SILICON ISOTOPE COMPOSITION OF UNGROUPED ACHONDRITE NORTHWEST AFRICA 7325.

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Introduction: Ungrouped achondrite Northwest Africa (NWA) 7325 is a reduced, Mg-rich cumulate olivine gabbro that mainly consists of calcic plagioclase, diopside, and forsterite [1]. The similarities in major elemental ratios and magnetic properties with the surface rocks of Mercury suggest that NWA 7325 may have originated from this planet [1,2]. Bulk oxygen isotope compositions are in the range of ureilites, but Cr isotope compositions preclude a genetic link with ureilites [1,3]. Oxygen isotope values of mineral separates from NWA 7325 follow mass-dependent fractionations, but $\Delta^{17}O$ differs from those of Earth, Mars, or known asteroids, suggesting that it originated from a previously unsampled differentiated parent body [3,4]. The U-Pb age of NWA 7325 is 4562.5±4.4 Ma [5], which is consistent with an Al-Mg age of 4562.8±0.3 Ma [6]. The ancient formation age makes it unlikely that it originated from the evolved crust of a planetary-sized body [6]. A recent study reported fractionated highly siderophile element (HSE) patterns of NWA 7325 relative to bulk chondrite; these data are interpreted to be the result of multi-stage metal-silicate partitioning on the parent body [7]. Alternatively, an impact-melting of gabbroic material origin has been proposed to explain the HSE characteristics and high $\delta^{26}Mg_0$* of NWA 7325 [8].

Recent studies of silicon isotope compositions have demonstrated significant $\delta^{30}Si$ variability among objects in the inner Solar System [9-12]. Bulk silicate Earth (BSE) and lunar rocks have similar $\delta^{30}Si$ values, both higher than the average of chondrites, whereas Martian and HED meteorites have near chondritic $\delta^{30}Si$ values [9-12]. The difference in silicon isotope composition between BSE and chondrites has been attributed to Si isotopic fractionation between silicate and metals during core segregation on Earth, which can also explain the density deficit of the Earth's core relative to pure Fe-Ni alloy and the superchondritic Mg/Si ratio [9-12]. However, angrites also display higher $\delta^{30}Si$ values relative to chondrites, but Si partitioned into the core of angrite parent body (APB) is unlikely because the redox conditions required for sufficient Si partitioning do not match that of APB [13-15]. The correlation between $\delta^{30}Si$ values and Mg/Si ratio in chondrites has led to the interpretation that the variation of $\delta^{30}Si$ among planetary bodies is caused by nebular fractionation during forsterite condensation rather than core segregation [10,14,15]. An alternative explanation for the heavy Si isotope abundance in angrites is volatile loss during early accretional impacts [13]. In this study, Si isotopic compositions of NWA 7325 were measured to better understand its relation to other planetary materials.

Samples and Analytical Procedures: The silicon isotope compositions were measured using a multi-collector ICP-MS at University of Houston following the procedures detailed in a companion abstract (this meeting) [16]. In addition to NWA 7325, Si isotope ratios were measured for a suite of geostandards and meteorite samples that include BHVO-2 (basalt, USGS), BIR-1a (basalt, USGS), Allende (CV3), NWA 3134 (EL6), Pena Blanca Springs (aubrite), EET 87520 (eucrite), NWA 1068 (shergottite), and NWA 4931 (angrite). Enstatite chondrite (EC) and aubrite samples were selected because they have lower $\delta^{30}Si$ values relative to the average of carbonaceous chondrites (CC) and ordinary chondrites (OC) [9-12]. These meteorite types and the terrestrial rock standards have been extensively analyzed for Si isotopes by various laboratories [9-12], giving a robust framework for the interpretation of our Si isotope data. Uncertainties are reported as 2SE.

Results and Discussion: The complete dataset is given in Table 1. The $\delta^{30}Si$ values of geostandards, chondrites, aubrite and eucrite agree well with those reported in previous studies (Fig. 1) [9-15]. The shergottite sample yielded a $\delta^{30}Si$ value of -0.37±0.04‰ (n=9), which is within uncertainties of the range reported by [11]. The $\delta^{30}Si$ value of -0.19±0.04‰ (n=8) for the angrite agrees well with studies by [15] and is slightly higher than the average for angrites reported by [13], confirming that angrites have distinctive Si isotope signatures from chondrites. NWA 7325 has a $\delta^{30}Si$ value of -0.45±0.05‰ (n=8), which is significantly lower than for BSE and angrites, but indistinguishable from values for chondrites measured in this study or average $\delta^{30}Si$ value for carbonaceous/ordinary chondrites reported in the literature (Fig. 1) [9-15]. The Si isotope composition of NWA 7325 is also not resolvable from average $\delta^{30}Si$ compositions of HEDs and Martian meteorites [9-12].

The chondrite-like $\delta^{30}Si$ compositions of Mars and 4-Vesta have been ascribed to the lack of Si isotopic fractionation between silicate and metals due to their relative small sizes [11,12]. Additionally, core segregation in early accreted planetesimals may be unlikely to reach the temperature and pressure required for sufficient Si partitioning into a metal phase [11,12,15].

NWA 7325 is extremely Fe poor and HSE depleted [1,7,8], suggesting that its parent body may have experienced effective core formation. But metal-silicate differentiation did not shift its δ^{30}Si composition from that of chondrites, suggesting that core segregation in the NWA 7325 parent body did not likely reach the pressure necessary for significant Si partitioning into the metal phase. This is in agreement with the low pressure metal-silicate partitioning model for HSE pattern of NWA 7325 [7].

As demonstrated by [14,15], metal-silicate differentiation on the APB is unlikely to be the cause of the heavy δ^{30}Si compositions of angrites. Rather, it can be explained by nebular fractionation during forsterite condensation. Forsterite is suggested to be the first solid to condense from the solar nebular, which significantly altered the Mg/Si ratio and δ^{30}Si composition of the remaining nebular gas. Equilibrium fractionation during forsterite condensation can cause ~2‰ Si isotopic fractionation between solid and gas phases [15]. Mixing between the forsterite and gas end-members can result in different δ^{30}Si composition in planetesimals. The difference in δ^{30}Si values between planetary materials could be caused by variable extents of forsterite and nebular gas mixing. Higher fraction of forsterite mixing with the nebular gas during APB accretion may have caused the higher δ^{30}Si values observed in angrites. In this scenario, the δ^{30}Si values for NWA 7325 may indicate that it accreted from materials that inherited similar proportions of early gas and condensates as chondrites, ureilites, Mars and eucrites, but distinct from those of the angrite and aubrite parent bodies as well as the Earth-Moon system.

Sample	Description	δ^{30}Si (±2SE)	δ^{29}Si (±2SE)	n
BHVO-2	BSE	-0.27 (0.03)	-0.14 (0.02)	22
BIR-1a	BSE	-0.33 (0.03)	-0.16 (0.01)	22
Diatomite	Opal	1.25 (0.04)	0.66 (0.03)	13
Allende	CC	-0.42 (0.04)	-0.21 (0.02)	22
EET 87520	Eucrite	-0.46 (0.05)	-0.23 (0.03)	21
PBS	Aubrite	-0.59 (0.03)	-0.29 (0.02)	22
NWA 3134	EC	-0.52 (0.03)	-0.27 (0.02)	22
NWA 1068	Shergottite	-0.37 (0.03)	-0.20 (0.02)	9
NWA 4931	Angrite	-0.19 (0.04)	-0.07 (0.02)	8
NWA 7325	Achondrite	-0.45 (0.05)	-0.23 (0.02)	8

Table 1. δ^{30}Si values for samples in this study. Uncertainties are given as 2SE. BSE=bulk silicate Earth, CC=carbonaceous chondrite, EC=enstatite chondrite, PBS=Peña Blanca Spring.

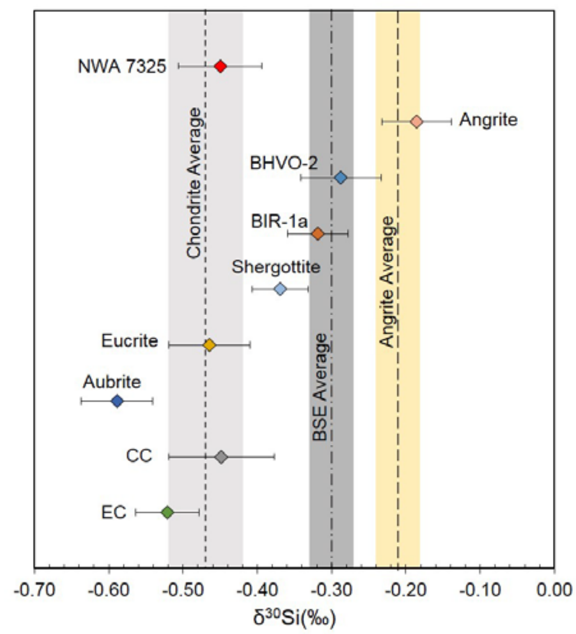

Figure 1. Silicon isotopic composition of NWA 7325 compared with values for the bulk silicate Earth (BSE) and other meteorite samples (CC=carbonaceous chondrite, EC=enstatite chondrite). Data with error bars are from this study. Data for BSE and chondrite average is taken from [9-15]. Angrite average is from [15]. Uncertainties are reported as 2SE.

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