

### A NEW PERSPECTIVE ON THE EVOLUTION OF MARS

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**Introduction:** Bouvier et al. [1, 2] interpreted the 4.1 Ga Pb-Pb ages of the enriched and intermediate shergottites (e.g., Zagami, EETA 79001) as a crystallization age. This age is remarkably close to the 4.0 Ga Pb-Pb age of ALHA 84001 carbonates [3]. The range of <sup>87</sup>Sr/<sup>86</sup>Sr in shergottites, as best illustrated by their whole-rock isochron [2], further calls for a >4 Ga age [4]. Such old ages are in agreement with surface ages estimated by crater densities [5]. In contrast, the young internal isochron ages at 150-550 Ma obtained on shergottites by phosphate-based chronometers date recent resetting associated with shock and aqueous alteration. We have expanded our earlier Pb-Pb isotope work to include new shergottites, and since contamination has been suggested to be a potential issue [6], we also ran Pb isotopes on the non-controversial 1.3 Ga old nakhlites and Chassigny.

**Samples and procedures:** We measured the Pb isotopic compositions of the basaltic NWA 480, lherzolitic RBT 04262, olivine-phyric NWA 1068, and olivine-orthopyroxene shergottite NWA 1195, plus the nakhlites Y-000593 and MIL 03346, as well as Chassigny. Mineral separates were acid-washed using 4M HF and 2.5M HCl, with a preliminary step using 1.5M HBr for whole-rocks to remove carbonates, phosphates, and terrestrial contamination, which is crucial for finds. Sample preparation, Pb separation, and mass spectrometry by MC-ICP-MS were carried out at ENS Lyon as described in [2].

**Results:** The new Pb isotope data on the shergottites NWA 480, NWA 1068, and RBT 04262 fall on the 4.1 Ga enriched and intermediate shergottite isochron [2], while NWA 1195 falls on the  $4.33 \pm 0.02$  Ga internal Pb-Pb isochron of the depleted basaltic shergottite QUE 94201 [6]. In contrast, the Pb-Pb isotope data for the nakhlites Y-000593 and MIL 03346, and for Chassigny, are concordant with the ~1.3 Ga Pb-Pb internal isochron obtained on Nakhla [2] demonstrating the lack of significant contamination and confirming that these samples can be dated successfully by Pb-Pb chronometry despite their low Pb concentrations.

**Discussion:** The new data confirm the very tight range of formation ages at 4.1 Ga for enriched and intermediate shergottites and at 4.3 Ga for depleted shergottites. Shergottite magmatic activity therefore predates the late heavy bombardment (LHB). The Martian mantle remained hot enough to sustain strong volcanic activity, but only for the first 500 Ma of the planet's history. The 4.0 Ga old carbonates of ALH 84001 [3] represent hydrothermal activity associated with the last gasps of shergottitic magmatism. Just as for the 3.9 Ga rocks of Isua, such a short history was too short to allow mantle convection to erase the <sup>142</sup>Nd heterogeneities of the mantle. The rogue 1.3 Ga event associated with nakhlites and chassignites may represent the infilling by late eruptions of the major volcanoes of Tharsis or Syrtys Major of the wide craters left by the LHB. The present interpretation relieves the need for elusive widespread modern volcanic activity and re-establishes Mars as an actively convecting planet.

[1] Bouvier A. et al. 2005. EPSL, 240, 221. [2] Bouvier A. et al. 2008. EPSL, 266, 105. [3] Borg L.E. et al. 1999. Science. 286 90. [4] Jagoutz E. 1991. SSR 56, 13. [5] Werner S.C. 2008. Icarus, 195, 45. [6] Gaffney A.M. et al. 2007. GCA, 71, 5016.