PIECING TOGETHER THE PORTALES VALLEY CHRONOLOGY PUZZLE: CLUES TO THE ORIGIN OF UNUSUALLY YOUNG Sm-Nd AGES.

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Introduction: The Portales Valley meteorite fell recently in New Mexico and attracted attention due to its unusual characteristics [e.g., 1–4]. It consists of H6-like chondrite material that is extensively invaded and cross cut by massive interconnected FeNi veins [1,5]. The metal in these veins displays a Widmanstätten texture, indicative of slow cooling [1,6].

Recent chronological studies further emphasize the unusual nature of this meteorite. Re-Os and U-Pb [7] systematics indicate early formation for the metal and silicates, respectively, and ^{40}Ar-^{39}Ar ages for two samples are well-defined at ~4.47 Ga [8]. However, Sm-Nd data for three samples of Portales Valley suggest young ages and substantial Sm/Nd fractionation [9]. The three samples have different Sm and Nd concentrations and are all strongly depleted in Sm/Nd relative to chondrites. The $\varepsilon(^{143}\mathrm{Nd}/^{144}\mathrm{Nd})$ values are depleted relative to chondrites and give T_{CHUR} model ages ranging from 1.16 to 1.57 Ga. One of the samples also exhibits disturbed Rb-Sr systematics. These data are all the more puzzling because the old ^{40}Ar-^{39}Ar ages were determined on portions of two of the same samples as the Sm-Nd data [8,9]. Because of these differences, Papanastassiou et al. [9] concluded that the silicate portion of Portales Valley is not directly related to chondritic material.

In this study we examine the distributions of the REE in Portales Valley in order to evaluate its Sm-Nd systematics and the relationship of this meteorite to H chondrites. We present data for Portales Valley, as well as the H6 chondrite Guareña, and discuss the implications of the results for the Sm/Nd fractionations observed by [9].

Experimental and Results: Using the ion microprobe, we measured the REE and other trace elements in all mineral phases expected to contain REE (i.e., phosphates, pyroxenes, plagioclase and olivine) in two sections of Portales Valley and one section of Guareña. One of the Portales Valley sections, UH275, comes from a piece adjacent to metal veins and is itself almost bisected by a narrow metal vein. The other, UH277, represents a fragment lacking metal veins that is also the source of clast E, described by [5] as modally similar to H chondrites.

Phosphates: REE concentrations are similar to those previously reported for chondrites [10]. In merrillite, they are uniform within each section analyzed. In UH277 and Guareña, merrillites have similar flat REE patterns with large negative Eu anomalies and abundances of 200 – 300 x CI. Merrillites from UH275 are concentrated along the border of the metal vein and have lower REE abundances (~100 x CI) and a smaller Eu anomaly. Apatite grains from the two Portales Valley sections have identical LREE-enriched patterns with small positive Eu anomalies and abundances of ~30 x CI. Guareña apatite has a similar pattern with slightly higher REE abundances.

Plagioclase: REE abundances are the same in Guareña and both Portales Valley samples at La = ~0.5 x CI. The pattern is strongly LREE-enriched with a positive Eu anomaly; HREE abundances are below detection limits.

Clinopyroxene: REE patterns are HREE-enriched with negative Eu anomalies. Abundances are uniform within Guareña and PV277 and are similar in the two meteorites with La = 1 – 2 x CI. In UH275 REE concentrations in clinopyroxene vary by almost an order of magnitude, with La ranging from ~0.5 – 4 x CI, although major element compositions are similar in all the grains analyzed.

Orthopyroxene: the REE pattern is strongly HREE-enriched with concentrations for REE lighter than Tb below detection limits. Guareña and UH277 have identical REE abundances at Lu = ~0.7 x CI; those of UH275 are lower by about a factor of 2.

Olivine: this mineral was measured only in UH277. It has very low REE abundances with Lu = 0.07 x CI and all REE lighter than Er below detection limits.

Discussion: The silicates and phosphates measured in Portales Valley clearly have REE distributions similar to those observed in the H6 chondrite Guareña. Furthermore, it is unlikely that any other phases reported to be present in this meteorite (kamacite, troilite, chromite) contain significant amounts of REE or Sr. Indeed, using reported modal abundances for H chondrites and Portales Valley [5,11] and average REE concentrations for the minerals analyzed here, we find that reconstructed whole rock compositions for Guareña, as well as the two Portales Valley sections, have flat REE patterns with abundances at ~1 x CI. Calculated bulk Sr and Rb abundances are also chondritic for both meteorites (Table 1). These calculated bulk compositions are also consistent with unpublished data for two other whole rock samples of

Portales Valley, that indicate flat REE patterns at ~1 x CI [12]. Thus, we confirm that the silicate portion of Portales Valley is clearly related to chondritic material.

In contrast, the whole rock samples (S1-S3) of [9] (Table 1) all have Nd concentrations higher than chondritic (particularly in S1 which also has elevated Sm). The Sm/Nd ratios of these samples range from 0.26 – 0.49 x CI. There is no combination of minerals with the REE concentrations we measured that can explain these results. The Sm-Nd budget in Portales Valley is dominated by merrillite (~75%) and clinopyroxene (~15-20%). However these phases have chondritic or superchondritic Sm/Nd ratios (Table 1) and, therefore, cannot account for the depleted Sm/Nd observed in S1–S3. We also note that the pronounced LREE enrichment in S1 was found mainly in the leach residue [9], which is not expected to contain any remaining phosphates. The only phase with appropriately low Sm/Nd ratios (0.07 – 0.11) is plagioclase but its REE concentrations are far too low to account for the Sm and Nd concentrations of S1–S3.

The absence of an appropriate phase in Portales Valley to account for the depleted Sm/Nd ratios in samples S1–S3 argues for the presence of an additional external component. We cannot exclude the possibility of laboratory contamination, but consider it unlikely given the long and consistently excellent record of the CalTech laboratory. However, although this meteorite is an observed fall, the possibility of terrestrial contamination must be addressed. Specimens were recovered for a period of almost three months after the fall and, while the thin sections we analyzed looked fresh and unaltered, some samples started to rust within days after the fall. LREE enrichments due to terrestrial contamination have been observed in hot desert meteorites [13,14] and mimic those of the local soil [15] and of typical continental crust and sediments [16]. However, they are not LREE-rich enough to account for the Sm/Nd ratios observed in samples S1-S3 (Table 1). Thus, the LREE-rich components observed in the three samples of Portales Valley are unlike typical crustal material. One possibility is that chemicals used to farm the lands on which Portales Valley fell may have contributed to the LREE enrichment [12]. But whatever the source of the LREE-rich external component is, it is clearly responsible for the negative $\varepsilon(^{143}Nd/^{144}Nd)$ values seen in these samples [9].

Conclusions: Our examination of two sections of Portales Valley shows that the silicate portion of this meteorite is indeed broadly chondritic in its REE distributions. The strong LREE enrichments observed by [9] cannot be accounted for by the mineral compositions of Portales Valley, nor are they attributable to typical terrestrial contamination. No special significance should be given to the T_{CHUR} model ages reported by [9].

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Table 1. Rb-Sr and Sm-Nd abundances and ratios.

	Rb (ppm)	Sr (ppm)	Rb/Sr x CI	Sm (ppm)	Nd (ppm)	Sm/Nd x CI
PV S1*	3.617	40.85	0.30	1.466	17.38	0.26
PV S2*	2.52	9.925	0.86	0.1674	1.0481	0.49
PV S3*	2.708	10.61	0.87	0.2037	2.185	0.29
bulk PV275	1.9	8.9	0.7	0.10	0.32	0.96
bulk PV277	2.1	8.5	0.8	0.29	0.80	1.1
bulk Guareña	2.3	7.9	1.0	0.18	0.46	1.2
% of element in	Rb (%)†	Sr (%)†	Rb/Sr x CI†	Sm (%)†	Nd (%)†	Sm/Nd x CI†
apatite	< 0.01	~1	0.005	~1	~1	0.71 – 0.80
merrillite	<0.5	~3	0.1	70 – 85	76 – 87	0.87 – 1.1
plagioclase	~96	~94	0.7 – 0.9	~0.02	~0.2	0.07 – 0.11
clinopyroxene	~0.5	~2	0.2 – 0.3	15 – 28	11 – 22	1.2 – 1.5
orthopyroxene	~0.5	<0.5	2.6 – 4.7	0	0	---
olivine	~3	<0.5	5.8	0	0	---
				Sm (ppm)	Nd (ppm)	Sm/Nd x CI
cont. crust§				3.5	16	0.67
sediments§				5.5 – 7.3	33 – 40	0.50 – 0.58

* data from [9]; §data from [16]; †calculated from data for PV275 and PV277.