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Autor: Dal Piaz, G.V. / Di Battistini, G. / Gosso, G.

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RODINGITIC GABBRO DYKES AND RODINGITIC REACTION ZONES IN THE UPPER VALTOURNANCHE-BREUIL AREA, PIEMONTE OPHIOLITE NAPPE, ITALIAN WESTERN ALPS

BY

G. V. DAL PIAZ [1], G. DI BATTISTINI [2], G. GOSSO [3], G. VENTURELLI [4]

ABSTRACT

Boudinaged rodingitic gabbros and rodingitic reaction zones on Mesozoic calcschists (*s.l.*) from the eclogitic Zermatt-Saas unit have been described. The rodingitic gabbros are constituted by relics of magmatic pyroxene mostly progressively transformed to more or less pure diopside coexisting with grandite, epidote, chlorite, ± idocrase matrix. The rodingitic reaction zones (epidote and clinopyroxene bearing massive rocks) developed possibly during ("omphacitic" pyroxene) and surely after (diopside + Ca-rich garnet) the *HP* early-Alpine metamorphic event.

GENERAL REMARKS

The Piemonte ophiolite nappe, i.e. the *falda Piemontese dei calcescisti con pietre verdi* of the Italian literature, outcrops within the continent-continent collisional chain of the Western Alps and is structurally sandwiched between the underlying internal Monte Rosa-Gran Paradiso + external Gran San Bernardo Pennine nappes and the overlying Dent Blanche + Sesia Lanzo Austroalpine composite nappes (COMPAGNONI et al., 1977; DAL PIAZ and ERNST, 1978 with references).

Several large bodies of antigorite serpentinites (mostly original peridotite tectonites) occur within the Piemonte ophiolite nappe. The occurrence of peculiar Ca-rich massive rocks-commonly indicated up to 1960 as *granatiti* or *Kalksilikatfels*-has long been recognized in the Piemonte ophiolite nappe of the Western Alps by BORSON (1811), SISMONDA (1834), BARELLI (1835), GASTALDI (1868), GERLACH (1869), JERVIS (1873) and others (references in DAL PIAZ, 1967). With the exception

[1] Istituto di Geologia, via Giotto 1, Padova, Italy.
[2] Istituto di Petrografia e Giacimenti Minerari, via Gramsci 9, Parma, Italy.
[3] Istituto di Petrografia, via S.Massimo, 24, Torino, Italy.
[4] Istituto di Mineralogia, via Gramsci 9, Parma, Italy.

of FRANCHI (1893), who considered rodingites as garnetized gabbro dykes and lenses, these rocks have been for long time described as magmatic skarns produced by peridotitic magmatic intrusions in Mesozoic dolostones and associated rocks. This hypothesis supported the STEINMAN's model of a magmatic and syn-volcanic emplacement of peridotites in the Tethyan ophiolite basin and similar interpretations.

Actually the Ca-rich massive rocks associated to serpentinites in the Western Alps in part correspond to rodingitic dykes of gabbro, pyroxenite and diabase, and partially to rodingitic reaction zones developed over calcschists, metabasites and associated rocks along contacts with serpentinite slices (PETERS, 1963; VUAGNAT, 1967; DAL PIAZ, 1967, 1969 with references). These rocks show a mineral assemblage essentially constituted by granditic garnet, diopside, epidote, chlorite, ±idocrase and prehnite in rodingitic dykes and of epidote, diopside, Ca-rich garnet, calcic amphibole, chlorite and idocrase in the rodingitic reaction zones. Rodingites are separated from the surrounding serpentinites by a regular to lobated rim of chloriteschist which sometimes includes white diopside±grossularite±opaques. The different groups of rodingites appear to be connected to relatively low-temperature metasomatism characterized by Ca-enrichment and Na, K, Si decrease, frequently up to complete depletion in alkalis. The metasomatism is essentially local and linked to serpentinization of associated ultramafics (mostly peridotitic tectonites) which released large amounts of Ca.

In the Piemonte ophiolite nappe serpentinization commonly developed during several stages of the extensional (lizardite and chrisotile) and compressional (antigorite) evolution of the ophiolite basin. A first pre-orogenic (ocean-floor) serpentinization and rodingitic alteration probably was generated by hydrothermal systems mostly acting along fracture zones. These rodingitic rocks completely recrystallized during the subsequent polyphase Alpine metamorphism (metarodingites). Further rodingitic transformation occurred essentially under greenschist facies conditions during the Lepontine metamorphic event. It developed on the early-Alpine eclogites and associated paraschists (see DAL PIAZ, 1969, for details and discussion).

This study deals with the abundant rodingitic gabbro dykes and boudinaged lenses (shortly RGD) occurring in the antigorite-bearing serpentinites of Les Perères-Gouffre de Bousserailles, upper Valtournanche, and with two rodingitic reaction zones (RRZ) in the Breuil area, which belong to the Zeramatt-Saas unit of the Piemonte ophiolite nappe, Italian Western Alps.

REGIONAL OUTLINES

In the Aosta valley and Valais, the Piemonte ophiolite nappe can be subdivided in two main tectonic units (BEARTH, 1967, 1973; ELTER, 1971; DAL PIAZ and ERNST, 1978 with references): (1) The underlying *Zermatt-Saas unit* which correspond to a thinned and largely disrupted section of oceanic crust and related upper mantle of the Mesozoic Piemonte basin (now sutured). It chiefly consists of pervasively serpentinized (antigorite) peridotitic tectonites, homogeneous and layered metagabbros with minor Fe-Tigabbros, metamorphic basalt-flows, pillow-lavas and hyaloclastites, and of a syn- to post-volcanic sedimentary sequence. This latter comprises manganiferous quarzitic schists, garnet + carbonate-bearing micaschists —which locally include little rounded fragments of basaltic eclogites (Rifelberg-Garten formation)— calcscists and scarce marbles of Upper Jurassic-Lower Cretaceous (?) age. These lithologies underwent oceanic alteration and two independent metamorphic events which developed during the compressional evolution of the Alpine belt: (a) A high pressure-low temperature early-Alpine stage with traces of subduction prograde path, a well preserved eclogite climax and decompressional blueschist assemblages (exhuming phase), partially overprinted by (b) the greenschist Lepontine event (BEARTH, 1967, 1973; DAL PIAZ and ERNST, 1978; ERNST and DAL PIAZ, 1978 with references).

TABLE 1

Olivine, titan-clinohumite and diopside from antigorite serpentinites, Zermatt-Saas unit (Sample MRO 2690, Gressoney Valley)

	Olivine		Ti-clinohumite			Diopside
	1-1	1-7	1-4	1-5	1-9	1-12
SiO_2	41.0	41.9	36.1	36.6	37.4	55.2
TiO_2	0.04	—	5.38	5.25	3.62	—
Al_2O_3	0.02	—	0.06	—	0.16	—
Cr_2O_3	—	—	—	—	—	0.06
FeO tot.	5.09	5.10	4.91	4.80	5.52	0.56
MnO	0.45	0.39	0.40	0.39	0.40	0.09
MgO	52.4	53.4	50.3	51.4	51.7	18.4
CaO	—	—	—	—	—	26.0
Tot.	99.0	100.8	97.2	98.4	98.8	100.3
	O = 4			O = 17		O = 6
Si	0.995	0.998	3.838	3.840	3.912	1.992
Al	< 0.001	—	0.008	—	0.020	—
Cr	—	—	—	—	—	0.002
Ti	< 0.001	—	0.430	0.414	0.285	—
Fe^{2+}	0.103	0.102	0.437	0.421	0.483	0.017
Mn	0.009	0.008	0.036	0.035	0.035	0.003
Mg	1.895	1.895	7.970	8.037	8.058	0.989
Ca	—	—	—	—	—	1.005

O = equivalent oxygens

Scattered nodules of reddish Ti-clinohumite commonly occur in the antigoritic serpentinites, sometimes associated to recrystallized olivine, white diopside, ±chlorite and calcic amphibole. This assemblage could be referred to the HP early-Alpine event (DAL PIAZ, 1969). Some microprobe analyses of Ti-clinohumite, olivine and diopside are shown in Table 1. (2) The overlying *Combin unit* of the Piemonte ophiolite nappe comprises a pre-ophiolitic basal complex of Upper Permian-Liassic age and an overlying ophiolite-bearing complex of repeatedly interbedded calcschists and prasinitic horizons, which, in turn, includes some lenses of metagabbro and antigorite serpentinite as sedimentary melange and/or tectonic slices. Although some scarce almandine-rich garnet and Na-amphibole have been found in the upper sections of the Combin sequence, this latter may be regarded as homogeneously equilibrated under greenschist facies conditions during the Lepontine metamorphic events. The serpentinite bodies of the Combin unit – which are lacking of Ti-clinohumite – include some lenses of rodingitic rocks. Scarce and thin rodingitic reaction zones have been also found in the surrounding calcschists and prasinites.

RODINGITES

RODINGITIC GABBRO DYKES (RGD) AT LES PERÈRES-GOUFFRE DE BOUSSERAILLES, UPPER VALTOURNANCHE

Along the Valtournanche road, near the tunnel of Les Perères and along the opposite side of the Marmore river, the antigorite serpentinites of the Zermatt-Saas unit include abundant more or less boudinaged dykes of coarse-grained rodingitic gabbro (10 cm to 2 m in thickness) and more scarce fine-grained rodingite (diabase?). The first usually preserve centimetric pale-gray to black cataclastic crystals of magmatic clinopyroxene. It is more or less substituted by pseudomorphic greenish diopside or by granoblastic pale-green to white diopside developed in fractures or as coronitic rims which is sometimes associated to garnet and chlorite. The matrix comprises interbedded layers and lenses of pink-reddish Ca-rich garnet, yellow epidote and more rare idocrase which are commonly associated to fine-grained intergrowth of chlorite, small diopside and scarce prehnite. These minerals are often recrystallized as elegant lithoclase crystals. Dykes and boudins are surrounded by a narrow rim of chloriteschist which sometimes includes thin beds of white diopside ± garnet.

The rodingitic minerals from Les Perères-Gouffre de Bousserailles have been described by RONDOLINO (1937, 1938), RIGAULT (1959, 1962) and DAL PIAZ (1967). Wet chemical analyses of one granditic garnet and two diopsides were performed by RIGAULT (1959, 1962).

Rodingitic reaction zones (RRZ) in the Breuil area

Several rodingitic reaction zones have been developed over carbonaceous micaschists, basaltic metabasites and metagabbros which surround the serpentinite bodies of the Zermatt-Saas unit in the Valtournanche, Gressoney and Ayas valleys. They appear as yellow (epidote-rich) to greenish (diopside-rich) massive horizons (10 cm to 5 m in thickness) which outcrop along the contact with serpentinites grading to the unrodingitized Mesozoic paraschists or metaophiolites. Sometimes these rocks include Ca-rich garnet, green amphibole, chlorite (Dal Piaz, 1967, 1969 with references).

Among the beds and lenses of rodiginditized carbonaceous micaschists and basaltic metaophiolites outcropping in the Breuil zone (upper Valtournanche), two areas have been investigated in detail. The former is located at 3225-3280 m along the western ridge of the Gobba di Rollin, 500 m E of Passo del Plateau Rosa and appears a tipically rodingitized calcschist; the latter outcrops on the left side of the upper Marmore river at 2600-2625 m, 400 m NE of the right shoulder of the Goillet dam and displays an unusual assemblage of epidote and Na-rich pyroxene.

(a) *Gobba di Rollin*

In this area the serpentinized peridotite tectonites of the Breithorn-Gobba di Rollin-Les Perères basal complex (Zermatt-Saas unit) are covered by carbonaceous garnet-bearing micaschists (which sometimes include fragments of eclogite), followed by a thick section of eclogitic to glaucophanitic metabasalts. Along the contact with the underlying serpentinites and as tectonic included fragments, the Mesozoic paraschists appear transformed to massive diopside+chlorite- or to garnet+diopside-bearing carbonaceous rocks showing sometimes minor green amphibole and epidote. Some relics of almandine-rich garnet occasionally occur.

(b) *Marmore river-Goillet*

A sequence including basal serpentinites, garnetiferous micaschists and overlying eclogites and glaucophanites is also exposed in this area. The high-pressure/low-temperature mineral assemblages are of Upper Cretaceous early-Alpine age (Hunziker, 1974; Dal Piaz and Ernst, 1978; Ernst and Dal Piaz, 1978).

Along the contact with serpentinites, the micaschists have been transformed to a yellow-greenish massive and very hard rock up to 5-8 m in thickness. It appears completely lacking of its original scistosity and grades to the overlying unrodingitized beds. These latter include abundant quartz, white mica and scattered almandine-rich garnet, together with scarce amounts of carbonate, chlorite, epidote and albite, and displays relics of a cranulated S_1 and a penetrative axial plane S_2. The rodingitized micachsist displays, on the contrary, abundant granoblastic epidote with interstitial more or less uralitized clinopyroxene of "omphacitic" composition and minor irregularely distributed green amphibole, albite, sphene, apatite and opaques. The unusual occurrence of "omphacitic" clinopyroxene in this rodingitic rock may be referred either to a pre-rodingitic eclogite or to an uncommon high pressure rodingite. The first hypothesis appears as less probable owing the lack of expected almandine relics in the "omphacite"-bearing beds as well as of omphacite in the overlying unrodingitized micaschists. Actually the sodic pyroxene very rarely occurs in the sedimentary covers of the Zermatt-Saas unit in the Valsesia-Valtournanche area. At present its occurrence is known only in the Vallone delle Cime Bianche (DAL PIAZ *et al.*, 1979).

STRUCTURAL SETTING

Four generations of Alpine folds are recorded in the Valsesia-Valtournanche sector of the northwestern italian Alps within the upper Pennine + Austroalpine structural level of the nappe pile which includes the sandwiched Piemonte ophiolite nappe (GOSSO et al., 1979). The two earliest deformation phases (nappe emplacement and 1st nappe pile refolding) occurred under the high pressure-low temperature conditions of the early-Alpine metamorphic event—before the greenschist reequilibration of the eclogite assemblage—while the two most recent sets of mesoscopic fabric elements were imprinted during and after the greenschist facies Lepontine event.

The metamorphic volcano-sedimentary sequence covering the metabasaltic section of the Zermatt-Saas unit in the upper Valtournanche-Breuil area suffered a similar deformation history that has been analyzed by GOSSO and MESSIGA (GRUPPO OFIOLITI, 1977) in a good outcrop at Promindo, above Les Perères. A multilayer of more or less retrogressed eclogites and Mesozoic carbonaceous micaschists with minor lenses of sheared serpentinites, metagabbros and rodingitic reaction rocks has recorded four Alpine generations of superposed folds. The two earlier generations (B_1 and B_2) produce almost complete transposition of the lithologic layering with occasional preservation of fold hinges. Differentiated axial plane layerings are much better developed in the calcschists than in the eclogites. The axial planes and fold axes attitude is variable, due to rotation operated by fold generations B_3 and B_4 (Fig. 1). No transposition effects are associated with these latest two fold generations. Crenulation cleavage types of layerings with some degree of differentiation form in the axial planes on the third generation folds. The attitude of the latter is visibly rotated by B_4 which is the generation most stable in orientation (subhorizontal axial planes and NE-SW axes). Very scarce microscopic cleavage traces and parasitic folds are associated to B_4.

The folds grouped according to their superposition relationships display a marked heterogeneity of profile shapes (Fig. 2): this confirm that grouping method based on style would not yeld chronological significance. Also the great variation

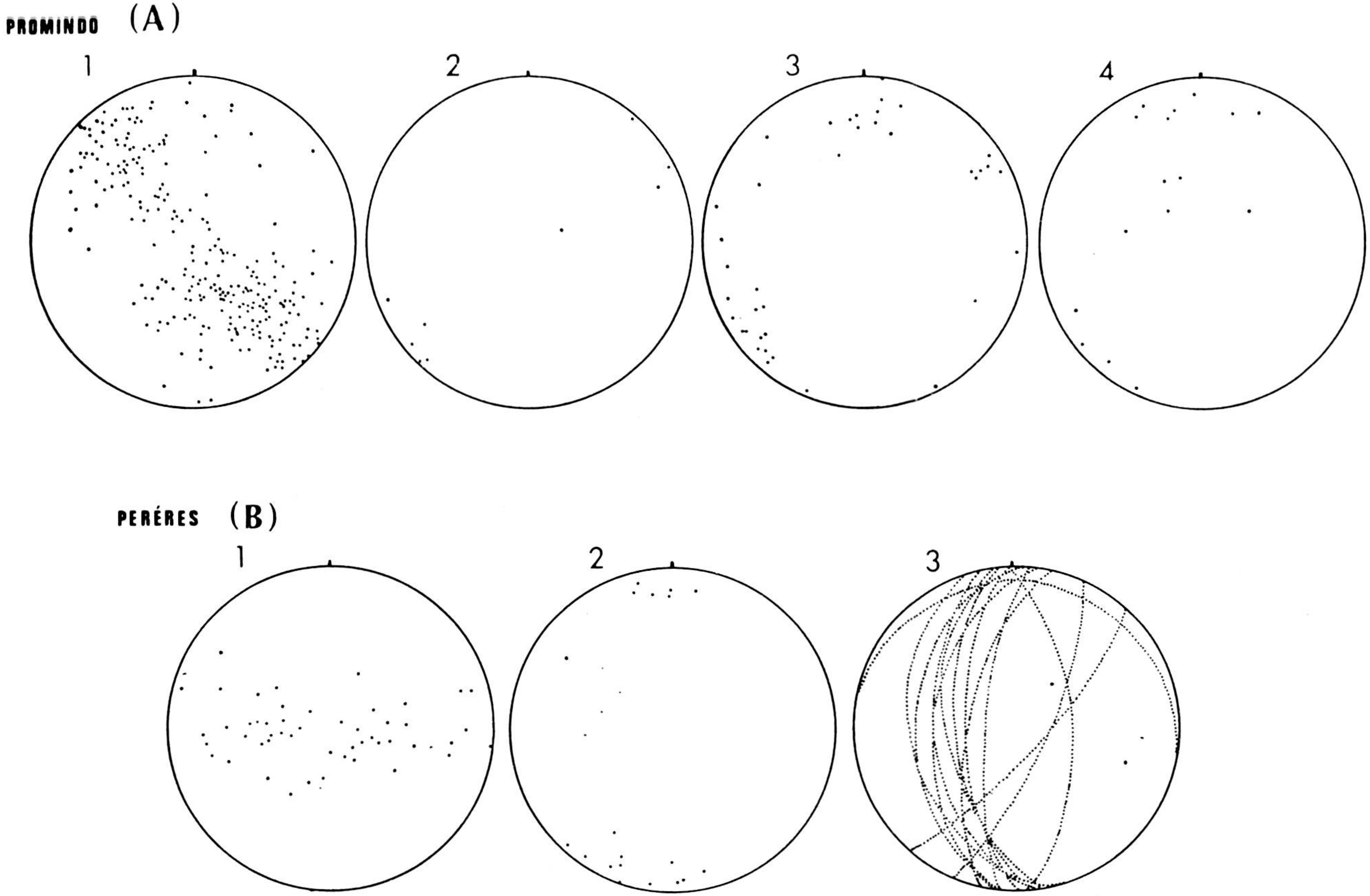

FIG. 1. — Orientiation of structural features in the basaltic eclogites and carbonaceous schists at Promindo (A) and in the serpentinites+rodingites at Perères (B), upper Valtournanche. (A) 1: 255 poles of lithological surfaces; 2: 9 fold axes of B_4 generation; 3: 39 B_3 axes; 4: 16 B_1 and B_2 axes, undifferentiated. (B) 1: 50 poles of lithologic layering and earliest foliation of serpentinites; 2: 19 B_2 axes; 3: 2 B_1 axes (dots) and 13 B_2 crenulation cleavages.

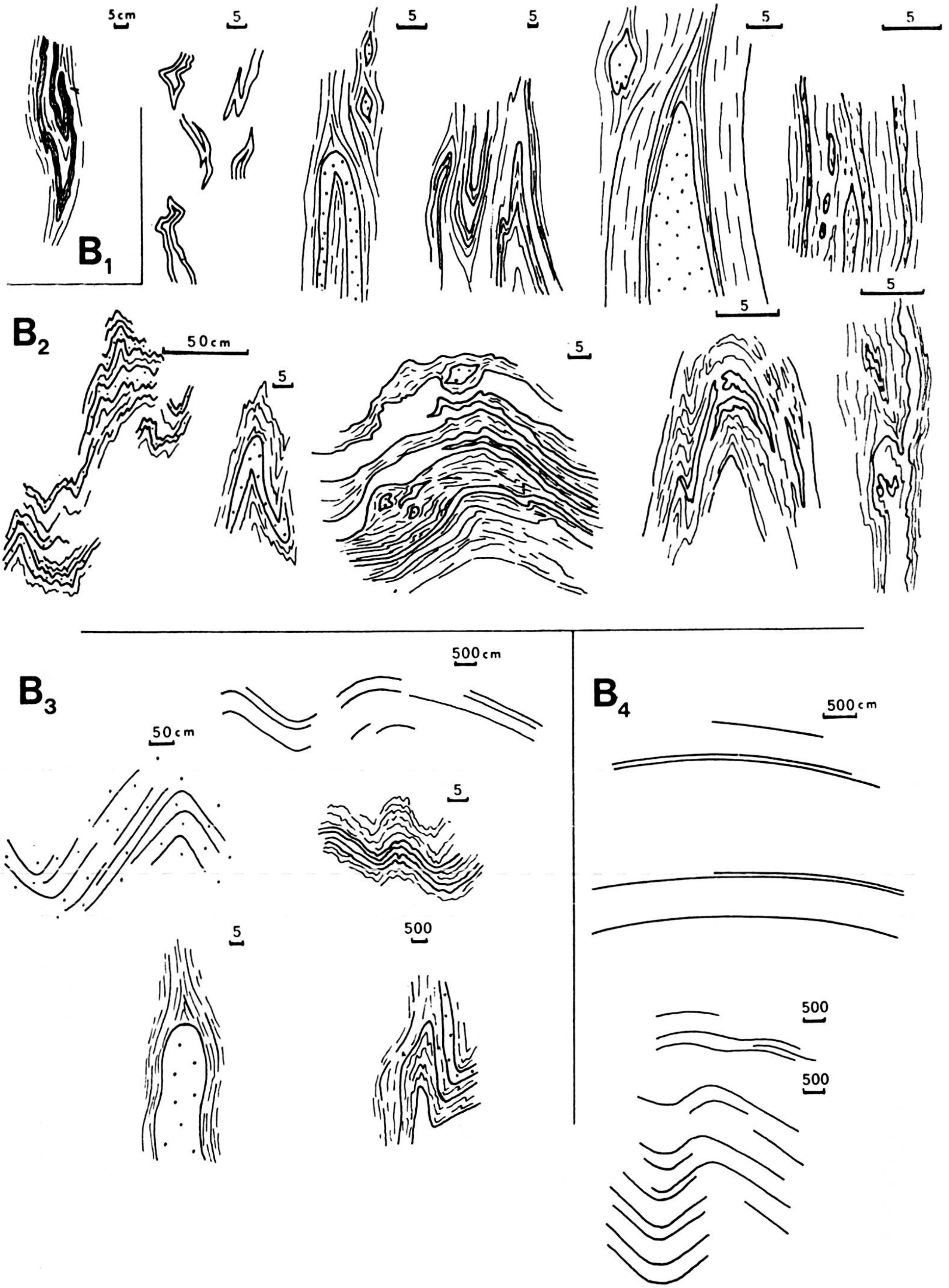

FIG. 2. — Shapes of fold profiles of B_1 to B_4 fold generations at Promindo, grouped on the basis of superposition. Note that members with the same style are recurrent at least in two chronologically different groups. Ornaments of lithologies: quarzites, shaded in B_1 group; metabasites, dotted in B_1 to B_4; carbonaceous schists with various mineral assemblages, dashed or unornamented in B_1 to B_4. Scale bars in cm.

in orientation of fold axes and axial planes does not suggest fold orientation to be a good base for solving chronological relationships.

The serpentinites with the described intercalations of rodingitic gabbro dykes crop out 150 m below the Promindo section, along the Marmore river at Les Perères-Gouffre de Bousserailles. Their geometrical relationships are not physically continuous. The serpentinites have composite mesoscopic fabric related to two sets of superposed folds. The most prominent structural feature of this outcrop is a coarse crenulation cleavage (cm-spaced) well developed in serpentinites and less evident in the rodingitic dykes and lenses. This foliation dips generally west (Fig. 1) and is axial plane to meter scale folds. It crenulates an earlier foliation which in turn can be demonstrated to be axial plane to isoclinal mesoscopic folds locally defined within serpentinites by a mm to cm white diopside-serpentine layering. The two sets of mesoscopic folds show clear overprinting relationships, as their axial plane foliations do at the microscope. The oldest S surface of the outcrop is hence the clinopyroxene layering in serpentinites. Where the latter is crenulated by the axial plane foliation of the isoclinal folds, the microstructure is marked both in the arcuate and rectilinear cleavage domains by elongated prismatic grains of diopside; the arcuate domains are richer in serpentine and the straight ones in oxides. Large porphyroclasts of clinopyroxene relics with an intragranular low angle extinction pattern defining elongated subgrains are preserved within the arcuate domains of the cleavage; the extinction zones inside the porphyroclasts are dimensionally subparallel to the prismatic elongation and interfinger with grains of similar shape and size which are progressively bent into the arcuate cleavage zone. The new subindividuals formed inside the porphyroclasts appear then to merge directly into the crenulated part of the cleavage. No impurity accumulation or coating is observed along the subindividual boundary. The subgrain formation process in the clinopyroxene can be suggested to predate or to have occurred along with the earliest fold generation of this outcrop. The second cleavage produces a gentle banding of the clinopyroxene multigranular domains and a co-planar fine scale kinkbanding in the serpentinite areas.

The lithologic layering surface of the rodingitic dykes is not showing the oldest set of mesoscopic folds. In the rodingites the microstructure of the cleavage associated to the second fold generation also shows two gain size classes in the diopsides. One size class is 10 to 15 times smaller than the other and forms polygonal arcs of strain free grains in the crenulated domains. The larger class is represented by optically strained diopsides and no relationships with the small grains can apparently be inferred.

If the wide range of orientation of the structural features and the large variation in fold styles are considered, caution is suggested for any temptative correlation of the chronology of fold development between the two groups of structural elements occurring in the eclogites and carbonaceous micaschists at Promindo and in the underlying serpentinites + rodingites at Les Perères-Gouffre de Bousserailles, in spite of the detailed mesostructural observations made.

MINERAL CHEMISTRY

The analyses of the main minerals constituting the investigated rodingites have been performed by an ARL microprobe at the Modena University. Some representative analyses of garnet, pyroxene, epidote, chlorite and amphibole are reported in Table 2 and following.

Garnet

In Table 2 and Table 5, after having normalized the formulas to $\sum$ cations = 8, the divalent iron has been calculated as follows: Fe^{2+} = 3-Ca-Mg-Mn. The composition of the garnet from the rodingitic gabbro dykes (RGD) of Les Perères (Table 2) significantly departs from the one from the rodingitized carbonaceous micaschists (RRZ) of Gobba di Rollin and Marmore-Goillet area (Table 5). In the former the grandite component is prevalent while in the latter the almandine and grossularite end-members are dominant and andradite is very scarce. Moreover, the garnet from RRZ is characterized by higher Mg, Mn and Cr contents. On the contrary, the relic garnet from the Gobba di Rollin RRZ (sample DBL471) is almanditic and may be referred to pre-rodingitic early-Alpine HP assemblages. This relic strictly resembles some garnet of the HP-paraschists of the Zermatt-Saas unit recently analysed by DAL PIAZ et al. (in press).

The composition of all the analysed garnets is reported in Fig. 3 in terms of Ca-Mg-(Fe^{2+} + Mn) together with other garnets both from RGD of Les Perères (RIGAULT, 1959) and from unrodingitized eclogites and micaschists of the Zermatt-Saas unit in the Breuil-St. Jaques area (ERNST and DAL PIAZ, 1978; DAL PIAZ et al., in press).

Clinopyroxenes

The different types of clinopyroxene previously referred to the poliphase hystory of the studied rocks show variable chemical features. (1) The relics of pyroxene are characterized by the highest Ti, Al, Fe, Mn and Na values and by the lowest Ca content. By comparison with the composition of the magmatic clinopyroxene from the Allalin metagabbro (BEARTH, 1967), a magmatic origin may be suggested for these relics. (2) The subgrains within the Pyroxene 1 show drastic lowering in Ti, Al, moderate to strong decrease in Fe, Na, Fe/Mg an increase in Ca. (3) The new generation of granoblastic pyroxene occurring in the matrix and in most veins within pyroxene 1 is nearly pure diopside almost completely devoid of Ti and very low in Al, Mn, Na and Fe contents. It crystallized in equilibrium with garnet, epidote and chlorite.

TABLE 2

Ca-garnet from rodingitic gabbro-dykes (RGD) of Les Perrères-Gouffre de Bousserailles, upper Valtournanche, Zermatt-Saas unit

	MRO 2902			MRO 2904		MRO 2905		MRO 2907		MRO 2911	
	1-2	7-7	7-3	2-6	3-4	3-3	3-6	1-1A c	1-3A r	1-2	1-7
SiO_2	39.6	39.3	38.9	38.7	39.7	39.2	39.5	37.9	38.0	39.0	39.6
TiO_2	0.55	0.41	0.51	0.63	0.24	0.15	0.31	0.30	0.29	0.27	0.31
Al_2O_3	18.0	18.4	16.9	15.7	17.7	18.9	17.8	19.0	19.3	20.6	21.8
Cr_2O_3	—	0.07	—	—	—	0.07	0.55	0.39	—	0.81	0.11
FeO tot.	7.78	4.57	9.15	11.8	6.40	4.02	4.68	11.3	8.12	6.37	2.79
MnO	0.37	0.76	0.62	0.64	0.16	0.16	0.40	0.50	0.34	0.30	0.24
MgO	0.74	0.42	0.51	0.58	0.04	0.08	0.51	0.96	0.78	0.84	0.56
CaO	33.3	34.1	33.3	31.2	36.6	36.0	35.5	28.4	31.7	32.7	35.4
Tot.	100.3	98.0	99.9	99.3	100.8	98.6	99.2	98.8	98.5	100.9	100.8
						Σ cations = 8					
Si	3.022	3.053	2.998	3.024	3.011	3.020	3.033	2.957	2.946	2.944	2.963
Al	1.619	1.685	1.535	1.446	1.582	1.717	1.610	1.747	1.764	1.833	1.923
Cr	—	0.004	—	—	—	0.004	0.034	0.023	—	0.049	0.007
Ti	0.032	0.024	0.029	0.037	0.014	0.009	0.018	0.018	0.017	0.015	0.017
Fe^{3+}	0.327	0.234	0.439	0.493	0.394	0.250	0.301	0.256	0.272	0.159	0.090
Fe^{2+}	0.169	0.063	0.151	0.278	0.012	0.009	—	0.481	0.254	0.243	0.084
Mn	0.024	0.050	0.040	0.042	0.010	0.011	0.026	0.033	0.023	0.019	0.015
Mg	0.084	0.049	0.059	0.068	0.005	0.009	0.058	0.112	0.090	0.094	0.063
Ca	2.723	2.838	2.750	2.612	2.973	2.971	2.920	2.374	2.633	2.644	2.838

r = rim; c = core. The capital letter indicates different analyses on the same crystal. Fe^{2+} = 3-Ca-Mg-Mn.

Table 2 *(Continued)*

	Matrix									
	MRO 2902		MRO 2904		MRO 2905			MRO 2909		MRO 2911
	4	5	1-6	2-1	1-3	2-2G c	2-3G r	1-6	1-8	1-10
SiO_2	54.9	54.1	55.1	55.6	54.7	55.2	54.8	55.0	54.1	54.3
TiO_2	—	—	—	—	—	—	—	—	—	—
Al_2O_3	0.44	0.37	0.26	0.25	0.18	0.58	0.17	0.34	0.61	0.46
Cr_2O_3	—	0.10	0.07	—	0.07	0.10	—	—	0.08	0.12
FeO tot.	1.44	1.86	2.33	2.14	0.38	0.48	0.54	2.31	2.47	1.02
MnO	—	0.07	—	—	0.09	0.09	—	—	—	—
MgO	16.7	16.4	16.4	16.8	17.4	17.1	17.4	17.1	16.6	18.0
CaO	25.4	24.6	25.0	25.7	25.6	25.8	25.8	24.9	24.5	25.2
Na_2O	0.22	0.34	0.33	0.23	0.03	—	0.09	0.26	0.44	0.18
Tot.	99.1	97.8	99.5	100.7	98.4	99.4	98.8	99.9	98.8	99.3
	$O = 6$									
Si	2.008	2.007	2.013	2.007	2.007	2.006	2.005	2.001	1.993	1.982
Al	0.019	0.016	0.011	0.011	0.008	0.025	0.007	0.015	0.026	0.020
Cr	—	0.003	0.002	—	0.002	0.003	—	—	0.002	0.003
Ti	—	—	—	—	—	—	—	—	—	—
Fe^{2+}	0.044	0.058	0.071	0.065	0.012	0.015	0.017	0.070	0.076	0.031
Mn	—	0.002	—	—	0.003	0.003	—	—	—	—
Mg	0.910	0.907	0.893	0.904	0.951	0.926	0.949	0.927	0.912	0.979
Ca	0.995	0.978	0.979	0.994	1.006	1.004	1.011	0.971	0.967	0.985
Na	0.016	0.024	0.023	0.016	0.002	—	0.006	0.018	0.031	0.013

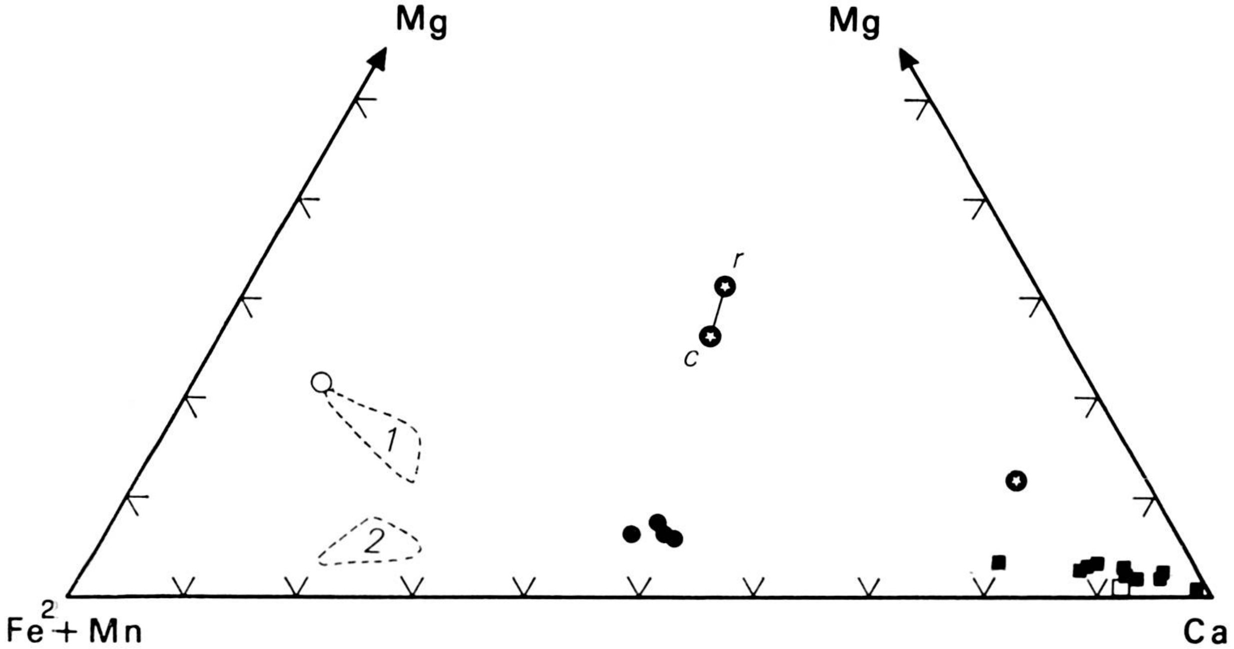

FIG. 3. — Composition of the garnets from the investigated rodingites. Rodingitic gabbro dykes: filled square, this work; open square, RIGAULT (1962). Rodingitic reaction zones: filled circle, rodingitic garnet; open circle, relic garnet. Data for garnets from micaschists of the Zermatt-Saas unit (DAL PIAZ et al., in press: 1, sample DBL 406; 2, sample MRO 832) and from eclogites-metarodingite at Cima di Gagnone (EVANS et al., 1979: star) are also reported for comparison. r = rim, c = core.

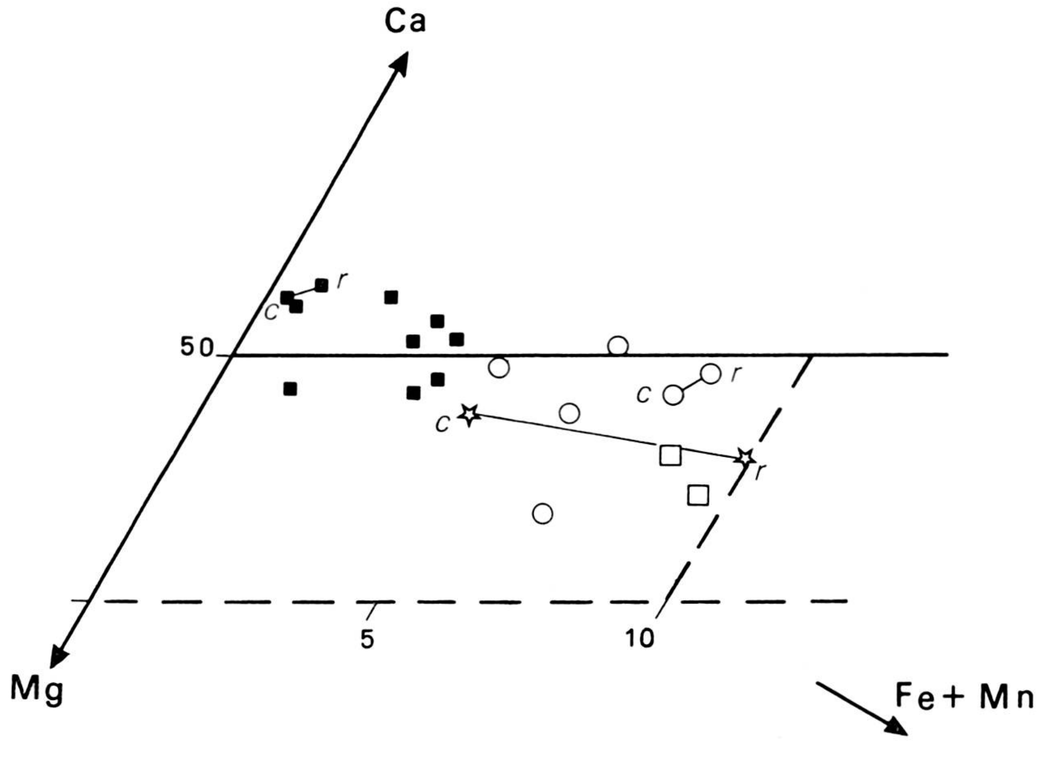

FIG. 4. — Ca-Mg-(Fe+Mn) diagram for the analysed clinopyroxenes. Rodingitic gabbro dykes: open square, magmatic relics; open circle, pseudomorphic transformations; filled square, crystals of the matrix. Rodingitic reaction zones: star, sample DBL 471. r = rim, c = core.

The chemical composition of some analysed pyroxenes is reported in Fig. 4 in terms of Ca-Mg-(Fetot. + Mn).

The pyroxene occurring in the RRZ of Marmore-Goillet is "omphacitic" in composition.

Epidote

Some analyses of epidote from RGD are reported in Table 4. Its composition is enough constant. The strong optical zonation observed in many crystals must be referred to moderate Al-Fe^{3+} substitution. The epidote from the Marmore-Goillet

TABLE 3

Clinopyroxenes from rodingitic gabbro-dykes (RGD) of Les Perrères-Gouffre de Bousserailles, upper Valtournanche, Zermatt-Saas unit

	Magmatic relics		Pseudomorphic transformations					
	MRO 2904		MRO 2902		MRO 2907	MRO 2909		MRO 2911
	1-1C	1-3C	1-5Z	2-2Z	1-1O	1-5A r	1-1A c	1-1
SiO_2	51.9	52.1	54.0	54.0	53.7	53.9	53.0	52.6
TiO_2	0.97	1.07	—	—	—	0.07	0.09	0.28
Al_2O_3	2.79	2.86	0.14	0.26	0.75	0.24	0.91	1.85
Cr_2O_3	0.10	0.15	—	—	—	—	—	0.86
FeO tot.	4.91	5.48	4.02	2.83	4.08	5.16	4.92	3.74
MnO	0.22	0.20	0.20	0.08	0.26	0.26	0.20	0.18
MgO	14.6	14.8	15.3	16.1	16.6	15.2	15.3	15.6
CaO	22.5	22.5	24.8	24.5	23.4	25.1	24.5	23.7
Na_2O	0.53	0.53	0.15	0.26	0.10	0.11	0.18	0.35
Tot.	98.5	99.7	99.6	98.9	98.9	100.0	99.1	99.2
				O = 6				
Si	1.935	1.924	2.009	2.008	1.986	1.990	1.972	1.946
Al	0.123	0.125	0.006	0.011	0.033	0.010	0.040	0.081
Cr	0.003	0.004	—	—	—	—	—	0.025
Ti	0.027	0.030	—	—	—	0.002	0.003	0.008
Fe^{2+}	0.153	0.169	0.125	0.088	0.126	0.159	0.153	0.116
Mn	0.007	0.006	0.006	0.003	0.008	0.008	0.006	0.006
Mg	0.811	0.815	0.848	0.892	0.915	0.836	0.848	0.860
Ca	0.899	0.890	0.989	0.976	0.927	0.993	0.977	0.940
Na	0.038	0.038	0.011	0.019	0.007	0.008	0.013	0.025

O = equivalent oxygens; r = rim; c = core. The same capital letters indicate different analyses on the same crystal.

RRZ (sample MR02915) is higher in iron and lower in aluminium in respect to the one from RGD of Les Perères-Gouffre de Bousserailles.

Chlorite

Chlorite from RGD (Table 4) is sometimes very low in iron (see analysie 6-1) and may be classified as sheridanite-clinochlore following the HEY's classification (1954). Its chemical composition is different from that of the chlorite occurring in the host micaschists which, in turn, is largely higher in iron.

TABLE 4

Epidote and chlorite in the matrix of rodingitic gabbro-dykes (RGD) from Les Perrères-Gouffres de Bousserailles, upper Valtournanche, Zermatt-Saas unit

	Epidote				Chlorite			
	MRO 2902		MRO 2907		MRO 2902	MRO 2904	MRO 2909	MRO 2911
	5-6H r	5-9H c	1-8	1-7	6-1	1-4	1-9	1-8
SiO_2	38.3	38.0	38.3	37.9	30.0	29.7	29.2	29.7
TiO_2	0.08	—	0.16	0.11	—	—	—	—
Al_2O_3	28.8	27.2	29.6	28.9	21.5	20.9	22.3	22.3
Cr_2O_3	—	—	—	0.17	—	—	—	0.51
Fe_2O_3 tot.	5.17	6.70	5.49	6.30	—	—	—	—
FeO tot.	—	—	—	—	1.86	5.32	4.23	4.58
MnO	—	0.07	—	—	0.05	0.19	0.03	—
MgO	0.17	0.12	0.12	0.12	30.5	29.0	30.9	30.9
CaO	23.7	23.4	23.2	23.5	—	0.05	0.03	0.06
Tot.	96.2	95.5	96.9	97.0	84.0	85.2	86.8	88.1
	Σ cations = 8				O = 28			
Si	3.008	3.027	2.990	2.964	5.789	5.766	5.543	5.568
Al	2.666	2.554	2.724	2.664	4.891	4.783	4.990	4.928
Cr	—	—	—	0.011	—	—	—	0.076
Ti	0.005	—	0.009	0.006	—	—	—	—
Fe^{3+}	0.306	0.402	0.323	0.371	—	—	—	—
Mn^{3+}	—	0.005	—	—	—	—	—	—
Fe^{2+}	—	—	—	—	0.300	0.864	0.671	0.718
Mn^{2+}	—	—	—	—	0.008	0.031	0.014	—
Mg	0.020	0.014	0.014	0.014	8.777	8.391	8.742	8.633
Ca	1.994	1.997	1.940	1.970	0.010	0.010	0.006	0.012

O = equivalent oxygens; r = rim; c = core. The capital letter indicates different analyses on the same crystal.

TABLE 5

Minerals from rodingitic reaction zone (RRZ) of the Gobba di Rollin Western Ridge, Zermatt-Saas unit (Sample DBL 471)

	Relic Garnet	Garnet				Diopside	
	2-6	1-1A	1-3A	1-5B	1-6B	2-2C i	2-3C r
SiO_2	37.8	37.5	38.0	37.6	37.5	54.2	54.4
TiO_2	0.02	0.23	0.08	0.15	0.22	—	—
Al_2O_3	21.7	20.4	20.8	20.3	20.0	0.18	0.51
Cr_2O_3	0.06	1.41	0.97	1.20	1.52	0.07	0.10
FeO tot.	30.1	20.9	20.6	20.3	20.6	3.08	6.44
MnO	0.81	1.31	1.18	1.36	1.34	0.12	0.10
MgO	5.56	1.64	2.00	1.69	1.56	17.0	15.5
CaO	4.18	16.0	16.9	16.9	17.7	24.9	24.6
Na_2O	—	—	—	—	—	0.08	0.37
Tot.	100.2	99.4	100.6	99.5	100.4	99.6	102.0
	Σ cations = 8	Σ cations = 8				O = 6	
Si	2.963	2.970	2.960	2.968	2.939	1.988	1.977
Al	2.005	1.905	1.910	1.889	1.848	0.008	0.022
Cr	0.004	0.088	0.060	0.075	0.094	0.002	0.003
Ti	0.001	0.014	0.005	0.009	0.013	—	—
Fe^{3+}	0.027	0.025	0.063	0.059	0.107	—	—
Fe^{2+}	1.946	1.360	1.279	1.281	1.243	0.094	0.196
Mn	0.054	0.088	0.078	0.091	0.089	0.004	0.003
Mg	0.649	0.194	0.232	0.199	0.182	0.929	0.840
Ca	0.351	1.358	1.411	1.429	1.486	0.979	0.958
Na	—	—	—	—	—	0.006	0.026

O = equivalent oxygens; i = intermediate; r = rim. The same capital letters indicate different analyses on the same crystal. For garnets Fe^{2+} = 3-Ca-Mg-Mn.

Amphiboles

Two analyses of amphiboles occurring as minor component in the Marmore-Goillet RRZ (sample MR02915) are reported in Table 6. They show edenitic-horneblenditic composition and are higher in Ti and Mn in respect to the coexisting pyroxene. Moreover, their composition is only rougly similar to that found by EVANS et al. (1979) for the amphiboles from the eclogite-metarodingite suite at Cima di Gagnone, Central Alps (Switzerland).

TABLE 6

Minerals from rodingitic reaction zone (RRZ) of the Marmore river-Goillet lake area, Zermatt-Saas unit (Sample MRO 2915)

	Pyroxene		Epidote		Amphibole	
	2-8P	2-10P	2-4N	2-5N	2-3	2-1
SiO_2	53.7	55.4	38.2	39.0	47.4	47.3
TiO_2	0.05	0.17	0.32	0.08	0.22	0.23
Al_2O_3	4.02	7.76	25.8	27.5	8.93	11.5
Cr_2O_3	0.12	—	0.11	0.09	—	0.06
Fe_2O_3 tot.	—	—	9.00	7.84	—	—
FeO tot.	8.38	5.22	—	—	10.6	10.5
MnO	0.34	0.26	0.35	0.25	0.42	0.38
MgO	10.8	9.85	0.06	0.05	14.4	13.9
CaO	18.9	16.3	23.4	23.9	9.93	10.0
Na_2O	3.52	5.66	—	—	3.57	3.53
K_2O	—	—	—	—	0.27	0.35
Tot.	99.8	100.6	97.2	98.7	95.7	97.8
	Σ cations = 4		Σ cations = 8		O = 23	
Si	1.971	1.972	3.021	3.019	6.899	6.726
Al	0.174	0.326	2.405	2.510	1.532	1.928
Cr	0.003	—	0.007	0.006	—	0.007
Ti	0.001	0.005	0.019	0.005	0.024	0.025
Fe^{3+}	0.115	0.062	0.535	0.456	0.643	0.626
Mn^{3+}	—	—	0.013	0.004	—	—
Fe^{2+}	0.141	0.093	—	—	0.643	0.626
Mn^{2+}	0.011	0.008	0.010	0.012	0.052	0.046
Mg	0.591	0.522	0.007	0.006	3.123	2.946
Ca	0.743	0.623	1.983	1.982	1.548	1.524
Na	0.250	0.390	—	—	1.007	0.973
K	—	—	—	—	0.050	0.063

O = equivalent oxygens. The same capital letters indicate different analyses on the same crystal. In the formulas of pyroxene Fe^{3+} = Fe tot.-Ca + Mg + Mn. In the amphibole formulas $Fe^{2+}/Fe^{3+} = 1$.

CONCLUDING REMARKS

The rodingitic gabbro dykes of Les Perères-Gouffre de Bousserailles area (upper Valtournanche) dysplayi poliphase mineral assemblages containing pre-rodingitic relics of magmatic pyroxene which is more or less completely substituted by subgranular diopsidic pyroxene or by an almost pure granoblastoc diopside. The latter coexists with the rodingitic matrix constituted by granditic garnet, epidote, chlorite, ±idocrase.

The rodingitic reaction zones developed over carbonaceous micaschists along the contact with the serpentinite bodies show both an usual rodingitic mineralogy with abundant Ca-garnet, diopside and chlorite and some relics of almanditic garnet (Gobba di Rollin), and an unusual assemblage of epidote and "omphacitic" pyroxene with minor edenitic-horneblenditic amphibole. They may be respectively referred to post-eclogitic (Lepontine) rodingitic transformations which occurred over garnet-bearing calcschists and to a high-pressure rodingite possibly of early-Alpine age and in some way similar to that of Cima di Gagnone (EVANS et al., 1979) but developed under relatively lower P-T conditions.

The mineral chemistry of RGD and RRZ confirms the strong chemical variations connected with the rodingitization process.

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