Sm-Nd and Initial $^{87}Sr/^{86}Sr$ Isotopic Systematics of Asuka 881394 and Cumulate Eucrites Yamato 980318/433 Compared. L. E. Nyquist[1] , C-Y. Shih[2], Y. D. Young[3], and H. Takeda[4], [1]NASA Johnson Space Center, [2]ESCG Jacobs-Sverdrup, Houston, TX 77058, [3]Mail Code JE-23, ESCG/Muniz Engineering, Houston, TX 77058, [4]Chiba Inst. Tech.

Introduction: The Asuka 881394 achondrite contains fossil ^{26}Al and ^{53}Mn [1,2,3] and has a ^{207}Pb/^{206}Pb age of 4566.5±0.2 Ma [3], the oldest for an achondrite. Recent re-investigation of A881394 [4] yielded revised initial ^{146}Sm/^{144}Sm = (9.1±1.4) x 10^{-3}, a ^{147}Sm-^{143}Nd age of 4525±58 Ma, a ^{87}Rb-^{87}Sr age of 4490±130 Ma, and initial ^{87}Sr/^{86}Sr = 0.698991±19, resp. The relatively large uncertainties in the Sm-Nd and Rb-Sr ages are due to disturbances of the isotopic systematics of tridymite and other minor phases [4].

A preliminary value for the ^{147}Sm-^{143}Nd age of the Yamato 980318 cumulate eucrite of 4560±150 Ma [5] was refined in later work to 4567±24 Ma as reported orally at LPSC 35. Similarly, a preliminary value for ^{146}Sm/^{144}Sm = (7.7±1.2) x 10^{-3} [5] was refined to (6.0±0.3) x 10^{-3}. For Yamato 980433, a ^{147}Sm-^{143}Nd age of 4542±42 Ma and ^{146}Sm/^{144}Sm = (5.7±0.5) x 10^{-3} has been reported [6]. Because these two cumulate eucrites are paired, we consider them to represent one igneous rock and present their combined isotopic data here.

^{147}Sm/^{143}Nd age of Y980318/433: The ^{147}Sm/^{143}Nd data are shown in Figure 1. The whole rock leachates for both samples plot considerably away from the isochron. It is probable that the most easily leachable phases of the rocks were disturbed by terrestrial weathering. When the corresponding analyses are omitted, the calculated age becomes 4.557±0.020 Ga for initial ε_{Nd} = 1.45±0.51 relative to the CHUR parameters of [7]. Among the remaining 14 analyses, one plagioclase and one pyroxene analysis have relatively large error limits, and are consistent with the isochron only at the limits of error. One analysis of a pyroxene separate plots ~2 ε-units below the isochron for unknown reasons. Omitting these data from the isochron fit does not significantly change the Model-1 (York) fit given by Isoplot. For all 14 data points, the MSWD = 9.3 for the isochron fit. Omitting the two most aberrant plagioclase and pyroxene data gives the age as 4.558±0.020 Ga, ε_{Nd} = 1.44±0.33, and MSWD = 8.9 for twelve data points.

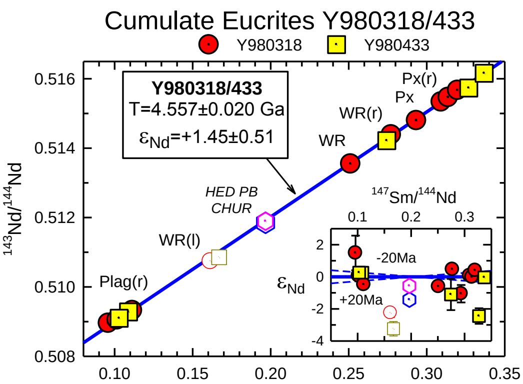

Figure 1. ^{147}Sm-^{143}Nd isochron for Y980318/433.

^{147}Sm/^{143}Nd age of A881394: Sm-Nd isotopic results for A 881394 were presented at the 74th Meeting of the Meteoritical Society (London) and the ^{147}Sm/^{143}Nd isochron is given in [8]. The A881394 data also show minor disturbances, with the ten "best" data giving a calculated age of 4.516±0.037 Ga and ε_{Nd} = 1.2±0.3 for an MSWD =7.6. For A881394, isotopic disturbance of tridymite is also reflected in the Rb-Sr system, and probably occurred ~3.9 Ga ago [5]. The ^{147}Sm-^{143}Nd systematics of both A881394 and Y980318/433 clearly establish the antiquity of both rocks.

^{146}Sm/^{142}Nd formation intervals: The ^{147}Sm-^{143}Nd isochrons of A881394 and Y980318/433 overlap within their 2-σ error limits, with the former implied to be <4553 Ma old, and the latter implied to be >4537 Ma old. Also, based on the ^{147}Sm-^{143}Nd data, one might conclude that Y980318/433 is "probably" somewhat older than A881394. Nevertheless, the ^{146}Sm-^{142}Nd data (Figure 2) directly show that A881394 is the more ancient rock. All ε^{142}Nd data for Y980318/433 samples having ^{147}Sm/^{144}Nd > ^{147}Sm/^{144}Nd$_{CHUR}$ = 0.1967 [7] lie below the A881394 isochron, whereas all Y980318/433 samples having ^{147}Sm/^{144}Nd < 0.1967 lie above the A881394 isochron. The generally larger error limits on the individual A881394 data points are a consequence of lower REE abundances ~2 x CI-chondrites in A881394 compared to ~ 3-5 x CI-chondrites in Y980318/433.

Model "absolute" ages, T_{LEW}, calculated relative to ^{146}Sm/^{144}Sm = (7.6±0.9) x 10^{-3} and an absolute age of 4558 Ma for the angrite LEW86010 [9,10] are 4584±23 and 4519±10 Ma, respectively, using the

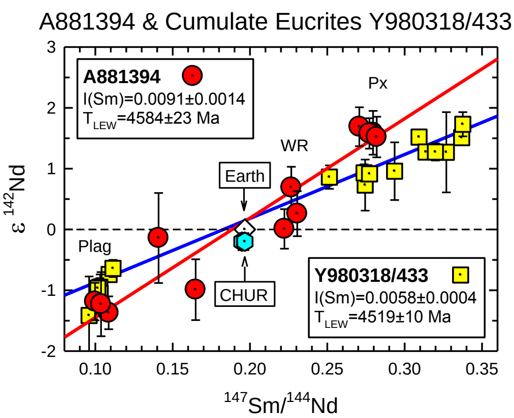

Figure 2. ^{146}Sm-^{142}Nd isochrons for A881394 and Y980318/433 compared.

currently accepted value for the ^{146}Sm halflife $t_{1/2}$ = 103 Ma [11]. Alternatively, T_{LEW} = 4575±15 and 4532±6 Ma, respectively, using the newly reported value, $t_{1/2}$ = 68 Ma [12]. Thus, Y980318/433 appears to be at least 43±16 Ma younger than A881394.

Initial ^{87}Sr/^{86}Sr: Initial ^{87}Sr/^{86}Sr was the same within error limits in A881394 as in the Y980318/433 cumulate eucrites. ^{87}Rb/^{86}Sr in A881394 plagioclase is more than twofold lower than in Y980318/433 as a consequence of its higher An content. The very low values of ^{87}Rb/^{86}Sr in the A881394 samples are matched only by plagioclase in angrites.

Discussion: The granulitic texture of A881394 led [13] to suggest that it had experienced an extensive thermal event in which it lost Na and other volatiles during catastrophic bombardment into a magma ocean during late-stage accretion, thereby accounting for its very calcic An_{98} plagioclase. In this scenario, A881394 is a metamorphosed rock from the surface of its parent body. Our earlier interpretation of A881394 as representative of the earliest crust on asteroid 4 Vesta [1] seems to be excluded by its O-isotopic composition, which differs from that of HED meteorites [14].

Cumulate eucrites such as Y980318/433 are currently widely accepted as samples of asteroid 4 Vesta. They are coarse-grained rocks with sub-rounded or lath-shaped plagioclase (An_{90}) up to 4.5×1.5 mm in size enclosed in continuous networks of pyroxene grains up to 4.4×2.9 mm in dimension. Exsolution and inversion textures to orthopyroxene of the inverted pigeonites are similar to those of Serra de Magé [13]. The thickness of augite lamellae ($Ca_{45}Mg_{37}Fe_{18}$) on (001) of the original pigeonite is ~30 μm. The host low-Ca pyroxene between the thick lamellae has decomposed into blebby augite inclusions in orthopyroxene ($Ca_2Mg_{50}Fe_{48}$). Inversion textures similar to those of Y980318/433 have been proposed as developing in cumulate piles in very slowly cooling magma in terrestrial layered intrusions. The cooling rates of several cumulate eucrites were calculated by [15]. For Sera de Mage, texturally similar to Y980318/433, they calculated a cooling interval of ~2 Ma for the temperature interval of 960-620°C.

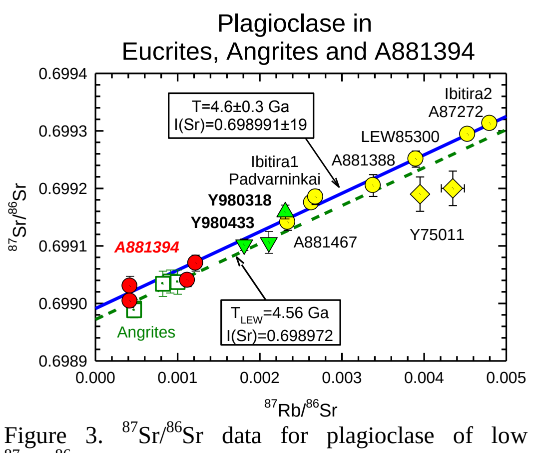

Figure 3. ^{87}Sr/^{86}Sr data for plagioclase of low ^{87}Rb/^{86}Sr for eucrites, angrites, and A881394.

Initial ^{146}Sm/^{144}Sm for the Y980318/433 cumulate eucrites may be compared to values for other cumulate eucrites (Figure 4). Data for Binda, Moore County, and Moama are from [16]. Binda appears to be older than Y980318/433, which is one of the youngest cumulate eucrites. The inverted pigeonite in Binda was produced by a different mechanism from that for Y980318/433, i.e., by the mechanism of Ishii and Takeda [17].

We hypothesize that after opx crystallization, the HED magma began to crystallize pigeonite, and that the Y980318/433 cumulate eucrites crystallized later than Binda. Because Binda initially was located below the cumulate eucrites, its cooling rate would have been slower than for Y980318/433, but nevertheless short compared to the age difference between Binda and Y980318/433 indicated by the ^{146}Sm-^{144}Sm data (Fig. 4). We tentatively conclude that the age difference between Binda and Y980318/433 is due to later crystallization of the latter, rather than to slow cooling of the parent body, presumably asteroid 4 Vesta. We note, however, that Binda has a monomict texture showing that it has undergone one or more impact events that could have slightly disturbed its isotopic systematics.

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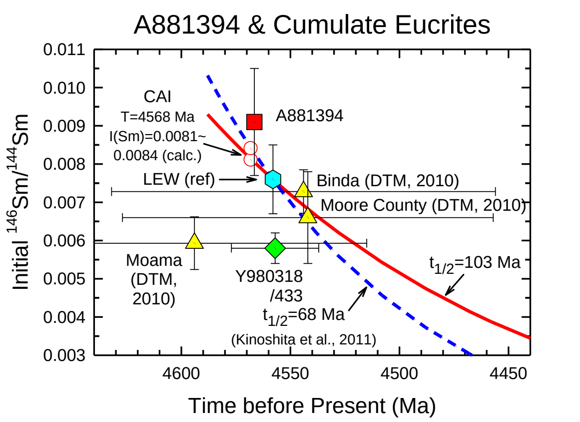

Figure 4. ^{146}Sm decay intervals for A881394 and some cumulate eucrites. Data for Moama, Binda, and Moore County are from [16].