URANIUM-LEAD DATING OF ZIRCON AND PHOSPHATE MINERALS IN A HIGHLY-SHOCKED EUCRITE NORTHWEST AFRICA 13166. Y. Sumiya[1], M. Koike[1], K. Onishi[1], A. Kurokawa[1], N. Takahata[2], H. Asamura[2], and Y. Sano[3], [1]Department of Earth and Planetary Systems Science, Hiroshima University (Higashi-Hiroshima 739-8526, JAPAN; (sumi_yuta@icloud.com), [2]Atmosphere and Ocean Research Institute, The University of Tokyo (Chiba, Japan), [3]Center for Advanced Marine Core Research, Kochi University (Kochi, Japan)

Introduction: Howardite-Eucrite-Diogenite (HED) clan possibly came from asteroid 4 Vesta, whose linkage is supported by oxygen isotope ratios [1] and surface mineralogy observed by NASA's Dawn spacecraft [2]. Early asteroids including Vesta have experienced complicated thermal metamorphism due to the internal process and multiple collisions [3, 4]. In general, meteorites recorded these thermal events in their mineralogy, geochemistry and chronological information. To better understand the complex collisional history, U-Pb dating of zircon and phosphate minerals (apatite [$Ca_5(PO_4)_3(F,Cl,OH)$] and merrillite [$Ca_9NaMg(PO_4)_7$]) is informative. The previous study using a secondary ion mass spectrometry (NanoSIMS 50) analyzed phosphates in three brecciated eucrites [4]. Their U-Pb systems suggest that Vesta or vestoids cluster underwent multiple impacts and moderate reheating during the period of ~4.4-4.15 Ga. However, the frequency of collisions is uncertain because of paucity of the analyzed samples.

In this study, we performed U-Pb dating of zircon and phosphates contained a highly shocked melt-breccia eucrite using a NanoSIMS. Then, we discuss correlation between their chronological records and collisional history of the parent body.

Method: A basaltic melt-breccia eucrite, Northwest Africa (NWA) 13166, is the target of this study. Its polished thin section was made and observed with a scanning electron microscope with energy dispersive X-ray spectroscopy (SEM-EDS; JEOL JSM-6390) at Hiroshima University, Japan to identify zircon and phosphates. Quantitative analyses of the identified zircon, phosphates, and surrounded silicate minerals were performed using an electron probe microanalyzer (EPMA; JEOL JXA 8200).

Fifteen various size of phosphate grains (>3 – 50 µm in diameter) and a zircon grain (~20 µm) are identified. Their U-Pb dating was conducted using a NanoSIMS 50 at Atmosphere and Ocean Research Institute (AORI), The University of Tokyo, Japan. A 2nA O^- primary beam was used to make a spot with a size of approximately 8 µm in diameter (Fig. 1). To obtain ^{238}U-^{206}Pb and ^{207}Pb-^{206}Pb age, the secondary ions of $^{31}P^+$, $^{43}Ca^+$, $^{204}Pb^+$, $^{206}Pb^+$, $^{207}Pb^+$, $^{238}U^{16}O^+$, and $^{238}U^{16}O_2^+$ were simultaneously measured using NanoSIMS multi-collector system and peak-jumping mode for about 1 hour. To calibrate $^{238}U/^{206}Pb$ ratios of the samples, a natural apatite called 'PRAP' (1156 Ma [5]) was used as a standard. To calculate isochron ages, we used Isoplot Ver.4 software [6]. Model $^{207}Pb^*/^{206}Pb^*$ ages for individual data were calculated assuming the initial $^{207/206/204}Pb$ compositions as those of CDT [7] and the $^{238}U/^{235}U$ ratio of basaltic eucrites as 137.8 [8].

Results and Discussion:

SEM-EDS and EPMA analyses:

Pyroxenes in NWA 13166 show exsolution texture and do not have remnant Ca-zoning (Fig. 1). The chemical compositions of pyroxenes (40 grains) surrounded phosphates and zircon plot $Wo_{3.1}En_{36.9}$ and $Wo_{45}En_{30}$ concentratively on the pyroxene quadrilateral (Fig. 2). These texture and compositions indicate that NWA 13166 was metamorphosed at ~1000°C for an extended period to homogenize Ca-Mg in pyroxenes (i.e. classified Type 5) [9].

NanoSIMS U-Pb dating:

We found 14 anhedral grains of merrillite in lithic clasts and a single anhedral grain of apatite in recrystallized matrix surrounded by pyroxene, plagioclase, and silica minerals (Fig. 1). Among them, 11 grains were dated. The others are too small for SIMS analysis. A single rounded grain of zircon was also dated.

The 10 merrillite grains with 11 spot data define a three-dimensional total U-Pb isochron age of 57 ± 35 Ma and 4141 ± 170 Ma (errors are 2-sigma) with the mean squared weighted deviation (MSWD) of 1.4 (Fig. 3). These data plot as discordia. Their ^{207}Pb-^{206}Pb isochron age of 3308 ± 810 Ma (MSWD = 0.91) presumably results from mixing of the older grains and the younger ones. The model $^{207}Pb^*/^{206}Pb^*$ ages of the older 3 grains (mer#9, mer#10, and mer#11) are calculated to be ~3923 – 4221 Ma, with a weighted mean of 4177 ± 162 Ma (Fig. 4). The model $^{207}Pb^*/^{206}Pb^*$ age of the apatite grain is 4157 + 79/ - 85 Ma. The zircon provides the oldest model $^{207}Pb^*/^{206}Pb^*$ age of 4543 ± 26 Ma, which is consistent with the global thermal metamorphism model of Vesta's crust [3]. The older merrillites and apatite indicate that moderate thermal metamorphism due to a collisional event occurred at ~4150 Ma, which was identical to the other brecciated eucrites [4]. Their U-Pb systems have been preserved since then. On the other hand, we found the considerably young metamorphic age (57 Ma) from some merrillites, which has not been reported for other eucrites. One of possible causes of this young age is that the meteorite was shock-reheated and/or weathered at Sahara Desert on the Earth followed by Pb loss. However, our metamorphic age of 57 ± 35 Ma is slightly older than the present. More presumable cause is that a collisional event occurred on the parent body (Vesta or vestoids) at 57 Ma, when the meteorite was ejected. The asteroidal collisional history seems more complex than conventionally expected.

References: [1] Greenwood et al. (2005) *Nature* 435, 916-918. [2] De Sanctis et al. (2012) *Science* 336, 697-700. [3] Iizuka et al. (2019) *GCA* 267, 275-299. [4] Koike et al. (2020) *EPSL* 549, 116497. [5] Sano et al. (1999) *Chem. Geol.* 153, 249-258. [6] Ludwig (2012) [7] Tatsumoto et al. (1973) *Science* 180, 1279 [8] Goldman et al. (2015) *GCA* 48, 145-18 [9] A. Yamaguchi et al. (2009) *GCA* 73, 7162-7182.

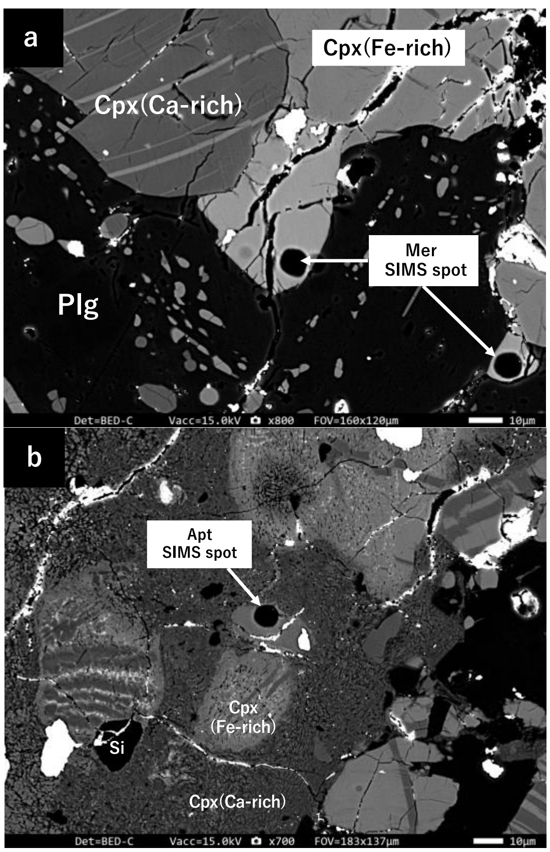

Fig. 1. Back-scattered electron images of the NWA 13166 phosphates in (a) the lithic clast and (b) the recrystallized matrix area. In both lithologies, pyroxenes have exsolution texture. The abbreviations are Apt: apatite, Mer: merrillite Cpx: pigeonite (Fe-rich) and augite (Ca-rich), Plg: plagioclase, Si: silica minerals

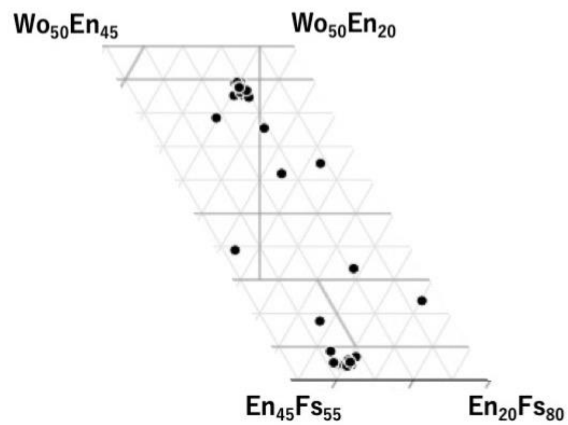

Fig. 2. Pyroxene quadrilateral. Obtained composition of pyroxenes are plotted. The abbreviations are En: enstatite [$MgSiO_3$], Fs: ferrosilite [$FeSiO_3$], Wo: wollastonite [$CaSiO_3$]

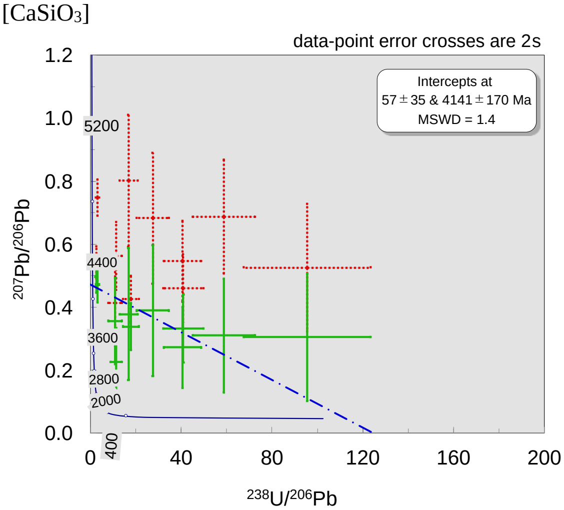

Fig. 3. Three-dimensional U-Pb isochron of merrillite in NWA 13166. The upper and lower intercepts indicate the U-Pb system was reset at 4141±170Ma and disturbed at 57±35Ma.

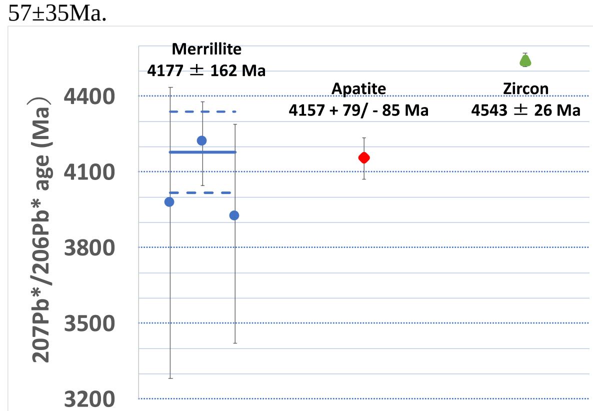

Fig. 4. The model $^{207}Pb^{*}/^{206}Pb^{*}$ ages of the phosphates and zircon found in this study of NWA 13166. (Starting from the left: mer#9, mer#10, mer#11, apt#1, zrn#1)