

## THE STRUCTURE OF THE GRAN PARADISO BASEMENT (PENNINE ZONE, ITALIAN W. ALPS)<sup>1</sup>

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### ABSTRACT

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Detailed structural analysis and mapping in the northern part of the Gran Paradiso massif suggest that the massif is a gneiss-cored fold nappe. The timing of the associated deformation relative to the Alpine metamorphism points to development of the nappe structure in a stage between the Eoalpine HP metamorphism and the peak of the Lepontine greenschist facies event.

### INTRODUCTION

The Gran Paradiso basement in the Pennine zone of the Italian Western Alps (Fig. 1) is made up of Alpine metamorphosed porphyritic granites of Late Carboniferous age intruded into a pre-Variscan basement ('Gneiss Minuti') of mainly metasediments with few metabasic rocks (BIANCHI & DAL PIAZ, 1958, 1959; CALLEGARI ET AL., 1969). These rocks occur in a circular outcrop of some 40 kilometres diameter underneath an allochthonous Mesozoic cover of mainly calcareous micaschists ('schistes lustrés') associated with thick layers of meta-ophiolites including metabasalt (prasinite), albite amphibolite, eclogitic metagabbro and lenses of serpentinite. The mafic rocks constitute the southern continuation of BEARTH'S (1967) zone of Zermatt-Saas Fee (ophiolite complex). Palaeogeographic reconstructions of the Western Alps commonly show the Gran Paradiso massif on the extreme southern margin of the European continent, adjacent to the Piemonte oceanic basin. During the Alpine orogeny the rocks of this continental margin were subject to a metamorphic evolution involving two marked stages: (1) Eoalpine glaucophanic to eclogitic metamorphism, yielding K/Ar ages of 65 to 100 Ma (BOCQUET ET AL., 1974; HUNZIKER, 1974) and (2) Lepontine metamorphism, with a thermal peak at 38 Ma (JÄGER ET AL., 1967), ranging from greenschist facies in the Western Alps to amphibolite facies in the Ticino culmination of the central Alps. During this metamorphic evolution the rocks involved were intensely deformed, leading to the development of various generations of deformational structures (see e.g. MILNES, 1978; PLATT & LISTER, 1978; MILNES ET AL., 1981).

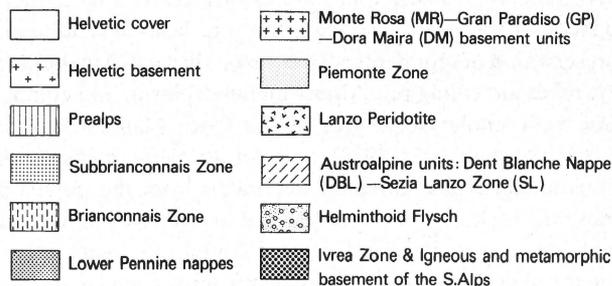
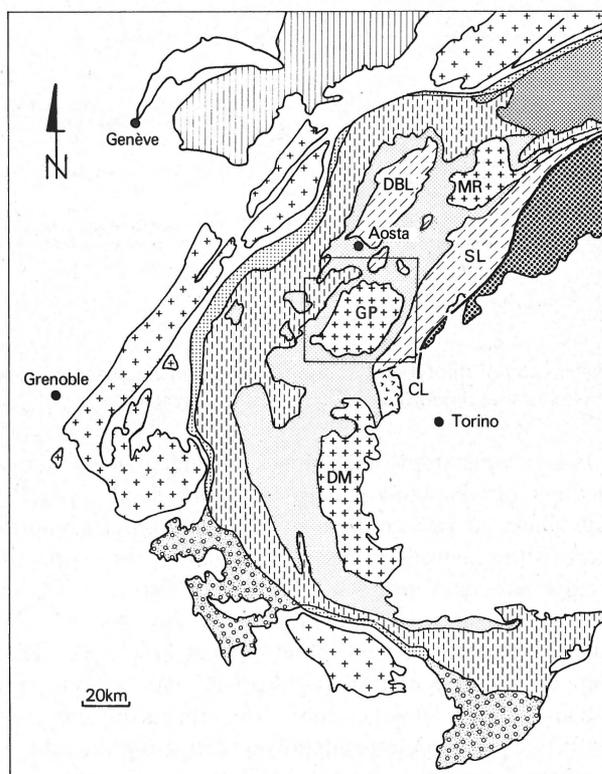


Fig. 1 Tectonic sketch-map of the Western Alps showing the location of the Gran Paradiso massif (enclosed area shown in Fig. 2).  
CL Canavese Line

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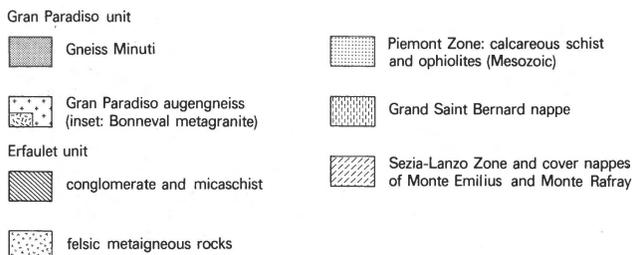
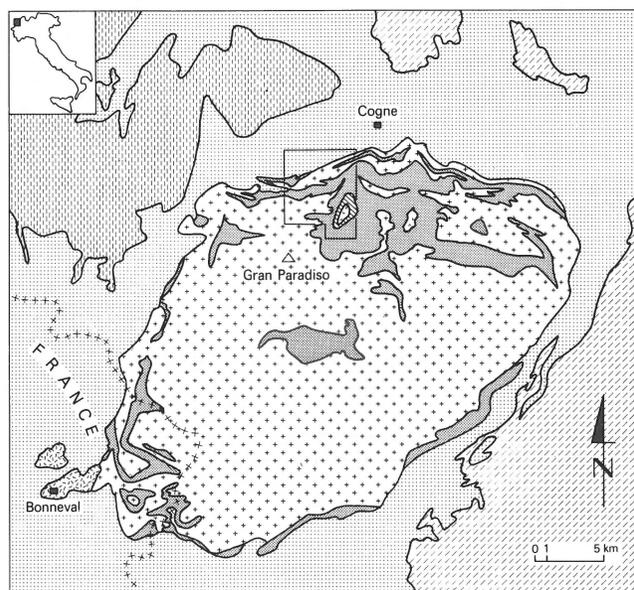


Fig. 2  
Sketch-map of the Gran Paradiso massif (from Compagnoni et al., 1974) showing the location of the area investigated.

In a previous study of the metasediments ('Gneiss Minuti') in the Gran Paradiso massif, COMPAGNONI ET AL., (1974) distinguished two groups of rocks. One group comprises most of the metasediments associated with the porphyritic metagranites and includes (garnet- and chloritoid-) quartz micaschists, albite-chlorite micaschists, fine-grained albite gneisses, and interlayered aplitic and metabasic rocks. These meta-sediments contain relics of pre-Alpine metamorphism and are hence polymetamorphic. The other group only crops out in two places underneath the polymetamorphic rocks and consists of graphitic albite micaschists and quartzose metaconglomerates. These rocks are associated with felsic metagneous rocks. The distinctly different lithology, the good preservation of sedimentary structures, the lack of metamorphic relics indicating pre-Alpine metamorphism, and comparison with similar sequences in the Dora Maira massif led COMPAGNONI ET AL. (1974) to refer to these rocks as the monometamorphic complex, separated from the polymetamorphic rocks by a subhorizontal overthrust contact. In addition, it was suggested that the complicated geometry of the porphyritic metagranites (augen gneisses) and associated polymetamorphic metasediments resulted from the deformation-related to overthrusting.

This paper is a preliminary report on detailed structural analysis and mapping in an area southwest of Cogne (Fig. 2). The analysis aims to demonstrate the macroscopic structure and the timing of the development of this structure relative to the Alpine metamorphism. The study area is made up of the two groups of rocks recognized by COMPAGNONI ET AL. (1974). The monometamorphic complex is referred to in this paper as the Erfault unit, and the polymetamorphic rocks and associated augen gneisses as the Gran Paradiso unit. Towards the north these units are overlain by the allochthonous Mesozoic cover and rocks of the ophiolite zone.

## STRUCTURAL HISTORY

The most prominent structural feature in the area is a penetrative foliation, (sub)parallel to the axial planes of tight to isoclinal folds. This penetrative foliation, referred to here as the main-phase foliation, probably cuts the contact of the Erfault and Paradiso units at a very low angle. This relationship follows from the construction of the cross sections (Fig. 3) and is unfortunately difficult to verify due to poor accessibility. The main-phase foliation has been used as a reference in structural correlation throughout the area.

Five generations of deformational structures ( $D_1$ - $D_5$ ) have been recognized. Two of these ( $D_1$  and  $D_2$ ) predate the main phase,  $D_3$  comprises the main-phase structures, whereas  $D_4$  and  $D_5$  are superimposed on the main-phase foliation.

The earliest ( $D_1$ ) generation of deformational structures recognized includes few tight cm-scale folds of a compositional layering refolded by (pre-mainphase)  $D_2$  folds. They occur in the polymetamorphic metasediments of the Gran Paradiso unit.

Tight to isoclinal  $D_2$  folds refolded by  $D_3$  folds occur at various localities in the metasediments.  $D_2$  folds display a shallow W-ward plunge. A penetrative foliation is (sub)parallel to the axial planes of these folds. In a few outcrops with weakly developed main-phase structures this foliation appears to be a differentiated layering, rarely with crenulations of an earlier foliation preserved in microlithons. In the augen gneisses, local relics of a pre-mainphase gneissic layering presumably represent  $D_2$  structures.

The structure of the area is dominated by a pervasive main-phase foliation related to the axial planes of tight to isoclinal  $D_3$  folds developed on all scales. In the metasedimentary rocks, the morphology of this foliation varies from a differentiated layering, with relics of crenulations in quartz-rich microlithons, to a pervasive schistosity. In many localities, the gneissic layering in the augen gneisses can be shown to be continuous with the  $D_3$  axial-plane foliation in the metasediments. With one exception, minor asymmetric main-phase folds of the contact between the augen gneiss and the metasediments have been observed to show a parasitic relationship with large-scale tongues of augen gneiss in

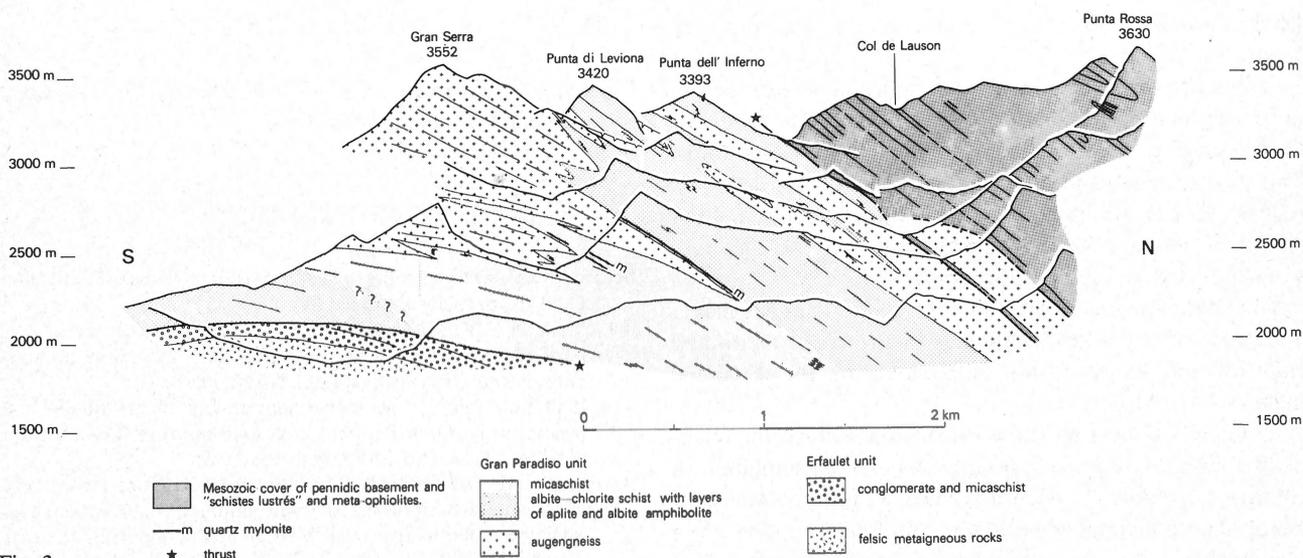


Fig. 3 Cross-sections through the area investigated showing major fold structure of the augen gneiss.

metasediments. These wedge-shaped structures must therefore represent strongly attenuated folds, with the main-phase foliation developed parallel to the axial planes (see Fig. 3). Locally, WNW-trending extension lineations have developed in the plane of the main-phase foliation.  $D_3$  fold axes commonly are subparallel to these lineations which possibly indicates a reorientation of the fold axes towards the  $D_3$  finite extension direction. This interpretation is supported by the local observation of metre-scale sheath folds, which poses the question as to possible large-scale effects of the  $D_3$  finite extension direction on the orientation of the gneiss-cored folds. Extended structural analysis over a larger portion of the Gran Paradiso massif is needed to verify such large-scale effects.

Quartz mylonite occurs in layers subparallel to the main-phase foliation. They are probably responsible for asymmetry in the spatial distribution of micaschist and albite-chlorite schist surrounding the large-scale gneiss-cored folds (Fig. 3), and may have caused considerable disruption of the fold structure. The mylonite zones could reflect the effects of ongoing  $D_3$  deformation localized in quartzite layers or, alternatively, be referred to a younger deformation episode which predates  $D_5$  described below.

Two generations of structures ( $D_4$  and  $D_5$ ) are superimposed on the main-phase foliation. As yet, their relative ages have not been established conclusively. The order in which they are referred to here is tentative, though considered as the most likely one in view of the nature of the associated strains. The  $D_4$  generation of structures comprises centimetre- to millimetre-scale ductile shear zones (extensional crenulation cleavages or shear bands) which deform the main-phase foliation either in single or in conjugate sets, the latter in a symmetric arrangement with respect to this foliation. They indicate deformation with a component of finite extension (sub)parallel to the main-phase foliation (PLATT & VISSERS,

1980) and might represent the effect of high-strain  $D_3$  deformation and/or correspond to the development of the quartz mylonites described above.

The  $D_5$  generation of deformational structures includes a moderately south-dipping crenulation cleavage parallel to the axial planes of minor folds which affect the main-phase foliation and the quartz mylonites. These structures are rare and mainly occur in a domain underneath the augen gneisses of the major fold structure. They might correspond to the doming of the main-phase foliation.

#### TIMING OF THE DEFORMATION RELATIVE TO THE ALPINE METAMORPHISM

The Eoalpine metamorphism in the rocks of the Gran Paradiso massif is reflected by the occurrence of omphacite + garnet  $\pm$  glaucophane in metabasic rocks, and talc + chloritoid  $\pm$  garnet or chlorite, glaucophane + chloritoid, and talc + phengite assemblages in Ca-poor aluminous micaschists (COMPAGNONI & LOMBARDO, 1974; CHOPIN, 1981).

The age of the  $D_1$  structures relative to this Eoalpine metamorphism is still obscure, for lack of diagnostic relationships of these structures with the above Alpine metamorphic minerals. The  $D_1$  structures occur in the polymetamorphic rocks of the Gran Paradiso unit which means that a pre-Alpine age of these structures cannot be excluded.

The rarely preserved omphacite and glaucophane bearing assemblages in the metabasic rocks are difficult to date relative to the deformation history for lack in these rocks of well developed pre-mainphase structures. If it occurs, the main-phase ( $D_3$ ) foliation is commonly defined by oriented blue-green amphibole, epidote and chlorite, indicating greenschist-facies conditions during the development of the  $D_3$  structures and suggesting a pre- $D_3$  age of the Eoalpine relics

which are mostly observed as inclusions in garnet porphyroblasts.

In chloritoid-garnet micaschists, chloritoid is included in pre-mainphase garnet, and has been observed in recrystallized aggregates delineating polygonal arcs of  $D_2$  microfolds. This probably indicates a pre- $D_2$  age of the chloritoid and suggests that  $D_2$  structures developed in the stability field of chloritoid, perhaps at elevated pressures. We envisage more work to elucidate these relationships.

The Lepontine metamorphism in the Gran Paradiso massif is characterized by the widespread blastesis of albite and chlorite, and concomitant replacement of the Eoalpine mineral assemblages.

In amphibole-bearing albite-chlorite micaschists the main-phase foliation is defined by oriented blue-green amphibole + chlorite  $\pm$  epidote  $\pm$  colourless mica. Porphyroblastesis of albite almost invariably postdates this foliation. The same relationship holds for albite-bearing garnet-quartz micaschists. In these rocks armoured relics of chloritoid may occur included in garnet indicating that chloritoid became unstable during the climax of the Lepontine metamorphism.

The  $D_4$  and  $D_5$  generations of deformational structures apparently postdate major albite growth, suggesting, that these structures developed in the waning stages of the Alpine metamorphic evolution.

## CONCLUSIONS

Structural analysis in the area investigated indicates that the geometry of the rocks of the Gran Paradiso unit primarily results from large-scale folding and concomitant development of the axial-plane (main-phase) foliation. We are inclined to conclude that the large-scale folding is related to individualisation of the Gran Paradiso unit, that is to say that the Gran Paradiso unit is a gneiss-cored fold nappe.

Our preliminary study of the microscopic deformational structures suggests that the main-phase structures postdate the Eoalpine HP assemblages and predate widespread porphyroblastesis of albite. These data suggest individualisation of the Gran Paradiso unit between the Eoalpine HP metamorphism and the culmination of the Lepontine greenschist-facies overprinting. This result correlates well with the timing of nappe development in the Zermatt-Saas Fee area (DAL PIAZ ET AL., 1972).

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