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DYNAMO-THERMAL METAMORPHISM RELATED TO EMPLACEMENT OF ULTRAMAFICS ON EXAMPLES FROM THE DINARIDES (*)

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2 fig. dans le texte et 1 tableau hors-texte)

ABSTRACT

Metamorphic rocks beneath ultramafic parts of ophiolite suites, viewed as contact dynamo-thermal aureoles related to the thermal capacity of ultramafics, from different parts of Dinarides are compared. They originated by influence of high temperature ultramafic bodies and represent (high to) middle pressure metamorphic series : (eclogite — granulite —) amphibolite — epidote-amphibolite — greenschist facies.

Such successions of metamorphic facies are considered to be characteristic of narrow oceanic areas with the midoceanic ridge, i.e. relatively high temperatures in the uppermost parts of the Mantle, near to the roots of the obduction zone.

The development of plate tectonic, and the investigations of oceanic crust and upper mantle performed in the last years, as well as the mostly accepted interpretation that the ophiolite suites represent transported oceanic crust and uppermost mantle, point the importance of investigations of ophiolites.

Since the origin of the upper magmatic parts of ophiolitic suite is cleared in main features, special attention was paid to explain the origin of the ultramafic part of these suites. Investigated in details were the mineralogy and petrology of these rocks — to explain the temperature and pressure during their formation, as well as their fabric — to explain the mechanism of their flowage, and these investigations furnished us with data on the conditions of ultramafic masses in the upper mantle at very high temperatures and in partly melted or highly mobil state. The metamorphic rocks which often in map-view surround, or exactly underlie the ultramafics may explain the state of the ultramafic masses at the time of their emplacement when they came in contact with supracrustal rocks whichover the ultramafics were obducted.

The ultramafics with welded metamorphic rocks in their base are common in many parts of the world, a very complete example is from the Brezovica area in Jugoslavia (Karamata, 1968), a very similar is from the White Hills in western Newfoundland (Williams and Smyth, 1973), but there are many others. Mostly these ultramafic masses with metamorphic aureoles represent tectonic slices transported over unmetamorphosed or previously only slightly metamorphosed rocks. In Dinarides we found on different places primary relationship between ultramafics and metamorphic rocks, as well as between metamorphic rocks and unmetamorphosed

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rocks in their base. In all these metamorphic aureoles the metamorphism always decreases with depth beneath the peridotites. It is characteristic that the intensity of metamorphism is different. The innermost zone may be formed by high temperature and middle pressure metamorphism, and then is the metamorphic aureole of a width up to a few hundreds of meters. If the innermost zone is of middle to low temperature, but of high pressure metamorphism the aureole of metamorphism is narrow.

The characteristics of some metamorphic aureoles below ultramafic bodies from Dinarides are given in Table I.

The metamorphism related to the emplacement of ultramafics depends mainly on the thermal capacity of the ultramafic mass at the moment when it came in contact with the rocks which were metamorphosed, the heat of friction is of minor importance. The thermal capacity of the peridotite body was the highest if the ultramafic mass was represented by a crystal mush with minor fluid phase, the thermal capacity was lower if the ultramafic crystal mush was without fluid phase, and much lower if the ultramafic mass was at middle to low temperature and presented an internally immobile ultramafic body. These characteristics of an ultramafic mass depend

— on the temperature in the upper mantle where the ultramafic mass was before its separation, i.e. was it nearer or further from the oceanic ridge (zone penetrated by melts),

— on the time of its rising into the upper parts of the crust, and on the temperatures of the rocks it passed through or over which it was obducted.

These conditions can be very variable at short distances but statistically they may provide us with data important for genetic and also tectonic considerations.

Since the ultramafic masses are during emplacement almost totally to totally crystallized and thus internally only slightly mobile to immobile, and of different thermal capacity, as mentioned before, their influence on the surrounding rocks is dynamic and thermal, i.e. DYNAMO-THERMAL. All transitions from intensive thermal with only slight dynamic to weak thermal but strong dynamic influence are noticed, as shown in Table I, and shematically presented on figure 1, where also the assumed temperatures and the consistences of the ultramafic masses are given.

Taking all these data in consideration the following succesions with increasing distance from the ultramafics appear :

/A/ (eclogitic —) granulitic — amphibolitic — epidote-amphibolitic — ? — facies mineral assemblages without or with weak orientation of constituents;

/B/ amphibolitic — epidote-amphibolitic — greenschist facies mineral assemblages with weak to good orientation of constituents;

/C/ (amphibolitic —) epidote-amphibolitic — greenschist facies mineral assemblages with good orientation of constituents;

/D/ (epidote-amphibolitic —) greenschist facies mineral assemblages with cataclasis and sometimes mylonitization.

The width of metamorphic aureoles decreases from /A/ to /D/ from a few hundreds of meters to a few meters.

If the rising of an ultramafic body was slow or stepwise the same ultramafic mass may introduce different metamorphic transformations in surrounding rocks, and may bring with it metamorphosed rocks from deeper parts as evidence for its

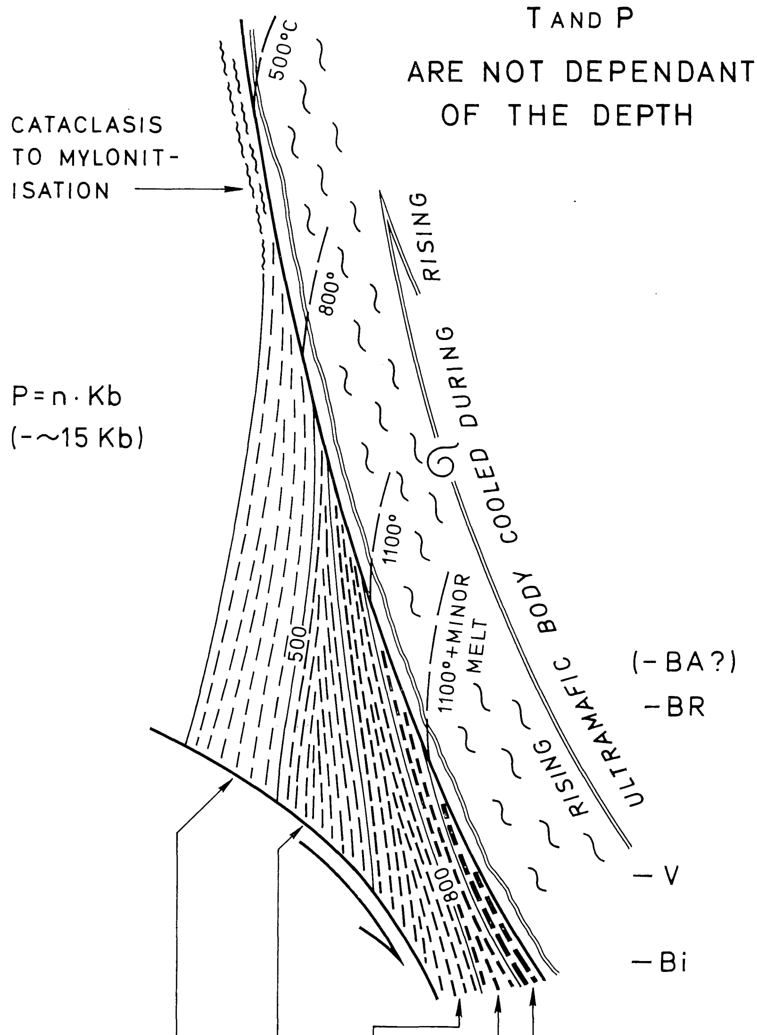

Fig. 1. — Zonality of metamorphic facies in dynamo-thermal aureoles associated with an ultramafic body, in dependence of its cooling during rising. The inner parts of the metamorphic aureole, welded to the ultramafic mass, are often by obduction separated from outern zones of lower metamorphism.

Facies : GS — greenschist, EpAM — epidote-amphibolite, AM — amphibolite, GR — granulite, EC — eclogite.

Localities : BA — Banija, BR — Brezovica, V — Vijaka, Bi — Bistrica.

thermal conditions during its passage through the crust. In table I there is an example : the Zlatibor metamorphic aureole is formed in situ, the Bistrica metamorphics are brought with the ultramafic mass from depths, both are connected with the same ultramafic mass of Zlatibor : the first from its central parts, the second one from its southern parts.

These zonations and such successions of metamorphic facies are probably characteristic for a narrow oceanic area, with an oceanic ridge near to the roots of the obduction zone, and where the thermic capacity of ultramafics was relatively high. These series of metamorphic facies are presented in the PT-diagram of metamorphic facies (Fig. 2). In the case when the uppermost part of the Mantle, as part of an oceanic plate, was conveyed further and was thus cooler during obduction, a different succession of metamorphic facies will originate : from low-temperature eclogitic to blueschist facies (Fig. 2), as in New Caledonia or California.

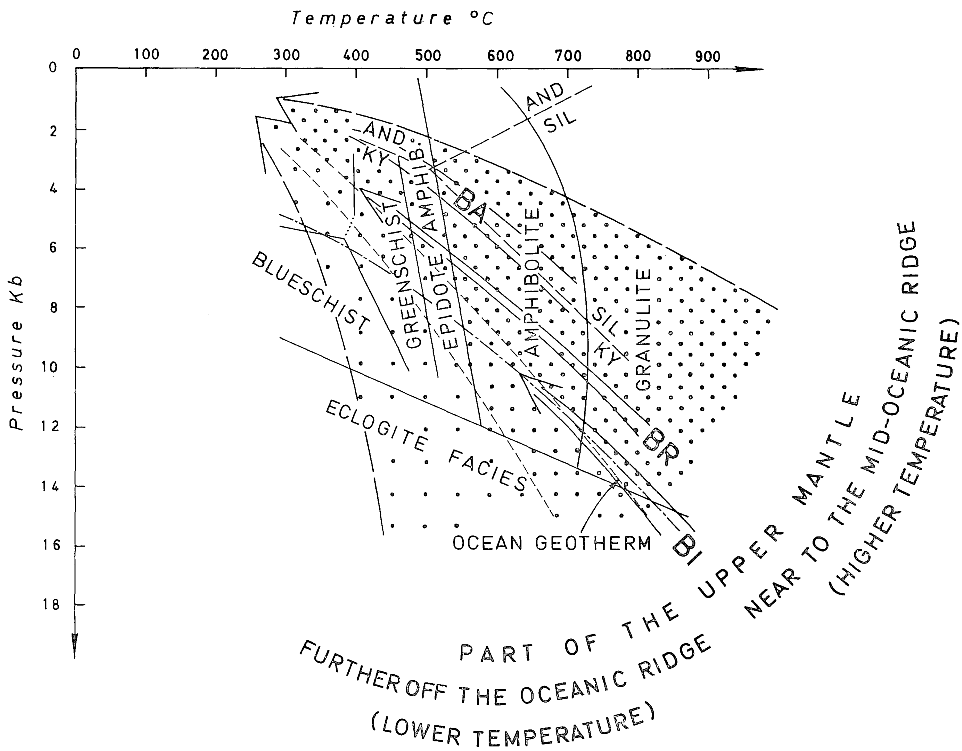

Fig. 2. — Metamorphic series in metamorphics originated by contact dynamo-thermal metamorphism related to ultramafics. The diagram of metamorphic facies is from Hyndman (1972, fig. 8-2), simplified and extrapolated to 1100° and 16 Kb. The stability limits of sillimanite (SI), andalusite (AN) and kyanite (KY) after Hyndman (1972, fig. 7-11). The oceanic geotherm after Ringwood (1969, fig. 2).
BA — Banija, BR — Brezovica, BI — Bistrica.

Future investigations of metamorphic aureoles related to ultramafics, and detailed world-wide comparisosns should provide a new insight into the mechanisms of emplacement and especially the consistence of ultramafics during emplacement, which will enable us to come closer to tectonic syntheses.

TABLE I

Characteristics of metamorphic aureoles beneath ultramafics from dinarides

Locality	T° C of ultramafic body by emplacement	Consistance of ultramafic body by emplacement	— Distance from the contact → Mineral assemblages /+ width/ originated from pelito-psammitic rocks / basic volcanic	Metamorphism
GOLEŠ	~ 300 —500 /?/	internally immobile	Se+Co+Q /n × m/ → Phyllites	Dynamic / pencil structures /
LJUBOTEN	~ 500 —800 /?/	internally immobile to slightly mobile	Ms+Co+Gl+Q → Tuffaceous sandstones Ca / +Q / → Limestones /n × 10 m/	Mainly dynamic / cataclastic textures /
ZLATIBOR	~ 1000	internally mobile without melt-phase	Bi+Ms+Q → Ms+Co+Q → Argillites and sandstones Ho+Pl+Ga /n × m/ → Ho+Ab+Ep /n × 10 m/ → Ac+Co+Ep+Ab /n × 100 m/ → Spilites and similar rocks	Dynamo-thermal
BANIJA (1)	~ 1100		Sil/Ky/And+Cd+Bi+Ms+Alm+Q → Phyllites → Argilites and sandstones Cpx+Ga —//→ Ho+Pl //	Dynamo-thermal
BREZOVICA (2)	~ 1100	internally mobile with minor melt-phase	Ab+Bi+Co+Ms +Alm+Q/+Ky/ → Ab+Ms+Pa+Co+Q /Ca+Ep+Ms/ → Ab+Ms+Co+Q /Ca/ → Pel.-Psam. /Carb. rocks/ Cpx+Ga+Ho+Pl /n × m/ → Ho+Pl+Ga /n × 10 m/ → Ho+Ep+Ab / 100 m/ → Ac+Ep+Co+Ab /n + × 100 m/ → Spilites+ similar rocks	Dynamo-thermal
VIJAKA (3)	~ 1100	— " —	Ho+parg+Cor /n × m/ → Ho+Ga/+Pl/ /n × 10 m/ → Ho+Ab+Ep /?/ / retrogressive ? / //	Dynamo-thermal
BIST-RICA (4)	~ 1100	— " —	Cpx+Ga /?/ // Ho—parg+Cor /n × m/ → Ho+Ga/+Pl/ /n × 10 m/ → Ho+Pl+Ga /?/ //	/ Dynamo-thermal

Ab — albite; Ac — actinolite; Alm — almandite; And — andalusite; Ca — calcite; Cd — cordierite; Co — chlorite; Cor — corundum; Cpx — clinopyroxene; Ep — epidote; Ga — garnet; Gl — glaucophane; Ho — hornblende; Ho-parg — pargasite; Ky — cyanite; Ms — muscovite; Pa — paragonite; Pl — plagioclase /30-50 An/; Q — quartz; Se — sericite; Sil — sillimanite.

1. Majer 1974; 2. Karamata 1968; 3. Pamić i Kapeler 1970; 4. Marić 1933, and Popević i Pamić 1973.

REFERENCES

ALLEN, J. C., MODRESKI, P. J., HAYGOOD, Ch. and BOETTCHER, A. L., 1972. — The role of water in the Mantle of the Earth : The stability of amphiboles and micas. Reports of the 24th Int. geol. congress, Section 2, 231-240. Montreal.

COLEMAN, R. G., 1967. — Glaucophane schists from California and New Caledonia. *Tectonophysics*, v. **4**, 479-498.

COLEMAN, R. G., 1971. — Plate tectonic emplacement of upper mantle peridotites along continental edges. *Jour. Geophys. Research*, v. **76**, 1212-1222.

DEN TEX, E., 1969. — Origin of ultramafic rocks, their tectonic setting and history. *Tectonophysics*, v. **7**, 457-488.

HYNDMAN, D. W., 1972. — Petrology of igneous and metamorphic rocks. McGraw-Hill Book Company, New York.

KARAMATA, S., 1968. — Zonality in contact metamorphic rocks around the ultramafic mass of Brezovica (Serbia, Yugoslavia). Reports of the 23th Int. geol. congress, v. **1**, 197-207. Praha.

KARAMATA, S., KEESMANN, I. und OKRUSCH, M., 1970. — Ein Paragonit führender Granatquarzit im Raum Brezovica, Südserbien. *N. Jb. Miner. Mh.*, Jg. 1970, H. **1**, 1-19, Stuttgart.

KARAMATA, S. and PAMIĆ, J., 1970. — Some consideration about the genesis of alpine ultramafites of the Dinarides. VII kongres geologa SFRJ, II, 139-156, Zagreb.

MAJER, V., 1956. — Petrografija i petrogeneza ultrabazićnih stijena Brezovice na sjevernoj strani Šar Planine. *Acta geologica, JAZU*, v. **1**, 89-148, Zagreb.

MAJER, V., 1974. — Nalaz novih metamorfnih stijena u Baniji (Hrvatska, Jugoslavija). *Bull. Sci, CASRSFY*, in press, Zagreb.

MARIĆ, L., 1933. — Prilog petrografiji Stare Raške. *Glas SKA*, CLVIII, 147-187, Beograd.

PAMIĆ, J. i KAPELER, I., 1970. — Korundski amfiboliti na južnom obodu Krivajsko-konjuškog ultramafitskog masiva. *Geološki anali Balk. poluostrva*, v. **35**, 399-408, Beograd.

PAMIĆ, J., ŠĆAVNIĆAR, S. and MEDJUMUREC, S., 1973. — Mineral assemblages of amphibolites associated with alpinetype ultramafics of Dinaride ophiolite zone (Yugoslavia). *J. Petrology*, v. **14**, 1, 133-157.

POPEVIĆ, A. i PAMIĆ, J., 1973. — Korud amfibolitski škriljci u amfibolitima Bistrice na južnom obodu zlatiborskog ultramafitskog masiva. *Glasnik Prir. muzeja, A*, v. **28**, 31-39, Boegrad.

RINGWOOD, A. E., 1969. — Composition and evolution of the Upper Mantle. — The Earth's Crust and Upper Mantle, Geoph. Monograph 13, 1-17, Washinton.

WILLIAMS, H. and SMYTH, W. R., 1973. — Metamorphic aureoles beneath ophiolite suites and alpine peridotits : tectonic implications with West Newfoundland examples. *American Journal of Science*, v. **273**, 594-621.

WINKLER, H. G. F., 1967. — Petrogenesis of metamorphic rocks. Revised second Edition. Springer Verlag, Berlin.