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EXCURSION TO THE SESIA-LANZO ZONE AND VALTOURNANCHE METAMORPHIC OPHIOLITES

GUIDE BOOK

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Two areas were selected for the Sesia-Lanzo Zone (Fig. 1):

A) the Mucrone area in the Eclogitic Micaschist Complex with eclogitized granitoids and paragneisses;

B) the Val d'Aosta cross section from the Eclogitic Micaschists to the Gneiss Minuti.

A review of the geology of the Sesia-Lanzo Zone, with extensive references, is given in COMPAGNONI et al. (Internal Report 2 of the Italy-U.S.A. Cooperative Project, 1975, and this volume).

The eclogitic metaophiolites of the underlying Piemonte Zone were visited in the Breuil area, upper Valtournanche (C in Fig. 1).

A. Eclogitic paraschists and metagranitoids of the Mucrone area - Biella

(Topographic Map 1:25.000: LILLIANES; 1:100.000 sheet nr. 42, IVREA)

The Mount Mucrone area (map in DAL PIAZ et al., 1973) has been known for its beautiful eclogites since the end of the 19th century; moreover the best examples of eclogitic metagranitoids and paraschists also occur in this area. Disregarding a weak thermal effect due to the intrusion of the post-metamorphic Biella stock, the Mt. Mucrone area is devoid of significant post-eclogitic transformations.

The outcrops described in 1, 2, 3 and 4 are located in the cirques above the terminal of the cable car that reaches Lake Mucrone from Oropa (fig. 2*a*).

Stops 1 and 2: EAST FACE OF MT. MUCRONE

Eclogitic metagranitoids with relic magmatic microstructures

From the northeastern side of Lake Mucrone a narrow path (red marks) leads in about twenty minutes to a saddle on the north ridge of Mt. Mucrone and thence to a little cirque at the foot of the east face. Stop 1 is reached in 10 min. from the saddle. Stop 2 is beyond the little notch on the crest limiting the cirque to the south.

In stop 1 eclogitic metagranitoids with the best preserved magmatic texture are exposed.

Quartz, biotite and *K-feldspar* in twinned phenocrysts are still preserved in these metagranitoids. *Plagioclase* is completely replaced by very fine-grained aggregates consisting of *jadeite, zoisite* and *quartz* (DAL PIAZ et al., 1972; COMPAGNONI and MAFFEO, 1973). *Biotite* is rimmed by *phengite + garnet.*

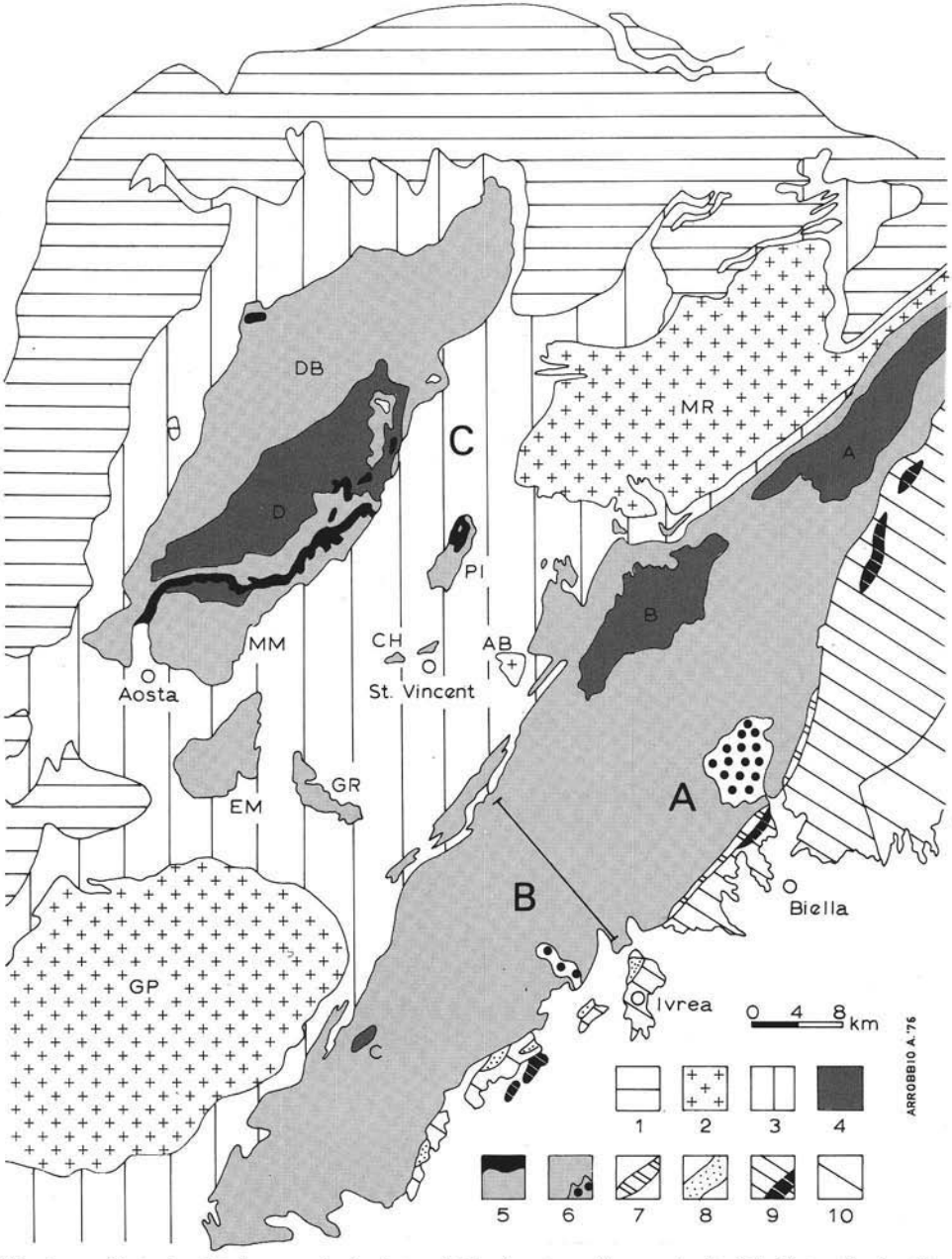

Fig. 1. — *Tectonic sketch map of the internal Northwestern Alps.* A, B, C indicate the location of the fieldtrips. 1) Bernhard Nappe. 2) Monte Rosa (MR) - Arceza-Brusson (AB) - Gran Paradiso (GP) Nappe. 3) Piemonte Zone. 4) and 5) Austroalpine complexes. 4) II Zona Diorito-Kinzigitica (A), Val Vogna-Valle di Gressoney Klippe (B), Vasaro Klippe (C), Valpelline Series (D). 5) Eclogitic Micaschist Complex and Gneiss Minuti Complex of the Sesia-Lanzo Zone; Arolla Gneisses of the Dent Blanche Nappe; black: Mesozoic sequences of Mont Dolin and Roisan Zone. 6) Biella and Traversella stocks. 7) Trachyandesite volcanics of Oligocene age. 8) Canavese Zone. 9) Ivrea-Verbano Zone; black: ultramafics. 10) Serie dei Laghi.
DB: Dent Blanche Nappe s.s. MM: Mont Mary Klippe. EM: Monte Emilius Klippe. GR: Glacier-Rafray Klippe. PI: Pillonet Klippe. CH: Chatillon-Saint Vincent Klippe.

The metagranitoids range in composition from granodiorites to quartzdiorites. Chemical compositions of four representative metagranitic rocks from Mt. Mucrone (MEC 97 and MEC 100: CALLEGARI et al., 1976, tab. 1; MEC 188 and MEC 189: an. H. SMITH, U. S. Geol. Survey, Menlo Park) are shown in table 1.

Cognate dark inclusions of the granitoids are transformed into *quartz-omphacite-garnet* rocks. Small xenoliths of country rocks (paragneisses) and aplite to pegmatite dykes are beautifully preserved. They show partial transformations into high - pressure assemblages as the granitoids. *Jadeite-clinozoisite* shear zones of pre-eclogitic age (CALLEGARI, pers. comm.) occur at the foot of the wall within the metagranitoids.

TABLE 1

Chemical compositions of four representative metagranitic rocks from Mt. Mucrone

	MEC 97	MEC 100	MEC 188	MEC 189
SiO_2	66.60	69.42	66.6	68.7
TiO_2	0.58	0.49	0.56	0.38
Al_2O_3	16.31	14.84	16.4	16.0
Fe_2O_3	0.36	0.35	0.40	0.50
FeO	3.99	3.15	4.2	2.9
MnO	0.07	0.06	0.07	0.07
MgO	1.22	0.88	1.4	0.80
CaO	3.93	2.95	3.7	3.2
Na_2O	3.54	2.98	3.5	2.9
K_2O	2.15	3.00	2.7	3.6
P_2O_5	0.18	0.12	0.19	0.11
H_2O^+	1.02	1.64	0.70	0.55
H_2O^-	n.d.	n.d.	0.04	0.02
CO_2	n.d.	n.d.	0.05	0.07
TOTAL	99.95	99.98	100.51	99.80

The granitoids grade into phengite micaschists with *garnet, Na-pyroxene, zoisite* ± *glaucophane*. All intermediate stages in the transformation from granitoids to orthomicaschists can be found in this site.

The same lithologies are found in stop 2, just below the summit of Mt. Mucrone. Fine-grained rocks consisting of *quartz, garnet* and *Na-pyroxenes* and possibly corresponding to pre-Alpine hornfelses are seen in contact with the metagranitoids.

Stop 3: EASTERN SLOPE OF MT. ROSSO

Eclogitic paraschists with relics of pre-Alpine assemblages

This outcrop is located 100 m above the narrow road connecting the cable car station with Lake Mucrone. It can be reached by a 10 min. walk along a path starting at the north side of the lake.

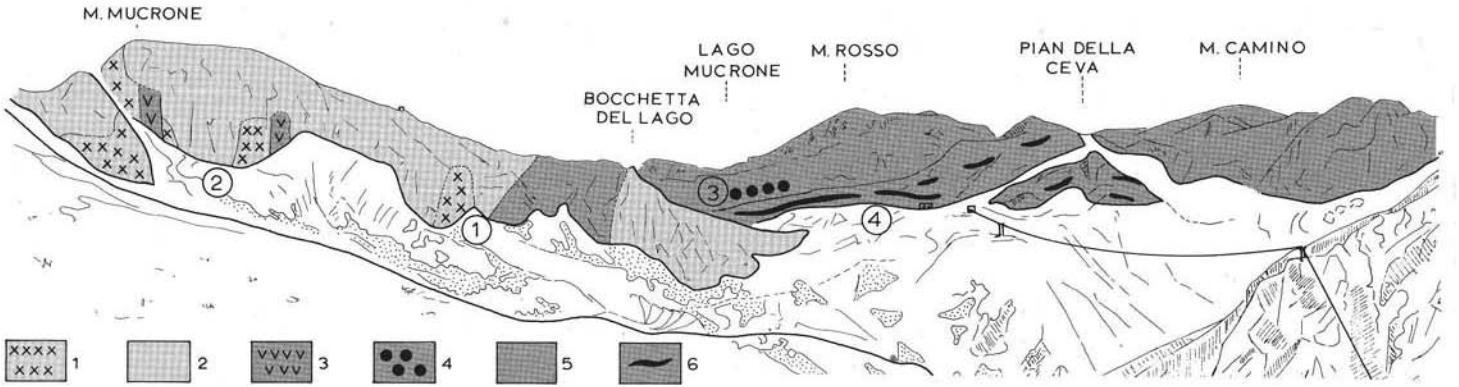

Fig. 2 *a*) — Geology of the ridge Monte Mucrone-Monte Camino. 1) Eclogitic metagranitoids. 2) Orthomicaschists. 3) Garnet-omphacite-quartz rocks. 4) Relics of pre-Alpine Kinzigitic rocks. 5) Eclogitic paraschists. 6) Major lenses of eclogites. Numbers in circles indicate the visited outcrops.

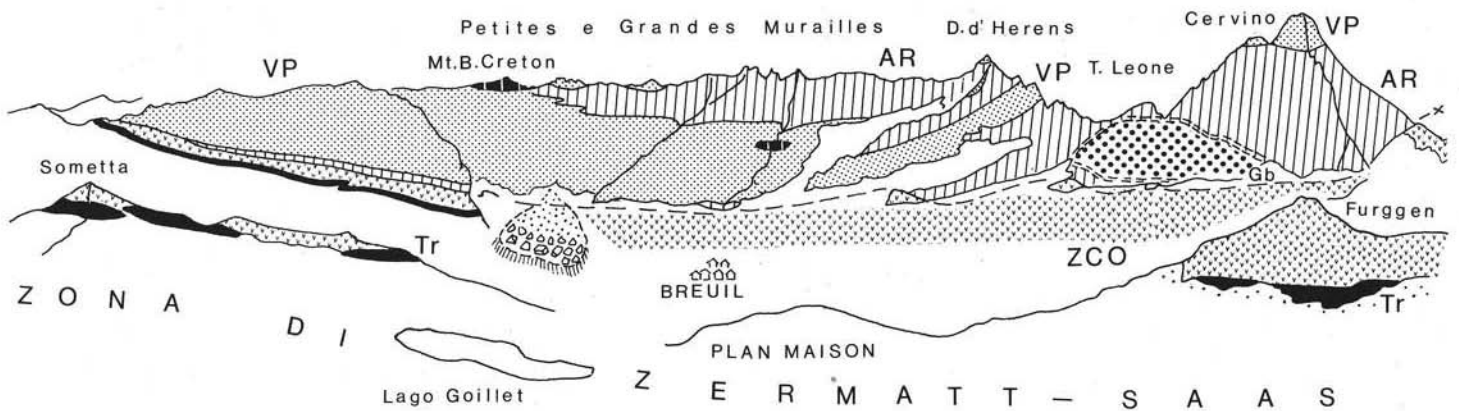

Fig. 2 *b*) — Panorama of the eastern margin of the Austroalpine Dent Blanche Nappe *s.l.* and of the underlying Piemonte Zone from Plateau Rosa. *Dent Blanche Nappe*: VP: Valpelline-Series; AR: Arolla Series (Gb: gabbros); black with white lines: Mt. Blanc du Creton-Bivacco Balestrieri Unit (Dal Piaz, 1976). Piemonte Zone: ZCO: Combin Zone (Tr-black: Triassic sequences); white: Zermatt-Saas Zone.

Relics of pre-Alpine high-grade paragneisses with pegmatitic mobilizates and metabasites are preserved here within eclogitic paraschists.

Biotite, garnet, sillimanite and *K-feldspar* of pre-Alpine age are still preserved in the paragneisses. As in the metagranitoids of locality 1 and 2 plagioclase is completely replaced by *jadeite, quartz* and *zoisite* pseudomorphs and *biotite* is partially replaced by *phengite* + *garnet*; *kyanite* pseudomorphs replace *sillimanite*.

Pre-Alpine metabasites are transformed into coarse-grained glaucophane eclogites; relics of *brown hornblende* are preserved in places.

Pegmatitic pods and veins in the paragneisses consist of *quartz, K-feldspar* ± ± *biotite* ± *plagioclase*. Biotite and plagioclase show the same mineral transformation as in the surrounding paragneisses.

Stop 4: Lake Mucrone - lift terminal

Eclogitic paraschists with intercalations of glaucophane eclogites

Typical eclogitic paraschists are exposed along the path from Lake Mucrone to the lift station; massive to foliated glaucophane-phengite-eclogites occur as large lenses in the paraschists (fig. 2) and can be sampled in loose blocks. These eclogites are described by Viterbo and Blackburn (1968).

Phengites of the paraschists give K-Ar and Rb-Sr early-Alpine ages (Hunziker, 1974).

Stop 5: Road from Oropa to Biella

(Topographic Map 1:25.000: *Andorno Micca*; 1.100.000 sheet nr. 43, *Biella*)

Andesite volcanics with blocks of eclogitic micaschists

The road from Oropa to Biella crosses near Favaro the andesite volcanics covering the internal margin of the Sesia-Lanzo Zone. The volcanics are exposed over 25 Km from the lower Aosta Valley to the Sesia Valley. They are unmetamorphosed and yield whole-rock K-Ar ages of 30 m.y. (Hunziker, 1974; Scheuring et al., 1974; see also Internal Report 2, sect 2.3, for discussion). Round shaped blocks of eclogitic micaschists occur in the volcanics (Bianchi and Gb. Dal Piaz, 1963, with earlier references). White micas of these micaschists give early-Alpine ages (Hunziker, 1974).

B. Section across the Sesia-Lanzo Zone in the lower Val d'Aosta

(Topographic and geological Maps 1:100.000 nr. 42, IVREA)

The lower Val d'Aosta exposes a complete section (about 20 Km long) across the Sesia-Lanzo Zone which can be visited in a single day. In spite of the rather low elevation, exposures are very good due to extensive glacial polishing.

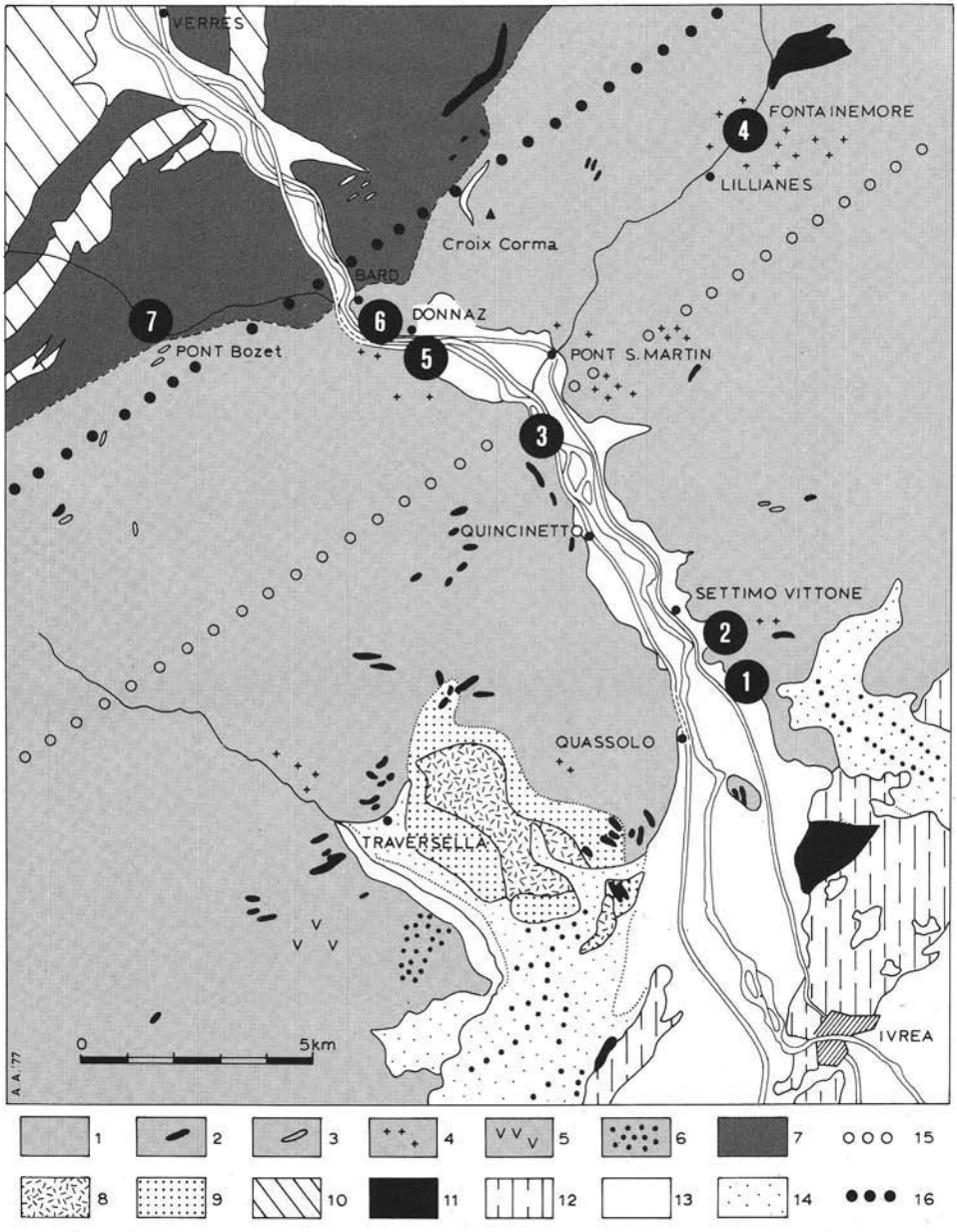

Fig. 3. — *Geologic sketch map of lower Val d'Aosta.* 1) Eclogitic micaschists. 2) Marbles. 3) Amphibolites. 4) Metagranitic rocks. 5) Metagabbros. 6) Glaucophanites. 7) « Gneiss Minuti » Complex. 8) Traversella stock. 9) Contact aureole of the Traversella stock. 10) Piemonte Zone. 11) Canavese Zone. 12) Ivrea-Verbano Zone. 13) Alluvial deposits. 14) Moraines. 15-16) Isograds of the greenschist-facies overprinting of Lepontine age: 15) jadeite-out, 16) glaucophane-out.
Numbers show location of the visited outcrops.

Location of the visited outcrops is shown in Fig. 3. Stops 1 to 6 are in the Eclogitic Micaschist Complex; stop 7 is in the Gneiss Minuti Complex. With respect to the greenschist-facies overprinting of Lepontine age, stops 1, 2 and 3 are in the zone where glaucophane and jadeite are preserved. Stops 4, 5 and 6 are in the zone where jadeite has been completely replaced but glaucophane is still preserved. Stop 7 is in the zone where also glaucophanes are completely replaced.

Stop 1: Ivozio (Topographic Map 1:25.000: *Borgofranco d'Ivrea*; coord. 1022 4318)
Metabasites with pseudomorphs after lawsonite

In this exposure (on the slope, 300 m north of the small village of Ivozio) layered metabasics contain abundant pseudomorphs after *lawsonite*. The Ivozio lawsonite extends further to the northeast the known occurrences of this mineral, previously restricted to the southernmost part of the Sesia-Lanzo Zone (see Compagnoni et al., this volume).

The metabasites consist of *zoisite*, colourless *amphibole* and *white mica*, with varying proportions of *omphacite* and *garnet* and minor *glaucophane* and *rutile*.

A possible derivation of these rocks from pre-Alpine amphibolites is suggested by the occurrence of large colourless amphiboles replacing older brown hornblendes.

The pseudomorphs after lawsonite have a rhombohedral shape and their size may reach 1 cm; they are very fine-grained aggregates consisting of *paragonite* and *zoisite* ± *albite*.

Bulk chemistry of this metabasite is presented in table 2 (SL 910).

Stop 2: Montestrutto
(Topographic Map 1:25.000: *Borgofranco d'Ivrea*; coord. 0990 4364)
Eclogitic paraschists with meta-aplitic dykes

The outcrops are located near a vantage point, 500 m east of the village of Montestrutto. Towards the west, the Fort of Bard stands in the middle of the valley. Eastward the Po plain appears; in a few points the Ivrea Zone outcrops through the Quaternary cover.

The gross lithology of the eclogitic micaschists dips gently westward. The nearly parallel association of light coloured layers of metagranitoids with darker paraschists is due to isoclinal folding of Alpine age.

The prevailing lithology is a micaschist with *Na-pyroxene, garnet, phengite, glaucophane* ± *zoisite* ± *rutile*. Small boundins of garnet omphacitites and glaucophane eclogites are common. Marbles occur in places (e.g. close to the road of the Aosta Valley).

The dykes have a leucogranitic and/or aplitic composition and consist of *quartz, jadeite, phengite* ± minor *garnet* and *glaucophane*. Relics of magmatic *K-feldspar* occur in place. Bulk chemistry of a meta-aplitic dyke (SL 664) is presented in table 2.

Within the largest dyke round-shaped megablasts of jadeite (Jd ≃ 95 %) occur. Similar dykes were recently described by Andreoli et al. (1976) from the Valchiu-

sella - Val d'Aosta ridge (Mount Le Colme). Meta-aplitic dykes with jadeite megacrysts also occur in several other sites of Valchiusella and Val d'Aosta; in the external part of the Eclogitic Micaschist Complex, however, the complete alteration of jadeite into albite makes very difficult to distinguish them from ordinary meta-aplitic dykes.

Stop 3: Bric Vert

(Topographic Map 1:25.000: *Traversella*; coord. 0650 4824)

Eclogitic paraschists with eclogites and marbles

All the lithologies typical of the Eclogitic Micaschist Complex can be collected in loose blocks fallen from the towering face of Bric Vert along the path leading from Chiapetti to Pramotton.

Table 2

Chemical composition of some rocks from the Val d'Aosta section of the Sesia-Lanzo Zone

	SL910	SL664	DM	MEC84	MEC60	MEC61
SiO_2	47.48	74.43	52.48	64.83	69.40	62.07
TiO_2	0.18	0.13	0.97	0.76	0.68	0.60
Al_2O_3	22.25	13.44	10.74	15.81	13.65	16.40
Fe_2O_3	0.75	0.16	2.97	1.35	0.93	1.23
FeO	3.59	1.36	3.94	3.54	3.63	4.28
MnO	0.01	0.05	0.11	0.07	0.06	0.09
MgO	7.98	0.93	8.29	2.01	1.76	2.41
CaO	10.86	0.56	7.94	4.65	3.36	3.99
Na_2O	3.99	3.38	1.39	3.06	2.92	1.74
K_2O	0.27	4.67	7.20	1.51	1.78	4.14
P_2O_5	0.06	0.26	1.44	0.20	0.18	0.18
H_2O+	2.86	0.98	1.68	1.77	1.60	2.95
	100.28	100.35	97.72 *	99.56	99.95	100.08

SL 910 : Ivozio metabasite. An.: L. Fiora, Istituto di Petrografia, Torino.
SL 664 : Metamorphic dyke of leucocratic type. Road Quincinetto-S. Maria (Lombardo et al., 1977).
DM : Case Chiapetti minette (De Marco, 1958). * Includes BaO 0.37 and H_2O^- 0.20.
MEC 84 : Lillianes metaquartzdiorite (Callegari et al., 1976, tab. 1).
MEC 60 : Clapey metaquartzdiorite (Callegari et al., 1976, tab. 1).
MEC 61 : Clapey metaquartzdiorite with metasomatic alteration (Callegari et al., 1976, tab. 1).

Both early-Alpine and retrogression minerals (which mostly occur in veins) are very coarse-grained. Omphacites in euhedral crystals (up to 1 cm long) were recently found here in veins.

The most frequent lithologies are:

phengite micaschists with *garnet* ± *Na-pyroxenes* ± *glaucophane,*

glaucophane eclogites and omphacitites with *phengite ± ferroan dolomite ± zoisite*, *calcite - dolomite - ankerite* marbles with *phengite - zoisite - omphacite*, *calcite - ankerite* micaschists with nodules of fibrous white *calcite* (deriving from *aragonite?*).

Dolomite appears to be in equilibrium with the other high-pressure minerals of some eclogites suggesting that the latter probably derive from marls.

Blocks of a post-metamorphic minette dyke crosscutting the eclogitic micaschists in the face above Case Chiapetti can also be sampled here. The composition of the Case Chiapetti minette is shown in Table 2 (DM).

The minette consists of phenocrysts of *augite, phlogopite,* and *apatite* in a groundmass of *orthoclase* with minor *quartz* and small needles of *arfvedsonitic amphibole* (De Marco, 1958).

Age relations and tectonic significance of the post-metamorphic magmatism are discussed in sect. 2.3 and 4.2.4 of Compagnoni et al. (this volume).

Some hundred meters towards the north along the riverside other interesting eclogitized rocks are exposed. The dominant lithology is here an *omphacite-glaucophane-garnet* micaschist containing small eclogitic boudins and marble layers. A body of pre-Alpine amphibolites occurs in the micaschists close to a sand pocket of the Dora river. The amphibolite has been converted into an eclogite which still retains mesoscopic relics of the amphibolite; these relics consist at the microscope of *brown hornblendes* aligned in S-planes and partially decoloured. Skeletal *garnet* and less abundant *glaucophane,* both of early-Alpine age, overgrow the hornblendes.

This stage of initial eclogitization in metabasics is not rare all over the Sesia-Lanzo Zone; the large amphibolite body of the Croix Corma ridge (above Donnaz) is perhaps the best example (Fig. 4).

In the same outcrop where this peculiar amphibolite → eclogite stage occurs other rocks types are found like *quartz - carbonate* micaschists containing small eclogitic boudins. A metamorphic leucocratic dyke cuts unconformably these lithologies.

Boudins of amphibolite also occur in the marbles exposed further north along the suspended path skirting the spur on which the ancient tower of Pramotton is built. Dykes of metagranitic rocks and eclogitic micaschists are interlayered with the marbles and repeatedly folded.

Stop 4: Torrente Bouro (Lillianes)

(Topographic Map 1:25.000: *Lillianes*; coord. 1080 5502)

Eclogitic metaquartzdiorite with cognate inclusions

One of the most conspicuous bodies of eclogitic metagranitoids extending from Mt. Mucrone to the lower Gressoney Valley can be observed in this stop, about midway between Lillianes and Fontainemore. Good outcrops can be found below the road, along the bed of the Lys river.

The eclogitic metagranitoids of Lillianes have quartz-dioritic composition (MEC 84, Table 2) and consist of coarse lens-shaped *quartz, garnet, phengite, Na-pyroxene* (omphacite) and *glaucophane* with *allanite* and *zircon* as accessory minerals.

Cognate inclusions are very common in this outcrop. They are very fine-grained and contrast with the enclosing parent rock, having much more abundant *Na-pyroxene* (omphacite), *garnet* and *glaucophane*; their shape is strongly elongate and they occur in swarms that evidentiate the folded foliation of the host rock.

The greenschist-facies overprinting of Lepontine age is here readily seen and produces *albite, epidote, chlorite,* blue-green *amphibole* and *actinolite*; actually we are now in the zone where jadeite is completely replaced by albite, but glaucophane still survives.

Stop 5: CLAPEY (DONNAZ)

(Topographic Map 1:25.000: *Bard*; coord. 0340 5050)

Metaquartzdiorites with cognate inclusions, and paraschists with metabasites

This outcrop, a flat bosse projecting above the alluvial deposits, is located south of Donnaz, between the highway and the Dora river. The metaquartzdiorite occupies the southern part of the outcrop; the paraschists occur close to the vineyard. Both the metaquartzdiorite and the paraschists are cut by leucocratic dykes.

The Clapey metaquartzdiorite is foliated, but in places (e.g. on freshly cut surfaces close to the highway fence) it preserves the original magmatic texture. *Allanite* and *zircon* are the only igneous minerals preserved; the high-pressure minerals are *glaucophane* and *phengite* + *garnet* replacing magmatic biotite.

The *Na-pyroxene* is completely replaced by overgrowths of *albite* and *epidote*, while glaucophane is partly replaced by pseudomorphs of *actinolite*, green *biotite*, *albite* and *chlorite* (we are here in the zone where the greenschist-facies overprinting becomes more and more prominent).

As usual, the cognate inclusions are very fine-grained and more massive than the host rock. They consist of *glaucophane, garnet, actinolite,* green *biotite,* white *mica, quartz, albite* and *epidote*; *albite* and *quartz* are less abundant than in the host rocks. Leucocratic dykes are *quartz-albite-white mica-epidote schists.*

The mineralogy of the paraschists is close to that of the meta-intrusives; the interbedded metabasites are *omphacitites* with minor *phengite* and *quartz*; they are rare and small lenses.

Bulk chemistry of two samples of metaquartzdiorite (MEC 60, MEC 61) showing different stages of textural evolution is presented in table 2.

A comparison of the two analyses suggests that mobilization must have occurred during Alpine metamorphism and deformation, since the more evoluted MEC 61 displays an abnormal composition (corresponding to the opdalitic type of granitic magmas in the NIGGLI classification) while the less evoluted MEC 60 shows a normal quartzdioritic composition.

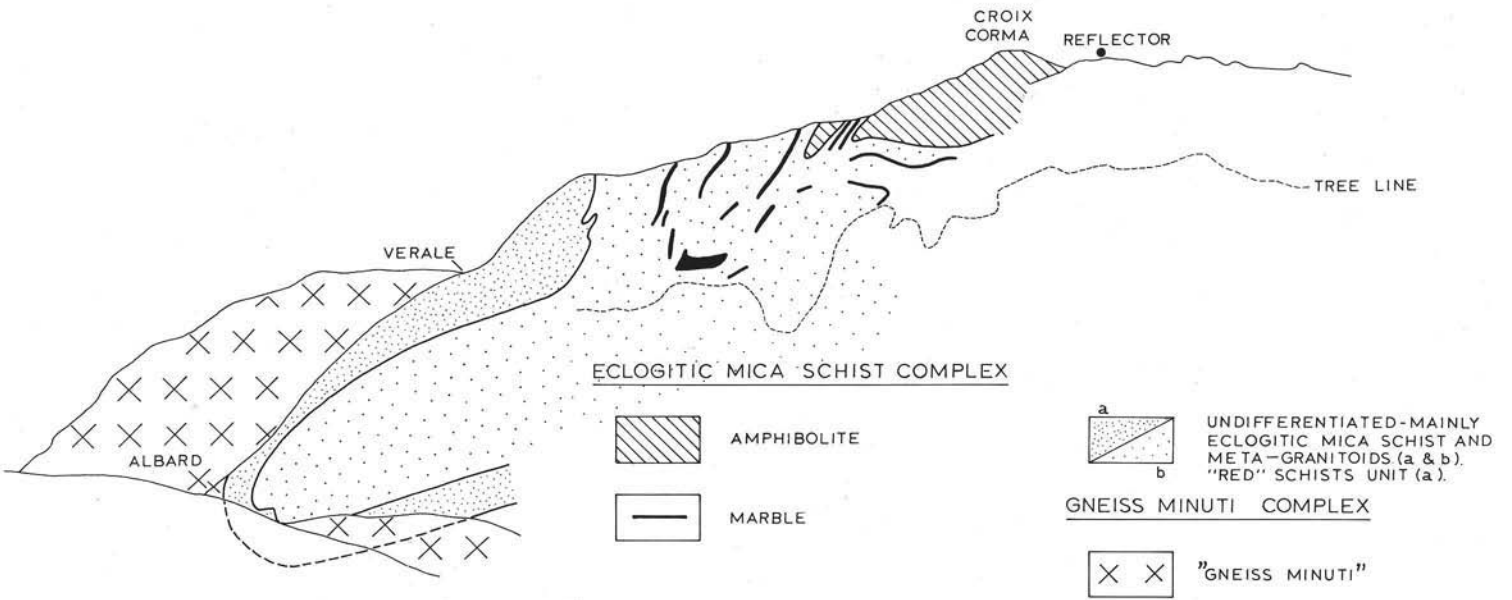

Fig. 4. — *Structural view of Croix Corma ridge.* — Looking northward from Clapey the external part of the Eclogitic Micaschist Complex appears in the Croix Corma ridge on clear days. A sharp contact separates the « Gneiss Minuti » Complex from the Eclogitic Micaschist Complex above the village of Albard di Donnaz. This contact is readily seen in the field as separating reddish brown exposures (Eclogitic Micaschist Complex) from grey exposures (Gneiss Minuti Complex). The Gneiss Minuti Complex consists largely of granitoid gneisses with occasional metabasite boudins and schistose layers. The evidence of high-pressure metamorphism in these rocks has been found in metabasite boudins and as *glaucophane* relics in the granitoid gneisses. The Eclogitic Micaschist Complex includes eclogitic micaschists, metabasites, marbles and metagranitoids. High-pressure assemblages are found in all of these rock types right up to the contact with the Gneiss Minuti Complex. Small metabasite lenses are composed largely of *glaucophane, omphacite* and *garnet* with occasional relics of earlier *hornblende*. The large « amphibolite » bodies shown on the section are metabasites composed largely of *hornblende*. They are only locally converted to eclogite assemblages, the latter occuring mainly along the contact with schists and metapegmatite veins. These amphibolites are visible from above Clapey on clear days. Four generations of folds are recognized in the area. F_1 folds are mainly small with an amplitude of a few tens of centimeters. Larger folds are however found in the marbles and the large amphibolite bodies shown in the section are believed to occupy the closure of very large P_1 folds. The marbles define a zone that wraps around these closures. F_2 occurs as large and small folds generally with a steep axial surface and steep northeasterly plunge. These folds are generally tight to isoclinal and the large synform seen in the section is a large example of this generation. A parasitic fold on the upper limb of the synform (near the top of the ridge) rotates the earlier F_1 fold defined by the amphibolite bodies and the zone of marbles. F_3 folds are common throughout the area on a centimeter to meter scale. They are chevron folds and have axial surfaces which dip shallowly NE and plunge in various directions within the axial surface. They modify the large scale structure but are not recognisable as separate folds in the section. F_4 folds occur commonly throughout the area on a microscale and are visible as a crenulation lineation. Larger folds also occur but are rare and since the amplitude of the largest is less than one meter, they are not visible in the section. They are generally open folds with steeply dipping axial surfaces and they plunge toward the north east.

Stop 6: SECTION ALONG THE ROMAN ROAD FROM DONNAZ TO BARD
(Topographic Map 1:25.000: *Bard*; coord. 0290 5095)
Eclogitic paraschists with greenschist-facies overprinting

The section begins near Donnaz where an arch and a milestone of the ancient Roman road across the Alps are carved in the rock.

We are here in the more external part of the Eclogitic Micaschist Complex. The prevailing lithology is a paraschist containing frequent leucocratic dykes, possibly related to the Clapey metagranitoids.

The greenschist-facies overprinting is here becoming stronger and stronger; *epidote, actinolite* and *albite* are widespread. In the paraschists the only relic of high pressure minerals is *garnet*; *glaucophane* is replaced by *albite-actinolite* ± ± *biotite* ± *chlorite* pseudomorphs. No traces of a transformed jadeitic pyroxene were found (if any was present). On the contrary, *omphacite* (partly replaced by albite + actinolite symplectites) is preserved in the metabasite boudins within the paraschists.

Further on, the steep face of True Chaveran exposes a set of folds (10 m amplitude) whose sense of asymmetry accounts for a large scale structure responsible of the abrupt rise of the regional lithology in the tract covered by this short profile. Actually, from the cemetery of Bard to the village the lithology is nearly vertical.

Near the Bard cemetery small boudins of metabasites (eclogites, white-mica omphacitites and ankerite-bearing glaucophanites) occur in metagranitoids. A boudinaged omphacitite seems to derive from a single layer, possibly a basic dyke.

The profile ends at the ancient village of Bard close to the imposing fortress of the 18th century.

Stop 7: PONT BOZET
(Topographic Map 1:25.000: *Champorcher*; coord. 9736 5115)
« Gneiss minuti » of the external Sesia-Lanzo Zone

This locality of the lower Champorcher Valley was selected as a typical outcrop of the Gneiss Minuti Complex (1).

In this external part of the Sesia-Lanzo Zone the rocks are mainly silicic metaintrusives. Here the early-Alpine metamorphic event is recognizable only for the occurrence of *garnet, glaucophane* and *phengite*. These minerals are overprinted by greenschist-facies assemblages that impose to the rocks the typical « gneiss minuti » appearance. However, the absence of the transformation products of jadeite and the direct replacement of the pre-Alpine plagioclases solely by albite demonstrate that in this sector the early-Alpine event never attained pressures as high as in the Eclogitic Micaschist Complex. At Pont Bozet the dominant lithology is a well foliated augengneiss with frequent leucocratic bands corresponding to transposed

(1) In the Val d'Aosta section the Gneiss Minuti Complex is exposed from Hône to Verres, where the boundary with the Piemonte Zone occurs (Fig. 3).

dykes of pre-Alpine age. Several sets of felsic dykes are crosscutting each other. An older generation of basic dykes is also present.

In these augengneisses magmatic *K-feldspar, plagioclase* and *biotite* are still recognizable under the microscope. K-feldspar is partly replaced by *chess-board albite*, and biotite by *white mica* + *sphene* with very fine-grained *garnet* coronas. Cognate inclusions and felsic dykes show similar transformations.

In all of these rock types *albite, phengite, epidote* and *actinolite* are the most abundant constituents.

Basic dykes are transformed into *two mica-epidote-actinolite* rocks with minor *albite* and *albite-amphibole* pseudomorphs replacing *glaucophane*.

C. Eclogites and related rocks of the ophiolitic Piemonte Zone in the Breuil area, Valtournanche; panorama of the Dent Blanche Nappe

(Topogr. Maps 1 : 25.000: M. CERVINO and VALTOURNANCHE; 1 : 100.000 sheet nr. 29, M. ROSA)

In the upper Valtournanche two main tectonic systems are exposed (Fig. 2 *b* and 5): *a*) the Austroalpine Dent Blanche Nappe and *b*) the underlying ophiolitic Piemonte Zone (or nappe), also known as «Complesso dei Calcescisti con Pietre Verdi». In the Breuil area, the Dent Blanche Nappe forms the ridge Cervino-Dent d'Herens-Petites and Grandes Murailles (Fig. 2 *b*) and is composed, as the Sesia-Lanzo Zone, of two tectonic units, the *Arolla Series* and the *Valpelline Series*, respectively corresponding to the Gneiss Minuti Complex and to the II Diorito-kinzigitic Zone of the Sesia-Lanzo Zone (COMPAGNONI et al., this volume, section 3.5).

Also the Piemonte Nappe (BEARTH, 1967, 1973, 1974; DAL PIAZ, 1965, 1974 a and b) is subdivided into two tectonic units (the *Combin Zone* and the *Zermatt-Saas Zone*), distinguished on the basis of different lithostratigraphic and metamorphic features. These ophiolitic units originated within different parts of the Piemonte basin (COMPAGNONI et al., this volume, section 1).

The *Combin Zone* comprises on ophiolite-bearing complex and a basal horizon of Triassic marbles and Lower Liassic calcschists.

The ophiolite-bearing complex of the Combin Zone consists of regularly repeated *calcschists* and *metabasites* with greenschist-facies assemblages (*prasiniti* of the Italian literature). The metabasites correspond to submarine basaltic flows and hyaloclastites (± tuffs and/or tuffites). Rare *metagabbro* and *serpentinite* wedges and/or olistholites also occur. *Metacherts*, sometimes manganiferous, and *chlorite* ± *albite-bearing schists* (hyaloclastites with palagonitic alteration?) frequently are associated to prasinites. The latter comprise some concentrations of layered Cu-Fe sulphides.

The metamorphic history of the Combin Zone appears to be characterized by a single, greenschist-facies event of Lepontine age. No traces of eclogitic assemblages

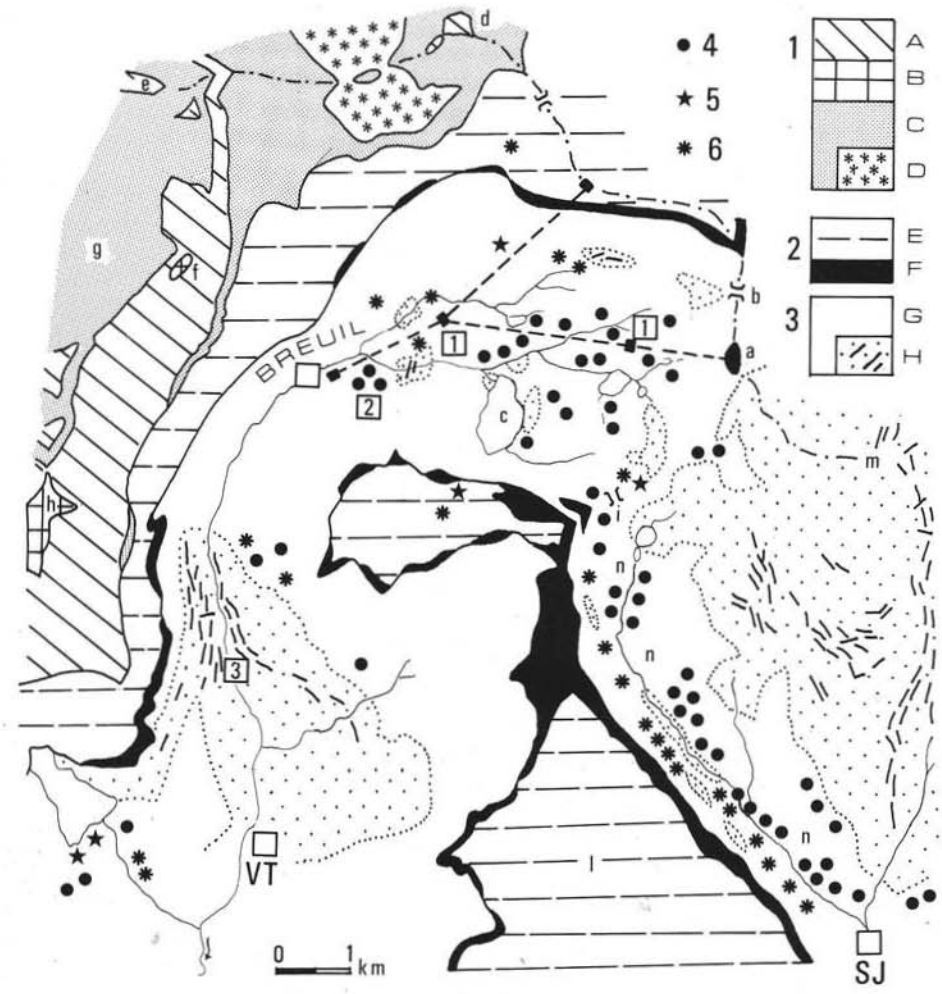

Fig. 5. — *Geologic sketch map of the Breuil area (upper Valtournanche), between the internal margin of the Dent Blanche Nappe and the Vallone delle Cime Bianche (Ayas Valley).* 1) *Dent Blanche Nappe s.l.*: Valpelline Series (A); Mt. Blanc du Creton-Bivacco Balestrieri Unit (B); Arolla Series (C); Gabbro of the Cervino (D). 2) *Combin Zone*, the upper tectonic element of the Piemonte Nappe: metaophiolitic complex and pre-ophiolitic sequence (E); Triassic marbles and quartzites (F). 3) *Zermatt-Saas Zone*, the lower tectonic element of the Piemonte Nappe: metagabbros, metavolcanics and sedimentary cover (G); major ultramafic masses with rodingitic layers and dykes (H). 4) Well preserved eclogites. 5) Manganiferous metacherts. 6) Gabbros.
VT: Valtournanche; SJ: St. Jacques; *a*) Plateau Rosa; *b*) Colle del Teodulo; *c*) Lago Goillet; *d*) Cervino; *e*) Dent d'Herens; *f*) Bivacco Balestrieri; *g*) P. Gastaldi or Cors; *h*) Mt. Blanc du Creton; *i*) Colle superiore delle Cime Bianche; *l*) Gran Tournalin; *m*) Gobba di Rollin; *n*) Vallone delle Cime Bianche. Numbers in squares indicate the visited sites.

have been found, in spite of the strong chemical similarity of these prasinites with the eclogitic metavolcanics of the Zermatt-Saas Zone.

The ophiolitic sequence of the underlying *Zermatt-Saas Zone* begins with a large

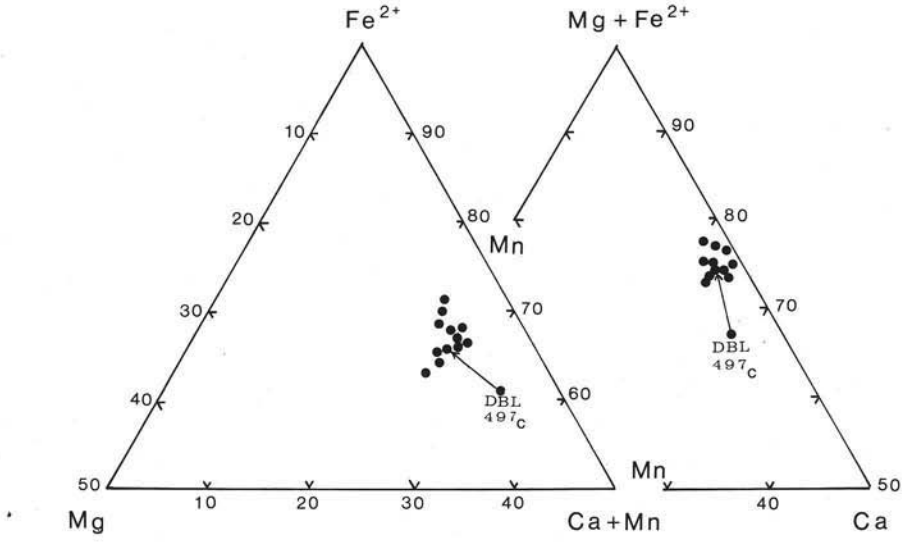

Fig. 6. — *Ternary atomic proportions for garnets from the Breuil eclogites and related rocks of the Zermatt-Saas. Zone.* C) Garnet core; R) Garnet rim. Only the iron-rich portions of the diagrams are shown. (After Dal Piaz and Ernst, in press).

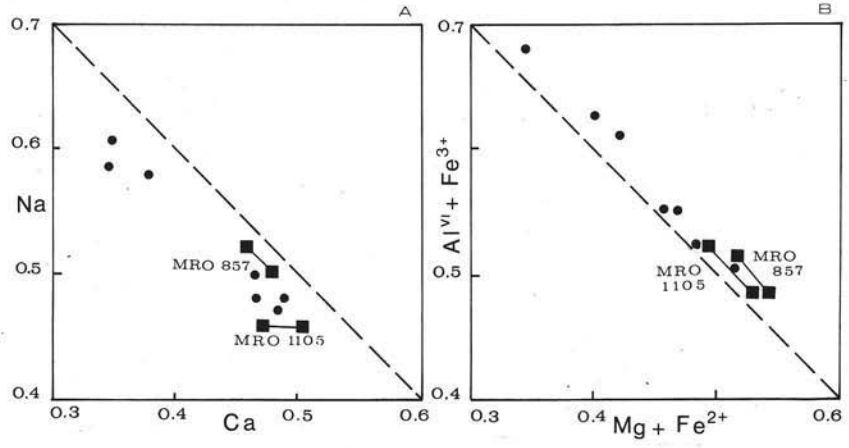

Fig. 7. — *Proportions of six-fold coordinated cations per formula unit in Breuil Na-clinopyroxenes from eclogites and related rocks.* A) Occupancy of the larger M_2 site; B) occupancy of the smaller M_1 structural position. Dashed lines indicate the locus of 100 percent filling of the site by the cations plotted; slight but systematic deviations from the lines reflect small proportions of $Mg + Fe^{2+}$ residing in M_2. Solid lines connect analyses of different grains in samples MRO 857 and MRO 1105. (After Dal Piaz and Ernst, in press).

slab of *serpentinites,* followed by discontinuous *metagabbros* and submarine *metavolcanics* with more or less preserved eclogitic assemblages. The syn- to postvolcanic sedimentary cover comprises mostly *garnet-chloritoid-ankerite-bearing micaschists*

(upper Jurassic and lower Cretaceous?), *marbles, calcschists* and *metacherts* in places manganiferous. The Zermatt-Saas Zone suffered two different tectonic and metamorphic cycles. The first is characterized by eclogitic assemblages, with *omphacitic pyroxenes, garnet, rutile,* unoriented *glaucophane, zoisite, white mica, chloritoid* I (?) and probably *lawsonite* (now replaced by pseudomorphic aggregates of epidote + white mica). These assemblages predate the thrusting phase and are related to the early-Alpine subduction metamorphism of upper Cretaceous age (DAL PIAZ et al., 1972; HUNZIKER, 1974). The second metamorphic event occurs, on the contrary, after the nappe piling, during polyphasic ductile deformations. It developes new generations of glaucophane (gl. II ± III) and chloritoid, followed by greenschist-facies associations of Eocene-lower Oligocene age (Lepontine event).

The eclogitic assemblages of the Breuil area are described by G. V. DAL PIAZ and W. G. ERNST (in press).

Analyzed *garnets* (Fig. 6) cluster tightly around the average composition $Alm_{66.5}Py_{8.1}Gross_{22.5}Spess_{2.9}$. The chemical zonation measured in one sample is from calcium + manganese-rich core to an iron + magnesium-rich rim. There is also an indication from the one analyzed core-rim pair that the Mg/Fe^{2+} ratio increased during the course of cristallization, although the absolute changes in cation proportions of Ca, Fe^{2+}, Mg and Mn are rather small.

Ignoring the small amounts of En + Fs solid solution (Fig. 7), the average composition of the *omphacites* from eclogitic metavolcanites is $Jd_{41}Ac_{12}Di_{34}Hd_{12}$.

The *Na-amphiboles* approach the $Na_2Mg_3Al_2Si_8O_{22}(OH)_2$ end member in composition. Chemical zoning evidently is not pronounced, but tends to enrich the grain margins in $Na_2Fe^{2+}_3Al_2Si_8O_{22}(OH)_2$ relative to the cores (Fig. 8).

Analyzed *Ca-amphiboles* appear to be intermediate members of the barroisite-actinolite series. Where compositional variation occurs, later members of the series are much more actinolitic than the earlier hornblendes.

Of twelve *white micas,* nine are paragonites, the remaining three being phengites. Coexisting paragonite and phengite also occur.

The *plagioclases* analyzed from metavolcanites and metagabbros are extremely albitic, possessing an average, rather uniform composition of $Or_{0.2}Ab_{98.7}An_{1.1}$.

Stop 1: PLAN MAISON - PLAN TENDRE

Eclogites and related roks of the Zermatt-Saas Zone and panorama of the Dent Blanche Nappe

In the Plan Tendre - Plan Maison area (loc. 1, Fig. 5) the volcanic and sedimentary cover of the big ultramafic complex of Breithorn-Gobba di Rollin-Perères is exposed.

Small eclogitic layers and lenses are preserved within more retrograded metabasic of basaltic composition. The early-Alpine metamorphic assemblages (garnet, omphacite, rutile ± zoisite ± unoriented glaucophane I ± white mica) are over-

printed by new mineral assemblages characterized by glaucophane II and III (sometimes lineated), blue-green barroisitic hornblende, actinolitic amphibole, epidotes, sphene ± albite, chlorite and brown-green biotite. In the more transformed eclogites, the pyroxenes are completely replaced by a diablastic aggregate of albite and actinolite, giving rise to garnet-bearing albite-amphibolites.

The associated Mesozoic micaschists comprise quartz, white mica, garnet and ankerite ± chloritoid ± chlorite ± actinolite ± epidotes. The chloritoid is partly replaced by white mica + chlorite. Relics of glaucophane and rare Na-pyroxene also occur. Lenses and small pebble-like inclusions of fine-grained and more or less

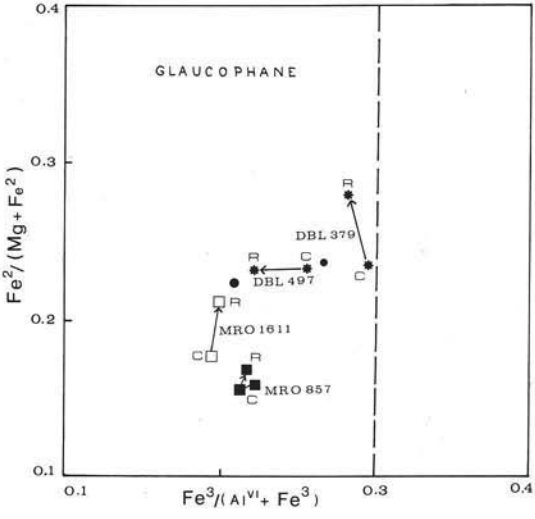

Fig. 8. — *Atomir proportions of six-fold coordinated cations in Breuil Na-amphiboles from eclogites and related rocks* (from Dal Piaz and Ernst, in press). C) Glaucophane cores; R) glaucophane rims. For sample MRO 857, cores were analyzed in two different parts of the microprobe section. The dashed line denotes the boundary between glaucophane *s.s.* and crossite (Miyashiro, 1957).

retrograded eclogites are frequently found in the micaschists (Rifelberg-Garten Formation; Bearth, 1967, 1975). Rare metacherts are associated with the metavolcanic sequence. At the contact between the serpentinites and both metavolcanic and paraschists a thin reaction zone of rodingitic type often developes giving rise to Ca-rich rocks with epidote and diopside.

Stop 2: Eclogites at Bardoney (Breuil)

This outcrop (loc. 2, Fig. 5) comprises typically massive eclogites with omphacite, garnet, rutile ± unoriented glaucophane I ± withe mica ± white mica-epidote aggregates probably after lawsonite.

Stop 3: RODINGITES AT PERÈRES

Along the Valtournanche road, close to the Perères tunnel (loc. 3, Fig. 5), the antigoritic serpentinites of the Zermatt-Saas Zone contain numerous dykes, often boudinaged, of coarse-grained gabbros and fine-grained metabasics strongly altered to rodingites (DAL PIAZ, 1967, 1969).

The rodingites consist of Ca-rich garnet, diopside, epidote, idocrase, chlorite ± ± prehnite. Relics of magmatic clinopyroxene often occur. The serpentinite-rodingite boundary is marked by a narrow rim, either regular or lobated, of chlorite schists (± diopside and garnet). A coarse crenulation cleavage postdates the rodingitic assemblage.

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