A NEW OCCURRENCE OF PHOSPHORAN OLIVINE IN UNGROUPED ACHONDRITE NORTHWEST AFRICA 12319.

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Introduction: Northwest Africa (NWA) 12319 was found in the desert of Northwest Africa in 2018 and classified as a brecciated dunite with pyroxene, plagioclase, chromite, and troilite [1]. Fe/Mn and oxygen isotopes show that NWA 12319 is an ungrouped achondrite, paired with other three dunitic achondrites Queen Alexandra Range (QUE) 93148, NWA 12217, and NWA 12562 [1]. Dunitic rocks carry important information about the interior of planetesimals, however, they are relatively rare in the meteorite collections. In this study, we perform detailed investigations on NWA 12319 and identify a new occurrence of phosphoran olivine, its possible origin will be discussed.

Analytical methods: Petrographic investigations and analysis of mineral compositions were performed by using field emission scanning electron microscope (FEI Scios Dual Beam FIB-SEM) and electron probe microanalysis (JXA 8230), respectively, at the Institute of Geochemistry, Chinese Academy of Sciences.

Results & Discussion: NWA 12319 is mainly consisting of olivine (up to 5 mm, ~ 70–80 vol%) and pyroxene fragments. Minor phases include plagioclase (An_{58-82}), chromite, troilite, FeNi metal, silica phase, and rare schreibersite (300 μm). Some pyroxene fragments show exsolution lamellae of high-Ca augite. Olivine and pyroxene show relatively wide compositional range（Figs. 1–2), with the Fo value of olivine varying from 11 to 91 (Fig. 1) and the Mg# of pyroxene ranging from 22 to 93, consistent with the diverse lithologies observed in NWA 12319.

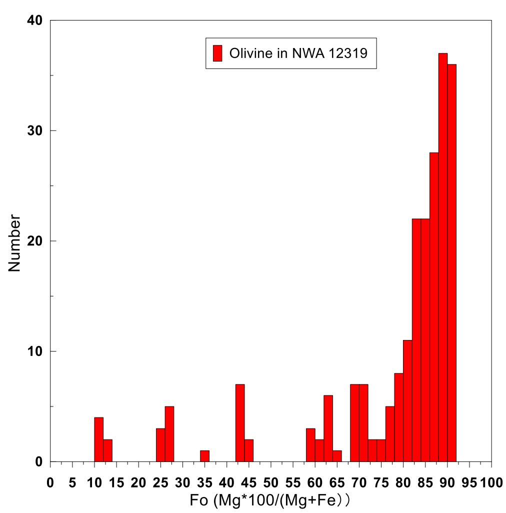

Figure 1. Composition of olivine in NWA 12319.

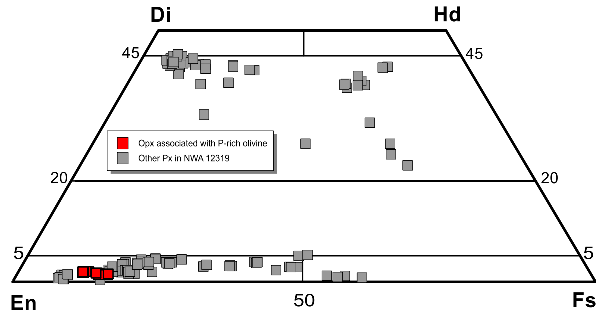

Figure 2. Composition of pyroxene in NWA 12319. The pyroxene associated with P-rich olivine is highlighted in red.

P-rich olivine was found closely associated with troilite, chromite, nickelphosphide $(Ni,Fe)_{3.1-3.2}P$, merrillite (inferred from EDS), and orthopyroxene (Fig. 3). Troilite and nickelphosphide have two size groups, the coarse-grained and the fine-grained group, the latter intimately grow with the P-rich olivine, orthopyroxene, and merrillite. The clast containing P-rich olivine show sharp contact against the P-free olivine and orthopyroxene nearby. The P-rich olivine contains 6.8–12.4 wt% P_2O_5, whereas the P_2O_5 in the associated orthopyroxene ($En_{83-87}Fs_{11-16}Wo_{1-2}$) is 0.10–0.68 wt%. The low NiO (0.05–0.25 wt%) and CaO (0.02–0.09 wt%) in P-rich olivine exclude the possibility that the enrichment of P is due to contamination from nickelphosphide and merrillite. Two types of chromite (chromite-I and chromite-II) are observed, chromite-I is virtually pure chromite ($Chr_{99.5}Spl_{0.1}Usp_{0.4}$), occurring at the margin of the clast, whereas chromite-II ($Chr_{76}Spl_{23}Usp_{2}$) occurs as inclusion in troilite (Fig. 3).

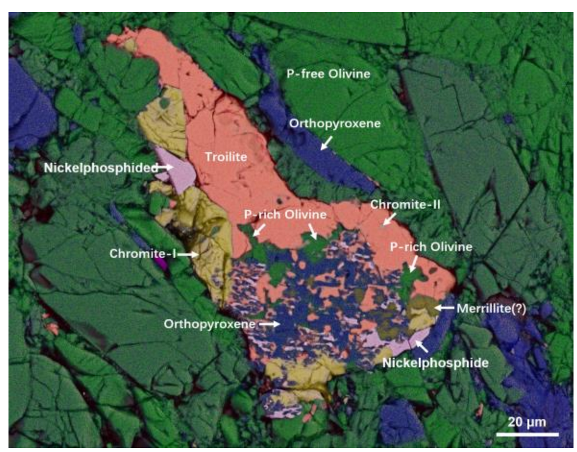

Figure 3. Phase map of the mineral assemblage of P-rich olivine, troilite, chromite, nickelphosphide, merrillite, and orthopyroxene.

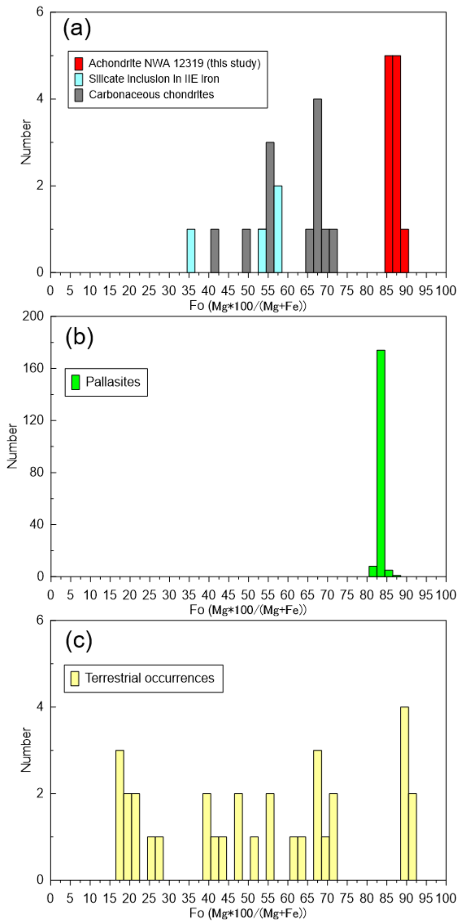

Figure 4. (a-c) Fo value of P-rich olivine in NWA 12319, carbonaceous chondrites, silicate inclusion in IIE iron meteorite, pallasites, and terrestrial occurrences [2–12].

P-rich olivine (> 1 wt%) has been described in extraterrestrial rocks. including pallasites [2–5], carbonaceous chondrites [6–7], and silicate inclusion in IIE iron meteorite [8]. P-rich olivine have also been found in the terrestrial rocks [9–10] and the manufactured objects [11–12]. However, to our knowledge, it is the first description of this mineral in a stony achondrite.

Previous studies have proposed two mechanisms for the formation of P-rich olivine by crystallization from high-T, P-rich melts [2–6, 8–12], or fluid-assisted metamorphism in carbonaceous chondrite [7]. In NWA 12319, the Fe/Mn ratio of P-rich olivine (31–43) are unlike the P-rich olivine in carbonaceous chondrites (e.g., 111–195 in [6], 111–147 in [7]), but falling with the range of other olivine (Fe/Mn=27–67) in NWA 12319, which implies that the clast is not of chondritic origin. The Fo value (86-89) of P-rich olivine in NWA 12319 is much higher than other P-rich olivine (with few exceptions in terrestrial rocks), but comparable to those in pallasites (81–87) (Fig. 4). It is well known that pallasites are materials sampling the core-mantle boundary. Similarly, the P-rich olivine in NWA 12319 might also originate from the core-mantle boundary. The presence of abundant high Fo (> 90), P-free olivine in NWA 12319 (Fig. 1), which might be of mantle origin, lends additional support to this inference. Therefore, we propose that the P-rich olivine in NWA 12319 might also form by crystallization from high-T, P-rich melts, which are residual melts after fractional crystallization of metal core [8, 13–14]. The linear correlation between Si and P of P-rich olivine in NWA 12319 are consistent the substitution scheme of $2Si^{4+} + {}^{VI}M^{2+} \longleftrightarrow 2P^{5+} + {}^{VI}\square$, as proposed in previous studies [5, 7, 12]. FIB-TEM investigations are undertaken to better characterize the structure of minerals in Fig. 3.

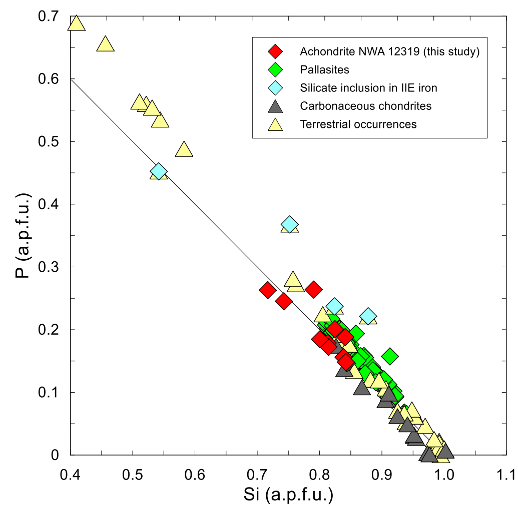

Fig. 5. Linear correlation between Si and P (a.p.f.u.) of P-rich olivine in NWA 12319 and those in the literature [2–12].

Conclusions: NWA 12319 is a highly brecciated achondrite and contains diverse lithologies. The clast containing P-rich olivine in NWA 12319 might be formed by crystallization from the high-T, P-rich residual liquids after core crystallization of asteroid.

References: [1] Meteorit. Bull. no.108, (2020) *Meteorit. Planet. Sci., 55,* 1146–1150. [2] Buseck P. R. (1977) *Geochim. Cosmochim. Acta, 41,* 711–740. [3] Buseck P. R. and Clark L. (1984) *Mineral. Mag., 48,* 229–235. [4] Sonzogni Y. et al. (2009) 72nd *Meteorit. Soc. Mtg.* Abstract #5070. [5] Fowler-Gerace N. A. and Tait K. T. (2013) *Am. Mineral., 100,* 2043–2052. [6] Wang Y. et al. (2007) *Sci. in China Series D: Earth Sci., 50,* 886–896. [7] Li Y. et al. (2017) *Am. Mineral., 102,* 98–107. [8] Van Roosbroek N. (2017) *Geochim. Cosmochim. Acta, 197,* 378–395. [9] Agrell S. O. et al. (1998) *Mineral. Mag., 62,* 265–269. [10] Goodrich C. A. (1984) *Geochim. Cosmochim. Acta, 48,* 2769–2771. [11] Tropper P. et al. (2004) *Eur. J. Mineral., 16,* 631–640. [12] Schneider P. et al. (2013) *Miner. Petrol., 107,* 327–340. [13] Olsen E. et al. (1999) *Meteorit. Planet. Sci., 29,* 200–213. [14] Hacck H. and Scott E.R.D. (1992) *J. Geophys. Res., 97.* 14,727–14,734.