IN SITU GEOCHRONOLOGY ON THE MARS 2020 ROVER WITH KArLE (POTASSIUM-ARGON LASER EXPERIMENT). B. A. Cohen[1], T. D. Swindle[2], S. E. Roark[3]. [1]NASA Marshall Space Flight Center, Huntsville AL 35812 (Barbara.A.Cohen@nasa.gov); [2]University of Arizona, Tucson AZ 85721; [2]Ball Aerospace and Technology Corporation, Boulder CO 80301

Introduction: If extinct and/or extant life is discovered on Mars, knowledge of the chronology of the biosphere will be of paramount importance [5]. KArLE will provide absolute ages of Mars 2020 rocks, which will allow us to understand them in the context of Mars' geologic history, connect them to other landing sites, and compare Martian epochs of habitability with the Earth's history and evolution of life. KArLE significantly enhances the ability of Mars 2020 to meet its science objectives by performing in situ age dating on key lithologies, enabling targeted searches for ancient biosignatures and increasing the chances of identifying evidence for Martian microbial life.

The KArLE investigation makes its measurements on a core sample obtained with the rover drill, inserted into a small, mechanically simple chamber, followed by interrogation by laser-induced breakdown spectroscopy (LIBS), mass spectrometry, and optical imaging. The KArLE experiment is flexible enough to accommodate any partner providing these instrument components, a creative approach that extends the ability of the Mars 2020 payload to accomplish an additional highly-desirable science measurement for low cost and risk and minimal extra hardware.

KArLE Breadboard: The analysis methods used to derive an age in the KArLE experiment have been developed, tested, and validated by three independent laboratories over 5+ years [7-14]. Under a PIDDP grant, we constructed a full breadboard of the KArLE concept to verify the measurement capabilities and performance, and to conduct trades in implementation, to bring the concept to TRL 4.

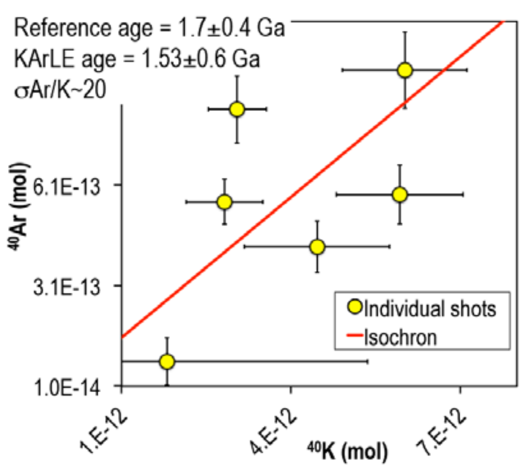

Fig. 1. KArLE measurements of Boulder Creek granite yield an isochron age within 10% of the accepted crystallization age.

LIBS spectra are collected with every shot or gated over multiple shots. Spectra are corrected for background, normalized to total radiance, and continuum subtracted before [K] is determined by peak areas referenced to standards. Quantitative gas abundance can be measured by different kinds of mass spectrometers, including quadrupole (QMS) and ion-trap (ITMS) mass spectrometers. ^{40}Ar levels in Martian samples are generally sufficient to measure against total gas backgrounds of 1E-6 torr with 500-750 laser shots.

To relate the absolute QMS and relative LIBS measurements to each other, KArLE measures the volume of the ablated material by z-stacking successive images at successive depths within the laser pit, and computes it to mass via density, which for the majority of planetary samples is acceptable without introducing significant uncertainty.

We previously reported results on Fish Canyon Tuff, a well-characterized Ar dating standard [12]. Here we update our results with Boulder Creek Granite, a natural sample with an Rb-Sr age of 1.7 Ga [15]. We polished one face to provide a reference surface for the microscopy work, then inserted the sample into our test chamber and collected simultaneous LIBS and QMS measurements. We then removed the sample to the laser confocal microscope for pit volume analysis and downsampled the data to the resolution of known microimagers [16]. Our preliminary results yield an age of 1.54 ± 0.6 Ga, which is within 10% of the accepted crystallization age (Fig. 1).

KArLE Implementation: KArLE uses flight-proven instrument components arranged around a vacuum chamber to measure K and Ar at the same time on the same sample to achieve a precise age, while also

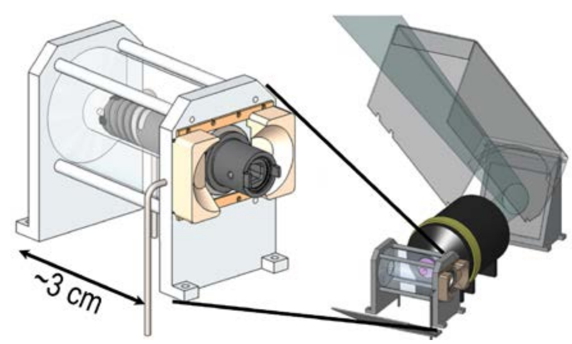

Fig. 2. KArLE flight concept. Left, KArLE chamber with a core sample inserted inside a drill bit. The drill bit forces dust cover doors open and forms an external seal on the chamber. Right, KArLE in its deployed position showing the chamber, optical assembly, fold mirror, and optical path for remote LIBS measurements and imaging.

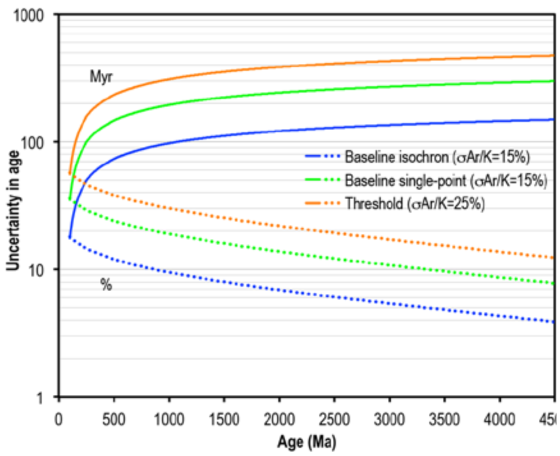

Fig. 3. Expected uncertainty in age (Myr, solid; %, dashed) as a function of rock age for the KArLE baseline and threshold values.

providing the mission a baseline ability to examine core samples and acquire elemental analysis and imaging, on Mars 2020 candidate cache samples.

KArLE measurements are achieved by providing a small, mechanically simple vacuum chamber and lens set (Fig. 2), drill bits with cut-out slots that enable remote LIBS and imaging of the core sample, and auxiliary hardware to enable mass spectrometer measurements. KArLE relies on the rover's coring system for sample collection, an optical camera for visual inspection, LIBS for elemental analysis, and mass spectrometry for noble-gas analysis. This makes the KArLE ex periment a simple, non-invasive system that requires few resources, no consumables, no chemicals, and limited sample handling.

K-Ar ages increase logarithmically with the Ar/K ratio, while uncertainties increase linearly as a function of each measurement. The KArLE baseline experiment for Mars 2020 adopts conservative uncertainty targets for each measurement based on established instrument performance and laboratory demonstration: 5% for ^{40}Ar abundance by mass spectrometry, 10% for K concentration via LIBS, 5% for density via bulk composition, and 10% in the ablated pit volume by optical methods – or 15% in ^{40}Ar/^{40}K ratio. In addition, the KArLE ability to construct an isochron of multiple points further reduces the combined uncertainty for a linear array (Fig. 3).

The extensive flight and laboratory-based work that has been conducted using the KArLE components establishes the limits of detection (LOD) for rocks datable by KArLE. For K, the LOD = 0.1 wt% using the 769.89 nm line. For Ar, the limit is set not by the ability of the mass spectrometer, but by the background Ar level, which we expect to be ~1E-6 torr (~1E-9 mol ^{40}Ar in the Martian atmosphere). Figure 4 shows the expected ability of KArLE to measure the age of rocks

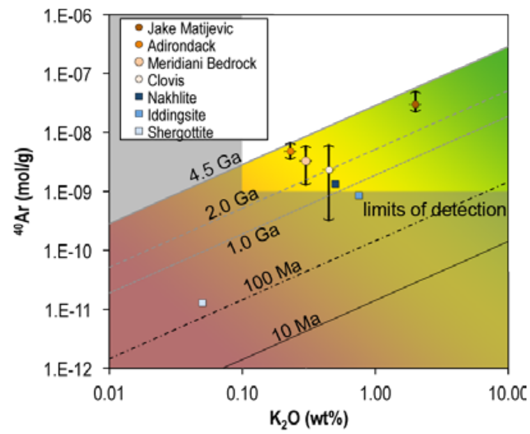

Fig. 4. Predicted ability of KArLE to achieve meaningful ages on Mars rocks [1, 2]. Uncertainties for surface rocks are from uncertainty in stratigraphy or age calibration [3, 4]. KArLE will measure the age of these rocks with uncertainties comparable to those with Martian meteorites [6].

encountered by Spirit, Opportunity, and Curiosity, with uncertainties comparable to those with Martian meteorites. This level of uncertainty will be a significant improvement over current efforts using Curiosity [17], allowing KArLE to place Mars 2020 rocks in a planetary and solar system-wide context.

Summary: The KArLE experiment uses flight-heritage components combined in a novel way to make in situ noble-gas geochronology measurements on future planetary science missions. Additional benefits derive from the fact that each KArLE component achieves analyses common to most planetary surface missions. The dual-use components make KArLE a highly attractive way to integrate geochronology into the Mars 2020 mission.

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