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MINISTRY OF MINERAL RESOURCES
GEOLOGICAL SURVEY
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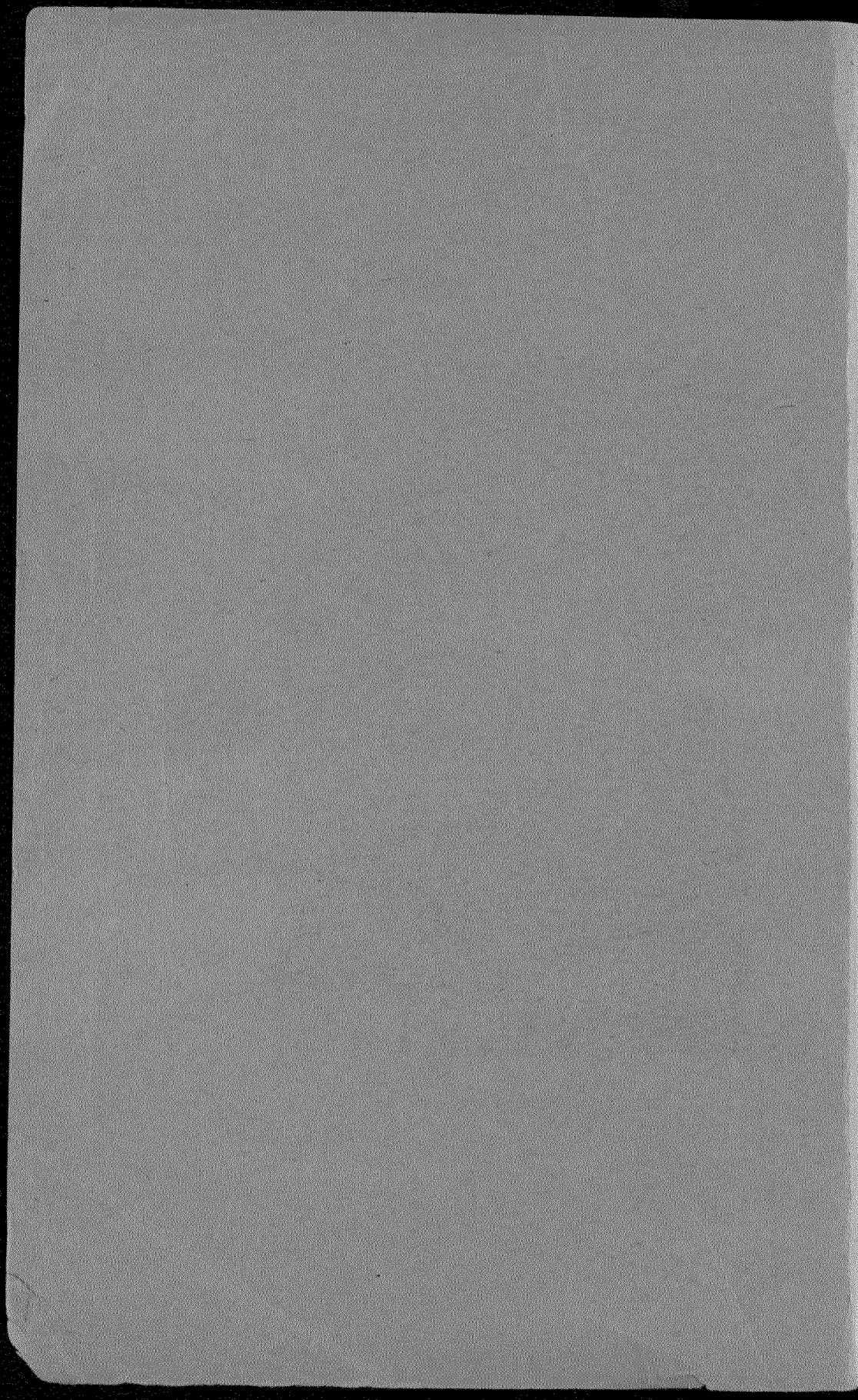
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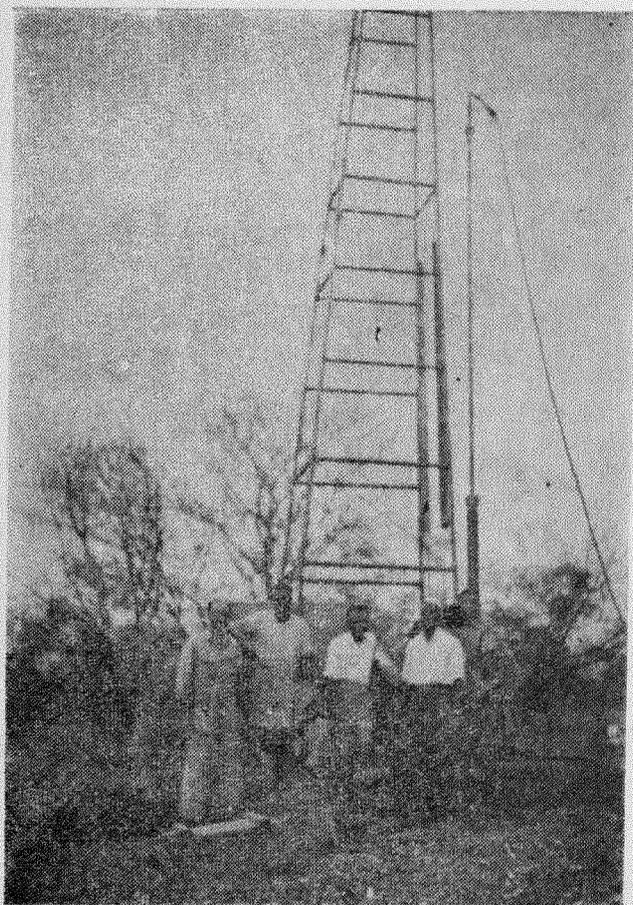
AN INVESTIGATION OF HOFRAT EN NAHAS
COPPER DEPOSIT,
SOUTHERN DARFUR

By

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A diamond drilling rig in position at Hofrat En Nahas

PREFACE

The Hofrat Mine had a prolonged and rather spectacular past. It was worked about the middle of the 19th. Century by the natives and smelting was done locally at the mine and the copper was then transported to the different parts of the country. The means of mining and treatment were of course very rudimentary and only the shallow and soft ore was removed. Apparently towards the end of the 19th. Century the workings became uneconomical and the mine was finally abandoned.

The mine was known in many parts of the world and was thus visited by a number of expeditions during its exploitation by the natives and later. However, it was never the object of serious enterprise at the time. In 1920 a concession was granted to the Nile Congo Divide Syndicate covering the area of the mine. This company did some prospecting work by shafts, bore-holes and trenches in the mine till 1925 when they gave it up because of its remoteness from existing means of transport. Two other expeditions visited the mine in 1948 and in the fifties, and in 1957 the Geological Survey of the Sudan started its investigation of the mine which is the subject of this report.

The mine was offered for exploitation in 1961 and was leased late that year to the African Mining Corporation. By the time this report reaches the hands of its readers, it is anticipated that some practical steps would have been taken to initiate the exploitation of Hofrat.

This work will be the inauguration of proper mining operations in this country, and will be a model for future mineral exploitation. It will also, no doubt, start a chain of social and economic reactions and developments in the communities in southern Darfur province which will bring them up to the standard of the better developed parts of the country. The operation of the mine will also start some dependant industries which will help in the industrial development of the country.

It is hoped that the opening of the Hofrat mine, will be the beginning of a sustained development in the mining industry in this country.

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CONTENTS

PAGE

ABSTRACT

INTRODUCTION	2
Location of the Mine	2
History	2

PREVIOUS WORK

Nile Congo Divides Syndicate's Work	5
Messina Company's Work	20
Anglo-American Corporation's Work	21

PHYSICAL CONDITIONS

Topography	24
Roads and Communications	24
Climate and Vegetation	25
Inhabitants and Occupation	26

REGIONAL GEOLOGY

The Older Plains Group	29
The Younger Group	30
Intrusives	32
Superficial Deposits	33
Tectonics	35
Ironstone	36

FIELD WORK BY THE GEOLOGICAL SURVEY EXPEDITION

Auger Boreholes	38
Trenching	40
Radiometric Survey	42

BORE-HOLES LOGGING OF THE PRESENT INVESTIGATION

Old Shafts	51
Bore Holes	55

	PAGE
PROFILE LINE (A)	56
Bore-hole No. III	56
Bore-hole No. I	61
" " " II	65
" " " IV	66
" " " VII	70
" " " VIII	73
PROFILE LINE (B)	74
Bore-hole No. V	74
" " " VI	78
" " " IX	83
" " " X	87
PROFILE LINE (C)	89
Bore-hole No. XI	90
" " " XII	91
" " " XIII	92
" " " XIV	94
Bore-hole No. XV	97
Bore-hole No. IV (Abandoned)	104
 GEOLOGY OF HOFRAT MINE	
Rock Formations	106
Mineralization	110
 EVALUATION OF HOFRAT MINE	
 COPPER ORES SOUTH WEST OF HOFRAT	
Jebel Bishura	125
Jebel Waranga	126
Jebel Yirongo	128
Jebel Jumbana	128
Jebel Gulmara	128
 SUMMARY AND CONCLUSIONS	
	129

LIST OF FIGURES

FIGURE

1. Key map, Scale 1 : 4,000,000.
2. Location map, Scale 1 : 250,000.
3. Aerial photograph, Hofrat workings encircled.
4. Sketch plan of main surface workings and bore-hole (N.C.D.S.).
5. Plan of bore-holes, near the south shaft (N.C.D.S.).
6. Section 1 (N.C.D.S.).
7. Section 2 (N.C.D.S.).
8. Section 3 (N.C.D.S.).
9. Section 4 (N.C.D.S.).
10. Magnetic Survey Chart (Messina).
11. Reconnaissance map in the neighbourhood of Hofrat (Anglo-American Corporation).
12. Auger bore-hole sites.
13. Sketches of trenches (14 plates).
14. Radio-activity chart.
15. Regional geological map, Scale, 1 : 3,000,000.
16. „ „ „ „ Scale, 1 : 2,000,000.
17. Hofrat mine, topographical contour map, Scale, 1 : 1,000.
18. Profile sections of the lodes (6 profiles)
19. Distribution of outcrops, Hofrat Mine.
20. Location map of Hofrat area.
21. Topographical contour sketch of J. Yirongo.
22. „ „ „ „ of J. Waranga

LIST OF ILLUSTRATIONS

PLATE I.

- Photo. A.* Muscovite-quartzite, Yirongo West.
Photo. B. Tourmaline bearing pegmatite, microcline shown, Bore-hole III.
Photo. C. Amphibolite, Bore-hole II.
Photo. D. Contorted epidote-biotite-Chlorite schist, Bore-hole XIV.

PLATE II

- Photo. A.* Biotite-Chlorite schist, with sulphide dissemination, Bore-hole IV.
Photo. B. Quartz-felspar-biotite-hornblende gneiss, Bore-hole XII
Photo. C. Tremolite-Talc, schist, with sulphide dissemination, Bore-hole I.
Photo. D. Talc schist, with tourmaline, Bore-hole IV.

PLATE III

- Photo. A.* Microfolding in felspar-sericite schist, Bore-hole XV
Photo. B. Amphibolite with tourmaline, Bore-hole VI.
Photo. C. Pyroxenite, Bore-hole X.
Photo. D. Stringer of Chalco-pyrite with epidote, in a country rock of quartz-plagioclase-chlorite schist, Bore-hole XV.

PLATE IV.

- Photo. A.* Quartz-tourmaline rock (tourmaline, sieved) Bore-hole III.
Photo. B. Chlorite-plagioclase-quartz schist, with injected tourmaline, Bore-hole XV.
Photo. C. Sulphide mineralization, replacing calcite, along cleavage planes, Bore-hole XV.
Photo. D. Vug filling, with chalcedonic quartz and malachite, Bore-hole IV.

PLATE V.

- Photo. A.* Chalco-pyrite embedded in a matrix of calcite, Bore-hole XV.
- Photo. B.* Malachite and Chryso-Colla, Bore-hole IV.
- Photo. C.* A stringer of chalco-pyrite in a gangue of quartz and calcite, Bore-hole XV.
- Photo. D.* A stringer of sulphides, enclosing bits of tourmaline, Bore-hole VII.

PLATE VI

- Photo. A.* Malachite and Azurite, cementing fragments of quartz, J. Yirongo.
- Photo. B.* Angular fragments of pyrite, cemented in quartz, Bore-hole VII.
- Photo. C.* Native Copper, rimmed with cuprite and embedded in calcite, Bore-hole XV.
- Photo. D.* Two specks of gold, embedded in chalco-pyrite, Bore-hole IV.

PLATE VII.

- Photo. A.* Crystal of pyrite, embedded in chalco-pyrite, Bore-hole IV.
- Photo. B.* Dissemination of pyrite cubes, in country rock, Bore-hole VI.

Plate A. *Chalcocyanus* embedded in a matrix of calcite. Bone
 Plate B. *Alabaster* and *Pyrite*. Bone No. 11.
 Plate C. A fragment of *Chalcocyanus* with a matrix of quartz and
 calcite. Bone No. 12.
 Plate D. A fragment of *Alabaster* containing bits of *Chalcocyanus*.
 Bone No. 13.

THE VII

Plate E. *Alabaster* and *Pyrite* containing fragments of *Chalcocyanus*.
 Plate F. *Alabaster* fragments of *Pyrite* embedded in *Pyrite*.
 Plate G. *Native Copper* found with *Chalcocyanus* and embedded
 in calcite. Bone No. 14.
 Plate H. Two species of *Gold* embedded in *Chalcocyanus*. Bone
 No. 15.

THE VIII

Plate I. Crystals of *Pyrite* embedded in *Chalcocyanus*. Bone No.
 16.
 Plate J. Distribution of *Pyrite* veins in country rock. Bone
 No. 17.

Plate K. *Alabaster* and *Pyrite* containing fragments of *Chalcocyanus*.
 Bone No. 18.

Plate L. *Alabaster* and *Pyrite* containing fragments of *Chalcocyanus*.
 Bone No. 19.

Plate M. *Alabaster* and *Pyrite* containing fragments of *Chalcocyanus*.
 Bone No. 20.

Plate N. *Alabaster* and *Pyrite* containing fragments of *Chalcocyanus*.
 Bone No. 21.

ABSTRACT

Hofrat En Nahas copper mine has been well known in the Sudan and abroad for a very long time. It was worked by the native tribes of the area during last century and probably until the beginning of this century.

The main exploration work on the mine, was previously undertaken by the Nile Congo Divide syndicate, a subsidiary of Tanganyika Concessions during the nineteen twenties. However, later visits by mining experts have also left some information on the mine.

The Geological Survey undertook a serious evaluation of the mine during 1957 and the following two work seasons. The findings of this investigation are the subject of this report. The mine is located in Southern Darfur, about two miles south of the Umm Belacha river. It is in the form of two lodes extending in a N.E. to S.W. direction with a branch lode running N.N.W. to S.S.E. at their eastern extremity. The mineralized area is approximately 900 x 400 metres and is conspicuous as a result of the pits of the old workings of the natives.

The country rock in the area of the mine, is comprised of metamorphosed old sediments and associated intrusive rocks, which are all presumably of pre-cambrian age. The rocks represented in the area include chlorite schist, sericite schist, acid gneisses, amphibolites and talc schists.

These rocks were subjected to intense shearing and shattering and the later-mineralizing emanations, were injected along the shear planes. The ore in the mine is mainly chalcopyrite and pyrite occurring in a gangue of vein quartz and calcite. The mineralization is apparently associated with intense tourmalinization. The ore in the oxidation zone, above the water table, (at 100' depth) is mainly malachite with minor chrysocolla and azurite. Gold was detected in the mineralized area together with some uranium minerals.

This ore can be considered as of epigenetic origin with supergene enrichment in the upper horizons of the mine.

The investigation by the Geological Survey of the Hofrat mine, proved the existence of over ten million tons of ore, containing on the average about 2.78 per cent copper. This represents the ore reserves down to a depth of 500 ft., being the greatest vertical depth of bore holes put down in the area.

In the hill ranges to the South West of Hofrat, copper occurrences were recorded on and off, along a strike extending to 18 miles away from Hofrat. This strike runs in a N.E. to S.W. direction and the occurrences of copper remain to be investigated in detail as an asset for the mine.

INTRODUCTION

Location of the Mine

The Hofrat mine is located in south western Darfur at latitude $9^{\circ}45'$ and longitude $24^{\circ}18'$. It is about 2 miles south of the Umm Belacha river, a tributary of Bahr el Arab, and lies slightly off the motor track from Nyala and Buram to Raja, in Bahr El Ghazal Province. The mine is about 220 miles from Nyala, the present railway terminus, and slightly under 200 miles from Da'cin, the nearest point on the railway (Fig. 1.).

HISTORY

It appears that the ore has been worked intermittently over an extended period of time by Kreish natives from the district.

The mines were abandoned about 1897, before the time of the Khalifa's defeat.

During the years 1838-1839, Burgrath Russegger, the Austrian mining authority, was commissioned by Mohammed Ali Pasha, the then Ruler of Egypt, to explore the mining possibilities in the Sudan. Concerning copper, Russegger wrote the following in his report:—

“The copper comes from the mines of Hofrat Petah Nahas, lying south of Darfur, about the 10th degree of the northern latitude and is sent as an article of commerce to Darfur, and thence in the main to Kordofan. Brown saw it in the form of great rings, each weighing 10 to 12 pounds. What I, on the contrary obtained from the merchants of Kordofan, was in the shape of small granules, doubtless the original form in which the copper comes from the workings, which, according to the description of the Negroes, resembles the process employed in Kordofan for iron. This copper is of a light yellowish colour, extremely fine and pliable, and so pure that I was unable by any reagent to detect traces of any other metal in it.”

Russegger tried in vain to obtain specimens of the ore that contains this copper. The natives asserted him that it was found in a pure state as such, immediately beneath the surface, so that it was worked with very little trouble. Under such conditions it would be easy to accept the production of the pure metal by native processes, a thing that would otherwise be almost incredible.

Hofrat was visited in 1876 by Purdy's expedition and some information could probably be obtained from his records. It was then visited in 1903 by Colonel Sparkes who reported the mine abandoned but with signs of native villages still evident. Selected samples of Colonel Sparkes, assayed in Khartoum, showed a 14 per cent copper content. He reports that the abandonment, coincided with the first Mahdist rising, “when Ibrahim Murad and his people, the former inhabitants, went to Kafia Kingi, which is now the nearest village.”

In the "Handbook of the Sudan" issued in 1898, the following is written:—

"Hofrat en Nahas is situated in a plain half a mile from the right bank of the Bahr-el-Fertit; N. latitude $9^{\circ}48'23''$, E. longitude $24^{\circ}5'38''$.

The famous copper mines lie 1,000 yards south-west of the village, 100 feet above the river. The vein runs north-west and south-east, and sticks two feet above the ground. In 1876, $500' \times 50' \times 9'$ had been dug out. This ground is very rich in almost pure carbonate and bi-carbonate of copper, only the richest parts worked and smelted on the spot in clay furnances and numerous other old workings.

The caravan roads from Dem Nduggo to Darfur traverse the region of Hofrat en Nahas where the renowned copper mines exist. These mines are about five days journey north of Mango land. The copper is brought into market in the shape of rings or cakes, but no systematic mining is carried on by the natives."

Again, in the "Supplement to the Handbook of the Sudan, 1899" there is a hint which reads as follows:

"Incredible as it may seem to those who do not know the history of Bahr-el-Ghazal, the veins of copper of Hofrat en Nahas, which are celebrated throughout the Sudan, have never been the object of serious enterprise, although in Europe attention was drawn to them over fifty years ago."

The mine was visited in 1918 by Mr. Burgess-Watson (then Inspector, Raga District), who obtained samples with a view to opening up the property. The ore was reported to have stuck up in ridges above the surface, which is quite probable.

In 1920, a concession was granted to the Nile-Congo Divide Syndicate. This concession covered an area of 60,000 square miles, in both Bahr-el-Ghazal Province and Managalla Province (the latter is now Equatoria Province). The Nile-Congo Divide Syndicate was a subsidiary of the Tanganyika Concessions Ltd. The Syndicate carried out prospecting work for different minerals such as gold, with special interest in the copper ores of Hofrat en Nahas and the other localities to the south west. The work in Hofrat area continued till the end of 1925, including numerous geological traverses, trenching, sinking shafts and boreholing.

In 1948, Dr. T. D. Guernsey and Mr. P. E. Fairbairn spent six weeks on a reconnaissance trip in the Hofrat area. Then, during 1954, Mr. Maxwell McGuinness applied for a licence to explore the old Hofrat Mine but his application was refused. A Geological Commission sent by the German Democratic Republic in 1956, made a current investigation in the Provinces of Bahr el Ghazal and Darfur and recorded a few observations on the Hofrat deposit.

The Geological Survey Department of the Sudan commenced its own investigations in February, 1957. The field work lasted for three successive seasons, comprising detailed topographical contour mapping, digging trenches, boreholing and a radiometric grid survey. Meanwhile, a short visit was paid to other occurrences of copper which lie to the south west of Hofrat, namely Jebel Bishura, Jebel Yirongo and Jebel Waranga.

At the time of the Geological Survey party's visit, the site was quite deserted. Few native settlements are scattered nearby; the nearest village is Songo, which lies on the northern bank of Khor Umm Belacha. The main occupation of the people there is agriculture. There is no single survivor among the elderly natives who remembers any mining activity that took place during his life-time. The Geological party found many slag heaps beside the old workings. The slag still retains minute globules of copper. This is an obvious indication that treatment of the ore was not confined to native copper and that former miners must have utilised the carbonate and probably the oxides as well. As regards the method of mining and smelting, there was no clue left for any interpretation. The old diggings had long collapsed and there is not a single smelting furnace left. It is said that at one time, after the abandonment of the mines, part of the slag was re-smelted for a final extraction of the remaining copper globules.

PREVIOUS WORK

The real tentative prospecting operations were done by the Nile-Congo Divide Syndicate staff. The importance of their work rests mainly on the fact that they left a good deal of written records.

Nile Congo Divide Syndicate's Work :

The Syndicate was granted a concession for prospecting over an area of about 60,000 square miles in 1920. The field work started in January 1921 and was directed by the mining Engineers: A. B. Thomson and J. Grabham Bower; and the Geologist F. T. Mansfield. During the working seasons of 1921 and 1922, numbers one and two vertical shafts were driven, together with some pits and trenches. Shaft No. 1 was sunk to 64 feet, and from that depth a 5' x 4' cross-cut was driven for 101 feet. No. 2 shaft was carried to a depth of 76 feet, and from that depth a 5' x 3' crosscut was driven for 93 feet. Other crosscuts were made at varying levels. Two pits were also sunk, one to a depth of 50', the other to 17'; and three trenches, one 36' x 3' x 13' deep, another 20' x 4' x 18' deep with a leg 8' deep. The investigation continued till June 20th, 1922, when heavy rains necessitated the cessation of operations. Water level had apparently not been reached in either of the two deep shafts. Gold was to be found, Mr. Thomson states, in all the lodes in more or less degree. Some non-copper bearing ferruginous quartz veins yield very good tails of gold, attaining in some cases 11 to 12 dwt. per ton. The replacement ores also yielded good gold.

No. 1 shaft, crosscut, disclosed a body of rich malachite, gold-bearing ore, 22 feet in width. As the result of his survey of Hofrat, Mr. Bower calculated that the old workings of such well defined character represented a reserve of 20,000 tons of copper ore per foot of depth, or 20,000,000 tons for a depth of 1,000 feet, with a reasonable gold content.

As soon as the rainy season precluded further work at Hofrat, Mr. Bower and Mr. Thomson proceeded to examine the chain of malachite outcrops discovered by the latter in the hills to the south west of the old mine. These copper and gold bearing lodes, were found by the Company to be far more extensive than had been supposed. These lodes, numbering 6 to 7 main occurrences and several small ones, extend nearly continuously over a distance of 18 miles, their general trend being directly towards Hofrat (Fig. 2).

In his report, Mr. Bower states that: "the wide spread distribution of copper-bearing outcrops over such a large area makes the speculative possibilities enormous"

At that stage of work, the Company reached the following conclusion: "It is clear that the value of these lodes is for the present purely a matter of speculation, but, Mr. Bower says, taking the main west lode and assuming that it is continuous, as it appears to be, for a distance of 18 miles and that the width averages 50 feet, it would be equivalent to 400,000,000

tons of ore for a depth of 1000 feet. It is more than probable that all this strike would contain payable mineral, but if only a small fraction of it is assumed to do so, the tonnage would still be considerable, apart from the Hofrat mine."

"Flux material, such as dolomite and limestone, have not yet been located within reasonable reach of Hofrat, and timber if required in any quantity might have to be brought for several miles."

No. 1 shaft was originally a native working which went down 33 feet at which depth a small oxidized quartz stringer containing copper and gold had been followed for a short distance. During the 1921 season, the old working was deepened to 35'6" and then a short crosscut was driven towards the lode. The following season this shaft was carried down to a depth of 64 feet and a crosscut 5' x 4' was driven at 193 degrees for 100 feet. The latter crosscut encountered a lode 50 feet in width dipping south at 72 degrees. At 19'6" from the side of the shaft, a ferruginous quartz stringer, dipping at 72 degrees and carrying copper and gold, showed in the face. This corresponded to one observed in the former crosscut at the 35'6" level. Again, at 24 feet, in the deeper crosscut, a second stringer of a similar nature and dip showed up. A ferruginous quartz stringer also showed on the west side of the crosscut and continued to run parallel with it till the lode proper was entered at 34 feet from the side of the shaft. From 34 to 50 feet, a distance of 16 feet, quartzitic ore (kaolin and schist) showed. From 50 to 70 feet, a distance of 20 feet, a very rich porphyry replacement ore with complete kaolinization, was passed through. From 70 to 84 feet, a distance of 14 feet, schist, partially kaolinized, contained stringers of ferruginous quartz ore, carrying copper (Fig. 4).

From this it was concluded at that time, that the hanging and footwall sides of the lode, are of a lower grade, with a rich central portion 20 feet wide.

At 48 feet, a small part of an old working showed in the west side of the crosscut near the top, and again from 53'6" to 63' for the full height of the side of the crosscut indicating that it went to a greater depth. On the east side, the old working only showed for a distance of 2 feet down from the top of the crosscut. In the area of the old workings the ore was very rich. Chalcocite was found at this point, the specimens being ringed round with malachite. Traces of azurite were noticed at a point 12'6" from the side of the shaft.

According to Mr. Bower, the cross cut would seem to be in a narrow portion of the lode. No. 3 shaft, which was sunk in 1921, helped him to confirm this. It was sited at a point 36 feet west and 12 feet south of No. 1 shaft, and went down to a depth of 31 feet, exposing boulders of a similar ore. From the presence of chalcocite, azurite and pyrites in the trench on the surface, he felt justified in assuming that rich sulphide ores are to be found below water level. He considered that although the hanging and footwall formations are of lower grade, the cheapest method of mining would be to mine the ore body across its entire width.

No. 2 vertical shaft was laid down in the north lode. It ran through debris for 17 feet. From there onwards, to a depth of 40 feet, the formation was a soft schist, and at this point a rich quartzitic ore vein showed on the south side of the shaft, passing out in the north side at 47 feet. This was thought to be a branch vein. From this point to where the work of sinking was stopped, at a depth of 76 feet, the formation was again a soft schist rather dark in colour.

At 76 feet a 5' x 3' crosscut was driven for 93 feet at 318 degrees. Owing to numerous slips in the formation it was found necessary to use timber in several places.

From 4' to 9'6", vein stuff in the form of schist, kaolin and oxidised matter containing veins of quartzitic ore, was passed through. From 19' to 33'6", a distance of 14'6", an ore body, formed of small veins of oxidized quartz ore intersected with kaolin, felspar and porphyry, was passed through.

From 43' to 56'6", a distance of 13'6", a form of felspathic dyke highly coloured with malachite, and also containing tourmaline, mica, kaolin and schist, was passed through. For the next 18 feet the formation was faulted and shattered schist. From 75 to 80 feet, a very hard, rich, siliceous quartzitic ore was passed through. The formation from there onwards was again schist. At 93 feet the work of crosscutting was stopped.

Owing to the faulted and shattered nature of the formation in this area, of which there was no visible indication on the surface, the crosscut did not show a well defined ore body as in the south lode crosscut, and it was difficult to state definitely what its actual width was. After the completion of that crosscut, the mining engineers were inclined to consider the north lode as dipping northward at 70 degrees, with a width of at least 72 feet.

In a report to the Syndicate, Mr. Thomson describes the copper ore localities to the south west of Hofrat. The party sent out to explore that area, stated that they found malachite staining in Jebel Bishura, and on following it up, discovered a copper lode striking at 35 degrees. It starts at the bottom of the north end of the Jebel, and runs right to the top, a distance of roughly half a mile. The formation is of dense, dark hard rock, provisionally termed trap rock.

Measured across the strike, the lode varies in width from 12 feet and 20 feet at the bottom to 100 feet at the top of the hill. The mineralization also extends into the country rock, and faint staining of malachite could be traced along the top of the hill for a considerable distance. Panning yielded traces of gold, and there were signs of extensive leaching.

The report described Jebel Yirongo North as formed of the same trap rock containing copper and gold. The strike of the lode is 35 degrees, running from the bottom north end, right up to the top of the hill, and varying in width from 5 to 25 feet. Panning yielded malachite, gold and pyrites. In Jebel Yirongo South, the same dark trap rock, (the copper

bearing formation) was again picked up. The malachite starts about two thirds of the way up the north slope and runs right to the top. The south peak, 300 yards distant, is similar and in both instances the copper is strong. Thirty feet down the western slope of the south peak there is a totally different formation of copper bearing quartzitic ore. The lode strikes at 39 degrees, with a best width of 30 feet. They recorded the occurrence of copper in four other hills around J. Yirongo.

They then reported on the presence of a copper bearing outcrop three quarters of a mile before reaching the northern end of Jebel Waranga West. Malachite staining was slight but quite definite. Ascending the Jebel itself, copper was again found in a formation similar to that in which the other lodes occurred. It could be traced here and there with breaks along the top of the hill.

Copper was also discovered on Jebel Waranga East. This could be an entirely different lode, as it strikes at 44 degrees, probably accounting for the Jebel Zanad deposit. On the flats, three quarters of a mile from J. Waranga and at the same strike, there was another outcrop. In the valley between Jebels Waranga West and East, there were other exposures on a hillock striking 20 degrees.

Jebel Zanad was stated by Mr. Mansfield to enclose a series of small copper workings. That deposit showed some malachite-bearing, ferruginous quartz reefs, giving some gold in the pannings.

The Syndicate's experts noticed no outcrops on the flats between the hills. Jebel Serrie, with the same dark trap rock formation, contained very faint but definite stainings of malachite. Three places were noticed where the natives seemed to have made attempts to work the copper, but evidently gave up owing to the hardness of the formation.

The summary report on the work done by the Syndicate during 1923-1924 included more information. The assay results of samples taken from the south shaft crosscut are as follows:—

Over length of	38'2"	=1.1%	cu. and	15	grains	gold/ton.
" "	"	16'9"	=1.7%	" "	13	" " "
" "	"	23'9"	=6.3%	" "	15	" " "
" "	"	23'0"	=0.7%	" "	0	" " "

The assay results of samples from the north shaft crosscut are as follows:—

Over length of	17'2"	=0.6%	cu. and	0	grains	gold/ton
" "	"	14'7"	=1.1%	" "	22	" " "
" "	"	18'9"	=0.8%	" "	11	" " "
" "	"	14'7"	=1.3%	" "	4	" " "
" "	"	10'8"	=0.6%	" "	0	" " "
" "	"	16'9"	=3.5%	" "	0	" " "

It was realised that the formation, is kaolinized gneiss with schists having foliation planes dipping 25 to 30 degrees to the north, and the mineral veins, chiefly of carbonate ore, cut this rock at steep angles having a dip of 70 to 80 degrees to the north on the north side and a similar dip to the south on the south edge of the deposit.

The report also included information about the copper strike extending from Bishura (to the south west of Hofrat) through Yirongo and Waranga to Khor Serrie (a distance of about 18 miles). The following are the assay results of various samples taken from surface outcrops from different places on these deposits :

Average of 5 samples from Waranga west ridge gave 2.8 per cent copper and 7 grains gold per ton.

Average of 2 samples from Waranga east ridge gave 1.6 per cent copper and 4 grains gold per ton.

Average of 4 samples from southern end of Waranga gave 4.8 dwt. of gold per ton.

Average of 3 samples between Waranga and Khor Serrie gave 1.5 per cent copper and traces of gold.

Single sample from tributary of Khor Serrie gave 4.8 dwt. of gold per ton.

Average of 2 samples from Jebel Yirongo gave 4.7 per cent copper and 14 grains gold per ton.

Single sample from Bishura gave 3.04 per cent copper and a trace of gold.

The strike of the deposits was extended in a south westward direction from Khor Serrie by the discovery of 6 further locations of copper outcrops, viz : at Jebel Jambana, Khor Vungreni, Jebel Morai, Jebel Kyria, Jebel "A", and finally in the bed of Khor Adda near Jebel Nebi, a few miles from the border of French Equatorial Africa (Republic of Central Africa). These all showed copper minerals chiefly malachite, with some chalcocite and chalcopyrite associated with iron oxides and in some cases the outcrops have been worked over by the natives.

These discoveries made the total length of the copper strike from Jebel Bishura to Jebel Nebi about 55 miles in length. All the occurrences in this extension of the strike showed the presence of gold when panned.

Crystalline limestone, suitable for fluxing purposes, had been discovered at Khor Ndingo and Jebel Nagdi, close to the west of the line of the copper deposits. Ironstone deposits suitable for fluxing purposes have been found at various localities.

On Jebel Zanad a total of about 350 feet of trenching was done and 10 samples taken and sent for assay. These assays averaged 0.52 per cent copper and 16 grains of gold per ton. The formation there consists of a

highly ferruginous quartzite with a north-south strike and a dip of 50 degrees to the east. There are five reefs, each about 2 feet wide which appear to be traversed by a N.E.-S.W. fault, marked by a line of low hills of indurated rocks. The average of 10 samples taken by Mr. Mansfield from surface outcrops in 1921 gave 5.2 per cent copper and 9 grains of gold per ton.

The Jebel Jungai deposit is situated about 6 miles to the west of Kafja Kingi and is traceable for 700 yards in an E.N.E. direction. It consists of ferruginous quartz lodes in a ferruginous quartzite and schist country with gneiss. There are native workings on the northern end; and the southern 300 yards show a series of parallel cupriferous veins from 6 to 18 inches wide. A total of about 650 feet of trenching was done on the outcrops of the reef to an average depth of 6 feet and samples were taken for assay. Three shafts were also dug, No. 1 at the southern end of the deposit, 20 feet deep; No. 2 in the middle part of the strike, 36 feet deep with a 20 feet crosscut at the bottom; and No. 3 at the north end of the strike was 30 feet deep. Twelve samples were taken for assay and gave the following results:—

Shaft No. 1 samples at surface 2.9 oz. gold/ton

„ „ „ 2 samples at 22' depth 6.5 dwt. gold/ton.

„ „ „ sample at 25' depth 5.0 dwt. gold/ton.

„ „ „ „ „ 28' depth 1.2 dwt. gold/ton.

Copper averages 2.3 per cent in shaft No. 1 samples.

Shaft No. 2 samples at surface, 7.6 dwt. gold/ton.

„ „ „ „ „ 16' depth 1.0 dwt. gold/ton.

„ „ „ „ „ 22' depth 3.4 dwt. gold/ton

Copper averages 5.4 per cent in shaft No. 2 samples.

Trench B sample, 4.4 dwt. gold/ton.

„ F „ 3.4 „ „ „ and 1.2 per cent copper

„ I „ 7.6 „ „ „ „ 3.5 per cent copper

The three trench samples were taken from the portion of the strike between shafts No. 1 and No. 2. The crosscut from the bottom of shaft 2 showed only traces of gold in pyritic quartz stringers in depth, with small amounts of malachite and chalcopyrite. The assay results as well as the panning results showed that there is a superficial enrichment of the gold at the surface, but on the other hand the copper results seemed to improve with depth, due probably to superficial leaching. The copper in those samples occurred as malachite, chalcocite and chalcopyrite with traces of cuprite.

The summary report of the work accomplished during 1925-1926 was particularly rich in information.

Messrs. Higham, MacLeod and Cayley left El Obeid on 27.11.1925 by motor car for Kafia Kingi, a distance of 614 miles. This was the first time the journey had been accomplished by car. After this, a monthly car service was run throughout the dry season up to May, 1926. This was very successful as regards saving of time, as the journey from Khartoum to Kafia Kingi could be made in about a week.

In February, 1926, Higham made a preliminary report on the copper mines. He said the rock at Hofrat is schist and gneiss; at Waranga, it is largely quartz porphyry; at Bishura it is quartzite, while at Zanad it is granitic in type.

On both flanks of the Hofrat mine there are quartz-hematite lodes and similar lodes are developed on Bishura and between the Waranga ridges and on Waranga west ridge. Similar lodes are developed at Yirongo, Zanad, Jungei and near the copper outcrops to the east of Kafia Kingi.

At Waranga the central quartz-haematite lode is closely associated with granite intrusion. The copper development occurs in quartz, cemented, crush or shatter zones forming the adjacent ridges. At Hofrat, the rich ore, occurring at shallow depths, was supposed to be associated with country rock, which has been intensely altered by kaolinization and related reactions. All the copper developments seemed to be in faulted ground and the richest ores are in the shattered parts of the country.

Higham regarded the Hofrat mine as a complicated trough fault, the so-called north and south lodes being the mineralized walls, the trough being the sunken area in the centre. This trough was subsequently traversed by two main diagonal faults, of which, the western one is the largest but is unmineralized, while the smaller transverse fault is represented by the so-called 25 degrees branch lode. The intensely dislocated area is about 900 yards by 400 yards, and the rocks were considerably broken up by the faulting, and this permitted easy alteration by subsequent nearby intrusions. Mineral dissemination has been fairly general throughout the zone, but was most intense along the fault planes themselves. The central unmineralized transverse fault is probably of a later date than the others.

The main country rocks are granite, porphyrites and chloritic schists, but there are some porphyry intrusives, whose strike is not along the lines of mineralization. These have suffered decomposition along with the other rocks so that they were probably intruded some time prior to mineralization.

The Hofrat ore is mainly associated with quartz as a pyritic quartzose ore, and as silicified and kaolinized gneiss with pyrite impregnations. This ore was formed in a hydrothermal zone of medium depth. The ores have been considerably enriched both in copper and gold values near the surface by secondary reactions, and these richer surface ores afford no guide to the value of the primary ore in depth. The primary ore appears to be a

cupriferous pyrite and not true chalcopyrite. In some of the bores, the pyrite, in parts, carried very little copper. It seemed unlikely that a clear-walled lodes will occur, but there may be moderately rich cement shoots of ore in the fracture zones at Hofrat.

During May and June, Higham completed his examination of the southern western extension of the Bishura-Waranga strike of copper deposits, far as the source of the Adda river near the border, and made a general geological examination of that part of the country.

The following is a summary of the geology of this line of country: Broadly speaking, the rocks of this north portion of the Bahr el Ghazal may be divided into two main groups,

" A " An older group of rocks comprising

(1) An important formation (well developed at K. Ledada) of limonitic mangesia silicate rocks, which are probably the highly metamorphosed remnants of calcareous clay beds, and are now largely epidotized with frequent talc developments. They have occasional carbonate residues and some graphite. There are also some occurrences of crystalline limestone with siliceous zones.

(2) Other schistose types represented by true quartzites, quartz mica schists and certain spotted bands in the older gneisses.

(3) An extensive series of more or less altered (kaolinized) gneisses which occasionally become more basic. They may partly represent ancient granitic rocks which have become foliated by earth movements but more generally represent early injections into the older calcareous and schistose rocks. They are frequently epidotic and are sometimes garnetiferous. They are typically developed near Jebel Njoro. Closely related to these are the gneissose pegmatites, with much quartz injection which occur at Jebel Morai and other places along the mineralized belt.

(4) Certain highly fractured and mylonitic quartz reefs recemented by later mineralizing influences.

" B " A younger group of rocks: which represent a later, probably extended, period of igneous activity and earth movements, which had a dominant N.E.-S.W. axis of development and obliquely crossed the general more northerly strike of the older rocks. These rocks comprise:

(1) A series of fresh (unkaolinized) granites which are generally porphyritic and seldom gneissic, but have occasional flow structure developed. They occur as intrusions into the older rocks. At Jebel Jungai, the rock is a biotite granite with some hornblende and sphene, but at Ambinji it is tourmaliniferous, while at Hofrat it has pink felspar, well developed. Certain syenite and porphyrite intrusions into the older rocks probably belong to this group.

(2) Certain fresh gneisses, well developed at Khor Ndongo, are probably local variants of the last series occurring as injections into the older gneisses and schists with a marked discordance of foliation strike. These gneisses are also, sometimes, tourmaliniferous.

(3) A prominent granular quartz rock, having haematite crystals and some kaolinized felspar, occurs in many places and notably at Jebel "A," and is closely related to the last two series of rocks.

(4) A series of veins and gash veins of quartz-haematite type and certain ferruginous quartz injections cement older fractured quartz reefs. These veins show patchy values in copper and gold.

The earth movements, which accompanied this later period of igneous activity, resulted in much faulting and crushing of the older rocks, and was followed by a period of mineralization which frequently occurred in the older rocks themselves, rather than in the newer intrusions. The metamorphosed calcareous rocks proved to be of a type very favourable for mineral replacement. The mineralisation was broadly of two types:

- (a) mineralization by replacement in favourable rocks described above.
- (b) mineralization of the crush and shatter zone and fault planes, resulting from the earth movements.

The mineralization along the whole belt is almost entirely of the quartz-haematite type, which has in many places been accompanied by small copper-gold values, which were, almost certainly, carried by original pyrite. Where the rocks of the calcareous (Ledada) series have formed the country rock of the veins, there has been a more intense deposition of haematite as specularite or micaceous haematite along with an accompanying increase in the valuable metals.

There has been much oxidation of the lodes near the surface, particularly where they are richest in iron. There has been a resultant mechanical surface concentration of gold and a painting of the rock with copper stains. In no case were the outcrop values found to increase in depth and they almost invariably grew poorer. There is however, an increasing amount of mineralization as one proceeds northwards from the source of the Adda river near the border. This mineralization reaches its culmination at the Waranga deposit. The detailed examination of this deposit however, has given unsatisfactory results from an economic point of view, and Higham considered that, apart from Hofrat, none of the other mines can be regarded as a possible asset.

In the same report of 1925-1926 the Syndicate gave a somewhat detailed account on boreholing that has been carried out at Hofrat el Nahas mine itself. Ten boreholes have been put down by diamond drill on this deposit. Six of these bores were placed along what was called the south lode. Bores 1, 2 and 7 were put down inclined towards the lode from the south; and bores 8, 9 and 10 were put down with an inclination

towards the reef from the north side. Borehole No. 3 was put down from the north side of the north lode in the north west part of the mine. Owing to caving of the hole, the rods jammed at 140 feet and the hole had to be abandoned. No. 4 bore was put down in its stead, a little nearer to the lode. The No. 5 hole was put down to the south of the north lode opposite No. 4 hole. No. 6 hole was put down in the central part of the mine near the 25 degrees branch lode. Considerable trouble was experienced with all these boreholes owing to the shattered nature of the ore body and the return water was frequently lost, so that the cuttings could not always be obtained. The percentage of core made was also low so that the records for the holes are very incomplete and this fact must be taken into account when appraising the results obtained.

The following are the principal assay results from the work done:—

Section No. 1 (Fig. 6)

No. 1 Borehole to south of the south shaft (south lode) inclined 70 degrees towards lode.

From 171' to 189' along rods=18' depth or 6.4' width gave 0.61 per cent copper (oxide zone).

From 189' to 219' along rods=30' depth or 10.7' width gave 0.085 per cent copper.

From 219' to 235' along rods=16' depth or 5.7' width gave 0.04 per cent copper.

From 235' to (bottom)=34' depth or 12.1' width gave less than 0.01 per cent copper.

No. 8 Borehole to the north of the south shaft inclined 70 degrees towards lode opposite No. 1 bore. This borehole was continued to 400 feet depth, where it had to be stopped because of the caving of the hole causing the rods to jam fast. Core recovery was only 16.2 per cent.

From 190' to 270' depth the ground passed through was only slightly mineralized; and from 270' to 300' it was more mineralized but samples were not perfect enough to give reliable assays.

From 300' to 394' along rods=94' depth or 34' width gave 1.96 per cent copper.

The south shaft between the above boreholes has a crosscut driven to the S.S.W. at 64' below the surface. This was sampled by Mr. Bower in 1922, giving variable and patchy values. The average of these values showed:

From shaft to	55'	average	1.4	cu. over 40' width across strike.
„	55'	„ 75'	„ 7.1	„ „ 15' „ „ „
„	75'	„ 102	„ 1.0	„ „ 20' „ „ „

The north east shaft was put down on the north side of the north lode workings to 60' depth and a crosscut driven to the S.E. for 100'. This crosscut only exposed some small veins of ore and apart from these, there were only traces of copper as carbonate stainings in the country rock, where the north lode should have been cut through.

From these results it was seen that the No. 1 borehole showed more than traces of copper below the oxidised zone which extends nearly to the 190' level, and there is no evidence of its having cut the extension in depth of the ore shown in the S.S.W. crosscut from the south shaft. There is also no evidence of having cut any depth extension representing the 25 degrees branch lode. It was subsequently supposed that the dip of the ore zone must have changed in depth from a south to a northern dip and the No. 8 borehole was put down to see if this was the case. The result appeared to confirm this view and it appeared from the results as if the ore cut in the S.S.W. crosscut was represented by material cut by the borehole No. 8 below 300' depth along rod.

Unfortunately, the borehole entered a cavity between 390' and 400' depth which caused the rods to jam and prevented drilling to greater depth. This was most unfortunate, because the drill was still in ore so that it was impossible to correlate exactly the ore cut by the drill with that cut by the cross-cut. It however appeared to show, that the south lode ore body in this part of the mine extended from the surface to near the 400' level as a zone over 45' wide across the strike and assaying about 2 per cent of copper. There is no special evidence that this borehole cut any depth extension of the 25 degrees branch lode.

Section No. 2 (Fig. 7)

This is a section perpendicular to the 25 degrees branch lode.

The W.N.W. crosscut from the south shaft at the 64' level was driven for 101'; and the branch lode ore body was cut between 71' and 86'6" and samples gave an average of 10¼ per cent copper over this width. The dip in the crosscut was 75 degrees. Apart from this, only a few stringers carrying traces of copper were cut in the shaft.

The No. 6 vertical borehole was put down about 150' further along the strike to N.N.E. from the south shaft and at a distance of 200' from the outcrops. This borehole entered the ore body at 200' vertical depth and gave the following assays:

From 200' to 236'	or	36'	rod depth	=	7.46%	copper
„ 236'	„	341'	„ 105'	„	2.39%	„
„ 341'	„	355'	„ 14'	„	0.44%	„

The hole was subsequently deepened to 383' and in this extended part of the hole the pyrite mineralization, with the exception of a small vug at 356', amounted to little more than a trace; and below 364' pyrite was particularly absent. No samples for assay were taken of this part of the borehole.

From the section it was seen that the $10\frac{1}{4}$ cu. ore cut in the crosscut was represented by the $7\frac{1}{2}$ per cent cu. ore cut in the borehole just below the 200' level and showed an average dip from the level of about 65 degrees. The lower grade ore (2.4 per cent cu.) below this did not show up in the crosscut at the 64' level.

They thus found evidence of a zone of ore, some 60' wide across the strike and assaying from 2.4 per cent to 10 per cent. cu., extending from the surface to below the 300' level in the branch lode.

Section No. 3 (Fig. 8)

This section is across the south lode at the eastern end of the mine.

The No. 7 borehole was put down on the southern side of the lode and inclined to the lode at 70 degrees as with the No. 1 borehole. It was drilled to 300 feet depth along rods. At 135 feet along the rods there was a 3" pegmatite vein with some malachite. The first traces of pyrite were met at 200 feet rod measure and these traces of pyrite continued to the bottom of the hole. There was no definite ore body in this hole. The core from 214 to 215 feet assayed 0.1 per cent cu. and all other values were less than this. From 199 to 215 feet the assay average was 0.045 per cent of copper.

The No. 10 borehole was put down from the north side of the lode and inclined towards it. The full results of this borehole were not given, but the mineralization was generally very patchy. There was a fairly good ore band at 250' to 255' along rods and some further mineralization from 316 to 326'.

From these indications it appeared that, although there was some evidence of the south lode extending to this part of the mine, which is about 500' along the strike from the No. 1 section, it is unlikely that there is any economically workable ore there.

Section No. 4 (Fig. 9.)

This is across the south western part of the mine to the west of the unmineralized central fault. It is about 800' along the strike to the south west of the No. 1 section.

The No. 2 borehole was put down on the south side of the south lode and inclined at 70 degrees towards the lode as in the case of No. 1 and No. 7 boreholes described above. The following are the assay results obtained from this work. The first mineralization encountered in the borehole was at about 200 feet depth.

From 197	to 209	ft. = 12	ft. along rods = 0.1%	cu.
" 209	" 245	" = 36	" " " = 0.06%	"
" 245	" 290	" = 45	" " " = 0.5%	"
" 290	" 299	" = 9	" " " = 0.01%	"
" 299	" 321	" = 22	" " " = 0.2%	"
" 321	" 345	" = 24	" " " = traces of	cu.
" 345	" 250	" = 5	" " " = 0.08%	of cu.
" 350	" 396	" = 46	" " " = traces of	cu.

The values found between 245 and 290 feet were due to some small veins of chalcopyrite passed through and were not evenly distributed. The results do not seem to indicate any particularly defined ore body.

The No. 9 borehole was put down from the north side of the lode (corresponding to the No. 10 borehole and the No. 8 borehole opposite No. 1) to see whether there was any indication of the lode having changed its dip in depth. The results showed little more than traces of copper with occasional narrow veinlets of pyrite. The slight mineralization commenced at 193' and continued to the bottom of the hole. The results were no better than the No. 2 borehole.

Thus, these two boreholes did not indicate that there was any economically workable ore in the south lode in depth in this part of the mine area.

The north shaft was put down to the 90' level on the north lode and a crosscut to the north, 92' long, was sampled by Bower in 1922 with the following results:—

From shaft to	17 ft.	=	17 ft.	gave	0.6% cu.
„	17	„	65	„	= 48 „ „ 1.04% „
„	65	„	75	„	= 10 „ „ 0.6% „
„	75	„	92	„	= 17 „ „ 3.5% „

Subsequently, a crosscut to the south was driven 250 feet on the 60 feet level by Thomson to see whether there were any defined ore zones occurring towards the central part of the area. This crosscut met with no defined ore body throughout its whole length, but only with small veins and veinlets carrying traces of copper and gold, the copper being in the form of malachite and chrysocolla. The principal locations of these veins are at 156 to 170 feet and 213 to 234 feet from the shaft. The mineralization in these cases consists of ferruginous quartz veins in a kaolinized gneiss and shows only traces of oxidized copper.

The No. 3 borehole was put down from the north side of the lode to cut the extension in depth and was inclined 70 degrees towards the lode. The hole had to be abandoned at a depth of 140 feet owing to caving and jamming of the rods.

The No. 4 borehole was put down in place of No. 3, somewhat nearer to the lode with an 80 degrees dip. In this hole the mineralization was first met with at 191 feet in depth as traces of pyrites.

From	191 ft.	to	200 ft.	=	9 ft. along rods	=	under 0.01% cu
„	200	„	223	„	= 23 „ „	=	„ 0.03% cu.
„	223	„	239	„	= 16 „ „	=	Nil
„	239	„	274	„	= 35 „ „	=	about 0.03% cu
„	274	„	290	„	= 16 „ „	=	Nil
„	290	„	307	„	= 17 „ „	=	under 0.01% cu

At 307 feet the bore encountered a cavity which extended to 313 feet and the sloping side of this cave prevented deeper drilling due to jamming of the rods. Here, the copper values of the core recovery could only be regarded as traces. The dip of the lode near the surface was 74 degrees north. If the dip had changed over, from north to south, it would have been expected that some of the ore represented by the $3\frac{1}{2}$ per cent cu. material in the north crosscut, would have been cut by the bore, but there is no evidence of it.

The No. 5 vertical bore was put down near the section line in the area between the two lodes to a depth of 340 ft. Here again, the first traces of mineralization were met at 206' depth, and there were traces of pyritic mineralization right to the bottom of the hole at 340 feet. The best results were from 250 to 270 feet depth, but even here there were only traces of copper as cupriferous pyrites.

From the above results it was seen that there was no evidence of the extension of the north lode in depth, nor was there any evidence of any defined ore body in the central part of the mine in this section. There was only a general dissemination of traces of pyrites with small amounts of copper in the country rock below the 200 foot level.

In addition to the above work, a prospecting shaft was sunk to the water level at the north western end of the mine. Crosscuts were driven north and south from this shaft at the water level.

Thus the only part of the Hofrat mine which was found by the Syndicate to be of any interest was the central part of the area comprising the squares C₃, C₄, D₃, D₄ shown on the sketch plan of the mine (Fig. 4.). The results so far, indicated that the south lode and the branch lode extend below the 300 foot level as low grade (averaging about 3 per cent cu.) ore bodies, probably 50 to 60 feet wide in this part of the mine. The drilling work for investigation of depth extensions was very unsatisfactory.

With regard to the other copper deposits to the south west of Hofrat, investigation work is summarized as follows:

Waranga Copper Deposit :

The work done on this deposit consisted of a 6' x 4' adit driven 263' into the main ridge, 85' below the hill top. In the east hill a 4' diameter shaft was put down 30 feet and a crosscut driven 35' from the bottom of the shaft. In the valley between the ridges, another 4' diameter shaft was sunk 27 feet and a crosscut driven 17' from the bottom of the shaft. None of this underground work however, exposed any exploitable ore and all the work shows that the superficial ores near the outcrops have been enriched near the surface and decrease to small values (little more than traces) at short distances below the surface (Fig. 2).

Bishura Copper Deposit :

Here a 6' x 4' adit was driven into the hillside for 50' and in addition, a series of trenches each about 25' in length were also dug. The work shows no economic ore. Higham, from his examination of the deposits, said that if the Waranga work showed no workable ore then further work on the Bishura deposit would not be warranted. The copper occurrences were in the nature of traces of malachite in joints and stainings. Some haematite veins were exposed carrying a little copper as malachite and some pyrite but on the whole the copper values were regarded as little more than traces (Fig. 2.).

Jebel Jangi Copper Deposit :

Lat. $9^{\circ}16'$, Long. $24^{\circ}22'$.

Two boreholes were put down on this deposit. The site of the holes is 58' to W.N.W. of the No. 2 shaft. This shaft was put down to 22' depth and two samples averaged 5.4 per cent cu., from narrow veins. The lode at the surface dips 55 degrees to W.N.W. (Fig. 2).

The No. 1 borehole was put down vertically to 268' depth and should have cut the lode at about 115'. From 70' to 100' the rock was granite. From 100' to 145' it was granite with plentiful quartz injections and traces of oxidized copper and some pyrites. These traces continued to 240' depth. Below 240' the rock changed to a biotite-hornblende granite with practically no copper. The percentage of core obtained was from 80 to nearly 100 per cent.

The No. 2 borehole, like the No. 1 bore, showed no definite ore body and only traces of copper. The No. 2 hole was put down from the same spot but inclined at 60 degrees towards the lode, so as to cut it at about 65' deep. The ground was soft granite down to 70' which became harder below. From 85' to 130' traces of oxidized copper and pyrites were again found. From 88' down to the bottom of the hole at 150', about 75 per cent of core recovery was obtained, but practically no copper.

It was evident that there was little or no depth extension of the superficial copper minerals at Yangei and no probability of developing any economic ore there.

Jebel Terezol Copper Deposit :

Lat. $9^{\circ}1'$ Long. $24^{\circ}18'$.

This was discovered at about $5\frac{1}{2}$ miles to the south west of Jangi. Here, there are a series of outcrops and native workings on the western flanks of some small hills. The main rock is a granite with lenticular veins of ferruginous quartz, carrying small values of copper and giving gold pannings which vary from a trace to about 15 dwts per ton. When, however, the reefs were opened by trenching, the larger values disappeared at 4' or 5' depth and only small traces could be obtained. After examining

the deposit, Higham said that the granite has numerous pegmatitic intrusions into the joint planes. The area was subsequently subjected to faulting and considerable talc developed near the fault planes. The faulting was followed by intrusions of quartz-haematite lodes along the primary joints in the granite, as well as in the fault planes themselves. The strikes of the lodes vary considerably (N.N.W. to N.E.) and outcrops are from a few yards to half a mile in length. Trenches show that the lodes do not persist far beyond the outcrops. They narrow considerably in depth, and widths vary considerably along the strike.

A little pyrite occurs in the haematite lodes and this occasionally approaches chalcopyrite in composition. The gold present is mainly associated with the quartz. Enrichment in the outcrops has been intense, and in one trench 15 dwts at the surface decreased to 4 dwts at about 3 feet depth, and this to a mere trace a few feet deeper. The copper is present, chiefly as malachite stainings on the walls, and the values are all small and very patchy. The native workings have not been made for copper but for iron, and the deposit is of a similar type to that at Jebel Jangi.

In 1927, the company stopped further operations. The following is an extract from their report for that year:—

A large amount of work has been done on this mine, including 10 boreholes totalling 3,370 feet of drilling.

The results of the work done indicate a zone of ore some 60 feet wide across the strike, and showing assays of up to 10 per cent copper at the 64 foot level, and from 2.4 to 7.5 per cent cu. between the 200 and 300 foot level, and extending below the 300 foot level. The deeper portions of both the south lode and the branch lode will probably average about 3 per cent cu. over some 50 to 60 feet in width in the central part of the mine.

The strike line of copper deposits, extending from 20 to 75 miles to the south west of Hofrat, has been investigated by prospecting shafts, crosscuts, adits, surface trenches and drill holes and a large number of samples was taken for assay, but no economically workable deposits of copper were found on this strike, apart from the Hofrat mine.

The work at the Hofrat mine has reached the stage where a deep shaft and development work is required. It would, however, be inadvisable to incur further large expenditure on this property until there is a prospect of a railway connection in the near future.

Messina Company's Work :

During the year 1952 a party from the Messina (Transvaal) Development Company Ltd. visited Hofrat en Nehas. The party tried a magnetometric survey over the mine. Two traverses, at right angles across the Hofrat old workings, proved that this method was not applicable. No anomalous changes were recorded over or away from the workings. Another geophysical method was then applied, namely a self potential survey.

The self-potential contour plan showed up the outline of the sulphide zone in relation to the outcrops of oxidized ore (Fig. 10). In respect of gold, they stated that the surface rubble contained more or less gold values, varying from minute traces to about one ounce per ton. They also stated that the occasional rich gold values were due to secondary alluvial concentration. The party did not decide in favour of any large scale development work on behalf of their Company.

Anglo-American Corporation's Work :

In February and March 1948, Dr. T. D. Guernsey and Mr. P. E. Fairbairn (of the Anglo American Corporation of South Africa) spent six weeks on a reconnaissance trip in the area of copper deposits in Bahr el Ghazal. The purpose of the reconnaissance was to investigate the possibility of large copper deposits associated with rocks known to contain copper in relatively small amount. The following is an extract from the report prepared by the two geologists :—

“ bedrock formations on the plain are largely concealed by deposits of residual soils, alluvium, laterite and sheet talus. The few exposures of bedrock found, displayed schists, foliated igneous rocks of granitic habit and unfoliated granite, the latter outcrops near Jebels Zanad and Siomo on the east edge of the area. Coarsely crystalline basic intrusives were found as float (Fig. 11).

This plains group is apparently older than the rocks making up the hills which were tentatively grouped into two series :—

- (a) hard white quartzites and calcareous quartzites and
- (b) brown weathering calcareous schists. Both series strike generally north to north-east and show strong folding. They were, however, not observed in normal contact.

At several places throughout the area the white quartzites have been much shattered and display numerous steeply dipping joints, transverse to the general strike and often filled with practically barren veins of comb and ribbon quartz. These shatter zones are considered to be related to true breccias which form the spines of the two highest hills, Jebels Waranga and Bishura. The breccia at Waranga carries tourmaline and specularite and these minerals were noted in quartz veins on some of the other hills.

Very fine tourmaline and granular quartz, with subordinate specularite, are strongly developed along two lines diverging northward from Jebel Waranga. These tourmaline zones apparently follow the structure of the brown schists. The tourmaline-quartz-specularite impregnation forms hard, dense, fine grained rock, very resistant to weathering.

The copper deposits are of two types :—

- (a) Hofrat en Nehas is in the older foliated rocks and apparently directly associated with vein quartz.
- (b) Those at Jebels Bishura, Zanad and Waranga are in the Brown schists with little or no vein quartz, but with some silicification. They are all assumed to be contemporaneous.

The copper mineralization at Jebels Bishura, Zanad and Waranga is restricted entirely to the brown schists along the line of the tourmaline mineralization. The two types—tourmaline quartz specularite and copper (sulphide) appear to be distinct from each other, but no definite conclusion as to their relative ages can be reached from the observations made. It is thought, however, that the tourmaline may be the later. This concept is based on (a) the fact that the tourmaline is certainly later than some of the quartz and (b) the total lack, with two meagre exceptions, of any traces of sulphide mineralization in the breccia and shatter zones. It is also in accord with observations at Hofrat en Nehas, where a white, kaolinized felsite carrying tourmaline bears no evidence of primary sulphide mineralization, either in itself or in its narrow quartz veinlets.

The presence of iron oxides without traces of copper at Jebels Patapan, Bishura east and parts of Waranga leads to the conclusion that the copper is subordinate to a somewhat more extensive pyritic mineralization, which, in itself, is markedly subordinate to the tourmaline-specularite-quartz mineralization.

The five deposits may be listed in order of size as follows :

Jebel Zanad	very small
„ Waranga east	
„ Waranga west	
„ Bishura	
Hofrat en Nehas	largest

Hofrat en Nehas will, it is thought, convert at depth into two or more sulphide-bearing quartz lodes.

At the other deposits, excepting Jebel Zanad, tourmaline-bearing members of the brown schists are evidently favourable hosts for the deposition of sulphide minerals. Against this must be balanced (a) an apparent predominance of iron sulphides over copper sulphides (b) the comparatively limited extent of the sulphide mineralization in comparison with the tourmaline — specularite mineralization ; and (c) the structure of the brown schists. An impression was gained during the field work that the hills are isolated remnants detached from each other and floating on the older group. Whether this is true or not, the presence of older granitic rocks north of Waranga, west of Patapan and near Zanad—that is, within the Zanad-Bishura-Waranga triangle—suggests that the structure is complex and the brown schists are not always continuous between the hills.

"It is concluded that these factors do not favour the occurrence of larger bodies of copper mineralization, either in the triangle itself or in the general area."

During 1956, a geological party belonging to the German Democratic Republic made a reconnaissance trip to Bahr el Ghazal and Darfur Provinces. Hofrat en Nehas was visited and a sketch topographical map was produced together with a Geiger counter survey. They stated that the mine area was characterized by a high level of radio activity, but did not give an estimate of either radio-active material reserves or copper reserves.

PHYSICAL CONDITIONS

Topography

Hofrat en Nahas lies about two miles to the south of river Umbelacha one of the main tributaries of Bahr el Arab. Its geographical position is at latitude 9°45' and long. 24°18', in south western Darfur Province. The area is rather flat, rising gradually and gently westwards till it reaches the foot of a range of hills running roughly north-south and demarcating the watershed between the Nile basin and the drainage to Lake Chad. This range of hills comprises J. Ramla (▲3323'), J. Chakka (▲3893'), J. Tinga (▲4307') and J. Moho (▲3949'). The same range of hills was taken as the International boundary between the Republic of the Sudan and the Republic of Central Africa. The distance between Hofrat and the nearest point on the International boundary is about 45 miles.

Most of the water system which feeds the Umbelacha is located to the south of it and drains in a north-eastern direction. Its tributaries includes W. Miri, K. Jumbana, R. Adda and R. Biki, all of which are characterized by a complicated system of meanderings and ox-bows. Some parts of these streams are more of a swamp than a restricted channel specially during the rainy season.

The vast plain in the Hofrat area is sprinkled with a multitude of isolated hillocks and low-lying ridges, a group of which protrudes in a certain pattern and runs along a common trend, due N.N.E.—S.S.W. This group begins from the north by J. Gulmara (2586'), then continues southwards to J. Ngaga, J. Jumbana, J. Angbeigi, J. Bishura (2295'), J. Yirongo, J. Ku (2711'), J. Waranga (2916') J. Patapan, J. Jator, J. Yambana, J. Ngala. It then follows a long ridge, with its northern peaks at J. Mongo and J. Kulu and its southern peak at J. Kidi-kidi. There is another group of hillocks located sporadically without any special orientation. These include J. Siomo (▲2310'), J. Ndare (▲2263'), J. Zanad, J. Junguyo (▲2470'), J. Jedi, and J. Kusagi. These two groups are all located to the south of the Umbelacha. To the north of Umbelacha there is a group of hillocks arranged nearly along one line, running east-west. These hillocks are, from east to west, J. Dumbaroro (2047'), Sarafain Mhono, J. Marafain, J. Eshaqq, J. Tangtanga, and J. Motoia (▲2204') (Fig. 2).

Roads and Communications :

The nearest village to Hofrat en Nahas is Songo, lying on the northern bank of the Umbelacha about two miles from Hofrat. There are, however, other smaller villages along the river west of Songo. Radom is a big village which lies at the junction of Umbelacha and R. Adda, about 35 miles east of Songo. At Radom there is a Police station, a dispensary and an elementary school. The regions to the west of Goreisho village (on the Umbelacha, 12 miles west of Songo) till the frontier and to the south of Songo till Kafia Kingi, are very thinly populated. Kafia Kingi was once a District Headquarters but since the nineteen twenties it was gradually and forcibly depopulated.

There is a motor track which extends from Songo westwards till it crosses the International Boundary at Namla, and eastwards to Radom. From Radom the motor road reaches Buram, the nearest town, which is about 75 miles away. Nyala, the headquarters for southern Darfur, is some 95 miles north of Buram. Nyala is now the terminus of a railway extension connected with the newly constructed railway line between Al Obeid and Wau. Nyala is also connected with Khartoum by an aeroplane service, once a week. It has a proper hospital, a regular post and telegraph service and the market is well provided with food stuffs, clothing materials and other commodities.

The road from Hofrat to Nyala is open during the dry season only and needs annual minor repairs after the rainy season. There is another motor route, from Songo, running southward to Kafia Kingi, then to Raga, Deim Zubeir and Wau. This is also a dry season route with numerous temporary timber bridges over the streams. Its maintenance is rather difficult in the parts where the bridges are annually drifted by the floods or burnt by bush fire.

Climate and Vegetation :

During the winter months of November, December, January and February it is generally warm in the day time and cool at night. It is hot during the rest of the year and is particularly uncomfortable before the rainy season, *i.e.* during April and May. It begins to rain in late May or early June and continues until August. The average annual rainfall is around 1000 millimeters. The area becomes absolutely unpassable during this rainy season as the streams flow continuously and tremendous stretches of land become swampy or at least very muddy.

The parts of R. Umbelacha and R. Adda upstream of Radom cease to flow as from October, but separate pools are left in the main channels till probably the end of December. After that date the pools dry out and the local people get their water by digging shallow pits (gam-mam) in the sands of the khor beds. Some shallow depressions which exist away from the main streams are able to retain small quantities of water all the year round. Again, some traps in the stony hillocks could keep very small quantities of water for several months. These pools and traps are extremely valuable for the people who have to traverse this hinterland on foot during the dry season.

The area is well forested with rather scrubby types of trees and shrubs, which include a fair proportion carrying thorns. Larger trees, some apparently of good timber types, are sparsely distributed along the banks of Umbelacha, Adda and to a lesser extent along the minor channels. *tebeldi* (Baobab) trees are not present, but bamboos are widespread and in some places fairly thick; Liban trees (*Euphorbia*) are also widely distributed in some localities. Grasses, largely burned off in the dry season, are usually thick and grow about six feet high.

Inhabitants and Occupation :

The area north of Umbelacha is inhabited mainly by the Habbaniya tribes. Around Umbelacha and further south the inhabitants are the Kreish tribes, with no sharp tribal boundary between them and the Habbaniya. Besides the original settlers there are always newcomers of Fallata, from across the western borders of the country. The main occupation of the Kreish, who are always village dwellers, is agriculture ; dukhu and fatarrita comprise the main crops, with limited sesame cultivation. On the other hand, the Habbaniya and Fallata are herdsmen owning cattle in big numbers. These people are in constant migration between central and south Darfur, seeking good grazing places. When the rainy season is over groups of them flock southward and cross the Umbelacha. The only natural barrier against their seasonal advance southward is the infection of the area by the Tse-Tse fly (responsible for sleeping sickness). This area south of Umbelacha is still teeming with big game, wild animals and reptiles. There are still a few hunters who are interested in crocodile, lizard and python skins, together with ivory. There are also small groups of young men who wander in the hinterland during May, every year, to collect honey.

REGIONAL GEOLOGY

The country, extending to the south and west of Hofrat, is rather a difficult tract for regional geological mapping. It is generally very bushy and infested with malaria and sleeping sickness, and due to its being devoid of any motor tracks one has to traverse long distances on foot in such work. This region is completely uninhabited and a worker there must depend exclusively on his initial resources. In addition, the country is generally very flat and has a mantle of soil or ironstone, rendering it quite unfavourable for mapping. Rarely is a rock outcrop encountered outside the water courses or on the few prominent hills scattered in the area.

The first record on the geology of this area is the unpublished report "On the Geology of Undelimited Portions of the Anglo-French Sudan Boundary" by G. W. Grabham, who was the Sudan Government Geologist. He wrote this report while he was attached to the Anglo-French Sudan Boundary Commission during 1922. He stated that the Shala mountains, comprising J. Gi, J. Shala and J. Tenga, were composed of unmineralized quartz schist resting on a base of biotite gneiss. He thought that these hills were most unlikely to contain minerals of economic value. He also examined the Raga mountains a few miles to the north of the Shala Bobai. This range consisted of J. Komo, J. Ramla, J. Shaka and J. Raga, and Grabham stated that they were composed of unmineralized, hungry looking, micaceous quartz schists. He, however, recorded quartz intrusions near the triangulation station at the southern end of J. Komo, though they did not appear to be mineralized.

The departmental files also contain a little information on the geology of the region. It appears from these records, that J. Dango ($10^{\circ}00'$, $24^{\circ}45'$), is composed of crystalline rocks. This hill trends in a N.N.E. direction and is mainly composed of white quartzite with some muscovite and feldspar. These quartzites are, in places, impregnated with iron. It is also stated that the quartz schists exposed in the Um Belacha river generally strike in the direction of J. Dango. It seems that some concretionary ironstone exists in these hills and the discovery of black slag, with charcoal, indicates that it has been smelted locally on a small scale.

Reports of the Nile Congo Divide Syndicate indicate that J. Abu Ali ($9^{\circ}40'$, $25^{\circ}14'$), J. Abu Tagiya to the east of it and J. Walinga, J. Hoka and J. Tagalla-Daryegi are all composed of quartzites and quartz schists. The latter hills are located at approximately lat. $9^{\circ}30'$, long. $25^{\circ}20'$. These reports further mention that among the J. Abu Ali group of hills granite is exposed. J. Oro el Khala ($9^{\circ}25'$, $25^{\circ}06'$) and J. Ambusa ($9^{\circ}16'$, $24^{\circ}47'$) are also composed of quartzite.

In the same general area of the region, schorl is recorded at J. Tebi ($9^{\circ}22'$, $25^{\circ}25'$) and pegmatite is reported to exist in a valley north of J. Deleti ($9^{\circ}16'$, $25^{\circ}17'$).

Tourmaline was again recorded to the east and west of J. Shalleikha ($9^{\circ}02'$, $24^{\circ}52'$), the hill itself being composed of gneiss.

Ironstone is widely outcropping in the area, specially east of the Adda river at lat. $9^{\circ}37'$, long. $24^{\circ}47'$ and it is also exposed at Hofrat En Nahas. This rock is usually of an orange to reddish brown colour and forms flat outcrops. It contains reddened masses of quartz and gneiss in the form of rounded or rolled pebbles, up to 30 mms long.

Prospectors of the Nile Congo Divide Syndicate report that porphyry dykes occur in the Um Belacha river, north of J. Ngaga, which is composed of quartzite. J. Bishura, to the south of the Gulmara — Ngaga — Angbeig range, is stated to contain dense, hard, trap rock with quartz lodes, which strike due south west. This trap rock was later proved to contain mainly minute crystals of black tourmaline and quartz (Plate IV, Photo A). G. V. Colchester states that quartzite, which outcrops north and east of J. Bishura has a N-S strike and dips due east. He further reports that granite outcrops east of Bishura, together with aplitic rocks.

To the east of this quartzite range of J. Gulmara, Ngaga etc., an altered calcareous series is reported to exist. This calcareous series is stated to exist in the J. Waranja mass by Colchester, who goes on to say that the eastern hill of this mass is composed of metagabbro. This rock is described as a melanocratic, granoblastic, foliated, hornblende—plagioclase—quartz rock. Similar rock is reported on the west side of J. Patapan and at Hofrat En Nahas. J. Patapan also exhibits a highly foliated, pale olive green, chlorite schist, together with similar, but more felspathic, rocks. Such rocks also exist at Hofrat.

In K. Bishura, to the north of J. Yirongo, the rock is a pink, fine grained aplite, which contains some quartz veins. J. Mandoro, west of Bishura and near Um Belacha is composed of gneiss with white quartz veins. To the west of this hill, the gneiss is acidic, strongly foliated and contains streaks of biotite. A marble band is reported to run through J. Ngala ($9^{\circ}14'$, $23^{\circ}52'$).

The watershed between Um Belacha and W. Khadra yielded a white granoblastic feldspar-quartz rock of medium grain together with a highly foliated, pink, felspathic gneiss, containing muscovite.

T. D. Guernsey and P. E. Fairbairn who made a reconnaissance on behalf of the Anglo-American Corporation of South Africa Ltd., during 1948, gave certain information about the geology of the region. First of all, they stated that "it must be stressed that, because of the fineness of grain, metamorphism, weathering and close jointing, several rock types were difficult to classify. For this reason the nomenclature adopted should not be taken as precise." The following are extracts from their report:—

"Apart from the superficial deposits, which are extensive and in places relatively thick, the bedrock formations of the area were divided into two major groups, related, more or less, to the topography: (a) an older, largely igneous group and (b) a younger, dominantly sedimentary group, making up the hills, but also judged to be present to some degree on the plains. In addition, there are throughout the area intrusive

granites and associated dykes, large zones of brecciation and silicification with considerable ribbon and comb vein quartz, glassy vein-quartz and mica-bearing pegmatites. The relative ages of these latter groups were not determined, (Fig. 11).

The Older Plains Group :

Although exposures of bedrock formations are singularly sparse on the plains, those found in place, differ markedly from the rock types making up the hills. They include grey, sheared granite, hornblende and chlorite schists believed to be derived from basic igneous rocks, together with basic intrusives with hornblende or augite and varying amounts of feldspar; and hard, pink, fine grained crystalline quartzite. The finer grained crystallized quartzites, noted on the plains, are thought to belong to the younger group.

Intrusive into this older group and perhaps also into the younger, though never well exposed, are light, medium-grained granitic dykes consisting of white feldspar and quartz with only very minor ferromagnesian constituents. Other intrusive rocks include light coloured felsitic rocks apparently related to the white granites and grey, medium grained biotite granite.

Sheared grey and white granite is exposed at several places to the south and east of Khor Yirongo between Jebels Waranga and Patapan. The foliation strikes at about 83 degrees and dips northwards at from 30° to 80°. The rocks are cut by granitic dykes, also sheared to some extent and at least one pegmatite dyke follows the foliation. This is about 100 feet long by 6 feet wide and contains 4 by 5 inch books of poor quality mica.

The hard, fine grained, sheared and closely jointed granite is exposed at the northern end of Jebel Cheili and in the bed of Umbelacha river to the east and west of Birka Biogo, the water hole for Songo village. The rock has eyes of pink feldspar in a fine-grained, platy groundmass and at Cheili encloses small, irregular, vaguely defined enclaves of a grey rock with the appearance of anorthosite. Near Songo, where the rocks contain some specularite, the foliation is apparently contorted and varies from 50° to 74°. The dips also vary, being to the north on the western exposures, and to the south on the eastern exposures.

The grey schist was observed only to the east of Songo and occurs in several small exposures over an area 600 feet long in the bed of the river. It is a soft, much weathered, grey and rather fine grained rock, with threads of pink feldspar in the groundmass. It has the appearance of a sheared granite and shows considerable contortion, with the foliation striking from 15° to 54° and dipping from 30° to 65° to the north west (Plate I, Photo. D). It is cut by a dyke of rather coarse, white granite and at one exposure there is quartz-epidote veining along the foliation.

Rubble, about the ancient workings at Hofrat en Nahas, yielded hornblende and chlorite schists (Plate II, Photo. A.), some rather massive talcose and tremolitic types (Plate II, Photo. C), and a grey, massive coarse grained rock with yellowish green feldspars in a micaceous and silicious matrix. A dyke, or minor intrusive, of fine grained, white granite is exposed near one of the old workings.

The coarser basic intrusives were noted only as float on the plains east and northward from J. Bishura. They consist mainly of hornblende and feldspar in varying proportions. Both massive and foliated types were noted.

Quartzite is present in the bed of Umbelacha river to the west of J. Matiyi and in the bed of a small stream west of Songo village. That at Matiyi is considered to belong to the younger group forming the hills. Quartzite as float, was found occasionally in traverses on the flat ground, but never in quantity and in most cases was judged to belong to the younger group". (Plate I, Photo. A.).

The Younger Group :

" This group, which may be divided into two or more parts, will here be described as one entity. It builds all the hills, save one, examined in the area and, as mentioned above, may underlie parts of the plains."

" Hard, recrystallised, white, slightly felspathic quartzites, with small scales of specularite along pronounced linear foliation are the most prominent, if not the most abundant, members of the group. They are associated with softer, more felspathic quartzites and other quartzose rocks, with varying elongated cavities filled or lined with yellowish and brownish earthy oxides. These latter were seldom seen in place, but were fairly prominent in the talus aprons mantling the central spines of the hills. They are considered to be leached, calcareous quartzites."

" This group builds all the hills to the north of Umbelacha river and the major part of the range stretching from J. Gulmara southward to J. Mundongo, as well as Jebels Matiyi and Cheili to the west. The quartzites strike from 5° west of north to 40° east of north, with the general bearing at about 20° . Dips are generally steep to the west, but on J. Jumbana the beds may be overturned. West and south of J. Bishura there are some gentle dips and open folds. The hills are seldom aligned along the strike of the quartzites and on J. Jumbana this is well illustrated along the spine of the ridge which crosses the general strike at a sharp angle."

" Multiple fractures at angles, transverse to the strike, are very common in the harder quartzites. These fractures vary in direction from 55° to 117° and as a rule dip steeply to the north. At Jebels Matiyi and Cheili, however, the dip is due south. The fractures are frequently filled with comb and ribbon vein-quartz and apparently related to the zones of brecciation and silicification. Movement along such fracture zones is indicated on Jebel Jumbana where crush zones are developed. In a slight offset in the crest of the ridge, the north side has moved in a direction of 85 degrees to the east."

"At the north east end of Jebel Gulmara and the west side of Jebel Matiyi, what are apparently calcareous quartzites, have been altered to hard pinkish and greenish rocks, massive or with numerous large elongated cavities on weathered surfaces, which are now composed dominantly of quartz and fine epidote. At Gulmara, these rocks, exposed near some fine greenish quartzites, have complex structures and contain thin intercalations of an obscure, metamorphic type composed essentially of a soft sulphur-coloured mineral, with some quartz, pink felspar and thread-like veins of quartz and felspar. At Jebel Matiyi, these quartz epidote rocks lie close to an exposure of a medium-grained intrusive, made up of white felspar, quartz and greenish alteration pseudomorphs after hornblende. The exposure has a rude foliation at 85 to 90 degrees with a dip to the south. It holds fragments, taken to be altered epidote—quartzite and was considered to be intrusive into the younger group."

"A second part of this group forms the eastern part of Jebel Bishura, the whole of Jebel Waranga and parts at least of Jebel Patapan and Jebel Zanad. It is exposed also in small ridges east of Jebels Bishura and Yirongo and west of Jebel Patapan and may be present beneath a sheet of laterite on the plain, about half a mile west of the Jumbana swamp. These rocks, for the greatest part, are brown weathering, light grey, fine- to medium-grained quartzose types, often with greenish and yellowish micaceous material. Where exposed on Jebel Bishura and the low ridge to the east, they are brown weathering, fine-grained, well jointed, somewhat shaley quartzites. On Jebel Waranga they are coarser, with little visible structure and contain considerable quartz and variable amounts of material judged to be calcareous. Jebel Patapan exhibits similar types, slightly foliated, with no distinct bedding. On weathered surfaces the rock has the appearance of a sheared granite. Similar types are exposed in the Jebel Zanad area, where they are somewhat foliated, and bear, at times, numerous small flakes of specularite."

"These rocks were never observed in normal contact with the white quartzites, and on Jebel Bishura the two were separated by a zone of white, silicified breccia, about 35 feet thick, striking 40 degrees with a steep dip to the northwest. For convenience they were referred to as the "brown schists".

"Included with the brown schists are one to three or more beds 6 to 45 feet in thickness, of grey, fine-grained, massive but generally well jointed rock, thought from its colour and appearance on weathered surfaces to be of volcanic origin. They are apparently aligned with the general structures and on Jebel Bishura are conformable with the adjacent brown schists. Opinions on the classification of these rocks varied during the course of the work and no definite conclusion on their classification was reached."

"Microscopic examination of the so called "volcanic" rock seems to show clearly, though some obscure structures were not interpreted, that these rocks are not of volcanic origin. Quartz in mosaics of interlocking grains, with some angular and rounded grains and aggregates, is the dominant mineral in all sections. With it, and varying in density from

one part of a section to another, is a profusion of very fine tourmaline mainly in idiomorphic shapes. The quartz mosaic and the fine tourmaline indicate that the rocks have been more or less completely reconstituted. A little white mica is distributed through the quartz mosaic. From this and from the fact that it is tabular, it is concluded that the "volcanic" is of sedimentary origin and is a metamorphosed shale or siltstone."

"On Jebel Bishura, only one of the "volcanic" bodies outcrop on the crest, at a distance of 80 feet from the breccia, but two are exposed on the north slope, striking 50° (west) and 70° (east), with steep, easterly dips. On the low ridge east of Bishura there are two bodies, each 6 to 10 feet thick, separated by 15 to 20 feet of somewhat shaley calcareous quartzites (brown schists)."

"The contact between the white quartzites and the brown schists appears to continue southward from Jebel Bishura, between Jebel Yirongo and the low ridges to the east, and to pass within half a mile of the west slopes of Jebel Waranga. Waranga itself, is a double hill with two north-south ridges, separated by a deep wide trough, with grey, sheared granite exposed well within the V formed by the two ridges. There are three bodies of "volcanic" rock on the crest of the west ridge and at least two on the east ridge. On the west ridge, the "volcanics" strike along the crest and dip steeply westward. They are separated by from 50 to 130 feet of brown schists. On the east ridge the "volcanics" exposed on the northwest spur, converge at the crest of the ridge with a second body occupying the north east spur. A strong zone of quartz breccia, with specularite and tourmaline, trends along the west side of the crest at 35°. The quartz veining was not noted to be of the banded or comb variety."

"Rocks classified as "volcanics" form a small ridge on the southwest flank of Jebel Patapan, and are present on the western slope where they are cut by granitic dykes. A small exposure of granite was noted between the ridge and the main hill. No further exposures of the "volcanic" type were observed on the eastern side of the Yirongo valley, to the north of Jebel Patapan."

"**Intrusives** : Mention has already been made of the white, granitic dykes in Umbelacha river near Songo village and at Hofrat ; the hornblende-syenite or quartz-poor granite at Jebel Matiyi ; and the granite and granitic dykes on Jebel Patapan. No other intrusives were observed within either group. About 15 miles east of Jumbana swamp, a relatively high part of the plain is surmounted by a small round hill—Jebel Siomo—which, with its few satellite ridges, exhibits two, apparently fresh, medium grained granites, cut by granitic and pegmatitic dykes. One rock, considered on varying and inconclusive evidence to be older, is grey, medium grained and composed essentially of feldspar, quartz and mica, principally biotite. The second is a nearly white rock of feldspar and quartz with little or no mica. Both types carry black tourmaline in varying amounts; in the grey variety,

distributed in fine or coarse needles throughout the mass, and in the white variety in single crystals or more commonly, in clusters of coarse crystals, which give a "knotted" appearance to a weathered surface. At one place highly tourmalinized rock was noted to be cut by a light granitic rock without tourmaline. The dykes—up to 3 feet or more in thickness nearly all carry tourmaline, generally in coarse crystals or aggregates but never in quantity (Plate I, Photo. B)."

"Superficial Deposits: Superficial deposits of alluvium, residual hills, laterite and sheet talus occupy nearly all the plains area and effectively conceal the bedrock formations. The alluvium is extensive and relatively thick along Umbelacha river, Khor Yirongo and their tributary streams. Where seen, it consists of vaguely and coarsely bedded yellowish clays, containing variable amounts of fine sands and concretionary bodies, principally of lime. No sharp line between alluvium and residual soils was observed and it seems probable that some of the superficial material, away from the sometimes ill defined stream courses, is also of alluvial nature, having been transported to some extent by sheet floods. Laterite is widespread and apparently extensive in some localities. It generally forms sheets of aggregated botryoidal concretions, a quarter to half an inch in diameter. Laterite sheets, from 1 to 4 feet thick, are present at several places in Umbelacha river."

"Sheet talus is widespread in the neighbourhood of and between Gebels Waranga and Patapan. It may also be present further north but, if so, it was not particularly well displayed. These deposits consist of an assemblage of heterogeneous rock fragments, bearing little relation to the nearby bedrock. The fragments show signs of wear on corners and edges and are often coated with a thin film of varnish. The talus sheets were observed to rest on weathered granite and to be overlain by laterite. They are considered to represent talus, derived in the largest part from the adjacent hills and transported by sheet floods."

The work of the French geologists in the parts of The Republic of Central Africa adjacent to the Hofrat area is another source of information. A geological map compiled by Harcel E. Denaeyer (Prof. a L'Universite' de Bruxelles) was published in 1928. Its heading was "Esquisse Geologique de L'Afrique Equatoriale Francaise, Du Cameroun et Des Regions Voisines" and it had a scale of 1:3,000,000. This map included the western part of Bahr el Ghazal Province (Fig. 15).

In this map, an area covering both the Sudan and the Republic of Central African borders, beginning at nearly lat. $9^{\circ}30'$ and extending to the north, is shown as superficial formations. These formations include alluvials, eluvials, laterites, sands and the argillaceous and calcareous Chad series. These superficiales did not reach the Hofrat mine. The mine lies in the crystalline system which occupies vast areas to the east. This system includes a much diversified collection of formations, (ortho and para gneisses, gneissose granites, alkaline gneisses, ortho and para-amphibolites, pyroxenites, eclogites epidiorites etc.). The range of hills demarcating the Nile-Chad watershed (south of lat. $9^{\circ}30'$) is formed of the

metamorphic system, comprising mainly, quartzites, arkoses, psammities, itabirites etc. This system forms the upper reaches of rivers Adda, Umbelacha and Sirri. Patches of this system outcrop further to the north east, and beyond the Umbelacha. Other types of rocks recorded are the intrusive rocks comprising granites, monzonitic granites and gneissos granites. These, outcrop in the quartzite series at the watershed. Other outcrops are recorded on the Umbelacha, east of Hofrat and to the north west of Kafia Kingi.

A more recent work was published by the 'Le Direction Des Mines et De La Geologie' of the A.E.T. in the Bulletin No. 7, 1956. The sheet 'Ouanda Djalle' east, lying between long. $22^{\circ}30' - 24^{\circ}00'$ and lats. $8^{\circ}00'$ and $10^{\circ}00'$ (immediately beyond the frontier opposite the Hofrat area) was surveyed by R. Delafosse and completed during 1955. Some of the formations shown on this map extend into Sudanese territory to the west and south of Hofrat. The following is a description of formations given by Delafosse:—

I — The Chad Formations

These consist mainly of argillaceous sands covering the northern part of the sheet. Outcrops in this formation near the frontier are mainly mylonites, quartzites, quartz and granites.

II — Quartzitic Series of Bahr Kwadjia :

This series extends in a single sheet till Said Bandas. It is formed essentially of pure quartzites and quartzites with fine grained muscovite together with some localised amphibolitic schists and metamorphosed arkoses.

III — Basement Complex :

The basement comprises quartzites, gneisses, and amphibolites, a group of migmatites, anatexites and migmatitic amphibolites.

(a) *Quartzite* : It forms considerable outcrops representing the heart of the massif of Dar Challa range. Other than that, it may be found interstratified with the gneisses, amphibolites or migmatites. The quartzites may be of the vitreous type or muscovitic and sometimes carry magnetite.

(b) *Gneiss* : This comprises varieties with biotite, or biotite and amphibole. It is represented by gneisses of upper Bahr Kwadjia, opposite Said Bandas and Deim Zubeir. Varieties with biotite and muscovite are not very common, occurring sparsely in lenticular shaped exposures, interstratified with the quartzites of Dar Challa.

(c) *Amphibolites* : The amphibolites represent the interior parts of the basement complex. They are either felspathic or amphibole-pyroxenites. It is probable that the bands of the amphibolite at Bahr Kwadjia are para-amphibolites. Some of them have undergone migmatization, which rendered them very heterogeneous, and are manifested by very irregular bands.

V—Intrusive Rocks :

The outstanding member of this group is syntectonic granite. This represents ancient granite of different orientations, now concordant with the surrounding rocks. It is recorded in the basin of the Kotto river. This granite is homogeneous, partly oriented; its facies principally leucocratic and fine grained and it contains biotite.

Tectonics :

The basement complex series were the only rocks affected by major tectonics. The quartzitic series of Bahr Kwadjia were subjected to folding but the movements were weak. There were no observed signs of friction or violent shearing, normal in the case of basement rocks. The general trend of the axis of folding is N.N.E.-S.S.W.

There is also a vast zone of mylonitization which affected principally the quartzites of Delembe and north of Dar Challa. In these mylonitized areas, indications of the existence of copper ores were found.

From the foregoing extracts, it could be seen that no systematic surveying was done and that there is not enough data to establish an accurate map. However, the accompanying regional sketch map represents the major formations (Fig. 16). It follows the same divisions applied by the French geologists who worked the area across the border. Quartzites are dominant along the whole watershed from lat. $9^{\circ}00'$ to $9^{\circ}40'$, and constitute the majority of the elongated ranges of hills to the east of Umbelacha river. Some of the quartzites are very pure, some contain varying proportions of tiny flakes of muscovite or sericite (Plate I, Photo A) and some are ferruginous. Chlorite schists, biotite schists and quartz sericite schists occur in scattered outcrops, usually occupying rather flattish land or low hillocks. The schists are most probably of much wider extension than thought, but they are mostly concealed by the superficial formations. Marble is recorded in a band running from lat. $9^{\circ}17'$ long. $23^{\circ}50'$ in a S.S.W. direction through J. Ngala, J. Kulu and outcropping again in Khor Ndongo.

The regional trend of foliation is common to both schists and quartzites, ranging from N.N.E.-S.S.W. to N.-S. with local anticlines and synclines. The age relation between the different metamorphosed formations is not quite clear yet. There is a series of parallel shearing zones, trending generally N.E.-S.W. and could be traced for considerable distances. One of these shear zones extends from beyond the northern limit of Hofrat en Nahas, in a south westward direction to J. Bishura, J. Yirongo, J. Waranga, to beyond Khor Ndongo in the south. The zone is characterised by intense silicification which occupies the prominent ridges on the crests of the hills. This zone is usually of quartz or conglomerate with siliceous cementation. The zones of shearing were also used as channels for the introduction of boron emanations into the surrounding rocks. The quartz veins and the quartz-cemented conglomerate are invariably tourmaline bearing. Tourmaline-quartz veins are of a semi regional distribution in the whole

area (Plate IV, Photo B). The dominant variety of tourmaline is the black schorl. Tourmalinization, due to pneumatolitic action, is observed in the wall rocks around the shear zones with varying degrees and some slides of quartz-sercite schist show the two minerals in very fine grains; these are intruded by multitudes of stringers of well developed tourmaline prisms with quartz. More advanced degrees of tourmalinization were also observed, where all the minerals in the rock, except the quartz, were attacked by boron emanations, with the formation of tourmaline. The ultimate result in this case, as observed in thin sections, is the formation of quartz-tourmaline schist with the preservation of the structure of the original metamorphic rock. This widespread tourmalinization could possibly be related to the granite intrusions exposed in several localities like J. Siomo, Khor Bishura (lat. $9^{\circ}31'$ long. $24^{\circ}03'$) J. Ambuigi, J. Patapan and J. Zanad. In J. Siomo the rock is medium grained, grey granite. Under the microscope it shows nearly equal amounts of quartz and felspar (orthoclase and oligoclase). Biotite exists in elongated, non-oriented shreds, while minute prisms of tourmaline are numerous and evenly distributed. Apatite is also present as an accessory mineral.

Ironstone :

Another point of interest concerning the regional geology of the area is the very extensive occurrence of ironstone. This is found practically in every plain land, in Bahr el Ghazal Province, either directly exposed or covered by a thin mantle of dark soil. The following is an extract from a contribution to "The Iron Ore Resources of the World" Stockholm 1910, written by S. C. Dunn and G. W. Grabham :—

"In the Bahr el Ghazal, Equatoria and Upper Nile Provinces, the principal rocks are gneisses and these are generally covered by a ferruginous conglomerate, associated with a lateritic formation. In a rapid traverse, through the eastern portion of the Bahr el Ghazal, the extent and thickness of this conglomerate was noted. The rivers and streams expose it admirably and in places, between Rumbek and Mvolo for instance, the thickness is as much as fifteen metres. Usually the surface consists of red, loamy soil, strewn with box-shaped boulders of different sizes and supporting a dense growth of forest and grass. In places however, the ferruginous conglomerate forms isolated patches of the large area in the forest, so free of soil, that only a scanty supply of short grass succeeds in growing. In this province alone, the iron ores cover an area of about 80,000 square kilometres and though the thickness varies from one to five metres, it may be much more in places.

A sample from Wau, analysed by Dr. Beam, gave the following result :—

Ferric oxide . . . . .	.. ..	52.20 (=37.24 Fe)
Sand etc. insoluble in acid	.. ..	28.24
Organic matter and moisture	.. ..	15.42
		<hr/>
		96.86

Another sample showed 47 per cent of metal. Titanium, phosphorus, etc. do not appear to have been tested for in either case.

These iron ores remind one of the "Murram" found associated with the laterite in India, and may have arisen by a similar process. The red earth with which they are associated is no doubt formed by the decomposition and disintegration of the underlying crystalline rocks and the iron resulting from the breaking down of the coloured constituents is concentrated at certain points by circulating waters."

In a recent tour in Bahr el Ghazal, the two authors collected many samples of ironstone along the road between the vicinity of Hofrat and affili rapids on the Jur river, south of Wau. The following table gives the iron content of some of these samples:—

Sample No.	Fe %	Sample No.	Fe %	Sample No.	Fe %
18951	16.75	18952	25.69	18954	15.63
18965	21.78	18974	21.78	18989	22.34
18992	27.63	18995	25.69	18996	29.04
18997	37.69	19009	27.36	19010	23.73
19015	62.82	19103	32.39	19111	23.45

This ironstone could be considered as an enormous reserve of low grade iron ore for future utilisation.

FIELD WORK ACCOMPLISHED BY THE GEOLOGICAL SURVEY EXPEDITION AT HOFRAT EN NAHAS

The programme of field investigations which was carried out in the Hofrat en Nahas area took three working seasons to accomplish. The first season began on 15th February, 1957 and ended on 26th April, 1958. The second season's work commenced in mid January 1958 and was terminated at the end of April 1958. The third field season began in mid November 1958 and was stopped at the end of May 1959. The total period of field work was about 12 months.

During the first season a grid radiometric survey was carried out on the Hofrat mine itself and an isoradic map was produced (Fig. 14). At the same time, surface topographic contour mapping was commenced to a scale of 1 : 1000 and contour intervals of 25 centimetres. Ten trenches were dug with a total length of 115 meters and an excavation of about 259 cubic meters of material. During this season also, two boreholes were completed, utilizing a diamond rotary rig. Forty two auger boreholes (hand drills) were completed to shallow depths.

During the second season the topographical surveying was resumed but was not completed. Ninety auger boreholes were dug in addition to the ones done during the previous season, which made up the total number of holes to 132. The total depths of the holes dug by this method reached 773 feet, with an average depth of 6 feet per auger borehole. Four shallow trenches were dug and one of the trenches of the year before was widened and deepened. Three more diamond drill holes were put down as pre-planned from the year before.

The third season was the final and the longest of all. Ten deep diamond drill holes were dug, so that the programme of drilling fifteen boreholes was fulfilled. The total depth along rods of the boreholes reached 5875 feet, with an average depth of 375 feet per borehole. An extension of the mineralized zone, immediately adjacent to the old workings, was investigated. Seven shallow trenches were dug and a radiometric grid survey was done. Then an excursion was arranged and executed to the copper occurrences at Bishura, Waranga and Yirongo. The trip was undertaken on foot during the period December 7th to December 30th 1958.

Auger Boreholes :

To prepare for the auger boreholing, the area of the old workings (900 x 400 metres) was pegged in the form of a grid. The grid lines were spaced at 30 metres in the E.N.E.-W.S.W. direction and at 50 metres in the N.N.W.-S.S.E. direction. These grid lines were denoted by SI, SII etc. to the south of the base line, which runs along the centre of the area; and by NI, NII etc. to the north of this base line. The lines running perpendicular to the base line were simply denoted by I, II, III etc. The aim of utilizing this hand drill was to dig shallow holes in the old working and the dumped

material. The holes were not confined to the corners of the grid but were distributed along its lines. This served a twofold purpose; first, it enabled the probing of the downward extension of the loose material of both the mounds on the flanks of the pits and the caved-in material inside the pits themselves; and second, the soil and pebbles extracted from the holes were analysed for their copper content. In the following table, the depths of the 132 Auger boreholes are recorded together with the average copper content of each hole (Fig. 12).

B.H. No.	Depth	CU %	B.H. No.	Depth	CU %
1	6' 0"	0.5	2	5' 9"	0.6
3	8' 7"	2.8	4	6' 1"	0.6
5	15' 9"	1.1	6	5' 6"	0.6
7	5' 6"	0.9	8	15' 0"	2.8
9	4' 9"	0.3	10	9' 10"	1.2
11	2' 7"	1.2	12	7' 10"	0.7
13	9' 8"	0.5	14	4' 6"	1.6
15	4' 5"	0.95	16	6' 3"	4.4
17	6' 3"	2.05	18	4' 5"	0.16
19	9' 4"	7.7	20	5' 10"	0.1
21	4' 8"	0.1	22	4' 8"	0.16
23	4' 9"	0.3	24	5' 4"	1.1
25	5' 3"	0.12	26	4' 9"	0.03
27	4' 4"	0.16	28	5' 4"	0.06
29	6' 0"	0.96	30	5' 0"	0.5
31	3' 9"	0.6	32	5' 2"	0.12
33	5' 4"	0.03	34	3' 6"	0.35
35	4' 6"	0.95	36	3' 10"	0.03
37	5' 0"	0.03	38	5' 0"	1.9
39	3' 8"	0.03	40	3' 7"	1.58
41	16' 3"	0.12	42	4' 10"	0.32
43	3' 4"	0.79	44	3' 1"	0.31
45	4' 2"	1.11	46	3' 1"	1.42
47	10' 4"	3.01	48	3' 5"	5.08
49	3' 9"	6.19	50	3' 9"	1.42
51	3' 6"	2.85	52	3' 4"	0.47
53	4' 7"	0.47	54	3' 6"	0.95
55	3' 4"	0.79	56	6' 6"	2.06
57	3' 6"	0.47	58		0.63
59		0.95	60	2' 9"	0.47
61	4' 6"	0.95	62	4' 1"	1.27
63	8' 3"	0.95	64	4' 10"	0.79
65	4' 3"	0.63	66	4' 2"	0.63
67	4' 6"	1.11	68	4' 0"	0.47
69	4' 7"	0.63	70	5' 3"	0.15
71	19' 10"	2.22	72	4' 5"	2.22

B.H. No.	Depth	CU %	B.H. No.	Depth	CU %
73	5' 5"	1.11	74	5' 10"	0.47
75	14' 10"	2.06	76	5' 9"	2.54
77	5' 7"	2.54	78	2' 8"	2.85
79	4' 4"	1.58	80	5' 0"	1.9
81	4' 6"	1.11	82	3' 9"	1.42
83	1' 6"	0.31	84	4' 8"	0.31
85	5' 1"	0.79	86	9' 1"	2.54
87	4' 9"	2.22	88	5' 2"	0.63
89	8' 1"	1.42	90	6' 8"	3.17
91	9' 4"	0.79	92	5' 3"	0.47
93	5' 10"	0.31	94	5' 7"	0.16
95	5' 5"	0.16	96	17' 6"	0.95
97	4' 9"	4.95	98	7' 4"	0.47
99	4' 3"	0.16	100	6' 0"	0.23
101	10' 10"	0.31	102	5' 5"	1.11
103	4' 9"	1.58	104	4' 5"	1.9
105	3' 8"	1.27	106	5' 3"	0.79
107	6' 7"	0.79	108	3' 4"	0.47
109	4' 6"	2.38	110	4' 8"	2.06
111	3' 8"	1.27	112	24' 0"	2.22
113	15' 9"	1.58	114	6' 4"	3.41
115	3' 11"	2.69	116	4' 2"	1.9
117	4' 5"	0.63	118	4' 1"	1.42
119	5' 9"	1.11	120	6' 5"	0.95
121	7' 0"	1.42	122	7' 11"	1.74
123	4' 8"	0.63	124	6' 7"	0.79
125	4' 11"	0.47	126	5' 10"	0.63
127	3' 1"	0.47	128	4' 3"	0.16
129	5' 9"	0.63	130	4' 4"	0.31
131	3' 11"	0.47	132	19' 0"	2.22

The calculated tonnage of the dumped material on the flanks of the pits and inside them, for the north, south and branch lodes totalled 185,377 tons. The average copper content was found to be 1.53 per cent, so that the total copper content in the dumps is expected to amount to about 2844 tons of copper.

Trenching :

Fourteen trenches were sited at the flanks of the pits of the old workings with the aim of finding out whether there were any well defined lodes below the dumps and to examine the nature of the wall rocks of these lodes. They also served for sampling the dumps and the wall rocks and for taking radioactivity readings below the surface (Fig. 12).

Though some of these trenches were dug to depths of over four metres they went through dumped material in the old workings without coming across a solid lode, except in two cases. The dumped material is mostly very friable, pale greenish schist. Flaky chloritic material together with epidote, kaolinized feldspar and quartz pebbles could be detected occasionally. Sometimes a whitish, kaolinized material predominated, with quartz pebbles. In other cases a ferruginous material was present in abundance giving the dumps a red tint. It was sometimes not easy to differentiate between the dumped material and the decayed country rock. The accompanying sketches of the trenches also give the chemical analyses (copper content) of groove and grab samples taken (Fig. 13).

The following are some analyses of bulk samples taken from the excavated material from each trench:—

Trench No.	% CU	Trench No.	% CU
1	1.40	2	2.38
3	1.75	4	1.59
5	1.12	6	1.90
7	0.50	8	0.79
9	0.95	10	0.50

The sketches show that the ferruginous material and also the ironstone, so characteristic of this area, were revealed in most trenches. In trench No. 10, a quartz vein which carries an appreciable amount of malachite and some tourmaline and iron oxide was met with. Here the malachite displayed very beautiful rosette shaped aggregates. In trench No. 6, as could be seen from the sketch, one side disclosed the presence of a kaolinized country rock, with abundant tourmaline and disseminated malachite and chrysocolla. Trench No. 14 was dug around an exposure of conglomerate, which was extraordinarily high in radio-activity. It was found that the conglomerate was superficial, but the radio-activity persisted till the bottom of the trench, in both the chloritic wall rock and the dumped material of the old workings. It also persisted in an Auger borehole driven at the bottom of this trench. It is worth noting that the dumps, which were cleared from the trenches, were invariably copper-bearing, malachite being visible particularly as crustations and crack filling in the quartz pebbles.

An extension to the already known mineralized zone was first detected in the aerial photographs (Fig. 3). A faintly distinct line of thin vegetation, similar to that covering the old workings themselves, lies immediately adjacent to the workings at their extreme western end and appears to be a natural extension. No pits or dumps or any trace of previous working could be detected on the surface; but numerous heaps of slag still retaining some copper are scattered there together with some broken pottery. Seven trenches were dug in this inferred extension. Unfortunately they

all failed to meet any vein or even dumped material. One of the trenches cut through a barren quartz vein, which however, gave a rather high response to the Geiger counter.

Radiometric Surveying :

The area of Hofrat en Nahas covered by old workings is approximately 900 x 400 metres as stated before. This area was marked off in a grid pattern ; with parallel lines directed at N. 70 E. and 10 metres apart and a perpendicular series of parallel lines 30 metres apart. Thus the area was divided into rectangles of 30 x 10 metres. About 4,000 radio-activity readings were taken on the surface at regular intervals with the aid of a Geiger counter. The type used in the field was a Nuclimeter provided with 25 Geiger Muller tubes, six of which are bismuth screen tubes for extra sensitivity. The model used covers a sensitivity range from 20 MR./HR. to 0.01 MR./HR. in three ranges (MR./HR. = Milliroentgen per hour). A nuclimeter reading was taken at every station of the grid already established ; the background response being checked at the camp once or twice every day. Afterwards the readings were plotted on a chart and lines of equal radio-activity *i.e.* isorads were drawn. The direct readings of the nuclimeter were used in the above radio-activity map, without deducting the values of the background which varied little from day to day.

It was considered that the readings of up to 0.04 MR/HR were within the background response and so no isorads were drawn for values below this. Areas between isorads 0.04 MR/HR and 0.06 MR/HR were considered as of low radio-activity, those between isorads 0.06 MR/HR and 0.10 MR/HR were considered as areas of medium radio-activity ; whereas areas above isorad 0.10 MR/HR were considered to have high radio-activity. Some limited parts of the area, gave values up to 0.20 MR/HR and at still fewer points the reading reached 0.40 MR/HR (Fig. 14).

It was noticed that the areas which gave radio-activity above 0.10 MR/HR occupied the whole areas of the old workings and dumped material together with many spaces in between ; with the result that the radio-activity showed continuously along the north lode, south lode and branch lode. The north and south lodges are connected through the branch lode and are also connected, near their western ends, by areas of weak to medium radio-activity. The following table gives the measured surface areas which showed strong to very strong response to the Geiger counter.

RADIO-ACTIVITY	Areas (In Square Metres)		
	North Lode	South Lode	Branch Lode
Above 0.10 MR/HR ..	21,095	14,120	1,350
Above 0.15 MR/HR ..	6,075	4,270	20
Above 0.20 MR/HR ..	1,570	355	—

From the table it could be seen that the north lode responded to the Geiger counter on wider areas than the south and branch lodes combined. The total area, which gave readings above 0.20 MR/HR on the north lode, is roughly five times the corresponding area on the south lode, while on the branch lode there was no reading recorded above 0.20 MR/HR. The patches of radio-activity above 0.20 MR/HR on the south lode lie between the following lines of the grid: SII-SIII and VIII-XIII. The corresponding patches on the north lode lie at the following positions; one very close to trench No. 10, another around point XX on the base line, the third and the biggest patch (area 1095 sq. mts.) lies between the lines SI-SII and XXIV.

Another radiometric survey was carried out on the extension of the mineralized zone. The survey covered an area of about 900 x 200 mts. Here the instrument applied for measuring radio-activity was a Ratemeter with four sensitivity ranges.

The highest reading in this extension was the equivalent of 0.06-0.10 MR/HR approximately, and it was restricted around an exposure of quartz. A trench was dug around the quartz which proved to be a superficial conglomerate, formed mostly of quartz pebbles embedded in a ferruginous matrix with no copper mineralization.

The Nuclimeter was also used to measure radio-activity inside the first 42 Auger boreholes. This was facilitated by the use of a specially devised long probe. The following table gives readings at different depths in the holes:—

Depth at which reading was taken	Nucleometer —reading—	Depth at which reading was taken	Nucleometer —reading—
No. 1	MR/HR	No. 2	MR/HR
Surface	0.046	Surface	0.102
10"	0.055	10"	0.128
2' 0"	0.077	2' 0"	0.128
3' 0"	0.085	3' 0"	0.134
4' 0"	0.107	4' 0"	0.120
5' 0"	0.081	5' 0"	0.095
6' 0"	0.072	5' 9"	0.075

Depth at which reading was taken	Nucleometer—reading— MR/HR	Depth at which reading was taken	Nucleometer—reading— MR/HR
No. 3		No. 4	
Surface	0.089	Surface	0.058
10"	0.100	10"	0.068
2' 0"	0.128	2' 0"	0.071
3' 0"	0.107	3' 0"	0.073
4' 0"	0.085	4' 0"	0.082
5' 0"	0.064	5' 0"	0.063
6' 0"	0.066	6' 0"	0.054
7' 0"	0.068	6' 1"	0.068
8' 0"	0.042		
8' 7"	0.028		
No. 5		No. 6	
Surface	0.102	Surface	0.042
10"	0.122	10"	0.068
2' 0"	0.130	2' 0"	0.067
3' 0"	0.138	3' 0"	0.079
4' 0"	0.121	4' 0"	0.76
5' 0"	0.134	5' 0"	0.039
6' 0"	0.147	5' 0"	0.049
7' 0"	0.197		
8' 0"	0.185		
9' 0"	0.123		
10' 0"	0.150		
11' 0"	0.175		
12' 0"	0.150		
13' 0"	0.149		
14' 0"	0.164		
15' 0"	0.175		
15' 9"	0.180		
No. 7		No. 8.	
Surface	0.105	Surface	0.260
10"	0.132	10"	0.270
2' 0"	0.151	2' 0"	0.250
3' 0"	0.165	3' 0"	0.210
4' 0"	0.197	4' 0"	0.210
5' 0"	0.220	5' 0"	0.220
5' 6"	0.193	6' 0"	0.250
		7' 0"	0.300
		8' 0"	0.310
		9' 0"	0.330
		10' 0"	0.460
		11' 0"	I. 11
		12' 0"	I. 22
		13' 0"	I. 19
		14' 0"	I. 39
		14' 1"	I. 40

Depth at which reading was taken	Nucleometer —reading— MR/HR	Depth at which reading was taken	Nucleometer —reading— MR/HR
No. 9.		No. 10.	
Surface	0.062	Surface	0.21
10"	0.665	10"	0.24
2' 0"	0.073	2' 0"	0.23
3' 0"	0.082	3' 0"	0.175
4' 0"	0.058	4' 0"	0.21
4' 9"	0.078	5' 0"	0.24
No. 11.		6' 0"	0.21
Surface	0.074	7' 0"	0.23
10"	0.090	8' 0"	0.22
2' 0"	0.197	9' 0"	0.16
3' 7"	0.240	9' 10"	0.17
No. 12.		No. 13.	
Surface	0.103	Surface	0.30
10"	0.168	10"	0.56
2' 0"	0.143	2' 0"	0.90
3' 0"	0.121	3' 0"	0.34
4' 0"	0.083	4' 0"	0.16
5' 0"	0.089	5' 0"	0.09
6' 0"	0.073	6' 0"	0.190 Fes.
7' 0"	0.102	7' 0"	0.20
7' 10"	0.086	8' 0"	0.178
No. 14.		9' 0"	0.164
Surface	0.197	9' 0"	0.167
10"	0.25	No. 15.	
2' 0"	0.27	Surface	0.113
3' 0"	0.31	10"	0.124
4' 0"	0.24	2' 0"	0.066
4' 6"	0.21	3' 0"	0.070
No. 16.		4' 0"	0.070
Surface	0.097	4' 0"	0.068
10"	0.144	No. 17.	
2' 0"	0.187	Surface	0.091
3' 0"	0.198	10"	0.137
4' 0"	0.210	2' 0"	0.174
5' 0"	0.220	3' 0"	0.198
6' 0"	0.20	4' 0"	0.187
6' 5"	0.21	5' 0"	0.137
		6' 0"	0.143
		6' 32"	0.152

Depth at which reading was taken	Nucleometer —reading— MR/HR	Depth at which reading was taken	Nucleometer —reading— MR/HR
No. 18		No. 19	
Surface	0.119	Surface	0.125
10"	0.130	10"	0.198
2' 0"	0.042	2' 0"	0.20
3' 0"	0.021	3' 0"	0.21
4' 0"	0.042	4' 0"	0.22
4' 5"	0.038	5' 0"	0.21
No. 20		No. 22	
Surface	0.043	Surface	0.036
10"	0.053	10"	0.047
2' 0"	0.048	2' 0"	0.043
3' 0"	0.053	3' 0"	0.047
4' 0"	0.051	4' 0"	0.057
5' 0"	0.048	4' 8"	0.054
5' 10"	0.042	No. 24.	
No. 21.		Surface	
Surface	0.042	10"	0.21
10"	0.063	2' 0"	0.22
2' 0"	0.049	3' 0"	0.20
3' 0"	0.058	4' 0"	0.063
4' 0"	0.056	5' 0"	0.051
4' 8"	0.049	5' 0"	0.068
No. 23.		5' 4"	
Surface		0.076	
10"		No. 25	
2' 0"		Surface	
3' 0"		10"	
4' 0"		2' 0"	
4' 9"		3' 0"	
0.053		4' 0"	
0.042		5' 0"	
0.046		5' 3"	
0.055		0.079	
0.060		0.102	
0.070		0.157	
No. 25		0.200	
Surface		0.210	
10"		0.184	
2' 0"		0.195	
3' 0"		No. 26	
4' 0"		Surface	
5' 0"		10"	
5' 3"		2' 0"	
0.102		3' 0"	
0.157		4' 0"	
0.200		4' 9"	
0.210		0.132	
0.184		0.109	
0.195		0.161	
No. 26		0.060	
Surface		0.057	
10"		0.054	
2' 0"			
3' 0"			
4' 0"			
4' 9"			
0.132			
0.109			
0.161			
0.060			
0.057			
0.054			

Depth at which reading was taken	Nucleometer —reading— MR/HR	Depth at which reading was taken	Nucleometer —reading— MR/HR
No. 27		No. 28.	
Surface	0.125	Surface	0.120
10"	0.146	10"	0.097
2' 0"	0.073	2' 0"	0.059
3' 0"	0.073	3' 0"	0.073
4' 0"	0.117	4' 0"	0.054
4' 4"	0.142	5' 0"	0.053
		5' 4"	0.056
No. 29.		No. 30.	
Surface	0.185	Surface	0.103
10"	0.200	10"	0.108
2' 0"	0.119	2' 0"	0.106
3' 0"	0.072	3' 0"	0.082
4' 0"	0.073	4' 0"	0.079
5' 0"	0.069	5' 0"	0.083
6' 0"	0.049		
No. 31.		No. 32.	
Surface	0.139	Surface	0.21
10"	0.104	10"	0.22
2' 0"	0.069	2' 0"	0.089
3' 0"	0.086	3' 0"	0.050
3' 9"	0.066	4' 0"	0.040
		5' 0"	0.056
		5' 2"	0.054
No. 33.		No. 34.	
Surface	0.073	Surface	0.147
10"	0.087	10"	0.21
2' 0"	0.083	2' 0"	0.20
3' 0"	0.082	3' 0"	0.22
4' 0"	0.080	3' 6"	0.21
5' 0"	0.083		
5' 0"	0.054		
No. 35.		No. 36.	
Surface	0.096	Surface	0.051
10"	0.092	10"	0.052
2' 0"	0.138	2' 0"	0.040
3' 0"	0.071	3' 0"	0.052
4' 0"	0.037	3' 0"	0.047
4' 6"	0.072		

Depth at which reading was taken	Nucleometer—reading— MR/HR	Depth at which reading was taken	Nucleometer—reading— MR/HR
No. 37.		No. 38.	
Surface	0.110	Surface	0.22
10"	0.097	10"	0.27
2' 0"	0.053	2' 0"	0.36
3' 0"	0.042	3' 0"	0.39
4' 0"	0.063	4' 0"	0.25
5' 0"	0.061	5' 0"	0.21
		5' 9"	0.22
No. 39.		No. 40.	
Surface	0.040	Surface	0.077
10"	0.050	10"	0.089
2' 0"	0.052	2' 0"	0.040
3' 0"	0.058	3' 0"	0.049
3' 8"	0.049	3' 7"	0.055
No. 41.		No. 42.	
Surface	0.075	Surface	0.051
10"	0.143	10"	0.056
2' 0"	0.117	2' 0"	0.064
3' 0"	0.100	3' 0"	0.061
4' 0"	0.092	4' 0"	0.065
5' 0"	0.103	4' 10"	0.057
6' 0"	0.102		
7' 0"	0.127		
8' 0"	0.107		
9' 0"	0.114		
10' 0"	0.110		
11' 0"	0.126		
12' 0"	0.0129		
13' 0"	0.021		
14' 0"	0.148		
15' 0"	0.123		
16' 0"	0.154		
16' 3"	0.152		

It can be seen from the table that the great majority of the holes gave readings much higher than 0.04 MR/HR down to the bottom. Generally speaking, it was noticed that the readings did not acquire an appreciable rise from the surface to the bottom of the Auger boreholes and it even tended to fall in cases where the hole passed through ironstone.

Radio-activity readings were also taken in 10 trenches.

The following table gives the results which were measured at different spots in those trenches:—

Trench No.	Radio-activity readings (in MR/HR)		
	Top of Trench	Middle	Bottom
1	0.096	0.100	0.095
2	0.200	0.190	0.260
3	0.193	0.102	0.198
4	0.158	0.126	0.124
5	0.056	0.083	0.077
6	0.200	0.162	0.175
7	—	—	0.041 (ironstone)
8	0.113	—	0.070
9	0.093	—	0.089
10	—	—	0.200

BOREHOLE LOGGING OF THE PRESENT INVESTIGATION

The ground around Hofrat en Nahas is fairly flat with a gradual and gentle slope north-westwards, directed to Umbelacha river. The gradient of this slope is 1 : 500. There is scarcely any country rock outcropping except perhaps on the banks of Umbelacha. The ground is covered with soil to a depth of over a metre ; this soil is partly ferruginous. Red pebbles of ironstone, characteristic of many parts of Bahr el Ghazal Province, was revealed here in Hofrat under the soil and was proved by auger boring. An exposure of this nature flanks one of the pits in the south lode to a thickness of more than two metres.

The veins of copper mineralization could have been once exposed above the surface. Old travellers, who happened to visit Hofrat during the last century, claimed that there was still a few quartz exposures carrying appreciable amounts of malachite. The present authors also observed and trenched around a malachite-bearing quartz vein in the north lode. It seems that the old workers who mined Hofrat, were not interested in the quartz veins, due to their compactness and difficulty of extracting malachite from them. At the same time they have mined the softer parts of the mineralized zones of country rock to depths of more than 50 feet below the surface, which include the goassanic cap of the ore together with a good deal of the carbonate zone. Evidence collected during shaft sinking by the N.C.D. Syndicate, points to the strong possibility that the old miners had extracted the ore by close shaft sinking along and across the outcrops between the wall rocks. In many places they have sunk shafts outside the lode, either to cut the lodes in depth or in the hope of finding more ore in the country rock. They appear to have sunk shafts moderately close together at first, then filled them in with debris to make the walls stand and then sunk more shafts in the intervening ore. A member of the staff of the N.C.D.S., was reported to have crawled through an old tunnel between recently sunk shafts, which means that driving and cross cutting may have been done to a certain extent. The old miners were also reported to have filled in the shafts when they left.

Several heaps of slag are scattered around the Hofrat workings. The slag is dark in colour, glassy, slightly magnetic and contains pellets of copper metal, varying in dimension from a fraction of a millimetre up to two millimetres. The size of the slag heaps is not such as might result from large scale smelting. The material used for fluxes and the procedure of smelting, practiced by the old miners, is still a matter of speculation.

The general shape of the Hofrat mine as it stands now is a succession of shallow pits, varying in dimensions and surrounded by dumped material. These pits and the dumped material, constitute the major surface guide to the former pre-existing outcrops of mineralization and to the lodes below. They are arranged roughly into two main rows, both extending N.E.-S.W. ; one is called the north lode and the other is the south lode. A third set of pits arranged obliquely to the direction of the north and

outh lodes lies between them; this is the branch lode. The general surface trends are, N. 45 E. for the north lode, N. 60 E. for the south lode and N. 25 E. for the branch lode. The pits were grouped under alphabetical figures to facilitate further reference. The south lode is composed of groups O-P-A-B-C-D, the north lode comprises the groups E-F-G-H-I, whereas the branch lode includes groups J-K-L-M-N (Fig. 19).

The very few rock exposures in the old workings offered but little help in identifying the rock types. The major pit in group (A) is probably the best in revealing some information. Exposures on its northern flank are formed of decayed and weathered chloritic schist, devoid of any indication of strike and dip. There is a small protruding exposure of a highly ferruginous conglomeratic rock at this flank, which proved to be only superficial. It was in this exposure of conglomerate that the first prominent radio-activity indication was detected. The southern flank of this pit is formed of badly weathered kaolinized material, whitish in colour, friable, and full of blebs and streaks of quartz. This kaolinized material is characterised by the presence of tourmaline along irregular channels. Other than these exposures it was difficult to know much from the dumped material which is intermingled with the ferruginous soil. However, some few scattered detrital pieces of pegmatite could be found in both the south and north lodes, specially in pits of groups C and G.

Old Shafts :

Core drilling and shaft sinking were the only means to establish a picture of the country rock in the vicinity of the mine and the wall rocks of the mineralized veins. The N.C.D.S. put down three shafts. The data available from their reports was not very informative regarding the description of rocks (Fig. 5). The following are records of depth with general remarks on the rocks met with; for two shafts and cross cuts, one in the north lode and the other in the south lode.

No. 1 Shaft and Crosscut (south lode)

Depth

Ft.	Ins.	
35	6	Hard metamorphosed country rock
54	6	slightly softer, shot with kaolinized matter
56	0	very small quartz stringers
58	3	veinlets of quartz, very hard
61	0	shot with kaolin
64	0	stopped sinking
Started a 4 by 5 ft. crosscut, direction 193 degrees		
1	0	hard metamorphosed country rock

Depth		REMARKS
Ft.	Ins.	
4	8	oxidised veinlet showing, dipping southward
5	4	metamorphosed country rock
6	7	„ „ Qz. veinlets, very faint staining of malachite
8	1	„ „ veinlets oxidized matter, dipping south
9	8	„ „ slightly oxidised
11	6	„ „ slightly softer, kaolin showing face
12	6	kaolinised matter, quartz, traces of azurite
13	6	„ „ „ oxidised veinlets, tourmaline
18	0	country rock containing quartz, felspar, tourmaline kaolin
19	6	oxidised quartz vein, malachite staining, good gold ferruginous qz. stringers on west side
24	0	oxidised matter, kaolin slightly stained with malachite
26	6	face soft, ferruginous qz. oxidised, good gold and slight colours of malachite
30	6	schist, kaolin, ferr. qz., stringer still on west side malachite stringers, gold
35	6	found chalcocite
37	0	oxidised qz., malac., kaolin, schist
38	6	schist, felspar, malac., qz., very good gold
45	6	qz., malac., oxidation, kaolin
48	0	„ „ „ „ old working showing
50	6	malac., kaolin
53	0	„ „ splendid specimen of malac. obtained
53	6	porphyry replacement ore, kaolinization complete, old workings, face soft
57	0	porphyry replacement ore
59	6	porphyry replacement ore, old working passed through they extend to greater depth on west side
61	0	face white with kaolin, shot with malachite

Depth

REMARKS

Ft.	Ins.	REMARKS
63	0	kaolin shot with veinlets of malac. ($\frac{1}{2}$ to $1\frac{1}{2}$ ins—wide), more old workings on west side
64	0	oxidised quartzitic ore
65	6	good gold
66	6	oxidised quartzitic ore, kaolin
68	0	still in ore body, quartzitic ore, kaolin, oxidation
69	0	still in ore body, quartzitic ore, kaolin, oxidation, copper getting less
71	0	still in lode stuff, white kaolin shot with malachite
72	6	„ „ „ „ veinlets oxidised, quartzitic ore malachite, kaolin
75	6	„ „ „ „
78	6	schist stained with malachite
81	0	schist, oxidised quartzitic ore, veinlets containing malac. and gold
84	6	oxidised quartzitic ore, veinlets containing malac., faint gold, slight fault
86	0	lode petering out
87	0	schist, quartz
89	3	schist
101	0	schist, stopped crosscutting, face in shattered schist

No. 2 Shaft and Crosscut (north lode)

7	3	debris
17	0	debris containing fragments of quartzitic ore
21	8	soft schist
36	0	„ „ traces of kaolin
39	6	„ „ stained with malachite
44	0	quartzitic ore showing on south side of shaft, strong tail of gold
45	0	hard oxidised quartzitic ore, right across bottom of shaft.

Depth		REMARKS
Ft.	Ins.	
46	6	quartzitic ore, north side of shaft, very soft schist very good gold
48	0	passed out of ore, soft schist and kaolinized matter
51	6	soft schist, dark in colour
56	0	„ „ „ „ „ with unaltered felspar
57	6	felspar-quartz-hornblende needles, kaolinized matter
61	0	soft schist, kaolinized matter
63	6	„ „ dampness showing
67	0	„ „ „ „
68	8	soft schist
71	0	soft schist felspar veinlets
72	0	„ „ „ „ pegmatite
76	0	„ „ „ „ „ stopped sinking
Started 4 by 5 feet crosscut, direction 318 degrees		
2	0	soft schist, felspar veinlet
4	0	4" ore vein, contains malac. and gold, dips steeply northwards
6	6	soft schist
9	6	„ „ passing through vein matter containing gold and malac.
11	0	schist, face slightly harder
13	6	diorite schist
16	6	schist
17	6	„ quartz, slightly oxidised
19	0	vein quartzitic ore, dips 50 degrees, schist, malac., and gold
20	6	vein quartzitic ore schist, good tail, malac. and gold
22	0	kaolin, qz., felspar, porphyry shot with veinlets of copper ore
23	6	porphyry intrusion, shot with qz., malac. kaolin and aplite, schorl.
25	6	vein matter, schist

Depth

REMARKS

Ft.	Ins.	REMARKS
27	0	qz., vein, copper ore, schist, felspar
28	6	„ „ „ „ „ „ „ good tail of gold
30	6	vein matter, kaolin, schist, felspar
32	0	„ „ „ „ „ „ „ good tail of gold
33	6	„ „ „ „ „ „ „
35	0	felspar, tourmaline, micaceous schist
36	6	„ „ „ epidote
43	0	oxidation, felspar, tourmaline, vein qz., traces of malac.
45	6	felspar, tourmaline, epidote, kaolin, highly coloured with malachite
48	0	felspar, tourmaline, epidote, veinlets of malac.
56	6	„ „ „ „ traces of malac. only
60	0	formation similar, little qz., malac. ceased, schist
65	6	„ „ „ „ very shattered, full of slips
66	6	„ „ „ „ „ „ „
69	6	faulted and shattered, fault apparently a N.-S. one schist.
75	0	faulted oxidation, traces of malac.
76	6	highly siliceous copper ore, very hard, dips 75 degrees
77	6	siliceous copper ore body, very hard
80	0	schist, siliceous ore ceased
85	0	very soft schist
93	0	„ „ „ „ stopped driving

Unfortunately, there is no record at all of the cores obtained from the drilling campaign undertaken by the Syndicate. The only data available in their reports covers the assay results of the mineralized portions.

Bore Holes :

The present field work, carried out by the Geological Survey Department, was fairly successful in core recovery from the fifteen bore holes sunk in the Hofrat mine. Three out of the fifteen bore holes were driven vertically, while the rest were directed at angles varying between 65 and 75 degrees from the horizontal. Some difficulties were experienced in drilling the

oblique holes and special precautions had to be taken to prevent the jamming of drilling rods. Certain portions of the ground proved to be cavernous, where casings or cementation had to be resorted to. The upper one hundred feet and sometimes the upper one hundred and fifty feet of each hole usually yielded very poor core recovery. The small fragmentary pieces, together with the sand recovery, were then our only means to identify the nature of these parts. The total footage along rods drilled, amounted to 5,875 feet.

The bore holes were arranged along three parallel lines having a bearing N. 49° W., which is apparently at right angles to the trend of both the north and south lodes. These lines are given in their alphabetical order (a), (b) and (c) going from east to west. Line (a) includes holes number III, I, II, IV, VII and VIII; line (b) includes holes number V, VI, IX and X; line (c) includes holes number XIII XIV, XI and XII; and bore hole number XV was dug at the extreme western corner of the mine.

Profile Line (a)

This profile crosses the three mineralized lodes near their north eastern extremity.

Bore hole number III was directed north westward at an angle of 65 degrees from the horizontal, to cross the mineralized zone below the pits in group (P); its total depth along rods was 555'. Bore hole number I was directed vertically, among pits of group (P), for a depth of 414'. Bore hole II was also directed vertically on the edge of the pits of group (L), for a depth of 282'. Bore hole number IV is directed south eastwards at an angle of 65 degrees from the horizontal to cross the mineralized zone below the pits of groups (L) and (P); its total depth along rods is 550'. Bore hole number VII is directed north westward at an angle of 75 degrees from the horizontal to cross mineralization below the pits of groups (K) and (J); its total depth along rods is 380'. Bore hole number VIII is directed south eastwards at an angle of 75 degrees from the horizontal to meet mineralization below the pits of group (J); its total depth along rods is 260'.

In the following columns a detailed description of the different rocks encountered by these bore holes is given:—

Bore Hole Number III.

Depth along rods

From ft. inch	To ft. inch	REMARKS
5 0	18 0	recovery sand, Qz. with felspar, some malachite
18 0	30 0	recovery sand, Qz. with felspar, some malachite
30 0	45 0	recovery sand, Qz. with felspar, some malachite

From ft. inch	To ft. inch	REMARKS
45 0	55 0	recovery sand, Qz. with felspar with some mal- achite.
55 0	65 0	" " " " " " " " with some mal- achite.
65 0	70 0	" " " " " " " " with much mal- chite
70 0	77 0	" " " " " " " " with much mal- chite
77 0	80 0	badly weathered chloritic schist
80 0	85 0	acid gneiss (Qz., kaolinized felspar) porphyro- blastic.
85 0	110 0	recovery sand, Qz. and felspar
110 0	120 0	acidic gneiss, sericitic
120 0	170 0	chlorite schist
170 0	177 6	acidic gneiss
177 6	179 6	amphibolite
179 6	180 0	acidic gneiss
180 0	181 0	no core or sand recovery
181 0	182 0	chlorite schist
182 0	185 6	acidic gneiss, tourmaline and some sulphides
185 6	189 0	chlorite schist. Intercalations of tourmaline- bearing pegmatite
189 0	204 0	talc schist with pyrite dissemination. Joints lined with chlorite, show slickensiding
204 0	205 0	chlorite talc schist
205 0	213 0	small piece of chlorite schist. Sand recovery rich in pyrite and chalcopryrite
220 0	222 0	chlorite-actinolite-talc schist, with minute stringers of calcite. Pyrite dissemination
222 0	231 0	acidic gneiss with sericite, few bands of chlo- ritic schist
231 0	235 2	small pieces of pegmatite
235 2	236 0	mostly chlorite schist, with vugs lined by chalcedonic quartz

From		To		REMARKS
ft.	inch	ft.	inch	
236	0	27	0	particularly siliceous and vuggy rock, vug filled with chalcedonic quartz and colloform siderite
237	0	241	0	recovery nearly nil
241	0	247	0	chloritic schist and amphibolite
247	0	252	0	recovery poor, white pegmatite
252	0	269	0	recovery sand only, rich in sulphides
269	0	270	0	amphibolite
270	0	275	0	poor recovery, pegmatite
275	0	279	0	„ „ partly pegmatite and partly amphibolite
279	0	284	0	chlorite talc schist
284	0	286	0	amphibolite
286	0	290	8	„ with felspar porphyroblasts, some pyrite dissemination
290	8	291	0	amphibolite with joints lined with sulphides
291	0	291	6	tourmaline pegmatite
291	6	294	0	Qz.-sericite-chlorite-amphibole schist
294	0	298	0	pegmatite
298	0	300	6	hornfelsic Qz.-plagioclase rock, with some hornblende, veined with calcite
300	6	303	10	plagioclase-amphibole schist, stringers of sulphide-rich pegmatite
303	10	308	0	amphibolite (some blades of tremolite), pyrite dissemination in good crystals
308	0	313	0	chlorite schist, stringers of tourmaline-bearing pegmatite with some sulphides
313	0	319	0	amphibolite
319	0	322	0	barren pink pegmatite
322	0	330	6	alternating schist and barren pegmatite
330	6	331	0	mineralized part of pegm., with tourm. and calcite
331	0	333	6	mylonitic hornblende-biotite granite

From ft.	inch	To ft.	inch	REMARKS
383	6	334	0	amphibole-felspar schist, barren
384	0	335	0	tourm-bearing pegm. with sulphide
385	0	338	0	amphibolite, pegm. stringers with big tourm. x-tals
388	0	340	0	amphibolite pegm. fairly rich in sulphides
340	0	343	0	alternating schist with mylonitic horn-biotite granite, Qz.-calcite stringers.
343	0	355	0	chlorite schist
355	0	357	0	horn.-biotite-quartz-felspar schist (porphyroblasts of felspar)
357	0	357	9	interlocking sulphide-bearing pegmatite
357	9	362	6	amphibole-felspar schist, sulphide-bearing peg.
362	6	365	6	barren tourmaline-bearing pegmatite
365	6	375	0	gradation between talc and chlorite schist, magnetite dissemination, stringers of qz-calcite
375	0	376	3	barren pegm., vuggy, partly lined with minute quartz crystals
376	3	377	9	chlorite schist, pegm. stringers (some chalcopyrite)
377	9	378	6	barren pink pegm.
378	6	379	9	chlorite schist, quartz stringers
379	9	381	0	veining pegm. with some sulphide
381	0	381	10	rich sulphide-bearing pegm. with tourmaline
381	10	382	4	chlorite schist
382	4	384	6	pegmatite, feeble dissemination of sulphide
384	6	385	2	some concentration of sulphide with tourmaline
385	2	387	6	amphibole-sauserite schist
387	6	400	0	talc schist with dissemination of magnetite and pyrite
400	0	419	0	fine grained quartz-chlorite schist
419	0	425	0	barren pegmatite, stringers of calcite
425	0	435	0	recovery very poor, pegm. and schist

From		To		REMARKS
ft.	inch	ft.	inch	
435	0	445	0	recovery sand only, no sulphide in the recovery
445	0	445	6	biotite-chlorite schist (dense ilmenite dusting)
445	0	448	0	talc schist
448	0	451	9	chlorite schist with pegmatite
451	9	452	0	recovery poor, pieces of pegm. showing faint sulphide mineralization
452	0	460	0	sand recovery rich in chalcopyrite and covellite
460	0	465	0	core recovery poor, mostly chlorite schist
465	0	472	0	recovery sand, very poor in sulphides
472	0	474	0	core recovery very poor, amphibole plagio. schist
474	0	476	0	amphibolite
476	0	476	10	barren pegmatite
476	10	477	4	amphibolite
477	4	480	0	alternating pegmatite and amphibolite
480	0	489	7	rather coarse grained sericite-hornblende gneiss
489	7	490	2	acidic gneiss
490	2	498	0	barren amphibolite
498	0	500	0	acidic gneiss
500	0	502	6	plagioclase-amphibole gneiss
502	6	506	0	amphibolite, veined by tourm-bearing pegmatite
506	0	510	0	acid gneiss; rich mineralization (3") at 507
510	0	514	0	amphibolite, stringers of tourmaline
514	6	516	8	amphibolite
516	8	517	6	talc actinolite rock
517	6	519	6	amphibolite
519	6	520	6	pegmatite
520	6	524	0	talc rock merging gradually to amphibolite
524	0	530	0	recovery sand only, rich in sulphides
530	0	535	0	recovery poor; aggregates of tourmaline-bearing pegm.; sand recovery rich in sulphides

From ft. inch	To ft. inch	REMARKS
535 0	540 0	recovery sand only ; rich in sulphides
540 0	545 0	recovery very poor. Bits of quartz with sulphides and amphibolitic rock. Sand recovery rich in sulphides
545 0	555 0	poor recovery. Gap at top, then sericite quartzite with sulphide bearing chlorite stringers. Near base, 2" of very rich sulphide

Bore Hole Number 1 :—

Depth along rods

0 0	42 0	recovery sand, ferruginous
42 0	46 0	loose kaolinized sand
46 0	48 0	pieces of chlorite schist
48 0	63 0	loose sand, quartz and kaolinized material
63 0	65 0	fragments of chlorite schist with blebs of malachite and chrysocolla
65 0	80 0	loose material, chloritic
80 0	100 0	,, ,, kaolinized, Fragments of acid gneiss partly epidotized
100 0	130 0	fragments of chlorite schist with some quartz
130 0	138 0	core recovery chlorite schist
138 0	145 0	acidic gneiss, with epidote, biotite and some chlorite. Tourmaline detected. Amphibolite bands
145 0	150 0	acid gneiss, with quartz-tourmaline stringers
150 0	155 0	loose chloritic material
155 0	164 0	felspar-chlorite schist
164 0	168 0	biotite-amphibolite
168 0	170 0	chlorite schist
170 0	171 0	shattered kaolinized pegmatite
171 0	175 0	chlorite schist
175 0	178 0	acidic gneiss, some epidote and few needles of actinolite

From		To		REMARKS
ft.	inch	ft.	inch	
178	0	180	0	alternating acid gneiss with epidote-amphibole-quartz-felspar gneiss. One stringer rich in pyrite
180	0	194	0	acidic gneiss, strongly shattered. Stringers of quartz-tourmaline with some pyrite
194	0	195	0	intercalations of acidic gneiss with chlorite schist.
195	0	200	0	recovery sand, mineralization very feeble
200	0	204	0	barren pegmatite
204	0	215	0	chlorite amphibolite, with stringers of tourmaline pegmatite carrying some sulphide
215	0	218	0	amphibolite with augen quartz-felspar gneiss
218	0	221	0	quartz-sericite-chlorite schist. Pyrite dissemination
221	0	222	0	conglomeratic aggregate of Qz., matrix of calcite
222	0	223	0	chlorite schist
223	0	223	6	biotite amphibolite. Rich sulphides in 5" quartz-tourmaline veinlet
223	6	224	0	pegmatite with some epidote
224	0	225	9	chlorite schist merging to talc antigorite rock downwards. Dissemination of pyrite in the latter
225	9	229	10	biotite-amphibole-talc schist. Specks of pyrite
229	10	234	7	same rock. Vuggy, partly filled with silica
234	7	237	8	biotite amphibolite, partly talcose
237	8	244	0	recovery sand, greenish. Some sulphides
244	0	245	0	chlorite schist
245	0	245	4	barren pegmatite
245	4	248	7	chlorite schist
248	7	249	0	barren pegm., this is cut by a vuggy quartz stringer with pyrite
249	0	250	5	chlorite schist
250	5	250	10	barren pegmatite

	From ft. inch	To ft. inch	REMARKS	
250	10	260	10	recovery sand. Much Qz. and very little sulphides
260	10	262	0	intercalation of felsitic rock and chlorite schist
262	0	262	3	pegmatite
262	3	264	0	talc chlorite schist
264	0	264	4	chlorite schist with Qz. stringers
264	4	265	10	talcose rock
265	10	266	0	mineralized pegmatite
266	0	266	3	granitic gneiss with some sulphides
266	3	269	7	talc and talc-chlorite schist with tiny specks of pyrite
269	7	271	7	coarse grained plagioclase-amphibole gneiss
271	7	279	0	core recovery poor. Talc antigorite rock, stringers of sulphide-bearing quartz
279	0	280	6	talcose chlorite schist with stringers of pegm.
280	6	282	9	chlorite schist. Sulphide-rich tourmaline pegmatite stringers
282	9	283	3	pegmatite, barren
283	3	297	0	recovery sand. Good percentage of sulphides
297	0	299	6	plagioclase amphibole schist
299	6	303	0	core recovery poor. Biotite plagioclase—amphibole schist, vuggy, vugs lined with secondary quartz.
303	0	308	8	plagioclase amphibole gneiss. Fissures filled with epidote and carbonate. Numerous pegm. veinlets
308	8	310	0	Augen quartz-felspar gneiss
310	0	311	0	Porphyroblastic plagioclase-amphibole gneiss
311	0	313	0	pegmatite enclosing pieces of country rock
313	0	315	5	biotite-plagioclase-amphibole gneiss
315	5	317	9	biotite sericite schist. Joints coated with sulphides
317	9	319	3	quartz-felspar-biotite-hornblende hornfels

From		To		REMARKS
ft.	inch	ft.	inch	
319	3	322	0	quartz-felspar gneiss with dark bands rich in epidote and chlorite. Angle of dip. 60-70 degrees
322	0	329	6	alternating light and dark coloured horizons of gneiss. Dark bands particularly rich in pyrite
329	6	338	10	plagioclase-amphibole gneiss varying vertically in grain size
338	10	341	0	pegmatite ramifications in the country rock
341	0	355	0	recovery sand. Panning gave some sulphides
355	0	357	0	recovery shattered particles of acid gneiss and chloritic schist
357	0	358	0	pegmatite with much epidote
358	0	362	8	amphibolite
362	8	365	4	alternating bands of epidote-rich, acid gneiss and darker plagioclase-amphibole gneiss.
365	4	368	6	amphibolite
368	6	370	6	tremolite-talc schist. Dissemination of sulphides
370	6	377	2	mostly acidic gneiss. Encloses chloritic material. Numerous stringers of quartz, rich in sulphides
377	2	377	8	talc schist
377	8	378	8	actinolite-tremolite schist. Stringers of tourmaline
378	8	379	10	talc schist with disseminated sulphides
379	10	381	4	intercalating chlorite schist and pegmatite. Very tiny quartz stringers cut both pegm. and schist.
381	4	383	0	pegmatite and acid gneiss. Chlorite with sulphides fill in cross joints
383	0	384	3	talc and talc-chlorite schist
384	3	388	0	recovery sand with bits of chlorite schist. Small concentrate of sulphides after panning
388	0	389	2	pegmatite
389	2	394	0	amphibolite, partly talcose and partly white tremolite fibres. Dissemination of sulphides

	From ft. inch	To ft. inch	REMARKS	
394	0	402	0	sand recovery, contains much sulphides
402	0	405	0	mostly formed of sulphides with bits of country rock
405	0	414	0	sand recovery contains much sulphides
394	0	414	0	the few bits of core recovered are formed of almost solid sulphides, mainly chalcopyrite with pyrite

Bore Hole Number II

0	0	65	0	recovery sand only. Ferruginous material containing some bits of malachite
65	0	70	0	sand recovery like the above, besides, there are bits of clayey material partly ferruginous
70	0	110	0	sand recovery, less ochreous than previous. Malachite is present in whole depth
110	0	112	0	decayed chlorite schist, rich in ochreous material
112	0	117	6	friable greenish schist, probably originally amphibolite
117	6	117	10	altered pegmatite
117	10	119	0	friable greenish schist
119	0	125	0	recovery sand, showing some malachite
125	0	130	0	„ „ bits of chlorite-quartz-malachite
130	0	140	0	recovery sand, richer in malachite
140	0	144	0	„ „ particularly rich in malachite
144	0	146	0	recovery sand, much angular bits of qz. with malachite
146	0	153	0	recovery sand with bits of core. Conglomerate of qz. embedded in malachite and dull brownish material
153	0	158	0	recovery sand, colour dark greyish. Rich in sulphides together with malachite
158	0	163	0	conglomerate, quartz cemented with carbonates, oxides and sulphides of copper and iron

From		To		REMARKS
ft.	inch	ft.	inch	
163	0	167	0	the upper two feet formed of conglomerate rich in sulphides and brownish material, and malachite. Below, bits of pegmatite with malachite, vuggy, partly filled with calcite
167	0	175	0	kaolinized pegmatite, malachite and chrysocolla together with some chalcopyrite
175	0	183	0	friable kaolinized and epidotized rock. Cracks filled with iron ochre
183	0	190	0	recovery sand. Much kaolin and epidote. Small sulphide content
190	0	196	0	greyish green rock, with little amount of sulphides
196	0	203	0	kaolinized pegmatite
203	0	210	0	porphyroblastic biotite-chlorite-epidote-felspar schist. Feeble content of sulphides
210	0	225	0	mainly chlorite-quartz-felspar gneiss, with pegmatite
225	0	233	0	amphibole-quartz-felspar schist with pyrite dissemination
233	0	240	0	recovery sand. Some sulphide
240	0	250	0	recovery sand, sulphides very poor
250	0	257	0	oligoclase-hornblende-quartz gneiss, few pegmatites
257	0	275	0	recovery sand, sulphides generally fair in amount
275	0	282	0	dark green amphibolite, interbedded with acid gneiss and quartz-felspar-biotite schist
Note:	At	195	0	small piece of core formed of solid sulphides

Bore Hole Number IV :

0	0	10	0	dark brown clayey sand
10	0	20	0	light brown, clayey sand with micaceous constituent
20	0	57	0	recovery sand, qz. and felspar with some malachite

From ft. inch	To ft. inch	REMARKS
57 0	64 0	core highly weathered, ochreous, with stringers of malachite
64 0	76 0	only sands, qz. with some epidote and tourm. and few micaceous flakes
76 0	90 0	fragments of conglomerate, qz. in matrix of iron and copper salts
90 0	126 0	recovery sand, qz., kaolinized fiespar, epidote and few tourmalines. Malachite
126 0	130 0	fragments of highly weathered qz. and felspar embedded in matrix of iron and copper salts
130 0	150 0	recovery sand, qz., kaolin, micaceous material, and dense brownish iron oxides
150 0	160 0	recovery sand, weathered chloritic material
160 0	180 0	conglomeratic rock with iron oxides and malachite as cement. Pyrite appears at lower half
180 0	190 0	conglomerate of particles of kaolinized rock in matrix with little malachite and much pyrite. Some chalcocite is shown at the base
190 0	200 0	core recovery poor, fragments of kaolinized felspathic rock rich in pyrite
200 0	200 0	sand recovery of qz. and felspar with chloritic material, fair amount of pyrite and chalcopyrite
220 0	230 0	acid gneiss (highly kaolinized), faint mineralization
230 0	240 0	sand recovery (qz. + felspar), some sulphides
240 0	250 0	„ „ „ rich in sulphides
250 0	260 0	recovery poor, acid gneiss with sulphides
260 0	267 0	small piece of qz. recovered sand rich in sulphides
267 0	270 0	no recovery at all
270 0	280 0	fine clayey material rich in sulphides with chloritic material at the base
280 0	290 0	recovery very fine sand with high sulphide content

From		To		REMARKS
ft.	inch	ft.	inch	
290	0	300	0	recovery sand with some pebbles of qz., rich in chalcopyrite, covellite and some pyrite
300	0	310	0	pebbles of qz. and chloritic material. Sand rich in sulphides
310	0	320	0	recovery sand, rich in sulphides including some covellite
320	0	327	0	upper three feet recovered as sand only extremely rich in sulphides, then core of acid gneiss
327	0	336	0	recovery sand probably from the disintegration of amphibolitic rock. Barren
336	0	340	0	amphibolite, fairly fresh, some pyrite dissemination
340	0	346	0	rock ranges between talc-amphibole schist, amphibole-chlorite schist and amphibolite. Faint pyrite dissemination. Tourm. pegm. at the base
346	0	356	0	differs between talc-chlorite schist, talc schist and talc-antigorite-chlorite schist. Faint diss. of pyrite. Barren pegm. stringers
356	0	371	0	pegmatite very rich in sulphides with remnants of biotite chlorite schist and chlorite talc schist
371	0	378	0	acid gneiss alternating with qz.-felspar-chlorite schist. Barren
378	0	386	0	qz.-felspar-epidote gneiss giving way below to amphibolite
386	0	401	0	qz.-felspar-chlorite schist, scant mineralization. Rock slickensided. Stringers of pegm. with sulphides
401	0	416	0	recovery very poor, felspar-amphibole schist. Upper part very rich in pyrite
416	0	418	0	quartz-felspar-chlorite schist. Fair mineralization
418	0	420	0	quartz-felspar-amphibole-epidote-chlorite schist, dense mineralization at contact with above rocks

From ft. inch	To ft. inch	REMARKS
420 0	428 0	at top, hornblende-quartz-felspar hornfels, then turns to plagioclase-amphibole schist
428 0	431 0	recovery rather low. Rock plagioclase-hornblende schist with sulphide-bearing tourmaline pegmatite
431 0	435 0	amphibolite with tourmaline-quartz veins
435 0	446 0	recovery poor. Fragments of amphibolitic schist
446 0	456 0	recovery poor. Upper part acid gneiss followed by amphibolite. Sand recovery very rich in sulphide
456 0	466 0	quartz-felspar-biotite-hornblende schist. Veined by sulphide-rich quartz-tourmaline stringers
466 0	469 0	mainly quartz-tourmaline rock invading country rock
469 0	474 0	tourmaline pegmatite with dense mineralization
476 6	486 0	amphibolite with some dissemination of pyrite
486 0	488 0	chlorite talc schist. Traces of sulphide dissemination
488 0	490 0	mostly formed of pegmatite. Tourmaline bearing
490 0	496 0	quartz with sulphides in the upper part, then turns to acid gneiss
496 0	503 0	acid gneiss veined by sulphide-bearing pegmatites
503 0	506 0	recovery very poor. Amphibolite with scant diss. of sulphides
506 0	513 0	core changes from amphibolite to qz-plagioclase amphibole schist, with stringers of tourmaline
513 0	516 0	coarse grained tourmaline pegmatite, little amount of sulphides
516 0	526 0	recovery very poor, pegmatite changes to amphibole rock, with very little sulphide
526 0	536 0	pegmatite gives way to qz.-plagioclase-amphibole rock, then pegmatite appears again

From		To		REMARKS
ft.	inch	ft.	inch	
536	0	538	0	qz.-plagioclase-amphibole schist, hard fresh, some sulphide dissemination, occasional stringers of tourmaline
538	0	550	0	first few inches tourmaline pegmatite, then amphibole rock with scant mineralization

Bore Hole Number VII

0	0	20	0	sand recovery only. Ferruginous material with bits of ironstone
20	0	80	0	sand recovery. Kaolinized sand, slightly ferruginous
80	0	85	0	poor core recovery. Kaolinized material with red staining and malachite. Pebbles of quartz conglomeratic
85	0	90	0	kaolinized material. Sand contains some malachite
90	0	105	0	sand recovery only. Quartz and feldspar with malachite and ferruginous material
105	0	121	0	poor core recovery. Similar to the above. Sand apparently with no malachite
121	0	136	0	core recovery poor. Kaolinized material with streaks and stringers of malachite. The lower part, of several feet, composed of ferruginous material with malachite
136	0	151	0	core recovery very poor. Kaolinized material with some malachite
151	0	159	0	kaolinized material, conglomeratic. Malachite, some chrysocolla and ochreous material
159	0	168	0	barren, friable and altered plagioclase chlorite schist
168	0	173	0	conglomeratic material mostly quartz pebbles with kaolinized feldspar embedded in a ferruginous matrix with malachite. The lower part is pegmatitic, with tourmaline and devoid of malachite
173	0	190	0	strongly crushed tourmaline pegmatite. Recovery poor
190	0	200	0	no recovery at all

From		To		REMARKS
ft.	inch	ft.	inch	
200	0	205	0	very poor recovery. Acidic gneiss with quartz-tourmaline-sulphide veining
205	0	221	0	acidic augen gneiss, tourmaline bearing. Barren
221	0	230	0	augen acid gneiss, intruded by pink pegmatite with tourmaline and sulphides
230	0	234	0	acid gneiss intruded by sulphide-tourmaline-bearing pegmatite. Micro faulting under the microscope well demonstrated
234	0	237	0	barren acid gneiss
237	0	243	6	acid gneiss with reddish tourmaline-pegmatite rich in sulphides. It shows faulting and brecciation specially at 242'
243	6	245	0	acid gneiss alternating with quartz-felspar-chlorite schist. Thick veinlet of calcite cuts across the rock
245	0	245	6	reddish pegmatite with remnants of chlorite schist. Mineralization in the pegmatite accompanied with tourmaline and chlorite linings. Barren chlorite-calcite stringers to exist
245	6	247	0	barren acid gneiss
247	0	251	0	porphyroblastic plagioclase-chlorite schist, chlorite probably after amphibole. Calcite forms numerous stringers. At contact with above core, there is a narrow mineralized zone associated with chlorite
251	0	253	0	barren acid gneiss. The lower 3" is formed of crushed microcline granite fairly rich in sulphides. Calcite veining in abundance
253	0	261	0	alternating acid gneiss with quartz-felspar-chlorite schist. Tourmaline sulphide veining. Also calcite-chlorite veining, barren
261	0	270	0	chlorite-epidote-quartz-felspar schist, porphyroblastic felspar. Calcite in big quantity. Alternating bands of chlorite-epidote and quartz-felspar. Tourmaline accompanied with some mineralization

From ft. inch		To ft. inch		REMARKS
270	0	278	0	begins with muscovite-chlorite-quartz-felspar schist, loaded with sulphides along narrow channels with tourmaline. It turns to very dense sulphide dissemination in marble, at 272' and 273'. Below this, it turns to strongly crushed microcline pegmatite, barren in itself, but carries sulphides along stringers with tourmaline, and chlorite. Calcite-quartz in barren stringers are the youngest
278	0	301	0	strongly crushed tourmaline pegmatite. Veined with stringers of calcite, bordered with chlorite. Also stringers of tourmaline-chlorite, both types of stringers may carry some sulphides specially at 291'-291' 6" and at 295'-296'
301	0	305	0	porphyroblastic chlorite-quartz-felspar gneiss. Restricted mineralization along narrow channels with chlorite and occasional tourmaline
305	0	307	0	stressed pink pegmatite with tourmaline. Nearly barren
307	0	309	0	barren pink pegmatite
309	0	315	0	crushed pegmatite, cemented in epidote and chlorite
315	0	330	6	quartz-felspar-chlorite schist with porphyroblasts of felspar. Permeated with pegmatitic stringers which carry sulphides in part
330	6	333	0	barren acid gneiss
333	0	337	0	quartz-felspar-chlorite schist, barren
337	0	338	6	crushed pegmatite, cemented with calcite, epidote, and chlorite. Zone of mineralization at the lower 2"
338	6	346	0	biotite-chlorite-felspar-amphibole schist, and biotite-chlorite-quartz-felspar gneiss. Stringers of calcite. Zone of rich mineralization 343'-344', at the contact with reddish pegmatite
346	0	348	0	acid gneiss strongly veined with calcite. Mineralization accompanied with chlorite
348	0	352	0	chlorite-quartz-felspar schist. Stringers of calcite

From ft. inch	To ft. inch	REMARKS
352 0	354 0	pink pegmatite. Calcite stringers. Barren
354 0	356 0	granitized chlorite-quartz-felspar schist quartz stringers carry some sulphides. At 356' a peculiar clayey material was recovered, greyish in colour and very light in weight
356 0	367 0	quartz-felspar-chlorite schist alternating with acid gneiss. Ramifying stringers of calcite. Barren
367 0	369 0	pegmatite with some mineralization
369 0	374 0	dark greyish quartz-felspar-chlorite schist with much calcite veining. Barren
374 0	380 0	crushed pink pegmatite. Tiny stringers of calcite. Faint mineralization

Bore Hole Number VIII

0 0	30 0	recovery sand, light coloured, grains of quartz decayed felspar greenish material. No mineralization
30 0	50 0	recovery sand, as the previous, with some black ferromagnesian, No mineralization
50 0	120 0	recovery sand, as previous, with few flakes of muscovite. No mineralization
120 0	126 0	recovery sand. Higher percentage of greenish and blackish material
126 0	136 0	bits of chlorite-plagioclase gneiss. Calcite veinlets numerous. Pegmatite vein, $\frac{1}{2}$ foot near the top
136 0	146 0	recovery sand. Quartz-felspar-ferromagnesian. Barren
146 0	149 0	chlorite-plagioclase gneiss. Stringers of carbonate
149 0	164 0	poor core recovery, same as above. Frequent stringers of pegmatite. No mineralization
164 0	172 0	core recovery poor, decayed material. Conglomerate, bits of quartz and felspar cemented in calcite together with some epidote and chlorite. Mineralization of malachite and azurite. This is underlain by pegmatite with sulphides, mainly pyrite

From ft.	From inch	To ft.	To inch	REMARKS
172	0	193	0	brecciated quartz-felspar rock alternating with quartz-felspar-chlorite schist. Mineralization concentrated in the brecciated horizons at 173', 184' and 191' 6", sulphides associated with carbonate
193	0	223	0	crushed pegmatitic material enclosing relics of qz.-felspar-chlorite schist. Few pyrite disseminations in the chist. Pegmatite practically barren
223	0	227	0	crushed pegmatite, barren. tourmaline bearing. Chlorite and calcite form stringers and cement part of the crushed pegmatite.
227	0	234	0	plagioclase-chlorite schist. Barren
234	0	235	6	pink pegmatite. Barren
235	6	245	0	gneissose granite in greenish schist. Barren
245	0	256	3	tourmaline granite. Barren except for a thin stringer at 248' 6"
256	3	260	0	gneissose granite in chlorite-quartz-felspar gneiss. Between 257' and 258' stringers carrying reasonable amount of sulphides

Profile Line (b)

This profile line crosses the south lode near the western end of its major pit group. It passes west of the 25" branch lode, to cross the easternmost pit group of the north lode. Bore hole number V is directed north westward at an angle of 75 degrees from the horizontal, to cross the mineralization below pit group (A); its total depth along rods is 360'. Bore hole number VI is directed south eastward at an angle of 75 degrees from the horizontal, to cross the mineralization below pit group (A); its total depth along rods is 529'. Bore hole number IX is directed north westward at an angle of 75 degrees, to cross the mineralization below pit group (I); its total depth along rods is 360'. Bore hole number X is directed south eastward at an angle of 75 degrees from the horizontal, to cross the mineralization below pit group (I); its total depth along rods is 360'.

Bore Hole Number V

0	0	18	0	recovery sand, contains tiny mica flakes and bits of dark mineral, no malachite
18	0	30	0	recovery sand, no flakes of mica. No mineralization

From		To		REMARKS
ft.	inch	ft.	inch	
30	0	41	0	,, ,, epidote abundant
41	0	50	0	,, ,, angular qz. fragments abundant
50	0	79	0	,, ,, bits of quartz and felspar with epidote and few grains of dark mineral
79	0	82	0	core recovery, decayed greenish chloritic schist
82	0	95	0	very poor core recovery. Acidic gneiss, kaolinized
95	0	98	6	acid gneiss intruded by quartz stringers
98	6	99	6	chloritic schist
99	6	103	0	acid gneiss, contains few flakes of mica, dips parallel to rods (75 degrees)
103	0	117	0	alternating chloritic schist and acid gneiss
117	0	128	0	qz-plagioclase-amphibole schist, strongly weathered, veined with tourmaline-bearing pegmatite. Tiny bits of malachite recovered with the sands
128	0	134	0	quartz-felspar-chlorite schist with tourm-qz. veining. A fault detected, dislocation of 8 mms running roughly parallel to elongation of rods. At base, a piece of qz.-tourm.-malachite is seen
134	0	142	0	plagioclase-chlorite schist, much altered
142	0	146	0	totally kaolinized material with tourmaline, stained with malachite
146	0	153	6	chloritic schist
153	6	154	0	very strongly crushed and recrystallized quartz vein with tourmaline, malachite fills in cracks
154	0	168	0	plagioclase-chlorite schist with occasional felspar predominance. Malachite-tourmaline occur intermitently
168	0	170	0	acid gneiss, decayed felspar, no mineralization
170	0	171	6	alternating porphyroblastic acid gneiss with chloritic schist. No copper mineralization
171	6	171	8	quartz-tourmaline rock

From		To		REMARKS
ft.	inch	ft.	inch	
171	8	180	0	alternating, porphyroblastic acid gneiss and quartz-chlorite schist. Irregular stringers of quartz, partly malachite-bearing
180	0	193	0	chlorite and quartz-felspar-chlorite schist. Kaolinization strong. Malachite at 180-181 6' and at 190'. Torbernite with tourmaline dissemination at 184'-186'
193	0	199	0	porphyroblastic quartz-felspar-muscovite-epidote rock, felspar kaolinized. Dissemination of sulphides at 195'-197'
199	0	201	8	chlorite-talc schist, few sulphide disseminations
201	8	202	2	highly kaolinized material soaked with numerous stringers of tourmaline-pegmatite carrying sulphides at the walls
202	2	205	4	kaolinized rock with sulphide-bearing quartz stringers. Rock suggests being a microgranite. At the lower 8" chrysocolla occurs with sulphide
205	4	208	0	mostly chlorite schist. Sulphide dissemination mainly pyrite with or without tourmaline
208	0	214	0	chlorite schist merges to chlorite-biotite-antigorite schist. Some dissemination of sulphide and partial concentration in joints
214	0	226	0	core recovery low. Generally talcose schist. Mineralization associated with quartz veining
226	0	236	0	recovery sand only. Coarse fragments of different constituents, rich in silica. Sulphide fairly rich together with tourmaline fragments
236	0	243	0	core recovery fragmentary, chloritic schist. Qz. vein carries sulphides at lower 1".
243	0	245	0	recovery sand. Coarse fragments including appreciable percentage of sulphides including covellite
245	0	247	0	core fragmentary, acidic gneiss with some sulph. Joints filled with carbonate
247	0	251	0	high core recovery, hard and compact, chlorite-quartz-felspar gneiss. Porphyroblastic. Network of quartz stringers. Sulphides in stringers and in joints

From		To		REMARKS
ft.	inch	ft.	inch	
251	0	260	0	brecciated quartz-felspar rock with sulphides
260	0	261	0	same as above. Particularly rich in sulphides
261	0	266	0	acid gneiss with few specks of sulphides
266	0	272	0	" " devoid of mineralization
272	0	274	0	" " sulphides in joints and thin stringers
274	0	275	0	recovery sand, dark coloured, some sulphides
275	0	278	0	quartz-felspar-chlorite schist. Sulphides confined to joints only
278	0	281	0	amphibolite
281	6	286	0	acid gneiss
286	0	293	0	high recovery, amphibolitic and chloritic schist Veinlet of pegmatite 8" thick. Sulphides scarce
293	0	302	0	plagioclase chlorite schist
302	0	304	0	recovery dark greyish clayey material, no sulphide
304	0	315	0	mainly quartz-felspar-hornblende-chlorite schist with variations in different constituents. Few stringers of quartz-calcite
315	0	329	0	alternating acid gneiss with chlorite schist porphyroblastic. Sulphides along joints only
329	0	331	0	as above, with some pyrite dissemination
331	0	337	0	mylonitic augen gneiss. Scarce mineralization
337	0	347	0	acid gneiss with stringers of pegmatite
347	0	348	0	red granite with tourmaline and sulphides
348	0	352	0	diorite gneiss. No mineralization
352	0	357	4	chloritic quartz-felspar gneiss, cut by two veins of granite, 6" and 8" thick.
357	4	360	6	actinolite-chlorite-quartz-felspar gneiss, with porphyroblasts of felspar. Pegmatite veining. No mineralization. Bore hole ends at 365 feet

From		To		REMARKS
ft.	inch	ft.	inch	
Bore Hole Number VI				
0	0	40	0	ironstone and sand
40	0	45	0	recovery coarse sand. Quartz, felspar, greenish mineral, and some tourmaline and malachite
45	0	50	5	recovery sand, chloritic flakes, some qz. and malachite
50	0	55	0	„ „ as the above with more quartz content
55	0	70	0	„ „ chlorite flakes prominent. Quartz and malachite abundant
70	0	73	0	chlorite schist, no mineralization
73	0	74	0	talcose rock, no mineralization
74	0	75	0	pinkish gneissose granite, barren
75	0	78	0	bits of chlorite schist, barren
78	0	80	0	non-foliated amphibolitic rock with vugs partly filled-in with carbonate
80	0	100	0	talcose and chloritic schist, no mineralization
100	0	100	6	bits of the non foliated amphibolitic rock
100	6	104	0	bits of pinkish gneissose granite, barren
104	0	120	0	recovery sand only, qz. and felspar, barren
120	0	126	0	alternating bands of granite gneiss and chlorite schist. Tourmaline begins to show up, barren
126	0	131	0	granitic gneiss, epidote and sericite present. Kaolinization intense. Few calcite stringers
131	0	134	0	chlorite schist
134	0	143	0	alternating chloritic schist and talcose rock, barren
143	0	145	0	sillimanite-anthophyllite-talc schist
145	0	146	0	talcose rock, barren
146	0	148	0	amphibole-chlorite schist
148	0	161	0	chlorite schist and antigorite-chlorite-talc schist. No mineralization
161	0	173	0	coarse grained gneissose granite. The lower part formed of quartz-tourmaline associated with chlorite and some mineralization

	From ft. inch	To ft. inch	REMARKS	
173	0	185	0	bits of ill-defined chlorite schist, barren
185	0	186	0	gneissose granite, barren
186	0	187	0	tourmaline pegmatite. Abundant tourmaline associated with some mineralization
187	0	190	0	gneissose fine grained tourmaline granite, some sulphides present
190	0	193	8	partly altered acid gneiss, barren
193	8	194	0	quartz vein with some sulphides
194	0	194	3	a piece of tourmaline soaked with chalcopyrite
194	3	197	0	biotite amphibolite veined with sulphide - rich tourmaline specially at the upper 2'6".
197	0	211	0	amphibolite with pegmatites. No mineralization to be mentioned. Near base tourmaline becomes dense
211	0	219	0	chlorite schist veined by barren quartz. Near the base few inches showed pyrite mineralization.
219	0	224	0	nearly same rocks, between 222' 6" and 224' tourmaline is very conspicuous together with sulphides
224	0	229	6	fine grained plagioclase-amphibole gneiss, weak dissemination of sulphides. Pegmatite stringer at 229' with some sulphides
229	6	232	0	chloritic schist, sulphide-bearing stringers of pegmatite
232	0	234	0	chlorite-quartz-felspar gneiss, porphyroblasts of felspar, calcite veining. Some sulphide dissem.
234	0	243	0	porphyroblastic quartz-felspar gneiss with varying proportions of chlorite. Faint mineralization.
243	0	250	0	alternating altered acid gneiss with chloritic schist
250	0	260	0	acid gneiss, veined by pegmatite stringers partly mineralized
260	0	266	0	crushed pegmatite with some chlorite and epidote. Fair amount of sulphides specially pyrite

From		To		REMARKS
ft.	inch	ft.	inch	
266	0	270	0	alternating acid gneiss and chlorite schist. These are veined by sulphide-bearing stringers of quartz
270	0	280	0	acid gneiss enclosing pockets of talcose rock. Sulphides persist but in small amount
280	0	286	6	acid gneiss with darker horizons rich in chlorite and amphibole. Weak dissemination of sulphides
286	6	296	0	strongly crushed pegmatite, densely mineralized. Among sulphides chalcopyrite dominates with some covellite
296	0	301	0	pegmatite with occasional concentration of chlorite. Mineralization is less prominent than the previous. Tourmaline is associated with the mineralization
301	0	309	0	strongly crushed tourmaline granite, with calcite cementing. Latter accompanied with mineralization
309	0	318	0	same crushed granite, occasionally vuggy with quartz and calcite filling the vugs. Sulphides in the joint planes only
318	0	323	0	same crushed granite, tourmaline less prominent; sand recovery rich in sulphides
323	0	327	0	granitic rock, occasionally enclosing bits of talcose material. Mineralization occupies joint planes and fractures only
327	0	339	0	mainly pegmatite with pink feldspar. The upper two feet are veined by fine stringers of quartz and calcite, carrying some sulphides. Pegmatite is generally crushed. Feeble dissemination of sulphides
339	0	340	6	Core very rich in sulphides embedded in dark matrix of lead grey colour. From 339' 9" to 340' 6" core mainly formed of chalcopyrite with parts of pyrite and quartz veinlets containing tourmaline.
340	6	346	0	this length was practically a gap from the point of view of the drillers. It had to be cemented and redrilled. The cement caught a few separate particles richly bearing sulphides

From ft.	To		REMARKS
	inch	ft. inch	
346	0	348 0	poor core recovery, still rich in sulphides
348	0	350 0	no core or sand recovery
350	0	356 0	dark coloured plagioclase-amphibole schist, with some dissemination of sulphides. At the lower 3' pink network of sulphide-bearing pegmatite stringers, are very frequent
356	0	358 6	pinkish coloured pegmatite, slightly mineralized, veined by quartz and calcite
358	6	363 0	pinkish pegmatite, enclosing some green schist. The lower two feet formed of fine grained dioritic gneiss. Rocks veined with quartz and calcite. Weak mineralization
363	0	364 6	rich zone of sulphide-bearing pegmatite
364	6	373 10	dioritic gneiss. At 373' there are vugs filled with clear quartz crystals and calcite. Mineralization is moderate, in thin stringers and in dissemination
373	10	376 0	fairly rich mineralized zone
376	0	380 4	mostly dioritic gneiss, with interveining pegmatite. Mineralization not rich, even poor in parts
380	4	380 9	rich zone
380	9	382 6	barren zone. Pegmatite enclosing some schist
382	6	382 10	particularly rich zone
382	10	384 8	poorly mineralized zone
384	8	385 4	good mineralization
385	4	389 0	barren dioritic gneiss
389	0	390 0	highly mineralized
390	0	394 8	poorly mineralized gneiss
394	8	396 4	highly mineralized
396	4	396 8	poorly mineralized
396	8	397 1	fairly rich in sulphides
397	1	404 5	fresh dioritic gneiss, with porphyroblastic feldspar. Sulphides sparsely disseminated

From		To		REMARKS
ft.	inch	ft.	inch	
404	5	406	3	highly mineralized zone. Upper part rich in stringers of pyrite and chalcopyrite. Lower part, dissemination of both sulphides, pyrite in perfect cubes
406	3	407	4	acid gneiss with some sulphide
407	4	427	6	dark greyish plagioclase-chlorite schist, strongly decomposed, and veined by later calcite. Sulphide concentrations associated with intruding pegmatite
427	6	438	0	greenish amphibolite. Traversed by quartz and calcite stringers. Mineralization is weak but better with the qz. - calcite stringers
438	0	445	6	alternating quartz-felspar-hornblende schist with a rock lighter in colour and richer in felspar. Highly veined with calcite; this is usually bordered with films of sulphides
445	6	452	0	dark greyish dioritic gneiss. Occasionally veined by pegmatite stringers and later calcite. Few sulphides dispersed along the whole length. Better concentration at 445' 6"-445' 11" and at 448' 10"-449' 6"
452	0	453	0	quartz-plagioclase-chlorite schist, strongly crushed, with porphyroblasts of felspar. Blebs of chalcopyrite irregularly dispersed
453	0	455	0	same rock, fairly mineralized
455	0	464	0	pegmatite predominant, with remnants of the quartz-plagioclase-chlorite schist. Calcite in stringers is present in abundance. Sulphides in fair amount
464	0	480	2	very rich horizon of the core. The rock is mainly pegmatite with calcite. Sulphides form embricating veinlets and fill in the matrix. In some parts, the sulphides constitute more than 60 per cent of the core, the gangue being carbonate with some silica
480	2	485	0	mainly pegmatite with some actinolite-chlorite schist. The latter may predominate in part. The two types are veined by later carbonate stringers. Mineralization is poor. The lower 6" is formed of a quartz vein showing fair amount of chalcopyrite

	From ft. inch	To ft. inch		REMARKS
485	0	487	4	biotite-plagioclase-chlorite schist. Ramifying stringers of calcite in all directions. The upper 3" are mineralized. In the rest of rock mineralization is nearly nil
487	4	490	10	fairly rich pegmatite. Calcite is associated
490	10	492	0	quartz with some calcite, poorly mineralized
492	0	496	0	plagioclase-chlorite schist, partly granitized. Calcite in thin stringers, fair sulphide content
496	0	512	4	very rich horizon. Sulphides in a gangue of quartz and calcite
512	4	513	6	quartz-amphibole-plagioclase-chlorite schist, partly granitized
513	6	521	0	very rich horizon. Sulphides in gangue of quartz and calcite. Remnants of schist
521	0	523	6	recovery sand only. Very rich in sulphides and a dark coloured mineral
523	0	525	0	bits of the dark grey schist, some sulphides disseminated
525	0	525	6	barren pegmatite
525	6	527	9	alternating schist with pegmatite. Veining of calcite stringers. Sulphide dissemination
527	9	528	0	fairly mineralized pegmatite
528	0	529	0	schist with poor sulphide dissemination

Bore Hole Number IX :—

0	0	25	0	recovery sand. Light coloured, consists of few grains of quartz-felspar-epidote. Barren
25	0	45	0	recovery sand, same as above, with some greenish flaky mineral. Barren
45	0	55	0	recovery sand, as above, with much quartz. Barren
55	0	65	0	" " " " few grains of tourmaline appear. Barren
65	0	75	0	recovery fine sand, light coloured, with much epidote, and some muscovite flakes. Barren

From		To		REMARKS
ft.	inch	ft.	inch	
75	0	105	0	recovery sand, same as above, barren
105	0	110	0	core recovery poor. Decayed felspathic epidote schist with flaky ferromagnesian Barren
110	0	119	0	core recovery poor. Same as above. Small patches of ochreous material with malachite and azurite
119	0	126	0	white pegmatite with tourmaline. Crushed and kaolinized. Some malachite associated with chlorite
126	0	134	0	plagioclase chlorite schist. Barren
134	0	139	0	alternating white pegmatite with chlorite schist, generally barren except for malachite stainings
139	0	143	0	alternating white pegmatite with a schist rich in epidote. Malachite staining
143	0	146	0	quartz-felspar-biotite schist with much epidote and some chlorite. Apparently barren
146	0	156	0	recovery sand, very rich in malachite
156	0	158	0	„ „ fairly rich in malachite
158	0	160	0	core recovery poor. Bits of conglomeratic quartz embedded in ochreous matrix, malachite, azurite and chrysocolla present
160	0	166	0	quartz-felspar-biotite schist, crushed, bits of rock in a matrix of copper and iron salts
166	0	167	0	core very poor. Bits of conglomeratic quartz in malachite and ochre
167	0	168	0	quartz-felspar-biotite-amphibole gneiss alternating with white bands of quartz and felspar. Barren. Bands of the gneiss dipping along extension of rods
168	0	168	5	conglomeratic aggregate of pegmatitic composition, cemented with iron oxides, malachite, azurite and chrysocolla
168	5	171	0	schist again, also banded along the extension of the core

From inch	To ft. inch	REMARKS
0	176 0	dark coloured quartz-felspar-biotite-chlorite schist, with light bands of acid gneiss. At the upper part, the foliation is parallel to the elongation of the core, then deflects to nearly perpendicular at the lower part. Malachite is patchy, here begins the first trace of sulphides
0	186 6	quartz-felspar-biotite-amphibole schist. Barren
6	187 6	tourmaline-bearing pegmatite. Crushed, kaolinized felspar, barren
6	190 0	barren schist
0	191 2	barren pegmatite. Some chlorite and epidote occupy narrow fissures
2	195 6	quartz-felspar-biotite-hornblende gneiss. Barren
6	198 0	white pegmatite, sulphides occupy the narrow joints
0	202 0	quartz-felspar-biotite-hornblende schist. Barren except for very thin films with pyrite, filling joints
0	206 2	white pegmatite, barren
2	208 0	barren quartz-amphibole schist
0	211 0	recovery sand only, with some chalcopryite
0	212 7	hard compact quartz-felspar-biotite-hornblende gneiss. Barren except at 212 where there is a thin stringer of sulphide mostly chalcopryite
7	215 6	bits of conglomeratic material. The shattered bits of pegmatite are embedded in highly mineralized matrix. The core is very vuggy
6	218 0	barren quartz amphibole gneiss
0	220 0	crushed pegmatite with minute dissemination, mostly of chalcopryite
0	221 11	dark coloured compact, plagioclase-hornblende-biotite schist. Contains tiny dissemination of sulphide
11	226 0	tourmaline pegmatite. Faint dissemination of sulphide

From ft.	inch	To ft.	inch	REMARKS
226	0	231	0	plagioclase-hornblende-biotite schist, barren. The sand recovery contains fair amount of sulphides, this may be due to the lower feet which were not recovered in the core
231	0	241	0	core recovery very poor. Bits of quartz-felspar-chlorite-biotite-amphibole schist, pegmatite. Mineralization plentiful at contact of pegm. and schist. Sand recovery extremely rich in sulphides which constitute about 50 per cent of sand recovery. This could be attributed to vuggy nature of rock and friability of sulphides
241	0	256	0	core recovery poor. Bits of schist and pegmatite rich in chalcopyrite. Sand recovery fairly rich
256	0	265	0	fine grained red granite and quartz-tourmaline rock. Sulphide mineralization in fair amount
265	0	275	0	pegmatite with stringers of quartz-tourmaline. Mineralization rather low
275	0	284	0	recovery poor. Hard fresh pegmatite with very little mineralization
284	0	293	0	hard compact quartz-hornblende-felspar-biotite schist. Stringers of quartz-tourmaline with some sulphides
293	0	308	0	quartz-biotite-plagioclase-amphibole schist, with pegmatite veinlets. Mineralization along joints
308	0	316	0	amphibolite. Dissemination mostly of pyrite
316	0	323	0	plagioclase amphibole gneiss, turns at the lower part to pegmatite rich in sulphide stringers. Sand recovery very rich in sulphides
323	0	332	0	recovery poor. Amphibole rock. Sand recovery rather rich
334	0	352	0	mostly formed of schist with veinlets of quartz-tourmaline partly sulphide bearing
352	0	360	0	quartz-felspar-hornblende-biotite schist with pegmatite veining. Mineralization restricted along joints only

	From ft. inch	To ft. inch	REMARKS	
Core Hole Number X :—				
0	0	20	0	recovery sand only. Fine grained and ferruginous
20	0	30	0	„ „ „ Coarse grained, less ferruginous
30	0	60	0	„ „ „ Grains of quartz, decayed felspar and flakes of greenish material
60	0	90	0	recovery sand. Similar to the previous, some malachite
90	0	100	0	„ „ No malachite
100	0	110	0	core recovery very poor. Bits of tourmaline-bearing pegmatite with decayed epidote
110	0	120	0	recovery sand only. Barren
120	0	130	0	core recovery very poor. Mostly epidote rock, barren
130	0	132	0	barren white pegmatite
132	0	142	0	barren quartz-felspar-epidote gneiss
142	0	161	0	amphibolitic schist. Composed of porphyroblasts of both amphibole and plagioclase in a ground mass of fine grains of same composition. Numerous thin stringers of pegmatite. Barren. At about 155' there is evidence of slight faulting
161	0	170	0	plagioclase-amphibole gneiss. Ramifying veinlets of tourmaline granite. Barren
170	0	171	0	conglomeratic rock. Shattered amphibolitic schist cemented with silica. The matrix contains sulphides, mostly chalcopyrite
171	0	176	0	plagioclase-chlorite schist, barren
176	0	177	0	schist, cavernous. Filled with quartz and ochre
177	0	182	0	barren schist
182	0	186	0	acid gneiss. Epidote filling cracks. Barren
186	0	194	0	core recovery fairly good. Dark greenish scratchable schist. Chlorite amphibolite. Dissemination of minute pyrite crystals evenly distributed. At about 189' to 190' there is a white barren pegmatite with tourmaline

From		To		REMARKS
ft.	inch	ft.	inch	
194	0	196	0	epidote quartz gneiss. Stringers cutting across, formed of chlorite with sulphide crustation
196	0	197	0	acid gneiss. Mineralization along joints as crustations, together with chlorite
197	0	200	0	quartz-felspar-chlorite schist. A stringer of epidote containing some sulphide. Fault detected between 196'-200'
200	0	207	0	amphibole-plagioclase schist, few grains of pyroxene. Epidote and chlorite in cracks and joints with some sulphides
207	0	209	0	crushed quartz-felspar-epidote rock with chlorite
209	0	214	0	same as above. Weak mineralization as crustations along joints
214	0	220	0	tourmaline pegmatite. Crushed, some shreds of chloritized biotite. Some sulphides along fractures. Sand recovery contains little sulphides
220	0	230	0	hornblende plagioclase schist, hard and fresh. Interstitial chlorite. Sulphide crustation as joint lining
230	0	240	0	quartz-biotite-chlorite schist. Pyrite dissemination
240	0	250	0	recovery mostly sand with little bits of pegmatitic rock. Quite rich in sulphides
250	0	257	0	tourmaline-bearing pegmatite. Highly crushed. A little muscovite at 257'
257	0	258	0	recovery mostly sand, very rich in sulphide
258	0	260	0	pegmatitic rock with little sulphide
260	0	261	0	pegmatite rich in sulphide, specially at the contact with the underlying rock
261	0	262	0	quartz-plagioclase-biotite schist. Rather big grains of tourmaline together with epidote occupying veinlets
262	0	264	0	quartz-plagioclase-biotite-hornblende schist
264	0	268	0	pyroxenite, partly uralitized
268	0	281	0	pegmatite, strongly crushed. No apparent mineralization. Rock fresh and hard

From inch	To		REMARKS
	ft.	inch	
0	294	0	ranges between amphibolite and plagioclase-biotite-hornblende schist. Pegmatite veining with little mineralization
0	298	6	recovery sand only. Very rich in sulphides
6	304	0	tourmaline granite. Medium grained, pink. Slightly mineralized in place
0	308	0	recovery sand only. Quartz, tourmaline and some little mica. Contains appreciable amount of sulphides
0	317	0	plagioclase amphibolite. Shreds of biotite and chloritized biotite present. Some sulphide dissemination
0	322	0	epidote-chlorite-amphibolite. Chlorite associated with some biotite. Rock partly altered. Mineralization very faint
0	328	0	recovery poor. Quartz-plagioclase-biotite schist. Sand recovery contains some sulphide
0	334	0	no recovery at all. There is probably a cavity
0	344	0	quartz-felspar-amphibole-chlorite schist. This is veined with pegmatite. Sand recovery contains appreciable amount of sulphides
0	350	0	recovery poor, pegmatite with mineralization along fractures and joints
0	355	0	tourmaline bearing pegmatite, intruding a highly felspathic rock with chlorite. Both rocks undergone stress. Both are barren
0	357	0	chlorite-amphibole-biotite-quartz-plagioclase schist
0	360	0	pegmatite. Chalcopyrite present, restricted to certain channels formed of chlorite, sphene chalcopyrite

Line (c)

This profile crosses the south and north lodes in the central part of area of the mine.

Bore hole number XI is directed north westward at an angle of 75 degrees from the horizontal, to cross them mineralized zone below pit group (F); vertical depth along rods is 231 feet. Bore hole No. XII is directed south

eastward at an angle of 75 degrees from the horizontal, to cross the mineralized zone below pit groups (F) ; its total depth along rods is 230'. Bore hole number XIII is directed north westward at an angle of 75 degrees from the horizontal, to cross the mineralized zone below pit group (C) ; its total depth along rods is 261'. Bore hole number XIV is directed south eastward at an angle of 75 degrees from the horizontal, to cross the mineralized zone below pit group (C) ; its total depth along rods is 331'.

The following is a detailed description of the different rocks encountered by the bore holes :—

From		To		REMARKS
ft.	inch	ft.	inch	
Bore Hole Number XI :—				
0	0	30	0	clayey sand. No mineralization
30	0	55	0	recovery sand, mainly quartz with very scarce malachite grains
55	0	75	0	recovery sand. Mainly quartz, feldspar and little tourmaline. Few grains of malachite present
75	0	80	0	poor core recovery. Acid gneiss with occasional tourmaline. Scant mineralization
80	0	99	0	chloritic schist, badly weathered
99	0	100	0	barren pegmatite
100	0	118	0	actinolite-chlorite-plagioclase schist. Some biotite and some epidote. Rock weathered
118	0	134	0	weathered acid gneiss alternating with the above schist. No mineralization
134	0	137	6	plagioclase-hornblende gneiss, fresh and hard. Barren
137	6	144	0	quartz-chlorite schist. Barren
144	0	146	0	porphyritic pink granite. Barren
146	0	158	0	plagioclase-hornblende gneiss, with some quartz, hard, fresh, barren
158	0	166	0	chlorite-hornblende-quartz-plagioclase schist with some interstitial epidote. Pegmatite veins. Barren
166	0	190	0	quartz-feldspar-chlorite-biotite schist. Barren
190	0	200	0	biotite-hornblende-quartz-feldspar schist, with some epidote. Barren

From ft. inch	To ft. inch	REMARKS
200 0	202 0	quartz-chlorite-felspar gneiss, with some biotite. Permeation of pegmatite veinlets. Barren
202 0	205 0	recovery sand only. Contains little amount of pyrite
205 0	206 10	Actinolite-plagioclase schist, with much epidote. Sulphide dissemination
206 10	207 0	barren pegmatite
207 0	210 0	stressed pink pegmatite, devoid of tourmaline. It contains some dissemination of sulphides
210 0	212 0	dark coloured gneiss without any mineralization
212 0	231 0	quartz-felspar-biotite schist, with some actinolitic hornblende. Veined by pegmatite. This is occasionally sulphide bearing

Bore Hole Number XII

0 0	20 0	recovery reddish brown clayey sand
20 0	30 0	clayey sand, barren
30 0	60 0	coarse sand of quartz and felspar, few malachite grains
60 0	70 0	decayed bits of kaolinized material with copper staining, together with decayed chloritic material
70 0	110 0	medium to coarse grained sand of quartz, felspar, few epidote grains and chloritic material
110 0	115 0	soft, weathered quartz-biotite-chlorite schist
115 0	120 0	biotite-chlorite-plagioclase schist, veined by quartz. Malachite and ochreous material permeate the rock
120 0	124 0	mostly crushed quartz embedded in malachite and ochre
124 0	126 0	coarse grained acid gneiss, Barren
126 0	130 0	quartz-felspar-biotite-hornblende gneiss, minerals fairly fresh. Barren
130 0	134 6	acid gneiss. Chlorite filling in the joints
134 6	140 0	porphyroblastic acid gneiss, intruded by tourmaline-bearing granite

From		To		REMARKS
ft.	inch	ft.	inch	
140	0	142	0	acid gneiss, barren. Intruded by fairly pegmatite
142	0	149	0	quartz-plagioclase-biotite-hornblende schist, partly mineralized with malachite along fractures.
149	0	159	0	quartz plagioclase biotite hornblende gneiss. Little and limited dissemination of sulphides (mostly pyrite)
159	0	160	0	acid gneiss
160	0	180	0	quartz-plagioclase-biotite-hornblende gneiss. Local variations in mineral proportions. Apatite is distinctly widely distributed. Dissemination of iron oxides. Very little sulphide with pegmatite stringers
180	0	190	0	acid gneiss, partly porphyroblastic. Alternating with schist. These are permeated with microcline granite, rich in apatite. Mineralization very rare
190	0	200	0	chlorite-quartz-felspar gneiss. Very few grains of sulphide associated with chlorite, filling joints
200	0	215	0	quartz-plagioclase-biotite-chlorite schist, intruded by a rock formed of felspar-quartz-chlorite-epidote. Little dissemination of sulphide
215	0	221	6	chlorite-plagioclase-hornblende schist. The rock is very fresh and hard, and shows joints along which most of the mineralization occurs
221	6	230	0	chlorite-biotite-hornblende-plagioclase schist. Fine grained and shattered. Mineralization along fractures and joints

Bore Hole Number XIII :—

0	0	10	0	no recovery
10	0	35	0	recovery sand, ferruginous material
35	0	45	0	„ „ slightly ferruginous
45	0	80	0	„ „ light coloured, with traces of malachite

From ft.	inch	To ft.	inch	REMARKS
80	0	85	0	„ „ coarse grained, with malachite
85	0	90	0	„ „ „ „ ferruginous with much malachite
90	0	99	0	core recovery, conglomerate. Big angular grains of quartz with finer fragments of sericite in dense iron oxides and malachite. Some flakes of muscovite may appear
99	0	104	0	small piece of rock recovered. Acid gneiss with tourmaline, barren
104	0	147	0	fine grained quartz-orthoclase gneiss. Occa- sional porphyroblasts of sericitized orthoclase. Tiny shreds of chloritized biotite arranged in parallel rows. Sand recoveries 110'-125' and 126'-147' contain some malachite
147	0	165	0	conglomerate of crushed fragments of quartz, tourmaline, and some sericitized and sausserit- ized feldspar. Matrix formed of iron oxides and carbonate. Also copper carbonates and prob- ably oxide. Few specks of chalcopyrite forming kernels to the oxides of both iron and copper. There are few bands of chlorite-quartz-sericite trapped in the conglomerate
165	0	167	0	white coloured acidic gneiss, with occasional feldspar porphyroblasts. Gneiss is cut by fine stringers of microcline granite. Along same channels, malachite may partly fill-in
167	0	173	0	kaolinized material, friable. Contains tourma- line, and carries malachite and some sulphide
173	0	185	0	core recovery gneissic quartz-plagioclase-chlo- rite-epidote rock with some dissemination of sulphide. Cracks occasionally filled with malachite. Sand recovery for the same length, fairly rich in sulphide. This may be due to the presence of a mineralized zone (unrecovered) between 180' and 185'
185	0	196	0	chlorite-plagioclase-quartz gneiss, cut by much younger quartz vein. The upper 4' contain chalcopyrite in blebs. Sand recovery of the same length contains reasonable sulphide con- tent

From		To		REMARKS
ft.	inch	ft.	inch	
196	0	206	0	core recovery poor. Bits of quartz, carrying some sulphides. Intermittent bits of chlorite schist
206	0	212	0	recovery sand only. Rich in sulphides
212	0	219	0	core recovery, greenish porphyroblastic plagioclase-epidote-chlorite-quartz schist. Traversed by pegmatite. Both rocks contain dissemination of sulphide. Sand recovery rich in sulphides
219	0	225	0	reddish pegmatite rich in disseminated sulphide. Sands are the only recovery between 224' 4" and 224' 9", very rich in sulphides
225	0	232	0	porphyrite, formed of chlorite-quartz-felspar, highly crushed. Intruded by pinkish pegmatite. At 226' 6" a minor fault is detected. Very faint sulphide distribution in the whole length
232	0	234	0	greenish chlorite-epidote-quartz-plagioclase gneiss. Some porphyroblast of felspar, and some sulphide dissemination
234	0	237	0	pink coloured microcline pegmatite with tourmaline. Crushed, barren
237	0	282	9	fine grained quartz-epidote-felspar-chlorite rock. Local variations in felspar and chlorite content. At 261' there could be traced a faint sulphide mineralization.

Bore Hole Number XIV :—

0	0	10	0	reddish brown clayey sand
10	0	20	0	yellowish brown sand including quartz pebbles
20	0	50	0	sand. Grains of quartz, felspar with some brownish grains
50	0	90	0	different shades of light and dark coloured sand
90	0	95	0	badly weathered chloritic rock with quartz veining. Recovery very poor, no mineralization
95	0	105	0	recovery sand, recovered probably from chloritic rock
105	0	107	0	micropegmatite, with iron stained quartz stringer

From ft. inch	To ft. inch	REMARKS
107	0 122 0	recovery fine grained sand. Light brown, no mineralization
122	0 140 0	micropegmatite. Some quartz veinlets carrying iron oxides. No copper mineralization
140	0 155 0	recovery extremely poor. Begins with bits of chloritic rock, then bits of conglomerate (angular Qz. cemented in ochre and malachite), then turns to barren acid gneiss
155	0 160 0	porphyroblastic quartz-felspar-chlorite schist
160	0 165 0	recovery sand, barren
165	0 175 0	quartz-plagioclase-chlorite-biotite schist. Rock decayed and friable. A few crystals of pyrite
175	0 185 0	decomposed acid gneiss, with some chlorite and epidote iron stained
185	0 195 0	crushed pegmatite, incorporating parts of the schist. Apparently no visible mineralization. Sand recovery contains some sulphides
195	0 201 0	very fine grained dark coloured rock. Altered felspathic gneiss, mainly sausseritized felspar, with interstitial quartz and chlorite and some epidote. Rock fractured, these are filled with crystalline Qz. Few specks of pyrite distributed in the rock
201	0 202 0	recovery sand only, very rich in pyrite and chalcopyrite, the former predominant
202	0 205 0	fine grained quartz-plagioclase-chlorite-biotite schist. Fair dissemination of opaque granules
205	0 214 0	begins with 6" of pegmatite, then turns to the schist. Sand recovery from 202' till 213' is rich in sulphide which is mainly pyrite
214	0 227 0	rock is fine grained biotite-quartz-plagioclase to biotite-hornblende-plagioclase schist, with dissemination of sulphides. This is intruded by pegmatitic material
227	0 235 0	hornblende-biotite-plagioclase schist, with some chlorite and epidote. Some pyrite dissemination
235	0 238 0	quartz-felspar-sericite-hornblende gneiss

From		To		REMARKS
ft.	inch	ft.	inch	
238	0	253	0	acid gneiss, with remnants of plagioclase-chlorite-biotite schist. Few specks of pyrite
253	0	259	6	quartz-plagioclase-chlorite-hornblende schist. Joints filled with quartz and some sulphide
259	6	260	4	recovery sand only. Contains some pyrite
260	4	266	0	amphibolitic rock, rather altered, and much fractured. Sulphide filling along the fractures
266	0	279	0	pegmatitic rock, highly shattered, carries an appreciable amount of sulphides as veinlets
279	0	283	0	no recovery at all; there is probably a cavity
283	0	285	0	quartz-plagioclase-chlorite schist
285	0	288	0	crushed pegmatite. Cracks filled with chlorite and chlorite-epidote with sulphides
288	0	292	0	gneiss formed of alternating bands of quartz-felspar with pistachite-chlorite
292	0	294	0	no recovery at all; there is probably a cavity
294	0	302	0	alternating quartz-felspar gneiss, with occasional clots of chlorite after hornblende; with quartz-chlorite-plagioclase gneiss. The latter gneiss is peculiarly loaded with sphene in trains. Between 296' and 298' the rock is fairly rich in sulphide veinlets, together with the crustations in the joints
302	0	320	0	porphyroblastic quartz-felspar-biotite gneiss. Sphene fairly distributed. This is intruded by pegmatite, strongly crushed. Mineralization is very limited
320	0	323	6	epidote-biotite-chlorite schist. The fibrous minerals show severe twisting due to movement. Sphene is present next in abundance to epidote. Very little sulphide
323	6	328	0	recovery sand only. Light coloured grains, mainly quartz. Bits of quartz with sulphide
328	0	331	0	fresh and hard pegmatite. Tourmaline-bearing microcline pegmatite. Strongly crushed. Sulphides disseminated and fill-in joints. Driller could not make any further progress

Bore Hole Number XV :—

This bore hole was driven vertically to cross the mineralization below pit group (D), at the extreme south western corner of the mine. The following is the logging of this bore hole :—

From ft.	inch	To ft.	inch	REMARKS
0	0	70	0	recovery sand only. Brownish, containing quartz pebbles. No malachite
70	0	80	0	recovery fragmented core of weathered chloritic rock with some kaolinized material
80	00	90	0	recovery sand only. Mostly coarse Qz. grains with fragments of iron oxide
90	0	97	0	recovery fragmented, highly weathered pegmatitic rock. It is stained with iron oxide together with malachite and chrysocolla
97	0	108	0	same as above with evident mineralization mostly of chrysocolla. Rock fairly weathered. Some tourmaline
108	0	116	0	recovery partly core and partly sand. Core is weathered granitic rock. Sand contains few flakes of mica
116	0	135	0	crushed and fragmented pegmatite, shows faulting in parts. Cracks filled with silica-chlorite-epidote, and lined with cubes of pyrite.
135	0	135	6	porphyroblastic acid gneiss, sausseritized plagioclase
135	6	144	0	pegmatitic rock, iron stained
144	0	147	0	angular fragments of quartz embedded in a compact matrix of iron oxide and carbonate, together with some malachite and copper oxide. Native copper was detected here. Interstitial calcite and some quartz (Plate VI, Photo. C.)
147	0	151	0	pegmatitic rock, not particularly mineralized
151	0	160	0	conglomerate. Angular Qz. pebbles embedded in calcite. In the matrix could be seen some chlorite and few prisms of tourmaline. Young and fresh Qz. veins the rock densely with sulphide mineralization. Some of the sulphides are enclosed in copper oxide. Iron oxides are abundant. Native copper was also traced here

From		To		REMARKS
ft.	inch	ft.	inch	
160	0	166	0	chalcopyrite mineralization in calcite marble (Plate V, Photo. A). Big irregular ramifying patches of chalcopyrite embedded in a matrix of marble. The sulphide particles are partly rimmed by oxides, whereas the calcite marbles contain some siderite. Haematite may be seen under the microscope partly occupying the cleavage planes of the calcite. The marble contains recrystallised quartz
166	0	174	0	at the upper part the rock is chloritic with radiating needles of tremolite, specially at 168'. It then turns to a greyish amphibolitic rock, slightly talcose. This contains an appreciable dissemination of sulphides
174	0	183	0	the greyish amphibolitic rock contains little amount of disseminated sulphides
183	0	186	0	sulphide dissemination in marble. Very dense mineralization, mainly of chalcopyrite together with native copper. There is a younger generation of calcite, non-metamorphosed and devoid of sulphides
186	0	201	0	plagioclase-quartz-chlorite schist, shows micro folding. Part of the plagioclase in porphyroblasts. Dissemination of pyrite (Plate III Photo A).
201	0	214	0	chlorite-plagioclase-quartz schist, particularly rich in sphene. Some pyrite dissemination. Calcite fills-in some cracks with little sulphide
214	0	234	0	severely crushed chlorite-quartz-felspar rock. Felspar totally altered, dissemination of little sulphide, calcite filling some joints
234	0	244	0	severely crushed pegmatite, quartz recrystallized. Stringers of introduced calcite, barren
244	0	252	0	highly crushed chlorite-quartz-epidote-felspar rock. The felspar is totally altered to flakes of sericite. Pistachite in beautiful prisms accompanied by calcite apparently had not undergone crushing. Sulphide mineralization weak.
252	0	264	0	calcite-quartz-chlorite schist. Calcite forms elongated pouches in the schist, and not as stringers. Sulphide mineralization not much

From ft. inch	To ft. inch	REMARKS
264	0 269	0 epidote-hornblende-sericite-quartz schist. Mineralization weak, sulphide closely related to epidote
269	0 279	0 fine grained chlorite-quartz-felspar schist. Epidote occupies certain channels. Tourmaline fairly distributed. Very weak mineralization.
279	0 290	0 quartz-felspar gneiss. Felspar sericitized, partly prophyroblastic. Skeletal chalcopyrite, diffused in the rock with quartz. At 282', the schist is Qz-sericite with tourmaline occupying channels with calcite and quartz. At 285' the schist is epidote-chlorite-Qz.—sericite, with tourmaline and sulphides. At 287', there is a stringer filled with calcite and lined on both sides by chlorite
290	0 294	0 sericite schist, partly quartz-chlorite sericite schist. Sphene present, sometimes in big concentration. There is heavy concentration of disseminated sulphides
294	0 294	6 dark band of hornblende-chlorite-biotite-quartz-plagioclase schist. Dense dissemination of sulphides
294	6 312	0 quartz-sericite schist with tourmaline present, either oriented with the schistosity or non oriented. Orthoclase may be present in porphyroblasts. There may be some biotite, chlorite and epidote. Mineralization is generally dense along the whole length. It has got no direct bearing to the presence of tourmaline. The sulphides occupy certain channels crossing the rock, accompanied by calcite and silica and probably some chlorite
312	0 326	0 epidote-quartz-plagioclase-chlorite schist, with some tourmaline. Few particles of sulphides filling in the cracks with chlorite. At 318' the rock turns to a quartz-biotite-plagioclase-chlorite schist, with pyrite dissemination. At 319' rock becomes biotite-chlorite schist alternating with a coarse grained pyroxene rock. The latter contains talcose and chloritic material and some actinolite. Dissemination of pyrite is fair in amount. At 324' rock turns to

From ft. inch		To ft. inch		REMARKS
				tourmalinized quartz-felspar gneiss, where the felspar is partly replaced by multitudes of very tiny crystals of tourmaline. At 325' there is an appreciable concentration of sulphides
326	0	336	0	generally quartz-plagioclase-chlorite schist, with some epidote. At 333' it is chlorite-biotite-amphibole schist. In both types calcite permeates the whole rock, this is related to the concentration of sulphides
336	0	338	0	no recovery at all, probably a cavity
338	0	345	0	the upper part is a highly crushed quartz-felspar rock, enclosed in plagioclase-chlorite schist. Then turns to biotite-chlorite-quartz-felspar schist. Tourmaline with quartz forms stringers, almost barren. At 342' there a vein of calcite with disseminated sulphides in abundance, together with some quartz and chlorite. Below that the rock is epidote-chlorite-quartz-plagioclase schist
345	0	352	8	alternating bands of plagioclase-chlorite schist, and quartz-sericite schist. Spene is present in the first. Sulphides and some tourmaline are present in the second schist. Between 346' and 347' rock merges between fine grained quartzite and quartz-sericite schist. Below that becomes plagioclase-chlorite schist; then epidote-quartz-plagioclase or musovite-quartz-felspar rock. They are all cut by quartz-calcite stringers carrying sulphides. Tourmaline is present but not strictly related to the mineralization (Plate V, Phot C.)
352	8	352	10	tourmaline bearing quartz-plagioclase-chlorite schist. Epidote and spene, with some biotite also present
352	10	354	6	quartz-plagioclase-biotite-chlorite schist, with some tourmaline, Clinzoisite, epidote and spene
354	6	357	0	quartz-felspar gneiss with calcite-tourmaline stringers
357	0	359	0	plagioclase-chlorite-amphibole schist. Spene and epidote abundant

From ft.	inch	To ft.	inch	REMARKS
0	359	6		quartz-sauserite gneiss. Barren
6	359	10		tourmaline-bearing epidote-chlorite-sericite schist
10	362	10		sericitic quartzite. Barren
10	363	6		quartz-epidote-chlorite schist. No tourmaline. Veining of well developed epidote prisms with calcite, rich in sulphides
6	367	0		remnants of quartz-plagioclase-chlorite schist with sphene; permeated by quartz-calcite rich in chalcopyrite
0	367	6		very fine grained quartz-sericite schist
6	368	0		chlorite-quartz-felspar gneiss, with some epidote
0	370	6		quartz-chlorite-biotite-plagioclase schist
6	373	10		white kaolinized pegmatite. Chlorite with some epidote fill-in some cracks in the rock
10	375	6		quartz-felspar-chlorite rock. Some biotite and muscovite present. Sphene fairly accumulated
6	379	0		strongly crushed and faulted pegmatite. Faulting is seen in the hand specimen. Cracks filled with quartz-chlorite-epidote
0	383	0		pink coloured acid gneiss with flakes of muscovite and biotite. Veinlets of barren calcite
0	393	0		quartz-chlorite-felspar-actionolite schist, in alternating light and dark bands
0	396	6		fine grained acid gneiss. Stringers filled with chalcopyrite in a gangue of epidote-chlorite
6	408	0		quartz-felspar-chlorite schist. Tiny stringers of calcite carrying some chalcopyrite
0	417	0		fine grained quartz-felspar-chlorite schist. Sphene and magnetite fairly distributed. Stringers of chlorite-calcite
0	421	0		biotite amphibolite. Calcite permeates the rock. Dusting of tiny cubes of magnetite fairly distributed

From		To		REMARKS
ft.	inch	ft.	inch	
421	0	427	0	quartz-epidote-felspar-chlorite schist. Heavy dissemination of magnetite
427	0	434	0	fine grained quartz-felspar-biotite-chlorite schist. Epidote and a few magnetite crystals present. At 433'-433' 8" there is rich sulphide mineralization
434	0	437	0	porphyroblastic felspar-chlorite schist, with dense pyrite dissemination
437	0	445	0	pegmatite with tourmaline. Ramifying quartz calcite stringers
445	0	450	6	plagioclase-chlorite schist. Biotite in thin shreds, epidote and sphene. Veinlets of pegmatite. Barren
450	6	452	6	pinkish pegmatite with trapped schist. Barren except at 451' where there is some pyrite mineralization
452	6	459	0	plagioclase-chlorite schist. Biotite, epidote and sphene present. Pegmatite veinlets. All barren
459	0	463	10	Barren schist. At contact with the above rock is a zone half centimetre thick, rich in chalcopyrite. At 463' 10" very thin interrupted stringer of chalcopyrite associated with pegmatite
463	10	467	0	barren schist
467	0	468	2	pinkish pegmatite, very faint mineralization chalcopyrite with tourmaline
468	2	472	0	compact quartz-plagioclase-chlorite schist. Stringers of carbonate, could be traced around 468'. At 471' there is a veinlet of carbonate with some chalcopyrite
472	0	476	0	near the top chlorite-plagioclase-quartz schist then becomes chlorite-quartz-felspar schist then from 474' downwards, becomes plagioclase-chlorite-biotite-amphibolite. Few stringers of calcite with sulphides
476	0	476	5	white coloured pegmatite, barren

From ft. inch	To ft. inch	REMARKS
476 5	478 0	there is a fault shown in the core for a length of 1' 7", it runs along the length of the core and the dislocation is only ± 1 ". There is a fairly rich stringer of sulphides running along the fault, at its lower 10", associated with much carbonate, its width does not exceed one centimetre
478 0	479 7	the fault still continues in this part. The rock turns gradually to an amphibole-rich schist with big grains of plagioclase. Nearly barren
479 7	480 4	fair amount of mineralization in the form of sulphide, mostly chalcopyrite
480 4	482 0	biotite-amphibolite. Rock permeated with veinlets of quartz-epidote-calcite, carrying much sulphides
482 0	489 0	quartz-amphibole-plagioclase schist. Stringers of chlorite-calcite
489 0	489 6	white pegmatite, with streaks of chlorite. Barren
489 6	491 7	schist, rich in sphene. At contact with the underlying rock, there is a mineralized zone of chalcopyrite rimmed with epidote and chlorite
491 7	493 10	plagioclase amphibolite with some mineralization at 492' 11"
493 10	494 2	fairly rich sulphide, associated with white pegmatite
494 2	505 0	plagioclase-chlorite schist, with light bands of quartz-felspar. Pegmatite veinlets with tourmaline. Occasional carbonate stringers. Slight mineralization at 501' 3"
505 0	508 6	acid gneiss, turns to biotite-chlorite-felspar rock
508 6	510 7	mineralized micropegmatite. Heavy mineralization in the intergranular spaces of Qz. and felspar. Sulphides related to chlorite and tourmaline. Calcite absent
510 7	515 0	sericite schist. Microfolding under microscope. Opaque minerals dusting the rock. Mineralization at the base. Violently shattered tourmaline-bearing pegmatite

Bore Hole Number IV. (abandoned hole)

This bore hole was dug four metres away from the position of the hole bearing the same number. It reached the depth of 230 feet when the walls collapsed and the rods jammed and it had to be abandoned. The following is a description of the rocks encountered during drilling.

From		To		REMARKS
ft.	inch	ft.	inch	
0	0	25	0	recovery sand, reddish coloured coarse grained. No visible malachite
25	0	70	0	recovery sand. Qz. + feldspar + greenish ferromagnesian with few bits of muscovite
70	0	90	0	same sand recovery, with some malachite
90	0	95	0	core recovery poor. Pegmatite with some malachite and azurite and reddish ochreous material
95	0	105	0	recovery sand. Very rich in malachite
105	0	124	0	conglomeratic aggregate of pegmatitic material in a matrix of malachite, chrysocolla and reddish material
124	0	143	0	red ochreous material with some malachite in the crevices.
143	0	148	6	conglomerate, very rich in carbonate and reddish oxides
148	6	150	8	bits of pegmatitic material in matrix of malachite and probably cuprite
150	8	151	0	dense cuprite and chalcocite with some malachite
151	0	152	0	conglomerate with a matrix of malachite. Globules of cuprite could be seen embedded in malachite
152	0	160	0	small bits of pegmatitic material embedded in dense matrix of cuprite and chalcocite with some malachite. There are remnants of chalcocopyrite
160	0	160	8	very rich part. Nearly solid chalcocite and cuprite with stringers of malachite and remnants of chalcocopyrite

	From ft. inch	To ft. inch	REMARKS	
160	8	165	0	malachite and azurite together with cuprite and chalcocite and a very limited amount of chalcopyrite, form the matrix, to conglomeratic grains of pegmatite
165	0	200	0	badly weathered kaolinized material with malachite and azurite filling in cracks. Some sulphides
200	0	202	0	sand recovered by dry drilling. Appreciable amount of sulphides
202	0	205	0	pegmatite with some sulphides
205	0	210	0	recovery sand, quartz pebbles rich in sulphides
210	0	213	0	acidic gneiss very rich in sulphides
213	0	216	0	recovery sand very rich in sulphides
216	0	220	0	highly weathered kaolinized rock. Nearly barren
220	0	230	0	recovery sand only, contains some sulphide

GEOLOGY OF HOFRAT MINE

Rock Formations :

The rock formations at the Hofrat en Nahas mine could be divided into a series of meta-sediments and a series of metamorphosed igneous rocks. The meta-sediments include diversified varieties, of originally argillaceous or arenaceous material, with calcareous content in both cases.

The major groups of rocks can be divided as follows :—

- (a) Meta-sediments of psammo-pelitic constitution and calcareous psammo-pelites.
 - (b) Metamorphosed schists of intermediate to basic composition probably after diorites and gabbros
 - (c) Metamorphosed rocks of ultrabasic composition
 - (d) Acid gneisses partly porphyroblastic
 - (e) Granite pegmatites, aplites and rather fresh granites
- (a) The group of meta-sediments include the following assemblages :—
- Plagioclase-quartz-chlorite schist
 - Chlorite-epidote-sericite-plagioclase-quartz schist quartz-sericite schist
 - epidote-chlorite-quartz-sericite schist
 - sericite schist
 - quartz-chlorite-sericite schist
 - epidote-quartz-plagioclase-chlorite schist
 - quartz-chlorite schist
 - epidote-quartz gneiss

The meta-sediments studied, include metamorphosed psammities and psammo-pelites, which are partly calcareous. Quartzite, sericitic quartzite and epidote-quartz gneiss represent the more psammitic types. The schists of psammo-pelitic composition are represented by sericite and chlorite schists. The meta-sediments are generally very fine grained, highly foliated and varying in colour from light creamy shades to light greyish green. Chlorite-sericite schist is a common type, displaying phyllitic texture.

- (b) Under this group, the following assemblages were recognized :—
- calcite-quartz-chlorite schist
 - biotite-chlorite schist
 - quartz-plagioclase-chlorite schist

quartz-plagioclase-biotite-chlorite schist
quartz-epidote-chlorite schist
epidote-biotite-chlorite schist
actinolite-chlorite schist
chlorite-biotite-amphibole schist
quartz-chlorite-felspar-actinolite schist
biotite amphibolite
quartz-felspar-hornblende gneiss
quartz-felspar-biotite-hornblende gneiss
chlorite-plagioclase-hornblende schist
quartz-felspar-biotite schist
quartz-plagioclase-chlorite-biotite schist
biotite-quartz-epidote-felspar rock
epidote-hornblende-sericite-quartz schist

In the hand specimen these rocks are fine grained to medium grained, foliated and generally hard and compact. Their colour varies between dark greyish to greenish. They are normally jointed and show slickensiding. They are represented by chlorite schist, amphibolite, amphibole schists and biotite schist.

The chlorite schist is formed of lathes and prisms of chlorite, generally in alternating bands with grains of plagioclase in varying proportions. The plagioclase is dominantly of the labradorite composition, and is usually, always sausseritized with the formation of epidote and zoisite. The grains of plagioclase may be occasionally porphyroblastic. Calcite is present in ramifying stringers, sometimes in noticeable concentrations. Sphene is present in most of the rocks examined, and occasionally sometimes as an accumulation of fairly big crystals. Quartz takes a minor part in the composition of these rocks; and when present it is always interstitial and shows strong undulose extinction.

Biotite is present in tiny shreds in some varieties of the chlorite schist, and when present, it is aligned in parallel rows, giving a distinct schistosity to the rock. Chlorite is always related to biotite as its alteration product. When biotite becomes the dominant mineral, then the schist could be called biotite schist. Quartz is also present in some of these rocks but in subordinate amount.

The presence of hornblende is sometimes noted in the biotite schist. This is a transition to another type of rock of wide distribution and with the essential constituents of plagioclase, biotite, chlorite and hornblende. This assemblage generally occurs in medium to coarse grains, with a gneissic structure. The plagioclase averages around labradorite in composition, and is not much altered. Hornblende, sometimes of the actinolitic variety, is the normal and dominant mineral in this rock, and in some cases it is a product of the hydrothermal uralitization of the original pyroxene. Amphibolites are compact dark greenish rocks which show no foliation under

the microscope. They are formed of rather big imbricating lathes and prisms of hornblende, with plagioclase felspar as a minor constituent. The rock may be cavernous, with prochlorite filling the cavities in radiating flakes. Chlorite may be related to the amphibole as an alteration product, and it is then dusted with specks of iron oxide.

(c) The metamorphosed rocks of ultra basic origin include the following assemblages :—

- talc-antigorite rock
- pyroxenite
- anthophyllite-talc schist
- antigorite-talc schist
- chlorite-talc schist
- talc-tremolite schist

The group of ultra basic rocks is represented by pyroxenite, talc amphibole schist and talc antigorite rock. The only case where pyroxenite was encountered was in bore hole number 10 at a depth of 268 feet. The rock there is dark grey in colour. Under the microscope it is formed of medium grained equigranular diopsidic augite, some grains being partially altered. There are also a few enstatite grains partly altered to antigorite. The talc rock is essentially formed of confused aggregate of talc always associated with scales of antigorite. Bundles of asbestiform amphibole occasionally occur. These proved to be tremolite in the majority of cases, whereas anthophyllite was present in a few cases. Clusters of tiny needles of rutile are frequently met with in the talc schist. Fine specks of magnetite with some pyrite are sometimes sparsely disseminated in the rock.

(d) The acid gneisses are represented by the following assemblages :—

- Porphyroblastic quartz-felspar gneiss
- tourmaline-epidote-quartz-plagioclase gneiss
- muscovite-biotite-quartz-felspar gneiss
- porphyroblastic chlorite-epidote-quartz-plagioclase gneiss

The acid gneisses are mainly formed of quartz and felspar. The grain size is dominantly coarse, and a common feature is the presence of felspar in a porphyroblastic texture. Quartz generally shows signs of destruction and partial recrystallisation with sutured outliners. Felspars are mainly orthoclase accompanied by a certain proportion of oligoclase. The felspars show partial crushing and sericitization specially around the bigger grains which stood the action of stress. Kaolinization strongly affected the orthoclase, whereas epidote is found associated with the plagioclase. In a few cases tiny flakes of muscovite and biotite could be traced, arranged in parallel alignment. Tourmaline in tiny stringers was seen in many sections of this acid gneiss.

(e) The group of granites includes the following:—

normal coarse grained granite, pegmatite and micropegmatite
Biotite-tourmaline-microcline granite

In this group, granite is rather rare in occurrence compared with the other members. In the hand specimen it is pinkish in colour, medium grained and compact. It is composed of quartz, orthoclase, microcline and some perthite. Muscovite and some biotite occasionally occur. The grains show that they have undergone stress to a certain extent. Alteration of the feldspars was noted. The accessory minerals present are mostly apatite, zoisite, few tiny grains of zircon and occasional sphene crystals. Tourmaline occurs as an original mineral in the rock in varying abundance.

Pegmatites are nearly of the same composition as the granites but have a much bigger grain size, and show the effect of stress more distinctly. They are in the form of veinlets and stringers, cutting across the other groups of rocks. Tourmaline is very abundant in these veinlets, occasionally being associated with dense concentrations of sulphides.

The sequence of geological events which took place could be of the following manner :

The oldest group of rocks is the meta-sediments, which are taken to be of Pre-Cambrian age. These were intruded by the diorites and gabbros, then several small dykes of ultrabasic rocks subsequently cut through them and were, later on, altered to a talcose rock. An acidic porphyry intrusion permeated the older formations, and is now very widely represented among the rock groups. At that stage a movement could have taken place on a regional scale, causing intense shearing in three well developed planes in the Hofrat mine itself. The planes of weakness facilitated the diffusion of later granitic and pegmatitic solutions. This last stage of granite intrusion could have been a prolonged one. It was accompanied by boron emanations in considerable quantities, which were detected in the granite in the form of tourmaline. Boron vapours were still in quantities at the pegmatitic stage of the granite intrusion and reacted deeply, with the wall rocks of the shear zones forming tourmaline in multitudes of narrow stringers. It is also at this stage that part of the mineralization took place, mainly as pyrite with very little chalcopyrite. Soon after the termination of the pegmatitic stage or probably towards its end, faulting took place along almost the same planes of weakness. It is more than probable that this faulting caused the subsidence of the central part of the country enclosed between the now existing north and south lodes. One clear result of the faulting is demonstrated by the intense crushing which happened to rocks occupying the old shear zone, namely the granite and pegmatites with part of the wall rocks. Many small and minor faults, parallel to the major ones, occurred simultaneously. Such faulting is proved by the very widely distributed slickensiding encountered in practically every foot of core recovered from bore holing. The faulting widened considerably the old channels of shearing and created new ones, which were later used by ascending mineralized solutions. These solutions

deposited the main bulk of the present ore. The rock cores obtained from drilling show the dynamic action, without a single exception. They were either from the shear zone proper or from the walls which still retain part of the dynamic effect. Hence strike and dip were very difficult to measure as the whole series of rocks might have been subjected to a succession of acute and complicated folding. However, from surface observations the general strike of the rocks is N.E.-S.W. and the dip is moderate to the N.W. The shear zones and fault planes are directed N. 60 E., N. 45 E. and N. 25 E. These directions are possibly general to the region. In examining the sections drawn for the mineralized lodes occupying the north and south shear zones, one feels justified to assume that the southern plane of shearing is dipping steeply north westwards, while the northern one is dipping steeply south eastward. There is then, the strong possibility that the two zones coalesce at a deeper horizon than that reached by drilling.

Mineralization :

It is thought that there were two stages of mineralization, one before and the other post faulting. The first generation of mineralization is most probably attributed to pegmatitic solutions rich in iron sulphides and rather poor in copper sulphides. The ore formed at that stage had a limited distribution in the lodes, and is characterised by having been subjected to faulting and brecciation. Tourmaline is recorded in abundance related to this ore. The later mineralized solutions were most probably hydrothermal, and were rich in copper and uranium. Whether they were related to the older generation of mineralization in origin is still a matter of conjecture. In both stages of mineralization the solutions had an effect on the wall rocks lining their channels. These rock effects are as follows :—

Kaolinization :—

This had the most prominent effect on the group of acid gneisses. The potash feldspars could be seen in different degrees of transformation to kaolin. Near the surface the kaolinized gneiss became a white, crumbly friable rock.

Sericitization :—

Sericitization was also noted in many grains of potash feldspar, and the process could be due to dynamic effects beside the effect of solution.

Sausseritization :—

The formation of epidote and zoisite is noted on a very wide scale in the different groups of rocks. Epidote formed at the expense of plagioclase feldspar is a common phenomenon in the wall rocks studied. In some advanced cases the rock is composed entirely of quartz-epidote or chlorite-epidote.

Tourmalinization :—

The solutions and vapours of the granitic intrusion carried a certain amount of boron, which reacted actively with some minerals specially with the felspars, yielding well developed tourmaline crystals. This tourmalinization was of a regional character and schorl is very common in the rocks of the area to the south of Hofrat. It was accompanied by silicification in Jebels Bishura, Yirongo and Waranga.

The Ore Lodes :—

The upper levels of the ore lodes are occupied by the zone of oxidation. The outcrops do not represent the true widths of the lodes accurately, being somewhat exaggerated. This is due to the high solubility of malachite, and the wider dissemination of copper staining by surface waters. The mineralised zone tapers a little below the surface till the level where the sulphides begin to appear, then the width becomes uniform in depth. The level at which the sulphides begin to appear ranges between 45 and 50 metres below the surface. The ore in the zone of oxidation is in the form of a cementing material to the brecciated country rock and stringers and crustations in the cracks and joints. The following minerals were recognised in the zone of oxidation :—

Malachite-azurite-chrysocolla-cuprite-chalcocite-native copper-haematite-limonite-siderite-torbernite.

The presence of native copper was recorded in bore hole number 15 at the depth of 150-160 feet. Irregular and dendritic specks of native copper are disseminated in a dense dark brownish matrix, enclosing angular bits of quartz and felspar. This matrix is mainly formed of siderite and cuprite, with calcite, haematite and very little limonite. The presence of native copper in the zone of oxidation is rather peculiar. There must have been a reducing medium prevailing in this particular horizon, where a reaction could have possibly taken place between chalcocite and iron oxide, giving rise to native copper. The occurrence was recognized so far in that bore hole only (Plate VI, Photo. C).

Malachite, azurite and chrysocolla are closely associated in occurrence. They display beautiful colours in circular patches and concentric cavity fillings. Malachite is seen in bundles of needle-like crystals or in the banded form. Chrysocolla is not as abundant as the other two components (Plate V, Photo. B.)

Haematite and limonite are concentrated at the topmost gossanic part of the ore. They are always amorphous and powdery, but haematite may be in the form of a honey comb, with malachite filling its pores.

Steel grey chalcocite, as a thin stringer in quartz, was revealed near the surface in trench number 10. The chalcocite was partly replaced by malachite in very tiny streaks. This same copper sulphide was traced in association with native copper. It was also detected in bore holes number 2 and 4, replacing chalcopyrite at horizons below 130 feet.

The dull reddish coloured cuprite is widely distributed in minor quantities with chalcocite and malachite. It was seen in some sections fringing and cutting across the stringers of chalcocite.

Torbernite was first detected in a conglomeratic exposure near the northern flank of the biggest pit of the south lode. The conglomerate is composed of bits of quartz, embedded in an ochreous and siliceous matrix and is very vuggy. These vugs were lined sporadically by crystals of the copper-uranium-phosphate mineral $(\text{Cu}(\text{UO}_2)_2(\text{PO}_4)_2 \cdot 8\text{H}_2\text{O})$. The crystals are clear grass green in colour, tabular and averaging 2×2 millimetres in dimensions. They were also found afterwards to be distributed in the dumped quartz, in the north and south lodes in small amounts. A deep trench dug around the exposure of the conglomerate mentioned, proved that the torbernite was disseminated in the chlorite schist as well.

The mineralization in the sulphide zone is formed of a ramifying meshwork of veinlets and stringers, rather than a solid mass of well defined and sharp contacts. The meshwork is diffused through the sheared and brecciated rocks, sometimes forming a matrix for these rocks. It is also diffused through the very narrow fault planes and permeates the wall rocks (Plate VI, Photo. B).

As mentioned before, it is believed that there were two generations of mineralization. The first generation, which was introduced with the pegmatitic injection, was remarkably richer in pyrite than in chalcopyrite. The gangue minerals in this case were principally quartz and felspar with lots of apatite and tourmaline. These sulphides were subjected to shearing and crushing; the effects of which are seen in many polished sections, where the sulphide grains are thrown into aligned bands. The grains are crushed into minute angular fragments, frequently contorted, and subsequently veined by calcite and quartz. The younger generation of mineralization was not affected by any dynamic action, and represents the main bulk of the lodes. Sulphides of iron and copper together with uraninite and gold were introduced in a gangue of quartz and calcite. Epidote and chlorite form sheaths surrounding the ore veinlets. Tourmaline has a special affinity for the sulphides, and in many cases the sulphides were observed microscopically to be embedded in big tourmaline crystals as inclusions. On the other hand, in the majority of sections examined, the sulphides were not related to tourmaline. Calcite as a gangue mineral was occasionally so dominating, that it reached up to about 60 per cent of the whole bulk of the ore, whereas quartz was only 8-9 per cent, such a case is demonstrated in bore hole number 15 at a depth of 150-160 feet. Calcite still plays its role as a gangue mineral to depths of over 340 feet, where it may constitute about 35 per cent of the whole bulk of the ore.

The following group of minerals was recognised in this sulphide zone: pyrite-chalcopyrite-covellite-chalcocite-uraninite and gold.

Pyrite grains differ in size from about 0.08 of a millimetre up to about 1.0 millimetres, and the crushed grains may be still smaller in size than 0.08 millimetres. The big grains are generally corroded and partly replaced by other sulphides. Examples of pyrite grains enclosed or replaced by chalcopyrite in a fashion of atoll texture are quite frequent. Quartz could have been deposited partly simultaneous with, but mostly somewhat later than, pyrite. This is reflected in the presence of inclusions of quartz in some pyrite grains and the presence of quartz surrounding and filling the intergranular spaces of pyrite crystals. In some instances remnants of pyrite crystals could be seen under the microscope in skeletal form, nearly totally replaced by uraninite. The replacement could have taken place along the cleavage planes of the pyrite. Dissemination of minute but euhedral crystals of pyrite is well known in the country rock specially in the talcose rocks (Plate VII, Photo. B). Chalcopyrite is evidently later in deposition than the pyrite. It is always seen surrounding the grains of pyrite, cutting through its cracks and replacing it (Plate VII, Photo. A). Fine specks of gold were occasionally traced in a few specimens of chalcopyrite probably as an ex-solution (Plate VI, Photo. D). Chalcopyrite is rarely replaced by covellite, but is very frequently replaced by chalcocite.

To conclude the above description of the polymetallic ore of Hofrat, the following could be stated:—the sulphides of iron and copper were deposited in a zone of shearing and faulting. The solution, responsible for the ore deposition, is supposed to be partly of pegmatitic origin in the first phase of mineralization, and partly of hydrothermal origin (probably of the mesothermal stage) in the second phase. This was judged by the mineral assemblage of the ore and the gangue minerals associated. The time which elapsed between the two phases could have been a short one, during which faulting took place; and the two phases could be related to one and the same granite magma, characterised by being particularly rich in boron. The wide spread occurrence of tourmaline in the mineralized zones and the wall rocks, and its special affinity to sulphides, suggests the similarity of this mode of occurrence to be copper-tourmaline deposits from Chile and the United States, described by W. Lindgren. The ore at Hofrat is principally epigenetic, with partial supergene enrichment which includes the whole of the zone of oxidation and part of the sulphides below it.

EVALUATION OF THE HOFRAT MINE

It has been mentioned before, that investigations carried out by the Nile Congo Divide Syndicate in the nineteen twenties, ended in 1927, with the conclusion that the work had reached a stage where a deep shaft and development work were required. The Syndicate's experts stated that the richest parts of the mine are the south and branch lodes, where the copper content averaged about 3 per cent copper, over a horizontal width of some 50 to 60 feet. It was also stated that the two lodes extend downwards below the 300 feet level. At that stage their investigations ended, pending an improvement in the situation concerning transport. In those days the railway line in western Sudan extended only to El Obeid, which is very far from Hofrat mine.

During the present investigations carried out by the Geological Survey Department, the tonnage of ore was estimated with the aid of bore holing. Hundreds of samples of core and sand recovery from the holes were analysed for their copper content in the chemical laboratory of the Department.

The dumped material, which was left by the miners of successive generations, was partly piled on the flanks of the pits, but the majority of the material was filled in the old shafts. Auger bore hole tests, carried out in the dumps, enabled us to estimate their tonnage. The average copper content of each individual bore hole was tabulated and given before. The tonnage of dumps of every group of pits was calculated separately and the average copper content is given for every group. For convenience, alphabetical figures were given for the different groups of pits. The following table shows the tonnage of dump, the average copper percentage and the total copper content of each group of pits:—

Groups of pits	Tonnage	Copper per cent	Total Copper Content
South lode "A"	18,300	2.4	439.20
" " "B"	3,190	0.8	25.52
" " "C"	23,400	2.85	666.90
" " "D"	18,240	1.08	197.00
" " "E"	12,454	0.63	78.50
" " "F"	8,728	0.57	49.80
" " "G"	14,080	3.2	422.40
" " "H"	3,836	0.63	24.17
" " "I"	9,798	2.12	207.70
" " "J"	23,760	1.35	320.80
" " "K"	12,180	0.5	60.90
" " "L"	6,630	1.85	61.33
" " "M"	3,550	0.85	30.18
" " "N"	3,570	0.47	16.78
" " "O"	10,395	1.35	63.41
" " "P"	13,266	0.61	179.09
	185,377	1.53	2,843.68

The estimated copper content in the dumped material, which totals 43.68 tons, occurs mainly in the form of malachite, azurite and chrysocholla, impregnated in the loose material.

The ore estimates of the three lodes were calculated only to the depths reached by diamond drilling. These calculations were thus confined to the proved and sampled parts of the ore body, though the mineralization seemed to continue persistently beyond the limits reached by drilling. The results of the chemical analyses, for the mineralized portions of the ore and sand recovery, were plotted at their corresponding depths in the borehole columns. Profiles were drawn for the lodes at the locations of the bore holes, using the chemical analyses for eventual estimation of ore reserves, (Fig. 18). These profiles showed the downward extensions of the ore from the surface to the lower limits of the holes, as well as the width of mineralization. No drilling was done in the spaces of ground between the successive pits, and consequently we assumed that the lodes of mineralization were not continuous laterally along the whole extension of the mine. This had a direct bearing on our estimation, confining the calculation of tonnage to the ore extending below the outcrops only. Thus, the ore was divided into separate blocks, bounded laterally by the outlines of the surface outcrops, and vertically by the depths reached by drilling. The outcrops were marked alphabetically, similar to what has been done in the case of the dumps. From the data of lateral extensions and downward depths reached by drilling, together with the widths of mineralization, the volume of each block was calculated. Then taking the average specific gravity of the rock as 2.7, the tonnages of the blocks were computed.

The copper percentages of the mineralized zones cut by each bore hole are given in the following tables:—

Depth		Analysis	Depth		Analysis
From	To		From	To	
	mts.	% cu		mts.	% cu
Bore Hole Number I					
0	9.6	1.7	9.6	11.7	1.65
11.7	12.6	1.5	12.6	13.8	0.8
13.8	14.4	1.9	14.4	16.5	0.98
16.5	18.0	0.95	18.0	18.9	0.06
18.9	19.5	0.95	19.5	21.0	1.2
21.0	22.2	1.02	22.2	24.0	0.3
24.0	25.5	0.3	25.5	27.0	0.22
27.0	28.5	0.22	28.5	30.0	0.6
30.0	31.5	0.54	31.5	33.0	1.02
33.0	34.5	1.11	34.5	36.0	0.95
36.0	37.5	0.51	37.5	39.0	0.19

Depth		Analysis	Depth		Analysis
From	To		From	To	
	mts.	% cu		mts.	% cu
Bore Hole Number I (Contd.)					
39.0	41.4	0.19	41.4	43.5	0.25
43.5	45.0	0.19	45.0	47.5	0.19
47.5	49.2	0.03	54.0	58.5	0.06
58.5	60.0	0.06	60.0	66.9	0.06
7.3	73.0	0.12	78.3	81.3	0.06
81.3	83.7	0.03	85.0	89.1	0.03
93.0	95.2	0.015	98.8	102.3	0.03
102.3	106.5	0.10	110.5	112.2	0.10
112.2	114.4	0.05	114.4	118.2	00.015
118.2	124.2	29.2			
Bore Hole Number II					
39.0	40.5	0.22	40.5	42.0	0.3
42.0	43.2	22.2	43.2	43.8	2.6
47.4	48.9	18.4	48.9	50.1	16.5
50.1	52.5	7.3	57.0	58.8	1.8
67.5	69.9	0.5	69.9	72.0	2.6
72.0	73.5	0.24	73.5	75.0	0.3
77.1	78.9	0.4	78.9	80.19	0.83
80.1	82.5	0.66			
Bore Hole Number III					
75.6	76.5	0.65	78.5	78.0	1.6
78.0	81.0	0.32	159.0	160.5	0.32
160.5	162.0	0.6	162.0	163.5	0.62
Bore Hole Number IV					
15.0	17.1	0.8	22.2	22.8	1.4
27.0	28.5	0.7	28.5	31.5	6.3
31.5	37.5	12.6	37.5	43.5	17.4
43.5	49.5	20.6	49.5	52.2	6.3
52.2	54.0	0.15	54.0	57.0	14.2
57.0	60.0	10.3	60.0	61.5	28.5
61.5	63.0	17.4	63.0	63.9	17.4
63.9	64.8	14.2	64.8	66.0	1.9
66.0	67.1	17.4	67.0	70.8	2.25
70.8	72.0	1.5	72.0	75.0	7.5
75.0	78.0	6.75	78.0	80.1	10.3
84.0	87.0	12.2	87.0	90.0	17.4
90.0	93.0	19.5	93.0	96.0	16.0

Depth		Analysis	Depth		Analysis
From	To		From	To	
	mts.	% cu		mts.	% cu
Bore Hole Number V					
30.9	35.1	0.3	35.1	38.4	0.19
38.4	40.2	0.15	40.2	46.2	0.42
46.2	50.4	0.38	50.4	51.9	0.51
51.9	54.9	3.05	54.9	57.9	0.38
59.7	60.2	2.79	64.2	67.8	0.19
67.8	70.8	10.16	70.8	72.9	5.46
72.9	73.5	1.77	73.5	75.0	2.66
78.0	79.5	0.83	79.5	81.0	0.38
81.6	82.2	0.06	84.3	84.6	0.05
84.6	85.2	0.19	93.0	94.8	1.02
97.2	98.7	0.13	104.0	107.0	0.13
Bor Hole Number VI					
13.5	15.0	4.44	15.0	16.5	3.83
19.5	21.0	1.28	55.0	57.0	0.16
63.3	65.4	0.32	66.9	68.7	0.16
68.7	70.5	0.16	75.0	76.5	0.6
76.5	78.0	0.48	78.0	79.8	0.32
79.8	81.0	0.3	84.0	85.8	1.6
85.8	88.8	4.44	88.8	90.3	5.16
91.6	92.1	1.92	95.4	96.9	0.72
101.1	102.1	4.12	108.9	109.3	2.22
111.0	111.5	0.32	112.1	112.8	2.56
114.1	114.2	3.84	114.7	114.8	3.2
115.4	115.6	0.48	116.7	117.0	1.28
118.4	119.1	2.88	121.3	121.9	1.6
123.9	126.5	0.06	126.5	129.5	0.06
129.5	131.7	0.19	131.7	133.2	0.06
134.4	134.9	0.95	134.9	135.6	0.03
135.6	136.5	0.76	137.5	138.0	0.66
138.0	141.0	1.14	141.0	144.0	9.2
144.0	147.0	1.52	147.0	148.8	0.13
148.8	149.4	5.33	149.4	150.9	11.94
150.9	153.6	6.24	153.6	156.3	6.19
156.3	157.0	7.4	157.0	157.5	0.51
158.8	158.7	0.03			

Depth		Analysis	Depth		Analysis
From	To		From	To	
	mts.	% cu		mts.	% cu
Bore Hole Number VII					
6.0	12.0	0.6	12.0	18.0	0.3
18.0	24.0	0.35	24.0	25.5	10.5
25.5	27.0	0.95	36.3	40.8	4.6
45.3	47.7	6.3	50.4	51.9	13.3
51.9	57.0	0.54	57.0	61.5	0.3
61.5	64.5	0.44	64.5	69.0	1.6
70.8	72.0	1.3	72.0	73.5	0.29
75.9	78.3	0.03	78.3	81.0	0.03
81.0	83.4	0.54	94.5	99.1	0.86
99.1	102.0	0.3	102.0	103.8	1.36
103.8	104.0	0.35	106.5	106.8	0.38
Bore Hole Number VIII					
49.2	51.6	0.29	51.6	52.5	0.13
52.5	54.9	0.06	54.9	57.6	0.16
57.6	59.7	0.13	59.7	62.4	0.06
73.6	66.0	0.13	68.1	70.8	0.19
70.8	72.0	1.3	72.0	73.5	0.29
5.1	76.9	0.19	76.9	77.6	0.95
Bore Hole Number IX					
33.0	36.3	2.09	37.2	38.7	0.22
46.8	47.4	3.55	47.4	48.0	12.4
49.8	50.4	0.88	50.4	51.3	3.6
62.4	63.3	3.87	63.3	65.4	2.88
65.4	67.8	2.41	67.8	69.3	2.41
69.3	72.5	5.18	72.5	73.5	1.5
73.5	76.8	3.3	91.8	94.8	0.03
94.8	96.9	4.05	96.9	99.6	7.75
100.2	102.6	7.49	102.6	105.6	7.49
Bore Hole Number X					
18.0	21.0	1.3	21.0	24.0	0.63
24.0	27.0	0.83	30.0	33.0	0.86
64.2	66.0	0.06	66.0	69.0	0.09
69.0	72.0	0.41	72.0	75.0	2.73
75.0	77.1	6.0	77.1	78.6	4.98
84.3	87.3	0.12	88.2	89.5	5.58
91.0	92.4	1.05	92.4	95.1	3.51
96.6	98.4	2.57	100.2	103.2	3.15
103.2	105.0	1.78	105.0	107.0	1.46
107.0	108.0	1.63			

Depth			Depth		
From	To	Analysis	From	To	Analysis
	mts.	% cu.		mts.	% cu.
Bore Hole Number XI					
16.5	19.5	0.24	19.5	22.5	0.12
60.6	61.5	3.87			
Bore Hole Number XII					
24.0	27.0	0.15	27.0	30.0	0.25
30.0	33.0	0.69	33.0	34.5	5.4
34.5	37.2	8.83	37.2	39.0	0.51
60.0	64.5	1.26			
Bore Hole Number XIII					
13.5	16.5	0.5	16.5	19.0	0.69
19.5	22.5	0.86	22.5	24.0	1.08
24.0	25.5	0.29	25.5	27.0	2.6
27.0	29.7	7.11	33.0	37.5	0.62
37.5	44.1	0.44	44.1	49.5	7.46
52.0	55.5	9.05	55.5	58.8	2.29
61.8	63.6	4.73	63.6	65.7	4.22
65.7	76.5	2.13			
Bore Hole Number XIV					
55.5	58.5	1.8	60.3	60.6	4.49
62.7	64.5	1.49	64.5	66.7	0.5
67.0	68.4	1.75	69.0	70.2	2.6
78.0	78.3	1.38	82.5	85.5	1.05
Bore Hole Number XV					
27.0	29.1	8.73	29.1	32.4	12.7
37.8	40.8	3.18	43.2	45.3	8.73
45.3	48.0	17.42	48.0	49.8	1.59
54.9	55.8	1.59	83.7	68.7	0.06
86.7	88.8	0.03	90.6	91.6	0.8
91.6	93.0	0.9	101.4	103.5	3.24
103.5	104.4	0.64	105.8	106.2	0.03
109.6	110.4	0.38	143.7	144.0	1.14
147.3	148.4	1.74	152.5	153.2	3.20

Then, the average copper percentage for each bore-hole was calculated by applying the following formula:—

$$\text{Average copper percentage} = \frac{L \times A + L_1 \times A_1 + L_2 \times A_2 + L_3 \times A_3 + L_4 \times A_4}{L + L_1 + L_2 + L_3 + L_4 + \dots}$$

where L = length along rods of core, from which a representative sample was taken for analysis.

A = copper percentage for the length L

The same method was used to calculate the average copper content for every profile section, including two bore-holes or more. These averages were then utilised in the calculation of the tonnages of copper content for each corresponding block of ore.

A section to scale was drawn wherever the bore hole lines crossed the outcrops of ore. This section was drawn only to the depth reached by the bore holes and its width was controlled by the width of the outcrops and that of the mineralization as shown in the bore hole sections. The area of this section, which was drawn to scale, was then measured by a planimeter and, where a block of ore was crossed by more than one profile, an average area was taken for these profiles. Then from the length of the outcrop, at the surface, a volume for each block was calculated. Then, assuming a specific gravity of 2.7, the tonnage of each block of ore was reckoned. Then using the same averaging method as given above, the average copper content for each block of ore was calculated to get the tonnage of copper metal in each block. Where a block is crossed by more than one profile, the average of the chemical analysis of these profiles was calculated in the same way. The tonnage of blocks of ore, not crossed by a bore hole line, was calculated in the same way, but using the data for the nearest profile to it.

The following table gives the tonnage of ore and average copper percentage for each block as well as the total copper content for the block.

Block	Tonnage of Ore	Average % cu	Tonnage cu content
A + P	1,901,435	2.818	53,582
B	221,724	1.318	2,922
C	1,108,620	1.318	14,612
D	665,172	1.318	8,767
E + F	564,300	1.858	10,485
G	723,600	1.858	13,444
H	11,474	1.858	213
I	940,680	1.914	18,005
J	1,110,239	1.730	19,207
K	834,003	1.730	9,174
L + M	657,720	8.400	55,249
N	263,088	8.400	22,099
O	1,089,099	4.656	50,708
Vein south of A + P	91,125	7.360	6,953
	10,182,279 (tons)		283,420 (tons)

Thus, the proved ore, to shallow depths ranging between 70 and 155 meters, amounted to about 10,182,300 tons, averaging 2.78 per cent copper. This means that about 283,420 tons of blister copper could theoretically be obtained from that tonnage of ore.

The mineralized zones included in the above estimation have no sharply defined contact with the wall rocks. There are, consequently, some very low values of copper in the walls, for a certain additional width, due to their permeation by very tiny mineralized stringers. Any part of the rock which gave copper value below 0.15 per cent was considered outside the limits of mineable ore. Such a consideration, is of course, liable to variations, mostly due to economical rather than to mineralogical aspects.

In the mineralized zones pouches of rather high quality ore were encountered by boreholes number 1, 2, 4, 6, 7 and 13. There is no doubt that the best parts of the mine are the south and branch lodes represented by blocks A, P, L, M, N and O. (Fig. 19).

The zone of oxidation extends from the surface down to a vertical depth of around 47 meters, where the first sulphides begin to appear. It is probable that the sulphides, crossed by drilling, are exclusively in the secondary sulphide enrichment, and that the primary sulphides have not been reached.

Pyrite plays a very important role in the mineral assemblage, together with chalcopyrite. In many parts of the veins pyrite predominates and constitutes the major part of the aggregate. The sulphur content in the sulphide ore is worth taking into consideration, as a source of sulphuric acid for the treatment of the oxidized ore by leaching. Three picked samples of sulphide ore from the core recovery were analysed for several elements including S, SiO₂, CaO, and iron. The following is the result:—

Element	B.H. 15	B.H. 6	B.H. 15
	(342'-343')	(496'-512')	(163')
Sulphur (S)	11.73%	15.90%	7.60%
Copper (ch)	8.00%	10.67%	2.40%
Silica (Si O)	13.20%	7.90%	8.70%
Iron (Fe)	15.64%	26.24%	9.50%
Calcium (Ca O)	26.32%	16.80%	40.15%
Aluminium (Al O)	2.40%	3.50%	n.d
Manganese (Mn)	0.165%	trace	0.055%
Magnesium (Mg)	n.d	n.d	n.d
Lead (Pb)	n.d	n.d	nd.
Silver (Ag)	"	"	"
Arsenic (As)	"	"	"
Antimony (Sb)	"	"	"
Molybdenum (Mo)	"	"	"
Cobalt (Co)	"	"	"
Nickel (Ni)	"	"	"
Zinc (Zn)	"	"	"
Phosphorus (P)	"	"	"

From the table it can be noticed that the iron content is nearly double to treble the copper content. The iron is partly combined with copper in the form of chalcopyrite, but the main bulk is in the form of separate pyrite. The gangue in the above three samples analysed is very deficient in magnesia, while alumina is also very low. Aluminium silicates, with calcium and iron, are not abundant, but free calcium carbonate is dominant in the gangue, together with free silica.

Uranium occurs together with the iron-copper mineralization. In the upper horizons of the ore, uranium was detected principally as the phosphate "Torbernite." Uraninite was detected in the sulphide zone, intimately related to the other sulphides but somewhat later in deposition. It was proved in nearly all the bore holes drilled, but was particularly noted in abundance in bore holes number 1, 2, 4 and 6; that is around the junction between the south and branch lodes. It was also noted in bore hole number 15, at the western corner of the mine. However, there was actually no thorough effort to estimate the tonnage of uranium in the ore.

Gold was recorded in the Hofrat mine by the Nile Congo Divide Syndicate in their report of 1923-24. Samples from the south shaft cross-cut gave assays ranging between 0 and 15 grains of gold (24 grains=one dwt.), whereas other samples taken from the north shaft cross-cut gave assay results ranging between 0 and 22, grains of gold.

Three bulk samples representing the dumped material of each lode, and ten bulk samples representing the material excavated from the first ten trenches, were analysed for minor elements including cobalt, molybdenum, silver, lead, zinc and gold. The analysis was carried out at the chemical research laboratories at Cairo. The following table gives the results:—

Sample	Co	Mo	Ag	Pb	Zn	Au
South lode ..	± 0.011	> 0.010	traces	> 0.010	> 0.010	> 0.001
North lode ..	> 0.001	± 0.001	> 0.001	> 0.001	> 0.010	> 0.001
Branch lode ..	± 0.001	± 0.010	traces	> 0.10	> 0.020	> 0.001
Trench No. 1 ..	± 0.001	± 0.010	> 0.001	> 0.010	> 0.020	> 0.001
„ „ 2 ..	± 0.001	± 0.010	> 0.001	> 0.100	> 0.010	> 0.001
„ „ 3 ..	± 0.001	± 0.010	traces	> 0.020	> 0.010	> 0.001
„ „ 4 ..	± 0.010	± 0.010	„	> 0.020	> 0.010	> 0.001
„ „ 5 ..	± 0.010	± 0.001	> 0.001	> 0.010	> 0.010	> 0.001

Sample	Co	Mo	Ag	Pb	Zn	Au
Trench No. 6 ..	±0.001	±0.010	>0.001	>0.020	>0.010	>0.001
" " 7 ..	±0.001	±0.010	>0.001	>0.010	>0.010	>0.001
" " 8 ..	±0.001	±0.010	traces	>0.010	>0.010	>0.001
" " 9 ..	±0.001	±0.001	traces	>0.100	>0.010	>0.001
" " 10 ..	±0.001	±0.010	"	>0.010	>0.010	>0.001

From the table it is noted that the minor elements occur in traces or slightly more. Lead and zinc gave results higher than the rest of the elements. The samples analysed were all collected from the surface, so that it is expected that their positive content of minor elements could be due to local concentration by percolating waters.

From the foregoing results, it could be concluded that Hofrat mine is an iron-copper-uranium mine, with minor amounts of gold and silver. The mineralization occurs in three lodes, occupying a surface area of 900 x 400 metres. The ore was proved as far down as the bore holes were sunk, to a maximum vertical depth of 153 metres. Beyond that depth the ore still extended without showing any signs of getting weaker. The true width of the mineable parts of the lodes ranged between 12 and 28 metres. The present authors estimated a proved ore of over 10 million tons, averaging 2.78 per cent copper. Rich pockets of high copper content were encountered in some bore holes, as shown in the table below:—

ZONES OF RICH ORE

Bore hole No. I.	118.2 to 124.2 metres
Bore hole No. II.	28.5 " 52.2 " 54.0 " 67.1 " 72.0 " 96.0 "
Bore hole No. V.	67.8 " 72.9 "
Bore hole No. VI.	13.5 " 16.5 " 95.4 " 109.3 " 147 " 157 "
Bore hole No. VII.	24.0 " 51.9 "

ZONES OF RICH ORE (Contd.)

Bore hole No. IX	..	..	..	46.8	„	48.0	„
				50.4	„	72.5	„
				94.8	„	105.6	„
Bore hole No. XIII.	..	..	..	44.1	„	76.5	„
Bore hole No. XV	..	..	..	27.0	„	48.0	„

ZONES OF RICH ORE

COPPER ORES SOUTH WEST OF HOFRAT MINE

The range of hills to the south west of Hofrat was mentioned in the reports of the Nile Congo Divide Syndicate, as containing some copper occurrences. It was thought advisable by the present writers to pay a visit to these occurrences for a complete presentation of the prospects of the area. This part of the country is completely uninhabited and lacks motor tracks of any description. Therefore the trip which was undertaken from 7th December to 31st December 1958 was done on foot, using animals for loading equipment and food stuffs (Fig. 20).

(1) J. Bishura

The first occurrence examined was J. Bishura ($9^{\circ}31'-24^{\circ}03'$). The backbone of this hill trends in a N. ($45-52$) $^{\circ}$ E. direction, and the bearing of the conspicuous surrounding hills from the top of Bishura are as follows:—

(1) Gulmaru	..	..	..	..	N22 $^{\circ}$ E
(2) Jumbana	..	..	..	..	N31 $^{\circ}$ E
(3) Siomo	..	..	..	..	N77 $^{\circ}$ E
(4) Zanad	..	..	..	..	S70 $^{\circ}$ E
(5) Patapan	..	..	..	..	S 4 $^{\circ}$ E
(6) Waranga East	..	..	..	..	S31 $^{\circ}$ W
(7) Waranga West	..	..	..	..	S33 $^{\circ}$ W
(8) Yirongo	..	..	..	..	S43 $^{\circ}$ W

The conspicuous geological formations here are the (a) quartz tourmaline rock (b) brown schists and (c) a zone of silicification.

The quartz tourmaline rock is a very dark and fine grained rock, with the appearance of a siltstone. It occupies the north eastern part of the hill, extending along one third of its length. It rises from the surrounding ground into a steep cliff, which forms the northern peak of the jebel. This rock can also be traced to the east of the main hill.

The brown schists are exposed in the lower slopes at the north western end of the jebel and continue up hill, adjacent to the quartz tourmaline rock and eventually occupy the flat top of the jebel.

Next to these brown schist there is a zone of intense silicification, which completely obliterated the original nature of the rocks. With the silicified masses of rock, crystalline quartz occurs and small outcrops of conglomerate (probably cemented breccia) can be seen. This zone of silicification forms the backbone of the hill and extends to its western slopes. It also forms the western peak of the jebel. Jebel Bishura west is mainly formed of quartzite which dips to the west; between the two hills lateritic ironstone outcrops.

Mineralization here is confined to the quartz tourmaline rock. Five old trenches in this rock were examined. All of them are located along the top of the hill and the copper, which occurs as malachite, exists in the form of thin stringers and encrustations. A sample from this locality (20842) was analysed for copper and gave 9.5 per cent copper metal. The mineralized rock did not show any conspicuous radioactivity response.

(2) J. Waranga :

(a) Waranga East

This jebel lies to the south west of Bishura and the ridge trends in a N. 30° E. direction. The highest point on this hill is some 500 ft. above the surrounding plain. Ascending this hill from its south eastern end, the predominant formation is a gneissose granite, highly sericitized. Going up, silicification becomes more evident and outcrops of the quartz tourmaline rock appear. Slickensides were seen on loose boulders on this slope. Higher up, a strong ridge of conglomeratic rock shows and continues northwards along the spine of the hill. This rock has a matrix of silica and iron enclosing fragments of the gneissose granite. As one moves north, the granitic fragments give way to quartz fragments. Micaceous haematite could be traced in this conglomerate (cemented breccia). The quartz tourmaline rock outcrops frequently here, and in places takes the place of the gneissose granite at the contact with the conglomeritic rock. This rock here exhibits a strike due N. 50° E. and a dip of 53° roughly to the east (Fig. 22).

At the northern end of this hill a spur runs from the western slope due north. On this spur there is a cave trending in a N. 43° E. direction. This cave is in the quartz tourmaline rock and a specimen from the rock in this cave (20849) gave a value of 8.8 per cent copper metal. Going down the slope of this spur, about 100 metres, there is an old trench running east-west and a shaft about 35 ft. deep with a cross-cut running in the general direction of the trench. Altogether, the quartz tourmaline rock which shows some copper mineralization is about 15 metres wide. A sample from the dumps of the trench and shaft (20850) gave a value of 22.2 per cent copper metal.

Moving along the western slope of this hill from the shaft there is another old trench, where the rock is mainly gneissose granite, cut by a ridge of quartz tourmaline rock running in a N. 55° W. direction. Slickensides are evident on boulders in this locality. A sample from this trench gave a value of 0.15 per cent copper metal (20851).

Nearby, there is another trench running up-hill and exposing the quartz tourmaline rock. This trench showed a high radioactivity value and a sample from it (20852) gave a value of 18.3 per cent copper metal.

Granitic rocks around this site show frequent slickensides running N. 10° E. and surfaces dipping at about 17°, indicating movement in the rocks.

In the lower reaches of the western slope of this hill there is a trench and a shallow pit. The trench is exclusively of a granitic rock, while the pit shows an outcrop of marble, carrying appreciable amounts of chalcopyrite, covellite and other copper compounds. These sulphides form irregular patches and disseminations in the rock. A sample of this rock (20856) gave a value of 11.9 per cent copper metal.

b) Waranga West

This hill is really a long range which runs parallel to Waranga east. Between the two, there are some small hillocks composed mainly of granitic rocks, traversed by quartz veins and showing tourmalinization in some places. Many old trenches were encountered on the eastern slopes of Waranga West, but with no apparent mineralization. The quartz tourmaline zone on this slope trends in a N. 23° E. direction. On the western slope of this range, opposite the southern end of Waranga east, there is a cliff face some 95 metres above the surrounding plain. On this cliff face there is an adit 2 x 2 metres at the entrance and narrowing down as one goes in. This adit is over 50 metres long and runs in a S. 53° E. direction. Slickensides were seen on the walls of this tunnel, running parallel to its direction. The wall rock in the tunnel and in the cliff generally is a dark, hard, siliceous rock, very fine grained and composed of quartz and tourmaline with some iron oxides. A thin layer of azurite could be seen on the walls of the tunnel and on the cliff face outside, while malachite is also evident on the rocks nearby. Encrustations of malachite are also quite common on the eastern face of the cliff. A specimen of rock from the cliff, near the mouth of the tunnel (20858), gave a value of 1.58 per cent copper metal. On the walls of the tunnel near its entrance there is a thin deposit of azurite, malachite and another white mineral, all of which have apparently been deposited after the excavation of the tunnel. A specimen from this deposit (20859) gave a value of 0.79 per cent copper metal.

South of this tunnel, on the western slopes of the hill, the rock is a schist with the foliation striking S. 26° W. and dipping at 47° to the west. This schist is exposed between the weathered granite outcrops which form the bulk of the hill here. Along the top of the ridge, the granitic rock is silicified and impregnated with the quartz tourmaline rock. This zone of silicification extends along the whole ridge of Waranga west and shows some iron enrichment. Slickensides are evident as indication of movements to which these rocks were subjected. These movements seem to have also affected the country rock of the plains nearby, which is a white rock composed of quartz and sericite. The foliation of this rock strikes S. 26° W. and dips 47° to the west.

Malachite staining was noted in the silicified zone of the ridge near the southern extremity. The host is again a quartz-tourmaline rock.

In the plain east of the range, the rocks are mainly a gneissose biotite granite. North of Waranga East, the rocks on the eastern slope of Waranga West are a hornblende gneiss striking N. 46° E. and dipping 65° to the east and then a gneissose granite veined with quartz and showing slickensides, running N. 46° E. and their planes dipping at 77° to the south.

Waranga east also extends to the north in the form of small hillocks which are not very evident in the overgrowth. These hillocks show rocks varying between hornblende gneisses and gneissose granites. Evidence of movement was again seen here and silicification and tourmalinization are exhibited on the spines of these hills. No copper mineralization was detected. Iron stone is also outcropping in this area.

3. J. Yirongo

This hill has a bearing of N. 36° E. to Bishura, S. 23° W. to Waranga east, N. 32° E. to Jumbana and N. 68° E. to Siomo.

J. Yirongo East is of two peaks and is formed of schists trending at a N. 26° E. direction and dipping steeply to the west. The ridge is formed of a zone of silicification showing iron enrichment. The silicified rock contains hexagonal hollows, probably remnants of the original mineral which was removed. Evidence of movement is again seen here. On the western slopes of this hill an old trench was found, which did not contain any evident mineralization. However, nearby, a piece of loose schist was found which contained a fair amount of malachite, azurite and streaks of cuprite or chalcocite. Its relation to the trench is doubtful. This piece when analysed (20867) gave a value of 22.2 per cent copper metal (Fig. 21).

Yirongo west is an elongated hill with a number of peaks, exclusively formed of white quartzite. The quartzite trends N-S and dips at 66° to the west, at the southern end of the hill. On the eastern slope of the hill the quartzite shows interlaminated mica, and further down it becomes darker in colour and contains kaolinized felspathic material together with some iron compounds. The trend here is N. 41° E. (Plate I, Photo. A).

4. J-Jumbana

This hill is formed of white quartzite running N-S and dipping at 61° to the west. J. Grindaga, next to Jumbana, is also formed of quartzite, which in this case contains ferruginous material and the rock is fairly soft.

5. J-Gulmara

This hill is again formed of a dark coloured quartzite trending in the same regional direction to N-S. No good surfaces for measuring dip could be found.

SUMMARY AND CONCLUSIONS

The Hofrat Mine lies in southern Darfur, in a tract of subtropical land, rich in all types of vegetation. The area is generally very flat, but some hills rise to the south west of the mine and extend in that direction till they join the hilly country at the borders. The rocks in this general area are all of the Precambrian Basement complex. They are comprised mainly of schists, gneisses and quartzites with some igneous intrusions. These intrusions are granitic in most cases. These rocks have been subjected to intense shearing and faulting, in the planes of which, silicifying and tourmalinizing solutions have later risen. These are now represented by numerous zones of silicification; forming the backbones of many hills and by the existence of a widely distributed tourmaline-rich rock. The rock is associated with the copper mineralization in many localities though apparently copper ore does occur independent of it.

The major rock types recorded at the mine include, chlorite schists, acid gneisses, amphibolitic and talcose rocks, together with some granites and related pegmatitic types. The general strike of foliation of these rocks is NE-SW with a variable dip to the NW. This strike and dip can best be seen in the quartzites forming some of the hills to the south west, as most of the other rocks have been subjected to such intense shearing and faulting, that such measurements are very difficult. This is particularly true of the area of the mine, where such shearing and faulting was very intense and took the directions N. 60° E. N. 45° E. and N. 25° E. The mineralized solutions, when later injected, favoured these existing planes of shearing and faulting.

The ore at Hofrat is a polymetallic body, containing pyrite, chalcopyrite and some gold, in a gangue mainly composed of quartz and calcite. Mineralization seems to have been introduced in two stages separated by a period of faulting. The earlier injection contained mainly iron minerals, while the second injection introduced the main bulk of copper mineralization. Thus the pyrite mineralization carries some of the effects of shearing and faulting. This mineralization occurs now in the form of a mesh-work of veinlets occupying the shear zones and part of the wall rock. Consequently, no zone of solid ore with sharply defined boundaries exists, but rather, a cement of ore binding together the brecciated rocks of the shearing zones.

The wall rocks of the mineralized zones have undergone many alterations including sericitization, kaolinization, chloritization, sausseritization and tourmalinization.

The ore in Hofrat is in the oxidized state down to a depth of about 45 metres. In this zone the main mineral is malachite occurring together with some azurite and chrysocolla. It is interesting to mention that some native copper was also recorded in this zone.

The investigation for the assessment of the ore, included the sinking of fifteen boreholes, varying in depth been 60 metres and 160 metres. Fourteen trenches were dug, and 132 auger holes were put down in the dumped material of the old workings. The deposit, as finally estimated, amounted to over ten million tons of copper ore, containing an average of about 2.78 per cent copper. This estimate did not take into account any ore occurring below 160 metres, the maximum depth to which bores were sunk. The occurrence of such ore, has however, been indicated by the results of the bore-holes, in which mineralization continued persistently to the bottom.

In the area to the south west of Hofrat, copper occurrences were recorded on the hills of Bishura, Waranga, Yirongo and others. These occurrences extend along a line over 18 miles in length from Hofrat. The similarity of these occurrences to the Hofrat ore body suggests that the mineralization might be of a regional character. In any case, they constitute a promising reserve for the Hofrat mine, which can be further investigated by the eventual lessee of the mines, to prove their real value. A road needs to be opened to the area for any serious investigation of these occurrences.

The experts of the Nile Congo Divide Syndicate recorded the occurrence of limestone south of J. Ingala (lat. $9^{\circ}14'$ long. $23^{\circ}53'$) and at (lat. $9^{\circ}5'$, long. $23^{\circ}49'$) at a location just west of jebel "A". Ironstone is also plentiful in the area and fairly high grade patches can easily be selected when wanted. Thus, two important subordinate materials for the mine are available in the area.

As far as timber is concerned, the following types are available:—

(a) *Anogeissus schimperi* (Sahab).

This is stated to be suitable for pit props and exists in considerable amounts in the area.

(b) *Khaya Senegalensis* (Muraiya) is stated to be suitable for the production of sawn timber and a big number of these trees is reported to exist in the area. They are usually of large diameter.

(c) *Pseudo cedrila Kotschi* (Shedarah El Beidah), *Diospyros mespiliformis* (Joghan) and *Schlerovanya birrea* (Homeid) are also given as suitable trees for the production of sawn timber in the area.

(d) Fuel wood in plentiful quantities is available from the dense bush of the area.

Water Supply in The Area: From the nature of the rocks in the area, it is apparent that there is no possibility of finding ground water in any useful amounts. However, the Umm Balacha, a tributary of Bahr el Arab river, is only two miles from the mine. This river flows for about 5 months every year and then it breaks into separate pools, some of which persist to the following rainy season. However for mining and domestic

purposes it would be necessary to dam this river for the storage of the required amounts of water. This should not be a difficult or an expensive undertaking, as the river is a narrow one and a small reservoir will suffice for the needs of the mine.

Transport: At the moment, the mine can only be approached by a motor track, which is only open during the dry season between December and May. The railway terminus is now at Nyala, some 220 miles to the north and the nearest point to the mine is Da'ain, which is 200 miles away.

Thus it seems that a railway extension and an all weather road would be necessary for the exploitation of the mine.

Labour: The area is very thinly populated and at the moment only unskilled labour is available, at very low wages. Semi-skilled and skilled labour have to be imported to the area. Again, most food stuffs, with the exception of meat, have to be brought in from outside, though eventually, it will certainly be possible to grow many crops in the area, if this is found economical.



PHOTO A :—Muscovite-quartzite, Yirongo West. Crossed nicols. $\times 27$



PHOTO B :—Tourmaline-bearing pegmatite, microcline shown, B.H.3. Crossed nicols. $\times 85$



PHOTO C :—Amphibolite. B.H. 2. Crossed nicols. $\times 27$



PHOTO D :—Contorted epidote-biotite-chlorite schist, B.H. 14. Ordinary light. $\times 83$



PHOTO A :—Biotite-chlorite schist with sulphide dissemination, B.H. 4. Crossed nicols. $\times 27$



PHOTO B :—Quartz-felsparbiotite - hornblende gneiss, B.H. 12. Crossed nicols. $\times 52$



PHOTO C :—Tremolite-talc schist with sulphide dissemination, B.H.1. Ordinary light. $\times 27$

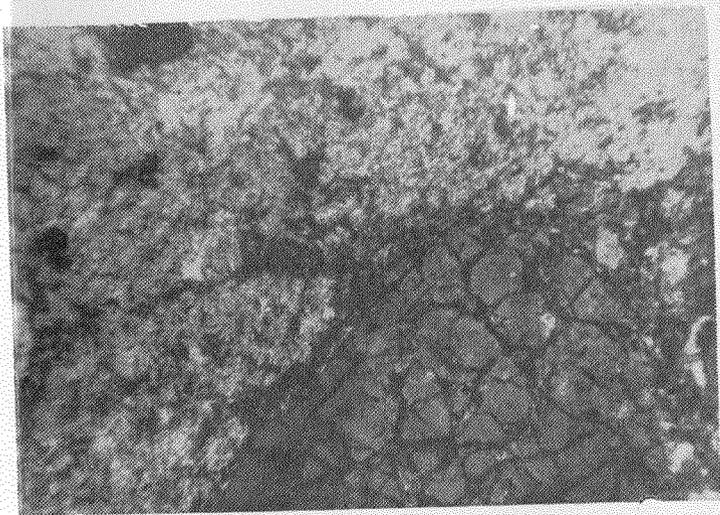


PHOTO D :—Talc schist with tourmaline. B.H. 4. Crossed nicols. $\times 50$



PHOTO A :—Micro folding in felspar-sericite schist, B.H. 15. Crossed nicols. $\times 27$



PHOTO B :—Amphibolite with tourmaline, B.H. 6. Ordinary light. $\times 27$



PHOTO C :—Pyroxenite, B.H. 10. Ordinary light. $\times 50$

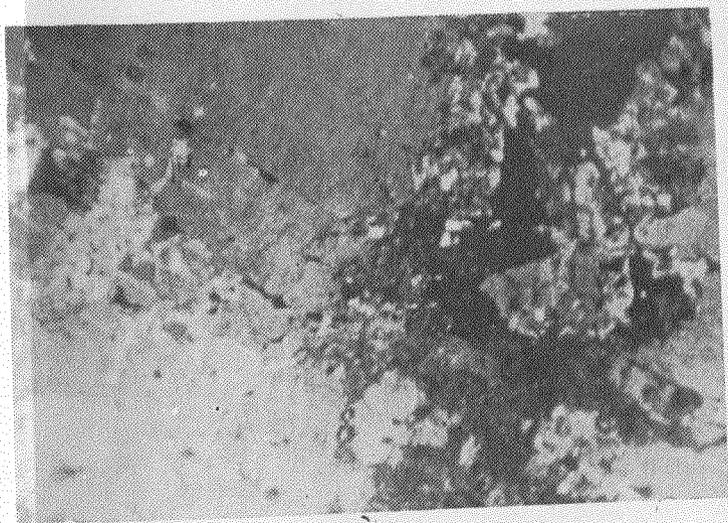


PHOTO D :—Stringer of chalcopyrite with epidote in a country rock of quartz-plagioclase-chlorite schist, B.H. 15. Crossed nicols. $\times 27$



PLATE A :—Chalcopyrite embedded in a matrix of calcite, B.H. 15. Crossed nicols. $\times 51$



PHOTO B :—Malachite and chrysocolla, B.H. 4. Crossed nicols. $\times 27$.

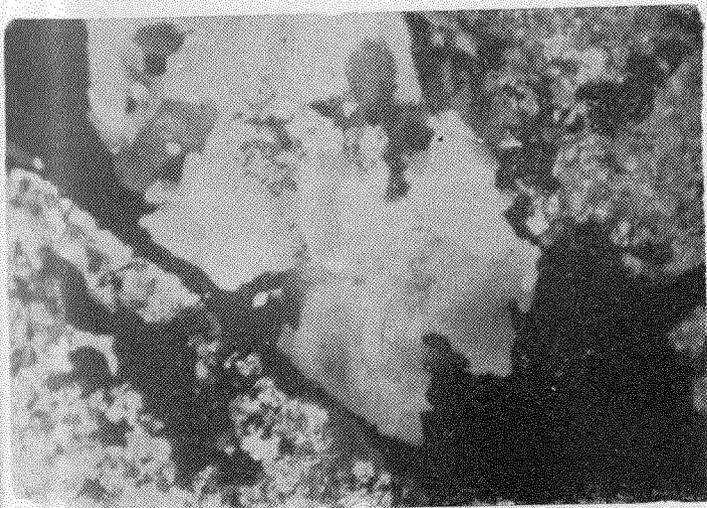


PHOTO C :—A stringer of chalcopyrite in a gangue of quartz and calcite, crossing highly crushed muscovite-quartz-felspar rock, B.H. 15. Crossed nicols. $\times 28$

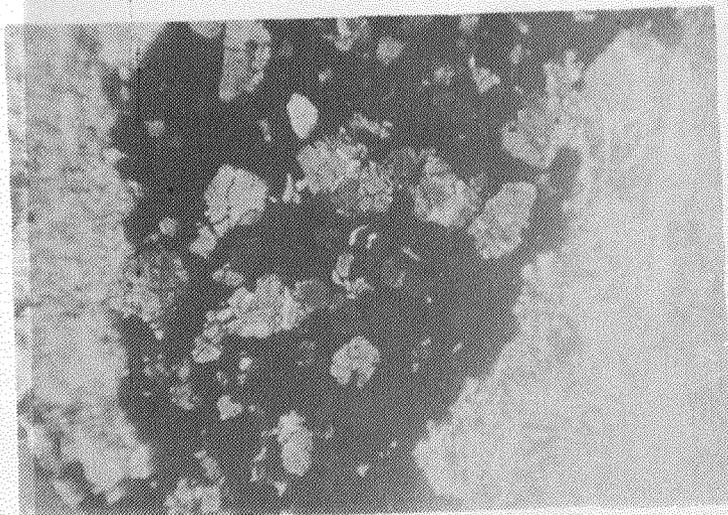


PHOTO D :—A stringer of sulphides enclosing bits of tourmaline, crossing crushed quartz-felspar rock, B.H. 7. Crossed nicols. $\times 51$



PLATE A :—Chalcopyrite embedded in a matrix of calcite, B.H. 15. Crossed nicols. $\times 51$

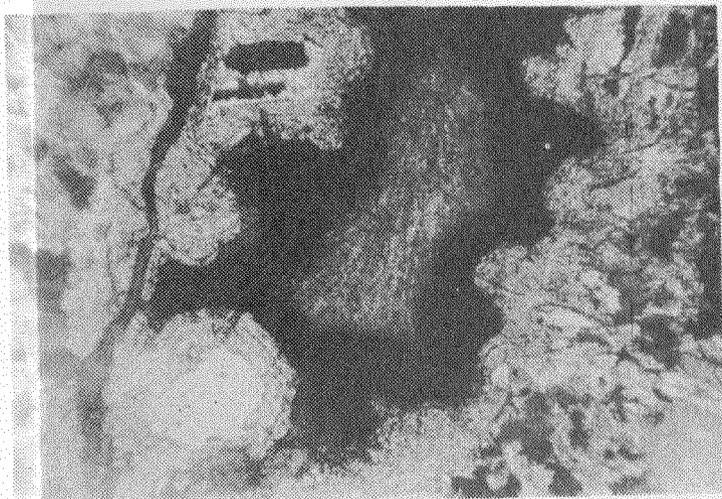


PHOTO B :—Malachite and chrysocolla, B.H. 4. Crossed nicols. $\times 27$.



PHOTO C :—A stringer of chalcopyrite in a gangue of quartz and calcite, crossing highly crushed muscovite-quartz-felspar rock, B.H. 15. Crossed nicols. $\times 28$

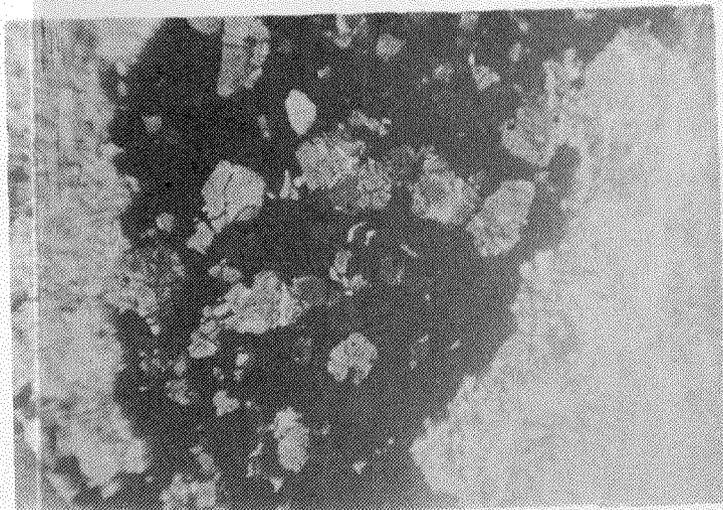


PHOTO D :—A stringer of sulphides enclosing bits of tourmaline, crossing crushed quartz-felspar rock, B.H. 7. Crossed nicols. $\times 51$

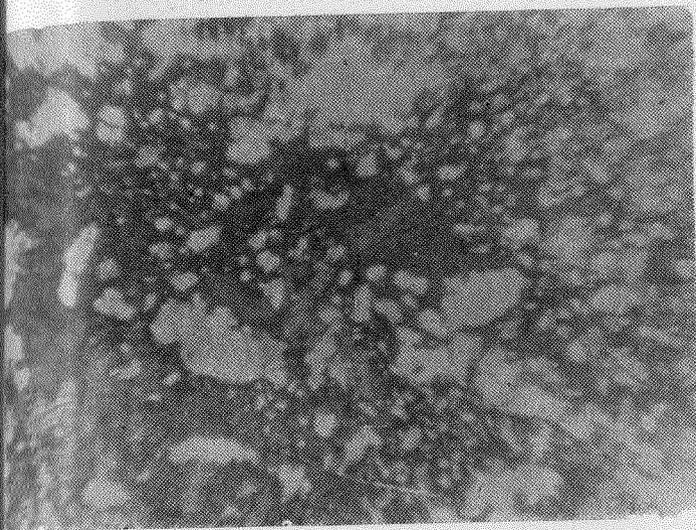


PHOTO A :—Malachite and azurite cementing fragments of quartz. J. Yirongo, Reflected light. $\times 27$

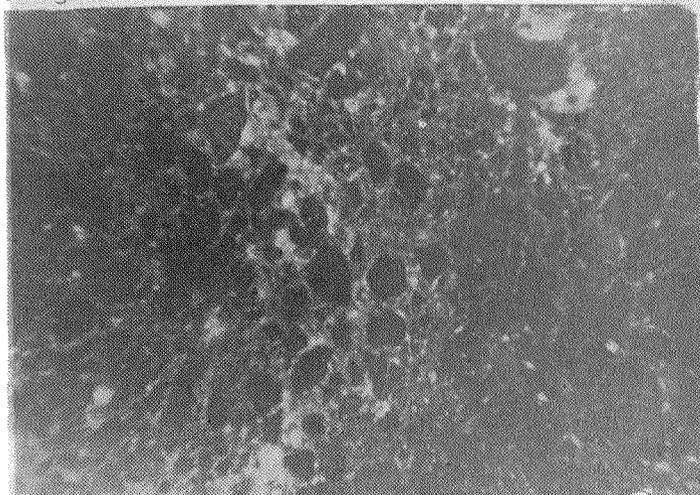


PHOTO B :—Angular fragments of pyrite cemented in quartz, B.H. 7. Reflected light. $\times 27$

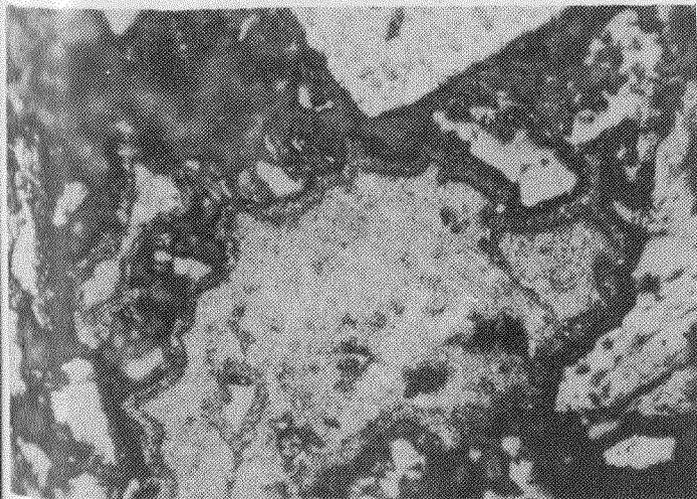


PHOTO C :—Native copper rimmed with cuprite embedded in calcite. Pyrite in white grains. B.H. 15 Reflected light. $\times 27$

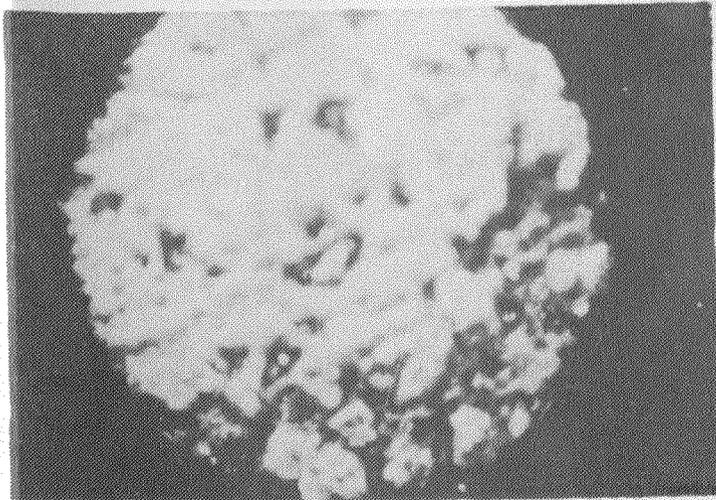


PHOTO D :—Two specks of gold included in chalcopyrite, B.H. 6. Reflected light. $\times 84$

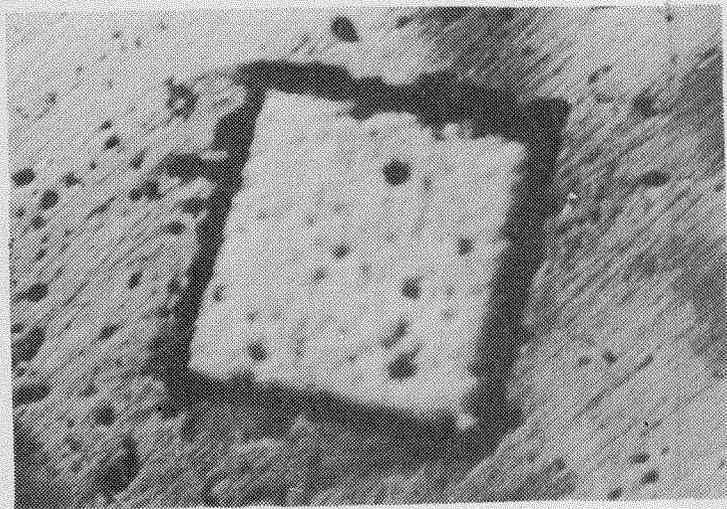


PHOTO A :—Crystal of pyrite embedded in chalcopyrite, B.H. 4. Reflected light. $\times 84$

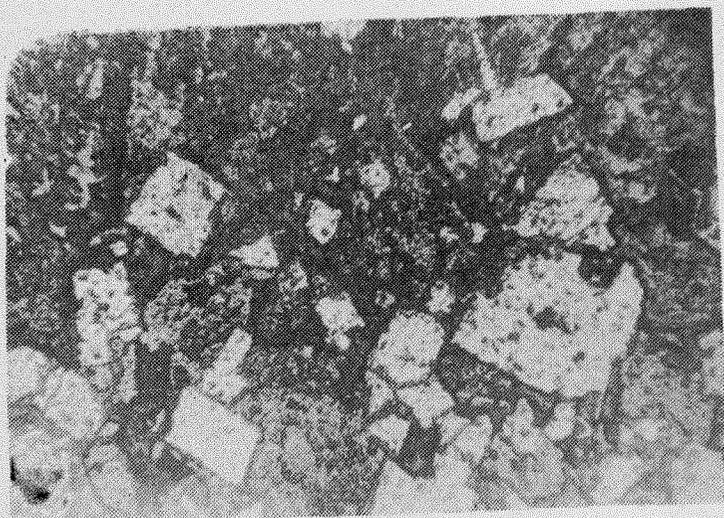


PHOTO B :—Dissemination of pyrite cubes in country rock, B.H. 6. Reflected light. $\times 84$

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