UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

PROJECT REPORT
Liberian Investigations
(IR) LI-64B

GEOLOGY OF THE HARPER QUADRANGLE, LIBERIA

U. S. Geological Survey
OPEN FILE REPORT 74-310

Prepared under the auspices of the
Government of Liberia and the
Agency for International Development
U. S. Department of State

1974

GEOLOGY OF THE HARPER QUADRANGLE, LIBERIA

By

M. R. Brock and A. H. Chidester
U. S. Geological Survey

and

M. G. W. Baker
Liberian Geological Survey

CONTENTS

GEOLOGY OF THE HARPER QUADRANGLE

By M. R. Brock[1/], A. H. Chidester[1/], and M. W. G Baker[2/]

INTRODUCTION

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, Liberia was mapped by geologic and geophysical methods during the period 1965 to 1972. The resulting geologic and geophysical maps are published in ten folios, each covering one quadrangle (see index map). The first systematic mapping in the Harper quadrangle was by Baker, S. P. Srivastava, and W. E. Stewart (LGS) at a scale of 1:500,000 in the vicinity of Harper in the southeastern, and of Karloke in the northeastern part of the quadrangle in 1960-61. Brock and Chidester carried out systematic mapping of the quadrangle at a scale of 1:250,000 in the period September 1971-May 1972; the geologic map was compiled from field data gathered by project geologists and private companies as indicated in the source diagram, photogeologic maps, interpretation of airborne magnetic and radiometric surveys, field mapping, and ground-based radiometric surveys in which hand-held scintillators were used. R. W. Bromery, C. S. Wotorson, and J. C. Behrendt contributed to the interpretation of geophysical data. Total-intensity aeromagnetic and total-count gamma radiation maps (Behrendt and Wotorson, in press a, b), and unpublished data derived from those maps, including the near-surface and the regional magnetic components and aeromagnetic/radiometric correlations, were used in the interpretation.

1/ U. S. Geological Survey

2/ Liberian Geological Survey

Relief in the Harper quadrangle is about 300 meters. Coastal areas in which narrow sandy beaches separated by rock promontories are backed by broad rolling savannahs contain irregularly distributed but locally abundant outcrops of unweathered rock. Inland areas are hilly and covered by dense high forest in which are interspersed patches of low bush and small farms; a thick cover of saprolite and laterite commonly obscures the bedrock, except locally in the larger streambeds and on some of the steeper hills. Ranges of hills and courses of streams in many places reflect the structural grain and lithology of the country rock.

The coastal area and the Cavalla River area contain several small towns; inland there are only small villages and scattered farms. Access by motor vehicle is limited to the main road north from Harper, and to a few short side roads and lumber roads. Elsewhere, travel is by streams navigable by small boat, and by foot trails between villages. Beaches and savannahs along the coast offer many sites of ready access by helicopter; inland, numerous small airstrips for light planes provide access to otherwise isolated areas.

ROCKS

The Harper quadrangle is entirely in the Eburnean age province of Hurley and others (1971), at the western margin of the Guinea shield. Bedrock consists of metamorphic gneisses and schists of Precambrian age, scattered small bodies of unfoliated granitic rocks of probable Precambrian age, diabase dikes of Jurassic age, and a few intermediate and felsic dikes of probable Jurassic or Cretaceous age. In general, rock units were distinguished primarily on the basis of field observations, but magnetic and radiometric properties were used extensively in delineating units on the geologic map.

Map units are designated by a symbol appropriate for the rock type or range of rock types that characterize a unit. Units that are appropriately characterized by the same symbol, but which differ distinctively in some aspects, are shown by separate but related symbols. The discussion below is organized by rock type and has no stratigraphic implication. Beach sands and lagoonal deposits of Quaternary age, narrow river deposits, and laterite and saprolite, which obscure much of the underlying bedrock, are not distinguished on the map.

Metamorphic rocks

Gneiss and schist constitute the predominant metamorphic rocks in the Harper quadrangle. Amphibolite and quartzite are minor but common. Iron-formation and manganese formation are quantitatively very minor, but they commonly crop out in bold and distinctive ridges.

The simple classification of gneissic rocks that is used follows broad igneous compositional parameters based on the ratio of plagioclase to potassium feldspar. (See map explanation.) No implication of igneous origin is necessarily intended. For gneisses that do not fall readily into such a classification, or where there are insufficient data for such classification, appropriate mineral modifiers (e.g., garnet-zoisite-hypersthene gneiss) or suitable descriptive terms (e.g., leucocratic gneiss) are used.

Granite gneiss

Narrow bands of granite gneiss (gngg), are delineated on the basis of a few outcrops, high radioactivity as determined by surface scintillation readings, topographic expression, and magnetic pattern, in the northeast and southeast parts of the quadrangle. The few outcrops observed are biotite granite gneiss, and range in texture from massive to weakly foliated.

Granodiorite gneiss

Biotite granodiorite gneiss (gngd), chiefly associated with belts of schist, forms several small bands in the eastern part of the quadrangle. The foliation is generally weak, and is imparted chiefly by the subparallel orientation of biotite. A few small masses of granite, locally pegmatitic, are associated.

Granitic gneiss

Granitic gneiss (gng) forms a small body in the northeastern part of the quadrangle, and a broad belt that extends east-northeastward across the quadrangle from just north of Sasstown. The gneiss ranges in composition chiefly from granodiorite to granite, but includes also minor amounts of quartz diorite and intercalated amphibolite. Porphyroblasts and augen of microcline, some as much as 7 cm long. characterize zones that can be traced for several kilometers, such as those in and north of Sasstown. The gneiss unit is characterized by magnetic variations of low amplitude and by moderately high aeroradiometric counts.

Quartz diorite gneiss

Four major belts and several smaller belts of quartz diorite gneiss ($gndq_1$) underlie about half the Harper quadrangle. Both biotitic and hornblendic phases are locally interlayered at outcrop scale. Pronounced layering and parallel foliation reflect alternation in relative proportions of light and dark minerals. The units include appreciable but minor amounts of interlayered amphibolite, quartzite, and muscovite schist, plus reported small occurrences of itabirite.

Leucocratic gneiss

A unit designated as "leucocratic gneiss" (gnl) is centered about 25 km northeast of Grand Cess. Almost no outcrop of the unit has been seen. It is distinguished by a flat, low-intensity magnetic pattern such as would be expected to characterize a rather homogeneous body of leucocratic gneiss.

Composite gneiss

A composite gneiss unit (gn_2) in the northwesternmost part of the quadrangle consists predominantly of biotite quartz diorite, but contains abundant interstratified amphibolite and quartzite; it is characterized by several zones that contain abundant graphite. Several small aeroradiometric highs suggest the presence of small granitic bodies. Some of the quartz diorite gneiss contains abundant magnetite, which imparts moderate to strong magnetic contrasts.

Migmatite

Migmatite (mi) underlies a broad area in the south-central part of the quadrangle, and is strikingly displayed in bold outcrops along the coast and in the savannah near Sasstown. Foliated fragments, lenses, and layers of mafic rock form the paleosome (Mehnert, 1968, p. 7-8) in a massive to weakly foliated leucocratic matrix or neosome. The migmatite displays striking variations in texture and structure, ranging from agmatic (breccia) to schollen (raft) (Mehnert, 1968, p. 8-17), commonly within the same outcrop. Amphibolite is the predominant paleosome, but biotitic quartz diorite gneiss is common. Amphibolite agmatite is magnificently exposed on the coast near Sasstown.

The migmatite is characterized by, and delineated largely on the basis of, moderately high amplitude magnetic contrasts and by a varied aeromagnetic pattern.

Mica schist

Mica schist (sm) underlies a broad area in the eastern part of the quadrangle. It is predominantly medium- to coarse-grained quartz-muscovite schist, with minor amounts of quartz-biotite schist. Sillimanite is common in the northeastern part of the unit, and staurolite forms conspicuous prismatic crystals 2-3 cm long just south of Karloke. Garnet and tourmaline are locally conspicuous. Biotite schist crops out in a wide band along the left bank of the Cavalla River near Nyaake. The schist is poorly exposed and deeply weathered, so observations on fresh outcrop are rare; but terranes underlain by micaceous schist are generally distinguished by abundant float of coarse muscovite on the ground surface, and by distinctive texture and appearance of the saprolite. Included with areas designated as schist are minor, though locally abundant, interstratified amphibolite, quartz, and quartz dioritic and granitic gneisses. Dikes and lenses of pegmatite are abundant.

Quartzite

In the southeastern part of the quadrangle, in the vicinity of Plibo, quartzite (q) forms conspicuous marker beds associated with belts of muscovite and biotite schist. The quartzite upholds prominent ridges. It is predominantly massive and medium to dark gray; where it intergrades with schist, relict bedding is locally discernible. In terranes consisting predominantly of quartz diorite, quartzite has been reported at numerous localities; most of these reports have not been verified, and the character and relation of the quartzite are unknown.

Amphibolite

Amphibolite (am), which because of its resistance to weathering upholds prominent ridges, crops out in the vicinity of Harper in several bands as much as 2 km wide. The amphibolite is medium to coarse grained, and consists of roughly equal proportions of hornblende and plagioclase, commonly with 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 millimeters to as much as several tens of centimeters. A pronounced though imperfect foliation is nearly everywhere parallel to the layering. Commonly, felsic veins associated with felsic layers impart a migmatitic aspect to the rock.

Iron-formation

Iron-formation (i) is mapped in four places in the east-central part of the quadrangle. Identification and delineation of the units are based upon a few observed itabirite outcrops and upon associated moderately strong, negative aeromagnetic anomalies. Minor amounts of interbedded schist and amphibolite are included with the iron-formation.

Silicate facies iron-formation is reported (H. Van Griethuysen, written commun., 1970) to be associated with schist in a belt 25 km north of Plibo. This marker bed is shown on the geologic map by the symbol (is).

Itabirite (it) is distinguished on the map in widely scattered marker beds, based upon reported observations only a few of which were verified by project geologists. The rock is a fine- to medium-grained, bluish-gray quartzose rock rich in magnetite and hematite.

Manganese formation

Manganese formation (mn) rocks are characterized by a sooty black manganiferous rind on weathered surfaces. They crop out in narrow linear bands within belts of schist (sm) in the southeastern part of the quadrangle. Both silicate facies and carbonate facies occur: the silicate facies is a massive quartz-manganiferous garnet rock; the carbonate facies is a thinly laminated quartzose manganiferous rock. The characteristic sooty black rind grades sharply into the less weathered rock along an irregular boundary.

Composite unit

A composite unit (z) consisting chiefly of mica schist with abundant interstratified amphibolite and quartzite is associated with iron-formation in the east-central part of the quadrangle. The unit is surrounded by a broad terrane of mica schist and is probably intergradational with it. It is distinguished from the schist by the magnetic pattern, attributable to the strong magnetic contrasts of the interstratified iron-formation, amphibolite, and quartzite.

Hypabyssal igneous rocks

Dikes of hypabyssal igneous rock in the quadrangle trend northwestward and lie within a broad belt of dikes that extends across the full length of Liberia. Most of the dikes in the quadrangle are diabase, but two other kinds have been found: a single dike of hornblende andesite porphyry, and a single occurrence of bostonite porphyry.

Diabase

Diabase dikes (Jd) occur mainly in the northeast part of the quadrangle. The largest dike is about 30 km long and several tens of meters thick. Most dikes show typical medium-grained diabasic texture, but the central zones of some of the larger dikes are gabbroic. The diabase dike on the coast near the mouth of the Dubo River has pronounced trachytoidal texture with tabular plagioclase phenocrysts (1-1 1/2 cm long) enclosed in a diabasic groundmass.

Bostonite porphyry

A single dike of bostonite porphyry (KJb) crops out in a small stream about 12 km northeast of Sasstown along the Kahnwia-Sasstown trail. The pink, fine-grained groundmass consists of about equal amounts of albite and potassium feldspar, with abundant light-gray, 2-5 mm plagioclase phenocrysts.

Hornblende andesite porphyry

A lavender-gray, fine-grained andesite (KJa), believed to be a dike, crops out along the trail about a half-mile south from the locality of the bostonite porphyry.

STRATIGRAPHY AND STRUCTURE

Schist and intercalated gneiss in the eastern part of the quadrangle are inferred to be metasedimentary, but the nature of the parent rock of much of the gneissic terrane is uncertain and both ortho- 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. The general equivalence of separated tracts of schist and associated rocks, such as iron-formation, is suggested by similarities in lithology and rock associations, and is compatible with available structural information; but such correlations are only tentative at best.

Because rocks are tightly folded about east-northeast-trending axes, layering in steep limbs of folds imparts a pronounced structural grain approximately parallel to the fold trends. Transecting this grain is the Dube shear zone, which trends northeast and separates gneissic terrane on the northwest from interlayered schists and gneisses on the southeast. This shear zone, delineated on the basis of outcrops, magnetic data, and topography, is 2-3 km wide, and has sharply delimited boundaries. It contains abundant mylonite and protomylonite that enclose islands of unsheared or only slightly sheared rock. Shear surfaces within the zone are parallel to the trends of the zone, and topographic features are predominantly parallel to the trends of shear surfaces and shear zones. The shear zone is strongly reflected in the aeromagnetic map (Behrendt and Wotorson, in press, a) by sharp flexures and discontinuities in the trends of magnetic contours, and shows on both the near-surface and the regional-component magnetic maps (Behrendt and Wotorson, unpub. data). Drag patterns along the margins of the shear zone suggest that the east plate moved northeastward. The displacement may be tens of kilometers.

Several faults of less fundamental character occur east of the Dube shear. They are reflected by stratigraphic pattern, topographic features, and the near-surface aeromagnetic component but not the regional aeromagnetic component. The largest intersects the Dube shear near the coast and extends east beyond the quadrangle boundary.

Tight folds having wave length amplitudes of several kilometers are indicated by stratigraphic patterns, based on outcrop data, photogeology, and aeromagnetic trends. Conceivably some of the schist belts in the eastern part of the quadrangle may reflect one or two schist zones that have been repeated by folding. In the northwestern part of the quadrangle fold patterns indicated by topographic and aeromagnetic forms, but unsupported by local outcrop data, suggest two generations of folding.

Folds are evident in outcrop throughout the quadrangle. Plastic isoclinal folds predominate. In several outcrops the isoclinal plastic folds are refolded by open folds that have an associated axial-plane slip cleavage. A crinkle lineation, and in some places a strong mineral lineation, parallels the axes of the later open folds.

METAMORPHISM

Metamorphic rocks in the quadrangle include both schist and gneiss that range in metamorphic grade from lower amphibolite facies (e.g., quartz-muscovite-staurolite schist) to upper amphibolite facies (e.g., hornblende-clinopyroxene-plagioclase gneiss). East of the Dube shear, interstratified schist and gneiss of approximately the same age are in the lower and middle amphibolite facies. The schist is predominately quartz-muscovite rock containing variable amounts of biotite, sillimanite, and garnet, derivatives chiefly of pelitic sedimentary rocks. West of the Dube fault, schist is greatly subordinate to gneiss, or is absent, and the rocks are in the middle or upper amphibolite facies.

Some of the nonfoliated, medium- to coarse-grained granitic rocks observed in isolated outcrops throughout the quadrangle may represent post-metamorphic igneous bodies. Identification and delineation of such post-metamorphic rocks will require more detailed study than was possible during this reconnaissance mapping program.

MINERAL RESOURCES

Mineral production in the quadrangle has been limited to small amounts of placer gold from a few streams within the schist zones. Although manganese oxides are concentrated in the weathered zone of manganese-rich metasedimentary carbonate and siliceous rocks within the schist zones, none is known to be of commercial value. Sheet mica as much as 10 cm in diameter is fairly common in pegmatite bodies within muscovite schist zones in the northeast section of the quadrangle.

Bedrock quarry material for construction purposes is available in the vicinity of the larger villages and towns along the coast and can be obtained from some of the many inland ridges and hills. Siliceous laterite soil, a good unprocessed road-surfacing material, is sparse within a coastal belt 15-25 km wide, but is abundant in much of the interior region.

REFERENCES

Behrendt, J. C., and Wotorson, C. S., in press, a, Aeromagnetic map of the Harper quadrangle, Liberia: U. S. Geol. Survey Misc. Inv. Map I-780-B.

__________, in press, b, Total-count gamma radiation map of the Harper quadrangle, Liberia: U. S. Geol. Survey Misc. Inv. Map I-780-C.

Hurley, P. M., Leo, G. W., White, R. W., and Fairbairn, H. W., 1971, Liberian age province (about 2700 m.y.) and adjacent provinces in Liberia and Sierra Leone: Geol. Soc. America Bull., v. 82, p. 3483-3490.

Mehnert, K. R., 1968, Migmatities and the origin of granitic rocks: New York, American Elsevier Publishing Co., Inc., 393 p.