CONTINENTAL AND OCEANIC MAGNETIC ANOMALIES: ENHANCEMENT THROUGH GRM

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Earth-orbiting satellites over the past two decades have provided consistent global magnetic anomaly data sets which have given us unique insight on regional petrologic variations of the crust and upper mantle and crustal thickness and thermal perturbations. Verification of the satellite magnetic data has been demonstrated by quantitative comparisons with aeromagnetic anomalies of the conterminous U.S. and western Canada. In contrast to the POGO and MAGSAT satellites, the GRM satellite system will orbit at a minimum elevation to provide significantly better resolved lithospheric magnetic anomalies for more detailed and improved geologic analysis. In addition, GRM will measure corresponding gravity anomalies to enhance our understanding of the gravity field for vast regions of the earth which are largely inaccessible to more conventional surface mapping. Crustal studies will greatly benefit from the dual data sets as modeling has shown that lithospheric sources of long-wavelength magnetic anomalies frequently involve density variations which may produce detectable gravity anomalies at satellite elevations. Furthermore, GRM will provide an important replication of lithospheric magnetic anomalies as an aid to identifying and extracting these anomalies from satellite magnetic measurements.

After the question of the formation of the earth itself, the most fundamental problem of the geosciences concerns the origin and characterization of the continents and oceans. An essential difference in the earth is between the continents and oceans which is reflected in gravity via the Bouguer anomaly. However, as in the case of free-air and isostatic gravity anomalies, satellite magnetic measurements indicate no overwhelming difference between these regions. This is illustrated in Figure 1 which shows scalar 2^{o}-averaged MAGSAT anomalies differentially reduced to the radial pole of intensity 60,000 nT at 400 km elevation for the eastern Pacific Ocean, North and South America, the Atlantic Ocean, and Euro-Africa. These radially polarized anomalies have been adjusted for differential inclination, declination and intensity effects of the geomagnetic field, so that in principle these anomalies directly reflect the geometric and magnetic polarization attributes of crustal magnetic sources. Characteristics of the data given in Figure 1 include the amplitude range (AR), amplitude mean (AM), contour interval (CI), and the normalization amplitude (AMP) for the radially polarizing field.

A subtle indication of the difference between oceans and continents is obtained by computing mean magnetic anomalies for the region shown in Figure 1. The analysis indicates that the mean magnetic anomaly of the continents (0.3 nT) is greater than the average for the oceans (-1.8 nT). This observation is compatible with the shallow crust of the ocean basins and evidence that suggests that the Moho is a magnetic boundary between crustal magnetic and upper mantle non-magnetic rocks. However, this result may be muted by remanence effects which for regional crustal magnetic sources are generally not well known and at MAGSAT elevations are not well resolved.

Low-level observations of the oceans indicate that most of the magnetic anomalies reflect the age of the crust and are caused by the acquisition of remanent magnetization in the reversing magnetic field as the rocks pass through their Curie Point. However, as shown in Figure 1, only the broader scale Mesozoic and Cretaceous quiet zones seem to be clearly affiliated, respectively, with pronounced negative and positive radially polarized anomalies at MAGSAT elevations. In contrast, the satellite elevation magnetic anomalies of the continents seem to have a predominance of induction effects. There are remanent effects, but these are characteristically high wavenumber anomalies and are attenuated at higher elevations in the continental areas. The increased anomaly resolution derived from GRM's 160 km elevation orbits will significantly contribute to an understanding of the role which remanence has in causing regional anomalies of the oceans and continents.

Continental satellite magnetic data show an apparent sharp truncation and even parallelism of the anomalies along the leading edges of the North and South American plates, whereas across trailing plate continental margins prominent anomalies tend to continue into the ocean. Detailed analysis of the MAGSAT orbital data for South America indicates that the trailing edge anomalies have no apparent relationship to external fields, so these anomalies appear to be internally derived. Many of these anomalies show a striking parallelism with the tracks of hotspots particularly in the south Atlantic, although there is little consistency in the sign of the radially polarized anomalies and the hotspot tracks. Gravity and bathymetric correlations also suggest possible affiliation of some of these anomalies with subsided continental fragments. Clearly, information on these features is very limited and their origin is an important area of inquiry. High resolution magnetic data and correlative gravity anomalies provided by GRM will significantly facilitate understanding their origin and possible role in the evolution and dynamics of the continents and oceans.

The radially polarized anomalies of Figure 1 permit testing the reconstruction of the continents prior to the origin of the present day Atlantic Ocean in the Mesozoic Era. Indeed, as demonstrated in Figure 2, the radially polarized MAGSAT anomalies of North and South America, Euro-Africa, India, Australia and Antarctica exhibit remarkably detailed correlation of regional magnetic crustal sources across rifted margins when plotted on a reconstruction of Pangea. Obviously, these results suggest great ages for the geologic conditions which these anomalies describe and provide new and fundamental constraints on the geologic evolution of the continents. The high-resolution regional magnetic and correlative gravity anomaly data potentially available from the GRM offer the clear promise to improve quantitative geologic modeling of these features and to detail their development through geologic time.

RADIALLY POLARIZED <2°> MAGSAT MAGNETIC ANOMALIES

Z = 400 km AMP = 60,000 nT

AR = [32.8, -25.1] nT CI = 4 nT AM = -0.8 nT

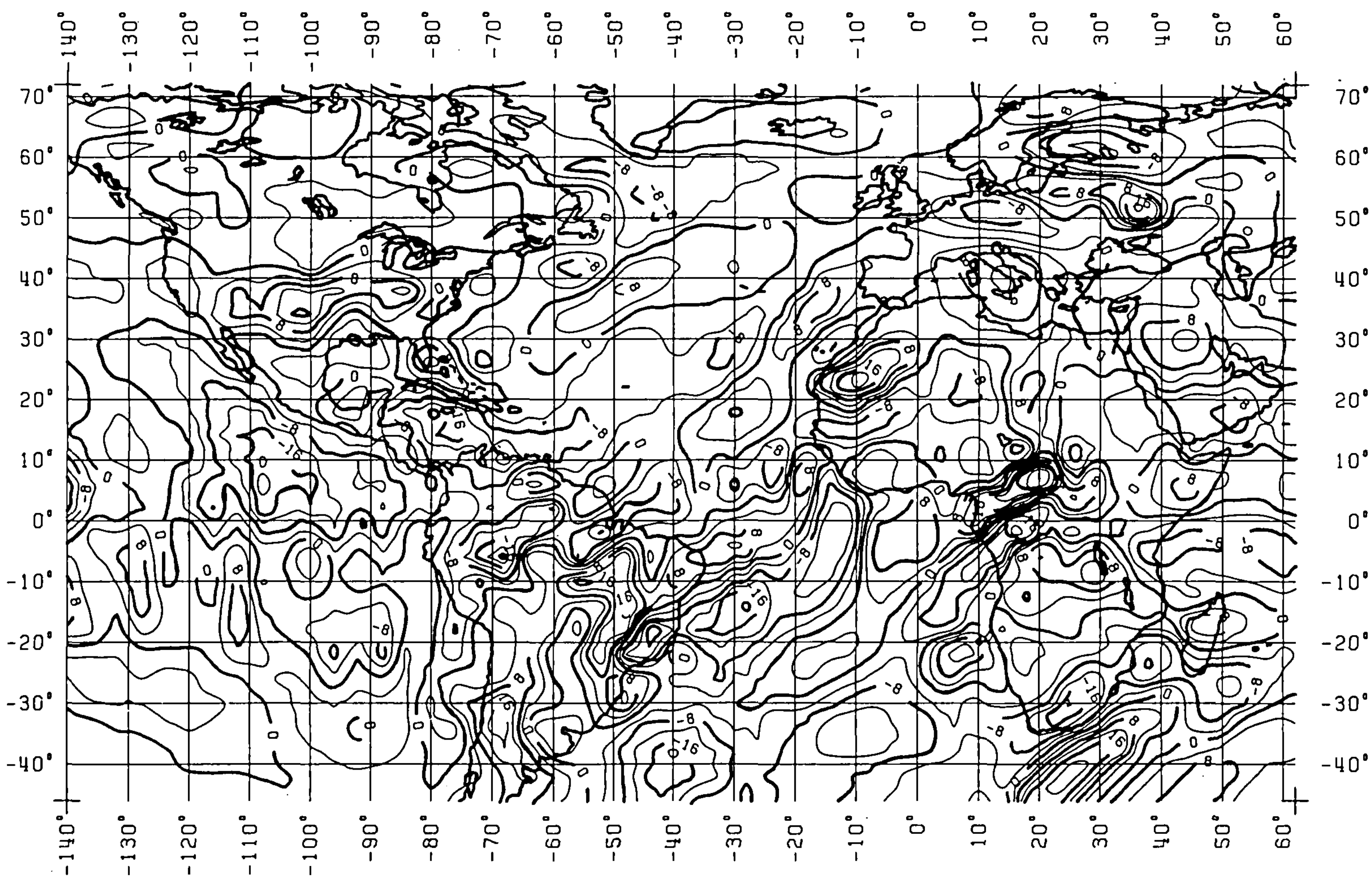

FIGURE 1

PANGEA AND RADIALLY POLARIZED <2°> MAGSAT MAGNETIC ANOMALIES

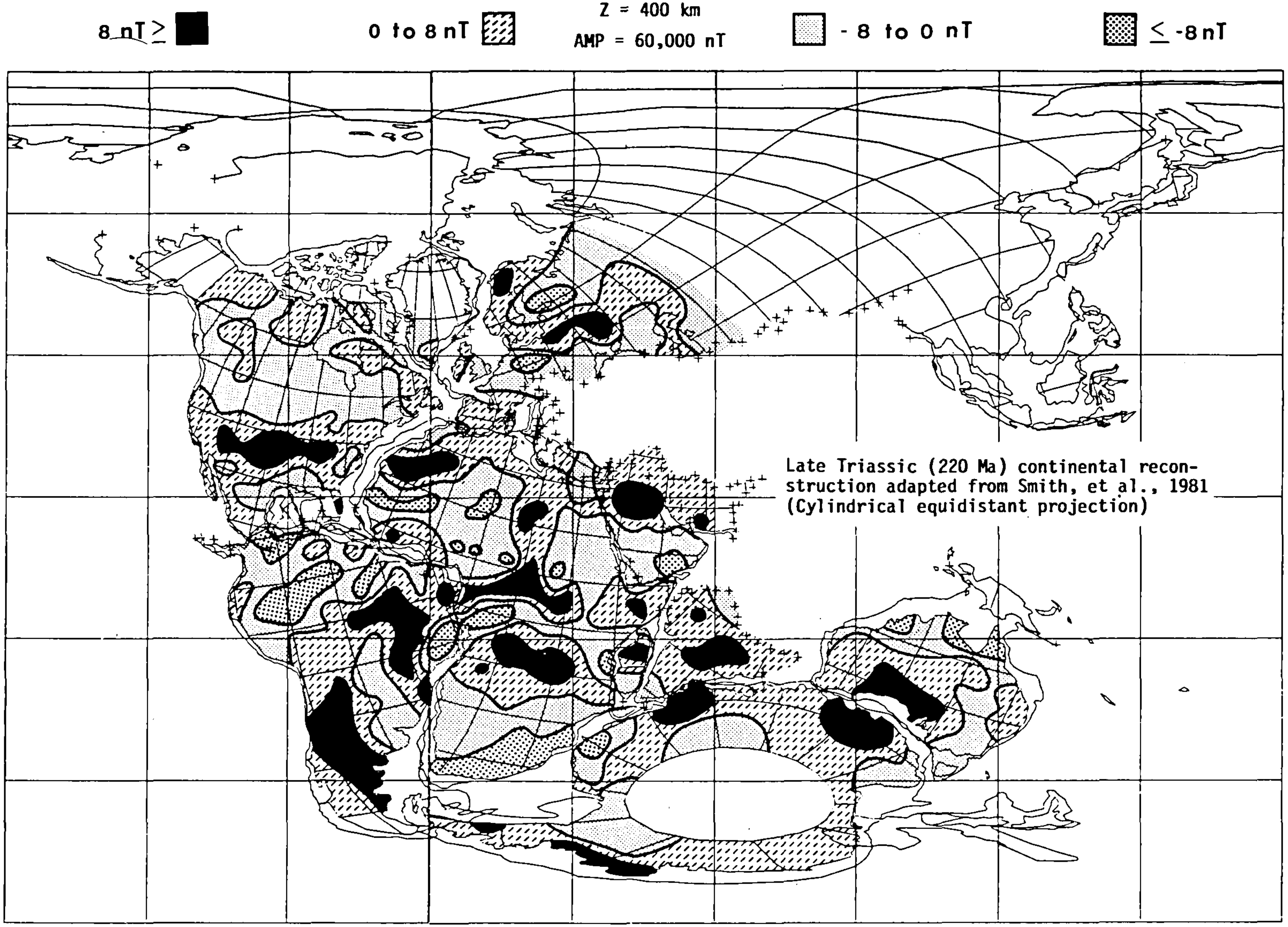

FIGURE 2