

PARTIAL MELTING OF CARBONACEOUS CHONDRITES I: ALLENDE (CV) AND (ANHYDROUS) MURCHISON (CM); A. J. G. Jurewicz⁺, John H. Jones[#], David W. Mittlefehldt⁺: ⁺Mail Code C23, Lockheed ESC, 2400 NASA Rd. 1, Houston, TX 77058; [#]SN2/Planetary Sciences Branch, NASA/Johnson Space Center, Houston, TX 77058.

Eucrites and angrites are basaltic meteorites thought to be derived from generally "chondritic" materials^{1,2,3}. However, the exact nature of the parent bodies are not yet known. In fact, it is not yet known whether these "basalts" are direct, primary melts¹, or evolved liquids^{4,5} of complex and/or multiple origins^{1,5}.

To illuminate the origins of eucrites and angrites, partial melting experiments on both the Allende (CV) and the Murchison (CM) carbonaceous chondrites were performed. Experimental conditions were selected from a matrix of temperatures and redox states*. The highest temperature (1200°C) was just above the liquidus temperatures experimentally determined for both eucrites¹ and angrites⁶. The lowest temperature (1140°C) was just below the solidus we determined for Allende under reducing conditions. Similarly, the range of redox states bracketed the conditions of formation inferred from natural eucrites¹ (IW-1) and angrites^{7,8} (\leq IW+2).

All experiments were performed near one atmosphere, using flowing CO/CO₂ gas to control the redox state⁹. Natural samples (obtained from E. King, University of Houston) were ground to ≤ 74 microns, pressed into pellets, placed in open, reusable Pt baskets and then suspended in the furnace. Run times were varied to test for equilibrium, but were usually 5 days. In addition, several experiments were performed to delineate the extent of reversibility and reproducibility. Iron loss was not found to be a problem. No attempt was made to retain either volatile compounds, such as water and organics in the case of Murchison, or volatile elements, such as Na. Water drop-quenches were used to minimize changes in melt composition during cooling¹⁰. Compositional analyses were performed using wavelength dispersive analysis on the electron microprobe. Fe/MgK_D 's for olivine/melt were 0.28 to 0.34.

At 1200°C, the results for both Allende and Murchison as a function of redox state were similar. Below IW, the primary phases were Fe-Ni metal, olivine, chrome spinel, and a strongly hypersthene normative melt. These melts have a strong affinity to eucrites (Table 1). Above IW, the primary phases were olivine, (\pm Ni metal), Fe-Mg-Al-Cr spinel, and a melt relatively low in silica (only 8.4% normative hypersthene for Murchison, and nepheline normative for Allende), with high Ca/Al ratios. These melts, especially those from Allende, have a strong affinity to angrites (Table 1). Moreover, because of the high CaO content of these melts, the olivines in these charges were relatively calcium-rich.

At lower temperatures and IW-1, the preliminary results indicated that the melt compositions approach the peritectic point of Stolper¹ for both Allende and Murchison. However, as the temperature is decreased to $\geq 1180^\circ\text{C}$, plagioclase appears in the Allende charges, while pyroxene appears in the Murchison charges. Pyroxene does not appear in the Allende charges until just above the solidus. The Allende solidus at IW-1 is 1150°C ($\pm 10^\circ\text{C}$); the Murchison solidus is still being determined.

Determination of the phase equilibria and solidi for both meteorites at redox conditions above IW are still in progress.

The experimental results presented here are consistent with those of other workers who studied Allende. Seitz and Kushiro¹¹ produced low-silica melts which coexisted with (aluminous?) spinel, olivine and pyroxene; however, their ambient pressures were greater than those likely to be encountered within asteroids. Mysen and Kushiro¹² found redox-dependent melt compositions and phase assemblages similar to those found in this study under similar laboratory conditions, but at 1275°C . Unfortunately, the olivine/liquid Fe/MgK_D 's calculated

* The redox state is reported relative to the Fe-FeO oxygen buffer (IW). The experimentally controlled oxygen partial pressure ranged from an order of magnitude less than IW (IW-1) to two orders of magnitude higher than IW (IW+2).

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from the data published in both of these studies^{11,12} are low, suggesting experimental problems quenching the partial melt¹⁰. Geiger *et al.*¹³ recognized that the one-atmosphere Allende solidus was between 1100°C and 1200°C, but did not report melt compositions.

In summary, we have produced partial melts of eucritic- and angritic-like compositions from both Allende (CV) and Murchison (CM) chondrites. The experiments were performed at near one-atmosphere, in an open system (i.e., volatiles could escape), and at temperatures and oxygen fugacities relevant to natural meteorites. The implications for meteorite genesis suggested by these results are discussed at length in a companion abstract¹⁵.

References: 1. Stolper *Geochim. Cosmochim. Acta* 41 587 (1977); 2. Mittlefehldt and Lindstrom *Geochim. Cosmochim. Acta* 54 3209 (1990); 3. Jurewicz et al. *Science* (submitted 1990); 4. Mason *Meteorites* (Wiley, New York, 1962), pp. 116; 5. Hewins and Newsom, in *Meteorites and the Early Solar System*, Kerridge and Matthews, Eds. (U. Arizona Press, Tucson, 1989), p. 73; 6. McKay et al. *Lunar Planet. Sci. XIX* (1988) 760; 7. McKay et al. *Lunar Planet. Sci. XX* 675 (1989); 8. Brett et al. *Earth Planet. Sci. Lett.*, 35, 363 (1977); 9. Williams and Mullins *NASA TMX-58167* (1981); 10. Kring and McKay *Lunar Planet. Sci. XV* 461; 11. Seitz and Kushiro *Science* 183 954 (1974); 12. Mysen and Kushiro *Carn. Inst. Washington Ybk.* 75 678 (1976); 13. Geiger et al. *Lunar Planet. Sci. XX* 337-338 (1989); 14. Jones et al. (1991) this volume.

Table 1. Comparison of composition and CIPW Norms of selected achondrites and experimentally-derived partial melts of Allende and Murchison. Note: results for volatiles (eg., Na and P) depended upon the experimental conditions and run time; Ca/Al is the weight ratio.

				----ALLENDE----			Murch.		-----ALLENDE-----			MURCHISON	
	ADoR	LEW1	LEW2	1200 IW+1	1200 IW+2	1150 IW+2	1200 IW+2	SC	1200 IW-1	1180 IW-1	1170 IW-1	1200 IW-1	1170 IW-1
SiO ₂	43.7	39.6	40.4	39.0	38.3	40.5	39.3	49.0	47.0	49.9	49.4	45.7	49.2
TiO ₂	2.05	1.15	0.73	0.83	0.87	0.9	0.73	0.6	0.83	0.74	0.93	0.58	0.63
Al ₂ O ₃	9.35	14.1	9.19	18.1	12.1	12.7	12.0	12.8	13.5	13.3	13.0	12.9	13.7
FeO	9.4	18.5	19.0	23.5	22.9	22.2	26.0	18.6	19.0	17.2	17.4	21.6	18.9
MnO	0.1	0.20	0.24	0.2	0.2	0.2	0.24	0.6	0.2	0.16	0.18	0.26	0.26
MgO	10.8	7.0	19.5	5.95	5.89	5.82	6.67	7.1	7.55	7.51	7.26	7.47	7.09
CaO	22.9	17.5	10.8	15.0	15.3	16.3	12.4	10.4	12.2	11.6	11.8	10.1	10.6
Na ₂ O	0.03	tr	0.02	0.36	0.51	tr	0.13	0.45	0.14	0.10	tr	0.12	tr
Cr ₂ O ₃	0.21	0.11	0.17	tr	tr	0.3	tr	0.35	0.28	0.34	0.31	0.3	0.31
NiO	0.01		tr	tr	0.2								
P ₂ O ₅	0.13	-0.2	-0.1	1.0	1.5	1.5	1.20		0.43	0.26	0.24	0.21	0.22
Total	98.7	98.2	99.9	99.0	97.1	100.4	98.7	100.02	99.6	101.1	100.5	99.2	101.0
Mg#	67	40	65	31	32	32	31	44	41	44	43	38	40
Ca/Al	3.31	1.68	1.59	1.54	1.71	1.73	1.40	1.10	1.22	1.18	1.22	1.06	1.04
Q								2.2		4.4	0.7		1.0
Or											5.5		3.7
Ab							1.1	3.8	1.4	0.8	0.4	1.0	0.5
An	25.7	39.1	25.0	34.5	30.3	31.0	32.6	33.0	38.2	35.4	32.3	35.0	35.1
Ne	0.1	0.1	0.1	1.7	2.3	3.4							
Di	46.0	20.9	16.5	23.4	22.0	30.9	18.5	15.5	12.0	16.8	21.7	12.0	14.5
Hy							8.4	43.7	43.9	40.2	38.4	44.5	44.3
Ol	13.7	29.9	54.8	34.3	37.8	28.5	35.1		1.6			5.4	
Cs	9.9	7.3	1.8	2.2	2.3	1.1							
Il	4.0	2.2	1.4	1.6	1.6	1.7	1.4	1.2	1.4	1.4	0.6	1.1	0.6
Cm	0.3	0.2	0.2	0.1	0.1		0.1	0.5	0.5	0.5	0.4	0.5	0.3
Ap	0.3	0.3	0.2	2.3	3.6	3.5	2.8		1.0	0.6		0.5	