THERMAL COOLING OF THE OCEANIC LITHOSPHERE FROM GEOID HEIGHT DATA

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To study thermal cooling of the oceanic lithosphere another type of geophysical observation has proved recently to be very useful: it is the geoid height derivative with respect to plate age, a quantity computed from the short wavelength geoid step across fracture zones measured by altimeter satellites.

Cooling of the lithosphere causes the geoid height to decrease regularly with increasing plate age with a symmetrical behavior with respect to the ridge crest. This geoid is in turn responsible for the geoid offset observed across fracture zones due to the abrupt change in plate age between the two sides of the fracture zone. The variation in geoid height due to lithospheric cooling is typically of 5-10 m over distances of 1000-2000 km, which is very difficult to isolate from other unrelated long wavelength anomalies. Fortunately, geoid offsets across fracture zones represent a particularly useful constraint: such is the case because fracture zones give rise in the geoid to a characteristic step-like signature, downward from the younger, shallower side to the older, deeper side, with an amplitude ranging from a few tens of centimeters to a few meters over distances of 100-150 km. This signature is easily detectable and presumably little contaminated by medium and large scale features unrelated to cooling. The geoid offset observed across fracture zones divided by the age offset represents the first order derivative with respect to age of the geoid slope due to lithospheric cooling. If the age on the two sides of the fracture zone is known, and observed the (geoid offset over age offset) versus age relation can be established and compared to theoretical relations computed from the cooling models, allowing an estimate of some thermal parameters from fits to the data.

Two categories of simples models have been proposed to describe cooling and contraction of the oceanic lithosphere with age. Both plate model and half-space model, give almost similar results up to ages of 50-70 ma but predict quite distinct behavior of seafloor depth, heat flow and other parameters in old basins. To date, tests of thermal models have been mainly based on heat flow and topography data. However, heat flow is not very sensitive to the form of the thermal model. On the other hand, large areas of the ocean floor are particularly shallow, and as a result topography data may not be very appropriate to discriminate between plate and half-space models, so that no clear concensus on a preferred model as yet exists.

We have analyzed Seasat geoid height data across 15 fracture zones of the South Pacific and Northeast Pacific. We find that geoid data clearly appear incompatible with the half-space cooling model at all plate ages and that for plate ages larger than 30 ma, the data follow reasonably well the behavior predicted by the plate model with a thermal thickness of 95 km. However, at younger plate ages, this conclusion no longer holds: the data could still be interpreted in terms of plate model with a plate thickness of 65 km but do not present the same initial behavior seen in the model curves. These results suggest the existence of two distinct trends: one for seafloor ages less than 30 ma, the other for ages greater than 30 ma. The apparent thermal thinning in the younger portion of the plate might result from a thermal perturbation beneath the plate. From the analysis of geoid data, it appears that the thermal evolution for young lithosphere is more complex than that described by the usual plate model in its simplest version and these observations would offer important constraints on any proposed alternative. Besides, it would be important to know if the behavior observed in the Pacific is specific to that ocean or instead is a worldwide phenomenon. In addition to analyze Seasat data in other oceans, the use of the future GRM data no doubt will help to bring a better understanding of this important problem.