

TOTAL INTENSITY AEROMAGNETIC MAP OF LIBERIA, WEST AFRICA, INCLUDING THE CONTINENTAL SHELF

INTRODUCTION

Aeromagnetic and total-count gamma-radiation surveys (Behrendt and Woterson, 1970) were flown simultaneously during the 1967-68 dry season and consist of 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 elevation was 150 m above mean terrain. Time variations in the magnetic field measured with a fluxgate magnetometer were removed by adjustment at crossings of east-west control lines. Variable contour intervals of 10, 50, 250, and 1,000 gammas were used, depending on horizontal gradient. This map shows the contoured aeromagnetic data of Liberia.

The aeromagnetic and aeroradiometric surveys were made possible through a loan from the Agency for International Development, U. S. Department of State, to the Government of Liberia, and the study is supported by the Government of Liberia and the Agency for International Development. The purpose of both surveys was to assist in the geologic mapping project currently in progress by the Liberian Geological Survey in cooperation with the U. S. Geological Survey and to obtain information that would help locate potential targets for mineral exploration. The entire country is heavily forested, access is difficult, and outcrops are sparse or covered by a thick zone of laterite in this high-rainfall climate. Consequently, the surveys are presently being used to interpolate and extrapolate from the known geologic information. A number of the most obvious and significant features and anomalies are described and delineated here.

SUMMARY OF KNOWN GEOLOGY

Most of the obvious magnetic and radiometric anomalies are related to near-surface geology as would be expected in this predominantly Precambrian basement terrane (White and Leo, in press) described the rocks as "... mostly granitic gneisses, associated quartzite and metapelite rocks, hornblende amphibolites largely of intrusive origin, and locally, metasedimentary rocks with iron formation and possible volcanic rocks." They noted that most of the metamorphic rocks are amphibolite grade but granulite facies rocks are exposed near the coast. Most of the unmetamorphosed sedimentary rocks are restricted to the coastal area between Monrovia and Buchanan. These have been discussed in detail by White (1969) and consist of a Paleozoic(?) sandstone sequence 1 km or less thick overlain by Cretaceous sandstone which may reach 2 km in thickness. This deposit of Tertiary age sandstone crop out in a few places along the coast but are probably more extensive on the continental shelf. Diabase dikes have been mapped in three zones. East-trending dikes crop out in the Voinjama area. Northwest-trending dikes are parallel to the coast in a zone starting about 90 km inland and can be traced on the basis of magnetic data from the Sierra Leone to the Ivory Coast border (Behrendt and Woterson, 1969). Bagarre and Tagini (1965) show these dikes continuing on trend in Ivory Coast as far as the coast. Another series of diabase is present in the coastal area from the Sierra Leone border southeast to the vicinity of Greenville. We have inferred the existence of these dikes beneath the continental shelf on the basis of the magnetic data (Behrendt and Woterson, 1969). Two sills in this zone have been dated about 185 m.y. (White and Leo, in press). Intrusion of the coastal series of dikes is interpreted to be a result of the tectonic activity associated with the beginning of the separation of Africa from South America (Behrendt and Woterson, 1969).

Radioactive age determinations on several metamorphic rock types by Hurley and others (1967, 1969) have allowed the recognition of three distinct provinces. The oldest is a Liberian province of 2,700-3,400 m.y. age, which includes the western two-thirds of Liberia exclusive of the coastal area; the Eburnean province of 1,800-2,000 m.y. age in the eastern one-third of Liberia which extends into Ivory Coast and Ghana, and the Pan-African province of 500-600 m.y. age, which lies along the Liberian coastal area north-west of Greenville and extends into Sierra Leone.

DISCUSSION OF MAGNETIC MAP

The steep gradients associated with shallow basement are apparent over most of the area. The predominant northeast grain associated with the Liberian-age province gives way to the northwest grain in the coastal area over the Pan-African-age rocks. We interpret the prominent break in the magnetic fabric extending northeast from the vicinity of Greenville as the dividing line between paragneisses and migmatites to the southeast and granitic gneiss to the northwest within the Eburnean age province.

A band of northwest-trending anomalies clearly delineates the dike zone about 90 km inland. This can be traced from Sierra Leone to Ivory Coast. The anomalies are mainly the result of high remanent magnetization close to the present field direction (average magnetization, $J = 3.4 \times 10^{-3}$ emu; S. Cromie, written commun., 1969).

The diabase dikes in the coastal area are also well indicated by northwest-trending linear anomalies. S. Cromie (written commun., 1969) measured high remanent magnetizations for these dikes also and found a nearly horizontal inclination ($J \approx 10^{-3}$ emu). We traced these beneath the continental shelf on the basis of the magnetic maps (Behrendt and Woterson, 1969). The dikes in the coastal zone become sparse southeast of Greenville and apparently cease to exist beyond Sastown, based on geologic traverses along the coast (R. W. White, written commun., 1968); it would be difficult to trace them through the high-amplitude northeast-trending anomalies in this area even if they were present. We believe that these diabase dikes are more closely associated with the separation of South America and Africa at the opening of the southern extremity of the North Atlantic than with the later (perhaps 130-150 m.y. B.P.) opening of the South Atlantic. The Bullard and others (1965) reconstruction of the continents around the Atlantic shows a poor fit in the area of the Liberian coast northwest of approximately Greenville; at this point the edge of the continent, as indicated by the 200- and 500-meter bathymetric contours, changes from a south-east trend to an east-west trend into the Gulf of Guinea. That this is the southern limit of the early opening of the North Atlantic in this area of Africa is suggested by the lack of the coastal diabase to the southeast.

The east-west dikes in the Voinjama area in the northernmost part of Liberia have small positive anomalies associated with them that indicate a reversed field direction and are probably much older than the other dikes; nonetheless, many are easily located on the large-scale magnetic maps.

The characteristics of the magnetic field change dramatically offshore over the shallow water on the continental shelf. We have interpreted this as the effect of fault-bounded basins containing sedimentary rocks of Cretaceous and Tertiary age, in which depth to magnetic basement may be as great as 5 km. We constructed a map of depth to magnetic basement and discussed the interpretation at some length in an earlier paper (Behrendt and Woterson, 1969).

Because of the difficulty of studying the contours in detail at 1:500,000 scale, we have indicated the relative amplitudes of all of the anomalies greater than 600 gammas. In an essentially horizontal magnetic field, a more magnetic rock would in general have a predominantly negative anomaly, which is the case in Liberia. Where reversed remanent magnetizations and complex structures are present, positive anomalies also occur over magnetic rocks. The amplitudes shown here were measured peak to trough and are shown without regard to sign, although the positive and negative portions of anomalies are generally apparent. We have attempted to indicate all of the high-amplitude anomalies in the country, with the qualification that in the very high anomaly zones associated with iron formation, only selected amplitudes are shown.

Although we cannot identify the sources of all of these anomalies, several generalizations are warranted. Essentially all anomalies having amplitudes greater than 2,000 gammas are due to iron-formation which in Liberia is mainly itabirite (White and Leo, in press). Several of these anomalies exist over iron-mining areas where magnetite is present in high concentrations (as much as 70 percent Fe). Some of the ore is hematite, however, which would display no magnetic anomaly. From experience, we infer that the known ore bodies themselves cannot account for the amplitudes of the anomalies, and thus sizable concentrations of magnetite-containing rock (not necessarily ore) must extend over a significant depth range to cause the anomalies. The highest amplitude anomalies are 18,000 gammas in the Nibba Range, 18,000 gammas in the Nwa Nwan-tains, 12,000 gammas in the Wologiti Range, 12,000 gammas at Mt. Demina about 25 km northeast of Ganta, and 9,000 gammas in the Putu Range. The 4,000-gamma anomaly near River Gee possibly is caused by a source other than iron-formation; the shape of this anomaly is different from the linear anomalies associated with iron-formation, and no iron deposits are known in this area. There are no known ore deposits in Liberia that do not have associated high-amplitude magnetic anomalies.

Many of the 1,000-2,000 gamma anomalies are over iron-formation but several are known to be associated with ultramafic intrusions. One of these is over an ultramafic body near Juarzon which also has an associated 30-mgal positive gravity anomaly. Preliminary investigation of this feature indicates the presence of anomalous amounts of nickel and cobalt in laterite (H. Crujts, oral commun., 1969). Other high-amplitude anomalies are probably caused by mafic intrusions such as the composite gabbro-norite near Robertport (White and Leo, in press). Rosenblum and Srivastava (written commun., 1970) have found traces of chromite that may be associated with this intrusion.

Many of the linear anomalies having amplitudes of 1,000 gammas or less are caused by bands of amphibolite, although some could be iron-formation as well. We know that iron-formation is associated with the anomalies that cross the coast about 35 km east of Greenville (R. W. White, written commun., 1969).

The relatively high amplitude, strongly lineated anomalies in the Eburnean age province are probably the result of isoclinally folded paragneisses including amphibolite and iron-formation, as these rocks and structures have been identified along the coastline in this area (R. W. White, written commun., 1969; Rosenblum, written commun., 1969). In Ivory Coast, evidence of manganese has been found on trend and in association with these magnetic anomalies in the area east of Harper (Bagarre and Tagini, 1965) and in Liberia along these anomalies near the Ivory Coast border at lat. 6°N.

Some of these high-amplitude anomalies may be economically important and should be investigated. This is also true of many other anomalies of lower amplitude which careful study of the map reveals.

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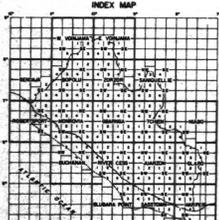
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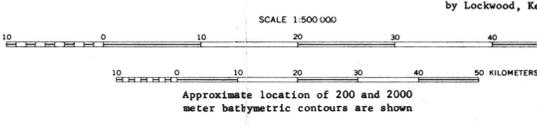
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LEGEND

CONTOUR INTERVAL	10 OR 50 GAMMA WHERE APPROPRIATE
10 GAMMA CONTOUR
50 GAMMA CONTOUR
250 GAMMA CONTOUR
1000 GAMMA CONTOUR
MAGNETIC LOW
SURVEY ALTITUDE	180 meter A.M.T.
FLIGHT LINE NUMBER, FLIGHT PATH AND POSITIONING PHOTO NUMBERS	P-80-0-0
FLIGHT LINE SPACING	0.8 km
REGIONAL MAGNETIC GRADIENT NOT REMOVED
TOTAL INTENSITY BASED ON ARBITRARY DATUM
SHEETS AND COORDINATES BASED ON HOTINES RECTIFIED BREW ORTHOMOGRAPHIC PROJECTION, U. S. COAST AND GEODETIC SURVEY PUBLICATION, 1956	



APPROXIMATE MEAN DECLINATION, 1968
To obtain absolute datum add 25980235 gammas
MEAN INCLINATION = 7.5°

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by John C. Behrendt, U. S. Geological Survey and Cletus S. Woterson, Liberian Geological Survey 1970

EAST HALF