acta geologica polonica

Vol. 32, No. 1-2 Warszawa 1982

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Accumulation of drifted logs and other large plant debris in a Carboniferous fluvial channel at Czerwionka, Upper Silesia

ABSTRACT: A fragment of transverse section through a fill of a great fluvial channel in coal-bearing deposits of the Mudstone Series (Westphalian *A* and *B*) is exposed at Czerwionka in Upper Silesia. The depositional environment of this series is interpreted as an extensive, plant covered, alluvial plain constructed by low-gradient suspended-load rivers. Intraformational conglomerate on the channel bottom is overlain by a thick (up to 6.5 m) layer of fine-grained sandstone with mass occurrence of coalified logs and other large plant debris. The fossil flora is dominated by *Cordaites* but other plants are also present. Most of the logs are filled with sand, which is often laminated. Long logs lie horizontally and are preferentially orientated transversally to the channel axis. The accumulation of large plant debris at Czerwionka was deposited in an active channel of a large river. Heavy, partly rotten and waterlogged logs were dragged as bedload along the bottom, successively trapped, and buried with sand.

INTRODUCTION

Although drifted logs are fairly often encountered in ancient fluvial-channel deposits, their occurrence is only marginally reported in most sedimentological papers (*see* Gradziński 1970; Brzyski & *al.* 1976; Gersib & McCabe 1981; Flores 1981). There are records of single logs or of thin accumulations small in relation to the depth of the channel. An exceptionally thick accumulation of logs and other large plant debris is exposed at Czerwionka in the Upper Silesian coal-bearing deposits. Attention was first drawn to this occurrence by Mrs. R. Krzanowska in 1973. Sedimentological investigations of the section were carried out by the first authors (*RG* and *MD*) and palaeontological investigations by the third (*BB*).

Acknowledgements. The authors are pleased to record their thanks to Dr. E. Turnau, Dr. G. Haczewski, and Dr. S. J. Porębski for reading the manuscript and for constructive discussion. This work was carried out under the Project No *MR-I-16* of the Polish Academy of Sciences.

LOCATION AND GEOLOGICAL SETTING

Czerwionka is situated in Upper Silesia, approx. 30 km SW of Katowice (Text-fig. 1 *A*). The great brickyard at Czerwionka exploits mudstones of the Orzesze Beds, dipping about 10° to ESE. The Orzesze Beds from the upper part of the so-called Mudstone Series (Westphalian *A* and *B*).

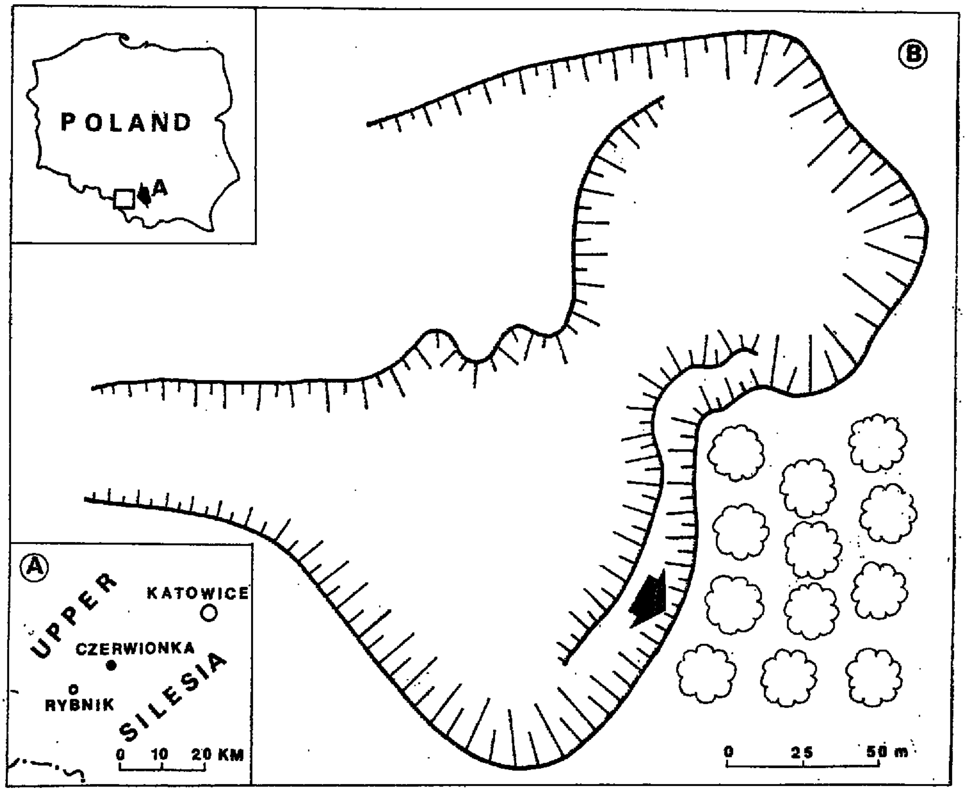

Fig. 1. Sketch map showing location of Czerwionka (**A**) and situation of exposure with fossil channel (*arrowed*) within the brickyard excavation (**B**)

The Upper Silesian coal-bearing succession (Namurian *A* to Westphalian *D*) is divided into four main informal units, traditionally named series; these are subdivided into smaller units named beds (*see* Dembowski 1972). The total stratigraphic thickness of these units reaches 7,000 m. The general lithology, petrography, biostratigraphy, and tectonics are fairly well understood as a result of geological investigations connected with coal exploitation. The coal-bearing deposits were laid down in continental environments, except for the oldest series which contains intercalations with marine and brackish water fauna.

The Mudstone Series (*see* Porzycki 1972) is the third from the base of the coal-bearing succession. It reaches a thickness of 2,000 m and consists of fine-

-grained sediments, mainly mudstones, with numerous siderite concretions. The sandstones making up about 20% of the sequence are mostly fine and very fine-grained. Intraformational conglomerates occur frequently but are insignificant in volume. There are numerous but mainly thin coal seams.

The depositional environment of the Mudstone Series is interpreted as an extensive alluvial plain constructed by low-gradient rivers transporting and depositing mainly fine-grained sediments (Radomski & Gradziński 1981). The rivers are believed to be partly of meandering and partly of anastomosing type (Doktor & Gradziński 1982). The thick sandstone layers (3—8 m, exceptionally > 10 m), often having a basal erosional surface covered with intraformational conglomerate, are regarded as fluvial-channel deposits. The thinner sandstone layers occurring among fine-grained deposits and containing subordinate mudstone intercalations were probably deposited as crevasse splays. Standing *Sigillaria* and *Calamites* stems are common in such layers (*see* Brzyski & *al.* 1976). Traces of roots in autochthonous position are a common feature of fine deposits of the Mudstone Series, indicating that during the accumulation of the series, extensive areas of the alluvial plain were permanently vegetated.

THE EROSIONAL CHANNEL AT CZERWIONKA

A fragment of a large erosional channel is exposed at Czerwionka in the brickyard excavation, namely in the upper part of the southern segment of its eastern wall (Text-fig. 1 *B*). This segment of the wall has not been mined for a long time and is now covered in the most part by rubble. The vertical section described below is about 50 m long and up to 10 m high; its central fragment is schematically shown (Text-fig. 2). The channel is incised in mudstones and very fine-grained sandstones with flat or slightly undulating horizontal lamination.

The bottom of the channel in its visible part is a scoured surface, rising to S; the rise is about 4.5 m over a distance of 17 m (after correction for tectonic tilt). In the bottom surface are carved secondary scour pools, one of which has overhanging walls; isolated, slightly rotated blocks of wall material are found within the intraformational conglomerate near the wall of this scour pool (Text-fig. 2*c*).

Three lithologically different layers rest upon the scoured surface (Text-fig. 2). These are: (*A*) intraformational conglomerate, (*B*) sandstones with large plant debris, and (*C*) sandstones lacking such debris.

The conglomerate layer (*A*) is essentially unstratified and reaches 1.6 m in the deepest visible part of the channel. The layer consists of redeposited siderite concretions chaotically dispersed in a matrix consisting of fine-grained, poorly sorted sandstone which makes 20—40% of the whole rock (Pl. 1, Fig. 2). The diameter of concretions usually ranges from 1 to 4 cm, reaching a maximum value of 8 cm. All four Zingg's shape classes are found among the concretions. Rare, isolated plant fragments, coalified and heavily compact occur near the top of the conglomerate (Text-fig. 2a). They are most numerous in the deepest part of the channel. The transition to the overlying sandstones (*B*) is gradual but rapid.

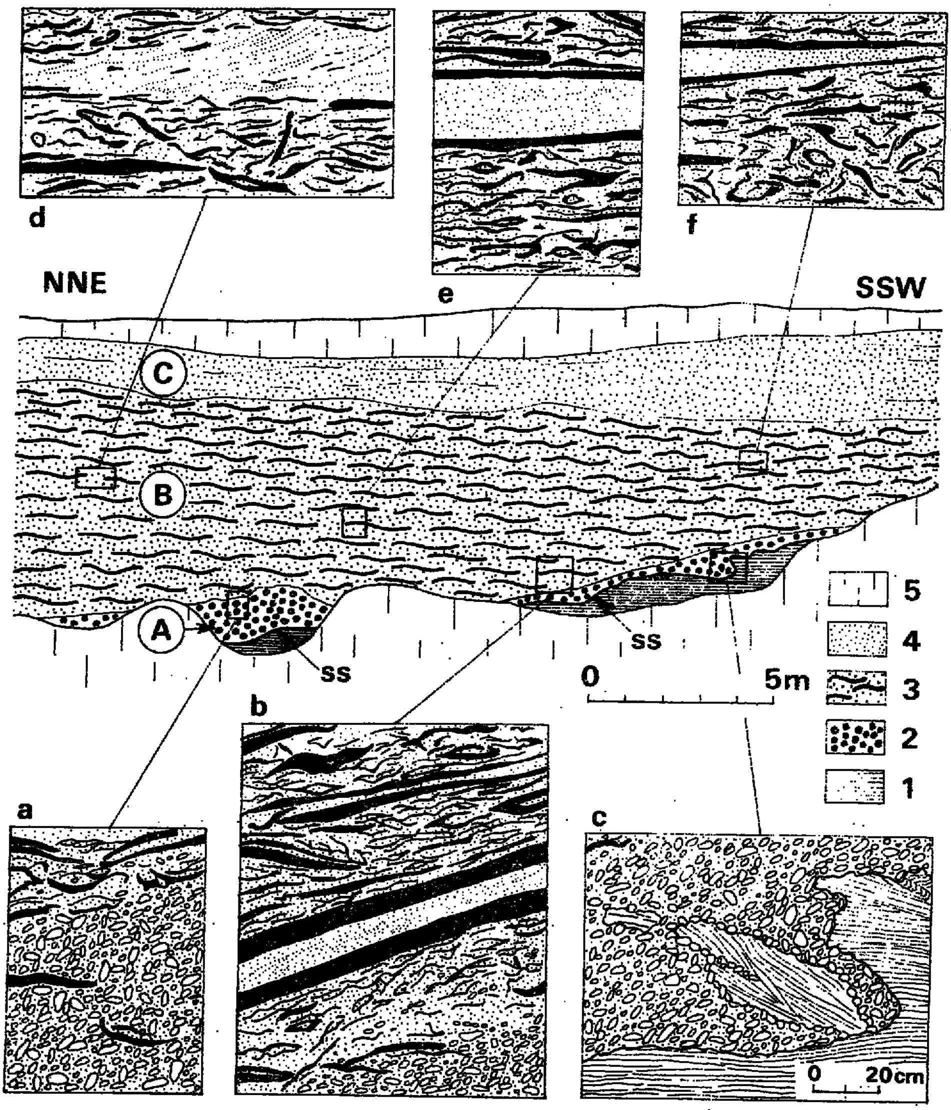

Fig. 2. Sketch of section through a fragment of the channel fill (in center) and its fragments (*a—f*) illustrating details

1 sediments of channel substrate; *2* intraformational conglomerate; *3* sandstone with mass occurrence of coalified plant debris; *4* sandstone; *5* rubble; *ss* scoured surface; *A, B, C* layers detail with in text.

In the insets bright coal is shown in black, sedimentary structures in clastic sediments are omitted

A striking feature of the overlying thick sandstone layer (*B*) is the mass occurrence of coalified large plant debris. Only subordinately do there occur lenses (up to a few tens of centimetres thick) poor in plant debris (Text-fig. 2d). The sandstones in layer *B* are poorly or moderately sorted, with a slight positive skewness. Isolated small accumulations of siderite concretions are scattered in the lowermost part of this layer. In general, layer *B* shows a crude bedding, approximately following the top of the intraformational conglomerate (*A*) in the lower part, and becoming gradually horizontal upwards. The upper boundary of layer *B* is not a scoured surface but is marked by a gradual change in lithology. A detailed description of the plant debris and of sedimentary features of this layer is given below.

The uppermost layer (*C*) consists of fine-grained sandstones, moderately sorted, with slightly positive skewness. They occur in more or less horizontal lenses, of various lateral extent. The maximum thickness of individual lenses varies from 0.2 to 1 m. Their internal structure is only rarely discernible as horizontal or inclined lamination. The bundles of inclined laminae represent large-scale cross-stratification.

PLANT DEBRIS

Plant remains occurring in abundance in layer *B* and sporadically in layer *A* are dominated by drifted large plant debris (logs, limbs, and rootwands). Neither leaves nor autochthonous underground parts of plants were found.

The remnants of plant matter are preserved in sediments as bright coal (vitrinite), usually in amorphous variety (collinite). Relatively rare are imprints and casts lacking adherent coalified plant matter.

Of all the plant remains, the numerous straight logs are most striking. Most of the logs lie horizontally or sub-horizontally. Only in the lowermost part of

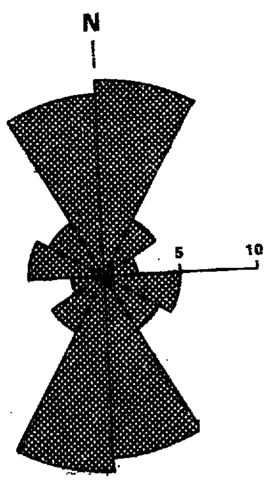

Fig. 3
Rose diagram showing orientation of logs in layer *B* (40 readings); number of readings shown on radius

layer *B* are some logs inclined up to 15°, most of them being approximately parallel to the top of the underlying conglomerate (Text-fig. 2b; Pl. 2, Fig. 2).

Regardless of inclination, the logs display preferred orientation of their long axes (Text-fig. 3). Dominating are orientations close to meridional, *i.e.* approximately parallel to the exposure wall.

The maximum log diameter (measured vertically, together with the coal envelope) reaches 30 cm, but it is smaller in most specimens. The true length of the logs is difficult to determine in the vertical wall of the exposure, because most of them are broken on the projecting side and penetrate into the rock on the other. The greatest observed log length is 4.5 m, and many logs are visible for 2—3 m.

Most of them are preserved with an outer envelope of bright coal filled with clastic material and are flattened to a varying extent. The most flattened logs are in cross-section merely elongated lenses of coal without or with only faint traces of clastic fill. In cross-sections of flattened logs the coalified envelope forms characteristic "wings" on each side (Text-fig. 4 *A, C, D, G, H*). The thickness of the envelopes, measured in the middle part of log section, attains a maximum of 6 cm, varying from one specimen to another. No correlation was found between the envelope thickness, diameter of the fill, and log diameter.

The casts of log fills are frequently covered with longitudinal, often deep furrows. In cross-section the material of the coal envelope is seen penetrating the clastic fills through the furrows (Text-fig. 4 *F, I*). In many cases the envelopes are incomplete, there being no traces of cast in the interruptions; the boundary between the clastic fill and encompassing sediment is barely discernible in such places.

Along with the specimens readily recognizable as fossilized trunks, there occurs a mass of coalified plant debris in such a state of preservation that the

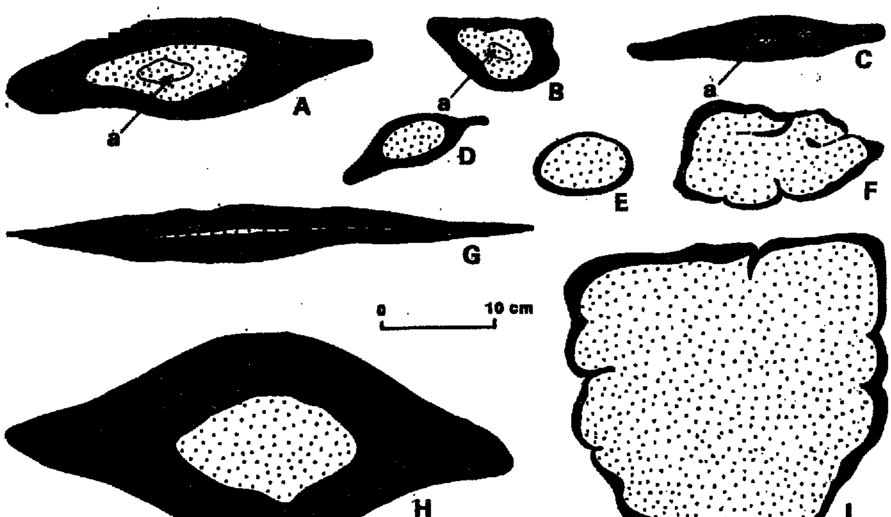

Fig. 4. Examples of log cross-sections
Coal envelopes are shown in black, sedimentary structures in clastic fills are omitted; a — *Artisia*

identification of morphological plant elements is practically impossible. These are probably remnants of branches and roots as well as fragments of trunks which at the moment of their burial resembled sheets of bark. Preserved in rock, this debris occurs as layers and fragments of bright coal, variously bent. In places, the coal layers are nearly horizontal or steeply inclined, occasionally coalescing to form an irregular network. Some represent coal envelopes enclosing clastic lenses similar to the log fills described above. Coal layers representing this type of fossil plant debris are usually one to a few milimetres thick, only exceptionally exceeding 2 cm.

In general, the plant debris in the described exposure is poorly preserved, rendering taxonomic determinations difficult or impossible. The *Cordaites* can be considered dominating forms, most logs belonging to this group, as does probably the major part of the smaller debris.

The *Cordaites* trunks commonly have a central void in the place of a parenchymatic core. In the course of fossilization the voids became filled with clastic material, giving rise to characteristic casts with transversally ribbed surfaces. The casts belong to an artificial genus *Artisia*, their different morphological varieties being species of this genus. The *Artisia* casts were found inside some of the logs at Czerwionka (Text-fig. 4 *A*—*C*) or as separate specimens. The few specimen of *Artisia* found are usually flattened and measure from 1.4 × 0.3 cm to 4.2 × 1.6 cm in cross-section. They have densely spaced ribs (7—8 ribs per one centimetre) and are tentatively attributed to the common species *Artisia approximata*.

Most logs lack artisias and the cross-sectional dimensions of their clastic fills are much larger than those of the parenchymatic core diameters. This indicates an advanced stage of decay of the inner tissue of the trunks, so that before being filled with sediment they were tube-like with relatively large hollows.

Coalified plant fragments slightly flattened, irregularly bent, and distinctly thinning in one direction were found in layer *B*. These are probably fragments of *Cordaites* trunk bases, roots, limbs, and branches.

Among the straight logs, apart from *Cordaites* trunks, some moulds of trunks of ribbed *Sigillaria* (*S*. cf. *voltzi*) were found as well as casts of *Calamites* trunks (*Calamites* cf. *cisti*, rarely *Calamites* cf. *undulatus*, sporadically *Calamites* cf. *suckowi*), belonging to the most common subgenus *Stylocalamites*. Both sigillarias and calamites usually lack coal envelopes or have only their traces.

Specimens of *Sigillaria* are fairly common in the lower part of layer *B* and those of *Calamites* in the upper part.

Another kind of plant debris found are some undeterminable trunk fragments, several centimetres in diameter, slightly flattened or occasionally regularly elliptic in cross-section (Text-fig. 4 *E*). They are coated with a thin (1—2 mm) coal envelope. These specimens have a smooth surface (both inner and outer) and do not bear any features characteristic of *Cordaites, Calamites, Sigillaria*, or *Lepidodendron*. They may be shoots of vine-like plants of true ferns (Coenopteridales) or of seed ferns.

One fragment belonging to the common species *Lepidodendron acculeatum* was found in the upper part of layer *B*.

The plant debris found in the channel fill is derived mainly from plants growing in relatively dry areas (*Cordaites*), that of plants inhabiting wet grounds occurring in subordinate quantities.

SEDIMENTARY FEATURES OF CLASTIC SEDIMENTS OF LAYER *B*

LOG FILLS

The sediment occurring inside the coal envelopes of the logs and inside other plant remains is usually similar in texture to the fine-grained sandstone bearing the debris. Only exceptionally are fills composed of sandy mudstone. The filling sediment is either structureless or laminated, the lamination usually being faint. In log cross-sections the lamine are often bent upwards at the margins. Often the laminated sediment forms lenses, many of which were subjected to various deformations.

In the longest of the observed logs (*see* Text-fig. 2 b; Pl. 2, Fig. 2), which has preserved a thick, continuous coal envelope, the sandy mudstone fill has a deformed structure consisting of two different parts (Pl. 3, Fig. 2). The type of deformations suggests that the log was rotated together with its fill before final deposition and burial.

SEDIMENTS DEPOSITED AMID PLANT DEBRIS

The sandstone containig coalified plant debris is in its greater part faintly laminated. The laminae are from a fraction of a millimetre to several millimetres thick, most of them thinning or wedging out laterally over short distances (Pl. 5, Fig. 1). In cross-section many laminae are variously bent. Bundles of laminae pass gradually into one another, but in some places there are local erosional disconformities. Wedge-shaped bundles of laminae inclined at up to 20° were also observed. In many cases it is difficult to distinguish whether a given part of rock is a sediment laid down between plant fragments or a fill of a strongly deformed log (*see* Pl. 5, Fig. 2).

Two extreme varieties can be distinguished among the sandstones with mass occurrence of plant debris. In the first, the coal layers are more or less horizontal (Pl. 4, Fig. 2), while in the second they are strongly irregularly crumpled (Pl. 5, Fig. 1). In cross-section many laminae are variously bent. Bundles of lalayer *B* (see Text-fig. 2).

Lenses of sandstone poor in plant debris, occurring sporadically in layer *B*, are apparently structureless. Only in some places is a faint lamination discernible, similar to that in sediments of layer *C*.

SEDIMENTOLOGICAL INTERPRETATION

Leaving aside for a moment the problem of the accumulation of large plant debris, it can be concluded that the erosional channel exposed at Czerwionka was carved by one of the greatest rivers crossing the alluvial plain on which the sediments of the Mudstone Series were deposited. This is suggested by the sedimentary features of the clastic fill of the channel.

The sedimentological investigations of the Mudstone Series indicate that the thick sandstone layers are of fluvial-channel origin. Intraformational conglomerates occurring frequently at the base of these layers are interpreted as channel lag deposits. Two extreme types are represented among these conglomerates, one composed of mudstone and/or claystone intraclasts and the other of redeposited siderite concretions. The conglomerate layers are usually 10—25 cm thick, thus the conglomerate at Czerwionka is exceptional in its great thickness. Moreover, it is relatively mature with respect to resistivity of clasts for transport, as compared with other intraformational conglomerates in the Mudstone Series. The absence of stratification and chaotic orientation of conretions in this conglomerate indicate a very rapid and continuous process of deposition of the whole layer. This conclusion is additionally supported by the presence of rotated blocks buried almost on the spot by the channel lag deposit.

The channel lag deposits are usually accumulated only in the deepest part of modern fluvial channels (*see* Levey 1978, p. 123), filling scour pools in the channel bottoms. Thus the original depth of the channel at Czerwionka could have been several times greater than the denivelation of the intraformational conglomerate base, reaching 4.5 m in the visible part. It may be judged from the thickness of the channel fill (layers *A*, *B*, and *C*) and gradual transitions between them that the channel was at least 10 m deep.

The shape of the channel bottom in its visible part and the orientation of the erosional undercuts indicate that the channel axis was generally perpendicular to the wall of the exposure. The original width of the channel is difficult to determine; probably it reached up to a hundred metres or more. This is suggested by the wide lateral extent of layers *B* and *C*, which are visible to the outcrop limits, *i. e.* for 50 m. It should also be noted that sandstones containing abundant large plant debris, probably representing a continuation of layer *B* are visible also in the NE part of the excavation.

The grain-size of the sediments is generally the same all over the section of layers *B* and *C*, indicating generally constant hydrodynamic conditions during the burial of the large plant debris (layer *B*) and later (layer *C*), and suggesting that the plant debris accumulated in an active not an abandoned channel. The presence of a current is also demonstrated by the well-expressed orientation of the logs, transverse to the channel axis.

The accumulation of the large plant debris at Czerwionka occurs in the lower part of the channel fill. This position is the main argument against a possible interpretation of this accumulation as a fossil logjam. Logjams are common in modern rivers crossing forested areas but their occurrence is limited to rivers that are either shallow or deep and narrow (*see* Keller & Swanson 1979). Logjam formation is initiated either by trees fallen from the banks owing to bank erosion or by floating logs grounded in shallow water. These obstacles start trapping large plant debris floating. Such jams usually originate during high water stage. It may be expected that if buried and preserved in fossil record, logjams would be encountered in the upper part of the channel fill section.

The accumulation of large plant debris at Czerwionka is thought to have been formed by the successive trapping and burial of large plant

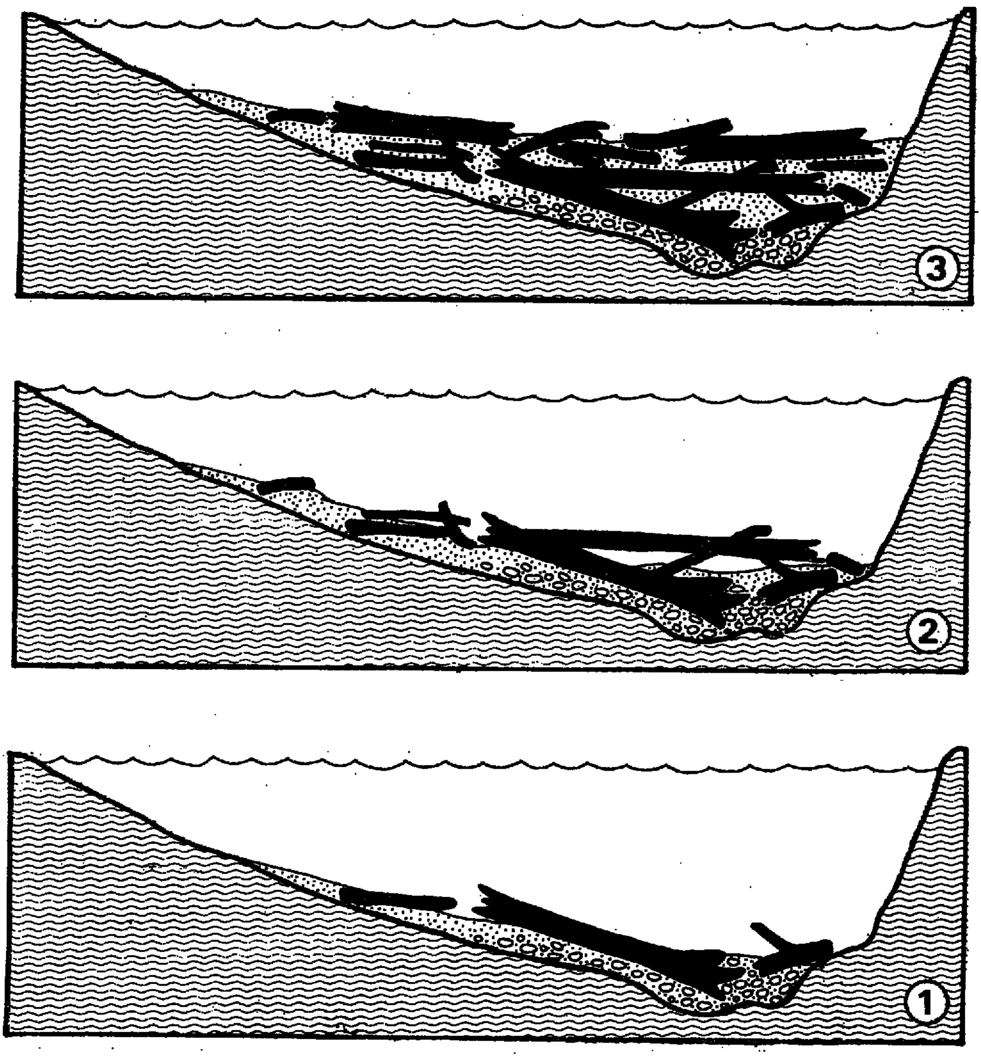

Fig. 5. Model for successive deposition of large plant debris in channel at Czerwionka; no relative scale implied

debris dragged by the current (*see* Text-fig. 5). The logs and other plant remnants were heavily waterlogged and partly rotten. Hold and partly buried, the plant fragments projected above the bottom, facilitating the immobilization of further plant debris in the same place. The presence of such underwater obstacles favoured the orientation of logs perpendicular to the channel axis. Some of the logs once immobilized and filled with sediment would later be shifted and/or rotated (*e. g.* owing to the collapse of this particular log or of other supporting ones), giving rise to the characteristic deformation found in some fills. The presence of a near-bottom "framework" consisting of large plant debris created specific conditions for deposition of the clastic material burying it. This resulted in local washouts and sand shadows, and prevented the development of normal bedforms.

Sandstones with mass occurrence of coalified large plant debris are commonly observed in many Carboniferous coal-bearing successions. In the Pocahontas Basin this type of rock was described by Ferm & Melton (1977, pp. 13 and 18) as "sandstone with coal spars". In the Mudstone Series of the Upper Silesian Basin, sediments of this facies occur frequently in the lower part of thick sandstone layers interpreted as fluvial-channel deposits; the thickness of the plant-bearing sandstone usually does not exceed 30—40 cm (Pl. 6). In the authors' opinion, the majority of fluvial-channel sandstones with mass occurrence of coalified large plant debris originated in the same manner as at Czerwionka, *i. e.* by the successive deposition of current-dragged, heavy plant fragments.

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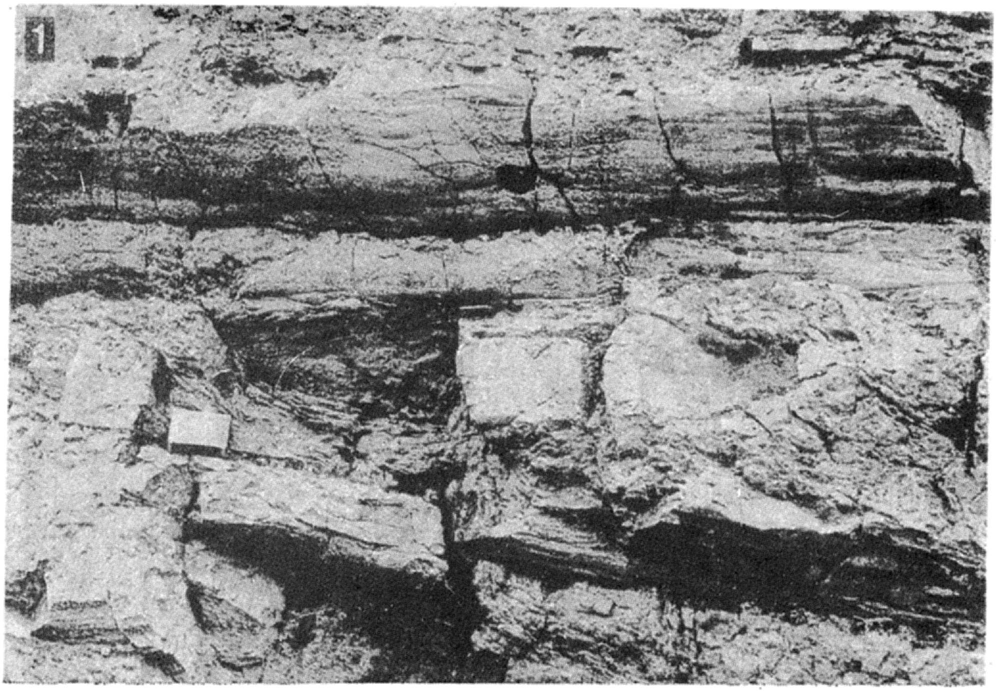
NAGROMADZENIE NANIESIONYCH PNI I INNYCH FRAGMENTÓW ROŚLIN W OSADACH GÓRNOKARBOŃSKIEGO KORYTA RZECZNEGO W CZERWIONCE

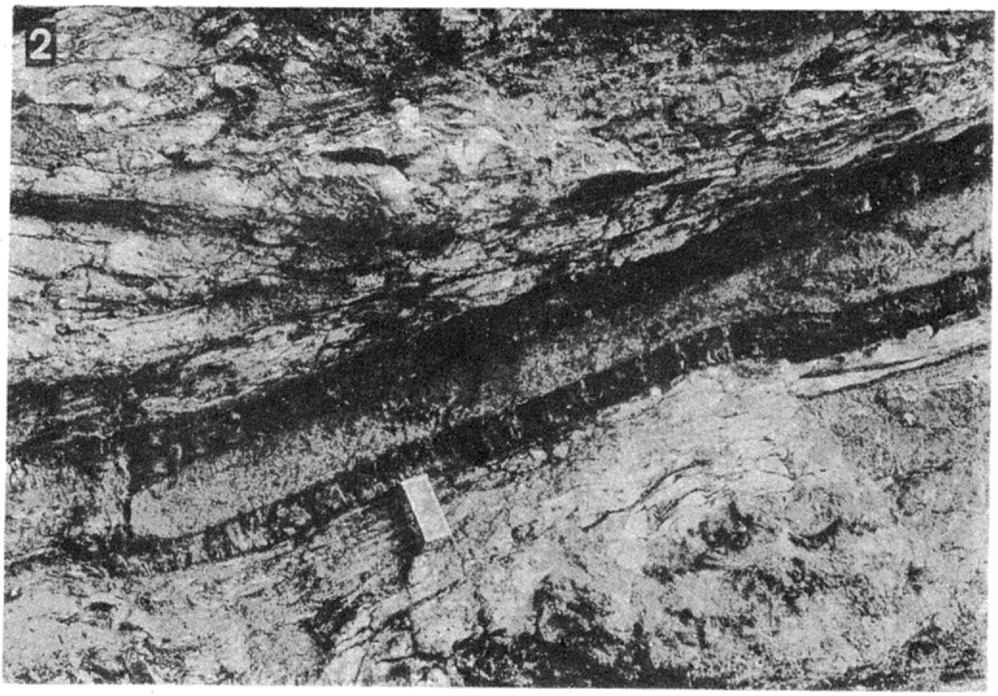
(Streszczenie)

W wyrobisku cegielni Czerwionka na Górnym Śląsku (fig. 1) w osadach serii mułowcowej odsłonięty jest fragment poprzecznego przekroju dużego, kopalnego koryta rzecznego (fig. 2). Środowisko sedymentacyjne tej serii interpretowane jest jako rozległa, zarośnięta równina aluwialna formowana przez rzeki o małym spadku, niosące i deponujące głównie materiał drobnoziarnisty. Nierówne, erozyjne dno koryta odsłoniętego w Czerwionce wyściela warstwa zlepieńca śródformacyjnego złożonego z redeponowanych konkrecji syderytowych (pl. 1). Wyżej leży gruba (do 6,5 m) i rozległa (co najmniej 50 m) warstwa piaskowców przepełnionych uwęglonymi, dużymi szczątkami roślin — pniami, gałęziami i fragmentami korzeni (pl. 2, 4, 5). Szczątki te należą głównie do kordaitów, podrzędnie jednak reprezentowane są też inne grupy roślin. Większość pni jest wypełniona w środku materiałem klastycznym (fig. 4 oraz pl. 3). Długie pnie ułożone są mniej więcej poziomo i w przewadze zorientowane są poprzecznie do osi koryta (fig. 3). Nagromadzenie szczątków roślinnych w Czerwionce powstało w głębokim (co najmniej 10 m), aktywnym korycie dużej rzeki. Ciężkie, przesycone wodą i częściowo już zbutwiałe szczątki roślin wleczone po dnie były sukcesywnie unieruchamiane i pogrzebywane osadem (fig. 5). W analogiczny sposób powstawały najprawdopodobniej ławice piaskowców przepełnione uwęglonymi szczątkami roślin (pl. 6), pospolicie obserwowane w dolnej części grubych pakietów piaskowcowych.

1 — Fragment of scour pool filled with intraformational conglomerate with embedded block of substrate (*see* Text-fig. 2*c*); matchbox is 5 cm long

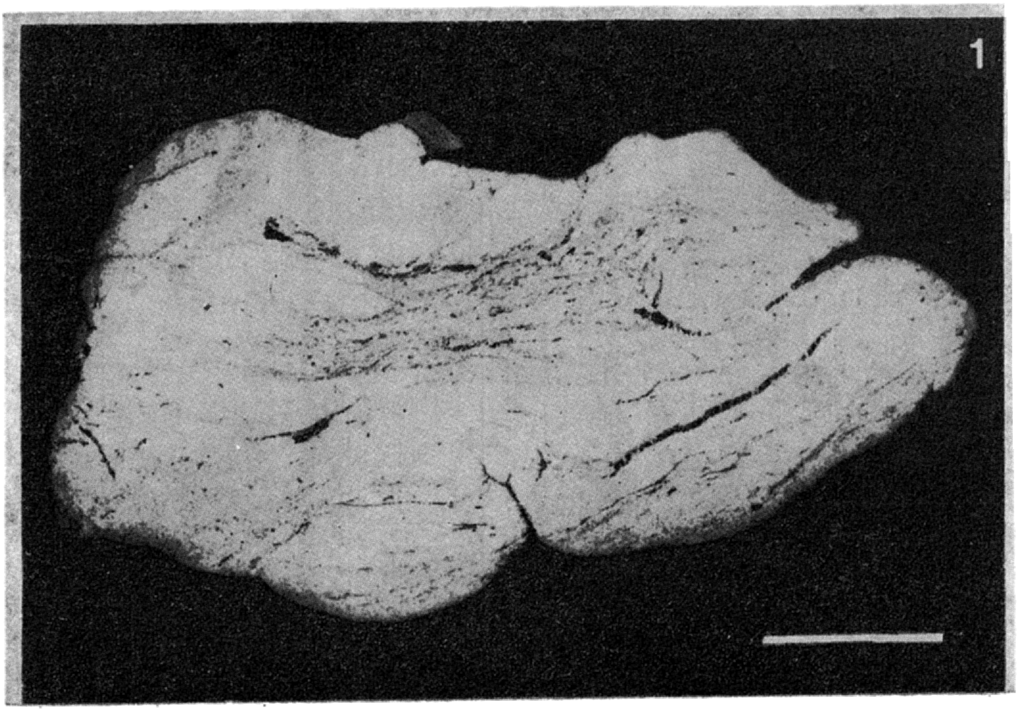
2 — Intraformational conglomerate composed of redeposited siderite concretions, layer *A*; match for scale

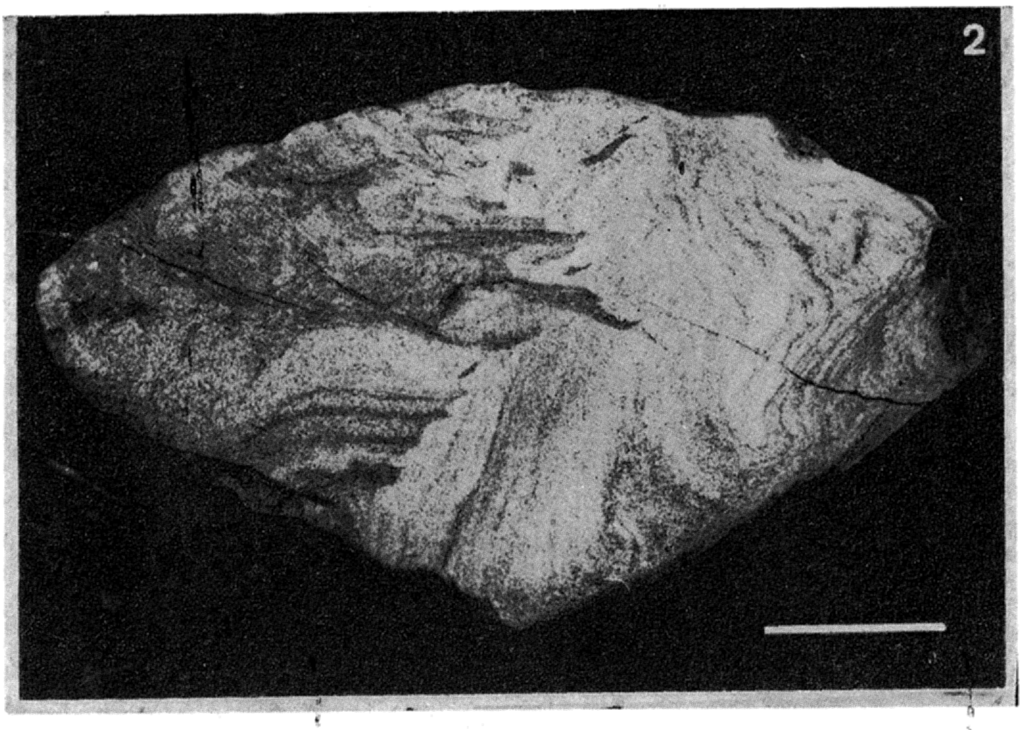




1 — Thick longs lying horizontally, middle part of layer *B*; matchbox for scale

2 — Longitudinal section of large inclined log with thick coal envelope and clastic fill (*see* Text-fig. 2 *b*); box length 7 cm; cross-section of the log is shown in Pl. 3, Fig. 2 and in Text-fig. 4 *H*

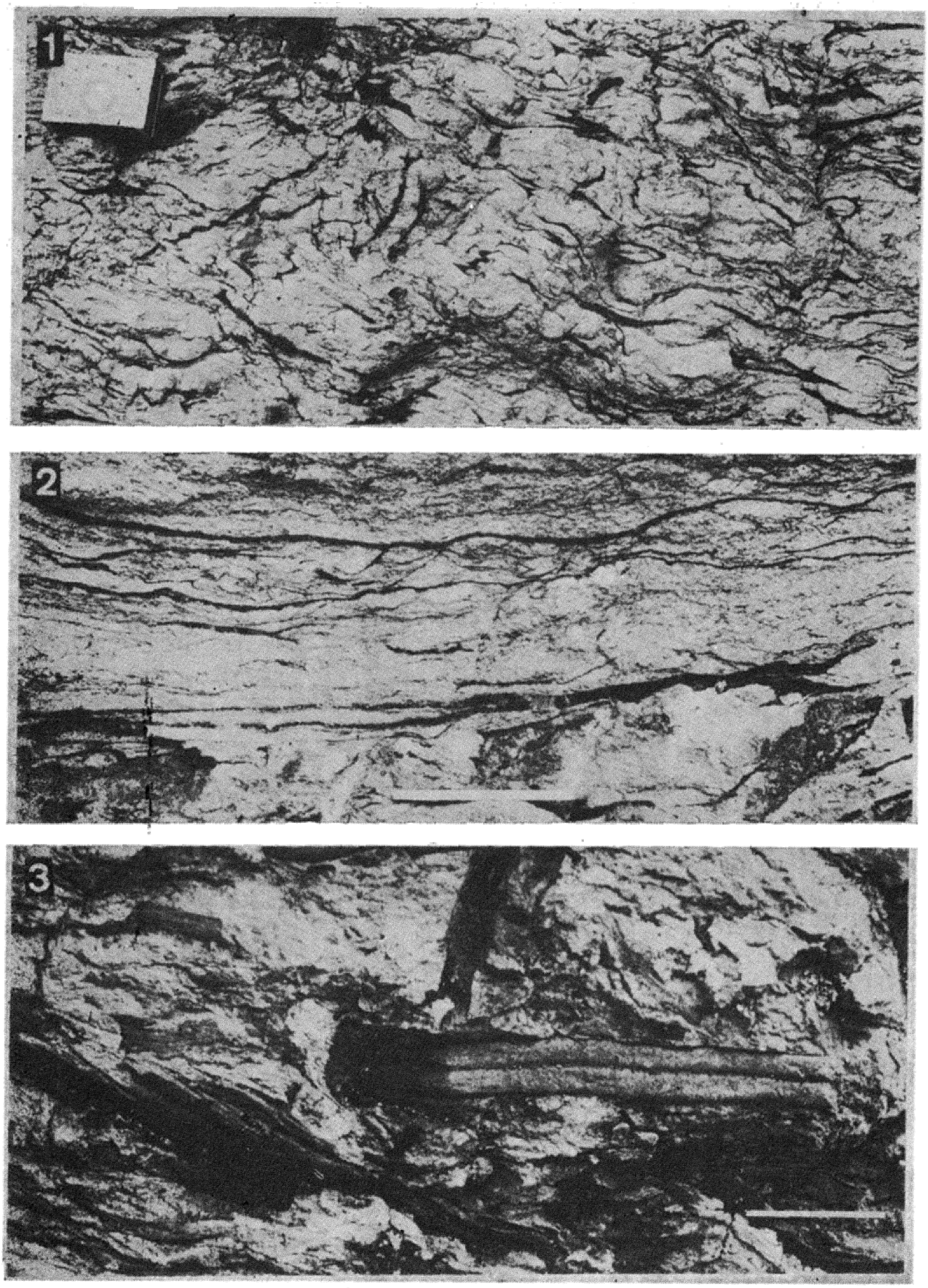




Cross sections of log fills; coal envelope lost during cutting of specimens

1 — Long, slightly flattened log with thick coal envelope (*see* Text-fig. 4 *H* and Pl. 2, Fig. 2); bar length 3 cm

2 — Long log with thin coal envelope (*see* Text-fig. 4 *F*); traces of log deformation present in form of coal protrusions, thin layers of bright coal are visible in sediment; bar length 3 cm

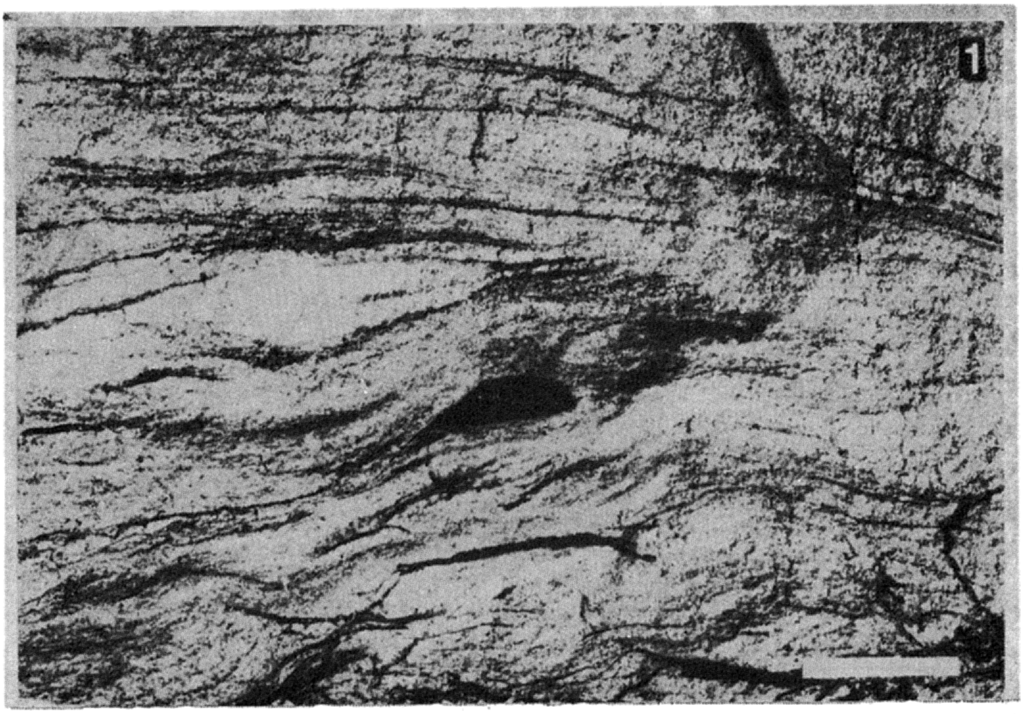


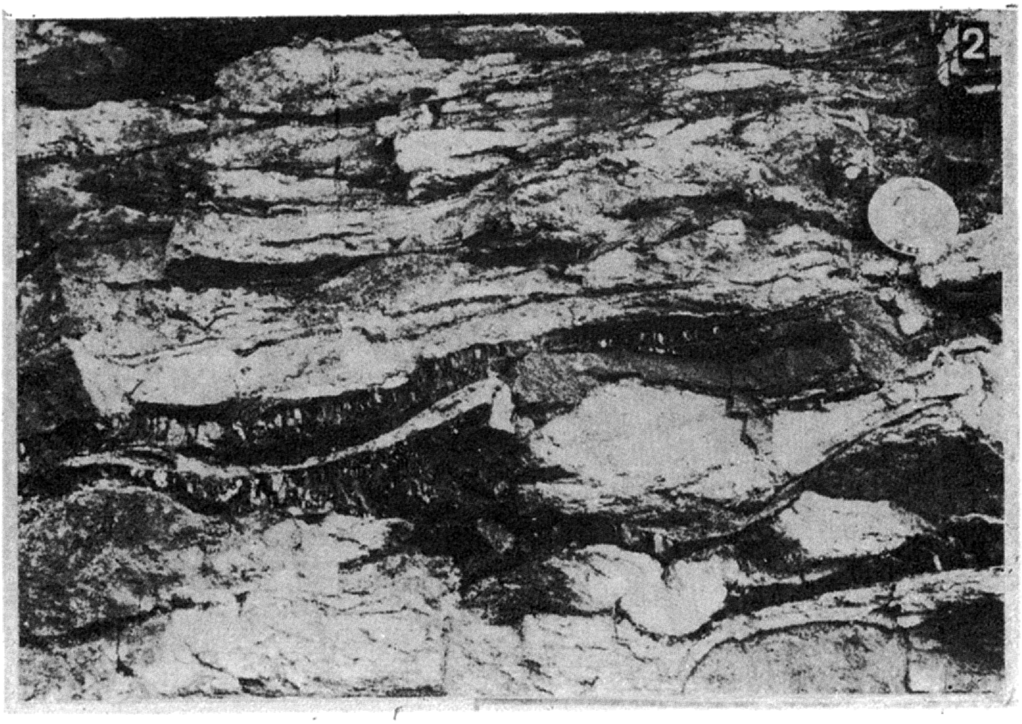
Types of occurrence of coalified large plant debris in sandstones (layer *B*)

1 — Irregularly bent and dispersed coal layers; box length 5 cm

2 — Subhorizontal orientation of coal layers; match for scale

3 — Chaotically dispersed straight plant fragments; bar length 2 cm





Examples of lamination in sandstones (layer *B*)

1 — Sediment laid down between large logs (bar length 2 cm)

2 — Sediment laid down between plant fragments of various size (coin diameter 25 mm)

Core with sandstone with aboundant coalified large plant debris; Mudstone Series, borehole Mikołów 5; core diameter 10 cm