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COMPARATIVE PETROLOGICAL INVESTIGATIONS OF METAGABBROS FROM WESTERN ALPS OPHIOLITES

A-A. M. ABDEL-KARIM—Z. PUSKÁS

Department of Petrology and Geochemistry, L. Eötvös University

ABSTRACT

Data on field relation, petrography and trace element geochemistry are presented for metagabbro bodies from a few small tectonic slices in the Piedmont oceanic — type sequence. They are from east Arc valley and Monviso from the eastern internal Piedmont unit and from middle Arc valley, Montgenevre, and Cristillan from western external Piedmont unit.

The metagabbros from Monviso are re-equilibrated under early Alpine eclogitic conditions and were successively involved in a polyphase retrograde tectono-metamorphic evolution. They include eclogitic — and smaragdite — metagabbros which underwent into greenschist facies metamorphism of a later stage. Some gabbros have partially escaped the Alpine metamorphism.

The Arc metagabbros are characterized by glaucophaneschist facies which retrogressed to greenschist facies. The well-preserved gabbroic sequence ranging from talc serpentine metagabbro to late gabbroic differentiated products (albitite) are present in Chenaillet.

In these gabbros, the early — Alpine HP prograde metamorphic events produced blueschist and eclogitic mineral assemblages (glaucophane, phengite, clinozoisite and omphacite ± zoisite ± garnet ± rutile) while the HP retrograde events produced blueschist, greenschist and amphibolite mineral assemblages.

These gabbros appear to be derived from different magma sources in different geotectonic environments and suffered different kinds of metamorphism. Moreover during the early stage of crystallization, Mg—Al gabbros were produced, characterizing a primitive magma while late stage crystallization produced more differentiated Fe—Ti gabbros.

KEYWORDS: petrology, trace element geochemistry, metamorphic evolution, ophiolite metagabbros, Piedmont Zone, Western Alps.

INTRODUCTION

The metaophiolite nappes of the Western Alps display a close connection with some sequences of the Piedmont ophiolite. They are described as remnants of the Tethyan oceanic crust structurally pinched between the Austro-Alpine continental crust (Sesia-Lanzo Zone) and European continental margin (Monte Rose—Grand Paradiso and Grand Saint Bernard nappes) (DAL PIAZ, 1974; COMPAGNONI *et al.* 1977; CARON, 1977, 1984; NISIO and LARDEAUX, 1987). Recently, the ophiolitic associations of the Western Alps were described as rocks formed in the Piedmont-Ligurian oceanic basin during Jurassic time (MESSIGA, 1987). They contain eo-Alpine HP-LT metamorphic assemblages of eclogite and/or blueschist facies, overprinted by a later Alpine re-equilibration in the greenschist facies (DAL PIAZ *et al.* 1972; OBERHAENSLI *et al.* 1982; CARPENA, 1983; NISIO and LARDEAUX, 1987; KUBOVICS and ABDEL-KARIM (1, 2), in press; ABDEL-KARIM and BILIK in press).

The metagabbro bodies of the Western Alps are either strongly metamorphosed, or partly preserved their igneous mineralogy and original relations with ultramafics, basalts and sedimentary sequences.

H—1088 Budapest, Múzeum krt. 4/a, Hungary.

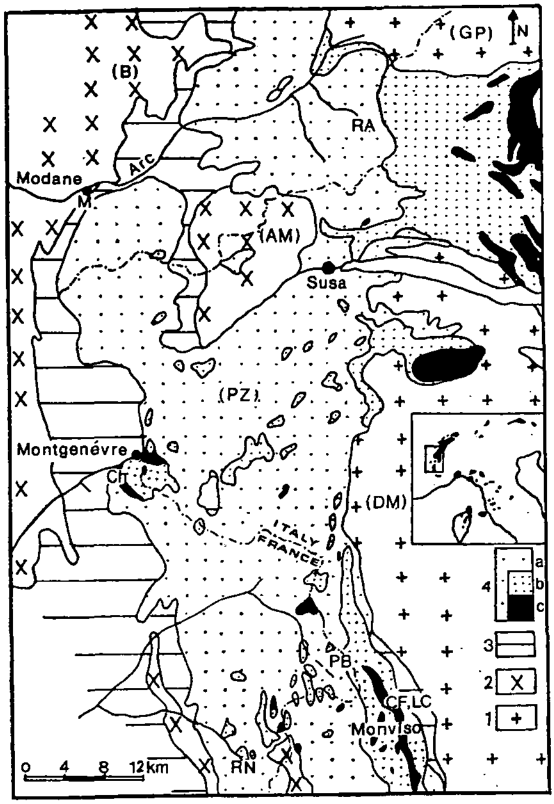

Fig. 1. Tectonic sketch map of the Internal Western Alps showing the location of the main ophiolite complexes. 1. Dora-Maire (DM) and Gran Paradiso (GP) continental units (European Paleomargin); 2. Vanoise, Ambin (AM) and Brianconnais (B) continental units (European Paleomargin); 3. Mesozoic epicontinental covers; 4. Piedmont Zones (PZ) Schistes Lustrés' nappe (Mesozoic, mainly oceanic material): a) undifferentiated metasediments with subordinate ophiolites, b) ophiolite complex with minor metasediments, c) metagabbro bodies.
Location of samples: Arc valley: RA) Refuge d'Averole, M) Modane; Monviso: PB) Petit Belvedere, CF: Colletto Fiorenza, LC: Lago Chiaretto, Montgenévre: CH) Chenaillet; RN) Roche Noire

The distribution of the gabbroic rocks in the Piedmont Zone is, as follows: (1) Large bodies associated with ultramafics and metabasalts in an ophiolite nappe (Eastern Piedmont unit) *(Fig. 1.)*. They derived from the oceanic crust and mantle of the Mesozoic Piedmont-Ligurian basin (Bertolami and Dal Piaz, 1970; Dal Piaz and Ernst, 1978; Lombardo *et al.* 1978, Lombardo and Pognante, 1982) and display widespread eclogotic assemblages which are believed to reflect a late Cretaceous subduction (Dal Piaz, 1974). (2) Smaller tectonic slices or olistoliths associated with metasediments in a westernmost composite unit (Western Piedmont unit) (Bearth, 1967; Dal Piaz, 1974; Dietrich, 1980; Lombardo and Pognante, 1982) *(Fig. 1.)*. In this unit only blueschist facies assemblages were produced.

Other units, consisting of Ligurian-type sedimentary series and resting on ophiolite bodies are believed to have been formed in the fracture zone of the Piedmont-Ligurian ocean (Lemoine, 1980).

Geological setting and primary features of metagabbros

Field study and sampling of the ophiolitic metagabbros were carried out from Arc valley in the north, Montgenèvre in the central as well as Cristillan and Monviso in the south Piedmont zone *(Fig. 1.)*. Some of the gabbroic bodies partly escaped the Alpine deformation. Although the magmatic features of some bodies are similar, as a result of their different structural setting, different relationship between the gabbros and the other ophiolite members (peridotites, basalts and sediments) can be observed.

The *Arc metagabbros* from Zermatt-Saas zone have been collected in Modane and Refuge d'Averole between Ambin and Gran Paradiso units *(Fig. 1.)*. They represent heterogeneous metamorphic rocks and show strong effects of the Alpine deformation and all the magmatic minerals and structures are more or less obliterated. (a) Refuge d'Averole metagabbros (greenschistic metagabbros) are situated in the east Arc valley, about 15 km North of Susa *(Fig. 1.)*. They are covered by metabasites (prasinites and ovardites) and overlying metaultramafics (serpentinites and metapyroxenites). They are schistose, flasered and porphyroblastic and usually variable in grain size. (b) Modane metagabbros (glaucophanites) are interposed between Mesozoic epicontinental covers and the western Piedmont zone, forming a small body enclosed in marble and gyps. They are massive, coarse-grained with appearance of gabbroic texture.

The *Chenaillet gabbroic sequence* (on the western side of the Alpine belt) is a part of the Montgenévre-unit which represents one of the best preserved ophiolite complexes in the W. Alps (BERTRAND *et al.* 1987). The primary structure and, in part, the primary mineral assemblage are well preserved. The gabbroic, ultramafic and basaltic rocks occur as separate tectonic units. The Chenaillet gabbroic sequence (130 m thick) has a typically Alpine-character with green cpx and whitish-green plagioclase. Grain size varies widely and sometimes is pegmatitic. They are separated from the pillow lavas by a shear zone which in some places contains serpentinite lenses. They finally differentiated into albitites.

The *Monviso rocks* were collected near Petit Belvedere (Guil valley, French Monviso) and Colletto Fiorenza and Lago Chiaretto (Italian Monviso) on the eastern side of the Alpine belt. The Monviso ophiolite represents a section of the Piedmont-Ligurian oceanic lithosphere and constitutes the most complete metamorphic ophiolite section in the Western Alps (KIENAST and MESSIGA, 1987). It shows four stages of metamorphism namely oceanic event, eclogitic, blueschist and greenschist facies metamorphism.

In the basement of the Monviso gabbroic sequence one can find the Dora-Maire unit and other metasediments. The tectonic contact (few m. thick) consists mainly of strongly sheared serpentinite and talc carbonate schist. Small bodies of ultramafics and layers of eclogitic Fe-gabbros occur within the isotropic metagabbros. The metagabbros exhibit a well developed foliation consisting of bright-green phenoclasts of smaragdite (Cr-omphacite) up to 2 cm length. They sometimes occur within the eclogitic sequence (few cm — few dm thick). The eclogitic metagabbros which are strongly retrogressed mostly consist of greenschist facies mineral assemblage. Some relics of the original pegmatoid gabbroic structure are preserved within the mylonitic foliation of the layered eclogites. Some gabbroic (smaragditic) rocks are crosscut by fine grained greenish coloured metabasalt dykes (several dm thick).

The *Roche Noire metagabbros* (Cristillan) occur in one of the small ophiolitic bodies enclosed in the calcschists found in the southern Piedmont nappe, internal Western Alps *(Fig. 1.)*. They are usually composed of big blocks and crosscut by

TABLE 1

Main petrographic features of representative rocks from Western Alps metagabbros

Rock name	Texture	Main primary minerals (magmatic and late-stage magmatic)	Main secondary minerals (hydrothermal and metamorphic)	Metamorphic facies	Possible primary rock
		1.1. Arc valley; Refuge d'Averole			
(a) Chl-actin metagab.	porph, poikil, nemato, flas		actin-trem, chl, ab, clinoz, ep, leuc, cc	greensch. f.	Mg—Al gab.
(b) Clinoz-chl metagab.	poikil, she		chl, clinoz, actin, trem, ab, gar, tit	greensch. f.	Mg—Al gab.
		1.2. Arc valley; Modane			
Glaucophanite	fibro, nemato		rut. glau, ep, chl, ab, bio, white mi, law, qz, cros	glau. sch. — greensch. f.	Fe—Ti gab.
		2.1. Montgenèvre; Chenaillet			
(a) Talc-serp-gab.	hypid	cpx, pl	trem, serp, talc, preh	greensch. f.	Mg—Al gab.
(b) Chloritized metagab.	hypid	pl	chl, ep, preh, tit	greensch. f.	Mg—Al gab.
(c) Cpx. metagab.	flas, hypid	cpx, pl, Fe-oxide	amp, ep, clinoz, chl	greensch. f.	Mg—Al gab.
(d) Leucogab.	hypid	pl	ep, zo, preh, chl	greensch. f.	Fe-gab.
(e) Albitite	hypid, gran	olig, qz, hb	chl, ep, ab	greensch. f.	plagiogr.
		3.1. Monviso; Petit Belvedere (Guil valley)			
(a) Corund cumm. gab.	pseudoph, sch	pl	Corund, cumm, preh, chl, white mi	glau. sch. —	Mg—Al gab.
(b) She. cpx. metagab.	oph, she, kink	cpx, ap	trem-actin, ep. leuc, cc, preh, glau	greensch. f.	Mg—Al and Fe—Ti gab.
		3.2. Monviso; Colletto Fiorenza			
(a) Smaragdite metagab.	porph	cpx	Cr—omp, trem, jad, talc, ab, qz, chl, gar, tit	eclogite- -greensch. f.	Mg—Al gab.
(b) Eclogitic metagab.	porph	cpx	omp, trem, zo, gar, qz, tit, blue amp, phen	eclogite f.	Fe—Ti gab.
		4.1. Cristillan valley; Roche Noire			
Hb-metagab.	hypid, sch	pl, hb	ep, trem, chl	amph?- greensch. f.	Fe—Ti gab.

Abbreviations: cpx = clinopyroxene; jad = jadeite; omp = omphacite; amp = amphibole; cumm = cummingtonite; glau = glaucophane; cros = crossite; trem-actin = tremolite-actinolite; hb = hornblende; ep = epidote; clinoz = clinozoisite; zo = zoisite; chl = chlorite; preh = prehnite; cc = calcite; ap = apatite; leuc = leucoxene; rut = rutile; tit = titanite; bio = biotite; mi = mica; phen = phengite; gar = garnet; law = lawsonite; ab = albite; olig = oligoclase; qz = quartz; pl = plagioclase; porph = porphyroblastic; poikil = poikiloblastic; nemato = nematoblastic; fibro = fibroblastic; flas = flaser; hypid = hypidiomorphic; oph = ophitic; pseudoph = pseudoophitic; interg = intergranular; she = sheared; gran = granoblastic; sch = schistose; gab = gabbro; amph = amphibolite; greensch = greenschist; glau. sch = glaucophane schist; f = facies; plagiogr = plagiogranite basalt dykes. The small fragments of gabbros and minor basalt in a matrix of the same materials are usually composed of an ophiolitic breccia. These gabbros are coarse-grained, massive, banded and whitish-green in colour. They appear to be overprinted by amphibolite facies.

Mineralogy and petrography

The primary (magmatic and late-stage magmatic) as well as the secondary (hydrothermal and metamorphic) mineral assemblages and textures are summarized in Table 1. The metamorphic evolution and some petrographic features are given in Table 2.

TABLE 2

Metamorphic evolution of the Western Alps ophiolitic metagabbros

	magmatic parageneses	Alpine metamorphic parageneses		
		eclogite f.	blueschist f.	greenschist f.
mag. pyroxene	—			
plagioclase	—			
Fe-Ti oxide	—			
omphacite		—		
garnet		—	—	
zoisite		—		
rutile		—	—	
talc		—	—	
phengite		—	—	
Mg chlorite		—	—	
tremolite		—	—	—
jadeite		—	—	
glaucophane		—	—	—
albite			—	—
green amphibole				—
Fe-chlorite				—
clinozoisite				—
titanite				—

1.1. Two varieties of metagabbros in greenschist facies have been recorded in the Piedmont zone from Refuge d'Averole (Arc), French Western Alps:

(a) *Chlorite actinolite metagabbros* show large crystals (5—7 mm long) of actinolitic amphibole (pseudomorph after magmatic pyroxene) which in turn enucleated aggregates of actinolite. The granoblastic matrix consists of albite, epidote-clinozoisite, chlorite, actinolite-tremolite *(Fig. 2.)* and minor titanite-leucoxene and calcite (Table 1.). The albite (25.1 v%*) forms anhedral crystals, sometimes contains epidote, clinozoisite, tremolite and titanite as inclusions. The chlorite (23.8 v%) is rich in Mg and replaced the former olivine (?). The epidote-clinozoisite (20 v%) is strongly pleochroic and is embedded in a chloritic matrix. The actinolite-tremolite (30.8 v%) replaced the former pyroxene and sometimes altered to chlorite. Leucoxene/titanite is usually associated with epidote. Fine grains of calcite replaced the plagioclase.

* v%: volume per cent.

TABLE 3

Trace element composition of some gabbroic rocks from the Western Alps ophiolites (in ppm)

Locality	Arc valley (Refuge d'Averole)		Monviso (Petit Belvedere)				Montgenevre (Chenaillet)			
Rock name	Greenschist metagabbros		Corund cumm. gab.	Sheared cpx metagabbros			Cpx metagabbro	Ferrogabbro	Albitites	
Sample No. Symbol	1▲	2▲	3▲	4▲	5■	6●	A (9)■	B (4)●	9 ×	C (7) ×
Be	1	<1	<1	<1	<1	<1	—	—	21	—
Sc	27	32	5	26	34	75	33.8	51	2	0.7
Rb	3.2	3.8	14.1	2.9	<4	<4	<4	<4	<2.5	<4
Sr	330	157	110	172	390	420	233	383.7	10	79.6
Y	20	8	<2	21	35	150	22.5	69	224	215.8
Zr	70	29	8	72	290	320	187.5	152.5	465	815.5
Nb	4	2	4	2	8	6	3	3.5	16	22.8
Ba	688	579	739	718	27	80.5	25	70.3	89	30.8
La	10	<10	16	11	20	35	<12	45.8	40	13
M.I.	0.4	0.32	0.24	0.38	0.45	0.71	0.38	0.69	0.71	0.48

▲: Mg—Al metagabbros; ■: altered (intermediate) metagabbros; ●: Fe—Ti metagabbros; × = albitites A, B, and C: average of samples, after Bertrand et al. (1987)

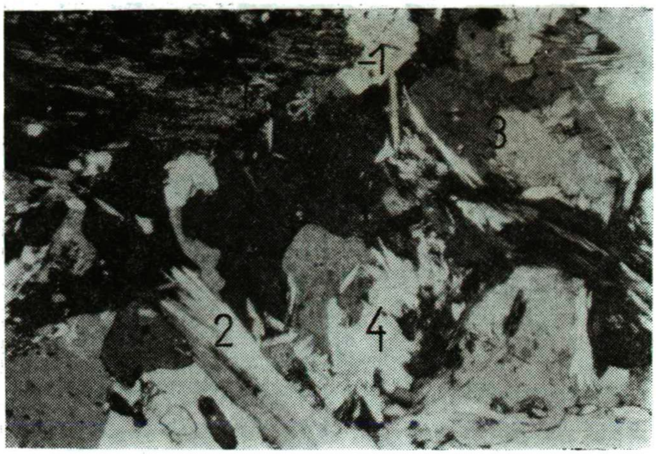

Fig. 2. Photomicrograph of chlorite actinolite greenschist metagabbros from Refuge d'Averole (Arc valley) W. Alps showing the pseudomorphic replacement of pyroxene (1) by actinolite (2) and the growth of albite (3) and tremolite (4) C. N., X=50

b) The primary textures in the *clinozoisite chlorite metagabbros* have nearly adpTpeared, and from the primary minerals only relics of clinopyroxene are preserved. egy(s are composed of Mg-chlorite, clinozoisite-epidote, albite, actinolite-tremolite, harnet and minor titanite and iron oxide. The Mg-chlorite (30 v%) probably replaced former olivine (?), while the clinozoisite-zoisite (37 v%, up to 2—5 mm long) with characteristic zonation and anomalous blue-grey interference colour, replaced the former plagioclase. They contain fine grains of garnet and titanite. The actinolite - tremolite (10.5 v%) mostly replaced the former pyroxene. Interstitial albite (9.7 v%, 0.4—1.8 mm across) and chloritized garnet (8.5 v%) were determined, too.

1.2. In the *glaucophanites,* collected near Modane (Arc), the primary pyroxene is completely replaced by glaucophane-crossite, chlorite and albite; with large amounts of rutile-leucoxene and minor jadeite, biotite, phengite, lawsonite and quartz *(Fig. 3.).* The glaucophane (43 v%) preserved the shape of the former pyroxene-crystals and sometimes is associated with crossite. It is often rimmed by actinolite. The Fe-rich chlorite (18.2 v%) occurs as aggregated matrix *(Fig. 3.).* Fe-rich epidote and scarce lawsonite (5.9 v%) form euhedral prisms usually embedded in the matrix. The albite (12 v%) is sometimes replaced by calcite. Rutile-leucoxene (12.2 v%, 4.2—5.2 mm) is rarely transformed to titanite. Biotite is Ti-rich, usually grew along chlorite edges. The jadeite (2.3 v%) is partially replaced by chlorite and glaucophane, while phengite were only locally observed.

2. The Chenaillet metagabbros (Montgenévre ophiolite) have a complete gabbroic sequence (Table 1.), that are;

(a) *Talc serpentine gabbros* mainly consist of olivine, clinopyroxene and plagioclase with minor tremolite, serpentine, talc and prehnite (Table 1.). The augitic clinopyroxene (40.6 v%) is moderately replaced by tremolite and chlorite. Olivine is replaced by serpentine and talc *(Fig. 4.).* The bytownitic plagioclase (An_{85-95}, 24.5 v%) is often traversed by veinlets of serpentine and is transformed to prehnite. Serpentine (20 v%) is often replaced by talc (14.6 v%, *Fig. 4.*).

(b) *Chloritized metagabbros* essentially consist of plagioclase and chlorite, with epidote, titanite and prehnite as only accessory minerals. The plagioclase

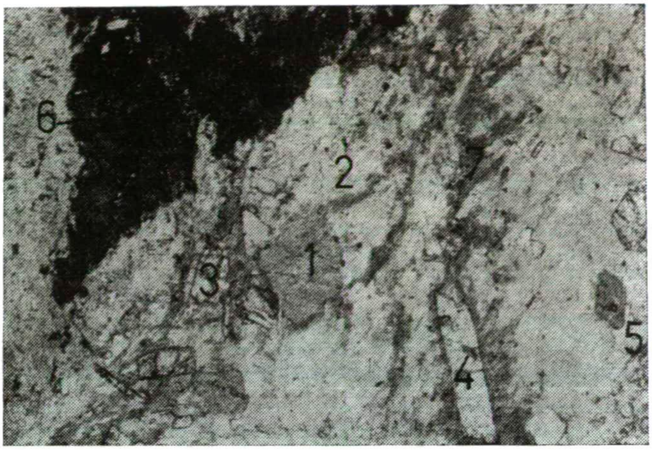

Fig. 3. Photomicrograph of glaucophanite from Modane (Arc valley) W. Alps showing the replacement of the former clinopyroxene by single crystal of glaucophane (1), chlorite (2) and epidote (3) +/− lawsonite (4) +/− quartz (5), and usually associated with leucoxene (6) Ti-biotite (stilpnomelane, 7) grew along the chlorite edges, P. P., X=44

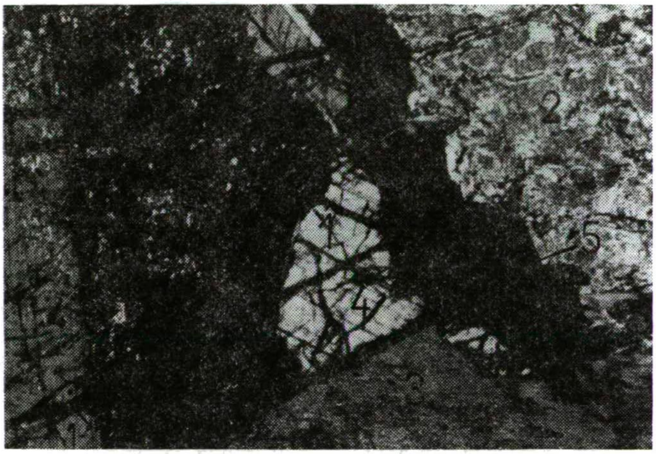

Fig. 4. Photomicrograph of talc serpentine gabbro from Chenaillet (Montgenévre) W. Alps showing the replacement of olivine by serpentine (1) and talc (2); clinopyroxene (3) and plagioclase (4) by chlorite (5). C. N., X=50

(40.7 v%) is of magmatic origin, which survived metamorphism and is commonly deformed and transformed to epidote, kaoline, prehnite and chlorite. Chlorite (52 v%) formed single pseudomorphs after magmatic pyroxene. Epidote (6.3 v%) replaced the plagioclase or is embedded in chlorite. Titanite is enclosed in chlorite, particularly along cracks and grain boundaries. Prehnite is also embedded in the plagioclase.

(c) The *clinopyroxene gabbros* are mainly made up of magmatic clinopyroxene (diallage) and plagioclase. Amphibole, epidote-clinozoisite, chlorite and iron oxide are subordinate constituents. The diallage (48 v%) usually show kink-band deformation, and is partially transformed to hornblendic and actinolitic amphibole and, rarely to chlorite. The plagioclase (38.5 v%) changed into albite and epidote-clinozoisite. Amphiboles (8.5 v%) are represented by actinolite and hornblende. The Mg-Fe rich chlorite (4.2 v%) usually forms pseudomorphs after pyroxene and is associated with iron oxides.

(d) The *leucogabbros* are composed of hypidiomorphic plagioclase with subordinate epidote, zoisite, prehnite and chlorite. The bytownitic (An_{80-85}) plagioclase (more than 90 v%, *Fig. 5.)* is always transformed to epidote, zoisite and prehnite. The last three minerals usually fill the cracks and cavities of the leucogabbros.

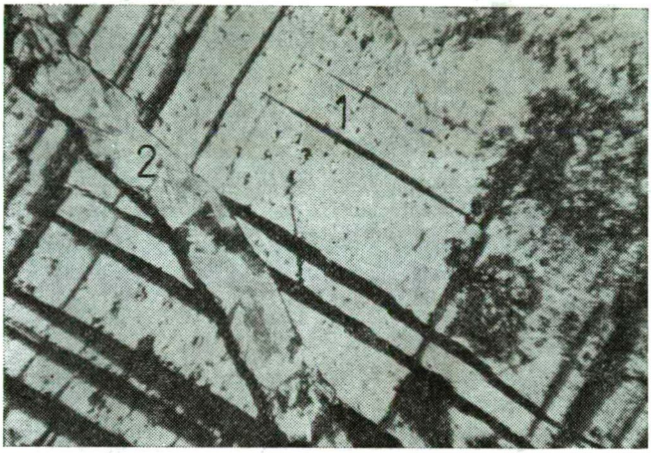

Fig. 5. Photomicrograph of leucogabbro from Chenaillet (Montgenévre), W. Alps showing the dislocated twinned labradorite (1) with several glide planes. The cracks in the rock are occupied by prehnite, epidote and zoisite (2). C. N., X=44

(e) *Albitites* are considered to be final products of the differentiation processes in the gabbroic magma at Chenaillet. They consist mainly of oligoclase-albitic plagioclase (94.8 v%), and minor amphibole, quartz, biotite and chlorite *(Fig. 6.)*. Epidote and titanite are accessories (Table 1.). The plagioclase is cataclastically deformed and included fine grains of other minerals. Hornblende (3 v%), quartz (0.7 v%) were also determined. Biotite (0.6 v%) and pale green chlorite are also present.

3. The Monviso metagabbros have the following petrographic features (Table 1.):

3.1. (a) In the *corund cummingtonite gabbros* which were collected in Petit Belverede (French Monviso) the primary magmatic minerals (plagioclase) are plastically deformed and tectonized *(Fig. 7.)*. Prehnite, chlorite and white mica are the main accessories.

The cummingtonite (64.3 v%, 2.1—3.4 mm long) usually contains fine grains of plagioclase, sometimes is transformed into white mica, chlorite and/or prehnite. The anorthitic plagioclase (An_{85-95}, 14.4 v%) is frequently replaced by prehnite. Corund (2.2 v%) usually appear in thin layers (1 mm thick). The matrix (19.2 v%) consists of fine grained prehnite, white mica and Mg-chlorite.

(b) *Sheared clinopyroxene metagabbros* are either massive or layered and display rapid grain size variations from fine to pegmatoid varieties. From the primary mine-

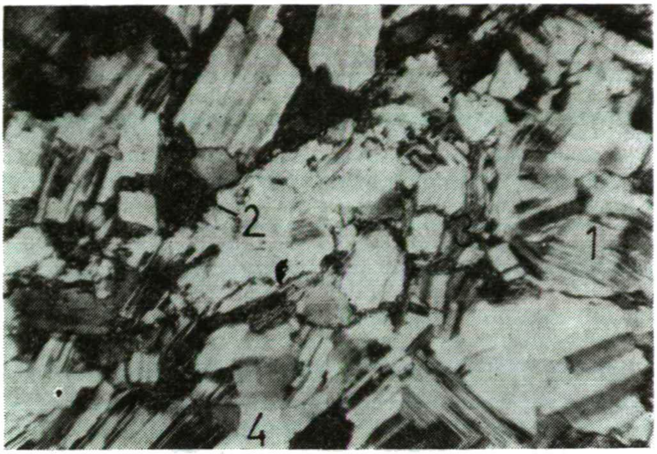

Fig. 6. Photomicrograph of albitite from Chenaillet (Montgenévre) W. Alps showing the cataclastically deformed twinned plagioclase (1) hornblende (2), biotite (3) and quartz (4) giving rise to granitic texture. C. N., X=44

Fig. 7. Photomicrograph of corund-cummingtonite metagabbros (Monviso), W. Alps showing oriented and plastically deformed corund (1), cummingtonite (2) and plagioclase (3). C. N., X=44

rals only cpx could remain. They consist of cpx, plagioclase and tremolite-actinolite as well as scarce hornblende and glaucophane. Some epidote, clinozoisite, leucoxene, calcite, prehnite and apatite are also present. The augite-diallage clinopyroxene (37.5 v%) occur in two generations *(Fig. 8.)*. There are magmatically resorbed augite on the one hand and strongly sheared, deformed and kink-banded diallage on the other hand. They are always rimmed by hornblendic amphibole *(Fig. 8.)*. The plagioclase (54 v%) is replaced by epidote, clinozoisite, albite and calcite or greenish masses of prehnite, chlorite and albite. The amphiboles (8.5 v%) are usually derived from clinopyroxene. They consist of older blue glaucophane which were subsequently replaced by tremolite-actinolite. Later, the tremolite-actinolite was replaced by

Fig. 8. Photomicrograph of sheared clinopyroxene metagabbro from Petit Belvedere (French-Monviso), W. Alps showing two generations of clinopyroxene (1 and 2) replaced by tremolite-actinolite along the rim and cleavage plane (3). The plagioclase is replaced by albite and saussurite (4). C. N., X=50

actinolite or hornblende. Leucoxene-titanite can be derived from ilmenite, and calcite from plagioclase.

3.2. (a) In the *smaragdite metagabbros* from Colletto Fiorenza a well developed foliation can be observed: in whitish matrix, bright-green phenoclasts of smaragdite occur. They consist of Cr-omphacite phenoclasts (14 v%), which are embedded in a fine matrix of zoisite, jadeite, garnet, Mg-chlorite, talc, rutile or retrograde products such as albite, tremolite-actinolite, Fe-chlorite, clinozoisite-epidote, quartz and titanite. The magmatic clinopyroxene (diopside) is replaced by single crystals of Cr-omphacite and/or tremolite and/or talc ("-smaragdite") or by aggregates of fine-grained omphacite. Tremolite (7 v%) and plagioclase (totally transformed to jadeite, albite, Mg-Fe chlorite and zoisite) are usually enclosed in the matrix. The olivine is also completely altered to talc and/or tremolite.

(b) *Eclogitic metagabbros* from the same locality originally make up of porphyroclastic omphacite (pseudomorphs after cpx) enclosed in a matrix of tremolite, zoisite, fine-grained omphacite, garnet, rutile and accessory apatite, quartz and titanite. Phenoblasts of blue amphibole and phengite locally were also found. The rock is strongly retrogressed and mostly consists of greenschist facies mineral assemblages. During retrograde processes omphacite was usually replaced by tremolite and Mg-Fe chlorite along their margins and cleavages. The plagioclase is completely altered to albite and/or epidote-clinozoisite and/or chlorite. Porphyroblasts of glaucophane-crossite (up to 11 mm long) and sometimes phengite (0.5 mm long) are embedded in the matrix. Fine grains of garnet (up to 0.3 mm across) are partly resorbed and altered to chlorite. Very fine grains of fresh quartz are usually enclosed in the matrix.

4. The gabbroic rock from Roche Noire (Cristillan) are mainly hornblende gabbros. They generally consist of hornblende and plagioclase (Fig. 9.) with minor epidote/clinozoisite, tremolite, chlorite and titanite (Table 1.). The hornblende (63 v%) is usually replaced by tremolite or chlorite. The andesinic (An_{35-45}) plagioclase (31.0 v%) is partly replaced by epidote/clinozoisite and kaoline *(Fig. 9.)*. It is cracked, the cracks are filled by titanite, epidote/clinozoisite and chlorite.

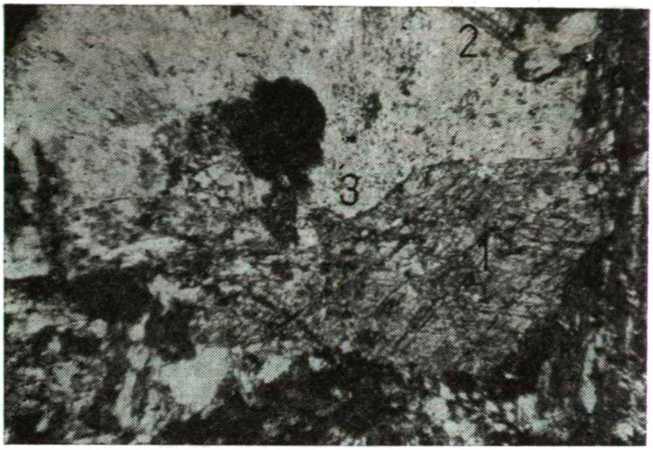

Fig. 9. Photomicrograph of hornblende gabbro from Roche Noire (Cristillan), W. Alps showing the abundance of hornblende (1) with variable size. Plagioclase (2) is partly transformed into kaolin and epidote (3). C. N., X=44

PETROGENESIS

Trace element composition (Table 3.) and their variations against MI [$FeO^+/(FeO^+ + MgO)$], *(Fig. 10.)*, as well as Zr and Y *(Fig. 11.)* are consistent with mineral and textural evidences for most gabbroic rocks.

Trace element analyses for Be, Sc, Y, Zr, Nb and La have been quantitively carried out by optical atomic spectrographical method (Model PGS, Zeiss Jena) and for Rb, Sr and Ba by atomic absorption spectrophotometric method (Model AA. 475 Varian).

According to the chemical as well as mineralogical composition, these gabbroic rocks can be separated into Mg-Al metagabbros, altered (intermediate) metagabbros and Fe-Ti metagabbros (ABDEL-KARIM and BILIK, in press).

Since the gabbros result mostly from cumulate liquidus phases plus variable amounts of trapped liquid, their composition will not define a liquid line-of-descent, but would only provide a rough idea on fractionation processes of the parental magma (POGNANTE *et al.*, 1982). The evolutionary trends shown in diagrams *(Fig. 10.* and *11.)* indicate their enrichment in Sc, Zr, Y, La and Y/Sc during differentiation.

The early stages of crystallization are characterized by segregation of pl, cpx, Mg-olivin which produced large amount of Mg-Al rich gabbros, indicating little fractionation. The results are consistent with a more primitive nature of the magma. They appear to have occurred under low fO_2 conditions. The rather erratic variation of Sr and Ba should be an effect of post-magmatic transformations.

The later stages of crystallization producing Fe-Ti-rich gabbros probably occurred in relatively rather oxidative condition. Processes producing a peculiar partition of Zr into the more SiO_2-rich liquid may have accompanied this differentiation (POGNANTE *et al.*, 1982). Geochemical data show high Zr, Sc and Y contents

FeO^+ = total iron as FeO.

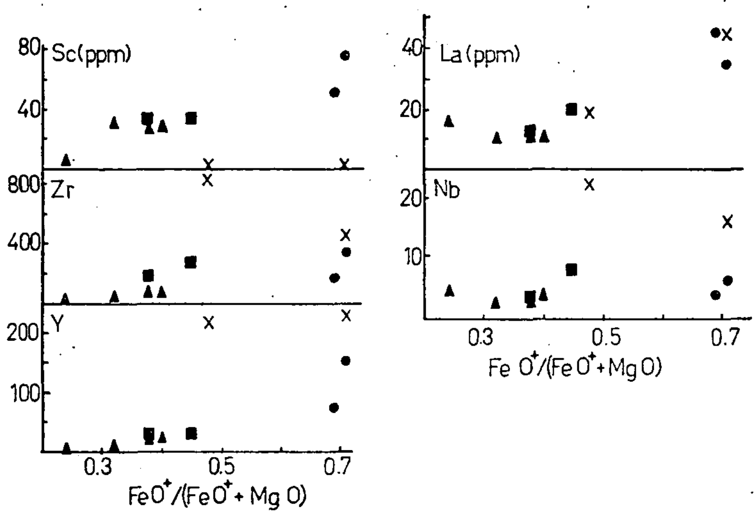

Fig. 10. Some trace elements variation diagrams vs. MI[$FeO^+/(FeO^+ + MgO)$ ratio] in the gabbroic rocks from W. Alps ophiolites. (Symbols as in table 3)

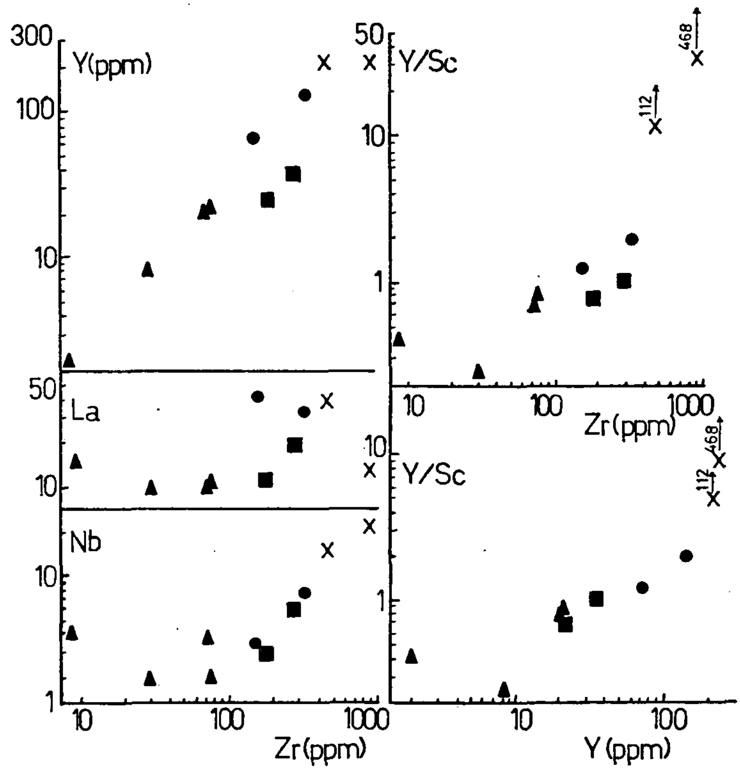

Fig. 11. Y, La and Nb vs. Zr and Y/Sc ratio vs. Zr and Y diagrams showing the evolution trend of the gabbroic rocks from W. Alps ophiolites. (Symbols as in table 3)

indicating that they are highly differentiated with abundant amphibole and Fe-Ti oxides. Higher contents of Ba and La might be attributed to their enrichment in the evolved melt or to later hydrothermal activity.

The albitites from Chenaillet show very high concentration of Be, Nb, Y and Zr supporting the idea of their crystallization from late differentiated melts. Low Sc, Ti, Mn and Ba values are also consistent with this interpretation.

Similar processes and evolution trends have been discussed for gabbroic and basaltic rocks from Lanzo and Montgenievre (POGNANTE *et al.*, 1982; BERTRAND *et al.*, 1987).

CONCLUDING REMARKS

The Piedmont Zone of the Western Alps consists of metamorphic dismembered ophiolite bodies and their Mesozoic metasedimentary cover.

I. In the eastern Piedmont Zone, two of the most significant ophiolitic metagabbros with eclogitic overprint were studied. They are from south to north:

1. The *Monviso metagabbros* can be characterized by prograde glaucophane and eclogite and retrograde glaucophane and greenschist facies metamorphism. The eclogitic stage produced dominantly Na-cpx, garnet, Mg-epidote, Mg-chlorite, rutile$\pm$talc$\pm$white mica$\pm$tremolite paragenesis. During the retromorphism in smaragdite metagabbros (Mg-Al rich metagabbros) and eclogitic metagabbros (Fe-Ti metagabbros), Cr-omphacite pseudomorphosed after magmatic cpx; jadeite, albite and zoisite after plagioclase; Mg-chlorite$\pm$tremolite$\pm$talc after cpx and olivine.

The sheared cpx metagabbros (Mg-Al and Fe-Ti metagabbros) are characterized by the presence of magmatic cpx in two generations. The cpx is altered to hornblende indicating ocean floor metamorphism.

Some gabbroic rocks have partially escaped the Alpine metamorphism. They show magmatic clinopyroxene, amphibole and plagioclase which are plastically deformed with preferred orientation.

2. The *Arc metagabbros* consist of two greenschist-facies metagabbroic body. They are considered as Mg-Al metagabbros.

II. In the western Piedmont Zone, three metagabbroic bodies were studied (from north to south):

1. *Arc glaucophanites* (Fe-Ti metagabbros) that partly retrogressed into greenschist facies (green amphibole grew around blue amphibole; titanite/leucoxene after ilmenite; chlorite after jadeite, biotite after white mica).

2. *Chenaillet metagabbros* are well preserved gabbroic bodies ranging from talc serpentine metagabbros (Mg-Al rich) to leucocratic gabbros (Fe-Ti metagabbro) and albitite. In these gabbros olivine is replaced by tremolite-actinolite and chlorite; plagioclase is transformed to albite and saussurite. Fe-Ti oxide appear as leucoxene/titanite assemblage. Cpx is rimmed by hornblende which has in turn been overgrown by actinolite.

3. *Cristillan metagabbros* (Fe-Ti rich) show an amphibolite facies overprint, in which the plagioclase and hornblende are the dominant minerals.

These gabbros can probably be regarded as separated differentiated rocks derived from different magma sources at different times, in different geotectonic environments that subsequently suffered different types of metamorphism.

During the early stage of crystallization plagioclase, cpx$\pm$Mg-olivine produced Mg-Al rich gabbros which characterized the primitive magma. They have low Zr, Sc and Y contents, and were probably formed under low fO_2 condition.

The later stage of crystallization producing Fe-Ti rich gabbro is characterized by more oxidative conditions, abundance of amphibole and Fe-Ti oxide and higher Zr, Sc and Y content with more signs of differentiation.

In some places, the late differentiated melts of gabbros produced albitites, which are also consistent with this interpretation.

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