MINERALOGY AND BULK ELEMENTAL COMPOSITION OF UNGROUPED RELATIVELY SODIC GABBROIC ACHONDRITE ERG CHECH 002: AN ANCIENT PLANETARY CRUSTAL SAMPLE?

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Introduction: Sodium-rich mafic igneous rocks are rare, even on planet Earth. Among meteorites, one of the few examples is Graves Nunataks 06128/06129 (paired stones), which is a unique achondrite with affinities to brachinites [1]. Minor albitic plagioclase also occurs in aubrites and other enstatite achondrites. A very different sort of plutonic igneous achondrite was found in May 2020 as multiple specimens (total weight >32 kilograms) in the barren desert region of far southern Algeria near the mutual borders with Mali and Mauritania. Distinctive features of this unique unbrecciated gabbroic achondrite are large resorbed pyroxene megacrysts, a relatively sodic bulk composition, and oxygen isotopes ($\Delta^{17}O$ = -0.13±0.02 per mil) plotting below the terrestrial fractionation line [2, 3].

Figure 1. *Erg Chech 002 stone containing a very large (4 cm long) prismatic pyroxene megacryst in gabbroic matrix. Image courtesy of Luc Labenne.*

Petrography: Erg Chech 002 contains sporadic large (up to 9 cm by 4 cm) green, yellow-green and less commonly yellow-brown crystals of both orthopyroxene and clinopyroxenes, plus sparse relatively large grains (up to 4 mm) of low-Ti chromite. The pyroxene megacrysts comprise orthopyroxene ($Fs_{14.4-31.1}Wo_{1.2-3.8}$, FeO/MnO = 16-26, Cr_2O_3 = 0.3-1.0 wt.%), pigeonite ($Fs_{21.3-40.7}Wo_{7.0-5.0}$, FeO/MnO = 17-20, Cr_2O_3 = 0.3-0.8 wt.%) and augite ($Fs_{14.7-24.7}Wo_{38.5-38.1}$, FeO/MnO = 15-18, Cr_2O_3 = 1.1 wt.%). They exhibit embayed shapes and reaction rims against the dominant coarse-grained gabbroic groundmass (see Figures 1, 2).

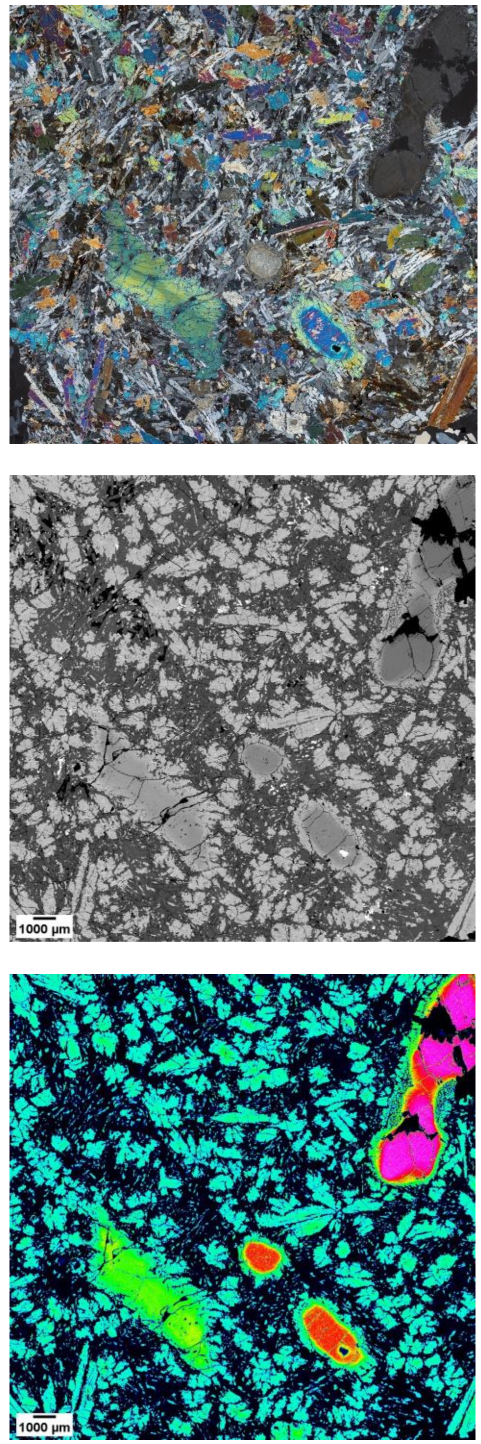

Figure 2 (right). *Correlated XPL image (**top**), BSE image (**middle**) and Mg X-ray map (**bottom**)*

The groundmass (mean grainsize ~1.5 mm) is composed of clustered prismatic grains of exsolved pigeonite (host $Fs_{42.3\text{-}52.2}Wo_{2.9\text{-}4.6}$, exsolution lamellae $Fs_{18.1\text{-}25.9}Wo_{40.8\text{-}38.1}$, FeO/MnO = 18-23) and laths of zoned oligoclase-albite ($Ab_{68.8\text{-}85.9}An_{26.7\text{-}7.1}Or_{7.0\text{-}4.4}$), plus accessory Ti-chromite, ilmenite, cristobalite, merrillite, K-feldspar ($Or_{84.1}Ab_{11.3}An_{4.6}$), troilite, rare Ni-poor iron metal, and rare tiny (1-2 µm) grains of Zr-rich phase(s).

Bulk Major and Trace Elements: Whole rock elemental abundances were determined on a representative whole rock powder by ICP-OES and QQQ-ICPMS. Results (in wt.%): SiO_2 58.43, TiO_2 0.40, Al_2O_3 8.89, Cr_2O_3 0.57, FeO 10.96, MnO 0.46, MgO 8.23, CaO 7.74, Na_2O 3.62, K_2O 0.60, P_2O_5 0.11; *Mg/(Mg+Fe)* = 0.572, FeO/MnO = 24); (in ppm) Sc 21.9, Ni 4.3, Rb 9.0, Sr 78, Ba 45, Zr 20.2, Hf 0.56, Th 0.17. The chondrite-normalized REE pattern (Figure 3) is relatively flat at ~4 times chondrites with a small negative Eu anomaly, and is subparallel to patterns for most Main Group eucrites (including Juvinas and Millbillillie), but at lower abundances than for all such specimens.

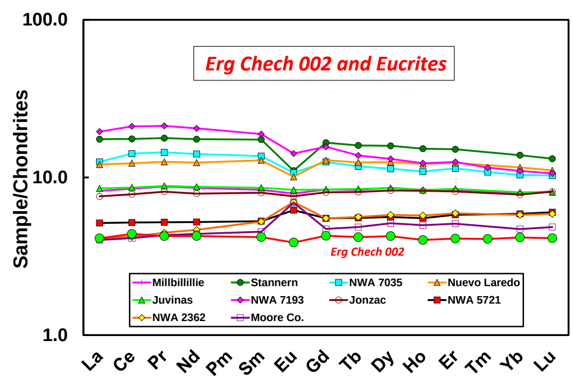

Figure 3. *Chondrite-normalized whole rock REE abundances for Erg Chech 002 compared with those for some Main Group (Na-poor) eucrites. Data for specimens other than Erg Chech 002 are from a literature compilation and our unpublished analyses.*

Nomenclature: If, despite the presence of reacted megacrysts, Erg Chech 002 were regarded as a congealed liquid composition, then according to terrestrial TAS (total alkali *vs*. silica) terminology it would plot in the andesite field (close to the basaltic andesite field). However, given its relatively coarse grainsize, it could be instead called a diorite or a gabbro.

We do not favor referring to this extra-terrestrial rock as either andesitic or dioritic, because of the inevitable connotation that its petrogenesis could involve subduction processes and a role for hydrous fluids, which may not operate anywhere else but on Earth. Furthermore, although there certainly are terrestrial igneous rocks which are much more sodic, among achondrites Erg Chech 002 is a unique specimen and one of the most sodium-rich.

Discussion and Conclusions: The non-terrestrial nature of this material can be established from several lines of evidence: 1) the presence in the gabbroic groundmass of rare grains of Fe-Ni metal, 2) whole rock FeO/MnO ratios of ~24 (much lower than for terrestrial rocks or even typical eucrites), and 3) oxygen isotopic compositions ($\Delta^{17}O$) which plot significantly below the established trend for terrestrial rocks (but at higher values than the field for typical Main Group eucrites).

The pyroxene and chromite megacrysts may represent an earlier-formed cumulus assemblage from a magma related to the melt from which the gabbroic groundmass crystallized. However, the resorption features, reaction rims and slightly different oxygen isotopic composition [3] of the large pyroxene grains demonstrate that they were not in equilibrium with the melt from which the groundmass crystallized (that is, the larger pyroxene and chromite grains are perhaps pseudo-cognate xenocrysts).

Although all of the oxygen isotopic compositions are close to values for four anomalous eucrites (Bunburra Rockhole, Emmaville, Asuka 881394 and EET 92023 [4, 5]), Erg Chech 002 differs significantly from those rocks in having highly sodic rather than highly calcic plagioclase. Yet we suspect (by analogy with the ~4.55 Ga eucrites) that this sodic achondrite may also have a very ancient formation age, and may be derived ultimately from a previously unsampled differentiated, planet-like parent body, possibly one that suffered collisional destruction and dispersion of its crustal rocks early in solar system history. The specimens now under study may have been ejected more recently from remnants of that catastrophic event, which had been fortuitously captured into orbit within the main asteroid belt between Mars and Jupiter.

References: [1] Day J. *et al.* (2012) *Geochim. Cosmochim. Acta* **81**, 94-128 [2] Irving A. *et al.* (2020) *Fall AGU Mtg.*, #DI019-0004 [3] *Meteorit. Bull.* (2020) [4] Benedix G. *et al.* (2017) *Geochim. Cosmochim. Acta* **208**, 145-159 [5] Barrett T. *et al.* (2017) *Meteorit. Planet. Sci.* **52**, 656-668.

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