GEOCHEMISTRY OF TRANSITION ELEMENTS IN GARNET LHERZOLITE NODULES IN KIMBERLITES.

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Introduction- The purpose of the study is to describe distributions of •transition elements among major phases of garnet lherzolite nodules in kimberlites in order to obtain information on upper mantle chemical processes and to assess possible use of the partitioning of trace transition elements among phases as geothermometric-geobarometric indicators. The lherzolite nodules analyzed here(all from Lesotho and South Africa) include garnet lherzolites with sheared(or mosaic) texture, granular garnet lherzolites and lherzolites with K-richterite and/or phlogopite.

Procedures- The secondary ion mass spectrometry(SIMS) techniques were applied for quantitative analyses of minerals for Na, Mg, Al, Si, K, Ca, Sc, Ti, V, Cr, Mn, Co, Ni, Sr and Zr on spots of approximately 30x50µm using a Cameca IMS 300 ion-microprobe. Interferences of molecular ion species (oxide ions, for example) were practically eliminated by suppressing their intensities relative to those of single-atom ions with the energy filtering technique based on the difference in the kinetic energy distributions between single-atom and molecular ion species(Shimizu et al. 1977). The single-atom ions have significantly higher initial kinetic energy acquired during sputtering-ionization process compared with molecular ions, so that by counting secondary ions in a population with high energy(150 eV higher that the energy due to acceleration), contributions from molecular ions on a single nominal mass number could be practically eliminated. The interference-free intensities of major elements relative to Si measured in samples were then converted to atomic ratios(against Si) using empirical relationships between relative intensities and atomic ratios established separately for each group of minerals with well-analyzed standard samples. The major element compositions were calculated as cation atomic percentage by normalizing the total to 100%. The precision of the major element analysis is within 2-3% and the accuracy(relative to the electron probe data) is within 2-3%. The trace element concentrations were obtained from the empirical relationships between relative intensity (against Si) and concentration established for standard samples. Those standard samples were checked for their homogeneity with the ion-microprobe and analyzed with isotope dilution and neutron activation techniques. The analytical uncertainties for trace elements are determined essentially by the counting statistics and range, for clinopyroxene for example, from +14%(2 σ) for Co to less than +2% for Mn.

Distribution of elements- homogeneity of minerals is critical to usefulness of trace element partitioning data. The individual mineral grains were found to be homogeneous with respect to all the elements analyzed, suggesting that equilibrium was closely approached. However, significant inter-grain variations were observed in some of the nodules as shown by Boyd and Finger(1975). For example, clinopyroxene grains in a sheared garnet lherzolite PHN 1611 show variations of Cr from 2000 to 2600 ppm (individual grains being homogeneous) and of Sc from 12 to 16 ppm, high Cr being associated with high Sc. In contrast, other transition elements do not show variations. The high Cr-Sc grains appear to be more abundant than the low Cr-Sc ones and there appear to be no peculiarities in Cr and

302

Sc contents of orthopyroxene and olivine grains surrounding the low Cr-Sc clinopyroxene grain.

An attempt was made to compare partitioning of transition elements between mineral pairs and P-T values estimated from the major element compositions of pyroxenes. For clinopyroxene-garnet pairs, for example, the partition coefficient of $Sc(K_{Sc}=(Sc/A1)cpx/(Sc/A1)gar)$ was found to be constant(0.17±0.02) for the ranges of P(40-60 kb) and T(1370-970°C). Significant variations of the partition coefficients were observed for Mn $(K_{Mn}=(Mn/Mg)cpx/(Mn/Mg)gar)$ ranging from 0.49 to 0.17(high values being associated with high P and T) and for V(Ky=(V/A1)cpx/(V/A1)gar) ranging from 0.80 to 0.35(low values being associated with high P and T). Ti, Cr, Co do not show definite correlations with P and/or T.

Chemistry of nodules- Chemical classification of nodules is a useful basis for considering genetic relationships among the nodules and for discussing chemical processes in the mantle. Erlank and Rickard (1977) suggest a metasomatic process for deriving peridotites containing phlogopite and K-richterite. The results of Erlank and Shimizu(1977) suggest that Sr content of clinopyroxene could be a good indicator of metasomatism as it is high(higher than 500 ppm) in lherzolites affected by metasomatism. Zr in clinopyroxenes was found to be consistent with Sr, being high(by more than a factor of 2) in metasomatized lherzolites. Combination of Sr, Zr, Sc, Ti and Cr contents of minerals, notably those of clinopyroxene and garnet allows a classification of the lherzolite nodules into three groups. Group I: relatively undepleted, high Fe/Fe+Mg, typically high P Clinopyroxenes are characterized by low Sr(around 100 ppm), low and T. Zr(10-20 ppm), low Sc(16 ppm), low Cr(typically below 4200 ppm) and high Ti(1300-1800 ppm); Group II: depleted, low Fe/Fe+Mg, typically low P and T. Clinopyroxenes characterized by intermediate Sr(200-250 ppm), low Zr(10-35 ppm), intermediate Sc(17-21 ppm), high Cr(6200 ppm-1.4%) and low Ti(typically around 250 ppm); Group III: metasomatic, low Fe/Fe+Mg, low P and T. Clinopyroxenes characterized by high Sr(500-970 ppm), high Zr(70-120 ppm), high Sc(27-90 ppm), high Cr(higher than 1.1%) and intermediate Ti(up to 920 ppm). All three types exist as garnet lherzolites and only Group III rocks contain phlogopite and/or K-richterite. The depleted nature of the Group II garnet lherzolites suggests that they could be residua of partial melting of relatively undepleted Group I rocks.

References

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