

CONCENTRIC ZONING OF PHOSPHORUS AND BIMODAL ALKALI CONTENTS OF MESOSTASIS IN TYPE II CHONDRULES. Jeffrey N. Grossman, U.S. Geological Survey, 954 National Center, Reston, VA 20192, USA, jgrossman@usgs.gov.

Introduction: The distribution of phosphorus in type 3 chondrites is highly complex. In the least metamorphosed meteorites, P can be dissolved in metallic Fe-Ni, or be present as minute phosphate or phosphide inclusions in metal. Phosphates commonly rim metal grains in type 3 chondrites, presumably because P that was once dissolved in metal has reacted with an external source of Ca and O to form merrillite [1]. Literature data also shows that FeO-rich (type II) chondrules can have mesostasis that contains up to 3.5 wt% P_2O_5 [2], whereas mesostasis in FeO-poor chondrules tends to be very low in P_2O_5 . Systematic x-ray mapping studies of type 3 chondrites in progress at the USGS reveal further complexity in P distribution. Calcium phosphate rims also surround many chondrules in these meteorites. And, some P-rich type-II chondrules in ordinary and CO3 chondrites contain mesostasis that is richer in P near the chondrule surface than in the interior. I report here on my initial studies of these “P-zoned” chondrules, and the bimodal (!) distribution of Na and K found in the mesostasis of these and other type-II chondrules.

Experimental: P-zoned chondrules were discovered in P-K α x-ray maps of 3×3 to 4×4 mm areas of Chainpur (LL3.4), Sharps (H3.4), Krymka (LL3.1), Ngawi (LL3.4), and Kainsaz (CO3.2). One or two positive identifications of these chondrules could be made in each area. The absolute abundance of P-zoned chondrules cannot be determined due to poor sampling, but they appear to be much rarer in CO3 chondrites (which contain relatively few type-II chondrules) than in H and LL chondrites. None were found in a 4×4 mm x-ray map of Semarkona, which contained images of ~60 chondrules. Due to the statistics of small numbers, this may not be a significantly different abundance than was found in the other UOCs.

Seven P-zoned chondrules were selected for further study. High-resolution (1 μ m raster interval, ~75 ms dwell time, 100 nA beam current) x-ray maps of each chondrule were obtained for Na, Al, P, K and Ca. Microprobe analyses (Na, Mg, Al, Si, P, Cl, K, Ca, Ti, Cr, Mn, Fe) of mesostasis, following transects across each chondrule and in areas of interest selected from x-ray images, were obtained using a 5×5 μ m rastered-beam. Crystallites, common in these mesostases, were avoided as much as possible, but some beam overlap inevitably occurred. Olivine and pyroxene microprobe analyses were also obtained.

Petrologic features. All of the P-zoned chondrules that were examined have textures and mineral composi-

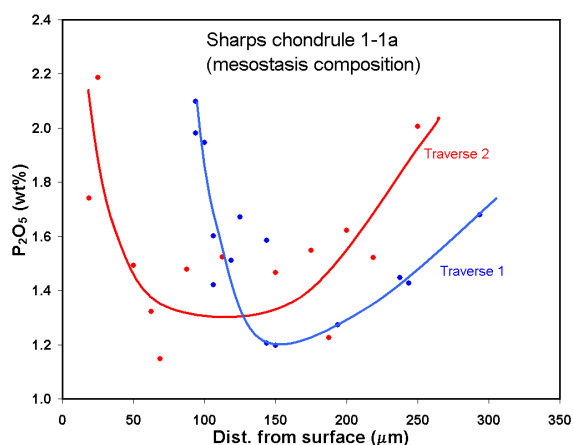


Figure 1

tions typical of type II porphyritic olivine (PO) chondrules [2]. Coarse olivines (many > 100 μ m) are set in glass crowded with dendrites and tiny crystals of pyroxene. Euhedral, 5-10 μ m crystals of augite are also common in the mesostases. These chondrules are all type A5 in the Sears classification scheme [3]. Normative compositions of mesostases are in the range of 40-80 wt% albite, <10 wt% anorthite, <10 wt% quartz, and 10-40 wt% pyroxene. Olivines are moderately ferroan, Fa₁₅₋₃₀, except in Kainsaz (Fa₄₀), and CaO poor (<0.2 wt%).

Zoning-profiles: Microprobe spot analyses confirm the zoning profiles observed in x-ray maps. Figure 1 shows the concentration of P_2O_5 in Sharps chondrule 1-1a along two traverses from near the chondrule surface into its interior. Although the profile is somewhat different in the two directions, P_2O_5 decreases from >2 wt% near the surface to ~1.4 wt% in the interior. This pattern is typical of those found in chondrules from all of the meteorites.

In some, but not all of the measured chondrules, CaO concentration correlates with P_2O_5 in the mesostasis. No other measured element correlates positively with P_2O_5 in any chondrule. Anticorrelations between P_2O_5 and some or all of the major oxides, Na₂O, SiO₂ and Al₂O₃, are observed in mesostasis from five of the chondrules.

Alkali element distribution: High resolution x-ray maps of P-zoned chondrules revealed an unexpected distribution of alkali elements in many of the mesostases. Chondrules in Chainpur, Krymka, Sharps, and Ngawi all showed this feature, although the one Kainsaz chondrule did not. Most areas of mesostasis have the typical composition of that in group A5, albeit rich

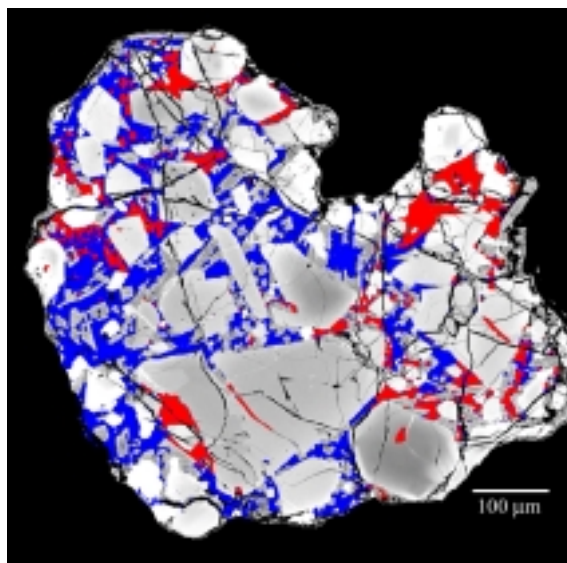


Figure 2.

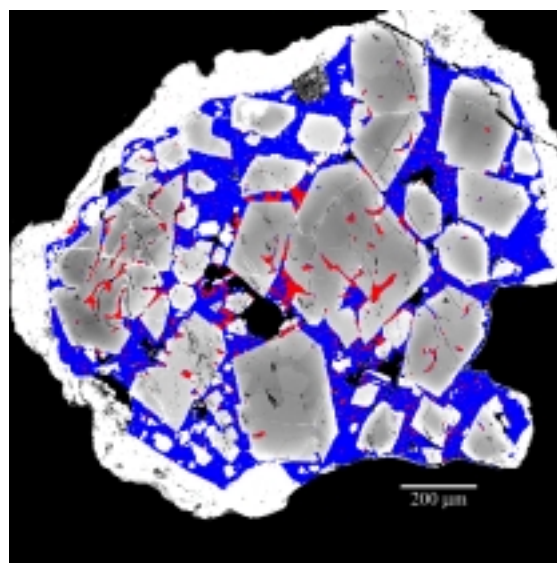


Figure 3.

in P_2O_5 . In these, Na/K is typically 5-100 \times the solar ratio, with 7 to 10 wt% Na_2O and 0.1 to 0.2 wt% K_2O . High Na/K ratios were also reported in A5 chondrule glass in Semarkona and Krymka by [4], although not as high as in the present data. Potassium-rich areas of mesostasis are also present in the same chondrules. These areas have generally at least 2 \times less extent than albitic glass. Potassic glass typically has 1 to 2 wt% K_2O and 2 to 4 wt% Na_2O , and Na/K ratios significantly below solar. Compositions of Na- and K-rich mesostasis within a single chondrule are nearly identical for all elements except alkalis.

The distribution of Na- and K-rich mesostasis in the P-zoned Chainpur chondrules, numbers 2-1a and 2-2a, is shown in Figs. 2 and 3, above. Na-rich and K-rich mesostasis have been colored blue and red, respectively, based on x-ray maps, and the rest of the image area is normal backscattered electron intensity. K-rich mesostasis preferentially occurs as glassy inclusions in olivine and in thin areas of mesostasis sandwiched between adjacent olivine crystals. In Fig. 1, it also can be seen that K-rich mesostasis may occur as isolated patches in physical contact with Na-rich mesostasis. (The white area surrounding the chondrule in Fig. 3 is an FeS-rich rim.)

A search was made using x-ray mapping, for similar bimodal mesostasis occurrences in P_2O_5 -poor chondrules in Semarkona and Chainpur. It was found in several Na-rich, FeO-rich (type II/group A5 or B) chondrules in each meteorite. In FeO-poor chondrules with zoned mesostasis [5], and in Na-rich, FeO-poor chondrules, Na and K are well-correlated, with no evidence for bimodal mesostasis compositions.

Discussion: P-zoned chondrules do not seem to be closely related to zoned low-FeO chondrules [5,6]. The

latter show radial zonation of all volatile elements, in which the chondrules were originally depleted. P-zoned chondrules were P-rich at the time of melting, as is certain due to the strong correlation between P_2O_5 in mesostasis with P_2O_5 in olivine phenocrysts [2, and confirmed by the present data]. It now appears that all P-rich material in chondrites, including reduced-P-rich metal grains and P_2O_5 -rich chondrules, is susceptible to the formation of phosphate-rich rims during parent-body alteration or metamorphism. My interpretation of P-zoned chondrules is that secondary phosphate was able to nucleate not just at the chondrule surface, but also within the outer portions of the microcrystalline mesostasis, aided by abundant grain boundaries along which diffusion might occur. An external source of CaO, most likely chondrite matrix, is required.

The bimodal composition of alkalis in mesostasis in FeO-rich chondrules, including P-zoned chondrules, is more problematic. Igneous models involving fractional crystallization and liquid immiscibility all seem to fail. The coexisting mesostasis compositions seem to require a low-temperature origin to prevent interdiffusion of alkalis between glasses that seem far from equilibrium with each other. It seems possible that all of the Na-rich mesostasis in these (and perhaps all?) chondrules has a secondary, low-temperature origin. TEM and ion probe studies of this material are planned, and may help better determine its origin.

References: [1] Rubin and Grossman (1985). [2] Jones (1990) *GCA* 54, 1785-1802. [3] Sears, Huang, and Benoit (1995) *EPSL* 131, 27-39. [4] Huang and Sears (1997) *GCA* 61, 4689-4704. [5] Grossman (1996) *LPS* 27, 467-468. [6] Matsunami et al. (1993) *GCA* 57, 2102-2110.