Mössbauer characterization of upper mantle ferrikaersutite

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ABSTRACT

Mössbauer spectroscopy, H2O, and microprobe analysis techniques have been used to study upper mantle ferrikaersutite megacrysts from the scoria cones of the Ash Sham alkaline volcanic field, northeastern part of the Arabian plate. Mössbauer spectra, collected at 298 K, indicate that the kaersutites are highly oxidized and all iron occurs as Fe3+. Two components were detected within the Fe3+ quadrupole splitting distribution of the C-type sites and were assigned to M1 and M2-3 sites. The quadrupole splitting (QS) varies between 0.73–0.87 mm/s (Fe3+ M1) and 1.28–1.45 mm/s (Fe3+ M2-3). The kaersutite has a large oxy component in the amphibole OH-site (1.49–1.85 O2– apfu) similar to the mantle-derived kaersutites. The very high ferric concentration in the kaersutites would suggest crystallization from a relatively oxidizing magma, perhaps with fo2 close to the fayalite-magnetite-quartz (FMQ), and may be a function of the high Fe3+/Fe2+ of the metasomatic fluid that crystallized these amphiboles.

Keywords: Mössbauer, microprobe, ferrikaersutite, upper mantle, Arabian plate, oxidation, metasomatism

INTRODUCTION

Kaersutite, NaCa4[(Mg,Fe2+)4Ti]3(Si6Al2)O23(OH) belongs to the calcic subgroup of amphiboles (Leake et al. 1997). It is formed through crystallization from mafic-ultramafic melts at low to moderate pressure (≤1.0 GPa), high temperature (>950 °C) and low to moderate oxygen fugacity (Allen and Boettcher 1978; Obata et al. 1986; Wallace and Green 1991; Dyar et al. 1992a, 1992b; Oba 1997; Ernst and Liu 1998).

Several geochemical and mineralogical studies on amphiboles have been focused on mineral analyses and H isotope behavior (e.g., Graham et al. 1984; Bryndzia et al. 1990; Deloule et al. 1991). Crystallographic studies of the kaersutite structures and compositions have been carried out by several authors (e.g., Pechar et al. 1989; Popp et al. 1990, 1995a, 1995b, 2006; Young et al. 1997; King et al. 1999a). Investigations on metasomatized upper mantle xenoliths and associated megacrysts indicate that metasomatism is associated with distinctive sets of high ferric percentages in upper mantle mineral phases and suggest an interrelationship between Fe3+ and H+ in these minerals (Wood and Virgo 1989; McGuire et al. 1989, 1991; Dyar et al. 1989, 1992a, 1992b, 1993; Popp et al. 1995a, 1995b; Young et al. 1997; King et al. 1999a; Gunter et al. 2003).

Mössbauer spectroscopy of minerals is an established technique that provides precise, highly reproducible Fe3+/Fe2+ ratios and yields quantitative information about Fe3+ and Fe2+ site occupancy (Dyar 1984). Hawthorne (1983) and Gunter et al. (2003) summarized numerous Mössbauer studies of amphibole sample from the literature. However, there are few existing analyses of mantle kaersutite for which Fe3+ has been measured (e.g., Schwartz and Irving 1978; McGuire et al. 1989; Dyar et al. 1993; Popp et al. 1995b, 2006), and only little is known about the Mössbauer spectra of upper mantle oxy kaersutite. Because routine electron microprobe analyses do not give direct data on ferric/ferrous ratios of amphiboles, recourse has been made to calculations of valence states from simple assumptions on stoichiometry. Problems and major drawbacks of such calculations have been extensively discussed (e.g., Droop 1987; Deer et al. 1997; Schumacher 1991, 1997).

This paper presents the results of a study of upper mantle ferrikaersutite megacrysts hosted in scoria cones from the Harrat Ash Sham volcanic field (Fig. 1), using Mössbauer spectroscopy, H2O, and microprobe analysis. We then discuss the implications of the findings for the origin of these ferrikaersutite megacrysts in relation to mantle oxygen fugacity and metasomatism.

PETROGRAPHY

The megacrysts and associated upper mantle xenoliths occur in Tertiary to Quaternary alkali olivine basalts and basanites of the Harrat Ash Sham volcanic field. The dominant megacryst phases in the Harrat Ash Sham Volcanic field are Al-clinopyroxene, Al-bronzite, pleonaste spinel, and kaersutite amphibole (Nasir 1995). Major and trace element partitioning in these megacrysts indicates that most of the megacrysts may have been in equilibrium with their host magmas at high pressure (Nasir 1995). The megacrysts are distinct in their petrography and chemistry from minerals in the associated Cr-diopside Iherzolite xenoliths, but are similar in their chemistry to minerals of the Al-rich augite xenolith group (Nasir 1995). Several kaersutite megacrysts were collected from the scoria cone of the Tertiary Dhanoon volcano in the Harrat Ash Shama alkaline volcanic field (Fig. 1). Five representative megacrysts (KM1, KM2, KM3, KM4, and KM5) were selected for this study. Kaersutite