EFFECT OF LOW INTENSITY IMPACTS ON CHONDRITE MATRIX. P.A. Bland[1,2,3], A.R. Muxworthy[1], G.S. Collins[1], J. Moore[1], T.M. Davison[4], D.J. Prior[5], J. Wheeler[6], F.J. Ciesla[4], and K.A. Dyl[1,2,3]. [1]Impacts & Astromaterials Research Centre (IARC), Dept. Earth Science & Engineering, Imperial College London, SW7 2AZ, UK (p.a.bland@imperial.ac.uk). [2]IARC, Dept. Mineralogy, Natural History Museum, London SW7 5BD, UK. [3]Dept. Applied Geology, Curtin University of Technology, GPO Box U1987, Perth WA 6845, Australia. [4]Dept. Geophysical Science, University of Chicago, 5734 South Ellis Av., Chicago, IL 60430, USA. [5]Dept. Geology, University of Otago, 360 Leith Walk, PO Box 56, Dunedin, Otago 9054, New Zealand. [6]Dept. Earth and Ocean Sciences, University of Liverpool, 4 Brownlow Street, Liverpool L69 3GP, UK.

Introduction: Shock metamoprhism of carbonaceous chondrites is rarely considered as a dominant factor in their evolution. In a study of 51 CM, CO, and CV carbonaceous chondrites [1], 43 were found to be shock level S1 (peak shock pressures <4-5GPa). These low intensity impacts are thought to leave a meteorite essentially unscathed, with no effects resulting from local P-T excursions, and estimated post-shock temperature increases of <10-20K [2].

The level of impact processing in chondritic meteorites is principally quantified based on shock metamorphic textures in large (>50-100µm) chondrule olivines [1,2]. But chondrites are bimodal materials: (nominally) zero-porosity spherical chondrules set in a matrix aggregate composed of sub-µm monomers. Shock effects in matrix grains are rarely considered. An obstacle to understanding shock effects in porous meteorites has been the absence of direct information on the nature of the porosity prior to the shock event [3]. But a methodology using EBSD data to quantitatively relate fabric intensity to net compression [4] has overcome this obstacle, allowing us to reconstruct a pre-compaction porosity for matrix and the parent body as a whole. In this study we use a combination of EBSD observations [4,5], fabric analysis [4], and numerical modelling to understand impact processing of primitive chondrites. We show that although these meteorites may have only experienced low intensity impacts, the effects of compacting initially highly porous [4] matrix aggregates are profound, with large temperature excursions even at low shock pressures.

Results and Discussion: Although computational modelling has been utilised in attempting to understand the complexities of shock in porous materials [6,7] there have been no numerical studies of shock in the bimodal materials that are chondritic meteorites. This is unfortunate given that high porosity chondritic planetesimals were (arguably) the starting point for all inner solar system solids. To begin exploring this area we conducted 2D meso-scale numerical simulations of shock propagation in bimodal mixtures (Table 1 and Figure 1) using the iSALE hydrocode [8]. All simulations are for low-intensity impacts: bulk shock pressures well within the S1 region.

Our results indicate that matrix and chondrules behave very differently (Table 1 and Figure 1). Although bulk T(final) is consistent with macro-scale modeling [6], the meso-scale simulations reveal that matrix expe-

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BULK						
P(peak)	1.36	1.53	1.66	1.78	1.87	3.52
T(final)	450	410	385	375	355	700
Porosity (%)^i	0.49	0.42	0.35	0.28	0.21	0.49
Porosity (%)^f	0.17	0.15	0.13	0.11	0.09	0.03
MATRIX						
Abundance (%)^i	70	60	50	40	30	70
Abundance (%)^f	0.51	0.41	0.33	0.26	0.20	0.44
Porosity (%)^f	0.32	0.37	0.41	0.41	0.44	0.08
***Z* value**	0.45	0.46	0.49	0.52	0.57	0.34
T(final) mean	630	625	630	635	600	1160
T(final) (1σ)	60	70	80	75	85	110
P(peak) mean	1.7	1.9	2.0	2.1	2.1	6.6
P(peak) (1σ)	0.3	0.3	0.4	0.5	0.6	2.1
CHONDRULES						
T(final) mean	310	310	310	320	320	370
T(final) (1σ)	10	20	30	15	15	40
P(peak) mean	1.5	1.7	1.9	2.1	2.2	5.4
P(peak) (1σ)	0.3	0.4	0.5	0.6	0.7	0.4

Table 1. The results of various meso-scale iSALE simulations of shock propagation through a chondrule/matrix mixture. The porosity in the continuous matrix is parameterized as it exists on a length-scale too small to be resolved in the simulation. A planar shock wave was formed by a simulated plate impact. Plate impact speed was held constant in scenarios 1 through 5 (initial matrix abundance varies); impact speed is increased in scenario 6. In all meso-scale scenarios initial matrix porosity is 70% (estimate from EBSD observations [4]) and initial temperature is 300K. Temperature in Kelvin; shock pressure in GPa. Superscript ‘i’ indicates initial (e.g. initial porosity); ‘f’ indicates final. *Z* value is a quantitative measure of degree of compaction (see [4] for detail). It can be derived from EBSD analysis of matrix [4]. In the case of meso-scale modelling it is calculated from initial and final (post-impact) bulk porosity.

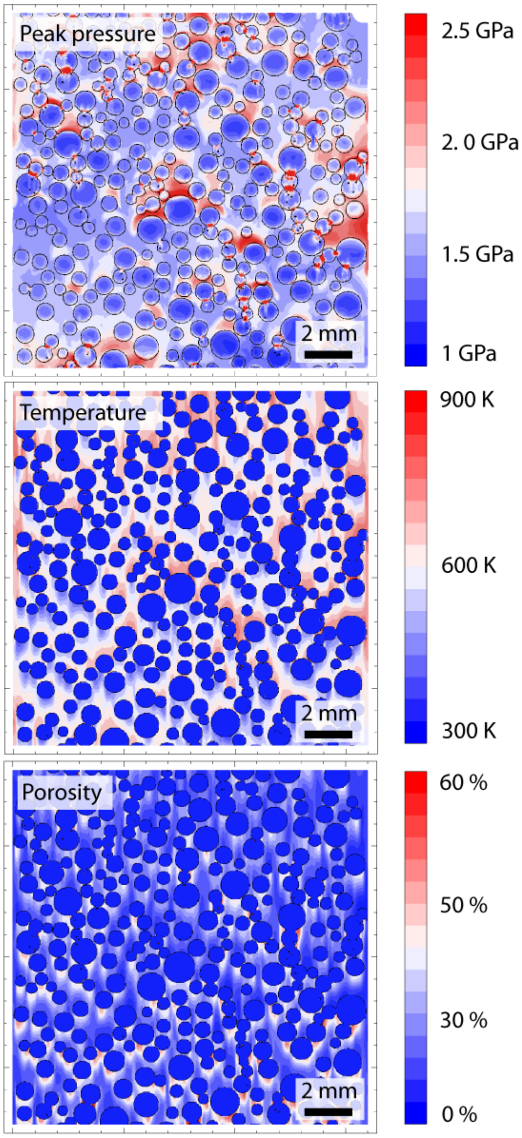

Figure 1. The variation in peak shock pressure, post-shock temperature, and post-shock porosity in an example meso-scale simulation (a 1.36GPa bulk P(peak) event). In each case, the image illustrates the variation in the stated variable over a region of the compacted bimodal mixture at a time of 25μs (after release).

riences much higher mean T(final): 630K T(final) in the case of the 1.36GPa bulk P(peak) event (60K 1σ variation) and 1160K T(final) (1220K T(peak)) in the case of the 3.52GPa bulk P(shock) event (110K 1σ variation). Chondrules are barely heated above their initial temperature: 310K and 370K T(final) respectively. This strongly bimodal matrix/chondrule heat distribution is illustrated in Figure 1. It is also apparent from Figure 1 (a 1.36GPa bulk P(peak) event) that matrix P(peak) and T(final) is highly variable across the computational mesh e.g. small areas of matrix between chondrules achieved temperatures of ~800K even in this very low bulk P(peak) event. In terms of final matrix porosity, this heterogeneity has structure: porosity on the side of chondrules facing the shock wave is significantly lower than on the lee side (Fig. 1). This should be observable in SEM and may offer a potential 'way-up' indicator with respect to an initial major impact event.

Implications for chondrite palaeomagnetism have already been discussed [9]. But high transient matrix temperatures (~10 sec to equilibrate with bulk continuum temperatures) also have significance for lithification of primitive chondrites and the survival of presolar grains. Presolar silicate abundances in even the most primitive meteorites are only ~320ppm [10]. Previous estimates of post-shock temperature increases in chondrites are low (<50K for a 10GPa impact [1,2]). But as we have shown, the effect on porous matrix – the host for presolar grains – is very different. A 3.5GPa bulk P(peak) event can generate a matrix T(peak) mean of 1220K, with local variation to much higher T. And this with a (conservative) T(initial) of 300K. Higher T(initial) equals higher T(final). Our analysis indicates that transient temperatures <1450K and timescales of ~0.1 sec are capable of homogenizing isotopic anomalies; hence, processing in low-intensity impacts should be considered as a factor in removing presolar silicates. High transient matrix temperatures may also be a mechanism for lithification of primordial materials. Chondrite regolith breccia clasts are cemented by interstitial shock melt material [11]. Thermal metamorphism, aqueous alteration, and gravitational compaction have all been suggested as mechanisms for meteorite lithification. But some primitive meteorites have escaped these processes, and yet are lithified rocks. We note that experimental sintering of olivine is favoured in situations involving rapid heating of fine-grained aggregates [12] – a scenario identical to that encountered by matrix in low-intensity impacts.

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