INCLUSIONS IN DIAMONDS

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The purpose of this study of inclusions in diamonds is to learn more about the earth's upper mantle. The inclusions tell us about minerals which have formed at pressures of 40 kilobars or more, at temperatures of about 1200 °C, otherwise they would not be present in the diamond which formed at these conditions. We need to know more about what kinds of inclusions are present, their compositions, whether they are equilibrated, and how they compare with mineral assemblages of xenoliths found in kimberlite pipes. So we look for "flawed" diamonds and study them with a petrographic microscope, x-ray diffraction, electron microprobe, and scanning electron microscope techniques. Without all of these methods it would not be possible to fully document the inclusions.

The diamonds were obtained in New York from diamond dealers and cutters. The inclusions are usually removed by burning the diamond at about 800 °C until it is completely oxidized or vaporized. The diamonds leave no ash and the inclusions can be studied internally and externally. Sometimes the diamond is crushed, or the inclusion is analyzed in place within a cut diamond.

We find that inclusions in diamonds are usually present as single crystals in different parts of the diamond, and sometimes the minerals are in contact, but this is very rare. The inclusions may be of only one mineral, or several. Sometimes there are hundreds of crystals within a single diamond. The chemical composition of each mineral within the diamond is always the same, but varies from diamond to diamond. The similarity of the compositions of minerals as well as the compositions of coexisting minerals indicate that these are equilibrated mineral assemblages. It has previously been shown that the compositions of minerals within a diamond are the same as those of the rock originally surrounding the diamond. Therefore by studying mineral assemblages within diamonds we are really studying upper mantle mineral assemblages even though the rock is missing.

It was found that two types of assemblages, which are never mixed, are found within diamonds. One we have called the garnet lherzolite assemblage and the other the eclogite assemblage. The garnet lherzolite assemblage is a general name for a group of rocks which may also include dunite, harzburgite, websterite, etc. which have similar mineral compositions. It is not possible to determine the modal abundance of each mineral in the assemblage and the term garnet lherzolite is used because it is the most abundant rock type present as a xenolith.

The garnet lherzolite assemblage contains chrome-rich pyrope garnet (wine-red in color), chromian diopside, chromian enstatite, Cr-bearing olivine, and chromite. All the minerals are Mg-rich. Pyroxene crystals have been found which are partly diopside and partly enstatite, with a simple dividing plane, and these are interpreted as completely exsolved subcalcic diopsides. Some of the assemblages are similar to known xenolith assemblages, but the more Mg-rich assemblages are still unique to diamonds.

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The eclogite assemblage contains mainly Cr-, Mg-poor pyrope garnet (honey-brown in color), and omphacitic pyroxene. It also contains kyanite, rutile, phlogopite, magnetite and sulfides. Kyanite is reported here for the first time as an inclusion in diamond. Phlogopite has an unusual composition and was difficult to analyze. Magnetite is intergrown with sulfides and is nearly pure magnetite with very few minor elements. Sanidine and a silicaphase were also found in some eclogite assemblage diamonds but it is still uncertain whether they are part of the primary mineral assemblage. Mineral compositions show a wide range of composition from diamond to diamond, and they are similar in composition to xenolithic diamondiferous and non-diamondiferous eclogite assemblages.

One unique feature of inclusions in diamonds is their morphology. The inclusions appear to have the outer morphology of the enclosing diamond although many of the forms are distorted. Octahedra are most easily recognized and they have been found as the dominant form for pyroxenes, garnets, and olivines. The internal structures of these minerals is normal. This remarkable phenomenon is difficult to explain but is thought to be the result of negative crystals of diamond imposing their morphology on the inclusions.

There is still much to be learned about the nature of the inclusion assemblages in diamond and their comparison with kimberlitic xenoliths. These inclusions appear to be a unique window into the earth's upper mantle.