MINERALOGIA POLONICA
Vol. 4 — 1973

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THE FORMATION OF KAOLINITE, MONTMORILLONITE AND MIXED-LAYER MONTMORILLONITE-ILLITES DURING THE ALTERATION OF CARBONIFEROUS TUFF (THE UPPER SILESIAN COAL BASIN)

UKD [549.623.9+549.623.6]01:562.313.8:551.735(438.312)

Abstract. Mineralogical studies were carried out on the unique profile of an intercalation in a coal-seam (Westphalian A/B — the Upper Silesian Coal Basin), showing in a 1 m thick layer a continuous vertical gradation from pseudomorphosen tonstein to bentonite. Non-clay minerals are identical throughout the layer, testifying to the pyroclastic character of the primary material (sanidine, high-temperature plagioclase, biotite, quartz with the uniform extinction, apatite). Sedimentological observations demonstrated *in situ* alteration of this material. Vegetation affected the relative intensity of montmorillonite and the consequent kaolinite formation. During the latter process, the transformation of biotite structure led to the formation of D-kaolinite, whereas crystallization from the solution produced T-kaolinite. The montmorillonitoids show variation from pure dioctahedral montmorillonite, through random and partly ordered mixed-layer montmorillonite-illites (10—50% I), to those of allevardite type, characterized by maximum ordering of their structure. A hypothesis has been put forward on the mixed-layers having formed from montmorillonite as a result of sorption of potassium released during the kaolinization of tuff.

INTRODUCTION

Investigations carried on for several years have demonstrated that the alteration of pyroclastic materials deposited in coal basins leads to the formation of kaolinite and montmorillonite (mixed-layer montmorillonite-illites M/I). The occurrence of mixed-layer M/I in tonsteins has been ascertained by Hallbauer *et al.* (1962), Francis (1961), Králik (1961), Kulbicki, Vetter (1955), Price, Duff (1969). Several Carboniferous bentonite

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Table 1

Synthetic sedimentologic description of the profile

Number of layer	Petrographical name	Colour	Sedimentary structures		Type of bottom contacts	Organic matter	Roundness and orientation of coarse material	Clay minerals in the matrix (microscope estimation)	Others
			depositional	deformational					
1 and 2	coarse-silty claystone	pale brown	—	—	gradational	fine, dispersed in clayey matrix; lenses of coal	sharp-edged, unoriented	rientation present only near coal lenses and in fragments of coaly claystone	lenses of coaly claystone
3	silty claystone	pale yellow-brown	—	convolute lamination in bottom part, horizontal microstylolites	sharp	coalified plants stems	sharp-edged, unoriented	lack of orientation	lenses of coaly claystone in bottom part
4	claystone	greenish, upper part brownish	indistinct horizontal lamination	load casts in upper part, horizontal microstylolites	sharp	fine, dispersed and coaly claystone lenses in upper part	lack of nonpelitic material	good orientation	layer occurs locally, veinlets of dolomite in tectonic fissures in underlying coaly claystone
5	upward transition from silty to sandy claystone	greenish-gray	simple reverse graded bedding	horizontal microstylolites	sharp	coalified plants stems	sharp edged, slightly oriented	lack of orientation	lenses of brownish claystone in bottom part
6	sandy claystone	pink	—	—	gradational	coalified plants stems	sharp edged, unoriented	lack of orientation	
7	silty claystone	gray	multiple graded bedding, in upper part locally horizontal lamination and small-scale cross-bedding	indistinct horizontal microstylolites	sharp, slightly deformed	rare and small coalified plants stems	sharp edged, slightly oriented only in fine-grained parts of layers	a slight orientation present only in fine-grained parts of layers	
8	claystone grading upward into mudstone	dark gray	horizontal lamination with coal detritus	clastic dikes	very sharp	coal detritus abundant; coalified plants stems	oriented	orientation changes upward from good to medium	
9	mudstone	gray	small-scale cross-bedding	convolute lamination, horizontal microstylolites	very sharp — erosional	coal detritus concentrated in lee sides of ripples. rare coalified plants stems	unoriented	lack of orientation	
10	mudstone	dark gray	undistinct lenticular bedding disturbed by plants activity	—	gradational	fine, dispersed; coal detritus; coal lenses; appendices	oriented	lack of orientation	

horizons with accessory kaolinite have been described as well (Jansa, Durčakova 1965; Nelson 1959; Spears 1971—1972; Trewin 1968).

These facts have encouraged a hypothesis on the genetic relation of bentonites and tonsteins (Francis 1969; Spears 1971). It has been confirmed by one of the present authors (Środoń 1972 a, b), who discussed the co-occurrence of tonstein and K-bentonite, both owing their origin to the same pyroclastic material. The present work is an attempt at a more definite determination of the conditions and mechanisms of the formation of kaolinite, montmorillonite and mixed-layer M/I, based on the materials from the tuffite horizon in the Orzesze beds (Westphalian A/B) of the Upper Silesian Coal Basin.

The tuffite horizon in question occupies the area of over 1000 km^2 (Kuhl 1955; Ryszka, Misiarz 1959) and is used as the correlation horizon. It always occurs within, or in the close neighbourhood of, the coal-seam denoted as 327 or 328. Its thickness ranges from some centimetres to over 1 metre. The investigations were performed on the thickest profile known, exposed in the Brzeszcze coal mine. For comparison's sake, a sample of the same tuffite obtained from a bore-hole near Pszczyna (about 30 km west of the Brzeszcze mine — sample X) was used.

SEDIMENTOLOGICAL STUDIES

The pyroclastic rock horizon under study occurs in the Brzeszcze mine as an intercalation in the coal-seam 327. The thickness of the underlying and overlying coal layers is 0.8 m and 1.2 m, respectively. The horizon is internally differentiated into several layers, the continuity of which has been checked over a length of about 0.5 km.

The geological profile has been presented in Figure 1. A synthetic macroscopic description is given in Table 1, the name of rock, the degree of clay matrix orientation, and the roundness and orientation of coarse-grained material being added.

Carbonized plant stems (Tab. 1) form thin coal membranes with more or less ellipsoidal outlines in cross-sections. They usually lie horizontally, but when their position happens to be close to vertical, the adjacent depositional structures are, as a rule, deformed. The membranes are generally filled with the material whose grain-size composition is somewhat different from that of the enclosing rock. Preserved morphological details allow the identification of the membranes as plant stems or, in many cases, also as appendices of Carboniferous plants. Kaolinite incrustation of plant remains, observed in the tonsteins from the Upper Silesian Coal Basin (Bocheński, Bolewski 1958; Bolewski, Kubisz 1959), has not been noted here.

Microstylolites noted may be classified as being of aggregate, horizontal and sutured type (Park, Schot 1968). They can be best observed in the finest-grained rocks (layers 3 and 4). Distances between the sutures are constant in a given layer. Their changes in the profile, ranging from 0.5 to 1 mm, correspond to the differences in the host rock grain-size. The formation of these structures followed the deformations connected with unstable density stratification (convolute lamination).

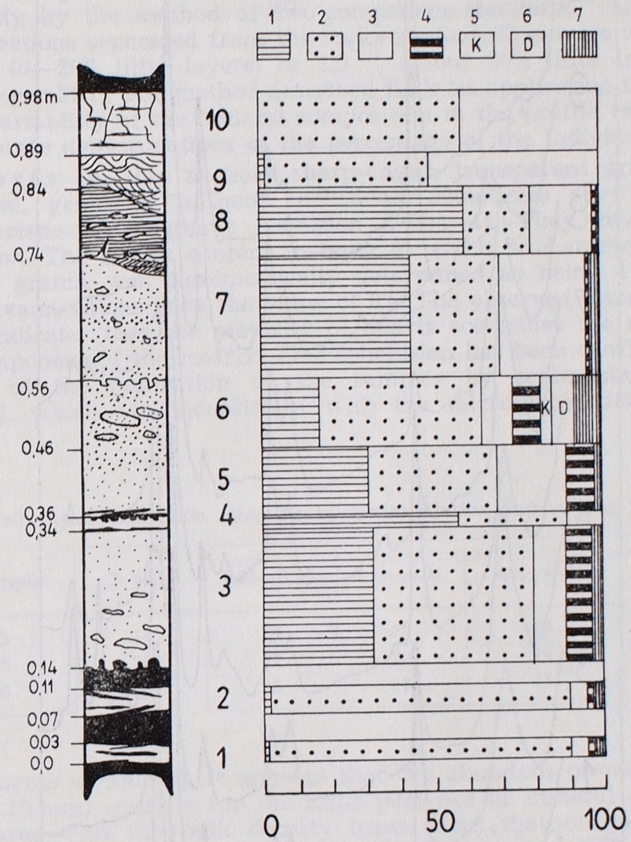


Fig. 1. Sedimentological profile and mineral composition
1 — montmorillonite or mixed-layer montmorillonite-illites, *2* — kaolinite, *3* — quartz, *4* — feldspars, *5* — calcite, *6* — dolomite, *7* — siderite

MINERALOGICAL AND PETROGRAPHICAL STUDIES

An identification of the mineral constituents of the rocks studied was based on X-ray examinations and, for the minerals of the montmorillonite group, also on thermal analyses. The morphological features of grains and their alteration processes were being observed in thin sections and powder preparations under the microscope.

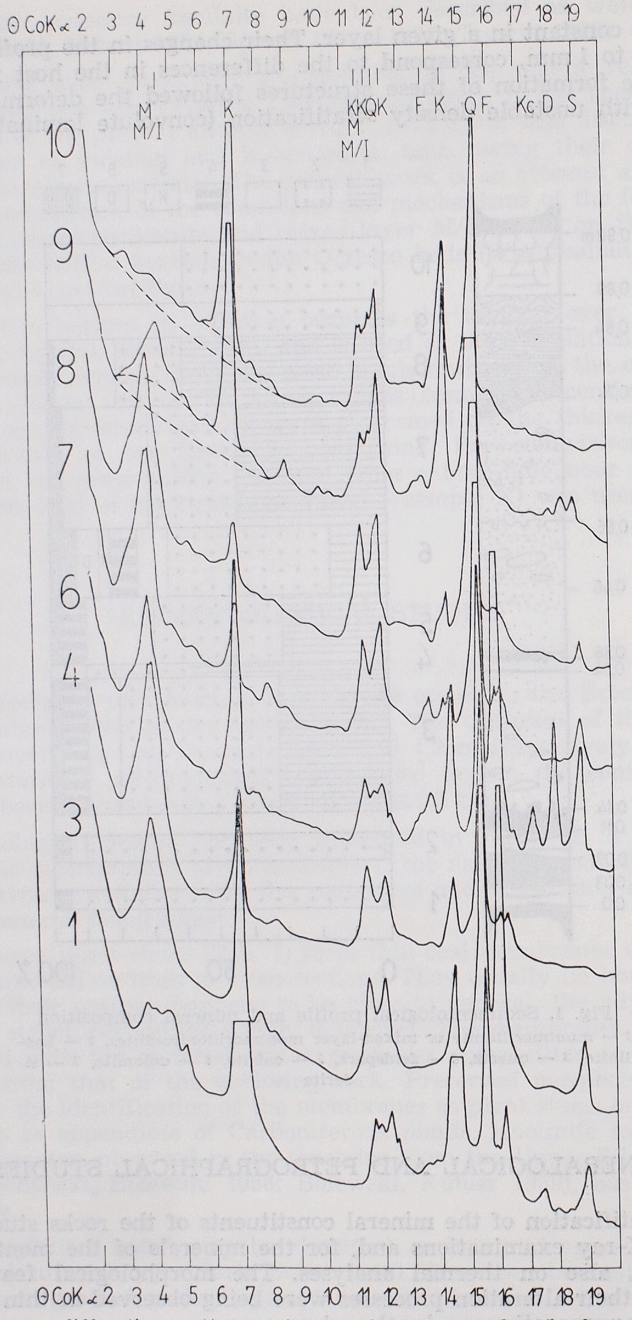


Fig. 2. X-ray diffraction patterns of natural rock samples (broken lines enclose the bands appearing in quartz-rich samples

M — montmorillonite, *M/I* — mixed-layer montmorillonite-illite, *K* — kaolinite, *Q* — quartz, *F* — feldspars, *Kc* — calcite, *D* — dolomite, *S* — siderite

Variations in the mineral composition of rocks along the investigated profile are presented in Figure 1. They were established on the basis of planimetric microscopic determinations and measurements of reflection intensity on the diffraction patterns of the rock samples (Fig. 2). The intensity ratio of the reflections about 11—14 Å of montmorillonite and mixed-layer M/I to *001* reflection of kaolinite was determined experimentally by the method of two-component standards, using monomineral fractions separated from the rocks studied. This ratio was found to be 3 : 1 (0—20% illite layers) or 1.5 : 1 (about 50% illite layers in the mixed-layer M/I). The method described finds its application in the studies of the variability of the mineral composition in the profile rather than in the accurate determinations of the percentage of the individual minerals.

Q u a r t z. In thin sections sharp-edged, transparent grains are encountered, generally without inclusions, sometimes showing features characteristic of magmatic corrosion (Phot. 1). They reveal uniform extinction. The quartz content in layer 6, which is characterized by the coarsest grains, was planimetrically determined as being 1.7%, whereas X-ray examinations gave the value of 8%. The observed discrepancy very likely indicates that the majority of quartz constitues the microcrystalline component of the matrix. This conclusion has been confirmed by the results of the separation of the samples by sedimentation method (Tab. 2), which are inconsistent with the microscopic data (petrographical name in Tab. 1). It appears that the abundant psammitic fraction ($\phi > 0.10$ mm) consists for the most part not of mineral grains but of aggregates with the bulk density lesser than that of quartz. Though stirred for several hours and treated with H_2O_2 or 1 : 1 HCl when heated, the aggregate failed to disintegrate. Compared with the whole rock, their mineral composition reveals enrichment in quartz and impoverishment in clay minerals. It seems feasible then that microcrystalline quartz plays the role of cement in these aggregates.

Table 2

Grain-size distribution (analysis by sedimentation and sieving methods)

Sample	> 0.25	0.25—0.10	0.10—0.01	0.01—0.002	< 0.002 mm
3	14	25	22	26	13
5	22	17	20	24	17
6	38	23	13	14	12

F e l d s p a r s. Microscopic examinations showed the presence of potassium feldspar with the optic axial angle approximating 0° in samples 1—9 and, additionally, plagioclase revealing polysynthetic twinnings in samples 5 and 6. Measurements of the extinction angles performed on specimens twinned according to albite law demonstrated that they represent basic andesine (about 60% Ab). Feldspar grains are sharp-edged and, in most cases, elongated. Under the microscope, kaolinization and carbonization were observed (Phot. 2), the former being confirmed by X-ray examinations.

Feldspar were separated in heavy liquids from sample 6. Their chemical composition and the degree of ordering of their structure were determined by X-ray examinations (Tab. 3), using the method of three reflections for potassium feldspar (Wright 1968) and that of KCl fusion for plagioclase (Viswanathan 1971). The values of d_{hkl} of diagnostic reflections are the mean values from the measurements of three diffraction patterns.

Table 3

X-ray determination of feldspars

Feldspar	$\bar{2}01$	Chemical composition	060	$\bar{2}04$	Structural state
K-feldspar	4,202	$Or_{80}Ab_{20}$	2,170	1,797	disordered, intermediate between Puye and S62-34 samples — high-temperature phase
Plagioclase *	4,149	$Ab_{64}An_{36}$	2,166	1,788	high-temperature phase

* d_{hkl} values for plagioclase transferred into K-form.

Carbonates. The dominant carbonate mineral is siderite, forming rhombohedral crystals, about 0.03 mm in size, disseminated in the clay matrix. In sample 6, where calcite and dolomite are present as well, carbonates metasomatize feldspar grains (Phot. 2) and biotite flakes (Phot. 3). Dolomite also fills small tectonic fissures in coaly claystones from the bottom part of the profile.

Heavy minerals. The heavy fraction was separated in bromoform from samples 1—9. Apatite, forming idiomorphic crystals of columnar habit, is the only transparent heavy mineral.

Montmorillonite and mixed-layer montmorillonite-illites. Their presence is indicated in thin sections by bright interference colours (with a greenish tint) of clay matrix, coming out particularly well when the matrix orientation is parallel to the bedding (samples 4 and 8). In sample X, concentrations of mixed-layer M/I, 0.2—0.3 mm in size, showing fluidal structure were noted (Phot. 4). This may be a relic structure, inherited from volcanic glass fragments.

The formation of complexes with ethylene glycol and the position of the reflections *060* ($d = 1.50$ Å) and *001* after one-hour heating at 600°C ($d = 10$ Å) seem to point to pure dioctahedral montmorillonite or else to montmorillonite interstratified with illite. A precise identification (Tab. 4) was based on the diffraction patterns of glycol saturated samples (Fig. 3) (Reynolds, Hower 1970). The content of swelling layers was estimated from the position of the reflection 5.3—5.6 Å, whereas the type of ordering of the structure — from the reflection in the range 13.3—17.1 Å. Broadening of the reflection 8.8—8.7 Å in the direction of low angles and of the reflection about 5.6 Å towards high angles, in accordance with the values of these reflections for ordered interstratifications, permits to presume that there is a small admixture of the ordered structure in samples 3, 6 and 7. Another proof is furnished by the presence of a low-angle reflection on the diffraction patterns of samples that have not been treated with ethylene glycol. Its position, however, is difficult to establish, seeing that it is broadened and the diffraction pattern background is raised.

Table 4

Determination of mixed-layer montmorillonite-illites by Reynolds' and Hower's method (1970)

Sample	Percent expandable	Ordering
9	50	0.5
7	100	— a small admixture of ordered structure
6	85	random, a small admixture of ordered structure
3	95	random, a small admixture of ordered structure
1	45	maximum
X	45	< 0.5

Samples 9, 1 and X contain mixed-layers, in which the ratio of I : M is approximately 1 : 1. They differ from one another in the degree of ordering of the structure. The diffraction pattern of a fully ordered interstratification (Fig. 3, sample 1) of allevardite type (Brindley 1956) shows a strong 1st order reflection about 27 Å. Its intensity decreases with the decrease in the degree of ordering.

Thermal curves of the rock samples and of the fraction $< 2\,\mu$ (Fig. 4) reveal a splitting of the dehydration effect (best seen on DTG curves), which is characteristic of montmorillonite with the prevalence of bivalent exchange cations.

Thermal analysis confirmed the presence of mixed-layer M/I in the majority of samples, which fact had been previously established by X-ray examinations. Compared with the samples containing pure montmorillonite, these ones are characterized by a lesser weight loss resulting from dehydration and dehydroxylation at about 650°C, the loss being greater for dehydroxylation at about 550°C. The temperature of montmorillonite dehydroxylation (650—680°C) and that of the effect of crystalline network collapse (860°C) permit to classify montmorillonite as a dioctahedral mineral with replacement of Mg^{2+} for Al^{3+} in octahedral sheets (Chantert *et al.* 1971).

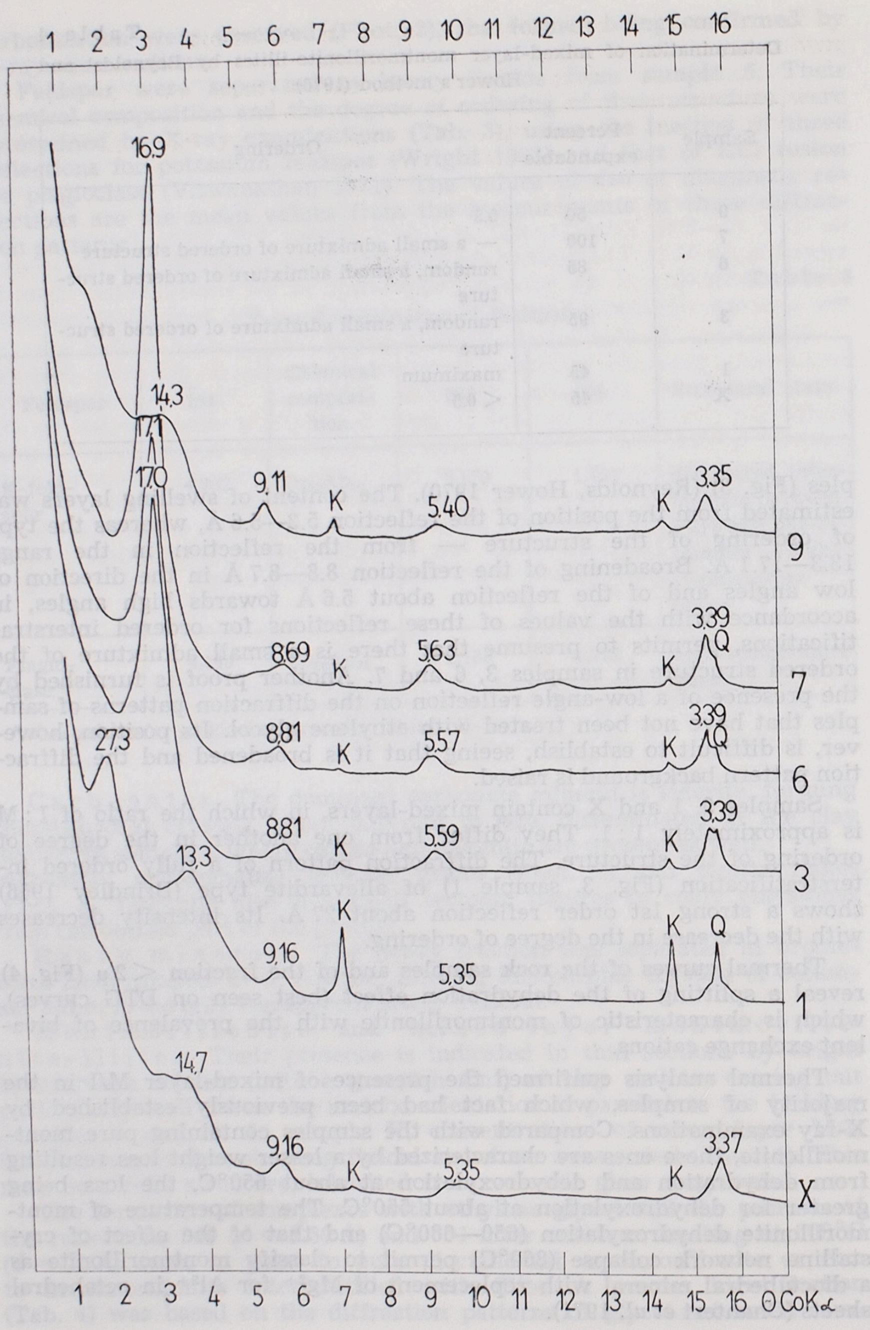


Fig. 3. X-ray diffraction patterns of ethylene glycol saturated samples ($< 2\,\mu$ fraction, oriented preparations)

K a o l i n i t e. The following forms of occurrence of this mineral have been distinguished:

Component of the matrix, present in small quantities in the $< 2\,\mu$ fraction, but for the most part coarse-grained;

Kaolinitic pseudomorphs of biotite (Phot. 5). They are oriented aggregates (uniform extinction) with barrel-like habit, cleavage parallel

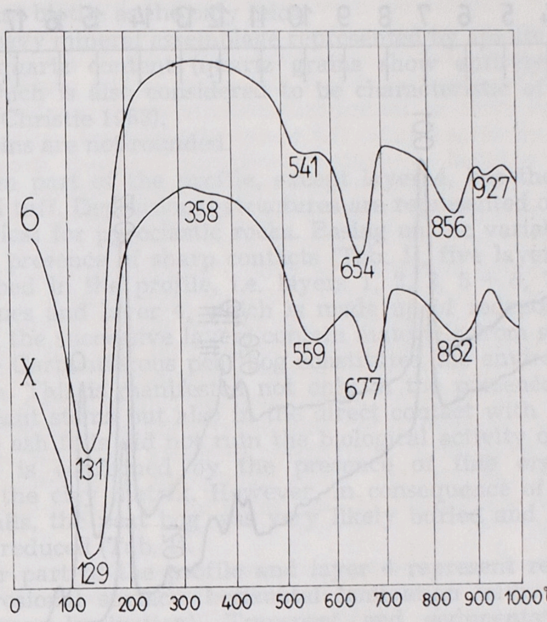


Fig. 4. DTA curves of $< 2\,\mu$ fraction
Sample 6 — montmorillonite, sample X — mixed-layer montmorillonite-illite (45% I)

to elongation and frequently hexagonal outlines. Aggregates or their zones reveal optical features of altered biotite (weak pleochroism in brown-green colours and bright interference colours). As appears from X-ray examinations (Fig. 5), they are built of kaolinite with an admixture of quartz. Their content in samples 1—7 (except sample 4) ranges between 6 and 15 per cent.

— Vermicular, oriented aggregates (wavy extinction) with optical features of kaolinite and dense cleavage parallel to orientation but perpendicular to elongation (Phot. 6). Such aggregates have been encountered only in rocks richest in kaolinite (layers 1 and 2). They are, for the most part, grown with pseudomorphs of biotite along the surfaces parallel to orientation surfaces of kaolinite plates. During the separation of samples, vermicular aggregates split into isometric fragments, delimited from the two opposite sides by cleavage surfaces.

Both, these fragments and pseudomorphs of biotite, were separated manually from the fraction 0.10—0.25 mm of samples 1 and 5 so as to enable an X-ray determination of the degree of ordering of the kaolinite structure. Considering the scantiness of the sample, film technique was applied (Fig. 5). Pseudomorphs of biotite are made up of kaolinite characterized by a medium degree of ordering of the structure (D-kaolinite), whereas vermicular aggregates are built of kaolinite with a high degree

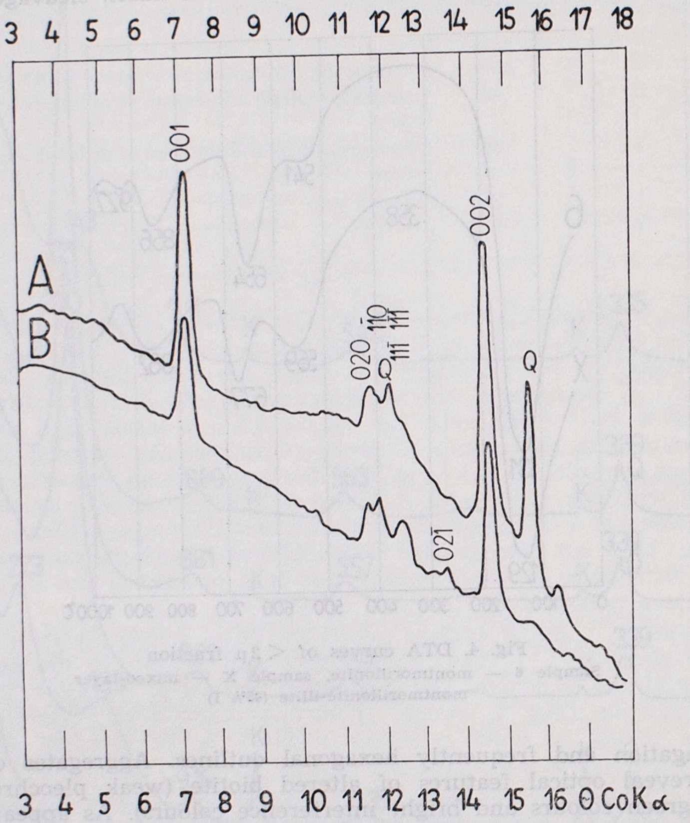


Fig. 5. Microphotometric traces from X-ray powder photographs
A — kaolinized biotite flakes, *B* — vermicular kaolinite aggregate

of ordering, close to T-kaolinite (Stoch, Sikora 1966). The same highly ordered kaolinite has been also found in the 2—10 μ fraction of sample 1. Pseudomorphs of biotite contain a significant quantity of Fe, which is manifested in the considerable increase of incoherent scattering (raised background of X-ray diffractograms).

None of these samples have shown the degradation of biotite towards montmorillonite, which phenomenon has been ascertained in the Upper Namurian A montmorillonite rocks in the northern part of the Upper Silesian Coal Basin (Bolewski *et al.* 1969, 1970).

CONCLUSIONS

The rocks under study show mineralogical and petrographical features characteristic for Palaeozoic pyroclastic materials (Środoń 1972b):

— sanidine and subordinate plagioclase as the only feldspars,
— abundant biotite as the only mica,
— poor heavy mineral assemblage represented by apatite,
— small quartz content (quartz grains show entirely the uniform extinction, which is also considered to be characteristic of volcanic materials (Blatt, Christie 1963),
— the grains are not rounded.

The bottom part of the profile, except layer 4, has the character of *in situ* altered tuff. Depositional structures are represented only by graded beddings, typical for pyroclastic rocks. Basing on the variations in grain-size and the presence of sharp contacts (Tab. 1), five layers of tuff may be distinguished in the profile, i.e. layers 1, 2, 3, 5 + 6, 7. Intercalated coaly claystones and layer 4, which is made up of redeposited material, evidence that the successive layers contain materials from several distinct ash falls. The Carboniferous peat bog constituted the environment of tuff sedimentation. This is manifested not only in the presence of numerous carbonized plant stems but also in the direct contact with the coal-seam. The first two ash falls did not ruin the biological activity of the environment, which is confirmed by the presence of fine organic material dispersed in the clay matrix. However, in consequence of the following bigger ash falls, the peat bog was very likely buried and the vegetation considerably reduced (Tab. 1).

The upper part of the profile and layer 4 represent redeposited tuff materials (erosional surface, horizontal lamination with plant detritus, small-scale cross-lamination). Transport and sedimentation processes fractionated the pyroclastic material and led to the concentration of fine-grained (now mainly montmorillonite or mixed-layer M/I — layers 4 and 8) and coarse-grained material (now mainly quartz and kaolinite — layers 8 and 10). A considerable variability and discontinuity of redeposited layers over the length of 0.5 km together with the lack of contamination with epiclastic material suggest the local character of erosion and deposition.

Horizontal orientation of montmorillonite (mixed-layer M/I) plates in the redeposited layers as compared with the lack of orientation in *in situ* layers points to the connection of orientation phenomenon with sedimentation. It seems therefore that the platy minerals in question had been probably formed before redeposition, being the products of almost syn-sedimentary weathering (montmorillonite formation), especially of fine-grained tuff matrix.

It is impossible to establish the precise time of kaolinization. In the rocks rich in montmorillonite (mixed-layer M/I), not only a part of fine-grained material but also big flakes of biotite and partly feldspar grains, i.e. the material relatively more resistant to weathering, underwent kaolinization. This would suggest that kaolinization followed montmorillonization.

It appears that in the swamp environment tuff could have been subject to montmorillonization only during a short period following deposition, when the chemical equilibrium with the surrounding was not yet established and the weathering tuff alkalized water in its closest neighbourhood. Equilibrium conditions must have entailed a decrease in pH and, consequently, a decrease in SiO_2 solubility, which favoured kaolinite formation. Similar conclusions have been reached by Spears (1971, 1972), who studied English tonsteins. Unlike this investigator, however, the present authors believe that the intensity of vegetation growth decided the change rate of the direction of tuff alteration. In the profile under study, the quantitative ratio of montmorillonite (mixed-layer M/I) to kaolinite increases and, simultaneously, the traces of biological activity of the environment are reduced. A similar correlation has been already described (Środoń 1972b). A possibility of the formation of kaolinite or montmorillonite from the same parent material (albite) depending on SiO_2 concentration has been demonstrated experimentally (Oberlin, County 1970).

In the successive layers of the profile studied, mixed-layer montmorillonite-illites with various content of illite layers (up to 50%) have been detected beside montmorillonite. The nearly similar quantitative constitution of the primary mineral assemblage in all the tuff layers seems to attest to the fact that the weathering neoformation of the structure of 2 : 1 type, resulting from different chemical composition of the primary material, is not responsible for this differentiation. Neither are mixed-layer M/I the products of degradation of micas since the latter (biotite) underwent only kaolinization. These data point to aggradation as being the most likely mechanism of the formation of mixed-layer M/I from montmorillonite.

Neither potassium sorption from sea water (Weaver 1953) nor the effect of deep burial (Shutov *et al.* 1969; Perry, Hower 1970) can satisfactorily account for the variations in illite content in mixed-layers, observed in the 1-m thick profile. From the geological position it also appears that the rocks under study are neither marine sediments nor were they ever deeply buried.

There is a strict reverse correlation between the content of mixed-layers in the total rock mass (Tab. 4, Fig. 1) and that of illite in the mixed-layers. The latter increases with an increase in kaolinite content. The obvious explanation is that mixed-layer M/I formed from montmorillonite as a result of sorption of potassium released during the kaolinization of the rock (particularly of biotite and potassium feldspar). Illite content in the mixed-layers would be in this case controlled by the ratio of the released potassium mass to the mass of montmorillonite, i.e. the intensity of kaolinization in a given layer. The noted tendency to form ordered interstratifications is in agreement with the data obtained from experimental studies of the process of potassium sorption by montmorillonite (Muravyov, Sakharov 1970). The afore-said investigations confirm as well the possibility of transformation in the period of early diagenesis, occurring under close-to-normal pressure and at moderate temperature. It should be cleared up, however, whether the hypothesis of simultaneous kaolinization and aggradation: montmorillonite → mixed-layer M/I is acceptable from the viewpoint of thermodynamics.

In the rocks under study, T-kaolinite has been found in the matrix $< 10\ \mu$ and in vermicular aggregates, D-kaolinite — in the barrel-like pseudomorphs of biotite. The co-occurrence of these varieties of kaolinite in the rock altered *in situ* excludes the possibility of their formation in a process other than weathering (*cf.* Dunoyer de Segonzac 1970) and points to the process proceeding along two distinct lines:

1. Direct transformation of biotite into kaolinite structure, due to removing of tetrahedral or building in of octahedral sheets without the stage of complete dissolution and crystallization. Such mechanism explains the low degree of ordering of the kaolinite structure, the orientation of kaolinite plates in pseudomorphs parallel to *001* plane of biotite, and the presence of iron in pseudomorphs, which is indicated by optical features and a considerable increase of incoherent scattering.

2. Kaolinite neoformation resulting from hydrolysis of framework silicates and, probably, of glass, i.e. crystallization of highly ordered kaolinite with a small Fe content in the form of fine-grained matrix, and epitactic crystallization on the pseudomorphs of biotite. The vermicular aggregates formed in this process are not contaminated by the surrounding material; they were therefore very likely growing in a relatively soft sediment. Kaolinization could not have then occurred later than is early diagenesis. These observations together with the ones described previously (Środoń 1972a) corroborate the hypothesis on the formation of vermicular kaolinite aggregates (leverrierite) that has been put forward by Kulbicki and Vetter (1955).

Acknowledgements: The authors are grateful to Mr. Tadeusz Wardyła for informing them about the occurrence of the tuffite horizon in the Brzeszcze mine and his kind help in field works. They also wish to thank Professor Andrzej Bolewski, and Assistant Professor Leszek Stoch for the critical reading of the manuscript.

REFERENCES

BLATT H., CHRISTIE J. M., 1963: Undulatory extinction in quartz of igneous and metamorphic rocks and its significance in provenance studies of sedimentary rocks. *J. Sediment. Petrol.* 33, 559—579.

BOCHEŃSKI T., BOLEWSKI A., 1958: Bemerkungen über die Entstehung der Tonsteine im süd-östlichen Teile der Oberschlesischen Steinkohlenbeckens. *Bull. Acad. Polon. Sci., Sér. Sci. Chim. Géol. et Géogr.* 6, 469—473.

BOLEWSKI A., KUBISZ J., 1959: Mineralbestand von Pflanzeninkrustaten aus Tonsteinen aus dem süd-östlichen Teil des Oberschlesischen Steinkohlenbeckens. *Bull. Acad. Polon. Sci., Sér. Sci. Chim. Géol. et Géogr.* 7, 427—432.

BOLEWSKI A., KUBISZ J., PARACHONIAK W., 1969: Produkty degradacji mik w skałach montmorillonitowych karbonu górnośląskiego I. Skały montmorillonitowe z Chorzowa. *Prace Mineral.* 20, 37—64.

BOLEWSKI A., KUBISZ J., PARACHONIAK W., KŁAPYTA Z., 1970: Produkty degradacji mik w skałach montmorillonitowych karbonu górnośląskiego II. Skały montmorillonitowe z Milowic. *Prace Mineral.* 22, 7—44.

BRINDLEY G. W., 1956: Allevardite, a swelling double-layer mica mineral. *Am. Miner.* 41, 91—103.

CHANTERT F., DESPRAIRIES A., DOUILLET P., JACOB C., STEINBERG M., TRAUTH H., 1971: Révision critique de l'utilisation des méthodes thermiques

en sédimentologie: cas des smectites (montmorillonites). *Bull. Groupe franç. Argiles* 23, 129—140.
DUNOYER de SEGONZAC G., 1970: The transformation of clay minerals during diagenesis and low-grade metamorphism. *Sedimentology* 15, 281—346.
FRANCIS E. H., 1961: Thin bed of graded kaolinized tuff and tuffaceous siltstone in the Carboniferous of Fife. *Bull. Geol. Surv. Great Brit.* 17, 191—215.
FRANCIS E. H., 1969: Les tonstein du Royaume-Uni. *Ann. Soc. Géol. Nord* 89, 209—214.
HALLBAUER D., KIRSCH H., POLSMANN S., 1962: Tonsteine des Ruhrkarbons mit eine Montmorillonit-Illit Weschellagerungsstruktur. *N. Jb. Mineral. Abh.*, Bd 98. H. 3, A. 5, 283—294.
JANSA L., DURČAKOVA L., 1965: Jilove mineraly se smišenymi illit-montmorillonitovymi strukturami v ostravskem karbonu. *Cas. pro Mineral. Geol.* 10, 391—402.
KRÁLIK J., 1961: Sanidin v tonsteinach ostravsko-karvinského reviru. *Sbornik vedeckých praci Vysoké skoly bánské v Ostrave* 7, geol. 55, 519—532.
KUHL J., 1955: Petrograficzna klasyfikacja skał towarzyszących pokładom węgla w Zagłębiu Górnego Śląska. *Prace GIG* s. A, nr 171.
KULBICKI G., VETTER P., 1955: Étude des roches argileuses de quelques bassins houillers de la bordure occidentale du Massif Central. *Bull. Soc. géol. France*, ser. 6, t. 5, fasc. 7—9, 645—651.
MURAVYOV V. I., SAKHAROV B. A., 1970: Experimental study of the sorption of potassium by montmorillonite. *Sedimentology* 15, 103—113.
NELSON B. W., 1959: New bentonite zone from Pennsylvanian of southwestern Wirginia (abs.) *Geol. Soc. Amer. Bull.* 70, 1651.
OBERLIN A., COUNTY R., 1970: Conditions of kaolinite formation during alteration of some silicates by water at 200°C. *Clays and Clay Miner.* 18, 347—356.
PARK W., SCHOT E. H., 1968: Stylolitization in carbonate rocks. in: MÜLLER G., FRIEDMAN G. M., ed. — Recent developments in carbonate sedimentology in Central Europe. Springer-Verlag.
PERRY E., HOWER J., 1970: Burial diagenesis in Gulf Coast pelitic sediments. *Clays and Clay Miner.* 18, 165—177.
PRICE N. B., DUFF P. Mc L. D., 1969: Mineralogy and chemistry of tonsteins of Carboniferous sequences in Great Britain. *Sedimentology* 13, 45—67.
REYNOLDS R. C. Jr., HOWER J., 1970: The nature of interlayering in mixed layer illite-montmorillonite. *Clays and Miner.* 18, 25—36.
RYSZKA J., MISIARZ J., 1959: Utwory tufogeniczne w warstwach orzeskich w rejonie Rybnika jako horyzonty przewodnie. *Przegl. Geol.* 11, 515.
SHUTOV V. D., DRITS V. A., SAKHAROV B. A., 1969: On the mechanism of a post-sedimentary transformation of montmorillonite into hydromica. *Proc. Intern. Clay Conf. Tokyo* 1, 523—532.
SPEARS D. A., 1971: A kaolinite mudstone (tonstein) in the British Coal Measures. *J. Sediment. Petrol.* 40, 386—394.
SPEARS D. A., 1971/1972: The mineralogy of the Stafford tonstein. *Proc. Yorkshire geol. Soc.* 38, 497—516.
STOCH L., SIKORA W., 1966: Określenie stopnia uporządkowania struktury minerałów grupy kaolinitu. *Spraw. Pos. Kom. Oddz. PAN w Krakowie*, lipiec—grudzień, 651—654.
ŚRODOŃ J., 1972a: Mineralogy of coal-tonstein and K-bentonite from coal-seam no 610, Bytom trough (Upper Silesian Coal Basin, Poland). *Bull. Acad. Polon Sci. Sér. Sci. de la Terre* 20, 155—164.
ŚRODOŃ J., 1972b: Comparative study of K-bentonite and coal-tonstein from the Upper Silesian Coal Basin (Poland). *Bull. Acad. Polon. Sci., Sér. Sci. de la Terre* 20, 165—173.
TREWIN N. H., 1968: Potassium bentonites in the Namurian of Staffordshire and Derbyshire. *Proc. Yorkshire geol. Soc.* 37, 73—91.
VISWANATHAN K., 1971: A new X-ray method to determine the anortite content and structural state of plagioclases. *Contr. Mineral. Petrol.* 30, 332—335.
WEAVER C. E., 1953: Mineralogy and petrology of some ordovician K-bentonites and related limestones. *Bull. Geol. Soc. Am.* 64, 921—943.
WRIGHT T. L., 1968: X-ray and optical study of alkali feldspar: II. An X-ray method for determining the composition and structural state from measurement of 2Θ values for three reflections. *Am. Miner.* 53, 88—104.

Włodzimierz PARACHONIAK, Jan ŚRODOŃ

O TWORZENIU SIĘ KAOLINITU, MONTMORILLONITU I PRZEROSTÓW MONTMORILLONITOWO-ILLITOWYCH W WYNIKU PRZEOBRAŻENIA TUFU KARBOŃSKIEGO (GÓRNOŚLĄSKIE ZAGŁĘBIE WĘGLOWE)

Streszczenie

Badaniom mineralogicznym poddano unikalny profil przerostu w pokładzie węgla 327 (Westfal A/B — kopalnia Brzeszcze) wykazujący w warstwie 1 m ciągłe przejście od „pseudomorphosen" tonsteinu do bentonitu. Minerały nieilaste są w całej warstwie identyczne i wskazują na piroklastyczny charakter materiału pierwotnego (sanidyn, plagioklaz wysokotemperaturowy, biotyt, kwarc o równym sciemnianiu światła, apatyt). Z obserwacji sedymentologicznych wynika, że uległ on przeobrażeniu *in situ*. Stwierdzono wpływ świata roślinnego na względną intensywność następujących po sobie procesów montmorillonityzacji i kaolinityzacji. W ramach tego drugiego procesu transformacja struktury biotytu doprowadziła do powstania D-kaolinitu, a krystalizacja z roztworu — T-kaolinitu. Montmorillonitoidy wykazują duże zróżnicowanie: od czystego diooktaedrycznego montmorillonitu poprzez montmorillonitowo-illitowe przerosty nieuporządkowane i częściowo uporządkowane (10—50% I) do maksymalnie uporządkowanych typu allewardytu. Wysunięto koncepcję o powstaniu przerostów z montmorillonitu w wyniku sorpcji potasu uwolnionego w trakcie kaolinizacji tufu.

OBJAŚNIENIA FIGUR

Fig. 1. Profil sedymentologiczny oraz skład mineralny skał w kolejnych warstwach
1 — montmorillonit lub przerosty montmorillonitowo-illitowe, *2* — kaolinit, *3* — kwarc, *4* — skalenie, *5* — kalcyt, *6* — dolomit, *7* — syderyt

Fig. 2. Dyfraktogramy naturalnych próbek skał (linia przerywana ogranicza pasmo pojawiające się w próbkach bogatych w kwarc
M — montmorillonit, *M/I* — przerosty montmorillonitowo-illitowe, *K* — kaolinit, *Q* — kwarc, *F* — skalenie, *Kc* — kalcyt, *D* — dolomit, *S* — syderyt

Fig. 3. Dyfraktogramy frakcji $< 2\mu$ z glikolem etylowym (preparaty orientowane)

Fig. 4. Krzywe DTA frakcji $< 2\mu$
Próbka 6 — montmorillonit, próbka X — przerosty montmorillonitowo-illitowe (45% I)

Fig. 5. Obrazy mikrofotometryczne filmów rentgenowskich
A — skaolinityzowane blaszki biotytu, *B* — robakowate agregaty kaolinitu

Влодзимеж ПАРАХОНЯК, *Ян* СЬРОДОНЬ

ОБ ОБРАЗОВАНИИ КАОЛИНИТА, МОНТМОРИЛЛОНИТА И СМЕШАННОСЛОЙНЫХ МОНТМОРИЛЛОНИТ-ИЛЛИТОВ В ИТОГЕ ПРЕОБРАЖЕНИЯ КАРБОНСКОГО ТУФА (ВЕРХНЕСИЛЕЗСКИЙ УГОЛЬНЫЙ БАССЕЙН)

Резюме

Проведено минералогическое исследование уникального включения в угольном пласте (вестфаль A/B — шахта Бжеще), представляющего слой мощностью 1 м, в котором наблюдается последовательный переход псевдоморфического тонштейна в бентонит. Неглинистые минералы во всем слое одинаковы и определяют пирокластический характер первичного материала (санидин, высокотемпературный плагиоклаз, биотит, кварц с равномерным угасанием света, апатит). Седиментологические наблюдения показывают, что этот материал подвергался изменениям *in situ*. Констатировано воздействие растительного вещества на характер следующих друг за другом процессов монтмориллонитизации и каолинитизации. В итоге проявления второго процесса преобразование структуры биотита привело к образованию D-каолинита, а кристаллизация из раствора — T-каолинит. Монтмориллонитоиды характеризуются большим разнообразием — от чистого диоктаэдрического монтмориллонита, через смешаннослойные монтмориллонит-иллиты, неупорядоченные и частично упорядоченные (10—50% I), по максимально упорядоченные разновидности типа аллавердита. Высказывается предположение об образовании смешаннослойных монтмориллонит-иллитов за счет поглощения монтмориллонитом калия, выпавшего в процессе каолинитизации туфа.

ОБЪЯСНЕНИЯ К ФИГУРАМ

Фиг. 1. Седиментологический профиль и минеральный состав пород в последовательных слоях
1 — монтмориллонит или монтмориллонит-иллит пакеты, *2* — каолинит, *3* — кварц, *4* — полевые шпаты, *5* — кальцит, *6* — доломит, *7* — сидерит

Фиг. 2. Дифрактограммы естественных образцов пород
M — монтмориллонит, *M/I* — монтмориллонит-иллит, *K* — каолинит, **Q** — кварц, ***F*** — полевые шпаты, *Kc* — кальцит, ***D*** — доломит, ***S*** — сидерит

Фиг. 3. Дифрактограммы фракции $<2\mu$ с этиловым гликолем (ориентированные препараты)

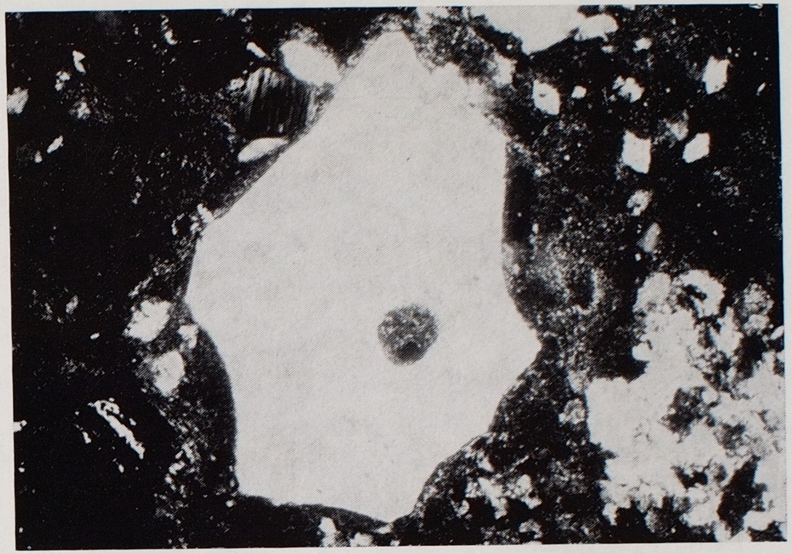
Фиг. 4. Кривые ДТА фракции $<2\mu$
Образец 6 — монтмориллонит, образец X — монтмориллонит-иллит (45% I)

Фиг. 5. Микрофотометрические кривые из рентгеновских снимок
A — каолинитизированные чешуйки биотита, *B* — червеобразные агрегаты каолинита

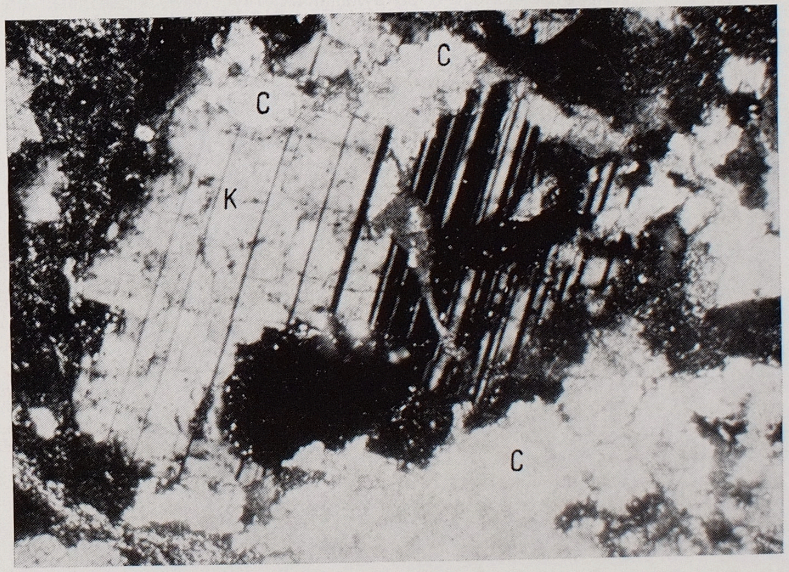
PLATE I (PLANSZA I, ТАБЛИЦА I)

Phot. 1. Corroded quartz grain with uniform extinction, crossed nicols, enlarged 80 ×
Skorodowane ziarno kwarcu wykazujące równe wygaszanie światła, nikole skrzyżowane, pow. 80 ×
Корродированное зерно кварца, проявляющее равномерное угасание света, николи скрещенные, 80 ×

Phot. 2. Altered plagioclase grain: *K* — kaolinite, *C* — carbonate, crossed nicols, enlarged 200 ×
Ziarno plagioklazu z objawami: *K* — kaolinityzacji, *C* — karbonatyzacji, nikole skrzyżowane, pow. 200 ×
Зерно плагиоклаза с проявлениями каолинитизации (K) и карбонатизации (C), николи скрещенные, 200 ×



Phot. 1



Phot. 2

Włodzimierz PARACHONIAK, Jan ŚRODOŃ — The formation of kaolinite, montmorillonite and mixed-layer montmorillonite-illites during the alteration of carboniferous tuff (the Upper Silesian Coal Basin)

PLATE II (PLANSZA II, ТАБЛИЦА II)

Phot. 3. Biotite flake metasomatized by carbonate along cleavage planes, 1 nicol, enlarged 220 ×

Blaszka biotytu zmetasomatyzowana wzdłuż powierzchni łupliwości przez węglan, 1 nikol, pow. 220 ×

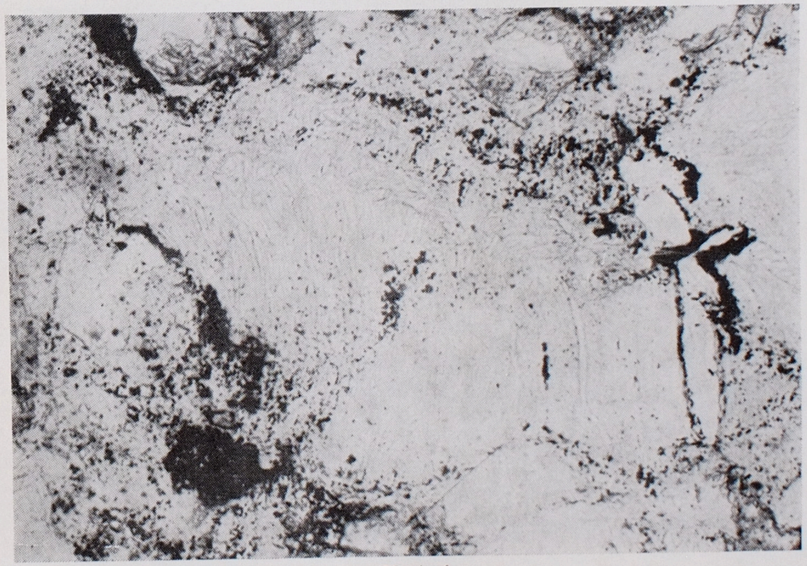
Чешуйка биотита, метасоматически замещенная карбонатом вдоль плоскостей сланцеватости, 1 николь, 220 ×

Phot. 4. Glass fragment (?) altered to mixed-layer montmorillonite-illite, with relic fluidal structure, 1 nicol, enlarged 270 ×

Prawdopodobnie pseudomorfoza po szkliwie, zbudowana z przerostów montmorillonitowo-illitowych, z zachowaną strukturą fluidalną, 1 nikol, pow. 270 ×

Предполагаемый псевдоморфоз по вулканическому стеклу сложенный монтмориллонит-иллитовыми пакетами, с сохраненной флюидальной структурой, 1 николь, 270 ×

Phot. 3



Phot. 4

Włodzimierz PARACHONIAK, Jan ŚRODOŃ — The formation of kaolinite, montmorillonite and mixed-layer montmorillonite-illites during the alteration of carboniferous tuff (the Upper Silesian Coal Basin)

PLATE III (PLANSZA III, ТАБЛИЦА III)

Phot. 5. Kaolinitic pseudomorphs of biotite with barrel-like habit and cleavage parallel to elongation, crossed nicols, enlarged 300 ×

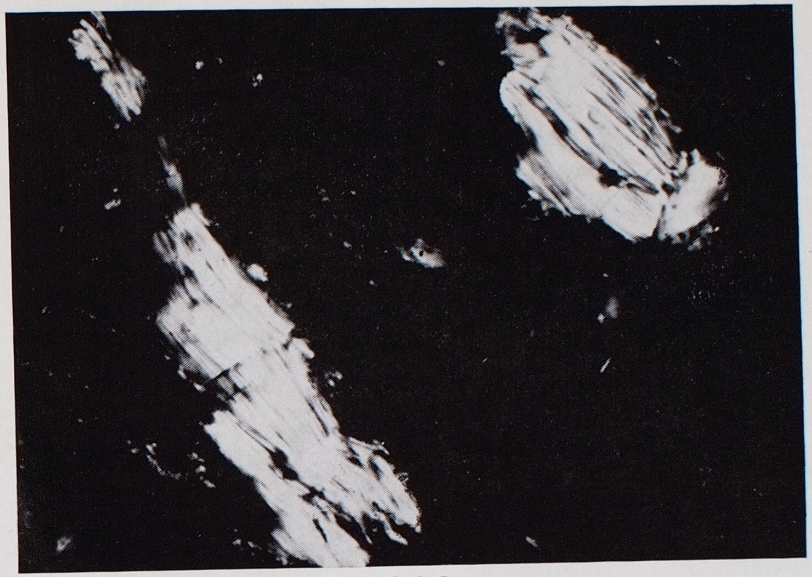
Pseudomorfozy kaolinitowe po biotycie o pokroju beczułkowym, łupliwości równoległej do wydłużenia, nikole skrzyżowane, pow. 300 ×

Каолинитовые псевдоморфозы по биотиту, бочонкообразной формы, со сланцеватостью параллельной удлинению, николи скрещенные, 300 ×

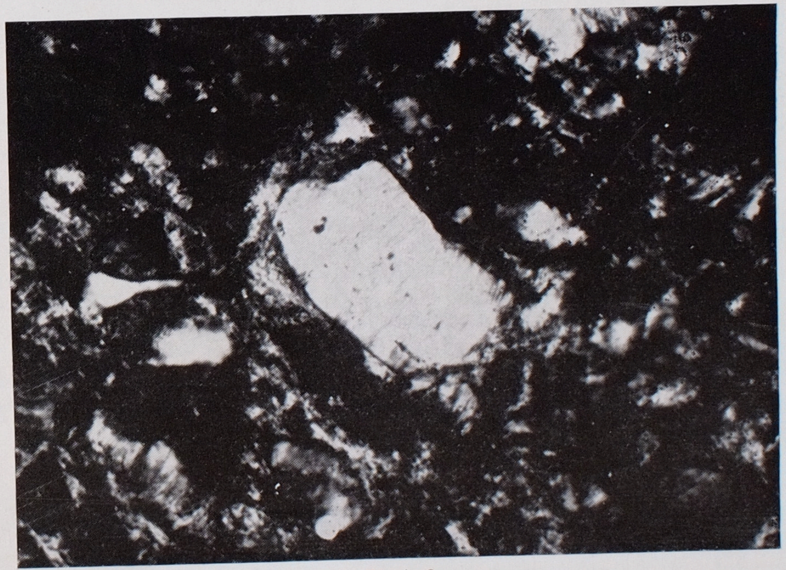
Phot. 6. Vermicular aggregate of kaolinite with cleavage perpendicular to elongation, crossed nicols, enlarged 230 ×

Robakowaty agregat kaolinitu o łupliwości prostopadłej do wydłużenia, nikole skrzyżowane, pow. 230 ×

Червеобразный агрегат каолинита со сланцеватостью перпендикулярной к удлинению, николи скрещенные, 230 ×



Phot. 5



Phot. 6

Włodzimierz PARACHONIAK, Jan ŚRODOŃ — The formation of kaolinite, montmorillonite and mixed-layer montmorillonite-illites during the alteration of carboniferous tuff (the Upper Silesian Coal Basin)