UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
[Reports - Open file series]

PROJECT REPORT
Liberia Investigations
(IR) LI-1

FEASIBILITY STUDY FOR AN AIRBORNE GEOPHYSICAL SURVEY OF THE REPUBLIC OF LIBERIA

by

Randolph W. Bromery, 1926-
U. S. Geological Survey

U. S. Geological Survey
OPEN FILE REPORT
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1968

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Randolph W. Bromery
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accompanies:

Weld - Int. 2905

U. S. GEOLOGICAL SURVEY
Washington, D. C.
20242

[Reports - Open file series]

For release Dec. 2, 1968

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1. Preliminary report on the engineering geology of the Boulder quadrangle, Boulder County, Colorado, by Maxwell E. Gardner. 9 p., plus 3 large sheets of tables, 1 map and explanation (2 sheets), scale 1:24,000. 8102 Federal Office Bldg., Salt Lake City, Utah 84111; 1012 Federal Bldg., Denver, Colo. 80202. Material from which copy can be made at private expense is available at this Denver address.

2. A list of references on lead isotope geochemistry through 1966, by Bruce R. Doe. 97 p. Material from which copy can be made at private expense is available in the USGS Library, Bldg. 25, Federal Center, Denver, Colo. 80225.

3. Feasibility study for an airborne geophysical survey of the Republic of Liberia, by Randolph W. Bromery. 23 p.

4. Summary of mineral resources encountered in Colombia, by C. M. Tschanz, R. B. Hall, T. Feininger, D. Ward, R. Goldsmith, D. H. MacLaughlin, and E. Maughan. 58 p., 6 figs., 5 tables.

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FEASIBILITY STUDY FOR AN AIRBORNE
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ABSTRACT

A feasibility study for an airborne geophysical survey of the Republic of Liberia indicates that airborne magnetometer and airborne scintillation detector surveys would be useful 1) in providing support for the current geologic mapping program, 2) as a guide in locating concentrations of economic minerals, and 3) delimiting the extent of known mineral deposits. Preliminary study of earlier airborne magnetometer surveys covering several iron ore localities shows that future geophysical surveys should be flown at a slightly closer flight-line spacing, and that the iron ore localities are characterized by anomalies interpreted as being produced by rocks having a strong anomalous remanent magnetization. In areas of the United States and Canada underlain by crystalline rock types similar to those found in Liberia, airborne geophysical surveys have been successful in locating additional buried economic mineral deposits, in extending known economic mineral deposits, and in contributing useful information to geologic mapping programs, especially in areas overlain by thick glacial deposits or by weathered rock.

Some problems regarding the availability of accurate base maps for Liberia, combined with the inherent complex relationships that exist between a rock's geological properties and its magnetization, are briefly reviewed. The importance of obtaining a meaningful geologic interpretation of the geophysical data and coordinating the geophysical survey with the geological mapping program is stressed. Specifications and tolerances for the proposed airborne magnetometer and scintillometer survey of the Republic of Liberia are outlined.

INTRODUCTION

Scope of report

At the request of the Agency for International Development, U. S. Department of State, and the Republic of Liberia, the U. S. Geological Survey, in cooperation with the Liberian Geological Survey, undertook a study of the feasibility of an airborne geophysical survey of Liberia. This report discusses the usefulness of such a survey in support of the current geological mapping program and as a guide in locating new concentrations of economic minerals and delimiting the extent of known mineral deposits. Geophysical and geological background information is reviewed as an aid to the officials in the Agency for International Development and the Government of Liberia in better evaluating the need for the proposed geophysical survey.

Airborne magnetometer and radiometric surveys in other countries

Airborne magnetometer and radiometric surveys have been flown and used successfully in Sierra Leone (Wilson, 1965), Ivory Coast, Ghana, and probably in some of the other nearby countries.

Airborne geophysical programs are now an integral part of the geological mapping program in many areas of the United States and Canada. Geophysicists work closely with the geologists and in some areas of sparse outcrop and complex structure and lithology, properly interpreted geophysical data may actually be the major source of information for the compilation of a geologic map. Faults can be mapped, vertical and horizontal offsets along faults can be calculated, magnetic rock lithologies can be traced, and other geologic information can be obtained by the proper interpretation of airborne geophysical data. Thus, these data can provide both a direct and indirect means of mineral prospecting.

The 20 years experience of the U. S. Geological Survey in aeromagnetic and aeroradioactivity surveys has proven beyond doubt that geophysical data are an extremely valuable aid in the search for economic mineral deposits and in support of geologic mapping programs. Two recently discovered major blind iron ore deposits in the United States (Morgantown, Pennsylvania, and Pea Ridge, Missouri) were located by airborne magnetometer surveys (Jensen, 1951, Dempsey, 1951, Leney, 1966). Early aeromagnetic surveys produced only qualitative analytical results, but, in recent years, the application of aeromagnetic and airborne radiometric surveys specifically applied to geologic mapping programs has made significant progress with extremely sophisticated surveying techniques and equipment, combined with rigorous, geologically meaningful data analyses (Bromery and Griscom, 1967; Allingham, 1960; Boucot, Griscom, and Allingham, 1964; Bromery, 1967; Griscom and Larrabee, 1963; Bates, 1967). It has proved of immense aid in geological mapping programs in areas of sparse outcrop, thick glacial deposits, weathered rock cover, and difficult access in the United States and Canada. Examples of such areas are the heavily forested, deeply-weathered eastern United States Piedmont Province and the glacial-detritus-covered New England area. Aeromagnetic and aeroradioactivity maps are interpreted and used 1) to accurately delineate and trace rock units having relatively small physical property contrasts, 2) to locate new and extend known economic mineral deposits, and 3) to locate areas of significant anomalous structural or petrologic character. In a comparable manner a properly interpreted airborne geophysical survey would be useful to the Republic of Liberia where there is a similar area of deeply weathered crystalline rocks and difficult access.

Acknowledgments

The author gratefully acknowledges the assistance and useful geologic information provided by Mr. Warren L. Coonrad and Mr. G. W. Leo, U. S. Geological Survey, and Dr. A. E. Nyema Jones and other members of the Liberian Geological Survey, and members of the Agency for International Development. Much useful information was obtained from visits to the Bong and LAMCO mining facilities and several

outcrop areas. My sincere appreciation is extended to Mr. A. Momolu Massaquoi and Mr. Joseph Richards, Director and Assistant Director of the Bureau of Natural Resources and Surveys of the Government of Liberia, for providing the excellent logistical support which enabled me to accomplish the study in the limited time available.

GENERAL GEOLOGY OF LIBERIA

The metamorphic rocks of Liberia have a general northeast trend and consist of granitic orthogneiss and paragneiss, mica-amphibole schist, amphibolite, metagabbro, and ultramafic rocks. The rocks are foliated, dip steeply, and are tightly folded. The structures are extremely complex at many places in Liberia. Recently discovered linear structures observed in the field and on aerial photographs indicate that faults may be more common than previously recognized. Faults in or nearly parallel to the foliation planes of the rocks would be difficult to recognize under the best of conditions. Some minor faults and shears are associated with the small-scale folds. Diabasic dikes are abundant in many places in Liberia. A few dikes parallel the northeast regional grain of the country rock, but most of the dikes have a northwest trend.

Itabirite, a banded quartz-magnetite-hematite rock, and other iron-bearing rocks form the crests of many of the higher ridges throughout the country, with the possible exception of those in the south-central part. These iron-bearing rocks in general are believed to be structurally located in the axial parts of tightly folded synclines, and subsequent erosion has left them as ridge crests. The iron-rich rocks are currently being mined in four localities.

Other economic minerals mined in Liberia on a much smaller scale include diamonds and gold, both of which are found as placer deposits. Occurrences of ilmenite, rutile, manganese, cassiterite, columbite-tantalite, monazite, barite, bauxite, and kyanite have been reported. Weathering is intense and an extensive laterite soil covers large areas of Liberia. The laterite soil, alluvial deposits, and dense vegetation effectively mask most deposits and sources of potentially valuable minerals.

PREVIOUS AIRBORNE GEOPHYSICAL SURVEYS IN LIBERIA

Scope and results

In 1952 and 1953 aeromagnetic and aeroradioactivity surveys were flown in six areas selected by the United States Economic Mission to Liberia in cooperation with the Republic of Liberia. The purpose of the surveys was to delineate the known iron deposits, locate favorable new areas of iron deposits, and explore for areas of possible uranium mineral concentrations. The surveys were made along predetermined traverses at altitudes of 500 feet and 1,000 feet above the ground and were spaced 1 mile apart, with the exception of a small area flown at half-a-mile flight-line spacing. Horizontal control was acquired through use of a continuously recording 35-mm strip-film camera and by plotting of traverse locations from the strip-film print to an uncontrolled photomosaic. Vertical control was established by using a continuously monitored radio-altimeter.

The symmetry of the magnetic anomalies indicated that the dikes are in general vertical or nearly vertical. Using very simple analytical methods, the dip, width, and depth of burial to the tops of these dikes could be calculated with a fair degree of accuracy, especially in areas where the magnetic anomalies could be correlated with some geologic outcrop data. The linear magnetic anomalies associated with these dikes are easily traced and show that some dikes extend continuously for miles across the entire width of the area of the magnetic map, whereas other dikes continue along the same trend but in an en echelon pattern. In addition to the possibility of discovering potentially economic mineralized zones, important structural information can be revealed from analyses of the magnetic anomalies associated with these dikes.

The aeromagnetic data were measured by means of a flux-gate-type magnetometer and were recorded on a 10-inch rectilinear Leeds and Northrup recorder. Not much information is available concerning the instrumentation used for the aeroradioactivity surveys. However, judging by the fact that the resultant records are referred to as scintillometer records, the instrumentation probably consisted of an early version of the multiple crystal thallium-activated NaI scintillation gamma-ray detectors described by Davis and Reinhardt (1957). The data were continuously recorded on a curvilinear Esterline-Angus recorder, and a study of these data indicate that they were not compensated for variations in altitude above the ground.

The aeromagnetic data were compiled on rectangular uncontrolled photomosaic base sheets; geographic control points were established at the center of each sheet. The approximate scale of these maps is 1:40,000, and the magnetic contours (10-gamma interval) were drawn on stable-base plastic overlays. Numbered control points were plotted on the photomosaic sheets, for use when attempting to correlate the magnetometer and scintillometer profiles with a ground location. The material furnished to the Republic of Liberia consisted of: (1) 1:40,000-scale photomosaic bases showing flight-line locations and numbered control points, (2) stable-base plastic magnetic contour sheets at the scale of the photomosaic bases, (3) blue linen drafted magnetic-contour sheets at 1:40,000 scale, (4) 35-mm strip-film negatives of flight tracks, (5) 10-inch rectilinear Leeds and Northrup original magnetometer records, (6) ozalid copies of the curvilinear Esterline-Angus scintillometer records, and (7) flight log books of the 1952 and 1953 surveys.

Preliminary evaluation

A very preliminary study of the airborne magnetometer and scintillometer surveys flown in 1952 and 1953 was made by the author. Analysis of the scintillometer records indicates that they would be useful only in locating anomalously large concentrations of uranium, thorium, and potassium-rich minerals. No information was furnished with the records for scaling; however, some profiles showed point-source type anomalies as much as four times the normal background radiation. Using the plotted control points on the photomosaic, some of the more pronounced radiation anomalies were plotted and found to be associated with topographic highs and cleared areas probably underlain by potassium-rich granitic or syenitic rocks. As some of these rocks form topographic highs, and as the early survey was probably not compensated for altitude variations, some of the radiation anomaly amplitudes may have been generated by variations of the plane's flight altitude above the ground.

The meaningfulness of the relative values of the background radiation is somewhat in doubt because calibration flights were not made to determine values of average background radiation over a thickly foliated and swampy area relative to cleared areas and lakes and rivers. Water exhibits a shielding effect on ground radiation, and care must be exercised in analyzing background radiation data in swampy, tropical jungle areas.

The background radiation measured by the scintillation detector is composed of: (1) radon products in the air, (2) radioactive minerals in the ground, and (3) cosmic ray radiation. Thus, during the course of this early survey, it is possible that temperature inversions and other meteorological and solar phenomenia could have caused fluctuations in the radon concentration in the air and changes in the cosmic ray component, thus producing a marked effect on the value of the background radiation.

The negative aspects of the earlier surveys can be in large part eliminated in modern surveys by the use of more sensitive, reliable detection equipment and cosmic-ray and altitude-compensating mechanisms. Modern equipment can reliably measure small differences in radioactive mineral content in the surface rocks, and these data have been used successfully in mapping lithologies of limited areal extent in the eastern United States. The U. S. Geological Survey has also been experimenting recently with advanced airborne gamma-ray detection equipment that can further differentiate the measured ground radiation into those components due to the potassium, the uranium, and the thorium content of rocks. Equipment of this type will be able to delineate variations within a particular rock lithology and could be used to delimit those zones containing small amounts of radioactive minerals such as potassic feldspars, rare earth minerals, and monazite.

Preliminary analyses of the aeromagnetic maps were made to determine the usefulness of the 1-mile spaced aeromagnetic data for geologic mapping, to calculate shape and depth of burial parameters on the highly magnetic iron deposits and the less magnetic diabase bodies, and to study the effect of anomalous remanent magnetizations in an area where the earth's inducing magnetic field is nearly horizontal. At the time these surveys were flown, aeromagnetic data acquisition methods were routine, and standardized data reduction practices were in common usage throughout the industry. Therefore, the surveys were doubtless flown in a competent manner and the resulting magnetic-contour maps were drawn as accurately as possible on to the uncontrolled mosaics. Datum control is good throughout the surveyed areas.

The wide spacing of the flight lines precludes the possibility of mapping any but the areally larger, more magnetic lithologic units.

In general, the magnetic anomaly patterns that characterize these units can be correlated with pronounced linear magnetic lows and associated flanking magnetic highs; the diabase dikes show on the maps as long linear magnetic lows and very low amplitude flanking highs; and the three areally large rock types exhibit the following general magnetic anomaly patterns:

(1) Low to moderate linear magnetic anomalies having a pronounced grain parallel to the regional strike of the rocks of the area.

(2) A low-amplitude "bird's-eye-maple" magnetic anomaly pattern locally having no preferred grain, a slight east-west grain, or a slightly more pronounced northeast grain paralleling the regional strike of the rocks.

(3) A relatively flat magnetic zone associated with the small areas between the magnetic iron formations.

These magnetic anomaly patterns, although slight in contrast, reflect rocks of differing magnetic properties that could be correlated with a particular lithology by field checking. If the surveys had been flown at 1/2-mile or 1-kilometer flight spacing, areally smaller magnetic sub-units could have been delineated and thus contributed even more support to the geologic mapping program. However, it should be noted that the relationship between a rock's geological properties and its magnetization is not simple, and in Liberia the commonly well foliated, steeply dipping metamorphic rocks in the horizontally oriented inducing magnetic field introduce additional complexities. Magnetic anomaly patterns in some localities will be less pronounced and definitive.

The magnetic minerals in these metamorphic rocks have a platy, crystalline grain structure parallel to the rock foliation, and the magnetic anisotropy of these minerals will in effect reduce the bulk susceptibility of the rock when the magnetizing field is in a direction normal to the schistosity or gneissosity. In Liberia, this would occur where the strongly foliated metamorphic rocks strike nearly east-west and dip steeply. In general, however, the variations in the amount and distribution of these same magnetic minerals in a rock will produce the differing characteristic magnetic anomaly patterns.

Random anomalous orientations of magnetic anomaly pairs (a magnetic low and its associated magnetic high) away from the direction of the earth's inducing field vector (the magnetic north direction), and the presence of high-amplitude positive magnetic anomalies indicate that the iron formations are characterized by anomalous remanent magnetization. The magnetic iron formations along the crests of the higher ridges have been exposed for a considerable length of time to tropical meteorological phenomena. Lightning strokes are accompanied by very intense magnetic fields and can produce a strong isothermal remanent magnetization (IRM) in rocks. This effect, although generally very local, may account for some of the magnetic anomalies of varying orientation and amplitude that have been observed on the magnetic maps. However, most of the remanent magnetization in these rocks is probably thermoremanent magnetization (TRM), if during metamorphism the rocks were heated above the Curie temperature for magnetite and cooled in a strong magnetic field, or it is chemical remanent magnetization (CRM) where the ferromagnetic grains grow or are transformed from one form to another at a temperature below their Curie point during metamorphism. Post-metamorphic deformation could also reorient these permanently magnetized rocks, giving rise to some of the anomalous orientations of the magnetic anomaly pairs. Although this property of anomalous remanent magnetization makes shape analyses and magnetic susceptibility determinations from aeromagnetic data extremely difficult, and in many cases impossible, it can be used in interpreting geologic structures. This type of interpretation is useful only when combined with a well planned program of ground sampling to obtain oriented specimens of the rocks involved. The aeromagnetic map will help locate favorable areas for this type of ground geological work. Magnetic-properties studies, including detailed petrographic and petrofabric analyses similar to the work being performed at the magnetic properties laboratory of the U. S. Geological Survey in Washington, D. C., could reveal useful data regarding ore genesis and other geologic problems.

The magnetic anomalies associated with the diabase dikes exhibit the characteristics of normally induced magnetic rocks. The symmetry of the magnetic anomalies indicates that the dikes are in general vertical or nearly vertical. Using very simple analytical methods, the dip, width, and depth of burial to the tops of these dikes could be calculated with a fair degree of accuracy, especially in areas where the magnetic analyses could be correlated with some outcrop data. The linear magnetic anomalies associated with these dikes are easily traced and show that some dikes extend continuously for miles across the entire width of the magnetic map area, whereas other dikes continue along the same trend but in an en echelon pattern. In addition to the possibility of discovering potentially economic mineralized zones, important structural information can be revealed from analyses of the magnetic anomalies associated with these dikes.

PROPOSED AIRBORNE GEOPHYSICAL SURVEY IN LIBERIA

Application of the proposed survey

Properly interpreted aeromagnetic and aeroradioactivity data would prove very useful in support of the geological mapping program in Liberia. Variations in magnetic and radioactivity anomaly patterns could be used in delineating rock units of contrasting physical properties. The correlation of these distinct anomaly zones with outcrop data would be useful in producing a more meaningful reconnaissance geologic map. Mathematical or graphical analyses of individual anomalies or magnetic gradients would provide additional information on shapes, attitudes, and depths of burial of the magnetic rocks. In addition, buried magnetic mineral concentrations may be located that would probably not be discovered during the course of a geological mapping program. Correlation of the various radioactivity levels with outcrop data would also be useful in delineating rocks with contrasting amounts of radioactive minerals. This method can divide broad nonmagnetic rock formations into sub-units of varying radioactivity levels. Near-surface concentration of radioactive minerals may be located by this type of airborne geophysical survey.

To insure the maximum use of the airborne geophysical data, the Government of Liberia and/or U. S. Agency for International Development should develop an interpretation capability within the country. This would require that an individual or individuals having a background in mathematics, physics, and geology receive training in the geological interpretation of geophysical data obtained from airborne surveys.

Problems in conducting the survey

Some problems connected with performing airborne geophysical surveys in the Republic of Liberia should be considered. In addition to the complex relationship that exists between the magnetization and the geological properties of rocks as described previously, the logistics of data acquisition in unfavorable terrain and the accurate reduction of these data to a poorly controlled planimetric base present special problems. Geophysical anomalies are useful only if they can be accurately located on the ground. Accurate topographic base maps are not available of the Republic of Liberia. Although the lack of accurately controlled base maps does not negate the usefulness of an airborne geophysical survey, the execution of the survey and the subsequent data reduction and interpretation are more difficult to perform. The specifications for an airborne geophysical survey in an area without adequate base-map control should require less rigid aircraft positioning, and the acquisition of supplemental flight control data to provide for later recompilation if new base materials become available.

Airborne geophysical surveying in Liberia would require the use of an electronic navigational system. Two types are available. One makes use of multiple fixed-position ground stations and a mobile station located in the aircraft, and the other system is completely contained within the aircraft. The multiple station system is more accurate, but the costs would be prohibitive in an area the size of the Republic of Liberia (110,000 square kilometers; 43 square miles). Accuracies of this high order are not necessary for a regional survey; this system is generally used in detailed surveys of specific anomalies discovered during the course of a regional survey.

The airborne electronic Doppler navigation system makes use of an on-board radar scanning device and computer to determine long-track (distances along a flight traverse) information and cross-track (distance between parallel flight traverses) information relative to a fixed point, such as an airport or any observable landmark. A system of this type, combined with the auxiliary use of the presently available Shoran-controlled photomosaics and maps should provide sufficient control for an airborne geophysical survey of Liberia at a 1-kilometer flight line spacing. Supplemental control data should consist of continuously recorded 35-mm strip-film prints or negatives of the surveyed flight tracks which would be used as a convenient cross check on the Doppler data and in more precisely locating any specific significant geophysical anomaly on the aerial photographs and subsequently on the ground. In addition, the strip film could be useful in future agricultural or forestry surveys.

Specifications and tolerances for the proposed airborne magnetometer and scintillometer surveys

The purpose of the proposed geophysical survey to cover the entire area of Liberia is to delineate magnetic and radioactive rock lithologies, locate new magnetic and radioactive mineral concentrations, and extend known deposits. The area of the country is approximately 110,000 square kilometers (43,000 square miles) and the dimensions are approximately 500 kilometers (300 miles) in a northwest-southeast direction by 250 kilometers (150 miles) in a northeast-southwest direction. General specifications and tolerances for the proposed survey are detailed below. Reflights would be required if these were not adhered to.

A. Survey flight traverses and datum-control traverses

1. All traverses to be flown at a flight altitude of 150 meters (500 feet) above the ground, except locally in areas of rough topography.
2. Overall length of all traverses: 130,000 linear kilometers (80,600 miles).
3. Each survey flight traverse must be intersected by a minimum of two datum-control traverses.
4. Horizontal flight path deviation should not exceed 500 meters (1,640 feet).
5. Vertical flight-path deviation should not exceed 30 meters (100 feet), except in areas of rough topography.
6. Survey flight traverses:
    a. Alignment: north-south and parallel
    b. Spacing: 1 kilometer (0.6 mile).

c. Average approximate length: 250 kilometers (150 miles).

d. Approximate number: 500.

e. Overall length: 125,000 linear kilometers (77,500 miles)

7. Datum control traverses:

a. Alignment: at right angles to survey flight traverses.

b. Spacing: 30 kilometers (19 miles).

c. Approximate number: 15.

d. Overall length: 5,000 linear kilometers (3,100 miles).

B. Geophysical instrumentation:

1. Magnetometer sensitivity:

a. 200-gamma full scale defection in magnetically quiet areas.

b. 1,000-gamma full scale deflection in magnetically active area.

c. Noise less than 2 gammas.

d. Diurnal variation of earth's field should not exceed 3 gammas per minute gradient.

2. Scintillometer sensitivity: highest possible dependent upon background radiation at time of survey, hence, negotiable at time of survey.

C. Base-map materials to be supplied contractor by Government of Liberia:

1. Presently available scale 1:125,000 planimetric maps.

2. Additional base data as can be supplied by the Bureau of Natural Resources and Surveys.

3. New aerial photography will not be specifically required for the geophysical survey, but, if available, it will be utilized to upgrade base map data for flight control purposes.

D. Geophysical data to be supplied Government of Liberia by contractor:

1. Magnetic-contour maps and aeroradioactivity-level-contour maps:

   a. Format: contours, flight line ticks, and fiducial numbers printed in full black on screened drainage and culture base maps; for good contrast in analyzing geophysical anomaly patterns, all lows should be hachured out to the last closed contour surrounding the geophysical low. Explanatory information on the maps should include title, scale, contour interval, flight line spacing, altitude, magnetic north arrow, index map, etc.

   b. Scales: one set of each type at scale 1:40,000; it is recommended that composite maps be required of specified areas at scale 1:125,000 and, possibly, scale 1:250,000, depending on the closeness of the geophysical anomaly pattern on the larger scale maps.

   c. Materials: stable base originals and ozalid reproductions.

2. Magnetic-contour maps, specifically:

   a. Contours of total magnetic intensity will be shown.

   b. Contour interval: 10 gammas (50 gammas in those areas where magnetic anomalies are high amplitude).

   c. Removal of regional magnetic gradient not necessary.

3. Aeroradioactivity level contour maps, specifically:

   a. Contours of radiation level will be shown.

   b. Contour interval: 10 counts per second (50 counts per second in those areas where radiation anomalies are high amplitude).

   c. Compensation required for altitude variation and cosmic componet.

4. Magnetometer and scintillometer records:

   a. Profiles.

   b. Strip-film negatives (33 mm.) of flight tracks.

E. Schedule:

1. Survey flight traverses and datum control traverses will require perhaps as much as 2 aircraft years to fly, based on an estimated average of 10,000 kilometers (6,200 miles) of traverse per month during dry seasons (October through May).

2. Survey should start not later than the beginning of the first dry season after signing of the contract.

3. Provision should be made for at least one dry season extension, if necessary.

4. Compilation of data should require approximately 1 year, with delivery of completed maps and all other data within 3 years of the start of the survey. Partial delivery of data can be requested to be made, as available.

CONCLUSIONS

Based on favorable results achieved by airborne geophysical surveys in the United States, Canada, and elsewhere in the world, it is concluded that an airborne magnetometer and radioactivity survey of the Republic of Liberia would be extremely useful to identify and delineate rock units and structures in support of the current geological mapping program, to locate new areas of magnetic and radioactive mineral deposits, and to delimit and extend the known economic mineral deposits. Airborne geophysical methods could be more valuable in Liberia than in many countries because the dense jungle cover and thick laterite soils of Liberia make surface geological mapping and most ground mineral exploration methods extremely difficult.

Preliminary studies of earlier (1952 and 1953) geophysical surveys in Liberia indicate that data resulting from more closely spaced flight lines would provide more detailed information for the geologic mapping program.

The logistical problems of making airborne geophysical surveys in Liberia, combined with the inherent problems in the relationship between the geological and magnetic properties of rocks, should be considered, but do not appreciably alter the value of such surveys. However, the airborne geophysical surveys would be valuable only if properly interpreted by a well trained specialist, either from Liberia and/or the United States. The present geological mapping program should be geared to rapidly produce a regional geologic map of Liberia to provide the framework necessary to perform a more meaningful geological interpretation of the geophysical data.

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