GEOCHEMISTRY, PETROLOGY, AND SM–ND DATING OF A STANNERN GROUP EUCRITE, NORTHWEST AFRICA 7188.

S. Kagami[1], M. K. Haba[1], T. Yokoyama[1], T. Usui[2], and R. C. Greenwood[3], [1]Dept. of Earth & Planetary Sciences, Tokyo Institute of Technology, 2-12-1 Ookayama, Meguro-ku, Tokyo 152-8551, Japan, (e-mail: kagami.s.ab@m.titech.ac.jp), [2]ELSI, Tokyo Institute of Technology, 2-12-1 Ookayama, Meguro-ku, Tokyo 152-8551, Japan. [3]Planetary and Space Sciences, The Open University, Milton Keynes MK7 6AA, UK.

Introduction: Basaltic eucrites are generally considered to have formed at, or near, the surface of the eucrite parent body (EPB). Most basaltic eucrites have experienced various degrees of thermal metamorphism and/or impact events on the EPB [1, 2]. To constrain the early thermal history of the EPB, unweathered meteorites, which display relatively small degrees of brecciation, need to be investigated. Northwest Africa (NWA) 7188 is one such eucrite. However, to date relatively little petrological or geochemical information has been obtained for this important sample. We have previously determined the mineral isochron ages using the ^{147}Sm–^{143}Nd and ^{146}Sm–^{142}Nd systems for this meteorite [3], and concluded that the age that was obtained, which most likely corresponds to the timing of the EPB's crustal formation, was older then the Sm–Nd age of cumulate eucrites.

Here we discuss the results of new study of NWA 7188, which examines its geochemistry, petrology, and Sm-Nd chronology, with the aim of understanding the origin of this meteorite and more generally, the thermal history of the EPB's crust. To this end, we have determined the oxygen isotopic composition of NWA 7188 to confirm whether it represents an isotopically normal member of the HED suite. The origin of NWA 7188 meteorite is examined from the perspective of both the bulk rock and its constituent minerals. Furthermore, we revise the ^{147}Sm–^{143}Nd and ^{146}Sm–^{142}Nd ages of NWA 7188 and so place additional constraints on the timing of igneous activity on the EPB and the formation of its basaltic crust.

Samples: In addition to the sample specimen prepared for our previous study [3], we used a new 7 g chip of NWA 7188 for the mineralogical observations and oxygen isotope analysis discussed here. For the mineralogical observations, the chip was cut into a small slab (1 in. × 1 in.) and embedded in an epoxy resin disk. The sample surface was polished successively by 3, 1, and 1/4 µm diamond paste. For the oxygen isotope analysis, we cut a ~1 g fragment from the rock chip. This was subsequently crushed and homogenized and ~2 mg aliquots were then taken for oxygen isotope measurements.

Experimental: The polished thick section was examined using an electron microprobe analyzer (EPMA) (JEOL-JXA-8530F) installed at Tokyo Tech. Oxygen isotope analysis was carried out using an infrared laser fluorination system at the Open University following the procedures described in [4]. The major (Fe, Mg, Ti) and trace element (REEs) bulk rock abundances of NWA 7188 were measured by a quadrupole type ICP-MS installed at Tokyo Tech. In addition, we revised the previously obtained ^{147}Sm–^{143}Nd and ^{146}Sm–^{142}Nd ages of NWA 7188 [3] by additionally measuring the fractions of magnetic and non-magnetic minerals of which the grain size was < 45 µm. The analytical protocol for the determination of Nd isotope ratios and Sm/Nd ratios was the same as [3].

Results and Discussion: Fig. 1 shows the oxygen isotope composition of NWA 7188 obtained in this study, along with the data for other HED samples compiled by [5]. The δ^{17}O, δ^{18}O, and Δ^{17}O values of NWA 7188 are 1.968 ± 0.008‰, 4.224 ± 0.016‰, and –0.245 ± 0.017‰ (2SD), respectively. Δ^{17}O, which represents the deviation from an assigned reference fractionation line, has been calculated according to the formulation of [6]. The slope of the assigned reference line used is 0.5247 [6]. The Δ^{17}O value is similar to the average HED value (Δ^{17}O = –0.240) defined by [5]. In addition, we previously reported that NWA 7188 has a similar Fe/Mn ratio in pyroxenes to that of other eucrites [3]. These results indicate that this meteorite is a normal member of HED suite.

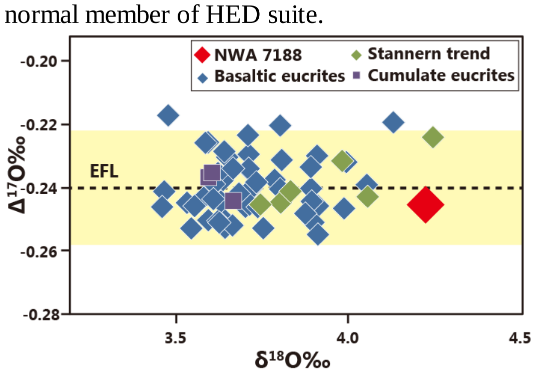

Fig. 1 *Oxygen isotopic composition of eucrites. EFL represents Eucrite Fractionation Line (average $\Delta^{17}O$ = − 0.240 ± 0.014, 2σ) reported in [5].*

As shown in Fig. 2, the REE pattern of the bulk NWA 7188 sample is characterized by the elevated REE abundances (~20 × CI) with a prominent Eu negative anomaly (Eu/Eu^* = 0.57) and a relative depletion of HREEs (Gd_n/Lu_n = 1.3). In addition, the sample has elevated La and TiO_2 abundances at a given FeO/MgO ratio compared to the main group–Nuevo Laredo eucrites. These chemical characteristics suggest that NWA 7188 should be classified as a member of the Stannern group eucrites. The EPMA analysis of the polished thick section indicated that remnant Ca-zoning and exsolution lamella of augite in pyroxene (Fig. 3a), is consistent with a type 4 metamorphic grade [7] for NWA 7188. In addition, elemental mapping of Zr revealed the presence of small zircon grains in this meteorite, with typical sizes of < 5 µm, but with a maximum size of ~20 µm (Fig. 3b). The maximum size of zircon in NWA 7188 is consistent with that found in the Stannern meteorite, which also has a type 4 metamorphic grade [8, 9].

The ^{147}Sm–^{143}Nd and ^{146}Sm–^{142}Nd ages updated in this study yielded 4582 ± 190 Ma (MSWD = 1.1) and 4553 $^{+17}/_{-20}$ Ma (MSWD = 1.9), respectively. To identify the thermal event that corresponds to the ^{146}Sm–^{142}Nd age, the Sm–Nd closure temperature (T_c) of plagioclase was estimated because it potentially has a lower T_c than the other major minerals used in Sm–Nd dating. In the calculation, we applied the diffusion parameters of [10], the diffusion equation of [11], and the cooling rate of 0.2 °C/yr estimated from [12]. As shown in Fig. 4, the closure temperature for Nd in plagioclase was obtained to 925–1070 °C, which was equal to or slightly lower than the solidus temperature of basaltic eucrites (~1060 °C, [13]).

The ^{146}Sm–^{142}Nd age of NWA 7188 obtained here is the oldest among basaltic eucrites reported in previous studies, indicating that this meteorite did not suffer significant resetting during later impact events. However, the age is substantially younger than the crystallization age of the main group eucrite Juvinas that was estimated from the ^{53}Mn–^{53}Cr mineral isochron (4562.5 ± 1.0 Ma, [14]). Rather, the ^{146}Sm–^{142}Nd age of NWA 7188 coincides with the Pb–Pb age of zircons in the basaltic eucrite Agoult (4554.4 ± 1.7 Ma, [15]) that most likely indicates the timing of global crustal metamorphism. Therefore, the age obtained from NWA 7188 suggests that either the timing of crystallization for the Stannern group eucrites postdates by ~10 Myrs the formation of the EPB's crust, or the crystallization age of NWA 7188 was reset by the global metamorphism that occurred at 4554 Ma. If the latter is the case, the peak temperature of the global metamorphism was near the solidus of basaltic eucrites and so was high enough to disturb the Sm-Nd isotope systematics of plagioclase in NWA 7188.

References: [1] Barrat J.A. et al. (2011) *GCA, 75*, 3839. [2] Warren P.H. et al. (2014) *GCA*, *141*, 199. [3] Kagami S. et al. (2017) *LPSC*, Abstract, #1975. [4] Miller M.F. et al. (1999) *Rapid Commun. Mass Spectrom.*, *13*, 1211. [5] Greenwood R.C. et al. (2017) *Chem. Erde Geochem.*, *77*, 1. [6] Miller M.F. (2002) *GCA*, *66*, 1881.[7] Takeda H. and Graham A.L. (1991) *Meteoritics*, 26, 129. [8] Haba M.K. (2014) *EPSL*, *387*, 10. [9] Ireland T.R. and Bukovanska M. (1992) *Meteoritics*, Abstract, 27, 273. [10] Cherniak D.J. (2003) *Chem. Geol.*, *193*, 25. [11] Dodson M.H. (1973) *CMP*, *40*, 259. [12] Miyamoto M. et al. (1985) *JGR*, *90*, 629. [13] Stolper E. (1977) *GCA*, *41*, 587. [14] Lugmair G.W. and Shukolyukov A. (1998) *GCA*, *62*, 2863. [15] Iizuka T. et al. (2015) *EPSL*, *409*, 182. [16] Barrat J.A. et al. (2000) *MAPS*, *35*, 1087. [17] Barrat J.A. et al. (2007) *GCA*, *71*, 4108.

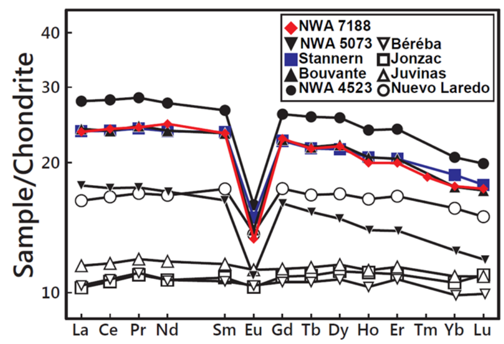

Fig. 2 *REE patterns of NWA 7188 (this study) and the other basaltic eucrites [16, 17].*

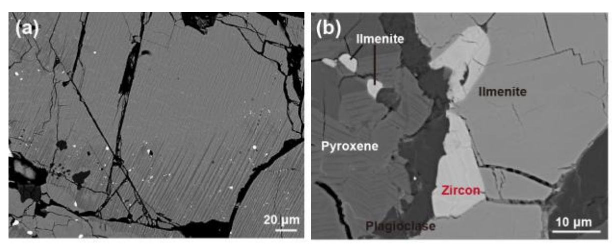

Fig. 3 *Backscattered electron images of (a) pyroxene with Ca-zoning and augite lamella and (b) the largest zircon grain including circumjacent minerals.*

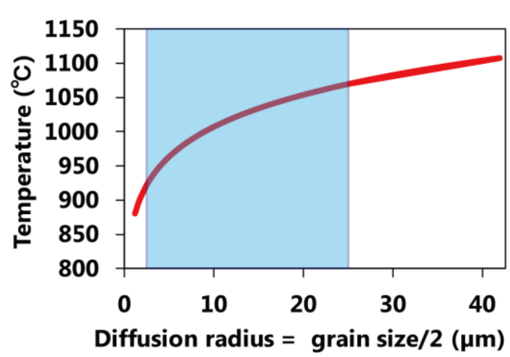

Fig. 4 *Closure temperature for Nd in plagioclase. Blue area represents typical size of plagioclase.*