

SHOCK METAMORPHISM OF CARBONACEOUS CHONDRITES; E.R.D. Scott¹, K. Keil¹, and D. Stöffler^{1, 2}. (1) Planetary Geosciences Division, Dept. Geol. & Geophysics, SOEST, University of Hawaii, Honolulu, HI 96822, (2) Institut für Planetologie, Westfälische Wilhelms-Universität, D-4400, Münster, Germany.

We present the first quantitative estimates of the shock intensities experienced by CM2, CO3, CV3 and CK4-6 chondrites and their ingredients. The shock classification we use is that of Stöffler et al. [1]. Like earlier schemes [2], it is based on optically visible shock effects in large olivine and plagioclase grains. The chief shock features in olivine [3] are as follows: stage S1, sharp optical extinction, <5 GPa; stage S2, undulatory extinction (>20°); stage S3, planar fractures, 5-10 to 15-20 GPa; stage S4, mosaic extinction; stage S5, planar deformation features or 'elements' plus maskelynite, 30-35 to 45-55 GPa; stage S6, recrystallization near melt zones. We find that most carbonaceous chondrites have been shocked to stages S1 and S2; the most heavily shocked are members of the CK4-6 group. In another abstract [4], we compare the shock levels in ordinary and carbonaceous chondrites and discuss reasons for the observed differences.

CM2 chondrites. Although large olivines (100-500 µm in size) are comparatively rare in many CM2 chondrites, our survey indicates that Murray, Murchison, Nogoya, Crescent, Bells, EET 83224/6 and ALH 81002/82100 are very largely composed of shock stage S1 material. In Murray and Murchison a small fraction of isolated and chondrule olivines show abundant irregular fractures and undulatory extinction (S2) and some chondrules were probably shocked prior to aggregation of the ingredients. The low abundance of irregular fractures in olivine (except in certain partly altered crystals), absence of planar fractures, opaque shock veins, melt pockets and veins also testify to a mild shock history for CM2 material.

CV3 chondrites. The most heavily shocked of the 9 CV3 chondrites studied are Efremovka (S3) and Leoville (S2). In Efremovka there is localized shock melting of FeS and silicate forming networks of narrow veins (<50 µm wide) that contain FeS-Fe,Ni spherules. Allende, Mokoia, Vigarano (all 3 contain solar-wind gases) and Arch are all largely composed of stage S1 material. Rare chondrules showing stage S2 or S3 features were observed in Vigarano and Allende. These were probably shocked prior to aggregation [5], but heterogeneous shock intensities cannot be excluded as shock stage S1-S3 features have been observed in different parts of a single chondrule in ordinary chondrites. ALHA 81258 and 84028 are both stage S1.

The two highly shocked chondrites, Leoville and Efremovka, have chondrules that are much more elongated and aligned than those in Allende, which are round [6, 7]. This correlation between the degree of chondrule flattening and the shock level is analogous to that found in ordinary chondrites by Sneyd et al. [8] and probably results from squeezing of chondrules into voids at shock levels above 5-10 GPa.

CO3 chondrites. All of the 5 non-Antarctic, 7 ALH and 2 Yamato CO3 chondrites studied show very few signs of hypervelocity shock and are classed as shock stage S1. About 5% of large olivines show undulatory

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extinction (S2), notably in ALHA 77003, Kainsaz and Ornans; shock effects are commonly enhanced at crystal edges. Troilite-filled olivine fractures and shocked constituents are exceedingly rare and shock melt veins are absent. But in Lancé, metal-troilite interfaces show 'fizzed' textures [9] due to local melting; this melt did not penetrate into adjacent silicates. How unshocked or lightly shocked material can coexist with apparently shock melted troilite is not known; this association has also been observed in ordinary chondrites and irons [10].

CK4-6 chondrites. Our preliminary data for this newly defined group [10] show that shock levels are higher than in other carbonaceous chondrites as first noted by Rubin [12], but not significantly higher than those in ordinary chondrites. The most heavily shocked are EET 83311 (S5 or S6) and LEW 87009 (S3-4), which both have impact melt veins [12] that are quite analogous to those in S3-S6 ordinary chondrites, except for the absence of Fe,Ni and presence of pentlandite instead of troilite. Apart from EET 87860 (S2 or S3), the other CK chondrites studied (ALH 82135, 85002, EET 87507, LEW 86258) all show undulatory extinction in olivine and plagioclase (S2). Contrary to Kallemeyn *et al.* [11], we believe that the ubiquitous blackening caused by abundant magnetites and the plagioclase compositional heterogeneity are not shock features.

Other C chondrites. The following ungrouped carbonaceous chondrites are all shock stage S1-S2: Al Rais, S1; MAC 87320 and EET 87770 (both Renazzo-like), S2; Y-82094, unique C3, S2; LEW 85332, unique C3, S1; Coolidge, C4, S2.

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