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GEOLOGY OF THE HALL'S REWARD COPPER MINE AREA

NORTHERN QUEENSLAND

by

D.A. White, C.D. Branch and D.H. Green

(With Mineragraphic Appendix by W.M.B. Roberts)

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SUMMARY

Sedimentary, metamorphic, and igneous rocks of Precambrian and Palaeozoic age crop out in the Hall's Reward Copper Mine area, Northern Queensland. Here the rocks form part of a major lineament which trends north-north-east between the "Georgetown Massif" of Precambrian age and Palaeozoic rocks of the Tasman Geosyncline. This lineament has been the site of extensive faulting and intrusion of ultrabasic and basic igneous rocks from Precambrian to Lower Devonian time.

Precambrian metamorphics occupy most of the area. Their eastern margin is faulted against Silurian sediments, and their western margin against phyllite and quartzite of probable Proterozoic age.

There are two ages of Precambrian metamorphics in the Hall's Reward Mine area. The Archaean(?) metamorphics consist of amphibolite, mica schist, quartzite, and migmatite. These are tightly folded, faulted, and intruded by serpentinite, gabbro, and granitic rocks. The degree of metamorphism ranges from the top of the albite-epidote amphibolite facies to the bottom of the amphibolite facies. The Proterozoic(?) metamorphics consist of phyllite and quartzite.

Serpentinite and gabbro are the most abundant igneous rocks in the area. Two ages of intrusion have been recognized: the earlier intrusion probably took place towards the end of the Precambrian orogeny and the later intrusion during the early Lower Devonian orogeny. The later serpentinite intrusion, which was the larger, has domed and fractured the Precambrian metamorphics.

Copper is the most abundant mineral in the area. Since 1933 2,200 tons of copper have been produced from the Hall's Reward Mine (Ninety Mile). The copper lode at the Hall's Reward Mine has an average width of eight feet and has been developed over a length of 630 feet and to a depth of about 190 feet. The lode is kaolinic, soapy, and siliceous. The copper is present as malachite, azurite, cuprite, tenorite, and native copper, with some chalcocite, covellite, and chalcopyrite in the deeper levels.

Geochemical testing in the area has shown the presence of small amounts of nickel in the serpentinite and the over-lying laterite. Deeper testing of the nickeliferous laterite deposit has been recommended. Chromium and manganese are also present in the serpentinite.

INTRODUCTION

In 1957 a joint geological survey by the Geological Survey of Queensland and the Bureau of Mineral Resources was carried out on the Hall's Reward Copper Mine (formerly and locally known as the Ninety Mile) and about thirty square miles of the surrounding area. The new workings of the mine were mapped at a scale of one inch to ten feet by chain and compass, and the surrounding area at a scale of one inch to about 1,200 feet with the aid of enlarged aerial photographs. Geochemical prospecting for copper was carried out in soils over the trend of lode in an attempt to define its limits. Other geochemical prospecting included testing the serpentinites and overlying laterite of the area for nickel.

Previous geological mapping in the area has been carried out mainly by the Geological Survey of Queensland. Maitland (1891) was the first geologist to carry out a reconnaissance of the area; he showed a boundary between Precambrian metamorphics and Palaeozoic sediments coinciding with the Burdekin River and trending south-west through the Hall's Reward Mine. Subsequent geological mapping has not greatly altered the position of this boundary. Morton (1941 and 1943), Denmead (1947), and other geologists of the Geological Survey of Queensland, dealt mainly with the old workings of the Hall's Reward Mine. A reconnaissance of the area was conducted in 1956 by the Geological Survey of Queensland and the Bureau of Mineral Resources (White and Hughes, 1957), of which the 1957 detailed survey is a continuation. These surveys are part of a programme of geological mapping of the Etheridge Goldfields, that covers the Georgetown, Einasleigh, Clarke River, and Gilberton Four-mile Sheets of the Australian National Grid. The work will be completed in 1958 and will be published as a Bulletin of the Bureau of Mineral Resources.

TOPOGRAPHY

The area is situated about ten miles to the east of the Great Dividing Range of Northern Queensland, which here consists of an undulating plateau about 1,700 feet above sea level. The country is moderately dissected and consists of low hills, which rise to a maximum height of about 200 feet above the surrounding country. Some of the hills are mesas formed by the dissection of a flat-lying cover of Cainozoic basalt and sediments.

The Burdekin River is the major river draining the dissected area; it generally flows all the year. The headwaters of the Burdekin River are some 50 miles to the north of the area. The main tributaries in the Hall's Reward area are Moores Creek, Copper Creek and Stenhouse Creek. These creeks flow east; they are generally dry or contain isolated pools through the winter months.

REGIONAL GEOLOGY

STRATIGRAPHY

The area lies near the boundary between the Precambrian "Georgetown Massif" (Hill, 1951) and Palaeozoic rocks of the Tasman Geosyncline.

The rocks of the "Georgetown Massif" form part of the "Etheridge (Etheridgean) Series" (Jensen, 1920), the "Einasleigh Series" (Bryan, 1925) and the "Einasleigh Gneiss" (Whitehouse, 1930) and consist mainly of gneiss, schist, quartzite, and amphibolite.

In the Hall's Reward Copper Mine area the sediments of the Tasman Geosyncline consists of shale, sandstone, and siltstone, which are part of the "Wairuna Beds" (Maitland, 1891).

More recently White and Hughes (1957) recognized geosynclinal deposits in the "Georgetown Massif" and suggested that these deposits were probably of Precambrian age, separated from the Palaeozoic succession near the Hall's Reward area by a thrust zone, along which serpentinite and basic igneous rocks were emplaced. Amphibolite, quartzite, and mica schist of probable Precambrian age were described in the Mine area and correlated with a succession of actinolite schist, marble, quartzite, and mica schist in the Lucky Creek and Paddys Creek areas about ten miles west of the mine.

The 1957 survey suggests that the amphibolite and mica schist beds of the Hall's Reward Mine area are the oldest beds in the Precambrian, probably of Archaean age, since they are partly unconformably overlain by, and partly faulted against, a phyllite and quartzite succession, which itself is faulted against the Palaeozoic succession to the east of the area. Moreover, this phyllite and quartzite succession is similar in lithology and structure to the metamorphics of the Paddys Creek area, which are considered part of the Precambrian succession, probably of Proterozoic age.

Precambrian

Archaean(?)

Metamorphics of probable Archaean age occupy most of the area. They are faulted to the east against Silurian sediments and to the west against a succession of probable Proterozoic(?) age. The metamorphics are unconformably overlain on their southern margin by the Proterozoic(?) succession.

Two rock units have been recognized in the Archaean(?) region of the Hall's Reward Mine area:

Stenhouse Amphibolite is well exposed in Stenhouse Creek, which drains the central part of the area and joins the Burdekin River at longitude 145°02'S. and latitude 18°57'E. The amphibolite is generally finely banded and consists of hornblende and saussuritized plagioclase with narrow bands or lenses of diopside, clinozoisite, and epidote. The hornblende occurs as well orientated needles. The rock is regionally metamorphosed; the mineral assemblage suggests that it belongs to the top of the albite-epidote amphibolite metamorphic facies (Turner and Verhoogen, 1951), or bottom of the amphibolite facies. In some places the amphibolite contains lenses of impure marble and other calcsilicate metamorphics.

The Stenhouse Amphibolite crops out in a linear belt extending from the Hall's Reward Mine to about five miles south of the mine. In this area the amphibolite lenses out and interfingers with schist and quartzite of the Hall's Reward Metamorphics.

Hall's Reward Metamorphics, consisting of quartz-mica schist, mica schist, garnet-mica schist, quartzite, and migmatite, are well exposed in Moores Creek, which drains the northern part of the area and joins the Burdekin River at about longitude 145°00'S. and latitude 18°55'E. They are intensely veined with quartz and pegmatite. Large areas of ptygmatically folded migmatite, interlayered with schist and quartzite, crop out in the central part of the area. All gradations between schist and migmatite can be recognized.

The Hall's Reward Metamorphics crop out in a broad belt about eight miles long and three miles wide in the Hall's Reward Mine area. The metamorphics extend about three miles north of the Burdekin River, which is immediately to the north of the area of outcrop shown on Plate 1.

In the central and eastern parts of the area the Hall's Reward Metamorphics in part overlie and in part interfinger with the Stenhouse Creek Amphibolite.

Proterozoic(?)

A sequence of quartz phyllite and quartzite with some fine-grained quartz sandstone and siltstone unconformably overlies the Stenhouse Amphibolite and the Hall's Reward Metamorphics in the southern part of the area. This sequence, the Paddys Formation, is best exposed in Paddys Creek, about five miles to the west of the area shown in Plate 1. Paddys Creek is a tributary of Lucky Creek, which joins the Burdekin River at about longitude 144°52'S. and latitude 18°55'E.

The age of the Paddys Formation is not precisely known. No fossils have been found in the sequence, nor in the calcareous sediments which interfinger with the Paddys Formation about three miles to the west of the area shown in Plate 1. However, since it lies unconformably above high grade metamorphics of Archaean(?) age at its northern margin, the Paddys Formation is considered to be Proterozoic in age

Silurian

A sequence of interbedded shale, thinly bedded impure quartz sandstone and quartz siltstone crops out along the eastern margin of the Halls Reward Mine area. Along its western boundary the sequence is faulted against the Precambrian metamorphics.

The sediments extend with little variation for about 40 miles north-north-east of the Halls Reward Mine along the valley of the Burdekin River to Wairuna Station. Here Maitland (1891) described similar sediments as the "Wairuna Beds". This unit is used here as the "Wairuna Formation". About 8 miles south of the Halls Reward Mine, the Wairuna Formation conformably underlies a limestone containing corals of Lower Silurian age.

Tertiary

Laterite and lateritic soils ranging from a few feet to about 15 feet thick overlie serpentinite in the south-western part of the area. They cover an area of about 1½ square miles and form a local divide between the Stenhouse Creek and Paddys Creek systems.

The texture of the laterite varies from pisolitic to vesicular. The pisolites consist mainly of iron and range from about 1/32 inch to ½ inch in diameter. They are embedded in a ferruginous or clayey matrix. The vesicular laterite contains encrusted irregular channels which are partially filled with ferruginous and clayey material.

Geochemical testing has shown that the laterite and lateritic soils in this area contain small amounts of nickel and cobalt.

About 30 feet of shale and conglomerate of probable Tertiary age overlie the Paddys Formation in the western part of the area.

IGNEOUS ROCKS

Igneous rocks, consisting mainly of serpentinite, gabbro with some diorite, granite, and porphyry, intrude the Precambrian metamorphics of the Hall's Reward Mine area.

Serpentinite

Two ages of serpentinite intrusion have been recognised in the area. The first intrusion is pre-Silurian, probably Precambrian, and the second took place in the early Lower Devonian.

Sandalwood Serpentinite. This is the elder of the two serpentinite intrusions. It consists mainly of lenses of serpentinite with small pods of talc and tremolite and some sheared and altered gabbro.

The Sandalwood Serpentinite crops out immediately east of the Hall's Reward Mine and trends south-south-west in a discontinuous belt about 20 miles long and up to 900 feet wide. This belt is known to continue for about 3½ miles north of the mine beyond the Sandalwood Homestead, after which the intrusion is named. The small lenses of serpentinite exposed in the central and northern part of the area about ¾ of a mile west of the main belt are also considered to be part of the Sandalwood Serpentinite.

The serpentinite crops out as low rugged mounds. In many places it is silicified with the formation of a silica boxwork. The serpentinite lenses are concordant with the general trend of the Precambrian metamorphics, but in detail they are commonly discordant to the metamorphic banding and schistosity.

Thin sections of the serpentinite show partial or complete replacement of mesh texture and bastite serpentine by antigorite, e.g. specimens No. 395a (co-ordinates 8000E, 2130N), 2121 (8000E, 2050N), 407a and b (8105E, 2155N). Hess, Dengo and Smith (1952) and Wilkinson (1953) have shown that this reaction takes place at the bottom of the albite-epidote amphibolite metamorphic facies. In the southern part of the area, near 7970E, 1857N, the serpentinite commonly has a marginal phase consisting of a chlorite rock containing magnetite porphyroblasts and accessory vesuvianite. Similar chlorite-rich rocks, derived from the serpentinite, contain epidote and tremolite-actinolite porphyroblasts. Massive and schistose talc and pods of coarse-grained acicular tremolite are common in the Sandalwood Serpentinite.

The gabbro in the Sandalwood Serpentinite is medium to coarse-grained, with a strong schistosity trending about north-north-east. A thin section of specimen 340 (8150E, 2250N) contains albite, (?)zoisite, tremolite-actinolite, chlorite, and rutile, with some secondary carbonate. This mineral assemblage is consistent with the metamorphism to the top of the greenschist facies or bottom of the albite-epidote amphibolite facies.

Many serpentinite and basic rocks (specimens 407a, 408, 233 and 340) are partly replaced by a carbonate, probably dolomite or magnesite. Whe e the serpentinite (specimens 408a and b at 8100E, 2100N) is intruded by granite the contact rocks have been partially or completely replaced by a carbonate and a fine-grained quartz mosaic with relict magnetite and chlorite.

The grade of metamorphism of the Sandalwood Serpentinite is lower than that of the Precambrian metamorphics. This suggests that the emplacement of the serpentinite took place after the maximum intensity of the regional metamorphism, but possibly during the waning phase. In this case the intrusions would have been under similar stress conditions, but at a lower temperature, resulting in metamorphism of a lower grade than that of the metamorphics, and in minor transgressions of the pre-existing metamorphic structures by the intrusions.

The age of the intrusion is before Upper Silurian, and probably Precambrian or early Palaeozoic. It is displaced by faulting which accompanied later serpentinite intrusion of probable Lower Devonian age. The Sandalwood Serpentinite extends for about 15 miles to the south-west of the area shown in Plate 1, where it forms part of the provenance of a Silure-Devonian conglomerate.

<u>Boiler Serpentinite</u>. This, together with the <u>Bob West Gabbro</u> crop out in a triangular mass three square miles in area, in the Boiler Gully and Bob West Dam region. The serpentinite includes the linear serpentinite belts which trend north-north-east from north-east and north-west corners of the triangular mass (Plate 1).

The Boiler Serpentinite forms the core of the mass. Thin sections of some of the serpentinite (specimens Nos. 2131, 2144a, b, c & d, 2141, 2135e, 2104) show that it was derived from ultrabasic rocks varying from dunite through enstatite olivinite to enstatolite. In these rocks pseudomorphs of bastite and mesh-texture serpentine after orthopyroxene and olivine are common, with chromite as an interstitial primary mineral. Interstitial magnetite, chlorite, and antigorite are probably secondary after rare interstitial clinopyroxene. Talc and chlorite rocks, antigorite serpentinite, and tremolitite are not present in the Boiler Serpentinite.

Basic rocks form a mantling zone to the serpentinite core and consist of uralitized, saussuritized, and prehnitized gabbro. The gabbro is well exposed one mile east of Bob West Dam after which it is named. The gabbro is generally medium-grained and is foliated owing to the alignment of saussuritized feldspar and amphibole. The foliation is parallel to the margin of the serpentinite core and dips outwards from it at about 55 degrees to the north and with a steeper dip on the eastern and western margins. The retrogressive mineral alteration and the foliation of the gabbro probably took place during shearing due to the emplacement of the serpentinite core whilst the gabbro was in the late magmatic stage of cooling.

Diallagite, some hornblende diorite and granodiorite are exposed in the structurally highest part of the intrusion. The relationship of these rocks to the Bob West Gabbro and Boiler Serpentinite is not precisely known. The diallage is partially altered to actinolite; it crops out in two small areas about 400 feet long and 400 feet wide. Its contact with the surrounding gabbro is not exposed.

The structure of the Precambrian basement in this area has been determined largely by the intrusion of the Boiler Serpentinite and Bob West Gabbro. For example near 7970E, 2160N the gabbro has domed the Archaean metamorphics and formed subconcordant gabbro layers, in amphibolite and mica schist, trending east and west and dipping at a low angle to the north. The intrusion of the serpentinite core is thought to have closely followed the gabbro intrusion with the formation of radial faults and the foliation within the mantling gabbro. The transcurrent fault immediately south of Stenhouse Creek is probably a part of the radial fault system and the major movement plane which made room for the serpentinite core. This fault appears to be contemporaneous with Hall's Fault on the eastern margin of the Precambrian basement. This, together with the fact that the Boiler Serpentinite intrudes the Proterozoic(?) Paddys Formation and is later than the Precambrian metamorphism, suggests that the emplacement of the Boiler Serpentinite and Bob West Gabbro took place during the early Lower Devonian orogeny.

Granite

Coarse-grained porphyritic muscovite granite generally containing garnet intrudes the Precambrian metamorphics in a number of places. Numerous pegmatite and quartz veins are associated with the granite. In the central part of the area similar granite intrudes the Sandalwood Serpentinite. Its relationship to the Boiler Serpentinite is not known. The restriction of the granite intrusion to the Precambrian basement suggests that it was emplaced during the late Precambrian.

Microdiorite

A number of small dykes of microdiorite intrude the Precambrian and Palaeozoic successions. The dykes are porphyritic, consisting of quartz, feldspar, and chloritized pyroxene or hornblende phenocrysts in a sericite, quartz and chlorite groundmass. The microdiorite is massive and unsheared.

Porphyry

Several small quartz-feldspar porphyry masses intrude the Precambrian succession, generally along faults such as the Lucky Downs Fault and the transcurrent fault in the central part of the area. The porphyry is probably related to the Croydon "Felsites" (Honman, 1937) and other porphyries of Upper Palaeozoic age in Northern Queensland.

Basalt

In the southern part of the area two basalt dykes intrude the Precambrian metamorphics. The age of these dykes is not known, but they may be related to the Cainozoic basalt in the surrounding area.

STRUCTURE

The Hall's Reward Mine area forms part of a major lineament, which trends north-north-east and coincides with a pronounced change in the course of the Burdekin River. This lineament has been the site of several orogenies in the Precambrian and Palaeozoic.

The Halls Reward Metamorphics and the Stenhouse Amphibolite are considered to constitute the Precambrian basement. They occupy a rectangular area about $3\frac{1}{2}$ miles wide and 15 miles long, trending north-north-east. They are tightly folded, sheared, and bounded on the eastern and western margins by two steeply-dipping parallel faults, here named Hall's Fault and Lucky Downs Fault (Plate 1).

The Hall's Fault is well exposed in Copper Creek about 4,000 feet north-east of Hall's Reward Copper Mine, where it separates the Precambrian metamorphics from the Silurian sediments. Here the fault dips about 80 degrees to the east; the beds are brecciated and sheared over a 15-foot zone with the formation of dragfolds, shear cleavage planes and slickensides, indicating that the faulting took place under compression. The dragfolds suggest that the movement was essentially vertical with the Precambrian basement upthrown against the Palaeozoic block. This is also shown by the orientation of the quartz rods in the fault zone, which have their long axes horizontal and parallel to the dragfold axial lines, and perpendicular to the vertical or steeply plunging slickensides.

The Lucky Downs Fault on the western margin of the Precambrian basement separates the Paddys Formation from the Halls Reward Metamorphics. The direction and amount of displacement is not precisely known, although the intense vertical shearing indicates that the movement was essentially vertical. The fault consists of a shear zone up to half a mile wide in which the bedding planes are minutely crenulated and quartz grains have been strongly rolled out.

The Hall's and Lucky Downs Faults are difficult to trace to the south of the area, where they pass into broad shear zones in the Paddys Formation. In this part of the area the basement is delineated by a structural and metamorphic unconformity between the Archaean and Proterozoic successions. The unconformity has been folded and modified by the intrusion of serpentinite. In this region the Paddys Formation appears to have behaved as a non-rigid plastic medium undergoing compression on a semi-rigid basement. This movement has imparted a near horizontal attitude to the Paddys Formation, steepening near the unconformity. Dome and basin micro-folding without fracturing suggests that at the time of the folding the Proterozoic sediments were relatively unconsolid-ated and under little cover.

The main structure in the Archaean basement is a broad north-plunging syncline on the western edge, and a tight anticline on the eastern edge. The broad syncline has been partly formed by the intrusion of the Boiler Serpentinite and Bob West Gabbro into tightly folded and sheared Archaean metamorphics. Dragfolds of varying size are associated with the folding and shearing. The general trend of the bedding and axial-plane foliation in the area is north-north-east, with dips ranging from 40 to 90 degrees.

Along the axial line of the main syncline in the headwaters of Copper Creek, muscovite granite, pegmatite, and quartz have been injected along the foliation to form migmatite.

In the central and western part of the area the Archaean metamorphics have been domed and fractured by the emplacement of the Boiler Serpentinite. During this movement, probably in the Lower Devonian, the main transcurrent fault immediately south of Stenhouse Creek was formed, probably contemporaneous with the Hall's Fault.

THE HALL'S REWARD COPPER MINE

LOCATION AND ACCESS

The Hall's Reward Copper Mine is situated near the Burdekin River about ten miles north-north-west of Greenvale Station (Plate 1). The mine is connected by a fair dry-weather road of some 85 miles, to the nearest railhead at Einasleigh. The mine is also accessible by a road of some 210 miles from Hughenden, from where the ore is railed to Mt. Isa. The mine can also be reached by good road of about 200 miles from Cairns via Mt. Garnet and Conjuboy Station. A track of about 90 miles via Greenvale, Camel Creek, and Kangaroo Stations connects with Ingham on the coast but crosses the Burdekin River near Greenvale, where it is impassable during, and for some time after, the wet season.

HISTORY

The first production from the mine was in 1933 when C. H. Adair and party forwarded to Chillagoe 76 tons of ore from an open cut about 100 feet long, and from a few shallow shafts below it. Subsequently the mine lay idle till late in 1936 when it was taken up by J. H. Norcott and family. Since that time it has been a steady producer of copper ore.

In 1944 the property was taken over by A. Hall, H. D. and J.H. Atkinson. The Atkinsons relinquished their interests in 1955, and the current tenure, M.L. application No.288, is in the name of A. and J. Hall.

Between 1936 and 1942 production came mostly from the stopes above the 50-foot and 89-foot levels in No.2 shaft (Plate 4). During this period a new vertical shaft, the No. 3 or "main" shaft, had been sunk to facilitate development at greater depth and a level was opened up from it at a vertical depth of 150 feet. In 1943 this shaft was sunk to its present depth of 193 feet.

From 1943 to 1947 production came mainly from stopes above the 150-foot level. In the following three years these stopes were carried up to and above the 89-foot level. The years 1950-1954 saw the exploitation of the hangingwall section north of No. 2 shaft, together with salvage of ore remaining in other parts of the mine. Since then activities have been concentrated on the development of a new, No. 4, shaft.

Ore was shipped to the Chillagoe Smelters until their closure in 1943 and subsequently to Mt. Morgan. Since 1953 the ore has mainly been sent to Mt. Isa, which involves a saving in freight but a loss of payment for the gold and silver content.

Up to the end of 1957 total production from the mine was 12,634.5339 tons of ore, the metal content paid for being 2,201.2089 tons of copper, 2050 (fine) oz. of gold, and 9506 oz. of silver (see Table 1 for annual production figures from 1933 to 1957, and Table II for the average grades).

WORKINGS OF THE MINE

Until recent years the main workings consisted of three shafts, viz., Main or No.3 (193 feet vertical depth), No.1 South (40 feet), and No.2 North (150 feet), connected by three main levels as shown on the accompanying longitudinal projection (Plate 2).

These workings are now abandoned, and efforts are being concentrated on sinking the new No.4 vertical shaft about 300 feet to the south of No.3 shaft. No.4 shaft is being sunk to test a possible southerly extension of the orebody suggested by the promising copper values intersected at depths of about 80 feet and 160 feet respectively in two drill holes, D.D.5 and D.D.3 (Plate 2), selected and drilled during 1953/54 by the Geological Survey of Queensland. Most of the recent development has consisted of driving to the south, where the lode is wider and more consistent. The longest drive is on the 100-foot level, where the lode has been developed over a length of 30 feet and has an average width of 5 feet.

At the end of October, 1957, the shaft had been sunk to a vertical depth of 125 feet, with levels at vertical depths of 50 feet, 75 feet, 100 feet, and 125 feet (Plate 2). Each level consists of a westerly crosscut which intersects the lode at distances from the shaft of 9 feet, 1 foot, 3 feet and 10 feet respectively.

On the 50-foot level the new workings are connected to the inaccessible old workings by a 115-foot north drive. At this point the level connects with a new ventilation shaft on the footwall of the lode. The 50, 75, 100 and 125-foot levels are connected by winzes sunk at about 35 feet along the south drives. The 75-foot and 100-foot levels are also connected by a winze at the end of the north drives on these levels.

No stoping has yet been carried out in the new workings.

GEOLOGY AND STRUCTURE OF THE LODE

The lode in the old abandoned workings has been previously described by Morton (1941, 1943). Blanchard and Morton (1942), Connah (1954), and Denmead (1947). Most of the characteristics of the lode described in these papers can be recognized in the present workings.

The lode is located within a steeply dipping shear zone near the contact of the Stenhouse Amphibolite and the Halls Reward Metamorphics, and probably on an easterly limb of a major anticline.

The hangingwall (east wall) of the lode consists of quartz-mica schist and the footwall of altered amphibolite in the northern part of the lode, and an extremely altered sericitic and talcy(?) "soapstone" in the southern part. The mica-schist wall-rock is weathered to 125 feet below the surface in the No. 4 shaft and is generally altered to a chlorite and sericite schist close to the lode channel.

The "soapstone" is generally massive, well jointed, soft, pale brown or pale green, and greasy to the touch. Relic structures of ferromagnesian minerals and feldspar are exposed in the footwall on the 100 and 125 foot levels. Petrographical examination of some thin sections of the "soapstone" from the 75 and 100 foot levels of the new workings has shown that it generally consists of fine-grained sericite and quartz.

One specimen of the "soapstone" collected from 50 feet south of the drive in the 100-foot level suggests that it may be a hydrothermally altered garnet-biotite granite similar to the garnetiferous granite elsewhere in the area. In thin section the rock contains about 35% of corroded skeletal or lath shaped biotite (0.5-2.5 mm. long) in a sericite matrix (45%) with irregular anhedral quartz (15%) and some apatite. The quartz is clear and unstressed. Sericite is very fine-grained and often shows a mesh structure, probably an alteration from an acid feldspar. The biotite flakes are generally deep brown with some corrosion in the altered parts. Colourless unaltered garnet and apatite are present throughout the section. The original rock could have been a garnet-mica schist or a garnet-biotite granite, but the absence of schistosity and orientation of mica favours a granitic origin. A little magnesite is exposed in the "soapstone" directly opposite the shaft on the 75-foot level.

The lode material is extremely altered and varies from kaolinic to siliceous. In places, in the northern part, the lode is soapy and resembles the "soapstone" wall in the southern part. The degree of alteration and extent of the kaolinic "soap" are closely proportional to the degree of shearing within the lode channel, as is also the extent and grade of the ore. Detailed mapping of the southern portion of the lode suggests that the kaolinic and siliceous portions were originally mica schist and quartzite, now extremely altered, probably hydrothermally. Previous geologists including Morton (1941, 1943) have suggested that the kaolinised "soap" product in the northern part of the lode has been partly derived from the amphibolite wall rock.

The shearing between the hangingwall and footwall rocks trends north and has a general steep easterly dip. However, the dip is variable (Plate 3) from nearly vertical to as low as 50 degrees to the east or, locally, steeply to the west. In the new workings of the No. 4 shaft the dip of shearing ranges from about 60 degrees to the east in the upper levels, though vertical in the 75-foot level, to about 75 degrees to the west in the 125-foot level. Owing to changes in its dip the position of the shear, projected to the next lower level, is not closely predictable.

The lode channel has a normal width of 8 to 12 feet and is well defined along a proved ore-bearing length of 470 feet in the abandoned workings. Recent developments at No. 4 shaft suggest that this figure can be increased to 630 feet.

The lode pinches and swells along the strike as well as down the dip (Plate 3). In the new workings the lode has been developed over a length of 160 feet and a width which ranges from 2 feet to 10 feet. On the 125-foot level in the south drive a roll in the "soapstone" footwall has increased the width to 12 feet. A further roll in this wall at the face of the drive has decreased the width of the lode to 3 feet.

In the upper levels of the mine the lode dips about 60 degrees to the east and in the lower levels the dip is reversed to about 60 degrees to the west. This reversal may be due to faulting which has been observed in the southern face of the 150-foot level, at the bottom of No. 4 shaft and No. 3 shaft. These faults dip between 35 and 60 degrees to the west.

The shape of the orebody in the abandoned workings is essentially that of a central ore-shoot averaging 6 to 8 feet in width and about 470 feet in length, tapering at its northern and southern limits into narrow veins and copper-stained lode material. The shoot has a vertical plunge. The shape of the orebody at No. 4 shaft is lenticular (Plate 3), tapering towards the surface and probably below the 125-foot level, with a maximum width of about 10 feet between the 75 and 100-foot levels.

Some branching of the lode has been observed in the northern part of the mine. The most important branch was that encountered in the hangingwall section north of No. 2 shaft. Here a rich "make" of ore was stoped over a maximum length of 80 feet from 20 feet below the 98-foot level up to the 50 foot level, where it merged with the original orebody. This is the only instance in which ore has been worked in the hangingwall. A rich "make" of ore has also been encountered in the footwall of the 50-foot level north of No. 2 shaft.

A split in the lode is reported on the 150-foot north level 75 feet from the main shaft. The western section tapers out in slightly-weathered amphibolite and as far as is known the eastern section has not been investigated.

The lode is not known to split in the southern part of the old workings, but little crosscutting and lateral development have been done in this part of the mine. However, the lode on the 50-foot level of the new workings is continuous with the lode on the 45-foot level in the southern part of the old workings. The face of the 105-foot level is reported to be still in ore, and it may prove to be continuous with the lode on the northern face of the 100-foot level.

An unusual feature of the lode is the existence of a strongly-leached and iron-impregnated rock on the 150-foot south level beneath oxidised ore. It extends from the main No. 3 shaft to near the winze from the No. 1 south shaft. Negligible values were reported in this section except for a patch of good quality ore 20 feet long about 150 feet from the main shaft. Morton and Blanchard (1942) considered the rock to be a gossan representing the leached copper portions of another oreshoot. However, Denmead (1947) states that the gossan is continuous with the ore on the No. 2 level. Diamond drilling in 1953-54 designed to test the lode below this gossan indicated very weak sulphide mineralization at 250 feet vertical depth.

MINERALIZATION

The copper ore exposed in the mine is mainly secondary, malachite being the most abundant ore mineral. On the 100-foot, and in particular on the 125-foot, levels, cuprite and tenorite, with some native copper, are also present. Sooty chalcocite and covellite with some disseminated pyrite or chalcopyrite occur in stringers in the foot of the rise at the southern end of the 125-foot level. Pyrite has also been observed as small specks associated with the copper ore on the 89 and 150-foot levels and as seamlets associated with jasper at No. 1 south shaft. Chalcopyrite has also been recorded at the bottom of the Main No. 3 shaft and at greater depths in bore cores.

On the 125-foot level cuprite and tenorite generally occur in the kaolinic lode as kernels up to three inches in diameter surrounded by a diffused halo of malachite. Native copper is present as minute disseminations and on joint planes in the siliceous lode.

Blanchard and Morton (1942) considered most of the copper minerals as replacements of the kaolinized "soap" varying from sparse impregnations to nearly massive ore. Malachite and chrysocolla are precipitated along "shrinkage" cracks in the jasper. Blanchard and Morton (1942) attribute the jasper to replacement of kaolinized country rock, first by silica and subsequently by iron carried in the ground waters during oxidation and leaching of the ore.

Gold and silver mineralization has also been reported in the old workings. Some indications of the Au/Cu and Ag/Cu ratios throughout the mine is shown in Table II. Denmead (1947) noted a decrease in the Au/Cu ratios in the ore shipped from the stopes between the 89 and 150-foot levels. An increase in the ratios is evident from 1945-50, when the stopes were carried up to the 89-foot level to the north of the main shaft, and above that level to the south. Subsequent production, mainly from the hangingwall section north of No. 2 shaft, shows a marked decline in Ag/Cu ratio but little variation in the Au/Cu ratio. These ratios suggest a residual gold enrichment in the lode.

DIAMOND DRILLING

During 1953-54 the Geological Survey of Queensland selected and drilled five holes on the Hall's Reward Mine (Plate 2). All holes were depressed at 50 degrees west. D.D.1 was cored from the surface; non-coring bits were used in the upper portions of the remaining holes.

D.D.1 and D.D.2 were drilled to test the lode below the workings at a vertical depth of about 250 feet. They intersected only very weak sulphide mineralization. Core recovery in these sections was rather low, but close scrutiny of the cores and assays of sludges indicated negligible copper and gold values.

D.D.3 and D.D.4 were then drilled to test the lode at a vertical depth of about 150 feet at positions opposite cupriferous jasper outcrops to the south of the workings. Both holes intersected oxidized copper ore containing cuprite, tenorite, and native copper. D.D.3 encountered about 20 feet of mineralization, and D.D.4 about 12 feet. The intersection in D.D.3 was considered sufficiently encouraging to warrant a further hole, D.D.5, 60 feet west of D.D.3, to test the lode at a shallow depth; D.D.5 intersected about 13 feet of similar mineralization with higher values than the other holes.

FUTURE PROSPECTS OF THE MINE

The ore reserves of the old workings are apparently exhausted. What happens to the lode channel immediately below the 150-foot south level is not known, as the No. 3 main shaft is close-timbered and no exploratory winze was ever sunk. Beyond the southern limits of the gossan on the 150-foot level, the lode channel is only one foot wide, and though copper stained, it is devoid of gossan. North of the main shaft the only working below the 150-foot level is a small underhand stope some 20 feet north of the shaft.

Evidence from No. 3 shaft and from D.D.1 and D.D.2 suggests that there is no prospect of appreciable reserves, either of enriched secondary ore below the 150-foot level, or of primary ore at greater depth below these workings. Since the lode is not split in the southern part of the old workings it appears that it is continuous with the lode in the No. 4 shaft, where it is expected to pass into disseminated chalcopyrite at about 250 feet.

It is apparent that a zone of secondary enrichment commences at about the 125-foot level on the new workings, and this zone could be expected to extend another 75 feet to the water table.

Detailed surface mapping to the north of the mine has shown that the amphibolite and quartz-mica schist boundary is displaced about 250 feet to the east by a fault before it passes under the alluvium of the Burdekin River. Geochemical soil sampling in this area did not reveal any promising copper values.

There is some prospect for an increase in the length of the lode to the south of the mine beyond that proved by the diamond drilling.

The shear zone between the amphibolite and the quartz-mica schist which contains the copper lode is parallel to the Hall's Fault about 2,000 feet to the east of the mine. The southward extent of this shear zone is not precisely known, as outcrop is poor here. However, quartz rubble suggests that the shear continues to the south for about another 1,000 feet. Geochemical soil sampling in this area revealed copper values of about 50 parts per million, which continued for about 1,250 feet south of No. 4 shaft. Higher copper values from 300 p.p.m. to 1,900 p.p.m. were obtained about 100 feet to the west of the trend of the lode. The significance of these values is not precisely known, but they may represent concentration of copper down the slope by surface waters or soil creep.

The geological and geochemical evidence together with the lode intersection obtained in D.D.4 are sufficiently encouraging to warrant a drill hole about 150 feet south of D.D.4 to test the extension of the lode to the south and at a vertical depth of 150 feet.

TABLE I

ANNUAL PRODUCTION FIGURES

HALL'S REWARD COPPER MINE

The following table has been prepared from official figures supplied by the Mines Warden. Since 1950 returns for the Hall's Reward Mine have been included in the Ingham Warden's District:

Year	Ore Treated Tons	F Gold Fine Oz.	Silver Fine Oz.	Copper Tons
1933	76.1910	22.1729	86.1394	12.3865
1937	442.5912	98.2458	559.0000	92.1030
1938	495.5296	139.2892	681.0000	106.8804
1939	635.2733	170.2460	823.5626	133.9512
1940	918.5467	215.3719	948.9117	192.3563
1941	635.2842	157.2552	831.3375	116.1993
1942	1011.0224	213.7755	1121.5000	145.5580
1943	606.7000	171.0000	469.0000	94.2800
1944	711.7000	110.9900	280.9700	128.6800
1945	1002.7805	152.1300	642.1391	178.8443
1946	879.4046	103.1343	411.5343	127.6025
1947	726.9773	64.6283	247.2655	114.0180
1948	845.3004	130.2448	1065.4440	142.2209
1949	749.8233	142.4348	680.1515	125.3246
1950	483.8171	95.6882	475.8392	89.0721
1951	263.1289	52.9319	22.9993	48.7947
1952	421.9551	71.0121	135.4087	82.4029
1953**	261.7749	39.5281	24.5705	46.5010
*	114.2131	-	-	19.2731
1954*	394.5208	-	-	72.8140
1955*	276.6397	-	-	48.5674
1956	313.9925	-	-	42.3500
1957*	341.7628	-	-	36.9944
**	26.3384	-	-	4.0343
	12,634.5339	2150.0790	9506.7733	2201.2089

** Shipments to Mount Morgan

* Shipments to Mount Isa

TABLE II

THE YIELD PER TON FOR ORE TREATED FROM THE HALL'S REWARD COPPER MINE

Year	Au (dwt/ton)	Ag (dwt/ton)	Cu (%)
1933	5.82	1.13	16.26
1937	4.44	1.26	20.81
1938	5.62	1.37	21.57
1939	5.36	1.29	21.09
1940	4.69	1.03	20.94
1941	4.95	1.31	18.29
1942	4.23	22.18	14.40
1943	5.64	15.46	15.54
1944	3.09	7.89	18.08
1945	3.04	12.82	17.84
1946	2.34	9.36	14.51
1947	1.80	6.80	15.70
1948	3.1	25.2	16.8
1949	3.8	18.1	16.7
1950	4.0	19.7	18.4
1951	4.0	1.8	18.5
1952	3.4	6.4	19.5
1953	3.0	1.9	17.8
	-	-	16.9
1954	-	-	18.6
1955	-	-	17.7
1956	-	-	13.5
1957	-	-	11.1
Average	3.854*	17.036*	17.41

* Excluding shipments to Mount Isa.

GEOCHEMICAL TESTING

COPPER

Soils were tested for copper along the northern and southern ends of the lode of the Hall's Reward Copper Mine and in the surrounding area. Samples were taken at a depth of four feet where possible by hand auger. They were crushed and treated with hot concentrated sulphuric acid to bring the copper into solution. In each case one gram of soil was used for acid treatment, so that, using dithizone of known strength, a direct reading in parts per million was obtained from the millilitres of dithizone reagent required to form the complex.

In area "A" (Plate 1) to the north of the mine, 28 samples were taken at intervals of 100 feet over a length and width of 500 feet, so as to try to locate copper mineralization along the amphibolite and mica schist boundary, which here is displaced about 250 feet to the east of the main trend of the copper lode. The highest copper value was 60 p.p.m., but most of the samples averaged about 5 p.p.m. Further testing was abandoned in the area.

Results obtained over the southern end of the copper lode (Area "B" in Plate 1) were more encouraging. Here 42 samples were taken on a 30-foot by 20-foot grid, over a length of 150 feet and a width of 120 feet starting about 100 feet to the south of No. 4 shaft. The copper values obtained show that peak values up to 1,900 p.p.m. are distributed along a line trending 15 degrees west of south, roughly parallel to the lode line, but displaced about 40 feet to the west. These copper values decreased more abruptly to the east than to the west. The 40-foot displacement to the west may be due to soil creep, the slope of the land being in that direction. Further sampling was carried out for about 1,000 feet to the south of this grid, where copper values decreased and ranged between 20 and 45 p.p.m.

Samples were also taken along the amphibolite and mica schist boundary between areas "C_2" and "C_3" (Plate 1) about $\frac{3}{4}$ of a mile south-south-west of the Hall's Reward Mine. Here 122 samples were taken over a length of 2,700 feet and a width of 450 feet. A value of 2,000 p.p.m. of copper was obtained in the southern part of this area at point "C_3", but copper values decreased to 200 p.p.m. within 30 feet, and to 350 p.p.m. at a depth of 8 feet below "C_3".

Whether the 2,000 p.p.m. anomaly is related to mineralization at depth is not known. It may be significant that the mica schist along this contact near the anomaly is altered to a chlorite schist, which is characteristic of the footwall schist near the copper lode in the Hall's Reward Mine. Moreover, the 2,000 p.p.m. of copper compares favourably with the results obtained over the southern part of the lode.

NICKEL

The northern part of the Sandalwood Serpentinite between the Hall's Reward Mine and Stenhouse Creek was tested for nickel. Qualitative tests were conducted in the field, and samples giving positive results were later submitted to the laboratory for quantitative analysis.

The highest nickel value was 2.55%, associated with manganese and chromium obtained in a lenticular serpentinite mass about 75 feet long and 25 feet wide situated one mile south of the mine (Plate 1). The average nickel value in the serpentinite between the mine and Stenhouse Creek is 0.2%, and immediately south of the creek the nickel values decreased to 0.02%.

Part of the Tertiary laterite overlying the serpentinite of the Boiler Gully Complex in the south-western part of the area was sampled and tested for nickel and cobalt in an attempt to find a zone of enrichment in the lateritic profile. The areas sampled ("D" to "J") are shown on Plate 1.

Summary of the results is as follows:

Locality	Area in square feet	No. of Samples Tested	Av. % Ni. at surface	Max. % Ni at surface	Av. % Ni of serpentinite near area	Av. % Ni at depth of 4 ft.	Max % Ni at 4 ft.
D	0.01×10^6	3	0.07	0.08		Not known	
E	1×10	12	0.07	0.12	0.1	Not known	
F	0.09×10^6	9	0.08	0.18	0.1	"	
G	0.09×10^6	6	0.10	0.27	0.2	"	
H	5×10^6	16	0.23	0.34	Not known	0.25	0.33
I	2×10^6	8	0.19	0.50	"	Not known	
J	1×10^5	10	0.08	0.17	"	0.1	0.18

The cobalt values in these areas were generally very low, ranging from a trace to 0.2% with an average of 0.05%.

The nickel values from areas "H", "I" and "J" were considered sufficiently encouraging to warrant further testing at deeper levels. Accordingly a further series of test holes ranging in depth from 6 ft. to 14 ft. were bored at the sites L1, and L3 to L10 shown on Plate I. In addition a series of samples were taken each at a depth of 2 ft. down the scarp of a deep erosion gutter starting from the site of L1. This gave an effective vertical depth of approximately 33 ft. All samples were tested in the field for cobalt and nickel by paper chromatographic separation of the cobalt and nickel after fusion of the sample with potassium bisulphate. The chromatograms were developed with rubeanic acid and values estimated by visual comparison with a series of standards, following the procedure of The Imperial College of Science & Technology, Geochemical Prospecting Research Centre modified from Hunt, North and Wells (1955).

The results for nickel are summarised below:

Locality	Max. depth in feet	Average % Ni.	Max % Ni.	Remarks
L1	14	0.85	1.2 at 8-10 ft	ferruginous zone
L1	33	2.4	3.3 at 30-33 "	" "
L3	6	0.47	0.6 at 4 ft.	" "
L4	14	0.43	0.5 at 10-12 "	" "
L5	4	0.05	0.06 at surface	mottled zone
L6	6	0.55	0.7 at 4 ft	ferruginous rubble
L7	10	0.40	0.5 at 0-4 ft	" zone
L8	8	0.10	0.2 at 4 ft	4 in. ferruginous gravel at 4' overlain by recent alluvial clays
L9	6	0.10	no maximum	mottled zone
L10	6	0.15	0.3 at surface	" ".

The values for cobalt were very similar to those obtained in the first sampling being generally 0.05% or less with some profiles showing a maximum of 0.1-0.2% at the surface and decreasing with depth.

The greatest thickness of ferruginous zone is found on the eastern side of the laterite area, being approximately 50 feet as shown by dissection, while on the western side the ferruginous zone is less than 6 feet with some deeper alluvial areas. Although mottled zone material was found no true pallid zone was observed in any of the holes. Buckshot and ironstone concretions are common throughout the area but the typical laterite is only found on the higher eastern portion.

The nickel values follow the anticipated pattern of close association with the ferruginous zone, in all cases decreasing rapidly on entering the mottled zone. There is no correlation between nickel content and the amount of buckshot or ironstone gravel.

The occurrence of laterite overlying serpentinite in this area of Northern Queensland is similar to the nickeliferous laterites of Cuba and Dutch New Guinea. In one of the Cuban Deposits enrichment of 0.8% Ni. at the surface increasing to 1.6% Ni at depth has been found in the ferruginous zone derived from serpentinite containing 0.1-0.2% Ni. However in the laterite of the Hall's Reward area significant enrichment appears to be confined to a small area on the south eastern boundary of the laterite.

MINERALIZATION IN THE AREA

COPPER

Copper is the most abundant mineral in the area. Seven small copper prospects were located (Plate 1); they generally consist of one or two pits about 10 feet deep sunk on a malachite and azurite-stained ferruginous quartz vein or a small shear. The deepest workings apart from the Hall's Reward Mine are situated on the north-central margin of the area, where a siliceous vein in the Hall's Reward Metamorphics has been worked to a vertical depth of about 70 feet. In one prospect, near the central western margin, sulphides (chalcopyrite and pyrite) were recognized.

In places ferruginous gossans are exposed. The longest of these crops out in the southern part of the area (Plate 1), over a length of about 150 feet and a width of 6 feet. Several pits have been sunk on the gossan to a depth of 10 feet, exposing malachite and azurite.

OTHER METALS

Nickel occurs in serpentinite and overlying laterites. No definite nickel mineral has been identified, but it probably occurs as one or more of the hydrated nickel silicates such as garnierite.

Nickel values averaging about 0.2% Ni were obtained in the northern part of the Sandalwood Serpentinite, near the Hall's Reward Mine. Higher nickel values (2.55%) occur with manganese (24.75%) and chromium (0.19%) in a lens of the serpentinite about 75 feet long and 25 feet wide, one mile south of the Hall's Reward Mine (Plate 1).

Chromium is also found as massive chromite in small patches on the eastern margin of the Boiler Serpentinite (Plate 1). These deposits rarely exceed a few feet in length and width. No analysis was made of the chromite, but from comparison with the chromite deposit in Gray Creek about 15 miles to the south, it would probably average 30% Cr_2O_3.

ACKNOWLEDGMENTS

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REFERENCES

BLANCHARD, R., and MORTON, C.C., 1942 - Unpublished report on the Ninety Mile Mine to the Under Secretary for Mines, Queensland.

BRYAN, W.H., 1925 - Earth movements in Queensland. Proc.Roy.Soc.Qld, 37, 1-82.

CONNAH, T.H., 1954 - Unpublished report on the Ninety Mile Copper Mine to the Chief Geologist, Geological Survey of Queensland.

DE VLETTER, D.R., 1955 - How Cuban nickel ore was formed. Engng Min. J., 156 (10), 84-87 and 176.

DENMEAD, A.K., 1947 - Ninety Mile Copper Mine. Qld Govt. Min. J., 48, 402-3.

HESS, H.H., DENGO, G., and SMITH, R.J., 1952 - Antigorite from the vicinity of Caracas, Venezuela. Amer. Miner., 37, 68-75.

HILL, D., 1951 - Geology in HANDBOOK FOR QUEENSLAND. Aust. Ass. Adv. Sci., Brisbane, 13-24.

HUNT, E.C., NORTH, A.A., and WELLS, R.A., 1955 - Application of Paper-chromatographic Methods of Analysis to Geochemical Prospecting. Analyst, 80, 172-194.

JACK, R.L., and ETHERIDGE, R. Junr., 1892 - THE GEOLOGY AND PALAEONTOLOGY OF QUEENSLAND AND NEW GUINEA. Government Printer (Brisbane).

JENSEN, H.I., 1920 - The geology, mineral prospects and future of North Queensland. Qld geogr. J., 34-35, 23-36.

MAITLAND, A.G., 1891 - Geology and mineral resources of the Upper Burdekin. Qld geol. Surv. Publ. 71, Parl. Pap. C.A., 19-1891.

MORTON, C.C., 1941 - Ninety Mile Copper Mine, Qld Govt Min. J., 42 (January), 87.

__________, 1943 - Ninety Mile Copper Mine, Greenvale Holding. Qld Govt Min. J., 44 (October), 68.

RUTLEDGE, C.G., 1942 - Unpublished Report on the Ninety Mile Copper Mine to the Under Secretary for Mines, Queensland.

TURNER, F.J., and VERHOOGEN, J., 1951 - IGNEOUS AND METAMORPHIC PETROLOGY, N.Y., McGraw-Hill.

SMITH, E.C.S., 1920 - Geology and mineral resources of portion of the southern section of Oaky Creek District. Kangaroo Hills Mineral Field. Qld Govt Min. J., 23, 309-314.

WHITE, D.A. and HUGHES, K.K., 1957 - Progress report on regional geological mapping, Northern Queensland. Bur.Min.Resour.Aust. Rec. 1957/58 (unpublished).

WHITEHOUSE, F.W., 1930 - The geology of Queensland in HANDBOOK FOR QUEENSLAND. Aust. Ass. Adv. Sci., Brisbane.

WILKINSON, J.F.G., 1953 - Some aspects of the Alpine-type serpentinites of Queensland. Geol.Mag. 90 (5), 305-321.

APPENDIX

MINERAGRAPHIC INVESTIGATION OF ORES FROM HALL'S REWARD MINE

by

W.M.B. Roberts.

The specimens examined came from the zone of secondary enrichment and from the oxidized zone of the orebody.

Those from the zone of secondary enrichment are breccias and some sulphide-rich shattered vein quartz.

The breccia is a compact, reddish-brown rock containing a large quantity of sulphide. It consists of angular bodies of fine-grained calcite, which has completely replaced the original fragments of the rock.

These bodies range up to 0.15 mm. in size, and are set in a matrix of hydrated iron oxide. The rock is cut by calcite veins, some of which exhibit a comb-structure and, with the exception of a few interconnecting veinlets, have a parallel disposition, imparting to the rock a schistose texture. Some quartz is distributed randomly throughout the specimen as irregular areas and subhedral crystals. It is not fractured and shows no evidence of any stress subsequent to deposition.

The ore minerals are pyrite, blue chalcocite, covellite and chalcopyrite. Pyrite, the principal opaque mineral, forms small, strongly fractured masses which have been recemented by blue chalcocite. The mineral has a strong anomalous anisotropism. It contains large irregular grains of marcasite up to 0.6 mm. across. It also forms sub-parallel veins up to 1.5 mm. thick. Associated with these veins and the fractured masses is a mineral having a slightly lower relief and reflectivity, and is somewhat greyish compared with pyrite. At extremely high magnification this was shown to be a severely crushed mineral, the grain-size of which is about 0.001 mm. These small grains are recemented into what appears as a single mineral at lower magnification but which by X-ray diffraction was shown to be pyrite recemented by blue chalcocite.

Covellite and blue chalcocite are widely disseminated as small irregular blebs in calcite; chalcocite also forms large veins up to 1.0 mm. wide, parts of which have been altered to covellite. Chalcopyrite occurs very sporadically as small irregular remnants in blue chalcocite.

The specimen of shattered vein quartz is recemented mainly by blue chalcocite. It contains a small quantity of calcite, covellite and pyrite.

Chalcocite, the principal opaque mineral, as well as recementing the quartz, forms irregular patches intimately associated with calcite, and has altered extensively to covellite. These patches contain small masses of chalcopyrite, which are possibly unaltered residuals of what was once all chalcopyrite.

Pyrite forms irregular masses and euhedral crystals ranging up to 0.5 mm. across; these have been extensively fractured and partly altered to hydrated iron oxide.

The two specimens from the oxidized zone differ considerably in mineral composition. One is a friable, fine-grained rock consisting mainly of a pinkish, very fine-grained mineral, probably a clay, containing quartz grains, and small grains of native copper up to 1.0 mm. in diameter.

The only other opaque mineral is hydrated iron oxide, which forms large irregular veins and lenses lying more or less parallel. In places well developed cubic pseudomorphs consisting of this mineral are formed, probably from original pyrite.

The other specimen from this zone is a chlorite rock, containing quartz and a mineral resembling sericite, but which could be talc. The quartz occurs both as strongly fractured aggregates and as large fine-grained recrystallized masses.

Cuprite is the principal ore mineral, forming large veins which have altered extensively to malachite, and which contain thread-like veinlets of native copper. These veins are composed of coarsely crystalline granular material and are bordered by colloform tenorite.

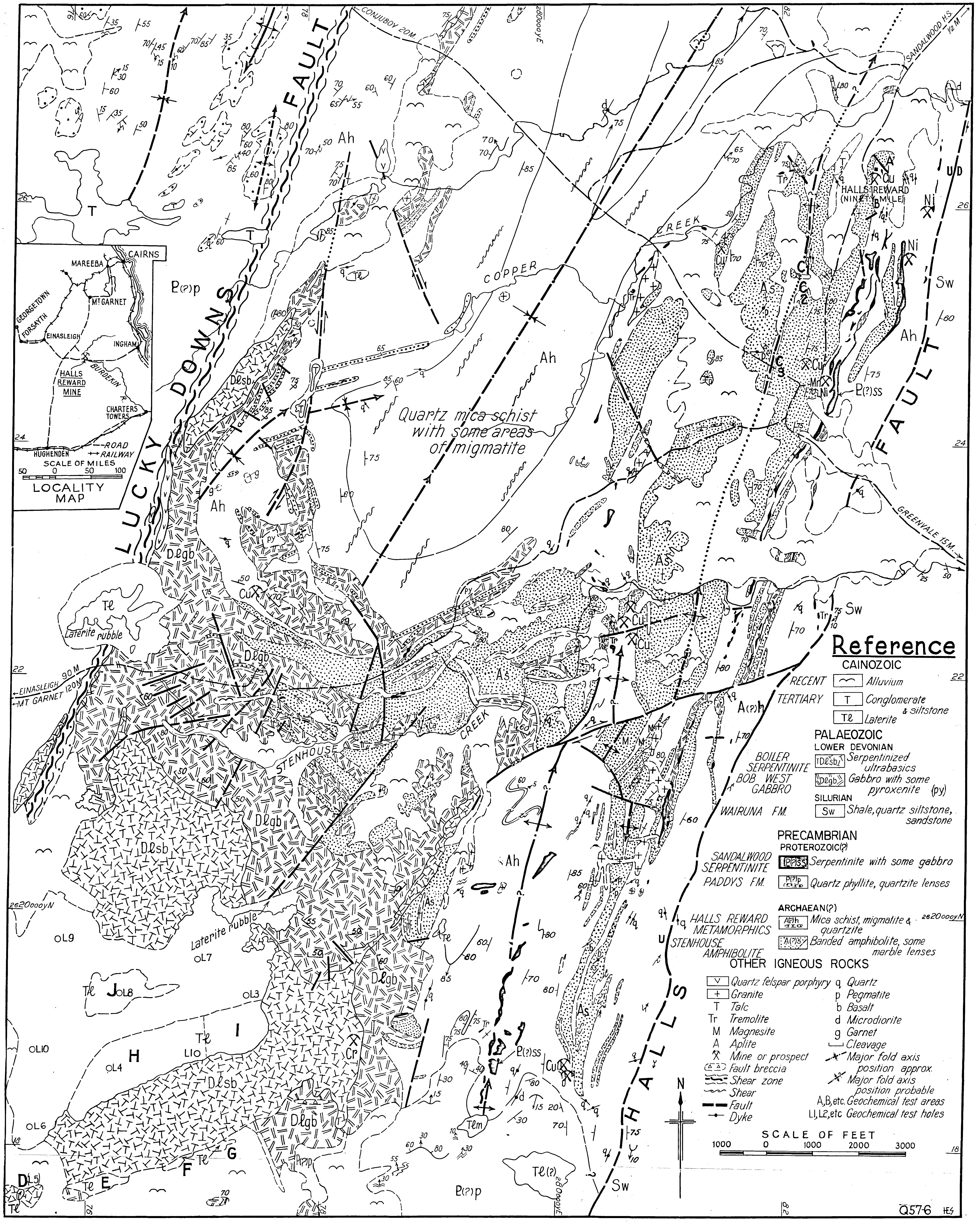
Discussion

Very little of the history of the deposit can be gained from the few specimens examined, but it is evident that pyrite is the earliest deposited of the sulphide minerals. Two generations could be observed; the first was probably emplaced before the first period of deformation, and is now represented by the extremely finely ground material identified by X-ray diffraction. The second generation is represented by the numerous veins and irregular masses cutting across the finely ground material. These veins and masses have in turn been extensively fractured and recemented by copper sulphide. The time relationship of the copper sulphides is rather obscure, and examination of specimens from the primary zone would give a clearer picture. Chalcocite and calcite appear to be related, but whether the chalcocite is primary can only be determined from examination of specimens from the primary zone.

The residuals of chalcopyrite in blue chalcocite recementing shattered pyrite suggest a secondary origin for at least some of this mineral.

Quartz has been introduced some time before calcite, as the veining of quartz masses by calcite shows. Marcasite is probably of the same age as the second generation pyrite. Assuming that the blue chalcocite recementing the second generation pyrite is an alteration product of chalcopyrite, then chalcopyrite follows the deposition and fracturing of this mineral.

GEOLOGICAL MAP OF
HALLS REWARD MINE AREA
QUEENSLAND



HALL'S REWARD COPPER MINE
GREENVALE, QUEENSLAND

Compiled from Queensland Land Dept. plans with additional compass surveys by the 1957 field party.

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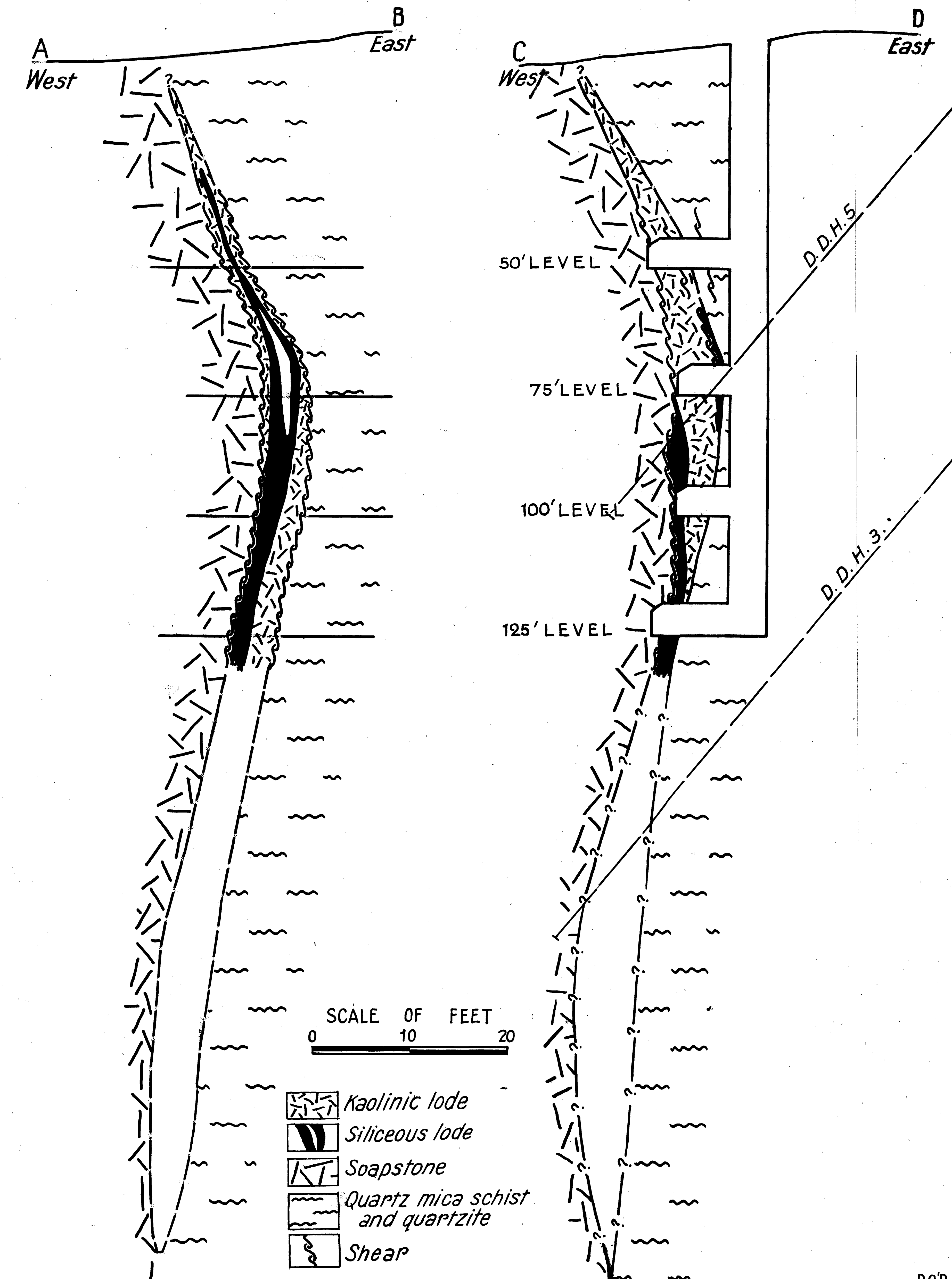
Q57-4 D.O'D / H.E.S

HALL'S REWARD COPPER MINE
GREENVALE, QUEENSLAND.
CROSS SECTIONS "A-B" & "C-D" OF NEW WORKINGS.



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Q57-5 D.O'D / H.E.S