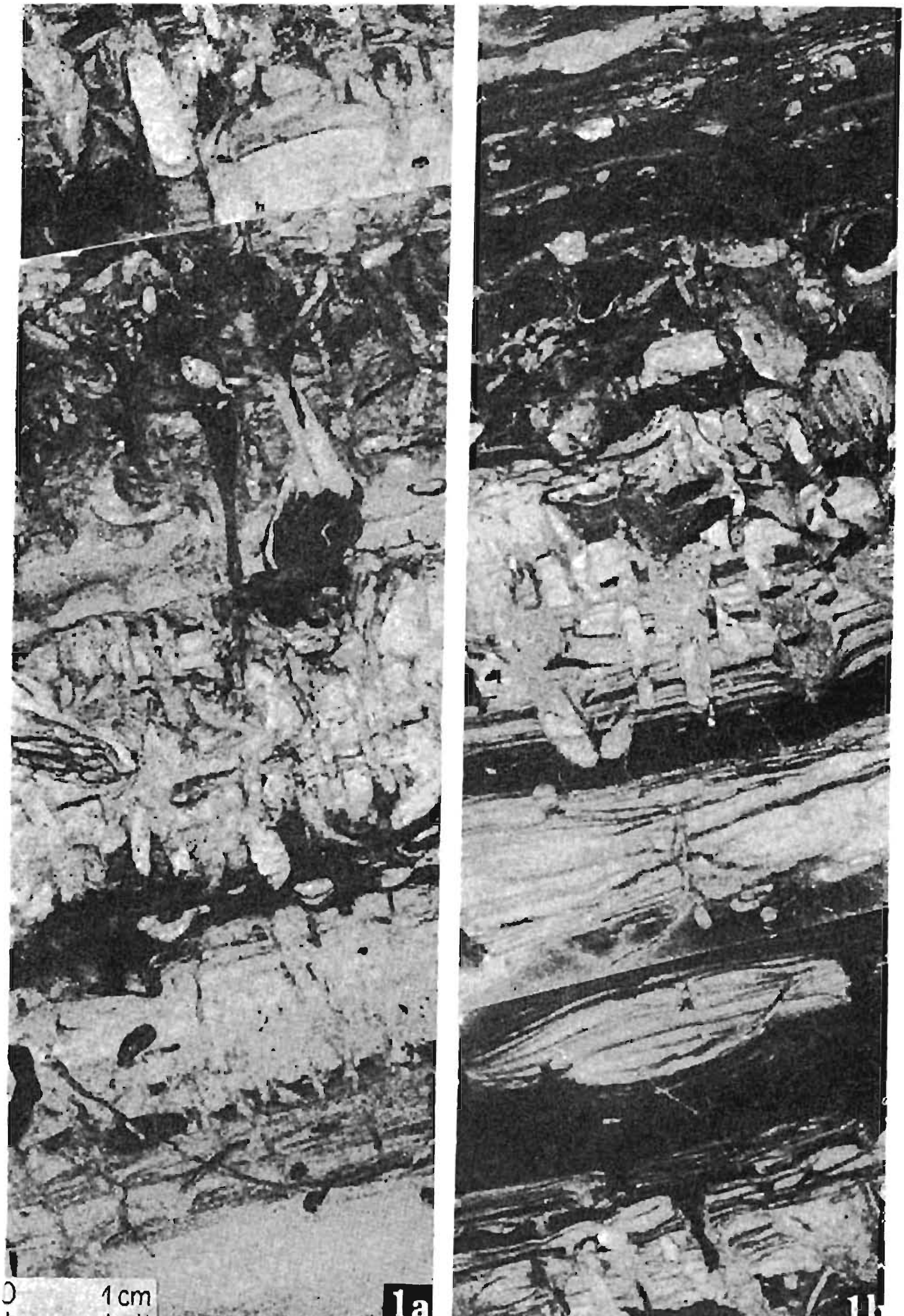
2 — Flaser bedding in light siltstone with bifurcating lenses of dark siltstone. Pionki *4*, sample 14, 2552.1—2546.1 m

1 — Load structures at the boundary of two rock types: underlying dark siltstone and overlying light sandstone. At left interbeds of dark siltstone bent bottomward. Primarily possibly horizontal. Pionki *4*, sample 17, 2438.3—2432.3 m

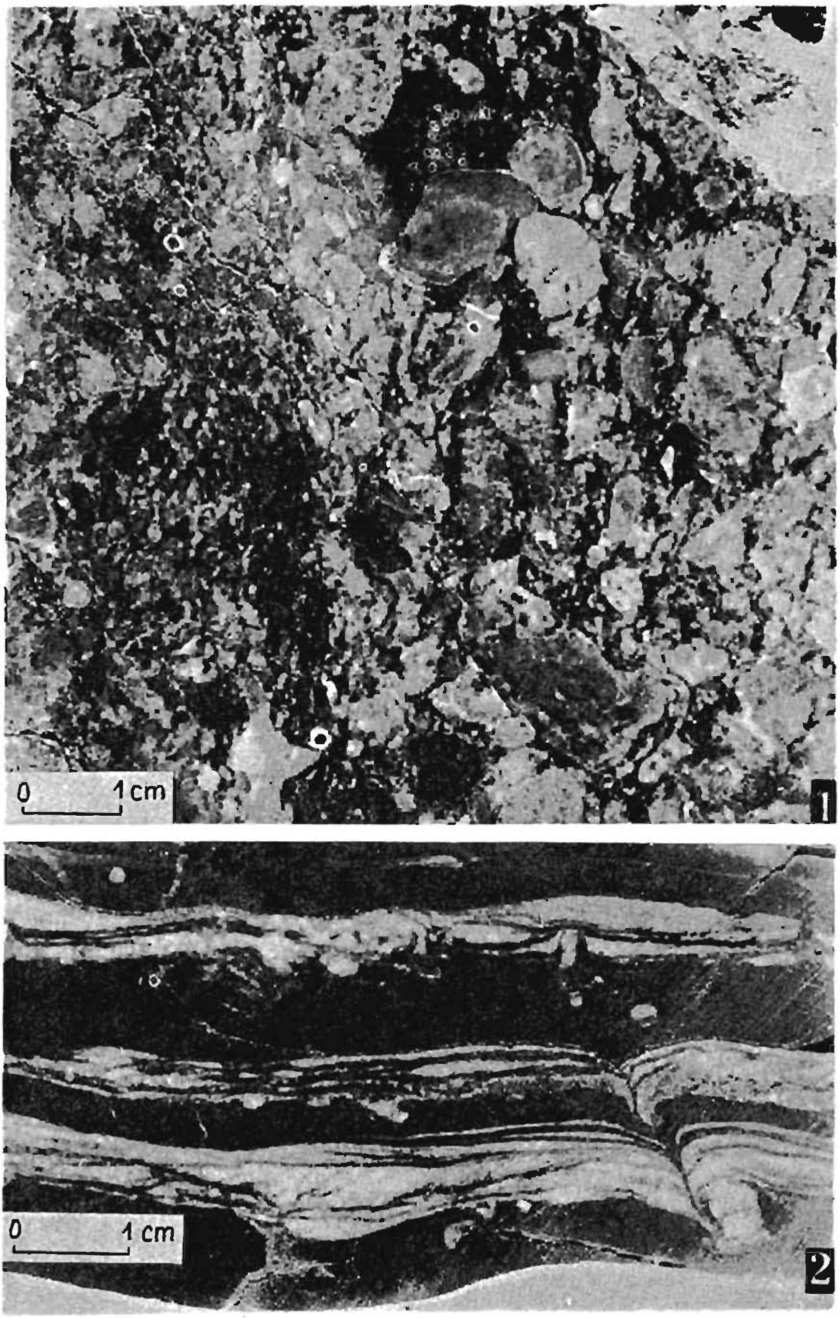


1 — Bioturbation structures at top of sediments with vanishing marine fossils. Visible are vertical, oblique and horizontal canals. Pionki *4*, sample 4, 2882.1—2876.1 m

2 — A type of bioturbation structures at top of sediment complex of tidal flat, passing into sediments of flood plain. Bedding characteristic in tidal flat is observable. Pionki *4*, sample 9, 2713.5—2707.5 m



A core fragment consisting of two parts:
1*a* — bottom of core fragment, 1*b* — top part of the same core fragment. Bioturbation structures in a sediment complex of bedding characteristic in tidal flat (particularly in Fig. 1*b*). Vertical canals are associated with sediment of light siltstone. Horizontal — with dark siltstone. Pionki 4, sample 7, 2775.7—2770.6 m



1 — Tectonic breccia composed of siltstone. Pionki *1*, 1805.0—1799.0 m
2 — Bioturbation structures and bedding characteristic of tidal flat. Siltstone. Pionki *4*, sample 7, 2775.7—2770.6 m

1a—b — Tectonic disturbances in siltstone formed probably in the near fault zone. Pionki *4*, sample 28, 1938.4—1934.0 m

Table 1

Mineral composition of Devonian sandstones in the column of the Pionki *4* borehole (in volume percents)

Depth (in meters)	Number of sample	Quartz	Plagioclase	Potassium feldspar	Muscovite	Biotite	Chlorite	Clay fragments	Siliceous fragments	Accessory minerals	Non transparent minerals	Argillaceous cement	Carbonates
1862.5—1868.0	30	80.0	2.0	4.2	1.7	—	—	0.7	2.2	0.8	0.7	—	7.7
1910.0—1916.0	29	82.0	1,5	8.1	2.5	trace	—	2.2	0.6	0.4	0.5	—	2.2
1964.0—1966.0	27	74.0	1.8	5.2	2.4	1,2	3.4	0.7	0.8	0.4	0.7	6.7	2.7
2163.5—2169.5	22	64.2	1.3	3.6	1.9	2.0	1.1	0.9	trace	0.4	0.7	23.9	—
2216.2—2220.0	21	81.3	2.1	5.8	1.5	—	0.7	3.3	3.0	0.3	0.9	—	1.1
2283.3—2286.3	19	65.1	4.3	13.2	2.5	1.5	2.1	7.2	0.8	0.1	1.1	—	2.1
2432.3—2438.3	17	62.8	4.4	8.0	4.7	8.4	8.6	2.6	—	0.2	0.3	—	trace
2499.0—2505.3	16	74.9	4.7	8.0	0.7	0.3	0.8	6.7	1.2	0.1	0.4	—	2.2
2546.1—2552.1	14	74.8	2.2	3.3	2.7	2.0	2.5	4.4	—	0.1	0.5	—	7.5
2584.5—2590.5	13	64.0	2.6	3.5	1.9	1.3	2.1	1.1	—	0.3	0.4	6.1	16.7
2645.3—2650.3	11	52.3	2.6	5.6	2.4	1.2	0.5	—	1.2	0.2	0.5	32.9	0.6
2736.8—2741.5	8	69.2	5.1	7.7	2.7	3.0	1.3	2.2	—	0.1	trace	7.8	0.9
2770.6—2775.5	7	62.2	5.8	7.3	3.6	6.7	3.4	5.5	—	0.4	0.8	4.0	0.3

olive-green, sometimes brownish). Aside of biotite and muscovite flakes, there is also light-green flaky chlorite, commonly with subnormal interferential colors. The chlorite flakes resemble the biotite ones in dimensions. One may claim that those chlorite flakes associated with a fresh biotite with no evidence for chloritization are indeed of detritic origin. The amounts of chlorite and biotite are variable in the section (Fig. 5). Aside of the flaky chlorite, there are also fine-scaled chlorite aggregates in form of minute, rounded, aquamarine grains. There are also in the rocks some clay grains (Pl. 6, Figs 1—2), sometimes with an oriented structure, composed mostly of illite-type minerals, kaolinite, and illite-chlorite mixture. One may suppose that those minute grains originated from some clayey rocks, which hypothesis is indeed supported by the occurrence of a few clay grains containing quartz grains of aleuritic fraction, attributable to quartz-clayey siltstones. There are also some grains of fine-crystallic siliceous rocks (Pl. 6, Fig. 2). All those grains are rounded, equal in size to the quartz grains. They represent merely a subordinate proportion of the rock.

As to the accessory minerals, all the investigated samples comprise zircon and tourmaline with a yellow-green pleochroism. Some samples contain also golden-yellow rutile, and the samples 9 and 11 garnet grains. All these mineral grains range usually from 0.04 to 0.06 mm in size; only in the samples 29 and 30 they range up to 0.2 mm. Opaque minerals occur in very minor amounts. They include iron and titanium oxides (leucoxene) and pyrite.

The investigated rocks are usually poor in cement that is complex in mineral composition as a rule. A considerable role is played by quartz cement filling up intergranular voids among the

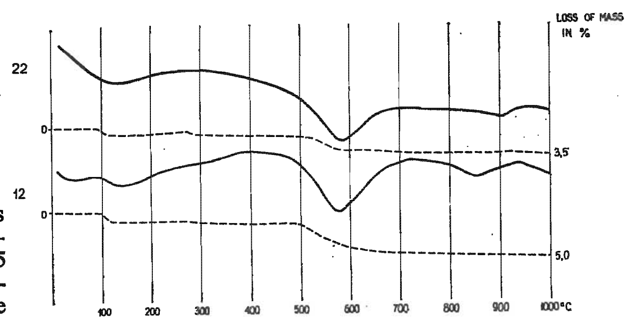


Fig. 6

Derivatograms of clayey minerals from samples 12 (depth 2631.2—2625.2 m) and 22 (2169.5—2163.5 m) from the Lower Devonian sediments of the Pionki 4 borehole quartz grains; most commonly, the quartz cement is optically consistent with but a single adjacent quartz grain. Sometimes, there are regeneration rims of quartz cement around the quartz grains. Detritic quartz can hardly be distinguished from quartz cement and hence, both these components have been treated jointly in the planimeter analyses. Some intergranular voids are filled up with carbonate minerals in form of aggregate-like accumulations; the only sample where they predominate in the cement (16.7% of the rock volume) is the sample 13. The carbonates are represented mostly by fine-crystallic calcite; the sample 27 contains also accumulations of siderite oxidated here and there. The samples 29 and 30 comprise also rhombohedral dolomite with ribboned structure discernible in some crystals. The light-aquamarine clay cement consists mainly of a mixture of chlorite and illite-type minerals. This mixture forms in some sandstones bands and/or lense-like accumulations; it may also occur in aggregates filling up some intergranular voids but in the samples 11 and 22 it makes up the sandstone matrix, as it accounts for 24—33% of the rock volume. The thermoanalyses of the samples 12 and 22 (Fig. 6) confirm indeed the microscopic observations and indicate that the illite accompanied by chlorite is the dominant mineral component. In fact, there are three endothermic effects (*I* at 140°C, *II* at 580°C, and *III* at 890—910°C) and a single weak exothermic one (at 930—960°C).

CONCLUSIONS

The investigated Lower Devonian sedimentary rocks found in the borehole Pionki *4* comprise fine-grained feldspar arenites (Fig. 7), feldspar wackes (Pettijohn & al. 1972) recorded merely in the samples 11 and 22, and siltstones. Their oriented to laminar structure and sharp-edged, fine-grained, equigranular detritic material suggest that the transporting medium was water and the accumulation took place in a calm depositional basin distant from the source area. The microscopic analyses

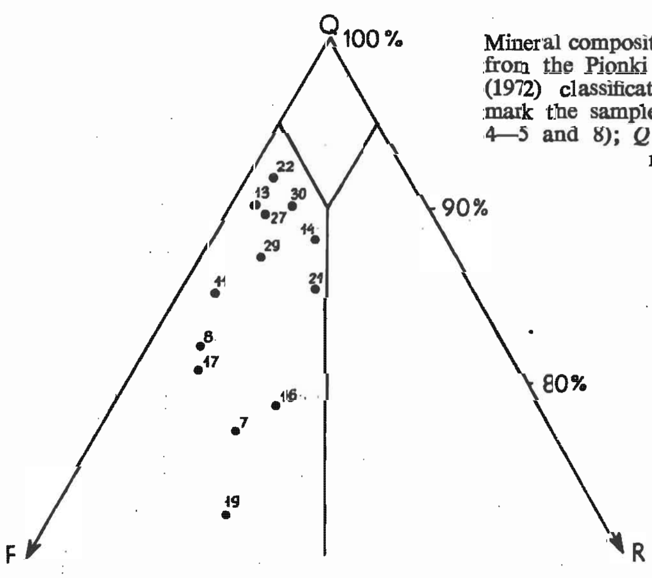


Fig. 7

Mineral composition of the Devonian sandstones from the Pionki 4 borehole in Pettijohn & al. (1972) classification triangle. Numbers 7—30 mark the sample numbers (compare with Figs 4—5 and 8); *Q* — quartz, *F* — feldspars, *R* — rock fragments

do not point to any qualitative variation in mineral composition in the section but merely to a considerable variation in proportions od the rock components (Tab. 1; Fig. 5). This may indicate that the souce area was all the time the same but erosional intensity was variable. There are two distinct horizons (depth intervals 2775.5 to 2736.8 m and 2438.3 to 2283.3 m) with an increased proportion by implication, and influx to the basin, of feldspars, biotite, and chlorite. One may claim that the detritic material derived at least in part directly from a crystallic massif (or massifs) built up by rather fine-crystallic rocks, e.g. granitoids or metamorphic schists. This is indicated by the preservation state of fresh and clear feldspar, biotite, and muscovite grains, and clorite flakes, as well as by the occurrence of biotite patches intergrown with muscovite. One can hardly assume that so well preserved detritic components might persist through successive sedimentary cycles. This is especially the case with the biotite and chlorite flakes. On the other hand, the clastic nature of quartz, feldspars, and biotite, the characteristic path-like intergrowths of biotite and muscovite, and the absence of any grains with a shape typical of volcanic material make the empirical basis to claim that a non-sedimentary origin of the analysed rock material seems implausible. In fact, this claim is not refuted by the observations on the other rock constituents present in the whole investigated section of 1236.0 m in total thickness.

SEDIMENTOLOGICAL OBSERVATIONS

The section is dominated by siltstones and the core recovery is rather poor; hence, several characteristics important for the analysis of sedimentary environment can hardly be recognized. In fact, the core intervals attain at most 5—6 m in the boreholes Pionki *1* and Pionki *4*. One can hardly investigate sedimentary cycles in fine-grained sediments in such short section intervals. Erosional structures on bed surfaces could not be investigated either.

The most interesting sedimentary structures recorded in the course of the logging process are described below. Their analysis permitted a recognition and subsequent interpretation of the most important characteristics of the Lower Devonian sedimentary environment in the western Lublin Uplands (Fig. 8).

DEPOSITIONAL STRUCTURES

BEDDING

In the investigated bedded rocks, the laminae range in thickness from a few millimeters in sandy rocks down to ca 0.1 mm in silty-clayey rocks.

PARALLEL BEDDING

Parallel bedding occurs rather rarely in the investigated Lower Devonian deposits. In a discontinuous form, it has been recorded in siltstones; there are sets making part of cosets in composite bedding (Pl. 7; Pl. 8; Pl. 9, Fig. 2; Pl. 10, Fig. 1a—b; Pl. 11, Figs 1—2). Less commonly, parallel bedding occurs in sandstones where the laminae exceed 1 mm in thickness (Pl. 11, Fig. 2).

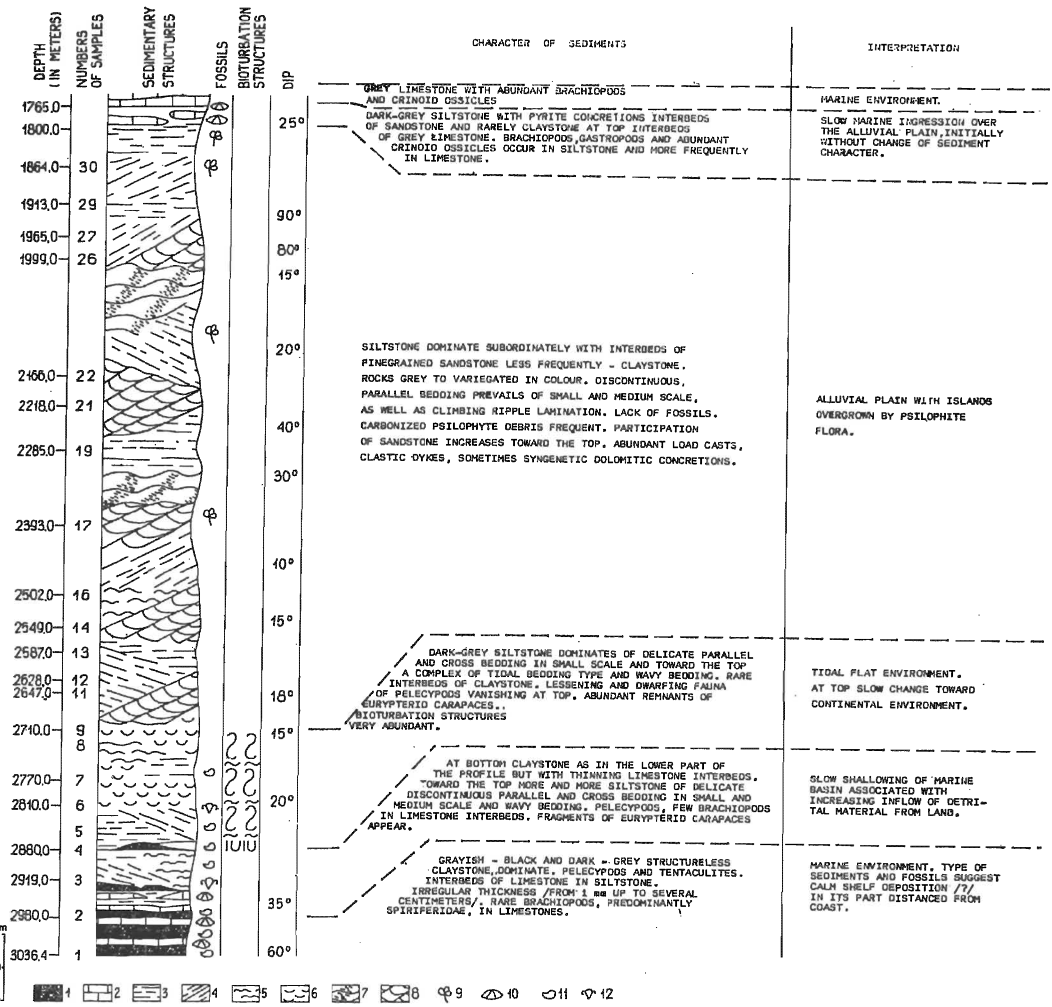


Fig. 8. Ideal synthetic profile of the most important sedimentary characters of the Devonian sediments from the Pionki 4 borehole showing the changes of the sedimentary environment during the period Lower Siegenian — Lower Givetian (compare with Figs 2 and 3)

1 — macroscopically structureless claystone, *2* — carbonates, *3* — discontinuous parallel bedding, *4* — discontinuous tabular cross bedding, *5* — wavy bedding, *6* — flaser bedding, *7—8* — various types of climbing ripple lamination, *9* — psilophite carbonized debris, *10* — brachiopods, *11* — pelecypods, *12* — fragments of eurypterid carapaces

CROSS BEDDING

It occurs commonly in the investigated deposits, in siltstones and sandstones as well. It is however impossible to recognize particular cross-bedding categories in the fine-grained material. Most commonly, these are sets of indistinct boundaries, making part of cosets. Their modal thickness is moderate (sensu Conybeare & Crook 1968). In a section parallel to current direction, the laminae are most commonly arcuately concave or convex, or wavy in shape (Pl. 7; Pl. 10, Fig. 1b; Pl. 13, Fig. 1). The most common forms of cross bedding are: tabular and wedge-shaped cross bedding. In turn, trough cross bedding occurs but very rarely (Pl. 12, Fig. 1). The present authors are of the opinion that the cross bedding recorded in the Lower Devonian deposits of the boreholes Pionki *1* and Pionki *4* refers to forms of drag cross bedding (cf. Jopling 1966).

CLIMBING RIPPLE LAMINATION

The structure of this type occur extremely commonly in the investigated sediments, especially in those with no marine fossils. The following categories of climbing ripple lamination can be recognized (cf. Jopling & Walker 1968):

1. ripple-drift cross lamination, type *A* (Pl. 9, Fig. 1);
2. ripple-drift cross lamination, type *B* (Pl. 9, Fig. 2);
3. sinusoidal ripple lamination, type *S* (Pl. 8).

FLASER AND LENTICULAR BEDDING

Accordingly to the classification by Reineck & Wunderlich (1969) and Reineck & Singh (1973), the following categories can be recognized in the analysed deposits from the boreholes Pionki *1* and Pionki *4*:

1. flaser bedding (Pl. 7; Pl. 10, Fig. 1a);
2. simple flaser bedding (Pl. 12, Fig. 2);
3. bifurcated flaser bedding (Pl. 12, Fig. 2; Pl. 13, Fig. 2).

TIDAL BEDDING

Structures of this type (cf. Reineck 1972; Reineck & Singh 1973) occur in the borehole Pionki *4* along with bioturbation structures (Pl. 15, Figs 1, 2; Pl. 16, Fig. 1a—b; Pl. 17, Fig. 2).

PENECONTEMPORANEOUS DEFORMATION STRUCTURES

There are in the investigated material:

1. load structures developed at a siltstone/sandstone boundary (Pl. 14) (cf. Kelling & Walton 1957; Dżułyński 1966; Cegła & Dżułyński 1970);
2. clastic dykes (the specimen presented in Pl. 13, Fig. 1 shows a single larger-sized, clastic dyke, up to at least a dozen centimeters in length, and several minute ones, a few millimeters to some centimeters in length; the origin of these dykes can hardly be explained at the moment; they comprise the same material as that building up the surrounding rock).

BIOTURBATION STRUCTURES

In the borehole Pionki *4*, the deposits transitional from marine to continental ones (an analogous lithological set was recognized in the borehole Ciepielów *IG-1* at the depth interval 2210.3 to 2061.0 m by Miłaczewski (1974) (Figs 2—3) comprise abundant bioturbation structures (Pl. 15; Pl. 16; Pl. 17, Fig. 2). As judged from the study by Hertweck (1970), the lebensspuren presented in the above cited photos are to be interpreted as internal lebensspuren and dwelling structures.

1. Internal lebensspuren. These are channels parallel or oblique to a bedding plane, cutting most commonly across a fine-grained, clayey deposit (dark) and filled up with more coarse material (light) (Pl. 15, Fig. 1; Pl. 16, Fig. 1b — top of the bed).

2. Dwelling structures—burrows. The investigated rocks contain vertical channels filled secondarily up with a deposit, widened at the bottom and narrowing upwards, cut in a more or less sandy deposit as a rule. The channels are predominantly straight, pencil-like in shape, normal to a bedding

plane. However, some U-shaped channels do also occur (Pl. 15, Fig. 1 — base of the bed), as well as traces of organisms burrowing by a rotation of the body (Pl. 17, Fig. 2). Basing upon the observations made by van Straaten (1954) and Reineck (1958) on tidal flats of the North Sea, the rock specimens presented in this paper may permit a recognition of the relative sedimentation rates in life environments of those organisms. The specimen in Pl. 15, Fig. 1 exemplifies a slow sedimentation in a sheltered or deeper zone of tidal flat. Organisms living in the vertical and oblique channels make up a population associated with beds of more coarse-grained (lighter) siltstone. The slow and quiet sedimentation allows them to move gradually upwards along with the bottom surface shifting due to the sediment accumulation. In contrast, the successive populations discernible in Pl. 16, Fig. 1a—b were killed each by a rapid deposition of black mud layer.

Two distinct core fragments with the above described trace fossils are presented in Pl. 15. A sample taken from the transition from typically marine deposits to highly bioturbated sediments with more and more rare marine fossils (sample 4) is presented in Fig. 1. In turn, a sample taken from continental deposits with rare bioturbation structures (sample 9; cf. Fig. 8) is illustrated in Fig. 2.

ANALYSIS OF DEPOSITIONAL ENVIRONMENT

The analysis of the sedimentary structures described above and presented in Pls 8—17 makes possible recognition of the nature of the Gedinian to Eifelian depositional environment in the western Lublin Uplands (Figs 1, 8).

At the bottom of the borehole Pionki *4* (depth interval 3036.4 to 2980.0 m), there are dark-grey to black claystones with no macroscopic structure, intercalated with limestones. At the depth interval 2980.0 to 2810.0 m, the limestone intercalations in claystones become less common, and gradually siltstones become dominant. The siltstones show a subtle and discontinuous parallel bedding, subtle cross bedding in cosets of small to moderate thickness, and wavy bedding (Pl. 7; Pl. 8; Pl. 12, Fig. 2). The bivalves accompanied by rare brachiopods (restricted to the limestone intercalations) are associated with the claystones and point to a marine depositional environment. The brachiopods decrease in abundance and finally disappear at all, and the bivalves decrease in generic diversity and individual size with the increase in modal diameter of the sandy fraction (Fig. 4) and the gradual replacement of the claystones with siltstones. Beginning with the depth of 2919.0 m, eurypterid fragments appear more and more commonly. At the depth of 2880.0 m, bioturbation structures appear in masses aside of a few bivalves. Beginning with the latter depth, the siltstones show also bedding structures (Pl. 12, Fig. 2; Pl. 15, Fig. 1; Pl. 16, Fig. 1a—b; Pl. 17, Fig. 2) typical of the tidal flats of the modern North Sea (Reineck 1972; Reineck & Singh 1973). The bivalves persist up to the depth of 2770.0 m, and the bioturbation structures up to 2710.0 m. One may thus conclude that the considered lithological set is typical of tidal-flat depositional environment.

A thick set of siltstones intercalated with fine-grained sandstones occurs at the depth interval 2710.0 to 1800.0 m (910 m in thickness) in the borehole Pionki *4*; there is no fauna in those deposits but only a plant detritus. An analogous lithological set has been recorded in the borehole Pionki *1* (Fig. 2) at the depth interval 1805.0 to 1396.0 m. In both the sets, the dominant sedimentary structures are:

1. climbing ripple lamination (Pl. 9, Figs 1, 2);
2. suble tabular cross bedding (Pl. 10, Fig. 1b; Pl. 13, Fig. 1);
3. subtle, mostly discontinuous parallel bedding (Pl. 10, Fig. 1b; Pl. 11, Fig. 1).

Other bedding structures occur but sporadically. Load structures (Pl. 14) and clastic dykes (Pl. 13, Fig. 1) do also occur commonly in those two sets. Dolomitic concretions have also been found in the siltstones; they are probably syngenetic and Miłaczewski (1975) regards them as related to evaporation of groundwaters under hot climatic conditions. The recorded bedding structures, and especially the climbing ripple lamination (cf. McKee 1965, 1966), large thickness of the fine--grained sediments, the absence of fossil fauna, and the occurrence of carbonized plant detritus indicative of proximity of a swampy land covered with plants prove that the sea retreated from the western Lublin Uplands and the depositional environment changed into a continental one. The present authors are of the opinion that the considered lithological set represents a fluvial environment, namely a flood plain (cf. Allen 1965; McKee 1965, 1966; McKee & al. 1967; Schumm & Lichty 1963; Reineck & Singh 1973).

At the top of the continental deposits (at depth about 1800 m), the Upper Eifelian or Lower Givetian brachiopods appear in the borehole Pionki 4 indicative of a marine ingression in the western Lublin Uplands (Fig. 8). The brachiopods appear at first in silty-sandy deposits resembling closely the underlying continental ones. Higher in the section, limestone intercalations appear, whereas limestones and dolomites indicative of a complete change in sedimentary regime appear but at the depth of 1765.0 m.

PALEOGEOGRAPHIC REMARKS

The following differences in petrography are to be noted when the Lower Devonian deposits of the western Lublin Uplands (cf. also Miłaczewski & Radlicz 1974) are compared to their time equivalents of the Klonów Belt, Łysogóry region of the Holy Cross Mts (Łobanowski 1971):

1. the mineralogical composition is widely different in both the regions;

2. the Lower Devonian quartzitic sandstones of the Holy Cross Mts are composed almost entirely of quartz with minor amounts of muscovite; they do not comprise flaky chlorite, biotite, potasium feldspars, or plagioclase (Kamieński & Kubicz 1962; Łobanowski 1971; Tarnowska 1976), which contrasts with the Lower Devonian sandstones from the boreholes located in the western Lublin Uplands (Tab. 1; Fig. 5; Miłaczewski & Radlicz 1974).

This demonstrates clearly that the material for the Lower Devonian sandstones of the Holy Cross Mts was supplied by older sediments that had already underwent some sedimentary cycles; while the Lower Devonian material found in the western Lublin Uplands derived to a considerable extent from a direct erosion of some crystallic massifs.

It is to be emphasized that the Łysogóry region of the Holy Cross Mts was submerged during the Late Emsian to Eifelian (Łobanowski 1971), whereas a continental deposition was then taking place in the western Lublin Uplands (Fig. 3; cf. also Miłaczewski 1975). No doubt therefore that a geomorphologic boundary must have separated both the regions at that time (Fig. 1). The rock material derived from degradation of that barrier and deposited in the basin of Klonów Belt does not differ from that eroded south of the latter basin (Łobanowski 1971). Be the

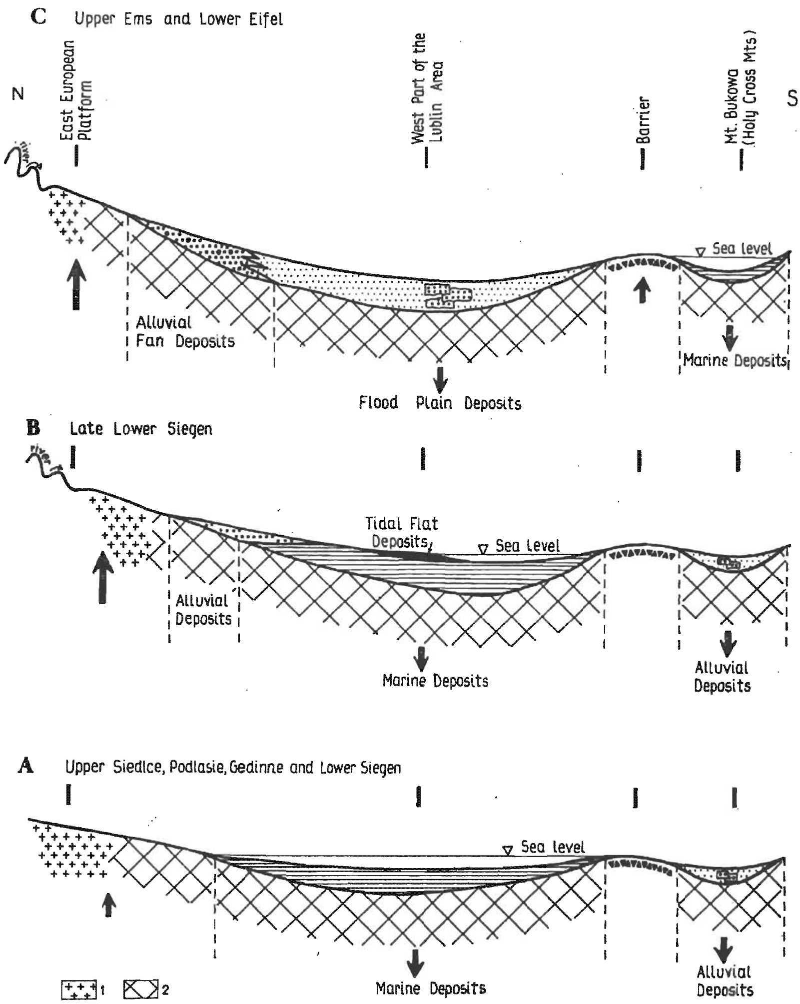


Fig. 9. Evolution of the Devonian sedimentary basin in the western part of the Lublin region and in the area of Bukowa Góra (the Klonów Belt, Łysa Góra region of the Holy Cross Mts). Ideal drawing not to scale showing cross-section along line: from the central part of the Mazury—Suwałki Elevation through the city of Radom and farther south (see Fig. 1)

1 — Precambrian crystalline rocks and sedimentary rocks of the western margin of the East-European Platform and of other massifs situated generally north of the western part of the Lublin region, *2* — substratum built of Old Palaeozoic sedimentary rocks

Length of arrows is proportional to relative intensity of vertical movements clastic material deposited in the Lublin basin derived from the south, its mineralogical composition should resemble very closely that of the Lower Devonian sandstones of the Holy Cross Mts. Since this is not the case, the only source area for the Lower Devonian sedimentation in the western Lublin Uplands is an area at the East-European platform. One may point to the Mazury—Suwałki elevation where crystallic rocks were exposed since the Precambrian; the Lower Paleozoic deposits covered merely the slopes of the elevation (Figs 1, 9; cf. also Znosko 1966; Kubicki et al. 1973; Areń 1974). Another source area for the investigated sedimentary basin could probably be the Sławatycze horst (Fig. 1); however, it has insofar not been established beyond any doubt that crystallic rocks were indeed exposed during the Early Devonian in that area (Areń 1974).

Owing to the continuous uplift of the western part of the East—European platform beginning with the Late Silurian, and especially amplified beginning with the Middle Siegenian, the detritic influx to the Lower Devonian basin of the Lublin Uplands was gradually increasing. This is indicated by the following phenomena:

1. modal grain diameter in sandstones increases upwards in the borehole Pionki *4* (Fig. 4);

2. amounts of mineral grains derived from erosion of crystallic rocks increase upwards (Fig. 5);

3. subsidence does not counterbalance the sedimentation which results in shallowing of the basin (Fig. 8).

The detritic material derived from erosion of crystallic and sedimentary rocks exposed at that time in the western part of the East—European platform was transported to the basin by rivers running from the northeast, that is from the uplifted platform. There were no geomorphologic barriers hampering the transport from the platform to the alluvial plain in the western Lublin Uplands.

CONCLUSIONS

The above presented analysis of the Lower to partly Middle Devonian deposits found in the boreholes Pionki *1* and Pionki *4*, western Lublin Uplands, permits the following conclusions:

1. There is a sedimentary continuity from the Upper Silurian to Middle Devonian, in spite of two periods of a change in sedimentary regime: from marine to continental environment (Siegenian), and from continental to marine environment again (Late Eifelian or Early Givetian).

2. There is a close relationship between the uplift of the western part of the East—European platform and the environmental changes in its southwestern marginal regions.

3. The Upper Silurian to Middle Devonian facies sequence can be summarized as follows: marine environment, tidal flat, flood plain, and again marine environment.

4. There are considerable paleogeographic differences between the western Lublin Uplands and the Holy Cross Mts during the Late Emsian to Eifelian, which reflects the existence of a geomorphologic barrier separating those two regions.

5. The analysis of dip distribution in the Lower Devonian strata of the borehole Pionki *4* (Fig. 8) shows that the dips measured in that borehole cannot be applied to tectonic analysis.

Polish Academy of Sciences
Institute of Geological Sciences
Laboratory of Stratigraphy
Al. Żwirki i Wigury 93, 02-089 Warszawa, Poland

REFERENCES

ALLEN J. R. L. 1965. A reviev of the origin and characteristics of recent alluvial sediments. *Sedimentology*, **5**, 89—191. Amsterdam.

AREŃ B. 1974. Budowa geologiczna pokrywy osadowej na podstawie głębokich otworów wiertniczych i badań sejsmicznych (General statement). *In*: ŁASZKIEWICZ A. (Ed.) Skały Platformy Prekambryjskiej w Polsce.2. Pokrywa osadowa (Rocks of the Precambrian Platform in Poland. 2. Sedimentary cover). *Prace IG*, **74**, 10—20 (233). Warszawa.

BIERNAT G. 1966. Middle Devonian Brachiopods of the Bodzentyn Syncline (Holy Cross Mountains, Poland). *Palaeont. Pol.*, **17**, 1—162. Warszawa.

CĘGŁA J. & DŻUŁYŃSKI S. 1970. Układy niestatecznie warstwowane i ich występowanie w środowisku peryglacjalnym (Systems with reversed density gradient and their occurence in periglacial zones). *Acta Univ. Vratisl., Stud. Geogr.*, **13**, 17—39. Wrocław.

CONYBEARE C. E. B. & CROOK K. A. W. 1968. Manual of sedimentary structures. *Bur. of Min. Resourc., Geol. & Geoph., Canberra A. C. T.*, **102**, 1—327. Canberra.

DŻUŁYŃSKI S. 1966. Sedimentary structures resulting from convection-like pattern of motion. *Rocz. P T Geol. (Ann. Soc. Geol. Pol.)*, **36**, 3—21. Kraków.

GRADZIŃSKI R., KOSTECKA A., RADOMSKI A. & UNRUG R. 1976. Sedymentologia. 1—614. *Wyd. Geol.* Warszawa.

HAJŁASZ B. 1968. Dolnodewońskie tentakulity z otworu wiertniczego Ciepielów *IG-1* (Lower Devonian Tentaculites from borehole Ciepielów *IG-1*) *Kwart. Geol.*, **12**, 812—825. Warszawa.

HERTWECK G. 1970. Die Bewohner des Wattenmeeres in ihren Auswirkungen auf das Sediment. *In*: REINECK H.—E. (*Ed.*): Das Watt, Ablagerungs und Lebensraum, 108—130. Kramer. Frankfurt a.M.

JAKUBOWSKA L. 1968. Badania paleobotaniczno-stratygraficzne osadów dewońskich z wierceń Ciepielów i Dorohucza (Paleobotanic — Stratigraphical studies on Devonian deposits pierced by bore holes Ciepielów and Dorohucza). *Kwart. Geol.*, **12**, 507—518. Warszawa.

JOPLING A. V. 1966. Some principles and techniques used in reconstructing the hydraulic parameters of a paleo-flow regime. *J. Sedim. Petrol.*, **36**, 5—49. Menasha.

— & WALKER R. G. 1968. Morphology and origin of ripple-drift cross lamination, with examples from the Pleistocene of Massachusetts. *J. Sedim. Petrol.*, **38**, 971—984. Menasha.

KAMIEŃSKI M. & KUBICZ A. 1962. Kwasoodporność piaskowców Gór Świętokrzyskich i Dolnego Śląska na tle ich własności petrograficznych (Acid resistance of sanstones from the Święty Krzyż Mts. and Lower Silesia on the backround of their petrographic properties). *Biul. Inst. Geol.*, **178**, 1—100. Warszawa.

KRASSOWSKA A. & KULCZYCKI J. 1963. Dewon w okolicy Ciepielowa (Devonian in the vicinity of Ciepielów). *Przegl. Geol.*, **8**, 394—395. Warszawa.

KAYSER E. 1871. Die Brachiopoden des Mittel- und Oberdevons der Eifel. *Ztschr. Deutsch. Geol. Ges.*, **23**, 491—643. Berlin.

KELLING G. & WALTON E. K. 1957. Load cast structures: Their relationship to upper surface structures and their mode of formation. *Geol. Mag.*, **94**, 481—490. Cambridge.

KUBICKI S., RYKA W. & ZNOSKO J. 1973. Tektonika (Tectonics). *In*: ŁASZKIEWICZ A. (*Ed.*), Skały Platformy Prekambryjskiej w Polsce. 1: Podłoże krystaliczne (Rocks of the Precambrian Platform in Poland. 1: Crystalline basement) *Prace Inst. Geol.*, **68**, 129—137 (168). Warszawa.

LJASHENKO A. J. 1959. Atlas brakhjopod i stratigrafija devonskikh otlozhenij tsentralnikh oblastej Russkoj Platformy. 1—267. *GOSTOPTEKHIZDAT*. Moskva.

LOTZE F. 1928. Das Mitteldevon des Wennetals nördlich der Elsper Mulde. *Abh. Preuss. Geol Landesants.*, *N. F.*, **104**, 1—104. Berlin.

ŁOBANOWSKI H. 1967. Stratygrafia i litologia utworów dewońskich z otworu wiertniczego Pionki *4* (głęb. 1378,5—3036,4 m), (Unpublished manuscript), 1—16. *Arch. Biura Dok. i Proj. Geol. Zjedn. Górn. Naft. w Warszawie.*

— 1971. The Lower Devonian in the western part of the Klonów Belt (Holy Cross Mts), 1, Upper Emsian. *Acta Geol. Pol.*, **21**, 629—687. Warszawa.

— 1976. Szczegółowa analiza lito- i biostratygraficzna warstw granicznych dolnego dewonu morskiego i lądowego, oraz środkowego dewonu morskiego na przykładzie profilu z wiercenia Pionki *4*. (*Unpublished manuscript*), 1—10. *Arch. Zakl. Nauk Geol. PAN w Warszawie.*

McKEE E. D. 1965. Experiments on ripple lamination. *In*: MIDDLETON G. V. (*Ed.*), Primary sedimentary structures and their hydrodynamic interpretation. *Soc. Econ. Paleontologists Mineralogists, Spec. Publ.*, **12**, 66—83. Tulsa.

— 1966. Significance of climbing-ripple structure. *U.S. Geol. Profess. Papers*, **550-D**, D94—D103. Washington.

— CROSBY E. J. & BERRYHILL H. L. 1967. Flood deposits, Bijou Creek, Colorado, June 1965. *J. Sediment. Petrol.*, **37**, 829—851. Menasha.

MIŁACZEWSKI L. 1974. Dewon. *In*: NIEMCZYCKA T. (*Ed.*), Profile głębokich otworów wiertniczych Inst. Geol., **20**, Ciepielów *IG-1*, 83—90. *Wyd. Geol.* Warszawa.

— 1975. Dewon na południowo-wschodniej Lubelszczyźnie. (*Unpubl. Ph. D. Dissertation*), 1—179. *Arch. Inst. Geol. w Warszawie.*

— & RADLICZ K. 1974. Dewon (Devonian). *In*: ŁASZKIEWICZ A. (*Ed.*), Skały Platformy Prekambryjskiej w Polsce, 2: Pokrywa osadowa (Rocks of the Precambrian Platform in Poland, 2: Sedimentary cover). *Prace IG*, **74**, 83—98 (253). Warszawa.

NIEMCZYCKA T. (*Ed.*) 1974. Profile głębokich otworów wiertniczych Inst. Geol., **20**, Ciepielów *IG-1*, 1—247. *Wyd. Geol.* Warszawa.

PAJCHLOWA M. 1964. Wstępne dane o dewonie na Niżu Polskim (Preliminary data on Devonian in the Polish Lowland Area). *Kwart. Geol.*, **8**, 224—231. Warszawa.

PETTIJOHN F. J., POTTER P. E. & SIEVER R. 1972. Sand and Sandstone. 1—618. *Springer--Verlag*, Berlin, Heidelberg, New York.

REINECK H.—E. 1958. Wühlbau—Gefüge in Abhängigkeit von Sediment—Umlagerungen. *Senck. Leth.*, **39**, 1—23. Frankfurt a.M.

— 1972. Tidal flats. *In*: RIGBY J. K. & HAMBLIN W. K. (*Eds*), Recognition of ancient sedimentary environments. *Soc. Econ. Paleontologists Mineralogists Spec. Publ.*, **17**, 146—159. Tulsa.

— & WUNDERLICH, F. 1968. Classification and origin of flaser and lenticular bedding. *Sedimentology*, **11**, 99—104. Amsterdam.

— & SINGH J. B. 1973. Depositional Sedimentary Environments. 1—439. *Springer—Verlag*, Berlin, Heidelberg, New York.

SCHMIDT H. 1941. Die Mitteldevonischen Rhynchonelliden der Eifel. *Abh. Senckenberg. Nat. Ges.*, **459**, 1—79. Frankfurt a.M.

SCHUMM S. A. & LICHTY R. W. 1963. Channel widening and flood plain construction along Cimarron River in south-western Kansas. *U.S. Geol. Surv. Profess. Papers*, **352 D**, 71—88. Washington.

SOBOLEV D. 1904. Devonskie otlozhenija profila Grzegorzowice—Skały—Włochy. *Izv. Vars. Polit. Inst.*, 1—107. Warszawa.

SOLLE G. 1953. Die Spiriferen der Gruppe *arduennensis-intermedius* im Rheinischen Devon. *Abh. Hess. Landesamt Bodenforsch.*, **5**, 1—148. Wiesbaden.

STRAATEN L. M. J. U. van 1954. Composition and structure of Recent marine sediments in the Netherlands. *Leidse Geol. Mededel.*, **19**, 1—110, Leiden.

TARNOWSKA M. 1976. Korelacja litologiczna dewonu dolnego we wschodniej części Gór Świętokrzyskich (Lithological correlation of the Lower Devonian in the Eastern part of the Góry Świętokrzyskie). *Biul. IG*, **296**, 75—127. Warszawa.

TOMCZYKOWA E. 1974. Charakterystyka faunistyczna i stratygrafia żedynu oraz zigenu dolnego. *In*: NIEMCZYCKA T. (*Ed.*), Profile głębokich otworów wiertniczych Inst. Geol., **20**. Ciepielów *IG-1*, 90—96. *Wyd. Geol.* Warszawa.

— & TOMCZYK H. 1979. Stratigraphy of the Polish Silurian and Lower Devonian and development of the Proto-Tethys. *Acta Palaeont. Pol.*, **24**, 165—183. Warszawa.

TOMCZYK H. 1974. Sylur. *In*: NIEMCZYCKA T. (*Ed.*), Profile głębokich otworów wiertniczych Inst. Geol., **20**. Ciepielów *IG-1*, 80—82; 92—93. *Wyd. Geol.* Warszawa.

VANDERCAMMEN A. 1963. Spiriferidae du Dévonien de la Belgique. *Mém. Mus. Roy. Hist. Nat. Belg.*, **150**, 1—181. Bruxelles.

ZNOSKO J. 1966. Jednostki geologiczne Polski i ich stanowisko w tektonice Europy (Geological Units of Poland and their situation in the Tectonics of Europe). *Kwart. Geol.*, **10**, 646—665. Warszawa.

— & PAJCHLOWA M. 1968. Geological Atlas of Poland 1:2 000 000: Devonian. *Geological Institute*. Warsaw.

ŻELICHOWSKI A. M. 1972. Rozwój budowy geologicznej obszaru między Górami Świętokrzyskimi i Bugiem (Evolution of the geological structure of the area between the Góry Świętokrzyskie and the River Bug). *Biul. IG*, **263**, 7—75. Warszawa.

H. ŁOBANOWSKI & T. PRZYBYŁOWICZ

DOLNODEWOŃSKIE OSADY RÓWNI PŁYWOWEJ I RÓWNINY ALUWIALNEJ W ZACHODNIEJ LUBELSZCZYŹNIE

(Streszczenie)

Ruchy kaledońskie u schyłku okresu sylurskiego spowodowały w Polsce, podobnie jak w dużej części Europy, zmiany w środowisku sedymentacyjnym. Obserwuje się je przede wszystkim na obszarze położonym na południowy zachód od krawędzi platformy wschodnioeuropejskiej, gdzie górnosylurskie osady morskie z graptolitami zostały zastąpione przez dolnodewońskie, przeważnie aluwialne osady lądowe z fauną ryb pancernych. Obok Gór Świętokrzyskich i Sudetów, gdzie zmiany te obserwować można w odsłonięciach, poznano je, z pomocą głębokich wierceń, również w innych regionach Polski.

Jednym z bardziej interesujących obszarów jest region lubelski, położony pomiędzy Górami Świętokrzyskimi i Bugiem, przylegający od południa do skłonu platformy wschodnioeuropejskiej (fig. 1).

Miąższość osadów dolnodewońskich jest największa w zachodniej jego części, w regionie radomsko-zwoleńskim. Osiąga tam około 1500,0 m (fig. 1—2), a więc dwukrotnie więcej niż w regionie łysogórskim w Górach Świętokrzyskich.

Pełny profil osadów dolnodewońskich przy ciągłości sedymentacyjnej z niżejległym sylurem i nadległym środkowym dewonem występuje w dwóch wzajemnie uzupełniających się wierceniach: Ciepielów *IG-1* i Pionki *4* (fig. 2—3).

Po zbadaniu następstwa osadów dewońskich w wierceniach Pionki *1* i Pionki *4* metodami: biostratygraficzną, litologiczno-petrograficzną i sedymentologiczną oraz po uzupełnieniu osiągniętych wyników danymi uzyskanymi z opracowania utworów analogicznego wieku z wiercenia Ciepielów *IG-1* (Miłaczewski 1974; Miłaczewski & Radlicz 1974; Tomczykowa 1974; Tomczyk 1974; Miłaczewski 1975) autorzy odtworzyli historię rozwoju zachodniej części obszaru lubelskiego od schyłku okresu sylurskiego po dewon środkowy. W wyniku badań udowodniono nieprzerwaną sedymentację osadów od górnego syluru po dewon środkowy przy dwukrotnej zmianie środowiska: z morskiego na lądowe (w zigenię) i ponownie na morskie (w górnym eiflu lub dolnym żywecie) (fig. 2—3, 8—9).

Stwierdzono, że dźwiganie się platformy wschodnioeuropejskiej i położonych wzdłuż jej krawędzi pomniejszych masywów zbudowanych ze skał krystalicznych i osadowych (fig. 1, 9), wiązało się ze wzmożoną erozją tychże i wpłynęło decydująco na skład mineralny osadów tworzących się w zachodniej części basenu lubelskiego (fig. 1, 5, 7, 9). Materiał okruchowy donoszony był do zbiornika rzekami płynącymi z północnego wschodu, które na swej drodze nie natrafiały na istotne przeszkody naturalne.

Stwierdzono również, szczególnie w górnym emsie i eiflu, istnienie dużych różnic facjalnych pomiędzy obszarem zachodniej Lubelszczyzny i Górami Świętokrzyskimi spowodowanych obecnością bariery morfologicznej dzielącej oba te obszary (fig. 1, 3, 9).