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MAGSAT DATA INVESTIGATION M-004

An investigation of Magsat and complementary data emphasizing Precambrian shields and adjacent areas of West Africa and South America.

Quarterly report^{1/} covering activities of the investigation during the period January 1 through March 31, 1982.

(E82-10318) AN INVESTIGATION OF MAGSAT AND COMPLEMENTARY DATA EMPHASIZING PRECAMERIAN SHIELDS AND ADJACENT AREAS OF WEST AFRICA AND SOUTH AMERICA Quarterly Report, 1 Jan. - 31 Mar. 1982 (Technicolor Graphic

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^{1/}This report is in "letter format." It has not been formally edited for compliance with U.S. Geological Survey standards or nomenclature.

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1. Introduction

This quarterly report, on Magsat Data Investigation M-004, covers the period January 1, through March 31, 1982.

2. Problems

A bug in the EROS Data Center's interactive magnetic modeling program hampered its use during this quarterly period. The program would take data, but would not print or plot a model. Toward the end of the period the bug was found in a test for data that was inappropriate for the data being used. The bug has been corrected.

This program is being used for initial modeling because (1) of its speed and interactive features--particularly with modifications currently being made to the program and (2) because it is currently online. It has a disadvantage in that it cannot directly take variations in magnetic inclination and declination with different latitudes (through a partial compensation can be made by producing a hybrid plot based on models incorporating various inclinations and declinations appropriate to parts of each model).

It is intended that final modeling use at least two modeling routines as a crosscheck for accuracy.

3. Accomplishments

Initial findings for Africa were summarized in a manuscript (attached) that was accepted for publication in Geophysical Research Letters.

4. Significant Results

No significant results were obtained during the quarter.

5. Publications

The paper entitled "A first look at the Magsat Scalar anomaly map for Africa", mentioned in my first quarterly report was renamed:

Preliminary corrections of MAGSAT anomalies with tectonic features of Africa,

and was accepted for publication in Geophysical Research Letters.

In addition, the special issue of Geop Exploration devoted to geophysics, tectonics and mineral deposits of Africa, of which I am the special editor, is progressing toward publication. This issue, which contains some ancillary data, includes the following papers (partial list):

On the availability of geoscientific data and scientific collaborators of and in Africa (David A. Hastings).

Paleogeoid changes and their possible impact on the formation of natural resources in Africa (Nils-Axel "Morner").

Integration of satellite and conventional data with tectonic and structural information over the African continent (Birendra K. Jain and Robert D. Regan).

Gravity anomalies and continental collision in the Precambrian (Alain Lesquer and Pierre Louis).

On the tectonics and metallogenesis of West Africa: a model incorporating new geophysical data (David A. Hastings).

6. Recommendations

I have no new recommendations at this time. My earlier request for the gridded anomaly data has been met at the end of the quarter with the supply of a computer tape.

7. Funds expected January 1, - December 31, 1982

Salaries

D. A. Hastings, Principal Investigator	40 @ \$14/hr.	\$ 560.00
Secretarial	10 @ \$4.50/hr.	45.00
Drafting	5 @ \$5/hr.	25.00
		<u>\$ 630.00</u>
	Employee benefits (17% of direct labor)	75.00
	Labor subtotal	<u>\$ 705.00</u>
	Overhead (60% of labor)	420.00
	Labor total	<u>\$1,125.00</u>

Materials

Custom laboratory photographic products \$ 228.00

Miscellaneous

Office supplies	\$ 5.00	
Express mail	<u>10.00</u>	
	15.00	
	Subtotal	<u>\$1,363.00</u>
	General and Administrative (13.3%)	181.20
	Grand total	<u>\$1,544.20</u>

8. Data Utility

I have no new comments on this topic at this time.

PRELIMINARY CORRELATIONS OF MAGSAT ANOMALIES WITH TECTONIC FEATURES OF AFRICA

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^{1/} Work performed for the U.S. Geological
Survey Contract Number 14-08-0001-20129.

Abstract. An overview of the MAGSAT scalar anomaly map for Africa has suggested a correlation of MAGSAT anomalies with major crustal blocks of uplift or depression and different degrees of regional metamorphism. The strongest MAGSAT anomalies in Africa are closely correlated spatially with major tectonic features. Although a magnetic anomaly caused by a rectangular crustal block would be offset from the block's center by the effects of magnetic inclination, an anomaly caused by real crustal blocks of varying uplift, depression, and degree of regional metamorphism would be located nearer to the locus of greatest vertical movement and highest grade of metamorphism. Thus, the Bangui anomaly may be caused by a central old Precambrian shield, flanked to the north and south by two relatively young sedimentary basins.

Introduction

This paper discusses the total-field MAGSAT anomalies for Africa and the possible tectonic associations and interpretations of these anomalies. The general characteristics of the MAGSAT anomaly map are treated elsewhere in this issue (Langel and others). Preliminary discussions of global aspects of the data are presented by Frey (1981 and this issue) and Hastings (1981a and 1981b). The anomaly map is preliminary, and subject to change as the MAGSAT global field model is modified and as data processing techniques are changed. Two different versions of the anomaly map (figures 1 and 2) show similarities in areas of strong anomalies and minor differences where anomalies are weak.

Before attempting to correlate regional magnetic anomalies spatially with their possible causes, many scientists apply the reduction-to-the-pole technique (Baranov, 1957, Cordell and Taylor, 1971). This technique is useful at high magnetic latitude but is error-prone at low latitudes (Leu, 1982). It is therefore of little use

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figure 1

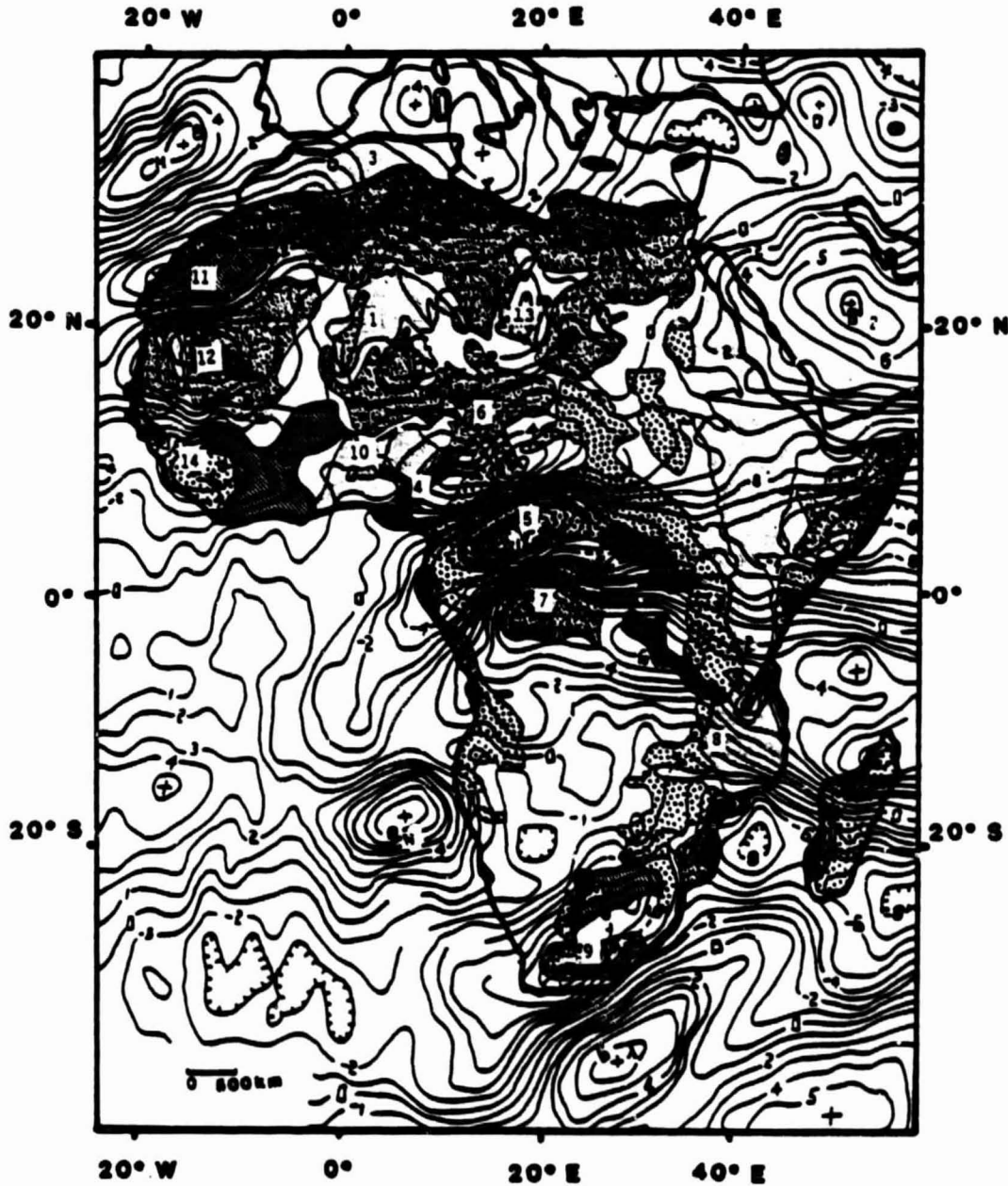


figure 1

Fig. 1. Preliminary total-field MAGSAT anomaly map for Africa, showing significant tectonic features:

CONTINENTAL FEATURES

1. Ahaggar plateau
2. Arabian basin
3. Atlas Mountains
4. Benue trough
5. Central African uplift
6. Chad basin
7. Congo basin
8. East African rift
9. Karroo basin
10. Pan-African shield (of Nigeria)
11. Reguibat shield
12. Taoudeni basin
13. Tibest plateau
14. West African craton (nucleus)

OCEANIC FEATURES

- A. Agulhas plateau
- M. Madeira-Torre rise
- W. Walvis ridge

KEY



UPLIFTED AREAS

- Archaean shields (over 2400 million years old)
- Middle Precambrian shields (2400-1000 m.y.)
- Uplifted areas less than 1000 m.y. in age

DEPRESSED AREAS

- Moderate depressions
- Deep portions of basins

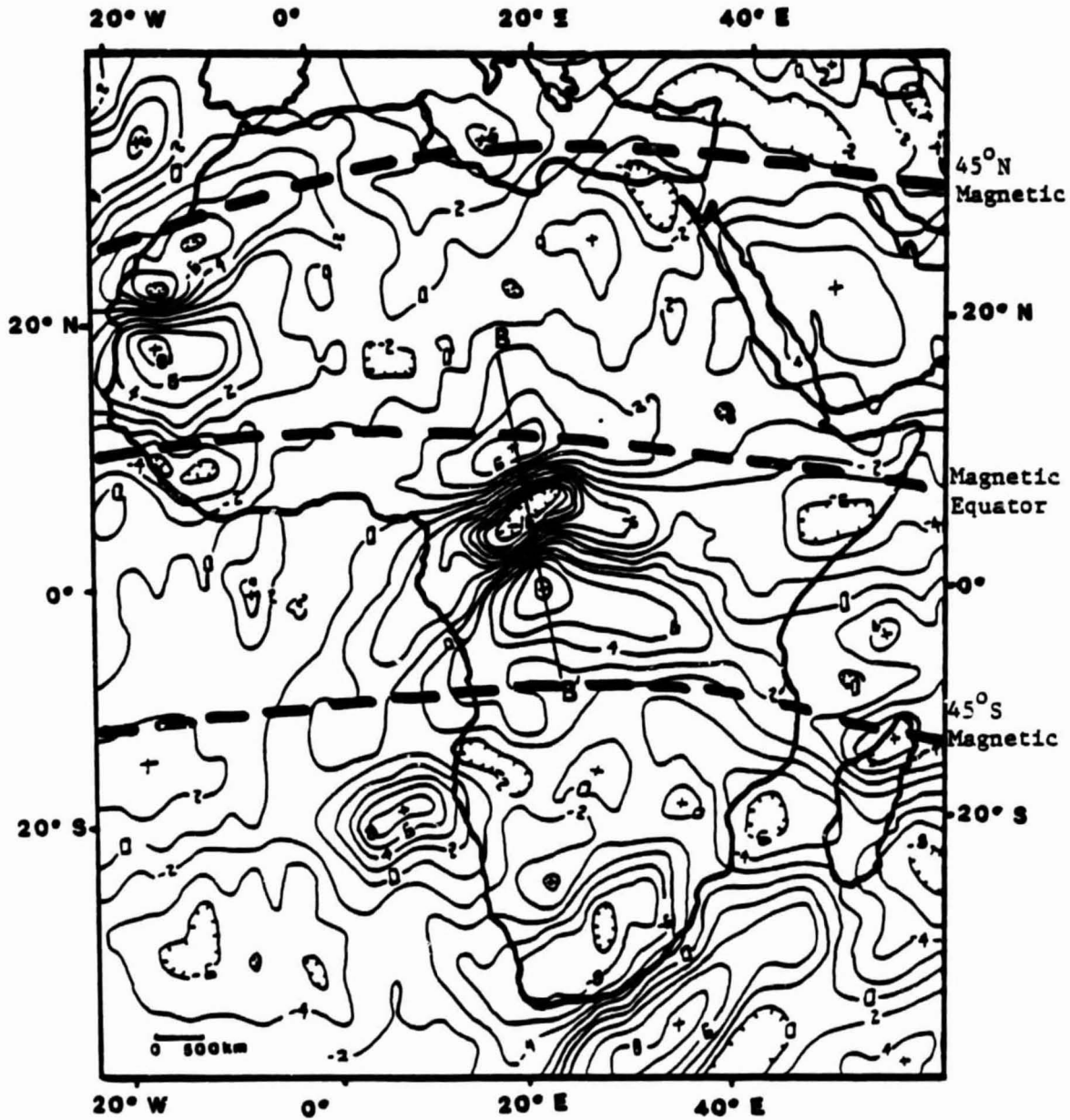
MAGSAT contours are 1 nanotesla (nT).

Continental areas without shading are covered with relatively shallow sedimentary sequences. Tectonic features modified from United Nations Educational, Scientific and Cultural Organization (1971, map in pocket). MAGSAT anomaly map courtesy of the (NASA) MAGSAT Project Scientist (R. A. Langel, written communication, 1981).

Fig. 2. Another version of the total-field MAGSAT anomaly map for Africa that utilizes a different selection of MAGSAT data (R. A. Langel, NASA Goddard Space Flight Center, oral communication, 1981). Contour interval 2 nT. Profile B-B' marks the location of the model shown in Figure 3.

Fig. 3. Two-dimensional model (solid line) and observed POGO data (dots) over the Bangui anomaly at 150 km altitude. Normalized susceptibilities are near 0 for basin sediments (dot pattern), 1.0 for average crustal rock (no shading) and 1.5 for shield rocks (random hatchured pattern).

figure 2



in Africa and for overall global magnetic data sets. Leu (1982) has begun the development of a reduction-to-the-equator technique that he claims is useful at all latitudes. However, until such a globally useful reduction technique is applied to MAGSAT data, we must rely on modeling to check correlations of MAGSAT anomalies with possible causes.

Published models of total-field magnetic anomalies, such as those by Andreasen and Zeitz (1969), show that anomalies for simple rectangular crustal blocks are centered over the block at the magnetic equator, with an arithmetic sign opposite to that of the anomalous susceptibility. Thus a positive susceptibility contrast leads to a negative anomaly induced at the magnetic equator. In addition, there are cusps of opposite sign to that of the anomaly that flank the block on the north and south (ibid, Plate 1).

For a simple rectangular block with magnetic inclination between 0° and 45° , the peak of the induced total-field anomaly moves away from the equator. The cusp on the equatorial flank of the block intensifies in magnitude with increasing latitude, while the other cusp weakens (ibid, Plate 9).

At magnetic inclinations greater than 45° , the anomaly pattern shifts so that the anomaly of the same sign as the susceptibility contrast (formerly a cusp) lies toward the equatorial flank of the crustal block, while the anomaly of opposite sign becomes a cusp (ibid, Plates 18 and 27). At the magnetic pole a single anomaly of the same sign as that of the susceptibility contrast is centered over the crustal block, with no cusps (ibid, Plate 35).

A terrestrial block, such as a sedimentary basin, is usually better modeled as a series of stacked crustal blocks, with the smallest and narrowest block being on the bottom of the stack at the deepest part of the basin. Such a model tends to place the anomaly caused by a sedimentary basin closer to the deepest part of the basin than would a model that uses a simple rectangular block for the basin. In such a manner the anomalies produced by the Congo and Taoudeni basins are closer to the centers of the basins than one would expect from using simple Andreasen and Zeitz models.

MAGSAT Anomaly Patterns in Africa

Africa has received attention from investigators of global magnetic anomaly maps since the presentation of the pioneering maps by Regan and others (1975). Much of this attention has been

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focused on the three bulls-eye anomalies over and near the Central African Republic, anomalies which have been referred to collectively as the Bangui anomaly (anomalies labeled 5a and 7 on figure 1 and the +6 nanotesla anomaly between 5 and 6 on that figure).

In addition to the Bangui anomaly, the preliminary total-field MAGSAT anomaly map for Africa shows several other prominent anomalies that appear to correlate spatially with major tectonic features of the continent (figure 1).

The Archaean nucleus of the West African craton (10° W, 7° N) is associated with a strong negative anomaly, as is the Archaean exposure of the western Reguibat shield (10° W, 28° N) which produces an anomaly along its northern flank. A somewhat weaker, but nevertheless significant, correlation exists between negative anomalies and exposures of middle-Precambrian shields in the West African craton (5° W, 7° N) and in the eastern Reguibat Dorsal. The Taoudeni basin (10° W, 17° N), which overlies the West African craton, is closely associated with a prominent positive anomaly whose strength at any given point within the basin is roughly proportional to the thickness of the sedimentary sequence at that point. The Pan-African shield province of Nigeria (5° E, 8° N) and the Ahaggar plateau (8° E, 23° N) produce weak anomalies that tend to be dominated by magnetic effects of nearby features. The combined enclosure of the Ahaggar and Tibesti plateaus (18° E, 23° N) shows only a slight saddle in the MAGSAT anomaly where the two uplifts are breached by sediments at about 14° E, which suggests that the two features produce an anomaly characteristic of a single crustal block (that is, an uplift surrounded by basins). The Atlas Mountains do not produce a noticeable anomaly on the anomaly map; neither does the Benue trough (10° E, 8° N), probably because of its narrowness. The effect of the Chad basin (15° E, 13° N) is unclear. The Saharan basins in eastern Algeria and Libya correspond weakly with positive MAGSAT anomalies.

The rift system is the major tectonic feature in East Africa. It is oriented approximately north-south, parallel to the orbital path of MAGSAT. Data processing techniques, the orientation and relative narrowness of the rifts, and the general weakness of components of magnetic susceptibility contrast perpendicular to magnetic north preclude strong MAGSAT anomalies from this source. There is only a slight perturbation of

the total-field MAGSAT anomalies that may correlate with the rift. However, a negative anomaly in the Turkey-Syria-Lebanon border area (37° E, 38° N) might be related to the northern extremity of the rift system. The major MAGSAT feature in this area is the strong positive anomaly over the central-eastern parts of the Arabian shield and Persian Gulf.

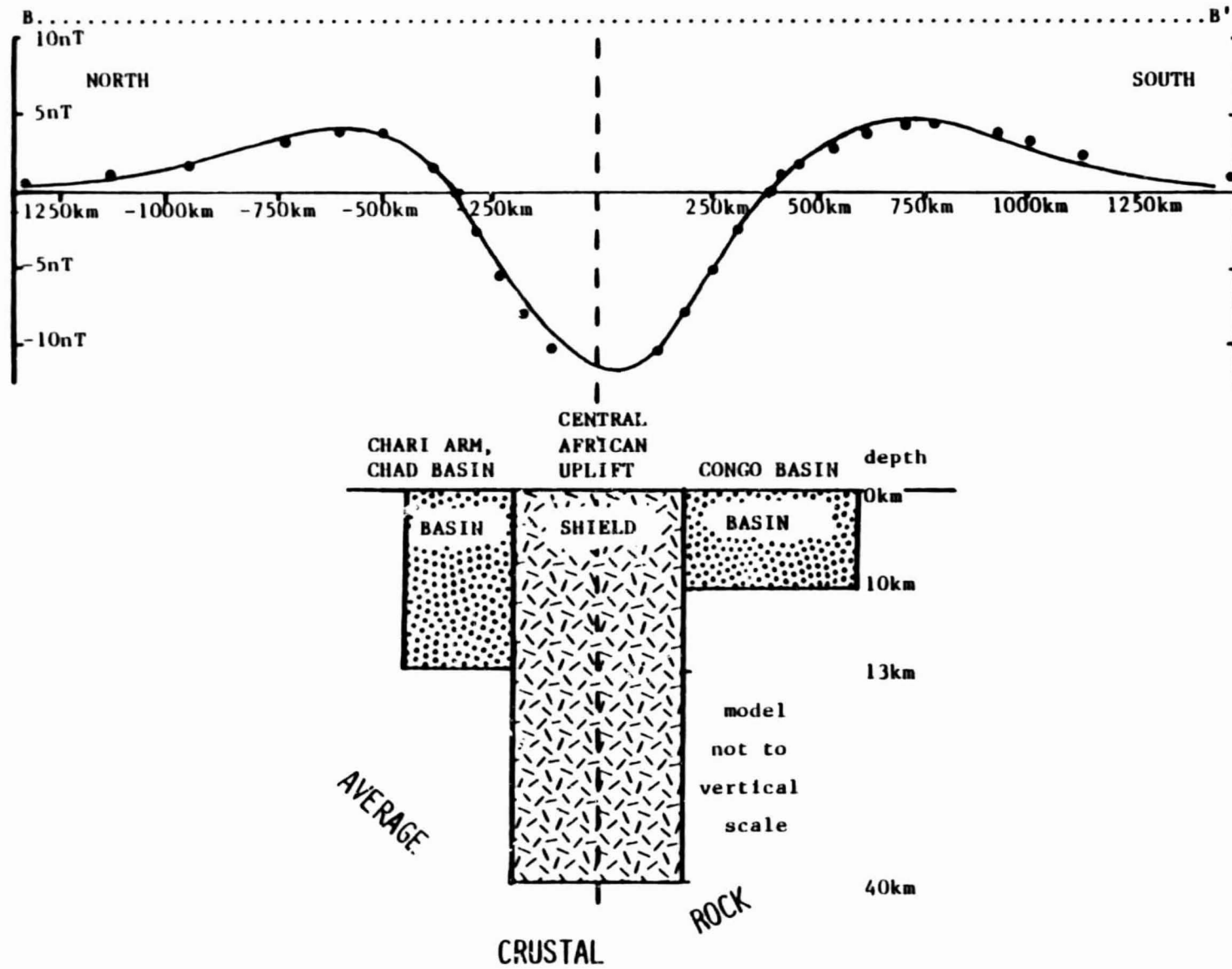
The only major features in southern Africa shown on the anomaly map (figure 1) are the gradient trending east-southeast from Cabinda (12° E, 4° S) to central Madagascar, the strong negative anomaly that connects coastal basins in southern Mozambique and southern Madagascar (40° E, 20° S), and the anomaly over the Karroo basin (24° E, 30° S).

For magnetic inclinations greater than 45° , the signs of the anomalies tend to reverse. An example of this is the negative anomaly associated with the Karroo basin.

An Initial Interpretation of the Bangui Anomaly

Based on a modeling program (GEOGRAPH.TEST) at the U.S. Geological Survey's Earth Resources Observation Systems (EROS) Data Center, several models have been produced to test the hypothesis that the three anomalies that constitute the Bangui anomaly could be caused by a Precambrian shield flanked to the north and south by sedimentary basins. A simplified two-dimensional model of such an arrangement is shown in figure 3. This model produces an anomaly profile that agrees with the pattern seen along profile B-B' on figure 2 (this preliminary model uses similar POGO data and a satellite altitude of 550 km).

Thus the Bangui anomaly is actually three anomalies that correlate with three major crustal features. The central magnetic low corresponds closely to the shape, orientation and (10° S magnetic) inclination of a major Archaean shield seen on figure 1 at 20° E, 2° N. The positive anomaly to the south (20° E, 3° S) corresponds closely to the deepest part of the Congo basin. The positive anomaly to the north (18° E, 9° N) fits the deep Chari River arm of the Chad basin. Regan and Marsh (1982) attempted the first interpretation of the Bangui anomaly; they concluded that the positive anomalies to the north and south are similar to those found in total-field models for near-horizontal magnetic inclinations. However, the complex shapes of the major crustal features of the area, and the strong correspondence of the satellite magnetic anomalies with



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Figure 3

these features, suggest that the Regan-Marsh model can be improved. The northern flanking anomaly suggests that there is a cusp with a magnitude of about +4 nT flanking the central Bangui anomaly and an anomaly of about +2 to +3 nT caused by the Chari arm of the Chad basin. This model and a similar one for the anomaly over the Congo basin are complicated by the east-west banding of the global MAGSAT anomalies.

Possible Tectonic Associations of the Anomalies

In general, the oldest African Precambrian shields that lie at magnetic inclinations less than 45° tend to cause strong negative anomalies, whereas progressively younger uplifted areas cause progressively weaker anomalies. Conversely, depressions tend to be associated with positive total-field MAGSAT anomalies in proportion to the thickness of sediments. This appears to be consistent (Hastings, 1981a and 1981b) with a greater magnetic susceptibility [probably caused by a combination of (1) greater degree of regional metamorphism and (2) greater uplift of more highly susceptible deeper crustal materials above the Curie isotherm] above the Curie point isotherm for the older shields, and lower susceptibility [probably caused by a combination of (1) a veneer of relatively nonmagnetic sediments near the surface and (2) a depressed crustal column containing relatively less magnetic upper crustal materials above the Curie isotherm] above the Curie isotherm in the basins.

Similar correlations occur in oceanic regions. The Walvis Ridge (10° E, 20° S), the Agulhas Plateau (30° E, 39° S), and the Madeira-Torre Rise (30° E, 33° N) all exhibit strong positive anomalies that are consistent with a model of uplifted areas in higher magnetic latitudes. An investigation of global MAGSAT anomalies produces some additional support for this hypothesis, but it also shows a need for further studies.

Acknowledgments. This study has been supported by the National Aeronautics and Space Administration as MAGSAT Data Investigation M-004 and by the U.S. Geological Survey's EROS Data Center. Early support was provided by Michigan Technological University. Reviewed by Robert D. Regan.

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