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Diamonds in stone meteorites

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Abstract—A search for diamonds in the chondrites Richardton, Forest City, Holbrook. Warrenton, Indarch, Cold Bokaveld and Cape Girardeau and in the Goalpara achondrite has been made. Diamonds were found in Goalpara only.

DIAMONDS were first observed in meteorites by JEROFEJEFF and SATSCHINOFF (1888) in the achondritic stone meteorite, Novo Urei. They reported one per cent by weight on small black diamonds. This was confirmed by KUNZ (1888, 1890). SANDBERGER (1889) reported that he observed a small black diamond in the Carcote crystalline bronzite chondrite. Since these dates, no one has reported the presence of diamonds in stone meteorites. FOOTE (1891) reported diamonds in the Canon Diablo octahedrite and this observation has been confirmed by many workers and by KSANDA and HENDERSON (1939) using X-ray techniques. WEINSCHENK (1889) found diamonds in the Magura octahedrite. Graphite carbon in cubic form has been reported in Magura by HAIDINGER and PARTSCH (1846) in Youndegin and Cosby Creek, by FLETCHER (1887) in Toluca by COHEN and WEINSCHENK (1891) and in Smithville by HUNTINGTON (1894). These cubes of graphite are believed to be pseudomorphs of diamonds. Diamonds and these pseudomorphs have been found only in coarse octahedrites with the exception of Toluca, which is a medium octahedrite. Graphite nodules are also present in some of these. These facts indicate that iron meteorites first separated some carbon as graphite at temperatures and pressures such that this was the stable phase and then came under temperature and pressure conditions such that diamond was stable and then subsequently under conditions such that graphite was again stable. Also they were not within the diamond region long enough for all the graphite nodules to be converted to diamond.

Apparently no search for diamonds in stone meteorites has been made since 1890 until the present search was undertaken in September 1956. It would be particularly interesting if diamonds could be found in stone meteorites which have been dated by the potassium argon method because this would fix the minimum time since they were formed. Diamonds can hardly grow at low temperatures and, if temperatures were high, argon would be lost from the meteoritic material. Hence we attempted to find diamonds in the Richardton, Forest City, and Holbrook

meteorites which have been dated by this method. Large amounts of these meteorites exist so that we felt justified in sacrificing rather large amounts in our attempt to find diamonds in these stones. This search was unsuccessful, as will be described below. Smaller amounts of more rare meteorites were used also. We found diamonds only in Goalpara which is a Ureilite of which Novo Urei is the type specimen.

ANALYTICAL METHOD

The larger samples were broken from larger pieces with a cold chisel and surfaces were cleaned with a corundum wheel. The smaller samples were in powdered form and were residual samples from other work. The ground material was heated for 20–24 hr at 60–70°C with a solution of nitric and hydrochloric acid. The residue was centrifuged from the solution and washed with dilute nitric acid. In this way the metal was oxidized and some of the cations were removed. The residue was treated with sulphuric acid and hydrofluoric acid. The latter was added from time to time during one or two days until the silica was removed. The residual hydrogen fluoride was removed by evaporation. The remainder was washed with water and dried and constituted about 5 or 10 per cent of the original material.

After some preliminary experiments with $NaHSO_4$ and NaOH, it was found that the latter was more satisfactory as a flux for some very resistant minerals. The fusion was carried out in a nickel or silver crucible at 450°C for some hours, depending on the amount of material and its appearance, and the temperature was then raised to 600°C for a few minutes. The fused material was dissolved in dilute nitric acid, the insoluble residue was centrifuged from the solution, washed and dried. The dried sample was suspended in 5 ml of bromoform, then centrifuged and the top layer removed. Both the top and bottom layers were dried. Throughout the procedure all waste solutions were saved and examined with a microscope for solids and were only discarded if no solids were observed.

The final residues were subjected to X-ray diffraction analysis in order to detect the presence of diamond.

Finely ground commercial diamonds and graphite were subjected to the procedure. The diamonds were completely recovered and 40 per cent of the graphite was recovered.

RESULTS

Table 1 summarizes the results. The only sample containing diamond was that of Goalpara which is a Ureilite. The residue in this case consisted of a black powder whose grains were easily visible with the naked eye and had a black matt surface appearance under the microscope. The X-ray pattern also showed the presence of graphite. From the intensity of the X-ray lines it was judged that these grains were 60 per cent diamond. Fig. 1 is a reproduction of the X-ray diffraction patterns of the Goalpara diamonds and finely ground commercial diamonds. It is evident that the CuK_{α_1} and K_{α_2} lines are separated by the commercial diamonds but not by the meteoritic diamonds. From the diffuseness of these lines Professor W. H. Zachariasen estimated the size of the ultimate crystals

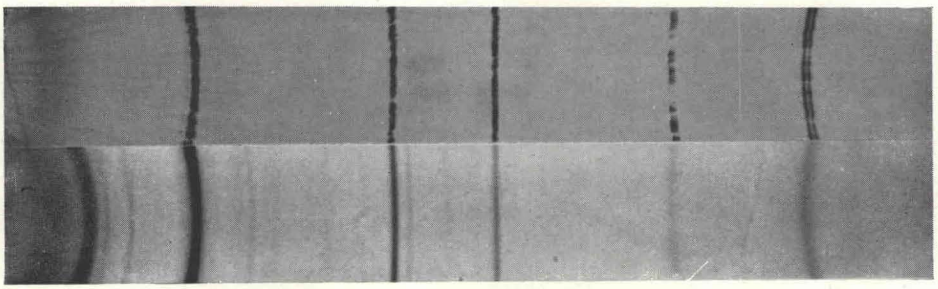

Fig. 1. X-ray diffraction patterns.
Top: Commercial diamonds. Bottom: Goalpara diamonds.

as ~100 Å. This very small size favours the view that these diamonds were produced under unfavourable conditions for the growth of large crystals, i.e., either at comparatively low temperatures during a long period of time or at higher temperatures during shorter times. It will be noted that no smaller limit is reported in the case of the larger quantities of Richardton, Forest City, and Holbrook. This is due to a residue of resistant minerals, presumably chromites,

Table 1

Meteorite	Sample weight before acid treatment (g)	Upper limit for diamond
Richardton (chond.)	102	<0·02%
Forest City (chond.)	71	<0·02%
Holbrook (chond.)	116	<0·02%
Warrenton (carb. chond.)	2·1	<0·05%
Indarch (carb. chond.)	2·6	<0·03%
Cold Bokkaveld (carb. chond.)	0·8	<0·03%
Goalpara (achond.)	1·8	0·3%
Cape Girardeaux (chond.)	1·5	<0·05%
White diamond finely powdered	0·005	~100% recovered
Graphite	0·3	> 40% recovered

which resisted our flux treatment and this decreased the sensitivity of the X-ray detection method. However, the residue was examined with the microscope and no visible diamond particles, such as those observed in the case of Goalpara, were observed. We believe the true limit of diamonds in these objects to be about 0·1 to 0·01 of those reported in the table.

The problem of the origin of diamonds and of the kamacite and taenite of iron and stone meteorites has been discussed by Urey (1956). The problem is a most intricate one, but it seems likely that they originated in the primary objects discussed by Urey.

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