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Petrographic Details in the Metaclasts of a Debritic Facies of the Podu Secu Formation in the Tarcău Unit of the Eastern Carpathians (Siriu Dam Area)

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Abstract

In the context of the analysis of a debritic facies of the Podu Secu Eocene formation in the Tarcau Unit of the Eastern Carpathians, the paper presents the petrographic study of the metaclasts of the respective facies in the Siriu dam area. Besides the lithoclasts of plagioclase gneisses which are most frequently encountered, the study presents observations about augen gneisses with microcline, micaschists as well as fragments from the matrix of the ruditic metaclasts. The detected microfissures are thought to have been generated by mild deformation in the source area and not by diagenetic processes. However, the quasi-presence of microfissures suggests a common source. The low degree of roundness of the large lithoclasts indicates a short transport to the depocentre from where they were relocated by the submarine movements of the older sediment masses. Multiple reworking in the older sedimentary bodies is suggested.

Key words: *Eastern Carpathians, Tarcau Unit, debris-flow deposit, Podu Secu Formation, metaclasts, petrographic remarks*

Introduction

In the side slopes of the national road DN 10 Siriu-Brasov, in the adjacent area of the Siriu dam area, the outcrops of the Paleogene flysch in the Tarcău Unit show a variety of petrogrtaphic and sedimentological facies. One of them represents a remarkable occurrence of paraconglomerates that may also be interpreted as a debritic flow related to the Podu Secu Formation. This paper is intended to be a petrographic study of the metaclasts of the facies in the Siriu dam area. The study of the lithoclasts in the paraconglomeratic body helped the understanding of the source area/ areas and the clarification of some sedimentological aspects.

Stratigraphic-Sedimentological Setting

Podu Secu layers (Băncilă, 1955), which are the internal facies of the Priabonian Tarcău Unit, consist of a thick alternation of frequently diaclased calcareous sandstones, grey and green marls and claystones. In some areas they contain fucoids with *Globigerina marls* in the upper part, and are intercalated with or replaced by thick banks of Fusaru sandstones. The Paleocene-Eocene sequence, dominated by lithic sandstones (with subordinate polymictic conglomerates) and clays, contains ruditic petrofacies of *paraconglomerates* and *orthoconglomerates* with lithoclasts (quartzites, micaschists and gneisses) in arenitic matrix, suggesting a *debris* flow to *mud flow* setting. [1, 2, 3, 4, 5]

The *debris flow* (*F*1 facies – paraconglomerates = *unstratified boulders*) formed a grey, unstratified matrix which, in some places, is brick-coloured due to alteration and is bounded by clear margins. At the top it has exaggerated structures of the *load-casts* type related to the rapid buildup of the facies overlying the orthoconglomerates (*F*2 facies). The matrix consists of decimetric and metric blocks that are disposed in a subparallel or fluidal pattern, and generally have a chaotic stratification; they are grouped in the lower half of the matrix and have a matrix-like constitution (ruditic metaclasts, marly limestones, diagenized Mesozoic limestones, Tarcău sandstones, finely weathered lithic sandstones, micaceous or conglomeratic sandstones, clay-silt shales and finely grey-blackish orthoquartzite sandstones). [4, 5, 6]

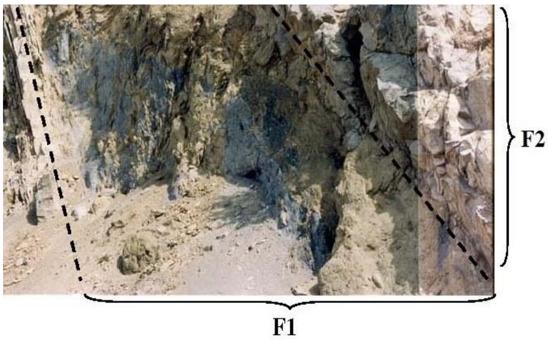

Fig. 1 *Panoramic view of the Eocene top in the arenite-silt-lutite piles of the Podu Secu Formation, showing the mega debris flow and the base of the 10 m thick suprajacent sequence of massive coarse sandstones with load cast structures.* [5]

Fig. 2 *Panoramic view of the mega debris flow in the Podu Secu Formation (on the left side of the Buzău Valley, downstream of the Siriu dam, near the large water spillway).* [6]

Mineralogical-Petrographic Setting

The paraconglomeratic body under study is considered to have been formed by debris flow deposition. It is poorly sorted and has a very complex composition from both mineralogic and petrographic. All granulometric fractions can be noticed in its structure, that is, the arentic, siltic and lutitic fractions. Lithoclasts are best noticed in the ruditic fraction, but subordinate lithoclasts can be found in the coarse arenitic fraction too. The maximum dimensions of the largest lithoclasts exceed 10 cm. If these large centimetric lithoclasts are regarded as points of reference, then the rest of the petrographic body, including all its granulometric variety, can be considered a matrix of the geological body. The volume of the matrix is much larger than the volume of the centimetric coarse lithoclasts. In our opinion, the matrix includes, along with the siltic, arenitic and lutitic granulometric fractions, the fine ruditic (microruditic) fraction too.

The matrix of the paraconglomeratic body is structurally very heterogeneous on a microscopic scale, and looks like greywacke. In this matrix, the fine ruditic epiclasts and the arenitic ones occur in a finer-grained mass whose granulation is mainly silty. As regards its composition, it is chiefly phyllosilicatic and serves as a binder. The phyllosilicates in this binder are principally illite, chlorite and muscovite. The morphological features of muscovite show that it is terrigenous whereas chlorite and illite may have formed diagenetically. The degree of consolidation given by this phyllosilicatic fraction varies according to the place. At the macroscopic level, there are areas where the matrix is very friable and areas where coarse ruditic clasts (epiclasts) are relatively well-preserved in the matrix.

The arenitic fraction is mostly siliciclastic and contains both granoclasts and polygranular clasts. Lithoclasts are few in this fraction. The most common arenitic granoclasts are those of quartz, feldspar (both potassium and plagioclase), partially chloritized biotite, chlorite and muscovite. The arenitic polygranular clasts are mostly quartz polygranular clasts or clasts containing mineral associations such as quartz and mica, quartz and feldspar, quartz and chlorite, quartz and chlorite and feldspar. In the arenitic fraction there are also subordinate carbonate particles. Some of them may be limestone lithoclasts, others are bioclasts or tests, or the origin of others cannot be determined with certainty.

The lithoclasts found in this paraconglomeratic body belong to the three genetic categories of rocks: magmatic, metamorphic and exogenous. Exogenous rock lithoclasts chiefly consist of sandstones and limestones, and occur in the largest proportion. They represent 50-60% of all lithoclasts. There are also metamorphic rock lithoclasts (approx. 35-40% of the total volume of the lithoclasts) and, in the smallest proportion, magmatic rock lithoclasts. Morphologically, lithoclasts may be of various shapes and their degree of roundness is variable. Magmatic rock lithoclasts generally have higher roundness. Metamorphic rock lithoclasts are slightly rounded and even angular (some fragments of schist). Exogenous rock lithoclasts are generally angular in shape, but there are exceptions too (for instance, some white limestone lithoclasts).

The emphasis of the petrographic study was upon the lithoclasts and the matrix of the paraconglomeratic body. More than 100 samples were tested and 64 thin sections were made for this research. Aiming at a better highlight of the diversity of the types of the present lithoclasts, a macroscopic selection of the lithoclasts and the matrix samples was made before performing the thin sections.

The study of the lithoclasts rests on the microscopic analysis of the thin sections from both the coarse epiclasts with centimetric dimensions and the microruditic epiclasts of the matrix. The study of the thin sections from the matrix paid particular attention to the microruditic lithoclasts.

Metamorphic lithoclasts (metaclasts)

After the microscopic study of the large (centimetre size) lithoclasts was performed, the following groups of metamorphic rocks were separated:

1. Gneisses

- Augen gneisses with microcline (they also contain plagioclase feldspar);
- Retromorphosized augen gneisses with microcline (they also contain plagioclase feldspar);
- Plagioclase gneisses with garnet (they do not contain potassium feldspar);
- Plagioclase gneisses without garnet (they do not contain potassium feldspar);

2. Metamorphic schists

- Micaschists with both micas and garnet (schists with muscovite quartz, biotite and garnet);
- Schists with quartz, plagioclase, micas and garnet.

It should be mentioned that the terms above are notions used in order to classify the metamorphic rocks lithoclasts that were found. Moreover, these terms were not used according to all the requirements of I.U.G.S. (International Union of Geological Sciences). [7] Each of these types will be further discussed and the most important details of the petrographic features will also be presented.

Augen gneisses with microcline

These gneisses are structurally composed of ocelli of microcline twins (fig. 3) and a matrix of these ocelli (fig. 4). The matrices always contain quartz (with strong undulatory extinction), oligoclase (which can be argillized and/or sericitized), one or both micas and chlorite (formed on biotite). Other constituents may be added to these ones depending on the variety of augen gneisses. On the rim or near it, microcline ocelli contain groups of small oligoclase crystals and/or groups of myrmekitic concretions (fig. 3) in the form of a continuous crown. These ocelli may also contain intergrowths of mica, plagioclase chlorite and quartz, and may be microperthitic.

Two types (varieties) of gneisses were identified according to the presence of micas:

i. Augen gneisses with microcline, which contain muscovite and biotite in the matrix;

ii. Augen gneisses that contain only biotite as mica of the matrix.

In the muscovite and biotite varieties, apart from quartz and oligoclase, only accessory minerals like zircon and apatite were found in the matrix. Some lithoclasts included in this type contain micas and chlorite in a very small proportion that is <10% of the total volume. As a result, they can be classified as leucogneisses.

The varieties that contain only biotite as mica also comprise other minerals in the matrix:

- garnet – the crystals have a relict appearance and are often located close to the biotite crystals (fig. 5);
- epidote (rare anhedral crystals) (fig. 6);
- accessory minerals: titanite and apatite.

The varieties that contain only biotite as mica may also comprise muscovite in a small proportion. However, this was not found in the matrix but in the space of the microcline ocelli.

The following late-formed minerals were found: opaque mineral (also deposited in microfissures) and carbonate (usually developed metasomatically in the space of oligoclase).

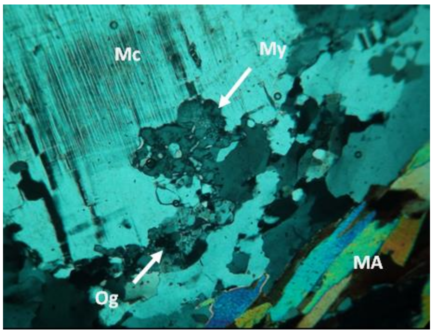

Fig. 3. *Microcline ocellus (Mc) containing myrmekitic concretions (My) and groups of small oligoclase (Og) crystals in the peripheral area; the matrix (MA) containing quartz and micas is in the bottom right of the image. (N+, 40x)*

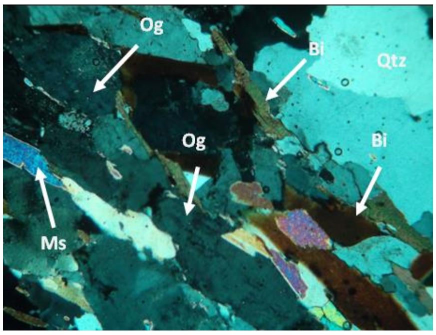

Fig. 4. *Matrix of augen gneiss containing both muscovite and biotite: oligoclase (Og) is present along with quartz (Qtz), muscovite (Ms) and biotite (Bi) (N+, 40x).*

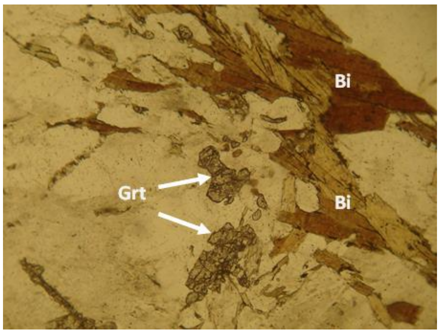

Fig. 5. *Relict garnet crystals (Grt) occur in some of the augen gneiss lithoclasts; garnet is close to the biotite crystals (Bi) (NII, 100x).*

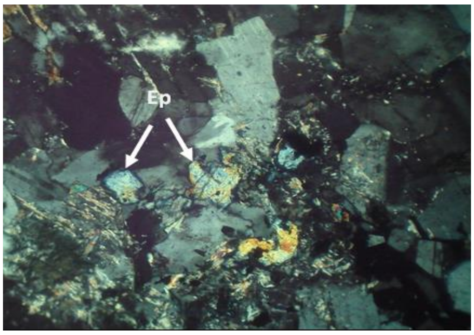

Fig. 6. *Epidote crystals (Ep) in the matrix of augen gneisses with biotite (NII, 100x).*

Retromorphosized augen gneisses with microcline

These rocks are similar to those described above and have the following features:

- Almost all biotite crystals in the matrix are substituted by chlorite (fig. 7); this chlorite is formed in a stage of retromorphism and is spatially associated with titanite;
- Relict biotite (the unchloritized one) is very rare;
- The plagioclase feldspar (oligoclase) is partially substituted by sericite (which in some cases is largely crystallized, showing muscovite characteristics) and zoisite;
- Undulatory extinction in quartz crystals may be generally poor;

Microcline ocelli also contain crowns of myrmekitic concretions at their periphery. Some of them have Karlsbad twins and plagioclase feldspar inclusions (fig. 8). Muscovite formed through processes of retromorphism can be found on some of the microcline ocelli. As accessory minerals, (very rare) zircon and an opaque mineral were found. No relict garnet was found in this type of lithoclasts.

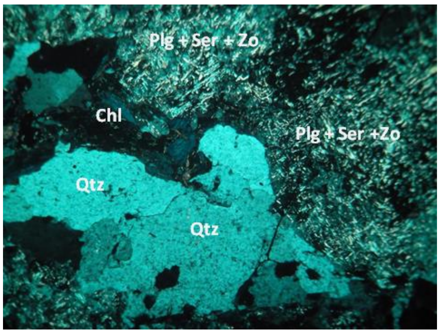

Fig. 7. *Retromorphosized matrix of augen gneiss: oligoclase (Plg) is partially substituted by sericite (Ser) and zoisite (Zo), chlorite that pseudomorphosizes biotite (Chl) and quartz (Qtz) (N+, 40x).*

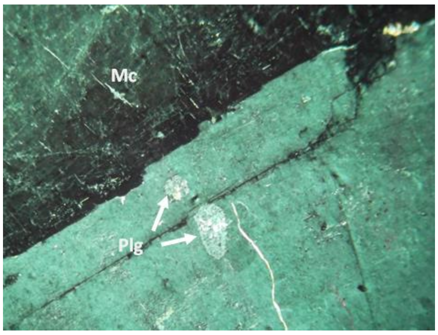

Fig. 8. *A domain of microcline ocellus (Mc) (not twinned); however, a Karlsbad twin and inclusions of partially sericitisized plagioclase feldspar can be noticed (Plg) (N+, 40x).*

Plagioclase gneisses with garnet

The main mineral constituents of these rocks are quartz, plagioclase feldspar (oligoclase), biotite, and muscovite only in some lithoclasts (fig. 9). There are lithoclasts of such gneisses where the dominant mica is biotite and muscovite is mostly subordinate. Chlorite can also be present, being formed through the replacement of biotite. Oligoclase is twinned or not, slightly argillized and very common. The subordinate constituents are garnet, apatite, titanite, opaque minerals (definitely secondary and present in microfissures), carbonate (formed later in the oligoclase space) and zircon.

In some lithoclasts, garnet occurs as small crystals (tens of millimetres in size), which are isometric and anhedral (fig. 10). In other lithoclasts, garnet occurs as atollic crystals, with contours that may be subhedral or euhedral (fig. 11). A structural feature encountered in some of these lithoclasts is the high frequency of round quartz inclusions in plagioclase feldspar crystals or twins (fig. 12). Titanite is a mineral most likely formed in a stage of retromorphism as pseudomorphoses on pre-existing crystals of titanium minerals.

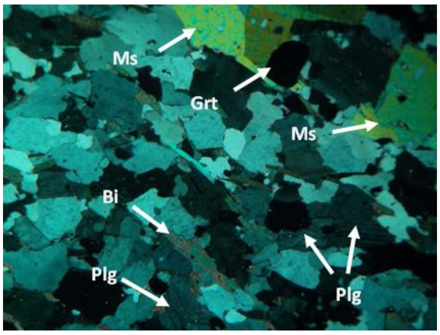

Fig. 9. *Image of the overall structure: schistosity is poorly expressed; most of the mineral constituents can be noticed: quartz (Qtz), oligoclase (twinned in some cases) (Plg), biotite (Bi), muscovite (Ms) and garnet (Grt) (N+, 40x).*

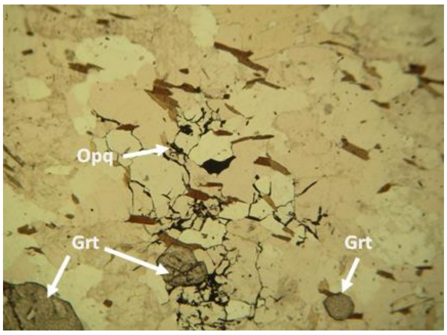

Fig. 10. *Garnet crystals (Grt) in some varieties of plagioclase gneisses are relatively small and anhedral; a microfissure system, on which the secondary opaque mineral (Opq) is deposited, and the light argillisation of oligoclase can be noticed (Plg-a) (NII, 40x).*

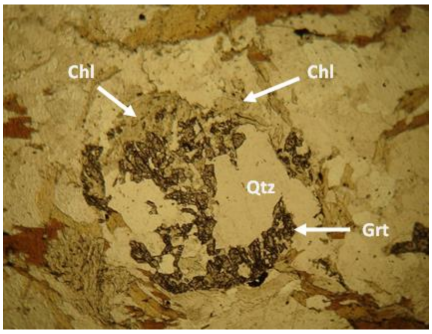

Fig. 11. *Atollic garnet with subhedral shape along with quartz (Qtz) and chlorite (Chl); such crystals occur only in some varieties of plagioclase gneisses (NII, 40x).*

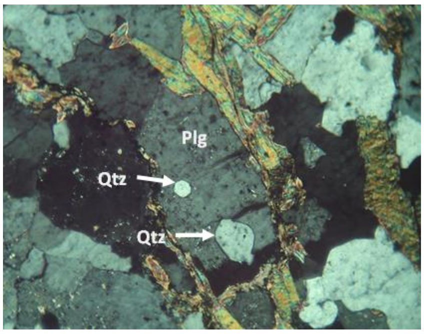

Fig. 12. *Rounded quartz inclusions (Qtz) in plagioclase feldspar (Plg) twins or crystals (N+, 100x).*

Plagioclase gneisses without garnet

These rocks consist mainly of plagioclase feldspar (oligoclase), quartz (with moderate undulatory extinction) and biotite. There is a tendency for these constituents to be segregated in the rock. Thus, quartz is mainly located in lenticular microdomains (fig. 13) and biotite crystals tend to be locally grouped (fig. 14). There are also relatively large microdomains containing only oligoclase (fig. 15). Oligoclase is, in some areas, substituted by sericite, but this phyllosilicate formed on feldspar is broadly crystallized locally and has the microscopic optical features of muscovite (fig. 16). Chlorite is present in a very small proportion as a substitute for biotite. In these rocks, accessory minerals are titanite (spatially associated with biotite) and zircon. A definitely secondary mineral is an opaque mineral present in microcracks.

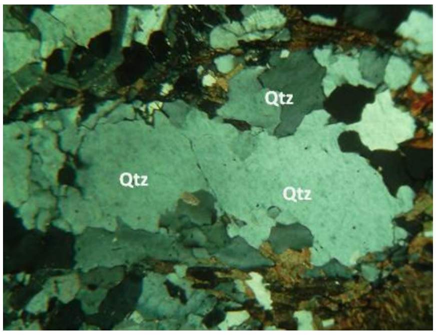

Fig. 13. *Microlenticular domains composed of quartz (Qtz) (N+, 40x).*

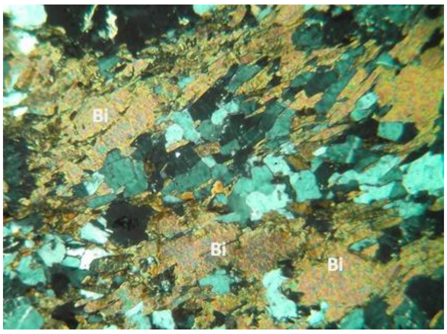

Fig. 14. *Microdomain where biotite crystals (Bi) are concentrated (N+, 40x)*

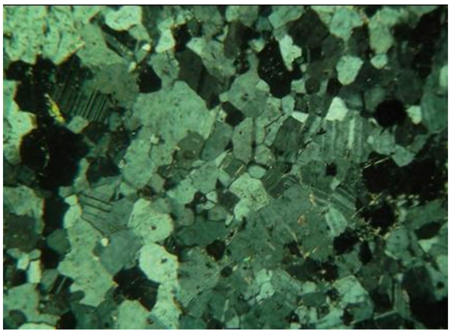

Fig. 15. *Microdomain composed almost exclusively of oligoclase crystals and twins (N+, 40x).*

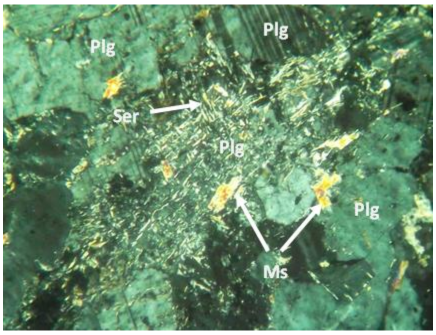

Fig. 16. *Substitution of plagioclase (Plg) by sericite (Ser); local phyllosilicate looks like muscovite (Ms) (N+, 100x).*

Micaschists with muscovite, biotite and garnet

This type of micaschists has as a specific compositional feature the fact that they consist mainly of quartz, muscovite and biotite (fig. 17). Feldspar is present in a very small proportion (less than 5% of the total volume) and is oligoclase. Phyllosilicates are largely segregated from quartz. Thus, the rock displays an alternation of laminae with micas and laminae with quartz. Besides micas and quartz, the rocks contain, in small proportions, garnet, oligoclase, chlorite (formed on biotite), titanite, opaque mineral (probably ilmenite), calcite, apatite and zircon. Rare oligoclase crystals are located in quartz-rich areas. Schistosity is well expressed due to the fact that micas are in a large proportion and have a high degree of preferential orientation. In some of the lithoclasts of these rocks, the foliation surfaces contain microfolds. Garnet crystals arranged as crowns on chlorite crystals can also be found in the lithoclasts of micaschists. This garnet was actually formed by prograde reaction on a former biotite crystal, which is now substituted by chlorite. A proof to support this idea is the zircon inclusion in chlorite (fig. 18).

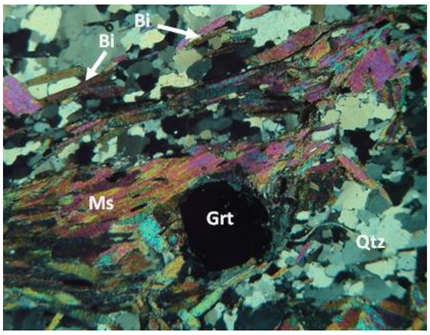

Fig. 17. *Rock structure and the main mineral constituents like quartz (Qtz), muscovite (Ms) and biotite (Bi), and garnet (Grt) (N+, 40x)*

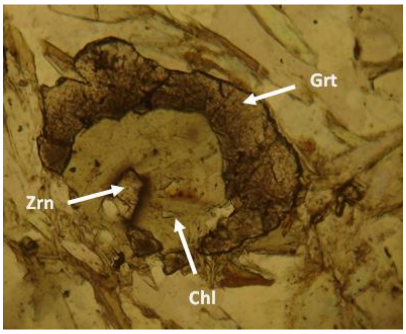

Fig. 18. *Garnet crystal (Grt) developed as a crown around a chlorite (Chl) crystal that includes zircon (Zrn) (NII, 100x).*

Schists with quartz, plagioclase, micas and garnet

These rocks consist mainly of quartz, oligoclase, muscovite and biotite. Muscovite is the dominant mica (fig. 19). The minority constituents are sericite (very likely two kinds), chlorite, garnet, carbonate, opaque minerals, apatite and zircon. Garnet, apatite and zircon can be considered accessory minerals. The schist structure is given by the good preferential orientation of the micas (fig. 19); the foliation surfaces are slightly folded. Although similar from the point of view of their optic properties, these rocks are most likely two types of sericite:

- the first type replaces the plagioclase feldspar (fig. 20);
- the second type replaces the relatively isometric or slightly anisometric former crystals (most likely garnet crystals) (fig. 21); there are also non-transformed garnet crystals, which are most frequently found as inclusions in the plagioclase feldspar (fig. 22).

Chlorite was formed by replacing biotite (fig. 20); this substitution may be partial or total. There are two categories of opaque minerals: one is most likely primary (fig. 20) and the other, present in microfissures, was later formed (fig. 22).

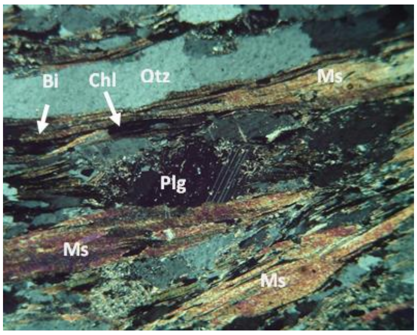

Fig. 19. *Rock structure showing good preferential orientation of micas can be noticed; the dominant constituents are quartz (Qtz), muscovite (Ms), biotite (Bi) and plagioclase feldspar (Plg) (N +, 40x).*

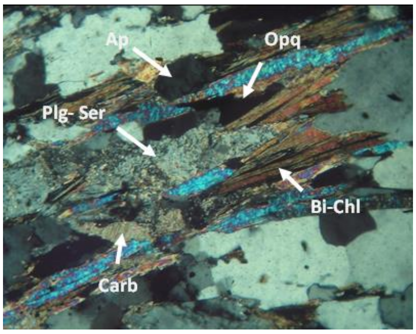

Fig. 20. *Detailed image showing the partial sericitization of plagioclase feldspar (Plg-Ser), partially chloritized biotite (Bi-Chl) in some domains, carbonate (Carb) and opaque mineral (Opq) (N+, 100x)*

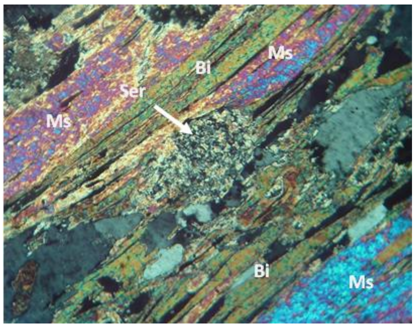

Fig. 21. *Pseudomorphosis with sericite (Ser) on isometric crystals (most likely garnet crystals); the two micas can also be noticed: muscovite (Ms) and biotite (Bi) (N+, 100x).*

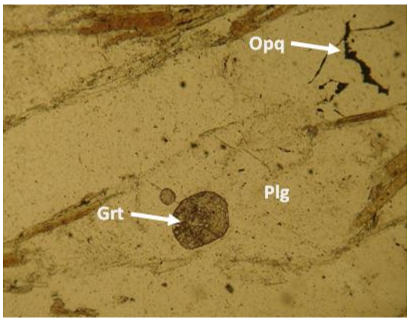

Fig. 22. *Non-transformed isometric garnet (Grt) crystals included in plagioclase (oligoclase) feldspar (Plg); a secondary opaque mineral is present in microcracks (NII, 100x).*

Microruditic metaclasts

Microruditic lithoclasts of metamorphic rocks (metaclasts) were found when the study of the matrix was performed. Most of the microruditic lithoclasts are metamorphic rocks. The table below (Table 1) shows mineral associations in metamorphic rock lithoclasts, which were most frequently encountered in the matrix, and the type of rock they could derive from, according to the classification previously made. Given the fact that the dimensions of these lithoclasts are millimetric, it is not certain that they contain all the minerals and microstructures specific to the original petrographical body (the geological body of the rock in the source area). For this reason their classification as a petrographic type cannot be made with certainty.

Table 1 Mineral associations encountered in the microrudite lithoclasts of metamorphic rocks identified in the matrix of the debris-flow

The mineral association encountered in the lithoclast	The type of rock from which the lithoclast most likely derived	Figure
Plagioclase + quartz + biotite + garnet ± primary opaque mineral (probably ilmenite)	Plagioclase gneisses with garnet	Fig. 23
Plagioclase + quartz + chlorite + muscovite ± titanite ± turmaline ± opaque mineral	Plagioclase gneisses without garnet	Fig. 24
Plagioclase + quartz + biotite + chlorite + garnet ± opaque mineral	Plagioclase gneisses with garnet	Fig. 25

Although there were no microruditic lithoclasts with petrographic features that could enable their categorization as augen gneisses with microcline, we found polygranular clasts which are most likely derived from the geological bodies of these gneisses. Such polygranular clasts are composed of potassium feldspar, quartz, chlorite ± muscovite, carbonate, opaque mineral and iron hydroxide. Almost without exception, the chlorite in such polygranular clasts was formed by replacing biotite. An example is shown in fig. 26.

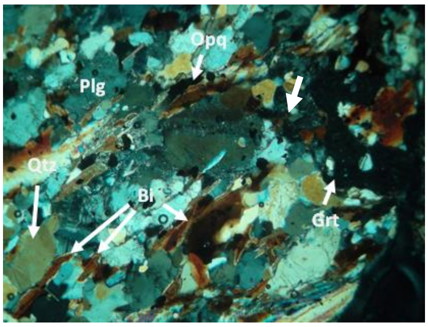

Fig. 23. *Metamorphic rock lithoclast consisting of plagioclase (Plg), quartz (Qtz), biotite (Bi), garnet (Grt) and primary opaque mineral (Opq) (N+, 40x)*

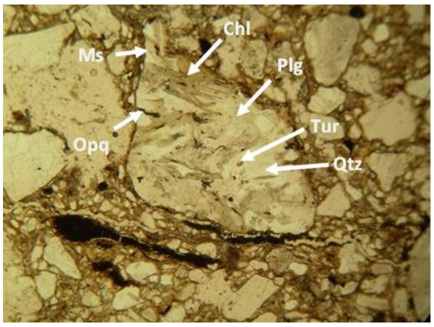

Fig. 24. *Metamorphic rock lithoclast consisting of plagioclase (Plg), quartz (Qtz), chlorite (Chl), muscovite (Ms), titanite (Ttn), turmaline (Tur) and opaque mineral (NII,100x)*

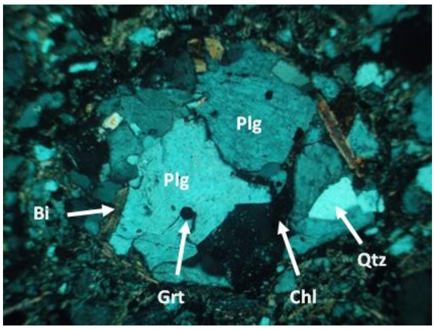

Fig. 25. *Methamorphic rock lithoclast consisting of plagioclase (Plg), quartz (Qtz), biotite (Bi), chlorite (Chl), opaque mineral (Opq) and garnet (N+, 60x).*

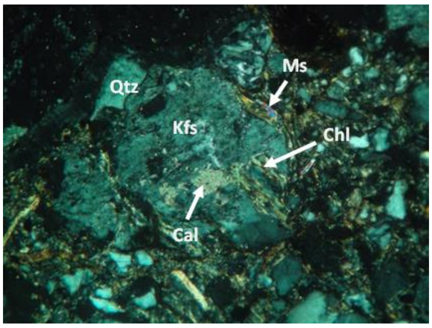

Fig. 26. *Polygranular clast consisting of potassium feldspar (Kfs), quartz (Qtz), chlorite (Chl), muscovite (Ms), calcite (Cal) and iron hydroxide (N+,100x).*

Conclusions

Plagioclase gneisses seem to be the most common lithoclasts of the types encountered. However, due to the fact that microcline ocelli are relatively large and spaced in the bodies of augen gneisses with microcline and that microcline may be absent in the matrices of these rocks, the microscopic study of the smaller fragments resulting from the matrices of these rock bodies indicates that they belong to plagioclase gneisses (plagioclase feldspar, micas ± chlorite and quartz). Taking into account the fact that there are relatively frequent microcline granoclasts with a low degree of transformation in the matrix of the debris-flow, it is not certain that augen gneisses with microcline were more difficult to disaggregate. Thus, the ratio of the volume of the augen gneiss lithoclasts to the plagioclase gneiss ones could not be estimated.

The same types of microfissures, especially along the boundaries between the crystals and currently filled with opaque mineral (fig. 10 and 22), can be locally found both in the plagioclase gneisses lithoclasts (with and without garnet) and in the augen gneisses lithoclasts with retromorphic microcline. These microfissures with opaque mineral were most likely formed during mild deforming events that occurred in source areas and are not the result of the diagenetic processes. Although not used as a certain indicator, the presence of this type of microfissures suggests that both plagioclase gneisses and at least some of the augen gneisses come from the same source area. It is relatively certain that the schist lithoclasts (both micaschists and those with plagioclase feldspar) are rare in the debris-flow that was studied. This may show that they were subordinate to the source area.

We consider that, due to the numerous common mineralogical features, the schists with quartz, plagioclase, mica and garnet also originate from the same source area as plagioclase gneisses with garnet. We also consider that they represent only a more advanced stage of deformation of the same precursor rocks. The fact that the large (centimetric) metamorphic rocks lithoclasts have a low degree of roundness indicates a short distance transport from the source area to the sedimentary basin where these fragments were relocated by the submarine movements of the sediment mass. Considering their low degree of roundness and the fact that they are frequently encountered, it is unlikely that these metamorphic rock lithoclasts were reworked in the sedimentary basin from older detritic sedimentary bodies.

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Detalii petrografice asupra metaclastelor unui facies debritic al formatiunii de Podu Secu din Unitatea de Tarcău a Carpatilor Orientali (zona barajului Siriu)

Rezumat

In contextul analizei unui facies debritic al formatiunii eocene de Podu Secu din Unitatea de Tarcau a Carpatilor Orientali se prezinta studiul petrografic al metaclastelor respectivului facies din zona barajului Siriu. Pe langa litoclastele mai frecvente de gnaise plagioclazice se prezinta consideratii despre gnaisele oculare cu microclin, micasisturi, precum si fragmentele din matricea metaclastelor ruditice. Microfisurile detectate sunt considerate ca generate prin usoara deformare casanta in aria sursa si nu prin procese diagenetice. Cvasiprezenta microfisurilor sugereaza totusi o sursa comuna. Gradul redus de rotunjire al litoclastelor mari sugereaza un transport scurt catre depocentru de unde au fost relocate prin miscari submarine ale maselor de sedimente. Se sugereaza multiple remanieri din corpuri sedimentare mai vechi.