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NORTHWEST AFRICA 4255, AN OLIVINE-BEARING DIOGENITE, RELICS OF PRIMITIVE RESIDUAL MANTLE.

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Introduction:

Diogenites and olivine-bearing diogenite are petrogenetically associated with basaltic magmatism linked to the earliest stages of asteroidal melting on the parent body for the howardite–eucrite–diogenite (HED) meteorites [1]. The HED (Howardite, Eucrite and Diogenite) group meteorites likely originate from the Asteroid 4 Vesta [2]. The petrology and geochemistry of Diogenites is a central issue to understand the magma ocean stage and the differentiation of 4Vesta [3]. In this study we will describe NorthWest Africa 4255, a dimict olivine-bearing Diogenite containing low-Ni iron metal.

Methods: Three polished sections of NWA 4255 with cumulative area of 4cm^2 were studied using electron microprobe (CAMECA SX 100, 15kV, 20nA), and scanning electron microscope (Jeol JSM-5910 LV) and whole-rock analyses were done by ICPMS solution (Agilent 7500CX) in Magmas & Volcanoes laboratory–Clermont-Ferrand-France.

Petrology and texture:

The sample is mainly composed of orthopyroxenes, and chromite, scarce olivine and low-Ni iron metal. Clinopyroxene appears as trace in large orthopyroxene. The sample displays shocked texture, with finely fragmented or brecciated zones. We observe two lithologies that consist of olivine, iron metal and orthopyroxene (Fig.1) and another with orthopyroxene, spinel and sulfide.

The orthopyroxene is centimeter scale, associated with spinel and sulfide inclusions. Large porphyroclasts are preserved in an orthopyroxene breccia. There are also some unusually orthopyroxene found as inclusion in olivines. These orthopyroxenes are xenomorphic and show tortuous boundaries **(Fig.2).** The distribution of olivines is heterogeneous, and olivine appears as millimeter sized fragmented crystals in magmatic contact with large orthopyroxene, or as small (2-50µm) rounded inclusions in orthopyroxene.

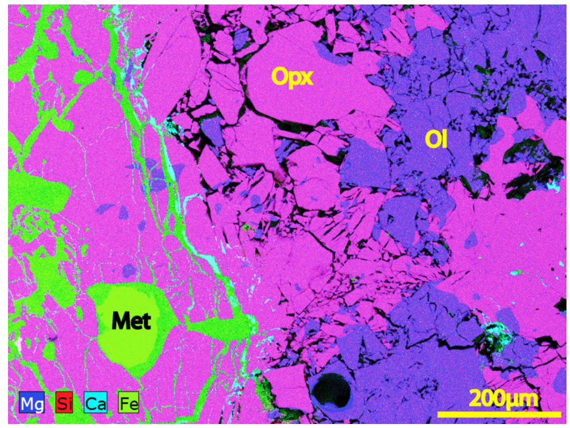

Fig.1: EDS image representing X-ray mapping, showing the distribution of constituent minerals of NWA 4255 Diogenite ; Opx: Orthopyroxene, Ol: Olivine, Met: Metal.

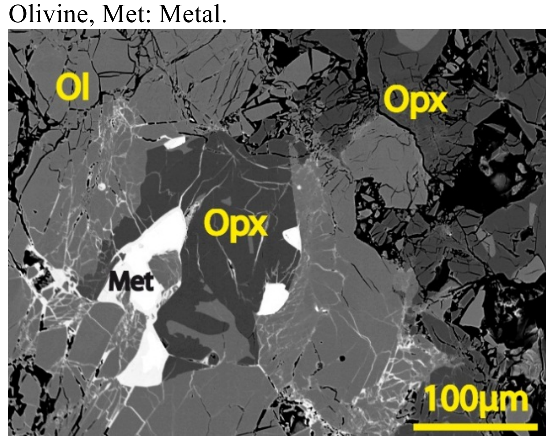

Fig.2: Back scattered electron (BSE) image of the Diogenite NWA 4255 showing an orthopyroxene associated with metal inclusion in olivine.

Chromite appears as large sub-automorph fragmented crystals, (100-500µm) between orthopyroxene grains or as line of micrometric inclusions in cleavage plans of orthopyroxene. It is more abundant in areas without olivines

The iron metal occurs as irregular shaped. It appears as small grains in the orthopyroxene and sometime associated with olivine. Probably under shock, the metal is injected into the fragmented orthopyroxene and seals the fractures. These areas are preferentially weathered and the metal slightly transformed into limonite.

Composition:

Electron microprobe analyses yielded relatively high magnesian orthopyroxene compositions and bimodal distribution **(Fig.3)** linked to lithologic associations. Large orthopyroxene crystals display homogeneous composition ($En_{73.69-74.52}$ $Wo_{1.31-1.76}$) with relatively high Al_2O_3 (0.26-0.45wt%), CaO (0.72-0.88wt%) and low Cr_2O_3 (0.21-0.42wt%) contents. Orthopyroxenes included in olivine displays a wider range of composition and are more magnesian ($En_{70.24-75.89}$ $Wo_{1.17-1.75}$) with lower Al_2O_3 (0.12-0.19wt%,), CaO (0.67% to 0.73wt%) and higher Cr_2O_3 (0.60-0.90wt%) contents than main orthopyroxene.

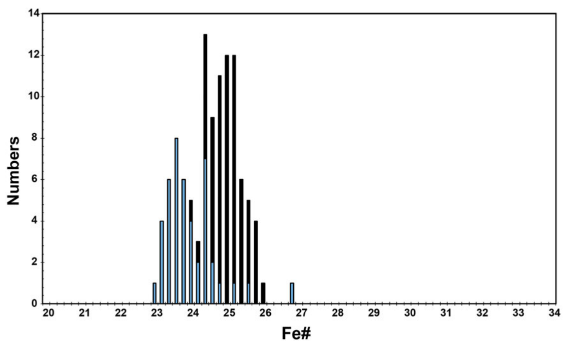

Fig.3: Distribution of Fe# of orthopyroxenes showing the bimodal distribution, less ferroan correspond to orthopyroxene included in olivine

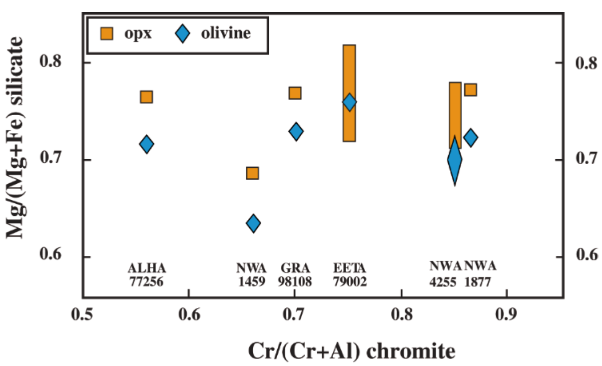

Fig.4 : Mg# for silicates versus Cr# for chromite show a comparison between NWA 4255 and other olivine diogenites [4].

Olivine displays a wide asymmetric unimodal composition (Fa_{25-32}) with an average of Fa_{28} for largest crystal and more ferroan for small rounded inclusions in orthopyroxene. Spinel is very homogeneous and displays a very high Cr# (Cr/Cr+Al molar) = 0.83-0.85) **(fig. 4)**. Iron metal displays very low Ni content (Ni<0.1wt%) and Co content range to 0.27-0.59wt%

Whole-rock geochemistry:

The rare earth element pattern of the whole-rock is concave **(fig. 5)** and displays that this diogenite is highly depleted in comparison with chondrite, especially for LREEs and MREEs.

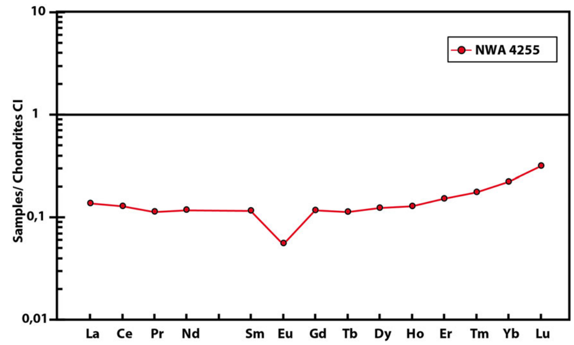

Fig.5: REE pattern of NWA 4255 Diogenite, normalized to chondrite [5]

Discussion:

Large orthopyroxene including small rounded or large olivine crystals could be reflect peritectic reactions between primitive melt (high magnesium, chromium and low calcium and aluminium) and a pre-existing harzburgitic mantle whose relics are the olivine fragment containing orthopyroxenes. Small rounded olivines included in orthopyroxene are witnesses of this uncompleted peritectic reaction. Chromite with high Cr# (as NWA1877) previously interpreted as residual spinel from mantle [4], precipitate from a primitive melt at chromium saturation according [6] and the chemical estimations of the silicate fraction of 4Vesta [e.g. 7]. The REE pattern of NWA4255 is incompatible with an origin as orthopyroxene cumulate in equilibrium with chondritic melt that must be convex. Diogenite NWA4255 would be rather a melange between fragments of harzburgitic residua with melt from magma.

References:

[1] Shearer C. K. (2010) *Geochim. et Cosmochim. Acta* 74, 4865-4880, [2] Drake M.J. (2001) *MAPS* 36 :501-5013, [3] Mittlefehldt D.W (2015) Chem. *Der Erd-Geochim* 75, 155–183, [4] Irving *et al.* (2005) LPS XXXV, #2188, [5] Anders & Grevesses, (1989), Geoch. Chim. Act., Vol53, 197-214, [6] Irvine T.N., (1968) Yearbook Carnegie Institution, [7] Lodders K., (2000) *Space Science Rev. 92, 341-354.*

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