COMBINED ANALYSIS OF THORIUM AND FAST NEUTRON DATA AT THE LUNAR SURFACE.

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Introduction: The global distribution of the radioactive elements (U, K, Th) at the lunar surface is an important parameter for an understanding of lunar evolution, because they have provided continuous heat over the lifetime of the Moon. Today, only the thorium distribution is available for the whole lunar surface [1].

Another key parameter that characterize the surface of the Moon is the presence of mare basalts. These basalts are concentrated on the nearside and are represented by materials with high-Fe content, sometimes associated with high-Ti. We demonstrated elsewhere that the fast neutron measurement made by Lunar Prospector is representative of the average soil atomic mass <A> [2]. <A> is primarily dominated by Fe and Ti in basaltic terranes, and therefore the map of the fast neutrons provides a good delineation of mare basalts.

We focus here on the correlated variations of thorium abundances and fast neutron fluxes averaged over areas of 360 km in diameter, in an attempt to provide a better understanding of the thorium emplacement on the surface of the Moon.

Covariance Map: A map is constructed by calculating the covariance between thorium and fast neutron data sets in a ~180 km radius area centered on each 2^ox2^o equal-area pixel. The result is shown Figure 1. The covariance map enhances the regions where the variations in both parameters are correlated. The data are initially standardized; therefore the covariance values could range from –1 (anti-correlation) to +1 (perfect correlation). Figure 1 shows pixels with values ranging between –1 and +0.55. Inspection shows two features in places where thorium abundances and fast neutron fluxes are significant.

(1) A positive line matches the limits of the Procellarum KREEP Terrane [3]. These simultaneous increases of thorium abundances and fast neutron fluxes support the hypothesis of a correlated emplacement process for thorium and {iron, titanium} (represented by the fast neutrons), but does not imply a common reservoir.

(2) Four major areas inside Procellarum KREEP Terrane present high negative covariance values: The region Copernicus-Mare Insullarum-Kepler, the Aristarchus plateau, the highlands north and northwest of Mare Imbrium, and Montes Apenninus-Montes Caucasus region. These negative covariance values express a local anti-correlation between Th and {Fe, Ti}, whereas their variations are correlated on most part of the near side. They occur only at locations where thorium abundances are very high. They could be explained by the presence of KREEP basalt or thorium enriched mafic melt breccias, lower in Fe content than the surrounding mare basalts.

These negative covariance values inside a region of positive correlation suggest a non-local origin for very high-Th materials.

Basin Signature and Origin of high-Th Materials: Impacts into multi-layered targets lead to a redis-

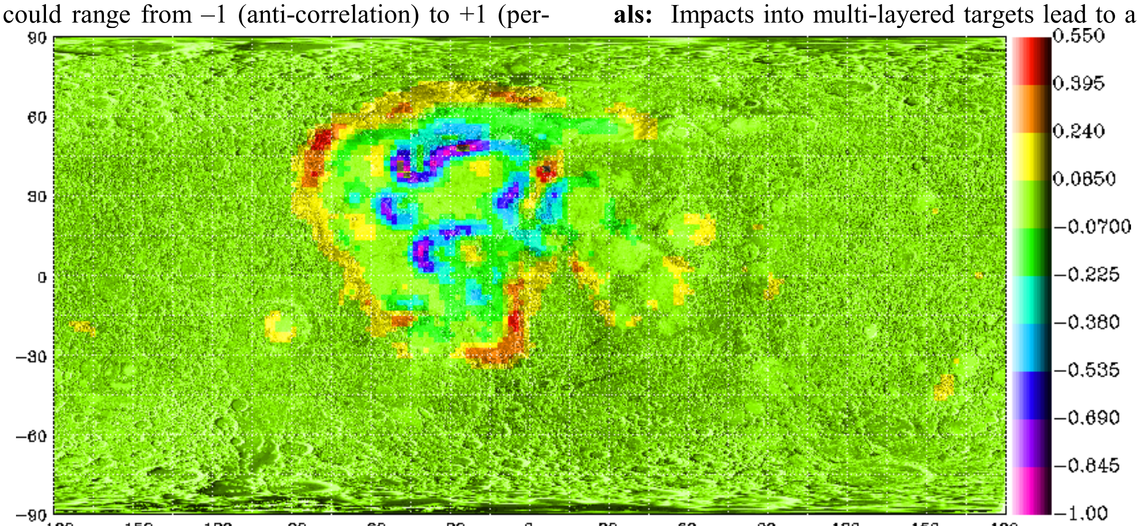

Figure 1. Covariance map of Th vs. fast neutrons. Equal area pixel distribution with a resolution of 60 km. The covariance area radius is 6^o. The data sets were initially standardized over the Moon.

tribution of materials with most of the ejecta falling back near the transient crater [4]. If those materials survive subsequent cratering and lava flows, and if their composition is different from that of their surroundings (high-Th for instance), then one can expect to observe a ring pattern in the rim area in the composition map.

Such a ring is visible around Imbrium basin (Figure 2). This is consistent with the assumption of a high-thorium oval region that covered Oceanus Procellarum [5], which was redistributed by Imbrium impact. This hypothesis is also supported by the negative covariance values, which match the ring around Imbrium. It is legitimate to look for other thorium ring(s) in this region that could support this scenario.

Inspection of thorium map reveals a circular structure in the northwestern sector of Oceanus Procellarum (Figure 2). This structure presents low-Th abundance at the center and a high-Th composition ring, in a very similar way to Imbrium case. We therefore adopt the hypothesis that this new circular structure may be associated with an unknown basin. This hypothesis is reinforced by a shallow circular depression seen in Clementine topography data [6], and by local high variations of the fast neutron flux [7].

Summary and Conclusion: Two major terranes on the nearside of the Moon are revealed in a covariance map of Th vs. fast neutrons. (1) The Procellarum KREEP Terrane (PKT) boundaries show up with smooth transitions from very low to medium-high Th contents, which are correlated with variations of the fast neutron flux (an index of composition for {Fe, Ti}). (2) Inside PKT, some regions present very-high thorium contents with sharp spatial variations that are strongly anti-correlated with the fast neutron flux. This result is consistent with the hypothesis of the redistribution of thorium from shallow depth to the surface during a large impact.

This is also supported by the existence of thorium rings around two major structures inside PKT: Imbrium basin and a circular pattern, which may be a previously unrecognized impact basin. This last basin would be located near 42.5°N latitude, and 62.5°N longitude, with a radius of about 410 km.

If this structure is actually a basin marked by Th-rich ejecta, the determination of its dimensions and of its age relative to the Imbrium impact will be very important. This basin is much smaller than Imbrium, and thus its ejecta should be representative of a composition of material closer to the surface than that of Imbrium. If it is older than Imbrium, then this impact must have reached the thorium-rich layer by itself, which might imply a new limit of the crustal thickness in this region.

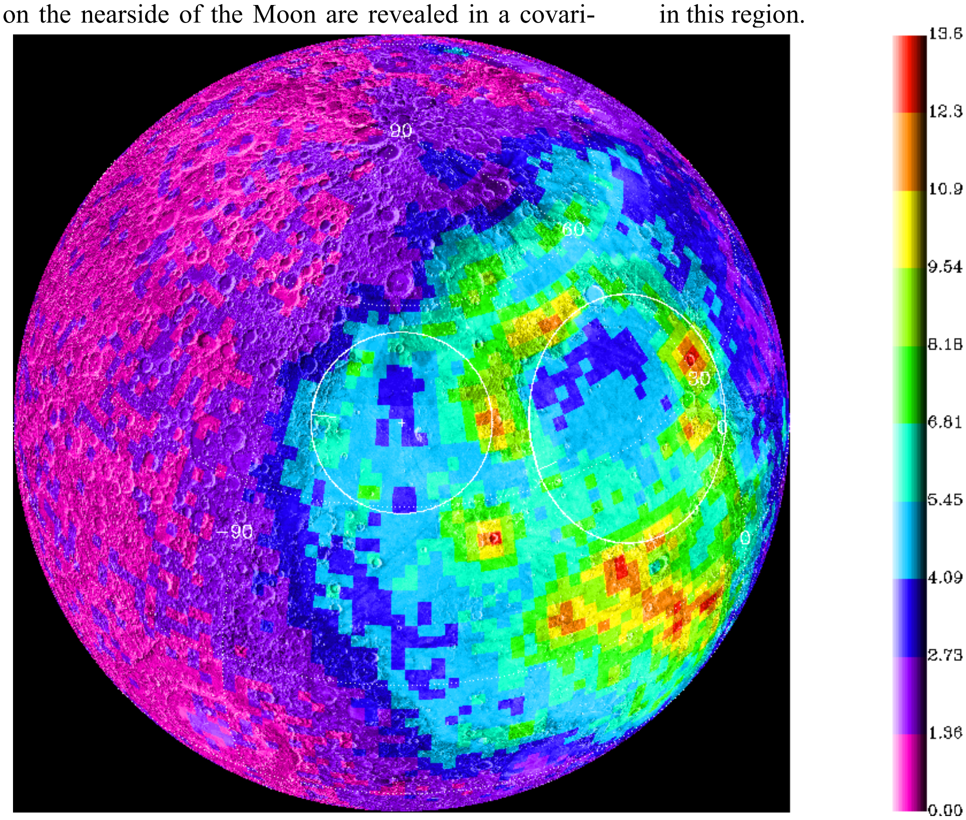

Figure 2. Map of thorium abundances (ppm) in the northern part of Oceanus Procellarum. The circles mark Mare Imbrium and the newly identified structure.

References:

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