EGU2020-4495: Chemical composition of the Moon's ‘primary’ crust – a clue at a terrestrial origin

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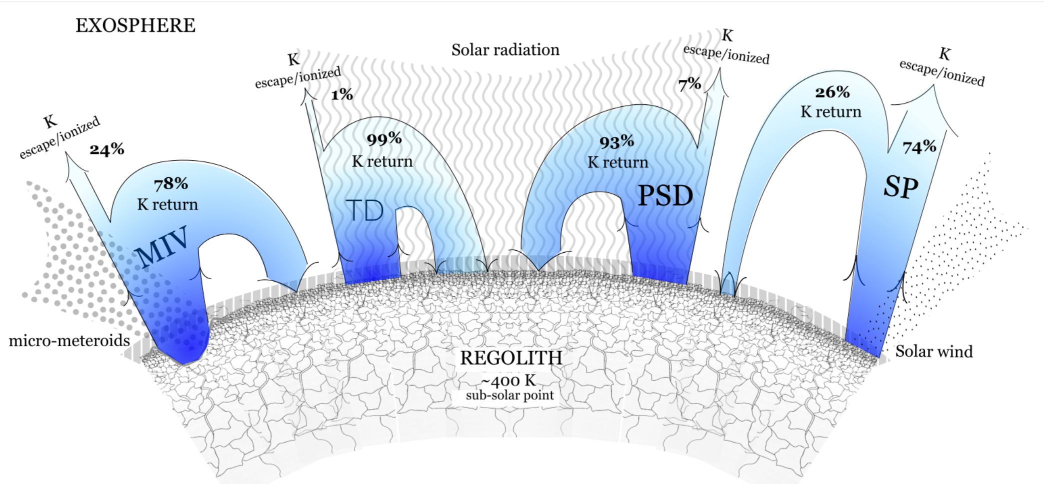
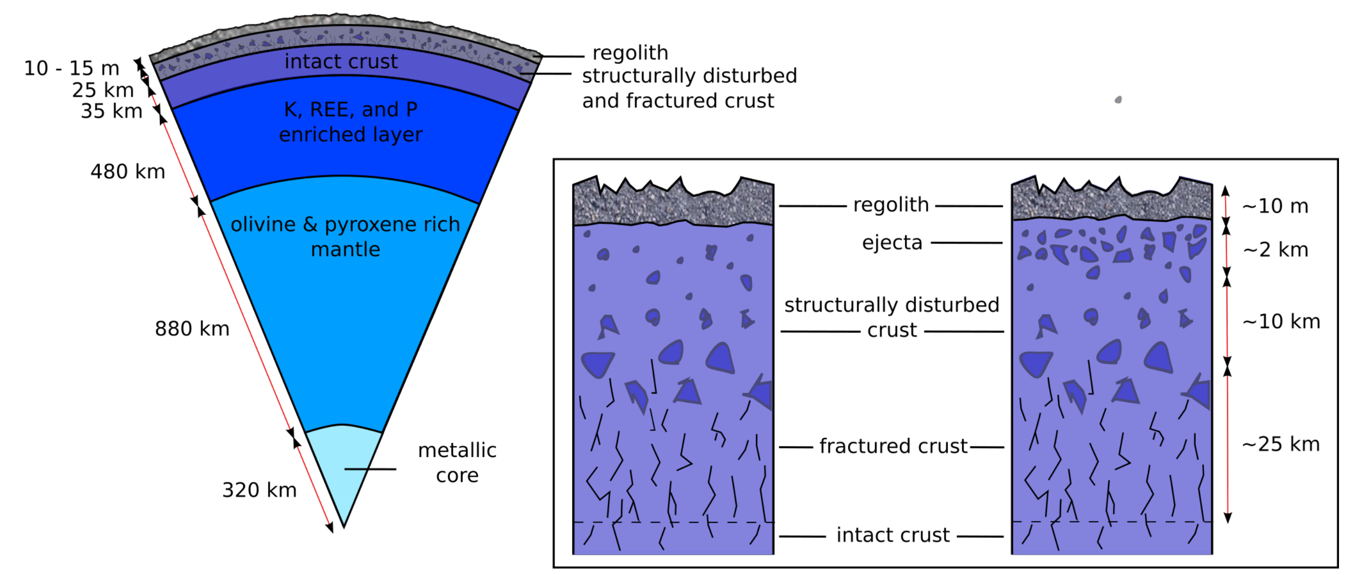
The Moon's surface is being continuously processed ('aged') due to its direct exposure to space **(1)**. Over time, effects of this exposure have led to the Moon being covered in a fine-grained regolith **(2)**, with a chemical composition as we measure it today **(3)**. At present, solar wind and meteoroid impacts modify the lunar surface in about equal parts. 4.4 billion years ago, though, when the Moon was freshly formed, space posed a very different environment to our Moon. The Sun was much more active than today, and the infant Moon was downright pummeled by meteoroids of varying sizes **(4)**. We model the 'ageing' of the lunar surface due to solar wind and meteoroid bombardment at different epochs in time, with a focus on the associated changes in chemical surface composition. During the Moon's lifetime, the local surface 'ageing' has sporadically been interrupted and partially resetted by impacts big enough to penetrate through the current regolith layer, i.e., impacts excavating fresh material from below. Nevertheless, lunar surface 'ageing' acts incessantly, and its effects have to be taken into account when modelling the Moon's origin and evolution. Today, the lunar surface is significantly depleted in volatile elements such as K and Na, standing apart from the terrestrial planets in K versus K/U diagrams **(5)**. To show the maximal extent surface 'ageing' can have on the lunar K/U ratio, we show the Moon's position in said diagram assuming 4.4 billion years of uninterrupted surface processing **(6)**.

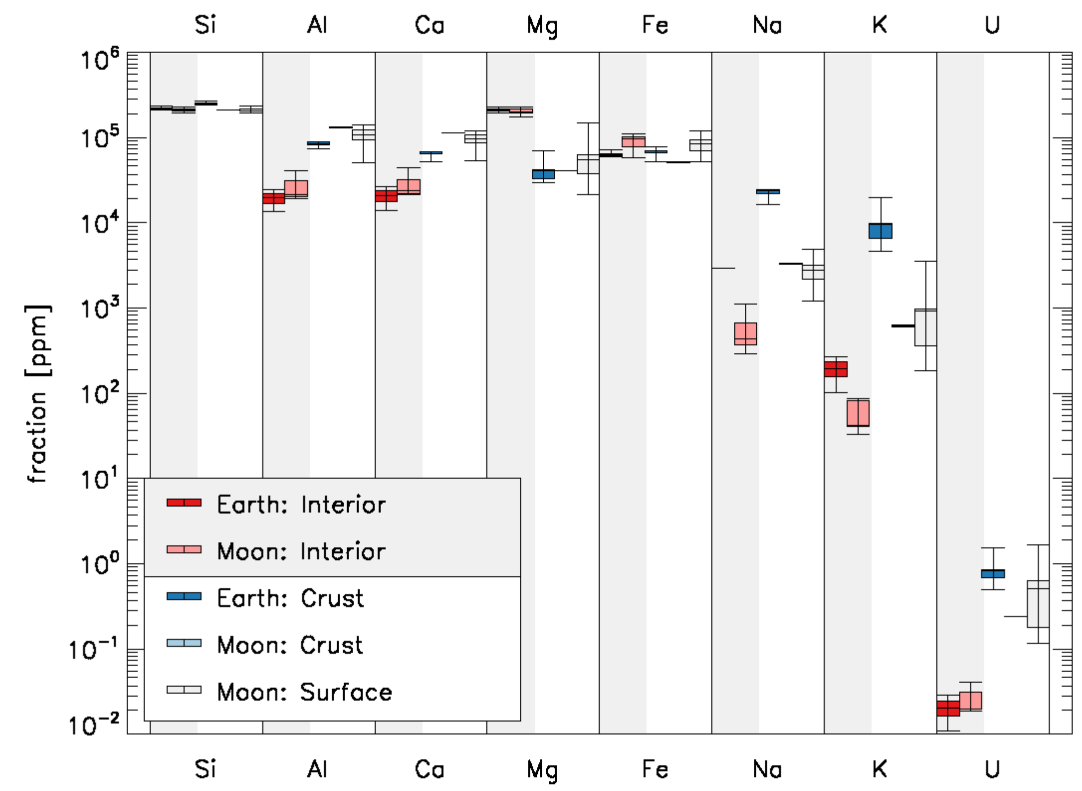
(1) The chemical composition of the topmost surface layer is a direct result of the balance between the number of particles that are released from and the number of particles that return to the lunar surface. There are four main drivers for particle release from the lunar surface: meteoroid impact vaporization (MIV), thermal desorption (TD), photon-stimulated desorption (PSD), and sputtering (SP), each imposing a different energy distribution onto the particles being released. Depending on the energy distribution, a certain number of particles is lost to space through gravitational escape whereas a certain number of particles returns to the surface. In addition, particles can be lost during their flight due to ionization and fragmentation.

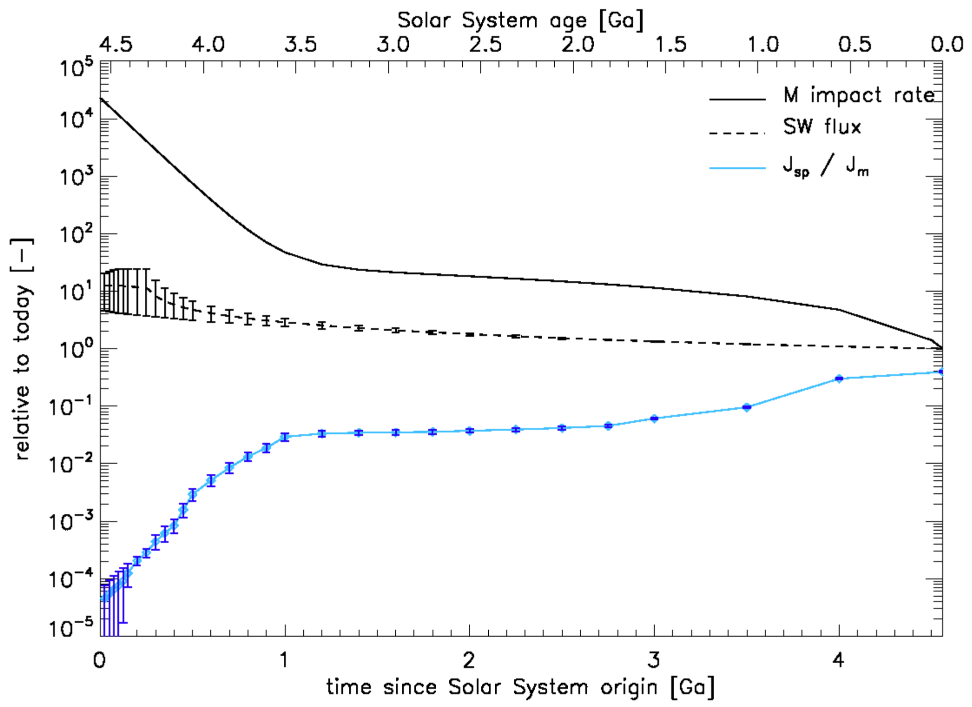




(2) As particles interact with the lunar surface, the topmost surface material is shattered, fragmented, pulverized, welded, overturned, mixed, churned, and homogenized, creating a loose layer of fine-grained regolith in the process. This layer is expected to measure 4–5 m for the mare regions and 10–15 m for the highland regions. When bigger meteoroids impact, the local stratigraphy may be abruptly overridden, exposing a new surface layer. Depending on the impact record, the lateral layering may be manifold, with ejecta layers woven in intermittently.

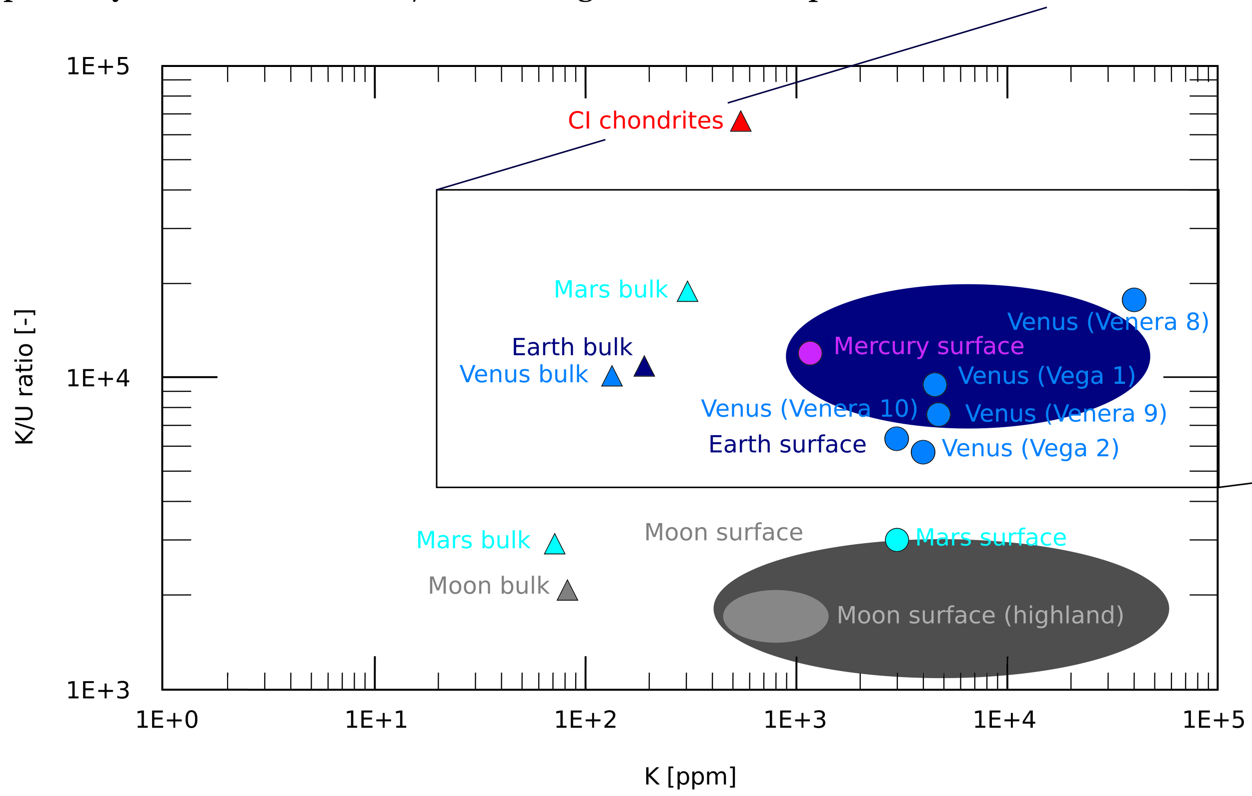
(3) We compare published compositions for Earth's interior, the Moon's interior, Earth's oceanic & continental crust, the Moon's crust, and the lunar surface (basalts & regolith). Models predict that planetary interiors are richer in Mg & Fe, and poorer in Al, Ca, Na, K, and U than planetary surfaces.

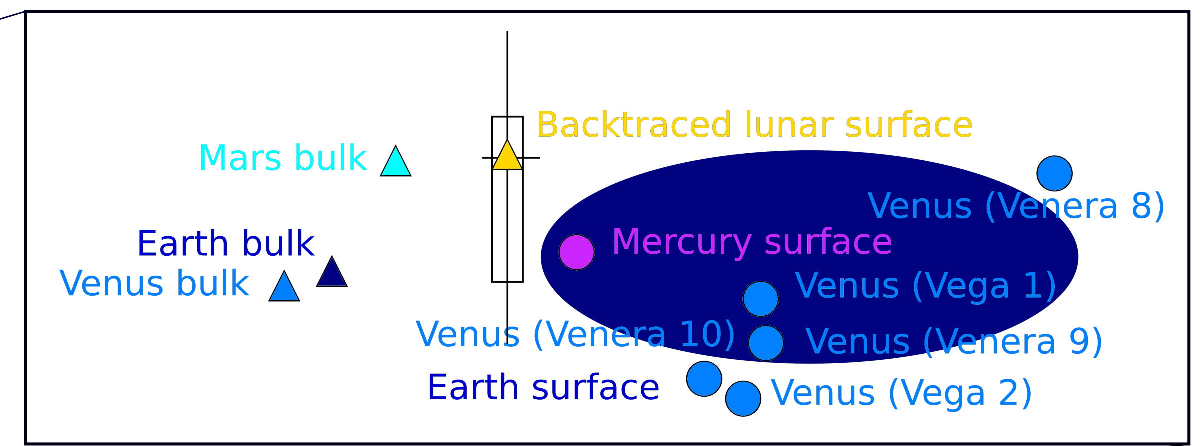




(4) Space was a much harsher environment at early times. Solar wind ion fluxes were uo tp 10-20 times higher and meteoroid particle fluxes were uo tp ~10,000 times higher than today (100 Myr half-life model). Consequently, the surface released particle flux was much higher at early epochs, with the contribution due to MIV being up to 100,000 times higher than the contribution due to SP.

(5) Whereas the lunar surface U abundance value is similar, the lunar surface K abundance value is much lower than the terrestrial counterparts. This leads to the Moon being positioned exceptionally low in a K versus K/U ratio diagram. Note that published Mars values differ widely.





(6) We model the lunar surface 'ageing' effects due to meteoroids and solar wind particles as a function of time, continuously tracing the chemical composition of the topmost surface layer. By reversing the 'ageing' process, we can determine the chemical composition of the original lunar surface 4.4 billion years ago, if **no major impacts** had interrupted the 'ageing' process. Our model results in a surface composition that is much less depleted in volatiles than the surface observable today, exhibiting a K/U ratio compatible with Earth and the other terrestrial planets, which strengthens the theory of a terrestrial origin for the Moon.