LEIDSE GEOLOGISCHE MEDEDELINGEN, Deel 51, Aflevering 2, pp. 313–329, 15–11–1978

PETROLOGICAL OUTLINE OF AN AREA NEAR SPARONE (ORCO VALLEY, WESTERN ITALIAN ALPS)

BY

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ABSTRACT

Several rocktypes and their metamorphic mineral growth are described from an area on the western border of the Sesia–Lanzo Zone in the Orco Valley (NW Italy). It is argued that in some rocks (garnet-rich gneisses and micaceous gneisses) pre-Alpine metamorphic minerals are present, in other rocks (carbonate-bearing schists, albite–chlorite gneisses) such minerals are rare or absent. For the latter rocks it is therefore difficult to establish whether they are strongly retrograded Alpine basement rocks, or rocks belonging to the suite of ophiolitic schistes lustrés. The two possibilities are discussed.

INTRODUCTION

The investigated area is situated on the external (western) border of the Sesia–Lanzo Zone, and lies in the Orco Valley (NW Italy) (Fig. 1). The rocks of the area comprise several types of gneiss, carbonate-bearing schists, impure marbles and micaschists.

Previous work dealing with the area has been published by Stella (1894), Novarese (1894) and Franchi (1911), and resulted in 1:25,000 geological maps (sheet 42, Foglio Ivrea of the Italian Geological Survey is based on their work). Michel (1953) has described rocks belonging to the Gran Paradiso Massif, the surrounding metasedimentary rocks, and rocks belonging to the Sesia–Lanzo Zone. Elter (1971) has made a detailed study of the stratigraphy of the schistes lustrés (calcescisti).

The aim of the present study is to unravel the metamorphic history of the area. Similar metamorphic parageneses from different parts of the area are placed in the same metamorphic episode, indicated by M_1, M_2, etc. The numbers indicate the interpreted chronological order.

Four main rock-units are distinguished:

1. garnet-rich gneisses
2. micaceous gneisses
3. albite–chlorite gneisses
4. carbonate-bearing micaschists and associated rocks.

GARNET-RICH GNEISSES

Introduction

Immediately north of Sparone and in a few other areas (see Fig. 2) a reddish weathered, garnet-rich gneiss occurs. Amphibolitic rocks have been found in some places within the gneisses.

Description of the garnet-rich gneisses

The rocks have a poorly developed foliation. Macroscopically they can be recognized by the abundance of garnet, blue-grey quartz, the presence of metapegmatoid veins and the reddish alteration colours (Minnigh, 1977). Near the contacts with the adjacent rocks, the gneisses become more foliated, and mylonites, variable in thickness, occur.

The garnet-rich gneisses consist mainly of quartz, albite, white-mica and garnet. Glaucophane, chloritoid, several epidote-group minerals and chlorite are present

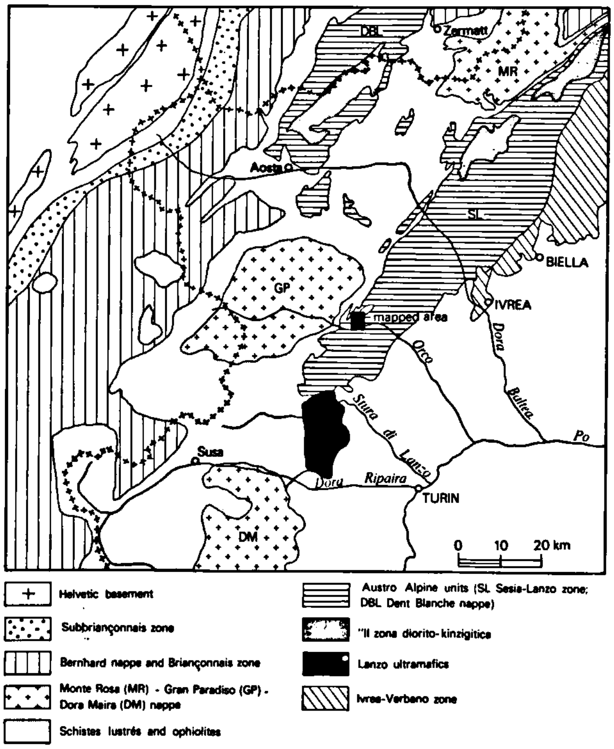

Fig. 1. Tectonic sketch map of the northwestern Alps (from Carraro et al., 1970; Dal Piaz et. al., 1971; Compagnoni et al., 1977).

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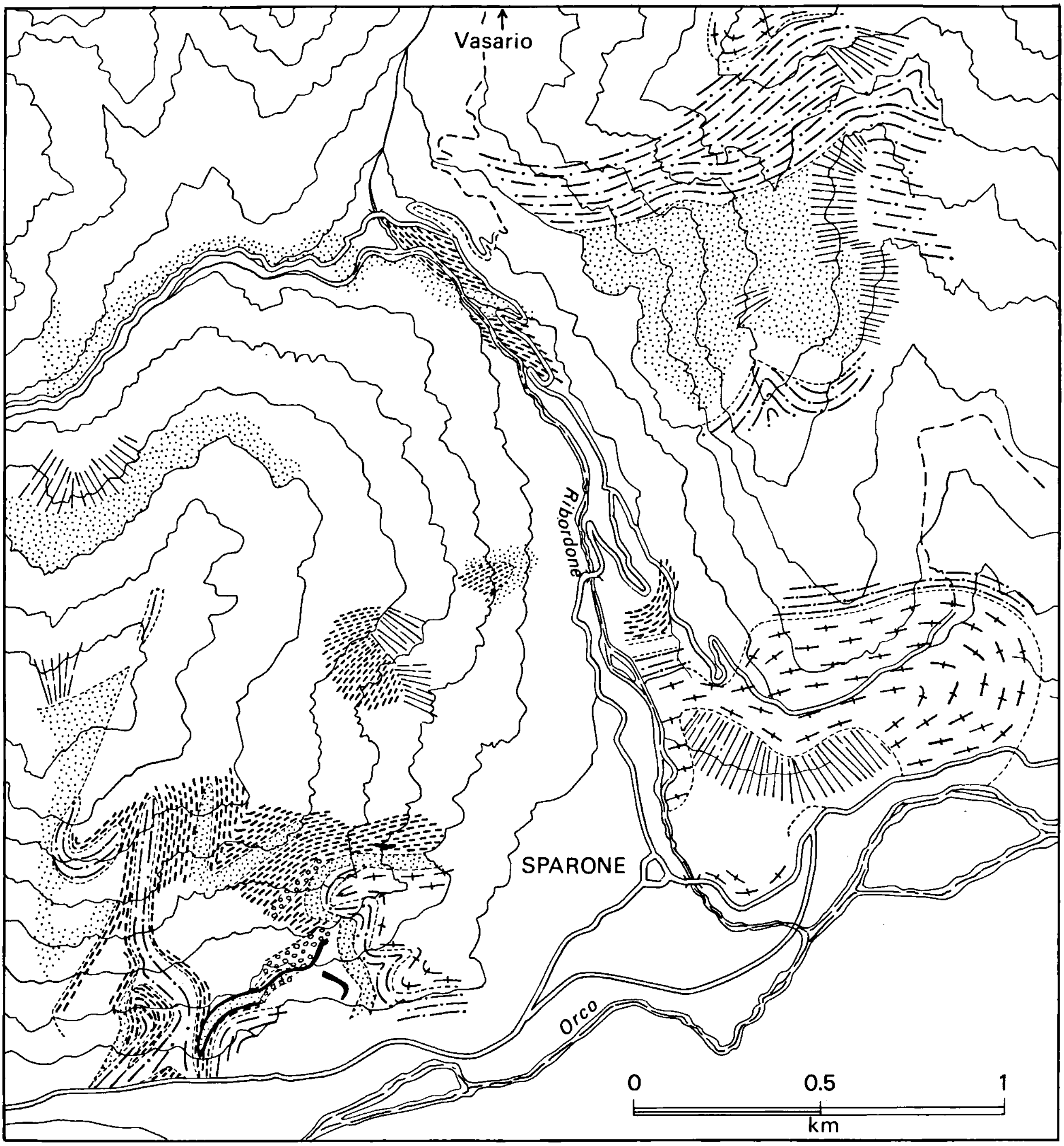

Fig. 2. Geological map of the area described with the main lithological rock types. In the northeast the II DK-Klippe of Vasario is indicated.

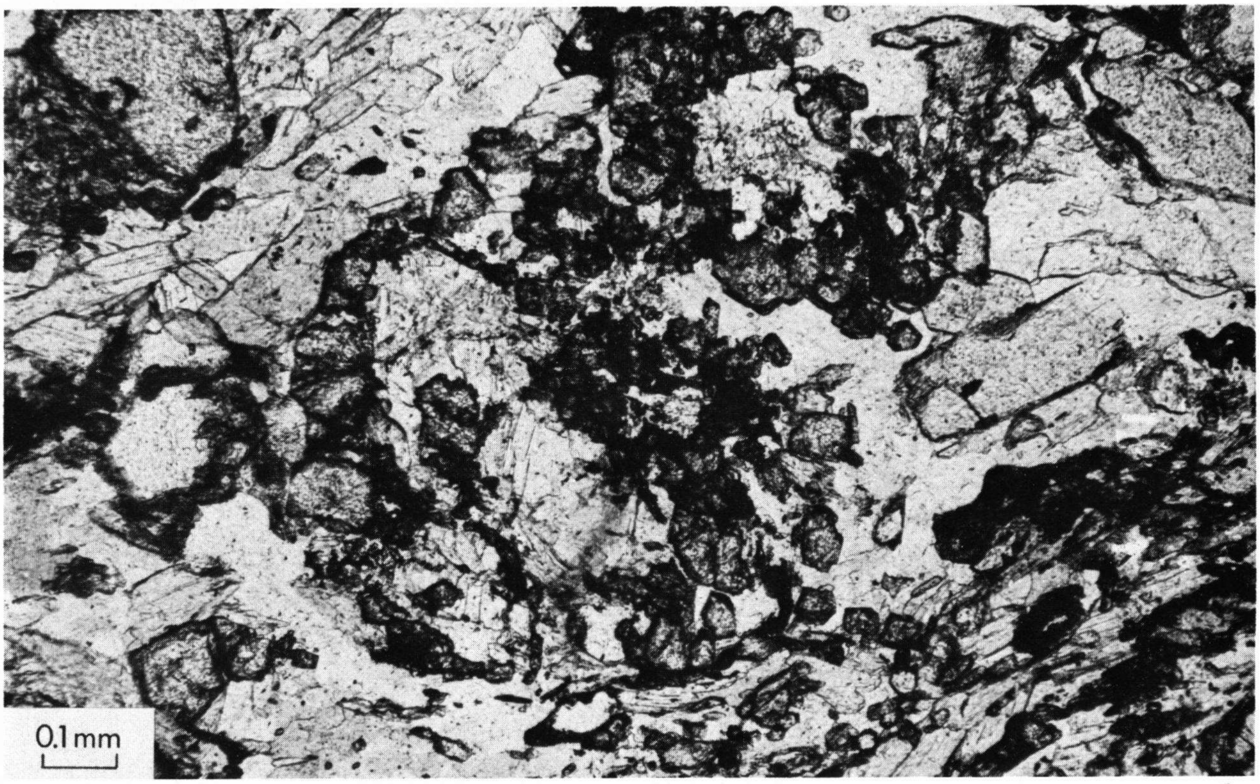

Fig. 3. Garnet rim around white mica. This is probably an indication of the reaction biotite → white mica + garnet.

in variable amounts; rutile is sometimes, sphene is often present as accessory. In thin section the poorly developed foliation is defined by zoisite, fine-grained mica and ribbons of quartz.

Garnet-porphyroblasts are present in different habits and generations. The oldest garnets (I) are extensively broken into rounded, cloudy fragments. From clusters of these fragments the outlines of a former porphyroblast can sometimes be inferred. Commonly garnet I is recrystallized into a slightly pink-coloured, idiomorphic garnet II. This later generation also occurs as corroded (less than garnet I) porphyroblasts but have not been broken.

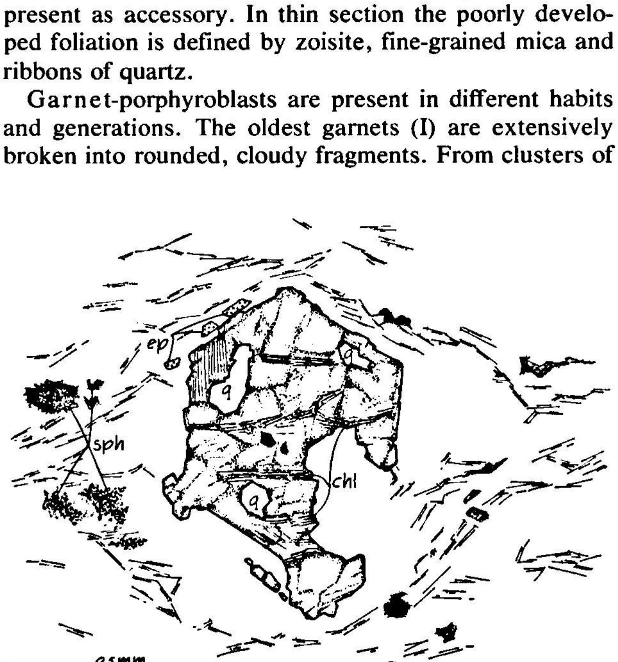

Fig. 4. Garnet transformation into chlorite in a garnet-rich gneiss. White-micas (thin lines) bend around the garnet. Chl=chlorite; ep=epidote; q=quartz; sph=sphene.

Local regular alignments of rutile are present within these garnets. From other areas Compagnoni has demonstrated that garnet II forms after biotite (Compagnoni & Maffeo, 1973; Compagnoni, 1977). During this transformation exsolved rutile needles remain from the biotite and are now seen enclosed in the garnets. In one case garnet rims have been observed around white mica (Fig. 3); this is an indication of biotite transforming into white-mica and garnet, as is seen elsewhere (Compagnoni & Maffeo, 1973). However, brown biotite has not been found in these rocks in the area discussed. Garnet I as well as garnet II alter into chlorite, apparently accompanied by some sphene (Fig. 4).

A vague main foliation (S_m) bends around both generations of garnet.

Brown hornblende is observed in several thin sections of amphibolitic rocks. The mineral is mostly altered, so that only brown stains and concentrations of sphene along the cleavage planes of the hornblende are visible (Fig. 5). Brown hornblende is older than glaucophane (see below) and is enclosed by garnet II (Fig. 6). This same phenomenon has been observed by Dal Piaz et al. (1971) and Compagnoni (1977).

Fig. 5. Rutile concentrations along the cleavage planes of a brown hornblende, due to alteration.

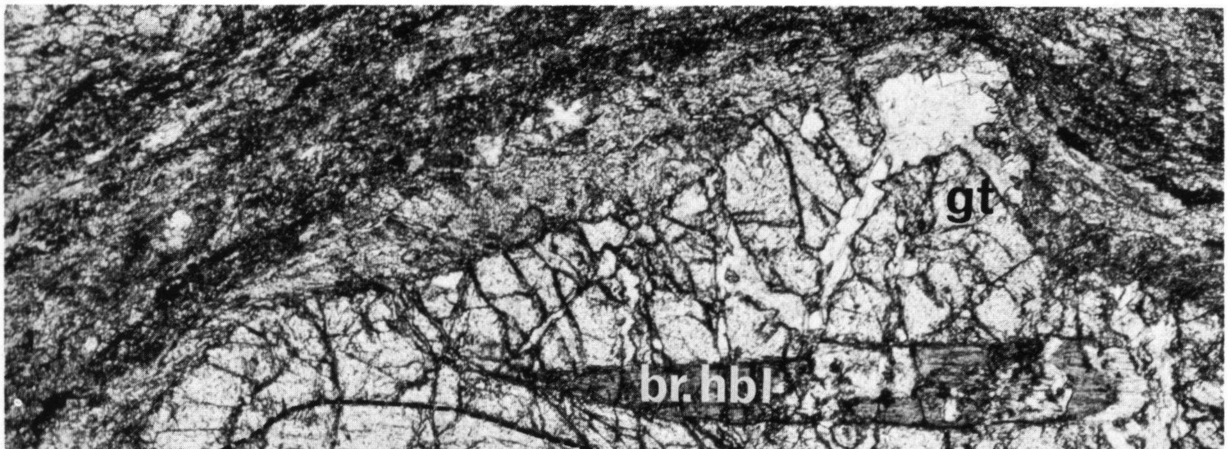

Fig. 6. Brown hornblende (br. hbl) and clinopyroxene (clpx) enclosed in garnet (gt), indicating a high-grade metamorphism.

The following alteration reactions have been observed:
Brown hornblende → chlorite + white-mica + zoisite
Brown hornblende → colourless hornblende + sphene ± epidote
Brown hornblende → colourless glaucophane + sphene + epidote

The second reaction probably represents the same phenomenon mentioned as decolouring of the brown hornblende by Dal Piaz et al. (1971).

Glaucophane is a common metamorphic mineral in the garnet-rich gneisses. It is a very pale glaucophane with $2V_x$ = 45–50° and a weak dispersion (r<v), the birefringence is somewhat higher ($\Delta \simeq 0.02$) than for the more coloured glaucophanes observed in other rocks of this area; these properties indicate a Mg-rich glaucophane (Miyashiro, 1957).

Several different habits of glaucophane as well as zoning within one porphyroblast have been observed. Large porphyroblasts (1 mm) always have a nearly colourless core, sometimes the rim is pale-blue. Often, also small, pale-blue glaucophanes are present. The smaller glaucophanes always bend around the larger porphyroblasts. It is therefore concluded that the colourless glaucophanes are older than the slightly coloured ones, and that the coloured rim around the large glaucophanes (I) is formed contemporaneous with the smaller glaucophanes (II). A similar succession has been reported from the Sanbagawa metamorphic belt (Iwasaki, 1960). Gosso (1977) has observed two generations of glaucophane, whereby the older has recrystallized into smaller glaucophanes.

In some samples the formation of glaucophane I after brown hornblende (third alteration reaction of brown hornblende mentioned above) can be inferred. Sphene is oriented parallel to the (110) cleavage of the former brown hornblende (Fig. 7), which is a very distinctive feature and different from the biotite transformation described previously. Inclusions of garnet I and rutile-alignments, representing biotite remnants, are present. Tourmaline has been observed only once as an inclusion. Glaucophane I and II alter via a fibrous barroisitic hornblende into actinolite. Also fine aggregates of mica and twinned albite have been observed as alteration products.

Chloritoid is commonly present as a main metamorphic mineral. Like glaucophane, chloritoid is also developed in two generations, and the older (chloritoid I) is normally larger than the younger one (chloritoid II) (Fig. 8). Chloritoid can be an important mineral in defining the main foliation.

The coarse and generally extensively twinned chloritoid I is pale-grey with weak pleochroism (x=grey-blue, y=green-blue, z=yellow-colourless). The optic axial

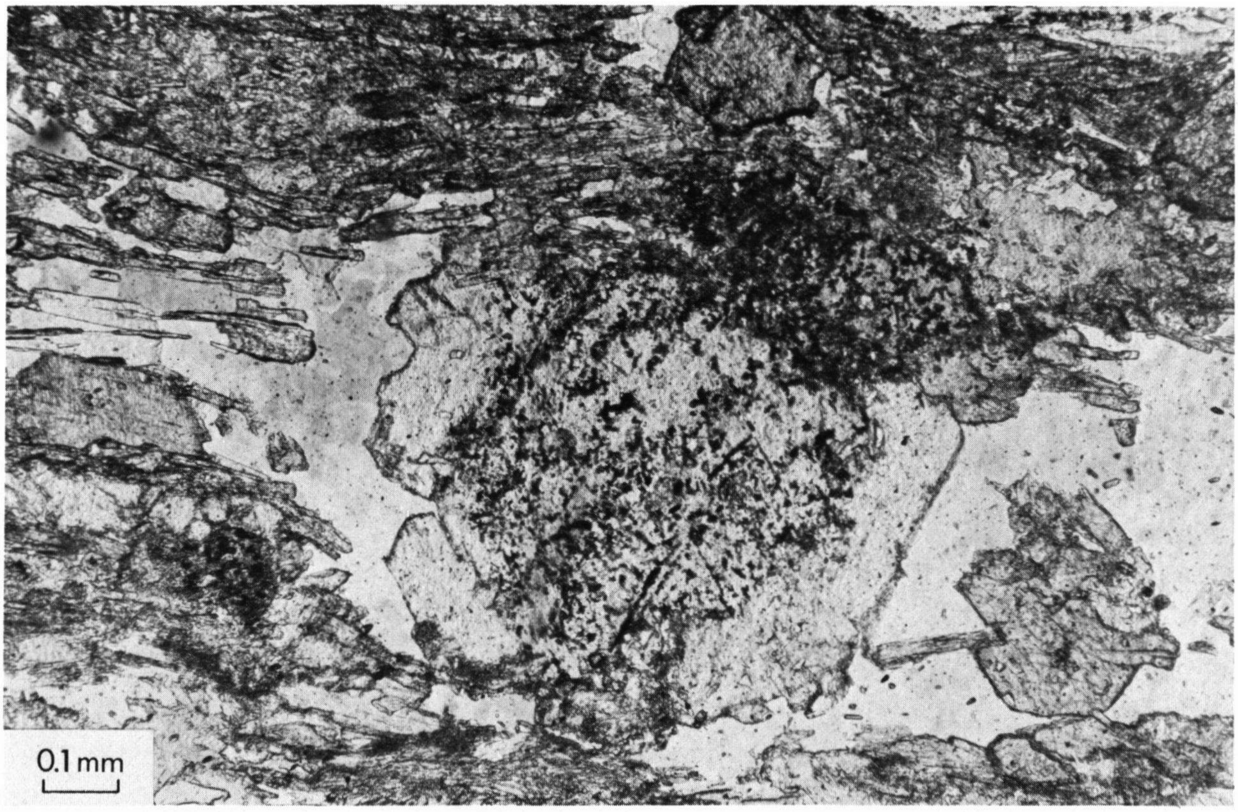

Fig. 7. Concentrations of sphene indicate a former brown hornblende, now transformed into glaucophane I.

Fig. 8. Micro-boudinage of chloritoid I. Smaller chloritoid II is parallel to the foliation.

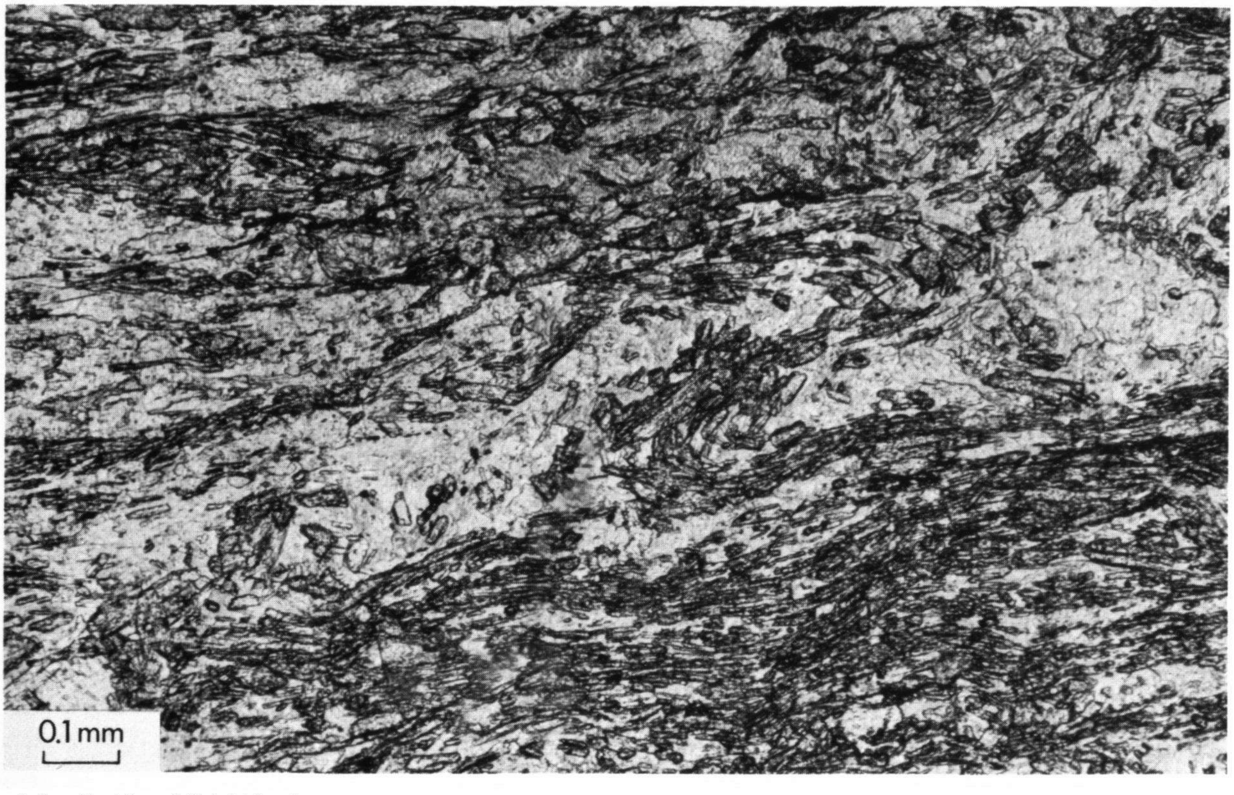

Fig. 9. Isoclinal intrafolial folds of zoisite in a garnet-rich gneiss.

angle is variable ($2V_z=20$–$45°$), dispersion r>v, and the birefringence $\Delta=0.006$.

Rutile-alignments from former biotites, broken garnet I and sometimes glaucophane I have been observed as inclusions in chloritoid I. A commonly observed alteration reaction of chloritoid is:
chloritoid → white-mica + chlorite + quartz ± opaques ± epidote (?)

In the mylonitic rocks near the contacts of the garnet-rich gneisses with the adjacent rocks, porphyroblasts of glaucophane I and chloritoid I are commonly larger than elsewhere.

Epidote-group minerals are common. Clinozoisite is an important component that defines the main foliation. Probably zoisite is older because isoclinal intrafolial folds are present (Fig. 9); epidote sometimes is present as an accessory.

Large xenoblastic rutile is present in a few places; probably this mineral has the same age as garnet I.

Possible pseudomorphs after sillimanite are present as very fine elongate mica in quartz-rich domains (Compagnoni, pers. comm.). Fresh sillimanite has not been found.

In one thin section of metabasite Ca-clinopyroxene has been found (Fig. 6); both, pyroxene and brown hornblende are armoured by garnet and thus preserved.

Two generations of white-mica are present. The oldest mica I is very fine-grained and gives rise in certain places to a vague foliation (S_1). White-mica II is coarser and is one of the minerals that defines the main foliation (S^m); sometimes it is seen that S^m is a crenulation cleavage.

Fine-grained quartz is commonly concentrated in lenses or ribbons. The numerous sutured quartz subgrains have undulose extinction. In the mylonites mortar textures are common. Albite is common and overgrows S_m.

Of the above-mentioned minerals, garnet I, biotite, sillimanite, brown hornblende and clinopyroxene suggest high-grade metamorphic conditions, and are different from the later high-pressure and low-temperature regime. Metamorphic minerals found in other areas in the Sesia–Lanzo Zone (e.g. Carraro et al., 1970; Dal Piaz et al., 1971; Compagnoni et al., 1977), and interpreted as pre-Alpine, are comparable with the high-grade assemblage from the garnet-rich gneisses.

Certain characteristics of the rocks, such as mylonitic contacts, meta-pegmatoid veins, reddish alteration colours, pre-Alpine minerals, show great similarities with rocks that Carraro et al. (1970) and Dal Piaz et al. (1971) have interpreted as belonging to the 'II Zona Diorito-kinzigitica' (II DK). Carraro et al. (1970) have interpreted the II DK occurrences in the Sesia–Lanzo Zone as remnants of a nappe rooted in the Ivrea–Verbano Zone ('Zona Diorito-kinzigitica') (Southern Alps). They have described several Klippen of these rocks (Fig. 1):

A. the northern part of the Sesia–Lanzo Zone between Rima San Giuseppe and the Ossola Valley. Here, partly autochthonous and allochthonous II DK occurs, according to Isler & Zingg (1974).

B. the Val Vogna–Valle di Gressoney Klippe. This Klippe has been described in detail by Dal Piaz et al. (1971).

C. the Klippe of Vasario (Orco Valley).

Recently also other small occurrences of II DK rocks have been found (Compagnoni et al., 1977; Boriani et al., 1976). The garnet-rich gneisses are interpreted as rocks belonging to II DK (Minnigh, 1977), however the Alpine metamorphic imprint in the area discussed is intense, and therefore the pre-Alpine mineral assemblage is not as striking as in other II DK-bodies.

MICACEOUS GNEISSES

Introduction

The mica-rich gneisses differ in several aspects from the II DK-rocks: alteration colours are grey-brown, a well-developed foliation is always present, and therefore folds are common, blue-grey quartz and meta-pegmatoid veins are absent and garnet is scarce. The rocks occur in several places in the area, sometimes as small lenses (<0.5 m) intercalated with other rocktypes.

Description

Macroscopically, mica, feldspar, quartz, and sometimes chloritoid and glaucophane can be distinguished. In thin section the micaceous gneisses are coarser grained than the garnet-rich gneisses. The main constituents are quartz, a slightly green mica (phengite) and albite; sometimes epidote, chloritoid, glaucophane or garnet are present. Sphene and rutile are present in greater amounts than in the II DK-gneisses.

Garnet I shows the same features as in the II DK-gneisses. In a few places a small idiomorphic garnet II is present, sometimes as a recrystallized product of garnet I. Both garnets are older than S_m.

Glaucophane and chloritoid as in the garnet-rich gneisses, are present in two generations, and the older porphyroblasts are the larger ones. Both minerals have also more intense colours, and dispersion is more pronounced. Glaucophane alters into a blue-green amphibole but, like chloritoid, is also replaced by chlorite.

Clinozoisite is sometimes abundant. It is parallel to S_m, together with phengite. Epidote crystals are more common than in the II DK-gneisses; epidote overgrows S_m.

Rutile and sphene are locally important components. 'Strings' of sphene-grains sometimes define S_m, which is characteristic of these rocks.

Fine-grained mica is often present as a mineral older than S_m. A coarse greenish mica (phengite) defines the main foliation.

Near the contacts with the II DK-gneisses, in some localities, pseudomorphs after lawsonite have been found.

The normally equant, medium-grained quartz distinguishes this rock from the II DK-gneisses. Sometimes exaggerated grain growth is developed. Often zones oblique to S_m show undulose extinction. The grain boundaries are lobate (not sutured as in the garnet-rich gneisses).

Zircon, apatite and opaque minerals are common accessories.

ALBITE-CHLORITE GNEISSES

Introduction

In Italian literature the albite–chlorite gneisses are known as 'gneiss minuti' (= fine-grained gneisses) and are interpreted as a special type of 'Sesia-gneiss' (e.g. Dal Piaz et al., 1971; Dal Piaz et al., 1972; Compagnoni et al., 1977). Here a descriptive term without an interpretation of possible origin and age is preferred.

Coarse-grained albite–chlorite gneiss is common in the present area. The colour of the rock varies with the amount of albite: grey-green (little albite, much chlorite) to light-grey with a greenish lustre (abundant albite). The rock occurs mainly together with carbonate schists, micaceous gneisses (Fig. 10) or very light-coloured gneisses. Layers of these rocks have a variable thickness from several centimetres to tens of metres. Sometimes there is a quick repetition of this lithology due to intensive folding.

Description

The gneisses are mainly composed of albite, chlorite, greenish mica and some epidote, quartz and green biotite; sometimes actinolite, graphite and sphene are present too. The foliation is defined by mica and, if present, actinolite.

Small garnets are found in a few places and are not corroded or broken, but are retrograded to chlorite.

Pale actinolite, always lying parallel to the main foliation, is sometimes present in fairly large amounts.

The rarely twinned albite seems to be present in two generations: sometimes the foliation bends around albite (I), sometimes albite (II) includes minerals that are lying parallel to the foliation.

Epidote commonly has a yellow rim of pistacite and is sometimes pre S_m, or parallel to S_m, but can also include S_m. Single pistacite crystals always overgrow the foliation. In a few instances allanite is present as an accessory mineral.

Small, xenomorphic mica (I)-flakes define an old foliation. Crenulation of this plane gives rise to the main foliation. Coarse phengite (II) lies parallel to S_m. An irregular crenulation of S_m in certain places gives rise to a new, poorly developed S-plane. The coarse phengite II is often rimmed by green biotite.

Chlorite is darker than in the micaceous gneisses or the garnet-rich gneisses and has anomalous purple-blue interference colours.

Green biotite forms mostly rims around phengite, but is also present within phengite in distinct zones, aligned parallel to the cleavage. Sometimes flakes of

Fig. 10. Contact of greenish albite-chlorite (ab–chl.) gneisses and brown micaceous gneisses.

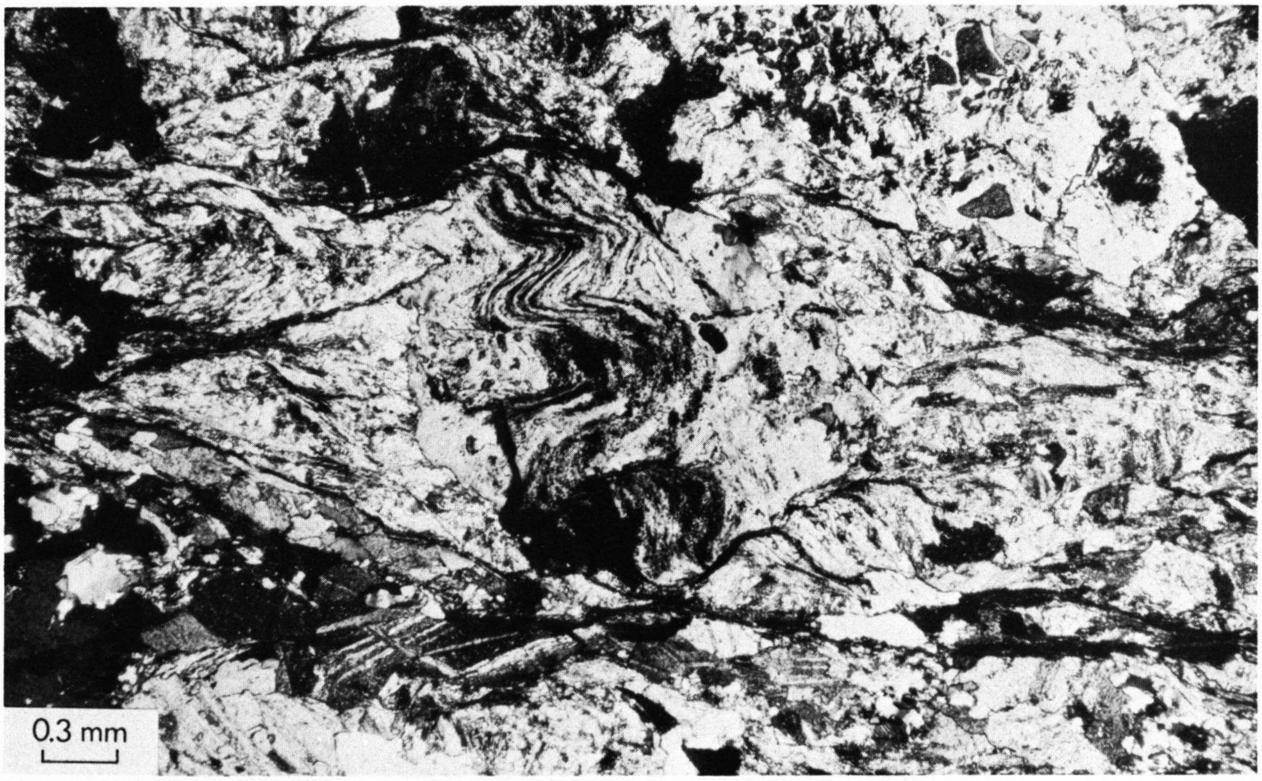

Fig. 11. Albite porphyroblast with graphite-inclusions showing that the main foliation is a crenulation cleavage.

Fig. 12. Albite porphyroblast with complex inclusion pattern of graphite. Same thin section as Fig. 11.

green biotite are present, probably representing completely recrystallized phengites.

In certain places (north of the Ribordone Valley) graphite-rich albite–chlorite gneisses occur. The graphite is present as fine alignments parallel to an S-plane. Spectacular inclusion patterns in albite show that S_m is a crenulation cleavage (Figs. 11 and 12).

Tourmaline and apatite are sometimes common accessories.

In the albite–chlorite gneisses of the area discussed, relics of pre-Alpine metamorphism, as found elsewhere (e.g. K-feldspar or chessboard albite), are absent. Allanite has been found in only a few places where the albite–chlorite gneisses are associated with micaceous gneisses, probably indicating an igneous origin of the rocks.

CARBONATE-BEARING MICA SCHISTS

Introduction

Carbonate-bearing schists known in Italian literature as 'calcescisti' (= schistes lustrés) occur in many places in the present area. The carbonate-rich parts commonly are extensively weathered and therefore the discontinuous layering is often visible. In the schists, small white quartz-veins, sometimes folded by several deformations are characteristic.

Intercalations with other rocks are commonly observed. Gradual transitions from carbonate-bearing schists to mica-schists into albite–chlorite gneisses have been observed in several localities. Other rock types, in close association with the carbonate-bearing mica schists, are mica schists, sometimes rich in quartz, albite–chlorite gneisses, very light coloured gneisses, impure marbles and chert layers. Due to the variable lithology and well-developed schistosity, several generations of folds can be observed.

Description

The main constituents of the carbonate schists and mica schists are albite, white mica, chlorite, epidote (pistacite), quartz and carbonate minerals. Variable quantities of actinolite, sphene and graphite are present. The main foliation is a crenulation cleavage and is defined by white-mica, graphite, chlorite aggregates, carbonate concentrations and, if present, actinolite needles. S_m is often irregularly crenulated, and a new surface, defined by axial surfaces of the crenulations, is present.

Small idiomorphic garnet is sometimes present, extensively replaced by chlorite.

In several places close to the garnet-rich gneisses on the eastern side of the Ribordone Valley, pseudomorphs after metamorphic minerals are common. The regular shape of original lawsonite is sometimes well preserved. Normally the pseudomorphs are formed by flakes of irregular white-mica and small amounts of epidote. The foliation clearly bends around the pseudomorph (Fig. 13).

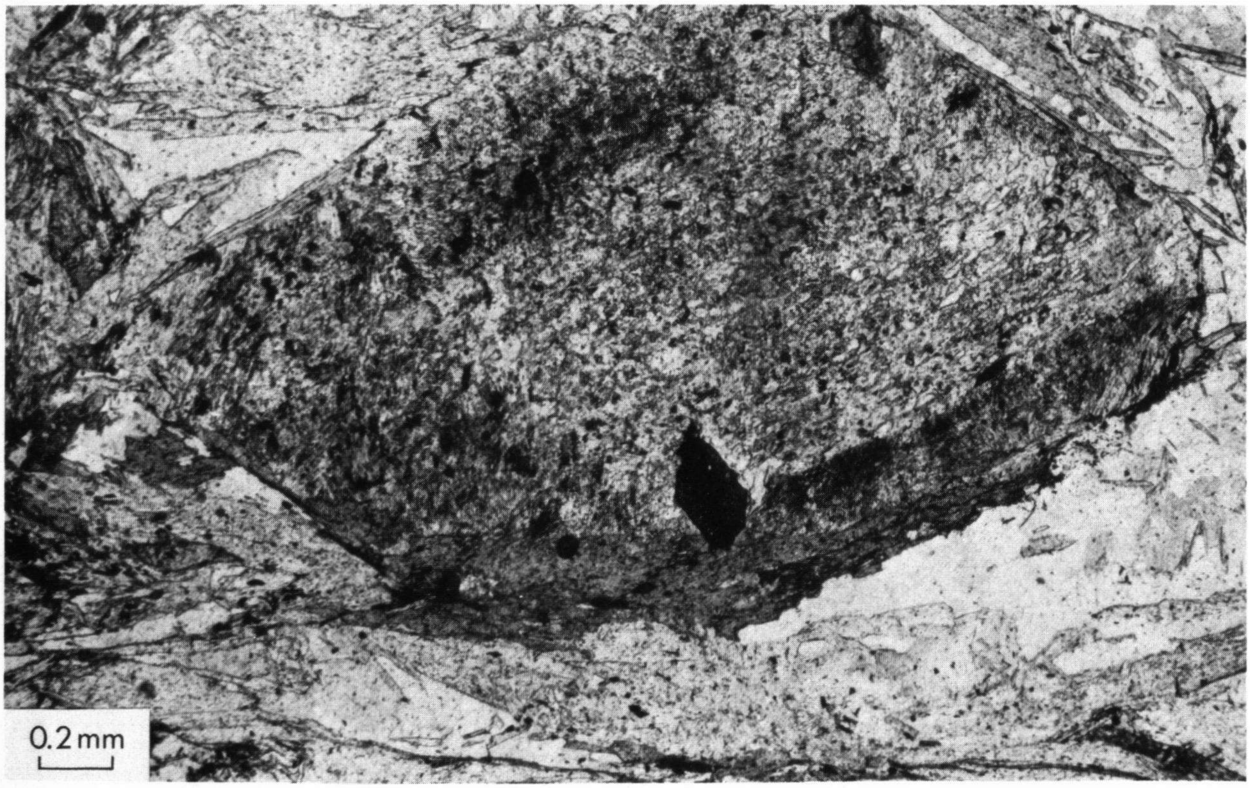

Fig. 13. Fine aggregate of mainly white-mica forms a pseudomorph after lawsonite.

Chlorite or albite–actinolite aggregates after glaucophane are common. Sometimes glaucophane is still preserved and two possible generations may be recognized. The older (glaucophane I) has a blue colour (darker than in the II DK-gneisses or micaceous gneisses) and occurs together with clinozoisite. Glaucophane II is present as a light-coloured rim around glaucophane I or as small light-coloured porphyroblasts; sometimes it is a recrystallized glaucophane I, accompanied by the transformation of clinozoisite into epidote.

Chloritoid-porphyroblasts are also sometimes present as two generations. Chloritoid too is more intensely coloured than in other rock units. The following retrograde reactions have run to nearly completion (see also Bearth, 1963):

chloritoid → chlorite ± magnetite
chloritoid → white-mica + epidote ± magnetite

Actinolite is present as a rare transformation product of glaucophane, but needles of actinolite are also present where no relationship with glaucophane is seen.

Two generations of white-mica are commonly present, as in the albite–chlorite gneisses. Sometimes a third generation (white-mica III) is developed. In the axial surfaces of the crenulations of the main foliation, sporadic newly formed crystals have been found. It seems that white-mica III is of the same generation as green biotite.

Green stilpnomelane ($2V_x$=ca. 10°; pleochroism x=yellow-green, y=green, z=blue-green) has occasionally been found in the carbonate schists.

Medium-grained quartz is present in variable amounts. There are often mutual foam-textures, which occur also between quartz and carbonate (Fig. 14).

Zoned yellow-brown tourmaline is always present as a sometimes important accessory.

For chlorite, green biotite, and epidote the same relationships with other minerals have been found as in the albite–chlorite gneisses.

Gosso (1977) has pointed out the transformation of white-mica into albite. In the present area the same phenomenon has been observed in all rock units. This transformation is seen in Fig. 15, where an elongated albite is embedded in quartz, while in the continuation of the albite some mica is still preserved. The timing of this process deduced by Gosso is post B_3; for the area discussed this means post-crenulation of the main (B_2-) foliation, a phenomenon that is seen in Fig. 16 (see also Fig. 11).

The oligoclase-rim around albite, commonly observed in northern parts of the Sesia–Lanzo Zone (e.g. Compagnoni, 1977; Gosso, 1977), has not been found in the present area.

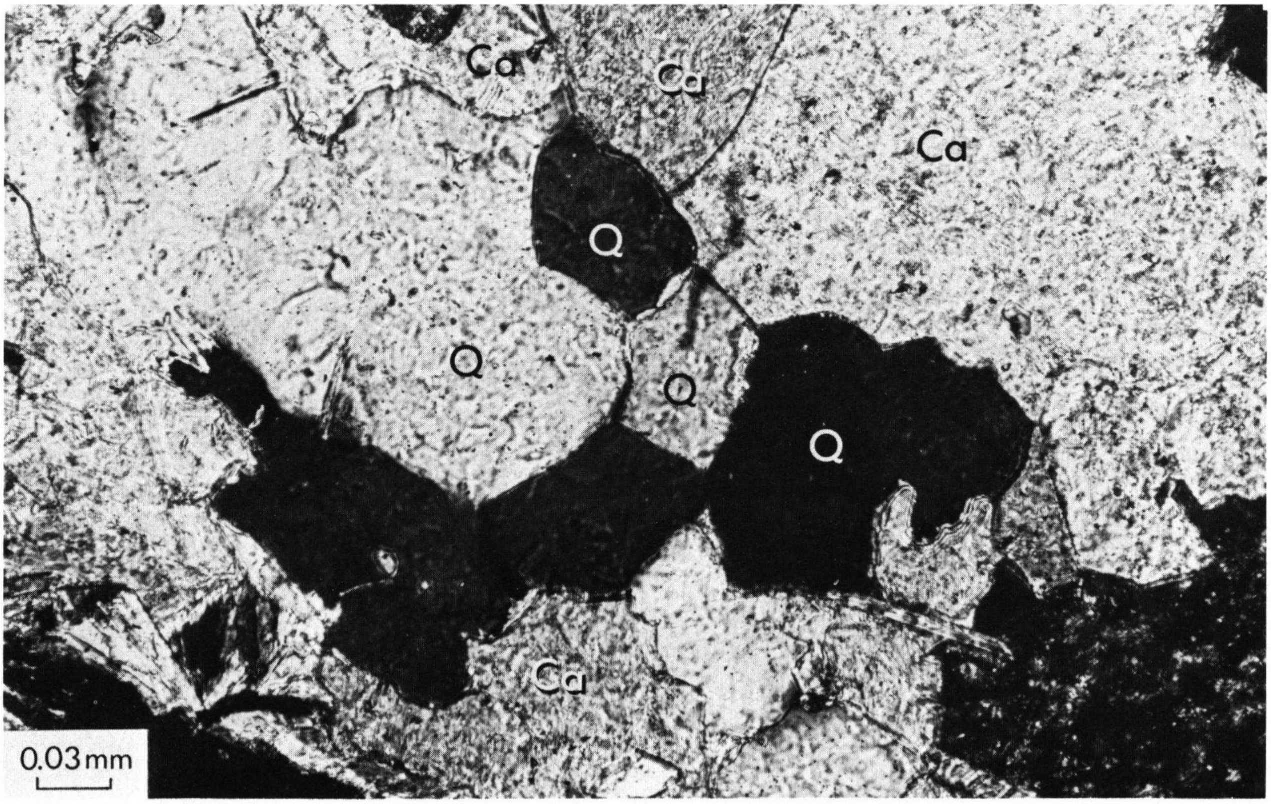

Fig. 14. Slightly curved grain boundaries with triple junctions of carbonate (Ca) and quartz (Q).

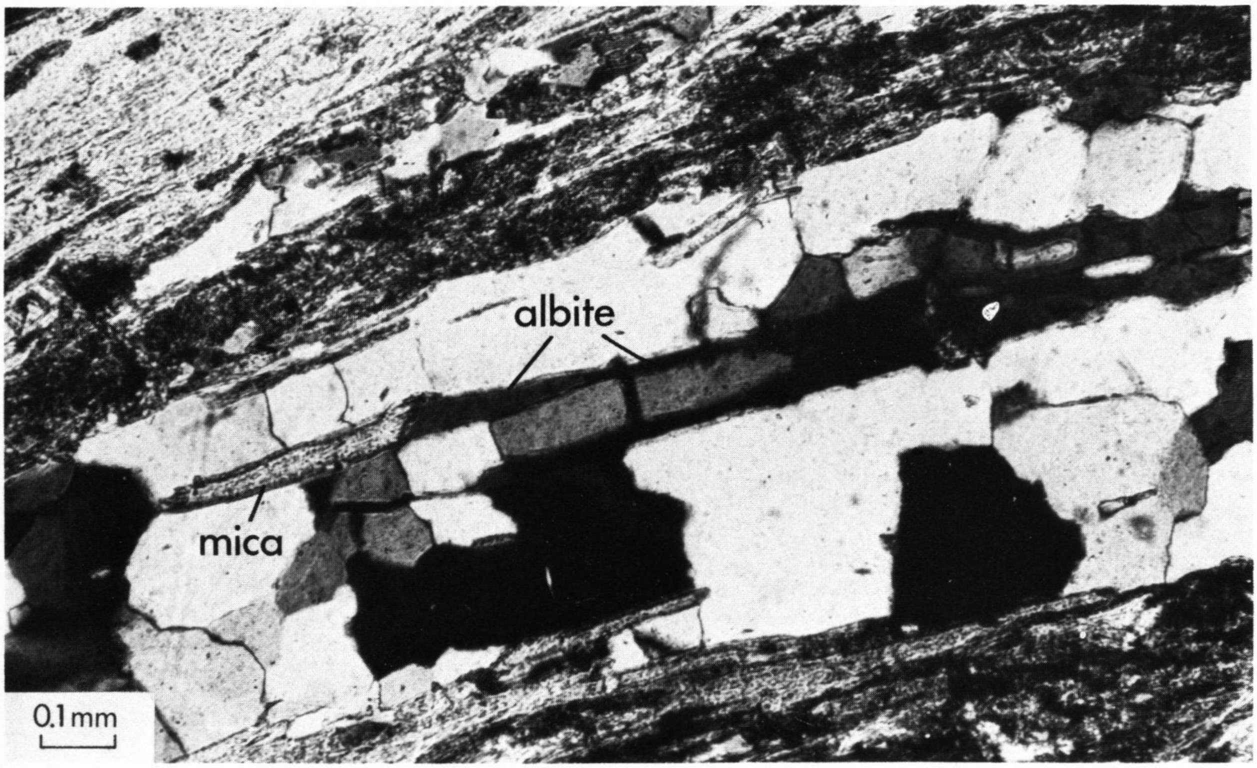

Fig. 15. Formerly elongate white-mica embedded in quartz is nearly completely replaced by albite.

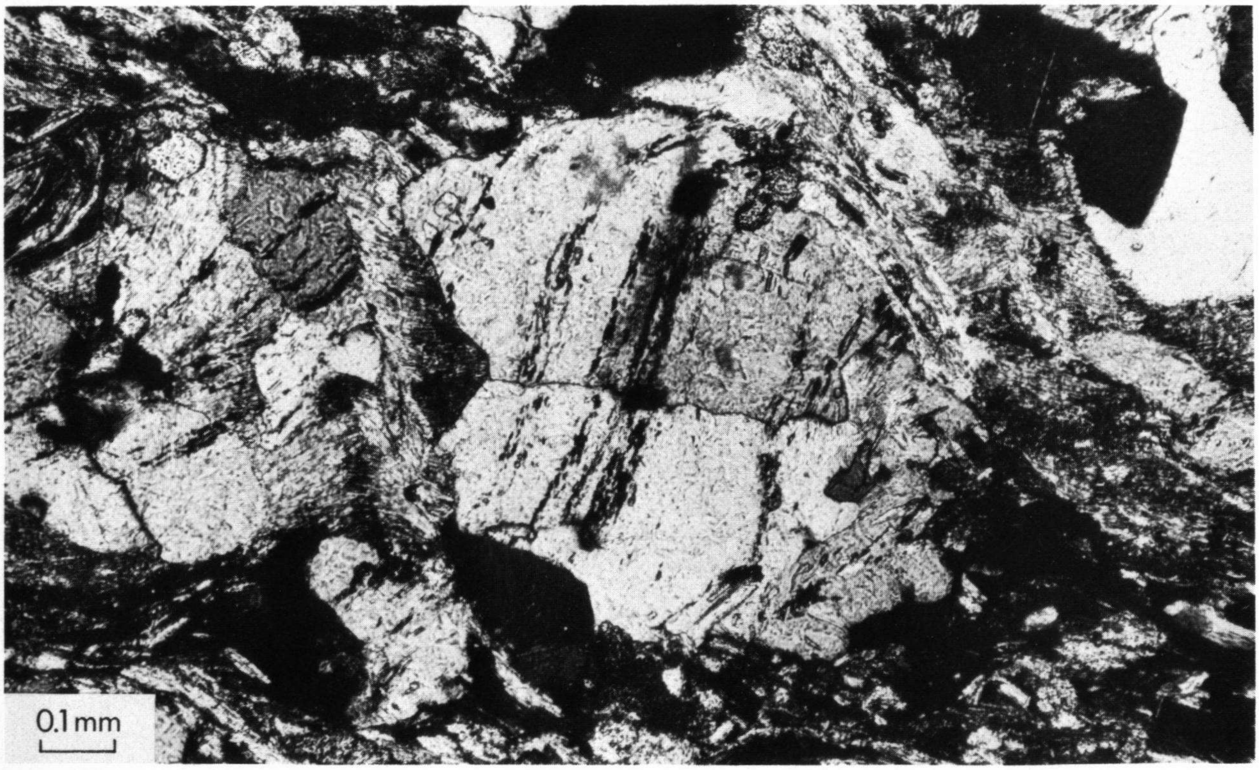

Fig. 16. Crenulated white mica is replaced by albite. Rutile- and graphite-fragments are enclosed in albite.

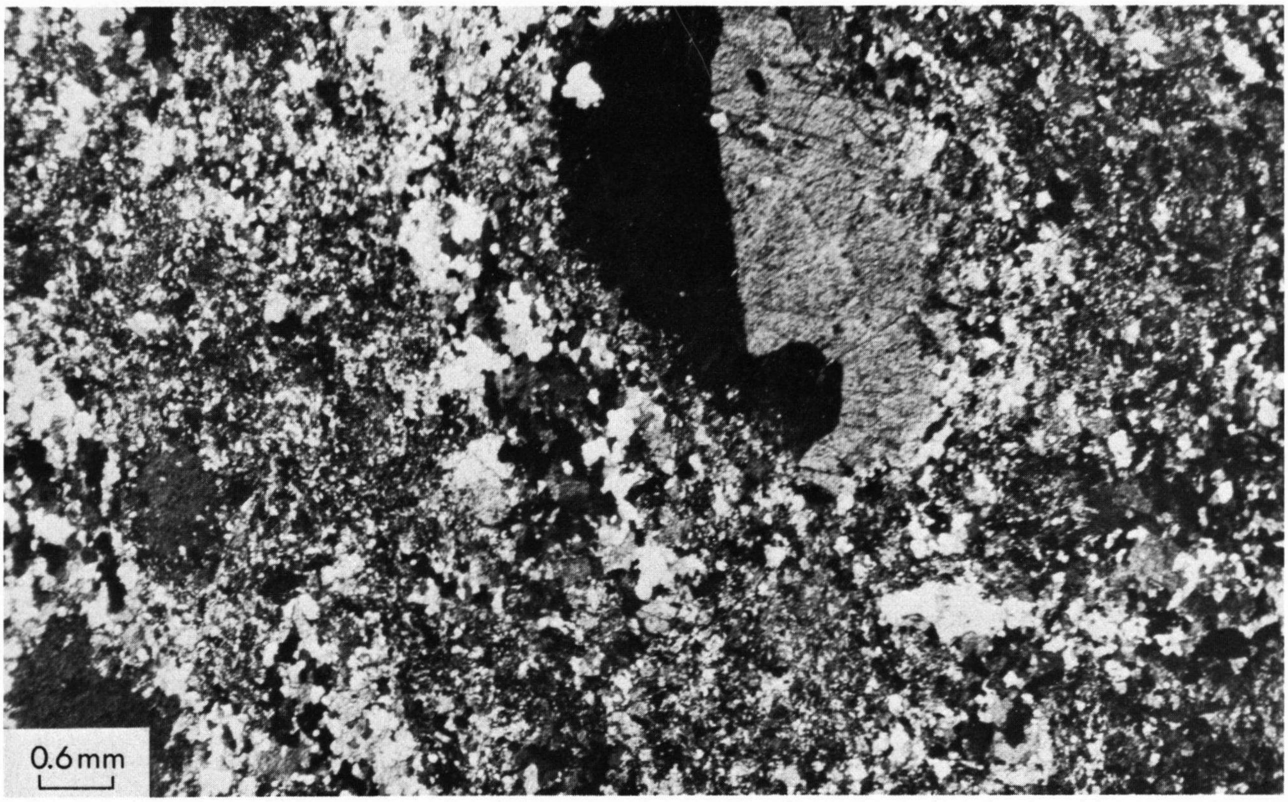

Fig. 17. Single-twinned albite phenocryst in a fine-grained albite–quartz matrix resembling a light-coloured gneiss.

Rocks in association with carbonate-bearing mica schists

West of the Ribordone Valley carbonate schists are quite common. They are intercalated with different rocks: light-coloured gneiss, quartz-mica schist, thin quartzites, and albite–chlorite gneisses. The thickness of these layers varies considerably.

Light-coloured gneisses occur in several places (Fig. 2). The rock is in contact with quartz-rich mica schists or carbonate-bearing schists, and always with albite-chlorite gneisses. The extreme light colour of the gneiss, and the presence of feldspar-augen (up to 3 cm), are striking features to distinguish the rock from other gneisses.

Microscopically the feldspar-augen are large microclines, chessboard albites or single-twinned albites (Fig. 17). The matrix consists mainly of albite and quartz; very little white-mica and chlorite are present. A chemical investigation and the possible origin of this rock will be published elsewhere (Minnigh in prep.).

Thin layers of quartzite have been reported by R. Prato, 1970, unpubl. map, Petrographical Inst., Turin) and lie in the vicinity of the light-coloured gneisses (Fig. 18). A rough description will be given. The variable thickness, from less than 1 cm up to 1 m, is due to folding. It is a well-laminated, sometimes reddish, sometimes yellow or grey-black coloured rock. The quartzite

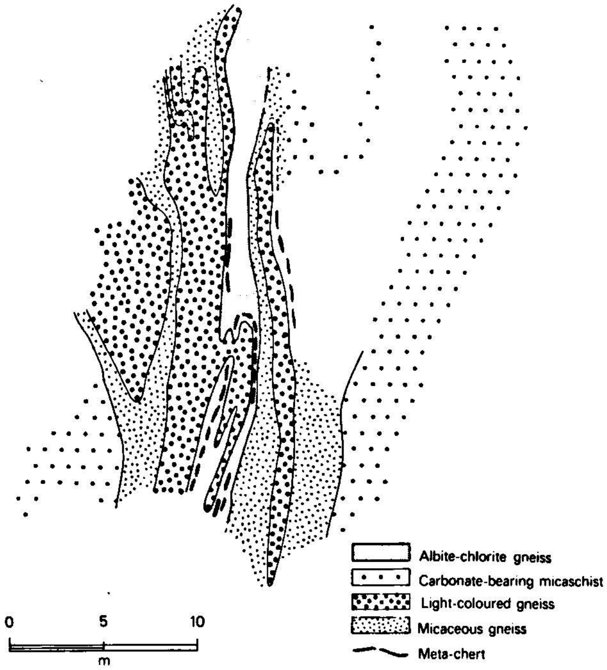

Fig. 18. Outcrop pattern with the characteristic lithologies of the region near Apperè.

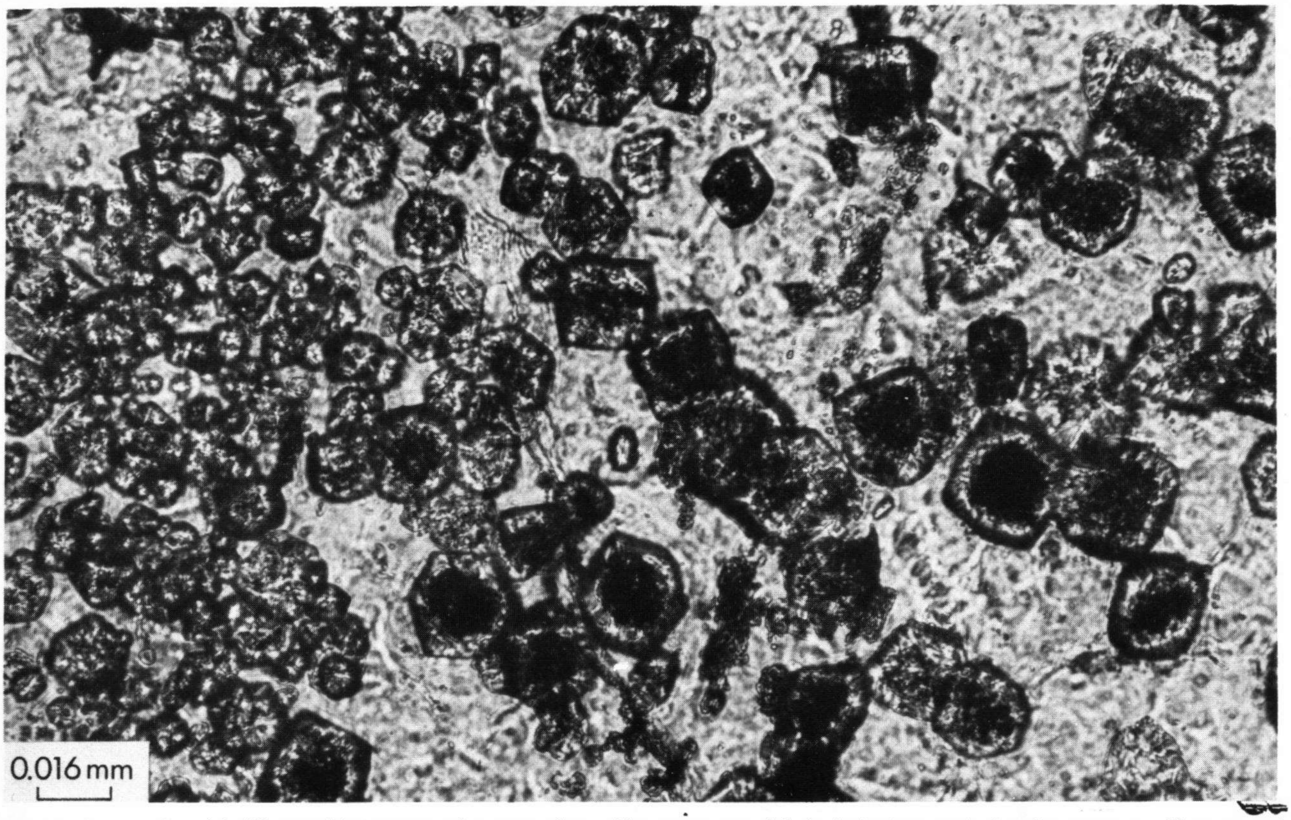

Fig. 19. Spessartine-rich idiomorphic garnets of a meta-chert. The cores are rich in inclusions and give the garnets a 'frog-spawn' appearance.

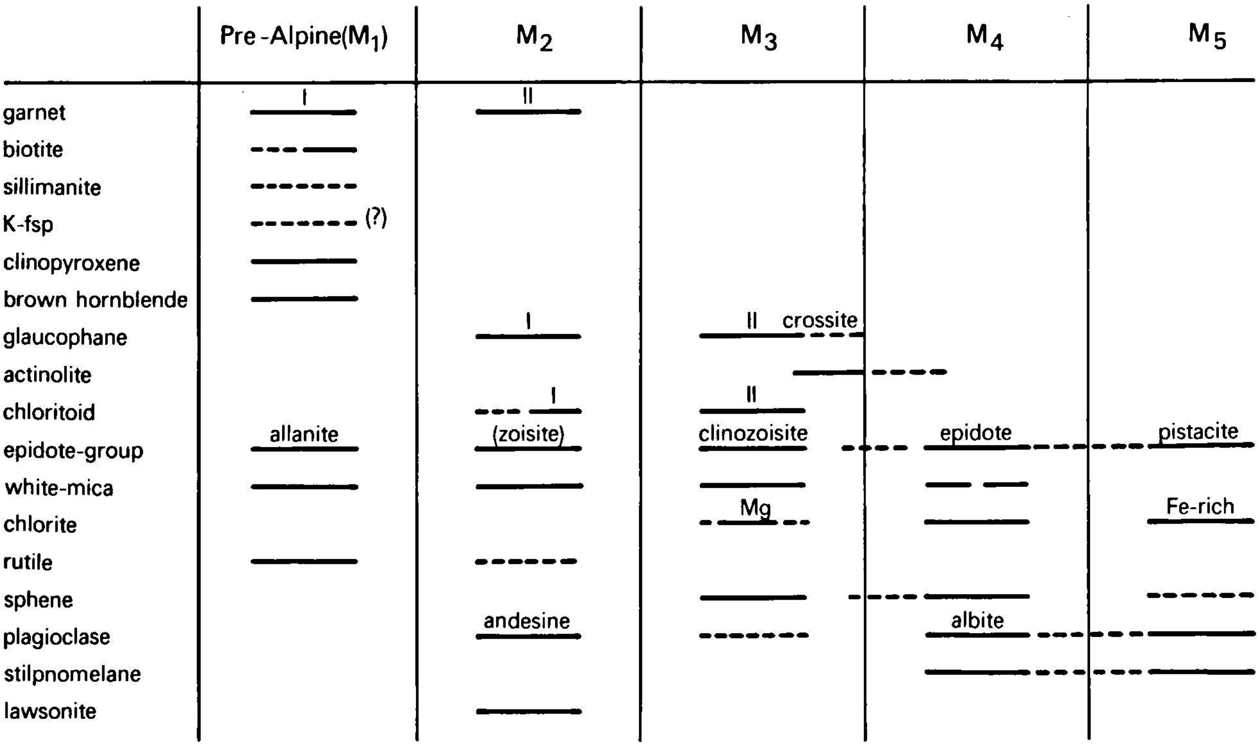

Table I. Time-table showing relative order of growth of the described metamorphic minerals.

appears a good structural marker; however, because of lack of continuous outcrop and the sometimes very small dimensions, it is difficult to trace it over large distances. The fine layering within the quartzite gives rise to fold-interference patterns. Fold structures and deformation history, will be published in an other paper (Minnigh, in prep.).

The main component is fine-grained quartz. Microscopically the layering is defined principally by fine-grained idiomorphic, spessartine-rich garnets. If the garnet is inclusion-free the layer is macroscopically yellow. Often a cluster of reddish needles (possibly hematite) is present as inclusion in the garnet, which gives the garnet a 'frog-spawn' appearance (Fig. 19). The inclusion-rich garnet layers are pink coloured.

Some of the minerals commonly found in the quartzites are epidote, crossite, piemontite, stilpnomelane. The quartzite is probably a meta-chert, since Mn-rich minerals are an important component.

DISCUSSION

From the above data on metamorphic mineral growth and relative time-relationships a time table can be compiled (Table I). This time table conforms with observations reported elsewhere (e.g. Compagnoni, 1977). The oldest metamorphic minerals garnet I, biotite, brown hornblende, sillimanite, and clinopyroxene, clearly represent a metamorphism of high temperature and moderate pressures, and have been interpreted as the metamorphic regime of pre-Alpine age (generally inferred to be Hercynian; see e.g. Boriani et al., 1976).

Microscopically it is difficult to establish whether the metamorphic conditions after the pre-Alpine episode represent events separate from one another, or a more or less continuous process of decreasing pressure and rising temperature. The tendency from high-pressure–low-temperature conditions (glaucophane, chloritoid, lawsonite) to moderate pressures and higher temperatures (albite, green biotite, chlorite) is a commonly observed feature in the Alps (Frey et al., 1974). From radiometric age determinations (Bocquet et al., 1974; Dal Piaz et al., 1972; Hunziker, 1974) two distinct metamorphic episodes have been ascertained: eoalpine (the above cited M_2 and M_3) started with glaucophanes possessing K-Ar ages of 80–100 my, and late Alpine, normally related to the Lepontine phase (ca. 35 my) probably present on a regional scale (M_4). In the present area omphacite, jadeite or kyanite have not been found, therefore the eoalpine metamorphic grade is probably lower than in the more northern and internal parts of the Sesia–Lanzo Zone, where micaschists in eclogite facies are abundant; it is also possible that these minerals have been completely retrograded (see Compagnoni, 1977). The late Alpine event is expressed by the subsequent alteration of pre-Alpine and eoalpine metamorphic minerals, local formation of green biotite and stilpnomelane, and growth of albite (variable in intensity in the different rock units). This greenschist facies metamorphism probably caused the scarcity of pre-Alpine metamorphic minerals in the garnet-rich gneisses and micaceous gneisses in respect to other areas (see e.g. Carraro et al., 1970 for pre-Alpine minerals in several II DK-bodies).

In the Sesia–Lanzo Zone the rocks have been subdivided on lithologic and metamorphic grounds by several authors (e.g. Carraro et al., 1970; Dal Piaz et al., 1971; Dal Piaz et al., 1972; Compagnoni et al., 1977). The general picture of this subdivision, based on their observations, is a metamorphic zonation from East to West. Internally (east), high-pressure and low-temperature metamorphism (eoalpine) and relics of pre-Alpine high temperature metamorphism are preserved in several rock types. In the external (western) part of the Sesia–Lanzo Zone, late Alpine greenschist-facies metamorphism is important. Relics of high-pressure–low-temperature metamorphic minerals are present, but no traces of pre-Alpine metamorphism have been found. Between the internal and external part there is a zone where, from east to west, eoalpine metamorphic influence decreases and late Alpine greenschist facies metamorphism increases. In the same zone pre-Alpine relics become rare or are lacking. This zone roughly corresponds with a change in lithology: externally, gneisses mainly composed of albite, quartz, phengite, epidote ± green biotite, actinolite and stilpnomelane, known as 'gneiss minuti', occur, while internally micaschists with eclogite facies paragenesis (eclogitic micaschists) dominate (Dal Piaz et al., 1972).

Metagranitoid rocks occur in localities lying externally as well as internally in the Sesia–Lanzo Zone (Callegari et al., 1976). These rocks comprise an important part of the pre-Alpine basement. During the subsequent metamorphic and tectonic episodes, some of the rocks are transformed into augen-gneisses, gneisses with potassium feldspar-relics (sometimes chessboard albite) or gneisses where original texture and mineralogy are completely transformed ('gneiss minuti') (Compagnoni et al., 1977).

According to this interpretation and terminology the micaceous gneisses and albite–chlorite gneisses of the area discussed are 'gneiss minuti' or so-called 'Sesia-gneisses' (e.g. Dal Piaz et al., 1972). Compagnoni et al. (1977) have interpreted the light-coloured gneiss as a leucocratic dyke derived from a granitoid stock.

The lithological units found in the area discussed can be divided into two groups: one group with pre-Alpine metamorphic relics, and one without a trace of pre-Alpine minerals. The first group consists of the garnet-rich gneisses and the micaceous gneisses. Albite–chlorite gneisses, carbonate-bearing schists and quartzites belong to the second group.

The garnet-rich gneisses are interpreted as a Klippe of II DK. Elsewhere (Dal Piaz et al., 1971; Dal Piaz et al., 1972; Compagnoni et al., 1977) the timing of the tectonic emplacement of II DK-rocks is argued to have been after the eoalpine high-pressure–low-temperature metamorphism, because of lack of minerals representing that metamorphic event. This interpretation cannot be tested in the area discussed, since no eoalpine metamorphic 'jump' between the garnet-rich gneisses and the adjacent rocks has been found.

In the micaceous gneisses, garnet I is a remnant of pre-Alpine metamorphism. In the albite–chlorite gneisses, allanite as a possible pre-Alpine mineral, has been found in very few places only. In the carbonate-bearing schists and also in the quartzites no indications of pre-Alpine elements has been observed.

The close association of carbonate-bearing micaschists with meta-cherts and albite–chlorite gneisses is of great interest. Frequently observed ovarditic gneisses in the schistes lustrés are interpreted as albitized lavaflows or tuffs (Nicolas, 1967; Elter, 1971; Compagnoni et al., 1977), or as former spilitic rocks (e.g. Amstutz, 1968; Vallance, 1960; see also Hughes, 1973), The commonly strong resemblance between the albite–chlorite gneisses and ovarditic gneisses is striking in several places.

The quartzites rich in manganese minerals in the area discussed are probably meta-radiolarian cherts. The possible environment of these cherts is that of the ophiolites of the schistes lustrés. Investigations of Elter (1971) and Bearth (1976) on the schistes lustrés of the Gran Paradiso and the Zermatt region, respectively, show the same rock-assemblages found in the present area. Manganese-rich cherts in schistes lustrés have also been reported by Debenedetti (1965), Grunau (1965) and Dal Piaz (1969). In the Lanzo Valley near Ceres, which lies in the continuation of the cherts of the Orco Valley, Zambonini (1922) and Gennaro (1925) have reported manganese-rich rocks. For all these cherts a Malm-age is suggested (Debenedetti, 1965). It is therefore proposed that the present cherts with (some of) the albite–chlorite gneisses belong to the 'vrais schistes lustrés' of Elter (1971) or the 'ozeanische Serie' of Bearth (1976).

The complex metamorphic and structural history of the rocks makes it difficult to determine whether contacts between different rocktypes are primary or not. Therefore the albite–chlorite gneisses may be partly basement rocks, partly ovarditic gneisses belonging to the schistes lustrés. Detailed investigations on this rocktype are necessary to unravel the possible origin, may be the presence of certain accessories such as allanite (believed to be of igneous origin) and tourmaline (an important accessory of the carbonate schists) as is proposed by Compagnoni (pers. comm.) can be of help.

A definite interpretation of the rock assemblage described above is not yet possible, but the two possibilities of origin (strongly retrogressed basement rocks or rocks belonging to the ophiolitic schistes lustrés) deserve further attention.

ACKNOWLEDGEMENTS

The author is greatly indebted to P. W. C. van Calsteren, R. Compagnoni, G. Gosso, R. P. Kuijper, B. Lombardo, E. den Tex, P. F. Williams and H. J. Zwart for the discussions and their suggestions during the preparation of the manuscript.

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