

FILLING IN THE GAP: AN EXPERIMENTAL STUDY ON EARLY DIFFERENTIATION

PROCESSES. R. Ford¹, T. Rushmer¹, G. K. Benedix^{2,3} and T. J. McCoy² ¹University of Vermont (Department of Geology, Burlington, VT 05405; rford@zoo.uvm.edu), ²Dept. of Mineral Sciences, National Museum of Natural History, Smithsonian Institute, Washington, D.C., 20560-0119; ³Present Address: Washington University, Dept. of Earth and Planetary Sciences, Saint Louis, MO 63130 USA.

Introduction: An “oxidation gap” exists in chondrites between E and H types [1] yet some meteorite groups, typically the primitive achondrites, seem to fill that gap (e.g. pallasites, acapulcoites, lodranites, winonaites, and IAB, IIE families). Previous experimental studies [2] indicate that reduction of mineral compositions may occur during differentiation. It is possible that differentiation of precursor chondrite material under a variety of conditions (e.g. different fO_2) can change the geochemistry, both elemental and isotopic, such that the end products cannot be easily related to their parent material. Although, oxygen isotopic composition of silicates in IAB and winonaite indicates that the parent chondrite of these meteorites has not been sampled, this type of process might help explain the formation of the winonaite-IAB meteorite group.

Unraveling such a history is difficult because the known starting composition is needed in order to assess how much the differentiation conditions have affected the chemistry of the product. A good way to test the effect of variable oxidation state during differentiation is to look for changes in metal composition and Fe-end member compositions of low-Ca pyroxene [2,3]. We are testing this approach by comparing the compositions of partial melting experiments on an ordinary chondrite (Kernouvé) and an enstatite chondrite (Indarch) under controlled, and opposite, fO_2 conditions.

Samples and Analytical Methods: Two chondrites, an enstatite EH4 chondrite and an ordinary H6 chondrite, have been investigated experimentally. Indarch is composed of enstatite, plagioclase, free SiO_2 , FeO-bearing pyroxene, Fe,Ni, S-rich and P-rich metal; and Fe-rich and Fe, Mn, Mg, Ca-rich sulfide. The Kernouvé H6 chondrite is composed primarily of olivine, orthopyroxene, clinopyroxene, plagioclase, chromite and chlorapatite. Metal is Fe-Ni and FeS and composes 25% of the sample. Bulk analysis (wt%) of the starting material shows that the chondrite is typical in bulk composition. Analyses

of the silicate and metal phases were collected by electron microprobe (housed at McGill University).

Experimental study: The partial melting experiments on the Indarch meteorite being considered in this study were conducted as part of the investigation reported in McCoy et al 1999 [4]. In these experiments, a small amount of powdered Indarch was placed in a graphite crucible within an evacuated, sealed silica tube. No additional buffer was used. Because enstatite meteorites are very reduced having $\log fO_2$ of IW – 5, the presence of the graphite buffer serves to oxidize the enstatite chondrite. Experiments TD-258 and TD-255 were heated for 24 hours at 1000°C and 1100°C respectively at ambient pressures.

Experiments in graphite capsules have also been performed on the Kernouvé, but here the material being reduced from its original oxidation state. Powders of the starting Kernouvé meteorite have also been partially melted in graphite crucibles in a piston-cylinder apparatus (located in D. Baker’s laboratory, McGill University). Experiments were conducted at 1.0 GPa between 1000-1050°C (Kmdb experiments). Geochemical data from piston-cylinder samples Kmdb1000°C (24 and 48 hours at conditions) and Kmdb1050°C (24 hours at conditions) are reported here.

Results: Silicate and metal data are listed in Tables 1, 2 and pyroxene data are shown in Figure 1. Pyroxene data show some variation from the starting composition in both the Kmdb and Indarch experiments. Fs content of OPX in Indarch changes from the starting composition of $Fs_{1.2}$ to $Fs_{0.8-2.1}$ in the 1000°C experiment and then to $Fs_{0.9-2.0}$ in the 1100°C experiment (see Figure 1). We observe reactions forming CPX. CPX is found as a new phase associated with OPX, quench pyroxene/glass and metal. Ca and Fe may be derived from the associated metal phases during oxidation. The Fs content of OPX in the Kmdb experiments decreases from the starting composition of $Fs_{17.0}$ to $Fs_{16.7}$ in the 1000°C and 1050°C experiments.

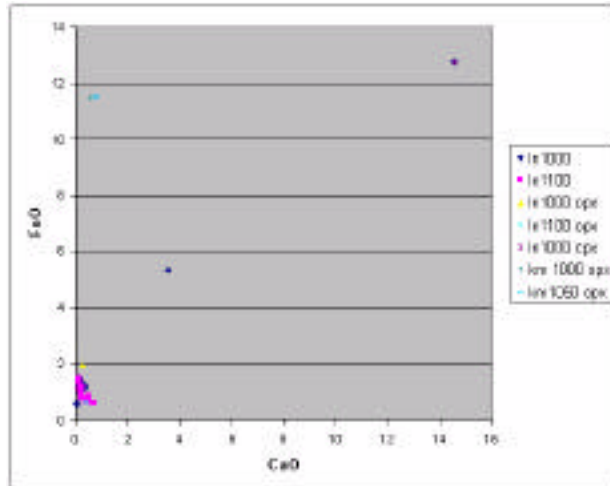


Figure 1. FeO vs CaO in pyroxenes from the Indarch (In) and Kmdb melting experiments (km in legend). The variations in the data close to the origin of the graph represent modifications made by the experiments to the OPX compositions in Indarch. New CPX are observed in Indarch and plot at higher CaO. Kmdb OPX plot along the origin at higher FeO.

Oxide (wt%)	Opx Indarch (Starting Material) [5]	Opx TD-258 1000°C	Opx TD-255 1100C	Cpx TD-258 1000C
SiO ₂ :	59.90	58.80	59.31	53.75
TiO ₂ :	0.0	0.03	0.08	0.27
Al ₂ O ₃ :	0.28	0.23	0.35	3.57
Cr ₂ O ₃ :	0.0	0.40	0.23	0.77
FeO:	0.84	1.97	0.78	12.76
MnO:	0.21	0.08	0.23	0.68
MgO:	39.40	38.86	39.14	12.76
CaO:	0.31	0.25	0.22	14.58
Na ₂ O:	0.0	0.04	0.04	0.85
Total:	100.94	100.7	100.4	99.98

Table 1. Electron microprobe analyses of representative orthopyroxene and clinopyroxene for starting Indarch and Indarch experiments.

Metal analyses do not show much change in terms of Fe composition in the Kernouvé graphite reducing experiments when compared to those of [2], which used a more reducing jacket material (aluminum, which reduced the Kernouvé so Si behaved as a siderophile and Ca and Mg were observed in sulfides).

Element (wt%)	Indarch Fe-Ni-Si Metal [5]	TD-255 Fe-Ni metal	Indarch Fe-S-rich	TD-255 Fe-S-rich
Fe:	89.30	89.05	61.00	59.83
Ni:	7.10	8.31	NA	1.20
Co:	0.48	0.41	NA	0.03
Ti:	NA	0.0	0.29	0.02
Cr:	NA	0.13	1.51	1.2
P:	0.09	0.56	NA	0.0
S:	NA	0.22	37.50	36.51
Mg:	NA	0.01	NA	0.02
Si:	3.50	0.0	NA	0.0
Mn:	NA	0.0	0.11	0.02
Ca:	NA	0.05	NA	0.07
Total	100.47	98.74	100.41	98.98

Table 2. Metal (Fe-Ni+/-Si) and troilite from Indarch experiments TD-258 and TD-255 and Indarch [5]. (Mg,Fe)-bearing S and Ca-bearing S have not been observed in TD-258 and TD-255 but are present in Indarch.

Metal analyses from the Indarch experiments no longer contain Si as observed in the starting material and sulfides no longer contain significant Ca or Mg. We do observe the presence of Ca in silicate phases, such as CPX. We suggest that the graphite buffer, which oxidizes these samples, is responsible for the changes observed in phase chemistry.

Summary: Due to the nature of the graphite buffer, changing pressures and temperatures in these kinds of experiments will be important for our future work. Our current experiments help constrain our experimental considerations aimed at reproducing the conditions of the winonaite – IAB parent body differentiation.

References:

- [1] Dodd, R.T., *Petrological and Geochemical Analyses*, 1988; [2] Rushmer, T., Gaetani, G. and Jones, J.H., *LPSC #1318*, 2002; [3] Rubin, A. et al., *Meteorites and the Early Solar System*, 1988; [4] T.J. McCoy, T. Dickinson and G. Lofgren, *MAPS*, 34, 735-746 (1999). [5] Keil, K. *JGR*, 73, 6945-6976.