PLUTONIC ANGRITE NWA 4801 AND A MODEL FOR THE ANGRITE PARENT BODY CONSISTENT WITH PETROLOGICAL AND CHRONOLOGICAL CONSTRAINTS.
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Introduction: The discovery of angrite NWA 4801 brings the total number of these enigmatic achondrites to 12, of which 6 have been found in the deserts of northwest Africa since 1999. One of the most remarkable aspects of this group of very ancient achondrites is the great variety among the specimens, ranging from rapidly quenched melts (with or without xenocrysts), ophitic "basaltic" rocks with prominent vesicles, and plutonic igneous rocks with cumulate textures to metamorphically-annealed, formerly brecciated plutonic rocks. This variety by itself tends to imply that the angrite parent body (APB) is or was a planet of sufficient size to undergo internal heating, differentiation, partial melting and metamorphism, and that it has or had a substantial regolith. The very ancient formation ages for angrites (4557-4564 Ga [1]) would then require that core formation, magmatism and regolith-forming collisions all occurred in a very short time (within ~4-11 Ma) after accretion. Given the very refractory bulk compositions of angrites, such a rapid and very high temperature process is not implausible.

Northwest Africa 4801: When found (probably in Algeria) this 252 gram, friable stone had broken into 4 pieces that fit together (Figure 1). This specimen (grainsize 0.1-1.2 mm) has an overall cumulus texture, but with evidence of subsequent annealing (see Figure 2). It is composed mostly of dark brown Al-Ti clinopyroxene ($Fs_{11.8}Wo_{56.9}$, Al_2O_3 = 10.6 wt.%, TiO_2 = 2.4 wt.%, FeO/MnO = 133) and pure anorthite (some as polycrystalline aggregates), with sporadic Cr-pleonaste grains (Cr_2O_3 = 6.3 wt.%), calcic olivine ($Fa_{45.5}Ln_{2.4}$, FeO/MnO = 88), pleonaste, poikilitic merrillite and minor troilite and altered metal. Some clinopyroxene and olivine are poikilitically enclosed in the pleonaste mantles around large Cr-pleonaste grains (Figure 3). Kirschsteinite is absent, and merrillite is more abundant than in most other known angrites.

Figure 1. Largest piece of NWA 4801 showing granular texture and anorthite aggregates (white).

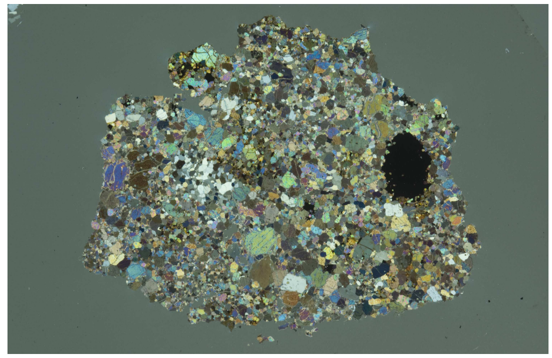

Figure 2. Partially cross-polarized light image (width 1.5 cm) showing clinopyroxene and olivine (colors), anorthite (white to gray) and spinels (black).

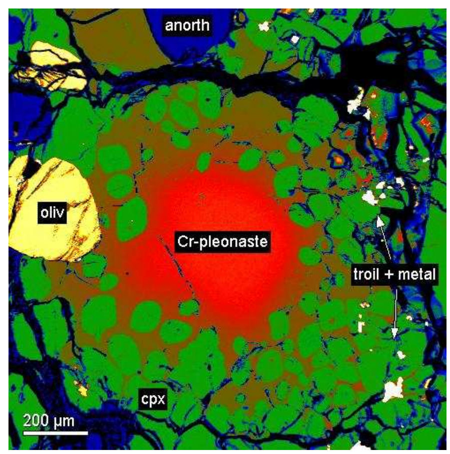

Figure 3. False-color, BSE image of an early-formed Cr-pleonaste grain (red) mantled by Cr-poor pleonaste containing Al-Ti diopside and olivine chadacrysts.

Metasomatism in Northwest Africa 2999: In comparison with other angrites, NWA 2999 is anomalous in several ways. It is an annealed breccia formed originally by disruption of a very coarse grained plutonic, igneous (olivine gabbroic) protolith, and it contains reaction textures [3] like those in exhumed terrestrial plutonic rocks. Although the symplectite and corona textures appear to represent high temperature solid-solid reactions, further modeling since our original description [3] implies that the reactions are not isochemical, and may require the presence of metasomatic fluids or melts to add and remove Cr and Ti. The unexpectedly high sulfur contents of angrites (given their strong depletion in moderately volatile elements) suggest that an S-bearing fluid phase may be involved. NWA 2999 also is anomalous in its high content of metal (~8 vol.%), which may not be exotic to the APB [4]. This invites an analogy with mesosiderites and their presumed affinity with HED meteorites.

Age Systematics and Model: Based upon recent U-Pb and Hf-W isotopic studies [1, 5], the oldest angrites are the ophitic, vesicular specimens, with the quenched, xenocrystic specimens being up to 2 Ma younger. This permits the inference that the former may represent portions of early crust on the APB and the latter disrupted magma ocean samples ejected by penetrating impacts. Although it has been suggested that the vesicle-forming gas might be CO_2 or even rock vapor [6, 3], we propose that SO_2 or another S-rich phase may be more likely. The 4561.8 Ga age of NWA 2999 [5] is very significant in establishing that regolith formation, mixing with interior metal, burial, annealing and metasomatism all occurred in the evolving APB crust at a very early stage. The younger ages of NWA 4801, NWA 4590, LEW 86010 and Angra dos Reis [5] show that plutonic igneous intrusion, impact disruption and metamorphism continued to occur within the APB crust over at least the next 1.5-2 Ma.

We have illustrated a possible model in Figure 4. We propose that the ultimate source of the angrites was a fairly large differentiated planet that probably accreted relatively close to the Sun [2, 3], but whether this is related to present Mercury is difficult to prove. The evidence for a molten core on Mercury and the implication of its high S content [7] may argue for relatively high chalcophile element abundances in Hermean mantle and crustal rocks. If the angrite meteorites represent material ejected from such a planet by a lithosphere-stripping giant impact, then it must have resided for at least 4 Ga somewhere else to be resampled episodically and repeatedly over the last 55 Ma (based on available CRE ages [8]). The immediate source could be one or more relatively large spalled objects now within the main asteroid belt, or perhaps even objects in orbit around another planetary body (e.g., 'Vulcanoids' around Mercury?). The conspicuous lack of shock effects in angrites may not be inconsistent with this model, if the original spallation was on a sufficient scale and at sufficiently high temperatures.

References: [1] Amelin Y. (2007) *LPS XXVIII*, #1669; Zartman R. (2006) *LPS XXVII*, #1580; Markowski A. et al. (2007) *EPSL*, in press. [2] Irving A. et al. (2006) *EOS 87*, #P51E-1245; Kuehner S. and Irving A. (2007) *LPS XXVIII*, #1522 [3] Irving A. et al. (2005) *EOS 86*, #P51A-0898; Kuehner S. et al. (2006) *LPS XXVII*, #1344 [4] Gellissen M. et al. (2007) *LPS XXVIII*, #1612; Humayun M. et al. (2007) *LPS XXVIII*, #1221 [5] Amelin Y. and Irving A.. (2007) This conference [6] McCoy T. et al. (1999) *LPS XXXIII*, #1402 [7] Margot J. et al. (2007) *Science* **316**, 710-714 [8] Eugster O. (2003) *Chemie Erde* **63**, 3-30; Busemann H. et al. (2006) *GCA* **70**, 5403-5425.

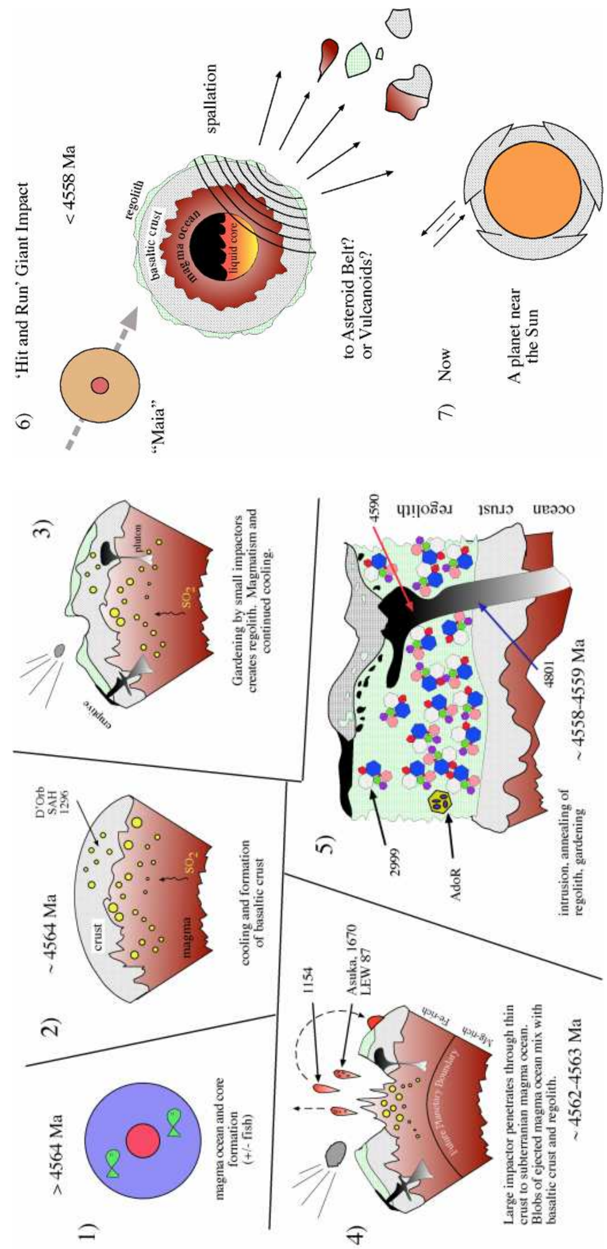

Figure 4. Schematic model for the evolution of the angrite parent body.