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Prograde metamorphic evolution and development of chloritoid-bearing eclogitic assemblages in subcontinental metagabbro (Sesia–Lanzo zone, Italy)

G. Rebay *, B. Messiga

Dipartimento di Scienze della Terra, Università di Pavia, Via Ferrata, 1, I-27100 Pavia, Italy

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Abstract

In the coronitic metagabbroic rocks of the Corio and Monastero metagabbro bodies in the continental Sesia–Lanzo zone of the western Italian Alps, a variety of mineral reactions that testify to prograde conditions from greenschist to eclogite-facies can be recognised. A microstructural and microchemical study of a series of samples characterized by coronitic textures and pseudomorphic replacement of the original igneous minerals has allowed the prograde reactions undergone by the rocks to be established.

In completely eclogitized coronitic samples, paragonite, blue amphibole, garnet, epidote, fine grained jadeite and chloritoid occur in plagioclase microdomains (former igneous plagioclase). The mafic mineral microdomains consist of glaucophane and garnet. Complexly-zoned amphiboles constrain changing metamorphic conditions: cores of pre-Alpine brown hornblende and/or tremolite are preserved inside rims of a sodic–calcic amphibole that are in turn surrounded by a sodic amphibole. The main high-pressure mineral assemblage, as seen in mylonites, involves glaucophane, chloritoid, epidote, garnet±phengite, ±paragonite. Some layers within the gabbro contain garnet, omphacite, ±glaucophane, and acid dykes crosscutting the gabbro body contain jadeite, quartz, garnet, epidote and paragonite.

The presence of chloritoid-bearing high-pressure assemblages reflects hydration of the gabbros during their pre-Alpine exhumation prior to subduction, as well as the composition of the microdomains operating during subduction. The pressure and temperature conditions of gabbro transformation during subduction are inferred to be 450–550 °C at up to 2 GPa on the basis of the chloritoid-bearing assemblages. The factors controlling the reaction pathway to form chloritoid-bearing high-pressure assemblages in mafic rocks are inferred from these observations.

Keywords: Metagabbro; Chloritoid-bearing assemblage; Eclogite-facies; Sesia–Lanzo; Italian western Alps

1. Introduction

The typical anhydrous eclogite-facies assemblage garnet-omphacite was first described by Haüy (1822) almost two centuries ago (see Godard, 2001). Since then, such a high-pressure assemblage also involving hydrous phases has been described from various parts of the world. It is known that the study of these assemblages can give an insight into the mechanisms working in subduction zones (Poli, 1993; Poli and Schmidt, 1995; Forneris and Holloway, 2003). In

* Corresponding author.
E-mail address: rebay@crystal.unipv.it (G. Rebay).

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particular devolatilization in subduction zones is essential to arc magmatism and volatile recycling. The principal volatile components (H_2O and CO_2) are contained in hydrous and carbonate minerals. In the oceanic crust, volatile components in basalts are introduced by hydrothermal alteration at mid-ocean ridges. In the continental crust, hydrothermal alteration of basaltic rocks may occur by several mechanisms, and in rocks such as those studied here, it is ascribed to hydration of gabbroic rocks of the lower continental crust during exhumation in a rifting setting (Rebay and Spalla, 2001). One world-known example of continental rocks having been subducted is represented by the Sesia–Lanzo zone, in which the rocks studied here occur. It is therefore important to estimate the relevance of the continental crust to the budget of fluids that can go to mantle depths during subduction.

In the Western Alps several units, either of oceanic or continental origin have rocks that preserve high pressure assemblages with chloritoid that were exumed before the final collision. The presence of chloritoid in mafic compositions is particularly interesting because this mineral is stable at high pressures (Poli and Schmidt, 1995; Schmidt and Poli, 1998) and has been envisaged as one of the main carriers of fluids in the subducted plates (together with amphibole, zoisite and lawsonite). Experimentally determined stability conditions in basaltic compositions suggest that chloritoid is stable in mafic rocks at pressures between 2.2 and 3.1 GPa (Schmidt and Poli, 1998, and refs. therein). On the other hand, many other experimental and thermodynamic models do not observe chloritoid in basaltic compositions (Liu et al., 1996). It is therefore interesting to understand what are the factors leading to chloritoid formation, in order to understand in what tectonic setting (for example, hot vs. cold subduction) chloritoid is formed.

The Corio and Monastero metagabbro of the western Alps displays variably developed, locally chloritoid-bearing eclogite-facies mineral assemblages of Alpine age. Hence it has been studied here in order to throw light on the stability of chloritoid-bearing HP-mineral assemblages and the role of fluids in such continental gabbros.

The increasing percentage of Alpine high-pressure metamorphic minerals observed in a series of samples of these rocks allowed the identification of the different steps leading to the formation of a sequence of different high-pressure metamorphic associations in coronitic metagabbros. The sequence is recognizable both in space, that is in different microdomains (in the original plagioclase, amphibole and pyroxene grains), and in time, that is in relation to the pre-eclogitic transformations.

Samples coming from slightly deformed lenses in the eclogitized metagabbro body (Rebay, 2003) have been studied. These lenses are separated by mylonitic zones completely transformed under eclogite-facies and/or later greenschist-facies Alpine conditions. The rocks in the lenses preserve pre-eclogitic, pre-Alpine relics (Rebay and Spalla, 2001) and rocks with coronitic textures (coronites) display different Alpine metamorphic imprints (prograde assemblages). They show incomplete Alpine high-pressure re-equilibration, preserve prograde to peak mineral assemblages, and are only slightly retrogressed under greenschist-facies conditions. Moreover they preserve zoned minerals, especially amphiboles, whose compositional changes witness the progressive change of pressure–temperature (PT) conditions.

The variety of reactions leading to the high-pressure assemblages allows determination and quantification of both the factors influencing prograde metamorphism (i.e. the actual paragenesis present in the rock and microdomain composition in undeformed rocks), and those controlling the formation of the chloritoid-bearing high-pressure parageneses (i.e. mineralogy of the original rock, pre-Alpine metamorphism and whole rock composition).

2. Geological setting

The Sesia–Lanzo Zone (SLZ) is a tectonic unit of the western Alps consisting of eclogitized continental rocks deriving from the African margin (Fig. 1). The Variscan continental crust had a complex evolution (Nicot, 1977; Lardeaux and Spalla, 1991; Venturini, 1995; Rubatto and Gebauer, 1997). It was intruded, mainly in Permian times, by gabbro bodies (Dal Piaz et al., 1977; Lardeaux and Spalla, 1991; Rebay and Spalla, 2001) and granitoids, for example at Monte Mucrone, (Compagnoni and Maffeo, 1973; Compagnoni et al., 1977; Oberhänsli et al., 1985; Rubbo et al., 1999; Zucali et al., 2002). The SLZ was then subducted to depths of at least 60 km, with estimated P–T conditions of 550±50 °C and 1.8–2.1 GPa (Dal Piaz et al., 1972; Compagnoni, 1977; Pognante et al., 1980; Lardeaux et al., 1982; Oberhänsli et al., 1985; Pognante, 1989; Lardeaux and Spalla, 1991; Venturini, 1995; Inger et al., 1996; Tropper et al., 1999). The late Cretaceous age of the high-pressure re-equilibration (60–70 Ma, Inger et al., 1996; 69.2±2.7 Ma, Duchêne et al., 1997; 75–73 Ma, Cortiana et al., 1998; 65±5 Ma, Rubatto et al., 1999) is older than the high-pressure re-equilibration of the ophiolites of the Penninic nappes. Before the metamorphic peak, a pre-eclogitic stage in the glaucophane–zoisite or glaucophane–lawsonite stability field is recorded (Reinsch, 1979; Pognante et al., 1980). Following