Sm-Nd Age and Nd- and Sr- Isotopic Evidence for the Petrogenesis of Dhofar 378. L. E. Nyquist¹, Y. Ikeda², C.-Y. Shih³, Y. D. Reese⁴, N. Nakamura⁵, and H. Takeda⁶, ¹Mail Code KR, NASA Johnson Space Center, Houston, TX 77058-3696, USA, laurence.e.nyquist@nasa.gov, ²Dept. of Material and Biological Sci., Ibaraki University, Mito 310-8512, Japan, y-ikeda@mx.ibaraki.ac.jp, ³Mail Code JE-23, ESGC/Jacobs Sverdrup, P.O. Box 58477, Houston, TX 77258-8477, USA, ⁴Mail Code JE-23, ESGC/Muniz Engineering, Houston, TX 77058, USA, ⁵Dept. of Earth and Planet. Sci., Kobe University, Nada, Kobe 657-8501, Japan, ⁶Research Institute, Chiba Institute of Technology, Narashino 257-0016, Japan.

Introduction:

Dhofar 378 (hereafter Dho 378) is one of the most ferroan lithologies among martian meteorites, resembling the Los Angeles basaltic shergottite in lithology and mineral chemistry, although it is more highly shocked than Los Angeles [1,2]. All plagioclase (Pl) grains in the original lithology were melted by an intense shock in the range 55-75 GPa. Clinopyroxenes (Cpx) sometimes show mosaic extinction under a microscope showing that they, too, experienced intense shock. Nevertheless, they zone from magnesian cores to ferroan rims, reflecting the original lithology. Cpx grains also often contain exsolution lamellae, showing that the original lithology cooled slowly enough for the lamellae to form. Because all plagioclase grains were melted by the intense shock and subsequently quenched, the main plagioclase component is glass (Pl-glass) rather than maskelynite. Like Los Angeles, but unlike most basaltic shergottites, Dho 378 contains approximately equal modal abundances of Cpx and Pl-glass. The grain sizes of the original minerals were comparatively large (~1 mm). The original plagioclase zoning has been severely modified. Following shock melting, the plagioclase melts crystallized from the outside inward, first forming outer rims of Cpx-Pl intergrowths (~10 μm) followed by inner rims (10’s to 100 μm) of AAn₄₀-₅₀ feldspar, and finally Pl-glass cores of compositions AAn₃₃-₅₀ with orthoclase compositions up to Or₁₂ [2].

Sample Preparation:

At JSC two bulk aliquants weighing 26 and 31 mg, resp., were taken from the 340 mg remainder of 550 mg of finely ground material used for major element analyses [2]. The smaller aliquant was analysed directly, the larger was sonicated for 10 min. in 2 N HCl prior to analysis. Mineral separates were prepared from a second ~70 mg piece of this sample. A PTS was made from an ~70 mg piece of this sample. The remainder was powdered and sieved to obtain fractions of grain size <74 μm and 74-149 μm, respectively. A 17 mg Pl-glass sample was obtained from the <74 μm fraction by repeated separations with liquids of density 3.32 and 2.85 g/cm³. A sample of Pl-glass from the 74-149 μm fraction was used for the Ar-Ar study [3]. Pyroxene samples, Px1 and Px2, resp., were obtained as more magnetic and less magnetic subsamples of density >3.45 g/cm³. Sm-Nd Age:

Measured Sm and Nd concentrations in the whole rock powder were 1.12 and 2.83 ppm, respectively, in good agreement with 1.13 and 2.7 ppm previously reported for another 97 mg bulk sample [4]. ¹⁴⁷Sm/¹⁴⁴Nd = 0.239 is similar to 0.234 for Zagami ([5] and unpublished JSC data), and 0.232 for a bulk sample of Los Angeles Stone 1 (LA1, unpub. JSC data). The Sm and Nd abundances in our sample of LA1 were 4.5 and 11.8 ppm, significantly higher than those in Dho 378. Our analysis of LA1 may have been unrepresentative, however. Rubin et al. [6] report Sm = 1.94 ppm in LA1, but Sm = 3.4 ppm in LA2. Zagami, Dho 378, LA1, and LA2 show an approximately linear correlation of La to P₂O₅; i.e.; La (ppm) ∼ 3 x P₂O₅ (%). P₂O₅ = 0.77 wt% in Dho 378 [2], in good agreement with 0.66 wt% in a 352 mg sample of LA1, but about ½ that of a 207 mg sample of LA2 [6].

![Sm-Nd isochron for Dho 378.](https://ntrs.nasa.gov/search.jsp?R=20060022081 2019-07-11T00:53:55+00:00Z)
whole rock leachate (WR(l)) data lie within error limits of an isochron determined primarily by the pyroxene and whole rock data. The WR(l) data are dominated by Sm and Nd from Dho 378 phosphates. Thus, we interpret the Sm-Nd isochron age of 157±24 Ma for Dho 378 as its crystallization age.

Basaltic Shergottite - Dho 378

Figure 2. Rb-Sr data for Dho 378.

Rb-Sr Data

Rb-Sr data obtained at JSC and in prior analyses at Kobe University are shown in Fig. 2. The data from both laboratories show the pervasive effect of terrestrial weathering and contamination. The effect of contamination was minimized by leaching four samples of high Sr content: two Pl-gl samples analysed at Kobe, and Pl-gl(r) and WR(r) analysed at JSC. The data for these samples, combined with the Sm-Nd age of 157 Ma, yields initial 87Sr/86Sr = 0.720779±14. Combining this initial 87Sr/86Sr value with data for Px1(r) gives an apparent age of ~21 Ma. Possibly this “age” is that of a minor Rb-rich phase produced during shock melting and contained within the Px1 separate. The possibility that the Px1 analysis simply shows less contamination than evident for the other pyroxenes cannot be excluded.

Initial εNd

Negative εNd = -6.5±0.3 at T = 157 Ma ago for Dho 378 is similar to that of other shergottites of its class (Fig. 3). NWA 1068 is classified among the Ol-bearing doleritic type of the Ol-phyric subgroup [1]. Negative 88Sr/86Sr values indicate assimilation of LREE-enriched crustal materials by basaltic shergottite magmas. The occurrence of the same REE and isotopic signatures among different shergottite subgroups shows the REE- and P-rich “crustal” component has no detectable impact on the major element composition of the magma, suggesting contamination by metasomatic fluids. The (T, εNd) data for Dho 378 data match most closely to those of NWA 1068 and Los Angeles.

Discussion

The similarity in lithology and mineralogy of Dho 378 and Los Angeles has already been noted [2]. This study extends the similarity to include Nd- and Sr-isotopic systematics. If the three stones, LA1, LA2, and Dho 378 were indeed co-magmatic, the slightly younger Sm-Nd age of Dho 378 compared to previously determined Sm-Nd ages of 172±8 Ma and 174±12 Ma for LA1 and LA2, respectively, may reflect some resetting during shock melting. Park and Bogard [3] suggest that an Ar-Ar isochron age of 143(+18,-10) Ma for Dho 378 may date Ar outgassing in an impact event predating the ~3 Ma ejection event. If so, the Sm-Nd age may have been partially reset at that time. However, some other volatile species show no evidence of post-magmatic losses. Bulk Na2O = 2.08 wt% [2] is nearly the same as for LA1 (2.22 wt%) and LA2 (2.13 wt%). The more refractory alkali, K, also is lower in Dho 378: K2O = 0.17 wt% in Dho 378 vs 0.24 and 0.31 wt% in LA1 and LA2, resp. The K/Rb ratio has been shown to be a sensitive indicator of in vacuo volatile loss of alkalis. The K/Rb ratio of Dho 378 (~256) is nearly identical to that of LA2 (~245). The possibility that the Ar-Ar age approximates the age of crystallization of very high K phases (alkali feldspar, rhyolitic glass) stochastically enriched in the feldspar sample used for Ar-Ar analysis merits thorough evaluation.

References: