**Bulk Composition of the Moon: Importance, Uncertainties, and What We Need to Know.**

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**Introduction:** The bulk composition of the Moon is important to test models for how the Moon formed and to understand how the terrestrial planets accreted. Models of the accretion of the terrestrial planets from a disk of lunar to Mars-sized embryos [1] indicate widespread mixing of the embryos and their fragments, so that each terrestrial planet formed from material originally located throughout the inner solar system (0.5 to 2.5 AU). Such a process would erase any initial radial chemical variations in the compositions of the planetesimals and in the final assembled planets. However, Robinson and Taylor [2] suggest that a distinct compositional gradient remains as shown by the FeO contents of the terrestrial planets: Mercury (3 wt%), Venus and Earth (8 wt%), and Mars (18 wt%). Drake and Righter [3] discuss the unique composition of the Earth and also conclude that planets accreted mostly from narrow feeding zones. Knowing the composition of the Moon will help us understand the full extent of the Earth’s accretion zone. We examine what we know about the composition of the Moon, with emphasis on elements that can be determined by remote sensing techniques (FeO, Al₂O₃, and Th).

**The Complex Structure and Composition of the Crust:** The Clementine and Prospector missions have revolutionized our view of the lunar crust, but numerous uncertainties remain. For example, Jolliff et al. [4] identified several compositionally distinct terranes on the Moon. The compositions of the terranes are reasonably well established, but the volumes they occupy are not known very well. Using their nominal values for volumes and Th contents, and our measurements of FeO and Al₂O₃, we infer that the crust contributes 0.11 ppm Th, 0.6 wt% FeO, and 2.9 wt% Al₂O₃ to the lunar bulk composition. In contrast, we [5-7] have presented a somewhat different view of the crust. We suggest that it is layered with an upper mixed, somewhat mafic zone, underlain by an anorthosite zone, which overlies a more mafic lower crust. Using the volumes given by Taylor et al. [6], but with Jolliff’s Procellarum KREEP terrain added as a separate unit, we calculate the following contributions to the lunar bulk composition: Th, 0.14 ppm; FeO, 0.7 wt%; Al₂O₃, 2.7 wt%. Both estimates indicate Th higher than in the nominal primitive terrestrial mantle (0.08 ppm [e.g., 8]).

**Mantle Composition:** We know even less about the mantle. We can use the compositions of mare basalts to estimate the composition, but there are great uncertainties in Th, because magmas likely assimilated KREEP as they migrated to the surface. One could assume that Th concentrated almost completely in the crust during initial lunar differentiation, leaving essentially none in the mantle, but we do not know if all lunar material participated in the primary differentiation. Experiments on mare basalts suggest derivation from olivine-pyroxene sources with FeO around 18 wt%, which would contribute 16.5 wt% FeO to the lunar bulk composition (if the mantle is 89.8 wt% of the Moon). The experiments also indicate that aluminous phases were exhausted, so Al₂O₃ might have been about 0.4 wt% in the mare basalts. Robinson and Taylor [2] suggest that a distinct composition of the Earth and also conclude that planets accreted mostly from narrow feeding zones. Knowing the composition of the Moon will help us understand the full extent of the Earth’s accretion zone. We examine what we know about the composition of the Moon, with emphasis on elements that can be determined by remote sensing techniques (FeO, Al₂O₃, and Th).

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