RARE EARTH ELEMENT GEOCHEMISTRY OF ANGRITES NORTHWEST AFRICA 4590 AND NORTHWEST AFRICA 4801. M. E. Sanborn[1] and M. Wadhwa[1], [1]Center for Meteorite Studies, School of Earth and Space Exploration, Arizona State University, Tempe, AZ 85287-1404, USA (Matthew.Sanborn@asu.edu).

Introduction: The angrites are a small group of differentiated achondrites of basaltic composition distinguished by unique mineralogical and geochemical characteristics [1]. The sixteen known angrites can be divided into two textural subgroups: (1) coarse-grained (plutonic) angrites that exhibit evidence of slow cooling (e.g., LEW 86010) and (2) fine-grained (quenched) angrites that exhibit evidence of rapid cooling (e.g., Sahara 99555). Prior to the recent recovery of the angrites Northwest Africa (NWA) 4590 and NWA 4801, the only other known plutonic angrites were LEW 86010 and Angra dos Reis. Therefore, NWA 4590 and NWA 4801 provide the opportunity to better understand the petrogenetic history of this rare angrite subgroup.

NWA 4590 is comprised primarily of Al, Ti-bearing diopside, pure anorthite, olivine (with exsolution lamellae of kirschteinite) and accessory phases such as merrillite, troilite, and glass [2]. Likewise, NWA 4801 is comprised of Al, Ti- bearing diopside, pure anorthite, and olivine with minor to trace phases such as troilite and merrillite; however, no kirschteinite is observed [3]. A recent investigation of the Pb-Pb ages of NWA 4590 and NWA 4801 indicates that the crystallization age of these angrites is ~4558 Ma [4]. The goal of this investigation of rare earth element distributions in the various phases of NWA 4590 and NWA 4801 is to understand their petrogenetic histories and their relationships to previously studied angrites.

Analytical Techniques: Polished thick sections of NWA 4590 and NWA 4801 were characterized using a JEOL 845 scanning electron microscope at Arizona State University (ASU). After initial characterization and documentation, major element abundances in various mineral phases were measured using a JEOL 8800 electron microprobe at ASU. Rare earth element (REE) and select additional trace element abundances were measured *in situ* in clinopyroxene, anorthite, olivine and merrillite using the Cameca 6f-ion microprobe at ASU following the methods similar to those described by [5].

Results and Discussion: Figure 1 shows representative REE abundances in clinopyroxenes of NWA 4590 and NWA 4801. The clinopyroxenes of NWA 4590 show a relatively large range of REE concentrations from core to rim (La ~2.5-12.7 × CI). The clinopyroxenes of NWA 4801 exhibit a somewhat narrower range of REE abundances (La ~3.5-8.6 x CI). Both NWA 4801 and NWA 4590 clinopyroxenes exhibit small to moderate negative Eu anomalies (Eu/Eu^*~0.50-0.59 for NWA 4590 and ~0.66-0.71 for NWA 4801). The REE patterns of NWA 4590 clinopyroxenes exhibit a concave-down pattern that parallels that observed in clinopyroxenes of the plutonic angrite LEW 86010 (Fig. 1). NWA 4801 clinopyroxenes also show concave-down REE patterns; however, their HREE patterns are slightly flatter than those observed in NWA 4590 clinopyroxenes.

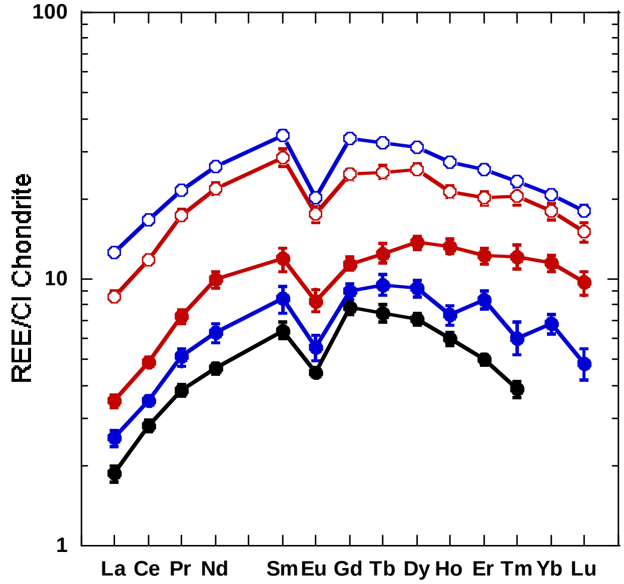

Figure 1. Representative REE abundances in clinopyroxenes of NWA 4590 (blue) and NWA 4801 (red). Closed symbols represent core compositions and open symbols represent rim compositions. For comparison, representative REE abundances in clinopyroxene cores of the plutonic angrite LEW 86010 [6] are also shown (black).

The anorthite in both NWA 4590 and NWA 4801 have LREE-enriched patterns with characteristic large positive Eu anomalies (Eu/Eu^*~40 for NWA 4590 and ~38 for NWA 4801); most HREE were present at such low concentrations that their abundances could not be reliably determined in this mineral. The olivine in NWA 4590 contained abundant kirschteinite exsolution lamellae. With the spatial resolution of the ion microprobe, it was not possible to analyze olivine and kirschteinite separately. The olivine/kirschteinite grains analyzed in NWA 4590 exhibit a HREE-enriched pattern with relatively high HREE abundances (Lu ~28 × CI). Unlike the olivine in NWA 4590, olivine in NWA 4801 lacks kirschteinite exsolution lamellae. NWA 4801 olivine also exhibited a HREE-enriched pattern, but had lower HREE abundances (La ~10 × CI) than those in NWA 4590.

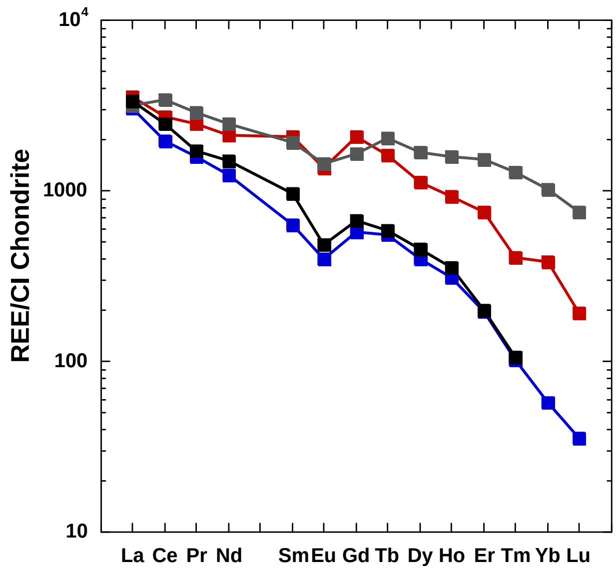

Figure 2. Representative REE abundances in merrillite of NWA 4590 (blue) and NWA 4801 (red). For comparison, REE abundances in the merrillite of LEW 86010 [6] (black squares) and Sahara 99555 (gray squares) [6] are also shown.

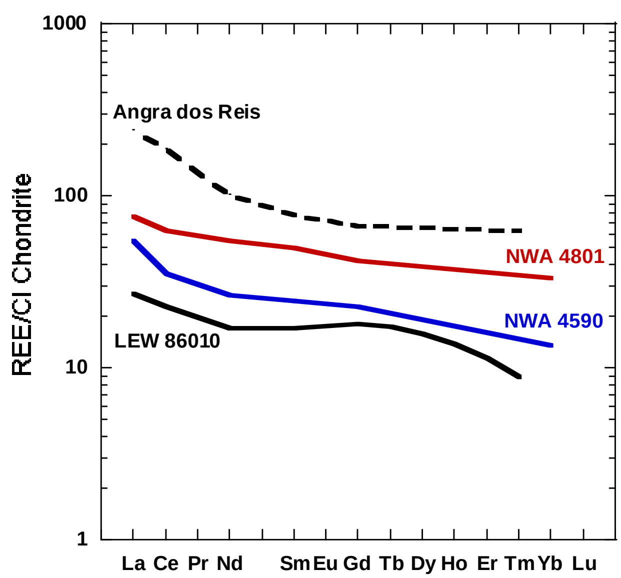

Figure 3. Parent melts calculated to be in equilibrium with the clinopyroxene cores of NWA 4590 (blue) and NWA 4801 (red). Also shown are the melts calculated to be in equilibrium with the clinopyroxene cores of LEW 86010 [6] and Angra dos Reis [7].

Merrillite is the phase that has the highest REE abundances in both NWA 4590 and NWA 4801 (La ~3000-3500 × CI) (Fig. 2). In both meteorites, this mineral has a LREE-enriched pattern with moderate negative Eu anomalies (Eu/Eu*~0.65). However, while merrillite in NWA 4590 has a steep LREE-enriched pattern that closely parallels that of LEW 86010 merrillite, this mineral in NWA 4801 has a less steep LREE-enriched pattern that is similar to merrillite in one of the quenched angrites, Sahara 99555.

We have estimated the parent melt compositions of NWA 4590 and NWA 4801 using REE concentrations in their clinopyroxenes cores and the REE partition coefficient given in [6]. The calculated parent melts for both these meteorites have LREE-enriched patterns (Fig. 3). However, while the NWA 4590 parent melt REE pattern is very similar to that of the other plutonic angrites (particularly LEW 86010), the NWA 4801 parent melt REE pattern has a slightly shallower LREE-enrichment (Fig. 3).

Conclusions: The REE patterns of several mineral phases (e.g., clinopyroxene and merrillite) of NWA 4590 closely parallel those of the plutonic angrite LEW 86010. In addition, the calculated parent melt of NWA 4590 has a REE pattern similar to that of LEW 86010. These results suggest that parent melt composition and the crystallization history of NWA 4590 were almost identical to those for LEW 86010. NWA 4801, however, exhibits some distinct differences from NWA 4590 and the other plutonic angrites. REE patterns of the individual phases (particularly, clinopyroxene and merrillite) differ somewhat from those observed in NWA 4590. Also, the REE pattern of the calculated parent melt of NWA 4801 is less steep than that of NWA 4590. These characteristics suggest that NWA 4801 may have crystallized from a parent melt with geochemical characteristics that were distinct from the parent melts of the other known plutonic angrites.

Acknowledgments: We are grateful to Tony Irving for generously providing us with the sections of NWA 4590 and NWA 4801.

References: [1] Mittlefehldt D. et al. (1998) *Rev. Mineralogy 36*, *Planetary Materials*, Chapter 4, pp. 195. [2] Kuehner S. M. and Irving A. J. (2007) *LPS XXXVIII*, Abstract #1522. [3] Irving A. J. and Kuehner S. M. (2007) *Workshop on Chronology of Meteorites*, Abstract #4050. [4] Amelin Y. and Irving A. J. (2007) *Workshop on Chronology of Meteorites*. Abstract #4061. [5] Zinner E. and Crozaz G. (1986) *International Journal of Mass Spectrometry and Ion Processes*, *69*, 17-38. [6] Floss C. et al. (2003) *GCA*, *58*, 4775-4789. [7] Crozaz G. and McKay G (1990) *EPSL*, *97*, 369-381.