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Potassium-Thorium Ratio on the moon: new results from Kaguya-GRS

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Abstract

The lunar surface offers a variety of rock and regolith compositions that result from the complex evolution of the Moon during the first third of its existence [1]. Today's crust is a mixing of feldspathic suites, various basalts (a small part in volume), and some materials enriched in incompatible and rare earth elements (KREEP). The global compositional maps, such as those returned by gamma-ray and X-ray spectrometers or derived from imagery cameras, are useful to study these geologic processes in more details. The SELENE mission is the first to employ a germanium (Ge) detector to observe lunar gamma rays [2]. In particular, the Potassium line at 1461 keV and the Thorium line at 2615 keV are well observed. These two elements, though well correlated [3], show some discrepancies. Since Potassium and Thorium are not carried by the same phases, the variation of their ratio puts important constrain on the lunar history. One of the goals for measuring global K abundances, is to find where they deviate from Th abundances, which for non-mare regions would indicate the occurrence of materials with non-KREEP-like K/Th

1. Observation

The SELENE satellites were launched on Sep. 14, 2007. The main orbiter Kaguya has been in the circular polar orbit around the Moon at 100 km altitude for more than one year. The GRS data were obtained from 14 Dec. 2007, to 17 Feb. 2008 (Period 1) and from 7 July 2008 to 11 Dec. 2008 (Period 2) with an effective measurement time of approximately 2700 hours [2]. These two periods differs in their energy resolution, which was poorer for the second period. Finally, from 11 Feb. 2009 to 11 May 2009, the moon was observed at an altitude of 50 km with good energy resolution. Results for several elements from these data have been reported [e.g., 4, 5, 6].

2. Methodology

We use the Healpix representation to project the data on the sphere. Healpix [7] is a Hierarchical, Equal Area, and iso-Latitude Pixelisation of the sphere and the final dataset is therefore a "spherical cube" of 3072 spatial elements times' 8192 spectral channels. In this analysis we have only used the spectra of the third period because of their better quality.

Then we have applied an Independent Component Analysis (ICA) method on the filtered data. ICA, like PCA, tries to transform the original representative space by searching for directions in a new space, so that the resulting vectors are independent, and not only uncorrelated like with PCA [8].

3. Results

Using this procedure it appears that the radioactive element component is split into two new components, the first one bears the lines of Uranium and Thorium, and the second one bears only the line of Potassium. This means that Potassium on one side and Thorium and Uranium of the other side are statistically spectrally independent.

To calibrate the two components, we used the same method described in [9] that established an empirical ground-truth calibrations for Lunar Prospector gamma-ray spectrometer data [10, 11] (Fig. 1).

The distribution of Thorium vs. Potassium (Fig. 2) shows two different trends; The first one is the general one described in [3] with a slope of 363, but a second trend of fractionation is also present with a higher slope of 453 indicating a different melting episode. This trend seems to be correlated with the Imbrium impact event.

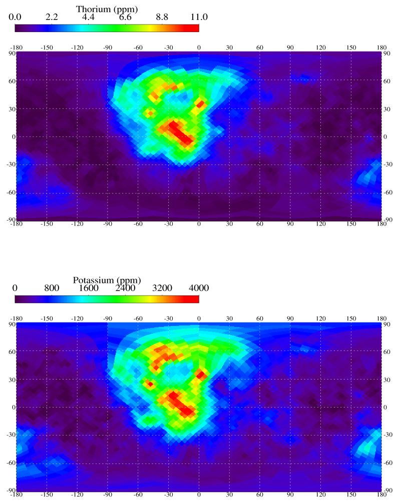

Figure 1: Calibrated maps of the Thorium and the Potassium

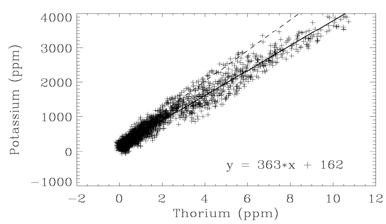

Figure 2: Plot of the Thorium concentration vs. the Potassium concentration

6. Summary and Conclusions

In conclusion, we demonstrate a clear statistical distinction between Potassium and Thorium-Uranium. We see that the higher K/Th ratio is located around Imbrium with moderate to high Thorium content. This behaviour could be due to a possible excavation of material different from the KREEP basalts [12] and/or a partial fractionation of K and Th, indicating a transient partial melting history.

Acknowledgements

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References

[1] Lunar Sourcebook, Cambridge University Press. Cambridge, 1991.

[2] Hasebe N., et al., Gamma-Ray Spectrometer (GRS) for lunar polar orbiter SELENE, Earth Planets Space, 60, 299-312, 2008.

[3] Lucey P. et al., Understanding the lunar surface and space-Moon interactions. Reviews in Mineralogy & Geochemistry, Vol. 60, pp. 83-219, 2006.

[4] Kobayashi, S., et al.: Determining the absolute abundances of natural radioactive elements on the lunar surface by the Kaguya Gamma-Ray Spectrometer, Space Sci. Rev., in press, 2010.

[5] Yamashita, N., et al.: Uranium on the Moon: Global distribution and U/Th ratio, Geophys. Res. Lett., 37, L10201, 2010

[6] Forni O. et al., Independent component analysis of the gamma-ray spectrometer data of Selene (Kaguya), IEEE Whispers09, pp. 1-4, 2009.

[7] Gorski K.M. et al., HEALPix: a framework for high-resolution discretization and fast analysis of data distributed on the sphere, ApJ, Vol. 622 pp. 759-771, 2005.

[8] Comon P., Signal Processing, Vol. 36, pp. 287-314, 1994.

[9] Gillis J. J. et al., Lunar surface geochemistry: Global concentrations of Th, K, and FeO as derived from lunar prospector and Clementine data. Geochimica et Cosmochimica Acta, Vol. 68, pp. 3791–3805, 2004.

[10] Lawrence D. J. et al., Thorium abundances on the lunar surface. JGR, Vol. 105(E8), pp. 20,307–20,331, 2000.

[11] Prettyman T. H. et al. Elemental composition of the lunar surface: Analysis of gamma ray spectroscopy data from Lunar Prospector. JGR, Vol. 111 doi:10.1029/2005JE002656, 2006.

[12] Haskin L. A., The Imbrium impact event and the thorium distribution at the highlands lunar surface. JGR, Vol. 103, pp. 1679–1689, 1998.