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Middle Eocene in the Sołokija Graben on Roztocze Upland

Lithological-mineralogical characteristics of quartz-glauconitic sands as well as physical features and chemical composition of glauconite from new stand on Roztocze are presented. X-ray diffraction showed disordered structure of glauconite as a mixture of illite and smectite. The potassium-argon age of glauconite was determined. Development of Sołokija Graben took place in the Laramian and the end-Eocene tectonic phases.

INTRODUCTION

Eocene deposits in the Lublin region, represented by quartz-glauconitic sands and silts, are found in the foreland of the Lublin Upland among Puławy, Lubartów and Parczew (J. E. Mojski *et al.*, 1966; J. Uberna, 1981; J. Uberna E. Odrzywolska-Bieńkowa, 1970). The age of those deposits is dated as the lowest level of the Upper Eocene based on micropalaeontological studies (K. Pożaryska, Locker, 1972; J. Uberna, E. Odrzywolska-Bieńkowa, 1977). The Eocene deposits were formed in the epicontinental European sea consisting of western and eastern basins (F. Kockel, 1988; A. Vinken, 1988; A. P. Vinogradov, 1966; B. Kosmowska-Ceranowicz *et al.*, 1990).

Geological studies performed in the western part of the Lublin Upland show numerous sites of Eocene deposits (Fig. 1). They appear to be well preserved in the Radawiec Graben at a level of 185–205 m a.s.l. (A. Henkiel, 1988*a*) as well as on the residual hills near Piotrków (A. Henkiel, 1988*b*), Białowoda at 251 m a.s.l. (S. Marszałek *et al.*, 1991) and Wola Studziańska at 292 m a.s.l. (S. Cieśliński, personal communication).

South of this area, glauconite sands were also found on Roztocze Upland (Fig. 2). W. Rogala (1912) was the first to report glauconite sand occurrence in Roztocze in the vicinity of Magierów and Potylicz dating them for Oligocene. Glauconite sands occurring at the southern border of Roztocze near Sopot and Horyniec (R. Ney, 1969) as well as near Terespol (T. Musiał, 1987) belong to the sandy-clay series of the Badenian. While exploring

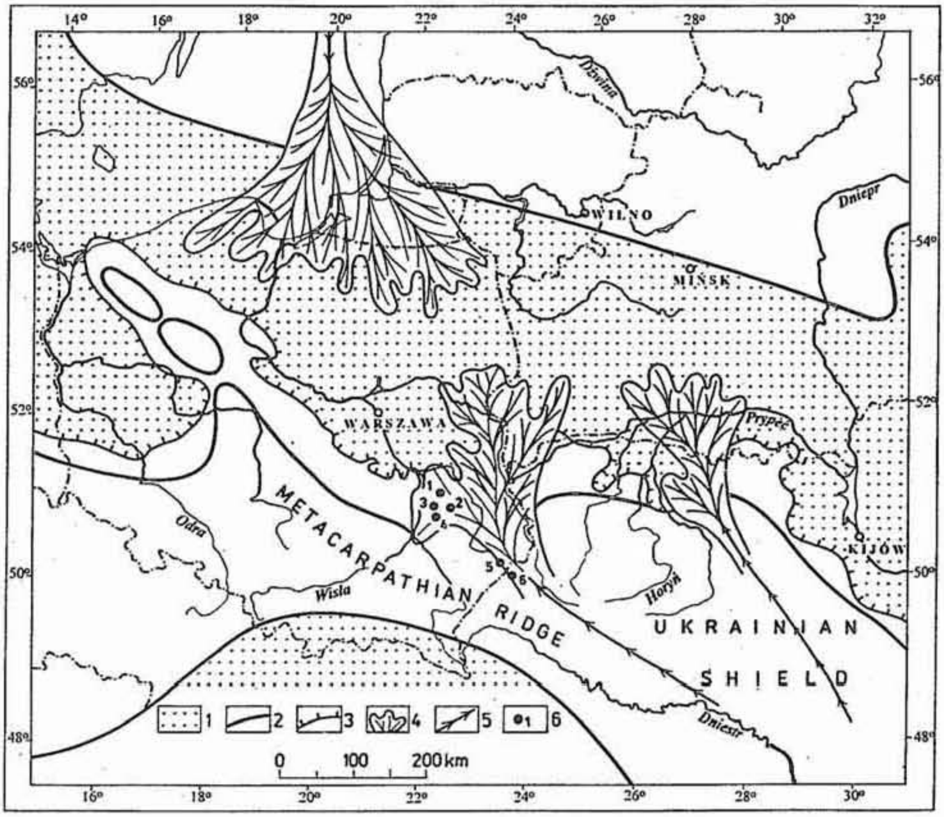

Fig. 1. Palaeogeography of Central Europe during the Eocene (after J. Kasiński *et al.*, 1993, supplemented)
1 — marine area of north and south basins; 2 — range of the Middle Eocene lagoon; 3 — range of occurrence of Eocene sediments; 4 — delta; 5 — direction of palaeorivers; 6 — occurrence of Eocene sediments in the Lublin Upland according to: 1 — A. Henkiel (1988*a*), 2 — A. Henkiel (1988*b*), 3 — S. Marszałek *et al.* (1991), 4 — S. Cieśliński, 5 — J. Buraczyński *et al.* (1992), 6 — W. Rogala (1912)

Paleogeografia środkowej Europy w eocenie (według J. Kasińskiego i in., 1993, uzupełnione)
1 — obszar morza basenu północnego i południowego; 2 — zasięg zalewu środkowoeoceńskiego; 3 — granica występowania osadów eoceńskich; 4 — delta; 5 — kierunek rzek transportujących materiał; 6 — stanowiska eocenu na Wyżynie Lubelskiej według: 1 — A. Henkla (1988*a*), 2 — A. Henkla (1988*b*), 3 — S. Marszałka i in. (1991), 4 — S. Cieślińskiego, 5 — J. Buraczyńskiego i in. (1992), 6 — W. Rogali (1912)

the Tomaszów Lubelski areas, J. Kulczycka (1975) found glauconite sands in several boreholes. Based on preliminary lithological characteristics, the deposits situated in the Sołokija valley were classified as Oligocene (J. Buraczyński, J. Gurba, 1977/1978). Within the cartographic works on *the Detailed Geological Map of Poland* (Tomaszów Lubelski 1:50 000 sheet), some studies were undertaken to determine the stratigraphic position of the glauconite sands (J. Buraczyński *et al.*, 1992). Lithological, mineralogical (K. Radlicz) and phytopalynological (E. Gaździcka, 1994) analyses were carried out. To determine glauco-

Fig. 2. Geological sketch of the Tomaszów Lubelski environs (after J. Buraczyński, 1980/1981; S. Cieśliński, J. Rzechowski, 1993; R. Ney, 1969)

1 — marls, opokas and gaises, Maestrichtian: Cr_{m1} — lower, Cr_{m3} — upper; 2 — quartz-glauconitic sands, Middle Eocene (E); 3 — sands and detrital limestones, Badenian (M_4); 4 — clays, Sarmatian (M_5); 5 — confirmed faults; 6 — supposed faults; -o--o- — section line of profile Fig. 3; contour line every 10 m

Szkic geologiczny okolic Tomaszowa Lubelskiego (według J. Buraczyńskiego, 1980/1881; S. Cieślińskiego, J. Rzechowskiego, 1993; R. Neya, 1969)

1 — margle, opoki i gezy, mastrycht: Cr_{m1} — dolny, Cr_{m3} — górny; 2 — piaski kwarcowo-glaukonitowe, eocen środkowy (E); 3 — piaski i wapienie detrytyczne, baden (M_4); 4 — iły, sarmat (M_5); 5 — uskoki pewne; 6 — uskoki przypuszczalne; -o--o- — linia przekroju fig. 3; poziomice co 10 m

nite age by the potassium-argon method, it was subjected to complex chemical, x-ray, thermal and radiometric studies (Z. Krzowski, 1993).

Heavy mineral composition

Profile	Depth [m]	Weight percent	OPM	GLA	TRM	AMF	PYR	EPI
Piekiełko 16	10	0.57	31.8	44.0	23.6	0.6	–	4.3
Piekiełko 20	14	0.78	87.5	4.6	7.9	–	–	7.6
Szarowola 4	4	0.10	80.7	–	17.4	0.7	1.8	2.1

OPM — opaque minarals, GLA — glauconite, TRM — transparent minerals, AMF — amphibole, PYR — pyrodisthene, STA — staurolite, AND — andalusite, TOP — topaz

GEOLOGICAL-LITHOLOGICAL CHARACTERISTICS

Geological mapping showed that glauconitic sands occurred in the Sołokija Graben under a thin (3–10 m) Quaternary formation cover in an area 2–3 km wide and 20 km long (Fig. 2). Only near Ruda Wołoska, where they are artificially exposed, do they come up onto the surface at a level of 255 m a.s.l. (J. Buraczyński *et al.*, 1992). A residual hill (315 m a.s.l.) is found on the graben edge, NW of Tomaszów Lubelski. It is built of finely grained, weathered, rust-yellow coloured quartz-glauconitic sands (7 m). Among heavy minerals there are found the resistant ones, tourmaline 42.5%, staurolite and disthene 23.1% as well as rutile 13.2%, of similar compositions to the unweathered formations (Tab. 1). At its ceiling in a one meter layer, there are sandstone concretions with goethite-hematitic cement (Pl. I, Fig. 8). They are flat, 20–50 cm in diameter and 5–10 cm in thickness. Their surface is smooth, of mettalic brown colour and the floor is not equal to appendices.

In the Sołokija valley near Łaszczówka, two boreholes were made on the terrace. Under the Quaternary sediments (9–10 m), quartz-glauconitic sands and silts were drilled. Their thickness was 19 m in the Łaszczówka 29 borehole and 40 m in the Piekiełko 30 borehole which is 400 m away (Fig. 3).

Eocene formations in both boreholes are lithologically similar (J. Buraczyński *et al.*, 1992). They are formed of grey-green quartz-glauconitic sands of streaked texture and micrite clay binder. In grain-size composition, they are fine-grained sands predominantly in the 0.05–0.1 mm fraction (70%) with silt added (Figs. 4 and 5). The fraction above 0.2 mm is concentrated in streaks constituting 25%. In some sites, thin interbedding of coarse sands (0.5–1.0 mm) is found. The carbonate contents are about 5%. Eocene outcrops near Ruda Wołoska are built of medium-grained sands ($Mz = 3$), intensely green and decalcified (J. Buraczyński, J. Gurba, 1977/1978).

Studied deposits for the Łaszczówka (Fig. 4) and Piekiełko (Fig. 5) profiles are characterized by grain-size parameters: mean grain diameter Mz = 4.40–4.67 and 3.87–4.64; standard deviation σ_I = 1.39–1.69 and 1.15–1.53, skewness Sk_I = 0.58–0.74 and 0.42–0.71 and kurtosis K_G = 0.60–0.76 and 0.72–0.77, respectively. Deviation values (σ_I) point to poor sorting of the deposits under dynamically changing conditions. The formations accumulated from the suspension in an environment of weak currents favouring sedimentation.

in fraction 0.05–0.1 mm

Table 1

GAR	TUR	ZIR	RUT	TIT	DIS	STA	AND	TOP
9.6	42.9	8.7	13.3	6.1	4.6	5.5	2.0	1.4
11.5	45.5	3.8	4.9	1.9	15.0	4.5	0.3	–
7.5	42.5	3.9	13.2	0.5	14.8	8.3	2.3	4.6

xene, EPI — epidote, GAR — garnet, TUR — tourmaline, ZIR — zircon, RUT — rutile, TIT — titanite, DIS —

Quartz (80%) is the main mineral material and glauconite of 0.05–0.1 mm diameter constitutes 10–15%. The content of heavy minerals in the fraction 0.1–0.25 mm is 0.2–0.3 % and in some places increases to 0.7%. Opaque minerals (50–80%) are predominant (Tab. 1). Among transparent minerals, a set of resistant and of medium-resistance mineral

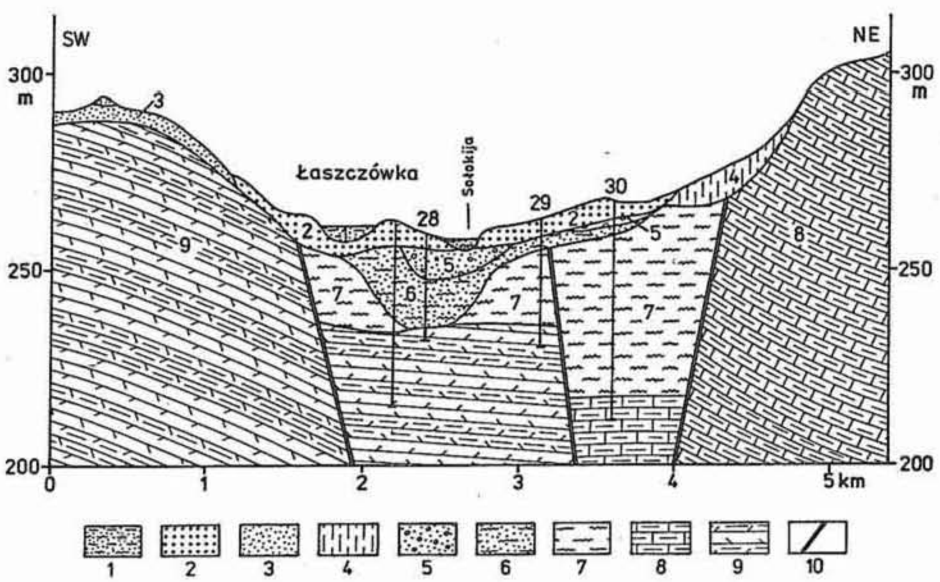

Fig. 3. Geological section of Sołokija Graben (after J. Buraczyński *et al.*, 1992)

Quaternary: 1 — alluvial deposits, 2 — terrace sands, 3 — eolian-deluvial sands, 4 — loesses, 5 — fluvial sands, 6 — sandy till; Pliocene: 7 — quartz-glauconitic sands; Maestrichtian: 8 — marls, 9 — gaizes; 10 — faults; boreholes: 28 — Łaszczówka 28, 29 — Łaszczówka 29, 30 — Piekiełko 30

Przekrój geologiczny przez rów Sołokiji (według J. Buraczyńskiego i in., 1992)

Czwartorzęd: 1 — aluwia, 2 — piaski tarasowe, 3 — piaski eoliczno-deluwialne, 4 — lessy, 5 — piaski rzeczne, 6 — glina zwałowa; pliocen: 7 — piaski kwarcowo-glaukonitowe; mastrycht: 8 — margle, 9 — opoki; 10 — uskoki; otwory wiertnicze: 28 — Łaszczówka 28, 29 — Łaszczówka 29, 30 — Piekiełko 30

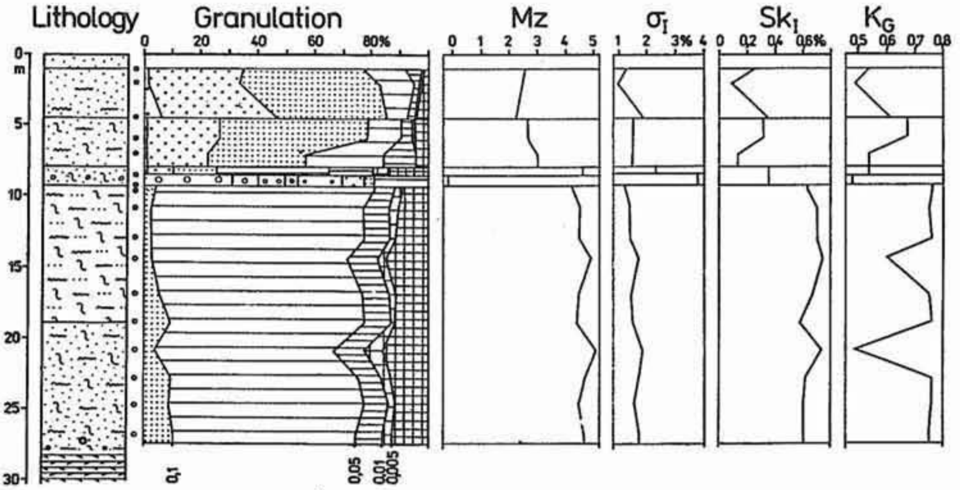

Fig. 4. Grain-size composition and parameters in phi scale in Łaszczówka 29 profile

Mz — mean diameter, σ_I — standard deviation, Sk_I — skewness, K_G — curtosis; lithology explanations as in Fig. 3

Uziarnienie i parametry uziarnienia w skali phi w profilu Łaszczówka 29

Mz — średnia średnica, σ_I — graficzny współczynnik wysortowania, Sk_I — graficzna skośność, K_G — kurtoza; objaśnienia litologii jak na fig. 3

associations are predominant. In the Łaszczówka profile, there are found tourmaline and disthene and staurolite (10% each), zircon and rutille (5% each), as well as epidote (3%). However, in the Piekiełko profile tourmaline (40%) as well as disthene and staurolite (20%) occur in larger amounts. The amount of individual transparent minerals in the vertical profile is variable. In the upper part of the Łaszczówka profile there are amphiboles, chlorites and garnets whereas they are not found in the lower part. Moreover, there are larger amounts of disthen, staurolite and rutille there. Compared with the Luszawa profile (J. E. Mojski *et al.*, 1966) they contain more quartz by 20% and half as much glauconite. In these profiles an association of resistant minerals is predominant and in the Luszawa profile their amount is twice as much. The differences in heavy mineral composition can be explained by different fields of sources and sea depth. Moreover, the examined profiles lack phosphorite concretions.

CHARACTERISTICS OF GLAUCONITE

Characteristics of glauconite were measured for a sample from 27.6 m from the Łaszczówka 29 borehole and 9.6 m from the Piekiełko 30 borehole. Glauconite removed by a magnetic separator was subjected to chemical, x-ray, thermal and radiometric studies (Z. Krzowski, 1993).

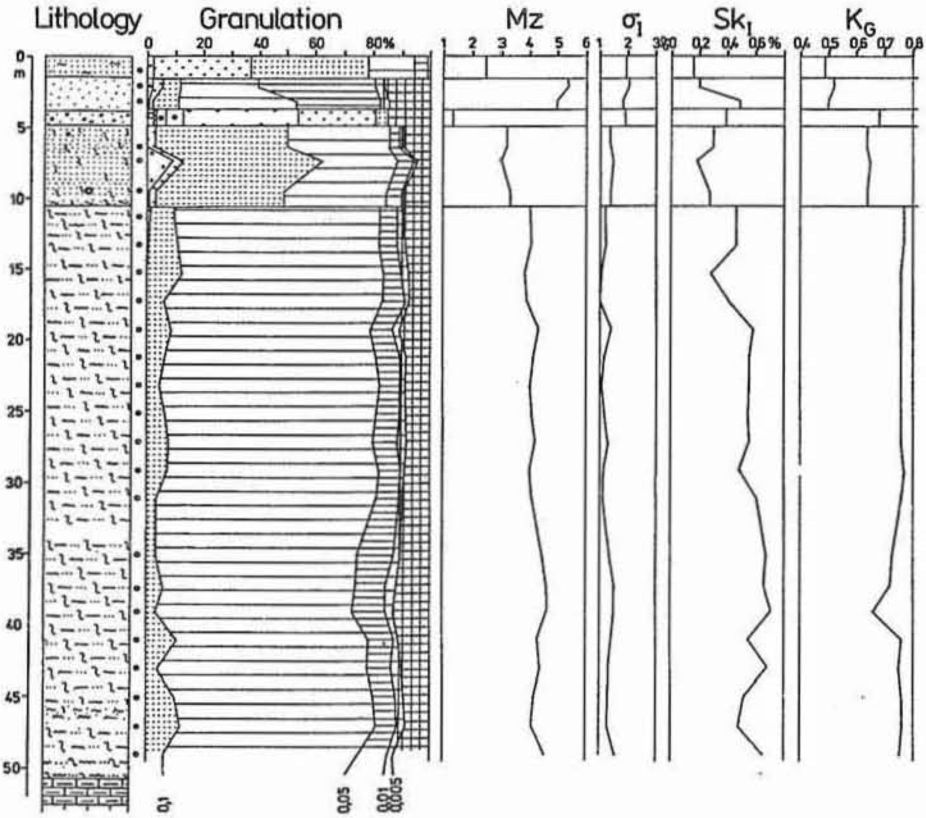

Fig. 5. Grain-size composition and parameters in phi scale in Piekiełko 30 profile
Explanations — see Fig. 3 and 4
Uziarnienie i parametry uziarnienia w skali phi w profilu Piekiełko 30
Objaśnienia jak na fig. 3 i 4

A sample from Łaszczówka contains 13.2% glauconite. Glauconite grains are, green, black, beige and rust coloured. Black colour is most frequent. In the grain-size composition, the 0.2–0.24 mm fraction (69.3%) is predominant. Grain morphology is varied. There are egg, capsular, tabular, spheroidal, verrucose, discoidal and mixed shapes.

Glauconite occurs in three density fractions. The 2.5–2.5 g/cm^3 fraction includes 76.3% of the glauconite, the 2.4–2.5 g/cm^3 fraction — 19.3% and the 2.3–2.4 g/cm^{3}fraction — only 3.4%. The percentage content of glauconite, prevalence of thick grains of various morphology and lack of detrital grains as well as relatively high density indicate that glauconite is authigenic, syngenetic with deposit accumulation.

X-ray diffraction, besides diagnostic reflexes for glauconite, did not show strange minerals (Fig. 6a). A broadened and indistinct basic reflex (001) points to a low degree of glauconite structure order. Diffraction of air-dried preparation after saturation with glycol allows classifation of glauconite as disordered, constituting a mixture of illite and smectite

Table 2

Chemical composition of glauconite

Component	Łaszczówka		Piekiełko	
	weight percent	number of cations per molecule of glauconite	weight percent	number of cations per molecule of glauconite
SiO_2	50.90	Si 3.791	47.00	Si 3.574
Al_2O_3	6.96	Al_4 0.209	7.94	Al_4 0.426
Fe_2O_3 total	20.40	Al_6 0.400	21.90	Al_6 0.287
Fe_2O_3	17.60	Fe^{3+} 0.985	19.40	Fe^{3+} 1.111
FeO	2.48	Fe^{2+} 0.157	2.25	Fe^{2+} 0.142
MgO	3.92	Mg 0.434	4.57	Mg 0.517
K_2O	7.38	K 0.703	7.92	K 0.768
Na_2O	0.04	Na 0.006	0.47	Na 0.069
CaO	1.89	Ca 0.078	1.02	Ca 0.036
H_2O^-	3.56		4.12	
H_2O^+	6.13		5.69	
TiO_2	0.16		0.12	
P_2O_5	0.77		0.49	
ST	0.08		0.06	
V	0.019		0.015	
Ba	0.002		0.032	
LOI (600°C)	6.19		8.09	
LOI (1000°C)	7.56		0.04	
Sum	99.79		99.89	

(I/S). The content of smectite packs is 20–30%, which indicates a polymorphous type 1 Md. The disordered inner structure of glauconite grains and their great porosity are shown in scanning photos (Pl. II, Fig. 9).

The curves of thermal differentiation analysis show three distinct endothermal effects at the temperature maxima 160, 575 and 950°C (Fig. 7a). Mass losses were 2.7 and 4.2% for the first and second endoeffects, respectively. The total loss of the heated sample mass was 10.4%.

The chemical composition of glauconite from Łaszczówka is as follows: SiO_2 — 50.9%, Al_2O_3 — 6.9%, Fe_2O_3 — 17.6%, FeO — 2.5%, MgO — 3.9% , K_2O — 7.4%, Na_2O — 0.04%, CaO — 1.9%. Besides the increased content of Fe_2O_3 (17.6%), this is a typical chemical composition of glauconite, not differing from the average (K. Smulikowski, 1924).

The crystallographic formulas of glauconite, after calculating the results of chemical analysis to sum to 22 negative elementary charges (Tab. 2) using the Hendrick and Ross method, are of the form:

$$(K_{0.703}Na_{0.006}Ca_{0.078})(Fe^{3+}_{0.985}Mg_{0.434}Al^{VI}_{0.400})[Si_{3.791}Al^{IV}_{0.209}O_{10}(OH)_2]$$

$$(K, Na, Ca)_{0.787}(Fe^{3+}Fe^{2+}Mg, Al^{VI})_{1.976}[Si_{3.791}Al^{IV}_{0.209}O_{10}(OH)_2].$$

The sample from the Piekiełko borehole includes 17.1% glauconite. In the grain-size distribution there can be observed different grain sizes. The 0.5–0.25 mm fraction constitutes 15.8%, the 0.25–0.2 mm fraction — 25.2%, the 0.2–0.16 mm fraction — 26.3% and the 0.16–0.1 mm fraction — 21.7%. The grains of over 0.5 mm diameter occur individually.

The most frequent colour of glauconite is dark green though there can be found light green, black, beige and brown grains. Glauconite grain morphology is differentiated. There are egg-shaped, ball-shaped, verrucose, capsular and discoidal grains. The density fraction 2.4–2.5 g/cm^3 is definitely predominant (99.1%) in spite of great morphological diversity of grains.

Morphological features, great diversity of shapes and sizes as well as lack of high content of detrital grains in the deposit points to the glauconite's authigenic character syngenetic with the deposit development. Beige and brown colours of some grains are the evidence of weathering processes. Lack of density variability in the glauconite roof layer indicates that it was washed by waves.

X-ray examinations show poor ordering of glauconite internal structure and diagnostic reflexes are found on its powder diffraction pattern (Fig. 6b). X-ray diffraction of air-dried dreparation after saturation with ethylene glycol shows that it is a mixture of illite and smectite. The 20–30% content of smectite packs is the evidence for a polymorphous type 1Md. The glauconite grains are characterized by disordered internal structure and great porosity.

Thermal studies confirm glauconite mineral heterogeneity and high content of swelling packs. The thermal curves show endothermal effects with three maxima. The mass loss for the endoeffect at 160°C is 3% and at 575°C is 4%. The total mass loss for the heated sample is 10% (Fig.7b).

The chemical composition of glauconite from Piekiełko is average except for low SiO_2 content (47.0%). The chemical analysis of glauconite (Tab. 2) allowed calculation of structural formulas which are as follows:

$$(K_{0.768}Na_{0.069}Ca_{0.036})(Fe^{3+}_{1.111}Mg_{0.516}Al^{VI}_{0.287})[Si_{3.574}Al^{IV}_{0.426}O_{10}(OH)_2]$$

$$(K, Na, Ca)_{0.873}(Fe^{3+}Fe^{2+}Mg, Al^{VI})_{2.057}[Si_{3.574}Al^{IV}_{0.426}O_{10}(OH)_2].$$

Composition of octahedral cations and their number not exceeding 2.0 enable classification of glauconite from the Łaszczówka and Piekiełko profiles as mica dioctahedra with small defects in octahedra. Analysis of glauconite external features (decolourization of some grains) and x-ray characteristics as well as chemical composition show that the examined glauconite underwent weathering which caused its secondary transformation.

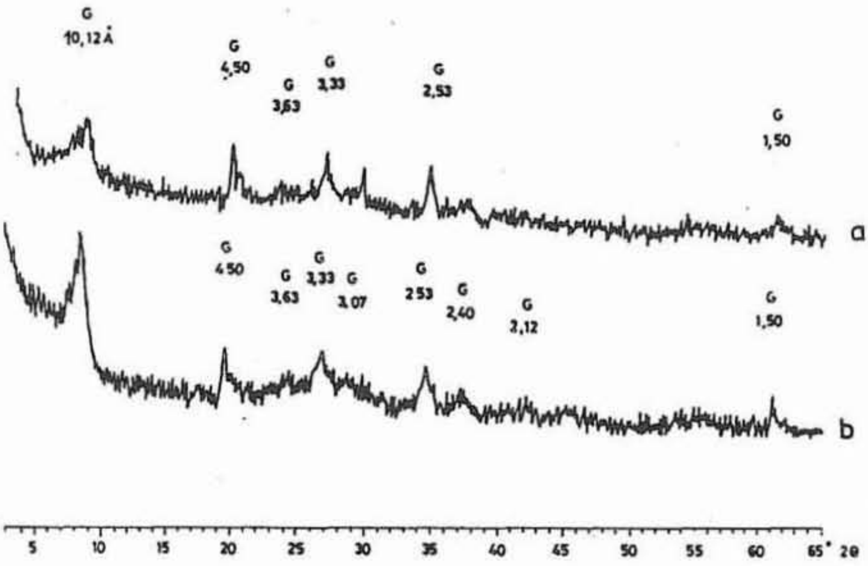

Fig. 6. X-ray diffractograms of powder specimen of glauconite: a — from Łaszczówka 29 profile, b — from Piekiełko 30 profile

Dyfraktogramy rentgenowskie preparatu proszkowego glaukonitu: a — z profilu Łaszczówka 29, b — z profilu Piekiełko 30

ABSOLUTE DATING OF GLAUCONITE

Lately, much attention has been paid to importance of dates obtained by isotope geochronology methods. Of minerals suitable for radiometric dating of sedimentary rocks, glauconite plays an important role. It is formed in the under-surface layer of sediments and is sensitive to temperature, salinity, oxidizing-reducing potential changes as well as to other environment parameters. It is one of the sedimentary minerals containing potassium in amounts sufficient to determine isotopic age. Glauconite has been used as a marine sediment index for stratigraphic-palaeogeographical aims.

Numerous studies of sedimentary rock age by means of glauconite show that convergence of geochronological and geological data can not always be obtained. Glauconites tend to lower radiometric data compared with geological methods by about 20% and sometimes even by 40% (G. R. Thompson, J. Hower, 1973).

Glauconite from the Łaszczówka and Piekiełko profiles was subjected to radiometric dating. This mineral is characterized by high K_2O content in spite of partial weathering and imperfect internal structure ordering. In the Łaszczówka profile its content is 7.38% and in the Piekiełko profile 7.92%.

The radiometric dating showed the argon age for the sample from the bottom layer of the Łaszczówka profile to be 39.5±3.0 million years and for the sample from the top layer of the Piekiełko profile to be 42.2±3.0 million years (Z. Krzowski, 1993). The age difference

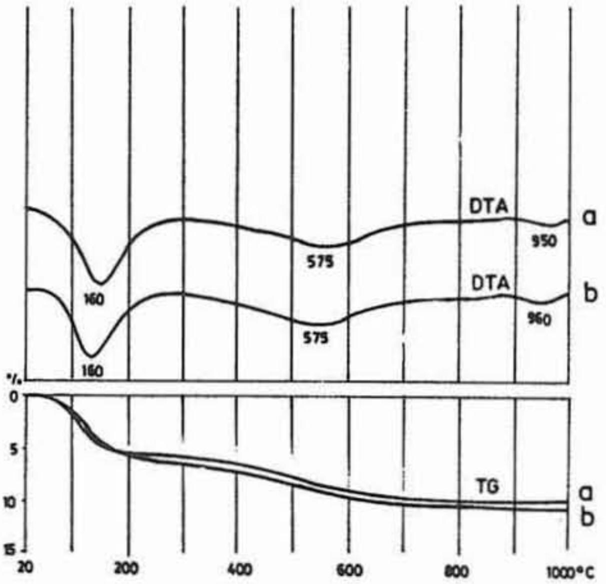

Fig. 7. Differential thermal analysis (DTA) curves of glauconite: a — from Łaszczówka 29 profile, b — from Piekiełko 30 profile

Krzywe termiczne analizy różnicowej glaukonitu: a — z profilu Łaszczówka 29, b — z profilu Piekiełko 30

of 2.7 million years for both samples is within the error limit. The obtained dates correspond to Bartonian, at present numbered as Middle Eocene (W. B. Harland *et al.*, 1989). This age is also confirmed by studies on carbonate nannoplankton by E. Gaździcka (1994) which specify the age of these sediments as Middle Eocene, level NP 16 (E. Odrzywolska-Bieńkowa, K. Pożaryska, 1978).

Convergence of the dates obtained by different methods confirms reliability of the potassium-argon (K-Ar) method in doubtful stratigraphic problems concerning Tertiary sediment series in the Lublin region.

PALAEOGEOGRAPHY OF SOŁOKIJA GRABEN

Gradually damping movements of Laramian orogenesis rejuvenated lability of rigid foreland during the Palaeogene (K. Pożaryska, E. Odrzywolska-Bieńkowa, 1982). Transgression developed due to eustatic changes of the world see level. The Eocene sea consisted of two basins: the eastern European and the western European.

In the Middle Eocene the marine transgression from the West reached the Lublin Upland joining the eastern basin (F. Kockel, 1988; S. A. Moroz, J. P. Sokolov, 1988; A. P. Vinogradov, 1966). Numerous Eocene sites on the Lublin Upland indicate that the sea reached the Metacarpathian Ridge. The sediments dated in the Sołokija Graben indicate that flooding of the Upland happened in the Middle Eocene, level NP 16 (E. Gaździcka, 1994). The studied sediments come from the transgression described so far as Upper Eocene (K. Pożaryska, E. Odrzywolska-Bieńkowa, 1977; B. Kosmowska-Ceranowicz *et al.*, 1990).

Regeneration of old faults and development of folds took place at the turn of the Cretaceous and Tertiary periods in the Laramian orogenic phase (R. Ney, 1969; W. Pożaryski, 1974; M. Harasimiuk, A. Henkiel, 1981; A. Henkiel, 1984). The tectonic activity intensified in the Zamość – Rawa Ruska fault zone due to which the Sołokija Graben developed. The Sołokija Graben is bordered by a tectonic edge in the east and the Krasnobród – Lubycza Anticline in the West. Directions of main structural elements correspond to main tectonic trends NW–SE (J. Buraczyński *et al.*, 1992; S. Cieśliński, J. Rzechowski, 1993).

Clastic material deposited in the shallow coastal zone formed a delta. The Ukrainian Shield and Metacarpathian Ridge were the alimentation region for the delta. The river flowed to the West from the contemporary basin of the upper Bug and upper Dniester rivers. It formed the delta with the face reaching the Wisła valley to the West and the Lubartów region to the North (J. Kasiński *et al.*, 1993). From the South, delta range is determined by the Wyżnica and Por valleys as well as the northern edge of Roztocze bordering with the land of the Metacarpathian Ridge (Fig. 1). The beginning of delta development is determined by the Middle Eocene sediments found in the Sołokija Graben near Tomaszów Lubelski (J. Buraczyński *et al.*, 1992) and near Rawa Ruska and Magierów (W. Rogala, 1912).

At the end of the Eocene, during the synchronous movements in the Pyrenees phase of Alpine orogenesis, there developed weak block movements which displaced Eocene formations 20 m (Fig. 2). Slight mobility of geosyncline foreland affected poorly developed and residual Eocene sediments preserved only in the Sołokija Graben.

After recession of the sea, in continental conditions, sandstone concretions of goethite-hematitic cement developed (K. Radlicz *fide* J. Buraczyński *et al.*, 1992). The character of concretions shows that they developed in desert climate conditions probably in the Upper Oligocene. These concretions are still found on the residual hill (315 m a.s.l.) situated close to the graben edge near Szarowola, which is built of strongly weathered quartz-glauconite sands. Similar concretions overlaying weathered Eocene sediments were found near Wola Studziańska on the residual hill, at 292 m a.s.l. (S. Cieśliński, personal communication).

In recent times the roof of Eocene formations in the Sołokija Graben is at 255 m a.s.l. and on the residual hill at a height of 315 m a.s.l. From this position it can be concluded that original thickness of the Eocene sediments was greater by at least 50 m. Thus, areal extent during the Eocene was significantly larger, and later denudation removed it from the areas close to the graben. In modern times Eocene sediments are found only in the graben axis and on the residual hill.

CONCLUSIONS

1. On the Roztocze Upland in the tectonic graben a homogeneous series (40 m) of slightly carbonate (5%) quartz-glauconite sands is found. The 0.05–0.1 mm fraction (70%)

is prevalent in the grain-size composition. The parameters in phi scale are: mean diameter Mz = 3.87–4.64, sorting σ_1 = 1.15–1.61, skewness Sk_1 = 0.42–0.74. Poorly sorted formations accumulated by suspension from weak currents under changing, dynamic conditions.

2. In the mineral composition, quartz content is 80% and glauconite content is 10–15%. Opaque minerals (50–80%) prevail in the heavy mineral composition. Among transparent minerals are found the resistant ones: tourmaline (40%), disthene and staurolite (20%).

3. As regards morphology, glauconite is represented by different size and shape grains; the grains of fraction 0.1–0.25 mm (73%) are predominant. Morphological features indicate an authigenic character of glauconite which is syngenetic with the sediment development.

4. Glauconite chemical composition is typical, not differing from the average. The internal structure is characterized by a low degree of order and large porosity. The composition of octahedral cations, not exceeding 2.0 in number, makes it possible to include it into dioctahedral micas of small defects in octahedrons.

5. The studied glauconite has a high content of K_2O (7.4–7.9%). The radiometric dating showed the argon age to be 39.5–42.2±3.0 million years. The obtained data indicate Middle Eocene, corresponding to phytopalynological dating of level NP 16.

6. The studies show that marine transgression took place in Middle Eocene, not in the Upper Eocene as it has been assumed so far. Clastic material was deposited in the shallow coastal zone, whose alimentation areas were the Ukrainian Shield and Metacarpathian Ridge — the area of the contemporary basin of the upper Bug and Dniester rivers.

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REFERENCES

BURACZYŃSKI J. (1980/1981) — Development of valleys in the escarpment zone of the Roztocze (in Polish with English summary). Ann. UMCS, B, **25/26**, p. 81–102.

BURACZYŃSKI J., GURBA J. (1977/1978) — Sandstones of Batiatycze in Piekiełko sacred spot on Tomaszowskie Roztocze (in Polish with English summary). Ann. UMCS, B, **32/33**, p. 219–235.

BURACZYŃSKI J., BRZEZIŃSKA-WÓJCIK T., SUPERSON J. (1992) — Objaśnienia do Szczegółowej mapy geologicznej Polski 1:50 000, ark. Tomaszów Lubelski. Państw. Inst. Geol. Warszawa.

CIEŚLIŃSKI S., RZECHOWSKI J. (1993) — Mapa geologiczna podłoża czwartorzędu Roztocza między Tomaszowem Lubelskim a Hrebennem. In: Tektonika Roztocza i jej aspekty sedymentologiczne, hydrogeologiczne i geomorfologiczno-krajobrazowe (eds. M. Harasimiuk i in.), p. 39–46. UMCS. Lublin.

GAŹDZICKA E. (1994) — Middle Eocene calcareous nannofossils from the Roztocze region (SE Poland) — their biostratigraphic and palaeogeographic significance. Geol. Quart., **38**, p. 727–738, no. 4.
HARASIMIUK M., HENKIEL A. (1981) — Post-Cretaceous tectonics at northern slope of the meta-Carpathian Swell in the Lublin area (in Polish with English summary). Prz. Geol., **29**, p. 571–573, no. 11.
HARLAND W. B., ARMSTRONG R. L., COX A. V., CRAIG L. E., SMITH A. G., SMITH D. G. (1989) — A geological time scale 1989. Cambridge Univ. Press. Cambridge.
HENKIEL A. (1984) — Tectonics of Meso-Cainozoic cover of the northern slope of the Metacarpathian Swell (in Polish with English summary). Ann. UMCS, B, **39**, p. 15–38.
HENKIEL A. (1988*a*) — New investigations of the Tertiary cover in the north-western part of the Lublin Upland (in Polish with English summary). Biul. LTN, **30**, p. 73–78, no. 2.
HENKIEL A. (1988*b*) — New investigations of the Paleocene in the north-western part of the Lublin Upland (in Polish with English summary). Biul. LTN, **30**, p. 67–71, no. 2.
KASIŃSKI J., PIWOCKI M., TOŁKANOWICZ E. (1993) — Upper Paleocene facies setting in northeast Poland and its control of amber distribution. 2-nd Baltic Conference Vilnius. Abstracts, **39**.
KOCKEL F. ed. (1988) — The NW European Tertiary basin, Eocene, palaeogeography. 1:2,500,000. In: The northwest European Tertiary basin (ed. A. Vincken). Geol. Jb., **A 100.**
KOSMOWSKA-CERANOWICZ B., KOCISZEWSKA-MUSIAŁ G., MUSIAŁ T., MÜLLER C. (1990) — The amber-bearing Tertiary sediments near Parczew (in Polish with English summary). Pr. Muz. Ziemi, **41**, p. 21–35.
KRZOWSKI Z. (1993) — Trzeciorzędowe osady glaukonitowe na Wyżynie Lubelskiej w świetle geochronologii izotopowej glaukonitu. Pr. Nauk. PL., **231**.
KULCZYCKA J. (1975) — Sprawozdanie z badań geologiczno-zwiadowczych za żwirami w rejonie Tomaszowa Lubelskiego. Arch. Państw. Inst. Geol. Warszawa.
MARSZAŁEK S., ALBRYCHT A., BUŁA S. (1991) — Objaśnienia do Szczegółowej mapy geologicznej Polski 1:50 000, ark. Niedźwica. Państw. Inst. Geol. Warszawa.
MOJSKI J. E., RZECHOWSKI J., WOŹNY E. (1966) — Upper Eocene at Luszawa on Wieprz river near Lubartów (in Polish with English summary). Prz. Geol., **14**, p. 513–517, no. 12.
MOROZ S. A., SOKOLOV J. P. (1988) — Stratigrafija niżniego paleogena sieviernoj Ukrainy. Tektonika i stratigrafija. AN USSR, Inst. Geol. Nauk., **29**, p. 74–78.
MUSIAŁ T. (1987) — Miocene of Roztocze (south-eastern Poland) (in Polish with English summary). Biul. Geol. Wydz. Geol. UW, **31**, p. 5–149.
NEY R. (1969) — The Miocene of the southern Roztocze, between Horyniec and Łówcza, and the adjacent area of the Carpathian foredeep (in Polish with English summary). Pr. Geol. Komis. Nauk Geol. PAN, Kraków, **60**.
ODRZYWOLSKA-BIEŃKOWA E., POŻARYSKA K. (1978) — Biostratigraphy and isotopic age of Middle and Upper Eocene junction beds from the Szczecin IG 1 borehole (in Polish with English summary). Kwart. Geol., **22**, p. 611–618, no. 3.
POŻARYSKA K., LOCKER S. (1972) — Les organismes planctoniques de l'Eocene superieur de Siemień. Pologne oriental. Rev. Micropaleont., **14**, p. 57–72, no. 5.
POŻARYSKA K., ODRZYWOLSKA-BIEŃKOWA E. (1977) — On the Upper Eocene in Poland (in Polish with English summary). Kwart. Geol., **21**, p. 59–72, no. 1.
POŻARYSKA K., ODRZYWOLSKA-BIEŃKOWA E. (1982) — The influence of tectonics on sedimentation in the Polish Lowlands in the Tertiary (in Polish with English summary). Prz. Geol., **30**, p. 589–591, no. 11.
POŻARYSKI W. (1974) — Obszar świętokrzysko-lubelski. In: Budowa geologiczna Polski, **4**, Tektonika, cz. 1, p. 349–363.
ROGALA W. (1912) — O utworach oligoceńskich na Roztoczu Lwowsko-Rawskim. Księga Pam. XI Zjazdu Lekarzy i Przyr. Kraków, **228**.
SMULIKOWSKI K. (1924) — O glaukonicie. Kosmos, **49**, p. 502–544.
THOMPSON G. R., HOWER J. (1973) — An explanation for the radiometric ages from glauconite. Geochim. Cosmochim. Acta, **37**, p. 1473–1491.
UBERNA J. (1981) — Upper Eocene phosphate-bearing deposits in northern and eastern Poland. Bull. Acad. Pol. Sc., **29**, p. 81–90, no. 1.
UBERNA J., ODRZYWOLSKA-BIEŃKOWA E. (1977) — New localities of the Upper Eocene in northern parts of the Lublin region (in Polish with English summary). Kwart. Geol., **21**, p. 73–84, no. 1.
VINKEN A. (1988) — The Northwest European Tertiary Basin. Geol. Jb., **A 100.**
VINOGRADOV A. P. ed. (1966) — Atlas of lithological-paleogeographical maps of the USSR. Acad. Sc. USSR, **4**.

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EOCEN ŚRODKOWY W ROWIE SOŁOKIJI NA ROZTOCZU

Streszczenie

W rowie Sołokiji, na obszarze 2 x 20 km, występują utwory eoceńskie pod cienką pokrywą czwartorzędu, w poziomie 255 m n.p.m. Tworzą one drobnoziarniste piaski kwarcowo-glaukonitowe o spoiwie ilastym i maksymalnej miąszości 40 m (otwór wiertniczy Piekiełko 30). W ich składzie granulometrycznym przeważa frakcja 0,5–0,1 mm (70%). Cechują się wskaźnikami uziarnienia Mz = 3,87–4,64, wysortowaniem σ_I = 1,15–1,53, skośnością S_k = 0,42–0,71 oraz kurtozą K_G = 0,72–0,77. Wysortowanie osadu jest słabe, co wskazuje na zmienną dynamikę i akumulację zawiesiny w środowisku słabych prądów. Głównym tworzywem mineralnym jest kwarc (80%); glaukonit o średnicy ziarn 0,05–0,1 mm występuje w ilości 10–15%.

W składzie minerałów ciężkich przeważają minerały nieprzezroczyste (50–80%). Minerały przezroczyste reprezentuje zespół minerałów odpornych i średnioodpornych: turmalin i dysten + staurolit po 10%, cyrkon i rutyl po 5% oraz epidot 3%. W badanych profilach nie stwierdzono konkrecji fosforytów.

Próbka z otworu Piekiełko 30 zawiera 17,1% glaukonitu barwy ciemnozielonej o zróżnicowanej morfologii ziarn. Zdecydowanie przeważa (99,1%) frakcja gęstościowa 2,4–2,5 g/cm^3. Cechy morfologiczne ziarn glaukonitu wskazują na autigeniczny charakter, syngenetyczny z rozwojem osadu. Ziarna te cechuje nieuporządkowana struktura wewnętrzna i duża porowatość. Skład chemiczny glaukonitu oprócz niskiej zawartości SiO_2 nie odbiega od przeciętnego. Jego wzór strukturalny ma postać:

$$(K_{0,768}Na_{0,069}Ca_{0,036})(Fe^{3+}_{1,111}Mg_{0,516}Al^{VI}_{0,287})[Si_{3,574}Al^{IV}_{0,426}O_{10}(OH)_2]$$

$$(K, Na, Ca)_{0,873}(Fe^{3+}Fe^{2+}Mg, Al^{VI})_{2,057}[Si_{3,574}Al^{IV}_{0,426}O_{10}(OH)_2].$$

Skład kationów oktaedrycznych i ich liczba (poniżej 2,0) wskazują, że glaukonit należy do mik dioktaedrycznych o niewielkich defektach w oktaedrach. Datowaniem glaukonitu metodą potasowo-argonową stwierdzono wiek 39,5±3,0 i 42,2±3,0 mln lat, wskazujący na eocen środkowy. Badania nannoplanktonu węglanowego zaliczają te utwory również do eocenu środkowego (E. Gaździcka, 1994).

Liczne stanowiska osadów eocenu na Wyżynie Lubelskiej wskazują, że morze wkroczyło na wał metakarpacki. Materiał klastyczny osadził się w płytkiej zatoce tworząc deltę. Obszarem alimentacyjnym delty lubelskiej była tarcza ukraińska i wał metakarpacki. Rzeka płynąca na zachód obejmowała współczesne dorzecze górnego Bugu i górnego Dniestru. Początek delty wyznaczają osady położone w okolicy Tomaszowa Lubelskiego, Rawy Ruskiej i Magierowa. Południowy brzeg delty wyznacza dolina Sołokiji, północna krawędź Roztocza oraz doliny Poru i Wyżnicy.

Po wycofaniu się morza, w utworach tych utworzyły się konkrecje piaskowca o spoiwie getytowo-hematytowym. Rozwinęły się one w warunkach klimatu pustynnego. Konkrecje te występują na zwietrzałych osadach eocenu, na ostańcu o wysokości 315 m n.p.m. przy krawędzi rowu Sołokiji oraz na ostańcu 292 m n.p.m. przy północnej krawędzi Roztocza koło Woli Studziańskiej.

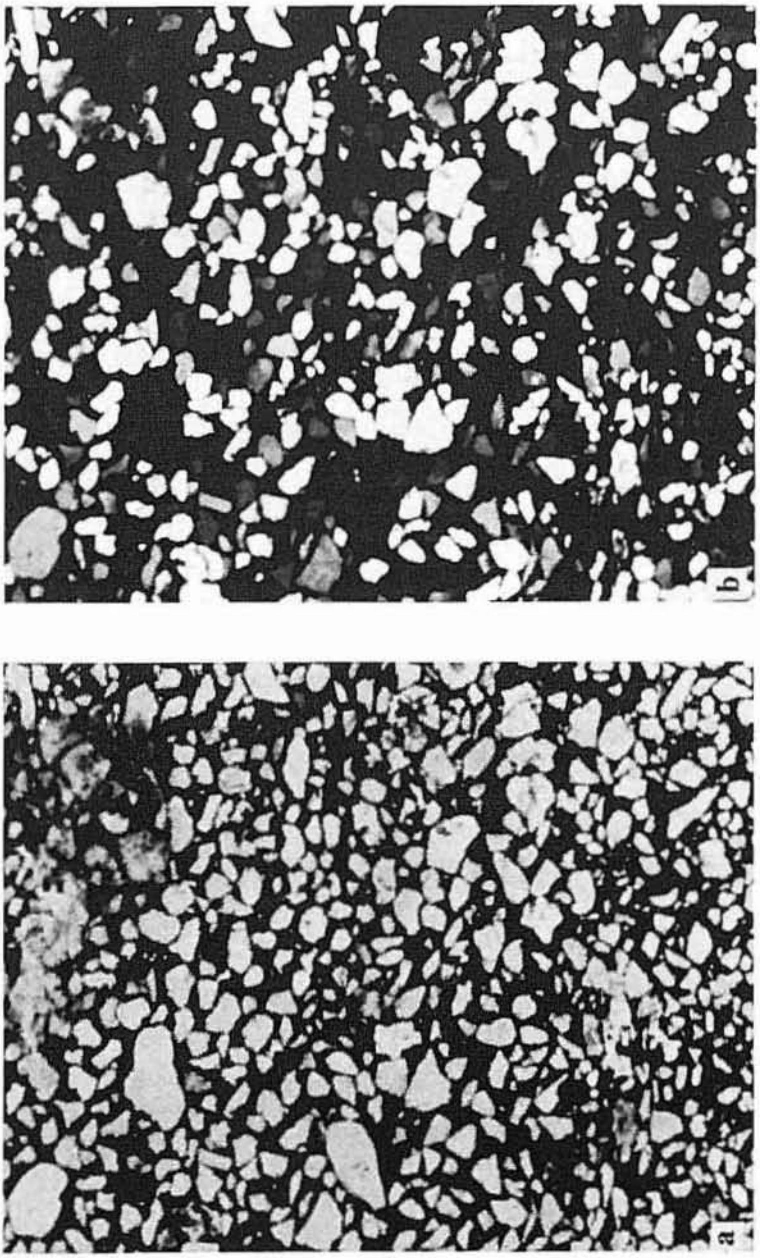

Fig. 8. Sandstone of goethite-hematite binder from Szarowola; rounded and sharp-edged quartz grains; x 32; a — without nicol, b — with nicol

Piaskowiec o spoiwie getytowo-hematytowym z Szarowoli; ziarna kwarcu obtoczone i ostrokrawędziste; 32 x; a — bez analizatora, b — z analizatorem

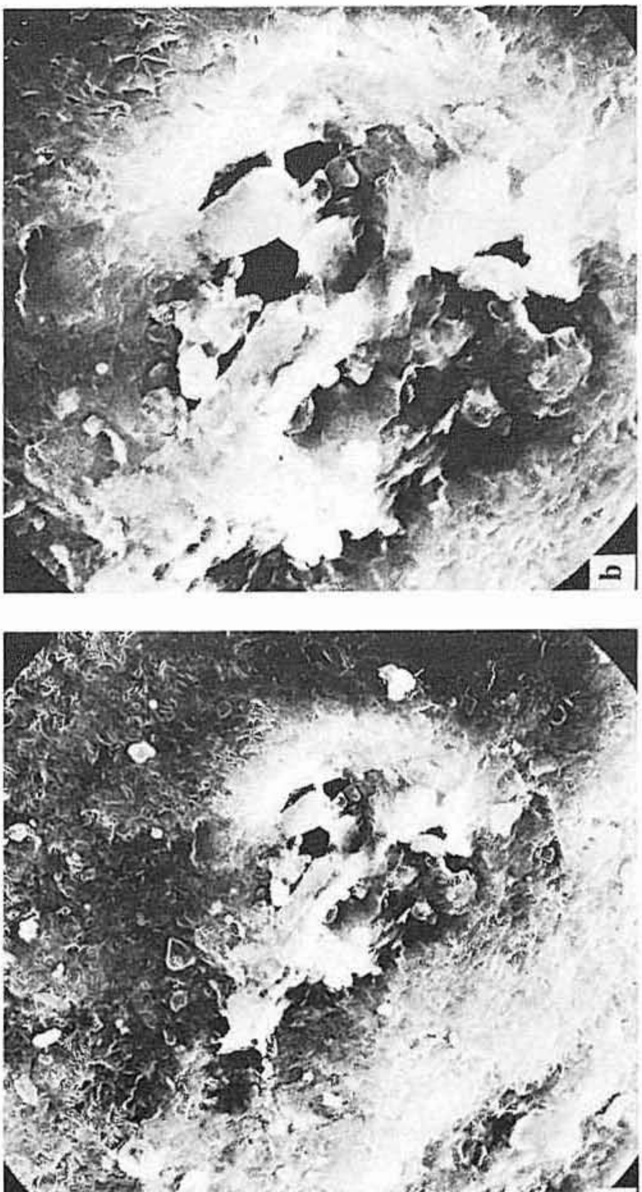

Fig. 9. Scanning-electron micrograph of glauconite grain from Piekiełko 30 borehole; density fraction 2.4–2.5 g/cm^3; a — x 1500, b — x 4000

Ziarno glaukonitu z otworu Piekiełko 30; gęstość 2,4–2,5 g/cm^3; a — 1500 x, b — 4000 x