Jan BURACZYŃSKI, Zdzisław KRZOWSKI

Middle Eocene in the Sołokija Graben on Roztocze Upland

Lithological-mineralogical characteristics of quartz-glaucnitic 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


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, 1988a) as well as on the residual hills near Piotrków (A. Henkiel, 1988b), Białowoda at 251 m a.s.l. (S. Marszałek et al., 1991) and Wola Studzińska 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
the Tomaszów Lubelski areas, J. Kulczycka (1975) found glauconite sands in several boreholes. Based on preliminary lithological characteristics, the deposits situated in the Solokija 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. Radličz) and phytopalynological (E. Gażdźicka, 1994) analyses were carried out. To determine glauco-
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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 guises, Maestrichtian; Crm1 — lower, Crm3 — upper; 2 — quartz-glaucophane sands, Middle Eocene (E); 3 — sands and detrital limestones, Badenian (M4); 4 — clays, Sarmatian (M5); 5 — confirmed faults; 6 — supposed faults; —— — section line of profile Fig. 3; contour line every 10 m

Szkic geologiczny okolic Tomaszowa Lubelskiego (według J. Buraczynskiego, 1980/1881; S. Cieslińskiego, J. Rzechowskiego, 1993; R. Ney, 1969)

1 — marge, opoki and gezy, mastricht: Crm1 — dolny, Crm3 — górny; 2 — piaski kwarcowo-glaucenitowe, eocen środkowy (E); 3 — piaski i wapienie detrytyczne, baden (M4); 4 — ły, sarmat (M5); 5 — uskoki pewne; 6 — uskoki przypuszczalne; —— — linia przekroju fig. 3; poziomice co 10 m

nate age by the potassium-argon method, it was subjected to complex chemical, x-ray, thermal and radiometric studies (Z. Krzowski, 1993).
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 Wołosza, where they are artificially exposed, do they come up onto the surface at a level of 255 m a.s.l. (J. Buraczynski 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 (3m). 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 metallic brown colour and the floor is not equal to appendices.

In the Sołokija valley near Łaszcówka, 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 Łaszcówka 29 borehole and 40 m in the Piekielko 30 borehole which is 400 m away (Fig. 3).

Eocene formations in both boreholes are lithologically similar (J. Buraczynski 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 ($M_z = 3$), intensely green and decalcified (J. Buraczynski, J. Gurba, 1977/1978).

Studied deposits for the Łaszcówka (Fig. 4) and Piekielko (Fig. 5) profiles are characterized by grain-size parameters: mean grain diameter $M_z = 4.40–4.67$ and 3.87–4.64; standard deviation $\sigma_1 = 1.39–1.69$ and 1.15–1.53, skewness $S_{k_1} = 0.58–0.74$ and 0.42–0.71 and kurtosis $K_{G} = 0.60–0.76$ and 0.72–0.77, respectively. Deviation values ($\sigma_1$) 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.

### Heavy mineral composition

<table>
<thead>
<tr>
<th>Profile</th>
<th>Depth [m]</th>
<th>Weight percent</th>
<th>OPM</th>
<th>GLA</th>
<th>TRM</th>
<th>AMF</th>
<th>PYR</th>
<th>EPI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Piekielko 16</td>
<td>10</td>
<td>0.57</td>
<td>31.8</td>
<td>44.0</td>
<td>23.6</td>
<td>0.6</td>
<td>–</td>
<td>4.3</td>
</tr>
<tr>
<td>Piekielko 20</td>
<td>14</td>
<td>0.78</td>
<td>87.5</td>
<td>4.6</td>
<td>7.9</td>
<td>–</td>
<td>–</td>
<td>7.6</td>
</tr>
<tr>
<td>Szarośwola 4</td>
<td>4</td>
<td>0.10</td>
<td>80.7</td>
<td>–</td>
<td>17.4</td>
<td>0.7</td>
<td>1.8</td>
<td>2.1</td>
</tr>
</tbody>
</table>

OPM — opaque minerals, GLA — glauconite, TRM — transparent minerals, AMF — amphibole, PYR — pyrodisthene, STA — staurolite, AND — andalusite, TOP — topaz
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
associations are predominant. In the Łaszcówka profile, there are found tourmaline and disthene and staurolite (10% each), zircon and rutile (5% each), as well as epidote (3%). However, in the Piekielko 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 Łaszcówka profile there are amphiboles, chlorites and garnets whereas they are not found in the lower part. Moreover, there are larger amounts of disthene, staurolite and rutile 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 Łaszcówka 29 borehole and 9.6 m from the Piekielko 30 borehole. Glauconite removed by a magnetic separator was subjected to chemical, x-ray, thermal and radiometric studies (Z. Krzowski, 1993).
A sample from Łaszcówka 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/cm³ fraction includes 76.3% of the glauconite, the 2.4–2.5 g/cm³ fraction — 19.3% and the 2.3–2.4 g/cm³ 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 classification of glauconite as disordered, constituting a mixture of illite and smectite
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 Łaszczyńska is as follows: SiO₂ — 50.9%, Al₂O₃ — 6.9%, Fe₂O₃ — 17.6%, FeO — 2.5%, MgO — 3.9%, K₂O — 7.4%, Na₂O — 0.04%, CaO — 1.9%. Besides the increased content of Fe₂O₃ (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:

\[
(K_{0.703}Na_{0.006}Ca_{0.078})(Fe^{3+}_{0.985}Mg_{0.434}Al_{0.400})[Si_{3.791}Al_{0.209}O_{10}(OH)_{2}]
\]

\[
(K, Na, Ca)_{0.787}(Fe^{3+}_{0.7}Fe^{2+}_{0.3}Mg, Al^{VI}_{0.976}[Si_{3.791}Al_{0.209}O_{10}(OH)_{2}].
\]
The sample from the Piekielko 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/cm³ 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 preparation 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 endothermic 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 Piekielko is average except for low SiO₂ content (47.0%). The chemical analysis of glauconite (Tab. 2) allowed calculation of structural formulas which are as follows:

$$(\text{K}_0.768\text{Na}_0.069\text{Ca}_0.036)(\text{Fe}^{3+}_{1.11}\text{Mg}_{0.516}\text{Al}_{0.287})[\text{Si}_3.574\text{Al}_{0.426}\text{O}_{10}\text{(OH)}_2]$$

$$(\text{K}, \text{Na}, \text{Ca})_{0.873}(\text{Fe}^{3+}_{3+}\text{Fe}^{2+}_{4+}\text{Mg}_{1.507}[\text{Si}_3.574\text{Al}_{0.426}\text{O}_{10}\text{(OH)}_2].$$

Composition of octahedral cations and their number not exceeding 2.0 enable classification of glauconite from the Łaszechówka and Piekielko 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.
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 Łaszczyówka and Piekielko profiles was subjected to radiometric dating. This mineral is characterized by high K₂O content in spite of partial weathering and imperfect internal structure ordering. In the Łaszczyówka profile its content is 7.38% and in the Piekielko profile 7.92%.

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

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

Dyfraktogramy rentgenowskie preparatu proszkowego glaukonitu: a — z profilu Łaszczyówka 29, b — z profilu Piekielko 30
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. Pożarska, E. Odrzywolska-Bieńkowa, 1982). Transgression developed due to eustatic changes of the world sea 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 Metacarpethian Ridge. The sediments dated in the Solokija 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. Pożarska, E. Odrzywolska-Biewkowa, 1977; B. Kosmowska-Ceranowicz et al., 1990).


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 Solokija 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 Solokija Graben.

After recession of the sea, in continental conditions, sandstone concretions of goethite-hematitic cement developed (K. Radlicki 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-glaucnite sands. Similar concretions overlaying weathered Eocene sediments were found near Wola Studzińska on the residual hill, at 292 m a.s.l. (S. Cieśliński, personal communication).

In recent times the roof of Eocene formations in the Solokija 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-glaucnite 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 $M_2 = 3.87-4.64$, sorting $\sigma = 1.15-1.61$, skewness $Sk = 0.42-0.74$. 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


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**EOCEN ŚRODKOWY W ROWIE SOŁOKIJI NA ROZTOCZU**

**Streszczenie**

W rowie Sołoki, 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 maksy- malnej mieszaninie 40 m (otrąb wiertniczy Piekiełko 30). W ich składzie granulometrycznym przeważy frakcja 0,5–0,1 mm (70%). Cechują się wskaźnikami uznania $M_z = 3,87$–4,64, wysortowaniem $\alpha_1 = 1,15$–1,53, skośnością $S_k = 0,42$–0,71 oraz kurtózą $K_G = 0,72$–0,77. Wysortowanie osadu jest słabe, co wskazuje na zmieną ruchliwości i akumulację zawiesiny w środowisku słabych prądów. Głównym tworzywem minerałowym jest kwarc (80%); glaukonit o średnicy ziarn 0,05–0,1 mm występuje w ilości 10–15%.

W składzie minerałów ciężkich przeważają minerały niepłynne (50–80%). Minerały przekraczające reprezentują zespół minerałów odpornych i średnioodpornych: turmalin i dysten + staurolit po 10%, cyrkon i rutyl po 5% oraz epidot 3%. W badanychprofilach nie stwierdzono konkretacji fosforowych.

Próbka z otworu Piekiełko 30 zawiera 17,1% glaukonitu barwy cienkoziarnistej o zróżnicowanej morfologii ziarn. Zdecydowanie przeważy (99,1%) frakcja gestościowa 2,4–2,5 g/cm³. Cechy morfologiczne ziarna glaukonitu wskazują na autogeniczny charakter, syntetyczny z rozwijaniem osadu. Zjawienie to cechuje nieuporządkowaną strukturę wewnętrznzą i dużą porowatość. Skład chemiczny glaukonitu o próbie naładowania 15% zawiera $SiO_2$ nie odbierny od przeciętnego. Jego wizerunek strukturalny ma postać:

$$(K_0, 75)Na_0, 069Ca_0, 036(Fe^{3+}Al_{VI})_{0, 11}\{Mg_{0, 516Al_{2, 37}}[Si_{3, 574Al_{IV}}]_2, 027[Si_{3, 574Al_{IV}}]_2Al_{0, 426}O_{10}(OH)_2]$$

$$(K, Na, Ca_{0, 873}[Fe^{3+Fe^{2+}Mg}_VI]_{2, 037}[Si_{3, 574Al_{IV}}]_{2Al_{0, 426}O_{10}(OH)_2}]$$

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


Po wycofaniu się morza, w utworach tych utworzyły się konkretiony piaskowca o spowite getytyowo-hebatymo- wym. Rozwinęły się one w warunkach klimatu pustynnego. Konkrece te występują na zwietrzałych osadach eocenu, na ostańcu o wysokości 315 m n.p.m. przy krawędzi rowu Sołoki oraz na ostańcu 292 m n.p.m. przy północnej krawędzi Roztocza koło Woli Studzińskiej.
Fig. 8. Sandstone of goethite-hematite-binder from Szarowola: rounded and sharp-edged quartz grains. x 32; a — without nicol, b — with nicol.

Plaško: křída s pružně-obloženým a porostlým kříd, anizotropní, b — z analízátorem

Jan BURACZYNSKI, Zdzisław KRZOWSKI — Middle Eocene in the Solokija Graben on Roztocze Upland
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