UNGROUPED ACHONDRITE NORTHWEST AFRICA 13272/13351 IS A CHONDRITE MELT BRECCIA COMPOSED OF L4 AND L7 MATERIALS. Zilong Wang[1,2], Wei Tian[1], and Wei-(RZ) Wang[2], [1]School of Earth and Space Sciences, Peking University, Beijing 100871, China [zilong.wang@pku.edu.cn; davidtian@pku.edu.cn], [2]Key Laboratory of Paleomagnetism and Tectonic Reconstruction of MNR, Institute of Geomechanics, Chinese Academy of Geological Sciences, Beijing 100871, China.

Introduction: Northwest Africa (NWA) 13272 and its paired stone NWA 13351 were found at the same location in Mauritania in 2019. These two meteorites are classified as ungrouped achondrites in The Meteoritical Bulletin No. 109 [1]. The unique brown and black appearance of these meteorites has aroused extensive interest in their petrogenesis.

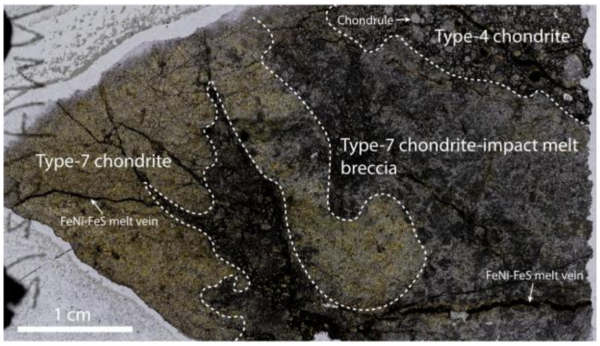

Fig. 1. Optical image of NWA 13272 thin section.

Results: NWA 13272/13351 can be divided into three petrologic lithologies: Type-4 chondrite, Type-7 chondrite, and Type-7 chondrite-impact melt breccia (Fig. 1). The brownish regions are weathered chondrite exhibiting igneous texture, while the darkish regions are a mixture of chondritic breccia and shock-darkened melt enriched in opaque phases (chromite, FeNi metal/oxides, and troilite).

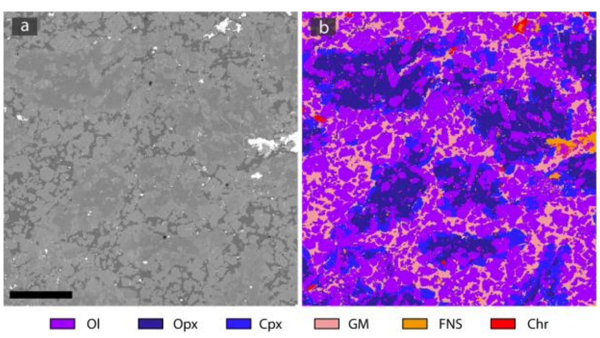

Fig. 2. The petrology of Type-7 chondrite lithology in NWA 13272/13351. (a) BSE image. (b) The phase-distribution map corresponding to (a). The black bar indicates a scale of 500 µm. Ol – olivine; Opx – orthopyroxene; Cpx – clinopyroxene; GM – groundmass; FNS – FeNi-FeS alloy; Chr – chromite.

The mineral modal abundance of the thin section (Fig. 1) is olivine 47.29%, orthopyroxene 26.06%, clinopyroxene 8.84%, groundmass 12.19%, FeNi+FeS 5.1%, chromite 0.53%.

The region of Type-4 chondritic lithology exhibits abundant well-defined chondrules, which is quite akin to those in Type-4 chondrites (Fig. 1). The region of Type-7 chondritic lithology presents poikilitic igneous texture, with olivine and pyroxene grains embedded in glassy groundmass (Fig. 2a). The orthopyroxene usually encloses olivine, and is surrounded by clinopyroxene, forming inside-out ol-opx-cpx assemblage (Fig. 2b). Groundmass distributes outside the ol-opx-cpx assemblage. The compositions of olivine and pyroxene in this region are indistinguishable from those in the Type-4 chondrite region. However, plagioclase and chondrule are absent in the region. The igneous texture indicates that this region has been completely melted before impact brecciation, therefore, the region should belong to a part of Type-7 chondrite.

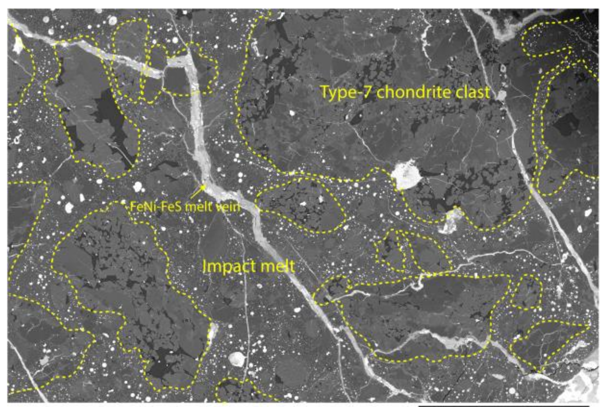

Fig. 3. BSE image of Type-7 chondrite-impact melt breccia in NWA 13272/13351. Yellow dashed curves outline the main silicate clasts present. The black bar indicates a scale of 500 µm.

The region of Type-7 chondrite-impact melt breccia is composed of Type-7 chondritic rounded clasts textually and compositionally analogous to the region of Type-7 chondritic lithology, and fine-grained impact melt with abundant immiscible spherical sulfides (Fig. 3). The silicate breccias and impact melt are coherently cut by straight or network-like sulfide veins (Fig. 3). No high-pressure mineral typically produced by impact (e.g. majorite and ringwoodite, [2]) is found in this region.

The groundmass can be classified as trachytic in average composition with 65.7 wt.% SiO_2, 19.4 wt.% Al_2O_3, 1.2 wt.% FeO, 0.4 wt.% MgO, 2.5 wt.% CaO, 7.5 wt.% Na_2O, 0.7 wt.% K_2O, and 1.1 wt.% P_2O_5, corresponding to a CIPW normalization content of 17 wt.% quartz, 67 wt.% plagioclase, 4 wt.% orthoclase, and 3 wt.% hypersthene. This result indicates that the groundmass is mainly formed by the remelting of Na-plagioclase, quartz, and minor mafic minerals. It is noted that the reported remarkably low Na_2O content (1.0 wt.%) of groundmass in NWA 13351 in the Meteoritical Bulletin Database could be due to a loss of Na in the alkaline-rich glass during EMP measurement. EPMA results show a measured groundmass Na_2O content of 0.8-1.3 wt.% at a condition of 15kV, 10nA, and a focused beam size of 2 µm. However, when the beam size is set to be 5 and 10 µm, the measured Na_2O content raises to 4 and 7 wt.% respectively. Therefore, a defocused beam (>10 µm) and low current (10 nA) should be used to acquire the exact EPMA contents of glassy groundmass in NWA 13272/13351.

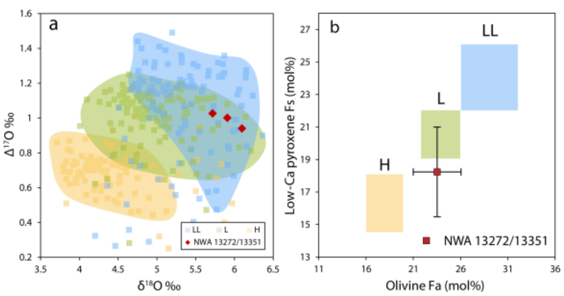

Fig. 4. Classification parameters of NWA 13272/13351 compared to ordinary-chondrite group ranges. (a) Oxygen isotopes. (b) Fayalite (Fa) vs. ferrosilite (Fs) compositions, modified after [3]. The oxygen isotope data are from Meteoritical Bulletin Database.

Classification: The bulk triple-oxygen isotope data of NWA 13272/13351 are consistent with those of L and LL chondrites (Fig. 4a). The olivine compositions (Fa_{21-26}, n = 22) fall within the L-group range (Fig. 4b). The low-Ca pyroxene compositions (Fs_{15-21}, n = 9) is slightly lower than the L-group range, but this is likely due to Fe priority loss during impact melting [3]. Besides, EDS data reveals that no discernable Co content is identified in FeNi metal, consistent with low Co content of L-group chondrites (<1 wt.% in FeNi metal) [3]. The bulk composition of NWA 13272/13351 has a higher Fe/Si ratio of 0.77 but lower FeO content of 16.11 wt.% than L-group chondrite (0.57 and 22 wt.% respectively [4]), probably due to the mobility of Fe and Si during impact melting. Therefore, we conclude that NWA 13272/13351 is an L chondrite, composed of L4 and L7 silicate clasts and recrystallized impact melt.

Implications: The poikilitic igneous texture and the absence of plagioclase in the region of Type-7 chondritic lithology are unusual for Type-7 chondrites, which typically exhibit poikilitic to equigranular metamorphic texture and contain plagioclase [5]. Besides, the two-pyroxene thermometer [6] indicates an equilibrium temperature range of 1118-1124 °C (n = 6), which is supersolidus predicted by MELTS (solidus at ~1027 °C). This indicates that the Type-7 chondritic lithology in NWA 13272/13351 may have originated from melt solidification (instead of subsolidus metamorphism). After the crystallization of olivine and pyroxene, the cooling rate was high enough to inhibit the plagioclase formation from the glassy groundmass. The melt could be produced by large-scale impact heating, or by endogenous magmatism on the L chondrite parent body. Therefore, it would be intriguing to unravel the igneous processes undergone in the parent body through the meteorite. On 4 Vesta, whether the driving force of eucrite evolution comes from volcanism or impact remains an unresolved problem [7]. However, based on the comparisons between the cases on the L chondrite parent body and 4 Vesta, it is hopeful to better understand the igneous process on small bodies in our solar system.

Conclusions: Three lithologies (Type-4 chondrite, Type-7 chondrite, and Type-7 chondrite-impact melt breccia) are present in ungrouped achondrite NWA 13272/13351. The mineralogy and isotope chemistry of the meteorite indicate that they have an affinity to L chondrites. The meteorite was low-degree shocked, but has undergone remarkable igneous processes during its formation. The pristine Type-7 chondritic lithology in the meteorite originated from magma crystallization, possibly indicating large-scale impact heating or early-stage endogenous magmatism on the L chondrite parent body. Further studies would enhance our understanding of these processes.

Acknowledgments: We thank Huijuan Li for assisting with EPMA measurements. This research is financially supported by the National Natural Science Foundation of China (Grant Number 42272348).

References: [1] Gattacceca J. (2021) *Meteoritics & Planet. Sci., 56, 8,* 1626–1630. [2] Xie Z. D. et al. (2016) *GCA, 70, 2,* 504–515. [3] Li Y. et al. (2020) *JGR Planets, 125,* e2019JE006360. [4] Váci Z. et al. (2020) *Meteoritics & Planet. Sci., 55, Nr 3,* 622–648. [5] Tait A. W. (2014) *GCA, 134,* 175–196. [6] Taylor W. R. (1998) NJM, 381–408. [7] Mittlefehldt D. W. (2015) *Geochemistry, 75, 2,* 155–183.