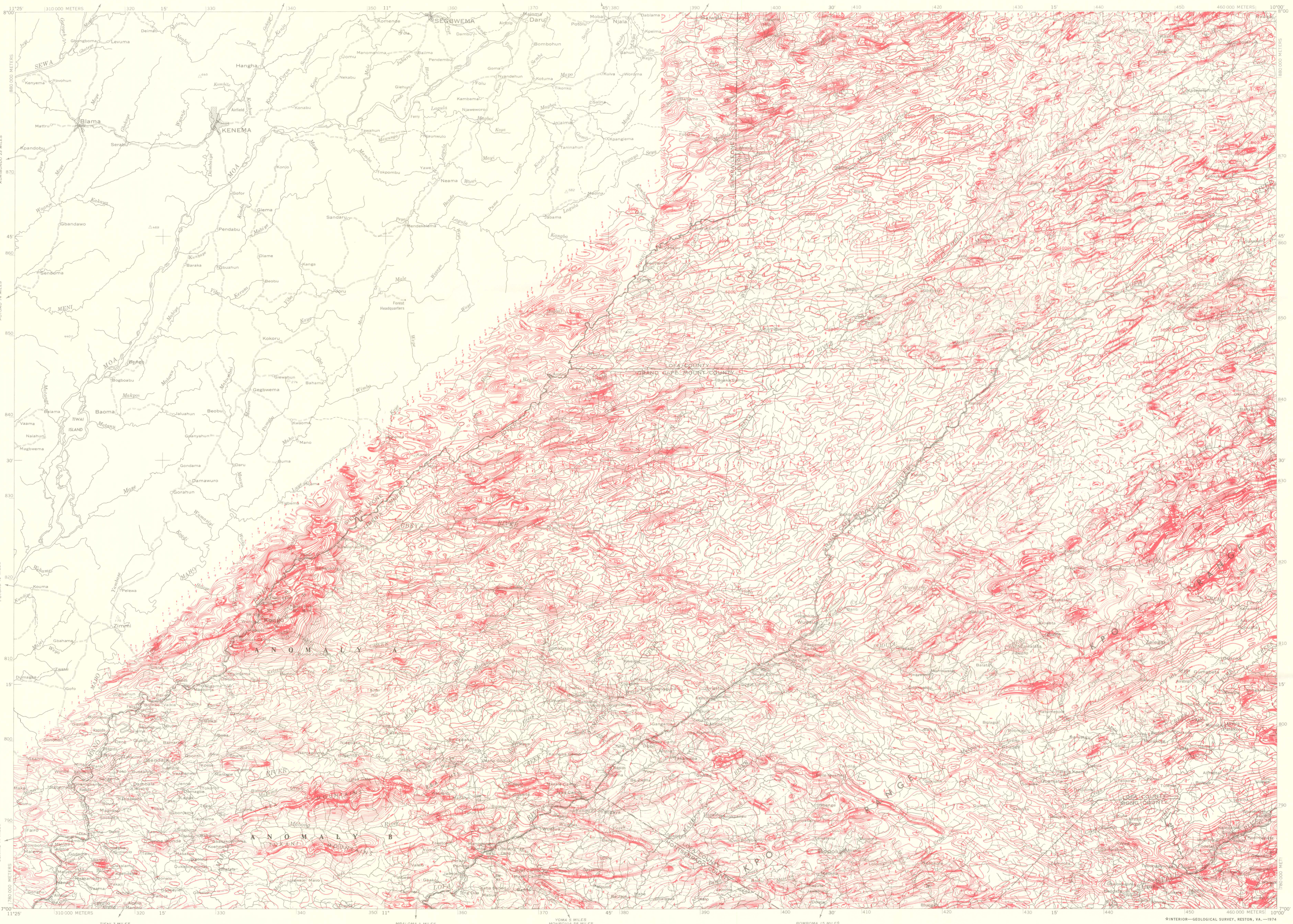


Coordinates based on Hotines rectified skew orthomorphic projection, U.S. Coast and Geodetic Survey, 1956

NOTE: Country boundaries indefinite

SCALE 1:250,000

5 0 5 10 15 20 25 30 KILOMETERS

5 0 5 10 15 20 MILES

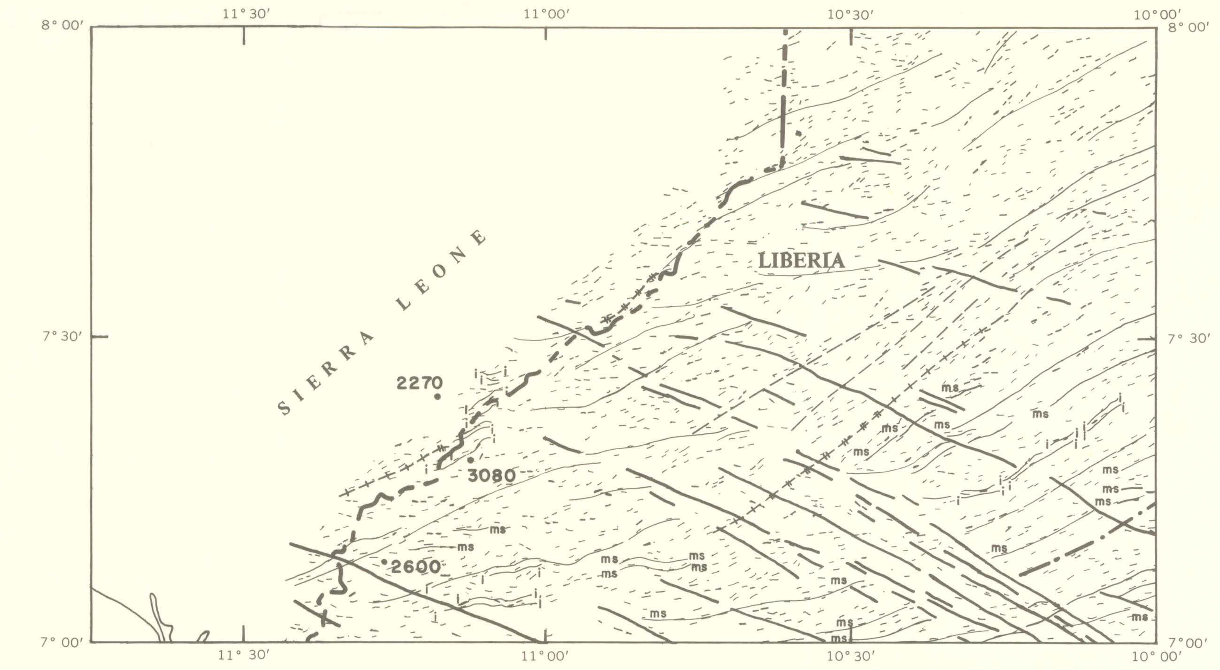
1970 MAGNETIC DECLINATION VARIES FROM 13°40′ WESTERLY FOR THE CENTER OF THE WEST EDGE TO 13°00′ WESTERLY FOR THE CENTER OF THE EAST EDGE. MEAN ANNUAL CHANGE IS 0°06′ EASTERLY

EXPLANATION

MAGNETIC CONTOURS – Showing total intensity magnetic field of the earth in gammas relative to arbitrary datum. Regional magnetic gradient not removed. Hachured to indicate closed areas of lower magnetic intensity. Contour intervals are 10, 50, 250, and 1,000 gammas. Selected contour values shown in larger type

FLIGHT PATH

Aeromagnetic survey flown by Lockwood, Kessler, and Bartlet, Inc. at 150 meters above terrain, 1967–68. Flight-line spacing of 0.8 kilometers over land. Geophysical data reduced from original compilation at 1:40,000-scale by Lockwood, Kessler, and Bartlet, Inc., with minor modifications to improve legibility.



10 0 10 20 30 40 KILOMETERS

10 0 10 20 MILES

EXPLANATION

TREND DIRECTION OF SHORT-WAVELENGTH MAGNETIC ANOMALIES – Assumed to be associated with near-surface geology and interpreted as indicative of rock foliation directions

LOCATION OF LONG LINEAR MAGNETIC ANOMALIES – Interpreted as being caused by diabase dikes

SIGNIFICANT CHANGE IN MAGNETIC AND (OR) RADIOMETRIC CONTOURS – Inferred to be a geologic boundary of unspecified origin or type

LINEAR MAGNETIC ANOMALIES – Caused by magnetization contrasts interpreted as geologic structures that may include folds, faults, and contacts

ms

MAGNETICALLY DETERMINED LINEAR STRUCTURE – Inferred to be locally associated with magnetic metasedimentary rocks including schist, quartzite, amphibolites, iron-formation, paragneiss, and migmatite. May include folds, faults, and contacts

i

MAGNETICALLY DETERMINED LINEAR STRUCTURE – With anomaly greater than 1,000 gammas interpreted as being caused by magnatite iron-formation. May include folds, faults, and contacts

POSSIBLE FAULT – Suggested by linear change in magnetic or radiometric contour

PROBABLE FAULT – Suggested by linear change in magnetic or radiometric contour

FAULT, ASSOCIATED WITH GEOLOGICALLY KNOWN FAULT – Suggested by linear change in magnetic or radiometric contour

2270

RADIOMETRIC AGE DETERMINATION IN M.Y. – From Hurley and others (1971)

FIGURE 1. – Tectonic map, Bopolu quadrangle. Construction is based primarily on magnetic data.

INTERPRETATION

By John C. Behrendt, U.S. Geological Survey, and
Cletus S. Wotorson, Liberian Geological Survey

INTRODUCTION

Aeromagnetic and total-count gamma radiation surveys were flown simultaneously over Liberia during the 1967-68 dry season. These geophysical surveys were designed to contribute to the geologic mapping program undertaken cooperatively by the Liberian Geological Survey and the U.S. Geological Survey under the auspices of the Liberian Government and the Agency for International Development, U.S. Department of State. The surveys were flown by Lockwood, Kessler, and Bartlett under contract to the Liberian Geological Survey. The geology of the quadrangle has been mapped by Wallace (in press) as part of the cooperative program.

The entire country of Liberia is heavily forested, access is difficult, outcrops are sparse, and thick laterite is widespread. Accordingly, throughout large areas aeromagnetic and aeroradiometric surveys are the only feasible means of gathering virtually continuous data which can be related to near-surface geology, and they are useful in extrapolating geologic observations and in locating potential targets for mineral exploration.

The airborne surveys, which cover the entire country, required approximately 140,000 km of traverse, mostly along north-south lines 0.8 km apart over land and 4 km apart over the continental shelf. Continuous photography and Doppler navigation provided horizontal control; flight altitude was 150 m above mean terrain. Temporal variations in the magnetic field measured with a fluxgate magnetometer were removed by adjustment at crossings of east-west control lines. Varied contour intervals of 10, 50, 250, and 1,000 gammas were used, depending on horizontal gradient.

The geophysical data obtained from these airborne surveys are presented, by quadrangle, in these folios of 1:250,000-scale maps that show on separate sheets geographic, geologic, aeromagnetic, and total-count gamma radiation data for each of 10 quadrangles. The index map shows the locations of these quadrangles and their folio number designations. The total-count gamma radiation map of the Bopolu quadrangle (Behrendt and Wotorson, 1974) should be used in conjunction with this aeromagnetic map.

Figure 1 shows the tectonic interpretation for the area covered by this map. The interpretation is based primarily on aeromagnetic data, but partly on aeroradiometric data and readily available geologic information (White and Leo, 1969; Liberian Geol. Survey, unpub. data).

Figure 2 shows part of the residual total magnetic intensity map of Liberia obtained by digitizing the data from the map area on a 1-minute grid, tying to an absolute survey (Lowrie and Escowitz, 1969) by a constant of $+25,980 \pm 35$ gammas, and removing Cain's "Field G" (Cain and others, 1965).

GEOLOGY

The rocks of the Bopolu quadrangle are predominantly granite gneiss (White and Leo, 1969) the foliation of which strikes northeast, typical of the Liberian age province (about 2,700 m.y.) (Hurley and others, 1971). White and Leo (1969) show an area of granite near the northeast corner of the quadrangle and a small area south of the Mano River mine. Mapped areas of iron-formation include the Mano River mine area, the Bea Mountains, and the northeasternmost part of the Kpo Range. A series of diabase dikes strikes northwest across the area and is well defined by the magnetic data (fig. 1).

AEROMAGNETIC INTERPRETATION

The aeromagnetic data shown on the Bopolu quadrangle are characteristic of the gneissic terrane of the Liberian age province. Distinctive linear -200-gamma anomalies that are traceable across the quadrangle can be correlated with diabase dikes which cross Liberia and indicate major tectonic activity and possible right-lateral shear and intrusion along fractures. The dikes trend roughly perpendicular to the northeast-striking bedrock of the Liberian age province but are parallel to a 176-192-m.y.-old diabase dike zone (White and Leo, 1969) near the Atlantic coast; these dikes may be a precursor to the rifting associated with the separation of Africa from South America.

Near the southeast corner of the quadrangle the dike-zone anomalies intersect a 12-km-wide zone of northeast-trending -200-gamma anomalies. This zone also shows up strongly in the radioactivity map (Behrendt and Wotorson, 1974). Hornblende gneiss, recently mapped southeast of Belle Kpamu (N. Jones, written commun., 1969) and between Palakole and the St. Paul River (G. Baker, written commun., 1969), probably explains the negative magnetic anomalies, but a higher concentration of radioactive minerals would be required than might be expected in a hornblende gneiss. Inferred geologic contacts in this area separating different gneisses are shown on figure 2 of the radiometric map.

Positive anomalies as great as 7,000 gammas over the iron-formation in the Mano River mine area suggest a high component of remanent magnetization. The iron ores at this mine are residual deposits that resulted from lateritic weathering (White and Baker, 1968) and are too thin to produce the observed anomalies. The amount of magnetite required for the observed amplitudes must have a greater extent both vertically and horizontally than the deposit being mined. Concentrations of iron great enough to produce the anomalies do not imply the presence of commercial deposits. These anomalies extend across the Mano River into Sierra Leone where Wilson (1965) has mapped "banded iron stone" at about the northwest edge of the high-amplitude anomalies in the Bopolu quadrangle. The linear northeast gradient is parallel to but offset from a linear gradient in Sierra Leone that is associated with Wilson's (1965) Webo fault ("known fault" in fig. 1). The much broader gradient on the southeast side of the high-amplitude anomaly suggests a dipping contact (fault?) separating the granite from the more magnetic rock. The highest amplitude anomalies, indicated by the 7,000- and 9,000-gamma contours (anomaly A on map) are near this contact, and the field is very high over the granite.

The Bea Mountains have an associated 18,000-gamma anomaly; White and Leo (1969) report iron-formation which undoubtedly is the source of the magnetic anomaly. They also show iron-formation in the area of the east-west 2,000-gamma anomaly (anomaly B on map) about 5 km south of the Bea Mountains. The high positive values above the regional level of about 5,000 gammas suggest a high remanent magnetization in a direction different from that of the present field.

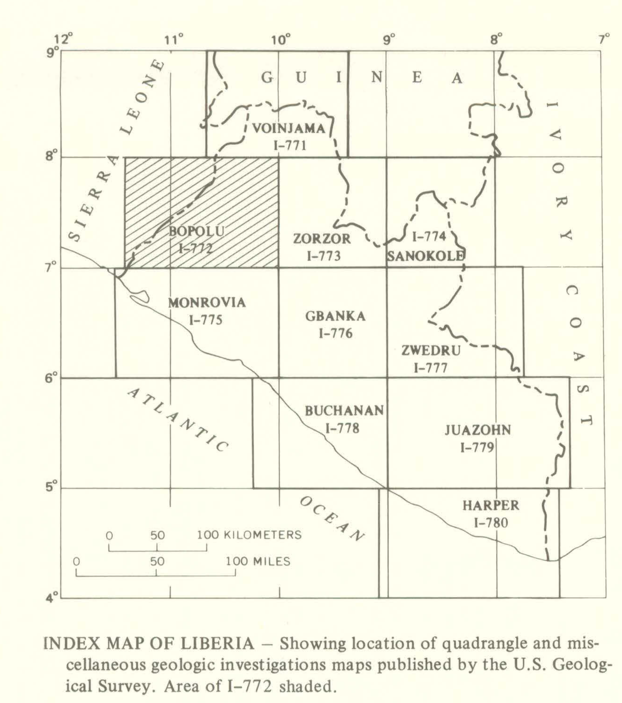
The general magnetic field over various parts of the quadrangle has significant differences that suggest contacts or gradational changes between geologic units. The magnetic data for almost the entire quadrangle suggest the presence of metamorphic rocks of a northeast trend. In addition to the obvious exception of anomalies associated with the northwest-trending diabase dikes, a slight change in the lineation in the southwest corner of the area suggests the northwest grain that has been noted near the Atlantic coast within the Pan-African age province.

Older faults and folds are suggested by many of the steep gradients in the northeast-trending anomalies (see fig. 1). White and Leo (1969) show faults along the Lofa River southwest of lat 7°20′ N., long 10°30′ W. The magnetic lineation associated with the Webo fault (Wilson, 1965) in Sierra Leone, indicated as a "known fault" on figure 1, is traceable continuously across the map for 170 km to the northeast corner. Other suggested structures are shown on figure 1.

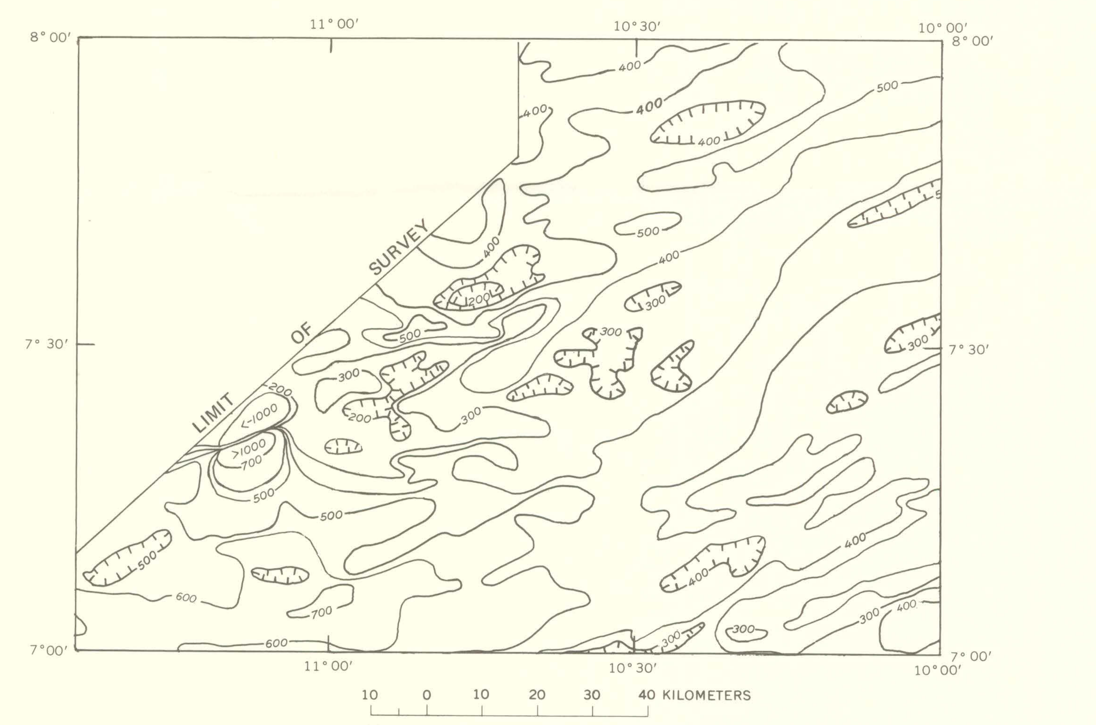
Examination of the residual map (fig. 2) reveals a pattern of broad positive and negative anomalies, 20-30 km in width and of 100-200 gammas in amplitude, that is part of a regional pattern extending across Liberia into Ivory Coast. Magnetic surveys over the Guyana Shield in South America (Strangway and Vogt, 1970) show a similar pattern. The similarity of these anomalies might be expected if the containing rocks originated during the Precambrian before the separation of Africa and South America. The geologic boundary in figure 1 was drawn on the basis of the residual magnetic data, and it is also indicated by the near-surface magnetic data and the radiometric data.

REFERENCES

Behrendt, J. C., and Wotorson, C. S., 1974. Total-count gamma radiation map of the Bopolu quadrangle, Liberia: U.S. Geol. Survey Misc. Geol. Inv. Map I-772-C, scale 1:250,000.
Cain, J. C., Daniels, W. E., Henricks, S. J., and Jenson, D. C., 1965, An evaluation of the main magnetic field, 1940-62: Jour. Geophys. Research, v. 70, no. 15, p. 3647-3674.
Hurley, P. M., Leo, G. W., White, R. W., and Fairbairn, H. W., 1971, Liberian age province (about 2,700 m.y.) and adjacent provinces in Liberia and Sierra Leone: Geol. Soc. America Bull., v. 82, no. 12, p. 3483-3490.
Lowrie, A., and Escowitz, E., ed., 1969, Kane 9, Global ocean floor analysis and research data series: U.S. Naval Oceanog. Office, v. 1, 971 p.
Strangway, D. W., and Vogt, P. R., 1970, Aeromagnetic tests for continental drift in Africa and South America: Earth and Planetary Sci. Letters, v. 7, p. 429-435.
Wallace, R. M., in press, Geologic map of the Bopolu quadrangle, Liberia: U.S. Geol. Survey Misc. Geol. Inv. Map I-772-D, scale 1:250,000.
White, R. W., and Baker, M. W. G., 1968, Geology of the Mano River mine area: Geol. Min. and Metalurg. Soc. of Liberia Bull., v. 3, p. 57-65.
White, R. W., and Leo, G. W., 1969, Geologic reconnaissance in western Liberia: Liberian Geol. Survey Spec. Paper 1, 18 p.
Wilson, N. W., 1965, Geology and mineral resources of part of the Gola Forest, southeastern Sierra Leone: Sierra Leone Geol. Survey Bull. 4, 102 p.



INDEX MAP OF LIBERIA – Showing location of quadrangle and miscellaneous geologic investigations maps published by the U.S. Geological Survey. Area of I–772 shaded.



10 0 10 20 30 40 KILOMETERS

10 0 10 20 MILES

FIGURE 2. – Residual total magnetic intensity map. Compiled by removing the main earth from the map and smoothing to generalized short wavelength anomalies. G. Andreasen and P. Zabel assisted in computer processing. Hachures indicate closed areas of lower magnetic intensity. Contour interval 100 gammas, except for areas of extreme anomaly

AEROMAGNETIC MAP OF THE BOPOLU QUADRANGLE, LIBERIA

By

John C. Behrendt and Cletus S. Wotorson

1974

PREPARED UNDER THE JOINT SPONSORSHIP OF THE
GOVERNMENT OF LIBERIA AND THE AGENCY FOR INTERNATIONAL DEVELOPMENT, U.S. DEPARTMENT OF STATE

☆ U.S. GOVERNMENT PRINTING OFFICE: 1974 O—543–586/163

For sale by U.S. Geological Survey, Reston, Va. 22092, price 75 cents