

**CRYSTALLIZATION AGE AND SOURCE SIGNATURE OF CHASSIGNY.** K. Misawa<sup>1</sup>, C.-Y. Shih<sup>2</sup>, Y. Reese<sup>2</sup> and L.E. Nyquist<sup>3</sup>, <sup>1</sup>NRC Research Associate, Mail Code SR, NASA Johnson Space Center, Houston, TX 77058 (misawa@npr.ac.jp), <sup>2</sup>Mail Code C23, Lockheed-Martin Space Operations, Houston, TX 77058, <sup>3</sup>Mail Code SR, NASA Johnson Space Center, Houston, TX 77058.

**Introduction:** Chassigny is the Martian dunite composed of cumulate olivine (92%), chromite (1.4%), pyroxene (5%) and interstitial feldspar (1.7%) [1-3]. Although nakhlites (clinopyroxenite) are less intensely affected by shock metamorphism, Chassigny has been subjected to a peak shock pressure of about 35 GPa [4]. The cosmic-ray exposure age of Chassigny ( $11.3 \pm 0.6$  Ma) is comparable to those of nakhlites, suggesting launch pairing of these meteorites [4]. Prior chemical and isotopic studies of Chassigny suggest that the meteorite crystallized  $\sim 1.3$  Ga ago and is closely related to nakhlites [4-8]. Nevertheless, compared to other Martian meteorites there are limited isotopic data for Chassigny [8-10]. To examine the relationship of Chassigny to nakhlites, we have undertaken new Rb-Sr and Sm-Nd isotopic studies. Here we present the new Sm-Nd isotopic data for Chassigny and discuss the nature of its source materials.

**Sample and Analytical Procedures:** The meteorite studied (USNM 624) was an  $\sim 1.7$  g chip with sawn surfaces. This sample was first washed with ethanol in an ultrasonic bath for 5 minutes to remove brownish surface deposits and rusts, and then processed by gently crushing to grain size  $< 149 \mu\text{m}$ . About 15% of the crushed material was taken as whole-rock samples (WR1, WR and reserve). The rest of this sample was further crushed and sieved into two size fractions,  $149-74 \mu\text{m}$  and  $< 74 \mu\text{m}$ . Mineral separates were made from the finer fraction using heavy liquids. A feldspar-rich sample (FELD) floated in the  $2.85 \text{ g/cm}^3$  heavy liquid was obtained. A pyroxene-rich sample (PX) and an olivine-rich sample were prepared using a heavy liquid of density  $3.45 \text{ g/cm}^3$ . Most pyroxenes floated in this heavy liquid, whereas most olivines sank. From the coarser fraction, we obtained a non-magnetic (NMAG) sample using a Frantz isodynamic magnetic separator. The WR sample was washed with 0.5N HCl in an ultrasonic bath for 10 minutes to leach out phosphate. Both residue and leachate of the whole-rock sample, WR(r) and WR(l), plus six unleached samples (WR1, FELD, NMAG, PX, OL and OL2) were analyzed for Sm and Nd following the procedures of [11]. The isotopic measurements were made on a Finnigan-MAT 262 multi-collector mass spectrometer following the procedures of [12]. Because of the low Sm and Nd contents of the samples, Sm and Nd isotopes were measured as  $\text{SmO}^+$  and  $\text{NdO}^+$ . The  $^{143}\text{Nd}/^{144}\text{Nd}$  results for samples reported here were renormalized to  $^{143}\text{Nd}/^{144}\text{Nd} = 0.511138$  for the Caltech Nd standard

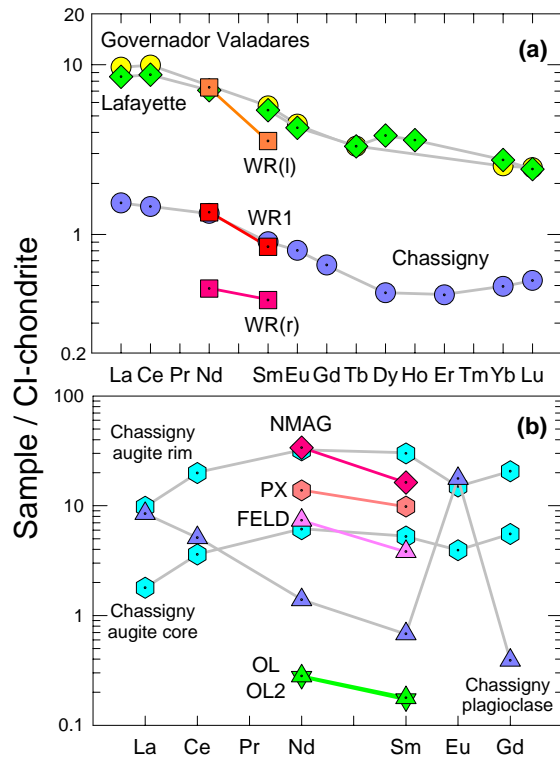
$n(\text{Nd})\beta$  [13]

**Results and Discussion:** The Sm and Nd concentrations of the whole-rock sample (WR1) of Chassigny are in good agreement with the previous results for this meteorite [5, 7] (Fig. 1a). We tried to selectively leach out chlorapatite by washing with 0.5N HCl, but the obtained leachate, WR(l), does not show a great REE enrichment ( $< 10 \times \text{CI}$ ); because REE abundances of chlorapatite in Chassigny usually exceed  $\sim 1000 \times \text{CI}$  [14]. The leaching results show that the WR(l) sample does not contain much chlorapatite, and that some olivine and feldspar were also dissolved by the procedure. Neodymium and Sm concentrations in the PX sample are in close agreement with the data for Chassigny augite by ion probe [14] (Fig. 1b). Our FELD sample seems to be impure and contains some REE-carrier phases, comparing to the data by ion probe (Fig. 1b). Olivine fractions (OL and OL2) possess the lowest REE abundances among all mineral concentrates but their Sm/Nd ratios are almost identical to that of WR1. All samples, including the acid leachate and residue of whole-rock, show LREE-enriched signatures. Nevertheless, we obtained a significant variation in  $^{147}\text{Sm}/^{144}\text{Nd}$  ratios from 0.0947 to 0.168 exceeding that previously obtained by acid leaching (0.107 to 0.151) [10].

The Sm-Nd isochron diagram of Chassigny is presented in Fig. 2. Eight data points, including whole-rock leachate, WR(l), and residue, WR(r), define a linear array corresponding to a Sm-Nd age of  $1.36 \pm 0.03$  Ga for  $\lambda(^{147}\text{Sm}) = 0.00654 \text{ Ga}^{-1}$  with an initial  $\epsilon^{143}\text{Nd} = +16.6 \pm 0.2$  using the Williamson regression program [15]. The FELD point slightly deviates upward from the isochron by  $0.46\epsilon$ , suggesting a minor isotopic disturbance due to the shock metamorphism [4]. The Sm-Nd age of  $1.36 \pm 0.03$  Ga is in agreement with the two-point Sm-Nd tie-line age of  $1.36 \pm 0.06$  Ga obtained by an acid leaching experiment [10] and with the  $^{39}\text{Ar}$ - $^{40}\text{Ar}$  age of  $1.32 \pm 0.07$  Ga [16], but is  $\sim 0.1$  Ga older than the Rb-Sr age of  $1.24 \pm 0.01$  Ga (recalculated using  $\lambda(^{87}\text{Rb}) = 0.01402 \text{ Ga}^{-1}$ ) by Nakamura et al. [8]. The initial  $\epsilon^{143}\text{Nd}$  value of  $+16.6 \pm 0.02$  differs by  $\sim 1 \epsilon$ -unit compared to that reported by Jagoutz [10].

Figure 3 shows the age (T) and  $\epsilon^{143}\text{Nd}$  parameters for Chassigny compared to nakhlites. Chassigny and nakhlites probably are genetically closely related. They all crystallized within  $\pm 0.1$  Ga and have positive ini-

tial  $\epsilon^{143}\text{Nd}$  values that vary by only 3  $\epsilon$ -units, suggesting they all came from LREE-depleted source regions. Assuming that the Chassigny source formed from a reservoir of chondritic  $^{143}\text{Nd}/^{144}\text{Nd}$  and  $^{147}\text{Sm}/^{144}\text{Nd}$  at 4.56 Ga, the time-averaged  $^{147}\text{Sm}/^{144}\text{Nd}$  ratio for the source is calculated to be 0.239. Similar  $^{147}\text{Sm}/^{144}\text{Nd}$  ratios for sources of Chassigny, Governador Valadares and Lafayette suggest that they could have been comagmatic, or at least could have come from very similar mantle sources. On the other hand, three nakhlites, Nakhla, Northwest Africa 998 and Yamato 000593, appear to be from 'similar' but distinct sources.

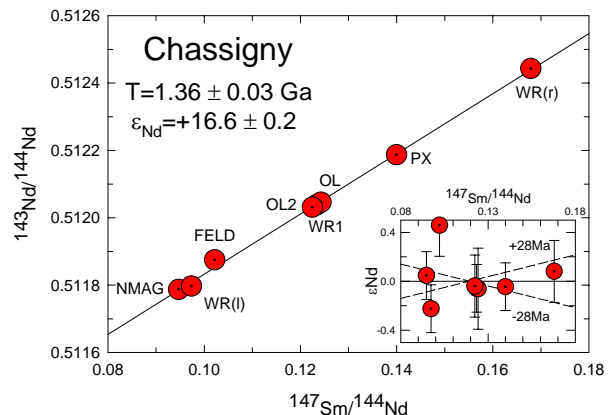


**Fig. 1.** (a) CI-chondrite normalized Nd and Sm abundances of Chassigny whole-rock samples (unleached whole-rock: WR1, leachate: WR(l) and residue: WR(r)). Rare earth patterns for whole-rock samples of Chassigny [7] and nakhlites Governador Valadares [17] and Lafayette [18] are also shown. (b) Nd and Sm abundances of mineral separate samples. The data for Chassigny augite (core and rim) and plagioclase by ion probe are from [14].

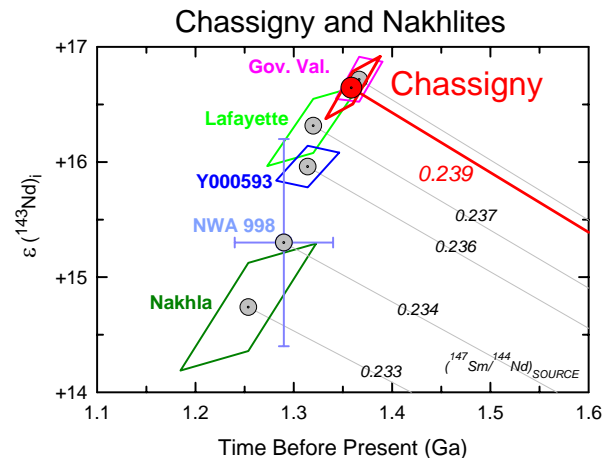
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**Fig. 2.** Sm-Nd isochron plot for Chassigny.



**Fig. 3.**  $\epsilon^{143}\text{Nd}$ -T diagram for Chassigny (this work), Nakhla [19], Lafayette [20], Governador Valadares [11], Yamato 000593 [21] and Northwest Africa 998 [22].