Zeitschrift: Schweizerische mineralogische und petrographische Mitteilungen = Bulletin suisse de minéralogie et pétrographie

Band: 68 (1988)

Heft: 2

Artikel: Comparison between two types of coronitic eclogites from the Western Alps : implications for a pre-eclogitic evolution

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DOI: https://doi.org/10.5169/seals-52062

SCHWEIZ. MINERAL. PETROGR. MITT. 68, 225-235, 1988

Comparison between two types of coronitic eclogites from the Western Alps: Implications for a pre-eclogitic evolution

by *Bruno Messiga*[1] and *Marco Scambelluri*[2 3]

Abstract

Coronitic metagabbros in eclogitic facies from Western Liguria and Western Alps underwent an Alpine polyphase metamorphic overprint after previous oceanic and prograde metamorphic events. Coronitic textures indicate metamorphism under low strain conditions, generating closed chemical systems, local equilibria and preserving both relics of primary mineral composition and textures. Microtextural and chemical criteria have been used to infer two pre-eclogitic metamorphic histories that these eclogites may have undergone. In the first case the eclogitic metamorphism overprints gabbros that have metastably escaped the previous oceanic and/or prograde events. Thus eclogites still retain widespread relics of primary minerals. In these eclogites high pressure phases have compositions clearly reflecting those of gabbroic minerals, after which they pseudomorphically developed. In the second case high pressure metamorphism affects gabbros that have experienced previous oceanic and/or prograde reactions. Only sporadical relics of primary phases are preserved and a better compositional homogeneity of the syn-eclogitic minerals suggests that the chemical reactions between phases already occurred during the prograde path.

Keywords: Eclogite, coronite, texture, metamorphism, metagabbroic evolution, Western Liguria, Western Alps, Italy.

Introduction

Relic mineral phases in metamorphic rocks constitute evidences constraining the reconstruction of P-T paths and of the rock history during orogenic processes. In absence of relics, earlier pre-climax events may be detected by the examination of the microstructural and the chemical features of the metamorphic assemblages. In this case it must be stated that metamorphic minerals have developed as pseudomorphic replacements in a low strain environment.

Similar cases are represented by the coronitic rocks. Coronitic reactions occur under low strain conditions and enhance the preservation of previous microstructural sites and of the chemical differences between these (MYSEN and HEIER, 1972; GRIFFIN and HEIER, 1976; MØRK, 1985; AUSTRHEIM and ROBINS, 1981; CIMMINO and MESSIGA, 1983; POGNANTE, 1985). The equilibrium is only locally and partially attained: it can be regarded as achieved within microdomains. Hence in such rocks it is possible to evaluate the chemical and metamorphic changes compared to the original mineral compositions.

This study compares two major types of coronitic eclogites from Western Alps, in order to get informations about the possible P-T evolution pre-dating the high pressure – low temperature climax. The attention has been focused only on eclogites derived from originally gabbroic lenses belonging to the ophiolite

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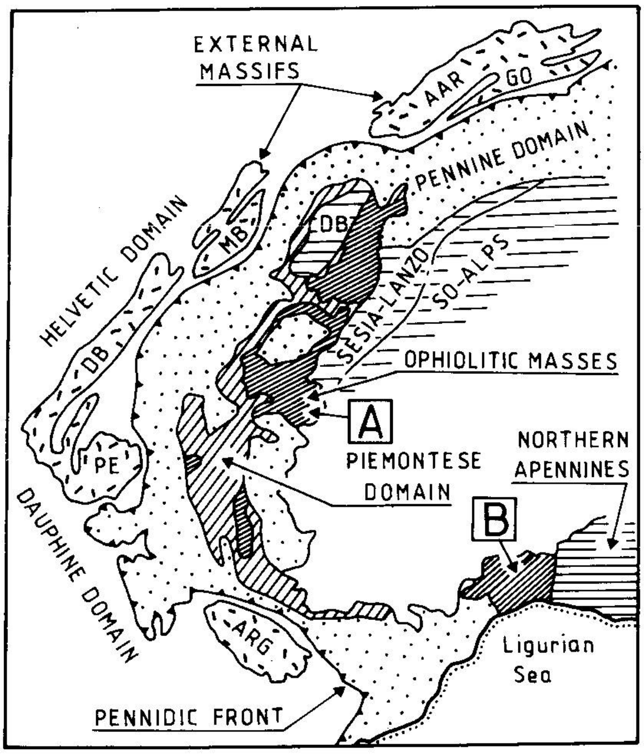

Fig. 1 Index map of the Western Alps; the main tectonic units are indicated as follows: AAR = Aar Massif; ARG = Argentera Massif; DB = Dent Blanche Nappe; GO = Gotthard Massif; MB = Mont Blanc Massif; PE = Pelvoux Massif; SO-ALPS = Southern Alps. A = Rocciavrè area; B = Western Liguria area.

sequences of Piemontese Ophiolite Nappe (Fig. 1). In particular, coronitic samples from the Ligurian Alps and from the Rocciavrè area (Sangone Valley) have been studied in detail. Petrological and microstructural data concerning the Rocciavrè eclogitic metagabbros have been entirely taken from POGNANTE (1985) and POGNANTE et al. (1982).

The polyphasic metamorphic evolution of Alpine age for the most part of Western Alps ophiolites is already well known (DAL PIAZ, 1974; ERNST, 1976; ERNST and DAL PIAZ, 1978). A few hornblende and lawsonite relics indicate early oceanic and prograde metamorphic events respectively. Furthermore, gabbros from the Apennine ophiolite sequences have bulk rock compositions analogous to the Ligurian alpine gabbros, and preserve widespread relics of a polyphasic oceanic evolution. In these rocks an amphibolitic paragenesis, developed in ridge-type metamorphic conditions, has been overprinted by a later green schistic off-ridge assemblage (MESSIGA, 1984; CORTESOGNO and LUCCHETTI, 1984).

During the Upper Cretaceous times the ophiolite and cover sequences of the Piemontese Ophiolite Nappe underwent eclogitic metamorphism and deformation due to subduction (DAL PIAZ, 1974; ERNST and DAL PIAZ, 1978).

Subsequent uplift caused the retrograde metamorphism ranging from intermediate pressure facies up to a later greenschists event. Such recrystallizations at lower pressure and/or temperature conditions are generally marked by different amphibole-bearing parageneses. Amphibole compositions range from sodic types (glaucophane-bearing stage), to sodic-calcic types (barroisite-bearing stage), to calcic types (actinolite-bearing stage), indicating a progressive change in metamorphic conditions. Such retrograde events are generally associated to pervasive deformative events (ERNST, 1976, 1979; SCAMBELLURI, 1987; LAIRD and ALBEE, 1981; LOMBARDO and POGNANTE, 1982).

High pressure metamorphic evolution

The Ligurian and Rocciavrè metagabbros show a tholeiitic trend from Mg-Cr-Ni rich compositions, to Fe-Ti rich varieties (POGNANTE, 1985; CORTESOGNO et al., 1977). In both localities the high pressure paragenesis are represented by Na-clinopyroxene + garnet bearing assemblages. The compositions of the high pressure phases are generally dependent on the bulk rock chemistry, as shown in Fig. 2a–b for Ligurian eclogites (MESSIGA et al., 1983; MESSIGA, 1987). The eclogitic Fe-Ti-gabbros, which originally consisted of augite + plagioclase + Fe-Ti-oxides + apatite contain chloromelanite + almandine rich garnet + rutile + apatite (Fig. 2a–b). In the Ligurian Mg-Al-rich gabbros the magmatic assemblage augite + plagioclase + olivine has been replaced by omphacite + pyrope - almandine garnet + zoisite ± talc (Fig. 2a–b). In Fig. 2c the bulk rock compositions of Fe-Ti-gabbros and Mg-Al-gabbros from Ligurian Alps have been plotted in a ACF diagram (THOMPSON, 1981). The chemographic relationships indicate that, excluding oxides, bimineralic parageneses can only be developed in meta Fe-Ti-gabbros.

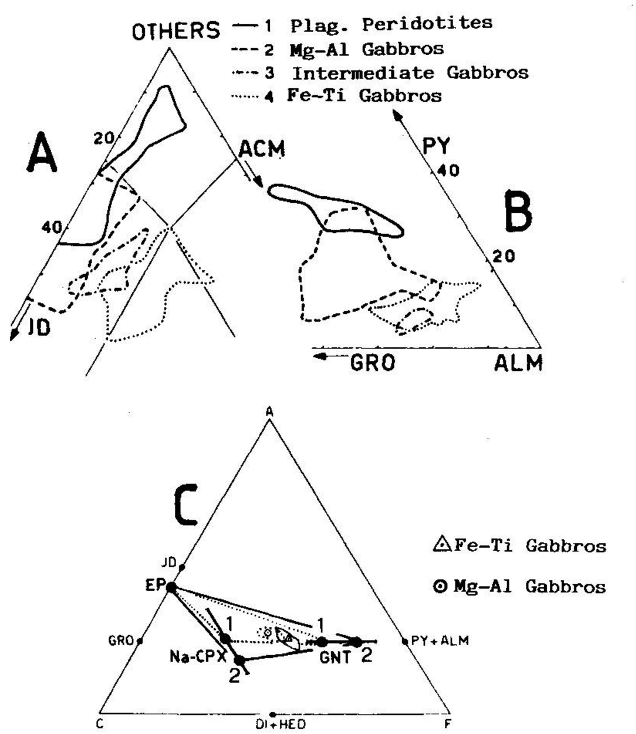

Fig. 2. Relationships between mineral chemistry and primary lithology compositions: Na-clinopyroxenes (A) and garnets (B). (C): ACF-type projection (from QZ, H_2O, $CaAlNa_{-1}Si_{-1}$, $FeAl_{-1}$, $MgFe_{-1}$; THOMPSON, 1981) showing chemographic relations for the eclogitic Mg-Al-gabbros and Fe-Ti-gabbros (MESSIGA, 1987).

Likewise, the Rocciavrè gabbros show primary and eclogitic assemblages analogous to the Ligurian gabbros. Eclogitic Fe-Ti-gabbros with augite + plagioclase (An 40%) + Fe-Ti oxides as primary relics, develope an omphacite/chloromelanite + garnet + rutile high pressure paragenesis. In Mg-Al-gabbros primary assemblage augite + bronzite + plagioclase + olivine is replaced by jadeite/omphacite + garnet + zoisite + talc.

Minimum pressure estimates have been made on the basis of coexisting quartz and jadeitic pyroxene (POPP and GILBERT, 1972; GANGULY, 1979; HOLLAND, 1980). Values of approximately 12–13 kb have been calculated for the Rocciavrè and Ligurian eclogites. Temperatures have been computed using the Fe-Mg exchange equilibria in garnet-clinopyroxene pairs. Corrections for Fe^{3+} have been applied according to CAWTHORN and COLLERSON (1974). The experimental calibration of ELLIS and GREEN (1979) yields values in the range of 430 ± 30°C for the Ligurian eclogites and of 450 ± 50°C for the Rocciavrè types (MESSIGA et al., 1983; POGNANTE, 1984; CIMMINO et al., 1981).

Microtextures

The coronitic microtextures from the Ligurian and Rocciavrè metagabbros are shown in Fig. 3.

In Fig. 3a an example of corona texture in Fe-Ti-metagabbros from Liguria is sketched. The primary augite is almost completely replaced by coarse chloromelanite crystals + small idioblastic garnets: primary pyroxene is only rarely preserved. The primary plagioclase is completely pseudomorphed by fine grained aggregates of chloromelanite/omphacite + garnet. The primary oxides are replaced by rutile and/or rutile + ilmenite intergrowths. The garnet coronas of variable thickness develope between plagioclase and augite or between plagioclase and oxides. Garnets from the different sites generally show optical zoning, defined by dark, inclusion-rich cores and clear rims.

In Fig. 3b a Ligurian coronitic Mg-Al-metagabbro is represented. Coarse chloromelanite/omphacite crystals develope after primary pyroxene: also in this case only rare spots with primary compositions are preserved. The plagioclase is totally pseudomorphed by omphacite + garnet + zoisite. The olivine is replaced by talc + glaucophanic amphibole + omphacite and shows slightly elongated shapes. In the pseudomorphs after olivine, omphacite generally nucleates close to the outermost rim of the aggregate. Usually garnet + omphacite coronas develope between the pseudomorphic replacements after olivine and plagioclase. The garnet coronas are not always present between primary plagioclase and pyroxene. Hence, also in the Ligurian eclogites richer in Mg the preservation of mineralogical relics of magmatic minerals is not common.

Textures from the Rocciavrè coronitic metagabbros are reported in Fig. 3c–d. In these samples relics of magmatic clino- and orthopyroxenes are common. The augite is coarse grained and developes garnet + omphacite reaction rims at contacts with plagioclase. The bronzite is pseudomorphically replaced by talc and shows thin garnet coronas at its rims in contact with plagioclase. The primary plagio-

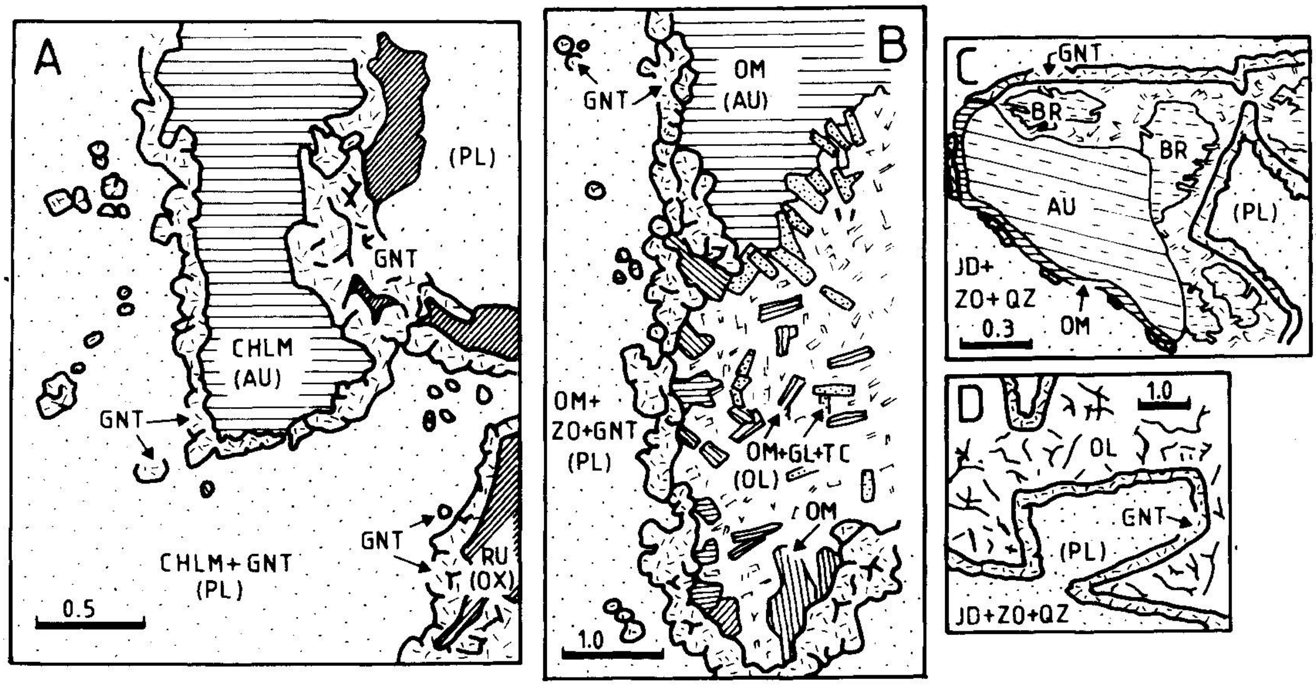

Fig. 3 A comparison between coronitic textures from: Fe-Ti-gabbros (A), Mg-Al-gabbros (B) (Western Liguria); gabbronorite (C) (D) (Rocciavrè). (C) and (D) are redrawn after POGNANTE (1985).

clase is almost completely replaced by fine-grained aggregates of jadeite + zoisite + quartz.

Mineral chemistry

Microprobe analyses of minerals constituting the previously described microtextures are listed in the Tab. 1. Original data on mineral compositions are available for ligurian eclogites only. The compositional data and diagrams concerning the Rocciavrè metagabbros have been redrawn from literature (POGNANTE, 1985).

The garnets from the Ligurian Fe-metagabbros have almandine rich compositions, as shown in Fig. 4b. In Fig. 5 garnets have been distinguished according to the microstructural nucleation site, in order to check if their compositional variations may be due to the different compositions of the pre-eclogitic minerals. This criterion does not seem to be efficient to describe changes in the Ligurian garnets compositions. The only systematic variations are in fact defined by core-rim zoning patterns. Garnets from the different microstructural domains are reported in Fig. 6: they generally have almandine enriched rims, while their cores are slightly richer in grossular and spessartine endmembers. The grossular and spessartine richer compositions probably represent earlier formed garnets and have been detected in the inner parts of coronas, as shown in Fig. 7. The clinopyroxene compositions from the same samples are reported in Fig. 4a: they may range from aegirin-augites, to chloromelanites, to omphacites; only in some cases they plot closer to the augite field. Such changes are principally due to the microstructural nucleation sites as underlined in Fig. 8a. Relics of primary pyroxenes have been only rarely detected in some coarse chloromelanite crystals developed after primary augite. Such coarse chloromelanites have slightly different compositions if compared to the fine grained pyroxenes developed after primary plagioclase, which plot close to the omphacite field of Fig. 8a.

The garnet compositional range for Ligurian Mg-Al-metagabbros is shown in Fig. 9a. The garnets are richer in Ca than garnets constituting the Fe-Ti-metagabbros; as a general rule compositional variation can be attributed to core-rim variations as shown in Fig. 9a. The Na-pyroxenes range from chloromelanite to omphacite and their compositions are generally affected by the nucleation site (Fig. 9b). The sodic pyroxenes after primary ones show a

Tab. 1 Representative analyses of sodic clinopyroxenes and garnets: numbers are referred to profiles of Fig. 7.

Tab. 1a Sodic clinopyroxenes

	80	81	85	86	110	111	112	118	119	120
SiO_2	54.10	54.64	53.01	54.90	55.78	55.09	55.48	54.36	54.90	54.91
TiO_2	0.09	0.00	0.09	0.02	0.00	0.04	0.07	0.07	0.07	0.02
Al_2O_3	2.85	6.21	8.33	8.09	8.12	5.10	8.04	8.18	8.78	7.74
Cr_2O_3	0.00	0.00	0.02	0.00	0.00	0.02	0.00	0.02	0.02	0.00
FeO	13.04	9.91	11.19	8.31	9.38	11.91	8.82	10.20	10.00	9.16
MnO	0.02	0.02	0.13	0.13	0.03	0.12	0.04	0.08	0.04	0.02
MgO	9.38	8.74	8.08	8.20	7.62	8.08	7.99	6.95	6.95	7.86
CaO	15.71	13.52	12.45	12.73	12.79	13.93	12.51	11.61	11.56	12.61
Na_2O	5.58	7.09	6.80	7.58	7.42	6.24	7.75	8.32	8.29	7.72
K_2O	0.00	0.02	0.02	0.00	0.00	0.00	0.01	0.00	0.02	0.00
Totale	100.77	100.15	100.12	99.96	101.14	100.53	100.71	99.79	100.63	100.04
N.Oss.	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00
Si^{4+}	2.02	2.01	1.96	2.00	2.02	2.04	2.01	2.00	2.00	2.01
Ti^{4+}	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Al^{3+}	0.13	0.27	0.36	0.35	0.35	0.22	0.34	0.36	0.38	0.33
Cr^{3+}	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fe^{2+}	0.41	0.31	0.35	0.25	0.28	0.37	0.27	0.31	0.31	0.28
Mn^{2+}	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mg^{2+}	0.52	0.48	0.45	0.45	0.41	0.45	0.43	0.38	0.38	0.43
Ca^{2+}	0.63	0.53	0.49	0.50	0.50	0.55	0.49	0.46	0.45	0.50
Na^{+}	0.40	0.51	0.49	0.54	0.52	0.45	0.55	0.60	0.59	0.55
K^{+}	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Totale	4.12	4.11	4.10	4.09	4.07	4.08	4.09	4.11	4.10	4.10

Tab. 1b Garnets

	82	83	84	113	114	115	116	117
SiO_2	36.86	36.85	37.50	37.38	37.17	37.11	37.29	37.33
TiO_2	0.00	0.15	0.06	0.00	0.13	0.09	0.06	0.10
Al_2O_3	21.23	20.80	21.09	21.39	20.84	21.13	21.08	21.21
Cr_2O_3	0.00	0.08	0.00	0.00	0.00	0.00	0.02	0.02
FeO	33.76	31.50	32.35	32.82	31.99	32.31	32.75	32.70
MnO	0.49	1.46	1.19	0.84	1.56	1.23	1.43	1.01
MgO	2.69	2.11	2.60	2.37	2.37	2.57	1.90	2.25
CaO	5.06	6.99	5.59	5.74	6.09	5.50	6.17	6.06
Na_2O	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.06
K_2O	0.01	0.00	0.01	0.00	0.01	0.00	0.03	0.03
Totale	100.10	99.99	100.39	100.54	100.16	99.94	100.73	100.77
N.Oss.	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00
Si^{4+}	2.96	2.97	2.99	2.98	2.98	2.98	2.98	2.98
Ti^{4+}	0.00	0.01	0.00	0.00	0.01	0.01	0.00	0.01
Al^{3+}	2.01	1.97	1.98	2.01	1.97	2.00	1.99	1.99
Cr^{3+}	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Fe^{2+}	2.27	2.12	2.16	2.19	2.15	2.17	2.19	2.18
Mn^{2+}	0.03	0.10	0.08	0.06	0.11	0.08	0.10	0.07
Mg^{2+}	0.32	0.25	0.31	0.28	0.28	0.31	0.23	0.27
Ca^{2+}	0.44	0.60	0.48	0.49	0.52	0.47	0.53	0.52
Na^{+}	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01
K^{+}	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Totale	8.03	8.04	8.01	8.01	8.02	8.02	8.02	8.02

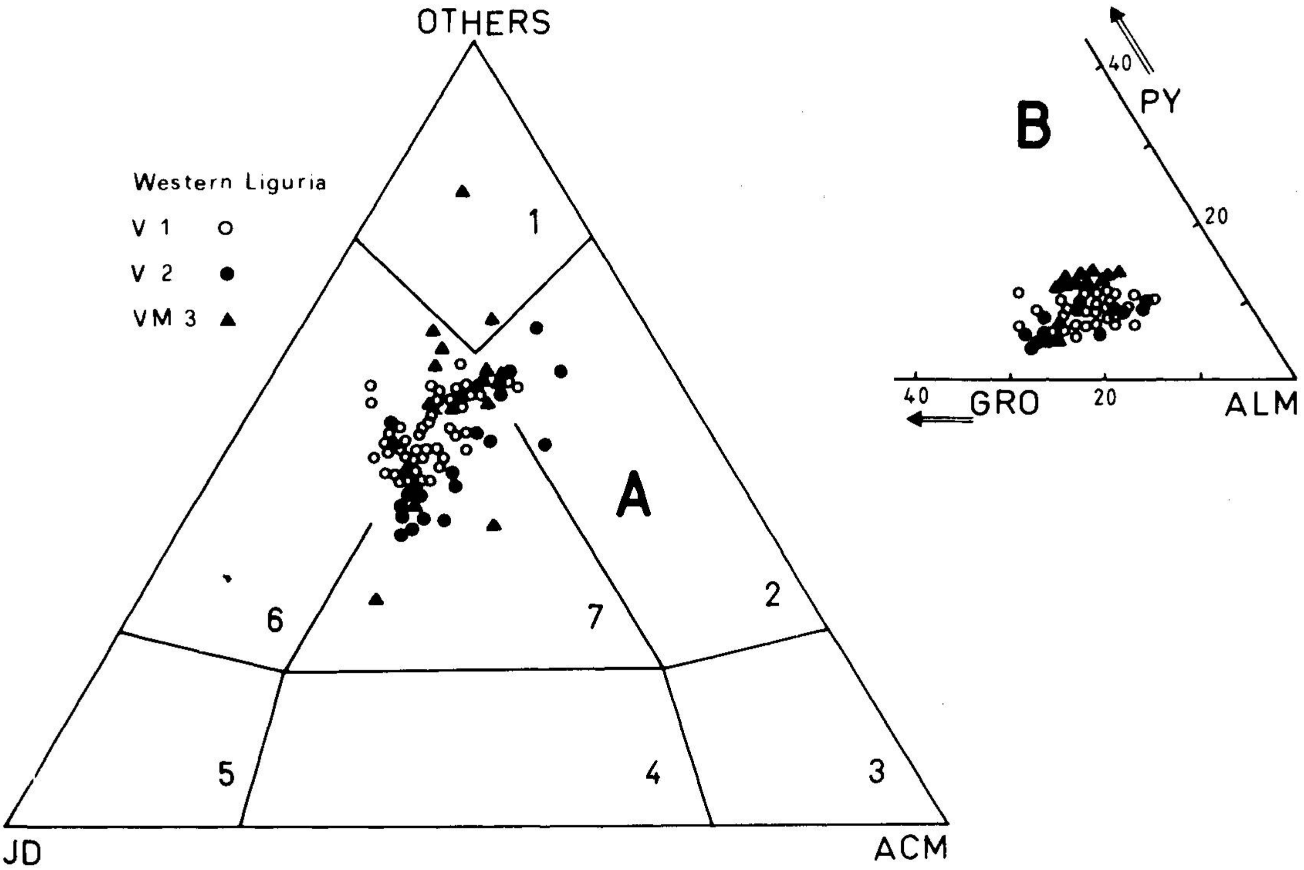

Fig. 4 Na-clinopyroxene (A) and garnet (B) composition from three different Fe-Ti-gabbros samples (Western Liguria). 1 = augites; 2 = aegirin-augites; 3 = acmites; 4 = aegirin-jadeites; 5 = jadeites; 6 = omphacites; 7 = chloromelanites.

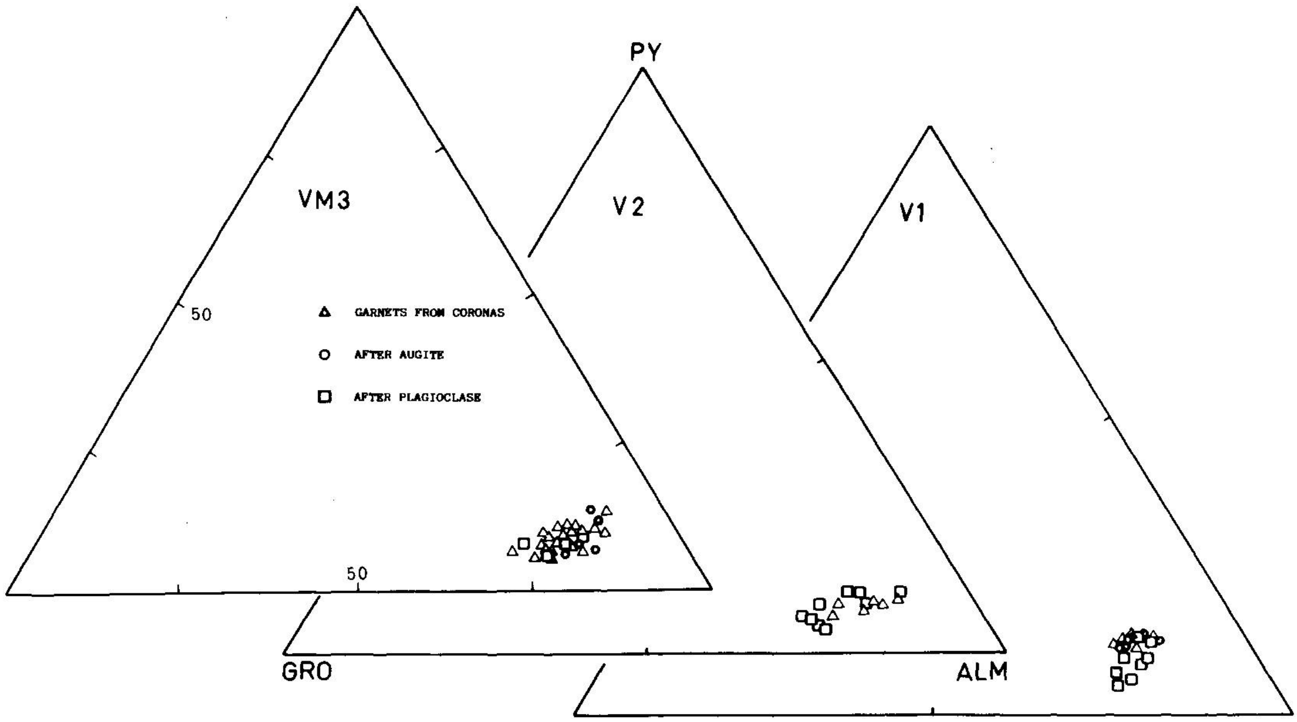

Fig. 5 Garnet compositions for the different samples of Fe-Ti-gabbros (Western Liguria). The garnets from coronas, from pseudomorphs after primary augite and from pseudomorphs after primary plagioclase are reported.

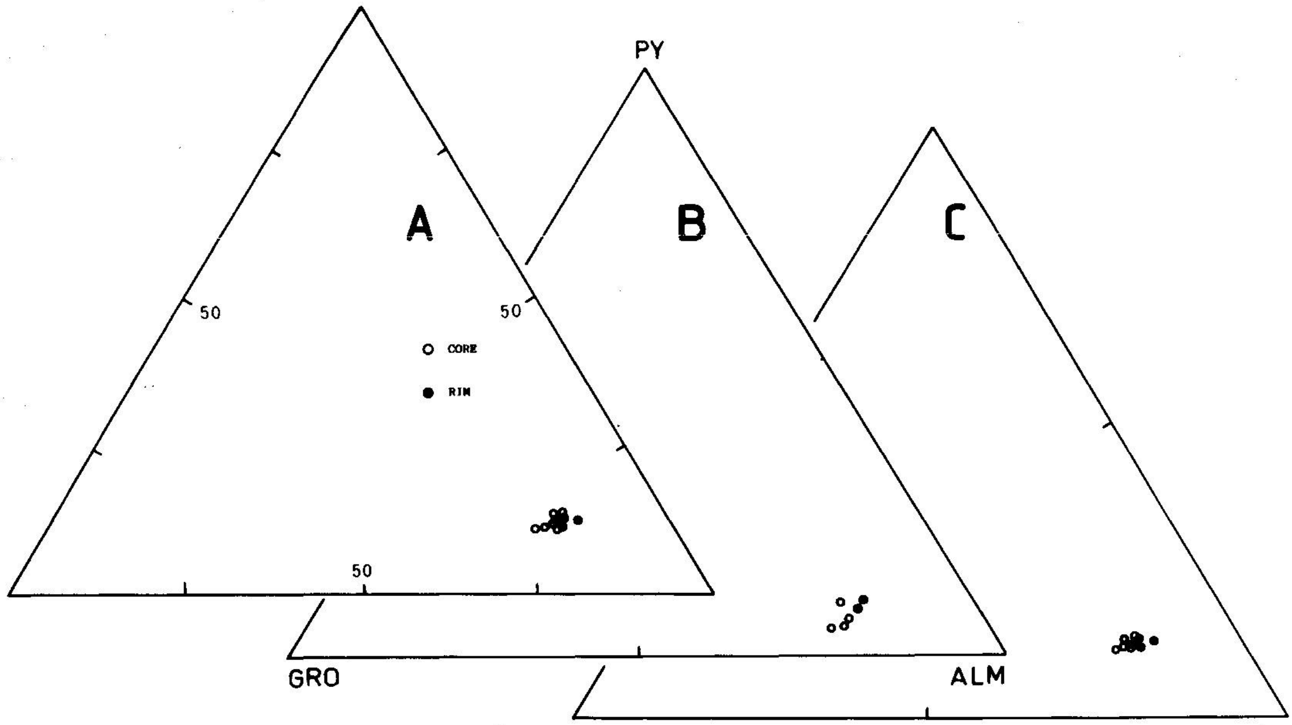

Fig. 6 Core and rim compositions for the garnets from different samples of Fe-Ti-gabbros (Western Liguria).

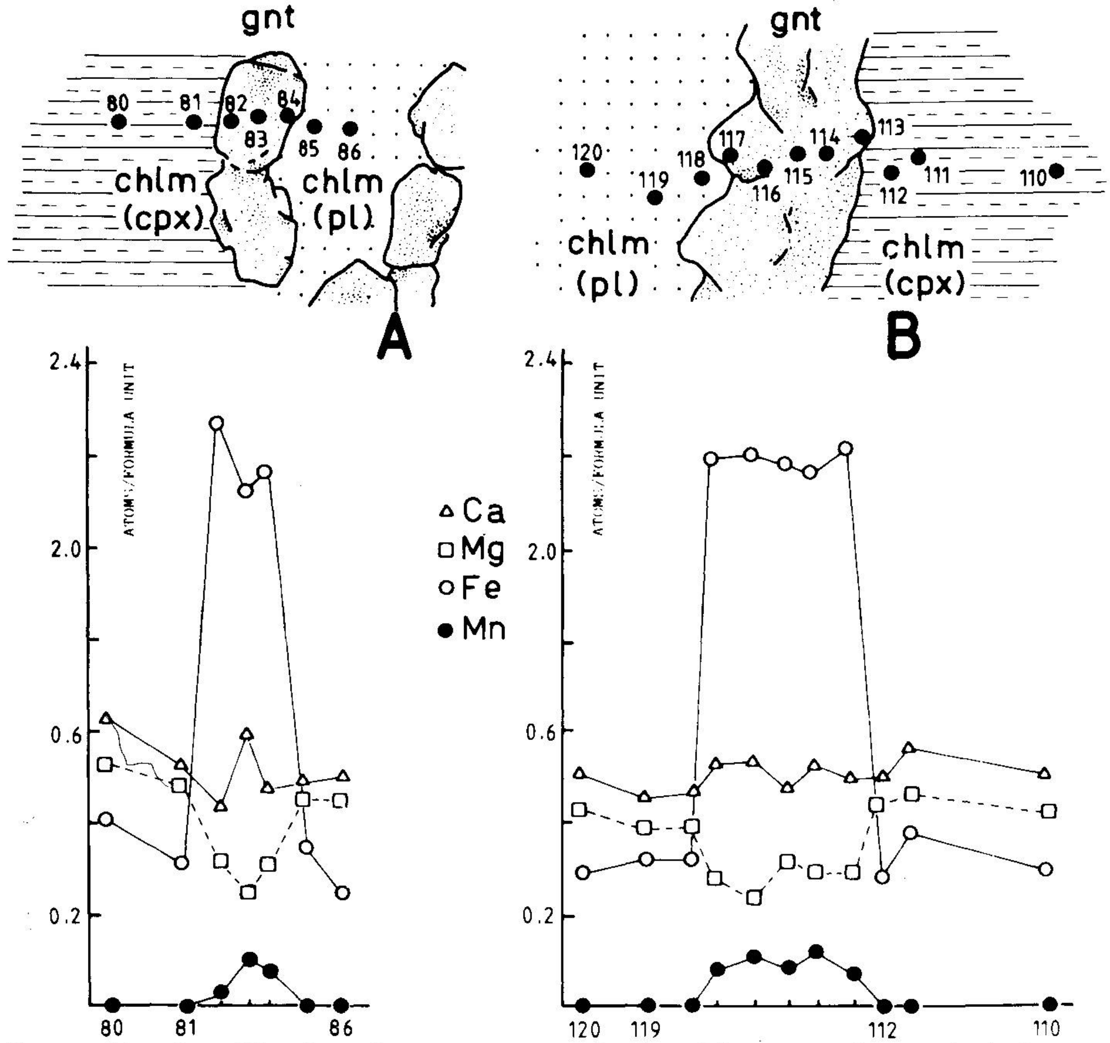

Fig. 7 Compositional profiles through garnet coronas developed between primary plagioclase and augite: Fe-Ti-gabbros, Samples VM3 and V2 (Western Liguria).

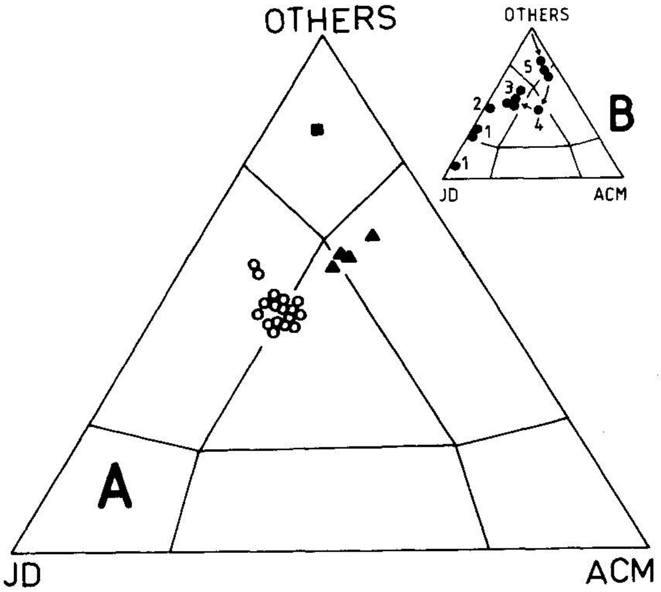

Fig. 8 A) The Na-clinopyroxene compositional trend for the Fe-Ti-gabbro V1 (Western Liguria), related to the microtextural sites: primary augite relic (full square), after primary augite (full triangle), after primary plagioclase (open circles). B) The Na-clinopyroxene compositional trend, redrawn after POGNANTE (1985) (Rocciavrè), related to the microtextural sites: after primary plagioclases (1), external rim on primary augite (2), from sheared Fe-Ti-gabbros (3), after primary augite (4), after primary augite (5).

compositional transition from chloromelanite to omphacite, probably due to successive recrystallization stages of Na-pyroxenes whose earlier eclogitic compositions can be assumed to be chloromelanite rich. The Na-pyroxenes after plagioclase plot in the omphacite field of Fig. 9b. The Na-pyroxenes from the Ligurian eclogites do not show trends like the Rocciavrè ones (also reported in Fig. 8b), whose strongly scattered compositions may reflect the chemistry of the original minerals. In this case pyroxenes growing after primary augites plot in the chloromelanite field, while the ones after primary plagioclase show jadeite and/or omphacite rich compositions.

Discussion and conclusions

The data shown above allow the distinction of two major types of coronitic eclogites in the Western Alps.

1) The first type (Rocciavrè) preserves widespread relics of the primary minerals. Eclogitic phases, especially pyroxenes, show a large compositional scatter, presumably reflecting the original compositional differences between

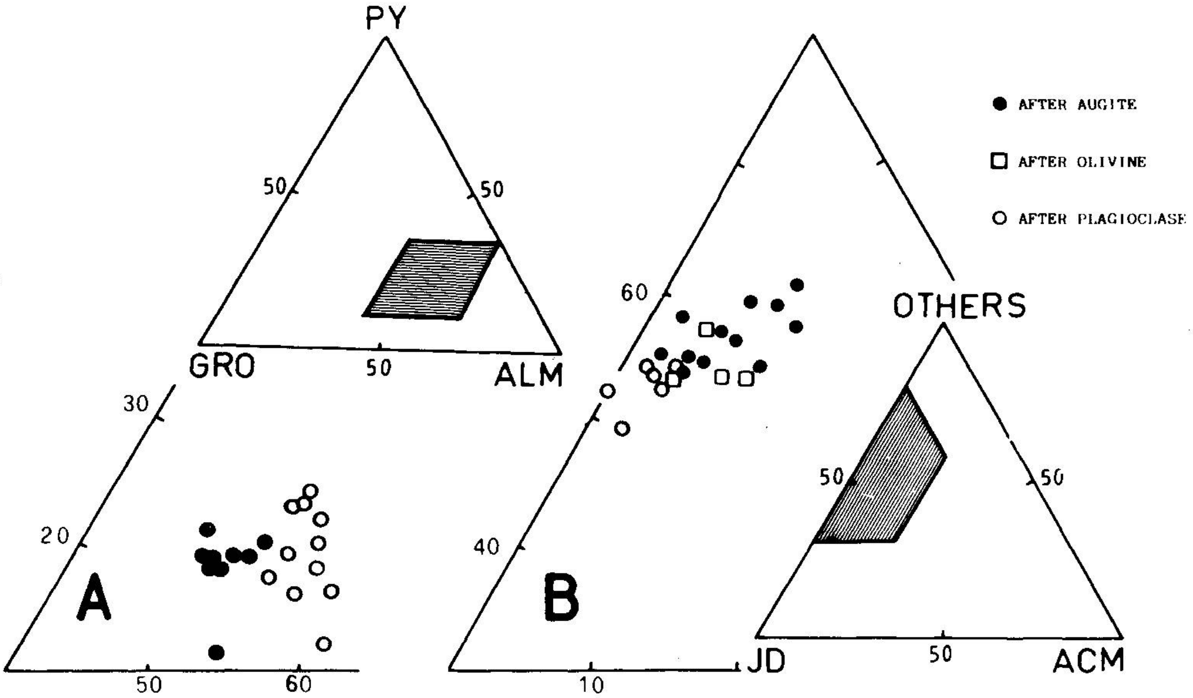

Fig. 9 Composition of relevant eclogitic minerals for VM 1/3 Mg-Al-gabbro (Western Liguria). (A) core-rim compositional variations of garnets; (B) compositions of Na-clinopyroxenes after primary augites, olivines and plagioclases.

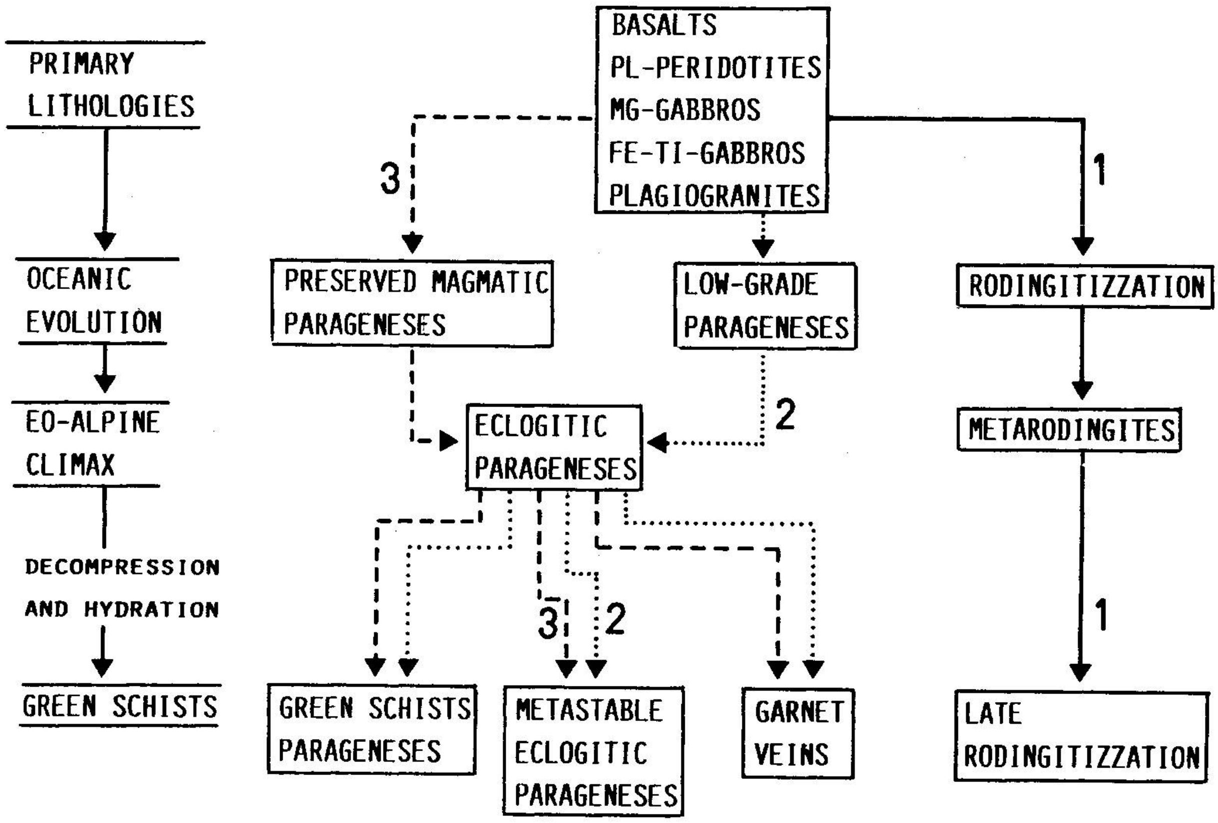

Fig. 10 Simplified metamorphic evolutive paths of ophiolitic intrusives.

magmatic phases. This may imply that these rocks have preserved the primary mineral compositions up to the high pressure event.

2) On the contrary the second type (Western Ligurian) does not show large microstructural relics of the gabbroic minerals. Furthermore high pressure phases have a tighter compositional range, which supposes a slight chemical homogeneization pre-dating the eclogitic climax.

In Fig. 10 are summarized the possible paths that primary lithologies constituting oceanic lithosphere may undergo during an orogenic and metamorphic cycles. In times pre-dating the eclogitic climax these rocks may: i) be completely rodingitized (path 1); ii) be involved in oceanic metamorphic reactions (path 2); iii) escape the oceanic evolution as metastable relics (path 3).

Coronitc textures previously examined underline two different pre-climax histories for oceanic metagabbros from Western Alps (Fig. 10).

a) The ligurian eclogites may have followed path 2: in this case oceanic metamorphic reaction have partially changed or homogeneized the compositions of the different microtextural sites. Therefore the eclogitic minerals have restricted compositional variations.

b) The eclogites from the Rocciavrè possibly followed path 3, preserving the compositions of magmatic minerals. In this way primary compositional differences are reflected by the eclogite minerals.

The further evolution may imply post-climax retrograde reactions in a decompressional regime up to greenschists conditions, and metastable relics of eclogitic parageneses can be preserved.

Acknowledgements

The reading of early draft and criticism by G. B. Piccardo, A. Ruendal and A. Stäubli and the final revision from J. Ganguin have been strongly appreciated. Electron microprobe analyses have been performed at the Centro di Studio per la Stratigrafia e Petrografia delle Alpi Centrali (CNR Milano) and at the IMP of the ETH-Zentrum, Zürich; we want to thank V. Diella, M. Liniger and J. Sommerauer for their courtesy and technical support during analytical work.

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Manuscript received May 16, 1988; revised manuscript accepted July 20, 1988.