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PROJECT COMPLETION REPORT

U.S. GEOLOGICAL SURVEY
PROJECT NO. 669-51-210-071

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PROJECT COMPLETION REPORT

GEOLOGICAL SURVEY AND APPRAISAL

The Geological Survey and Appraisal project was initiated in 1965 by the United States Geological Survey (USGS) and the Liberian Geological Survey (LGS) in the Bureau of Natural Resources and Surveys, now the Ministry of Lands and Mines, under the sponsorship of the U. S. Agency for International Development (USAID) and the Government of Liberia (GOL). The project was an intensification and expansion of cooperative geologic investigations begun in the Fall of 1963, which had their origins in cooperative work carried out by the USGS and the Liberian Bureau of Mines in 1943-44. The project was completed June 30, 1972, with the accomplishment of all major goals.

PURPOSE AND SCOPE OF PROJECT

To achieve the project purpose of providing the Liberian Geological Survey with the institutional capability and the data base necessary for the Government of Liberia to carry out the systematic development and utilization of its earth resources, the project was assigned four major objectives. These were (1) the carrying out of reconnaissance geological, geophysical, and mineral resources studies of the entire country of Liberia; (2) the development of a functional organization and a competent staff to carry out the functions of a national geological organization in Liberia; (3) to develop and equip office and laboratory facilities and field equipment necessary to carry out and support effective field and laboratory investigations; and (4) to establish a data base of maps,

reports, and files sufficient for the Liberian Geological Survey effectively to carry on further geological studies, earth resources evaluation, and geological engineering studies.

To achieve these objectives the U. S. Geological Survey has maintained a staff of trained personnel in Liberia on the project since 1963, working closely with a staff of counterparts in the Liberian Geological Survey. The staffing level of USGS personnel has varied from 2 full-time members to as many as 9 full-time and 6 TDY members. A total of 42 people has served on the staff at one time or another, 23 in full-time roles and others on temporary assignments of 1 to 6 months. Three served both full-time and temporary assignments, and temporary assignments, and several served more than one TDY. (See attachment 1.) The Liberian Geological Survey staff now totals seventeen professionals, including eleven geologists and one geophysicist. (See attachment 2.) During the project, active staffing level in Liberia ranged from about 5 to 10, owing to the absence of participant trainees. The project has carried out reconnaissance geological and geophysical studies of all Liberia, and detailed examinations at selected localities; a program of participant training; acquisition of laboratory and other supporting facilities; photogrammetric mapping of all Liberia; and the advisory functions of a government geological survey.

PROJECT ACTIVITIES AND METHODS

The project has carried out reconnaissance geological and geophysical studies of all Liberia, and detailed examinations of selected localities; a program of participant training, both in-house and at

educational institutions in the US; the development of offices, laboratories, and other supporting facilities; photogrammetric mapping of the entire country; and the advisory functions of a national geological survey organization.

At the beginning of the project, no adequate base maps existed for systematic geologic mapping of the country at a suitable scale. Consequently, it was necessary early to devote a major part of the project effort to the preparation of base maps, for publication at 1:250,000 scale, suitable for use in systematic geologic mapping and for presentation of the geologic data. This task diverted more than 80 man-months of project effort from geologic studies.

Motor access in Liberia is restricted to a few major roads. Access to large parts of the country is limited to foot trails, rivers navigable by rubber boat, and small aircraft capable of landing at numerous small airstrips. The heavy forest cover and deep cover of soil and weathered rock make field observations time consuming and difficult.

Because of these conditions, project work consisted largely of investigations in areas of relatively good access, which appeared to offer promise of significant return in geologic or mineral resource information, and for which aerial photography or other suitable bases for mapping were available. Thus much early work was carried out in the vicinity of major iron deposits, along beaches, and in the vicinity of major roads and railroads. Since the major streams provide both the most abundant outcrop of fresh rock and the most feasible access

to large areas, a large amount of effort was devoted to acquiring the necessary equipment for such river traverses, and to carrying them out. Much of the river work was carried out by U.S.G.S. personnel, experienced in river boating, on temporary assignments to Liberia.

It became apparent early in the field work that conventional methods of geologic mapping would not enable the project to achieve its goal of a reconnaissance geologic study of Liberia by June 1972. Either the goal had to be modified, or new and major innovative approaches had to be undertaken. Accordingly, in 1966, aeromagnetic and aeroradiometric surveys of the entire country were flown. As this geophysical information became available, and as geographic base maps in the form of preliminary form-line sheets at 1:40,000 scale became gradually available, the project effort was concentrated on systematic areal mapping for publication at 1:250,000 scale. An integrated approach utilizing full all available magnetic, gravimetric, and radiometric data, aerial photography, and geologic field data, was used. When quadrangle maps at 1:125,000 scale became available in 1970, all the data was compiled and analyzed, and the balance of field work was directed to resolving conflicting information and gathering additional critical data. Field work was completed in early May 1972, and final compilation of maps and reports completed by July 1972.

ACCOMPLISHMENTS OF THE PROJECT

The accomplishments of the project can be identified most readily by the maps, reports, data files, facilities, and trained personnel that have been produced. (See attachments 3 and 4.) The major products are as follows:

1. Files of basic data (rock samples, thin sections, petrographic and chemical analyse , field notes, analog radiometric and aeromagnetic data, aerial photographs and derivative photogrammetric data, systematic files of geologic information produced during the project); and some 70 project reports on topical subjects.

2. Radiometric and aeromagnetic maps of Liberia at scales 1:40,000, 1:125,000, and 1:250,000.

3. Geologic maps of Liberia in 10 quadrangles at 1:250,000 scale.

4. Form-line maps of Liberia at scales 1:40,000 (505 sheets) and 1:125,000 (10 quadrangles).

5. Shaded relief maps of Liberia at 1:250,000 (10 quadrangles).

6. Petrographic, analytical, and photographic laboratory facilities adequate for the continued activities of the Liberian Geological Survey.

7. Thirty-one (31) published reports.

8. Fourteen (14) professional personnel trained in U.S.A. in the participant-training program and field and laboratory assistants trained in-service.

9. A synoptic map and report on the geology of Liberia will be prepared back in the U.S., and several topical reports growing out of the Liberian project will be forthcoming.

In addition to these products, the project, throughout its existence, has participated actively in an advisory and consulting capacity to government agencies and government contractors, both in areas directly related to geology, such as mining, but also in peripheral areas, such as forestry, agriculture, and construction.

EVALUATION

The project accomplished its principal goals of developing trained personnel, facilities, and an organizational structure capable of carrying out the functions of a national geological survey; and of establishing the data base essential for further geological studies and resources appraisal. The geologic map of Liberia, in ten quadrangles at 1:250,000 scale, will provide the essential basis for continued geologic study of specific target areas at larger scales. The files of rocks, thin sections, analyses, field notes, and reports constitute reference materials essential to the operation and growth of the Geological Survey.

The base maps prepared by the project provide the only adequate geographic coverage of the country. From the time that the first 1:40,000 scale preliminary sheets became available, and particularly now that all ten quadrangles are available at 1:125,000 scale, these maps have had increasingly wide usage in a wide range of activities. They have been used extensively in such diverse activities as water resources and hydrologic studies, harbor studies, mineral resources studies by private companies, forestry, and road, railroad, powerline, and microwave relay systems construction.

The geophysical studies have already paid off. The aeromagnetic and gravity surveys established the presence off the coast of Liberia of thick sections of sedimentary rocks and of geologic structures favorable for the occurrence of oil. Several companies have drilled wells offshore, and it is anticipated that more will be drilled.

One of the most important uses might be in preparing a reconnaissance soils map of the country through the coordinated efforts of soil scientists and geologists. Such a map could be compiled by identifying the types of soils likely to be formed in a tropical climate on the various parent materials shown on the geological map, and in the different topographic situations and drainage conditions shown on the geographic map. The scientist preparing the soils map would be further aided by the airborne-radiometric map which shows variations in relative amounts of radiation mostly from potassium in the soil. Such a map, although preliminary in nature, would provide a useful and much-needed tool for agricultural development pending the completion of a more detailed soil survey, requiring several additional years of work.

In addition to a preliminary soils map, a series of special purpose maps could be prepared for general planning and non-technical users. Maps showing target areas for mineral exploration and geological associations favorable for future prospecting could be developed, for example, as well as maps showing conditions suitable for various kinds of construction, water supply, communications facilities, utility

installations, urban growth, and other purposes. Two highly simplified illustrations of special maps at very small scale are enclosed: a physiographic map that enables the planner to consider areal distribution and extent of flat land in relation to cultural features, drainage, and access; and a map showing suitability for roads and airfields. (See attachments 5 and 6.)

By using the maps in Monrovia, the vast amount of background data in the files there, and the knowledge accrued by geologists about the Liberian terrane, it would thus be possible to compile a set of highly useful special-purpose maps to support agricultural, land, water, mineral, communications, and other development activities in Liberia. As a test of what could be achieved, it might be desirable to consider a pilot project in one of the map areas (scale 1:250,000) to prepare a set of such maps, including a reconnaissance soils map, water resources map, construction suitability map, land use capability map, resources potential map, or other types of maps that would be useful.

Attachment 1

July 1972

USGS PERSONNEL ASSIGNED TO MONROVIA, LIBERIA

(From 1963 to present)

	From	To	Duration
Bachman, George O.	January 1971	April 1971	3 months
Behrendt, John C.	July 1968	July 1970	2 years
	March 1971	April 1971	1 month
	October 1971	November 1971	1 month
Beikman, Helen	October 1971	January 1972	4 months
Benton, Lee L.	July 1965	July 1967	2 years
Bergquist, Wenonah E.	March 1972	April 1972	1 month
Blade, Lawrence V.	June 1967	June 1969	2 years
Brock, Maurice R.	Sept. 1971	December 1971	3 months
	April 1972	June 1972	3 months
Bromery, R. W.	May 1966	June 1966	2 months
	January 1968		1 month
Chidester, Alfred H.	September 1970	October 1970	2 months
	March 1971	July 1972	1 year, 4 mo.
Clark, Lorin D.	May 1970	July 1970	3 months
Coonrad, Warren L.	December 1965	July 1972	6 years, 7 mo.
Davis, Allen	April 1965		1 month
	May 1969		1 week
Earhart, Robert L.	January 1971	April 1971	3 months
	January 1972	April 1972	3 months
Force, E. R.	November 1971	July 1972	1 year, 8 mo.
Gromme, C. S.	December 1968		1 month
Hall, Marlene L.	May 1966	May 1968	2 years
Hayes, Philip T.	January 1971	May 1971	3 months

	From	To	Duration
Heare, Johnson T.	December 1965	June 1970	4 years, 6 mo.
Hessin, Thomas D.	January 1972	April 1972	3 months
Hoare, Joseph M.	January 1972	March 1972	2 months
Jackson, Roy O.	July 1965	October 1967	2 years, 4 mo.
Jackson, Janet N. (WAE)			74 days
Johnson, Donald H.	September 1967	June 1969	1 year, 9 mo.
Kennedy, Phyllis K.	November 1968	July 1972	3 years, 9 mo.
Leo, Gerhard W.	July 1965	September 1967	2 years, 2 mo.
Loesch, Thomas L.	August 1969	February 1970	6 months
	December 1970	June 1971	6 months
	October 1971	November 1971	2 months
	February 1972	June 1972	5 months
Luce, Robert L.	May 1970	July 1970	2 months
Pomerene, Joel B.	November 1963	May 1966	2 years, 7 mo.
Rosenblum, Samuel	August 1967	July 1972	4 years, 10 mo.
Rossman, Darwin J.	December 1963	April 1966	2 years, 4 mo.
Sanders, Beatrice L.	January 1972	June 1972	6 months
Schoechle, G. L.	April 1970		2 weeks
	April 1971		3 weeks
	May 1972		3 weeks
Seitz, James F.	September 1967	July 1972	4 years, 10 mo.
Shelton, Ronald B.	February 1968	May 1970	2 years, 4 mo.
Simmons, George C.	January 1970	April 1970	3 months
Stanin, S. Anthony	June 1965	February 1968	2 years, 8 mo.
Thorman, Charles H.	June 1971	July 1972	1 year
Tysdal, Russell G.	November 1970	July 1972	1 year, 9 mo.

	From	To	Duration
Wallace, Roberts M.	October 1970	June 1972	1 year, 9 mo.
Weissenborn, Albert E.	July 1972		6 weeks
White, Amos M.	March 1972	April 1972	2 months
White, Richard W.	December 1966	December 1968	2 years

Attachment 2

ROSTER OF LGS PERSONNEL

C. S. Wotorson	Geophysicist	1964 - present
M. W. Goda Baker	Geologist	1964 - present
S. P. Srivastava	Geologist	1964 - present
B. R. Cooper	Geologist	1964 - present
J. Dunbar	Geologist	1971 - present
E. Phillips	Geologist	1970 - present
T. W. Sherman	Geologist	1969 - present
A. J. Holmes	Chemist	1964 - present
W. Snowe	Photogrammetrist	1970 - present
D. Greenfield	Carto. Engineer	1968 - present
J. Vincent	Photographer	1970 - present
J. K. Diakenah	Draftsman	1971 - present
J. W. Sharpe	Admin. Assist.	1969 - present
S. Ricks	Geologist	1972 - present
A. E. Nyema Jones	Geologist	1962 - present
D. S. B. Dinkins	Geologist	1971 - present
J. Dorbor	Geologist	1971 - present

Attachment 3

Reports of Geological Survey Appraisal Project

Author(s)
Title
Publication, page(s), year

Baker, M. W. G.
Geologic summary of Mosaic Block J-9
MR-32, 1 p., 1969

Baker, M. W. G.
Geologic summary of Mosaic Block J-10
MR-33, 1 p., 1969

Behrendt, J. C., and Wotorson, C. S.
Aeromagnetic, aeroradioactivity, and gravity surveys in Liberia (abs.)
LI-29, 2 p., 1969
MR-37, 2 p., 1969
Am. Geophys. Union Trans., v. 50, no. 4, p. 320, 1969

Behrendt, J. C., and Wotorson, C. S.
Preliminary map of basement elevation of the Liberian continental shelf interpreted from aeromagnetic data (map, scale 1:1,000,000)
LI-33, 1 sheet, 1969
Open file, 1 sheet, 1969
MR-41, 1 sheet, 1969

Behrendt, J. C., and Wotorson, C. S.
Preliminary bouguer anomaly map of Monrovia region of Liberia (map, scale 1:500,000)
LI-37, 1 sheet, 1969
Open file, 1 sheet, 1969
MR-44, 1 sheet, 1969

Behrendt, J. C.
Possible use of total-count gamma radiation survey for agricultural purposes
LI-43, 3 p., 1969
MR-49, 3 p., 1969

Behrendt, J. C., and Wotorson, C.S.
Aeromagnetic and gravity investigations of sedimentary basins on the continental shelf and coastal area of Liberia
LI-45, 11 p., 1969
MR-50, 11 p., 1969

Author(s)
Title
Publication, page(s), year

Behrendt, J. C., and Wotorson, C. S.
Aeromagnetic and gravity investigations of the basins of the continental shelf and coastal area of Liberia, West Africa
Open file, 20 p., 9 figs., 1969

Behrendt, J. C., and Wotorson, C. S.
Aeromagnetic and gravity investigations of the coastal area and the continental shelf of Liberia, West Africa, and their relation to continental drift
LI-45B, 11 p., 1970
MR-50B, 11 p., 1970
Geol. Soc. American Bull., v. 81, p. 3563-3574, 1970

Behrendt, J. C., and Wotorson, C. S.
Aeromagnetic survey unveils Liberian coastal basins
LI-45C, 5 p., 1970
MR-50C, 5 p., 1970
Oil and Gas Jour., p. 160-165, 1970

Behrendt, J. C., and Wotorson, C. S.
High-amplitude radioactivity anomalies in Liberia (map, scale 1:1,000,000)
LI-47, 1 sheet, 1970
Open file, 1 sheet, 1970
MR-54, 1 sheet, 1970

Behrendt, J. C., and Wotorson, C. S.
Total intensity aeromagnetic map of Liberia, including the continental shelf (map, scale 1:500,000)
LI-48, 2 sheets, 1970
Open file, 2 sheets, 1970
MR-55, 2 sheets, 1970

Behrendt, J. C., and Wotorson, C. S.
An aeromagnetic and aeroradioactivity survey of Liberia, West Africa
LI-49, 7 p., 1971
MR-56, 7 p., 1971
Geophysics, v. 36, no. 3, 590-604, 1971

Behrendt, J. C., and Wotorson, C. S.
Tectonic map of Liberia based on geophysical and geological surveys
LI-60, 77 p., 1972
Open file, 77 p., 1972
MR-60, 77 p., 1972

Author(s)
Title
Publication, page(s), year

Behrendt, J. C., and Wotorson, C. S.
Aeromagnetic map of the Bopolu quadrangle, Liberia (scale 1:250,000)
LI-61C, 6 p., 1971
Open file, 6 p., 1971
MR-61C, 6 p., 1971

Behrendt, J. C., and Wotroson, C. S.
Total-count gamma radiation map of the Bopolu quadrangle, Liberia (scale 1:250,000)
LI-61D, 5 p., 1971
Open file, 5 p., 1971
MR-61D, 5 p., 1971

Behrendt, J. C., and Wotorson, C. S.
Aeromagnetic map of the Buchanan quadrangle, Liberia (scale 1:250,000)
LI-62C, 5 p., 1971
Open file, 5 p., 1971
MR-62C, 5 p., 1971

Behrendt, J. C., and Wotorson, C. S.
Total-count gamma radiation map of the Buchanan quadrangle, Liberia (scale 1:250,000)
LI-62D, 5 p., 1971
Open file, 5 p., 1971
MR-62D, 5 p., 1971

Behrendt, J. C., and Wotorson, C. S.
Aeromagnetic map of the Gbanka quadrangle, Liberia (scale 1:250,000)
LI-63C, 5 p., 1971
Open file, 5 p., 1971
MR-63C, 5 p., 1971

Behrendt, J. C., and Wotorson, C. S.
Total-count gamma radiation map of the Gbanka quadrangle, Liberia (scale 1:250,000)
LI-63D, 5 p., 1971
Open file, 5 p., 1971
MR-63D, 5 p., 1971

Behrendt, J. C., and Wotorson, C. S.
Aeromagnetic map of the Harper quadrangle, Liberia (scale 1:250,000)
LI-64C, 5 p., 1971
Open file, 5 p., 1971
MR-64C, 5 p., 1971

Author(s)
Title
Publication, page(s), year

Behrendt

Behrendt, J. C., and Wotorson, C. S.
Total-count gamma radiation map of the Harper quadrangle, Liberia (scale 1:250,000)
LI-64D, 5 p., 1971
Open file, 5 p., 1971
MR-64D, 5 p., 1971

Behrendt, J. C., and Wotorson, C. S.
Total-count gamma radiation map of the Juazohn quadrangle, Liberia (scale 1:250,000)
LI-65D, 6 p., 1971
Open file, 6 p., 1971
MR-65D, 6 p., 1971

Behrendt, J. C., and Wotorson, C. S.
Aeromagnetic map of the Monrovia quadrangle, Liberia (scale 1:250,000)
LI-66C, 8 p., 1971
Open file, 8 p., 1971
MR-66C, 8 p., 1971

Behrendt, J. C., and Wotorson, C. S.
Total-count gamma radiation map of the Monrovia quadrangle, Liberia (scale 1:250,000)
LI-66D, 6 p., 1971
Open file, 6 p., 1971
MR-66D, 6 p., 1971

Behrendt, J. C., and Wotorson, C. S.
Bouguer anomaly map of the Monrovia quadrangle, Liberia (scale 1:250,000)
LI-66E, 5 p., 1971
Open file, 5 p., 1971
MR-66E, 5 p., 1971

Behrendt, J. C., and Wotorson, C. S.
Aeromagnetic map of the Sanokole quadrangle, Liberia (scale 1:250,000)
LI-67C, 6 p., 1971
Open file, 6 p., 1971
MR-67C, 6 p., 1971

Author(s)
Title
Publication, page(s), year

Behrendt, J. C., and Wotorson, C. S.
Total-count gamma radiation map of the San[illegible]le quadrangle, Liberia (scale 1:250,000)
LI-67D, 5 p., 1971
Open file, 5 p., 1971
MR-67D, 5 p., 1971

Behrendt, J. C., and Wotorson, C. S.
Aeromagnetic map of the Voinjama quadrangle, Liberia (scale 1:250,000)
LI-68C, 7 p., 1971
Open file, 7 p., 1971
MR-68C, 7 p., 1971

Behrendt, J. C., and Wotorson, C. S.
Total-count gamma radiation map of the Voinjama quadrangle, Liberia (scale 1:250,000)
LI-68D, 5 p., 1971
Open file, 5 p., 1971
MR-68D, 5 p., 1971

Behrendt, J. C., and Wotorson, C. S.
Aeromagnetic map of the Zorzor quadrangle, Liberia (scale 1:250,000)
LI-69C, 7 p., 1971
Open file, 7 p., 1971
MR-69C, 7 p., 1971

Behrendt, J. C., and Wotorson, C. S.
Total-count gamma radiation map of the Zorzor quadrangle, Liberia (scale 1:250,000)
LI-69D, 6 p., 1971
Open file, 6 p., 1971
MR-69D, 6 p., 1971

Behrendt, J. C., and Wotorson
The use of aeromagnetic and aeroradioactivity surveys for geologic mapping in Liberia, West Africa
LI-73, 20 p., 1971
MR-73, 20 p., 1971
in Proceedings of the Seventh International Symposium on remote sensing of environment
Willow Run Laboratories
Institute of Science and Technology,
Univ. of Michigan, p. 2133-2153, 1971

Author(s)
Title
Publication, page(s), year

Behrendt, J. C., and Wotorson, C. S.
Results of regional gravity survey of Liberia, West Africa
EOS, Am. Geophys. Union Trans., v. 52, no. 4, 1971

Behrendt, J. C., and Wotorson, C. S.
Aeromagnetic and gravity investigations of the sedimentary basins on the continental shelf and coastal area of Liberia, West Africa
Liberian Geol. Survey Special Paper 2
12 p., 4 plates (in press)

Blade, L. V.
Geology of the Bushrod Island-New Georgia clay deposit near Monrovia, Liberia
LI-26, 35 p., 1969
Open file, 35 p., 1970
MR-34, 35 p., 1969

Bromery, R. W.
Feasibility study for an airborne geophysical survey of the Republic of Liberia
TL-1, 21 p., 1966
LI-1, 23 p., 1968
Open file, 23 p., 1968

Bromery, R. W.
Application of airborne geophysical methods to mineral exploration and geologic mapping programs (abs.)
Geol. Mining Metall. Soc. Liberia Bull., v. II, p. 95, 1967 [1968]

Hurley, P. M. in collaboration with Leo, G. W.
Age investigations in Liberia, in Variations in isotopic abundances of strontium, calcium, and argon and related topics
Massachusetts Inst. Technology, Dept. Geology and Geophysics, 15th Ann. Prog. Rept., M.I.T. -1381-15, p. 1-5, 1967

Hurley, in collaboration with Leo, G. W., and White, R. W.
Age investigations in Liberia, in Variations in isotopic abundances of strontium, calcium, and argon and related topics
Massachusetts Inst. Technology, Dept. Geology and Geophysics, 16th Ann. Prog. Rept., M.I.T. -1381-16, p. 87-93, 1968

Author(s)
Title
Publication, page(s), year

Hurley, P. M., in collaboration with Leo, G. W., and White, R. W.
Approximate location of the boundary between the Eburnean and Liberian orogenic provinces in eastern Liberia, in Variations insotopic abundances of strontium, calcium, and argon and related topics
Massachusetts Inst. Technology, Dept. Earth Planetary Sci., 17th Ann. Prog. Rept., M.I.T. 1381-17, p. 25-26, 1969

Hurley, P. M., Leo, G. W., White, R. W., and Fairbairn, H. W.
The Liberian age province (ca. 2700 m.y.) and adjacent provinces in Liberia and Sierra Leone, in Variations in isotopic abundances of strontium, calcium, and argon and related topics
Massachusetts Inst. Technology, Dept. Earth Planetary Sci., 18th Ann. Prog. Rept., M.I.T. 1381-18, p. 17-35, 1970

Hurley, P. M., Leo, G. W., White, R. W., and Fairbairn, H. W.
Liberian age province (about 2,700 m.y.) and adjacent provinces, in Liberia and Sierra Leone
Geol. Soc. America Bull., v. 82, p. 3483-3490, 8 figs., 1971

Jackson, R. O., Coonrad, W. L., and Jones, Nyema
The definition and preparation of Memorandum Reports
LI-3, 2 p., 1966
MR-1, 2 p., 1966

Jackson, R. O., Coonrad, W. L., and Jones, Nyema
Reports series of the Geological Survey
LI-4, 3 p., 1966
MR-2, 3 p., 1966

Johnson, D. H., and White, R. W.
Bibliography of the geology and mineral industry of Liberia and adjacent countries
LI-32, 65 p., 1969
Open file, 65, p., 1969
MR-40, 65 p., 1969

Johnson, D. H., Holmes, A. J., and Cooper, B. R.
Geochemical investigations of base metal occurrence in western Liberia (abs.)
LI-36, 2 p., 1969
MR-43, 2 p., 1969
Geol. Mining Metall. Soc. Liberia Bull., v. III, p. 78-79, 1968 [1969]

Author(s)
Title
Publication, page(s), year

Johnson, D. H., and White, R. W.
Bibliography of the geology and mineral industry of Liberia and adjacent countries, Supplement I
LI-44, 41 p., 1969
Open file, 41 p., 1970
MR-40A, 41 p., 1969

Jones, A. E. N.
Annual report on the activities of the Geology Survey for the period of September 1, 1963 to August 31, 1964
Bur. Nat. Resources and Surveys, 10 p., 1964

Jones, A. E. N.
Annual report for the period Sept. 1964 to Aug. 1965, Liberian Geological Survey
Bur. Nat. Resources and Surveys, 10 p., 1965

Jones, A. E. N.
Annual report for the period September 1, 1965 to August 31, 1966, Liberian Geological Survey
Bur. Nat. Resources and Surveys, 12 p., 1966

Jones, A. E. N.
Five-year program of the Liberian Geological Survey, Bureau of Natural Resources and Surveys
Geol. Mining Metall. Soc. Liberia Bull., v. I, no. 1, p. 44-46, 1966 [1967]

Jones, A. E. N.
Liberia
World Mining, v. 19, no. 7, p. 165-166, 1966

Jones, A. E. N.
Annual report for the period September 1, 1966 to August 31, 1967, Liberian Geological Survey
Bur. Nat. Resources and Surveys, 18 p., 1967

Jones, A. E. N.
Development of the Liberian Geological Survey
Geol. Mining Metall. Soc. Liberia Bull., v. II, p. 78-85, 1967 [1968]

Jones, A. E. N.
Liberia
World Mining, v. 20, no. 7, p. 202, 1967

Jones, A. E. N.
Liberia, in Petroleum developments in central and southern Africa in 1966
Am. Assoc. Petroleum Geologists Bull., 1967

Author(s)
Title
Publication, page(s), year

Jones, A. E. N.
Mineral resources of Liberia
California Div. Mines and Geology,
Mineral Inf. Service, v. 20, no. 2, 18-21, 1967

Jones, A. E. N.
Progress of geologic mapping in Liberia
Liberia Univ. Jour., v. 7, no. 1, p. 44-47, 1967

Jones, A. E. N.
Annual report for the period September 1, 1967 to August 31, 1968
Liberian Geological Survey
Bur. Nat. Resources and Surveys, 14 p., 1968

Jones, A. E. N.
Liberia
World Mining, v. 21, no. 7, p. 138, 1968

Jones, A. E. N.
Liberia, in Littlefield, L. D., Developments in central and southern Africa in 1967
Am. Assoc. Petroleum Geologists Bull., v. 52, no. 8, p. 1530-1532, 1968

Jones, A. E. N., and Wotorson, C. S.
Geologic summary of Mosaic Blocks G-5, G-6, H-5, and H-6
MR-24, 3 p., 1968

Jones, A. E. N.
History of mining in Liberia
Liberian Hist. Rev., v. 5, 53-59, 1969

Jones, A. E. N.
Liberia in World-wide mining summary
World Mining, v. 22, no. 7, p. 194, 1969

Jones, A. E. N.
Annual report for the period September 1, 1968 to August 31, 1969,
Liberian Geological Survey
Bur. Nat. Resources and Surveys, p., 1969

Jones, A. E. N.
Liberia in World-wide mining summary
World Mining, v. 23, no. 7, p. 148-149, 1970

Author(s)
Title
Publication, page(s), year

Jones, A. E. N.
Annual report for the period September 1, 1969 to August 31, 1970
Liberian Geological Survey
Bur. Nat. Resources and Surveys, 30 p., 1970

Jones, A. E. N., Holmes, A. W., and Graves, A. D.
Liberia, in Littlefield, L. D., Developments in central and southern Africa in 1969
Am. Assoc. Petroleum Geologists Bull., v. 54, no. 8, p. 1970

Jones, A. E. N.
Annual report for the period September 1, 1970 to August 31, 1971
Liberian Geological Survey
Bur. Nat. Resources and Surveys, 30 p., 1971

Jones, A. E. N.
Liberia in World-wide mining summary
World Mining, v. 24, no. 7, p. 133, 1971

Kennedy, P. K.
Status of reports, manuscripts, and reference index, December 31, 1969
LI-71, 19 p., 1970
MR-71, 19 p., 1970

Leo, G. W.
Samples of Liberian rocks submitted to Massachusetts Institute of Technology for age dating
LI-6, 4 p., 1966
MR-13, 4 p., 1966

Leo, G. W.
Geologic summary of Mosaic Block E-14
LI-7, 4 p., 1966
MR-14, 4 p., 1966

Leo, G. W.
Geologic summary of Mosaic Block E-15
LI-8, 2 p., 1966
MR-15, 2 p., 1966

Leo, G. W., and Srivastava, S. P.
Geologic summary of Mosaic Block F-14
LI-9, 2 p., 1966
MR-16, 2 p., 1966

Author(s)
Title
Publication, page(s), year

Leo, G. W.
Geologic summary of Mosaic Block F-15
LI-10, 2 p., 1966
MR-17, 2 p., 1966

Leo, G. W.
Preliminary evaluation of gold-bearing rocks in Mosaic Block E-14
LI-11, 3 p., 1966
MR-18, 3 p., 1966

Leo, G. W., and White, R. W.
Geologic reconnaissance in western Liberia
LI-13, 29 p., 1967
Open file, 29 p., 1967
Symposium on Continental Drift, Montevideo, Uruguay, Oct. 16-19, 1967, Abstracts of Papers, LASCO/CD/4.4,, 2 p., 1967
in Wilson, J. T., convenor, Continental drift emphasizing the history of the South Atlantic area, a UNESCO/IUGS symposium held at Montevideo, Uruguay, on October 16-19, 1967
Am. Geophys. Union, Trans., v. 53, no. 2, p. 164-185, 1972

(Note: Microfilm copy of complete 1222-page text and illustrations of symposium proceedings available from AGU, Washington, D.C., $10.00.)

Leo, G. W.
Graphite schist at Kawayisi Creek, Gbapa area, Sanokole-Bahn Region
LI-16, 8 p., 1967

Leo, G. W.
Descriptive summary of Liberian rock types
LI-17, 14 p., 1967
MR-21, 14 p., 1967

Leo, G. W., and Holmes, A. J.
Evaluation of chromite content of some heavy mineral concentrates
LI-18, 7 p., 1969
MR-22, 7 p., 1969

Leo, G. W.
Geochronology program in Liberia (abs.)
Geol. Mining Metall. Soc. Liberia Bull., v. II, p. 96
1967 [1968]

Author(s)
Title
Publication, page(s), year

Pomerene, J. B., and Stewart, W. E.
Preliminary report on barite veins in Gibi area of Liberia
LI-2, 37 p., 1966
Open file, 37 p., 1966

Pomerene, J. B.
Aluminous laterite deposits in northwest Lofa County
LI-5, 2 p., 1966
MR-11, 2 p., 1966

Pomerene, J. B., and Stewart, W. E.
Barite veins in the Gibi area of Liberia (abs.)
Geol. Mining Metall. Soc. Liberia Bull., v. II, p. 94, 1967 [1968]

Pomerene, J. B., and Stewart, W. E.
Barite veins in the Gibi area of Liberia
Liberian Geol. Survey Bull., 23 p., 3 pl., 1967

Rosenblum, S.
Chemical and spectrographic analysis of kyanite from Mt. Montrol Grand Bassa County, Liberia
LI-27, 4 p., 1968
Open file, 4 p., 1969
MR-35, 4 p., 1968

Rosenblum, S., and Srivastava, S. P.
Methods of heavy mineral study in Liberia
LI-34, 2 p., 1969
MR-42A, 2 p., 1969
Geol. Mining Metall. Soc. Liberia Bull. (abs.), v. III, p. 80, 1968 [1969]

Rosenblum, S., and Srivastava, S. P.
Silica sand deposits in the Monrovia area
LI-41, 12 p., 1970
Open file, 12 p., 1970
MR-47, 12 p., 1970
Geol. Mining Metall. Soc. Liberia Bull., v. IV, p. 44-55, 1969-70 [1971]

Rosemblum, S.
Preliminary spectrographic analysis of monazite concentrates from western Liberia
LI-42, 7 p., 1969
Open file, 11 p., 1969
MR-48, 7 p., 1969

Author(s)
Title
Publication, page(s), year

Seitz, J. F.
New methods of surveying natural resources from aircraft and spacecraft (abs.)
Geol. Mining Metall. Soc. Liberia Bull., v. III, p. 76, 1968 [1969]

Seitz, J. F.
Geologic reports authored by LGS-USGS staff, Monrovia, Liberia
LI-30, 5 p., 1969
MR-38, 5 p., 1969

Strivastava, S. P.
Mineralogy of phosphate rock from Bambuta, Liberia
MR-51, 8 p., 1969
Geol. Mining Metall. Soc. Liberia Bull., v. IV, p. 21-32 1969-70 [1971]

Stanin, S. A.
Significance of geochemical analytical results
LI-12, 6 p., 1966
MR-12, 6 p., 1966

Stanin, S. A. and Cooper, B. R.
The Mt. Montro kyanite deposit, Grand Bassa County, Liberia
LI-14, 29 p., 1967
Open file, 33 p., 1968
Liberian Geol. Survey Bull. 2, 20 p., 1968

Stanin, S. A., and Cooper, B. R.
The Mt. Montro kyanite deposit, Grand Bassa County, Liberia (abs.)
Geol. Mining Metall. Soc. Liberia Bull. (abs.), v. II, p. 97-98, 1967 [1968]

Stanin, S. A. and Cooper, B. R.
Field descriptions of rocks from measured sections, Mt. Montro kyanite deposit
LI-15, 13 p., 1967
Open file, 13 p., 1968
MR-20, 13 p., 1967

Stanin, S. A., and Cooper, B. R.
Geologic summary of Mosaic Block I-6
LI-20, 2 p., 1969
MR-25, 2 p., 1969

Stanin, S. A., and Cooper, B. R.
Geologic and general information on Mosaic Block I-7
LI-21, 2 p., 1969
MR-26, 2 p., 1969

Author
Title
Publication, page(s), year

Stanin, S. A., and Cooper, B. R.
Geologic summary of Mosaic Block J-7
LI-22, 2 p., 1969
MR-27, 2 p., 1969

Stanin, S. A., and Cooper, B. R.
Geologic summary of Mosaic Block E-12
LI-23, 2 p., 1969
MR-28, 2 p., 1969

Stanin, S. A., and Cooper, B. R.
Geologic summary of Mosaic Block E-13
LI-24, 2 p., 1969
MR-29, 2 p., 1969

Stanin, S. A., and Cooper, B. R.
Geologic summary of Mosaic Block F-13
LI-25 2 p., 1969
MR-30, 2 p., 1969

Stewart, W. E.
Geologic summary of Mosaic Block D-14
MR-31, 3 p., 1969

Stewart, W. E., Freeman, W. A., and Dinkins, D. S. B.
Field investigations of Lot No. 3, near Bambuta, Lofa County (portion of Liberia Mining Co. Concession area and Mosaic Block G-16)
MR-53, 9 p., 1969

Thayer, T. P., and Lill, G. G.
Mineral exploration in Western Liberia, 1949-50
Liberian Geol. Survey Special Paper 4, p. (in press)

White, R. W., and Baker, M. W. G.
Geology of Mano River mine area
LI-28, 11 p., 1969
MR-36, 11 p., 1969
Geol. Mining Metall. Soc. Liberia Bull., v. III, p. 57-65, 1968 [1969]

White, R. W.
Reconnaissance mapping of deeply weathered crystalline rocks in Liberia
LI-38, 25 p., 1970
Open file, 47 p., 1970
MR-45, 25 p., 1970
Geol. Mining Metall. Soc. Liberia Bull., v. IV, p. 1-25, 1969-70 [1971]

Author(s)
Title
Publication, page(s), year

White, R. W.
Sedimentary rocks of the coast of Liberia
LI-39, 35 p., 1969
Open file, 28 p., 1969
MR-39, 35 p., 1969

White, R. W., and Leo, G. W.
Geologic summary of age provinces in Liberia
LI-50, 10 p., 1969-1970
MR-58, 10 p., 1969-1970
Geol. Mining Metall. Soc. Liberia Bull., v. IV, p. 96-106, 1969-1970 [1971]

White, R. W., and Leo, G. W.
Geologic reconnaissance in western Liberia
Liberian Geol. Survey Special Paper 1, 18 p., 1969 [1971]

White, R. W.
Stratigraphy and structure of basins on the Coast of Liberia
Liberian Geol. Survey Special Paper 3, 14 p., 1 pl.
(in press)

Wotorson, C. S., and Behrendt, J. C.
Aeromagnetic map of the Juazohn quadrangle, Liberia
LI-65C, 5 p., 1971
Open file, 5 p., 1971
MR-65C, 5 p., 1971

Wotorson, C. S., and Behrendt, J. C.
Aeromagnetic map of the Zwedru quadrangle, Liberia
LI-70C, 5 p., 1971
Open file, 5 p., 1971
MR-70C, 5 p., 1971

Wotorson, C. S., and Behrendt, J. C.
Total-count gamma radiation map of the Zwedru quadrangle, Liberia
LI-70D, 5 p., 1971
Open file, 5 p., 1971
MR-70D, 5 p., 1971

INFORMAL PUBLICATIONS

ADMINISTRATIVE REPORTS

USGS (IR)-LI No.	LGS No.	Year	Authors
3	MR-1	1966	Jackson, Coonrad, Jones
4	MR-2	1966	Jackson, Coonrad, Jones
30	MR-38	1969	Seitz
32	MR-40	1969	Johnson, White
44	MR-40A	1969	Johnson, White
71	MR-71	1970	Kennedy

GENERAL GEOLOGY

7	MR-14	1966	Leo
8	MR-15	1966	Leo
9	MR-16	1966	Leo, Srivastava
10	MR-17	1966	Leo
13		1967	Leo, White
16		1967	Leo
	MR-24	1968	Jones, Wotorson
20	MR-25	1969	Stanin, Cooper
21	MR-26	1969	Stanin, Cooper
22	MR-27	1969	Stanin, Cooper
23	MR-28	1969	Stanin, Cooper
24	MR-29	1969	Stanin, Cooper
25	MR-30	1969	Stanin, Cooper
	MR-31	1969	Stewart
	MR-32	1969	Baker
	MR-33	1969	Baker
28	MR-36	1969	White, Baker
38	MR-45	1970	White
39	MR-39	1969	White
50	MR-58	1969-1970	White, Leo
	SP-1	1969-1970	White, Leo
	SP-3	(in press)	White
	SP-4	(in press)	Thayer, Lill

GEOCHEMICAL INVESTIGATIONS

12	MR-12	1966	Stanin
36	MR-43	1969	Johnson, Holmes, Cooper

USGS (IR)-LI No.	LGS No.	Year	Authors
		GEOCHRONOLOGY	
6	MR-13	1966	Leo
		GEOPHYSICAL INVESTIGATIONS	
TL-1		1966	Bromery
1		1968	Bromery
29	MR-37	1969	Behrendt, Wotorson
33	MR-41	1969	Behrendt, Wotorson
37	MR-44	1969	Behrendt, Wotorson
43	MR-49	1969	Behrendt
45	MR-50	1969	Behrendt, Wotorson
45B	MR-50B	1970	Behrendt, Wotorson
45C	MR-50C	1970	Behrendt, Wotorson
47	MR-54	1970	Behrendt, Wotorson
48	MR-55	1070	Behrendt, Wotorson
49	MR-56	1971	Behrendt, Wotorson
60	MR-60	1972	Behrendt, Wotorson
61C	MR-61C	1971	Behrendt, Wotorson
61D	MR-61D	1971	Behrendt, Wotorson
62C	MR-62C	1971	Behrendt, Wotorson
62D	MR-62D	1971	Behrendt, Wotorson
63C	MR-63C	1971	Behrendt, Wotorson
63D	MR63D	1971	Behrendt, Wotorson
64C	MR-64C	1971	Behrendt, Wotorson
64D	MR-64D	1971	Behrendt, Wotorson
65C	MR-65C	1971	Wotorson, Behrendt
65D	MR-65D	1971	Behrendt, Wotorson
66C	MR-66C	1971	Behrendt, Wotorson
66D	MR-66D	1971	Behrendt, Wotorson
66E	MR-66E	1971	Behrendt, Wotorson
67C	MR-67C	1971	Behrendt, Wotorson
67D	MR-67D	1971	Behrendt, Wotorson
68C	MR-68C	1971	Behrendt, Wotorson
68D	MR-68D	1971	Behrendt, Wotorson
69C	MR-69C	1971	Behrendt, Wotorson
69D	MR-69D	1971	Behrendt, Wotorson
70C	MR-70C	1971	Wotorson, Behrendt
70D	MR-70D	1971	Wotorson, Behrendt
73	MR-73	1971	Behrendt, Wotorson
	SP-2	(in press)	Behrendt, Wotorson
		MINERALOGY AND PETROLOGY	
17	MR-21	1967	Leo
34	MR-42A	1969	Rosenblum, Srivastava
	MR-51	Srivastava	

USGS (IR)-LI No.	LGS No.	Year	Authors
	RESOURCE INVESTIGATIONS		
Barite			
2		1966	Pomerene, Stewart
	Bull. 1	1967	Pomerene, Stewart
Bauxite			
5	MR-11	1966	Pomerene
Chromite			
18	MR-22	1969	Leo, Holmes
Clay			
26	MR-34	1969	Blade
Gold			
11	MR-18	1966	Leo
Iron			
	MR-53	1969	Stewart, Freeman, Dinkins
Kyanite			
14		1967	Stanin, Cooper
15	MR-20	1967	Stanin, Cooper
	Bull. 2	1968	Stanin, Cooper
27	MR-35	1968	Rosenblum
Monazite			
42	MR-48	1969	Rosenblum
Phosphate			
	MR-51	1969	Srivastava
	MR-53	1969	Stewart, Freeman, Dinkins
Silica sand			
41	MR-47	1970	Rosenblum, Srivastava

FORMAL PUBLICATIONS

Am. Geophys. Union Trans., 1969		Behrendt, Wotorson
Am. Geophys. Union Trans., 1971		Behrendt, Wotorson
Am. Geophys. Union Trans., 1972	Leo	Leo, White
Am. Assoc. Petroleum Geologists Bull., 1967		Jones
Am. Assoc. Petroleum Geologists Bull., 1968		Jones
Am. Assoc. Petroleum Geologists Bull., 1970		Jones
Bur. Nat. Surveys, 1964-1971		Jones
Calif. Div. Mines and Geology, 1967		Jones
Geol. Mining Geol. Soc. Liberia Bull. 1, 1966		Jones
Geol. Mining Geol. Soc. Liberia Bull. 2, 1967		Bromery
		Jones
		Leo
		Pomerene, Stewart
		Stanin, Cooper
Geol. Mining Geol. Soc. Liberia Bull. 3, 1968		White, Baker
		Johnson, Holmes, Cooper
		Rosenblum, Srivastava
		Seitz
Geol. Mining Geol. Soc. Liberia Bull. 4		Rosenblum, Srivastava
		Srivastava
		White
		White, Leo
Geol. Soc. America Bull., 1970		Behrendt, Wotorson
Geol. Soc. America Bull., 1971		Hurley, Leo, White, Fairbairn
Geophysics, 1971		Behrendt, Wotorson
Liberia Hist. Rev., 1969		Jones
Liberia Univ. Journal, 1967		Jones
Massachusetts Inst. Tech.		
15th Ann. Prog. Rept., M.I.T. 1381-15, 1967		Hurley, Leo
16th Ann. Prog. Rept., M.I.T. 1381-16, 1968		Hurley, Leo, White
17th Ann. Prog. Rept., M.I.T. 1381-17, 1969		Hurley, Leo, White
18th Ann. Prog. Rept., M.I.T. 1381-18, 1970		Hurley, Leo, White, Fairbairn
Oil and Gas Jour., 1970		Behrendt, Wotorson
Proceedings of the Seventh International Symposium on remote sensing of environment, 1971		Behrendt, Wotorson
World Mining, 1966-71		Jones

LIBERIAN PARTICIPANTS WITH U. S. GEOLOGICAL SURVEY

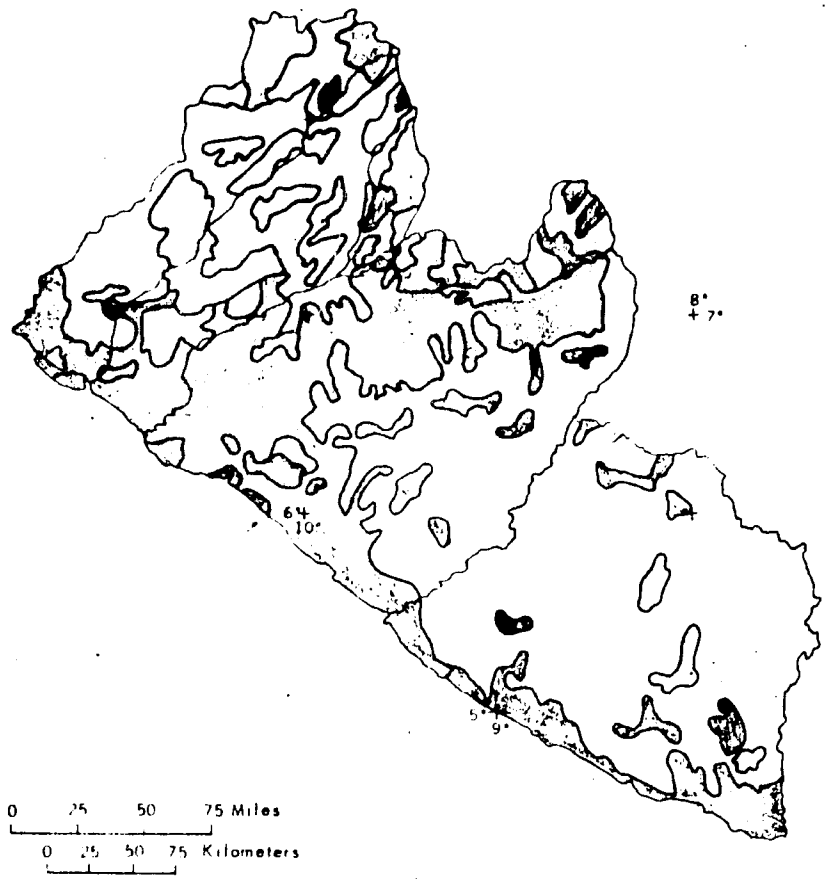
ATTACHMENT 4

Before 1964	1964 and later	Field of Interest	Dates of Training	Remarks
M. W. Goda Baker		Photogeology	7/1 - 10/19/58	BA Southern Illinois Univ. 1958 Post Graduate Training Center for Geology, Vienna, Austria, 1967 (9 mos.)
	Bismarck R. Cooper	Minerals Exploration	6/8 - 9/13/64	BS Wayne Univ., 1959 Post graduate work Univ. of Arizona, 1964 (5 mos.)
	Daniel S. B. Dinkins	Geology	4/8/66 - 8/9/68	BS Western Michigan University 1968
	Jenkins K. Dorbor	Geology	9/15/69 - 4/1/71	BS Ohio State University 1971
Mambu James		Photogrammetry and Cartography	11/26 - 12/26/62	
A. E. Nyema Jones		Economic Geology	1/31 - 7/15/62	BS Cuttington College 1955 MS Univ. of Chicago 1960 Ph.D Univ. of Chicago 1962 Mineral Exploration Course USGS/University of California
	Joseph G. Richards	Geologic Administration and Management	1/31 - 3/14/67	Howard University 1948 BS Univ. of Utah 1952 Photogeology Course International Training Center (Holland) 1953 Management Course Univ. of Pittsburg 1967
	Nathaniel R. Richardson, Jr.	Geology	6/7 - 8/29/69; 6/22 - 7/24/70; 9/71	BS Western Michigan Univ. 1971 Working toward MS at Michigan State University (1972?)

Before 1964	1964 and later	Field of Interest	Dates of Training	Remarks
	Eugene H. Shannon	Geology	6/7 - 8/29/69; 6/22 - 7/24/70	BS Western Michigan Univ. Working toward MS at Michigan State University (1972?)
	Richard W. Shannon	Surface Water Techniques	8/10 - 28/64	BS Utah State University 1965
	Thomas W. Sherman	Geology	4/8/66 - 7/17/69	BS Cuttington College 1964 BS Western Michigan Univ., 1969
William E. Stewart	William E. Stewart	Photogeology; Minerals Exploration	9/15/58 - 1/9/59 6/1 - 9/13/64	BA University of Liberia 1954 BA Michigan State Univ. 1958 Graduate Studies University of Arizona 1964 Geochemical Exploration Course Colorado School of Mines 1964
Cletus S. Wotorson	Cletus S. Wotorson	Geophysics; Economic Geology	10/15/61 - 7/7/62	BS University of Liberia 1961 Graduate Studies Michigan University 1957-61 Mineral Exploration Course USGS/University of California 1962 MA Wesleyan University 1968

ATTACHMENT 5

LIBERIA

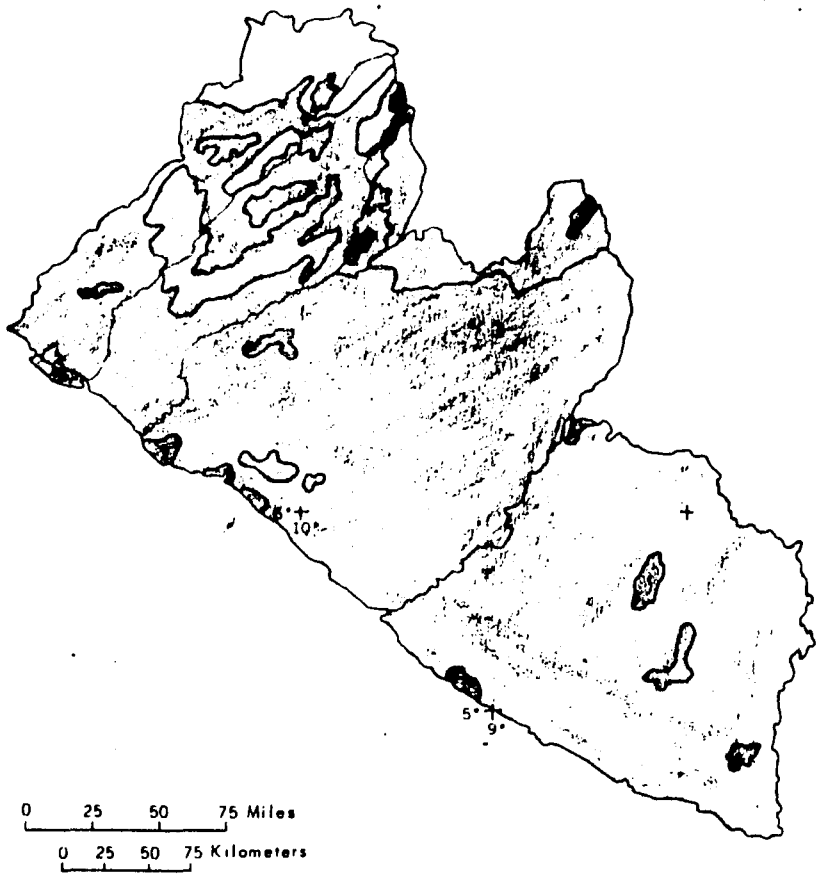


SUITABILITY FOR ROADS AND AIRFIELDS

Good	Lowland and plains covered with brush, grassland and cultivated crops
Fair to Poor	Lowlands and plains covered with forest
Fair to Poor	Hills covered with brush, grassland, and cultivated crops
Poor	Hills covered with forest
Poor	Swamp
Very Poor	Mountains covered with forest

ATTACHMENT 6

LIBERIA



PHYSIOGRAPHY

Swamps

Lowlands and plains

Hills and uplands

Mountains