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Tonstein from the coal seam no. 385 in the Lublin Formation (Lower Westphalian) from the Lublin Coal Basin

One or locally two layers of a tonstein (*Graupentonstein*) have been observed in the coal seam no. 385 (Westphalian B) between Ostrów Lubelski and Dorohuczka. Due to its wide reach the tonstein discussed represents a key horizon of a great practical significance. It is built, apart from the dominant kaolinite, of accessory or trace amounts of: organic matter, quartz, feldspars (sanidine, plagioclase), apatite, crandallite, chalcedone, siderite and pyrite. Due to the petrographic suggestions such as the presence of quartz, feldspars, biotite and apatite, displaying features suggesting their volcanic origin, it can be assumed that the tonstein has been formed resulting from the alteration of the pyroclastic material deposited in the peatbog.

INTRODUCTION

Interlayers of the clay rocks in the coal seam from the Lublin Formation (Westphalian B) have been sampled by the Geological Survey in the years 1970–1980 in exploration boreholes in the successive mining areas in the Lublin Coal Basin. Samples of those rocks have been routinely petrographically and chemically analyzed. The results were presented in several unpublished papers (M. Kałwa ed., 1975, 1976, 1977, 1981, 1983), whereas the recapitulation done in the following papers: W. Heflik et al. (1978), J. Stolecki (1988*a, b*).

Due to the analyses performed it has been proved, among others, that some of the clay rocks are built mainly of kaolinite and display a high refractoriness. Some of them are typical tonsteins — the rocks known from the other world coal basins, in that number — also from the Upper and Lower Silesian ones. Those rocks have been an object of studies held by different researchers since they are i.a. concerned significant

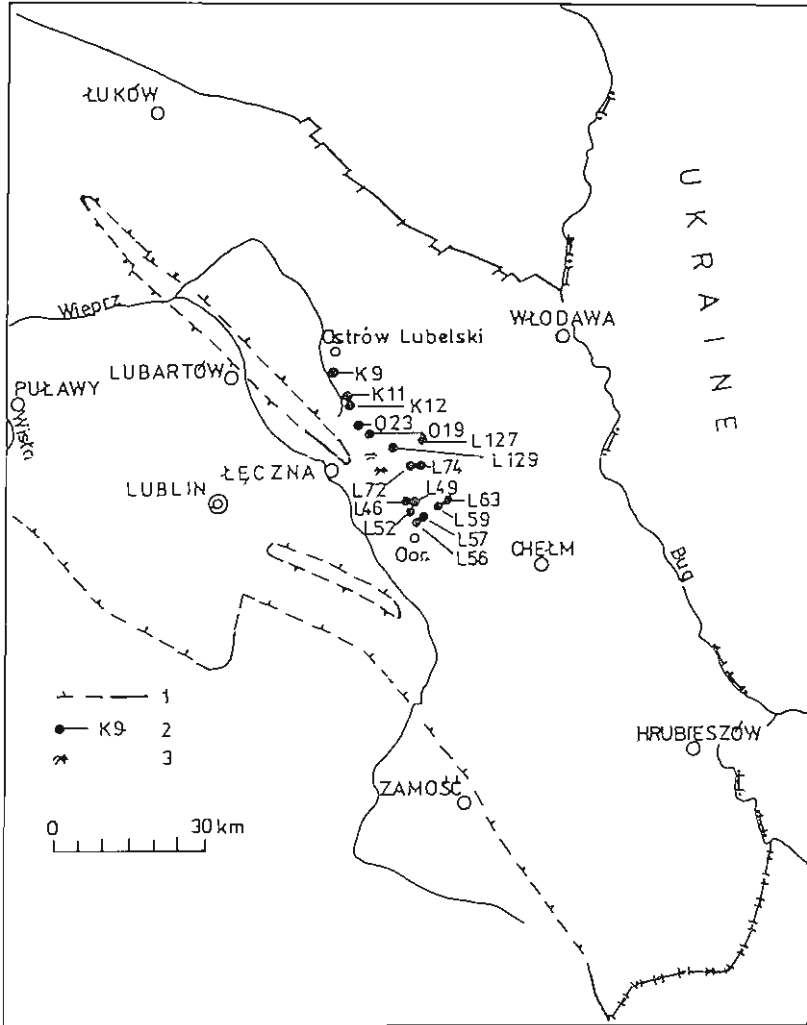


Fig. 1. Localization of boreholes analyzed in the area of the Lublin Coal Basin

1 — presumable extent of Carboniferous sediments (after J. Porzycki, 1988); 2 — localization and number of borehole; 3 — shaft; Dor. — Dorohuczka

Lokalizacja badanych otworów wiertniczych na obszarze Lubelskiego Zagłębia Węglowego

1 — przypuszczalny zasięg utworów karbonu (według J. Porzyckiego, 1988); 2 — lokalizacja i numer otworu wiertniczego; 3 — szymb kopalni; Dor. — Dorohuczka

for the correlation of the coal-bearing series. Tonstein rocks from the Lublin Coal Basin have not been till present analyzed in detail, but their one accessory component — crandallite (M. Muszyński, P. Wyszomirski, 1982). Aiming at filling this gap in informations, the research focused first on the tonstein occurring in the seam no. 385.

The available geological data were analysed and the archive samples studied by microscopic, X-ray and thermal methods. Results of chemical analyses and refractoriness determinations presented in the unpublished papers quoted above have been used, too.

It should be stressed when explaining the necessity of the tonstein recognition from the Carboniferous rocks of the Lublin Coal Basin that in the close future the interregional correlation between the coal-bearing series of different Carboniferous coal basins is planned. The tonstein beds are significant in those series as the key horizons. In the case of the tonstein from the Lublin Coal Basin the localization of the basin will enable correlation between the Upper Silesian and Donieck ones.

Boreholes sampled aiming at tonstein analyses lie in the middle part of the Lublin Coal Basin (Fig. 1). They are situated in the zone of the width of 10 km and length of 35 km between Kolechowice (Ostrów Lubelski) in the north and Dorohucza in the south, east of the line Lubartów — Łęczna. In the mining division of the basin those boreholes are in the Central Coal Region within the limits of the mining fields K₄, K₅, Ostrów 1, Kolechowice 1 and Kolechowice 2. From the geological point of view the area studied covers a part of the Radzyń — Bogdanka Syncline and is adjacent from the west to the Kock Anticline (J. Porzycki, 1988).

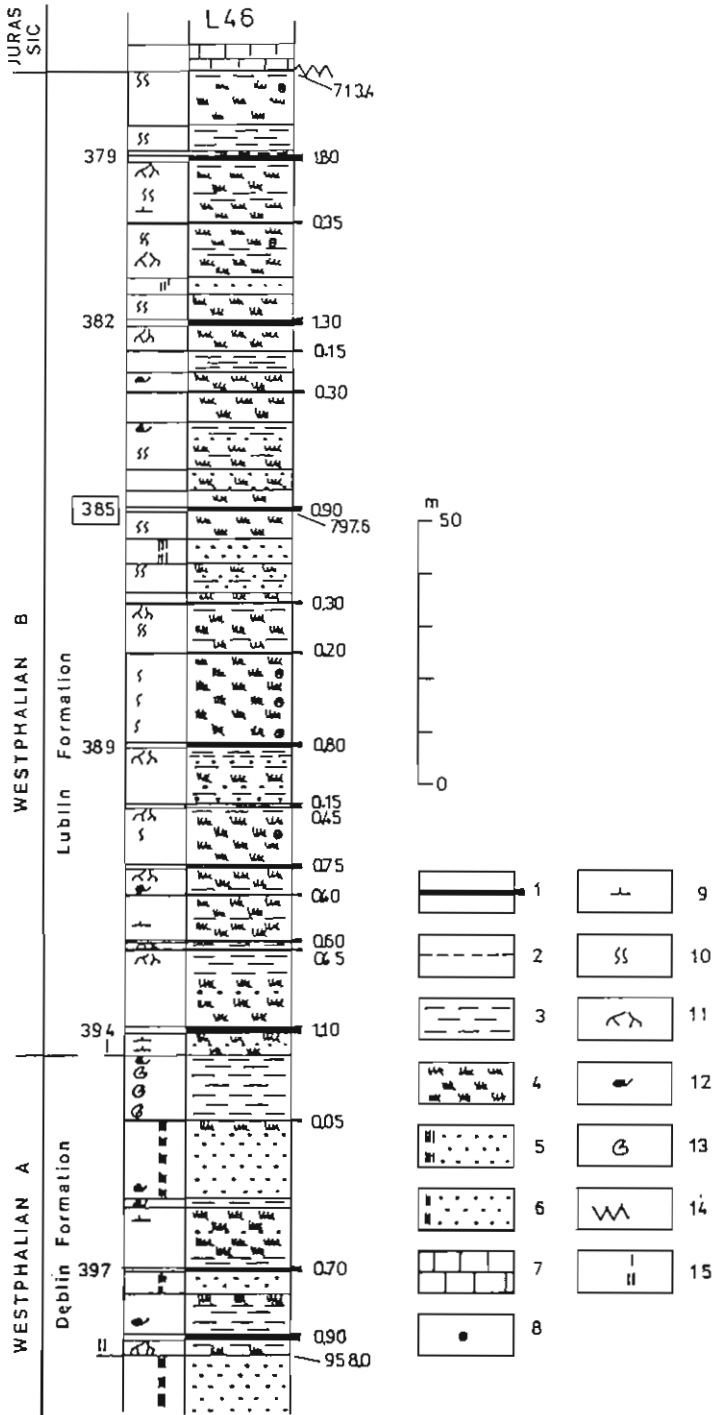
LOCALIZATION OF TONSTEIN IN THE STRATIGRAPHIC COLUMN

The Lublin Formation corresponds in the area studied to the uppermost part of the Carboniferous coal-bearing series of the thickness of about 300 m and of the Westphalian age (Westphalian B) — Fig. 2. In that series there occur about 30 coal seams numbered from 371 (at the top of the beds) to 394 (at the bottom) — I. Lipiarski (1991). The Carboniferous deposits are eroded and discordantly covered with the Jurassic, Cretaceous and Quaternary rocks.

The coal seam no. 385, displaying the tonstein occurrence, has the economic thickness over an entirely wide-spread area. It occurs locally in form of the clay rocks, while in the other parts of the basin — there are two separated beds (no. 385/1 and 385/2) — Fig. 3.

In the coal seam no. 385 there occurs in general one tonstein bed. In some places, however, two tonstein beds have been observed (boreholes: L 52 and L 129). In the Kolechowice 12 borehole there clay beds are present in the coal seam discussed, only the bottom one, however, displaying the tonstein properties (Fig. 3).

Tonstein occurs at different levels of the seam. For example — in the L 46 borehole the bed lies 20 cm over the bottom of the seam, in K 9 — 25 cm below the top, in the Bogdanka region (borehole L 127) — at the top, while in the Ostrów region (boreholes: O 19 and O 23) it lies nearly in the middle of the seam. The thickness of the tonstein ranges from 5 cm (borehole L 74) to 21 cm (borehole O 19). In the southern region the thickness is generally below 10 cm, in the fields Kolechowice and Ostrów it slightly exceeds 10 cm. The tonstein thickness over 15 cm is rare.



MINERALOGICAL-PETROGRAPHICAL CHARACTERISTICS

The tonstein from the Lublin Coal Basin is mainly composed of oval lens or "cloudly" aggregates ("groops") — Pl. I, Figs. 7, 8 — built in majority of microcrystalline, colourless or faint brown kaolinite. The size of those aggregates ranges from about 0.1 to 0.5 mm, in maximum about 2 mm. They are either densely packed or loose in the basic clayish or clayish-organic background. The clayish substance of the background is also mainly built of the microcrystalline kaolinite. The anisometric kaolinite aggregates are in general oriented with their longer axes in one direction which results in the parallel structure of the rocks.

The microscopic observations have been supported by X-ray (Fig. 4) and thermal (Fig. 5) analyses pointing to kaolinite as the main mineral component of the tonsteins under research. The X-ray studies have also proved a high order degree of the mineral structure which is characteristic for kaolinite- T_c (M. Muszyński, P. Wyszomirski, 1982). This fact results from the values of the X-ray indicator I_{020}/I_{111} (L. Stoch, W. Sikora, 1966), ranging from 0.65 to 0.75. According to the data of L. Stoch (1974) also typical for kaolinite- T_c is the symmetric shape of the endothermic effect of dehydroxylation of this mineral at about 550–570°C (Fig. 5).

As the accessory or trace components of the rock discussed there occur: pseudomorphs after mica, eventually non-altered micas, quartz post-feldspar pseudomorphs or relics of these minerals, autigenic columnar kaolinite aggregates, apatite and other phosphate minerals as well as occasionally — pyrite, carbonate minerals and chalcidone. Results of the chemical analyses (Fig. 6, Tab. 1) also suggest the presence of the titanium compounds as well as of iron oxides and hydroxides, not detected by the phase methods applied. The summaric content of the accessory and trace components listed above is low, generally not exceeding some volume percent, reaching in maximum about 8 volume percent. Those components are concentrated mainly in the clayish-organic background of the tonstein.

The post-mica pseudomorphs (apparently after biotite) reach the size of about 1.0 mm, being in general smaller — below 0.5 mm. They display a form of either the plates,

Fig. 2. Lithostratigraphic section of the Lublin Formation

1 — coal (from the left side — number of the coal seam; no. 385 in frame — seam with tonstein, section in Fig. 3; from the right side — thickness and depth of coal seam bottom); 2 — carbonaceous shale, coaly claystone; 3 — claystone; 4 — mudstone; 5 — fine-grained sandstone; 6 — medium-grained sandstone; 7 — Jurassic limestone; 8 — siderite concretion; 9 — fossilized plants, floral detritus; 10 — appendices; 11 — *Stigmara*; 12 — fresh water fauna; 13 — marine fauna (p. f. with *Dunbarella*); 14 — erosional boundary; 15 — boundary of formation: I — after I. Lipiarski (1991), II — after J. Porzycki (1988)

Profil litostratigraficzny formacji lubelskiej

1 — węgiel (z lewej strony — numer pokładu węgla; nr 385 w ramce — pokład z tonsteinem — profil na fig. 3; z prawej strony — miąższość i głębokość spągu pokładu węgla); 2 — łupce węglowe, ilowiec węglisty; 3 — ilowiec; 4 — mułowiec; 5 — piaskowiec drobnoziarnisty; 6 — piaskowiec średnioziarnisty; 7 — wapień jurajski; 8 — kongrecja syderytu; 9 — skamieliny roślin, detrytus roślinny; 10 — apendyksy; 11 — stygmarie; 12 — fauna słodkowodna; 13 — fauna morska (p. f. z *Dunbarella*); 14 — granica erozyjna; 15 — granica formacji: I — według I. Lipiarskiego (1991), II — według J. Porzyckiego (1988)

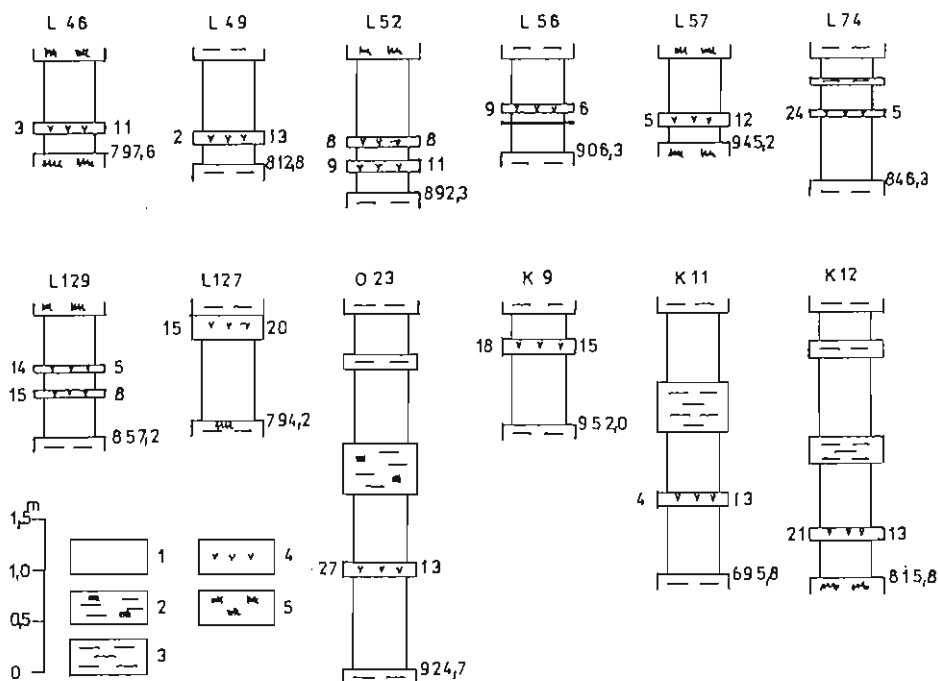


Fig. 3. Localization of tonstein in seam no. 385 in boreholes studied

1 — coal; 2 — coaly claystone; 3 — claystone; 4 — tonstein; 5 — mudstone; L 46 — number of borehole, 797,6 — depth of bottom of coal seam no. 385 (in meters), 3 — number of sample, 11 — thickness of tonstein bed in centimeters

Lokalizacja tonsteinu w pokładzie 385

1 — węgiel; 2 — ilowice węglisty; 3 — ilowiec; 4 — tonstein; 5 — mułowiec; oznaczenia na profilach: L 46 — numer otworu wiertniczego, 797,6 — głębokość spągu pokładu węgla 385 w metrach, 3 — numer próbki, 11 — miąższość warstwy tonsteinu w centymetrach

sometimes of pseudo-hexagonal habit (Pl. II, Fig. 9), or of the columnar aggregates. They are built of the clayish substance displaying microscopic properties of kaolinite, kaolinite with hydromica fragments or, sporadically, hydromica. The organic matter or iron compounds colour that clayish substance into brown. In some pseudomorphs there have been observed traces after zirkon inclusions occurring primarily in micas (Pl. II, Fig. 10). The post-mica pseudomorphs have been abundant in the tonstein from the boreholes L 63, L 72 and O 19.

Rare kaolinite columnar aggregates formed due to crystallization from the solutions are close in their crystal habit to some post-mica pseudomorphs. They differ, however, with their generally smaller sizes (below 0.2 mm) and display a tendency of taking the position parallel to the rock structure. Their kaolinite is clearer and colourless.

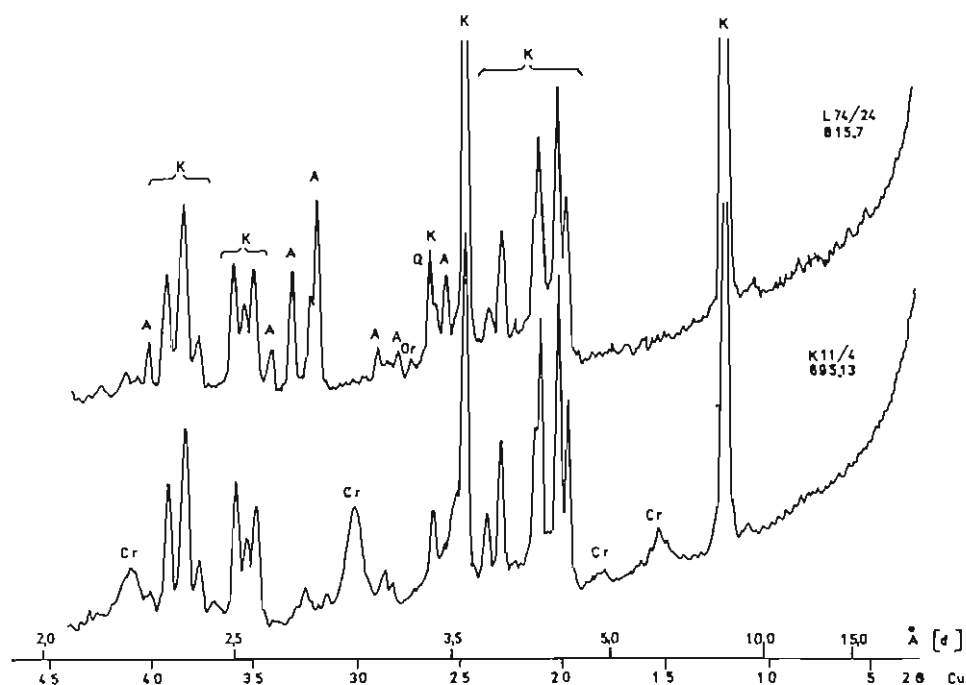


Fig. 4. Diffraction patterns of tonstein from the coal seam no. 385 from the Lublin Coal Basin

L 74 — number of borehole, 24 — number of sample, 815.7 — depth in meters; A — apatite; Cr — minerals of the crandallite group; K — kaolinite; Or — potassium feldspar; Q — quartz

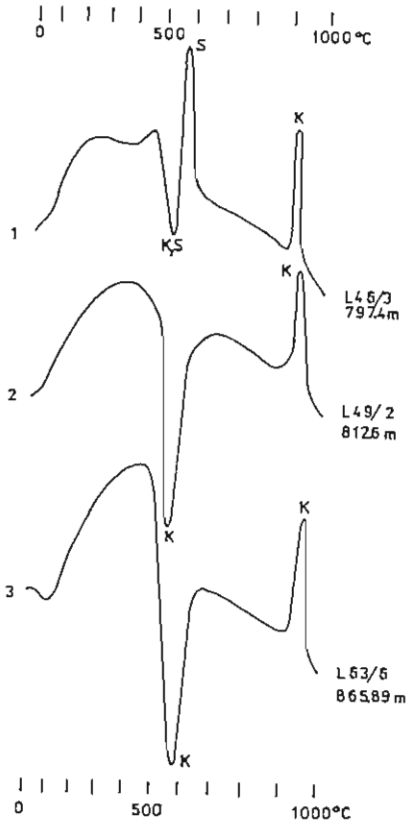
Dyfraktogramy tonsteinu z pokładu 385 LZW

L 74 — numer otworu, 24 — numer próbki, 815,7 — głębokość w metrach; A — apatyt; Cr — minerały grupy crandallitu; K — kaolinit; Or — skałki potasowy; Q — kwarc

In the tonstein from the boreholes L 49, L 72 and especially L 57 there occur, apart from the post-mica pseudomorphs, flakes and plates of the non-altered biotite (Pl. III, Fig. 11). That mineral displays a strong pleochroism in colours: α — colourless, pale-yellow, $\beta = \gamma$ — olive brown, reddish-brown as well as strong interference colours of I/II order. The biotite plates reach about 0.5 mm in length. Some opaque inclusions of the ore minerals have been observed there.

Quartz grains are sharp-edged, often with specific, anisometric, sharp shapes. Their extinction is uniform or wavy. Rarely they display the aggregate structure. The quartz grains are very small and do not exceed 0.15 mm.

Apart from the detritic quartz there have been observed autigenic silica accumulations of chalcedone type. Silica impregnates fragments of the rocks and coalified plant remnants. Sporadically also there appear chalcedone forms displaying round or weakly elliptic shapes — possibly of organic origin.



Quartz (chalcedone) has been marked on the X-ray diffraction patterns of the tonstein only by the weak reflexes of $d_{hkl} = 3.34$ and eventually 4.25 \AA , which partly coincide with kaolinite (Fig. 4).

Fragments of non-altered potassium feldspars rarely occur in the tonstein (Pl. II, Fig. 12). Trace abundance of those minerals are present at X-ray diffraction patterns due to the reflexes of $d_{hkl} = 3.24$ and 3.3 \AA (Fig. 4). Microscopically analyzed — they exhibit a small (close to zero) angle of the optical axes — characteristic for sanidine. In one case a relic of those polysynthetic twinned plagioclase has been observed. Much often there occur the pseudomorphs after feldspars being built of the microcrystalline, colourless, possibly clayish-siliceous substance. The components discussed display a different shape (Pl. IV, Fig. 13) — from the irregular, sharp-edged

Fig. 5. Differential thermal curve for tonstein from the coal seam no. 385 from the Lublin Coal Basin

S — siderite; other explanations as in Fig. 4

Różnicowe krzywe termiczne tonsteinu z pokładu 385 LZW

S — syderyt; pozostałe objaśnienia jak na fig. 4

ones to the tabular — typical for feldspars. Their size reaches 0.35 mm . The phosphate minerals in the tonstein studied are represented by the apatite and the minerals from the crandallite group (M. Muszyński, P. Wyszomirski, 1982). They either co-occur or appear separately.

Apatite occurs either in form of fragments or (rarely) as whole prisms of characteristic hexagonal cross-sections (Pl. IV, Fig. 14; Pl. V, Fig. 15). Mineral prisms reach the length of 0.1 mm , while their elongation varies from 1:14 to 1:3. Also irregular apatite grains are observed, being presumably the relics of its dissolved crystals. Apatite grains are colourless, clear, occasionally with some inclusions (Pl. V, Fig. 16). Microscopic identification of apatite has been supported by X-ray studies (Fig. 4). Lines $21\bar{3}1$ ($d = 2.80\text{--}2.76 \text{ \AA}$) and $30\bar{3}0$ ($d = 2.71\text{--}2.70 \text{ \AA}$) prove the existence of this mineral. Occasionally there occur also other, weaker reflexes (Fig. 4, Tab. 2) which together with the above mentioned ones correspond to the fluorine modification of apatite.

As it has resulted from the studies (M. Muszyński, P. Wyszomirski, 1982) the minerals of the crandallite group display a differentiated chemical composition corre-

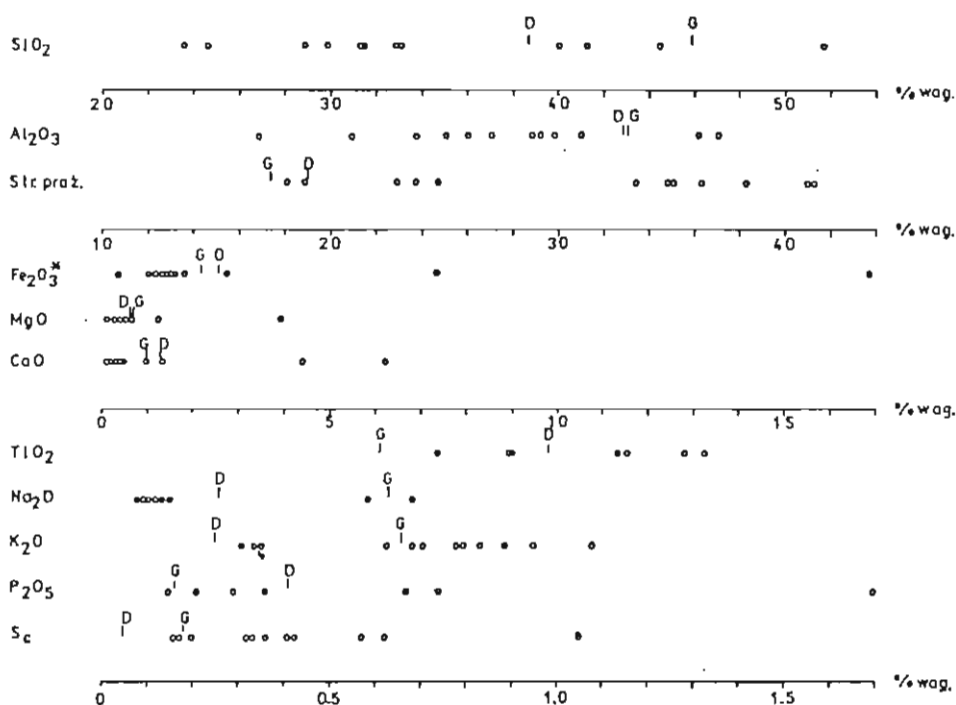


Fig. 6. Variation in content of main chemical components in tonstein from the coal seam no. 385 from the Lublin Coal Basin

Mean content of given element in tonstein: D — from the Lower Silesian Coal Basin, G — from the Upper Silesian Coal Basin (counted basing of data from *Katalogi analiz chemicznych...*, 1959, 1961, 1966, 1972, 1987)

Zmienność zawartości zasadniczych składników chemicznych w tonsteinie z pokładu 385 LZW

Średnie zawartości danego pierwiastka w tonsteinach: D — z DZW, G — z GZW, obliczone na podstawie danych z *Katalogów analiz chemicznych ...* (1959, 1961, 1966, 1972, 1987)

sponding to gorceixyte or to the mixed phases between crandallite *sensu stricto*, gorceixyte and goyasite. Those minerals occur in the accessory amounts and either form very fine microcrystalline aggregates or are dispersed. Due to their low birefringence and not distinct positive relief against kaolinite as well as small amounts they are practically invisible in the kaolinite background under the microscope. On the X-ray diffraction patterns (Fig. 4) the minerals from the crandallite group have distinct reflexes of the values of: $d_{10\bar{1}1} \cong 5.72 \text{ \AA}$, $d_{10\bar{1}2} \cong 4.90 \text{ \AA}$, $d_{11\bar{2}3} \cong 2.96 \text{ \AA}$, $d_{20\bar{2}4} \cong 2.43 \text{ \AA}$ and $d_{12\bar{3}2} \cong 2.16 \text{ \AA}$. The lines do not coincide with those characteristic for the other mineral components of the tonstein under research.

The opaque minerals occur sporadically and possibly are represented by pyrite. They either form circular microaggregates of the average size of 0.01 mm (bacteria-derived pyrite) or exhibit rectangular habit. Those last forms also do not exceed hundredths of millimeters in size.

Table 1

Chemical analyses of tonstein from the seam no. 385 from the Lublin Coal Basin (weight percent)

Component	L 46/3* 797.6/11**	L 49/2 812.8/13	L 52/8 892.3/8	L 56/9 906.3/8	L 57/5 945.2/12	L 74/24 816.3/5	L 129/14 857.2/5	L 129/15 857.2/8	K 9/18 952.0/15	K 11/4 695.8/13	K 12/21 815.8/13	O 23/27 924.7/13
SiO ₂	28.98	32.98	29.99	41.70	23.61	24.65	41.21	40.45	33.00	40.31	31.45	31.35
TiO ₂	n.d.	n.d.	n.d.	n.d.	n.d.	0.90	1.14	1.29	1.16	1.33	0.90	0.74
Al ₂ O ₃	26.13	29.20	25.19	36.29	16.88	20.83	27.10	29.98	28.63	31.31	37.09	23.82
Fe ₂ O ₃ ***	1.69	1.23	1.59	1.24	16.88	7.36	1.39	1.09	1.49	1.85	2.76	0.36
MnO	traces	traces	traces	traces	0.22	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
MgO	0.32	0.19	0.39	0.29	3.93	1.23	0.62	0.54	0.34	0.34	0.55	0.55
CaO	4.41	0.23	0.18	0.14	1.00	1.33	1.00	0.50	0.44	0.36	6.21	0.17
Na ₂ O	0.08	0.13	0.09	0.10	0.08	0.12	0.58	0.68	0.12	0.12	0.09	0.15
K ₂ O	0.35	0.31	0.69	0.40	0.79	1.08	0.95	0.89	0.34	0.78	0.63	0.83
P ₂ O ₅	n.d.	n.d.	n.d.	n.d.	n.d.	0.74	0.29	0.15	0.67	0.36	1.70	0.21
S _{total}	0.62	0.32	0.41	0.17	1.05	0.57	0.36	0.20	0.41	0.42	0.16	0.33
Calcination loss	36.40	34.86	41.04	18.87	34.52	38.31	24.75	23.77	33.40	22.95	18.17	41.13
Sum	98.98	99.45	99.57	99.20	98.96	97.12	99.39	99.54	100.00	100.13	99.71	99.64

* — number of borehole/number of sample; ** — depth of coal seam in meters/thickness of tonstein in centimeters; *** — total Fe as Fe₂O₃; n.d. — not determined

Carbonate minerals, thermally identified, as siderite (Fig. 5 — curve 1) have the form of micrite dispersed in the clayish background and forming fine irregular aggregates.

Phase composition of the tonstein from the seam no. 385 from the Lublin Coal Basin has been totally correlated with its chemical composition (Tab. 1, Fig. 6). From the chemical point of view in comparison to the composition of the analogic rocks from the Upper Silesian Coal Basin (Fig. 6) the Lublin tonstein contains less SiO_2 , Al_2O_3 , Fe_2O_3 , MgO and Na_2O and more TiO_2 , FeO , P_2O_5 and S_c as well as it exhibits higher calcination loss. In comparison to the tonstein from the Lower Silesian Coal Basin it has in general lower percentage of Al_2O_3 , FeO , MgO and Na_2O in contrary to higher K_2O , S_c , SiO_2 , TiO_2 and calcination loss. It is characteristic, therefore, for the tonstein from the Lublin Coal Basin in comparison to the adequate rocks from the Upper and Lower Silesian Coal Basins that it displays generally lower percentage of Al_2O_3 , MgO and Na_2O , higher TiO_2 and S_c and higher calcination loss.

REFRACTORINESS OF TONSTEIN

Fire-proofness of the tonstein samples from the seam no. 385 varies from about 135 to over 175 sP. As it is well-known (F. Nadachowski, 1970) this property is connected with the chemical composition of the rock, being dependant on the ratio of Al_2O_3 versus SiO_2 and the summaric percentage of the oxides concerned as fluxes: Fe_2O_3 , CaO , MgO , MnO , Na_2O and K_2O . The tonstein studied displays a high refractoriness (from 171 to over 175 sP) in case of a high Al_2O_3 content (40–46 weight percent in the calcinated rock) and of SiO_2 content not exceeding 53 weight percent (Tab. 3). Simultaneously — the percentage of the above mentioned oxides (fluxes) in the calcinated rock is low — up to 5 weight percent. In case when their content exceeds 10 weight percent, the refractoriness decreases to below 150 sP. Refractoriness remains high when Fe_2O_3 content does not exceed 3 weight percent, decreasing together with these oxides increase.

SYSTEMATIC POSITION

In the tonstein classification the following facts have been taken into account: genesis of the original material, structural properties of the rocks, geological processes leading to rock formation. The classification proposed by A. Schüller (*vide* P. Guthörl et al., 1956) based on the tonsteins from the Saar-Lorraine Basin is well-known and often cited in the Polish references.

The tonstein rocks are divided into two groups:

- A — grain tonstein (*körnige*);
- B — massive tonsteins (*dichte*).

The grain tonsteins, in their turn, comprise:

- 1 — crystalline tonsteins (*Kristalltonsteine*);

Table 2

X-ray data for apatite from tonstein from the coal seam no. 385 from the Lublin Coal Basin

Apatite from tonstein (Lublin Coal Basin, L 74 borehole, depth 816.3 m)		Fluoric apatite (D. McConnell, 1973)	
d [Å]	I	d [Å]	I
3.450	52	3.432	3
3.170	16	—	—
3.070	18	3.060	3
2.800	100	2.798	10
2.770	48	2.769	4
2.700	62	2.702	6
2.630	23	2.616	3
—	—	2.517	1
—	—	2.289	1
2.250	24	2.248	2
—	—	2.135	1
—	—	2.057	1
—	—	2.001	1
1.936	31	1.937	3
1.885	13	1.883	1
1.838	34	1.838	8
1.795	16	1.795	3
1.768	8	1.769	3
1.749	9	1.745	3
1.720	9	1.720	3

2 — groap tonsteins (*Graupentonsteine*);

3 — pseudomorphic tonsteins (*Pseudomorphosen-Tonsteine*).

In relation to the classification presented the tonstein from the seam no. 385 can be accounted to the tonstein (*Graupentonsteine*) with some components characteristic for the crystalline and pseudomorphic tonsteins.

A. Bouroz (1962), basing on the other principles, has distinguished four groups of the tonsteins, namely:

1 — orthotonsteins — altered tuffs;

2 — stratotonsteins — formed from the material which underwent the sedimentation processes;

3 — catatonsteins — formed *in situ* from the feldspar sandstones;

4 — metatonsteins — metamorphed orthotonsteins.

Applying that classification the tonstein studied should be concerned as the stratotonstein.

For the practical aims P. Martinec et al. (1989) have distinguished in the Ostrava-Karviná Basin two main tonstein modifications, namely:

1 — orthotonsteins — which display a high content of the autigenic, clay minerals formed due to the argillitization of the components of the volcanic origin (biotite, sanidine, glass);

Table 3

Chemical analyses (after subtraction of calcination loss) and refractoriness of tonstein from the coal seam no. 385 from the Lublin Coal Basin

Component [weight percent]	L 46/3 797.6/11	L 49/2 812.8/13	L 52/8 892.3/8	L 56/9 906.3/6	L 57/5 945.2/12	L 74/24 816.3/5	L 129/14 857.2/5	L 129/15 857.2/8	K 9/18 952.0/15	K 11/4 695.8/13	K 12/21 815.8/13	O 23/27 924.7/13
SiO ₂	45.83	50.79	51.02	51.51	36.26	40.72	54.87	53.14	49.55	52.30	38.46	53.39
TiO ₂	n.d.	n.d.	n.d.	n.d.	n.d.	1.49	1.52	1.70	1.74	1.72	1.10	1.26
Al ₂ O ₃	41.33	44.96	42.86	44.81	25.92	34.40	36.10	39.38	42.99	40.62	45.35	40.56
Fe ₂ O ₃ *	2.67	1.89	2.70	1.53	25.92	12.16	1.85	1.43	2.24	2.40	3.37	0.61
MnO	traces	traces	traces	traces	0.34	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
MgO	0.51	0.29	0.66	0.36	6.04	2.03	0.82	0.71	0.51	0.44	0.67	0.94
CaO	6.97	0.35	0.31	0.17	1.53	2.19	1.33	0.66	0.66	0.47	7.59	0.29
Na ₂ O	0.13	0.20	0.15	0.12	0.13	0.19	0.77	0.89	0.18	0.16	0.11	0.26
K ₂ O	0.56	0.48	1.17	0.49	1.21	1.78	1.26	1.17	0.51	1.01	0.77	1.41
P ₂ O ₅	n.d.	n.d.	n.d.	n.d.	n.d.	1.22	0.39	0.20	1.01	0.47	2.08	0.36
S _{total}	0.98	0.49	0.70	0.21	1.61	0.94	0.48	0.26	0.61	0.54	0.21	0.56
Sum	98.98	99.45	99.57	99.20	98.96	97.12	99.39	99.54	100.00	100.13	99.71	99.64
Sum of fluxes**	10.84	3.21	4.99	2.67	35.17	18.35	6.03	4.86	4.10	4.48	12.51	3.51
Refractoriness [sP]	143/146	> 175	171	> 175	135/138	148	167/169	175	175	173	150	173

* — total Fe as Fe₂O₃; ** — summaric content of oxides concerned as fluxes; other explanations as in Table 1

2 — paratonsteins — which contain less autigenic clay substance but more relics of the components of the volcanic origin.

In relation to those two modifications, the tonstein from the coal seam no. 385 can be classified as the orthotonstein.

J. Kralik (J. Kralik, J. Pešek, 1985) has distinguished the following two groups among the tonsteins in dependance on the dominant original material:

1 — tonsteins formed from the totally argillitized vitroclastic tuff (crystalline, microcrystalline and groap tonsteins);

2 — tonsteins formed from the totally argillitized crystaloclastic and lithoclastic tuff (pseudomorphic tonstein).

In the tonsteins of those two groups the content of the non-altered components may reach the value of 10 weight percent.

The tonstein under research — being mainly the groap one — represents the first group.

GENESIS

Among the components of the tonstein studied there occur the following minerals which may have the volcanic origin: biotite altered to a different degree, quartz of pirogenic type, potassium feldspar displaying a low angle of the optic axes (sanidine?) and apatite. The groap kaolinite aggregates present in many tonsteins are also concerned by some authors as pyroclastic, i.e., the kaolinized volcanic glass (J. Kuhl, 1972). Sizes of the grain components are small and in general do not exceed 0.2 mm. Weak heterogenization in grain size, lack of mineral grains showing water transport features suggest that the material of the volcanic origin was deposited directly onto the peatbog after a long air transport. A part of that mineral material underwent fast alteration in the acid environment (e.g., the volcanic glass) while the alteration of another part was slower (feldspars, micas). Successively from the ionic solutions there crystallized kaolinite in different forms as: microcrystalline, coarse-crystalline (“vermicular forms”) and possibly — “groaps”. The assumption on the deposition of the air transported material has been supported by the wide-spread extent of the tonstein from the Lublin Basin and its generally similar thickness in the whole area, as well as its analogic texture and structure and mineral content.

Deposition of the material displaying the analogic composition repeated at least twice in the formation period of the seam no. 385 which is evidenced by two tonstein beds of the similar petrographic characteristics. The volcanos remote from the place of deposition were possibly the source of the acid (or neutral) pyroclastic material. The eastern part of the Upper Silesian Coal Basin can be mentioned as one of the recently known regions where from the pyroclastic material could have been transported. Another source of the pyroclastic material can be in the east — in the vicinity of the Donieck Basin, where the tonstein beds have been observed, too (P.V. Zarickij, 1987).

COMPARATIVE REMARKS

The coal seam no. 385, which comprises the tonstein studied, lies in the Westphalian B series close to the stratigraphic boundary of Westphalian A/Westphalian B (Fig. 3). The tonsteins from the other two Polish coal basins, i.e., in the Upper and Lower Silesian ones have been observed in the comparative stratigraphic position. In the first basin mentioned the tonsteins have been observed in several seams apart from the well-known tuffite occurring at the boundary of the Załęcze (Westphalian A) and Orzesze Beds *sensu stricto* (Westphalian B).

The tonsteins have been found in 8 seams (L. Chodyniecka, J. Łabuś, 1984) between the seams nos. 208 and 324 (in the local nomenclature) in the Czczott mine, within the Westphalian B sediments (the Orzesze Beds *s.s.* and the Łaziska Beds *s.s.*). Six beds are built of the dominant crystalline tonstein and locally — of the compact and pseudomorphic one. Two beds, in their turn, comprise the graupentonstein. It is worth mentioning here, that one of those graupentonstein beds occurs in the seam no. 321 (according to the local nomenclature in the Czczott mine) which approximately corresponds stratigraphically to the seam no. 385 from the Lublin Coal Basin.

In the Jaworzno region the tonstein beds have been observed in four coal seams in the section of one of the boreholes (I. Lipiarski, 1993). In three Westphalian B seams there occur crystalline and pseudomorphic tonsteins, while in the fourth, the lowest (Westphalian A; the seam close to the stratigraphic boundary of Westphalian A and Westphalian B) there dominates the groap structure.

In the Lower Silesian Coal Basin several tonstein beds have been described in the coal seams of the Żacłef Beds (K. Hoehne, 1951; I. Lipiarski, 1985). The tonsteins in the Wałbrzych region within the upper Żacłef Beds (Westphalian B) in the seams nos. 314 and 309 are the typical pseudomorphic tonsteins, while those from nos. 430 and 428 (Westphalian A) which occur close to the Westphalian A/Westphalian B boundary represent a very characteristic graupentonstein displaying the structure analogic to the rocks from the seam no. 385 from the Lublin Coal Basin.

When summarizing the facts from above — it should be stated that in the Upper and Lower Silesian Coal Basins among the tonsteins of the differentiated structure there occur also the graupentonsteins similar in their petrographic character to those studied from the seam no. 385 from the Lublin Coal Basin. Localization of the graupentonsteins in the basins is close to the stratigraphic boundary of Westphalian A and Westphalian B.

Translated by Katarzyna Jaromowicz-Szulc

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TONSTEIN Z POKŁADU 385 FORMACJI LUBELSKIEJ Z LUBELSKIEGO ZAGŁĘBIA WĘGLOWEGO

Streszczenie

W typowym obszarze występowania formacji lubelskiej (fm) (obszar górniczy „Bogdanka”) stwierdzono jedną — a lokalnie — dwie ławice tonsteinu. Tonstein został zbadany w kilkudziesięciu otworach wiertniczych zlokalizowanych w synklinie Radzyna — Bogdanki — Chelma, między Ostrowem Lubelskim a Dorohuczą. Ma on miąższość od 5 do 15 cm i znajduje się w różnych częściach profilu pokładu węgla 385 (bliżej spągu lub bliżej stropu).

Głównym składnikiem tonsteinu jest kaolinit; występuje on w formie „krup”, które zdecydowanie przeważają, pseudomorfoz po biotycie i skałeniach, kolumnowych agregatów w kształcie „robaków” oraz w formie mikrokrystalicznej, która stanowi tło składników ziarnistych. Inne podrzędne minerały, zwykle o niewielkich rozmiarach ziarn, są reprezentowane przez: ostrokrawędziste ziarna kwarcu o jednostajnym lub w niewielkim stopniu falistym wygaszaniu światła, żółto-czerwonobrunatne blaszki biotytu o intensywnym pleochroizmie oraz tabliczki nieprzeobrażonych skałeni — sanidynu i sporadycznie plagioklazów. Udokumentowany został także apatyt, minerały z grupy crandallitu (M. Muszyński, P. Wyszomirski, 1982) syderyt oraz piryt(?). Rzadko obserwowano drobne skupienia mikrokrystalicznej krzemionki.

Niektóre składniki mineralne są pochodzenia autigenicznego (kaolinit mikrokrystaliczny, kolumnowy i pseudomorfozowy, crandallit, mikrokrystaliczna krzemionka, minerały kruszcowe i węglany). Do minerałów allogenicnych należą m.in. kwarc typu pirogenicznego, blaszki biotytu, skałenie o cechach optycznych sanidynu i apatyt, które reprezentują materiał najprawdopodobniej piroklastyczny. „Krupy” zbudowane z kaolinitu mogą być w tym zespole uważane za zdewitryfikowane szkliwo wulkaniczne (J. Kuhl, 1972). Wydaje się więc, że omawiany tonstein powstał z materiału piroklastycznego zdeponowanego na torfowisku. W historii tworzenia się pokładu (torfu) 385 przynajmniej dwukrotnie miał miejsce proces depozycji materiału piroklastycznego.

Ze względu na dominację w badanej skale „krup” kaolinitu można ją określić mianem tonsteinu krupowego (*Graupentonstein* według A. Schüllera *vide* P. Guthörl i in., 1956). W innych klasyfikacjach tonsteiny o podobnym składzie mineralnym są określane mianem stratotonsteinów (A. Bouroz, 1962) lub ortotonsteinów (P. Martinec i in., 1989).

Badana skała wykazuje typowy dla ogółu tonsteinów skład chemiczny. W porównaniu z tonsteinami z Górnośląskiego i Dolnośląskiego Zagłębia Węglowego charakteryzuje się mniejszym udziałem Al_2O_3 , MgO i Na_2O , natomiast większym TiO_2 i Se . Ze względu na dużą zawartość materii organicznej wykazuje też wysokie straty prażenia. Wahanie w składzie chemicznym skały wpływają na zmienną ogniotrwałość, która zależy od stosunku podstawowych składników, tj. krzemionki do glinki, i od zawartości topników; oznaczona ogniotrwałość waha się od 135 do powyżej 175 sP. Notowana lokalnie wysoka ogniotrwałość jest brana pod uwagę przy wykorzystaniu przyszłościowym skały jako surowca ceramicznego (W. Heflik i in., 1978).

Omawiany tonstein wyznacza horyzont izochroniczny. Ze względu na duże rozprzestrzenienie i możliwość łatwego stwierdzenia na tle pokładu węgla, tonstein stanowi poziom przewodni o dużej wartości

praktycznej dla stratygrafii, paleogeografii i geologii złożowej. W zmiennych bowiem stratygraficznie i horyzontalnie utworach formacji lubelskiej (Im), w których identyfikacja pokładów węgla w poszczególnych profilach nawet najlepiej zbadanej części zagłębia nie jest łatwa, rozpoznanie tego poziomu będzie przydatne i zwiększy stopień dokładności identyfikacji pokładów węgla.

PLATE I

Fig. 7. Aggregates of microcrystalline kaolinite against clay-organic background of tonstein; borehole L 72, depth of 844.4 m; one polaroid

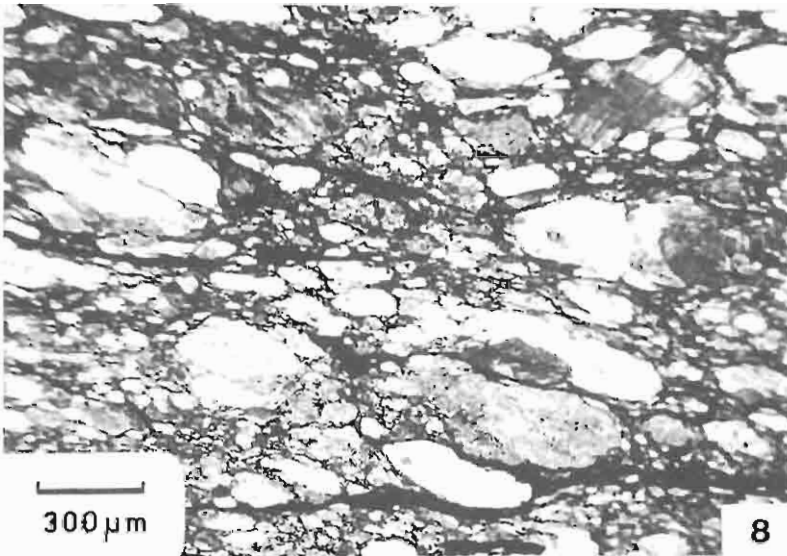
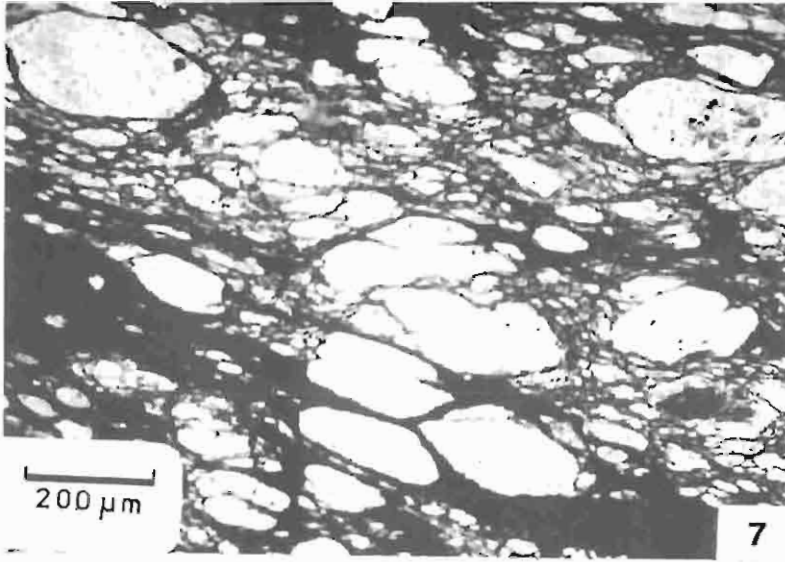
Agregaty mikrokrystalicznego kaolinitu w ilasto-organicznym tle tonsteinu; otwór L 72, głęb. 844,4 m; 1 polaroid

Fig. 8. Aggregates of microcrystalline kaolinite and post-mica pseudomorphs against clay-organic background of tonstein; upper tonstein, borehole L 129, depth of 857.2 m; crossed polaroids

Agregaty mikrokrystalicznego kaolinitu oraz pseudomorfozy pomikowe w ilasto-organicznym tle tonsteinu; tonstein górny, otwór L 129, głęb. 857,2 m; polaroidy x

All samples origin from the coal seam no. 385 in the Lublin Coal Basin

Wszystkie próbki pochodzą z pokładu 385 LZW



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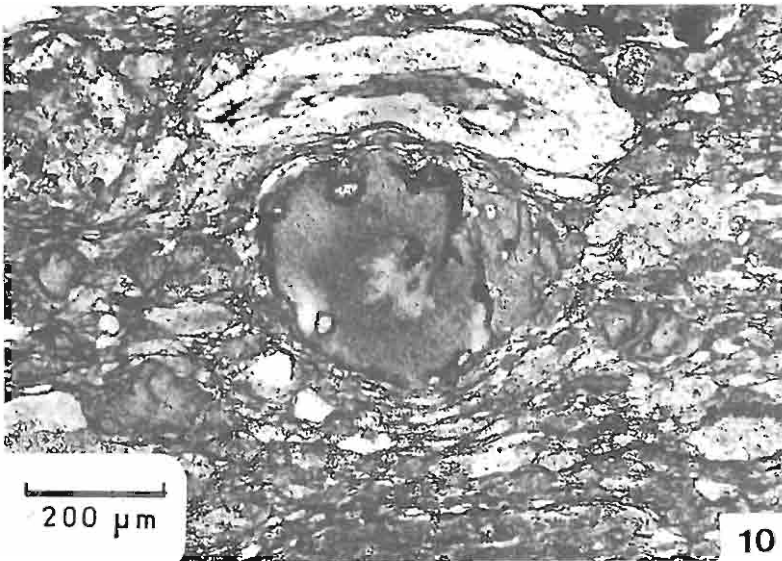
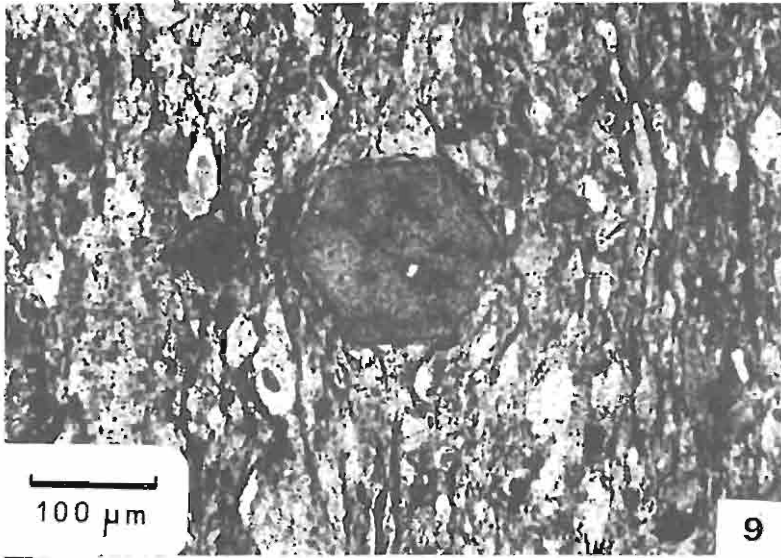
PLATE II

Fig. 9. Post-biotite(?) pseudomorph displaying pseudo-hexagonal habit in tonstein; borehole O 19, depth of 867.9 m; one polaroid

Pseudomorfoza pobiotytowa(?) o pseudoheksagonalnym pokroju w tonsteinie; otwór O 19, głęb. 867,9 m; 1 polaroid

Fig. 10. Post-biotite(?) pseudomorph in tonstein; traces after zircon inclusions occurring primarily in mica-well seen; borehole L 74, depth of 816.3 m; one polaroid

Pseudomorfoza pobiotytowa(?) w tonsteinie; widoczne ślady po występujących pierwotnie w micy wrostkach cyrkonu; otwór L 74, głęb. 816,3 m; 1 polaroid



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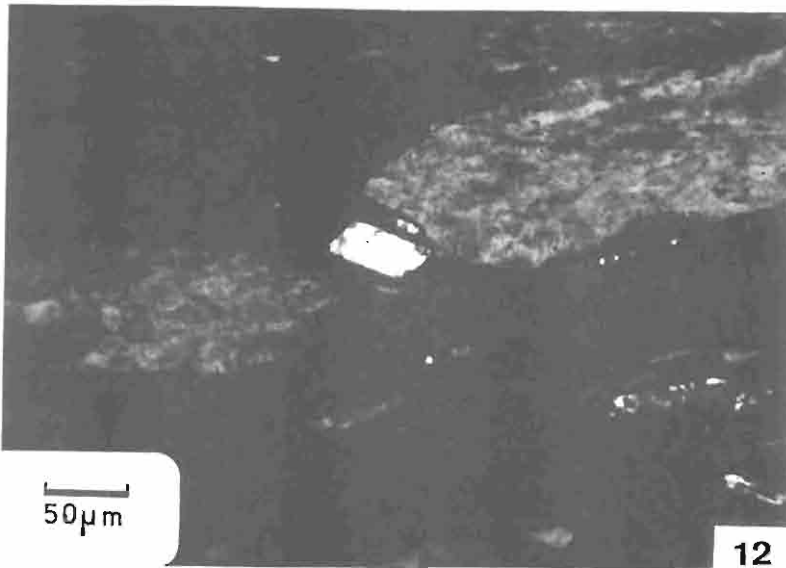
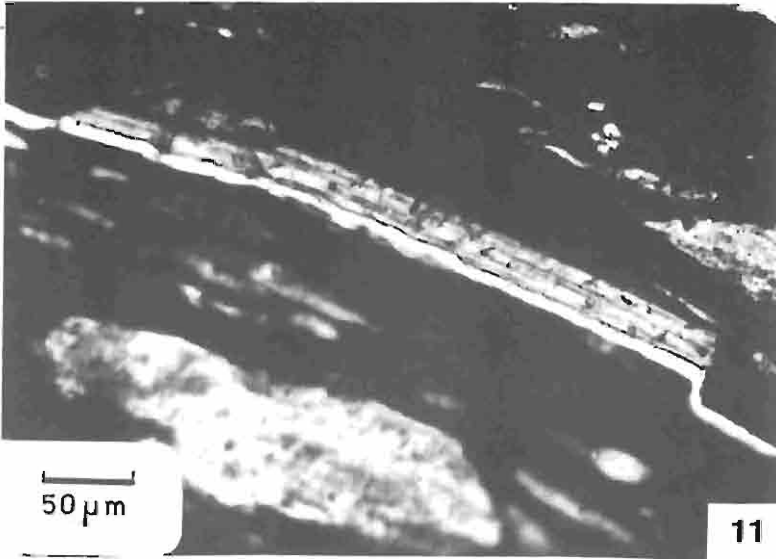
PLATE III

Fig. 11. Plate of non-altered biotite in tonstein; borehole L 57, depth of 845.2 m; crossed polaroids

Błazka niezmienionego biotyту w tonsteinie; otwór L 57, głęb. 845,2 m; polaroidy x

Fig. 12. Fragment of plate of potassium feldspar (sanidine?) in tonstein; borehole L 57, depth of 945.2 m; crossed polaroids

Fragment tabliczki skalenia potasowego (sanidynu?) w tonsteinie; otwór L 57, głęb. 945,2 m; polaroidy x



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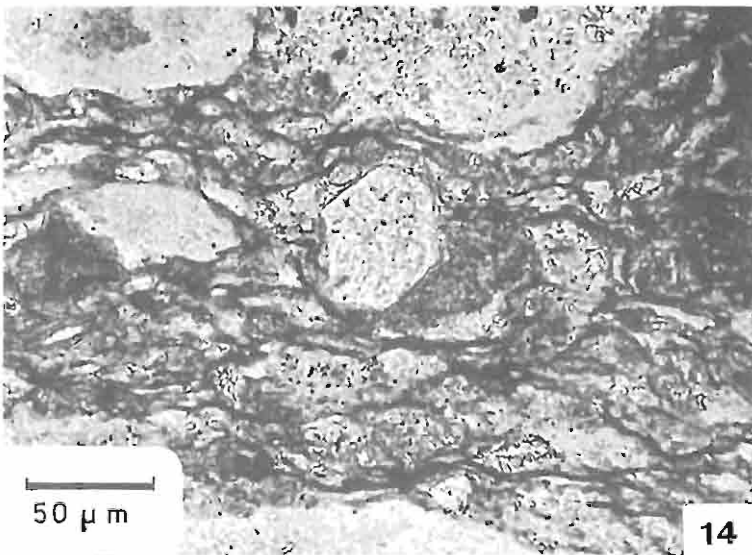
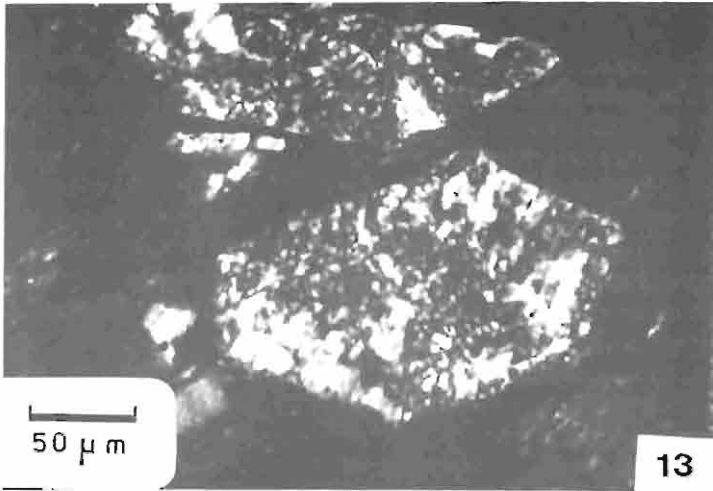
PLATE IV

Fig. 13. Clay-silica pseudomorphs after feldspars in tonstein; borehole L 63, depth of 866.4 m; crossed polaroids

Pseudomorfozy ilasto-krzemionkowe po skaleniach w tonsteinie; otwór L 63, głęb. 866,4 m; polaroidy x

Fig. 14. Apatite crystal (transverse section) in tonstein; borehole L 74, depth of 816.3 m; one polaroid

Kryształ apatytu (przekrój poprzeczny) w tonsteinie; otwór L 74, głęb. 816,3 m; 1 polaroid



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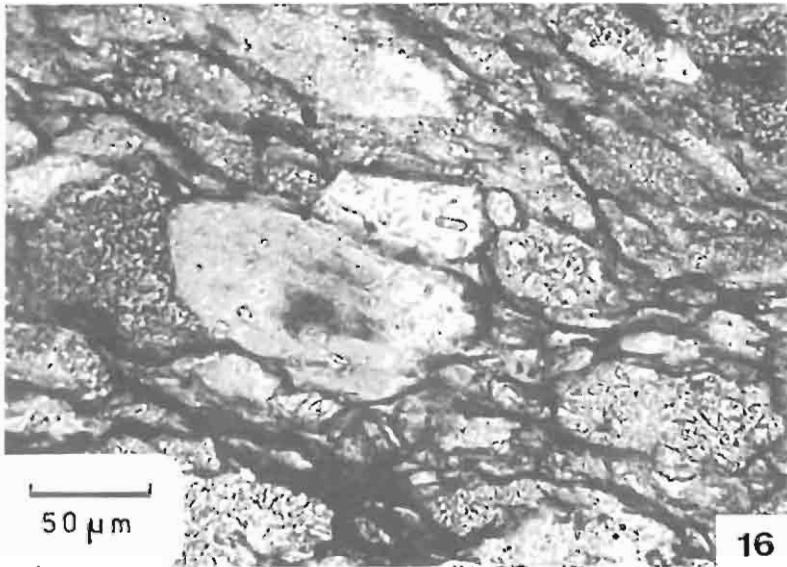
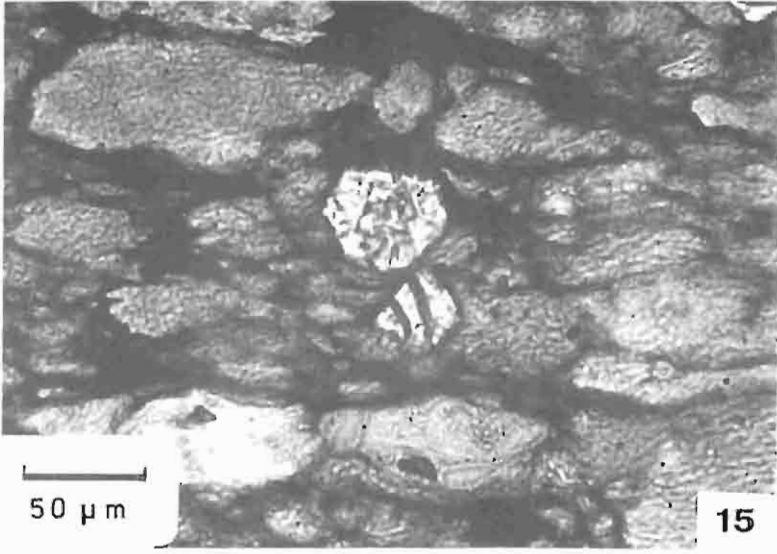
PLATE V

Fig. 15. Apatite crystal (transverse section) in tonstein; borehole L 72, depth of 844.4 m; one polaroid

Kryształ apatytu (przekrój poprzeczny) w tonsteinie; otwór L 72, głęb. 844,4 m; 1 polaroid

Fig. 16. Apatite crystal (longitudinal section) with individual inclusion in tonstein; borehole L 74, depth of 816.3 m; one polaroid

Kryształ apatytu (przekrój podłużny) z pojedynczym wrostkiem w tonsteinie; otwór L 74, głęb. 816,3 m; 1 polaroid



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