EUCRITE-MELT BRECCIA JIKHARRA 001: A POTENTIAL WINDOW FOR UNDERSTANDING THE PETROGENESIS OF FERROAN ANOMALOUS EUCRITES.

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Introduction: Although the majority of eucrites share similar petrology, mineralogy, and isotope geochemistry, there is evidence that some eucrites and eucritic clasts have compositions deviant from main-group eucrites [1, 2]. Recently, a series of anomalous eucrites have been identified, which are characterized by abnormally low En content of pyroxene (e.g. Northwest Africa (NWA) 11729, NWA 12445, NWA 13981, NWA 15076, NWA 15202). The petrogenesis of these ferroan eucrites has thus become an enigmatic problem.

Large-scale impact reheating process may produce impact melt with high contents of siderophile and incompatible elements, which could be the parental magma of evolved igneous rocks [3]. Most of the ferroan anomalous eucrites are highly shocked and contain recrystallized mesostasis, indicating that impact reheating may play an essential role in their formation. As such, studies of eucrite-melt breccia may help to better understand the nature of impact melt and may provide valuable information on the formation of ferroan anomalous eucrites.

A new eucrite-melt breccia meteorite, Jikharra 001, was recovered in Northeastern Libya in 2022. At least 2.5 metric tons of fragments were collected, making it the largest eucrite-melt breccia ever reported. This study presents the preliminary petrologic and mineralogic results of the sample, which could provide implications for the nature of parental magma of ferroan anomalous eucrites.

Results: Two distinct domains are classified in the Jikharra 001 (Fig. 1). One domain represents recrystallized melt, and the other represents restites after impact melting.

Recrystallized melt. The recrystallized melt is ophitic with 15 vol% pores, comprised of needle-like plagioclase and zoned clinopyroxene, with accessory silica, Fe-Ti oxides, and troilite (Fig. 1a). The plagioclase has an average width of 5-10 μm, with an average composition of An_{88} and 1.5 wt% FeO. The clinopyroxene is chemically zoned from pigeonite cores ($Wo_{8-10}En_{48-56}$) to ferroan augite rims ($Wo_{17-22}En_{21-24}$) (Fig. 2). Ulvöspinel, ilmenite, and troilite usually coexist in the interstitial regions.

Restites. The restites present two lithologies (hereinafter referred to as Res-1 and Res-2). Res-1 consists of lathlike plagioclase (~50 μm in width, An_{91}) and clinopyroxene ($Wo_{9-12}En_{33-35}$, Fig. 2), with minor silica, Cr-Ti-spinel (Cr#25), and troilite (Fig. 1b). Res-2 consists of larger plagioclase (~200-250 μm in width, An_{95}) and orthopyroxene ($Wo_{1-5}En_{56-60}$, Fig. 2), with minor Ti-bearing chromite (Cr#68) and troilite. Chemical zonings are absent from these minerals. Tidy needle-like plagioclase grains are superimposed on the mineral boundaries in these restites.

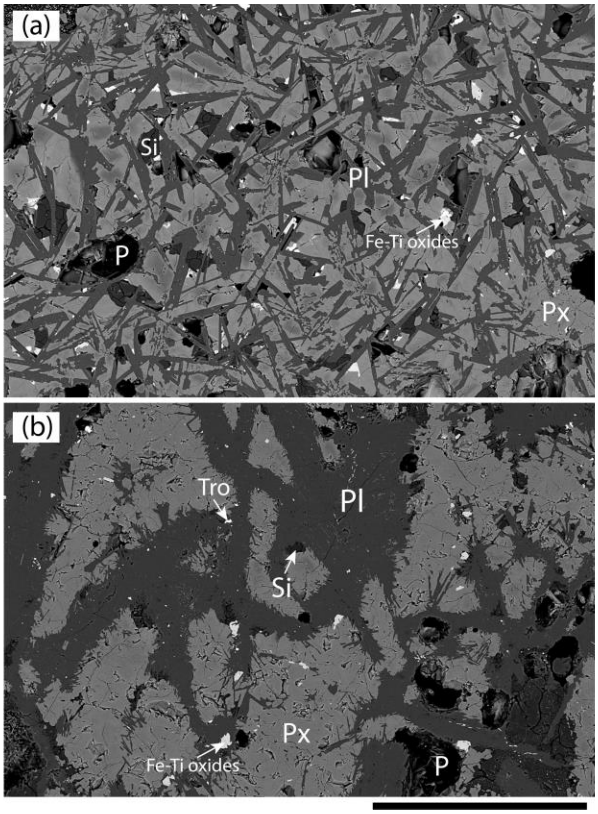

Fig. 1. The backscattered electron images of Jikharra 001. (a) Recrystallized melt. (b) Restites. The black bar indicates a scale of 300 μm. P=pores, Px=pyroxene, Pl=plagioclase, Si=silica, Tro=troilite.

Discussions: The fine-grained plagioclase and zoned clinopyroxene of recrystallized melt indicate the melt has undergone fast crystal growth and cooling after impact heating. 1-bar pyroxene geothermometer [4] indicates that the clinopyroxene crystallized at ~1000 °C, suggestive of near-isothermally fast growth (Fig. 2). At ~$Wo_{14}En_{30}$, the clinopyroxene composition enters the metastable "forbidden zone". Using the average size of plagioclase (5-10 μm), the cooling rate can be estimated as ~50-150 °C/h [5]. Such a cooling rate is fast enough to stabilize the clinopyroxene within the forbidden zone. Besides, the co-existing ilmenite and titanomagnetite equilibrated at an oxygen fugacity (fO_2) of IW – 1.25 ± 0.25 and a temperature range of 890-920 °C using Fe-Ti oxide thermo-oxybarometry [6], typical for the case of eucrites (IW ~ IW – 2, [7]).

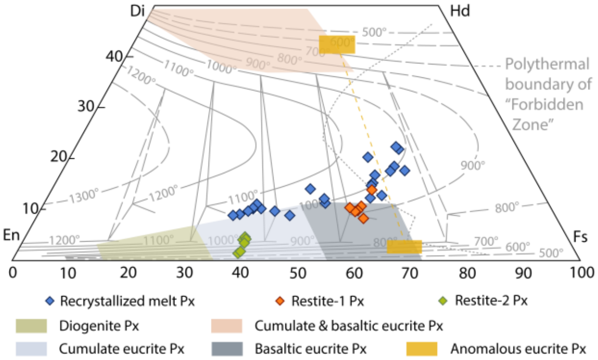

Fig. 2. Quadrilateral pyroxene composition of pyroxenes analyzed in Jikharra 001. Colored ranges for compositions of pyroxenes in diogenites, cumulate, and basaltic eucrites are from [8]. The composition range of anomalous eucrite pyroxene is from Meteoritical Bulletin Database.

The two lithologies of the restites have distinct mineralogy. Res-2 contains Mg-rich pyroxene and Cr-rich spinel relative to those in Res-1, implying that Res-2 has more primary compositions than Res-1. The pyroxene compositions of Res-1 fall within the range of basaltic eucrites, while those of Res-2 fall within the range of cumulate eucrites. In addition, minerals in Res-2 have remarkably larger sizes than those in Res-1, probably suggesting that Res-2 originated from a deeper location than Res-1 on their parent body. These interpretations suggest that the impact event has at least mixed upper-crust materials at different depths on their parent body, and the composition of the recrystallized melt is controlled by at least two end-member source rocks.

Relative to those of restites, the composition of recrystallized melt has more sodic compositions of plagioclase and lower En contents of pyroxene. It is noted that the clinopyroxene within the forbidden zone would exsolve to high-Ca and low-Ca pyroxene phases if the cooling rate is low enough (Fig. 2). Therefore, the pyroxene compositions observed in ferroan anomalous eucrites could be produced by the slow cooling of magma with compositions akin to recrystallized melt in Jikharra 001. The somewhat sodic plagioclase present in the recrystallized melt is also compositionally akin to those observed in ferroan anomalous eucrites. Besides, the presence of low-Cr ulvöspinel in the recrystallized melt also suggests the evolved nature of impact melt, consistent with the absence of Cr-bearing minerals in ferroan anomalous eucrites. Therefore, it would be expected to produce the lithology of ferroan anomalous eucrites, if the impact melt was buried deep within the regolith to cool slowly, after the impact excavation. Considering that the concentrations of siderophile and incompatible elements in the melt are dependent on the melting degree, the varying compositions of ferroan anomalous eucrites could be attributed to the variable degree of partial melting during the impact reheating event.

Future Work: It is noted that the large-scale fractional crystallization and crustal assimilation (as in the case of Stannern trend eucrites, [9]) could also produce evolved melt akin to the bulk compositions of ferroan anomalous eucrites. Therefore, it is essential to distinguish the nature of evolved melt produced by distinct igneous scenarios. This could include determining the bulk major and minor compositions of recrystallized melt and restite, then calculating the composition of source rock and modeling the degree and scale of partial melting. In addition, subsequent triple oxygen isotope data would probably further constrain the parent body of the meteorite, and the effect of impact melting on the isotope fractionation. These may have great potential to help us better understand the petrogenesis of Fe- and incompatible elements-rich anomalous eucrites.

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