copper sulphides and carbonates. The fractures all strike about N. 60°–70° W., and dip 60°–65° NE. Several of the prospects seem to lie along the same fracture zone. At most of the prospects the mineralization is rather scanty and consists of a little bornite and chalcocite and stains of malachite in a gangue of quartz. At several of the pits malachite was the only visible metallic mineral. The country rock is largely fine-grained purplish or reddish andesite, although a few small stocks appear to be intrusive porphyry. In all there are five principal prospects—Justin (No. 17), Reserve (No. 18), Charlestin (No. 19), Edmund (No. 20), and Caille Brulée (No. 21). These prospects are developed by small shafts and tunnels, which seem to have encountered only traces of ore and which give little encouragement for further development.

### GENERAL CONCLUSIONS AS TO VEINS.

Considerable work has been done in prospecting the veins in the Terre-Neuve district, and there seems to be enough evidence to warrant the conclusion that none of the veins are of present commercial value.

The enriched veins at Rocher, in which the tenor is rather high, are thin, or they are mere seams, and they would not warrant the outlay necessary to prospect or develop them. There is nothing to encourage the belief that these small seams will coalesce below to form veins of commercial value or that the enriched zones will extend to great depths. The silver, which constitutes the principal valuable mineral in these veins, would naturally be confined largely to the upper part of the chalcocite zone.

The larger and more persistent veins at Ravine Jeanty are only sporadically mineralized, and on the whole even the richer pockets contain only a moderate percentage of copper and little silver and gold. These veins are not enriched.

## COPPER BEARING VEINS IN PRE-TERTIARY ROCKS.

By Wilbur S. Burbank and John S. Brown.

### General Features and Origin.

Copper-bearing quartz and calcite veins carrying sulphides and iron oxides are widespread in the pre-Tertiary basement rocks in the northern part of the Republic. These veins are of late Mesozoic age and are genetically related to the regional intrusion of quartz diorite of that age. The veins are found in the intrusive rocks and in the old metamorphosed volcanic rocks and associated schists. Most of them are small but some attain widths of 40 centimeters or more. In the country rocks there are shear zones which are in places silicified and cemented by quartz for a width of several meters and which here and there contain sulphides. Large barren quartz veins were seen at a few places in the quartz diorite.

The most common association of minerals appears to be specularite, pyrite, chalcopyrite, and quartz. Many of the quartz veins contain small amounts of titanite and chlorite. The chalcopyrite in some veins accompanies later calcite. Both specularite and pyrite generally show good crystal development in the quartz. Some of the quartz veins carry pyrite and chalcopyrite but no specularite. It is reported [1] that quartz and calcite veins carrying highly argentiferous galena were found at Grande-Rivière du Nord, although no galena was seen in any veins examined during the reconnaissance.

Veinlets of primary calcite carrying pyrite or chalcopyrite occur in the volcanic rocks, especially in chlorite schist. These veins usually accompany quartz veins, and the calcite invariably appears to be of later origin than the quartz.

Many of the veins appear to have been brecciated and recemented before the chalcopyrite was introduced, the conditions indicating that movements were going on during the period of intrusive activity. Some shear zones in the quartz diorite contain quartz and pyrite but most of them contain little or no chalcopyrite.

Most of the veins occur within a few kilometers of intrusive bodies of quartz diorite or in the quartz diorite itself. The occurrence of primary specularite in some of the veins and their field association with intensely altered rocks indicate that they were formed at relatively high temperatures. Some veins containing specularite exhibit comb structure and contain cavities which indicate that they were formed by the filling of open spaces. Many of the veins, however, contain only pyrite and chalcopyrite and a few of them are not near known outcrops of quartz diorite. The alteration of the country rock and the mineral associations of the veins indicate that intrusive contacts are probably near, although possibly concealed.

Thomasset [2] reports that the quartz veins near Grande-Rivière du Nord and Limonade contain considerable quantities of platinum and iridosmium in addition to sulphides and iron oxides, but later investigators have not verified this report, and possibly the samples may have in some way become contaminated. Unfortunately, time was not available during the reconnaissance to permit a careful investigation of these reports.

Thomasset [3] also reports that some of the quartz veins carry free gold, but it probably occurs in quantities so small that its value is negligible. None of the veins have been exploited for gold.

### Enrichment of Primary Veins.

The lean primary veins have been somewhat enriched by downward leaching and redeposition, but the enrichment appears to have appreciably

[1] Thomasset, Henri, Notice sur les mines de cuivre de la Grande-Rivière du Nord: Le Moniteur, No. 45, p. 409, Port-au-Prince, 4 juin, 1904.
[2] Op. cit., pp. 408-409.
[3] Op. cit., p. 409.

affected the tenor of the veins only near Grande-Rivière du Nord. The enrichment, which is due to descending surface water, is of the ordinary type found in copper veins and has not only concentrated the copper but also to some extent, the silver. The secondary minerals are bornite, chalcocite, covellite, malachite, and azurite. This enrichment encouraged an attempt to exploit the veins near Grande-Rivière du Nord.

At other places there are small amounts of chalcocite but not enough to enrich the primary vein appreciably. The limonite and copper carbonates found near the surface were formed by the partial oxidation of the pyrite and chalcopyrite.

### Tenor of Veins and General Conditions.

The lean primary veins at every locality examined are too small or too low in tenor to be exploitable. Their copper content is low, and they contain only traces of gold or silver.

The enriched veins offer but little more encouragement to prospectors than the primary veins. Attempts to exploit the most promising veins at Grande-Rivière du Nord have been unsuccessful. The primary veins were so very poor and have been so slightly enriched that they hold little promise of yielding ore in commercial quantities. Good evidence of considerable silver enrichment, which seems to be lacking, would be necessary to warrant attempts to exploit any of these veins. The veins are very small and probably do not extend to great depths. Veins containing considerable galena as a primary mineral might contain more silver and show corresponding greater enrichment.

### General Distribution.

Veins of the types just described may be found at many places in the northern part of the Republic, where the surface formations are of pre-Tertiary age. (See geologic map, Pl. I.) The veins, however, are more abundant in the Mesozoic volcanic rocks that border intrusive contacts of the quartz diorite. Areas of the intrusive rock itself appear to be less favorable, except near their borders. No promising mineralized veins have been found in the argillites and sandstones of supposed lower or middle Cretaceous age. In general these rocks were probably too near the surface to be strongly altered or mineralized at the time of the intrusion. A large barren quartz vein was seen in the argillites near the crest of the first ridge north of Cerca-la-Source on the trail to Lamielle.

Copper veins occur in many areas that could not be visited during the reconnaissance, but most of the more promising ones were visited.

## Copper Veins Near Grande-Rivière du Nord.

### LOCATION AND ACCESS.

The copper-bearing veins near the town of Grande-Rivière du Nord have received considerable attention from prospectors. Figure 29, a map of the region around Grande-Rivière, shows the general geologic features and the approximate location of several of the more important prospects.

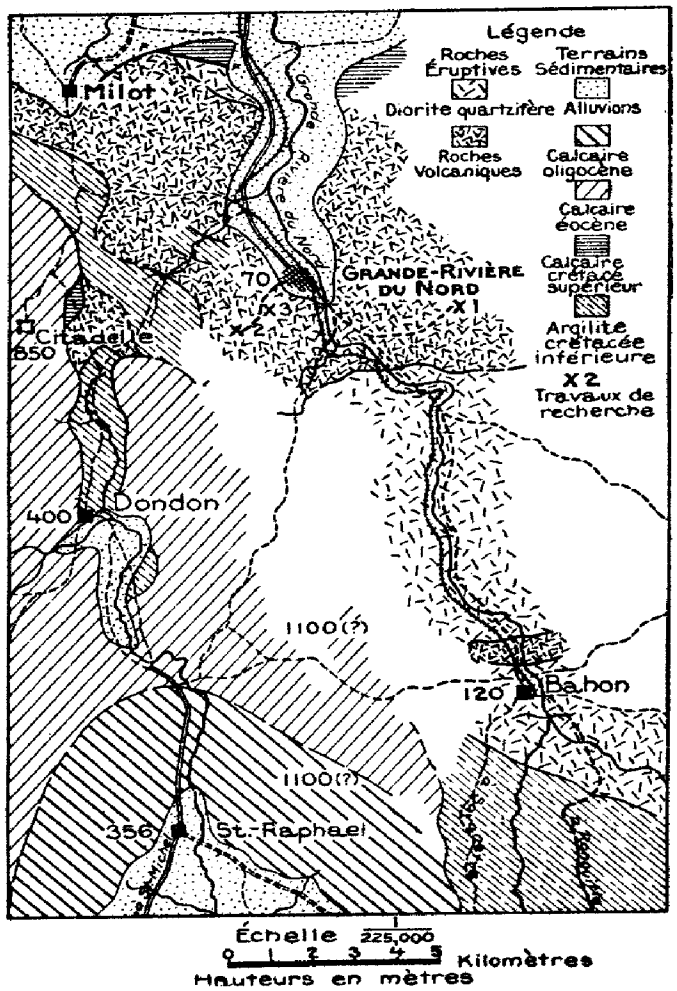


FIGURE 29.—Geologic sketch map of the vicinity of Grande-Rivière du Nord showing the location of the larger copper prospects.

The town itself is accessible from Cap-Haïtien both by railroad and improved road. The railroad extends up the river valley as far as Bahon, a total distance of 39 kilometers from Cap-Haïtien. The prospects, not all of which are shown on the map, are accessible from the river valley only by horse trails, many of which are very poor. Copper ore has been taken to Grande-Rivière du Nord on pack animals and shipped to Cap-Haïtien by railroad.

The surface rocks in the mountains consist principally of metamorphosed volcanic rocks, which are intricately dissected. The low mountains east and west of the town of Grande-Rivière rise 400 or 500 meters above sea level. The lower ridges or spurs, which extend to the sides of the river valley, stand at altitudes of less than 300 meters. The prospects at Zepiny are at an altitude of 190 meters, about 120 meters above the town of Grande-Rivière. The ridge to the north of the prospects at Zepiny rises to an altitude of 250 to 260 meters.

### GEOLOGY.

The rocks of immediate interest in the consideration of the copper veins are altered volcanic rocks, which are probably of middle Mesozoic age, and the intrusive quartz diorite, probably of late Cretaceous age. The volcanic rocks are greenish to reddish much-altered lavas, consisting principally of basalts and andesites. These rocks and the quartz diorite are fully described under the heading "Igneous rocks."

The argillites overlie the older volcanic rocks but are probably intruded by the quartz diorite. This igneous and metamorphic complex is overlain unconformably by limestones of late upper Cretaceous and Tertiary age.

Areas in which the Tertiary limestones are the surface rocks in this locality are, naturally, unfavorable for the occurrence of copper veins, and the areas of altered volcanic rocks appear to be the most favorable. Veins may also be found in the quartz diorite near the borders of the intrusion. No veins were seen in the argillite in this region.

### HISTORY OF DEVELOPMENT.

These veins, although probably known much earlier, first received serious attention in 1901, when they were examined by Henri Thomasset.[1] He obtained a concession for the district on July 26, 1901, and began prospecting on January 31, 1902. In his rather optimistic report in the Moniteur he states that in February, 1904, the total length of pits and galleries in hard rock was 290 meters (950 feet).

The work done since 1904 has apparently been intermittent and no records of it are available. According to local reports, work at Cormiers was stopped about 1915. At that time about 10 men were employed. Work at Zepiny was apparently stopped somewhat earlier, in 1913 or 1914. The inhabitants report that at times about 100 men were employed at Zepiny. Although many of the workings were flooded with water when visited and an estimate of the amount of work could not be made, it appears that the larger part of the development must have been done prior to 1904.

[1] Op. cit., pp. 408-409.

### VEINS AT HABITATION ZEPINY.

Habitation Zepiny is about 5 or 6 kilometers by trail southeast of Grande-Rivière. (See Fig. 29, No. 1.) The prospects are on both the north and south sides of the eastward trending ravine up which the trail leads from the main river valley. North of the ravine there are two tunnels, and an inclined shaft sunk in part along the intersection of two fractures. One of the fractures strikes about N. 50° E. and dips 70° NW., and a later one strikes north and dips 75° E. The principal mineralization is found along the earlier fracture and in the wall rock for a meter or so from the west wall.

The country rock is a reddish or purplish altered volcanic rock consisting near the vein largely of cemented breccia replaced here and there by quartz and albite and by some chlorite and potash feldspar. The rock is colored red by ferric oxide.

The richer ore in the veins is apparently of secondary origin, having been formed by concentration from downward circulating meteoric waters. It consists of bornite and chalcocite that are in part replaced by copper carbonates in the oxidized zone. The sulphides form veins along joint planes and impregnate the wall rock near the fissures. The brecciated wall rock contains a few sulphide veinlets, 5 to 10 millimeters wide.

Polished sections show that the ore minerals are bornite, chalcocite, and covellite. They cut the primary calcite and inclose primary quartz and specularite. The specularite and especially the calcite were apparently corroded during the secondary mineralization. Most of the specimens were taken in the oxidized zone, within 5 or 6 meters of the surface, and contain no primary sulphides, but a few showed traces of primary chalcopyrite, which, with calcite, had filled small spaces between the quartz crystals.

The veins south of the ravine contain primary quartz and subordinate amounts of calcite and supergene sulphides. They lie along a series of fractures that strike N. 10°–15° E. One of the larger veins is in places about 0.3 meter wide, and the later calcite stringers range in width from mere films up to 1 centimeter. The sulphides generally lie along stringers of calcite and consist principally of chalcocite and covellite. The veins south of the ravine contain less secondary sulphide than those north of it. The quartz is largely barren. Several small shafts have been sunk on these veins, and one on the larger vein is 12 to 15 meters deep.

### VEINS IN SECTION CORMIERS.

Prospecting has been done on several veins west of the Grande Rivière du Nord in Section Cormiers. About a kilometer west of the town (No. 3) two branching tunnels have been driven for 20 to 25 meters into a silicified zone in chlorite schist and altered volcanic rock. (For description of the chlorite schist see p. 309.) The metallic minerals are

pyrite and chalcopyrite in quartz and some calcite. Only traces of secondary sulphides were seen. The silicified breccia zone at this locality is at some places 5 or 6 meters wide, but the mineralization is very scanty. The sulphides were developed more freely along clayey gouge in the fractures. The lower tunnel was filled with water when the prospects were visited and could not be explored.

Farther southwest, at habitation La Selle, in the same rural section (No. 2), there are veins of nearly solid chalcocite in altered amygdaloidal basalt. (See p. 270.) Most of these veins are only a few millimeters wide, but at some places they impregnate the country rock in a brecciated zone so as to form small bunches of moderately rich ore. One vein, although it varies considerably, contains at one place a mass of solid chalcocite and malachite ore 5 or 6 centimeters wide.

Sections of the chalcocite ore show that it contains primary quartz, pyrite, and specularite and secondary bornite, chalcocite, covellite, malachite, and azurite. The primary copper mineral in these veins is not known, but float of quartz veins containing pyrite and chalcopyrite was seen on the hillside. Thomasset reports that cuprite was noted in the gossan of some of the veins.

### GENERAL CONCLUSIONS AS TO COPPER-BEARING VEINS.

Assays of sulphide ore from Grande-Rivière du Nord are reported to contain at some places as much as 40 or 50 per cent of copper and 3 or 4 ounces of silver per ton, and traces of gold.[1] An examination of the veins shows clearly that the samples giving very high returns were picked samples of copper minerals, most of them taken probably from the chalcocite veins. Although there are small bodies containing high-grade copper ore and small amounts of silver they are too small and scattered to mine profitably.

A sample from a vein of solid chalcocite and malachite ore at Cormiers, about 3 centimeters wide, was assayed by Ledoux & Co., of New York, and gave the following results:

*Assay of chalcocite ore from Cormiers, Grande-Rivière du Nord.*

| | | |
|---|---|---|
| Copper | per cent. | 64.38 |
| Silver | ounces per ton of 2,000 pounds avoirdupois. | 4.50 |
| Gold | ounce per ton of 2,000 pounds avoirdupois. | 0.01 |

The content of silver is low for secondary sulphide ore, indicating a lack of much silver in the primary ore.

The veins give little promise of great persistency, because they are small and because the country rock is faulted and brecciated. The chalcocitization may at some places extend laterally into the country rock for a

[1] Thomasset, Henri, op. cit., pp. 408, 409.

few centimeters or it may occur in small breccia zones, but it is generally so slight that it forms only small bodies of moderately rich ore. In following little seams of doubtful value much barren rock must be mined.

## Other Localities.

### SECTION LAS LOMAS.

About 6 kilometers northeast of St.-Michel de l'Atalaye, in Section Las Lomas, there are evidences of old mining operations, which are said to have been carried on by the Spaniards in search of gold. A stream near by is called l'Eau d'Or. This place is about 2 kilometers north of the plantation of the United West Indies Corporation, east of St.-Michel. A stream gap in the low limestone mountains on the north side of the Central Plain gives access to a small circular valley floored with volcanic rocks. A low hill at the north end of this valley, about a kilometer north of the gap, consists of metamorphosed volcanic rocks and chlorite schist. A number of veins of quartz containing some calcite carrying small amounts of pyrite and chalcopyrite crop out on this hill.

Besides the old workings, which have entirely caved in and have become grown over with trees, there is a vertical shaft about 15 meters deep and an inclined shaft about 30 meters long, which flattens out to two drifts below. These shafts were sunk on the same vein, which strikes about N. 60° W. and dips rather steeply to the northeast. According to the reports they were driven by an engineer who had been working at one time for the operators at Terre-Neuve.

The principal vein, which is at some places 30 to 50 centimeters wide, consists of quartz and some calcite and carries small amounts of pyrite and chalcopyrite. No secondary sulphides were seen and malachite and azurite are the principal alteration products of the primary sulphides. Veins of calcite and quartz carrying pyrite and chalcopyrite were seen in the chlorite schist on the east slope of the hill. The country rock at these prospects consists of altered amygdaloidal basaltic rocks, chlorite schist, and epidosite. Farther south, along the valley floor, float of partly serpentinized augite peridotite was found. Petrographic descriptions of these rocks are given on pages 287-288, and 309. The intense alteration of the rocks and the formation of the veins of quartz and calcite were probably the result of the regional metamorphism that attended the intrusions of quartz diorite. No outcrops of this rock were seen, but intrusive bodies may be concealed beneath the surface or may crop out farther north.

The veins are evidently not exploitable for copper ore and appear to contain no gold. Significantly large dumps of barren quartz and altered country rock lie near each shaft. Small piles of low-grade copper ore were also seen. The futility of attempting to exploit these lean primary veins is well illustrated by these workings.

### PLAISANCE AND VICINITY.

Innumerable small quartz veins carrying sulphides and iron oxides cut the pre-Tertiary volcanic and intrusive rocks near Plaisance and Ennery. They fill small fissures and shear zones, and are generally not more than a few centimeters wide, but at places they attain a width of 5 or 6 centimeters. The primary minerals are specularite, pyrite, and chalcopyrite. Many of the veins are stained with secondary copper carbonates and limonite. Near intrusive contacts veins carrying only quartz and epidote are found.

The country rock of the veins consists largely of much-metamorphosed volcanic rocks, which were partly converted into amphibolites during the batholithic intrusion of quartz diorite. No veins were seen in the argillites of Cretaceous age.

None of the veins examined are large enough or rich enough to be of any commercial interest, and so far as known no attempts have been made to prospect them.

### LIMONADE AND VICINITY.

Some copper-bearing quartz veins are found in the mountains that border the North Plain south of Limonade and in the low foothills and exposures of bedrock that crop out through the alluvial deposits of the plain to the north and northeast. The mountains south of Limonade are low spurs that apparently consist of metamorphic volcanic rocks, which extend northward into the plain from the main mass of the Massif du Nord to the south. According to Thomasset[1] and to local reports quartz veins containing copper sulphides, iron oxides, and some platinum and iridosmium are found in these mountains. This locality was not visited during the reconnaissance. Although the presence of copper-bearing quartz veins would be expected in the altered volcanic rocks adjoining the intrusive mass of quartz diorite to the south, the presence of platinum and iridosmium in workable quantities is doubtful. The reports concerning these deposits like those concerning deposits at Grande-Rivière du Nord, have not been confirmed.

At Morne Beckly, a low hill of pre-Tertiary schists and metamorphosed volcanic rocks about 6 kilometers east of Limonade, there are veins of quartz and chalcopyrite, which contain limonite and malachite as oxidation products. Farther east, near Le Trou, float of similar vein filling was found. These veins did not contain much primary iron oxide. Veins of quartz containing specularite and magnetite and in places epidote are described on pp. 468-469. These veins apparently are distinct from the copper veins.

### JEAN RABEL.

About 8 kilometers southwest of Jean Rabel some mineralization is found in the quartz diorite and granodiorite porphyries of Cretaceous age.

[1] Thomasset, Henri, op. cit., p. 409.

At the locality visited a small pit has been dug and a tunnel face started for a meter or two on a mineralized fracture containing quartz, chalcopyrite, and molybdenite. Both the chalcopyrite and molybdenite impregnate the brecciated quartz diorite porphyry to a slight extent near the fracture. Except for stains of malachite and limonite there are no secondary minerals and no signs of chalcocitization. These mineralized fractures are of no economic value. This is the only place where molybdenite was seen in the copper veins. The presence of this mineral probably indicates that the vein was formed at a relatively high temperature.

Altogether possibly 8 or 10 square kilometers of intrusive porphyries are exposed in this locality. Many of the porphyries are impregnated with pyrite and considerably altered. (See p. 295.) The conditions at this place do not seem to be particularly favorable for the discovery of valuable mineral deposits. The porphyries are overlain unconformably by the upper Eocene limestone, and boulders of the igneous rocks are abundant in the basal conglomerate of this formation.

## IRON DEPOSITS AT MORNE BECKLY.

By WILBUR S. BURBANK and JOHN S. BROWN.

### GEOGRAPHY AND GEOLOGY.

Morne Beckly lies about 5 kilometers east of Limonade, on the main road between Cap-Haïtien and Ouanaminthe. It is a low, dome-shaped swell, roughly 400 or 500 meters in diameter, standing about 35 or 40 meters above sea level, 10 meters higher than the surrounding plain. The hill, which is an outcrop of bed rock that projects above the alluvial deposits of the plain, consists largely of talcose, chloritic, and amphibolitic schists. The schistosity strikes about N. 30°–40° W. and dips steeply. The schist is intruded by small dikes of quartz diorite porphyry and felsite and by a number of small pegmatitic veins of quartz. Some of the quartz pegmatites have a pinch-and-swell structure that is characteristic of intrusion during deformation. Veins of quartz and epidote were seen, some of them containing iron oxides. The schists appear to be considerably deformed and are locally contorted and faulted.

The age of these schists is uncertain, but they show a degree of metamorphism greater than that noted at most other places in the Republic. Undoubtedly some deformation took place during or somewhat before the quartz diorite intrusion in Cretaceous time. The schists and intrusive porphyries are more fully described on pages 296, 308-309.

### CHARACTER AND OCCURRENCE OF ORE.

The presence of magnetic iron ore on this hill has been known for some time and is mentioned in a number of accounts published during the colonial period. Some prospecting has been done, principally by Henri