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PARTIAL MELTING OF ORDINARY CHONDRITES: LOST CITY (H) AND ST. SEVERIN (LL).

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Eucrites and diogenites are examples of asteroidal basalts and orthopyroxenites, respectively. As they are found intermingled in howardites, which are inferred to be regolith breccias, eucrites and diogenites are thought to be genetically related. But the details of this relationship and of their individual origins remain controversial.

Work by Jurewicz *et. al [1]* showed that 1170-1180°C partial melts of the (anhydrous) Murchison (CM) chondrite have major element compositions extremely similar to primitive eucrites, such as Sioux County. However, the MnO contents of these melts were about half that of Sioux County, a problem for the simple partial melting model. In addition, partial melting of Murchison could not produce diogenites, because residual pyroxenes in the Murchison experiments were too Fe- and Ca-rich and were minor phases at all but the lowest temperatures *[1]*. A parent magma for diogenites needs an expanded low-calcium pyroxene field. In their partial melting study of an L6 chondrite, Kushiro and Mysen *[2]* found that ordinary chondrites did have an expanded low-Ca pyroxene field over that of CV chondrites (i.e., Allende), probably because ordinary chondrites have lower Mg/Si ratios.

This study expands that of both Kushiro and Mysen *[2]* and Jurewicz *et. al [1]* to the Lost City (H) and St. Severin (LL) chondrites at temperatures ranging from 1170 to 1325°C, at an f_{O_2} of one log unit below the iron-wüstite buffer (IW-1).

EXPERIMENTAL: Chemically-characterized, silicate-rich and metal-rich separates of Lost City and St. Severin (obtained from E. Jarosewich) were used as starting materials. Initially, the silicate and metal fractions were mixed, pre-annealed at higher oxygen fugacity, and then re-ground to eliminate large metal flakes which might be distributed inhomogeneously among the small (100 mg) charges. Unfortunately, nucleation problems forced a change to a mix of the silicate-rich separate with an Fe_2O_3-NiO powder that duplicated the Fe/Ni ratio of the natural metal fraction. Flowing CO/CO_2 was used to control f_{O_2}. For experiments run at or below 1220°C, charges were placed in re-usable Pt-wire baskets; for higher temperature experiments, charges were spot-welded onto Pt-wire loops. Runs ranged from 4 to 7 days, depending on the temperature, and were drop-quenched into water. Chemical analyses were performed at NASA/JSC by EPMA.

RESULTS: Melt, olivine, low-calcium pyroxene, and minor Fe-Ni metal (Fe>80%) ±sulfides were present in all St. Severin and Lost City charges. Representative melt and pyroxene analyses are given in Tables 1 and 2. In Table 1, melts from CM and CV chondrites *[1]* are given for comparison. There was always less melt in the H and LL chondrites than in the CM or CV chondrites run under corresponding conditions *[1]*.

At 1170°C, the lowest temperature run to date, ~10-15% melt was present in both St. Severin and Lost City charges. Chromite (<1%) was also observed. By analogy with Murchison and Allende charges run under the same conditions *[1]*, the solidi are probably ~1150-1160°C. In examination of the 1170°C charges, plagioclase was not observed, but both melt compositions plot near the peritectic point of Stolper *[3]*.

In the charges run at high temperatures, melt fractions are again less than that observed in Murchison or Allende at equivalent conditions: ~22-28% for St. Severin at 1275°C; and ~25-30% for Lost City at 1325°C. Pyroxene is still a major phase (≥10%) in both. Chromite was not observed, although mass balance suggests that it may be present in the St. Severin charge in trace amounts.

DISCUSSION: This study, combined with *[1,4]*, gives preliminary data for partial melting in chondrites bracketing a wide range of likely compositions (refractory element/Si by ~2x; Fe/Si ratios by 30-50%). Partial melting of anhydrous CV and CM chondrites leaves a residue that is dominated by olivine, so there is little chance that diogenites could be formed from such materials. On the other hand, melts of Murchison at 1170°C had major element contents within 3% of those measured for the Sioux County eucrite, and melts of Allende at 1180°C were similarly close to Ibitira *[1]*. In contrast, partial melting of H and LL chondrites results in either a pyroxene-enriched residue or, at higher degrees of partial melting, a pyroxene-enriched melt, which has potential for producing large amounts of pyroxene cumulates. On the other hand, although the major elements in partial melts from St. Severin and Lost City are broadly eucritic (±10% of Sioux County; Table 1), they do not specifically match any known eucrite.

Eucrites. Although partial melts of ordinary chondrites at 1170°C and IW-1 are broadly eucritic, their MnO/FeO ratios are much too low (as are those from Murchison), their TiO_2 concentrations are 20% low, and their CaO/Al_2O_3 ratios are 5-10% lower than those of Sioux County. Fractional crystallization of higher temperature, pyroxene-saturated partial melts might alleviate some of these discrepancies. However, considering the low values of pyroxene/melt partition coefficients for CaO, Al_2O_3 and TiO_2, fractional crystallization of these higher temperature melts would probably help the CaO/Al_2O_3 problem somewhat, but not the discrepancy in TiO_2. Thus, we do not have a satisfactory model that uses a known chondrite as a protolith that will exactly produce eucrites, although the refractory lithophile major and minor elements (Si, Ti, Al, Cr, Fe, Mg, Ca) of the Murchison 1170-1180°C partial melts most closely match those of Sioux County.

Diogenites. The pyroxenes of our St. Severin and Lost City experiments seem to bracket the range of diogenitic pyroxenes in major element composition (Table 2). Even so, the complex processes that have produced diogenites are difficult to unravel. In diogenitic pyroxenes, large variations in Ti, Al and REE without commensurate changes in Mg# suggest that different cations have diffusively equilibrated at different rates *[5]*. However, we note that the TiO_2/Al_2O_3 and CaO/Al_2O_3 ratios of our experimental pyroxenes are similar to those of pyroxenes in diogenites. We take this similarity to indicate that most diogenites crystallized from melts that had ~chondritic relative proportions of Ca, Al and Ti. Exceptions are Y-75032, ALHA84001, and Manegaon *[5]*.

CONCLUSIONS: If not for the howardites, the simplest solution to the eucrite-diogenite problem would be to decouple their petrogenetic histories (e.g., formation on different parent bodies). If eucrites and diogenites truly are cogenetic, then one solution is to postulate an unknown type of chondrite source region, resembling an ordinary chondrite, but enriched in refractory lithophiles and MnO.

REFERENCES: [1] Jurewicz *et. al* (1993) *GCA* in press; [2] Kushiro and Mysen (1979) *Mem. NIPR, Sp. Issue 15*, p.165; [3] Stolper (1977) *GCA* **41** p.587; [4] Jurewicz *et. al* (1992) *Science* **252**(5) p.695; [5] Mittlefehldt (1993) *LPSC* **XXIV**, submitted.

Table 1. Example experimental melts: This study and [1] compared to Sioux County

	All. 1170	Murch. 1170	LC 1170	SS 1170	LC 1275	SS 1275	SC bulk
SiO_2	49.4	49.22	49.61	48.63	50.79	50.59	49.50
TiO_2	0.93	0.63	0.48	0.49	0.39	0.38	0.60
Al_2O_3	13.0	13.67	13.62	14.19	11.02	8.50	13.40
FeO	17.4	18.90	19.71	17.72	17.33	23.43	18.80
MnO	0.18	0.26	0.21	0.29	0.42	0.41	0.55
MgO	7.26	7.09	6.73	6.80	11.27	10.43	7.20
CaO	11.8	10.56	9.32	10.16	8.07	6.85	10.30
Cr_2O_3	0.31	0.31	0.30	0.25	0.67	0.72	0.32
Total	100.4	100.9	100.5	99.2	100.0	101.4	101.2
FeO/SC	0.93	1.01	1.05	0.94	0.92	1.25	
MgO/SC	1.01	0.98	0.93	0.94	1.57	1.45	
CaO/SC	1.15	1.03	0.90	0.99	0.78	0.66	
Al_2O_3/SC	0.97	1.02	1.02	1.06	0.82	0.63	
MnO/SC	0.33	0.47	0.39	0.53	0.76	0.74	

Table 2. Pyroxenes in the experimental charges *versus* those in diogenites.

	SS 1275	SS 1220	SS 1170	LC 1325	LC 1275	LC 1170	diogenites typical	diogenites magnesian	diogenites ferroan
SiO_2	55.09	54.32	52.98	55.62	54.92	53.91	54.22	54.9	53.98
TiO_2	0.04	0.04	0.11	0.02	0.03	0.08	0.1	0.09	0.09
Al_2O_3	0.48	0.66	2.20	0.38	0.48	0.95	0.82	0.97	0.49
Cr_2O_3	0.79	0.69	0.72	0.68	0.75	0.76	0.62	0.6	0.47
FeO	17.42	18.18	17.67	12.99	14.43	18.66	15.37	13.05	18.16
MnO	0.33	0.35	0.33	0.30	0.34	0.35	0.51	0.45	0.59
MgO	27.41	25.54	25.07	29.74	28.56	24.44	26.68	28.09	24.93
CaO	0.78	1.38	1.42	0.43	0.73	2.17	1.16	1.26	1.17
total	102.34	101.17	100.51	100.16	100.26	101.32	99.48	99.41	99.88
wo	1.5	2.70	2.84	0.83	1.42	4.27	2.3	2.5	2.3
en	72.6	69.53	69.63	79.65	76.81	67.02	73.8	77.3	69.3
fs	25.9	27.76	27.53	19.51	21.77	28.71	23.9	20.2	28.3