Acta Mineralogica-Petrographica, Szeged, XXXVII, 5–33, 1996

CASE HISTORIES OF SOME TRANSYLVANIAN GLAUCONIES

D. POP*

I. BEDELEAN*

Department of Mineralogy-Petrometallogeny
Babeş-Bolyai University

ABSTRACT

Several Romanian glaucony-bearing units (Cretaceous, Eocene, Oligocene and Miocene) from the Transylvanian Depression and, for comparision, one Cretaceous outcrop from the post-tectonic cover of the Southern Carpathians were studied from mineralogical, lithological and sedimentological point of view. The study focused on the morphological (as noticed under binocular, polarizing microscope, SEM and TEM-replica method) and the X-ray powder diffraction characteristics of the glauconitic grains.

The general lithological and sedimentological context, as well as data supplied by the mineralogical study of glauconies made possible a preliminary genetical characterization of the green grains (sensu AMOROSI 1993a).

Both Eocene occurrences, Luna de Sus and Ortelec (e.g. samples GE 2, GE 3 resp. GE 5) contain the most evolved glauconies under study: they consist of highly evolved, ordered glauconites (1M). They are considered authigenic, possibly perigenic glauconies.

The Miocene samples (e.g. GM 2, GM 7) from Tihău display a mineralogical variability: GM 2 represents transition from the ordered to the moderately disordered species (1Md) and GM 7 shows the features of moderately disordered glauconite (1Md). Both samples reflect the evolved stage of glauconitization. They are assumed to be perigenic glauconies.

The Cretaceous glauconies from Sebeşel are moderately disordered glauconites (1Md), with a maturity degree between slightly evolved to evolved glauconies (e.g. GC 28). The genetic type is either authigenic or perigenic. The other Cretaceous glauconies from Râşnov (e.g. GC 3) have a more opened and disordered structure: they contain extremely disordered glauconites (1Md) and represent the less evolved glauconies under study (slightly evolved stage). We assume a perigenic origin of these glauconies.

The Oligocene sample (GO 1) from Var displays XRD features which characterize also the extremely disordered glauconites (1Md), but the green grains show an intermediate glauconitization stage, between slightly evolved and evolved. They are transported (detrital/perigenic) glauconies.

INTRODUCTION

The Fe^{3+}-rich phyllosilicate species which form the family of glauconitic minerals are characterized by lamellar or lath-like crystallites (1—6 μm), which generally agglomerate in grains (pellets, or peloids, sensu BATHURST 1975, in FISCHER 1987), of a diameter usually between 100—1000 μm. Very rarely, other facies of glauconitic minerals (such as film habit or diffuse habit) develop, case in which the mineralogical identification is difficult.

* RO-3400 Cluj-Napoca, Kogălniceanu St. 1, Romania

Since the '70s, especially the papers of ODIN underlined the distinction which should be taken between the glauconitic facies — for which the term "glaucony" (plural "glauconies") (ODIN and LÉTOLLE 1978, ODIN and MATTER, 1981) was suggested, and the mineral species of the glauconitic group. The term "glauconite" is strongly recommended to be used only for defining the mineralogical species.

In 1978 the AIPEA Nomenclature Commission established the classifying criteria and redefined the species glauconite (BAILEY 1980). In agreement with this, the glauconitic minerals presented by ODOM (1984) are:

Glauconite s.s. (glauconitic mica, or ordered glauconite) is a dioctahedral, highly Fe^{3+} and K mica, with a generalized chemical formula:

$$K(R^{3+}{}_{1,33}\, R^{2+}{}_{0,67})\, (Si_{3,67}\, Al_{0,33})\, O_{10}\, (OH)_2,$$

where $Fe^{3+} >> Al$ and $Mg > Fe^{2+}$

The structure is of illitic-type, with less than 10 % expandable layers (exp.).

The disordered glauconites (glauconitic mixtures) are interlayered structures of Fe^{3+}-illitic and smectitic type, with 10—20 % exp., and usually 1Md polytype.

The interstratified glauconite/smectite is characterized by low K content, highly disordered structure (1Md or <1Md polytypes) and exp. between 20—60 %.

These minerals reflect the degree of maturity, i.e. the stage reached by the crystallization process. Glauconitic minerals form by neoformation or transformation. The semi-restrictive microenvironment in which the slow cation exchanges led to the glauconitization process are provided by an organic substrate or other minerals (ODIN 1975, ODIN and MATTER 1981).

SAMPLES

Sample selection; geological outline

A wide variety of glauconitic occurrences are to be found in the Transylvanian Depression, located in the central area of Romania (*Fig. 1*).

The Transylvanian Depression represents the result of the superposition of distinctive basins, starting their evolution in the Upper Permian, as a consequence of the existence of several different geological settings (BALINTONI 1996, in press). The glauconitic grains occur in sedimentary sequences formed during three distinctive evolutionary stages:

- the post-Gosau (post-Mediteranean) basin (Upper Cretaceous), displaying generally flysch-type deposits;
- the post-Laramic (Eocene—Oligocene) basin, in which mainly continental and epicontinental sediments formed on the Preapulian craton;
- the post-Meseș basin (Lower Miocene), characterized by marine deposits (Chechiș Beds), followed by molassic formations (Hida Beds).

The final stage of evolution of the Transylvanian Depression is represented by a molassic basin formed subsequently to Hida Beds (Medium Miocene—Pleistocene), in connection with an extension in the Pannonian Basin.

Samples representing this variety of stratigraphic ages, host-rock lithologies and general mineralogic features were collected and studied.

There is only one Cretaceous occurrence belonging to the Transylvanian Depression, the one near Sebeșel, Alba distr. For comparison, Upper Cretaceous samples from the post-Austric tectonic cover of the Southern Carpathians, near Râșnov, Brașov distr. were also studied.

Eocene samples were collected from two profiles of the almost 70 km long glaucony-ny-bearing Căpuşu Formation (Luna de Sus, Cluj distr. — as an extreme south-eastern end; Ortelec, Sălaj distr. — as the north-western end). More samples from the Luna de Sus profile were selected due to the distinctive lithology of the host-rock.

Oligocene age is represented among the samples by the isolated glauconitic occurrence in Var, Sălaj distr.

The most recent glauconitic level under study belongs to the basal part of the Chechiş Beds (Lower Miocene). It outcrops almost continuously from Coruş (Cluj distr.), through Tihău, to Surduc (Sălaj distr.), on about 70 km, as a 0.5–3.5 m thick stratigraphic marker (ŞURARU 1967).

This selection of samples (*Fig. 1*) is representative for the geological and mineralogical complexity of the various Transylvanian glauconitic occurrences. From the 79 studied samples 8 reference samples (Table 1) were selected for further, more detailed investigations (such as FTIR, Mössbauer spectroscopy, wet chemical analyses, REE content and others). The results of these studies will be published elsewhere.

Sample separation

In all the studied samples glauconies display dominantly granular facies, which enables a more accurate separation methodology and, subsequently, a more precise mineralogical investigation of them.

Principally, the procedure suggested by ODIN (1969) was performed (see also POP and BEDELEAN, 1996). The pure glauconitic loose A granulometric fractions (160—500 μm), magnetically separated and finally hand-picked, were submitted to further mineralogic investigations.

METHODS; NOMENCLATURE

The basic mineralogical data on glauconies were obtained using stereoscopic and polarizing microscopy, electron microscopy (SEM, TEM) and X-ray powder diffraction (XRD). Thus, the morphologic features of the green grains and the mineralogical aspects could be noted.

The study under binocular of loose A fractions evidenced the morphological types (as defined by TRIPLEHORN 1966 and completed by MCCONCHIE and LEWIS 1980), the colour and the surface features of the glauconitic grains. The internal structure (fabric) of the crystalline aggregates, following the same classifications as mentioned above, was studied in thin sections of the host-rock.

The SEM studies were carried out using a TESLA BS 340 unit, on gold-covered samples (Babeş-Bolyai University, Cluj-Napoca) and on uncovered samples, on a variable pressure HITACHI S-2360 unit (Eötvös L. University, Budapest).

Powdered glauconitic grains from the A magnetic fractions were examined using the TEM replica-method on a JEOL 100U device, at Eötvös L. University. As far as we know, this method is new for the description of the crystallites of the glauconitic minerals.

X-ray powder diffraction was used for identification of the glauconitic minerals and for the characterization of their ordering degree. The powder diffractograms of the magnetic loose fraction A of the samples were obtained on a SIEMENS D-500 unit with a Cu anticathode and graphite monochromator (Eötvös L. University, Budapest). The peaks were indexed as suggested by WARSHAW (WARSHAW 1957 in ODOM 1984).

Oriented samples of the clay fraction separated from the host-rock were studied by a DRON 3 *diffractometer* (*Cu anticathode, at* Babeş-Bolyai University, Cluj-Napoca) in order to evidence the possible relationship with the glauconitic grains (sensu BELL and GOODELL 1967).

We followed the main classification patterns proposed by BURST (1958), HOWER (1961) and BENTOR and KÄSTNER (1965, cf. ODOM 1984). The X-ray patterns were grouped according to the following criteria:

(1) ordered glauconite (glauconite s.s., glauconitic mica) — less than 10 % exp., 1M polytype, d(001) = 10.1 Å, d(003) = 3.3 Å represented by symmetric and sharp peaks;

(2) disordered glauconite (glauconitic mixtures) — 10—20 % exp., 1Md polytype, low intensity or absent 112, 112 peaks and d(001) after glycolation between 10.1—15 Å.

For a better distinction among the disordered glauconites, we used the suggestion of MCCONCHIE and LEWIS (1980), who separate two sub-species:

a) moderately disordered — X-ray diffraction pattern showing sometimes some peak asymmetry, and less than 40 % exp.;

b) extremely disordered glauconite — the same limit for the exp. content, but the X-ray diffraction pattern generally is showing pronounced peak asymmetry.

(3) interstratified glauconite-smectite (or interlayered glauconite, defined by MCCONCHIE and LEWIS 1980 with more than 40 % exp.) — in the AIPEA classification between 20—60 % exp., 1Md or <1Md polytypes, irregularly interstratified structure, and d(001) after glycolation between 10—17 Å.

The ordering degree (as a measure of the structural ordering of the interstratified illitic-and smectitic-type layers) was evaluated by comparing the intensities of 112, 003 and 112 peaks (BENTOR and KÄSTNER 1965, cf. ODIN 1975). The opening degree (suggesting the amount of exp.) was estimated using the shapes and ratios of the intensities of 001/003 peaks (ODIN 1975). The Ø opening index (as defined by ODIN 1975), depending on the intensity (mm), width (mm) and position (Å) of the 001 peak was also calculated.

CASE HISTORIES

CRETACEOUS GLAUCONIES

RÂŞNOV (BRAŞOV DISTRICT)

Geological data

The oldest glauconitic samples were collected from the profile on the Ghimbăşel Brook, near Râşnov, Braşov distr. (Table 1). They are hosted by the most deformed and lithified rocks under study, thus some diagenetic changes of the glauconies might be assumed.

Our study is the first focusing on the glauconitic facies in the area. Within the profile three lithological facies alternate: clayey limestones (which dominate the upper part of the profile), laminated clays and terrigenous limestones, which particularly host the glauconitic grains (*Fig. 2*). The terrigenous limestones intercalations (usually 0.5—3 cm thick) contain stratified levels of green grains concentrated in the basal part of the intercalation, where they constitute about 15—20 % of the rock (the average content is 5 %). The deposits are of Cenomanian–Coniacian(?) age (JEKELIUS 1938, Zărneşti map 1:50000).

In thin section the terrigenous limestones consist of two major petrographic types: packstone (biomicrite) with a siltic (subordinately arenitic) matrix and grainstone/ packstone (biosparite/biomicrite) with terrigenous, mainly arenitic content. Bioclasts, like planktonic foraminifera (Pithonella ovalis, Globotruncana sp., etc.), radiolarians, sponge spicules are abundant and suggest a basinal environment of sedimentation (200—400 m depth). The glauconitic grains are generally associated with the arenitic clasts (quartz, muscovite, biotite, feldspars) — sometimes forming laminated structures, which characterize the grainstones/packstones.

The mineral association of the clay fraction (Table 1) may characterize the external shelf (ANASTASIU 1988).

Glauconies morphology

Glauconies from Râşnov evidence the common granular habit. The grains are light green (the lightest shade among the grains under study) and display a porous, earthy surface. The main morphological types are listed in Table 2. Foraminifera moulds as substrates of glauconitization are the most characteristic feature of this occurrence (Pl. I–Fig. 1). The neoformation of glauconitic minerals affected the clay matrix which filled the fossil tests. The presence of the basinal species of foraminifera suggests an open sea paleoenvironmnet (GIRESSE et al. 1980). Morphological similarities with the recent glauconies forming in foraminiferal oozes on the south-eastern Atlantic shelf of United States (BELL and GOODELL 1967) can be noticed.

Organic inclusions (sponge spicules, radiolarians) or small detrital quartz grains caught in the glauconitic mass (Pl. I–Fig. 2) suggest that spheroidal-ovoidal grains might have had also agglutinated clays as substrates.

The TEM-replica images of sample GC 3A show lamellar xenomorphic crystallites, ranging between 0.3 to 0.7 μm. Sometimes the crystallites associate in poorly-developed rosettes; fan-like aspects are also noticeable. The irregular shape and the small sizes of the crystallites indicate a slightly evolved glauconitic mineral (Pl. V–Fig. 1).

Glauconies mineralogy

The diffractometric features (*Fig. 5*, Table 3) indicate extremely disordered glauconite, the less evolved glaucony under study.

Glauconies genesis

The clay mineral association, as well as the bioclasts included in the host-rock and the significant amount of foraminifera internal moulds as substrates of glauconitization suggest an external shelf, in which probably the neoformation of glauconitic minerals took place. The internal moulds of the microfossils confered the semi-restrictive microenvironment only until the dissolution of the thin tests of planktonic microorganisms. The open sea environment, geochemically less favourable for the glaucony formation, determined a slower evolution (slightly evolved to evolved stage). Diagenetic alterations might also be assumed.

As far as the genetic types of glauconies are concerned, the relative thick level in which glauconies occur and the lithological features (the rhythmic intercalations) indicate transport versus deeper waters, in a turbiditic facies. We assume that the Cretaceous green grains from Râşnov represent transported — probably perigenic (intrabasinal, intra-sequential) — sensu AMOROSI (1993a) glauconies.

SEBEŞEL (ALBA DISTRICT)

Geological data

The glauconitic samples belong to the Upper Cretaceous deposits (Table 1). The green grains are hosted by the basal part (Coniacian) of the Săsciori Beds (MARINCAŞ 1965), which represent a locally shallower facies developed in the south—south-eastern part of the region.

The outcrop in the Gorganu Hill (first mentioned by MAREŞ and TODIRITĂ-MIHĂILESCU 1970) preserved very badly, so that a profile is hard to sketch (*Fig. 2*). The basal part of the outcrop consists of coarser sandstones (poorly cemented, with quartzitic gravels) and silty sands (partly oxidized; containing green, altered biotite). Glauconitic grains first occur in the profile in form of nests and lenses or filling the bioturbations. In the subsequent strata they are distributed homogeneously in the rock. The glauconitic level, of 2.5 m thickness, contains about 70 % green grains (e.g. in sample GC 28). The glaucony concentration decreases towards the top of the outcrop.

In thin section the host-rock is represented by a sublithic sandstone with micritic, basal-type carbonate cement. The lithoclasts are represented mainly by carbonate and quartzitic rocks. Rare small hypidiomorphic pyrite crystals are present in some samples (e.g. GC 28). Quartz clasts are sometimes corroded by neoformed calcite.

The mineral association of the clay fraction is dominated by montmorillonite (Table 1).

Glauconies morphology

Table 2 shows the morphological characteristics of the glauconitic grains.

In thin section, the most remarkable are the vermicular grains (10 %), with linear or curved shapes, and micaceous fabrics (Pl. I–Figs. 3–4). Signs of various degrees of oxidation of the glauconitic grains are present, but not generalized; the most susceptible seem to have been the vermicular glauconies, in which films of iron oxi-hydroxides develop along the cleavages (Pl. I–Fig. 3).

Uncovered samples of the vermicular grains were studied in a variable pressure SEM (Pl. III–Figs. 1–2). The micaceous cleavages are still visible; the glauconitic minerals develop as new, authigenic phases between the cleavage planes (Pl. III–Fig. 3), which act as favourable semi-restrictive microenvironments (ODIN 1972). Patches of neoformed crystallites develop in quasi-parallel laminae, oblique to the relic micaceous phase (Pl. IV–Figs. 1–2). Another SEM image (Pl. IV–Fig. 3) shows a microfossil mould which was glauconitized and caught in a glauconitic mass.

TEM-replica images show crystallites of the size similar to those of the Râşnov samples (0.2–1.5 µm) but the lamellae are thicker and more irregular in shape; the margins are curved and folded (Pl. V–Fig. 2). The association of crystallites sometimes resembles dendritic aggregates; the individual lamellae develop quasi-parallel or fan-like (Pl. V–Fig. 3). Some granular structures might indicate mineral impurities inside the glauconitic grains. The general features show a slightly evolved to evolved glaucony.

Glauconies mineralogy

XRD studies (*Fig. 5*) indicate disordered glauconite, respectivelly a moderately disordered sub-species. The glauconitization surpassed the slightly evolved stage and reached the evolved maturity degree (Table 3).

Glauconies genesis

The general lithological context indicates a shallow water paleoenvironment, in which an increased alkalinity was registered.

The mechanism of biotite–chlorite–glauconite transformation is possible to have been more extended than it might be proved by the presence of vermicular grains (about 10 % of the glauconies), thus signifying a tectonically active continental margin (FISCHER 1987).

The fragile morphologies of the abundant lobate and mammillated glauconitic grains plead for an authigenic origin (TRIPLEHORN 1966), but a local transport towards deeper waters can not be excluded (perigenic origin), as proved by the significant amount of smectite with a high crystallinity in the clay association (BELL and GOODELL 1967). The lack of a representative outcrop does not allow a more detailed interpretation.

EOCENE GLAUCONIES

The Eocene of the Transylvanian Depression provides one of the most complex case of glaucony formation: the diversity of stratigraphic levels and geographic repartition of the occurrences is still a "puzzle" which needs further investigations.

The richest and most extended glaucony-bearing levels are the Sokolowia eszterhazyi and Nummulites perforatus ones. They are included in the Căpuşu Formation (Upper Lutetian, RUSU 1987, Terminal Lutetian—Bartonian, RUSU 1995). At the S. eszterhazyi level glauconies indicate a deeper paleoenvironment, as compared to the north-westwards one in which some oolitic ironstones formed (VINOGRADOV et al. 1963, STOICOVICI and MUREŞAN 1964, POPESCU et al. 1978), as a result of a progressive transgression of the Medium Eocene sea.

LUNA DE SUS (CLUJ DISTRICT)

Geological data

In the profile at Dâmbu Rotund Hill (first described by MAREŞ and TĂTĂRÎM 1967) glauconies were collected from both S. eszterhazyi and N. perforatus (the basal N. striatus lumachell) levels.

The deposits consist of intercalations of limestones with massive clays (*Fig. 3*). Sample GE 2 is hosted by a clayey silt (about 10 % green grains) with rare Sokolowia shells and GE 3 by a bioclastic packstone with a microsparitic cement, displaying frequent bioturbations and containing N. striatus, lamellibranchiate debris and algae (about 15—20 % green grains) (Table 1). The profile ends with nummulitic limestone interbedded with clays.

The mineral association in the clay fraction is presented in Table 1.

Glauconies morphology

These samples contain the darkest glauconitic grains under study (Table 2); their morphology and colour suggest favourable paleoenvironmental conditions.

In thin section, about 20 % of the glauconitic grains in sample GE 3 are broken and display fragmentary morphologies.

Light yellowish-green glauconitic(?) films formed inside the chambers of some microfossil tests (Pl. II–Figs. 1–2), probably substituting an argillaceous substrate. In some cases granular glauconies were transported inside broken organic tests, before the diagenetic cement crystallized (Pl. II–Fig. 3).

SEM studies on covered samples (POP and BEDELEAN, 1996) indicate that faecal pellets could provide, at least partially, the substrates for the spheroidal-ovoidal grains. Meanwhile, organic debris (echinoderms?) could supply the substrates of the tabular-discoidal grains (e.g. sample GE 3A). The shape, size and types of aggregates of crystallites reflect mainly the slightly evolved and evolved stages of glauconitization.

In TEM-replica images the crystallites are the largest in size (0.3–2.5 μm) among the samples studied. They are represented by xenomorphic, thin curved lamellae, with a "compact" distribution (sample GE 3A). The lamellae form quasi-parallel alignments which develop in larger fan-like aggregates (Pl. VI–Fig. 3). The general aspect is a rosette-like structure which indicates, together with the size of the crystallites, a highly evolved stage reached in the process of neoformation by the Eocene glauconies.

Glauconies mineralogy

The X-ray powder patterns indicate more closed, micaceous structures than the previous ones (*Fig. 5*, Table 3); in spite of that, the glauconitic minerals seem to have a reduced ordering degree. The samples are ordered glauconites, the most evolved green grains under study (highly evolved glauconies).

Glauconies genesis

The peculiar features of this occurrence are the presence of two distinctive host-rocks for the glauconies and the association of the green grains with the green films inside the foraminifera tests. The clay mineral association in sample GE 3, together with the dark green glauconies resemble the recent mollusc shell gravels cemented by carbonate in which evolved glauconies formed on the south-eastern Atlantic shelf of United States (BELL and GOODELL 1967).

The similitudes between the well crystallized illite and the highly evolved glauconies and the horizontal constance of the morphologies and mineralogical species on extended areas (AMOROSI 1993b) suggest an authigenic origin of the Eocene glauconies, especially at the S. eszterhazyi level (samples GE 2, GE 5). The paleoenvironment of formation must have been an open sea (shelf domain).

A possible transport due to paleocurrents might be responsible for the agglomeration of the microfossils and glauconitic grains in more protected areas, with reduced sedimentation rates, where both the granular glauconies and the pellicular ones could evolve. In this way, a perigenic (intrabasinal, intrasequential) origin — particularly in the case of N. perforatus level (GE 3) cannot be excluded, as suggested by the fragmentary grains and the clusters of bioclasts and glauconitic grains.

The shallower facies of the oolitic ironstones and the high degree of maturity of the glauconitic grains may indicate the presence of a paleodelta of a large Eocene river, which contributed with important terrigenous iron supply. Some changes of the sea level, eustatically or tectonically- controlled, can also be assumed.

ORTELEC (SĂLAJ DISTRICT)

Geological data

The stratigraphy of the outcrop in Răpaosului Valley was described by RUSU (1967, 1987), who also mentioned the presence of glaucony. The lithologic sequence consists of: fluvial/coastal plain varriegated clays, yellowish-greyish limestone, evaporitic breccia, condensed rhythmic intercalations of clay and carbonate deposits with Anomya –

suggesting a very reduced terrigenous supply (*Fig. 3*). Detrital glauconitic deposits and nummulitic lumachelles end the succession. The general trend is of shallowing-upward.

The green grains are concentrated on the stratification planes or form lenticular nests in a poorly consolidated silty clay, with rare fragments of S. eszterhazyi (Table 1).

The clay fraction mineral association shows a lower crystallinity, as compared to the Luna de Sus samples.

Glauconies morphology

The green grains from Ortelec show similar morphologies as compared with those from Luna de Sus (Table 2).

About 5–10 % of the glauconies consist of composite grains, usually containing quartz inclusions and displaying patch-oriented microcrystalline fabrics, which suggest an inhomogeneous substrate (McCONCHIE and LEWIS 1980).

A generalized oxidation affected both the clayey matrix of the rock and the glauconitic grains. The substitution is progressive, and several steps are visible. The complete substitution of about 10–20 % of the glauconitic grains led to the formation of goethite peloids.

Glauconies mineralogy

An ordered glauconite (*Fig. 5*, Table 3) with a relative higher amount of exp. layers, as compared with Luna de Sus samples was evidenced in the XRD pattern. The evolutionary stage is highly evolved glaucony.

Glauconies genesis

The similarities of the morphologies and the size of the green grains, as well as the common clay mineral association at Luna de Sus and Ortelec indicate the maintenance of similar micro- and paleoenvironments during the Upper Lutetian. The changes of the sea level might be responsible for the subsequent oxidation (RIGGS et al. 1989); meanwhile, the oolitic ironstone level is missing in the north-western area of the Transylvanian Depression.

The lithological and mineralogical features of the other Eocene occurence indicate an authigenic origin for the glauconies included in the Căpuşu Formation. The accumulation of the green grains in lenses or nests may be the result of intrabasinal transport, thus a perigenic origin may also be assumed.

OLIGOCENE GLAUCONIES

VAR (SĂLAJ DISTRICT)

Geological data

The glauconies are hosted by the shallow marine (littoral to internal shelf) deposits of the Var Sandstone (Upper Rupelian–Chattian, RUSU 1977, RUSU et al. 1978). In the basal part, a normal marine level with Cyprinids, representing the NP25 zone is worth to mention (N. MÉSZÁROS, personal communication).

The outcrop in village Var contains the Ileanda Beds shales, followed by the basal part of the Var Sandstone, consisting of a yellowish clayey silt (*Fig. 4*). The green grains form lenses, nodules (in some cases surrounding quartz clasts) or laminae, or they fill the frequent horizontal and oblique bioturbations. Iron oxi-hydroxides are frequent.

The clay fraction consists of an uncommon association of kaolinite with smectite, and subordinate illite (Table 1), all showing high crystallinity. The presence of kaolinite in the basal part of the Var Sandstone must be connected with the quartzitic-kaolinitic sands which occur in significant amounts towards the top of the unit.

Glauconies morphology

Morphologic similarities with the Eocene glauconies are listed in Table 2. The particular features are represented by the relatively frequent fragmentary grains (about 40 %) and by the dissolution(?) pits at the surface of the green grains – as a result of a chemical attack of a more acidic environment.

In thin section, a hydrodinamic sorting of the whole sediment is noticeable: the spheroidal-ovoidal grains are hosted by the coarser, arenitic clasts, while the small, fragmentary or spheriodal grains (below 50 μm) grouped in the finer, silty fraction.

The crystallites, as shown in the TEM-replica images are very similar with those which form the Cretaceous glauconies from Sebeşel. The xenomorphic lamellae are thick, curved and folded (Pl. VI–Fig. 1). Their sizes range between 0.2–1 μm. The aggregates are poorly developed. Some granular structures are also visible. The low crystallinity and the small size of the lamellae suggest a slightly evolved glauconitic mineral.

Glauconies mineralogy

The X-ray diffraction pattern indicates an opened structure, with low structural ordering degree (*Fig. 5*, Table 3), thus an extremely disordered glauconite. The stage of glauconitization is slightly evolved to evolved.

Glauconies genesis

The case of the Oligocene glauconies is the most complex one.

The significant amount of well crystallized kaolinite in in the clay fraction, the rests of a brackish fauna and the presence of coal in the upper part of the Var Sandstone indicate an internal shelf environment, possibly placed near a river-mouth. The paleoenvironment seems to have been very unfavourable for the authigenic glaucony formation. Meanwhile, the well-sorted clayey silt indicates a post-depositional size sorting which affected also the glauconitic grains. All these features contribute in assigning an allochtonous (perigenic/detrital) origin to the Oligocene glauconies.

Morphological similitudes with the Eocene glauconies, as well as the less evolved stage of maturity, which could signify a possible re-working and chemical depletion in K and Fe, could indicate an Eocene glauconitic level as the source of the green grains. In this case, the Oligocene glauconies would be detrital (intrabasinal, extrasequential). Meanwhile, the presence of a normal marine environment in the basal part of the Var Sandstone could be a possible argument for a perigenic (intrabasinal, intrasequential) origin. Further study is still requested.

MIOCENE GLAUCONIES

The most extended glauconitic level in the Transylvanian Depression was formed in the Lower Miocene (Eggenburgian) (MÉSZÁROS et al. 1978). It represents the basal part of the Chechiş Beds and signifies a well defined transgression stage on the whole north-western border of the depression.

From tectonic point of view, the Chechiş Beds overlap the Meseş thrust (Table 1), which was the first signal in Romania of the north-eastwards tectonic escape of the North-Pannonian block (BALINTONI 1996, in press).

TIHĂU (SĂLAJ DISTR.)

Geological data

The Cornul Corbilor Hill, near Tihău, Sălaj distr. is one of the best outcrops of the Eggenburgian glauconitic level (RUSU 1977). The profile (*Fig. 4*) starts with a littoral facies, the Coruş Beds: massive fossiliferous conglomerates and sandstones with Pectinids, displaying trough cross beddings (TCB) and ripple marks. A gravel-containing clay with dominant quartz (GM 1) forms the border between the Coruş and Chechiş Beds. The subsequent glauconitic level (about 3.5 m thick) consists of a heterogeneous, poorly sorted glauconitic silty sand. Quartz clasts are abundant in argillaceous matrix (GM 2); bioturbations are present. The upper part of the level is partially laminated (GM 7) (Table 1).

In some thin sections (e.g. GM 2, GM 7) iron oxi-hydroxides are frequent in the matrix of the rock, but they also occur as inclusions in the glauconitic grains. Their granular and quasi-rhombohedral shape may refer to pseudomorphs after siderite(?) or marcasite(?) (Pl. I–Fig. 6). Heavy minerals (titanite, magnetite) occur rarely.

The clay fraction mineralogy is dominated by montmorillonite and illite (Table 1).

Glauconies morphology

The Miocene glauconies are light green and, as in the case of the Cretaceous glauconies from Râşnov, their surface is mat and porous. Spongy morphologic type dominates (Table 2).

In thin section heterogeneous morphologies and internal fabrics are visible (POP and BEDELEAN, 1996). Granular facies is dominant, but also the film habit is present. In a few cases organic substrates (e.g. relic mollusc) may be assumed. They are included in the glauconitic mass, or affected partially by "verdissement" (e.g. sample GM 11 from Baica, Sălaj distr.; Pl. I–Fig. 5). The internal fabric is, in this case, the "zebra" type.

Green films inside quartzitic clasts were evidenced in thin sections of the loose fraction larger than 500 μm; the internal structure is random microcrystalline or oriented (Pl. II–Figs. 4–6). Due to optical similitudes, we assume a glauconitic nature of the green film. Some other mineral grains (feldspars) were also partially glauconitized.

SEM images on covered samples evidence mostly spheriodal-ovoidal morphologies. A microscopic "friction lens" and parallel scratches suggest mechanic impact during a possible transport (POP and BEDELEAN, 1996).

In TEM-replica images (sample GM 2A) the size and the mode of association of crystallites are similar to those of the Eocene glauconies (sample GE 3A). Quasi-parallel aggregates are visible, but also poorly developed dendritic associations of crystallites were noticed. The crystallites are xenomorphic lamellae, 0.4–2.5 μm in size; they are thicker than the Eocene ones, and more irregular in shape (Pl. VI–Fig. 2). An intermediate stage of neoformation between the slightly evolved glauconies (GC 3A, GO 1A) and highly evolved ones (GE 3A) is suggested.

Glauconies mineralogy

Differences in the XRD patterns of samples GM 2A and GM 7A indicate that the two samples are of very similar, but still not of the same structure (*Fig. 5*, Table 3).

GM 2A represents an intermediate case between ordered and disordered glauconites; due to the strictness of classification, we included GM 2A at the ordered glauconites. It represents an intermediate stage between the evolved and highly evolved glauconies.

GM 7A has a more opened structure, with more interstratified exp. layers. The mineral sub-species is moderately disordered glauconite. From the point of view of the glauconitization process, it is an evolved glaucony.

Glauconies genesis

Several controversal features meet in the reconstruction of the Miocene paleoenvironment of glaucony formation. The horizontal uniformity of the glaucony-containing basal part of the Chechiş Beds, pleads for a certain maintenance of a favourable paleoenvironment. Moreover the "verdissement" process, which finally led to the formation of glauconies was generalized, having affected all the possible types of substrates (mineral debris, organic fragments, clay aggregates etc.). Under these constant circumstances distinctive mineralogical types of evolved glauconites formed: in the basal part more closed structures, representing a transition from the ordered to the disordered glauconites (sample GM 2A) and more opened, disordered glauconites at the top of the glauconitic level. A mineralogical heterogenity within the same stratigraphic level (ODOM 1984) cannot be excluded either. The predominance of the spongy morphologic type suggests important diagenetic contribution.

Alternating geochemical environments led to the formation of siderite(?) or marcasite(?) followed by the substitution with iron oxi-hydroxides. The glauconitization process could benefit of an important iron supply resulting from these changes of Eh conditions.

The sedimentary sequence is connected with an important transgressive event.

A perigenic (intrabasinal, intrasequential) origin for the Miocene glauconies is assumed.

CONCLUSIONS

In our study the Cretaceous glauconies near Râşnov (Braşov distr.), the Eocene ones from Ortelec (Sălaj distr.), the Oligocene occurrence from Var (Sălaj distr.) and the Miocene level (mainly the outcrop near Tihău, Sălaj distr.) were studied for the first time from a mineralogical-genetical point of view.

Generally, classical TEM images on the less than 2 µm fraction of the glauconitic minerals were rarely provided by specialized papers (BURST 1958). The TEM-replica method was applied now for the first time – as far as we know – for the description of the morphology of the glauconitic crystallites. Thus, the interpretation of the images is informative and constitues a possible starting point for further studies.

New interpretations on the mineralogy of the Eocene and Miocene samples are presented (see POP and BEDELEAN, 1996), due to more accurate investigations and to the possibility of comparison between several mineralogical species of glauconies.

The values of the Ø opening index calculated by ODIN (1975) on XRD patterns range between 1.5 (for opened, disordered structures) and 7.5 (for closed, ordered structures); in our case, values between 3.72 and 10.1 were obtained. We assumed the same structural signification, e.g. the highest the value is the more closed and ordered the structure is, when defining the mineralogical characteristics.

Finally, the lithological and sedimentological data, as well as the informations supplied by the morphological and mineralogical study of the glauconitic grains allowed us to discuss some of the genetical features of each occurrence.

ACKNOWLEDGEMENT

We are grateful to Dr. Tamás G. WEISZBURG from Eötvös L. University in Budapest for very useful discussions, as well as for the detailed revising of the manuscript. Several colleagues from the Babeş-Bolyai University in Cluj contributed to the interpretation of the analyses: Prof. L. GHERGARI, Prof. I. BUCUR, Lecturer A. HOSU, or provided helpful discussions: Prof. L. GHERGARI, Prof. I. BALINTONI, Lecturer A. HOSU – who also reviewed the manuscript. We thank P. RĂCĂTOIANU for the photos on thin sections and M. GUZU for revising the English version of the manuscript. We express our thanks to Dr. GY. A. LOVAS and to Prof. I. GYURJÁN and Dr. Z. KRISTÓF, Eötvös L. University for the access to XRD resp. variable pressure SEM investigations, as well as to Ms. L. RUDNYÁNSZKY for the TEM-replica photos and to R. ZEMPLÉN for her support in performing the analyses.

The analytical work was supported by the Departments of Mineralogy at Babeş-Bolyai University (Cluj-Napoca) and Eötvös L. University (Budapest), in the latter case (XRD, SEM and TEM investigations) under the auspices of the Agreement of Understanding between the two Universities and the generous help of Dr. GY. BUDA, Head of Department.

One of the authors (DP) was sponsored by the interuniversity scientific exchange programme of the Babeş-Bolyai and the Eötvös L. Universities.

We thank all the Romanian and Hungarian friends who contributed in creating a stimulating and co-operative atmosphere.

REFERENCES

AMOROSI, A. (1993a): Use of glauconies for stratigraphic correlatios: review and case histories. Giornale di Geologia, ser. 3. **55/1**, 117-138.

AMOROSI, A. (1993b): Intérêt des niveaux glauconieux et volcano-sédimentaires en stratigraphie: exemple de dépôts de bassins tectoniques miocènes des Apennins et comparision avec quelques dépôts de plate-forme stable. Thèse Doct., Univ. P. et M. Curie Paris. Mémoires Sciences de la Terre. **93/12**, 194.

ANASTASIU, A. (1988): Petrologie sedimentară. Ed. Tehn., Bucureşti, 365.

BAILEY, S. W. (1980): Summary of recommendations of AIPEA Nomenclature Committee. Clays and Clay Minerals. **28/1**, 73-79.

BALINTONI, I. (1994): Once again about tectonic problems of the Crystalline Mesozoic Zone of the South Carpathians, around Braşov Curvature. Studia. **1-2** (in press).

BALINTONI, I. (1996): Transilvania — depresiune şi bazine. Sesiunea de Comunicări a cadrelor didactice şi studenţilor, Facultatea de Biologie şi Geologie, Universitatea Babeş-Bolyai, Cluj, 17—18 mai, 1996 (in press).

BELL, D. L., GOODELL, H. G. (1967): A comparative study of glauconite and the associated clay fraction in modern marine sediments. Sedimentology. **9**, 169-202.

BIELZ, E. A. (1889): Die Gesteine Siebenbürgens. Eine Systematische Aufzählung der in diesen Lande vorkommenden Mineralien und Fels arten mit ihren Fundorten und ihrem Vorkommen. II Auflage. Separatbuch. Buchdruckerei der G. von Closius, Hermannstadt, 82.

BURST, J. F. (1958): Mineral heterogenity in glauconite pellets. American Mineralogist. **43/5-6**, 481-497.

FISCHER, H. (1987): Excess K-Ar ages of glauconite from the Upper Marine Molasse and evidence for glauconitization of mica. Geologische Rundschau. **76/3**, 885-902.

GIRESSE, P., LAMBOY, M., ODIN, S. (1980): Évolution géométrique des supports de glauconitisation; application à la réconstitution du paléoenvironnement. Oceanologica Acta. **3/2**, 251-260.

HAUER, F., STACHE, G. (1863): Geologie Siebenbürgens. Ed. W. Braumüller, Wien, 636.

HOFMANN, K. (1879): Bericht über die im östlichen Theile des Szilágyer Comitates während der Sommer-campagne 1878 vollfürten geologischen Specialaufnahmen. Földtani Közlöny. **IX/5-6**, 231-283.

HOWER, J.(1961): Some factors concerning the nature and origin of glauconite. American Mineralogist. **46/3-4**, 313-334.

JEKELIUS, E. A. (1938): Das Gebirge von Braşov. Anuarul I.G.R. **XIX**, 379-408.

KOCH, A. (1883): Bericht über die Klausenburger Randgebirge und in dessen Nachbarschaft im Sommer 1882 ausgeführte geologische Special-Aufnahme.Földtani Közlöny. **13**, 117-140.

KOCH, A. (1900): Die Tertiärbildungen des Beckens des siebenbürgischen Landestheile. II. Neogene Abtheilung. Druck des Franklin Vereins. Budapest. 369.

MAREŞ, I., TĂTĂRÎM, N. (1967): Studiul glauconitului din depozitele eocene din regiunea Cluj (Luna de Sus–Lita). Analele Univ. Buc. Geol, Geogr. **16/2**, 25-48.

MAREŞ, I., TODIRIŢĂ-MIHĂILESCU, V. (1970): Asupra prezenţei glauconitului în depozitele neocretacice din regiunea Sebeşel–Săsciori. Analele Univ. Buc. Geol., Geogr. **19**, 61-68.

MARINCAŞ, V. (1965): Studii geologice în regiunea Sebeş–Cîlnic–Săsciori–Răchita–Pianu de Sus–Cioara, cu privire specială asupra stratigrafiei depozitelor cretacice. Teză de doctorat. Univ. Babeş-Bolyai, Cluj. 323.

MCCONCHIE, D. M., LEWIS, D. W. (1980): Varieties of glauconite in late Cretaceous and early Tertiary rocks of the South Island of New Zealand, and new proposals for classification. Journal of Geology and Geophysics. **23/4**, 413-438.

MÉSZÁROS, N., IANOLIU, C., PION, N. (1978): Nannoplanctonul stratelor de Chechiş şi paralelizarea lor cu depozite similare ca vîrstă din Carpaţii Orientali. Anuarul Muzeului de Ştiinţele Naturii Piatra Neamţ, 3, 213-218.

ODIN, G. S. (1969): Méthode de séparation des grains de glauconie. Intérêt de leur étude morphologique et structurale. Révue de Géographie Physique, Géologie Dynamique **11/2**, 171-176.

ODIN, G. S. (1972): Obsérvations nouvelles sur la structure de la glauconie en accordeon ("vermicular pellets"); déscription du processus de génese de ces granules par néoformation. Sedimentology. **19**, 285-294.

ODIN, G. S. (1975): De glauconarium: constitutione, origine, aetateque. Thèse, Univ. P. et M. Curie, Paris. 280.

ODIN, G. S., LÉTOLLE, R. (1978): Les glauconies et aspects voisins ou confondus; signification sédimentologique. Bulletin de la Societé géologique Française **20/4**, 553-558.

ODIN, G. S., MATTER, A. (1981): De glauconarium origine. Sedimentology. **28**, 611-641.

ODOM, E. I. (1984): Glauconite and celadonite minerals. In: S. W. BAILEY (Editor): Micas. Reviews in Mineralogy. **13**, 545-572.

POP, D., BEDELEAN, I. (1996): Glauconites from the Transylvania Basin: New Mineralogical Data. Romanian Journal of Mineralogy. 78 (in press).

POPESCU, B., BOMBIŢĂ, G. RUSU, A., IVA, M., GHEŢA, N., OLTEANU, R., POPESCU, D., TĂUTU, E. (1978): The Eocene of the Cluj—Huedin Area. Dări de Seamă, IV. **64/4**, 295-358.

RIGGS, S. R., SNYDER, S. W. O'BRIEN, W. G., COOK, P. J., HEGGIE D. T. (1989): Sedimentology of the Neogene to modern glauconite–goethite–phosphate system: East Australian continental margin between 29° and 32° south latitude. Sciences Géologiques. Bulletin. **42/3**, 186-204.

RUSU, A. (1967): Studiul geologic al regiunii Moigrad (nord-vestul bazinului Transilvaniei). Dări de Seamă Com. Stat Geol. **53/1**, 427-455.

RUSU, A. (1977): Stratigrafia depozitelor oligocene din nord-vestul Transilvaniei (regiunea Tresnea–Hida–Poiana Blenchii). Anuarul I.G.G. **51**, 69-224.

RUSU, A. (1987): Ostreina biohorizons in the Eocene of the NW Transylvania (Romania). In: I. PETRESCU (Editor-in-chief): The Eocene from the Transylvania Basin. University of Cluj-Napoca. 175-182.

RUSU, A. (1995): Eocene formations in the Călata region (NW Transylvania): a critical review. Romanian Journal of Tectonics and Regional Geology. **76**, 59-72.

RUSU, A., POPESCU, A., RĂDAN, S., GHEORGHIAN, M., IVA M., POPESCU G., CIOFLICA, G. OLTEANU, R., GHEŢA, N., JIPA, D. (1978): Studiul lito-biostratigrafic al forajului 34601 de la Zimbor (NW-ul Transilvaniei). Dări de Seamă I.G.G. **LXIV/4**, 359-376.

SĂNDULESCU, M. (1975): Essai de synthèse structurale des Carpathes. Bulletin de la Societé géologique de France, 7 ser., **XVII/3**, 299-358.

STOICOVICI, E., MUREŞAN, I. (1964): Studiul zăcămîntului de limonit oolitic şi de glauconit din formaţiunile eocene ale Bazinului Transilvaniei (1, 2). Studia Univ. Babeş-Bolyai, ser. Geol., Geogr. **1**, **2**, 7-16, 17-29.

ŞURARU, N. (1967): Beiträge zur Kenntnis des Burdigals im nord-westlichen Teil des Siebenbürger Beckens zwischen Cluj und Surduc (Rumänien). Neues Jahrbuch für Geologie und Paläontologie. Mhf. **8**, 489-497.

TRIPLEHORN, D. M. (1966): Morphology, internal structure and origin of glauconite pellets. Sedimentology. **6**, 247-266.

VINOGRADOV, C., BARBU, I. Z., HESSELMAN, A. (1963): Contribuţii la cunoaşterea zăcămîntului sedimentar de fier de la Căpuş (reg. Cluj). Studii şi Cercetări de Geologie. **VIII/2**, 235-252.

* * * (1972) : Harta geologică 1:50.000 , foaia Zărneşti (110b). Institutul Geologic Bucureşti.

Manuscript received 6. Sep. 1996.

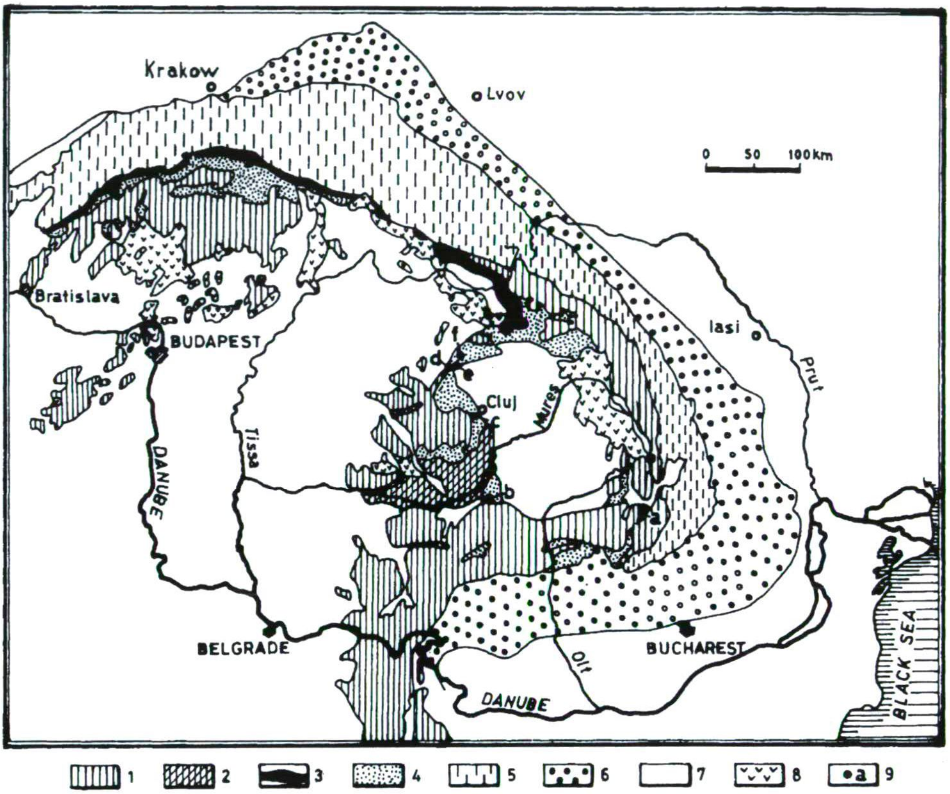


Fig. 1. The main structural units in the Carpathian area (1 - 8) (after SĂNDULESCU 1975, with modifications) and the glauconitic occurrences under study (a - f).

Legend: 1 - Dacides; 2 - Transylvanides; 3 - Pienides; 4 - Post-tectonic covers; 5 - Moldavides; 6 - Foreland basin; 7 - Depressions; 8 - Neogene volcanics; 9 - Glauconitic occurrences: a - Râşnov (Braşov distr.); b - Sebeşel (Alba distr.); c - Luna de Sus (Cluj distr.); d - Ortelec (Sălaj distr.); e - Var (Sălaj distr.); f - Tihău (Sălaj distr.).

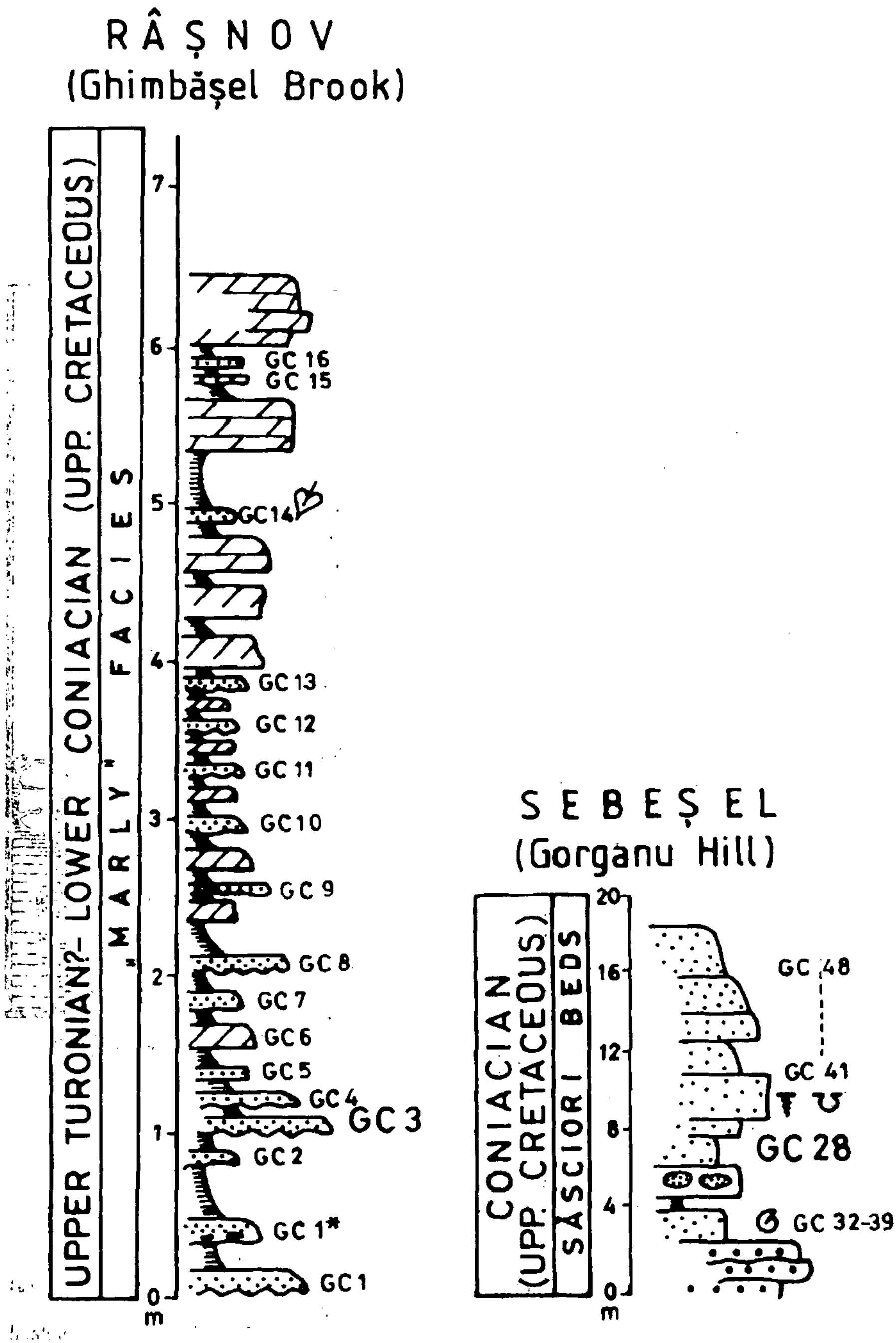


Fig. 2. The profiles of the Cretaceous outcrops from Râşnov and Sebeşel (see explanations in the text).

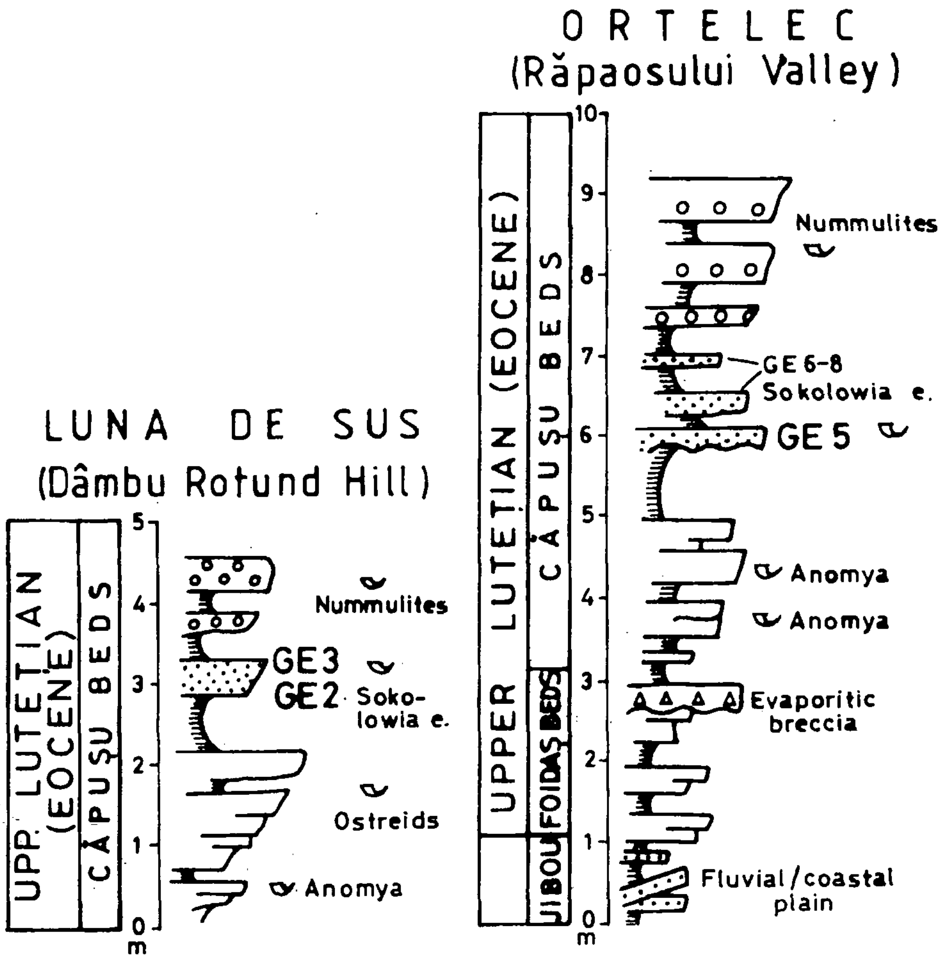


Fig. 3. The profiles of the Eocene outcrops from Luna de Sus and Ortelec (see explanations in the text).

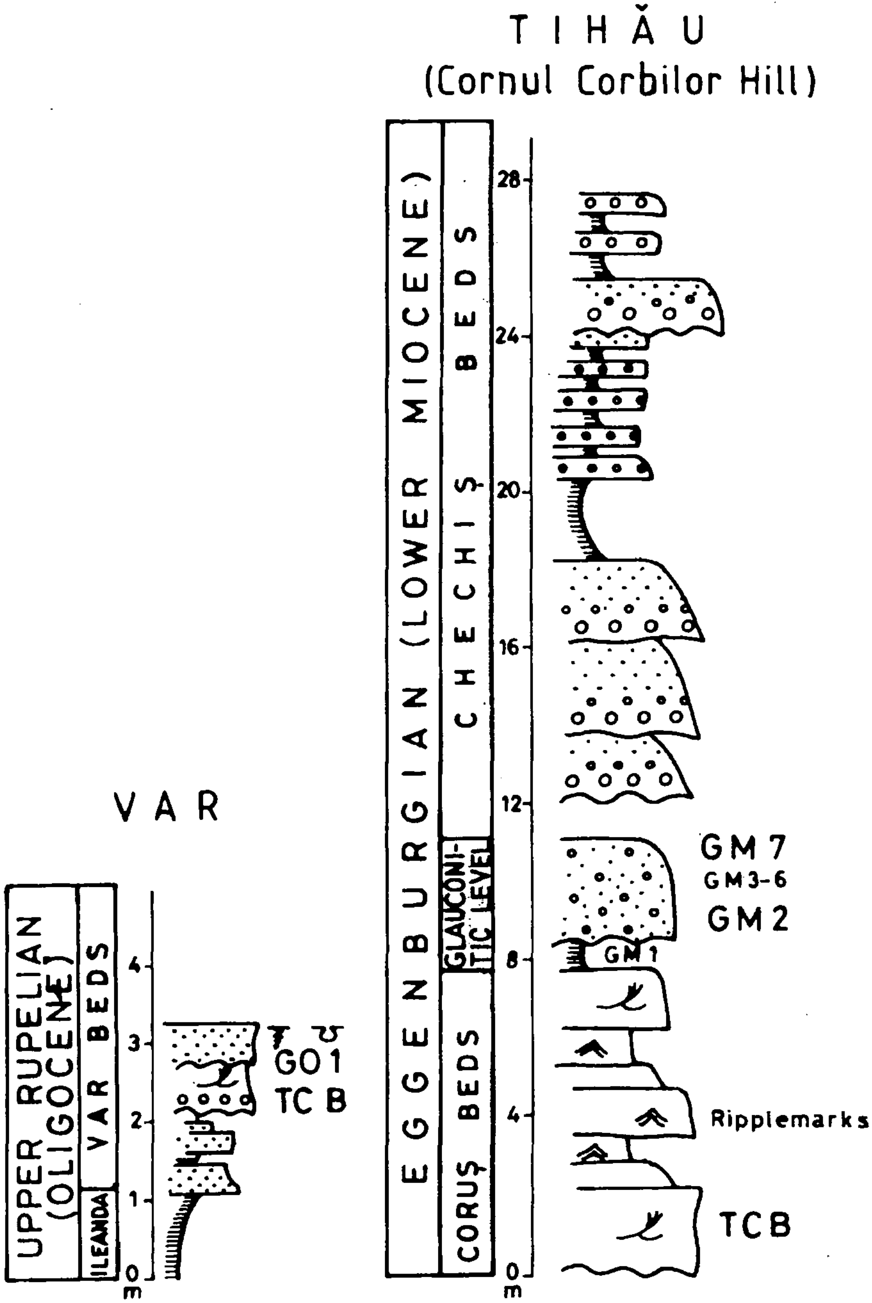


Fig. 4. The profiles of the Oligocene (Var) and Miocene (Tihău) outcrops (see explanations in the text; TCB - trough cross beddings).

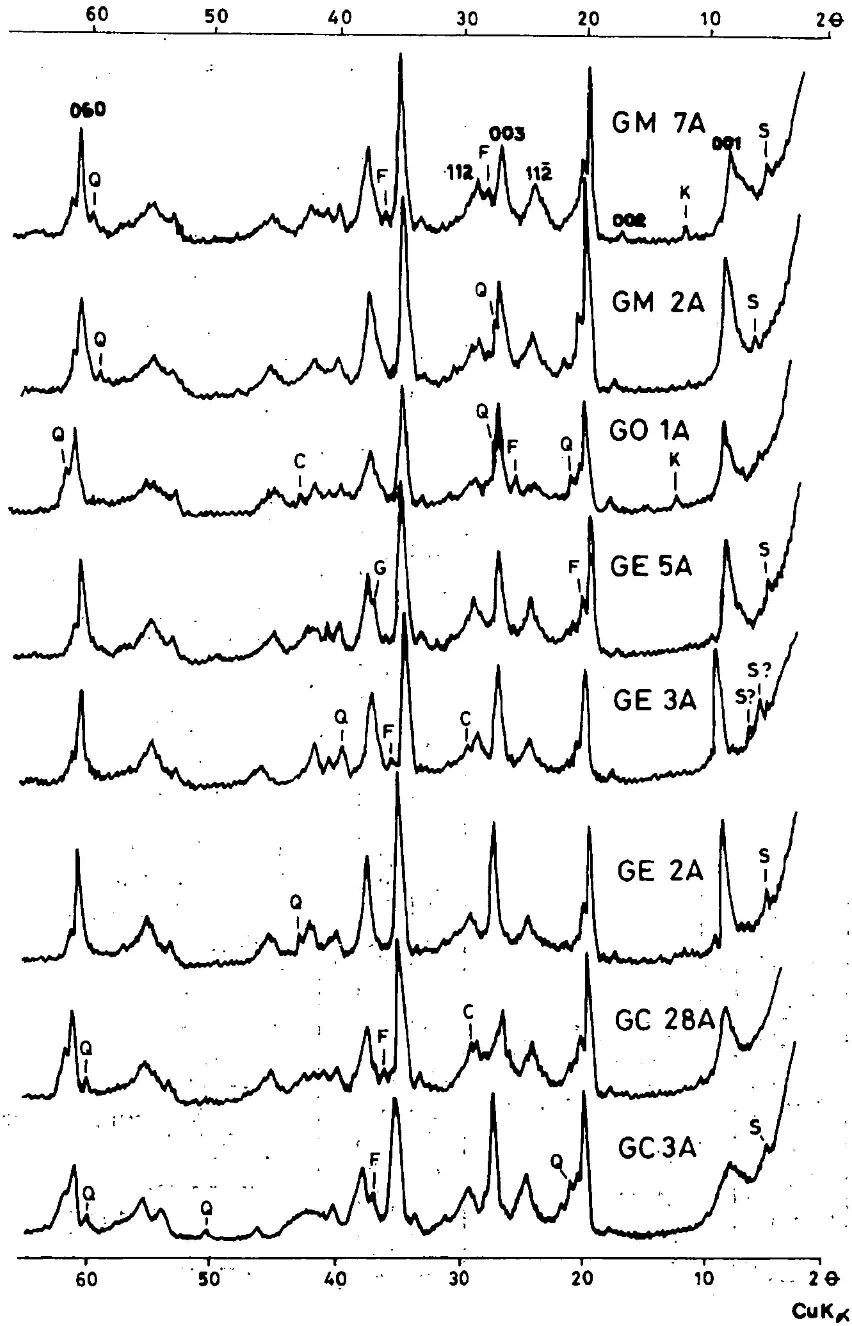


Fig. 5. X-ray powder diffractograms of the reference glauconite samples under study.
Legend: Q - quartz; F - feldspars; K - kaolinite; C - calcite; S - smectite.

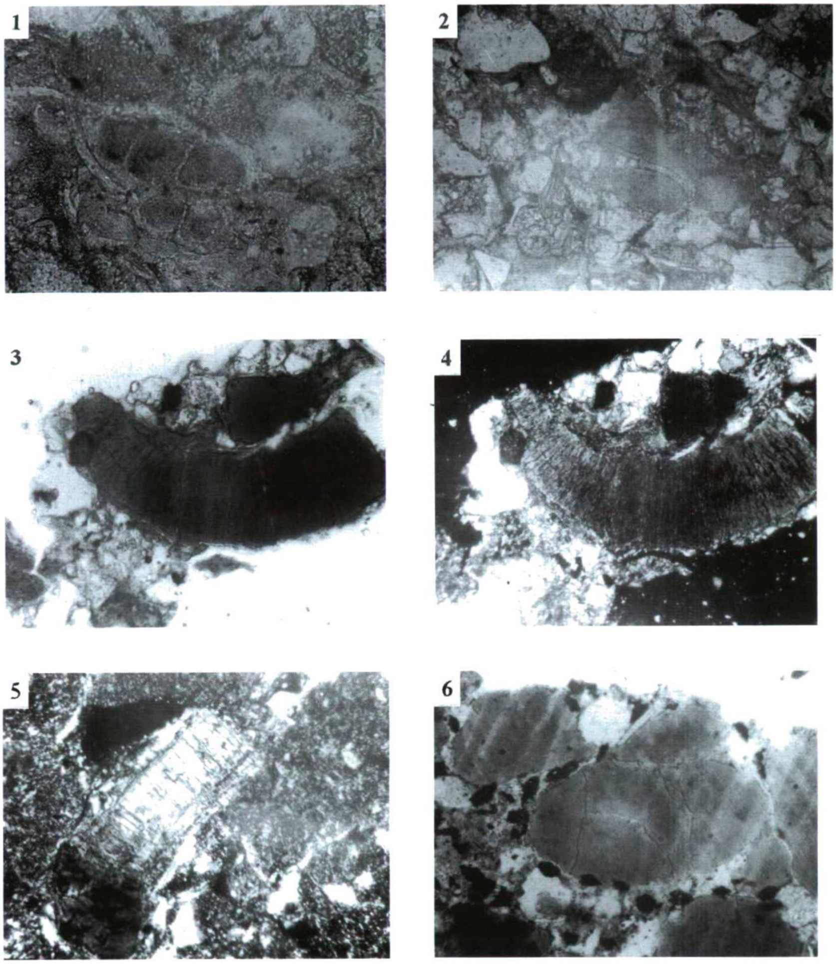


PLATE I

Pl. I–Fig. 1. Microfossil internal mould filled with glaucony (GC 11, Râşnov, 1N, x 190)

Pl. I–Fig. 2. Bioclast included in an ovoidal glauconitic grain (GC 11, Râşnov, 1N, x 100).

Pl. I–Fig. 3. Curved vermicular glauconitic grain; iron oxi-hydroxides develop on the micaceous cleavages and glauconitic cortex surrounds the grain (GC 27, Sebeşel, 1N, x 100).

Pl. I–Fig. 4. idem; micaceous microcrystalline internal fabric (N+).

Pl. I–Fig. 5. "Zebra" internal structure of a glauconitized mollusc relic(?) (GM 11, Baica, Chechiş Beds, N+, x 100).

Pl. I–Fig. 6. Iron oxi-hydroxides pseudomorphs after siderite(?) or marcasite(?) in the matrix of the rock and partially included in spheriodal-ovoidal glauconitic grains (GM 2, Tihău, 1N, x 100).

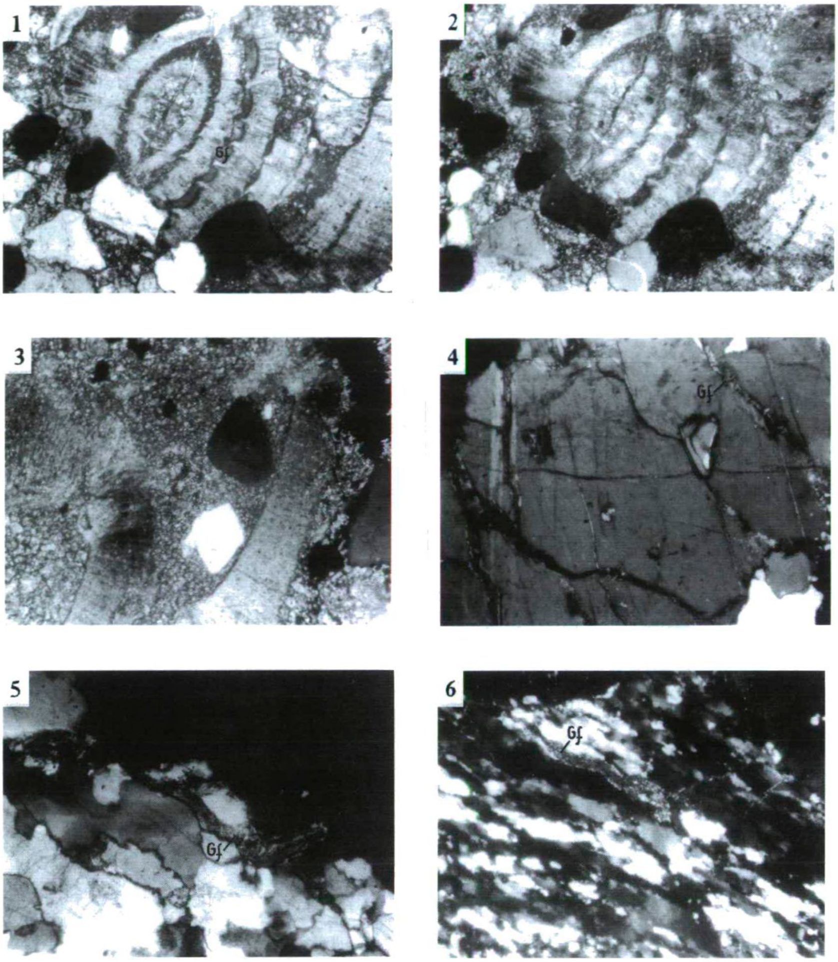


PLATE II
GREEN GLAUCONITIC (?) FILMS (Gf)

Pl. II–Fig. 1. Green fillings of Nummulites tests and granular glauconies agglomerated in transport structures (GE 3 -loose fraction > 500 μm, Luna de Sus, 1N x 65).

Pl. II–Fig. 2. idem (N+).

Pl. II–Fig. 3. Rounded glauconitic grain and subangular detrital quartz included in Nummulites tests and cemented by microsparite (GE 3, Luna de Sus, N+, x 100).

Pl. II–Fig. 4. Green film filling the fissures of quartzitic crystalloclast (GM 3 - loose > 500 μm fraction, Tihău, N+, x 65).

Pl. II–Fig. 5. Random and oriented microcrystalline internal fabric of green infilling in the fissures of quartzitic lithoclast (GM 3 - loose > 500 μm fraction, Tihău, N+, x 65).

Pl. II–Fig. 6. Random microcrystalline internal fabric of a green film formed between the crystals, in a quartzitic lithoclast (GM 3 - loose > 500 μm fraction, N+, x 65).

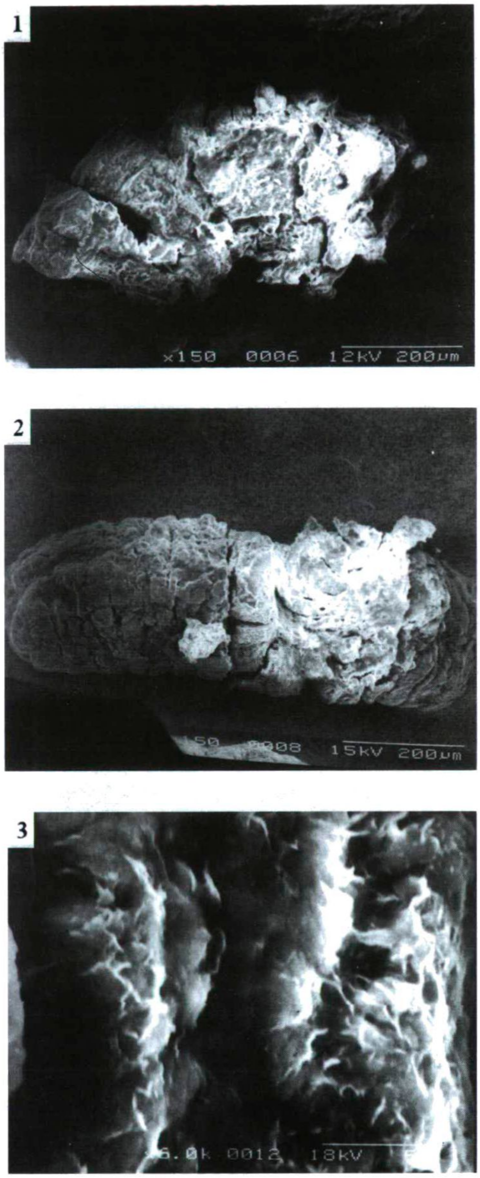
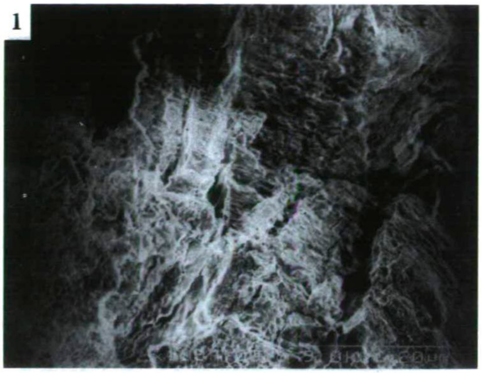


PLATE III
SEM IMAGES OF UNCOVERED SAMPLES.
Vermicular grains in sample GC 28A (Sebeşel, Upper Cretaceous)

Pl. III–Fig. 1. Curved vermicular grain.
Pl. III–Fig. 2. Crushed surface of an elongated vermicular grain; perpendicular cleavages are visible.
Pl. III–Fig. 3. Detail of Fig. 2; flaky crystallites develop in the cracks that follow the cleavage planes (scale bar: 5 µm).



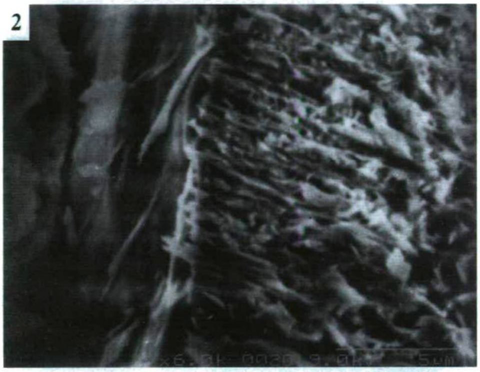


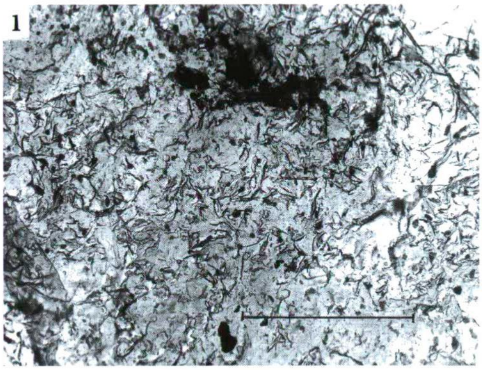
PLATE IV
SEM IMAGES OF UNCOVERED SAMPLES
Sample GC 28A (Sebeşel, Upper Cretaceous)

Pl. IV–Fig. 1. Detail of a vermicular grain, in which cracks following the cleavage planes and quasi-parallel lamellae can be noticed (scale bar: 20 μm).

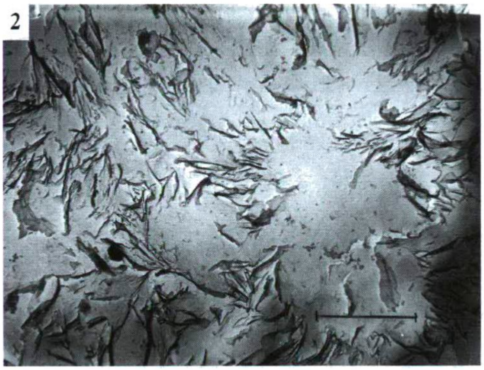
Pl. IV–Fig. 2. Detail of Fig. 1; the glauconitic quasi-parallel lamellae are oblique to the cleavage planes; relic(?) structures are visible (scale bar: 5 μm)

Pl. IV–Fig. 3. Glauconitized foraminifera mould caught in a mass of neoformed glauconitic lamellae (scale bar: 15 μm).

1



2



3

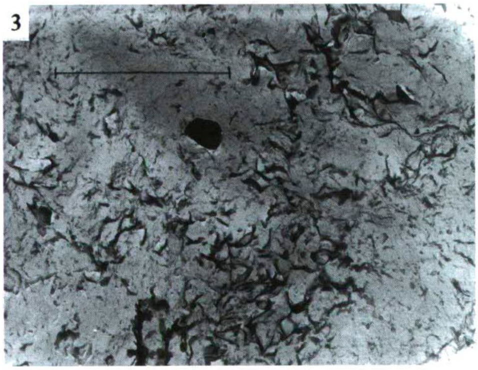


PLATE V
TEM-REPLICA METHOD

Fig. 1. GC 3A sample (scale bar: 5 μm)
Fig. 2. GC 28A sample (scale bar: 1 μm) Slightly evolved glauconies
Fig. 3. GC 28A sample (scale bar: 5 μm)

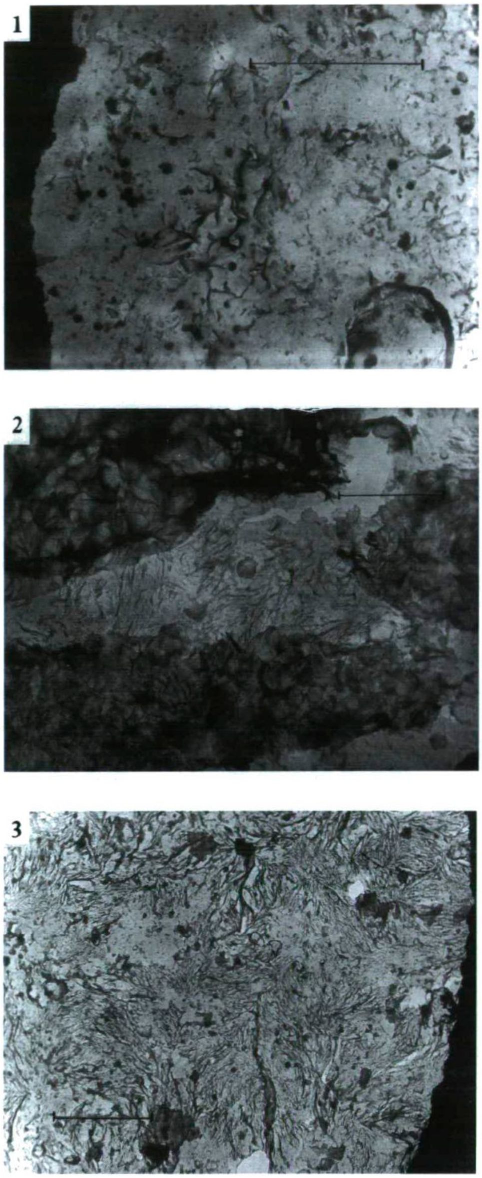


PLATE VI
TEM - REPLICA METHOD

Fig. 1. GO 1A sample (scale bar: 5 µm) Slightly evolved glaucony

Fig. 2. GM 2A sample (scale bar: 5 µm) Evolved glaucony

Fig. 3. GE 3A sample (scale bar: 5 µm) Highly evolved glaucony

TABLE 1

Geological and lithological characteristics of selected glauconitic samples

Sample	Age	Occurrence	Stratigraphy	Geological setting*	Selected references	Host-rock	Clay fraction mineralogy	Observations
GM 7	Miocene (Eggenburgian)	Tihău (Sălaj distr.)	Chechiş Beds	Post-Meseş tectonic cover	Hofmann (1879) Koch (1900) Şuraru (1967) Rusu (1977)	Sandy silt (75% G)	Ca-M+I/S (55%) I (45%)	- laminations -iron oxi-hydroxide pseudomorphs
GM 2	"	"	"	"	"	Silty sand (75% G)	Ca-M+I/S (60%) I(40%) better crystallized	-poorly sorted
GO 1	Oligocene (Upper Rupelian-Chattian)	Var (Sălaj distr.)	Var Sandstone	Post-Laramic tectonic cover of the Transylvanids	Rusu (1977)	Clayey silt (20% G)	Ca-M+I/S (50%) K (40%) I (10%)	-post-depositional sorting -transport structures
GE 5	Eocene (Upper Lutetian - Bartonian?)	Ortelec (Sălaj distr.)	Căpuşu Formation (S. eszterhazyi level)	"	Hauer and Stache (1863) Rusu (1967, 1987)	Silty clay (75% G)	I (65%) Ca-M+I/S (35%)	-medium sorted -G nests, laminae
GE 3	"	Luna de Sus (Cluj distr.)	Căpuşu Formation (N. perforatus level)	"	Hauer and Stache (1863) Koch (1883) Mareş and Tătărîm (1967)	Bioclastic packstone (15% G)	I (60%) Ca-M (40%)	-transport structures
GE 2	"	"	Căpuşu Formation (S. eszterhazyi level)	"	"	Clayey silt (10% G)	Ca-M+I/S (60%) I (35%) C (5%)	-poorly sorted
GC 28	Cretaceous (Coniacian)	Sebeşel (Alba distr.)	Săsciori Beds	Post-Gosau tectonic cover of the Transylvanids	Marincaş (1965) Mareş and Todiriţă-Mihăilescu (1970)	Sublithic sandstone (70% G)	Ca-M (75%) I (20%) K (5%)	-transport structures (basal part) -quartz corroded by calcite
GC 3	Cretaceous (Cenomanian - Coniacian?)	Râşnov (Braşov distr.)	"Marly" facies	Post-Austric tectonic cover of the Median Dacides (Southern Carpathians)	Bielz (1889) Jekelius (1938)	Grainstone/ packstone (5% G)	I (50%) Ca-M+Na-M (50%)	-turbiditic deposits -planktonic foraminifers -G associated with arenitic clasts

Legend: glauconies (G); illite-type structure (I); Ca-montmorillonite (Ca-M); Na-montmorillonite (Na-M); kaolinite (K); chlorite (C); randomly interstratified illite-smectite with small amounts of illite layers (I/S). * after BALINTONI (1994, 1996)

TABLE 2

Glauconies morphology

Sample	Colour	Surface features	Morphologic types	Internal structure (fabric)	Observations
GM 7A	light-green	mat, porous	S(85%), M(10%), C(5%)	r (rarely z, m, o)	- organic substrates -green films inside quartzitic clasts
GM 2A	"	"	S(80%), M(15%), C(5%)	"	"
GO 1A	light-yellowish green	glassy, "dissolution pits"	O-S(60%), F(37%), M(3%)	r	-possible transport of G -size sorting of the sediment and G
GE 5A	intense "grass-green"	smooth, glossy	O-S(95%), M(5%)	r (rarely p)	-generalized oxidation
GE 3A	dark-green to black	"	O-S(55%), T-D(25%), F(20%)	r (rarely "corona" structures)	-rarely, green films inside foraminifera tests
GE 2A	"	"	O-S(80%), M(15%), S(5%)	r	
GC 28A	dark yellowish "grass-green"	"	M(75%), V(10%), O-S(7%), T-D(5%), IM(3%)	r, m	-possible biotite-chlorite-glauconite transformation
GC 3A	light-green	earthy, porous	IM(45%), M(35%), S(15%), O-S(5%)	r (rarely c)	-basinal paleoenvironment of G formation (IM)

Legend: Morphologic types: ovoidal-spheroidal (O-S); mammillated (M); tabular-discoidal (T-D); composite (C); vermicular (V); internal moulds (IM); spongy (S); fragmentary (F). Fabric: random microcrystalline (r); composite (c); oriented (o); micaceous (m); patch-oriented (p); "zebra" structures (z)

TABLE 3

Glauconies mineralogy

Sample	XRD-characteristics						Mineralogic species	Maturity degree	Genetic type
	d (001) (Å)	d(060) (Å)	b (Å)	Ø	Ordering degree	Polytype			
GM 7A	10.36 (broad)	1.513	9.08	3.72 (opened)	moderate	1Md	MDG	E	P
GM 2A	10.23 (sharp)	1.516	9.10	8.01 (relatively closed)	moderate	1M/1Md	OG	E/HE	P
GO 1A	10.00 (relatively sharp)	1.517	9.11	6.79 (opened)	low	1M	EDG	SE/E	D/P
GE 5A	10.38 (broad)	1.518	9.11	7.68 (relatively opened)	moderate	1M	OG	HE	A/P
GE 3A	10.1 (sharp)	1.521	9.12	9.02 (closed)	moderate	1M	OG	HE	A/P
GE 2A	10.1 (sharp)	1.521	9.12	10.1 (closed)	moderate	1M	OG	HE	A
GC 28A	10.37 (broad)	1.515	9.09	5.06 (opened)	moderate	1Md	MDG	SE/E	A/P
GC 3A	10.8 (broad)	1.514	9.08	5.01 (opened)	low	1Md	EDG	SE	P

Legend: Mineralogic species: ordered (OG); moderately disordered (MDG); extremely disordered (EDG). Maturity degree: slightly evolved (SE); evolved (E); highly evolved (HE). Genetic type: authigenic (A); perigenic (P); detrital (D).