Metapyroxenites from New Idria, California, USA

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Rocks consisting of chlorite, diopside, and titaniferous garnet from from New Idria, California, USA, are interpreted as metamorphosed pyroxenites that are part of a serpentinite massif. These rocks represent fragments of oceanic crust or underlying mantle, emplaced within the Franciscan complex during subduction of the now-defunct Farallon plate during the Jurassic. The metapyroxenites, along with other tectonic inclusions in the serpentinite, carry important geochemical clues to the nature of subduction zone processes. The metapyroxenites may themselves be tectonic inclusions. The New Idria occurrences have strong affinities to metapyroxenites from the Malenco serpentinite in the Alps.

Introduction

The New Idria serpentinite is a large (23 by 8 km) serpentinite diapir that is a member of the Coast Range Ophiolite in California. The age of the ophiolite is 153 to 165 Ma. (Hopson *et al.*, 1981); its emplacement within the Franciscan Formation is related to subduction of the Farallon plate in the Jurassic. During the Miocene, the New Idria serpentinite experienced an interval of rapid uplift, low-greenschist facies metamorphism, and intrusion of small syenite stocks.

The mineralogy of the serpentinite is dominated by chrysotile; New Idria is the largest deposit of chrysotile asbestos in the northern hemisphere (Klein, 1993). Brucite, accessory magnetite, and minor lizardite and antigorite are present. The protolith for the serpentinite was a depleted peridotite consisting of dunite with minor harzburgite. Locally within the serpentinite, foliated blocks of chlorite + diopside + titaniferous andradite + accessory minerals are preserved. These blocks are of limited extent, with sheared and possibly faulted contacts against the surrounding serpentinite. They are recognizable in the field by distinct soil color and erosion properties, contrasting vegetation above, and anomalous mineral assemblages within. The bulk composition of the blocks is significantly different from the bulk serpentinite.

Analysis

The minerals of the blocks have been suggested to be metasomatic in nature. Coleman (1957) proposed a process of alteration of serpentine rock to one containing chlorite, diopside and garnet, by aqueous fluids importing Ca, Al, Ti, and Fe while exporting Mg and Si to the surrounding environment. Given the low abundance of Ti in the depleted serpentinite, long-distance Ti transport from a source region is required by this hypothesis. Current understanding of the very limited mobility of Ti in crustal rocks (e.g. Van Baalen, 1993), demands a search for a mechanism other than metasomatism. The penetratively foliated textures of the chlorite-diopside-garnet rocks suggest powerful shear during the crystallization of the chlorite. Serpentine rock in the area, while generally sheared, never shows this penetrative foliation, further weakening the metasomatism hypothesis.

A typical anhydrous bulk analysis of the chlorite-diopside-garnet rock is SiO_2 39.39%, TiO_2 1.25%, Al_2O_3 11.82%, Fe_2O_3 14.56%, MnO 0.21%, MgO 19.24%, CaO 12.81%, Na_2O 0.21%, K_2O 0.00%, P_2O_5 0.00%, Total 99.49 weight %. Recasting the bulk composition into its anhydrous mineral equivalent requires an alternate norm calculation, in which CIPW minerals are replaced by their high pressure equivalents. This calculation shows the dehydrated equivalent of the chlorite + diopside + Ti-garnet rock to be a pyroxenite, falling within the clinopyroxenite or olivine websterite fields in the IUGS classification. The two pyroxenes and lesser olivine in such a rock would have been accompanied by an aluminous phase, e.g. plagioclase, spinel, or pyrope garnet depending on the pressure at the time of crystallization. The Ti in such a rock would most probably have been concentrated in clinopyroxene or spinel.

It is therefore proposed that the chlorite-diopside-garnet blocks represent essentially isochemical metamorphism of pyroxenites contained within the larger serpentinite, with only H_2O required as an open system component. Based on fluid inclusion data (Van Baalen, 1991), the most recent metamorphism is believed to be of the greenschist facies (about 300–400°C, 1–3 kbar). The chlorites are mainly of clinochlore composition, with variable Fe. Many clinopyroxenes are near end-member diopside composition. Comparison of coexisting chlorite and clinopyroxene show that $[Mg/(Mg+Fe)_{cpx}]$ is always greater than $[Mg/(Mg+Fe)_{chlorite}]$. Total $Mg/(Mg+Fe)_{bulk}$ varies from outcrop to outcrop; mineral compositions vary accordingly.

The Ti-garnets in the blocks are titaniferous andradites (schorlomite), with Ti contents up to 16 wt %. This garnet is metamorphic; it contains a negligible pyrope component. A first generation of garnet occurs in foliation-parallel blebs and stringers; a second generation occurs in cross-cutting veins interpreted as tension cracks. The vein garnets are strongly zoned, with Ti-rich cores and Ti-poor rims; many are anisotropic and hydrous. Their presence demonstrates Ti mobility in aqueous fluids on a limited scale only. Compositional variation in these garnets is best explained by the exchange vectors $TiFe_{-1}$ and H_4Si_{-1}, applied to the andradite formula (this study; Lager *et al.*, 1989).

Discussion

Extreme weathering and alteration at New Idria make geological interpretations ambiguous in many cases. However, at Val Malenco in the Italian Alps, relatively unweathered chlorite + diopside + Ti-garnet rocks are preserved within the Penninic Malenco serpentinite (Müntener and Hermann, 1994). The rocks are interpreted by these authors as metapyroxenites contained within the larger serpentinite; they have been sheared into boudins. Locally, primary igneous layering is preserved. Peak metamorphic conditions at this locality are somewhat higher (400–450°C, 5 ± 2 kbar) than at New Idria, but the mineral assemblage and compositions of individual minerals are very similar to the New Idria occurrences (the New Idria chlorites are somewhat more Fe-rich). At Val Malenco the metapyroxenites are proposed to be of cumulate origin.

The tectonic environments in which the New Idria and Malenco serpentinites were formed have basic similarities but also major differences: the New Idria serpentinite is a diapir which has risen through the Franciscan accretionary prism; the Malenco serpentinite is a flake occupying a structural position between the Pennine and overlying Austroalpine nappes. The assemblage chlorite + diopside + Ti-garnet is uncommon in nature; its appearance in these two environments has implications for the emplacement and evolution of ophiolites.

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