DIVERSE PYROXENE Fe-Mn TRENDS AS RECORDERS OF REDOX WITHIN UNANNEALED EUCRITES. Paul H. Warren1 and Jason Utas1, 1Department of Earth, Planetary and Space Sciences, University of California, 405 Hilgard Avenue, Los Angeles, CA 90095, USA, pwarren@ucla.edu.

The oxides FeO and MnO show strong geochemical coherency among materials from any given planetary body, despite considerable diversity in whole-body FeO/MnO. These relationships are commonly exploited by employing measurements of FeO/MnO in pyroxene to distinguish parent-body provenance. The HED parent body is commonly represented by a single line on plots of pyroxene Fe vs. Mn [e.g., 1]. However, if we focus on the small minority of eucrites whose pyroxenes have not been equilibrated by annealing (thermal metamorphism; the type that [2] termed “pristine” eucrites), data for pyroxene FeO/MnO actually exhibit important diversity, within individual meteorites as well as between different meteorites.

This FeO/MnO diversity was highlighted in the case of troilite-rich eucrite QUE94484 by Mittlefehldt and Peng [3], who inferred an anomalous process of reduction of FeO by S2 during igneous crystallization. We have also studied QUE94484, along with eight other unannealed eucrites: Bluewing 001, NWA 1000, NWA 5073 [4], NWA 8661, Pasamonte, Y-981646 (an impact melt), the new, relatively metal-rich eucrite of [5], and a eucritic clast “CF4” in Kapoeta. In general (the main exception: Bluewing 001), Mn data were acquired using extra-long (50 s) counting duration and high beam current (30 nA) to enhance EPMA precision. Some of our results are shown in Figs. 1 and 2 (this page), where FeO/MnO is plotted against mg (= molar Mg/[Mg+Fe]), a ratio that tends to decrease during the course of igneous crystallization at eucritic-low fO2. For purposes of these plots, we distinguish high-Ca pyroxene as having Wo > 20. Except to a mild degree in the case of NWA5073, low and high-Ca pyroxene data tend to nearly conform to a single trend.

Note that to facilitate inter-comparison all of the figures use the same format in terms of range in mg and in FeO/MnO. The Bluewing 001 and NWA 8661 eucrites show trends of increasing FeO/MnO nearly throughout the course of crystallization (i.e., decrease in mg). At least some lunar VLT mare basalts show a
similar trend (except even steeper and at higher overall FeO/MnO). However, both QUE 94484 and NWA 5073 show trends that although beginning with constant or slightly increasing FeO/MnO, change with decreasing mg into trends of FeO/MnO decreasing along with mg. Not plotted in these figures are several intermediate cases, with FeO/MnO relatively constant across the full spectrum of mg: NWA 1000 (as far as can be determined for this complex, badly weathered sample), the new [5] eucrite, the Kapoeta CF4 clast, and also, based on data shown by [6], NWA 2061.

As noted by [3], the trends shown by QUE 94484 (and now also NWA 5073), and to a lesser extent also the unplotted eucrites with flat trends, suggest a process of FeO reduction. However, the nature and timing of this redox remain poorly constrained.

Note that the samples that most strongly manifest FeO reduction tend to show less diverse pyroxene mg. They tend to lack low-mg pyroxenes, presumably because reduction of FeO either prevented formation of low-mg pyroxene, and/or altered low-mg pyroxene that once existed. The new relatively metal-rich eucrite of [5], in which origin of the metal may have involved in-situ reduction, also shows a truncated mg range (albeit its pyroxene FeO/MnO ratios do not show much relation to mg).

A noteworthy trait shared by NWA 8661 and especially Bluewing 001 is that these eucrites almost completely lack secondary veining within pyroxene. In contrast, QUE 94484, NWA 5073 and NWA 1000 all have pyroxene commonly bearing olivine-dominated secondary veins, with which their lowest-mg pyroxenes tend to be spatially associated; and in the case of QUE 94484 and NWA 5073, these are also their most reduced, low-FeO/MnO pyroxenes. In the case of the metal-rich [5] eucrite, the secondary veins are dominantly anomalous-composition (FeO-rich) pyroxene instead of olivine, but otherwise the texture is similar and again indicates important secondary alteration.

Another unusual trait shared by QUE 94484 and especially the [5] eucrite is that pyroxene grain rims tend to appear extensively corroded (Fig. 3; back-scattered electron image), with the original pyroxene replaced by crystallographically controlled alteration into a lamellar mix of (altered) pyroxene, silica, troilite, and anomalously Na-poor plagioclase. Probably reduction of FeO out of the pyroxene, late, after its original igneous crystallization, was responsible for development of this distinctive texture. However, the change in slope on the mg vs. FeO/MnO diagrams occurs at such high (early) mg that it seems likely that much of the redox may have occurred already during the original igneous crystallization. Additional study of the unannealed eucrites should help to constrain the overall timing of their redox processing, and how that redox processing relates to the general phenomenon of secondary, volatile-driven alteration of the eucrites [3, 6, 7].