

## Geology of the Gebeit Gold Mine, Democratic Republic of the Sudan

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### Abstract

The Gebeit gold mine is located in the northern Red Sea Hills in the Democratic Republic of the Sudan. The mine probably was worked as long ago as 3,500 years. Total gold production is unknown but it is believed to be at least several hundred thousand ounces. The rocks of the mine area are mainly silicic metavolcanics of the Nafirdeib Series, a subdivision of the Basement Complex of the Red Sea Hills. The principal structures of the region are folds and faults that trend north to northeast. These structures are cut by two later sets of fractures that trend east and northwest, respectively; the latter set is parallel to, and perhaps associated with the Red Sea rift system. Gold occurs free in quartz-pyrite-arsenopyrite veins and in the adjacent wall rock. Wall rocks are altered to chlorite, epidote, pyrite, and calcite. The veins are irregular and discontinuous, and are as much as 10 feet thick. Gold mineralization is due to hydrothermal activity thought to be related to emplacement of Young Granite in the late Precambrian or early Paleozoic.

### Introduction

THE Gebeit gold mine is in the northern Red Sea Hills, in the northeasternmost part of the Democratic Republic of the Sudan, at latitude 21°04'N and longitude 36°19'E (Fig. 1). It is considered to be the oldest mine in the country and in recent times has been the biggest and most efficiently worked of the Sudan mines.

The Gebeit mine area has been visited by many geologists since the beginning of this century, but no detailed geologic work has been done prior to this investigation. Llewellyn (1903), Dunn (1911), and Hume (1935) reported on the gold-bearing rocks in the Gebeit area and compared them to the Egyptian gold mines. Twitchell (1932) described the Gebeit mine and its production. In 1936 Grabham made a reconnaissance trip from Port Sudan to Halaib via the Gebeit and Oyo gold mines (Grabham, 1940). Ruxton (1956) discussed the nature of the country rock and veins mined in Gebeit. Gass (1955) mapped the Dungunab sheet, including the area of the mine, and his map is incorporated in a report by Gabert, Ruxton, and Venzlaff (1960). Geologists of the Sudan Geological Survey have visited the mine from time to time and have discussed its geology in unpublished reports.

This paper summarizes part of an investigation carried out during a visit to the Gebeit area in 1968. Mineralized veins, mill tailings, and country rock were sampled, and selected material was analyzed for gold and silver. Other specimens were studied under the microscope. Panned concentrates were analyzed to identify the heavy minerals associated with gold.

### History of the Mine

Archaeologists date the start of gold mining in the northeastern Sudan as the Pharaonic age, some 3,500 years ago. Crushing stones, working tables, and ruins around the old gold mines indicate an active and systematic mining industry; in fact, ancient mine ruins are found at every modern gold mine in northeastern Sudan. The mines were operated efficiently by the ancient Egyptians, and were largely worked out when they finally were abandoned.

The recorded history of the Gebeit mine begins in 1903 when the Gebeit Mining Syndicate was registered. This company continued working the mine until 1933, but little is known of its activities and production. According to Twitchell (1932), about 60,000 tons of gold-bearing rock with an average gold content of 43.5 grams/ton (1.39 ounces/ton) was extracted from the Gebeit mine between 1914 and 1931, representing a value of £320,000 Sterling. In 1933 Gebeit Gold Mines was registered and started working the mine. This company installed a counter-current decantation plant to extract gold from the tailings using the cyanide process, erected five stamps in addition to the five already present, and built a dam for water storage. An average of 4,600 ounces of gold was produced annually from the tailings and crushed rock between 1933 and 1942. In the annual report of Gebeit Gold Mines for 1935-1936, as reported by Whiteman (1971, p. 221) the estimated grade of mill heads is given as 10.7 dwt/ton (0.535 ounces/ton) and that of tailings as 4.13 dwt/ton (0.206/ton). Because of labor shortage caused by World War II, operations of Gebeit Gold Mines stopped in 1942.

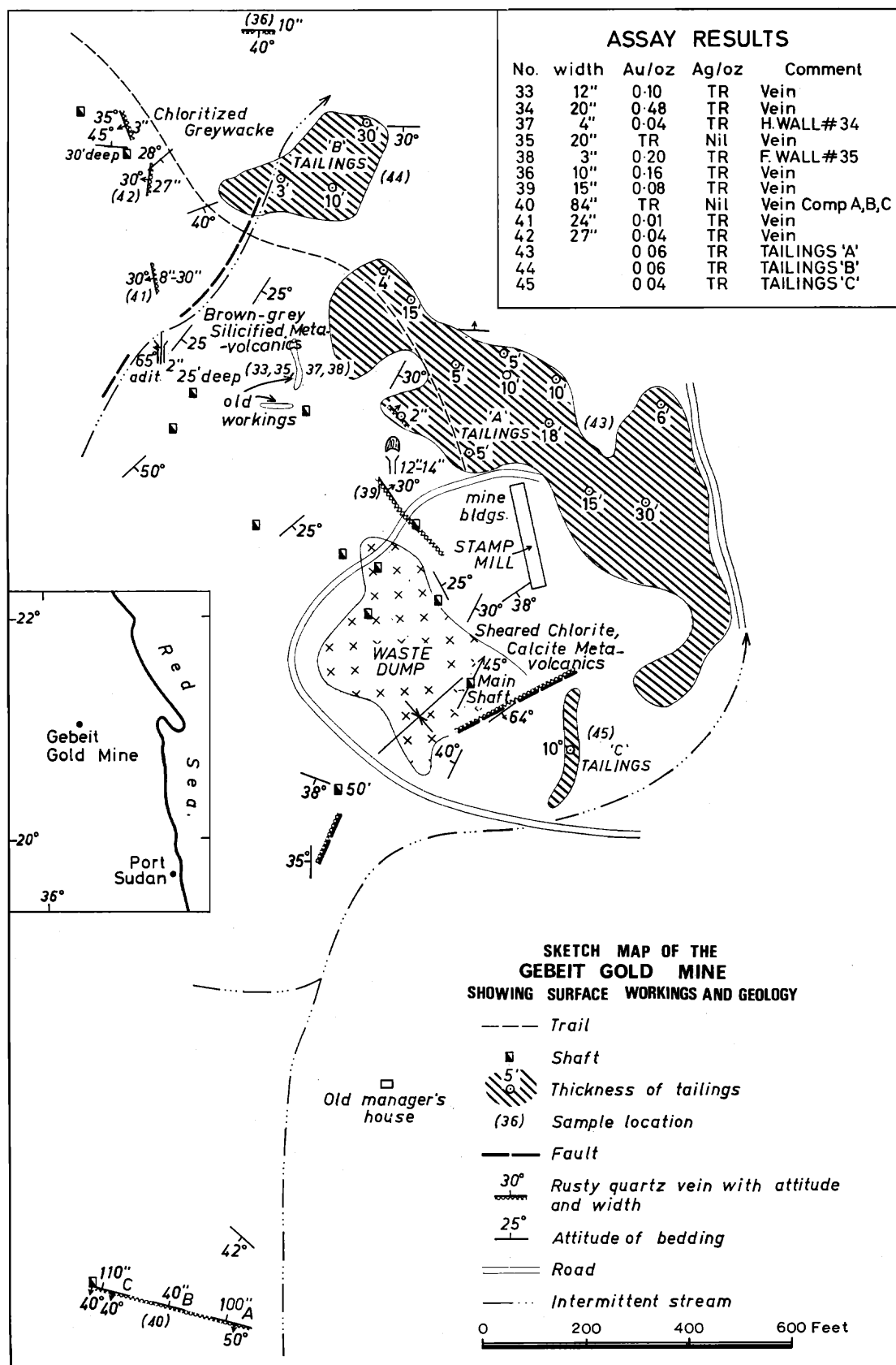


FIG. 1. Sketch map of the Gebeit gold mine area, showing surface workings and geology.

Atabai Gold Ltd. was established in 1947 and worked the mine until 1953 when its manager and owner, Mr. Bishop, died. The mine was then closed for three years during which time the main shaft flooded, thus limiting later development to the upper 60 to 70 feet, whereas previously the mine had been worked to a depth of 670 feet (Gass, 1955).

At present the mine is owned by a group of Port Sudan merchants, one of whom manages the work. Mining operations are primitive and on a very small scale, and the equipment used is old and obsolete. About 30 miners work underground at shallow depths. Crude ore is crushed in an ancient stamp mill, and gold is recovered from the finely crushed material by amalgamation. Between one half and two ounces of gold are extracted per day.

### General Geology

The Gebeit mine lies in the northern Red Sea Hills, which are underlain mainly by rocks of the Basement Complex, usually considered to be of Precambrian age. According to Ruxton (1956) the Basement Complex can be divided into three major sedimentary-volcanic divisions and four main groups of igneous intrusions. The subdivisions given by Ruxton were adopted by Kabesh (1962, p. 58) and discussed by Lotfi and Kabesh (1964) and by Whiteman (1970). From oldest to youngest, these subdivisions are:

- i) Primitive System: schist, silicic gneiss, and slate.
- ii) Nafirdeib Series: green andesitic tuff, agglomerate and meta-andesite with minor meta-dacite, quartzite, limestone, and graywacke. The rocks are typically green, and pyrite is abundant.
- iii) Basic intrusions: larger gabbroic masses in rocks of the Primitive System, and norites that cut calcareous members of the Nafirdeib Series.
- iv) Awat Series: gray, massive silty mudstone with some conglomerate. Andesitic lava occurs at the base of this series.
- v) Young Granites: these cut the Nafirdeib and Awat Series. Kabesh (1962) groups under the term Young Granite the following types:
  - 1) Microcline granite
  - 2) White granite
  - 3) Pink-red granite, mainly coarse grained and unfoliated.
- vi) Silicic, intermediate and basic dikes: swarms of dikes that cut the Young Granites. Dike rocks include quartz porphyry and quartz dolerite.

### Geology of the Mine and Surrounding Area

Figure 1 is a sketch map showing surface workings and the geology of the immediate mine area, and Figure 2 is a photogeologic map of the region

around the mine. The mine lies within the Nafirdeib Series, which in this area comprises interlayered andesite, trachyandesite, albitophyre tuff, and basalt. Individual beds range from a few meters to hundreds of meters in thickness.

The rocks of the mine and the area near it are highly crushed, fine-grained silicic volcanics that range in color from dark green to brownish green. They are highly sheared mylonitized and pseudoschistose, and crystals of quartz and orthoclase are distinctly elongated. Under the microscope the rock is seen to contain large crystals of albitic plagioclase imbedded in a groundmass of tiny subhedral crystals of quartz, orthoclase, albitic plagioclase, and epidote. Both phenocrysts and groundmass are highly altered to chlorite and sericite. Pyrite, epidote, and iron stains are found along the fractures. The rock is much weathered, especially along the fractures, and gray clay and zeolites have formed. Closely spaced fractures formed during a later episode of shearing and fracturing contain idiomorphic crystals of calcite. This set of fractures is the cause of the pseudoschistosity. Rocks are heavily pyritized and colored green by chlorite, serite, and epidote.

The silicic volcanic rocks are interbedded with layers of albitophyre tuff that are as much as two meters thick. These albitophyres are massive, dark brown, and contain well-developed crystals of albite as well as xenomorphic quartz. They are stained conspicuously brown by iron oxide.

In the northwestern part of the mine, and also about five miles from it, the rock is fine grained, green, sheared tuff composed of pyroclasts of feldspar and quartz imbedded in a matrix of glass. In hand specimen the rock resembles graywacke. It is strongly altered to chlorite and sericite, especially along fractures.

Massive, green, slightly foliated basalt intrudes the silicic volcanic rocks and tuffs in many places. The basalt is composed of microphenocrysts of plagioclase and augite, epidote, calcite, and iron oxide. The groundmass is altered to chlorite, sericite, and zoisite. The rock contains many amygdules filled with chlorite, calcite, actinolite, and epidote.

The Gebeit mine is in a part of the Sudan in which generally north- to northeast-trending structures prevail (Vail and Rex, 1970). The mine itself lies in the middle of the series of folds trending northeast. A major syncline passes just northwest of the Gebeit mine and extends northeastward to the coast. Beds in the limbs of the syncline dip between 25° and 60°, and most of the dips are about 35°. The syncline is flanked by anticlines that have the same northeasterly trend.

The area is highly faulted, and three sets of faults can be identified on aerial photographs. One major

set trends northeast, parallel to the trend of the folds, and a second less conspicuous set trends east; these two sets seem to be contemporaneous. A third set trends north-northwest and appears to be the youngest of the three as it cuts across and offsets both the other two. It is parallel to the Red Sea Rift Valley and may be associated with it. Stream valleys (called khors and wadis) are structurally con-

trolled, and most of the larger ones follow the lines of major faults as is evident from the clear trellis pattern of streams, especially in the southeastern corner of the area (Fig. 2).

### Gold Deposits

The ore deposits at the Gebeit mine are gold-bearing quartz veins that strike between  $10^{\circ}$  and  $30^{\circ}$

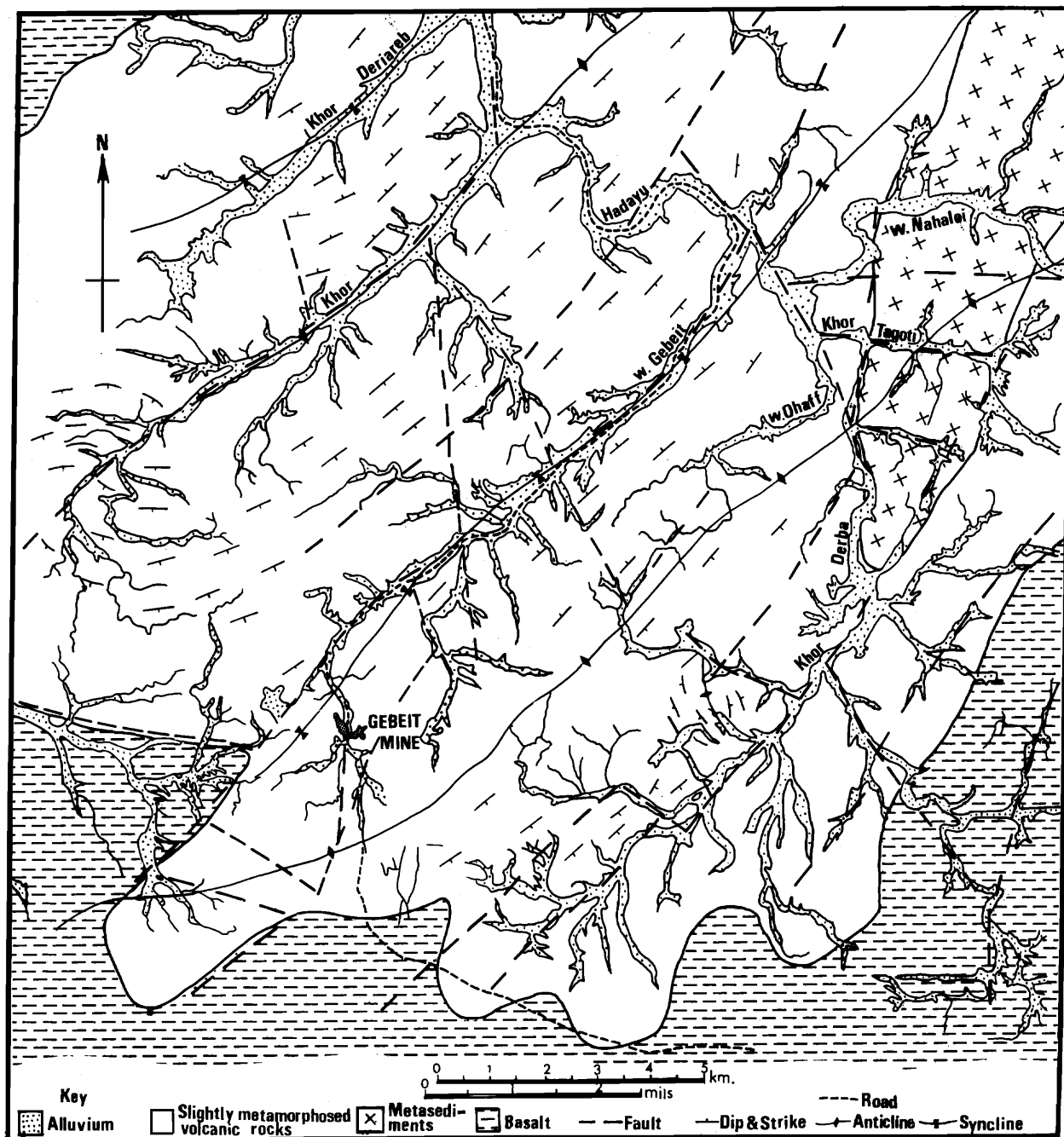


FIG. 2. Photogeologic map of the region around the Gebeit gold mine.

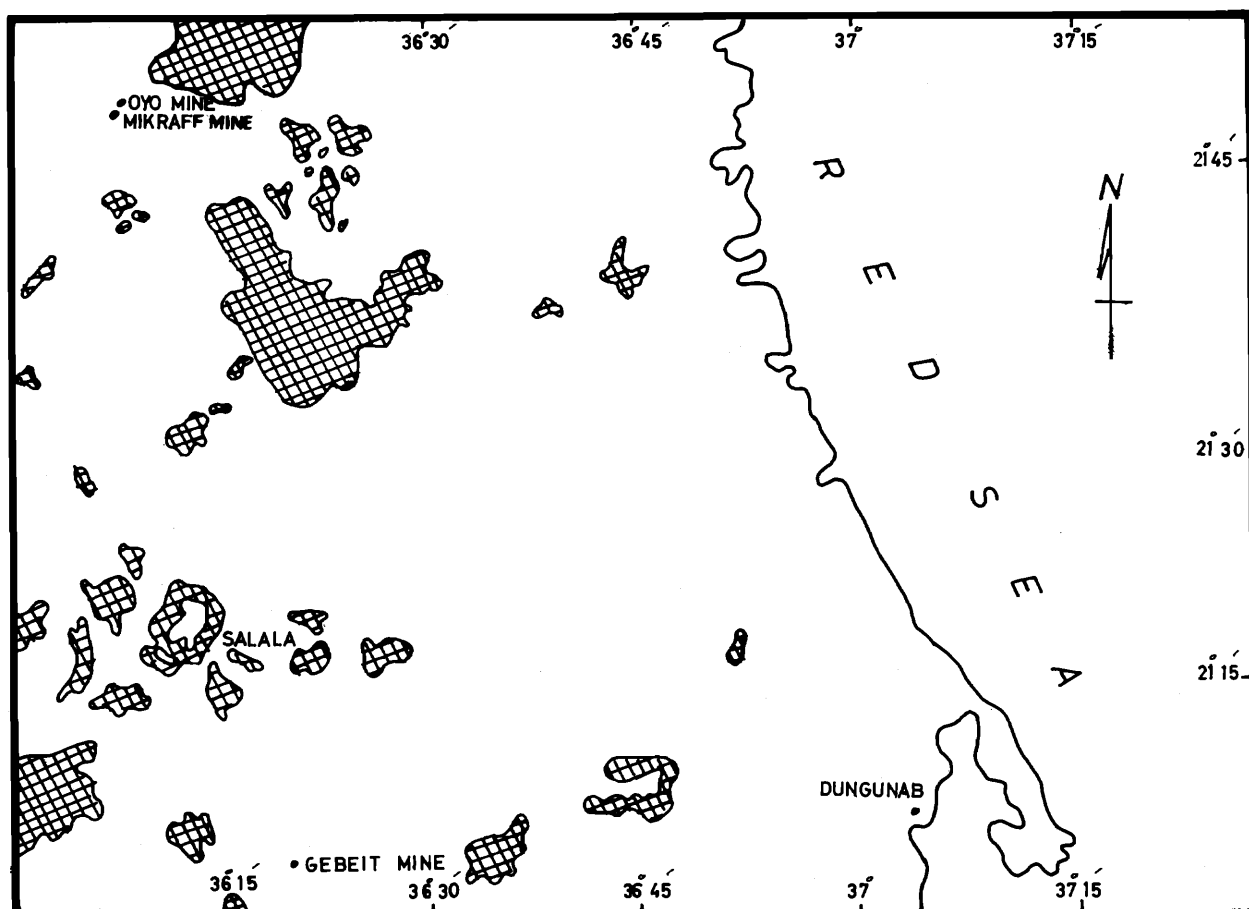


FIG. 3. Map of the Dungunab sheet, Red Sea Hills, Sudan, showing Young Granites (after Gass, 1955).

west of north and range in thickness from 3 inches to 10 feet. The veins generally follow fractures, but are irregular and in places cut unfractured country rock. They rarely continue for great length. Drusy and comb structures indicate that they have formed by filling pre-existing cavities. The silicic volcanic wall rock around the quartz veins is highly altered to pyrite, chlorite, and epidote, especially along the fractures. The quartz ranges from colorless to light blue. Metallic minerals are gold, pyrite, and arsenopyrite. The gold is free and is mainly concentrated in quartz veins, though country rock adjacent to the veins also carries gold. Some of the veins, as well as the country rock, are iron stained and contain a fine-grained red ochreous material resulting from the weathering pyrite.

Under the microscope the gold-bearing veins show coarse euhedral to subhedral crystals of quartz with undulatory extinction. The quartz crystals are parallel and are fractured perpendicular to the trend of their long axes. Some of the fractures are filled with secondary quartz crystals showing graphic

texture. Arsenopyrite and well-developed cubes of pyrite are also present along these fractures. The rock shows late fracturing like host rock, and calcite has been deposited along these later fractures.

The veins as well as the country rock have been assayed for gold and silver. Figure 1 shows results of some of the analyses done by Prospection Limited Company of Canada. Gold content of veins ranges from trace amounts to as much as 0.48 ounce per ton, and averages 0.11 ounce. Two assays of country rock gave an average of 0.12 ounce of gold per ton, about the same as the veins. The tailing dumps, which are estimated to contain 130,000 tons (A. P. Hutchinson, personal communication, 1969), averaged 0.6 ounces of gold per ton. According to workers in the mine, the higher gold assays are given by iron-stained and otherwise altered rock. Only trace amounts of silver were found in any sample.

It was reported by Llewellyn (1903) that the concentration of gold increases with depth. Although this theory has not been investigated during the present study, workers in the mine agree with it.

### Age of Mineralization

Gold mineralization at the Red Sea Hills, and northern Sudan, according to Gass (1955, p. 89), is associated with the emplacement of Young Granites. Gass based his conclusion on the proximity of Young Granites to the Oyo and Mifraff gold mines (Fig. 3). DeKun (1965, p. 311) states: "The auriferous quartz veins have been injected in the aureoles of small stocks. East of Luxor bend of the Nile and in the southern border of Egypt a series of veins follow the southern contact of an elongated batholith." Ruxton (1956, p. 327) relates the mineralization of galena and chalcocite near Dirbat well, 36°28'N, 19°54'E, to a vein of quartz that was derived directly from the Red Granite group of the Young Granites. Furthermore, according to Almond (1967, p. 10), the Young Granites are responsible for the tin mineralization in the Sudan and Nigeria. Accordingly it seems possible that the gold mineralization at Gebeit is also associated with the intrusion of Young Granite. Young Granite crops out a few miles west and east of the Gebeit area, and about 20 miles north, Young Granites in the form of a ring structure appear at Salala (Fig. 3).

A dike of Young Granite has been dated by the potassium-argon method, whole rock, at about  $740 \pm 80$  m.y. (million years) (Hamashaweib, in Whiteman, 1968 and 1970, p. 128). Almond (1967) gives ages of Young Granites in Sabaloka (Sudan) as ranging from  $476 \pm 25$  to  $540 \pm 25$  m.y. (potassium-argon whole analysis for biotite-muscovite granite and porphyritic microgranite, respectively). These age determinations suggest that the Young Granites may be of more than one age, and further research on the Young Granites and their possible association with mineralization is clearly needed.

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