PETROLOGIC AND ISOTOPIC CHARACTERIZATION OF NORTHWEST AFRICA 10961: AN INTERMEDIATE ULTRAMAFIC POIKILITIC SHERGOTTITE WITH PREVALENT SHOCK MELTING FEATURES. A. J. Irving[1], S. M. Kuehner[1], M. Righter[2], T. J. Lapen[2], Y. Gao[2], K. Ziegler[3], D. Weimer[4], H. Busemann[4], R. J. Falls and B. Hoefnagels [1]Dept. of Earth & Space Sciences, University of Washington, Seattle, WA 98195 (irvingaj@uw.edu), [2]Dept. of Earth & Atmospheric Sciences, University of Houston, Houston, TX, [3]Institute of Meteoritics, University of New Mexico, Albuquerque, NM, [4]ETH Zürich, Switzerland.

Introduction: A 2220 gram stone found in 2016 in Morocco is a coarse grained poikilitic shergottite containing unusually large amounts of quenched shock melt as veins and pockets. Among the 101 unpaired Martian meteorites now recognized [1], NWA 10961 is most similar to ALHA 77005 [2], Yamato 793605 [3] and NWA 4797 [4].

Figure 1. *Cut interior face of main mass showing primary poikilitic assemblage (pale green) and abundant dark shock melt pockets and veins.*

Primary Petrology: The specimen has a primary poikilitic texture. Large (up to 2.4 cm), essentially unzoned pyroxene oikocrysts (with undulose extinction) enclose chadacrysts of olivine ($Fa_{29.5\text{-}31.2}$, FeO/MnO = 41-46, some brownish in thin section) and Cr-rich chromite. Both orthopyroxene ($Fs_{19.4\text{-}20.7}Wo_{2.7\text{-}3.6}$; FeO/MnO = 20-28) and prismatically-twinned augite ($Fs_{13.0\text{-}13.8}Wo_{38.2\text{-}35.0}$, FeO/MnO = 22-24) are present. Sparse maskelynite (~2 vol.%, $An_{53.8\text{-}55.6}Or_{1.1\text{-}1.0}$) occurs interstitially; other accessory minerals are Ti-bearing chomite, ilmenite and rare Mg-merrillite.

Shock-Produced Fine Grained Zones: This specimen is remarkable for the abundance of shock veins (in part vesicular), which consist of fine grained euhedral olivine, pyroxene, oxides and glass enclosing angular and partly reacted mineral fragments. This vein network appears to have been injected from beyond the present meteoroid volume, but presumably resulted from shock-induced melting of the same lithology.

Figure 2. *Portion of an interior slice from which a large area 5.5 × 4 cm polished thin section was made.*

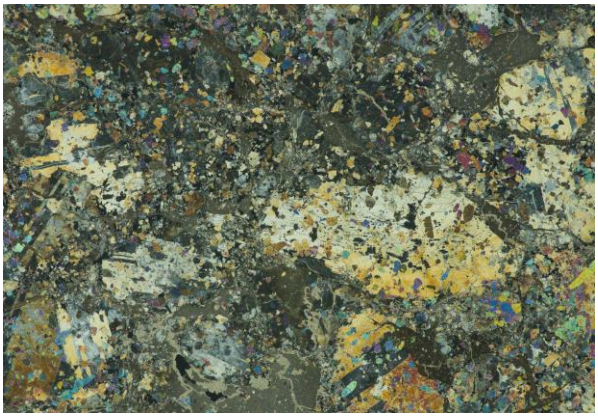

Figure 3. *Cross-polarized image of whole thin section, showing poikilitic texture and twinned clinopyroxene.*

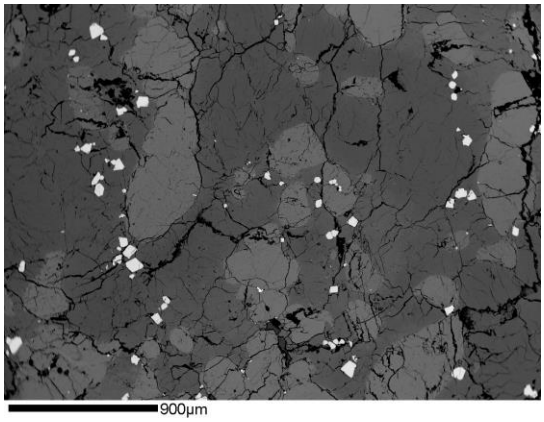

Figure 4. *BSE image of pyroxene oikocryst (medium gray) containing chadacrysts of olivine and chromite.*

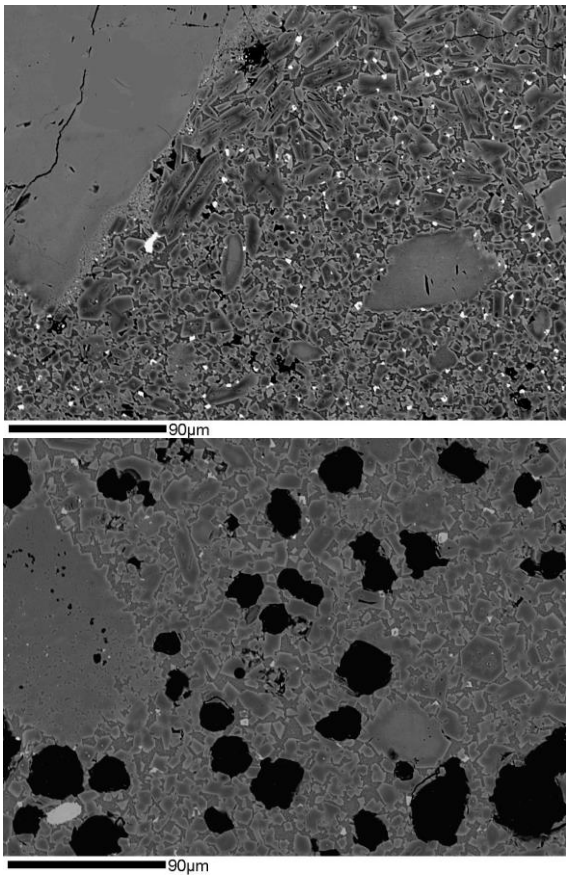

Figure 5a, b. *Details of quenched and vesicular shock veins with entrained crystalline debris.*

Oxygen Isotopes: Duplicate analyses of acid-washed interior material by laser fluorination gave, respectively, $\delta^{17}O$ 2.685, 2.552; $\delta^{18}O$ 4.662, 4.369; $\Delta^{17}O$ +0.223, +0.245 per mil. These $\Delta^{17}O$ values are at the low end of measured values for Martian meteorites, and may reflect a Mars crustal component within the shock veins immune to removal by acid pre-treatment.

Table 1. Whole Rock Elemental Abundances

SiO_2	42.72	La	0.48	Ba	41
TiO_2	0.53	Ce	1.22	Sr	21
Al_2O_3	2.63	Pr	0.15	Rb	0.75
Cr_2O_3	0.86	Nd	0.91	Sc	14.4
FeO	19.67	Sm	0.42	V	111
MnO	0.45	Eu	0.18	Zn	49
MgO	26.25	Gd	0.68	Y	5.1
CaO	4.69	Tb	0.15	Zr	16.8
Na_2O	0.49	Dy	1.00	Hf	0.55
K_2O	0.27	Ho	0.19	S	831
P_2O_5	1.14	Er	0.55	Se	0.4
SUM	100.00	Yb	0.49		
mg	0.704	Lu	0.05		

Bulk Major and Trace Elements: Wire-sawing of two interior slices produced 13 grams of cutting dust, which we judge to be very representative of the bulk rock. Major elements (in wt.%, by ICP-OES) and trace elements (in ppm, by QQQ-ICP-MS) were determined at the University of Houston (see Table 1).

Radiogenic Isotopic Compositions: Clean interior material was spiked for Lu-Hf and Sm-Nd analyses, bomb digested in HF-HNO_3 and measured by MC-ICP-MS. Although not as representative as cutting dust, the simultaneous analysis of parent-daughter elemental abundances ensures that the measured isotopic ratios mirror those of the mantle source. The $^{176}Hf/^{177}Hf$ ratio of 0.283558 (εHf = +27.68, Hf 0.383 ppm) establishes this specimen to be a member of the intermediate shergottites. Lu, Sm and Nd analyses are in progress.

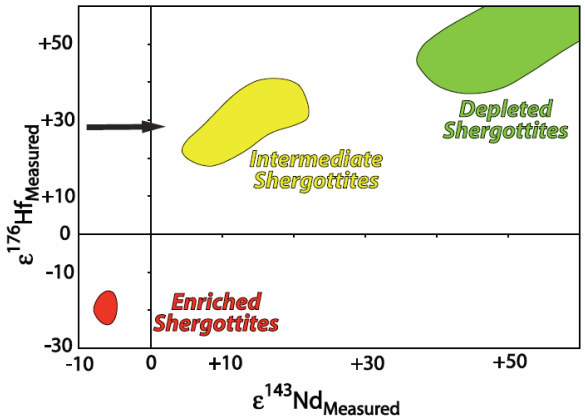

Figure 6. *Nd and Hf isotopic compositions of shergottites (from [5], [6] and our unpublished analyses). The Hf isotopic composition of NWA 10961(arrow) establishes its intermediate ITE signature.*

Noble Gases and Cosmic Ray Exposure Age: Cosmogenic and trapped noble gases are being measured at ETH, and will be presented and discussed in the context of CRE ages for other shergottites [7].

Concluding Remarks: NWA 10961 is an intermediate ultramafic poikilitic shergottite similar to ALHA 77005 [2], Yamato 793605 [3], NWA 4797 [4] and at least ten other Martian meteorites. However, the shock melt veining in NWA 10961 is much more prevalent.

References: [1] Irving A. et al. (2017) *LPS* **XLIX**, this conference [2] McSween H. et al. (1979) *EPSL* **45**, 275-284 [3] Mikouchi T. and Miyamoto M. (1997) *Antarctic Meteorite Res.* **10**, 41-60 [4] Walton E. et al. (2012) *MaPS* **47**, 1449-1474 [5] Irving A. et al. (2015) *LPS* **XLVI**, #2290 [6] Irving A. et al. (2016) *LPS* **XLVII**, #2330 [7] Wieler et al. (2016) *MaPS* **51**, 407-428.