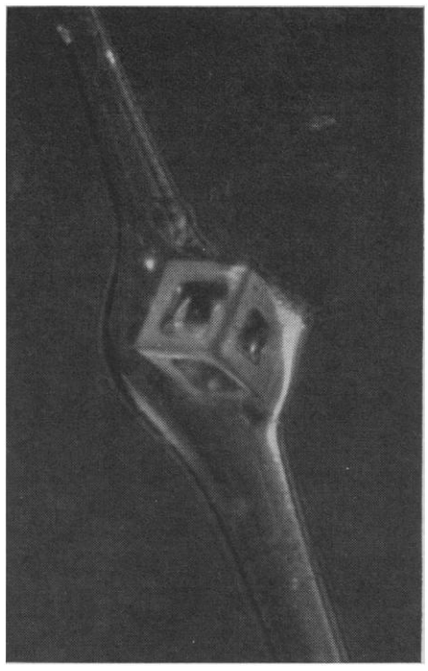

Fig. 1. A hoppered-cubic crystal of plutonium dioxide encased in the plutonium-bearing silicate glass.

cell edge a_0 was 5.397 Å, a value which compared favorably with the accepted lattice parameter for PuO_2, that is a_0 equal to 5.3960 Å (*3*). Because of this similarity in space group, $Fm3m$, and unit cell size, the crystal was identified as PuO_2, the apparent primary phase for the given composition.

The structure of PuO_2 has been established by powder diffraction techniques as being of the fluorite type, C 1 (*4*). With these single crystals of relatively simple habit and high internal symmetry, experimental atomic scattering factors for x-rays can be accurately calculated as Pu^{+4} as a function of the scattering angle (*5*). Roof (*6*) obtained such an experimental function from PuO_2 powder data, but no comparable single crystal values are available.

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31 July 1964

Electron Microscopy of Meteoritic and Artificially Shocked Graphite

Abstract. *Samples of graphite, partly converted to diamond by shock, and meteoritic graphite were studied by transmission electron microscopy. The shocked graphite remained in the form of single crystals and was mildly deformed while the diamond which had formed was anhedral and polycrystalline. The meteoritic graphite contained minor amounts of troilite (FeS) and elemental sulfur but no detectable carbon phase other than graphite.*

As an adjunct to an x-ray crystallographic study of meteoritic diamonds (*1*) we have studied the morphology of the phases present in meteoritic graphite, and in graphite which has been artificially shocked at pressures high enough (300 kbar) to produce diamond (*2*).

Samples of the starting material, high-purity graphite (*3*), as well as the resulting shock-product, and graphite from the interior of a 1.1-g graphite nodule from the Canyon Diablo iron meteorite were crushed to 100 mesh. Slurries in ethanol were then placed in an ultrasonic generator for 5 minutes to disperse the sample uniformly. The suspensions were placed on Formvar, collodion, or carbon substrates for examination in a Hitachi HU-11 electron microscope. Phases were identified by electron diffraction of selected areas with gold and palladium as standards.

Figure 1*a* shows a typical graphite-diamond intergrowth from the artificially shocked graphite. All of the diamonds formed in this manner were anhedral and polycrystalline. The graphite flakes seemed mildly deformed although they remained single crystals. Figure 1*b* shows a typical graphite flake from the starting material.

In both the starting material and shock product the only other phase that we found was in the form of euhedral cubes (Fig. 2) which were single crystals of uncertain origin. The cell dimension of these simple cubic crystals (a_0 = 5.55 Å) corresponds very closely to that of the "carbon II" phase (a_0 = 5.545 Å) reported by Aust and Drickamer (*4*). Inasmuch as the cubes were present in very small numbers (<<1 percent) in both the starting material and product we cannot say that they were produced by shock or, in fact, that they were composed of carbon. It seems very unlikely that some extraneous material would possess exactly the same cell dimension and crystallographic habit as "carbon II". Yet the cubes' euhedral appearance, the general perfection of these crystals, and their low abundance suggest that they were contaminants and not shock-formed. It could also be that these cubes were, indeed, "carbon II" which had grown relatively slowly during preparation of the original artificial graphite block. Unfortunately, all three alternatives (contamination, shock-formation, or slow growth) seem equally unlikely and it is impossible to decide among them with the available data.

The anhedral morphology of the artificial diamond might be expected from the short time available for crystal growth under the experimental shock conditions. Shocks generated

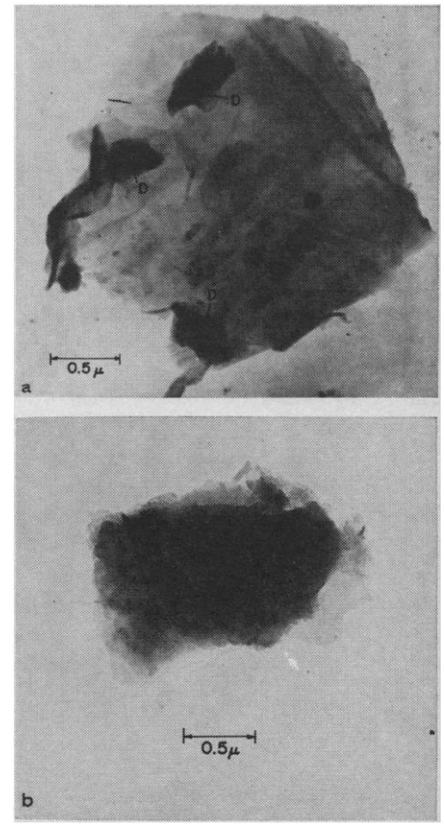

Fig. 1. (*a*) Diamond-graphite intergrowth in artificially shocked graphite. Note the anhedral morphology of the larger diamond grains (*D*). (*b*) Typical flake from the graphite starting material. The texture of this flake may be compared with that of the untransformed graphite in (*a*).

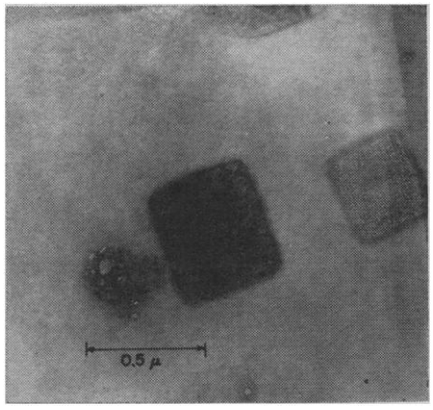

Fig. 2. Unidentified species present in both starting material and shock product. The cell dimension of these cubes is similar to that of the "carbon II" phase reported by Aust and Drickamer (*4*).

during asteroidal collision (*1*) on the other hand, no doubt were of longer duration and might well be expected to result in the formation of subhedral diamond grains. These grains would probably be polycrystalline aggregates, since the shock-induced conversion of graphite to diamond apparently proceeds by a mechanism other than the orderly diffusion and addition of carbon atoms to diamond nuclei (*1*, *2*).

X-ray fluorescence analysis of the interior of the Canyon Diablo nodule indicated the presence of only iron and sulfur. The only carbon phase detected was normal graphite. The cubic phase seen in the starting material and shock product was not observed in the Canyon Diablo nodule.

The sulfur in the Canyon Diablo material apparently exists in two forms; as free rhombic sulfur and as troilite (FeS). Figure 3*a* shows anhedral single crystals of sulfur in a graphite matrix at an electron accelerating voltage of 75 kv. At 100 kv, the normal operating voltage in these studies, the temperature reached was high enough to melt the sulfur (m.p. 113°C), and further aided in its identification (Fig. 3*b*). The troilite in the graphite nodule was identified by both x-ray and electron diffraction. It was present in amounts greater than about 5 percent while the sulfur was present in lesser amounts (about 2 percent).

The coexistence of troilite and elemental sulfur has been observed previously in Type I carbonaceous chondrites (*5*) although in these meteorites there is considerably more sulfur than troilite. Free sulfur has not previously been reported in iron meteorites. It may be that the sulfur was formed by terrestrial weathering of the troilite, the iron thus liberated forming amorphous limonite (*6*). An alternative is that these minerals are preterrestrial. If this was the case it is expected that the S^{32}/S^{34} ratios in the troilite and sulfur may differ.

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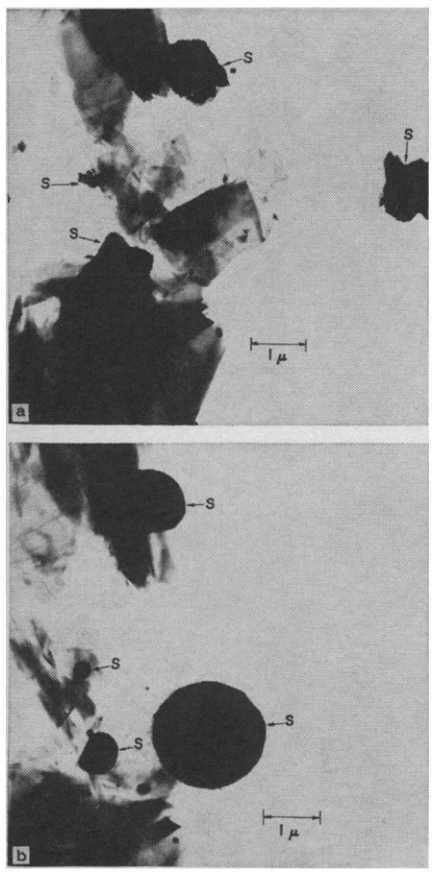

Fig. 3. (*a*) Sulfur (*S*), graphite mixture from Canyon Diablo (75-kv electrons). (*b*) The same area examined with 100-kv electrons. The higher accelerating voltage has sufficiently increased the temperature to melt the sulfur grains.

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6. We thank Prof. Paul Ramdohr for pointing out this possibility.
7. This study was carried out, in part, while M. E. Lipschutz was in the U.S. Army at the Goddard Space Flight Center. We thank Pedro D. Sarmiento of the Goddard Space Flight Center for his valuable assistance, and P. S. DeCarli (Stanford Research Institute) and E. P. Henderson (U.S. National Museum) for providing samples. One of us (M.E.L.) thanks the National Science Foundation for a postdoctoral fellowship at Bern, and the Schweizerischen Nationalsfonds.

13 April 1964

Solar Activity During the First Six Months of the International Years of the Quiet Sun

The first 6 months of the International Years of the Quiet Sun (IQSY) have passed. The solar activity at the start of the IQSY program has been described (*1*) and the present report constitutes a supplement to the earlier report.

In April 1964 the monthly mean relative sunspot number (Zurich) dropped below 10 for the first time in the declining phase of the present sunspot cycle. It was 7.7 in April, 9.4 in May, and 9.3 in June. Values below 5.0, which were characteristic of preceding solar minima, have not occurred (Table 1).

In the first half of 1964 the average latitude of old cycle spots, as observed at the McMath-Hulbert Observatory, dropped to 8.7° in the northern hemisphere and to 6.7° in the southern. All new cycle spots observed prior to 1 July 1964 have been in the northern hemisphere. Their mean latitude during the first six months of 1964 was 30.6°. In the same interval, the number of spotless days per month increased slightly, but it was not as high as 10 for any one month (Fig. 1). The number of sunspot groups per month diminished after March, but the lower total activity was accompanied by more frequent formation of members of the new cycle (Fig. 2).

Eight spot groups of the new cycle were observed at the McMath-Hulbert Observatory during the first 6 months of IQSY. For all of these spot groups the latitudes were $\leq 25°$, and the magnetic polarities were appropriate for the new cycle of activity. In general, the new cycle regions have been well developed and of relatively long duration. According to the four preceding minima, new cycle activity, once established, increases rapidly. If this is a