TRACE ELEMENTS IN GARNETS AND CHROMITES FROM COLORADO-WYOMING KIMBERLITES AS A GUIDE TO EXPLORATION

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Early Devonian aged Group I kimberlites occur primarily in two districts along the Front Range of the middle Rocky Mountains of Colorado and Wyoming, U.S.A. The State Line District straddles the Colorado-Wyoming state line, consisting of approximately 35 kimberlite pipes and dikes intruding Proterozoic crystalline rocks. This district is marginal to the Wyoming Archean Province. Most occurrences here contain diamond, with grades ranging from <1 cpht to >100 cpht. Currently the Kelsey Lake pipes are being developed for North America's first commercial diamond production. The Iron Mountain District, 80 km to the north, contains about 40 small pipes, blows, dikes and sills of kimberlite. These also intrude Proterozoic crystalline rocks, but occur much closer to the outcropping Archean basement of the Wyoming Province. The Iron Mountain kimberlites are essentially barren of diamond.

Distinct variation is seen in diamond mineralization between the districts and between individual clusters within the district. Variation is manifested in absolute grades, stone size distributions, primary and secondary diamond growth processes, diamond inclusions, and in resorption characteristics. These variations must be explained by differing degrees and areas of mantle sampling, metasomatic processes, emplacement styles, and resorption events.

Chrome Pyrope garnets from eight State Line and Iron Mountain District kimberlites, and chromites from two State Line District kimberlites have been analyzed for trace elements using the proton microprobe. The regional geotherm defined and constrained by garnet and spinel data from the State Line kimberlites shows a well defined 35 mW/m^2 conductive model to about 40 Kb to 50 Kb. Above this the geotherm jumps to 40 mW/m^2, showing a deviation from the conductive model above 1100 °C. It appears that the mantle was strongly heated at depths below about 175 km and this raised the geotherm in the lower part of the lithosphere. Steeper geotherms possibly existed at Aultman and especially at Iron Mountain.

The lithosphere, as defined by the presence of depleted rocks, probably did not extend deeper than 175 km at the time of kimberlite intrusion. The upper mantle in the State Line region contains 5-10% harzburgite, broadly distributed through the depth range of 90 to >180 km represented by garnets. Much of this harzburgite is relatively Ca-rich, and the lithology of the mantle section as a whole is more typical of a Proterozoic lithosphere than an Archean one. This probably reflects the craton-margin setting, where a significant thickness of Proterozoic lithosphere has tectonically replaced the Archean rocks at depth. The low geotherm allows diamond to be stable below about 125 km depth. Severe metasomatism of a type usually associated with phlogopite introduction affects the mantle in the 130-150 km depth range. Higher-T melt-related metasomatism becomes dominant at depths >160 km and is probably related to the heating event described above. It is unclear how these different metasomatic events have affected diamond preservation. Most suites of diamonds show a variety of resorption characteristics, from pristine octahedra to class 1 THH, indicating more than one process acting at different times and levels.

The "lherzolite trend" on a Cr_2O_3-CaO garnet plot consists of three en echelon segments; this is related to the stepped geotherm described above. The position and slope of the lherzolite trend depend on temperature and pressure, and a geotherm with a slope significantly steeper than the conductive models will allow chromite and garnet to coexist to higher T than along a normal conductive geotherm. This results in the occurrence of high-Cr lherzolite garnets at high T, as seen in, for example, the Zero pipe (Kuruman Province, South Africa) as well as in the State Line District.

Spinels from the Sloan #2 and Kelsey Lake #1 bodies cover a wide range of zinc temperatures (T_{Zn}) from <600°C to >1300°C, corresponding to the range of T_{Ni} seen in the garnets. Both bodies contain a population of high-T, relatively low-Cr (40-50% Cr_2O_3) spinels that are distinct from typical kimberlitic magmatic spinels, but similar to the magmatic population recognised in lamproites worldwide. This suggests that the kimberlites appear transitional between typical kimberlites and lamproites, although all other petrologic and chemical features of these pipes conform to normal Group I kimberlite. A group of high-Cr chromites from Kelsey Lake #1 has high Zn contents and T_{Zn}<600°C, suggesting that they have been derived from the graphite stability field and may be crustal; alternatively, they may suggest weak metamorphism of the kimberlite.

There is good grade correlation between diamond grade and the Gamma estimator for the Aultman, Chicken Park, George Creek, Kelsey Lake and Sloan 5 kimberlites. Diamonds in these kimberlites are derived mainly from peridotitic mantle. The grades of the Sloan 1&2 pipes are higher than predicted, relating to the dominantly eclogitic derivation of diamonds here. The highest grade kimberlite, the dikes at George Creek, is clearly identifiable by its high Gamma value, narrow T_{Ni} distribution and low degree of metasomatism. Diamonds at George Creek also show the least resorption. The intermediate grade localities at Chicken Park and Kelsey Lake are distinguished by low positive values of Gamma and intermediate degrees of metasomatism. The low grade localities at Aultman and Sloan 5 are identified by large negative Gamma values and high degrees of metasomatism. The geotherm for Iron Mountain is poorly constrained and may lie totally within the graphite stability field, which would explain the absence of diamonds here.