CONSTRAINING THE LUNAR CRUSTAL THICKNESS WITH SEISMOLOGY AND GRAVITY

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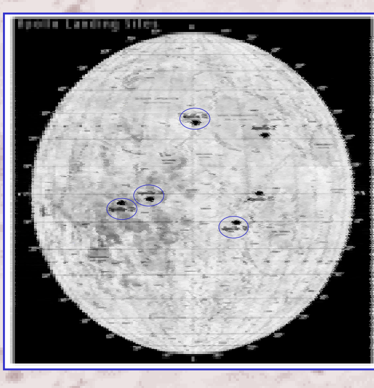
During the '70s, the Apollo missions set up a seismic network on the nearside of the Moon, allowing fundamental questions of lunar science to be adressed. Recently this data set was reinvestigated in order to shed light on ambiguous results of ancient studies. One of which was the proposed 60 km mean crustal thickness.

Our work first consisted of reprocessing the whole set of data, and then to perform a new independent analysis on arrival times. This inversion resulted in a new view of the seismic velocity distribution with depth, especially characterized by a much thinner crust : mantle velocities are reached at 30 km depth instead of 60 km in the older studies ([1], [3], [4]). This is coherent with our study of Receiver Functions ([5], [9]) which highlighted precursor arrivals related to S-to-P wave conversions at the crust-mantle boundary.

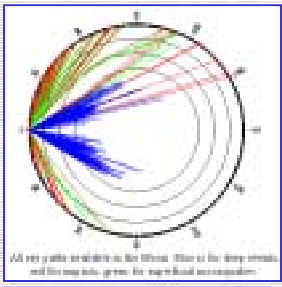
On the other hand, crustal thickness inversions from gravity data have a global coverage and show important lateral variations. The problem is that gravity inversion are non-unique and need to be anchored on at least one point. By exploring crustal models for the impact sites and the seismic stations, we intend to constrain the thickness of different locations on the lunar surface. These constraints can then be used to improve crustal inversions based on gravity data.

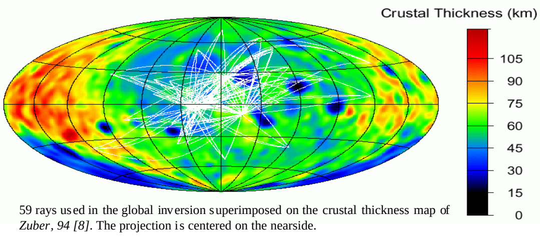
We present here the different aspects and results of this joint study of seismology and gravity data.



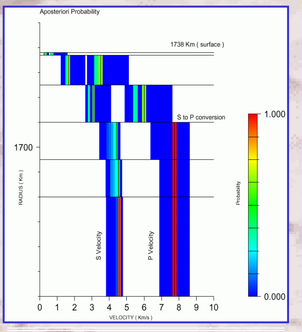
Resolution of the seismic data set

The geometry of the seismic network and the identified sources place limits on the resolution of seismic velocities in the lunar interior : the Apollo seismic data is blind related to the core and farside.





59 rays used in the global inversion superimposed on the crustal thickness map of *Zuber, 94 [8]*. The projection is centered on the nearside.

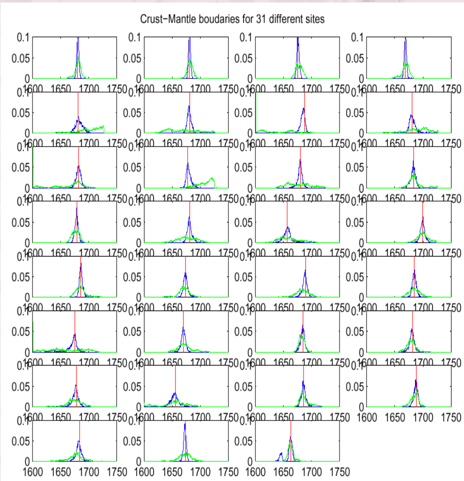


Distribution of seismic velocities in terms of *a posteriori* probabilities for the crust. Only impact arrival times are used for this inversion [9]. P wave mantle velocities are reached at a depth of 30 km, which makes the crust twice as thin when compared to the Apollo era value of 60 km.

Inversion of crustal thickness beneath impact and station sites

We use the mantle velocity model of *Lognonné et al*. [9] as our mean model, and consider one layer above for the crust. The velocity and thickness of this crust is determined at each artificial, meteoritic and seismic station sites (4 stations + 8 artif. + 19 meteorites = 31 locations). We use a Markov chain Monte Carlo inversion scheme for the available arrival times of these events. The total theoretical rays should be 216 [4 Stations * 27 sources *2 (P,S waves)], but only 105 data are reliable enough to be used.

A random walk is designed to converge to independent crust-mantle boundaries for the 31 different sites, which are coherent to our data set considering uncertainty. We show here results for synthetic data.



Results of an inversion of synthetic arrival times. We see here the *a posteriori* distribution of the crust-mantle boundary radius under 31 sites. From top to bottom : 4 station, 8 artificial impact, 19 meteorite impact sites. The blue line corresponds to an inversion of 216 synthetic data, while the green one stands for a more realistic 105 synthetic data inversion (105 real data available).The red values are the ones used to build the synthetic data. The resolution is good with the whole set of data (blue) and less with 105 arrivals (green). The (red) information is not retrieved at all in that case for 7 of the 8 artificial impact sites.

Importance of the anchoring point in gravity inversions

Because gravity modeling is non-unique , crustal thickness inversions must be anchored to at least one point.

Models employed here utilize a constant density crust and upper mantle, and account for the mare basalts.

Gravity and topography fields were recorded by *Clementine* and *Lunar Prospector* spacecrafts.

Parameters used for these models are :

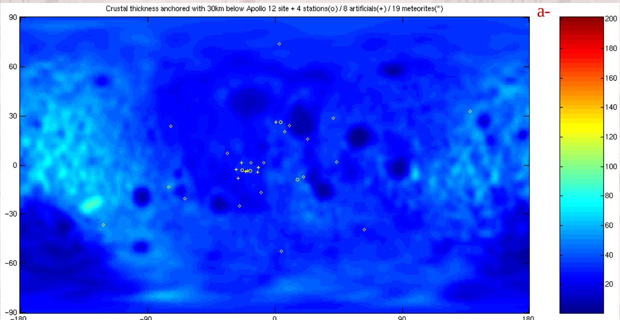
a- ρ_c=2760 g/cm3 ; ρ_m= 3350 g/cm3

b- ρ_c= 2850 g/cm3 ; ρ_m= 3300 g/cm3

c- ρ_c= 2900 g/cm3 ; ρ_m= 3300 g/cm3

Respectively for crust and mantle densities, with S12 thickness of 30, 45 and 60 km.

a-



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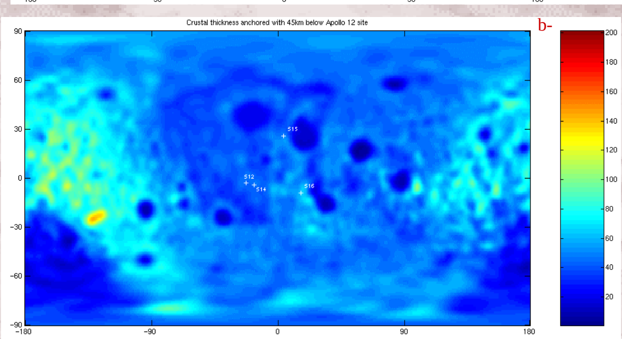
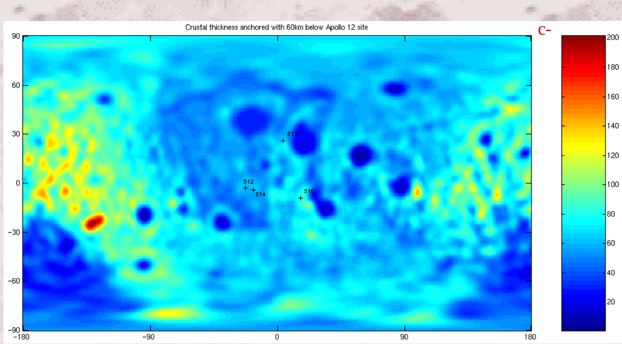


These three crustal thickness maps result from inversions of topography and gravity data. Each is anchored with a different value (a-30, b-45, c-60 km) under the Apollo 12 station. On map a- we superimposed the locations of the different sites used in the seismic inversion.

c-



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The inversions of synthetic seismic data sets in this study show that crustal thickness variations can be resolved, at least for the four Apollo stations. The amount and distributions of good arrival times might allow the determination of crustal thickness variations below other impact sites as well.

The lateral crustal thickness distribution as seen with seismic data will be compared with the gravity/topography inverted values, which assumed uniform densities for simple two layer models. Relative thickness variations should show similar patterns, if the uniform density is correct.With different anchoring sites, we will be able to constrain the gravity/topography inversions.

Références:

[1] Toksöz N.M. et al. (1974) *Rev. Geoph. Space Phys., 12*, 539-567. [2] Lognonné P. & B. Mosser (1993), *Survey in Geophysics, 14*, 239-302. [3] Goins N.R. et al. (1981) *JGR, 86*, 5061-5074. [4] Nakamura Y. (1983) *JGR, 88*, 677-686. [5] Vinnik et al. (2001) *GRL, 28*, 15, 3031-3034.[6] Khan A. et al. (2000) *GRL, 27*, 11, 1591-1594. [8] Zuber M.et al. (1994) Science, 266, 1839-1843. [9] [Lognonné et al., EPSL, accepted 2003]