U. S. Geological Survey.

REPORTS-OPEN FILE SERIES, No. 74- 309: 1974.

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

PROJECT REPORT
Liberian Investigations
(IR) LI-65B

GEOLOGY OF THE JUAZOHN QUADRANGLE, LIBERIA

U. S. Geological Survey
OPEN FILE REPORT 74-309
This report is preliminary and
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conformity with Geological Survey
standards or nomenclature

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

1974

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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 Juazohn quadrangle was systematically mapped by the author from December 1970 to June 1972. Field data provided by private companies and other members of the LGS-USGS project were used in map compilation, and are hereby acknowledged.

The topography of the Juazohn quadrangle is hilly and ranges mostly between 75 and 200 meters above sea level. The hilly area in the north-central part, however, is higher and culminates in Jide Mountain at more than 800 meters altitude. Much of the low-lying eastern and western thirds of the quadrangle contain thick laterite and few outcrops. Saprolite was observed in many road cuts. Traverses were made along trails, the two main roads, numerous short logging roads, and in rubber boats, floating the Cavalla, Dube, Grand Cess, Dugbe, Sehnkwehn, and Sino rivers.

Mineral exploration data of the Müller Company (unpub. data, 1968, 1969, 1970, 1971; van Griethuysen, 1970) were used extensively. Total-intensity aeromagnetic (Wotorson and Behrendt, ~~in press~~ 1974) and radiometric maps (Behrendt and Wotorson, ~~in press~~ 1974, a) were used to distinguish and delineate map units.

ROCKS

The Juazohn quadrangle forms part of the Guinean shield of West Africa and is composed mainly of quartz diorite gneiss, with lesser schist, amphibolite, iron-formation, and igneous rocks. Some of the rocks belong to the Eburnean (2,000 m.y.) metamorphic age province, but others are transitional in age between the Eburnean and Liberian (2,700 m.y.) age provinces (White and Leo, 1969-1970; and Hurley and others, 1971). Rock units are described in a sequence according to rock type, the order of which has no stratigraphic significance. Surficial and residual deposits, which commonly obscure bedrock, are not mapped separately.

Metamorphic rocks

Metamorphic rocks are classified according to the ratio of potassium feldspar to total feldspar (see map explanation), following igneous-rock terminology, with appropriate modifiers. An igneous origin is not necessarily implied. Rocks that do not fit this scheme are given descriptive names (e.g., amphibolite).

Granodiorite gneiss

The granodiorite gneiss unit (gngd) consists mainly of moderately dipping gneiss of granodiorite composition, but contains minor schist and amphibolite. In the northern part, the unit is characterized by linear magnetic highs and lows (see Wotorson and Behrendt, ~~in press~~ 1974). Southward, the pattern becomes more diffuse, broad, and flat, a pattern more typical of igneous bodies. It contains local radiometric highs (see Behrendt and Wotorson, ~~in press~~ 1974, a) in the western part, caused by small granitic intrusive bodies as much as 2 km across. Some granites are clearly discordant to the country rock, but elsewhere discordance is not obvious and there is a gradual change from granodiorite gneiss to intricately folded granodiorite gneiss locally containing pegmatites, to granite.

Granitic gneiss

The granitic gneiss (gng) is mainly of granodiorite composition but locally ranges from quartz diorite to granite. It contains minor intercalated amphibolite. The unit is distinguished on the basis of outcrops in the Harper quadrangle (Brock and others, 1974) where it has a distinct magnetic pattern. The pattern is less prominent in the Juazohn quadrangle and the boundaries are thus less certain.

Quartz diorite gneiss

The quartz diorite gneiss is divided into two units. Unit 1 ($gndq_1$) is immediately west of the Dube shear zone and is characterized by few outcrops and hilly topography. Biotite quartz diorite is the dominant rock type, but migmatitic rocks are also common. Quartzite was noted at two localities, and small dioritic to granitic bodies occur locally. Contacts of these small igneous bodies are not exposed.

Unit 2 ($gndq_2$) underlies a large area; from the Sino River to the Sehnkwehn River and northwest to the Cestos batholith, it is chiefly banded hornblende-quartz diorite gneiss, although biotite gneiss is also present. Northwest of the southeast-flowing length of the Sehnkwehn River, however, hornblende commonly constitutes 20 to 35 percent of the rock. In the central part of the area underlain by unit 2, the dominance of hornblende decreases and in the northern part biotite becomes the chief mafic mineral, commonly constituting 10 to 20 percent of the rock. Schist is locally interbedded with the gneiss. Gondite and fine-grained quartzite are present locally, and a small pyroxenitic body (u) is present north of Tibowehn. Amphibolite, which is common in map unit $gndq_2$, is locally tens of meters thick, weathers in relief, and in places defines large-scale structures easily seen on aerial photographs.

Leucocratic gneiss

Leucocratic gneiss (gnl), with minor associated schist, crops out east of the Dube shear zone and consists predominantly of banded biotite quartz diorite. Muscovite gneiss of granodiorite to granite composition is locally present. Quartz commonly constitutes 20 to 30 percent of the gneisses but may reach 50 percent.

The large area of leucocratic gneiss in the central part of the quadrangle is composed of a variety of rocks, but the widespread presence of itabirite characterizes it as an itabirite province. In much of the province, rocks are mainly leucocratic biotite-quartz diorite gneiss and biotite granodiorite gneiss. In the Juazohn area hornblende-quartz diorite is also present, along with minor amphibolite. Granitic intrusive rocks form hills in the Kahnwia area and in some places clearly crosscut the gneissic country rock. In the hilly southwestern part near Wudekehn, granite and quartz diorite intrusive bodies were noted by the Müller Company (unpub. data, 1970) along with abundant migmatites.

Leucocratic gneiss along the Cestos River commonly contains both biotite and lesser muscovite, and ranges from granodiorite to granite in composition. Pegmatites with muscovite are abundant.

Calc-silicate gneiss

Calc-silicate gneiss (gncs) occurs southwest of Pyne Town, forming resistant outcrops and low rounded hills. In one area, centimeter-thick bands of calc-silicate gneiss alternate with hornblende-rich calc-silicate gneiss layers. The rock is transitional into amphibolite by gradual increase in content of hornblende. This unit is not characterized by distinctive magnetic or radiometric patterns.

Composite gneiss

Composite gneiss is separated into two units on the basis of distribution of graphite. However, other rock types, as noted, are typical of each unit.

Composite gneiss unit 2 (gn_2) has graphite-bearing biotite-quartz diorite gneiss as its prominent rock type. In the western part of the unit, graphitic rocks form ten long parallel bands in which graphite commonly makes up about 5 percent of the rock. Narrow linear magnetic anomalies are associated locally with magnetite-bearing quartz diorite gneiss and magnetite-bearing migmatites (Müller Company, unpub. data, 1969). Clinopyroxene-bearing hornblende quartz diorite gneiss occurs locally along the Dugbe River and metamorphosed ultramafic rocks were reported by the Müller Company (unpub. data, 1970). Quartzite and amphibolite occur throughout the belt and are locally associated with manganese formation. Numerous small poorly foliated to massive quartz diorite bodies crop out in the eastern end of the unit. High-amplitude radiometric anomalies in the southwestern part of the unit appear to crosscut the regional stratigraphic and structural patterns. Limited data suggest that these are caused by small granitic intrusive bodies.

Composite gneiss unit 4 (gn_4) is characterized by low topographic relief and an abundance of dioritic to granitic gneiss, migmatite, pegmatite, and small granitic bodies. Large outcrops are generally migmatitic. Similar rocks with the same broad uniform magnetic pattern occur along strike in the Ivory Coast (Bos, 1964). Bos also described a large granite body about 9 km northeast of the Cavalla River and speculated that the assemblage of rocks reflects an unexposed granite massif. The magnetic pattern is certainly similar to those of the batholiths in the western part of the quadrangle, thus lending support to Bos' interpretation.

Schist and quartzite

Mica schist (sm) underlies hilly topography southeast of the Dube shear zone, containing an abundance of muscovite and minor tourmaline. Quartzite (q) is commonly interbedded with schist and locally contains garnet, pyrite, or hornblende as accessory minerals. Manganese formation is locally associated with quartzite. A few thin amphibolite units were also noted.

Schist (s) east of Babu is composed mainly of biotite quartz diorite and is best termed schist-gneiss. Quartzite (q), sillimanite schist, and amphibolite are also present. Isolated areas of similar rocks to the southwest in the granodiorite gneiss unit (gngd) are probably remnants of the schist unit east of Babu.

Schist along the Cestos River is partly pelitic, locally containing sillimanite and muscovite. It is a continuation of the belt of pelitic rocks extending from the Buchanan quadrangle (Tysdal, 1974) northeastward into the Zwedru quadrangle (cf. Force and Beikman, 1974).

Amphibolite

Amphibolite (am) is composed of about equal parts hornblende and plagioclase and commonly contains minor garnet. Clinopyroxene is a common accessory mineral in some amphibolite. Most of the amphibolite forms discontinuous tabular bodies that are too thin to map and are shown only as marker beds, but some are mappable units hundreds of meters thick. Many of the amphibolite bodies form ridges and have a negative magnetic anomaly of 100 to 300 gammas (see Wotorson and Behrendt, ~~in press~~ 1974).

Iron-formation

Iron-formation is represented by both oxide and silicate facies rocks. Itabirite (oxide facies) (it) is composed of magnetite (locally hematite), quartz, and minor iron silicate minerals. The magnetite content is commonly less than 25 percent of the rock, except in Jide Mountain where it reaches about 40 percent. It commonly forms linear bands marked by negative magnetic anomalies.

Iron silicate rocks (is) commonly flank the itabirite. In Jide Mountain they are composed of quartz-chlorite schist; in Ghi Mountain the iron silicate rocks are quartz-hornblende schist. Quartzite is commonly interbedded with these rocks.

Manganese formation

Metasedimentary manganese formation (mno,mns), shown on the map as marker beds, is composed mainly of spessartite with minor quartz and iron-oxide. It is resistant to erosion and commonly forms steep-sided ridges.

Igneous rocks

Mappable igneous rocks make up only a small part of the quadrangle. Diabase dikes are the most abundant and trend northwestward across the quadrangle.

Granitic rocks

Granitic bodies (gr) east of the Dube shear zone are granodiorite to granite in composition, and contain muscovite as the dominant mica. Some granites are rich in apatite and tourmaline. Coarse-grained hydrothermal veins with graphic texture and booklets of muscovite are associated with the granitic rocks (Müller Company, unpub. data, 1971). Granite pegmatites are common and contain abundant muscovite and lesser tourmaline and apatite.

Quartz diorite

Hornblende-quartz diorite (diq) underlies areas characterized by few outcrops and low-lying topography. It forms the Cestos and Sehnkwehn batholiths (Tysdal, 1974) and the Jubo batholith, herein named for the river which flows across it. The batholiths exhibit a broad flat magnetic pattern. An area of similar magnetic expression is northeast of the Cestos batholith and is assumed to represent another quartz diorite body.

Dioritic rocks

Intrusive dioritic rocks (dr) crop out adjacent to the ultramafic bodies near Juazohn, form massive rounded outcrops, and contain inclusions of the nearby ultramafic rocks. Mafic pegmatites are locally associate with the diorite.

Ultramafic rocks

Ultramafic (u) and associated rocks have intruded the country rock at Taju Hill southwest of Juazohn. The ultramafic rocks include pyroxenite (augite and (or) diopside), serpentinized dunite, and serpentinite (Müller Company, upub. data, 1970). A gravity anomaly of +40 milligals (Behrendt and Wotorson, ~~in press~~ 1974 b) and an aeromagnetic anomaly of -1,500 gammas marks the intrusive.

Syenite and trachyte

Aegirine syenite (sy) forms a resistant knoll on the southern flank of Taju Hill, within dioritic rocks of the Juazohn ultramafic complex. The syenite is locally gradational into granodiorite, both within and marginal to the syenite body, and drill cores show that it has been intruded by pegmatitic syenite (Müller Company, unpub. rept., 1970)

Sodic trachyte dikes (t) 1 to 5 meters thick locally crosscut gneisses in the Juazohn region and are probably related to the syenitic rocks.

Diabase

A swarm of diabase dikes (Jd) trends northwest across the quadrangle; the dikes form linear ridges that are commonly 10 to 30 meters high. Most of the dikes are steeply dipping. Field observations demonstrate that some are intruded along faults, and many others are believed to occupy faults. A linear negative magnetic anomaly typically caracterizes the diabase. The dikes are Early Jurassic in age (Grommé and Dalrymple, 1972).

A single north-trending dike (d) in the northeastern part of the quadrangle crosses the Cavalla River north of Drubo. It is diabasic, like the northwest-trending dikes, but its aberrent trend suggests the possibility of a different age.

METAMORPHISM

The greenschist facies of metamorphism is thought to be represented by the iron-formation of Jide Mountain, although the plagioclase composition of these chloritic rocks is unknown. Most of the rocks in the quadrangle, however, are of the amphibolite facies. The upper amphibolite facies is reached in the southwesternmost part of the quadrangle where sillimanite gneisses and clinopyroxene-bearing mafic rocks occur.

STRUCTURE

The quadrangle can be divided into three northeast-trending structural provinces. In the central part of the quadrangle, the itabirite province has gently to moderately dipping rocks in addition to local areas of steeply dipping rocks. In the adjoining province to the southeast, south of a major fault, the rocks dip steeply in isoclinal folds. In the northwest province, broad open folds are prominent, although isoclinal folds also occur.

Within this latter province is a zone of subtle northwest-trending structures that extend from the northwest corner of the quadrangle across the quartz diorite gneiss unit $gndq_2$. The width of the zone is uncertain, but along the Babu-Juazohn road it must extend at least from about Pyne Town to about 20 km southwestward. It is marked by the greatest density of diabase dikes and by both northeast-and northwest-trending structural features.

Unconformities

An unconformity separates the iron-formation of Jide Mountain from the underlying gneisses, according to J. Stobernack (oral commun., 1968, in White and Leo, 1969, p. 13). Stobernack's mapping, on which the map pattern of Jide Mountain is based (unpub. data, German-Liberian Mining Co., 1971), shows a tight syncline along most of the backbone of the mountain, and a shallow syncline at the northeastern end. Along this same trend, northeast of the mountain, itabirite dips 15° S., reflecting the low dips of rocks over much of the area northeast of the Putu Range. Thus it seems probable that all these low-dipping rocks may uncomformably overlie older rocks.

Folds

Isoclinal folds characterize the rocks southeast of the itabirite province. Most of the fold limbs dip to the south or southeast, parallel to the foliation, but some are vertical and a very few dip to the north.

In the northeastern half of the itabirite province, anticlines and synclines trend southwest and locally west. Dips on the flanks of these folds are commonly at moderate angles, but some limbs do dip steeply. The itabirite lenses in the northeastern part of the quadrangle occur within both tight, steeply dipping synclinal limbs and more open folds.

Folds in the southwestern part of the itabirite province are broad and open. On aerial photographs some of them reveal a swirly pattern characteristic of plastic deformation. In areas of swirly folds, itabirite occurs in short discontinuous lenses; elsewhere it forms long lenses. In general, areas of swirly folds show prominent topographic relief and crosscutting high radiometric patterns.

Major broad, open folds with axes that strike northwest to west occur in the structural province northwest of the itabirite province. The Müller Company (unpub. data, 1969) found isoclinal folding in rocks northwest of the itabirite province, but only open folds are prominent on aerial photographs. One of these is immediately south of Pyne Town and is unusual in that its northeastern limb contains an isoclinal recumbent fold, its axis striking about parallel to that of the major open fold.

Faults

Four major northeast-trending faults cut the quadrangle, three of which are marked by wide zones of shearing. The Dube shear zone, named after its exposure along the Dube River, is a vertical structure marked by strong linearity on the magnetic and radiometric maps (see Behrendt and Wotorson, 1974 ~~press~~ a, and Wotorson and Behrendt, 1974 ~~in press~~). The bouguer gravity map (Behrendt and Wotorson, 1974 ~~in press~~, b) shows a negative anomaly southeast of the shear zone and a positive correlation with rocks to the northwest. Brock and others (1974) noted evidence for left-lateral strike-slip movement along the shear zone in the Harper quadrangle.

The fault forming the southeast margin of the itabirite province marks strong magnetic and topographic contrasts and forms the contact between gnl and other units. Shearing was noted only in a few places along it. A low-angle fault near the northwest margin of the itabirite province is marked by a wide zone of shearing. Its continuation southwestward beyond the Putu Range is uncertain. The Cestos shear zone described by Tysdal (1974) cuts across the northwesternmost corner of the quadrangle.

Northwest-trending faults locally cut the northeast-trending faults and are emphasized by the diabase that has intruded some of them. Shearing has been observed in some of the gneisses adjacent to the diabase dikes and the strike of foliation locally changes from the regional northeast trend to northwest adjacent to the diabase. In the northwesternmost part of the quadrangle and in the adjacent Buchanan quadrangle (Tysdal, 1974), lateral movement is evident along some of the faults. Locally, magnetic patterns trending normal to the faults are abruptly truncated.

AGE PROVINCES

Three whole-rock Rb-Sr ages of rocks in the quadrangle were determined by Hurley and others (1971) and described in geologic context by White and Leo (1969-1970). Two of these (1950 m.y. and 2140 m.y.) are for intrusive granitic bodies and postdate regional metamorphism. The third (2,230 m.y.) is from a gneiss in the Jide Mountains. A 2,070 m.y. (Eburnean) date was yielded by graphitic rocks of unit gn_2 near Greenville, 1 km south of the quadrangle boundary (Hurley and others, 1971; and White and Leo, 1969-1970).

MINERAL RESOURCES

Gold is common in placer deposits of gn_2, and molybdenum is locally present in the same gneiss unit (Müller Company, unpub. data 1971). Itabirite occurences are being explored in Jide Mountain by the German-Liberian Mining Company.

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