U. S. Geological Survey.

Reports-Open file series, no. 78-1006.
1978.

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

PROJECT REPORT
Central African Investigations
(IR)CAE-1

THE BANGUI MAGNETIC ANOMALY, CENTRAL AFRICAN EMPIRE

FINAL TRIP REPORT

Prepared in cooperation with the
National Aeronautics and Space Administration
on behalf of the Central African Empire

1978

THE BANGUI MAGNETIC ANOMALY, CENTRAL AFRICAN EMPIRE

FINAL TRIP REPORT

By

R. D. Regan

U. S. Geological Survey

CONTENTS

FIGURES

TABLES

THE BANGUI MAGNETIC ANOMALY, CENTRAL AFRICAN EMPIRE

Final Trip Report

By R. D. Regan
U. S. Geological Survey

INTRODUCTION

Background for field trips and objectives

For the past 5 years the U. S. Geological Survey (USGS) and the National Aeronautics and Space Administration (NASA) have been involved in a joint project concerning the analysis of satellite magnetometer data for geological studies. The principal objectives of this project have been the detection, identification, and interpretation of magnetic anomalies of geological origin.

Although theoretical studies had indicated that such anomalies could exist in the satellite data, the actual detection of these structures proved to be problematical. The first indication of such an anomaly was noted on several satellite passes over the central African region. Detailed analysis of the data confirmed that a significant anomaly was present over the Central African Empire. This anomaly, termed the Bangui magnetic anomaly (Regan and others, 1973) was confirmed in an analysis of aircraft magnetic measurements, and a preliminary interpretation of the subsurface structure was made based on these data. However, an interpretation based only on magnetic data is not unique. A more complete interpretation requires obtaining rock samples for laboratory analysis and critical ground magnetic measurements. In this way the results of the rock analysis can be combined with ground, air, and satellite magnetic measurements to further refine the interpretation. In addition it is imperative that visits be made to various field sites, and to have discussions with resident geologists, in order that a better understanding of the local and regional geology be obtained.

The visit of the USGS team was arranged through the U. S. Department of State in cooperation with the Government of the Central African Empire and the Bangui office of the Office de la Recherche Scientifique et Technique Outre-Mer (ORSTOM). Funding for the trip was provided by the USGS-NASA Satellite Magnetometer Project.

Acknowledgments

We are greatly indebted to His Excellency,President for Life, Jean Bedel Bokassa, for his interest in our project and for his kind and generous hospitality. The fine hospitality, cooperation, and support provided by the Ministry of Mines and Geology and by local govenment officials during our field work were essential to the successful completion of the mission. The friendly concern for our comfort and enjoyment contributed to making the field trip an experience that we will long remember and treasure.

We are greatly indebted to the Office de la Recherche Scientifique et Technique Outre-Mer (ORSTOM) for their collaboration and support in planning and carrying out our mission. Their fine logistic support, their guidance in the field, and their free exchange and discussion of scientific data were indispensable to our mission.

Finally, we wish to acknowledge the fine support provided our team by the American Embassy in Bangui.

THE BANGUI ANOMALY

The Bangui magnetic anomaly was the first magnetic anomaly discovered by satellite measurements (Regan and others, 1973). Until that discovery it seemed quite unlikely that magnetic anomalies could be detected by satellite magnetometers because of the rapid attenuation of signal with distance. However, this anomaly indicated that there exists a new class of magnetic anomalies. Such "long wavelength" anomalies had not been noted in previous geophysical studies and are undoubtedly reflective of some basic crustal structures.

Primarily because it was the first to be discovered, but also because of the relationship between the anomaly and general tectonic patterns, the Bangui anomaly is the first long wavelength anomaly to be analyzed in detail. Employing the same data reduction schemes that were used in defining the Bangui anomaly, Regan and others (1975) were able to produce a global magnetic anomaly map from the satellite measurements. Although there probably is not a common origin for all such anomalies, significant insight into crustal structure and processes can be obtained through the analysis of these anomalies.

The analysis and reduction of satellite magnetometer data for anomaly studies is detailed by Regan and others (1975). Basically what is needed are satellite data obtained when the geomagnetic field is undisturbed and the satellite is at as low an altitude as possible. To obtain such data, the Polar Orbiting Geophysical Observatory (POGO) satellite observations, obtained during a period of variable magnetic field activity and over an altitude range of 400 to 1500 km, had to be screened for low altitude and minimal magnetic field activity.

The method then utilized to determine an anomaly is a regional-residual separation where the regional field is defined by a four-dimensional function $(f,(\phi,\Theta,\gamma,t))$. This function is computed by least squares fitting a thirteenth order spherical harmonic series to the observed data. The anomalies or residuals, termed ΔF, are defined as the difference between the measured and computed values at each observation point.

In examining residual values along satellite orbits, a secondary minimum was noted near the equatorial electrojet anomaly over the area of central Africa. This feature is quite evident when only the midnight (local time) portions of individual orbits in this area are examined. The ΔF values, in the area of this anomaly, were averaged over 1 degree latitude-longitude blocks in order to obtain more resolution. The resulting map at an average elevation of 525 km is shown in figure 1. The anomaly centered over an area slightly north of Bangui, Central African Empire is a broad low, trending approximately east-west, and having a maximum amplitude of -12 gammas. Fortunately there exist two project MAGNET (Stockard, 1971) flight lines in this immediate area. Residual values of these data relative to the thirteenth degree field model were calculated and are shown in figure 2. These reveal a magnetic low of approximately 800 gammas over a broad area of 2^{o}-3^{o} (200-300 km). The anomaly is also quite apparent in the raw (measured) values of the project MAGNET data and thus is not an artifact of the field model or any subsequent data reduction. Further evidence of the anomaly is available in the ground magnetic measurements obtained by L. LeDonche and R. Godivier of ORSTOM in 1956. Utilizing their measurements of both the horizontal and veritcal field components, the total field has been calculated and a thirteenth-order field model removed from the data. The resultant map is shown in figure 3. Although the measurement locations are quite sparse, there is ample evidence of a large negative anomaly.

The fact that the anomaly is of the same sense in the ground, aeromagnetic, and satellite data and is more intense at the lower aircraft altitude indicates that the source is internal to the earth. Continuation of the aircraft anomaly to satellite elevation (Regan and others, 1975) also demonstrates that the same anomaly is being measured by both satellite and aircraft magnetometers.

This anomaly is thus a real internal magnetic anomaly of several hundred kilometres wavelength and several hundred gammas amplitude. The inclination of the main field varies from approximately -30° to $+11^{\circ}$ over the extent of the area of figure 1. Thus the anomaly occurs approximately at the geomagnetic equator, and a magnetic low as observed here is characteristically caused by positive susceptibility contrasts in this region.

It was possible to compute a causative source for the magnetic anomaly by using all sets of data. The resultant analysis revealed a causative body of approximate dimensions 700 km by 200 km underlying the Central African Empire.

It was necessary, however, to obtain much more information before a detailed anlaysis could be completed. The size of the body and its relationship to crustal structure are significant, and only by obtaining enough information for boundary conditions could a more realistic and detailed interpretation be made. Such an interpretation is of scientific importance in establishing the origin of this body and of practical importance in determining whether or not the anomaly has economic value--either directly or indirectly.

Field studies

During January 17-26, 1976, the U. S. Geological Survey team visited the Central African Empire to conduct a field investigation of the Bangui magnetic anomaly. The objectives of the visit were to collect ground magnetometer measurements in certain areas, to measure the magnetic susceptibility of the various rock formations, to collect rock samples of various units, and to visit with local geologists. The information obtained by such studies would enable us to make a more complete interpretation of the causative body.

With the help of the members of the Department of Mines and ORSTOM, two field trips were planned. One, a 4-day, 1000-km field trip, was north from Bangui to Sibut, Dékoa, Kaga Bandoro, Mbrès, Bkala, Bémbi, Bambari, and Grimari. This trip passed through the heart of the anomaly and near the north-south project MAGNET line. The second trip was a 1-day 300-km trip south of Bangui to Mbaiki and the Lobaye river. This trip offered the opportunity to visit some dolerite outcrops and also passed through the area of the anomaly that was measured on the E-W project MAGNET flight line.

Northern field trip

The route of the first field trip is shown in figure 4. Members of the field trip were Messrs. Gbakpoma, Gboyarhe, Frignet, and Beucher,

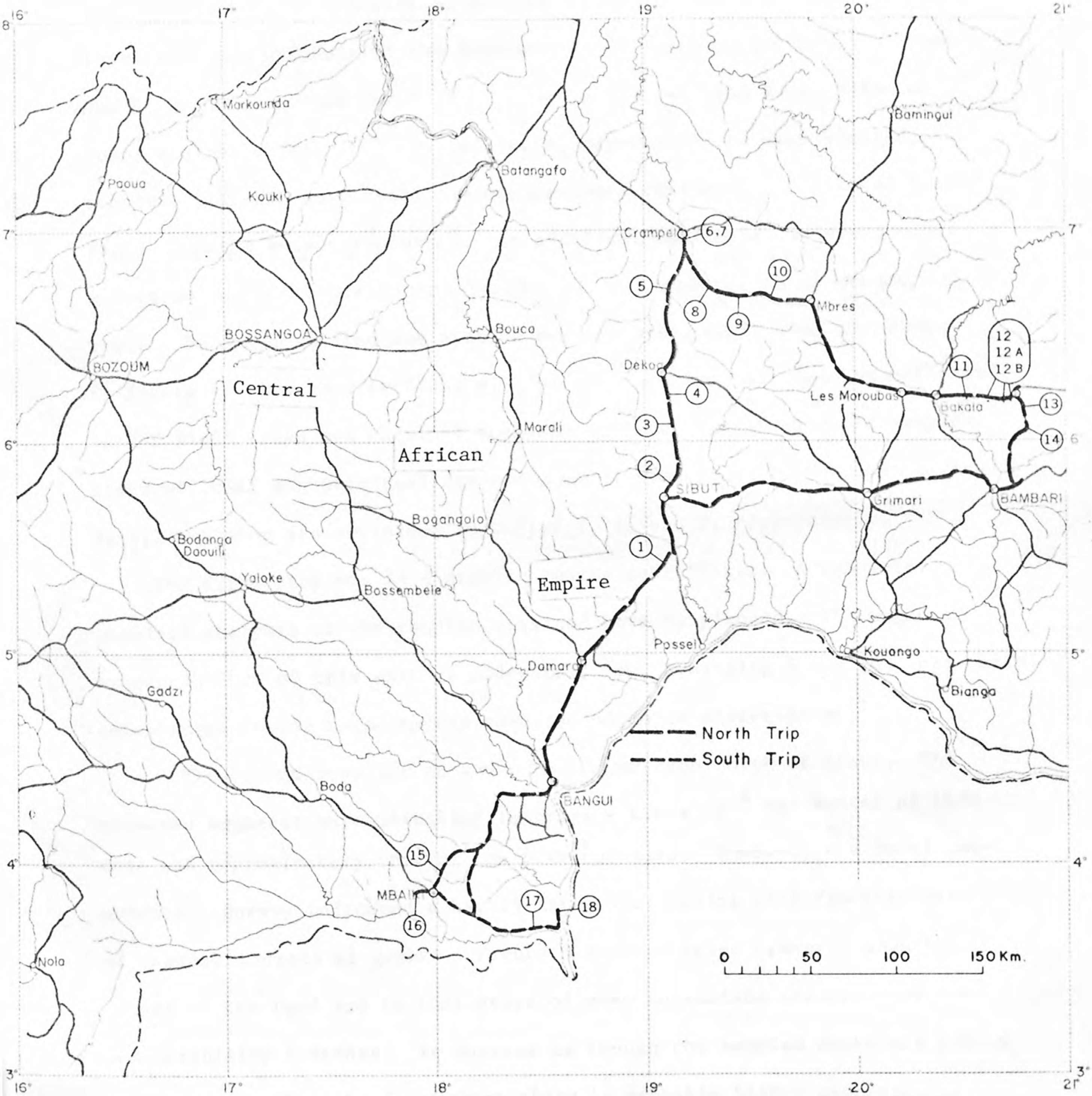

Figure 4. Field trip routes and station locations

of the Department of Mines of the Central African Empire; Messrs. Mourgues, Vassal, Chavin, and Godivier of ORSTOM; M. Poidevin of Jean Bedel Boukassa University; M. Gribbons of the Embassy of the United States; R. D. Regan and A. H. Chidester of the U. S. Geological Survey; and B. D. Marsh of Johns Hopkins University. On this trip, major outcrops were visited, sampled, magnetic susceptibility measurements obtained, and a local total-field magnetic survey conducted. In addition, ORSTOM had a team conduct a regional magnetic survey at a regular station spacing along the entire route. Outcrops visited and station numbers assigned to them are shown in figure 4. Two thin sections will be obtained from all samples collected in the field trips and chemical analyses will be made of selected samples. Lists of local magnetic readings and magnetic susceptibility values obtained at all stations are contained in tables 1, 2, and 3, respectively.

The first stop was in a granite quarry near Mangue. A complete chemical analysis of the samples obtained here is planned. The magnetic susceptibility of this unit is moderately low, averaging 8.8×10^{-4} cgs units. Local magnetometer measurements revealed no major disturbances.

The second stop was at a charnockite outcrop north of Sibut. The measured magnetic susceptibility (average = 6.6×10^{-4} cgs units) of this unit was approximately that of the previous site. However, the local magnetometer survey indicated a highly irregular reading with fluctuations of several hundreds of gammas. Figure 5 shows a brief traverse down the center of the road and is indicative of some subsurface structure or susceptibility contrast. It appears as though the sampled rocks are highly weathered and that the fresh charnockite is probably highly magnetic. A complete chemical analysis of samples obtained at this location is also planned.

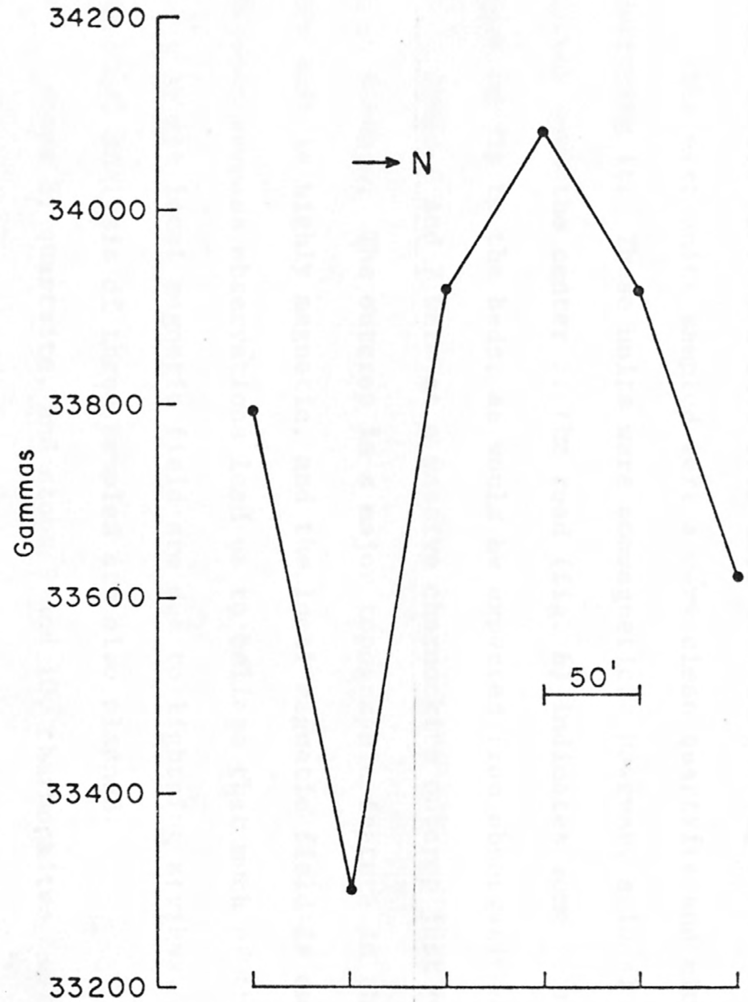

Figure 5 Traverse along center of road
Stop 2

Stop 3 was a granite outcrop containing charnockite inclusions. The magnetic susceptibility was quite low, 55×10^{-6} cgs units, and the local magnetic field was quite flat. A complete chemical analysis of this unit is also planned.

Stop 4 was at a massive quartzite just south of Dékoa. The rock is clean, laminated, and medium grained. The magnetic susceptibility is quite low, averaging 40×10^{-6} cgs units, and local magnetic field measurements confirmed that this unit is nonmagnetic.

The next units sampled were a very clean quartzite and mica schist overlying it. These units were nonmagnetic. However, a local magnetic survey down the center of the road (fig. 6) indicates some subtle structure or dip to the beds, as would be expected from observations at the outcrop.

Stops 6 and 7 were at a massive charnockite outcrop just east of Kaga Bandoro. The outcrop is a major topographic feature in the area. The unit is highly magnetic, and the local magnetic field is quite irregular. Brunton compass observations lead us to believe that much of the irregularities in the local magnetic field are due to lightning strikes. Complete chemical analysis of these samples are also planned.

Stops 8, quartzite, and stops 9 and 10, charnockites, were located on the road between Kaga Bandoro and M'Bres. The magnetic susceptibility of all units was quite low. However, the local magnetic field measurements at Stop 10 indicated that this was a magnetic rock unit. A complete chemical analysis of this sample is planned.

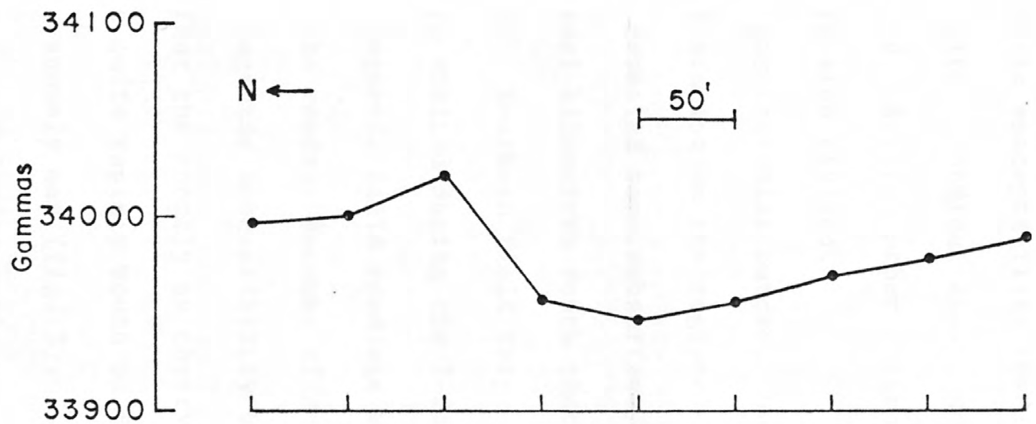

Figure 6 Traverse along center of road
Stop 5

Stop 11 was at a homogenious granite just east of Bakala. The nonmagnetic character of this rock is evident in the magnetometer traverse that was conducted across the length of the outcrop (fig. 7).

Stop 12 was at an iron formation. This is an extremely magnetic rock unit, and it was impossible to take any meaningful local magnetic field readings. This was also the last location on the northern field trip at which any magnetic susceptibility readings were obtained, because of a broken connector wire. Chemical analysis of this unit and Stop 11 samples are also planned. Several other outcrops of this formation (Stops 12A and 12B) were also visited.

Stop 13 was at a garnet schist outcrop south of Bémbi. This location was also a measurement station on the regional ORSTOM survey, and the local survey (fig. 8) revealed some subsurface structure. The next stop was at an outcrop several kilometres south that appeared to be a pelitic schist.

Southern field trip

Four outcrops were visited during the 1-day field trip south of Bangui. In addition, magnetic field readings were obtained at approximately 30-km intervals along the roads. Because of some expert repair work by ORSTOM personnel, the magnetic susceptibility bridge was again operational. This survey revealed that the anomaly as observed on the Project MAGNET flight line diminishes quite rapidly south of Bangui. This is also evident in the ground magnetic anomaly map (fig. 3).

All four stops were at dolerite outcrops. However, the low magnetic susceptibility readings obtained at several outcrops were quite deceiving. As indicated by a traverse along the center of the road (fig. 9) at Stop 17, this unit is highly magnetic. The results at Stop 17 suggests that this particular outcrop could be dikelike in structure. Some fresh

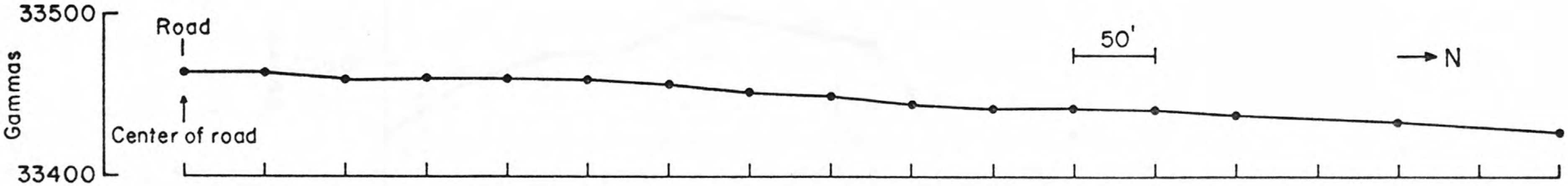

Figure 7 Traverse from center of road along outcrop
Stop 11

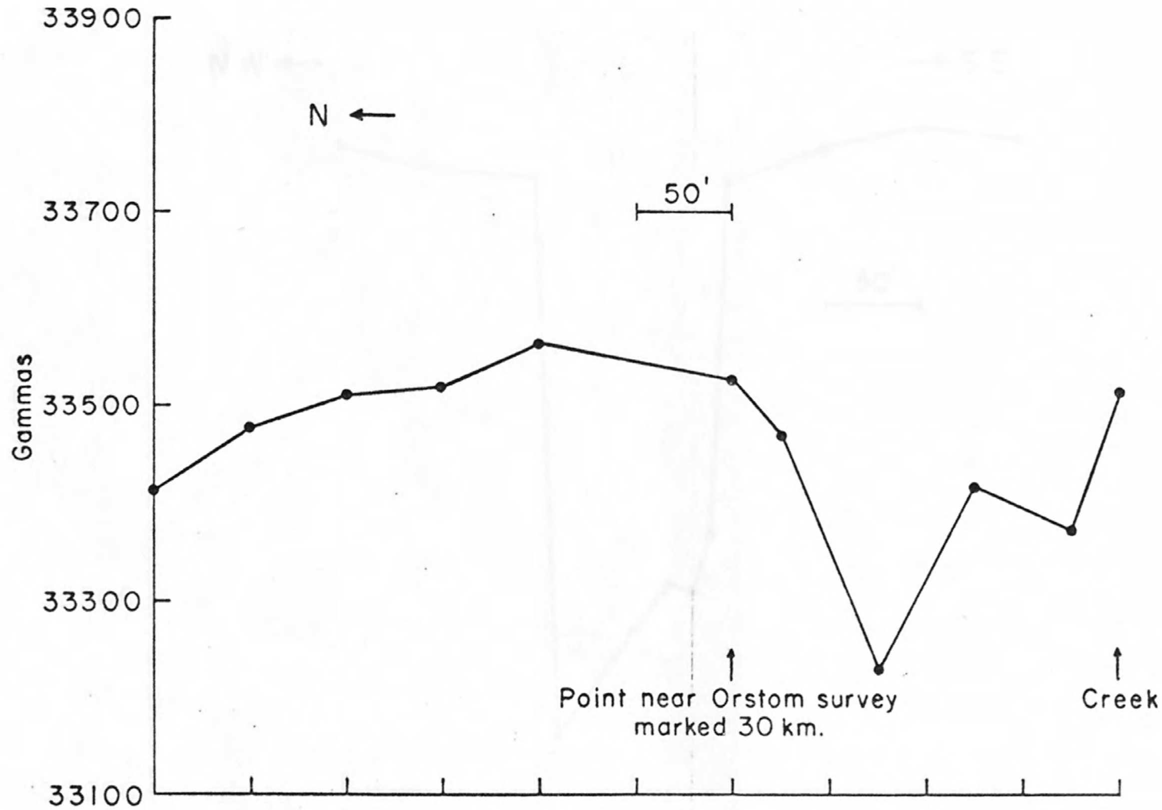

Figure 8 Traverse along center of road
Stop 13

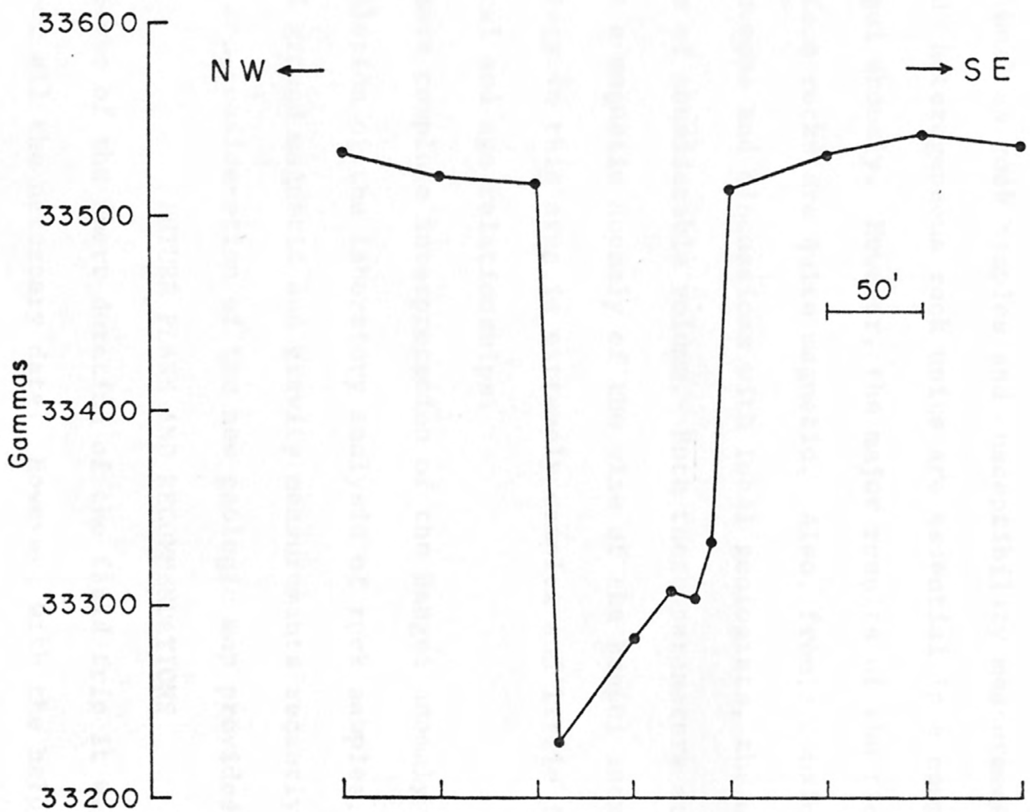

Figure 9 Traverse along center line of road
Stop 17

dolerite samples in the middle of the Oubangui River provided high susceptibility readings averaging 1.4×10^{-3}, and indicated that highly weathered material was being sampled at the previous locations. Complete chemical analysis of sample 18 is being planned.

PRELIMINARY CONCLUSIONS

It was indeed unfortunate that we did not have enough time to visit the area around Bossangoa and Bouca. Magnetic field measurements in this area as well as rock samples and susceptibility measurements of the charnockite and heterogeneous rock units are essential in a complete analysis of the Bangui anomaly. However, the major results of the field trip are that the surface rocks are quite magnetic. Also, from a consideration of the geologic maps and discussions with local geologists, the magnetic rocks are also of considerable volume. Both these parameters are required to generate a magnetic anomaly of the size of the Bangui anomaly. However, the geology in this area is extremely complex and little is known of structural and age relationships.

A more complete interpretation of the Bangui anomaly is attendent on the completion of the laboratory analysis of rock samples, analysis of obtained ground magnetic and gravity measurements recently obtained by ORSTOM, and consideration of the new geologic map provided to us by ORSTOM.

FUTURE PLANS AND RECOMMENDATIONS

Because of the short duration of the field trip it was not possible to collect all the necessary data. However, with the help of ORSTOM, we think that sufficient data can be obtained for a more thorough analysis of the Bangui anomaly.

First of all, the results of the regional total field magnetometer survey conducted by ORSTOM during the Northern field trip would be quite helpful. This survey should be extended into the region of the Southern field trip and into the Bossangoa-Bouca area. A suggested ground traverse is contained in figure 10.

In addition to this ground magnetic data, it would be useful to obtain a copy of the Bouguer anomaly station values map compiled by ORSTOM. This data would be digitized, combined with other ground data (e.g., Chad) and satellite data to produce a regional gravity anomaly map.

The 18 rock samples collected during the field trip are now being analyzed in USGS laboratories. It would be desirable to obtain some samples of charnockite and heterogeneous granite units in the Bossangou-Bouca regions. In situ susceptibility measurements of these units would also be necessary.

When all the data are reduced, we would propose to work on a more definite interpretation of the Bangui anomaly with ORSTOM, the Ministry of Mines and Geology, and the University. The model will be developed by using geological and structural constraints employing measured susceptibility values, and will consist of a computer-generated model whose anomalous magnetic field would fit the ground, air, and satellite measurements.

Figure 10. Route of suggested ground traverse

641

TABLE 1

Total Field Magnetometer Readings, in Gammas

North trip:

ORSTOM		33460
Stop 1	Average	33310
	Maximum	33375
	Minimum	33250
	No. of Samples	10
Stop 2	Average	33612
	Maximum	34080
	Minimum	32482
	No. of Samples	17
Stop 3	Average	33184
	Maximum	33188
	Minimum	33180
	No. of Samples	4
Stop 4	Average	32859
	Maximum	32901
	Minimum	32839
	No. of Samples	9
DEKOA	33310	
Stop 5	Average	33981
	Maximum	34021
	Minimum	33946
	No. of Samples	14
Stop 6	Average	33952
	Maximum	35081
	Minimum	32520
	No. of Samples	20

KAGA BANDORO		34407
Stop 7	Average	34892
	Maximum	35997
	Minimum	34218 -
	No. of Samples	11
Stop 8		No Readings
Stop 9	Average	33898
	Maximum	33975
	Minimum	33857
	No. of Samples	14
Stop 10	Average	34017
	Maximum	34470
	Minimum	33776
	No. of Samples	9
Stop 11	Average	33451
	Maximum	33465
	Minimum	33428
	No. of Samples	19
Stop 12		No Readings
Stop 13	Average	33453
	Maximum	33563
	Minimum	33228
	No. of Samples	11
Stop 14	Average	32409
	Maximum	32946
	Minimum	32220
	No. of Samples	12

Table 1. Total field magnetometer readings, in gammas, continued.

South trip:

ORSTOM	1/25/76	0730	33424
Stop 15	Average	33505	
	Maximum	33597	
	Minimum	33464	
	No. of Samples	7	
Stop 16	Average	33460	
	Maximum	33484	
	Minimum	33450	
	No. of Samples	7	
Stop 17	Average	33427	
	Maximum	33540	
	Minimum	33223	
	No. of Samples	12	
Stop 18	<u>Quartzite Island</u>		
	Average	33405	
	Maximum	33459	
	Minimum	33303	
	No. of Samples	3	
	<u>Dolerite Rocks</u>		
	Average	33456	
	Maximum	33459	
	Minimum	33454	
	No. of Samples	2	

TABLE 2

TOTAL FIELD MAGNETOMETER READINGS, IN GAMMAS

Traverse on Road Bangui - MBAIKI - OUBANGUI RIVER

ORSTOM	33424
19 km from MPOKO RIVER	32924
51 km from MPOKO RIVER	33185
82 km from MPOKO RIVER	33320
90 km from MPOKO RIVER	33400
101 km from MPOKO RIVER in MBAIKI (STOP 15)	33505
1 km toward OUBANGI RIVER from short cut road	33520
38 km toward OUBANGI River from short cut road (STOP 17)	33427
At OUBANGI RIVER	33100

TABLE 3

IN SITU MAGNETIC SUSCEPTIBILITIES AT FIELD LOCATIONS

IN 10^{-6} CGS UNITS

North trip:

1)	Stop 1	Average	888
		Maximum	1690
		Minimum	20
		No. of Samples	6
2)	Stop 2	Average	661
		Maximum	900
		Minimum	470
		No. of Samples	12
3)	Stop 3	Average	55
		Maximum	160
		Minimum	0
		No. of Samples	7
4)	Stop 4	Average	40
		Maximum	100
		Minimum	10
		No. of Samples	6
5)	Stop 5 Quartzite	Average	30
		Maximum	70
		Minimum	0
		No. of Samples	5
	Mica Schist	Average	25
		Maximum	55
		Minimum	0
		No. of Samples	4
6)	Stop 6	Average	1860
		Maximum	4090
		Minimum	526
		No. of Samples	10

TABLE 3, continued

IN SITU MAGNETIC SUSCEPTIBILITIES AT FIELD LOCATIONS
IN 10^{-6} CGS UNITS

7)	Stop 7	Average	1587
		Maximum	3270
		Minimum	300
		No. of Samples	28
8)	Stop 8	Average	27
		Maximum	50
		Minimum	10
		No. of Samples	3
9)	Stop 9	Average	65
		Maximum	100
		Minimum	50
		No. of Samples	6
10)	Stop 10	Average	40
		Maximum	70
		Minimum	0
		No. of Samples	6
11)	Stop 11	Average	35
		Maximum	60
		Minimum	22
		No. of Samples	16
12)	Stop 12	Average	8603
		Maximum	23050
		Minimum	2855
		No. of Samples	7
13)	Stops 13-14	No measurements--susceptibility bridge broken.	
South trip:			
14)	Stop 15	Average	59
		Maximum	85
		Minimum	40
		No. of Samples	6
15)	Stop 16	Average	57
		Maximum	72
		Minimum	49
		No. of Samples	4

South trip, continued:

16) Stop 17

a) Weathered outcrop

Average	59
Maximum	70
Minimum	39
No. of Samples	4

b) Fresh Face on boulder

Average	471
Maximum	570
Minimum	285
No. of Samples	4

17) Stop 18 dolerite

Average	1436
Maximum	1970
Minimum	1335
No. of Samples	4

24

REFERENCES CITED

Godivier, R., LeDonche, L., 1956, Reseau magnetique remene au 1er Janvier 1956: Republique Centrafricaine Tchad Meridional, ORSTOM.

Regan, R. D., Cain, J. C., and Davis, W. M., 1975, A global magnetic anomaly map: Jour. Geophys. Research, v. 80, no. 5, p. 794.

Regan, R. D., Davis, W. M., and Cain, J. C., 1973, The Bangui magnetic anomaly (abstract): Am. Geophys. Union EOS, Trans., v. 54, (4), p. 236.

Stockard, H. P., 1971, Worldwide surveys by Project MAGNET, World Magnetic Survey, 1957-1969: Internat. Assoc. Geomagnetism and Aeronautics, Bull. 28, p. 60-64.

GPO 907-614

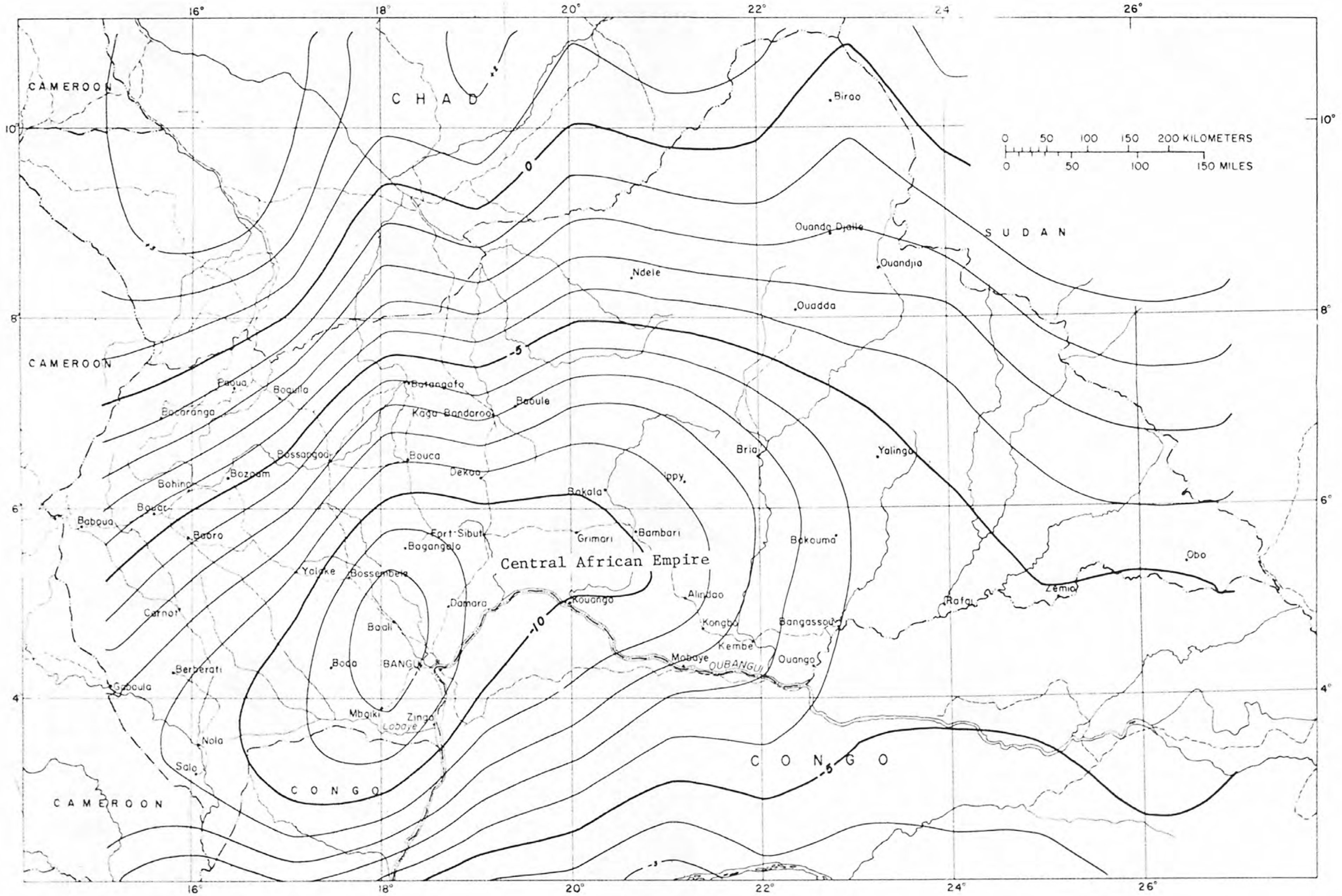

Figure 1. Total field magnetic anomaly at mean satellite elevation of 525 km.

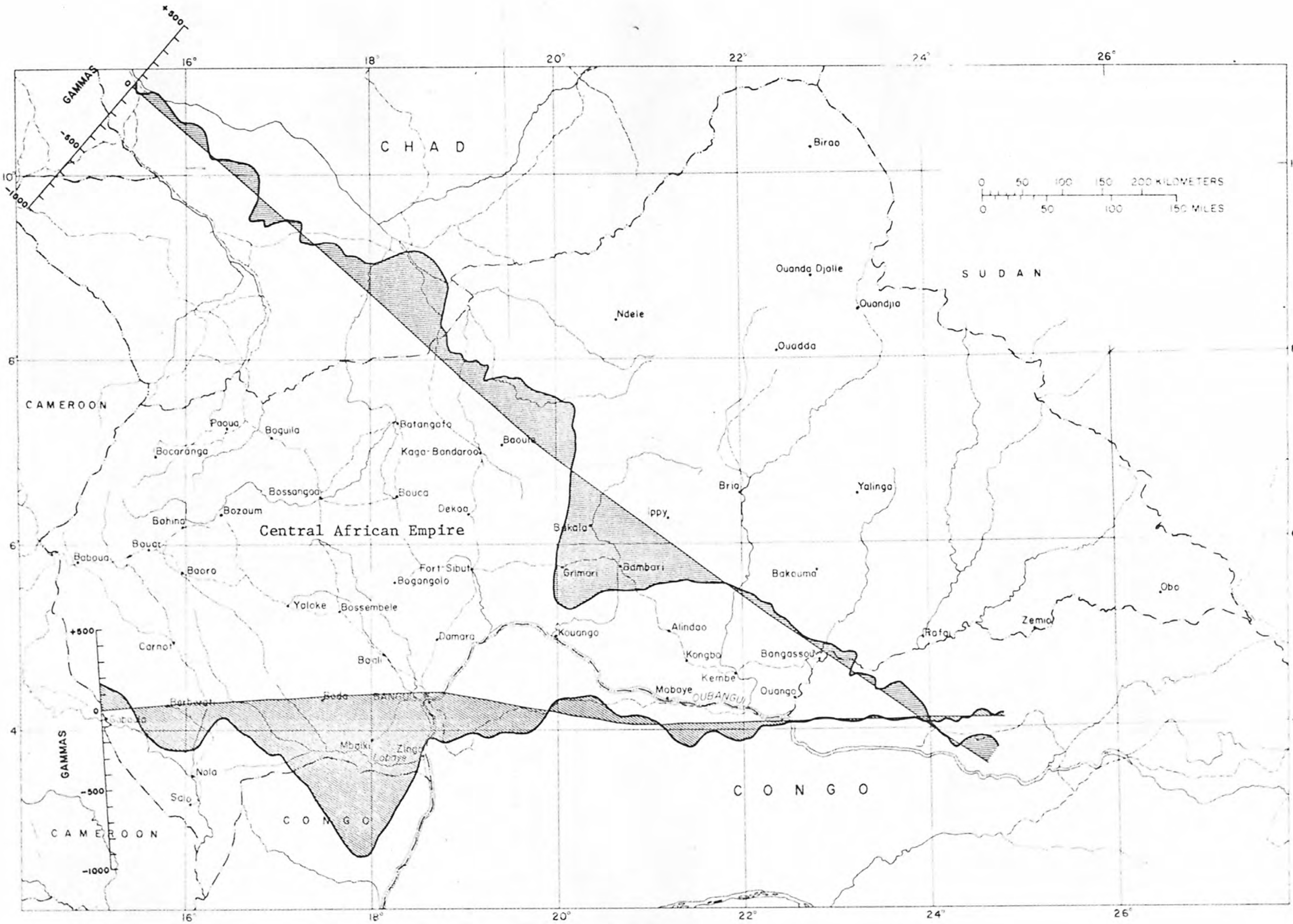

Figure 2. Total field magnetic anomaly along Project MAGNET flight lines.

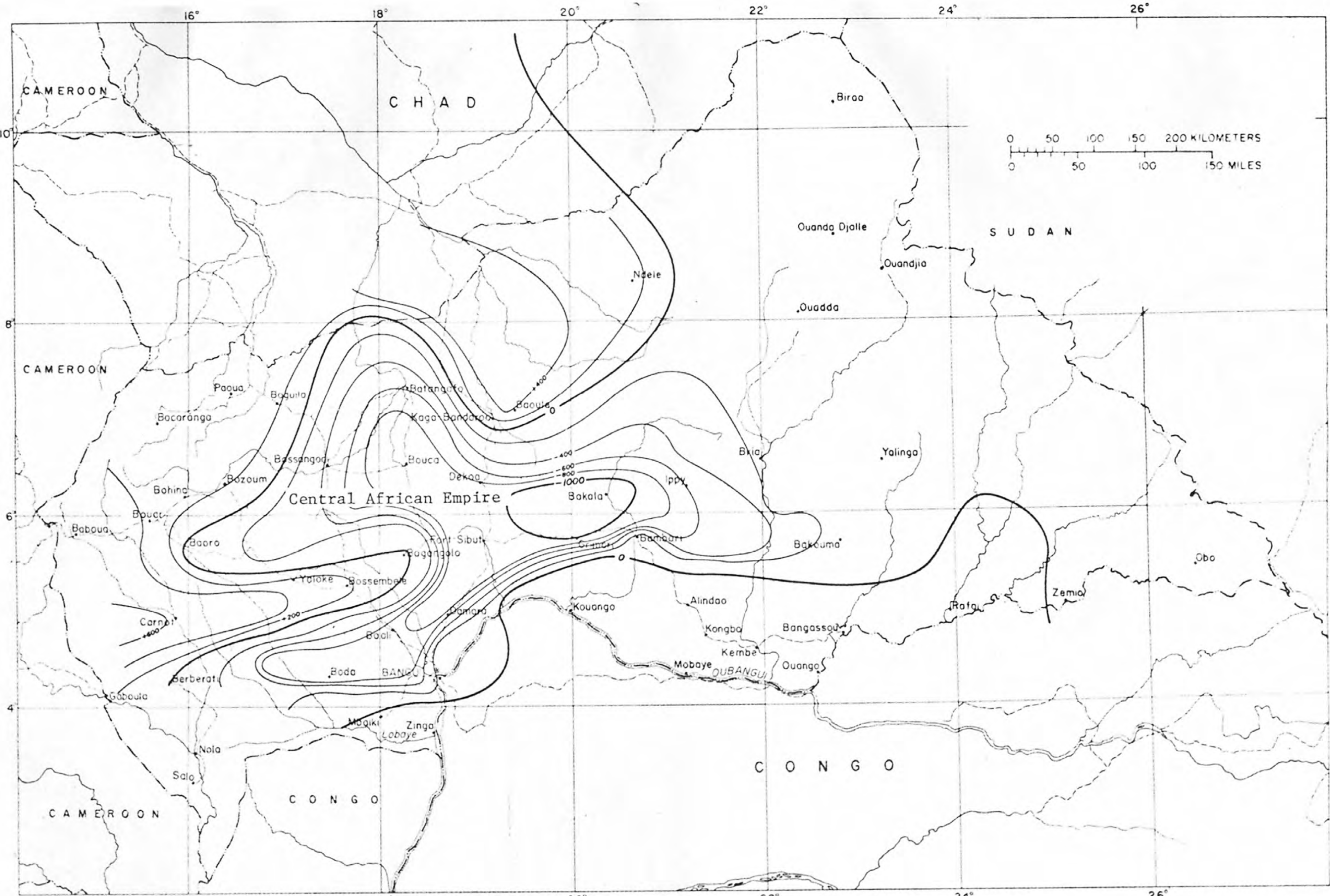

Figure 3. Total field magnetic anomaly at ground stations.