IMPACT ORIGIN OF THE MOON: NEW DATA, NEW MODELS, AND NEW CHALLENGES. K. Righter[1], R. M. Canup[2], N. Dauphas[3], T. Magna[4], [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, [3]Department of Geophysical Sciences, The University of Chicago, 5734 South Ellis Avenue Chicago, IL 60637, [4]Czech Geological Survey, Klarov 3, CZ-118 21 Prague 1, Czech Republic.

Chapter summary. The leading hypothesis for the origin of the Moon is the giant impact model, which can explain the high Earth-Moon system angular momentum and the small lunar core, and is consistent with an early lunar magma ocean [1-2]. In this chapter, we will discuss 1) key geochemical measurements that have prompted a healthy re-evaluation of the giant impact model, 2) varied impact scenarios that are either newly proposed or somewhat modified relative to prior ideas, 3) assessments of the likelihood that current models can explain the physical and dynamical constraints derived from the Earth-Moon system, and 4) key areas requiring additional research to enable further progress.

Background. The standard giant impact hypothesis implies that the Moon is made predominantly from material originating from the impactor. At face value, this seems at odds with the nearly identical oxygen isotopic composition of the Earth and Moon, which might be expected to be different if Moon came from a distinct impactor, given the quite different O compositions of Earth and Mars. Recent work has highlighted the similarity of both geochemical and isotopic compositions of the Earth and Moon across multiple elements [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. As such, much recent work has focused on attempts to reconcile an impact origin with the physical and chemical aspects of the Earth-Moon system.

New Datasets

Isotopic measurements: Many isotopic measurements of lunar and terrestrial materials have revealed nearly identical values. Although for some isotopic systems the inner solar system is quite uniform, there are some differences. For example a small difference between lunar and terrestrial W and O [5,6,22] isotopic composition has been measured, although for O other analyses find no difference [21]. 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]. Terrestrial zircons have O isotopic compositions indicating influence of water at the surface of the Earth [8], suggesting that the early Earth-Moon system may have contained more volatiles than previously thought [9]. Newly measured isotopic fractionation of volatiles (Zn and K) in lunar samples has been interpreted as evidence of volatile escape [10-11].

New Models. A variety of impact scenarios have been proposed to attempt to explain the Earth-Moon system characteristics. These include 1) a canonical impact by a Mars-sized projectile [12], with either post-impact equilibration [13] or an Earth-like composition impactor [3,14-15]; 2) a smaller, high-velocity impact into a rapidly rotating Earth, followed by a mechanism to remove excess angular momentum produced by such an event [16-17]; 3) a half-Earth impact, followed by a mechanism to remove excess angular momentum produced by this event [18]; 4) a hit-and-run impact by a relatively Earth-like composition impactor [19]; and 5) formation through a series of ~20 sub-Mars sized impactors [20].

In addition there have been a number of new works that have explored the protolunar disk conditions and evolution, the accumulation of the Moon and its expected composition, new dynamical evolutions of the early Earth-Moon system, the role of the evection resonance with the Sun, and the statistics of impactor properties based on terrestrial accretion models.

Changes since NVM-2 Houston. NVM-2 highlighted the need to cover stable and radiogenic isotope constraints on the origin of the Earth-Moon system because these would not be covered in any other chapter. In addition, there are multiple new relevant works as on topics discussed above.

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