**Testing a Possible Surge in Impacts on the Earth and Moon 2 Billion Years Ago.**

W. F. Bottke and F. S. Anderson, Southwest Research Institute and NASA’s SSERVI-ISET Team, Boulder, CO (bottke@boulder.swri.edu).

**Introduction:** The Moon has the best preserved and most accessible record of the last 3.5 Gyr of inner Solar System bombardment. By linking crater counts on Apollo terrains to the radiometric ages of samples, scientists have developed chronologies that can date cratered surfaces on the Moon, Mercury, and Mars. Standard chronologies (e.g., Neukum & Ivanov 2001) suggest large impacts on these worlds decreased from ~3.8 to 3 Ga and were constant from ~3 Ga to now. Recent advances (e.g., LRO) now allow us to assess the validity and improve traditional chronologies.

Challenges to the standard chronology can be found in recent work (e.g., Marchi et al. 2009; Robbins 2014). For example, Robbins (2014) used LRO images to show that crater spatial densities at Apollo calibration sites could be incorrect by a factor of 2. This suggests major chronological changes are required, with ~3 Ga ages derived via crater counts now ~2 Ga. This has major implications. For example, most lunar volcanism is thought to have occurred > 3 Ga, but the new chronologies would imply a surge of impacts and lunar volcanism ~2 Ga.

Tantalizing clues supporting this surge and the new chronology come from the following:

1) Two of Earth’s three known Chixculub-sized craters formed 1.85-2.0 Ga (Sudbury & Vredefort; Griere et al. 2008). Stable terrestrial terrains from ~2 Ga are limited (e.g., Mazrouei et al. 2019), so scaling from the observed craters yields ~10-20 such impacts near that time. This high number is needed to explain Earth’s record of impact spherule beds from this era (3 within 1.8-2.0 Ga; 4 within 2.4-2.6 Ga; Bottke et al. 2012; Mougel et al. 2017).

2) This putative “impactor shower” should have made a ~2 Ga Chixculub-sized crater on the Moon. While no such craters exist using the standard chronology, the 180 km Tsiolkovskiy crater is ~2 Ga in the new chronology. This young age is also a better fit with Tsiolkovskiy’s high rock abundances and steep slopes (Greenhagan et al. 2016; Kreslavsky & Head 2016).

3) Small craters superposed on younger, 70-100 km lunar craters suggest that more large lunar craters formed ~2 Ga than immediately before or after (Kirchoff et al. 2019; submitted).

4) Apollo 15 samples with 1.3 and 2.0 Ga ages are thought to come from the nearby craters Autolycus (39 km) and Aristillus (55 km) (e.g., Grange et al. 2013; see ACM-SAT Science Goal 1c). With the new chronology, crater counts on Aristillus by M. Kirchoff and on Autolycus’ least cratered ejecta unit by Hiesinger et al. (2016) reproduce these ages.

An implied surge of lunar volcanism ~2 Ga would revolutionize our ideas about the Moon’s internal evolution, while numerous impacts ~2 Ga may suggest a connection with Earth’s “Great Oxidation Event” at ~2.3 Ga (Lyons et al. 2014).

One possible way to test this scenario would be with sample return, but that is challenging and expensive. We believe a cost-effective alternative worth exploring is the in situ dating of lunar rocks from upcoming lunar landers with the Chemistry Dating EXperiment (CDEX).

CDEX has reached near-flight status through 15 years of NASA instrument development support. It is designed to date materials in situ using the $^{87}$Rb-$^{87}$Sr and Pb-Pb dating methods that have been employed for a wide range of igneous rocks, lunar, and Martian samples (Faure et al. 1986).

CDEX uses laser ablation resonance ionization mass spectroscopy (LA-RI-MS) to vaporize a small sample of target rock and obtain isobar free Rb, Sr and Pb isotopic measurements. It measures 100-300 locations on a rock sample in a raster pattern, ablating 50 μm diameter laser spots, thus allowing for Rb-Sr and Pb-Pb isotope ratios to be measured for a range of different minerals. At each spot, CDEX also produces thousands of Rb, Sr, Pb backgrounds and elemental abundances using laser ablation mass spectroscopy (LA-MS). The measurements are calibrated with standards to derive multiplicative corrections, correlated errors, and a final isochron.

As evidence CDEX works, we have published results for the Martian meteorite Zagami (Anderson et al., 2015b) and the Duluth Gabbro (Anderson et al., 2015a). Many additional samples have been tested. Our age results are typically within ~1σ of those in the literature. We suggest CDEX is perfectly positioned with NASA CLPS and Lunar Landing program to help us revolutionize our ideas about lunar and solar system chronology over the last few Gyr.