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CORDIERITE AND SILLIMANITE IN THE CENTRAL-EASTERN SOUTH CARPATHIANS (ROMANIA)

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Abstract. In this paper we report the presence of two generations of cordierite in all the metamorphic rocks of the central and eastern South Carpathian area (Sebeș, Cibin and Făgăraș Mountains). The cordierite I is part of the relic paragenesis of the Cadomian medium grade metamorphic event (M1), alongside with garnet, staurolite and kyanite, while the cordierite II is a product of the Hercynian metamorphic event (M2). In addition, in the central area of the Cibin Mountains and in the north-western Făgăraș Mountains, cordierite II is paragenetically associated with fibrolitic sillimanite. This paragenesis indicates a low-pressure, relatively high-temperature metamorphism that we also report in our paper. The two regions lie outside the classical area of low-pressure and high-temperature metamorphism of the Getic Nappe crystalline basement, currently circumscribed to the Danubian half-window (Godeanu, Mehedinți and Căpățâna mountains) as a result of post-thrust erosion of the nappe.

Keywords: cordierite, sillimanite, Făgăraș, Cibin, Sebeș mountains.

Rezumat. Cordierit și silimanit în Carpații Meridionali central-estici (România). În această lucrare raportăm prezența a două generații de cordierit în toate rocile metamorfice din aria Carpaților Meridionali centrali și de est (munții Sebeș, Cibin și Făgăraș). Cordieritul I face parte din parageneza relictă a evenimentului metamorfic Cadomian de grad mediu (M1), alături de granat, staurolit și disten, în timp ce cordieritul II este un produs al evenimentului metamorfic Hercinic (M2). În plus, în zona centrală a Munților Cibin și în nord-vestul Munților Făgăraș, cordieritul II se asociază paragenenetic cu silimanit fibrolitic. Această parageneză indică un metamorfism de presiune scăzută și temperatură relativ ridicată pe care de asemenea îl raportăm în lucrarea noastră. Cele două regiuni se află în afara ariei clasice cu metamorfism de presiune scăzută și temperatură ridicată al fundamentului cristalin al Pânzei Getice, actualmente circumscrisă semiferestrei danubiene (munții Godeanu, Mehedinți și Căpățâna), ca rezultat al eroziunii post-șariaj a pânzei.

Cuvinte cheie: cordierit, silimanit, munții Făgăraș, Cibin, Sebeș.

INTRODUCTION

In the South Carpathians area, the cordierite was mentioned for the first time in the Căpățâna Mountains, associated with sillimanite (MRAZEC & MUNTEANU-MURGOCI, 1897), then in the Lotru Mountains (GHIKA-BUDEȘTI, 1932), Godeanu Mountains (GHERASI, 1937; BERCIA, 1972), and Mehedinți Mountains (HÂRTOPANU, 1975). In fact, cordierite frequently occurs in all types of metamorphic rocks in the Sebeș, Cibin and Făgăraș mountains (Fig. 1), very likely also in the entire crystalline basement of the Carpathians. The reporting of the presence of cordierite on such a wide area, practically in the entire region of the central and eastern South Carpathians, represents the first contribution of the present paper.

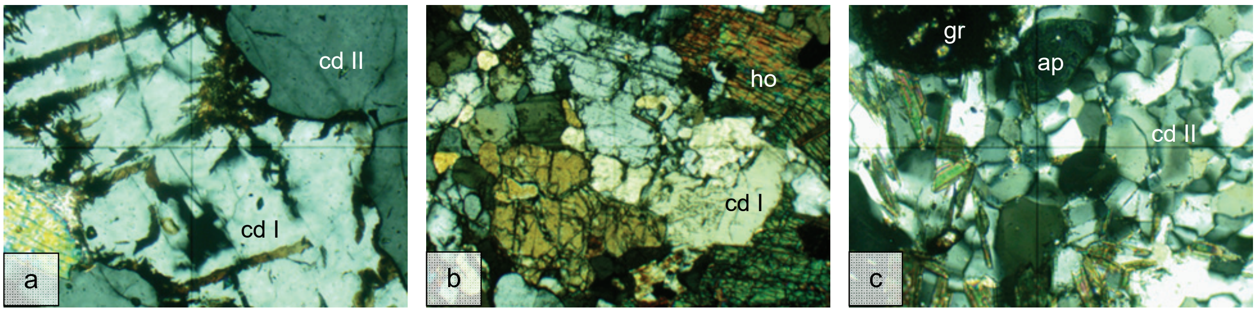

Figure 1. a) Mica schist with cordierite I (cd I) with biotite on the parting planes, corroded by cordierite II without parting (cd II); Cibin Mountains. b) Amphibolite with green hornblende (ho) and cordierite I (cd I) with lamellar and simple twins; Sebeș Mountains. c) Mylonitic gneiss with clasts of garnet (gr) and apatite (ap) in recrystallized matrix of cordierite II (cd II) and quartz; eastern Făgăraș Mountains. Cross-polarized light. The photos width is of 0,7 mm (a, c) and 4,2 mm (b).

In the central region of the Cibin Mountains (Păltiniș area and the upper basin of the Cibin River) as well as in the northwestern area of the Făgăraș Mountains, the cordierite-bearing rocks (micaschists, micaceous gneisses, quartzo-feldspathic gneisses) also contain fibrolitic sillimanite. The sillimanite-cordierite paragenesis indicates a low-pressure and relatively high-temperature facies of the M2 metamorphic event. The two regions with sillimanite and cordierite do not fit into the current metamorphic zonality in the crystalline basement of the South Carpathians according to which the areas of high-temperature and low-pressure metamorphism are arranged around the Danubian half-window of the Getic Nappe (BERCIA & HÂRTOPANU, 1980). Disparate occurrences of sillimanite and cordierite rocks also appear in the central region of the Sebeş Mountains. The identification of the cordierite-sillimanite paragenesis inside the medium-grade metamorphism area represents the second contribution of our paper. The fibrolitic sillimanite had already been mentioned previously in the south-western Sebeş Mountains (HÂRTOPANU, 1972), in the north-western Făgăraş Mountains (STELEA, 1992) and in the central area of the Cibin Mountains (STELEA, 2000).

THE METAMORPHIC REGIONAL CONTEXT

The cordierite was first identified in the South Carpathians by MRAZEC & MUNTEANU-MURGOCI (1897), in the gneisses of the Căpăţâna Mountains; the cordierite also contains acicular inclusions of sillimanite. Regarding the PT conditions of formation, the authors considered that there is a very probable thermal relationship between the cordierite-bearing gneisses and the granitic massifs in the Danubian half-window of the Getic Nappe. At that time, this assumption was reasonable because the Getic Nappe was not known, therefore neither the fact that the Getic gneisses and the Danubian granites belonged to different paleogeographic domains before the Mid-Cretaceous, when the Getic thrust took place (MUNTEANU-MURGOCI, 1910; CODARCEA, 1940).

GHIKA-BUDEŞTI (1934) described gneisses with cordierite, sillimanite and garnet in the Lotru Mountains, rocks which he also considered a thermal contact facies, with the mention that the author considered the Danubian granites, in this case the Parâng granitic massif, to be rooted. GHERASI (1937) described in the Godeanu Mountains gneisses and schists with sillimanite as well as gneisses with pinite which he considered to be very likely formed on the account of cordierite. The author does not make estimates regarding the PT formation conditions of the paragenesis sillimanite and cordierite.

A wide area of gneisses with fibrolitic sillimanite was outlined by GHIKA-BUDEŞTI (1940) in the Lotru Mountains and in the western part of the Căpăţâna Mountains, superimposed on the discontinuous areas of cordierite-bearing gneisses previously highlighted by the author in the same region (GHIKA-BUDEŞTI, 1934). In the western extension of this region, HÂRTOPANU (1972) identified disparate occurrences of sillimanite-bearing rocks (mica schists and gneisses) in the basin of the Eastern Jiu River and outlined a continuous area of sillimanite rocks on the south-western border of the Sebeş Mountains. In the author's opinion, the sillimanite was formed on account of an undeformed, second-generation of quartz, in fact a second-generation of cordierite.

BERCIA (1972) separated a domain of intermediate low-pressure metamorphism on the south-eastern border of the Godeanu Mountains, with three metamorphic zones: staurolite-andalusite, andalusite and sillimanite-cordierite-andalusite, delimited by metamorphic isogrades. It is noteworthy that the author attributes the PT conditions necessary to achieve this type of metamorphism to an isothermal decrease of pressure (i.e. rapid exhumation). HÂRTOPANU (1975) outlined an area of low-pressure metamorphism in the eastern Mehedinţi Mountains, with the following zones of metamorphism: andalusite-staurolite, andalusite-cordierite-staurolite, andalusite-sillimanite-cordierite and sillimanite-cordierite. In the author's opinion, the necessary favorable PT conditions were achieved by an isobaric growth of temperature (sic!), without further explanation. It is also worth noting that HÂRTOPANU (1986) excludes the staurolite from the low-pressure metamorphic paragenesis, a mineral that he rightly considers a relic, obviously referring to the first metamorphic event in the Getic Crystaline history, i.e. the medium-grade Cadomian metamorphism (M1).

Based on their previous works, BERCIA & HÂRTOPANU (1980) outline the low-pressure metamorphic domain in the Getic Crystalline (Sebeş-Lotru Series), circumscribed to the Danubian half-window (Căpăţâna, Godeanu and Mehedinţi mountains). The metamorphism zones in the Căpăţâna Mountains are sillimanite-cordierite and andalusite-staurolite-sillimanite. This is the Hercynian metamorphic event (M2), of low-pressure and relatively high-temperature. This time the two authors return to the old hypotheses regarding the cause of low-pressure metamorphism, namely the more or less direct contact of the Getic crystalline basement with the hot Danubian granites, therefore an isobaric increase of temperature. The authors omitted also to include in this metamorphic domain the area of gneisses with sillimanite and cordierite described by GHIKA-BUDEŞTI (1934) in the Lotru Mountains as a thermal contact facies.

PETROGRAPHIC STUDY

The general mineralogical association of cordierite-bearing rocks contains kyanite, staurolite, garnet and cordierite I (Figs. 1, 2), as relic minerals of the M1 metamorphic event, cordierite II (ubiquitous) and fibrolitic sillimanite, in some areas (Fig. 2), as neoformation minerals of the M2 metamorphic event. The two generations of cordierite have different physiographic characters. The cordierite I, of higher temperature, has lower refractive indices, shows obvious parting planes (Fig. 1a), is sometimes twinned, lamellar or simple twins (Fig. 1b), frequently pinitized, and contains inclusions of cordierite II, microblastic garnet (Fig. 1d), zircon, apatite (Fig. 1d), muscovite, biotite and opaque minerals, the last two frequently arranged on the parting planes (Fig.1a). It sometimes occurs as poikilitic phenoblasts, with inclusions of garnet, biotite and separations of cordierite II on discrete parting planes. Very rarely it includes idiomorphic biotite in the form of hexagonal crystals.

The cordierite II, of lower temperature, occurs in relatively large grains, usually in micaceous rocks, and in monomineralic aggregates or associated with quartz, usually in gneissic rocks. The mineral is fresh, untwined, without parting and shows anomalous birefringence colors (golden, blue), especially on the edges of the granules (Figs.1c, 2a). It contains inclusions of cordierite I, garnet, staurolite or kyanite, minerals which in turn may include cordierite II formed on their account. Relatively often, the sillimanite is formed on account of the cordierite II, especially in the Sebeş-Cibin Mountains and north-western Făgăraş Mountains (Fig. 2), sometimes at the expense of biotite.

Cordierite and sillimanite in the Cibin Mountains. The paragenesis sillimanite-cordierite II frequently occurs in the mica schists more or less mylonitized along the subhorizontal Păltiniş Shear Zone between the mica schists formation at the top of the Getic Crystalline and the underlying quartzo-feldspathic gneisses formation (STELEA, 2000). Geographically speaking, this paragenesis especially occurs in the Păltiniş area and the upper basin of the Cibin River. As a rule, sillimanite occurs in acicular fascicles (Fig. 2a, b), sometimes widely developed (Fig. 2c), included in post-kinematic aggregates of cordierite II. The mineral association also includes muscovite, margarite and post-cinematic chloritoid (STELEA, 2000). The relic M1 paragenesis consists of garnet, staurolite, kyanite and cordierite I. We also found cordierite II with acicular sillimanite inclusions in micaceous gneisses on the Valea Mânileasa, in the Lotru River basin (Fig. 2d).

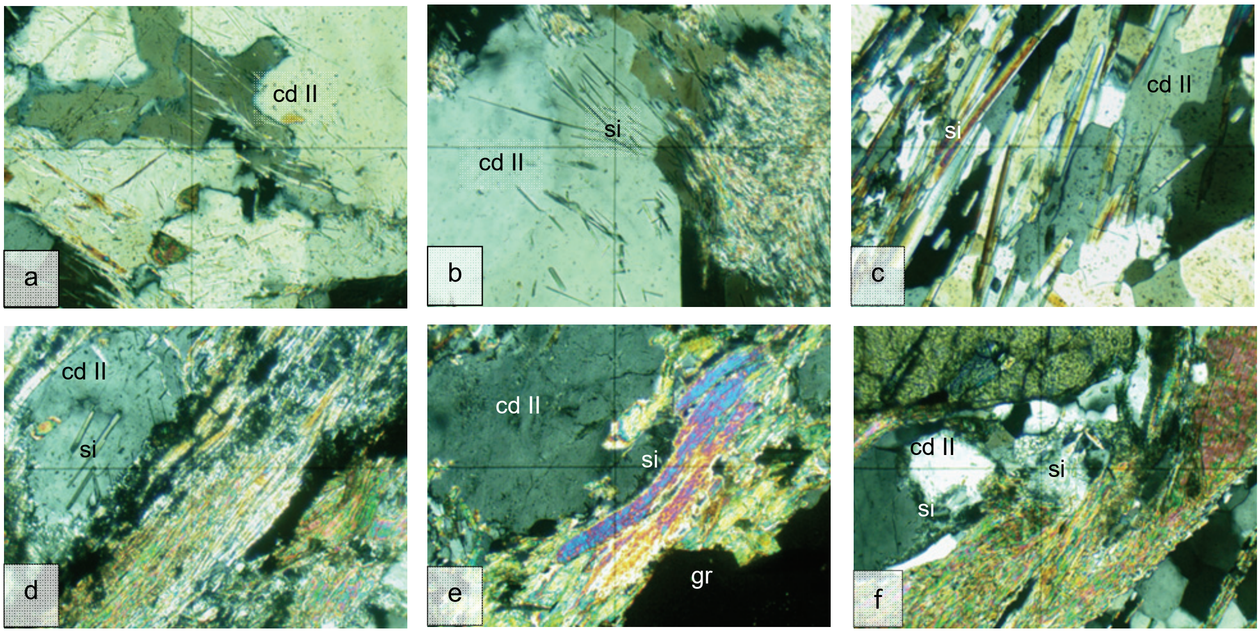

Figure 2. a). Mica schist with sillimanite fascicles in aggregates of cordierite II (cd II); Cibinul Mare Valley. b) Micaschist with sillimanite fascicles (si) in cordierite II (cd II); Păltiniș area. c) Mica schist with cordierite II (cd II) and large fascicle of sillimanite (si); Bătrâna Saddle. d) Gneiss with sillimanite (si) in cordierite II (cd II); Mânileasa Valley. e) Micaceous gneiss with relics of garnet (gr) and cordierite II (cd II) with microblastic sillimanite (si); Moașa Sebeșului Valley. f) Micaceous gneiss with relics of staurolite (st) and aggregates of cordierite II (cd II) with acicular sillimanite (si); Moașa Avrigului Valley. Cross-polarized light. The photos width is of 0,7 mm (a, b, d, e, f) and 1,4 mm (c).

Cordierite and sillimanite in the Făgăraş Mountains. The paragenesis sillimanite-cordierite II in this region is frequent the north-western part of the Făgăraş Mountains. Rare occurrences also occur in their central part, in the Negoiu Peak area. Sillimanite occurs as microblastic acicular nests in cordierite II (Fig. 2e, f) and even in cordierite I, frequently on the edge of the cordierite grains (Fig. 2e, f). Large sillimanite fascicles do not occur in the Făgăraş Mountains. As in the Cibin Mountains, the relic M1 paragenesis consist of garnet, staurolite, kyanite, cordierite I.

DISCUSSIONS AND CONCLUSIONS

The spatial distribution of the rocks with cordierite and sillimanite in the central area of the Cibin Mountains and the northwestern area of the Făgăraş Mountains is not circumscribed to the Getic Nappe half-window so that we can bring into discussion a possible thermal influence of the Danubian Hercynian granites, however incompatible with the Cretaceous age of the nappe, currently accepted without reservation by the geological community. As for the rocks with cordierite and sillimanite in the northwestern Făgăraş Mountains, they really have no tangency with the Danubian granites.

By the way, we do not see what thermal influence could have had the Hercynian granites of the Danubian domain on the crystalline of the Getic domain before these paleogeographic domains came into tectonic contact during the Cretaceous, when the Getic Nappe was emplaced. This fact would only have been possible if the Getic thrust had taken place during the Paleozoic. Of course, MUNTEANU-MURGOCI (1910) considered that the Getic thrust was initiated during the Paleozoic, a hypothesis also supported by STILLE (1953) and for which there are enough data in the southwestern part of the South Carpathians, in the area of the Almaj Mountains (e.g. BERCIA & BERCIA, 1980). But none of the authors cited above refers to a paroxysmal thrust phase during the Paleozoic, they only refer to the initiation or the first stage of the Getic thrust.

The cordierite-sillimanite paragenesis in the Cibin and Făgăraş mountains characterizes two crystalline islands located outside the known area of relatively high temperature and low-pressure metamorphism (Fig. 3). This paragenesis corresponds to the metamorphic zones with sillimanite and cordierite in the Lotru Mountains (GHIKA-BUDEŞTI, 1934), in the Mehedinți Mountains (HÂRTOPANU, 1975) and in the Căpățâna Mountains (BERCIA & HÂRTOPANU, 1980). The paragenesis with cordierite and sillimanite in the Cibin and Făgăraş mountains also indicates a low pressure and relatively high temperature metamorphism.

The presence of this type of metamorphism inside the medium-grade metamorphism area is a novelty that requires explanations. First, possible local causes can be invoked. In this sense, a tectonic heating could be taken into consideration on the Păltiniş Shear Zone, in the case of the Cibin Mountains, and on the ramifications of the Intramoesian Fault in its western compartment, where dykes of anatectic cordierite-bearing rhyodacites also appear (STELEA & GHENCIU, 2022), in the case of the Făgăraş Mountains. But it is unlikely that the tectonic movements on a subhorizontal shear zone, such as the Păltiniş Shear Zone, lead to low pressures in its adjacent compartments. The absence of andalusite in the associated mylonites is an argument for this. As for the Intramoesian Fault, it appeared late, during the Cretaceous, in the Alpine context of the differentiated movements of the peri-Carpathian platforms that led to the achievement of the current structure of the Carpathian arc.

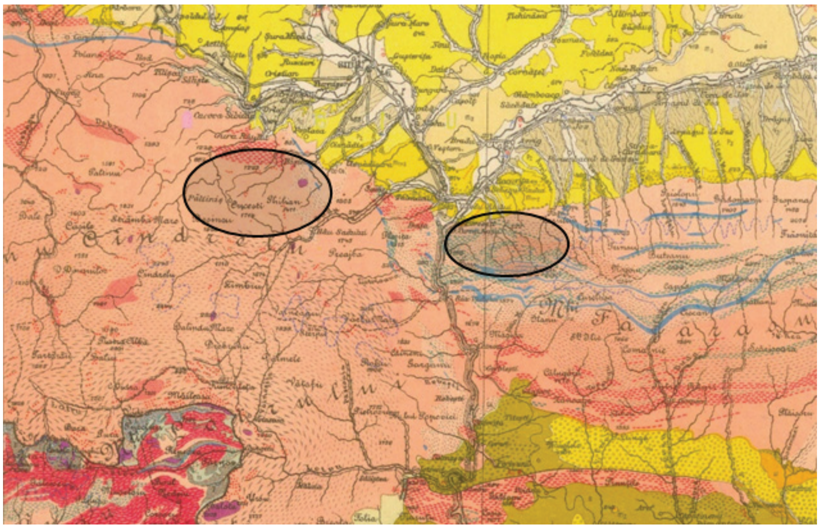

Figure 3. The two areas with frequent
cordierite and sillimanite in the Cibin and Făgăraş mountains.
Geological base according to the Geological Map of Romania, scale 1:500,000.

In our opinion, regional causes must be taken into account, the same ones that determined the metamorphic zonality in the southwestern area of the Getic Crystalline, with the difference that in the case of the Cibin and Făgăraş mountains cannot be invoked a possible thermal influence of the Danubian granites, anyway consolidated at the time of the Getic Nappe emplacement. These regional causes relate to the exhumation with different rates of the Getic Crystalline in its pre-Cretaceous paleogeographic domain, greater in the central area, today mostly eroded (the present areas of the Mehedinți, Godeanu, Căpățâna, Lotru, Cibin and northwestern Făgăraş mountains). It is reasonable to admit that the exhumation of such a large crustal block as the Getic Crystalline took place at different rates from one sector to another.

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