

**MAKING MELTS HAVING 40%, 50%, OR 60% SiO<sub>2</sub> FROM CHONDRITIC MATERIALS: A SYNOPSIS OF LOW-PRESSURE, LOW-VOLATILE, EQUILIBRIUM MELTING RELATIONS;** A.J.G. Jurewicz<sup>\*</sup>; J.H. Jones<sup>°</sup>; D.W. Mittlefehldt<sup>\*</sup>; J. Longhi<sup>†</sup>, (\*LESC mail code C23, PO Box 58561, Houston TX 77258; °NASA-JSC mail code SN4, Houston, TX 77058; †LDEO, Palisades, NY 10964).

This work takes a step beyond directly comparing experimentally-produced melts with natural meteorites. Rather, it considers how to use the silicate phase equilibria of chondrites as a tool for predicting the type of the basalt produced at given conditions. Accordingly, we present a phase diagram and general rules for extrapolating the effects of oxygen fugacity and composition on the silicate-melting characteristics of chondrites, so the results can be applied to silicate partial melting at low pressures for a wider variety of chondritic parents and conditions.

**Previous work.** The thesis that achondritic meteorites might have originated from chondritic parents<sup>1,2,3</sup> and others has given rise to research directed toward the low pressure, silicate phase equilibria of chondritic material, mostly under conditions chosen with regard to the Howardite-Eucrite-Diogenite (HED) and Angrite parent bodies.<sup>3-9</sup> The most successful of these are probably Jurewicz *et al.*<sup>5</sup> (1993) and Jones *et al.*<sup>7</sup> (1994), who showed that a melt produced from anhydrous CM (Murchison) chondrite was, within analytical uncertainty, identical to the bulk composition of the Sioux County eucrite in Si, Mg, Fe, Ca, Al, Ti, Cr, Sc, and V content.

**The Data Compilation.** Phase equilibria experiments using chondritic materials were often flawed by problems such as the quench modification of the silicate melts and iron loss<sup>4,6,10</sup>. Therefore, the data compiled for this study come primarily from this laboratory<sup>5,10,11</sup>. To maximize the applicability of our database, our starting materials were H, LL, CM, and CV chondrites (Lost City, St. Severin, Murchison, and Allende, respectively) as their compositions bracket those of L, CI and CO chondrites. Aliquots of these materials were run isothermally at temperatures between 1150-1350°C under flowing CO/CO<sub>2</sub> gas. The oxygen fugacity (fO<sub>2</sub>) was held at either one order of magnitude below (IW-1) or two orders of magnitude above (IW+2) the iron-wüstite (IW) buffer; thus fixing the <sup>0</sup>Fe/<sup>+2</sup>Fe/<sup>+3</sup>Fe ratios in each charge, and controlling their actual (FeO+MgO)/SiO<sub>2</sub> ratios. Although volatiles (e.g., Na<sub>2</sub>O, H<sub>2</sub>O) were typically lost during the experiment, St. Severin charges retained up to ~1/4 of their initial Na<sub>2</sub>O (i.e., ~2wt% Na<sub>2</sub>O at ~20 wt% melting). Results from otherwise comparable St. Severin experiments showed that the Na<sub>2</sub>O-content dramatically effected the silicate phase equilibria<sup>11,12</sup>.

**Phase Relations.** Volatile-free chondrites produced melts with ~40 wt% SiO<sub>2</sub> if melting begins at the olivine-low-calcium pyroxene-plagioclase-augite (Ol-Pyx-Pl+Aug) pseudo-invariant point<sup>1</sup> and 50 wt% SiO<sub>2</sub> if melting began at the olivine-plagioclase-spinel-augite (Ol-Pl-Sp+Aug) pseudo-invariant point<sup>14</sup>. Melting trends are given in Fig. 1 (olivine-silica-nepheline, calcium aluminate (Ol-Si-Ne, CA) projected from larnite (La), after [13]). The processed chondrites (starting compositions, Fig. 1B) have nearly constant La and Ne, CA components and form a trend of differing Ol/Si ratios. Because of the thermal divide on the Ol-Pl-Aug liquidus curve, there is a critical Ol/Si ratio (Ol/Si<sub>crit</sub>) such that if the bulk Ol/Si ratio is less than Ol/Si<sub>crit</sub> after processing, chondritic materials melt at Ol-Pl-Sp; conversely, if the bulk Ol/Si ratio is higher than Ol/Si<sub>crit</sub> after processing, they melt at Ol-Pyx-Pl. Since the Ol/Si ratio of each processed chondrite is a function of the amount of FeO present, it depends on both the bulk meteorite's (Fe+Mg)/Si cation fraction and the fO<sub>2</sub> of the processing. For example, St. Severin is still over Ol/Si<sub>crit</sub> even when all of its iron is oxidized at IW+2 (Fig. 1B).

Because chondritic La and Ne, CA components are nearly constant, the molar (FeO+MgO)/SiO<sub>2</sub> ratio of the processed meteorite can be used in lieu of Ol/Si<sub>crit</sub> as a simple means of estimating the character of the first melt (Fig. 2). Table 1 gives (FeO+MgO)/SiO<sub>2</sub> ratios for each chondrite at each condition, calculated by subtracting the experimentally-determined metal fraction, if any, from the bulk processed meteorite composition<sup>14</sup>, and assuming all remaining iron was FeO. In these systems, Ol/Si<sub>crit</sub> corresponds to a (FeO+MgO)/SiO<sub>2</sub> ratio of ~1.75. Fig. 3 suggests that Ol/Si<sub>crit</sub> can also be viewed as the composition where low-Ca pyroxene disappears from the solidus.

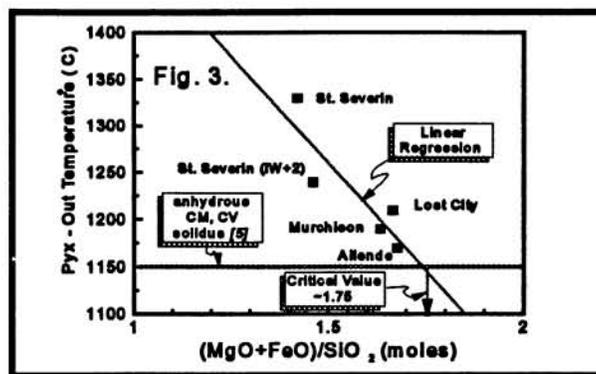
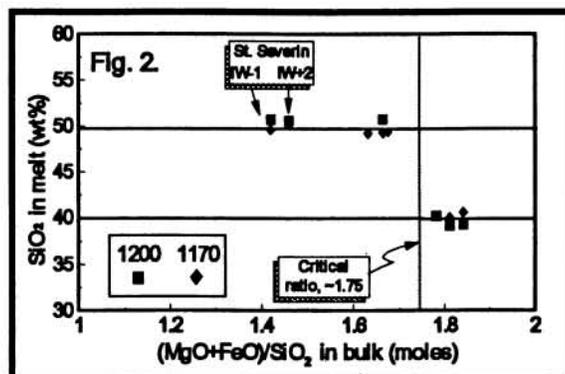
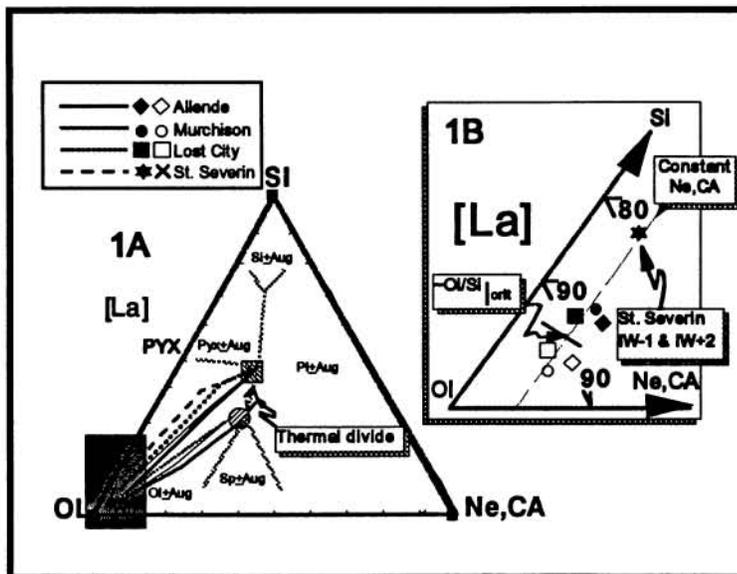
Processed chondrites with Ol/Si < Ol/Si<sub>crit</sub> have produced partial melts with up to 60 wt% SiO<sub>2</sub> when Na<sub>2</sub>O is retained in the system<sup>11</sup> (Fig. 4). The Na<sub>2</sub>O increases the Pl-component of the partial melt<sup>12</sup>. Experimentally, this retention occurred at high fO<sub>2</sub>s and low temperatures in the most siliceous system (LL-chondrite)<sup>11</sup>.

**References:** (1) Stolper (1977) *GCA* 41:587-611; (2) Mittlefehldt & Lindstrom (1990) *GCA* 54:3209-3218; (3) Kushiro & Mysen (1979) *Mem Natl Inst Polar Res (Japan) spec issue* 15:165-170; (4) Jurewicz *et al.* (1991) *Sci* 252:695-698; (5) Jurewicz *et al.* (1993) *GCA* 57:2123-2139; (6) Jurewicz *et al.*, (1995) *GCA in press*; (7) Jones *et al.* (1994) [abst] *LPSC XXV*:639-640; (8) Jurewicz *et al.* (1993) [abst] *LPSC XXIV*:739-740 (9) Boesenberg & Delaney (1994) [abst] *LPSC XXV*:135-136; (10) Jurewicz *et al.* (1994) [abst] *LPSC XXV*: 651-652; (11) McGuire *et al.* (1994) [abst] *LPSC XXV*:879-880; (12) Kushiro (1975) *Am J Sci* 275:411-431; (13) Pan & Longhi (1990) *CMP* 105:569-584; (14) Jarosewich (1990) *Meteoritics* 25:323-337.

MAKING 40, 50, 60 WT% SiO<sub>2</sub> MELTS FROM CHONDRITES: Jurewicz *et al.***Table 1.** Refractory element ratios of bulk meteorite compositions used in this study after [14] and the calculated (c.f., text) molar (FeO+MgO)/SiO<sub>2</sub> of processed charges. Ratios wt% oxide, moles, or cation fraction, as indicated.

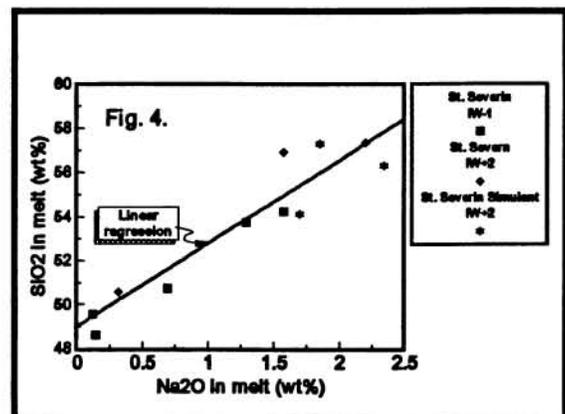
Meteorites		Allende (CV)	Murchison (CM)	Lost City (H)	St. Severin (LL)
bulk parameters	CaO/Al <sub>2</sub> O <sub>3</sub> (wt%)	0.81	0.88	0.83	0.81
	(Fe+Mg)/Si	2.42	2.51	2.46	1.81
FeO+MgO/SiO <sub>2</sub> (moles)	IW-1	1.68	1.63	1.66	1.42
	IW+2	1.82	1.84	1.78	1.46

**Fig. 1. A.** Partial melting trends for meteorites at each fO<sub>2</sub> and schematic phase-fields (La~0). La-component of bulk starting material is 1-2%. Augite (Aug) may be stabilized at low temperatures if enough residual Na<sub>2</sub>O is retained [13]. The hachured square is (Ol-Pyx-Pl ±Aug) and the circle is (Ol-Sp-Pl ±Aug). Note the thermal divide between them. These piercing points shift with Mg#, Ne#, [13] and La-content. **B.** starting compositions calculated as per text (projection is expansion of the shaded rectangle in A). Symbols: Open, melting at Ol-Sp-Pl (±Aug); closed, melting at Ol-Pyx-Pl (±Aug).



**Fig. 2.** SiO<sub>2</sub> content of 1200°C and 1170°C low-Na<sub>2</sub>O partial melts vs. calculated molar bulk (FeO+MgO)/SiO<sub>2</sub> ratio of the processed chondrites. The critical composition is near a (FeO+MgO)/SiO<sub>2</sub> ratio of ~1.75.

**Fig. 3.** Pyroxene-out temperature for processed (low-Na<sub>2</sub>O) chondrite vs. the molar (FeO+MgO)/SiO<sub>2</sub> ratio of bulk processed chondrite. Note that the regression intersects the CM, CV solidus ~1150°C [5] at (FeO+MgO)/SiO<sub>2</sub> ~1.75.



**Fig. 4.** SiO<sub>2</sub> content of low-temperature St. Severin melts vs. Na<sub>2</sub>O retained by melt. ~2 wt% Na<sub>2</sub>O in the melt is only ~1/4 of the Na<sub>2</sub>O initially in the meteorite. Increased SiO<sub>2</sub> reflects increased Pl (c.f., [12]).