SMART-1/CLEMENTINE STUDY OF HUMORUM AND PROCELLARUM BASINS: COUPLING BETWEEN IMPACTS, VOLCANISM AND TECTONICS

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Summary: We have combined SMART-1 AMIE camera images with Clementine UV/VIS data for two end-member lunar basins (circular – Mare Humorum and irregular – Oceanus Procellarum), to determine the coupling between basin origin, tectonics. For Humorum, these tectonic-induced features, which include graben, thrust faults and strike-slip faults, were mapped using ARC-GIS. Resulting tectonic maps agree well with an idealized tectonic model (Melosh 1978). In contrast, the main tectonic features at Procellarum are wrinkle ridges. In the absence of significant Bouguer anomalies at Procellarum, these features cannot be mascon-related.

Data and processing

We used Advanced Moon micro-Imager Experiment (AMIE) on ESA SMART-1 Moon mission [1], average pixel resolution of 80m. An IDL search routine was used to browse in PDS database. We combined filters and created mosaics using ENVIE3.0, with interpretation and annotation by use of ARC-GIS. We also used UV/VIS pictures (multi-spectral images assessing the surface mineralogy of the Moon) and gravity maps derived after Clementine Moon mission [2] (gravitational anomalies and crustal thickness maps) .

Fig. 1: SMART-1/AMIE image in Humorum (individual field 67 km from 1150 km distance) showing a pattern of strike-slip faulting

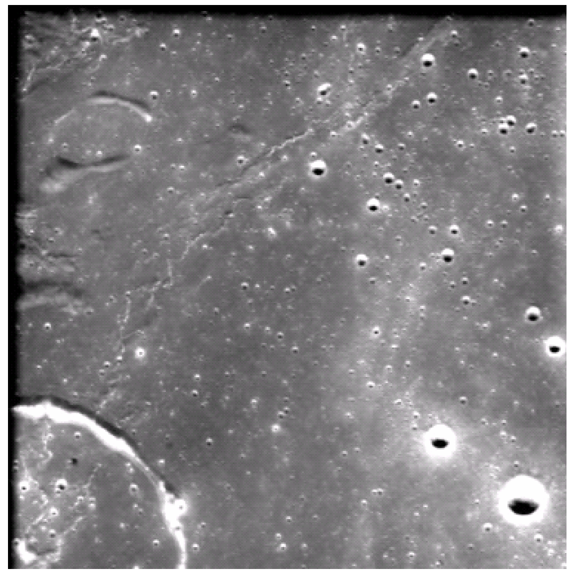

Fig. 2: Humorum pattern of wrinkle ridges

Tectonic analysis for Humorum and Procellarum

Clementine-derived Bouguer anomaly maps show significant mascons for circular basins such as Humorum, with mare basalt infill assumed to be the major cause. No mascon signature is associated to Procellarum. Mascon-related stresses induce a tectonic response when exceeding the yield strength of the lunar crust.
We looked for the tectonic counterpart of mass loading in mascon tectonics as seen in most lunar maria. We find signatures of tectonics for Humorum: such as and Strike-slip faults shifting an impact-caused fracture (Fig. 1) and concentric grabens in the outer edge (Fig. 3). The wrinkle ridge pattern (Fig. 2) does not match the inner zone of radial thrust faults (those could be buried underneath young basalts).

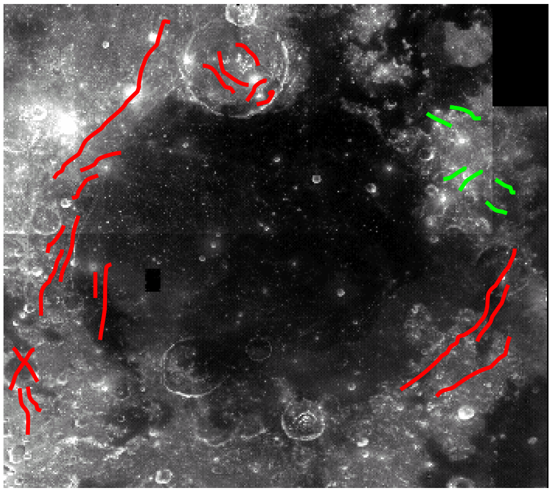

Fig. 3 Concentric grabens found around Humorum:

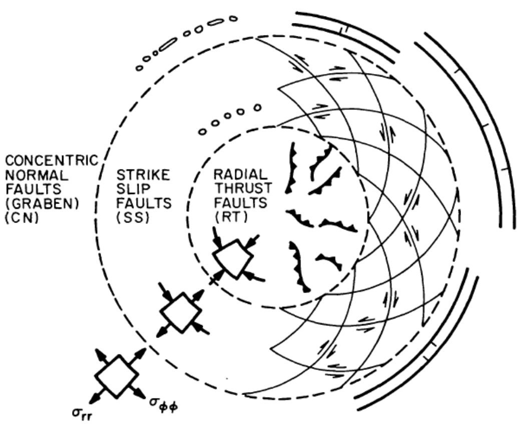

Fig. 4 Model for mascon tectonics by H.J. Melosh (1978): Idealised axially symmetric load, acting as a dense load on the lunar lithosphere, causes a fault sequence controlled $\sigma\varphi\varphi$ (Hoop stress) and σrr (radial stress)

Lack of Tectonic Faults in Procellarum

In the Procellarum area, we do not find normal faults, or strike-slip faults. That is consistent with the lack of mascon tectonics in Procellarum (as also indicated by for gravity) . The observed pattern of wrinkle ridges is not radially distributed however, not likely associated with mascon tectonics, but rather formed by thermal/mechanical contractions.

Physical interpretation

The evolution for Humorum follows a general model for lunar multi-ring basins [4], with a melt produced after basin forming impact after whole mantle convection, and extrusion caused by excavation of noritic crustal parts .

For Procellarum, irregular basin of graben origin, there is no clear evidence of a basin forming impact and thick anorthositic crust: melt production and extrusion controlled by processes other than multi-ring basins. Chemical components imply KREEP as primal source for Procellarum basalts. The melt is likely to be generated by radiogenic heating

In our working hypothesis, the mare basalt that flooded Humorum erupted as a result of the depressurization and impact heating associated with the impact that formed the Humorum basin. Impacts resulting in crater diameters smaller than 100 km are unlikely to form significant amounts of melt. In the case of Humorum, their flooding must therefore depend on the availability of melt generated by the formation of the main basin. This implies that the flooding of small craters within and around Humorum is contemporary with its mare activity. In contrast, Procellarum is thought to have formed by graben formation related to the Imbrium event (e.g. Cooper and Carter 1994). To generate the basalt that covers the basin floor, melt thus must have formed without the added energy of a large impact. Clementine UV/VIS data show KREEP enrichment for the area of Procellarum, suggesting that locally underlying KREEP basalts form the volcanic source for the rocks on the surface. In this case, the energy to generate partial melt is likely to come from radiogenic heat from the KREEP layer. Several geographically distinct pulses of volcanic activity have been identified at Procellarum, probably caused by spatial variations in thickness and/or composition of the KREEP layer. The mineralogy of flooded secondary crater floors is related to specific periods of basin volcanism and varies with time and proximity to the centre of volcanic activity. Therefore the mineralogical composition of flooded craters could constitute a stratigraphic tool to determine secondary impact crater ages in the Procellarum region.

References:

1) B.Foing, G.Racca, A.Marini et al, ASR 37 (2006), 6-13
2) S. Nozette, P Rustan et al, Science vol. 266 (1994) 1835
3) H.J. Melosh, LPSC 9th (1978), 3513-3525
4) P. Spudis. (1993) Geology Multi-ring Basins, CU Press