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CONTINENTAL AND OCEANIC CRUSTAL

MAGNETIZATION MODELLING

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Inversion of magnetic data from the MAGSAT satellite, to arrive at intensities of magnetization of the Earth's crust, has been performed by two different methods.

The first method uses a spherical harmonic model of the magnetic field. The coefficients believed to represent sources in the Earth's crust can then be inverted to arrive at vertical dipole moments per unit area at the Earth's surface (Chapman and Bartels, 1940). The spherical harmonic models we have used contain coefficients of degrees of harmonics up to 23 (Langel and Estes, 1982) and 29 (Cain et al., 1984). The dipole moment per unit area for a surface element can then be determined by summing the contribution for each individual degree of harmonic. The magnetic moments have been calculated for continental and oceanic areas separately as well as over certain latitudinal segments.

We wanted to investigate if there are any differences between continental and oceanic areas, which can be suspected from the great differences between these in terms of crustal thickness and composition. The difference between high and low latitudes should differ by approximately a factor of 2, because the strength of the geomagnetic field increases by this factor (30,000 to 65,000 nT) when going from equator to pole. Table 1 shows the results for the Langel and Estes and the Cain et al. models. Neither one of these shows any greater differences between continental and oceanic magnetization, and no latitudinal variation can be observed. In the case of the relation between oceanic and continental magnetization, the unit ratio would mean that the greater thickness of the continental crust, 30–40 km, compared with the oceanic crust, 6 km, is compensated by the same but inverse factor of susceptibility of continental compared with oceanic rocks. There is no reason why the magnetic field, believed to be generated in the core or at the core-mantle boundary, should have any preference for continental or oceanic crust in terms of intensity. Even more surprising is the lack of variation for different latitudes. This means that the crust is thinner and/or has a lower average susceptibility towards the poles.

The core magnetic field is believed to be represented by degrees of harmonics 1 through 13, of a spherical harmonic model. A pronounced change in slope in the power spectrum of such models, using the expression from Mauersberger (1956) and Lowes (1966), is occurring between degrees 13 and 14 (Langel and Estes, 1982). The other main reason for this choice is the white spectrum this band width represents at the core mantle boundary in terms of energy (Langel and Estes, 1982). Figure 1 shows that the energy, calculated by the Lowes function at the core mantle-boundary, has been constant during the last 2000 years if degrees of harmonics 1 through 18 are included, indicating that the core field is better represented by a wider span of harmonic coefficients.

The next analysis with magnetization intensities of the Earth's crust from spherical harmonic models was made by using narrower ranges of degrees of harmonics, thus assuming that degrees higher than 13 are present in the core field signal. Figure 2 illustrates the vertical dipole moment per unit aea for oceanic and continental areas when different spherical harmonic windows, as well as the latitudinal difference, have been included. A closer correlation with the theoretical variation as a function of latitude is obtained when spherical harmonic models with coefficients 17 or higher are representing the crustal magnetization.

These results are of the greatest importance when a data set is to be derived to represent the anomalous field arising from structural and compositional variations in the Earth's crust. Such an anomalous magnetic field has been used in our second approach to model crustal magnetizations, in which inversion is performed by applying the equivalent source technique (Dampney, 1969). The inversions have been performed by slightly modified Gauss-Jordan eliminations. We have used the scalar anomalous magnetic field of Langel et al. (1982) to investigate an entire ocean basin, the North and Equatorial Atlantic. The magnetization models have been adjusted with a certain amount of annihilator (Parker and Heustis, 1974) to arrive at entirely positive or zero magnetizations, a necessity if induced magnetization is the leading source for crustal magnetization. Remanent magnetization would also justify adjustment with an annihilator, when the magnetic reversal history of the area is considered. Local areas of the region have been inverted separately because we wanted to investigate local magnetic anomalies and specific physiographic features separately, and because the optimal solution (Bott and Hutton, 1970) varies from a source spacing of less than 3 to more than 4 degrees for different areas. In order to match adjacent magnetization models, the annihilator was used so as to give identical or almost identical source elements the same intensity of magnetization and entirely positive magnetizations.

The combined magnetization in the North and Equatorial Atlantic is shown in Figure 3. Some correlation with geologic structures can be recognized, for example the Puerto Rico Trench, the Rio Grande Rise, and perhaps the Walvis Ridge. Thus, the lack of anomalies over structures like the Bermuda Rise and the Canary and Cape Verde Islands is surprising.

During the spreading history of the North Atlantic the Earth's magnetic field has been stable during 2 periods of time, with such durations that the remanent imprint should be detectable at satellite altitude. Remanent magnetization is shown, by direct modelling, to be a possible source for long wavelength magnetic anomalies observed over oceanic areas when the geometry and location of the quiet zones make them observable. The magnetic field from two-dimensional magnetized slabs have been calculated to model the quiet zones in the North Atlantic. Figure 4 shows the theoretical field of a magnetized slab, representing the Cretaceous quiet zone (118-83 my, Harland et al., 1983) at 40 degrees north. The overall shape of the anomaly can be recognized in the MAGSAT scalar anomalous data set, but the intensity of magnetization of the oceanic crust is on the large side, when considering the results from direct studies of oceanic rock samples (e.g. Kent et al., 1978; Dunlop and Prevot, 1983). This discrepancy is even more pronounced in the case of induced magnetization.

The MAGSAT data, collected at an average altitude of 404 km, should enable resolution of signals with wavelengths down to 250 km (Sailor et al., 1982). To improve resolution, we have started to apply constrained least squares inversion routines to a scalar anomalous data set that only permits certain intensities of magnetization in the solution. So far, the Simplex algorithm has been used. This method offers the possibility to set different constraints for different areas in the same inversion, but has the disadvantage of considerably increasing the matrices that are to be inverted. Other routines, for example constraining by weights, have also been considered.

REFERENCES

Bott, M.H.P., and M.A. Hutton, 1970. A matrix method for interpreting oceanic magnetic anomalies. Geophys. J. Roy. Astr. Soc. 20, 149-157.

Cain, J.C., D.R. Schmitz, and L. Muth, 1984. Small scale features observed by MAGSAT, J. Geophys. Res., 89, 1070-1076.

Chapman, S., and J. Bartels, 1940. Geomagnetism, Oxford University Press, 2 vols., 1049 pp.

Dunlop, D.J., and M. Prevot, 1982. Magnetic properties and opaque mineralogy of drilled submarine intrusive rocks, Geophys. J. Roy. Astr. Soc., 69, 763-802.

Harland, W.B., A.V. Cox, P.G. Llwellen, C.A.G. Pickton, A.G. Smith, and R. Walters, 1982. A geological time scale, Cambridge University Press, 131 pp.

Kent, D.V., B.M. Honnorez, N.D. Opdyke, and P.J. Fox, 1978. Magnetic properties of dredged oceanic gabbros and the source of marine magnetic anomalies, Geophys. J. Roy. Astr. Soc., 55, 513-537.

Langel, R.A., and R.H. Estes, 1982. A geomagnetic field spectrum, Geophys. Res. Letts., 9, 250-253.

Lowes, F.J., 1966. Mean-square values on sphere of spherical harmonic vector fields, J. Geophys. Res., 71, 2179.

Mauersberger, P., 1956. Das Mittel der Energiedichte das geomagnetischen Hauptfeldes an der Erdoberfläsche und seine säkulare Änderung, Gerlands Beitr. Geophys., 65, 207-215.

Parker, R.L., and S.P. Heustis, 1974. The inversion of magnetic anomalies in the presence of topography, J. Geophys. Res., 79, 1587-1593.

Sailor, R.V., A.R. Lazarewicz, and R.F. Brammer, 1982. Spatial resolution and repeatability of MAGSAT crustal anomaly over the Indian Ocean, Geophys. Res. Letts., 9, 289-292.

Table 1
Vertical Dipole Moment/Area
(kA)

	Field Representation					
	Langel and Estes, 1982+			Cain *et al.*, 1984¶		
Latitude Band	Cont.	Ocean	Ratio*	Cont.	Ocean	Ratio*
90–53	8.63	9.48	0.910	7.36	7.47	0.985
53–37	5.99	6.03	0.993	6.61	6.84	0.966
37–23	6.35	4.90	1.296	6.45	6.60	0.978
23–13	5.96	6.02	0.990	6.45	6.62	0.975
13–0	5.76	6.45	0.893	6.37	6.85	0.931
Overall ratio			1.077@			0.990@

*Continent/Ocean ratio
+Degree 14–23
¶Degree 14–29
@Areally weighted means

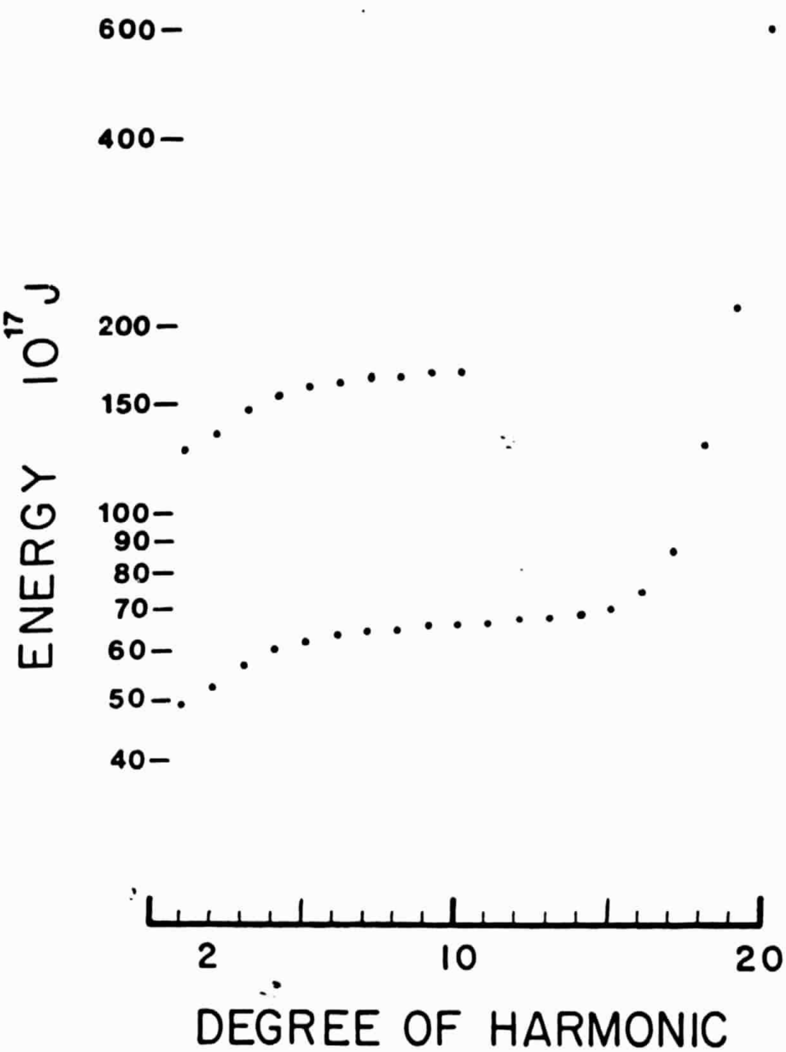

Figure 1. Total cumulative energy external to the core plotted as a function of the maximum degree of harmonic used in the calculation. The lower curve is for the present day field using spherical harmonics from Langel and Estes (1982). The upper curve is for the field about 2000 years ago, during which time the dipole component was about 50% larger than today. The energy from the dipole component is therefore 2.25 times its present value. The harmonics between 2 and 10 were assumed to have increased by the same percentage as the dipole term, because the secular variation, as far as we know, was about the same 2000 years ago as it is today. In order to achieve an energy which today is equivalent to that in the first ten degrees of harmonic 2000 years ago, we need to use all harmonics up to and including 18.

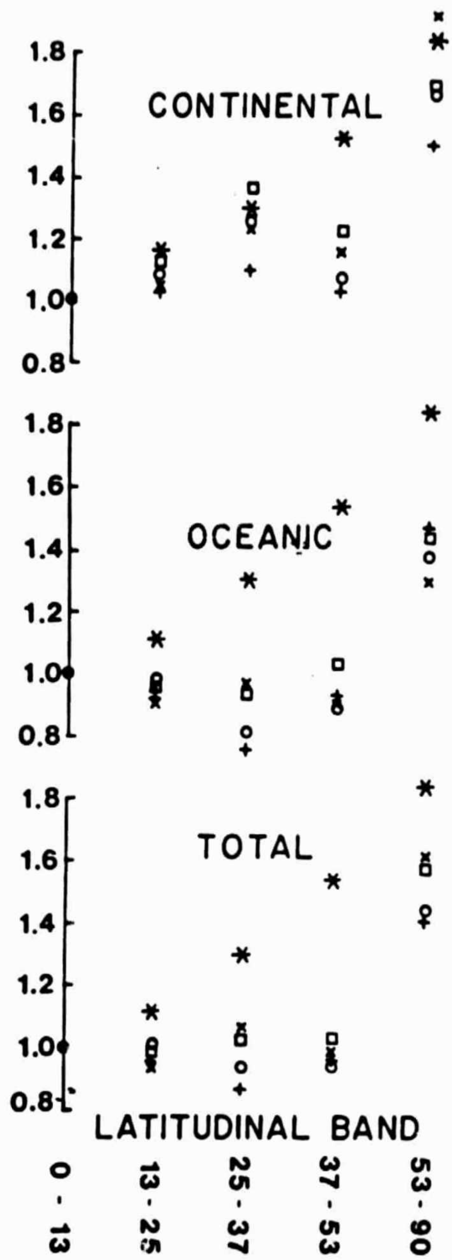

Figure 2. Vertical dipole moment per unit area (normalised to that in the lowest latitudinal band) for (a) continental areas, (b) oceanic areas, and (c) the Earth as a whole. The latitudinal bands are shown along the abscissa. The values expected from a dipole field intensity are shown by asterisks. The other symbols show results from different combinations of spherical harmonics. +, degrees 14-23; o, degrees 15-23; x, degrees 17-23; □ , degrees 19-23. The spherical harmonic model of Langel and Estes (1982) is used.

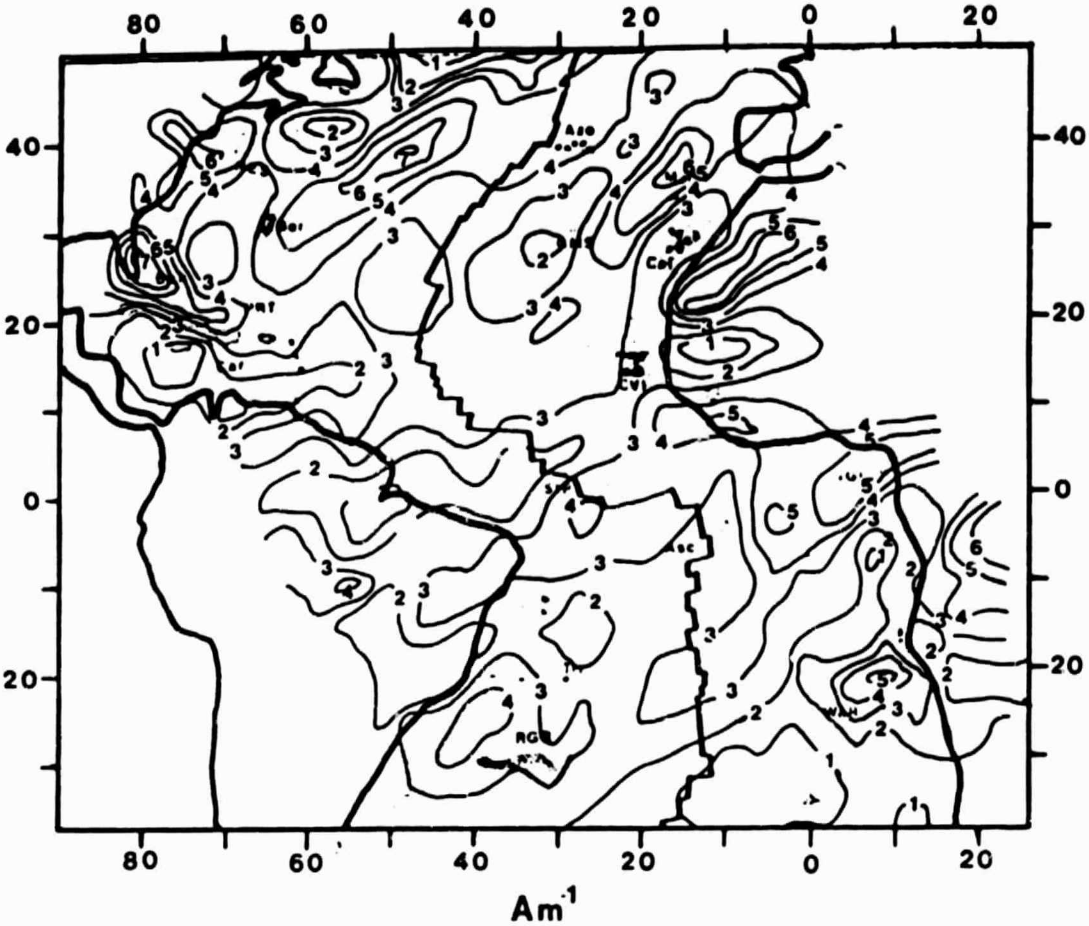

Figure 3. Modelled magnetization of the North and Equatorial Atlantic when all the subregions have been fitted together. Contours are given in $A.m^{-1}$, and a constant thickness of 6 km is assumed.

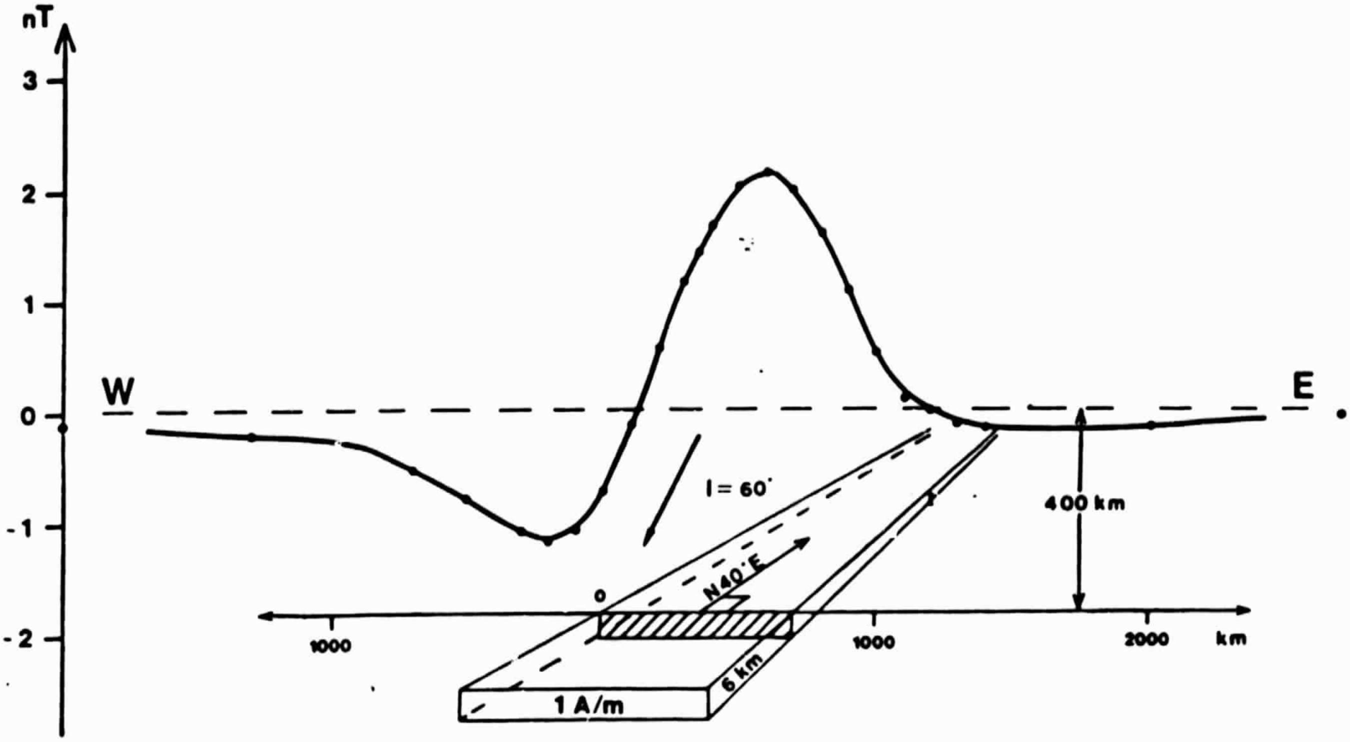

Figure 4. Theoretical magnetic field from a magnetized slab at 400 km altitude. The slab is magnetized to 1 A/m, has a thickness of 6 km, a width of 700 km, and is striking N40° E to the direction of the main field.

PUBLICATIONS

Harrison, C.G.A., 1984. "The Crustal Field", chapter in a book "Geomagnetism" edited by J.A. Jacobs, Academic Press, in press.

Harrison, C.G.A., H.M. Carle, and K.L. Hayling, 1984. Interpretation of satellite elevation magnetic anomalies. Submitted to J. Geophys. Res.

Hayling, K.L., and C.G.A. Harrison, 1984. Magnetization modelling in the North and Equatorial Atlantic using MAGSAT data. In preparation.

ORAL PRESENTATIONS (Abstracts attached)

Harrison, C.G.A., 1984. The source of the intermediate wavelength component of the Earth's magnetic field, Geopotential Research Mission Conference, Oct. 29-31.

Harrison, C.G.A., and K.L. Hayling, 1984. Inversion of satellite magnetic field data to obtain crustal magnetizations, EØS, 65, 201.

Hayling, K.L., and C.G.A. Harrison, 1984. The character of equivalent source solutions for magnetization in the Atlantic using MAGSAT data, EØS, 65, 201.