TRACE ELEMENT SYSTEMATICS OF NORTHWEST AFRICA 011: A "EUCRITIC" BASALT FROM A NON-EUCRITE PARENT BODY.

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Introduction: Northwest Africa (NWA) 011 was originally classified as a non-cumulate eucrite, albeit one with anomalously high Fe/Mn ratios in pyroxene [1]. However, oxygen isotopic data soon showed that it must have originated on a distinct parent body [2].

We used the Cameca 3f ion microprobe at Washington University to measure the REE and other trace elements in individual grains of plagioclase, pyroxene and phosphate from NWA 011 in order to better understand its origin.

Mineral Compositions: The petrography and mineral compositions of the thin section we studied are given by [3]. Plagioclase (An_{80-88}) is anhedral and the cores of two grains have similar LREE-enriched REE patterns (Fig. 1). Pigeonite is subhedral and contains abundant augite exsolution lamellae a few microns wide. REE abundances in pyroxene are uniform, indicating that we adequately sampled both pyroxene compositions. We also did not observe any core to rim zoning, consistent with the largely uniform major element compositions of the pigeonite [2, 3]. Four merrillite grains have similar REE patterns that are LREE-enriched with negative Eu anomalies and small positive Ce anomalies (Fig. 1).

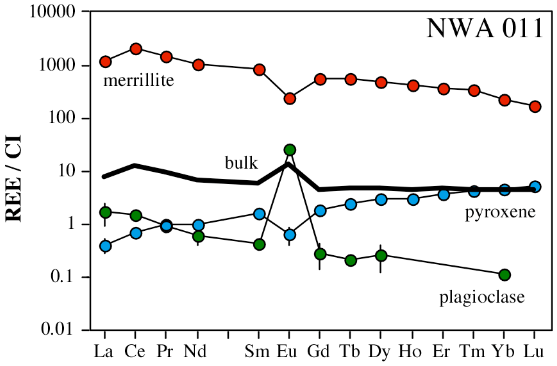

Figure 1. Chondrite-normalized average REE patterns for NWA 011 minerals. The solid line shows the calculated bulk composition for NWA 011.

Bulk Composition: We calculated the whole rock REE composition of NWA 011 using our mineral REE compositions and the mode determined by [3]. The pattern is approximately flat with small positive Ce and Eu anomalies (Fig. 1), reflecting the phosphate-rich nature of our section and, perhaps, a small overabundance of plagioclase. A mode determined by A. Yamaguchi (pers. comm.) for a different section yields virtually the same bulk composition. However, published whole rock REE patterns for NWA 011 are heterogeneous. HREE-rich patterns with large positive Eu anomalies [2, 4] can be reproduced assuming modal proportions of plagioclase and pyroxene [3], with little to no phosphate. A LREE-rich pattern with a positive Ce anomaly [4] is clearly dominated by excess Ca-phosphate. Moreover, the negative Eu anomaly in this pattern requires either a much larger fraction of pyroxene (and correspondingly less plagioclase) than is present in our section (~88% vs. 58%), or phases (*e.g.*, pyroxene or phosphate) with larger negative Eu anomalies than those measured here.

Discussion: NWA 011 shares many similarities with non-cumulate eucrites, including texture, mineralogy and major element compositions (except for higher Fe/Mn ratios) [2-4]. The similarities also extend to trace element compositions. The bulk composition of NWA 011 is around 10 x CI, similar to other eucrites [1, 5] and mineral REE abundances fall within the ranges seen in non-cumulate eucrites [5]. Melts calculated to be in equilibrium with plagioclase and pyroxene from NWA 011 have approximately flat REE patterns at ~20 x CI, indicating that both minerals crystallized from similar melts. However, the melt compositions are enriched by about a factor of two over the calculated bulk composition, and the melt calculated to be in equilibrium with pyroxene is also somewhat LREE-enriched (~50 x CI). This probably reflects homogenization of the REE within grains, which will tend to increase concentrations of the REE and, in pyroxene, particularly the LREE.

Hsu and Crozaz [5] showed that pyroxene and plagioclase from many non-cumulate eucrites have LREE/HREE ratios that fall along a single correlation line. For plagioclase, this line also represents the abundances expected for crystallization from melts with chondritic proportions of the REE. Figure 2 plots the LREE/HREE ratios of plagioclase and pyroxene in NWA 011 relative to the correlation lines seen in non-cumulate eucrites. NWA 011 plagioclase falls on the non-cumulate eucrite line, suggesting that it crystallized from a chondritic melt. Pyroxene from NWA 011, however, falls somewhat to the right of the line. This may indicate some redistribution of the REE, as has been observed in several highly metamorphosed eucrites [6, 7]. NWA 011 does have a number of mineralogical features that are similar to those of highly metamorphosed eucrites, such as Ibitira, EET 90020 and Y-86763 [6, 7], including the presence of type 5 pyroxene [8] and unequilibrated oxide assemblages associated with Fe-rich olivine and pyroxene [2]. Such features have been attributed to a rapid reheating and cooling event on the eucrite parent body [6, 7]. Other trace elements in NWA 011 pyroxene have abundances intermediate between those in non-cumulate eucrites and in highly metamorphosed eucrites (Fig. 3). Thus, if there was redistribution of trace elements, it may have been more limited in NWA 011 than in Ibitira, EET 90020 and Y-86763.

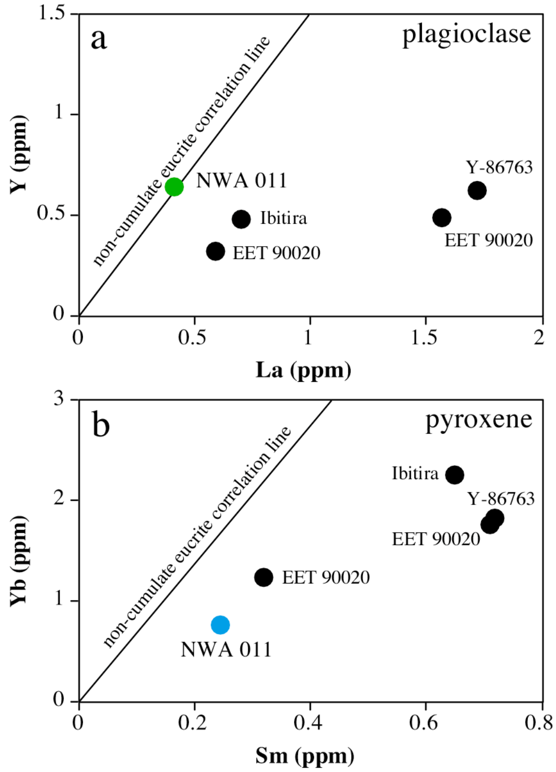

Figure 2. a) La vs. Y in plagioclase; b) Sm vs. Yb in pyroxene. Most non-cumulate eucrites fall along a single correlation line. Highly metamorphosed eucrites experienced redistribution of the REE and fall to the right of the line. Eucrite data from [5, 6].

Despite the similarities that NWA 011 shows with the eucrites, oxygen isotopic data indicate that it does not come from the same parent body. Our trace element data also suggest some differences. Whereas most minor and trace elements in plagioclase (*e.g.*, Na, K, Ba and La) have abundances within the eucrite range, Sr abundances are elevated relative to eucrites. Moreover, REE abundances in merrillite are lower by a factor of ~10 than in typical eucrites, and both pyroxene and phosphate have smaller Eu anomalies than most eucrites. The REE pattern of merrillite also has a small positive Ce anomaly. This is unlikely to be due to terrestrial contamination or weathering (*e.g.*, [9]), since phases with lower REE concentrations are not affected, and may reflect relatively oxidizing conditions on the NWA 011 parent body. An oxidized source has also been suggested on the basis of high Fe/Mn ratios and high P in NWA 011 [4].

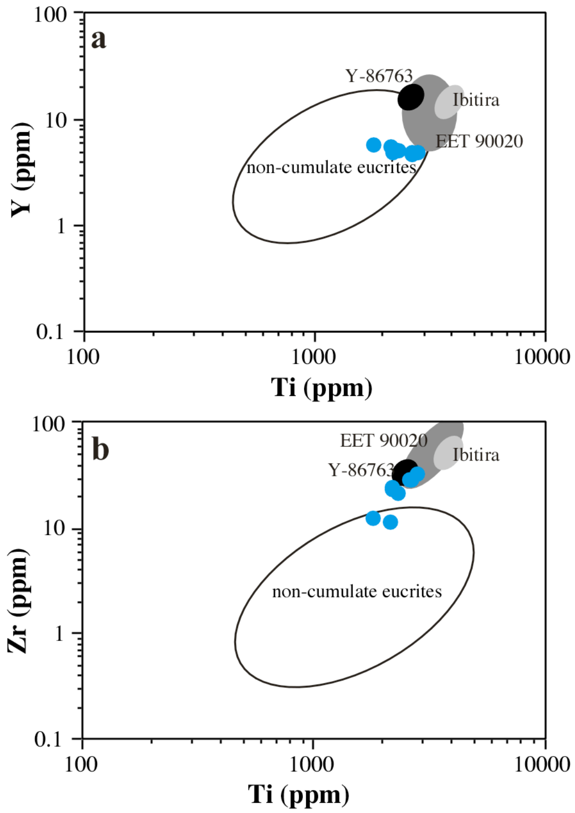

Figure 3. a) Ti vs. Y and b) Ti vs. Zr in pyroxene. Abundances in NWA 011 pyroxene are intermediate between most non-cumulate eucrites and highly metamorphosed eucrites. Eucrite data from [5, 6].

Conclusions: Like eucrites, the NWA 011 basalt originated from a source with chondritic proportions of the REE. It has been metamorphosed to temperatures possibly as high as 1110 °C [2] and, like highly metamorphosed eucrites, may have experienced some trace element redistribution. However, the parent body on which it originated appears to have been more oxidized than the eucrite parent body.

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