# STRUCTURAL AND LITHOLOGICAL RELICS IN THE GETIC CRYSTALLINE OF THE SOUTH CARPATHIANS

**STELEA Ion**

**Abstract.** The metamorphic history of the Getic Crystalline in the Central South Carpathians (Sebeș-Cibin Massif) is related to two medium-grade regional metamorphism events, the first syn-collisional, M1 (Cadomian), and the second synchronous with the post-collisional uplift, M2 (Hercynian) The structure of the metamorphic pile is tabular and subhorizontal, consistent with the S2 flattening foliation, resulting from the vertical compressive stress associated with the post-collisional uplift. In the Eastern South Carpathians (Făgăraș Massif) the metamorphic pile is partially affected by Alpine retromorphism (M3) and partially restructured according to the associated axial plane foliation (S3). In this regional framework, relict structures and lithologies (pre-M1) locally occur, suggesting the existence of a pre-collisional metamorphic episode M0 (Precambrian).

**Keywords:** Getic Crystalline, relict structures, granulites, hornfelses.

**Rezumat. Relicte structurale și litologice în Cristalinul Getic al Carpaților Meridionali.** Istoria metamorfică a Cristalinului Getic din Carpații Meridionali Centrali (Masivul Sebeș-Cibin) se raportează la două evenimente de metamorfism regional de grad mediu, primul sin-colizional, M1 (Cadomian), și al doilea sincron cu up-liftul post-colizional, M2 (Hercinic). Structura stivei metamorfice este tabulară și suborizontală, concordantă cu foliația de aplatizare S2, rezultat al stresului compresional vertical asociat up-liftului post-colizional. În Carpații Meridionali de Est (Masivul Făgăraș) stiva metamorfică este parțial afectată de retromorfism alpin (M3) și parțial restructurată conform foliației de plan axial asociate (S3). În acest cadru regional apar local structuri și litologii relicte (pre-M1) care sugerează existența unui episod metamorfic pre-colizional M0 (Precambrian).

**Cuvinte cheie:** Cristalinul Getic, structuri relicte, granulite, corneene.

## INTRODUCTION

At the current level of erosion, four metamorphic formations outcrop in the crystalline basement of the Central South Carpathians arranged in the following succession from bottom to top: augen gneisses, micaceous gneisses, quartz-feldspathic gneisses, frequently associated with amphibolitic rocks, and micaschists. Their metamorphic history is related to two medium-grade regional metamorphic events, the first syn-collisional, i.e. M1 (Cadomian), and the second synchronous with the post-collisional up-lift, i.e. M2 (Hercynian). The structure of the metamorphic pile is tabular and subhorizontal, consistent with the S2 flattening foliation, resulting from the vertical compressive stress associated with the post-collisional uplift. The structure is not affected by subsequent penetrative deformations.

East of the Olt River, the crystalline basement of the Făgăraș Mountains is affected by alpine folds, especially on their northern slope. The folds are large on the southern slope, where the four metamorphic formations from the Sebeș-Cibin Massif area can be recognized (STELEA, 2006), and isoclinal on the northern slope, where the metamorphic formations can only be intuited but not cartographically separated, they being strongly affected by the Alpine retromorphism (M3) and restructured according to associated subvertical axial plane foliation (S3).

Also relevant for the succession of metamorphic events in the area of the South Carpathians are the relict pre-M2 lithologies that appear in the four formations, associated with relatively simple mesostructures. Coarse biotite granite cores in augen gneisses (STELEA, 1994; 2000), microgranite facies in quartzo-feldspathic gneisses, and lenses of diorites and gabbros in amphibolite gneisses are common. Much rarer and more complex are the pre-M1 mesostructures, such as granulite enclaves in the granitic protoliths of the metagranitic gneisses or the particular lithologies such as the cordierite and sillimanite hornfels, found only as fragments. From a genetic point of view, this hornfels is analogous to the hornfels with cordierite and andalusite cited by IONESCU-BUJOR (1911) in the Şușita Granite. In the present paper we present some such particular aspects of the Getic Crystalline, recorded many years ago during the geological mapping and studies in the South Carpathians.

## STRUCTURAL AND PETROGRAPHIC STUDY

**Pre-M2 relict structures in the Sebeș Mountains**. In the stromatitic and augen gneisses of the upper basin of the Mărtinie Valley (left tributary of the Sebeș Valley) an outcrop occurred in 1988, with an ellipsoidal body of massive diorites (maximum dimensions 4x2 m) enveloped in amphibolitic gneisses with thicknesses of 1.5-0.5 m. The entire mesostructure is included in augen gneisses structured in the plane of the S2 regional foliation associated with the M2 metamorphic event (Fig. 1). Obviously, the diorite represents a syn-M1 relict lithology, a protolith of the amphibolitic gneisses structured in the plane of the syn-M2 metamorphic foliation.

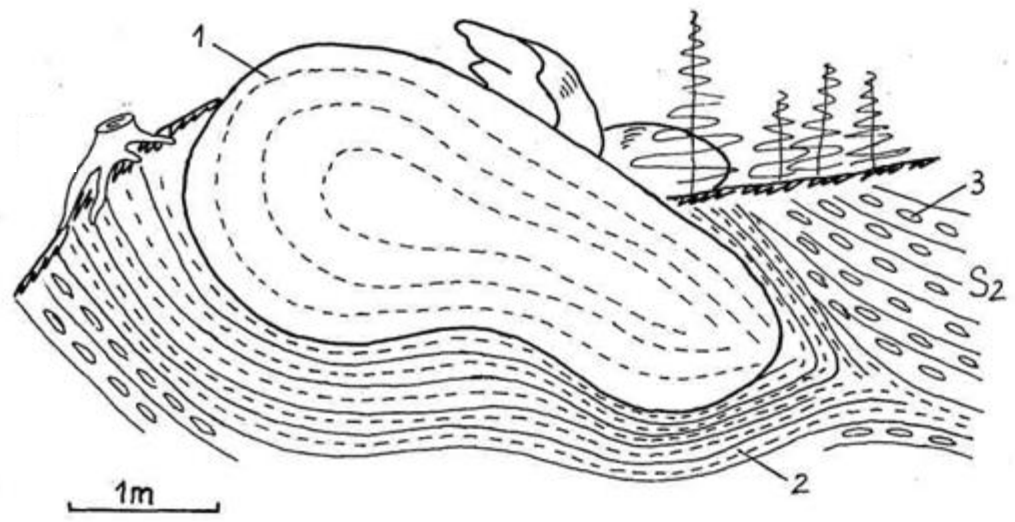


Figure 1. Outcrop sketch. Ellipsoidal body of massive diorites (1) enveloped by amphibolic gneisses (2) included in augen gneisses (3). Curves shown with dashed lines within the diorite body represent the preferential orientation of amphiboles. Mărtinie Valley.

The S2 foliation in the amphibolitic gneisses is circumscribed to the ellipsoidal shape of the relict diorite body. An early syn-M2 foliation within the diorite body is suggested by the preferential concentric orientation of the amphiboles, imposed by the curvature of the lithological contrast surface that induces the decomposition of the vertical compressive stress into a stress normal to the surface of the ellipsoid and one parallel to it (non-coaxial flow through solid state diffusion). Unfortunately, we did not sample the amphibolitic gneisses and the diorite protolith.

**Pre-M1 relict structures in the Cibin Mountains**. Also in 1988, on the right side of the Sebeș Valley, between the confluences with the Ciban and Prigoana rivers, there was (now it no longer exists) an outcrop of quartzo-feldspathic gneisses with muscovitized biotite in which a lens with a complex internal structure appeared (Fig. 2). The lens contains lithons of biotite-bearing quartzo-feldspathic gneisses showing convoluted folds typical of intensely metamorphosed rocks (sin-M1 plastic strain) and lithons of biotite and muscovite-bearing quartzo-feldspathic gneisses, locally affected by microfolds with an axial plane cleavage parallel to the S2 foliation from the outside of the lens (sin-M2 plastic-cataclastic strain). More interesting is the fact that the central lens of quartzo-feldspathic gneisses with biotite contains three granulite lenses with submetric dimensions and slightly plastically deformed (Fig. 2). Within this mesostructure, the granulite lenses can only be interpreted as enclaves from a metamorphosed rock in granulitic facies, lithological witnesses of a metamorphism episode prior to the M1 metamorphic event.

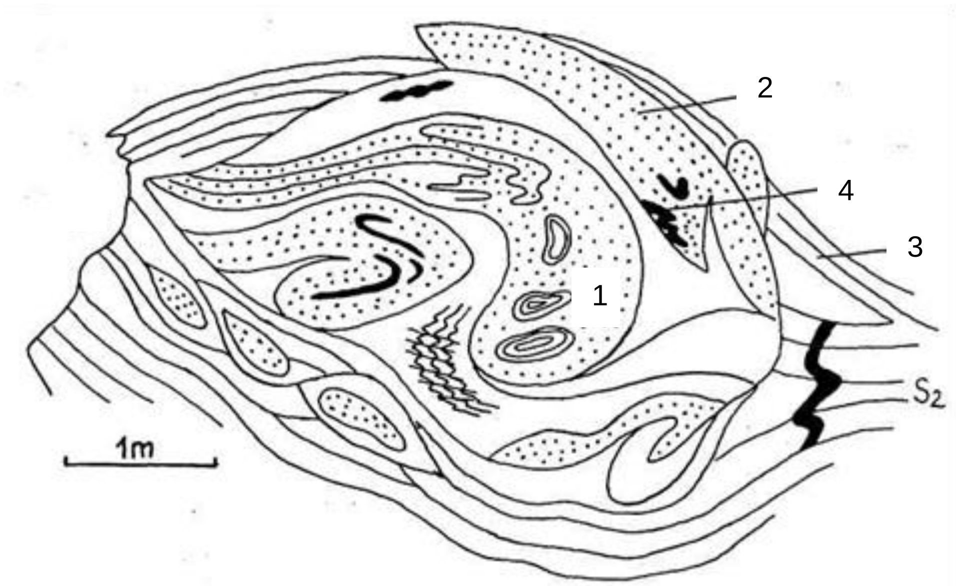


Figure 2. Outcrop sketch. Lens with complex internal structure flattened in the plane of S2 foliation (sin-M2). 1) three granulite lenses with cordierite (sin-M0); 2) biotite-bearing quartzo-feldspathic gneisses (syn-M1); 3) quartzo-feldspathic gneisses with muscovitized biotite (syn-M2); 4) quartz inclusions and veins. Sebeș Valley. Details in text.

The granulites in the three lenses are identical. Their mineralogical association consists of zoisite, hornblende, cordierite, garnet, quartz and oligoclase with 30% anorthite (Fig. 3a). Zircon, sphene, xenotime and monazite appear as accessory minerals. The rock texture is poorly oriented, the minerals are not altered and do not show internal deformations. The only transformation occurs in cordierite which goes from the high-temperature, anhydrous form to the lower-temperature, hydrated form. The anhydrous cordierite (I) has lower relief and shows good parting, while the low-temperature cordierite (II) has higher relief and does not show parting.

The pre-M2 lithon containing the granulite lenses consists of quartzo-feldspathic gneisses with oligoclase (15% anorthite) and reddish-brown biotite. The mineral association also contains cordierite (I and II), quartz, hematite, magnetite, apatite and zircon, the last as inclusions in biotite (Fig. 3b). The texture is massive, but the biotite alignments are oriented in the same direction. The quartzo-feldspathic gneisses outside of the lens, partially entrained inside, have a similar mineralogical composition but are relatively retromorphosed, the biotite being mostly replaced by muscovite.

If the interpretation of this structure is correct, we must admit that, before the M1 metamorphic event, another metamorphism (M0) took place, in the granulitic facies. This would mean that the metamorphic history of the Getic Crystalline in the Central South Carpathians actually relates to three metamorphic events, M0 Precambrian, pre-collisional, M1 Cadomian, syn-collisional, and M2 Hercynian, associated with the post-collisional uplift.

**Cordierite-bearing hornfels (Sebeș Mountains)**. It is a pelitic hornfels, with no known correspondent in the Getic Crystalline of the region. I found a single fragment, with dimensions of 20 x 10 cm, in 2006 on the upper course of Cugirul Mare Valley together with fragments and blocks of quartzo-feldspathic gneisses, ultrabasic rocks and pegmatites, rocks characteristic of the formation of quartzo-feldspathic gneisses. It is a rock of green colour, with films of iron hydroxides, extremely hard, with conchoidal breaking (Fig. 3a). Under the microscope it appears as a micro- and cryptocrystalline mass with massive texture, locally fluid with a chaotic appearance. It consists of cordierite, potassium feldspar and quartz, trapped in a network of secondary minerals (chlorite, sericite, iron oxides and hydroxides). Some cordierite grains have a radial structure. Relict cordierite phenocrysts, magmatically corroded by the matrix, also rarely occur, frequently with acicular inclusions of sillimanite.


Figure 3. a) Fragment of cordierite-bearing hornfels (Sebeș Mountains).
b) Granulite enclave in syn-M1 granites (Făgăraș Mountains).

The textural features of the rock suggest two phases of formation. In the first phase, a hornfels with cordierite phenocrysts and massively textured matrix formed in the thermal aureole of a granitic batholith. In the second phase, the rock or blocks of this rock were enclaved in the granitic body where they underwent partial melting, as shown by fluid textures in the matrix and magmatic corrosion of cordierite phenocrysts. Both phases of thermal contact metamorphism should predate the M1 metamorphic event when the granites were metamorphosed into gneisses. From a genetic point of view, the significance of the hornfels with cordierite and sillimanite is somewhat similar to that of the hornfels with cordierite and andalusite mentioned by IONESCU-BUJOR (1911) in the Sușita granite from the Vâlcan Mountains, the result of a thermal contact metamorphism.

Regarding the source area, the fragment definitely comes from the upper part of the quartzo-feldspathic gneiss formation, which outcrops on both sides of the valley and at its springs. The granite responsible for the formation of the cordierite bearing hornfels could even be the protolith granite of the quartzo-feldspathic gneisses of the Cugir Valley basin. The hornfels with cordierite and sillimanite described above would also be an argument regarding the existence of an older episode of metamorphism (M0) in the history of the Getic Crystalline of the Central South Carpathians.

**Granulite enclave in syn-M1 granites (Făgăraș Mountains)**. The coarse-grained biotite granites represent the protolith of the augen gneisses at the base of the crystalline in the Central and Eastern South Carpathians. In 2015, we found a granulite enclave in a block of biotite granite from the Făgăraș Mountains, Argeș River basin (Fig. 3b). The mineralogical association of this granulite consists of quartz, zoisite, clinozoisite, cordierite, chlorite, secondary to biotite, muscovite and garnet. Accessory minerals are sphene, xenotime, apatite, hematite, magnetite and zircon. The rock has a massive texture, the femic minerals (zoisite, clinozoisite, biotite, garnet) making up a network in the meshes of which crystallized the salic minerals (quartz, cordierite, oligoclase).

The relics of biotite-bearing granites in the augen gneisses from the basement of the Getic Crystalline are pre-M2. On the tectonic discrimination diagrams, the biotite granites are projected in the field of syn-collisional granites (STELEA, 2000), i.e. syn-M1. Therefore, the granulite enclaves in the granites are pre-M1. These enclaves also represent arguments of a pre-collision M0 metamorphic episode in the history of the crystalline basement of the Făgăraş Mountains.

## DISCUSSIONS AND CONCLUSIONS

Granulite enclaves with cordierite present in the biotite quartzo-feldspathic gneiss lenses (syn-M1) from the muscovitized biotite quartz-feldspathic gneisses (syn-M2) as in the granite cores (syn-M1) from the augen gneisses (sin-M2 ) represent relicts of a pre-M1 metamorphism in granulitic facies which in chronological order would be M0. In this logic, the Precambrian U/Pb age of 1000-1100 Ma (Neoproterozoic) on zircons from metagranitic gneisses (PAVELESCU et al., 1983) makes sense. This Precambrian age, unique in the Getic Crystalline, could represent the age of a syn-M0 metamorphic crust from which zircon was extracted by syn-M1 anatectic processes. Very likely, the thermal contact metamorphism that generated the cordierite and sillimanite bearing-hornfels is part of the history of an M0 metamorphic episode.

Of course, the presented data are scarce and currently cannot support the regional character of this metamorphism, which is why we avoided using the phrase “M0 metamorphic event” as much as possible, preferring the phrase “M0 metamorphic episode”. For the same reason, we also avoided making estimates regarding the PT conditions of the M0 metamorphic episode, which can only be local and variable from one point to another. However, such data, and it is very likely that others may also exist, cannot be ignored. They can open a wider perspective in the knowledge of the metamorphic history of the Getic Crystalline in the South Carpathians.

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