

AGE (ARGON GEOCHRONOLOGY EXPERIMENT): AN INSTRUMENT FOR IN SITU GEOCHRONOLOGY ON THE SURFACE OF MARS. T. D. Swindle¹, R. Bode¹, W. V. Boynton¹, D. A. Kring¹, M. Williams¹, A. Chutjian², M. R. Darrach², D. A. Cremers³, R. C. Wiens³ and S. L. Baldwin⁴ ¹Lunar and Planetary Laboratory, University of Arizona Tucson AZ 85721-0092 USA, ²Jet Propulsion Laboratory, Pasadena CA 91109-8099, USA, ³Los Alamos National Laboratory, Los Alamos NM 87545 USA, ⁴Department of Earth Sciences, Syracuse University, Syracuse NY 13244 USA. First author's e-mail address: tswindle@u.arizona.edu

Introduction: As our knowledge of the planet Mars continues to grow, one parameter that remains elusive is the absolute chronology of the planet's geological history. Although crater counts have provided a robust relative chronology, impactor fluxes are poorly-known that there are places on Mars where the absolute age is uncertain by a factor of two or more [1]. To resolve these uncertainties, it will be necessary to either analyze well-documented samples returned to the Earth from the Martian surface or to perform in situ measurements with sufficient precision. Sample return is still at least a decade away, and even then it might be from a biologically interesting area that might be geologically complex. Hence an in situ measurement, within an uncertainty of 20% or better, could greatly improve our knowledge of the history of Mars.

With funding from the Planetary Instrument Definition and Development Program (PIDDP), we have been working on an instrument to perform potassium-argon (K-Ar) and cosmic-ray exposure (CRE) dating in situ on the surface of Mars. For either of these techniques, it is necessary to measure the abundance of one or more major or minor elements (K in the case of K-Ar; all majors and minors in the case of CRE) and the abundance and isotopes composition of a noble gas (Ar in the case of K-Ar; He, Ne and Ar for CRE dating). The technology for either of these types of measurements exists, but has never before been integrated for a spacecraft. We refer to the instrument as "AGE", the Argon Geochronology Experiment (although we will measure the noble gases He and Ne as well for CRE ages). We report here on the basic components that go into such an instrument, both those that use existing technology and those that had to be developed to create the integrated package.

Components: Elemental abundance measurements are made with Laser-Induced Breakdown Spectroscopy (LIBS), using a system developed at Los Alamos National Laboratory. In LIBS, a variant of the well-established atomic emission spectroscopy, a laser is fired at a sample and generates a plasma, and the optical spectrum of the plasma is then analyzed. LIBS has been shown to be capable of generating elemental abundances that are reproducible to within 10% [2]. A

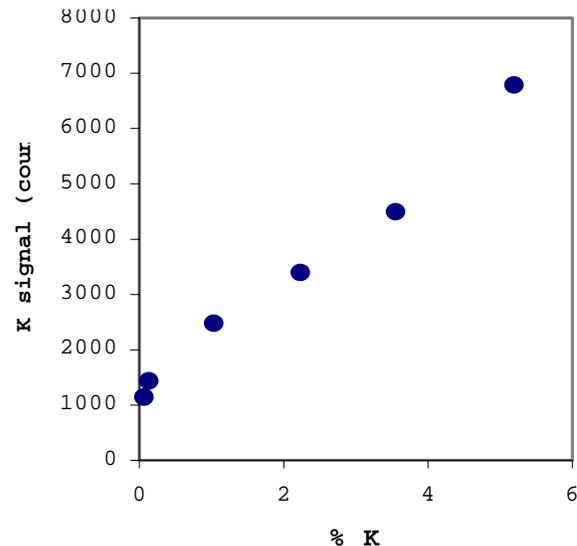


Fig. 1: Signal vs. K content for LIBS system.

sample of a calibration curve for K, using a miniature (i.e., spacecraft-instrument-sized) Ocean Optics spectrometer is shown in Fig. 1.

Noble gas measurements are made with a miniature Quadrupole Mass Spectrometry Array (QMSA). The QMSA, developed by Jet Propulsion Laboratory [3], has been used as a leak-detector aboard the International Space Station. Although its intrinsic sensitivity (in amps/torr) is roughly four orders of magnitude worse than a state-of-the-art laboratory noble gas mass spectrometer, the volume will be roughly two orders of magnitude smaller, which means that the effective sensitivity on Mars will be only about two orders of magnitude worse than that expected in a state-of-the-art terrestrial laboratory.

To release the gas for analysis, a furnace is needed. We targeted 1500°C, a temperature at which martian rocks would definitely be degassed, and most would be melted. Although we investigated many other options, including laser heating, resistance heating, and chemical heating, our final design, which gave the most reproducible results at the highest temperatures, involves radiative heating, by a set of filaments.

The QMSA measures absolute abundances, while LIBS measures relative abundances. To make the conversion, we required a method of measuring sample

mass. Although we expect to fill each sample crucible with approximately 5 mg of powdered rock on first use, we can measure melted samples more accurately than that by measuring the volume and calculating the density (given the measured elemental composition of the glass). For test samples of Columbia River Basalt, we found that our measurements were reproducible to within 7% (Fig. 2).

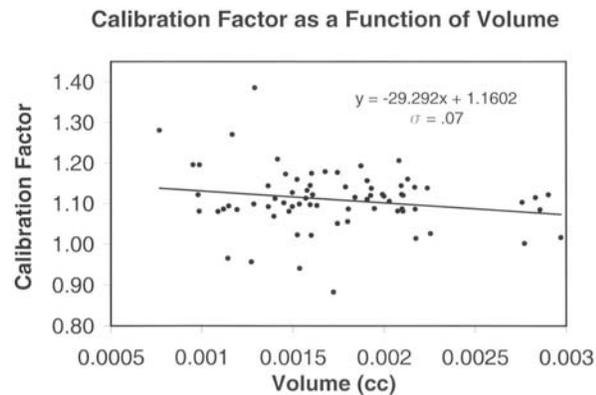


Fig. 2: Calibration factor (factor that has to be multiplied by the measured volume to get the volume implied by the measured mass and calculated density) as a function of volume.

One other component that is essential on Mars is the vacuum seal at the point where the sample is introduced to the furnace. We developed an elastomeric seal that was He leak-tight to terrestrial atmosphere for approximately a dozen uses, even when fine-grained grit was poured directly on the sealing mechanism.

Finally, as a part of the project, we developed a sample manipulation mechanism. It provides 12 sample crucibles, each of which can be used twice, and a mechanism for moving between stations for LIBS, QMSA, volume measurement, and sample loading. All motion is generated by a single paraffin actuator (Fig. 3).

The total package has an estimated mass of 5.7 kg, a volume of 30x29x16 cm (although not all of that volume is filled), and will require from 10 to 180 W to operate (the 180 W would be for approximately 10 minutes, while the furnace is at peak temperature). We anticipate relative uncertainties of 10% or less on mass, elemental abundances and noble gas isotope abundances (with isotope ratios measured to 1-2%), which should lead to overall uncertainties of 20% or less using either K-Ar or CRE ages for most samples older than 1 Ma.

Future work: The primary activity occurring at present is testing. Although the components have all

been tested individually, integrated testing will begin after submission of this abstract. In addition to simply testing that parts work together, we will also develop the protocols for maximizing measurement precision while minimizing consumption of power and time.

The next step after conclusion of PIDDP work is to begin work on a MIDP (Mars Instrumentation Development Program) phase, which is already funded. In this phase, as well as continued testing, we will also work on development of a Paul trap mass spectrometer [4], which is smaller and more sensitive than the QMSA, development of electronics, and construction of a complete breadboard system (breadboard for many components).

References:

- [1] Tanaka, K.L., *et al.* (1992) in *Mars*, 345-382.
 [2] Knight, A.K., *et al.* (2000) *Appl. Spectrosc.*, 54, 331-340. [3] Orient, O.J., *et al.* (1997) *Rev. Sci. Instrum.*, 68, 1393-1396. [4] Orient, O.J. and A. Chutjian (2002) *Rev. Sci. Instrum.*, 73(5), 1-4.

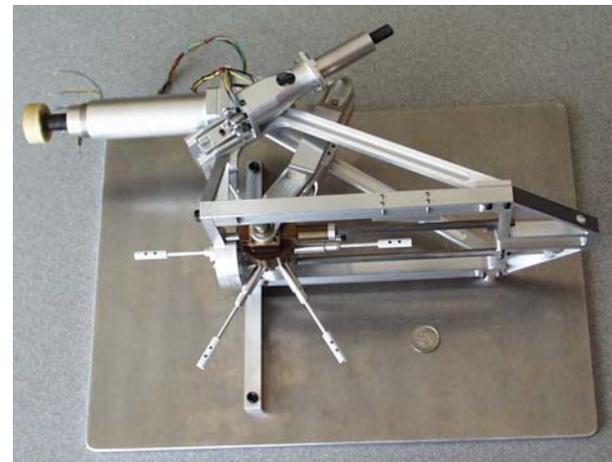


Fig. 3: Sample manipulation mechanism. Powdered sample will go in one of the crucibles (two crucibles are visible at the end of each spoke), and paraffin actuator (top left) moves mechanism to put crucible in desired location. Loading will be at right side, oven will be attached at left side (note that spoke pointing to the left is in the loaded position, extended through the seal into volume where furnace would be). American dime is on base plate for scale.