NORTHWEST AFRICA 11911: POLYMICT ROCK FROM VESTA WITH A VARIETY OF SECONDARY ALTERATION FEATURES. T. Shisseh[1,5], H. Chennaoui Aoudjehane[1], B. Zanda[2], R. Hewins[2], S. Pont[2], L. Folco[3,4], Carl B. Agee[5], E. Jacquet[2]. [1] Hassan II University of Casablanca, Faculty of Sciences Ain Chock, GAIA Laboratory, km 8 Route d'El Jadida 20150 Casablanca, Morocco (shisseh.taha1@gmail.com). [2]Institut de Minéralogie, de Physique des Matériaux, et de Cosmochimie (IMPMC), Sorbonne Université, Muséum national d'Histoire naturelle, UPMC Université Paris 06, UMR CNRS 7590, IRD UMR 206, 75005 Paris, France. [3]Dipartimento di Scienze della Terra, Università di Pisa, Via S. Maria 53, I-56126 Pisa, Italy. [4]CISUP, Centro per l'Integrazione della Strumentazione della Università di Pisa, Lungarno Pacinotti 43, Pisa, Italy.[5]Institute of Meteoritics, University of New Mexico, Albuquerque, NM 87131, USA.

Introduction: The number of Vestan rocks showing evidence of secondary (post-crystallization) processes has grown over the past 10 years [1] [2] [3] [4] [5] [8]. Features attributed to metasomatism include: Fe-enrichment in pyroxene, development of fayalitic veinlets cross-cutting pyroxene grains and frequently associated with Ca-rich plagioclase, Cr-spinel and troilite; Al-depletion in pyroxene for advanced metasomatism [1] [8]. Other less frequent features are secondary quartz veinlets found in Serra de Magé [2], Ni-free metal [3] and sulfurization of pyroxene and plagioclase [4]. Even though the metasomatic features are now amply described in the literature, the origin of the fluids that generated them is still not well understood. [3] however proposed that fluids could have been liberated from carbonaceous chondrite materials embedded in the vestan regolith upon impact heating. This is supported by the dark material mapped on 4 Vesta by the DAWN mission [6]. Here, we present Northwest Africa (NWA) 11911, a new polymict eucrite displaying a rare diversity of secondary alteration features. This work is a part of a project aiming to constrain metasomatic effects on the mineralogy and geochemistry of this kind of meteorite.

Methods: NWA 11911 is a single stone purchased in 2013 from a dealer in Morocco and provided by Luc Labenne to the MNHN of Paris, France. Petrography and mineralogy were studied on a single polished section. BSE images and minerals composition spectrum where collected using Zeiss SUPRA 55-VP FEGSE (15kV accelerating voltage) at ISTeP -Sorbonne University, Paris, France, and FEI Quanta 450 ESEM FEG with (EDS) Bruker QUANTAX XFlash Detector 6-10 at CISUP University of Pisa, Italy.

Results and discussion: NWA 11911 displays a wide variety of textures and compositions. Basaltic, gabbroic, granulitc and variolitic clasts as well as coarse fragments of pyroxene and plagioclase of variable in sizes are present. All are embedded in a clastic matrix dominated by mineral fragments (Fig 1a). Pyroxene is both equilibrated with mostly exsolved augite in pigeonite and unequilibrated showing Mg-Fe zoning (Fig 1b). Pseudotachylite veins are found containing rounded and angular fragments of the host rocks embedded in a glassy matrix. A 5 x 2 mm impact melt was observed containing prismatic pyroxene and plagioclase fragments in a glassy matrix.

Metasomatic features in Northwest Africa 11911

Unusual zoning in pyroxene: Mg-Fe zoning in pyroxene is considered a result of fast cooling or of partial equilibration. This zoning is erased by subsequent metamorphism to produce equilibrated lithologies [7].

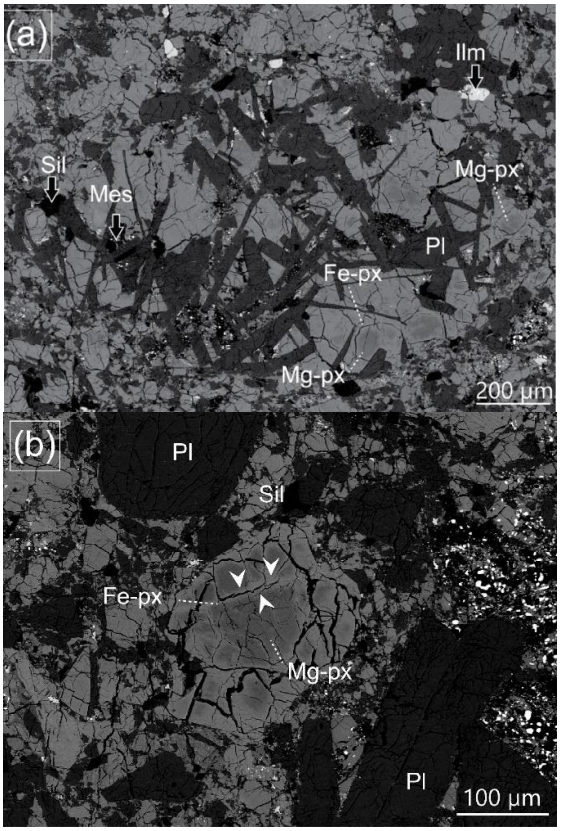

Figure 1*: Pyroxene Fe-enrichment in NWA 11911 (Fe-pyroxene: Iron-rich pyroxene, Mg-px: Magnesian pyroxene, Pl: Plagioclase, Sil: Silica, Ilm: Ilmenite, Mes: Mesostasis). (a) Subophitic clast displaying unusual Fe-enrichment in pyroxene following cracks direction. (b) Pyroxene fragment in the clastic matrix showing Fe-enrichment with Fe-enrichment following the crack that crosses the dark core (white arrows). Note the Iron rich network bands invading the Mg-core.*

A large number of pyroxene fragments, basaltic and gabbroic clasts in NWA 11911 displays an unusual Fe-enrichment along cracks that might be the result of fluid interaction with the rock [1] or of partial equilibration.

Fig 1a shows a BSE image of a subophitic clast dominated by pyroxene and plagioclase laths with minor ilmenite, silica and mesostasis. Fe-enrichments form a network of bright bands around the dark Mg-cores in the lower right side of the image. The pyroxene fragment in Fig 1b displays similar Fe-enrichment, greater in the vicinity of pyroxene cracks extending up to 10µm. Dark cores compositions are $En_{59}Fs_{35}Wo_6$ and bright margins are $En_{38}Fs_{56}Wo_6$. We also found plausible evidence of Fe-enrichment along cracks in equilibrated pyroxene, a feature never described beforehand.

Occurrence of fayalitic veinlets: NWA 11911 also contains pyroxene fragments crossed by Fe-rich olivine frequently associated with Ca-rich plagioclase plus Cr-spinel, troilite and rarely apatite/merrillite. Fig 2a, shows a pyroxene grain crossed by 3-10µm large olivine veinlets (Fa_{75-78}) surrounding magnesian cores ($En_{61}Fs_{34}Wo_5$). In the vicinity of veinlets, pyroxene becomes more Fe-rich, up to $En_{28}Fs_{69}Wo_3$. Secondary plagioclase within the veinlets (Fig 2a) displays compositions up to An_{96-98} more calcic than primary plagioclase (An_{73-91}). Note the presence of Ca-rich pyroxene surrounding olivine aggregates.

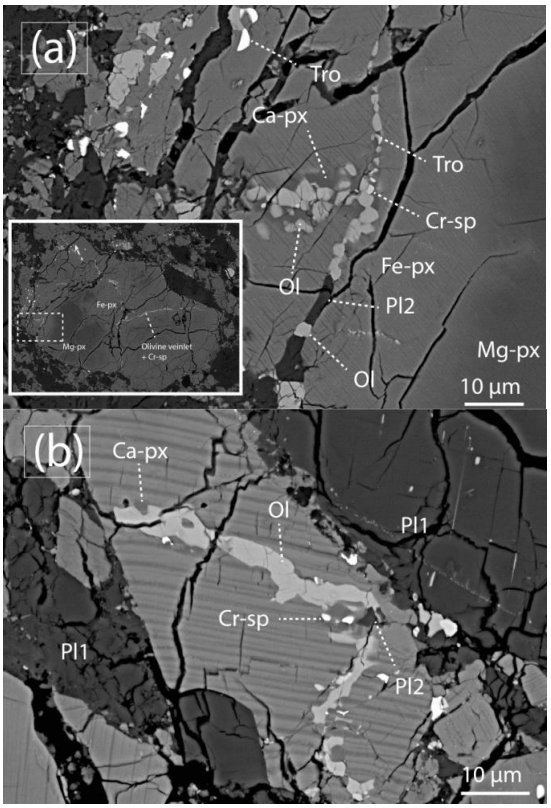

Figure 2: *Fayalitic veinlets in NWA 11911 pyroxene (Ca-Px: Ca-rich pyroxene, Fe-Px: Iron-rich pyroxene, Ol: Olivine, Pl: Plagioclase, Cr-spinel: Chrome-spinel, Tro: Troilite). (a) Unequilibrated pyroxene fragment crossed by olivine veinlet with Fe-enrichment and associated secondary phases. (2) Equilibrated pyroxene with exsolved augite in host pigeonite crossed by secondary olivine and associated phases.*

Pyroxene fragments showing equilibrated compositions with pigeonite host and exsolved augite lamellae, e.g. fragment in Fig 2b, are also affected by the same process. Olivine veinlet compositions are Fa_{77-81}. FeO, MgO and CaO profiles were collected across the veinlet showing the absence of Fe-enrichment in the pyroxene.

Al-depletion in pyroxene: In addition to Fe-enrichment in some pyroxene fragments, we noted their depletion in Al_2O_3 when approaching the olivine veinlets. Concentrations decreases down to 0.5 wt% in contrast to usual 1 wt% eucritic value [1]. This corresponds to advanced metasomatism [1].

Conclusion: Northwest Africa 11911 is a polymict eucrite with typical eucrite textures and overall eucritic compositions. This rock displays a large variety of secondary features corresponding to the three metasomatic stages suggested by [1] such as Fe-enrichment in pyroxene, fayalitic veinlets with associated secondary plagioclase, chromite, troilite and phosphates, as well as Al-depletion in pyroxene. We propose that the brecciated nature favored fluid circulation and interaction with the whole rock. Besides, we observed these effects on both equilibrated and unequilibrated clasts, so the responsible process(es) followed crystallization, metamorphism and brecciation.

Acknowledgment: This work, part of ATTARIK Foundation and AFIPS was supported by Erasmus+, Erasmus-KA107 (UH2C and Pisa University) and a Fulbright joint supervision grant.

References: [1] Barrat, J. A. et al. (2011). Geochimica et Cosmochimica Acta, 75, 3839–3852. [2] Treiman, A. H. et al. (2004). Earth and Planetary Science Letters, 219 (3–4), 189–199. [3] Warren, P. H. et al. (2014). Geochimica et Cosmochimica Acta, 141, 199–227. [4] Zhang, A. C. et al. (2013). Geochimica et Cosmochimica Acta, 109, 1–13. [5] Pang, R. L. et al. (2017), Meteoritics and Planetary Science, 52 (10), 2113–2131. [6] McCord, T. B. et al. (2012). Nature, 491 (7422), 83–86. [7] Takeda, H. & Graham, A. L. (1991). Meteoritics, 26, 129–134. [8] Roszjar, J. et al. (2011). Meteoritics & Planetary Science, 46, 1754-1773.