AGES: A NOBLE GAS MASS SPECTROMETER FOR FUTURE IN SITU COSMIC RADIATION EXPOSURE AGE AND K-Ar CHRONOLOGY INVESTIGATIONS.

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Introduction: The AGES (Analysis of Gas Evolved from Samples) mass spectrometer is an experiment for a future Mars, Lunar, asteroid, Phobos, or other similar mission, designed to provide definitive in situ measurements of cosmogenically and radiogenically produced noble gases. Surface exposure to energetic cosmic rays results in the transformation and modification of organic biosignatures, and such signatures are prime targets for in situ and sample-return measurements [1-4]. AGES can measure the effects of cosmogenic exposure, and could enable a selection of sample from these targets for return to Earth. Since, on Mars, the duration of near-surface exposure to cosmic radiation depends on erosion rates and thus varies from site to site, AGES could also guide a caching rover in selection of the optimal samples for eventual return to Earth.

Additional analysis capabilities of the AGES experiment capabilities include:

- a method to calibrate the Mars cratering record, confirm the ages of lunar provenances, and/or establish the last recorded age of formation of small planetary bodies with a determination of absolute rock formation ages; and,
- a sensitive search for organics and a survey of inorganic volatiles to characterize habitability

Cosmogenic Noble Gases in Martian Mudstone Samples: The core AGES experiment protocol has been demonstrated on the surface of Mars, with the Sample Analysis at Mars (SAM) [5] instrument on the Mars Science Laboratory (MSL) of the Curiosity rover. Exposure ages of 78 million years were established from independent measurements of ^{3}He and ^{21}Ne (produced by spallation) and ^{36}Ar (produced primarily by neutron capture on Cl) in samples from the Gale crater floor [6]. This experiment is enabled by SAM's wide dynamic range quadrupole mass spectrometer (QMS) and the incorporation of both scrubbers and getters into the gas manifold of SAM, which effectively remove chemically active gases such as CO_2 and N_2 thereby allowing trace noble gases from sub-picomole to nanomole abundances to be measured [6-Supplementary material]. The ratios of the spallation and neutron-capture products also enables us to discriminate between continuous erosion down a surface and exposure of site by scarp retreat, as illustrated in Figure 1. **A significant improvement in the AGES mass spectrometer compared to SAM is the incorporation of a larger capacity getter to more robustly operate the instrument in the fully static mode that is optimal for high sensitivity noble gas measurements.**

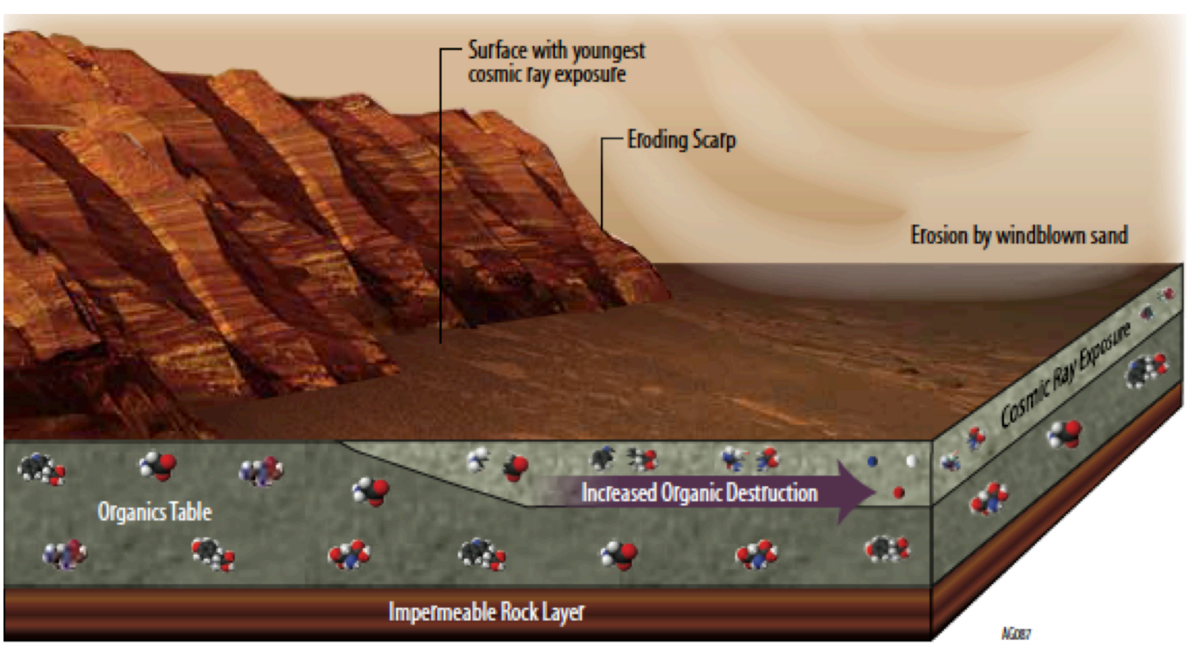

Figure 1. Near surface samples where possible organic compounds are least damaged by galactic cosmic rays may be located near the base of eroding scarps. These locations may provide an optimal sampling site for collection of samples to return to Earth that may preserve an ancient molecular record of biotic or prebiotic chemistries.

K-Ar Rock Formation Age: A rock formation age of 4.21 + 0.35 Ga was established through ^{40}Ar measurement by SAM in the same experiment that produced the exposure age results and K abundance data from MSL's Alpha Particle Backscatter X-ray Spectrometer (APXS) [6]. This result is consistent with erosion of material from the Gale crater rim, and ages of this material derived from the cratering record [7,8]. The precision of the K-Ar age determination can be greatly improved in a future in situ experiment from that demonstrated by SAM through use of a dual isotope dilution technique developed by the Caltech laboratory [9]. In this method, sample fines are combined with a lithium borate flux that fully releases argon from the sample and the potassium isotopes are measured by a thermal ionization source incorporated into the mass spectrometer. **Using this technique, the age determination depends only on measurements of the ratios for each of three isotope pairs ($^{40}Ar/^{39}Ar$, $^{39}Ar/^{36}Ar$ and $^{39}K/^{41}K$) and does NOT require an independent K measurement by another instrument or knowledge of the sample's mass, the two primary sources of error in the SAM K-Ar chronology experiments.**

There are two main sources of uncertainty in age determinations based on crater counting: calibration of the cratering rate ratio between Moon and Mars; and interpretation of the 'true' crater-production function [10-15]. The range of commonly used models is based on cratering rate estimates derived from current asteroid population impact probabilities. But by the absolute dating of Martian material in situ, **AGES has the potential to solve the cratering rate ratio calibration issue, and address a fundamental unsolved problem in planetary science.**

Organics Detection and Characterization: The detection of organic compounds by evolved gas analysis is complicated by the prevalence of perchlorates or oxychloride compounds on Mars which serve to oxidize a portion of the organic compounds upon heating. Nevertheless, the SAM experiment was able to detect several simple chlorinated organic compounds (Figure 2). When the AGES experiment is operated in a "dynamic" mode utilizing its turbomolecular pump, all thermally evolved gas derived during pyrolysis heating passes through the ion source of the mass spectrometer. As a result, this experiment is even more sensitive for organics detection (i.e., has a lower limit of detection) than the SAM evolved gas experiment by a factor of ~800 since in SAM most of the gas is flushed into a trap for GCMS analysis. AGES utilizes direct line-of-sight from the sample to the ionization region. Consequently, gas/wall interactions are minimized for reactive species, simplifying data analysis. A breadboard of this experiment has been field-tested a number of times by the Goddard Space Flight Center (GSFC) mass spectrometer group [16].

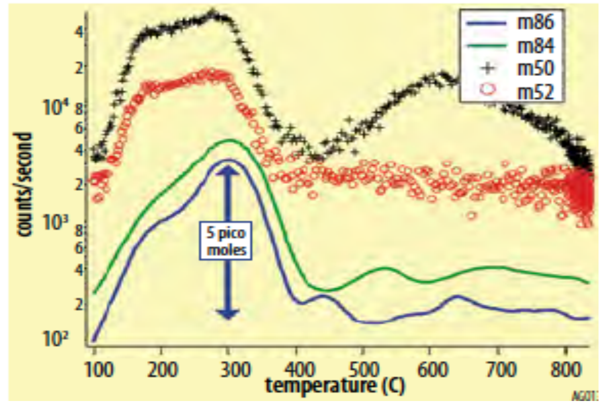

Figure 2. An example of detection of simple chlorinated organic compounds by the SAM experiment. The AGES sensitivity in this EGA mode is ~800 x greater since all the evolved gas passes through the ion source of the mass spectrometer.

Summary: An AGES type investigation is based on mature and flight proven technologies and protocols. On Mars, it could directly address significant priorities of the Mars exploration program by enabling the extensive chemical characterization of martian surface and subsurface materials, providing unequivocal insight into: i) radiation exposure and biosignatures preservation potential; ii) geological history, processing and evolution; and iii) organic and inorganic composition. Similar objectives could be realized on the surfaces of other solar system rocky surfaces.

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