

THE COMPOSITIONAL SIMILARITY BETWEEN SIOUX COUNTY AND EXPERIMENTALLY PRODUCED PARTIAL MELTS OF THE MURCHISON CHONDRITE FAVORS A PARTIAL MELTING ORIGIN FOR PRIMITIVE EUCRITES. J.H. Jones*, B.Z. Hanson‡, G.A. McKay*, A.J.G. Jurewicz†, J.W. Delano‡, and D.W. Mittlefehldt†. *SN4, NASA/JSC, Houston, TX 77058; ‡Dept. of Geology, SUNY Albany, Albany, NY 12222; †C23, Lockheed Engineering and Sciences Co., 2400 NASA Road 1, Houston, TX 77058.

Introduction. There has been a long-standing debate over the origin of the eucrites, a suite of basaltic achondrites [1,2]. High temperature experiments on eucrites and carbonaceous chondrites have, on balance, supported the viewpoint that primitive eucrites such as Sioux County are simple partial melts [1,3,4]. However, the intimate association of eucrites with cumulate pyroxenites (diogenites) in meteoritic breccias (howardites) argues that the eucrites formed after extensive fractional crystallization of orthopyroxene, which accumulated to form diogenites [2, 5].

This divergence of opinion is unfortunate. Eucrites are presumably very simple basalts, and their asteroidal origin seems well established [6]. Thus, it appears that neither high pressure (> 1 kbar) perturbations of phase relations nor volatile element fluxing have contributed to eucrite petrogenesis. Consequently, considering the relative simplicity of asteroidal basalts, it is disquieting that quite different petrogenetic models have successfully competed for over a decade. If we cannot understand the origins of simple basalts, the implications for understanding the petrogenesis of terrestrial, lunar and martian basalts are not reassuring.

Only minor variation is observed in the major element compositions of typical ("main group") eucrites [4] and the majority of their lithophile refractory trace elements have flat, chondrite-normalized abundances, ~10X CI [e.g., 3]. However, Sc, Cr and V are exceptions to this rule [3]. These elements are depleted in eucrites relative to other refractory lithophile elements by factors that are presumably related to their compatibility in mafic silicates and spinel. Of this trinity, only Sc is easily modeled [3], since the V/Cr ratio of a magma will be extremely sensitive to the amount of spinel present in the residuum. Regardless, it is clear that it should be of great importance to understand the process(es) that produced the signature depletions of Cr, Sc and V.

Partial melts of Murchison. In a previous study on the partial melting of the Murchison (CM) chondrite [4], we found that our experimental melts (1170-1200°C; $f_{O_2} = IW-1$) were nearly indistinguishable in their refractory, lithophile element abundances from those of eucrites. Specifically, Si, Ti, Al, Cr, Fe, Mg, and Ca concentrations were nearly identical to those of Sioux County, a primitive eucrite [4; and Table 1]. Only Mn, which is somewhat volatile, was depleted relative to eucrites. This was presumably because Murchison itself is depleted in Mn compared to the Eucrite Parent Body (EPB). We deemed this compositional agreement between Sioux County and our experimental glasses to be significant because the liquidus temperature of the Sioux County eucrite had already been determined to be within the range of our experiments [1].

Consequently, it appeared to us that another way to model the abundances of some elements in eucrites was not to perform calculations, but to perform experiments. If major element concentrations of experimental glasses produced from chondrites were sufficiently close to those of eucrites, then trace elements (especially Sc and V) should be analyzed as well.

Analytical. We have analyzed our 1170, 1180 and 1200°C Murchison experiments for V using the JEOL electron microprobe at the Rensselaer Polytechnic Institute and have made corrections for contributions from the Ti $K\beta$ to the V $K\alpha$. More analytical details are given in an accompanying abstract [8]. Abundances of Cr and Ti were also measured and were similar to those reported earlier [4]. For comparison, selected glasses from Allende and St. Severin experiments performed in the same temperature range as Murchison were also analyzed. In addition, we have also attempted to measure the Sc contents of our 1180°C Murchison glass using the JSC Cameca electron microprobe and the trace element analysis technique of [7]. Corrections for the large contribution to the Sc $K\alpha$ from the Ca $K\beta$ were made by analyzing a Sc-free glass having a CaO content similar to that of Sioux County.

Results and Discussion. Table 1 compares analyses of our 1180°C Murchison glass to those of Sioux County. The comparison is striking, and it seems to us that such close agreement is unlikely to be fortuitous. In our experiments, the abundance levels of these elements are

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established by partial melting, not by fractional crystallization. Thus, by analogy, our results favor the partial melting model over the fractional crystallization model. We envision an EPB that is similar to an anhydrous CM or CO chondrite, but which is enriched in Mn relative to the refractory lithophile elements. We also envision that primitive eucrites such as Sioux County are simple partial melts.

The V and TiO₂ abundances of our experimental glasses are clearly distinguished from those eucrites that are believed to substantially differ from Sioux County in their petrogenetic history, either in their degree of partial melting (e.g., Stannern and Bouvante) or by experiencing significant amounts of fractional crystallization (e.g., Nuevo Laredo and Lakangaon). Partial melts of Allende and St. Severin also show significant differences from those of Murchison. Thus, the fact that Cr, Sc and V are at near-Sioux County concentration levels in Murchison melts distinguishes Murchison melts both from partial melts of other chondrites and from eucrites with different petrogenetic histories than Sioux County.

Vanadium/Cr ratios of silicate liquids in spinel-saturated systems are strong functions of the bulk Cr concentration, as well as of temperature and fo₂ [9]. Thus, the agreement in Cr and V contents between our spinel-saturated glasses and natural eucrites further boosts our confidence in Murchison as a reasonable starting material. Initially influenced by the work of Stolper [1], we chose the temperature and fo₂ of our experiments to be 1200-1170°C and IW-1, respectively, and these choices also seem validated.

The error on our Sc measurement is quite large and is mainly attributable to an interference from a satellite Ca K_β peak. Our measured concentration of Sc may be compared to a calculated concentration, using D_{Sc}^{ol/liq} and D_{Sc}^{pyx/liq} [10], a bulk Sc concentration [11], and observed modal abundances [4]. Correcting for 16% volatile loss [12], 9% metal precipitation [4], 18% partial melting [4], and partitioning [4, 10], we calculate that our 1180°C melt should have a Sc content of 26 ppm. A similar calculation for La yields a liquid concentration of 2.3 ppm. Literature values for Sc and La in Sioux County are 29 ppm and 2.4 ppm, respectively ([13]; Table 1). Thus, it seems that our Sc may be slightly low compared to what would be expected, but only by about 10%.

Still, because Sc, Cr and V are all much more compatible in orthopyroxene than La, we infer that the similarity between the Sc/La, Cr/La, and V/La ratios of Sioux County and our 1180°C Murchison melt should be difficult to maintain if Sioux County had been produced by extensive orthopyroxene fractionation from a more primitive magma. Consequently, based on our partial melting experiments, we favor a partial melting origin for primitive eucrites such as Sioux County. Thus, the relationship, if any, between eucrites and diogenites remains obscure, and the MnO abundance of the EPB (and Mars? [14]) remains a problem.

Table 1
Comparison of a Murchison Experimental Glass to Sioux County

	wt. %							ppm		
	SiO ₂	TiO ₂	Al ₂ O ₃	Cr ₂ O ₃	FeO	MgO	CaO	V	Sc	La
Sioux Co. [†]	49.5	0.60	13.4	0.32	18.8	7.2	10.3	89±12	28.9±0.6	2.4±0.2
Murchison 1180°C [‡]	49.2	0.60	13.3	0.33	18.0	7.0	10.2	90±8	25±5	2.3*
Nuevo Laredo [†]	49.5	0.89	12.1	0.26	19.8	5.5	10.3	64±2	38±1.5	3.9±0.1
Bouvante [†]	50.2	1.02	11.1	0.31	19.7	6.7	10.4	51±2	30.7±0.3	6.1±0.2

[†]From [13]. [‡]From [4] and this work. *Calculated.

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