DIAMONDS FROM ACFER 182: MORPHOLOGY, C & N STABLE ISOTOPIC COMPOSITION AND CATHODOLUMINESCENCE PROPERTIES, Monica M. Grady[1], M. R. Lee[2], C. M. O'D. Alexander[3], J. W. Arden[4] and C. T. Pillinger[5]. [1]Dept. of Mineralogy, The Natural History Museum, Cromwell Road, London SW7 5BD, U.K., [2]Dept. of Geology & Geophysics, University of Edinburgh, Edinburgh EHG 3JW; [3]McDonnell Center for Space Sciences, Washington University, St. Louis MO 63130, U.S.A.; [4]Dept. of Geology, University of Oxford, Parks Road, Oxford; [5]Planetary Sciences Unit, Dept. Earth Sciences, The Open University, Walton Hall, Milton Keynes MK7 6AA, U.K.

The occurrence of diamond in meteorites is well-documented, and much debate has ensued over their possible modes of formation. Sub-millimetre-sized diamonds located in iron meteorites and veins in ureilites are generally thought to be the result of collision, either during terrestrial impact [1] or between parent-bodies in space [2], although origin by chemical vapour deposition (CVD) has also been proposed [3]. The carbon and nitrogen isotopic compositions of these diamonds probably reflect their solar system origin [4]. Primitive chondrites also contain diamonds, although in this case they are nm-sized and play host to nitrogen and noble gas components with unusual isotopic compositions [5, 6]. These Cδ diamonds are believed to be circumstellar grains. A third type of diamond, of unknown provenance, has recently been isolated from the Abee EH4 chondrite [7], as lath-shaped crystals with solar system carbon and nitrogen isotopic compositions. Since Abee is an unshocked meteorite, such diamonds are unlikely to be produced by collision. Thus far, all the samples studied have diamond of a single type, however, during study of the ungrouped chondrite Acfer 182, we have found diamond occurring in two morphologies. One is similar to Cδ, the other we consider in more detail here.

Acfer 182 is an unusual chondritic breccia, characterised by its fine-grained nature, high metal content, small average chondrule diameter and abundant clasts of dark matrix [8]. It is relatively unshocked, most of the sample being S2, with only a few olivine grains exhibiting S3 features [8]. An outstanding feature of the meteorite is its elevated nitrogen isotopic composition, with whole-rock $\delta^{15}N$ values up to *ca.* +800‰, reaching +1600‰ in a single step [9]. In the hope that the elevated $\delta^{15}N$ values represented an abundant concentration of a new population of pre-solar grains, different from any so far recognised in other primitive chondrites, a suite of acid-resistant residues was prepared. After treatment with HF, HCl, $Cr_2O_7^{2-}$ and $HClO_4$, a residue was obtained which represented 550 ppm of the original material. Combustion indicated that only *ca.* 7 wt.% of the residue was carbonaceous; EPMA confirmed that the bulk of the sample was in the form of the insoluble oxides corundum and spinel. Transmission electron microscopy (TEM) identified the carbonaceous material as diamond, most of which appeared as clumps of nm-sized grains, similar in appearance to Cδ diamond. However, in addition to these aggregates, several large, micron-sized individual diamond platelets were present, the largest of which had dimensions *ca.* 8μm x 5μm.

Diamonds in Acfer 182
Grady, M. M. *et al.*

Stepped combustion of the residue indicated that almost all of the heavy nitrogen had been removed by the acid treatment. The major release of carbon and nitrogen occurred between 510°C and 550°C, with $\delta^{15}N$ down to -200‰, and mean C/N by mass *ca.* 85. The combustion temperature is higher by *ca.* 20°C than that of Cδ isolated from CM chondrites [10], but the low absolute value of C/N and its variation with temperature is similar. These properties are consistent with identification of most of the residue as Cδ-type diamond, or at least a close relation, modified by the presence of small residual amounts of ^{15}N-enriched material.

Between 625°C and 700°C, almost 14% of the carbon present in the residue combusts; this temperature range is appropriate for combustion of micron-sized diamonds [11]. Nitrogen isotopic composition is variable, with $\delta^{15}N$ rising from -5‰ to +21‰, then decreasing to -6‰. Nitrogen isotopic composition is therefore quite distinct from that of Cδ diamond, as is the C/N ratio of *ca.* 1000. The combustion temperature, isotope characteristics and C/N ratio implies this material is also different from diamonds isolated from ureilites [12] and Abee [7].

Dark-field images obtained by TEM reveal that the largest diamond platelet found is morphologically different from Abee, exhibits symmetrical extinction features radiating from a void at the centre of one of the long edges. In an effort to determine whether this feature represented zoning associated with growth bands emanating from a "seed" nucleus, a scanning cathodoluminescence (CL) image was generated using a CL-SEM system with attached monochromator. The diamond luminesced only weakly, due to its size and transparency, but the CL exhibited was centred in the blue region of the spectrum, with strongest emission at 425nm. No sectored growth zoning corresponding to the dark-field symmetry was observed: rather, the CL was strongest at edge defects, also visible in the secondary electron image. Inferences drawn from the CL imagery are that the large diamond is a single crystal, not an aggregate of lath-shaped diamonds, and that the visible structures are either growth defects or shock-induced during collisions.

We conclude that Acfer 182 is a source of yet another type of diamond with solar system characteristics, for which a shock origin cannot be eliminated. The diamonds are of a sufficient size for individual crystals to be used for ion probe studies.

Acknowledgements: Dr Paul Wright and Oxford Instruments Ltd., Eynsham, U.K., are gratefully acknowledged for carrying out the scanning cathodoluminescence analysis of Acfer 182 diamond.

References: [1] Lipschutz, M. E. and Anders, E. (1961) *Geochim. Cosmochim. Acta* **24** 83-105; [2] Vdovykin, G. P. (1970) *Sp. Sci. Rev.* **10** 483-510; [3] Fukunaga, K. *et al.* (1987) *Nature* **328** 141-143; [4] Grady, M. M. *et al.* (1985) *Geochim. Cosmochim. Acta* **49** 903-915; [5] Lewis, R. S. *et al.* (1983) *Nature* **305** 767-771; [6] Lewis, R. S. *et al.* (1987) *Nature* **326** 160-162; [7] Russell, S. S. *et al.* (1992) *Science* **256** 206-209; [8] Bischoff, A. *et al.* (1993) *Geochim. Cosmochim. Acta* **57** 2631-2648; [9] Grady, M. M. & Pillinger, C. T. (1993) *Earth Planet. Sci. Lett.* **116** 165-180; [10] Russell, S. S. *et al.* (1991) *Science* **254** 1188-1191; [11] Wright, I. P. and Pillinger, C. T. (1989) *USGS Bulletin* **1890** 9-34; [12] Russell, S. S. *et al.* (1993) *LPSC* **XXIV** 1221-1222.