

the true isotopic composition of C% its concentration is *ca.* 5 ppm, the same as the concentration of C α in the CM2 meteorites as calculated on the basis of noble gas content (4).

The second heavy carbon component may be C β , the carrier of s-Xe (5), present in concentrations *ca.* 8 ppb, compared with 400 ppb in CM2s, although there is no definite data on this point and its isotopic composition cannot be matched to C β as previously determined on CM2 residues. In an attempt to measure a limiting $\delta^{13}\text{C}$ value for the high temperature heavy C a prolonged, higher temperature (500 °C) precombustion experiment was performed on PC(d) to reduce the tailing of the low temperature carbon to a minimum to give PC(e). In addition to reducing the overall carbon content to 0.13 wt.%, this extended precombustion also reduced the $\delta^{13}\text{C}$ values of both the isotopically heavy components to +248 and +340‰ respectively. This change was affected because a new, isotopically light component, $\delta^{13}\text{C} < -261\text{‰}$, burning at intermediate temperatures, has been revealed. At this point we are unable to decide whether the light component was masked by other carbonaceous material or whether it has been released by degradation of noncarbonaceous minerals in the oxygen associated with the combustion experiment. Because of the similarity of the combustion temperatures of the two heavy carbon components and the new light component, the $\delta^{13}\text{C}$ value of -261‰ measured for the latter may well be an upper limit for a substance dramatically enriched in ^{12}C . References: (1) Ash *et al.* (1988) *LPSC* **19**, 15–16. (2) Ash (Oral presentation) *LPSC* **19**, (3) Alaerts *et al.* (1980), *GCA* **44**, 189–209. (4) Anders (1987) *Phil. Trans. R. Soc. Lond.* **A323**, 287–304. (5) Swart *et al.* (1983) *Science* **220**, 406–410.

A Preliminary Study of Fluid Inclusions in Shock-Metamorphosed Sediments at the Houghton Impact Structure, Devon Island, Canada. J. G. Bain and S. A. Kissin. Dept. of Geology, Lakehead Univ., Thunder Bay, Ont. P7B 5E1, Canada.

The Houghton impact structure is a well preserved, 22 Ma old (Miocene), meteorite crater that lies in the lower Paleozoic shelf-type sediments, overlying gneissic Precambrian basement, on Devon Island in the Canadian Archipelago (1, 2). A suite of fallback breccias including biotite-granite gneisses from the Precambrian basement and monomict and polymict breccias that represent most of the sedimentary succession from the Houghton region was studied. All of the breccias have been shock metamorphosed. Monomict breccias, which are largely carbonate, show very few shock metamorphic effects. Shock effects are evident in gneisses and they have experienced pressures up to 25 GPa and temperatures up to 300 °C. Polymict breccias, containing thermally melted glass and shocked crystal fragments, display the highest degree of shock metamorphism, in the range of 25 to >55 GPa and 300 to more than 2000 °C. These glass-bearing, polymict breccias are highly vesicular due to the high-pressure vapourization of water and silicate minerals and to the decarbonation of calcite-rich sediments into CO₂ gas and CaO.

Small two-phase, liquid-vapour fluid inclusions are generally abundant in the normal glasses of the glass-bearing, polymict breccias. A thorough microthermometric study of these inclusions revealed that they are water-rich, CO₂-free and of low salinity, in the range 0.3 to 3.37 equivalent wt.% NaCl. Homogenization temperatures are most frequent between 140 and 150 °C, although the range spans 137 to 243 °C. The glasses are essentially pure SiO₂, and these temperatures could not possibly represent true trapping temperatures. The glasses in these polymict breccias are fresh and unfractured, however, indicating that the fluid in the inclusions was not introduced after solidification of the glasses. The following explanation is proposed.

Wet quartz- and carbonate-rich sedimentary rocks that were shocked to more than 28 GPa, a common occurrence at Houghton, were melted and sometimes vapourized. Water from these rocks was dissolved, forming a superheated solution with the silicate melt. Upon passage of rarefaction waves high-pressure, high-density, superheated water vapour exsolved from the superheated water-silicate melt. Much of this vapour was able to expand to atmospheric pressure, vesiculating the melt in the process. The high-pressure, high-density, superheated water vapours that did not escape before the melt quenched formed submicroscopic to 100 μm long vesicles. These vesicles, filled with high-pressure, high-density vapour, were the precursors to the two-phase, liquid-vapour fluid inclusions that were measured. As the quenched melt cooled below the temperature at which the high-density, high-pressure water vapour

was trapped, the water vapour condensed into low-density, metastably stretched water solution. Further cooling caused the stretched water in the inclusion to shrink more than its glass host, creating a non-metastable, two-phase, liquid-vapour inclusion. The homogenization temperatures that have been recorded indicate the temperature range over which the one-phase, metastably stretched water-filled fluid inclusions reverted into the stable, two-phase, liquid-vapour state. References: (1) Frisch T. and Thorsteinsson R. (1978) *Arctic* **31**, 108–124. (2) Bischoff L. and Ostertag R. (1986) *Geowiss. Unserer Zeit.* **4**, 105–115.

Thermoluminescence in Chondritic Mineral Separates—A Preliminary Report. J. David Batchelor and Derek W. G. Sears. Cosmochemistry Group, Department of Chemistry and Biochemistry, University of Arkansas, Fayetteville, AR 72701 USA.

It has been shown that plagioclase feldspar is the predominant thermoluminescence (TL) phosphor in chondritic meteorites. Van Schmus and Wood (1967) recognized the presence of secondary feldspar in chondrites of type 4 and higher, and specified the presence of well developed plagioclase as a defining characteristic of type 6. Van Schmus and Ribbe (1968) found plagioclases ranging from An 8 to An 16 in type 6 chondrites. Their X-ray diffraction studies showed a moderately high degree of disorder with [20(131)-20(131)] about 1.75 and with little spread. They saw no evidence for crystallographically distinct K-feldspar. Lalou *et al.* (1970) examined mineral separates from Saint Séverin (LL6), and found that about three-fourths of the TL signal (71% for the induced TL and 78% for the natural TL) was due to plagioclases, with about 10% from Merrillite/Whitlockite. They reported that 8% of the induced TL and 3% of the natural TL was in the olivine fraction. McDougall (1968) reported only a very weak TL signal from olivine at temperatures above 425 °C. Pasternak (1978) reported that the TL peak temperature (T_{max}) of albite increased with thermally induced Al/Si disorder, and Guimon *et al.* (1984) showed that annealing of a type 3.5 ordinary chondrite caused the peak to broaden and move to a higher T_{max}.

We are attempting to demonstrate a correlation between T_{max} and degree of ordering of feldspar in ordinary chondrites. We have performed mineral separations by heavy liquids on Bruderheim (L6), Dhajala (H3.8), and ALHA 77214.55 (L3.4). Each sample was ground, and the magnetic fraction separated. Density separation was by float/sink in heavy liquids. Each split was acetone washed, and its natural and induced TL measured. Each fraction was then further ground, and X-ray diffraction patterns obtained.

The bulk material showed TL levels of 1.4 for Bruderheim and 0.069 for ALHA 77214 (Dhajala = 1), consistent with their petrologic types. Peak temperatures were at 198 °C for Bruderheim, 160 °C for Dhajala, and 128 °C for ALHA 77214, as expected for their petrologic types. The first separation was done in CH₂I₂ with a measured density of 3.30 g/cc. Each meteorite showed 12 to 20% light material. ALHA 77214 and Dhajala both showed a 3-fold enhancement in the TL of the light fraction, but Bruderheim showed an 11-fold enhancement, consistent with feldspar being the major phosphor and its larger feldspar crystal size. X-ray diffraction showed the presence of olivine and pyroxene in all fractions, but only the 040 line for oligoclase. Further separations will be done at densities of 2.6 and 3.0 g/cc to extract the plagioclase component.

This research is supported by NASA grant NAG 9-81. References: Guimon R. K. *et al.* (1984) *Nature* **311**, 363–365. Pasternak E. S. (1978) Dissertation, Univ. of Pennsylvania. Lalou C. (1970) *C. R. Acad. Sc. Paris* **270**, Série B 1706–1708. Van Schmus W. R. and Ribbe P. H. (1968) *GCA* **32**, 1327–1342. Van Schmus W. R. and Wood J. A. (1966) *GCA* **31**, 747–765.

A Probable Asteroidal Parent Body for the CV or CO Chondrites. Jeffrey F. Bell. Hawaii Institute of Geophysics, 2525 Correa Road, Honolulu HI 96822 USA.

“Carbonaceous chondrites” have been traditionally associated with the Class C asteroids. In fact this identification only applies to the CI and CM chondrites. The asteroidal affiliations of the anhydrous CV and CO chondrites have been much more mysterious. Some spectroscopists have associated CV/CO mineralogies with atypical C-type objects, while others have selected certain S-type asteroids as the most likely candidates.

This long-standing mystery has been unexpectedly clarified by infrared spectral observations of the Eos asteroid dynamical family, which has traditionally posed a difficult problem for asteroid classification schemes. Gradie and Zellner (1) found that the UVB colors of the Eos family asteroids clustered tightly on the boundary between the S and C fields, and that their radiometric albedos were also intermediate to these two classes. This led to the apparently contradictory situation in which the Eos family was thought to be homogenous in composition, while the individual objects were classed as C, S, or U based on very small variations in color and albedo. The classification scheme of Tholen (2) eliminated this discrepancy by putting almost all Eos family objects into an enlarged S class.

The new IR spectral observations have revealed that most Eos family asteroids exhibit flat IR reflectance curves with very shallow silicate absorption bands. These spectra are totally atypical of other S-type asteroids, and more closely resemble classical C-type spectra. The visual and IR data as a whole suggest that the Eos family parent body was not a true member of either the C or S class.

Comparison of the spectral and albedo data with the available meteorite spectra reveals a close similarity with CV and CO chondrites. Other meteorites with similar intermediate albedos such as ureilites and highly shocked ordinary chondrites appear much less likely candidates from both spectral and petrologic grounds. If we accept both this compositional interpretation and the Tholen classifications, a new paradox exists: the most common classes of carbonaceous chondrites are derived from Class S asteroids, instead of the Class C asteroids usually associated with dark meteorites. To simplify terminology and properly recognise the unique properties of the Eos family asteroids, a new asteroid class "K" is proposed to incorporate them. This class is provisionally defined as objects with albedos near 0.09, S-like spectral curvature at visual wavelengths, weak 1-micron absorption bands, and flat reflectance from 1.1 to 2.5 microns. Although the known asteroids of this class to date are Eos family members, the existence of both CV and CO chondrites indicates that some other asteroids currently classed as S-types on the basis of visible spectra will turn out to be K-types as near-IR observations are extended to fainter objects. References: (1) Gradie and Zellner (1977) *Science* **197**, 254–255. (2) Tholen (1984) Ph.D. thesis.

Ion Probe Analysis of Melt Veins in META78008 Ureilite. J. L. Berkley. SUNY College at Fredonia, NY 14063 USA.

Siliceous melt veins occur in a number of ureilites (*e.g.*, 1, 2) interstitial to major silicate grains (olivine/pyroxene), and less commonly penetrating fractures in silicate grains. They consist of a siliceous glass (commonly also enriched in Al and alkalis) enclosing skeletal quench crystals of pyroxene, or rarely olivine. Unusually thick melt veins occur in META78008 (a rare, augite-bearing ureilite) approaching 200 microns in diameter in some areas (10–20 microns is the norm). Veins consist of glass with up to 70 wt.% SiO₂, 18% Al₂O₃, 7% CaO, 3% Na₂O, and 0.8% K₂O. Quench crystals include skeletal, magnesian pigeonite (Mg = 98; Wo = 6) and minor silica grains. Minute, low-Ni, Fe-Ni metal blebs are ubiquitous. Similar veins have been previously interpreted as originating externally to the ureilite host, introduced therein by injection during a late-stage shock-reduction event (1, 2). To better gauge the origin of melt veins in META78008, ion microprobe analyses (A. Shimizu lab, MIT; D. Hickmott, analyst) were performed on melt veins and major silicates for REE and other trace/minor elements (Sr, Sc, V, Cr, Ti).

REE analyses of glass plus quench crystals (no beam overlap with carbon or major silicates) show a relatively flat Cl-normalized pattern, with 3 × avg. enrichment relative to Cl. Neither batch nor fractional fusion of typical ureilite ultramafic assemblage can account for this pattern. Nevertheless, various lines of evidence suggest that most of the META78008 melt was derived by internal melting and concomitant reduction of *augite*. Specifically, (a) vein thickness significantly increases along augite grain boundaries, but thins or is absent at ol-ol and ol-pig boundaries, (b) augite grains display irregular (reaction?) grain boundaries with melt veins, and contain isolated pockets of melt internally ("islands" of unconsumed augite occur in melt veins in some areas), (c) transition elements and Sr trends in the melt show parallel trends compared to augite, (d) mass balance modeling shows that appropriate mixtures of melt plus reduced augite margins (enriched in Ca/Al, Mg/Fe relative to core) can reproduce augite core compositions reasonably well.

Better results are achieved by considering loss of Cr and Fe to reduced metal blebs, and addition of Si to the melt by ol reduction. Thus, in this particular ureilite, melt veins were wholly or mostly internally derived by non-equilibrium partial melting and reduction of augite and, to a much lesser extent, olivine. This process was probably triggered by sudden decompression coupled with rapid, temporal heating during an impact event. References: (1) Goodrich C. A., Keil K., Berkley J. L., Laul J. C., Smith M. R., Wacker J. F., Clayton R. N. and Mayeda T. K. (1988) *Meteoritics* **22**, 191–218. (2) Goodrich C. A. and Berkley J. L. (1985) *Lunar and Planetary Sci.* **16**, 280–281.

TEM Observations of Interstellar Silicon Carbide from the Murray and Murchison Carbonaceous Meteorites. T. Bernatowicz,¹ G. Fraundorf,² P. Fraundorf^{1,2,3} and Tang Ming.⁴ ¹McDonnell Center for the Space Sciences and the Physics Department, Washington University, St. Louis, MO 63130 USA. ²Monsanto Electronic Materials Company and Monsanto Corporate Research and Development Staff, Monsanto Research Center, St. Louis, MO 63167 USA. ³Physics Dept., Univ. of Missouri: SL, St. Louis, MO 63121, USA. ⁴Enrico Fermi Institute and Department of Chemistry, University of Chicago, Chicago, IL 60637 USA.

We report here results of TEM observations of interstellar SiC grains in dissolution residues from the Murray and Murchison carbonaceous meteorites, which have been subjected to previous isotopic studies (Zinner *et al.*, 1987; Tang *et al.*, 1988). These residues have been shown to have isotopically anomalous noble gas compositions, and to contain grains with isotopically anomalous Si, C, and N.

Darkfield imaging, tilting under brightfield conditions, electron energy loss spectroscopy (EELS) and energy dispersive X-ray spectroscopy (EDXS) show the major constituents of these residues to include crystalline grains in the 0.1 to 3 micron size range whose major elements are Si and C.

Electron diffraction patterns from individual grains and portions of grains invariably show one of the following: (a) single crystal cubic (β) silicon carbide spot spacings and interspot angles, in one case for patterns taken through a 90 degree range of incident electron illumination (Bernatowicz *et al.*, 1987); (b) the reciprocal lattice structure of β -SiC with fcc twinning in one or more {111} direction; or (c) spacings characteristic of β -SiC (and other SiC polytypes) orthogonal to a tetrahedral layering direction (*e.g.*, the cubic {111}), with nearly continuous streaking parallel to that direction. Diffraction patterns from one twinned β -SiC grain from a Murray residue further show 22 Å repeats whose explanation, as either a distinct polytype (*e.g.*, the 27R form) or as a result of twins upon twins, is still being investigated.

High resolution TEM imaging, using a Philips EM430ST TEM with point resolution near 1.9 Å and damping cutoff in that region as well, shows some of the twins to be in the form of {111} laths only about 20 Å in thickness. It also suggests separately the existence of "bulk twinning," on a scale comparable to grain dimensions. The habit for these "bulk" twins remains to be determined. We estimate on average between 10⁵ and 10⁶ cm² of twin interface per cm³ of SiC examined, although (as indicated above) the extent of disordering varies significantly from grain to grain. Finally, periodicity "phase" information in high resolution images down the cubic <110> direction reproduces the triangular symmetry for SiC atom columns expected of a structure consisting of separate interpenetrating fcc lattices of Si and C, offset in the <111> direction by about $\sqrt{3} a/4$.

β -SiC is a common form for SiC crystals nucleated from the vapor phase, but it is commonly formed under other conditions as well. Identification of coexisting polytypes may provide tighter constraints on formation times and temperatures. Twinning in β -SiC is also common. However, the details of the twinning such as twin lath thickness and number density may put constraints on grain formation rates and temperatures and subsequent thermal history. Since ion microprobe studies (Zinner *et al.*, 1987) point to isotopic differences from grain to grain, an opportunity to correlate these differences with grain structure might prove very interesting. The observations described here also constrain the prior irradiation history of the grains, although the nature of those constraints is still under investigation. For example, the grains certainly are not metamict and we also see no evidence for nuclear particle tracks or other irradiation induced defects. References: Bernatowicz T. *et al.*