THE PETROGRAPHIC STUDY OF THE GRAVELS WITHIN CÂNDEŞTI PIEDMONT

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Abstract. The petrographic nature of the gravels in Cândeşti Piedmont indicates the metamorphic basement of the Iezer Mountains as the main source area. The geological formations which provided the clastic material are the quartzo-feldspathic gneisses of the Cumpăna Series, the porphyroblastic albite gneisses of the Leaota Series, the interlayered amphibolic rocks within the two gneissic formations, and the Albeşti Granite. The frequency of different petrographic types of pebbles in the piedmont was controlled by their resistance to weathering and transport, by the structural level of the geological formations in the metamorphic pile, and by the tectonics of the source area.

Keywords: Cândeşti Piedmont, gravels, petrography, source area.

Rezumat. Studiul petrografic al pietrişurilor din Piemontul Cândeşti. Natura petrografică a pietrişurilor din Piemontul Cândeşti indică drept arie sursă principală fundamentul metamorfic al Munţilor Iezer. Cele mai importante formaţiuni geologice furnizoare de material clastic sunt gnaisele cuarţo-feldspatice din seria de Cumpăna, gnaisele cu porfiroblaste de albit din seria de Leaota, rocile amfibolice intercalate în cele două formaţiuni şi granitul de Albeşti. Frecvenţa diferitelor tipuri petrografice de galeţi a fost controlată de rezistenţa acestora la alterare şi dezintegrare mecanică, de nivelul structural al formaţiunilor geologice în stiva metamorfică şi de tectonica ariei sursă.

Cuvinte cheie: Piemontul Cândeşti, pietrişuri, petrografie, arie sursă.

INTRODUCTION

Many studies regarding the sedimentary formations in Romania discuss stratigraphy, palaeontology and sedimentology topics, but rarely the petrographic aspects. Petrographic study of the pebbles from gravels and conglomerates, as well as of the lithic fragments from sandstones, allow the reconstitution of sometimes completely eroded source areas and the identification of the existing ones. We mention here the classic paper of MURGEANU (1937) suggesting the existence of a cordillera (the Cuman cordillera) in the sedimentation area of the Carpathian flysch, inferred from the exotic rocks identified in the Senonian marls from Vrancea region.

The goal of this study is to identify the geological formations within the primary source area that provided the clastic material of Cândeşti Piedmont gravels. This source area is represented by the crystalline basement of the Iezer and Leaota Mountains, but we took into account a possible influx from the Făgăraş Mountains.

We also took into consideration the possibility to find some ores now eroded in the source area. For example, in this region the occurrence of gold in alluvial deposits of the rivers was attested in Cândeşti Piedmont (POPOVICI-HAŢEG, 1898; BÎRLEA & BÎRLEA, 1962) although there are no gold ores found in the source area to be taken into consideration. But, there may have been and were eroded.

In order to have a homogeneous geological overview of the source area we used as reference works geological maps at 1:50 000 scale (PATRULIUS et al., 1971; DIMITRESCU et al., 1971; DIMITRESCU et al., 1974; DIMITRESCU et al., 1978; DIMITRESCU et al., 1985), and our own field observations.

CÂNDEŞTI PIEDMONT

It is a geomorphological unit defined as *piedmont* by PARASCHIV (1960), the term meaning a relief unit with flat surface resulting through primary sedimentation, in opposition to the term *platform*, used by VÂLSAN (1915), defining a relief unit with flat surface resulting through erosion. Cândeşti Piedmont is bounded by the Dâmboviţa River to the east, the Argeşel and Doamnei rivers to the west, and the Argeş alluvial plain to the south (Fig. 1).

From the geological point of view, Cândeşti Piedmont consists of fluvial-lacustrine gravel deposits with sands and marls intercalations assigned to the Early Quaternary (ex. LITEANU & GHENEA, 1966; JIPA, 2010). This sedimentary formation, known as Cândeşti Beds or Cândeşti Gravels, represents an important stratigraphic marker for the Dacian Basin. The huge accumulation of gravels in this basin is subsequent to the Wallachian orogenic phase when the rise of the South Carpathians took place leading to the erosion rate acceleration of the source area and the increase of the eroded material influx.

According to PARASCHIV (1965), the gravel deposits have maximum thickness in the northern part of the piedmont where can reach 80 m, while in the southern part they do not exceed 35 m. On north-south direction, the thick deposits occupy the median area of the piedmont (Fig. 1). Following the same author, the only marker bed in Cândeşti Piedmont gravels is the so-called boulders level, outcropping in its north-eastern part.

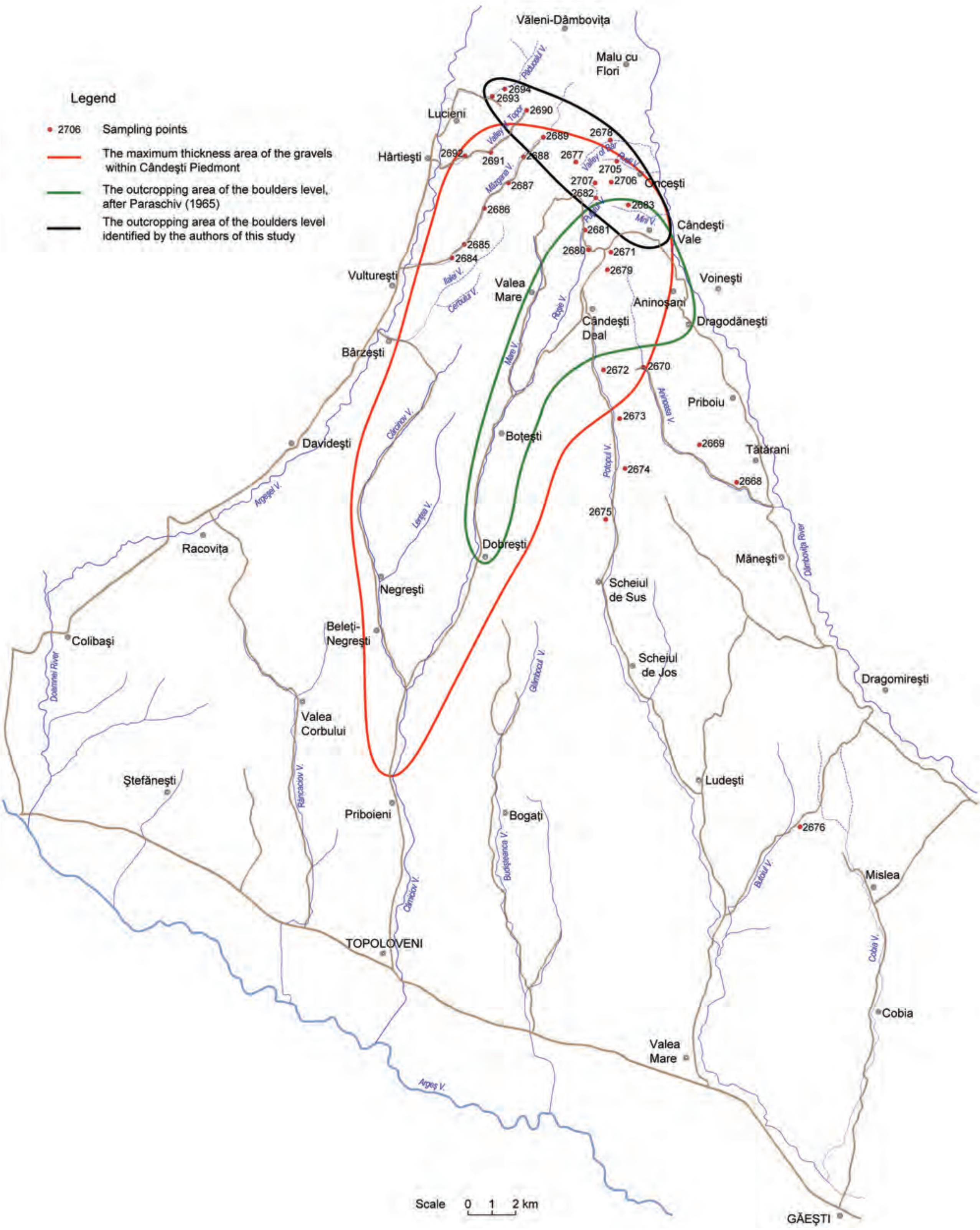

Figure 1. The sampling points of the gravels in Cândești Piedmont.

For these reasons, we chose for sampling and field observations the north-eastern part of the piedmont characterized by thick deposits of gravels and the presence of the boulders level at surface. With the occasion of this study, the boulders level has been identified on the entire northern border of the piedmont.

FIELD RESEARCHES

During the field researches, there were collected 120 samples of pebbles from 30 sampling points (Fig. 1). In each sampling point the different petrographic types of pebbles have been registered in their frequency order, on the basis of macroscopic diagnosis subsequently checked by microscopic diagnosis. The samples collected from the same sampling point were differentiated by capital letters.

Aninoasa Valley (3 sampling points, 17 samples): no outcrops, pebbles deposits;

- point 2668: quartz, quartzo-feldspathic gneisses, Albeşti granites, quartzites, amphibolites, sandstones, limy sandstones, and jaspers;
- point 2669: quartzo-feldspathic gneisses, Albeşti granites, quartzites, quartz, amphibolites, augen gneisses, and sandstones;
- point 2670: quartzites, quartz, quartzo-feldspathic gneisses, and sandstones.

Cândeşti Hill (3 points, 25 samples): outcrops of fine-grained gravels with intercalated sands and sandy marls, pebbles deposits;

- point 2671: quartzo-feldspathic gneisses, porphyroblastic albite gneisses, Albeşti granites, amphibolites, and quartzites;
- point 2679: quartzo-feldspathic gneisses, porphyroblastic albite gneisses, amphibolic gneisses, Albeşti granites, quartz, quartzites, and lamprophyres;
- point 2680: quartzo-feldspathic gneisses, quartz, quartzites, and sandstones.

Potopului Valley (4 points, 16 samples): gravel outcrops and pebbles deposits;

- point 2672: quartz, quartzo-feldspathic gneisses, porphyroblastic albite gneisses, quartzites, Albeşti granites, amphibolites, and reddish limestone with calcite joints;
- point 2673: quartz, hematite-bearing quartz, and quartzites;
- point 2674: quartz, hematite-bearing quartz, quartzo-feldspathic gneisses, black quartzites, and amphibolites;
- point 2675: quartz, quartzo-feldspathic gneisses, quartzites, and jaspers.

Butoiu Valley (1 point, 3 samples): outcrops of loamy sands with lenses of fine-grained gravels, pebbles deposits;

- point 2676: quartz (90 %), quartzo-feldspathic gneisses, amphibolites, amphibolic gneisses, and Albeşti granites.

Valley of Băr (2 points, 4 samples): outcrops of sandy clays with intercalated sandstones, outcrops of sands with thin intercalations of clays, pebbles deposits, and boulders;

- point 2677: quartzo-feldspathic gneisses (coarse pebbles, rarely boulders), quartzites, quartz, Albeşti granites, amphibolic gneisses, amphibolites, and sandstones;
- point 2678: boulders of quartzo-feldspathic gneisses, quartz pebbles, boulders of quartzites.

Red Valley-Puţului Valley (2 points, 7 samples): deposits of cobbles, boulders *in situ* (on the Puţului Valley);

- point 2681: pebbles of quartz, quartzo-feldspathic gneisses, black quartzites, Albeşti granites, and quartzitic sandstones;
- point 2682: boulders of quartz, quartzo-feldspathic gneisses, and black quartzites, rarely pebbles of chlorite schists.

Mirii Creek (1 point, 8 samples): no outcrops, pebbles deposits;

- point 2683: pebbles of porphyroblastic albite gneisses, pebbles and boulders of quartz, pebbles of quartzo-feldspathic gneisses, and amphibolites, rarely Albeşti granites, augen gneisses, and basalts;

Mâzgana Valley (6 points, 27 samples): outcrops of sandy marl, gravels with sand intercalations, sands with erosion channels filled with gravel, pebbles deposits, rarely boulders;

- point 2684: quartzo-feldspathic gneisses, quartz, hematite-bearing quartz, black quartzites, amphibolites, and Albeşti granites, rarely chlorite schists;
- point 2685: quartzo-feldspathic gneisses, quartz, hematite-bearing quartz, black quartzites, rarely chlorite schists, amphibolites, and Albeşti granites;
- point 2686: quartzo-feldspathic gneisses, quartz, and quartzites, rarely porphyroblastic albite gneisses, amphibolites, Albeşti granites, and porphyritic microgranodiorites;
- point 2687: quartzo-feldsphatic gneisses, quartz, hematite-bearing quartz (boulders), and amphibolites;
- point 2688: outcrops of fine-grained gravel, with sand intercalations, pebbles of quartz, quartzo-feldspathic gneisses, and quartzites;
- point 2689: boulders of quartz and quartzites, rarely pebbles of amphibolites, exotic rocks, and sandstones.

Valley of Topor (2 points, 2 samples): outcrops of sand with gravel intercalations; rarely pebbles;

- point 2690: pebbles of quartz and quartzo-feldspathic gneisses, marls and sandstones;
- point 2691: sand outcrops, pebbles of quartz and quartzo-feldspathic gneisses;
- point 2692: pebbles of quartz, garnet-bearing mica gneisses, quartzites, black quartzites, basalts, quartzitic sandstones, and limestones.

Păducelu Valley (2 points, 9 samples): outcrops with succession of marls, sands, and gravels with boulders at the top, pebbles deposits and boulders;

- point 2693: pebbles of quartz, hematite-bearing quartz, quartzo-feldspathic gneisses, quartzites (boulders), and amphibolites, rarely menilites; blocks and fragments of sandstones, limestones, and conglomerates;

- point 2694: boulders of porphyroblastic albite gneisses, black quartzites, augen gneisses, and amphibolites; blocks and fragments of sandstones, limestones, and breccias.

Rudii Valley-Bolovanu Hill (3 points, 2 samples): outcrops of gravels with sands intercalations, outcrops of loamy sand, pebbles deposits, and boulders;

- point 2705: pebbles of quartzo-feldspathic gneisses, boulders of quartz and quartzites, pebbles of amphibolic gneisses and amphibolites;
- point 2706: boulders of quartzo-feldspathic gneisses and quartz;
- point 2707: boulders of quartzo-feldspathic gneisses and quartz, pebbles of hematite-bearing quartz.

The relative frequency of the petrographic types identified in the sampling points is as follows: quartzo-feldspathic gneisses (27 points), quartzites (25 points), amphibolites (15 points), Albeşti granites (12 points), porphyroblastic albite gneisses (6 points), amphibolic gneisses (4 points), chlorite schists (3 points), augen gneisses (2 points), and mica gneisses (1 points). Pebbles of magmatic rocks sporadically occur (4 points). The quartz, less relevant to identify a geological formation, is present in 28 sampling points. The hematite-bearing quartz pebbles occur in 7 sampling points spread over a wide area in the central-northern part of the piedmont. The pebbles of sedimentary rocks were not sampled, most of them coming from the Eocene and Oligocene deposits outcropping north of piedmont.

In order to compare the pebbles with the rocks in the primary source area were sampled some geological formations in the Iezer Mountains with lithologies similar to those found in Cândeşti Piedmont (quartzo-feldspathic gneisses, amphibolites, porphyroblastic albite gneisses, Albeşti granitic body, basalt, and lamprophyre dikes).

MICROSCOPIC STUDY

Quartzo-feldspathic gneisses. They represent the most common petrographic type in the gravels of Cândești Piedmont. These are weakly foliated leucocratic rocks with low micas content and homogenous macroscopic structure, sometime layered or microporphyroblastic. Under microscope, they frequently show intergranular cataclastic textures (Figs. 2 a-c).

The first metamorphic paragenesis consists of oligoclase, brown-greenish biotite (rich in Fe^{2+}), garnet, and quartz, to which sometimes it adds green hornblende. The second metamorphic paragenesis is unequally developed in the examined samples and contains microcline replacing the deformed oligoclase, epidote, and muscovite with iron oxides on the cleavage planes resulting from oxidizing breakdown of the biotite. Part of the Fe^{3+} cations released by the biotite oxidation enter in the lattice of the newly formed epidote together with the Ca^{2+} cations released by the oligoclase breakdown to microcline. The presence of microcline in the deformed spaces or epidote on fissures proves the mobility of the K^{+}, Ca^{2+} and Fe^{3+} cations. Subsequent alteration processes enhanced by deformation consist in the biotite chloritisation and the partial substitution of oligoclase by sericite and albite giving it a poikilitic aspect (Fig. 2d).

The quartzo-feldspathic gneisses outcrop exclusively on the north-western border of the Iezer Mountains in the Cumpăna Series (DIMITRESCU et al., 1974). These rocks develop on large surfaces in the Făgăraş Mountains within the Topolog leptynitic-amphibolitic formation of the Cumpăna Series (DIMITRESCU et al., 1985). The quartzo-feldspathic gneisses with poikilitic oligoclase were defined in the source area as microcline-bearing albitic gneisses outcropping in the Iezer Mountains (DIMITRESCU et al., 1971; DIMITRESCU et al., 1974), as well as in the Leaota Mountains (PATRULIUS et al., 1971) as distinct levels in porphyroblastic albite gneisses.

Porphyroblastic albite gneisses. These rocks are in fact mylonitized quartzo-feldspathic gneisses. The share plane (i.e. mylonitic foliation) are highlighted by wavy alignments of muscovite and chlorite enveloping albite porphyroblasts (Figs. 2e, f), and quartz aggregates in various stages of postkinematic recrystallization. Sometimes, it occurs a tectonic layering consisting in alternating QF (quartz and albite) and MF (mainly muscovite, chlorite, and albite) mineral domains. The albite porphyroblasts show poikilitic texture with very small inclusions of epidote, zoizite, sphene, and iron oxides arranged on the cleavage plane, often oriented at low angle towards the adjoining share planes. Besides the newly generated minerals, the albite poikiloblasts also contain microclasts of tourmaline and remnants of oligoclase. In their pressure shadows calcite sometimes crystallizes.

Due to their mylonitic foliation, the porphyroblastic albite gneisses were defined in the source area as porphyroblastic albite schists. These rocks develop on large surfaces both in the Iezer and Leaota Mountains, in Lereşti-Tămaş complex at the bottom of the Leaota Series (DIMITRESCU et al., 1971; DIMITRESCU et al., 1974; PATRULIUS et al., 1971).

Augen gneisses. The augen gneisses are also mylonitic rocks with lens-shaped coarse-grained oligoclase in a recrystallized matrix of oligoclase, quartz and red-brown biotite (rich in Fe^{3+} and Ti) with zircon inclusions. Oligoclase is partially or totally replaced by microcline and sometimes shows myrmekite coronas. The biotite is partially replaced by muscovite with Fe-Ti oxides on the cleavage plane.

The augen gneisses outcrop in the Iezer and Făgăraş Mountains, at the bottom of the Cumpăna Series (DIMITRESCU et al., 1971; 1974; 1978; 1985).

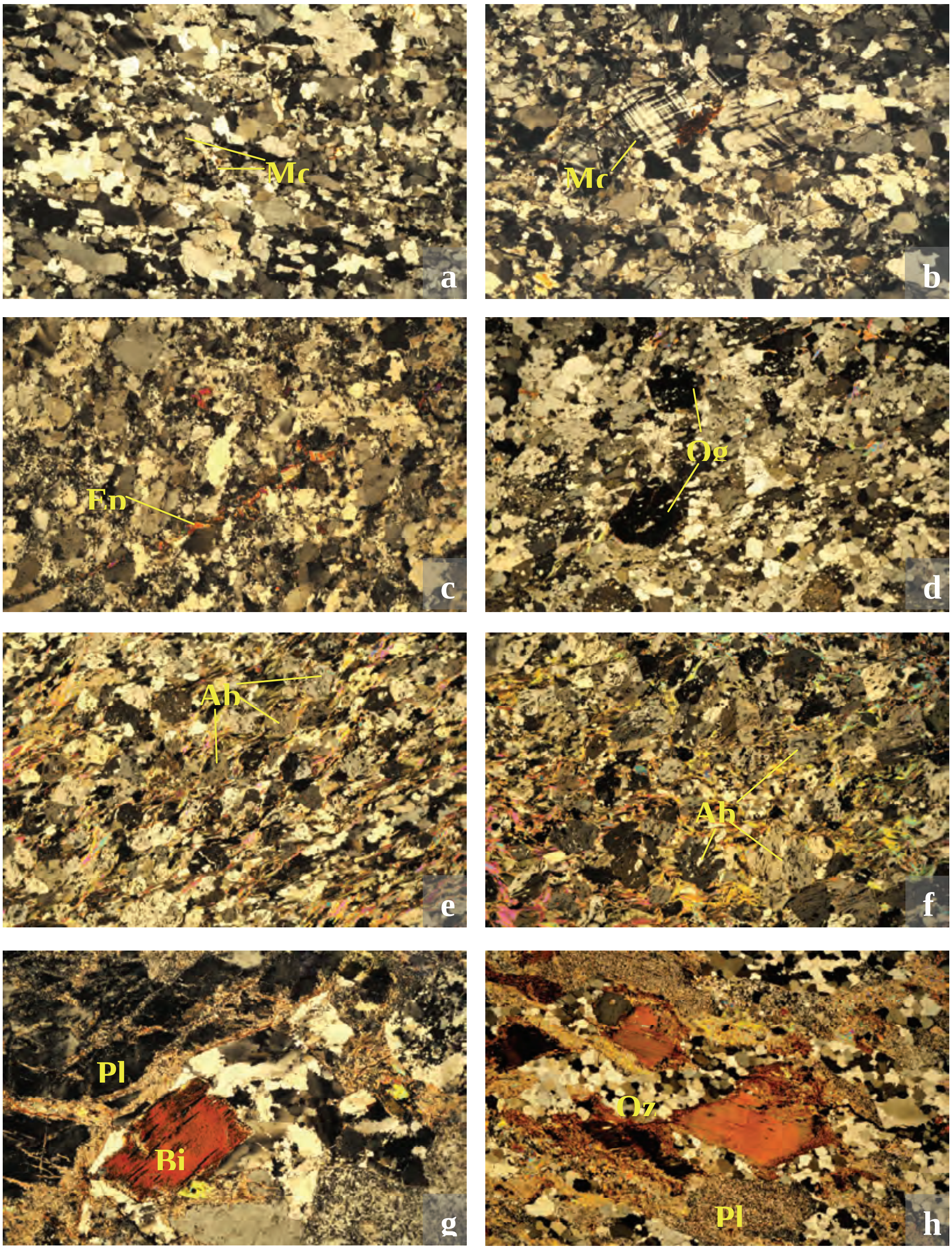

Figure 2. Microphotographs (30x, N+) in pebbles from Cândeşti Piedmont: a-c) quartzo-feldspathic gneisses with microcline in the deformed intergranular spaces (a, b) and epidote on fissures (c); d) quartzo-feldspathic gneisses with poikilitic oligoclase; e, f) porphyroblastic albite gneisses; g, h) deformed Albeşti granites with red biotite, sericitized plagioclase, and post-recrystallized quartz (h). Abbreviations: Mc - microcline; Ep - epidote; Og - oligoclase; Ab - albite; Pl - plagioclase; Bi - biotite; Qz - quartz.

Amphibolites. The mineralogical association of amphibolites is composed of green hornblende, as main mineral, plagioclase, quartz, garnet, and Fe-Ti oxides. As secondary minerals, there appear epidote, zoisite, clinozoisite, sphene, rutile, and chlorite formed at the expense of hornblende. The plagioclase is slightly sericitized and sometimes shows inclusions of epidote, sphene, and hornblende. The mylonitized samples contain two generations of hornblende, the first as porphyroclasts and the second as microblasts in the mylonitic matrix.

Amphibolic gneisses. In the amphibolic gneisses samples the amount of feldspar and quartz is higher to the detriment of hornblende and garnet. As secondary minerals, there appear chlorite and actinolite on hornblende, and sericite on plagioclase. Like the quartzo-feldspathic gneisses but less often, the amphibolic gneisses show intergranular cataclastic textures with microcline replacing the deformed oligoclase. In the mylonitized samples, both hornblende and garnet appear as porphyroclasts in a microblastic matrix of epidote, actinolite, and quartz.

The amphibolic rocks outcrop in the Iezer Mountains, the amphibolites as weakly retromorphosed levels in the chlorite schists of the Căluşu-Tămăşel complex at the upper part of the Leaota Series (PATRULIUS et al., 1971; DIMITRESCU et al., 1971; DIMITRESCU et al., 1974), and the amphibolic gneisses in various gneissic formations of the Cumpăna Series. The amphibolic gneisses are more frequent in the Făgăraş Mountains within the Topolog leptynitic-amphibolitic formation of the Cumpăna series (DIMITRESCU et al., 1985).

Chlorite schists. All three samples are mylonites with clasts of magnetite and chloritized Fe-Mg silicates, hornblende probably, in a matrix of chlorite, epidote, albite, quartz, zoisite and sphene. The albite grains contain chlorite and actinolite inclusions on the cleavage planes. The correspondent of chlorite schists in the source area is represented by the chlorite schists outcropping on large surfaces in the Iezer Mountains, in the Căluşu-Tămăşel metamorphic complex (DIMITRESCU et al., 1971).

Albeşti granites. The magmatic paragenesis is represented by coarse-grained plagioclase, red-brown biotite with inclusion of zircon and rutile (sagenitic texture), garnet, and apatite. The biotite show thin coronas of garnet on the contact with the plagioclase grains. Most of the plagioclase and garnet is sericitized while the biotite is partially replaced by muscovite and Fe-Ti oxides. The mineral substitutions were favoured by deformation, pointed out by anastomosing cracks in garnet, kink bands in biotite, deformation lamellae in plagioclase, and unstable grain boundary of quartz. However, the quartz often is post-kinematically recrystallized (Fig. 2 g, h).

The Albeşti Granite is a typical magmatic formation for the source area, for the Iezer Mountains especially. The reduced dimensions of the granitic bodies explain the relative scarcity of the granite pebbles in gravels.

Quartzites. The quartzites are fine-grained rocks composed almost entirely of quartz. As accessory minerals, there frequently appear powders of opaque minerals, rarely muscovite, magnetite, microblastic garnet, K-feldspar, rutile, and microclasts of tourmaline. Most of samples are in fact quartzitic mylonites in different stages of postkinematic recrystallization.

The quartzites occur as intercalations in various metamorphic formations in the Iezer Mountains and as quartzitic mylonites along the faults in the source area. The high frequency of quartzites in gravels is due to their high resistance to weathering and transport.

Hematite-bearing quartz. It is ~~a~~ white quartz, sometimes brecciated, with hematite occurring in scaly nests and on thin fissures together with muscovitised or chloritised biotite, albite, and biotitized garnet. The same minerals are also present in the quartz groundmass, but much rarer.

The hematite-bearing quartz pebbles sometimes contains remnants of porphyroblastic albite gneisses indicating their provenance from the porphyroblastic albite gneisses formation outcropping in the Iezer and Leaota Mountains, at the bottom of the Leaota Series.

Magmatic rocks. These rocks are represented by pebbles of lamprophyres, basalts and porphyritic microgranodiorites. The lamprophyre sample contains plagioclase and brown hornblende both in groundmass and phenocrysts. The basalt samples have a fine-grained groundmass of plagioclase and pyroxene with phenocrysts of clinopyroxene and sericitised plagioclase. The microgranodiorites are composed of a relative coarse-grained groundmass of plagioclase and small amounts of biotite and quartz, with rare plagioclase phenocrysts. In this groundmass, there sometimes appear restitic aggregates of plagioclase and biotite, suggesting the anatectic origin of magma.

In the source area, the basalt and the lamprophyre dikes outcrop in the Iezer Mountains only. The presence of the microgranodiorites pebbles is unexpected since these rocks outcrop in the Făgăraş Mountains far away from the source area.

Exotic petrographic types. In the upper basin of the Mâzgana Valley we found three pebbles with particular lithologies: a dark-blue hypersthenite, a black tourmalinite and a silicified wood. The hypersthenite is composed of primary coarse-grained hypersthene with intergranular secondary minerals (muscovite, antigorite, sphene, rutile, epidote, and clinozoisite) completely replacing another pyroxene species probably. The tourmalinite consists of a compact groundmass of microcrystalline tourmaline with intergranular opaque minerals.

Both pyroxenite and tourmalinite are rocks without correspondent in the proximal source area. The silicified wood is probably removed from the Miocene sedimentary formations outcropping south of Câmpulung-Muscel, where PETRESCU (1976) described oak wood (Quercoxylon).

CONCLUSIONS

Amongst the petrographic types identified in the gravels of Cândeşti Piedmont, only the quartzo-feldspathic gneisses, the porphyroblastic albite gneisses, and the chlorite schists outcrop as metamorphic formations widely developed in the source area. Without taking into account the quartz and the quartzites, most pebbles consists in quartzo-feldspathic gneisses outcropping in the Iezer Mountains as well as in the Făgăraş Muntains, at the upper part of the Cumpăna Series. The porphyroblastic albite gneisses outcrop in the Iezer and Leaota Mountains, in the lower metamorphic complex of the Leaota Series. The chlorite schists especially occur in the Iezer Mountains, in the upper complex of the Leaota Series.

The other petrographic types outcrop in the source area as thin intercalations or small geologic bodies in various metamorphic formations. Of these, the amphibolic rocks and the Albeşti granites are more frequent in gravels. The amphibolites outcrop in the Iezer Mountains as intercalations in chlorite schists and the amphibolic gneisses outcrop both in the Iezer and Făgăraş Mountains, associated with the quartzo-feldspathic gneisses of the Cumpăna Series. The Albeşti Granite mainly outcrops in the Iezer Mountains.

Hematite-bearing quartz occurrences are not known in the source area but it may be identified by detailed geological mapping. The hematite-bearing quartz originates from the porphyroblastic albite gneisses in which probably appear as small metamorphic segregations, unrepresented on the existing geological maps.

Geological formations widely developed in the Iezer Mountains, but poorly represented in the piedmont gravels are the mica gneisses and the micaschists (any pebble) outcropping in the Iezer Mountains, at the upper part of the Cumpăna Series. The explanation can only be their low weathering and transport resistance. The augen gneisses, also rare, were less exposed to erosion since these rocks represent the lower level of the Cumpăna Series.

It is assumed that the tectonized geological formations within the source area were more easily eroded. Many of the rocks that appear as pebbles in the piedmont gravels are frequently deformed whatever their petrographic type. The porphyroblastic albite gneisses, chlorite schists, quartzites, and Albeşti granites samples have an undoubted mylonitic character.

As a general conclusion, the main source area of the gravels within Cândeşti Piedmont is the crystalline basement of the Iezer Mountains with the two metamorphic entities, Cumpăna Series at the lower part and Leaota Series at the upper part. The anticipated influx from the Leaota Mountains is modest, but a certain contribution of quartzo-feldspathic gneisses from the Făgăraş Mountains could be taken into account. Based on these considerations, we appreciate that the main transport direction of the clastic material was NNW-SSE.

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