

## ON THE INTERPRETATION OF SATELLITE-DERIVED GRAVITY AND MAGNETIC DATA FOR STUDIES OF CRUSTAL GEOLOGY AND METALLOGENESIS

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Satellite-derived global gravity and magnetic maps have been shown to be useful in large-scale studies of the Earth's crust, despite the relative infancy of such studies. Numerous authors have made spatial associations of gravity or magnetic anomalies with geological provinces. Gravimetric interpretations are often made in terms of isostasy, regional variations of density, or of geodesy in general. Interpretations of satellite magnetic anomalies often base assumptions of overall crustal magnetism on concepts of the vertical and horizontal distribution of magnetic susceptibility, then make models of these assumed distributions. The opportunity of improving our satellite gravity and magnetic data through the proposed Geopotential Research Mission should considerably improve the scientific community's ability to analyze and interpret global magnetic and gravity data. As data processing techniques improve, we may expect to see even more useful results of the data.

The satellite magnetic anomaly maps produced to date contain a series of east-west bands upon which are superimposed anomalies of shorter wavelength that are interpretable in terms of known crustal geology. The east-west bands have been interpreted as being caused by (1) data reduction in the preparation of the gridded anomaly data set, (2) incomplete removal of signal from subcrustal sources, (3) magnetospheric "noise," or (4) a combination of these. Gaussian-Fourier band-pass filters can enhance the shorter wavelength anomalies resolvable by the satellite system while suppressing even shorter wavelength noise and longer wavelength banding. Such filtering is performed on a plane rather than on a curved earth, but the technique appears to be useful<sup>1</sup> for the relatively short wavelengths being enhanced.

The band-pass filtered Magsat scalar anomaly map shows anomalies that are more clearly correlated with geologic features than does the unfiltered map. For example, the North Atlantic Continental Rise and Shelf, Bermuda Rise, Mid-Atlantic Ridge, Madeira-Torre Rise and African Continental Rise contribute to a NNE trending series of parallel filtered Magsat anomaly highs in the North Atlantic Ocean, separated by parallel lows over the Blake-Bahama-Hatteras Abyssal Plains, Sohm-Narea Abyssal Plains, and Iberia-Maderia-Cape Verde Abyssal Plains. Although

<sup>1</sup>Keeping in mind that the filtering is in terms of degrees of latitude and longitude, not directly in terms of linear distance.

remanent magnetization is likely to be an important factor in these anomalies, there also appears to be a strong correlation between the sign of the anomalies and uplift or depression of the crust in the North Atlantic Ocean. These features are not clearly distinguishable from the east-west bands on the original unfiltered anomaly maps. Similar patterns are generally not clearly distinguishable in the Central and South Atlantic Oceans - perhaps because of the significantly weaker main field strength in these areas.

Partly because of the stronger residual anomaly pattern over continents than over oceans, satellite magnetics appear to be more useful in investigating possible vertical movement of blocks of continental crust than for oceanic crust. Magsat anomalies of the continental crust, especially band-pass filtered anomalies, tend to be defined by large-scale crustal features such as Archaean shields and (to a lesser degree) lower Proterozoic shields, basins, and rift systems. They are less responsive to individual mountain ranges within a mountain block such as the Himalayas, and to individual grabens within a rift system. This is probably partly a factor of scale (the latter features are too small to be clearly resolvable), and partly because of greater overall differences in magnetic susceptibility in crustal blocks defined by surface representations of major tectonic units than by surface representations of smaller structural features.

The Magsat anomaly response of Archaean shields tends to be characteristic of relatively high average magnetic susceptibility, consistent with a combination of higher upper crustal susceptibility (higher metamorphic grade, more mafic average composition, more igneous rocks, or simply more low-grade magnetite mineralization), and/or the existence of a greater amount of relatively highly susceptible lower crustal materials uplifted above the Curie isotherm. This is true, to a lesser extent, for lower Proterozoic shields. The deepest parts of basins, corresponding to the thickest cover of relatively nonmagnetic sedimentary rocks over a depressed crustal column (with relatively less susceptible materials at every depth relative to the Archaean shield) are generally marked by anomalies characteristic of low relative susceptibility.

The anomaly pattern in the North Atlantic is an example of the band-pass filters enhancement of relatively short wavelength features that, in retrospect, are visible but not clearly distinguishable in the original unfiltered anomaly maps. These and similar features on the continents may have fundamental significance to our understanding of global tectonics and the formation of mineral and hydrocarbon deposits.

One example is the Pisco-Jurua Fault of Szatmari (1983). This fault extends between Pisco on the southern Peruvian coast, along the trend of the Jurua River, to northern Guyana, and is marked by shear zones and intrusives of Jurassic age. In a reconstruction of Pangaea, this trend aligns with the axis of the North Atlantic Rift. Szatmari

(op. cit.) has suggested that the Pisco-Jurua fault formed the southwestern continuation of the North Atlantic Rift. As the North Atlantic opened, according to Szatmari, northwestern South America moved relatively southwestward along the Pisco-Jurua Fault creating several major tectonic features along this trend: the Takutu Graben in the Guyana Shield, the gently folded Jurua Zone in the middle Amazon Basin, and the Pisco-Abancay deflection of the Cordillera. A band-pass filtered Magsat scalar anomaly low follows the trend the Pisco-Jurua Fault. At near-equatorial latitudes, this signifies a band of relatively high susceptibility consistent with uplift, intrusion of mafic materials, and/or relatively high metamorphic grade. This analysis and Szatmari's hypothesis can be combined to suggest that the Pisco-Jurua Fault line and the axis of the North Atlantic Rift were the axis of a pattern of convectional upwelling in the early Mesozoic. The pattern caused break-up of North America from Europe, but apparently did not develop so far in South America. If this hypothesis is true, the flanks of this anomaly pattern may mark likely locations for the emplacement of kimberlites and carbonatites (in appropriate structural settings) and other forms of mineralization associated with convectional upwelling.

A second example lies along the trend of the Middle America Trench on the Pacific margin of Central America. The trench is characterized by Magsat anomaly highs, with Central America itself being marked by low latitude Magsat lows that blend into the mid-latitude lows of the western Caribbean Basin. The trend of Magsat highs can be followed southeasterly from the Middle America Trench across South America to the Santos Basin. The lows can be followed across South America to the Rio Grande Rise off the Brazilian coast. Whereas the highs mark the Middle America trench along the continent-ocean transition along Central America, they follow a trend of sedimentary basins in South America. Similarly, the lows follow a trend of Precambrian uplifts, plus the Rio Grande Rise. The general lack of deep focus earthquakes along the Andes Cordillera and the various views of the subduction process along the Pacific margin of Central America suggests that this process may not fit the classic model of subduction. That one of the two South American zones of deep-focus earthquakes lies under the Acre (western Amazon) Basin, along the aforementioned trend of Magsat highs, supports the suggestion that this trend may mark a trend of convectional downwelling. At the continental margin of Central America this downwelling is associated with a "classic" Benioff zone. Under South America, the less dense, more rigid continental crust responds to the downwelling with broad, subdued depressions (sedimentary basins) in place of trenching, with the continental crust providing boundary conditions that result in subduction and the formation of the Cordillera along the Pacific coast. A parallel trend of uplifts extends between Central America and the Rio Grande Rise, following the trend of Magsat lows.

Such anomalies have not been available for interpretation before the era of satellite geomagnetic surveys. Their interpretation is certainly in its infancy. But the existence of anomaly patterns that may represent ancient or unexpected current geodynamic activity may have profound benefits in terms of our understanding the geologic setting, history, and resources of the Earth.

The continued refinement of satellite magnetics, and no less importantly, the integration of a new generation of satellite gravity data collection into a combined Geopotential Research Mission may allow for the availability of improved satellite gravity and magnetic data with which to conduct crustal and other studies. It may also encourage the refinement of data processing, analytical, and interpretive techniques as researchers improve their abilities in working with global data.

#### Reference

Szatmari, Peter, 1983. Amazon rift and Pisco-Jurua fault: Their relation to the separation of North America from Gondwana. *Geology*, v. 11, p. 300-304.