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GEOCHEMISTRY OF SOME HP-METAVOLCANICS FROM WESTERN ALPS METAOPHIOLITES

I. KUBOVICS and ABDEL AAL M. ABDEL-KARIM

Department of Petrology and Geochemistry, Lóránd Eötvös University

ABSTRACT

Ophiolite metavolvanics from Monviso, Arc valley and Montgenévre in the Piedmont Zone of the Western Alps are geochemically investigated and compared with data obtained from oceanic crust.

Belonging to the Zermatt-Saas and Combin (Monviso and Arc valley) units they are characterized by HP-facies metamorphism including eclogite-facies metabasalts and garnet-bearing glaucophanites that underwent into greenschist-facies metamorphism. Few metavolcanics (Montgenévre) are partly escaped from ocean-floor metamorphism, but they are overprinted by Alpine deformation. They show a large variation in the bulk rock geochemistry and roughly compare to MORB and a few of them show an IAT character. Their geochemical characters prevalently similar to that of oceanic ridge basalts and they show abyssal tholeiitic differentiation trend.

KEYWORDS: HP-Facies metavolcanics, Geochemistry, metamorphic evolution, Peidmont Zone, Western Alps metaophiolite.

INTRODUCTION

The HP-metamorphism had an effect on large bodies of the pre-Alpine continental and organic crust in the Western Alps. During the Cretaceous, most of the oceanic crust (now represented by the Piedmont ophiolite nappe) and some parts of both continental margins underwent blueschist to eclogitic conditions that are followed by the greenschist facies conditions (LOMBARDO, 1988).

The geochemistry of the metavolcanics from the Western Alps have been subjected to various studies; previous researches had carried out from Monviso in Cottain Alps (LOMBARDO *et al.*, 1978, NISIO, 1985, NISIO and LARDEAUX, 1987, COMPAGNONI *et al.*, 1988), Arc valley in the Zermatt-Saas zone (BOCQUET, 1974, DAL PIAZ *et al.*, 1981; DEN TEX, 1987; LEARDI *et al.*, 1986) and from Chenaillet in Montgenévre (MÉVEL, 1975, LEWIS and SMEWING, 1980, BERTRAND *et al.*, 1981, 1982, 1987).

FIELD RELATIONS

Field study and sampling of the metavolcanics were carried out in the eastern, central and western parts of the Piedmont ophiolite nappe in the Western Alps, e.g. Monviso, Arc valley area and Montgenévre ophiolites *(Fig. 1.)*. The Piedmont ophiolite is represented by thinned, sheared, multistage folded and metamorphosed remnants of a narrow oceanic crust and related upper mantle (DAL PIAZ *et al.*, 1981).

H-1088 Budapest, Muzeum krt. 4/a, Hungary.

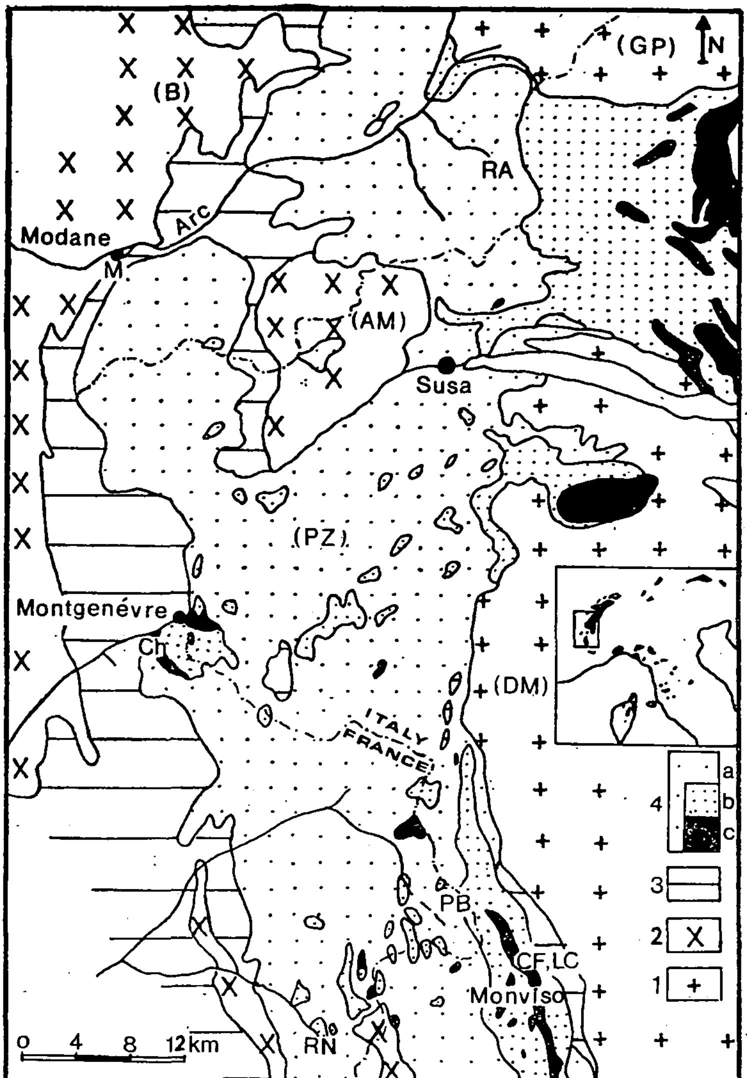

Fig. 1. Tectonic sketch map of the internal Western Alps showing the location of the main ophiolite complexes. 1. Dora-Maire (DM) and Gran Paradiso (GP) continental units (European Paleomargin), 2. Vanoise, Ambin (AM) and Brianconnais (B), continental units (European Paleomargin) Mesozoic epicontinental covers, 4. Piedmont Zones (PZ): Schistes Lustres'nappe (Mesozoic, mainly oceanic material): a. undifferentiated metasediments with subordinate ophiolites; b. ophiolite complex with minor metasediments; c. metagabbro bodies.

Location of samples: RA=Réfuge d'Averole; PC=Pre clos la Clapera; CP–MC=Carrieres du Paradis-Mont Cenis; PB=Petit Belvedere; LL=Lago Lausetto; CF=Colleto Fiorenza; C=Chenaillet

Some of these metavolcanics are partly escaped from the strong Alpine deformation while others have no primary minerals of features. Belonging to the Combin and Zermatt-Saas Units they are in different structural and stratigraphic settings compared with other parts of the ophiolite sequences (peridotite, gabbros and metasediments).

The overlying Combin unit displays pre-ophiolitic basal complex of Triassic to Liassic age with epicontinental affinity coverd by a thick volcanoclastic ophiolite bearing sequence (Dal Piaz, 1974; Dal Piaz *et al*, 1981; Bearth, 1967; Etler, 1971) which consists of metasediments and interbedded basaltic metavolcanics. This unit is also implied its relationship with other ophiolite sequences and characterized by an ocean-floor metamorphism which was overprinted by greenschist facies (Hunziker, 1974; Dal Piaz *et al.* 1981).

The underlying Zermatt-Saas unit consits of basal serpentinite, gabbro capped by retrograde eclogitic basalt and garnet-bearing metasediments (Bearth, 1973; Dal Piaz, 1974; Dal Piaz *et al.*, 1978, 1981). This unit has been deformed and affected by HP-metamorphism and greenschist facies conditions and are considered as oceanic crust (Bearth, 1967, Dal Piaz, 1974, Dal Piaz *et al.*, 1978, 1981. e.t.c.).

The Monviso metavolcanics show three successive Alpine metamorphic stages characterized by eclogitic, blueschist and greenschist facies. They include fine grained eclogitic metabasalts and banded metabasites (garnet-bearing glaucophanites and prasinites). From few cm-s up to several dm-s thick eclogitic metabasalts collected in Colletto Fiorenza, are crosscut by smaragditic metagabbros and younger albite

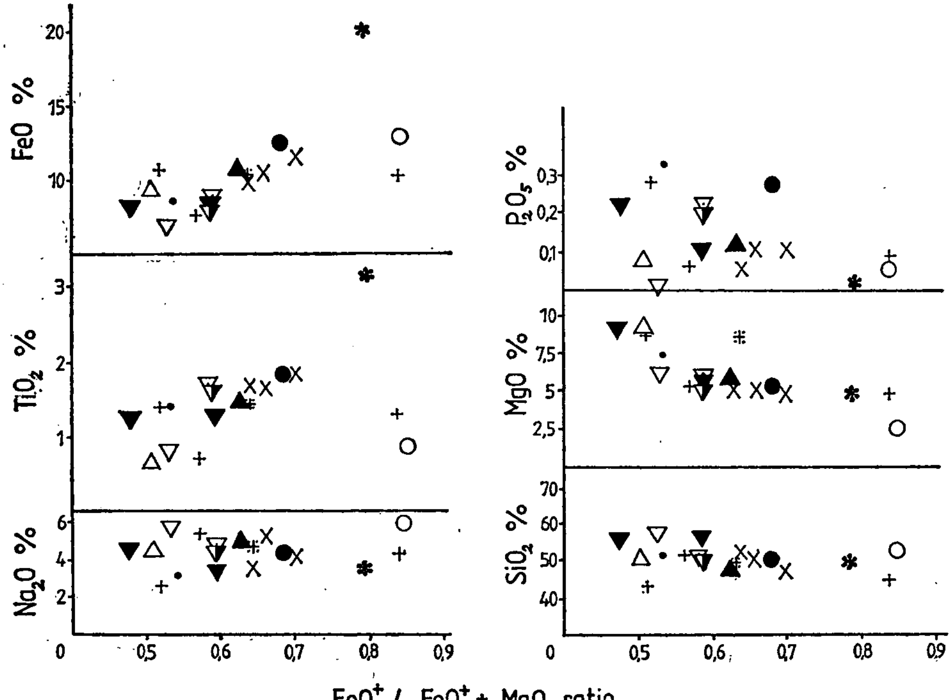

Fig. 2.: Major element oxide wt% versus $FeO^+/FeO^+ + MgO$ ratio diagram for ophiolitic metavolcanics from Western Alps. (Symbols as in Table 1)

veins. The garnet-bearing glaucophanite in Petit Belvedere is usually heterogeneous and it shows banded layering. The prasinite (Lago Lausetto) represents a homogenous thin layer (mm-scale) which differs in colour and mineral composition. The Monviso metavolcanics appear to belong to the Zermatt-Saas unit.

The Arc-valley metavolcanics of Combin unit consist of up to several hundered meters thick homogeneous prasinite which sometimes overlies on a thin ovardite level (the ovardite occurs as some thin interlations, too) and usually associate with garnet-bearing glaucophanite. They problably correspond to submarine flows, hyaloclastites and tuffites.

The metavolcanic sequence of Montgenévre represents the best preserved ophiolite complex in the Western Alps (BERTRAND *et al.*, 1987) and occurs as a separate tectonic unit. The pillow lavas are detached from the gabbros by a shear zone and sporadically contain serpentinite lenses.

PETROGRAPHY

The primary and secondary mineral assemblages, texture and metamorphic facies of the discussed metavolcanics are summarized in Table 1.

CHEMISTRY

Twelve selected metavolcanic samples collected from Monviso, Arc valley and Montgenévre in Western Alps were analysed. With the aim of the comparison we adapted six published analyses, as well. The location of samples are plotted in *Fig. 1.* and the chemical data appear in Table 2.

a) Analytical Methods

The silica was determined thermogravimetrically using the SAJO's method (1955). The ferrous Fe was analysed by HOFFMANN's method (301/87 OTH Patent). Ferric Fe was computed by the difference between FeO and total Fe, Al, total Fe, Mg, Ca, Na, K and Mn were measured by atomic absorption spectrophotometry. Other elements were determined by spectrophotometric method. H_2O, CO_2, and SO_2 were analysed by DTA method. The analyses were carried out by L. Hoffmann in the Department of Petrology and Geochemistry, Eötvös L. University, Budapest.

b) Results

The analysed HP-facies metavolcanics include 2 eclogitic metabasalts of Monviso (COMPAGNONI *et al.*, 1988) and 3 garnet-bearing glaucophanites of Monviso and Arc valley (Table 2).

The eclogitic metabasalts have large amounts of SiO_2 (50.61*/Al_2O_3/15.6*) and Mno (0.48*) and small amounts of FeO^+(8,47*) and TiO_2 (1,4*).

The garnet-bearing glaucophanite of Monviso differs from those of Arc valley in its much higher TiO_2 (3.23*) and FeO^+ (20.38*) and much lower Al_2O_3 (8.67*) and Na_2O (3.65*) content, which may be ascribed to the abundance of Fe—Ti rich

TABLE 1

Main petrographic features of representative rocks from Western Alps metavolcanics

Rock name	Texture	Main primary minerals (magmatic and late-stage primary)	Main secondary minerals (hydrothermal and metamorphic)	Metamorphic facies
		1. MONVISO: *Coletto Fiorenza*		
Eclogitic metabas.	porph, gran	cpx	omp, gar, rut, clinoz, glau, Mg-chl, leuc, ab, phen, actin, Fe-chl,tit.	Eclogitic f.
			Petit Belvedere	
Gar.-bearing glaucophanite	granonematobl, poikil, sch.		glau, leuc, ep, chl, ab, stilp, actin, gar.	Glaucophane schist f.
Greenschist	poikil, nematobl.		actin, chl, ab, tit, clinoz, cc.	Greenschist f.
			Lago Lausetto	
Prasinite	poikil,		ab, chl, ep, glau, actin, phen, rut-tit.	Greenschist f.
		2. ARC VALLEY		
Gar.-bearing Glaucophanite	granonematobl, poikil, sch.		glau, ep, chl, ab, gar, tit, phen, cc, qz, bio.	Glaucophane schist f.
Prasinite	poikil, sch.		ab, ep. actin, rieb, glau, chl, rut-tit, cc, phen, bio.	Greenschist f.
Ovardite	poikil, porp, gne.		ab, Fe-chl, glau, actin, ep, cc, rut-tit, phen, qz ± gar.	Greenschist f.
		3. MONTGENÉVRE: *Chenaillet*		
Metabas. pill. lava	inters, porp, aphy, que, vario, arb, ves.	cpx, pl	ab, chl, preh, ep, cc ± zeol, pump.	
Metabas. pill. breccia	inters, aphy, vario	cpx, pl,	epi, preh, chl, ab, hem ± pump.	low-grade met.-ocean floor met.
Metadol. lava flow and dyke	vario, subopth, interg,	ol, cpx, pl.	ab, chl, leuc, cc ± preh	Prehn.-pump. and greenschist facies
Microgabbro	hypid	cpx, pl. hb.	chl, actin-trem, leuc, ap, saus.	

HP met. to low-grade met.

Abbreviations: ol: olivine; cpx: clinopyroxene; pl: plagioclase; omp: omphacite; glau: glaucophane; actin: actionlite; trem: tremolite; rieb: riebeckite; hb: hornblende; ep: epidote; clinoz: clinozoisite; chl: chlorite; preh: prehnite; cc: calcite; ap: apatite; hem: hematite; leuc: leucoxene; rut: rutile, tit: titanite; bio: biotite; phen: phengite; stilp: stilpnomelane; gar: garnet; ab: albite; qz: quartz; pump: pumpellyite; zeo: zeolite; saus: saussurite; porp: porphyroblastic; poikil: poikiloblastic; nematobl: nematoblastic; granonematobl: granonematoblastic; gran: granular; hypid: hypidiomorphic, suboph: subophitic; inters: intersertal; interg: intergranular; sch: schistose, gne: gneissose; que: quench, vario: variolitic; arb: arborescent; ves: vesicular; metabas: metabasalt; pill: pillow; metadol: metadolerite; f: facies

Chemical composition of representative rock types from the ophiolitic

Locality	Arc valley								
	Carrieres du Paradis			Refuge d'Averole		Pre clos la Clapera		Carrieres du Paradis	
Rock name	Prasinites			Ovardites BOCGUET 1974				Glaucophanites BOCGUET 1974	
Symbols & Sample No.	$\times$1	$\times$2	$\times$3	+4	+5	+6	7 (3)	⊙8	9(4)●
SiO_2	47.94	50.95	51.81	52.13	44.55	42.75	49.80	53.05	51.46
TiO_2	1.85	1.66	1.71	0.72	1.33	1.41	1.43	0.90	1.84
Al_2O_3	15.95	15.74	14.92	14.72	13.01	11.23	16.88	16.9	14.68
Fe_2O_3	3.80	3.89	0.95	0.92	7.54	2.01	5.78	10.49	5.48
FeO	7.89	6.56	9.04	6.34	2.70	8.84	4.57	2.92	6.58
MnO	0.17	0.16	0.15	0.14	0.13	0.13	0.17	0.09	0.20
MgO	4.96	5.28	5.55	5.42	5.01	9.92	5.90	2.44	5.76
CaO	8.07	3.99	4.45	5.87	11.96	11.85	6.27	5.16	6.06
Na_2O	4.12	5.32	3.57	5.39	4.32	2.56	4.90	6.02	4.45
K_2O	0.70	0.23	1.73	0.10	0.15	0.82	0.48	0.93	0.80
H_2O^+	3.10	4.20	3.58	7.60	2.30	2.85	3.52	0.73	2.09
H_2O^-	0.3	0.60	0.35	0.40	0.4	0.70	0.05	0.36	0.05
CO_2	0.7	1.60	2.14	3.0	5.76	4.28	—	—	—
P_2O_5	0.11	0.11	0.06	0.07	0.09	0.29	—	0.04	0.29
SO_2	0.10	—	—	—	—	—	—	—	—
Σ	99.76	100.29	100.01	99.82	99.25	99.64	99.75	100.03	99.74

n.d.: non detected
( ): number of analyses

oxide. As these chemical features are also recognized in some Fe—Ti rich gabbros observed in the same area (in press) and in the others within the Alpine-Apennine belt (BACCALUVA *et al.*, 1977, LOMBERDO *et al.*, 1978, 1982, DAL PIAZ *et al.*, 1981, BERTRAND *et al.*, 1987), we can expect that both the glaucophanites and Fe—Ti gabbros were probably derived from the same magma.

The analysed greenschist facies metavolcanics are as follows: 1 greenschist (Monviso), 4 prasinites (Monviso and Arc valley) and 4 ovardites (Arc valley).

The greenschist has a higher MgO (9.15*) and lower TiO_2 (0,62*) and FeO^+ (9.83*) contents.

The prasinite from Monviso is characterized by a higher Al_2O_3 (19.01*), MgO (6.01*) and K_2O (3,46*) and a lower TiO_2 (1,4*) content than that of the samples collected in the Arc valley. The higher values of Al_2O_3 and MgO may be attributed to the dilution of plagioclase and olivine accumulation. The high TiO_2 content may due to the abundant phengite. The prasinites (from Arc) cover a wide compositional ranges of SiO_2 (47.94—51.8*), FeO^+ (9.99—11.69*), CaO (3.99—8.07*) and CO_2 (0,7—2.14*) and also those elements whitch are relatively stable during the alteration, such as P_2O_5 (0.06—0.11*) and TiO_2 (1.66—1.85*). Their higher Al_2O_3

volcanic sequence of Western Alps

TABLE 2

Monviso				Montgenèvre				
Petit Belvedere		Coletto Fiorenza	Lago Lausetto	Chenaillet				
	Green-schist	eclogitic metabas.	Prasinite	Metadolerite flow and dyke		Basaltic pill. lavas		
		COMPAGNONI *et al.*, 1988.		BERTRAND *et al.*, 1987		BERTRAND *et al.*, 1987		
★10	△11	·12(2)	▲13	▽14	15(9)▽	▼16	▼17	▼18(11)
50.05	50.63	50.61	47.62	57.00	51.25	56.20	56.43	50.16
3.23	0.62	1.40	1.40	0.81	1.68	1.25	1.29	1.62
8.67	13.36	15.60	19.01	13.52	15.35	10.41	11.64	15.79
12.52	2.97	1.40	10.46	1.57	2.59	1.94	2.92	2.43
7.84	6.42	7.07	n.d.	5.53	6.00	6.28	5.66	6.13
0.23	0.11	0.48	0.10	0.10	0.19	0.14	0.16	0.15
5.33	9.15	7.44	6.01	6.32	6.18	9.05	5.96	5.95
6.76	6.63	10.63	3.51	5.91	7.87	6.83	8.33	8.33
3.65	4.62	3.31	5.00	5.85	4.55	4.81	5.16	4.95
0.10	0.11	0.27	3.46	0.10	0.11	0.10	0.10	0.04
0.90	3.40	—	—	1.33	2.76	2.60	1.40	3.51
0.20	1.00	1.07	2.9	1.00	—	0.60	0.20	—
—	—	—	—	—	0.95	—	—	0.61
0.03	0.09	0.34	0.12	0.06	0.23	0.23	0.11	0.20
0.15	—	—	—	—	—	—	—	—
99.51	99.11	99.62	99.59	99.00	99.70	100.34	99.26	99.87

(14.72—15.95*) and CaO (3.99—8.07*) contents may attributed to the diluation of the plagioclase.

The Arc valley ovardites also show largely variable SiO_2 (42.75—52.13*), FeO+ (7.26—10.85*), CaO (5.87—11.96*), P_2O_5 (0.07—0.29*) and TiO_2 (0.72—1,43*) contents. The ovardite at Pre clos la Clapera has a significantly higher MgO content (9.92%) than the other ovardites of the Arc area, which suggest their strong dilution effect by olivine accumulation or fractionation.

The chemical features of both prasinites and ovardites are well compared, however, revealed certain significant differences themselves to be excepted in view of the ovardites. MgO, CaO, CO_2 contents are higher, while TiO_2 content is lower than the mean for prasinites. This is probably ascribable to the particulary high chlorite and calcite content in the ovardites.

The analysed samples from Mongenévre represent 1 metadolerite pillow and 2 basaltic pillow lavas (margin and core) compared with their averages (BERTRAND *et al.*, 1987). The metadolerite pillow flow is characterized by higher values of SiO_2 (57.0*) and Na_2O (5.58*) and by lower values of TiO_2 (0.81*), FeO* (7.71*), Al_2O_3 (13.52*) and P_2O_5 (0.14*), than the average given by BERTRAND *et al.* (1987).

The basaltic pillow lavas have a significantly higher SiO_2 (56.2—56.43*) and lower TiO_2 (1.25—1.29*) and Al_2O_3 (10.41—11.64*) range than the average (BERTRAND *et al.* 1987).

It is interesting that the pillow lava margin has fairly higher MgO and H_2O and lower Al_2O_3, total FeO, CaO and Na_2O contents than the core has.

All these geochemical features can be attributed probably to the variant influence of the metasomatic metamorphism.

DISCUSSION

Major element composition (Table 1.) and their variation againts $FeO^+/FeO^+ + MgO$ ratio of the metavolcanic rocks from Western Alps are shown in *Fig. 2.* Generally, the total FeO* and TiO_5 content are rapidly increased, Na_2O^* is constant while the MgO*, $P_2O_5^*$ and SiO_2^* are decreased with the increasing $FeO^+ + MgO$ ratio. The garnet-bearing glaucophanites are largely scattered which may be attributed to their different tectonic setting and mineralogic compositions.

The AFM diagram *(Fig. 3.)* applied by STRONG and MALPAS (1975) represents a tholeiitic differentiation. Some of the investigated metavolcanic rocks are tholeiitic character, while the others show calc-alkaline affinity because of their metamorphic effects and mixing with oceanic floor sediments. They mostly fall within the sheeted dyke and lava fields of the STRONG's and MALPAS's (1975) diagram. The garnet-bearing glaucophanites from Monviso, due to its higher content of total FeO which can be attributed to the dominance of the Fe-rich oxides, occur near the F-pole. Two samples of prasinites and one of dolerite flow have a more alkalic charcater than the others, indicating a more significant influence of the metamorphism.

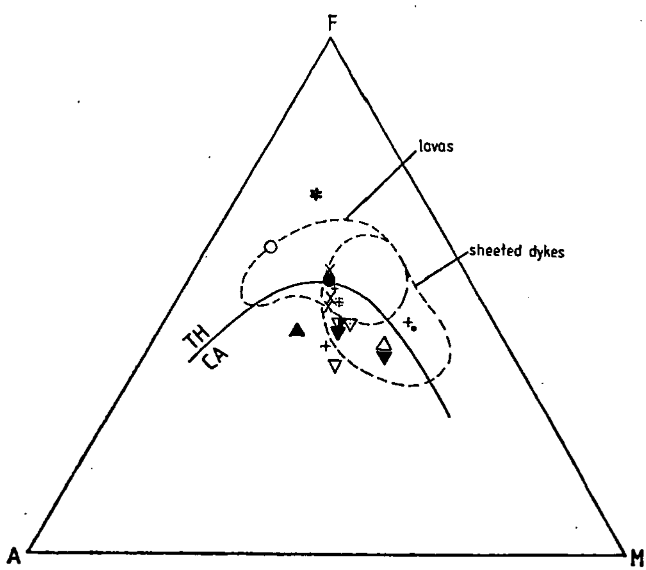

Fig. 3. AFM diagram (STRONG and MALPAS, 1975) for the ophiolitic metavolcanics from Western Alps. (Symbols as in Table 2.)

*: weight percentage $FeO^+ : FeO^* + Fe_2O_3^*$

The TiO_2 vs. P_2O_5 and the TiO_2 vs. FeO^+/MgO diagrams applied by BASS *et al.* (1973) and HEKINIAN and THOMPSON (1976), present the differentitation trend of the ophiolitic basaltic rocks *(Fig. 4.)*. In the diagram of TiO_2 vs. P_2O_5, the metavolcanic rocks are situated in the oceanic ridge basalt field showing a constant precipitation of apatite during the volcanic differentation. In the TiO_5 v. FeO^+/MgO diagram, the metavolcanics more or less correspond to the trend of the abyssal tholeiites showing an increasing TiO_2 content, together with the increasing FeO^*/MgO ratio. The garnet-bearing glaucophanite from Monviso in it higher content of TiO_2

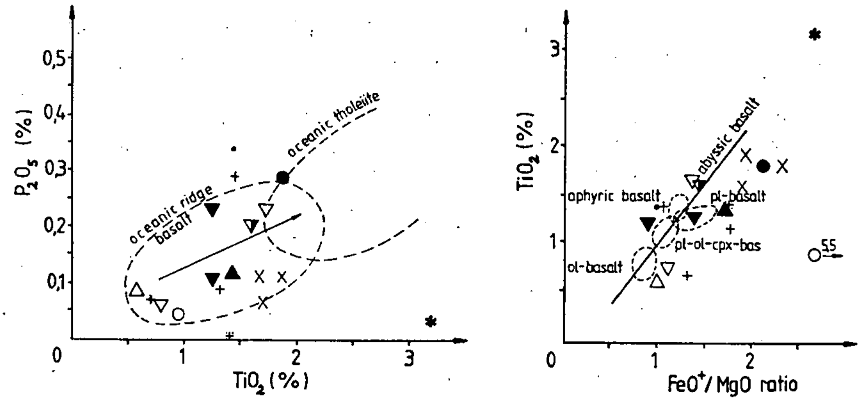

Fig. 4. (a) P_2O_5 wt% versus TiO_2 wt% diagram (HEKINIAN *et al.* 1976) and (b) TiO_2 wt% versus FeO^t /MgO ratio diagram (BASS *et al.* 1973) for the ophiolitic metavolcanics from Western Alps. (Symbols as in Table 2.)

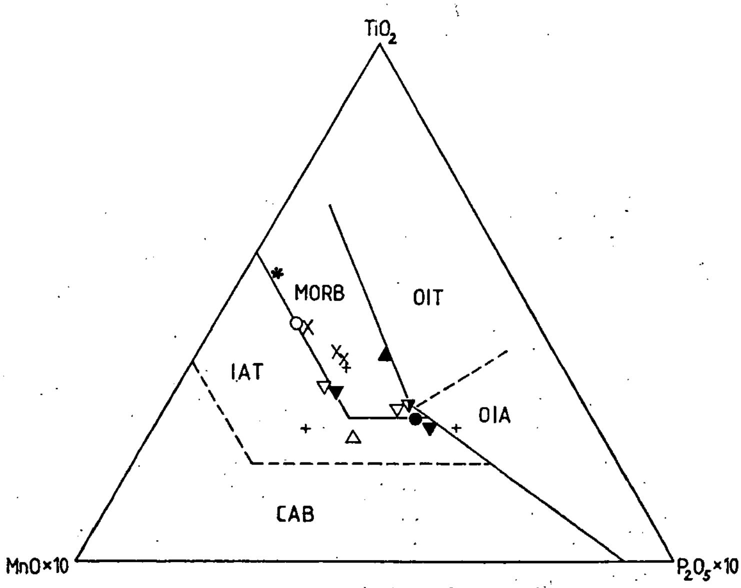

Fig. 5. $MnO \times 10$—TiO_2—$P_2O_5 \times 10$ diagram (MULLEN, 1983) for the ophiolitic metavolcanics from Western Alps. MORD=mid ocean ridge and marginal basin basalts, IAT=island arc tholeiites, CAB=calc-alkaline basalts, OIA=oceanic island alkalic basalts. (Symbols as in Table 2.)

and total FeO (which can be attributed to the abundance of Ti—Fe rich oxides) differs from that of the Arc valley rocks.

The TiO_2—$MnO \times 10 - P_2O_5 \times 10$ diagram *(Fig. 5.)* was initiated by MULLEN (1983) for the distinction of the tectonic settings of the basaltic and andesitic rocks. In this diagram, the metavolcanics of the Western Alps are almost situated in the MORB and Island Arc Tholeiites fields.

CONCLUSIONS

The Western Alps metavolcanics are distributed in both Combin and Zermatt-Saas units of the Piedmont metaophiolite. Three metavolcanic areas (Monviso, Arc valley and Montgenévre) in the Western Alps were investigated geochemicaly.

The metavolcanics of the Monviso and Montgenévre in the Zermatt-Saas unit show mostly oceanic crust origin. The Arc valley metavolcanics in the Combin unit are represented by basaltic metabasites (prasinites, ovardites and glaucophanites) and most of them probably consist of lava flows, hyaloclastites. tuffites and minor sills settled in Mesozoic calc-schists (DAL PIAZ, 1974).

The investigated metavolcanics from Western Alps, due to the significant changes in the mineral abundances, show a large variation in the bulk composition. This probably reflects an effect of the Alpine and sea-floor metamorphism. They are roughly comparable to MORB (HEKINIAN and THOMPSON, 1976; SUN *et al.*, 1979; WOOD *et al.*, 1979 b; LANGMUIR and BENDER, 1984), and a few metavolcanics belong to the Island Arc Tholeiites (as shown in MULLEN's 1983 diagram). They also show a geochemical characteristic prevalently similar to that of the oceanic ridge basalts (BASS *et al.* 1973) and differentiation path typical for abyssal tholeiites (HEKINIAN *et al.* 1976).

Morever, evidence for happened, distrinctive metamorphic and tectonic processes the oceanic stage can be recognized (MÉVEL *et al.* 1978; BERTRAND *et al.* 1985; TRICART and LEMOINE 1986).

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