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A GUIDE TO THE IDENTIFICATION OF KIMBERLITE "INDICATOR" MINERALS

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INTRODUCTION

Stream sediment sampling for kimberlite "indicator" minerals has long been accepted as one of the most efficient methods utilized in the search for new kimberlite bodies. Gold (1978) estimates that three quarters of the world's kimberlites have been discovered in this way. This method involves collecting sediment from selected heavy mineral trap sites in drainages and concentrating the material to recover any heavy minerals. The heavy mineral concentrates are then examined under binocular microscopes for the most common "indicator" minerals: picro-ilmenite, pyrope garnet and chrome-diopside. Identification of one or more of these minerals indicates the possible presence of kimberlite in the general vicinity of the sample and further sampling at close-spaced intervals upstream of the anomalous sample should eventually delineate the source of the minerals. The accurate identification of indicator minerals is therefore of utmost importance to any exploration program's success. It is important to note that indicator minerals can also be derived from non-kimberlitic volcanic sources containing upper mantle material. For example, the Vulcan's Throne basalt along the Grand Canyon of Arizona contains abundant peridotite fragments (Hausel et al., 1980). However, the presence of indicator minerals in an area of known kimberlite intrusions usually indicates a kimberlitic source. This report will introduce those unfamiliar with the indicator minerals to certain diagnostic characteristics which aid in distinguishing these minerals from seemingly similar heavy minerals derived from non-kimberlitic sources.

DESCRIPTION OF INDICATOR MINERALS

The minerals most commonly used as indicators are: picro-ilmenite (magnesian ilmenite), pyrope garnet and chrome-diopside. These minerals occur as discrete grains (megacrysts) disseminated throughout the kimberlite groundmass and as constituents of various ultramafic nodules (e.g. garnet-peridotite, eclogite) derived from the upper mantle and included in the kimberlite as xenoliths. During the physical and chemical weathering of kimberlite these minerals are released into the surrounding soil and drainages where they may be recovered and identified during the course of an exploration program. Attempts have been made to use other kimberlite derived minerals as indicators but these lack demonstrated practical success (Kresten et al., 1975; Turskiy, 1967). In addition to the more widely used indicator minerals, one of the most positive indicators of kimberlite is diamond. Due to its extreme hardness it can survive transportation for great distances and indicates a positive kimberlite source even if no other kimberlitic minerals are recovered in the vicinity. In recent years, however, diamond has also been recovered from rocks identified as highly potassic lamproites which, although related, are not true kimberlites. Although picro-ilmenite is absent and pyrope garnet is rare, heavy mineral surveys are effective in locating these rocks (E&MJ, 1983). Drawbacks to the use of diamond as a prospecting tool are its great rarity and the fact that many kimberlites do not contain diamond at all or only exceedingly small crystals (micro-diamonds), whereas all kimberlites usually contain varying amounts of picro-ilmenite, pyrope garnet and chrome-diopside. These minerals are described in more detail in the following pages.

Magnesian Ilmenite

Magnesian ilmenite (picro-ilmenite) is the magnesium-rich end member of the ilmenite series: ilmenite (iron end-member), pyrophanite (manganese end-member) and geikielite (magnesium end-member). It is produced when magnesium replaces some of the iron in the ilmenite structure. MgO content varies from 6.5% to nearly 20% (Mitchell, 1973). These high magnesium ilmenites appear to be uniquely confined to kimberlites (Mitchell, 1973) and thus are one of the most reliable kimberlite indicator minerals. Magnesian ilmenite forms short rhombohedral to rounded crystals with the rounded crystals being the most common. As is the case with pyrope garnet and chrome-diopside, this rounding is caused by abrasion of the grain during emplacement of the kimberlite. Grains are opaque with a specific gravity of approximately 4.05 (Sinkankas, 1964) and a hardness of 5-6. Color is a rich glossy metallic black. The tough and non-brittle nature of magnesian ilmenite enables it to survive transportation for considerable distances which enhances its importance as an indicator mineral. Kimberlitic ilmenite exhibits a very diagnostic lack of magnetism which aids in distinguishing it from ilmenite derived from other sources. Leighton and McCallum (1979) state that magnetic separation can be 100% effective in separating magnesian ilmenite from ferro-ilmenite. The characteristics used in identifying magnesian ilmenite are:

1) Color: glossy metallic black with high lustre.
2) Grain morphology: rounded grains, often with dull white coating (leucoxene).
3) Lack of magnetism.

Pyrope Garnet

Pyrope garnet is a very characteristic mineral of kimberlite, commonly occurring as rounded grains with crystal faces only rarely visible. It has a specific gravity of less than 3.80 and a hardness of 7.25. The index of refraction is less than 1.760 and grains are isotropic. Color is often diagnostic and ranges from deep red-purple and lavender through dark blood-red to orange and orange-yellow. Kimberlitic pyrope garnets also exhibit characteristic morphological features which aid in making a positive identification. They are often covered by a rim of "kelyphite", a microcrystalline aggregate of spinel, phlogopite, chlorite, amphibole and plagioclase (Dawson, 1980), which is caused by reaction of the garnet with the kimberlite groundmass at the expense of the garnet. Underneath the kelyphite rim the surface of the garnet becomes etched in a distinctive pattern commonly referred to as "orange-peel" texture. These features (kelyphite rim and orange-peel surface) help to positively identify garnet from kimberlite in addition to implying a proximate source, since weathering processes soon remove these features, especially the kelyphite rim. A summary of the characteristics used to distinguish pyrope garnet from other seemingly similar minerals (e.g. almandine garnet) is listed below.

1) Color: deep red-purple, purple, lavender, blood-red, orange, orange-yellow.
2) Grain morphology: rounded grains, kelyphite rind, orange-peel texture.
3) Refractive index: less than 1.760
4) Isotropism.

Chrome-diopside

Chrome-diopside crystals are easily recognized due to their characteristic bright emerald-green color. Crystals often exhibit excellent cleavage and parting which produces rough rectangular grains with flat surfaces and rounded edges. The index of refraction is 1.670-1.740, specific gravity ranges from 3.20 to 3.40 and grains are anisotropic. Hardness is 6. Due to the excellent parting and cleavage characteristics of chrome-diopside it breaks down very quickly in drainages and is seldom found more than half a mile from its source. Thus the identification of chrome-diopside in stream sediment samples indicates a very proximate source. Identifying characteristics are:

1) Color: bright emerald green, easily recognized.
2) Grain morphology: blocky, rectangular grains with flat smooth surfaces.

Figure 1. Picro-ilmenite from the Aultman 1 kimberlite. Note the well-rounded nature of the grains caused by abrasion during kimberlite emplacement and also the characteristic deep glossy black mirror-like internal surface of the fractured grains. Grain dimensions are approximately 2.0 mm.

Figure 2. Picro-ilmenite megacryst from the Schaffer 15 pipe. Note the rounded nature, glossy black color on fresh surfaces, and remnants of leucoxene (a mixture of rutile and perovskite) coating. Grain dimensions are: 1 cm x 7.0 mm.

Figure 3. Magnetite-ilmenite derived from the Laramie Anorthosite Complex. Compare the flat, tabular shape and well-developed crystal faces as well as the brown-black color to the picro-ilmenite in Figures 1 and 2. These grains possess very high magnetic susceptibility while picro-ilmenite has almost none. Grain dimensions are approximately 5 mm.

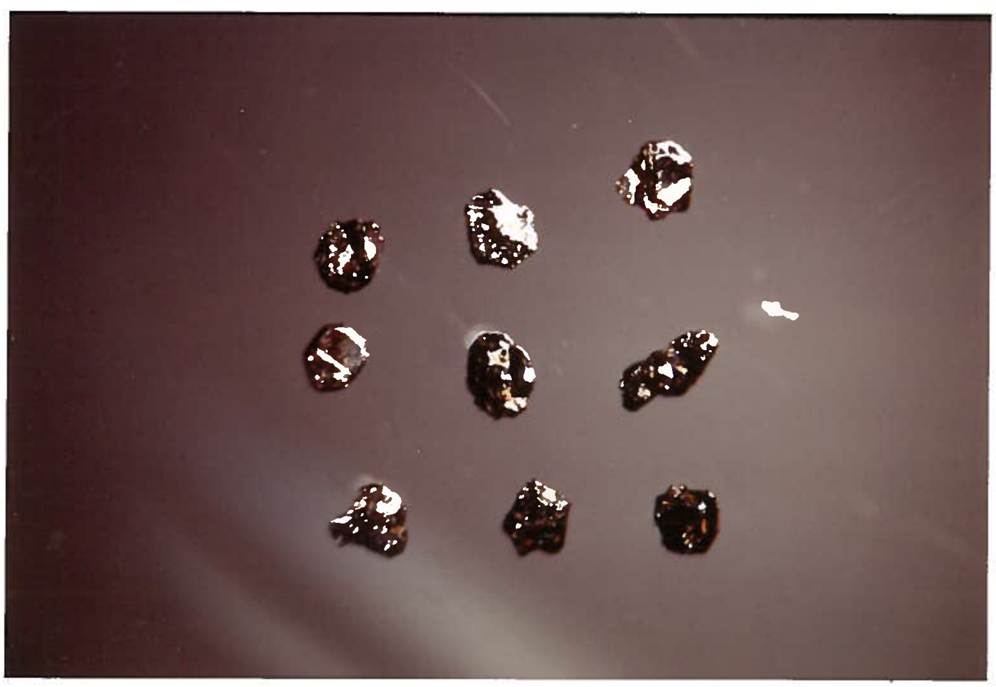

Figure 4. Ilmenite derived from the Sherman Granite. The grains are predominantly flat and show remnants of well-developed hexagonal crystal form. Magnetic susceptibility is moderate to high.
Average grain size is less than 0.25 mm.

Figure 5. Fresh pyrope garnet grains from the Aultman 1 pipe. Color ranges from orange-yellow through red to deep red-purple. Note clarity (lack of inclusions) and remnant of original rounded surface on the center grain. Average grain size is 2.0 mm.

Figure 6. Pyrope garnet grain showing well-rounded nature caused by abrasion during kimberlite emplacement. The grain is partially covered by a rind of kelyphite formed by reaction of the garnet with the kimberlite matrix.

Figure 7. Pyrope garnet showing rounded nature, kelyphite rind and typical "orange-peel" surface texture developed under the kelyphite.
Grain size is approximately 5.0 mm.

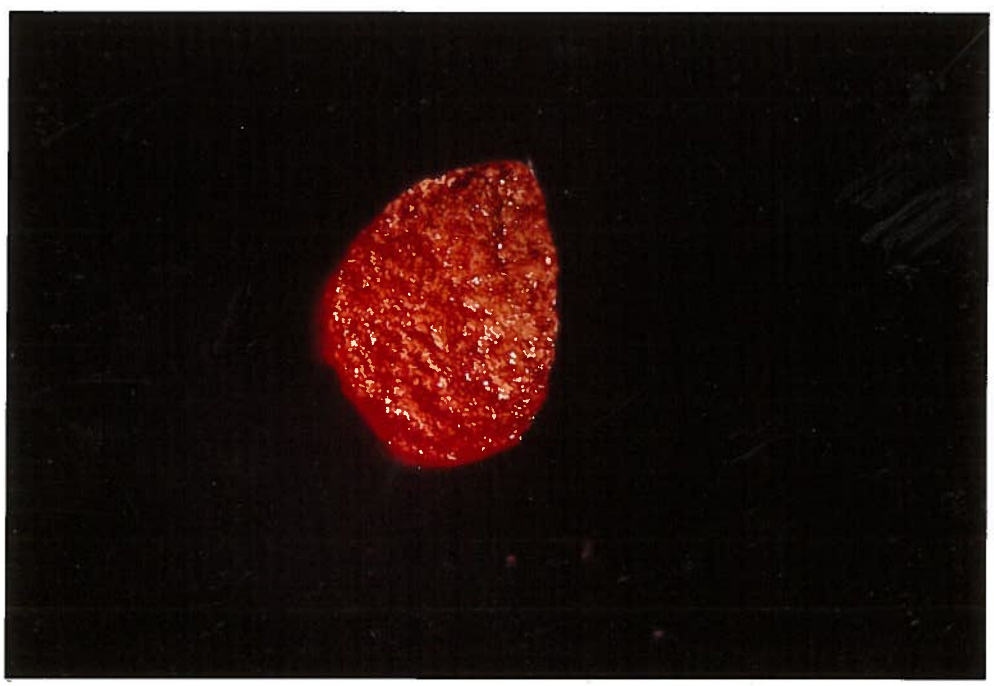

Figure 8. "Orange-peel" surface texture on pyrope garnet.
Grain dimensions are: 5.0 mm x 3.0 mm.

Figure 9. Pyrope garnet grains recovered from stream sediment sample concentrates collected in the Laramie Range. Note the distinctive red-purple color, translucence, rounded nature, and the expansion pit in the lower left grain. (Expansion pits are formed when stress due to expansion of high-pressure mineral inclusions within the garnet is released, blowing out a conical pit.) (McCandless, 1982.)

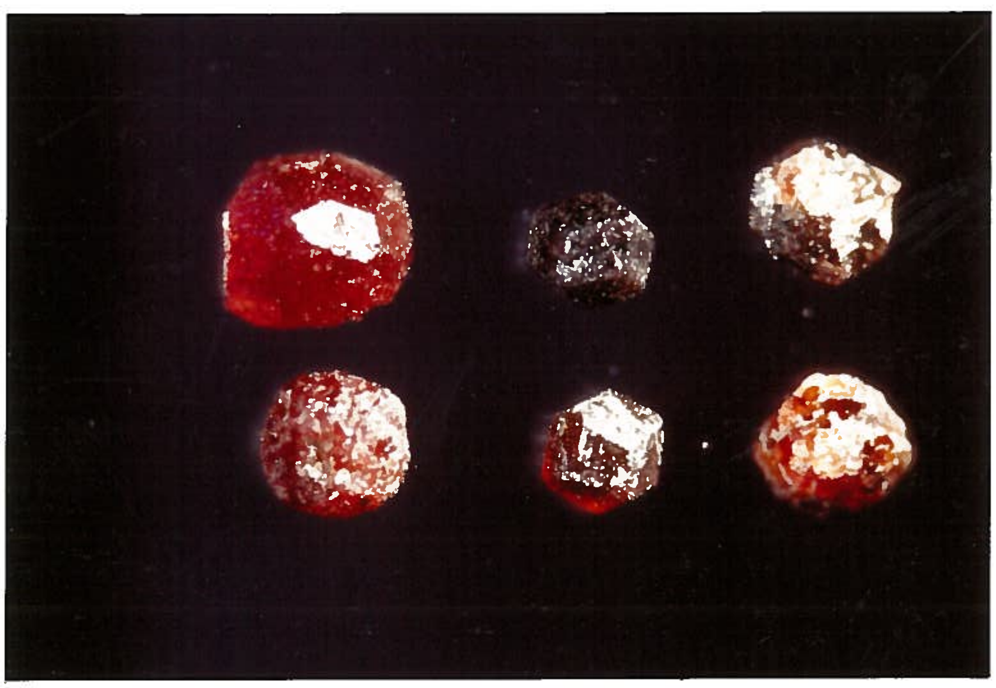

Figure 10. Euhedral non-kimberlitic garnet (almandine) from stream sediment concentrates in the Laramie Range. Compare the excellent dodecahedral crystal form, dark red to dark brown color, and the semi-opaque nature of these grains to those in Figure 9.

Figure 11. Kimberlitic pyrope garnet (center) compared to non-kimberlitic almandine garnets recovered from the same stream sediment sample concentrate.

Figure 12. Chrome-diopside from the Aultman 1 kimberlite, showing the distinctive emerald-green color and flat tabular shape caused by the excellent cleavage and parting of the mineral.
Average grain size is approximately 3.0 mm.

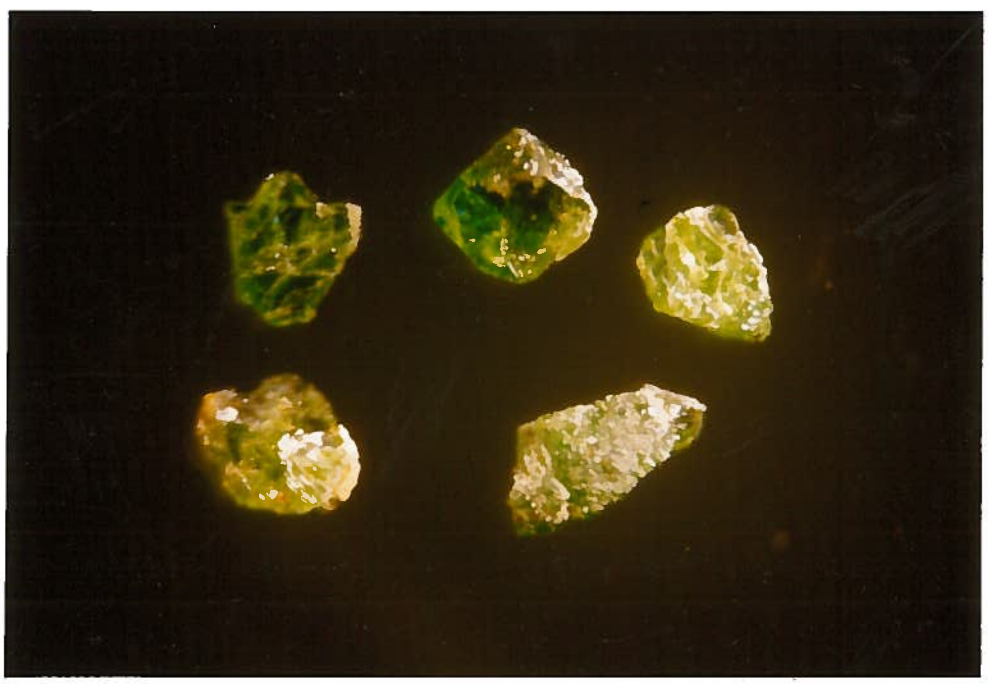

Figure 13. Chrome-diopside from the Schaffer 15 kimberlite. Average grain size is approximately 1.0 mm.

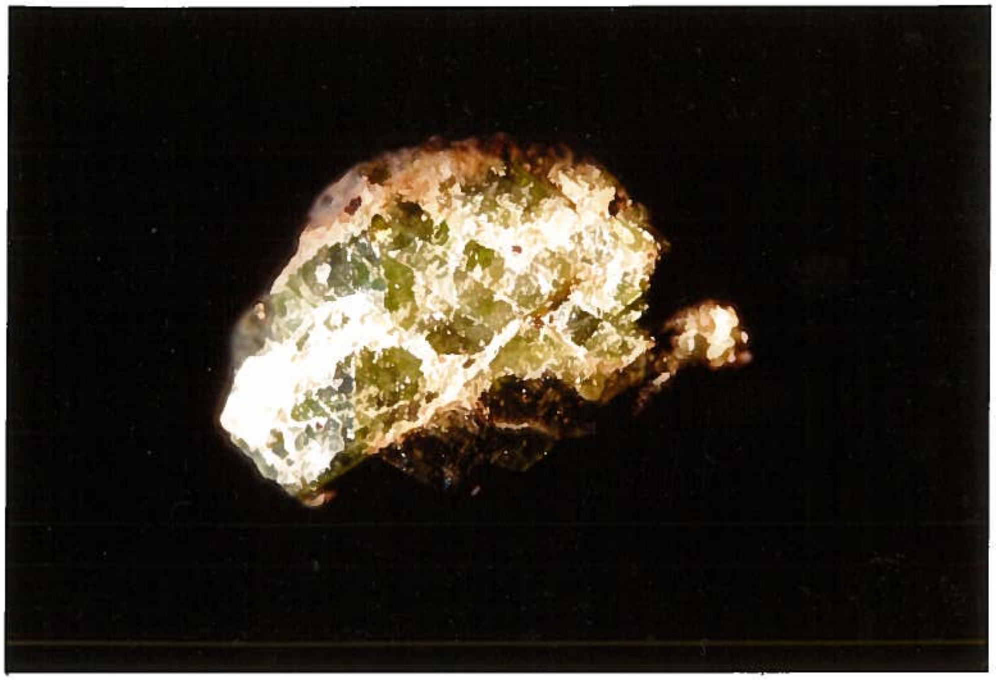

Figure 14. Chrome-diopside megacryst from the Aultman 1 pipe. Note the cleavage planes within the crystal and the generally rounded nature of the grain.
Grain dimensions are: 6.0 mm x 4.0 mm.

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