Sm-Nd and Lu-Hf Isotopic Systematics of Shock-melted Intermediate Olivine Gabbroic Shergottite Northwest Africa 11509

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Northwest Africa 11509

- A fresh 500 g stone found in Mali (Irving et al., 2018)
- Relatively coarse grained olivine gabbroic shergottite
- Shock-melted intercumulus zone
- It consists of relatively equant grains of clinopyroxene and olivi with vesicular plagioclase-rich interstitial regions.

Figure 1 : Photo of NWA 11509. *Photo courtesy A. Habibi.*

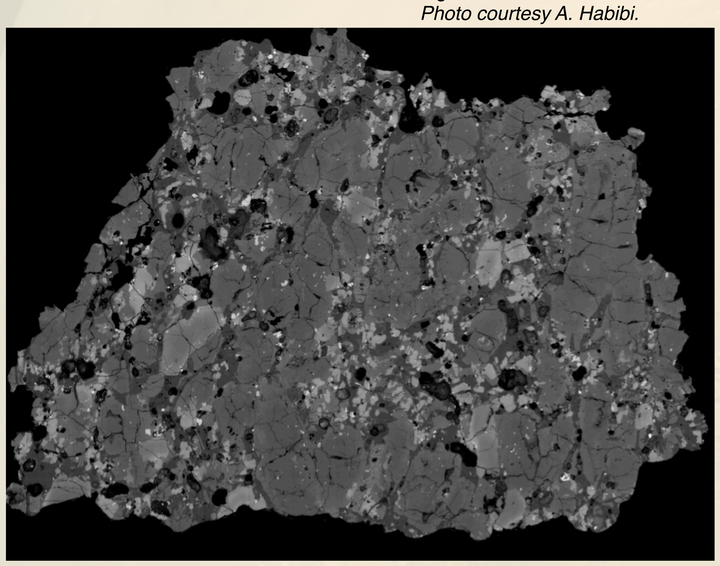

Figure 2 : Back scattered electron images of NWA 11509.

- Mineral mode 50.5 vol. % clinopyroxne
  17.1 vol. % olivine
  11.1 vol. % vesicles
  1.0 vol. % oxides (chromite+ilmenite)
  0.2 vol. % pyrrhotite
- Clinopyroxene: pigeonite and subcalcic augite ($Fs_{26.3-36.1}Wo_{6.4-21.7}$) ($Fs_{19.8-27.2}Wo_{33.3-32.9}$)
- Olivine ($Fa_{37.9-57.0}$)
- Cosmic exposure ages: 2.7 Myr (^{3}He), 3.0 Myr (^{21}Ne) similar to those for many other intermediate and some enriched shergottites

Bulk REE Composition

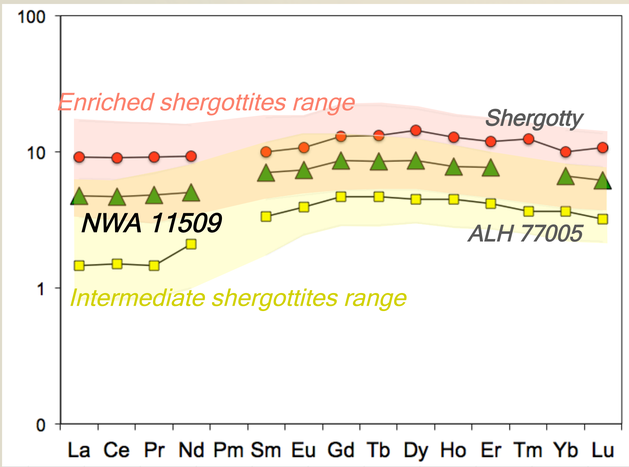

Figure 3 : Bulk REE pattern of NWA 11509 with other shergottites.

The REE pattern shows moderate light REE depletion, elevated heavy REE abundances and a negative Eu anomaly.

- Intermediate shergottite (?)

Whole rock Sm-Nd Lu-Hf

- The Sm-Nd analyses of NWA 11509 whole rock
  a present-day $\varepsilon^{143}Nd = 6.67$
  measured $^{147}Sm/^{144}Nd = 0.2651$
- The Lu-Hf
  a present-dayday $\varepsilon^{176}Hf = 3.60$
  measured $^{176}Lu/^{177}Hf = 0.01742$

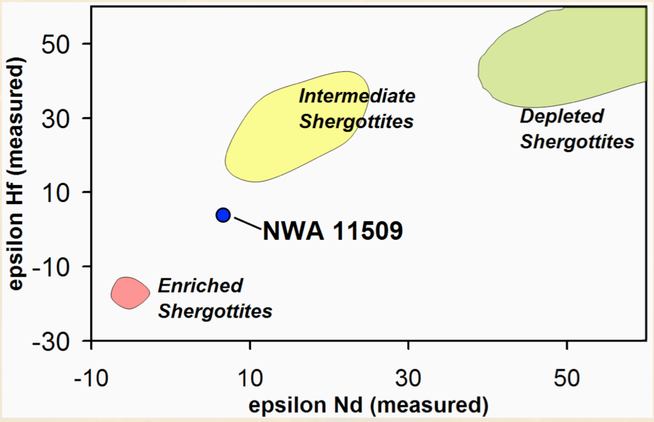

Figure 4 : Radiogenic isotopic compositions of shergottites (data from Irving et al (2015, 2016 and 2017) and our unpublished data.

- The Nd and Hf isotopic ratios for NWA 11509 falls between the established fields for intermediate and enriched shergottites.

Lu-Hf isochron age

- Another whole rock analyses using interior piece (WR-chunk) a present-dayday $\varepsilon^{176}Hf = 5.77$
  measured $^{176}Lu/^{177}Hf = 0.01669$

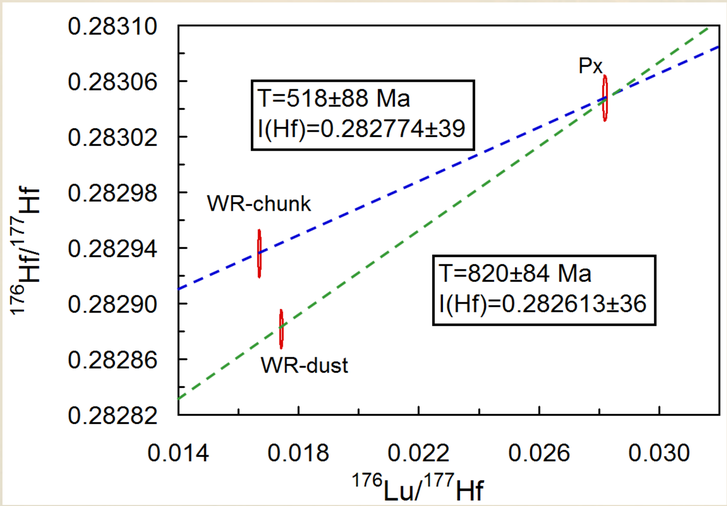

Figure 5: Lu-Hf systematics for NWA 11509. Error bars are 2σ. 'WR-chunk' = interior fragment, 'WR-dust' = IsoMet cutting dust and 'Px' = hand-picked pyroxene.

- Discrepancy in age of NWA 11509
  - **820 ± 84 Ma (WR-dust and Px)**
  - **518 ± 88 Ma (WR-chunk and Px)**

- *Apparent age range - older than any other ages of intermediate (166-345Ma) and enriched (150-207Ma)*

- Despite this discrepancy of 2.17 in epsilon Hf values, both WR-chunk' and 'WR-dust' results are still significantly different from values for other intermediate and enriched shergottites.

Source composition

- The modeled source $^{176}Lu/^{177}Hf$ and $^{147}Sm/^{144}Nd$ isotope ratios are calculated using two stage model assuming a differentiation age of 4.513 (Borg et al., 2003) and the CHUR parameters of Bouvier et al. (2008).
  - source $^{176}Lu/^{177}Hf = 0.0495$
  - source $^{147}Sm/^{144}Nd = 0.2504$
- The source compositions are plotted on a three component mixing array (Figure 6).
  820 Ma : $^{176}Lu/^{177}Hf = 0.03797$
  $^{147}Sm/^{144}Nd = 0.1957$
  518 Ma : $^{176}Lu/^{177}Hf = 0.03727$
  $^{147}Sm/^{144}Nd = 0.2008$
- It is delivered from source mixtures that are more similar to those that produced the intermediate shergottites than the enriched shergottites.

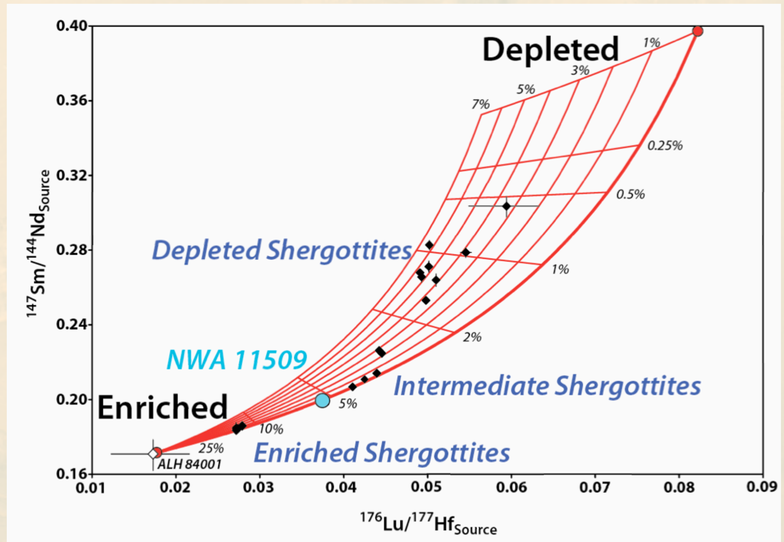

Figure 6: Source mixing array for shergottite Lu-Hf and Sm-Nd source compositions calculated using equations and mantle source compositions of Debaille et al. (2008). NWA 11509 (light blue), all other shergottites (black diamond) and ALH 84001 (ALH; open). Isotope data used for the source calculations of shergottites are from Lapen et al. (2017) and references therein.

Summary

- NWA 11509 is a unique permafic non-poikilitic olivine gabbroic shergottite.
  No maskelynite
  Old 'apparent' age of ~518-820 Ma
- The Lu-Hf and Sm-Nd soure composition falls in between in termediate and enriched shergottites.
- NWA 11509 is derived from source mixtures that are some what similar to those that produced the other known interm-ediate shergottites, but further extends the observed range in intermediate source compositions for both Lu/Hf and Sm/Nd isotopic systems.

References: [1] Irving A.J. et al. (2018) *LPS* XLIX, #2279. [2] http://www.imca.cc/mars/martian-meteorites-list.htm [3] Meyer C. (2012) The Martian Meteorite Com-pendium. https://curator.jsc.nasa.gov/antmet/mmc/ [4] Lud-wig K.R. (2003) *Berkeley Geochronology Center Spec. Pub.* 1a, 59. [5] Irving A. et al. (2015) *LPS* XLVI, #2290 [6] Ir-ving A. et al. (2016) *LPS* XLVII, #2330. [7] Irving A. et. al. (2017) *LPS* XLVIII, #2068. [8] Borg L.E. et al. (1998) *Me-teoritics & Planet. Sci., 33,* A20. [9] Borg L.E. et al. (2002) *GCA* 66, 2037–2053. [10] Nyquist L.E. et al. (2009) *GCA* 73, 4288–4309. [11] Borg L.E. et al. (2008) *LPS* XXXIX, #1851. [12] Shih C-Y. et al. (2009) *LPS* XL, #1360. [13] Borg L.E. et al. (2003) *GCA* 67, 3519–3536. [14] Bouvier A. et al. (2008) *Earth Planet. Sci. Lett.* 280, 285–295. [15] Debaille et al. (2008) *Earth Planet. Sci. Lett.* 269, 186–199. [16] Lapen T.J. et al. (2017) *Science Advances* 3, e160092