INDICATOR MINERALS FROM PRAIRIE CREEK AND TWIN KNOBS LAMPROITES: RELATION TO DIAMOND GRADE.

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Prairie Creek (PC) and Twin Knobs #1 (TK1) are Late Cretaceous diatremes of olivine lamproite in the Murfreesboro field, Arkansas, and are separated by ca. 1 km. Prairie Creek has a historical grade of 13 carats/ 100 tonnes, whereas TK1 has a grade of <1 carat/100 tonnes (Waldman et al., 1987). We have used the proton microprobe to obtain rapid, non-destructive trace-element analyses of macrocryst (>0.5 mm) garnet, chromite and ilmenite in heavy-mineral concentrates from PC and TK1. The aim is to test the usefulness of such analyses in evaluation of diamond exploration targets, and to explain the difference in grade of these adjacent diatremes.

Garnets: Garnet concentrates from PC and TK1 show similar ranges of Ca and Cr, and both contain ca. 10% of mildly subcalcic "G10" pyropes (Fig. 1). PC contains a higher proportion of relatively low-Cr, high-Ca garnets. Both diatremes contain a population of relatively Zr-rich (>50 ppm Zr) garnets with Zr/Y ≈5 (Fig. 2), high TiO2 (0.6-1%) and a strong Zr-Ti correlation. In PC this group has low Cr contents, whereas the high-Zr garnets in TK1 have >7% Cr2O3. Temperature has been estimated for each grain using the Nickel Thermometer of Griffin et al. (1989a). The garnet concentrates show markedly different temperature distributions (Fig. 3). The main population at PC lies in the range 850-1050 °C, with another peak at T>1250°C representing the highest-Cr grains. The main populations at TK1 lie from 700-900 °C and 1200-1500°C. On a cratonic geotherm, the diamond stability field extends from ca. 950°C (the intersection of the geotherm with the diamond-graphite curve) to ca. 1250°C (ca. 200 km, the probable base of the lithosphere). About 1/3 of the PC garnets, and 1/5 of the TK1 garnets, lie in this "diamond window". Temperature estimates for the "G10" garnets at both TK1 and PC show that the lower-Cr G10 grains are derived from the graphite stability field, while the high-Cr ones have unusually high temperatures. Similar high-Cr, high-T garnets are found at Sloan, where they have been described as high-Cr megacrysts (Eggler et al., 1979). The high-Zr,Ti garnets are interpreted as the result of interaction between magma and mantle wall rock, by analogy with the garnets of sheared garnet peridotite xenoliths (Griffin et al., 1989b; Smith et al., 1991). Most high-Cr garnets in TK1 have suffered such melt metasomatism, while most high-Cr garnets in PC are still depleted (<50 ppm Zr).

Chromites: PC and TK1 contain similar chromite macrocrysts; both show two populations (Fig. 4). The main population in both contains 30-55% Cr2O3 and >1000 ppm Ni; it is similar to the main population in lamproites worldwide. The other population contains 50->60% Cr2O3, 10-15% MgO, < 0.5% TiO2, and <600 ppm Ni. The high-Ni population shows a trend to high Ti (>5% TiO2) at low Al and high Cr. It essentially follows Mitchell's (1987) "Trend 2", and is interpreted as magmatic; it may have crystallized from the (proto-)lamproite magma.

The low-Ni population is similar in all respects to spinels from garnet lherzolite xenoliths from kimberlites in South Africa and Siberia. These grains have Zn contents from 800-1700 ppm, negatively correlated with Ni. This implies equilibration temperatures of ca. 700-900 °C (Griffin et al., 1991), and indicates that these spinels, despite their high Cr# and Mg# and low Ti, are derived from the graphite stability field. Neither of the diatremes contains spinels equivalent to the main population in Group 1 kimberlites, which is derived largely from harzburgites and dunites (Griffin et al., 1991).

Ilmenites: PC contains few picroilmenites, whereas they are abundant at TK1. The ilmenites from TK1 show a large range in MgO (9%-15%) and Cr2O3 (0.2-4.5%) and a very well-defined parabolic relation between Mg and Cr (Waldman et al., 1987). They also define smooth continuous curves on plots of Ni, Cr, Mg and Zr against Nb (Fig. 5). All of these features are consistent with extended fractional crystallization of a single batch of magma; similar patterns are seen in many kimberlites (Moore et al, 1991; Griffin et al, unpubl.). Many of the ilmenites at PC are low-Nb, Ni, Zr types of probable crustal derivation. However, several grains fall near the trends defined by the TK1 ilmenites, and are probably derived from a similar, magma. The unusually high Cr content of the ilmenites suggests a a relationship to the high-Cr garnet population.

Discussion: The garnet concentrate from TK1 contains a larger proportion of material from the graphite stability field than that from PC; it also contains a higher proportion of high-T, probably magmatic, garnets. The volume of mantle sampled by TK1 appears to have been more affected by melt metasomatism than that sampled by PC. Both of these factors are consistent with the lower diamond grade in TK1. The spinels in both diatremes consist of a magmatic population common to lamproites worldwide, and a smaller xenocryst population. The xenocrysts are all probably derived from lherzolites in the graphite stability field. Neither pipe has sampled typical depleted mantle in the diamond stability field; this may be related to the relatively low grade of both pipes. The ilmenites are all high-Mg types, of the type usually regarded as "good" indicators. However, the trace elements show that they represent an extended fractionation sequence, which may have allowed time for extensive metasomatism of the mantle wall rocks adjacent to the magma chamber. This study demonstrates the usefulness of trace-element data, especially on garnets, in evaluating the diamond potential of exploration targets. Whereas the major-element data on the garnets suggest similar potential for PC and TK1, the trace-element data clearly identify PC as the more attractive target. In addition, data on both garnets and spinels, when compared with our larger database, are consistent with a relatively low grade for PC.

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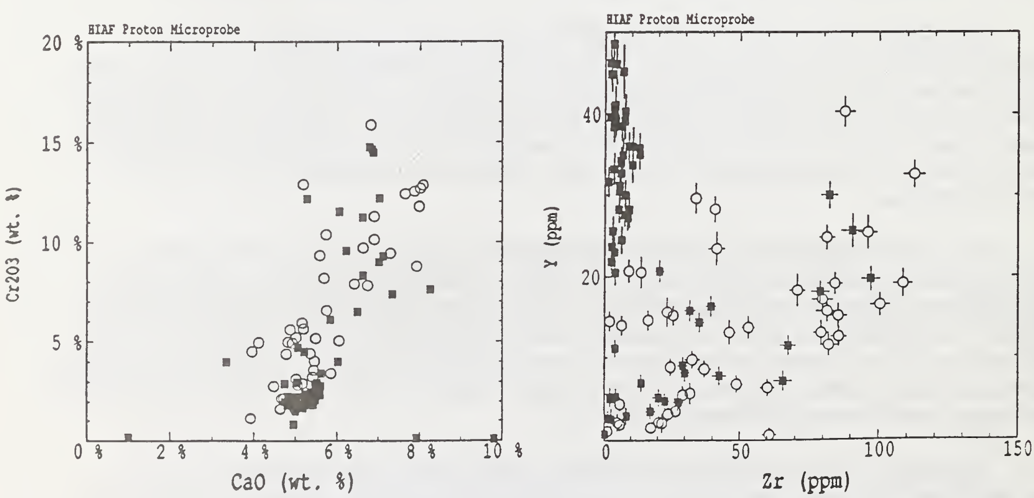
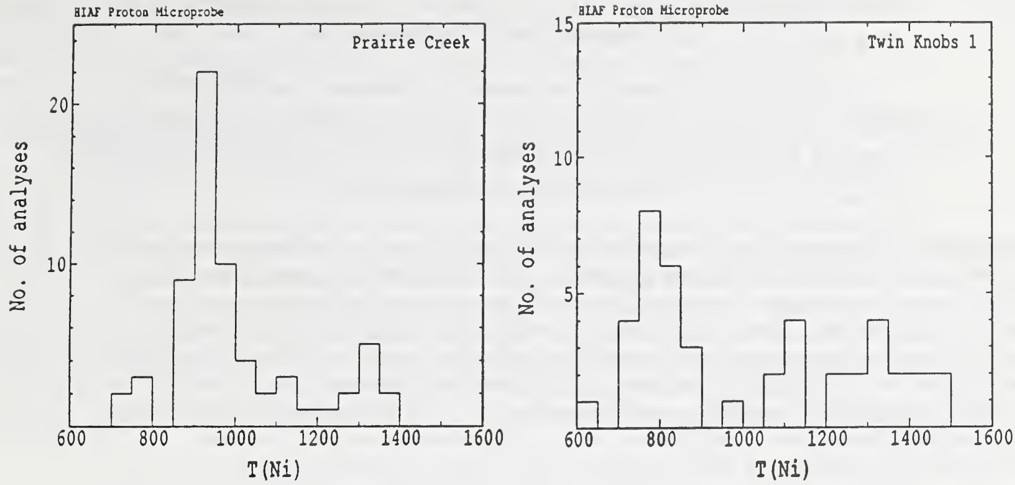
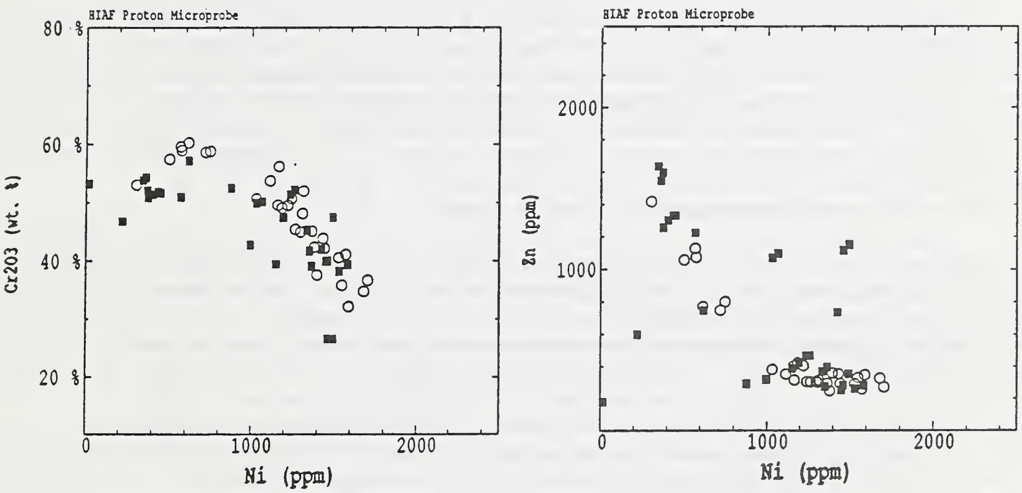


Fig. 1. Ca-Cr relations in garnets. Squares, PC; circles, TLK1.
Fig. 2. Zr-Y relations in garnets. Symbols as in Fig. 1.





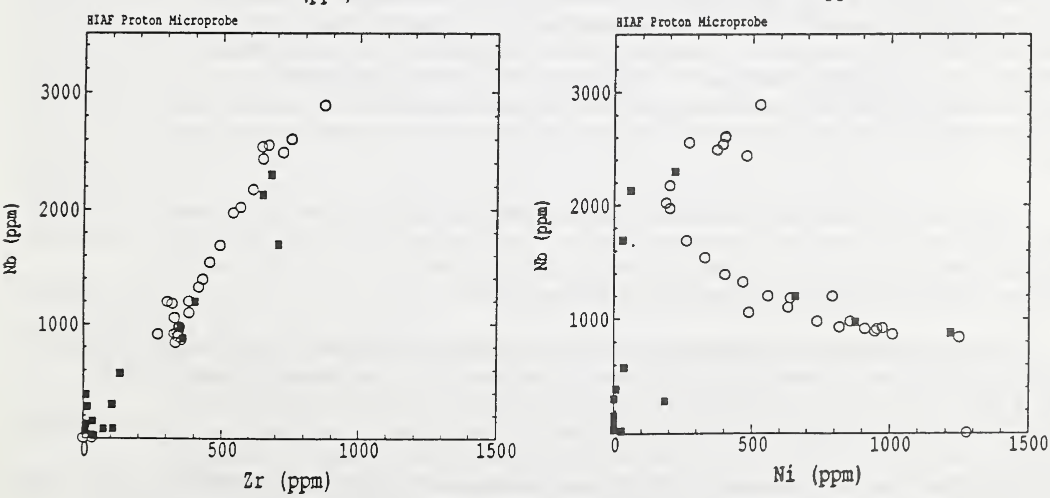


Fig. 3 (top). T_{Ni} histograms for PC and TK1.
Fig. 4 (middle). Cr-Ni and Zn-Ni relations in chromite macrocrysts. Symbols as in Fig.1.
Fig. 5 (bottom). Nb-Zr and Nb-Ni relations in ilmenites. Symbols as in Fig. 1.