THE MSFC NOBLE GAS RESEARCH LABORATORY (MNGRL), A NASA INVESTIGATOR FACILITY. B. A. Cohen, NASA Marshall Space Flight Center, Huntsville AL 35812 (Barbara.A.Cohen@nasa.gov).

Introduction: Noble-gas isotopes are a well-established technique for providing detailed temperature-time histories of rocks and meteorites. We have established the MSFC Noble Gas Research Laboratory (MNGRL) at Marshall Space Flight Center (Fig. 1) to serve as a NASA investigator facility in the wake of the closure of the JSC laboratory formerly run by Don Bogard. The MNGRL lab was constructed to be able to measure Ar-Ar and I-Xe radioactive dating to find the formation age of rocks and meteorites, and Ar/Kr/Ne cosmic-ray exposure ages to understand when the meteorites were launched from their parent planets. At this time, we have commissioned the Noblesse for ^{40}Ar-^{39}Ar dating and are pleased to share information on the facility calibration and capabilities.

Figure 1. MNGRL laboratory.

Laboratory: The MNGRL facility consists of:

- A Nu Noblesse magnetic sector mass spectrometer with a high-voltage Nier source for high-precision isotope ratio measurements, fitted with four discrete dynode ion-counting multipliers and a Faraday cup for simultaneous counting of up to five isotopes of Ne, Ar, Kr, and Xe. The Noblesse has a mass resolution of 3000 and ^{40}Ar sensitivity of 6.25×10^{19} cps/mol on the multipliers. Our Noblesse is under factory warranty and receives service via remote desktop.
- An ultra high vacuum (UHV) noble gas extraction system, with both manual and automatic control modes, pumped by a Varian StarCell pump, turbomolecular pump, and oil-free scroll pump. We purify gas samples using SAES SORB-AC getters. Noble gases can be separated for analysis using a Janis closed-cycle cryogenic cold trap.
- Standard gas mixtures and cleaned air for standards and calibration contained within three pipettes built by ASI Scientific Instruments. One pipette tank has been cross-calibrated with the Washington University noble-gas laboratory.
- A FUSIONS.970 laser heating system from Photon Machines with confocal optics and two-color infrared pyrometer. The laser hovers over two laser ports with quartz windows and has fully automated positioning and power. One laser port is equipped with a thermocouple to precisely calibrate the pyrometer readings. We enclose each sample in a Pt/Ir tube, which allows uniform heating of the samples by the diode laser. This approach eliminates the potential for uneven laser coupling to different mineral phases and also enables precise temperature determination for thermochronometry and diffusion studies. We also use laboratory-grade salts as irradiation standards and a variety of mineral standards for age determination. Our packages for ^{40}Ar-^{39}Ar work are irradiated at the Oregon State University's TRIGA facility in the cadmium-lined core position (CLICIT).
- Complete system automation and instrument communications using the Mass Spec software package written by Al Deino of the Berkeley Geochronology Center. This software is in wide use in Ar-Ar labs, providing an integrated system control, data collection, and data reduction package.
- Sample-preparation facilities for sample characterization and analysis, including rock crushing and separation, petrographic and stereomicroscopes, and a Medenbach microcorer for extracting individual clasts from thin or thick sections for analysis.

Our combined extraction line and mass spectrometer blanks (procedural background measurement) are ^{40}Ar = 8.08E-16 mol (±22%); ^{39}Ar = 4.15E-18 mol; ^{36}Ar = 1.15E-17 mol. Our hot blanks increase somewhat, probably from atmospheric desorption of the sample chamber blank targets; however the blanks are still quite low. We run blanks every morning and evening and average the blank series across days to apply to any given sample analysis set. Our air analyses yield a reproducible terrestrial atmospheric ratio of $^{40}Ar/^{36}Ar$ = 291.90 ± 0.06%. The baseline (off-peak) measurements on our air pipettes typically show 0-1 counts (after blank correction).

Calibration: We used unirradiated standards to calibrate the laser heating system and determine the sensitivity of our detectors and sample yield. Our first irradiation packages contained the standards Mmhb-1 hornblende, LP-6 biotite, and PP-20 hornblende. Multiple splits of Mmhb-1 yield ages consistent with the reference age of 523.1 ± 1.6 Ma [1].

We are aware of two community-identified issues with the Noblesse machines. One is that the sample ion beams degas hydrocarbons from the multipliers. We have an SAES getter in operation directly adjacent to the multipliers to alleviate this issue. The second is intercalibration of the detectors, where some have reported instability over both short and long timescales [2, 3]. We intercalibrate our detectors daily or more frequently using air shots run in an identical manner to our unknowns – that is, with the same isotopes on the same detectors, in the same sequences. Mass discrimination using this protocol may be unstable on the order of 1-2 per mil [3], but we have not yet achieved analyses that rival this uncertainty limit, so it is not the largest contributor to analysis error. If needed, all of the analyses for a delicate sample can be run on a single detector, obviating this source of uncertainty altogether. However, this level of uncertainty is most important when measuring very young samples, and the natural variability in the lunar and meteorite samples (as we have seen in previous analyses) swamps this source of error. In short, we are aware of this issue, but it is not a dominant uncertainty for our current protocol and samples.

Results: We have run multiple terrestrial samples to prove out the facility, including several suites of young volcanics from areas around the country and older (1 Ga), K-rich plagioclase samples from the Santa Fe Crater granite body. The youngest samples (3 Ma) rarely contained enough gas to yield good results, but our data on the Santa Fe Granite show it to be ~930 ± 30 Ma, reflecting regional exhumation of the area in the Proterozoic, which is the same age observed in previous analyses of this sample [4] (Fig. 2a). The first two heating steps in this sample also show young ages, consistent with Ar loss from the low-T domains, which was also seen previously.

We are presenting our results on lunar meteorite Dhofar 961 at this conference [5], which exhibits an apparent age of ~3.5 Ga, along with diffusive gas loss in the low-temperature steps, and recoil effects in the high-temperature steps (Fig. 2b). Our sensitivity and precise temperature control increases confidence in derived ages, reveals irregularities in gas release, and enables diffusion parameters to be recovered and multi-domain behavior to be investigated. As we run these samples and their duplicates, we continue to refine our sample run protocol, intercalibration, etc.

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References: [1] Renne, P. R., et al. (1998), Chemical Geology 145, 117-152. [2] Cosca, M. (2007), Eos Trans. AGU, 88, V32B-05. [3] Turrin, B. D. et al. (2010) Geochemistry Geophysics Geosystems, 11, doi:10.1029/2009GC003013. [4] Newsom, H. E. et al. (2007) Met. Planet. Sci. 42, 5307. [5] Cohen and Frasl (2015), LPSC 47, #2007.

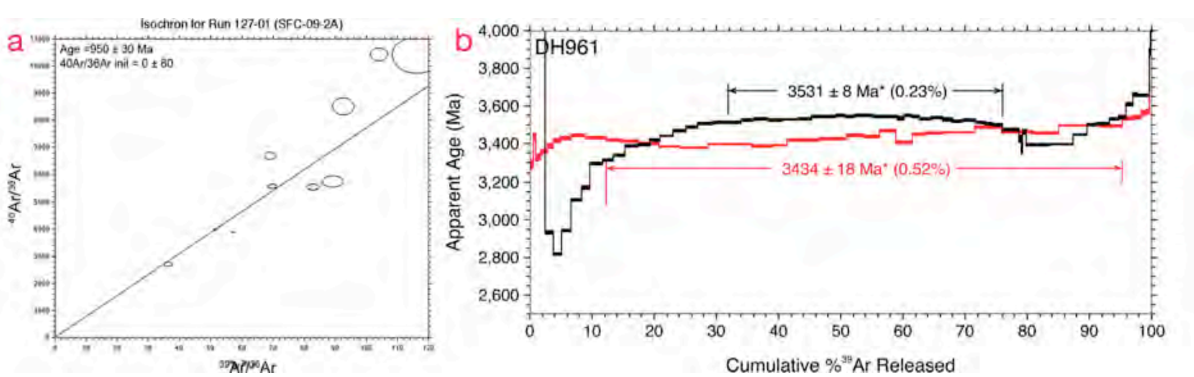

Figure 2. A) Isochron diagram for gas release from Santa Fe crater samples and b) preliminary plateau plot for two splits of Dhofar 961 impact melt breccia.