COMPOSITION OF LITHOSPHERIC MANTLE BENEATH SINO-KOREA CRATON

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Introduction Composition of lithospheric mantle beneath Archean craton is represented by mantle xenoliths in kimberlites. It was reported that the Kaapvaal cratonic lithosphere has lower Mg/Si, Ca/Al and higher Mg/Fe values, comparing with the residual peridotites forming oceanic and off-cratonic lithospheric mantle (Boyd and Mertzman, 1987; Boyd, 1989). Mg number [100Mg/(Mg+Fe)] of this cratonic peridotite olivine is greater than 92.0, differs markedly from the residues generated in other tectonic environments, which are smaller than 91.5. Compositions of other cratonic lithospheres are of course extremely important issue, in order to verify whether this chemical anomaly is only limited to the Kaapvaal craton or true for all the Archean cratons. However, this investigations are hampered by shortage of suitable mantle xenoliths in other Archean cratons. Garnet, for much stabler in alteration process, was partly preserved in kimberlite as single crystal xenocryst. In this report, we present the composition of lithospheric mantle beneath Sino-Korea craton, using garnet xenocrysts and diamond inclusions from two Chinese kimberlite pipes.

Sample and analysis Similar to South Africa, all kimberlite bodies in China are also located only inside craton. The oldest basement rock of Sino-Korea craton is 3.6-3.7 Ga, and consolidated at about 1.7-1.8 Ga. Studied samples were collected from two typical diamondiferous kimberlite pipes, e.g., Shengli 1 and No.50, located in Shandong and Liaoning province respectively. Details about these pipes were reported in Zhang et al.. (1989).

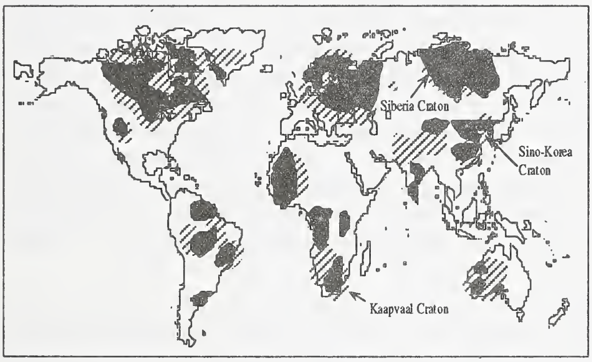

Figure 1. Distribution of Archean cratons in the world (solid black). High resolution seismic wave tomography shows that Archean cratons are mostly distributed within the S-wave velocity high regions (Zhang & Tanimoto, 1993), shaded regions correspond with higher seismic velocity regions (1.0% higher than average value) at 210km depth.

No fresh mantle xenoliths have been found from the Chinese kimberlites. Olivine and pyroxene are completely altered and replaced by serpentine. In the present study, therefore, only garnet xenocrysts which are partly free from alteration were studied. A few garnet and olivine inclusions in diamond are also investigated. About 400 fresh garnet grains with size about 2-4mm were randomly recovered from both pipes respectively. Forty diamonds with syngenetic silicate inclusions, were also selected and mechanically crushed for taking inclusions. Major element composition of these minerals are measured by a JEOL-XMA8800 electron microprobe at Tokyo Institute of Technology.

Pursuing Mg number of altered olivine Olivine is a main constitution mineral of the upper mantle, and knowing Mg number of olivine which used to be in equilibrium with xenocryst garnet is critical in understanding compositional characteristics of Archean lithospheric mantle. Theoretically the partition coefficient of Mg and Fe between garnet and olivine are temperature, pressure and composition dependent (Kawasaki and Matsui, 1983). Mg/(Mg+Fe) ratios of coexisting garnet and olivine in peridotite xenoliths from Kaapvaal craton (samples donated by K. Aoki) are analyzed, and shown in Fig.2 together with literature published data. It was found, however, the $K_D(Fe/Mg)^{ol\text{-}gt}$ of peridotite xenoliths from kimberlites of Kaapvaal craton remains constant in the range of 2.0-2.5 (Fig.2, inset). Given constant K_D value, composition of coexisting olivine can readily be calculated from Mg/Fe of coexisting garnet. As a matter of fact, a perfect linear and coherent correlation is observed between olivine and garnet in these xenoliths (Fig. 2). Following formula is obtained by a least square fitting method.

$$[Mg/(Mg+Fe)]_{ol} = 0.52 + 0.48[Mg/(Mg+Fe)]_{gt}$$

Without causing evident errors, this relation can be applied to estimate the Mg number of olivine in mantle peridotitic xenoliths from Chinese kimberlites, which used to be equilibrated with garnet xenocryst.

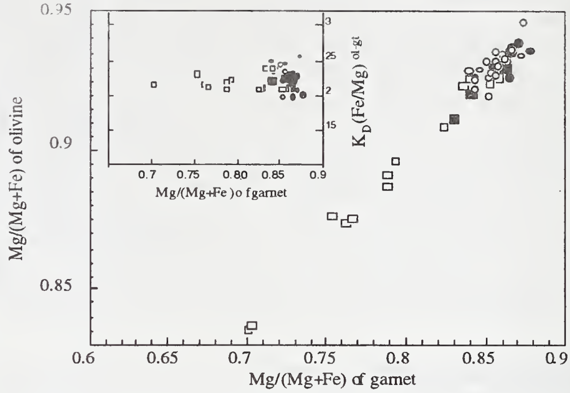

Figure 2. Partition coefficient of Fe, Mg between garnet and olivine remains constant, and a positive correlation of Mg/(Mg+Fe) ratios exists between the coexisting garnet and olivine in peridotite xenoliths from Kaapvaal craton, South Africa. In both pictures, open circles are peridotite xenoliths newly analyzed in this research (specimen donated by Dr. K. Aoki); black circles are harzburgite xenoliths from Boyd et al., (1993); black cubes are diamond bearing peridotites from Shee et al., (1982) and Viljoen et al., (1992); open cubes are xenoliths from Matsoku pipe, Lesotho, Cox et al., (1973).

Results EPMA data of both garnet xenocrysts and inclusions in diamonds are summarized in Fig.3. Most garnet xenocrysts are peridotitic paragensis. Mg number of garnet xenocrysts from both Shengli 1 and No.50 pipes are clustered mainly in the range of 82.0-87.0 (Fig.3 a,b). According to the previous formula, Mg number of the coexisting olivine should be 91.0-93.5 (Fig.3 d), with a peak around 92.5. Similar to Kaapvaal craton, Mg number of the lithospheric mantle under the Sino-Korea craton is significantly higher than that of oceanic lithosphere (89.0-91.0) (Maaloe and Aoki, 1977). Small part of analyzed garnet samples of Shengli 1 pipe, which are TiO_2 rich (>0.5wt% and may up to 2.0wt%) and with Mg number around 80.0-82.0, may have disaggregated from peridotites similar to the fertile high-T sheared peridotites found in South African kimberlties (Nixon and Boyd, 1973). Less than 10% of the analyzed samples are pyrope-almandine garnets with Mg number smaller than 75.0, which may be disaggrgation of eclogite xenoliths. All these observations indicate that the lithospheric mantle under Sino-Korea craton is composed mainly of very depleted peridotites but with a small proportion of eclogite, comparable with that of Kaapvaal craton.

Silicate inclusions in diamonds may represent lithospheric mantle composition deeper than 150km (Meyer, 1987). Syngenetic silicate inclusions in diamonds from the two Chinese kimberlite pipes are mainly olivine, garnet and orthopyroxene. No clinopyroxene was found in this study, suggesting that diamonds were formed in harzburgitic host rock. Host harzburgite is also Mg rich (Mg number of olivine to be 92.0-95.0), according to both garnet and olivine inclusion compositions (Fig. 3c). Olivine composition calculated from isolate garnet crystals is in the same range with real olivine inclusions in diamonds (Fig.3 c,e), demonstrating all the above calculations for xenocrysts are reasonable. Higher Mg number of diamond inclusions than majority of the minerals in peridotitic xenoliths means that the deepest part of the lithosphere under Sino-Korea craton to be more extensively depleted. Accordingly, structure of the lithospheric mantle under Sino-Korea craton ought to be very similar to Kaapvaal craton in composition and structure. Diamond inclusions, xenocrysts and xenoliths from Siberian craton (Sobolev, 1977) also show similarity with that of Kaapvaal and Sino-Korea cratons.

Discussion Based on seismology, Jordan (1979) found that old continents are underlaid by thick, cold and high seismic velocity lithosphere (tectosphere). Although the tectosphere is cold, they are

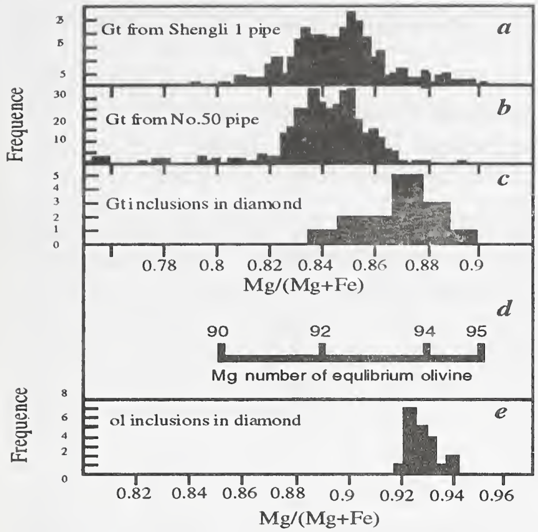

Figure 3. Composition of garnet xenocrysts and diamond inclusions from the Sino-Korea craton. **a.** Mg/(Mg+Fe) histogram of garnet xenocrysts from Shengli 1 kimberlite pipe, Shandong province; **b.** Mg/(Mg+Fe) histogram of garnet xenocrysts from No.50 kimberlite pipe, Liaoning province; **c.** Mg/(Mg+Fe) histogram of garnet inclusions in diamond, Mg number of coexisting olivine with garnet xenocrysts of both pipes ranges from 91.5 to 93.5, with peak around 92.5; **d.** Mg number of coexisting olivine with garnet, calculated according to the formula; **e.** Mg/(Mg+Fe) histogram of olivine inclusions in diamond.

neutrally buoyant in the upper mantle due to the very refractory chemical composition. At given temperatures, the Mg-rich cratonic mantle peridotites (Mg number - 93.0) have seismic wave velocities higher than normal peridotites (Mg number - 90.0). Recent high resolution seismic wave tomography shows positive correlation between Archean cratons and the S-wave velocity high regions even more clearly (Zhang and Tanimoto, 1993) (Fig. 1). Temperature is probably the dominant factor in controlling the lateral variations in S-wave velocity, but chemical depletion may also contribute to establishing high mantle S-wave velocity in the cratons (Jordan, 1978). Petrological similarity of the lithospheric mantles between Kaapvaal, Siberia and Sino-Korea cratons, combining with the three-dimensional seismic data, strongly suggests that lithospheric mantle beneath all of the Archean cratons are extensively depleted in Fe than nowadays oceanic ones.

Origin model has been proposed by Boyd (1989) and Takahashi (1990), who emphasized that the depleted garnet peridotite beneath Archean cratons can be formed as residue after extensive partial melting and extraction of komatiite magma from fertile mantle. If komatiites are the predominant mantle melts extracted at the hot spots or mid-ocean ridge, very depleted mantle residue may have accumulated under the large continent due to subsequent plate migration. The enormous volume, world wide distribution and unique composition of the Archean lithospheric mantle would be easily reconciled if komatiite was the dominant magma in the Archean as MORBs in the modern earth.

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