ULTRASODIC, ALBITE-RICH SYENITIC ACHONDRITE ERG ATOUILA 001: A HIGHLY EVOLVED FELSIC IGNEOUS DIFFERENTIATE FROM THE ACAPULCOITE-LODRANITE PARENT BODY

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Background: During 2021 we received small samples from two different Moroccan dealers of the same unusual pale achondrite and undertook electron microprobe and oxygen isotope investigations of them. Unbeknownst to us, a larger specimen of the same material (found in Mali) was sent to colleagues at the University of New Mexico and it has been formally classified as Erg Atouila 001 [1]. This achondrite is so unusual that we felt that we should present our independent findings in a public forum in order to add to the available information about this specimen for the benefit of future assessment of its origin, which we also discuss herein.

Mineralogy: Both of the samples examined by us are certainly much less representative of this material than that analyzed by [1], but the silicate compositions we found are essentially the same as those reported in [1]. Our samples are also dominated by albitic plagioclase ($Ab_{89.3-92.5}An_{5.3-2.6}Or_{5.4-3.9}$, N = 8), which is accompanied by minor diopside ($Fs_{8.9-12.7}Wo_{45.7-43.1}$, FeO/MnO 9-14, N = 9) and accessory relatively ferroan olivine ($Fa_{29.8-29.9}$, FeO.MnO = 19-20, N = 2), merrillite, stanfieldite, ilmenite, troilite, possible Fe metal, and minor secondary barite and strontianite. The texture is ambiguous, and could be either plutonic igneous or metamorphic (see Figures 1 and 2). If igneous, this material could be best termed a sodic felsic syenite. The dominance of albitic plagioclase could mean that this rock has a bulk Na_2O content exceeding 10 wt.%, making it the most sodic achondrite known.

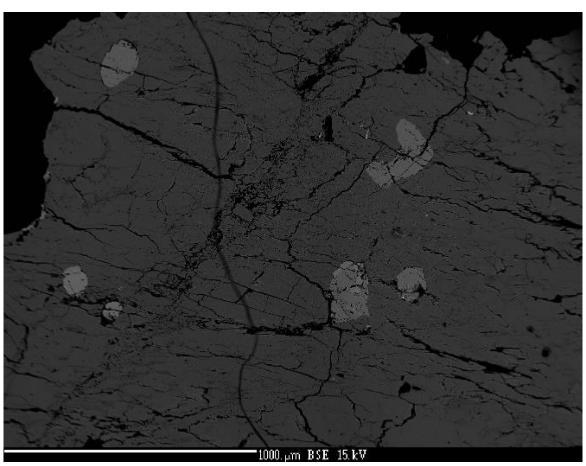

Figure 1. *BSE image showing dominant albite with enclosed smaller grains of diopside.*

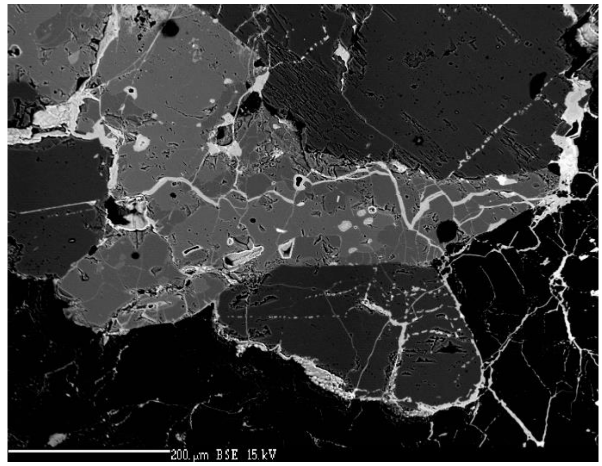

Figure 2. *BSE image showing albite (darkest gray), diopside (medium gray) and merrillite (light gray, containing darker gray inclusions of stanfieldite). Brighter grains are ilmenite and troilite.*

Oxygen Isotopes: Four acid-washed subsamples from one of our small specimens were analyzed by laser fluorination in the same laboratory as the three subsamples analyzed by [1]. Our results are, respectively, $\delta^{17}O$ 1.661, 1.096, 1.394, 1.064; $\delta^{18}O$ 5.126, 4.068, 4.663, 4.030; $\Delta^{17}O$ -1.046, -1.051, -1.068, -1.063 per mil (all data linearized). All seven determinations are very consistent, and plot in a tight linear array right on the mean regression through the broad field for acapulcoites-lodranites and related meteorites (see Figure 3).

Discussion: We agree with [1] that the overlap in oxygen isotopes for Erg Atouila 001 and the acapulcoite-lodranite clan does not necessarily signify any genetic affinity, and despite the very close match it could well be fortuitous. Plagioclase is a minor phase in acapulcoites, yet it ranges to compositions almost as sodic as those in Erg Atouila 001, for example Ab_{82} in NWA 090 and $Ab_{87.7}$ in NWA 6557. However, acapulcoites-lodranites contain olivine (Fa_{3-15}) which is considerably more magnesian than in Erg Atouila 001, plus significant amounts of orthopyroxene, accessory chromite and highly variable amounts of kamacite. Many examples do however contain accessory phosphates [5, 6], including Cl-F-apatite (reported in Erg Atouila 001 by [1]), merrillite and Na-rich chladniite (which might be expected to be present in Erg Atouila 001).

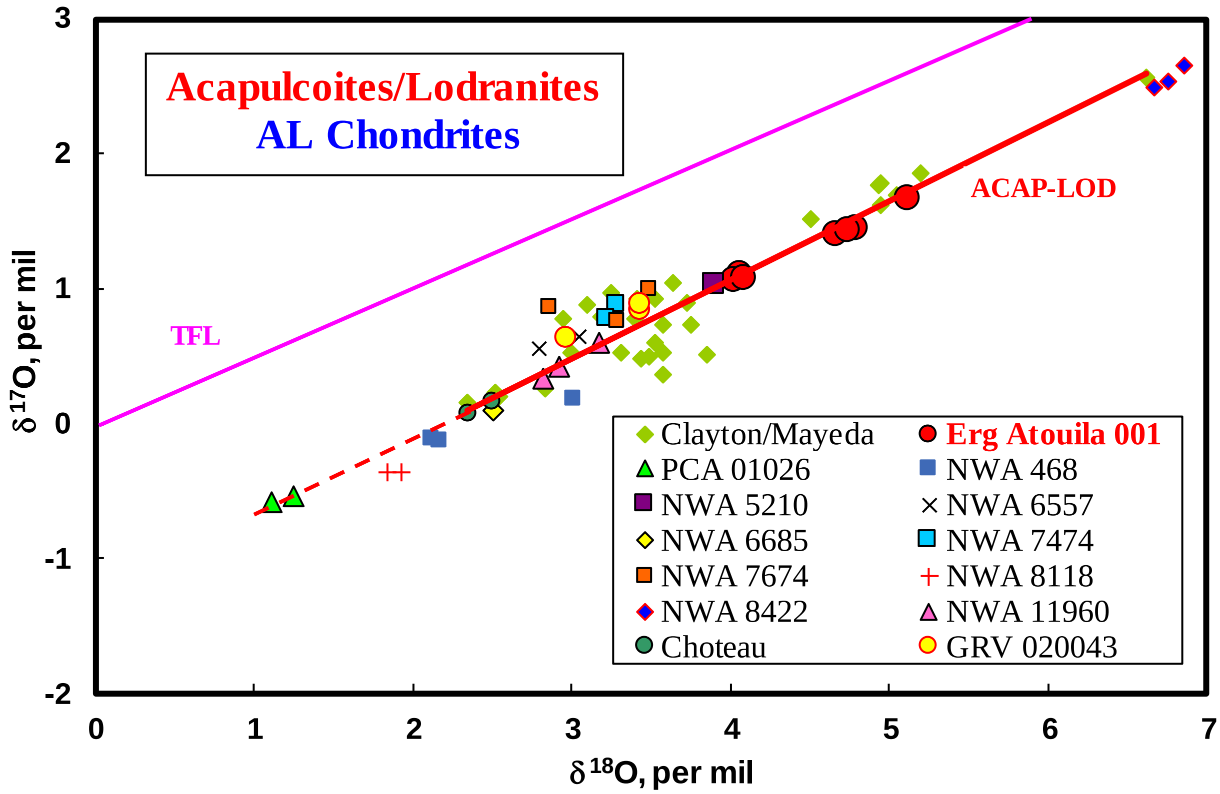

***Figure 3**. Oxygen isotopic compositions for Erg Atouila 001, acapulcoites-lodranites, related achondrites and AL chondrites (e.g., GRV 020043). Data are from this work, [1], [2], [3], our own unpublished analyses and a literature compilation. The solid red line is a least-squares regression through the Clayton/Mayeda data points. We have included results for Choteau (which was classified as an anomalous pallasite, but which we believe to be instead a metal-rich lodranite) and for metal-rich achondrite NWA 468 (see [4]).*

Acapulcoites and lodranites (which represent more or less a continuum in grainsize among otherwise mineralogically similar assemblages [7]) are usually regarded as metamorphic rocks derived from chondritic precursor protoliths. A key observation is the existence of several examples of mineralogically almost identical assemblages which contain obvious chondrules (notably Monument Draw, Yamato 74063 and Grove Mountains 020043 [3]). We have suggested that such rocks should be termed **AL chondrites** of petrologic types 4, 5 and 6.

If Erg Atouila 001 is a metamorphic achondrite related to acapulcoites-lodranites, then it is difficult to understand how this specimen became so plagioclase-rich and so sodic. Alternatively, this specmen could represent a highly evolved felsic *igneous* differentiate produced initially by partial melting within the acapulcoite-lodranite parent body from deep-seated metachondrite source rocks (leaving original metal, chromite plus most olivine and low-Ca pyroxene in the refractory residue). Such a model would in turn require that body to be sufficiently large (and ancient) to retain the heat necessary to generate magmas within its interior, and then to permit fractional crystallization of those magmas to form highly sodic evolved liquids. The much more ferroan accessory olivine in Erg Atouila 001 would not be inconsistent with this fractional melting and fractional crystallization model, and the very ancient ages (4563 ± 1 Ma [8]) of acapulcoites-lodranites are certainly permissive of an active role for ^{26}Al heating to propel such processes.

References: [1] *Meteoritical Bulletin* (2021). [2] Clayton R. and Mayeda T. (1996) *Geochim. Cosmochim. Acta* **60**, 186-203. [3] Li S. *et al.* (2018) *Geochim. Cosmochim. Acta* **242**, 82-101. [4] Sanborn M. *et al.* (2014) *77th Meteorit. Soc. Mtg.*, #5169. [5] Patzer A. *et al.* (2004) *Meteorit. Planet. Sci.* **39**, 61-85. [6] Floss C. (1999) *Amer. Mineral.* **84**, 1354-1359. [7] Bunch T. *et al.* (2011) *74th Meteorit. Soc. Mtg.*, #5225. [8] Touboul M. *et al.* (2009) *Earth Planet. Sci. Lett.* **284**, 168-178.