ENTRY OF ALKALIS INTO TYPE-I CHONDRULES AT BOTH HIGH AND LOW TEMPERATURES.

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Introduction: Abundance of moderately volatile elements, including alkalis, is a key constraint for any chondrule formation model. A longstanding problem has been that alkalis may be mobile in asteroidal environments, obscuring the earlier nebular record and making it difficult to construct meaningful models.

The distribution of alkali elements in type-I (low-FeO) chondrules must be understood prior to modeling chondrule formation. Many type-I chondrules in primitive chondrites are zoned, with mesostasis near outer surfaces being richer in alkalis than that in cores. We have argued [1] that alkalis entered chondrules during parent-body processing at low temperature because Ca decreases as alkalis increase and alkalis correlate with water content. Others [2,3] explained the zoning by recondensation of alkalis into cooling chondrules. Type-I chondrules also have alkali contents that are related to mineralogy: pyroxene-rich chondrules (type IB) have higher alkali and Si contents than olivine-rich chondrules (type IA) [1,4]. The observation that Na in clinopyroxene (CPX) correlates with Na in surrounding glass, consistent with igneous partitioning [4], is evidence that alkalis were present in chondrules at high temperature. This has led to the conclusion that the process responsible for chemical zoning must be identical to that which produced differences between type IA and IB chondrules: recondensation of moderately volatile elements and Si into chondrules at supersolidus temperatures [4]. How can these conflicting observations be reconciled?

Experimental results: We have located zoned type-IA and IB chondrules in Semarkona that contain CPX quench crystals in regions of mesostasis with high alkali-element gradients. If alkali zonation was established prior to CPX crystallization, then a relationship should exist between the Na contents of CPX and glass within each chondrule. However, despite up to a factor of 10 difference in mesostasis Na content between chondrule surfaces and cores, CPX contains a uniform Na concentration consistent with igneous partitioning between the CPX and alkali-poor mesostasis found in the chondrule core. In addition, we have replicated the data of [4] showing a relationship between chondrule mineralogy and mesostasis alkali content (see also [1]).

Discussion: Both high- and low-T processes are required to explain the observed alkali distributions. Alkali zoning is produced *entirely* by low-T entry of alkalis (and other volatiles) into chondrules, accompanied by Ca loss. This zoning is superimposed on a high-T alkali signature possibly derived from condensation processes. When chondrules initially cooled, they were likely unzoned with respect to alkalis, as predicted by diffusion calculations. At this time, different types of chondrules had different alkali contents, which may be preserved in cores after low-T alkali entry on the parent body. Mineralogical zoning, including pyroxene-rich shells developed around type-I chondrules, is also a high-T effect *unrelated* to alkali zonation.

References: [1] Grossman J. N. et al. 2002. *Meteoritics & Planetary Science* 37:49-73. [2] Matsunami S. et al. 1993. *Geochimica et Cosmochimica Acta* 57:2101-2110. [3] Nagahara H. et al. 1999. Abstract #1917. 30th Lunar & Planetary Science Conference. [4] Libourel G. et al. 2003. Abstract #1558. 34th Lunar & Planetary Science Conference.