

EVOLVED COMPONENTS IN THE LAYERED EUCRITE NORTHWEST AFRICA 8021. Y. He¹, X. W. Liu¹ and A. C. Zhang¹, ¹School of Earth Sciences and Engineering, Nanjing University, Nanjing 210023, China, E-mail: heyang@smail.nju.edu.cn.

Introduction: Evolved components are critical for understanding the differentiation degrees of asteroids. Howardite-eucrite-diogenite (HED) meteorites are a group of mafic to ultramafic achondrites, which are thought to be derived from asteroid 4-Vesta based on their similar reflectance spectra [1–3]. A few highly-evolved components have been reported in howardites and eucrite [4–9]. Their presences indicate a complex and diverse evolution of the parent body of HED meteorites.

In this study, we performed mineralogical and petrological study of the brecciated eucrite Northwest Africa (NWA) 8021. This meteorite contains a portion demonstrating a layered structure, with one layer distinctly differing from the other layers by the enrichment of silica phases, K-feldspar, and ilmenite. The evolved components recorded in NWA 8021 may shed light on the diverse evolution on Vesta.

Results: The two polished sections of NWA 8021 in this study demonstrate a zoned texture (Fig. 1), and are divided into three zones (Zone-A, Zone-B, and Zone-C, Fig. 1) based on the petrography and mineral assemblages.

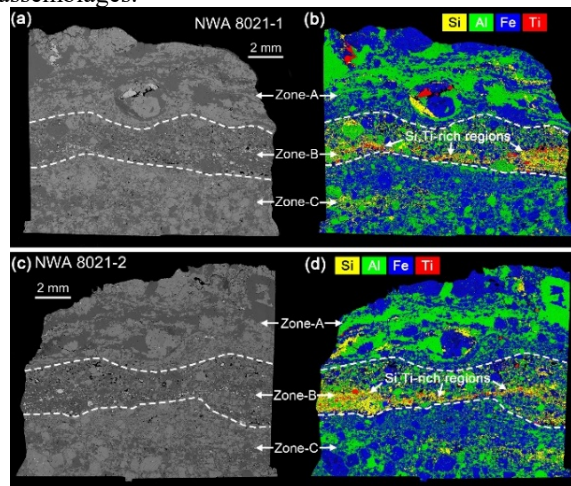


Fig. 1: Mosaic backscattered electron images (a and c) and combined X-ray elemental mapping results (b and d) of the two polished sections of the eucrite NWA 8021.

Zone-A and Zone-C have a brecciated texture and are composed of typically eucritic components (pyroxene, plagioclase, silica, ilmenite, chromite, and troilite). The compositions of pyroxene are $\text{En}_{29-41}\text{Fs}_{26-63}\text{Wo}_{2-44}$ with Fe/Mn values (27–31) consistent with the trend for typical HED pyroxene. Plagioclase is highly anorthitic (An_{87-94}).

Zone-B is approximately 2–4 mm in width and consists mainly of relatively fine-grained mineral fragments with minor amounts of lithic clasts. Zone-B are dominated by mineral fragments of pyroxene, plagioclase, silica phases (25.4 vol%), and ilmenite (3.2 vol%). Accessory minerals contain troilite, chromite, Ca-phosphate minerals, K-feldspar, zircon, and titanite. The pyroxene grains in this zone have a large chemical variation ($\text{En}_{8-43}\text{Fs}_{22-62}\text{Wo}_{1-46}$). The compositions of plagioclase are An_{86-90} . One of the characteristic features of Zone-B is the presence of Si,Ti-rich regions (Fig. 1), which have high modal abundances of silica phases (51.8 vol%) and ilmenite (9.4 vol%). The Si,Ti-rich regions also display a layered occurrence in Zone-B.

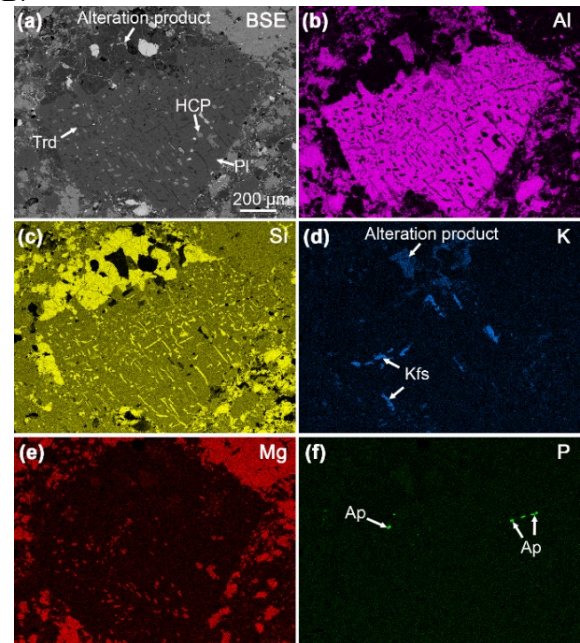


Fig. 2: Backscattered electron image (a) and X-ray elemental mapping results (b-f) of one graphic clast from Zone-B. Pl: plagioclase; HCP: high-Ca pyroxene; Trd: tridymite; Kfs: K-feldspar; Ap: apatite.

A few lithic clasts in Zone-B exhibit a graphic texture (abbreviated as graphic clasts, Fig. 2). They are mainly composed of host plagioclase and rod-like inclusions of silica phases (quartz, tridymite, and cristobalite), augite, Ca-phosphate minerals, and K-feldspar. In some of these graphic clasts, a few relatively coarse grains of K-feldspar (up to 150 μm in size), augite (up to 100 μm in size), and quartz are also present. The rod-like high-Ca pyroxene grains and relatively

coarse high-Ca pyroxene grains have similar major-element compositions ($\text{En}_{26-28}\text{Fs}_{27-32}\text{Wo}_{41-45}$). But the rod-like high-Ca pyroxene contains slightly higher TiO_2 contents (0.4–0.8 wt%) and lower Cr_2O_3 contents (0.1–0.2 wt%) than the relatively coarse grained high-Ca pyroxene (0.3–0.4 wt% TiO_2 and 0.2–0.3 wt% Cr_2O_3). The relatively coarse-grained orthoclase in the graphic clasts contains higher BaO (2.5–4.5 wt%) than the rod-like orthoclase (0.4–1.4 wt%).

Augite grains in Zone-A and Zone-C show a HREE-enriched pattern ($\text{La}_n/\text{Lu}_n=0.11\text{--}0.46$ and $\text{Lu}=17\text{--}21^*\text{CI}$) with a strongly negative Eu anomaly ($\text{Eu}/\text{Eu}^*=0.03\text{--}0.12$). One polycrystalline augite grain in Zone-B was measured with high REE concentration and HREE-enriched pattern ($\text{La}_n/\text{Lu}_n=0.31$, $\text{Lu}=61^*\text{CI}$). Augite grains in the graphic clasts also show HREE-enriched pattern and have the highest REE concentrations in this study (e.g., $\text{Lu}=51\text{--}103^*\text{CI}$). All the measured plagioclase grains from the three zones are LREE-enriched with a strongly positive Eu anomaly and a limited concentration variation. Both merrillite (e.g., $\text{La}=30000^*\text{CI}$) and apatite (e.g., $\text{La}=200\text{--}550^*\text{CI}$) are LREE-enriched and show a strongly negative Eu anomaly ($\text{Eu}/\text{Eu}^*=0.03$ and $0.13\text{--}0.16$, respectively).

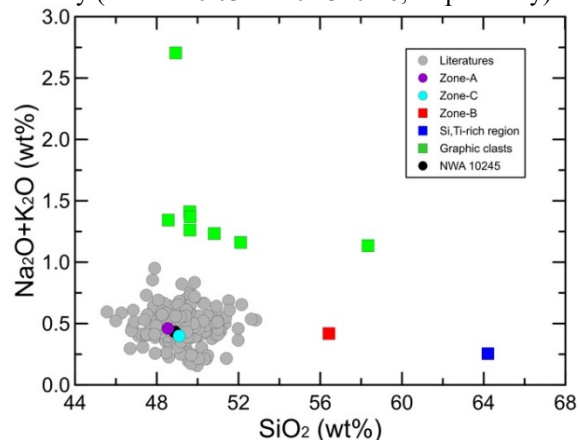


Fig. 3: Bulk chemical compositions of different regions or components in NWA 8021.

Bulk compositions of different regions and lithic clasts were calculated by the modal recombination analysis (MRA) method, following the procedure described in [10]. The results are shown in Fig. 3. The Si,Ti-rich regions have a high bulk SiO_2 content of 64.2 wt%. The graphic clasts have distinctly high $\text{Na}_2\text{O}+\text{K}_2\text{O}$ contents (1.2–2.7 wt%) while the SiO_2 contents have a large variation (48.6–58.4 wt%).

Discussion and Conclusion: The mineral assemblages observed in the Si,Ti-rich regions and graphic clasts in NWA 8021 are very similar to late-stage mineral assemblages in eucritic basalts or gabbros [7, 8]. However, the brecciated texture and the layered occurrence of the Si,Ti-rich regions argue against the

possibility of being a late-stage region in typical eucrites. Moreover, no late-stage mineral assemblages with the graphic texture have been reported. Here, we suggest that the graphic clasts and Si,Ti-rich regions in NWA 8021 are fragments from evolved rocks in the eucrite parent body.

The two types of K-feldspar and augite (rod-like and relatively coarse-grained) in the graphic clasts with different chemical features suggest that they have different origins. Two scenarios can be employed to explain the formation of the graphic clasts. First, an evolved magma intruded into the subsurface crust of the eucrite parent body and assimilated by the parental rock of the relatively coarse-grained orthoclase and high-Ca pyroxene. Second, an impact event that largely melted a pre-existing evolved rock and the graphic textures then formed during the subsequent crystallization with minor relatively coarse-grained K-feldspar and high-Ca pyroxene unmelted.

The Si,Ti-rich regions contain approximately 52 vol% silica phases and 9 vol% ilmenite. Such high modal abundances of silica phases and ilmenite have not been described for eucrite in literature. The REE concentrations of augite from the Zone-B and the graphic clasts are higher than typical eucritic augite from Zone-A and Zone-C. These features indicate they are new highly-evolved components in the eucrite parent body. Meanwhile, the highly-evolved components are different from those in previous investigations [7, 8], implying that the eucrite parent body experienced more diverse and complex evolution than previous thought.

References: [1] Russell C. T. et al. (2012) *Science*, 33, 684–686. [2] McCord T. B. et al. (1970) *Science*, 168, 1445–1447. [3] McSween H. Y. et al. (2013) *Meteorit. & Planet. Sci.*, 48, 2090–2104. [4] Takeda H. (1986) *JGR*, 91, D355–D363. [5] Barrat J. A. (2009a) *Meteorit. & Planet. Sci.*, 44, 359–374. [6] Barrat J. A. (2009b) *GCA*, 73, 5944–5958. [7] Barrat J. A. (2012) *GCA*, 99, 193–205. [8] Hahn T. M. et al. (2017) *Meteorit. & Planet. Sci.*, 52, 1173–1196. [9] Warren P. H. (2017) *80th Annual MetSoc Meeting*, #6162. [10] Seddio S. M. et al. (2013) *Am. Mineral.* 98, 1697–1713.

Acknowledgements: This work was financially supported by research grants from Natural Science Foundation of China (42025302, 41973061, 41673068), the B-type Strategic Priority Program of the Chinese Academy of Sciences (XDB41000000), and a pre-research Project on Civil Aerospace Technologies funded by CNSA (grant D020204).