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The high grade units of the Ivrea Zone in the Ossola Valley (Province Novara, Italy)*

by *Andy Stucki*[1]

Abstract

In an area of roughly 7 km^2 in the Ossola Valley, some of the lowermost crustal units of the Ivrea Zone are exposed. Virtually all rocks are of granulite facies grade. Metapelites and marbles, two types of basic and various ultramafic rocks occur. According to petrographic and structural criteria, the area studied has been divided into three units. These units are separated from each other by shear zones. Two large antiforms of different age are present within the area. Temperatures of metamorphism range from 700 °C to 950 °C while the pressures were at 7 to 9.5 kbars. After some isobaric cooling from peak metamorphic conditions, a decompressional phase was followed by another phase of isobaric cooling.

Keywords: metamorphic rocks, granulite facies, Ivrea Zone, Northern Italy.

Introduction

The Ivrea Zone in the Southern Alps represents a verticalized section through the attenuated lower adriatic continental crust (see excellent review by ZINGG [1990] for references). Today it is present as a suite of metamorphic rocks of amphibolite to granulite facies grade. It is generally believed that peak conditions of the high grade metamorphism are caused by the underplating of large volumes of basic magma. This event is of Permian age (VAVRA et al., 1995). The huge basic intrusive body ("Basischer Hauptzug" or "Main Basic Body") makes up most of the southwestern Ivrea Zone but also extends into the northeastern part. Metapelites, metacarbonate, older metabasic as well as ultramafic rocks are present throughout the entire Ivrea Zone. In the Val d'Ossola region, all these lithological units occur in close association. The high grade metamorphism has, as far as we know, erased all pre-Permian mineralogical features in these rocks. At least two phases of deformation predate the peak of metamorphism and are sometimes preserved (STECK and TIÈCHE, 1976; KRUHL and VOLL, 1976).

Along the eastern flanks of the lower Val d'Ossola, detailed work has been done (R. SCHMID, 1967) and the area presented here forms its western continuation up to the Insubric Line. Apart from studies on high temperature shear zones (BRODIE and RUTTER, 1987) and on the adjacent Insubric Line (S. SCHMID et al., 1987), the area was formerly not well known petrographically. Aim of this study is to confine the metamorphic conditions of the northeastern Ivrea Zone more precisely and to sketch the geodynamic evolution of this crustal part since the climax of metamorphism.

Petrography

LITHOLOGICAL UNITS (FIG. 1)

Many of the rock types encountered in the Ivrea Zone are shown in the rather small area shown here.

Metasediments are mostly metapelites. They are named stronalites, i.e. massive rocks forming layers up to 500 meters thick. They consist of feldspar, garnet, sillimanite, rutile and changing

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amounts of quartz and biotite. Metacarbonates are rare and confined to small layers and lenses. The main constituents are carbonate, diopside, olivine and spinel.

Basic rocks are present in two types. Pyriclasite is a term used for basic rocks containing plagioclase, pyroxenes and varying amounts of garnet. It represents the northeastern extension of the Main Basic Body. The term granofels is used to refer to a medium to coarse grained basic rock dominated by pargasitic hornblende. Apart from plagioclase, minor amounts of pyroxene and sometimes garnet are present. Granofels is not part of the Main Basic Body and seems to be of older age.

Ultramafics cover an impressive compositional range. Peridotites, as well as orthopyroxenites, clinopyroxenites, hornblendites and garnetites occur.

STRUCTURAL UNITS

Three units can be discerned based on petrographic and structural criteria. Their names, chosen rather arbitrarily, are not based on any previous work. The Vogogna Unit represents the wedge shaped western section made up primarily of granofels. The Vogogna Antiform is located in this unit. The eastern section is part of the Proman Antiform (R. SCHMID, 1967; BRODIE and RUTTER, 1987 and S. SCHMID et al., 1987). It can be divided into two units, Uppper and Lower Proman Unit. They are of different metamorphic grade and different prevailing microstructure (granoblastic versus porphyroclastic to mylonitic).

CONDITIONS OF METAMORPHISM

Introduction

Varying temperature and pressure estimates in the northeastern Ivrea Zone have been published: R. SCHMID and WOOD (1976) propose pressures in the range of 9 to 11 kbars for metapelites in the Valle d'Ossola and temperatures between 700 and 820 °C. HUNZIKER and ZINGG (1980) suggest that pressures from 4.7 to 10 kbars and temperatures from 540 to 820 °C prevailed. VOGLER (1991) carried out thermobarometry on basic rocks between

Geologic map 1:25.000

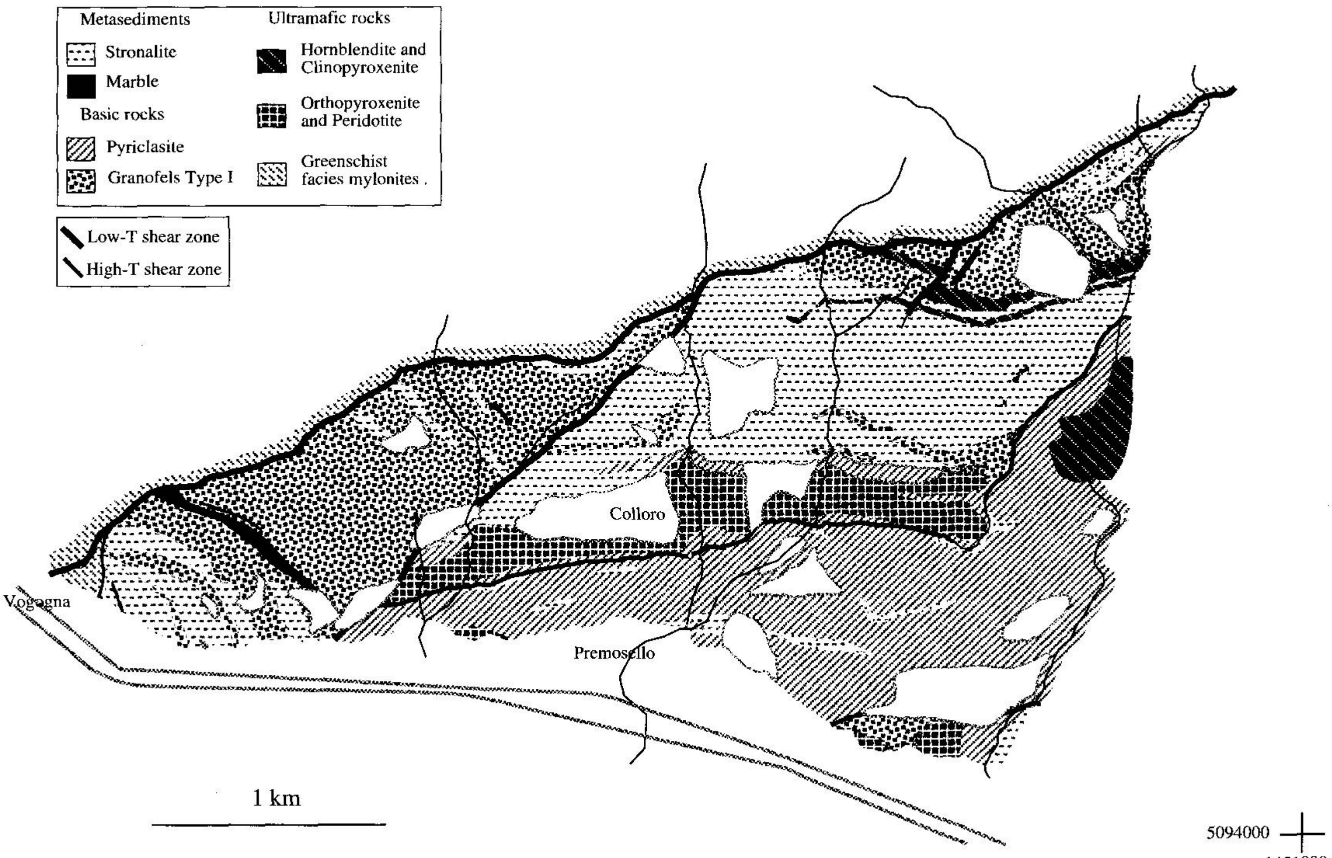

Fig. 1 Ivrea Zone/Val d'Ossola: geologic map.

Val Grande and Val Pogallo and proposes pressures from 7.5 to 9 kbars and temperatures from 800 to 900 °C. This scatter is partly due to the fact that rocks of different metamorphic grade were examined in these studies.

For this study, thermometry was done using the garnet-clinopyroxene thermometer from ELLIS and GREEN (1979) as well as the garnet-orthopyroxene thermometer (HARLEY, 1984). Pressure estimates were obtained from the garnet + sillimanite + plagioclase + quartz paragenesis (GASP, GHENT, 1976) in stronalite and from the orthopyroxene + plagioclase + garnet + quartz paragenesis in charnockites (MAGS, NEWTON and PERKINS, 1982) in quartz bearing basic rocks. Of special interest are thermobarometric results from retrograde solid-solid reactions. They help illuminate the P-T-history of the Ivrea Zone since the peak of high grade metamorphism.

Retrograde solid-solid reactions

Several retrograde solid-solid reactions have been described from basic rocks of the Ivrea Zone previously and were observed in this study. Among them are kelyphites around garnet (garnet + clinopyroxene = orthopyroxene + plagioclase + spinel) in pyriclasite and granofels (R. SCHMID, 1967; VOGLER, 1991) and garnet rims around orthopyroxene (orthopyroxene + plagioclase = garnet + clinopyroxene) in basic rocks of the Sesia Valley (SILLS, 1984). The formation of kelyphites is thought to have taken place during isothermal decompression with temperatures at around 800 to 850 °C and pressures dropping from 9 to 6 kbars (VOGLER, 1991). Garnet rimming orthopyroxene on the other hand results from a reaction taking place during isobaric cooling (SILLS, 1984).

In a garnet bearing clinopyroxenite, retrograde reactions unknown in the Ivrea Zone have been observed. In what is thought to be a former magmatic cumulate, garnet formed in two stages. At first garnet formed xenomorphic blasts between Al-rich clinopyroxene crystals and as rims around green spinel bordering plagioclase. In a later stage, garnet exsolved within Al-rich clinopyroxene as lamellae. This sequence of garnet forming reactions (including garnet rimming orthopyroxene) has been described in detail by ELLIS and GREEN (1985) from granulites of Enderby Land, Antarctica. All were interpreted to be cooling reactions.

Later retrograde phenomena are related to Alpine greenschist facies metamorphism. They are only present in localized, late shear zones or in close proximity to the Insubric Line.

Results

In the pyriclasites of the Lower Proman Unit, temperatures of 900 to 950 °C were obtained from crystal cores while the rims yield temperatures of 800 to 850 °C. Pressure estimates range from 8.5 to 10 kbars. In the Upper Proman Unit, charnockitic rocks yielded pressure estimates from 7.5 to 9 kbars and temperatures from 800 to 850 °C (cores) to roughly 750 °C (rims). Low P-T values were obtained from charnockites of the Vogogna Unit: about 700° and 6.5 to 7 kbars. This suggests it being an isolated block displaced from higher crustal levels.

The following results were obtained from retrograde solid-solid reactions: Thermometry on the garnet forming reactions in the above described clinopyroxenite yielded high temperatures of about 950 °C on the larger garnet blasts and roughly 900 °C on the garnet exsolution lamellae. As for the garnet rims around orthopyroxene, low temperatures between 600 and 650 °C were obtained. This set of data, in conjunction with formerly published thermobarometric data, allows to sketch a tentative pressure-temperature history for the Valle d'Ossola region of the Ivrea Zone (see Tab. 1).

Structural geology

The antiforms

A detailed description of geometry and characteristics of the Proman Antiform can be found in R. SCHMID'S (1967) work in the adjacent area to the east where more of the antiform is exposed. It has received further treatment by S. SCHMID et al. and BRODIE and RUTTER (both 1987) and is an isoclinal antiform displaying brittle deformation in the hinge zones and flexural slip parallel to the layering in the limb zones. It formed under greenschist facies conditions late during Alpine orogeny as a response to backthrusting along the Insubric Line (S. SCHMID et al., 1987).

The Vogogna Antiform to the west was considered to be of the same age as the Proman Antiform (S. SCHMID et al., 1987; BRODIE and RUTTER, 1987). However, there is some evidence for an earlier formation under higher temperatures. Its round open shape is completely different from that of the Proman Antiform. Apparently no brittle deformation accompanied its folding. This fact makes low temperature Alpine folding improbable considering the competent character of the rocks deformed (granofels and restitic stronalite). Furthermore, vergencies containing an earlier iso-

Tab. 1 Observations in rocks of the Ivrea Zone in the Valle d'Ossola region and their relation to large scale events in the Ivrea Zone.

	Ivrea Zone in general	Ivrea Zone in Valle d'Ossola	Time frame
PT1	Intrusion of large volumes of basic magma, peak of high grade metamorphism	Equilibration of granulite facies assemblage at temperatures up to 950 °C and pressures up to 10 kbars	Late Paleozoic: Permian (VAVRA et al., 1995)
PT2	Cooling from late magmatic temperatures in intrusive rocks	Garnet forming reactions in clinopyroxenite. Temperature drop by about 150 °C	Late Permian
PT3	Crustal extension	High temperature extensional shear zones; kelyphites rimming garnet in pyriclasites. Pressure drop by about 3 kbars down to 6 kbars	Early Mesozoic: Triassic (BRODIE et al., 1989)
PT4	Cooling in shallower crustal levels to temperatures below 600 °C	Garnet rims around orthopyroxene. Temperature drop down to 600 °C	Mesozoic (?)
PT5	Vertical movements during alpine backthrusting along Insubric Line	Folding of Proman Antiform, followed by low temperature faulting	Late Oligocene to Miocene (S.M. SCHMID et al., 1987)
PT6	Lateral strike-slip-movement along Insubric Line	Truncation of Proman Antiform and low temperature fault	Into Late Miocene (S.M. SCHMID et al., 1987)

clinal folding have been found in granofels with equilibrated microstructure matching the Vogogna Antiform geometry. This is in accordance with observations in the Valle Strona by CAPEDRI and RIVALENTI (1973), in the Finero complex by STECK and TIÈCHE (1976) and KRUHL and VOLL (1976) and in the Valle d'Ossola by SCHMATZ (1988) and TUCHSCHMID (1988). They observed that a first tight folding is followed by weaker, more open folding; both phases predating equilibration of microstructures during high grade metamorhpism.

HIGH TEMPERATURE SHEAR ZONES

Detailed work on high temperature shear zones in the Valle d'Ossola region was done by BRODIE and RUTTER (1987). Their work emphasized on the large shear zone separating Lower from Upper Proman Unit and pointed out the discrete nature of high temperature shear zones. However, high-T deformation was observed as pervasive mylonitization in all rock types of the Lower Proman Unit. Almost no undeformed textures were observed in this unit. In agreement with Brodie and Rutter's results is the fact that deformation, when present, is confined to discrete shear zones in the other two units. This high-T deformation took place during triassic crustal extension that brought the Ivrea Zone to shallower crustal levels (BRODIE, 1989).

LOW TEMPERATURE SHEAR ZONES

Low temperature mylonites of Alpine age are scattered throughout the area but confined to rather isolated, small shear zones. Very conspicuous are ubiquitous patches, veins and lenses of pseudotachylite cutting through all lithologic units. Besides numerous scattered occurrences pseudotachylites are concentrated in an intensely brecciated zone several meters wide along the large low temperature fault between the Vogogna Unit and the Proman Units. Apart from the Insubric Line, all structural features in the area studied are truncated by this vertically dipping fault which makes it younger than the Proman Antiform. It must have formed late during the Insubric backthrusting event and juxtaposed the Vogogna Unit to the Proman Units. The following Insubric strike-slip event then cut off all of the above structures. This sequence of movements along (and in the vicinity of) the Insubric Line was active between late Oligocene and late Miocene (S. SCHMID et al., 1987).

Conclusions

Most traces of a former geologic history predating Permian magmatism were erased by the subsequent high grade metamorphism.

Granulite facies metamorphism with temperatures between 700 to 950 °C, depending on crustal level, followed the intrusion of basic magma (PT1, see Tab. 1). A granoblastic microstructure developed in all rock types under pressures of 7 to 10 kbars. A slight cooling of 100 to 150 °C followed, indicated by garnet forming reactions in magmatic cumulates (PT2). During early Triassic crustal extension, the still hot Ivrea Zone was subsequently brought to shallower crustal levels. Uplift was accommodated by extensional high temperature shear zones. Kelyphites formed around garnet in basic rocks at roughly 6 kbars (PT3). Another phase of isobaric cooling then followed. Temperatures finally dropped below 600 °C, indicated by garnet rims around orthopyroxene (PT4). Any overprint of Alpine metamorphism on the high grade assemblages is very weak (greenschist facies) and is only locally present. Structurally however, some large scale features formed during Alpine deformation. The large Proman Antiform is a very prominent Alpine structure as well as a low-temperature fault which truncates the Proman Antiform. Both features formed during backthrusting along the Insubric Line (PT 5) which is then followed and truncated by a phase of strike-slip movements (PT 6).

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