Time constraints on the metamorphic and structural evolution of the southern Sesia-Lanzo Zone, Western Italian Alps

W. Ramsbotham*
S. Inger
B. Cliff
D. Rex
A. Barnicoat

University of Leeds, Leeds, LS2 9JT, UK.

Introduction

The Sesia-Lanzo Zone (SLZ) is important as one of the most extensive segments of continental crust metamorphosed under eclogite facies conditions (Compagnoni *et al.*, 1977). Parts of the SLZ record a complex thermal and structural evolution including metamorphism under widely varying conditions over a long (probably >300Ma) timespan, whereas other elements of the SLZ seem to record only portions of this history (Lardeaux and Spalla, 1991). Aiming primarily to understand the mechanisms by which deep crust is exhumed, this study had a number of objectives: 1) Definition of a structural framework based on progressive deformation phases, tracking changes in the nature and site of the deformation flow through time. 2) Characterisation of metamorphism conditions under which diagnostic mineral fabrics were formed, thereby linking the strain history with the P-T evolution. 3) Isotopic dating of minerals which could be related to specific segments of the P-T-deformation path, to define the age of the high-pressure metamorphic peak and rates of subsequent exhumation which might be related to regional tectonics.

Geological Setting

This study was based on the Valle dell'Orco section in NW Italy, which exposes a number of tectonic units constituting the Alpine 'suture'. From west to east these are: 1) The Gran Paradiso Massif. Continental basement of European affinity, preserving Hercynian metamorphic asemblages partially overprinted during the Alpine orogeny. 2) The Piémont Zone. Oceanic rocks recording an early-Alpine eclogite-blueschist facies metamorphism which has been variably overprinted by an Alpine greenschist facies cycle. 3) The Sesia Lanzo Zone. Continental rocks of the Austroalpine realm, having African affinities and divided into a number of structurally and metamorphically distinct elements: a) Eclogitic Micaschist Complex. (EMC) The upper, eastern part of the unit, comprising metamorphosed igneous and sedimentary rocks of diverse compositions, recording in most cases an early-Alpine eclogite facies event which overprinted pre-Alpine granulite-amphibolite facies assemblages. The main high-pressure planar fabric (T_E) is defined by alignment of minerals that appear to have formed in a regime of general non-coaxial shear (D_1), with mica fabrics accommodating almost pure-shear flattening, but with rotation of strain markers into parallelism with T_E indicating a top-east vorticity. A later stage of the D_1 high-pressure deformation generated crenulation cleavages (T_{E2}), and both high-pressure fabrics were kinked by a subvertical, partly transpositional cleavage (TCC)developed under retrograde (?blueschist-greenschist) conditions. b) A transition zone in which pre-Alpine granulite-amphibolite facies fabrics and early-Alpine high-pressure assemblages have been partially retrogressed under greenschist facies conditions. Here, T_E and T_{E2} fabrics are rotated into parallelism with fabrics in the Gneiss Minuti Complex (see below), but without significant transposition. This deformation is referred to as D_2. c) Gneiss Minuti Complex. The lowest, external part of the Sesia Zone shows a thorough-going recrystallisation under greenschist facies conditions, to the extent that it remains controversial whether eclogite facies relics can truly be identified here. A penetrative deformation D_3 formed a uniform and consistent L-S fabric (T_G) at greenschist facies conditions in the GMC but did not penetrate the EMC.

The general hypothesis offered for the stuctural evolution in the SLZ is that eclogite facies deformation in the eastern zone may have had a top-east assymetry, whereas later, as the locus of deformation propagated westwards during exhumation, a top-west non-coaxial flow was estab-

**This work formed part of Will Ramsbotham's PhD research before his tragic death in June 1993.*

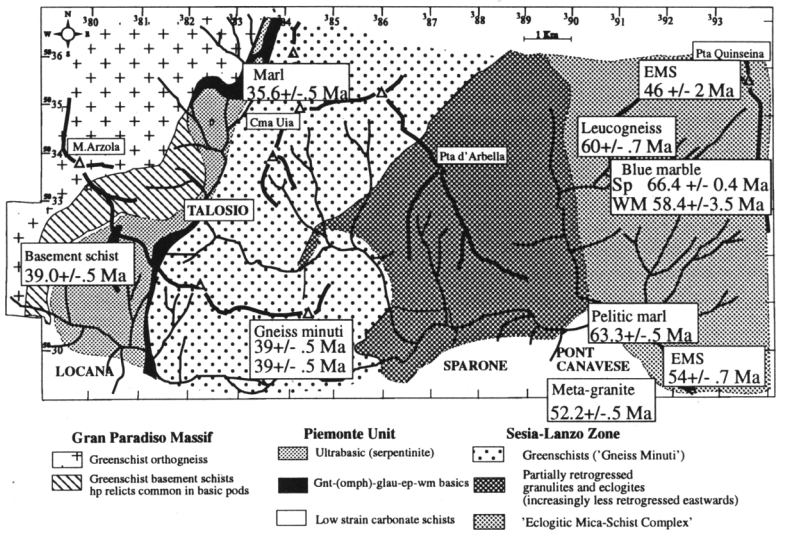

FIG. 1. Metamorphic sketch-map, with Rb/Sr dates, for the Valle dell'Orco.

lished. The basal contact of the GMC with the Piémont Zone is in turn characterised by top-SE directed shear (Wheeler and Butler, 1993).

Geochronology

Most of the previous geochronological studies in other parts of the SLZ yielded late Cretaceous mineral K-Ar ages, augmented by a single whole-rock and mineral Rb-Sr determination from which the widely-cited 'early-Cretaceous' age for the eclogite metamorphism was derived (Oberhnsli *et al.*, 1985). However, recent laser-^{40}Ar-^{39}Ar studies have shown that micas in the Ecogitic Micaschist Complex contain heterogeneously-distributed extraneous argon that must cast doubt on K-Ar determinations (Kelley *et al.*, 1993) This study utilises the Rb-Sr system on white micas because it is not susceptible to excess argon problems, and has a closure temperature closer to the thermal peak of the eclogite metamorphism. As a check, step-heated ^{40}Ar-^{39}Ar analyses were made on some of the same samples, and high-pressure titanite from calc-silicate lithologies has been dated by the U-Pb method because it probably has a closure temperature higher than the metamorphic temperature maximum and should therefore record the age of crystallisation of the assemblage in which titanite was stable.

Results are plotted on the map, showing their position in the geological framework. Rb-Sr phengite ages in the EMC vary from 46–63Ma, and could be interpreted as cooling ages since peak (eclogite) metamorphic conditions were probably 500–600°C, > 15kb. However, the large spread in ages of closely spaced samples suggests that additional processes besides cooling have influenced closure of the Rb-Sr system; partial rejuvenation during retrogression is ruled out by the near-absence of greenschist facies assemblages in the internal EMC. The U-Pb age of sphene at 66Ma is most likely to record an age during the high pressure event, although the exact point on the P-T path is poorly defined at present. Two ^{40}Ar-^{39}Ar determinations from the EMC yield good plateaux with ages exceeding the Rb-Sr date of the same sample by up to 11Ma.A third spectrum suggests minor argon loss and has a plateau 8Ma lower than the Rb-Sr age.An important point is that, even in the most internal, unretrogressed part of the EMC, no ages older than 70Ma were determined. Rb-Sr ages in rocks with pervasive greenschist fabrics cluster at 39Ma, the widely-accepted age of the Alpine regional metamorphism and penetrative top-west non-coaxial deformation at these levels (Hunziker *et al.*, 1992). A Piémont marl gives an age of 36Ma by Rb-Sr and ^{40}Ar-^{39}Ar; the concordance of these results probably reflects the thorough recrystallisation of assemblages under high fluid activities, and the younger age is consistent with many recent determinations from these levels (Inger, unpublished data) which may record the latest, top-east shear fabrics related to unroofing of the Piémont Zone.