12th International Workshop on Modeling of Mantle Convection and Lithospheric Dynamics

August 20th to 25th 2011, Döllnsee Germany
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Distribution of Volcanism, Topography and Geoid Highs on Terrestrial Bodies: A comparison

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Here, we compare the surface records of volcanic activity and its relationship to the topographical and geoidal expressions of the terrestrial planets and the Moon. Mantle convection distorts internal interfaces, and results in dynamically driven topography, revealed in the gravity field and geoid. Hot upwelling material and decompression melting in areas of extension cause volcanism. Correlation between volcanically formed topography and the geoid links internal processes and the surface but the elastic behavior of the lithosphere and on Earth plate tectonics make correlation more difficult back in time.

Earth: Plate tectonics dominates igneous activity on the Earth and probably has done since the moon-forming event. Decompression melting in active intra-continental rifts is next in importance today but plate rotation-reconstructed volcanic non-plate margin eruption centers (LIPs kimberlites) and active hotspots are related to plumes from the edges of two high density large low shear velocity provinces (LLSVPs) at the core-mantle boundary that appear to have been stable for at least 500 Ma. Both LLSVPs correlate with positive equatorial almost antipodal geoid anomalies. Geoid anomalies can be observed on other planets for which mantle density distribution information is lacking.

Mars resembles the Earth in revealing two almost antipodal and equatorial areoid anomalies. Volcanic activity is distributed at the edges of the Syrtis Major centered anomaly, volcanic provinces for which the activity ceased at least 1.5 Ga ago. The Tharsis volcanic province is spatially correlated with the Tharsis centered anomaly where minor volcanic activity has continued episodically until recently. Density anomaly models for Mars averaged over the whole mantle suggest low densities at shallow depths below Tharsis, which could indicate upwelling flow but those models do not take into account the possible existence of high density structures comparable to the LLSVPs on Earth.

Venus: Topographic highs and aphroditoid highs coincide with volcanic centers and rift systems, suggesting that the topographic expression of the volcanic provinces is supported by dynamic upwelling (plumes) and/or shallow decompression melting below rifts. No obvious large antipodal geoid anomalies are observed. The surface record of the volcanic activity on Venus indicates that it has occurred episodically over the entire geological history. Assuming a (debated) maximum surface age of about 1 Ga, mantle convection patterns on Venus have been stable over at least this period of time.

Moon and Mercury: Volcanism after the crustal formation is mostly limited to the lunar nearside mare units, and influences the selenoid strongly. An elliptic equatorial shape is observed for the Moon. Preliminary observations at Mercury also suggest an equatorial gravitational ellipticity. The distribution of volcanic activity appears more widespread than previously thought.

Mars and the Earth show intriguing similarities and differences in geoid/volcanism links but Venus, Mercury and the Moon do not.