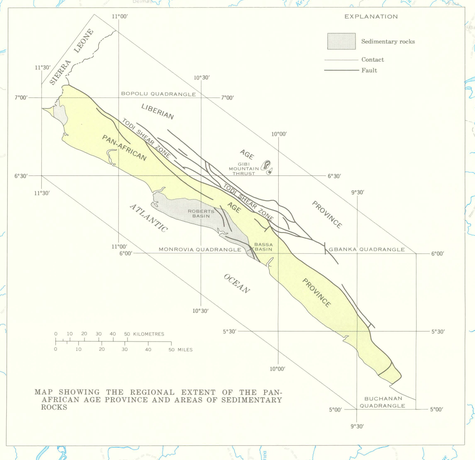
DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

REPUBLIC OF LIBERIA
MINISTRY OF LANDS AND MINES
LIBERIAN GEOLOGICAL SURVEY

FOLIO OF THE BOPOLU QUADRANGLE, LIBERIA
MAP I-772-D



MAP SHOWING THE REGIONAL EXTENT OF THE PAN-AFRICAN AGE PROVINCE AND AREAS OF SEDIMENTARY ROCKS

GEOLOGIC MAP OF THE BOPOLU QUADRANGLE, LIBERIA

By
R. M. Wallace

1977

Base compiled by photo-planimetric methods from aerial photographs taken 1968–69. Controlled from 1953 1:40,000-scale photomosaics by Aero Service Corporation

Hotines Rectified Skew Orthomorphic projection and rectangular coordinates

Shaded relief geographic map available as map I-772-A

INTERNATIONAL BOUNDARY SHOWN ON THIS MAP IS NOT NECESSARILY AUTHORITATIVE

SCALE 1:250,000

0 5 0 5 10 15 20 25 30 KILOMETRES
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.

ADMINISTRATIVE BOUNDARIES
1—Lofa County, Liberia
2—Grand Cape Mount County, Liberia
3—Bong County, Liberia
4—Montserrado County, Liberia
5—Sierra Leone

INTRODUCTION

Liberia was mapped by geologic and geophysical methods from 1965 to 1972 as part of a program undertaken cooperatively by the Liberian Geological Survey (LGS) and the U.S. Geological Survey (USGS), under the sponsorship of the Government of Liberia and the Agency for International Development, U.S. Department of State. The resulting geologic and geophysical maps are published in ten folios, each folio covering one quadrangle (see index map). The Bopolu quadrangle was systematically mapped by the author in late 1970. Field data provided by private companies and other members of the LGS—USGS project were used in map compilation and are hereby acknowledged. Limited gravity data (Behrendt and Wotorson, 1974b) and total-intensity aeromagnetic and total-count gamma radiation surveys (Behrendt and Wotorson, 1974a and c) were also used in compilation, as were other unpublished geophysical data (near-surface, regional magnetic component, and geologic correlations based on aeromagnetic and radiometric characteristics) furnished by Behrendt and Wotorson.

Northeast-trending hills and ridges as much as 1,000 m high and several tens of kilometres long dominate the topography, and thick rain forest covers much of the quadrangle. Population is largely in three small towns: Bopolu, Bendaja, and Bella Yella. Small villages and subsistence farms are scattered through the region, but large areas within the Kapelle National Forest are devoid of trails or inhabitants. Away from the jeep roads, except for a few landing strips for light aircraft, access is limited to foot trails or river travel. The principal rivers provide access by small rubber boat to many areas of good rock exposure, but numerous falls and rapids limit traverses to the early and middle parts of the dry season.

ROCKS

Bedrock in the Bopolu quadrangle, which, except the southwestern tip of the mapped area, is within the Liberian age province of White and Leo (1970) and Hurley and others (1971), lies within the Guinean shield and consists predominantly of Precambrian crystalline rocks, diabase dikes of Jurassic age, and kimberlite dikes of Cretaceous(?) age. River deposits of Quaternary age are distinguished on the map only along the Mano River where they have an appreciable continuous extent.

In general, rock units are distinguished primarily on the basis of field observations, but magnetic and radiometric properties have been used extensively in their delineation. Narrow river deposits, which, in spite of their geophysical maps are published in ten folios, each folio covering one quadrangle (see index map). The Bopolu quadrangle was systematically mapped by the author in late 1970. Field data provided by private companies and other members of the LGS—USGS project were used in map compilation and are hereby acknowledged. Limited gravity data (Behrendt and Wotorson, 1974b) and total-intensity aeromagnetic and total-count gamma radiation surveys (Behrendt and Wotorson, 1974a and c) were also used in compilation, as were other unpublished geophysical data (near-surface, regional magnetic component, and geologic correlations based on aeromagnetic and radiometric characteristics) furnished by Behrendt and Wotorson.

The classification of gneissic rocks used here follows broad igneous compositional parameters (see map explanation), and is based on plagioclase/potassium feldspar ratios. No implication of igneous origin is intended. In those cases where gneisses do not fall readily into the above scheme, or where data are insufficient for classification, suitable descriptive terms (e.g., melanocratic gneiss) are used.

METAMORPHIC ROCKS

The order of discussion of rock units has no implication as to genesis or stratigraphic order. Most of the felsic gneisses are strongly foliated and layered, and their structural relationship with interstated, obviously surface-accumulated rocks such as iron-formation, quartzite, schist, and amphibolite is highly suggestive that the gneisses are metasedimentary. Considerable orthogneiss may be present. However, no attempt was made to distinguish orthogneiss from paragneiss.

Granite gneiss

A unit designated as granite gneiss (gngg) in the northwestern part of the Bopolu quadrangle is closely associated with granite. It is distinguished from granite primarily by linear trends that are imparted by foliation observable in hand specimen and which are characteristic of the unit as seen on aerial photographs.

Granodiorite gneiss

Large bodies of granodiorite gneiss (gngd) are found predominantly in the central western margin of the quadrangle, and may include small bodies of granite. The foliation is generally weak, and is imparted chiefly by the subparallel orientation of biotite. The granodiorite gneiss has a predominant northeast trend.

Granitic gneiss

Granitic gneiss (gng) is the predominant rock unit in the Bopolu quadrangle and is characterized structurally by a consistent N. 40° E. trend visible in the field, and reflected on radiometric and magnetic maps (Behrendt and Wotorson, 1974a, c). The gneisses are layered and are predominantly granodioritic but range from granite to granodiorite in composition, and also include minor amounts of quartz diorite and intercalated amphibolite. The gneiss unit is characterized by magnetic variations of low amplitude and by moderately high aeroradiometric counts.

Quartz diorite gneiss

Two lenticular bodies of quartz diorite gneiss (gndq) are found in the southern half of the Bopolu quadrangle. They trend N. 70° E. to N. 45° E. Pronounced layering parallels the foliation and reflects alternation in the relative proportions of light and dark minerals. Associated with this unit are appreciable but minor ultramafic intrusions and lesser amounts of interlayered amphibolite, quartzite, and muscovite schist, and a small amount of itabirite.

Leucocratic gneiss

This map unit (gnl) is so designated because field data are sparse and the available data are insufficient to permit a more definite classification. The observed outcrops are predominantly light-colored gneiss, generally of granitic to quartz dioritic composition. A characteristic linear pattern as seen on aerial photographs, and a flat, low-intensity pattern of magnetic data have been relied on extensively to extrapolate the sparse field data throughout the unit as delineated.

Melanocratic gneiss

The unit designated as "melanocratic gneiss" (gnm) in the extreme southwest corner of the Bopolu quadrangle is a part of a larger body in the Monrovia quadrangle to the south (Thorman, 1977); it consists primarily of medium- to dark-colored granodioritic to gabbroic gneiss with subordinate intercalated quartzose leucocratic gneiss and amphibolite. Hypersthene and diopside are present in many rocks, often in association with hornblende. Radiometrically determined ages of approximately 550 m.y. of rocks south of the Todi shear zone in the adjacent Monrovia quadrangle indicate that these hypersthene-bearing rocks (gnm) are within the Pan-African province (see White and Leo, 1970, p. 100–101; Thorman, 1977; and Hedge and others 1975).

Composite gneiss unit 1

The composite gneiss unit (gn1) consists primarily of layered biotite-rich gneiss that in many places encloses or is associated with itabirite, schist, quartzite, and amphibolite. The composite gneiss unit (gn1) is characterized by generally higher magnetic anomalies than other gneiss units. Along the St. Paul River much of the rock is hornblende-bearing gneiss, in which feldspar is commonly altered to sericite.

Schist

Several large lenses of garnet- and staurolite-quartz-mica schist (s) occur within the granitic gneiss layers or near the boundaries of the gneiss. As the schist is poorly exposed and deeply weathered, observation of fresh outcrop is rare, but terranes underlain by micaceous schist are generally distinguished by abundant float of coarse muscovite on the ground surface, and by the distinctive texture and appearance of the saprolite (White, 1970, p. 15). Included with areas designated as schist are minor, though locally abundant, interstratified amphibolite, quartzite, and quartz-diorite and granitic gneisses. Small dikes and lenses of pegmatite are common in some places.

Amphibolite

Amphibolite (am) layers range from a few decimetres in thickness (too thin to show at the map scale) to units hundreds of metres thick. Most large units form ridges and are associated with negative magnetic anomalies. The amphibolite is medium to coarse grained and consists of roughly equal proportions of hornblende and plagioclase, as well as common accessory sphene. Variations in the relative proportions of hornblende and plagioclase produce varied, intergradational, and distinctive mafic to felsic interlayers on a scale ranging from a few millimetres to as much as several tens of centimetres. Pronounced, though imperfect foliation is parallel to the layering nearly everywhere. Commonly, felsic veins associated with felsic layers impart a migmatitic aspect to the rock.

Iron-formation, oxide facies (itabirite)

Hematite-magnetite itabirite (it) is the dominant type of iron-formation and forms the major iron ore of the Mano River mine and the protores of the Bea, Tokani, and Kpo Mountain ranges within the Bopolu quadrangle. Itabirite is associated with quartzite, schist, and amphibolite and commonly grades laterally into these rock types. It typically forms long narrow ridges and is marked by pronounced magnetic anomalies.

Composite unit

The Mano River mine area and the Bea, Tokani, and Kpo ranges are underlain by a composite (z) of rock units which are individually too small to show at the map scale. The unit comprises schist, quartzite, amphibolite, layered leucocratic gneiss and subordinate iron-formation. Iron silicate facies is present in the Bea Mountains (Rehfeldt, 1967) as amphibole schist, the most common silicates being cummingtonite-grunerite, with or without hornblende, and minor garnet, biotite, and pyroxene.

IGNEOUS ROCKS

Ultramafic rocks

Ultramafic rocks (u) form dikes, plugs, and sills in both the crystalline basement and the metasedimentary complexes. A metaperidotite plug is located at the confluence of the Yambesi and Lofa Rivers; its margins are serpentinized and slightly foliated in harmony with the foliation of the bordering gneiss. This plug consists mainly of olivine, clinopyroxene, tremolite, and anthophyllite. Other moderately large ultramafic intrusions, south of the Mano River iron mine area, are completely altered to talc and soapstone.

Granitic rocks

A large part of the northern half of the quadrangle is underlain by unfoliated or slightly foliated granitic rocks (gr). The rocks are quartz-rich, and range in composition from granite to trondhjemite; they are commonly medium grained, relatively massive, and in places form bare domes that very rarely exhibit a faint northeast-trending foliation. Small pegmatite dikes, and dikes or small plugs(?) of aplite are randomly distributed and not uncommon in some outcrops.

Syenite

One intrusive mass of syenite (sy) about 300 m long and 200 m wide has been observed in an area northeast of the Mano River iron mine at about the junction of the Mano and Morro Rivers. No other syenite was observed in the Bopolu quadrangle.

Pegmatite

Pegmatites (pg) are not commonly of mappable size within the quadrangle and most frequently are found within and near the granite bodies. However, three mappable pegmatites were observed within gneissic rocks. All specimens collected are granitic, and all pegmatites observed in the field are deeply weathered.

Diabase

East-trending, nonmagnetic metadiabase dikes (d) are present in the extreme northeast corner of the Bopolu quadrangle. Similar dikes are prominent in the Voinjama quadrangle to the north and the Zorzor quadrangle to the east (Seitz, 1977a, b). Hedge and others (1975) report an age of 2850 m.y. for hornblende from a mafic dike near Foya Kamara, approximately 37 km north of the Bopolu quadrangle.

Swarms of tholeiitic diabase (Jd) dikes cross the Bopolu quadrangle from northwest to southeast. They range from a few metres to more than 30 m in width and from a few kilometres to more than 50 km in length. They form high, straight, and narrow ridges, easily detectable on aerial photographs, and are associated with elongate northwest-trending negative magnetic anomalies on aeromagnetic maps (Behrendt and Wotorson, 1974a). The rock is generally composed of labradorite and titaniferous augite, with ubiquitous accessory magnetite and ilmenite. Ophitic texture is common and is prominent in specimens that are glomeroporphyritic. Grommé and Dalrymple (1972) have determined diabase (Jd) ages ranging from 173 to 192 m.y.

Kimberlite

Outcrops of kimberlite (Kjk) of Cretaceous or Jurassic age in the Bopolu quadrangle are extremely rare and nearly all the localities shown on the map have been discovered by drilling or excavation. The kimberlite bodies were located by heavy-mineral studies (Leuria, 1966, p. 30) of stream samples and soil samples, using such indicator minerals as pieroilmenite, pyrope garnet, and chrome diopside as guides. A 2.5-m thick fresh kimberlite body crops out as several resistant layers in a creek about 35 km northeast of the confluence of the Mano and Morro Rivers. The rock is fine grained, has the appearance of diabase, and contains large pieroilmenite crystals imbedded in the matrix, plus grains of garnet, olivine, mica, and augite.

SURFICIAL DEPOSITS

Fluvial deposits

Mappable fluvial deposits (Qf) of probable Quaternary age occur along the Mano River in the southwest corner of the Bopolu quadrangle. These deposits range in thickness from about 3 m to more than 12 m and consist of layers of silty sand underlain by layers of medium- to fine-grained sand. No other fluvial deposits were mapped in the Bopolu quadrangle.

STRATIGRAPHY AND STRUCTURE

Schist and some amphibolite and quartzite in the western part of the Bopolu quadrangle are inferred to be metasedimentary, but the nature of the parent rock of much of the gneissic terrane to the north, east, and south is uncertain and both orthogneiss and paragneiss are probably present. Consequently, no systematic stratigraphic relations can be demonstrated beyond the approximate contemporaneity of interstratified metasedimentary and metavolcanic rocks within limited areas. Separated areas of such rocks as schist, composite rock units, or iron-formation, may be generally equivalent to each other, as suggested by similarities in lithology and associated units; equivalence of such units is compatible with available structural information; however, such correlations are only tentative at best.

The regional stratigraphic pattern reflects the dominant northeast-trending grain of the Precambrian rocks, which swings to the west along the southwestern border of the quadrangle. Several linear features trend east-northeast, oblique to the predominant structural trend, and mark major faults. The Jurassic diabase dikes form northwest-trending swarms.

FOLDS

Folds range in size from small crenulations to broad antiforms and synforms; the folds are commonly isoclinal with axes predominantly steep but ranging from vertical to horizontal. Iron-formation commonly occurs in synclinal troughs.

FAULTS AND SHEAR ZONES

Most of the major faults in the Bopolu quadrangle are subparallel to regional stratigraphic trends and have probably had a major influence on the topography. The long, nearly straight, southwest-flowing major streams lie in valleys controlled by major faults that appear to have a predominant strike-slip component.

Some faults are complex and are marked by large mylonitic zones. The northwest-trending Todi shear zone, observed by C. H. Thorman (1977) in the Monrovia quadrangle, was traced into the southwest corner of the Bopolu quadrangle on the basis of intermittent mylonitic zones, some of which are more than a kilometre in width.

High-angle, east-trending faults are oblique to the regional stratigraphic and physiographic trends and appear to be younger than the strike-slip faults. Many minor faults are exposed in the Bea and Kpo Mountain ranges and are believed to be the youngest faults.

METAMORPHISM

Regional metamorphism.—Throughout most of the mapped area the rocks are of amphibolite facies metamorphic grade. In the southwest corner of the quadrangle hypersthene-bearing rocks mark a transition into the pyroxene-hornblende granulite facies of transitional granulite facies. The distribution of hypersthene indicates that the isograd trends northwest, passing to the west of the Bea Mountains, a trend well established in the Monrovia quadrangle (Thorman, 1977). Hypersthene is reported in itabirite at the Mano River mine, and hypersthene also occurs just north of the Bea Mountains. Thus the granulite-amphibolite facies isograd may be very irregular.

Dynamic metamorphism.—Cataclastic rocks have been collected from many of the major fault zones, some of which are as much as a kilometre wide. Only a few blastomylonites were observed. Most of the rocks are mylonite and protomylonite derived from felsic gneisses, indicating that deformation postdated the regional metamorphism.

MINERAL RESOURCES

IRON

Iron ore is mined in the Bopolu quadrangle at the Mano River iron mine (National Ore Company, Limited), located in the southwestern part of the quadrangle. Production is chiefly from enriched itabirite, but minor amounts of ore are extracted from canga (an iron-rich conglomerate) and from enriched laterite and iron-silicate formations. Geology of the bedrock in the Mano River iron mine area has been described by White and Baker (1968). Numerous occurrences of itabirite, the dominant iron-formation, and extensive tracts of metamorphosed sedimentary and volcanic rocks with which iron-formation is commonly associated, are in the Bea and Tokani Mountains and throughout the Kpo Range; they represent potentially large iron ore reserves.

DIAMONDS

Diamonds have been found in placer deposits along the Lofa and Mano Gbeya River systems, and in the Zoi-Kumgbo area. Many of the placers contain minerals (pieroilmenite, pyrope-garnet, and chrome-diopside) characteristic of kimberlite.

GOLD

Gold was formerly mined at a number of places within the Bopolu quadrangle. Geology of three lode occurrences and several of the placer deposits is described by Thayer and others (in press).

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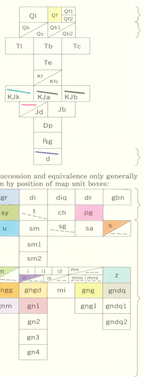
EXPLANATION

Rock symbols in the correlation diagram are standard for all of Liberia. Only rock units present in this quadrangle are shown in color in the correlation diagram.

CORRELATION OF MAP UNITS



Chronologic succession and equivalence only generally shown by position of map unit boxes:

DESCRIPTION OF MAP UNITS

The names of igneous and metamorphic rocks are based on composition as follows:

Igneous rock	*Metamorphic rock*	*Percent potassium feldspar of total feldspar*	*Percent quartz in rock*
Granitic rocks, undivided	*Granite gneiss*	*>10*	*>10*
Granite	*Granite gneiss*	*>50*	*>10*
Granodiorite	*Granodiorite gneiss*	*>10 and <50*	*>10*
Dioritic rocks, undivided	*Diorite gneiss*	*<10*	
Quartz diorite	*Quartz diorite gneiss*	*<10*	*>10*
Diorite	*Diorite gneiss*	*<10*	*<10*

Metamorphic rocks classified according to this scheme are not necessarily igneous in origin. Leucocratic (light colored) and melanocratic (dark colored) are used for gneiss units of verifiable or complex composition for which mineralogic classification is not applicable.

Qf — FLUVIAL AND DELTAIC DEPOSITS, UNDIVIDED—Forms flat to hummocky terrain. Upper unit: grayish-yellow to buff well-sorted silty sand, 4 to 5 m thick. Lower unit: light-yellow to buff well-sorted medium to fine sand, 0 to 5 m thick, grading upwards into silty sand

KJk — KIMBERLITE—Rarely exposed, commonly strongly weathered. Dark-gray fine-grained matrix with abundant large ilmenite crystals and minor garnet, olivine, mica, and augite. Diamonds are associated with kimberlite in the Bopolu quadrangle

Jd — DIABASE—Dark-gray fine-grained tholeiitic basaltic composition composed of labradorite and pyroxene. Locally shows ophitic texture. Weathers to dark-brown sand and clay

d — DIABASE—Dark-gray diabasic dike rock consisting primarily of pyroxene and plagioclase

pg — PEGMATITE—Coarsely crystalline masses of essentially granitic composition, generally within or near the granitic bodies. Columbite-tantalite is associated with some of the pegmatites

sy — SYENITE—Grayish-buff fine-grained structureless rock consisting essentially of perthite and minor hornblende and/or biotite

gr — GRANITIC ROCKS—Light-yellowish-gray to light-pinkish-yellow medium- to coarse-grained nearly structureless rock consisting essentially of quartz, potassium feldspar, and plagioclase with minor micas and hornblende

u — ULTRAMAFIC ROCKS, UNDIVIDED—Commonly very dark gray to black fine- to medium-grained massive to schistose metaperidotite; some bodies completely altered to talc

z — COMPOSITE UNIT—Quartzite, schist, and amphibolite with minor iron-formation; associated with major iron-formation units

it — IRON-FORMATION, OXIDE FACIES (ITABIRITE)—Thinly laminated light-gray fine- to medium-grained quartz layers, and dark- to blue-black fine-grained magnetite and/or hematite layers; grades into ferruginous quartzite

am — AMPHIBOLITE, UNDIVIDED—Banded medium-gray to black fine- to medium-grained rock consisting essentially of hornblende, plagioclase, with minor augitic pyroxene, sphene, biotite, epidote, and quartz

s — SCHIST, UNDIVIDED—About 300 m to about 1600 m thick including fine-grained mica, chloritic, and amphibolitic schists not associated with iron-formation and consisting of quartz, biotite, muscovite, plagioclase, hornblende, and epidote

gnm — MELANOCRATIC GNEISS—Dark-colored rocks consisting of hypersthene-diopside-hornblende-plagioclase-biotite gneiss with varying amounts of pyroxenes and hornblende; amphibolite; pyroxenic granitic gneiss; and sillimanite-hypersthene-garnet-two mica gneiss

gn1 — COMPOSITE GNEISS UNIT 1—This unit is typically associated with itabirite and composite unit z rocks and includes: light-colored medium-grained layered biotite-rich granitic gneiss; medium-colored medium-grained hornblende-bearing granodiorite to diorite gneiss; contains more amphibolite than adjacent units

gnl — LEUCOCRATIC GNEISSES—Undivided light-colored fine- to coarse-grained gneisses of granitic to quartz dioritic composition; includes minor amphibolite, quartzite, and schist

gndq — QUARTZ DIORITE GNEISS—Well-foliated medium-gray to tan and light-brown fine- to coarse-grained consisting essentially of sodic (andesine and/or oligoclase) plagioclase feldspar, hornblende, and/or biotite with small amounts of quartz and virtually no potassium feldspar

gngt — GRANITIC GNEISS—Light-colored medium-grained banded biotite-bearing gneiss; predominantly granodiorite, but ranging in composition from granite to granodiorite; magnetic and aerial photographic trends are parallel to regional structural trends; contains less amphibolite than adjacent units

gngd — GRANODIORITE GNEISS—Well-foliated light-gray to buff to tan fine- to coarse-grained consisting essentially of quartz and plagioclase feldspar with minor potassium feldspar with moderate hornblende and/or biotite

gngg — GRANITE GNEISS—Well-foliated light-gray to buff and light-pink to fine- to coarse-grained gneiss of granitic composition consisting essentially of quartz, plagioclase feldspar, and microcline with minor hornblende and biotite

Map symbols are standard for the geologic quadrangle maps of Liberia (I–771–D to I–780–D). Not all symbols are used on any one map.

Letter symbol within contact, fault, or other structural symbol indicates sources of information used in locating contact: **M**, aeromagnetic data; **P**, photointerpretation; **R**, near-surface radiometric data; **G**, gravity data; and **P/M**, combination source (predominant source given first). Segments without letter symbol were located by surface traverses. Break in line indicates change in source of information.

Where rock units are present only as marker beds within other formations, they are shown in black (see below) with the appropriate unit symbol.

M/P — Contact—Showing direction of dip where known

U / D, P/R — Fault—U, upthrown side; D, downthrown side; dip where known

Thrust fault—Sawteeth on upper plate

Fault zone or shear zone

Fault intruded by dike

M — Antiform—Showing trace of crestal plane and direction of plunge; degrees of dip and plunge given where known

Overturned antiform

P — Synform—Showing trace of trough plane and direction of plunge; degrees of dip and plunge given where known

Overturned synform

30 — Strike and dip of axial plane of minor fold
Inclined
Vertical

60 — Strike and dip of beds
Inclined
Vertical
Horizontal

60 60 — Strike and dip of foliation—Open symbol indicates foliation transecting earlier foliation or bedding; solid symbol indicates relation to bedding unknown
Inclined, degree of dip given where known
Vertical
Horizontal

60 — Strike and dip of parallel layering or bedding and foliation
Inclined
Vertical
Horizontal

Strike of foliation, no dip determined

70 — Strike and dip of joints
Inclined
Vertical
Horizontal

M 70 / M P — Strike and dip of planar features determined from photointerpretation (P) or aeromagnetic data (M)—One, two, three, or four ticks indicate gentle, medium, steep, or vertical dip

10 — Bearing and plunge of lineation formed by minor fold. Barbed arrow indicates crinkle axis or intersecting foliation; solid arrow indicates bearing and plunge of mineral lineation

Structural trend or lineation based on photointerpretation

M — Structural trend based on aeromagnetic data

Observed outcrop

q — Marker bed distinguished by rock symbol (q) or index mineral (ky)

HY — Index minerals:

AD, andalusite	EN, enstatite	K, kyanite
AN, anthophyllite	EP, epidote	M, muscovite
AU, augite	EU, eulite	PY, pyrite
B, biotite	GA, garnet	PX, pyroxene
CL, chlorite	GR, graphite	S, sillimanite
CG, cummingtonite-grunerite	H, hornblende	ST, staurolite
D, diopside	HY, hypersthene	TA, tremolite-actinolite
	IL, ilmenite	

Sand, gravel, clay, or placer pit—**B**, barite; **D**, diamond; **G**, gold

Mine or quarry—**S**, building stone or road metal; **C**, clay; **I**, iron

Prospect pit—**B**, barite; **K**, kyanite

Drill site for offshore well, abandoned

Fossil locality

Invertebrate

Plant

K2600 — Radiometric age in millions of years—K, potassium-argon; R, rubidium-strontium; F, fission track. Reset age given in parentheses where applicable

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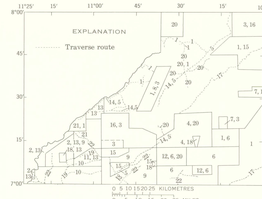

SOURCES OF FIELD DATA

1. M. W. G. Baker (LGS)
2. L. V. Blade (USGS)
3. Bismark Cooper (LGS)
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5. R. L. Earhart (USGS)
6. Nyema Jones (LGS)
7. E. O. Jackson (USGS)
8. D. Johnson (USGS)
9. G. W. Leo (USGS)
10. Liberian Mining Co. (Geologists)
11. J. B. Pomerene (USGS)
12. D. L. Rossman (USGS)
13. William Stewart (LGS)
14. G. C. Simmons (LGS)
15. S. P. Srivastava (LGS)
16. S. A. Stanin (USGS)
17. J. F. Seitz (USGS)
18. T. P. Thayer (USGS)
19. United Nations geologists
20. C. S. Wotorson (LGS)
21. R. W. White (USGS)
22. R. M. Wallace (USGS)

INDEX MAP OF LIBERIA SHOWING LOCATION OF QUADRANGLES IN THIS SERIES