A NEW NOT SO EUCRITE-LIKE UNGROUPED ACHONDRITE: NORTHWEST AFRICA 12338. Z. Guo[1,], A. Bouvier[1,2], L. Webb[1,], A. Alexandre[1,3], F. J. Longstaffe[1], R. A. Korotev[4], Z. Zajacz[5], and M. Boyet[6], [1]The University of Western Ontario, Department of Earth Sciences & Centre for Planetary Science and Exploration, Canada. [2]Universität Bayreuth, Bayerisches Geo-Institut, Germany. [3]Aix Marseille Université, CNRS, IRD, INRA, Collège de France, CEREGE, Aix-en-Provence, France. [4]Washington University in St Louis, USA. [5]University of Toronto, Department of Earth Sciences, Canada. [6]Université Clermont Auvergne, LMV, CNRS, France.

Introduction: Northwest Africa 12338 is the 82nd and last ungrouped achondrite meteorite approved in 2018. The single stone has a total known mass of 1127g and was purchased in November 2016 in Erfoud (Morocco) by Sean Tutorow. A 24g repository specimen was sent for classification to the Western Meteorite Collection (UWO). The hand sample (Fig. 1a) has a brown fusion crust and a light gray interior with apparent metal, which suggest a low weathering stage.

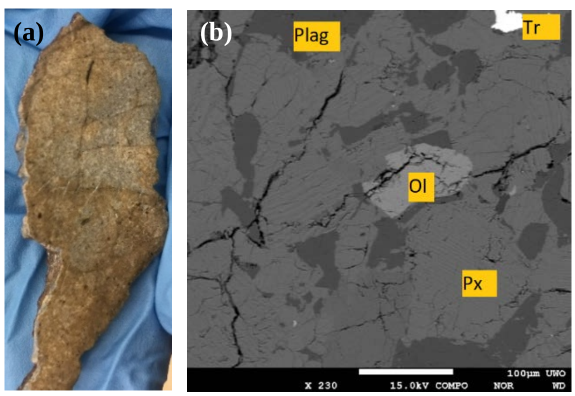

Fig. 1: (a) Image of the interior of the repository specimen of NWA 12338 (24g). (b) Back-scattered electron image of NWA 12338 (Plag=plagioclase; Px=pyroxene, Ol=olivine; Tr=troilite).

Results & Discussion: Petrography, and mineral and whole-rock chemical and isotopic analyses were performed to establish the origin and differentiation history of NWA 12338.

Petrography: NWA 12338 is a fine-grained and unbrecciated mafic achondrite (Fig. 1b). The modal abundances (determined in thin section) of clinopyroxene (~100 µm in size), plagioclase (100-500 µm in length), and anhedral olivine (~100 µm in size) are ~55%, ~40%, and ~4% respectively. NWA 12338 has low total contents (~1%) of metal, chromite, troilite, and silica. Plagioclase has undulatory (up to mosaic) extinction, which indicates a moderate shock stage. Additionally, some fractures are filled by a Ca-rich aluminosilicate glass which may be related to shock.

Mineral compositions: Major and minor element analyses of mineral phases were carried out using a JEOL JXA-8530F electron microprobe at Western. Olivine composition is homogeneous at Fa70.0±0.2 with Fe/Mn=44±1 (n=10). Low-Ca pyroxenes, some with sub-µm exsolution lamellas, have two compositional groups: Fs42.9±2.8(39.6-47.4)Wo12.4±4.3(5.3-16.7), with Fe/Mn=31±1, n=10, and Fs38.9±1.7(36.4-40.8)Wo10.4±3.1 (5.8-14.5), with Fe/Mn=29±1, n=10, respectively (Fig. 2). Plagioclase is on average An89.1±1.4 (n=10). Metal is 96% Fe and 4% Ni.

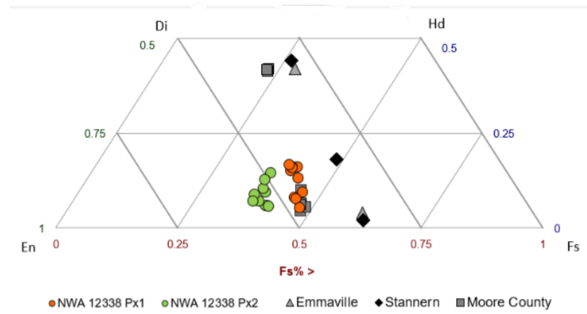

Fig. 2: Ternary diagram for pyroxene compositions for NWA 12338, and selected eucrites from [1].

Minor and trace element abundance analyses of pyroxene and plagioclase individual grains were obtained using a NWR193UC laser coupled with an Agilent 7900 qICP-MS at the University of Toronto. Average mineral compositions of pyroxene (n=2, 10 analyses from rim to rim for each crystal) and plagioclase (n=3), as well as measured and calculated whole-rock compositions, are presented in Fig. 3. The LA-ICPMS dataset for pyroxene light REE elements (La to Eu) have a relative large standard deviation of ~40% within a single crystal.

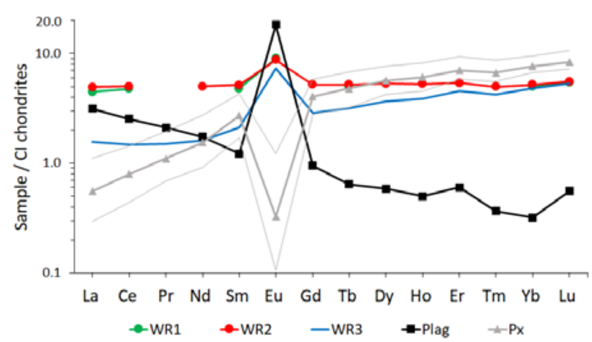

Fig. 3: REE patterns for NWA 12338 whole rock samples (see text) and mineral phases (pyroxene average and range in grey, and plagioclase average by LA-ICPMS).

Bulk chemistry: A ~35 mg whole-rock powder WR1 was first analyzed by INAA (methods in [2]): Na_2O 0.50%, CaO 10.2%, FeO 15.3%, and (all in ppm) Cr 3043, Co 16, Sr 92, Ba 19, La 1.1, Sm 0.74, Hf 0.52, Th 0.10, and U 0.16. The very low Ba abundance supports a low weathering grade [2]. A larger dissolved whole-rock sample WR2 (0.36g) was analyzed by qICPMS at Western. WR1 and WR2 are similar in REE (Fig. 3), but distinct for other elements such as Th and U, which indicate heterogeneities at the sampling scale. Using LA-ICPMS mineral phase compositions, a bulk composition WR3 can be calculated as a binary mixing corresponding to a mixture of 55% pyroxene and 45% plagioclase. This matches well the MREE and HREE of the dissolved whole-rock but not the LREE (Fig. 3). An additional phase with relatively high LREE, such as a phosphate, must be present (<1%) in the meteorite to explain the dissolved whole-rock composition, but has yet to be identified.

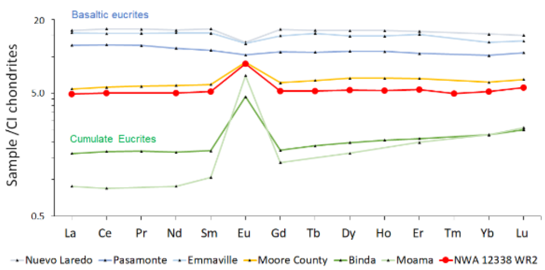

Fig. 4: REE paterns for NWA 12338 WR2 compared to basaltic eucrites (Stannern, NWA 4523, Nuevo Laredo), cumulate eucrite (Moore County), and two anomalous eucrites (Emmaville and Pasamonte). Literature data from [1, 3-5].

When compared to the main series of eucrites, NWA 12338 WR2 REE pattern is enriched (×5 CI) and flat, with a similar shape to Moore County with positive Eu anomaly (Eu/Eu*=1.7), but with slightly lower abundances (Fig. 4).

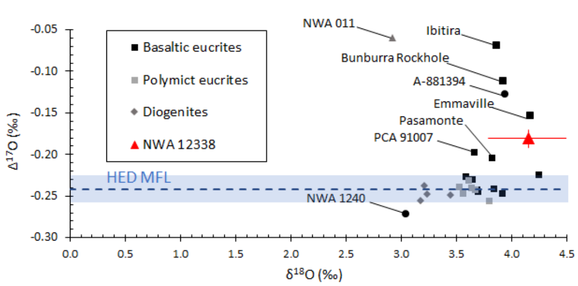

Fig. 5. O-isotope compositions of NWA 12338, compared with diogenites, eucrites, and anomalous eucrites. Literature data are from [6, 7]. The blue line is the HED mass fractionation line (MFL) and 95% confidence envelope [7].

Oxygen isotopes: Oxygen gas (O_2) was extracted with a 25W IR CO_2 laser using BrF_5 reagent, purified cryogenically and analysed on a Finnigan Delta V isotope ratio mass spectrometer at Western. The data was calibrated with daily analyses of NBS-28. Two aliquots of the meteorite sample produced values of $\delta^{18}O = 4.16 \pm 0.37$ ‰, $\delta^{17}O = 1.98 \pm 0.20$ ‰, $\Delta^{17}O = -0.18 \pm 0.01$ ‰ (Fig. 5). NWA 12338 is located significantly above the Howardite-Eucrite-Diogenite (HED) line, with an intermediate composition between PCA 91007 and Pasamonte, and other anomalous eucrites (e.g., Emmaville, Bunburra Rockhole).

Sm-Nd and Lu-Hf isotope geochemistry: In addition to WR2, a ~1g chip was processed for mineral separation of pyroxene (with olivine) and plagioclase for geochronology. Hand-picking effort was made to remove grains with inclusions and oxides such as chromites. To eliminate surface contamination and soluble phases potentially mixed with the grains, mineral separates were leached by 1M HF and 1M HCl sequentially prior to dissolution. All samples, including whole-rock material and mineral separate residues, were processed for Sm-Nd and Lu-Hf according to methods described in [8]. Prior to spiking, whole-rock and leached mineral separates were analyzed by solution qICP-MS Thermo iCAP Q at Western. Mass spectrometry analyses were carried out using a Thermo Neptune Plus MC-ICPMS at Clermont Université. Whole-rock isotopic data for NWA 12338 are $^{147}Sm/^{143}Nd = 0.1972$, $^{143}Nd/^{144}Nd = 0.512651 \pm 3$ and $\varepsilon Nd_i = -0.3_{@4.56Ga}$, and $^{176}Lu/^{177}Hf = 0.0317$, $^{176}Hf/^{177}Hf = 0.282590 \pm 3$ and $\varepsilon Hf_i = -0.8_{@4.56Ga}$ (unspiked fraction), which are similar to other basaltic achondrite compositions (e.g., eucrites, angrites) [9, 10]. Mineral analyses are in progress to obtain absolute ages.

Conclusions: NWA 12338 is a new ungrouped achondrite. While it has close geochemical characteristics to eucrites and other basaltic achondrites, its mineral assemblage with the presence of igneous olivine, its fine-grained gabbroic texture, and its oxygen isotope composition distinguish it from these and suggest a distinct parent body, or alternatively a parent body with other eucrite-like achondrites that did not experience large-scale melting.

References: [1] Barrett T. et al. (2017) *Meteoritics & Planet. Sci.*, *52*, 656-668. [2] Korotev R.L. et al. (2009) *Meteoritics & Planet. Sci.*, *44*, 1287-1322. [3] Barrat J.A. et al. (2000) *Meteoritics & Planet. Sci.*, *35*, 1087-1100. [4] Barrat J.A. et al. (2007) *Geochim. Cosmochim. Acta*, *71*, 4108-4124. [5] Hamet J. et al. (1978) *Proc. LPSC. 9th*, 1115–1136. [6] Bland P.A. et al. (2009) *Science*, *325*, 1525-1527. [7] Scott E.R. et al. (2009) *Geochim. Cosmochim. Acta*, *73*, 5835-5853. [8] Bouvier A. and Boyet M. (2016) *Nature*, *537*, 399-402. [9] Blichert-Toft J. et al. (2002) *Earth Planet. Sci. Letters*, *204*, 167-181. [10] Bouvier A. et al. (2015) *Meteoritics & Planet. Sci.*, *50*, 1896-1911.

Acknowledgments: We thank Sean Tutorow, Marc Beauchamp, and the Centre for Planetary Science & Exploration.