PROPERTIES OF THE LITHOSPHERE AND ASTHENOSPHERE DEDUCED FROM GEOID OBSERVATIONS

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Data from the GEOS 3 and SEASAT Satellites have provided a very accurate geoid map over the oceans. Broad bathymetric features in the oceans such as oceanic swells and plateaus are fully compensated. For these features it can be shown that the geoid anomalies due to the density structures of the lithosphere are proportional to the first moment of the density distribution. The deepening of the ocean basins is attributed to thermal isostasy. The thickness of the oceanic lithosphere increases with age due to the loss of heat to the sea floor. Bathymetry and the geoid provide constraints on the extent of this heat loss. Offsets in the geoid across major fracture zones can also be used to constrain this problem. Geoid-bathymetry correlations show that the Hawaiian and Bermuda swells and the Cape Verde Rise are probably due to lithospheric thinning.

Under some conditions the surface gravitational potential or acceleration can be related to the one-dimensional distribution of density beneath the point of measurement. One example of such a relationship is the Bouguer formula for the surface gravity anomaly. The Bouguer formula relates the surface gravity anomaly to the source density distribution beneath the point of measurement. It is valid if the mass anomaly is shallow and is slowly varying in the horizontal directions. If the near surface density distribution is isostatic the gravity anomaly given by the Bouguer formula is zero but the first moment of the density distribution can be related to the local potential and geoid anomalies. Thus the geoid anomaly can be directly related to the dipole distribution of density beneath the point of measurement if the condition of isostasy is applicable and if the geoid anomaly is caused by slowly varying near surface density variation.

Many of the observed geoid anomalies can be explained directly using the relationship between the geoid anomalies and the dipole density distribution. The positive geoid anomalies associated with the mid-ocean ridge system are consistent with thermal isostasy. However, the direct correlation between the geoid and bathymetry is noisy due to the geoid anomalies of deeper origin. Another approach to the study of geoid anomalies associated with ocean ridges is to utilize the geoid changes across major fracture zones. Major fracture zones are generated by transform faults on the ocean ridge system. Thus the ocean floors on the two sides of a fracture zone have age differences that are related to the offsets in the ridge at the transform fault that generates the fracture zone. The age difference can be determined from the sea floor magnetic anomalies.

Systematic correlations of geoid and bathymetry have also been found for oceanic swells. These are near circular regions of anomalously shallow bathymetry with a radius of 500-1000 km. Examples include the Hawaiian swell that surrounds the active volcanic center at the end of the Hawaiian island and seamount chain and the Bermuda swell. The good correlation can be explained by Pratt compensation with a 100 km depth of compensation. A physical mechanism that would appear to explain this correlation would be lithospheric thinning. Normal oceanic lithosphere has a thickness of about 100 km so that thinning of this lithosphere would have a depth of compensation of about this value. The observed correlation would appear to preclude any association of the geoid and gravity anomaly over the Hawaiian swell with mantle convection. If there is a mantle plume beneath Hawaii with a deep structure it does not appear to have an effect on the geoid.

A relatively simple model for rifting and mountain formation can be developed by introducing crustal and lithospheric thinning factors. The condition of isostasy and the measurement of the geoid constrains the two thinning factors. This approach appears promising for the study of sedimentary basins and major mountain belts.