CONCORDANT Rb-Sr AND Sm-Nd AGES FOR NWA 1460: A 340 Ma OLD BASALTIC SHERGOTTITE RELATED TO LHERZOLITIC SHERGOTTITES.

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Introduction: Preliminary Rb-Sr and Sm-Nd ages reported by [1] for the NWA 1460 basaltic shergottite are refined to 336±14 Ma and 345±21 Ma, respectively. These concordant ages are interpreted as dating a lava flow on the Martian surface. The initial Sr and Nd isotopic compositions of NWA 1460 suggest it is an earlier melting product of a Martian mantle source region similar to those of the lherzolitic shergottites and basaltic shergottite EETA79001, lithology B.

We also examine the suggestion that generally "young" ages for other Martian meteorites should be reinterpreted in light of $^{207}Pb/^{206}Pb$ - $^{204}Pb/^{206}Pb$ isotopic systematics [2]. Published U-Pb isotopic data for nakhlites are consistent with ages of ~1.36 Ga. The U-Pb isotopic systematics of some Martian shergottites and lherzolites that have been suggested to be ~4 Ga old [2] are complex. We nevertheless suggest the data are consistent with crystallization ages of ~173 Ma when variations in the composition of *in situ* initial Pb as well as extraneous Pb components are considered.

Rb-Sr Age and Initial $^{87}Sr/^{86}Sr$: Petrologic studies [3] indicate that NWA 1460 is a fresh, unweathered rock. The Rb-Sr age of 312±3 Ma reported earlier [1] was determined on a small sample of "fines". The new isotopic analyses reported here are of an interior sample generously provided by Nelson Oakes. The new Rb-Sr isotopic data are shown in Fig. 1.

An age of 336±14 Ma is determined from analyses of whole rock, plagioclase, pyroxene, and magnetic "opaques". The plagioclase separate was "washed" in 1 N HCl with sonication for 10 minutes, all other samples were washed in 2 N HCl. One bulk sample (WR2) was analysed without washing. A second bulk sample was washed to yield leachate WR2(l) and residue WR2(r). The acid washes of mineral separates were combined for the "Leach" sample. The preliminary Rb-Sr age reported in [1] was based on a single pyroxene analysis possibly affected by terrestrial contamination. Initial $^{87}Sr/^{86}Sr$ = 0.708980±30 obtained here agrees with 0.708979±10 for the earlier sample. Plagioclase, with a modal abundance of ~25 % and Sr concentration of ~193 ppm is the major host of Sr in the rock: Plagioclase alone could account for ~93% of the measured Sr abundance of 52 ppm in WR2. The leachate WR2(l) contained ~25% as much Sr as the residue WR(r), the majority of which could have been terrestrial contamination. WR2(l) also would have contained Sr from meteoritic phosphates.

The initial $^{87}Sr/^{86}Sr$ of NWA 1460 is close to those of lherzolitic shergottites ALHA77005 and LEW88516 and basaltic shergottite EETA79001(B) [5,6]. A two-stage model gives time-averaged $^{87}Rb/^{86}Sr$ ~0.16 for the mantle source of NWA 1460, ~10% lower than for the lherzolites, ~22% lower than for EETA79001, and identical to that estimated for bulk Mars by [7]. An independent estimate of $^{87}Rb/^{86}Sr$ ~0.13 for bulk Mars was made by [8]. Such values may be typical of the Martian mantle.

Sm-Nd Age and Initial $^{143}Nd/^{144}Nd$: The Sm-Nd isotopic data are shown in Figure 2. An isochron fit to nine of the ten data points yields an age T = 345±21 Ma and ε_{Nd} = 10.9±0.6 in good agreement with the Rb-Sr age, and with T = 352±30 Ma, ε_{Nd} = 10.4±0.8 determined for the earlier sample [1]. Although the Plag (r) data fall off the isochron, data for a second

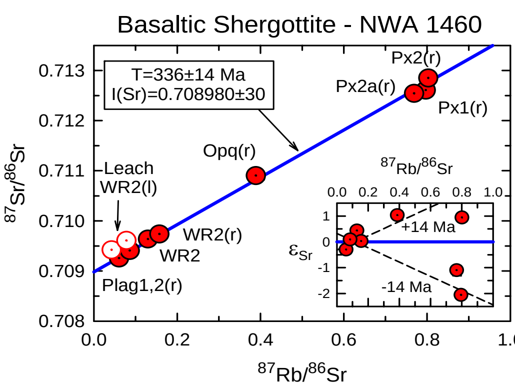

Figure 1. Rb-Sr isochron for NWA 1460. Open symbols are data excluded from the isochron regression.

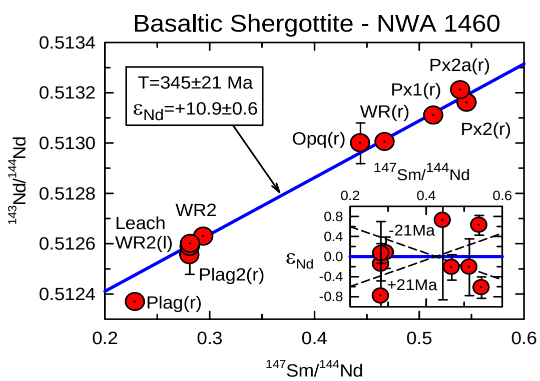

Figure 2. Sm-Nd isochron for NWA 1460. Plag (r) was excluded from the isochron regression.

sample (Plag2 (r)) fall on the isochron, suggesting the presence of contamination in the first sample. The Nd concentration in WR2(l) is ~240 times higher than in Plag2 (r), so phosphates contributing to WR2(l) were much less susceptible to terrestrial contamination than plagioclase. The coincidence of Sm-Nd isotopic data for phosphates and plagioclase shows that the phosphates present in NWA 1460 were produced by *igneous* crystallization (*cf.* [9]).

Discussion: The assertion [2] that "…most mineral ages were reset recently by acidic aqueous solutions…" applied to Martian meteorites is not substantiated by the NWA 1460 Rb-Sr and Sm-Nd data. However, the shergottites present a vexing challenge for chronologists, particularly when considered in the context of U-Pb systematics. The U-Pb systematics of nakhlites are less ambiguous, but also present some problems in their interpretation.

Figure 3 presents nakhlite data from the literature in an inverted Pb-Pb isochron plot [10]. On such a plot, mixtures of two components only will yield a straight line. If one of those components has the isotopic composition of purely radiogenic Pb; i.e., $^{204}Pb/^{206}Pb = 0$, the mixing line yields radiogenic $(^{207}Pb/^{206}Pb)^*$ (R) produced over the interval of decay. Rocks crystallized from a magma also contain initial Pb (I_{Pb}) present in the magma during crystallization. In an ideal case the line (R,I_{Pb}) gives an internal isochron having rigorous time significance. However, Pb isotopically analysed in a laboratory also may contain extraneous components. Pb with compositions similar to modern terrestrial Pb (MT, [11]) appears ubiquitously distributed. The published data for nakhlites lie within the triangle (R, MT, I_{Pb}), where $(^{207}Pb/^{206}Pb)^* = 0.0869$ at R for 1.36 Ga nakhlites. I_{Pb} has the composition in the nakhlite source region, and depends on the time-integrated value of $^{238}U/^{204}Pb$ (μ) in the source region. Figure 3 shows the simplest case for I_{Pb} produced in the Martian mantle between 4.56 Ga ago and 1.36 Ga ago with $\mu = 2$. Several data fall along the expected (R,I_{Pb}) isochron. For example, SIMS data for apatites in Yamato 000593/749 [12], shown averaged in Figure 3, fall within error limits of the isochron. Similar data for Lafayette scatter considerably with some data falling along the isochron, and some data displaced towards MT. Other data show similar behavior over a more limited range of isotopic variation (*cf.* [13, 18]).

The more complex situation arising for shergottites has recently been discussed by [14]. Selected literature data are shown in Figure 4. In this case the (R, MT, I_{Pb}) triangle has a vertex at R = (0, 0.0495) for 173 Ma old shergottites. The most radiogenic data are those for the Mg Px-R data of [14]. Again the averaged SIMS data for phosphates provide a useful reference. The data of [2] show the influence of MT, but other complexities exist as well. Whereas the data for some shergottites (EETA 79001, Shergotty, lherzolite Y793605) lie within an (R, MT, I_{Pb}) triangle for μ ~4-6, and T = 173 Ma, some data for Los Angeles, Zagami, and Y793605 indicate an older component of initial Pb ($^{207}Pb/^{206}Pb$) > I_{Pb} for the 2-stage model) that was not totally homogenized.

References: [1] Nyquist L. E. et al. (2004) *2nd Conf. Early Mars*, #8041. [2] Bouvier A. et al. (2005) *EPSL 240*, 221-233. [3] Irving A. J. and Kuehner S. M.. (2003) *LPS XXXIV*, #1503 [5] Borg L. E. et al. (2002) *GCA 66*, 2037-2053. [6] Nyquist L. E. et al. (2001) *LPS XXXII*, #1503. [7] Borg L. E. et al. (1997) *GCA 61*, 4915-4931. [8] Shih C.-Y. et al. (1999) *MAPS 34*, 647-655. [9] Wadhwa M. et al. (1994) *GCA 58*, 4213-4229. [10] Tera F. and Wasserburg G. J. (1974) *PLSC5*, 1571-1599. [11] Stacey J. S. and Kramers J. D. (1975) *EPSL 26*, 207-221. [12] Terada K. and Sano Y. (2004) *MAPS 39*, 2033-2041. [13] Nakamura N. et al. (1982) *GCA 46*, 1555-1573. [14] Borg L. E. et al. (2005) *GCA 69*, 5819-5830. [15] Sano et al. (2000) *MAPS 35*, 341-346. [16] Chen J. H. and Wasserburg G. J. (1986) *GCA 50*, 955-968. [17] Misawa K. et al. (1997) *AMR 10*, 95-108. [18] Carlson R. W. and Irving A. J. (2004) *LPS XXXV*, #1442.

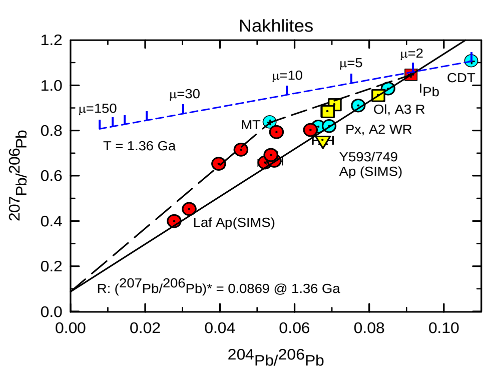

Figure 3. Inverted Pb-Pb isoschron plot for nakhlites. Nakhla: yellow squares [13], blue circles [2]; Lafayette apatites [12], Y593/749 apatites: weighted average of individual analyses [12].

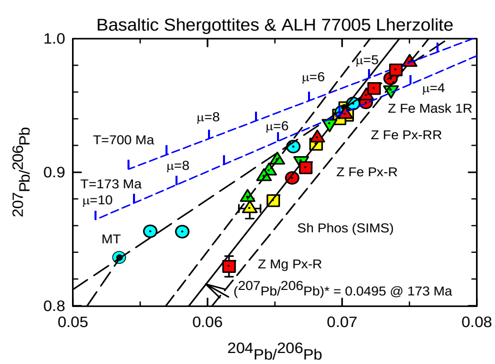

Figure 4. Inverted Pb-Pb isochron plot for shergottites. Zagami: blue circles [2], red squares [14], red circles [16]; Shergotty: yellow squares [15], yellow triangle [15] (weighted average), Los Angeles – red triangles; EET79001 – green triangles [16]; green inverted triangles: Yamato 793605 [17].