GEOL. CROAT.	51/1	27 - 32	6 Figs.			ZAGREB 1998

Discovery of Blueschists in the Medvednica Mountain (Northern Croatia) and Their Significance for the Interpretation of the Geotectonic Evolution of the Area

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Key words: Blueschist, Sodic amphibole, Omphacite, Garnet, Subduction, Tethys, Medvednica Mt., Croatia.

Abstract

Blueschists were discovered in the metamorphic rocks of the ledvednica mountain. Two varieties of blueschists are recognised, ne with garnets and another with omphacite. Determined mineral ssociations are composed of sodic amphibole (glaucophane and rossite), garnet, omphacite and white mica. These mineral associaions indicate metamorphic conditions which are transitional between lueschist and eclogite facies, i.e. high pressures at relatively modeate temperatures (LG, HP/LT). Such conditions are often characterisic of subduction zones.

The occurrence of high-pressure metamorphic rocks in the Medednica mountain, together with local outcrops of ultramafic rocks serpentinised harzburgite, dunite and serpentinite) indicate subducon related rocks of the Dinaric part of the Tethyan oceanic crust. In le northern part of the Dinarides, ultramafic rocks and glaucophane chists have also been found in the Motajica and Fruška gora mounins. The Medvednica-Motajica-Fruška gora zone probably repreents a relict subduction zone in the Dinaridic part of Tethys, along hich regional high-pressure metamorphism took place.

1. INTRODUCTION

On the north-eastern slopes of Medvednica mounin, in the source region of the Žitomirka creek, a 10 m ng outcrop of blueschists was found (Fig. 1). The cks are tectonised. On the northern side the bluechists are in tectonic contact with marble schist, to the outh they are in tectonic contact with poorly stratified nassive) greyish-white marbles, while on the flanks le contacts are covered.

On the basis of numerous findings of detrital glauophane grains in the heavy mineral fractions of Mioene sediments in the Medvednica mountain area, IUTIĆ & DMITROVIĆ (1991) concluded that glaucoiane originated from a metamorphic complex present the mountain.

Previous petrological and geological mapping of the metamorphic complex of the Medvednica mountain revealed only the presence of greenschist facies rocks, represented by different ortho- and para- varieties (ŠIKIĆ et al., 1979; BASCH, 1983), while blueschist facies rocks were unknown.

Here, preliminary results of mineralogical and petrological investigations of the blueschists, obtained by optical (simple petrographic microscope) and XRD methods, are given together with an interpretation of their significance in the geotectonic evolution of the surrounding area. Information about mineral and rock chemistry is necessary for the improved determination of metamorphic facies, and such data will be presented later in another paper.

2. PETROGRAPHY OF BLUESCHISTS

Two main varieties of blueschists can be distinguished in the field. The first is fine-grained, with alternating greyish-red and greenish-blue centimetre-scale layers, as represented by sample M-2444A. In the second greenish-blue massive variety with indistinct schistosity, grains are macroscopically visible (sample M-2444B).

Sample M-2444A is determined as a garnet-blueschist with granoblastic texture, and subparallel laminated structure. This structure is probably conditioned by the primary lamination of the protolith. Garnet is the most abundant constituent (Figs. 2 & 3). It is euhedral, with six-sided or spherical cross sections, up to 0.05 mm in size. Sodic amphibole is usually subordinate but in some laminae it is as equally abundant as garnet. It occurs in prismatic grains, up to 0.1 x 0.02 mm, with diamond-shaped or six-sided cross sections with typical amphibole cleavage. Generally, the grains are inhomogenous with small inclusions of zircon. Amphibole shows no preferred orientation and very often contains garnet inclusions. It is strongly pleochroic: X = colourless to pale greenish-yellow, Y = blue and Z = violet. The Z axis of the indicatrix is parallel to *b* and the Y axis is nearly parallel to *c*. The extinction angle is less than 9°. The observed optical characteristics indicate that this sodic amphibole is crossite (Figs. 2 & 3). In

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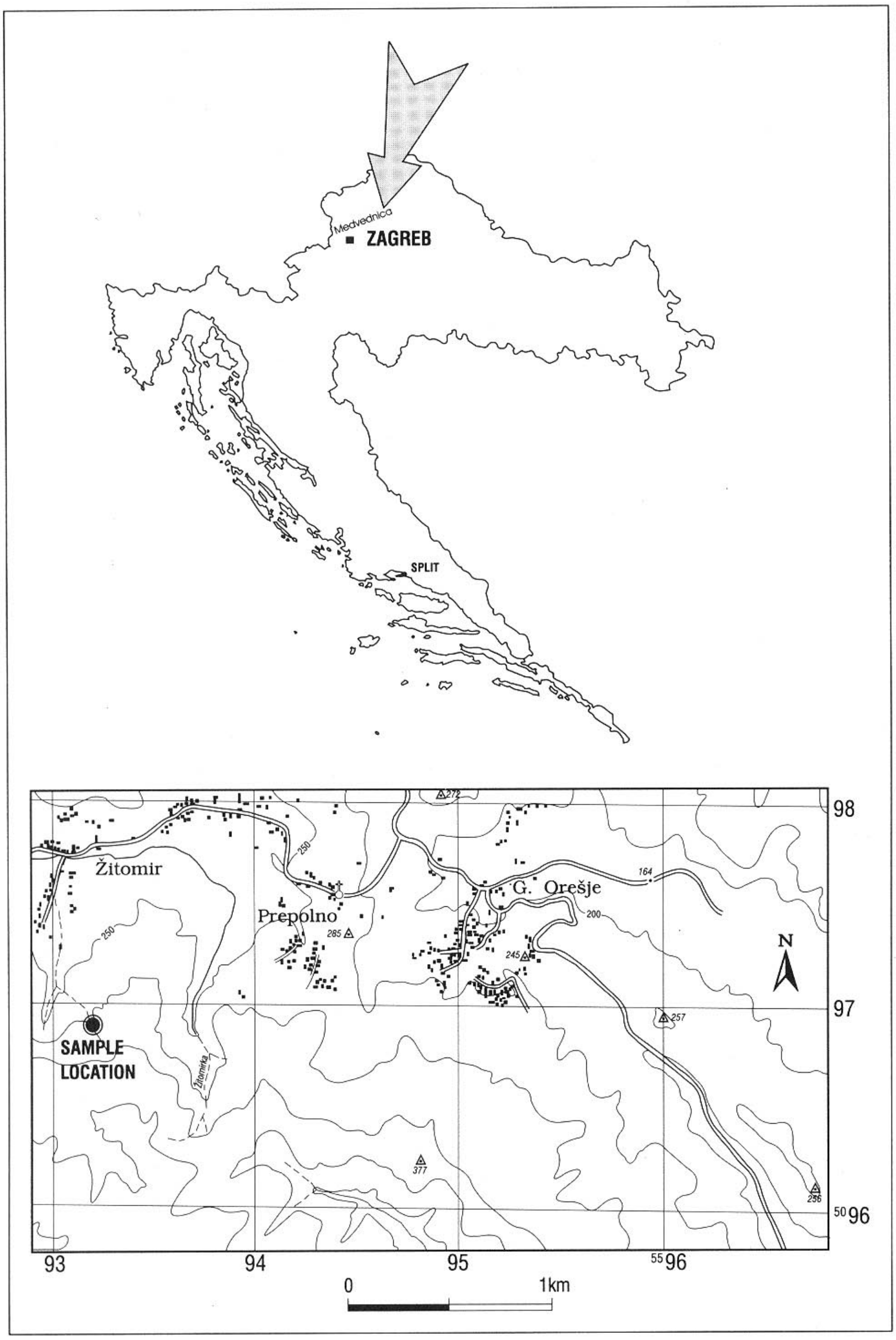

Fig. 1 Location map.

some layers agglomerates of inhomogenous plagioclase grains with carbonate inclusions were observed, while in others there is a somewhat higher concentration of hematite. White mica flakes are scarce.

Sample M-2444B is of omphacite-blueschist (Figs. 4 & 5). The texture is nematoblastic, while the structure is schistose because of the subparallel to crenulated orientation of white mica. The major constituent is sodic amphibole. The shape of this amphibole is the same as in the previous sample, but grains are bigger. It is usually 0.02 x 0.07 mm in size but some grains are up to 0.5 mm long. It is also inhomogeneous with small inclusions of zircon. Observed pleochroism is: X = colourless, Y = pale violet and Z = light blue. It is length slow with an extinction angle of 5-6. These optical characteristics correspond to glaucophane. The second major constituent is pyroxene, occuring in prismatic grains, up to 0.3 mm in size. In thin section, made perpendicular to schistosity, cross-sections are the most common with typical pyroxene cleavage. Grains are colourless to pale greenish-yellow and no pleochroism was observed. White mica is also an important constituent of the rock. Some plagioclase and quartz are also present. Unclear inhomogeneous sheaflike masses, derived by the alteration of opâque mineral to leucoxene, are an occasionally important accessory.

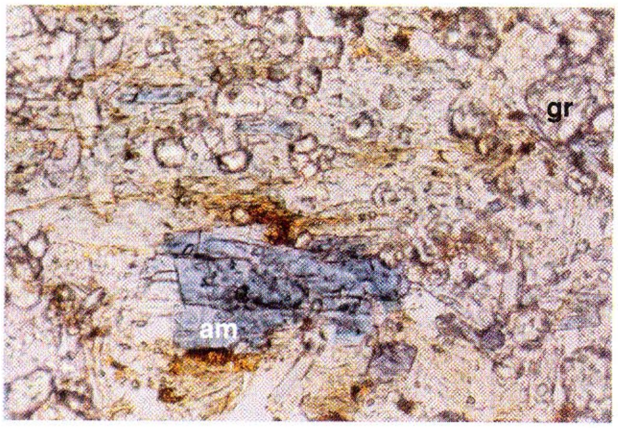

Fig. 2 Garnet-blueschist. Legend: gr) garnet with six-sided or spherical cross section; am) sodic amphibole (crossite) prismatic grains, showing blue colour characteristic for Y axis of indicatrix. N-, 205x, sample M-2444A.

Fig. 3 Garnet-blueschist. Legend: gr) garnet; am) sodic amphibole, violet colour is characteristic for Z axis of indicatrix. N-, 205x, sample M-2444A.

Whole rock powder samples of both varieties were investigated by the X-ray powder method. Powder patterns were recorded by a Philips powder diffractometer equipped with a vertical goniometer using CuK radiation and graphite monochromator. Quartz was added as an internal standard. Minerals were determined by comparison of the recorded patterns with the PDF-2 Database (ICDD, 1996). Unit cells dimensions were calculated by the UnitCell program (HOLLAND & REDFERN, 1997). Obtained results are in accordance with those obtained by optical methods.

In the sample M-2444A, hematite, amphibole group and garnet group minerals were determined. On the basis of the indexed X-ray pattern the following unit cell dimensions were calculated for amphibole:

$$a = 9.66\ (4)\ \text{Å}$$
$$b = 17.92\ (4)\ \text{Å}$$
$$c = 5.34\ (4)\ \text{Å}$$
$$\beta = 104.0\ (7)\ ^\circ$$

and garnet:

$$a = 11.675\ (6)\ \text{Å}.$$

The approximate composition of the amphibole group mineral was deduced by comparison of the recorded X-ray powder pattern and calculated unit cell dimensions, with the PDF-2 Database (ICDD, 1996). This amphibole belongs to the group of sodic amphiboles, and corresponds mostly to crossite.

In the sample M-2444B, the following mineral association was determined: mica (most probably 2M1 muscovite), amphibole and pyroxene. Because of line overlaps it was not possible to calculate the unit cell for this amphibole, but the shift of the 110 peak to the higher values, compared with amphibole in the first sample, indicate a somewhat different composition. The observed pattern of the pyroxene group mineral corresponds to omphacite. Calculated unit cell dimensions

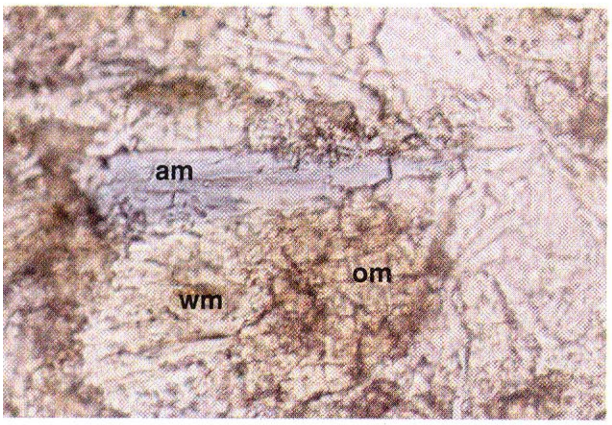

Fig. 4 Omphacite-blueschist. Legend: om) omphacite cross-sections with typical pyroxene cleavage; am) sodic amphibole (glaucophane) prismatic grains, showing light blue colour characteristic for Z axis of indicatrix; wm) white mica. N-, 205x, sample M-2444B.

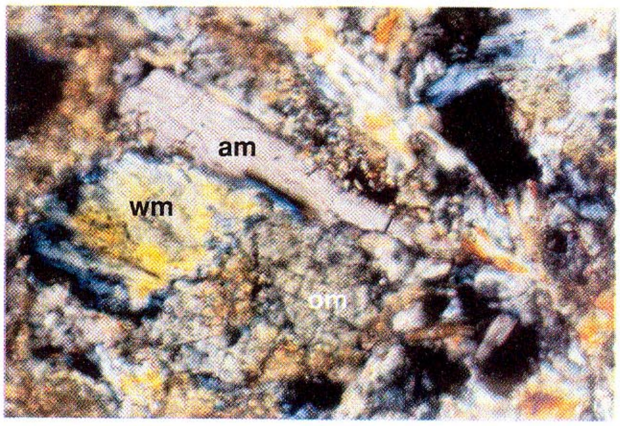

Fig. 5 Omphacite-blueschist. Legend: om) omphacite; am) sodic amphibole; wm) white mica. N+, 205x, sample M-2444B.

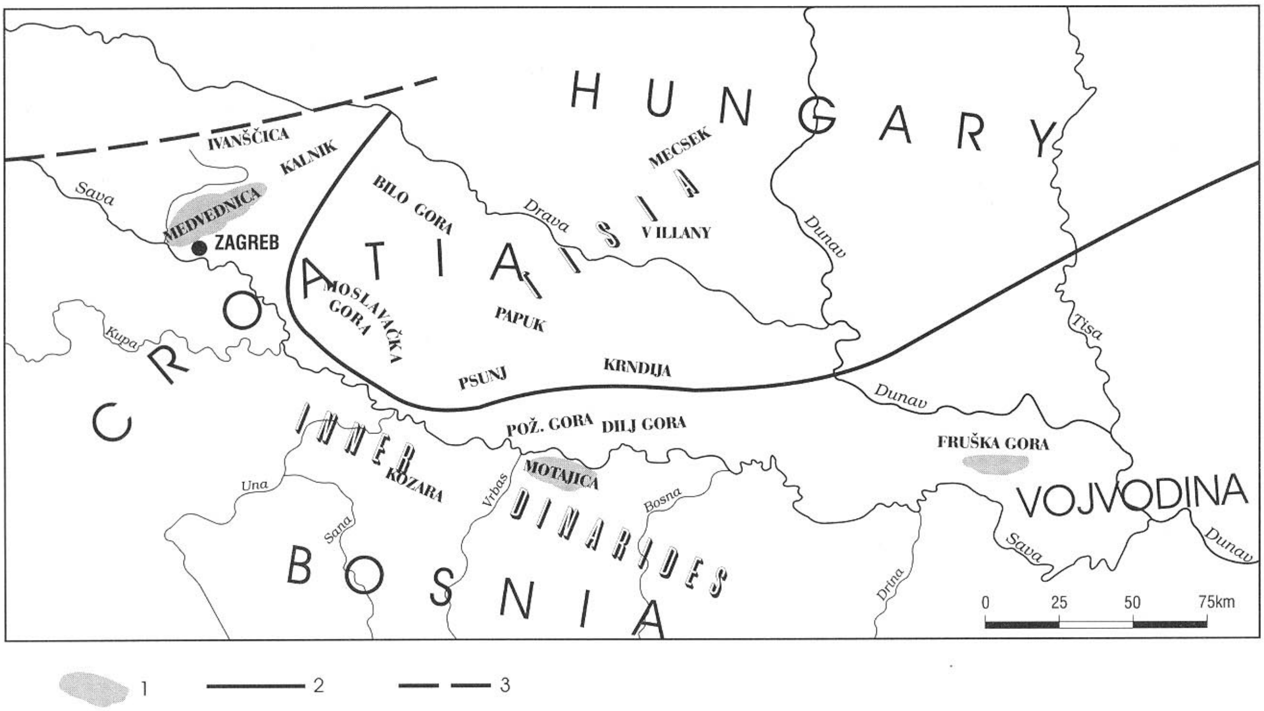

Fig. 6 Schematic map showing tectonic units in the northern Croatia, according to HERAK (1986), HERAK et al. (1990) and ŠIKIĆ (1995). Legend: 1) Medvednica, Motajica and Fruška gora; 2) boundary between the Inner Dinarides (Supradinaricum) and Tisia (Paradinaricum); 3) boundary toward the Alpine structures.

for this omphacite are:

$$a = 9.51\ (2)\ \text{Å}$$
$$b = 8.67\ (1)\ \text{Å}$$
$$c = 5.26\ (1)\ \text{Å}$$
$$\beta = 107.3\ (2)\ ^\circ$$

EDGAR et al. (1969) have demonstrated that, on the basis of the measured *b* parameters of diopside-jadeite solid solutions, the ratio of end members can be calculated. The calculated value of 8.67 Å indicate that this omphacite has approximately a 70% jadeite component.

3. DISCUSSION AND CONCLUSION

The mineral associations glaucophane - omphacite - white mica and crossite - garnet as well as the pyroxene composition indicate that these rocks belong to the higher blueschist facies at the transition to the blue eclogites (C-eclogites) of the Alpine orogenic zone (COLEMAN et al., 1965; WINKLER, 1979; SPEAR, 1995).

Depending on the subduction velocity, the transition between blueschist facies and eclogite facies takes place at different pressures. So, for slow subduction this transition is related to pressures between 13 and 14 kbar, for rapid subduction the boundary is shifted to 18-20 kbar, while most commonly this transition take place at 14-16 kbar (BUCHER & FREY, 1994). It can be presumed that similar pressures caused the formation of the investigated blueschists with their characteristic transitional mineral association.

Consequently such mineral associations indicate high-pressure and low-temperature metamorphic (LG, HP/LT) conditions which are representative of a subduction type of metamorphism (SPEAR, 1995). ERNST (1988) recognised two models of subduction related genesis of blueschists: the western Alpine and Franciscan (Californian) types. As no proper microstructural, textural and mineral paragenetic analyses were carried out, it cannot be said whether the analysed samples represent prograde blueschists or retrogressed eclogites. Since blueschist belts are mainly related to subduction zones along the destructive plate boundaries, where oceanic crust is subducted below continental crust (BUCHER & FREY, 1994), blueschists on the Medvednica mountain indicate the presence of a subduction zone. This conclusion is in accordance with the results of the investigations of Lower and Upper Cretaceous and Palaeogene sediments performed by CRNJAKOVIĆ (1987). Based on the detrital minerals and rock fragments in these sediments she concluded that part of the detritus originated from the subducted complex, while the other part originated from continental type rocks. BABIĆ et al. (1992) considered the presence of the chaotic complex north of Zagreb, to which Medvednica belongs, as evidence for the subduction zone in the south-western Pannonian realm. According to ŠIKIĆ (1995) subduction took place in the Medvednica area during the Lower Cretaceous, when part of the Inner Dinarides was subducted below the crystalline core of

Tisia and Palaeozoic and Mesozoic rocks were subjected to regional metamorphism.

Approximately 2 km to the east of the investigated outcrops, in the Gornje Orešje area, ultramafic rocks represented by serpentinised harzburgites, dunites and serpentinites crop out (ŠIMUNIĆ & PAMIĆ, 1989). Such rocks are representative of the Tethys of the Vardar ocean zone (KARAMATA et al., 1980) and for the Dinaridic parts of the Tethyan ocean area in which lherzolites are also present along with the above mentioned varieties of ultramafic rocks (PAMIĆ, 1996).

Blueschists and ultramafites have been found at some other localities along the southern edge of the Pannonian basin. VARIĆAK (1966) and MAJER & LUGOVIĆ (1991) described glaucophane schists and serpentinites (serpentinised dunites) from the Motajica mountain. In the Miocene sediments from the slopes of Dilj gora, MUTIĆ & DMITROVIĆ (1991) found detrital glaucophanes and presumed that they originated from metamorphic rocks of the Motajica. Serpentinites and glaucophane schists are also known from the Fruška gora (KIŠPATIĆ, 1883, 1886, 1887; MAJER & LUGOVIĆ, 1991), while in the southern Vojvodina in several boreholes, serpentinised harzburgites and dunites were found below Tertiary sediments (KAMENCI & ČANOVIĆ, 1975). DIMITRIJEVIĆ & DIMITRIJEVIĆ (1975) distinguished the zone between Medvednica and the Fruška gora mountains as a melange of the Vardar zone, on the basis of the geomagnetic anomaly (VUKAŠINOVIĆ, 1972, 1974), geotectonic structure and lithologic characteristics. According to PAMIĆ (1996), subduction accompanied by metamorphism, started in the upper Jurassic along the northern boundary of the Dinaridic Tethys.

In accordance with the determined mineral associations and preceding discussion it can be concluded that blueschists on the Medvednica mountain are the product of high pressure, relatively low temperature metamorphism (LG, HP/LT), i.e. at conditions representative for subduction zones in the Alpine orogenic cycle. Also, it can be presumed that blueschists and ultramafites in the zone Medvednica - Motajica - Fruška gora (Fig. 6) represent rocks from the relict subduction zone of the Dinaridic part of the Tethys along which high-pressure metamorphism occurred.

Acknowledgements

The authors are indebted to Prof. Dr. J. ZUPANIČ and Dr. D. BALEN for improving the early version of the manuscript. We also thank Prof. Dr. V. MAJER and Prof. Dr. P. ÁRKAI for their thoughtful reviews and useful comments.

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Manuscript received November 28, 1997.
Revised manuscript accepted May 18, 1998.