COMMONWEALTH OF AUSTRALIA
DEPARTMENT OF NATIONAL DEVELOPMENT
BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

BULLETIN No. 6

THE GEOLOGY AND MINERAL RESOURCES OF THE HATCHES CREEK WOLFRAM FIELD, NORTHERN TERRITORY

BY

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COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

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SUMMARY

The Hatches Creek Wolfram Field lies 300 miles by road north-east of Alice Springs in the Northern Territory of Australia.

Mining of wolfram began in 1913, but production was erratic and at times the field was closed down completely owing to an unfavourable market for wolfram. A big drop in the price of tungstic oxide caused all the mines on the field to close by late 1957. Official records indicate that 2,840 tons of wolfram and scheelite concentrates valued at £1,294,110 were produced between 1913 and 30th June, 1958; but the recording of production before 1940 was unreliable and the actual production is thought to be about 3,000 tons. In addition to wolfram the field has produced 5.58 tons of bismuth valued at £4,400 and 68.759 tons of copper ore valued at £7,148.

Wolframite is the commonest source of tungsten, but scheelite is present in some mines. Minerals of bismuth, copper, molybdenum, lead, tin, and iron have been identified in association with the tungsten minerals. Minor amounts of gold are also present.

The mineral-bearing lodes lie in sedimentary rocks, in volcanic rocks, and in intrusive rocks; in places the lodes traverse several types of country rock. The oldest rocks in the area are arenaceous sedimentary rocks of the Hatches Creek Group of (?)Upper Proterozoic age. These have been folded and faulted, and intruded by the Pedlar Gabbro. Granite, which is believed to be the source of the mineral deposits, intrudes feldspar porphyry four miles south of the field. Metasomatic and thermal alteration of the Hatches Creek Group adjacent to the Pedlar Gabbro is common.

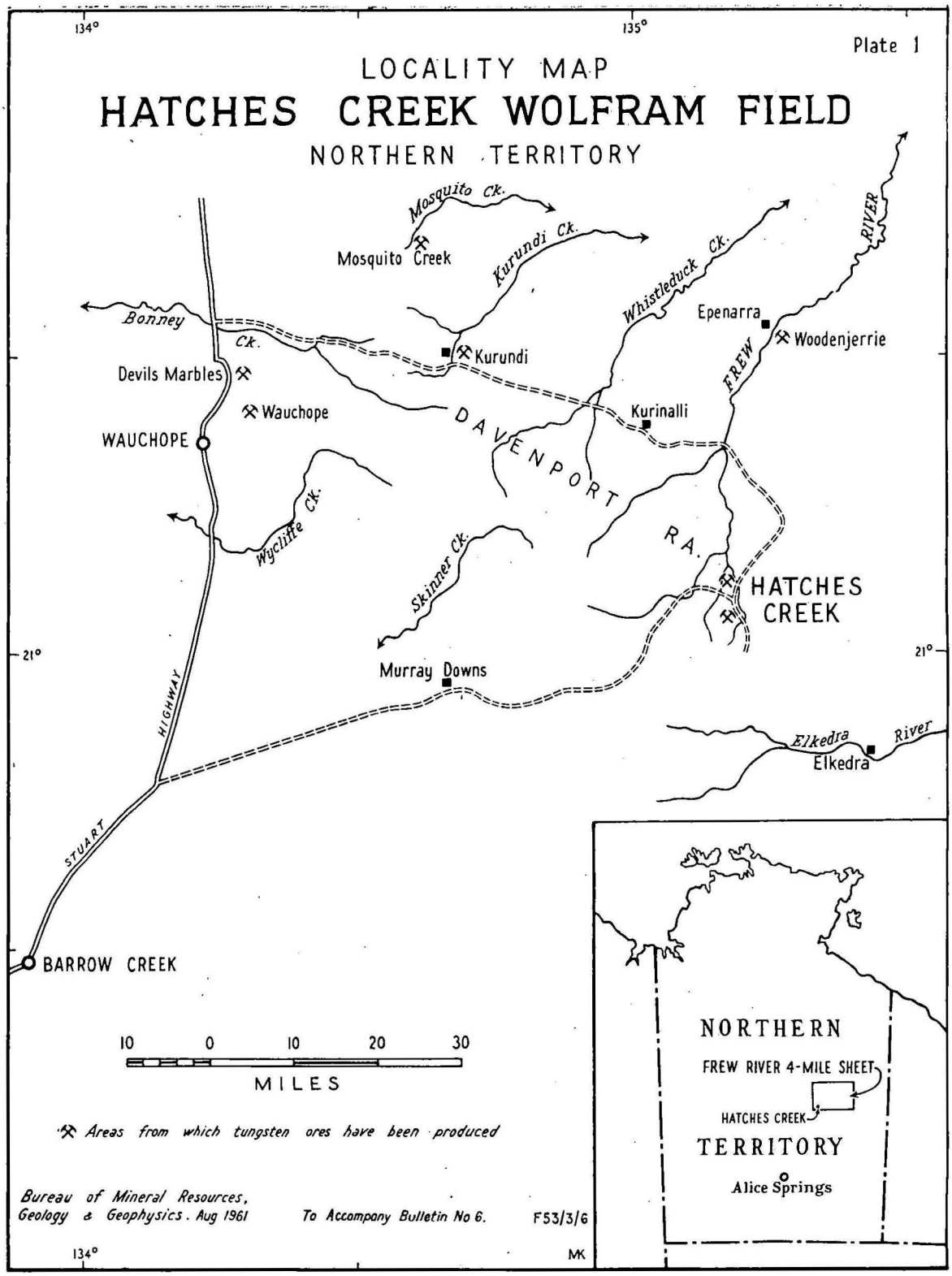
The mineral-bearing fluids intruded zones of shearing formed during the earlier main phase of faulting, and accompanied further slight movement. The mineral deposits lie in groups of lodes; within each group one or two lodes are dominant. Each lode consists of a zone of shearing, along which one or more quartz reefs, lying side by side or en echelon, have been emplaced.

The lodes carry between 1.0% and 3.0% of tungstic oxide. Most reefs are between 6 inches and 18 inches wide; a few are larger. The deposition of wolfram was effected by features on the reefs which caused an increase in the rate of loss of temperature and pressure in the mineral solutions.

Tungsten minerals have been won from a great number of lodes, which have been divided into sixteen groups. The Pioneer Group, the Treasure Group, and the Hit or Miss Group have contributed about 40% of the total tungsten production from Hatches Creek, and the Pioneer Group has been the sole source of bismuth. Copper ore has been sold from the Copper Show Group and the Hit or Miss Group. Descriptions of all the groups are included, but attention has been concentrated on the more important lodes.

Activity on the mining field has always been closely related to the demand for tungsten. High prices stimulate widespread activity on a large number of poorer lodes, but only a few lodes can support operations at a moderate price. The greater part of the ore near the surface has now been removed, and the time is approaching when the development of the tungsten deposits will require the investment of considerable capital, and the use of more efficient methods of mining and exploration.

There are no measured or indicated reserves of ore; inferred ore reserves total 1,000 tons of 65% WO_3 concentrate. Protore is estimated at about 500 tons.


134°
135°
Plate 1
LOCALITY MAP
HATCHES CREEK WOLFRAM FIELD
NORTHERN TERRITORY
Mosquito Ck.
Mosquito Creek
Kurundi Ck.
Whistleduck Ck.
RIVER
Epenarra
Woodenjerrie
FREW
Bonney Ck.
Kurundi
Devils Marbles
Wauchope
WAUCHOPE
Kurinalli
DAVENPORT RA.
Wycliffe Ck.
Skinner Ck.
HATCHES CREEK
21°
Murray Downs
HIGHWAY
Elkedra River
Elkedra
STUART
BARROW CREEK
10 0 10 20 30
MILES
Areas from which tungsten ores have been produced
Bureau of Mineral Resources, Geology & Geophysics. Aug 1961
To Accompany Bulletin No 6.
F53/3/6
MK
NORTHERN TERRITORY
FREW RIVER 4-MILE SHEET
HATCHES CREEK
Alice Springs

INTRODUCTION

The Hatches Creek Wolfram Field is situated near the north-eastern end of the Davenport Range in the Northern Territory. The Stuart Highway, a bitumenized road linking the port of Darwin with Tennant Creek and Alice Springs, crosses the Range at the north-western end. Wolfram deposits are present at Wauchope, The Devil's Marbles, Mosquito Creek, Kurunelli, Epenarra, Elkedra, and Hatches Creek; only the Wauchope and Hatches Creek deposits have proved to be economically important. The Wauchope deposits have been investigated by Sullivan (1952).

The Hatches Creek Wolfram Field is defined for the purpose of this report as a roughly triangular area bounded by Hatches Creek, Mia Mia Creek, and the Hit or Miss Gully (Pl. 2). The area extends roughly seven miles in a northerly direction and is about three miles across at the base. Only two small tungsten-bearing reefs and some reefs reputed to carry gold lie outside this area.

Location and Access

Hatches Creek lies 300 miles by road north-east of Alice Springs. Access is by a well-graded road which leaves the Stuart Highway 25 miles north of Barrow Creek. The mining field lies about 90 miles east-north-east of the turn-off. This road is normally accessible to all traffic, but may be closed if heavy rain floods the creeks. Hatches Creek may also be reached by a good earth road which leaves the Stuart Highway at Bonney Well on the north side of the Davenport Range, and runs via Kurundi and Kurunelli stations.

A weekly air service connects Hatches Creek with Alice Springs, Tennant Creek, and Mount Isa. The nearest telephone is at Barrow Creek, but regular contact by radio is maintained between the Hatches Creek Police Station and the Flying Doctor Base at Alice Springs. A store caters for the needs of the miners. Freight charges from Alice Springs in June 1956 were £15 per ton, with backloading at £12 per ton.

Topography and Drainage

Hatches Creek and Mia Mia Creek drain to the north, and are tributaries of the Frew River, which rises in the Davenport Range west of Hatches Creek. The Frew runs east towards Hatches Creek, then turns north, and floods out in the plains north of the Davenport Range.

The Davenport Range consists of hills two hundred to three hundred feet high and the topography is controlled by the lithology. The hills are of sandstone and quartzite, and the valleys are underlain by igneous rocks, greywacke, shale, and softer sandstone. The southern part of Hatches Creek field consists of a series of parallel ridges trending east, but in the centre and to the north the Pedlar Gabbro has been eroded to form a low-lying plain. Hills of quartzite 20 to about 300 feet high rise from the plain; Wolfram Hill, in the centre of the area, is the largest. In the north, the lower Poseidon Hills trend north-east. Wolfram Hill

and the ridges to the south are flat-topped and have steep sides mostly covered by scree. The wider valleys are moderately mature.

Climate and Vegetation

Hatches Creek lies within the tropics; the winters are mild with rare frosts, but the summers are unpleasantly hot. The daily maximum temperature may exceed 100°F for long periods and temperatures of more than 110° are frequent. Rainfall figures were not obtainable, but the yearly average rainfall is believed to be about fourteen inches, with most of the rain falling in the later summer months, usually in a few heavy storms; lighter winter rains may also fall. Drought conditions have been known to last three years.

The vegetation reflects the arid nature of the country. Spinifex grasses are widespread; various species of eucalypt grow sparsely on the hillsides, and more thickly along the creeks. Flowering shrubs also grow on the hills. A variety of grasses, together with some mosses and rushes, grow along the creeks.

Timber

Very little timber is used in the mines owing to the 'safe' country and the cut-and-fill method of mining. Where timbering is necessary, mulga *(Acacia aneura)* is used because it is resistant to termites and to dry rot. Mulga is scarce in the Hatches Creek area, and only small amounts are obtainable within 20 miles of the field. Large consignments are cut in the mulga stands between Barrow Creek and Alice Springs. Prices in 1956 averaged about 1/9 per linear foot, but varied according to the diameter of the timber.

Water Supply

Until 1937 the field was served by a few water holes lying along Hatches Creek, and these are still used. Kangaroo Hole, which lies towards the south end of the field, is the largest and the most persistent. However, in the boom years of 1937 to 1940 the water holes proved to be insufficient to support the increased population and the demands of the battery. A well was put down on Mia Mia Creek, south-west of the Poseidon Hills, and equipped by the Government. The well is now abandoned, but water is obtained from two bores nearby.

Other attempts to obtain water have had varying success. A well in volcanic rocks on the east bank of Hatches Creek, opposite the Treasure Gully (Pl. 2), is still accessible. Nothing is known of the yield from this well, but the water is reported to be unpleasant to drink. Water from a deep bore, also in volcanic rocks, near the Hit or Miss Extended Mine, was too saline for human consumption.

The deeper mines are making water in their lower levels, and the intake ranges from 1,000 to 4,000 gallons per day; it varies with the mine and the season. These waters are generally unsuitable for use with chemical reagents in the treating of ore, but are suitable for battery needs.

The prospects of obtaining water from the crystalline rocks are not good, as the quartzites are too hard to drill and the igneous rocks can be expected to yield water carrying a high percentage of dissolved solids. The sandstone and greywacke should prove more satisfactory, but may not provide water in sufficient

quantity for treatment plants. Water for domestic use should preferably be sought in the alluvium of the creeks.

Field Methods

The surface was mapped with the aid of low-level air photographs (12,000 ft.; 5,500 ft.) originally flown for the Aerial, Geological, and Geophysical Survey of Northern Australia (A.G.G.S.N.A.). Information was plotted on R.A.A.F. air photographs (25,000 ft.). Leases were mapped in detail with plane table and telescopic alidade at a scale of 40 feet to one inch. Underground mapping was done with tape and compass at a scale of 20 feet to one inch. Maps prepared by A.G.G.S.N.A. were used where available, and later workings were added to them.

Underground mapping of the mines was begun in May 1956, and was followed by surface mapping of the leases. This work was completed by August 1956. Regional geological mapping of the mineral field was done in April and May 1957.

History of Mining and Production

The earliest recorded visit to the Hatches Creek district was made by H. Y. L. Brown (1896), who mentions (p. 10), the presence of 'a few quartz reefs containing solid oxides of iron.' Brown was followed a few years later by a prospecting expedition led by A. A. Davidson (1905). Davidson had several men prospecting for gold in the area, but although one of his employees, D. Pedlar, showed him a black mineral which is believed to have been wolfram, the discovery was not followed up. A second prospecting expedition (George & Murray, 1907) passed through the area in 1906 and recorded the presence of traces of copper carbonates, gold, and galena (p. 21). Wolfram was not recorded.

In 1913 Pedlar returned to the field, having obtained Government assistance of £50. He prospected a reef on Wolfram Hill, probably near Windy Point, and sent a sample of ore to Darwin; the ore assayed 53.7% WO_3 (Oliver, 1916). The first lease was registered by Hanlon and Warne in 1915 on the site of the present Treasure and Hidden Treasure leases.

When T. G. Oliver visited the field in 1916 twenty men were working there. The British Government was providing a guaranteed market for wolfram at the time and production rose steadily to a maximum of 105 tons in 1920. The British Government ceased buying in 1919 and the price of wolfram dropped rapidly from 60/- per unit to about 11/- per unit in 192. Recorded production from Hatches Creek ceased in 1923, and was not resumed for eight years. The accuracy of early figures is much in doubt and tonnages quoted should be considered as approximate only: communications were bad and many miners neglected to send in their returns. Not until 1948 were production figures taken from buyers' returns. Assay data were first obtained at about the same time.

Until 1923 all wolfram had to be transported by camel to the railhead at Oodnadatta, 600 miles to the south in South Australia, or by similar transportation to Queensland. Official records show a total production to 1923 of 387 tons

of wolfram* valued at £65,623, but this figure is almost certainly much lower than the true output.

From 1923 to 1931 there was intermittent activity on the field, but not until 1931 was any further production (6.9 tons) recorded. Regular production recommenced in 1934. Between 1930 and 1932 some supposed gold-bearing reefs were discovered and examined in the Hatches Creek district (Ann. Rep. Administrator N.T., 1930-1932). Assays were reported to be promising but no development was undertaken.

The price of wolfram started to rise in the early 1930's, and in 1937, owing to the Japanese invasion of China and German stockpiling of both standard and sub-grade wolfram (Li & Wang, 1947), the price reached an unprecedented height of 130/- a unit. The railhead had been extended to Alice Springs by then, and motor transport was readily available, which considerably aided the development of the field. The field boomed from 1937 to 1941, and at the height of the boom more than 200 miners were working at Hatches Creek. Production rose steadily to a maximum of 241 tons of concentrate in 1941—about three-quarters of the wolfram production from the Northern Territory. A battery was installed by Mr J. Walsh, who owned several leases at Hatches Creek and at Wauchope. The Government provided a regular water supply and mail service.

In 1942 the Commonwealth Government took over the field, but concentrated attention on the larger mines; small-scale operations were allowed to continue independently. A large Chinese labour force was brought to the field. By 1944 the Allies' demand for wolfram had slackened, and mines were handed back to their owners. A Parliamentary Committee was set up to investigate the production of wolfram and mica in the Northern Territory, and it recommended that while the owners of mines already in operation should be given every opportunity to resume production, the opening of new mines should be discouraged. The committee also recommended that some compensation should be paid to owners of mines appropriated by the Commonwealth. It was considered that, in the light of the increase of wolfram prices during the war, the royalty originally agreed upon had been too low (N.T.W.M.I.C., 1944).

At the end of the war the price again fell drastically and remained very low until late 1950, but most of the larger mines continued operations on a small scale. The outbreak of the Korean War caused a sudden steep rise in the price of wolfram, which reached a maximum of 680/- per unit in 1951. But the boom was short-lived, and by 1954 wolfram was worth an uneconomical 155/- per unit. A slight rise in prices in 1955 and 1956 stimulated some further activity, but late in 1956 the price began to fall again. In mid-1957 the price was fluctuating around 115/- per unit and there was no market for wolfram. By August 1957, only the Pioneer Mine was operating at Hatches Creek, on a very limited basis, and it ceased operations before the end of the year.

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* Unless otherwise stated all tonnages given in this report are in long tons (2,240 lbs.).

A unit of tungstic oxide is 100th part of a ton. Standard wolfram concentrate ("wolfram") contains 65% tungstic oxide.

The total recorded production from the Hatches Creek Wolfram Field has been 2839.85 tons of wolfram and scheelite concentrates worth about £1,294,110. In addition some bismuth concentrates and copper ore have been produced. Tables 1, 2, and 3 give the recorded annual production from Hatches Creek of wolfram-scheelite, bismuth, and copper concentrates respectively to 30th June 1958. Figure 1 shows that the production of wolfram has always been closely related to the price of tungsten, and both have fluctuated widely. Table 4 gives the recorded production from all leases which are known to have produced more than one ton of concentrates since 1940. From the table it may be seen that six mines have contributed about half of the production from Hatches Creek in that period.

In June 1956, the following mines were producing: Pioneer, Endurance, Black Diamond, Green Diamond, Hen and Chickens, Masters Gully, Hit or Miss Extended, Hit or Miss, and several other lodes on the Hit or Miss lease, Silver Granites, Kangaroo, Lady Hamilton, and Copper Show. In addition, prospectors were active on the Kangaroo Group.

Previous Investigations

The area was visited by Brown (1896), Davidson (1905), and George & Murray (1907), before Hatches Creek was established as a wolfram mining field. Brief mention of Hatches Creek is made in each of their reports, but they were concerned primarily with prospecting for gold and did not examine the area thoroughly. T. G. Oliver (1916) made a brief survey of the mining field in 1916, and his report is the only reliable source of information on Hatches Creek before 1937.

In 1937 a brief ground reconnaissance of the area was made by officers of A.G.G.S.N.A., and an area, including the mining field, was photographed from 12,000 feet. This was followed by a detailed survey of the mines and the geology of the surrounding country in 1940. The area was photographed again, from 5,500 feet, in the same year (A.G.G.S.N.A., 1941).

During the Second World War the demand for wolfram increased; considerable interest was shown in the field and several brief reports were prepared (Knight, 1942; Raggatt, 1943; Sullivan, 1943). C. J. Sullivan examined the Treasure Mine in 1951 (Sullivan, 1951) and contributed a section on Hatches Creek in 'The Geology of Australian Ore Deposits' (Sullivan, 1953). E. B. Jensen (1955) has dealt with the treatment of the complex wolfram-scheelite-bismuth ore from the Pioneer Mine.

A ground party of the Bureau of Mineral Resources completed a regional geological survey of the Davenport Range in October, 1956 (Smith, Stewart, & Smith, 1960). In the same year an airborne scintillograph survey of selected areas in the Davenport Range was begun, also by the Bureau of Mineral Resources, and was completed in 1957. Maps showing the results of this survey were released later in the year.

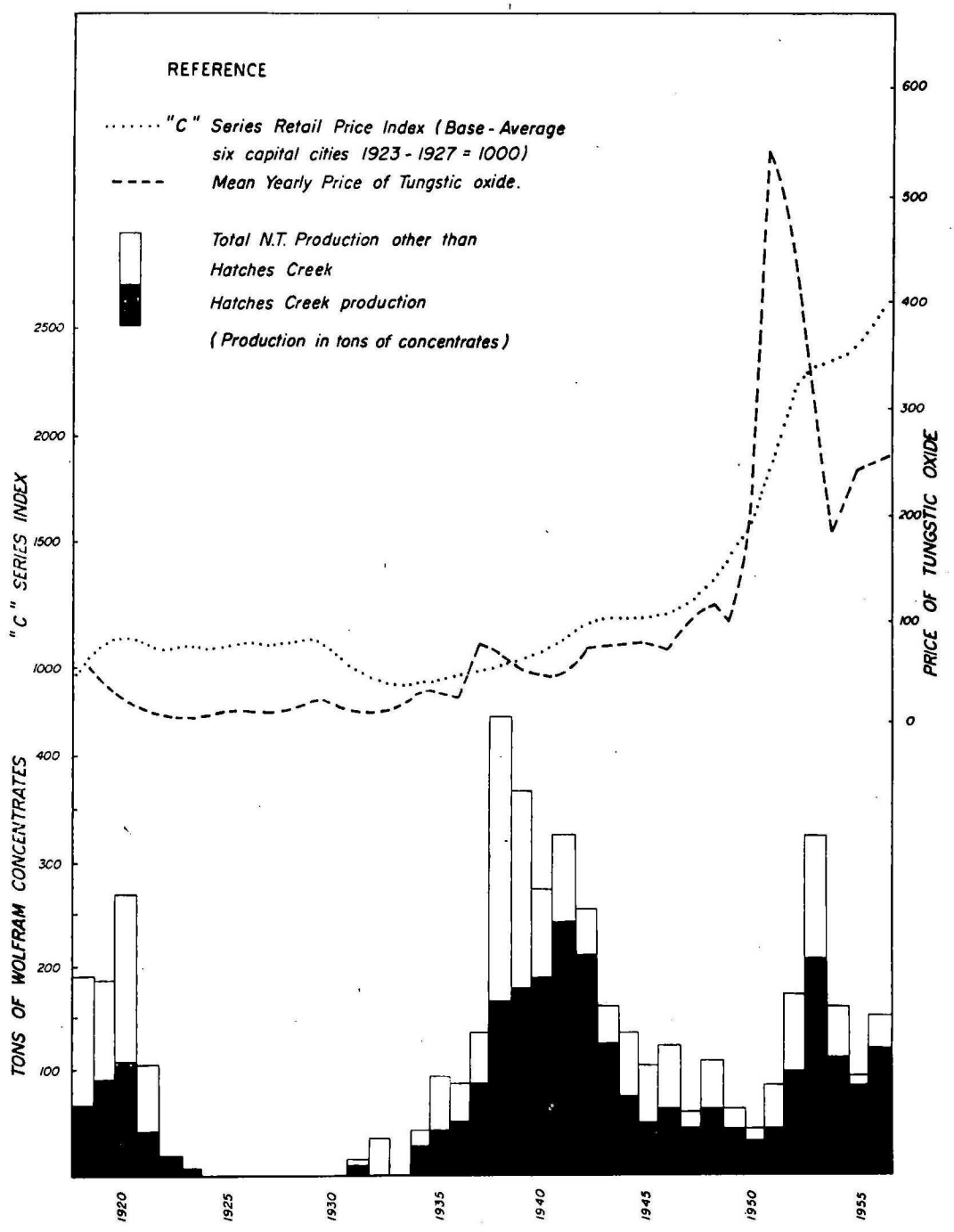

Fig. 1 Production of wolfram from Hatches Creek showing relationship to the price of tungstic oxide.

TABLE 1

HATCHES CREEK WOLFRAM FIELD
ANNUAL PRODUCTION OF WOLFRAM AND SCHEELITE CONCENTRATES
1915-1958

Year Ending 30th June	Concentrates Tons	Value £	Remarks
1915-1917	77	15,415	
1918	62	12,679	
1919	86.9 (b)	14,987	British Govt. ceased buying
1920	105.3 (a)	18,140	
1921	40.0	3,824	
1922	16.0	560	
1923	0.4	18	
1924-1930	Nil	—	None recorded.
1931	6.88	192	
1932-1933	Nil	—	None recorded.
1934	24	1,864	
1935	39.63	4,428	
1936	49.6	5,016	
1937	86.0 (b)	9,525	Invasion of China.
1938	164.34	44,298	
1939	177.25	31,903	World War II started.
1940	186.86	31,942	
1941	241.39 (a)	39.965	
1942	208.5	46,041	C'wealth Govt. operated field.
1943	120.85	33,740	
1944	71.59	20,937	
1945	49.17	16,212	
1946	60.2	19,511	British contract terminated.
1947	39.45	11,925	
1948	57.89	25,747	
1949	39.00	16,771	
1950	28.10	9,032	Korean War started.
1951	41.54 (b)	61,555	
1952	95.88	167,854	
1953	206.57 (a)	264,904	
1954	110.82	95,206	
1955	83.06	70,288	
1956	119.64	105,784	
1957	105.24	82,456	
1958	38.8	11,391	
Total	2,839.85	1,294,110	

(a) Note time lag between peak price and peak production.
(b) Peak price for each boom period.

TABLE 2

HATCHES CREEK WOLFRAM FIELD
ANNUAL PRODUCTION OF BISMUTH CONCENTRATES
1943-1958

Year Ending 30th June	Concentrates Tons	Value £
1943 (a)	3.56	3,721
1944	0.20	187
1946	Nil	—
1947	0.07	10
1948-1953	Nil	—
1954	1.75	482
1955-1958	Nil	—
Total	5.58 (b)	4,400

(a) Includes ore produced during 1941 and 1942, during which time Hatches Creek was the major source of bismuth in Australia.

(b) About 80% of total production for the Northern Territory.

TABLE 3

HATCHES CREEK WOLFRAM FIELD
ANNUAL PRODUCTION OF COPPER ORE
1950-1958

Year Ending 30th June	Ore Dry tons	Value £	Assay % Cu
1950	12.263	642	30.4
1951	4.25	300 (a)	30.0 (a)
1952	5.25	470 (a)	30.0 (a)
1953	Nil	—	—
1954	8.63	950	34.5
1955	20.6	1,940	—
1956	Nil	—	—
1957	14.76 (b)	2,391	45.0
1958	3.0	455	42.9
Total	68.75	7,148	

(a) Value approximate.
(b) 6.47 tons copper.

GENERAL GEOLOGY

With the exception of Cainozoic sediments, all the rocks present on the Hatches Creek field are thought to be Upper Proterozoic. They consist of a sequence of sedimentary and extrusive igneous rocks which Hossfeld (1954) named the Hatches Creek Group and which have been intruded by a differentiated igneous intrusive (here named the Pedlar Gabbro), by feldspar porphyry, and by granite. An area of 20 square miles was mapped in the course of this survey (Pl. 2). Mapping on a regional scale was completed by the Bureau of Mineral Resources in 1956 (Smith et al., 1960).

Hossfeld (1941) recognised three stratigraphic units in the area, separated by unconformities, for which he proposed the names 'Bottom Series,' Hatches Creek Series, and 'Top Series.' Subsequently, he discarded the upper unconformity and the name 'Top Series,' and included these beds, together with the Hatches Creek Series, in the Hatches Creek Group (Hossfeld, 1954). The Hatches Creek Group was placed in the 'Davenport Series' which Hossfeld considered to be Middle Proterozoic. At the same time, Hossfeld correlated the 'Bottom Series' with his 'Agicondi Series,' which he considered to be Lower Proterozoic.

Mapping by the Bureau of Mineral Resources proved that the lower unconformity did not exist either, and the 'Bottom Series' was included in the Hatches Creek Group. The Hatches Creek Group unconformably overlies the Warramunga Group, and is overlain by flat-lying Cambrian sediments; it is now considered to be Upper Proterozoic (Smith et al., 1960). The Pedlar Gabbro, and the other intrusives in the Davenport Range, intrude the Hatches Creek Group, but not the Cambrian sediments.

Hatches Creek Group

The Hatches Creek Group at Hatches Creek consists of arenaceous rocks, a few lutites, and two sequences of volcanic rocks in the upper part of the succession. Quartz greywacke is the commonest of the sedimentary rocks in the lower part of the succession; quartz sandstone predominates in the middle part, and quartzite (or quartzitic sandstone) predominates in the upper part of the succession. Beds of siltstone are present throughout, and thin beds of shale occur in a few places. A few small lenses of conglomerate are present in the sandstone and the quartzite.

Acid porphyry is the commonest volcanic rock type, with some andesite and lamprophyre (Sullivan, 1951) in the lower sequence of volcanic rocks. Hossfeld (1941) states that tuff is present in the upper sequence, but none was recognised during the present survey, although a fine light grey siltstone (Spec. 45, Appendix 1) is almost indistinguishable from tuff in hand-specimen.

The beds throughout the mineral field have been moderately folded and faulted, and dip to the south at an average of 55°. The strike is easterly, but swings gradually from east-south-east in the west to north-east in the east (Pl. 2).

The total thickness of the sequence cannot be measured, because in the northern part of the area only scattered blocks of the Hatches Creek Group remain within the Pedlar Gabbro. About 7,000 feet of the succession, interrupted only by two thin sills, is present between the southern margin of the Pedlar Gabbro and the south flank of the Hit or Miss Gully (Fig. 3).

The oldest rocks in the area lie to the north. Scattered blocks of the Hatches Creek Group, which have been extensively altered, lie in the Pedlar Gabbro between the Poseidon Hills and the Mia Mia Fault Zone (Pl. 2). They have been shattered and folded close to the fault zone. The Poseidon Hills are a series of low undulating ridges trending roughly north-east and are composed of fine-grained quartz greywacke and sandstone, with a few beds of siltstone and quartzite. No bedded igneous rocks were seen, but a plug of gabbro crops out in the centre of the hills.

Quartz greywacke is the dominant rock; it is dense, thin-bedded, and fine grained, and consists of angular grains of quartz in a matrix of sericite and altered feldspar. Limonite, leucoxene, muscovite, zircon, and tourmaline are present as accessories. The colour of the rock varies from brown to almost white and seems to be determined by the amount of limonite in it.

The Poseidon Hills are one of two very large blocks of sediments — the other being Wolfram Hill — which lie completely within the Pedlar Gabbro. The sediments have been hornfelsed at the contact, and small blocks of hornfelsed sediments lie within the igneous rock close to the contact. The dip of the beds is to the south-east and steepens from 40° in the north-east to a maximum of about 70° in the south-west (Pl. 4). Current bedding at the south-west end indicates that the beds are the right way up.

Wolfram Hill lies to the south of the Poseidon Hills, and the two are separated by a wide, flat-bottomed valley underlain to the north by the Pedlar Gabbro, and to the south by sediments of the Hatches Creek Group. Outcrops are rare and the contact was not seen. The sediments in the valley are siltstone, greywacke, and sandstone, but on Wolfram Hill the dominant rock is quartz sandstone, interbedded with quartzite, greywacke, and some siltstone. Two small outcrops of deeply-weathered acid igneous rocks were examined and appear to be intrusive; but the outcrops were limited, and the nature of their occurrence was not determined. They lie on the south side of Wolfram Hill.

The strata on Wolfram Hill strike roughly parallel to those on the Poseidon Hills, but the grain is coarser and the individual beds are generally thicker. Basically, the arenites consist of medium, subangular, fractured quartz grains, but the matrix, which may be siliceous, ferruginous, or composed of detrital feldspar, epidote, and other accessories, determines the appearance of the rock. In hand-specimen, the rock may be respectively a quartzitic sandstone, a ferruginous sandstone, or a silty sandstone. The silty sandstone becomes a greywacke by a decrease in the amount of quartz present; the few siltstone beds represent the lutitic matrix only.

PLATE 2

GEOLOGICAL MAP

HATCHES CREEK WOLFRAM FIELD

NORTHERN TERRITORY

Scale

1/4 1/8 0 1/4 1/2 3/4 Mile

1:15840

4 Inches to 1 Mile

REFERENCE

CAINOZOIC

Cza — Pluvial deposits, some travertine, conglomerate

PROTEROZOIC

"Divisions lithological only"

Hatches Creek Group

Ehq — Mainly quartzite, some sandstone, conglomerate

Ehv — Acid and intermediate lavas

Ehs — Mainly sandstone, greywacke, some siltstone, quartzite

Pedlar Gabbro

pgb — Gabbro, dolerite, gabbro pegmatite (strongly altered)

pgy — Granophyre, some hybrid rocks

Geological boundaries

- Established boundary, position accurate
- Established boundary, position approximate
- Boundary of outcrop

Bedding

- 50/ Inclined dip
- Dip of strata — photo interpretation
- Top of bed as indicated by current bedding

Joints

- Joint pattern

Faults

- Established fault, position accurate
- Established fault, position approximate
- Inferred fault
- Concealed fault
- Transcurrent fault showing relative horizontal movement

Folds

- Established synclinal trough (showing direction of plunge)
- Established anticlinal crest
- Inferred anticlinal crest

- Ore-bearing lodes
- Road
- Mine
- Building
- W Well
- B Bore
- B Bore with windpump
- Waterhole

True North approx. 4°30' Magnetic North

Bureau of Mineral Resources, Geology and Geophysics, Canberra. Aug 61

To Accompany Bulletin No 6.

F53/3/7

Area shown on plate 3

Area shown on plate 4

Section A—B

HORIZONTAL SCALE 1 inch to 1200 feet

VERTICAL SCALE 2:1 Exaggeration

A — MIA MIA FAULT ZONE — Hatches Creek Airstrip — "Pioneer" Group — POSEIDON HILLS — WOLFRAM HILL — HANLONS GULLY — TREASURE GULLY — DOOLEYS RIDGE — HIT OR MISS GULLY — B

PLATE 3

GEOLOGICAL MAP
NORTH END
HATCHES CREEK WOLFRAM FIELD
NORTHERN TERRITORY

Reference

CAINOZOIC

Cza — *Alluvium, scree, talus.*

PROTEROZOIC

Phs — Hatches Creek Group
Sandstone, greywacke, siltstone, some quartzite.

Pgb — Pedlar Gabbro
Gabbro, amphibolite, diorite.

Geological boundaries.
- *Established boundary - position accurate.*
- *Established boundary - position approximate.*

Bedding
- *Strike and dip of strata.*
- *Top of bed as indicated by cross-bedding.*

Folds
- *Anticlinal axis showing plunge.*
- *Synclinal axis showing plunge.*

Faults
- *Established fault - position accurate.*
- *Established fault - position approximate.*
- *Inferred fault.*
- *Concealed fault.*

- *Position of main tungsten bearing lodes.*
- *Main shaft.*
- *Track*
- *Watercourse*
- *Building*
- *Approximate limit of group described in text.*

Scale
500 0 500 1000 Feet

N

P O S E I D O N H I L L S

W O L F R A M

H A T C H E S C R E E K

Plate 5
Pioneer Group
Plate 12
Endurance Group
Ricketty Kate Group
"Ricketty Kate"
WINDY POINT △
Black Diamond Group
Plate 13
Bonanza Group
"Bonanza"
"Ajax"
"Reserve"
"Horrible Annie"
"Little Wonder"
"Bumboat"
Plate 16
Green Diamond Group
School
To Kurundi
to Alice Springs

Phs
Cza
Pgb

Bureau of Mineral Resources,
Geology and Geophysics, Canberra, Aug 1961.

To Accompany Bulletin No. 6.

F53/3/8

GEOLOGICAL MAP
SOUTH END
HATCHES CREEK WOLFRAM FIELD
NORTHERN TERRITORY

Scale
500 0 500 1000 FEET

N

CAINOZOIC
Cza — Alluvium, scree, talus

PROTEROZOIC
Hatches Creek Group
Ehq — Mainly quartzite, some sandstone, conglomerate, greywacke
Ehv — Acid and intermediate volcanic rocks
Ehs — Sandstone, greywacke, siltstone, some quartzite
Divisions undifferentiated only

Dip and strike of strata
Inclined dip
Dip of strata inferred from air photos

Tungsten bearing lodes
B.X.B.Group — Limit of main groups of tungsten bearing lodes
"Euro" — Leases not shown on other plans
Shaft
Building
Track

Geological boundaries
Established boundary, position accurate
Established boundary, position approximate

Faults
Established fault, position accurate
Established fault, position approximate
Inferred fault
Concealed fault
Transcurrent fault showing relative horizontal movement

BASED ON PHOTOMOSAIC BY A.G.G.S.N.A.

TREASURE GULLY
NEXT TREASURE GROUP
"Next Treasure"
TREASURE GROUP
Store
Plate 18
RIDGE
DOOLEYS
Goat Hole
Hatches Creek
Police Stn.
Plate 26
MASTERS
BULLY GROUP
Plate 27
HEN AND CHICKENS GROUP
Plate 24
"Euro"
Plate 38
Hitler's
Downfall
OR
MISS
GROUP
HIT
Plate 33
Plate 32
"Reward"
GULLY
B.X.B. GROUP
"Rocky Ridge"
Plate 23
"Good Luck"
KANGAROO HIT
GROUP
OR
"St John"
"Prodigal"
Copper Show

Bureau of Mineral Resources, Geology and Geophysics, Aug 1961

To Accompany Bulletin No 6.

F53/3/9 V.F.CHAMAGNE

On the northern side of Wolfram Hill the beds maintain a roughly uniform dip along the strike of 50-55° to the south-east; but on the southern side of the hill, particularly between Windy Point and the Green Diamond Mine (Pl. 3), the strata are faulted and tightly folded. Intense jointing has obscured most of the bedding in this vicinity and the commonest rock is an even-grained quartz sandstone. Although ripple marks indicate the bedding in a few places, these occurrences are not common enough to enable the structure, which appears to be most complex, to be properly determined. More detailed mapping will be necessary.

A low soil-covered plain, underlain by the Pedlar Gabbro, separates Wolfram Hill from the ridges to the south. The gabbro contains numerous blocks of partly digested sedimentary rocks, nearly all of which strike conformably with the regional trend. These blocks are more resistant to erosion: consequently, where the underlying rock does project above the soil cover, xenolithic material is usually present. The remnants which can be identified generally prove to have been quartzite or sandstone; fragments of softer rocks have been more completely assimilated, are concealed beneath the alluvium, or were originally absent.

The sequence is relatively undisturbed south of the Pedlar Gabbro and consists of quartz sandstone and quartzite, alternating with extrusive volcanic rocks and softer sediments. This has given rise to a linear topography of a series of five ridges and four gullies trending roughly east. The most northerly ridge is low and irregular, and is composed partly of metasomatized sandstone, and partly of granophyre. The granophyre has segregated from the Pedlar Gabbro and crops out along the southern margin of the main body of gabbro (Pl. 2).

The second ridge to the south is also composed predominantly of sandstone, in which metasomatism is still apparent. The sandstone is poorly bedded and massive, with ripple marks and cross bedding. It is a ferruginous quartz sandstone similar to those on Wolfram Hill. Quartzitic sandstone and silty sandstone beds are present but are less common than on Wolfram Hill.

The most northerly gully, Hanlons Gully (Pl. 2), is underlain by sandstone, greywacke, and siltstone which have been intruded by a thin sill of granophyre. Faulting in the area has displaced the sill and the sedimentary rocks.

The next gully to the south, Warnes Gully, is also underlain by sedimentary rocks, which have been intruded by dolerite. About 500 feet of sandstone, greywacke, and siltstone separate the sill from the third ridge to the south, which is composed of quartzite. Outcrops in the gully are rare; greywacke appears to be the commonest rock. A very iron-rich siltstone crops out in this gully, and Dallwitz (Appendix 1) considers that the iron may have been derived from sulphides.

The third and fourth ridges to the south are composed of a tough light-grey quartzite in which cross-bedding is common and indicates that the beds are the right way up. The quartzite consists of interlocking quartz grains 0.1 mm.

to 2.0 mm. in size, and contains a little hematite. It also contains beds of quartz sandstone and small lenses of conglomerate. The conglomerate is made up of pebbles of jasper and light grey and black quartzite in a coarse sandy matrix; the lenses of conglomerate are rarely more than 15 feet long and 5 feet wide. Irregular masses of quartz, a few feet long, are present in the arenites, and there are many silicified breccias along fault zones.

The quartzite dips south at 45-75°, mostly 55-60°. The quartzite of the third ridge passes abruptly into volcanic rocks of the Treasure Gully. The composition of the volcanic rocks ranges from andesite to acid porphyry; a few lenses of hard quartzite are intercalated with the lavas. In strong contrast to the Treasure Gully, the volcanic sequence in the Hit or Miss Gully contains a high proportion of sedimentary material and the volcanic rocks are all acid porphyries, so far as is known. Granophyre intrudes the volcanic rocks in the Treasure Gully at the western end, and also east of Hatches Creek (Pl. 2), but has not been found in the Hit or Miss Gully.

The volcanic rocks of the two gullies are separated by about 1,500 feet of sediments. Most of this is quartzite, but there is a basal bed, about 12 feet thick, of greywacke, and in the upper part of the succession the quartzite gives way to quartz sandstone. About 600 feet of interbedded lavas and arenaceous rocks overlie the quartz sandstone, and are in turn overlain by the main volcanic phase. Sedimentary rocks consisting of lenses of iron-rich quartzite and sandstone, and beds of siltstone, greywacke, and sandstone are still present in the volcanics. The lenses of iron-rich sediments resemble gossans from a distance, and at least part of the iron may be derived from iron-rich sulphides in the sedimentary rocks themselves, or in the surrounding porphyry.

The Hit or Miss Gully narrows markedly to the west: just east of Mia Mia Creek the volcanic phase is only about 1,500 feet thick, whereas to the east, near the Hit or Miss Group, the volcanic phase is almost twice as thick. In general, the lavas lens out to the west and the sediments lens out to the east along the south side of Dooleys Ridge (Pl. 2).

Porphyry is the commonest volcanic rock. It contains quartz phenocrysts, and in some specimens feldspar phenocrysts, in a groundmass of quartz grains together with sericite, hematite, magnetite, chlorite, biotite, phlogopite, sphene, and leucoxene. The absence of feldspar phenocrysts in some specimens may be due either to differences in the various lavas, or to irregularities within individual flows.

Many of the porphyries are amygdaloidal. The amygdales, which may be up to half an inch across, contain quartz. Secondary quartz has been identified in the rock in thin section. The porphyries have been converted to hornfels in places, and have been silicified and seriticized. Some secondary silicification has taken place, but the relative contributions of weathering and metamorphism to silicification and sericitization have not been determined.

In the Davenport Range area, the Hatches Creek Group is intruded by basic rocks, by granite, and by feldspar porphyry. The basic intrusives, in the

vicinity of the mining field, will be considered in a later section of this report; brief mention of feldspar porphyry and granite is pertinent here.

One body of feldspar porphyry lies in the core of a large dome about three miles south of the mining field (Smith et al., 1960). This porphyry is intruded by granite which is believed to be the source of the Hatches Creek tungsten deposits. The granite has only a small, low area of outcrop; in general it is of similar type to all of the granites in the Davenport Range area which are 'two-mica microcline granites' (Smith et. al.).

The age of the granite from the Hatches Creek area has been determined by Hurley, Fisher, Pinson, & Fairbairn (1961) as 1480 million years. This determination, based on K/A ratio, was made from one sample collected by the Bureau of Mineral Resources during a programme of sampling many granite bodies in Central Australia. Samples were also taken from five other granites which intrude the Hatches Creek Group, and the average age of the six granites was found to be 1440 million years. This establishes the age of the Hatches Creek Group as Lower Proterozoic (in the time-scale currently in use by the Bureau of Mineral Resources).

Pedlar Gabbro

The Pedlar Gabbro, named from Pedlars Creek (Pl. 2) is an intrusive complex which underlies most of the northern part of the field. The intrusive consists of a gabbro with late-stage acid differentiates. The original composition has been modified by assimilation of material from the Hatches Creek Group, and by auto-metamorphism.

The common rock type is a coarse saussuritized and uralitized gabbro consisting of actinolite, remnants of plagioclase, and interstitial quartz, with accessory iron oxide and apatite. Andesine has been identified in the remnants of plagioclase, but Dallwitz (Appendix 1) considers that it may not be representative of the original plagioclase. Patches, veinlets, and blebs of gabbro pegmatite, and more acid differentiates, are present throughout the gabbro. They are composed of saussuritized acid plagioclase and quartz, with accessory penninite, epidote, sphene, and iron oxides. Descriptions of these rocks are given in Appendix 1. Some samples seem to be dioritic, perhaps because of contamination of the gabbro by the Hatches Creek Group sediments. Xenolithic material is abundant throughout the intrusive, and some of the xenoliths have assumed an igneous texture (Spec. 26b, Appendix 1).

The outcrop of gabbro is oval in plan; the long axis extends about nine miles north-east, and the short axis about four and a half miles north-west. It ends abruptly against a large fault to the north and north-west (Smith et al., 1960). Granophyre crops out along the southern and south-eastern margin of the intrusion, and a granophyre sill intrudes the Hatches Creek Group in Hanlons Gully. A dolerite sill intrudes the Hatches Creek Group in Warnes Gully and granophyre crops out in two places in the Treasure Gully (Pl. 2).

The contact between the main bodies of granophyre and gabbro is almost entirely obscured. The contact zone is visible on the east bank of Pedlars

Creek. No definite contact was seen; the gabbro appears to grade into the granophyre, but the outcrop is discontinuous, and the presence of xenolithic material and other differentiates confuses the picture.

The granophyre is a potash-soda granophyre, or granophyric adamellite: descriptions are given in Appendix 1. It is composed of quartz, orthoclase, plagioclase, and biotite, with accessory chlorite, epidote, and iron oxides. Granophyric texture is poorly developed in some specimens. The granophyre which crops out at the western end of the Treasure Gully contains pyrite, iron oxide, and pyrrhotite, in a pocket of epidote (Spec. 35, Appendix 1). Secondary copper minerals are associated with segregations of quartz and epidote in Warnes Gully, south of Wolfram Hill, and in other places.

Veins, pockets, and stringers of epidote are abundant throughout the intrusive, and epidote in the metasomatized sandstone is thought to have come from the intrusive. The unusual abundance of epidote suggests an affinity with a dolerite which intrudes the Hatches Creek Group elsewhere in the Davenport Range, and which is also rich in epidote (Smith et al., 1960). However, Smith et al. state that 'The behaviour of the dolerite as a stratigraphic marker, and its continuity, suggest that it is intercalated with the sediments . . . rather than it intrudes them'; and: 'An alternative explanation of the origin of the dolerite is that it was intruded as a multiple sill. In this case the dolerite must have intruded either before consolidation of the Hatches Creek Group, or at an early stage of the period when the group was folded.'

The latter theory is consistent with that held by the present author for the time of intrusion of the Pedlar Gabbro. There is considerable evidence to suggest that the Pedlar Gabbro was intruded during the folding of the Hatches Creek Group.

Faulting and folding at Hatches Creek were contemporaneous, and field evidence suggests that intrusion took place at the same time as the faulting. Further, the folding is thought to have assisted, if it was not directly responsible for, the segregation of the granophyre. The composition of the granophyre, the abundance of epidote and late stage differentiates, and the field relationships, all suggest that the granophyre differentiated from the gabbro; whether before or after intrusion is not clear. A more detailed petrographic study will be needed to determine whether there has been differentiation within the gabbro. It is not apparent in the field, but may be obscured by the abundant xenolithic material.

Blocks of sedimentary rock ranging in length from a few feet to more than a mile are present in the gabbro, and with one known exception they lie parallel to the regional dip and strike of the country rock. The continuity of these blocks, and their abundance throughout the outcrop of the Pedlar Gabbro, suggest that the upper margin of the gabbro was not very far above the present level of erosion. Hossfeld (1941) has suggested that the larger blocks represent roof pendants. The continuity of the blocks also suggests that movement was slight during the consolidation of the gabbro.

Other Intrusives

A body of feldspar porphyry lies in the core of a large dome about three miles south of the mining field (Smith et al., 1960). It is one of several such occurrences in the Davenport Range. The porphyry is intruded by granite, which is believed to be the source of the tungsten deposits. The wolfram deposits at Wauchope are associated with a granite lying in the core of an anticline formed in the Hatches Creek Group (Sullivan, 1952).

Smith et al. (1960) state that 'all the granites (in the Davenport Range area) are two-mica microcline granites,' and also '. . . the granites show evidence of stress after consolidation'. In this the granites are similar to those at Tennant Creek (Smith et al., 1960; Ivanac, 1954).

Again following Smith et al.: 'Unless it is postulated that there were two metallogenic epochs, each of which produced the same minerals (of tungsten, copper, bismuth, also gold), then the granite of the Mosquito Creek area (and by inference, of Tennant Creek) may be regarded as equivalent in age to the granites which intrude the Hatches Creek Group.'

Current investigations by the Bureau of Mineral Resources into the age of granites in Central Australia may give some indication as to whether the deposits of copper, tin, wolfram, silver, lead, and gold which occur intermittently in association with granite from Mount Singleton in the west, through Barrow Creek and Aileron, to the Jervois Range in the east, can be related to the same period of mineralization as the mineral deposits of the Davenport Range and Tennant Creek.

Cainozoic

Small outcrops of thin impure travertine, containing much silty material, are scattered along the banks of Hatches Creek and Mia Mia Creek. A coarse, loosely consolidated conglomerate is visible in the upper parts of these creeks. The conglomerate consists of locally derived rounded pebbles, up to four inches across, set in a coarse gravelly base.

A few low talus-covered rises are scattered over the soil plain which overlies the Pedlar Gabbro. The talus consists of water-worn boulders of quartzite and sandstone, many of which show no signs of metasomatism, suggesting that they were not derived from their immediate environment. One of the rises has been dissected by Hatches Creek, just north of Bean Tree Hole (Pl. 2). The rise is formed of igneous rock, and no sedimentary rocks were seen *in situ*. Igneous rock also crops out on the sides of some of the other rises.

Metamorphism

Regional metamorphism of the rocks in the area has been very low grade, and has been obscured by thermal and metasomatic alteration near the Pedlar Gabbro. Many of the shear-zones in which the tungsten deposits have been emplaced contain schistose rocks.

The sedimentary rocks in and near the Pedlar Gabbro have been severely metasomatized, and many of the xenoliths have been reconstituted with an igneous texture. The altered rocks contain sericite, chlorite, epidote, sphene, apatite, and rare leucoxene. Dallwitz (Appendix 1) considers that feldspar and biotite have been formed by metasomatic processes and later altered to sericite and chlorite by the same processes. Scattered clots of sericite in the quartzite from the third ridge south of the Pedlar Gabbro are also attributed to metasomatism.

The volcanic and sedimentary rocks in the gullies south of the Pedlar Gabbro have been sericitized and silicified, and in places have assumed a hornfelsic texture, which suggests thermal alteration of the rocks, either by the Pedlar Gabbro or by the granite to the south. The Pedlar Gabbro is nearer and was probably intruded at a higher temperature than the granite. The presence of granophyre in the Treasure Gully and Hanlons Gully, and of dolerite in Warnes Gully, suggests that this part of the field is underlain at depth by the Pedlar Gabbro. It is considered that most of the metamorphism of the rocks in the field can be attributed to the Pedlar Gabbro.

Folding

Only one period of folding is apparent in the Hatches Creek Group at Hatches Creek. The regional strike of the folding in the Davenport Range is west-north-west; but this is interrupted by several domes, some of which, like some of the larger anticlines, are cored by igneous intrusions. At Hatches Creek the Pedlar Gabbro lies at the core of an asymmetrical faulted dome. The tungsten-bearing lodes crop out in the intrusive and on the southern limb of this structure.

The dips of the bedding on the southern limb are between 40° and 70° to the south and average about 55°. Cross-bedding and ripple marks indicate that these beds have not been overturned. The dips of the bedding on the northern limb are mainly very steep to the north, but the strata have been disturbed by a large fault striking at about 060°, which lies close to the crest of the dome. Hatches Creek lies at the locus of a marked change in the trend of the regional folding. West of Hatches Creek the fold axes trend north-west; east of Hatches Creek they trend north-east (Smith et al., 1960).

Faulting

The study of faulting on the mining field has been confined mainly to areas where sedimentary rocks crop out; very detailed mapping will be required to determine fully the faulting of the igneous rocks. Thus the fault pattern on the north end of the mineral field is not clear.

The largest fault feature in the area is the Mia Mia Zone (Pl. 2), which has a total horizontal displacement of about 5,000 feet. This is a wide, complex zone of dislocation trending 020°. At the western end of Warnes Gully, where the margins have been accurately determined, the zone is 1,800 feet wide. The western margin of the zone is distinguished by a single large fault which has been traced from the west end of the Hit or Miss Gully to the northern limits

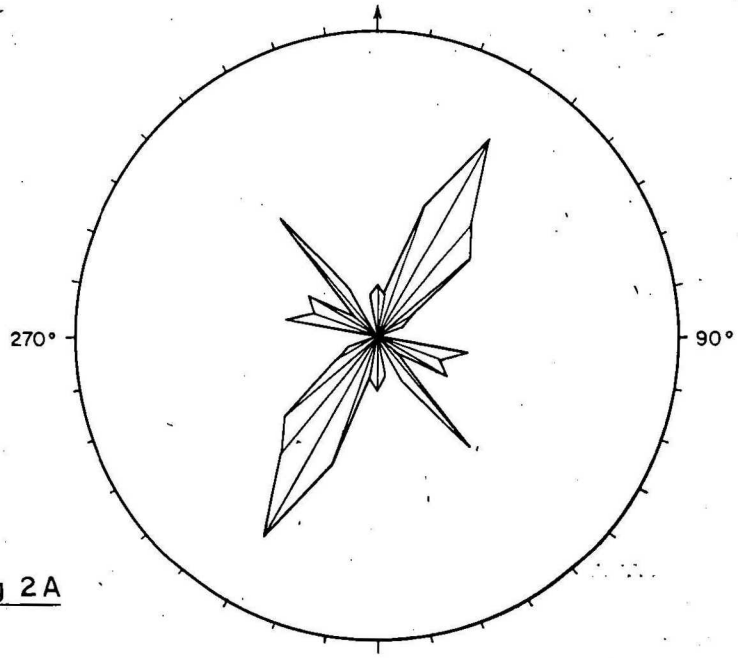

Fig 2A

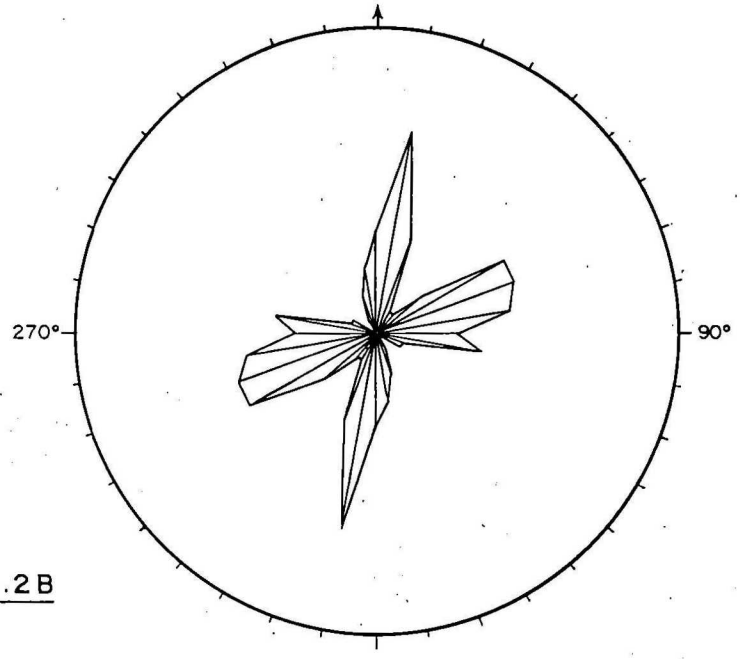

Fig. 2 B

HATCHES CREEK WOLFRAM FIELD

Strain rosettes for faults (A) and reefs (B)

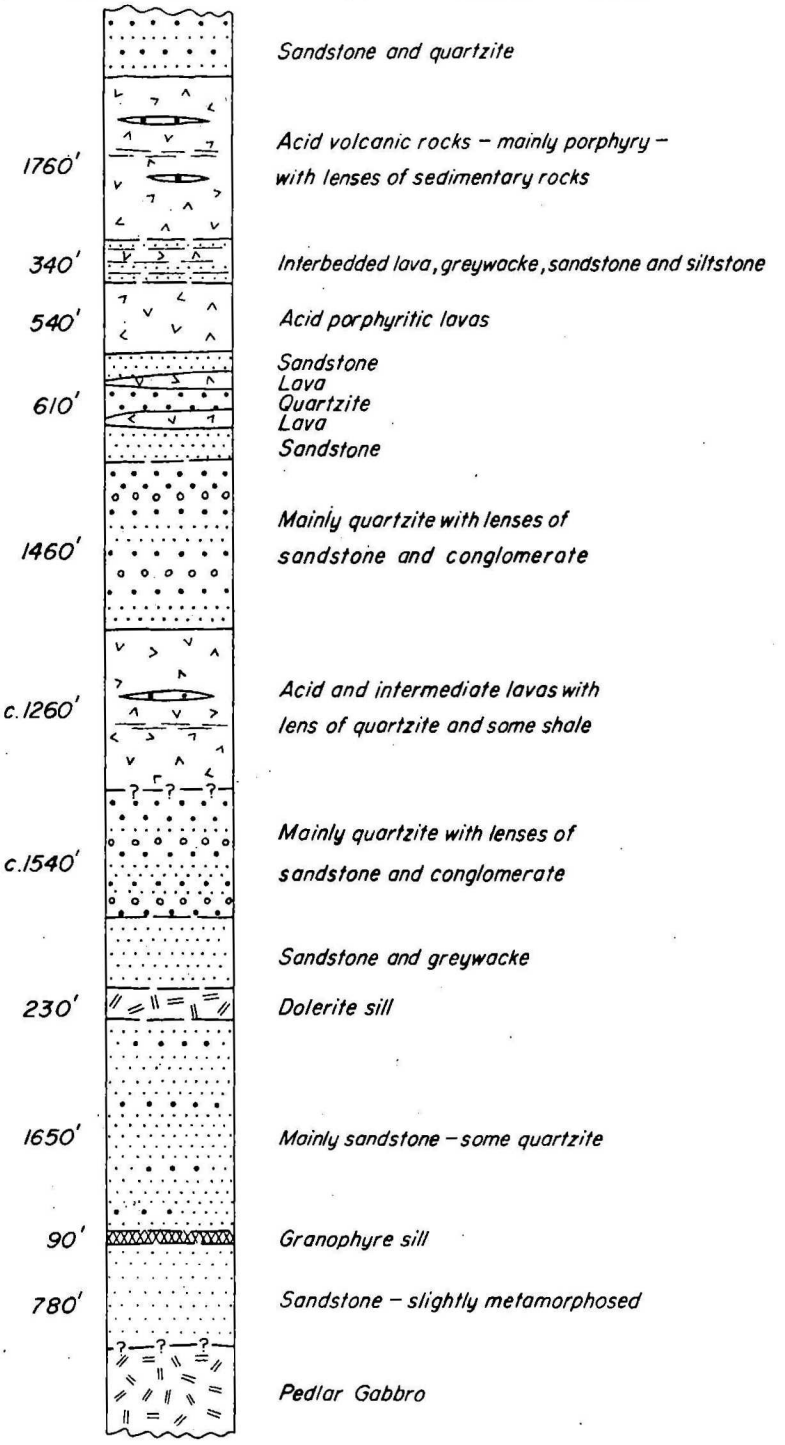

Figure 3. *Diagrammatic section of portion of Hatches Creek Group between the Pedlar Gabbro & Hit or Miss Gully*

of the mineral field (Pl. 2). In places this fault is marked by a wide zone of silicified quartz breccia. Its strike is 020° over most of its length, but changes to 040° north of the Hatches Creek airstrip. The breccia is unusually wide in this northern section of the fault, and forms an upstanding ridge about 100 feet high. The rocks on the south side of this ridge have been severely faulted. At the west end of Warnes Gully the fault zone has been displaced by a short fault striking at about 060°, which is apparently part of the fault zone but is slightly younger than the rest of the faulting.

A similar but more complex and less easily defined zone of faulting lies at the eastern end of the Hit or Miss Gully. This zone and the Mia Mia Fault Zone have been taken as the eastern and western limits of the mineral field: no tungsten deposits have been found outside them. Mia Mia Creek and Hatches Creek coincide roughly with the outcrop of the two zones of faulting.

Some of the smaller faults which lie between the major fault zones run parallel to the faults within the zones, and have many characteristics in common with them: (1) They are vertical or steeply dipping. (2) The strike of some of them varies considerably. (3) The apparent horizontal displacement varies considerably along the strike. (4) Some of them show a reversal in the direction of apparent downthrow. (5) Wide zones of breccia are common along the fault planes, and the larger faults are accompanied by extensive zones of shattering. These characteristics suggest that the faults may be wrench-faults. Brecciation is not restricted to wrench-faults, but its presence, combined with the other characteristics, is significant. Displacement along the two major fault zones was right-handed, but many of the smaller faults are left-handed, although they run parallel to the fault zones.

Wrench-faulting, which has obscured any evidence of earlier faulting, was probably associated with the same period of diastrophism that caused the folding of the Hatches Creek Group. The strike and displacement of the Mia Mia Fault Zone indicate that the direction of maximum stress was from north-east to south-west. This is consistent with the axis of folding in the Davenport Range west of Hatches Creek.

The strikes of the faults on the mineral field have been plotted on a strain rosette (Fig. 2A). By far the greatest number of faults strike between 020° and 050°, with the commonest direction of strike at 030°. A few faults strike at 360°. No direct relationship could be found between the directions of strike of these faults and the direction of maximum stress indicated by the Mia Mia Fault Zone.

Only one strike fault has been identified, at the western end of Dooleys Ridge (Pl. 2), but there has been abundant small-scale displacement along the bedding planes on the south side of Dooleys Ridge, and many strike faults may remain unidentified. Displacement along the bedding planes can be seen where mineral-bearing reefs strike across the beddding, and was contemporaneous with the emplacement of the reefs.

The reefs occupy shears of small horizontal displacement, most of which strike between 060° and 080°, or between 360° and 020°: the strikes have been plotted

on a strain rosette (Fig. 2B). The shears are thought to have been formed during the main period of faulting at Hatches Creek, but the reefs were intruded later, accompanied by further minor dislocation, which was probably caused by the intrusion of the granite. Although later movement has taken place, no distinct post-ore faulting has been traced. On the Green Diamond Main Lode on Wolfram Hill the Lehmann Fault is later than the main period of mineralization, but there is some evidence for a later period of mineralization associated with the fault.

Three loci of more intense dislocation have been developed within the general pattern of faulting at the south end of the mineral field. The type of faulting is different at each. The first locus, at the west end of Dooleys Ridge, is extremely complex. At least one strike fault is present and a block of volcanic rock has been faulted into the quartzite of Dooleys Ridge (Pl. 2). This locus is well removed from any tungsten deposits, and no attempt was made to elucidate the structure. The second locus, at the head of Pedlars Creek, consists of two sets of faults striking at about 320° and 035°. The faults striking at 035° are dominant and are parallel to the large wrench-faults in the Hatches Creek area. The faults traverse sedimentary rocks and a sill of granophyre in the south, and pass into the main body of the Pedlar Gabbro to the north. The granophyre sill has been displaced by the faults, but they appear to die out in the Pedlar Gabbro. The faulting seems to have been contemporaneous with the intrusion of the igneous rocks. The third locus lies at the eastern end of the Hit or Miss Gully and possibly owes some of its complexity to the major zone of faulting immediately to the east (Pl. 2). The most important feature of the faulting in this area is the presence of a set of short faults with an undulating north-westerly strike. The faults lie along gullies for the most part, and their presence has been inferred from the displacement of the sedimentary beds which lie within the volcanic rocks in the area (Pl. 2). The undulating strike of these faults is typical of tension gashes. They are thought to have been developed to compensate for differential movement between the blocks of quartzite which flank the Hit or Miss Gully to north and south. The greatest concentration of tungsten-bearing reefs at Hatches Creek lies within this locus of faulting.

Geomorphology

The flat-topped hills at Hatches Creek represent an old, undulating plain of unknown age. Smith et al. (1960) have reported that Cambrian sediments, and some Precambrian conglomerate, overlie a relief conforming in general with that now in evidence in the Davenport Range, and erosion of the Hatches Creek Group was considerably advanced before Cambrian time.

The existence of a Miocene peneplain has been postulated at Tennant Creek (Ivanac, 1954), and south of the Davenport Range. Subsurface data from Murray Downs Station and Warrabri Native Settlement, which lie along the south side of the Davenport Range, indicate a considerable depth of limestone and partly consolidated alluvium which is thought to be Tertiary. A dissected Tertiary plain is known at Mount Swan, 150 miles south of Hatches Creek (N. O. Jones, pers. comm.).

The age of the peneplanation at Hatches Creek could thus be Tertiary or Precambrian. The dissection of the plain which is represented by the flat-topped hills may therefore have begun early in the Cambrian period or at some time in the Cainozoic. Post-Mesozoic epeirogenic movement took place at Tennant Creek and to the south of the Davenport Range and probably caused rejuvenation at Hatches Creek. The presence, on the low rises round Wolfram Hill, of what may have been a mere extensive plain of boulders, and, in the creeks, of dissected travertine, points to some slight uplift in comparatively recent times.

Geological History

Greywacke and sandstone represent the earliest sedimentation in the Hatches Creek area and indicate deposition of ill-sorted material on a subsiding floor. Steady subsidence gave way to alternating periods of subsidence and quiescence. The periods of quiescence gradually became longer and gave rise to relatively large thicknesses of well-sorted sandstone. Two periods of vulcanicity interrupted the sedimentation; the source of the vulcanicity was probably to the east of Hatches Creek. The composition of the volcanic rocks indicates a non-orogenic association.

The deformation that followed was accompanied by the intrusion of the Pedlar Gabbro, probably at an early stage. It caused segregation of late-stage fluids which formed the granophyre, and were responsible for considerable metasomatic alteration of the country rock. Shear zones, formed during the main phase of deformation, acted as hosts to the mineralizing fluids which accompanied the intrusion of the granite, probably towards the end of the diastrophism. The strike and displacement of the main faults indicate a direction of maximum stress from north-east to south-west. If the faults are wrench-faults, the axis of intermediate stress was vertical and the axis of minimum stress was from south-east to north-west. This supposes either a considerable vertical confining pressure or tension from south-east to north-west. The low grade of regional metamorphism suggests that the area was never subjected to a great load, and it therefore seems likely that there was tension from south-east to north-west.

A period of erosion was followed by marine inundation in the Middle Cambrian. A further prolonged period of erosion followed and was not interrupted, so far as is known, until the Tertiary. At least 100 feet of Tertiary gravels were deposited along the south side of the Davenport Range, but Tertiary sediments have not been proven within the range. Post-Mesozoic epeirogenic movement may have caused some rejuvenation at Hatches Creek. The only evidence for uplift during the Cainozoic is provided by the low rubble-covered rises, and by the eroded travertine on the banks of the Mia Mia Creek and Hatches Creek.

ECONOMIC GEOLOGY

Most of the tungsten ore produced at Hatches Creek has been won from quartz reefs. Eluvial wolfram has also been won from the gullies on Wolfram Hill and Dooleys Ridge. Tungsten is present mainly as the iron manganese tungstates, an isomorphous series ranging in composition from ferberite ($FeWO_4$) to huebnerite ($MnWO_4$). The end members are rare, the intermediate member

wolframite $(Fe,Mn)WO_4$, being the usual form. No attempt is made in this report to distinguish the varieties and they are referred to collectively as wolfram. Scheelite ($CaWO_4$) is present in some mines. Some copper ore and bismuth ore have also been produced. The ore deposits have been localized between the Mia Mia Fault Zone to the west and a less distinct zone of faulting to the east. Between these two zones an area of intense fracturing has developed, into which ore-bearing fluids have intruded. The deformation at Hatches Creek is more severe than in the rest of the Davenport Range, perhaps because at this point the direction of fold axes in the Hatches Creek Group changes from north-west to north-north-east.

The dominant directions of strikes of the faults and the lodes have been graphically plotted on a strain rosette (Fig. 2). The figure shows that the commonest strike of the faults is at 030°, whereas the lodes strike in two main directions: at 010° and between 060° and 080°. Any strike-faults present would also strike between 060° and 080°, as this is parallel to the strike of the sedimentary rocks; but strike-faults are hard to detect, especially in the volcanic rocks. The strike of the sedimentary rocks changes from east to west (Pl. 2), which accounts for the dispersal of the strikes of lodes lying parallel to the stratification. Most of the groups of lodes lie close to at least one large fault, but no relationship between the lodes and these faults was discerned.

The lodes are concentrated in groups and the lode pattern within the groups varies so much (Fig. 4) that no distinct lode pattern can be recognised. Each lode consists of a shear zone occupied by several quartz reefs, which may lie side by side or en echelon with their ends overlapping slightly. The strike of the lode has no effect on the content of wolfram, but at the south end of the field it appears to have had some effect on the type of accessory mineralization. Lodes with a northerly strike are absent at the north end of the field, but lodes with an easterly strike are ubiquitous.

All the important lodes have dips steeper than 40°. Lodes striking north dip either east or west, but few lodes striking east dip to the north: some are vertical and most of the rest dip south. The lodes are 250 feet to 550 feet long, but the groups in which they lie may extend for 2,000 feet. The Kangaroo Line, which is exceptional, dips north and is about a mile long (Pl. 4).

The average width of the reefs in the lodes is about 12 inches, but some are as much as 60 inches wide in places. Nowhere has the bottom of a lode been exposed: the deepest development at the time of the survey was a little over 200 feet. The diamond drill hole intersected the Pioneer No. 2 Lode at a vertical depth of 297 feet and proved a width of 12 inches for the reef. This is consistent with the average width of the reef so far exposed in the mine.

A considerable amount of eluvial wolfram has been won from the steep-sided gullies adjacent to the lodes. Some eluvial deposits are reported to have been profitably reworked within ten years of the original exploitation. Plans were discussed for the bulk treatment of eluvial deposits from Wolfram Hill at

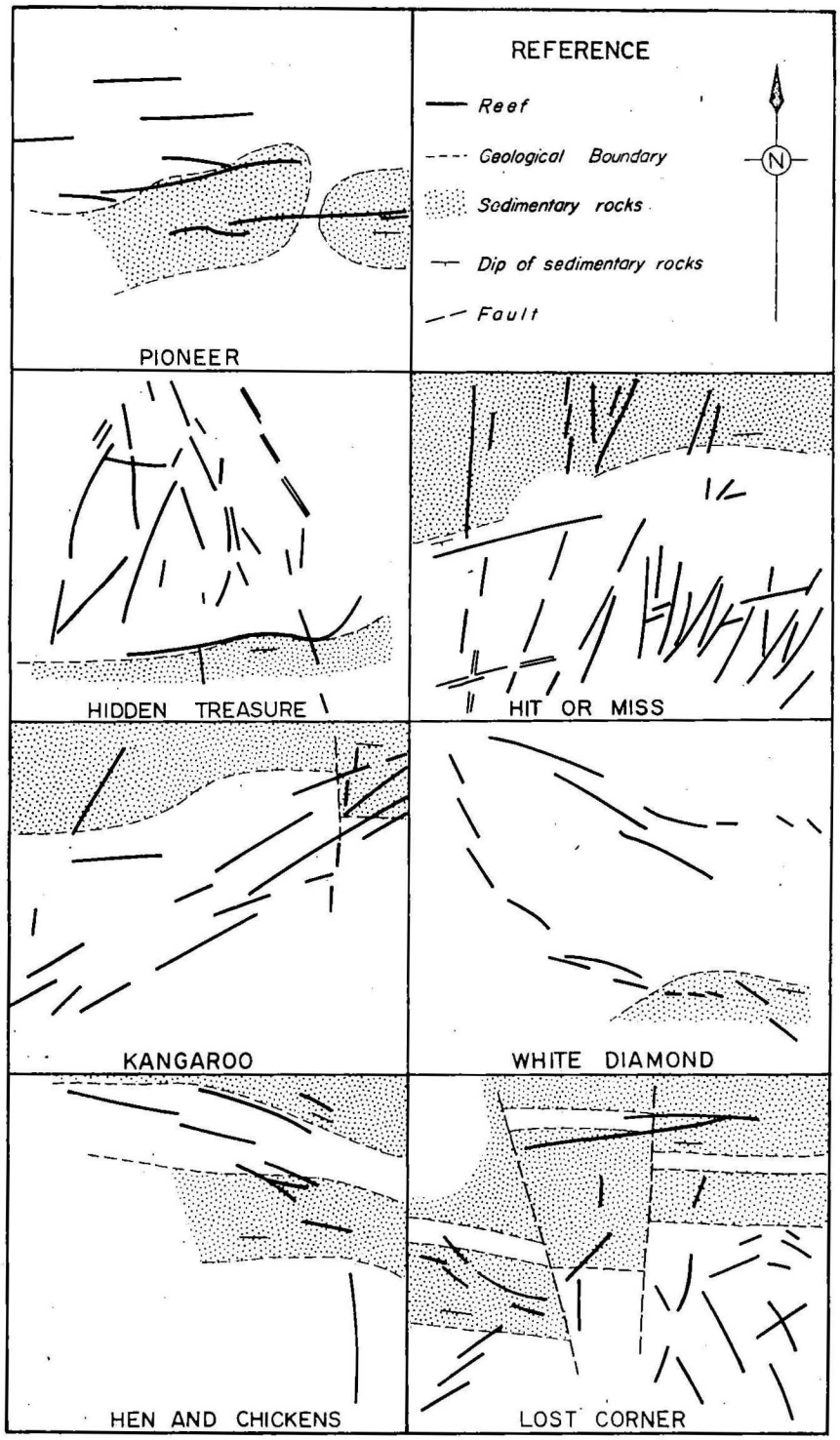

Fig. 4 REEF PATTERNS AT HATCHES CREEK
WOLFRAM FIELD

the Government Battery early in 1957, but the collapse of the wolfram market caused the operation to be shelved.

Mineralogy

Wolfram and scheelite are the predominant metallic minerals, but minerals of copper, bismuth, molybdenum, iron, lead, and tin are also present. They occur as accessories in the tungsten-bearing reefs, together with gangue minerals, of which quartz and mica are the commonest.

Tungsten Minerals

Wolfram is present either as metallic grey bladed crystals or as a darker massive form. Radiating clusters of crystals may be seen in the richer pockets of ore. Scheelite is virtually confined to those reefs which lie wholly or partly in igneous rocks and is common only where the Pedlar Gabbro is the host rock. The ratio of scheelite to wolfram decreases where the reefs pass into sedimentary rock (Sullivan, 1953). Scheelite constitutes some 60% of the ore at the higher levels in the Pioneer Mine (Sullivan, 1953). Other tungsten minerals include tungstic ochre (WO_3) and probably cupro-tungstite (Hossfeld, 1941).

Bismuth Minerals

Native bismuth, bismuthinite, and bismutite have been identified, and bismite is thought to be present. Bismuth is abundant in lodes in the Pioneer Locality, where attempts have been made to exploit it, but it occurs in only minor amounts in other localities. Light grey fibrous patches of bismuthinite are present in the Pioneer Group, where it is associated with native bismuth in small amounts, wolfram, scheelite, pyrite, and chalcopyrite; and up to four dwt of gold per ton of bismuthinite (Jensen, 1955). The yellow earthy carbonate, bismutite, is present in the oxidized zone.

Copper Minerals

Copper minerals are present in practically every ore-bearing lode in the mining field, and range from a trace to about half of the metallic minerals present. They are sufficiently abundant in the Hit or Miss Group and the Copper Show Group to warrant their separation as copper ore. Reefs carrying important amounts of copper lie in acid porphyries. The primary zone has only been reached at the Pioneer Mine and the Green Diamond Mine: chalcopyrite is present in both these mines. A large variety of copper minerals is present in the oxidized zone, some of them of striking beauty. The following minerals of copper have been recognised: chalcopyrite, chalcocite, covellite, bornite, tetrahedrite, atacamite, paratacamite, brochantite, malachite, azurite, chrysocolla, cuprite, and native copper.

Chalcocite is mined at the Silver Granites mine; malachite is the common ore mineral at the Copper Show Mine. Most of the minerals listed above are present in the Hit or Miss Group. Atacamite (Parkinson, 1955) paratacamite and brochantite (D. R. Walter, pers. comm.), and chrysocolla were first identified from this group. The copper minerals are intimately associated with wolfram, and are

the main impurities for which penalties in the payment for wolfram concentrates are imposed.

Other Minerals

Molybdenite is the commonest of the less important ore minerals which are not normally present in sufficient quantity to penalise the wolfram concentrates. Small amounts are present throughout the lodes on the field, but it is probably most abundant on the Hit or Miss Main Lode. Wulfenite ($PbMoS_2$) has been recognised at the Hit or Miss, and George & Murray (1907) have reported the presence of galena. Limonite is abundant everywhere, and pyrite has been exposed at the Pioneer Mine and the Green Diamond Mine.

A notable feature of the Hatches Creek mineral deposits is the paucity of cassiterite. Concentrates from the Pioneer Mine contain traces of tin (Jensen, 1955), and some cassiterite has been reported from a small reef in the Treasure Gully. The last parcel of concentrates from the Green Diamond Mine assayed 7% SnO_2.

Gold has been reported from several reefs north-east of the Pioneer Mine. The Pioneer concentrates carry three to five dwt of gold per ton, and the content increases with depth (Jensen, 1955).

Gangue Minerals

Quartz, mostly white and massive, makes up at least three-quarters of the mineral content of all reefs. Muscovite and biotite are relatively abundant in reefs lying in igneous rocks and have three distinct modes of occurrence: scattered throughout the reef, in places forming small hexagonal 'books' of mica up to 7 mm. across; as a selvage on one or both walls of the reef—the selvage sometimes attaining a width of two inches, but usually averaging about half an inch; and in small fissures leaving the reef at low angles, where mica may be associated with feldspar and quartz.

Feldspar is most common in reefs which lie in the Pedlar Gabbro. Kaolin, sericite, epidote, tourmaline, zircon, garnet, and fluorite have been identified, and are all more abundant where the host rock is igneous.

Zoning

The mica selvage is the only distinct mineralogical zone in the lodes at Hatches Creek, but the ore minerals show a tendency to segregate from the quartz in some reefs. At the Green Diamond Mine, wolfram lies towards the hangingwall and the footwall of the reefs, leaving a central zone of relatively barren quartz. In places the wolfram crystals are oriented with their long axes perpendicular to the walls of the reef. At the Silver Granites Mine wolfram and copper minerals lie in the centre of the reef, leaving marginal zones of barren quartz.

Types of Mineralization

Three types of mineralization, characterized by the constituent minerals, have been recognised.

Type 1, the **Wolfram-Scheelite Type,** is typified by the Pioneer Group, and is distinguished by the presence of abundant scheelite; it is confined to lodes lying within the Pedlar Gabbro, whether in the igneous rock or in the roof pendants composed of sedimentary rock. Bismuth is common, and minor amounts of copper, molybdenite, and gangue minerals are also present.

In type 2, the **Wolfram-Copper Type,** copper minerals are abundant but scheelite is rarely present. This type is confined to lodes lying in acid porphyritic volcanic rocks in the Hit or Miss Gully. Small amounts of bismuth and molybdenite are present. Minor gangue minerals are absent.

Type 3, **Wolfram** lodes, lie mainly in sedimentary rocks and in volcanic rocks, for example, in the Treasure Group, and are distinguished by the almost total lack of any minerals except wolfram, quartz, and mica. Molybdenite and traces of copper and bismuth are present.

The third type is the least distinct, especially where the lodes lie in volcanic rock. Lodes lying in acid porphyritic rocks do not necessarily carry enough copper to belong to Type 2, and some of the lodes on Wolfram Hill do not carry sufficiently large quantities of the distinguishing minerals to justify their classification as Type 1. The Green Diamond Main Lode is a marginal type as it carries as much copper as scheelite. It is assigned to Type 1 because of the presence of sericite and kaolin, and its location within the Pedlar Gabbro (Pl. 3).

Metallurgy

The complex ores of the wolfram-scheelite type and wolfram-copper type lodes have incurred heavy penalties in the past, and at times the wolfram-scheelite-bismuth concentrates from the Pioneer Group have proved difficult to sell. The method of separation of the impurities differs with the nature of the complexity and the percentage of accessory metallic minerals present. Gangue minerals are easily separated during gravity concentration of the ore.

Secondary copper and bismuth minerals are separated by hand and, although separation is not complete, this method is sufficient to reduce the content of impurities to a point where the concentrates incur little or no penalty. Small parcels of copper concentrates separated by hand from the Hit or Miss Group and the Copper Show Group have been sold.

Ore from the wolfram-scheelite type lodes is more difficult to separate. Pioneer Mines N.L., who operate the Pioneer Mine, have conducted considerable research into the treatment of ore from the lodes on the Pioneer Group. Ore from the primary zone is first treated magnetically to separate wolfram, then the bismuth sulphide is separated from scheelite by flotation. The bismuth carbonate is separated from the scheelite in ore from the secondary zone by leaching with acid. Hydrochloric acid was used in the separation of bismutite from concentrates from the Endurance Mine. Leaching was carried out in 44-gallon drums and proved satisfactory for the coarser concentrates, but was ineffective on the fines.

Origin and Age

The mineral-bearing fluids are believed to have come from an underlying extension of the granite which crops out about four miles south of the field, although there is no visible connexion between the outcropping granite and the lodes. The apparently lower-temperature assemblage of wolfram and copper is closer to the outcrop of the granite than the higher-temperature assemblage of wolfram, scheelite, and bismuth. Primary scheelite and bismuth and copper minerals are known at the Pioneer Mine and the Green Diamond Mine, and secondary copper sulphides are known in the Hit or Miss Group, where they are intimately associated with wolfram. The composition of the host rock appears to have determined the mineral assemblage of the lodes to a certain extent. Furthermore, on the south end of the field, lodes with an easterly strike are more heavily mineralized than lodes with a northerly strike, regardless of the host rock.

The mineral assemblage indicates moderate temperature and pressure. Cassiterite, tourmaline, and garnet are rare, and pyrrhotite, pyroxenes, and amphiboles are absent. Small amounts of pyrite, kaolin, and sericite are present, but the reefs are not typically vuggy.

Evidence of hydrothermal alteration has only been seen at the Green Diamond Mine, where the Main Lode has been sericitized and kaolinized.

The lode shears generally have a small horizontal displacement and have been offset by small faults, on which wolfram has been localized. Quartz stringers in the plane of the fault connect the reef on either side of the fault. This is particularly noticeable on the No. 1 Lode, Masters Gully Group, where the reef turns and follows the fault plane, and is continuous from one side of the fault to the other. One lode fissure displaces the other where two intersect, but the quartz in the two fissures is of one generation. On the Hit or Miss Group wolfram-copper-type reefs striking east intersect wolfram-type reefs striking north, and although the quartz and wolfram in the two types appear to be contemporaneous, the distinction in the accessory mineralization is clear-cut and absolute: the wolfram-type reefs are devoid of copper away from the intersection.

Mineragraphic investigation of the ore has been insufficient to determine the paragenesis, but examinations by W. M. B. Roberts (Appendix 2) suggest that the tungsten minerals may have preceded the bismuth and copper minerals. The distinction between wolfram-type reefs and wolfram-copper-type reefs on the Hit or Miss Group also suggests that copper was introduced after the initial stages of mineralization. The segregation of the metallic minerals from the quartz on the Green Diamond Lode, where there is strong evidence for a secondary phase of mineralization, supports this theory.

Tungsten may have remained in solution until the crystallization of quartz was advanced and the residual fluids became enriched in the metallic elements. Slight further activity may then have introduced fluids richer in copper and bismuth, so that the ore minerals were precipitated contemporaneously. Movement during

the latter stage of mineralization may have been such that ingress was restricted to lodes striking east.

The lodes have intruded Upper Proterozoic rocks and are presumed to be Precambrian, as the Cambrian is not known to be mineralized anywhere in Central Australia. The available evidence indicates that the tungsten deposits were emplaced at shallow depths and at relatively low temperature and pressure. Fracturing has been of the 'breccia' type rather than the 'shear' type (Butler, 1942). The lack of wall-rock alteration and paucity of volatile constituents, the fact that the mineral deposits were formed by injection rather than replacement, and the presence of numerous minor fissures associated with the lodes, all indicate that the fluids possessed considerable mobility and were not subject to great confining pressure.

The walls of the lodes have been slightly thermally metamorphosed, but the mineral assemblage indicates that the temperature of the intruding fluids was not high. It is considered that fluids of a moderate temperature intruded country rock which was not heated to any extent.

Ore Control

The control and location of tungsten deposits depend on two sets of factors: those favourable to the emplacement of the lodes, and those favourable to the deposition of tungsten minerals within the lodes.

Emplacement

Basic and intermediate igneous rocks, and some sandstones and greywackes, are the most favourable host rocks. They shear easily and cleanly and provide unimpeded passage to the intruding fluids. Rocks harder or softer than this are less favourable: the tough quartzites cause the reef to split into many narrow irregular veins, and the softer siltstones and shales do not form satisfactory lode walls as they tend to collapse into the lode channel. The volcanic rocks vary in their suitability. A soft, biotitic, lamprophyric rock on the Treasure Group is too soft, and has formed an unsatisfactory lode channel (Sullivan, 1951). Many of the lodes in the Hit or Miss Gully are emplaced in acid porphyritic volcanic rocks which appear to be satisfactory, but on the Hit or Miss Group these rocks are less favourable than a firm siltstone which is host to the richest part of the Main Lode and other lodes.

Deposition in the lodes

Deposition of minerals have been controlled by features of the lode fissures which caused a decrease in temperature and pressure, and has taken two forms: *shoots* and *pockets*.

Well defined shoots, carrying wolfram throughout, can be recognised on some of the larger and more important lodes. The wolfram is present as specks, crystals, and small lumps in the quartz; and the grade of the ore in the shoot is fairly consistent. This type of occurrence is known to the miners as 'spotted dog'.

The shoots lie in sections of the reef which have a different strike and dip from the adjacent poorer sections. Movement along the lode fissure opened these sections, thus effecting a decrease in pressure in the shoot. The fluids passed more slowly along these favourable sections and the loss of heat into the wall was more rapid. The consequent decrease in temperature and pressure over the length of the shoot caused precipitation of the wolfram. Figure 5 shows diagrammatically how the favourable sections of the lode were formed.

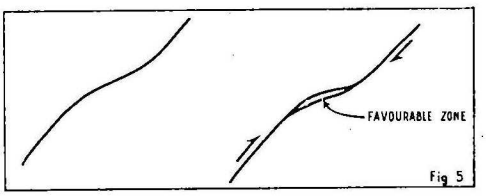

Fig 5

The dip and strike of the lode fissure depend on the 'angle of internal friction' (of the host rock), a specific property of the material which in itself may vary with normal stress (De Sitter, 1956, p. 27). The shoots on any lode are therefore restricted to the rock with a favourable angle of internal friction, and the plunge of the shoot can be predicted as long as the plunge of the intersection of the lode with the host rock can be predicted. The limits of the shoots are parallel where the favourable rock is stratified, but the shoots in the Pedlar Gabbro, which is a favourable rock on the Pioneer Group, are less predictable.

Few shoots have been positively identified, as considerable development of a lode is necessary before a shoot can be recognised, and other features which control wolfram deposition are usually present as well. Accessible openings are so rare in some mines that even where there has been a relatively large amount of development, little definite information can be obtained.

Pockets

Wolfram is more commonly localized on small features on the reef which have caused an immediate local decrease in pressure, and consequently in temperature. This has given rise to pockets of wolfram, which may yield anything from a hundredweight to over a ton of wolfram: the largest known pocket yielded two tons of wolfram uncontaminated by gangue minerals. Some of the features on which wolfram has been deposited are:

> faults intersecting the reef; 'horses' of country rock in the lode channels; splitting of the lode channel; intersection of two reefs; small fissures leaving the reef at low angles; constrictions in the lode channel.

Some of these features would seem more likely to cause an increase in pressure, but the release of pressure past the impediment is believed to have been the operative factor. The features listed above have not everywhere caused deposition of wolfram, but rich pockets are not known to occur except on one of them. It is also possible that residual mineral-rich fluids were concentrated on some of these features.

Enrichment is erratic, so that although the plunge of an intersection may be predicted, wolfram will not necessarily be found at a lower level. The features can sometimes be related to a particular rock: thus on the Green Diamond Main

Lode the host rock, a tough siliceous quartz sandstone, has caused the lode channel to split. Other features plunge parallel to the stratification of the country rock, and although the reason for this is not generally apparent, it is sufficiently common to provide a basis for locating a pocket when no other evidence is available.

Pockets are ubiquitous, and may be found within a shoot. They are more common on the thinner reefs and are mostly separated by barren or low-grade materials.

Grade of Ore

Accurate determination of grade of ore is difficult. The patchy nature of the ore necessitates very detailed and complete sampling, and this cannot be carried out unless the lodes are sampled at regular intervals over a considerable period.

Battery returns would normally be the most accurate source of information on grade in the absence of sampling data, but nearly all the ore at Hatches Creek is exhaustively hand-picked before treatment: crushing returns for the smaller mines have at times given an apparent grade of more than 10% WO_3 — a fabulous figure. The lack of accessible mine openings makes the estimation of total ore removed uncertain.

The total tonnage of ore mined can be estimated where the limits of development are known, and if the production of wolfram is known an approximate figure for the grade of the ore can be calculated. This has been done for the few mines where sufficient information is available. The percentage of wolfram won from a particular stope or level has been calculated wherever the miner has been able to supply the necessary information.

Some detailed sampling was carried out by Hossfeld (1941), and Sullivan (1943), at the Pioneer Mine and the Treasure Mine. The shoots in these mines have yielded 3% to 3.6% WO_3, but the overall grade of the lodes is about 2.5% WO_3. The grade on other lodes varies generally between 1.5% WO_3 and 3% WO_3. However, most of the reefs are so narrow that it is necessary to break up to 70% of country rock. Cut-and-fill stoping minimises the dilution of the ore, but some dilution is unavoidable, and the working grade of the narrower reefs is therefore less than the actual grade.

Calculation of ore reserves is difficult on all mines and impossible on some. The unstable price of wolfram militates against a long-term policy of development; wolfram is removed as it is found and consequently very little ore is available above the level of development, except in uncompleted stopes, which are completed in the shortest possible time. Even in the stopes the grade of ore is so uncertain, and the wolfram is so patchy, that reserves can only be inferred. Development on some of the larger lodes has reached a depth of about 200 feet to 250 feet, where the reefs maintain their width and grade. The only lode tested below this depth is the Pioneer No. 2 Lode, which has been proved at 297 feet by a diamond drill hole. The reef is 12 inches wide and carries 5% WO_3, which compares favourably with the proved width and grade at higher levels, but one intersection cannot be taken

as reliable. The persistence of the reefs below about 200 feet is therefore virtually unknown. In the absence of reliable data for the calculation of the grade, the limits of previous stopings have been taken as an indication of the extent of payable ore.

Mining and Marketing

Few mines at Hatches Creek are served by vertical shafts. Most of the mines are operated from an inclined shaft and on most lodes several of these shafts, now abandoned, have been sunk to various depths. Development on many of the lodes is now approaching a depth at which it will not be permissible under the Mining Ordinance to operate an inclined shaft or use the light equipment now in general use. Shafts are timbered only where heavy ground makes it necessary: usually only at the collar. Otherwise timbering is restricted to setts at irregular intervals for ladders, and air and water lines. Is is seldom necessary to ventilate the mines as there is abundant circulation through abandoned shafts and levels.

The mines are worked by cut-and-fill stoping from levels at intervals of 30 to 100 feet. A cut is first taken in the footwall and the reef is left on the hangingwall. The reef is later fired or barred down, often on to sacking or tin, and then passed by chutes to the level. The waste is left in the stopes, thus obviating the use of pillars or timbers. Pillars of barren quartz, supplemented by timber where necessary, are left where the reef is wide enough to be exploited without breaking waste rock.

The ore in the smaller mines is extensively handsorted, sometimes in the stope but more usually at the surface. A concentration of 75% is not unusual by this method. The ore is then treated at the Government battery. The Pioneer Mine possesses its own plant and ore is treated in bulk. In the earlier days on the mining field, before the establishment of a battery, the ore was burnt to render it brittle and was then knapped. This method is still employed by some prospectors.

Wolfram is marketed as a concentrate: standard concentrates carry 65% WO_3; below this the concentrate is penalized. Penalties are also imposed for impurities such as copper, bismuth, arsenic, etc. The permitted penalty-free content of these impurities may vary with the demand for tungsten. Details of the current penalties can be obtained from the buyers.

INDIVIDUAL MINES

The groups of tungsten-bearing lodes are congregated topographically into four distinct localities which provide natural divisions for description: the few exceptions have been included with the nearest locality where possible. The localities are, from north to south, the Pioneer Locality, Wolfram Hill Locality, Treasure Locality, and Hit or Miss Locality. The first two lie at the northern end of the mineral field and the second two at the southern end. In some groups the structural relationship between various shears in the group is not clear, and the lodes, as in the Masters Gully Group, have widely divergent strikes. In other groups, such as the Hit or Miss Group, the lodes have a distinct pattern.

The main groups, except on Wolfram Hill, are associated with blocks of sedimentary rock lying in igneous rocks, or with interbedded volcanic and sedimentary rocks. Furthermore, at least one large fault is present near most groups. The formation of the host shear-zones in each group is attributed to the different reactions of the various rock types to stresses which caused the faults. The shear-zones represent the resolution of these stresses.

Most of the production of wolfram from each group has come from one or two more important lodes, but in the past the less important lodes have also been exploited to a considerable extent, mainly during boom periods. Thus one group may contain one or two deeper mines and abundant shallow workings, and it is seldom possible to ascertain accurately the production from a given lode. The groups are generally covered by several leases, and production of concentrates has been recorded only from the various leases.

The known production from the more important leases is listed in Table 4, together with production from Crown Lands, unknown leases, and from the Walsh group of leases. Mr J. Walsh held five leases at Hatches Creek and two at Wauchope between 1936 and 1943, during which time all production from the leases was recorded in bulk in Walsh's name, and not in the name of the lease. Walsh's leases produced about 200 tons of concentrates, of which it is estimated that about 150 tons were won from the leases at Hatches Creek. About 85 tons of wolfram have also been won from unregistered land, i.e. Crown Land, and a further 120 tons have been listed in the name of the producer and not the lease. As many miners drifted from lease to lease, and sometimes held more than one lease, the source of this wolfram cannot be determined.

A great number of narrow quartz reefs, as distinct from the larger lodes, lying both within and outside the groups, have yielded small pockets of rich ore. The total production from these minor reefs between 1937 and 1940, and between 1951 and 1953, was considerable, but has gone unrecorded except in the total production from the mineral field. Many of the groups have also yielded considerable tonnages of eluvial wolfram, none of which has been differentiated from wolfram won from the lodes. The production of wolfram from the various groups has not been recorded for the years prior to 1940, and even up to 1948 the recording of production was unreliable. Thus the total tonnage of wolfram produced from the groups is usually greater than the recorded production.

Many of the older workings are now inaccessible, as they were abandoned during periods of depression, and the miners who developed them have moved on. Consequently, information on the extent of development, the width and grade of the reefs, and other details is often unreliable or unobtainable. Much of the information on the older parts of the mines, and particularly on the smaller lodes, has been drawn from Hossfeld (1941).

Four large lodes have contributed about a quarter of the total production of wolfram concentrates. These are the Pioneer No. 1 Lode, the Pioneer No. 2

Lode, the Treasure Main Lode, and the Hit or Miss Main Lode. Lodes of slightly less importance are the Black Diamond Main Lode, the Green Diamond Main Lode, the Hidden Treasure No. 1 Lode, the Hidden Treasure No. 2 Lode, and the Hen and Chickens No. 1 Lode.

Some small groups of gold and tungsten deposits have been described separately. The Copper Show Group and Dooleys Nob Group lie towards the western end of the Hit or Miss Gully, and have been included as the Copper Show Locality. The Crystal Gold Mine is a small group of quartz reefs which contain a little gold. It lies east of Hatches Creek and north-east of the Pioneer Group, and has been described separately, as also have other quartz reefs in the same area, which carry no wolfram, but are reputed to carry gold.

North End

The tungsten-bearing lodes at the northern end of the Mining Field lie partly in the Pedlar Gabbro and partly in the sedimentary blocks which lie within the gabbro. All the more important lodes have a strike and dip roughly parallel to that of the bedding in the sedimentary rocks. This is in strong contrast to the lodes at the south end of the field, where many of the more important lodes strike north. Tungsten deposits at the North End lie in the Pioneer Locality to the north, and the Wolfram Hill Locality to the south (Pl. 3).

Pioneer Locality

The Pioneer Locality includes two groups of lodes lying towards the south-west end of the Poseidon Hills, about four miles north-north-west of Goat Hole. The Pioneer Group lies on a low rise on the north side of the hills. The Endurance Group consists of a few small scattered lodes lying south-east of the Pioneer Group, on the south side of the Poseidon Hills.

Pioneer Group

(Pls 3, 5, 6, 7, 8, 9, 10, & 11)

The Pioneer Group does not contain as many lodes as the Hit or Miss Group or the Treasure Group at the southern end of the field, but has been more systematically and more deeply exploited than the other groups. More concentrates have been produced from this group than from any other group on the mineral field. Hossfeld (1941) has divided the group into the South-western Line, the Central Line, and the North-eastern Line. Each line is dominated by one major lode associated with one or more smaller lodes. A complex ore containing minerals of tungsten, copper, and bismuth is mined, and the presence of the accessory minerals has hindered the development of the group at times when mixed ores were difficult to sell.

TABLE 4

HATCHES CREEK WOLFRAM FIELD

RECORDED PRINCIPAL SOURCES OF WOLFRAM AND SCHEELITE CONCENTRATES TO JUNE 1958

Lease No.	Name	Concentrates Tons	Value (a) £
1F, 2F etc.	Pioneer; Poseidon, etc.	435.08	208,135
22F	Hit or Miss	223.57 (b)	157,349
31F, 30F	Treasure, Lost Ruby	198.81	117,687
35F	Hidden Treasure	125.43	49,256
124F	Masters Gully	93.50	84,257
100F	Black Diamond	85.64	63,974
20F	Bonanza	55.97	26,656
119F	Green Diamond	49.36	48,493
104F	Hen and Chickens	43.65	36,710
84F	White Diamond	34.06	16,374
91F	Lost Corner	30.88	15,647
25F	Hit or Miss Extended	29.59 (b)	26,657
254F	Lady Hamilton (c)	25.45 (b)	31,082
103F	Good Luck	19.94	4,779
223F	Silver Granites	18.64	15,557
85F	Reward	15.68	14,167
112F	B. X.B.	15.47	13,471
41F	Fortune	13.86 (b)	5,176
83F	Copper Show	12.32	6,953
74F	Bransons	9.78	14,811
77F	Next Treasure	9.57	9,972
10F	Ricketty Kate	9.02	2,000
76F	Gordons Hope	8.00	2,347
210F	Endurance	7.30	7,683
14F	Frenchman	5.57	2,530
Other Leases		14.12	16,607
Crown Lands (d)		89.61	53,514
Leases unknown (e)		120.00	31,700
Ex Walsh (b)		150.00	25,500

(a) Values given are unreliable as early records are inaccurate.

(b) Leases 22F, 23F, 24F, 25F, 41F owned by Mr. J. Walsh for different periods between 1936 and 1943. Production from all these leases, together with two at Wauchope, recorded in bulk during this time.

(c) Includes former leases Kangaroo (24F) and Hamilton (23F).

(d) Mainly from natives and from leases prior to their registration.

(e) Production before about 1943 recorded in name of miner. Origin of concentrates not known.

History

Little is known of the early history of the group. Hossfeld (1941) states that the group 'appears to have been worked from the early days of the field and from several leases'. The records of the Northern Territory Mines branch contain no mention of a Pioneer Lease between 1916 and 1922, but a Pioneer Lease appears on the map accompanying a report by T. G. Oliver (1916), and according to the topography shown on Oliver's map it was situated on Wolfram Hill, somewhere near Windy Point (Pl. 3).

Wolfram Industries Ltd acquired the Pioneer Lease and an adjacent lease in 1937. These were taken over in 1939 by Tantalite Ltd who also pegged two more leases, and this company held the leases until 1949, although the Commonwealth

Department of Supply and Shipping operated the Pioneer Mine from 1942 to 1944. In 1940 the leases were re-registered under a new Mining Ordinance with a slight readjustment of lease boundaries, and these boundaries have not been changed since. Between 1949 and 1952 the leases were held successively by Tungsten Industries Ltd, and Messrs McKenzie and Crespan, before they were acquired by Pioneer Scheelite N.L. The latter company was reconstituted in 1953 as Pioneer Mines N.L., which holds nine leases including the Pioneer Lease (2F). In 1954 Poseidon N.L. was formed, and acquired three leases, including the Poseidon lease (3F). Leases 2F and 3F include most of the Pioneer Group.

Production

The total recorded production of concentrates from the Pioneer Group from 1935 to 30th June 1958, was 435.08 tons worth £208,135, but records before 1942 are unreliable, and no information is available for the period 1916 to 1923. Hossfeld (1941) records that production 'has increased considerably to a steady output during the later half of 1940', and that this producton was being maintained in January 1941. It seems likely that the true total production from the Pioneer Group has been of the order of 500 to 550 tons of concentrates. Table 5 gives the recorded annual production from the group since 1935. In addition 5.58 tons of bismuth concentrate worth £4,400 have been won from the mine (Table 2).

Table 5 shows that production has been erratic; this can be attributed partly to the fluctuating price of tungstic oxide, and partly to the complexity of the ore. Recent operations have been concentrated in the primary zone because buyers prefer the bismuth sulphide to the carbonate. Between 1952 and 1956, 3,710 tons of ore were mined for 124.75 tons of concentrate assaying 66-67% WO_3.

Geology

The lodes strike at about 060° and dip south, and are arranged en echelon within the group over a distance of about 1,500 feet from south-west to north-east. Individual lodes are from 300 feet to 550 feet long. The No. 2 Lode (Pl. 5) marks the north-eastern limit of the group, but to the south-west the South-western Line disappears beneath alluvium and may continue farther in this direction. The reefs range in width from 3 inches to 36 inches, and average about 15 inches. Dips are to the south at 40-70°.

The lode-shears traverse both igneous and sedimentary rocks, with a noticeable change in the attitude, grade, and mineralization of the reefs when passing from one rock type to another. The sedimentary rocks are quartzite, sandstone, greywacke, and siltstone of the Hatches Creek Group. They lie in discrete blocks within the Pedlar Gabbro and their uniformity of strike and dip suggests that they are roof pendants rather than stoped blocks.

The sedimentary rocks have been converted to hornfels at the contact with the gabbro, and also to a lesser extent adjacent to some of the reefs. The Pedlar Gabbro commonly has a narrow chilled margin at the contact. The igneous rock has retained a relict ophitic texture, but is now an amphibolite. Lovering

(Appendix 1) considers that the original rock was a diorite, but the dioritic composition may be due to assimilation of sedimentary material.

The strike of the sedimentary rocks is roughly parallel to that of the lodes, namely about 060°. The bedding dips to the south at 55° to 65° and is generally steeper than the dip of the lodes.

Mineralogy

The proportions of wolfram and scheelite are about equal throughout the group, except that the ratio of scheelite to wolfram is higher where the host rock is igneous. These two minerals are accompanied by a suite of copper and bismuth minerals which are much more abundant at the eastern end of the group than farther west. Bismutite, chalcocite, azurite, malachite, and limonite have been identified from the oxidized zone, and below the water table native bismuth, bismuthinite, tetrahedrite, pyrite, and chalcopyrite are present. Small quantities of molybdenite are present throughout the mine. Copper and bismuth are considerably enriched in the supergene zone. No free gold is known, but gold is associated with bismuthinite and chalcopyrite to the extent of 4 ounces per ton of the former and 12 dwt per ton of the latter (Jensen, 1955). Traces of tin and lead are present, but no minerals of either metal have yet been identified.

TABLE 5

PIONEER GROUP, HATCHES CREEK

ANNUAL PRODUCTION OF WOLFRAM AND SCHEELITE CONCENTRATES

1935-1958

Year Ending 30th June	Concentrates Tons	Value £	
1935	4.0	?	
1936	—	—	
1937	6.35	598	
1938	—	—	
1939	3.49	1,020	(a)
1940	11.08	2,770	(a)
1941	76.81	12,890	(a)
1942	76.53	17,169	
1943	53.7	12,587	
1944	9.91	2,859	
1945	3.88	902	
1946	13.58	3,709	
1947	6.92	1,760	
1948	5.41	3,500	(a)
1949	4.85	1,598	
1950	3.28	925	
1951	0.29	95	
1952	10.41	16,828	
1953	50.98	60,928	
1954	0.8	686	
1955	6.35	6,004	
1956	46.37	32,850	
1957	38.09	26,883	
1958	6.0	1,574	
Total	435.08	208,135	(b)

(a) Value calculated from mean price of wolfram for relevant year.

(b) Excludes value of concentrates sold in 1935.

Mica and feldspar, and less commonly epidote and tourmaline, are the gangue minerals present with quartz. Mica may form a selvage up to two inches wide on one or both walls of the reef, and may also be present as discrete hexagonal 'books' up to 7 mm. across or as flakes disseminated throughout the reef — the two forms appear to be antipathetic. Pink potash feldspar is associated with the mica, particularly where the reef traverses igneous rock. Small radiating clusters of both epidote and tourmaline accompany the other minerals.

The gangue minerals and, to some extent, the accessory ore minerals tend to be most common where the host rock is igneous, but the ore minerals are usually associated with wolfram and scheelite and are more abundant along richer sections of the reefs. The composition of the wall rock has had little effect on the grade of ore, which is generally determined by the attitude of the reef. The reef tends to become barren and irregular in width where it traverses hornfels or quartzite.

Both Roberts (Appendix 2) and Knight (1943) found that scheelite replaces wolfram to a certain extent, probably by hydrothermal rather than supergene processes. The tentative paragenesis given by Roberts indicates that scheelite was deposited before the metallic sulphides. There is no positive indication of zoning, but in places the ore minerals tend to lie toward the walls of the reefs.

Metallurgy

The complexity of the ore has presented considerable metallurgical difficulties, and concentrates have been heavily penalized in the past for impurities. The present owners have conducted considerable research into the problem, and have evolved a satisfactory method of treatment. The results of this work have been published by Jensen (1955). Unfortunately the collapse of the wolfram market forestalled the erection of a treatment plant, but some parcels of treated ore have been sold.

Different methods of treatment have proved necessary for ore from the oxidized and primary zones. The oxidized concentrate consists of wolfram, scheelite, and carbonates of bismuth and copper. Concentrate from the primary zone consists of wolfram, scheelite, bismuthinite, bismuth, chalcopyrite, gold, and pyrite. Tests proved that neither concentrate could be separated by screening.

In the oxidized ore, wolfram is first separated magnetically, and the residue containing scheelite and carbonates is leached with acid. Concentrate from the primary zone is also treated magnetically to give a high grade and a low grade wolfram product. Flotation of the residue gives bismuth 'firsts' and 'seconds', leaving a scheelite concentrate of high grade. Table 6 gives assays of the various products.

The owners had some success with this method and were able to sell all the products. Jensen (1955) says '. . . the ready sale for comparatively low grade bismuth concentrates was rather surprising and suggests that bismuth may become a valuable by-product in due course.' Although the mine must remain primarily a producer of tungsten ores, the presence of bismuth and gold may prove beneficial when wolfram prices are marginal.

Ore Control

The grade of ore is more consistent in the reefs in the Pioneer Group than in the reefs at the southern end of the field, but moderately well-defined shoots are present. These correspond to the flatter parts of reefs, where the dip is 45-55°, and the reef is wider. The plunge of the shoots is controlled by the intersection of the reefs with favourable rock types. The lode-shears cross the bedding at 5-15° both along the strike and down the dip. The poorer sections lie where the shears are more nearly parallel to the bedding planes, both in strike and dip. Movement along the lode-shears has been nearly vertical, with the hangingwall block moving upwards relative to the footwall block, and has created favourable openings on the flatter parts of the shears.

The most favourable hosts are the Pedlar Gabbro and some beds of sandstone. The softer sedimentary rock and the hornfels are less favourable. Where the host is a bed of sedimentary rock the shoots have parallel sides and plunge south-west at 45-50°, but where the lode intersects the Pedlar Gabbro the limits of the shoot are irregular. Sullivan (1943) found that it was difficult to differentiate between favourable and unfavourable sedimentary host rocks from their appearance in hand-specimen. The lodes lie increasingly in igneous rock at successively lower levels, and the sedimentary rock at these levels has been affected to a greater degree by thermal metamorphism. Hence the favourable igneous host can be more easily distinguished from the unfavourable hornfels.

The concentration of wolfram on faults, splits, and other features on the reef is much less marked than on lodes at the southern end of the field.

South-western Line

The South-western Line represents the known western limit of the Pioneer Group. It consists of three lodes, of which only the Jensen Lode has been developed underground to any extent, and a few unimportant reefs.

Jensen Lode (Pl. 11). Shallow pits and a few shallow inclined shafts have been put down on this lode over a distance of 500 feet, but the lode does not crop out between them. Two levels have been driven on the lode from the vertical Boundary Shaft, so called because it lies on the boundary between the Pioneer Lease to the east and the Poseidon Lease to the west. As the two leases are owned by separate companies the development of the lode from this shaft has been complicated.

TABLE 6

PIONEER MINE, HATCHES CREEK
ASSAYS OF CONCENTRATES AFTER SEPARATION
(after Jensen, 1955)

	% WO_3	% Bi	% Cu	Au oz /ton
Magnetic A product	70.4	1.2	0.59	—
Magnetic B product	54.5	3.58	3.04	—
Bismuth 'firsts'	—	38.46	—	2.8 (a)
Bismuth 'seconds'	—	31.92	5.54	1.9 (a)
Scheelite	70.0	2.5	0.12	0.4

(a) The gold was paid for by the buyers.

The lode has been tested over a length of 330 feet at the 81-foot level; it consists of two parallel quartz reefs for a greater part of this length. A little stoping has been undertaken and rich ore was found to be present between 550W and 650W. In this section the lode consists of two reefs 6 to 12 inches wide, dipping south at 45°. These reefs die out to the west and at 705W are replaced by another reef which splits a little farther to the west, and is more steeply dipping and poorer than those to the east. The lode is exposed over 105 feet at the 127-foot level, where it is more irregular and consists of two reefs 6 to 12 inches wide, dipping south at 60-65°. The grade is lower than at the 81-foot level, but the lode has not been fully tested and richer ore may be present either east or west of the present limits of development.

Dempsey Lode (Pl. 11). This lode lies parallel to, and 30-40 feet north of, the Jensen Lode. It has been tested by shallow pits over a length of 240 feet at the surface, and by a drive 90 feet long from the Underlay Shaft at the 81-foot level. The lode consists of one reef dipping south at 45° and ranging in width from 3 inches to 12 inches. A small tonnage of ore has been won from the 81-foot level.

A cross-cut north from the 127-foot level in the Boundary Shaft has encountered a reef 12 inches wide dipping south at 45°, which is believed to be part of the Dempsey Lode. Some good-grade ore was showing in the backs, and this reef, because of its regularity in dip and width, appears to offer more favourable prospects for development than the Jensen Lode does at this level.

Xmas Lode (Pl. 5). Very little is known of this lode, which lies north-west of the Dempsey Lode. A vertical shaft, the Xmas Shaft, now inaccessible, has been put down to an unknown depth, but the size of the dump indicates that little development has been undertaken. A reef 3 to 6 inches wide and dipping south at 50° is exposed in a shallow pit at the suface. More information on this lode will be required before further development can be undertaken.

Central Line.

The Central Line consists of several lodes, but only one, the No. 1 lode, has so far proved of any importance. The other lodes lie north of the No. 1 lode, and have been tested in a few places at the surface and underground. An economical grade of ore has so far been proved only on the No. 1 lode and the No. 12 lode. The line was initially developed from many inclined shafts, mainly on the No. 1 Lode, but later Campbells Shaft and the Della Shaft were sunk vertically. They have since been abandoned in favour of the McArthur Shaft, which now serves the whole of the Central Line and the North-eastern Line (Pl. 5). This is the only mine at Hatches Creek in which several lodes are worked from one shaft.

No. 1 Lode (Pls. 6, 7, 8, & 10). The No. 1 Lode crops out over a length of 560 feet, and was originally developed from a very large number of shallow inclined shafts and open cuts, most of which are now filled. Two levels were driven later, at 81 feet and 120 feet, and most of the ore above 120 feet has now been removed. Much of the information on the lode at these levels has been drawn

from Hossfeld (1941) and Sullivan (1943). The lode has also been tested at the 206-foot level, where it is poor and narrow, and was abandoned.

The Pioneer Fault intersects the lode between 150W and 180W at the 81-foot level, and between 150W and 190W at the 120-foot level. It has displaced the east block about 20 feet north relative to the west block. The faulting is expressed as a wide zone of shearing which dips steeply to the west. The richest part of the lode lies west of the fault.

The 81-foot level is 550 feet long, but is inaccessible for the last 105 feet to the east owing to caving. Only a moderate grade of ore has been reported from the inaccessible section. The lode consists of two reefs in the accessible part of the level. Reef 1A lies to the west of Reef 1B. The two reefs overlap slightly at 200W with Reef 1A to the north. Reef 1A dips south at 45-55°, and is reported to have yielded 3.0% WO_3 (Sullivan, 1943). The eastern end of the reef plunges to the west at about 45° (Pl. 8). Reef 1B is less rich than Reef 1A. It dips south at 60° west of the Pioneer Fault, but the dip has flattened to 45-50° east of the fault.

The 120-foot level, which is 330 feet long, was under water in 1956. Both reefs persisted to this level, but have now been extensively stoped. The grade is reported to have decreased considerably at this level. Sullivan (1943) gives the grade of ore in Reef 1A as 1.7% WO_3.

An attempt was made to locate the lode by cross-cutting from Campbells Shaft at the 206-foot level, but only two narrow quartz veins, which probably represent the lode, were encountered.

High-grade ore appears to be restricted to a shoot on Reef 1A lying in the Pedlar Gabbro, where the lode dips at 45-55°. Some good-grade ore was also won from Reef 1B near the north cross-cut, where the lode also has a dip of 45-55°. The grade is poorer where the lode is steeper.

The No. 1 Lode appears to offer little prospect for further development. A small tonnage of ore may be available on Reef 1A below the 120-foot level, and on Reef 1B east of the north cross-cut, but in neither case does the amount of ore which may be present justify the reopening of the levels. The western limit of Reef 1A is not known, but is thought to be close to the present western limit of development: further large tonnages of ore cannot be expected in this direction. The lode may make again below the 206-foot level, and it should be tested accordingly; but present indications are that it is exhausted.

Della Lode (Pl. 6). The Della Lode has been followed for 220 feet at the 81-foot level, where it consists of two overlapping reefs which are nowhere more than 6 inches wide and which dip south at 50-60°. The lode was located by cross-cutting north from the No. 1 Lode at 170W. It has not been positively identified at the 206-foot level, and seems unlikely to prove of any importance.

No. 5 Lode (Pl. 5). This lode is prominent at the surface where it joins the No. 1 Lode, but has not been positively identified at the 81-foot level. The

cross-cut to the Della Lode was originally put in to locate the No. 5 Lode, but encountered only a few narrow veins of quartz. One of these, which is exposed at the south end of the cross-cut and is 3 inches wide, may represent the No. 5 Lode at this level. A second attempt to locate the lode was made from the western end of the drive on the Della Lode (Pl. 6), but this was also unsuccessful. No further exploration is warranted.

No. 12 Lode (Pl. 7). This lode has been developed over a length of 250 feet at the 206-foot level with moderate success. The lode consists of a hanging-wall reef 6 to 18 inches wide dipping south at 45-87°, and a smaller footwall reef. Rises were put up on the lode late in 1956, and a favourable grade of wolfram was obtained. The closing of the mine prevented further exploitation of this lode, which appears to offer the best prospects for further development of any of the lodes in the Central Line.

Other Lodes. Several smaller lodes and many quartz veins lie between and to the north of the lodes described above. They have been exposed in the north cross-cut at the 206-foot level and the 81-foot level, and some have been tested at the surface. So far none has proved to be of any importance, but they should be tested from each new level, as one or more may increase in width and grade below the 206-foot level.

North-eastern Line (Pls. 6, 7, 9, & 10).

This line consists of the No. 2 Lode and a few narrow veins of quartz. Operations have been concentrated on the No. 2 Lode in recent years, as it is the only lode which has been proved to carry a high grade of ore at the 206-foot level. The lode consists of several veins which have an average dip of about 55° to the south; individual veins dip between 45° and 70°.

The results of sampling by Sullivan (1943) and Jensen (1955) are given below:—

Level	% WO_3	% Bi	% Cu
81ft	3.6	0.09	0.06
135ft	2.3	1.78	0.99
206ft	2.8	0.4	0.19

The 206-foot level lies well within the primary zone and the lode should maintain the grade observed at this level in future development, provided the present width and dip persists.

The No. 2 Lode is between 500 feet and 550 feet long at the surface, but most of it is now obscured by debris. It dies out in a block of sedimentary rock to the east, but its western end is not exposed. The lode has been tested for 504 feet at the 81-foot level, between 122W and 382E, but a cave-in at 105E has blocked off the greater part of this length. The inaccessible part of the lode, as mapped by Sullivan (1943), is composed of one quartz reef 5-19 inches wide, and lies entirely within rocks of the Hatches Creek Group. It has been displaced by the Larsen Fault at 156E (Pl. 6). The lode lies in the Pedlar Gabbro between

95E and 15W, and consists of two parallel reefs, except towards the west, where it splits into a number of reefs which lie in hornfels between 6W and 22W, and become narrow and poor to the west. The hangingwall reef is 18-24 inches wide where it lies in the igneous rock, and it dips south at 45-55° except towards the contact of the hornfels and the gabbro, where the dip becomes irregular.

The length of lode lying in the Pedlar Gabbro at the 135-foot sub-level is greater than at the higher level. The 135-foot sub-level is 253 feet long, and the lode lies in igneous rock for about 170 feet. Driving was discontinued both to east and west shortly after sedimentary rock was encountered. The lode is very irregular at this level and there are many splits in the reef, as the level coincides with the junction of at least two lode shears (Pl. 10). The lode becomes barren towards the east and west faces. The Larsen Fault was met at 168W, and the reef had not been proved east of the fault at the time of the survey. It is reported that this has since been done, and that the level has been driven for a few feet on the lode.

The 135-foot level and the 81-foot level were originally accessible from the vertical East Shaft, which had been sunk to the 135-foot level. A rise was later put up from the 206-foot level, and the 135-foot level is now only accessible by way of this rise. The 206-foot level is 500 feet long, and the lode lies in the Pedlar Gabbro over a greater part of this length. The level was abandoned to the west shortly after sedimentary rock was encountered, but was driven a further 190 feet into the sedimentary rock to the east. The lode consists of one quartz reef, which splits in a few places, and which carries wolfram associated with pyrite, chalcopyrite, and bismuthinite, over the whole of its exposed length.

The richest section lies between 50W and 185E, where the reef is 12-24 inches wide, dips south at 45-55°, and has a more easterly strike than the rest of the lode. To the west of this section the dip is steeper and the grade is lower; to the east the reef is also steeper, but some rich patches of wolfram are exposed. The Larsen Fault intersects the lode at about 185E, and separates the richer central section from the patchy eastern section.

The reef splits above the 206-foot level. The footwall reef has been followed, and it has been traced to the 135-foot level in the rise to the East Shaft. Rich ore was encountered on the split, which plunges at a low angle to the west.

The reef shows no sign of a decrease in width or grade at the 206-foot level, and there is no reason to suspect that these will change below the level. No. 1 Diamond Drill Hole, put down during the Second World War, proved a quartz reef 12 inches wide assaying 5% WO_3 at 297 feet (Pl. 10). This reef is believed to be part of No. 2 Lode. Although a single intersection cannot be regarded as conclusive, the position of the intersection indicates that the dip of the reef is favourable, and the width and grade justify further exploration.

The highest grade ore has been won from a shoot within which the reef dips between 45° and 55°. The limits of the shoot are indicated on the vertical projection of the lode (Pl. 9), and correspond roughly to the margins of the Pedlar

PLATE 5

SURFACE PLAN
PIONEER GROUP
HATCHES CREEK N.T.

SCALE
20 10 0 20 40 60 FEET

4°30' TRUE MAG.

REFERENCE

- Reef, position accurate, showing width and dip.
- Reef, position approximate.
- Reef, concealed.
- Geological boundary, position accurate.
- Geological boundary, position approximate.
- Geological boundary, position concealed.
- Fault, position accurate showing dip.
- Fault, position approximate.
- Fault, concealed.
- Fault, inferred.
- Dip and strike of bedding.
- HATCHES CREEK GROUP
- Phs — Sandstone, greywacke, some quartzite, siltstone.
- pgb — PEDLAR GABBRO
- Gabbro, dolerite.
- Form lines, 10ft. interval. Datum - collar of McArthur Shaft, R.L. 1115 ft.
- Surface workings, showing depth.
- Underground workings
- Main shaft.
- Shaft.
- Inclined shaft.
- Disused or inaccessible shaft
- Dump
- Track

XMAS LODE
Xmas Shaft
Underlay Shaft
DEMPSEY LODE
JENSEN LODE
Boundary Shaft
PINK LODE
No 12 LODE
No 5 LODE
No 1 LODE
No 2 LODE
Della Shaft
Campbells Shaft
Manway
FAULT
PIONEER
East Shaft
McArthur Shaft
LARSEN FAULT
GOVERNMENT BATTERY
PIONEER BATTERY
pgb
Phs
1085
1105
1115
1125

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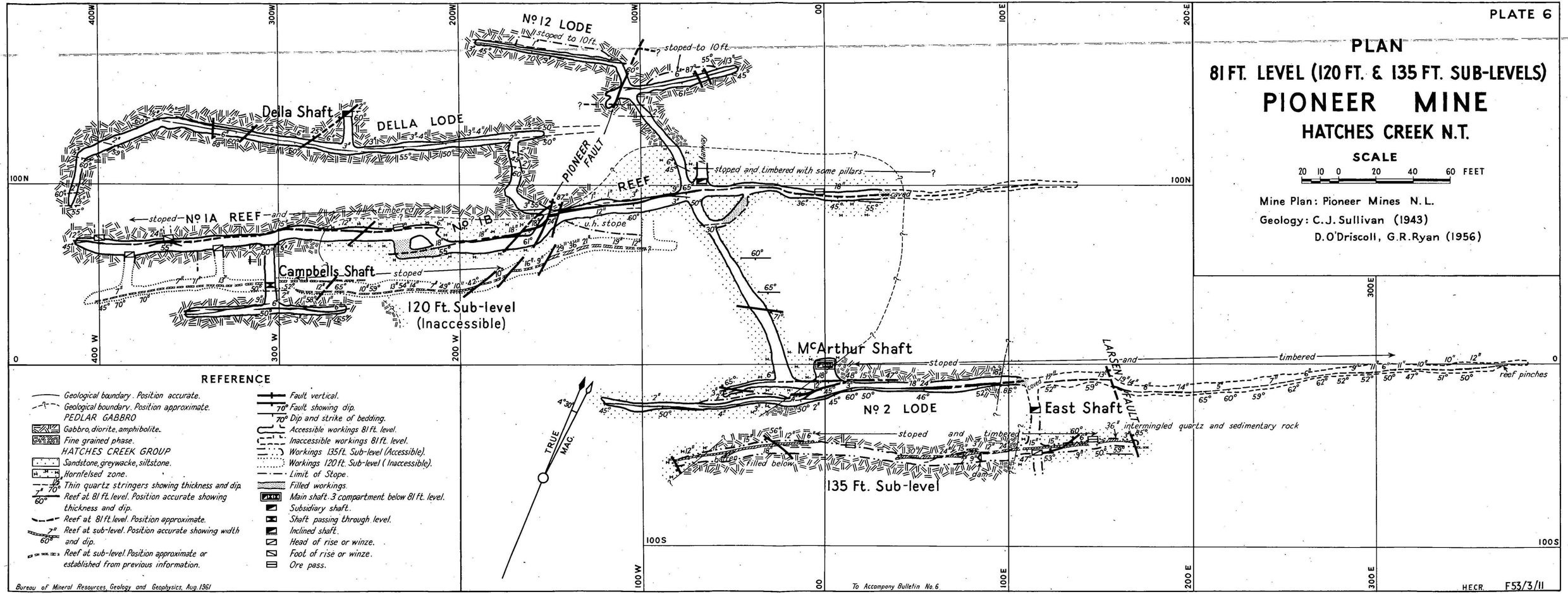
PLATE 6

PLAN
81 FT. LEVEL (120 FT. & 135 FT. SUB-LEVELS)
PIONEER MINE
HATCHES CREEK N.T.

SCALE
20 10 0 20 40 60 FEET

Mine Plan: Pioneer Mines N. L.
Geology: C.J. Sullivan (1943)
D.O'Driscoll, G.R.Ryan (1956)



REFERENCE

- Geological boundary. Position accurate.
- Geological boundary. Position approximate.
- PEDLAR GABBRO
- Gabbro, diorite, amphibolite.
- Fine grained phase.
- HATCHES CREEK GROUP
- Sandstone, greywacke, siltstone.
- Hornfelsed zone.
- Thin quartz stringers showing thickness and dip.
- Reef at 81 ft. level. Position accurate showing thickness and dip.
- Reef at 81 ft. level. Position approximate.
- Reef at sub-level. Position accurate showing width and dip.
- Reef at sub-level. Position approximate or established from previous information.
- Fault vertical.
- Fault showing dip.
- Dip and strike of bedding.
- Accessible workings 81 ft. level.
- Inaccessible workings 81 ft. level.
- Workings 135 ft. Sub-level (Accessible).
- Workings 120 ft. Sub-level (Inaccessible).
- Limit of Stope.
- Filled workings.
- Main shaft. 3 compartment below 81 ft. level.
- Subsidiary shaft.
- Shaft passing through level.
- Inclined shaft.
- Head of rise or winze.
- Foot of rise or winze.
- Ore pass.

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HECR F53/3/11

PLATE 7

PLAN
206 FT. LEVEL
PIONEER MINE
HATCHES CREEK N.T.

SCALE
20 10 0 20 40 60 FEET

REFERENCE

- Geological boundary - position accurate.
- Geological boundary - position approximate.
- PEDLAR GABBRO
- Gabbro, amphibolite.
- Fine grained phase.
- HATCHES CREEK GROUP
- Sandstone, greywacke; siltstone.
- Hornfelsed zone
- 12" / 60° Reef showing width and dip
- Reef - position approximate
- 70° Fault showing dip
- Workings
- Limits of stopes and rises
- Main shaft
- Shaft
- Foot of rise
- Ore pass

PIONEER FAULT

No 12 LODE

North X-Cut

Campbells Shaft

inaccessible

scattered quartz in shear zone.

No 1 LODE

reef much shattered

McArthur Shaft

intensely shattered with ragged quartz lenses

water dam

inaccessible

6" (estimated)

East Shaft

rise

stoped

stoped

LARSEN FAULT

No 2 LODE

4°30' TRUE MAG.

100 W 00 100 E 200 E 300 E

300 W 200 W 100 W 00 100 E 200 E 300 E

100 N 0 100 S

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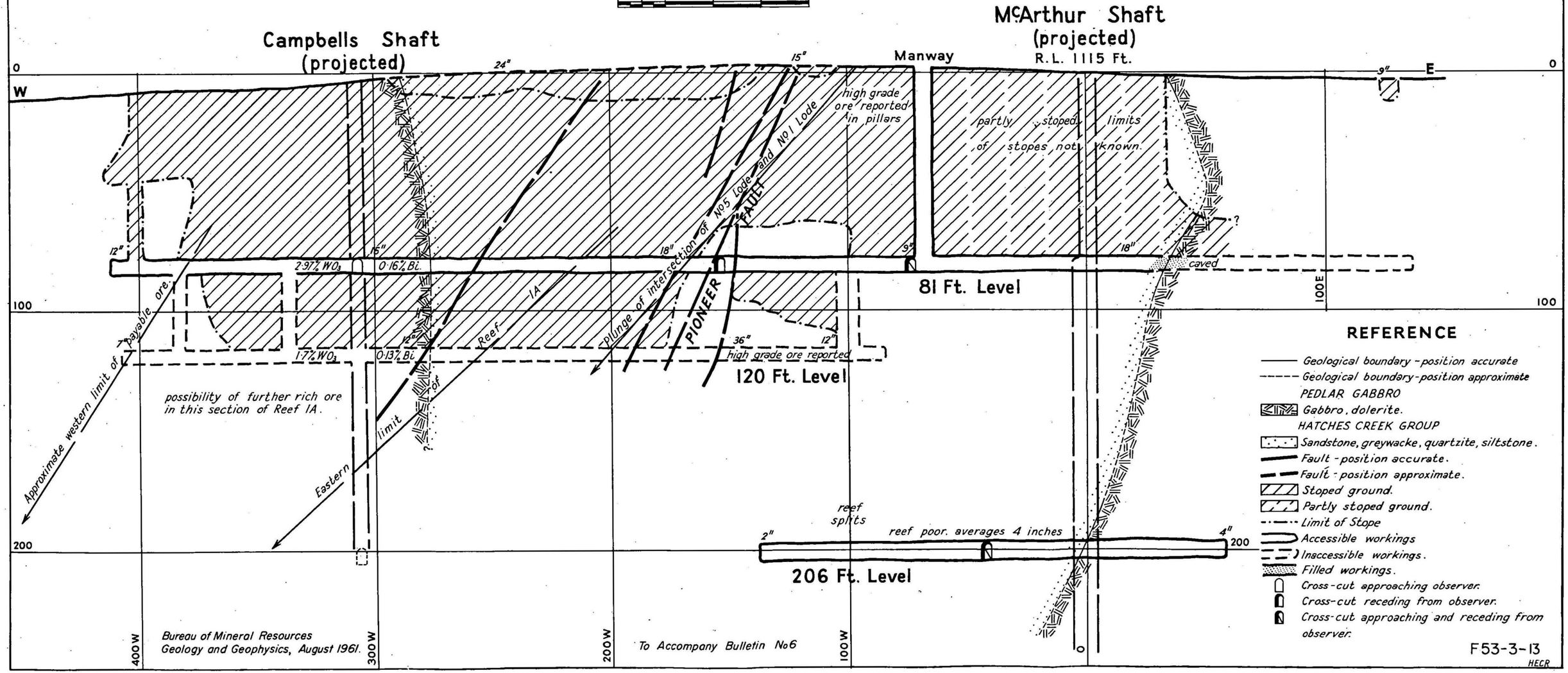
PLATE 8

VERTICAL PROJECTION
No. 1 LODE
PIONEER MINE
HATCHES CREEK, N.T.

SCALE
20 10 0 20 40 60 FEET



REFERENCE

- Geological boundary - position accurate
- Geological boundary - position approximate
- PEDLAR GABBRO
- Gabbro, dolerite.
- HATCHES CREEK GROUP
- Sandstone, greywacke, quartzite, siltstone.
- Fault - position accurate.
- Fault - position approximate.
- Stoped ground.
- Partly stoped ground.
- Limit of Stope
- Accessible workings
- Inaccessible workings.
- Filled workings.
- Cross-cut approaching observer.
- Cross-cut receding from observer.
- Cross-cut approaching and receding from observer.

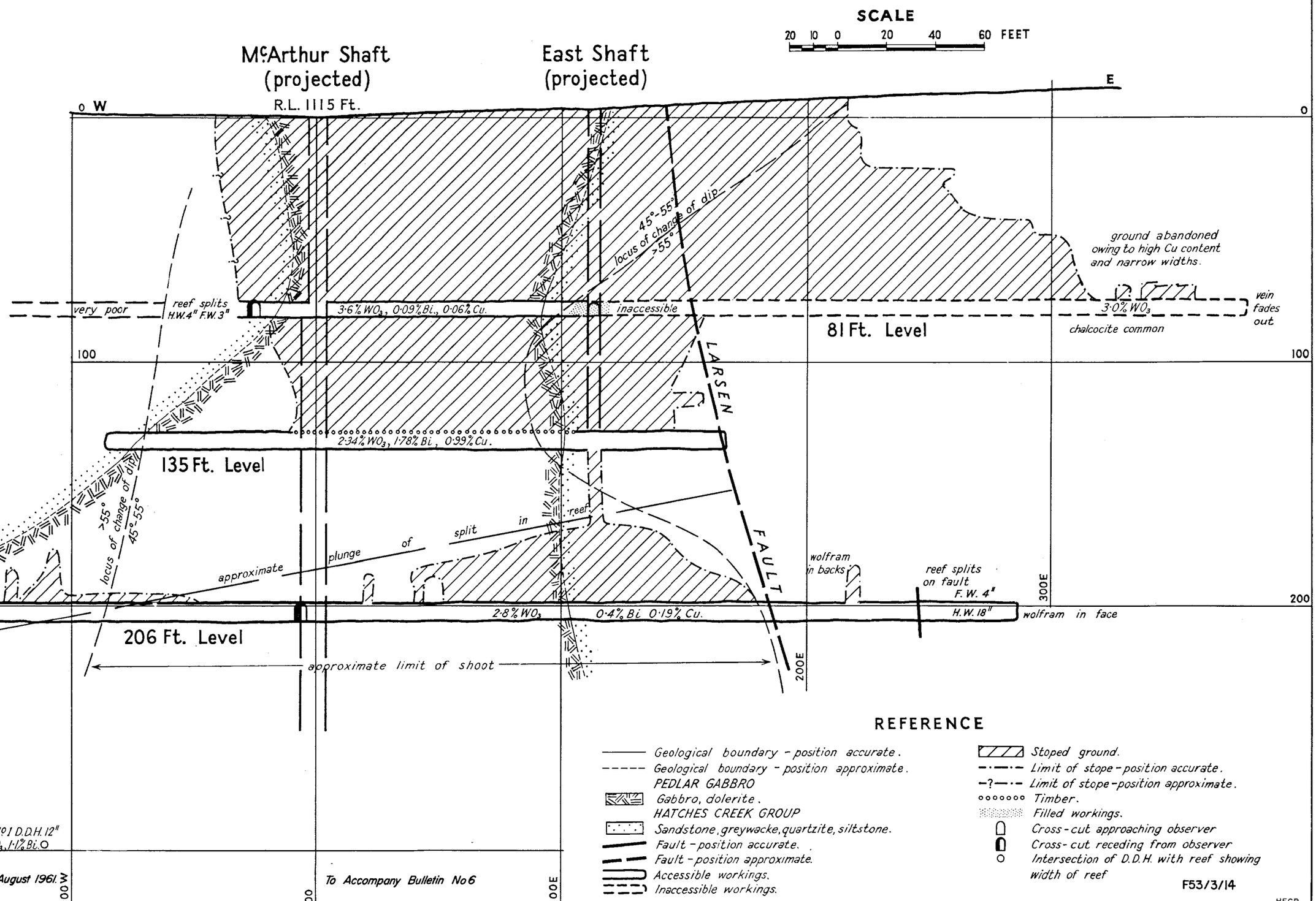
Bureau of Mineral Resources
Geology and Geophysics, August 1961.

To Accompany Bulletin No6

F53-3-13
HECR

PLATE 9

VERTICAL PROJECTION
No 2 LODE
PIONEER MINE
HATCHES CREEK N.T.



REFERENCE

- Geological boundary - position accurate.
- Geological boundary - position approximate.
- PEDLAR GABBRO
- Gabbro, dolerite.
- HATCHES CREEK GROUP
- Sandstone, greywacke, quartzite, siltstone.
- Fault - position accurate.
- Fault - position approximate.
- Accessible workings.
- Inaccessible workings.
- Stoped ground.
- Limit of stope - position accurate.
- Limit of stope - position approximate.
- Timber.
- Filled workings.
- Cross-cut approaching observer
- Cross-cut receding from observer
- Intersection of D.D.H. with reef showing width of reef

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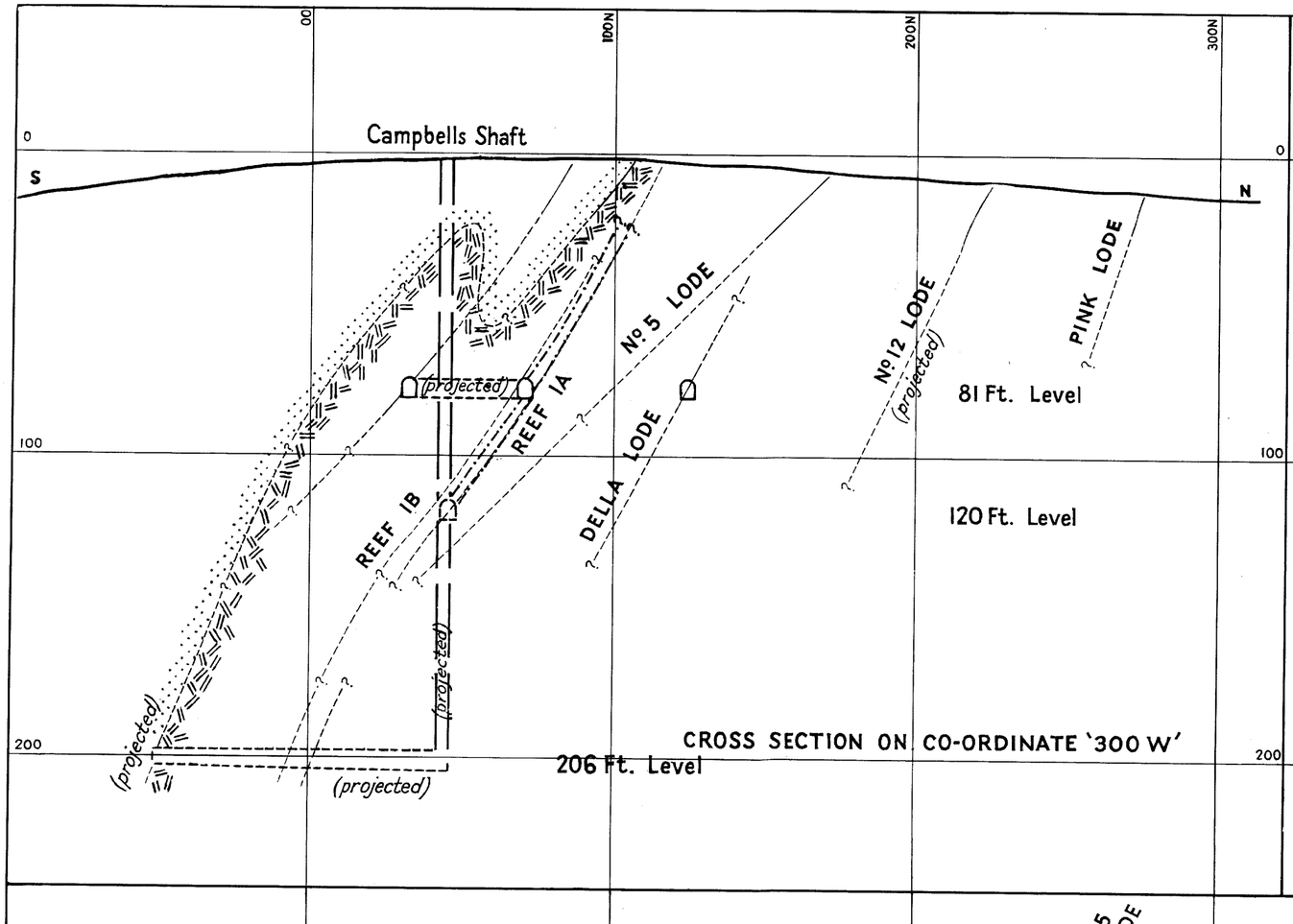
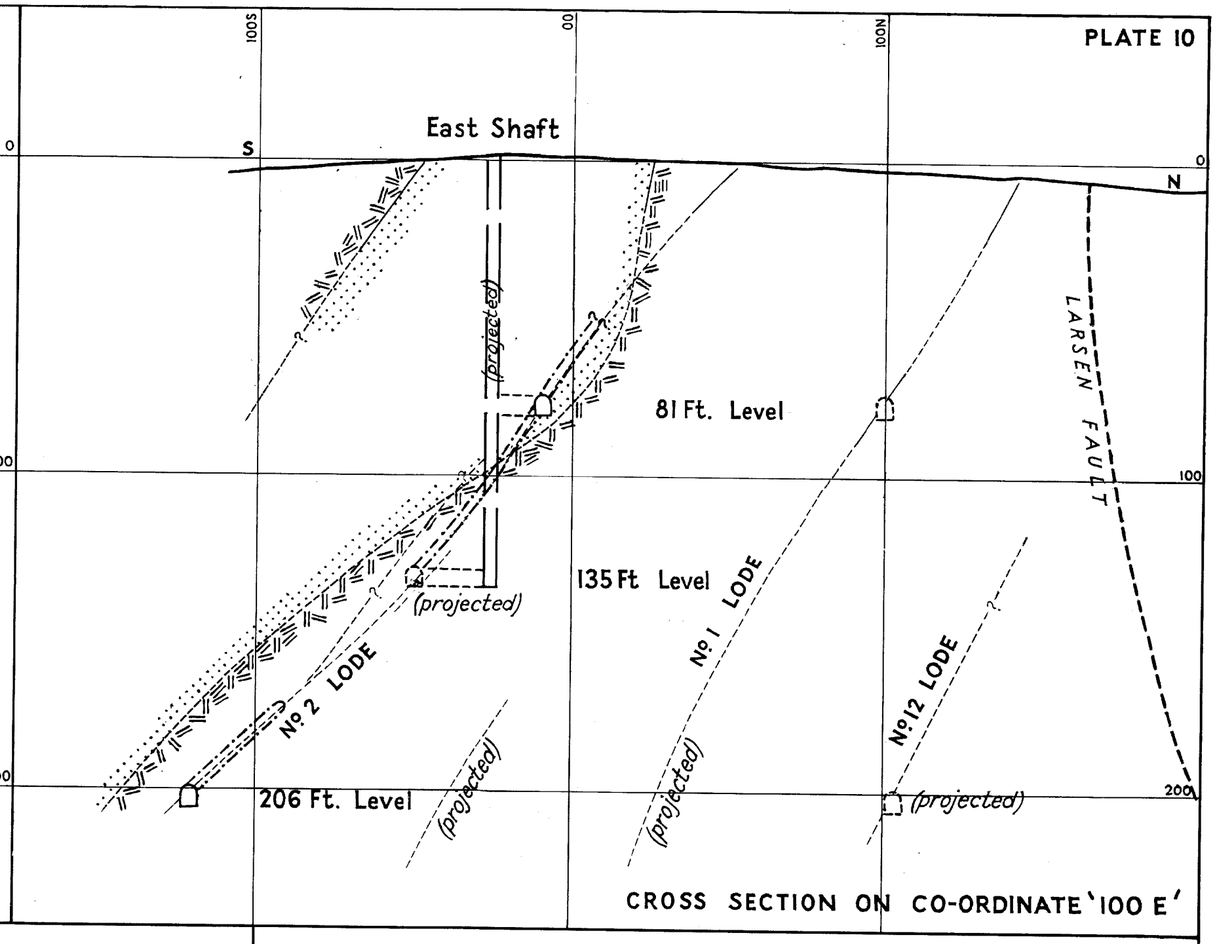
To Accompany Bulletin No 6

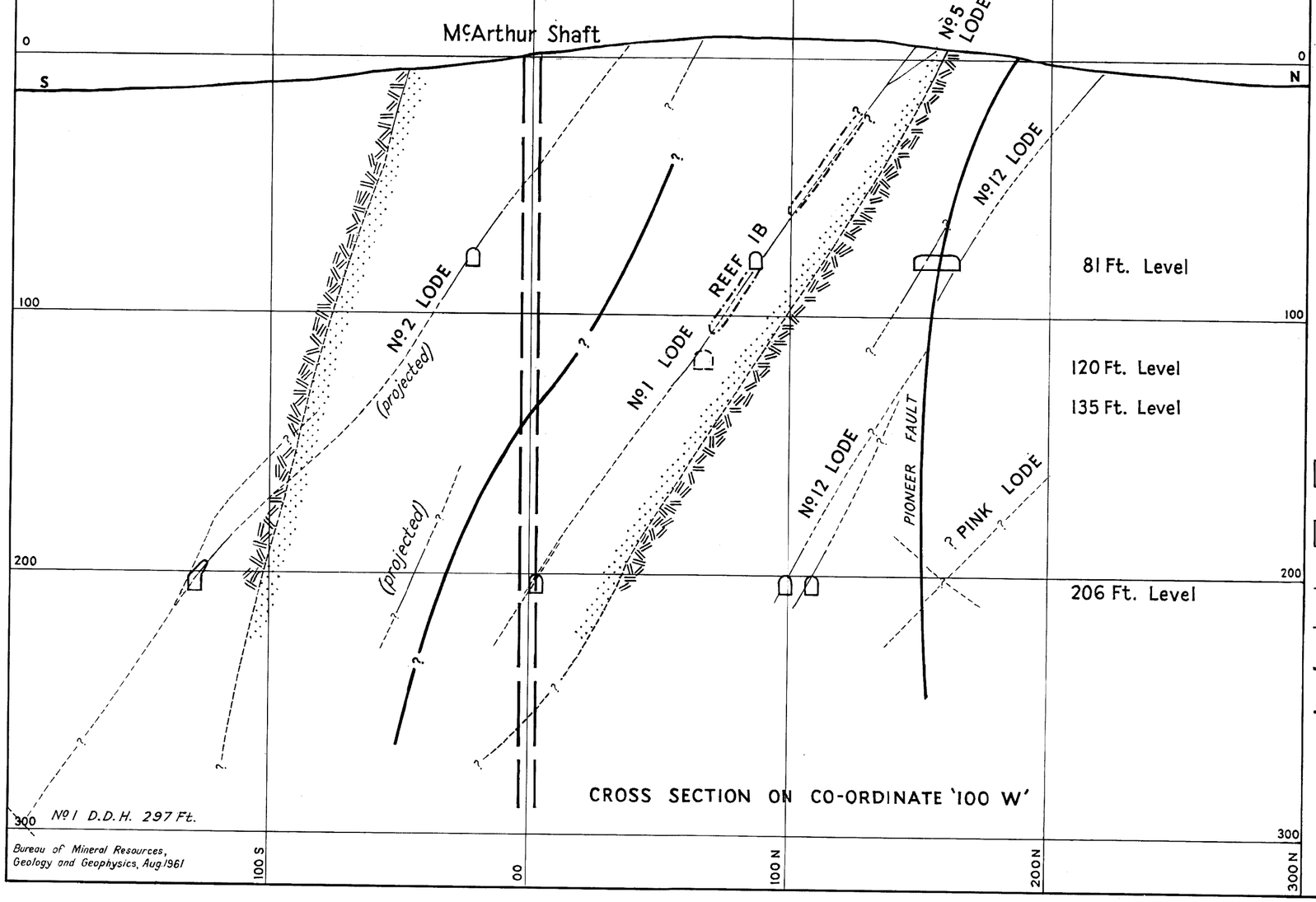
PLATE 10



CROSS SECTION ON CO-ORDINATE '300 W'



CROSS SECTION ON CO-ORDINATE '100 E'



CROSS SECTION ON CO-ORDINATE '100 W'

CROSS SECTIONS
PIONEER GROUP
HATCHES CREEK N.T.

SCALE
20 10 0 20 40 60 FEET

REFERENCE

- Pedlar Gabbro — Gabbro dolerite
- Hatches Creek Group — Sandstone, greywacke, quartzite, siltstone
- Geological boundary, position approximate.
- Geological boundary, position accurate
- Fault, position approximate
- Fault, position accurate
- Reef, position approximate
- Reef, position accurate
- Accessible drive
- Inaccessible drive
- Stope
- Cross-cut

Bureau of Mineral Resources, Geology and Geophysics, Aug 1961

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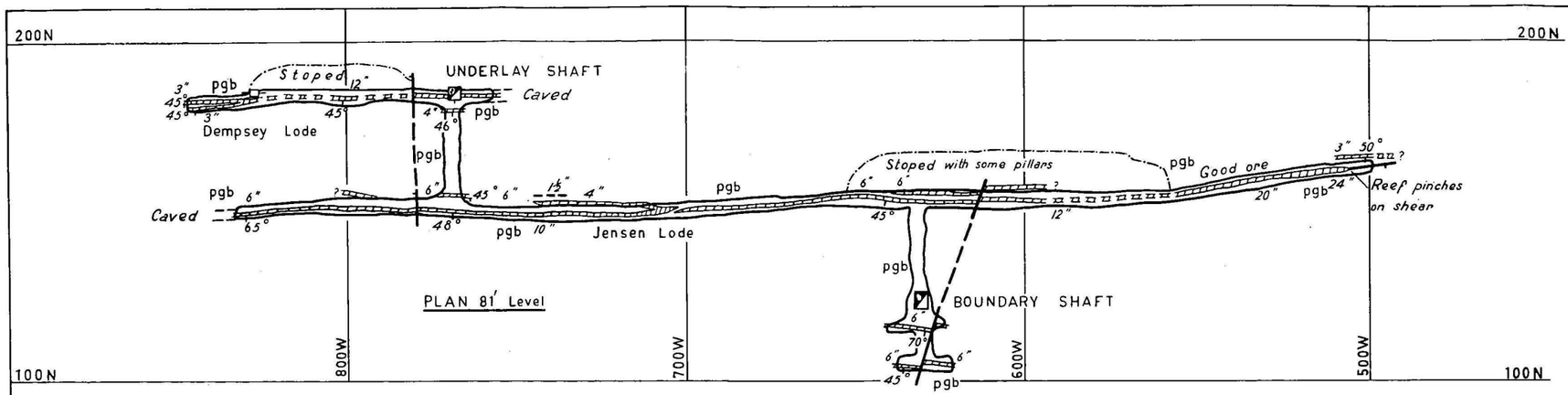
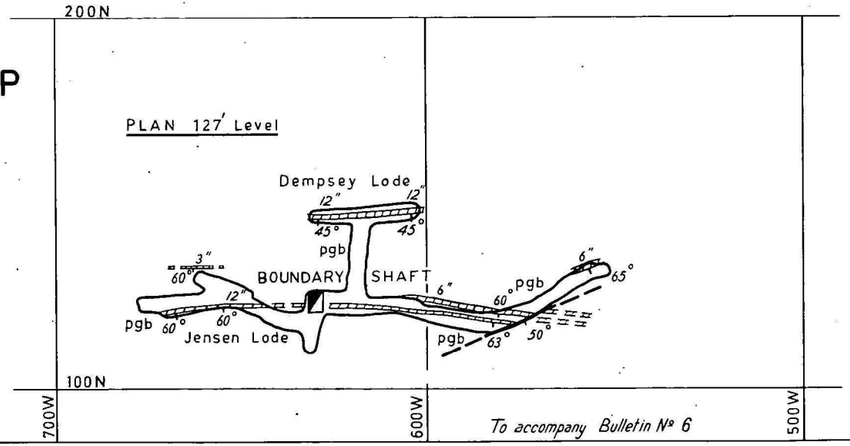




PLANS AND SECTION

BOUNDARY SHAFT PIONEER GROUP

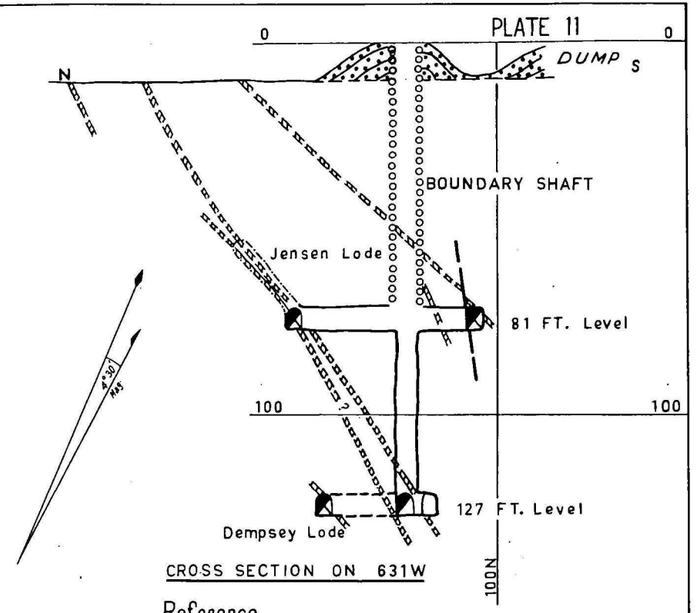
HATCHES CREEK. N.T.

MINE PLAN: PIONEER MINES N.L.

GEOLOGY: D.O'DRISCOLL. R.RYAN. 1956

SCALE

40 20 0 40 80 Ft.



Reference

- Reef position established showing width and dip
- Reef, position inferred
- Fault showing dip
- Accessible workings
- Inaccessible workings
- Timber
- Limit of stoping
- Shaft
- Shaft inclined
- Ore pass
- Drive approaching and receding from observer
- Drive receding from observer
- Drive approaching observer
- pgb Pedlar Gabbro

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Gabbro. The dip is steeper and the grade is lower in the sedimentary rocks. The western margin of the shoot plunges to the west; the eastern margin plunges west above the 135-foot level, and east below this level. The many splits in the reef may have been partly responsible for the enrichment of the lode.

The sedimentary blocks are thought to be roof pendants, and existing development shows that they are becoming narrower at depth. Thus at each new level the length of lode lying within the Pedlar Gabbro will be greater and consequently the horizontal extent of the shoot should be wider — always providing the lode persists. The evidence from Diamond Drill Hole No. 1 suggests that the lode does persist to at least 300 feet.

Recent data (E. B. Jensen, pers. comm.) give a grade of 2.2% WO_3 from 3,710 tons of ore from the 206-foot level: this includes development ore from other lodes at this level. The No. 2 Lode should bulk 2.2% WO_3, and should average at least 2.5% WO_3 from the shoot.

Assuming an average grade of 2.5% WO_3 over a width of 300 feet, it is estimated that about 5,300 tons of ore, containing about 200 tons of wolfram, lie between the 300-foot level and the 206-foot level. It was estimated that 80 tons of wolfram remained above the 206-foot level in June 1956, of which about half has since been removed. Possible ore reserves above the 300-foot level therefore total about 240 tons of wolfram and about 20 tons of bismuth.

Conclusions and Recommendations

The future development of the Pioneer Group will depend on the establishment of a treatment plant for the separation of the concentrates. This will require a substantial outlay of capital, and a guaranteed market for the concentrates must be obtained before the erection of a plant can be contemplated. There are no measured or indicated ore reserves on the group, but the inferred reserves total 240 tons of wolfram and 20 tons of bismuth from the No. 2 Lode. Exploration could double this total, and should be directed primarily at the proving of the No. 2 Lode below the 206-foot level, and subsequently to the testing of other lodes, particularly the No. 12 Lode and Dempseys Lode.

The richer sections of the lodes lie where the reefs dip between 45° and 55°. The dip could change at any level, and all the lodes should be tested at regular intervals. The lodes are arranged en echelon in plan, and high-grade ore persists to a greater depth on the No. 2 Lode than on the No. 1 Lode. The possible extension of this pattern in depth to the south and east of the No. 2 Lode cannot be overlooked although it seems unlikely.

The available evidence suggests that the lodes carry a higher grade of wolfram where they lie in the Pedlar Gabbro, and that they will lie increasingly in gabbro at greater depths. The lodes on the group are more consistent in grade than the lodes at the south end of the field, and they lie close enough together to be developed from a single shaft. They are probably more favourable for development than the other groups at Hatches Creek.

Endurance Group (Pls 3 & 12).

Several scattered lodes lie on the south side of the Poseidon Hills, and are here described together as the Endurance Group. The Endurance Lease covers the most important of these lodes, which are the only ones dealt with here. Lodes on the Mia Mia Lease, which lies south-west of the Endurance Lease, have yielded 15 cwt of concentrates from several shallow pits. The Ada Ward Lease lies to the north-west and has produced about 7 cwt of concentrates.

History and Production

The history of the Endurance Lease is incompletely known. It is first mentioned as the 'Scheelite Show' by Hossfeld (1941), but at that time the mine was closed down, most of the workings were inaccessible, and very little information on the ground could be obtained from local miners. The present lease was pegged in 1952, and operations ceased in December 1956.

Figures for production of concentrates are available only since 1952, and from that year to 30th June 1958, the Endurance Lease produced 7.37 tons of mixed wolfram-scheelite-bismuth concentrates worth £7,683. Very little work appears to have been done before 1952, and it is improbable that more than 10 tons of concentrates have been won from the lease. Table 7 gives the known production for the group from 1952 to 1958. The value of the concentrates has been low, owing to the abundance of impurities.

Geology

Two lodes, arranged en echelon, lie in sheared and altered Pedlar Gabbro, but outcrops are mainly obscured by a thin soil cover which thickens to the south and west. Operations have been concentrated on each lode at different times. No. 1 Lode has been traced more or less continuously for 250 feet, and No. 2 Lode has been traced for about 150 feet. Either may continue farther, but outcrops are too rare to permit the accurate identification of possible extensions. Intermittent outcrops of quartz have been followed for about half a mile to the south-west of the Endurance Lease, but they have never been examined in detail.

TABLE 7

ENDURANCE LEASE, HATCHES CREEK
ANNUAL PRODUCTION OF WOLFRAM CONCENTRATES
1952 - 1958

Year ending 30th June	Concentrates Tons	Value £
1952	0.86	1,490
1953	1.99	2,637
1954	1.35	839
1955	0.5	250
1956	1.47	1,404
1957	1.13	1,063
1958	Nil	—
Total	7.30	7,683

The lodes strike at about 060°, and each lode is composed of one or more quartz reefs lying roughly parallel to one another and to the strike of the lode. The reefs dip south at 55-70° and range in width from 4 inches to 14 inches.

The host rock is a coarse-grained, extensively altered gabbro. It has not been exposed below the water-table and weathering has partially obscured the nature of alteration, but some is attributed to hydrothermal activity.

Members of the Hatches Creek Group, chiefly sandstone, greywacke, and siltstone, crop out 50 to 60 feet north of No. 1 Lode. The strikes of the bedding, the margin of the Pedlar Gabbro, and the lodes are all roughly parallel. The dip of the sediments is steep and to the south. A quartz-filled fault-breccia lies to the north-east of the group and crops out right across the Poseidon Hills, traversing the bedding of the Hatches Creek Group (Pl. 3). The breccia dies out 300 feet north-east of the New Shaft, but the fault continues to the south and passes to the east of the group. Displacement along this fault is unknown; no reefs have been found east of the fault, but they may be concealed by alluvium. Small blocks of sedimentary rocks lie within the gabbro adjacent to the contact. A small stock of gabbro crops out in the sedimentary rocks east of the group.

The lode fissures are thought to have been formed in sedimentary rocks which overlay the igneous rocks in this area at no great height above the present level of erosion, and which have since been removed. The irregular nature of the contact may have been responsible for setting up local stresses which led directly to the fissuring of the rocks.

Mineralogy

Both wolfram and scheelite are present in the reefs, associated with minerals of bismuth and copper. Scheelite is more abundant than wolfram. Sulphides have not yet been encountered as no shaft is deeper than 40 feet. Bismutite is the commonest minor ore mineral, and bismuth and copper carbonates are present.

Epidote (?zoisite) is present in unusually large quantities, normally as radiating clusters of pale to dark green needle-like crystals. Mica and sericite are disseminated throughout the ore in fine flakes. Traces of arsenic, tin, and lead are present in the assays. No distinct zoning of the reefs was observed, but the ore minerals tend to lie towards the footwall and hangingwall.

The presence of as much as 10% of bismuth in the concentrate has militated against the successful exploitation of the lodes. Operations have never been on a sufficiently large scale to warrant detailed investigation of the ore, but it seems likely that the methods applied by Pioneer Mines N.L. to concentrates from the Pioneer Group would be equally applicable to the Endurance lodes.

In 1956 the owner of the Endurance Lease was leaching the concentrates with hydrochloric acid in 44-gallon drums. This method proved to be remarkably successful and resulted in a significant decrease in the percentage of bismuth in the coarser concentrates, but less so in the fines. However, the price of concentrated hydrochloric acid landed at Hatches Creek proved to be prohibitive.

If the mine is reopened, however, it should be possible to treat the concentrate in Adelaide, thus obviating the necessity of freighting the acid to Hatches Creek. The recovery of bismuth chloride is sufficiently good, and the percentage of bismuth in the concentrates is sufficiently high, to ensure the successful by-production of bismuth. With the removal of impurities, the tungsten concentrates are of a high standard owing to the high proportion of scheelite present.

Grade and Control of Ore

Too little is known about the lodes for an accurate estimate of grade to be made. Details are available for three parcels of ore crushed during 1956, and after screening and handpicking the ore returned 2.7% concentrates. At standard grade (65% WO_3) this gives a figure of 1.8% WO_3, which compares favourably with other mines at Hatches Creek.

Figures for the percentage of bismuth present are even more inconclusive. Assays of concentrates range from about 2% to over 10% Bi. Assuming an average of 6% Bi in the concentrates, the percentage of bismuth present in the lodes is of the order of 0.14%. A considerable enrichment of bismuth can be expected at the water table, which is estimated to stand at about 100 feet.

The lodes have been insufficiently developed to provide any conclusive evidence of the control of the ore. Local enrichment has been observed on 'horses', splits in the reefs, and small quartz stringers joining the reef. It appears that, in common with most of the smaller lodes at Hatches Creek, enrichment has taken place on minor features on the reefs, rather than in wide shoots controlled by the dip and strike of the reefs.

Individual Lodes

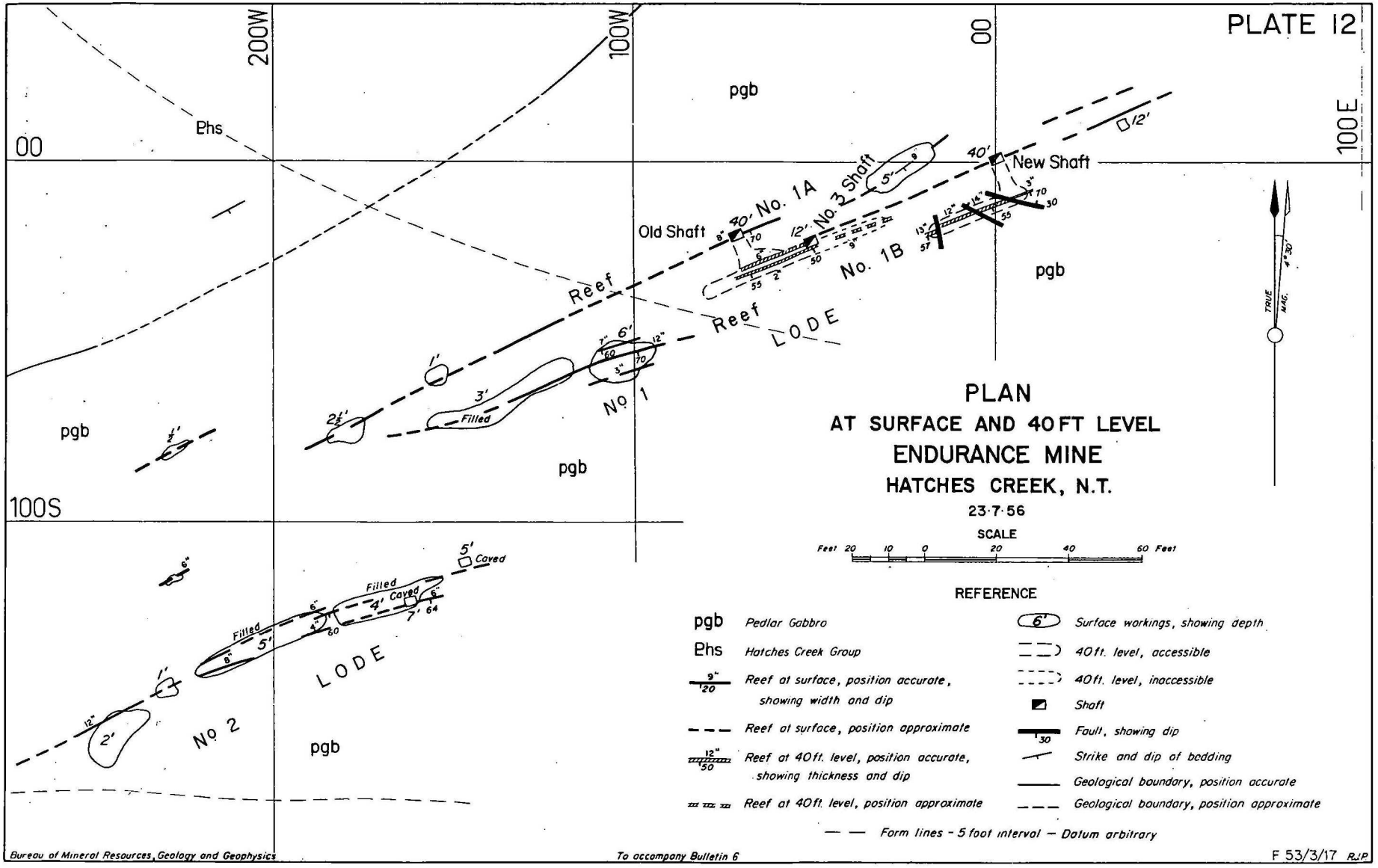
Only the two main lodes have been developed, but a few small quartz veins nearby have been tested by shallow pits.

No. 1 Lode. This lode crops out intermittently for about 300 feet and strikes at about 060°. It consists of several quartz reefs lying in a strong shear which is up to 20 feet wide. Two reefs, No. 1A and No. 1B, have been tested to depths of 60 feet and 40 feet respectively.

Some stoping was carried out from the Old Shaft. The stope is now filled and the backs are exposed for about 30 feet at a depth of 20 feet. A hangingwall reef 2 inches wide and a footwall reef 6 inches wide dip south at 55°. Nothing is known of the control or the grade of the ore.

The New Shaft was put down on Reef No. 1B to a depth of 40 feet in 1956, and a drive 30 feet long had been put in to the south before the present survey ended. The reef is 12-14 inches wide and dips south at 55°. It is cut by three small faults. The reef is only 3 inches wide east of the most easterly of these faults. The richest ore was obtained towards the west face and was associated with a small leader in the hangingwall.

No. 2 Lode. The No. 2 Lode crops out over a length of 120 feet, but is concealed by alluvium at its south-western end. It has been exploited from open



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cuts, and from two shafts which are now inaccessible. Heavy rain flooding off the Poseidon Hills caused the collapse of the workings.

The lode is composed of three reefs 4-8 inches wide at its north-eastern end, but these join to the south-west to form one reef 12 inches wide. The reefs dip south at 60-65°. Development has been confined to the north-eastern end of the lodes, where the reefs have split, which suggests that the splitting may have exercised some control over the deposition of wolfram.

Conclusions and Recommendations

The outcrop of the lodes is short, so they may not persist to any great depth. If further exploitation of the group is contemplated the true length of the lodes should be determined. The complex nature of the ore has always hampered operations in the past and will do so in the future, because the size of the deposit does not warrant the erection of a plant for separation of the ore. Further exploitation of this group cannot be recommended at present.

Wolfram Hill Locality

Four groups of tungsten deposits and many other smaller wolfram-bearing reefs are situated on Wolfram Hill (Pl. 3). The hill, which lies about 3 miles north of Goat Hole, is two miles long and a half a mile wide, and trends north-east. The northern part of the hill, where the wolfram deposits lie, is flat-topped and stands about 250 feet above the surrounding plain; it is deeply dissected by steep-sided gullies. The topography becomes more gentle to the south-west and the hill gradually dies away into the plain. There are no mineral deposits on this part of the hill.

Wolfram Hill is formed by a single large block of sedimentary rock lying within the Pedlar Gabbro. The dip and strike of the bedding are continuous with strata lying east of Hatches Creek (Pl. 2). Tungsten-bearing reefs are unknown in these rocks to the east. The strata are relatively undisturbed on the north-western side of Wolfram Hill. They strike north-east and dip south at 50-60°. On the south-eastern flank, between Windy Point and the Bonanza Group (Pl. 3), fracturing has been intense. The beds appear to have been tightly folded, and a small anticline and syncline have been identified near Windy Point (Pl. 3), but elsewhere the structure has not been determined. Detailed and painstaking mapping will be necessary to elucidate the complete structure in this area. The mineral deposits are absent where the dislocation has been most severe. They lie mainly in a zone of less disturbance around the fringes of this area, and are less common in the least distorted strata. The more important ore-bearing lodes are roughly parallel to the bedding in dip and strike, but some reefs of minor importance strike south-east or north.

The reefs in the Wolfram Hill locality are remarkable in that they are the only reefs at Hatches Creek which crop out entirely within sedimentary rocks, and yet carry relatively large amounts of scheelite and accessory ore minerals. The presence of scheelite, especially, is elsewhere restricted to reefs lying at least partly in the Pedlar Gabbro. It is considered that the intrusive probably under-

lies the sedimentary rocks of Wolfram Hill, and that the reefs lie in or close to the Pedlar Gabbro at depth. Accessory mineralization is most marked on the Green Diamond Group, where the orebodies lie close to the contact with the gabbro and dip towards it.

The heaviest concentration of reefs is about a mile south-west of Windy Point (Pl. 3), where three groups lie very close together. These are the Black Diamond Group, the Green Diamond Group, and the Bonanza Group, and they merge into one another. A fourth group, the Ricketty Kate Group, lies at the north-eastern end of the line, and is separated from the other groups by a relatively barren stretch of country in which reefs are rare. Hossfeld (1941) divided the deposits on Wolfram Hill into the North-eastern Section (Ricketty Kate Group) and the South-western Section (other groups).

Most of the lodes on Wolfram Hill are relatively small and unimportant, but on the other hand there are many more of these lesser lodes than in most of the groups on the mineral field. Consequently a large tonnage of concentrates has been produced from a large number of lodes, in contrast to the Pioneer Group for instance, where nearly all the wolfram has been obtained from a few large lodes. Activity is slight when the price of wolfram is low, but even a slight rise in the price has been sufficient to render profitable the operation of many of the lodes on Wolfram Hill. The lodes were extensively worked between 1937 and 1941, and many of them were developed to depths of between 25 feet and 50 feet. A very substantial tonnage of wolfram was won during that period. There are practically no records of the production from any of these lodes, most of which have since been abandoned, and little work has been done since 1941. The relative depth of past operations, combined with the lack of information on the lodes, makes the reopening of most of these old mines unattractive. Only three lodes have been extensively exploited since that time. Two of these, the Black Diamond Main Lode and Green Diamond Main Lode, were being worked in 1956 and 1957. Operations ceased on the third, the Bonanza Lode, in 1955.

Ricketty Kate Group (Pl. 3).

The Ricketty Kate Group includes all the lodes at the north-eastern end of the line of deposits on Wolfram Hill, the largest of which lie on the old Ricketty Kate Lease. The first reef to be exploited at Hatches Creek was in this group, but otherwise little is known of its early history. There was some activity on Wolfram Hill in 1916 (Oliver, 1916), presumably in this vicinity, but deposits described by Oliver cannot be precisely located.

Hossfeld (1941) records that the Ricketty Kate Lease had produced 7.25 tons of concentrates to the 30th June 1940. Recorded production ceased the following year, when 0.99 tons of wolfram concentrates were won. The lease was forfeited for non-payment of rent in 1945. There was a brief resumption of activity in 1952, when several leases were registered and a further 0.78 tons of concentrates were produced, making a recorded total of 9.02 tons. The actual total production from the group is certainly higher than this, as many small lodes were exploited between 1937 and 1940 and production from these is unknown.

The group lies across several steep-sided gullies which have yielded some eluvial wolfram.. The reefs, with few exceptions, have been mined solely by open-cutting to depths of about 10 feet. A few shallow shafts and short adits have been put in. The reefs lie parallel to the strike of the bedding, i.e., approximately north-east, and dip to the south at 45-85°. They are 6-12 inches wide, and few are more than 250 feet long. Wolfram is the only tungsten mineral present, and is accompanied by small amounts of copper and bismuth. Mica is present in most reefs.

Although nothing is known of the grade of the ore in these reefs, the limited extent of underground development indicates that they do not carry high percentages of wolfram. The reefs are short and narrow, and cannot be expected to persist to depths greater than 200 feet. A few small parcels of ore may still be won near the surface, but deeper exploration is not warranted. Some of the larger reefs might repay development from adits, which can be easily driven on the steep sides of the gullies, during a period of favourable wolfram prices.

Black Diamond Group (Pls 3, 13, 14, & 15)

The Black Diamond Group is the most north-easterly of the three south-western groups. It consists of three lodes and a few quartz reefs cropping out over about 600 feet from north-east to north-west; all lie on the Black Diamond Lease. The Main Lode is the most important, and has been the principal producer of wolfram in the locality.

The three lodes are parallel and lie side by side about 100 feet apart. They crop out mainly on the east side of a deeply incised gully which runs south from the Black Diamond Lease, past the Green Diamond Mine, and on to the plain south of Wolfram Hill. A substantial tonnage of eluvial wolfram has been won from this gully.

History

The group was apparently not in operation when Oliver (1916) visited the mining field, but by 1940 the Black Diamond Mine was recognised as one of the most important at Hatches Creek (Hossfeld, 1941). The lease has since changed hands several times, but it was not until 1951 that any further attempt was made to exploit the group systematically. It was under continuous operation from then until early in 1957.

Production

There is no official record of production from the Black Diamond Lease before 1940. Hossfeld (1941) records that 4 to 5 tons of wolfram were produced before June 1939, and that a further 6 tons of wolfram were won in the following year. The figures given by Hossfeld for the year ending 30th June 1941 do not agree with the official records. Hossfeld states that 14.5 tons of wolfram were won between 7th August 1940 and the end of October. In the official records the total recorded production for the year was 8.65 tons. However the official figure for the year ending 30th June 1940 is higher than that given by Hossfeld,

and the total for the two years from both sources is very similar. The official figures are given in Table 8, together with the value of the concentrates won.

A recorded total of 85.64 tons of concentrates worth £63,974 have been won from the group. The greatest part of this has come from the Main Lode, with lesser amounts from the South Lode, from the development of eluvial deposits, and from the other reefs in the group.

TABLE 8

BLACK DIAMOND GROUP, HATCHES CREEK
ANNUAL PRODUCTION OF WOLFRAM CONCENTRATES
1939-1958

Year Ending 30th June	Concentrates Tons	Value £
1939	4.5 (a)	?
1940	11.44	972
1941	8.65	1,452
1942	—	—
1943	—	—
1944	0.91	271
1945	—	—
1946	—	—
1947	—	—
1948	0.14	85 (b)
1949	—	—
1950	0.14	42
1951	0.33	629
1952	2.21	3,533
1953	8.20	11,327
1954	8.58	9,055
1955	14.40	10,645
1956	18.50	19,382
1957	6.64	6,456
1958	1.0	125
Total	85.64	£63,974 (c)

(a) Approximate production to 1939 (Hossfeld, 1941).
(b) Value calculated from mean price of wolfram for 1948.
(c) Excludes value of concentrates won before 1940.

Geology

The lodes lie in sandstone, quartzite, greywacke, and siltstone of the Hatches Creek Group. The bedding strikes approximately east and dips south. Dips ranging from 22° to 85° were recorded near the lodes. Jointing is severe and has obscured the bedding to a great extent.

The lodes strike at about 060° and dip to the south at 60-80°. They make an angle of about 30° with the dip of the bedding, but although they traverse several different types of rock no relationship between the host rock and the attitude of the reef or the grade of the ore could be discerned. The host rocks in the Black Diamond Mine on the Main Lode consist of alternating siltstone and siliceous sandstone, dipping to the south at 40-60°. Some minor drag-folding is present. The productive section of the lode lies on the southern limb of an anticline (Pl. 15), but not enough evidence is available to determine whether the northern limb has directly inhibited the deposition of economic-grade wolfram.

The outcrop of the lodes is obscured to a great extent by dumps and talus, and the lodes disappear beneath the alluvium of the gully to the south-west (Pl. 13). Narrow quartz veins crop out west of the gully, but although they are an extension of the main part of the group they will only support shallow development. More systematic exploitation of these veins will yield a further small tonnage of wolfram. The South Lode and No. 3 Lode crop out for about 180 feet east of the gully, but the Main Lode crops out for about 600 feet. Good grade ore is restricted to a central portion of the Main Lode and the South Lode. The No. 3 Lode is more irregular and has not been tested below 16 feet.

Mineralogy

The Black Diamond lodes are remarkably free of accessory mineralization compared with other lodes on Wolfram Hill. Wolfram and quartz are associated with a little mica, and very minor amounts of scheelite, bismutite, and malachite; iron oxides are rare. Separation of impurities from the ore has never proved necessary, and as far as is known the concentrates have never been penalized.

The secondary minerals are more common in the lower levels of the mine and can be expected to increase until the water-table is encountered. The water level is estimated to stand at about 250 feet. The lack of iron oxides and cavities and the low percentage of secondary minerals indicate that the primary ore is not likely to be heavily contaminated. It may be slightly contaminated by secondary enrichment between about 250 feet and 200 feet. Separation of the impurities by hand should be sufficient to avoid penalization of the concentrates.

Grade and Control of Ore

Hossfeld (1941) found that the highest grade of ore was present where the reef had a more easterly strike and a flatter dip, and was wider, than the adjoining sections. This distinction has been lost at lower levels, where the reef becomes more irregular and splits frequently. The irregularity appears to be caused by the junction of the reef which is exposed in the higher levels with a second reef in the footwall (Pl. 15). Enrichment is less consistent at the 154-foot level and the 108-foot level, although wolfram is present throughout the reefs. The presence of wolfram is not obviously related to the irregularities in the reefs.

The footwall reef has been developed in the Main Shaft below the 154-foot level and carries a high content of wolfram. It is reported to be more regular, and the splitting which prevails at the 154-foot level and the 108-foot level may cease below the 154-foot level. If this is so the richer and poorer zones may be as strongly differentiated as they are at the 28-foot level.

Development on the No. 3 Lode is too limited to determine the reason for the deposition of wolfram. Rich concentrations of wolfram on the South Lode are associated with small faults and other features.

According to Hossfeld (1941), 24 to 25 tons of wolfram had been obtained from about 1,000 tons of ore up to the end of 1940. This gives a grade of about 1.6% WO_3. It is estimated that about 2,400 tons of ore had been won from the Main Lode to 30th June 1956, and that this yielded about 60 tons of wolfram.

This gives a grade of approximately 1.6% WO_3, which agrees very well with the earlier figure determined by Hossfeld. The grade at the mill of 153 tons of ore won from the Main Lode during 1955 and 1956 was 8.95% WO_3, which gives some idea of the extent to which the ore was concentrated by hand before crushing. The South Lode yielded 4.25% WO_3 from 58 tons of ore during the same period. About 170 tons of ore have been mined from the lode, giving an overall grade of about 1.6% WO_3.

Individual Lodes

Main Lode. The Main Lode is the most northerly lode in the Black Diamond Group. It was originally developed from shafts and adits situated at various heights on the hill-side on which the lode crops out. The present Main Shaft (Pl. 13) was put down in 1951, and had reached a vertical depth of 154 feet by June 1956. The shaft was deepened late in 1956, and is now reported to be nearly 200 feet deep. No driving has been done below the 154-foot level.

The lode is about 600 feet long at the surface, but outcrop is rare. It has been developed at the surface by a continuous open cut up to 10 feet deep over the richer central portion, but very little work has been done at the extremities of the lode, which are narrow and poor. The open cut is now filled with debris. The central section is about 250 feet long, and the lode in this section consists of one reef 12-15 inches wide, and a very narrow vein in the footwall. The lode is obscured by spoil to the south-west, and gradually dies out in narrow veins to the north-east.

Two long adits had been driven in 1940, one at the level of the collar of the present Main Shaft, and one 28 feet below this. The portals of both adits are now obscured, but a short section of the 28-foot level is accessible from the Main Shaft. Both these tunnels were over 200 feet long. The richest ore was won from a shoot about 90 feet long in which the reef is 14-30 inches wide, and strikes more to the east than the poorer sections of the lode (Hossfeld, 1941). The dip is to the south at 78-84° (Pl. 14). The shoot is bounded to east and west by two faults dipping steeply to the west and striking, one at 360° and the other at 020°. The strike of these two faults changes gradually towards north-west with increasing depth. The two faults have been named the Kennedy Fault and the Bassula Fault, after the joint owners who reopened the mine in 1951, and they mark the approximate limits of high-grade ore in the two adits, but not at the deeper levels in the mine. They are horizontal shears of small displacement and have dragged the reefs where they cut them. The Bassula Fault is the more westerly of the two, and has displaced the east block north relative to the west block. The direction of displacement on the Kennedy Fault is the same above the 71-foot level, but is reversed at this level and below. The fault has been deflected where it crosses the axis of the anticline (Pl. 15).

The mine is inaccessible above the 71-foot level. Three new levels have been driven since 1951, at 71 feet, 108 feet, and 154 feet. Cave-ins have blocked the eastern end of the upper two levels and their total length is unknown. Ore

had been almost totally removed, pillars excepted, between the 154-foot level and the 28-foot level for at least 125 feet east of the Main Shaft, by June 1956. A small block of ore remained below the 28-foot level, and another block remained below the 108-foot level (Pl. 15), but the latter has since been removed. The eastern limit of stoping above the 108-foot level is not known.

The lode at the 71-foot level consists of one reef, which is 12-15 inches wide and dips south at 68-75°. The level has not been driven west of the shaft and the Bassula Fault has not been encountered. The Kennedy Fault was met at 104E, where the reef has been slightly displaced. The reef strikes at 065° at the 71-foot level, and at the 108-foot level except at the western end, where it changes to about 045°. A short drive was driven to the west at the 103-foot level, but was discontinued where the reef was lost on the Bassula Fault (Pl. 14).

The 108-foot level is reported to be about 200 feet long, but has collapsed at 124E. The lode at this level consists of a hangingwall reef 12-15 inches wide, and a footwall reef about 1 inch wide. The two reefs join at 102E, and east of this the footwall reef is the wider of the two. The reefs dip at 60-70° to the south, except at the western end of the level, where the hangingwall reef dips at 85° to the north near the Bassula Fault.

The lode is even more complex at the 154-foot level, where three reefs, arranged en echelon, are present. The most southerly reef is present in the west drive, where it is 12 inches wide: it dies out to the east. A second reef makes in the footwall to the west of the main shaft, and increases to a width of 12 inches to the east. This reef was followed in sinking the shaft below the 154-foot level, and it is reported that it widened and yielded high-grade ore. A third reef makes in the footwall of the second reef at 100E; the two join at 40E and continue to the east as a single reef 18 inches wide, which was finally lost on a fault which dips steeply to the east. An attempt was made later to locate the reef east of this fault, but only a few narrow quartz veins were found.

Wolfram is more patchy at the lower levels than it was above the 28-foot level, and this is attributed to the numerous splits in the reefs at these levels. Ore was present throughout the reefs at the 154-foot level and at the 108-foot level, but it is reported that the highest grade of ore was won between approximately 0 and 100E at both levels. The strike of the reefs in these sections is between 060° and 065°, whereas the strike of the shoot at the 28-foot level was about 075°. The deposition of wolfram has not been related to any definite feature on the reefs, but reports indicate that the richest sections of the lode lie farther to the west at successively lower levels. The zone of enrichment therefore plunges to the west, and coincides with the plunge of the intersection of the lode with the bedding of the country rock.

The exploited section of the reef lies on the southern limb of a tight anticline (Pl. 15), the axis of which strikes approximately east. The reef is not accessible where it lies on the northern limb of the anticline, but reports indicate that the grade of the ore is low. The dip of the bedding on the southern limb of the anticline is between 50° and 60° at the higher levels in the mine, and decreases with depth. A syncline may be present below the 154-foot level.

The difference in grade at the 154-foot level between the relatively enriched zone — it can hardly be called a shoot — and the adjacent zones is so slight that differentiation of the various zones is pointless, but if at greater depths the lode resumes the regularity it shows at the 28-foot level, it is possible that a shoot may be more easily delineated. Alternatively the dip of the relatively enriched zone may become less steep as the bedding becomes less steep; or the lode may die out on the southern limb of a syncline. Development since August 1956 has proved rich ore at 190 feet in the Main Shaft. Although the behaviour of the shoot is not known below the 154-foot level, ore of a grade comparable to that above this level can be expected to persist, over a comparable length of lode, to about 250 feet. The limits of existing stopes indicate that payable ore occurs over a length of about 200 feet.

Assuming a cut-off grade of 1.6% WO_3, it is estimated that about 1,400 tons of ore, containing about 34 tons of wolfram, are available above the 250-foot level. Further ore may be available to the east and west of the present limits of development.

No. 3 Lode The No. 3 Lode crops out over 180 feet, but may continue to the south-west for about another 200 feet. It consists of narrow discontinuous reefs at its north-eastern end. These have been tested by shallow open cuts. The No. 3 Shaft (Pl. 13), was put down to 16 feet during 1956 and encountered a fair grade of wolfram on a reef about 12 inches wide. The grade was not high enough to encourage further development at the time and the shaft was abandoned. The Bassula Fault displaces the reef 10 feet east of the shaft, and the wolfram may be associated with this fault.

No attempt has been made to explore the lode west of No. 3 Shaft. In view of the apparent length of the lode, a reef carrying a good grade of ore may be present beneath the talus and alluvium in this direction. The lode cannot be assessed until it has been explored.

South Lode. The South Lode crops out intermittently for about 180 feet, but may continue to the south-west beneath alluvium. No attempt has been made to explore it in this direction.

The lode consists of one reef 9-15 inches wide which dips south at 69-76°. The South Shaft has been put down on the lode to a vertical depth of 120 feet. Short drives have been put in to the west at 52 feet and 107 feet, and to the east at 52 feet and 120 feet. The lode has been stoped to 70 feet above the 120-foot level east of the shaft.

The reef has been displaced by several nearly vertical faults, striking at about 340°, close to which some wolfram has been deposited. A strong shear striking at 310° and dipping west at 35° is visible in the backs of the stope east of the shaft at 70 feet. It has displaced the east block four feet to the south, but the reef is connected across the shear by a vein of quartz 2 inches wide which lies in the plane of the shear. Another fault in the east face at the 52-foot level strikes at 030° and dips south-east. The reef has been deflected to the north on the fault plane.

Rich pockets of wolfram are distributed through the reef and are associated with faults, quartz leaders joining the reef, and changes in the dip and strike of the reef — although all these features may be present without enrichment of wolfram. It is estimated that the lode has yielded an overall grade of about 1.4%, and there is no reason to suspect that this grade will not be obtained in future development, provided that the reef maintains the width and strike observed in the mine.

The lode has not been sufficiently developed at any level to determine the extent of payable ore. Outcrop on the surface suggests that the lode does not extend far, and if this is so it cannot be expected to persist much below the 120-foot level. A small tonnage of wolfram is undoubtedly available above the 120-foot level to the east and west of the present limits of development, but the ore reserves cannot be fully assessed until the dimensions of the lode have been more satisfactorily determined.

Conclusions and Recommendations

The Main Lode is the most important in the group, and is the only one that has been developed enough to provide any satisfactory information. Exploration may prove the other lodes to be more important than they appear; the South Lode appears to be the better of these two.

Ore reserves have been calculatd only for a small part of the Main Lode, which, it is estimated, should yield about 34 tons of wolfram. Further exploration could prove a much larger tonnage. The possible western extension of all three lodes has so far been neglected, and both the Main Lode and the South Lode could continue considerably deeper than the present lower limits of development. But on none of the lodes is the grade sufficiently consistent, or the knowledge of control sufficiently accurate, to provide a basis for the prediction of further ore.

Green Diamond Group (Pls 3, 16, 17, & 18)

The Green Diamond group lies about 900 feet south of the Black Diamond group, and consists of an almost continuous line of lodes extending for 1,500 feet, trending a little north of east. Extensive surface workings exist on most of these lodes, but underground development has been restricted to a few of the widest and richest of them. The group lies predominantly in quartz sandstone which dips south, and the lodes lie roughly parallel to the bedding in dip and strike.

History

Very little mining appears to have been carried out before 1922, but by 1940 the lodes had been extensively prospected and five small mines developed on the main line of the group: from east to west they were the Bumboat Mine, Lehmann's Show, the Horrible Annie Mine, the Reserve Mine, and the Little Wonder Mine. Leases along this line have been constantly re-registered, usually with a change in the boundaries. In 1956 the Green Diamond Lease to the east and Gordons Hope Lease to the west included nearly all the lodes in the group. The present Green Diamond Mine corresponds to what was originally Lehmann's Show: it was

known as the Black Angel between 1941 and 1945, and only acquired its present name in 1951.

The group was extensively exploited between 1937 and 1939, but by early 1941 operations had all but ceased, and were not renewed to any extent until 1951. The Horrible Annie Mine and the then Black Angel Mine were taken over by the Commonwealth in 1942, but activity was restricted to the dumps, which were re-treated. The Green Diamond Main Lode has been the focus of operations since 1951, although other lodes in the group have been exploited briefly from time to time.

Production

The total recorded production of concentrates from the group has been 57.36 tons worth £50,830, of which more than 44 tons was won from the Green Diamond Mine between 1952 and 1958. Records of production before 1940 are incomplete, and in view of the considerable activity between 1937 and 1939 the total production from the group is likely to be 15 to 20 tons higher than the official figure.

As production is recorded for the leases only, the tonnages of concentrates won from individual lodes cannot be separated. But it is known that practically all concentrates produced on the Green Diamond Lease after 1951 were won from the Main Lode. Table 9 shows the total recorded production from the group.

TABLE 9

GREEN DIAMOND GROUP, HATCHES CREEK

ANNUAL PRODUCTION OF WOLFRAM CONCENTRATES

1937 AND 1940-1958

Year Ending 30th June	Green Diamond Lease		Gordons Hope Lease		Total	
	Conc. Tons	Value £	Conc. Tons	Value £	Conc. Tons	Value £
1937	0.55	50	—	—	0.55	50
1940	1.33	200 (a)	4.33	800 (a)	5.99	1,000 (a)
1941	0.09	7	0.37	61	0.46	68
1942	—	—	—	—	—	—
1943	2.55	330	1.65	260	4.20	590
1944	—	—	0.29	70	0.29	70
1945	—	—	0.23	73	0.23	73
1946	—	—	—	—	—	—
1947	—	—	—	—	—	—
1948	—	—	—	—	—	—
1949	—	—	—	—	—	—
1950	—	—	—	—	—	—
1951	—	—	—	—	—	—
1952	11.41	20,481	—	—	11.41	20,481
1953	15.20	16,235	—	—	15.20	16,235
1954	7.94	4,025	0.25	247	8.19	4,272
1955	0.10	85	—	—	0.10	85
1956	1.54	1,421	0.88	836	2.42	2,257
1957	4.65	4,259	—	—	4.65	4,259
1958	4.0	1,400	—	—	4.0	1,400
Total	49.36	48,493	8.00	2,347	57.36	50,830

(a) Estimated Value

Geology

The main line of lodes lies in a massive well-sorted quartz sandstone which becomes more massive and quartzitic toward the east. Intense jointing has all but obscured the bedding at the eastern end, but a few ripple-marked bedding planes are exposed. A higher proportion of finer material is present in sandstone toward the western end of the group, and bedding is more distinct. The strata have been slightly disturbed in places, but in general the strike swings from east-north-east in the west to east-south-east in the east. The lodes are approximately parallel to the bedding. The tougher quartzitic portions of the quartz sandstone have caused the lode channel to split, and these splits are believed to exercise some control over ore-deposition. The lodes in the group are more split than most of the lodes at Hatches Creek, and even along the main line they vary widely in dip, strike, and grade.

The Green Diamond Main Lode is more heavily mineralized than the adjoining lodes. Wolfram is accompanied by varying amounts of scheelite, and minerals of copper.

Detailed information is available only for the Green Diamond Main Lode. The others are described briefly.

The *Little Wonder Lode* lies at the western end of the group (Pl. 3). Hossfeld (1941) recorded the average width of the main reef as 12 inches and reported that the lode had been tested to a depth of 50 feet, where it died out. The lode averaged between 2% and 3% WO_3.

The *Reserve Lode* lies east of the Little Wonder and is separated from it by a relatively large gap in the line (Pl. 3). Two parallel reefs of irregular width and dip have been prospected with little success.

The *Horrible Annie Lode* is the most easterly lode on Gordons Hope Lease, which also includes the above two lodes (Pl. 3). Rich but patchy ore was obtained from a quartz reef dipping south at 38-52°, and ranging in width from 18 to 27 inches. Several small reefs adjacent to the main lode have been extensively worked from open cuts.

The *Bumboat Lode* lies at the eastern end of the line (Pl. 3). The main reef is from 16 to 30 inches wide and dips south at 35-40°. The grade appears to be low.

The Green Diamond (Pls 16, 17, & 18).

The Main Lode was originally developed from the Old Shaft (Pl. 17), but this was blown in when the owner was asphyxiated at the foot of the shaft in about 1939. The Main Shaft was put down in 1951 and is now 134 feet deep. The bottom of the Old Shaft was encountered in the present 24-foot level.

None of the several smaller lodes north and south of the Main Lode has proved rich enough to support underground development.

Geology. The Main Lode consists of an intricate set of quartz reefs with numerous 'horses', lying in a shear-zone four to five feet wide, and dipping south at 45-60°. The reefs generally aggregate about 30 inches in width, made up of one,

two, or three reefs (Pl. 17). They commonly bifurcate, and thin stringers are common between the various reefs and in the walls of the lode. The country rock is a tough siliceous quartz sandstone, which may have caused the unusual amount of splitting in the lode. It is composed of well sorted quartz grains, averaging about 1 mm. in diameter, in a primarily siliceous matrix.

Most of the outcrop of the lode is obscured by dump material and by open cuts filled with debris. Where visible it appears to consist of a single quartz reef 25 to 29 inches wide. The richest part of the lode lies on the steep east side of the gully which originates below the Black Diamond Mine. The whole gully has been worked for eluvial wolfram, but at the Green Diamond is now filled with spoil to a depth of about 15 feet. Several quartz reefs crop out on the west side of the gully and may be a continuation of the Main Lode. They are from 3 to 12 inches wide but do not carry much wolfram.

The eastern end of the lode runs into a body of barren brecciated quartz up to 5 feet wide, and 30 feet long. The breccia swings slightly to the south-east and tails off against the East Fault, which strikes at about 320°. The quartz dies out along the fault (Pl. 16). Although bodies of quartz breccia are present in fault zones in many places at Hatches Creek, this is the only place, so far as is known, where an ore-bearing lode is associated with one. The East Fault is nearly vertical; neither the fault nor the breccia has yet been encountered underground.

A fault of apparently large displacement, the Lehmann Fault, has been intersected at successive levels below ground, but at the surface its intersection with the lode is obscured by the spoil dump. No serious attempt has been made to locate the lode on the west side of the fault in the mine. The fault has a dip of 70° south-west and a strike of 295° at the 24-foot level; at the 134-foot level the dip is 50° and the strike is 305°. Several narrow quartz stringers are emplaced along the fault zone, which is about two feet wide. Slickensiding is roughly horizontal, and dragging of the lode in the footwall of the fault indicates that movement was right-handed.

The fault was followed for 25 feet to the south in a cross-cut at the 134-foot level (Pl. 17), before the lode was encountered, but the relative position of the quartz reefs on either bank of the gully at the surface suggest that, if these reefs represent the same lode, the displacement cannot have been large. Thus if the lode continues in the hangingwall of the fault it should not lie far north of the shaft at the 134-foot level. For the present, it must be assumed that the profitable section of the lode is confined between the Lehmann Fault and the East Fault.

Mineralogy. Wolfram is the common tungsten mineral, but scheelite and tungstite (WO_3) are present. The tungstite is associated with decomposed wolfram.

Water was struck at 129 feet, and at the 134-foot level the lode carries a suite of primary and secondary sulphides, and carbonates, of copper and bismuth. Concentrates from the higher levels have assayed as high as 7.63% Bi and 2.03% Cu, derived chiefly from azurite, malachite, and bismutite. Bismuthinite, cuprite, and native copper have also been identified in the oxidized zone, together with abundant iron oxides. Bornite, chalcocite, and covellite are present at the 134-foot

BLACK DIAMOND GROUP
HATCHES CREEK N.T.

Scale

40 20 0 40 80 FEET

Reference

- Reef at surface showing width
- Reef at surface - position approximate
- Faults - showing dip
- Dump
- Underground workings
- Surface workings
- Shaft - accessible
- Shaft - inaccessible
- Shaft - inclined
- Form lines. Datum collar No3 shaft. Appox. RL 1180'

4°30' Magnetic North

North

Lode

Main 4'-10'

KENNEDY FAULT

BASSULA FAULT

Debris

MAIN SHAFT

No. 3 Lode

No 3 SHAFT

South Lode

SOUTH SHAFT

Elluvial Workings

1260' 1250' 1240' 1230' 1220' 1210' 1200' 1190' 1180' 1170' 1160' 1150' 1140' 1130'

Bureau of Mineral Resources
Geology and Geophysics. August, 1961.

To Accompany. Bulletin No. 6.

F53/3/18 RM

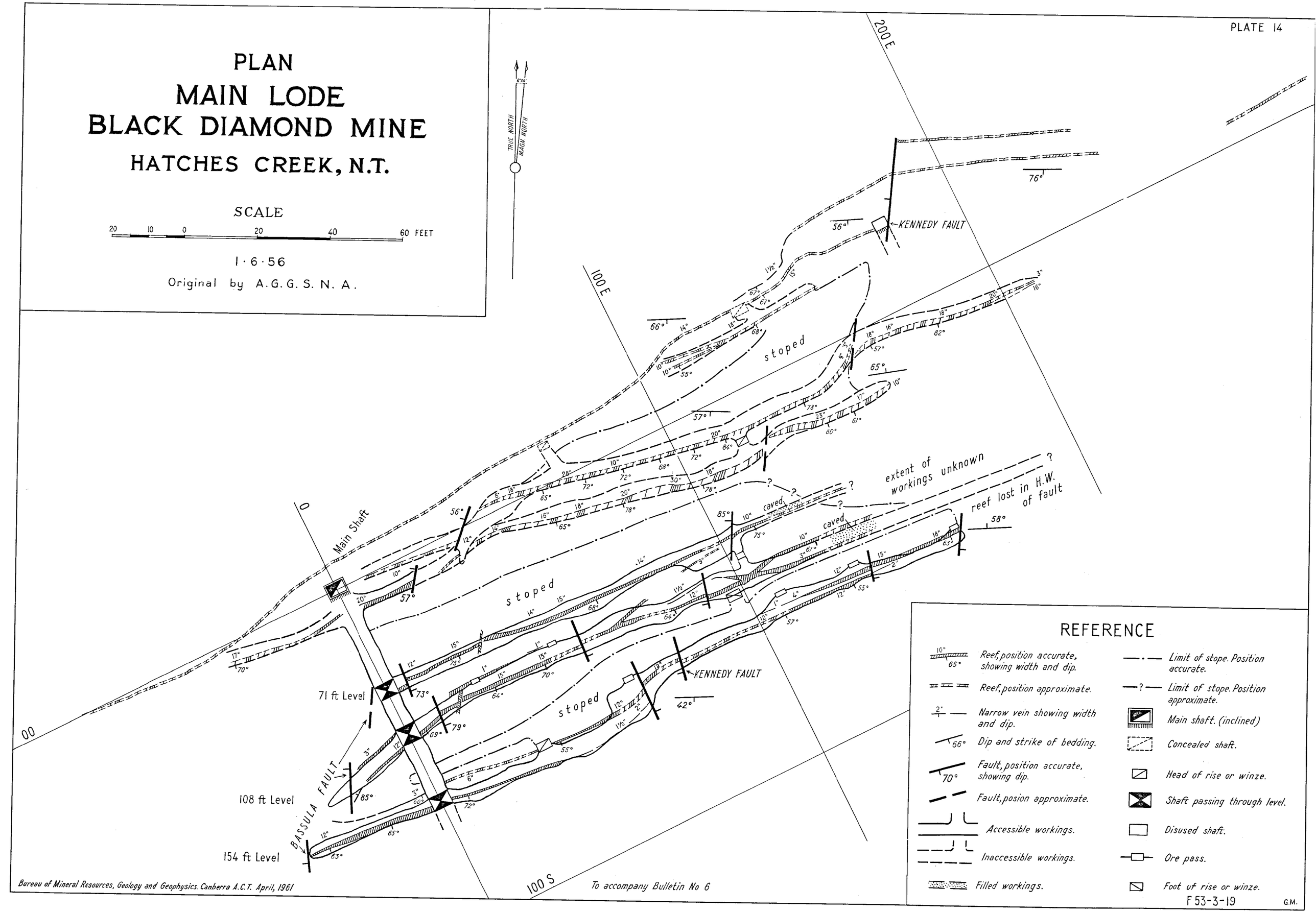
PLAN
MAIN LODE
BLACK DIAMOND MINE
HATCHES CREEK, N.T.

SCALE

20 10 0 20 40 60 FEET

1·6·56

Original by A.G.G.S.N.A.



REFERENCE

- Reef, position accurate, showing width and dip.
- Reef, position approximate.
- Narrow vein showing width and dip.
- Dip and strike of bedding.
- Fault, position accurate, showing dip.
- Fault, posion approximate.
- Accessible workings.
- Inaccessible workings.
- Filled workings.
- Limit of stope. Position accurate.
- Limit of stope. Position approximate.
- Main shaft. (inclined)
- Concealed shaft.
- Head of rise or winze.
- Shaft passing through level.
- Disused shaft.
- Ore pass.
- Foot of rise or winze.

F 53-3-19 G.M.

Bureau of Mineral Resources, Geology and Geophysics. Canberra A.C.T. April, 1961

To accompany Bulletin No 6

PLATE 15

VERTICAL PROJECTION AND CROSS-SECTION

MAIN LODE

BLACK DIAMOND MINE

HATCHES CREEK N.T.

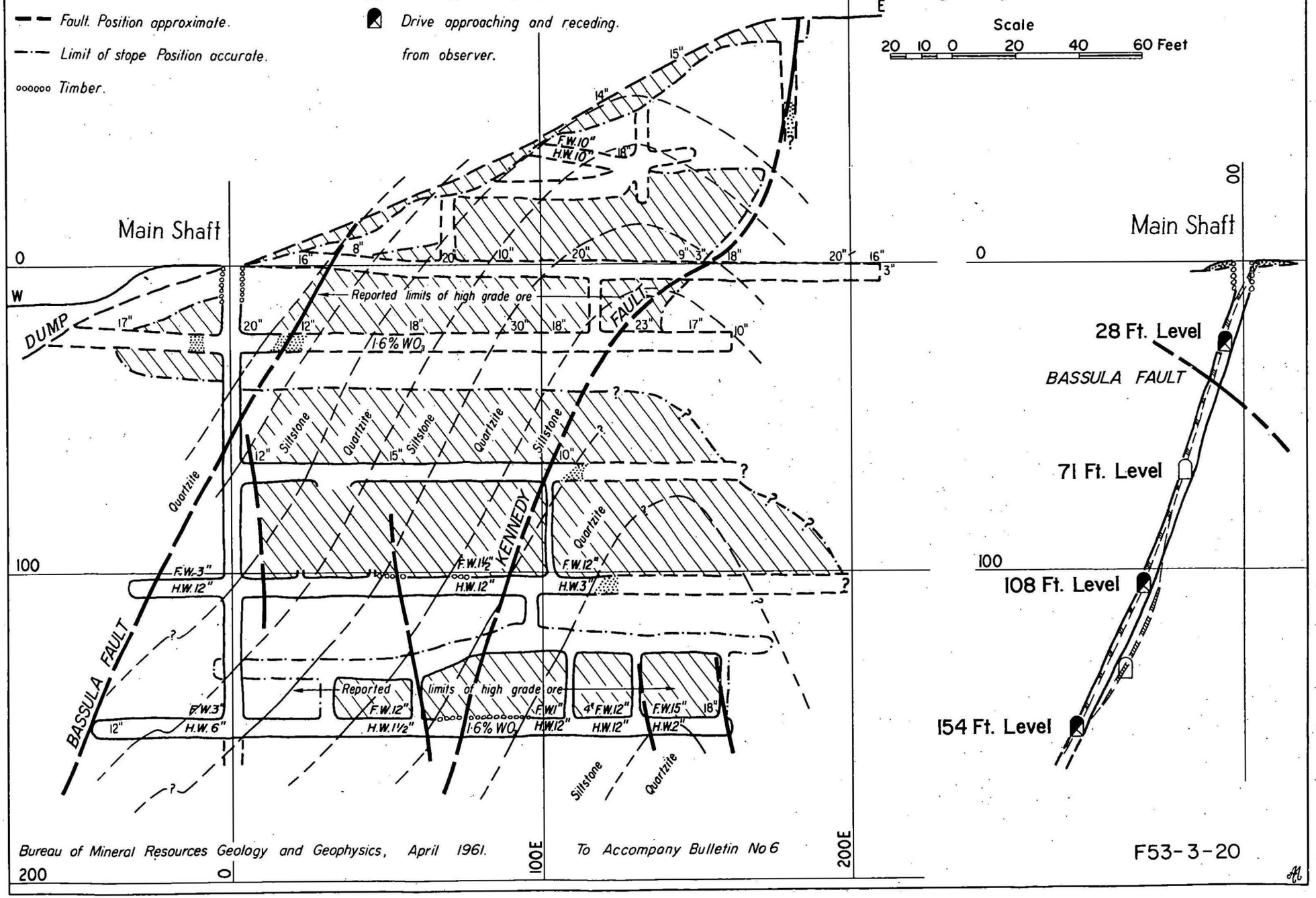
Original by A.G.G.S.N.A.

Scale

20 10 0 20 40 60 Feet

REFERENCE

- Reef. Position approximate.
- Narrow vein.
- Geological boundary. Position accurate.
- Geological boundary. Position approximate.
- Geological boundary. Position inferred.
- Fault. Position accurate.
- Fault. Position approximate.
- Limit of stope Position accurate.
- Timber.
- Limit of stope. Position approximate.
- Stoped ground.
- Assessible workings.
- Inaccessible workings.
- Filled workings.
- Drive approaching observer.
- Drive approaching and receding from observer.



Bureau of Mineral Resources Geology and Geophysics, April 1961.

To Accompany Bulletin No 6

F53-3-20

PLATE 16

SURFACE PLAN
GREEN DIAMOND
HATCHES CREEK N.T.

30-7-1956

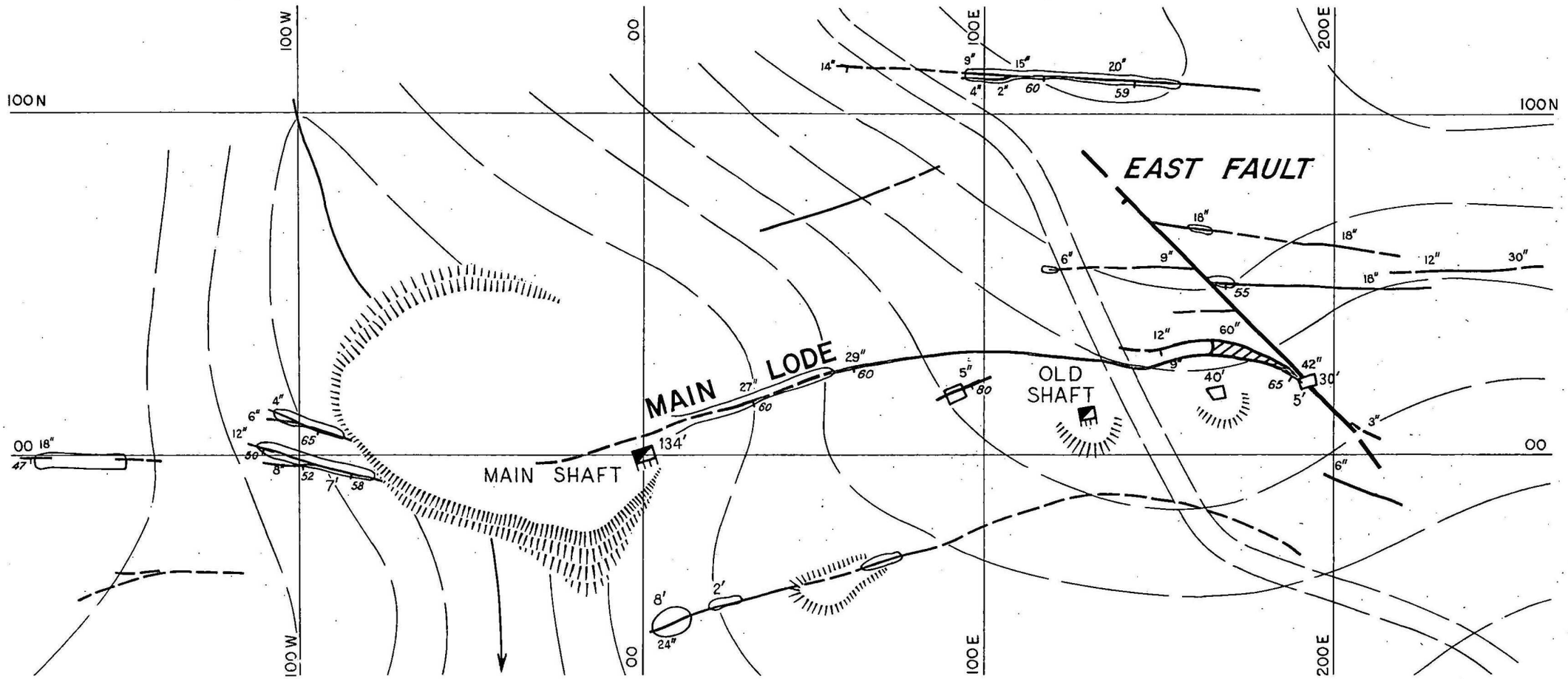
TRUE 4°30' MAG.

Scale

40 0 40 80 FEET

Reference

- Form lines, vertical interval 10' Datum Main Shaft
- Reef at surface. Position=established. Showing dip and width
- Reef at surface. Position approximate
- Surface workings, showing depth
- Fault, showing dip
- Track
- Dump
- Accessible shaft
- Disused shaft
- Inclined shaft



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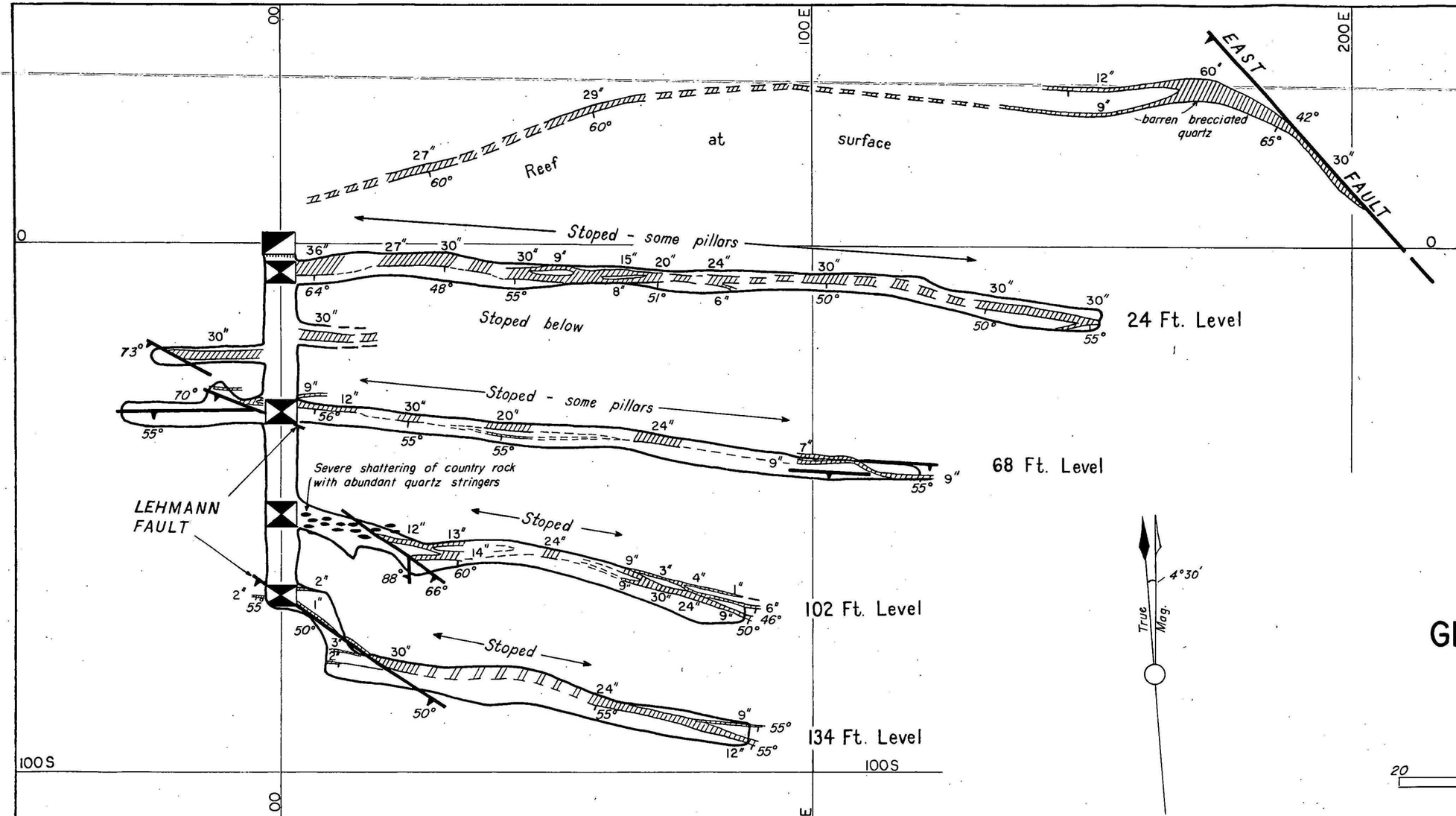
To accompany Bulletin No 6

F53/3/21 F.J.R.

PLATE 17



REFERENCE

- 16" / 60° — Reef, position accurate, showing dip and thickness.
- Reef, position approximate.
- 70 — Fault, position accurate, showing dip.
- Underground workings
- Shaft
- Shaft passing through level
- Inclined shaft

4°30' True Mag.

PLAN OF LEVELS
MAIN LODE
GREEN DIAMOND MINE
HATCHERS CREEK, N.T.

SCALE

20 0 20 40 60 FEET

Bureau of Mineral Resources, Geology and Geophysics, April 1961.

To accompany Bulletin No. 6.

F53/3/22 KC

PLATE 18

VERTICAL PROJECTION AND CROSS SECTION

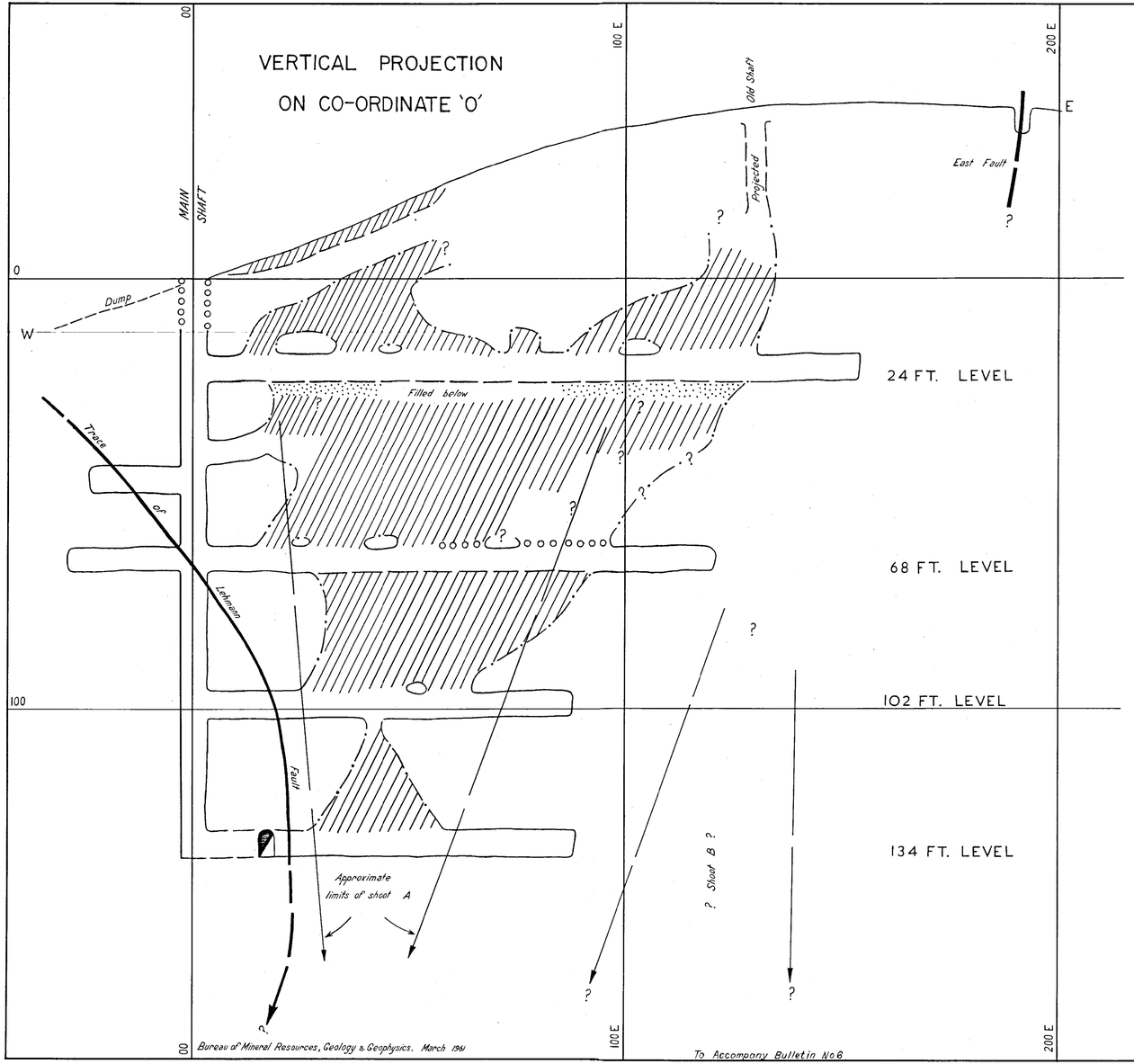
MAIN LODE
GREEN DIAMOND MINE
HATCHES CREEK, N.T.

Scale

20 10 0 20 40 60 Ft.

7.6.56

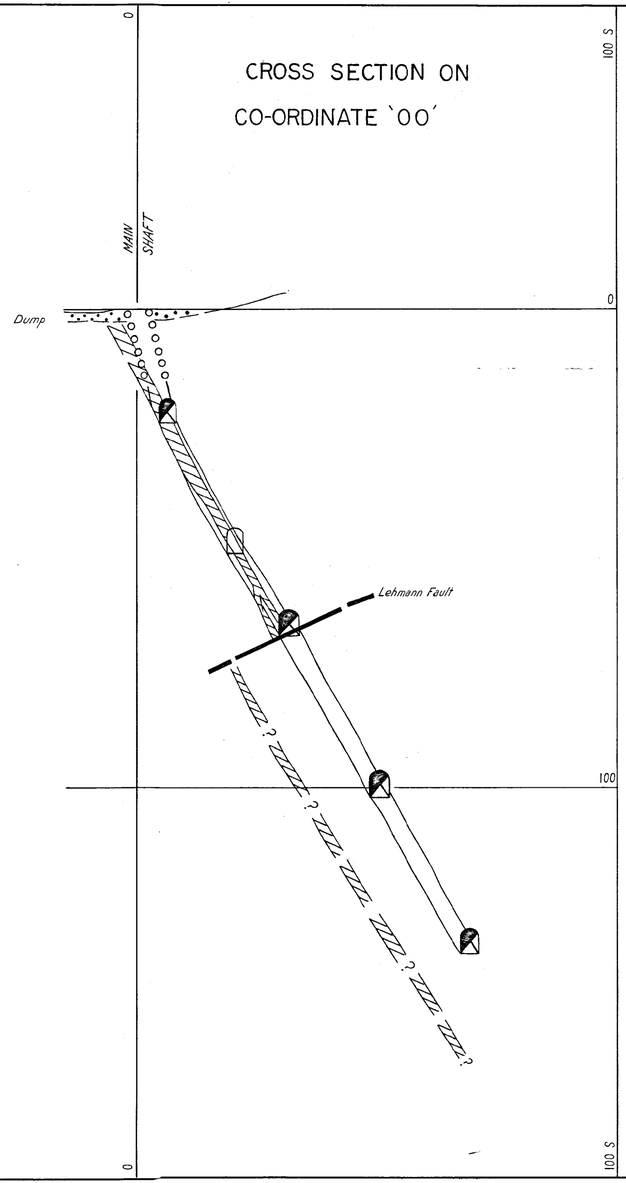
VERTICAL PROJECTION ON CO-ORDINATE '0'



Bureau of Mineral Resources, Geology & Geophysics. March 1961

To Accompany Bulletin No.6

CROSS SECTION ON CO-ORDINATE '00'



REFERENCE

- Trace of fault plane
- Reef, position accurate
- Reef, position inferred
- Timber
- Drive approaching and receding from observer
- Drive or cross-cut receding from observer
- Drive approaching observer
- Limit of stope
- Stoped ground
- Filled ground

F53/3/23 P.B.

level, associated with pyrite, bismuthinite, and chalcopyrite. The last parcel of concentrates won from the mine was sold in 1958, and assayed 7% SnO_2, although the presence of tin had not been recorded previously. Tin minerals have not been identified. The concentrates came from the 134-foot level. The reefs are unusually vuggy.

Muscovite is the commonest gangue mineral apart from quartz. It is disseminated throughout the reef in small flakes, or in other places forms a selvage up to one inch thick on either wall of the reef; it is also abundant in small stringers in the country rock, more commonly in the footwall. Sericite and kaolin lie mainly toward the footwall of the reef, and also in fissures in the footwall, which has been slightly altered. Wolfram appears to have been decomposed by hydrothermal activity, and kaolin next to altered wolfram has been stained pink. Limonite and tungstite are abundant.

The accessory minerals and vugs are concentrated toward the footwall, and to a lesser extent toward the hangingwall, of the reef. Hydrothermal fluids probably intruded at a late stage along the walls of the reef, and probably also along the Lehmann Fault at the same time as the faulting. The quartz and wolfram-bearing fluids were practically consolidated at this stage, and the later fluids were unable to penetrate the reefs to any great extent. As a result of this the wolfram and accessory minerals are rarely intimately associated, and the impurities are easily removed by hand. The ore is screened at the head and hand-picked to remove copper and bismuth minerals, and also barren lumps of quartz. The percentage of impurities remaining in the fines after screening is low enough not to incur severe penalization of the concentrates.

Grade and Control of Ore. No accurate details of the grade of the lode are available, but it is estimated from the measurement of the stopes that about 1,700 tons of ore have been mined since the reopening of the mine in 1951. This has yielded about 37 tons of concentrates, which gives a grade of about 1.4% WO_3 for the lode, including all development. The grade of ore in Shoot A (Pl. 18) is therefore a little higher than this — say, 1.7% WO_3. Crushing returns from the Government Battery during 1955 and 1956, based on estimated tonnage of ore crushed, indicate that grade at the mill was about 2.8% WO_3. From the 134-foot level, which was developed over 70 feet of lode, about a ton of concentrates was recovered. The grade of the lode at this level was 0.83% WO_3.

Wolfram is present throughout the lode, but at least one shoot contains relatively higher grade ore (Shoot A, Pl. 18). All the ore has been removed from this shoot, so it is difficult to determine the reason for the enrichment, but from observation of the accessible portions of the stope it appears that the shoot lies in the section of the lode with a more easterly strike, although the dip is no flatter in this section than in other parts of the lode. This change in strike is more pronounced at the 134-foot and 102-foot levels, and the shoot is narrower and more distinct. The shoot appears to widen, to become less well marked, and to decrease slightly in grade, at successively higher levels. The influence of splits in the reef, 'horses', and other such features, on the mineralizing fluids has been proved on many lodes

at Hatches Creek. As the Green Diamond lode exhibits these features wherever it has been exposed in the mine, the ubiquitous occurrence of wolfram is to be expected. The shoot appears to be a zone of relative enrichment imposed upon the overall deposition of wolfram.

The Main Shaft is inclined, and has been sunk on the lode to a vertical depth of 134 feet, with levels to the east at 24 feet, 68 feet, 102 feet, and 134 feet. The lode has also been tested in short drives to the west, but in each case the Lehmann Fault was encountered and the lode was lost. The east drives range in length from 80 feet to 150 feet; each has been abandoned in a relatively poor section of the lode, east of Shoot A.

The reef had not been explored beyond this barren section when the mine was surveyed in June, 1956; but at the end of that year the 134-foot level was extended about 50 feet to the east and a second zone of enrichment was encountered. No information is available on the attitude of the lode, but the zone is provisionally termed Shoot B. In view of the indefinite limits of Shoot A, no predictions can be made as to the size, shape, or plunge of Shoot B.

There is no evidence to suggest that the grade of ore will decrease below the 134-foot level, but the possible presence of tin and primary sulphides associated more intimately with the wolfram than has been the case above the primary zone cannot be overlooked. The presence of tin is especially unfortunate, because only magnetic separation will remove it from the concentrates. The above considerations apart, the lode is expected to maintain the grade of ore so far obtained, provided that the host rock remains the same. Should harder or softer rocks be encountered the lode may prove uneconomical. The possibility also exists that the host rock at depth is the Pedlar Gabbro: this is suggested by the type of mineralization, and the fact that the lode dips towards the contact with the gabbro, which is not far away to the south.

The lode has yielded about 7 cwt of wolfram per vertical foot over an average stoped length of 80 feet. Provided that Shoot A persists, or that Shoot B replaces Shoot A, and that no unfavourable host rocks are encountered, this yield should be maintained to at least 200 feet. Possible ore reserves between the 134-foot level and the 200-foot level are therefore considered to be about 28 tons of wolfram. In addition an unknown tonnage of ore remains above the 134-foot level between the East Fault and the eastern limits of existing development. A substantial tonnage of ore could be available in this section of the mine, and it is so placed that exploitation would not be costly.

Bonanza Group (Pl. 3)

The Bonanza Group, which includes the Ajax and Bonanza Mines on the Bonanza Lease, and some shallow workings on the adjacent Sunshine Lease, lies about 300 yards south-west of the Black Diamond Mine and about 100 yards north of the western end of the Green Diamond Group. The group stretches about 800 feet in a north-north-easterly direction, and consists of a number of lodes striking at about 060°, of which the Bonanza Lode is the most important.

History and Production

Production rarely ceased from 1937, when activity was first recorded, until 1954. The Bonanza Lode has the highest production figures, but the smaller lodes have contributed a greater proportion of the concentrates than in most groups. Operations finally ceased in 1954, and to 30th June of that year a recorded total of 55.97 tons of concentrates worth £26,656 had been produced from the Bonanza and Sunshine leases. Annual production from the group is given in Table 10.

Geology

All the larger lodes strike at about 060° and dip south. They range in width from 6 inches to 15 inches. Only one shaft was accessible in 1956. Hossfeld (1941) states that the richer lodes are those which have the flattest dips. The Bonanza Lode, which is the richest in the group, dips at about 60°; the Ajax lode to the south has much steeper dips, and is much poorer. A third lode north-east of the Bonanza is 6 to 15 inches wide, and the dip is from 60° to 75° to the south. This lode has been tested to 34 feet and drives have exposed the reef at this level for about 70 feet. Some stoping has been done. The main shaft on the Bonanza Lode is estimated to be at least 100 feet deep, but is inaccessible. The many shallow open-cuts on the various lodes in the group have been abandoned for some years.

TABLE 10

BONANZA GROUP, HATCHES CREEK

ANNUAL PRODUCTION OF WOLFRAM CONCENTRATES

1938-1954

Year ending 30th June	Concentrates Tons	Value £
1938	0.7	224
1939	—	—
1940	3.76	662
1941	3.53	571
1942	7.87	1,402
1943	0.14	41
1944	0.81	168
1945	6.46	2,022
1946	5.68	1,797
1947	2.91	1,013
1948	4.46	1,700 (a)
1949	3.54	1,496
1950	3.77	1,181
1951	1.96	1,191
1952	3.61	6,096
1953	5.32	6,016
1954	1.45	1,076
Total	55.97	26,656

(a) Estimated from average price of wolfram for 1948 (120/- per unit).

These lodes contain few accessory minerals. A little scheelite is present, but copper and bismuth minerals are not common. The lodes lie roughly parallel to the bedding in quartz sandstone and greywacke. The eastern end of the group has been somewhat faulted and the bedding is disturbed. The country rock is in-

tensely fractured and occupied by many short and thin quartz reefs, all of which are poor.

Conclusions and Recommendations

Only the Bonanza Lode and the unnamed lode to the north-east appear to be worth further exploration, though the Ajax Lode may prove more favourable at depth. The Bonanza Lode has already been exploited to a considerable extent, and little ore probably remains above 100 feet. The Bonanza Group does not appear to warrant further attention unless the market for wolfram is very favourable.

Other Lodes

Many smaller quartz reefs lie north of the Bonanza Group, and between the Black Diamond Group and the Green Diamond Group (Pl. 3). These lodes are pitted with shallow open cuts and shafts, and when the price of wolfram is high they repay limited surface development. Most of them were undoubtedly in operation between 1937 and 1940, but records of production are available only for the boom years 1951-1953. Production has been recorded from three leases in the area. The *Stella lease* lies north of and adjacent to the Bonanza Lease, and includes many quartz reefs, most of which strike north-east. The reefs are narrow but some carry good ore, and during 1951 and 1952 they yielded 1.68 tons of concentrates worth £2,862. The *We-ii lease* lies south-east of the Black Diamond. It includes a few very small quartz reefs from which about 3 cwt of concentrates worth £213 were produced during 1953. The country rock in this area is disturbed, and conditions are not favourable for the emplacement of large lodes. The *Spotted Diamond lease* embraces some isolated quartz reefs lying on the north side of Wolfram Hill, north-west of the Stella lease. Very little work has been done on this lease, and it is doubtful whether the 4 cwt of concentrates recorded as having been produced from this lease during 1955 was actually won from reefs on the lease.

SOUTH END

The tungsten-bearing lodes at the south end of the field lie in volcanic and sedimentary rocks of the Hatches Creek Group. The Treasure Locality includes one large and two small groups of lodes lying almost entirely in volcanic rocks towards the eastern end of the Treasure Gully. Five groups of lodes lying along the northern flank of the Hit or Miss Gully at its eastern end make up the Hit or Miss Locality.

The lodes have a wide range of strikes and dips, even within a single group, but the more important lodes strike either to the north or to the east. Most of the east-striking lodes are parallel to the country rocks, but the dip may be vertical, to the south, or to the north. Bismuth and scheelite are less common than at the north end of the mining field, but copper minerals are more abundant.

TREASURE LOCALITY

The Treasure Locality includes all mines and reefs lying in the Treasure Gully (Pl. 4), and also a small group of quartz reefs lying to the east of Hatches Creek at Frenchmans Point. Three groups have been recognised in the locality, and of these the Treasure Group, which includes the rich Treasure Mine, is by far

the most important. The Next Treasure Group is very small and lies west of the Treasure Group. The third group is the small and unimportant Frenchmans Point Group. All the lodes lie in volcanic rocks, with the exception of those in the Frenchmans Point Group and a few at the south end of the Treasure Group. The tungsten deposits occupy only a very small part of the Treasure Gully towards the eastern end. The rest of the gully is barren of mineralization.

Frenchmans Point Group

The reefs of this group and those of Dooleys Nob Group are the only ones lying completely in quartzite. Frenchmans Point lies immediately east of Hatches Creek on the eastern continuation of the ridge north of the Treasure Gully. The reefs are not more than six inches wide, strike east of north, and have steep dips. Some smaller stringers cut across the larger reefs and there has been some enrichment at the intersections. These reefs can only be operated from shallow open cuts because of the low grade, the width of the reefs, and the toughness of the country rock. 5.57 tons of concentrate worth £2,530 have been won from them since 1940, mainly in 1942, 1943, and 1944. They lie on the steep sides of the ridge, and this has made open-cutting relatively easy. Further ore may be won from these reefs during periods when the price of wolfram is high.

Next Treasure Group
(Pl. 4)

The Next Treasure Group consists of several small reefs lying about 1250 feet south-west of the Treasure Mine. All these reefs have been tested by shallow open cuts, but only two have been exposed underground. One of these is inaccessible.

There is no record of these reefs having been operated before about 1936. Since then the group has been exploited intermittently, but the reefs are narrow and poor. Total recorded production of concentrates since 1940 has been 9.57 tons worth £9,972 (Table 4), most of which was won during 1952 and 1953. The two most important lodes lie parallel to each other, and several smaller reefs strike parallel to, and across, the striker of the larger ones.

The westerly of the two main lodes is reported to have been stoped extensively above the 50-foot level, over a length of about 80 feet. An inclined shaft was put down on the lode, but is now inaccessible. The richest ore was won north of the shaft, particularly at the intersection with a cross-reef about 50 feet from the shaft. The lode is covered at the surface by spoil and shallow open cuts filled with debris. There is no available information on the width and number of reefs. The dip is very steep and to the west, and the exploitable length appears to be about 80 feet.

The second lode to the east has been tested to about 48 feet from an inclined shaft, and is exposed over 44 feet in drives at this level. The lode strikes at about 010°, and where exposed consists of one main reef 9-11 inches wide and a few thin leaders of quartz. It dips at 83-89° to the west. Two small faults striking about 060° have displaced the north side of the lode to the east. These faults strike parallel to the jointing in the host volcanic rock, but are almost vertical,

whereas the jointing dips south at about 60°. Rich ore is present north of the faults, but the drive only extended six feet beyond the fault at the time of the survey, and it is not known whether this ore persists. The strike and dip of the reef are unchanged north of the fault.

It appears that the wolfram has been localized on faults, reef intersections, and similar features in the reef. Provided stoping is confined to these rich pockets it should be possible to mine these lodes to at least 100 feet — subject to the price of wolfram. The total tonnage of ore is not large, but it could be won fairly easily.

Treasure Group
(Pls 4, 19, 20, 21, & 22)

The Treasure Group lies about three-quarters of a mile north-west of Goat Hole, and immediately west of the Hatches Creek store (Pl. 4). The southern end of the group lies on the steep northern flank of Dooleys Ridge, and the group extends north for about 1500 feet across two low ridges separated by gullies which run east.

The Treasure Group rivals the Pioneer Group in the number and richness of the lodes, but has not been so deeply or so systematically exploited. The lodes strike within 20° of north and nearly all dip west. Although the group is geologically continuous throughout, the northern (Treasure) and southern (Hidden Treasure) sections, in which the richest lodes lie, are separated by a relatively barren central section, and the two sections have always been operated separately.

History

The original Treasure Lease was the first to be registered at Hatches Creek, in the names of Hanlon and Warne, in July 1915. The Hidden Treasure Lease was registered a year later by the same people. Oliver (1916), describes a 'Hidden Treasure' in his report, but a 'Golden Treasure' is shown in the accompanying map. However he states that the Hidden Treasure lode can be followed for 20 chains (1320 feet) i.e. across the entire length of the Treasure Group. In 1940 four leases covered the group: from north to south the Lost Ruby, the Treasure, the Hidden Treasure, and J. Bailey's Lease. All except the last were reregistered in 1940 .

The Treasure Lease (31F) was pegged by Mr S. Rieff in 1933 and has remained in his hands ever since. In 1949 he also acquired the Lost Ruby Lease (30F) and since then the two leases have been operated jointly. The Treasure Mine lies partly on each of these leases. The Hidden Treasure Lease (35F) was owned by the Hidden Treasure Mining Company until 1951. Between 1951 and 1953 Messrs C. Perry, H. Davis, C. Johannsen, and E. Becker held varying interests in the lease. Mr T. Stephenson acquired all the shares in 1953, and still owns the lease.

Production

The Treasure Lease and the Lost Ruby Lease to the north cover the northern section of the group; the Hidden Treasure covers the southern section. Operations on all these leases were maintained almost continuously, though not intensively, between 1935 and 1958. The Treasure Mine in particular has been a consistent producer of wolfram.

Table 11 gives the total recorded production of concentrates from the Treasure Group, and also the production from the two separate sections. The accuracy of these figures is in some doubt as the leases appear to have been confused.

TABLE 11

TREASURE GROUP, HATCHES CREEK

ANNUAL PRODUCTION OF WOLFRAM CONCENTRATES

1936-1958

Year ending 30th June	Treasure/Lost Ruby Concentrates Tons	Treasure/Lost Ruby £ Value	Hidden Treasure Concentrates Tons	Hidden Treasure Value £	Total Concentrates Tons	Total Value £
1936	2.1	214				
1937	11.5	1,041				
1938	0.3	108	27	(a) 3,600	54.71	(c) 7,335
1939	3.85	685				
1940	9.96	1,687				
1941	8.41	1,370	8.43	1,493	16.84	2,863
1942	6.75	1,356	20.75	4,835	27.50	6,191
1943	26.78	8,459	1.5	419	28.28	8,878
1944	12.14	3,929	2.22	763	14.36	4,692
1945	4.64	1,658	8.64	3,060	13.28	4,718
1946	7.08	2,361	12.07	4,458	19.15	6,819
1947	10.14	3,285	9.89	3,202	20.03	6,487
1948	5.64	(b) 3,660	4.43	(b) 2,660	10.07	(b) 6,320
1949	10.48	4,558	9.06	3,962	19.54	8,520
1950	5.66	1,732	5.96	1,954	11.62	3,686
1951	6.29	9,873	3.45	4,140	9.74	14,013
1952	7.58	14,582	1.99	3,931	9.57	18,513
1953	21.25	28,918	6.11	7,313	27.36	36,231
1954	15.23	15,658	3.42	3,005	18.65	18,663
1955	2.95	2,926	0.10	65	3.05	2,991
1956	3.08	2,893	0.31	296	3.39	3,189
1957	7.00	3,573	0.10	98	7.10	3,671
1958	10.00	3,161	—	—	10.00	3,161
Total	198.81	117,687	125.43	(c) 49,254	324.24	(c) 166,941

(a) Value estimated from value of concentrates from Treasure/Lost Ruby over same period.
(b) Value estimated from mean price of tungstic oxide for 1948.
(c) Approximate only.

Hossfeld (1941) records that 27 tons of concentrates were won from the Hidden Treasure lodes up to and including 1940, but does not state their value. This figure is probably a rough estimate, but is the most reliable figure available. Also, the production from the Lost Ruby Lease may not always have been included with that of the Treasure Lease. In the absence of more accurate data these figures must suffice, but the true production from the group is believed to be higher than that officially recorded.

The total recorded production from the group has been 324.24 tons worth £166,941. Of this 198.81 tons has come from the Treasure and Lost Ruby Leases, mainly from the Treasure Mine. On the Hidden Treasure Lease the No. 1, No. 2, and No. 4 lodes (Pl. 19), have contributed the greater part of the production. A substantial tonnage of eluvial wolfram has also been won on this lease. More continuous and steadier production has been maintained on these leases than on others because the lack of impurities renders the concentrate marketable even when the market is tight; and the lodes are comparatively rich and can be profitably operated when the price of wolfram is low.

Geology

The main feature of the group is the long, almost continuous line of lodes which includes the Treasure Main Lode and the Hidden Treasure No. 1 Lode and No. 2 Lode and which can be traced from one end of the group to the other (Pl. 19). The lodes on this line strike between 340° and 350° and dip to the west at about 70°. Several less important lodes lie parallel to this line. A subsidiary set of lodes, of which the Hidden Treasure No. 3 and No. 4 are the most important, strikes at 360° to 020° and has vertical or steep westerly dips. A few other, smaller, lodes have more diverse dips and strikes.

The lodes occupy shears of small horizontal displacement lying mainly in acid and intermediate volcanic rocks. They die out to the south in the thick quartzite of Dooleys Ridge, which dips south at about 60° and overlies the volcanic rocks; and to the north in the volcanic rocks before the quartzite which forms the north ridge of the Treasure Gully is reached. A few small stringers of quartz are present in this quartzite north of the Treasure Group. They are short and have no visible connexion with the Treasure Group, although they represent a faint northern extension of the zone of fracturing in which the Treasure Group lies.

Striae along the walls of the main lode channels indicate that displacement has been horizontal; the east block has moved north relative to the west block. No information is available on the displacement along the subsidiary set of lodes, as the workings on these lodes are inaccessible, but these lodes may be complimentary to the main line of lodes in a minor wrench-fault system. If this is so, movement along the subsidiary lodes would have been opposite to that along the main line, i.e., west-block-north.

The lodes are cut by faults of small displacement striking parallel to the bedding in the sedimentary rocks and the jointing in the volcanic rocks. On all but a few of these faults the north block has moved east relative to the south block. The shearing and faulting are believed to have arisen in response to stresses set up by differential strike-slip movement of the two blocks of quartzite which flank the Treasure Gully, and to have been localized on a lens of quartzite which lies across the middle of the group (Pls 4, 19). It is significant that the most intense shearing has taken place between this lens and the quartzite to the south; that the subsidiary set of lodes lies only south of the lens; and that the lodes die out north of the lens before they reach the quartzite to the north. That the lens has acted as a barrier is demonstrated by the fact that whenever a well-defined lode approaches the quartzite it splits and becomes indefinite. The quartzite has been severely jointed and has been displaced along the line of the main lode on a large number of planes of movement; it has also been somewhat compacted in an east to west direction.

The volcanic rocks range in composition from an andesitic rock to an amygdaloidal acid porphyry, and the lodes of the Treasure Group traverse several flows. No attempt has been made to map the individual flows across the whole group, but the different rock types have been recognised along the Treasure Main Lode, where they exercise some control on the formation of the lode channel and the deposition of wolfram.

Plate 19

SURFACE PLAN
TREASURE GROUP
HATCHES CREEK N.T
• Reference •
Reef at surface. Position accurate. Showing width and dip.
Reef at surface. Position approximate.
Reef reported at surface, now concealed by mullock. Showing width and dip.
Underground workings showing thickness and dip of reef.
Surface workings showing depth.
Fault at surface showing dip & strike.
Fault underground showing dip & strike.
Dip and strike of bedding.
Geological boundary. Position accurate.
Geological boundary. Position approximate.
Dump.
Form lines, 10 ft. interval. Datum arbitrary.
Shaft - accessible.
Shaft - inaccessible or disused.
Shaft - inclined.
Shaft - reported, now concealed by mullock.
Known stopes - now filled.
SCALE
40 20 0 40 80 120 Feet
Based on original by the A.G.G.S.N.A 1940
MAG
TRUE
NOTE... Dumps in general have been omitted for convenience.
Tommys Shaft
Sharpes Shaft
Tonys Shaft
Nº 3 LODE
Boundary
Chinamans Shaft
Nº 2 LODE
Hoskins Shaft
Dempseys Shaft
LODE
Bills Shaft
MAIN
Lease
Volcanic rocks
Main Shaft
"LOST RUBY"
"TREASURE"
Nº4 Shaft
HANLONS FAULT (Projected)
Stringers
Movement along lode channel
Debris
Poor
Quartzite
Dempseys Nº2 Shaft
Bottom of shaft in quartzite
Water to collar
Lease
Boundary
Nº2 Main Shaft
Nº 1 LODE
Herreens Shaft
J. Baileys Shaft
Water Shaft
Vertical Shaft
Nº 2
Mariboo Shaft
LODE
Shaft reported
The Boys Shaft
Perrys Shaft
Reported 15'
Reported 30' now filled
Narrow vein
Filled
Reef
3B Shallow
Nº 3 LODE
Nº 4 LODE
Change of dip & strike
Reef 3C
Good ore in drive
Volcanic rocks
Quartzite
"HIDDEN TREASURE"
Eluvial workings
Bureau of Mineral Resources, Geology & Geophysics. August 1961.
To accompany Bulletin 6.
F53/3/24

PLATE 20

MAIN REEF WORKINGS

TREASURE MINE

HATCHES CREEK N. T.

Scale

20 10 0 20 40 60 ft

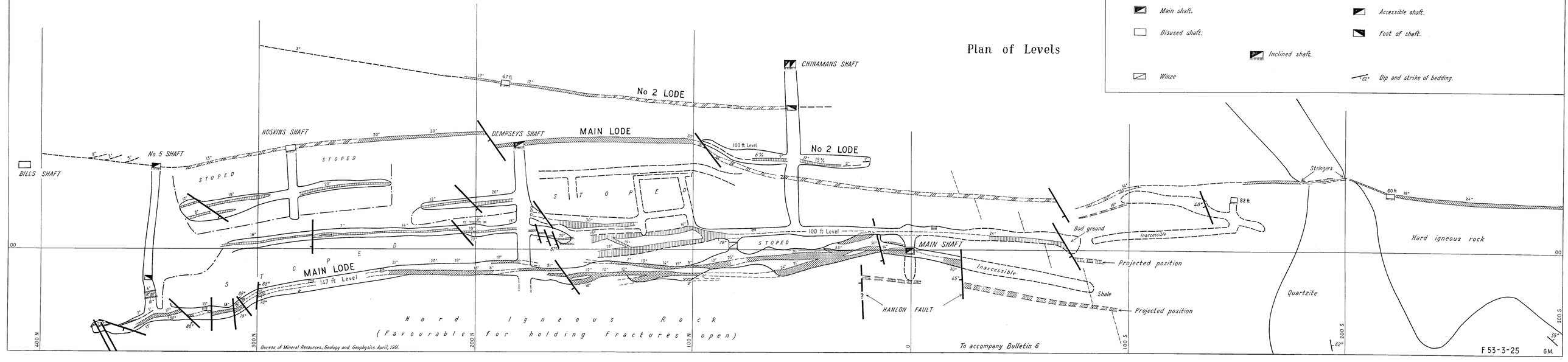
17/2/57

Original by A.G.G.S.N.A.

REFERENCE

- Geological boundary – position accurate.
- Geological boundary – position approximate.
- Fault – showing dip.
- Fault – position inferred.
- Workings – accessible.
- Workings – inaccessible.
- Main shaft.
- Disused shaft.
- Winze
- Reef at surface – position accurate – showing width and dip.
- Reef at surface – position approximate.
- Reef at 100 ft. level.
- Reef at 147 ft. level.
- Reef at 182 ft. level.
- Ore pass.
- Accessible shaft.
- Foot of shaft.
- Inclined shaft.
- Dip and strike of bedding.

Plan of Levels



Bureau of Mineral Resources, Geology and Geophysics April, 1961.

To accompany Bulletin 6

F 53-3-25 6.M.

PLATE 21

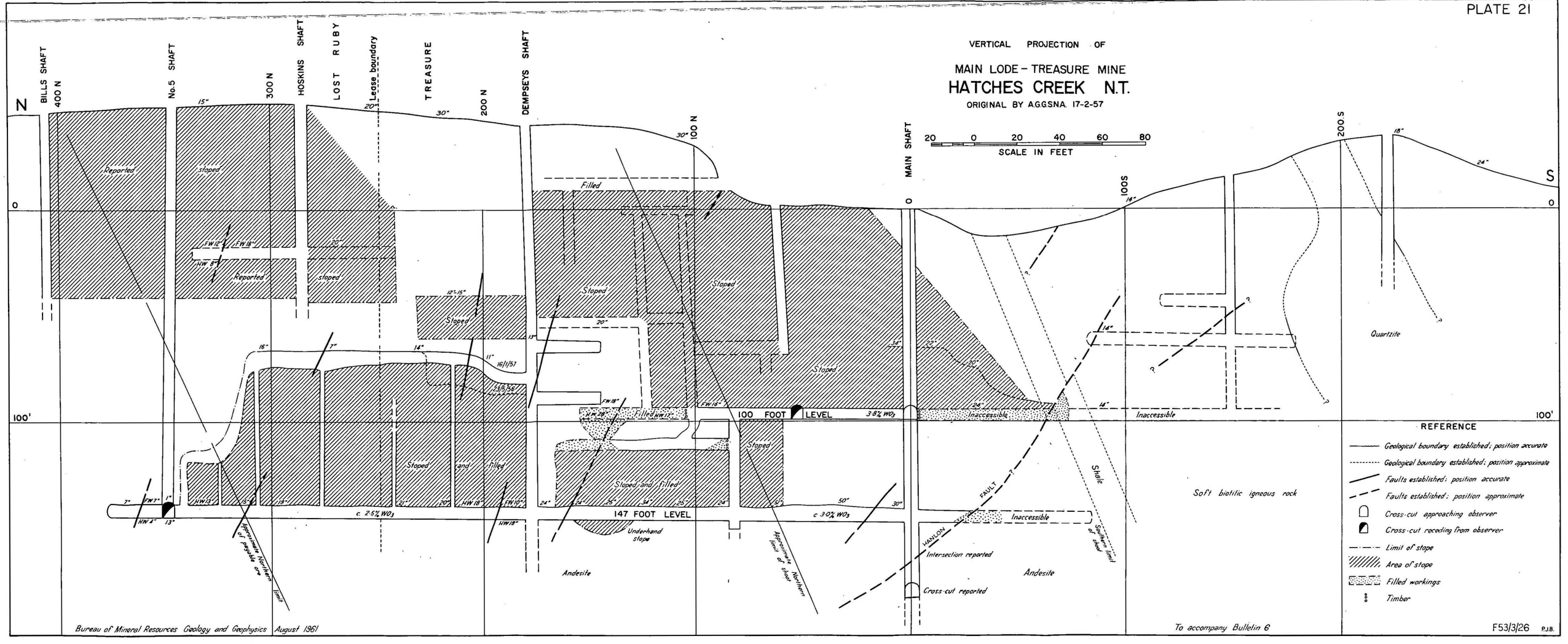
VERTICAL PROJECTION OF

MAIN LODE - TREASURE MINE

HATCHES CREEK N.T.

ORIGINAL BY A.G.G.S.N.A. 17-2-57

SCALE IN FEET 20 0 20 40 60 80



REFERENCE

- Geological boundary established; position accurate
- Geological boundary established; position approximate
- Faults established; position accurate
- Faults established; position approximate
- Cross-cut approaching observer
- Cross-cut receding from observer
- Limit of stope
- Area of stope
- Filled workings
- Timber

Bureau of Mineral Resources Geology and Geophysics August 1961

To accompany Bulletin 6

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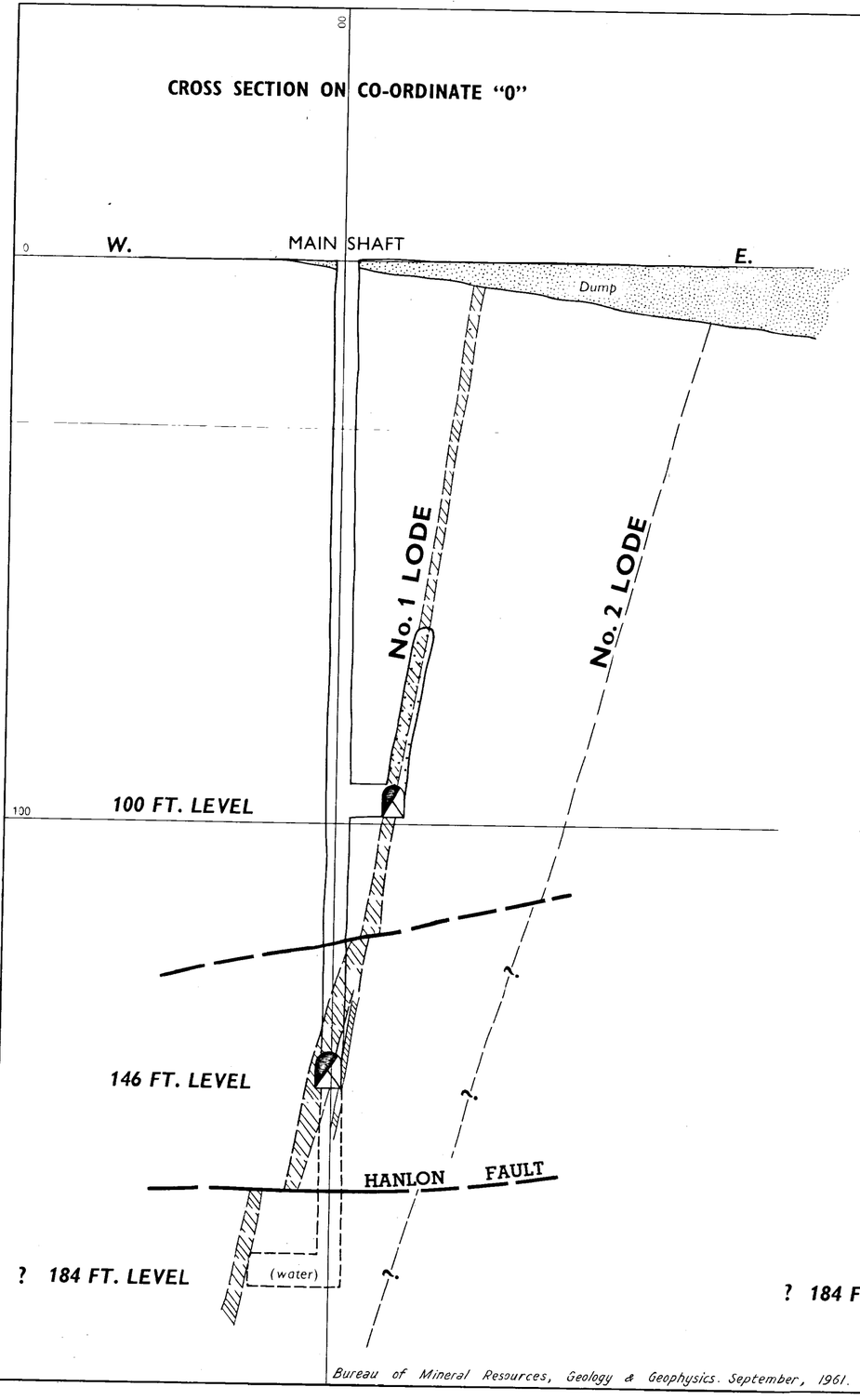
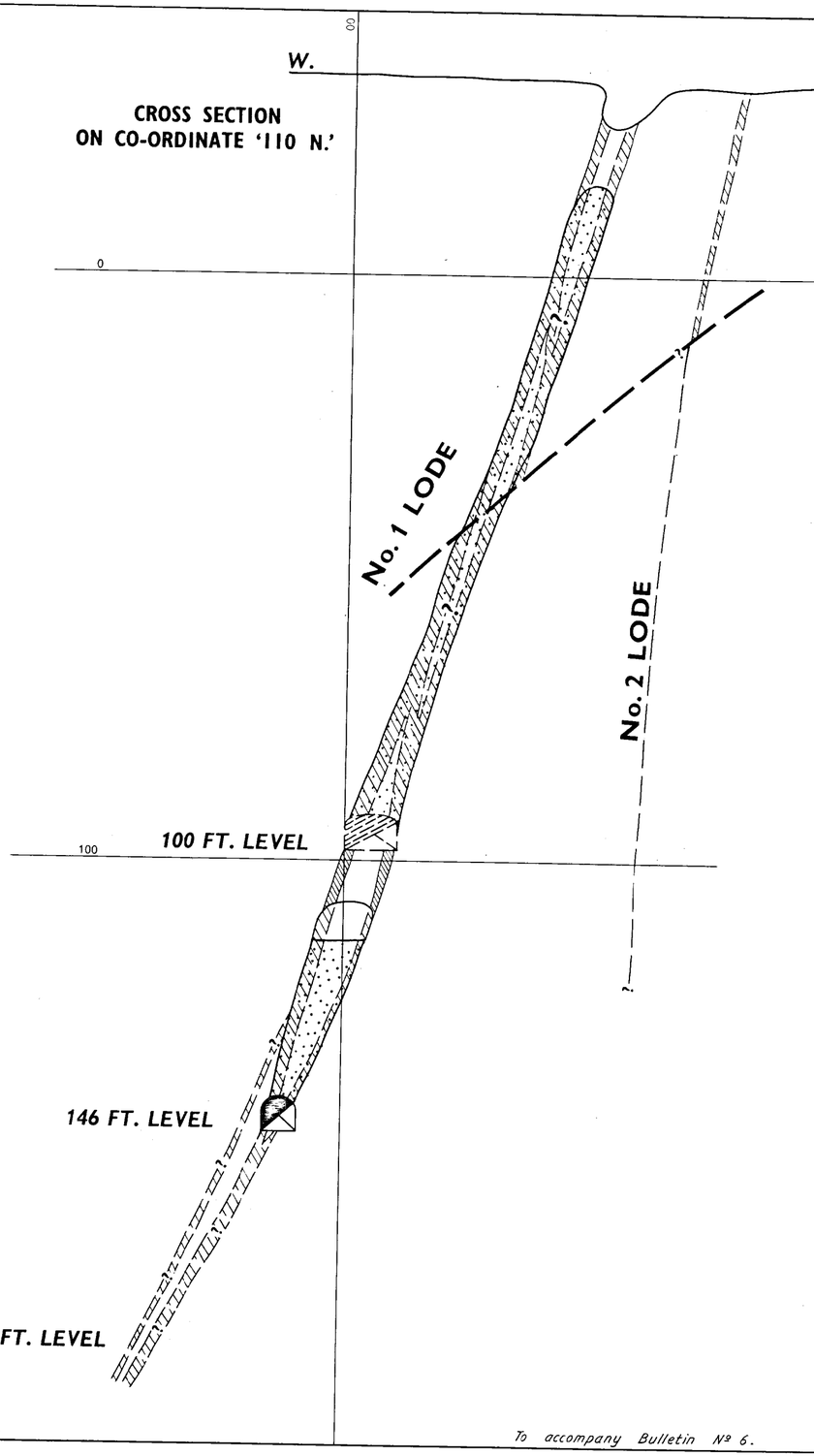
PLATE 22

CROSS SECTION ON CO-ORDINATE "0"



CROSS SECTION ON CO-ORDINATE '110 N.'



CROSS SECTIONS
MAIN LODE AND No. 2 LODE
TREASURE MINE
HATCHES CREEK N.T.

SCALE

20 10 0 20 40 60 Feet

17.2.57

REFERENCE

- Reef, position accurate
- Reef, position approximate
- Narrow reef
- Fault, position accurate
- Fault, position approximate
- Fault, position inferred
- Drive or cross cut approaching or receding from observer
- Inaccessible drive
- Stope accessbile
- Stope inaccessible
- Inaccessible workings
- Accessible workings

Bureau of Mineral Resources, Geology & Geophysics. September, 1961.

To accompany Bulletin No 6.

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The andesite is the most favourable rock type for the formation of the lode channel because it forms well defined firm walls to the channel, thus facilitating the emplacement of ore-bearing solutions. The softer, more acid rocks are less favourable because they form unstable walls. The sedimentary rocks are the least favourable. The tough quartzite has caused the lode to split into thin quartz stringers. A soft shale encountered in the Treasure Mine is unfavourable not only to the formation of the lode channel, but also to mining operations (Sullivan, 1951).

Mineralogy

The lodes of the Treasure Group are remarkably free of impurities. No scheelite has been recognised, and there are only traces of copper, bismuth, and lead. The low limonite content of the lode, and the lack of cavities and of secondary ore minerals, suggests that no metallurgical difficulties will be experienced in the primary zone. A little biotite is present in small flakes in the lode and in places as a selvage.

Grade and Control of Ore

Movement along the lode-channel in the larger lodes has formed shoots where the strike and dip of the lode are favourable. In all the lodes, enriched shoots have formed on splits in the reefs, faults, and other features.

On the Treasure Main Lode the andesite is the most favourable host rock and reefs are most prone to split in it, so that the richest and best defined shoots lie in this rock. The dip of the lodes is commonly flatter and the strike more westerly in the andesites but the reefs are very irregular. The shoots plunge to the south-west at 70°, parallel to the plunge of the intersection of the lode with the stratification of the country rocks.

Nothing is known of the control of ore on the Hidden Treasure No. 3 Lode and No. 4 Lode, but there is no reason to suspect that deposition is influenced by factors other than those operative on the eastern lodes and the Treasure Main Lode. Any shoots on the No. 3 and No. 4 lodes can therefore be expected to plunge to the south-west at 40° to 55°.

Sullivan (1951) states that the grade of ore on the Treasure Main Lode was 3.83% WO_3 at the 147-foot level. These figures are based on tonnages of ore mined and concentrates produced from the Treasure Mine, between 1942 and 1944, by the Commonwealth Government. Ore from the Treasure Mine crushed during 1955 and 1956 graded about 4.5% WO_3 at the mill. This ore was won mainly to the north of Dempseys Shaft (Pl. 21), and therefore not from the richest shoot. A concentration of at least 50% by hand-picking can be assumed.

No information is available on the grade of the Hidden Treasure lodes, but Hossfeld (1941) states that they are poorer than the Treasure Main Lode (about 3% WO_3), and also that the eastern lodes are richer than the western lodes.

Treasure Lodes

The Treasure Lodes lie in the northern part of the Treasure Group, on the Treasure and Lost Ruby Leases, and include the Main Lode, No. 2 Lode, and

No. 3 Lode, as well as several reefs of lesser importance. These lodes lie to the north of the quartzite lens. Lodes to the south of this lens, although occurring within the Treasure Lease, are treated as part of the Hidden Treasure section.

Main Lode. The lode extends for about 800 feet north from the quartzite lens, but the outcrop is obscured for most of this length by dump material (Pl. 19). It has been tested by shallow open cuts and shafts over most of its length, but deeper operations have been concentrated on the richest central portion, which is about 400 feet long. This section has been almost entirely worked out to a depth of 147 feet. Only the Main Shaft, which is reported to be about 180 feet deep but was full of water at the time of the survey, continues below the 147-foot level. The Main Shaft was put down to the 147-foot level by the Government during its operations at the mine, and the drive at this level was begun. The level was extended to the north when the owner of the mine later acquired the Lost Ruby Lease. Most of the stoping on the 147-foot level was done under tribute during 1951, 1952, and 1953.

The drives at both the 100-foot level and the 147-foot level are now inaccessible south of the Main Shaft. Mining at both levels was discontinued when a bed of soft shale was encountered at the south end of the 100-foot level and the 147-foot level. The shoot is about 150 feet wide and plunges to the south-west at about 70°. The lode has a slightly flatter dip, and the aggregate width of quartz is greater within the shoot. The shoot has been completely stoped above the 147-foot level. In February 1957, a small block of ore remained above the level immediately north of the Main Shaft. This has since been removed and was very rich. Sullivan (1951) states that the shoot yielded 3.8% WO_3 above the 100-foot level, and this grade has been maintained in recent stoping.

The lode is cut by several small faults. The Hanlon Fault (Pl. 20), which is the largest, has displaced the lode about 12 feet south-block-west. The drive at the 100-foot level was not continued past the fault as it coincides with the shale at this level. The drive was continued for about 60 feet in the footwall of the lode at the 147-foot level until the shale was encountered, when driving ceased. The lode has not been proved south of the Hanlon Fault on this level, although it is reported that a short cross-cut was put out to the west to locate it. The cross-cut is believed to have been driven at a sharp angle to the drive; hence it may not have penetrated far enough into the hangingwall. Although stoping of this section of the lode will be complicated by the presence of the Hanlon Fault, the lode here lies within the projected limits of the shoot, and should carry high-grade ore.

The Hanlon Fault was intersected in the Main Shaft at an unknown depth below the 147-foot level. The lode has been proved in a short cross-cut to the west at about 180 feet, where it shows no decrease in width and is carrying good wolfram. It is expected that the Hanlon Fault will be met between 10N and 40N at this level.

The Main Lode has been tested to the 100-foot level from a shaft at 148S lying south of the shale. The lode lies in a biotitic igneous rock, possibly a lamprophyre,

which forms poor walls to the lode channel. This shaft, and a shallower one to the south, are now inaccessible. The lode is reported to be poor.

No. 2 Lode. The No. 2 Lode lies parallel to, and between 20 feet and 50 feet east of, the Main Lode. Its outcrop is about 500 feet long and consists of discontinuous quartz reefs of very variable width. The most productive section of the lode lies opposite that of the Main Lode, i.e. in andesite. The lode dips at about 85° to the west over most of its length, but where two reefs overlap their dip becomes more irregular. Hossfeld (1941) reports that two tons of wolfram had been won from this lode from open cuts. A shaft now covered by dumps was sunk on this reef to a vertical depth of 47 feet, east of Dempseys Shaft (Pl. 19). The lode at this point consists of a quartz reef 12 inches wide dipping west at 80°, and it seems probable that most of the wolfram was won from this section. At the 100-foot level, the lode, which is exposed in a drive 60 feet long, is very irregular in width (Pl. 20), and does not warrant further exploration.

No. 3 Lode. This lode lies about 150 feet east of No. 2 Lode. It is about 200 feet long at the surface and consists of one or two quartz reefs with an aggregate width of 5 to 14 inches. Three shafts have been put down to an approximate vertical depth of 50 feet (Pl. 19). The stopes are now inaccessible, but according to the owner, about 38 feet of stoping was done on tribute and 7 tons of wolfram were won. This gives an approximate grade of about 1.7% WO_3.

The lode has an arcuate outcrop. At the northern end the strike is roughly parallel to the Main Lode, and the dip 70-75° to the west. At the southern end the dip becomes steeper as the strike swings more nearly north. The northern part of the lode is the richer.

Other Lodes. Although most of the ore has been won from the rich sections of the lodes, a little wolfram has been obtained from shallow open cuts on the poorer sections of the lodes, and from other quartz reefs adjacent to the lodes. These sections may yield further ore near the surface, but cannot be expected to support deeper operations.

Ore Reserves. Some wolfram may be won from No. 2 and No. 3 Lodes, but the Main Lode offers the best prospects of development. More is known about this than about most of the lodes at Hatches Creek. The average aggregate width of quartz over 400 feet of the lode is about 24 inches, and the grade is known to be at least 2% WO_3. The lode also carries about 3% WO_3 in a shoot 150 feet wide. This shoot should prove profitable even under relatively adverse conditions in the wolfram market. The lode is 800 feet long at the surface and can be expected to persist without change in width and grade to a depth of at least 300 feet. It is estimated that about 230 tons of wolfram can be extracted between the 250-foot level and the 147-foot level, and a similar tonnage may be present between the 350-foot level and the 250-foot level. In addition a small block of ore lies above the 147-foot level south of the Main Shaft. This ore should contain 25 tons of standard concentrate, but some may not be minable owing to the presence of the Hanlon Fault.

Hidden Treasure Lodes

The Hidden Treasure Lodes lie on the steep southern flank of the Treasure Gully and die out either north of or in the quartzite of Dooleys Ridge. The lodes spread out like the rays of a fan southwards from an area south of the quartzite lens. They have been extensively exploited in this area, from shafts reported to be at least 100 feet deep, situated on both sides of the gully which crosses the lease at the northern end. These shafts are all inaccessible and some have been concealed by dumps. The exact relationship between the lodes south of the gully and the lodes to the north could not be determined for lack of outcrop.

South of the gully the lodes are more distinct. The most easterly lodes, No. 1 and No. 2, lie close together and roughly parallel. They are contiguous with the Treasure Lodes in strike and dip, and are reported to have been the richest of the Hidden Treasure Lodes. No. 3 Lode and No. 4 Lode lie to the west, and strike at an angle of about 30° to the eastern lodes. The outcrops of all the lodes are mostly obscured by dumps and filled open cuts. Most of the information on these lodes is derived from Hossfeld (1941), and from the miners.

No. 1 Lode. This is the most easterly, the largest, and the richest of the lodes. It crops out for about 480 feet across the lease and strikes at about 340°. It persists for about 100 feet into the quartzite to the south, and is the only one of the four main lodes to do so.

The lode consists of two parallel quartz reefs aggregating about 10 inches in width towards the north end, but to the south only one reef, 6 to 9 inches wide, is present. Several smaller leaders and veins of quartz join the reefs at low angles, but these are narrow, short, and poor. The main reefs dip west at between 65° and 85°. Hossfeld (1941) reports that shoots have been formed where the dips are relatively flat and the strike is more to the west; in fact the shoots are subject to the same structural control as the Treasure Main Lode.

The lode has been open-cut over the greater part of its length, and in the richer northern section is reported to have been stoped to a depth of about 100 feet below the collar of Herreens Shaft (Pl. 19). The outcrop is almost completely obscured by spoil between Herreens Shaft and Perrys Shaft, but very little work has been done south of Perrys Shaft, where the lode lies in the quartzite and is irregular in width and dip and inconsistent in grade.

No. 2 Lode. This lode lies immediately west of No. 1 Lode, and the two are connected by several quartz veins and leaders. It consists of two reefs which dip west at about 80°, and strike slightly more to the north than the No. 1 Lode. The two lodes are nearer together at their northern end.

The lode is reported to consist of two very wide reefs near the Water Shaft (Pl. 19), but these narrow rapidly to the south and die out north of the quartzite of Dooleys Ridge. At the south end of the lode, two reefs diverge rapidly, one to the east and one to the west. The reef to the west dips east at about 85°. Stopes are believed to be continuous between The Boys Shaft and the Water Shaft at the northern end of the lode.

No. 3 Lode. This lode consists of three quartz reefs, arcuate in outcrop, emplaced along two intersecting shears. One shear strikes at about 025°, and dips steeply south-east. The other strikes at about 355°, and dips steeply west. The reefs have been numbered 3A, 3B, and 3C from north to south (Pl. 19). Reefs 3B and 3C are narrow and poor, and it is doubtful whether they will support other than surface operations. Reef 3A offers better prospects for development as the strike and dip are more favourable. A shallow shaft, now inaccessible, has been put down at the northern end of Reef 3A, but it is not known whether any good ore was found. No. 3 Lode is the least favourable of the four main lodes.

No. 4 Lode. The No. 4 Lode crops out for 400 feet between the quartzite of Dooleys Ridge and the northern boundary of the lease. The lode strikes between 005° and 015°, and is almost vertical with steep dips to both east and west. It has been extensively open-cut over most of its length, and has been exploited to a considerable depth from at least three shafts. Spoil obscures all but one of these shafts.

Two quartz reefs are reported to be present over most of the length of the lode, and they range in width from 3 inches to 12 inches. Nothing is known of the grade or the control of the ore, but judging from the amount of stoping the lode is comparatively rich, especially in the central and northern part. If the ore is controlled by the intersection of the lode with favourable host rocks, the shoots can be expected to plunge to the south-west at 40-55°, depending upon the dip of the lode. Very rich ore was obtained from a shallow shaft toward the southern end of the lode. This shaft was put down just south of a small fault which has displaced the lode, and the deposition of the wolfram may have been controlled by the fault.

None of the several smaller reefs on the lease warrants exploration. The largest crops out near and parallel to the contact between the quartzite and the volcanic rocks, but dips to the north at 75-85°. It is 3 - 6 inches wide and about 400 feet long. There has been some enrichment at the intersection of this reef with the No. 1 Lode (Pl. 19), but the reef is poor along the rest of the outcrop.

Some small quartz reefs lie between No. 2 Lode and No. 3 Lode, and west of No. 4 Lode. They all have been tested by shallow open cuts without success.

Rich eluvial wolfram has been won from the gullies to the west, east, and north of the lodes. Experience at Hatches Creek has shown that many eluvial deposits can be profitably reworked, and this could well apply to the deposits on the Hidden Treasure Lease.

Ore Reserves. In the absence of any accurate information on the grade or width of the reefs, or on the extent of operations, an estimation of ore reserves must be very tentative. It appears that the limits of open-cutting on the larger lodes have been reached, though small amounts of wolfram may be available to prospectors in places.

Only the four main lodes offer any prospect of deeper development; and of these No. 3 Lode is doubtful, and Nos. 1, 2, and 4 have already been exhausted to a

depth of between 50 and 100 feet. The fact that stoping has been confined to the northern portions of the lodes suggests that only these portions need be considered as further sources of ore. A tentative grade has already been given for the lodes and it is assumed that this grade is only present in the shoots, over widths of 150 feet to 200 feet. Nos. 1, 2, and 4 Lodes are long, continuous, and well defined, and have already yielded considerable tonnages of ore. It is assumed that no ore remains in the shoots on these lodes above the 100-foot level, but the shoots will probably persist for at least 100 feet below this level. The No. 1 Lode is the most likely to persist below this again.

The average aggregate width of quartz in the lodes appears to be 12 inches or less. Large tonnages of country rock will therefore have to be broken, but cut-and-fill methods should minimise the dilution of the ore. Where the lodes consist of two parallel reefs, stoping will be facilitated.

On the assumption that the lodes will carry 2.0% WO_3 and that the reefs will average 12 inches in width over a length of 150 feet in each lode, there should be about 100 tons of standard concentrate available from the three principal lodes between the 100-foot level and the 200-foot level.

Conclusions

Four lodes, of which the Treasure Main Lode is the richest, have contributed the greater part of the wolfram won from the Treasure Group. Unfortunately, information on the Hidden Treasure lodes is too scarce to make a proper evaluation of them, but on the evidence available there seems to be no reason why they should not maintain a grade of about 2% WO_3, to a depth of 200 feet. The Treasure Main Lode, which is 800 feet long at the surface, could maintain the proved grade of about 2.5% WO_3, over 400 feet to a depth of 400 feet. As the Treasure lodes and the Hidden Treasure lodes occupy a conjugate system of shearing 1,500 feet long, payable ore may well be found below 400 feet.

The mines can be expected to make a considerable amount of water, by local standards, at the deeper levels, and provision will have to be made for pumping. On the other hand, the three Hidden Treasure Lodes are so placed that they could be developed from a single, centrally-placed vertical shaft, thus reducing costs. Possible ore reserves for the group are estimated at 330 tons. Exploration of the main lodes should prove more than this, and a small tonnage will be available from the smaller lodes in the group, particularly the Hidden Treasure No. 3 Lode, and the Treasure No. 3 Lode.

Hit or Miss Locality

Tungsten deposits are more heavily concentrated at the eastern end of the Hit or Miss Gully than anywhere else on the mineral field. Five groups of deposits stretch for a mile and a half west-south-west from Goat Hole, along the southern side of Dooleys Ridge (Pl. 4). Three of the groups, the Hen and Chickens Group, the Masters Gully Group, and the Kangaroo Group, occupy approximately the same stratigraphic horizon in the Hatches Creek Group. The

Hit or Miss Group, the largest at Hatches Creek, lies slightly higher in the sequence. The small, and relatively unimportant, B.X.B. Group lies south-east of the Hen and Chickens Group.

B.X.B. Group
(Pls 4 & 23)

The B.X.B. Group consists of two sets of lodes lying about 400 yards apart, but described together for convenience. The two sets are covered by separate leases. The more important lodes lie on the B.X.B. Lease, which is 600 yards south of Goat Hole; the unimportant Rocky Ridge lodes lie to the south.

History

Oliver (1916) mentions the group as 'The Only One' and reports that a small amount of rich ore was mined. In 1940 some surface development had been done and three shallow shafts put down on the B.X.B. lodes. The northern lodes are described as 'Purdy's Old Workings'; the southern lodes as 'Mathews Lease' (Hossfeld, 1941).

Nothing more is known of the group until 1951, when the B.X.B. and Rocky Ridge leases were registered. The B.X.B. was under continuous operation until 1956, when the Main Shaft was abandoned because of water, but the Rocky Ridge lodes are too poor to support underground development, and operations on these lodes have been limited.

Production

Oliver (1916) reported that 1.5 tons of wolfram were won in six weeks, probably from the B.X.B. No. 1 Lode (Pl. 23), in either 1915 or 1916. Hossfeld (1941) records that 4 tons of concentrate were reported to have been won from the B.X.B. lodes, and between 0.5 and 1 ton from the Rocky Ridge lodes, up to 1940. There is no record of production from either set of lodes between 1940 and 1951. The B.X.B. Lease produced 11.47 tons of concentrates valued at £11,282 between 1951 and 1957, and the Rocky Ridge Lease produced 0.36 tons worth £570 in 1952. The known production from the group is 18.95 tons, and the total production from the group is not thought to be much more than this.

Geology

The B.X.B. lodes lie west of, and the Rocky Ridge lodes east of, a major wrench-fault, and the lodes make an acute angle with the fault. The fault is part of the fault zone which forms the eastern limit of mineralization at Hatches Creek. It appears that the shear zones which acted as host to the ore-bearing solutions were displaced by the fault.

The lodes consist of several reefs emplaced along wide shear zones. The reefs range in width from 3 inches to 15 inches and are vertical, or dip steeply to the east or west. The lodes lie mainly in acid volcanic rocks, but the south end of the B.X.B. No. 1 Lode lies in sandstone and quartzite which dip south at about 75°. The reefs become more irregular and indeterminate where they lie in the sedimentary rocks, and their strike changes slightly but definitely. The volcanic and the sedimentary rocks are severely jointed owing to their proximity

to the wrench-fault, and this jointing of the country rock has given rise to more than usual irregularity in the width of the reefs, and to a great number of minor fissures filled with quartz. The reefs are also displaced by many small faults.

The formation of the lode fissures may be due to the presence of a lens of tough sedimentary rock lying in the volcanic rocks, close to the major fault. Movement along the fault was resisted by the harder sedimentary rocks, thus forming a zone of shearing along which ore-bearing fluids intruded.

Mineralogy

Wolfram is the common tungsten mineral, and is associated with minor amounts of scheelite, particularly on the Rocky Ridge Lease. Copper and bismuth carbonates are also present. It has been verbally reported that a specimen of monazite was obtained from the No. 2 Shaft on the B.X.B. Lease, but this report has not been substantiated, and tests with a Geiger Counter revealed no radioactivity in the dumps or the lode.

Biotite is commonly present, generally as a selvage, but also disseminated through the quartz. Kaolin and iron oxides are relatively abundant. The reefs are not sufficiently exposed for a study of the mineralization, but in general they are more highly mineralized than any of the other north-striking reefs at Hatches Creek, though no reason for this is apparent.

Grade and Control of Ore

As the reefs are now rarely exposed either in the open cuts or underground, very little is known about the control of the deposition of wolfram. The lode is visible for 30 feet in the backs of the stope in the Main Shaft, where it is intersected and displaced by many small faults, but none of these faults appears to exercise any control on the deposition of wolfram. However, the stope is reported to be bounded to the north by a relatively large fault dipping to the north. The reef is narrow and poor north of this fault, but it is not known whether the wolfram is localized on the fault, or whether the fault coincides with a change in the strike, width, and dip of the reef. The richest ore is reported to have been obtained south of the Main Shaft where the reef splits. The reefs are irregular, and split frequently, and small leaders and faults are abundant. These features are so closely spaced that if they were responsible for deposition of wolfram, it would be continuous along the reef.

Very little information is available on which to base estimates of the grade of the lodes. A limited amount of stoping has been undertaken from the Main Shaft on the B.X.B. No. 1 Lode (Pl. 23), and it is estimated from reports on the extent of the stoping that about 150 tons of ore was won, and yielded 6.27 tons of wolfram. This is based on an assumed average width of 9 inches for the reef. These figures give an approximate grade of 2.6% WO_3. The grade at the mill of ore crushed during 1955 and 1956 was about 8% WO_3, and the ore must have been hand-picked. The grade appears to be of the order of 2% to 3% WO_3, but this may be confined to a rich section of the reef corresponding roughly to the present limits of the stope.

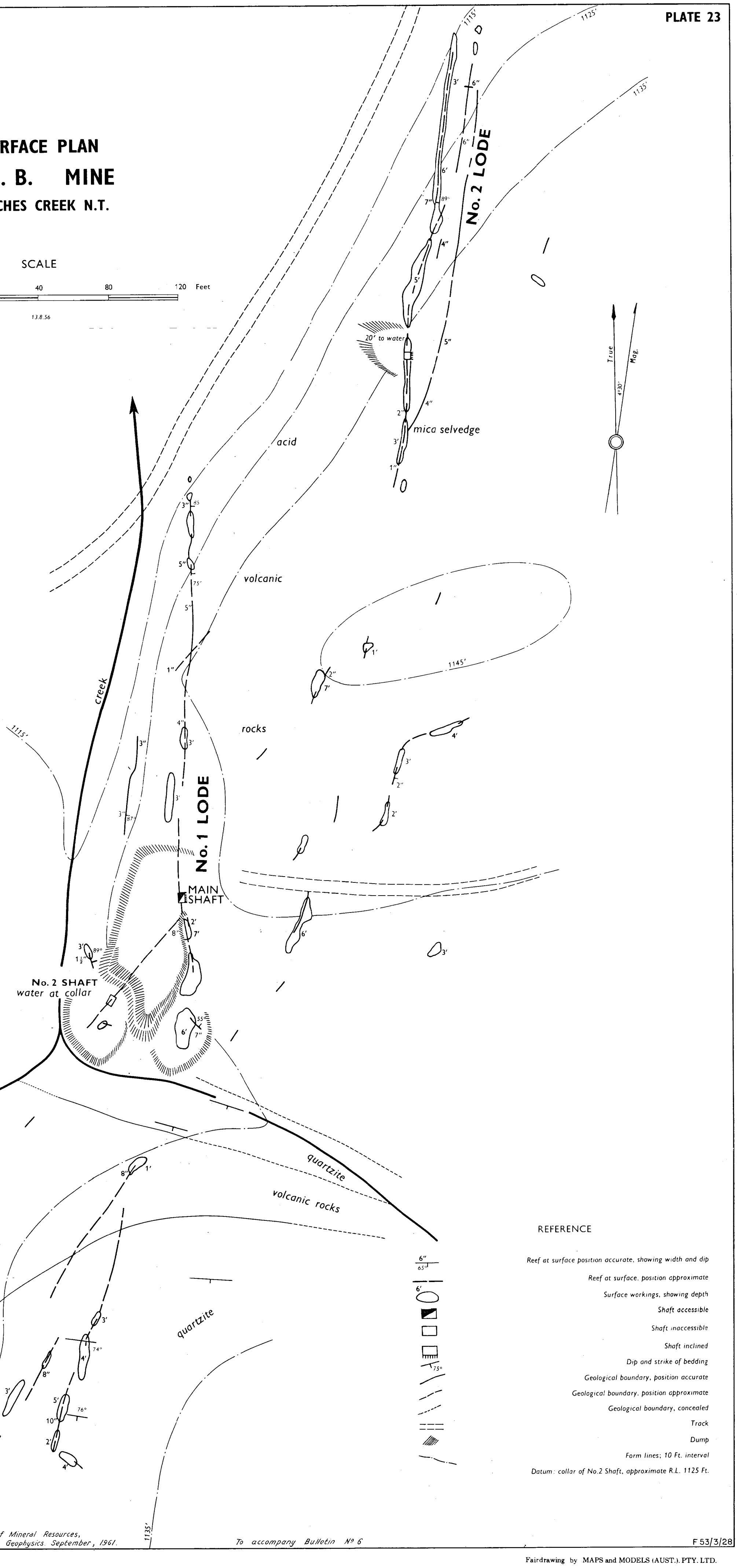
PLATE 23

SURFACE PLAN
B. X. B. MINE
HATCHES CREEK N.T.

SCALE

40 20 0 40 80 120 Feet

13.8.56



REFERENCE

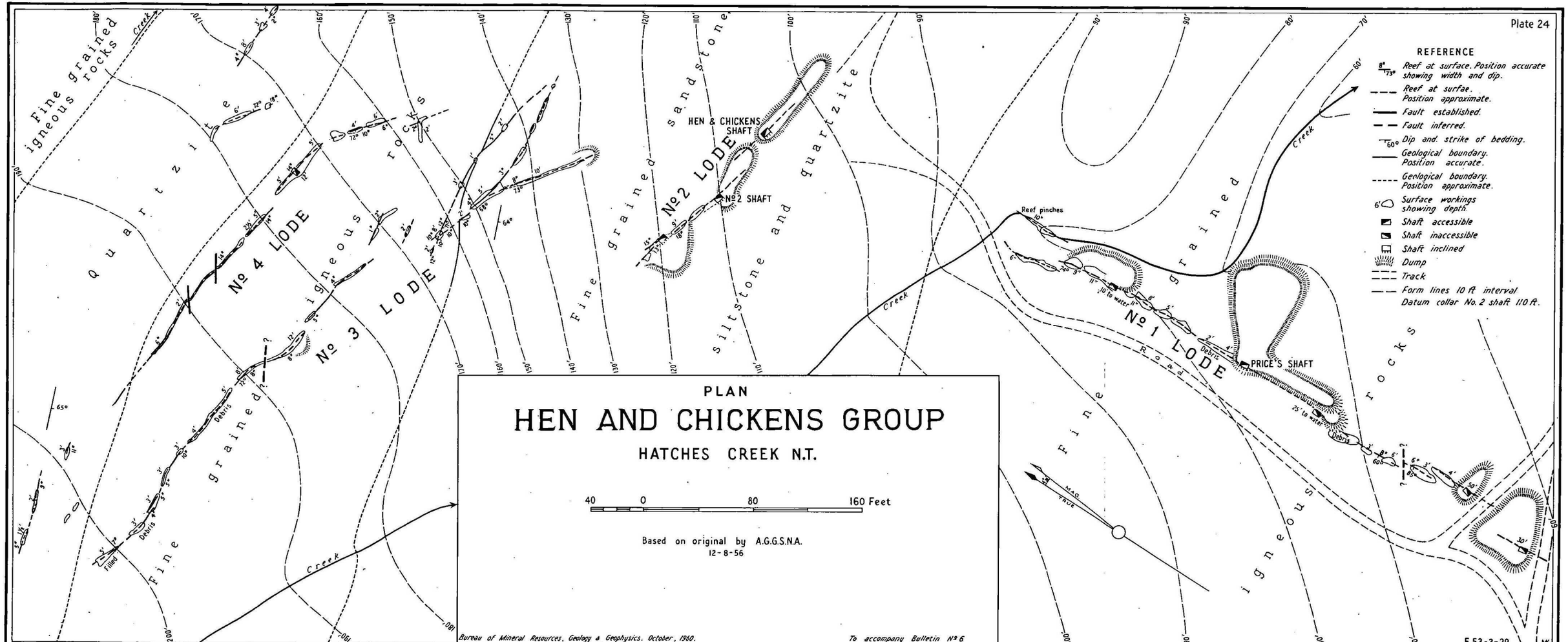
- 6"/65° — Reef at surface position accurate, showing width and dip
- Reef at surface, position approximate
- 6' — Surface workings, showing depth
- Shaft accessible
- Shaft inaccessible
- Shaft inclined
- 75° — Dip and strike of bedding
- Geological boundary, position accurate
- Geological boundary, position approximate
- Geological boundary, concealed
- Track
- Dump
- Form lines; 10 Ft. interval
- Datum: collar of No.2 Shaft, approximate R.L. 1125 Ft.

Bureau of Mineral Resources, Geology & Geophysics. September, 1961.

To accompany Bulletin Nº 6

F 53/3/28

Fairdrawing by MAPS and MODELS (AUST.). PTY. LTD.



PLAN

HEN AND CHICKENS GROUP

HATCHES CREEK N.T.

40 0 80 160 Feet

Based on original by A.G.G.S.N.A.
12-8-56

Bureau of Mineral Resources, Geology & Geophysics. October, 1960.

To accompany Bulletin Nº 6

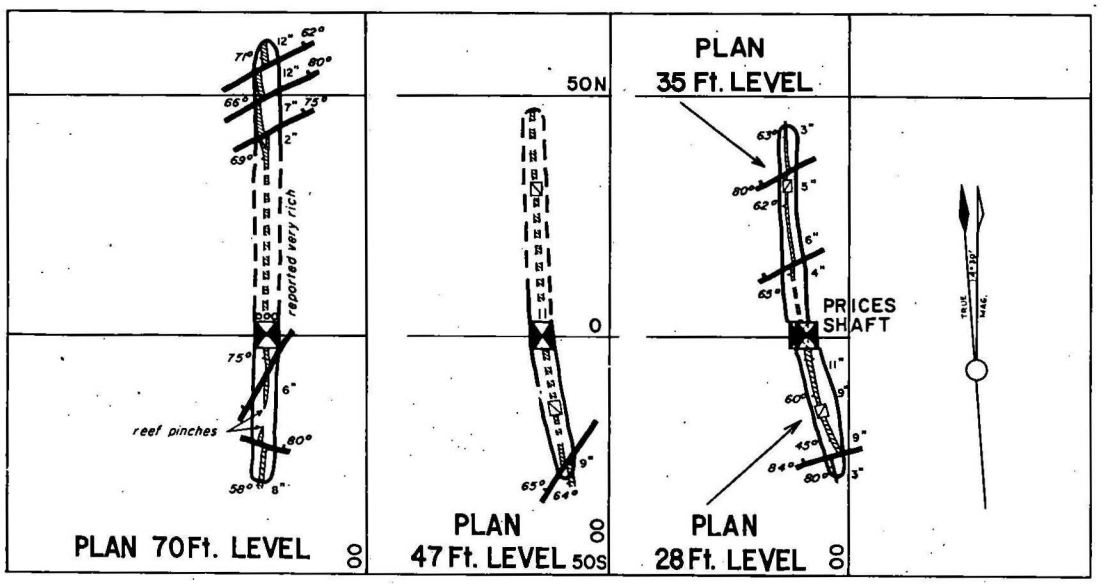
F 53-3-29

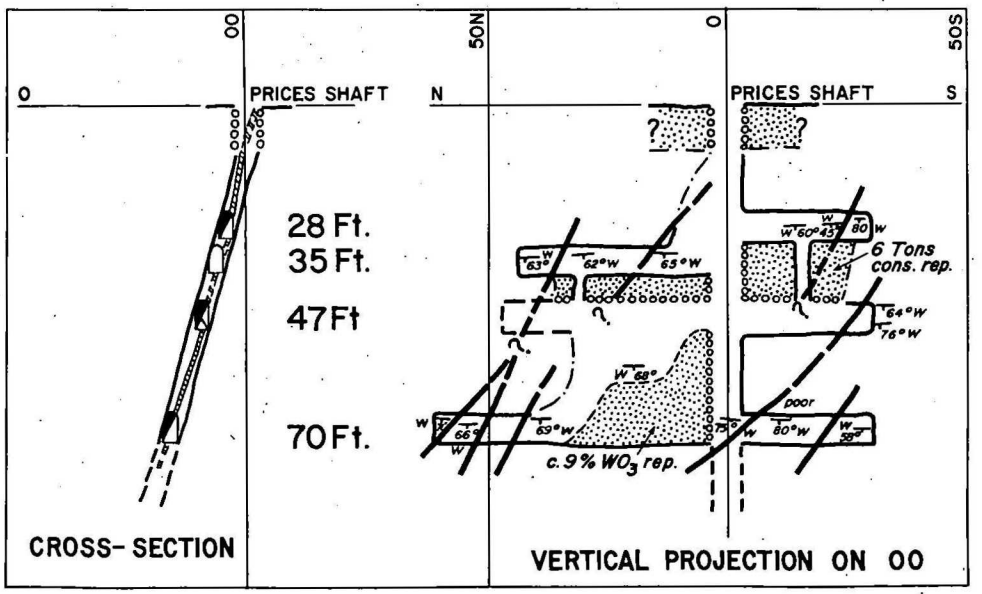
PLATE 25

PLANS AND SECTIONS
PRICES SHAFT Nº1 LODE
HEN AND CHICKENS GROUP
HATCHES CREEK, N.T.

22·7·1956

Scale
20 10 0 20 40 60 Feet





REFERENCE

- Reef. Position accurate showing width and dip.
- Reef. Position approximate or inferred.
- Fault showing dip and strike.
- Accessible workings.
- Inaccessible workings.
- Limit of stope.
- Filled stope
- Timber.
- Shaft passing through level.
- Head of rise or winze.
- Foot of rise or winze.
- Drive receding from observer.
- Drive approaching observer.
- Drive receding from and approaching observer.

Bureau of Mineral Resources, Geology and Geophysics. Aug. 1961. To accompany Bulletin Nº6.

F 53/3/30 EJ

A C B

Reduce AB (18") to AC (9")

Individual Lodes

B.X.B. No. 1 Lode. This lode consists of a complex arrangement of quartz reefs about 550 feet long. It strikes about north-south where it lies in volcanic rocks, and at 012° where it lies in sedimentary rocks. The reefs are too narrow and too poor to justify underground development, other than on a short central portion near the Main Shaft (Pl. 23). The outcrop of this section of the lode is almost totally obscured by mullock, and the underground workings are inaccessible.

The lode lies in sedimentary rocks at the southern end, and the reefs are narrow and discontinuous, but to the north they are more continuous. They range in width from 3 inches to 15 inches and are vertical or dip very steeply to the west. The Main Shaft has been put down on the most easterly reef, which is the richest. The shaft, in which water now stands at 38 feet, is reported to be about 60 feet deep. A drive extends 40 feet to the north at the 60-foot level, and a second drive extends 70 feet to the south at the 45-foot level. The lode is stoped out above these levels to 20 feet below the collar of the shaft, where it is exposed for 30 feet. It is about 12 inches wide throughout this section, except to the north of a small fault at the extreme north end of the exposure, which strikes north-east and dips steeply to the north. Beyond the fault the reef is 6 inches wide, narrowing northwards to 2 inches. The reef dips east at 65° at the south end, but steepens to 85° at the north end, where it is displaced by the fault. It is also cut by several other smaller faults which dip steeply to the south, but which have very small displacements.

No. 2 Shaft (Pl. 23) was put down on another reef which strikes at about 040° and which is reported to intersect the main reef of the No. 1 Lode south of where it is exposed in the backs. Water now stands at the collar of No. 2 Shaft and nothing is known of the reef or the extent of the workings in the shaft.

B.X.B. No. 2 Lode. This lode, which is relatively unimportant, consists of three quartz reefs striking between 360° and 010° and cropping out continuously for about 250 feet. The reefs may continue under alluvium to the north, but this is considered unlikely. Only the most westerly of the reefs has been developed: shallow open cuts extend over most of its length, and one shaft has been put down. Water stands at 20 feet in the shaft, but the size of the dump suggests that it may be fairly deep. The reefs are from 3 to 7 inches wide, and are vertical or dip steeply to the east. They carry very little wolfram, except for a short section of the westerly reef adjacent to the shaft.

A series of short discontinuous reefs continues south of the lode and may represent a continuation of the lode-shear. This line of small reefs intersects the No. 1 Lode south of the Main Shaft and continues into the sedimentary rocks (Pl. 23).

Rocky Ridge Lodes. These are two short lodes containing discontinuous quartz reefs which are 9 to 12 inches wide and dip steeply to the west. One lode is about 300 feet long and strikes at about 010°. The second is shorter and strikes approximately north; it intersects the first lode.

Two shafts of 24 feet and 14 feet were reported to have been sunk (Hossfeld, 1941), but there is now no sign of them. Shallow open cuts extend almost continuously along the lodes. Although as wide as the B.X.B. lodes, these lodes are much poorer, and so far as is known have produced about one ton of concentrates.

Conclusions

With the exception of a short section of the B.X.B. No. 1 Lode, the B.X.B. Group has been developed only by shallow open cuts. The No. 1 Lode offers the best prospects for development, but the presence of water — which has already caused the abandonment of the mine once — and the lack of information render further exploitation uncertain. The re-opening of the mine cannot be recommended except under the most favourable economic conditions.

Hen and Chickens Group
(Pls. 14, 24, & 25)

The Hen and Chickens Group consists of three lodes striking between 280° and 300° and a fourth to the south striking approximately 180°. The group lies about 500 yards south-west of Goat Hole, and about 500 yards north-west of the B.X.B. No. 1 Lode, on the southern flank of Dooleys Ridge.

History

The group has been operated under the name of 'Hen and Chickens' since before 1916. In that year two lodes, believed to be No. 1 and No. 2 (Pl. 24), were being worked and some rich ore was mined (Oliver, 1916). The lease lapsed in 1922 and was reregistered in 1935, since when operations have been almost continuous, although different lodes have been exploited at different times. The lease was held by several successive owners before Mr F. Vandenberg acquired it in 1951. Production ceased in 1957, and the lease has since been sold for a nominal sum.

Production

The group is known to have produced at least 68 tons of concentrates. Hossfeld (1941), states that production up to 1940 was reported to be 24 to 25 tons. Since 1940, 43.65 tons of concentrates worth £36,710 have been sold. It is likely that a considerable tonnage was also won between 1916 and 1922, so that the true production from the group is higher than the recorded production.

Table 12 gives the annual production of concentrates since 1940. No details are available as to the source of the wolfram except for 12.39 tons of concentrate known to have been won from Price's Shaft. However, this is only a part of the total production from that shaft.

Geology

The four main lodes have been numbered consecutively from south to north. No. 1 Lode strikes at about 180° and dips west at 60° to 80°. Nos. 2, 3, and 4 strike between 280° and 300° and dip south at varying angles.

TABLE 12

HEN AND CHICKENS GROUP, HATCHES CREEK

ANNUAL PRODUCTION OF WOLFRAM CONCENTRATES

1940 - 1958

Year ending 30th June	Concentrates Tons	Value £
1940	1.13	194 (a)
1941	1.58	257
1942	0.71	230
1943	—	—
1944	2.14	584
1945	3.19	1,021
1946	1.99	682
1947	0.81	381
1948	0.31	160 (a)
1949	—	—
1950	—	—
1951	1.48	2,340
1952	4.24	6,951
1953	4.29	5,304
1954	11.85	9,982
1955	4.13	3,425
1956	2.33	2,163
1957	3.47	3,036
1958	—	—
Total	43.65	£36,710

(a) Value calculated from mean price of wolfram for relevant year.

The lodes lie in interbedded sedimentary rocks and volcanic rocks which overlie the main body of quartzite forming Dooleys Ridge. Two large faults striking north-west lie one on either side of the group. The lode fissures are thought to have been formed as a result of stresses set up by the different competence of the various host rocks in which the lodes lie.

No. 1 Lode lies entirely in volcanic rocks, and terminates to the south, so far as is known, in finely interbedded siltstone and volcanic rock. They do not crop out, however, and the extent to which the lode penetrates them is not known. North of the No. 1 Lode, the No. 2 Lode lies in interbedded sandstone, siltstone, and quartzite. These are succeeded to the north by acid porphyry, quartzite, and again acid porphyry, before the main body of quartzite is encountered. The sedimentary rocks strike at about 070° and dip south at 65°.

Nos. 1, 2, and 4 Lodes consist of a dominant reef with subsidiary quartz stringers, but No. 3 Lode consists of a series of small reefs emplaced along a complicated shear system. Few of the reefs are more than 12 inches wide.

Mineralogy

Wolfram is the dominant ore mineral; scheelite is rare. The lodes, especially No. 1 Lode, carry widespread but slight copper minerals. Malachite, chalcocite, covellite, and a little chalcopyrite have been identified from the No. 1 Lode, and native bismuth may be present (Appendix 2). Iron oxides are abundant, but the reefs have few cavities. Mica is present as a selvage, in small stringers, and as small flakes disseminated through the ore. The primary zone has not been entered, but the presence of grains of chalcopyrite in the specimens examined

suggests that it is the source of the secondary copper minerals. Pyrite may also be present below the water table.

The minor ore minerals have been separated by hand in the past without much difficulty. The percentage of copper present does not warrant the separation of copper as a by-product as is done on other mines. The lowest level of operations on the No. 1 Lode, which carries the highest percentage of copper, is below the water table, and is inaccessible. The amount of copper mineralization can be expected to decrease as the primary zone is entered, and difficulties are not likely to be experienced from contamination of the ore by copper or bismuth.

Grade and Control of Ore

The scanty evidence available on the control of the deposition of wolfram suggests that shoots may not be determined by the attitude of the reef. Hossfeld (1941) found that the richest ore on the No. 2 Lode was located on sections of the reef with a strike of about 280° and a steep dip. Only a short section of the reef on the No. 2 Lode was exposed during the present survey, at the 57-foot level in the Hen and Chickens Shaft. It was found that high-grade ore was present where the reef had a relatively flat dip of 54°; where the reef was steeper and had a strike of about 290° it was poorer. These observations do not agree with those recorded by Hossfeld. The reef is cut by a small fault, however, and the highest grade of ore lies to the west of this fault.

Examination of the reef in Price's Shaft on the No. 1 Lode was equally inconclusive. The reef is displaced by small faults, and the width, strike, and dip on either side of these faults is in places markedly different. Very rich ore is localized along some sections of the reef, but whether the deposition of the wolfram was controlled by the faults, or by the attitude of the reef between the faults, could not be determined.

In view of the conflicting evidence obtained on the No. 2 Lode with regard to the attitude of the reef it is more probable that the presence of a fault is the reason for the deposition of the wolfram. If this is so, the rich sections of the lode will plunge parallel to the intersection of the faults with the reef.

Few figures are available on the tonnage of ore produced from the various lodes, and as a great proportion of the stopes on the No. 1 Lode and No. 2 Lode are now inaccessible, no estimate can be made of the tonnage of ore won. The milling grade of 126 tons of ore crushed from Price's Shaft during 1955 and 1956 was 6.26% WO_3. The ore is very patchy, however, and it is reported that a small stope north of Price's Shaft at the 28-foot level yielded 6 tons of concentrates. If the reef was 9 inches wide, about 27 tons of ore were obtained from this stope, and the ore therefore contained about 15% WO_3. The presence of this shoot pocket tends to support the theory that ore is localized along individual features on the reef, rather than along shoots whose attitude and limits can be determined.

No figures are available on the grade or tonnage of ore obtained from Nos. 2, 3, or 4 Lodes but the grade of No. 2 Lode is expected to be comparable with that of the No. 1 Lode, and the other lodes are probably poorer.

Individual Lodes

No. 1 lode. This is the most southerly lode in the Hen and Chickens Group. It consists essentially of one reef emplaced along a shear of small horizontal displacement, and ranging in width from 2 inches to 12 inches. The lode strikes at about 180° and dips to the west at 60 - 80°. It has been tested over a length of about 500 feet from almost continuous open cuts and from four shafts, only one of which, Price's Shaft, was accessible at the time of the survey.

Two shafts, one reported to be about 50 feet deep, the other about 30 feet deep, were put down on the southern end of the lode and it is reported that some very rich ore was obtained. Price's Shaft was accessible to the 70-foot level and extends some distance below this under water. The richer sections of the reef, both north and south of the shaft, above the 70-foot level, have been removed.

The reef is offset by several small north-dipping faults, most of them striking at about 065°, that is, roughly parallel with the strike of the country rocks. The most intense faulting was observed at the north end of the 70-foot level, where the width and dip of the reef change sharply from one side of a fault to the other.

A rich pocket was encountered south of the shaft above the 47-foot level, where the reef has been dragged along a horizontal shear which is visible in the backs of the 28-foot level at 25S. The concentration of wolfram appears to be associated with this shear (Pl. 25). The reef is 9 - 12 inches wide and the dip changes from vertical to 45° to the south as the shear is approached. A second rich section was present south of the shaft at the 70-foot level. Where the reef is visible in this drive it is not more than 6 inches wide, and is reported to have yielded about 8% WO_3.

The ore is so sporadic that no predictions can be made as to its persistence at depth. Further patches of high-grade ore may be present below the present level of operations.

No. 2 Lode. This short lode crops out for about 150 feet and lies about 380 feet north of Price's Shaft. The lode, which consists primarily of one reef, strikes about 280° and dips to the south at 60-75°. The lode has been developed from three shafts. The most easterly of these, the Hen and Chickens Shaft, was the only one accessible in 1956, and the lowest accessible level was at 75 feet. Water stands 20 feet below this level and the shaft is timbered to below the water level. Most of the reef has been removed above the 75-foot level from all three shafts.

The outcrop of the lode is now obscured by spoil except at the western end, where it splits into two reefs 15 inches and 3 inches wide. A short section of reef was visible in the backs at the 57-foot level in the Hen and Chickens Shaft. The reef is about 6 inches wide at the western end of the exposure, where it dips south at 54°, strikes at about 275°, and carries rich ore. At the eastern end it dips at 74°, strikes at 290°, and is much poorer. The two sections of the reef are separated by a small fault striking at 030° and dipping steeply to the west.

Hossfeld (1941) found that 'the ore was concentrated in two sections of the reef which sections are approximately 60 feet in length and contain shoots of wolfram ore 6 feet to 8 feet long. These sections are linked by a barren cross shear striking at about 250 degrees and dipping south-easterly at 50 degrees'. The ore-shoots pitch steeply to the west.

The lode has been exploited to at least 70 feet and at that depth the grade of the ore remains unchanged, and will probably persist for some distance below that level. A small tonnage of ore still remains in the stopes, but will be difficult to extract as the previous random stoping has left the mine in a dangerous condition.

Reopening of the lode will require a certain amount of preliminary cleaning-up. The lack of predictable ore reserves, and the depth to which the lode has already been exploited, coupled with the unfavourable condition of the mine, do not enhance the prospects for future development.

No. 3 Lode. The No. 3 Lode corresponds to the No. 3 and No. 4 Lodes of Hossfeld (1941): it consists of a continuous shear-zone about 500 feet long containing several quartz reefs and quartz stringers. The strikes of the reefs range from 085° to 125°. The lode lies in volcanic rocks except at the eastern end, where it enters sedimentary rocks, and it is in this section that the arrangement of reefs is the most complex.

The reefs are 2 - 12 inches wide and dip south at 65 - 80°. They are generally poor in comparison with those of No. 1 and No. 2 Lodes. Hossfeld (1941) reports that shoots of wolfram 6 to 8 feet long are present and he considered that the reefs had been insufficiently tested in 1940. Very little work has been done since that time except on the most south-easterly reef, which has been tested to a depth of 10 feet. The results of this are not known, but the reef has been abandoned and apparently was not profitable. The No. 3 Lode appears to be the poorest of the four lodes in the group. Further exploration will not be warranted except when the price of wolfram is very high.

No. 4 Lode. This lode lies about 50 feet north of the No. 3 Lode and is parallel to it. Quartz reefs crop out discontinuously for about 600 feet, but only two sections have been developed. Hossfeld (1941) reports that a section 50 feet long near the eastern end of the lode had been tested by two shafts 80 feet and 30 feet deep. This section of the reef was 12 to 14 inches wide and carried rich ore.

No sign of these shafts remained in 1956 and it appears that little, if any, development has been undertaken since 1940. However, two shallow shafts, now inaccessible, have been put down on the western end of the lode, where the reef averages about 12 inches in width and dips steeply to the south. No information is available on the grade of the ore in these shafts.

The reefs are narrow and poor in the central section and dip at 70 - 80° to the south. Wolfram is reported to be present in short shoots. Further ore may be available, particularly at the eastern and western ends of the lode, but in the absence of any information on the extent of underground development or the grade of ore, the reopening of the lode cannot be recommended.

Conclusions

The lodes on this group are narrow but relatively rich. They are admirably suited to operations by small tribute parties, and have been so operated with some success in the past. However, insufficient control has been exercised on the operations of tributers, with the result that some sections of the reefs are now inaccessible or require the removal of considerable quantities of waste before development can be renewed.

The ore is present in rich patches and short impersistent shoots, and the reefs are irregular. The scanty figures available on the grade of the ore are too indefinite to use as a basis for the estimation of reserves, but it is considered that the sections of the lodes which have been profitably operated in the past will continue to prove economical under similar conditions, and that rich pockets can be expected to a depth of at least 200 feet, particularly on the No. 1 Lode. A higher price for wolfram would justify the exploration of those sections of the lodes which have not been thoroughly tested.

Masters Gully Group
(Pls 4, 26, 27, 28, 29, 30, & 31)

The Masters Gully Group lies about three quarters of a mile south-west of Goat Hole, and is remarkable for the diversity of strike and dip exhibited by the main lodes in the group. The lodes lie in sedimentary rocks and volcanic rocks. The group is elongated in a south-easterly direction and lies on two leases, the Masters Gully Lease to the north-west (Pl. 26) and the White Diamond Lease to the south-east (Pl. 27). No. 1 Lode, No. 2 Lode, and No. 3 Lode lie on the Masters Gully Lease. No. 4 Lode and No. 5 Lode lie on the White Diamond Lease. The group lies astride Masters Gully, which has precipitous sides in the north, where it traverses sedimentary rocks, but is much less rugged to the south, where it traverses volcanic rocks. The gully has yielded rich eluvial wolfram.

History

The group was covered by the 'Maypole' and 'Syndicate (No. 7)' claims in 1916 (Oliver, 1916), but the exact location of these leases is unknown. The lodes are naturally divided by Masters Gully however, and the original leases probably occupied much the same ground as the present leases. The original leases lapsed in 1922 and the ground was not taken up again until 1936.

Operations on the group have been continuous since 1936, though attention was concentrated on the south-easterly lodes in the early years, and later switched to the north-westerly lodes. In 1940 'Koppocks Lease' included the present White Diamond mineral deposits. The north-westerly deposits were known simply as the 'workings north of Koppocks'. So little was known of the northern part of the group that no description of the lodes is included in the report by Hossfeld (1941).

Since 1940 the Masters Gully lodes have assumed increasing importance, to the detriment of the White Diamond lodes. Both leases were acquired by the present owner, Mr J. Bailey, in 1951. Before that they had been held separately

and successively by several owners. The presence of long discrete lodes has been conducive to tributing, and tribute operations have contributed substantially to the production from the group.

Production

Production data for the period up to 1940 are lacking for the White Diamond Lease, and are incomplete for the Masters Gully Lease. The White Diamond Lease is known to have produced a considerable tonnage of wolfram between 1936 and 1942, and it is possible that the production from the lease in those years exceeded the production recorded since 1942. The production recorded from the Masters Gully Lease is thought to be close to the actual total production. Table 13 gives the known production of concentrates from the group.

Geology

The Masters Gully Group consists of five main lodes and many less important quartz reefs lying partly in sedimentary rocks and partly in volcanic rocks. The lodes have been numbered 1 to 5 from north-west to south-east. Except for No. 1 Lode, they do not strike parallel to other important lodes at Hatches Creek.

The No. 1 Lode strikes at 360° to 015°. An isolated and unimportant lode some distance to the west of No. 1 Lode lies roughly parallel to this and can be traced almost continuously south-westwards into the Hit or Miss Group. Although these lodes do not persist northwards into the main quartzite of Dooleys Ridge, the projection of their strike can be continued into the Treasure Group on the north side of that ridge (Pl. 4). These two lodes lie within a zone of fracturing which extends from the Treasure Group to the Hit or Miss Group. The origin of the other lodes is less obvious, but is thought to be connected with this zone.

The group has been displaced east-block-south by a fault trending roughly north-east. The outcrop of the fault is concealed by alluvium in Masters Gully at the south-east end of the No. 3 Lode (pl. 26).

The White Diamond lodes lie at the same stratigraphical horizon as the Hen and Chickens No. 1 Lode, and they terminate to the south in the same series of interbedded sandstone, siltstone, and volcanic rock (Pl. 4). The south end of the No. 5 Lode lies in fine-grained sandstone and siltstone. The lode has been severely faulted, and the strike and dip of the bedding are irregular. The dip of the beds ranges from 35° to 55° to the south, and the strike between 090° and 070°. To the north of these sediments the White Diamond Lodes lie in fine-grained acid volcanic rocks, and are composed of a large number of short irregular quartz reefs, lying in wide fracture zones which have an undulating trend.

The Masters Gully lodes to the north lie in sedimentary rocks and are more clearly defined and continuous. The host rock is a medium-grained to coarse-grained friable quartz sandstone containing narrow lenses of quartzite, and it strikes at about 075° and dips south at about 65°. Faulting has been slight and the lodes for the most part occupy clean-cut continuous fissures. The lodes are most irregular, and are more faulted, near the contact between volcanic rock and sedimentary rock.

PLATE 26

PLAN OF SURFACE WORKINGS

MASTERS GULLY LEASE

HATCHES CREEK N.T.

23rd. July 1956

SCALE

40 0 40 80 120 Feet

Based on original by the A.G.G.S.N.A.

69° 13"
8' to water
330'
320'
sandstone
Masters Gully
TRUE
MAG.
4°30'
BIG TUNNEL
greywacke
1" 78° 2" 3' 2" 5" 74°
8' 2"-3" 72°
6"
28 bags concentrates reported 10" 15°
LODE
and quartzite
9' 17"
16"
20"
20"
20"
BIG TUNNEL FAULT
MORO'S SHAFT 143'
18"
20"
1' 8"
See Plate 28
24"
No. 1
20"
390'
380'
370'
360'
350'
340'
330'
320'
310'
300'
290'
280'
270'
250'
LITTLE TUNNEL
Creek
65°
3½' filled No 2 10'
2' 5"
1'
16" 57°
3' 5'-6'
9" 2½" 6'
18" 72° 4'
debris 30° 3'
reef much shattered
BAILEYS SHAFT
LODE 4'
debris 18" 80° 3' caved
No 3
No2 SHAFT
6"
4'-5'
LODE
3'-4' 7" 82°
15" 4'-6' 85°
2' 7" 82° 5'
1½'
8" 80°
4' 70° 3" 8"
6" 67°
12½' 57° 30° 11"
290'
280'
240'
See Plate 30
82° 24"
88° 8"
67° 24"
6"

REFERENCE

- Reef at surface, position accurate, showing width and dip (75° / 18")
- Reef at surface, position approximate
- Fault, position accurate, showing dip
- Fault, inferred (—?—)
- Strike and dip of bedding (40°)
- Form lines, 10ft. interval. Datum, collar of Baileys Shaft 323ft.
- Surface workings (4')
- Tunnel entrance
- Shaft, in use
- Shaft, disused
- Inclined shaft
- Dump

F 53-3-31

MERCURY

Bureau of Mineral Resources, Geology and Geophysics Aug. 1961.

To Accompany Bulletin No 6

PLAN OF SURFACE WORKINGS

WHITE DIAMOND LEASE

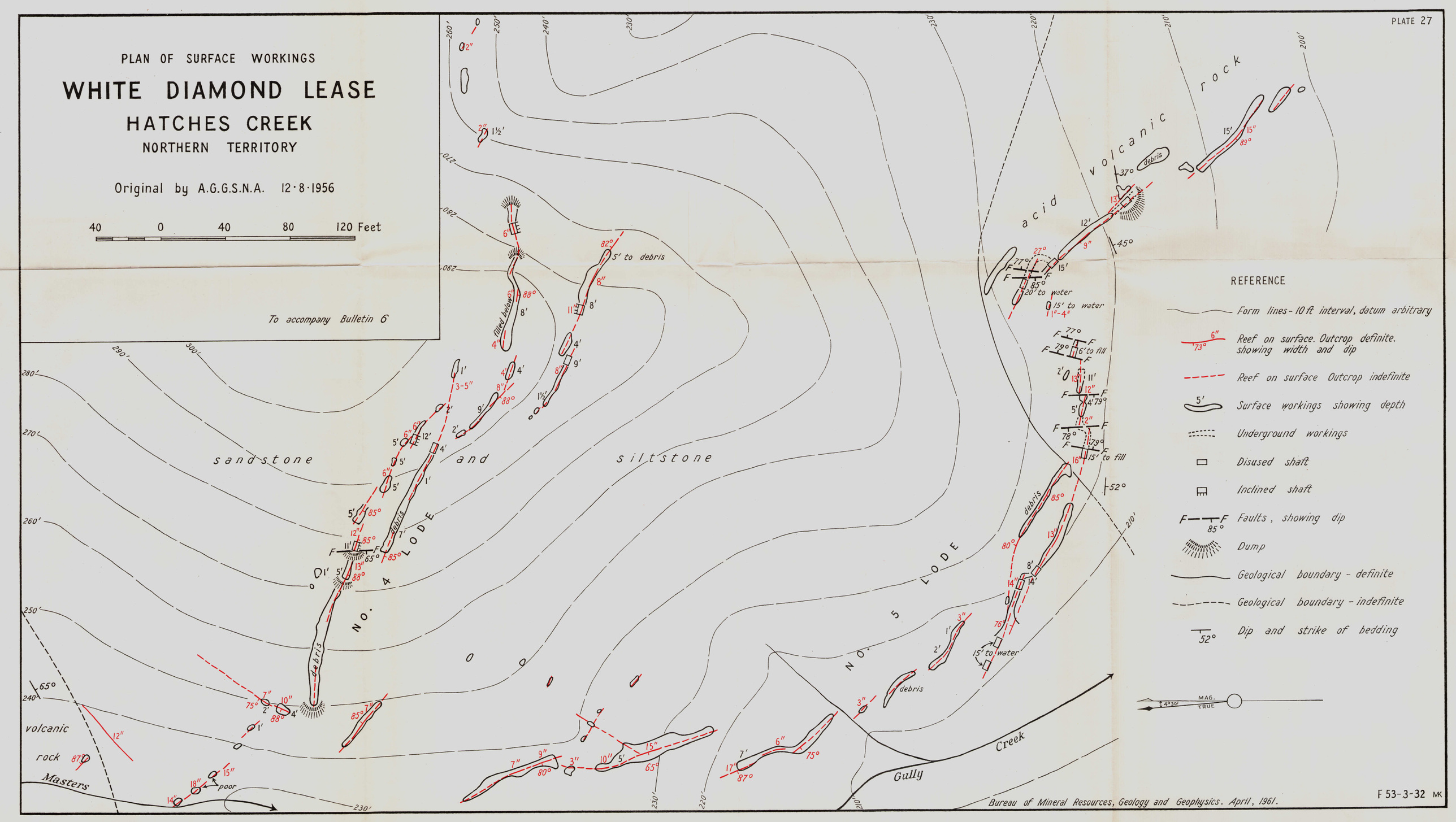
HATCHES CREEK

NORTHERN TERRITORY

Original by A.G.G.S.N.A. 12·8·1956

40 0 40 80 120 Feet

To accompany Bulletin 6



REFERENCE

- Form lines - 10 ft. interval, datum arbitrary
- 6" / 73° — Reef on surface. Outcrop definite, showing width and dip
- Reef on surface Outcrop indefinite
- 5' — Surface workings showing depth
- Underground workings
- Disused shaft
- Inclined shaft
- F — F / 85° — Faults, showing dip
- Dump
- Geological boundary - definite
- Geological boundary - indefinite
- 52° — Dip and strike of bedding

Bureau of Mineral Resources, Geology and Geophysics. April, 1961.

F 53-3-32 MK

PLATE 28

PLAN
BIG TUNNEL WORKINGS
MASTERS GULLY GROUP
HATCHES CREEK N.T.

Scale

20 0 20 40 FEET

Reference

- 70° 6" — Reef at surface-position definite-showing width and dip
- Reef at surface-position indefinite
- 70° 6" — Reef at Tunnel Level
- 70° 6" — Reef at 101 FT Level
- Known limit of stopes
- Shaft accessible
- Shaft concealed
- Winze
- 70° — Fault-position definite-showing dip
- ?—?— Fault-position inferred
- 62° — Dip and strike of bedding

4°30 Magnetic North / North

200W.

200N.

Much shattered with quartz stringers in all directions

Filled

2"

49°

33°

70°

30

65°

21"

13"

8"

72°

12"

16"

66°

22"

64°

16"

36"

17

Lode

20"

100N.

300W.

Timbered

Pillar

Stoped

56°

36°

?

20"

projected

Reported 30'

Stoped

70°

Timbered

69°

LINE OF X-SECTION

55N.

MOROS SHAFT

68°

Reported 25'

Caved

25°

Rep. 24"

BIG TUNNEL FAULT

No. 1

18"

143 FT LEVEL

Reported 60'

Stoped Below

18'

Stoped

20"

62°

65°

24"

5"

3'

75°

18"

68°

9"

24"

00

300W.

Bureau of Mineral Resources
Geology and Geophysics

To Accompany Bulletin No. 6.

F53/3/33

200W.

PLATE 29

BIG TUNNEL WORKINGS

MASTERS GULLY GROUP

HATCHES CREEK . N. T.

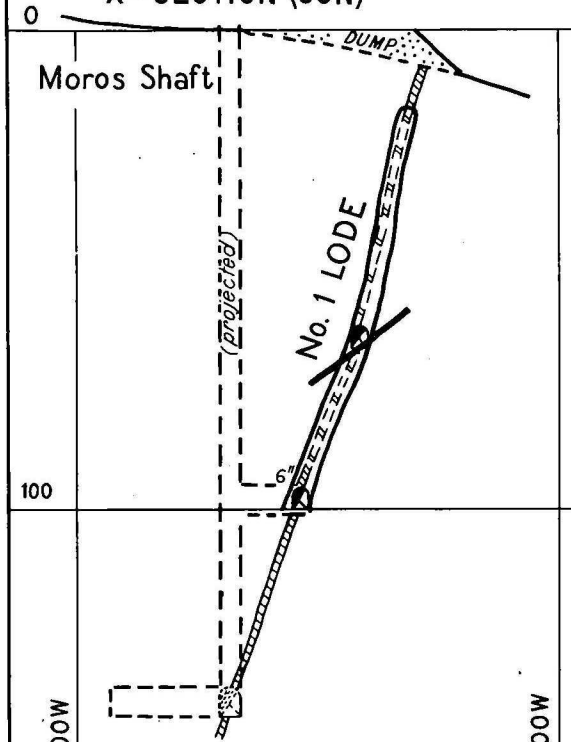
SCALE

20 10 0 20 40 60 Ft.

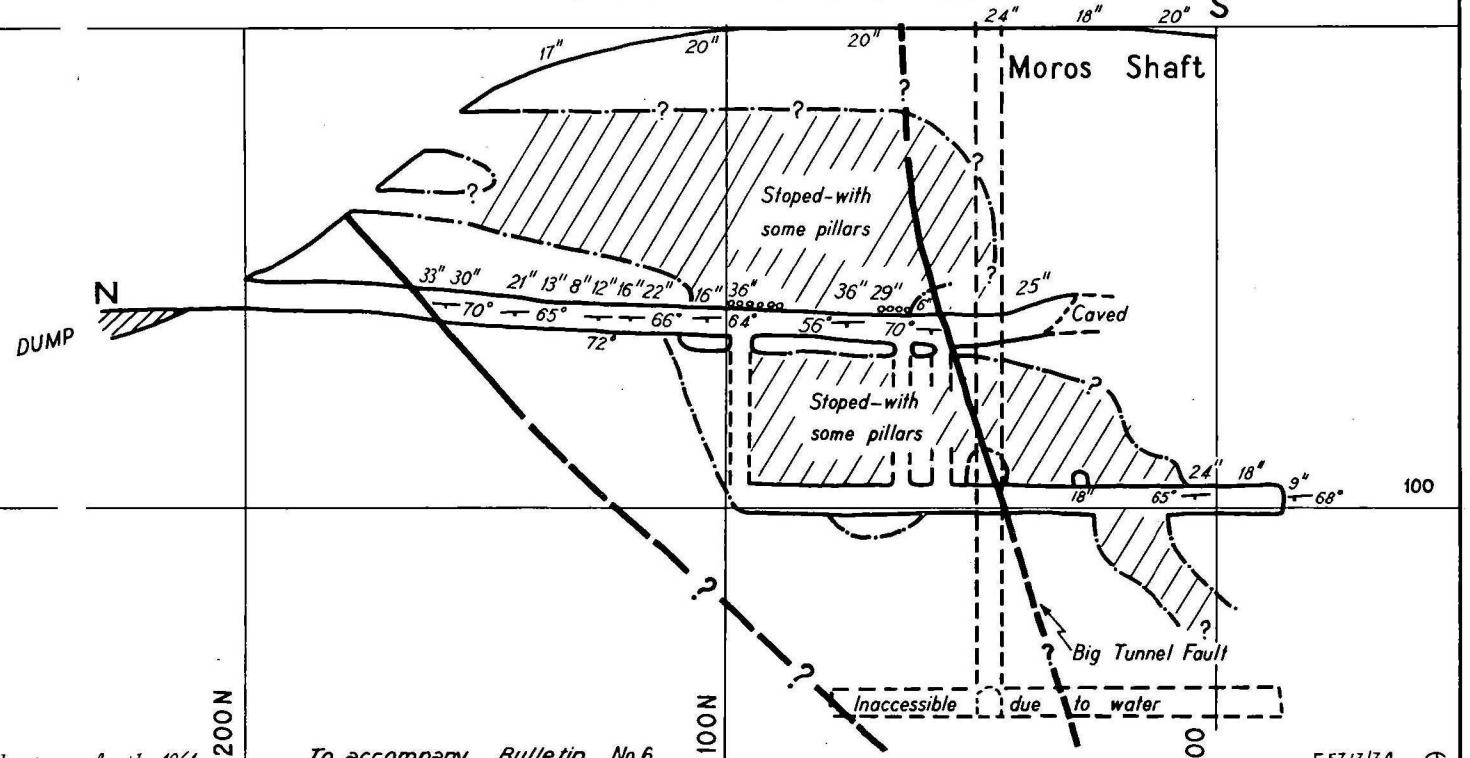
REFERENCE

- Reef position accurate
- Reef position approximate
- Inaccessible workings
- Accessible workings
- Drive approaching and receding from observer
- Cross cut approaching observer
- 6" / 70° Dip and width of reef
- Timber
- Limit of stope. Approximate
- Limit of stope. Accurate
- Fault, position accurate
- Fault, position inferred

X–SECTION (55N)



VERTICAL PROJECTION ON 200W



Bureau of Mineral Resources, Geology & Geophysics . April, 1961.

To accompany Bulletin No.6.

F 53/3/34

LITTLE TUNNEL WORKINGS

MASTERS GULLY GROUP

HATCHES CREEK N.T.

SCALE

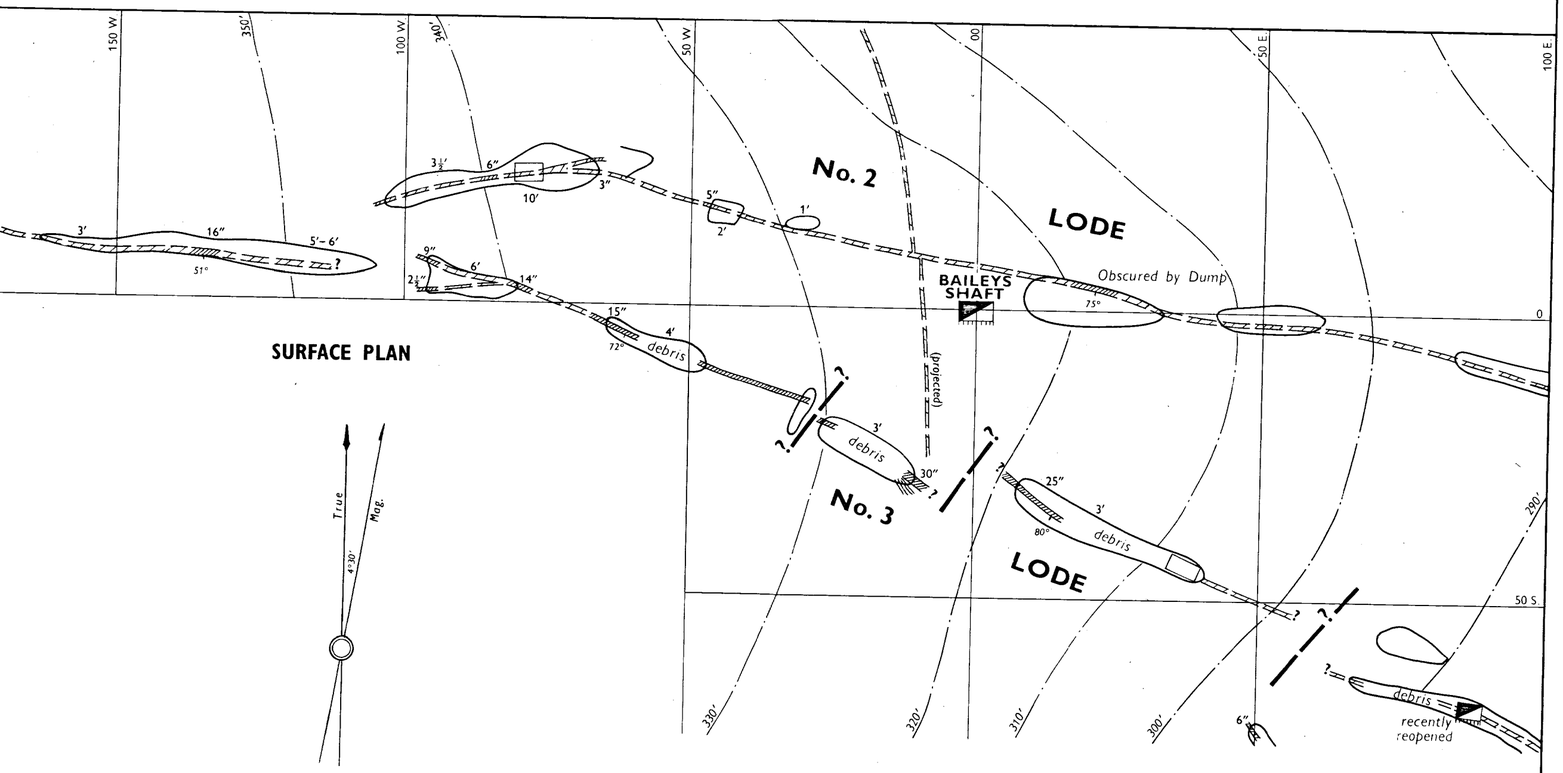
20 10 0 20 40 60 Feet

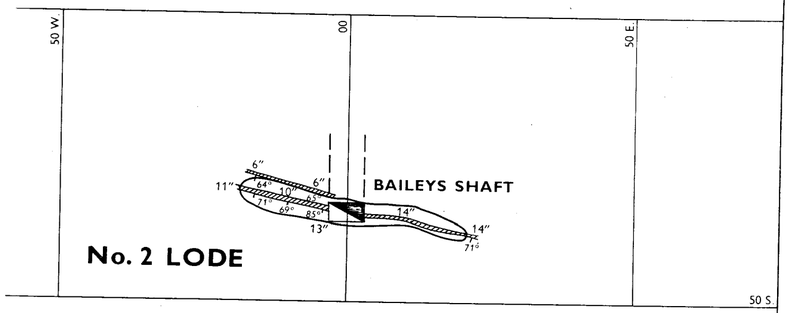
23.7.56

REFERENCE

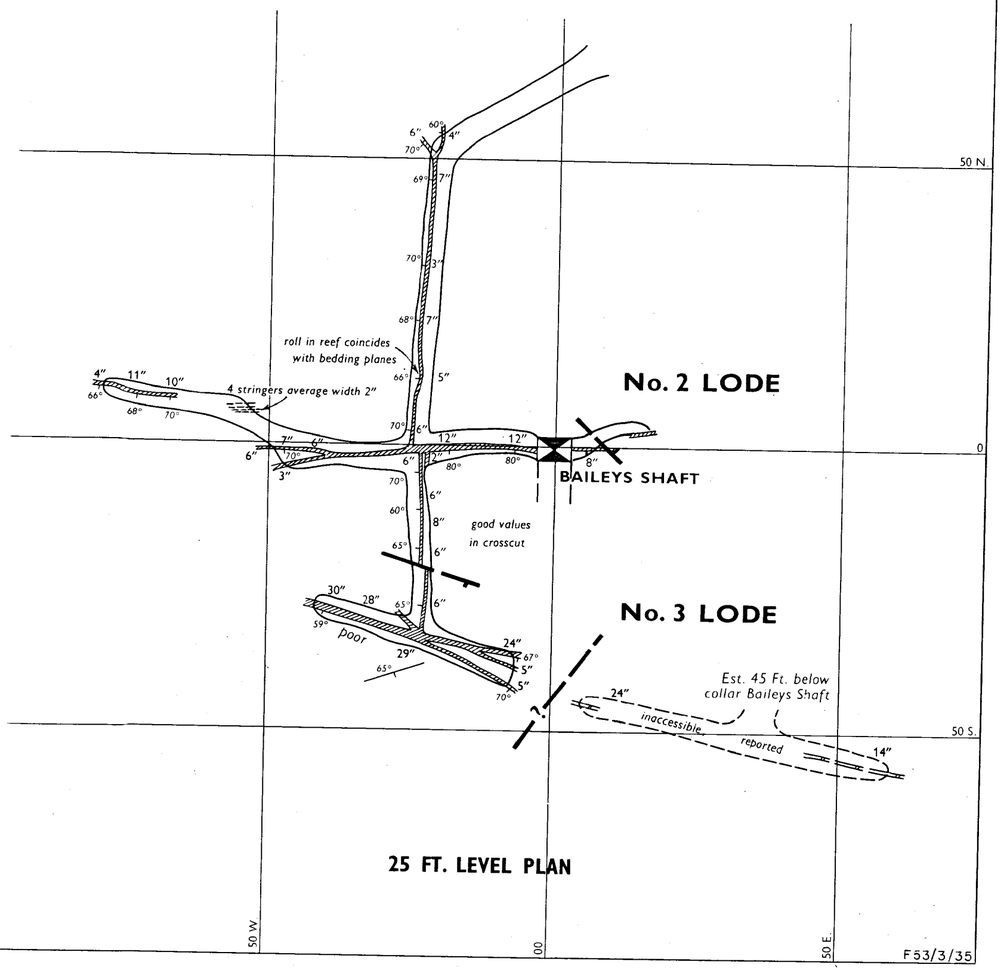
- Reef, position accurate, showing width and dip
- Reef, position approximate
- Reef, position inferred
- Dip and strike of bedding
- Fault, position accurate
- Fault, position inferred
- Surface workings showing depth
- Underground workings, accessible
- Underground workings inaccessible
- Shaft, accessible (inclined)
- Shaft inaccessible

Form lines 10 Ft. Interval. Datum: Collar of Baileys Shaft 323 Ft.





152 FT. LEVEL PLAN



F53/3/35

Bureau of Mineral Resources, Geology & Geophysics. September, 1961.

To accompany Bulletin No 6.

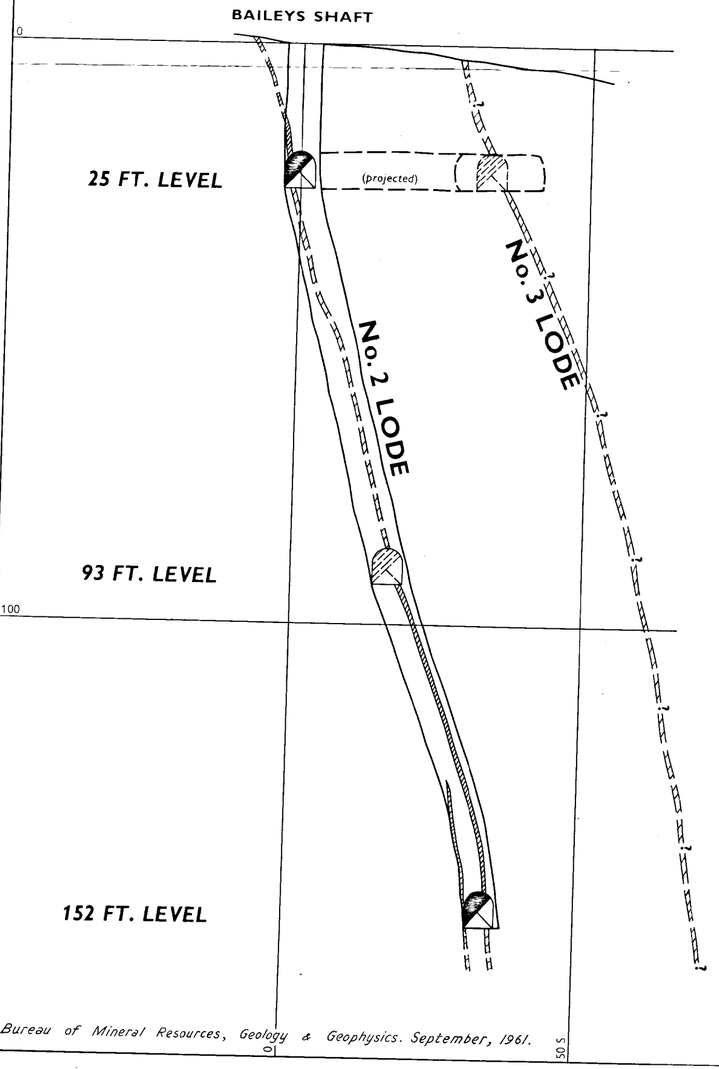
VERTICAL PROJECTION AND CROSS SECTION

LITTLE TUNNEL WORKINGS

MASTERS GULLY GROUP

HATCHES CREEK N.T.

CROSS SECTION ON CO-ORDINATE 0



SCALE

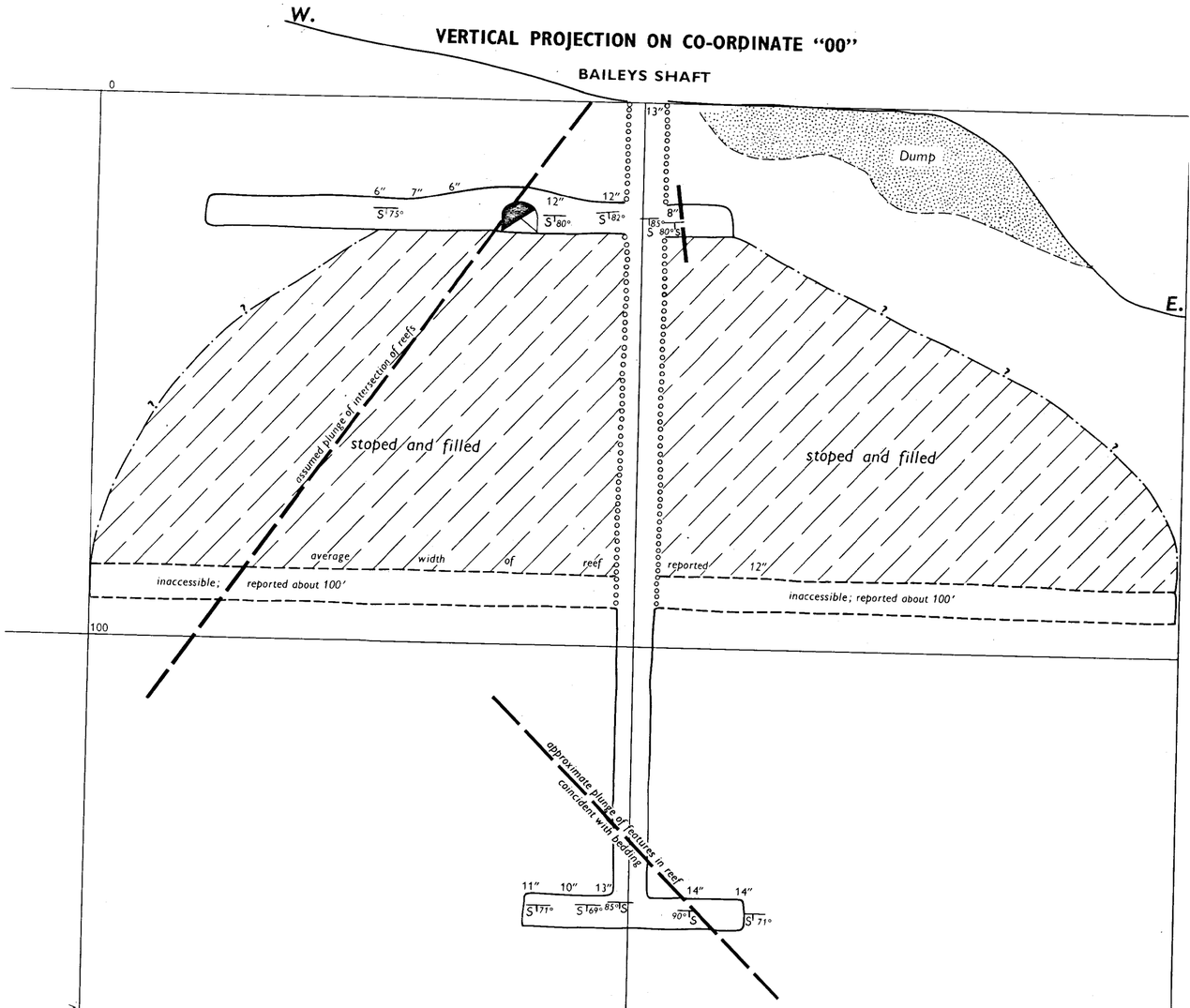
20 10 0 20 40 60 Feet

23.7.56

REFERENCE

- Reef, position accurate
- Reef, position approximate
- Reef, position inferred
- Accessible workings
- Inaccessible workings
- Timber
- Stoped ground
- Limit of Stope (approximate)
- Accessible level, approaching and receding from observer
- Inaccessible level approaching and receding from observer
- 10" S 85° — Width and dip of reef

VERTICAL PROJECTION ON CO-ORDINATE "00"



Bureau of Mineral Resources, Geology & Geophysics. September, 1961.

To accompany Bulletin Nº 6.

F53/3/36

TABLE 13

MASTERS GULLY GROUP, HATCHES CREEK

ANNUAL PRODUCTION OF WOLFRAM CONCENTRATES

1937-1958

Year ending 30th June	MASTERS GULLY LEASE Concentrates tons	Value £	WHITE DIAMOND LEASE Concentrates tons	Value £	TOTAL Concentrates tons	Value £
1937	1.5	144			1.5	144
1938	0.55	170(a)			0.55	170(a)
1939	—	—	UNAVAILABLE		—	—
1940	6.96	1,375			6.96	1,375
1941	1.16	230			1.16	230
1942	3.70	1,013	17.2	3,680	20.90	4,693
1943	3.67	1,358	2.6	851	6.27	2,209
1944	1.81	609	1.48	449	3.29	1,058
1945	1.54	563	1.29	303	2.83	866
1946	1.25	427	0.73	221	1.98	648
1947	1.19	480	—	—	1.19	480
1848	5.68	3,640(a)	0.55	310(a)	6.23	3,950(a)
1949	3.55	1,723	0.94	342	4.49	2,065
1950	1.39	460	1.14	427	2.53	887
1951	5.45	9,019	1.46	1,301	6.91	10,320
1952	9.25	16,965	1.66	3,104	10.91	20,069
1953	15.57	21,074	1.06	1,506	16.63	22,580
1954	11.27	9,036	1.29	1,534	12.56	10,570
1955	12.01	10,185	—	—	12.01	10,185
1956	4.95	5,154	(b)	(b)	4.95	5,154
1957	0.60	557	2.66	2,346	3.26	2,903
1958	0.45	75	—	—	0.45	75
Total	93.50	84,257	34.06	16,374	127.56	100,631

(a) Value calculated from mean price of wolfram for relevant year.
(b) Included with Masters Gully lease.

Mineralogy

The lodes in the sedimentary rocks are almost free of accessory minerals: wolfram and quartz predominate, with lesser amounts of mica and traces of copper. However, the No. 5 Lode, which lies mainly in volcanic rocks, carries more copper, and malachite, azurite, and chalcocite have been identified. Traces of bismuth and molybdenum are also present. Muscovite and biotite are more abundant than in the other lodes. The accessory minerals are not present in sufficiently large amounts to present any metallurgical difficulties, and are easily separated by hand.

Grade and Control of Ore

The grade at the mill of ore crushed from No. 1 Lode and No. 2 Lode during 1955 and 1956 was about 5.14% WO_3; 186 tons of ore yielded 14.72 tons of concentrate. The bulk of this was won from the No. 2 Lode in the Little Tunnel workings (Pls 30, 31) but some came from the No. 1 Lode and from other sources. These are the only figures from which the grade of the ore can be calculated.

It is estimated from the reported and measured limits of the stopes in the Big Tunnel and the Little Tunnel that about 2,100 tons of ore have been won from the two mines. On the assumption that these two mines have produced about 60 tons of the total production recorded from the Masters Gully Lease, a grade of about 1.8% WO_3 is indicated; this includes development ore. These figures are purely

tentative. With increased knowledge of the control of the ore it should be possible to mine ore carrying between 2% and 3% WO_3.

Factors controlling the deposition of wolfram have not been identified. Most of the stopes are now inaccessible, and the reef is exposed in only a few places. It appears that the richest ore on the No. 1 Lode was obtained from a shoot on a section of the reef with a strike of about 360° and an average width of 30 - 36 inches. The poorer sections of the reef strike at about 010° and are not so wide. No marked difference in the dip could be detected. Judging by the location of the stopes, the shoot plunges to the south at about 70°.

The shoot lies in the footwall of the Big Tunnel Fault, which dips to the south at about 70° (Pls 28, 29). The bedding of the host rock also dips south at 65-70°, and the plunge of the shoot is parallel to the intersection of the reef with both the Big Tunnel Fault and the bedding in the country rock. Either factor may have been responsible for the localization of wolfram in the lode.

The richest ore on the No. 2 Lode was won from a section of the reef which strikes at about 090°, and which, judging from the inclination of Baileys Shaft, is slightly flatter than the rest of the lode. The poorer sections of the reef have a strike of about 100° and are steeper. The lode is not intersected by any major fault so far as is known, but is crossed by a narrow reef striking approximately 360°. The intersection of this reef with the lode at the 25-foot level is not enriched. Development since July 1956, at the 152-foot level, indicates that the lode becomes richer to the west.

It appears that ore on the No. 2 Lode lies in a shoot whose limits have been determined by the attitude of the reef rather than by features on the reef, but the control and plunge of this shoot are not known. Small pockets of wolfram are present in the reef at the 152-foot level. The reason for their presence could not be determined.

It is reported that the richest ore on the White Diamond Lease was won from the south-west end of the No. 5 Lode. In view of the discontinuity and irregularity of the quartz reefs in this part of the group, shoots are unlikely to be well defined. The control of the deposition of the wolfram was probably exercised by the many faults which displace the lode, the richest part of the lode being where the faulting has been most intense.

Individual Lodes

No. 1 Lode. The No. 1 Lode is about 700 feet long at the surface, but apart from a few shallow open cuts, only a short central section has been developed. It strikes at 360 - 015° and dips to the west at 55 - 88°, and consists of one quartz reef emplaced in a single well-defined shear, along which movement has been horizontal. The reef is irregular and varies in width from 8 inches to 36 inches, with an average width of about 24 inches over the central section.

The lode was originally developed from an adit known as the Big Tunnel. Moros Shaft was later put down vertically, and intersected the lode at 143 feet. The Big Tunnel Fault, which strikes at from 100 - 125°, and dips south at about 70°, displaces the northern part of the lode to the west. The displacement is small,

and the reef has been dragged on the fault. A leader of quartz lying along the fault-plane is continuous with the reef on either side of the fault, which suggests that faulting was contemporaneous with the intrusion of the quartz. The richest ore was present in a short shoot lying in the footwall of the fault. The reef strikes at about 360° in this shoot and is believed to have averaged a width of 30 inches. All the ore has been removed from this shoot above the 101-foot level and the Tunnel Level.

The reef has been tested for 120 feet at the 101-foot level but has been stoped over a greater part of this length. It is not as rich to the south of the Big Tunnel Fault, but carries some wolfram. An underhand stope between 10N and 25N connects with the 143-foot level, which was under water at the time of the examination. It is reported that the reef was lost in the north drive at this level.

The lode has been tested south of the Big Tunnel Fault at the Tunnel Level, but the drive has caved at 38N and the extent of the development is not known. A second fault striking at 080° and dipping south at 49° intersects the reef at 166N, and has caused considerable displacement, moving the south block west relative to the north block. The intersection of this fault at the 143-foot level may have caused the reported difficulty in locating the reef (Pl. 29).

It has been estimated that a grade of about 2% was obtained in the stopes between the 101-foot level and the surface, but the grade is reported to have decreased at the 143-foot level, and the shoot may therefore not extend much below this level. However, the backs at the 143-foot level are almost intact as far as is known, and if the mine were to be reopened detailed sampling would determine the grade of the ore.

A southern extension of the lode has been tested from a short adit without success, and a shaft put down north of the portal of the Big Tunnel is now full of water. Neither of these operations has been extensive. Very little exploration has been done south of Moros Shaft, where the reef at the surface is up to 24 inches wide. Another shoot similar to that in the present mine workings may exist in this section of the lode.

No. 2 Lode. The No. 2 Lode strikes at 090 - 100°, and dips south at 65 - 80°. It intersects the No. 1 Lode at its western end, and disappears beneath the alluvium of Masters Gully at its eastern end. The lode consists of a number of quartz reefs ranging in width from 6 inches to 12 inches. It is narrow and poor at its western end, and at the eastern end the reefs become irregular. Underground operations have been restricted to a short central section. No. 3 Lode joins the No. 2 Lode at about 125W, 10N, at the surface. The plunge of the intersection is thought to be to the west, but cannot be accurately predicted, because of the lack of information, and the irregular dips of the two lodes.

A quartz reef of regular width and dip crosses the No. 2 Lode at right angles and terminates in the No. 3 Lode (Pl. 30). This reef, which has been tested at the level of the Little Tunnel, strikes between 180° and 185°, and dips west. The fissure in which the reef lies has been displaced along the No. 2 Lode, but the quartz in both fissures is of a single generation. The No. 2 Lode has been tested to a vertical

depth of 152 feet by Baileys Shaft, which is inclined. The lode was exposed for 40 feet at this level, and consisted of a hangingwall reef, 12 inches to 14 inches wide, dipping from 69 - 85° south, and a footwall reef 6 inches wide dipping at 65° south. The footwall reef makes in the shaft 25 feet above the level, and may represent the top of a new reef which will replace the hangingwall reef below the 152-foot level.

Some small pockets of wolfram were showing in the backs, and it is reported that better grade ore has been encountered in the west drive, which has since been extended. The owners were advised to drive westwards to the intersection of the No. 2 Lode with the No. 3 Lode, but it is not known whether this has been done.

The drives at the 93-foot level extended about 100 feet to the east and west of Baileys Shaft. The reef has been entirely removed between the 93-foot level and the 25-foot level and the stopes are now filled. The bulk of the production in recent years has come from this section and it was estimated above that a grade of about 1.8% WO_3 was obtained. The grade below the 93-foot level is reported to have decreased, possibly because the dip of the lode steepens between the 93-foot level and the 152-foot level.

The lode is exposed for a short distance at the 25-foot level west of Baileys Shaft. It strikes at 090°, dips to the south, and is composed of one reef 6 to 12 inches wide which splits to the west and becomes poor. A second reef, increasing in width to the west, was proved 7 feet to the north.

The lode has been tested from many shallow open cuts at the surface. Small pockets of rich ore have been won, but the development of the lode other than from Baileys Shaft does not appear to be justified.

No. 3 Lode. The No. 3 Lode strikes at 100-110°. It runs south-east from the intersection with the No. 2 Lode to disappear beneath the alluvium of Masters Gully. The north-eastern lode on the White Diamond Lease (No. 4 Lode, Pl. 27), is parallel in strike with the No. 3 Lode, but lies to the south-west of the projection of No. 3 Lode across Masters Gully (Pl. 4). Although differing markedly in many characteristics it is believed to occupy an extension of the shear-zone in which the No. 3 Lode lies. The two lodes are economically distinct, and will therefore be described separately.

No. 3 Lode crops out for 300 feet between its intersection with No. 2 Lode and Masters Gully (Pl. 26), and has been developed mainly from shallow open cuts. It consists of one or more irregular quartz reefs ranging in width from 9 inches to 30 inches and dipping south-west at 70 - 85°.

The lode has been tested by short drives at three places, but has not otherwise been developed:

(1) It is exposed for 37 feet in a short drive at the Little Tunnel level. It is irregular in width, poor, and splits to the south-east at the face (Pl. 30).

(2) A short drive, estimated to lie about 45 feet below the collar of Baileys Shaft, is shown on a plan of the area by Hossfeld (1941). It lies immediately to the south-east of the Little Tunnel, and was developed from a shaft which is now filled. The roof was 14-21 inches wide (Pl. 30).

(3) The lode has also been tested from the No. 2 Shaft, but the size of the dump indicates that development was small. Plans were in hand in 1956 to reopen this shaft, but very little work had been done (Pl. 26).

The grade of ore on the No. 3 Lode is unknown, but the irregular nature of the exploitation suggests that ore may be patchy. Further exploration does not appear to be justified, except during periods of high wolfram prices.

No. 4 Lode. The No. 4 Lode consists of a series of short discontinuous reefs lying entirely in volcanic rocks, and striking between 100° and 130°. The reefs lie in a wide zone of shearing, are narrow and relatively poor, and because of their discontinuity are difficult to mine. Operations have been confined to numerous shallow shafts and open-cuts, most of which are now filled. Further small parcels of wolfram may be won, if the price is high enough, but future development of the lode cannot be recommended.

No. 5 Lode. The No. 5 Lode consists of an unusually large number of short reefs arranged en echelon along a complex zone of shearing. The zone has an S-shaped outcrop which is emphasized by faulting in the central, and richer, section of the lode. The extremities of the lode strike south to south-east, and the reefs are not severely faulted. They are up to 15 inches wide, dip west, and are so arranged that each reef in the lode lies in the right-hand wall at the end of the previous one.

The reefs are abundantly faulted, with left-handed displacement, in the central section. The faults strike roughly north, and dip steeply to east or west. The reefs are up to 16 inches wide, and dip within a few degrees of the vertical, either to north or south. They are rarely visible in the abandoned workings. Operations on the lode have been confined to shallow open-cutting, except in the central section, where Hossfeld (1941) reports that shafts had been put down to 50 feet. Nothing was accessible below 15 feet in 1956.

The shape of the lode has been related to the fact that it lies in two types of host rock, crossing the boundary just north of the central section. The high grade in this section is attributed to the abundant faults, which are absent on the poorer sections.

This lode offers very little prospect of further development, as the discontinuity of the quartz reefs will make mining expensive. High-grade ore is confined to the most severely faulted section of the lode, where development will require considerable timbering and development in waste rock. As the lode has already been exploited to a considerable depth, its reopening is not justified.

Other Reefs. The group includes several smaller quartz reefs which have yielded rich ore. They are narrow and short, and in general will only support surface operations.

The quartz reef which intersects the No. 2 and No. 3 Lodes in the Little Tunnel is the exception to this, by reason of its situation. This reef, which is displaced by the No. 2 Lode and terminates on the No. 3 Lode (Pl. 30), is notable for regularity of width and dip. It is 6-8 inches wide and dips at 65° to 70° to the west. Some rich patches of wolfram are present, particularly between the No. 2 and No. 3 Lodes. The reef occupies a joint and not a shear.

Several narrow quartz reefs crop out on the west side of Masters Gully between the Little Tunnel and the Big Tunnel. They vary in width from 1 inch to 12 inches and are in general poor. Only one reef, lying about 110 feet north-west of the Little Tunnel, has produced good-grade ore. It yielded about 1.4 tons of concentrate from a short and shallow open cut (Pl. 26).

Two short quartz reefs crop out west of the south end of the No. 3 Lode. They strike at an angle to the main lode and probably occupy subsidiary fissures associated with the lode. They are narrow and irregular, and dip steeply to the west. Their production is unknown.

Eluvial Deposits. Masters Gully has been extensively exploited for eluvial wolfram, particularly on the White Diamond Lease; the deposits are now approaching exhaustion.

Conclusions

Further small parcels of concentrates may be won from the smaller reefs, and from the No. 4 and No. 5 Lodes, depending on the price of wolfram, but only three lodes offer a substantial basis for future development. No. 3 Lode is the least promising of these, but this may be due to the scarcity of information. Considerable exploration will be needed before it can be developed, whereas not only are the No. 1 and No. 2 Lodes known to carry good-grade ore, but in both a substantial tonnage of ore remains above the lowest level of operations. Whether the past grade of ore persists in these remaining blocks is doubtful; but on the other hand less development will be needed to exploit them. In view of the doubt about the persistence of grade the lodes will have to be sampled in detail. The operative grade will depend on the current price of wolfram, but a grade of 1.5% WO_3 would be high enough to justify further exploration below the lowest levels.

An average grade of 1.5% WO_3 has been assumed for the No. 1 and No. 2 Lodes within the limits of existing development, and the length of payable reef has been taken as these limits. Possible ore reserves have been calculated as 7 tons of wolfram for the No. 1 Lode above the 143-foot level, and 13 tons of wolfram for the No. 2 Lode above the 152-foot level. These calculations are based on the flimsiest of evidence, and are deliberately conservative.

Both lodes could maintain a favourable grade to depths of 200 feet or more, and, with a return to the wolfram price of early 1956, they should support development to this depth at least. But they should be thoroughly explored, because the grade on the lower levels of both lodes is suspect.

Hit or Miss Group

(Pls. 4, 32, 33, 34, 35, 36, & 37)

The Hit or Miss Group lies just over a mile south-west of Goat Hole, and is the largest and most complex concentration of wolfram-bearing reefs at Hatches Creek. Five of the more important lodes have been developed to depths of 100 feet or more, and several other reefs have been developed to depths of more than

30 feet. Shallow open cuts are extremely abundant (Pl. 32). The reefs cover an area about 1600 feet square and crop out on three ridges which trend roughly east. The group was covered by six leases in 1956: the central Hit or Miss Lease is surrounded by the Silver Granites Lease to the west, the Fortune Lease to the south, the Hit or Miss Extended Lease to the east, and the Reward Lease and Hitlers Downfall Lease to the north.

The reefs commonly lie along well defined lodes except in the central part of the group, where they are present as irregular concentrations of discontinuous reefs with an approximately common strike. These have been termed 'lines' (Pl. 32) to distinguish them from the lodes. The reefs, with few exceptions, conform to four dominant directions of strike: about 180°, between 200° and 210°, from 220° to 225°, and about 250°. The Hit or Miss Main Lode, which strikes at 180°, has produced about half the total tonnage of concentrates from the group.

History

A 'Hit or Miss' claim was among the first to be registered, by Hanlon and Warne, after the discovery of wolfram at Hatches Creek. The ground covered by this claim was much the same as that covered by the present Hit or Miss Lease. The map accompanying the report by Oliver (1916) shows four other claims adjacent to the 'Hit or Miss'. These were 'The Reward' to the north, the 'No. 12' and 'No. 12 East' to the east, and 'The Wallaby' or 'Haddock's' to the west. The five claims embraced most of the group. They were all abandoned by 1922 and were not repegged until 1936.

Mr J. Walsh acquired the Hit or Miss Lease and Hit or Miss Extended Lease about this time, and these two leases and later the 'Fortune Lease' were held by him, and then by his estate, until 1951, when they were bought by Mr J. Fowles. Walsh also owned other leases at Hatches Creek and at Wauchope, and for a great part of his tenure the production from all his leases was recorded in bulk.

A substantial amount of work had been done on the group by 1940, when officers of A.G.G.S.N.A. began a survey of the mineral field (Hossfeld, 1941). At that time 'Ross's Lease' lay to the north of the Hit or Miss and 'Cadogan's Lease' lay to the south. The Commonwealth Government operated the Main Lode from 1942 to 1944. Development since then has been concentrated on the Hit or Miss Lease, the Hit or Miss Extended Lease, and the Silver Granites Lease, and only a little work has been done on the other three leases.

In 1956 four of the leases were held by Mr J. English, who acquired them from Fowles, and were being operated on his behalf by Mr R. Coxon. The Silver Granites Lease was held under tribute by Messrs Blundell and Spreadborough, and the Reward Lease was not in operation. Mr Coxon and Mr English were employing several parties of tributers on development of various lodes on the group. Compressed air, water, and pumping facilities were supplied by the management, and the tributers were subsidized to encourage efficient methods of mining. This arrangement was proving successful in the operation of smaller lodes on the group, as well as on the larger lodes.

Production

Very little information is available on production of wolfram from the group before 1940, but a considerable tonnage was won between 1916 and 1922, and between 1936 and 1940. Total recorded production to June 1958 from the various leases on the group has been 302.66 tons of concentrates, but this does not include wolfram won from the leases owned by Walsh between 1939 and 1942. It is estimated that of a total of about 200 tons of concentrates won from Walsh's leases in this period, about 100 tons, worth about £17,000, came from the Hit or Miss Group. Total production from the individual leases has been as follows:—

Hit or Miss	223.57 tons
Hit or Miss Extended	29.59 tons
Fortune	13.86 tons
Silver Granites	18.64 tons
Reward	15.68 tons
Hitlers Downfall	1.32 tons
Total	302.66 tons
Ex Walsh	100 tons app.

Table 14 gives the known annual production from the group since 1937, but figures for the years before 1942 are inaccurate and certainly too low.

Geology

The Hit or Miss Group is remarkable for the unusually heavy concentration of wolfram-bearing quartz reefs and for the regularity of their orientation. The group lies at the southern corner of an irregular rhomb whose other corners are occupied by the Kangaroo Group, the Treasure Group, and the Masters Gully Group (Pl. 4). The pattern of reefs in each of these groups is completely different from the others. The Treasure Group and the Hit or Miss Group lie at either end of a major line of fracturing, trending a little east of north, which runs through the western end of the Masters Gully Group.

The structure must be examined in more detail before the relationship between the four groups can be determined. The difference in the pattern of the reefs in each group is attributed to the difference in type and sequence of the country rocks which each group occupies. The northern part of the Hit or Miss Group lies in a sequence of interbedded siltstone, sandstone, quartzite, and volcanic rocks, striking at about 070° and dipping south at 55 - 60°. Few of the beds are more than 20 feet thick. The amount of volcanic material is very small in the higher part of the sequence, but increases, at the expense of the sedimentary rocks, in the lower part, i.e. to the north. The widest and best-defined sections of the Main Lode, the No. 1 Lode, and the No. 3 Lode lie in the southern part of the sequence (Pl. 32).

Most of the reefs lie in acid porphyritic volcanic rocks which overlie the sedimentary sequence. These rocks are very similar in hand specimen throughout, but the presence of amygdales in some parts suggests that several flows may be present. No attempt was made to differentiate individual flows. These rocks are

HIT OR MISS GROUP

HATCHES CREEK N.T.

Scale

40 20 0 40 80 120 FEET

Reference

Phv	Volcanic rocks - mainly acid porphyry	} HATCHES CREEK GROUP	
Phs	Interbedded siltstone, sandstone, quartzite and volcanic rocks		
70	Dip and strike of bedding	7" / 72°	Underground workings - showing width & dip of reef
	Geological boundary - position accurate		Stoped ground
	Geological boundary - position approximate		Shaft - vertical accessible
	Geological boundary - concealed		Shaft - inclined accessible
7" / 60	Reef at surface, showing width and dip - position accurate		Shaft - inaccessible or disused
	Reef at surface - position approximate		Dump
	Concealed line of main lodes		Track
	Concealed line of main lodes - inferred		Form lines - interval 10'. Datum - collar of Chinamans Shaft. Approx. R.L. 1160'
7'	Surface workings - showing depth		

Bureau of Mineral Resources, Geology and Geophysics. Aug 1960

To Accompany Bulletin No. 6.

F53/3/37 RM

PLATE 33

REFERENCE

- Reef at surface, position accurate showing width and dip (80° / 6″)
- Reef at surface, position approximate
- Reef at surface, position inferred
- Reef underground, showing width and dip (81° / 6″)
- Fault, position accurate
- Fault, position approximate
- Form lines, 10ft. interval. Datum, collar of Main Shaft; approx. R.L. 1220ft.
- Surface workings, showing depth (3′)
- Underground workings
- Main shaft, inclined
- Shaft, accessible
- Shaft, inaccessible
- Shaft, inclined
- Dump
- Track

acid porphyritic volcanic rocks

SULTANS SHAFT

SULTANS LODE

COPPER LODE

SILVER GRANITES LODE

MAIN SHAFT

No 2 SHAFT

22′ to water

Creek

1200′ 1210′ 1220′ 1230′ 1240′ 1250′

PLAN

SILVER GRANITES LEASE

HIT OR MISS GROUP

HATCHES CREEK N.T.

16th. Aug. 1956

SCALE

40 0 40 80 120 Feet

TRUE MAG.

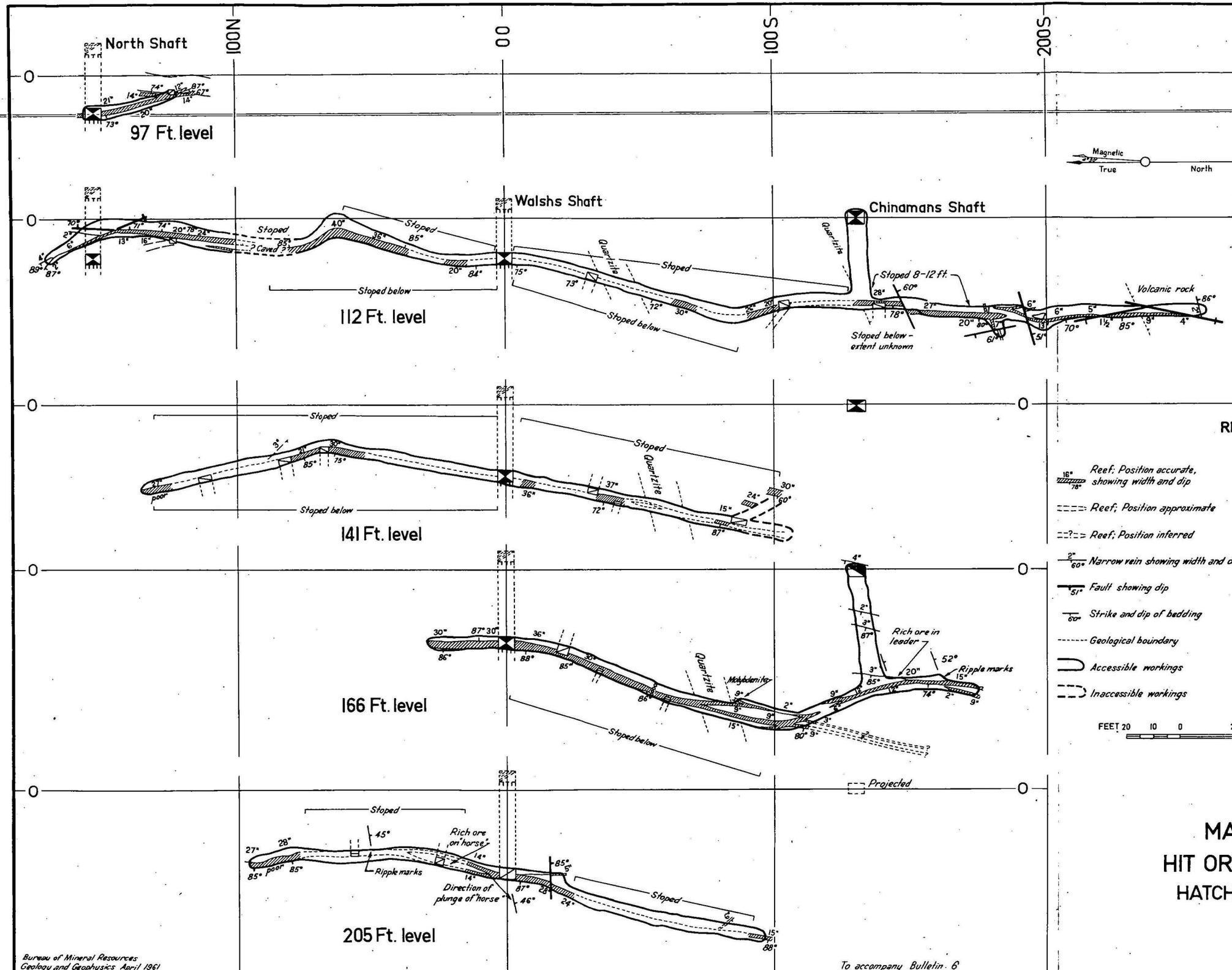
Bureau of Mineral Resources, Geology and Geophysics Aug. 1961.

To Accompany Bulletin No 6

F 53-3-38

MERCURY

PLATE 34



REFERENCE

- Reef; Position accurate, showing width and dip
- Reef; Position approximate
- Reef; Position inferred
- Narrow vein showing width and dip
- Fault showing dip
- Strike and dip of bedding
- Geological boundary
- Accessible workings
- Inaccessible workings
- Shaft passing through level
- Foot of shaft
- Position of shaft at surface
- Chinamans shaft at 205 ft. level
- Inclined shaft
- Foot of rise or winze
- Head of rise or winze.
- Ore pass

FEET 20 10 0 20 40 60 80 FEET
SCALE

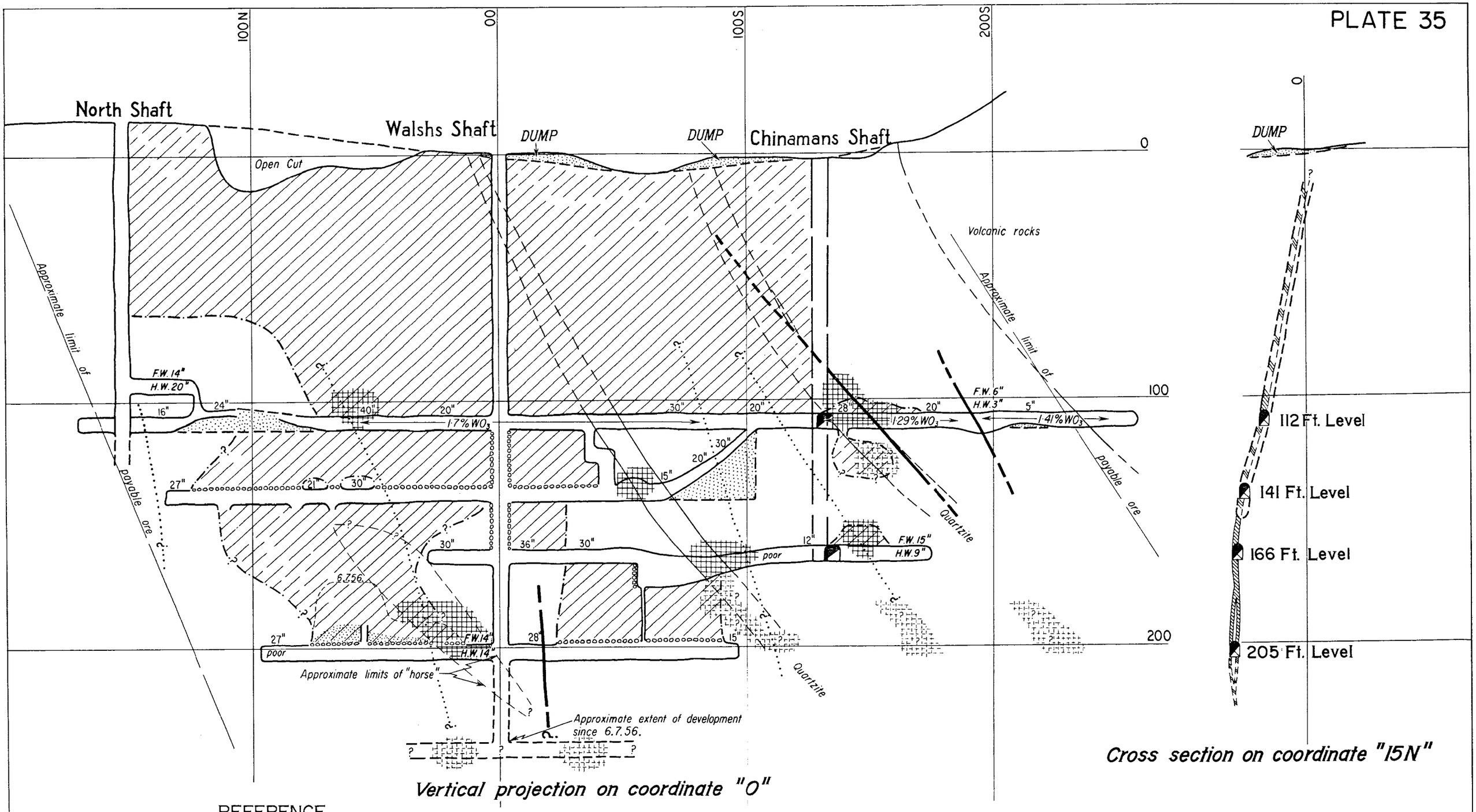
PLAN
MAIN LODE
HIT OR MISS MINE
HATCHES CREEK, N.T.

Bureau of Mineral Resources
Geology and Geophysics April 1961

To accompany Bulletin. 6

F53/3/39 P.J.B.

PLATE 35



REFERENCE

- Reef. Position accurate.
- Reef. Position approximate.
- Fault. Position accurate.
- Fault. Position approximate.
- Fault. Inferred.
- Geological boundary. Position accurate.
- Geological boundary. Position approximate.
- Locus of change of strike of reef.
- Position of known enrichment of wolfram.
- Position of reported enrichment of wolfram.
- Inferred position of enrichment of wolfram.
- Accessible workings.
- Inaccessible workings.
- Limit of stope. Position accurate.
- Limit of stope. Position approximate.
- Stoped ground. Established.
- Stoped ground. Reported.
- Filled workings.
- Timber.
- Drive approaching and receding from observer.
- Cross-cut receding from observer.

VERTICAL PROJECTION AND CROSS-SECTION

HIT OR MISS MINE

HATCHES CREEK N.T.

Original by A.G.G.S.N.A.

Scale

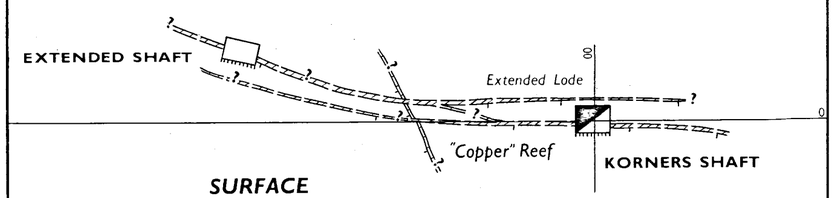
20 10 0 20 40 60 Feet

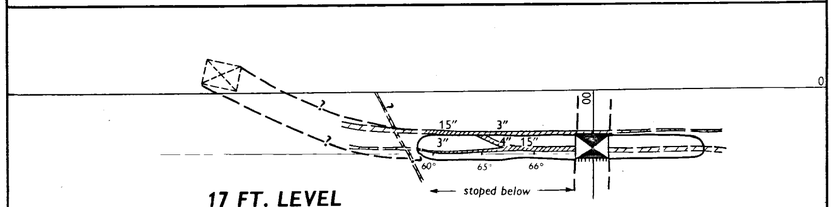
Bureau of Mineral Resources Geology and Geophysics, June 1961.

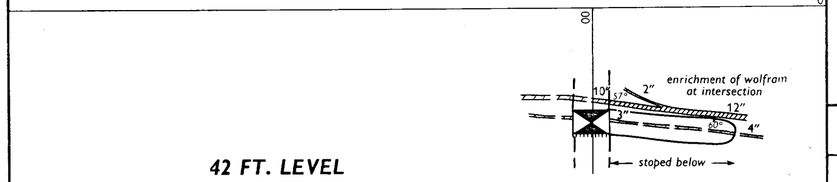
To Accompany Bulletin No 6

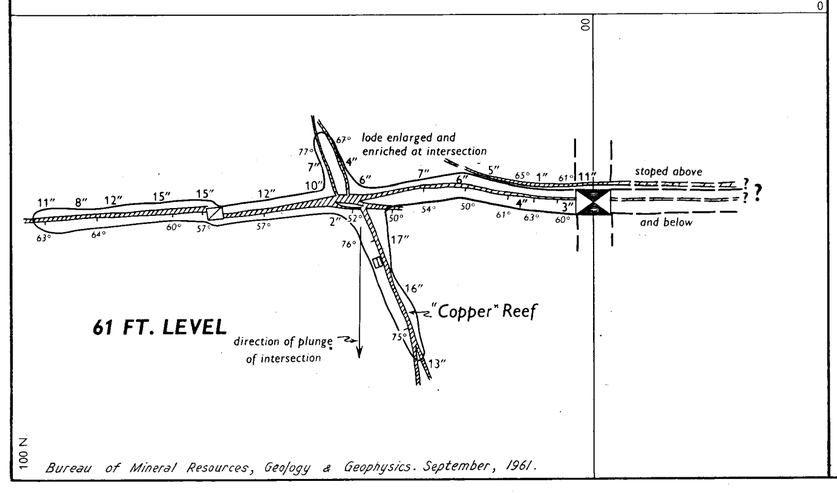
F53-3-40

PLANS









REFERENCE

- Reef, position accurate showing width and dip
- Reef, position approximate
- Reef position inferred
- Accessible workings
- Inaccessible workings
- Workings, position approximate
- Limit of stope, position accurate
- Limit of stope, position approximate
- Stoped ground, extent of stoping known
- Stoped ground extent of stoping unknown
- Timber
- Head of accessible shaft
- Shaft passing through level
- Inaccessible shaft
- Inclined shaft
- Approximate position of Extended Shaft at 17 Ft. Level
- Foot of rise
- Ore Pass
- Drive receding from observer
- Drive approaching observer

PLANS AND SECTIONS

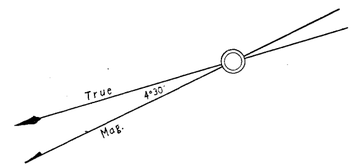
HIT OR MISS EXTENDED MINE

HIT OR MISS GROUP

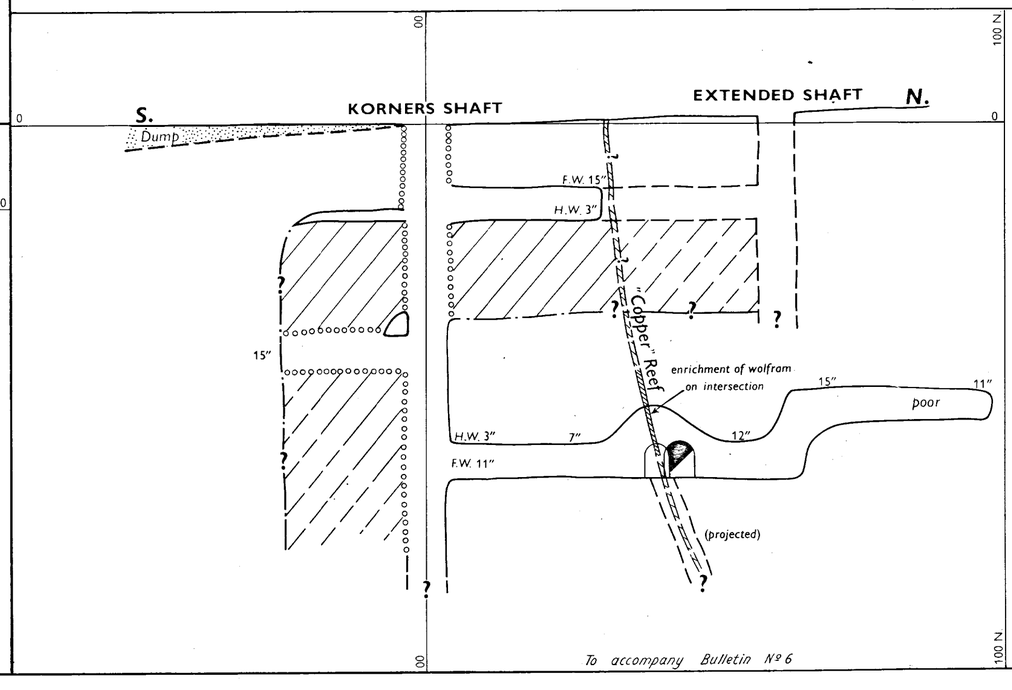
HATCHES CREEK N.T.

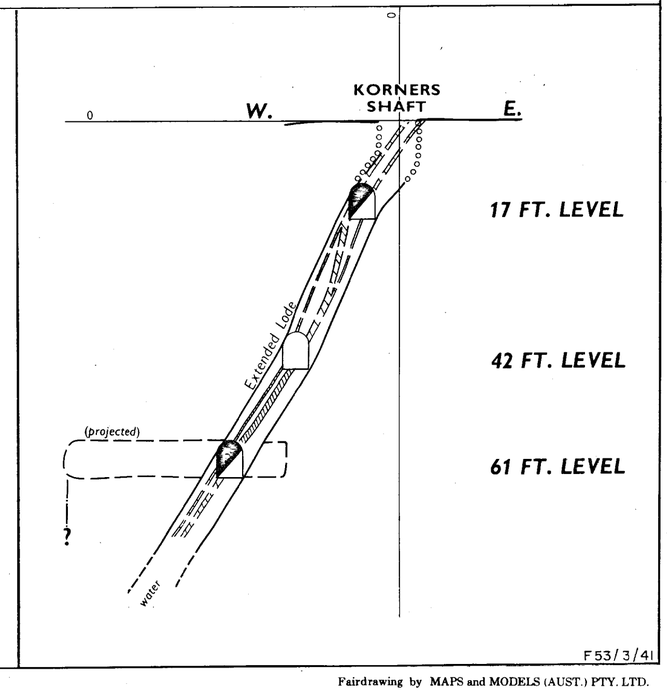
SCALE

20 10 0 20 40 60 Feet



SECTIONS





Bureau of Mineral Resources, Geology & Geophysics. September, 1961.

To accompany Bulletin Nº 6

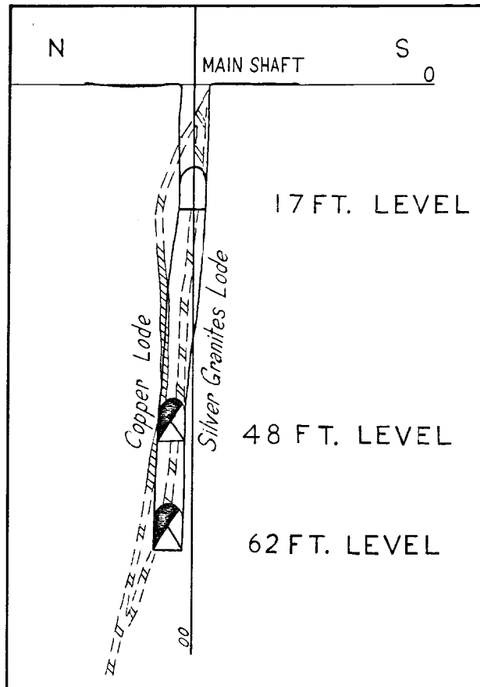
F53/3/41

Fairdrawing by MAPS and MODELS (AUST.) PTY. LTD.

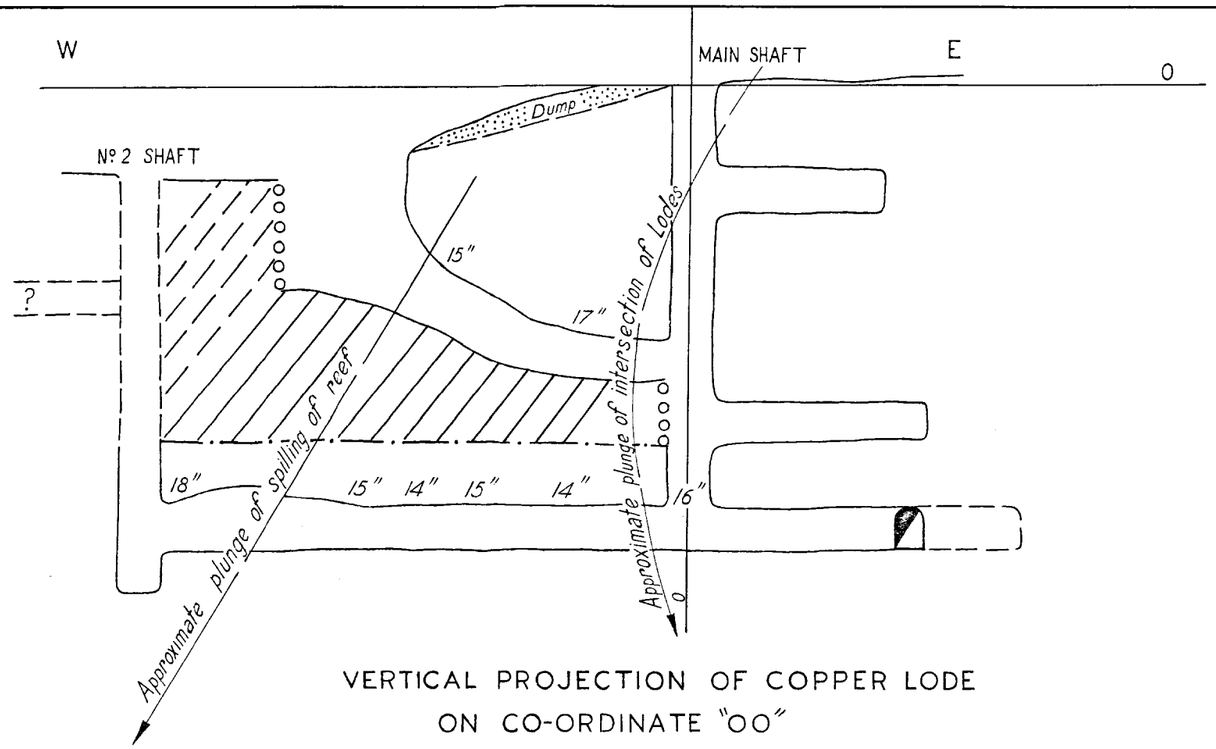
PLATE 37

PLANS AND SECTIONS
SILVER GRANITE MINE
HIT OR MISS MINE
HATCHES CREEK, N.T.

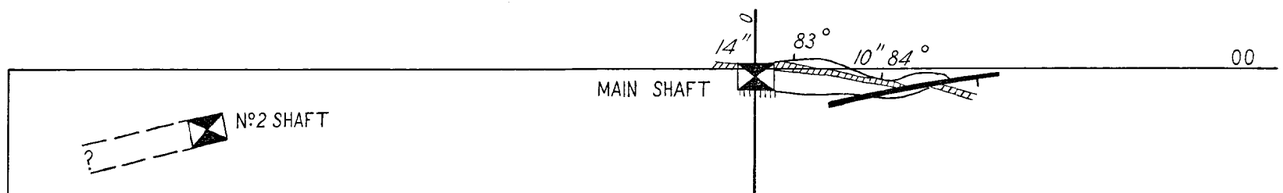
Scale
20 10 0 20 40 60 Ft.

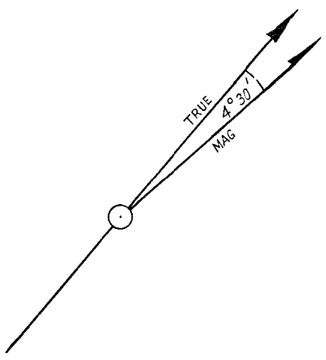


CROSS-SECTION ON
CO-ORDINATE "4W"

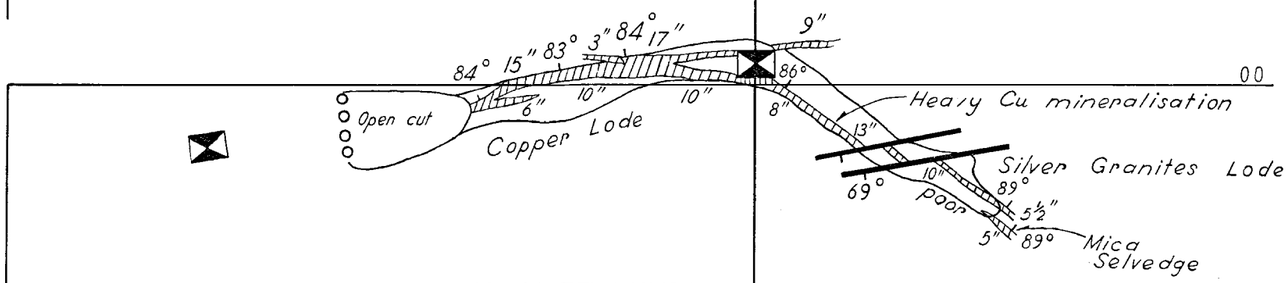


VERTICAL PROJECTION OF COPPER LODE
ON CO-ORDINATE "OO"

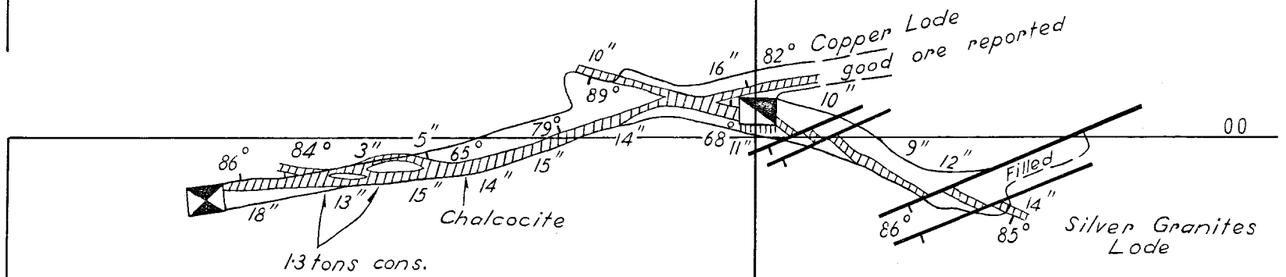




PLAN 17 FT. LEVEL



PLAN 48 FT. LEVEL



PLAN 62 FT. LEVEL

REFERENCE

- 6" / 60° — Reef, position accurate, showing width and dip
- Reef, position approximate
- Accessible workings
- Inaccessible workings
- Limit of stope
- Stoped ground - known
- Stoped ground - reported
- Timber
- Shaft passing through level
- Foot of shaft
- Inclined shaft
- Drive or cross-cut receding from observer
- Drive or cross-cut receding from and approaching observer
- Fault, position accurate

Bureau of Mineral Resources, Geology & Geophysics. April 1961

To Accompany Bulletin No. 6

F53/3/42

P.B

TABLE 14

HIT OR MISS GROUP, HATCHES CREEK
ANNUAL PRODUCTION OF WOLFRAM CONCENTRATES
1937-1958

Year Ending 30th June	HIT OR MISS		HIT OR MISS EXTENDED		FORTUNE		SILVER GRANITES		REWARD		HITLERS DOWNFALL		TOTAL	
	Concentrates Tons	Value £	Concentrates Tons	Value £	Concentrates Tons	Value £	Concentrates Tons	Value £	Concentrates Tons	Value £	Concentrates Tons	Value £	Concentrates Tons	Value £
1937	28.1	2,512	—	—	—	—	—	—	—	—	—	—	28.1	2,512
1938	21.4	4,290(a)	—	—	—	—	0.3	132	0.21	100(a)	—	—	21.91	4,522(d)
1939-1942	Combined production ex Walsh est.				100 Tons	£17,000(a)	0.11	37	0.96	215(a)	—	—	101.07(d)	17,252(d)
1943	5.23	1,755	0.37	118	2.04	647	2.10	748	—	—	—	—	9.74	3,268
1944	6.78	1,778	9.87	2,881	2.45	639	0.5	16	0.58	159	—	—	20.18	5,473
1945	6.23	2,162	0.7	213	1.53	478	—	—	1.06	375	0.88	289	10.40	3,517
1946	7.41	2,565	0.12	30	0.27	73	—	—	0.98	334	0.29	99	9.07	3,101
1947	0.98	382	—	—	—	—	—	—	1.01	357	—	—	1.99	739
1948	7.56	4,540(a)	0.16	100(a)	0.09	50(a)	2.33	1,300(a)	1.46	820(a)	—	—	11.60	6,810(d)
1949	—	—	0.63	21	4.32	2,204	—	—	0.87	328	—	—	5.82	2,553
1950	—	—	—	—	3.16	1,085	—	—	0.72	224	—	—	3.88	1,309
1951	10.41	17,125	1.37	2,315	—	—	0.34	240(a)	0.58	954	0.15	250	12.85	20,884
1952	4.93	8,503	2.79	4,937	—	—	1.68	3,118	4.83	8,390	—	—	14.23	24,948
1953	21.61	28,186	5.38	8,536	—	—	3.93	4,497	0.43	561	—	—	31.35	41,780
1954	13.42	11,985	4.39	4,493	—	—	4.01	2,672	1.99	1,350	—	—	23.81	20,500
1955	18.70	17,171	3.52	2,765	—	—	1.05	805	—	—	—	—	23.27	20,741
1956	27.45	27,033	(b)	(b)	—	—	0.99	971	—	—	—	—	28.44	28,004
1957	26.36	22,357	0.29	248	—	—	1.30	1,021	—	—	—	—	27.95	23,626
1958	17.00	5,005	—	—	—	—	—	—	—	—	—	—	17.00	5,005
Total	323.57(c)	174,349(e)	29.59	26,657	13.86	5,176	18.64	15,557	15.68	14,167	1.32	638	402.66 (d)	236,544 (d)

(a) Value estimated from mean price of wolfram for relevant years.
(b) Production included with Hit or Miss.
(c) Includes 100 tons ex Walsh.
(d) Includes estimated data.
(e) Includes £17,000 ex Walsh.

less favourable to the formation of well-defined lode channels than the siltstone which is host to the Main Lode, No. 1 Lode, and No. 3 Lode.

Three lines and nine lodes have been distinguished. The lines lie in the centre of the group, where the dislocation is more intense, and the lodes lie for the most part towards the edges of the group (Pl. 32). As mentioned above, the reefs, with very few exceptions, conform to four dominant directions of strike.

The location and habit of the reefs are related to their strike. Those in the north-western corner of the group strike at 180° and form lodes; those in the central part of the group may strike at either 180° or 200 - 210° and form lines; those in the south-western part of the group strike between 200 and 210°, and lie either in lines or lodes. All these reefs are vertical or dip to the west at 60° or more. In the central part of the group are a few narrow quartz reefs striking at about 250°, but they are short and poor. Lodes striking at 225° or 250° lie at the eastern and western edges of the group. The two lodes at the western side of the group have steep dips to north or south, or are vertical. The two eastern lodes dip to the north, one at about 45° and the other at 75°.

The group is located between at least three relatively large faults which were formed during the main period of faulting of the mineral field. Two faults, striking north-west, bound the group to the north-east and south-west, and are believed to be tension faults formed as a result of differential movement between the blocks of quartzite which form the ridges south and north of the Hit or Miss Gully. The third fault, which strikes north-east, lies immediately to the west of the Hit or Miss Group. It crops out as a wide zone of shearing. The unusually heavy fracturing represented on the group is attributed to its situation within these faults.

Mineralogy

Mineralization in the group is of two types, directly related to the strike of the host reef. Reefs striking north carry wolfram and quartz with minor amounts of molybdenite and mica. They are practically devoid of copper, whereas reefs striking at 250° and 225° carry considerable amounts of copper. The distinction is absolute, and is clearly exhibited at the intersection of two reefs in the Water Shaft on Walsh's Line (Pl. 32). Wolfram and copper are heavily concentrated at the intersection, but the reef which strikes north carries no copper away from the intersection, whereas copper minerals are abundant over the whole of the exposed length of the reef striking east. A similar phenomenon is present at the intersection of a cross reef with the Hit or Miss Extended Lode north of Korners Shaft (Pl. 36). The intersecting reefs are contemporaneous in both places. The copper, where present, is intimately associated with wolfram and with other ore minerals present.

No scheelite has been identified from the group. Molybdenite is present in all reefs regardless of strike. Traces of lead have been obtained from assays of ore from the Main Lode, and though no galena has been identified, a little wulfenite is present. Secondary copper minerals include azurite, malachite, chrysocolla, atacamite, brochantite, chalcocite, and bornite. Native bismuth is thought to be present.

Evidence of zoning was observed only on the Copper Lode (Pl. 33), where the ore minerals are segregated from the quartz in places and lie in the centre of the reef. There is no evidence of hydrothermal alteration of the wolfram comparable with that seen on the Green Diamond Main Lode.

Grade and Control of Ore

The deposition of wolfram in most of the smaller and less regular reefs in the group has been controlled by the intersections of reefs, by 'horses' on the reefs, and by the presence of faults, and other features. Rich but irregular concentrations of wolfram are the rule. However, the reefs become wider and more regular where the lodes traverse the sedimentary rocks (Pl. 32). At the higher levels on the Main Lode, Hossfeld (1941) determined the presence of a shoot lying in a section of the lode which had a more easterly strike than the rest of the lode. The presence of the shoot was revealed by structure contouring of the reef relative to a vertical plane. This contouring was continued to lower levels, but the shoot loses its definition and the contouring has little significance. Rich pockets are associated with splits in the reef, faults, 'horses', and leaders intersecting the reef, though in some of these cases the reef also changes strike locally towards the east. Some of these features can be related to a particular host rock, which may also have caused deflection of the lode-shear.

Information on the grade of the lodes is scarce. Grade at the mill of 534 tons of ore from the Hit or Miss Lease, crushed during 1955 and 1956, was 3.8% WO_3. Figures for the Hit or Miss Extended Lease and the Silver Granites Lease were 6.4% WO_3 and 6.6% WO_3 respectively, which only implies a greater concentration by hand before treatment. Hossfeld (1941) calculated a grade of 2.49% wolfram (c. 1.7% WO_3) for the Hit or Miss Main Lode, but gave no figures for other lodes.

Individual Lodes

All the lodes, and many of the less important reefs, have been tested to depths of 30 feet or more, but in 1956 few of these workings were accessible. Only five lodes have been tested below 100 feet, and all of these were in operation in 1956. Nine lodes and three 'lines' have been recognised within the group. They are listed below, together with their dominant direction of strike.

Name	*Strike*	
Main Lode	180°	(plate 32)
No. 1 Lode	180°	(plate 32)
No 2 Lode	200-210°	(plate 32)
No. 3 Lode	200-210°	(plate 32)
West Line	180°	(plate 32)
Central Line	180-210°	(plate 32)
Walsh's Line	200-210°	(plate 32)
Extended Lode	200-210°	(plate 32)
Silver Granites Lode	250°	(plate 33)
Copper Lode	220-250°	(plate 33)
No. 4 Lode	225°	(plate 32)
No. 5 Lode	250°	(plate 32)

Leases are so distributed that in only one place does the productive section of a line or lode lie on more than one lease. This exception is at the south-western corner of the Hit or Miss Lease, where the richer reefs in Walsh's Line lie across three leases. These are, from north to south, the Hit or Miss Extended Lease, the Hit or Miss Lease, and the Fortune Lease (Pl. 32). The Main Lode, No. 1 Lode, No. 2 Lode, and No. 3 Lode extend northwards on to the Reward and Hitlers Downfall leases, where they are poor and relatively unimportant.

In the past the name 'Copper Reef' has been assigned to any of the east-striking copper bearing-reefs. This has led to some confusion, and in this report the name 'Copper Lode' has been assigned to one of the lodes on the Silver Granites Lease (Pl. 33). Other copper-bearing lodes striking east have been given distinct names, and the name 'Copper Reef' is not used.

Main Lode (Pls 32, 34, & 35). The Hit or Miss Mine lies on the Main Lode. which is the most important in the group, and has contributed about half of the total production. Although the lode can be traced for about 1,000 feet, only a central section 450 feet long has been exploited to any depth. This section lies almost entirely in siltstone; to the south and north the lode lies in volcanic rocks, is more irregular, and carries less wolfram.

In the central section the lode consists essentially of one reef 20 inches to 40 inches wide. North of this it consists of two or more reefs up to 20 inches wide, and to the south it becomes irregular and dies out in a number of barren veins. Development beyond the central section has been confined to shallow open cuts, except in the extreme south, where the intersection of the Main Lode with an easterly extension of the Silver Granites Lode has been locally worked.

Three shafts serve the central section. One of these, Chinaman's Shaft, is vertical and was put down by the Commonwealth Government. It lies in the footwall of the lode, and is connected by short cross-cuts to the 112-foot level and the 166-foot level. Walsh's Shaft which, is inclined, serves as the main shaft, and had reached a vertical depth of 205 feet in June 1956. It has since been deepened to about 245 feet, but development at this level had barely begun when the mine was closed down. A third shaft, the North Shaft, was not in use during 1956. It is also inclined, and is accessible to the 97-foot level. Water stands about 15 feet below this level and the depth of the shaft is not known, but is believed to be about 120 feet. It is situated at the extreme western limit of the productive section of the lode. Ore had been almost entirely removed above the 141-foot level by 1940 (Hossfeld, 1941). Since then the mine has been worked from the 166-foot level and the 205-foot level.

The lode has an average strike of 180°, but in the rich section the reef has two distinct directions of strike. The wider, flatter-dipping sections strike at 190 - 200°, and the narrower, steeper sections strike at 160 - 170°. Hossfeld (1941) states that in the then accessible levels high-grade ore was present in the wider, flatter sections of the reef; but more recent evidence suggests that the attitude of the reef is not wholly responsible for the enrichment. Local enrichment of wolfram has taken place along faults, 'horses', at the junction of the reef with small leaders, and also

where the strike of the reef changes from east of north to west of north. 'Spotted dog', which elsewhere characterizes the shoots, is typically absent, at least in the lower levels of the mine.

The reef is now exposed in only a few places at the 141-foot level and the 112-foot level, and these exposed sections are in general barren. At the north end of the 112-foot level the reef splits into two reefs of equal width. The North Shaft was put down on the hangingwall reef, whereas the level was driven on the footwall reef, thus failing to intersect the shaft. A cave-in at about 100N has rendered the level inaccessible from Walsh's Shaft, but the 97-foot level connects with the 112-foot level north of the cave-in. The footwall reef strikes at about 190° near the break-through, but to the north it pinches on a shear striking at 160° (Pl. 34).

The strike of the reef changes abruptly at 64N at the 112-foot level. Very rich ore has been reported above this level between 63N and the North Shaft, and rich ore was showing at the intersection of the two reefs in the 97-foot sub-level. The enrichment may have been caused by either or both of the two features.

Between 83S and 63N the reef strikes at about 195°, but at 83S there is another marked change in strike. Hossfeld (1941) assumed the presence of a shoot between 82S and 63N. South of 83S, the reef strikes at 160° for a short distance, but then assumes a strike of about 160°, which persists to the face at 252S. The reef is faulted and irregular in this section, and development south of the cross-cut to the Chinaman's Shaft is said to have yielded 1.2 - 1.4% WO_3. The reef narrows and is lost on a vertical shear striking at 192°.

The 141-foot level has been driven for at least 100 feet, both north and south of Walsh's Shaft. The drive has been partly filled to the south, but the backs are accessible. The reef is 15 to 30 inches wide, and is irregular and faulted. The accessible section of the level strikes at about 195°, but at 66N the strike changes to 165°. The northern limit of the level is unknown.

Development at the 166-foot level has been entirely south of Walsh's Shaft, except for a short drive 26 feet long to the north. The reef strikes at 180° in the north drive, but swings to a strike of 120° south of Walsh's Shaft. A moderate grade of ore is said to have been encountered in this section.

The strike changes again at about 100S, where the reef intersects a bed of tough quartzite. The reef is split and irregular for about 40 feet, and is joined from the north by a footwall reef 9 inches wide. Two reefs continue to the south, striking at about 200°, but have been neglected in favour of a short reef striking at 160°, which pinches to the south but makes again. Still farther south, the strike of the lode gradually swings back towards 190°, and a second reef makes in the hangingwall just north of the south face.

High-grade ore was mined where the reef splits between 80S and 110S, and some patchy wolfram was present in the southern section, where the strike swings towards 190°, but the reef was barren where it strikes at 160° between these two sections (Pl. 34). The prolific splitting at 80S and 110S is attributed to the coincidence of the change in strike of the lode and its intersection with the quartzite. At the 112-foot level the two features do not coincide, and the effects are not so pro-

nounced. The splitting of the reef is believed to have been mainly responsible for the localization of wolfram. Molybdenite is unusually common in this section. Another rich pocket was present at 150S, where a 3-inch wide quartz leader, striking at 188°, joins the reef.

The 205-foot level is 195 feet long. No ore remains above the level south of Walsh's Shaft, within the limits of the drive, but further ore may be won to the south of these limits, as the reef strikes at approximately 015° in the south face. A rich pocket, localized on a 'horse' which plunges to the south at about 45°, was being mined immediately north of Walsh's Shaft at the time of the survey. The strike of the reef swings to the west north of the 'horse' and the reef is poor. Stoping was continued above the 205-foot level north of Walsh's Shaft late in 1956, and no ore remains between this level and the 141-foot level within the limits of the drive. The north drive was abandoned at 97N when the reef became poor, but further development is recommended in this direction, as the strike may well change again and further payable ore be encountered.

Walsh's Shaft was put down about another 30 feet late in 1956 and unusually rich ore was encountered within 15 feet of the shaft, to the north. High-grade ore was also present south of the shaft for a reported distance of 30 feet.

The intersection of the lode with the bedding of the country rock plunges to the south at about 45°, and this corresponds with the plunge of most of the features of the reef, except the changes in strike, which plunge much more steeply to the south, or are vertical. The trace of the changes in strike is shown in Plate 35, from which it is apparent that they plunge steeply at depth. No reason for this could be detected.

The lode has not been sufficiently tested to the north or south of the present limits of the 205-foot level to determine whether features observed at higher levels persist. It is important that the location of the expected change of strike to the south be determined, as experience has shown that the presence of wolfram south of this is spasmodic. If the plunge of this feature continues to steepen, as is indicated in the vertical projection on the lode (Pl. 35), the change in strike will be encountered within 30 feet of the present south face at the 205-foot level. Information on the lode north of Walsh's Shaft is scanty and the north drive will have to be extended at the 205-foot level to determine whether features present at higher levels persist. Present evidence indicates that most of the features on the reef plunge to the south parallel with the intersection of the lode with the bedding of the country rock, and similar behaviour has been observed on almost every large lode on the field. The plunge of any new feature can thus be tentatively predicted.

The lode has been mined successfully over a length of about 350 feet at the 112-foot level, and has a total known length of 1,000 feet. It is considered that the present grade in the mine will persist to at least 350 feet. The mine has yielded between 150 tons and 200 tons of concentrates from an estimated 9,000 tons of ore, a grade of 1.7 - 2.3% WO_3, a little higher than Hossfeld's 1941 figure. However, Hossfeld's calculation was based on all ore mined, whereas recognition of the features which control the enrichment should permit selective mining to a grade of at least 2% WO_3.

It is estimated that a further 9,000 tons of ore are available above the 350-foot level. The total possible wolfram ore reserves are between 150 tons and 200 tons.

No. 1 Lode. The No. 1 Lode lies between 150 and 180 feet east of, and parallel to, the Main Lode. It is about 600 feet long in outcrop and strikes at about 360°. The richest and widest section of the lode, where the reef attains a maximum observed width of 15 inches, lies in the same belt of siltstone as the rich section of the Main Lode. To the north of this section the lode consists of one reef ranging in width from 2 inches to 10 inches. Scattered open cuts indicate that the lode was unprofitable to mine. Three shafts have been put down on the richer section, but the depths and extents of development are not known. The lode disappears to the south beneath the alluvium of the gully which crosses the centre of the group (Pl. 32). A projection of the strike of the lode intersects the No. 2 Lode at the No. 2 Shaft.

The lode is reported to carry moderately rich but patchy ore, and this fact, together with the small width of the reef, has militated against its profitable operation. Further rich patches of wolfram are undoubtedly available, but their exploitation will be dependent upon suitable economic conditions.

No. 2 Lode. The No. 2 Lode strikes between 020° and 130°, and has been traced for 300 feet south of, and 400 feet north of, the central gully. The lode is poorly defined and consists of a large number of narrow quartz reefs dipping steeply to the west. In strong contrast to other lodes it fans out into an unusually large number of veins, up to 6 inches wide, where it lies in the siltstone north of the gully. These veins have been prospected, with little success, from many shallow pits.

The No. 2 Shaft was put down at the intersection of the No. 2 Lode with the No. 5 Lode and the No. 1 Lode (Pl. 32), and, judging by the amount of waste rock in the dump, a considerable amount of development was undertaken. This appears to be the only place on the lode where a payable grade of wolfram was obtained. The lode does not warrant further exploration.

No. 3 Lode. The No. 3 Lode lies parallel to and about 100 feet east of the No. 2 Lode and is the same length. It conforms to the normal behaviour of the lodes in that the widest and richest section lies in siltstone. It consists of one reef in this section, but to the south it splits and becomes irregular. The richest section has been extensively open-cut, and an adit, now inaccessible, was put in. The adit is probably not very long, as the reef does not maintain its width or continuity to the north. No information is available on the grade of the ore won from this reef. The observed maximum width was 23 inches and the reef dips west at about 80°. Further exploration of this section of the reef is definitely justified, and should be directed towards testing the reef below the large open cut, where it is at its widest.

The lode has been tested in Olsens Tunnel (Pl. 32), where it consists of one reef, which is narrow, vertical, and poor. Local rich patches of wolfram are present in the southern section of the lode, but underground development does not appear to be justified.

A possibility of further rich ore exists at the projected intersection of the No. 3 and No. 5 Lodes north of Olsens Tunnel (Pl. 32). If this intersection exists, and

it is believed that it does, a limited tonnage of wolfram should be available, but the intersection is at present covered by dump.

West Line. The West Line consists of a series of discontinuous irregular reefs striking between 360° and 020°, and extending for about 700 feet from north to south. The reefs range in width from 5 inches to 15 inches and dip west at 60 - 80°.

Hossfeld (1941) reports that at least two tons of wolfram were won from a shallow shaft on the Fortune Lease (Pl. 32), on a reef which has also been developed from an adit. The reef is 14 inches wide and dips west at 70°. Other shallow shafts have been put down on various reefs in the line, but none is now accessible. It appears that nowhere are any of the reefs rich enough or consistent enough to support extensive development: they are suitable only for rapid exploitation of small rich patches of ore lying near the surface during periods of high wolfram prices. A recurrence of such conditions might justify the exploration of reefs on the line for further ore near the surface.

Central Line. The Central Line exhibits much the same characteristics as the West Line, except at the northern end, and lies north-east from the West Line. It is about 700 feet long, and in the south it trends at about 025°; but the trend changes gradually to the north, and at the northern end the line consists essentially of one lode striking at 360°.

In the south payable wolfram is limited to irregular rich patches exploitable only near the surface, but to the north the lode seems to have been enriched to a greater degree at two places. The first of these is at the intersection of the line with what is thought to be the eastern end of the No. 5 Lode (Pl. 32). A shaft, in which water stands a few feet below the collar, was put down on the intersection. No results are known, but the amount of mullock indicates that development was not extensive.

The greatest amount of development has been done in the lode at the northern end of the line, where two shafts 25 feet and 30 feet deep have been sunk. The lode consists of two parallel reefs up to 11 inches wide. Further ore may be won from this section, and from other parts of the line, but the irregularity and discontinuity of the reefs do not enhance the prospects for future development.

Walsh's Line. Walsh's Line is the largest and most complex of the three lines in the centre of the group. It consists of a mass of intersecting reefs, which have strikes ranging from about 360° to 030°.

The dip of the reefs ranges from 70° west to vertical, and the width from 2 inches to 12 inches. Because of the numerous intersections, local enrichment of the reefs is unusually common. All the wider reefs have been exploited from extensive open cuts and there has been considerable underground development, particularly towards the southern end of the line. Four shafts were accessible during 1956, but several other shafts up to 50 feet deep had been abandoned.

Dodds Shaft and the Water Shaft (Pl. 32) were put down on a reef striking between 075° and 080° which crosses the line. This reef is vertical and dips steeply to the north, and is heavily mineralized with copper. It intersects several reefs which

strike north, and these intersections are usually the foci for enrichment of wolfram and copper. Wolfram and copper are also enriched on faults in the reef, and a split in the reef which strikes north in the Water Shaft is locally enriched in wolfram. Drives about 60 feet long extend west from each shaft, and there is a short cross-cut from each drive on one of the larger cross reefs.

Little ground now remains unbroken between the two drives. The drive from the Water Shaft is filled below to an unknown depth for about 30 feet west from the shaft, and some ground has been stoped above the upper drive. Future development will involve testing of the reef below the stoped ground in the lower drive, and will be hampered by water.

Stewarts Shaft (Pl. 32) was being cleaned out in 1956 and was accessible to 125 feet. Development to the south has ceased where the reef pinches on a strong shear striking at about 040°. Movement along the shear has been horizontal and the reef has been dragged to the west. The stopes to the north of the shaft were inaccessible and their extent is unknown, but very rich ore is reported to have been obtained. Stewarts Shaft was started on the reef which runs through the Old Shaft (Pl. 32), but a second reef was encountered in the hangingwall and this was followed thereafter. The hangingwall reef dips at 85° or steeper to the west, and is from 3 to 11 inches wide.

Three shafts have been put down on the southern end of the line. These were in existence in 1940 (Hossfeld, 1941), and as far as can be ascertained have not been used since. They all lie on the Fortune Lease, which was known as 'Cadogans Lease' in 1940. According to Hossfeld, two of the shafts were 51.5 feet deep, and the third was 36.5 feet deep. He further states that:

'The most northerly shaft, 51.5 feet in depth, has been sunk on two reefs each 12 inches in width at the surface, which junction below the surface, to form a reef 24 inches wide. At a depth of 34 feet a drive was put in for a distance of 15 feet to the southward. At the bottom of the shaft drives have been put in for 10 feet northward and 15 feet southward. In the face of both drives the width of the reef is 12 inches.

'Thirty feet to the south of this shaft a second shaft was sunk to a depth of 51.5 feet on a reef which was 12 inches wide at the surface. Short drives were put in at the 20 and 46-foot levels. In the drive at the 46-foot level two reefs occur 4 and 2 inches in width respectively. A drive at the bottom of the shaft showed a reef which was 12 inches in width. A third shaft, 36.5 feet in depth, is situated 95 feet to the south of No. 2 Shaft. A few short drives were put in from this shaft'.

The underground and surface development on these reefs had produced about 7 tons of wolfram, but Hossfeld states that 'the present owner . . . reported that results obtained by him have been very poor'.

Some rich ore has been won from reefs on Walsh's Line and further rich patches of wolfram certainly remain. The richer reefs have already been exploited to a considerable depth, and, in view of the uncertainty concerning the persistence of the reefs and the location of further high-grade ore, future development must be undertaken with caution.

Extended Lode. The Extended Lode marks the eastern limit of the Hit or Miss Group. It strikes at about 030° and crops out over a length of about 500 feet, but most of the outcrop is obscured by spoil. It may continue to the south under alluvium, but any southern extension is unlikely to prove profitable, because its richest part, like that of other lodes, is confined to a short central section. This section has been developed from two shafts. The Extended Shaft to the north has been abandoned, and was inaccessible in 1956. It is inclined to the west but is of unknown depth. Korners Shaft to the south (Pl. 32) is also inclined to the west, and the total depth is unknown as the shaft contained water below the 61-foot level.

The mine was abandoned in July 1956, and the 61-foot level is now also under water.

The lode in Korners Shaft consists of two parallel reefs dipping west at 57° to 66°. The two reefs are joined by leaders at intervals and their width varies from place to place. The aggregate width of quartz varies from 5 inches to 22 inches (Pl. 36).

The footwall reef has been lost 20 feet north of the shaft at the 61-foot level, but the hangingwall reef has been followed for nearly 100 feet to the north. The reef ranges in width from 6 inches to 15 inches and dips west at 50 - 64°. It is generally poor, except between 40N and 47N, where it intersects a 'copper reef' striking at 080° and dipping north at 75 - 77°. The channel of the 'copper reef' has been displaced by the main reef, the east block moving north relative to the west block, but the quartz in both reefs is contemporaneous.

The 'copper reef' is 9 - 17 inches wide. It carries abundant secondary copper minerals and some wolfram. The reef has been stoped below the 61-foot level to an unknown depth, and has been driven on for 29 feet west from the intersection at the 61 foot level. It is split at the face, and also east of the intersection. This reef could not be accurately identified at the surface either east or west of the Extended Lode, and its extent is unknown.

The hangingwall reef of the Extended Lode has been removed to an unknown depth south of Korners Shaft, but the stope ends 20 feet south of the shaft at the 42-foot level. The tonnage of wolfram won from this stope is not known. The footwall reef remains at the 42-foot level, and local enrichment has taken place at the junction of this reef with two narrow leaders in the footwall. It is reported that the lode has been entirely stoped above the 33-foot level between Korners Shaft and the Extended Shaft. A drive to the north 27 feet long remains at the 17-foot level. The reefs in this drive have an aggregate width of 18 inches to 22 inches, and wolfram was showing in the hangingwall reef near the northern end of the drive.

The reopening of this mine would require a considerable amount of cleaning out. It is reported that rich patches of ore have been mined on the lode, but owing to the total lack of information on the location and plunge of these patches, and the depth of the workings, no recommendations for further development can be made.

No. 4 Lode. The No. 4 Lode differs considerably from the other lodes in the group in dip and strike. It has been traced for 360 feet, and over most of this length

consists of one of two reefs striking at about 045° and dipping north at 45°. It becomes irregular and ends against the Extended Lode at its north-eastern end, and it disappears beneath rubble and alluvium at its south-western end (Pl. 32). It has been exploited over a greater part of its length from shallow shafts and open cuts.

Although it apparently carries a more consistent grade of ore than many of the lodes in the group, the shallowness of the openings suggests that the grade was low. Development of the lode at deeper levels, particularly to the south-west where it intersects Walsh's Line, may be possible during a period of high wolfram prices.

No. 5 Lode. The existence of this lode has been inferred from the presence of short sections of reef, which are contiguous in dip and strike, at either end of the postulated position of the lode (Pl. 32). At the western end a reef intersects the No. 2 Lode and the Main Lode, and at the eastern end a reef intersects the Central Line. The two reefs dip north at about 70°, and strike at about 080°.

The presence of shafts, now inaccessible, at the intersection of the No. 5 Lode with the No. 2 Lode and with the Central Line indicate that there has been some enrichment at these intersections. The No. 5 Lode may also, therefore, have been enriched where it intersects the No. 3 Lode. Suitable economic conditions might justify the testing of this possibility, and the lode might also support development at other places along its length.

Silver Granites Lode and Copper Lode (Pls. 33, 37). These two lodes are intimately associated in the Silver Granites Mine and are therefore described together. They strike at 040 - 070° and are almost parallel at the eastern end. They form a discrete westerly extension of the Hit or Miss Group, and die out to the east, where they meet the rest of the group.

Sultans Reef is the most westerly north-striking reef on the Hit or Miss Group. It strikes at 340°, dips either east or west of vertical, and is from 6 to 13 inches wide. It has been tested over a length of 160 feet by drives north and south from Sultans Shaft (Pl. 33). Small patches of rich ore were encountered in the drive, mainly at the intersection of the reef with narrow cross-veins. Sultans Reef intersects the Silver Granites Lode and the Copper Lode at their eastern end, and marks their eastern limit, as they are represented only by a few barren veins to the east of the intersection.

The Silver Granites Lode and the Copper Lode lie in a wide zone of shearing which can be traced east from Sultans Reef into the body of the Hit or Miss Group; and west from Sultans Reef for about 650 feet, where it ends in a zone of shearing which strikes north-east and is associated with one of the major faults which bound the Hit or Miss Group. The two lodes are 80 feet apart at their eastern end, but converge slowly to the west, until the Copper Lode splits, the southern reef crossing the Silver Granites Lode, and the northern reef, which is indeterminate, continuing roughly parallel to the Silver Granites Lode (Pl. 33). The Silver Granites Lode strikes at 075° and dips steeply to the north. The Copper Lode strikes at 060° east of the split, and the southern limb strikes at 040°.

Underground development has been restricted to a short section where the two lodes cross. West of the mine both lodes become irregular and die out in

sheared volcanic rocks. Both carry large quantities of copper, and two parcels of ore from the mine were sold in 1956 and 1957. One of these included ore from the Copper Show Group, and the tonnage from the respective groups is not known. About 15 tons of ore assaying between 39% and 47% Cu were sold.

Four shafts have been put down on the two lodes, two of which were inaccessible in 1956. The Main Shaft had been put down close to the intersection of the two lodes and was 62 feet deep in July 1956. A drive connects this shaft with No. 2 Shaft to the south-west. A second drive at the 48-foot level has been filled from the No. 2 Shaft and was only partly accessible. These two drives follow the Copper Lode, but east of the Main Shaft two short drives at the 62-foot level and the 48-foot level have been put in on the Silver Granites Lode. The Main Shaft was sunk to a new level early in 1957 and a drive was put in on the Copper Lode north-east of the Main Shaft, revealing very rich wolfram and copper.

The Silver Granites Lode is extremely irregular in width and dip. It is exposed east of the Main Shaft for about 40 feet at the 62-foot level, and for a similar length at the 48-foot level, and consists of one or more reefs ranging in width from 8 inches to 14 inches, and in dip from 85° south to 68° north. It has been displaced by several faults which strike roughly parallel to the Copper Lode and dip between 69° and 85° to the south-east. The reef has not been tested in the present workings west of the intersection with the Copper Lode, but a disused shaft lies on the lode further to the west.

The Copper Lode is more prone to splitting, and has been displaced to a small extent by the Silver Granites Lode, but the quartz in the two lodes is of the same age. The lode consists essentially of one reef 9 to 15 inches wide which dips north at from 65° to 84°.

Both lodes carry malachite, bornite, chalcocite, and molybdenite in addition to wolfram. Native bismuth is thought to be present and mica is common. 'Spotted dog' is common in the more regular sections of the reefs, but there has been enrichment of wolfram, and to a lesser extent copper, where the reef has split. The intersection of the two lodes is not enriched.

The lodes have been proved to carry high-grade ore, but have not been exhaustively tested to the north-east or south-west. Evidence from the surface indicates that the reefs become narrower away from the intersection of the lodes, but, providing a high grade of ore is maintained, it should be possible to exploit both lodes farther to the north-east than has so far been done. The deepest level of development is now about 90 feet, but little work has been done at this level. The reefs show no sign of decrease in grade or width at depth and there is no reason to suspect that they will not persist to at least 200 feet. No information is available on the overall grade grade of ore won, but verbal reports indicate that it compares favourably with the other lodes at Hatches Creek. It is estimated that a grade of at least 1.5% WO_3 can be confidently expected at lower levels within the lateral limits of existing development.

On present indications the production of copper ore will considerably augment earnings from the sale of wolfram, and will certainly offset the penalties in-

curred by the incomplete separation of copper from the wolfram. The ores have been separated by hand in the past, but it should be possible to develop a small unit which can be installed at the mine, capable of magnetic separation of the wolfram and copper in the concentrates.

Development has been mainly restricted to a section of the Copper Lode about 120 feet long. Assuming a grade of 1.5% WO_3 it is estimated that 1100 tons of ore containing 24 tons of concentrates are available above the 200-foot level.

Conclusions and Recommendations

Wolfram has been won in the past from a very large number of reefs within the Hit or Miss Group, some of which are very rich but patchy, which renders their exploration uncertain. Most of the smaller reefs will not support other than surface operations, and near-surface ore in these reefs has been extensively exploited. Systematic exploration of these smaller reefs during periods of high prices will yield a small tonnage of ore; but attention should be concentrated on those lodes which have been successfully exploited at depth in the past. The amount of information on the lodes, and the disrepair of the mines, vary considerably, and the reopening or exploration of any lode will be dependent on the prevailing economic conditions.

If the group is to be developed as a whole, quickest returns will be obtained from the Main Lode and the Copper Lode, and this will provide a sound basis for further exploration. The method of employing several tribute parties on the various lodes has proved successful in the past and is likely to prove the most satisfactory method of development in the future. However, any large-scale operations at greater depths than about 250 feet will require the sinking of vertical shafts and the installation of heavier equipment than has been used in the past. Although development has not reached 200 feet except on the Main Lode, many of the more important lodes have been tested to about 100 feet. If a long-term policy of development is envisaged these factors must be taken into account.

Two lines of exploration should be followed. The lodes lying in siltstone, that is No. 1 Lode and No. 3 Lode, should be tested. These lodes are relatively long and well defined, and they could become both wider and richer at lower levels. Exploration elsewhere should be concentrated on sections of reefs known to be rich, and on intersections of lodes and reefs striking north with lodes and reefs striking east.

Attention should also be given to the possibility of developing Walsh's Line from one vertical shaft centrally placed. There is in this area a very heavy concentration of reefs, striking east and north, some of which are known to carry high-grade ore, and it would be possible to explore the line thoroughly by driving and cross-cutting on the various reefs, thus obviating the unnecessary breaking of waste rock.

Possible ore reserves have been calculated only for the Main Lode and the Copper Lode, as these are the only two about which enough is known. Exploration on other lodes, however, could prove several times as much wolfram within 200 feet of the surface.

Kangaroo Group

(Pls. 4, 38, 39, 40, & 41)

The Kangaroo Group was named by Hossfeld (1941), but according to his description, he included the Silver Granites Lode and the Copper Lode in it. The group lies about half a mile north-west of the Hit or Miss Group, and a little over a mile and a half south-west of Goat Hole.

The dominant feature of the group is the Kangaroo Line (Hossfeld, 1941), a continuously mineralized line of shearing about a mile long and trending north-east. This line has no equivalent at Hatches Creek. It is poor at the extremities, where it consists of short discontinuous quartz reefs, but richer in the central part, where it consists of many reefs lying parallel or on echelon along a wide shear zone. Many other reefs and lodes of varying strike lie in this central section, which is covered by the Lady Hamilton Lease, Bransons Lease, and the Lost Corner Lease (Pl. 38). Some of them are wide and well defined, but they have not proved as rich as the more important lodes in other groups.

The central part of the group underlies an area of about 1500 feet by 1250 feet. The Kangaroo Line projects 1500 feet to the north-east, where it traverses the Euro Lease, and about 2,000 feet to the south-west, where it traverses the Prodigal Lease and the St John Lease. Some small unconnected reefs lie on the Good Luck Lease, which lies to the south of the Lady Hamilton Lease and Bransons Lease (Pl. 4).

History

The 'Kangaroo Claim' and 'Hamilton Claim', occupying much the same ground as the present Lady Hamilton Lease, were held in 1916 (Oliver, 1916). The 'Edith Claim' lay to the west of the 'Kangaroo', and the 'Burgess Claim' lay to the south. All these claims had been abandoned by 1923. Mr J. Walsh acquired the Hamilton Lease and Kangaroo Lease in about 1937, and these two leases were held by him and his estate until 1949, when they were bought by the present owner, Mr V. Knight. They were later re-registered as the Lady Hamilton Lease, in the name of Mrs V. Knight. The early history of the other leases is uncertain. They have been held from time to time by different owners but operations have been confined mainly to unsystematic open-cutting. The Lost Corner Lease has been under continuous operation since 1939 at least, but at that time it was known as the 'Business'. The other leases were registered in their present names, and with their present boundaries, in 1949 or later.

Production

The recorded production from the group is 89.41 tons of concentrate worth £70,581. To this must be added production from the Kangaroo Lease and the Hamilton Lease between 1939 and 1943, and which was included in the bulk production from all of Walsh's Leases. Production from the group prior to 1940 must also be added. Both these amounts are totally unknown. The total production from the group has almost certainly been more than 100 tons. Production recorded from the individual leases is as follows:—

Lease	Concentrates	Value
Lost Corner	30.88 tons	£15,647
Lady Hamilton	25.45 tons	£31,082
Good Luck	19.94 tons	£4,779
Bransons	9.78 tons	£14,811
Prodigal	1.78 tons	£2,179
Euro	1.34 tons	£1,800
St. John	0.24 tons	£283
Total	89.41 tons	£70,581

The Good Luck Lease produced more than 16 tons of wolfram during 1943, but the owner of the lease at that time also owned other leases at Hatches Creek, and production from his other leases may be included in this total. Table 15 gives the recorded production of wolfram from the three leases which cover the richer central part of the group. Production from Bransons Lease before 1950 is not known, but may have been relatively large.

TABLE 15

PART OF KANGAROO GROUP, HATCHES CREEK

ANNUAL PRODUCTION OF WOLFRAM CONCENTRATES, 1939-1958

	LADY HAMILTON LEASE		BRANSONS LEASE		LOST CORNER LEASE		TOTAL	
Year Ending 30th June	Concentrates Tons	Value £	Concentrates Tons	Value £	Concentrates Tons	Value £	Concentrates Tons	Value £
1939	(b)	(b)	(c)	(c)	0.30	45(a)	0.30	45(d)
1940	(b)	(b)			0.95	137	0.95	137
1941	(b)	(b)			5.14	1,230(a)	5.14	1,230(d)
1942	(b)	(b)			1.10	353	1.10	353
1943	(b)	(b)			3.06	1,095	3.06	1,095
1944	0.29	65			3.20	918	3.49	983
1945	—	—			2.38	862	2.38	862
1946	—	—			1.16	411	1.16	411
1947	—	—			2.34	823	2.34	823
1948	0.62	372			3.30	1,700(a)	3.92	2,072(d)
1949	1.70	691			0.98	401	2.68	1,092
1950	1.30	462	0.1	25	0.23	91	1.63	578
1951	3.20	5,269	0.06	54	1.03	1,225	4.29	6,548
1952	4.59	8,612	3.98	6,855	1.17	1,928	9.74	17,395
1953	4.84	6,778	4.56	6,846	1.79	2,608	11.19	16,232
1954	6.41	6,351	0.54	544	0.84	709	7.79	7,604
1955	0.01	29	—	—	1.31	737	1.32	766
1956	1.93	1,899	0.54	487	—	—	2.47	2,386
1957	0.56	544	—	—	0.35	334	0.91	1,039
1958	—	—	—	—	0.25	40	0.25	40
Total	25.45	31,082	9.78	14,811	30.88	15,647	66.11	61,691(d)

(a) Value calculated from mean price of wolfram for relevant year.
(b) Production included with that from other leases owned by Walsh.
(c) No production recorded prior to 1950.
(d) Includes estimated figures.

Geology

The Kangaroo Group is situated on the south flank of Dooleys Ridge, and the lodes lie in interbedded sedimentary rocks and volcanic rocks to the north, and in volcanic rocks containing a few small isolated lenses of quartzite to the south (Pl. 38). The dip is to the south at 42 - 65° and the strike 070 - 080°. Faulting, mainly on the Lost Corner Lease, is common, but displacement has been small. The rocks are siltstone, greywacke, sandstone, and quartzite, interbedded with flows of acid porphyritic volcanic rock. Only the two thickest flows have been differentiated on the map. These lens sharply, one to the east and the other to the west (Pl. 38). The southern part of the group lies in volcanic rocks containing a few small, sharply lenticular bodies of tough light-coloured quartzite. The volcanic rocks are acid porphyries and have been hornfelsed and recrystallized in places.

The main part of the group is bounded to the south by a thick quartzite, which is a western extension of the sedimentary rocks on the northern part of the Hit or Miss Group. The Kangaroo Group lies at the same stratigraphic horizon as the Masters Gully Group (Pl. 4).

The central part of the group contains two intersecting lines of reefs, one trending at about 055° and the other at about 015°. The lines intersect towards the north-eastern corner of Bransons Lease. Intense fracturing appears to have been associated with this intersection, and possibly with the faults in the country rock, as the other reefs in the area are short and irregular, and have varying strikes.

The reefs are relatively free of impurities. Mica is common, mainly as a selvage. Reefs lying in the sedimentary rocks carry little but wolfram, quartz, and mica. Molybdenite and copper minerals are present in small amounts in reefs lying in the volcanic rocks. Separation of impurities has not so far proved necessary, and the lack of iron oxides and secondary copper mineralization suggest that the ore is not contaminated in the primary zone.

Grade and Control of Ore

As far as can be seen from the few accessible workings, wolfram has been deposited mainly where faults of small displacement, which dip north and strike roughly east, intersect the reefs. The reefs are also offset by many small faults caused by movement along the bedding planes, but these have not served as foci for the deposition of wolfram. It is known from verbal reports that rich pockets are present and that disseminated ore is rare. One of these pockets in the Lady Hamilton Mine yielded 8 tons of concentrates from 170 tons of ore, a grade of 3.05% WO_3. It is estimated that about 620 tons of ore were won from the shaft, and according to the owner, 7.2 tons of wolfram concentrates were obtained, assaying just over 65% WO_3. The overall grade of ore from the mine has therefore been about 0.8% WO_3, or 1.2% of concentrates. Figures provided by the owner for the Kangaroo Shaft (Pl. 39) indicate a grade of 0.26% WO_3, which seems unusually low. The owner reports that the reef is very poor, but that richer ore was obtained in the old part of the mine.

PLAN

KANGAROO GROUP

HATCHES CREEK N.T.

LOST CORNER LEASE

CROWN LAND

BRANSONS LEASE

LADY HAMILTON LEASE

GOOD LUCK LEASE

ACTIVITIES LODE

No 1 LODE

LADY HAMILTON LODE

LADY HAMILTON LINE

KANGAROO LINE

Creek

No 1 SHAFT

LADY HAMILTON SHAFT

OTTOLINIS SHAFT

ANDERSONS SHAFT

KANGAROO SHAFT

water

2 tons concentrates reported

strong shear with blebs of quartz

SCALE

40 0 40 80 120 Feet

Hatches Creek Group

- Phs — Siltstone, sandstone, greywacke, quartzite, volcanic rock
- Phv — Volcanic rock
- Phq — Quartzite

- Reef, position accurate, showing width and dip
- Reef, vertical
- Reef, position approximate
- Reef, concealed
- Reef, inferred
- Geological boundary, position accurate
- Geological boundary, position approximate
- Geological boundary, concealed
- Fault, position accurate, showing dip
- Fault, position approximate
- Fault, position inferred
- Fault, concealed
- Strike and dip of bedding
- Form lines, 10 ft. interval. Datum, collar Lady Hamilton Shaft - approx. R.L. 1260 ft.
- Surface workings
- Underground workings
- Shaft, in use
- Shaft, disused or inaccessible
- Shaft, inclined
- Track
- Dump
- Lease boundary

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To Accompany Bulletin No 6

MERCURY

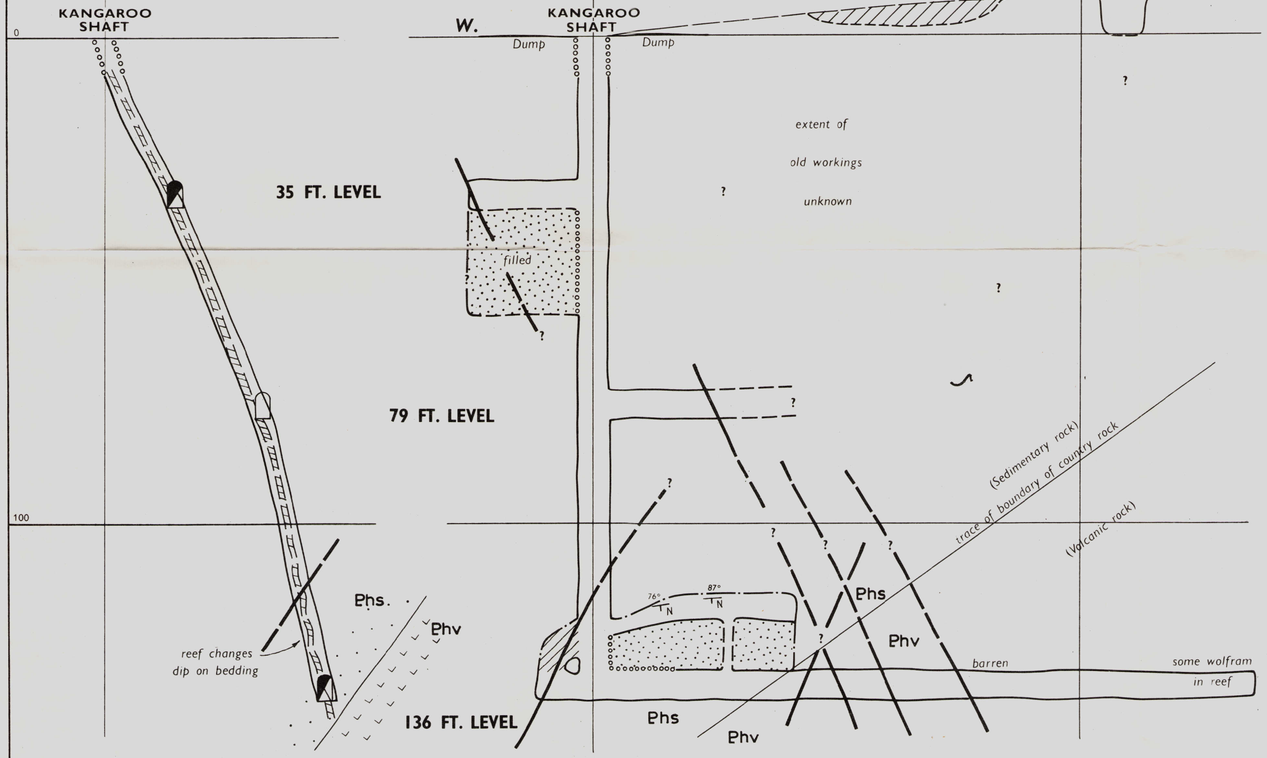
PLANS AND SECTIONS
KANGAROO SHAFT
KANGAROO GROUP
HATCHES CREEK N.T.

SCALE

20 10 0 20 40 60 Feet

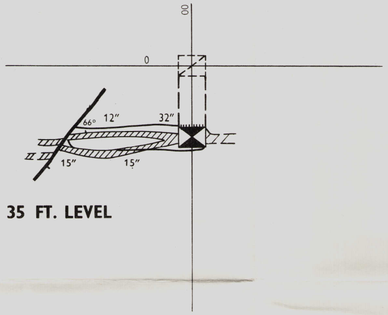
24.5.56

CROSS SECTION ON CO-ORDINATE "00"

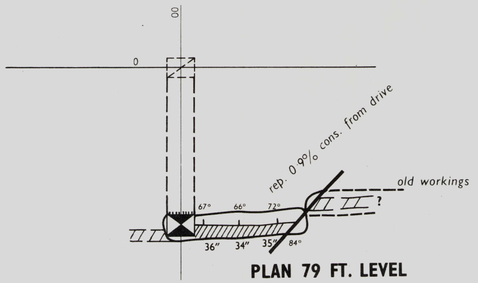


VERTICAL PROJECTION ON CO-ORDINATE "0"

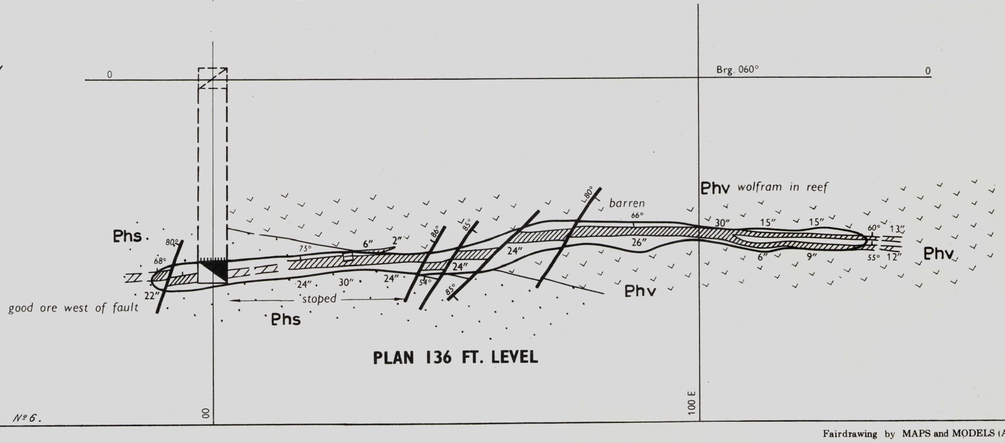
PLAN 35 FT. LEVEL

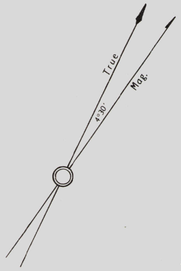


PLAN 79 FT. LEVEL



PLAN 136 FT. LEVEL





REFERENCE

HATCHES CREEK GROUP

- Phs — Sedimentary rocks
- Phv — Acid volcanic rocks
- Reef, position accurate showing width and dip
- Reef, position approximate
- Geological boundary, position accurate showing dip
- Fault, position accurate showing dip
- Fault, position inferred
- Inclined shaft passing through level
- Foot of inclined shaft
- Accessible workings
- Dip and strike of reef
- Inaccessible workings
- Limit of Stope
- Stoped ground
- Filled ground
- Timber
- Drive approaching and receding from observer
- Drive receding from observer
- Drive approaching observer
- Ore Pass

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To accompany Bulletin No 6.

F53/3/44

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PLANS

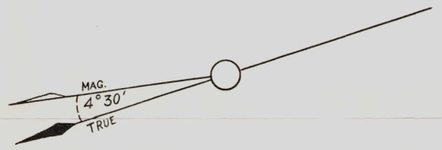
LADY HAMILTON LODE

KANGAROO GROUP

HATCHES CREEK N.T.

REFERENCE

- 6" / 70° — Reef, position accurate, showing width and dip
- 70° — Dip and strike of bedding
- Fault, position accurate, showing dip
- Shaft passing through level
- Foot of shaft
- Foot of rise
- Ore pass
- Accessible workings
- Inaccessible workings



Scale

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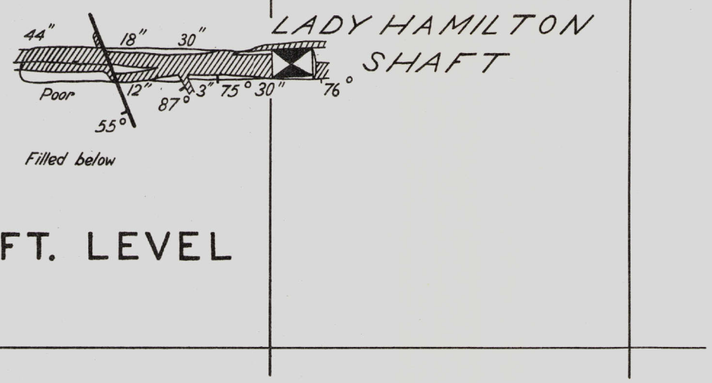
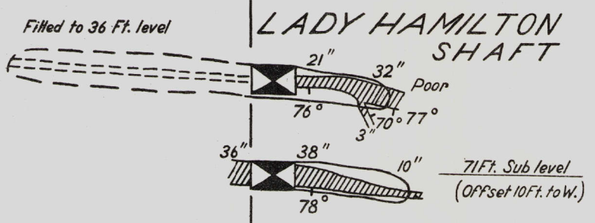
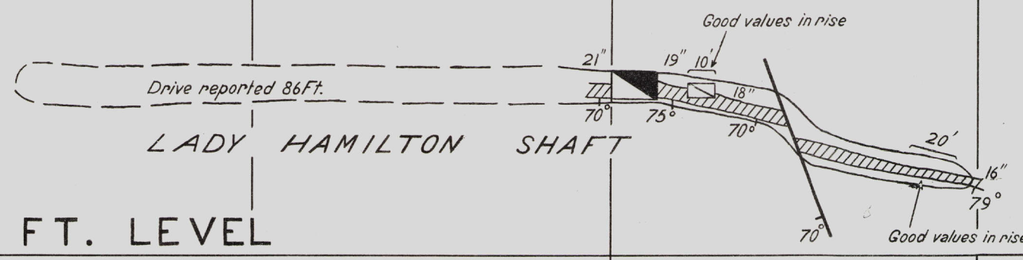


36 FT. LEVEL

93 FT. LEVEL



55 FT. LEVEL



108 FT. LEVEL

VERTICAL PROJECTION AND CROSS-SECTION

LADY HAMILTON LODE

KANGAROO GROUP

HATCHES CREEK N.T.

REFERENCE

Reef, showing width

Width and dip of reef

Fault, position accurate

Fault, position approximate

Limit of stope

Drive approaching and receding from observer

Drive receding from observer

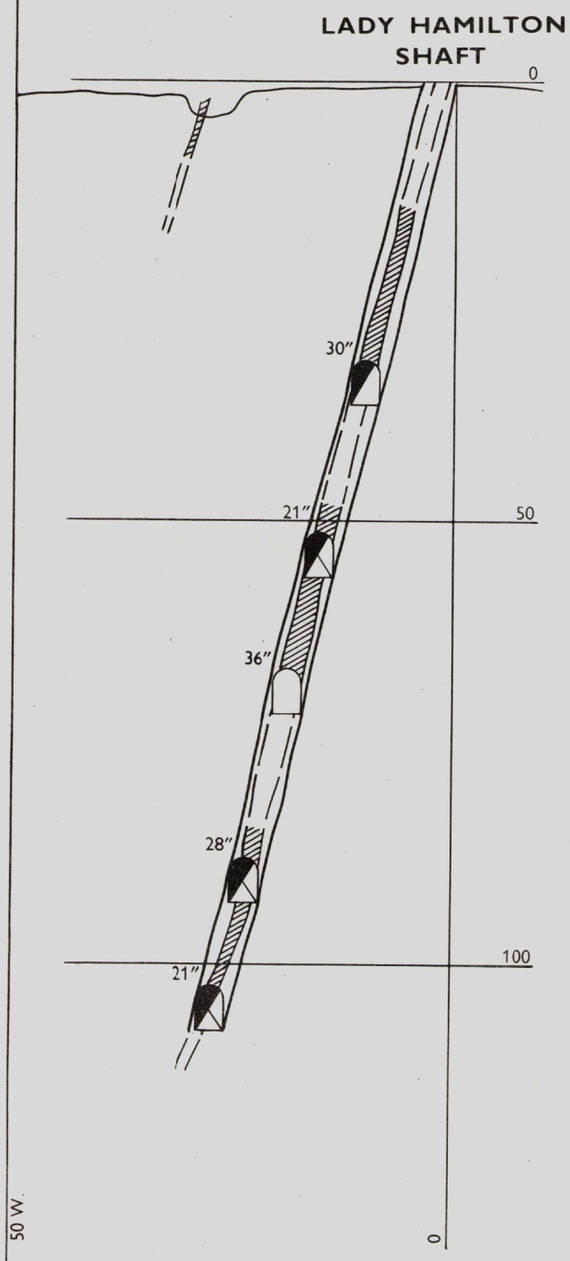
Drive approaching observer

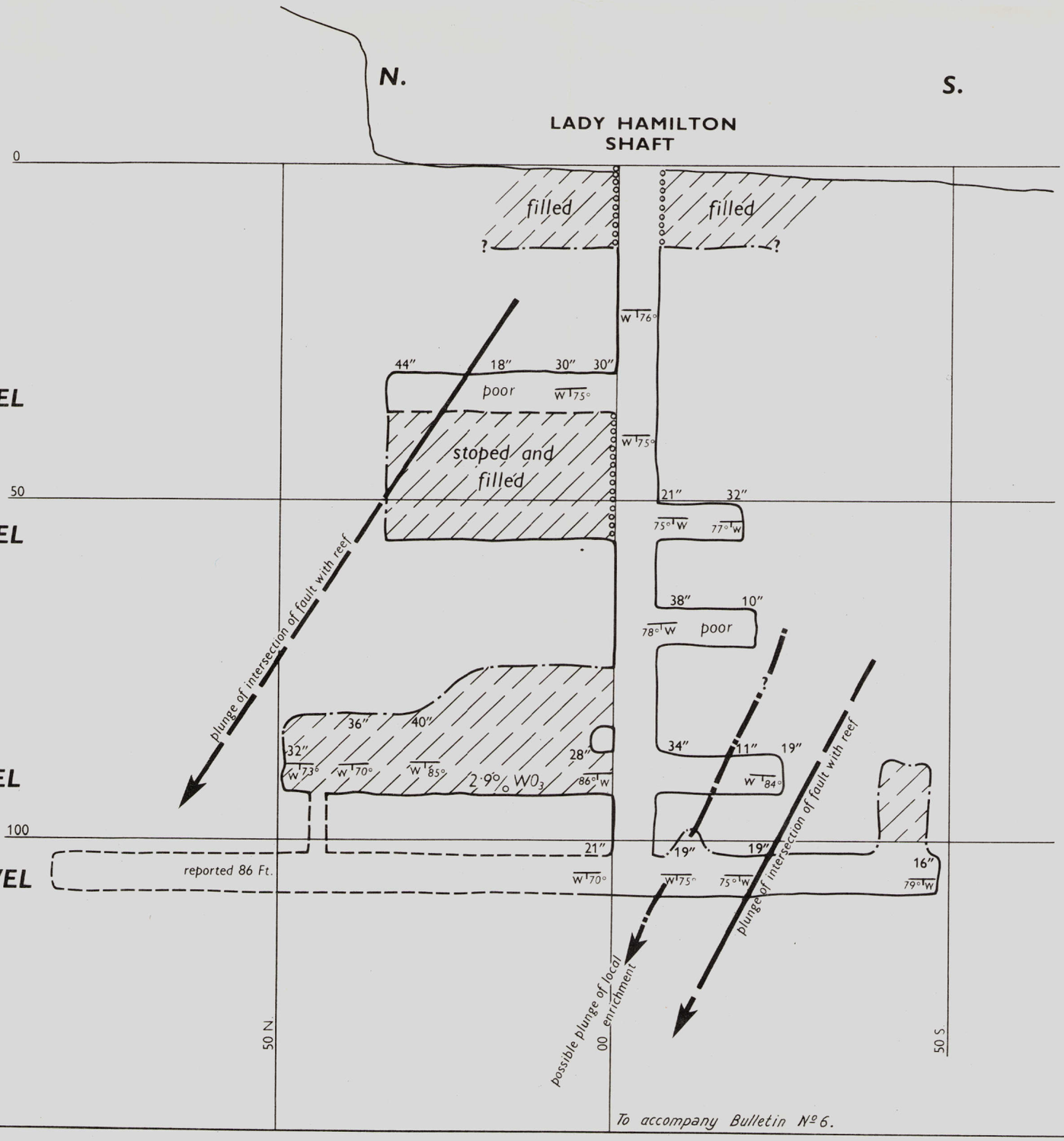
Stoped ground

Timbering

SCALE

20 10 0 20 40 60 Feet





Bureau of Mineral Resources, Geology & Geophysics. September, 1961.

To accompany Bulletin No 6.

F53/3/46

Fairdrawing by MAPS and MODELS (AUST.). PTY. LTD.

Kangaroo Line

Although the Kangaroo Line can be traced for nearly a mile, the richer reefs are confined to the central part (Pls 4, 38). In this section the line consists of a wide shear-zone containing many reefs lying en echelon and side by side. The reefs strike at 055° to 060°, and dip north at 50° to 80°. They are 36 inches wide in places. Most of the line has been tested from many shallow pits and shafts, but deeper shafts are confined to the central section. Only one of these, the Kangaroo Shaft, was accessible in 1956; the others are now filled with water or debris, and no information is available for any of them except Andersons Shaft (Pl. 38), which is reported to have been sunk to an inclined depth of about 120 feet on a reef 15 inches wide. Some rich pockets were mined.

Several shafts have been put down on the line on Bransons Lease (Pl. 38), some believed to be of considerable depth, and it is reported that a large tonnage of concentrates was won. The line becomes increasingly dispersed and irregular to the south-west of Bransons Lease, in contrast to its north-eastern end, where it narrows to a line of single reefs. The dispersion is apparent at the south-western corner of Bransons Lease (Pl. 38), and beyond this, on the St John Lease and the Prodigal Lease, short narrow reefs are spread across a zone about 2,500 feet from east to west and about 2,000 feet from north to south. In the northern part of this area most reefs have an easterly strike, but in the southern part, on the Prodigal Lease, they have a northerly strike. Most of the area has been developed only by shallow open cuts, but there are a few shallow shafts.

The Kangaroo Shaft has been put down on one of the largest reefs on the line to a vertical depth of 136 feet. The reef, which has been exposed for 147 feet at the 136-foot level, has an average width of about 24 inches and dips north at 65 - 75°; east of 107E it splits into two reefs of equal width dipping 55 - 60°. The reef has been displaced by faults striking approximately north and dipping very steeply either to the east or to the west. The contact between sedimentary rocks and volcanic rocks was met 45 feet east of the shaft (Pl. 39).

The reef is barren from about 60N to 105N. Some wolfram is present towards the east face of the drive, and also immediately east of the shaft, but the greatest enrichment has taken place in the hangingwall of a fault which dips steeply to the west and intersects the reef at 9W. The reef had been removed to a height of 12 feet in this section and wolfram was showing abundantly in the backs. Some stoping had also been undertaken between the shaft and 40E but very little ore was produced.

A drive to the east at the 79-foot level was abandoned when, at 26 feet, it broke through into the old workings. A fault striking east of north and dipping steeply to the east has displaced the reef four feet into the footwall at the breakthrough. Loss of the reef on this fault was probably the reason why the old workings were abandoned. Ore from this drive bulked 1.7% WO_3.

Some ore has been stoped west of the shaft above the 79-foot level. The stope is now filled, but the reef is exposed for 26 feet in the backs. It has split into a hangingwall reef 12 inches wide and a footwall reef 15 inches wide, and the reefs

are displaced at the face by a fault dipping steeply to the east. The lode may have been enriched by either the split or the fault.

Rich ore is reported to have been won from the old workings, now inaccessible, to the east of the Kangaroo Shaft. The limits of underground development are not known. A rich shoot was localized at the intersection of the lode with a narrow reef striking west of north.

Recent development from the Kangaroo Shaft has been disappointing for no discernible reason. The present owner put in the long drive at the 136-foot level in an attempt to locate a downward extension of the rich ore encountered in the old workings, but was not successful. Evidence from other lodes at Hatches Creek suggest that if a shoot is present it will plunge approximately parallel to the stratification of the country rock, but at the Kangaroo Mine this has not happened. Two alternatives remain: either the shoot, if present, plunges to the east and has not yet been located at the 136-foot level, or the enrichment reported in the old workings was purely local and controlled by some feature unknown, which seems more likely.

A little wolfram should be available below the 136-foot level on the fault which intersects the reef at 9W at that level, but deepening of the shaft does not appear to be justified merely to obtain such a small amount. Past experience has indicated that wolfram is present in patches not only in the Kangaroo Mine, but elsewhere along the Kangaroo Line. Future prospecting will therefore be uncertain and cannot be recommended except under very favourable economic conditions.

Lady Hamilton Line

The Lady Hamilton Line trends a little west of south from the north-west corner of the Lady Hamilton Lease to an intersection with the Kangaroo Line on Bransons Lease (Pl. 38). It consists of several lodes, striking between 340° and 020°, which are vertical or dip to the west at 65° or steeper. The line lies in interbedded siltstone, sandstone, greywacke, quartzite, and volcanic rock at the northern end, and in acid volcanic rocks at the southern end. The lodes are more numerous to the north. All the lodes have been tested extensively from shallow open cuts, but only three have been developed below ground.

Lady Hamilton Lode. This lode has been tested to a depth of 107 feet from the Lady Hamilton Shaft (Pl. 38). The north drive at this level, reported to be 86 feet long, was inaccessible in 1956. The south drive is 45 feet long, and the reef in this drive is 16 to 19 inches wide. Two patches of rich wolfram were risen on (Pl. 41), but the patches were small. The reef is displaced to the east by a fault striking parallel to the bedding of country rocks but dipping north at 70°. The country rocks strike at 070 - 080° and dip south at 45 - 55°.

A short drive to the south at the 93-foot level encountered a pocket of rich ore at 16S, where the reef pinches to a width of 11 inches (Pl. 40). This pocket had not been fully explored at the time of the examination. The reef has been driven on for 49 feet north of the shaft at this level, and some stoping has been carried out. It changes strike at 25N and is 40 inches wide in the backs of the stope at this point, but no relationship between the change of strike and the deposition of wolfram was

apparent. Narrow reefs cross the lode at this level and at other levels. They are 4 to 6 inches wide, strike parallel with the bedding of the host rock, and dip steeply to the north or to the south.

A short drive has been put in to the south at 71 feet, but was abandoned because the reef narrows rapidly to the south from 38 inches to 10 inches. The pinching in the reef plunges to the south, parallel to the bedding. A drive was put in to the south at the 55-foot level and was also abandoned, but some stoping has been carried out north of the shaft at this level. The stope is now filled, but the reef is visible in the backs.

The behaviour of the reef at the 36-foot sub-level is unusual. The reef, which is 30 inches wide at the shaft, splits to the north; the two branches of the split rejoin farther to the north on the hangingwall of a fault (Pl. 40), but remain as two distinct reefs with a common wall. This phenomenon has not been observed anywhere else at Hatches Creek. One of the reefs follows the fault for a short distance, but the other has not been affected by it. The fault strikes at 083° and dips to the north at 55°, and was almost certainly contemporaneous with the introduction of the quartz. The reef is not enriched near the fault. Whether wolfram has been localized by minor features of the reef or whether a shoot is present cannot be determined because of inadequate development. Many of the minor features on the reef are controlled by the bedding of the host rock, and plunge to the south-west at about 45°. The faults which intersect the reef dip to the north at varying angles. The plunge of wolfram enrichment could be in either direction.

Activities Lode. This lode lies 60 feet west of the Lady Hamilton Shaft. A tunnel has been driven for 89 feet on a reef striking between 339° and 348° and dipping west at 60 - 70°. The reef is 5 to 10 inches wide. The tunnel is reported to have yielded 0.75 tons of concentrates from about 37 tons of ore. Enrichment of wolfram has taken place along faults of small displacement which dip steeply to the north. Bedding-plane faults have had no effect on the deposition of wolfram.

The reported production indicates a grade of over 1% WO_3 which is sufficiently high to justify further exploration of the lode.

No. 1 Lode. The No. 1 Lode consists essentially of one quartz reef ranging in width from 5 to 16 inches and dipping west at 73 - 84°. It has been developed from a tunnel 180 feet long, and has been partly stoped above and below the level of the tunnel. The portal of the tunnel lies about 150 feet south-west of the Lady Hamilton Shaft.

The reef has a zig-zag strike with components at about 355° and 010°. The changes of strike plunge south-west, parallel to the bedding of the country rock. Enrichment of the lode has been controlled by faults of small displacement striking parallel to the bedding but dipping north. Faults which dip parallel to the bedding have had no effect on the deposition of wolfram.

The lode is reported to have yielded 6.45 tons of concentrates, but as the stopes are mainly inaccessible the approximate tonnage of ore mined cannot be estimated. Two tons of wolfram were won in one day from a pocket of almost pure wolfram

associated with a steep north-dipping fault. This lode was developed by a tributer, and operations ceased when the tributer left the mining field. Further rich pockets may, perhaps, exist.

Other Lodes. Many other, less important, lodes lie in the group (Pl. 38). The lode fissures are associated with at least three faults on the Lost Corner Lease. On Bransons Lease to the south the lodes lie in volcanic rocks which contain small lenses of tough quartzite, and these may have caused irregular fissuring in this area.

The reefs exhibit a diversity of strike and dip and are nowhere very long or very extensively developed. It is reported that some extremely rich but limited pockets of wolfram have been mined, and many similar pockets must remain.

Conclusions and Recommendations

Little is known about the Kangaroo Group. Available evidence suggests that rich pockets of wolfram are present, but that they are irregular, and subject to control only by features on the various reefs, which are themselves irregular. Shoots may be present on some of the better-defined lodes, but their discovery must await considerable further development. The future prospects of the group are not encouraging.

Copper Show Locality

Two small groups of tungsten-bearing deposits half a mile apart lie about 1¼ miles west of the Kangaroo Group, and because of their isolation have been included as a separate locality. A third group of tungsten and copper bearing reefs has been reported 2½ miles south-west of this locality, but the deposit was not visited because reports on it were unfavourable. The Copper Show Group lies in volcanic rocks in the Hit or Miss Gully. The Dooleys Nob Group lies half a mile to the north in sandstone and quartzite of Dooleys Ridge. These three groups mark the western limit of known tungsten mineralization in the Hatches Creek district.

Dooley's Nob Group
(Pl. 2)

The Dooleys Nob Group is unimportant, and remarkable only because the tungsten-bearing reefs lie wholly in sedimentary rocks. The reefs are short and contain small pockets of wolfram which have been won from shallow open cuts.

The history of the group is confused. Oliver (1916) mentions a claim held by Ward and Dooley lying 500 yards west of 'Warnes Copper Wolfram Show'. The 'Copper Wolfram Show' corresponds to the Copper Show Group, but the Dooleys Nob Group lies about 800 yards north of the Copper Show Group. No tungsten deposits are known west of the Copper Show Group, and Oliver's description of 'Ward and Dooley's Claim' can be applied to the Dooley's Nob Group. 'Ward and Dooley's Claim', therefore, corresponds to the 'Dooleys Knob' Lease which covered the Dooleys Nob Group from 1951 to 1954.

The reefs lie parallel to the bedding of the host rock and dip to the south at about 60°. They are short, narrow, and poor, and do not warrant deeper exploration.

Copper Show Group
(Pls 2 & 42)

The Copper Show Group consists of a few quartz reefs lying in a strong shear-zone which trends south-east. A great deal of disorganised development has been carried out from many shallow shafts, but all are now abandoned and most are inaccessible. The complex wolfram-scheelite-copper ore present in the reefs has proved difficult to market and has militated against successful operation of the group.

History

Oliver (1916) mentions the presence of copper minerals on 'Warnes Copper Wolfram Show' in his report. Hossfeld (1941) states that operations before 1938 had been 'negligible', and also mentions the presence of 'deleterious minerals'. Some development was carried out by Chinese labour under the direction of the Commonwealth Government during the Second World War, but there was little production, so far as is known, until 1950. Since that year the group has yielded a small tonnage of both wolfram and copper concentrates. The group was under operation in June 1956, but was abandoned shortly afterwards because of the difficulty of marketing the concentrates.

Production

The official records show that the group has produced 12.32 tons of wolfram concentrates worth £6,953, and 44.29 tons of copper ore worth £3,679, since 1941. Hossfeld (1941) records that about 10 tons of concentrates were won between 1938 and 1940. Thus the known production from the group has been about 22 tons of wolfram concentrates, a figure which is probably close to the total production. Table 16 gives the recorded production of wolfram and copper from the group since 1941.

TABLE 16
COPPER SHOW GROUP, HATCHES CREEK
ANNUAL PRODUCTION OF WOLFRAM CONCENTRATES AND COPPER ORE
1941-1956

Year Ending 30th June	WOLFRAM		COPPER	
	Tons Cons.	Value £	Tons Cons.	Value £
1941	1.81	150(a)	—	—
1942	0.75	97	—	—
1943	—	—	—	—
1944	1.5	485	—	—
1945-1949	—	—	—	—
1950	—	—	12.26	642
1951	—	—	4.25	300(b)
1952	0.71	816	5.25	470
1953	1.77	1,763	—	—
1954	4.51	2,771	8.63	950(b)
1955	0.20	117	13.9	1,317
1956	1.07	754	—	—
Total	12.32	6,953	44.29(c)	3,679

(a) Value estimated from mean annual price of wolfram.
(b) Approximate only.
(c) Reported assay about 32% Cu on average.

Geology

As far as can be ascertained, the group consists of two main reefs, and a few of less importance, lying in a wide shear zone which trends south-east. The reefs are obscured by alluvium and by numerous spoil dumps, and crop out only in a few open cuts. Only sheared volcanic rock was seen *in situ,* but mica schist, derived from fine-grained sediments, is present in some of the dumps. The sediments are believed to be small lenses intercalated with the volcanic rocks.

The reefs range in strike from 280° to 320° and dip to the north at 40 - 80°. The two main reefs have an average width of about 24 inches.

The group lies north of a line of quartzite lenses, which occupy one horizon in the volcanic rocks, and west of the intersection of two large faults which strike north-east and north-west. The shearing in the group is thought to be associated with these features.

Mineralogy

The reefs in the group carry more copper than any other group at Hatches Creek. Oliver (1916) stated that wolfram, copper, and iron were present in about equal proportions. The following minerals have been identified: wolfram, scheelite, tungstite; cupro-tungstite, malachite, azurite, chalcocite, bornite; ?bismite; limonite; ?fuchsite, muscovite, quartz.

The ore minerals are intimately associated, making separation by hand extremely unsatisfactory. Magnetic separation of wolfram from the concentrates is the most feasible method of treatment.

The abundance of secondary minerals and of limonite indicates that a high percentage of sulphides can be expected in the primary zone. The position of the water table is not known, but the primary zone is likely to be entered within fifty feet of the lowest level of development. A similar method to that evolved by Pioneer Mines N.L. should prove suitable for treatment of ore from this zone.

Little is known of either the grade or the control of the ore. Hossfeld (1941) gives an overall grade of 3% wolfram and scheelite for the richest central reef in the group, and the reefs have an estimated copper content of 2% to 3%. Owing to the inaccessibility of the greater part of the underground workings, which are considerable, no estimate can be made of the total tonnage of ore mined. Verbal reports state that reefs are rich, and that complexity of the ore has been the only barrier to greater exploitation of the group. Parcels of hand-picked copper ore dispatched from the mine have assayed as high as 48% Cu.

Information on the control of the deposition of wolfram has been mainly derived from Hossfeld (1941). He states that the highest grade of ore was found to lie in narrow shoots where the reef is widest, has a more easterly strike, and dips at 40° to 45°. Sections of the reef dipping more steeply than this are poorer. These shoots plunge at very low angles to the east, and their vertical extent is small. As a result of this, shafts put down on a shoot where it crops out have passed into poorer ore at shallow depths, and have been abandoned, which accounts for the unusually large number of shallow shafts on the group. No enrichment of the reef on faults,

leaders, or splits in the reef was observed in the few exposures of the reefs now accessible, and Hossfeld makes no mention of this type of deposition. The persistence of the ore throughout the reefs suggests that deposition has been primarily controlled by the attitude of the reef.

Individual Reefs

Past development has been haphazard and uncoordinated, with the result that the area is a warren of short shafts, drives, and stopes, many of which are now filled or collapsed. The ground is unusually heavy and abandoned openings seldom remain accessible for long. Termites have assisted the general decay. Only Greens Shaft and Shirleys Shaft, of 12 shafts mapped, were accessible in 1956, and in each only a few feet of drive could be examined. The shafts range in depth from 20 feet to 80 feet.

Greens Shaft, 40 feet deep and vertical, was in use in June 1956. A cross-cut 21 feet long to the south-west proved a reef 9 - 18 inches wide, striking at 303°, and dipping north-east at 45 - 55°. The reef was exposed for 34 feet at the time of the examination. A second reef, 15 inches wide and dipping north-east at 55°, makes in the hangingwall towards the south-east face. Both reefs carry some wolfram and copper over their exposed lengths. The north-west of the drive lies just above an old level extending south-east from near Shirleys Shaft (Pl. 42).

Shirleys Shaft was abandoned but accessible, and is vertical, with a depth of 52 feet. A reef 24 inches wide and dipping north-east at 40° is exposed over a length of 54 feet at the 52-foot level. Good-grade ore is present north-west of Shirleys Shaft, but the grade decreases to the south-east. A narrow hangingwall vein strikes parallel to the main reef, but dips at 85°.

An angled cross-cut, bearing at 060°, enters a second drive to the north-east, which is now inaccessible, and it is this drive which extends to the south-east below the drive from Greens Shaft.

Information on the group is so incomplete and erratic that the arrangement of the reefs has not been fully recognised. One interpretation of the evidence is shown on Plate 42; available information has been extrapolated to the 50-foot level in an attempt to make the picture clearer. The interpretation involves the assumption of two faults, striking roughly north-east. The easterly fault, running just west of Shirleys Shaft and dipping west, was postulated by Hossfeld (1941). The interpretation is very tentative, and could well be disproved by future operations.

The presence of two reefs lying roughly parallel is postulated, with the No. 2 Reef lying between 50 and 100 feet beyond the hangingwall of the No. 1 Reef. The two reefs are faulted, with right-handed displacement, by the shear mentioned above, which lies west of Shirleys Shaft at the surface. They are connected, towards the south-east, by a reef striking more to the east: this is the reef exposed at the foot of Shirleys Shaft. The No. 2 Reef is exposed in the drive from Greens Shaft: the connecting reef joins the No. 2 Reef beyond the north-west face of this drive. The No. 1 Reef swings sharply to the south, and dies out rapidly, at its south-eastern end.

The No. 2 Reef could continue a little farther to the south-east, but does not crop out in the rocks which are exposed *in situ* within 100 feet to the south-east. The north-western limits of the two reefs are unknown.

A series of shallow pits extends north-west from the main workings. A narrow reef is exposed in one of them. There is a most significant outcrop in the foot-wall of the No. 1 Reef at its south-eastern end: a shallow pit has revealed two reefs, 12 inches and 18 inches in width, below the alluvium. This discovery was not followed up because no wolfram was exposed, but this reef must be traced in future exploration. It could represent a larger and richer reef system lying to the south-west of the No. 1 Reef and concealed by alluvium.

Some attempts to win eluvial wolfram from nearby gullies have been unsuccessful because the relief is not sufficiently rugged to provide efficient transport and concentration.

Summary and Conclusions

Operations on this group have been inhibited more by the nature of the ore than by its grade, which is relatively high. Unsuccessful attempts to exploit the group from time to time have been responsible for the present extremely unsatisfactory condition of the underground workings, and the obscuring of what little surface detail was originally visible by indiscriminate dumping of mullock. As a result of this the group cannot be accurately assessed.

The reefs are undoubtedly rich in wolfram and carry sufficient copper to warrant the investigation of suitable methods for the separation of the various components of the ore. If only limited development were planned, and extensive treatment of the concentrates were not desired, magnetic separation would yield a marketable wolfram concentrate not liable to heavy penalization for impurities. The scheelite, bismuth, and copper components could be separated by flotation of primary ore and leaching and flotation of secondary ore. In this respect the mining of primary ore is more desirable.

The persistence of the reefs and the wolfram at depth cannot be estimated. The reefs show no decrease of width or grade at the 50-foot level, but the known length of the reefs is small, and the position of the primary zone is unknown. These factors will have to be determined before the reefs are developed. The reefs are sufficiently close to justify their development from a single centrally-placed main shaft, and Shirleys Shaft, already 50 feet deep, could be used. The group offers good prospects for development to a depth of 100 feet to 150 feet, and possibly deeper, but this would be conditional on a guaranteed price for wolfram, because quick results cannot be expected. The sale of copper should justify its separation. The possible existence of a third reef, or line of reefs, to the south-west is encouraging, and suggests that the group is larger than has been thought.

Gold Deposits

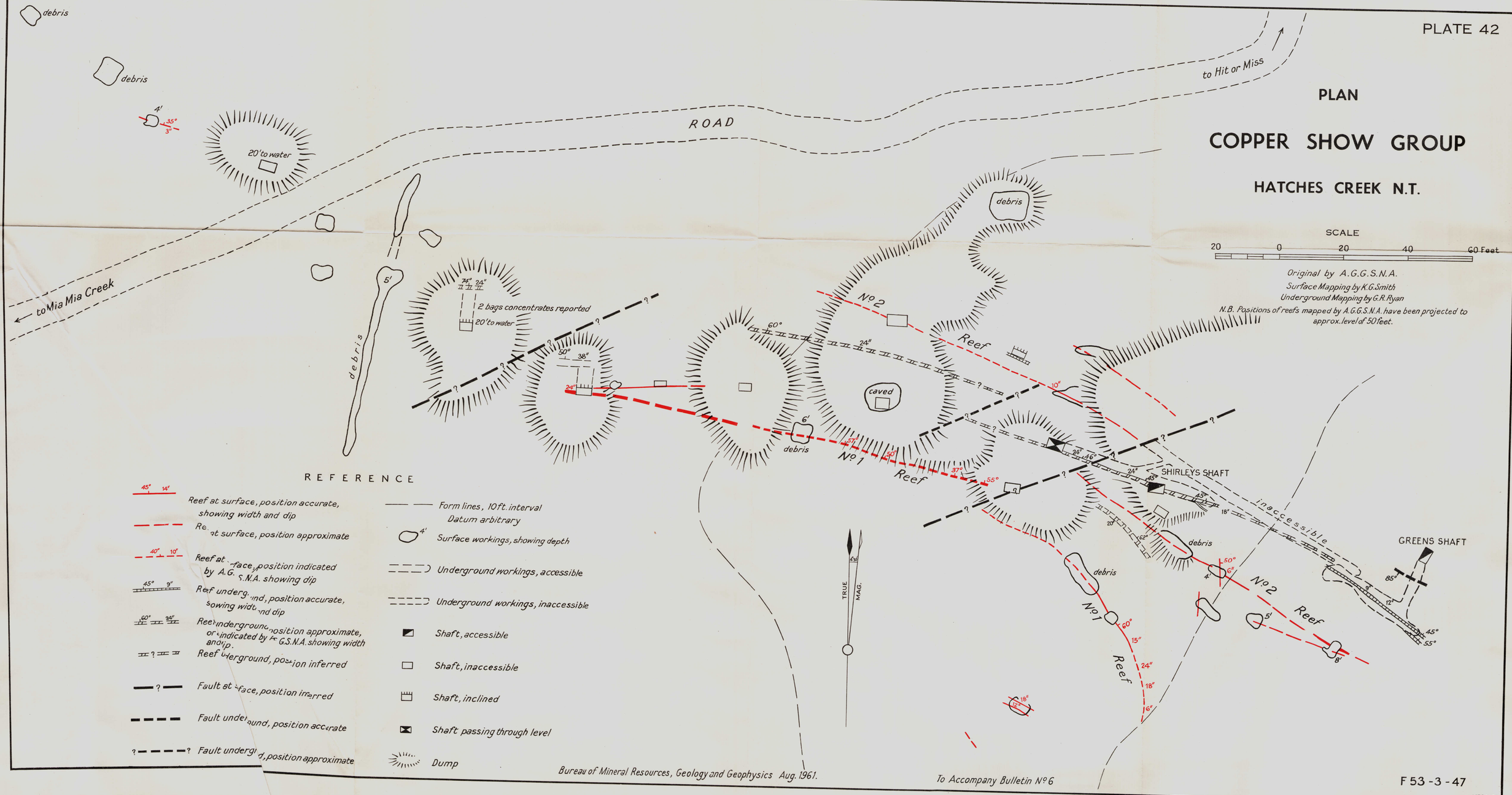
The Hatches Creek district was first prospected for gold by A. A. Davidson in 1898-9, but with no success. Since then various attempts to find and mine gold in the area have been marked with equally little success. Traces of gold are known

PLATE 42

PLAN

COPPER SHOW GROUP

HATCHES CREEK N.T.



SCALE

20 0 20 40 60 Feet

Original by A.G.G.S.N.A.
Surface Mapping by K.G.Smith
Underground Mapping by G.R.Ryan

N.B. Positions of reefs mapped by A.G.G.S.N.A. have been projected to approx. level of 50 feet.

REFERENCE

- 45° 14' — Reef at surface, position accurate, showing width and dip
- Reef at surface, position approximate
- 40' 10' — Reef at surface, position indicated by A.G.S.N.A. showing dip
- 45° 9" — Reef underground, position accurate, showing width and dip
- 60° 24" — Reef underground, position approximate, or indicated by A.G.S.N.A. showing width and dip
- ? — Reef underground, position inferred
- Fault at surface, position inferred
- Fault underground, position accurate
- ? — Fault underground, position approximate
- Form lines, 10 ft. interval Datum arbitrary
- 4' — Surface workings, showing depth
- Underground workings, accessible
- Underground workings, inaccessible
- Shaft, accessible
- Shaft, inaccessible
- Shaft, inclined
- Shaft passing through level
- Dump

Bureau of Mineral Resources, Geology and Geophysics Aug. 1961.

To Accompany Bulletin No 6

F 53-3-47

MERCURY

from the Pioneer lodes and comprehensive assaying of the concentrates would probably reveal the presence of gold in the ore from other groups on the mineral field, particularly where accessory ore minerals are common. The gold content of concentrates from the Pioneer Mine is high enough for the buyers to pay for it.

Some deposits of quartz lying to the north-east of the Pioneer Group have been tested for their gold content alone, and carry no wolfram. Three small groups lie along the north-eastern flank of the Poseidon Hills. They are unimportant and need not be considered further. A fourth group, which is larger, lies east of Hatches Creek and is known as the Crystal Gold Mine.

Crystal Gold Mine Group

The Crystal Gold Mine lies three miles north-east of the Pioneer Group and about 200 feet west of the road to Kurundi and Bonney Well. Gold was first reported from this locality in 1930 (Ann. Rep. N. Terr. Administrator, 1930) but although favourable results were reported to have been obtained from assays, no gold was produced. No further exploration was carried out until about 1950, when two shafts were put down in a further attempt to exploit the reefs. These were abandoned after intersecting quartz reefs at shallow depths, and, as far as is known, gold was not obtained in economic quantities.

The group lies on a low rise formed by the presence of small altered blocks of sedimentary rocks lying in the Pedlar Gabbro. The bedding in these blocks dips east at 40 - 50° and strikes approximately north. It is parallel to the bedding of the sedimentary rocks of the Hatches Creek Group which bound the Pedlar Gabbro 500 yards to the east.

The quartz reefs are exposed intermittently over about 1300 feet, but appear to be short, and of irregular width. The group is dominated by one reef, or a line of discontinuous reefs, ranging in width from 1 foot to 20 feet. It strikes at about 025° and dips to the east at 45 - 50°. Many other shorter and thinner reefs strike in one of three directions: at about 025°, at 070°, and at 135°. Reefs striking at 025° are the most abundant.

In the original programme of testing, the main line of reefs was extensively sampled, and a few samples were taken from some of the smaller reefs. The results of the testing have been summarized by Hossfeld (1941) and are given below.

'A detailed sampling campaign showed that of 67 samples taken on the main line, 41 returned traces or nil, 10 returned less than 1 dwt., 9 returned between 1 and 2 dwt., 5 between 2 and 3 dwt., and only two samples returned over 3 dwt., the figures being 3.2 dwt. and 3.5 dwt. of gold per ton over widths of 33 and 30 inches respectively. Six samples taken on reefs parallel to the main line, returned traces of gold only.

'At the northern end two samples taken across two narrow reefs returned respectively 3.7 dwt. over 11 inches, and 22.4 dwt. over 5 inches. Only a small part of these reefs is exposed and they are not expected to yield much ore.'

The reef carrying the highest percentage of gold (22.4 dwt per ton) contained a considerable amount of limonite. The figures quoted above indicate that the richest concentration of gold lies in the narrower sections of the reefs. The group does not warrant any further investigation.

CONCLUSIONS AND FUTURE PROSPECTS

The history of mining at Hatches Creek falls into three distinct phases, each stimulated by the demand for tungsten. During the first phase, from the discovery of wolfram in 1913 to the closing down of the mining field in 1923, many new deposits were discovered, and known deposits exploited to shallow depths. It was almost universally believed at this time that the wolfram did not persist at depth, and therefore few attempts were made to develop the lodes below about 50 feet.

The second phase, between 1934 and 1944, saw the most widespread and continuous development of the mineral deposits: at one stage more than 200 miners were working in the area. Practically every reef was explored and prospecting was extensive. The third phase, from the end of the second world war to the closing of the field in 1957, was characterized by more than usual instability in the market for tungsten, and as a result only a few mines stayed in continuous production. Most of the easily accessible ore had been won, and only those lodes which could support development at deeper levels remained in operation.

The fluctuation in price was so frequent that wolfram won during a period of favourable prices was often sold at a loss. These conditions quickly discouraged most miners, and only a nucleus stayed on in the hope of better conditions. The field was at a very low ebb by 1950, but the sudden rise in prices in 1951 considerably benefited the miners who had stayed on as they were able to resume full production immediately; the late-comers found that the boom was already over by the time they were established.

The reopening of the field in the event of a renewed demand for tungsten would of necessity introduce a fourth phase. Systematic exploration and development would be necessary, and capital would be needed to install heavier equipment and to sink vertical shafts for development at deeper levels. This would be beyond the scope of the small miner, who would require financial backing in the initial stages.

The area around the known wolfram deposits has been thoroughly prospected, and it is considered that no new groups remain to be found. Exploration will necessarily be confined to the thorough testing of known lodes. No attempt was made to do this in the past, so that nothing is known of the extension in depth of the lodes. The haphazard nature of past mining methods, which have been governed by the necessity to exploit proven ore while the market remained favourable, and the lack of proper records, either of production or of development, make a complete assessment of any lode almost impossible.

Possible ore reserves have been calculated for some of the lodes on the field, where knowledge of grade, and other information, have been sufficient to justify it. The calculated tonnage of possible ore reserves is:

Pioneer Group	240 tons
Black Diamond Group	34 tons
Green Diamond Group	28 tons
Treasure Group	355 tons
Masters Gully Group	20 tons
Hit or Miss Group	200 tons
Total	877 tons

Although the knowledge of grade is slight, the tonnages quoted above have been calculated as standard-grade wolfram (65% WO_3), giving a content of 570 tons WO_3, from ore containing 1.5% to 3.0% WO_3. This does not constitute the whole of the ore reserves of this grade, but only that on lodes where a calculation can be made. Further ore of a similar grade is undoubtedly present, both on the lodes for which an estimate has been made, and on other lodes. Inferred ore reserves for the field are therefore considered to be about 1,000 tons.* A considerable tonnage of protore† is also present, and is estimated to be about 500 tons WO_3.

The lodes at Hatches Creek are not suited to large-scale development, and do not justify the interest of any large mining organisation. Nevertheless, a syndicate, or a cooperative movement, formed by the miners themselves, could, by initially raising some capital, and by the provision of heavier equipment and a subsidy while miners were on development, enable the mines to maintain production during periods of depression of the wolfram market. The operation of such a system would still be dependent on a minimum price for tungstic oxide, but this minimum would be considerably lower than at present. The movement could further aid the field by supplying treatment, transport, and shopping facilities at minimum cost; and would be in a position to negotiate contracts and to press for facilities for the field. However, the successful operation of such a system would require the full cooperation of the miners, who have, in the past, shown few signs of cooperation.

The field, and the miners, can only benefit from such an organisation. The hit-and-run methods of mining, which have been successful in the past, cannot be expected to remain so now that most of the easily won ore has been removed. The field may never reopen, but if it does, past experience suggests that unless the methods of mining are improved (which would almost certainly require some kind of coordination of activities), the reopening will be shortlived.

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*Inferred ore reserves are here held to be ore reserves which, on geological and other evidence, are known to be present, but which have not been proven by any exploration.

†Protore is held to be ore of lower grade which could only be exploited if the market for wolfram boomed to the same extent as in 1951 and 1952.

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APPENDIX I

Rocks from Hatches Creek, Northern Territory

By W. B. Dallwitz

No. 23a. Pedlar Gabbro, south-west of Wolfram Hill

The handspecimen is a dark grey medium-grained rock containing a small pegmatite vein.

The *gabbro pegmatite* consists of grains of actinolite, saussuritized plagioclase, interstitial quartz and accessory iron oxide.

Remnants of plagioclase consist of andesine, but whether this represents the bulk of the altered plagioclase is indeterminable.

The actinolite has probably replaced pyroxene. The rock enclosing the pegmatite is a *uralitized gabbro,* consisting almost entirely of actinolite and saussuritized plagioclase.

No. 24. Pedlar Gabbro, west of Mia Mia Creek

The handspecimen is very coarse-grained, and consists of large greenish-black, grey-green, and pink clots of minerals.

Quartz, commonly in graphic intergrowth with albite, is the dominant mineral. Next in order of abundance are penninite and epidote. Accessory minerals are sphene and iron oxide.

The rock is probably a *gabbro pegmatite,* though it is unusually acid.

No. 27. Pedlar Gabbro, south side of Wolfram Hill

The rock is pale pink and white, with small black patches. It appears to be medium-grained.

Grains of quartz and extensively saussuritized acid plagioclase make up most of the rock. A few eutectic intergrowths of quartz and plagioclase are scattered through the rock. Accessory minerals are accumulations of fibrous-radiating penninite, and grains of epidote, sphene, and iron oxide.

The rock is probably pegmatitic and, as the field notes indicate that it is associated with No. 24, it is most probable that No. 27 represents the *acidic differentiate of a gabbro pegmatite.*

No. 28a. Pedlar Gabbro, east of Hatches Creek

The handspecimen is a mottled, brownish-pink, grey, and black rock of medium to fine grainsize.

The rock consists mainly of eutectic, radiating intergrowths of albite and quartz, together with interstitial clots consisting of micropegmatite (orthoclase and quartz in eutectic intergrowth), quartz, and subhedral oligoclase. Some porphyritic grains of sericitized plagioclase are also present. (The grey areas noted in the handspecimen are those consisting of radiating intergrowths of albite and quartz.)

Dark minerals comprise biotite, a little chlorite, and iron oxide.

The rock is a *potash-soda granophyre* or *granophyric adamellite,* which is similar to others from the Hatches Creek area. These rocks are considered to be acid differentiates of a basic magma, and this impression was confirmed by Professor F. Walker, lately of Capetown, during a visit to Canberra: similar rocks are associated with the Karoo dolerites in South Africa.

No. 42. Granophyre sill, Hanlons Gully

This is a fine-grained, massive, dark-grey rock with a tendency to fracture conchoidally. Small crystals of probable feldspar, visible mainly by virtue of their good cleavage, are scattered through the rock; these crystals are about 0.25 mm. across.

In thin section the rock is seen to be a fine-grained version of specimens 28a and 28b. As far as can be ascertained, plagioclase is rather scarce, though the texture of the rock and abundant inclusions of biotite and chlorite in the feldspars make accurate identification difficult. Graphic intergrowth of quartz and orthoclase is on a very fine scale, so much so that, even

under high magnifications, it is not everywhere possible to clearly resolve the granophyric texture. Flared or flamboyant shapes are fairly commonly seen in these intergrowths.

The principal minerals in this rock are orthoclase, quartz, biotite, and altered plagioclase. Most of the plagioclase occurs as subhedral to euhedral porphyritic crystals, which are almost completely sericitized; these are the small crystals visible in the handspecimen. Biotite is generally very fine-grained and is fairly evenly distributed; it makes up about 20 percent of the rock. Some of it is altered to chlorite. Small pockets of coarser-grained biotite are scattered through the slide; these are usually associated with interstitial granular quartz and orthoclase.

Magnetite and a little hematite or hydrated iron oxide are the only accessories.

The rock is a *fine-grained, potassic, biotite granophyre,* probably a differentiate from a basic magma.

No. 26a. Pedlar Gabbro, north of Hanlons Gully and east of Mia Mia Creek

Specimen 26a is a hard, light-grey quartzitic rock containing scattered greenish-grey spots and several veinlets of probable epidote.

In thin section the rock is seen to be of medium grain-size and to consist mainly of severely cracked (not crushed) grains of quartz (60%) and dusty grains of albite (30%). In one small area the feldspar is more coarsely crystallized, is clear of inclusions, and has the composition of oligoclase. The mineral in the veinlets is epidote; this mineral is also irregularly distributed through the slide (the greenish-grey spots noted in handspecimen).

Accessories are chlorite, sphene, black iron oxide, leucoxene, rare apatite needles, and detrital zircon.

This rock is similar to several others previously examined from the area. It is an *albitized and epidotized quartzite.* The formation of chlorite, sphene, and apatite is probably due to the action of 'emanations' from the basic rock on the original quartzite.

No. 26b

Specimen 26b is similar to specimen 26a, but differs in that the grey spots are larger and more prominent.

In thin section the rock is seen to be more heavily feldspathized than is specimen 26a. The feldspar was identified as acid oligoclase, though some orthoclase may be present. Fine-grained myrmekitic texture is prominent in places, and the rock has assumed, in some parts, an igneous texture, similar to that of a granite aplite, though the shapes of most of the quartz grains are still unmistakably those characteristic of a quartzite. The dark clots noted in handspecimen are due to local enrichments in chlorite. Local sericitization of feldspar has given rise to less prominent clots.

The rock is a *feldspathized* (oligoclase) *quartzite* having some characteristics of an igneous rock.

No. 29. Pedlar Gabbro, east of Hatches Creek.

Specimen 29 is a grey, massive rock of medium to fine grainsize. Mr Ryan states that it is 'part of the main intrusion close to quartzites.'

Examination of the slide alone would not give a satisfactory clue to the true nature of this rock. However, when considered in conjunction with other rocks studied, it is reasonably certain that specimen 29 represents a quartzite which has been severely metasomatized through contact with a basic intrusion.

The principal minerals are quartz (45%), sericite (30%), and biotite (20%). Chlorite and rare leucoxene and apatite needles are accessories.

It seems probable that feldspar and biotite have been formed in this rock by metasomatic processes, and that the feldspar has later (probably soon after formation, and as a continuation of the same process) been changed to sericite; the biotite was probably locally chloritized at the same time.

However, the possibility that the rock is a straightout biotite-sericite-quartz hornfels formed by contact metamorphism of a sediment, without any substantial addition of material, cannot be dismissed. Even if the biotite and sericite have a metasomatic origin, the above name would still apply quite satisfactorily. It is mainly because Mr. Ryan considered the rock to be a part of the main intrusion that I favour slightly the idea that the rock has the metasomatic origin first postulated.

No. 35. Granophyre, west end of Treasure Gully

Specimen 35 is a dense, dark-grey, igneous rock containing what appear to be pink phenocrysts of feldspar measuring up to about 1 mm. in cross-section.

In thin section the rock is seen to be generally similar to specimens 28a, 28b, and 42. It consists of finely granophyric intergrowths of orthoclase and quartz in which are embedded abundant subhedral grains of andesine (the feldspar noted in handspecimen), scattered grains of quartz, and clots of fine-grained biotite. Accessories are pyrite, black iron oxide, pyrrhotite, and epidote. The epidote forms a small pocket which contains pyrite, quartz and pyrrhotite. Some of the biotite clots are elongated; these may represent pre-existing hornblende or pyroxene (cf. specimen 28b).

The rock is a *potash-soda granophyre* or a *granophyric biotite adamellite*, probably a differentiate of a basic igneous magma.

No. 38. Hatches Creek Group volcanic rock, Treasure Gully

Specimen 38 is a massive, dark-grey, felsitic rock in which elongated clots of a micaceous mineral and small iron-stained phenocrysts can be distinguished. The rock is brown to red-brown on weathered surfaces.

In thin section the rock is seen to be essentially the same as specimen 36. The main differences are insignificant — the rock shows far less iron-staining, and all trace of feldspar phenocrysts has disappeared. The groundmass has been completely reconstituted, and consists of a mosaic of quartz grains (average diameter 0.4 mm.) crowded with minute flakes of sericite; any feldspar phenocrysts that may have been present have been incorporated into this material.

Small phenocrysts of quartz, some of which have been embayed, are more plentiful than in specimen 36. A few bi-pyramidal crystals were noted. An outer zone of sericite-studded quartz has grown in optical continuity with some of the phenocrysts (cf. Specimen 36).

Small octahedra and aggregates of grains of magnetite are plentiful throughout the rock. Some of the magnetite has been marginally altered to hematite.

Clots consisting of fine-grained biotite alone, or of biotite and quartz, with or without sericite, probably represent original phenocrysts of ferromagnesian mineral.

The rock is a *sericitized and silicified acid porphyry;* field evidence alone can provide clues as to whether it is intrusive or extrusive.

No. 45. Siltstone from Hatches Creek Group, Hit or Miss Locality

Specimen 45 is a massive, greyish-brown, fine-grained, soft rock. It contains numerous light-brown specks.

In thin section the rock is found to have a hornfelsic texture. Biotite makes up about 70 percent of the rock; the rest is quartz, accessory sericite, and clots of limonitic material, which form the specks noted in handspecimen.

The rock is a *quartz-biotite hornfels,* probably derived from a sericitic and chloritic siltstone.

No. 30. Granophyre, east of Hatches Creek opposite Treasure Gully

Specimen 30 is a weathered, felsitic, buff-coloured rock; along cracks and joints it is light red-brown.

The first impression, when this rock is examined under the microscope, is one of similarity to specimens of granophyric rock already examined. Eutectic intergrowths of quartz and

orthoclase make up most of the slide, but weathering and alteration have obscured the original nature of the rock, which is very heavily impregnated with hydrated iron oxide, and contains irregular clots of 'limonite.' Some of these clots contain remnants of black iron oxide (hematite or magnetite). A few limonite pseudomorphs after probable subhedral to euhedral porphyritic crystals of plagioclase are present. The suggestion that these pseudomorphs are after plagioclase is based entirely on analogy with the other granophyric rocks examined.

Clots consisting of 'limonite' together with small to high percentages of sericite may represent clots of fine-grained biotite, such as were noted in less altered specimens already described.

Small (0.3 to 0.1 mm) porphyritic grains and crystals (bipyramids) of quartz are conspicuous. Veins and pockets of secondary quartz are also present.

The rock is an *altered, limonitic potash granophyre.*

No. 33. Quartzite, north side of Warnes Gully

Specimen 33 is a hard, dense, pale-buff rock which appears to be a quartzite.

In thin section the specimen is seen to consist of interlocking cracked (not shattered) quartz grains in which are set irregular scattered clots of sericite. Hematite is a sparse accessory. The size range of the quartz grains is 2 mm. to 0.1 mm.

The sericite has probably been derived from acid plagioclase, as the distribution of the clots is similar to that of clots and grains of albite or oligoclase in feldspathized quartzites previously examined. Certainly the sericite is not of detrital origin, though it could have been formed through alteration of detrital feldspar; however, its distribution in detail is against such a mode of origin.

The rock is a *quartzite containing clots of sericite.*

No. 44. Greywacke, south of Pioneer Mine on Poseidon Hills

Specimen 44 is a pale-buff to pinkish-buff, fine-grained, coarsely-bedded sandstone.

In thin section the rock is seen to consist mainly of angular quartz grains (diameter 0.1 mm. or less), interstitial sericite, and grains of probable altered feldspar. Accessories are leucoxene, granules and dusty particles of 'limonite', small detrital flakes of muscovite, zircon, and tourmaline.

The stratification noted in hand specimen is due to differences in the concentrations of interstitial sericite and limonite.

The rock is a very fine *quartz greywacke* or *sericitic sandstone.*

No. 43. Greywacke, south of Pioneer Mine on Poseidon Hills

Specimen 43 (listed as 45) is a very pale-buff or off-white, fine-grained, rather massive sandstone.

In the slide the rock is seen to be similar to specimen 44. The only essential differences are that the distribution of interstitial sericite is constant throughout and that there is virtually no 'limonite' present.

The rock is a very fine *quartz-greywacke or sericite sandstone.*

No. 46. Siltstone from Hanlons Gully

Specimen 46 is a massive, fine-grained, weathered rock which is mostly brown and golden yellow, though some parts are red-brown. Thin veinlets of 'limonite' fill cracks and closely-spaced joints. Small flakes of white mica can be seen in some parts of the rock.

In thin section the rock is found to be made up of sericite, irregular clots of 'limonite', and accessory quartz. Small groups of sericite flakes are scattered through the rocks, and are several times coarser than is the bulk of the mica. Nearly all the sericite is stained golden brown by hydrated iron oxide.

'Limonite' is so abundant in this rock that it seems probable that it has deen derived from pyrite or other iron-rich sulphide.

The rock is a fine-grained *'limonitic' sericite hornfels,* probably derived from a sericite claystone or siltstone.

No. 2. Pioneer Mine, 206-foot level, North Crosscut

The dark-grey handspecimen is fairly homogeneous.

Recrystallized irregularly-shaped grains of quartz, oligoclase, biotite commonly altered to penninite, and accessory sphene, epidote, and magnetite, are intergrown in a hornfelsic texture.

Patches of quartz and feldspar showing myrmekitic intergrowth indicate relict phenocrysts. Accumulations of green biotite, clinozoisite, sphene, and magnetite are common in the rock; the same minerals are found in veins.

The original rock was probably an acidic igneous rock; the rock might, possibly, have been conglomerate, but this is very unlikely. After metasomatism and recrystallization the rock is now an *oligoclase-quartz hornfels.*

No. 3. Pioneer Mine, 206-foot level, No. 2 Lode

This homogeneous, black, handspecimen is fine-grained and consists of grains about 0.3 mm. in diameter of quartz, biotite, and penninite. Clear, anhedral, recrystallized quartz grains are surrounded by small flakes of biotite and muscovite. Larger biotite grains, commonly containing pleochroic halos, have been partly reconstituted and are lepidoblastic.

Patches of penninite replacing biotite occur throughout the rock. Magnetite and tourmaline are accessory.

Cracks in the rock are filled with biotite, penninite, quartz, and some tourmaline.

The rock has been metamorphosed and has reached the biotite facies. Some material was probably introduced during metamorphism. The original rock was sedimentary, and relict lamination can be seen; the former shaly sandstone is now a *biotite-quartz hornfels.*

No. 5. Pioneer Mine, 206-foot level, Della Lode

The black, homogeneous, handspecimen has a hornfelsic texture, and contains 1 - 2 mm. diameter grains of quartz, feldspar, biotite, secondary minerals and accessories.

Quartz grains are commonly recrystallized; quartz-orthoclase micrographic patches are common. Oligoclase is seen as patches in quartz. Euhedral grains of plagioclase have been completely altered to sericite and epidote. Orthoclase, with quartz and as euhedral grains, has been kaolinized.

Small recrystallized grains of biotite cluster into the space of former large grains. Pleochroic halos around zircon grains occur in biotite and in corundophilite which replaces biotite.

Ferrohastingsite, a greenish-yellow to blue-green pleochroic amphibole with a small negative optic angle, contains globules of quartz in a sieve-like texture and has probably been reconstituted from brown-yellow hornblende, remnants of which are surrounded by ferrohastingsite.

Magnetic grains are irregular in shape. Apatite is accessory.

The rock, a *quartz-amphibolite,* is probably the result of metamorphism of a rock of the composition of a diorite.

With no field data, the origin of this rock cannot be determined.

No. 9. Acid intrusion from Wolfram Hill

The compact, red, handspecimen is fine-grained and homogeneous and extremely weathered.

The rock consists of fine, ragged grains of quartz in a matrix of hydrated iron oxide. Through the rock are quartz veins containing rutile needles, and a vein of iron oxide surrounded by a zone of hydrated iron oxides.

The rock has been metamorphosed and has probably been deformed; it may have been an *acid volcanic, a granophyre,* or an *aplite.*

No. 16. Mica schist from Copper Show Group

The fine-grained, homogeneous handspecimen has been extensively sheared.

Fine recrystallized grains of biotite and quartz are the main constituents of the rock. A few muscovite grains pseudomorph feldspar grains. Accumulations of biotite are probably pseudomorphing a former ferromagnesian mineral.

The rock is is now a *mica schist* and is probably of sedimentary origin.

No. 17. Acid porphyry from Water Shaft, Hit or Miss Group

The handspecimen is black and porphyritic.

Blasto-porphyritic quartz grains (10%), showing evidence of stress during metamorphism, sericitic pseudomorphs of former feldspar phenocrysts (5%), and biotite pseudomorphs of former ferromagnesian phenocrysts (7%), lie in a groundmass of recrystallized grains of quartz (55%), biotite (5%), and sericite (20%).

The rock was a *porphyritic acid volcanic.*

APPENDIX 2

Ore Specimens from Hatches Creek Wolfram Field, Northern Territory

By W. M. B. Roberts

Nos. 52a and 52b. 206-foot level, No. 2 Lode, Pioneer Group

These specimens consist of massive vein quartz and contain large areas of wolframite, scheelite, and molybdenite.

Four sections of the two specimens were examined and the following ore minerals were found to be present:

Wolframite, scheelite, molybdenite, pyrite, chalcopyrite, bismuth, and (?) tetrahedrite.

Wolframite is quantitatively the principal mineral present; it forms typical large blade-like intergrowths with quartz and accounts for about 75% of the total ore mineral.

Scheelite, the next most abundant mineral in the specimens, forms euhedral crystals and has grown along the cleavages and filled small fractures in wolframite. In places it appears to have replaced this mineral.

Molybdenite occurs as small isolated blade-like structures moulded by scheelite and bismuthinite, but there is no concrete evidence of its paragenesis.

Pyrite is quantitatively unimportant and appears to have been deposited after molybdenite. It fills vugs in the specimen, moulding and cementing the euhedral scheelite, and forms small irregular masses and veinlets in both scheelite and wolframite.

Bismuthinite forms irregular areas in the ore minerals throughout the specimen, and appears to have replaced chlorite, wolframite, and, to a lesser extent, scheelite. It forms distinct continuations of the grain boundaries of these minerals and can be seen to have grown along the cleavage planes of the chlorite.

Chalcopyrite occurs both with bismuthinite and isolated in the quartz gangue. It is a minor constituent, the largest areas measuring 5.0 mm. across.

Bismuth forms thin, elongate, lenticular bodies oriented along a cleavage of bismuthinite, and also small irregular veinlets in wolframite and scheelite.

(?)Tetrahedrite is of minor quantitative importance in the ore, and was seen only twice during this examination, once as a small irregular area in bismuthinite, measuring roughly 0.3 mm. across, and once as a small vein in wolframite. The mineral could not be separated for positive identification, but etching with HNO_3 and concentrated HCl produced an iridescent film.

From the foregoing examination a tentative paragenesis would be: first, wolframite, then scheelite, molybdenite?, pyrite, and finally chalcopyrite, bismuthinite, and bismuth.

The position of tetrahedrite is obscure because of its small quantity and isolated occurrence.

This paragenesis need not be correct and should not be used as a basis for any conclusions relating to the origin of the ore minerals: any paragenetic sequence based on textural evidence alone can be quite misleading unless it takes into account the behaviour of such a heterogeneous system under the conditions of temperature and pressure operative during and after deposition. Unfortunately these complex systems have yet to be studied and until such evidence is available any paragenesis based on textures alone should be treated with reserve.

No. 49. Main Lode, Green Diamond Group

The specimen appears to consist of a nodule of crystalline pyrite containing a small quantity of white vein quartz. Polished section examination confirmed that the major ore mineral is pyrite; however, extremely small quantities of chalcopyrite, covellite, sphalerite, and (?) bornite were observed. Some idea of their abundance may be gathered from the sizes of the grains: chalcopyrite, 0.06 mm. across; covellite, very thin fringes on the chalcopyrite areas; sphalerite, 1.2 mm. across; and (?) bornite 0.004 mm. across.

No. 50. Copper Lode, Hit or Miss Group

This consists of massive chalcocite containing some copper carbonate and white quartz.

The only important opaque mineral is chalcocite, fairly coarsely crystalline and showing a very distinct cleavage. Small irregular areas of bornite are randomly distributed throughout the chalcocite, the largest measuring 0.05 mm. across. Small masses of a yellowish-white highly reflecting mineral were observed; these may have been native bismuth, but could not be positively identified.

No. 51. No. 1 Lode, Hen and Chickens Group

Two specimens were included under this number. One appears to be a vein-filling of iron oxide containing some copper carbonate, with selvages of white mica oriented so that the (001) cleavage is at right angles to the vein walls.

The vein-filling itself is a very-fine-grained hydrated iron oxide containing some malachite and very small grains of chalcocite and covellite.

The other specimen is massive vein quartz containing large quantities of chalcocite and malachite. In polished section very small amounts of chalcopyrite ranging up to 0.02 mm. across, and possibly some native bismuth, were observed; the bismuth could not be positively identified.

The accessory minerals in specimens 50 and 51 are generally distributed as isolated grains, which precluded any attempt to determine their paragenesis.

INDEX OF LODES AND LEASES

(Principal references in italics)