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LATE METASOMATIC ADDITION OF GARNET TO THE SCLM: OS-ISOTOPE EVIDENCE

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INTRODUCTION

Archean cratons are underlain by highly depleted subcontinental lithospheric mantle (SCLM). However, xenolith and xenocryst data suggest that Archean SCLM has been extensively refertilized by metasomatic processes, with the addition of Fe, Ca, and Al to depleted protoliths. The distribution of sub-calcic pyropes in the SCLM beneath the Siberian craton suggests that (1) sub-calcic pyropes and diamonds are metasomatic phases in the cratonic SCLM; (2) the distribution of both phases is laterally heterogeneous on relatively small scales and related to ancient structural controls (Malkovets et al., 2007). More advanced metasomatism of sub-calcic garnets leads to formation of lherzolitic pyropes varying widelt in Cr and Ca contents along the lherzolitic trend (Griffin et al., 1999b; Burgess et al., 2004). However, the timing of such metasomatic events and formation of pyropes in cratonic mantle is still unclear.

Conventional Sr and Nd methods of isotope dating have failed to give any reasonable ages for garnet-bearing lherzolites. Sr and Nd isochron ages calculated for Cpx and Gar typically give ages close to the eruption age of the host magma. Bulk Earth Sm-Nd model ages of harzburgitic sub-calcic pyropes from the Udachnaya pipe vary from Paleoproterozoic to Archean (1.7-3.0 Ga; Pearson et al., 1995). Whole-rock Re-Os dating of peridotites reflects the mixing of different generations of sulfides and the interpretation of such data in terms of depletion ages therefore becomes ambiguous (Alard et al,. 2000, 2002; Griffin et al., 2002).

Sulfides, which are commonly found as an accessory mineral in mantle peridotites, usually have high concentrations of highly siderophile elements (HSE). Recent developments in the *in situ* analysis of sulfide phases made them available for *in situ* Re-Os dating (Pearson et al., 2002, Griffin et al., 2002, Alard et al., 2002). To *In situ* Re-Os dating of sulfides inclusions in olivine xenocrysts from the Udachnaya pipe gave model ages between 2.5 and 3.6 Ga with majority being older than 2.8 Ga (Griffin et al., 2002). To constrain the timing of the deposition of pyrope in the Siberian cratonic lithosphere we have picked pyropes with sulfide inclusions from heavy concentratse of kimberlites for *in situ* Re-Os dating.

Here we present the results of *in situ* Re-Os study of individual sulfide grains enclosed in xenocrystic pyropes from the middle-Paleozoic diamondiferous Internationalnaya kimberlite pipe, Malobotuobia field, Siberian craton, Yakutia.

GEOLOGICAL BACKGROUND

The Internationalnaya pipe is situated in the middle Paleozoic Malobotuobia kimberlite field in the southern part of the Yakutian diamondiferous province. Malobotuobia field consist of seven kimberlite bodies, of which four contain diamonds in economic quantities – XXIII Party Congress, Mir, Internationalnaya and Dachnaya pipes. U/Pb dating of zircons from Mir pipe gives a middle Paleozoic age for kimberlite intrusion in the Malobotuobia field (Davis et al., 1980; Griffin et al., 1999a). Fresh mantle xenoliths occur in the Mir pipe, while in the Internationalnaya pipe most of them are completely altered. Diamond inclusion studies show an overwhelming preponderance of peridotitic over eclogitic parageneses (Sobolev et al., 1997).

Kimberlites of the Malobotuobia field intruded within the Archean Magan terrane of the Siberian Platform. The Archean basement is covered by a thick section of Paleozoic sediments. Sparse Nd model ages for crustal xenoliths from the Mir pipe and basement rocks from the drillholes around the Malobotuobia field suggest crustal formation from 2.6 to 3.45 Ga, with a major metamorphic event >2.6 Ga, and minor magmatic events associated with craton amalgamation around 1.9-2.0 Ga (Rosen et al., 1994; Smelov et al., 2007).

SAMPLE DESCRIPTION

Pyropes

More than 3000 pyropes from the -4+2 sieve class mm were carefully examined under binocular microscope to find grains with sulfide inclusions. 110 pyrope grains with single or multiple sulfide inclusions have been selected for this study. They were set in individual epoxy mounts and polished to expose sulfide inclusions, which vary in size from 25 to 70 microns.

ANALYTICAL METHODS

Major element analyses of the sulfide phases and the host pyropes were done on a JEOL Superprobe at VS Sobolev Institute of Geology and Mineralogy SB RAS, Novosibirsk, Russia and on a CAMECA SX100 at GEMOC National Key Centre, Macquarie University, Sydney, Australia. The distribution of elements was mapped using energy-dispersive detectors INCA 350 attached to a LEO 1430VP electron microscope (Novosibirsk) and LINK attached to the CAMECA SX100 (Sydney). Re-Os isotope data have been collected *in situ* using a Merchantek LUV266 laser microprobe attached to a Nu Plasma multi-collector ICPMS. The analytical and calibration procedures and the applied corrections as well as reproducibility of analyses of standard materials are described in detail by Pearson et al. (2002).

MINERALOGY

Pyropes

The compositions of the pyropes with sulfide inclusions are presented in Figure 1. All are Cr-bearing (>2wt.%) and thus classified as peridotitic. Most fall into the lherzolitic field, indicating equilibrium with both clinopyroxene and orthopyroxene. Pyrope Int-92 with high CaO (10.65 wt.%) and low Cr_2O_3 (3.44 wt.%) represents a wehrlitic paragenesis (i.e. equilibrium with clinopyroxene only). Ten pyropes classify as sub-calcic or G10 (i.e. equilibrium with orthopyroxene only), similar to those found as inclusions in diamonds (Sobolev et al., 1973).

Sulfides

Sulfide images show that most sulfides consist of several phases varying in Fe, Ni, Cu, and S contents. Based on the morphology of the sulfide inclusions, their internal structure and the compositions of coexisting phases we interpret these as low-temperature assemblages that exsolved from single high-temperature solid solutions during cooling subsequent eruption of the host kimberlite.

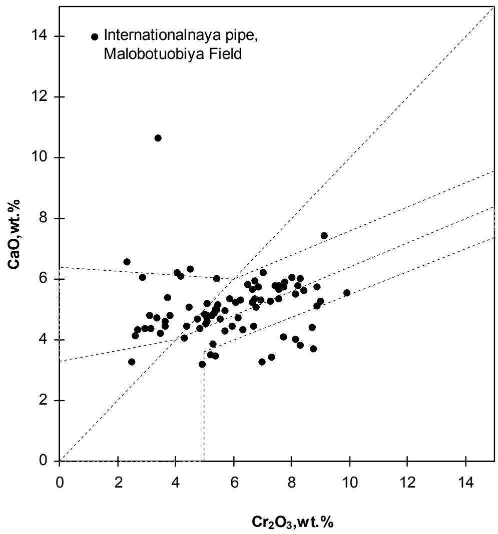

Figure 1. Cr_2O_3 vs CaO in pyropes with sulfide inclusions. Fields after Sobolev et al. (1973).

RE-OS DATA

Re-Os isotopic compositions have been determined by laser ablation MC-ICPMS for 105 sulfides included in pyropes. Most analysed sulfides (~84%) have very low $^{187}Re/^{188}Os$ ratios (<0.07). Modeling by Griffin et al. (2002) suggested that sulfides with $^{187}Re/^{188}Os$ <0.07 are unlikely to have been disturbed any metasomatic events.

T_{CHUR} and T_{RD} model ages for most sulfides are >2.2 Ga (Figure 2 and 3). T_{CHUR} ages fall mainly between 2.2 and 3.2 Ga (±0.03 Ga, mean 2s analytical uncertainty; Figure 2).

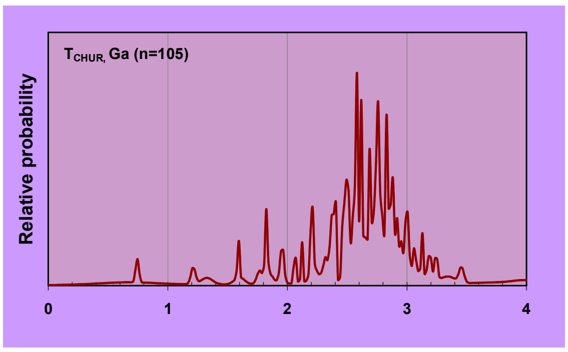

Figure 2. Cumulative probability diagram of T_{CHUR} model ages (model parameters of Shirey and Walker, 1998).

Re-depletion ages (TRD) als fall between 2.2 and 3.0 Ga (±0.03 Ga, mean 2s analytical uncertainty; Figure 3). 10 to 15% of the sulfides give younger TRD down to 600 Ma.

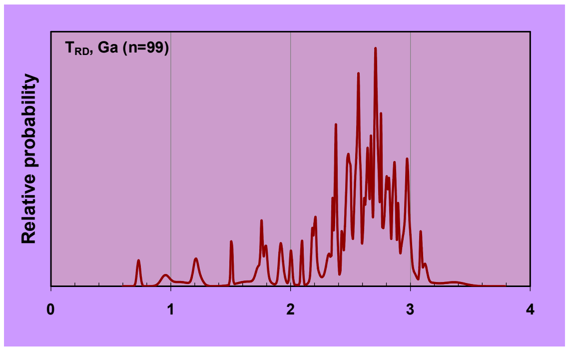

Figure 3. Cumulative probability diagram of T_{RD} model ages (defined by Walker, 1989).

In cumulative probability plots one mode with the maximum at 2.7 Ga is evident for both T_{CHUR} and T_{RD} ages. This age correlates with the age of the major crustal metamorphic event (M_1) in the Magan and the Daldyn terrains.

DISCUSSION

There are few published Re-Os data for sulfides from Siberian xenoliths (Pearson et al., 1995) and xenocrysts (Griffin et al., 2002). Both of these papers deal with samples from the Udachnaya pipe, in Daldyn kimberlite field which is situated 700 km north of the Malobotuobia field. However, Udachnaya is the only pipe with which we can compare our data.

T_{CHUR} model ages for sulfides from olivine xenocrysts from Udachnaya pipe (Griffin et al., 2002) and our T_{CHUR} model ages for sulfides from pyrope xenocrysts from Internationalnaya pipe are plotted for comparison on Figure 4.

Our previous study of sulfide inclusions in megacrystic olivines from the Udachnaya pipe suggests that most of the SCLM beneath the Daldyn kimberlite field formed at 3-3.5 Ga, and that lithosphere formation culminated at ca 2.9 Ga (the biggest peak at the Figure 4) (Griffin et al., 2002).

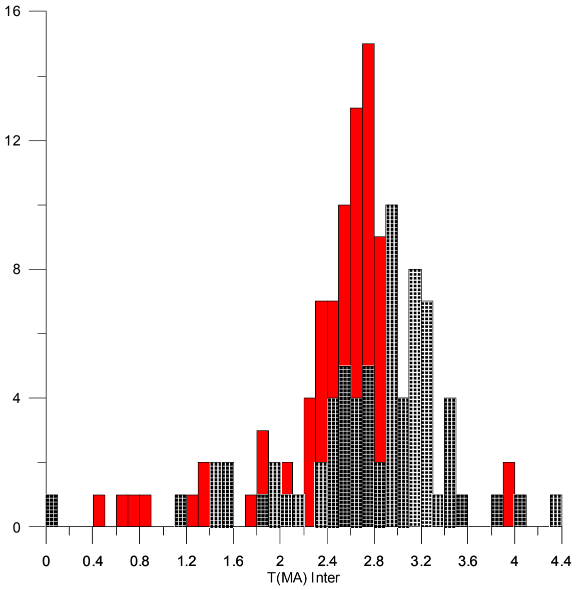

Figure 4. Hystogram of T_{CHUR} model ages for sulfides included in pyrope xenocrysts from the Internationalnaya pipe (red) and in olivine xenocrysts from the Udachnaya pipe (white) (model parameters of Shirey and Walker, 1998).

Our new data suggest that refertilization of the depleted SCLM and the introduction of Cr-pyrope garnet occurred between 2.2 and 3.0 Ga; little garnet was present before 3 Ga. Pyropes with young sulfides (between ~1.7 and ~2.2 Ga) may have crystallized in response to metasomatism during the amalgamation of the Siberian craton.

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