Sm-Nd SYSTEMATICS OF NAKHLITE GOVERNADOR VALADARES. C.-Y. Shih[1], L.E. Nyquist[2] and H. Wiesmann[1], [1]Lockheed Martin Engineering and Science Services, Mail Code C23, 2400 NASA Road 1, Houston, TX 77058, [2]Mail Code SN4, NASA Johnson Space Center, Houston, TX 77058.

Sm-Nd systematics of two whole rock and three mineral separate samples from nakhlite Governador Valadares define a ^{147}Sm-^{143}Nd age of 1.36±0.03 Ga. This age is in excellent agreement with the Rb-Sr and ^{39}Ar-^{40}Ar ages obtained previously for this meteorite. The petrographic evidence suggests that this rock is a pyroxene cumulate crystallized in a subsurface sill [1]. Thus, the isotopic age probably represents the age of such a magmatic event. The initial ε^{143}Nd value determined for the rock at 1.36 Ga is +17±1, indicating the parent magma of the rock came from a LREE-depleted source. Our Sm-Nd age and ε^{143}Nd data, and the previously published ε^{142}Nd datum for the rock are consistent with the early formation of its source ~4.56 Ga ago, and late melting of the source and formation of the rock ~1.3 Ga ago. The good agreement of isotopic ages and textures among Governador Valadares, Nakhla and Lafayette strongly suggests that all nakhlites probably have undergone similar two-stage evolution.

Introduction: Nakhlites are unique meteorites, probably from Mars [e.g. 1]. Only three known nakhlites (Nakhla, Governador Valadares and Lafayette) have been identified so far [2,3]. Extensive isotopic age studies were performed on Nakhla [4-7]. Only a few age studies have been done on Governador Valadares and Lafayette [4,8,9]. The objectives of this study were to determine the Sm-Nd age of Governador Valadares and to correlate the isotopic data with that of other nakhlites. Furthermore, the initial ε^{143}Nd and ε^{142}Nd data of the rock can be used to characterize the Sm/Nd of its source and to deduce the genesis of this source material. The study could lead to better understand magmatic processes on Mars if nakhlites are Martian igneous rocks.

Samples: A sample of Governador Valadares, weighing ~1.15 g, was kindly provided by Dr. G. Cavaretta of the Centro Studi Geologia Italia Centrale del CNR, Rome. A chunk of ~0.58 g was gently crushed to grain size <149 μm. The sample was then sieved into three size fractions, 149-74 μm, 74-44 μm, and <44 μm. Two whole rock samples (WR1 and WR2) weighing ~25 mg each were taken from the 149-74 μm size fraction. Four density fractions were separated from the 74-44 μm size fractions by heavy liquids. The density fraction 3.7-4.05 g/cm^3 (Ol) was mostly olivine. The 3.3-3.45 g/cm^3 fraction (Px1) was mainly high-Ca pyroxene (augite), and the 3.45-3.7 g/cm^3 fraction (Px2) contained both high-Ca and low-Ca pyroxenes. The 2.65-2.85 g/cm^3 fraction was mesostasis mainly consisting of fine grains of feldspar, pyroxene and glass. All density fractions were leached with 1N HCl in an ultrasonic bath for 10 min. The residues were analyzed and the results reported here. The leaches were saved for further study later. The Sm and Nd isotopic measurements were made on a Finnigan-MAT 261 multi-collector mass spectrometer. Nd isotopic data were measured by both Nd^+ and NdO^+ modes. Because of the low Nd contents of Px2 and Ol (~2-8 ng), only NdO^+ analyses were made.

Sm-Nd isochron: The Sm-Nd isotopic data for whole rocks and mineral separates are presented in Fig. 1. Except for the mesostasis datum, the five other data define a good linear array corresponding to a Sm-Nd age of 1.36±0.03 Ga using the York program [10] and $\lambda(^{147}Sm) = 0.00654$ Ga^{-1}. It is not clear why the mesostasis datum does not plot on the regression line defined by whole rock and olivine and pyroxene separates. However, petrographic evidence shows that nakhlites have undergone various degrees of late-magmatic and subsolidus diffusion [11]. Perhaps, the fine-grained mesostasis portions of the rock were more affected by these processes. The Sm-Nd age is in good agreement with the Rb-Sr age of 1.33±0.01 Ga [8] and the ^{39}Ar-^{40}Ar age of 1.32±0.04 Ga [9]. The concordancy of these isotopic ages plus the petrographic evidence [e.g. 11-12] strongly suggests the rock crystallized from a magma ~1.3 Ga ago. Ages of ~1.3 Ga also have been reported for the other two known nakhlites [4-7].

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Petrogenesis: The Sm-Nd age and initial ε^{143}Nd data of Governador Valadares are shown in Fig. 2. The Nakhla data of [7] are also plotted for comparison. The two nahklites are resolvable from each other, indicating that they could be derived from two different flows of similar composition. If the nahklites were derived from partial melts, a simple two-stage evolution calculation yields the time-averaged ^{147}Sm/^{144}Nd of 0.231-0.237 for nakhlite sources. The model assumes that the nakhlite parent body (NPB) has a chondritic initial ^{143}Nd/^{144}Nd of 0.505895 at 4.558 Ga [13]. The data also indicate that nakhlite sources are depleted in LREE, probably cumulates formed through early differentiation of the NPB. A very similar magmatic process was thought to have produced the mafic cumulate sources for the lunar basalts. Some of the lunar cumulate sources are even more depleted in LREE. In this model, the cumulate sources in the NPB melted at ~1.3 Ga and produced the LREE-enriched basaltic magmas of ^{147}Sm/^{144}Nd ~0.136 from which pyroxene and minor olivine crystallized along with some intercumulus trapped liquids to form nahklites. A two-stage process modeling both ^{143}Nd/^{144}Nd and ^{142}Nd/^{144}Nd evolutions in the derivation of nakhlite Governador Valadares is demonstrated in Fig. 3. The model assumes that the NPB has initial ^{146}Sm/^{144}Sm=0.0076, the LEW 86010 value of [14]. The ε^{142}Nd value for Governador Valadares published in [15] was used in the calculation. The Nd isotopic evolution calculations follow the mathematics developed in detail for a lunar basalt by [16]. The good match of the calculated (in open circles) and measured (in close circles) values strongly indicates the validity of the two-stage petrogenetic model for Governador Valadares in particular and nakhlites in general.

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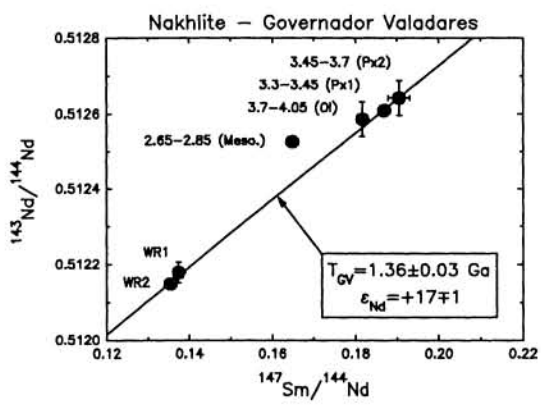

Fig. 1. Sm-Nd Mineral Isochron.

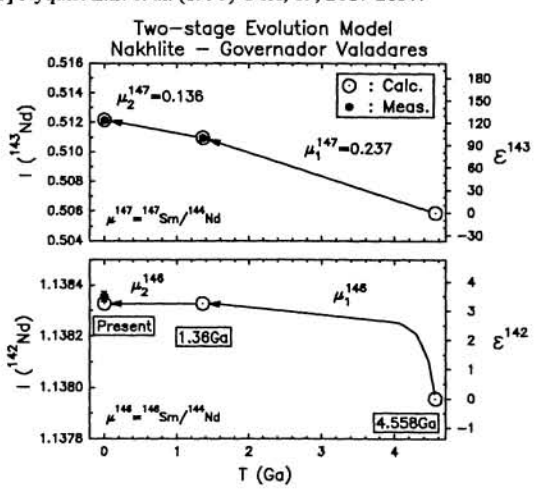

Fig. 3. Two-stage Nd Evolution Model.

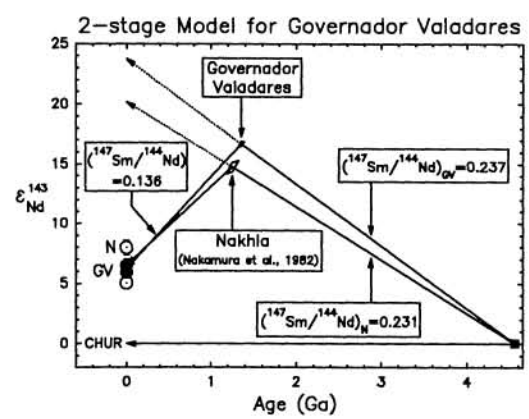

Fig. 2. Age vs. Initial ε^{143}Nd Diagram.