Metasomatism in two natural peridotites: effects of low-$aSiO_2$ melts

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Introduction

Metasomatism of upper mantle peridotites is a crucial process in the genesis and evolution of magmas in the mantle, yet the knowledge about actual metasomatic agents and processes during metasomatism is still imperfect. No clarity exists about chemical signatures enabling one to distinguish between possible agents (fluids, silicate melts, carbonatite melts) interacting with the peridotites. We are studying two occurrences of peridotites showing metasomatic reaction relationships, in which the responsible agents are preserved or can be shown to be alkaline silicate melts. These are the Inagli Dunite, Siberia, and the Gees xenolith suite, West Eifel.

Inagli Dunite

The Inagli Dunite is a magmatic cumulate dunite within an alkaline-ultramafic high-level (P ≈ 1 kb) magma chamber on the Aldan Shield in Eastern Siberia. Primary phases are very magnesian olivine (Fo_{90-95}) that is rich in CaO (up to 0.6 wt%), and spinel forming a picrochromite-magnetite series, with Cr/Cr+Al > 0.8. The dunite is cut by felsic pegmatite and apatite-clinopyroxenite veins. Within the dunite, pervasive melt infiltration textures are preserved. A melt volume is traced by newly formed chrome diopside (up to 3 wt% Cr_2O_3) and phlogopite. Infiltration was simultaneous with a deformation event, and an accessory paragenesis including apatite, sphene, magnetite, perovskite and monticellite is present . Thermometric analysis of mineral chemistries yields cooling reequilibration T of 700 to 900°C. Log f_{O_2} recorded by olivine-spinel, expressed as ≈FMQ, is +3 to +5, using the Ballhaus *et al.* (1991) formulation. As the dunite is part of a magma chamber and the metasomatically introduced phases are the same as present in circumdunitic cpx cumulates, the metasomatizing melt can be no other than an alkaline silicate melt fractionated to some degree. Phase chemistries (Ti, Ba, Sr enrichments and frequent lack of sufficient Si+Al to fill tetrahedral sites) point to a basic lamprophyric melt as metasomatizing agent. CaO in melt can be estimated at 8–12 wt% and Na+K/Al ≈ 0.9. Olivine + Cpx define $aSiO_2$; using the program QUILF of Andersen *et al.* (1993) its value during metasomatism has been calculated (Fig. 1). As values depend on accurate analysis of very small quantities of Ca in Ol, there is large scatter, but the bulk of results fall within $aSiO_2$ of 0.1-0.3, consistent with actual occurrence of leucite-bearing cumulates.

Gees xenoliths

Metasomatized Dunites with similar phase compositions (high-Fo, high-Ca Ol, accessory chromian diopsidic cpx ± phl) are known from mantle xenolith suites (e.g. Olmani+Lashaine; Eifel) and form part of a harzburgite-wehrlite-dunite metasomatic series which has been linked to carbonatite metasomatism (Thibault *et al.*, 1992). We have investigated about 50 fresh xenoliths from Gees in the West Eifel, where carbonatite metasomatism has been suspected (Dalton and

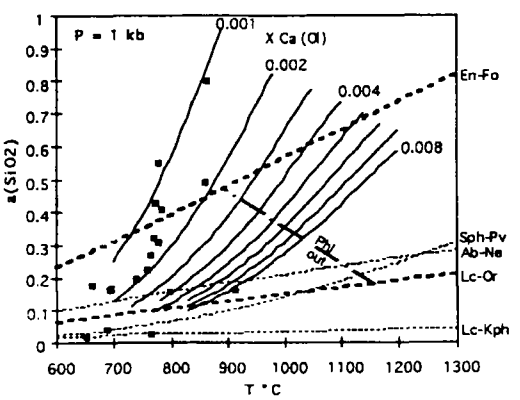

FIG. 1. T–$aSiO_2$ analysis of metasomatism in the Inagli Dunite. Silica buffers: En = enstatite, Fo = forsterite, Sph = sphene, Pv = perovskite, Ne = nepheline, Ab = albite, Lc = leucite, Or = orthoclase, Kph = kaliophilite. Contoured for XCa (Ol) = Ca/(Ca + Fe + Mg) in olivine in equilibrium with cpx. Line 'Phl out' is stability limit of phlogopite after Wones & Gilbert (1982). Squares: calculated T–$aSiO_2$ values for individual Ol/Cpx pairs using the program of Andersen *et al.* (1993).

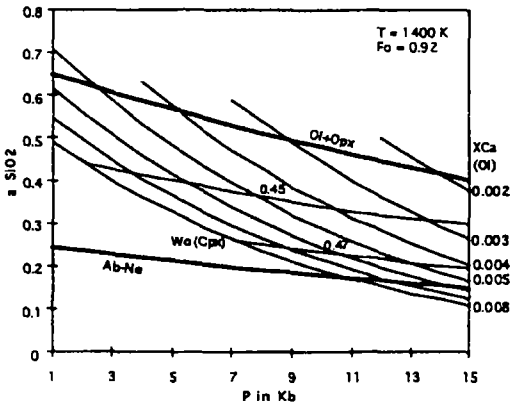

FIG. 2. Calculation of ol + cpx compositions at $aSiO_2$ lower than ol + opx equilibrium. Thick solid lines are silica buffers; Ab–Ne buffer is taken to represent silica-undersaturated melt activities. Thin lines give $aSiO_2$ at labelled values of XCa (Ol) or XWo (Cpx). All values for XFo = 92 in Ol; change of $aSiO_2$ with Fo is insignificant. Calculated as Fig. 1. using the program QUILF of Andersen *et al.*, 1993.

Wood 1993). The general petrography of this spinel lherzolite suite, which is entrained in a primitive basanite, has been given by Lloyd *et al.* (1991). It consists of harzburgites (protogranular and sheared), lherzolites and a dunite-wehrlite series formed by metasomatic introduction of cpx and abundant phlogopite. Further there are various types of magmatic clinopyroxenite and websterite cumulates. Most xenoliths have ubiquitous intergranular melt quenched to glass (see Edgar *et al.*, 1989), which is highly alkaline (Na_2O+ K_2O 4–11 wt%), and aluminous (20wt%) at varying silica contents. Edgar *et al.* assumed it to be of mantle origin. Our data support this interpretation, arguing against low-pressure melting or amphibole breakdown, but approx. 5% olivine or 20% cpx must be remixed into the glass to achieve equilibrium compositions (both phases occur as quench crystals). Reconstructed melt compositions are similar to those of Schiano and Clocchiatti 1994. The melt is highly reactive with respect to opx which decomposes to glass + ol + cpx, strongly enriching the melt in silica.

Discussion

Comparison of the opx-consuming reactions of Gees with the opx-absent, low-$aSiO_2$ metasomatism in Inagli demonstrates that the dunite-wehrlite association can be explained by interaction with opx-undersaturated silicate melt alone, without invoking an ephemeral carbonatite melt. Calculation of phase compositions of ol + cpx (1130°C, 15kb) at silica activities typical of alkaline melts ($\approx$ 0.2 compared to $\approx$0.4 as buffered by harzburgite) shows that high-Ca compositions are attained in both phases with decreasing silica activity (Fig. 2). Typical values are Wo = 0.47 in cpx and XCa = 0.005 in olivine. Such Ca-enrichment of phases in contact with intergranular glass is well visible in the Gees xenoliths. Calculation of silica activities of metasomatic ol + cpx in samples still bearing opx typically yields values slightly lower than opx-buffered equilibrium, and in cumulate clinopyroxenites are even lower. Yet, as equilibrium Ca concentrations decrease more rapidly with increasing pressure than buffered silica activities, we expect high-Ca ol+cpx to be a feature of alkaline melt metasomatism in comparatively shallow upper mantle only.

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