THE PUBLISHING HOUSE
OF THE ROMANIAN ACADEMY

GEONOMY
Research article

EVOLUTION OF ULTRAMAFIC ROCKS DURING THE REGIONAL METAMORPHISM IN SOUTH CARPATHIANS, ROMANIA

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Received January 21, 2012

The ultramafic bodies of peridotites and eclogites from the different series of crystalline schists from the South Carpathians represent olistoliths torn off from different ocean crusts and deposited in an ocean sedimentary formation. They have been metamorphosed together with the sedimentary formations, thus resulting the actual series of crystalline schists. In the Mesozoic anchimetamorphic Severin Nappe olistostrome (Mehedinti Plateau) and in the Paleozoic crystalline schists of the Poiana Ruscă Mountains, metamorphosed under the greenschist facies PT conditions, below 500^0C, the ultramafic rocks are represented by serpentinites. In the Pre-Variscan Sebeş-Lotru series, affected by a regional metamorphism of Barrovian-type, that reached the sillimanite isograde, the ultramafic bodies, metamorphosed at higher temperatures than 500^0C, are represented by recrystallized (secondary) peridotites. Under the same conditions of metamorphism the eclogite olistoliths have been amphibolized, either on the margins or totally, passing into retro-eclogites.

Key words: magmatic peridotite; eclogites; secondary peridotites; retro-eclogites; PT conditions.

INTRODUCTION

Except for the rocks from the thermal dome from the Getic Nappe crystalline schists[1] and those affected by the regional-contact metamorphism from the Danubian Autochthone[2], all the crystalline schists from the South Carpathians have been affected by the regional metamorphism of Barrovian-type, which reached the sillimanite isograde in the Sebeş-Lotru series.

The blocks of ultramafic rocks, including eclogites, which occur in the crystalline schists of mentioned series of South Carpathians, do not represent intrusive bodies, as it was previously supposed. They are olistoliths taken from the crust of the Pre-Variscan ocean, which evolved along the actual chain of South Carpathians, during its closing, and included in the ocean sedimentary deposits, where they have been metamorphosed together[3]. It is of note that within an ophiolitic suture ultramafic rocks may occur either as cumulate peridotites and troctolites formed at the base of some gabbroic and melagabbroic intrusive bodies, or as exotic blocks of peridotites and eclogites, all of them obducted from the ocean crust.

During the regional metamorphism the ultramafic olistoliths underwent different degrees of transformations. Therefore, in the present paper I studied the changes intervened in the mineral assemblages of ultramafic olistoliths from the different crystalline schists series of South Carpathians and compared them.

OCCURRENCE OF THE ULTRAMAFIC OLISTOLITHS IN THE OCEANIC SEDIMENTS AND THEIR METAMORPHISM

It is already known that the closing of the oceans is achieved by processes of subduction, either of ocean plate under ocean plate, or of ocean

*Paper presented by Acad. R. Dimitrescu.

plate under continental plate. During this process, in both cases, the oceanic crust is consumed either by subduction or by obduction and retro-obduction. Due to the last processes slabs (olistoliths) of different size are torn off from the oceanic crust, which are formed of basic rocks (basalts, gabbros) and ultramafic rocks like peridotites.and serpentinites. At the same time, the oceanic plate subducted through the subduction plane undergoes an eclogitization process. Thanks to the tectonic movements manifested themselves in the ocean area the eclogites formed along the subduction plane are also broken into slabs, which are deposited as olistoliths in the ocean sedimentary deposits. Further on, during the evolution of the ocean up to the collision process, the sedimentary deposits, including olistoliths, are affected by the regional metamorphism of different degrees, going from the anchimetamorphism stage up to the amphibolite and granulite stages (Table 1).

a. Ultramafic rocks in the unmetamorphosed ophiolitic sutures

Within the ophiolitic sutures, which have not been affected by any metamorphism, the ultramafic exotic blocks occur as formed of Alpine-type peridotites and serpentinites. There may also occur blocks of eclogites. The undeformed ultramafic blocks are present either as blocks of magmatic peridotites, obducted from the base of the ocean crust and the upper mantle, or as blocks of cumulate peridotites. In the first case the ultramafic rocks are represented by dunites, harzburgites and lherzolites, which present a massive structure and contain the following mineral assemblages:

1. Olivine (81 %) – diopside – hornblende – magnetite – chromite – platinum, in dunites.

2. Olivine (75 %) – orthopyroxene – diopside – picotite – magnetite – chromite, in lherzolites.

3. Olivine – diallage (diopside) – hornblende – biotite – magnetite, in harzburgites.

The blocks of cumulate peridottites came from the layers of peridotites formed at the base of some gabbro or melagabbro intrusions, located in the basalt complex of the oceanic crust, like in the Mureş ophiolitic suture[4]. The rocks show also a massive structure and contain the following mineral assemblage:

4. Olivine – clinopyroxene – brown hornblende – biotite – magnetite; sometimes small quantities of basic plagioclase are associated with.

It is of note that there are evident geochemical differences between the Alpine-type peridotites and the cumulate peridotites, the last being richer in both vanadium and chromium[5].

Although the stress was not active in the undeformed ophiolitic sutures, yet some olistoliths or olistoplates of serpentinites show local schistose structures, which could have been determined by the stress occurred between the two convergent plates, which determined the closing of the ocean and the obduction of the basic and ultramafic olistoliths. Similarly, they could have been deformed along some shear zones occurring in the ophiolitic suture, like the Gealacuta serpentinites from the Mureş ophiolitic suture[6]. These rocks show a schistose structure and contain the following mineral assemblage:

5. Antigorite – lizardite – chrisotile – iron oxidea; remnants of olivine crystals rarely occur associated in the assemblage. It is noteworthy to show that the easy serpentinization of ultramafic rocks is determined by the break of olivine, the main component of these rocks, which under metamorphic conditions is unstable below 500^0C[7].

b. Ultramafic rocks in the anchimetamorphic schists

An example of anchimetamorphic zone in the Alpine Carpathian amphibolitic suture, is the segment of the Mehedinti Plateau. There is characteristic the anchimetamorphic olistostrome from the Severin Nappe[8]. The age of the anchimetamorphism is of about 130 Ma (K/Ar). It manifested itself at temperatures of 200^0 to 345^0C, and affected both the ultramafic olistoliths and olistoplates from the Severin Nappe, as well as the Upper Jurassic- Neocomian sedimentary deposits from the matrix of the olistostrome. A general result of this anchimetamorphim was the flattening of the basalt pillows and the more advanced chloritization of the clinopyroxene from the basalts, so that these rocks exhibit a green tint in contrast with the black color of the undeformed basalts. In the anchimetamorphosed layers of jaspers from the olistostrome matrix the radiolaria forms have been flattened, too. The anchimetamorphim was a regional process influenced to a certain extent by the Getic Nappe load metamorphism, because in the pelitic matrix prehnite was sometimes observed.

The anchimetamorphosed ultramafic olistoliths have been strongly deformed and serpentinized, so

that they show a schistose structure. However, vestiges of the initial structure of the ultramafic rocks formed at the base of the oceanic crust are locally preserved. These are represented by a layered structure, which consists of a wehrlite horizon with inner pyroxenite layers, present in the serpentinites from the Severin Nappe olistostrome, but not deformed.

The most characteristic mineral assemblages from the ultramafic rocks occurring in the Severin Nappe olistostrome, determined by different laboratory equipments, look as follows:

6. Antigorite - magnetite
7. Chrysotile - magnetite
8. Antigorite-chrysotile-magnetite,

taken as a characteristic assemblage.

9. Talc-antigorite-montmorillonite, formed under the conditions of a supply of Al_2O_3 and SiO_2, introduced by the synmetamorphic aqueous solutions.

c. Ultramafic rocks in the crystalline schists of the greenschist facies.

As the metamorphism in the greenschist facies manifested itself at temperatures below 500^0C (Table 1), there are not important differences as against the features determined by the anchimetamorphism in the ultramafic rocks. However, it is of note that in the crystalline schists metamorphosed under the greenschist facies conditions from the Poiana Ruscă Mountains some serpentinite bodies occur, which do not show any phenomena of contact metamorphism. They also represent olistoliths of ultramafic rocks, metamorphosed under the same PT conditions as the host crystalline schists. The mineral assemblage in one of these ultramafic bodies, studied by Pavelescu[9], is as follows:

10. Antigorite – chrysotile – magnetite.

Some bodies of ultramafic rocks have been transformed into talc of low temperature, a mineral occurring in fine lamellae. Such bodies of talc occur at Lelese and Cerişor[10].

It is of note that during the metamorphism of low temperature the olistoliths of eclogites and jadeites have not been influenced in any way, as the olistoliths of such rocks from the Karaganda anchimetamorphic olistostrome from Central Asia and the Franciscan Formation of California showed.

d. Ultramafic rocks in the crystalline schists of the amphibolite and granulite facies

In the high-grade crystalline schists of the Sebeş-Lotru series, South Carpathians, there are numerous metamorphosed olistoliths of ultramafic rocks[11,3,12,13]. As shown on the maps by Savu *et al.*[14, 15], such bodies may occur between Voineasa, Ciunget, Şasa-Poeni and Măru. The ultramafic rocks occur as concordant lenses, intercalated in the terigenous and volcanogeneous crystalline schists of the Sebeş-Lotru series, which have been metamorphosed under the conditions of the kyanite and sillimanite isograde, from the Barrovian-type[16] of regional metamorphism, at 650^0 to 700^0C (Fig. 1).

A typical ultramafic body in the region is that situated on the Păscoaia Valley[3]. It has a length of 750 m and a thickness of about 200 m. The body consists of secondary (recrystallized) peridotites and is crossed by dykes of amphibolites resulted from initial dykes of pyroxenites. In these secondary peridotites the following general mineral assemblage occurs:

11. Olivine – rhombic pyroxene – talc – magnetite.

Table 1

Evolution of the ultramafic rocks during the regional metamorphism of Barrovian-type in South Carpathians

Metamorphism	Temperature^{0}C	Ultramafic rocks	Eclogites
Unmetamorphosed ultramafic rocks	–	Peridotites, erpentinites, pyroxenites	Eclogites
Anchimetamorphism	200–345	Serpentinites	Eclogites
Greenschist facies.	450–470	Serpentinites	Eclogites
Amphibolite facies and granulite facies.	650- <700	Recrystallized (secondary) peridotites	Amphibolized eclogites (retro-eclogites)

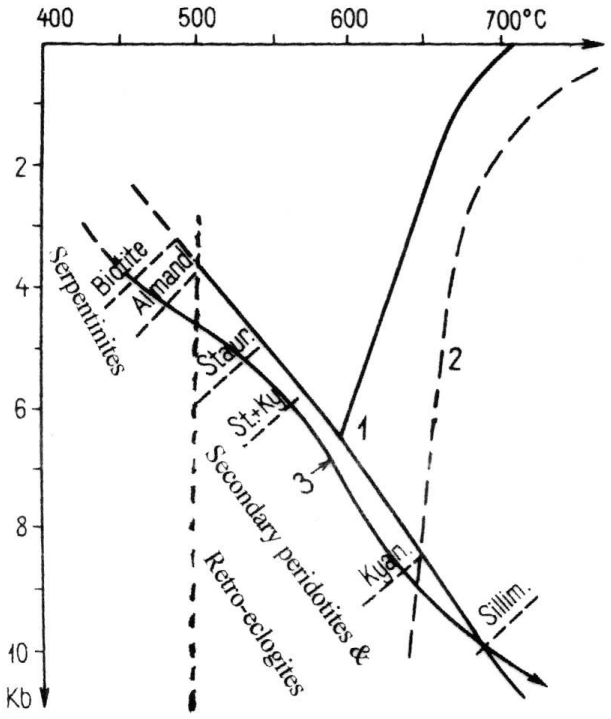

Fig. 1. PT diagram showing the curve of the regional metamorphism of Barrovian-type of the Sebeş-Lotru series and the position of ultramafic rocks as against it. 1, triple point[21]; 2, melting curve of granite[22]; 3, curve of the Barrovian-type metamorphism[23].

Taking into consideration the high temperatures at which the regional metamorphism manifested itself in the ultramafic body area, it results that the above mineral assemblage indicates a recrystallized ultramafic body, or a secondary peridotite body. This conclusion is supported by the presence of talc in the mineral assemblage, a mineral, which does not occur in the magmatic peridotites. Talc is present in these peridotites in well formed lamellae, which show that it represents a mineral of high temperature, differing from the talc of low temperature present as fine lamellae in the altered serpentinite bodies from the low temperature crystalline schists.

During the manifestation of the medium and high-grade regional metamorphism weak exchanges of substances took place between the ultramafic bodies rich in magnesium and the silica-aluminous host crystalline schists[17,18]. In this respect very interesting is the reaction of the talc body from the Pârvova Valley (Miniş series) from the Semenic Mountains and the host rocks represented by biotite – muscovite quartzitic schists from the biotite zone of regional metamorphism. At the contact of this talc body and the silica-aluminous crystalline schists a reaction zone of a reduced thickness was formed[17]. This zone is a monomineral zone, formed of biotitite. It reminds of the reaction zones described by Read[19]and Matthews [20] in Scotland.

The reaction biotitite zone was formed by the diffusion of Mg from the ultramafic rock and of Si, Al and K from the surrounding silica-aluminous crystalline schists during the regional metamorphism, under the biotite zone conditions (about 470^0C), according to the set-up made by Savu[17] (Fig. 7).

The recrystallized peridotite bodies have also been affected by the serpentinization. This process manifested itself only on the margins of the bodies, under the conditions of the diffusion of substances like Si, Al and Ca from the silica-aluminous crystalline schists into the ultramafic body. It shows that the reaction process was determined by the late-metamorphic solutions of low temperature, acting during the so-called autoretromorphism process.

Olistoliths of eclogites are also present in the Sebeş-Lotru series, as shown by the above quoted authors. Usually, they are amphibolized like retro-eclogites[13], either on the margins or totally, the new rock looking like a garnet amphibolite. A characteristic example is, in this respect, the body of eclogite located in the middle of an amphibolite lens from the crystalline schists of Leaota[24]. This structure suggests that this occurrence initially represented an eclogite olistolith, which was transformed into amphibolite (retro-eclogite) on the margin during the regional metamorphism of the Leaota crystalline schists.

DISCUSIONS AND CONCLUSIONS

The bodies of ultramafic rocks, including those of eclogites, from the crystalline schists of the Sebeş-Lotru series and other series of South Carpathians represent olistoliths, torn off from an Alpine-type oceanic crust and deposited in an olistostrome with a terigenous and tuffaceous matrix. All these rock-complexes have been metamorphosed during the regional metamorphism of Barrovian-type, which reached in the Sebeş-Lotru crystalline schist, for instnce, the sillimanite isograde.

Under these metamorphim conditions shown on the diagram in Figure 1, the ultramafic olistoliths formed of primary magmatic peridotites were transformed into serpentinites at low pressure and tenperature below 500^0C[7]. Above this temperature and at higher pressures the ultramafic olistoliths, serpentinized or not, recrystallized into secondary peridotites, in which talc of high temperature is

present. There results the following general assemblage: olivine – pyroxene – talc – magnetite.

Turner and Verhoogen[25], considering the results of the experimental researches, showed that above 500^0C olivine could not be converted into serpentine by any means. On the contrary, at these temperatures this mineral underwent the following transformations:

1. Between 500^0 and 625^0C, olivine changes into talc (of high temperature).

2. Between 625^0 and 800^0C, olivine passes to enstatite and talc.

These reactions confirm the general mineral assemblage formed in the recrystallized (secondary) peridotites from the Sebeş-Lotru series of South Carpathians.

Shortly, during the regional metamorphism the ultramafic rocks, intrusive bodies or olistoliths, pass through the following stages: First of all, the magmatic peridotites get serpentinized during the beginning of metamorphism under the greenschist facies conditions, below 500^oC, then, as the metamorphism increases above 500^oC, under the conditions of the amphibolite and granulite facies, the ultramafic rocks, peridotites or serpentinites, recrystallized as 'secondary peridotites'.

The olistoliths of eclogite have not been affected by the retromorphism during the anchimetamorphism and the metamorphism in the greenschist facies, but they have been amphibolized, either on the margins or totally depending on their size, during the regional metamorphism of high temperatures, thus changing into retro-eclogites[13].

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