**TESTING AND RESILIENCE OF THE IMPACT ORIGIN OF THE MOON.** K. Righter[1] and R.M. Canup[2], [1]NASA JSC, Mailcode XI2, NASA Parkway, Houston TX 77058; kevin.righter-1@nasa.gov, [2]Southwest Research Institute, 1050 Walnut Street - Suite 300, Boulder, CO, USA.

**Introduction:** The leading hypothesis for the origin of the Moon is the giant impact model, which grew out of the post-Apollo science community [1]. The hypothesis was able to explain the high E-M system angular momentum, the small lunar core, and consistent with the idea that the early Moon melted substantially. The standard hypothesis requires that the Moon be made entirely from the impactor, strangely at odds with the nearly identical O isotopic composition of the Earth and Moon, compositions that might be expected to be different if Moon came from a distinct impactor [2]. Subsequent geochemical research has highlighted the similarity of both geochemical and isotopic composition of the Earth and Moon [3], and measured small but significant amounts of volatiles in lunar glassy materials [4], both of which are seemingly at odds with the standard giant impact model. Here we focus on key geochemical measurements and spacecraft observations that have prompted a healthy re-evaluation of the giant impact model, provide an overview of physical models that are either newly proposed or slightly revised from previous ideas, to explain the new datasets.

**Isotopic measurements Si, Mg, K, O, Fe, Ti, Cr, W, Mo, Ru:** Many isotopic measurements of lunar and terrestrial materials have revealed nearly identical values for the two bodies. Although for some isotopic systems the inner solar system is quite uniform, there are some isotopic differences. For example a small difference between lunar and terrestrial W and O [5,6] isotopic composition has been measured. The significance of the similarities/differences is actively debated.

**Volatiles:** Lunar glasses contain measurable amounts of H, C, and S, which was surprising since many previous studies had concluded that lunar materials are dry or even “bone dry” [4,7]. The rock record on Earth does not extend back as far as that on the Moon, but it comes close with studies of zircons from various Archean terranes such as the Jack Hills in Australia [8]. Such zircons have O isotopic compositions indicating influence of water at the surface of the Earth, suggesting water was delivered early in Earth’s history, and that the early Earth-Moon system may have contained more volatiles than previously thought. New LRO measurements of volatiles at the lunar surface has also prompted re-evaluation of the origin and abundance of lunar volatiles [9].

**Response to new data:** These new geochemical data, especially the isotopic data – have forced the issue of why the Moon is not different in composition from Earth, as apparently predicted by the standard giant impact scenario. Various revised or new ideas have been proposed to explain the new data.

*Exploration of planetary dynamics:* If a spun up Earth was impacted, the material ejected is mostly from Earth [10]; a drawback is that this hotter resulting disk may be at odds with a volatile-bearing Moon. In a hit and run collision [11], impact geometry allows more of the Moon to originate from proto-Earth’s mantle, but raises the question “where is the impactor now?”. Solutions involving orbital resonances and Trojan Moons allow the Moon to be accreted from material originating from nearly the same region as that of Earth [12].

*Exploration of disk dynamics:* The dynamics and evolution of the circumterrestrial disk include many unexplored aspects. Outcomes of recent modelling [13] indicate that silicate Earth material might mantle impactor material in the lunar interior as the circumterrestrial disc collapses into the Moon. Alternatively, isotopic equilibration between hot Earth and the lunar disk may explain the Earth-like Moon [14], but this might cause disk instabilities that make it unviable.

*New ideas motivated by geochemical data:* Late stochastic accretion, in which Earth and Moon get different amounts of late chondritic additions, was proposed to explain W differences [15]. Other geochemical and isotopic modelling indicate that inner solar system material is Earth-like; in that case O isotopes are expected to be similar, and W can be explained by Monte Carlo simulations [3].

Each of these new or revised ideas has pros and cons, which will be evaluated. Attempts will be made to propose tests that might help distinguish these models and test their viability, including geochemical, dynamic, and exploration-based data or measurements.

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