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ROBERTO COMPAGNONI (*), BRUNO LOMBARDO (*)

THE ALPINE AGE OF THE GRAN PARADISO ECLOGITES (**)

RIASSUNTO. — Nel cristallino pretriassico del Massiccio del Gran Paradiso si rinvengono numerose masse di eclogiti glaucofaniche, sulla cui età esistono in letteratura pareri controversi. Vengono descritti alcuni affioramenti dell'alta Valle di Piantonetto (settore centrale del Massiccio del Gran Paradiso) nei quali le rocce eclogitiche sono in contatto primario con graniti ercinici, che hanno esercitato una sensibile azione termometamorfica sugli scisti incassanti, con sviluppo di cornubianiti. Poichè la paragenesi eclogitica è instabile nelle condizioni di P e T del termometamorfismo, ne consegue che la formazione delle eclogiti in questione deve essere posteriore all'intrusione dei graniti ercinici e pertanto attribuibile al ciclo metamorfico alpino.

D'altra parte, poichè la paragenesi eclogitica è chiaramente anteriore a quelle in facies scisti verdi che rappresentano nella regione l'effetto della principale fase metamorfica alpina, ne deriva che le eclogiti del Gran Paradiso devono essere riferite ad un evento alpino precoce, con caratteri di alta pressione e bassa temperatura, del quale si trovano ampie testimonianze anche negli scisti incassanti e negli ortogneiss granitici.

ABSTRACT. — The age of the glaucophanic eclogites occuring in the pre-Triassic schists of the Gran Paradiso Massif (Western Alps) is discussed. Eclogite bodies, showing primary contacts with Hercynian granites whose thermal action has converted the surrounding schists into hornfelses, were found in the upper Piantonetto Valley (central part of the Gran Paradiso Massif). Since eclogitic assemblages are unstable in the P-T range of contact metamorphism, the Piantonetto eclogites must have formed after the intrusion of the Hercynian granites and are therefore to be ascribed to the Alpine metamorphism. Furthermore, since the eclogitic assemblage (omphacite-garnet-glaucophane) is clearly older than the greenschist-facies assemblages produced by the main phase of the Alpine metamorphism, it may be concluded that the Gran Paradiso eclogites are most likely related to an early Alpine high pressure-low temperature event, widespread relics of which are found also in the pre-granitic schists and associated orthogneisses.

(*) Istituto di Petrografia dell'Università di Torino e Centro di Studio sui Problemi dell'Orogeno delle Alpi Occidentali del C.N.R. - Via San Massimo, 24 - 10123 Torino.

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Introduction.

Different opinions are found in the geological literature as to the age of the eclogites occurring in the Pennidic and Austridic domains of the Western Alps. An Alpine (Tertiary) age is currently assigned to the glaucophanic eclogites associated with the Mesozoic « Calcescisti » Complex (see e.g. BEARTH, 1959, 1965, 1967). A pre-Alpine age was hitherto ascribed to the widespread masses of glaucophanic eclogites of the Sesia-Lanzo Zone (NOVARESE, 1929; BIANCHI & DAL PIAZ, 1963; VITERBO-BASSANI & BLACKBURN, 1968; CARRARO et al., 1970; CARRARO & CHARRIER, 1972). The pre-Alpine age was inferred from the assumed late-Paleozoic age of the Canavese volcanic and Elvo volcanodetrital series, both including boulders of Sesia-Lanzo eclogites. However, according to a recent paleobotanical and geochronological work (SCHEURING et al., 1974) these volcanics seem to be of Tertiary age.

Presently the interpretation given by most geologists of the occurrence of the eclogitic rocks in the Sesia-Lanzo Zone and in the « Calcescisti » Complex is concordant: the eclogites would have formed in a high pressure-low temperature environment at an early stage of the Alpine metamorphism (DAL PIAZ, 1971; DAL PIAZ et al., 1971, 1972; COMPAGNONI & MAFFEO, 1973). This interpretation is in good agreement with the polyphase character of the Alpine metamorphism, which displays an early high pressure—low temperature phase, followed by a higher-temperature phase (BEARTH, 1967; NIGGLI, 1970).

Other occurrences of eclogitic rocks in the Western Alps are found in the pre-Triassic schists of the Monte Rosa-Gran Paradiso nappe (DAL PIAZ & GATTO, 1963; COMPAGNONI & PRATO, 1970). The age relationships of these rocks in the Monte Rosa Massif were discussed by DAL PIAZ (1964), who then could not find any element to ascertain their age; in a subsequent paper (DAL PIAZ, 1965) however, the same author is inclined to accept an Alpine age, on the basis of the mineralogical and textural similarity between the Mesozoic eclogites and those occurring in the pre-Triassic schists. More recently DAL PIAZ et al. (1972) stated that these rocks must have an Alpine age since they are interlayered in a characteristic pre-Triassic complex, i.e. the Furgg Zone l.s., which surely originated later than the Hercynotype metamorphic cycle. A similar interpretation has been

proposed by WETZEL (1972) for the Furgg-Zone eclogites occurring in the Swiss side of the Monte Rosa Massif.

In a recent paper on the eclogites of the Western Alps, MOTTANA (1972) suggested that the eclogites included in the schists of the Monte Rosa-Gran Paradiso nappe could be related to a pre-Alpine metamorphism, probably of Caledonian age. According to his interpretation, these rocks would be equivalent to the eclogites which are locally found in the pre-Alpine basement of the Helvetic domain (Aiguilles Rouges- and Argentera Massif); during the Alpine metamorphism (which only slightly affected the Helvetic domain) they would have been subjected to glaucophane-schist-facies conditions and partly retrograded.

So far there has been no field evidence as to the age of the eclogites occurring in the Gran Paradiso Massif. Furthermore, the interpretation put forward by DAL PIAZ et al. (1972) and WETZEL (1972) for the Monte Rosa Massif cannot be applied to the Gran Paradiso eclogites since they are included in a gneiss complex older than the Hercynian granites (see later on). However, some recent findings in the Piantonetto Valley (central part of the Gran Paradiso Massif), where eclogites are cut by Hercynian granites, enabled us to establish the Alpine age of these eclogites. They will be described in this paper.

Geological outline of the Gran Paradiso Massif.

The main features of the geology of the Gran Paradiso Massif are rather similar to those described for the Monte Rosa Massif by BEARTH (1952). The pre-Triassic basement consisted, prior to the Alpine metamorphism, of a complex of meso- to catazonal schists (1)., cut by Hercynian (2) porphyritic granites (BIANCHI & DAL PIAZ, 1959; CALLEGARI et al., 1969); the schists were locally affected by the thermal

(1) Relics of sillimanite-bearing schists were found at some localities (e.g. Pian della Valletta, cf. COMPAGNONI & PRATO, 1969). New occurrences were recently found in the northern part of the Massif (Valeille and Bardoney Valley); they will be described in a forthcoming paper by COMPAGNONI et al. (1974).

(2) Only the Scalari granite (upper Orco Valley) has been so far dated radiometrically; the determined values are 301, 340, 350 m. y. (cf. PANGAUD et al., 1957; BUCHS et al., 1962; CHESSEX et al., 1964).

activity of the Hercynian granites, as shown by the hornfelses developed near the contacts with the granitic rocks (CALLEGARI et al., 1969; COMPAGNONI & PRATO, 1969).

We would like to stress, however, some differences between the Gran Paradiso- and the Monte Rosa basement: 1) in the former, amphibolites are much more widespread than in the latter; 2) in the Gran Paradiso Massif we do not find the lithological association marbles + amphibolites typical of the Furgg Zone of the Monte Rosa Massif, marbles being almost absent in the Gran Paradiso Massif.

During the Alpine orogeny the pre-Triassic basement underwent strong mineralogical and structural changes: the Hercynian granites were transformed into orthogneisses (« *gneiss occhiadini* » *auct.*) and the pre-granitic rocks into epizonal schists (« *gneiss minuti* » *auct.*). In the Gran Paradiso Massif the Alpine metamorphism shows a polyphase character (BERTRAND, 1968), as shown by the occurrence of Alpine minerals like kyanite, chloritoid and glaucophane (3), which are clearly older than greenschists-facies mineral assemblages. A high-pressure phase (*eo-Alpine phase*) which developed, among other minerals, phengite, chloritoid, kyanite, glaucophane, omphacite and garnet (Fig. 1) (4), was followed, and partly obscured, by a later episode characterized by assemblages in which albite, biotite, chlorite, actinolite and epidotes are the major constituents (*Alpine phase s.s.*). A similar situation was found by DAL PIAZ (1971) in the Monte Rosa Massif.

The basic rocks interlayered in the pre-granitic schists of the Gran Paradiso Massif are mainly *albite-epidote amphibolites; eclogites*, first described by COMPAGNONI & PRATO (1970), occur as scattered relics, preserved in, and grading into, albite amphibolites. Only at few localities (Roc Valley, Valeille, Ribordone Valley) the eclogites are more widespread that the albite amphibolites. There is strong mi-

(3) The Alpine age of these minerals is inferred from their development either at the expense of the Hercynian granites (e.g. chloritoid, glaucophane, kyanite) or at the expense of their hornfelses (e.g. kyanite pseudomorphs after sillimanite, COMPAGNONI & PRATO, 1969).

(4) Further evidence of high-pressure conditions in the eo-Alpine phase is provided by the recent finding of jadeite in the sialic gneisses (« gneiss de Bonneval », MICHEL, 1953) of the French side of the Gran Paradiso Massif (SALIOT, 1973).

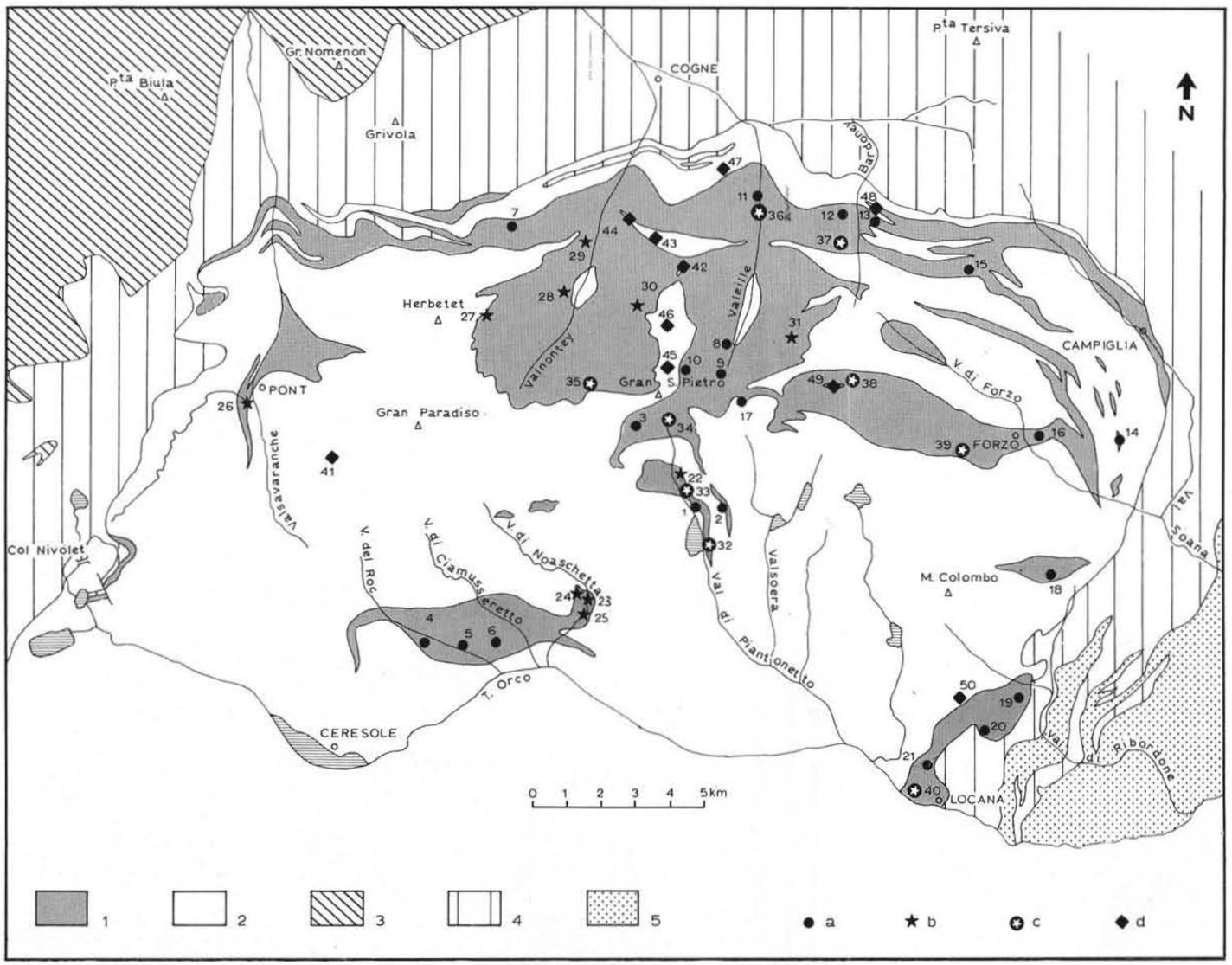

Fig. 1. — Distribution of the eo-Alpine high pressure - low temperature assemblages or minerals in the northern part of the Gran Paradiso Massif.

Structural units

1 «*Gneiss Minuti*» *Complex* } Gran Paradiso
2 «*Gneiss Occhiadini*» *Complex* } Massif.

3 Valsavaranche Massif (Great St. Bernard Nappe);

4 « Calcescisti » Complex and Mesozoic cover of the Gran Paradiso- and Valsavaranche Massifs;

5 Sesia-Lanzo Zone.

High presure - low temperature assemblages

a) *omphacite* + *garnet* + *glaucophane* assemblages of the eclogites deriving from the pregranitic metabasites.

b) *phengite* + *chloritoid* ± *kyanite* ± *garnet* assemblages of the pregranitic schists.

c) *kyanite pseudomorphs after sillimanite.* The kyanite pseudomorphs replace either the prismatic sillimanite developed in the contact aureole of the Hercynian granites (outcrops n. 32, 33, 35, 39, 40) or the fibrolitic sillimanite of the pregranitic regional metamorphism (outcrops n. 34, 36, 37, 38).

d) *phengite* + *chloritoid* + *Mg-chlorite* ± ± *kyanite* ± *glaucophane* assemblages of the s.c. « micascisti argentei » (silvery micaschists) developed at the expense of the Hercynian granites along particular shear planes.

NOTE - The map is based on personal observations, on the data of CALLEGARI et al., (1969), COMPAGNONI & PRATO (1969), PRATO (1970) and on unpubblished data of R. PRATO. For the exact location of the outcrops see Appendix.

neralogical evidence, however, that most albite amphibolites passed through an eclogitic stage as shown, for example, by the widespread occurrence in these rocks of the typical *albite + actinolite symplectite* developing from the eclogite pyroxenes (see page 374).

The eclogites of the upper Piantonetto Valley.

Primary eclogite-granite contacts were found in two outcrops (Bocchetta di Valsoera and Pian Telessio Lake) both located in the upper Piantonetto Valley (Fig. 1, outcrops n. 1 and 2). In this area relics of primary intrusive contacts are well preserved (Bianchi & Dal Piaz, 1959; Callegari et al., 1969): Hercynian granites, probably emplaced as multiple intrusions, inject a complex of metamorphic rocks exhibiting a clear pre-granitic schistosity; fragments of country rocks are frequently found within the igneous body near the contact zone. Relics of hornfelsic rocks containing *K-feldspar, oligoclase, red biotite, sillimanite, corundum* and *green spinel,* occur along the eastern side of the Pian Telessio Lake (Callegari et al., 1969; Compagnoni & Prato, 1969).

The granites and the country rocks were subsequently affected by the Alpine metamorphism. The development of the Alpine schistosity is especially evident in the granitic rocks, which were converted into *albite-phengite-biotite-clinozoisite-garnet augen gneisses,* with relics of the primary *K-feldspar* and *biotite.*

Bocchetta di Valsoera. - The outcrop lies on the western slope of the Bocchetta di Valsoera (at an elevation of about 2400 m), near the lower limit of the thick band of pre-granitic schists which follows the eastern side of the upper Piantonetto Valley (5). Relics of a discordant intrusive contact between a schist complex and a porphyritic granite are here recognizable; near the contact zone relics are found of *biotite-oligoclase-bearing rocks* with hornfelsic structure. Both the granite and the country rocks have been deeply rearranged by the Alpine metamorphism which produced *albite-phengite-biotite-clinozoisite schists* (at the expense of the pre-granitic schists) and converted the granitic rocks into augen gneisses.

(5) For the location of the outcrop see the Appendix, n. 2.

About ten metres from the primary granite-schist contact the schists enclose a boudinaged layer (a few dm thick) of metabasites. The dark green core of the boudins is made up of a fine-grained rock which under the microscope appears as *glaucophanic eclogite* (Fig. 2); it consists of *garnet* and *omphacite* in nearly equal amounts (totalling about 80 vol. %), *glaucophane* and accessory *rutile*, *white mica* and

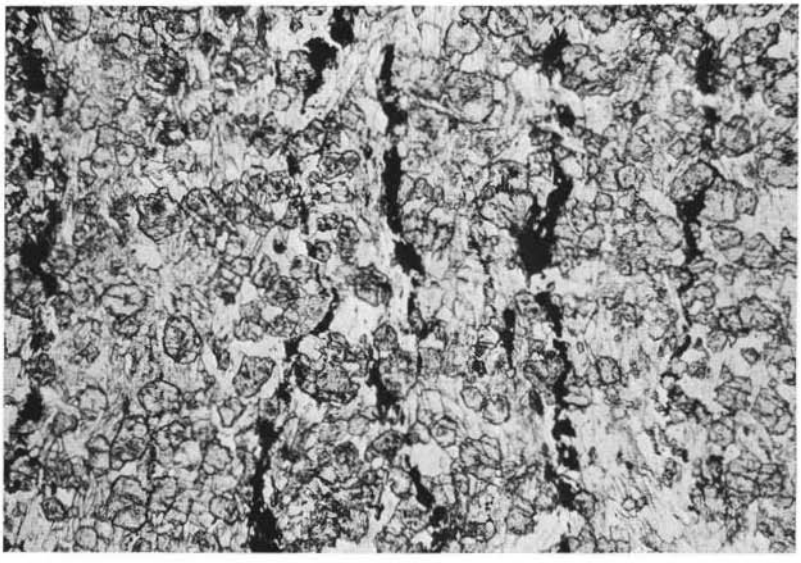

Fig. 2. — *Glaucophanic eclogite* of the Bocchetta di Valsoera.

Garnet (high relief), omphacite (light grey), glaucophane (light) and rutile are the main constituents of this eclogite, occurring very near the contact with the Hercynian granites. Rutile stringers mark a poorly-developed foliation, with alternating omphacite- and glaucophane - rich layers. × 80 — Plane polarized light.

quartz. Optical and physical properties of the main constituents are as follows:

— *garnet*: $n_D = 1.792 \pm 0.002$; $a_O = 11.665$ Å; Mn in traces only, which should correspond to a garnet of composition $Alm_{60}Gro_{38}Py_2$ (cf. WINCHELL, 1958).

— *pyroxene*: $n_\beta = 1.680 \pm 0.002$; $2V_\gamma = 63\text{-}65°$; $c\hat{}\gamma = 46°$; $d_{221} = 2.970$ Å which correspond to an omphacite of composition $Aug_{59}Jd_{29}Ac_{12}$ (cf. ESSENE & FYFE, 1967).

— *glaucophane*: $2V_a = 70\text{-}72^\circ$; $c\hat{}\gamma = 0\text{-}3^\circ$; it is the very pale-coloured variety known as *gastaldite*.

According to the molecular composition of the omphacite and the garnet this rock can be classified as an *ophiolitic* eclogite (SMULIKOWSKI, 1964) or a *C-group* eclogite (COLEMAN et al., 1965).

Fig. 3. — *Pian Telessio Lake, upper Piantonetto Valley.*

Sharp discordant contact between a porphyritic Hercynian granite (light) and an amphibolite mass containing relics of eclogitic assemblages. The pre-Alpine foliation (approximately horizontal in the picture) of the metabasites is cut by the granite, whose Alpine schistosity is strongly slanting to the amphibolite foliation

The outer portion of the boudins is a coarser-grained amphibolite which in hand specimen appears lighter-coloured than the eclogitic core. This is due to the progressive transformation of the eclogite into an albite-epidote amphibolite; under the microscope this transformation is marked by the progressive disappearance of the pyroxene (and of the glaucophane) which are replaced by the typical symplectite of albite + actinolite occurring in most eclogites of the Gran Paradiso Massif (COMPAGNONI & PRATO, 1970). The rocks originating from this

typical transformation of the omphacitic pyroxene shall be called here « *Ab-Act-symplectite amphibolites* »; they represent the first stage of the *eclogite* → *albite-amphibolite* transformation ([6]). In the more advanced stages of this transformation the size of the neoblastic minerals increases and the garnet totally disappears, so that the primary eclogite is finally converted into an albite-epidote amphibolite with accessory *sphene*.

Pian Telessio Lake. - The outcrop is located on the eastern side of the artificial Pian Telessio Lake, where the trail to the Rifugio Pontese starts ([7]).

A large body of eclogite exhibiting a clear pre-granitic foliation is cut by a porphyritic granite, now partially converted into an augen gneiss (Fig. 3). Evidence of the intrusive nature of the contact is provided by eclogite inclusions in the neighbouring augen gneisses.

Under the microscope the Pian Telessio eclogite is very similar to the « Ab-Act-symplectite amphibolite » of the Bocchetta di Valsoera, being largely composed of the typical *albite* + *actinolite* intergrowths which replace omphacite. A few relics of *omphacite* and *glaucophane* are still preserved, the former « armoured » by large *zoisite* poikiloblasts, the latter in the core of zoned *green amphiboles* growing at the expense either of the diablastic intergrowths or of the garnet. Typical accessory minerals include *clinozoisite, rutile, apatite, opaque ores* and, in very small amounts, *quartz, white mica,* and *yellow-brownish biotite*.

A peculiar feature of the Pian Telessio eclogites is the seemingly large size (up to 0.5 cm) of the *garnets,* which under the microscope appear as glomeroblastic aggregates of small idioblastic garnets not larger than 0.5 mm.

The age of the eclogitic assemblage.

The mineral assemblage of the glaucophanic eclogites of the Piantonetto Valley developed on metabasites interlayered in a pre-granitic complex of meso- to catazonal schists.

The occurrence of eclogites in primary contact with granitic rocks gives strong evidence that the eclogitic assemblage must be younger

([6]) Just from the Piantonetto Valley, ZUCCHETTI (1956) reported a garnet amphibolite which from the microscopical description seems to correspond to this type of amphibolites.

([7]) For the location of the outcrop see the Appendix, n. 1.

than the emplacement of the granites. Indeed recent investigations on the contact aureole of the Tertiary Biella and Traversella plutons showed that the assemblages of the *glaucophanic eclogites* are highly unstable under the P — T range of thermal metamorphism; in particular omphacite and glaucophane are the first minerals to break down when temperature increases, the eclogitic assemblage being replaced by plagioclase, hornblende, diopside and biotite (CALLEGARI, pers. comm.). Consequently, since the Piantonetto eclogites are found near a primary intrusive contact it follows that the eclogitic parageneses must be younger than the granite intrusion; otherwise they would have been converted to contact assemblages (8).

On the other hand these eclogites (in common with most eclogites of the Gran Paradiso Massif) are partly replaced by assemblages that are typical of the Alpine greenschist-facies phase; they, therefore must have formed between the emplacement of the Hercynian granites and the development of this Alpine phase. It may be concluded that the Gran Paradiso eclogites are related to a high-pressure metamorphism of Alpine age which preceded the greenschist-facies metamorphism.

This event is also recognizable in the other rock types of the Gran Paradiso Massif, the most significant high-pressure assemblages or minerals being (Fig. 1):

— *phengite* + *chloritoid* + *Mg-chlorite* ± *kyanite* ± *glaucophane*, in granitic rocks;
— *phengite* + *chloritoid* ± *kyanite* ± *garnet*, in pre-granitic schists;
— *kyanite pseudomorphs* after sillimanite, in hornfelses and pre-granitic schists.

The eo-Alpine age of these assemblages is unquestionable: firstly because typical high-pressure minerals (such as kyanite and glaucophane) were developed at the expense of Hercynian granites (or contact minerals: e.g. Kyanite pseudomorphs after sillimanite); secondly because the high-pressure mineral assemblages are older than those of the greenschist facies which represent the main mineral assemblages of the Alpine metamorphism.

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(8) Even making allowance for a deeper intrusion level of the Hercynian granites of the Gran Paradiso Massif, their sharp discordant contact relationships and the development of hornfelses in the surrounding schists suggest the reliability of the comparison with the thermal effects observed around the Biella and Traversella plutons.

A chronological interpretation like that recently suggested by MOTTANA (1972) seems to us unacceptable. In fact, if the Gran Paradiso eclogites were Caledonian in age, then these rocks should have escaped the Hercynian regional metamorphism, the thermal metamorphism induced by the granite intrusions and (finally) the Alpine polyphase metamorphism. Moreover, the glaucophanic eclogites of the Gran Paradiso Massif have mineralogical and textural characters strongly differing from those of the older (Caledonian?) eclogites occurring in the pre-Alpine basement of the Helvetic domain, e.g. in the Aiguilles Rouges Massif (BRIÈRE, 1920; BELLIÈRE, 1958) and in the Argentera Massif (FRANCHI, 1894; FAURE-MURET, 1955; MALARODA, 1970; MOTTANA, 1972; also personal observations): the former belonging to the ophiolitic eclogites of SMULIKOWSKI (1964) or C-group eclogites of COLEMAN et al. (1965), the latter to the gneiss-migmatite-complex eclogites of SMULIKOWSKI (1964) or B-group eclogites of COLEMAN et al. (1965).

In conclusion, field, mineralogical and petrographic evidence shows that the eclogites occurring in the Gran Paradiso basement are eo-Alpine in age ;they are therefore coeval with the ophiolitic eclogites associated with the Mesozoic « Calcescisti » Complex and with the *glaucophanic eclogites* occurring in the Sesia-Lanzo Zone.

Acknowledgements.

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Appendix.

LOCATION OF THE OCCURRENCES OF THE HIGH PRESSURE-LOW TEMPERATURE ASSEMBLAGES LISTED IN Fig. 1 (*).

a) *Omphacite + garnet + glaucophane (glaucophanic eclogites).*

1) Pian Telessio lake, upper Piantonetto Valley: 728390 (Fornolosa).
2) Western slope of Bocchetta di Valsoera; upper Piantonetto Valley: 732393 (Fornolosa).

(*) References are given to nearest 100 meters in the U.T.M. grid, zone 32T, 100.000 meter square LR; names enclosed in brackets refer to the sheets of Italy 1 : 25.000 of the Italian Military Geographic Institute.

3) 2886 topographic point, near Bivacco Carpano in the upper Piantonetto Valley: 713417 (Torre del Gran San Pietro).
4) Alpe Ciasel, Roc Valley: 645358 (Ceresole Reale).
5) Potes, Roc Valley: cf. PRATO (1971, p. 460).
6) Maison, Roc Valley: 665354 (Ceresole Reale).
7) 2656 topographic point south of the Rifugio Sella, Valnontey: 681482 (Gran Paradiso).
8) Valle Gran San Pietro, Valeille: 734445 (Torre del Gran San Pietro).
9) Bivacco Antoldi, Valeille: 736436 (Torre del Gran San Pietro).
10) Eastern slope of Colle Coupé di Money, Valeille: 725438 (Torre del Gran San Pietro).
11) Eastern and western slope of Valeille about 1 Km south of 1684 topographic point; eastern slope: 747485; western slope: 742484 (Torre del Gran San Pietro).
12) East of Punta del Rossin between the 2605 and 2690 topographic points, Bardoney Valley: 766483 (Torre del Gran San Pietro).
13) Punta di Acque Rosse, Bardoney Valley: 783476 (Torre del Gran San Pietro).
14) Grange Malpensata, southwest of Valprato Soana: 848415 (Valprato Soana).
15) Rio Arolei, Campiglia Valley: 812457 (Valprato Soana).
16) Rio Tressi, Forzo Valley: 823414 (Valprato Soana).
17) Colle Ciardoney, Forzo Valley: 739421 (Torre del Gran San Pietro).
18) Punta del Vallone, Ribordone Valley: 825371 (Locana).
19) Tricet near Talosio, Ribordone Valley: 817333 (Locana).
20) Punta Busiera, Ribordone Valley: 805326 (Locana).
21) Rio Furà, near Locana: 795322 (Locana).

b) *Phengite + chloritoid ± kyanite ± garnet (in the pre-granitic schists of the «Gneiss Minuti» Complex).*

22) Rifugio Pontese, upper Piantonetto Valley: 728398 (Fornolosa).
23) Alpe Brengi, Noaschetta Valley: cf. PRATO (1971, p. 459).
24) Alpe Arculà, Noaschetta Valley: cf. PRATO (1971, p. 459).
25) Pian dell'Alpe, Noaschetta Valley: cf. PRATO (1971, p. 459).
26) Roley waterfall, near Pont Valsavaranche: 594432 (Rhêmes Notre Dame).

27) Bivacco Leonessa, Valnontey: 673455 (Gran Paradiso).
28) Trail to the Herbetet hut south of Ponte dell'Erfaulet, Valnontey: 689457 (Gran Paradiso).
29) Western slope of Valnontey between Valmiana and Ponte dell'Erfaulet: 694466 (Gran Paradiso).
30) Comba Couteleina, Valnontey: 712457 (Torre del Gran San Pietro).
31) Ghiacciaio delle Sengie, Valeille: 753448 (Torre del Gran San Pietro).

c) *Kyanite pseudomorphs after sillimanite (in hornfelses and pre-granitic schists).*

32) Pian Telessio Lake, Piantonetto Valley: cf. CALLEGARI et al. (1969, p. 65).
33) 2256 topographic point near Rifugio Pontese, upper Piantonetto Valley: 730396 (Fornolosa).
34) 2981 topographic point near the Teleccio Glacier, upper Piantonetto Valley: 721417 (Torre del Gran San Pietro).
35) NW face of Roccia Viva, Valnontey: 688426 (Gran Paradiso).
36) Eastern slope of Valeille, about 1 km SSE of 1684 topographic point: 747484 (Torre del Gran San Pietro).
37) Western slope of Bardoney Valley, southwest of 2272 topographic point: 771478 (Torre del Gran San Pietro).
38) Pian della Valletta, Forzo Valley: cf. COMPAGNONI & PRATO (1969, p. 538).
39) Western face of Monte Colombino, Forzo Valley: cf. COMPAGNONI & PRATO (1969, p. 538).
40) Northern slope of Orco Valley between Rio Furà and Albrella: 791315 (Fornolosa).

d) *Phengite + Mg-chlorite + chloritoid ± kyanite ± glaucophane (in schists developed at the expense of the Hercynian granites).*

41) Rifugio Vittorio Emanuele II, Valsavaranche: cf. PRATO (1971, p. 457).
42) Colle di Valmiana, Valeille: 724464 (Torre del Gran San Pietro).
43) Between Pian della Turnetta and 2740 topographic point, Valnontey: 711474 (Torre del Gran San Pietro).

44) Between Pian della Turnetta and 2057 topographic point, Valnontey: 705478 (Torre del Gran San Pietro).
45) Eastern slope of Colle Coupé di Money, Valeille: 724437 (Torre del Gran San Pietro).
46) Colle Patrì, Valeille: 721449 (Torre del Gran San Pietro).
47) 2425 topographic point southeast of Punta Vigeusa, Valeille: 736487 (Torre del Gran San Pietro).
48) Eastern slope of Bardoney Valley near Punta di Acque Rosse: 784483 (Torre del Gran San Pietro).
49) Cirque between Monveso di Forzo and Roccia Azzurra, Forzo Valley: 769433 (Torre del Gran San Pietro).
50) Eastern ridge of Monte Arzola, Ribordone Valley: 801338 (Locana).

REFERENCES

BEARTH P. (1952) - *Geologie und Petrographie des Monte Rosa.* Beitr. Geol. Karte Schweiz., 96, 1-94.

BEARTH P. (1959) - *Uber Eklogite, Glaukophanschiefer und metamorphe Pillowlaven.* Schweiz. Min. Petr. Mitt., 39, 267-286.

BEARTH P. (1965) - *Zur Entstehung alpinotyper Eklogite.* Schweiz. Min. Petr. Mitt., 45, 179-188.

BEARTH P. (1967) - *Die Ophiolithe der Zone von Zermatt-Saas Fee.* Beitr. Geol. Karte Schweiz., 132, 1-130.

BELLIÈRE J. (1958) - *Contribution à l'étude pétrogénétique des schistes cristallins du massif des Aiguilles Rouges (Haute-Savoie).* Ann. Soc. Géol. Belgique, Mém. 81, 1-198.

BERTRAND J. M. (1968) - *Étude structurale du versant occidental du Massif du Grand Paradis (Alpes Graies).* Trav. Labor. Géol. Faculté Sci. Grenoble, 44, 55-87.

BIANCHI A. & DAL PIAZ GB. (1959) - *La memoria geologico-petrografica di R. Michel sul Massiccio del Gran Paradiso e regioni adiacenti. Osservazioni critiche.* Rend. Soc. Min. It., 15, 21-24.

BIANCHI A. & DAL PIAZ GB. (1963) - *Gli inclusi di « micascisti eclogitici » della zona Sesia nella formazione porfiritica permiana della zona del Canavese fra Biella ed Oropa. Caratteristiche et età dei fenomeni metamorfici.* Giornale di Geol., 31, 39-76.

BRIÈRE Y. (1920) - *Les éclogites françaises.* Bull. Soc. Franç. Miner., 42, 72-222.

BUCHS A., CHESSEX R., KRUMMENACHER D. & VUAGNAT M. (1962) - *Ages « plomb total » déterminés par fluorescence X sur les zircons de quelques roches des Alpes.* Schweiz. Min. Petr. Mitt., 42, 295-305.

CALLEGARI E., COMPAGNONI R. & DAL PIAZ G. V. (1969) - *Relitti di strutture intrusive erciniche e scisti a sillimanite nel Massiccio del Gran Paradiso.* Boll. Soc. Geol. It., 88, 59-69.

CARRARO F. (1966) - *Scoperta di una serie carbonifera di copertura degli gneiss-Sesia.* Boll. Soc. Geol. It., 85, 241-252.

CARRARO F., DAL PIAZ G. V. & SACCHI R. (1970) - *Serie di Valpelline e II Zona Diorito-Kinzigitica sono i relitti di un ricoprimento proveniente dalla Zona Ivrea-Verbano.* Mem. Soc. Geol. It., 9, 197-224.

CARRARO F. & CHARRIER G. (1972) - *Paleontological evidence for the late-Carboniferous age of the volcano-detrital cover of the « Micascisti eclogitici » (Sesia-Lanzo Zone, Western Alps).* Boll. Soc. Geol. It., 91, 185-194.

CHESSEX R., DELALOYE M., KRUMMENACHER D. & VUAGNAT M. (1964) - *Nouvelles déterminations d'âges « plomb total » sur des zircons alpins.* Schweiz. Min. Petr. Mitt., 44, 43-60.

COLEMAN R. G., LEE D. E., BEATTY L. B. & BRANNOCH W. W. (1965) - *Eclogites and eclogites: their differences and similarities.* Geol. Soc. Am. Bull., 76, 483-508.

COMPAGNONI R. & PRATO R. (1969) - *Paramorfosi di cianite su sillimanite in scisti pregranitici del Massiccio del Gran Paradiso.* Boll. Soc. Geol. It., 88, 537-549.

COMPAGNONI R. & PRATO R. (1970) - *Prima segnalazione di rocce eclogitiche nel massiccio cristallino del Gran Paradiso.* (Comunicazione orale presentata al Convegno di Bologna della SIMP).

COMPAGNONI R. & MAFFEO B. (1973) - *Jadeite-bearing metagranites l.s. and related rocks in the Mount Mucrone area (Sesia-Lanzo Zone, Western Italian Alps).* Schweiz. Min. Petr. Mitt., 53, 355-378.

COMPAGNONI R., ELTER G. & LOMBARDO B. (1974) - *Eterogeneità stratigrafica del complesso degli « gneiss minuti » nel Massiccio del Gran Paradiso.* Colloquio sull'Orogenesi Ercinica nelle Alpi, Bergamo 14-16 Marzo 1974.

DAL PIAZ G. V. & GATTO G. (1963) - *Considerazioni geologico-petrografiche sul versante meridionale del Monte Rosa.* Rend. Accad. Naz. Lincei, cl. Sci. F.M.N., 34, 190-194.

DAL PIAZ G. V. (1964) - *Il cristallino antico del versante meridionale del Monte Rosa: paraderivati a prevalente metamorfismo alpino (nota preliminare).* Rend. Soc. Min. It., 20, 101-135.

DAL PIAZ G. V. (1965) - *La formazione mesozoica dei calcescisti con pietre verdi fra la Valsesia e la Valtournanche ed i suoi rapporti strutturali con il ricoprimento Monte Rosa e con la Zona Sesia-Lanzo.* Boll. Soc. Geol. It., 84, 67-104.

DAL PIAZ G. V. (1971) - *Nuovi ritrovamenti di cianite alpina nel cristallino antico del Monte Rosa.* Rend. Soc. It. Min. Petr., 27, 437-477.

DAL PIAZ G. V., GOSSO G. & MARTINOTTI G. (1971) - *La II Zona Diorito-Kinzigitica tra la Valsesia e la Valle d'Ayas (Alpi occidentali).* Mem. Soc. Geol. It., 10, 257-276.

DAL PIAZ G. V., HUNZIKER J. C. & MARTINOTTI G. (1972) - *La Zona Sesia-Lanzo e l'evoluzione tettonico-metamorfica delle Alpi nordoccidentali interne.* Mem. Soc. Geol. It., 11, 433-460.

ESSENE E. J. & FYFE W. S. (1967) - *Omphacite in Californian Metamorphic Rocks.* Contr. Min. Petr., 15, 1-23.

FAURE-MURET A. (1955) - *Études géologiques sur le Massif de l'Argentera - Mercantour et ses enveloppes sédimentaires.* Mem. Carte Géol. France, 336 pp.

FRANCHI S. (1894) - *Relazione sui principali risultati del rilevamento geologico nelle Alpi Marittime eseguito nelle campagne 1891-1892-1893.* Boll. R. Comit. Geol. It., 25, 231-258.

MALARODA R. (1970) - *Carta geologica del Massiccio dell'Argentera alla scala 1 : 50.000 e Note Illustrative* (a cura di F. CARRARO, G. V. DAL PIAZ, B. FRANCESCHETTI, R. MALARODA, C. STURANI & E. ZANELLA). Mem. Soc. Geol. It., 9, 557-663.

MICHEL R. (1953) - *Les schistes cristallins des Massifs du Grand Paradis et de Sesia-Lanzo (Alpes franco-italiennes).* Thèse, Sciences de la Terre, 1, 287 pp.

MOTTANA A. (1972) - *Eclogite occurrences in gneiss as indicators of a Caledonian high-pressure metamorphism in the Western Alps.* 24th Intern. Geol. Congress Montreal, section 2, 35-41.

NIGGLI E. (1970) - *Alpine Metamorphose und alpine Gebirgsbildung.* Fortschr. Miner., 47, 16-26.

NOVARESE V. (1929) - *La Zona del Canavese e le formazioni adiacenti.* Mem. descr. Carta Geol. It., 22, 65-212.

PANGAUD G., LAMEYRE J. & MICHEL R. (1957) - *Age absolu des migmatites du Grand Paradis (Alpes franco-italiennes).* C.R. Acad. Sci. Paris, 245, 331-333.

PRATO R. (1971) - *Il settore centro-occidentale del Massiccio del Gran Paradiso. I. Relazione preliminare sul rilevamento e sugli studi geologico-petrografici del Massiccio del Gran Paradiso.* Atti Accad. Sci. Torino, 105, 453-467.

SALIOT P. (1973) - *Les principales zones de métamorphisme dans les Alpes françaises. Répartition et signification.* C. R. Acad. Sci. Paris, 276, 3081-3088.

SCHEURING B., AHRENDT H., HUNZIKER J. C. & ZINGG A. (1974) - *A Tertiary andesite Complex NW Biella on the Boundary between central and southern Alps.* Geol. Rundschau, in print.

SMULIKOWSKI K. (1964) - *An attempt at eclogite classification.* Bull. Acad. Polon. Sci. Sér. Sci. Geol. Geogr., 12, 27-33.

VITERBO-BASSANI C. & BLACKBURN C. (1968) - *The eclogitic rocks of the « Eclogitic micaschist formation », Sesia-Lanzo Zone (Western Alps, Italy).* Mem. Ist. Min. Geol. Univ. Padova, 27, 1-45.

WETZEL R. (1972) - *Zur Petrographie und Mineralogie der Furgg-Zone (Monte Rosa-Decke).* Schweiz. Min. Petr. Mitt., 52, 161-236.

WINCHELL H. (1958) - *The composition and physical properties of garnet.* Amer. Miner., 43, 595-600.

ZUCCHETTI S. (1956) - *Studio di due rocce filoniane rinvenute nell'ortogneiss del Gran Paradiso.* Per. Mineralogia, 24, 349-359.