

PANETHITE-BEARING ASSEMBLAGE IN THE BISHUNPUR LL3.1 ORDINARY CHONDRITE: POSSIBLE ALTERATION PRODUCT. Craig L. Johnson, Dante S. Lauretta, and Peter R. Buseck, Arizona State University, Departments of Chemistry and Geology, Tempe, AZ 85287-1604. cljohnson@asu.edu.

Introduction: Phosphorous mineralogy in meteorites is complex and offers a sensitive gauge of solar nebula and meteorite parent-body processes. A variety of P-bearing minerals occur across the different classes of meteorites. This range of P minerals can be used to better constrain the events taking place in the early solar system. Phosphorous can act as a lithophile or a siderophile element depending on the conditions under which it is reacting. It occurs in reduced form associated with meteoritic metal either as a solute in the metal or as a phosphide. It also exists as various phosphates [1-6]. The Bishunpur LL3.1 is one of the least altered ordinary chondrites and contains an interesting P-bearing assemblage.

Analytical Methods: A thin section of the LL3.1 ordinary chondrite Bishunpur was analyzed using a JEOL JXA 8600 electron microprobe (EMP) and a Hitachi 4700 field-emission scanning electron microscope (FESEM). Quantitative broad-beam (70 μm beam dia.) and focused-beam (1 to 2 μm beam dia.) chemical analyses were performed with the EMP using wavelength dispersive spectrometry (WDS) to determine the compositions of phases containing P. The analyses were performed for all major elements: O, Na, Mg, Al, Si, P, S, Ca, Cr, Mn, Fe, Co, and Ni (the broad-beam analyses also included K and Ti). Known mineral standards were used to calibrate the EMP. The analyses were done at an accelerating voltage of 15 kV and a beam current of 10 nA. The FESEM was used to obtain high-resolution images of the assemblages containing the P and to obtain semi-quantitative chemical data using energy dispersive spectrometry (EDS). The FESEM images were obtained with an accelerating voltage of 15 kV and a beam current of 10 nA.

Results: Phosphorous-rich material was located in Bishunpur using EDS and chemical mapping. The P-bearing assemblage in Figure 1A was found in the matrix using this technique. Table 1 lists the elemental abundances (wt%) for each phase determined by focused-beam EMP analysis. The grain is predominantly composed of troilite and metal phases. There are numerous cracks and veins throughout the troilite. Minor phases included in the troilite are fayalite, magnetite, tetrataenite, graphite, and Cr- and P-rich phases. The P-bearing phases occur as inclusions in troilite (~500 μm dia.) and coexisting tetrataenite (Fig. 1). The phosphate contains significant amounts of Na, Ca, and Mg with no detectable K or Mn. The analysis indicated 2.4 wt. % Ni, which may result from metal below the sample surface. Its composition

corresponds to panethite $[(\text{Na,Ca,K})_2(\text{Mg,Fe,Mn})_2(\text{PO}_4)_2]$ [1]. However, we were unable to determine the exact stoichiometry because it is intimately intergrown with magnetite. The phosphate grain also contains a Cr-rich submicron inclusion which we assume is chromite. The weight percent total was low (92.0) for the analysis of the phosphate grain, indicating light elements or porosity.

Conclusions: Panethite occurs in many iron meteorites, but is rare in chondrites [5,7]. Its association with kamacite, troilite and magnetite suggests that its origin is related to these phases. Phosphorous is associated with metal in Bishunpur as a solute in the alloy, as phosphide inclusions, and as Fe,Na- or Ca-bearing phosphates [6,8]. Panethite has a composition intermediate to these phosphates. The Fe,Na-phosphates may have formed prior to the Bishunpur parent body [8]. Ca-bearing phosphates are common in meteorites that are more altered than Bishunpur [3]. Thus, Ca- (and Mg-) bearing phosphates may have formed during parent-body alteration. Numerous cracks and veins penetrate this assemblage. The morphology of these veins is compatible with aqueous alteration, which occurred on Bishunpur [9]. Aqueous alteration could also deliver Ca and Mg to the phosphate, since they are susceptible to aqueous transport [10]. Further study of this and similar assemblages using transmission electron microscopy and electron microprobe analysis will be necessary to determine the origin of phosphate and associated phases.

References: [1] Fuchs L. H. et al. (1967) *GCA*, 31, 1711-1719. [2] Buseck P. R. (1969) *Science*, 165, 169-171. [3] Rubin A. E. and Grossman J. N. (1985) *Meteoritics*, 20, 479-489. [4] Zanda B. et al. (1994) *Science*, 265, 1846-1849. [5] Olsen E. J. et al. (1999) *Meteoritics & Planet. Sci.*, 34, 285-300. [6] Lauretta D. S. et al. (1999) *LPSC XXX*, 1160. [7] Hua X. and Buseck P. R. *GCA*, 62, 1443-1457 [8] Lauretta D. S. and Buseck P. R. (2000), this volume. [9] Alexander, C. M. O'D. (1989) *GCA*, 53, 3045-3057. [10] Krot A. N. et al. (1997) *GCA*, 61, 219-237.

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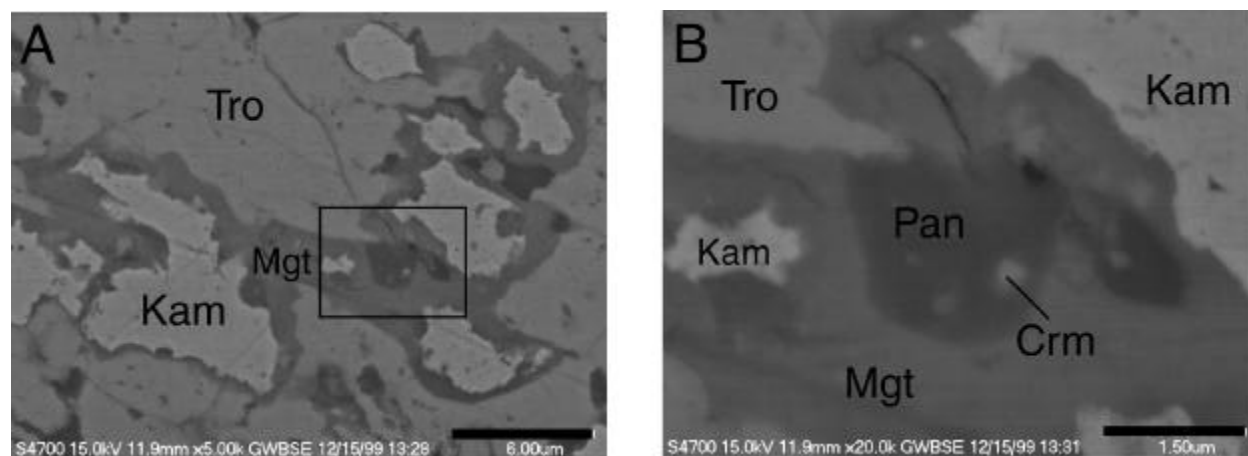


Figure 1. Back scattered electron images of a P-bearing assemblage in Bishunpur. (A) The lightest phase is kamacite (Kam) surrounded by the darker magnetite (Mgt) all of which is imbedded in a large troilite (Tro) grain. The scale bar is 6 μm . (B) a high-resolution image of the assemblage in the boxed area in (A). The panethite (Pan) grain is located at the center of the image and is almost entirely surrounded by magnetite. The Cr-rich inclusion (Crm) is in the lower right of the panethite grain. The scale bar is 1.5 μm .

Table 1. Elemental abundances (wt. %) for phosphate-metal assemblage in Figure 1.

Element	Kamacite	Troilite	Magnetite	Panethite/Magnetite/Cr mix
O	0.1	1.7	36.2	27.9
Na	0.0	0.0	0.6	1.5
Mg	0.0	0.0	0.2	1.0
Al	0.0	0.0	0.0	0.0
Si	0.1	0.1	0.5	0.7
P	0.0	0.1	0.1	4.2
S	0.1	35.1	1.7	0.8
Ca	0.0	0.1	0.0	4.2
Cr	0.4	0.6	0.6	2.0
Mn	0.0	0.0	0.0	0.0
Fe	96.8	61.2	54.7	47.0
Co	0.5	0.1	0.4	0.2
Ni	3.6	0.3	4.9	2.4
Total	101.6	99.5	99.9	92.0