TRACE-ELEMENT ABUNDANCES IN THE PORTALES VALLEY METEORITE: EVIDENCE FOR GEOCHEMICAL FRACTIONATIONS.

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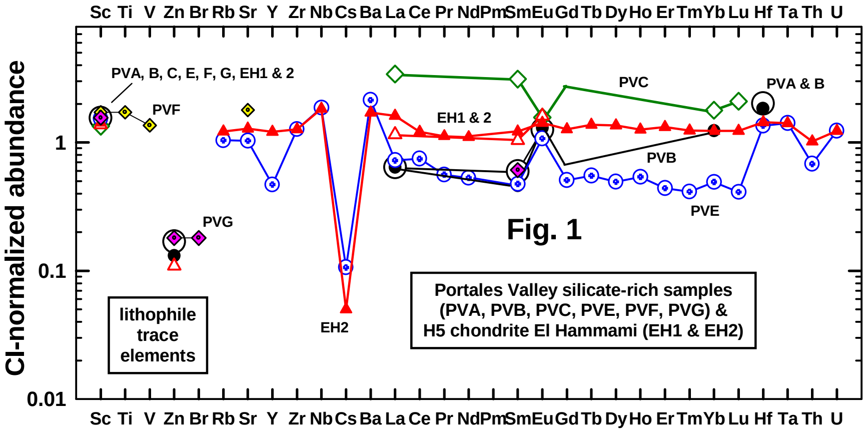
Abstract: The Portales Valley (PV) metal-silicate breccia, although classified as an H6 chondrite [1], is unique in several respects. These include distinctive texture [1,2], mineralogy and modes [3-5], N-isotopic composition of metal unlike that found in ordinary chondrites (OC) [6], young T_{CHUR} ages of 1.2-1.6 Ga [7-8], and evidence for LREE-enrichments [7-8]. We used INAA, XRF, and ICPMS to analyze various splits of PV for elements spanning a range of geochemical and cosmochemical behavior, to better constrain the petrology and origin of the meteorite. We conclude that both the silicate-rich and metallic portions of the meteorite experienced geochemical fractionation, and that the silicate-rich portion of the meteorite was derived from an OC-like protolith. Contrary to recent suggestions [8], we find no evidence to support the idea that the silicate portion of PV was fractionated during melting events.

Samples and methods: Aliquots (PVA, PVB, PVE, PVF, PVG) of PV were obtained from a 5.7 g powder of 4 separate, silicate-rich fragments. Another aliquot (PVC) was obtained from a powder of a separate 1.7 g fragment that contained a coarse (~5x2 mm) patch of phosphate. Nearly pure FeNi-metal (PVD, 166 mg) was cut from another fragment that contained intersecting coarse metal veins. Aliquots of a powder of the El Hammami (H5) chondrite (EH1 & EH2) were analyzed for comparison with PV. Samples were analyzed by INAA at OSU-Corvallis (PVA, PVB, PVC, PVD, EH1), INAA at PSU–Portland (PVG), ICPMS at WSU-Pullman (PVE, EH2), and XRF at WSU-Pullman (PVF).

Lithophile elements: Fig. 1 shows CI-normalized abundances of lithophile trace elements in the silicate-rich aliquots. Large depletions are evident for volatile elements (Zn, Br, Cs), but these are typical for Type 5-6 OC. Among non-volatile elements, fractionated abundances (both low and high relative to OC) are observed for those elements that are strongly partitioned into merrillite (i.e., REE, Th, Y), and nearly chondritic abundances are obtained for other elements. Complementary REE patterns are seen.



These data suggest that lithophile elements were fractionated as a result of phosphate segregation. In contrast, the overall chondritic abundances for those lithophile elements not concentrated in merrillite, including elements that have different compatibilities (e.g., Sc and Rb), suggest that the silicate portion of PV was derived from an OC-like precursor, and that it was not significantly affected by crystal-liquid segregation.

In sample PVE, Th but not U is fractionated compared to the El Hammami chondrite (Fig. 1). This suggests that merrillite, not apatite, controls the fractionation of REE and actinides in PVE, as Th and U partition preferentially into merrillite and apatite, respectively [9]. The REE abundances in the PV samples, including especially the sign and magnitude of the observed Eu anomalies, can be modelled by assuming that the absolute proportion of merrillite in an H-chondrite assemblage varies between ~0.05-1.5 wt%. This is ~12-375% the amount typical for H-chondrites. Evidently, either merrillite was removed, or REE, Th, and Y were scavenged, from large portions (>1 cm^3) of the meteorite to make merrillite elsewhere. The complementary REE patterns for those elements that are concentrated in phosphate, and the overall REE abundances in these samples, are consistent with the derivation of PV from an OC-like precursor.

Siderophile-chalcophile elements: The abundances of siderophile and chalcophile elements vary greatly in various splits of PV (Fig. 2). Included in Fig. 2 are data for five thin-sections of PV 4978, which include high metal contents (up to ~60 wt% metal), and bulk data for the silicate-rich splits, which are low in metal content.

The composition obtained for coarse metal in PV(sample PVD) largely agrees with other analyses [2]. This metal has a composition similar to that observed in H-chondrites and in IIE iron meteorites, except that it is richer in Ni (~10.7 wt% in PVD). It is distinct from that in L- or LL-chondrites. The Ga abundance in our coarse metal sample is more similar to the metal in IIE irons than to metal in H-chondrites, but the reverse is true for the coarse metal analyzed by Rubin et al. [2].

Siderophile element abundance patterns in the silicate-rich aliquots (PVA, B, C, G) are similar to one another (Fig. 2), suggestive of control by a single phase. This phase is probably FeNi-metal, as the siderophile elements should be concentrated largely in this phase, except for Fe and Ga, which are also contained in silicates and (for Fe) in troilite. Excluding Fe and Ga, the siderophile element patterns in all splits of PV are largely similar (Fig. 2), except that values of Ir/Ni, Co/Ni, Au/Ni, and As/Ni are lower in the matrix metal. This suggests that the metal phase in PV is fractionated, with bulk metal in the silicate-rich matrix containing lower Ni contents. Microprobe analyses show that kamacite in coarse veins and in the matrix has the same abundances of Fe, Ni, and Co. Thus, the matrix of PV must contain a higher proportion of kamacite and a lower proportion of taenite or plessite than the vein metal, which agrees with petrographic observations.

One possibility is that fractionation of metal occurred during partial melting of metal. A partly molten origin for the coarse metal in PV seems likely on textural grounds [2]. However, there is no obvious correlation between the inferred fractionation and solid-metal/liquid-metal partition coefficients [9,10], as one might expect for this model. Additional work on the composition of metal in PV is needed to understand how and why siderophile elements were redistributed.

Phase segregation: Our samples of PV are chemically fractionated compared to ordinary chondrites primarily in those elements that partition into phosphate and metal. Mechanical segregation of these phases probably was responsible for the observed chemical fractionations. In PV, phosphate is concentrated along the margins of coarse FeNi-metal and evidently formed by metamorphic reaction between a P-bearing metal phase and the silicate host [3,4]. Phosphate may also have attached to molten metal by a surface tension effect [11]. In either case, REE and actinides were effectively scavenged and redistributed throughout large portions of the breccia during vein formation. We speculate that this process affected the Sm-Nd chronometer and that the young T_{CHUR} ages reported for PV [7,8] date the time of coarse vein formation and phosphate segregation. If so, an impact event occurring ~1.2-1.6 Ga ago may have been responsible for assembling the PV breccia in its present form.

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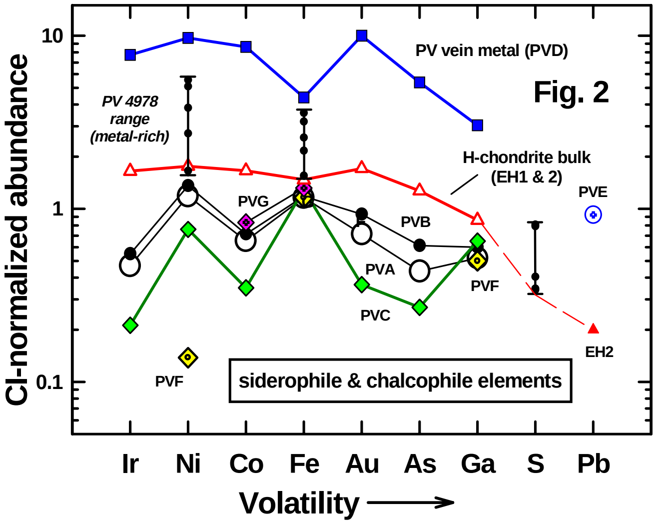

Fig. 2