HASSI EL MADANI 002: UNGROUPED POLYMICT ACHONDRITE WITH TWO DISTINCT OXYGEN ISOTOPE LITHOLOGIES. C. B. Agee, A. J. Ross, M. N. Spilde, K. Ziegler, Institute of Meteoritics, University of New Mexico, Albuquerque, NM 87131, agee@unm.edu.

Introduction: Hassi el Madani 002 (HeM 002) is an ungrouped polymict achondrite consisting of two distinctly different lithologies originating from two separate parent bodies with significantly different oxygen isotope values. One lithology (“light lithology”) has oxygen isotopes that plot within the martian meteorite (SNC) array whereas the “dark lithology” has oxygen isotopes that plot within the LL chondrite field. The mineralogy, geochemistry, and oxygen isotopes of the light lithology resemble martian chassignites. The mineralogy, geochemistry, and oxygen isotopes of the second lithology (“dark lithology”) are consistent with an ungrouped achondrite having ordinary chondrite-affinities.

Fig. 1. Photograph of the 465 gram main mass of Hassi el Madani 002. Light lithology is highlighted with yellow outlines. Black patches are fusion crust.

Fig. 2. Photograph of a 2D section from an X-ray computed tomography scan of the interior of the main mass of Hassi el Madani 002 performed at UNM. The light lithology fragments are highlighted in yellow which lack significant metal and appear as darker regions in the scan (lower average Z). The light lithology is estimated to make up approximately 15% by volume of the main mass.

History: This meteorite is a single stone of 465 grams purchased by Habib-naji Naji on August 4, 2022 in Tindouf, Algeria, and subsequently purchased by Jay Piatak in 2023. It was found 2 km south-southwest of the hamlet of Hassi M'dakane and approximately 130 km southwest of highway N6 in Algeria. The deposit sample resides at the Institute of Meteoritics, University of New Mexico.

Physical Characteristics: Hassi el Madani 002 is a single stone with two visually distinct lithologies and apparent sharp boundaries which are designated 1) “light” lithology and 2) “dark” lithology. The light lithology makes up approximately 15% of the total surface area and is light green in color with patches of smooth black fusion crust. A fresh chipped surface of the light lithology reveals a granular texture with light-yellow color lacking significant metallic/sulfide grains. The dark lithology makes up ~85% of the surface area and is dark brown in color with some patches of remnant fusion crust but with a mostly smooth, sandblasted appearance. A sawcut of the dark lithology shows a medium to fine matrix texture of gray grains with scattered reflective sulfides.

Fig. 3. Backscatter electron image of the light lithology. Light gray = olivine, medium gray = augite, dark gray = maskelynite, white = chromite.

Petroleum and Geochemistry: Microprobe examination and reflected light microscopy were performed on three polished mounts. 1) Light lithology: two polished mounts of the light lithology were analyzed showing a mineralogy consistent with a plagioclase bearing dunite with approximately 85-90% olivine, 5-10% oligoclase (maskelynite), 2-5% augite, with minor chromite and Cr-rich apatite, and with trace amounts of ilmenite, kamacite and taenite. Mean olivine grain size is approximately 200 microns with a range of approximately 50-500 microns. Maskelynite is primarily interstitial between olivine grains. 2) Dark lithology: one polished mount of the dark lithology was analyzed showing a mineralogy consistent with a harzburgite (i.e.: achondrite with no chondrules observed) with
approximately 50% olivine, 35% orthopyroxene, with minor pyrrhotite, plagioclase (oligoclase), merrillite, Cl-rich apatite, chromite, kamacite and taenite. Numerous very fine Fe-oxide veinlets are ubiquitous in the dark lithology.

Electron Microprobe Results:

**Light lithology:**
- Olivine Fa25.2±0.3, Fe/Mn=49±2, n=13
- Maskelynite Ab74.9±5.1An19.2±4.0Or5.9±1.5, n=10
- Augite Fs7.9±0.5Wo45.2±0.7, Fe/Mn=22±3, n=12
- Chromite Cr2O3=51.6±1.6 (wt%), n=4
- Apatite Cl=4.3±0.8, F=0.32±0.11 (wt%) n=11

**Dark lithology:**
- Olivine Fa25.4±0.5, Fe/Mn=51±2, n=10
- Pyroxene Fs22.6±0.1Wo1.6±0.2, Fe/Mn=31±3, n=9
- Plagioclase Ab83.2±1.0An10.2±0.5Or6.6±0.6, n=12
- Chromite Cr2O3=54.9±0.3 (wt%), n=6
- Apatite Cl=4.5±0.5, F=0.23±0.11 (wt%) n=9
- Pyrrhotite Fe=44.4±3.0, S=55.2±2.8 (atom%)

**Oxygen Isotope Results:**

**Light lithology:** 5 acid-washed fragments analyzed by laser fluorination gave δ18O=4.519, 4.622, 4.416, 4.311, 4.267; δ17O=2.714, 2.784, 2.658, 2.639, 2.607; Δ17O=0.328, 0.344, 0.327, 0.363, 0.354 (linearized, all per mil, TFL slope=0.528).

**Dark lithology:** 2 acid-washed fragments analyzed by laser fluorination gave δ18O=5.298, 5.438; δ17O=3.807, 3.867; Δ17O=1.010, 0.996 (linearized, all per mil, TFL slope=0.528).

**Origin and Parent Body of Hassi el Madani 002:**
- A chondritic polymict breccia can consist of multiple distinct petrologic lithologies as seen for example in the HED meteorites, lunar fragmental and regolith breccias, and the unique martian polymict breccia NWA 7034. HeM 002 possesses two distinct petrologic lithologies but it is an unusual achondrite polymict breccia in that these two lithologies have completely different oxygen isotopes – one that plots with the SNC meteorites and the other with LL chondrites suggesting origins from two different parent bodies. Although polymict breccias derived from multiple parent bodies are unusual, they are not unheard of; for example CM clasts are found in some howardites and polymict ordinary chondrites can have mixed H-LL lithologies. Kaidun is also an example of polymict breccia with a rich inventory of lithologies derived from multiple parent bodies, which led to the speculation that they were assembled to form the Martian moon Phobos [1]. A similar hypothesis can also be explored in the context of HeM 002 in a scenario where Phobos was formed from a giant impact that mingled Martian crust and mantle material with an ordinary chondrite-like impactor. Future missions such as the Martian Moons eXploration (MMX) Mission [2] may be able to test such hypotheses.