Ελληνικής Γεωλογικής Εταιρείας τομ. XXV 2, 67-80, 1991
5ου Επιστημονικού Συνεδρίου, Θεσσαλονίκη, Μάιος 1990

Bulletin of the Geological Society of Greece vol. XXV 2, 67-80, 1991
Proceedings of the 5th Congress, Thessaloniki, May 1990

EVIDENCE FOR HIGH PRESSURE METAMORPHISM IN THE VERTISKOS GROUP OF THE SERBOMACEDONIAN MASSIF: THE ECLOGITE OF NEA RODA, CHALKIDIKI

S. Dimitriadis* and A. Godelitsas*

ABSTRACT

Small eclogitic bodies participate in the Vertiskos group of the Serbomacedonian massif. They crop out among folded migmatitic gneisses and amphibolites. The eclogites have been amphibolitized and further retrograded to greenschist assemblages. Near Nea Roda in Chalkidiki, however, retrogression of the eclogites was not very extensive and the original high pressure assemblage is well preserved. Clinopyroxenes are omphacites (jadeite ≈ 30 mol per cent), garnets are almandines with ≈ 20 mol per cent pyrope. Amphiboles are mostly secondary and are ferroan pargasitic hornblendes to ferroan pargasites. Albite is forming during the amphibolitization and the following greenschist overprinting. Ompacitic pyroxenes are partly converted to amphibole-albite symplectites. Deformation of the eclogites was certainly pre-greenschist but its relation to the amphibolization event is not certain. Garnet-clinopyroxene geothermometry yielded temperatures around 530°C.

ΠΕΡΙΛΗΨΗ

Μελετώνται μικρά εκλογιτικά σώματα που βρέθηκαν στην περιοχή του χωριου Νέα Ρόδα Χαλκιδικής. Οι εκλογίτες είναι αμφιβολιτιωμένοι και παραπέρα υποβαθμισμένοι σε πρασινοσχιστολιθικές παραγενέσεις. Διατηρουνται όμως κατά θέσεις και οι αρχικές εκλογιτικές παραγενέσεις. Οι κλινοπυρόξενοι είναι ομφακίτες με 30% ιαδείτη. Οι γρανάτες αλμανδίνες με 20% πυρωπό. Οι δευτερογενείς μάλλον αμφίβολοι είναι σιδηροπαργασιτικές κεροστίλβες και σιδηροπαργασίτες. Κατά την υποβαθμιση των εκλογιτων στην αμφιβολιτική και πρασινοσχιστολιθική φάση σχηματίζεται αλβίτης ενώ οι ομφακίτες μετατρέπονται σε συμπλεκτίτες αμφιβόλου-αλβίτη. Η παραμόρφωση των εκλογιτικών αυτών σωμάτων είναι προγενέστερη από την πρασινοσχιστολιθίωσή τους, αλλά δεν είναι βέβαιη η σχέση της με τη φάση της αμφιβολιτίωσής τους. Εφαρμογή του γεωθερμομέτρου γρανάτη-κλινοπυρόξενου έδωσε θερμοκρασίες γύρω στους 530°C

INTRODUCTION

The metamorphic evolution of the Serbomacedonian massif is as yet inadequately known. Hercynian magmatism and metamorphism has rather certainly affected the massif (BORSI et al. 1964), while its older formations had probably been metamorphosed in the Early Paleozoic or even in the Precambrian (ALEKSIĆ et al. 1988). The polymetamorphic character of a certain group of this massif -the Vertiskos group- has been confirmed by DIXON and DIMITRIADIS (1987) in pelitic members of this group, in which mineralogical evidence exists for a sequence of distinct high temperature and high pressure events. The regional extent of these events and the maximum pressures reached remained however unclear, due to scarsity of apropriate assemblages. Evidence has been accumulated recently

---

*University of Thessaloniki, Department of Mineralogy-Petrology and Economic Geology, 54006 Thessaloniki, Greece

however[1], that a number of metabasites participating in the Vertiskos group are in fact retrograded eclogites; this leaves little doupt that pressures in this group reached or exceeded 12 kb at some stage (or stages) during its tectonometamorphic evolution.

In this paper we present the limited data at hand of a preliminary study of one of the Vertiskos group eclogitic rocks, recently found near Nea Roda at the isthmus of Athos (Agion Oros) peninsula in Chalkidiki (map, fig.1). Other lithologies present in the area are migmatitic gneisses, mica schists, amphibolites and a fault bounded serpentinized ultramafic body; Tertiary granites and granodiorites intrude nearby (see also the IGME 1:50000 Ierissos sheet).

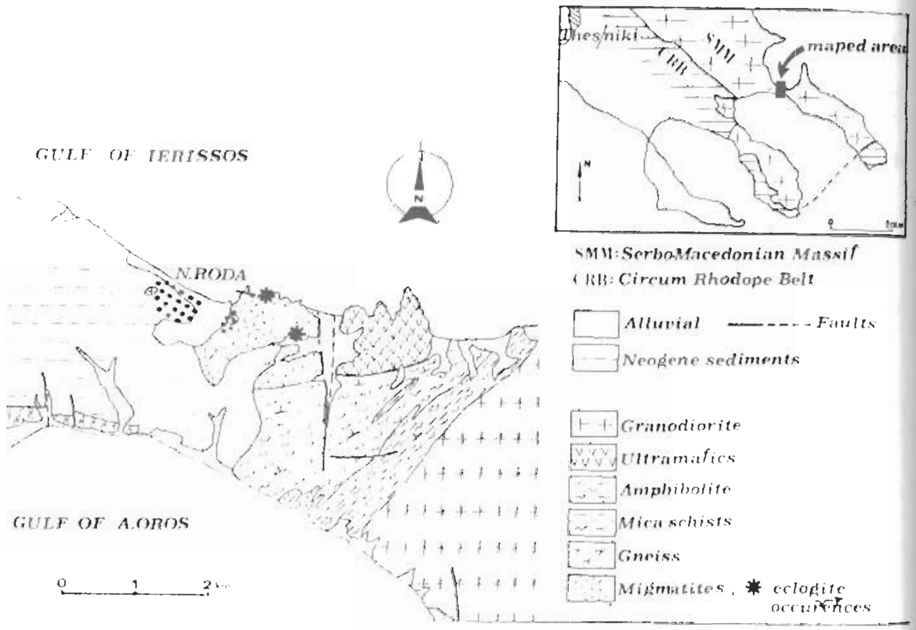

Fig. 1. Geological map of the area of N. Roda, Chalkidiki.

We do not adress here either the geotectonic significance of the "eclogite event" or its age, since a much wider perspective is needed for such an attempt; these are anyhow subjects to be considered in the beforementioned Theses projects. Also, we do not discuss regional corellations with the Rhodope eclogites recently discovered and studied by LIATI (1986).

FIELD OBSERVATIONS

The two eclogitic exposures in the area are not impressive in the field. The larger (the inland one, map fig.1) crops out of the alluvials as a 50 x 100 m isolated hummock, densely covered by thick bushes. Contacts with the surrounding folded migmatitic gneisses are nowhere visible. The eclogite is rather isotropic and lacks any penetrative fabric.

The smaller eclogite (at the north shore, map fig.1) is a mere 5 x 20 m body comformably enveloped by the surrounding gneiss. The internal part of the eclogite is mesoscopically isotropic but its margins possess the same planar fabric as the enveloping gneiss, which is parallel to the contacts between the two lithologies. The impression is that the eclogite body, apart from its outer shell which sheared, behaved more coherently during deformation than its gneissic envelope. Extensive greenschist overprinting in this body wiped out most of the original eclogite mineralogy, leaving behind a retrograde greenschist assemblage with a random orientation of its minerals even in the case they replace the sheared outer shell of the eclogite. Shearing thus around the eclogitic body apparently happened while it was possessing the eclogitic (or rather a pre-greenschist) mineralogy and prior to a static greenschist overprinting.

The sporadic présence of eclogitic bodies among the migmatitic gneisses (we believe there are more such bodies scattered bellow the alluvial cover), their elongate shape and the localization of intense shearing only at their margins rather suggest that they are far separated parts (possibly boudins) of an originally more continuous mafic formation.

PETROGRAPHY AND MINERAL CHEMISTRY

The Nea Roda eclogite is an isotropic, medium grained rock composed mainly of garnet and clinopyroxene, with a green to bluish green amphibole interstitialy or synanteticaly grown among them (fig.2a). Amphiboles have been observed in a few cases tottaly inside garnet crystals, but it is not clear whether they are true inclusions traped during garnet growth or are late infilings of cracks and holes in garnets. In most cases however there is no doubt that amphibole invades and partly replaces garnet (fig.2b). Extensive amphibole growth may eventually form large poiciloblasts including isolated remnants of the original garnets. Finer grained (second generation?) amphibole commonly rims or replaces pyroxenes along cracks; in such cases the two minerals share a common c crystallographic axis (fig.2c).

Plagioclase is always spatially related with amphibole. It forms pools and streems at the contacts between garnets and pyroxenes; in these pools amphibole grows in almost completely idioblastic crystals (fig.2d) or as poiciloblasts (fig.2e).

Other minerals present are: rutile, zoisite, apatite and occasionally quartz, white mica, clinozoisite, biotite and titanite.

---

[1] Theses projects in progress by A. Koutou and by N. Sidiropoulos in the Vertiskos group under the supervision of the first of the present authors.

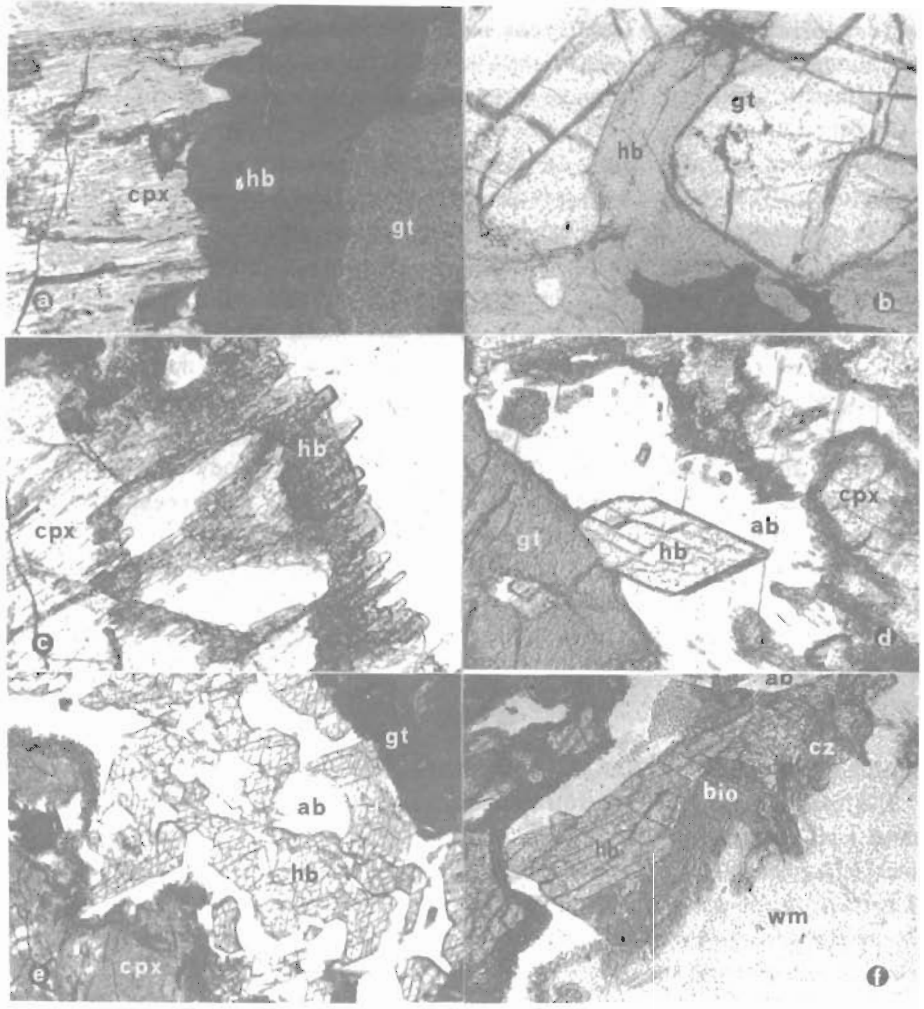

Fig. 2. a. Hornblende (hb) grown at the contact between garnet (gt) and clinopyroxene (cpx). N parallel, x 125.
b. Hornblende (hb) replacing garnet (gt). N parallel x 125.
c. Actinolitic amphibole (act) replacing clinopyroxene (cpx). N parallel x 125.
d. Idioblastic hornblende (hb) grown with albite (ab) at the contact between garnet (gt) and clinopyroxene (cpx). N parallel x 125.
e. Idioblastic poiciloblast of hornblende (hb) including albite (ab), between garnet (gt) and clinopyroxene (cpx). N parallel x 125.
f. Formation of biotite (bio) by reaction between hornblende (hb) and white mica (wm), albite (ab) and clinozoisite (cz) are likely products of the same reaction.

The garnets (analyses 1-3, table I) are ~60 per cent almandine with ~20 per cent in each pyrope and grossular. In fig.3 the analyzed garnets have been plotted in the diagrams of SMULIKOWSKI (1968) and LOVERING and WHITE (1969).

According to the field relations, the eclogites here studied could be type B (or III) i.e. eclogites found among high grade gneisses and migmatites, but there is no reason to exclude the possibility of being type C (or II) i.e. eclogites related with glaucophane schists, although glaucophane rocks have not been found. Lets note here, however, that the above distinction is old fashioned and is today considered rather unnecessary (YARDLEY 1989).

The clinopyroxenes (analyses 4-6, table I) are omphacites with a tendency towards chloromelanitic compositions (fig.4a). Jadeite content is ~30 per cent. They plot (fig.4b) in the area of II type eclogites in the diagram of SMULIKOWSKI (1968).

Three green amphiboles have been analyzed (analyses 7-9, table I). They are all typical ferroan pargasitic hornblendes (nomenclature after LEAKE 1978, as modified by ROCK and LEAKE 1984). Two amphibole analyses (nos 10, 11, table I) are from the greenish blue margins sometimes present in these amphibole crystals; their composition is ferroan pargasitic with comparatively higher Fe:Mg and higher Al in relation to the green amphiboles they rim.

The plagioclase (analysis no 12) is $Ab_{91}An_9$.

The possibility exists that the pargasitic hornblende was an equilibrium member of an original garnet + omphacite + hornblende eclogitic assemblage. However, textural features rather suggest that it mainly formed by a reaction between garnet and clinopyroxene, during which albitic plagioclase was also formed. This had to be a hydration reaction for which a semiquantitative scheme could be:

$$\underset{\text{Garnet}}{(Fe^{2+},Mg,Ca)_3Al_2Si_3O_{12}} + \underset{\text{Clinopyroxene}}{(NaAl,NaFe^{3+},Ca_2,Mg_2,Fe^{2+})Si_2O_6} + n\,SiO_2 + H_2O$$

$$\underset{\text{Hornblende}}{Ca_2,Na(Mg,Fe^{2+},Fe^{3+},Al)_5(Si,Al)_8O_{22}(OH)_2} + \underset{\text{Albite}}{NaAlSi_3O_8}$$

The presence of free quartz is a prerequisite for this reaction to proceed; it will cease when either water or quartz is no more available at the site of the reaction. In our case it is possible that the reaction did not completed due to exhaustion of free quartz rather, than due to lack of water, since free quartz is very scarse in the rocks studied here.

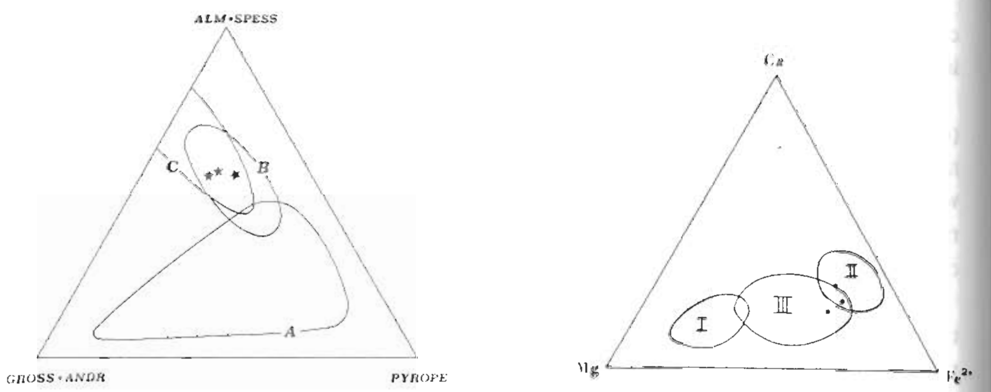

Fig. 3. Plots of the analyzed garnets in:
a. The (Alm + Spess) - (Gross + And) - Pyrope diagram
b. The Ca - Mg - Fe^{2+} diagram.

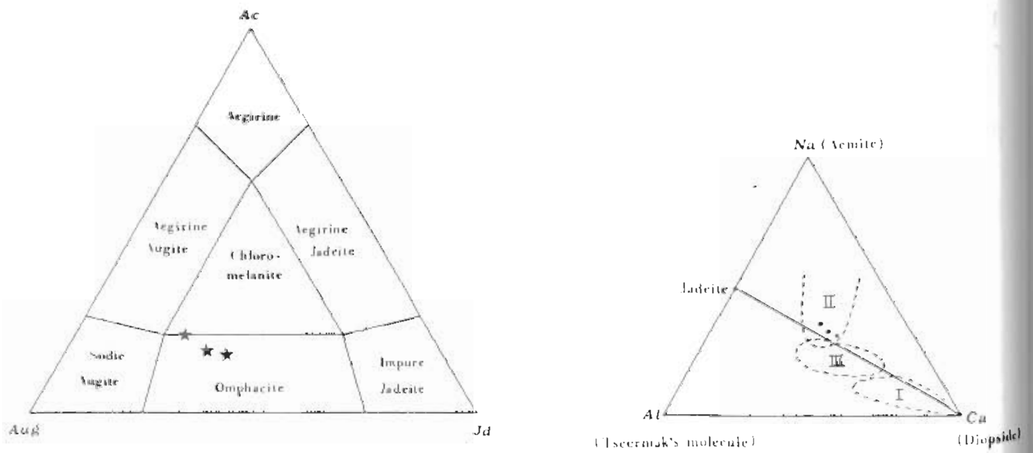

Fig. 4. Plots of the analyzed clinopyroxenes in:
a. The Ac - Aug - Jd diagram (after the Ryburn et al. 1976 correction for Fe^{3+})
b. The Na - Al - Ca diagram

The proposed amphibole producing reaction was not necessarily retrogressive; it could had been progressive if hydration of the rock was accompanied by heating under nearly the same pressure to that prevailed during the main eclogite event. This suggestion is strengtnened by the fact that pargasitic hornblendes are the typical amphiboles forming during hydration of mantle rocks at high pressures and temperatures (JENKINS 1983; OLAFSSON and EGGLER 1983; GALER and O'NIONS 1989).

Retrogressive reactions and textures in eclogites are known for long and have been extensively described in the literature (ALDERMAN 1936; SMULIKOWSKI 1968; SANTALLIER 1983; KLEIN and WIMMENAUER 1984; TAKASU 1984; GODARD 1988, among others). A common retrogressive reaction is the replacement of the original omphacite by a diopside-plagioclase symplectite. This reaction is, however, favoured in dry conditions. Destabilization of omphacitic pyroxene with simultaneous hydration will most probably lead to the formation of amphibole + plagioclase symplectites. In our rocks such a reaction is probably responsible for the riming of the clinopyroxenes by needls of actinolitic amphiboles (fig.2c).

White mica (analysis 13, table I) is scarcely present in the N. Roda eclogite. It is 66.73% muscovite, 23.44% celadonite and 9.83% paragonite, with 6.48 Si atoms p.f.u.

Wherever the white mica comes in contact with green hornblende a biotite + albite symplectite with clinozoisite intervenes between the two minerals. Textural evidence suggests (fig.2f) that biotite is forming at the expence of both, hornblende and white mica. The following reaction is likely:

hornblende + white mica = biotite + clinozoisite + albite

ROCK CHEMISTRY

There is only one complete analysis of N. Roda eclogite available at the moment (table II). The provisional conclusion is that this eclogite belongs to the Fe-Ti gabbro type (MOTTANA 1977). In a MORB-normalized trace element variation diagram (fig.5) a general enrichment in all but the large ion lithophiles is marked. The depletion in Nb might be due to crustal contamination; an accompanied enrichment in K and Rb is unlikely in eclogite rocks due to lack of potassium rich phases in them. The general enrichment in all trace elements (apart from Cr) relative to MORB and the gentle sloping from Ba to Sc are suggestive of a transitional basalt type protolith; the pattern resembles (PEARCE 1983) oceanic island and continental flood basalts.

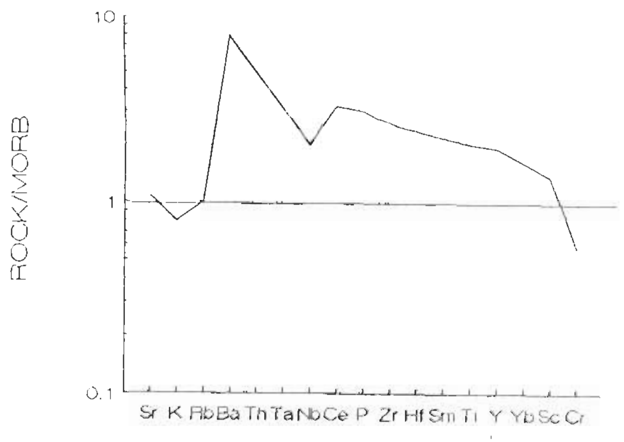

Fig. 5. MORB normalized trace element variation diagram of the N. Roda eclogite.

CONDITIONS OF METAMORPHISM

The garnet-clinopyroxene K_D Fe/Mg geothermometer has been aplied to eight pairs of mineral analyses for an infered pressure of 12 Kb (fig.6). Although this geothermometer is not strictly aplicable to eclogitic rocks (ESSENE 1982,1989) it has been extensively used with reasonable results and forms the basis for the most recent temperature based classification of eclogites in low T, medium T and high T types: (NEWTON 1986; CARSWELL 1990). The calibrations of ELLIS and GREEN (1979) and of POWELL (1985), combined with the RYBURN et al. (1976) correction for Fe^{3+}, are generally accepted as the most reliable for this geothermometer (CARSWELL and HARLEY 1990). In accordance with common experience, the lowest temperatures were yielded with the KROGH (1988) calibration, while the CANGULY (1979) calibration yielded substantially higher temperatures.

An equilibration temperature of ~520°C (Powell's callibration) or ~550°C (Ellis & Green calibration) characterizes the N. Roda eclogite as transitional between the low T and medium T types of the eclogite facies (CARSWELL 1990).

There is a very limited choise of geobarometers for typical eclogitic rocks.

In summary, we propose the following scheme for the metamorphic evolution of the N. Roda eclogite (fig.7):

1. ECLOGITE STAGE: (520-550°C, ~12 kb).

assemblage: garnet + omphacite + rutile + quartz + zoisite ± white mica + apatite

2. PROGRADE AMPHIBOLITIZATION (hydration and heating at high pressures).

reactions:

a: garnet + omphacite + quartz $+H_2O$ = hornblende + albite

b: white mica + hornblende = biotite + clinozoisite/epidote + albite

assemblage (metastable): garnet + omphacite + hornblende + albite + rutile + zoisite ± white mica ± biotite ± clinozoisite/epidote + apatite ± quartz

3. RETROGRADE GREENSCHIST OVERPRINTING (depressurisation and cooling).

reactions:

a: omphacite + H2O = actinolite + albite

b: garnet chlorite + clinozoisite/epidote

c: rutile titanite ± ilmenite

assemblage:

albite + chlorite + actinolite + clinozoisite/epidote + titanite + apatite

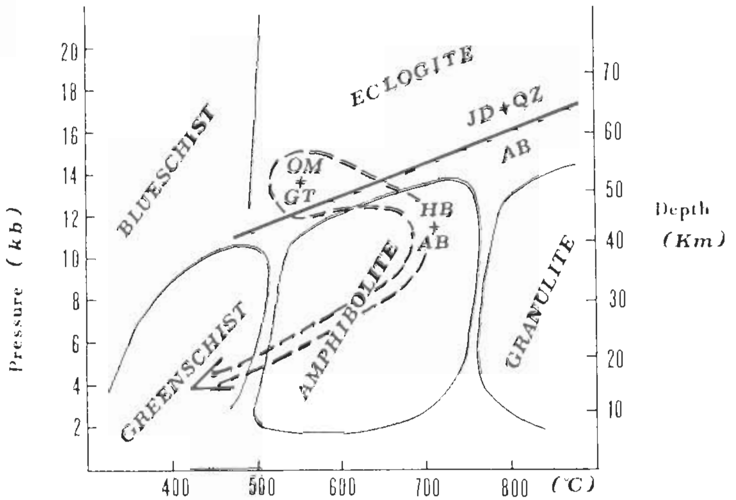

Fig. 7. Schematic diagram of the metamorphic evolution of the N. Roda eclogite.

The only one aplicable to our rocks is the jadeite + quartz + albite (HOLLAND 1980) geobarometer. The presence of jadeitic pyroxene ($X_{jd} = 0.3$) in equilibrium with quartz and albite (at least in the few cases where quartz is present) testifies for pressures around 12 kb for infered temperatures in the range 500-550°C.

We proposed that the amphibolitization event reflects a high pressure (near isobaric to the eclogite event) heating of the rock accompanied by hydration. It is difficult to determine specific values of P and T for this event. The garnet-hornblende geothermometer is not aplicable to eclogites in which, as in our case, amphibole growth might have occured later than the garnet and clinopyroxene (GRAHAM and POWELL 1984). We applied this thermometer in one pair of garnet and amphibole however, and the obtained temperature of 748°C only demonstrates the anyway expected lack of chemical equilibrium between hornblende on the one hand and garnet and clinopyroxene on the other.

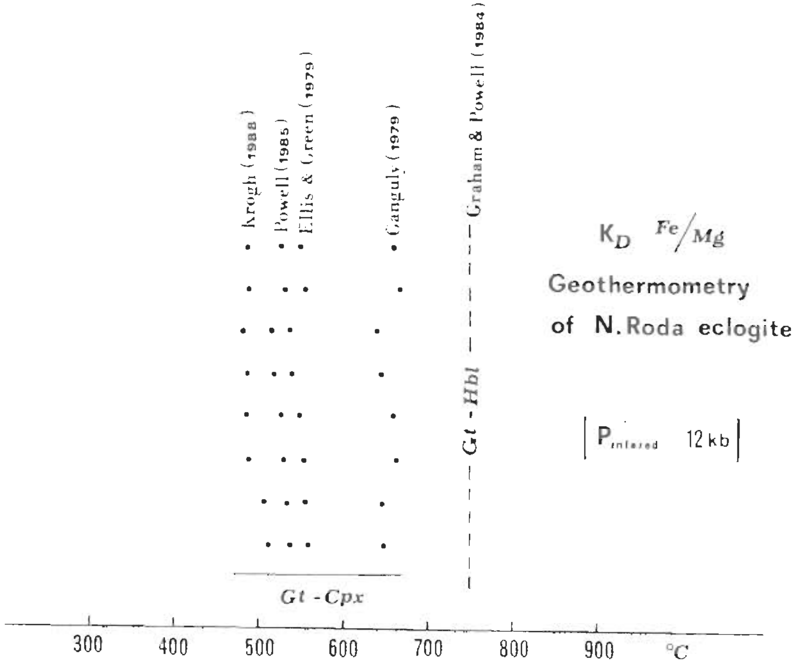

Fig. 6. Gt - Cpx K_D Fe - Mg and Gt - Hbl K_D Fe/Mg geothermometry of N. Roda eclogite.

At present we do not have enough evidence concerning possible relationships between the N. Roda eclogite and the garnet amphibolites also occurring among the migmatitic gneisses in the wider area. We also just stress the possibility that the ultramafic body near N. Roda could have genetic links with the eclogite. We hope that future work will clarify these subjects.

Table I. Microprobe analyses of minerals of the N. Roda eclogite.

Analyses: 1,2,3: clinopyroxenes; 4,5,6: garnets; 7,8,9,10,11: amphiboles; 12: plagioclase; 13: white mica.

	1	2	3		4	5	6		7	8	9	10	11		12		13
SiO_2	54.82	54.32	53.62	SiO_2	38.48	39.52	38.14	SiO_2	42.94	43.41	43.24	41.85	42.00	SiO_2	66.72	SiO_2	47.68
Al_2O_3	10.09	9.57	8.64	Al_2O_3	20.94	21.84	20.89	Al_2O_3	14.44	14.66	14.87	15.14	15.14	Al_2O_3	20.64	Al_2O_3	29.24
FeO	6.73	7.27	7.22	FeO	24.89	25.67	26.26	FeO	14.22	14.38	14.69	15.94	15.98	FeO	0.19	FeO	2.86
MgO	7.53	7.86	8.68	MgO	4.77	6.57	4.95	MgO	10.46	10.35	10.07	8.88	9.19	MgO	0.00	MgO	2.57
MnO	0.05	0.05	0.04	MnO	0.92	0.28	1.08	MnO	0.07	0.07	0.10	0.18	0.21	CaO	1.87	TiO_2	0.94
CaO	13.24	14.31	14.93	CaO	10.03	7.49	8.61	CaO	9.24	9.47	9.58	9.71	9.65	BaO	0.00	Na_2O	0.74
TiO_2	0.20	0.20	0.19	TiO_2	0.10	0.04	0.08	TiO_2	0.78	0.86	0.65	0.62	0.45	Na_2O	11.26	K_2O	10.27
Na_2O	7.20	6.74	6.24	Cr_2O_3	0.03	0.00	0.00	Na_2O	4.48	4.35	4.13	4.12	4.01	K_2O	0.01		
Cr_2O_3	0.04	0.03	—					K_2O	0.45	0.54	0.41	0.35	0.48				
SUM	99.90	100.35	99.56	SUM	100.16	101.41	100.01	SUM	97.08	98.09	97.74	96.79	97.11	SUM	100.69	SUM	94.30

Numbers of ions

	O=6	O=6	O=6		O=24	O=24	O=24		O-23	O-23	O=23	O=23	O=23		O=32		O=22
Si	1.98	1.97	1.96	Si	6.01	6.03	5.99	Si	6.39	6.39	6.39	6.30	6.30	Si	11.67	Si	6.48
Al	0.43	0.41	0.37	Al	3.86	3.93	3.87	Al	2.53	2.54	2.59	2.69	2.68	Al	4.25	Al	4.68
Fe	0.20	0.22	0.22	Fe	3.25	3.28	3.44	Fe	1.77	1.77	1.82	2.01	2.01	Fe	0.03	Fe	0.32
Mg	0.41	0.42	0.47	Mg	1.11	1.49	1.16	Mg	2.32	2.27	2.22	1.99	2.06	Mg	0.00	Mg	0.52
Mn	0.00	0.00	0.00	Mn	0.12	0.04	0.15	Mn	0.00	0.00	0.01	0.02	0.03	Ca	0.35	Ti	0.10
Ca	0.51	0.56	0.59	Ca	1.68	1.22	1.45	Ca	1.47	1.49	1.52	1.57	1.55	Ba	0.00	Na	0.19
Ti	0.01	0.01	0.00	Ti	0.01	0.00	0.00	Ti	0.09	0.10	0.07	0.00	0.05	Na	3.82	K	1.78
Na	0.51	0.47	0.44	Cr	0.00	0.00	0.00	Na	1.29	1.24	1.18	1.20	1.17	K	0.00		
Cr	0.00	0.00	---					K	0.09	0.10	0.08	0.00	0.09				
SUM	4.05	4.06	4.05	SUM	16.05	16.00	16.06	SUM	15.95	15.91	15.87	15.92	15.93	SUM	20.12	SUM	14.07

Table II. Chemical analysis of the N. Roda eclogite.

	%		p.p.m.
SiO_2	46.06	Ni	59
Al_2O_3	14.62	Cr	148
Fe_2O_3	3.08	V	393
FeO	11.49	Sc	55
MnO	0.26	Zn	120
MgO	7.02	Sr	130
CaO	10.33	Rb	2
Na_2O	3.67	Th	---
K_2O	0.12	La	10
TiO_2	3.00	Ce	32
P_2O_5	0.32	Nd	20
		Y	58

REFERENCES

ALDERMAN, A.R. (1936) Eclogites in the neighbourhood of Glenelg. Inverness-Shire. *Quarterly Journal of the Geological Society,* **92**, 488-530.

ALEKSIC, V., DIMITRIADIS, S., KALENIC, M., STOJANOV, R., ZAGORCEV, I. (1986) Precambrian in the Serbo-Macedonian Massif. In: V. ZOUBEK (ed.). Precambrian in Younger Fold Belts; European Variscides, the Carpathians and Balcans. *John Wiley & Sons,* 779-820.

BORSI, S., FERRARA, G., MERCIER, J. (1965) Determination de l' age des series metamorphiques du Massif Serbo-Macédonien au Nord-Est de Thessalonique (Grèce) par les methodes Rb/Sr et K/Ar. *Ann. Soc. géol. du Nord,* **84**, 223-225.

CARSWELL, D.A. (1990) Eclogites and the eclogite facies: definitions and classification. In: D.A. CARSWELL (ed.). Eclogite facies rocks. *Blackie,* 1-13.

CARSWELL, D.A., HARLEY, S.L. (1990) Mineral barometry and thermometry. In: D.A. CARSWELL (ed.). Eclogite facies rocks. *Blackie,* 83-110.

COLEMAN, R.G., LEE, D.E., BEATTY, L.B., BRANNOCK, W.W. (1985) Eclogites and eclogites: their differences and similarities. *Geological Society of America Bulletin,* **76**, 483-508.

DIXON, J.E., DIMITRIADIS, S. (1987) The metamorphic evolution of the Serbo-Macedonian Massif in Greece. *Terra Cognita,* **7**, 106.

ELLIS, D.S., GREEN, D.H. (1974) An experimental study of the effect of Ca upon garnet-clinopyroxene Fe-Mg exchange equilibria. *Contributions to Mineralogy and Petrology,* **71**, 13-22.

ESSENE, E.J. (1982) Geologic thermometry and barometry. In: FERRY, J.M. (ed.). *Characterization of Metamorphism Through Mineral Equilibria, Reviews in Mineralogy,* **10**, 153-206.

ESSENE, E.J. (1989) The current status of thermobarometry in metamorphic rocks. In: DAILY, J.S., CLIFF, R.A., YARDLEY, B.W.D. (eds). Evolution of Metamorphic Belts, *Geological Society Special Publication,* No **43**, 1-44.

GALER, S.J.Q., O'NIONS, R.K. (1989) Chemical and isotopic studies of Ultramafic Inclusions from the San Carlos Volcanic field, Arizona: A bearing on their Petrogenesis. *J. Petrology,* **30**, 1033-1064.

GANGULY, I. (1979) Garnet and clinopyroxene solid solutions and geochemistry based on Fe-Mg distribution coefficient. *Geochimica Cosmochimica Acta,* **43**, 1021-1029.

GODARD, G. (1988) Petrology of some eclogites in the Hercynides: The eclogites from the southern Armorican massif, France. In: SMITH, D.C. (ed.). Eclogites and Eclogite-facies rocks, *Elsevier,* 451-510.

GRAHAM, C.M., POWELL, R. (1984) A garnet-hornblende geothermometer: Calibration, testing and application to the Pelona Schist, Southern California. *Journal of Metamorphic Geology,* **2**, 13-31.

HOLLAND, T.J.B. (1980) The reaction albite = jadeite + quartz determined experimentally in the range 600-1200°C. *Am. Mineral,* **65**, 129-134.

JENKINS, D.M. (1983) Stability and composition relations of calcic amphiboles in ultramafic rocks. *Contr. Mineral. Petrol.,* **83**, 375-384.

KLEIN, H., WIMMENAUER, W. (1984) Eclogites and their retrograde transformation in the Schwarzwald (Fed. Rep. Germany). *N. Jb. Miner. Mh.,* **H1**, 25-38.

KROGH, E.J. (1988) The garnet-clinopyroxene Fe-Mg geothermometer: A reinterpretation of existing experimental data. *Contribution to Mineralogy and Petrology,* **99**, 44-48.

LEAKE, B.E. (1978) Nomenclature of amphiboles. *American Mineralogist,* **63**, 1023-1052.

LIATI, A. (1986) Regional metamorphism and overprinting contact metamorphism of the Rhodope zone, Near Xanthi (N. Greece). *Dissertation,* Technischen Universität Carolo-Wilhelmina zu Braunschweig.

LOVERING, J.E., WHITE, A.J.R. (1969) Granulitic and eclogite inclusions from basic pipes at Delegate, Australia. *Contrib. Mineral. Petrol.,* **21**, 9-52.

MOTTANA, A. (1977) Petrochemical characteristics of the Western Alps eclogites. *N. Jb. Mineral. Abh.,* **130**, 78-88.

NEWTON, R.C. (1986) Metamorphic temperatures and pressures of group B and C eclogites. In: EVANS, B.W. and BROWN, E.H. (eds). Blueschists and eclogites. *Geol. Soc. Amer. Mem.,* **164**, 17-30.

OLAFSSON, M., EGGLER, D.H. (1983) Phase relations of amphibole, amphibole-carbonate and phlogopite-carbonate peridotite: petrologic constraints on the asthenosphere. *Earth Planet. Sci. Letters,* **64**, 305-315.

PEARCE, J.A. (1983) Role of the subcontinental lithosphere in magma genesis at active continental margins. In: HAWKESWORTH, C.J., NORRY, M.J. (eds). Continental basalts and mantle xenoliths. *Shiva,* 230-249.

POWELL, R. (1985) Regression diagnostics and robust regression in geothermometer / geobarometer calibration: the garnet-clinopyroxene geothermometer revisited. *Journal of Metamorphic Geology*, **3**, 231-243.

ROCK, N.M.S., LEAKE, B.E. (1984) Amphibole nomenclature scheme: Computerization and its consequenses. *Mineralogical Magazine*, **48**, 211-227.

RYBURN, R.J., RAHEIM, A., GREEN, D.H. (1976) Determination of the P, T paths of natural eclogites during metamorphism - record of subduction. *Lithos*, **9**, 161-164.

SANTALLIER, D.S. (1983) Les éclogites du Bas-Limousin, Massif Central français. Comportement des clinopyroxènes et des plagioclases antérieurement à l'amphibolitization. *Bull. Minéral.*, **106**, 691-707.

SMULIKOWSKI, K. (1968) Differentiation of eclogites and its possible causes. *Lithos*, **1**, 89-101.

TAKASU, A. (1984) Prograde and Retrograde Eclogites in the Sambagawa Metamorphic Belt, Besshi District, Japan. *J. Petrology*, **25**, 619-643.

YARDLEY, B.W.D. (1989) An Introduction to Metamorphic Petrology. *Longman Earth Science Series*, 248 pp.