COMMONWEALTH OF AUSTRALIA.

DEPARTMENT OF NATIONAL DEVELOPMENT.

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS.

BULLETIN No. 22.

THE GEOLOGY AND MINERAL DEPOSITS OF THE TENNANT CREEK GOLD-FIELD, NORTHERN TERRITORY

BY

J. F. IVANAC.

VOLUME I.—DESCRIPTION.

VOLUME II.—MAPS.

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Minister : SENATOR THE HON. W. H. SPOONER.

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BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS.

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SUMMARY.

This Bulletin presents the results of a regional and detailed geological survey of the Tennant Creek Gold-field. The main object of the investigation was to determine the structural controls of ore deposition.

Systematic mining began on the Tennant Creek Gold-field in 1932. One hundred and thirteen mines were in operation before 1947. In 1951 only four mines, Noble's Nob, Eldorado, Peko, and Northern Star, were producing gold ore.

To the end of June, 1950, 166,400 tons of ore of average grade 18.1 dwt. per ton were won.

The sedimentary rocks of the region consist of folded and brecciated sediments which are thought to range from the upper part of the Lower Proterozoic (Warramunga Group) to the lower part of the Upper Proterozoic (Ashburton Sandstone). The Warramunga Group consists of sandstones, siltstones, mudstones, and shales which grade into the overlying quartzite sandstone and conglomerate of the Ashburton Sandstone. The Warramunga Group are unconformably overlain by the Rising Sun Conglomerates, which are possibly Upper Proterozoic in age.

These rock units have been intruded by adamellite and related porphyries. In one place a magnetite amphibolite dyke was noted.

Gold-bearing quartz-hematite lodes replace crush zone in the Warramunga Group. They are confined entirely to this Group.

Downwarping on the eastern margin of the region led to a marine transgression in the Middle Cambrian. This transgression was preceded by volcanic activity in the Lower Cambrian.

Since Middle Cambrian times the region has been comparatively stable. The only records of uplifts are from Tertiary time, when several small uplifts brought the peneplaned land-surface to its present level.

The major controlling structural feature was the shape of the deepest part of the original (?Lower Proterozoic) geosyncline. The regional structure of the Gold-field is not fully solved, but some major anticlines have been determined.

The Tennant Creek mineral deposits are classified as gold-bearing quartz-hematite lodes, auriferous quartz veins, and barren lodes (quartz reefs and jasper lenses).

The quartz-hematite lodes crop out as east-trending groups of isolated bodies. Gold, magnetite, hematite, quartz, and bismuth carbonate are the lode minerals; chalcopyrite occurs in the Peko mine ore-body. The ore is a gold-bearing hematite-rich brecciated mudstone or shale.

The lodes are localized in breccia zones on the limbs and crestal regions of anticlines. Where the mineralized zone replaces a mudstone or shale horizon gold ore has been concentrated. Sandstones are unfavorable host rocks for gold.

The possibility exists of some secondary enrichment of the lodes.

In only five mines have ore shoots averaged more than 500 tons per vertical foot. They are generally lenticular in shape.

Descriptions of individual mines have been compiled.

The future prospects of the Tennant Creek Gold-field are discussed. Ore reserves are about 200,000 tons, and this includes measured, indicated, and inferred ore.

Results of the Bureau of Mineral Resources diamond-drilling campaign are appended. Two new ore repetitions were discovered.

INTRODUCTION.

GENERAL.

Gold has been produced from the Tennant Creek Gold-field only since 1932, although the area was recommended to prospectors as early as 1897.

The Geological Section, Bureau of Mineral Resources, Geology and Geophysics, as part of its field activities and at the request of the Director of Mines, Northern Territory, carried out a detailed investigation of the Gold-field. The objects of the work were to determine the chief structural controls of ore deposition, to prepare a geological map of the area, to provide geological assistance and advice to prospectors and mining companies and if possible to assess the future life of the Gold-field.

Field work was carried out in the winter months of 1948, 1949 and 1950. In 1948 and 1949, N. H. Krasenstein and the writer mapped part of the regional geology and several of the more important gold mines. In 1950, E. K. Carter, B. P. Walpole, E. M. Bennett and the writer completed the investigation of the regional geology and mapped the geology of additional mines. The geological investigation was conducted under the supervision of C. J. Sullivan, Supervising Geologist of the Bureau of Mineral Resources.

A total of 38 "man-months" was spent on field work.

Towards the end of the survey, in 1950, the Bureau began diamond drilling to test ore-search theories. A Sullivan H.22 drill was used and the drilling carried out under geological supervision. J. Green, foreman driller, and two assistants worked for three months on the drill for a total footage of 2,055 feet.

An area of approximately 2,500 square miles was geologically mapped, and the data plotted on a base map compiled by radial-line plot from aerial photographs on a scale of 1:46,000. A complete coverage of the area was obtained from photographs flown at 25,000 feet by the Royal Australian Air Force in 1947. In addition to these runs, the more important mineralized areas were covered by photographs from 12,000 feet by the Royal Australian Air Force in 1935.

Geological surveys, using plane table and telescopic alidade, were made of the mining leases examined on scales of 40 or 80 feet to the inch. Detailed underground mapping, in most cases, entailed compass and tape surveys of underground levels before geological data could be plotted.

In many cases, geological maps were passed on to mining companies and suggestions for exploration made within a few days of the conclusion of the investigation of a particular lease. One or more of the members of the geological party was always available to offer help and advice to prospectors and mining companies.

SITUATION AND ACCESS.

The gold deposits of the Tennant Creek area are situated in the Northern Territory of Australia, and are scattered throughout an area of approximately 2,000 square miles. The area (Fig. 1) lies between the 19th and 20th parallels

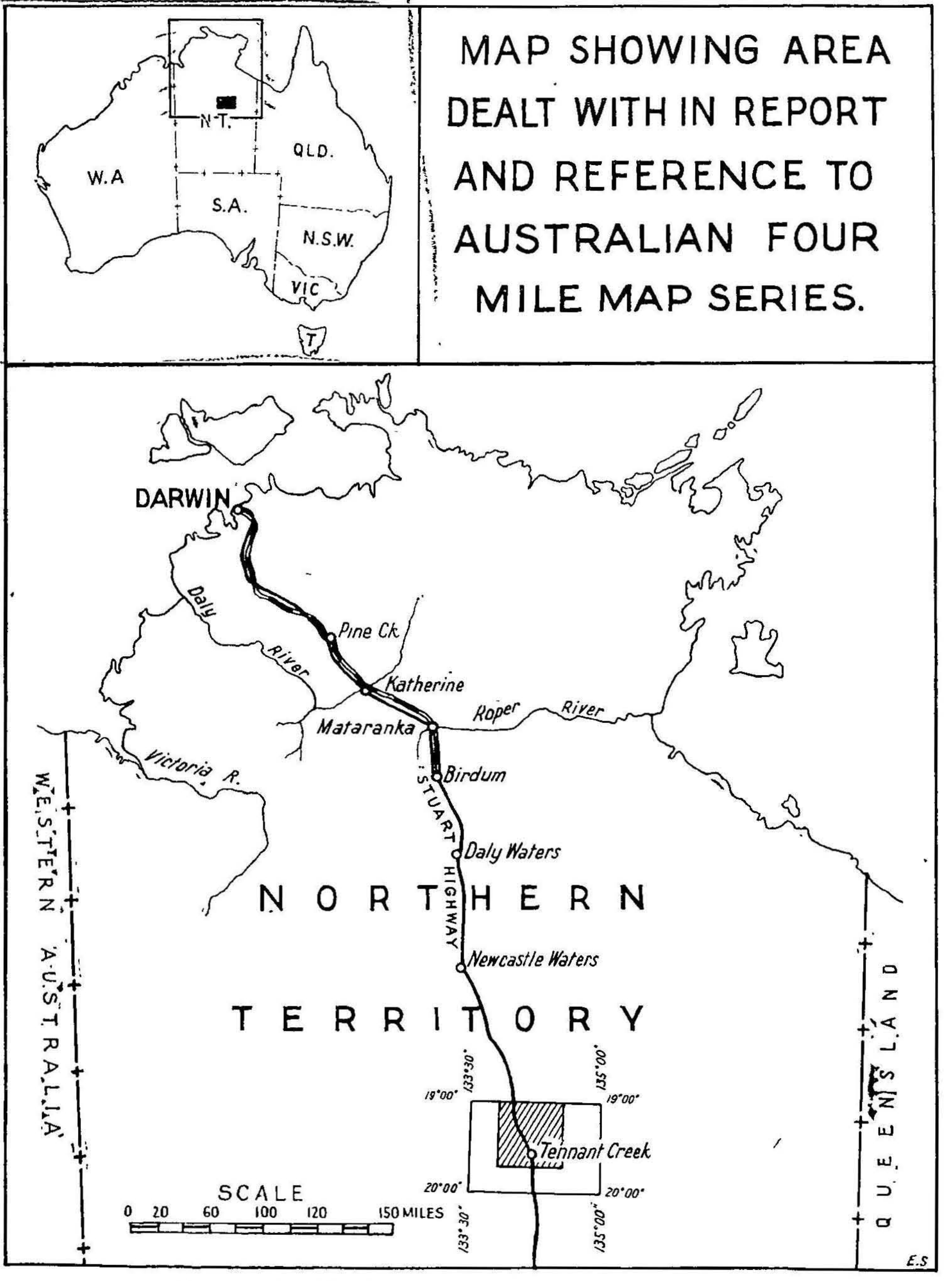


Fig. 1.—Locality Map of the Tennant Creek Gold-field.

of south latitude and astride the 134th meridian of longitude. Tennant Creek township lies in the centre of the southern half of the field, and is situated on the Stuart Highway 313 miles north of Alice Springs. The Stuart Highway, a first-class bitumen-surfaced road, joins the Northern Territory Administration towns of Darwin and Alice Springs. The nearest railheads are at Alice Springs, Birdum (307 miles north of Tennant Creek) and Mount Isa (416 miles east of Tennant Creek, and connected with it by a bitumen highway). Birdum is connected by rail to the port of Darwin. From these towns mining equipment and foodstuffs are carted by road. A two-runway airport at Tennant Creek is serviced by the Department of Civil Aviation, and Trans-Australia Airlines operate passenger, mail, and freight services from Adelaide, Darwin, and Brisbane.

Access to the mining properties is by an extensive network of fire-ploughed roads which radiate from the Tennant Creek township. Several of these roads are impassable for short periods during the annual wet season from December to February.

TOPOGRAPHY.

The relief of the Tennant Creek district is low, and consists of sub-parallel lines of flat-topped hills rising from an extensive plain, which at Tennant Creek township is 1,114 feet above sea-level.

The types of hill occurring, which are typical of arid areas, are mesas, buttes, and razor-backed ridges, and form parts of elongate east-west ridges dissected by numerous dry watercourses. The steep scarp of the hills gives way rapidly to the flat alluviated plains which cover most of the Gold-field.

The mesas are typical of outcrops of sediments of the Warramunga Group, whereas razor-back ridges are characteristic of the Ashburton Sandstone. The parallel hills formed by Ashburton Sandstone rocks present a low east-west scarp in the northern part of the area. Granite and porphyry crop out chiefly in the central part of the field, as low rounded hills which consist of numerous tors. Rocks of Middle Cambrian age overlap the older rocks along the eastern flank of the area and have a flat to rounded topography, gently sloping in some directions, but with an abrupt scarp in others.

Tennant Creek and Phillip Creek are the main drainage channels: Tennant Creek drains the southern, and Phillip Creek the northern, part of the area. The creeks are normally dry and consist of a chain of small waterholes during the rainy seasons. Tennant Creek flows east-north-east and has a dendritic-patterned source which passes into a well defined channel near the Old Telegraph Station. Farther east along its course, it diverges into several channels and finally loses its identity in a wide alluvial plain, a possible remnant of an ancient lake area. In the middle section of its course it has formed fossil meanders. Phillip Creek drains into an alluviated area near the Warramunga Mission Station. Some large waterholes such as Butchers' Hole and Kerramun Lagoon are along its course and on its main tributaries.

Tributary streams are generally steep-sided, and follow structural features in the rocks they dissect. The pattern is close-dendritic in the granites and open-type dendritic where Cambrian rocks are dissected.

There is no permanent surface water, but rock holes and billabongs hold a moderate supply for short periods after rainfall.

CLIMATE AND VEGETATION.

Tennant Creek lies in the semi-arid region of Australia, and the climate is characterized by long hot summers and short mild winters. Summer temperatures range from 90° F. to 115° F.; and in the winter, temperatures seldom fall below 55° F.

Rain falls mostly in the summer months (known in the Northern Territory as the "wet season") of December and January. The yearly average is 14 inches.

The prevailing wind is a strong south-easterly; and northerly and westerly winds blow during stormy periods.

The winter months from May to September are the most congenial months for field work.

Plant types and communities are typical of the arid to semi-arid conditions. These plants include spinifex (*Triodia* and *Plectrachere*), mulga (*Acacia aneura*), snappy gum (*Eucalyptus pallidifolia*), ghost gum (*Eucalyptus papuana*), and the tall white-barked tree (*Eucalyptus comaldulensis*). In addition there is a wide variety of flowering plants and shrubs, including wattles, mallee, grevillea, and field grasses.

PREVIOUS INVESTIGATIONS.

Geological investigations on the Tennant Creek Gold-field have been very few, and most of the work before the present Survey was carried out by Government Geologists.

In 1895, H. Y. L. Brown, in the course of a journey from Darwin to Adelaide, spent eight days in the Tennant Creek district. He panned wash from Bishop's Creek and found traces of gold. On the results of this finding, he recommended the area to the attention of prospectors. However, later prospecting showed that Brown was extremely fortunate to find gold in the Bishop's Creek area.

Davidson, in 1905, extensively sampled the numerous quartz reefs which outcrop in the centre of the Gold-field. He was not particularly impressed by the possibilities of the field, and thought that there was little prospect of making a big discovery.

The geology and ore deposits of the gold-field were discussed in very general terms by Dr. Woolnough (1936). Diagrams and photographs were included in his report but no geological map.

Rudd (1937) examined the Gold-field for Broken Hill Pty. Ltd., and in his report discussed the geology of the field in general terms, and of a few individual mines in particular. He suggested that the gold has been reconcentrated by secondary enrichment, but considered that some hypogene or primary gold is present. Rudd did not consider the deposits of the field were of a size sufficient to warrant operations on a large company basis.

Information on concealed quartz-hematite lodes is contained in three detailed reports by the Aerial, Geological and Geophysical Survey of Northern Australia in 1935, 1936, and 1937. A magnetometer survey, along the known "lines of lode", resulted in the discovery of many concealed quartz-hematite bodies. These sub-surface bodies are shown on the plans by closed magnetic contour lines; several of these bodies were tested by diamond drilling. Some useful geological and mining information is contained in the reports.

Owen mapped the geology of part of the Gold-field and submitted a report in 1942. He discussed the general geology of 450 square miles of the gold-field and described several of the more important mining areas.

Individual mining reports were made by Sullivan (1942), Knight (1947), and McKeown (1948).

Stillwell and Edwards (1942 and 1950) have discussed the mineral associations of the gold ores. Valuable information is contained in Commonwealth Scientific and Industrial Research Organization reports from Melbourne and Bonython Laboratories.

Noakes and Traves (1949), Bureau of Mineral Resources, in the course of a regional geological survey of the Barkly Tablelands and its extensions, visited the Tennant Creek Gold-field.

HISTORY OF MINING AND PRODUCTION.

Traces of gold were first reported by H. Y. L. Brown, South Australian Government Geologist, in 1895, and he recommended the area to the attention of prospectors. Towards the end of the 1920 to 1930 decade, prospectors casually examined the area and met with little or no success, as they confined their attention to barren quartz ridges. This was to be expected as most of the prospectors had gained their mining experience in gold-quartz lodes. Eventually the miners examined the quartz-hematite lodes, and in 1933 rich gold was discovered in an abandoned shaft 6 miles south-south-west of the Old Telegraph Station. Assay results show that the grade of ore was approximately 6 oz. per ton. Later 9 tons of selected ore were sent to the Peterborough Battery, South Australia, and yielded 23 oz. of gold by amalgamation. Tailings were reported to assay 25 dwt. per ton. Subsequently, gold was discovered 3 miles east of the original locality at a mine named the Pinnacles.

The news of the discoveries spread quickly, and towards the end of August, 1933, a rush to the field set in. This was followed by a crowd of mining speculators and investors. The usual "get-rich-quick" tactics were adopted by miners and shareholders alike. Very high prices were asked for lease options, but funds were soon exhausted and men on the field were forced to settle down to systematic mining. Selected ore was sent to the South Australian Government Battery at Peterborough, and this necessitated cartage by rail and road for 830 miles. The crushing results, of some of the parcels of ore sent, are listed below:—

Local Mine.	Tonnage.		Total Ounces.
	Tons.	Cwt.	
Pinnacles	6	10	62
Weaber's Rising Sun	55	..	315
Scott's Wheal Doria	1	7¾	48

A continuous water supply for operating plant was an early problem; a bore put down 10½ miles south of the Old Telegraph Station yielded enough water to run a private battery consisting of two single-output stamps.

Towards the end of 1935 the population of the town and surroundings was between 500 and 600; another battery, Central Gold Milling Company's Empire Mill, was erected 7½ miles east of Tennant Creek. In the same year the area was officially proclaimed the Tennant Creek Gold-field. It covered an area of 2,146 square miles and was 65 miles from east to west. In 1936, treatment plants were being erected at Mammoth and Eldorado gold mines. Later, two Government Batteries were erected with the object of encouraging interest in the field.

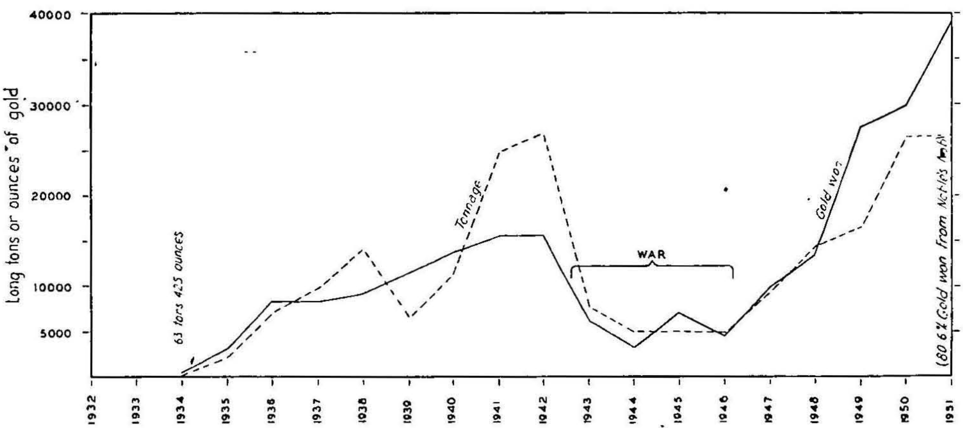


Fig. 2.—Relation of Tonnage of Ore mined to Gold won by amalgamation.

Records of ore production are fairly complete. The information is contained in reports of the Administrator and Mines Department of the Northern Territory, and Government Battery records.

Production gradually increased from 63.0 tons of ore in 1934 to 24,732 tons in 1942. The annual tonnage and grade of ore produced since 1934 is shown in Table 1 and graphically in Figure 2.

TABLE 1.

YEARLY PRODUCTION FIGURES AND AVERAGE GRADE OF ORE PRODUCED ON TENNANT CREEK GOLD-FIELD.

Year ending 30th June.	Long Tons.	Gold Won—Oz.	Average Grade—Dwt. per Ton.
1933	..	.	..
1934	63.0	425.0	135.0
1935	2,297.35	2,983 12	25.9
1936	7,092.0	8,468.66	24.9
1937	9,849.6	8,400.0	17.0
1938	14,118.53	9,128.80	12.9
1939	6,538.69	5,897.92	18.0
1940	11,435.88	13,844.547	24.2
1941	24,732.137	15,406.827	12.2
1942	26,908.0	15,760.0	11.7
1943	7,737.5	6,065.5	15.7
1944	5,395.0	3,451.84	12.8
1945	5,156	7,147.16	27.7
1946	4,933	4,615.33	18.7
1947	9,308	9,930.0	21.4
1948	14,221 94	14,478.0	20.4
1949	16,614 0	27,522.0	33.2
1950	26,530.0	29,976.0	22.6
1951	26,617.0	39,322.27	29.5
1952	27,427.0	36,822.44	26.9
Total	246,974.6	259,645.41	21.0

Production (Fig. 2) seriously declined during the war years, owing to compulsory conscription of most of the miners and the closing down of many mines under National Security Regulations. The well-established Eldorado Mine remained in production and was responsible for most of the tonnage produced during this period. With the return of prospectors to the field after the war, production steadily increased, and received an additional boost when Australian currency was devalued on the 19th September, 1949, and the price of gold rose from £10 15s. 3d. to £15 9s. 10d. per fine ounce. This increase in the price of gold lowered the cut-off grade and allowed ore that was previously uneconomic to be mined; but it did not stimulate prospecting to any great extent. From 1946 to the middle of 1950, the annual tonnage came from 25 mines, whereas before the war 113 mines were in operation. In 1951, the high prices for tungsten and tin coupled with a substantial increase in the Government Battery crushing charges led to a general exodus of prospectors from Tennant Creek, and production has since been maintained by five mines (80.6 per cent. of total production was obtained from Noble's Nob mine). The sudden decrease in prospecting activity, and the lack of new finds as shown by the diminished number of workings in operation since the war, is a function of the small irregular size of the ore-shoots and the difficulties of finding new ones. However, the established mines in operation contribute a greater tonnage (Fig. 2) than the 113 mines in production before 1942.

The individual production of all mines which have produced gold on the Tennant Creek Gold-field is shown in Table 2 below. Those mines at present (1952) in production are italicized:—

TABLE 2.

PRODUCTION FIGURES OF INDIVIDUAL PROSPECTS, TENNANT CREEK GOLD-FIELD.

To June, 1952.

Mine.	Ore. Long tons.	Gold Won by Amalgamation. Fine oz.	Gold Won by Amalgamation. Dwt. per ton.	Tailings (Approximate Grade). Dwt. per ton.	Dollied Gold. Fine oz.
Ace High	53.9	97.7	36.2	5.8	..
Ajax	17.75	4.3	4.9	..	..
Argo	142.11	36.27	5.1	2.6	..
Arizona	72.63	21.97	6.1	3.0	..
Black Angel and White Devil	6,374.59	3,019.33	9.4	2.7	..
Big Ben	13.0	7.08	10.9	0.9	2.33
Black Cat	2,206.69	1,023.49	9.1	0.8	..
Black Eye	590.94	162.3	4.8	4.1	..
Blue Bird	171.96	51.58	6.0	1.1	..
Blue Moon	3,288.38	11,854.95	72.0	14.6	..
Bobbie Burns	11.68	6.44	11.9	4.2	..
Burnt Shirt	1,011.09	1,051.53	20.8	1.1	..
Caroline	503.71	282.05	11.2	1.0	..
Carraman	34.15	103.53	60.63	17.5	..
Cat's Whiskers	381.37	99.16	5.2	0.7	..
Cleo's Gift	40.5	9.95	4.8	..	..
Colorado	11.4	4.2	7.5	3.8	..
Crown Lands	..	..	..	..	2.13
Crusader	78.42	34.41	8.8	2.4	..
Desert Gold	21.8	27.68	25.4	3.0	..
Desert Hope	68.16	40.16	11.8	2.4	..
Desert Queen	23.25	9.6	8.1	6.4	..
Destiny Star	25.02	6.42	5.1	2.3	..
Dot Six	70.95	13.97	3.8	..	..
Edna Beryl	2,644.92	4,239.33	32.1	4.6	..
Eldorado	91,341.0	65,809.25	14.4	..	..
Ellen M	31.3	13.98	8.3	1.7	..
Ellen Ruby	63.96	43.44	13.58	2.2	..
Enterprise	6,137.49	5,678.61	18.5	..	..
Euro			No production		..
Fassifern	125.05	107.5	17.2	1.0	..
Gigantic	1,124.35	518.92	9.1	6.3	..
Golden Chance	422.47	1,257.40	59.5	2.8	..
Golden Forty	2,044.18	501.1	5.1	1.5	..
Golden Kangaroo	28.0	48.85	34.9	3.8	..
Golden Key	10.6	12.94	24.4	4.6	..
Golden Mile	142.5	96.68	13.5	..	..
Golden Slipper	378.31	124.49	6.6	5.3	..
Granites	13.5	1.48	2.2	..	..
Great Bear	325.8	179.5	11.0	0.79	..
Great Eastern	829.0	279.7	6.7	3.2	..
Great Northern	778.93	448.83	11.5	0.36	..
Great Western	1,857.99	501.6	5.4	..	..
Hammerjack	5,880.81	5,519.0	18.7	5.5	..
Havelock			See Tasman		..
Hidden Mystery	23.0	11.5	10.0	0.9	..
Hill 98	59.5	177.5	59.7	6.4	..
Hopeful Star	1,615.42	170.5	2.1	1.8	..
International			See Rosebud		..
Joker	3,175.11	714.1	4.5	..	..
Jubilee	1,278.5	480.15	7.5	..	..
Kathleen	894.55	362.17	8.1	3.0	..

TABLE 2—*continued.*

Production Figures of Individual Prospects, Tennant Creek Gold-field—continued.

Mine.	Ore. Long tons.	Gold Won by Amalgamation.		Tailings (Approximate Grade).	Dollied Gold.
		Fine oz.	Dwt. per ton.	Dwt. per ton.	Fine oz.
Kiora	681.68	425.8	12.4	3.6	..
Lady Mary	11.6	13.8	23.8	8.6	..
Last Hope	64.73	179.03	55.3	..	41.86 6.50 alluvial
Leichhardt	700.42	269.66	7.7	3.6	..
Leviathan	No production				
Little Ben	213.85	106.67	10.0	1.0	..
Little Wonder	114.0	27.32	4.8	..	..
Lone Star	6,426.63	3,443.16	10.7	2.7	..
Mammoth	439.0	102.6	4.7	..	..
Maple Leaf	No production				
Marion Ross	22.45	16.29	14.5	2.8	..
Mary Ann	256.67	182.37	14.2	8.9	..
Mascot	100.85	22.69	4.5	0.8	..
Mauretania	48.6	210.0	86.4	..	..
Memsahib	201.34	131.69	13.1	4.1	..
Metallic Hill East	49.14	12.5	5.1	..	..
Metallic Hill	147.1	137.6	18.7	4.4	..
Mint	87.0	15.66	3.6	2.2	..
Mirium	8.5	8.0	18.8	2.8	..
Mount Otto	65.3	16.32	5.0	1.0	..
Mount Samuel	2,530.62	3,933.46	31.1	7.1	..
Never in Doubt	48.6	113.0	46.5	20.0	..
New Hope	107.51	88.05	16.4	2.9	..
New Moon	No production				
Noble's Nob	46,370.0	110,459.96	47.6	5.3	..
Northern Star	14,263.0	4,959.03	7.0	2.4	..
Olive Wood	262.86	118.48	9.0	1.2	..
Orlando Central	46.0	9.27	4.0	1.8	..
Orlando East	No production				
Ortelle Star	33.0	9.11	5.5	..	..
P.A. 134E	32.0	3.15	1.97	0.9	..
Patties	1,488.48	1,436.2	19.3	4.0	..
Peko	6,079.0	1,119.2	3.5	..	12.8 dwt. per ton in Cu ore, 1952
Perseverance	..	..	..	..	192.34
Peter Pan	231.78	73.0	6.3	0.74	..
Pinnacles	1,355.11	927.95	13.7	5.3	..
Plain Jane	1,171.34	674.15	11.4	..	..
Plonk	4.38	10.95	50.0	7.5	..
Premier	24.0	11.64	9.7	7.4	..
Pup	74.0	25.57	6.9	..	..
Queen of Sheba	666.1	371.0	11.4	5.5	..
Red Terror	593.32	1,307.13	44.1	12.87	..
Renate	19.85	13.5	13.6	2.1	..
Rio Grande	51.55	18.0	7.0	..	..
Rising Sun . ..	10,300.6	7,997.8	15.1	4.4	(by cyanidation)
Rosebud	20.0	1.9	1.9	..	..
Rosemary	178.0	97.2	10.9	..	..
Shamrock	62.0	6.2	2.0	2.6	..
Skipper Extended	2,126.5	4,228.73	39.8	15.1	..
Southern Cross	653.0	297.67	9.1	..	..
Southern Star East ..	133.89	83.0	12.38	8.0	..
Southern Star West ..	161.72	37.16	4.6	0.8	..

TABLE 2—*continued.*

Production Figures of Individual Prospects, Tennant Creek Gold-field—continued.

Mine.	Ore. Long tons.	Gold Won by Amalgamation.		Tailings (Approximate Grade). Dwt. per ton.	Dollied Gold. Fine oz.
		Fine oz.	Dwt. per ton.		
Tasman	57.12	20.9	7.3	1.3	..
The Nipples	112.75	22.96	4.1	..	..
Three Keys	458.02	293.0	12.8	0.6	..
Three Thirty	1,703.09	567.9	6.6	3.0	..
Tunnel	63.08	19.2	6.1	1.1	..
Two Blues	490.68	548.8	22.4	3.3	..
Two Chances	10.9	3.83	7.5	2.9	..
Valhalla	12.0	15.4	25.9	..	..
Wedge	1,133.4	254.8	4.5	1.6	..
Westward Ho	529.08	695.8	26.3	2.7	..
Wheal Doria	1,831.26	1,769.8	19.3	4.6	..
Whippet	12,374.89	13,981.82	22.6	6.7	..
White Devil	372.33	122.1	6.5	4.1	..
Wizard	10.87	15.3	28.1	3.2	..
Wolseley	104.72	13.6	2.6	..	..

GENERAL GEOLOGY.

STRATIGRAPHY.

PRE-MINERAL ROCKS.

The rocks of the Tennant Creek Gold-field form part of the Australian Pre-Cambrian Shield, which has been comparatively stable since Pre-Cambrian time. The geological record indicates that since the Pre-Cambrian there has been only one marine transgression—in the lower Middle Cambrian. Along this submerged section of the Pre-Cambrian, volcanoes were active and some sediments were deposited. Since that time the whole area has been very stable, apart from a slight general uplift in the Tertiary which initiated the dissection of the peneplain.

The Proterozoic sediments have been folded and metamorphosed; but the thin and incomplete cover of lower Middle Cambrian sediments is of unaltered rocks.

Soda-granite and related porphyry intrude Proterozoic rocks but not the Cambrian succession; granodiorite and gneiss crop out south of the Tennant Creek Gold-field and may be related to the adamellite. Volcanic rocks occur in several places below the thin cover of lower Middle Cambrian sediments.

An extensive Tertiary-Recent soil cover conceals large areas of rock on the Gold-field, particularly rocks of the upper part of the Lower Proterozoic, which are older than the mineralization.

The two major rock units, the Warramunga Group and the Ashburton Sandstone, have been named by previous investigators New names and in one case a change in status of a unit have been suggested in accordance with the principles set out in the *Australian Code of Stratigraphical Nomenclature* (Glaessner, Raggatt, Teichert and Thomas, 1948).

TABLE 3.

STRATIGRAPHY OF THE TENNANT CREEK GOLD-FIELD.

Age.		Formation.	Lithology.	Igneous Activity, Fossils, &c.
Quaternary ..	..	—	Alluvia, re-cemented wash, talus	
Tertiary ..	..	—	Laterite	
	UN	CONFORMITY		Erosion and deep weathering
Cambrian	Lower Middle	Gum Ridge formation	Calcareous sandstone, sandy shale, chert, bedded sandstone	Trilobites, brachiopods, sponges, hyolithids
	UN	CONFORMITY		
	Lower (?) ..	Helen Springs Volcanics	Lavas and pyroclastic rocks	
	UN	CONFORMITY		Ore Deposits Soda-granite, porphyry
Proterozoic	Middle (?) Upper	Rising Sun Conglomerate	Conglomerate, sandstone, quartzite	
	UN	CONFORMITY		
	Lower (?) Upper	Ashburton sandstone	Sandstone, conglomerate, quartzite, volcanics	
	Upper (?) Lower	Warramunga Group	Sandstone, tuffaceous sandstone, grit, mudstone, shale	

The suggested classification and nomenclature are set out in the accompanying table (Table 3).

Warramunga Group.

The Warramunga Group is the name given to the sedimentary succession which contains the gold-bearing quartz-hematite lodes of the Tennant Creek Gold-field. This succession was originally named by Owen (1940) after completion of a regional survey of a portion of the Gold-field. The term "Series" used in his original discussion has been changed to Group.

The rocks of the Group crop out as sub-parallel lines of flat-topped and pinnacled hills separated by large flat areas of soil and alluvium (Plate 1). The general area of outcrop distribution is rhomboidal in plan with the long diagonal trending in a north-westerly direction.

In general, the relationship of the sediments of the Warramunga Group to other rock units in the area can be clearly seen. To the north, the Warramunga Group sediments grade into the younger Ashburton Sandstone—a transition chiefly due to a change in character of the cementing materials in the sediments from argillaceous to siliceous. Transitional sedimentary types have been included in the Warramunga Group and the boundary between it and the Ashburton Sandstone has been drawn at the southernmost outcrops of massive quartzite, which form a well-defined scarp.

Immediately south of a line connecting Noble's Nob and Plumb mines, the Group, in part, is unconformably overlain by Rising Sun Conglomerates, and in some places is intruded by adamellite or overlain by Recent soil and alluvium. Gneissic rocks are also present but the relationship between gneisses and Warramunga Group is not clear, because the contact is nowhere exposed.

Twenty miles east of Tennant Creek township the Warramunga Group is overlain unconformably by a discontinuous cover of Cambrian lavas and flat-lying lower Middle Cambrian fossiliferous beds.

Soda-granite stocks and associated porphyry intrude the Group, and in some places contact metamorphism in the form of silicification is noticeable. Quartz-hematite lodes, both auriferous and barren, replace crush zones in the Warramunga Group.

The distribution of sediments of this Group conforms to a general pattern of a sandy facies grading into a shaly facies from the margins of the region to the centre. The gradation is not uniform, and the outcrops available are insufficient to allow a boundary to be drawn between the sandy and shaly facies. Individual beds are generally lenticular and can seldom be traced for any distance along the strike.

The sandy facies consists of medium and fine ripple-marked sandstone, medium and fine tuffaceous sandstone, tuffaceous siltstone, grits, fine conglomerate, intraformational breccia, and lenses and beds of mudstone, hematite shale, and shale. Ripple-marked sandstones are widely distributed. The ripple-marks are generally asymmetrical with rounded crests, but some have sharp angular crests. Tuffaceous sandstones are interbedded with both the sandy and shaly facies, and near the Black Angel Mine are interlayered with altered lavas.

The mudstone or silty claystone lenses have a maximum measured thickness of 73 feet, and normally grade rapidly into sandstone both across and along the strike. The mudstone is deep red in the oxidized zone and blue-green below water-table level. This rock has been brecciated and selectively mineralized in crush-zones.

Narrow beds and lenses of blocky hematite shale are found in many places associated with quartz-hematite lodes.

The character of the sediments which make up the sandy facies suggests deposition in shallow water near the coastline.

Shales predominate in the centre of the gold-field. They are banded red, purple, and grey, and are generally highly contorted with steep dips; they contain interbedded lenses of sandstone and tuffaceous sandstone.

Detailed plane-table and telescopic-alidade mapping has identified a more or less typical succession in the sandy facies in the vicinity of the gold mines. A typical section (Noble's Nob gold mine) is described below. This succession is important as it shows both the gold-bearing member—the mudstone—and the massive quartzitic sandstone in which the lode shear fades out.

SECTION OF WARRAMUNGA GROUP SEDIMENTS FROM NOBLE'S NOB MINE.

	Thickness.
Interbedded fine-grained sandstone and mudstone .. .. .. Approx.	60
Tuffaceous sandstone	8
Interbedded fine-medium grained sandstone and mudstone	35
Massive quartzitic sandstone	50
Interbedded fine-grained sandstone, shale and mudstone	80
Medium-grained argillaceous and tuffaceous sandstone	27
Hematite shale (silicified)	7
Mudstone—Brecciated in the crush zone and selectively mineralized with gold	27
Medium-grained tuffaceous sandstone .. .. Approx.	45
Mudstone and cherty slate	16
Medium-grained tuffaceous sandstone	43
Mudstone	17
Interbedded fine-grained sandstone and shale	85

Rocks transitional between the Warramunga Group sediments and the Ashburton sandstone crop out in the north-western portion of the Gold-field. These rocks are grey fine-grained quartzite, and medium-grained flaggy sandstone, in many cases siliceous, with interlayered lava flows on the extreme northern limits of outcrop area.

Metamorphism of the Warramunga Group has taken place only along the margins of igneous intrusions and is of a low order. The main alteration is by silicification, which extends out from the contact over widths ranging from a few feet to 500 feet.

The character and distribution of the Warramunga Group sediments suggest that they were deposited in a moderately deep elongated geosynclinal basin flanked by shallow seas.

Shales and fine sandstones were laid down in the centre of the geosyncline, where the basin was comparatively deep, and elsewhere the sediments are of the shallow-water type. For this reason sedimentary members tend to lens out rapidly both down-dip and along the strike.

The age of the deposition of the Warramunga Group sediments is uncertain in view of the lack of age determinations and incomplete structural geological investigations in the surrounding region. The sediments are not fossiliferous and can definitely be assigned to the Pre-Cambrian era. Most investigators before 1948 assigned the Group to the Proterozoic, but some considered it to be Archean; Sullivan (1946) correlated it with the rocks of Brock's Creek and Mosquito Creek, and suggested a lower Proterozoic age; Noakes and Traves (1949) mapped part of the Gold-field in the course of an examination of the Barkly Tableland, and tentatively proposed an upper Lower or lower Upper Proterozoic age for the Group.

The results of field work described herein show that the Warramunga Group rocks cannot definitely be placed in either the Upper or the Lower Proterozoic until further evidence in the form of age determinations based on radio-activity is available.

Ashburton Sandstone.

The name Ashburton Sandstone refers to a succession of quartzite, conglomerate, and sandstones which crop out on the northern margin of the Tennant Creek Gold-field. The name was originally applied to the Formation by Noakes and Traves (1949), who mapped it in a general way, during their investigation of the Barkly Tableland and its extensions. They did not establish the relationship between the Warramunga Group and this Formation.

The Ashburton Sandstone outcrops 25 miles north of Tennant Creek, and extends in a general west and east direction on either side of the Stuart Highway. Twelve miles east of the Highway the trend of the rocks swings from east to north. Only the southern fringe of these rocks has been mapped, but the complete regional extent has been studied by Traves (1948), who has shown that similar rocks continue to Helen Springs, 70 miles north of Tennant Creek.

The Ashburton Sandstone consists of medium and coarse sandstone, quartz conglomerate, fine and medium current-bedded quartzite, sandstone, and greywacke, interlayered with conformable bands of igneous rock, probably basalt or dolerite.

The conglomerates are the predominant rock type in the lower beds of the formation and consist of grey and white coarse-grained rocks with well-rounded quartz pebbles of average diameter 1 inch. Two pebbles of rocks other than quartz were found in the conglomerates, a fine tuffaceous sandstone and a possible igneous fragment with fine granitic texture. The groundmass is made up of sub-rounded to rounded quartz grains bound together by a siliceous cement.

The sandstones show marked cross-bedding in some places. Where the cementing material changes from "argillo-siliceous" to entirely siliceous or where some secondary alteration has taken place these rocks are quartzitic in character. The massive quartzite forms the razor-backed ridges characteristic of the Formation.

North of the Last Hope mine flows of basalt are interlayered conformably with the Ashburton Sandstone.

The Ashburton Sandstone was mapped only along its southern margin, and a thickness of 11,000 feet for the section examined was estimated.

The relationship of the Ashburton Sandstone to the Warramunga Group was evident in traverses from the Black Angel Mine to the northern edge of the Gold-field. A gradual transition from sandy shale and sandstone with argillaceous cementing material to siliceous sandstone, quartzite, and conglomerate with siliceous cementing material was noted. The boundary between the two successions is thus an arbitrary one and is shown on Plate 1 as coinciding with the first massive quartzite outcrops, which form the fore-rocks of the Ashburton Sandstone scarp. Northern extensions of this Formation are overlain unconformably by Lower Cambrian (?) volcanics and lower Middle Cambrian sediments.

East of the Stuart Highway the Sandstone is folded into broad domes and basins. The Stuart Highway coincides with a north-striking axis of pitch change and beds on the east side of the road dip east and on the west of the road dip west. From the Stuart Highway towards the west the dip steepens to 60° north to vertical and the strike gradually swings to the east.

In this part of the Formation, 10 miles west of the Highway, there is a sudden reversal of dip from north to south. This reversal of dip has been caused by the folding movements, and has resulted in much faulting of the Ashburton Sandstone. Faults strike north and are partly filled with introduced quartz veins. West of this section the dip reverses to the north and the strike gradually changes to north-west.

The Ashburton Sandstone is pre-mineral, as it is intruded by porphyry (Traves 1949) 27 miles north of Tennant Creek, and is intersected by quartz veins which are associated with the Tennant Creek mineralization.

Sullivan (1946) tentatively suggested a Middle Proterozoic age for this Formation in view of its folded nature and the unconformable relationship of similar rocks to "typically looking Nullagine rocks" in the Davenport Ranges. Noakes and Traves (1949) have referred this Formation to the Upper Proterozoic. The gradational nature of the contact between the Warramunga Group and the Ashburton Sandstone suggests definite age affinity with the Warramunga Group. The folding and intrusion which took place before the effusion of Lower Cambrian (?) lavas, and the dissimilarity to Nullagine rocks which are typically unfolded points to the fact that this formation could be of the age suggested by Sullivan (1946). However, the present framework of age classification does not include a Middle Proterozoic period—therefore the age of deposition of these rocks would be in the lower part of the Upper Proterozoic.

The Ashburton Sandstones are epicontinental sediments deposited on the edge of a continental shelf. The origin of vein quartz for the conglomerates is unknown, but it may have been derived from quartz veins intersecting the Warramunga Group in the early stages of folding.

They may be correlated with the Davenport Range Group which are also epi-continental sediments.

Rising Sun Conglomerate.

The Rising Sun Conglomerate is the name given to flatly-dipping and gently-folded beds of conglomerate, cross-bedded sandstone, quartzite, and grits, which crop out as isolated groups of hills, south and east of the Rising Sun Gold Mine. The name Rising Sun was selected because of the close proximity of this mine to these outcrops and because of the lack of any suitable geographical name which could adequately describe the location of the succession. Conglomerate is suggested because of the distinctive nature of the basal beds and lenses in the sequence.

Owen (1940), in an unpublished report on the Tennant Creek Gold-field, discussed the lithology of a section south-east of the Rising Sun Mine. He noted that quartz-felspar porphyry intruded the Warramunga Group and the Rising Sun Conglomerate at their contact. Owen did not name the formation.

The succession consists of approximately 50 feet of conglomerate overlain by an indeterminate thickness of current-bedded sandstone, quartzite, and grit, which dip to the south at 25°. Eastwards, near the Plumb mine, the basal conglomerate is not visible and the main rock types are quartzite and sandstone.

The conglomerate consists of rounded quartzite and sandstone boulders in a siliceous matrix. Some of the boulders have been derived from a pre-existing conglomerate; pebbles within these composite boulders are chert, jasper and quartzite. The size of the boulders ranges from ½ inch to 12 inches diameter.

The Conglomerate has been deposited in a shallow arm of the sea possibly connected with the " Ashburton " or a similar epi-continental sea.

The Rising Sun Conglomerates overlie the Warramunga Group with an angular unconformity of 60°, south of the Red Terror mine. This relationship was established in one place only, but it probably holds for the rest of the section. Tongues of quartz-felspar porphyry intrude the basal conglomerates at their contact with the Warramunga Group sediments. The Rising Sun Conglomerate has been down-faulted against Warramunga Group. Some hematite and quartz veins were introduced into the conglomerates by the intrusion, which, apart from a narrow zone of silicification at the contact, produced no other metamorphic effect.

The provenance of boulders of the composite conglomerate is unknown, but may possibly have been the Davenport Range Group (30 miles south of Tennant Creek). No other sediments from which the conglomerate could be derived are known in the surrounding area.

The Conglomerate is younger than the Warramunga Group, and the Davenport Range Group. Folding, faulting, and intrusion have taken place after deposition of the formation. In view of the limited evidence, no definite age can be assigned to the conglomerates. They could possibly be assigned to one of the minor stages in lower Upper or middle Upper Proterozoic, as their folded and intruded character preclude them from Nullagine age.

Soda-granites.

Two irregular stocks of soda-granite (adamellite), each with an average diameter of three miles, and several smaller outcrops, have been mapped in the centre of the Gold-field. Because of the lack of continuity of outcrop no general locality name is proposed for these rocks.

Previous investigators have described these rocks as microcline granites. Owen (1940) discussed the distribution of the main area of outcrop, and also recorded that granite was discovered below a thin cover of alluvial material in a bore approximately a quarter of a mile south of Mount Samuel Trigonometrical Station.

The main mass of granite extends from the Old Telegraph Station (7 miles north of Tennant Creek township) westwards to Quartz Hill, 6½ miles distant. West of Quartz Hill, 5 miles east of the Black Angel Mine, are small isolated outcrops of granite; and immediately north of the Old Telegraph Station are further isolated outcrops, the largest of which occurs round White Hill.

These outcrops extend to 2 miles north of the Barkly Highway.

One mile south and 4 miles east of Rocky Range, in the south-eastern portion of the Gold-field, two small outcrops of adamellite were found. Seven miles south of Noble's Nob mine an area of granodiorite and gneiss was mapped. The granodiorite may be related to the adamellite stocks in the centre of the Gold-field; the gneisses may represent granitized sedimentary rocks intruded by granodiorite.

Aplite dykes, 6 inches to 6 feet wide, intersect the intrusive rocks and gneisses, but do not persist into Warramunga Group sediments.

In general, granites in the centre of the field are pink, whereas those in the south and south-eastern margin of the area are grey in outcrop. This is owing to the difference in colour of the felspar phenocrysts.

Microscopically the rock is a porphyritic soda-granite, the dominant phenocrysts being perthite, and ranging from half an inch to an inch in diameter. Many of the crystal facets of the perthite have been rounded, possibly by tectonic stresses, and some crystals are broken by small faults. Quartz, plagioclase (probably oligoclase-andesine), microcline, and biotite are the main constituents of the granite. Quartz grains exhibit undulose extinction.

The plagioclase, which has been very strongly sericitized, is strongly zoned in places. Accessory minerals are apatite, epidote, hornblende, zircon (in biotite), and iron ore. Variations in felspar ratio indicate that the rock ranges from granite, through soda-granite (adamellite) to granodiorite, with sola-granite the dominant type.

Practically unaltered xenoliths are common in the stocks in the centre of the Gold-field: quartzite and silicified sandstone are the commonest xenoliths, and apart from the addition of silica and the presence of some biotite, there has been no alteration. In the southern outcrops the xenoliths have been partly recrystallized and are aligned parallel to the east-striking gneissosity; the original rock type may possibly have been a sandstone.

The soda-granites have a well-defined east-south-east gneissosity trending parallel to the long axis of the Gold-field, which suggests that they were emplaced during the folding. Faults in the granite, formed either after or during the last stages of the folding, have been filled by large quartz veins. There are two sets of veins, one of which strikes in a general easterly direction and the other in a general northerly direction; the latter are confined entirely within the limits of the granite.

The long axis of the granite has an arcuate shape, which may reflect the original shape of the geosyncline: it was suggested in the discussion on the Warramunga Group that the shale, which the granite intrudes, marks the deeper parts or main basin of the geosyncline.

Contact metamorphism by the granite is generally slight, and is confined to silicification which may extend up to 50 feet from the contact. The main area of silicification is found in highly cleaved slates and shales, 4½ miles west-south-west of the Old Telegraph Station. Near the Old Telegraph Station and in other places, quartz veins 3 to 5 feet wide occur on the contact of the granite with the Warramunga sediments.

The granites do not intrude the Ashburton Group or the Cambrian volcanics and sediments; but the Ashburton Group is intruded by porphyry genetically related to the granite. Thus the granite is older than the Cambrian and younger than the upper Lower Proterozoic. Folding of the Warramunga Group possibly began at the beginning of the Upper Proterozoic, and igneous intrusion may also have begun about that time.

Porphyry.

In the Tennant Creek Gold-field several dykes, pipes, lenses, and tongues of porphyry have been mapped; particular attention has been paid to its distribution because it is probably genetically related to the gold. Plate 2 shows the distribution of the porphyry, which tends to ring the main western outcrops of soda-granite.

Owen (1940) has discussed the porphyry in a general way, has drawn attention to some of the main outcrop areas, and has described their petrology. His "rhyolite" has been here included with the porphyry, because regional mapping has shown that the rhyolite has mineralogical affinities with the porphyry, and occupies a narrow band round one inclusion. Owen's "older porphyries" represent Warramunga Group sediments to which quartz or felspar or both have been added by the intrusive, and may be included with the porphyries.

The porphyry dykes range in width from one-quarter to three-quarters of a mile; the length is generally indeterminate as these rocks are largely covered by sand and alluvium along the strike.

In the field, porphyry is readily recognized by its brilliant reddish-orange to brown colour when weathered. Unaltered specimens are grey-green holocrystalline rocks with phenocrysts of quartz, microcline, and plagioclase. It has contaminated the intruded Warramunga sediments by the addition of quartz, felspar, or both: a gradual change in the sediment from the unaltered state to the completely replaced state—porphyry—can be noticed in the field in some places, whereas in others the porphyry has caused a minor amount of contact metamorphism. Three miles east of the Peko mine are roof pendants of Warramunga Group sediments, in places contaminated, with preserved bedding parallel to the regional structure.

The time-relationship of porphyry with other rock units can be clearly seen. Tongues invade the Rising Sun Conglomerate south of the Red Terror mine, and metamorphic effects are limited to a narrow zone of quartz and hematite stringers in the basal conglomerates. Traves (personal communication) has noted that porphyry intrudes Ashburton Sandstone 27 miles north of Tennant Creek. The Helen Springs Volcanics, Gum Ridge Formation, and Owen Hill Beds were not found to be intruded by the porphyry.

The relationship of the porphyry with the quartz-hematite lodes is well shown half a mile west of Tennant Creek township, where an apophysis from a wide dyke of porphyry terminates a few hundred yards west of the Wheal Doria mine, and is surrounded by lodes which range from massive quartz-hematite with gold to quartz-jasper lenses with beds of hematite. This is shown in Fig. 3, where the jasper lenses are contact bodies, and quartz-hematite fills *en échelon* shears near the end of the porphyry. Further evidence of the relationship between porphyry and lode is shown by the gradation of porphyrytized sandstone into porphyry with massive quartz-hematite veins, in the contact aureole of the porphyry in the Rising Sun Conglomerate, and by the association of felspar and hematite in a crush zone near Quartz Hill.

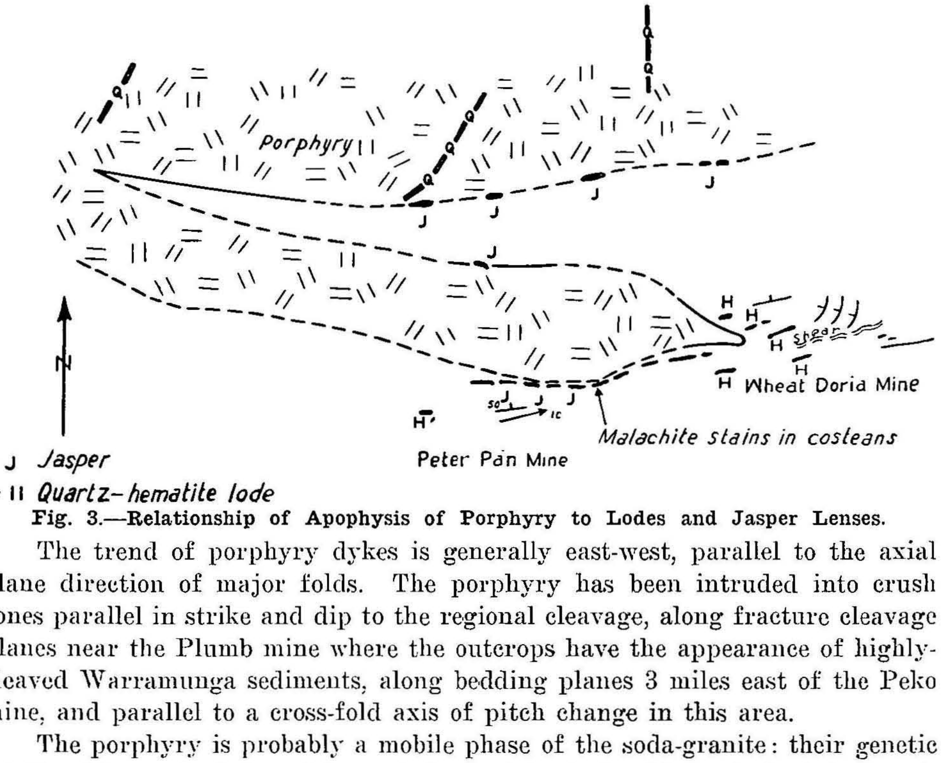


Fig. 3.—Relationship of Apophysis of Porphyry to Lodes and Jasper Lenses.

The trend of porphyry dykes is generally east-west, parallel to the axial plane direction of major folds. The porphyry has been intruded into crush zones parallel in strike and dip to the regional cleavage, along fracture cleavage planes near the Plumb mine where the outcrops have the appearance of highly-cleaved Warramunga sediments, along bedding planes 3 miles east of the Peko mine, and parallel to a cross-fold axis of pitch change in this area.

The porphyry is probably a mobile phase of the soda-granite: their genetic relationship can be inferred from their spacial relationship, and the inference is strengthened by the similarity in mineral composition, particularly the phenocrysts of microcline and soda-felspar. It was intruded late in the folding of the Warramunga Group, because it occupies areas of pitch change, and has been sheared and faulted in places. The movements were apparently waning, because the central areas of large dykes do not have a strongly impressed "cleavage" or gneissosity. The approximate age of intrusion is Upper Proterozoic, and earlier than the extrusion of the Helen Springs Volcanics.

Basic Dykes.

Small dykes of basic rocks occur in a few places in the Gold-field. Owen (1940) has reported on hornblende-serpentine schists containing magnetite, from the Pinnacle and Mary Jane leases. He reports that at the Pinnacles gold has been won from the magnetite-bearing "greenstone" schists, and that a body of rock composed of minute octahedra of magnetite and possibly hornblende has been exposed west of the open cut. This body—4 feet wide— was examined by the present investigators, and was shown to be a small dyke consisting of magnetite, biotite, and chlorite (possibly pseudomorphous after hornblende). The biotite is a green-brown variety and is partly replaced along cleavages by magnetite. The dyke was emplaced before mineralization. It intrudes sediments of the Warramunga Group parallel to the east-striking crush-zone; to some extent it separates the gold-bearing lode from the copper-bearing lode. The relationship between the porphyry and the basic dyke could not be established.

The age of the dyke is probably that of the first introduction of magnetite into the Warramunga Group, that is, Upper Proterozoic.

POST-MINERAL ROCKS.

Helen Springs Volcanics.

Volcanic rocks crop out in the vicinity of the Blue Moon gold mine, 18 miles east-north-east of Tennant Creek township. These rocks have not been recorded previously, and consist of basalts, tuffs, and agglomerates; they represent the southern continuation of the Helen Springs Volcanics (Noakes and Traves, 1949).

The volcanics are exposed 1 mile east of the Blue Moon gold mine as low rounded and pinnacled hills or as irregular layers on the western edge of a scarp formed by Cambrian rocks in this area. They extend as a narrow band from this locality to three-quarters of a mile south of Pigeon's Waterhole, and some isolated outcrops have been mapped five miles north-west of this locality. Another outcrop of volcanics was found 11 miles north-east of the Whippet gold mine.

The volcanic rocks unconformably overlie sediments of the Warramunga Group (Fig. 4). In the Blue Moon area they are unconformably overlain by the Gum Ridge Formation.

The Helen Springs Volcanics consist of fine-grained to coarse-gained vesicular basalts with lenses of tuff and agglomerate in the upper part of the section. The rocks are strongly weathered and range in colour from reddish-brown to grey and white. The basalts have an intergranular texture interrupted by almostly completely altered plagioclase crystals, zeolite-filed vugs, and kaolin-filled vesicles. The plagioclase phenocrysts are zoned but are too weathered to be identified. Magnetite in the groundmass has been altered to hematite by weathering. Tuffaceous beds in the basalt range from six inches to one foot in width; agglomerate and breccia occur as lenticular layers and bands. Flow layers in the basalt are common and range in dip from horizontal to 10°.

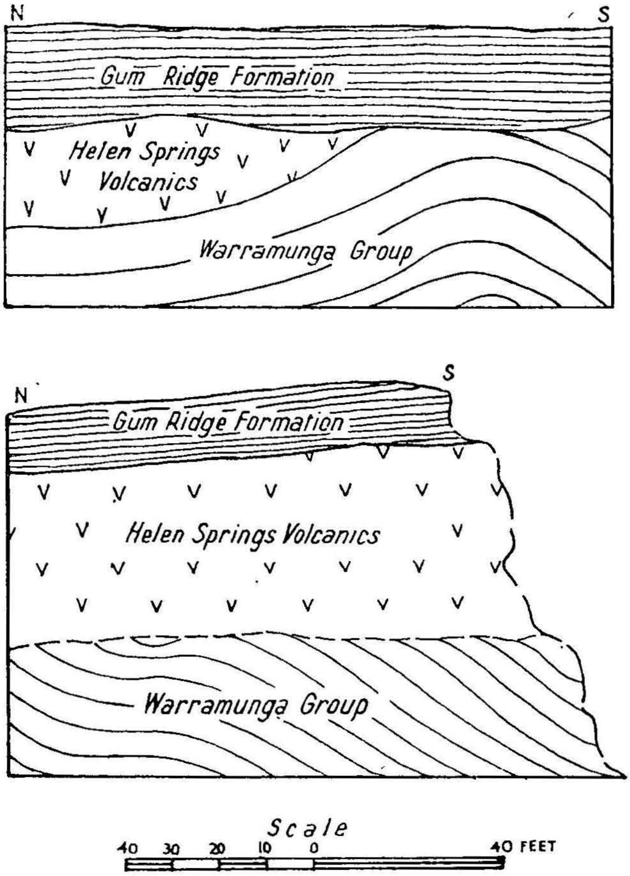


Fig. 4.—Relationship of Helen Springs Volcanics to Warramunga Group and Gum Ridge Formation.

The age of the Helen Springs Volcanics is suggested as Lower Cambrian (Noakes and Traves, 1949). Evidence accumulated in the Tennant Creek Gold-field supports this contention. The volcanics are overlain by the Middle Cambrian Gum Ridge Formation, and, north-west of Gum Ridge, overlie a contact-metamorphic zone between Warramunga sediments and granite: they are therefore younger than the Upper Proterozoic granite and older than the Middle Cambrian sediments.

The exposed basalts in the area show evidence of explosive volcanic activity by the inclusion of tuffs and agglomerates; and the presence of volcanic bombs in the Blue Moon area indicates that the vents were located close at hand.

Gum Ridge Formation.

The name Gum Ridge Formation has been proposed by Öpik (1950) for fossiliferous impure sandy limestones, cherts, siliceous shales, and sandstones, of lower Middle Cambrian age, which crop out three-quarters of a mile east of the Blue Moon gold mine. The Formation includes isolated outcrops which have been traced to 11 miles north of the Whippet mine. Gum Ridge is the name of a trigonometrical station on an outcrop of these rocks.

In 1948, Traves visited the area and collected trilobites, brachiopods and other fossils. In 1949, Dr. Öpik, assisted by the Tennant Creek party, collected a large number of fossils from the Blue Moon locality and the Owen Hills

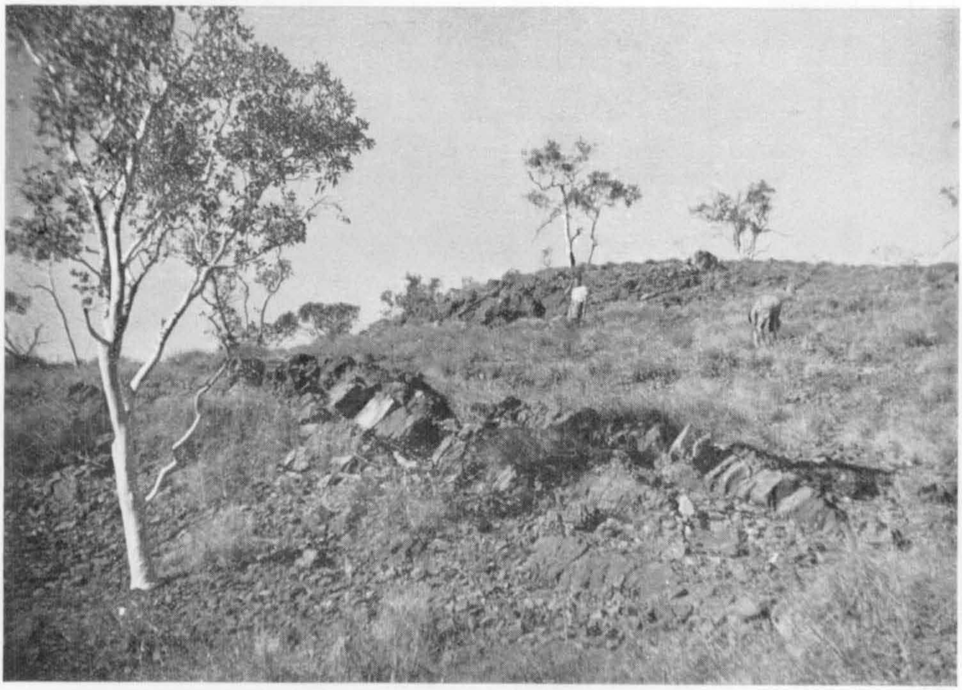


Fig. 5.—Unconformity between Warramunga Group and Gum Ridge Formation.

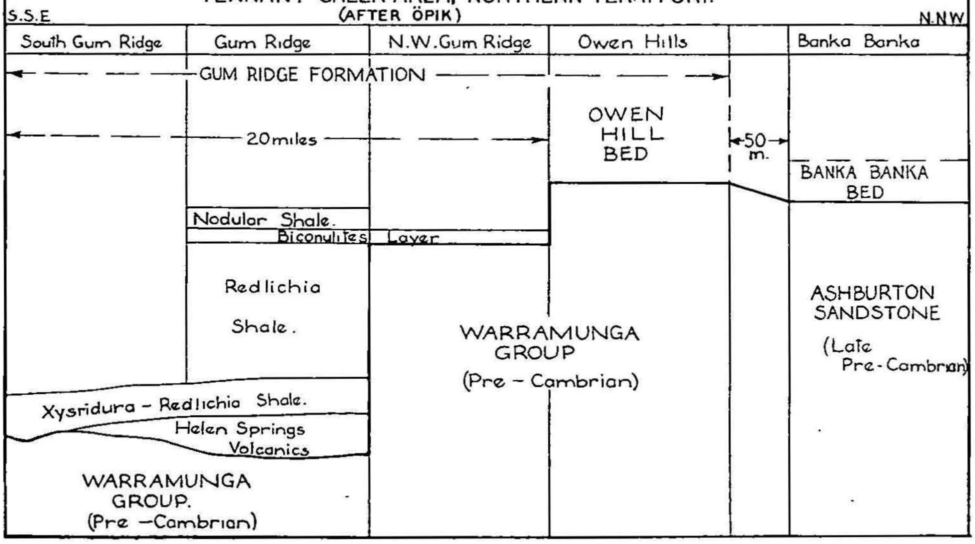
locality (30 miles north-east of Tennant Creek and along the Barkly Highway). Dr. Öpik is preparing a comprehensive report on the fossils and has correlated different horizons in the Formation.

The Gum Ridge Formation crops out between the Blue Moon locality and Pigeon Holes Waterhole as a long ridge with an abrupt scarp to the west. Outliers are found a few miles north and south-east of this locality as residual cappings on an old land surface of Warramunga sediments and on Helen Springs Volcanics (Fig. 4). A tongue of these sediments covers some of the eastern granite outcrops. Other outcrops have been found at Owen Hill and 11 miles north-east of the Whippet gold mine (Plate 1).

The Gum Ridge Formation and associated sediments unconformably overlie both the Helen Springs Volcanics and the Warramunga Group (Fig. 4) with an angular unconformity ranging from 5–40°. The sediments were laid down after the folding of the Warramunga Group, Ashburton Sandstone, and Rising Sun Conglomerates and their intrusion by granites.

The Formation consists of fossiliferous sandy limestone and chert, siliceous shale, and thinly bedded fine sandstone, which have been very highly weathered. A thickness of 45 feet was measured below Gum Ridge Trigonometrical Station. The rocks have formed part of a stable land surface which has existed on the edge of the stable Pre-Cambrian Shield, probably since Middle Cambrian time. Fossil evidence has enabled Öpik to divide the Formation into beds which are named after a typical fossil genus present (*see* Table 4). This table shows the distribution and character of beds of the Gum Ridge Formation. The transgressive nature of the deposits is evident.

TABLE 4.
CORRELATION CHART OF REDLICHIA (NEGNAV) TIME
TENNANT CREEK AREA, NORTHERN TERRITORY.
(AFTER ÖPIK)



Dr. Öpik (1950, report in preparation) has correlated this Formation with the lowest unit of the Barkly Group (Noakes and Traves, 1949). He has supplied the following list of fossils (collected in Blue Moon and Owen Hills locality) :—

Brachiopoda—
- *Wimanella* sp.
- *Billingsella* cf. *humboldti* Walcott.
- *Lingulella* sp.
- *Obolus*.

Trilobites—
- *Redlichia*, 2 sp.

Xystridura warramunga n.sp. (M.S. Öpik).
"Ptychoparia" sp. (sensulatissimo).
Pagetia cf. *significans* (Etheridge).
Peronopsis cf. *elkedrensis* (Etheridge).

Hyolithidae—
Hyolithes, 2 sp.
Biconulites hardmani (Foord).

Spongia—
Chancelloria delzur n.sp. (M.S. Öpik).
Eiffelia (?) sp.

The sediments of Gum Ridge Formation were deposited during an epicontinental marine transgression in Middle Cambrian time.

Recent Deposits.

Recemented and unconsolidated talus and alluvium covers approximately 80 per cent. of the Tennant Creek Gold-field (Plate 1).

Near the Black Angel mine, a narrow creek has cut through a 5-ft. thickness of consolidated talus and alluvium. The cementing material is a limonitic clay which binds fragments of quartz-hematite and Waramunga group sediments. These deposits are widely distributed in the valleys between mesa-like groups of hills, and may represent a period of still-stand during the uplift of the Tennant Creek area.

Unconsolidated talus and red soil form extensive deposits of shallow depth on the sides and tops of hills.

A large portion of the flat plain area of the Tennant Creek Gold-field is covered by white and grey powdery and incoherent alluvium. The thickness of the alluvium is unknown, but in the Pigeon Holes area it is greater than 10 feet. Creeks which enter the alluviated areas have braided channels with meanders. The alluvium may represent the sites of old lakes subsquently filled by sediment brought in by the creeks. The fine nature of the alluvium may possibly be the result of chemical weathering of the sedimentary rocks in the area: in some places, e.g., near No. 3 Government Battery, chemical weathering of shales has produced a grey powdery soil similar to the alluvium.

Structure.

Detailed structural investigation of the rocks of the Tennant Creek Gold-field show that there is little possibility of correlating the numerous minor structural features mapped, except in a broad and general sense. The sediments are markedly lenticular in character and discontinuous in outcrop, and no suitable marker horizon could be found.

Previous investigations have been confined to individual mines or small areas and no discussion of the regional structure of the Warramunga group has been offered.

FOLDING.

Bedding planes are generally very well defined both on the surface and underground and range in dip from 30° to 80°. The regional bedding strike is westerly in the southern portion of the Gold-fields and west-north-west to north-west in the northern portion. This structure is reflected in the topography by parallel ridges which trend in a general westerly direction. A

Fig. 6.—Symmetrical Anticlinal Fold in Ripple-marked Warramunga Sandstone.

west-striking regional fracture cleavage and strongly developed drag-folding have affected bedding over the whole area. However, from correlation of the measured directions of drag-fold plunges coupled with pitch of bedding on cleavage, the nature and geographical positions of some of the limbs of major folds have been established.

In the area around Peko, Golden Forty and Mount Rugged the main structure was found to be the north limb of a 20° to 30° west-plunging anticline. Three miles south of this area along the group of hills between Noble's Nob and Rising Sun, the structure was found to be the south limb of a west-plunging anticline. Between these two areas the structure of isolated outcrops indicated the crestal region of a west-plunging anticline. The axis of this feature strikes approximately east.

West of this structure in the vicinity of the Eldorado mine the pitch of bedding on cleavage and pitch of drag folds is east. On the Skipper Extended—Westward Ho group the pitch is west. Such reversals of pitch are common over the whole Gold-field. The strike of axes of pitch-change is suggested as north-east, parallel to minor folds which trend in this direction.

In the Black Angel area the plunge is to the west at approximately 30° and from the nature of bedding-cleavage relationships it is suggested that this area represents the crestal region of an anticlinal fold.

South of the western extension of the adamellite the attitude of the beds and of drag-folds indicates the south limb of an anticlinal fold. East of the north-eastern adamellite outcrops drag-folds pitch constantly east. North of the adamellite the attitude of the beds is obscured by faulting and porphyry intrusions, or by lack of outcrop. However, collectively the data obtained points to the possibility that the main structure might well be a boomerang-shaped dome with an east-west axis from the Old Telegraph Station to the Black Angel area, and a north-east axis from the Old Telegraph Station to the Owen Hills area.

The east-west direction is probably the main direction of structural weakness, as an overall gneissosity trends in this direction in all adamellites in the area. The trend of the axis of the north-east outcrops is parallel to the north-easterly trending axis of pitch-change.

In the eastern portion of the Ashburton Sandstone outcrop area in the region, the trend changes from east-west to north-south. This change in structural trend is reflected in the change in strike of the main axis of the adamellite intrusion.

FAULTING.

Faulting has taken place simultaneously with and later than the folding, and consequently two distinct fault groups can be recognized—

- (*a*) east-west trending shears complicated by bedding-plane slips and low-angle thrusts;
- (*b*) quartz-filled faults.

The shears trending east-west are a sequence of disconnected crush zones in which quartz-hematite mineralization has taken place. Individual shears are arranged *en echelon* as discontinuous breaks, which for convenience can be included in general zones. Individual shears are parallel to the axial plane of cleavage and dip very steeply, 70°–85° either north or south. Such zones are generally of short extent and have a maximum length of 5 miles, on the Eldorado to Mount Samuel line. A discussion of the more important crush zones is contained in the section on gold mines.

Three systems of quartz-filled faults, striking north, north-west, and north-east, can be recognized. A major north-west break extends as a disconnected line of quartz-reefs for 46 miles from a granite outcrop in the south-east corner of the Gold-field to 10 miles north-west of the Old Telegraph Station. The width of the quartz vein ranges from 1 to 25 feet. Some displacement has taken place along this line, particularly near the Mammoth Mine, where the fault zone is characterized by three independent parallel breaks situated approximately a mile apart. The southernmost break continues to the west as the main fault. The strike direction of these faults is parallel to the trend of the axis of the western adamellite stock. The extent of the displacement along the faults is not known.

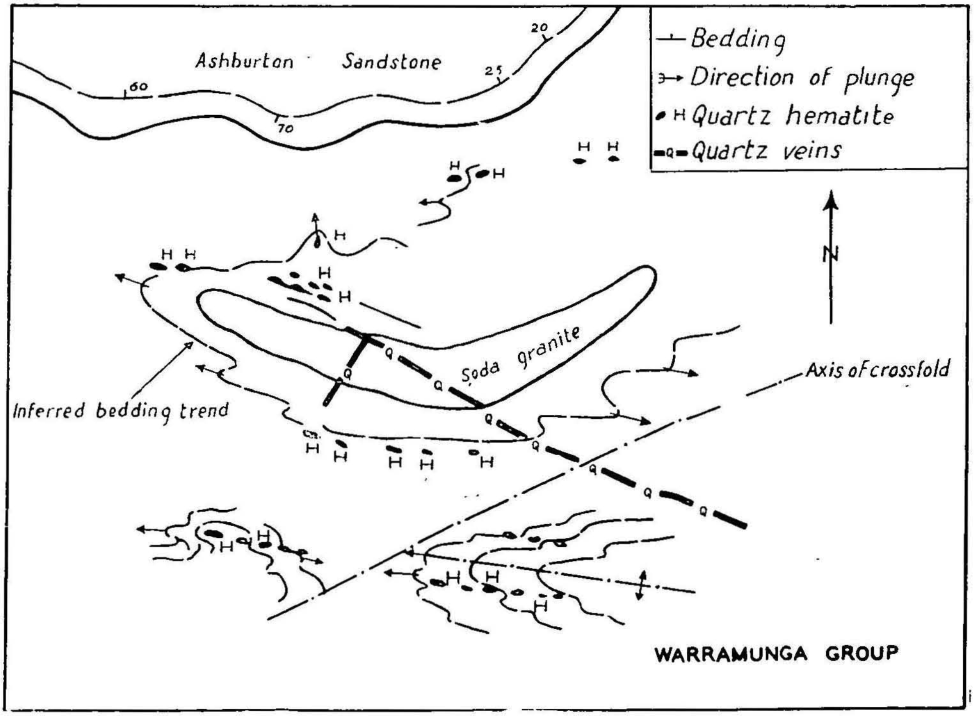


Fig. 7.—Dominant Structural Features of the Gold-field.

Other quartz-filled faults, of less importance, are the north-east breaks and north-south breaks, which are situated very close to and within the adamellite stocks. Where these faults cut through the Warramunga Group the sediments have been displaced but the amount of displacement is not known.

The discontinuous nature of these fault zones indicates that they are short sharp breaks which probably took place toward the end of adamellite and porphyry intrusions, and could possibly be the result of stretching of the overlying sediments by the intrusive adamellite.

The Ashburton Sandstone has been faulted by a number of north-south faults, which are mainly master joints along which some movement has taken place. In some places these faults are quartz-filled, but generally they are tight unfilled fractures. This faulting has not materially affected the generally east-west trend of the Ashburton Sandstone except locally.

CONCLUSION.

Fig. 7 shows diagrammatically the close structural affinities between trends of major fold and pitch change axes, the axes of the west and north-east granites, the major quartz-filled fault systems, and the strike of the contact of the Ashburton Sandstone and the Warramunga Group.

The major controlling feature was probably the shape of the deepest part of the original geosyncline, which may now be indicated by the shape of the area of adamellite outcrop.

GEOMORPHOGENY.

The uniformly flat crests of sub-parallel hills and ridges in the Tennant Creek region represent the surface of an old peneplain which was formed in a period of continuous erosion, and was followed by uplift in Miocene or later times. This peneplain cuts across all rock units and igneous intrusions and is 150 to 200 feet above the general level of the plain. The present land surface consequently results from elevation and erosion of the old peneplain.

The streams which caused the erosion to present base level, and which eroded valleys in the peneplain, may be the result of rejuvenation by uplift. Different terrace levels and eroded consolidated scree and talus at heights ranging from 10–50 feet above the present plain level indicate that rejuvenation was by uplift, probably in several stages.

The age of formation of the peneplain is unknown, but erosion of the rock units began in the Middle Cambrian, when the Tennant Creek region became a stable land-surface.

Weathering of the present surface extends down to the 300-ft. level and could be partly caused by alteration before and during the lateritization which has affected the rock units. This alteration may be confined to the Miocene, but it is also possible that the weathering of the peneplained surface has been continuous since Cambrian time. The laterite profile could thus have been superimposed on an already deep zone of weathering.

The time of lateritization therefore dates the time of uplift, which rejuvenated streams that subsequently exposed the laterite profile.

Further evidence for uplift is suggested by the perched zone of weathering above the present water-table level. The base of this zone is approximately 100 feet above the present water-table; and in the perched zone pallid and mottled zones of lateritization are in evidence.

Post-Miocene drainage of the region is along older east-trending valleys. The present ridges are relict ridges which in general contain massive quartz-hematite and jasper lodes that are very resistant to erosion. Rivers emptied into lakes in the same manner in which present-day streams lose their identity in broad alluvial fans. These lakes may have existed before Miocene time and were silted up when uplifts rejuvenated the streams in the region with a consequent increase in the amount of material transported.

An old divide, where streams drain east on the eastern side, extends from Tennant Creek township in a north-westerly direction to the Ashburton Sandstone.

Wind erosion, resulting chiefly from the strong south-easterly prevailing winds of the area, has laid bare the sides of mesas in the area and is considered to be of greater importance than stream erosion under present conditions.

There is no evidence of any major epeirogenic movement having affected the area since Miocene (?) time.

Geological History.

The geological history of the Tennant Creek area may be considered as the history of a distinct unit, although closely connected with widespread sedimentation and tectonic movements, and as such may provide a key to a more thorough understanding of history in other regions. The Tennant Creek geosyncline is "boomerang-shaped" and lies in the central-northern section of the Warramunga geosyncline (Noakes, 1953).

Sedimentation in the Tennant Creek geosyncline commenced in Pre-Cambrian times, when shales and fine sandstones were deposited in the deeper parts of the basin, and shallow-water sediments, chiefly medium-grained and coarse-grained ripple-marked sandstone, intraformational breccia, grit, mudstone, and shale, on the shallow flanks. Towards the end of the Lower Proterozoic some uplift and tectonic movement with incipient folding of the sedimentary pile probably took place. Continuous deposition in shallow epicontinental seas along the borderland resulted in a sedimentary gradation from Warramunga Group to Ashburton Sandstone rocks. Folding movements continued with compaction of the sediments. On the south-eastern flank of the Gold-field the Rising Sun Conglomerates, which were probably derived from the Davenport Range quartzites, were deposited. Some adamellite may have been intruded in the central part of the basin during this period.

With the deposition of the Rising Sun Conglomerates the folding movements reached a maximum intensity; the development of crossfolds, fracture cleavage and faults was closely followed by igneous intrusions and mineralization. The period of folding and intrusion ended in Upper Proterozoic time and the area became part of a relatively stable landsurface.

In the Lower Cambrian, volcanic activity gave rise to basalt flows on the eastern flank of the region. These flows filled old valleys in the eroded surface of the Warramunga Group and Ashburton Sandstone. Some erosion of the basalts took place before the influx of a transgressive lower Middle Cambrian sea, in which were deposited the fossiliferous Gum Ridge Formation and Owen Hill beds. The deposition of these sediments was followed by a general uplift and subsequent erosion. Other uplifts between this time and the (?) Miocene uplift may have taken place, but no definite record of any such epeirogenic movement has been preserved.

ECONOMIC GEOLOGY.

ORE DEPOSITS.

CLASSIFICATION AND DISTRIBUTION.

Lodes on the Tennant Creek Gold-field may be classified as follows:—

Quartz-hematite lodes;
Auriferous quartz veins;
Barren lodes (quartz reefs and jasper lenses).

This classification separates auriferous lodes from barren lodes. It is generally believed that all the quartz-hematite lodes contain some gold, whether in economically minable quantity or not.

The distribution of quartz-hematite lodes is shown on Plate 1. This plate indicates that most of the mineral shears are found in the area south of the adamellite stocks. The most productive mines are located in the perimeter of the field: in the northern area Whippet and Northern Star, in the southern area Noble's Nob, Eldorado, Peko, and Rising Sun. There is a general decrease in productivity from the perimeter to the centre of the Gold-field.

In general, the quartz-hematite lodes outcrop as east-trending groups of isolated bodies, locally known as "lines", but many isolated bodies are situated some distance from a "line". Within an individual lease repetition of shoots may occur down-dip and down-pitch from the outcropping quartz-hematite lens.

Auriferous quartz veins have been mined 1 mile south of Pinnacles mine and at the Last Hope gold mine, but not at any other place on the Gold-field.

Barren quartz veins are confined almost entirely to the centre of the field. Jasper lenses are widely distributed—mostly at the contact of porphyry and Warramunga Group sediments.

QUARTZ-HEMATITE LODES.

Almost all the gold won from the Tennant Creek Gold-field has been mined from outcropping quartz-hematite replacement bodies. The hematite is mostly derived from oxidation of primary magnetite. This association of gold and magnetite, with the former in economic quantities, is most unusual. No non-outcropping lodes have been worked. Surface examination of some lodes would suggest that they are completely massive quartz-hematite, but underground inspection shows that the lode consists of quartz-hematite lenses, pipes, and stringers, in brecciated sediments.

Two types of lode have been recognized, gold and gold-copper lodes. It is possible that gold-bearing lodes become gold-copper lodes below the water-table level, as in the Peko Mine. In the Eldorado Mine, for example, although no copper minerals can be seen in and below water-table level on the 400-ft. sub-level, deep-drilling of non-outcropping lodes has disclosed the presence of a little chalcopyrite-pyrite mineralization.

Ore-sheets may be regarded as enriched sections of the lodes and have no distinctive mineralogical features. Generally, the presence of ore is determined by continuous pan assaying.

The ore is free-milling and the gold is amalgamated with mercury on copper plates. Using this method the Eldorado mine averages a 71 per cent. recovery. Cyanidation plants are being completed at the larger mines to treat the tailings.

Size and Shape.

The Tennant Creek lodes are typically small and range in width from one foot on the Great Eastern mine to 210 feet on the Eldorado mine. On Noble's Nob mine the lode has a maximum width of 95 feet at the surface and is 120

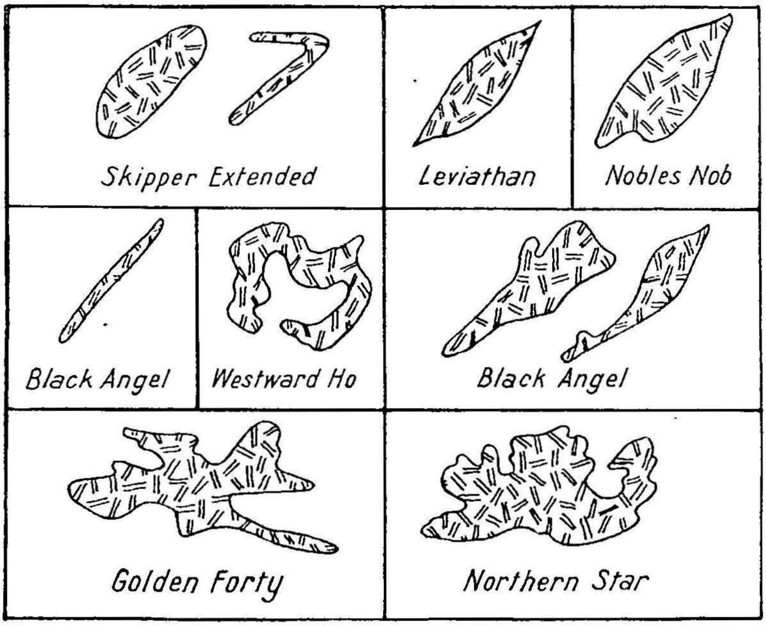


Fig. 8.—Diagrammatic Outlines of Quartz-hematite Lodes.

feet wide at the 183-ft. level. The Eldorado lode is the largest on the Gold-field and has a maximum width of 210 feet at the 200-ft. level. The length of individual lodes ranges from a few feet up to 400 feet.

In shape the lodes may be lenticular bodies or pipes, or may occur as irregular replacements. Lenticular bodies are the most common—examples are the Noble's Nob, Eldorado, Skipper Extended, and Blue Moon lodes. The Northern Star and Golden Forty lodes have very irregular outlines (Fig. 8).

In vertical section the lodes are invariably lens-like, with a steep to vertical dip which may change at depth to a flatter dip, as does the Peko Lode. Underground the overall lens-like shape is extremely irregular and is controlled chiefly by pre-existing structures.

Mineralogy.

The mineralogical composition of the lodes, though unusual, is relatively simple and, with two exceptions, remarkably uniform in type. The ore mineral is gold, which is associated with quartz, hematite, and magnetite gangue and minor amounts of bismuth carbonate. In two lodes copper minerals, in the form of malachite, cuprite and native copper in the oxidized zone, and chalcopyrite in the unoxidized zone, are known to be present.

Gold.

Gold is, at present, the only valuable constituent of the lodes and is generally bright yellow in colour. An exception is the reddish-coloured gold won from the Kiora mine. The gold fineness is as high as 987 (Whippet mine), but an average figure could not be arrived at because of the incompleteness of assay records. In the oxidized zone gold occurs as small nuggets, grains, flakes, scales, and specks, or it may be so finely divided that it is invisible to the naked eye. Nuggets are extremely rare but have been found up to 7 ounces in weight in the Red Terror workings, as "shot" gold and "slugs" on the Edna Beryl, and as ½-oz. pellets on the East Hope mines.

The most common ore-types found on the Gold-field are—

(i) gold associated with quartz-hematite lodes (Fig. 9);

(ii) gold disseminated in kaolinised and brecciated hematite-rich mudstone;

(iii) gold as flat grains on cleavage and bedding planes (Fig. 10);

(iv) gold as pellets in limonite-rich shears or intimately intergrown with bismuth carbonate.

In the Little Wonder mine, gold occurs as large irregular particles in racks in quartz stringers with micaceous hematite on the edges of the stringers. Gold with a finely granular surface occurs as scales and pods in a soft kaolin-filled vug in the Nobles Nob mine.

In ore examined by Stillwell (1950) from the primary zone of the Peko gold mine, gold was generally observed as particles included in chalcopyrite, although some was found attached to the outside of minute inclusions of gangue in the chalcopyrite. Two gold particles, 0.010 and 0.005 mm. in diameter, were observed in magnetite, the gold being in contact with gangue on one surface.

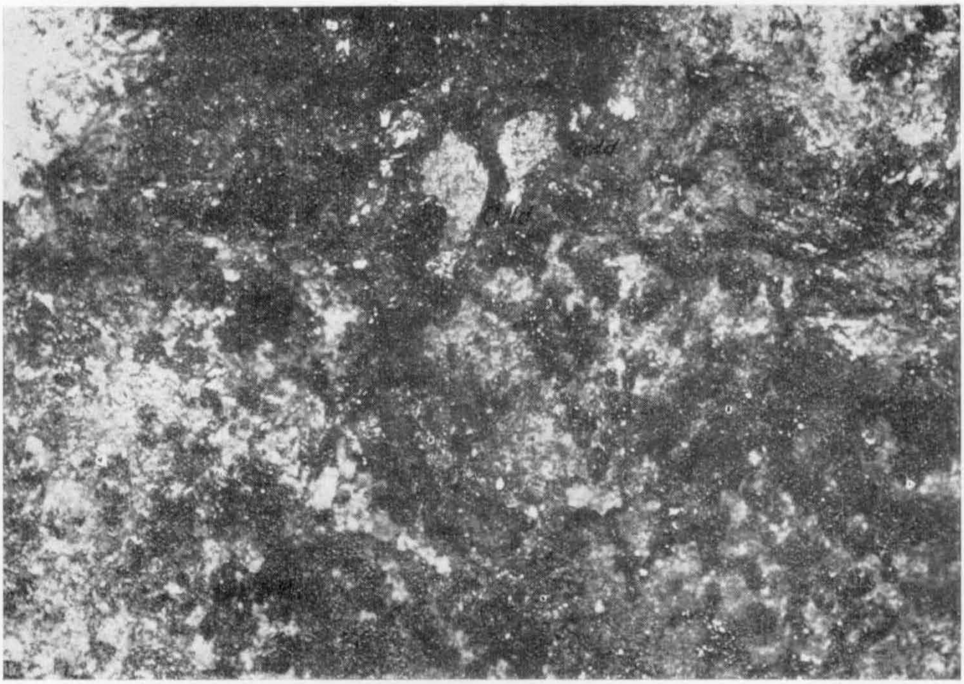


Fig. 9.—Gold Ore from the Enterprise Mine.

Fig. 10.—Gold Ore from the Eldorado Mine.

Iron Ore Minerals.

The presence of magnetite in the lodes was first realized when erroneous compass readings were obtained in the vicinity of the lodes. A magnetometer survey of the field conducted by the Aerial, Geological and Geophysical Survey of Northern Australia in 1935, 1936, and 1937 suggested that the many magnetic anomalies discovered were obtained from subsurface magnetite bodies. Stillwell and Edwards (1942) after examination of several specimens of lode from Tennant Creek mines suggested that magnetite may have been the original iron-ore constituent of the lodes. They also demonstrated that in the Eldorado gold mine diamond-drill hole No. 2 there was increase in a magnetite content with depth. The results of drilling of the Peko lode below water-table level show that whereas hematite (martite) is the predominant iron mineral above water-table level, magnetite predominates below.

Magnetite predominates in the tough siliceous lodes, but not in the softer, more vuggy types of lodes. The iron ore mineral is black and lustrous, or may be closely intergrown with quartz to give a dull, structureless rock. It occurs as veins, stringers, and segregations, and as cores surrounded by its alteration product, martite. Octagonal crystals of magnetite were found in a talc-carbonate rock and as subhedral crystals intergrown with chlorite in a basic dyke on the Pinnacles mine. Lodes which are very siliceous and even-grained tend to be highly magnetic. The vuggy pitted type of lode is generally non-magnetic at the surface.

Hematite is the most abundant constituent of the lodes and is associated with all the orebodies on the Tennant Creek Gold-field. It occurs as martite (Stillwell and Edwards, 1942) and as several other varieties of hematite. Martite is probably the result of alteration of magnetite and generally surrounds a residual core of magnetite. Consequently its distribution and nature of occurrence are very similar to those of magnetite, except that it is not found below water-table level.

Micaceous hematite has been observed in the form of post-magnetite veins, ranging in width from one-sixteenth of an inch to 2 feet, which have been found on the northern margin of the Northern Star lode and the southern edge of the Whippet lode. Such veins are soft and friable, and consist of closely intergrown sheaves of lustrous hematite plates. It is possible that they were introduced during faulting of the lodes.

Specular hematite has been observed in many places as intergrown tabular crystals or, as on the Red Ned mine, as narrow veins intersecting massive quartz-hematite-magnetite lodes.

A specimen of hematite from near the Euro mine shows polysynthetic twin lamellae which have given rise to pseudo-cleavage.*

Stillwell and Edwards (1942) have distinguished a "bladed hematite", which is free from residual crystals of magnetite. Such hematite may be found at the contact of quartz and martite.

* This mineral was not seen *in situ*.

Isolated occurrences of reniform masses of hematite were observed on the 85-ft. level, Noble's Nob mine.

The information available on the iron-ore minerals present in the Tennant Creek lodes shows that there are five varieties of hematite, two of which, specular hematite and micaceous hematite, are of primary or magmatic origin. Martite is derived from weathering of the magnetite by supergene agencies, as may be inferred from the increase in the proportion of magnetite with depth. Stillwell and Edwards (1942) first suggested that supergene agencies carried out the alteration and the present investigation tends to support this assumption. Stillwell and Edwards (1942) have also suggested that the bladed hematite was formed by re-solution of martite and magnetite by quartz-vein intrusions. There is some evidence, however, to suggest that in some cases primary hematite has crystallized simultaneously with this quartz injection.

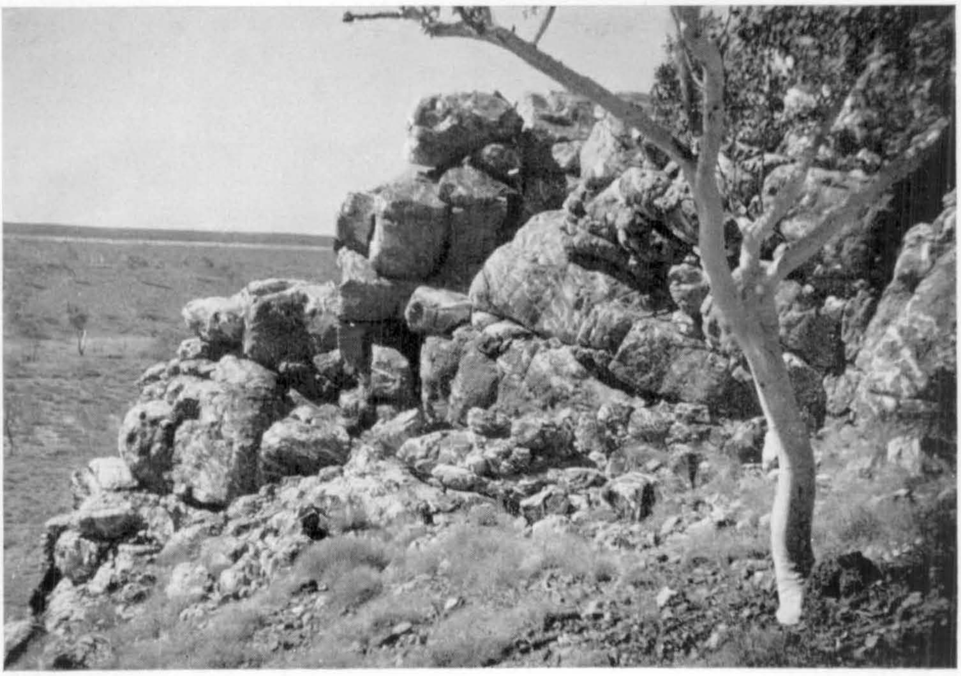


Fig. 11.—Ramifying Quartz Veins in Lode, Queen of Sheba Mine.

Quartz.

Apart from magnetite and its alteration product martite, quartz is the most abundant constituent of the lodes. In the Mount Samuel lode, quartz is grey and dull white in colour, finely crystalline, and closely intergrown with magnetite to give a tough massive lode. More widely distributed is the milky white variety, which may constitute up to 50 per cent. of the lode material. This type of quartz is also closely intergrown with the iron-ore minerals and may contain vugs, which suggests a low temperature of crystallization.

Narrow quartz veins and stringers with micaceous hematite along partings in the veins cut the quartz-hematite lodes in many places, and are more noticeable in the outcropping sections of the lode (Fig. 11).

Barren quartz veins comparatively free of hematite cut the lodes in many places, as, for example, on the 300-ft. level, Eldorado mine. The veins, in some places, are vuggy and have well-formed crystals projecting into the cavities.

The information suggests that there have been at least three generations of quartz, the last of which is a barren type of quartz veining which is later in age than the formation of the lodes.

Muscovite.

A muscovite-quartz vein, 1 inch in width, was found cutting the quartz-hematite lode on the 300-ft. level, Eldorado mine. The muscovite occurs as bunches in the vein.

Sericitization, possibly the result of metasomatic alteration of country by introduced material, is associated with the lodes and the ore in most of the mines on the field. At the 60-ft. level, Black Angel mine, a halo of sericite-rich country rock surrounds the ore. In Noble's Nob No. 5 shaft there is a well-defined sericite-rich zone in the crushed and brecciated rock on the margin of the quartz-hematite lode. Sericitization indicates that the lodes were of hydrothermal origin and its field relationship to the quartz-hematite suggests that it took place later than the main lode injection. Its relation to the age of gold deposition is unknown.

Chalcopyrite.

There is generally little chalcopyrite in the lodes at Tennant Creek. The most important occurrence is in the Peko gold mine, where a diamond-drill core from below the oxidized zone has shown that chalcopyrite is the host of most of the gold and of the minor minerals.

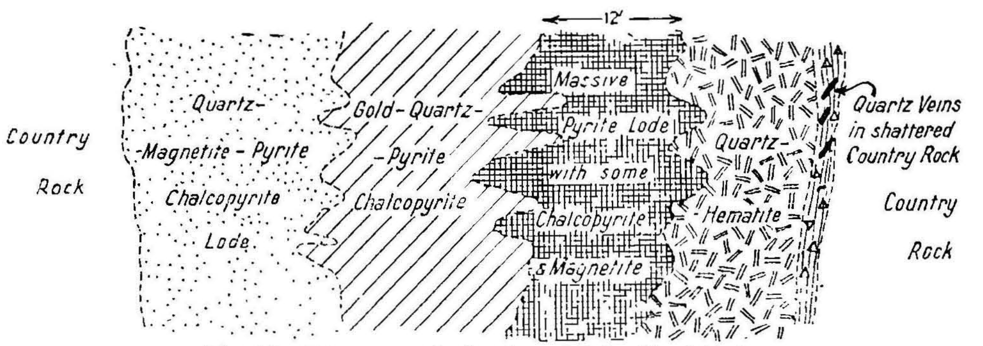


Fig. 12.—Diagrammatic Section of Peko No. 2 Lode.

Chalcopyrite occurs as massive segregations, as stringers, and as intergrowths with magnetite, pyrite, and quartz in the Peko lode (Fig. 12) or as isolated crystals in quartz in the Maple Leaf mine. In the Red Ned mine $\frac{1}{4}$-in. crystals of chalcopyrite occur in the lode.

In the Peko No. 2 lode, intersected by diamond drill, silvery-white pyrite occurs in places in veins and segregations and intimately associated with chalcopyrite. Pyrite with included chalcopyrite occurs in a band 12 feet wide on the southern side of the lodes (Fig. 12).

Bismuth.

Bismuth oxide and bismuth carbonate occur as small isolated grains and large clots and segregations, or are associated with quartz and magnetite in narrow veins. Minor occurrences of metallic bismuth have also been noted. Bismuth minerals are commonly associated with ore and in some mines are used as an indicator of high values.

Stillwell and Edwards (1942) have identified native bismuth in gold-copper ore from the Peko mine, and bismuth and bismutite from other mines. Bismutite is the most common representative of this group and is straw yellow in colour. It is amorphous and clayey-looking, as in Noble's Nob and Susan mines, or lustrous and crystalline as in the Whippet mine. Assays of the Whippet lode for bismuth of samples taken by Sullivan (1942) ranged from 0.29 per cent. to 1.35 per cent. The mineral is widely disseminated through the lode and may occur as large clots, in places up to 4 inches in diameter. These clots always contain a considerable quantity of gold. On the 215-ft. level, Noble's Nob mine, gold and bismuth carbonate veins cut through the lode, and yield high gold assays. High gold values on the Enterprise mine are also associated with comparatively high bismuth content.

Pyrite.

Pyrite has a limited distribution and generally occurs as isolated cubes or pyritohedra. Complete pyrite crystals are rare, but boxworks possibly of pyritic origin were seen in many places.

Massive pyrite has been found in the Peko lode (Fig. 12). A width of approximately 23 feet of pyrite was intersected by diamond drilling.

Copper.

Native copper has been found in the Peko mine in the water-table zone from 212 to 230 feet below the surface. The copper fills cracks and joint planes in a massive siliceous hematite lode.

Covellite.

Deep-blue massive covellite from the Shamrock mine occurs in veins replacing carbonaceous schist. The mineral is intensely veined with malachite and contains inclusions of magnetite. This is the only known occurrence of covellite on the field.

Cuprite.

Bright red cuprite closely associated with native copper is found disseminated through the lode on the 210-ft. level Peko gold mine. This is the only record of this mineral on the Gold-field.

Malachite.

Malachite stains, blebs, and veins have been found in many places and are probably the result of oxidation of chalcopyrite. Malachite is associated with the ore in the water-table zone on the Peko mine and is mined as a copper ore at the Pinnacles mine. It occurs in the hornfelsed zone along the margin of intrusive porphyry near the Wheal Doria mine.

Chrysocolla.

Veins of chrysocolla filling fractures in a malachite lode have been found in the Pinnacles and Ajax mines.

Limonite.

Limonite is found in some mines as a secondary filling in veins, or as concentric patterned fillings in vugs (Hammerjack mine). Limonite stains massive ribwork from the Northern Star mine and has probably been derived from pyrite by weathering.

Other Minerals.

Stillwell and Edwards (1942) have recognized cobaltite, wittichenite ($3Cu_2S\ Bi_2S_3$), sphalerite, pyrrhotite, marcasite, lillianite ($3PbS\ Bi_2S_3$), and galena (Peko mine). These minerals are present only in minute quantities.

Wolfram.

A few grains of wolfram were observed at the Olive Wood and Wedge mines.

ORE-SHOOTS.

Size and Shape.

The Tennant Creek ore-shoots are typically small and only five ore-shoots have averaged greater than 500 tons per vertical foot. Table 2 showing production by individual mines on the Gold-field gives some indication of the range in size and grade of the ore-shoots.

In size ore-shoots range from small pockets to bodies 210 feet in strike length and with a pitch length of 320 feet. Table 5 shows the maximum pitch length, strike length, and breadth of several of the larger ore-shoots on the Gold-field.

TABLE 5.

DIMENSIONS OF ORE-SHOOTS, TENNANT CREEK GOLD-FIELD.

Mine.	Pitch Length.	Strike Length.	Breadth.	Remarks.
	feet.	feet.	feet.	
Eldorado	..	47	40	200-ft. level } East stope
	..	74	21	300-ft. level } East stope
	..	20	20	400-ft. level } East stope
Noble's Nob	325	170	80	135-ft. level
Northern Star	320	210	24	50-ft. level
Blue Moon	65	50	18	60-ft. level
Peko	220	120	20	62-ft. level
Skipper Extended ..	80	40	14	50-ft. level
Rising Sun	130	80	30	Surface
Black Angel	90 (approx.)	65	17	60-ft. level

The horizontal dimensions of ore-shoots are not constant; for instance, on the Eldorado mine the strike length was 74 feet on the 30-ft. level as compared to 47 feet on the 200-ft. level and 20 feet on the 400-ft. level.

No ore-shoots have yet been mined below water-table level, but in one instance diamond drilling has shown that good grade ore exists below this level. The size of this ore-shoot, which is an *en echelon* repetition of No. 1 Peko lode, is unknown, but it has a width of 12 feet where intersected by the diamond drill.

In form the ore-shoots are very similar, and elliptical bodies are the most common. Typical of these are the ore-shoots mined on the Eldorado lease. Tabular ore-shoots have been worked on the Black Cat mine, where favorable sedimentary horizons have been enriched. Narrow lenticular crush zones of irregular outline have been mined on the Great Western and Queen of Sheba mines. On the Archangel and Hammerjack mines, narrow cylindrical pipes were worked; in other places irregularly shaped pockets have yielded small tonnages.

Character of the Ore.

In most cases it is very difficult to distinguish ore in the lode without thorough and continuous sampling. On most of the small mines, the usual procedure is to dolly and pan grab samples from each bucket of dirt. The larger mines, such as Noble's Nob and Eldorado, have assay offices for detailed determinations. However, the only reliable figures for the overall grade are those showing actual mill recovery.

The ore is generally hematite-rich brecciated mudstone, which has been selectively mineralized with gold. Although ore from the field in general is qualitatively similar, ore from specific mines can often be recognized by its appearance in the hand specimen. Ore won from the Patties mine and the central stope of the Eldorado mine is a reddish-brown lightly brecciated mudstone cut by narrow hematite stringers. Bismuth carbonate and sericite (particularly) are abundant. In the east stope, Eldorado mine, the mudstone is more highly brecciated and has been oxidized to a purple and white rock which gradually changes colour with depth to blue-green. This type of ore is common in many of the mines on the field, particularly in mineralized zones on the margins of quartz-hematite lenses.

At Noble's Nob mine the ore ranges in type from a grey granular replacement of mudstone to a massive kaolin-rich hematite. The grey ore was found in a winze on the 135-ft. level and consists of a hydrothermal partial replacement of mudstone by talc and sericite with irregular hematite grains and veins around the margins of the breccia fragments. Minute hematite crystals pepper the altered mudstone, but no gold is visible megascopically, although assays of up to 300 ounces per ton have been recorded. This particular type of ore is very soft and has a low specific gravity compared to the massive hematite replacement ore in other parts of the mine. The massive type of ore contains residual grey patches of mudstone, veins and clots of bismuth carbonate, and some sericite and talc. Gold is visible in some hand specimens.

The ore from the Kiora mine is a brecciated green slate which has been partly replaced in the crushed section by finely divided hematite. Gold is found in minute patches in the hematite portion of the ore. A highly sericitized mudstone on the Red Terror mine contained one or two nuggets of gold. Ore containing masses of bismuth carbonate on the Whippet mine yielded very high gold assays. On the Eldorado mine, pockets in the ore partly filled with limonite invariably contained shot and slug gold.

The Peko ore, above water-table level, is red and grey and consists of a gold-enriched altered shale which has been almost completely oxidized. In the water-table zone the character of the ore changes to a quartz-hematite lode containing gold, malachite, native copper, and cuprite, which on the 210-ft. level (according to mine assay plans) carries 23 per cent. copper and 5 dwt. of gold per ton. In the primary zone below this level, diamond drilling has shown that the lode is composed of quartz, pyrite, chalcopyrite, and magnetite, in which chalcopyrite is host to the gold (Stillwell, 1951). It is probable that ore above the water-table was originally very similar in type, but has been subjected to intensive weathering.

The Northern Star and Whippet ores are replacements of crushed shale in which some of the original bedding has been retained.

Partial analyses of Peko and Northern Star ores are shown in Table 6 below:—

TABLE 6.

PARTIAL ANALYSES OF PEKO AND NORTHERN STAR ORES.

——	Peko—210-ft. Level.	Peko—120-ft. Level.	Partial Analyses, Ore Samples from 100, 150, 200 ft. Levels Northern Star.
Au	5.2 dwt. per long ton	1 oz. 18 dwt.	8.5 dwt.–26.3 dwt.
Ag	5.0 dwt. per long ton	5.0 dwt.	..
Fe_3O_4	58.8 per cent.	56.7 per cent.	51.2–55.4 per cent.
Cu	0.6 per cent.	0.9 per cent.	0.06–0.12 per cent.
Bi	0.4 per cent.	..	0.05–0.80 per cent.
Pb	..	0.4 per cent.	0.03–0.15 per cent.
Zn	..	..	..
As	Tr.	1.4 per cent.	..
Insoluble	21.5 per cent.	24.8 per cent.	..

The percentage concentration of Fe_3O_4 has a wide range in the deposits found on the Gold-field.

The grade of ore in any particular ore-shoot is never constant: assay results from mines on the field show that samples cut within a few feet of each other in what appears to be identical lode material might differ by anything from a trace to several ounces. Perhaps the most outstanding range of assays has been recorded from Noble's Nob mine, where assays from a trace to over 300 ounces per ton have been recorded.

STRUCTURE.

Structural Control of Lode.

The investigation of the structural control of Tennant Creek lodes shows that they are narrow lenses replacing crush zones in Warramunga Group sediments rather than infillings of deeply penetrating fissures. Distinctive sedimentary and structural controls have combined to localize the deposition of lode and ore material; this is why lodes and associated ore-shoots have little continuity in depth. In general lodes on the Tennant Creek Gold-field are formed in crush zones on the limbs of plunging anticlinal folds; where a mudstone or shale bed intersects such a crush zone an ore-shoot may be formed.

Tectonic movements which led to brecciation, faulting, and folding are pre-mineral movements, although there is some evidence of movement during mineralization.

The main reaction of the Warramunga Group sediments to compressional and rotational forces has been to form plunging anticlines and synclines. The angle of plunge of individual folds is not constant; reversals are very common. The folds are generally of short amplitude, with axial planes dipping steeply north or south, and parallel to the regional cleavage. Overturning is not common, although an overturned fold occurs on the Skipper Extended lease: the axial plane of this structure dips 50° north. Crushing and brecciation of the limbs of folds have taken place and these zones are now marked by quartz-hematite replacements. All such zones are parallel, or at a slight angle, to the axial planes of folds.

The nature of the folding is well shown on the Blue Moon lease (Fig. 13A), where interbedded sandstone and mudstone lenses have been folded into a syncline and anticline plunging east at 23°. A crush zone has been subsequently filled with quartz-hematite near the crest of the anticline.

The folding in the Whippet mine area (Fig. 13B) is comparatively sharp with dips ranging from 65° to 70° on the north limb. Available information indicates that the Whippet lode is situated in the arm of a short sharp dragfold on this northern limb. Other similar cases, such as Noble's Nob and Eldorado, occur on the field.

No. 1 quartz-hematite lens on the Northern Star mine is localized on the north limb and crestal region of an anticline plunging at 35° to 50° to the west. On the same lease No. 2 lens is localised in the crestal region of an east-plunging fold, No. 3 lens on the north limb of a west-plunging fold.

The reaction of rocks of different competency to folding and faulting has played an important part in ore and lode localisation. The more competent massive sandstone and quartzite have folded more or less uniformly under stress. The less competent sediments such as fine argillaceous sandstone, shale, and mudstone have buckled sharply with a tendency to flowage into the crests of folds; in places they have been brecciated.

Normally, plunge reversals, indicated by minor cross-folds and bedding-cleavage relationship, are of major importance in limiting the length of the mineralized zones. Measurement of plunge direction in the incompetent beds is not usually as reliable as that measured in the competent rocks. The plunge of the latter generally gives a close approximation to the pitch of the lode.

On the Enterprise mine drag-folding immediately south of the line of lode is indicated by a swing in the strike of beds from 100° to 60° (magnetic) with a resultant reversal of plunge from east to west. No. 1 lode is localized in the arm of this drag-fold. Similar reversals of plunge are well shown on the Blue Moon gold mine, where many quartz-hematite lodes three to five feet in length are localized by plunge reversals in the surrounding sediments. A projection of the axis of pitch-change cuts across the eastern end of the main lode on the Blue Moon lease, and may be a limiting factor in lode distribution. Many reversals of plunge were mapped on the Northern Star lease, where the central fold, which contains No. 2 quartz-hematite lens, plunges east, and other folds plunge west.

Whereas fracture cleavage and folds were formed in the Warramunga Group sediments on a regional scale during movements, rock failure reflected by faulting and brecciation took place in selected areas only, now defined by quartz-hematite replacements and quartz veins. Failure in the initial stages led to brecciation and was followed in some places by faults parallel to the dip and strike of the crush zone and in other places by low-angle thrusts with resultant vertically-dipping tension-breaks.

Breccia zones are found singly as at Hidden Mystery mine or as *en echelon* groups in the Skipper and Skipper Extended lodes. The strike of these crush zones parallels the regional strike and the dip is normally a reflection of the attitude of the regional fracture cleavage. On the Whippet mine the zone of brecciation changes in strike from south-east to east to north-east as it passes through competent sandstone, incompetent shale, and competent sandstone. One mile west of the Peko mine the strike of a crush zone filled with quartz-hematite parallels the strike of the cleavage in the incompetent beds, and changes in strike to follow the bedding when it passes into the competent beds.

Bedding-plane faults are generally very difficult to recognize and for this reason their importance is not generally realized. They are normally combined with fracture-cleavage faults. On the Skipper Extended mine vertical tension fractures which localize the lode are possibly the result of movement along fault A (Plate 2), a bedding-plane fault at the contact between massive cherty sandstone and mudstone. Buckles in the underlying cherty slate have led to possible discordance of this fault with the bedding. The Thomas Fault, Eldorado mine (Plate 12) alternates between bedding and cleavage, although it is generally parallel to the cleavage.

All available evidence supports the concept that once a main control fault enters a bedding plane the lode and ore will peter out.

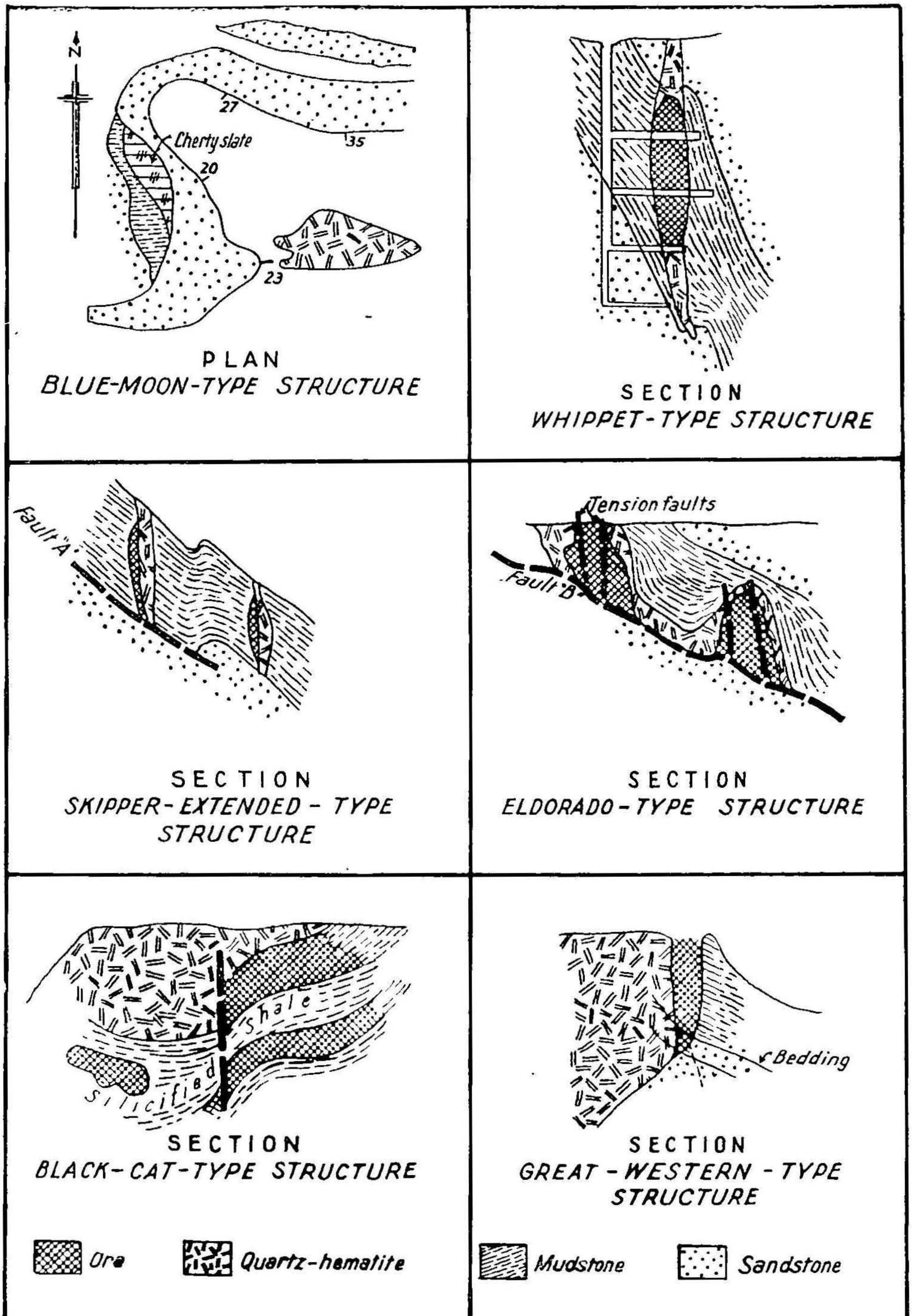


Fig. 13.—Types of Ore Structure in Tennant Creek Gold-field.

Fracture-cleavage faults are the main fault type present where incompetent beds have been sheared. Such faults have well defined foot-walls and hanging-walls and play an important part in the localization of ore within the lode.

Low-angled thrust faults are associated with some lode-filled crush zones —for example on the Eldorado and Lone Star mines. On the Eldorado mine. Fault B (Plate 14), a low-angled thrust fault, strikes north and dips east at 20–25° on the 200-ft. level, 40° on the 300-ft. level and 20° on the 400-ft. level. Coupled with the steepening in dip is a change in strike of 37° (Plate 14). Fault B marks the base of the lode. The change in strike and dip has given rise to high-angled tension faults (Fault A and Pug Seam fault, Plate 14), which have displaced the ore shoot.

Tension faults may form zones a few inches to three feet in width. They normally strike parallel to the north-easterly strike of the axis of pitch change which has been measured in several places along the Eldorado-Mount Samuel line. Slickensides are common features, and on the Eldorado mine they dip parallel to the dip of Fault B. The recognition of tension faults with slickensides is important because invariably they have displaced the lode. Mining experience shows that the displacement is in the direction of the dip of Fault B and in the same direction as the dip of the slickensides. This applies to the Eldorado mine and may apply to other mines which have similar structural controls.

The following type structures for the Tennant Creek Gold-field are illustrated in Fig. 13. They are—

Fig. 13A.—Blue-Moon-type structure.—Replacement of a crush zone in the crestal region of a plunging fold. Where the crush zone intersects a brecciated mudstone bed gold ore has been localized.

Fig. 13B.—Whippet-type structure. Brecciation and replacements of shale in a zone parallel to the regional cleavage. The crush zone either terminates in the competent sandstone or continues along the contact between sandstone and shale.

Fig. 13C.—Skipper-Extended-type structure.—Replacement of a vertical crush zone formed by a complementary tension fault deflected from a bedding-plane fault along a partly discordant contact between mudstone and cherty sandstone.

Fig. 13D.—Eldorado-type structure.—Ore shoots are localized in a brecciated mudstone bed intersected by vertical tension faults. Such faults are the result of movement along Fault B, a low-angle thrust fault.

Fig. 13E.—Black-Cat-type structure.—Selective gold enrichment of brecciated and replaced gently dipping mudstone beds.

Fig. 13F.—Great-Western-type structure.—Selective enrichment of crush zone in mudstone on the edge of a vertically dipping quartz-hematite lode.

Complete descriptions of individual mine structures are included in the reports on those mines. (P. 58 *et seq.*)

Sedimentary and Structural Control of Ore.

Investigation of the structural localization of ore shows that ore shoots have been formed where an incompetent mudstone or shale bed intersects the mineralized zone. The importance of mudstone and shale in the control of ore is shown by the fact that high-grade ore is either a mineralized brecciated mudstone or a shale and that the grade of ore decreases rapidly as the proportion of sand to silt in the beds increases.

At Noble's Nob mine (Plate 17) a mudstone bed at the surface can be correlated with the mudstone breccia of the ore. The major importance of sedimentary control is well shown on the Whippet mine (Fig. 13B), where a shale bed is overlain and underlain by competent sandstone beds. The main ore-shoot is in the shale bed, and the grade of the ore rapidly decreases to nil where the shear which forms the ore channel enters the sandy beds.

Limits to ore continuity, apart from sedimentary control and the size of crush zones, are found in the many structural breaks, mainly faults, which intersect the lode.

On the Northern Star, the ore abuts onto a fault which dips 85° to vertical and is strongly grooved. It strikes east and clearly marks the footwall of the ore; the hanging-wall of the ore, as in many other mines on the Gold-field, is an assay wall. The base of the ore on this mine is determined by the Higgins Fault (Plate 42) which dips 55° south-west. On the Skipper Extended mine, a similar fault terminates lode and ore. Within the western quartz-hematite body of the Enterprise mine, ore-shoots are localized in crush zones between two intersecting sets of fractures (Plate 10), the King fault which forms the main controlling feature, and minor faults which feather off it.

Local structural breaks such as minor shears, possibly formed during emplacement of the lode, may contain very high-grade ore, as is the case on the 215-ft. level of Noble's Nob gold mine.

The spatial relationship of ore to lode ranges from an ore shoot that lies centrally within the lodge as in Noble's Nob mine, to one lying on the edge of the lode as in the Skipper Extended mine. On the Hammerjack lease, joints, probably post-lode and pre-ore, have acted as ore channels. On the Black Cat, the ore shoot is formed in tabular mudstone beds surrounded by quartz-hematite. An unusual relationship of ore to lode was observed on the Queen of Sheba mine, where the ore shoot strikes at right angles to north-striking quartz-hematite lodes.

AURIFEROUS QUARTZ VEINS.

Except in two known cases—P.G.A. 134E south-west of Pinnacles Extended and the Last Hope mine—quartz reefs and veins of the Tennant Creek Gold-field are barren. These two cases are exceptional in that the quartz veins do not intersect sediments of the Warramunga Group, but quartz-felspar porphyry and basalt respectively. The porphyry intrudes the Warramunga Group and is genetically related to the adamellite stocks; the basalt occurs as flows interbedded with transitional sedimentary phases of the Warramunga Group.

The gold-quartz veins of P.G.A. 134E are very low-grade, and fill joint factures in the porphyry. They range in width from a few inches to 2 feet. The gold is associated with hematite in the quartz veins, is bright yellow in colour, and is free milling.

In the Last Hope mine, free-milling gold is found in quartz leaders and reefs, and is associated with chalcopyrite, pyrite and hematite. The gold is of fine grain-size in the reefs and is generally coarse in the leaders.

Small nuggets have been found in the leaders and in nearby alluvium.

WEATHERING AND SECONDARY ENRICHMENT.

The present Tennant Creek topography is the result of uplift and erosion of an old peneplain which is now represented by the flat crests of isolated mesas and parallel ridges. Before the uplift there was probably a long period of still-stand, when the rocks were subjected to deep weathering. This weathering led to the development of a lateritic profile in the sediments and in the quartz-hematite lodes; the profile is now represented by a siliceous capping to the mesas, underlain by a grey-white and purple pallid zone. A narrow mottled zone has been preserved in some places in the lode material but not in the surrounding country rocks. Uplift after lateritization has lowered the water-table level, so that in most mines evidence of two distinct base levels of weathering is apparent.

On the Eldorado gold mine the base of the "laterite-profile" water-table level in country rock is approximately 250 feet below the present surface, whereas the present water-table level is at 306 feet. The lode changes from oxidized earthy-red ore above the 200-ft. level to purple and grey ore below this level. The main change in the ore is below the present water-table level, where the ore is the same dark green colour as the country rock. The perched zone of weathering and oxidation of lode to the present water-table level suggests the possibility of secondary enrichment. Other factors which support this possibility, but which are not necessarily conclusive, are—

(1) Much of the gold is flaky, filling cracks and partings in the lode and country rock. Coarse plate and leaf gold, and in some places nuggets, have been seen in the zone of oxidation. So far no such coarse gold has been noted below this zone. Below the ore horizon on the Gigantic mine, some rich gold ore was obtained from gold flakes on cleavage planes and joints in massive sandstone.

(2) Very little alluvial gold is found. Several of the richest deposits, Noble's Nob, Blue Moon, Whippet and Skipper Extended and Enterprise have been relatively barren from the surface to the 50-ft. level. This suggests that leaching of gold may have taken place. On the Whippet mine rich ore extended from the 70-ft. to the 140-ft. level, but the grade below this level has substantially fallen. In the Eldorado mine, a widening of the ore-shoot coupled with an increase in the grade of the ore has been reported near the base of the perched zone of oxidation and also immediately above the present water-table level, where gold assays as high as 80 oz.

per ton have been recorded. By contrast, immediately below this level recorded assays show a maximum grade of 1 oz. per ton. Generally, it is possible to correlate the lower part of the pallid zone of lateritization with high-grade ore and this suggests a possible explanation for the sudden decrease in grade below the perched zone of weathering.

(3) Enrichment has taken place on the Peko by downward leaching of the copper sulphide and pyrite from above the water-table level, with resultant deposition of copper at this level.

ELUVIAL PLACER DEPOSITS.

Only two eluvial placer deposits have been worked with some measure of success on the Tennant Creek Gold-field. They are situated on the Moonlight Rockhole Area and south of the Pinnacles Extended mine (Plate 1). Production figures from these two localities are unknown.

In the Moonlight Rockhole area 40 miles north-west of Tennant Creek, gold has been found as slugs and grains, reported to range in weight from a pennyweight to 32 ounces. The gold is shed from ramifying quartz veins which intersect an altered basalt flow. After heavy rains gold slugs may be picked up on the surface, or won by dry-blowing the sands in nearby creeks. Early prospectors constructed a grid-pattern of water channels through the eluvial area, so that after heavy rains there would be a maximum erosion of the placers, possibly yielding more gold.

In the eluvial area half a mile south of Pinnacles Extended mine, an area 300 by 60 feet was systematically dry-blown. The gold occurs as slugs and nuggets and is derived from the weathering of gold-quartz stringers in the contact zone of porphyry with Warramunga Group sediments. The stringers are confined to the porphyry.

Some eluvial gold has been obtained from the soil on the northern side of the Lone Star quartz-hematite lode, and the southern side of the Southern Star lode. Such deposits are of no importance.

BARREN LODES.

Barren lodes such as quartz veins and jasper lenses are found in many places in the Gold-field. Early prospectors confined their attention to these lodes, because they had gained their experience in quartz-reef gold-fields.

Quartz Veins.

Quartz veins have their widest distribution in the centre of the Gold-field, particularly in the areas close to the adamellite stocks. The longest vein extends from Quartz Hill to Rocky Range (Plate 1), not as a continuous vein but as a series of disconnected veins parallel or *en echelon* to one another. Individual quartz veins range in size from a few inches to 30 feet in width. The quartz is milky white (buck quartz) replacing breccia zones, and remnants of the breccia can be seen in some places. Jasper and some hematite may be present in the lodes and massive hematite has been recorded from one lode.

Quartz veins 6 inches wide on the Skipper Extended lease contain hematite segregations on the margins of the veins.

In places the quartz reefs are intersected by later ramifying quartz veins.

Quartz-Tourmaline Veins.

Quartz-tourmaline veins have been noted in various parts of the field, but were first recorded on the Great Eastern lease. The tourmaline occurs as luxulianite in quartz; the base of the cones is found on one wall of the vein and the apices extend almost to the other edge. In thin section the tourmaline, an iron-rich variety, consists of aggregates of long and short prismatic crystals, the former being of the order of 0.3 mm. in length. Some micaceous-hematite has been found in the veins.

Jasper Lenses.

The jasper lenses are less prominent and less widely distributed than the quartz veins and quartz-hematite lodes. The lenses are found in the contact zone (Fig. 3) between adamellite porphyry and Warramunga Group sediments. Colour ranges from red to dark grey to yellow-brown. Length of the lenses may range from 15 feet to a few inches.

Cryptocrystalline quartz is the dominant mineral constituent. Crystals and segregations of hematite and ramifying quartz veins are found in many places. No gold has been found associated with these lenses.

Jasper bodies in the Tennant Creek Gold-field are generally of contact metamorphic origin.

ORIGIN.

Lindgren (1933) and others have demonstrated the general association of magnetite bodies with soda-rich granites. On the Tennant Creek Gold-field quartz-magnetite lodes occur in association with adamellite and adamellite porphyry.

The term magnetite includes "martite", an alteration product of magnetite, which predominates in the lodes above water-table level. A general increase in magnetite content of the lodes with depth has been shown by Stillwell and Edwards (1942), and can also be seen on the Peko mine. There, the lode which is predominantly quartz-martite above water-table level is quartz-magnetite below this level.

Fig. 3 shows the relationship between jasper bodies, quartz-magnetite bodies, and porphyry. At the immediate contact between porphyry and Warramunga Group, magnetite-rich jasper bodies have been found. They consist of hornfelsed sandy shales and fine sandstones, segregations of dull white quartz and blebs of magnetite. Along the southern edge of an offshoot of the main dyke, grey-black very siliceous jasper bodies with blebs of magnetite are found. These bodies occur in an altered zone, approximately 10 feet wide, which continues along the southern edge almost to the Peter Pan mine, where the zone becomes indistinct. Copper stainings and gold have been found in this zone.

A study of quartz-magnetite lenses in the vicinity of this tongue of porphyry shows that there is an increase in magnetite content as the distance of the lenses from the porphyry increases. There is also an increase in grain size in the components of the lens. This fact is well shown in the Mount Samuel area, where dense siliceous magnetite bodies were found to overlie "granitic" rocks (Owen, 1940). Down-pitch or east from Mount Samuel the quartz-magnetite lodes are very coarse-grained.

One and a half miles east-south-east of the Red Terror mine, porphyry and porphyry-intruded sediments contain quartz-magnetite lenses in the contact zone with Warramunga Group sediments. Here, in places, quartz-magnetite bodies appear to give way gradually to partly "porphyritized" sediments.

At the contact of the porphyry with the Rising Sun Conglomerate the contact zone contains ramifying quartz-hematite stringers. Magnetite intergrown with sediment possibly altered by felspar contamination has been found a few hundred yards from an adamellite outcrop, 2 miles north-west of Quartz Hill.

The evidence outlined above strongly suggests that the gold-rich quartz-magnetite bodies were derived from the adamellite intrusives.

Such gold-magnetite, and in one place gold-chalcopyrite-pyrite-magnetite, bodies appear to be unique; a search of the literature failed to reveal any record of similar deposits.

According to Lindgren's classification (1933) the deposits are of the hypothermal type (high temperature minerals magnetite and specularite are present) and could not have been formed at great depth. That they have been formed at shallow depth is shown by the character of the crush zones which are replaced by mineralizing solutions: they are *en echelon* breaks of shallow horizontal extent (Table 5).

The Tennant Creek gold-bearing magnetic lodes are therefore hypothermal replacement deposits probably derived from the adamellite intrusives.

AGE.

The Tennant Creek lodes are found as replacement bodies in the Warramunga Group and as narrow hematite stringers and segregations in the Ashburton Sandstone and Rising Sun Conglomerate. No traces of quartz-hematite or quartz veins were found in the Lower Cambrian volcanics.

Lodes were introduced into the Proterozoic sediments after or simultaneously with the adamellite-porphyry intrusions: this is shown by the occurrence of contact quartz-jasper hematite lodes and quartz-hematite lenses in partly altered Warramunga Group sediments.

It has been shown that the porphyry is later than the Rising Sun Conglomerate in age. From this it is suggested that the ore deposits were introduced at the close of middle (?) Upper Proterozoic time.

INDIVIDUAL MINES.

Descriptions of individual mines and prospects are contained in the following pages. Geology and structure of the larger mines have been described and where possible ore reserves have been indicated. Computations of ore-reserves have been made without access to assay plans and without detailed sampling of the deposits. However, the estimate of 200,000 tons of ore of average grade 1 oz. per ton is considered a fair average figure for the Gold-field.

MOUNT SAMUEL AREA.

Skipper Extended Mine. (Plates 2 and 3.)

Summary.

1. The Skipper Extended gold mine lies on the sheared limb and crestal region of a 23° west-plunging fold.

2. Ore has formed along a vertical tension fault, off a probable bedding plane shear, where the fault intersects a brecciated mudstone.

Introduction.

The examination of the Skipper Extended gold mine was carried out as part of the geological field work during 1948, and new exposures underground were mapped during 1949.

The Skipper Extended gold mine is situated 6½ miles from Tennant Creek township on a magnetic bearing of 245°. It is approached by travelling 4 miles south from the town along the Stuart Highway and thence about 5 miles west along a graded gravel track. The mine is situated on the most westerly outcrop of the Arcadia-Skipper Line of quartz-hematite lenses. It was owned by Skipper Extended Gold Mines N.L. until 1950, when it reverted back to the original leaseholders, J. Smith and S. Price. Ore was treated at No. 3 Government Battery, 9½ miles distant from the mine.

History and Production.

The deposit was found by systematic loaming, along the line of quartz-hematite outcrops, which involved detailed sampling on a 3-ft. grid pattern. This has been shown by the leaseholder, on this and many other occasions, to be the most scientific approach to prospecting ever used on the Gold-field. The work was carried out by J. Smith and S. Price, who detected a few colours of gold only; but these colours, together with the "favourable" look of the country, induced them to sink a shaft (No. 1 shaft). No results were obtained until a drive was opened for 30 feet north from the 54-ft. level, where the top of a high-grade ore shoot was discovered.

The mineral bodies on the lease were explored by two shafts, one of which (No. 1) was used in mining the ore body, and the other (No. 3) was an exploration shaft. No. 1 shaft was sunk to a depth of 135 feet and short drives were put in at the 53, 85, and 135 ft. levels. A winze and rise were put in from the 135-ft. level. No. 3 shaft extends to 95 feet below the collar, and a drive was completed from this level south for 57 feet and then south-west for another 42 feet; no ore has been intersected to date.

In 1935-36, the Aerial, Geological, and Geophysical Survey of Northern Australia conducted a magnetometer survey of the area. No major magnetic anomaly was discovered.

2,126.5 tons of ore have been mined for an average grade of 40 dwt. per ton by amalgamation and 15.14 dwt. per ton in the tailings. Gold fineness figures were extremely high, from 940 to 970 parts of gold per thousand. The oreshoot has been completely stoped out and the future of the mine depends on the discovery of new pay-ore.

General Geology.

The mine is situated on the western extremity of a line of dissected hills which extends from the Eldorado gold mine, 9 miles to the east. This hill is the last in the group and is a low tapering spur which grades into alluvium 350 feet west of the mine.

Outcrops of country rock are poor and disconnected.

The rocks consist of red and purple tuffaceous sandstone, red medium-grained sandstone, fine-grained sandstone, quartzite, and mudstone. Interbedded green cherty slate and massive chlorite schist were mapped on the 135-ft. level. A microscopic study of the schist shows that it consists of small rod-like crystals of hematite arranged at random in a green cryptocrystalline groundmass of chlorite and sericite. At the 85-ft. level, leached and kaolinized representatives of the cherty slate and chlorite schist have been exposed.

Economic Geology.

Lode.—The surface geological plan (Plate 2) shows two *en echelon* groups of massive quartz-hematite bodies. These bodies are lenticular in shape; their length ranges from 140 feet to 10 feet, and width from 30 feet to 5 feet.

The quartz-hematites (the hematite is probably martite after magnetite) show little variation in mineralogical composition, but marked variation in mineral proportions. They grade from a lustrous black hematite rock with no visible quartz to one which contains well over 50 per cent. of quartz in ramifying veinlets and vuggy segregations. The hematite is gossan-like in places, and is intersected by barren quartz veins which range from stringers to 2 inches in width.

Underground the massive quartz-hematite contains pockets and veins of lustrous micaceous hematite and patches of red jasper. Joint fractures are filled with secondary kaolin. The quartz-hematite lodes are separated from one another by a brecciated mudstone, which has been impregnated with quartz and quartz-hematite stringers. Where visible on the surface this crush zone is a mottled ochre-yellow, red, and brown. Underground it is a dark red mudstone breccia with narrow quartz-hematite segregations.

The only ore shoot found on the lease has been worked from No. 1 shaft, and is lenticular in plan and cross-section but rhomboid in longitudinal section. The strike length was 40 feet and maximum width 14 feet, and these figures show that the ore averaged 56 tons per vertical foot of development. The rake or pitch length of the ore is 72 feet. The ore-shoot lies alongside the massive quartz-hematite lode and has a strike of 57°, a dip of 80° south-east, and a pitch of 62° north-east. The ore consists of a red brecciated mudstone with gold-bearing limonite stringers, numerous narrow veins, and patches of massive quartz-hematite. Bismuth carbonate and limonite are common minerals and occur irregularly throughout the ore. Generally they mark the presence of high-grade ore. Gold is found mostly as finely divided particles and also as flakes, grains, and small slugs.

The presence of flake and slug gold along joint-planes in the lode and country rock below the ore suggests that secondary enrichment may have played a part in concentrating the high values found in some parts of the lode. Further, high-grade ore is associated not only with a favorable sedimentary horizon, but also with a zone of intense oxidation and weathering (probably formed before Tertiary uplift), in the long period of erosion which took place from Pre-Cambrian times. The effects of this weathering and later uplift are shown by the perched zone of oxidation which extends to 115 feet below the collar of the shaft, and is at least 100 feet above present water-table level. Such intense and prolonged weathering, therefore, must have played a part in solution and re-concentration of gold.

Structural Control.

The lack of surface outcrops and underground openings has prevented a complete study of structural controls of the Skipper Extended lodes and ore-shoot, but the following observations provide clues from which a reasonable conclusion may be drawn:—

(*a*) One-quarter of a mile east of Skipper Extended an overturned anticline with a north-dipping axial plane and west plunge was mapped during regional geological studies. On the 135-ft. level, No. 1 shaft, intersection of bedding and fracture-cleavage (dip vertical to 55° north) suggested that these sediments were the lower limb of an overturned structure plunging west, possibly a continuation of that mapped east of the mine. Plunge of the structure averaged 23°, with many local pitch changes.

(*b*) On the 135-ft. level two important sedimentary beds—incompetent mudstone and competent cherty sandstone with poorly developed slaty cleavage—are in contact, the former lying stratigraphically below but topographically above the latter. At the contact of these beds (on the 135-ft. level) is a strong bedding-plane fault dipping 55°. The strike and dip of this fault changes on the 176-ft. level, where there is an abrupt drag-fold in the competent member. It is possible that the fault may die out in cherty rocks. On the upper levels this fault, Fault A (Plate 3), steepens in dip to 60°.

(*c*) The quartz-hematite lode and ore-shoot strike at approximately 45° to the strike at Fault A and are parallel to *en échelon* quartz-hematite-filled shears on the south-east side of No. 1 shaft.

(*d*) Interpolated outcrops of sandstone, on the surface and underground (85-ft. level), on the north side of the *en échelon* quartz-hematite bodies suggest that the mudstone bed may be overlain by a massive competent bed, possibly dipping north.

(*e*) The ore-shoot is confined to the brecciated mudstone bed and is emplaced on the south side of a vertically dipping massive quartz-hematite lode.

(*f*) Parallel quartz-hematite lodes at the western end of the lease may fill fractures in the crestal region of the anticline. There is no ore associated with these lodes.

From these observations it may be deduced that the lodes are found in incompetent mudstone lying between two competent sandstone beds, on the crestal region and south limb of an overturned anticline plunging 23° west. Bedding-plane shearing and folding have given rise to *en échelon* tension-breaks, with subsequent brecciation, and quartz-hematite emplacement. Such bedding-plane shears tend to die out where they change in strike and dip near buckles in the underlying competent rocks. The ore shoot is localized where an *en échelon* shear intersects the brecciated mudstone.

Westward Ho Mine. (Plate 4.)

The Westward Ho lease was geologically surveyed in October, 1950, by E. K. Carter, J. F. Ivanac and E. M. Bennett. The lease is situated approximately 7 miles from Tennant Creek on a magnetic bearing of 245°. Ore won is treated at No. 3 Government Battery, 1 mile east of the township and 8 miles north-east of the mine. F. Johnson, M.L.C., Northern Territory, owns and manages the mine, which is at times leased to tributors.

In 1936, a magnetic survey of the lease and adjacent areas, conducted by the Geophysical Section, Aerial, Geological and Geophysical Survey of Northern Australia, failed to reveal any anomalies which could be correlated with the lode. One large-scale anomaly was found in the area west of the Skipper Extended mine, but this has no possible connexion with the Westward Ho area.

The mine was operated initially in 1935, and local reports state that the first person to operate the mine successfully was J. Weaber. These reports also state that in 1936, 300.45 tons of ore yielding 611.65 oz. of gold were mined by open-cut methods and from a stope connected to the surface by an inclined adit. The ore mined at this time was to a depth of 25 feet. Complete records of ore production are not available as the ore was treated at private batteries, Fasal

Deen and Central Gold Milling, which did not keep systematic records. Some figures have been obtained from Government battery records and these are listed below:—

Date.	Ore.	Recovery by Amalgamation.	Tailings.	Gold Fineness.
	Long tons.	Dwt. per ton.	Dwt. per ton.	
Not available but possibly 1936 ..	300.45 *	40.7*	..	..
May, 1949	97.05	5.0	2.1	840
August, 1949	74.58	5.4	1.6	790
February, 1950	57.0	15.58	5.3	916
Totals	529.08	26.53	2.7	..

* Possibly includes cyanidation figures as well.

The underground development has been very haphazard with four shafts sunk in country rock in an area 100 feet by 45 feet. The surface workings include open cuts at 15S, 00 and 54S, 18W (Plate 4). From the former, an adit from which a stope has been developed, was "mined-out" in ore. The stope was connected to the open cut (54S, 18W, Plate 4) and to No. 1 shaft. This connecting drive is now filled with gangue.

The lodes consist of quartz-hematite replacement lenses in crushed Warramunga Group sandstone and mudstone. The quartz-hematite lenses are found on the lease, and have generally similar mineralogical composition—dark, lustrous, siliceous hematite—but with no megascopic quartz in the western lens.

The eastern lode has been worked at the contact of the breccia and ironstone, where brecciation is more intense than in other parts of the lode. Gold is won from a brecciated and mineralized silty claystone with some micaceous hematite stringers.

The mine is situated on the drag-folded southern limb of a 50° west-plunging anticline. The axial planes of the drag-folds have a maximum dip of 80° north. Impressed on this folding is a possible north-east-striking axis of pitch change which has apparently played an important part in localization of the lode. Sympathetic east-west and north-east faults, older than the lode, intersect it.

Ore is confined to the brecciated silty claystone found in the crestal region of the drag-folds.

Mount Samuel Mine. (Plate 5.)

Introduction.

A geological survey of part of the Mount Samuel gold mine was carried out by J. F. Ivanac, B. P. Walpole and E. M. Bennett in 1950. Not all the workings were accessible at the time of the survey.

The Mount Samuel gold mine is situated 6 miles from Tennant Creek township on a magnetic bearing of 213°. It is reached by travelling south from the township along the Stuart Highway for a distance of 3 miles where a graded road running due west past the Hammerjack and Red Ned gold mines leads to Mount Samuel, a distance of 2 miles from the turn off. The mine is approximately 6 miles distant from the No. 3 Government Battery.

History and Production.

The first record of production from the Mount Samuel lease (G.M.L. 808, P.G.L. 269, P.G.L. 286, P.G.L. 352) was in 1935.

Period.	Ore.	Recovery by Amalgamation.	Tailings.
	Long tons.	Dwt. per ton.	Dwt. per ton.
1935–36	767.0	64.1	12.8
1936–37	377.0	23.6	4.7
1938–39	382.5	20.1	4.0
1939–40	343.7	17.7	3.9
1940–41	327.52	15.0	7.9
1941–42	229.15	5.7	3.3
1942–43	103.75	7.6	2.5
Total	2,530.62	31.2	7.1

Production since 1945 has been spasmodic and limited, and has required considerable exploratory and developmental work.

The surface and underground plans accompanying this report show the position of the workings, and the underground development accessible at the time the survey was undertaken.

Economic Geology.

Fig. 14 shows the shape, size and distribution of lodes on the lease. The lodes are massive, compact siliceous quartz-hematite-magnetite bodies, with small

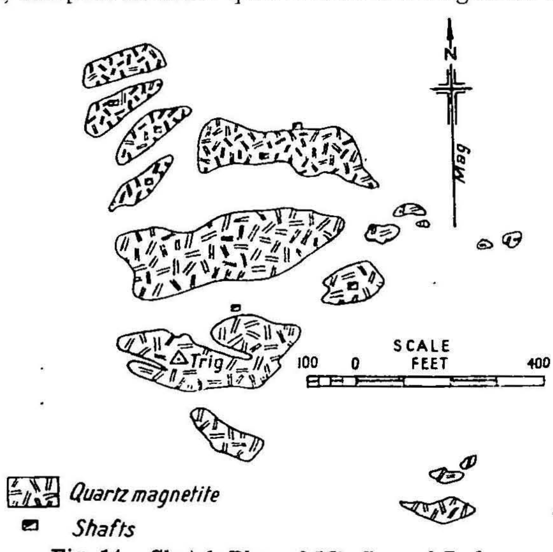


Fig. 14.—Sketch Plan of Mt. Samual Lodes.

ore-pockets, in partly replaced, highly altered soft mudstone and fine sandstone. Structurally the lodes fill crush zones on the limbs of drag-folds, which plunge 8° east.

Hammerjack Mine. (Plates 6 and 7.)

Introduction.

The Hammerjack gold mine is situated 4 miles due south of the Tennant Creek township. The mine is reached by travelling south along the Stuart Highway for 4 miles and thence due west along a graded road for three-quarters of a mile. The lease is at present held by a syndicate and is managed by Mr. R. Ferguson.

The lease was geologically surveyed during the 1950 field season by J. F. Ivanac, E. M. Bennett and B. P. Walpole.

History and Production.

The first recorded production from the mine was in 1934 when 44 tons of ore averaging 8.6 dwt. per ton by amalgamation were treated. Operations ceased during World War II., 1943-45, and were resumed in 1946. Production figures for the mine are listed in the table below.

Period.	Ore.	Recovery by Amalgamation.	Tailings.
	Long tons.	Dwt. per ton.	Dwt. per ton.
1934-35	44.60	7.2	1.4
1935-36	30.0	11.2	2.2
1936-37	345.10	30.7	6.2
1937-38	674.50	12.7	2.5
1938-39	524.57	18.9	2.5
1939-40	1,739.12	27.8	9.5
1940-41	1,108.93	9.7	2.1
1941-42	671.16	13.8	7.3
1942-43	12.25	84.1	23.1
1946-47	284.80	3.7	2.5
1947-48	371.78	24.1	5.3
1950-51	74.0	15.6	Not available
Total	5,880.81	18.6	5.5 (to 1947-48)

In general, recovery by amalgamation has been good, the gold being sufficiently coarse not to slime. Recovery is approximately constant.

Considerable developmental prospecting has been carried out since 1948 with no results. Most of this work has involved a considerable waste of money and labour which might well have been avoided if even elementary geological principles had been understood.

General Geology.

The Hammerjack gold mine lies in the group of dissected hills running east-west, which form the southernmost outcrop of Warramunga Group sediments on the gold-field. To the east is the Enterprise-Eldorado group of mines separated from the Hammerjack by a wide wind gap through which runs the Stuart Highway. West of the mine the strike ridge is continuous and contains the Red Ned, Outlaw, Mount Samuel and Southern Cross gold mines.

The sediments (Plate 6) consist of ripple-marked green and red medium-grained sandstone, sandy shale, cherty silty claystone or mudstone and cherty slate. The sandstone is almost completely confined to the southern section of the lease, and is overlain by the finer-grained rocks.

Economic Geology.

Lodes.—One large quartz-hematite mass and two smaller ones outcrop on the lease. Plate 7 shows that the main body is an extremely irregular elongate lens with long axis striking east. It is 700 feet in length with a maximum width of approximately 200 feet. The lode consists of a mixture of a close intergrowth of quartz and specular hematite, a dense, fine intergrowth of quartz and hematite, and partially iron-replaced red sandstone and mudstone. Some of the ironstone shows relict bedding. In solution channels in joint planes pisolitic limonite concretions have been precipitated.

Several small lenticular pockets and pipes of ore occur in the centre of the quartz-hematite mass, and their sizes are shown in the following table:—

—	Maximum Length.	Average Width.	Maximum Vertical Depth.	Tons per Vertical Foot. (Calculated)
	Feet.	Feet.	Feet.	
No. 1 lens	48	7	27	33
No. 2 lens	22	8	13	17
No. 3 lens	107	22	23	235
No. 4 lens	40	24	12	96
No. 5 lens	22	30	34	66
Total	..	..	..	447

The total of 447 tons per vertical foot is approximately 2 per cent. of the outcropping lode. No specimens of ore were available at the time of investigation but it is reported that the gold was in hematite replacing mudstone, massive quartz-hematite, and limonite-rich pipes along vertically intersecting joint planes. The gold is free-milling and occurs as finely divided particles and small slugs. Shed gold was very common in parts of the northern flank of the Hammerjack hill.

Structural Control.

The complete geological structure of the Hammerjack gold mine is not fully understood but certain important localizing factors have been mapped.

The lode fills an irregular east-west crush zone on the north limb of an east-plunging anticline. Buckles and folds in the sediments underlying the lode have produced vertical tension gashes which form the main site for ore localization within the lode. Shearing has taken place before the lode was emplaced along or near the bedding-plane contact of competent ripple-marked sandstone with overlying fine-grained sediments. Folding of the sediments has made this shear a discordant type of break which partly follows the bedding planes and partly the cleavage direction. Thus, the southern base of the quartz-hematite has a north dip which ranges from 15° (bedding dip) to 80° (cleavage dip).

The northern edge of the quartz-hematite dips from 60° to 70° to the north and apparently follows an east-west shear (possibly an initial major break) parallel to the cleavage.

The pitch of the sediments averages 20° to the east. The longitudinal section shows the important influence of this on the pitch of the lode, which trends east at 14°–20°.

The ore lenses are localized along minor independent vertical or north-dipping fractures, which may be limited in horizontal extent by pitch changes. Plate 7 shows that the base of the ore horizon corresponds very closely with the base of the quartz-hematite in that section. Plate 7 also shows that in cross-section the position of the ore is approximately above the sharp bends in the shear marking the contact between lode and country rock. Associated also with these buckles are numerous very strong joints and fractures which played an important part in the guidance of gold solutions.

There is little evidence to show which sedimentary rock type localized the ore; but in some pits in the lode a breccia of mudstone and fine sandstone has been exposed. Probably, as in other deposits on the Gold-field, mudstone is the main " ore-localizer ".

ELDORADO AREA.

Enterprise Mine. (Plates 8 to 10.)

Introduction.

A geological survey of the Enterprise gold mine was carried out in 1950 by B. P. Walpole and J. F. Ivanac, assisted for a short period by E. M. Bennett. The leases comprise P.G.L. 775, P.G.L. 811 and G.M.L. 4E. The Enterprise gold mine is situated 3¼ miles from Tennant Creek township on a magnetic bearing of 170°. It is reached by travelling south from the township along the Stuart Highway for a distance of 3 miles and thence due east for approximately 1 mile along an all-weather fire-plough road.

The mine is approximately 5 miles distant by road from the No. 3 Government Battery. The Eldorado mine is situated approximately 1 mile to the east.

History and Production.

The Enterprise ore body was discovered in 1935. Production began in that year, and was maintained until 1942, when mining operations were suspended under National Security Regulations introduced during World War II. After the war, the mine was worked by a company, who erected a small three-head stamp battery on the lease. The battery stamps, however, proved to be too light for the massive hematite, and ore had to be carted to No. 3 Government Battery. After cessation of operations by the company the mine was worked for a short period by the owner, Mr. G. F. Richards, and later and more successfully worked on tribute by Mr. D. King and Mr. S. Sanderson. The tribute expired in February, 1951, and the owner, Mr. Richards, resumed operations. The mine leases and their immediate environs were included in a magnetometer survey of the Eldorado-Mount Samuel Line in 1936. The results of this survey are contained in the Second Report on Magnetic Prospecting by the Aerial, Geological and Geophysical Survey of Northern Australia.

Production figures of the mine are listed in the table below:—

Period.	Ore Production.	Recovery by Amalgamation.	Tailings.
	Long tons.	Dwt. per ton.	Dwt. per ton.
1935–36	58.50	21.4	..
1937–38	152.00	22.8	..
1938–39	313.19	31.96	..
1939–40	92.16	6.5	..
1940–41	550.67	33.5	..
1941–42	1,692.93	12.8	..
1942–43	*	*	*
1944–45	35.00	20.6	..
1945–46	32.00	64.7	..
1946–47	355.51	12.9	..
1947–48	685.97	27.14	7.7
1948–49	286.6	11.8	3.1
1949–50	962.97	19.4	4.95
1950–51	671.00	11.2	..
1951–52	249.00	6.9	..
Total	6,137.49	18.5	..

* No production.

The surface and underground plans accompanying this report indicate the development which has been carried out to the end of October, 1950. All levels were accessible at the time of the survey. Timber supports have not been found necessary at any stage of the development. At the time the survey was carried out, ore was being mined chiefly from the western end of the main stope below the 122-ft. level. The broken ore is rilled down an ore pass, through a "grizzly" on the 183-ft. level, and then passed into an ore chute on the 223-ft. level, from where it is hauled to the surface.

The mine workings are confined to the western quartz-hematite body shown on Plate 8; the eastern quartz-hematite body has been prospected only by a few shallow costeans. All ore is now treated at the No. 3 Government Battery. Mr. W. A. McDonald, mines inspector at Tennant Creek, estimated mining and treatment costs for the Enterprise mine in 1950 as £6 1s. 3d. per ton, i.e. equal to 8 dwt. per ton.

General Geology.

The Enterprise gold mine is situated on a highly dissected east-west ridge, which forms the southernmost outcrop of Warramunga Group sediments on the Tennant Creek Gold-field. The mine hill itself is partly razor-backed in shape and falls steeply to the south-east and west, and less steeply to the north. It is almost completely surrounded by other small hills which are similar in shape, and flat or gently sloping mesa-type hills.

To the north and south, the dissected ridge slopes into extensive alluvial plains.

Rock outcrops on the lease are good, and allowed the sedimentary succession to be studied in detail. South of the lode, a thickness of 200 feet of sediments was mapped, but this figure does not represent the total thickness exposed. The character of these sediments and their thickness has an important bearing on ore localization. For this reason these features are listed below and will be discussed in the section of the report devoted to economic geology—

Type of sediment.	Thickness (feet)
Medium-grained sandstone and cherty slate	25
Argillaceous sandstone with sandstone, mudstone and siltstone as interbedded lenses	32
Medium-grained tuffaceous and cherty sandstone	8
Interbedded siltstone, mudstone and sandy siltstone	60
Sandstone with lenses of siltstone and mudstone	5
Pink tuffaceous sandy shale with interbedded lenses of medium-grained sandstone .	15
Medium to coarse sandstone	55
Total	200

The sediments which outcrop to the north of the lode dip away from it and hence play no part in ore localization. Sedimentary types mapped consist of interbedded hematite shale, coarse-grained, medium-grained, and cherty sandstone, tuffaceous sandstone, siltstone, and sandy siltstone. Marked lensing of the sediments produced by gradational changes is very common and points to shallow-water coastline conditions of sedimentation.

Underground development headings have penetrated the country rock in several places. The principal rock types exposed underground are green medium-grained sandstone, pink fine-grained to medium-grained cherty sandstone, buff-coloured siltstone, red mudstone and chloride schist.

The predominant rock colour in the upper levels is reddish brown, which passes downwards into buff-coloured rocks and finally to the green sandstones. This change in colour from red through buff to green is a function of weathering and has been noted on other mines on the Tennant Creek Gold-field.

Plate 10 shows that the shaft passes through the following rock succession :—

- Collar of shaft to 71 feet—reddish competent sandstone with lenses of siltstone.
- 71 to 120 feet—buff coloured siltstone with mudstone and argillaceous sandstone lenses.
- 120 to 223 feet—buff coloured sandstone gradually passing into medium-grained green sandstone.

There is a possible correlation between the incompetent sedimentary horizon outcropping at the surface between 100S and 200S (Plate 8), and the incompetent sediments intersected between 72 feet and 122 feet below the collar of the shaft.

Economic Geology.

Lodes.—The two quartz-hematite bodies which outcrop on the lease are roughly "tear-drop" in shape, tapering out towards the west. The axes of both bodies strike approximately east-west. Both are 200 to 250 feet in length and each has a maximum width at the surface of approximately 50 feet.

At the surface, the quartz-hematite of the western body is a hard, massive blue-black highly magnetic variety, and contains very little megascopically visible quartz. The southern boundaries of both bodies are linear in plan. The northern boundaries are serrated—probably owing to the control of the distribution of lode material by feather faults.

The quartz-hematite of the eastern body ranges in character from the dense massive and magnetic variety to a more vuggy type which in some places shows faint ribwork structures.

The western quartz-hematite body has been mined on five levels at 32 feet, 72 feet, 122 feet, 183 feet and 223 feet below the collar of the shaft. The levels are connected by rises or winzes, most of which are now inaccessible or are being used as ore passes. A cross cut along 00 (Plate 9) at the 128-ft. level intersected 87 feet of lode before passing into country rock. This is probably the maximum thickness attained by the lode. On this level the lode has been developed over a length of 120 feet. Ore has been stoped from 50N 35E to 8S 53W (Plate 9), a length of 89 feet, and an average width of 10 feet. The distribution of gold values in this ore-shoot was extremely erratic, ranging from patches and stringers which assayed up to 60 oz. of gold per ton to sections as low as 3 dwt. per ton.

Much smaller ore shoots, in places connected by thin "stringers" of ore to the main shoot at the 122-ft. level, have been mined from the 183-ft., 72-ft. and 32-ft. levels. At the 223-ft. level, a small independent ore shoot has been stoped.

At all levels except the 223-ft. level, a marked change in character between lode and ore is apparent; the lode is generally strongly-jointed dense massive crystalline quartz-hematite, or as on the 183-ft. level, grey black and white material with patches of pulverulent hematite and in places manganese dioxide staining. The ore on the upper levels and in the main stope below the 122-ft. level is a pulverulent sericite-rich brecciated mudstone impregnated with hematite and containing small pods of hard hematite. The ore on the 183-ft. level is a crushed red mudstone containing free gold and stringers of hematite. On the 223-ft. level, the values occur in hard massive quartz-hematite containing relatively softer patches which localize the higher values.

The richer sections of the ore contain a high proportion of bismuth carbonate, probably bismutite, which usually occurs in intimate association with, and may mask, the free gold. The gold is often megascopically visible and varies from fine to coarse in grain-size.

Despite the high proportion of bismuth carbonate in the richer section, the ore amalgamates successfully. Gold fineness of ore treated in 1949-50 varied between 936 and 982.

The distribution of payable ore throughout the whole mine is erratic. Assay walls and flat-lying layers of dense hematite containing very low gold values are common in the main stope. The highest assay values are obtained from thin stringers of ore which parallel the strike of the lode and commonly connect separate ore-shoots.

Structural Control.

A study of the regional geology of the area shows that the Enterprise lodes lie in a fracture zone on the northern limb of an east-plunging anticline.

South of the line of the lode, the beds strike at approximately 100° magnetic, and dip at angles which range from 15° and 45° to the north. Fracture cleavage strikes between 80° and 90° magnetic and is generally vertical. To the north, and on the southern side adjacent to the western hematite body, the beds have been contorted by shearing stress which has been resolved as drag-folds, shear fractures, and brecciation. Movement along the shear planes is west block south.

Drag-folding south of the line of lode is indicated by a swing in the strike of the beds from 100° to 60° (*see* 00–100E and 00–100S, Plate 8), with a resultant reversal of plunge to the west. It is probable that a similar drag-fold occurs immediately south-east of the eastern quartz-hematite body, but lack of outcrops prevented this from being definitely established. The reversals of plunge have probably terminated the horizontal extent of the quartz-hematite lodes.

Within the western quartz-hematite body, the ore-shoots are localized in crush zones between two intersecting sets of fractures. The main ore control is a general east-west faulting of which the King fault (*see* Plate 10) is the most pronounced unit. The main ore-shoot is localized by the intersection of the Sanderson fault and the King fault, both of which dip at angles between 70° and 75° to the north.

Reversal of plunge caused by the drag-folding has imparted a steep westerly plunge to the lode, though the overall pitch of the ore-shoot is to the east. The outline of the main stope closely approximates to the outline of the main ore-shoot and shows it to be cuspate in longitudinal section with the eastern extremity pitching west and the western extremity pitching east.

Drag-folding of the beds under shearing stress and the difference in degree of competency of the beds have resulted in strong faulting and fracturing off the nose of the drag-fold and along the limb of the major structure. The fractures assume a rhomboidal pattern of stress relief, the direction of the arms of which corresponds very closely to the strike of the fracture cleavage and to the strike of the axes of miniature cross-folds which occur in a bed of hematite shale outcropping at 30N 120E. Resolution of the forces has led to pronounced faulting along a general direction of 90° to 100° and the formation of feather faults striking at between 55° and 75°. The conjugate pattern of fractures thus set up has directly controlled the shape and dimensions of the lode at the surface as well as being one of the prime factors in localizing the ore underground (Fig. 15).

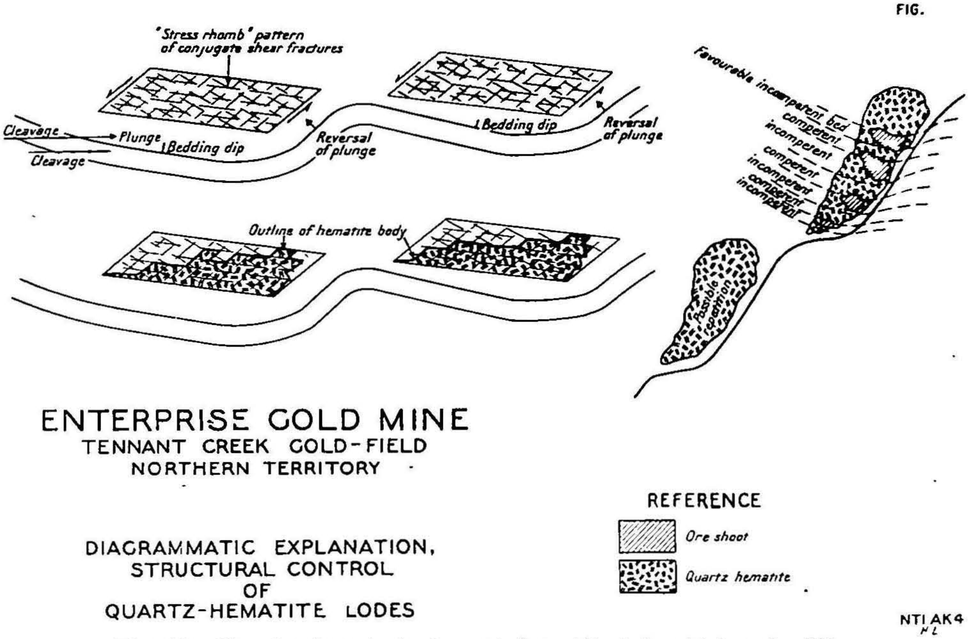


Fig. 15.—Structural control of quartz-hematite lodes, Enterprise Mine.

Sedimentary Control.

The gold values in the Enterprise mine are closely associated with the incompetent beds and with mudstone in particular, as they are in other ore-bodies on the Tennant Creek Gold-field. The potential ore horizon on the Enterprise lease is markedly gradational in character, a feature which may be seen both underground and on the surface. The erratic distribution of the gold values is partly due to this, and is probably further accentuated by the tendency of the mudstone to flow under stress.

The low-grade sections which occur in the ore-shoots are probably caused primarily by lenses of unfavorable sediment which intersect the lode.

The overall east pitch of the ore-shoots is considered to be a reflection of that of the favourable incompetent sedimentary horizons, which pitch into the zone of fracturing from the west.

Secondary Enrichment.

Secondary enrichment has probably played an important part in the concentration of high gold values. In support of this assumption, the following reasons are advanced :—

(1) The zone is impoverished from the surface to the 32-ft. level, where high assays should have been expected.

(2) Apparently favorable host rock on the 183-ft. level yields low gold assays.

(3) The richest ore shoots lie in a perched zone of highly weathered country rock which extends from the surface roughly to the 183-ft. level. This zone is a considerable distance above the present water-table level, and represents long and continued weathering of a more or less stable land surface. Its present position above the waterhole is due either to uplift of the land surface or to a depression of the water-table level. Kaolinization in this zone is fairly marked and it is suggested that such intense weathering must have played a part in solution and redeposition of gold.

(4) Gold occurs as flakes, scales, and grains in cracks and along cleavage planes in lode as well as in the ore.

Patties Mine (Plate 11).

The Patties gold mine is situated 3½ miles south of Tennant Creek township and the lease has common boundaries with the Eldorado and Enterprise leases. Production commenced in 1939, ceased during World War II., and was recommenced in 1947. In 1949, exploration of quartz-hematite blows on the lease was carried out by percussion drilling, but without result. In 1950, D. King obtained an option on the lease; 1,488.48 tons of ore, which averaged 19.3 dwt. per ton by amalgamation and 4 dwt. per ton in the sands, have been mined.

The lode has been worked from two shafts, one 85 feet deep and the other 170 feet deep (vertical to 85 feet and underlay for the remaining 85 feet). Drives and crosscuts have been put in at 85, 110, 135 and 170 feet.

The sediments (interbedded sandstone, mudstone, siltstone, and hematite-shale) which crop out on the lease have been folded and sheared. Bedding dips and intersection of bedding and cleavage indicate that these sediments lie in the north limb of an east-plunging anticline. Rock failure as a result of folding has induced brecciation and shearing in the country rocks, and such breccia zones have been partly or completely replaced by quartz-hematite.

Several quartz-hematite lenses striking east-west crop out on the lease, and mining activities have been concentrated in the partly replaced crush zone on the south side of the westernmost outcrop.

The main ore shoot is lenticular, extends from the 52-ft. to 135-ft. levels and aggregates 11.2 tons of ore per vertical foot. The ore consists of red brecciated mudstone, sericitized and impregnated with quartz-hematite stringers. Gold occurs as grains, flakes, and scales on cleavage-fracture planes, and is in places visible to the naked eye. Finely disseminated gold visible only by dollying and panning is more widely distributed.

From the 85-ft. level to the 110-ft. level dense massive hematite has been worked over a length of 15 feet and a width of 11 feet, a total of 16.5 tons per foot of development. The grade was reported to be sporadic, although some high-grade ore, probably due to enrichment of fractures in the quartz-hematite, was mined.

Eldorado Mine (Plates 12 to 16).

Summary.

The Eldorado gold mine is the largest producer of gold on the Tennant Creek gold-field. The gold-bearing lodes lie in an area of pitch-change on the north limb of a west-plunging anticline. The lode bottoms on a north-dipping thrust fault. Ore is localized where a brecciated mudstone bed is intersected by steeply dipping faults. Results of previous geophysical investigations are included.

Introduction.

The examination of the Eldorado gold mine was commenced during the 1948 field season and mapping of development headings was brought up to date in 1949 and 1950. J. F. Ivanac and N. H. Krasenstein mapped the geology of the mine. The Eldorado gold mine is operated by a private company and is under the management of Mr. Clive Palmer.

The mine is situated approximately 3½ miles south of the Tennant Creek township and is approached either by a gravel track which runs direct from the town to the mine, or by following the Stuart Highway southward for about 3 miles, and then turning eastwards along an all-weather fireplough road for about a mile and a half. The mine has its own battery treatment plant, which is, however, only operated for about eight hours per day. A cyanidation plant has been erected on the lease, but has not yet been used for ore treatment. Water for treatment purposes is obtained from the company's bore 1 mile south of the mine and from seepage into a sump below the 300-ft. level. Potable water has to be transported from the Town bores 10 miles north of the mine.

History, Production, and Workings.

The Eldorado deposits were discovered in 1932, but large scale production did not begin until 1934.

Several prospectors and one or two companies attempted to work the deposit, but with little success. In 1938, a Government bailiff was placed in charge of the mine to administer its affairs. Following this, Eldorado Pty. Ltd. was formed, and this company prospected the lode by shallow shafts arranged on a grid pattern and by several long north-south costeans.

In the years 1935-36 the Aerial, Geological and Geophysical Survey of Northern Australia conducted a geophysical survey of the Eldorado and adjacent bases. Three major magnetic anomalies were discovered (Plate 16) in close proximity to the Eldorado gold mine.

The recorded production of the mine is listed below:—

Date.	Tonnage.	Gold Won by Amalgamation.	Tailings.
	Long tons.	Dwt. per ton.	Dwt. per ton.
July, 1934, to June, 1935	489	11.2	Note.—Prior to 1941–42, 18,425.2 long tons averaging 2.3 dwt. per ton.
July, 1935. to June, 1936	3,914	10.8	
July, 1937, to June, 1938	5,834	9.1	
July, 1938, to June, 1939	3,349	12.8	
July, 1939, to June, 1940	6,681	10.2	
July, 1940, to June, 1941	7,945	11.8	
July, 1941, to June, 1942	8,355	11.8	
July, 1942, to June, 1943	6,037	17.4	
July, 1943, to June, 1944	5,385	13.0	
July, 1944, to June, 1945	5,121	28.0	
July, 1945, to June, 1946	4,844	18.4	
July, 1946, to June, 1947	6,534	17.2	
July, 1947, to June, 1948	6,188	14.2	
July, 1948, to June, 1949	5,168	11.0	
July, 1949, to June, 1950	5,475	15.7	
July, 1950, to June, 1951	4,881	15.5	
July, 1951, to June, 1952	5,141	16.7	
Total	91,341	14.3	Not available

The Eldorado was the only established mine operating at Tennant Creek when World War II. began, and for this reason was permitted to continue in production.

The ore deposits have been won from an open cut and by underground workings. From the open cut the ore was rilled down to the 200-ft. level and hauled to the surface through the main shaft. The open cut is 150 feet long, 35 feet wide, and approximately 50 feet deep. Ore was extracted from two-thirds of this cut, and the remainder of the mined material was used as filling.

Several shallow pits, Nos. 2, 3 and 4 (Plate 12), have been sunk to depths of 15, 6 and 5 feet respectively. These and the narrow costeans were used in the early exploration of the deposits. Most of them have been subsequently covered by talus and mine waste.

No. 1 shaft, the only haulage shaft on the lease, is a three-compartment shaft measuring 10 feet by 6 feet and has been sunk to a depth of 307 feet. Levels have been opened up at 50, 100, 150, 200, and 300 feet below the collar of the shaft (Plates 13 and 14). Winzes and rises connect these levels and serve as manways and ore-chutes. Exploration at the 400-ft. level has been carried out by a vertical winze from the 300-ft. level (Plate 13), and by an easterly cross-cut with short drives north and south. At 330 feet a shallow drive and cross-cut were put in. From the 400-ft. level (Plate 13) an underlay rise was connected to the 300-ft. level.

All ore hauled to the surface is tipped through a grizzly into a jaw crusher; from here it is conveyed by rubber belt to battery stamps and a treatment plant, where part of the gold is amalgamated with mercury and tailings are stockpiled pending cyanidation. The cyanidation plant is almost completed and some 62,000 tons of tailings will be treated.

The exploitation of the ore has necessitated over 3,000 feet of driving and crosscutting. The workings are in good condition and the ground "holds" exceptionally well. Timber is used only in the main shaft, winze collars, and stope chutes. Ventilation is not a great problem, as the 50-ft. and 100-ft. levels are connected to the open cut, which allows for an effective downdraught of air. The east stope also reaches the surface east of the open cut. The company possesses an underground E100 diamond drill, but to the present this has never been used in exploration.

General Geology.

The Eldorado gold mine is situated on a ridge trending east-west, which falls very steeply to the south of the mine, but slopes very gently to the north and east. This part of the ridge is lower than the general level of the old Tertiary peneplain. Outcrops are partly concealed by soil and talus and by the tailings dump and abandoned mining equipment. Several shallow dry watercourses dissect the lease.

The sediments consist of interbedded medium-grained ripple-marked sandstone, tuffaceous sandstone, tuffaceous siltstone, hematite shale, and mudstone. The sedimentary succession shows competent sandstone overlain by the less competent and finer-grained facies and a measured sedimentary succession is shown below:—

—	Thickness.	Description.
	Feet.	
From 0 to 95	95	Hard red medium-grained sandstone, in places ripple-marked
95 to 100	5	Blocky hematite shale. This rock is reddish-brown in colour with ⅛-in. thick hematite stringers which are parallel to bedding
100 to 111	11	Pale purple siltstone
111 to 121	10	Hematite shale
121 to 137	16	Thinly bedded fine-grained sandstone
137 to 210	73	Mudstone
210	..	Gradation into tuffaceous siltstone

The sediments have been thoroughly leached between the surface and the 250-ft. level. Colours are those which characterize the zone of oxidation, such as brown, purple, and white. Below this zone the rocks are predominantly green with a slight change to reddish green near the present water-table level.

The base of the oxidized zone may be described as a perched water-table level which is probably the relic of a Tertiary water-table.

Economic Geology.

Lode.—Several quartz-hematite lodes outcrop on the lease and are either elongate or lenticular in plan. The lenticular blows trend north-east and the largest is 115 feet long and 40 feet wide. The elongate bodies strike east-west parallel to the cleavage and the largest is 150 feet long and 4 feet wide.

The quartz-hematite lodes lie in a crush zone, and consist of an intimate mixture of quartz-jasper and hematite (probably martite after magnetite). The variations in percentage of these constituents partly depend on the sedimentary rock types the quartz-hematite has replaced. Where the sediments are interbedded sandstone and slate, the composition of the lode is approximately 35 per cent. jasper, 30 per cent. quartz, and 35 per cent. hematite, and where quartzitic sandstone is replaced the ratio is approximately 50 per cent. quartz and 50 per cent. hematite.

The hematite is a blue-black variety with a dull lustre. In places this type gives way to the lustrous specular type. Micaceous hematite occurs on the 300-ft. level. Underground quartz-hematite segregations and massive replacement bodies are surrounded by partly replaced brecciated mudstone and sandstones. The edges of breccia fragments are surrounded by thin hematite stringers with no preferred orientation. Sericite, limonite, manganese oxide, kaolin, possibly bismuth oxide and carbonate, and quartz-muscovite veins are associated with the lode. The limonite is ochre-yellow in colour and forms the main part of a narrow vein, rich in gold, at the intersection of the Thomas Fault and Pug Seam Fault in the Central Stope on the 100-ft. level (Plate 14). Manganese oxide stains are very common on the 300-ft. level. Kaolin is widely distributed and occurs as thick seams along curved tension-joint planes in the massive hematite. A quartz-muscovite vein approximately 1 inch wide was observed in a fracture in the hematite on the 200-ft. level.

Massive barren quartz veins cut the lode in places but are not widely distributed. They belong possibly to a third phase of quartz injection. From present knowledge of the mine the writer is inclined to the opinion that there are three periods of quartz injection—

(i) Closely associated with the introduction of magnetite.
(ii) Quártz-muscovite veins.
(iii) Barren quartz-veins.

Several ore-shoots have been worked in the quartz-hematite lode and these are known as East Shoot, Central Shoot, and the Western Lenses. They are pipe-like bodies with a circular or elliptical cross-section. The ore-shoots are confined to the one lode and consequently are interrelated.

1. East Shoot.

Plate 14 shows the general outline of the East Stope which has been worked on the 100, 200, 300 and 400 ft. levels. The stope is divided into two sections, the south-western limb and the north-eastern limb, which are separated by the Thomas Fault. On the 100-ft. level the south-western limb is 35 feet wide and 52 feet long, and has yielded approximately 180 tons of ore per vertical foot. This portion of the East Lode extends from the surface to about 10 feet below the 100-ft. level. The ore-shoot is terminated to the west by the Pug Seam Fault (Plate 14) and to the north by the Thomas Fault. Assay walls limit the ore to the south and east.

The north-eastern limb (Plate 14) has its maximum dimensions on the 200-ft. level where it is 40 feet wide and 50 feet long, and averages 180 tons of ore per vertical foot. It is bounded to the west and to the south by the Pug Seam and Thomas Faults respectively. The east and west limits are determined by assay. This limb of the lode considerably overlaps the south-western limb (Plate 14), and originated 35 feet below the 100-ft. level. It continues as an uninterrupted pipe to the 400-ft. level where there is a marked decrease in size and grade of the ore-body. At this level the yield is only 40 tons per vertical foot.

Present production from the Eldorado mine is solely from the north-eastern limb of the East Shoot.

2. Central Shoot.

The Central ore-shoot has been worked at the surface and at the 50 and 100 and above the 200 ft. levels. The outline is similar to the East Shoot in that the ore-body has a north-eastern and a south-western limb, which have a pipe-like outline in section. The north-eastern limb lies in the hanging wall of the Thomas Fault and has been mined from the 100-ft. level to about 10 feet above the 200-ft. level. A maximum of 210 tons of ore per vertical foot of development has been mined from this section. The ore is bounded to the west by Fault A, and to the east by the Pug Seam Fault. The Thomas Fault determines the footwall and the northern limits are determined by assay.

The south-western limb extends from the 100-ft. level to the surface. It is bounded to the west and east by Fault A and the Pug Seam Fault respectively. The Thomas Fault determines the hanging wall and the southern limits have been established by assay. There is a marked sedimentary change from mudstone to sandstone in the footwall of the ore and this appears to be responsible for the decrease in grade.

At the surface the ore body was 80 feet long and 35 feet wide, but decreased in size to 50 feet long and 10 feet wide at 100 feet below the surface.

The ore is a lightly brecciated mudstone dissected by ramifying quartz-hematite stringers and massive quartz-hematite replacement bodies.

3. Western Lenses.

West of the east and central ore-shoots a group of irregular ore lenses, known as the Western Lenses, have been mined. The 100-ft. level plan shows some of these lenses, which have given a production tonnage of 70, 45, 25 and 21 tons per vertical foot of development. There are several other lenses but these were inaccessible at the time of the survey.

The ore is contained in soft mudstone and sandy mudstone fragments in dense hard blue quartz-hematite. In some places gold was found in kaolin seams in the lode. The distribution of gold values was erratic and as the lenses were all relatively small in size and of irregular occurrence, the mining costs in this section were high.

These observations have been made in and above water-table level. Deep drilling north of this deposit located grains of chalcopyrite, pyrite and a little calcite. The iron mineral was predominantly magnetite, as the core was highly magnetic.

Structural Control.

The Eldorado lode and ore-shoots have been localized by combined structural and sedimentary controls. The relationship of bedding to cleavage, direction of plunge, and attitude of drag-folds show that the Eldorado lode is situated in the north limb of an anticline plunging 22° east. The axial plane of the anticline strikes east parallel to the regional cleavage, and dip is 65°-75° north. There are two major plunge-changes in the sediments on the lease; the most important is situated at 110S, 150E, where the plunge is 8° east. The strike of the axis of plunge-change is possibly north-east parallel to a measured direction on the Enterprise mine 1 mile west of the Eldorado. This plunge-change has resulted in the formation of a basin in the crests of drag-folds (east-striking axial planes). This could not be verified underground, where bedding is greatly disturbed by faults.

Associated with this folding are three prominent fault types, all of which also play equally as important a part in the localization of lode and ore.

The base of the lode is determined by Fault B, a north-striking thrust fault. The angle of dip of this fault is from 20-25° on the 200-ft. level, 40° on the 300-ft. level and 20° at the 400-ft. level. This important change of dip (to 40°) is associated with a change in strike of Fault B of 37°, and possibly may have led to the formation of vertical tension faults Fault A and Pug Seam Fault. These faults terminate on Fault B; they strike north-east parallel to the main axis of plunge-change. Crush zones of these faults consist of a chlorite-talc schist, with slickensides plunging 20° east, in the same direction as the dip of Fault B. The walls of the ore-shoots are determined by Fault A and Pug Seam Fault on the 100-ft. and 200-ft. levels. On the 300-ft. level the long axis of the ore is parallel to the strike of the Pug Seam Fault and to that of the axis of plunge-change.

A very important fault control independent of Fault B and associated tension faults is the 40°-70° north-dipping Thomas Fault. This fault is generally parallel to fracture cleavage in strike and dip from the 200-ft. level to the surface, but as depth increases, it gradually assumes the bedding-plane direction. The Thomas Fault may have been originally a bedding-plane fault, but attenuation and distortion of the incompetent sediments in the limb of the structure has almost obliterated bedding and substituted a fracture cleavage. The central and east ore-shoots have been faulted by the Thomas Fault (Plate 14), which has been displaced 55 feet by the Pug Seam Fault.

Considerable brecciation and attenuation of sediments is associated with the faulting, and the crush zone has formed the locus for lode and ore accumulation.

A consideration of the relationship of ore to structure shows that the strike of the ore axis is parallel to the fracture-cleavage or axial plane of folds, from the surface to the 200-ft. level; from this level the strike of the axis gradually changes until it is parallel to the strike of tension faults and axis of pitch-change. Fault B and Thomas Fault structures do not weaken in depth, whereas the vertical tension fault probably terminates in Fault B.

Sedimentary control plays an important part in ore localization. The ore is a replaced brecciated mudstone, and may be considered as a sedimentary bed, which can be correlated with a mudstone bed, 73 feet thick, which crops out on the surface. Underlying the mudstone is a massive ripple-marked sandstone and quartzitic sandstone which has folded as a competent horizon, and which controls the dip of the Thomas Fault on the 330-ft. sub-level.

Geophysical Investigation.

A magnetometer survey of the Eldorado leases was conducted by the Aerial, Geological and Geophysical Survey of Northern Australia in the year 1935. The results of the survey disclosed five magnetic anomalies which occurred (*see* Plate 16) at varying depths (from 223 to 750 feet) below the surface. All five anomaly centre points lie down-dip and down-plunge from the outcropping lode.

Details of these anomalies are contained in the following table*:—

TENNANT CREEK MAGNETIC SURVEY.

TABLE SHOWING DETAILS OF MAJOR ANOMALIES DETECTED TO END OF 1936.

Anomaly Number.	Co-ordinates.		Amount of Anomaly.	Approximate Depth Predicted.	Depth as Proved by Drilling.	Approximate Distance of Centre of Anomaly from Nearest Outcropping Body being developed.	Remarks.
	Centre of Anomaly	Site for Drill Hole.					
			Gammas.	Feet.	Feet.	Feet.	
1	430W/ 530N	420W/ 430N	1,600	300	223	600	Detected in 1935. No. 1 drill hole intersected dense siliceous hematite at 223 feet, 235 feet. Drilling stopped in hematite at 235 feet
2	0/650S		500	..	..	600	
3	1,440E/ 750S	1,438E/ 800S	450	500	413	1,300	No. 2 drill hole encountered talc-carbonate-magnetite formation at 413 feet, containing disseminated sulphides. This formation continued to 452 feet (drilling then stopped)
4	2,820E/ 2,100S	..	470	..	..	350	
5	427E/ 2,530S	..	400	..	..	1,400	More deep-seated than Nos 1–4

* This table was copied from Richardson and Rayner, 1937.

Structural Explanation of Magnetic Anomalies.

Plate 15 illustrates a possible explanation for the localization of Magnetic Anomaly No. 1. It is possible that structural conditions which influenced the position of the present lode are somewhat similar, i.e., shearing on the north limb of an east-plunging anticline with thrust-faulting of the Fault B type. A suggested axis of synclinal pitch-change passes through the centre of the anomaly.

Plate 15 also illustrates a possible explanation for the structural control of Magnetic Anomaly No. 3. Its position is thought to be due to shattering of the bedding caused by a change in dip of Fault B. There is a possibility, however, that the anomaly may be due to the increased magnetite content of the lodes, because it is located below water-table level. A brief examination of the surface rocks near and above the anomaly show that the beds have been lightly sheared and steepened from their normal dip of 20°–30° to 65°. This shearing is in an east-west direction parallel to the fracture cleavage and takes place on the north limb of an east-plunging anticline. Shale, sandstone, and mudstone are the rock types present.

Ore Reserves.

The ore reserves of the Eldorado gold mine have been compiled from ore outlines, indicated on level plans by the manager of the mine, Mr. Thomas. No sampling campaign was attempted as it was thought that the outline of the ore, as shown to the writer, was reliable. The Eldorado is an established mine, and as is consistent with practice on the Tennant Creek Gold-field, the average grade of the ore may be taken as the average recovery by amalgamation plus the grade of the tailings.

The ore reserves are considered to be as indicated—

Block.	Tons.
Above 300-ft. level in East Stope ..	3,000
Between 300-ft. level and 400-ft. sub-level ..	17,000
Below 400-ft. sub-level assumed that ore may continue for 20 feet vertically ..	700
Total ..	20,700

The grade of the ore ranges from 15 to 23 dwt. per ton and it is considered that 17 dwt. per ton is a fair average grade. This figure is based on the average recovery by amalgamation of 15 dwt. per ton plus an average grade of 2.3 dwt. per ton in the tailings.

RISING SUN AREA.

Noble's Nob Mine. (Plates 17 to 20.)

Summary.

The Noble's Nob lode lies in the south limb of a west plunging anticline. The relationship of shearing to the bedding has imparted an easterly pitch to the lode. The main gold concentration has occurred where a mudstone intersects the shear zone. A new ore-shoot has been discovered by Bureau of Mineral Resources. A repetition pattern for ore-shoots is suggested.

Introduction.

The Noble's Nob gold mine was geologically surveyed in 1949 as part of the Bureau of Mineral Resources field activities on the Tennant Creek Gold-field. In the 1950 field season new development was mapped. The objects of the survey were to determine the factors which localize the ore; to assist in the discovery of new deposits; and to plan a diamond drilling campaign to test ore search theories.

The work was carried out by J. F. Ivanac and N. H. Krasenstein in 1949 and in 1950 by J. F. Ivanac and B. P. Walpole, under the supervision of C. J. Sullivan, Superintending Mining Geologist.

Noble's Nob gold mine is situated 8½ miles from Tennant Creek township on a magnetic bearing of 120°. The mine is reached by travelling south along the Stuart Highway for 3 miles and thence due east along a fireplough all-weather road for 8 miles.

The mine is owned by Australian Development No Liability, and is managed by Mr. I. Crowe.

History and Production.

The first orebody on the lease was discovered in 1939, when good assays were obtained from 50 feet below the surface in the present No. 2 shaft. The prospectors were no doubt encouraged by surface prospects as this original work was carried out with hammer and tap, in hard massive hematite. About this time several shallow pits were also sunk in the locality. From 1939-43 the mine was worked by a small syndicate. Operations were terminated under National Security Regulation in 1942. In 1947, Australian Development No Liability was formed to explore the lode at depth. This company is still operating and has carried development in high-grade ore to 263 feet.

In 1937 a magnetometer survey of the area was conducted by the Aerial, Geological and Geophysical Survey of Northern Australia. The results of this work are set out in an unpublished report by J. M. Rayner, L. A. Richardson and P. B. Nye. No marked magnetic anomaly was discovered in the Noble's Nob area. With reference to the general geophysical results the report states:—"At the Rising Sun end of the area, there is a broad magnetic feature centred at about Noble's Nob and suggestive of a bedrock effect. It is deep seated and little significance can be attached to it at its present stage." The limits of the 1937 survey were extended in 1950 by M. Allen and J. Quilty, but no magnetic anomaly was discovered.

Despite the unfavorable results of the magnetometer surveys a decision was made to prospect for a repetition of an outcropping quartz-hematite mass at depth on structural and lithological evidence and in October, 1950, the Bureau of Mineral Resources commenced drilling south-east of the main shaft.

The recorded production from the mine is shown in the table below:—

Date	Ore	Recovery by Amalgamation	Tailings.	—
	Long tons.	Dwt. per ton.	Dwt. per ton.	
July, 1939, to June, 1940 ..	671	14.6	..	1940–41, 300 tons tailings cyanided for 19.98 fine oz. recovery
July, 1940, to June, 1941 ..	1,634	10.6	..	
July, 1941, to June, 1942 ..	1,135	17.0	..	
July, 1942, to June, 1943 ..	166	15.3	..	
July, 1948, to June, 1949 ..	3,726	51.9	10.9	
July, 1949, to June, 1950 ..	9,764	74.2	No record	
July, 1950, to June, 1951 ..	14,114	44.3	..	
July, 1951, to June, 1952 ..	15,160	40.1	..	
Total	46,370	47.6	..	

The average recovery of 47.6 dwt. per ton is bound to increase as very rich sections of the ore have been opened up since the beginning of 1950. Yearly production is also likely to increase when the present installation of ore passes is completed. This tonnage will be maintained for some time to come as the mine has considerable ore reserves. Prior to operations by the company the average grade of ore mined was 14 dwt. per ton. The present high grade is due to the discovery of very rich patches in the ore, below the former syndicate's workings; the marked increase in tonnage is due to modern mining methods and increased man-power.

The ore is free milling and is treated by amalgamation on copper plates supplemented by grinding pans. The exact bismuth content of the ore is unknown, but it is believed to have an adverse effect on recovery by amalgamation.

The eastern lode is worked from a main three-compartment shaft, with levels at 135 feet, 183 feet and 215 feet below the collar of the shaft. Several sub-levels have been opened up also. Ore is hauled to the brace from the three levels and run from an elevated tramway to the ore bin and battery stamps.

General Geology.

Noble's Nob gold mine is situated on the southern edge of a steep-sided residual of the old Tertiary peneplain. The residual has a very abrupt scarp to the south and west, but slopes away gently to the north and east where outcrop gives way to talus and the alluvium of a broad flat valley. Other similar residuals are situated east and west of the lease.

The lode is localized in sediments of the Warramunga group. South of the mine a quartzitic facies of the Rising Sun conglomerate of Upper Proterozoic age unconformably overlies the Warramunga Group. Two and a half miles east of the mine a band of quartz-felspar porphyry intrudes the Warramunga sediments and Rising Sun conglomerates.

The mine lies in steeply south-dipping medium-grained argillaceous and tuffaceous sandstone, fine-grained sandstone, mudstone, shale, hematite shale and cherty slate.

Economic Geology.

Lodes.—Two quartz-hematite bodies of the type generally associated with the gold deposits of the Tennant Creek Gold-field crop out on the lease. The western lens (No. 1) is 320 feet long with a maximum width of 90 feet. Two hundred feet east of No. 1 lens is the second quartz-hematite body (No. 2 lens), which consists of two lenses 80 feet long and 30 feet wide. Parts of these lenses are concealed by ironstone talus and mining equipment. No. 1 lens has been explored from seven levels, the 57, 86 and 101 ft. levels from No. 2 shaft and 135, 183 and 215 ft. levels and 263-ft. sub-level from No. 1 shaft.

Underground the southern margin of the lode has been exposed in several places as a sharp contact of massive quartz-hematite with partly altered sediments.

The northern limit of the lode is gradational and is represented by narrow quartz-hematite lenses, veins and stringers, which gradually give way to unaltered country rock.

On the 135-ft. level the lode has been exposed over a width of 110 feet and a length of 180 feet. The outline is approximately quadrangular with long axis 150 feet and short axis 85 feet, thus aggregating 810 tons per vertical foot. On the 183-ft. level the lode has been exposed over a width of 120 feet and a length of 220 feet. The ore is irregular in outline with a maximum length of 200 feet and a maximum width of 100 feet, i.e. 956 tons per vertical foot of development. On the 215-ft. level the ore is 170 feet in length and has an average width of 80 feet, and some good grade ore has been found on the 243-ft. sub-level.

In general the ore-body is lenticular in shape, in both plan and cross-section.

The underground workings and diamond drilling show that the gold-bearing part of the lode lies in massive quartz-hematite with no visible quartz veins; in medium-hard hematite with soft white patches of kaolinized mudstone; in sericitized and talcose brecciated mudstone with hematite crystals and veins; and in bismuth-rich quartz-hematite along shears in altered mudstone. Lode and ore are very similar in appearance and economic limits have to be determined by assay. This marked irregularity of values is common in all lodes on the Tennant Creek Gold-field and it is necessary to explore the lode at close intervals, in order to assess the ore reserves accurately.

Towards the northern limits of the lode, the grade of ore falls very sharply, and in some places there is a noticeable change in type of sediment from a mudstone to a sandstone.

On the whole the massive ore is not of very high grade and assays in the vicinity of 1 ounce per ton have been obtained. The massive ore tends to grade into an extremely hard siliceous hematite containing little or no gold. The rock is blocky and well-jointed with thick kaolin pug seams along the openings. Gold found in the hematite is probably primary.

The medium-hard ore contains angular particles of kaolinized mudstone surrounded by massive quartz-hematite. Jointing is not as well defined. This rock may represent a slightly sandier phase of the mudstone, as replacement has been more complete than in the mudstone itself.

The medium-hard ore grades into a soft, highly kaolinized mass of altered brecciated mudstone. The mudstone is greyish white and can be scratched with a finger-nail. In detail, the ore consists of angular polygonal fragments of mudstone partly replaced by muscovite, bismuth minerals, and finely divided hematite particles. The gold content of this ore ranges from 2 to 300 ounces per ton and occurs as finely divided particles, shot gold, and irregular aggregations. At 36 feet below the collar of No. 1 winze, 135-ft. level, the greyish-white mudstone changes to a reddish mudstone with numerous quartz-hematite stringers and lenses. At this junction coarse gold was discovered. On the 215-ft. level (Plate 18) bismuth-rich shears in massive hematite yielded very high gold assays (pan assays, up to 60 ounces per ton).

No. 2 quartz-hematite lens is similar in composition to No. 1 lens, but very little ore has been found in this lode.

Diamond drilling (Plate 20) south of No. 2 lens has revealed a non-outcropping lens of quartz hematite (No. 3 lens). It may have the same dimensions as those of No. 1 lens.

Structural Control.

The complete geological structure of the Noble's Nob deposits is not yet fully known, but a number of important structural controls have been determined.

Regional mapping shows that the lodes lie in the south limb of a 30° west-plunging anticline. On the mine leases, bedding strikes are east and dips range from 60° to 85° south. Plunge reversals are common, and it is probable that a major axis of a pitch-change is situated along the western edge and parallel to the strike of No. 2 quartz-hematite lens. Fracture cleavage strikes east and dips north at angles which range from 75° north to vertical.

The strike of the long axis of the lode is parallel to that of the fracture cleavage, and dip is steeply north. The southern edge of No. 1 lens is defined by an 80° north-dipping fault, which intersects the bedding of adjacent sediments at angles which range from 40° to 60°. Such beds trend east and dip 20° to 40° south.

On the 135-ft. level a relic drag-fold with axial plane trending east was observed. This fold may be a replica of the major structure. On the northern margin of the lode structural breaks—probably relic bedding—dip south. This information and the writer's experience of structures in other gold mines on the Tennant Creek Gold-field suggest that the lode lies in the limb and crestal region of a drag-fold (Plate 18).

Underground observations (Plate 19) show that the lode pitches east—in the opposite direction to the plunge of the regional structure. The explanation for this reversal was not discovered, although it is possible that reversal of plunge and drag-folds has taken place. Such reversals of plunge have been observed in other parts of the Gold-field.

The western extremity of the lode shear appears to fade out in sandstone on the 86-ft. level. On the 215-ft. level, the lode terminates on a shear dipping 40° south-west, with its footwall in sandstone. This shear dips parallel to the pitch of the lode and ore.

From these observations it is suggested that No. 1 quartz-hematite lens lies in the crushed limb and crestal region of an east-plunging drag-fold. The lode may terminate on a shear dipping 40° south-west, which may approximate to a mudstone-sandstone contact. In depth the lode shears may peter out in a massive quartzitic sandstone (Plate 19), which has been projected from the surface.

The character of the very-high-grade portion of the ore and projection of a mudstone horizon into the lode show that the most important gold enrichments have taken place where the crush zone intersects this mudstone bed. The mudstone has been brecciated and sheared and the original dip of 60° south at the surface has possibly steepened to 80°. The pitch of the ore is parallel to the pitch of the lode, i.e. 42° east. The distribution of very-high-grade lenses within the ore does not conform to any general pitch pattern.

On the 215-ft. level north-west striking shears with a very steep northerly dip localize high-grade ore.

The No. 2 lens strikes at 29° magnetic, approximately parallel to the axis of pitch change. The distribution of the quartz-hematite (Plan 132-ft. and 70-ft. levels No. 5 shaft) is controlled by shears striking north-east and dipping at 40° to 45° south-east which intersect the main crush zone. Cross section 4,000E shows that the present overall dip of the quartz-hematite mass is approximately parallel to the dip of the cleavage. Ore distribution in this lode is very sporadic and may be due to brecciation and replacement of narrow mudstone lenses.

Diamond Drilling Results.

From interpretation of the structural controls of the lode it was suggested that a possible non-outcropping lode could occur south and east of No. 1 lens. To test this hypothesis exploratory diamond drilling from the surface was begun in October, 1950, by the Bureau of Mineral Resources. (Full Drill Logs are given in Appendix 1.)

Three holes were drilled, No. 1, 2, and 3, and their positions are shown on the surface plan (Plate 17). Details of the holes are shown below:—

Hole.	Depression.	Length.	Direction.
No. 1	45 degrees	500 ft.	True north
No. 2	60 degrees	652 ft.	True north
No. 3	45 degrees	..	True north

J. Green was foreman driller and was assisted by C. White and J. English. The results of the drilling and rock types intersected are as follows (assays for gold were carried out by Messrs. Allsop and Don, of Kalgoorlie) :—

No. 1 Diamond Drill Hole.—A quartz-hematite lode was intersected over a distance of 130 feet from 202 to 332 feet. Assuming that the lode is approximately vertical in dip, the intersection represents a horizontal width of 90 feet. The most significant assays are listed in the table below:—

Footage.	Width of Core Recovery.		Assay.		True Width.
	ft.	in.	Dwt. per long ton.		Feet.
244-248	3	7	15.0	15.5 dwt. per ton	15
248-252	4	0	10.05		
252-254	2	4	0.8		
254-259	3	8	8.95		
259-264	4	0	33.20		
284-290	6	0	54.90	17.7 dwt. per ton	16
303-305	2	0	21.15		

No. 2 Diamond Drill Hole was commenced on 14th December, 1950, and 34 days were spent in drilling. Cross-section 4,000E shows that tongues of quartz-hematite which form the base of the lode were intersected. Gold assays, as expected, were low, and they are recorded alongside the log of the rock types. An intersection of hematite from 564-567 feet assayed 3.75 dwt. per ton. This intersection is well in the primary zone below the water-table level.

Similar results were obtained from Diamond Drill Hole No. 3, and these are shown on Plate 19. It is probable that No. 2 and No. 3 drill holes have intersected the base of No. 3 quartz-hematite lens.

In general, core recovery in the lode averaged 70 per cent. in the lode and 60 per cent. in country rock. The average drilling rate was 15 feet per day.

Ore Reserves.

No. 1 Ore Shoot.—The ore-body on Noble's Nob mine has been developed by several levels (Plate 18), winzes, and rises, and detailed assays of these openings have been carried out by the mine staff. No sampling of the lode was carried out by the writer. General outlines of the ore were readily obtained on the 86, 135, and 183 ft. levels. On the 215-ft. level and 263-ft. sub-level the boundary of the ore was projected for some distance, to include the possible ore outline on those levels. It is assumed that the blocks between levels are entirely ore.

It is considered that 80 per cent. of the ore, of uncertain grade, above the 183-ft. level can be regarded as measured, and the remaining 20 per cent. as indicated and inferred. Ore between the 183-ft. level and 215-ft. level, together with 5 feet below the 215-ft. level, can be assumed as indicated; and 40 feet below the 215-ft. level as inferred. The total ore tonnage the mine is capable of producing is listed below. This includes ore which has been won between the 86-ft. and 135-ft. levels.

	Tons.
30 feet above 86-ft. level	9,000
Between 86 feet and 135-ft. levels	27,500
Between 135 and 183-ft. levels	42,800
Between 183 and 215-ft. levels	37,000
Below 215-ft. level	40,000
	156,300
Less the total ore won to July, 1951	31,210
	125,100

Ore reserves, 125,000 tons.

The average grade of the ore is unknown, although the average return by amalgamation is 48 dwt. per ton, plus a reported 12 dwt. per ton in the tailings. It is probable that this grade can be maintained as there are large sections of the ore which range in assay value from 60 to 300 oz. per ton.

No. 2 Ore Shoot.—A possible repetition of No. 1 ore shoot has been intersected in Bureau of Mineral Resources diamond drill hole No. 1. It is possible that the ore reserves of this lode may be similar to that of No. 1 ore-shoot, although it is indicated from the width and grade of 15 feet of 15.5 dwt. per ton and 16 feet of 17.7 dwt. per ton that the ore-shoot will be smaller.

Rising Sun Mine.

Introduction.

The Rising Sun gold mine was examined during the course of the Bureau of Mineral Resources field activities in 1950 by J. F. Ivanac.

The mine is owned by a company, Weaber's Rising Sun No Liability, and is managed by Mr. I. Crowe.

The Rising Sun gold mine is situated 9 miles from Tennant Creek township on a magnetic bearing of 120°. It is reached by following the Stuart Highway for 3 miles south of the township and thence due east along a graded gravel road for 10 miles. This road is impassable for a very short period during the annual wet season.

History and Production.

Gold was first discovered on the lease in 1933 and in that year a small parcel of ore was treated at the No. 3 Government Battery. Later a small five-head stamp battery was erected near the lease and the gold ore amalgamated on copper plates with mercury. The sands were subsequently cyanided by Weaber Brothers, who owned the original interest in the mine. In 1948, Weaber's Rising Sun was formed, and this company has explored the lode by cross-cutting, driving and winzing and by diamond drilling from the surface and underground.

The production figures of the mine are listed in the following table:—

Date.	Production.	Recovery by Amalgamation.	Tailings.	Recovery by Cyanidation.
	Long tons.	Dwt. per ton.	Dwt. per ton.	
July, 1933, to June, 1934 ..	54.95	70.9	No record	4,316 tons averaged 4.4 dwt. per ton. Gold yield—941.85 fine oz.
July, 1934, to June, 1935 ..	124.9	35.8		
July, 1935, to June, 1936 ..	1,105.75	16.3		
July, 1936, to June, 1937 ..	1,585.48	18.3		
July, 1937, to June, 1938 ..	3,251.0	15.6		
July, 1938, to June, 1939 ..	2,356.0	10.7		
July, 1939, to June, 1940 ..	1,272.5	7.2		
July, 1940, to June, 1949 ..	No production			
July, 1949, to June, 1950 ..	396.0	23.9		
July, 1950, to June, 1951 ..	154.0	35.3		
	10,300.6	15.1	..	

Production records are not complete as most of the ore was treated at the syndicate's plant.

The surface and underground plans included with the report show the extent of the workings.

General Geology.

The Rising Sun gold mine lies on a very low rise which slopes gently away to wide flat alluviated areas surrounding the lease. About a mile to the west and east of the mine the plains give way to mesas and buttes with silicified cappings.

The sediments outcropping on the lease consist of coarse, medium, and fine argillaceous and tuffaceous sandstone, cherty slate, mudstone, and siltstone. On the 150-ft. level the south crosscuts have exposed silicified sandstone. Above the 150-ft. level the rocks are red-brown and yellow, typical of the zone of oxidation, whereas below this level the colour is predominantly green. This zone of oxidation represents a perched zone probably associated with an ancient water-table level of pre-Tertiary age.

Economic Geology.

Several minor quartz-hematite blows outcrop on the lease but these have little or no economic importance. The main lode has been worked by open-cut methods and detailed examination showed that a band of hematite 3 feet in width outcrops at the eastern end. The Aerial, Geological and Geophysical Survey of Northern Australia (1936) plans show a lens of hematite 6 feet wide on the southern edge of the open cut, but this has since been removed by mining operations.

Underground the quartz-hematite and crushed sandstone and mudstone have been exposed on the 105, 127, and 150 ft. levels. The best exposure is on the 150-ft. level, where the hematite occurs as lenses, pods, and dome-shaped bodies in highly crushed and altered sandstones. The hematite is the massive blue-black variety with little visible quartz that is commonly associated with other ore deposits on the field.

The lode has been worked over a maximum length of 125 feet and width of 50 feet.

The ore is a medium-hard partly replaced sandstone and fine-grained argillaceous sandstone in the upper levels and a dense massive quartz-hematite in the lower levels.

The main ore-shoot is lenticular in shape (Plate 21) and at the surface is 84 feet in length and 34 feet in width. These same dimensions are preserved to the 97-ft. level. Apparently the whole lode was mined irrespective of grade, but fortunately very rich sections were present which allowed the 14.4 dwt. per ton average to be maintained. All this ore-shoot is in the perched zone of oxidation, associated with deep weathering of the Warramunga Group prior to uplift.

In some places a greenish mica is associated with the ore, and this is believed to be an indicator of good values.

Structural Control.

The complete geological structure of the Rising Sun deposits is not fully known. However, some important structural controls were recognized.

Regional mapping suggests that the lodes lie in the south limb of a west-plunging anticline. On the lease, bedding strikes are east-west and dips range from 45° to 72° south.

The strike of the main ore-shoot is parallel to the strike of the bedding and cleavage. The dip is almost vertical. The longitudinal projection (Plate 23) shows that the ore-shoot has a vertical or steep west pitch.

Underground the country plunges east on the north side and west on the south side of the lode. On the 150-ft. level, projection of fault contacts of the lode with the country rock shows that the lode has a flat " S " shape which could conceivably indicate a movement of the north block to the east and the south block to the west. This direction of movement supports the conclusion that the lode is in the south limb of a west-plunging structure. A west plunge to the lode is suggested also by the west-plunging intersection of lode and country rock at the eastern extremity of the mineralized area. Quartz lenses and quartz-hematite are very approximately arranged in an *en echelon* pattern (Plate 21), stepped west and south. This may indicate shearing in the opposite direction to that suggested by other evidence. Further evidence is necessary before the overall plunge of the lode can be determined conclusively. Minor structures within the lode, suggested by the shape of the hematite masses, indicate that the area is one of considerable plunge reversals.

Surface investigation showed a band of sericitized mudstone on the eastern edge of the open cut and dipping at 80° to the south. This sedimentary horizon was the main ore localizer and was probably brecciated during folding of the sediments.

Joker Mine.

The Joker mine is situated 16 miles from Tennant Creek on a magnetic bearing of 111°.

A magnetometer survey of the lease and adjacent areas was conducted by the Aerial, Geological and Geophysical Survey of Northern Australia in 1937, but no major magnetic anomalies were discovered. Mining has been by shallow open cut, shafts, drives, and crosscuts. The mine has produced 3,175 tons of ore which assayed 4.5 dwt. per ton.

Outcrops of sedimentary rock around the mine are scarce. Small outcrops of dense ironstone occur on the north-western edge of the lease and a hematite-rich brecciated slate occurs on the southern side. The latter has been open cut at the surface and a small ore body worked.

Stillwell (1940) examined specimens of auriferous ore from this mine. The specimens studied were massive hematite, altered talc-magnetite rock, and hematite-rich mudstone. Minerals identified include gold, hematite (martite), magnetite, pyrite, native bismuth, bismuth oxide, limonite, talc, and malachite.

WHEAL DORIA AREA.

Wheal Doria Mine.

The Wheal Doria gold mine was one of the three original gold mines discovered on the Tennant Creek Gold-field. The mine is situated half a mile due west of the township and is owned and worked by Mr. A. Rogers. The production figures of the mine are as follows:—

Date.	Production.	Gold won by Amalgamation.	Tailings.	Dollied Gold.
	Long tons.	Dwt per ton.	Dwt. per ton.	Oz.
July, 1934, to June, 1935 ..	4.65	276.1	53.4	14
July, 1935, to June, 1936 ..	143.00	16.9	3.4	..
July, 1937, to June, 1938 ..	102.15	116.9	20.0	..
July, 1938, to June, 1939 ..	305.68	12.4	3.6	..
July, 1939, to June, 1940 ..	121.61	16.1	3.1	..
July, 1940, to June, 1941 ..	327.34	9.7	1.0	..
July, 1946, to June, 1947 ..	477.54	12.6	4.6	..
July, 1947, to June, 1948 ..	349.29	13.9	4.7	..
Total	1,831.26	19.3	4.6	14

The original parcel (1934-35) of ore was sent to Peterborough, South Australia, for treatment, and later parcels were treated at No. 3 Government Battery.

The lode lies in crushed interbedded fine-grained and medium-grained sandstone, shale, and mudstone, which are intruded by an apophysis of quartz-felspar porphyry 400 yards west of the lease. The ore is generally a limonite-rich crushed shale, with the gold as pellets, flakes, and finely divided grains. Some kaolin and talc are associated with the ore, and the talc is probably of hydrothermal origin.

The lode and associated ore-shoot lie on the north limb of a west-plunging anticline.

Big Ben Mine.

The Big Ben mine is situated on a razor-back ridge about 2 miles west of the township. It has produced 13.9 tons of ore which assayed 11.8 dwt. per ton. The rocks of the lease consist of lightly crushed shale and sandstone which lie on the south side of a quartz-felspar porphyry dyke. Gold is contained in brecciated purple shales and red mudstones. Wad, bismuth oxide, and limonite are associated with crushed hematite-rich shales and yellow-brown jasper-hematite bodies.

Peter Pan Mine.

The Peter Pan gold mine is situated 1 mile west of the township, and on the eastern edge of a low mesa; 231.78 tons of ore, which assayed 7.04 dwt. per ton, have been produced. The last parcel of ore crushed was in 1948, when 24 tons of ore assayed 9.04 dwt. per ton. Gold fineness in this case was 826.

Mineralized bodies on the lease consist of highly siliceous hematite lodes which strike approximately parallel to a contact between sediment and quartz-felspar porphyry 200 yards north of the mine.

Ore has been won from altered purple slates, stained in places with malachite. Gold has also been won from quartz stringers. Of interest is the intense manganese oxide staining.

PINNACLES AREA.

Ajax Mine.

The Ajax gold mine is situated on the lease adjacent to and west of the Pinnacles Extended gold mine, on a very steep-sided flat-topped residual of the old Tertiary peneplain. It has produced 17.75 tons of ore which assayed 4.9 dwt. per ton. The workings consist of two shallow shafts 40 feet and 36 feet deep with a north crosscut from the base of the latter.

The rocks consist of interbedded sandstone and mudstone which have been buckled to form the south limb of a west plunging anticline. Shearing of this tightly compressed structure has formed a crush zone dipping 80° north, which has been replaced by an S-shaped quartz-hematite lode. Plunge of the lode is probably west. Gold is found in isolated patches in the softer parts of the hematite and is closely associated with a 2-inch band of malachite and chrysocolla. Bismuth carbonate and manganese oxide are also present in the ore.

Pinnacles Mine (Plate 24).

Introduction.

The Pinnacles gold and copper mine is situated 3½ miles east of Tennant Creek township. At the time of the survey in 1950 by geologists of Bureau of Mineral Resources, the mine was owned and operated by S. Standley.

Gold was first won from the lease in 1934, when a parcel of 6 tons 10 cwt. of ore was treated at Peterborough, South Australia. From 1934 to 1939, small tonnages of ore were mined and treated at the Government Battery, Tennant Creek. In 1950, Standley broke 447 tons of 5.5 dwt. ore from the gold-bearing lode, and apparently he extracted most of or all the remaining ore. The total gold won from the mine is shown in the following table:—

Date.	Ore produced.	Recovery by Amalgamation.	Tailings	Fineness.
	Long tons.	Dwt. per ton.	Dwt. per ton.	
July, 1934, to June, 1935 ..	168.55	24.0	4.8	..
July, 1936, to June, 1937 ..	252.00	14.1	2.8	..
July, 1937, to June, 1938 ..	422.90	18.6	9.2	..
July, 1938, to June, 1939 ..	64.66	24.2	12.0	..
February, 1950	447.00	3.4	2.1	775
Total	1,355.11	13.7	5.3	..

Standley then turned his attention to the small copper lode on the lease and sent small tonnages of ore to Port Kembla. The quantity and grade of ore sent by the owner is unknown, but the grade must have been high to cover the cost of transport by road and rail. Consequently the ore was very carefully hand-picked to ensure that only high-grade parcels were sent to the treatment plant.

General Geology.

Outcrops in the vicinity of the mine are few as the lease is almost completely covered by alluvium. The rocks are part of the Warramunga Group and consist of coarse-grained and medium-grained tuffaceous sandstone, silty claystone, tuffaceous siltstone, siltstone, talcose slate, and some narrow beds of graphitic (?) slate. A magnetite amphibolite dyke intrudes the sediments and appears to separate the gold and copper lodes.

Economic Geology.

The Pinnacles lodes consist of lenticular quartz-hematite-magnetite replacements in sheared and brecciated sediments. Both the gold and copper ore-bodies are partial replacements of crushed slates and fine sandstones.

The gold ore-body is 35 feet in length and 13 feet in width and has been mined to a depth of 50 feet. The gold is free-milling and is associated with a hydrothermally altered silty claystone and fine chloritic sandstone. Segregations of magnetite partially altered to hematite are found in the ore. Sericite, talc and bismuth carbonate are also present.

The copper ore-body is 20 feet in length and 6 feet in width, and at the time of the survey had been mined to a depth of 10 feet. The lode is found in a talc-chlorite-hematite schist at the contact of slates and bedded sandstone. Malachite, earthy red copper oxide and chrysocolla are the minerals in the copper ore. The malachite occurs as encrustations and infillings in fractures and cavities in the lode.

Immediately west, and in part overlying the western end, of the copper lode is a mass of siliceous talc-magnetite kaolin rock. The magnetite occurs both as segregations and as small idiomorphic crystals in the rock. This lode may represent partial hydrothermal replacement of crushed slates.

The lodes have partly replaced a crush zone in the south limb of a west-plunging drag-fold. The evidence for the drag-fold is scanty and the statement is made on analysis of the available structural information. The crush zone trends east, parallel to the regional cleavage.

The ore is probably found where the crush zone intersects the favorable silty claystone beds—this being consistent with observations in other parts of the Gold-field.

Prospects.

The future of the mine, as a gold mine, depends entirely on the discovery of new ore-shoots, as the present ore-shoot appears to be worked out. The gold-bearing ore-shoot is small and it is probable that repetitions of this shoot may be of similar size.

The copper-bearing ore-shoot is extremely small and for that reason is not worthy of further consideration.

PEKO AREA.

Peko Mine (Plates 25 to 27).

Summary.

The Peko lode lies in the north limb of a west plunging anticline. Gold is the economic mineral above the 210-ft. level, gold and copper on and below the 210-ft. level. A new ore-shoot has been discovered by the Bureau of Mineral Resources. A repetition pattern for ore-shoots is suggested.

Introduction.

A geological survey of the Peko gold mine was conducted as part of the field activities of the Bureau of Mineral Resources in 1950. The objects of the survey were to study the factors localizing the ore, to suggest possibilities for the discovery of new ore-shoots, and to plan a diamond-drilling campaign to test these possibilities. J. F. Ivanac and B. P. Walpole mapped the geology of the mine. The plane table survey of the surface outcrops was carried out by E. M. Bennett.

The Peko gold mine is situated $6\frac{1}{4}$ miles from Tennant Creek township on a magnetic bearing of 114°. It is reached by following a well-formed sealed road from the township to the No. 3 Government Battery for 1 mile and thence due east along a fire-ploughed road for 6 miles. The road is traversable for most of the year, but is impassable for a short period during the annual wet season, from December to February.

The mine is owned by Peko Gold Mine No Liability and is managed by Mr. W. MacDonald.

History and Production.

The Peko gold mine was discovered in 1935 and mining began in that year. Activities were terminated in 1942 by World War II. and since that date there has been no production. A company, Peko Gold Mines No Liability, was formed in 1947, and in 1950 started to dewater the mine as a preliminary step towards further mining activity. The company has begun to erect its own treatment plant for the extraction of gold and copper from the ore.

In 1936, a magnetometer survey was conducted by the Aerial, Geological and Geophysical Survey of Northern Australia.

At the conclusion of the Geological Survey in 1950 a diamond drill hole 529 feet in length was put down by the Bureau of Mineral Resources.

Production figures of the mine are listed in the table below.

Date.	Tonnage.	Recovery by Amalgamation.	Tailings.
	Long tons.	Dwt. per ton.	Dwt. per ton.
1st July, 1935, to 30th June, 1936 ..	173.5	1.5	..
1st July, 1936, to 30th June, 1937 ..	1,571.0	3.3	Reported to be about
1st July, 1939, to 30th June, 1940 ..	3,046.0	3.8	12 dwt. per ton
1st July, 1940, to 30th June, 1941 ..	710.0	3.5	..
1st July, 1950, to 30th June, 1951 ..	497.0	3.6	..
1st July, 1951, to 30th June, 1952 ..	82.0 (Cu. ore)	12.8	..
Total	6,079.5	3.55	..

The low recovery by amalgamation is reported to be due to the very fine grainsize of the gold and to the tendency of the ore to "slime". The tailings were cyanided by Central Gold Milling Company, but records of these operations have been lost. The reported figure of 12 dwt. per ton was supplied by Mr. J. Higgins.

The surface and underground plans accompanying this report show the position of workings. All levels except the 210-ft. were accessible at the time of the survey.

On some of these levels native timbers—carbeen, snappy gum, and mulga—have been used as supports. At the time the survey was carried out they were in excellent condition. On the 120-ft. level these timbers were supporting the weight of fill which extends up to the 62-ft. level.

General Geology.

The Peko gold mine lies in the extensive alluvial plain which covers large areas of the Tennant Creek Gold-field. This flat-lying area is almost completely devoid of rock outcrops and extends for 3 to 4 miles around the mine.

A body of massive quartz-hematite is the only outcrop on the lease.

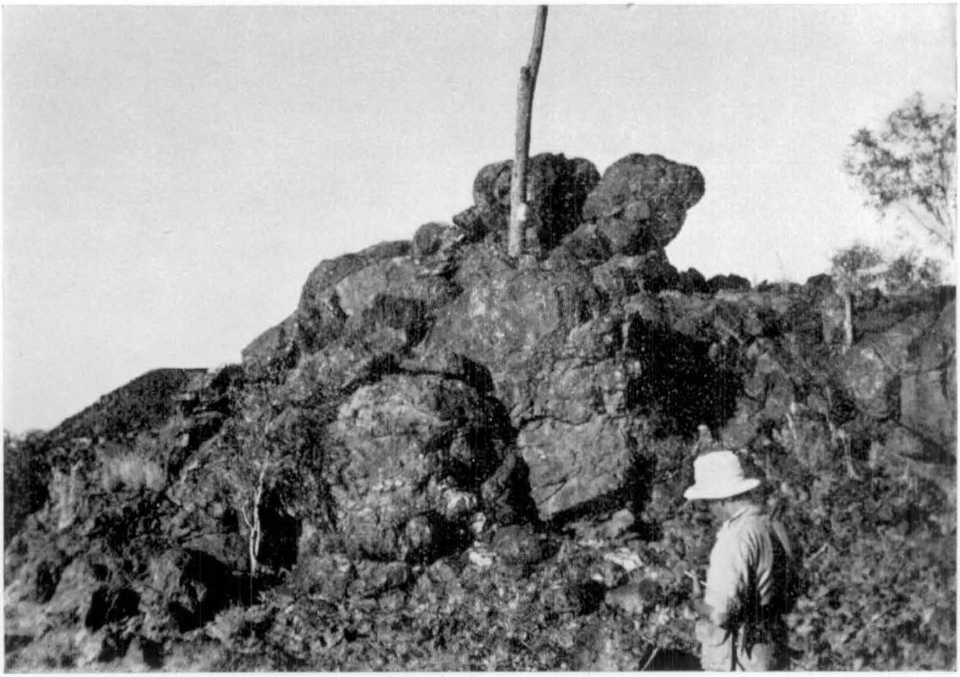


Fig. 16.—Quartz-hematite Lode, Peko Mine.

In 1936, sediments were exposed by open-cutting on the northern edge of the lode.

The sediments consist of interbedded red medium-grained sandstone, red fine-grained siliceous sandstone, tuffaceous sandstone, silty claystone, and sandy shale. The total sedimentary thickness exposed in the open cut is 46 feet, including sandstone 12 feet, silty claystone 3 feet, shale 31 feet.

Underground development headings have penetrated the country rock in several places. Sandstone and narrow lenses of mudstone are the main rock types exposed. On the 120-ft. level, a sandstone bed containing casts of pyrite crystals can be traced from 8S, 58E to 8S, 75W. This bed has a maximum width of 2½ feet. The pyrite casts range in size from ⅜ inch to ¼ inch.

Economic Geology.

Lodes.—The surface exposure of the Peko lode is a quartz-hematite body similar to other lodes on the Tennant Creek Gold-field. It may be considered as two lenticular bodies joined at 00,00. The larger mass strikes at 77° magnetic and is 210 feet long, the smaller at 121° magnetic and is 130 feet long. The lode at the surface has a maximum width of 80 feet; at the point where the two lenticular masses join it is 30 feet wide.

The quartz-hematite is a hard massive blue-black variety in the eastern portion and becomes more quartzose towards the western extremity, where numerous quartz veinlets parallel to the long axis of the lenses cut through the quartz-hematite.

The lode has been developed by four levels, the 62-ft., 120-ft., 170-ft., and 210-ft. levels. On the 62-ft. level the average width of the lode is 65 feet and length 210 feet. The full length has not been exposed but it is probably about 290 feet. The enriched section extends from 00,38W to 20N, 38E, with a maximum width of 20 feet. The strike of the lode changes abruptly from east to north-east near the eastern extremity.

On the 120-ft. level (Plate 26) the lode has been intersected over a length of 220 feet and a width of 95 feet. The ore extends from 30N, 27W to 33N, 89E, a length of 116 feet, and has an average width of 14 feet. From 71N, 42W to 66N, 18W, a small ore-shoot has been mined over a horizontal width of 8 feet and by inclined stoping overhead at an angle of 50°. The rise was continued into the main stope but no ore was intersected above 16 feet.

Development headings have intersected some ore on the 170-ft. level over a length of 50 feet and a width of 30 feet. Further development will probably reveal a much greater length of ore. No. 3 diamond drill hole of the Aerial, Geological and Geophysical Survey of Northern Australia intersected a north crosscut at 94N, 70W. Sludge from 168-186 feet assayed 16.8 dwt. per ton, but subsequent mining showed that the assay was of little significance.

The 210-ft. level was inaccessible at the time the survey was carried out but old mine plans show that the width of the lode has increased from 30 to 47 feet. However, the width of 40 feet of ore is the greatest intersected in the mine and may probably be due to the spreading out of values in the water-table zone.

Above the 210-ft. level the mineralogical composition of the lode material is very similar on all levels. It is yellow, red, black, or white, soft highly-weathered brecciated and iron-impregnated sediments intermixed with hard blue-black hematite. The sediments were probably interbedded shales and sandy shales, highly crushed and folded. The softer portions of the lode contain the high values, and the harder sections and edges of the lode which partly consist of very hard massive hematite lenses are low-grade. The proportion of massive hematite lenses increases towards the edges of the lode.

The gold has an extremely fine grain-size and thus does not amalgamate very successfully. Bismuth minerals and sericite are present, and are further deterrents to successful amalgamation. Manganese oxide is very common and is believed to be an indicator of secondary enrichment.

Below the 170-ft. level there is a marked change in the character of the lode. Although the workings on the 210-ft. level were inaccessible, a review of old mine plans showed that the lode had split into dominantly copper-rich and dominantly gold-rich sections. The cupriferous section forms the northern side of the lode and the auriferous section the southern side. Specimens collected from the dump showed that the copper minerals were native copper, cuprite and some malachite. Assays in this section are reported to be as high as 25 per cent. copper, a value which is undoubtedly due chiefly to secondary enrichment. Gold assays are also generally much higher on this level than on the levels above.

Diamond drilling results from the primary sulphide zone show that the lode minerals consist of gold, magnetite, hematite, chalcopyrite, pyrite, quartz, and a little calcite. Chalcopyrite is the host for the gold (Stillwell, 1951).

Structural Control.

The geological survey of the Peko gold mine has revealed several important structural controls. Full explanation requires some inference as development headings have not proceeded very far beyond the end of the lode.

Regional geological studies have shown that the Peko gold mine probably lies on the north limb of a west-pitching anticline. The pitch in this section is unknown, but is believed to range from 30° to 40° west.

The beds exposed by open cutting on the north side of the lode and by underground development dip north at angles which range from 65° to almost vertical. Generally the beds strike due east, but at 32N, 40E on the 170-ft. level there is a possible change in strike to north-east.

Strike and dip of fracture cleavage almost parallels the bedding. The angle of intersection of bedding and cleavage is flat; and the mine area represents a marked flattening of pitch in the general west-pitching structure.

This marked change of pitch, with steepening of the bedding and the interbedded nature of competent and incompetent sandstone, has led to crumpling and brecciation of the sediments prior to the introduction of mineralizing solutions. The lode is of the replacement type and shows a distinct banding, which is a reflection of selective replacement of different lithological horizons.

To the east the lode appears to bottom on a fault which dips to the north-west at 30°, and is probably sympathetic with a similar possible bedding-strike change. In cross-section 50E, the flattening of the lode points to the possibility of a flattening of the dip of the bedding with development of a shear across the flattened portion.

The control of the ore-shoot in the lodes is not obvious but is possibly due to selective replacement of a shale horizon lying above a competent sandstone horizon. The ore-shoot lies centrally in the lode and has the same general dip and pitch, although there is a possibility that the ore pitches steeply east in the upper levels and then reverses to a west pitch in the lower workings.

Secondary Enrichment.

Evidence obtained from underground investigation and diamond drilling indicates the possibility of considerable secondary enrichment in the Peko lode. The zone of surface impoverishment from the surface to a point above the 62-ft. level and the apparent absence of visible copper minerals above the water-table level support this assumption. However, on present evidence, this enrichment does not appear to affect the assay value of the ore as, above the water-table, it averages about 15 dwt. per ton (based on previous records), and below it may average gold 13.3 dwt. per ton and copper 7.3 per cent. (figures based on core assays from the Bureau of Mineral Resources diamond drill hole).

However, there is a marked variation in size of the ore-shoot above and below the water-table level and there is some suggestion (from present evidence) that gold values spread out above the 210-ft. level. Enrichment has therefore probably taken the form of subtraction of cupriferous minerals and pyrite gangue with subsequent increase in the width of gold ore above water-table level. Copper minerals subtracted from the lode above water-table level have been deposited in the water-table zone.

Diamond Drilling Results.

Exploratory diamond drilling to test a possible new ore occurrence was begun on the 26th August, 1950, under the supervision of the Bureau of Mineral Resources. Interpretation of structural and lithological features of the lode and country rock pointed to the conclusion that the lode would probably steepen in dip below the flat section. This coincided with magnetic anomaly No. 1 discovered by the Aerial, Geological and Geophysical Survey of Northern Australia.

The examination of the present lode showed that ore occurs on the steeply dipping sections, and Diamond Drill Hole No. 1 was designed to intersect this possible steep section of the lode. The position of this hole is shown on Plate 25. The bearing was 176° magnetic, and the depression 76° south.

J. Green was foreman driller and he was assisted by C. White and R. Billings.

The lode was intersected from 397 feet to 500 feet, a distance of 103 feet. Assay of the drill core showed that approximately 22 feet of ore was intersected of true width 12 feet. The assay results are as follows:—

From—	To—	Au.	Cu.
Feet.	Feet.	Dwt. per ton.	Per cent.
405	409	1.0	4.0
410	420	25.15	11.1
420	425	5.90	5.3
425	427	3.6	4.1
22 feet averaging ..	.. ..	13.3	7.3

Assuming 100 per cent. extraction the value of 1 ton of ore at prices ruling at the 4th January, 1951, may be calculated as follows:—

	Per ton. £ s. d.
13.3 dwt. per ton	10 6 0
7.3 per cent. copper	15 13 10
Total	23 19 10

Core recovery was reasonably high even though part of the drilling was in very soft country rock. Drilling statistics are shown in the following table:—

Total core recovery	227½ feet
Length of hole	529 feet
Percentage recovery	43 per cent.
Total lode recovery	66 feet
Length of lode	103 feet
Percentage recovery	64 per cent.

From 0–200 feet, the highly weathered character of the country rock prevented a high core recovery. However, water return was, on the whole, very good in this section except for the very porous initial 30 feet. Subsequently this section was cased.

The lode was extremely hard and the initial drilling rate of 50 feet per day could not be maintained. Between 410 and 420 feet and at 427 feet water supplies were completely lost in vuggy rock. It was found necessary to cement these sections of the hole. From 460–475 feet the lode was excessively hard and closely aggregated quartz-hematite-magnetite with the consequence that the drill bit had to be replaced every 5 feet. The pyrite-magnetite lode was easily drilled and usually gave a good core recovery. Eighteen days were spent on the diamond drilling with an average of 29.3 feet per day.

Geophysical Investigations.

In 1936, the Aerial, Geological and Geophysical Survey of Northern Australia discovered a major magnetic anomaly with a maximum value of 5,500 gammas. The centre of this anomaly is 200 feet north-west of the main shaft. The anomaly was partly tested by two diamond drill holes, No. 3 and No. 6 (third Report on Magnetic Prospecting at Tennant Creek (1937), L. A. Richardson and J. M. Rayner). In No. 3 hole the main lode was intersected on the 170-ft. level and a sludge assay of 16.8 dwt. per ton was recorded from 168–186 feet. However, this result was not confirmed by core assays. No. 6 hole penetrated copper-quartz-magnetite-hematite lode for 35 feet and was then abandoned.

Ore Reserves.

No. 1 Ore-Shoot.—The estimation of the ore reserves of the Peko gold mine is not based on results obtained from detailed sampling. The reserves are based on the propection of ore boundaries, in drives and cross cuts, as indicated by Mr. J. Higgins. The extent of ore on the levels has been defined, also, from geological observations and the interpretation of these results on longitudinal and cross sections. Of this ore, 10 per cent. of the ore is regarded as measured, 40 per cent. as indicated and 50 per cent. as inferred.

Sections.	Tons.
62-ft. stope level to surface (assuming 50 feet of backs) . . .	10,000
120-ft. level to 170-ft. level (allowing 25 per cent. for pillars)	7,500
170-ft. level to 210-ft. level	7,000
210-ft. level (ore assumed to extend 30 feet)	6,500
Total	31,000

The possible grade of this ore is suggested by the 5,500 tons of ore milled (62-ft. to 120-ft. level stope) for a recovery of 3.1 dwt. per ton by amalgamation and a reported 12 dwt. per ton in the tailings. This suggests the ore may bulk 15 dwt. per ton.

From the 170-ft. level to the 240-ft. level there is a high percentage of secondary copper ore in the northern portion of the ore shoot. According to samples taken on the 210-ft. level, 16 feet of ore which assayed 26 per cent. copper has been intersected. It is assumed that the copper ore body has the same length as the gold ore body, and that the average width is the same. The copper-bearing ore reserves are estimated at 9,000 tons of possible grade 10 to 20 per cent.

No. 2 Ore-Shoot.—No. 2 ore-shoot has been intersected in one place only by Bureau of Mineral Resources diamond drill hole No. 1. The ore is a primary gold-chalcopyrite deposit in which the chalcopyrite, in part, is the host for the gold. This ore assayed 13.3 dwt. of gold per ton and 7.3 per cent. copper over a true width of 12 feet.

From a projection of the No. 1 lode in depth, it is suggested that No. 2 lode is its continuation and that the ore intersection represents a new ore-shoot (No. 2 ore-shoot) possibly of similar size to No. 1 ore-shoot.

Prospects.

Prospects of further discovery lie in a continuation of the ore-making structures down dip and down pitch, and a continuation of the assay grade. With the discovery of the No. 2 ore-shoot it is possible to postulate a further new repetition to the north and west. Further exploration of the new ore-shoot is desirable, and when the exact position and outline of this body have been ascertained, underground drilling for another shoot is recommended. Surface drilling may be costly unless perhaps a churn bit is used in the initial stages.

GOLDEN FORTY AREA.

Golden Forty Mine.

Introduction.

The Golden Forty gold mine was geologically surveyed by J. F. Ivanac and N. H. Krasenstein.

The mine is situated 16 miles east of Tennant Creek and is reached by following a fireplough road which runs from the No. 3 Government Battery to the mine.

History and Production.

The ore body was discovered in 1938. Since that date, until the mine was closed down in 1943 under National Security Regulations, small yearly tonnages of ore have been consistently produced. In 1948, two parcels of ore were treated at No. 3 Government Battery.

Production figures of the mine are shown in the following table:—

Date.	Ore Produced.	Recovery by Amalgamation.
	Long tons.	Dwt. per ton.
December, 1938, to June, 1939	229.0	6.8
1st July, 1939, to 30th June, 1940	347.0	3.6
1st July, 1940, to 30th June, 1951	217.0	7.1
1st July, 1941, to 30th June, 1942	1,027.0	4.9
1st July, 1942, to 30th June, 1943	137.5.	4.7
1st July, 1943, to 30th June, 1948	No production	
1st July, 1948, to 30th June, 1949	40.83	3.11
1st July, 1949, to 30th June, 1950	45.85	4.8
Total	2,044.13	5.1

The average gold content of the tailings is reported to be 1.46 dwt. per ton. Consequently the average gold content of the lode is 6.56 dwt. per ton: the mine could not, therefore, have been worked at a profit. Gold fineness ranges from 875 to 890.

The workings on the mine include extensive costeans, an open cut and an adit. The adit was the result of exploratory work carried out by Tennant Creek Development Company in 1943. It is reported that this work cost £3,970.

General Geology.

The Golden Forty mine lies on the crest and slopes of a spur which tapers abruptly to the west. The sedimentary rocks consist of medium-grained tuffaceous sandstone with lenses of fine-grained rocks—mudstone, shale, and fine-grained sandstone. One mile north-west of the mine the sediments have been intruded by adamellite porphyry.

Economic Geology.

Lode.—Three distinct types of quartz-hematite lode combine to form the Golden Forty mineralized area—a hard blue-black variety which consists of a mixture of quartz and hematite, a gossanous-looking hematite, and a blue-grey siliceous type probably very similar to the first type. The massive quartz-hematite is found as "blows" which range in length from 180 to 10 feet and width from 50 to 5 feet. These lenses are surrounded by red and yellow-brown gossanous hematite which is soft and pulverulent in places. It contains numerous narrow limonite seams, and may represent replacement of a fine tuffaceous sandstone. The siliceous hematite is a dull hard variety which is found parallel to the bedding in the open cut. It is generally associated with good grade ore.

Ore has been mined in two places on the lease, but the most important is the main open cut, 45 feet in length, 35 feet in width, and 35 feet in depth. The ore consisted of partly altered fine-grained sandstone, silty claystone, and siliceous hematite. The very uneven character of the open-cutting suggests that the grade of ore was very "patchy".

Structural Control.

The main structural controls are not well defined, but it is probable that an axis of plunge-change on the north limb of a west-plunging structure, associated with brecciation and shearing, has led to localization of the lode. Beds strike east and dip 70° north at the eastern end and 15° north at the western end of the lode. Ore is found on the northern flank of the lode, and the dip of the ore is parallel to the bedding.

Geophysical Investigations.

Geophysical investigations conducted by the Aerial, Geological and Geophysical Survey of Northern Australia in 1935 located two large magnetic anomalies on the Golden Forty lease and two on the southern boundaries. The survey has not predicted the possible depth of the centre of the anomaly. No. 8 anomaly is adjacent to the present workings and No. 9 anomaly 600 feet north-west.

Great Eastern Mine.

Introduction.

The Great Eastern gold mine is situated 9½ miles east of Tennant Creek township and is reached by following a gravel road, which starts near the centre of the township. Ore won from the mine is crushed at No. 3 Government Battery, situated 1 mile east of the township. M. Bradwell and T. Stitt were co-partners of the mine at the time of the survey.

History and Production.

In 1934, a mineralized shear zone, exposed at the surface, was explored by three shallow shafts and several cross cuts. A small ore shoot was discovered. This ore shoot was mined by open-cut methods, and later a haulage shaft was sunk at the western end of the open cut. Mining stopped in 1940. In 1948, the shaft at the western end of the open cut was re-opened by the present owners.

The recorded production of the mine is as follows:—

Date.	Ore.	Recovery by Amalgamation.
	Long tons.	Dwt. per ton.
1st July, 1935, to 30th June, 1936..	160	6.7
1st July, 1936, to 30th June, 1937..	24	6.2
1st July, 1937, to 30th June, 1938..	97	6.2
1st July, 1938, to 30th June, 1939..	106	5.6
1st July, 1939, to 30th June, 1940..	97	4.3
1st July, 1940, to 30th June, 1948..	No production	
1st July, 1948, to 30th June, 1949..	267	8.5
1st July, 1949, to 30th June, 1950..	78	6.3
Total	829	6.75

Tailings assay results are incomplete. Records show that the tailings from the 1949-50 ore assayed 3.2 dwt. per ton. Gold fineness of the ore ranges from 753 to 930. There has been no ore mined since 1950, as the ore-shoot has been completely stoped out.

Economic Geology.

Lode.—No large quartz-hematite masses outcrop on this property, and the only one visible is about 1 foot in diameter. It is found in a shear zone at the eastern end of the open cut. The shear zone is parallel to the bedding and ranges in width from 2 feet to 14 feet. It cannot be traced to the west of the shaft on the surface, but has been observed as far as 160E, 15N, on the eastern side of the shaft. This zone consists of brecciated sandstones and shales impregnated with quartz and quartz-hematite stringers.

The ore body is lenticular in shape and is found in the greatest width of the shear zone. It is 45 feet long, 14 feet wide, and 40 feet in depth. At and below the 30-ft. level, the ore diminishes to a body 2 to 4 feet wide and 16 feet long, although the width of the lode channel (18 feet) has not changed. The dip of the ore body ranges from vertical to steeply north, and the pitch is 76° west. The richest gold assays were obtained from mudstone and fine-grained sandstone, impregnated with quartz-hematite stringers. It is not known to what extent the deposit has been enriched by secondary processes.

Structural Control.

Field observations have shown that the mineralized zone lies close to the contact of coarse and fine-grained sediments. Movement along this contact has caused brecciation of the country rock, which has been subsequently impregnated with quartz stringers and quartz-hematite stringers, carrying gold. The sediments have been folded into anticlines and synclines which plunge at 60° to 80° north. Mapping showed that the mineralized zone transgresses these folds, and dies out approximately 5 feet west of the shaft, at what might be the sandstone-slate contact. This possible contact is obscured by soil and talus. The eastern end of the mineralized zone terminates 160 feet east of the shaft, probably where the zone passes from a fine-grained to a coarse-grained sediment.

Golden Kangaroo Mine.

The Golden Kangaroo (P.G.L. 912) is situated 17 miles from Tennant Creek on a magnetic bearing of 100°. It lies at the northern base of the Golden Forty hills, and has produced 28 tons of ore which assayed 34.9 dwt. per ton by amalgamation and 3.8 dwt. per ton in the tailings.

The lode consists of a very irregular line of siliceous and gossanous-looking hematite bodies which lie in a crush zone on the south limb of a west-plunging anticline. The hematite-filled shears are parallel to the fracture cleavage. Specimens of the ore were not available at the time of survey, but altered mudstone in the lode and on the dumps suggest that the ore may have been a replaced mudstone.

Three Thirty Mine.

The Three Thirty gold mine lease, originally known as the Black Snake lease, is situated in the Peko area, and is about 17 miles east-south-east of Tennant Creek.

1,703.09 tons of ore which assayed 6.6 dwt. per ton by amalgamation and 3 dwt. per ton in the tailings have been produced. The lease and workings occupy a steep-sided mesa in the centre of an east-west striking range of hills.

Ore has been mined from a crush zone by open-cut methods. It is reported that little or no hematite was associated with the lode.

The lode lies on the north limb of a west-plunging anticline. A minor drag-fold in this limb has caused faulting of the country rock with consequent brecciation. This breccia zone dips vertically and strikes east parallel to axial plane cleavage.

Kiora Mine.

The Kiora gold mine is situated 20 miles east of Tennant Creek and lies at the base of a group of flat-topped steep-sided residuals of the old Tertiary peneplain.

681.68 tons of ore, which yielded 12.4 dwt. per ton by amalgamation and 3.6 dwt. per ton in the tailings, have been produced. Four shafts with associated short cross cuts and a boomerang-shaped open cut constitute the workings.

The lode consists of lightly mineralized sheared and tightly folded greenish sandstones and shales with included bands of intraformational breccia, and talc-sericite schist. The ore is a brecciated sandy shale impregnated with hematite around the margins of the fragments. Gold is visible as reddish-yellow specks, maximum size one-hundredth of an inch, in the hematite.

THE GOLDEN MILE AREA.

Perseverance Mine.

The Perseverance gold mine is situated in the Golden Mile area about 20 miles east of the township. The mine is inaccessible for long periods during the annual wet season (December-February). J. Smith discovered the mine in 1950, by systematic loaming on a 3-ft. grid pattern. Since that date 192.34 oz. of dollied gold have been won.

Outcrops of country rock are extremely scarce and no reliable structural conclusions can be drawn.

The lode is irregular in outline and consists of massive quartz-hematite, and hematite-rich brecciated mudstone. Altered mudstone in the shaft section suggests the possibility of the occurrence of ore where this mudstone horizon intersects the lode.

LONE STAR AREA.

Lone Star Mine. (Plates 28 and 29.)

Summary.

The Lone Star gold mine has produced 6,426 tons of ore for a return of 13.4 dwt. per ton. The lode consists of massive quartz-hematite replacement of crushed sediments. The ore is formed where tension faults reflected from a change in dip of the Minogue thrust fault intersect a brecciated mudstone bed.

Introduction.

A geological survey of the surface and underground workings of the Lone Star mine was made in September, 1950, by E. M. Bennett and J. F. Ivanac. The mine is situated 8 miles from the township of Tennant Creek, on a magnetic bearing of 60°. The road, from the mine to the town and No. 3 Government Battery, is well graded and is serviceable for twelve months of the year.

The mine is owned, jointly, by G. McNamara, J. Prendiville and E. Minogue. The mine is managed by E. Minogue, who employs from one to two miners.

History, Production and Workings.

The mine was first discovered and worked in 1935. Production figures from that date are available and are shown in the table below:—

Date.	Ore.	Amalgamation.	Sands.	Gold Fineness.
	Long tons.	Dwt. per ton.	Dwt. per ton.	
1st July, 1935, to 30th June, 1936 ..	2,249.00	15.9	3.3	..
1st July, 1936, to 30th June, 1937 ..	235.00	13.0	2.6	..
1st July, 1938, to 30th June, 1939 ..	107.00	12.2	2.4	..
	51.40	4.0	1.6	..
1st July, 1939, to 30th June, 1940 ..	507.28	7.5	4.7	..
1st July, 1940, to 30th June, 1941 ..	307.03	10.9	2.5	..
1st July, 1941, to 30th June, 1942 ..	517.23	9.0	3.5	..
1st July, 1942, to 30th June, 1947 ..		No production		
1st July, 1947, to 30th June, 1948 ..	453.63	3.8	1.8	..
	206.80	5.2	2.3	..
	513.46	4.0	2.9	..
June, 1948	118.6	8.65	2.9	..
May, 1950	139.7	10.08	2.62	878
November, 1950	501.5	8.05	2.2	970
1st July, 1950, to 30th June, 1951 ..	519.00	10.4	..	..
Total	6,426.63	10.71	2.71	..

The mine has been operated continuously from 1935, except for the war period 1942-47, when it was closed under National Security Regulations.

Most of the ore won has been mined by open-cut methods; some has been stoped from an adit level and some won by selective scrapings from an eluvial placer.

The open cut has a maximum depth of 25 feet and a maximum width of 43 feet. In November, 1950, the open cut was connected with the stope. It is also connected with the underground workings of the adit level by an ore chute.

The adit portal (00,00 Plate 28) provides access to the main level (Plate 29). The stope is located at 50S, 50W and rises on an inclined surface to connect with the 51-ft. level from No. 1 shaft.

The total length of workings is 381 feet on the adit level and 54 feet on the 51-ft. level from No. 1 shaft.

The ore mined in the open cut is forced through a grizzly down a chute and trucked from the west cross cut out through the adit to the ore dump.

The western quartz-hematite lens has been examined by an adit (42S, 195W) 43 feet long, but no further development has been undertaken.

In 1936, the Geophysical Survey of the Aerial, Geological and Geophysical Survey of Northern Australia conducted a magnetometer survey of the lease and adjacent areas. Their profiles indicate a regional anomaly (Richardson and Rayner, 1937) considered to be due to bedrock effect. One major anomaly was found centred well off the north-west corner of the lease. In the immediate vicinity of the mine the magnetic overburden disturbs any possible results. Two lines of weak anomaly were revealed, but their dimensions are not what would be expected from concealed ironstone bodies of the normal type.

General Geology.

The lease covers the eastern end of a razorback ridge which falls very steeply to the east, north, and south. The summit of the ridge consists of two massive quartz-hematite outcrops, 150 feet above the level of the alluvial flats. The quartz-hermatite blows show an advanced stage of denudation and the steep slopes of the ridge are covered with large boulders of ironstone talus.

To the north lies a ridge of hills with steep escarpments. The relief of this line of hills decreases both to the west and to the east, the maximum height being 200 feet at a trigonometric station near the Plain Jane mine. Alluvial flats extend in the south to a low range of hills about 1½ miles distant, and to the east to small hills with outcropping quartz veins.

The dominant sediments on the lease are sandstone interbedded with sandy shales, slates, and lenses of siltstone and mudstone. Ripple-marked sandstone is exposed in a saddle west of the western quartz-hematite blow. The exposures on the slopes are almost completely concealed by the heavy scree.

Underground the sediments exposed are similar to the surface outcrops with the exception of an altered sedimentary type not observed on the surface, where it is probably covered by talus. The sediments consist of sandy shales, slates, and lenses of siltstone and talcose slates. The green talcose slates which lie in the crush zone of a fault are lightly metamorphosed fine tuffs and quartz siltstone.

Economic Geology.

The quartz-hematite lodes on the Lone Star lease are replacement bodies in the crushed and brecciated sediments of the Warramunga Group. For convenience the quartz-hematite segregations and the partly replaced breccia will be discussed separately below.

Lodes.

Eastern Lode.—The quartz-hematite body on the eastern end of the ridge is 128 feet long and approximately 20 to 30 feet wide. Its maximum width is 70 feet. The lode is hard lustrous blue-black quartz-hematite with no megascopic quartz visible over the whole length. Isolated patches were magnetic. The quartz-hematite is in a crush zone, which is easily identified on the margins of the replacement lodes. The sediments in this zone are fine-grained, mainly siltstone with lenses of mudstone.

The ore won by the open-cut and underground stoping methods was friable and consisted of a very highly mineralized and completely replaced siltstone and mudstone. The ore was mined down the pitch in the ore-shoot. Underground the footwall of the ore is made up of a layer of kaolin 9 to 12 inches thick which contains coarse gold particles. One of the backs in the stope, which are blocky quartz-hematite, is reported to be of economic grade.

Western Lode.—The western quartz-hematite body is similar to the eastern lode in mineralogical composition, with some megascopic quartz present in places. The lode is 126 feet long and 30 feet wide. As with the eastern lode a brecciated sedimentary zone occurs along the northern and southern edges of the quartz-hematite.

Sediments are predominantly fine-grained sandstone with large pods of limonite-stained kaolin. On the south-eastern end of this body a cave-like excavation has been made on the contact of the brecciated zone and the lode with a prospect value of 9 dwt. The whole length of the lode was sampled by the owners but a trace of gold only was the highest value recorded.

Structural Control.

The structural control of the lodes is not yet fully understood, but some important structural features are recorded during the survey. The lodes lie in an east-plunging anticline. Structural information on the direction of the plunge of the folding is not complete, and west and east plunges have been recorded on the lease. However, the regional plunge is east and it has been presumed that the folds on the lease follow a similar trend. Fracture cleavage strikes east and dips steeply north to vertical.

The eastern lode bottoms on the north-dipping Minogue Fault, which alters in dip from 32° to 20° in the vicinity of the lode. This change in dip is accompanied by a change in strike and has probably resulted in the formation of vertical tension fractures which in some degree limit the extent of the ore.

Where the crush zone and tension faults intersect a mudstone horizon, gold has been concentrated. This deduction is made from the character of the ore, replaced mudstone, and from the nature of ore in other mines on the Gold-field.

The lenticular nature of the mudstone beds may limit the ore laterally; vertically it is limited by the Minogue Fault.

Mint Prospect.

The Mint gold mine is situated 9 miles from the township, on a magnetic bearing of 56°.

Eighty-seven tons of ore have been produced which assayed 5.3 dwt. per ton. The occurrence of malachite as veins and scales in the lode is of interest at this prospect.

Three Keys Mine.

Introduction.

The Three Keys gold mine is situated 9 miles from Tennant Creek township on a magnetic bearing of 63°. A graded track leads from the township to the mine and by-passes the No. 3 Government Battery 9 miles south of the mine.

In 1948, the mine was manned by the McGrath brothers, but in 1949 was leased under option to a company, Northern Consolidated Limited.

History and Production.

It appears that about 1938 prospectors were favourably impressed by the "look" of the outcropping ironstone blow at 00 and 70S, and decided to put an adit into the hillside about 50 feet below the highest point of the outcrop. No. 1 ore body was intersected at 80 feet from the mouth of the adit. The discovery of this ore body may be considered very fortunate as the ore did not outcrop at the surface.

After the ore had been extracted, a winze was sunk which followed the contact of quartz-hematite and hematite-rich brecciated slates. The war prevented further exploration at that time. At the end of the war, the McGrath brothers drove a second adit (No. 2 adit), 30 feet below the previous one, and 188 feet in length. A little very coarse gold was found at 178 feet from the portal.

Recorded production from the mine is as follows:—

Date.	Ore.	Gold (by Amalgamation).	Recovery by Amalgamation.
	Long tons.	Fine oz.	Dwt. per ton.
July, 1938, to June, 1939	296	207	14.0
July, 1940, to June, 1941	122	55	9.1
July, 1941, to June, 1942	40	31	15.5
Total	458	293	12.8

The gold content of the sands is unknown. Private reports indicate that not all the above ore came from the Three Keys mine. There has been no production since July, 1952.

General Geology.

The Three Keys gold mine is situated on the northern slopes of a steep-sided residual of Tertiary peneplain. Outcropping quartz-hematite bodies, which are the dominant features of the hill, appear to project above the level of the former Tertiary peneplain, indicating that they were possibly island hills in the old land surface. The flat surrounding country is generally referred to as the "bulldust" plain.

The country rocks in the area covered by the lease are chiefly blocky slates, shales and tuffaceous sandstones. In some places, jasper bands lie parallel to the bedding of the slates. Interbanding of the slates and sandstones is very common, and it is difficult to draw a boundary which would divide areas in which sandstone predominates from those mainly composed of slate. However, the mapping shows that the older rocks on the lease are mostly sandstone, and are overlain by predominantly fine-grained beds.

Economic Geology.

Lodes.—Two large lenticular quartz-hematite bodies, one 190 feet long and 70 feet wide, and the other 87 feet long and 30 feet wide, occur on the leases. Several very small ironstone bodies outcrop near the south-west corner of the area mapped. These quartz-hematite masses are strongly jointed, and slickensides are present on some of the surfaces exposed. Underground, the joints are invariably filled with a kaolin-like white clay. Underlying the largest mass of ironstone is a zone of white leached breccia, conformable with the bedding of the surrounding sediments.

Closely associated with the quartz-hematite bodies is the hematite-rich slate breccia in which the ore-shoot has been localized. A cross-section of the hematite-rich slates shows a decrease in the width of the lode from 36 feet on the upper adit to 25 feet on the lower adit. It is possible that the lode may bottom on the sandstone-slate contact at 60-70 feet below No. 2 adit. No. 1 orebody is of extremely small size, its dimensions being length 26 feet, width 6-11 feet, vertical extent 22 feet. In section, the ore-shoot is more or less rectangular, and is bounded by faults on the western margin and by quartz-hematite on the southern and eastern margins.

A shallow shaft sunk in the larger quartz-hematite body at 210W, 130S is reported to have exposed low-grade ore. The gold may be confined to the kaolin which fills joints in the ironstone mass.

Structural Control.

Bedding and pitch readings show that the sediments have been folded to form a broad basin-like structure with the major axis trending east-west. Regional studies show that the basin is possibly part of an east-plunging structure.

Folding movements have induced east-striking breccia and a north-striking fault zone in the sediments; the breccia has been replaced by quartz-hematite lodes.

The ore shoot is localized along north-striking Fault A, near the base of the eastern quartz-hematite lode.

Maple Leaf Mine.

The Maple Leaf mine is situated 7½ miles from Tennant Creek on a magnetic bearing of 67°. The mine was owned and worked by L. Purkis and E. Wallers in 1948-50, but has since been abandoned. No ore has been obtained from the lease but it is reported that 27 oz. of gold were obtained from the vuggy quartz-hematite near the present shaft.

Rock types exposed on the lease consist of coarse-grained and medium-grained tuffaceous sandstone, and well-bedded blocky slates, silicified in part. These rocks form part of the north limb of an asymmetrical anticline whose axis trends in a general easterly direction. Shearing and crushing has taken place along the steep limb (80° north to vertical), and the crush zone has been partly replaced by a quartz-hematite mass 2½ feet wide, with intergrown chalcopyrite crystals in places. The quartz-hematite is a vuggy mass at the surface, is gossanous-looking, and lies in a greenish chlorite and talc schist peppered with microscopic grains of hematite. Underground the schist contains small siliceous quartz-hematite lenses heavily stained with manganese oxide.

This mine has no prospects, because of the small size of the lode and the absence of any favorable sedimentary horizons of appreciable size.

Mem-Sahib Mine.

Introduction.

The Mem-Sahib gold mine was surveyed and mapped in May, 1950, by J. F. Ivanac, B. P. Walpole, and E. M. Bennett.

The road serving the mine is well graded and accessible for most of the year. The distance on this road to the Government Battery is about 8 miles.

The owners and joint managers are K. Kittle and J. Monckton.

History and Production.

The first recorded production from the mine was for the year 1937-38 and production was continuous up till 1942. During World War II. production ceased and no further crushings were recorded till July, 1949, when the owner was G. Kittle.

Year.	Tonnage.	Recovery by Amalgamation.	Tailings.	Fineness.
	Long tons.	Dwt. per ton.	Dwt. per ton.	
1937–38	29.0	11.8	4.3	..
	23.5	25.8	6.6	..
	22.0	22.4	4.4	..
1938–39	10.68	12.8	3.1	..
1939–40	33.03	3.9	..	..
1940-41	39.36	13.9	5.9	..
1941–42	22.17	6.1	3.0	..
July, 1949	21.6	11.33	1.9	890
Total	201.34	13.1	4.1	..

The first workings on the lease were shallow open cuts in mineralized mudstone and kaolin. These were followed by a shaft which was sunk to a depth of approximately 20 feet. This shaft is in disrepair and not accessible, owing to partial filling with mullock. At a later date another shaft was sunk from which levels were put in at 20, 55 and 78 feet.

At the time of the survey work on one level only was in progress—the 55-ft. level.

Economic Geology.

The main quartz-hematite lode, in the western side of the lease, is ovoid, and is 50 feet in length and has a maximum width of 30 feet. It is composed of blue-black hard lustrous hematite which gradually gives place on the margins to kaolinized and highly mineralized mudstone. This lode has been worked from shafts and shallow pits, and most of the ore mined has been obtained from the contact between the quartz-hematite and the mudstone. No ore has been found in the lode exposed by the underground workings.

The eastern lode is lenticular with a minimum of curvature of the southern edge. Generally the lode is ochre-yellow, banded, vuggy, and cavernous with quartz crystals, and is jasperoid in character. No ore has been found in or near it.

Little Wonder Mine. (Plates 30 and 31).

Introduction.

The Little Wonder gold mine is situated approximately 9 miles from Tennant Creek township, on a bearing of 65°. The mine is reached by following a graded track which runs from the township to the mine. No. 3 Government Battery is 9 miles south of the lease. The lease was manned by Mr. W. Spredborough, Sr., and Mr. W. Spredborough, Jr., at the time of the examination.

History and Production.

Before the war, shallow pits and costeans were sunk on the lease, and it is reported that 114 tons of ore, which yielded 27.32 oz. of gold, were mined. In view of the limited size of the mine workings it is difficult to see how 114 tons of ore could have been obtained.

After the war, W. Spredborough and son took over the lease and carried out some prospecting. No. 2 shaft was sunk in lode material but was abandoned in favour of the present shaft, No. 1. This shaft has been sunk to a depth of 60 feet, but to date no production has resulted from this work, and no ore was in sight at the time of inspection.

Economic Geology.

Lode.—The only indication of quartz-hematite at the surface is a small outcrop 5 feet in diameter exposed in a costean at 15W, 20S. In the 38-ft. level drive from No. 1 shaft, a hard dense quartz-hematite mass, with a steep northerly dip, has been intersected. The mass is fractured and many of the fractures are filled with kaolin but no gold has so far been found in this rock.

A hematite-rich brecciated slate has been exposed in No. 2 shaft, and over a width of 20 feet is reported by the owners to assay 7 to 8 dwt. per ton.

Ore of payable grade is reported from the elongated pit at 30S, 20W (Plate 30). A sample of the ore shows that the bright yellow gold is found in fractures in quartz. The quartz occurs as ramifying veins, dull white in colour and exceedingly vuggy. The ore represents a small local concentration and has not been traced beyond the limits of the open cut.

Coarse gold has been found in the soil south-east of the open cut, and "colours" extend from the present mine workings to the shallow shaft near the road. Efforts to find the source of gold have not been successful and it seems likely that this surface gold has been shed from an eroded ore body.

Structural Geology.

The quartz-hematite body and the hematite body and the hematite-rich brecciated slates are localized in the northern limb of a syncline plunging south-east. The dip of the sediments ranges from 42° to 70° south; minor drag-folds plunge at 55° south-east.

The dip of the quartz-hematite body ranges from vertical to 85° north, parallel to regional fracture cleavage. Its pitch is unknown, but is thought to be in the same direction as the plunge of minor drag-folds, though considerably steeper.

Mount Margaret Mine.

The Mount Margaret mine is situated 9½ miles from the Tennant Creek township on a magnetic bearing of 65°. The mine was worked for a short period in 1948, but since that date the lease has been abandoned. Workings consist of two very shallow shafts, the northern one of which was 9 feet deep at the time of investigation.

The rocks consist of interbedded sandstone, hematite, shale, and mudstone, which have been folded to form the south limb of an anticline plunging 22° east. Shearing on the limb of this fold has led to the formation of crush zones which have been replaced by quartz-hematite.

Two quartz-hematite bodies crop out on the lease, the larger of which is 40 feet wide. They consist of dense specular hematite, quartz, and large patches of red jasper. Some bismuth oxide and limonite are also present. Gold, visible to the naked eye, and visible by dollying and panning, has been found.

Mauretania Mine.

The Mauretania gold-mining lease is situated 11 miles east-north-east of Tennant Creek township. The lease has not been worked since 1942, and up to that date 48.6 tons of ore had been produced for a total recovery of 86.5 dwt. per ton.

The lode forms portion of an east tapering ridge, which rises about 50 feet above the surrounding alluvial plains. The ridge consists of interbedded medium-grained and fine-grained tuffaceous sandstone, mudstone, and hematitic shale, which have been folded and sheared. Quartz-hematite lodes, subsequently enriched with gold, have replaced the crush-zones. Crushings have been obtained from the richer portions of the lode and from shed gold in eluvial placers on the edge of the lode. The richest "shed" gold was obtained from pebbles intersected by ramifying limonite stringers. Bismuth carbonate and quartz veins are associated with the ore.

Plain Jane Mine.

Introduction.

The Plain Jane gold mine (G.M.L. No. 38E) is 7 miles by formed road north-east of Tennant Creek township. It lies on the south-eastern flank of a line of flat-topped residuals of the old Tertiary peneplain. The Lone Star gold mine lies 300 yards to the south-west.

At the time of the survey the mine was being worked on tribute by C. Jenkins.

History and Production.

Production figures for ore treated at the Government Battery show that the mine was producing in 1936-37, but it is not known whether any earlier work on the present lease was done. Spasmodic production has taken place from 1936 to the present date. The following table gives the production figures of the mine for ore treated at Government batteries:—

Date.	Ore Produced.	Gold Won by Amalgamation.	Tailings
	Long tons.	Dwt. per ton.	Dwt. per ton.
1st July, 1936, to 30th June, 1937 ..	112.0	10.4	No record
1st July, 1937, to 30th June, 1938 ..	57.4	24.0	
1st July, 1938, to 30th June, 1939 ..	5.35	33.7	
1st July, 1939, to 30th June, 1940 ..	117.84	12.2	
1st July, 1940, to 30th June, 1941 ..	154.02	20.4	
1st July, 1941, to 30th June, 1942 ..	400.85	5.06	
1st July, 1942, to 30th June, 1946 ..		No production	
1st July, 1946, to 30th June, 1947 ..	207.23	17.5	..
1st July, 1947, to 30th June, 1948 ..	33.65	6.86	..
1st July, 1948, to 30th June, 1949 ..		No production	
1st July, 1949, to 30th June, 1950 ..	53.0	3.4	..
1st July, 1950, to 30th June, 1951 ..	30.0	3.5	..
Total	1,171.34	11.4	..

Access to the main workings is by means of a 40-ft. vertical shaft (now filled to 32 feet) to the east of the main stope and by a 150-ft. horizontal adit which penetrates the hillside from the 500-ft. datum and is connected to the main stope by ladder ways. The adit is 63 feet below the collar of the shaft; it ends to the west of the main stope. An inclined way leads from the present floor of the shaft at 32 feet to the main stope. Also there is an open cut and two sub-levels joined by winzes a few feet to the west of, and connected to, the shaft. They probably extend to 26 feet. Horizontal development in the mine totals 300 feet and vertical development 70 feet.

Ore has also been taken from a small open cut in the north side of the northernmost outcrop of quartz-hematite. Prospecting costeans are indicated in the surface plan of portion of the lease.

General Geology.

The quartz-hematite blows with which the gold is associated on the Plain Jane lease form part of a disconnected line of lode which includes the True Blue, Arizona, Maple Leaf, The Trump, and Great Bean gold mines, and many unworked quartz-hematite blows.

The sediments on the lease are typically sandstones, though some more incompetent beds such as shale and claystone are present. They belong to the Warramunga Group. Silicification has given rise to some jaspery beds near the major quartz-hematite bodies.

The quartz-hematite bodies are generally massive and sharply defined. There are two major bodies near the crest of the mine hill, and a third group of smaller outcrops with which the main lode is associated. The westernmost occurrences of the quartz-hematite are more quartz-rich than elsewhere and contain jasper lenses.

The ore is contained in a hematite-rich brecciated mudstone. The main structural controls may be summarized as follows:—

(*a*) east–striking shears show marked evidence of movement on the eastern end and are traceable by a crush zone only in the western end;

(*b*) north-east–striking cross-faults intersect the east–striking faults and form the east and west walls of the ore;

(*c*) the intersection of these two types of shears imparts a westerly pitch to the lode;

(*d*) ore has been localized where these shears intersect a mudstone horizon.

Black Cat Mine. (Plate 32.)

Introduction.

The geology of the Black Cat mine was mapped in October, 1950, by J. F. Ivanac and E. M. Bennett. The mine is situated on the Pigeon Holes road, 10½ miles from Tennant Creek and 9½ miles from the No. 3 Government Battery. L. Purkis and E. Vallens owned and operated the mine at the time of the survey.

History and Production.

The mine was worked before 1937, but the records of owners and tributors is not known up to that date.

Total production figures up to the end of 1936 were 472.4 tons of ore yielding 282.58 oz. of gold. Detailed production and yields of the ore mined after 1937 are given in the table below:—

Date.	Production.	Recovery by Amalgamation.	Tailings.
	Long tons.	Dwt. per ton.	Dwt. per ton.
To December, 1936	472.4	11.9 (probably includes recovery from tailings)	..
1st July, 1937, to 30th June, 1938 ..	332.25	12.1	(Dec., 1938, av. 2.6)
1st July, 1938, to 30th June, 1939 ..	610.45	10.8	..
1st July, 1939, to 30th June, 1940 ..	609.78	5.27	..
1st July, 1940, to 30th June, 1941 ..	173.0	5.5	..
1st July, 1941, to 30th June, 1942 ..	8.81	8.0	5.3
Total	2,206.69	9.12	..

A geophysical survey of the lease was conducted in 1936 by the Aerial Geological and Geophysical Survey of Northern Australia (Geophysical Division). They concluded that a low normal value of magnetic intensity is present, but no correlation between the lode and magnetic results were obtained. No major magnetic anomalies in the area were revealed.

The surface workings consist of three shafts, No. 1, No. 2 and No. 3 (Plate 32), and an adit level.

Two of the shafts, No. 2 and No. 3, were in a bad state of repair and inaccessible at the time of the survey and the collar of No. 2 shaft had collapsed.

No. 1 shaft was in excellent condition, but the absence of ladderways and hoisting gear prevented access.

The adit level portal is situated at 20N, 77E and opens out into a stope approximately 85 feet in length to the west and with a maximum width of 30 feet and maximum height of 22 feet.

General Geology.

The mine is situated on a low escarped hill which consists of quartz-hematite, quartz-jasper-hematite, and sediments of the Warramunga Group. Outcrops on the hill slopes are poor owing to the heavy scree cover. The sediments are predominantly sandy in character, the larger part being coarse sandstone, fine argillaceous sandstone, and coarse tuffaceous sandstone. Silicified hematite-rich slates, sandy shales, and fawn slates, have been exposed in a costean (60S, 30W, Plate 32), and in the road cutting (100N, 80E, Plate 32).

Economic Geology.

Lodes.—Two quartz-hematite bodies crop out on the lease. Of these, the smaller is of no importance and will not be discussed here. The larger quartz-hematite body is lenticular and is centred at 00, 50N (Plate 32). Generally the quartz-hematite is hard lustrous blue-black with no megascopic quartz. In the north-east section it grades into a silicified sediment or jasper with quartz-hematite segregations. The quartz-hematite has partly replaced brecciated sandstones, slates, and mudstones. It forms the backs of the stope and is "underlain" by altered sediments. Plate 32 shows the position of the ore in these sediments. Mineralogically, the ore is a highly weathered friable brecciated fine sediment, possibly a siltstone. The low-grade beds of ore which separate the workable ore-shoots are slightly coarser in grain than the siltstone. It was reported that the ore is free of massive quartz-hematite segregations, and that the massive hematite in the backs of the stope contains no gold.

From the limited amount of structural information available it is suggested that the lode and associated ore-shoots occur in the faulted south limb of an anticline which plunges flatly west. Plunge-changes have been mapped in many places and these may play a part in lode localization.

High grade ore is found where the crush zone intersects a mudstone or siltstone member. Consequently the ore occurs as beds which range in dip from 20° to 40° south.

Mammoth Mine.

The Mammoth gold mine is situated near the remnants of No. 2 Government Battery and 14½ miles north-east of Tennant Creek township. This mine was the proposed site of major operations by a company which erected a ten-head stamp battery before any ore was discovered. Subsequently the company went into liquidation and the Battery was taken over by the Mines Department, Northern Territory Administration. The lodes form portion of a conical residual which rises about 75 feet above the general level of the plain. Workings consist of shallow cuts into the hillside and three short adits (two are 15 feet in length). Four hundred and thirty-nine tons of ore, which assayed 4.9 dwt. per ton, have been produced.

Interbedded sandstone, shale and hematite shale have been folded to form a steep north limb of an east-plunging anticline. Shearing and brecciation have taken place on the north limb and crestal region of the drag-fold. The north-dipping crush zone has been partly replaced by a lenticular mass of quartz-hematite.

The lode is 40 feet wide and consists of 20 feet of crushed and altered sandstone, mudstone and siltstone, and 20 feet of quartz-hematite. The hematite is dull, hard, massive, and contains very little gold.

Most of the gold ore was taken from shallow surface workings, in partly replaced brecciated mudstone and siltstone.

BLUE MOON AREA.

Blue Moon Mine (Plates 33 and 34).

Introduction.

In 1949, N. H. Krasenstein and J. F. Ivanac, in the course of field work on the Tennant Creek Gold-field, mapped the geology of the Blue Moon gold mine. The mine is 18 miles by road from Tennant Creek, and is situated 27 miles from the township on a magnetic bearing of 74°.

The mine was discovered by H. J. Ward, who successfully mined a small ore-shoot, and then passed the lease over, under option, to Gold Boring and Prospecting No Liability. This company carried out some underground development coupled with diamond drilling, but met with no success. In 1950, the option was relinquished and the mine reverted to the original owner.

Production and Workings.

Production figures of the mine are shown in the table below.

Date.	Production.	Recovery by Amalgamation.	Recovery (by Cyanidation) of Tailings.
	Long tons.	Dwt. per ton.	
April, 1935	17.5	40.6	8.1
July, 1935, to June, 1936	68.5	16.0	3.2
July, 1937, to June. 1938	61.25	21.2	9.8
July, 1938, to June, 1939	370.70	60.9	15.5
July, 1939, to June, 1940 . ..	1,056.98	113.9	23.5
July, 1940, to June, 1941	539.70	90.2	9.7
July, 1941, to June, 1942	609.58	51.7	11.8
July, 1942, to June, 1943	564.17	19.2	7.2
Total	3,288.38	72.0	14.6

The ore mined by Mr. Ward was treated at the now dismantled Ghan's Battery situated about 4 miles south of Tennant Creek. Mr. Ward subsequently carted the tailings back to the Blue Moon lease and extracted the remaining gold by cyanidation.

The lease has been developed by five shafts (Plate 33), with short crosscuts and drives at the base of the shafts and at intermediate levels.

General Geology.

The mine is situated on a low-lying residual of the old Tertiary peneplain, which presents an abrupt scarp to the north and north-west and slopes away gently to the south-east. The sedimentary succession exposed is as follows:—

Top—

Medium fine-grained sandstone and cherty slate.

Medium-grained sandstone.

Fine-grained sandstone.

Bottom—

Mudstone with fine-grained sandstone bands.

These rocks have been folded to form the south limb of an anticline pitching 20° east. Shearing and brecciation as a result of the folding movements have localized two major quartz-hematite bodies and several minor ones, near the crestal region of the fold.

Economic Geology.

Lode.—Two large and several smaller quartz-hematite blows outcrop on the lease and form the only visible lode for 2 miles around. The main lode, or northernmost lens, is 240 feet in length and 85 feet in width, and the southern lode is 140 feet in length and 55 feet in width. The lodes are similar in mineralogical composition to other lodes on the field: the northern margin of the main lode is very quartzose with intergrown and randomly-arranged hematite plates, and its southern margin consists of intergrown quartz and hematite. Underground, the lode has a massive footwall of quartz-hematite with stringers, blocks, and segregations partly or completely replacing the crush zone, and extending into the hanging wall.

The ore shoot is contained in this crush zone, and has been mined over a length of 55 feet, a width of 20 feet, and a vertical extent of 56 feet. The ore-shoot had been completely mined out at the time of inspection, but samples of ore shown by the owner consisted of hematite-rich brecciated mudstone, massive quartz-hematite segregations, and quartz-stringers; bismuth carbonate is present in the ore and indicates high grade. Gold is free-milling and is readily extracted from the ore by amalgamation and cyanidation.

Structural Control.

Distinctive structural and sedimentary control have combined to localize the ore-shoot and lode of the Blue Moon gold mine.

The lode lies in a crush zone in the drag-folded south limb of an anticline plunging 20° east, with its axis striking 80° magnetic, and the dip of its axial plane steeply south. A north-south axis of pitch-change at the eastern extremity of the lode may have played an important part in limiting the length of the original crush zone.

Massive sandstone members in the sedimentary succession have folded uniformly, whereas less competent overlying members have been markedly contorted and brecciated.

The cross section (Plate 34) shows that the ore-shoot is localized where the mudstone member of the incompetent beds is intersected by the crush zone. This constitutes the sedimentary control, which obtains on most other mines on the Gold-field.

Prospects of Further Discovery.

The present ore-shoot has been completely worked out, and there seems little prospect of further ore near this shoot.

Metallic Hill Mine.

The Metallic Hill gold mine is situated 25 miles from Tennant Creek on a magnetic bearing of 76°. The lodes were discovered in 1938 and since that date only 147.1 tons of ore, which assayed 23.1 dwt. per ton, have been produced. There has been no production since 1940. In 1949, Muturoo Copper Company took over the mine and carried out over 200 feet of development, with no results. Work was continued in 1950 without success, and the lease was subsequently abandoned.

The lease forms part of an isolated low rounded hill, surrounded by an extensive flat plain. The rocks consist, predominantly, of bedded sandstones with very narrow mudstone lenses. These rocks have been folded into gentle anticlines and synclines with an overall 18° east plunge. The axes of the major folds trend in a general east-west direction. Shearing of the north limb and crestal region of the structure has induced a zone of brecciation, which has been replaced by massive quartz-hematite lenses. The vertical structural controls, apart from the zone of brecciation, are unknown, but the horizontal controls are partly due to crossfolding. The eastern extremity of the lode is terminated by a possible north-south fault.

There are no ore reserves on this mine, and the brief inspection of the Geological Party suggests that other quartz-hematite lodes in the immediate vicinity will not contain gold, because of the thickness of unfavorable sandstone passing through the lode.

Gigantic Mine. (Plate 35.)

Introduction.

The Gigantic gold mine was geologically mapped in October, 1950, by E. K. Carter and E. M. Bennett. The mine is 16 miles by road from Tennant Creek township in an east-north-easterly direction. Two miles to the south-east is the Blue Moon gold mine. The lease (G.M.L. 46E), held by J. Hall, covers an area of more than 30 acres including a T-shaped hill with steep flanks in all directions except to the north-east where the slope is gradual. The mine workings are confined to the western "arm" of the T-shaped hill. A water-course passes 200–300 yards to the north of the lease. In it, within several hundred yards, is a lagoon which holds water for several months in the year. More permanent water is to be found at "The Pigeon Holes", 3 miles down-stream.

History and Production.

The lease was first worked in 1937, when gold was found on the surface at co-ordinates 20N, 55W (*see* Plate 35). Development on a large scale has never been undertaken, the usual number of men engaged in mining on the lease being one to three.

The lease has been explored by costeans of from 1–6 feet deep—*see* surface plan (Plate 35), and by four shafts with associated drives and cross cuts. No. 3 shaft through which ore is hauled by diesel-powered winch passes through the main stope to the 102-ft. level.

Access to the main workings is by an horizontal adit (driven from the north face of the hill and leading to the main stope) at a depth of 42 feet below the collar of the main shaft (No. 3). Several small drives off the adit and main stope followed a small "leader" of ore. The greatest depth below the collar of the main shaft which the workings have reached is 118 feet in a winze from the south cross cut off the 102-ft. level.

Production, as recorded by the Mines Branch, Northern Territory Administration, is set out in the table below:—

Year.	Ore Treated.	Gold Yield by Amalgamation	Tailings.	Gold Fineness.
	Long tons.	Dwt. per ton.	Dwt. per ton.	
1937–38	73.75	19.9	6.4	..
1938–39	..	..	..	..
1939–40	79.55	17.6	8.8	..
1940–41	39.4	6.7	4.1	..
1941–42	20.05	7.7	2.0	..
1942–43 to 1947–48		(World War II.)		
1948–49	161.4	7.3	3.7	885 and 910 (two crushings)
1949–50	374.9	7.8	5.9	.
September, 1950	375.3	7.7	5.3	..
Total	1,124.35	9.1	6.3	..

General Geology.

The hill which occupies most of the area of the lease is composed of massive quartz-hematite, unaltered sediments, and brecciated and hematite-impregnated sediments. The high points of the hill are generally of massive quartz-hematite.

Massive quartzitic sandstone, tuffaceous sandstone, fine-grained sandstone, argillaceous sandstone, sandy claystone, sandy shale, and mudstone are the main rocks on the lease.

Underground, the sediments consist of shales and mudstone. On the 102-ft. level red mudstone is very fine and towards the surface grades into siltstone. Both the shales and the mudstone are very incompetent rocks.

Economic Geology.

Lode.—There are several massive quartz-hematite bodies on the lease. Their distribution can be seen from the surface plan (Plate 35). The bodies are interconnected by hematite-rich sediments. It will be seen that the long axes of the bodies lie in two general directions on bearings of 300° and 60°.

The quartz-hematite is hard, lustrous, and blue black, and variations in quartz content and grain size within the bodies are apparent. Late-stage micaceous hematite is also present. The quartz-hematite mases are replacement bodies, hence the boundaries are normally gradational, giving way to hematite-rich sediments, particularly in crush zones.

The ore is found in crushed hematite-rich mudstone and fine-grained argillaceous sandstone, generally underlying massive quartz-hematite bodies. Ore found in the 26-ft. stope and the main adit form portions of the one ore body, separated by a transverse pillar. The ore-shoot has a pitch length of 54 feet, maximum horizontal length of 30 feet and maximum width of 13 feet. It dips steeply to the north and pitches towards the east.

The main ore body is defined by the outline of the main stope. It has a width of 18 feet. It dips south at approximately 45° and pitches 60° east. Additional ore has been won from leaders followed from the main ore body.

On the 102-ft level ore has been located in three places (*see* Plate 35); it is probable that the three occurrences are parts of the one ore body. If so, a minimum of several hundred tons of ore would appear to be available for immediate extraction. The lode material on the 102-ft. level is not crushed to any degree and hematite stringers are plentiful. The gold is free, and has a coarse grain size in places.

Structural Control.

The lodes occur on the south limb of an east-plunging anticline, in a zone of marked pitch change. Considerable faulting is associated with the folding. The ore-shoots are localized where shear zones intersect favourable siltstone and mudstone horizons.

The folding is asymmetrical with fold axes inclined steeply to the south: this is shown clearly by the shales on the 102-ft. level. Cleavage is not strongly developed, except locally; where observed, it dips south at 56° to 66°.

There appears to be a major crush zone striking east-west, with minor faults striking off it at various angles. Possibly the ore bodies have been localized at the intersection of minor faults with the main east-west crush zone, which is strongly brecciated. The lesser degree of brecciation on the 102-ft. level is possible offset by the more favourable character of the mudstone.

Prospects of Further Discovery of Ore.

Mining of the recently located ore-shoot on the 102-ft. level should provide the additional information necessary to predict new ore repetitions. Present evidence is scanty because of the lack of development outside the confines of the lode.

However, it appears that the general pitch direction of the lode is to the east-south-east and future exploration underground should be down dip and down pitch. In this connexion it is pointed out that a rapid magnetometer traverse by a geophysical party from the Bureau of Mineral Resources (Mr. M. Allen and Mr. J. Quilty) showed that there is a magnetic body (i.e., quartz-hematite or quartz-magnetite) at a depth of some 200 feet east-south-east of the present workings. This suggests that the quartz-hematite bodies pitch east-south-east at approximately 60°.

New Moon Mine. (Plates 36 and 37.)

The New Moon gold mine is situated 12 miles from Tennant Creek on a magnetic bearing of 70°, and is reached by following a graded gravel track which runs from the town to the lease. Mr. C. Jenkyns owns and works the mine.

The lease has been prospected intermittently for about seven years, and although high gold assays have been yielded from samples in some places no ore bodies have been discovered. The exploration has no doubt been encouraged by the close proximity of the Blue Moon gold mine, a producer of £200,000 to date.

The mine is situated on the southern side of a conical hill which rises to a height of about 35 feet above the surrounding alluvial plains. Rock exposures are very poor, and where observed consist of interbedded slate, sandy shale, and pale purple tuffaceous sandstone.

Several elongated lenses of quartz-hematite are exposed on the lease. They outcrop in a leached brecciated zone, 85 feet wide at the surface, and 45 feet wide on the 60-ft. level. The quartz-hematite lenses are very siliceous and in places stained with manganese oxide. This mineral is very common on the 60-ft. level. Micaceous hematite and limonite are also present.

The fracture zone (from the limited information) appears to be localized on the crest and limbs of an anticline plunging 30° south.

BLACK ANGEL AREA (Plates 38 and 39).

Introduction.

The Black Angel–White Devil leases were examined as part of the Bureau of Mineral Resources field activities in 1949. These leases, 22 miles from Tennant Creek along a magnetic bearing of 296°, were of particular interest because they are situated on the westernmost outcrops of quartz-hematite on the Tennant Creek Gold-field. A graded gravel track leads from the township to the mine, which is approached by travelling north along the Stuart Highway for 2 miles and thence in a general north-westerly direction for 25 miles. About one-third of this track has been cut in alluvium and consequently is impassable for short periods in the annual wet season. In this case an alternative road via No. 1 Battery can be used—north along the Stuart Highway for 7 miles, north-west for 16 miles to No. 1 Battery, thence 13 miles south-west.

Mr. R. Turner owns the leases and he employs two miners to carry out development work. There are four leases included in his property, Black Angel, Black Angel Extended, White Devil, and White Devil Extended, and these have been amalgamated.

These leases will be discussed together in the general geology section, but will be sub-divided into Black Angel–Black Angel Extended and White Devil–White Devil Extended in the economic geology section.

The field work was carried out by J. F. Ivanac and N. H. Krasenstein.

History and Production.

The lode was discovered in 1935, and systematic panning of surface outcrops the soil resulted in the location of several small ore-shoots, which were mined by open-cut methods. Since that date yearly production was moderately consistent until 1942, when, under National Security Regulations, the mine was closed down. In 1947, the mine was re-opened and a search for new ore-shoots began.

The Geophysical Section of the Aerial Geological and Geophysical Survey of Northern Australia conducted a magnetic survey of the Black Angel, White Devil, and adjacent Crusader lease in 1937. Two major and a number of minor anomalies were discovered, but the former are not within the range of present mining operations.

Yearly production figures of the mine are listed in the following table:—

Year.	Ore Produced.	Recovery by Amalgamation.
	Long tons.	Dwt. per ton.
1st July, 1935, to 30th June, 1936..	221.3	18.0
1st July, 1936, to 30th June, 1937..	87.5	2.6
1st July, 1937, to 30th June, 1938..	134.8	18.2
1st July, 1938, to 30th June, 1939..	430.0	21.7
1st July, 1939, to 30th June, 1940..	1,163.06	6.9
1st July, 1940, to 30th June, 1941..	992.28	12.6
1st July, 1941, to 30th June, 1942..	1,207.63	7.6
1st July, 1942, to 30th June, 1947..	No production	
1st July, 1947, to 30th June, 1948..	575.52	7.3
1st July, 1948, to 30th June, 1949..	No production	
1st July, 1949, to 30th June, 1950..	1,183.5	6.7
1st July, 1950, to 30th June, 1951..	379.0	3.9
Total	6,374.59	9.4

The tonnage produced represents about 3 per cent. of the total gold mined at Tennant Creek, and the number of fine ounces is about 16 per cent. of total production, to the end of June, 1949. Till the end of 1942 ore from the mine was treated at No. 1 Government Battery, 11 miles north-east of the mine. This battery has closed down and ore has to be carted 28 miles to No. 3 Government Battery, 1 mile east of Tennant Creek township.

Plate 38 shows the workings on the leases, and at the time of the investigation only No. 2 shaft workings were being used. Most of the development was being done on the 103-ft. level (Plate 39).

General Geology.

The Black Angel–White Devil Leases lie on the north-western edge of a group of low-lying hills, which are bordered by a low flat-lying plain observed elsewhere on the Gold-field. Creeks trend in a general north-westerly direction and disappear in the alluvium of the plain. One of these creeks, Kras Creek, has cut its lower course in a wide river terrace which consists of partly consolidated scree and alluvium.

The rocks on the leases consist of interbedded conglomerate, coarse, medium and fine sandstones, cross-bedded sandy shale, shale, silty claystone, and medium-grained and fine-grained tuffaceous sandstones. The conglomerates are greenish-grey hard rocks which characteristically form the crests of ridges in the area, because of selective silicification by quartz veins and secondary processes.

Sandstones and shales predominate to the south of the mineralized area, whereas the sandy tuffs are almost entirely confined to the northern portion. The latter appear to abut sharply on to the quartz-hematite line. Red mudstone and fine-grained argillaceous sandstone, silicified at the surface, but soft and smooth underground, are predominant in the vicinity of the shear-zone. Southwards the rocks become sandier, and coarse-grained and medium-grained sandstones are present.

Conditions of sedimentation are probably shallow coastal or estuarine. The sediments were probably deposited along the edge of a coastline, where either the basin deepened slowly or the coastline receded. Deposition of the sandstones and shales coincided with the formation of the sandy tuffs. The gradation of sandstones into sandy tuffs indicates that some volcanic activity may have been in progress during sedimentation.

Economic Geology.

The mineralized lode on the Black Angel and White Devil leases consists of quartz-hematite lenses completely or partly surrounded by brecciated shales and fine-grained shaly sandstone impregnated with quartz and hematite stringers.

(*a*) *Black Angel Leases*.—The quartz-hematite lenses are of the type generally associated with gold on the Tennant Creek field. They are long narrow lodes with a maximum length of 260 feet and maximum width of 6 feet. The hematite fills parallel shears in a brecciated assemblage of shale, sandy shale, and very fine-grained sandstone; the crush zone has a maximum width of 80 feet. An outstanding metasomatic change accompanying the introduction of the lode was the sericitization of the crush rock, particularly in the vicinity of ore bodies.

Small ore bodies have been mined in several places, but the most important one was mined at 220E, 50S, where open-cut ore is indirectly connected to the main stope underground. This stope extends from 45 feet below the surface to the 103-ft. level, and has been mined over a length of 60 feet and a width of 17 feet.

Generally, the ore consists of sericitized lightly brecciated silty claystone with very little quartz-hematite. Bismuth oxide and bismuth carbonate are found in the ore and lode, either as irregular clots or associated with hematite in narrow stringers.

Gold is free-milling, and is commonly visible in the ore.

(*b*) *White Devil Leases*.—The quartz-hematite lodes that outcrop on the leases are among the largest on the Gold-field; that lying between 1,700E and 2,000E is 370 feet in length and 54 feet in average width, and that between 1,400E and 1,650E is 310 feet in length and 54 feet in width at the east end, and tapers to a point at the western end. There are numerous other ironstone blows of much smaller size (Plate 38). These lodes are surrounded or partly surrounded by brecciated mudstone and fine-grained argillaceous sandstone, impregnated with quartz-hematite stringers.

Structural Control.

The key to the general structural control of the lodes has been provided by the massive competent conglomerate beds. These beds have been drag-folded, and the nature and attitude of the bedding indicate that the overall structure is the south limb of a west-plunging anticline. The limb of the fold dips approximately 60° south and plunge ranges from 45° to 50° west. Whereas the conglomerate has folded uniformly, the only alteration being slight shearing and jointing, the overlying less competent lenses have buckled and sheared. The brecciated zone consists of strongly folded crushed mudstone and fine-grained sandstone, with east-west faults (now hematite-filled) parallel to the direction of regional cleavage. This zone is not continuous, as three beds of conglomerate intersect the crush zone, and it tends to die out at these intersections.

Small ore-shoots are found where a mudstone lens has been brecciated and attenuated by shearing forces, within the crush zone.

The main ore-shoot—that mined from No. 2 shaft—is associated with a bedding-plane fault, with dip ranging from 50° to 60° north-west. This fault may have been induced by shearing along a sandstone-mudstone contact (noted in No. 1 shaft on 150-ft. level).

The lode on the White Devil lease is a direct continuation of the main crush zone and probably represents an extension of the crush zone to the east.

Post-lode faulting, at the junction of Kras Creek and the lode, is suggested by displacement of the conglomerate and flexing of the fracture cleavage. This faulting has not affected the ore bodies.

Secondary Enrichment.

The concentration of high-grade ore near the base of a lateritic profile (a fossil water-table level) suggests that secondary enrichment may have played a part in gold concentration. However, there is no apparent zone of surface impoverishment of gold on these leases as small ore-shoots have been mined at the surface.

Prospects of Further Discovery.

The Black Angel and White Devil leases cannot be expected to be large producers of gold, in view of the working history of the mine and the wide distribution of ore-shoots (Plate 38). However, it is possible that small ore-shoots will be found along the present line of lode at the surface or as a continuation down-pitch of mined-out ore-shoots.

MARION ROSS AREA.

Great Western Mine.

The Great Western mine is situated 25 miles north-west of Tennant Creek township, and is reached by following the Stuart Highway for 7 miles north of the town, thence along a formed road west-north-west for 16 miles to No. 1 Government Battery, and thence south-west for three miles. The mine is owned by Mr. R. Turner, and is worked by two men under contract. To date, 1,857.99 tons of ore which assayed 5.4 dwt. per ton by amalgamation have been produced.

Ore has been obtained from a shallow elongated open cut; apart from this the only other workings on the lease are a 48-ft. shaft and a long south adit.

The workings are situated on the north side of a very steep-sided residual of the Tertiary peneplain. Rocks outcropping on the lease belong to the Warramunga Group and consist of interbedded sandstones, mudstones, and blocky hematite shale. Sharp folding of these beds has resulted in the formation of a strong east-striking crush zone which has been partly replaced by massive quartz-magnetite-hematite bodies, veins and segregations. The residual crush zone consists of kaolinized mudstone, cherty slate, and sandstone. The ore-shoot lies in the crush zone on the north edge of the main quartz-hematite mass, and was probably a mineralized brecciated mudstone.

The lode lies in the crestal region and sheared northern limb of an anticline plunging 15° west. The axial plane of the fold is probably parallel to regional fracture cleavage, which strikes east and dips 75° north. There are several minor pitch reversals of the main fold which are probably responsible for the ultimate termination of the lode.

Geophysical results in this area showed very large and irregular anomalies, probably the result of the high magnetite content of the lode. The normal value of magnetic intensity is generally high in this part of the Gold-field.

Olive Wood.

The Olive Wood gold mine, situated 2 miles south of No. 1 Government Battery, has produced 262.86 tons of ore, which assayed 10.26 dwt. per ton. The prospect is owned by Mrs. Makinson. The workings consist of two shallow open cuts, two shafts (the main shaft is 70 feet deep and has a north cross cut from the 70-ft. level) and several costeans.

An elongated quartz-hematite lode 150 feet in length, striking 220° and dipping 68° south, constitutes the main lode. This massive lode is cut by numerous quartz veins and stringers ranging in width from one-eighth of an inch to an inch. A conjugate crush zone which contacts the main lode at the 70-ft. level strikes 202° and dips vertically. This zone has been worked in two places for gold, which was associated in some places with rose-coloured translucent quartz. Wolfram has been found on the 70-ft. level, but systematic sampling of this level revealed very low grades.

The ore-shoots on this mine are probably localized in a tension gash complementary to the main crush zone.

Havelock Mine.

The Havelock mine is situated 1 mile south of No. 1 Government Battery and has produced 57.12 tons of ore of average grade 8.5 dwt. per ton. Workings consist of costeans, 65-ft. shaft from which 100 feet of cross-cutting has been done, and a shallow open cut.

Interbedded sandstones and mudstones have been folded into a fold probably plunging east, with brecciation and shearing on the southern limb. Two quartz-hematite bodies, one lenticular and the other Z-shaped, replace the crush zone, which probably dips steeply south. Ore has been won from the crush zone on the south side of the Z-shaped lode.

NORTH STAR AREA.

Northern Star Mine. (Plates 40 and 41.)

Summary.

The Northern Star gold mine is in the northernmost group of gold mines on the Tennant Creek Gold-field, 22 miles north of Tennant Creek township.

The ore-shoot, which is possibly an east-pitching shoot in a west-pitching lode, is localized in lightly sheared shales and mudstone.

An exploration programme is suggested.

Introduction.

A geological survey of the Northern Star gold mine was carried out in 1950. The objects of the survey were to determine the factors which localized the present ore-shoot, and to suggest an exploration programme to test the possibility of occurrence of further ore-shoots on the company's holdings.

The mine is at present being operated by Northern Star (T.C.) Gold Mines No Liability, and is managed by Mr. J. S. Higgins. The company holds three adjacent leases, namely:—

Northern Star No. 1—G.M.L. 85E.
,, ,, No. 2— ,, 86E.
,, ,, No. 3— ,, 87E.

The geology of the mine and of the area covered by the three leases was mapped by J. F. Ivanac, E. K. Carter, E. M. Bennett, and B. P. Walpole. The surface was mapped by plane table, the contours being established by spot height measurements with a telescopic alidade. The company's level plans were used for plotting underground geological information.

Location and Access.

The mine is situated approximately 22 miles from Tennant Creek township on a magnetic bearing of 350°. It is reached by travelling north along the Stuart Highway for a distance of 23 miles from the township and thence due west along an all-weather fireplough road for 2½ miles.

History, Production, and Workings.

First recorded production was in the financial year 1934-35, when 428 tons of ore were mined by open-cut methods in the vicinity of co-ordinates 500S, 400E (*see* Plate 40). Later the exploration was continued by sinking a vertical shaft to a depth of 100 feet. In 1937 exploration and development of the main shoot was conducted by the Central Gold Milling Company. This ore-shoot was outlined at the surface by deep costeaning and systematic sampling. No. 1 shaft was begun and sunk to a depth of 200 feet, and later deepened to 240 feet. Levels were opened at 100 feet, 200 feet, and 235 feet. A sub-level was also opened up at 150 feet from a rise from the 200-ft. level.

By 1942, when the mine was closed under National Security Regulations, the ore body has been developed to the 200-ft. level. It had been stoped out between the 50-ft. and 100-ft. levels, and between the 200-ft. and 235-ft. levels, for a total of 13,500 tons of ore. The stoped portions between the 50-ft. and 100-ft. levels were filled with mullock from a "glory hole" 100 feet north-west of the main shaft. The fill was rilled from the "glory hole" through passes into and from the 50-ft. stope. Of the 13,500 tons of ore mined, 5,194 tons were crushed and treated at the No. 1 Government Battery, 11 miles to the south-west, for an average yield of 4.2 dwt. of (fine) gold per ton by amalgamation, leaving an average of 5.4 dwt. per ton of gold in the sands; in addition to this, 6,902 tons of first-grade ore were treated at the Central Gold Milling Company's Battery, 6 miles east of Tennant Creek, and averaged 8.56 dwt. of (fine) gold per ton "over the plates". This gave a total recovery of gold won by amalgamation of 4,061 oz., fine. At the shaft head 1,172 tons of ore was left "at grass". This was treated at No. 3 Government Battery in two lots in January and August, 1949, to give an average of 5.1 dwt. per ton over the plates and 4.78 dwt. per ton in the sands.

The production figures recorded by the Mines Branch, Tennant Creek, are set out in the following table:—

Year.	Tonnage.	Gold (Fine) by Amalgamation.	Tailings.	Gold Fineness.
	Long tons.	Dwt. per ton.	Dwt. per ton.	
1934–35	100.0	25.5	No record	..
1935–36	328.0	20.3	No record	..
1936–37	50.1	3.6	6.4	..
1937–38	..	..	..	..
1938–39	1,868.29	8.7	2.3	..
1939–40	3,479.8	6.9	0.6	..
1940–41	4,232.2	6.9	1.9	..
1941–42	2,629.0	4.6	4.1	..
1948–49	515.55	5.5	4.6	..
1949–50	656.8	4.9	5.0	932 940 (two crushings)
1950	403.3	5.4	6.6	930
Total	14,263.04	6.95	2.37	..

After World War II. mining activities were resumed, and in 1947 a new company, Northern Star (T.C.) Gold Mines No Liability, was formed. Efforts have been concentrated on the development of the mine plant to facilitate efficient operation. A ten-head battery and cyanidation plant has been installed; the main shaft has been stripped to make it a three-compartment shaft capable of handling a regular tonnage of 2,000 tons of ore per month. In addition, the shaft has been deepened to 280 feet to reach the water-table. Seepage into the shaft will provide the necessary water for the treatment plant. This supply will be assisted by water from a nearby earth tank on the lease. Before the war, water had been obtained from a bore 2,000 feet to the north-east of the mine. The treatment plant started work in November, 1950, but was not in full production in February, 1951.

Previous Work.

The area covered by and surrounding the Northern Star and the adjacent North Star leases was included in a magnetometer survey of the Tennant Creek Gold-field carried out by the Aerial, Geological and Geophysical Survey of Northern Australia in 1937. The magnetic profiles showed disturbed conditions in the vicinity of outcropping quartz-hematite bodies. Some definite anomaly zones were discovered and these are shown on Plate 40.

C. L. Knight (1947) made a brief survey of the geology of the mine to estimate the ore reserves to that date. No further ore has been proved since then.

The results of a survey of the bismuth reserves of the mine are contained in an unpublished report by C. J. Sullivan in 1942. His results are shown in the assay plan (Plate 41). Some notes from his report are recorded below:—

235-ft. level—Six samples were taken; one returned 0.64 per cent. Bi over 7 feet and another 0.81 per cent. Bi over 5.5 feet. The remainder of the samples were very low in bismuth.

200-ft. level—Nine samples were taken; one assayed 1.12 per cent. Bi over 8 feet and another returned 0.30 per cent. over 7 feet; the remainder were very low.

150-ft. level—Thirty-four samples were taken from this section. One returned 0.72 per cent. Bi over 5 feet, another 0.68 per cent. Bi over 5 feet and a third 0.60 per cent. Bi over 33 inches. Two others gave 0.40 per cent. and 0.42 per cent. Bi over 5 feet. The remainder were very low.

100-ft. level—Seventeen samples were taken here. The three highest samples were 0.5 per cent. Bi over 8 feet, 0.6 per cent. Bi over 16 feet, and 0.90 per cent. Bi over 42 inches. The remainder were low. The first two samples mentioned were taken from a crosscut reported to be in lode.

50-ft. level—Of a total of 32 samples taken, the highest of six assayed was 0.15 per cent. Bi.

General Geology.

The region in which the Northern Star leases lie contains typical Warramunga Group sediments: fine-grained argillaceous and tuffaceous sandstone, some mudstone, and shales of various types. Seven miles to the north and north-west the massive quartzite and conglomerate of the Ashburton sandstone crop out, flanked to the south by interbedded sandstones, shales and quartzites.

For the purpose of this report the rocks which outcrop on the lease may be divided into two formations, A and B. Formation A has been mapped in the northern part of the lease and consists of massive ripple-marked sandstone, medium-grained argillaceous sandstone and cherty slate. Formation B comprises the rocks of the rest of the leases, and consists of fine-grained argillaceous and tuffaceous sandstone, shale and sandy shale, mudstone and hematite shale. The distribution of individual members is shown on Plate 40, but consistent segregation and interpretation of each type has been made impossible by paucity of continuous outcrop and irregularity of structure.

Formation A is overlain by Formation B and represents a more or less normal type of sedimentary gradation from coarser-grained to finer-grained facies.

Economic Geology.

The distribution of lodes on the Northern Star lease is shown on Plate 40, and for convenience the main lenses from north to south have been named No. 1, No. 2 and No. 3 lenses.

Dimensions of the Lode.

No. 1 *Lens.*—This lode is roughly triangular in shape with broadly concave margins. The base of the triangle is 470 feet long, in an east-north-east direction. The other sides of the triangle trend in a west-north-west and north-east direction and are 340 feet and 280 feet long, respectively.

Underground the lode has been developed in the Main Shaft to 273 feet, and on the 50, 100, 150, 200, and 235-ft. levels, and in no place have the developmental headings penetrated country rock. Maximum development is on the 100-ft. level where the lode has been opened up over a length of 225 feet and width of 90 feet. The plans show that little attempt has been made to explore outside the limits of the present ore-shoot.

No. 2 *Lens.*—This lens is very broadly lenticular with undulating edges. It tapers suddenly at the eastern end, and then expands slightly to an irregular north-south off-shoot. The long axis of the lens trends in an east-north-east direction and is 600 feet long. The maximum length of the axis of the off-shoot is 240 feet. The area of the outcrop is roughly 94,450 square feet.

The south-eastern section of this lode has been developed by shallow open-cutting, and by a shaft sunk to a depth of 104 feet. At 80 feet depth a level was driven 90 feet in an easterly direction. The shaft was developed in slate and the drive intersected the lode at 50 feet. Low values were reported. (This information was obtained from the Third Report on Magnetic Prospecting at Tennant Creek (A.G.G.S.N.A., 1937).)

No. 3 Lens.—This is the southernmost lens and up to the present time has not been explored for possible ore-shoots. The lode is approximately lenticular in shape with an extremely irregular outline. The long axis of the deposit, like those of No. 1 and No. 2 lens, trends in an east-north-east direction, and is 370 feet long. At right angles to this axis the maximum width is 160 feet. The southern edge of the lode runs roughly east-west.

Other Quartz-hematite Outcrops.—Many other lenses of quartz-hematite crop out on the lease. They are very variable in size, but nearly all have their long axis parallel to the east-north-east direction, except where the lode has replaced bedding. An example of the latter is a boomerang-shaped "blow" 130 feet long and 20 feet wide, which outcrops near 400N, 200E.

Mineralogical Composition.

The quartz-hematite lodes are very similar to those associated with other gold deposits on the field. The mineralogical content is limited, but the nature of crystallization, replacement, and alteration has necessitated the following classification:—

Type A: A limonite-rich quartz-hematite with cavities in the weathered surfaces separated by a thin ribwork of limonite, in some places silicified. The cavities range in size from 2 inches across to sub-microscopic. They are thought to have been formed by differential erosion and redeposition of limonite and secondary silica along cracks and fracture planes, even though they somewhat resemble leached gossans derived from sulphides.

Massive and crumbly quartz-hematite due to incomplete replacement of sediments may be associated with this type. Type A contains a bladed and micaceous hematite, which is soft, generally friable, and of brilliant lustre. It usually occurs as a filling in joint planes and fissures and in places as blebs in crushed hematite-rich sediment in association with limonite and kaolin.

Type B: A massive fine-grained quartz-hematite rock generally blue-black in colour. It is well-jointed and forms prominent outcrops owing to its resistance to erosion. In places joints in this lode are filled with late-stage micaceous hematite.

Type C: A massive quartz-jasper hematite. The jasper occurs as irregular blobs. Quartz has a similar character but may also form ramifying veins. This type is common on the southern leases.

Type D: A vein-filling type which has been altered to goethite. It has a radial or comb-like growth in section and its free surfaces are botryoidal or mammillary in form.

In No. 1 lens there is a continuous change in the nature of the hematite. On the surface the changes are from partially replaced sediment to dense massive quartz-hematite. The north-western margin consists of red and black quartz-jasper-hematites, which have formed a low steep scarp owing to their resistance to weathering; the rest of the lode consists of a partly-banded crumbly rock which represents a granular type of hematite replacement. In places there are massive dense black hematite segregations which strike parallel to the bedding. Along the eastern scarp the quartz-hematite is very pitted, with a prominent ribwork structure. The cavities are filled with a pulverulent type of hematite or limonite. This ribwork imparts a gossanous structure to the lode.

Underground the lode consists of massive hematite, micaceous hematite, bismuth oxide and carbonate, and partly replaced sandy shale. Micaceous hematite is found as veins on the northern wall of the lode, and in the footwall of the Higgins's Fault on the 200-ft. level and in the shaft at 273 feet.

TONNAGE OF No. 1 LENS.

Level.	Tons per vertical foot.
50-ft.	530
100-ft.	540
150-ft.	160
200-ft.	110
235-ft.	60

No. 2 and No. 3 lenses are very similar in composition, and unlike No. 1 lens in that the surface outcrop consists predominantly of quartz, hematite, and jasper.

In lens No. 2, lozenge-shaped boxworks and ribwork are very common. Botryoidal and mammillary hematite and goethite (after hematite) have been observed. The hematite in places is markedly stained with a scale of manganese oxide.

Later quartz-veins, 6 to 12 inches wide, which generally strike in a north-easterly direction, cut through a massive quartz-hematite body outcropping at 750S, 150W.

Silicified sandstone, mapped as jasper, outcrops in the northern part of the lease. Jasper lenses with no hematite have a comparatively limited distribution. Where mapped, the jasper is a reddish grey, dense, homogeneous rock, with a glassy to greasy lustre. It has no economic significance.

Structural Control.

General.—The Northern Star lodes lie in a markedly distorted section of the south limb of a west-plunging anticline. The folding movements have led to the development of major fold axes striking east-north-east, with minor ones striking north-north-west, and to associated shearing and crushing of the beds.

The major folds are upright with axial planes vertical or dipping very steeply north or south. In the competent massive sandstones the folds are symmetrical and broad, whereas the folding in the overlying less competent shales and fine sandstone is tight. With this range in degree of folding it has been impossible to interpolate accurately the positions of the main fold axes. The problem has been complicated also by the constant change in pitch of the minor folds and of the bedding on cleavage of the incompetent shales. Such pitch changes have limited the lateral (east-west) extent of the lode. The folding of the sediments was accompanied by intense development of fracture cleavage, which ranges in strike from east to north, and is either vertical or dipping steeply south. Undulating cleavages are very common.

Folding movements have developed simple thrust faults, and possibly more complicated rotational faults. Higgins's Fault, a simple thrust fault, does not show on the surface, but has been observed underground on the 100, 200, and 235 ft. levels. The strike is very constant to the north-east, and the dip is approximately 50° south-west. The thickness of the associated crush zone ranges from 3 feet to 10 feet.

The footwall of the lode on the 50-ft. level has been partly formed by a strongly-grooved fault, the Mann Fault, dipping 85° south; this fault is probably structurally associated with the Higgins's Fault, because the grooves pitch 7° east, in the same general direction as the Higgins's Fault. A similar association has been observed on the Eldorado mine, where the pitch of slickensides of the vertical Pug Seam Fault is in the same direction as the dip of the controlling, and much flatter-dipping, Fault B.

Measurement of plunge of bedding on cleavage discloses significant pitch changes in the overall west pitch: these changes have been observed on opposite sides of a shear filled with quartz-hematite, and strongly suggest that the movement along the shear was rotational. The strike of the shear, and of others like it, is parallel to the main east-west folding, and they may represent one of the early phases of movement affecting the sediments.

Many minor faults have been observed, the most important being the centre of the southern edge of No. 2 lens, where micaceous hematite is abundant. This fracture trends parallel to the Higgins's Fault, and no observations could be made on its dip.

A suggested history for the development of these structures is as follows:—

(1) Rotational faulting of interbedded sandstones and shales underlain by ripple-marked sandstone; in the mine, the north block moves east and the south block west. Rotational faulting may have continued throughout the period of movement.

(2) Almost simultaneous development of pitch-change axes, due to the varying competency of rock types and the nature of the folding.

(3) Intense fracture cleavage.

(4) Thrust faulting from the south, exemplified by the Higgins's Fault.

No. 1 Lens.—This lens has been localized on the north limb and crestal region of a fold which plunges 34°–50° west. Shearing on the limb parallel to the axial plane directions, together with the composite effects of marked plunge changes, has led to the formation of a zone of moderately intense crushing. Steepening of the incompetent shale beds to a vertical position has also assisted the alteration.

Into this zone, mineralizing solutions have penetrated along cleavages, bedding planes, and faults. In many places, both underground and on the surface, relict bedding may be seen (Plate 40). The edges of the lode are determined partly by faults and partly by differential replacement of beds.

Underground the ore has been localized in a lightly altered shale and sandy shale. Bedding remnants are visible, and where located in the shear zone are indicators of high-grade ore. Dips range from 80° north to 75° south On the 100-ft level minor buckles in the replaced shales support the suggestion of west plunge of the shales.

The northern limit of the ore is determined by the Mann Fault. This fault has not been intersected on lower levels, owing to the narrow limit of exploration development.

The Higgins's Fault determines the base of the ore. Plates 40 and 41 show the nature of this fault and its relationship to the ore. The cross-section 50W shows a complementary off-shoot of this fault dipping 70° south. This may be a similar fault to the Mann Fault, but definite classification is dependent on further development.

Plate 41 shows the approximate position of the west-plunging unfavourable Formation B. In view of this it is suggested that future prospecting operations to the east would be futile. The presence of this sandstone suggests the possibility of east-pitching ore-shoots in west-plunging sediments.

No. 2 Lens.—No. 2 lens lies in the crestal region and limbs of an east-plunging anticline, where the fold has been distorted by plunge changes to form a marked basin and dome. The outline of the lode conforms partly to bedding and partly to cleavage and fault directions. The relationship to the bedding is noticeable on the eastern edge of the lode where it has been explored by numerous parallel costeans, and points to a definite east pitch for the quartz-hematite. However, this may be only a superficial feature, as No. 2 shaft, sunk to a depth of 100 feet, did not pass through any quartz-hematite.

No. 3 Lens.—This lens is localized on the north limb and crestal region of an east-plunging fold. The lode also lies astride a synclinal and anticlinal axis of pitch change. These localization features may be superficial, with the main control probably dependent on folding in the underlying sandstone (Plate 40). The outline as in the other lodes is largely controlled by both bedding and cleavage.

Others.—The many small quartz-hematite lodes on the lease are mostly localized by minor shears and sharp buckles in the sediments.

Geophysical Results.

The results of a magnetic survey conducted by the Aerial Geological and Geophysical Survey of Northern Australia are contained in the Third

Report on Magnetic Prospecting at Tennant Creek (1937). The report reads as follows:—

> Profiles (Plate 5) show disturbed conditions in the vicinity of outcropping ironstone and the more definite anomaly zones are shown in the plan (Plate 4). On the Northern Star Lease one zone coincides closely, in part, with an outcropping auriferous body, but this does not mean that other zones necessarily have a similar relation.

The positions of the principal zones of magnetic anomalies are shown on Plate 40. Apart from the southernmost anomaly the outlines coincide very closely with surface quartz-hematite outcrops.

Ore Reserves.

The ore blocked out between the 100-ft. and 200-ft. levels was estimated by C. L. Knight (1947) as 26,800 tons with an average grade of 12 dwt./ton. This figure was based on the results of a comprehensive sampling programme. It assumes that known ore between the 100-ft. and 235-ft. levels, with the exception of a transverse 10-ft. pillar above the 200-ft. level, could be extracted. However, this figure may prove to be conservative.

Prospects of Further Discovery.

The complicated nature of the geology has made an assessment of prospects rather difficult.

Plate 41 shows a suggested repetition pattern. The exploration of this possibility may be carried out by underground development or by diamond drilling from the bottom level. Underground development would necessitate driving 60 feet on a magnetic bearing of 240°. There is not a great amount of evidence on which to base these assumptions. However, the following points have led towards the suggestions:—

(*a*) the westerly plunge of the incompetent sandstone—these are unfavorable host rocks and appear to plunge into the shear zone. Thus, easterly development at this stage is not warranted;

(*b*) the 70° fault on the 200-ft. level, which may be similar to the Mann Fault, which forms the footwall of the ore on the 50-ft. level;

(*c*) the hematite in the footwall of the Higgins's Fault and the position of the magnetic anomaly.

These suggestions are based on interpretations of complicated geological structure, where no sedimentary marker horizons were present.

No. 2 and No. 3 lenses may be potential bearers of ore-shoots. Scout drilling would be necesary, and the interpretation of these results may have a successful outcome.

North Star.

The North Star lease is adjacent to and east of the Northern Star gold mine. There has been no production up to the present date. The surface of this lease was not geologically surveyed, but notes were made on underground workings. No production has been recorded, although work has been conducted by individual prospectors, and by a company, Gold Bearing and Prospecting. The workings consist of three shafts, an adit, and several shallow costeans. Two of the shafts are 81 ft. 6 in. and 129 feet deep.

The lodes at the surface consist of several very gossanous-looking quartz-hematite outcrops. They are lenticular in shape and are strongly pitted and very soft and crumbly in part. Micaceous hematite is present in places.

Underground the quartz-hematite is very similar (Type A, Northern Star), and in places has a prominent ribwork structure. Massive quartz-hematite lenses and narrow quartz veins were observed on both levels and partially replaced hematite on the 129-ft. level in No. 2 shaft.

The structural controls are unknown, but are probably closely related to folding and faulting. The *en echelon* arrangement of the lodes suggests a rotational movement, giving, in the mine, a displacement of the north-block to the west and the south-block to the east. Further work is necessary, however, before any final conclusions can be reached.

Golden Slipper Mine.

The Golden Slipper workings are situated 25 miles north-west of Tennant Creek township, and about 4 miles north-east of the disused No. 1 Government Battery. The mine was discovered in 1937 and since that date has produced 378.31 tons of ore which assayed 5.95 dwt. per ton by amalgamation and 5.3 dwt. per ton in the tailings. Gold fineness in the last two parcels, August, 1949, and October, 1948, was 760 and 810 respectively.

Two lodes outcropping on the lease are situated 1,000 feet apart. The northern lode has been worked by open cuts, shaft and costeans. The southern lode has been explored by three shafts, 20, 90 and 50 feet deep, by two small open cuts 12 and 26 feet long, and by several costeans.

The rocks on the lease strike north-south and consist of quartzitic sandstone, cherty slate and subordinate mudstone. The rocks dip very steeply either to the north or to the south and have been strongly cleaved.

The northern lode consists of massive hematite partly surrounded by crushed and altered mudstone and fine-grained sandstone. This lode has a high bismuth content, and assays of gold are reported as ranging from 5 dwt. to 25 dwt. per ton. The southern lode consists of highly silicified sandstone and slate with minor amounts of quartz and hematite. The silicification is probably due to hydrothermal alteration and may indicate the close proximity of porphyry in the shear zone. The ore-shoots are extremely small and extremely difficult to find (as indicated by the number of pits, costeans, &c.), and careful sampling of each bucket of ore is necessary before it is certain that it is of high enough grade for treatment. The gold is associated with minor quartz-stringers disseminated in the silicified crush zone.

Edna Beryl Mine.

The Edna Beryl gold mine is situated 25 miles north of the township, and 1 mile south of Kerramun Lagoon. The mine was discovered in 1935 and is owned by A. McDonald. In 1945-46, Murina-Malay Tin Company took over the option of the lease, but later relinquished it to the owner. The workings lie on the south-western edge of a low rounded hill, and are not extensive. 2,644.9 tons of ore, which assayed 32.06 dwt. per ton by amalgamation, and 4.6 dwt. per ton in the tailings, were produced; 12.07 oz. of gold were dollied.

Surface observations show that the lode lies in a shear zone at the contact of coarse to medium-grained sandstone with red slate, which dip vertically or steeply north. The lode is a brecciated slate injected with quartz veins and partly replaced by small quartz-hematite lenses and stringers. The gold has either a fine grain-size, or occurs as slugs, with a gold fineness of 950.

Klondyke Mine.

The Klondyke gold mine is situated 25 miles north of the Tennant Creek township, and 300 yards east of the Carraman mine. There has been no production. Surface workings include irregular costeans and shallow open cuts.

Sedimentary rocks in the immediate vicinity of the mine consist of red banded shales which have been lightly folded, and sheared in a direction parallel to their east-west strike. Two parallel shears have formed in these sediments and have been replaced by quartz-hematite bodies 4 feet and 12 feet wide. Dense specular hematite, quartz, jasper and veinose micaceous hematite make up the lode.

Carraman.

The Carraman gold mine is situated about 1 mile east of Karramun Lagoon on a flat alluviated stretch of country. The lease was worked for a time in 1947, but little or no work has been done since that date; 15.15 tons of ore, assaying 117.6 dwt. per ton, were produced. The mine has been worked by three shafts, the deepest being 70 feet, and underground drives and cross cuts. Sedimentary rocks associated with the lode consist of ribbon shales, and fine-grained to medium-grained ripple-marked sandstone.

A quartz-hematite lode crops out on the surface, and consists of 80 per cent. massive and micaceous hematite and 20 per cent. quartz.

WHIPPET AREA.

Whippet Mine (Plates 42 and 43).

Introduction.

The Whippet gold mine lies in the northernmost belt of the gold mines on the Tennant Creek Gold-field, and is the easternmost mine on this line. Other mines in this belt are the Edna Beryl, 7 miles to the west, and the Northern Star, 10 miles west.

The mine was geologically surveyed in 1948 by J. F. Ivanac and N. H. Krasenstein; mapping of new development was carried out in 1949 and 1950.

The Whippet gold mine is situated 26 miles from Tennant Creek on a magnetic bearing of 7°. Access to the mine may be had either by following the Stuart Highway north from the township for 23 miles and thence east along a poorly formed gravel road for 7 miles, or by travelling north along the Stuart Highway for 16 miles, thence east along the Barkly Highway for 1½ miles, and then generally north and east along a graded road for about 10 miles. Both gravel tracks are inaccessible for short periods during the annual wet season (from December to March).

History and Production.

The orebody was discovered in 1938 by J. English and partners, who loamed around the small hematite outcrops shown on Plate 42. Traces of gold were originally discovered in the vicinity of the present No. 3 shaft. No. 3 shaft was sunk, but the owners did not consider the results of this work very encouraging, even though ore averaging 12 dwt. of gold per ton was discovered at 20 feet below the surface. Operations were then moved to the present site of No. 2 shaft and gold ore yielding 1–2 oz. per ton was intersected at 35 feet below the surface. One thousand four hundred and twenty-six tons of ore with an average grade of 14.7 dwt. per ton were produced before production was halted for three years by World War II., when all mines on the field except Eldorado Pty. Ltd. closed down under National Security Regulations.

In 1948 the property was purchased by a Melbourne company, Gold Boring and Prospecting No Liability, who have operated the mine since that date. The high purchase price of the mine and the initial heavy capital expenditure on new equipment have seriously hampered exploration development. Development, to 1949, has merely attempted to delineate the boundaries of the ore-shoots.

In 1950, some diamond drilling for possible new ore-shoots was carried out, but no ore was located. Coupled with exploration by drilling, some driving and cross cutting within the limits of the present lode were carried out.

The total production figures of the mine are contained in the following table:—

Date.	Ore.	Recovery by Amalgamation.	Tailings.
	Long tons.	Dwt. per ton.	Dwt. per ton.
July, 1938, to June, 1939	40.42	13.3	11.0
July, 1939, to June, 1940	30.53	2.3	2.0
July, 1940, to June, 1941	50.08	3.0	2.1
July, 1941, to June, 1942	208.38	14.7	7.6
July, 1942, to June, 1943	153.79	31.7	18.4
July, 1943, to June, 1946	No production—World War II.		
July, 1946, to June, 1947	938.80	58.7	19.4
July, 1947, to June, 1948	1,320.89	49.97	27.4
July, 1948, to June, 1949	3,116.0	20.4	7.5
July, 1949, to June, 1950	5,581.0	13.1	..
July, 1950, to June, 1951	930.0	14.1	..
Total	12,374.89	22.6	6.7

Ore was originally treated at No. 1 Government Battery, 20 miles west of the Whippet mine. Later, when Gold Boring and Prospecting No Liability acquired the lease, this battery was hired to them by the Mines Branch of the Northern Territory Administration. In 1949 the company erected its own ten-head stamp battery and gold was extracted by amalgamation with mercury on copper plates.

Adequate water for treatment and underground purposes was obtained from a bore 1 mile east of the mine, and also from the 250-ft. level, which lies in the present water-table zone. The water from the latter sourc is collected in a sump on the 250-ft. level, is pumped to the surface, and is almost sufficient to supply the needs of the mine. Unfortunately, this water is saline. Potable water has to be carried 23 miles from the Government fresh water bores, 7 miles north of the township.

C. J. Sullivan* investigated the bismuth reserves of the mine in 1942. Some of his results are recorded below:—

No. 3 Shaft (30 feet deep).—Three samples were taken and the highest assay was 0.29 per cent. bismuth.

48 *feet Level No. 2 Shaft*.—Four samples cut from the north and south, cross-cut returned nil, nil, trace, and 0.34 per cent., over a width of 8 feet. At the bottom of this shaft in an east drive an assay returned 1 per cent. bismuth. In other places 1.15 per cent. and 1.35 per cent. bismuth were obtained. The mineral occurs mostly as the carbonate and oxide.

A magnetometer survey of the leases was carried out in September, 1950, by M. Allen and J. Quilty, of the Geophysical Section of the Bureau of Mineral Resources. The large amount of magnetic interference caused by mine buildings and steel structures prevented the establishment of any recognizable magnetic contours from which conclusions could be drawn.

General Geology.

The Whippet gold mine is situated in a very flat-lying area bounded on the east, west and south by low rounded hills. To the immediate north the topography is very flat with no well-defined creeks.

Rock exposures near the mine are poor, and very little information could be obtained from these outcrops. Regional mapping has shown that the sediments are interbedded ripple-marked medium-grained sandstone, sandy slate, fine-grained and medium-grained tuffaceous sandstone, shale, and some mudstone, The predominant colours are purple, grey, and white. South of the mine these rocks have been altered by a quartz-felspar porphyry, solutions from which have permeated the sediments, without completely replacing them.

Underground, ripple-marked sandstone and shale have been exposed on the 90-ft. level. Shale and cherty slate were mapped on the 144, 200, and 250-ft. levels. The mapping shows that the rocks may be divided into two types—competent sandstone and cherty slate and incompetent shale.

* Unpublished report 1942.

Economic Geology.

Lodes.—Two lenticular quartz-hematite bodies of the type generally associated with the gold deposits of the Tennant Creek area crop out on the lease. The easterly body is 40 feet in length and averages some 12 feet in width at the surface. Underground, the maximum development of the lode is on the 144-ft. level where it has been exposed over a length of 230 feet and a width of 36 feet.

The western lode is 300 feet west of the eastern lode. It is 140 feet in length and averages 10 feet in width. It has been developed on the 90-ft. level where it has been exposed over a length of 80 feet and an average width of 30 feet.

These bodies consist of quartz, hematite, and jasper, and carry very little gold. The eastern outcrop is composed predominantly of massive hematite, whereas the western lode is a mixture of red jasper, quartz, and finely divided specular hematite. The western tip of the western lens contains approximately 10 per cent. hematite and 90 per cent. jasper.

The underground workings show that the gold-bearing lode consists of crushed shale impregnated by quartz and quartz-hematite stringers and contains massive quartz-hematite segregations. A distinct banding of the lode is in evidence on the 144-ft. level. The banding consists of (from south to north)—

Soft micaceous hematite;

Crushed shale, cavernous in part, impregnated with iron and quartz: kaolin and manganese oxide are common with a little micaceous hematite;

Hard blue-black massive quartz-hematite.

The micaceous hematite is easily powdered and has a brilliant lustre. Manganese dioxide and limonite are scattered throughout the lode.

The ore is mostly confined to the middle band. The longitudinal limits are generally determined by assay, but there is some suggestion of a lithological sedimentary change from shale to sandstone.

Other minerals in the ore and lode include bismuth carbonate and malachite. Sullivan (1942) concluded that the ore may contain up to 1 per cent. Bi_2O_3. in the form of oxide and carbonate minerals. Gold is very closely associated, and is in places coated, with bismuth minerals. Bismuth-rich pockets in the ore assay up to 140 oz. per ton with the Bi content as high as 30 per cent. The mineral is a carbonate and is glistening white in colour. Some very fine talc particles (less than one-fiftieth of an inch diameter) and sericite are associated with the ore. Malachite was observed only in one place, in the water-table zone.

Later quartz veins occupy an irregular east-trending zone on the surface (Plate 42). The quartz is barren of gold and contains a few flakes of micaceous hematite.

The longitudinal projection (Plate 43) shows that the crush zone has been worked in two places, namely the eastern and western ore-shoots. The eastern ore-shoot has been exposed over a length of 70 feet and width of 30 feet on the

90-ft. level and a length of 80 feet and width of 25 feet on the 144-ft level. Only two narrow legs of ore reach the 200-ft. level. The top of the ore-shoot is 40 feet below the surface (as shown by cross-section AA, Plate 43).

The western ore-shoot is approximately circular in plan and pipe-like in section. It has a maximum length of 20 feet and a width of 10 feet. The ore-shoot forms about 8 per cent. by volume of the exposed western lode.

Structural Control.

Because of the limited number of observations possible, the geological structure is not yet fully understood. However, a number of important localizing factors have emerged from the study undertaken. These are as follows:—

(*a*) The lodes lie in the fractured north limb of a west-plunging anticline. The ore is localized where a shale horizon intersects this crush zone.

(*b*) The main rock types involved in the fracture can be divided into competent sandstone and cherty slate and incompetent shale. The former tend to buckle and fracture slightly, the latter to crumple, brecciate, and flow, during folding. The axial trend of the folding strikes approximately east-west and dips at 85° to the north. This is an important direction as the main ore "make" is parallel to it (*see* plan, 144-ft. level, and cross section AA, Plate 43). Further, the ore markedly decreases in grade and finally cuts out where the strike changes to the north-east. This change in strike is a reflection of the fact that the ore-shear in the incompetent rocks is parallel to the cleavage direction and in the competent rocks to the bedding direction.

(*c*) Another very important structural feature is that the ore-shoot and lode are "sandwiched" between two massive sandstone horizons and the position of the ore-shoot is clearly controlled by the structure and not related to secondary enrichment.

(*d*) Several important minor structures have been mapped, and these have given valuable clues towards the understanding of structure control. Grain elongation of pyrite crystals on the 215-ft. sub-level was 70° east, parallel to the pitch of the ore-shoot. Many minor buckles of variable pitch indicate that the area is one of considerable pitch change. Plate 43 shows that the pitch given by bedding on cleavage across the plane of the lode indicates that the major ore-shoot "makes" in the zone of flat pitch.

These features together with the important structural controls previously specified point to the conclusion that on the Whippet gold mine there are east pitching ore-shoots in west pitching lode.

The western ore-shoot has been localized by bedding-plane shearing at the contact of sandstone with purple shale.

Secondary Enrichment.

The very high gold content of the lode is considered to have been due partly to secondary enrichment, and partly to structural sedimentary controls. The evidence suggestive of secondary enrichment is based on the rich nature of the ore above the 200-ft. level, whereas at this level, although the rock types are lithologically similar, the grade of ore is decidedly low.

In the country rock surrounding the lodes several of the zones commonly associated with the ideal lateritic profile are present. A zone of surface silicification is present and is underlain by the mottled and kaolinized zones. These may be associated partly with the lateritization in Tertiary times and partly with the long period of oxidation and erosion which affected the Tennant Creek Gold-field from the Upper Proterozoic to the present day. The gold enrichment zone can be related to the kaolinized and mottled zones: the base of the kaolinized zone is above the 200-ft. level. Also, there is the zone of surface impoverishment from the surface to approximately the 50-ft. level.

On the other hand, near the base and possibly near the top of the ore-shoot, the lode is cut by unfavorable sandstone. This indicates that the ore-shoot may be limited by lithological changes in the sediments in which the ore has been emplaced.

Some malachite was reported from the water-table zone. In similar rocks on the Peko gold mine the ore changes from a gold lode above water table to a gold-copper lode below the water-table level. This may be the case on the Whippet, and, if so, any other bodies of lode material which may be found and which contain payable gold above the water table may continue as workable gold-copper bodies below the water table.

Prospect of Further Discovery.

The future life of the mine lies entirely in the discovery of new ore-shoots as the present "shoots" have been completely worked out.

ALLUVIALS.

Last Hope Mine (Plate 44).

Introduction.

A geological survey of the Last Hope gold mine was carried out by J. F. Ivanac and B. P. Walpole in 1950.

The Last Hope gold mine is situated 40 miles north-west of Tennant Creek township in an area known as the Alluvials. It is reached by travelling north along the Stuart Highway to the Old Telegraph Station, whence a formed all-weather gravel road leads west to No. 1 Government Battery; 3 miles west of No. 1 Battery a track turns off to the north-west and leads direct to the Last Hope mine, a distance of approximately 26 miles from the turnoff. This track is generally in poor condition and is not always useable after rain.

History and Production.

In 1936, there was a minor rush to this area after the discovery of some alluvial gold. Several small nuggets, some reported to weigh as much as 15 oz., were found. Alluvial prospecting was continued in a desultory manner, until in 1947 underlay open cuts were started on the quartz reef on which the present mine is situated. In October of that year, a small parcel of ore was crushed to yield 140.4 fine oz. of gold. In addition 7.2 oz. were submitted as dollied gold. Mining activity has continued on the lease (P.G.L. 348 and G.M.L. 11E) since that date, and ore won is crushed at the owner's three-head stamp Riverside battery.

Hans Hackmann is the present owner of the lease, and he uses the "hammer and tap" technique in mining.

The production figures of the mine are listed below. The information is incomplete as no accurate check is kept on the amount of ore mined.

Date.	Ore Produced.	Fine Ounces by Amalgamation.	Dollied Gold.
	Long tons.	Fine oz.	Fine oz.
October, 1947	..	140.4	..
January, 1948	56.725	24.319	..
April, 1948	..	..	20.2
April, 1949	..	..	4.59
May, 1950	..	..	6.89
July, 1950, to June, 1951	8.0	14.31	7.86

The figures are probably incomplete and do not represent the total amount of gold won from the lease since it was first prospected.

The mine workings consist of two shafts joined at a depth of 45 feet by a drive, which continues west of No. 2 shaft and links up with an underlay open-cut from the surface.

Ore is hauled to the surface via No. 1 shaft, which is equipped with steel skids for 40 feet. It is then carted to the owner's three-head Riverside Battery where it is crushed at the rate of 1 ton per eight hours. The mill stamps weigh 3 cwt., which is ample weight to cope with the easily-crushed quartz lode.

Continuous supplies of water for underground and crushing needs can be had from nearby waterholes and a bore. The bore is 219 feet deep and has been cased for the total distance.

General Geology.

Outcrops in the area immediately surrounding the mine are very few, with the exception of the numerous quartz leaders and the quartz reef on which the present workings are situated. Sediments and volcanics exposed in creek beds and to the north of the mine belong to the uppermost beds of the Warramunga Group. They consist mainly of interbedded lavas, sandstones, and shales, with some thin beds of quartzite.

Economic Geology.

Gold occurs in quartz reefs and stringers which fill fractures in the volcanics in this area. Two main sets of fractures are evident, one striking at approximately 310° and the second and less well developed set at approximately 10°. The main quartz reef strikes at 310° magnetic and, although probably discontinuous, can be traced by scattered outcrops over a length of 600 feet. The reef is approximately 4 feet wide at the surface and dips to the north at angles which range from 35° to 50°.

In general, the gold is much coarser in grain-size in the quartz bodies than in the reefs, and small nuggets up to 1 oz. in weight are reported to have been found. It is also reported that larger nuggets up to 32 oz. in weight have been found, but it is doubted if any credence can be given to the reports.

The occurrence of both primary and secondary gold was noted. The secondary gold is dendritic in character. A primary association of gold and quartz with pyrite and hematite is present. The pyrite occurs in veinlets or is disseminated through the quartz, the maximum size of the crystals noted being approximately one-tenth of an inch in diameter. Hematite is present in clots or blobs in the quartz, which is vuggy in character, and in some places contains fragments of silty claystone (mudstone) up to half an inch in diameter.

The average grade of the ore mined is of the order of 14 dwt. Au per ton.

The cross-section along A–A shows that the quartz reef on which the main workings are situated is considerably narrower on the 45-ft. level than on the surface.

Scattered eluvial placer deposits are worked on the lease after heavy rains. The deposits result from weathering of gold from the surrounding quartz gangue.

Structural Control.

Mine and regional geological studies have revealed the following structural and sedimentary controls:—

(1) The quartz lodes lie in the north limb of an east-plunging fold. In this section the main lode is parallel to the dip and strike of the siltstone lens in the lavas.

(2) Strike of the main reef ranges from 125° to 150°, a variation of 25°. Movement along a shear with such strike variations may have led to the formation of favorable openings on the 150° strike direction. The lean section of the ore is probably on the 125° strike.

(3) Dip of the quartz lode ranges from 35° to 50°. Underlay stopes and open cuts have been worked in the 35° to 40° dip section and it is possible that the more favourable ore lies in the flatter section of the reef.

(4) The pitch of the ore-shoot is probably easterly at a flat angle.

Prospects of Further Discovery.

A considerable amount of ore is in sight, and with present development techniques will take several years to extract. Repetitions of this ore-shoot will probably be too deep for economic mining by present methods. The mine is not a company proposition, as its size and distance from the Tennant Creek centre are prohibitive for large-scale operation.

FUTURE PROSPECTS OF THE TENNANT CREEK GOLD-FIELD.

It is considered that most of the outcropping ore has been found at Tennant Creek, mainly because all the gold deposits are associated with bodies of quartz-hematite which are conspicuous in colour and owing to their resistance to weathering stand out as small black outcrops. Once it was known that gold was associated with the hematite all these conspicuous outcrops were prospected. The quantity of shed gold found near most deposits is small but sufficient for the purpose of "loaming", and by this method all the surface ore deposits of the Tennant Creek Gold-field have been found. It was found during geological examination that every outcrop of hematite had been tested by costeans, pits, or shafts.

It has been shown that non-outcropping deposits occur at Tennant Creek and that it is possible to discover these especially if the geological structure of the deposits is understood. Magnetometer surveys are often also of great assistance. Thus, geological and geophysical work, followed by diamond drilling, led to the discovery of ore on the Peko mine at a depth of 400 feet below the surface. At Noble's Nob, drilling based on geological mapping found a new deposit (or repetition of the original ore-shoot), which does not reach the surface; it was intersected at a depth of 250 feet. Non-outcropping shoots have also been discovered by shaft-sinking on the Whippet, Skipper Extended, and Blue Moon gold mines.

However, it is important to note that the deposits are normally small and generally very irregular. They are not tabular bodies which are comparatively easy targets for drilling, and have been shown to be quite discontinuous in every dimension. Further, owing to the probable effects of secondary enrichment, a drop in grade is likely below the oxidized zone (150-300 feet) and this adds to the risk of deeper exploration. However, it is considered that in the deposits in which the larger shoots have been proved to exist in the upper levels, quite good chances exist of finding further ore well below the present working levels. At present, no limits can be placed on the depth at which gold-quartz-hematite deposits could occur.

Some scope exists for the search for copper-gold ore of the Peko type, especially along the "line" joining the Peko, Shamrock, Pinnacles, and Euro mines. The hematite outcrop at Peko did not give much evidence of the existence of high-grade copper ore below, and other non-outcropping copper deposits could occur in the district. But there is as yet no evidence that large copper deposits occur at Tennant Creek.

The present ore reserves of the Gold-field are those contained in four mines, Noble's Nob, Eldorado, Peko and Northern Star, and are in the vicinity of 200,000 tons—this includes measured, indicated, and inferred ore. At least 40 per cent. of this ore is inferred. The annual production of the Gold-field, when Peko and Northern Star mines begin systematic work, will be about 30,000 tons of ore per year, of grade which ranges from 15 to 40 dwt. per ton. At this rate it will take from six to twelve years to extract the known ore reserves.

The writer believes that further ore will be discovered on the Gold-field, and that the yearly production will range probably from 30,000 to 50,000 tons per annum and that the average grade of this ore may be in the vicinity of 1 oz. per ton.

The Tennant Creek Gold-field has almost passed from the initial stages of a gold-field's history, when new finds are reported at frequent intervals. Further development depends mainly on the discovery of non-outcropping ore. It is hoped that the present survey, which is believed to have revealed for the first time some of the major factors controlling ore deposition, will help considerably in discovering sufficient ore to keep a number of mines operating for many years.

ACKNOWLEDGMENTS.

Appreciation is expressed of the assistance rendered by the Mines Branch, Northern Territory Administration. Mr. A. Richards and Mr. M. O'Loughlin, Mining Registrars at Tennant Creek, gave valuable assistance to the party.

Thanks are due to the mining companies and the many mine owners and prospectors whose assistance did so much to facilitate the work of the survey.

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APPENDIX 1.

DIAMOND DRILLING RESULTS.

(a) 1950-51 (Bureau of Mineral Resources).

In 1950, when the Tennant Creek Gold-field Survey was nearly complete, it was decided to test ore-search theories by diamond drilling. Drilling sites were selected at Peko (Plate 24) and Noble's Nob (Plate 17) gold mines. Operators (J. Green, foreman driller, and assistants), were supplied by Mines Branch, Northern Territory Administration; the drill, a Sullivan H.22, was made available by the Mining and Engineering Section, Department of National Development.

Analyses of results are contained in the section on "Individual Mines". These show that repetitions of lode in depth were intersected on all four lodes drilled (one on Peko mine and three on Noble's Nob mine). Good grade ore was discovered in two bores.

The detailed logs of the drill-cores, combined with assay results, are contained in the following lists:—

Peko Gold Mine.			Diamond Drill Hole No. 1.	
Footage.			Description.	Assay.
From	To	Recovery.		
		ft. in.		
0	50	2 8	Pale buff sandy shale, fine and medium grained tuffaceous sandstone	
50	90	10 0	Pink, yellow, and grey shale with sandy bands. Bedding flatly dipping	
90	100	2 6	Pale buff fine and medium grained sandstone and shale	
110	120	9 6	0–4′ fine to medium grained sandstone—shaly in part 4–9′6″ pink sandy slate with some medium-grained sandstone	
120	130	4 0	0–6″ pale purple sandstone 6″–2′0″ pale purple sandy shale 2′0″–3′6″ sandstone 3′6″–4′0″ sandy slate	
130	140	1 8	0–8″ pale purple fine-grained sandstone 8″–1′8″ sandy slate	
140	150	6 6	0–1′ sandstone 1′–6′6″ pale purple sandy shale with fine-grained sandstone bands	
150	156	2 8	Pale buff and pale pink fine and medium grained sandstone with 6″ of siltstone	
156	170	13 0	White and pale purplish grey fine and medium grained tuffaceous sandstone with shale bands in parts	
170	180	6 6	0–1′6″ pale buff siltstone 1′6″–6′6″ medium-grained sandstone	
180	186	4 0	Banded sandy shale	
186	198	7 0	0–1′ sandy shale 1′–6′ sandstone 6′–7′ sandy shale, cherty in part	
198	210	3 0	0–1′2″ reddish-brown banded fine-grained sandstone 1′2″–3′ pale purple interbedded cherty slate and fine-grained sandstone	
210	220	8 7	0–4′10″ cross-bedded sandstone with fine cherty slate lenses 4′10″–7′1″ fine-grained sandstone grading into coarse-grained tuffaceous sandstone—pale purplish-green 7′1″–8′7″ banded cherty slate in the fine-grained argillaceous sandstone bands	

Peko Gold Mine.			Diamond Drill Hole No. 1.	
Footage.			Description.	Assay.
From	To	Recovery.		
		ft. in.		
220	231	6 0	0–2′4″ pale purple cherty slate with fine-grained sandstone bands 2′4″–2′8″ fine-grained tuffaceous sandstone 2′8″–6′ purple cherty slate	
231	240	0 5	Purple slate	
240	250	0 6	Green and purple slate	
250	260	4 8	0–2′ pale green banded slate 2′–3′8″ pale green medium-grained tuffaceous sandstone 3′8″–4′8″ slate and sandy slate	
260	270	4 0	0–7″ pale green slate 7″–4′ purple cherty slate with some sandstone	
270	280	4 8	0–4′5″ banded cherty slate with fine-grained cross-bedded sandstone 4′5″–4′8″ light purple slate	
280	292	3 4	0–4′3″ pale purple cross-bedded fine-grained sandstone and slate Note at 1′, thin lenses and veins of malachite. At 3′4″ malachite stringers	
292	300	1 5	Pale purple sandy slate	
300	310	7 0	0–1′7″ sandy slate with some thin malachite stringers 1′7″–6′1″ fine-grained sandstone grading into coarse-grained tuffaceous sandstone with thin malachite stringers 6′1″–6′2″ purple slate 6′2″–6′8″ dark green quartz breccia 6′8″–7′ purple slate with narrow malachite stringers	
310	320	7 0	0–1′ purple slate 1′–1′6″ fine-grained purply-green sandstone with some malachite stringers 1′6″–6′ sandy slate 6′–7′ pink and green medium-grained tuffaceous sandstone At 6′2″, ½-in. breccia parallel to bedding	
320	330	2 6	0–10″ pale green slate 10″–1′1″ medium-grained tuffaceous sandstone 1′1″–1′8″ pale green sandy slate 1′8″–1′9″ medium-grained tuffaceous sandstone 1′9″–2′2″ pale green slate with ½-in. hematite stringer 2′2″–2′5″ medium-grained tuffaceous sandstone 2′5″–2′6″ green cherty slate	
330	340	2 0	0–8″ purplish-brown medium-grained tuffaceous sandstone 8″–1′3″ hard green cherty slate 1′3″–2′ purplish-green cross-bedded medium-grained sandstone	
340	350	0 6	Green slate	
350	360	9 4	0–6′10″ interbedded tuffaceous sandstone and banded purple slate 6′10″–9′4″ green cherty slate	
360	369	4 10	0–4′10″ green cherty slate with occasional quartz stringers	
369	374	1 9	0–1′2″ grey-green medium-grained tuffaceous sandstone 1′2″–1′6″ brown lode—altered slate with quartz and (?) hematite stringers and some botryoidal MnO_2 1′6″–1′9″ green cherty slate	

PEKO GOLD MINE.			DIAMOND DRILL HOLE NO. 1.		
Footage.			Description.	Assay.	
From	To	Recovery.		Au. Dwt. per ton.	Cu. %
		ft. in.			
374	384	2 4	0–1′9″ green cherty slate		
			1′9″–2′4″ quartz and magnetite		
384	391	2 1	0–5″ pyritic sandstone		
			5″–1′10″ green sandy slate with some quartz and hematite stringers		
			1′10″–1′11″ green cherty slate, pyrite crystals and quartz crystals		
391	397	1 10	0–3″ green sandy slate		
			3″–1′10″ quartz—magnetite (?) pyrite, hematite lode	Tr.	Tr.
397	400	3 0	Quartz, magnetite, hematite, pyrite, chalcopyrite, lode with a little chlorite towards the end of the core	Tr.	Tr.
400	409	6 5	0–4′5″ quartz-chalcopyrite lode. Chalcopyrite later than magnetite and quartz, intergrown texture, segregations and veinlets	Tr.	Tr.
			4′5″–5′1″ massive magnetite-chalcopyrite lode—veins and segregations	(405–409)	..
			5′1″–5′8″ same as 0–4′5″, at 5′7″ green slate fragments	1.0	4.0
			5′8″–6′5″ chalcopyrite, pyrite, magnetite lode, (?) arsenopyrite		
			6′3″–6′5″ well formed pyrite crystals, in vuggy lode		
410	420	2 0	Pyrite—magnetite-chalcopyrite lode predominantly chalcopyrite in massive segregations	25.15	11.1
420	425	5 0	Pyrite, chalcopyrite and magnetite lode, with the sulphides in stringers	5.90	5.3
425	434	3 0	0–11″ chalcopyrite, magnetite, pyrite ; chalcopyrite and pyrite in clots. At 4″ colourless zeolite in vug	(425–427) ? 3.60	4.1
			11″–1′8″ massive pyrite-chalcopyrite-magnetite lode		
			1′8″–3′0″ massive pyrite lode with a little magnetite	(427–434) ? 0.6	0.7
434	440	6 0	0–1′ massive pyrite lode with a little chalcopyrite and magnetite	(434–438)	
			1′–4′6″ pyrite, chalcopyrite, pyrrhotite (?), magnetite lode. (Low sulphide)	Tr.	0.3
			4′6″–6′0″ same as above but with quartz veins—tendency to form bands		
440	450	7 5	Banded quartz—magnetite lode (prob. some hematite) with streaks of pyrite, (?). Slightly vuggy in part		
			From 4′8″–5′5″ green slate breccia. Soft black powdery mineral in vugs (?MnO_2). Some crystals of chalcopyrite	Tr.	Tr.
450	460	10 0	0–8′6″ low sulphide		
			8′–10′ low sulphide	Trace	..
460	464	4 0	Same. Disseminated pyrite, chalcopyrite, in massive quartz-magnetite lode	Trace	..
			Pyrite in vugs at 464	Trace	..
464	471	7 0	Quartz-magnetite lode with some pyrite and chalcopyrite	Trace	..
471	478	5 6	Same as above but with pyrite clots	Trace	..
478	489	7 0	Same, with pyrite and chalcopyrite	Trace	0.5
489	500	1 10	Shattered country with some quartz veins		
500	529	12 0	Green sandstone and slate		

529 feet. END OF HOLE.

Noble's Nob Gold Mine.			Diamond Drill Hole No. 1.	
Footage.			Description.	Assay.
From	To	Recovery.		
		ft. in.		
0	50	3 4	Grey tuffaceous sandstone	
50	55	1 8	Grey tuffaceous sandstone with siltstone lenses	
55	62	6 0	Grey tuffaceous sandstone with siltstone lenses. (Bedding dip 45°–50°S.)	
62	73	8 0	0–1′ interbedded siltstone and fine-grained sandstone 1′–4′2″ grey medium-grained tuffaceous sandstone 4′2″–8′0″ interbedded siltstone and very fine grey sandstone	
73	83	10 0	Interbedded ochre-coloured siltstones and very fine-grained tuffaceous sandstone	
83	101	11 5	0′–1′1″ interbedded siltstone 1′1″–4′3″ fine-grained purple tuffaceous sandstone 4′3″–11′5″ interbedded siltstone and fine tuffaceous sandstone	
101	108	5 9	Purple fine to medium grained tuffaceous sandstone with some siltstone bands	
108	110	1 10	0–1′6″ fine-grained sandstone 1′6″–1′7″ soft mudstone (puggy when wet) 1′7″–1′10″ siltstone	
110	113	2 7	Interbedded siltstone and fine-grained tuffaceous sandstone with some medium-grained tuffaceous sandstone bands	
113	123	5 4	0–1′7″ fine-grained purple tuffaceous sandstone 1′7″–5′4″ pink, very fine-grained tuffaceous sandstone and siltstone	
123	130	4 10	Interbedded fine-grained purple tuffaceous sandstone and siltstone with some lenses of coarse-grained tuffaceous sandstone	
130	133	1 7	Purple coarse-grained tuffaceous sandstone and buff-coloured siltstone	
133	143	9 7	Interbedded siltstone and very fine-grained tuffaceous sandstones with some bands of coarse tuffaceous sandstone	
143	149	3 8	0–2′9″ reddish-purple medium-grained tuffaceous sandstone with ¼″ lenses of pink silty claystone 2′9″–3′8″ interbedded siltstone (some) fine-grained sandstone	
149	160	5 10	Interbedded pink siltstone and fine-grained sandstone	
160	163	2 5	Siltstone with very fine-grained sandstone bands	
163	174	6 7	0–4′2″ predominantly siltstone with fine sandy bands; at 1′6″ $\frac{3}{16}$″ wide quartz vein with fine hematite plates at right angles to quartz vein 4′2″–6′7″ fine tuffaceous sandstone with siltstone lenses	
174	179	3 2	Red fine to medium grained sandstone with quartz hematite stringers. Vuggy hematite in places	
179	189	6 9	Red-brown medium-grained tuffaceous sandstone with siltstone lenses. Quartz veins present up to ¼″ in width	
189	192	2 6	Red, fine-grained sandstone and cherty claystone	
192	198	5 0	0–2′0″ red cherty claystone 2′0″–5′0″ gradational colour change to green cherty claystone with thin quartz stringers	
198	202	4 3	0–2″ green cherty claystone 2″–6″ quartz filled breccia zone, green cherty slate fragments 0′6″–4′3″ green cherty slate. At 3′9″ ⅛″ sericite stringer. At 4′2″ 2″ x ¼″ clots of hematite. 4′2½″–4′3″ highly sericitised mudstone	

Noble's Nob Gold Mine.			Diamond Drill Hole No. 1.	
Footage.				
From	To	Recovery.	Description.	Assay.
		ft. in.		Au. dwt. per ton.
202	207′5″	5 3	Blue hematite with fine boxworks, patches of sericite-replaced country-kaolin-filled vugs; ¼″ wide vein of green (?) mica . . . . Some red mudstone fragments	20 Tr.
207′5″	209	0 5	Green (hard) fine-grained sandstone	0.40
209	219	8 0	0–7′2″ green medium and fine grained tuffaceous sandstone	Tr.
			7′2″–8′0″ green cherty slate	
219	220	0 8	Green cherty slate	Tr.
220	223	3 4	0–2′4″ highly sericitised sandy mudstone ..	(220–222) 0.50
			2′4″–3′4″ blue-black hematite; contact gradational	(222–223) Tr.
223	227	3 4	Dense blue hematite with very fine quartz stringers	Tr.
227	230	3 0	0′-10″ hematite-rich sericitised mudstone 70% hematite	
			10″–3′ mudstone grading into cherty siltstone. At 1′0″, 1″ of breccia (mudstone)	Tr.
230	232	1 9	0–5″ sericitised hematite-rich mudstone	
			5″–1′8″ almost completely replaced breccia with pale green mudstone fragments	1.00
			1′8″–1′9″ sericitised hematite-rich mudstone	
232	238	6 3	0′–4′1″ sericite-rich mudstone	4.60
			4′1″–6′3″ vuggy hematite with quartz stringers	
238	239	1 0	Dense, vuggy hematite—some quartz stringers—fine boxworks—small mudstone fragments ..	0.70
239	244	4 10	0–2′5″ dense hematite with rare quartz stringers	
			2′5″–3′11″ vuggy hematite with some mudstone fragments less than ⅛″ diameter	0.40
			3′11″–4′10″ vuggy hematite with disseminated greenish-grey to grey mica	
244	248	3 7	Vuggy sericitised hematite-rich mudstone and hematite (80%). Quartz content increases towards the end of the section. At 247′6″ *free gold* and ?? *chalcopyrite*	15.00
248	252	4 0	0″ *Free gold*—Dense vuggy hematite with kaolin stringers	
			3′1″ vug with *free gold*	10.05
252	254	2 4	Dense (vuggy) hematite with quartz stringers. Irregular pods of limonite. Occasional remnants of mudstone in vugs	0.80
254	259	3 8	0′–1′3″ same as above—kaolin stringers at 1 foot	
			1′3″–3′8″ dense hematite with sericite veins up to $\frac{3}{16}$″ wide—limonite	8.95
259	264	4 0	0–9″ dense (vuggy) hematite with sericite stringers	33.20
			9″-4′0″ dense (vuggy) hematite with sericite stringers. *Free gold* at 2′8″. (Last 8″ contains sericite stringers)	
264	269	5 7	Dense vuggy hematite with some sericite clots—some mudstone (⅛″), pink and greenish—Boxworks (fine) towards end of section—at 5′7″, pocket of micaceous hematite	4.05
269	271	2 7	Dense vuggy hematite. *Free gold* at 9″ ..	3.15
271	272	1 0	Dense hematite with $\frac{1}{16}$″ vugs	0.50
272	280	5 3	0–4′6″ dense massive hematite with fine vugs in places filled with green mudstone	(272′–276′) 0.90
			4′6″–5′3″ dense massive hematite with fine vugs in places filled with sericite	(276′–280′) 0.30
280	284	4 0	Partly hematite-replaced green argillaceous sandstone grading into massive hematite	0.70
284	290	6 0	Chloritic argillaceous sandstone almost completely replaced by hematite	54.90

Noble's Nob Gold Mine.			Diamond Drill Hole No. 1.	
Footage.			Description.	Assay.
From	To	Recovery.		
		ft. in.		Au. dwt. per ton.
290	294	4 0	Hematite stringers in brecciated sericitised chlorite slate. Green mica (?)	1.70
294	300	5 8	0–4′2″ massive hematite with sericite	
			4′2″–5′8″ hematite stringers segregations in chloritic slate	5.20
300	303	3 0	*Free gold* at 299′. Hematite stringers, segregations, in chloritic sandy mudstone	0.80
303	305	2 0	Hematite veins and segregations and sericitized sandy mudstone	21.15
305	308	3 0	0–2′ sericitized hematite-rich green sandy slate, grades into massive hematite	2.10
			2′–3′ massive hematite	
308	312	4 0	Lightly brecciated hematite-rich chloritic sandy sandy and cherty slate. Some bismuth present	0.30
312	322	7 10	0′–1′6″ coarse-grained grey sandstone	
			1′6″–3′6″ medium to fine grained sandstone with small seams of hematite showing dark blue " steely " tarnish	
			3′6″–7′10″ medium to fine grained green sandstone with small seams of hematite showing dark blue " steely " tarnish	
322	327	2 9	0′–2′9″ medium to fine grained grey sandstone with a small seam of hematite ? at 1′6″	
327	330	2 5	0′–1′ medium-grained grey sandstone with a small seam of quartz and hematite at 1′6″	
			1′–2′ fine-grained massive hematite with $\frac{1}{4}$″ to $\frac{1}{2}$″ patches showing dark blue " steely " tarnish ..	*Assay* 0′6″–2′0″ *Trace*
			2′–2′5″ medium-grained sandstone	
330	335	3 6	0′–1′10″ medium to fine grained sandstone with $\frac{1}{8}$″ seam of hematite at 6″	
			1′10″–2′9″ brecciated hematite with small seams showing dark blue " steely " tarnish	
			2′9″–3′6″ fine-grained grey sandstone with $\frac{1}{4}$″ seam of dark green soft mineral (chlorite ?) ..	*Assay* 1′7″–3′1″ *Trace*
335	337	1 4	0′–1′4″ medium-grained grey sandstone with 2″ of red sandstone at 10″	
337	341	3 0	0–3′ medium-grained sandstone. 1″ seam of brecciated micaceous hematite at 1′5″	
341	344	1 7	0′–0′6″ clay pug seam	
			0′–1′7″ medium-grained grey sandstone, very broken	
344	354	9 0	0′–9′ medium to fine grained sandstone with 4″ purple mudstone at 4′3″	
354	361	6 5	0′–3′0″ grey mudstone ?	
			3′0″–4′8″ thoroughly brecciated sandstone and mudstone ; possible bedding plane	*Assay* 3′2″–5′4″ *Trace*
			4′8″–5′3″ banded cherty hematite replacing mudstone ?	
			5′3″–6′5″ fine-grained cherty sandstone	
361	368	3 2	0′–3′2″ fine to medium grained sandstone, last 4″ cherty	
368	375	6 2	0′–6′2″ fine to medium grained sandstone with small quartz seams and mudstone ? veins	
375	377	2 0	0′–2′0″ medium-grained light grey silicified sandstone	
377	382	5 0	0′–5′0″ medium-grained light grey silicified sandstone with fine-grained cherty seam at 3′1″ to 3′6″	

Noble's Nob Gold Mine.			Diamond Drill Hole No. 1.	
Footage.				
From	To	Recovery.	Description.	Assay.
		ft. in.		
382	392	10 0	0′0″ to 1′0″ medium-grained siliceous sandstone 1′0″ to 5′2″ fine-grained cherty sandstone ? with numerous small seams showing reddish oxidised replacements ; highly silicified quartzite ? 5′2″–9′2″ fine to medium-grained light grey siliceous sandstone 9′2″–10′0″ fine-grained cherty quartzite	
392	398	4 0	0′0″–4′0″ fine-grained cherty quartzite ? with 1″ medium-grained sandstone at 1′0″	
398	405	2 0	0′0″–2′0″ medium-grained sandstone with small replacement seams and occasional seams of chert	
405	415	8 0	0′0″–8′0″ medium-grained sandstone with small replacement seams and one small seam of hematite at 7′8″	
415	423	1 5	0′8″–1′5″ medium-grained sandstone with replacement seams ; core very broken	
423	427	4 0	0′0″–4′0″ medium-grained light grey silicified sandstone	
427	433	5 0	0′0″–5′0″ medium-grained light grey silicified sandstone	
433	440	6 0	0′0″–5′6″ medium-grained siliceous sandstone 5′6″–6′0″ pink cherty banded quartzite ; core very broken	
440	446	1 1	0′0″–8″ pink quartzite ; core very broken 0′8″–1′1″ quartz seam with bands of dark greenish mineral (chlorite) ?	
446	454	7 3	0′0″–7′3″ massive hematite with numerous white quartz seams and vugs $\frac{1}{16}$″ to $\frac{1}{4}$″ and showing dark blue steely tarnish at 6′3″ to 7′0″ ..	*Assay* 446′ to 454′ *Trace* Trace
454	456	1 3	0′0″–0′9″ fine-grained quartzite .. .. 0′9″–1′3″ fine-grained dark grey sandstone	
456	461	4 7	0′0″–0′10″ fine-grained silicified sandstone 0′10″–1′0″ a 2″ seam of mica and hematite showing dark blue steely tarnish 1′0″–1′10″ fine-grained grey sandstone with quartz seams and $\frac{1}{16}$″ flakes of mica 1′10″–2′4″ seam of hematite showing dark blue steely tarnish and thoroughly impregnated with mica 2′4″–3′6″ medium-grained silicified sandstone ; 1″ seam of hematite and mica at 3′6″ (hematite showing dark blue steely tarnish) 3′6″–4′7″ medium-grained sandstone with small quartz mica seams and thin seams of hematite	
461	463	2 0	0′0″–2′0″ medium-grained light grey sandstone	
463	472	4 5	0′0″–4′5″ medium-grained light grey sandstone with numerous fine quartz veins	
472	474	2 0	0′0″–2′0″ fine-grained light grey sandstone with quartz veins	
474	481	6 9	0′0″–6′9″ medium-grained light grey sandstone with scattered quartz veins	
481	491	10 0	0′0″–2′10″ medium-grained grey sandstone, sheared and cracked, with some fine quartz veins 2′10″–3′6″ fine-grained sandstone 3′6″–10′0″ medium-grained sandstone	
491	500	6 5	0′0″–6′5″ medium-grained sandstone with numerous small quartz veins (about $\frac{1}{16}$″ wide)	

End of Hole.

Noble's Nob Gold Mine.			Diamond Drill Hole No. 2.	
Footage			Description.	Assay.
From	To	Recovery.		
		ft. in.		
0	33	4 10	Pale purple medium-grained tuffaceous sandstone	
33	37	7 1	Pink and yellow siltstone with fine and medium-grained tuffaceous sandstone bands	
37	40		Mudstone lenses $\frac{1}{8}''$–$\frac{1}{4}''$ wide Pink medium-grained tuffaceous sandstone with siltstone bands	
40	60	..	Fine grained argillaceous sandstone with siltstone lenses	
60	75	10 0	0–6″ grey medium-grained tuffaceous sandstone 6″–1′1″ grey siltstone 1′1″–1′6″ medium-grained tuffaceous sandstone 1′6″–1′11″ siltstone 1′11″–6′2″ light grey to pink fine and medium grained tuffaceous sandstone 6′2″–8′8″ siltstone 8′8″–10′0″ interbedded siltstone and medium-grained tuffaceous sandstone	
75	100	8 3	0–4′9″ purplish grey fine and medium grained tuffaceous sandstone 4′9″–8′3″ grey siltstone and fine-grained tuffaceous sandstone	
100	111	8 3	0–7′6″ fine and medium grained tuffaceous sandstone with mudstone and siltstone bands 7′6″–8′3″ grey and red siltstone	
111	123	10 0	0–10′0″ purple fine and medium-grained tuffaceous sandstone with bands and lenses of siltstone	
123	130	1 0	0–10″ purple medium grained tuffaceous sandstone 10″–1′ grey siltstone	
130	140	2 11	0–2′11″ purply-pink medium-grained tuffaceous sandstone	
140	150	4 8	0–2′8″ yellow-ochre and grey sandy shale 2′8″–4′8″ medium-grained tuffaceous sandstone	
150	160	9 4	Evenly banded siltstone, fine-grained and medium-grained tuffaceous sandstone	
160	170	5 6	0–2′10″ pink and purple siltstone with fine-grained tuffaceous sandstone bands 2′10″–5′6″ purple medium to fine grained tuffaceous sandstone	
170	180	2 3	0–2′3″ purple medium and fine grained sandstone	
180	190	6 10	Red, pink, and purple siltstone with fine-grained tuffaceous sandstone bands, cherty slate. Cross bedding	
190	200	5 3	Purple-red cherty slate grading into siliceous fine-grained sandstone	
200	233	22 5	0–9″ grey-pink slate 0′9″–8′8″ green medium-grained tuffaceous sandstone 8′8″–16′11″ green slate with bands of medium-grained tuffaceous sandstone 16′11″–17′7″ quartz hematite and carbonate stringers in red slate 17′7″–19′10″ green slate and fine-grained sandstone with argillo-siliceous cement 19′10″–22′5″ green coarse and medium grained tuffaceous sandstone	
233	244	10 0	0–2′9″ red and green cherty slate with fine-grained sandstone bands 2′9″–10′0″ green medium-grained tuffaceous sandstone	

Footage.			Description.	Assay.
From	To	Recovery.		
		ft. in.		
244	253	7 10	0–2′11″ green coarse-grained tuffaceous sandstone with quartz stringers	
			2′11″–4′6″ green cherty slate	
			4′6″–7′10″ green medium-grained tuffaceous sandstone with last 2″ lightly fractured slate with sericite and quartz veins	
253	263	8 9	Green medium-grained tuffaceous sandstone	
268	278	9 10	0–2′0″ lightly brecciated chloritised and sericitized sandy slate with quartz stringers, quartz and hematite segregations, chalcopyrite—crossbedding	Au. dwt. per ton.
			2′0″–6′10″ fine and medium grained tuffaceous sandstone with senior quartz stringers	275′–278′ Tr.
			6′10″–7′2″ pale green to red sandy mudstone	
			7′2″–9′8″ quartz-hematite lode with malachite staining pyrite boxworks, weathered pyrite; pyrite-chalcopyrite intergrowth in places	
			9′8″–9′10″ red sandy siltstone	
278	288	8 2	Green fine-grained sandstone with red and yellow stainings	
288	293	5 9	Green fine medium and coarse grained sandstone with narrow siltstone lenses and numerous quartz stringers	
293	301	4 3	0–4′3″ green coarse-grained tuffaceous sandstone grading into fine-grained tuffaceous sandstone with slate bands	
301	305	3 10	0–2′2″ green fine-grained sandstone	
			2′2″–2′8″ lightly brecciated medium-grained tuffaceous sandstone with narrow quartz and hematite veins	
			2′8′-3′10″ fine-grained tuffaceous sandstone grading into medium-grained tuffaceous sandstone	
305	311	5 5	0-3′10″ lightly crushed medium-grained tuffaceous sandstone with some quartz and hematite stringers	
			3′10″–5′5″ lode: hematite-sericite-rich sandy mudstone	(309′–314′) 1.65
321	331	7 6	0–1′5″ massive hematite lode	
			1′5″–1′10″ sericitized chloritic sandstone to finely divided hematite	(314′–318′) 2.45
			1′10″–7′6″ green fine and medium-grained tuffaceous sandstone at 7¼″ a ¼″ vein with pyrite-chalcopyrite segregation	(318′–323′) 0.20
331	339	3 0	0–2′0″ green fine-grained sandstone	
			2′0″–3′0″ green sandy slate	(340′–341′) Tr.
339	349	4 4	0–1′5″ green fine-grained tuffaceous sandstone grading into sandy slate	(341′–350′) Tr.
			1′5″–2′3″ sericitized hematite-rich chloritic slate	
			2′3″–4′4″ sericitized hematite-rich chloritic slate but with less hematite	
349	358	5 5	0–1′4″ sericitized hematite-rich chloritic slate but with less hematite	
			1′4″–5′5″ green fine and medium grained tuffaceous sandstone	
358	359	1 0	Green fine-grained sandstone and sandy slate with sericite—hematite stringers	
359	367	6 11	0–5′5″ lightly-sericitized fine and medium grained tuffaceous sandstone and slate with hematite veins	(363′–364′) Tr.

Noble's Nob Gold Mine.			Diamond Drill Hole No. 2.	
Footage.			Description.	Assay.
From	To	Recovery.		
		ft. in.		Au dwt. per ton.
			5′5″–6′3″ green massive medium-grained tuffaceous sandstone 6′3″–6′11″ massive hematite lode with numerous boxworks. Replacement of sandy mudstone ..	(365′–369′) Tr.
367	372	4 0	0–4′0″ lode : consists of quartz-hematite with $\frac{1}{8}$″–$\frac{1}{4}$″ muscovite flakes and hematite-rich sericitized sandstone. Some green chlorite flakes ..	(369′–373′) Tr.
372	381	7 0	0–9″ siliceous hematite with veins of micaceous hematite 9″–7′0″ lightly-sericitized fine-grained sandstone, fractured, irregular quartz and hematite veins	
381	385	4 6	0–1′5″ as above 1′5″–1′6″ breccia with partial quartz replacement 1′6″–4′6″ green fine and medium-grained sandstone with quartz stringers	
385	393	8 0	Purply-grey medium-grained sandstone with quartz and hematite stringers. (Primary chlorite at 393′)	
393	403	9 7	0–4′1″ purply-grey fine-grained tuffaceous sandstone lightly brecciated at 3′11″ to 4′1″ 4′1″–7′0″ fine-grained sandstone with siliceous slate 7′0″–8′0″ purply-grey fine to medium grained sandstone 8′0″–9′7″ cherty slate	
403	433	16 6	Purply-grey fine to medium-grained sandstone with cherty bands. Some quartz-hematite veins	
433	457	24 0	Same	
457	470	10 0	Same	
470	490	8 8	0–6′3″ grey slate with mostly argillaceous cement. At 5′3″ quartz-chlorite stringers with vugs ($\frac{1}{4}$″ diameter) 6′3″–8′8″ purply-green and grey medium and fine grained sandstone	
490	496	5 0	Same	
496	501	4 0	0–4′0″ medium and coarse grained sandstone with cherty slate bands	
501	511	8 6	Cherty slate and tuffaceous sandstone, marked lensing and crossbedding	
511	514	3 7	Cherty slate and tuffaceous sandstone, marked lensing and crossbedding	
514	520	5 0	Purply-grey fine and medium grained tuffaceous sandstone with irregular hematite-quartz stringers	
520	525	4 3	Purply-grey fine and medium grained tuffaceous sandstone with irregular hematite-quartz stringers	
525	527	2 0	Fault zone, impregnated with hematite chlorite quartz veins. some finely-divided hematite	
527	532	4 6	0″–2″ fault zone, impregnated with hematite chlorite quartz veins. Some finely-divided hematite 2″–1′3″ fine-grained tuffaceous sandstone 1′3″–3′5″ grey-green cherty slate 3′5″–4′6″ fine to medium grained tuffaceous sandstone with quartz-hematite stringers	
532	537	3 0	2″–1′3″ fine-grained tuffaceous sandstone 1′3″–3′5″ grey-green cherty slate 3′5″–4′6″ fine to medium grained tuffaceous sandstone with quartz-hematite stringers	
537	544	4 10	Interbedded grey cherty slate and fine-grained sandstone. 4′5″–4′10″ fractured	

End of Hole.

Footage. From	To	Recovery. ft. in.	Description.	Assay.
0	50	..	Nil	
50	60	1 0	Buff medium sandstone with quartz stringers	
60	70	0 9	Buff siltstone	
70	80	1 0	Mudstone with thin sandstone lenses	
80	90	1 0	Sandstone with mudstone lenses	
90	98	3 9	Medium sandstone with lenses of fine cherty sandstone	
98	110	7 0	Medium sandstone with lenses of fine cherty sandstone	
110	121	1 0	Medium sandstone with quartz stringers	
121	130	2 3	Purple medium sandstone	
130	140	2 6	Medium to fine sandstone, lenses of sandy siltstone	
140	152	3 2	Interbedded fine cherty and medium sandstone	
152	162	6 0	Interbedded fine and medium sandstone	
162	166	4 0	0–2′ sandstone with siltstone lenses 2′–2′3″ thin hematite stringers, $\frac{1}{8}$″ width 2′–4′ fine sandstone with siltstone lenses	
166	182	3 8	Interbedded fine and medium sandstone, thin siltstone lenses	
182	190	7 9	Interbedded fine and medium sandstone, thin siltstone lenses	
190	200	9 8	Interbedded fine and medium sandstone, thin siltstone lenses	
200	212	8 7	Interbedded fine and medium sandstone, thin siltstone lenses	
212	216	2 7	Interbedded fine and medium sandstone, thin siltstone lenses	
216	218	0 8	Medium sandstone	
218	240	22 0	0–17′6″ interbedded fine and medium sandstone 17′6″–22′ brown fine cherty sandstone	
240	250	6 0	Grey-green and buff fine cherty sandstone with thin lenses of quartz siltstone	
250	252	2 0	Fine–medium sandstone	
252	260	4 0	Fine–medium sandstone	
260	270	1 6	Medium sandstone with $\frac{1}{16}$″ hematite and quartz stringers	
270	281	6 6	Interbedded cherty sandstone and sandy siltstone	
281	290	5 6	Red cherty sandstone	
290	296	1 0	Sandstone	
296	308	2 6	Green and red hematite-rich sandstone with segregations of dense hematite with quartz and hematite stringers	
308	310	1 0	Green slaty rock with a little quartz and hematite	
310	315	4 0	Grey-green cherty slate	
315	320	3 3	0–1′9″ grey-green cherty slate 1′9″–3′3″ fine to medium sandstone, minor hematite with quartz veins ($\frac{1}{4}$″)	
320	330	4 0	Fine to medium sandstone, minor hematite with quartz veins ($\frac{1}{4}$″)	
330	340	4 2	Fine to medium sandstone, minor hematite with quartz veins ($\frac{1}{4}$″)	
340	345	1 6	Green cherty sandstone	
345	348	2 5	Sericite and hematite-rich sandstone grading into massive quartz hematite with quartz segregations	Trace
348	350	2 0	0–1′ dense quartz hematite .. .. .. 1′–2′ sericite-rich breccia	Trace
350	353	2 7	0–9″ sericite-rich sandy crush rock .. .. 9″–2′7″ dense quartz-hematite	Trace
353	355	1 0	Quartz-hematite	Trace
355	361	4 6	Quartz-hematite	Trace

Noble's Nob Gold Mine.			Diamond Drill Hole No. 3.	
Footage.			Description.	Assay.
From	To	Recovery.		
		ft. in.		
361	368	5 6	Quartz-hematite	361–363½ Trace 363½–368 0.6
368	371	1 6	Sericite-rich sheared fine sandstone	Trace
371	374	1 4	Sheared fine sandstone	Trace
374	378	1 3	Sheared sericite-rich crush rock with hematite stringers	Trace
378	381	1 9	Sheared sericite-rich crush rock with hematite stringers	Trace
381	393	4 0	0–3′4″ sheared sericite-rich crush rock with hematite stringers .. .. 3′4″–4′0″ interbedded slate and quartzite	387–391 Trace
393	399	10 5	Interbedded slate and quartzite	
410	420	10 5	Interbedded slate and quartzite	
420	430	9 8	0–7′ interbedded slate and quartzite 7′–9′8″ slate	
430	450	19 7	Interbedded slate and fine-grained quartzitic sandstone	
450	460	7 0	Grey-green quartzitic sandstone with thin slaty bands	
460	464	2 10	Quartzitic sandstone with quartz veinlets	
464	465	1 0	Slate with thin quartz and quartz-hematite stringers	
465	473	8 0	0–2′ slate with thin quartz and quartz-hematite stringers 2′–8′ quartzitic sandstone with quartz stringers	
473	483	10 0	Quartzitic sandstone, with hematite stringers in the last 7′	
483	493	10 0	Interbedded fine quartzitic sandstone and slate	
493	503	10 0	Interbedded fine quartzitic sandstone and slate	
503	513	5 6	Interbedded fine quartzitic sandstone and slate	
513	518½	5 0	0–1′ fine quartzitic sandstone with hematite stringers 1′–2′ brecciated mudstone with some sericite 2′–5′ vuggy lode (partly replaced sandstone). Dense hematite, quartz, micaceous hematite, chlorite, and sericite	
518½	523	4 10	Green quartzitic sandstone with quartz and quartz-hematite stringers	
523	544	9 0	Green quartzitic sandstone with quartz and quartz-hematite stringers	
544	549	1 0	Sericite-rich crushed sandstone	
549	560	3 6	Fine quartzitic sandstone with quartz stringers	

End of Hole.

(*b*) 1936 (Aerial, Geological and Geophysical Survey of Northern Australia).

In 1936 the Aerial, Geological and Geophysical Survey of Northern Australia discovered at the Peko mine a major magnetic anomaly with a maximum value of 5,500 gammas. The centre of this anomaly is tested by two diamond drill holes No. 3 and No. 6, Third Report on Magnetic Prospecting at Tennant Creek (1937, L. A. Richardson and J. M. Rayner). In No. 3 hole the main lode was intersected on the 170′ level and a sludge assay of 16.8 dwt. per ton was recorded from 168′–186′, but this result was not confirmed by core assays. No. 6 hole penetrated copper-quartz-magnetite-hematite lode for 35′ and was then abandoned. The results of this drilling are tabulated below. ..

No. 3 Diamond Drill Hole.

Location.—Peko No. 1 Anomaly at 604W/188, 80′ south of anomaly centre.

Description of drill cores—

0–39′	Brown massive slate.
39′–43′6″	Brown coarse-grained slate with occasional quartz veins.
43′6″–72′	Pale brown fine-grained slate.
72′–100′	Brown slate with hematite and quartz veins.
100′–120′	As for 72′–100′.
120′–128′	As for 100′–120′.
128′–150′	Hematite and quartz with soft patches; 75% core recovery.
150′–186′	Soft friable ferruginous material with occasional bands hard hematite and quartz. About 15% core recovery.

NOTE.—Casing was seated at 135′. Water lost at 170′ and hole cemented here.

Where core recovery was unsatisfactory, sludge as well as core was assayed.

Assay results—

Core samples—

			Au.
Sample No. 1,	39′–43′	Brown slate with quartz veins ..	tr.
No. 2,	72′6″–78′ ..	Chocolate-red schist with hematite (?) or quartz veins	2.58
No. 3,	78′–85′ ..	„ „ „ „ „ ..	5.85
No. 4,	85′–90′ ..	„ „ „ „ „ ..	1.29
No. 5,	90′–95′ ..	„ „ „ „ „ ..	1.5
No. 6,	95′–100′ ..	„ „ „ „ „ ..	tr.
No. 7,	100′–105′ ..	Brown slate or schist	tr.
No. 8,	105′–110′ ..	„ „ „	.4
No. 9,	100′–115′ ..	„ „ „	.4
No. 10,	115′–120′ ..	Chocolate-red schist with hematite (?) or quartz veins	.4
No. 11,	120′–128′ ..	Brown slate or schist	tr.
No. 12,	128′–135′ ..	Dense hematite and quartz	tr.
No. 13,	135′–138′ ..	„ „ „ „	tr.
No. 14,	138′–141′ ..	„ „ „ „	tr.
No. 15,	141′–144′ ..	„ „ „ „	.85
No. 16,	144′–147′ ..	„ „ „ „	.62
No. 17,	147′–150′ ..	„ „ „ „	tr.
No. 18,	150′–156′ ..	Fragments of hematite and quartz ..	tr.
No. 19,	156′–170′ ..	Hematite and quartz	tr.
No. 20,	170′–186′ ..	Fragments hematite and quartz ..	2.62

Sludge samples—

		Au.
Sample A,	53′–60′	tr.
B,	60′–66′	0.4
C,	66′–72′	0.62
D,	128′–130′	tr.
E,	130′–135′	tr.
F,	150′–154′	tr.
G,	154′–160′	tr.
H,	160′–165′	6.08
I,	165′–168′	17.85
J,	168′–173′	23.50
K,	173′–186′	10.62

Diamond Drill Hole No. 6.

Location—

Peko No. 1 Anomaly, angle hole at 610W/155N.

Depression 60 from horizontal to south, in direction of No. 3 Diamond Drill Hole.

Description of cores—

0–232′ ..	.. Brown slate or schist.
232′–239′6″ ..	.. Slate or schist with pseudomorphs after pyrite.
239′6″–240′ ..	.. Hematite, ferruginous slate with quartz veins and native copper.
240′–244′ ..	.. Grey fine-grained slate or schist with copper stains and quartz.
244′–250′6″ ..	.. Siliceous and ferruginous rock (altered slate?) with native copper and calcite.
250′6″–255′ ..	.. Hematite and quartz.
255′–267′5″ ..	.. Hematite and quartz with native copper and sulphide (pyrite).
267′5″–271′ ..	.. Dense hematite with some magnetite, quartz, native copper, pyrite and arsenopyrite.

Drilling was difficult and slow in the dense ironstone, possibly owing largely to poor condition of the diamonds.

Static water level apparently not reached.

Assay results—

Core samples—

		Au.	Cu.
Sample No. 1, 232′6″–239′6″ ..	Schist with pseudomorphs after pyrite	tr.	—
No. 2, 239′6″–240′ ..	Hematite ferruginous slate with quartz veins and native copper	tr.	no tr.
No. 3, 240′–244′ ..	Grey schist with copper stains and quartz	tr.	no tr.
No. 4, 244′–247′ ..	Siliceous and ferruginous rock	tr.	7.85%
No. 5, 247′–250′6″ ..	Siliceous and ferruginous rock	tr.	1.20%
No. 6, 250′6″–252′6″ ..	Hematite and quartz.. ..	tr.	...
No. 7, 252′6″–255′ ..	Hematite and quartz.. ..	tr.	..
No. 8, 255′–257′ ..	Hematite and quartz with native copper and sulphides and some magnetite	tr.	1.72%
No. 9, 257′–259′ ..	„ „ „ „ ..	tr.	0.68%
No. 10, 259′–261′ ..	„ „ „ „ ..	tr.	1.20%
No. 11, 261′–263′ ..	„ „ „ „ ..	tr.	1.32%
No. 12, 263′–265′ ..	„ „ „ „ ..	tr.	1.25%
No. 13, 265′–267′5″ ..	„ „ „ „ ..	tr.	no tr.
No. 14, 267′5″–271′ ..	„ „ „ „ .. with increasing magnetite.	tr.	0.54%

Sludge samples—

	Au.	Cu.
Sample A, 240′–245′	tr.	1.72%
B, 245′–250′	tr	no tr.
C, 250′–255′	tr.	tr.
D, 255′–260′	tr.	tr.
E, 260′–265′	tr.	tr.
F, 270′–271′	tr.	0.20%

Other drilling results and assays are also appended below: —

No. 1 Diamond Drill Hole.

Location.—Eldorado No. 1 Anomaly at 430W/425N on Eldorado 1935 plan. About 100′ south of anomaly centre.

Description of cores—

0–163′ ..	.. Alternating soft and hard slaty schist with a few small quartz bands.
163′–233′3″ ..	.. Brown and grey chloritic schist impregnated and veined with hematite.
223′3″–235′3″ ..	Dense fine-grained siliceous hematite. Drilling very slow and costly. Hole abandoned on account of cost.

Static water level was not reached.

The material from 163′–235′3″ was possible gold-bearing stone, and this section of the hole was assayed.

Assay results—

Core samples—

Sample number.	Depth.		Description.	Gold. dwt.
No. 1,	158′–163′	..	Slate veined and impregnated with hematite	traces
No. 2,	163′–167′6″	..	" " " " " "	"
No. 3,	167′6″–172′	..	" " " " " "	"
No. 4,	172′–176′	..	" " " " " "	"
No. 5,	176′–180′	..	" " " " " "	"
No. 6,	180′–181′	..	" " " " " "	"
No. 7,	181′–181′6″	..	" " " " " "	"
No. 8,	181′6″–185′	..	Slate veined and impregnated with quartz and calcite.	"
No. 9,	185′–188′	..	Slate veined and impregnated with hematite	
No. 10,	188′–192′	..	" " " " " "	0.67
No. 11,	192′–195′	..	" " " " " "	traces
No. 12,	195′–198′	..	" " " " " "	"
No. 13,	198′–203′	.	" " " " " "	0.67
No. 14,	203′–208′	..	Chloritic slate with hematite	traces
No. 15,	208′–211′	.	" " " "	"
No. 16,	211′–215′	..	" " " "	"
No. 17,	215′6″–217′6″	..	Slate with hematite impregnation	"
No. 18,	217′6″–220′	..	" " " "	"
No. 19,	220′–223′3″	..	" " " "	"
No. 20,	223′3″–224′9″	..	Siliceous hematite	"
No. 21,	225′1″–225′9″	.	" "	"
No. 22,	226′–227′8″	..	" "	"
No. 23,	227′8″–230′1″	.	" "	"
No. 24,	230′1″–231′6″	.	" "	0.7
No. 25,	231′6″–232′3″	..	" "	traces
No. 26,	233′6″–234′5″		" "	"

Small pieces of hematite at 234′9″ and 235′3″ not assayed.

Sludge samples—

		Gold.
Sample A, 198′	.. ..	Tr.
B, 231′6″	. .. .	Tr.
C, 233′6″	. .. .	Tr.
D, 235′	.. ..	Tr.

The hematitic slate from 163′ to 223′ is considered to represent a normal type of alteration found adjacent to the ironstone bodies.

The relative magnetic properties of drill cores were determined by rough field tests on the variometers. It was found that the hematite was not polarized, and it was not strongly magnetic, indicating that the magnetite content is very small.

Diamond Drill Hole No. 2.

Location.—Eldorado No. 3 anomaly at 143E, 800S, Eldorado 1936 plan, 45′ south of anomaly centre.

Description of cores—

0–86′	.. ..	Red weathered massive slate.
86′–130′	.. ..	No core recovered.
130′–260′	.. ...	Red weathered massive slate with some red felspathic sandstone or tuff.
260′–340′	.. ..	Soft quartzite and massive slate.
340′–400′	.. ..	Grey slightly schistose chloritic rock.
400′–408′	.. .	Soft grey impure sandstone or tuff.
408′–410′	.. ..	Grey massive slate.
410′–413′	.. ..	Reddish-brown soft breccia-like material, veined with quartz.
413′–435′6″	.. ..	Variegated soft formation with some quartz, chalcopyrite, and pyrite. Considerable fine-grained octahedral mineral (magnetite). Core strongly magnetic.
435′6″–441′	. ..	Magnetite, calcite, and chalcopyrite. Heavy dark and fine-grained. Strongly magnetic.
441′–452′	.. .	Sericite or talcose schist, soft and crumbly. Fine magnetite and chalcopyrite. Strongly magnetic.

Static water level was about 350′. The magnetite-bearing material from 413′–452′ was strongly magnetic, especially the portion from 435′6″ to 441′. The hole was abandoned at 452′ on account of caving at the bottom.

Core from 420′ to 452′ was assayed for gold and copper with results as follows:—

Assay results—

		Au.	Cu.
Sample	8, 420′–426′	tr.	0.45%
	9, 426′–435′	tr.	0.68%
	10, 435′–441′	tr.	tr.
	11, 441′–445′	tr.	0.38%
	12, 445′–452′	tr.	0.88%

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Vol. 2 BMR OOMPACTUS

A

COMMONWEALTH OF AUSTRALIA.

DEPARTMENT OF NATIONAL DEVELOPMENT.

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS.

BULLETIN No. 22.

A

THE GEOLOGY AND MINERAL DEPOSITS OF THE TENNANT CREEK GOLD-FIELD, NORTHERN TERRITORY

BY

J. F. IVANAC.

VOLUME I.—DESCRIPTION.

VOLUME II.—MAPS.

Issued under the Authority of Senator the Honourable W. H. Spooner, Minister for National Development.

1954.

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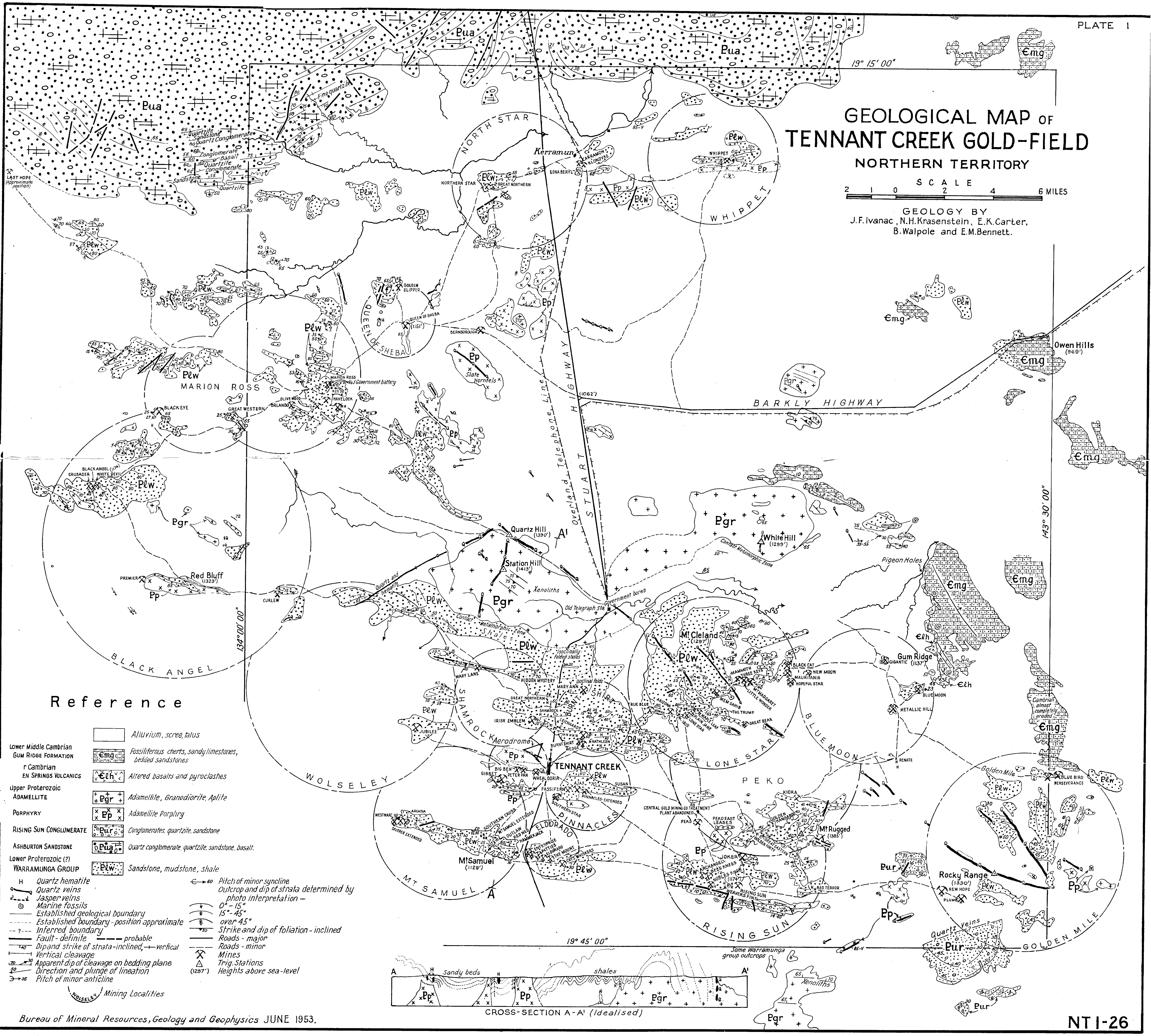
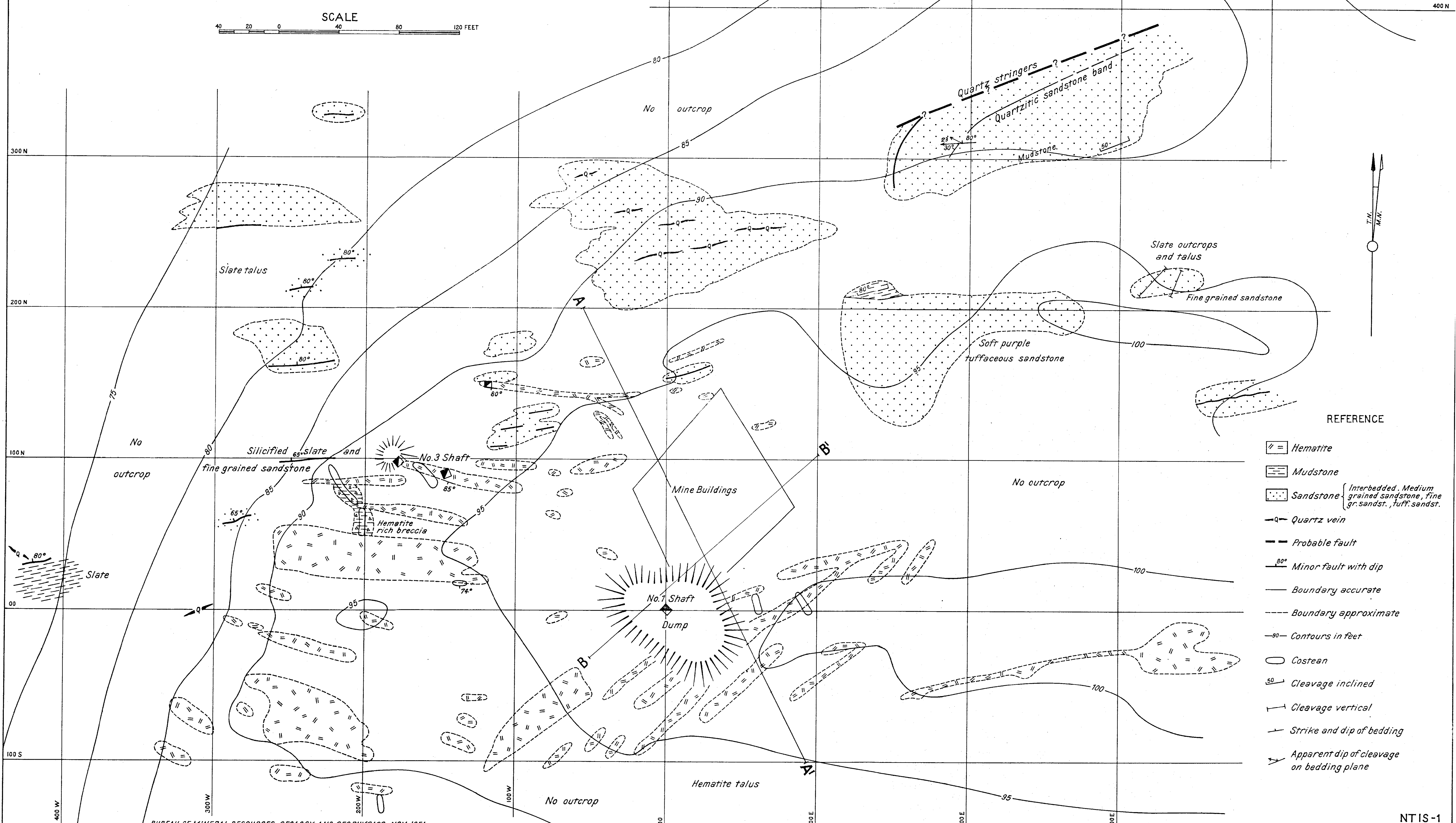


PLATE I
GEOLOGICAL MAP OF
TENNANT CREEK GOLD-FIELD
NORTHERN TERRITORY
SCALE
2 1 0 2 4 6 MILES
GEOLOGY BY
J.F. Ivanac, N.H. Krasenstein, E.K. Carter, B. Walpole and E.M. Bennett.
19° 15' 00"
19° 45' 00"
134° 00' 00"
134° 30' 00"
NORTH STAR
WHIPPET
QUEEN OF SHEBA
MARION ROSS
BLACK ANGEL
WOLSELEY
SHAMROCK
BURNT SHIRT
MT SAMUEL
ELDORADO
PINNACLES
LONE STAR
BLUE MOON
PEKO
RISING SUN
GOLDEN MILE
Kerramun
Owen Hills (969')
BARKLY HIGHWAY
STUART HIGHWAY
Overland Telephone Line
Quartz Hill (1390')
Station Hill (1413')
White Hill (1299')
Red Bluff (1323')
Mt Cleland (1297')
Gum Ridge (1137')
Mt Rugged (1385')
Rocky Range (1330')
Mt Samuel (1129')
TENNANT CREEK
Aerodrome
Government bores
Old Telegraph Sta.
Pigeon Holes
Xenoliths
Contact Metamorphic Zone
Cambrian almost completely eroded
Some Warramunga group outcrops
Quartz Veins
LAST HOPE (Approximate position)
Reference
Lower Middle Cambrian GUM RIDGE FORMATION — Emg — Fossiliferous cherts, sandy limestones, bedded sandstones
Lower Cambrian HELEN SPRINGS VOLCANICS — Elh — Altered basalts and pyroclastes
Upper Proterozoic ADAMELLITE — Pgr — Adamellite, Granodiorite, Aplite
PORPHYRY — Pp — Adamellite Porphyry
RISING SUN CONGLOMERATE — Pur — Conglomerates, quartzite, sandstone
ASHBURTON SANDSTONE — Pua — Quartz conglomerate, quartzite, sandstone, basalt.
Lower Proterozoic (?) WARRAMUNGA GROUP — Plw — Sandstone, mudstone, shale
Alluvium, scree, talus
Quartz hematite
Quartz veins
Jasper veins
Marine fossils
Established geological boundary
Established boundary - position approximate
Inferred boundary
Fault - definite — probable
Dip and strike of strata - inclined, — vertical
Vertical cleavage
Apparent dip of cleavage on bedding plane
Direction and plunge of lineation
Pitch of minor anticline
Pitch of minor syncline
Outcrop and dip of strata determined by photo interpretation —
0° - 15°
15° - 45°
over 45°
Strike and dip of foliation - inclined
Roads - major
Roads - minor
Mines
Trig. Stations
(1297') Heights above sea-level
WOLSELEY Mining Localities
CROSS-SECTION A-A' (Idealised)
Sandy beds
shales
Bureau of Mineral Resources, Geology and Geophysics JUNE 1953.
NT I-26

PLATE 2

GEOLOGICAL PLAN
SKIPPER - EXTENDED GOLD MINE
TENNANT CREEK GOLD-FIELD
NORTHERN TERRITORY



BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS, NOV. 1951

NT IS -1
H.J.

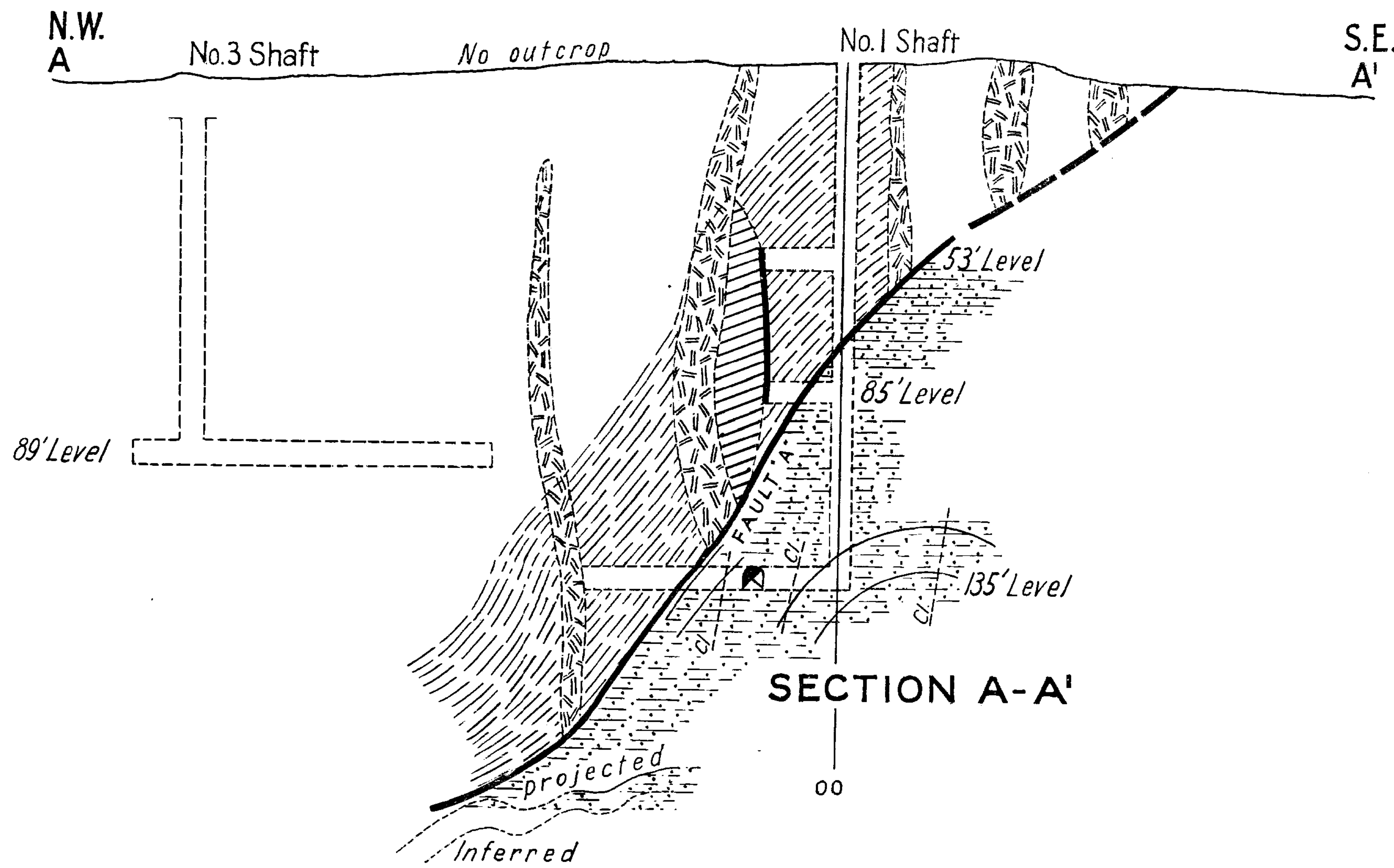
GEOLOGICAL SECTIONS, LEVEL PLANS
SKIPPER - EXTENDED GOLD MINE
TENNANT CREEK GOLD-FIELD
NORTHERN TERRITORY

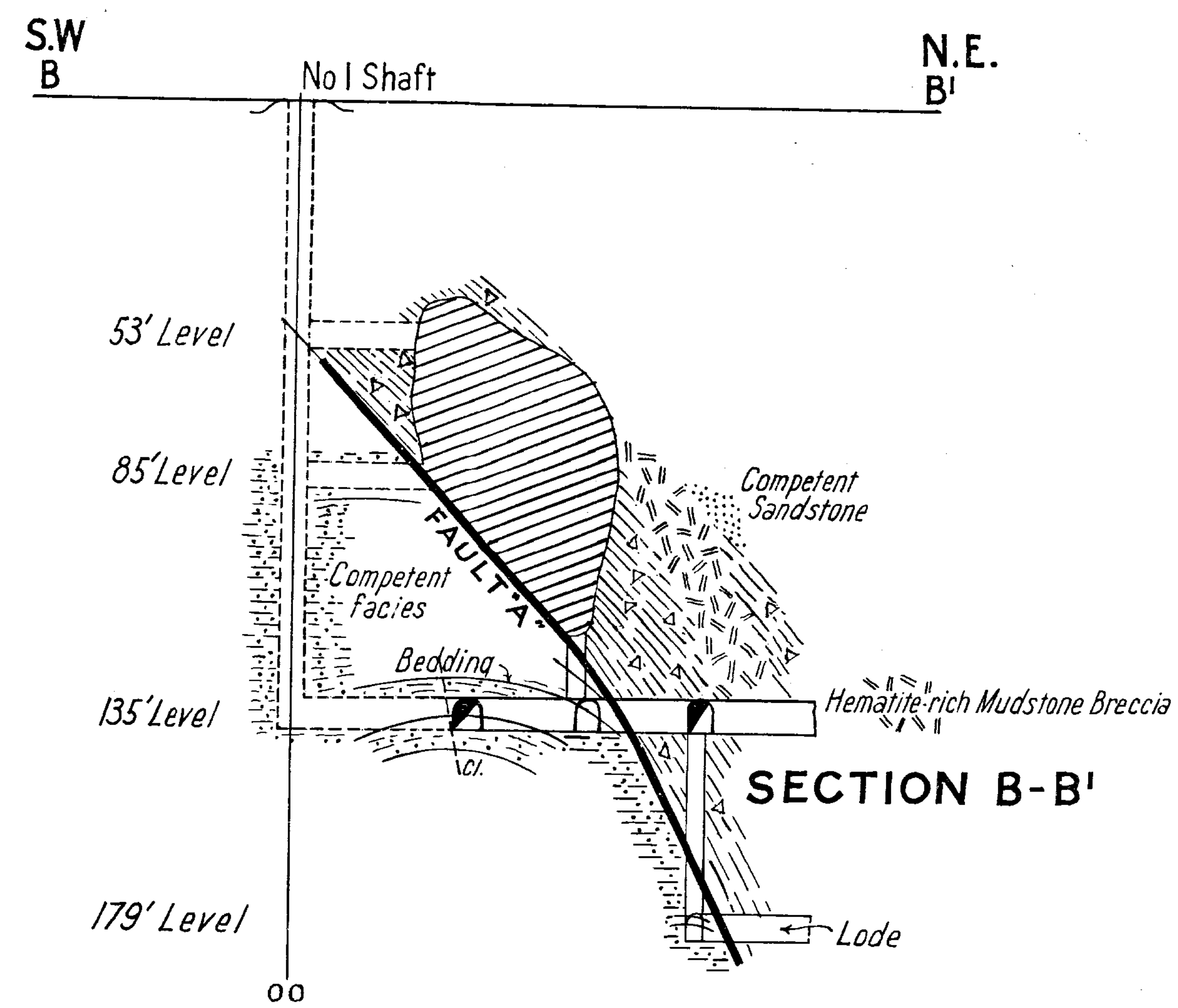
SCALE

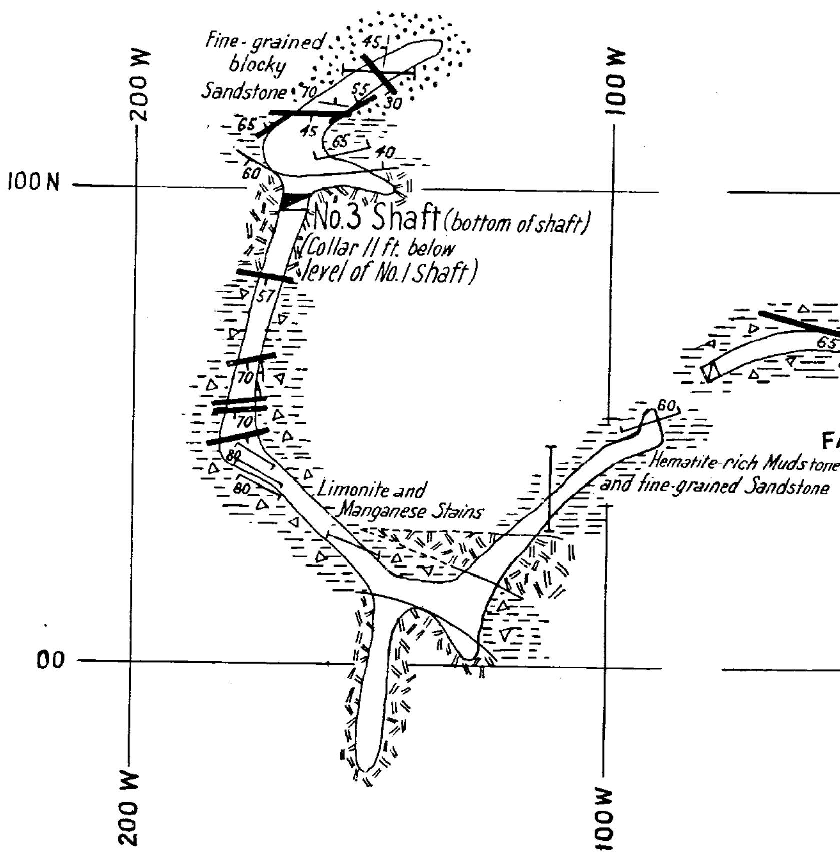
40 20 0 40 80 120 FEET

Reference

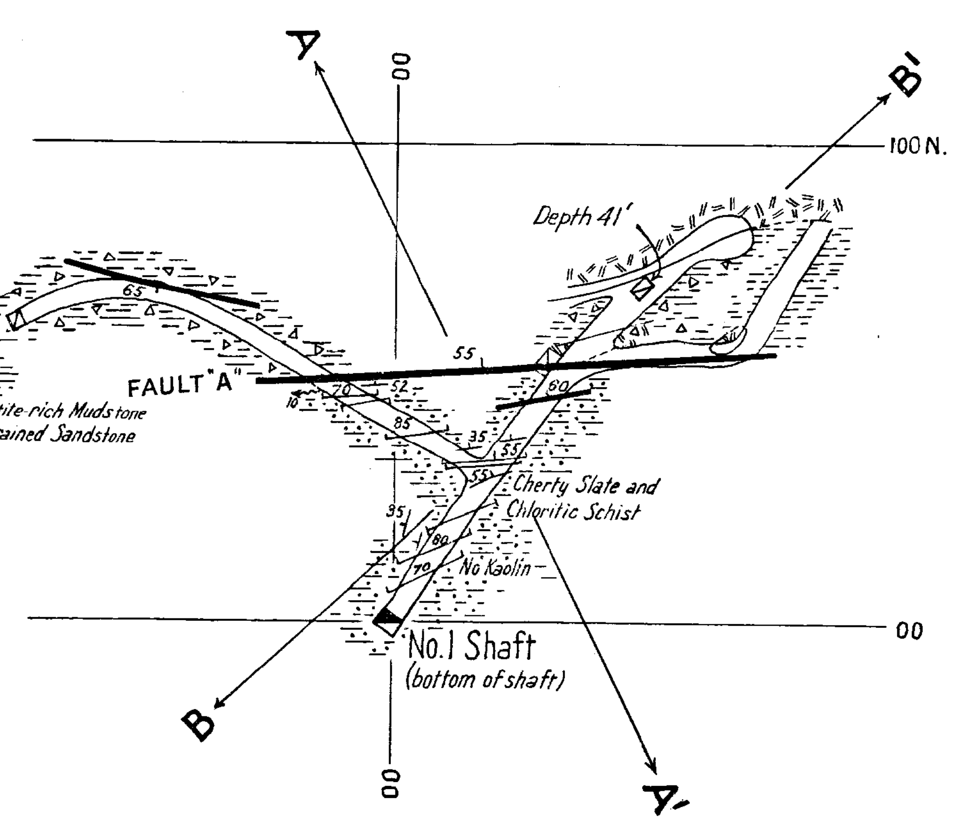
- Hematite
- Mudstone
- Sandstone
- Bedded sandstone, shale, cherty sandstone, mudstone.
- Breccia
- Stoped ore
- 30 Strike and dip of bedding
- Bedding vertical
- 65 Strike and dip of cleavage - inclined.
- Cleavage - vertical
- Strike and dip of joints - inclined
- 10 Prevailing dip of strata
- 60 Fault-position accurate - with dip
- Fault-position approximate
- Shaft - accessible
- Foot of winze
- Head of winze
- Shaft - extending above and below level
- Cross-cut or drive - extending across plane of section
- Cross-cut or drive - opposite side of plane of section from observer.
- Cross-cut or drive - same side of plane of section as observer.



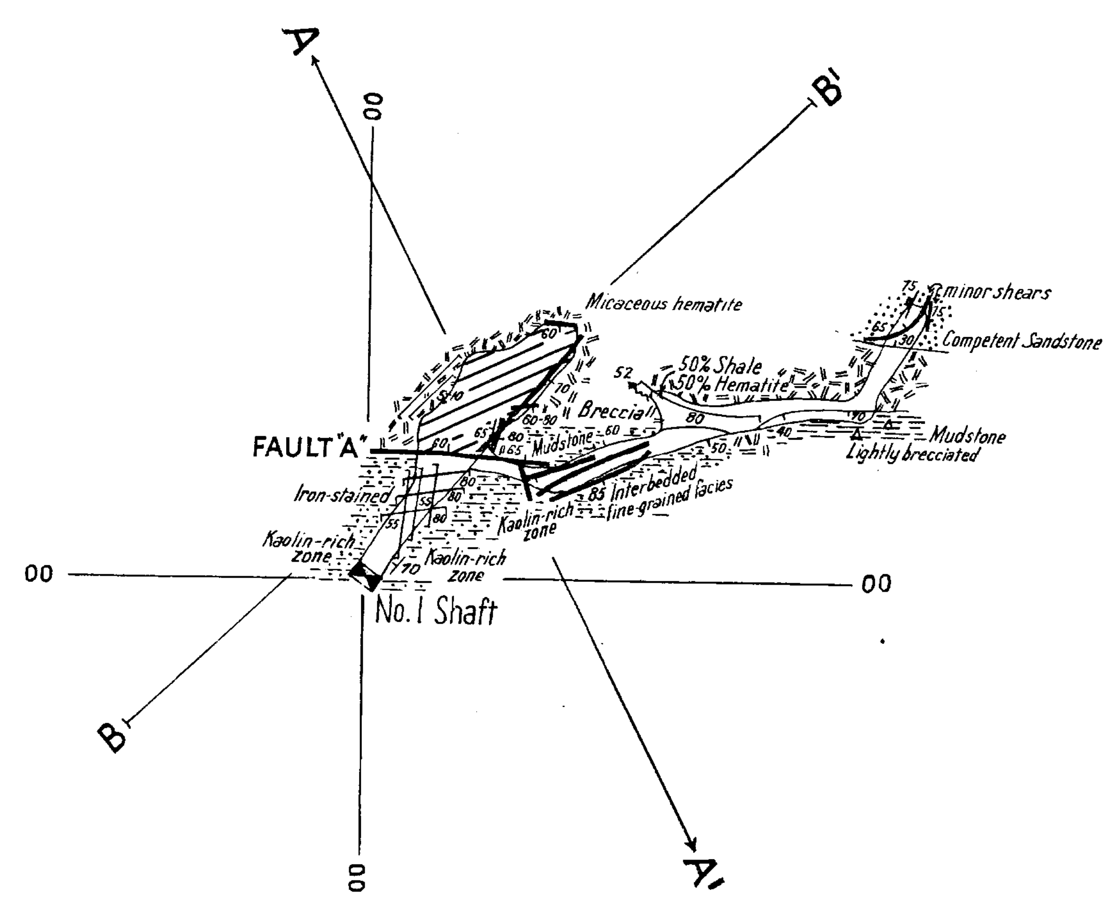




89 FOOT LEVEL



135 FOOT LEVEL



85 FOOT LEVEL

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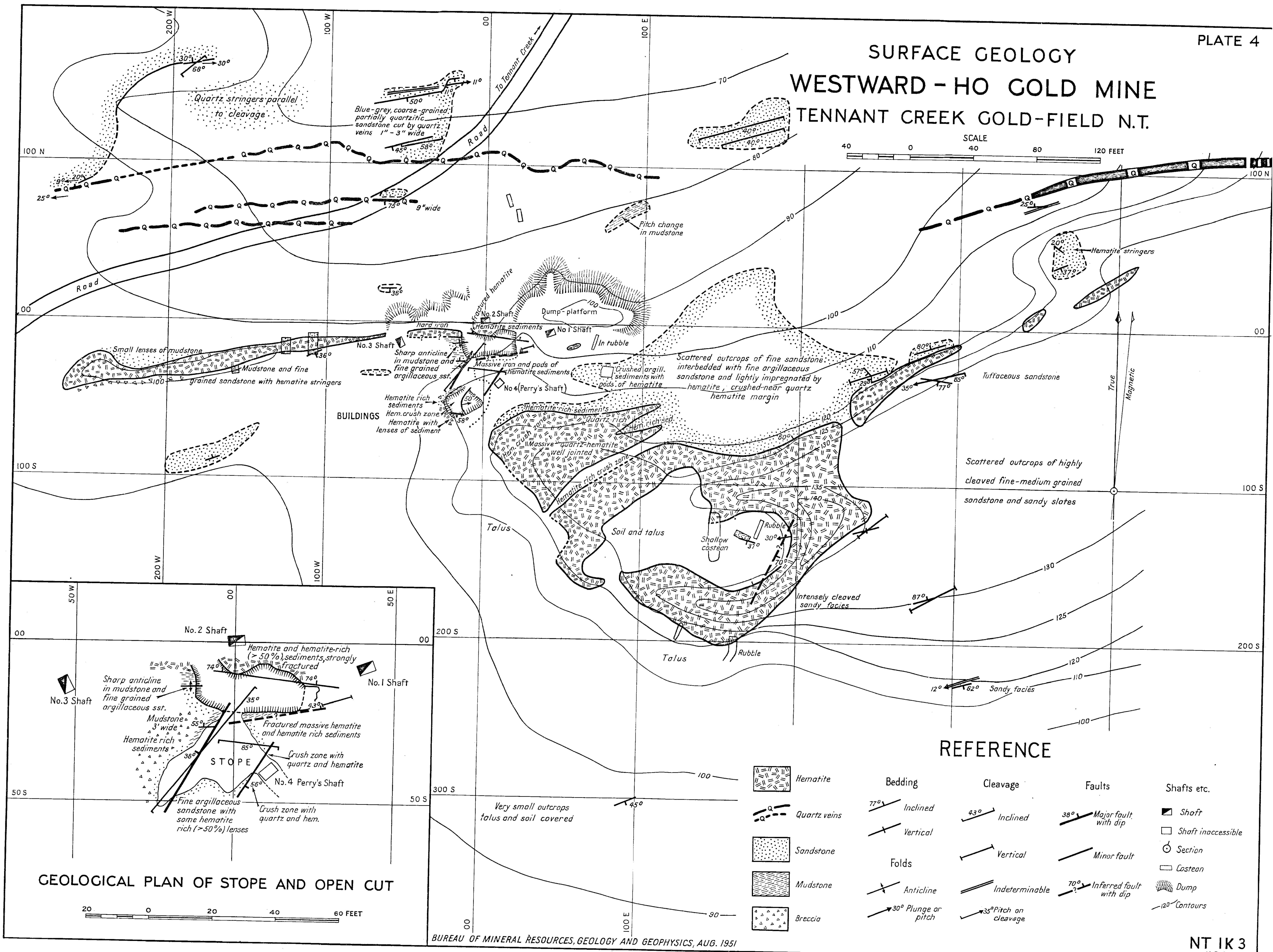


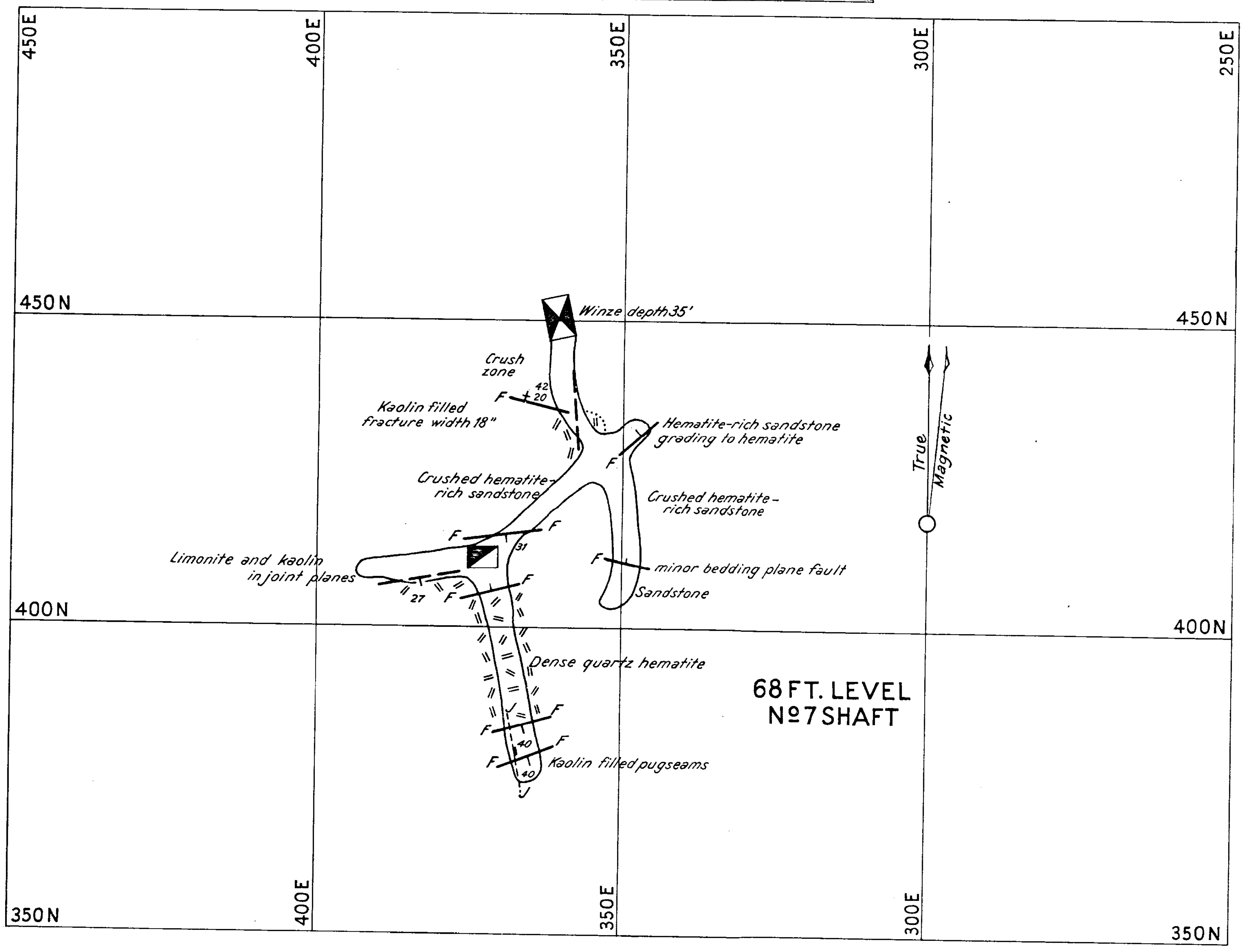
PLATE 4
SURFACE GEOLOGY
WESTWARD - HO GOLD MINE
TENNANT CREEK GOLD-FIELD N.T.
SCALE
40 0 40 80 120 FEET
Quartz stringers parallel to cleavage
Blue-grey, coarse-grained partially quartzitic sandstone cut by quartz veins 1" - 3" wide
To Tennant Creek
Road
9" wide
Pitch change in mudstone
Hematite stringers
Fractured hematite
No. 2 Shaft
Dump - platform
Hard iron
Hematite sediments
No 1 Shaft
In rubble
No.3 Shaft
Small lenses of mudstone
Mudstone and fine grained sandstone with hematite stringers
Sharp anticline in mudstone and fine grained argillaceous sst.
Massive iron and pods of hematite sediments
Crushed argill. sediments with pods of hematite
No 4 (Perry's Shaft)
Scattered outcrops of fine sandstone interbedded with fine argillaceous sandstone and lightly impregnated by hematite, crushed near quartz hematite margin
Tuffaceous sandstone
Hematite rich sediments
Hem. crush zone
Hematite with lenses of sediment
BUILDINGS
Hematite rich sediments
Quartz rich
Hem. rich sed.
Massive quartz-hematite well jointed
Hematite rich crush zone
Scattered outcrops of highly cleaved fine-medium grained sandstone and sandy slates
True
Magnetic
Talus
Soil and talus
Shallow costean
Rubble
Intensely cleaved sandy facies
Talus
Rubble
Sandy facies
REFERENCE
Very small outcrops talus and soil covered
Hematite
Quartz veins
Sandstone
Mudstone
Breccia
Bedding
Inclined
Vertical
Folds
Anticline
30° Plunge or pitch
Cleavage
Inclined
Vertical
Indeterminable
35° Pitch on cleavage
Faults
Major fault with dip
Minor fault
Inferred fault with dip
Shafts etc.
Shaft
Shaft inaccessible
Section
Costean
Dump
Contours
GEOLOGICAL PLAN OF STOPE AND OPEN CUT
No. 2 Shaft
Hematite and hematite-rich (> 50%) sediments, strongly fractured
No. 1 Shaft
No.3 Shaft
Sharp anticline in mudstone and fine grained argillaceous sst.
Mudstone 3' wide
Hematite rich sediments
Fractured massive hematite and hematite rich sediments
STOPE
Crush zone with quartz and hematite
No. 4 Perry's Shaft
Fine argillaceous sandstone with some hematite rich (> 50%) lenses
Crush zone with quartz and hem.
20 0 20 40 60 FEET
BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS, AUG. 1951
NT IK 3
H.R.L.

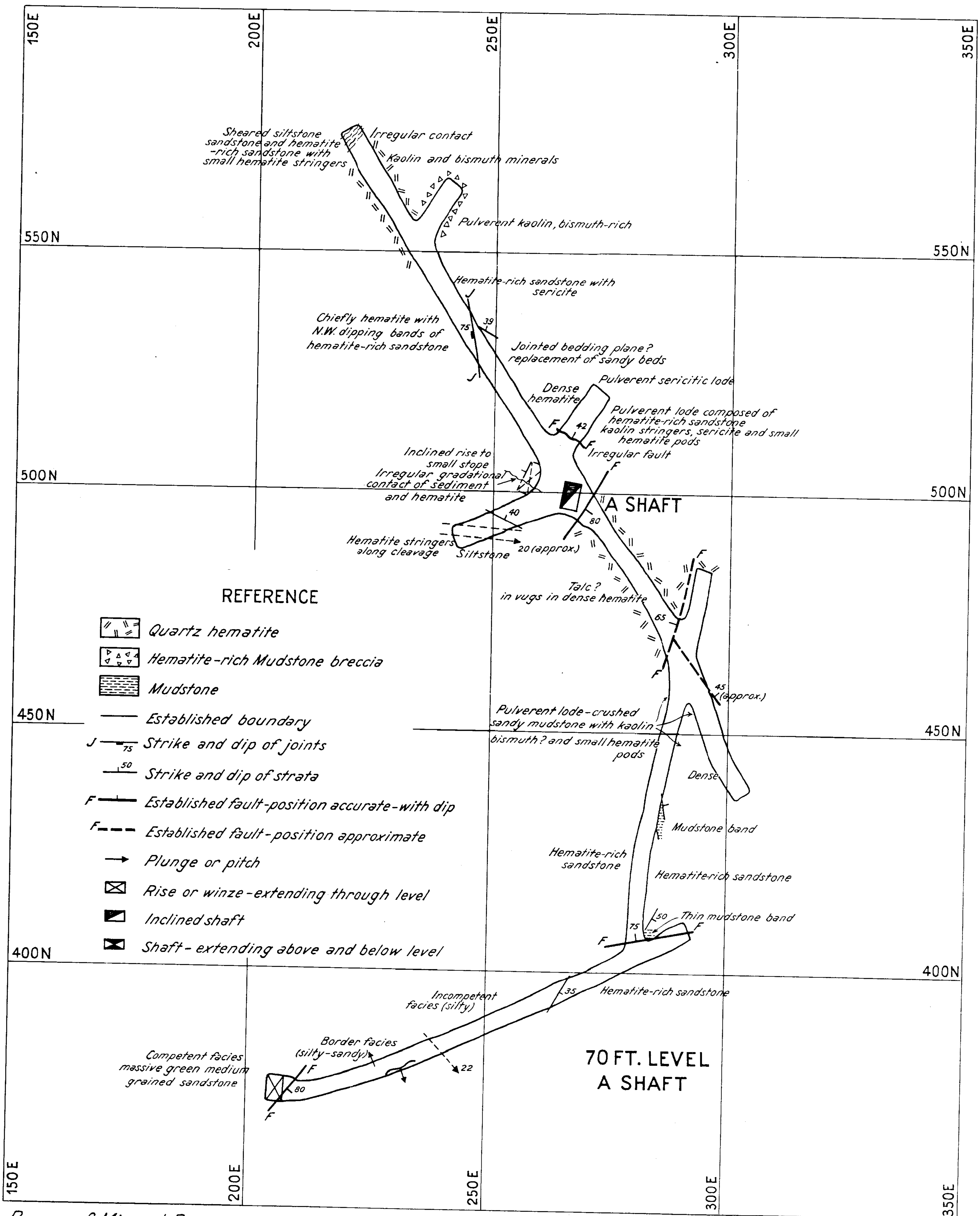
MT. SAMUEL GOLD MINE

TENNANT CREEK GOLD-FIELD

NORTHERN TERRITORY

Scale
20 10 0 20 40 60 FEET





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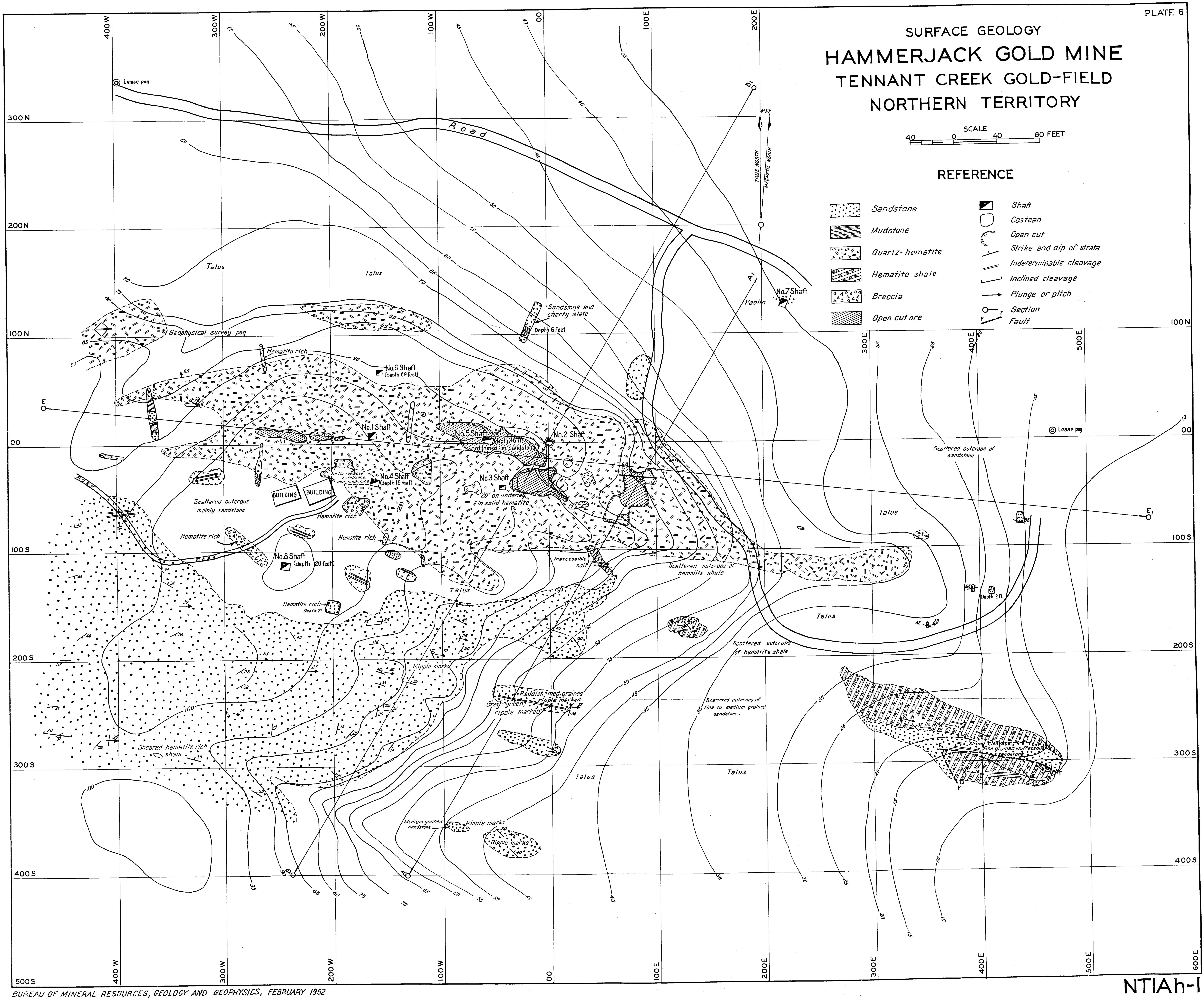
W.K.



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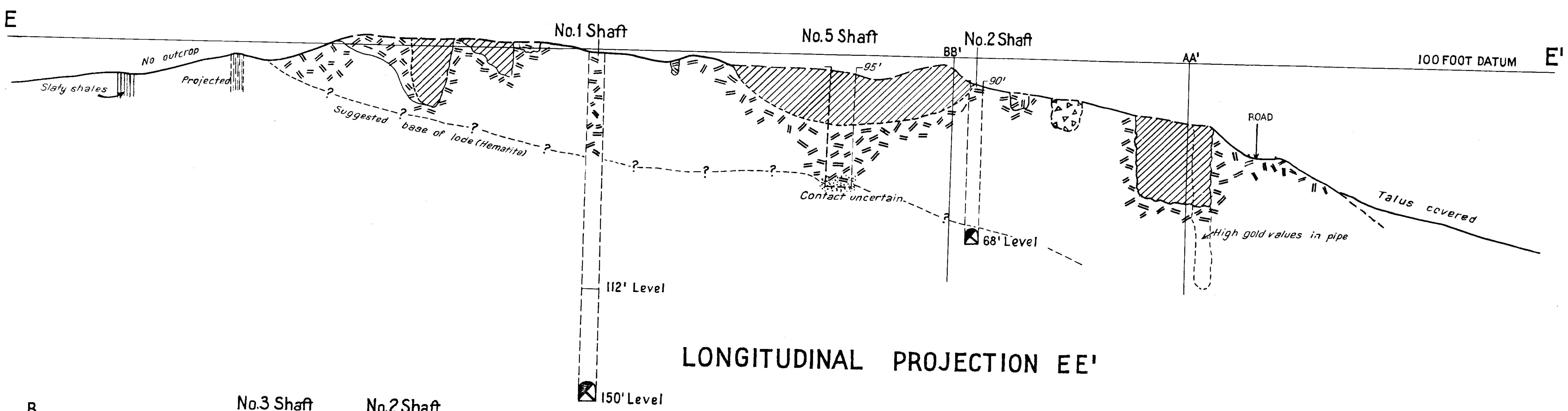
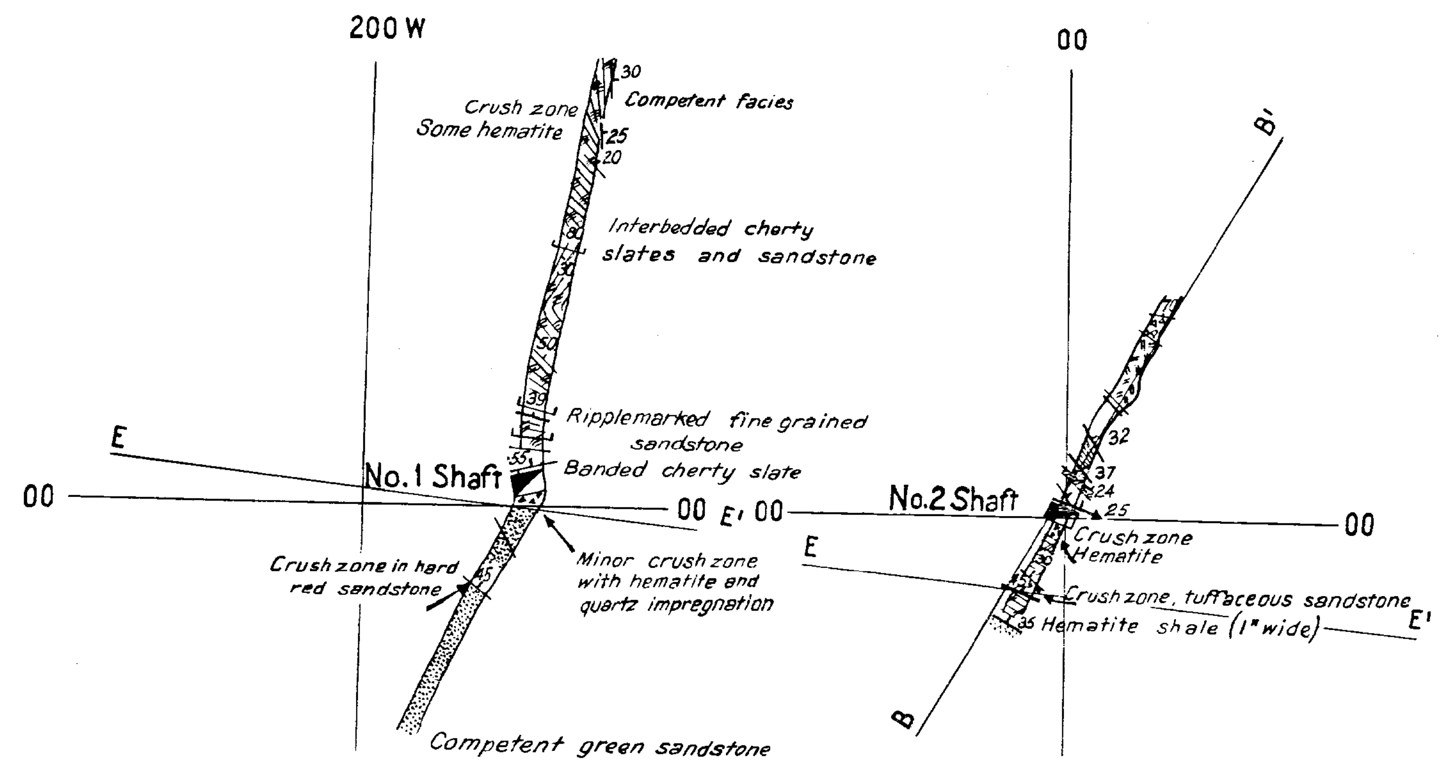
NTIAh-1

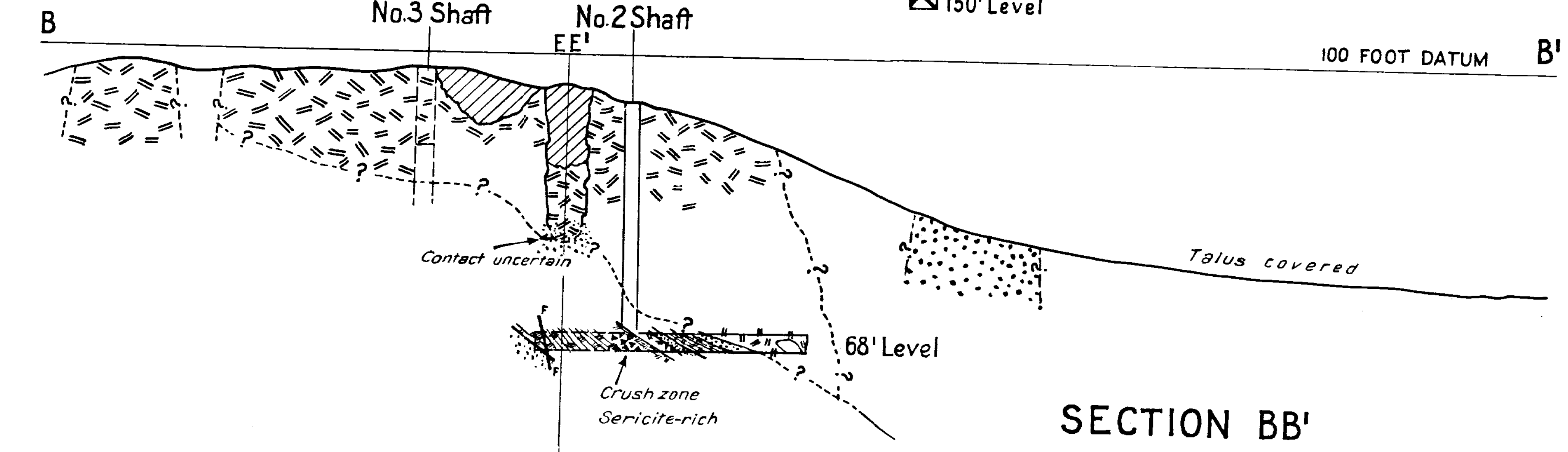


LONGITUDINAL PROJECTION EE'

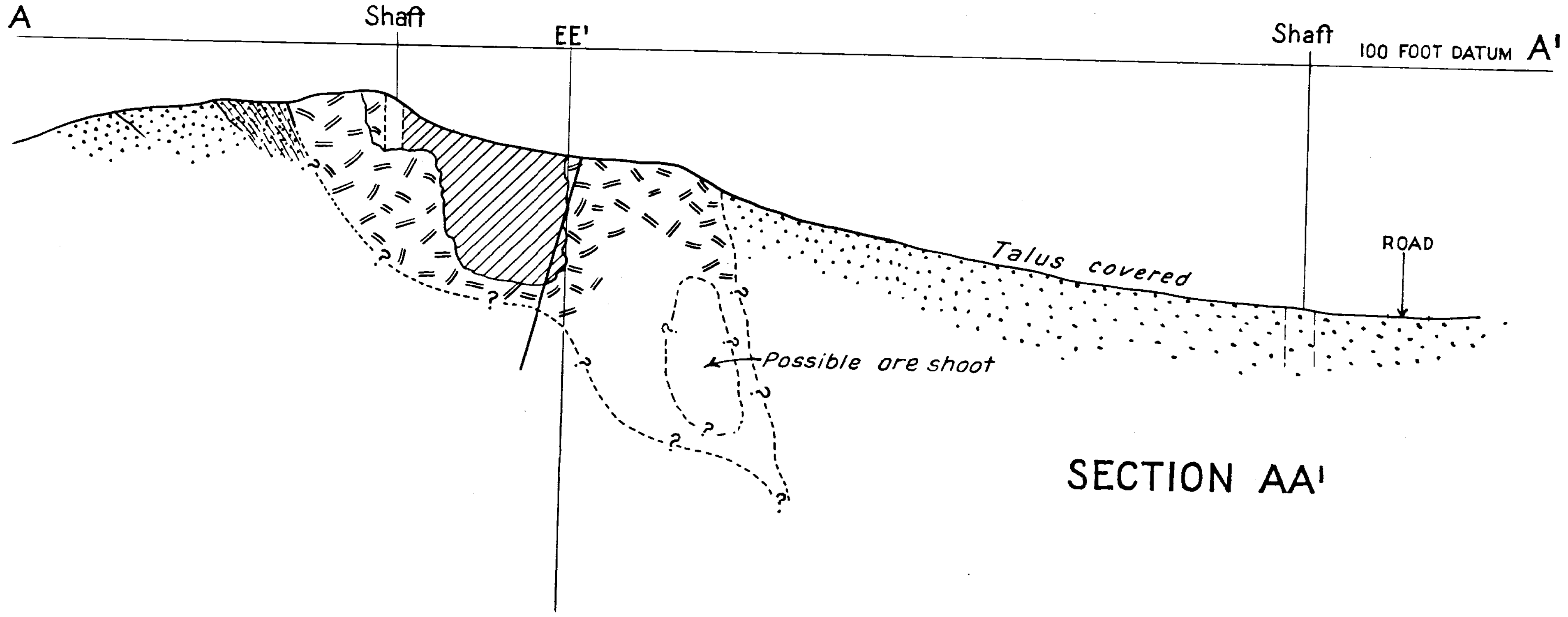


150' LEVEL

68' LEVEL



SECTION BB'



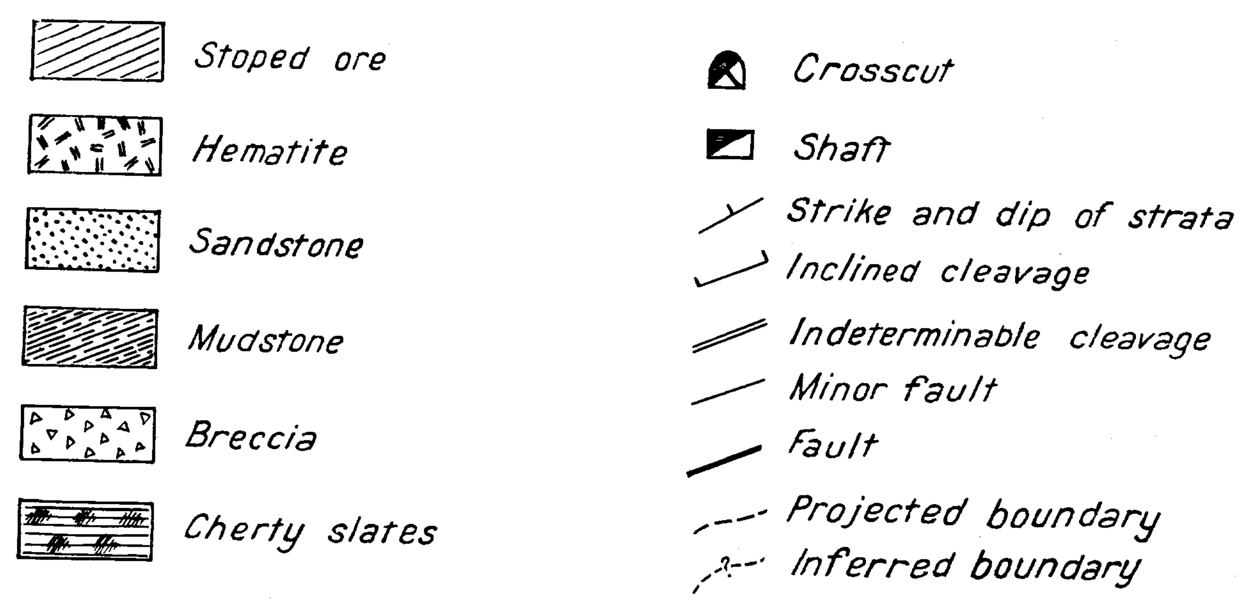
SECTION AA'

HAMMERJACK GOLD MINE
TENNANT CREEK GOLD-FIELD
NORTHERN TERRITORY

SCALE

40 0 40 80 FEET

REFERENCE



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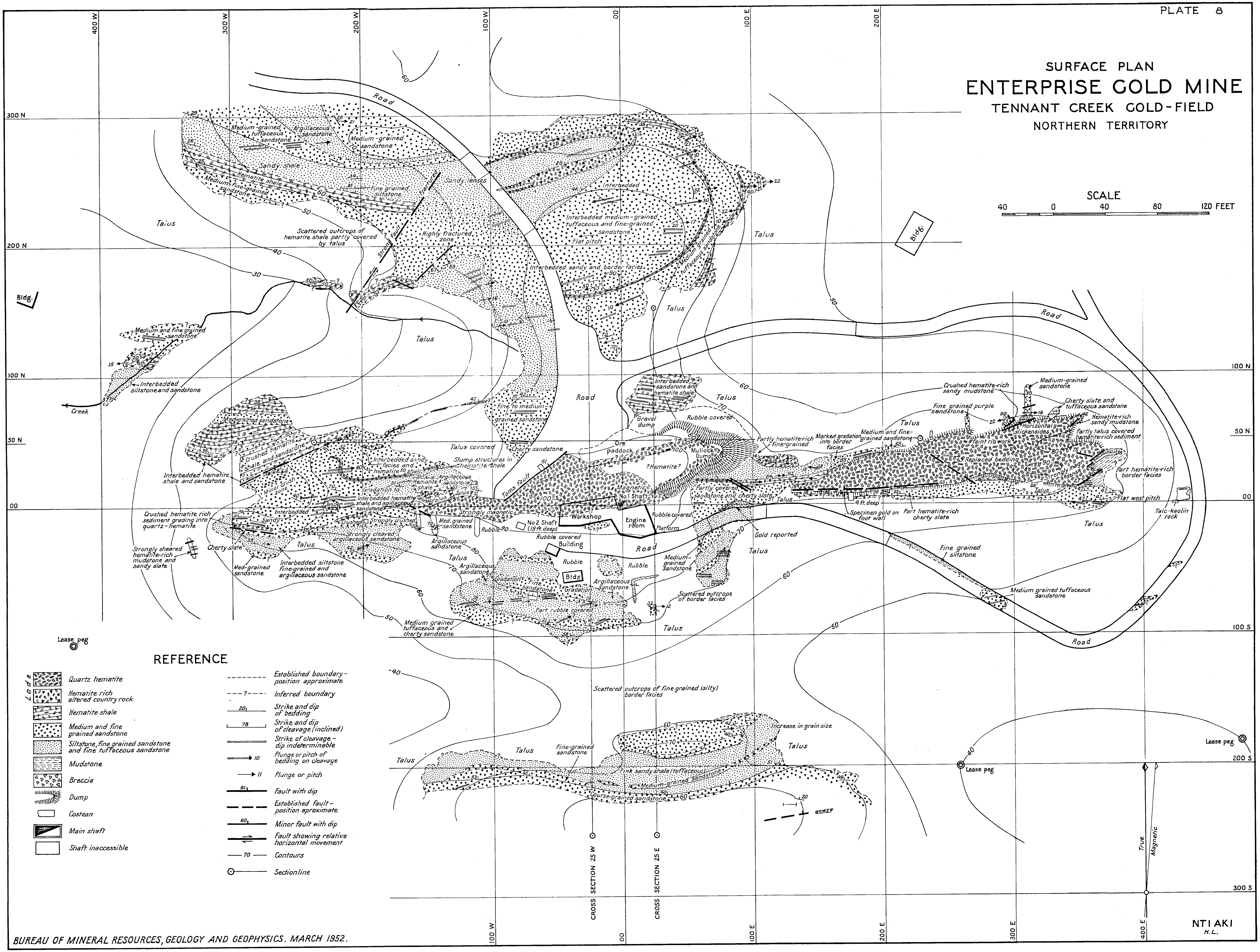
NT1Ah-2

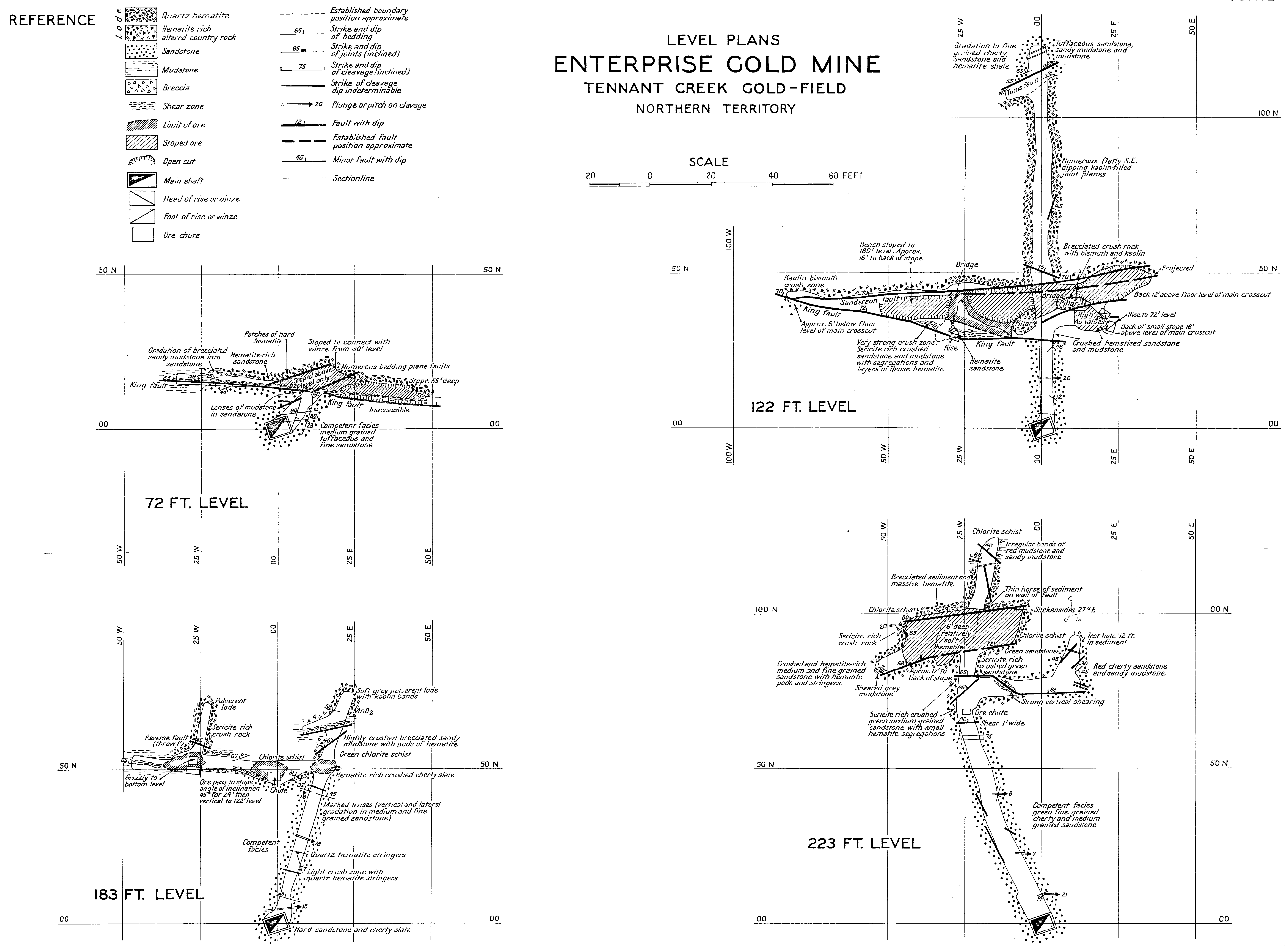
PLATE 8

SURFACE PLAN
ENTERPRISE GOLD MINE
TENNANT CREEK GOLD-FIELD
NORTHERN TERRITORY

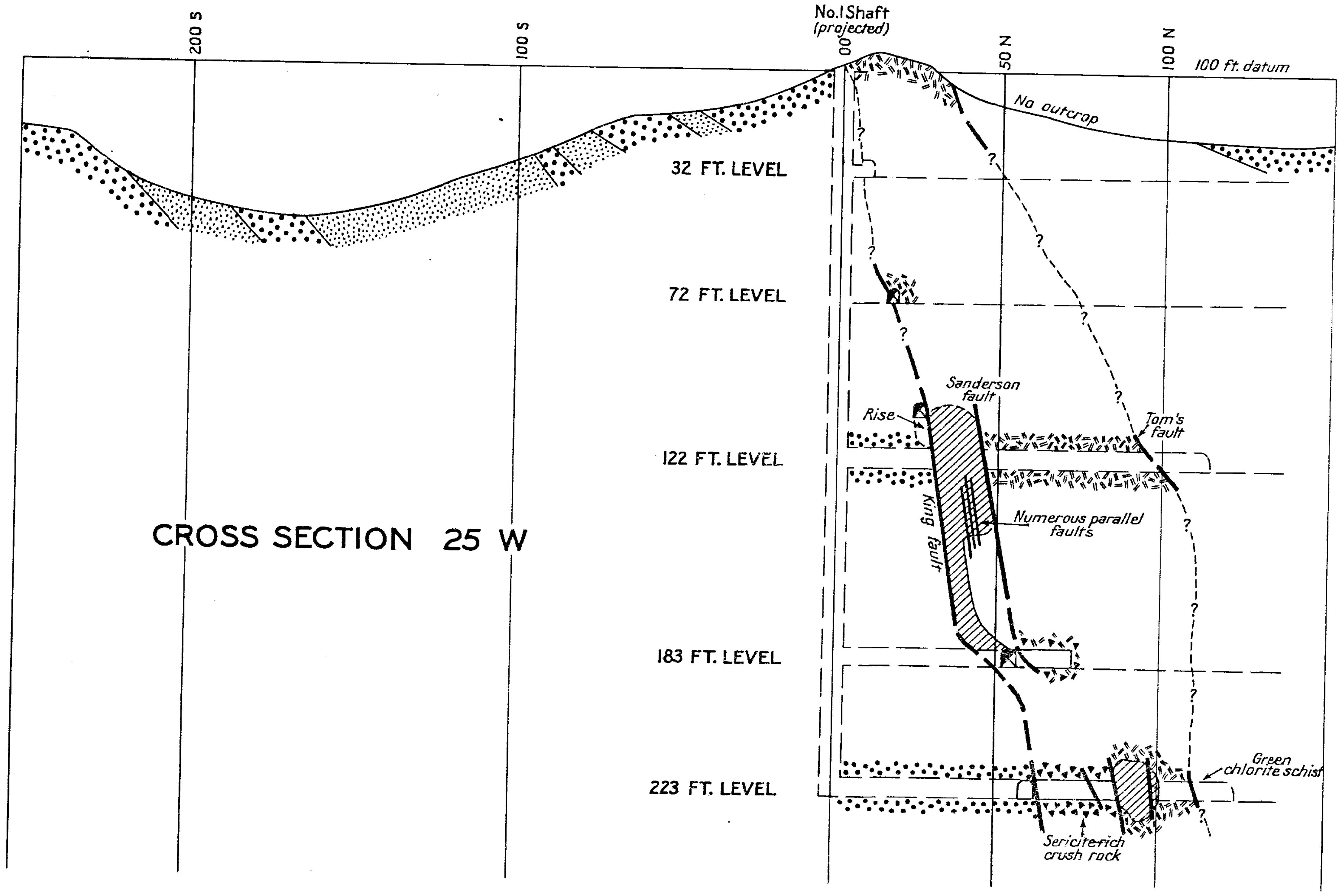


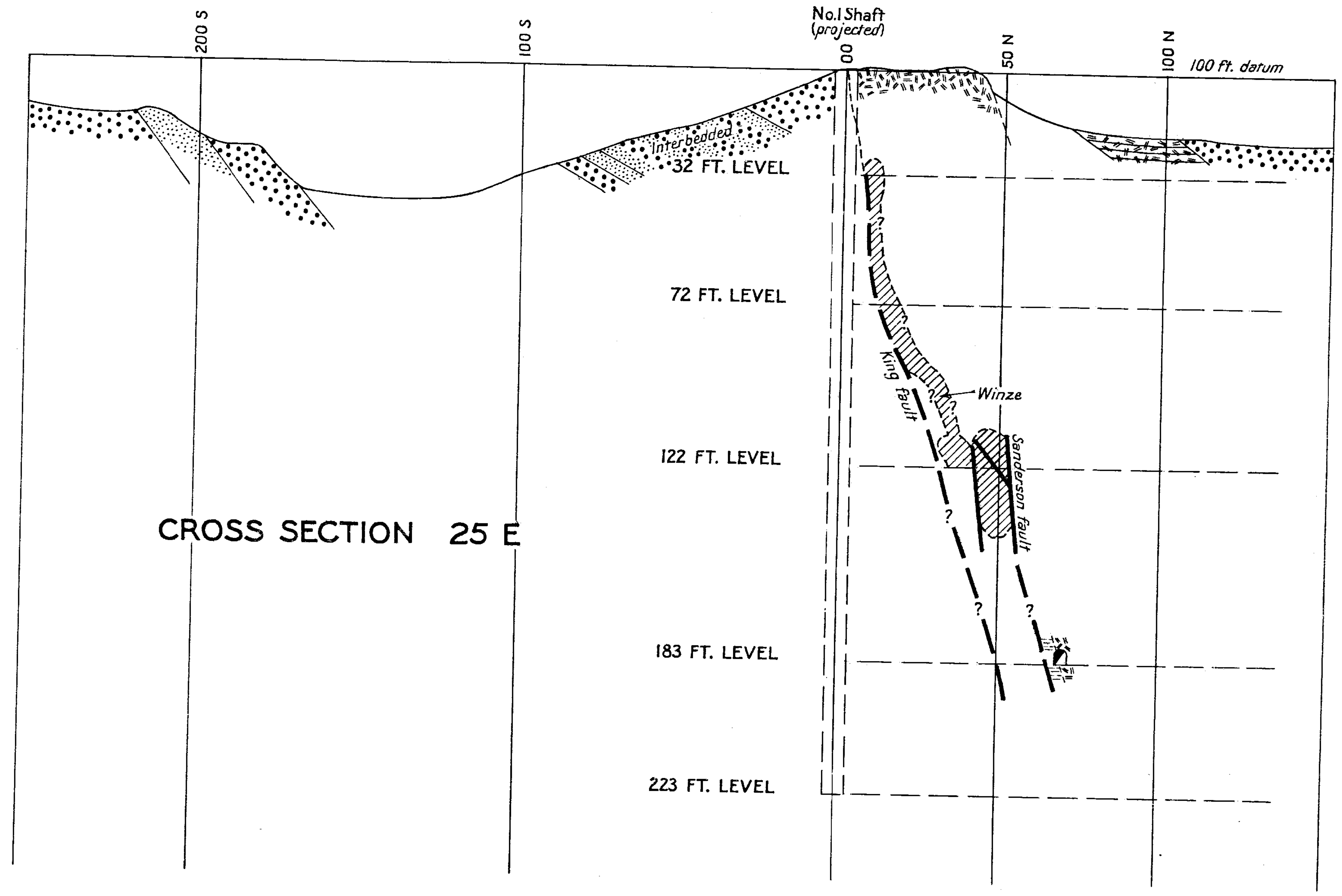
BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS. MARCH 1952.

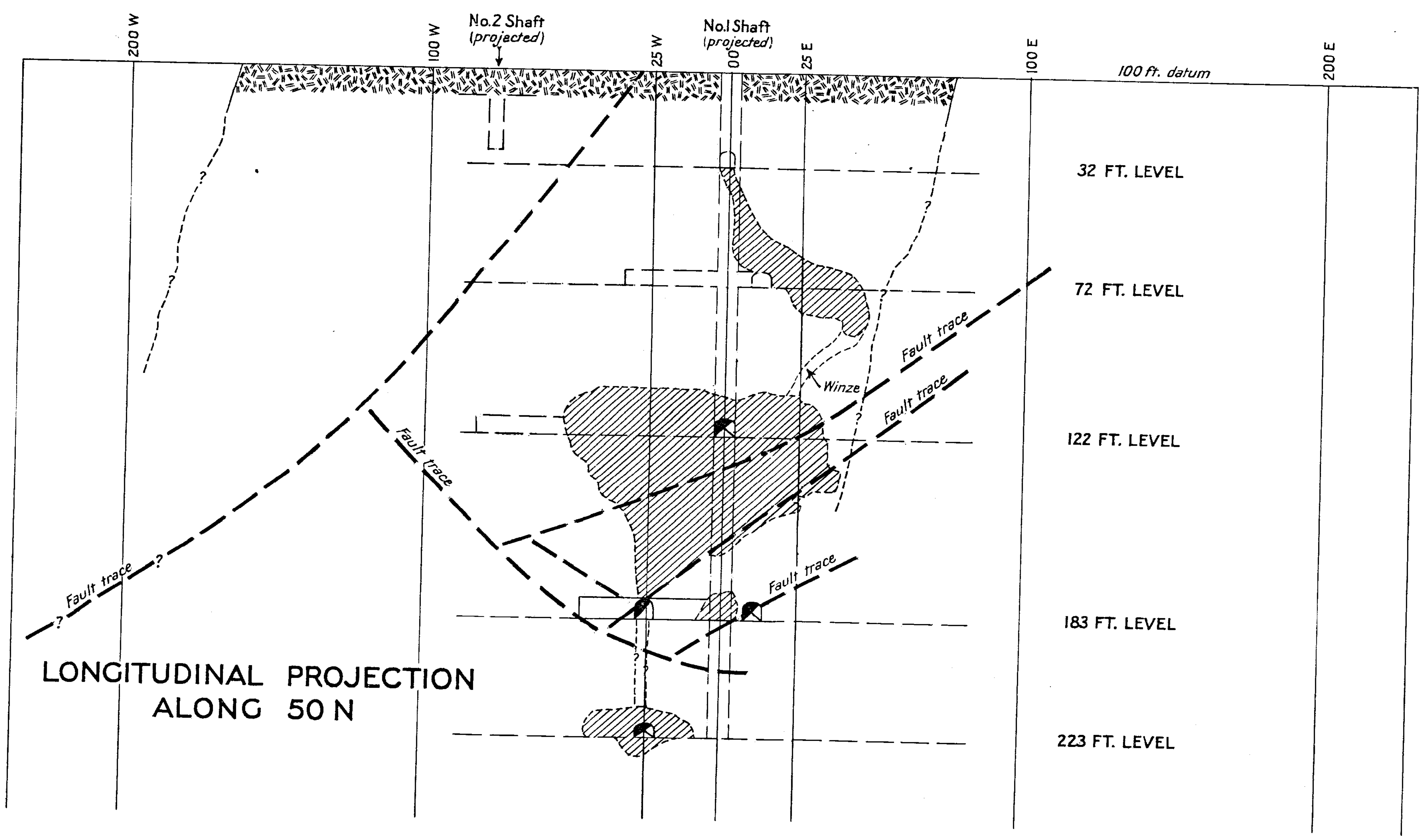
LEVEL PLANS
ENTERPRISE GOLD MINE
TENNANT CREEK GOLD-FIELD
NORTHERN TERRITORY



NT1 AK2
H.L







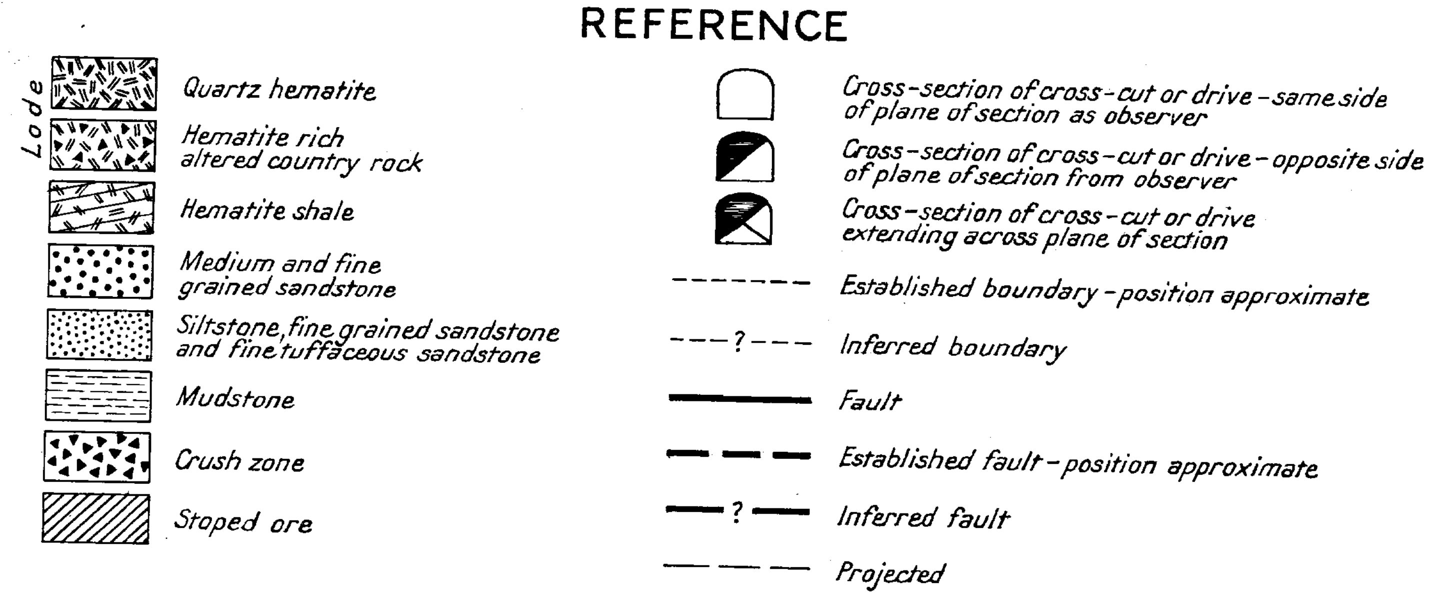
ENTERPRISE GOLD MINE

TENNANT CREEK GOLD-FIELD

NORTHERN TERRITORY

SCALE

40 0 40 80 120 FEET



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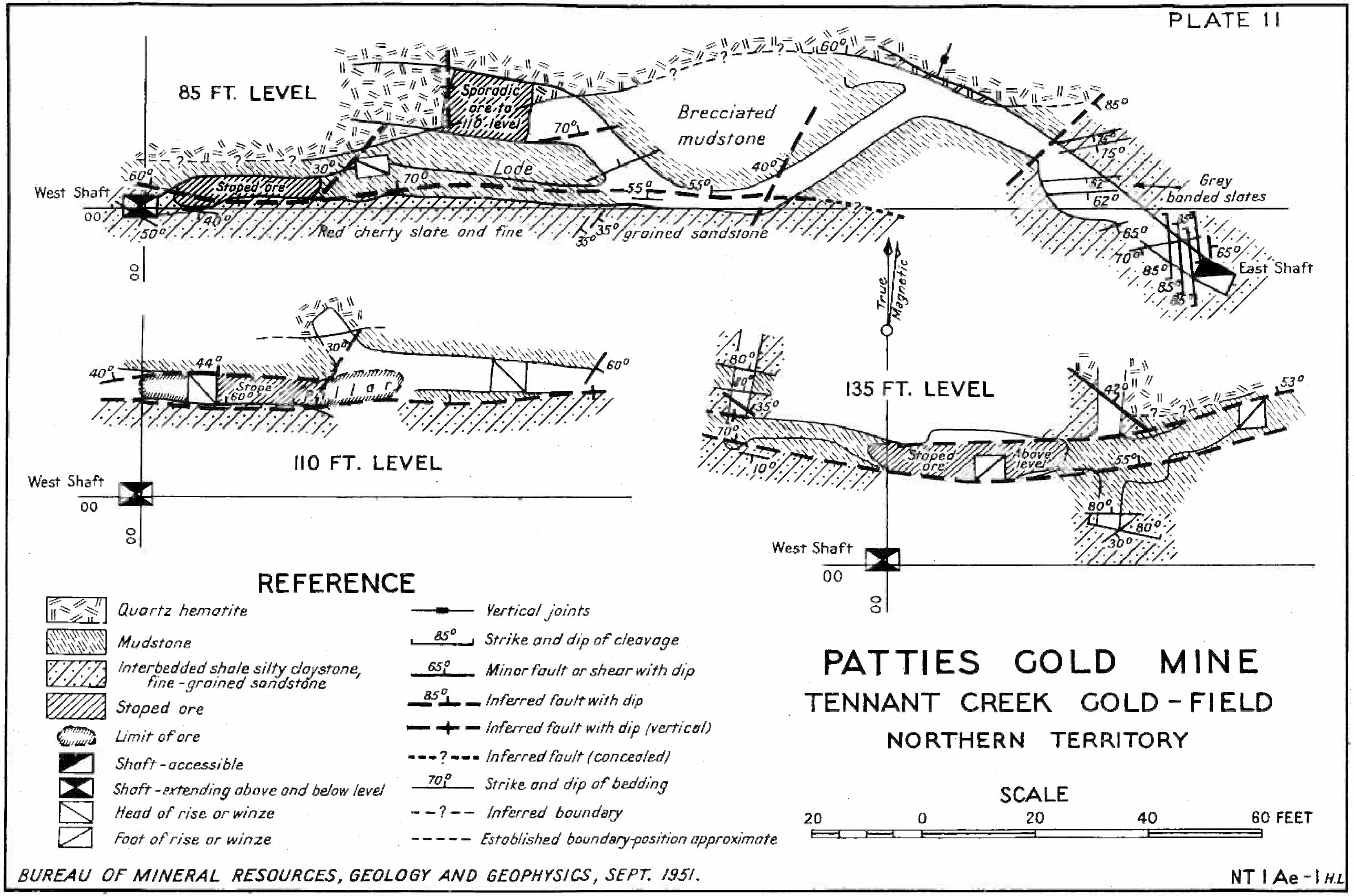

PLATE 11
85 FT. LEVEL
Sporadic ore to 110 level
Brecciated mudstone
Lode
Stoped ore
West Shaft
Red cherty slate and fine grained sandstone
Grey banded slates
East Shaft
True
Magnetic
110 FT. LEVEL
Stope
Pillar
135 FT. LEVEL
Stoped ore
Above level
REFERENCE
Quartz hematite
Mudstone
Interbedded shale silty claystone, fine-grained sandstone
Stoped ore
Limit of ore
Shaft - accessible
Shaft - extending above and below level
Head of rise or winze
Foot of rise or winze
Vertical joints
Strike and dip of cleavage
Minor fault or shear with dip
Inferred fault with dip
Inferred fault with dip (vertical)
Inferred fault (concealed)
Strike and dip of bedding
Inferred boundary
Established boundary-position approximate
PATTIES GOLD MINE
TENNANT CREEK GOLD-FIELD
NORTHERN TERRITORY
SCALE
20 0 20 40 60 FEET
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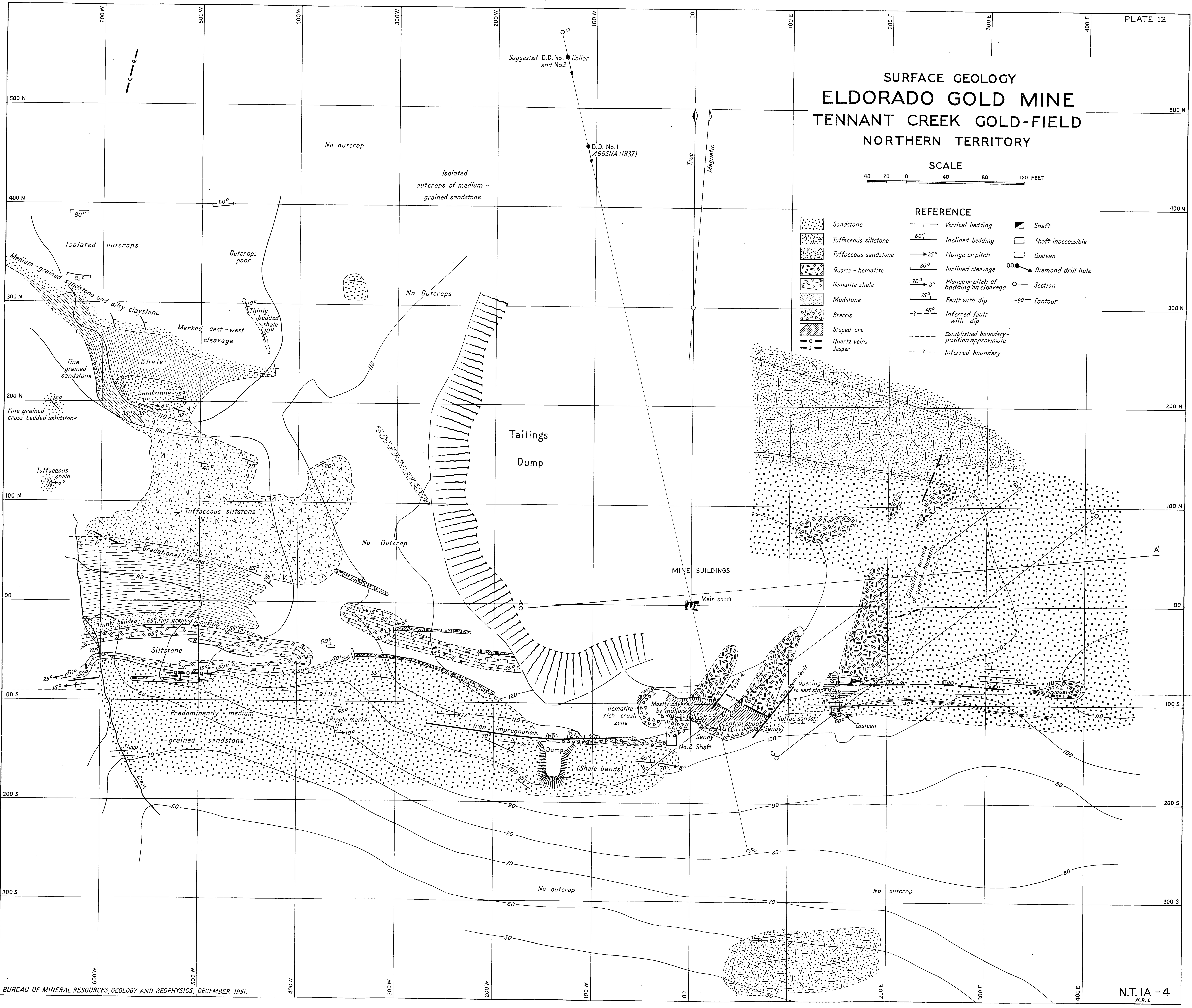
NT 1 Ae - 1 H.L

PLATE 12


SURFACE GEOLOGY
ELDORADO GOLD MINE
TENNANT CREEK GOLD-FIELD
NORTHERN TERRITORY
SCALE
40 20 0 40 80 120 FEET
REFERENCE
Sandstone
Tuffaceous siltstone
Tuffaceous sandstone
Quartz - hematite
Hematite shale
Mudstone
Breccia
Stoped ore
Quartz veins
Jasper
Vertical bedding
Inclined bedding
Plunge or pitch
Inclined cleavage
Plunge or pitch of bedding on cleavage
Fault with dip
Inferred fault with dip
Established boundary - position approximate
Inferred boundary
Shaft
Shaft inaccessible
Costean
Diamond drill hole
Section
Contour
True
Magnetic
Suggested D.D. No.1 Collar and No.2
D.D. No.1 AGGSNA (1937)
No outcrop
Isolated outcrops of medium - grained sandstone
Isolated outcrops
Outcrops poor
No Outcrops
Medium - grained sandstone and silty claystone
Marked east - west cleavage
Thinly bedded shale
Shale
Fine grained sandstone
Sandstone
Fine grained cross bedded sandstone
Tuffaceous shale
Tuffaceous siltstone
Gradational facies
No Outcrop
Tailings Dump
MINE BUILDINGS
Main shaft
Thinly banded
Fine grained sandstone
Siltstone
Talus
Predominantly medium - grained sandstone
(Ripple marks)
Iron impregnation
Dump
(Shale bands)
Steep
Creek
Hematite - rich crush zone
Mostly covered by mullock
Stoped ore
Central shoot
Fault A
Sandy
No.2 Shaft
Tuffac sandst.
Opening to east stope
Costean
Residual
Silicified aureole of quartz - hematite
No outcrop
BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS, DECEMBER 1951.
N.T. IA - 4
H.R.L

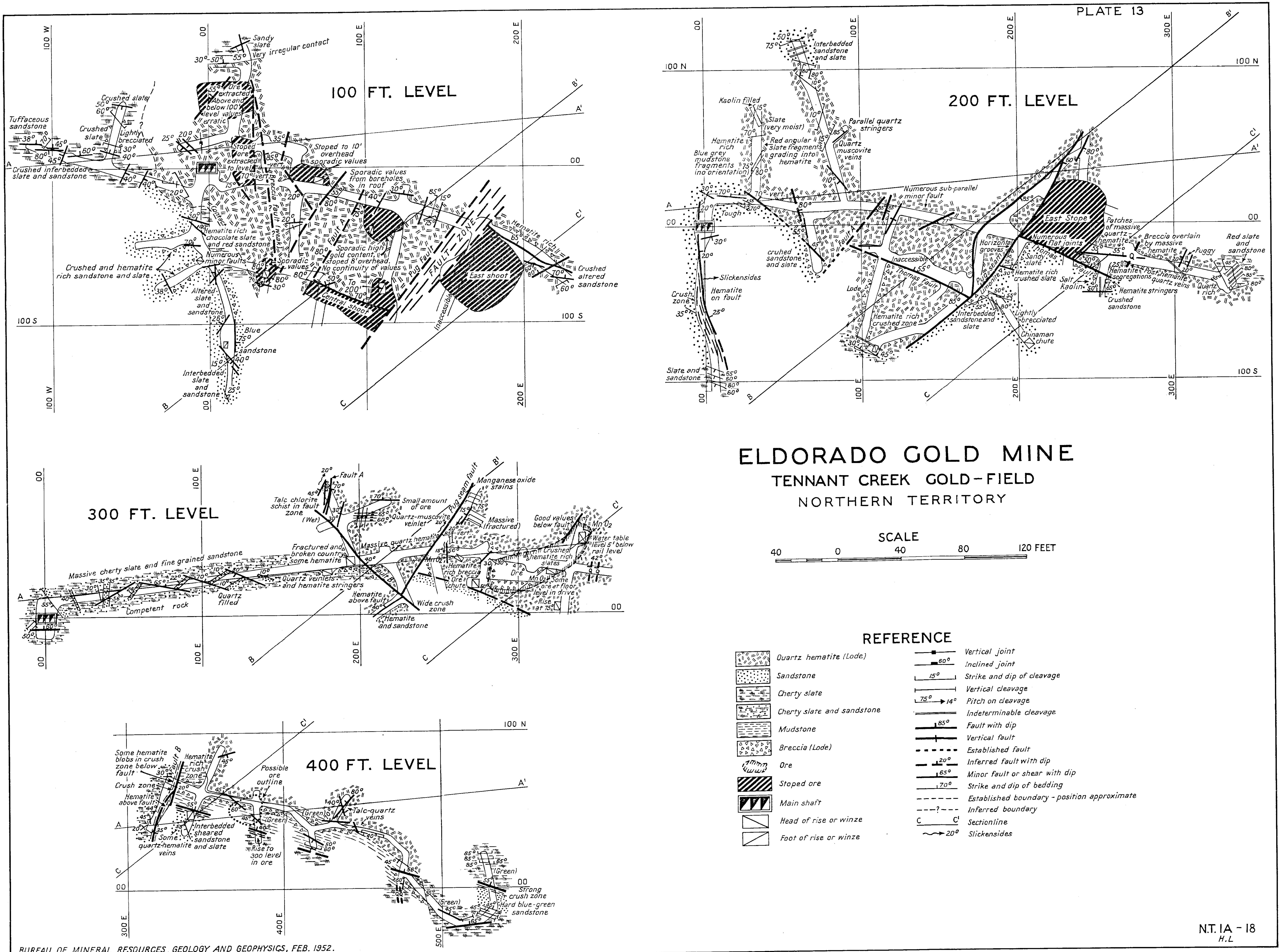
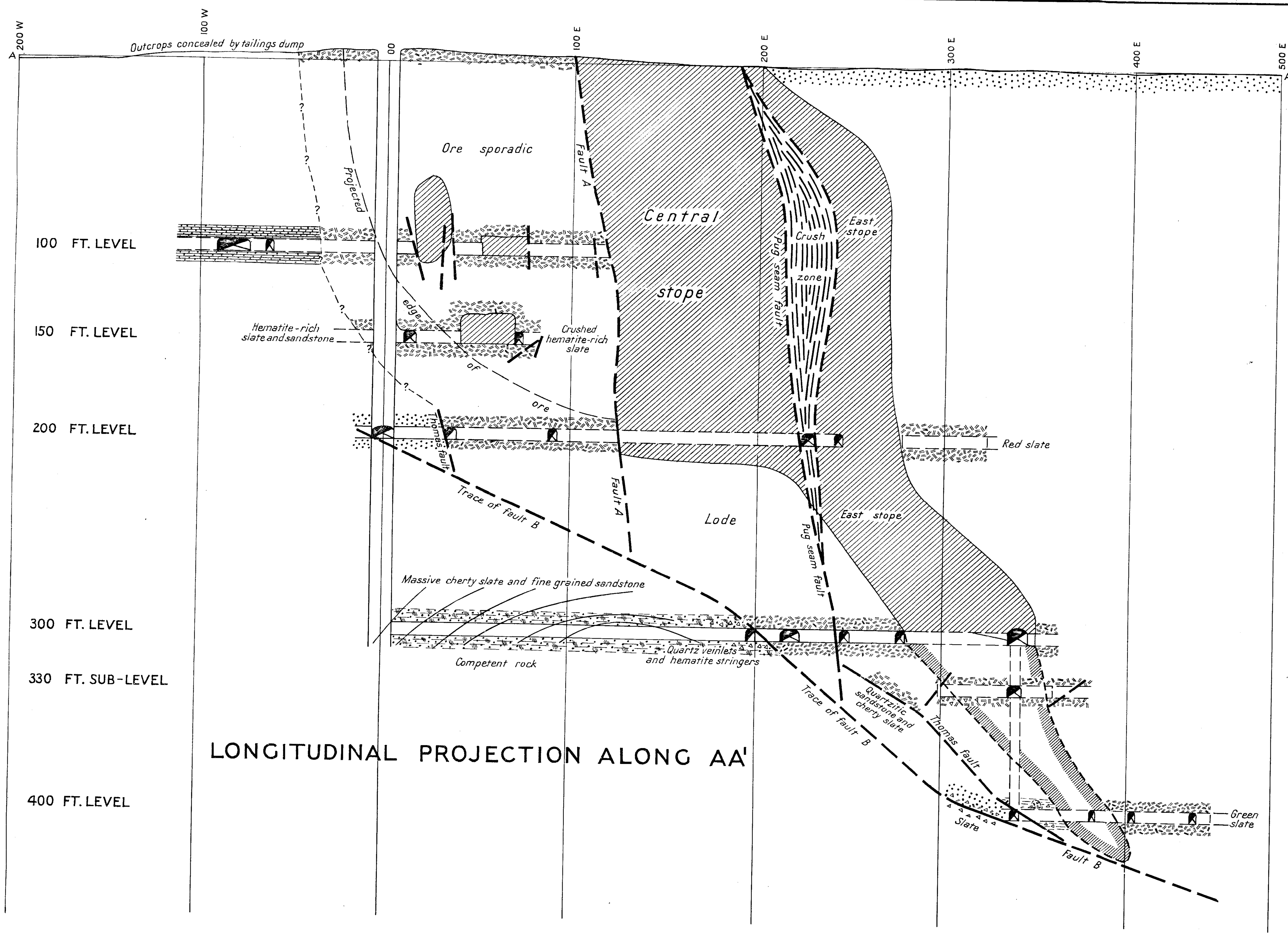
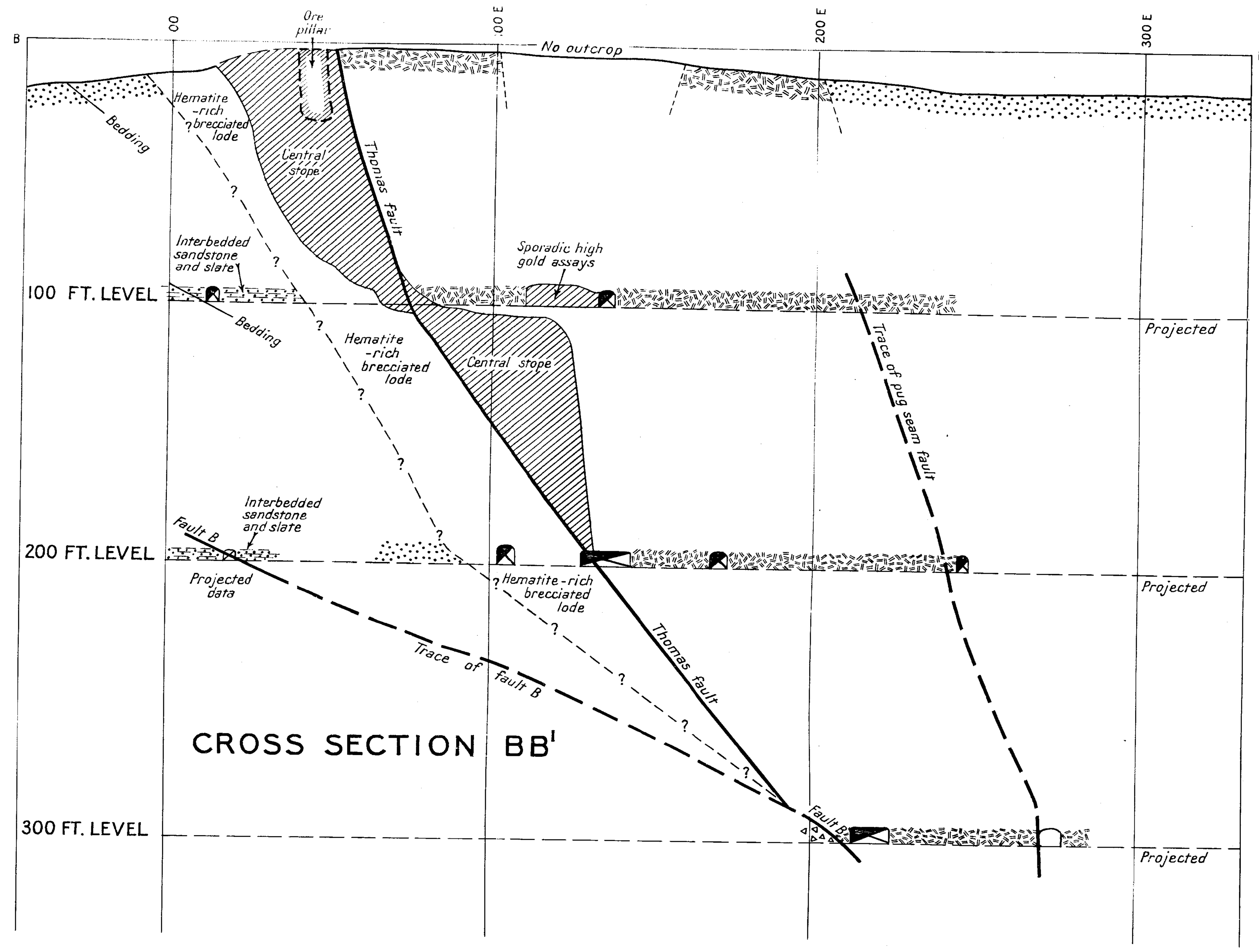
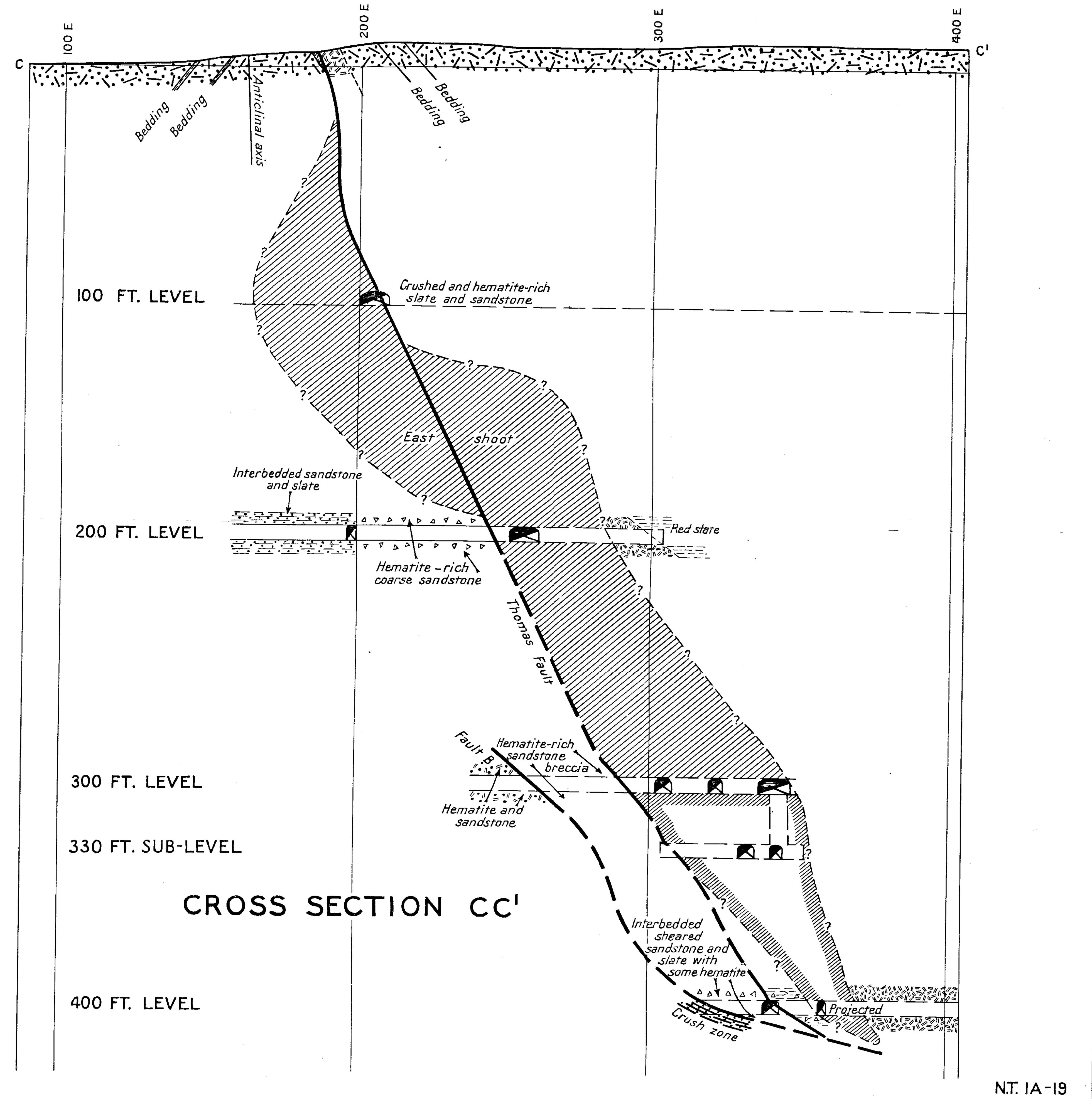


PLATE 13
ELDORADO GOLD MINE
TENNANT CREEK GOLD-FIELD
NORTHERN TERRITORY
SCALE
40 0 40 80 120 FEET
100 FT. LEVEL
200 FT. LEVEL
300 FT. LEVEL
400 FT. LEVEL
REFERENCE
Quartz hematite (Lode)
Sandstone
Cherty slate
Cherty slate and sandstone
Mudstone
Breccia (Lode)
Ore
Stoped ore
Main shaft
Head of rise or winze
Foot of rise or winze
Vertical joint
Inclined joint
Strike and dip of cleavage
Vertical cleavage
Pitch on cleavage
Indeterminable cleavage
Fault with dip
Vertical fault
Established fault
Inferred fault with dip
Minor fault or shear with dip
Strike and dip of bedding
Established boundary - position approximate
Inferred boundary
Sectionline
Slickensides
East shoot
Central shoot
East Stope
Thomas fault
Pug seam fault
Fault A
Fault B
FAULT ZONE
BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS, FEB. 1952.
N.T. IA - 18
H.L







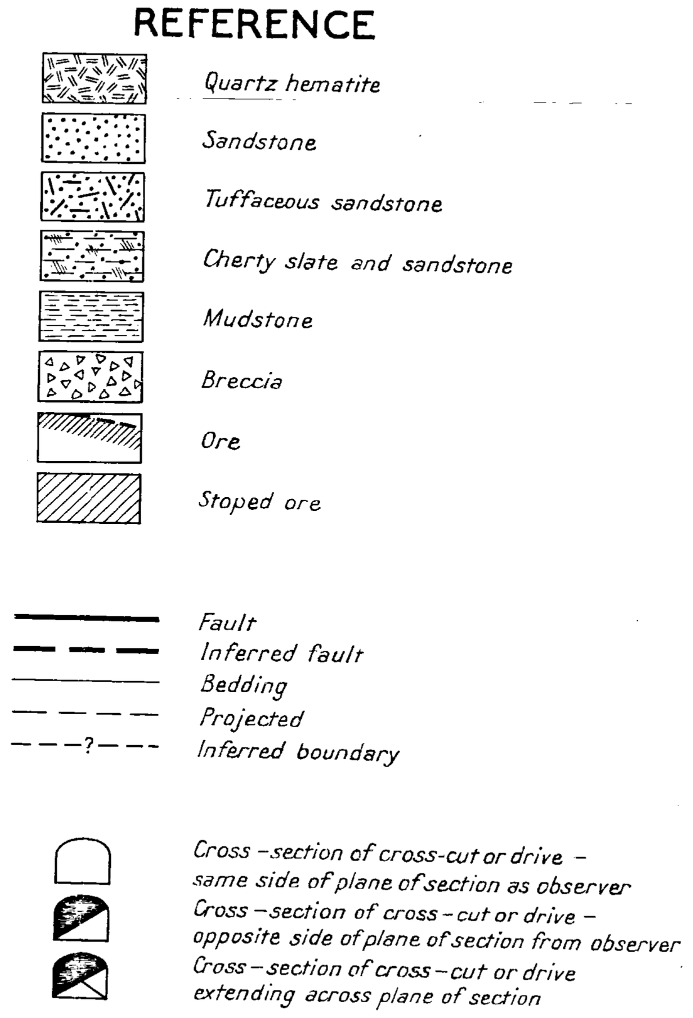
ELDORADO GOLD MINE

TENNANT CREEK GOLD-FIELD

NORTHERN TERRITORY

SCALE

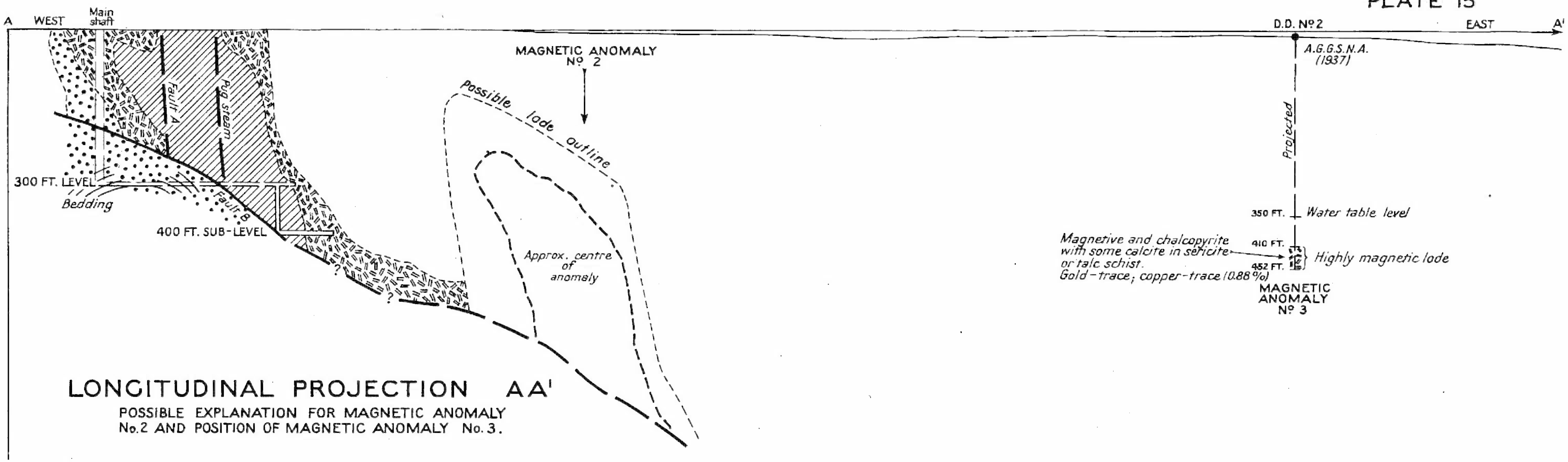
REFERENCE



BUREAU OF MINERAL RESOURCES GEOLOGY AND GEOPHYSICS. FEBRUARY 1952.

N.T. 1A-19
H.L.

PLATE 15



LONGITUDINAL PROJECTION AA'

POSSIBLE EXPLANATION FOR MAGNETIC ANOMALY No. 2 AND POSITION OF MAGNETIC ANOMALY No. 3.

REFERENCE

- Quartz-hematite
- Sandstone
- Mudstone
- Ore
- Stoped ore
- D.D. Diamond drill hole
- Established boundary position approximate
- Inferred boundary
- Probable trend of bedding
- Fault
- Established fault position approximate
- Inferred fault
- Projected

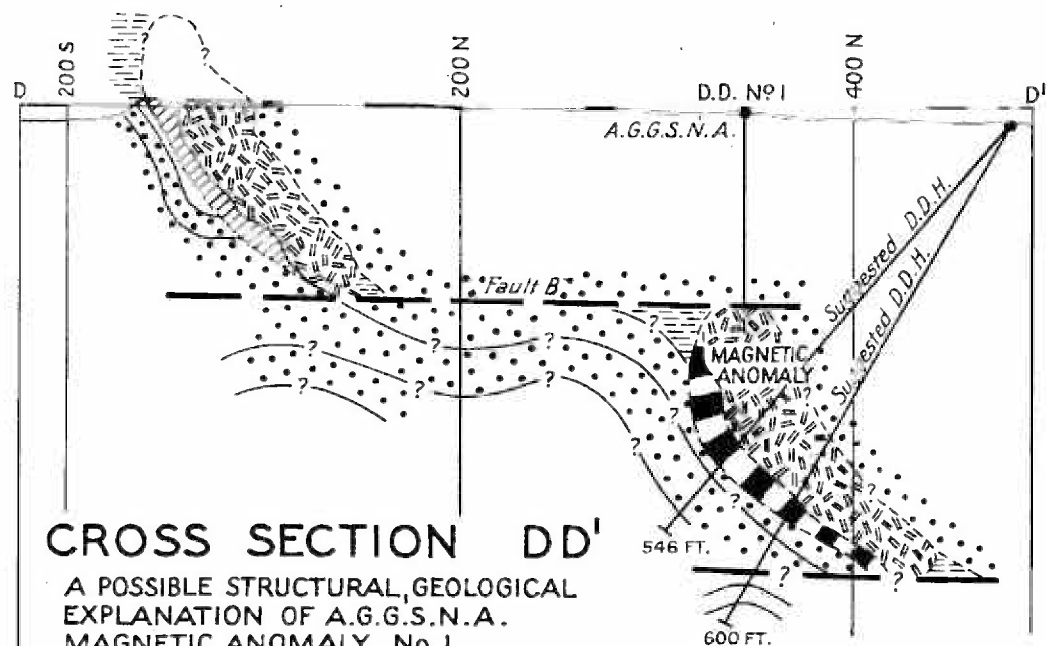
ELDORADO GOLD MINE

TENNANT CREEK GOLD FIELD

NORTHERN TERRITORY

SCALE

200 0 200 400 600 FEET



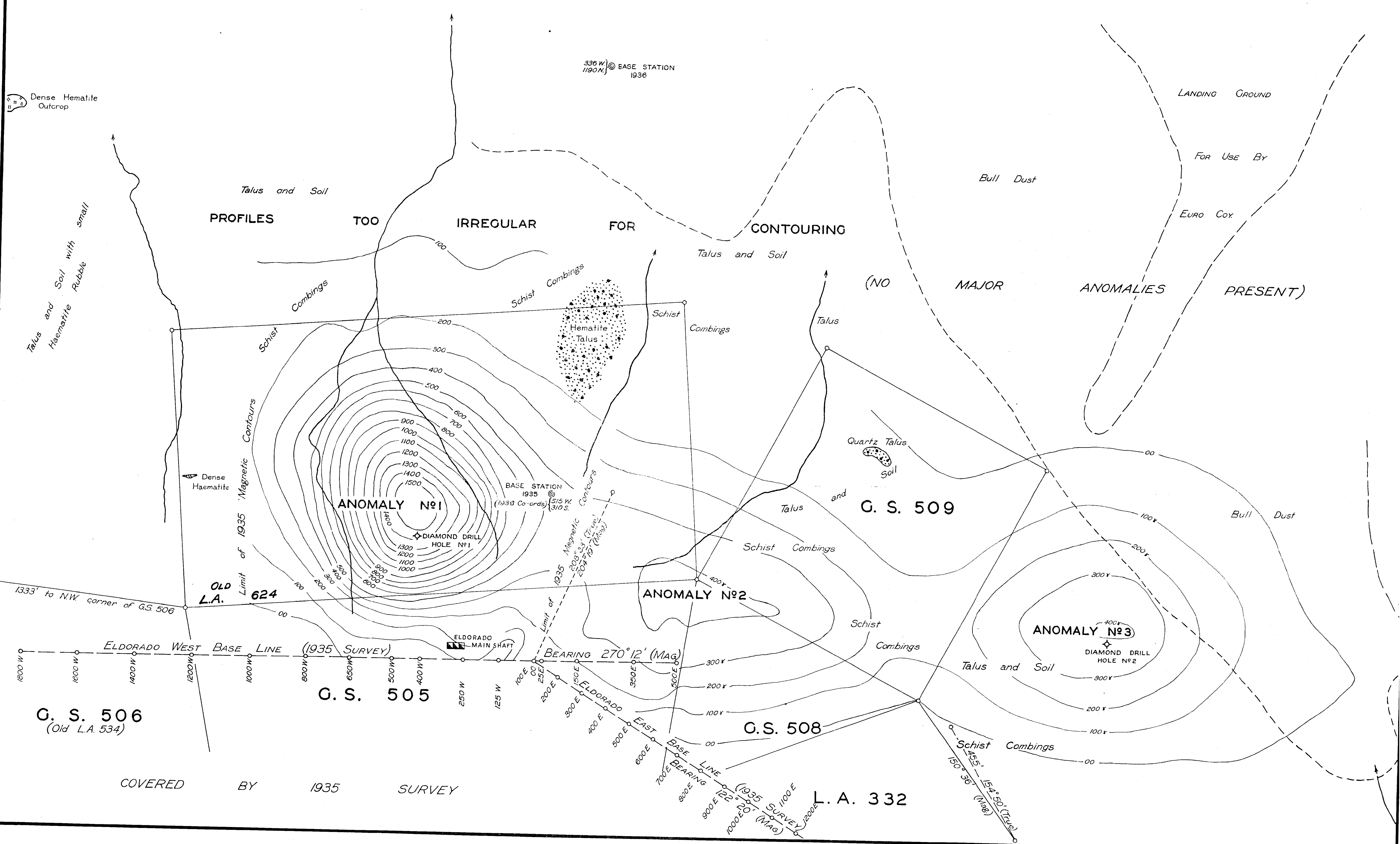
CROSS SECTION DD'

A POSSIBLE STRUCTURAL, GEOLOGICAL EXPLANATION OF A.G.G.S.N.A. MAGNETIC ANOMALY No. 1. SUGGESTED DIAMOND DRILL HOLES No. 1 AND No. 2 TO TEST POSSIBLE ORE SHOOT.

NT IA 20

H.L.

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS, JUNE 1952.



TENNANT CREEK MAGNETIC SURVEY

ELDORADO M^{T} SAMUEL AREA

CONTOURS OF THE VERTICAL COMPONENT OF THE MAGNETIC FIELD

From Second Report on Magnetic Prospecting at Tennant Creek (1936)

(Report N.T. No 23 Plate 3 Sheet 1)

SCALE

200 100 0 200 400 600

Bureau of Mineral Resources, Geology and Geophysics, April, 1949.

PLATE 17

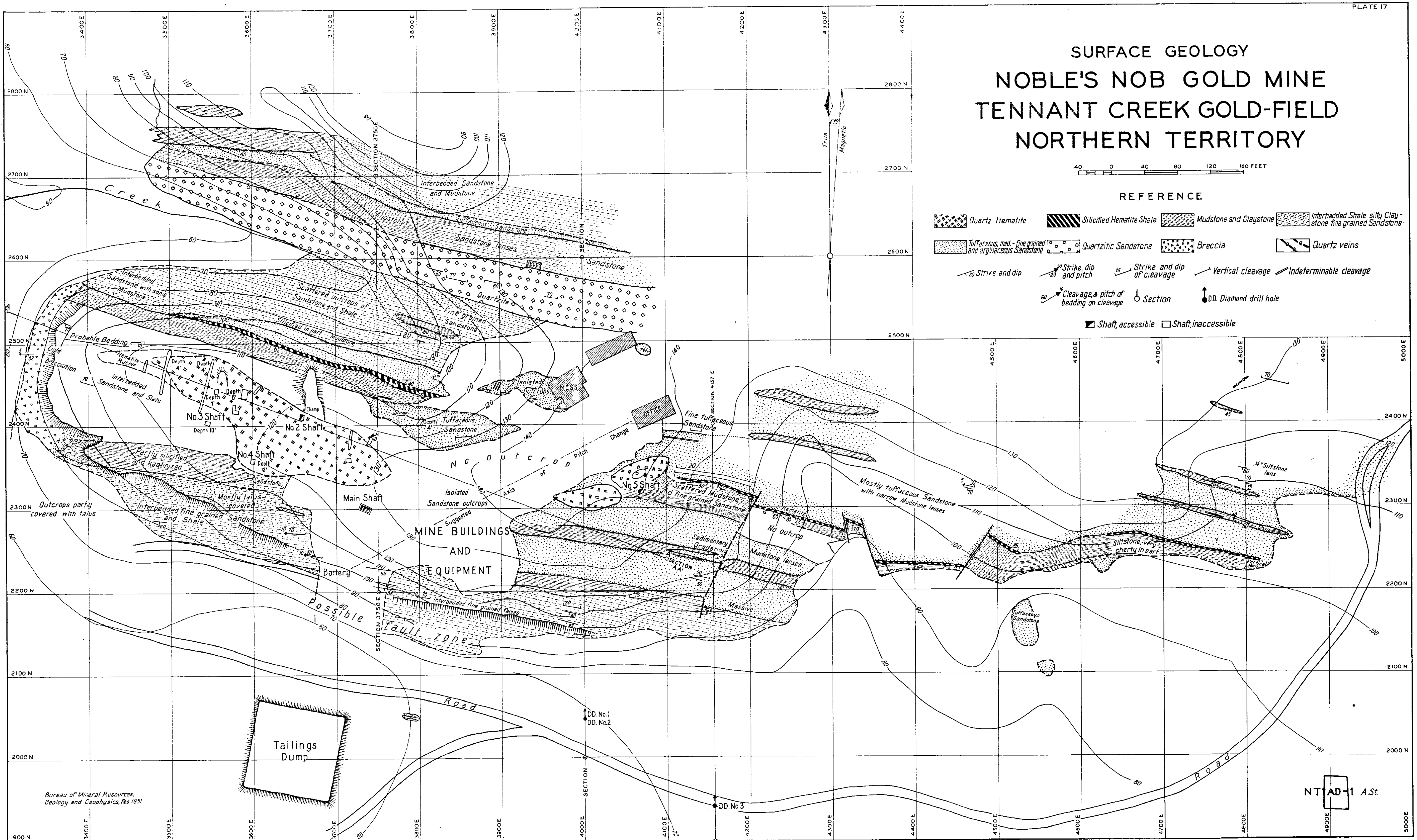
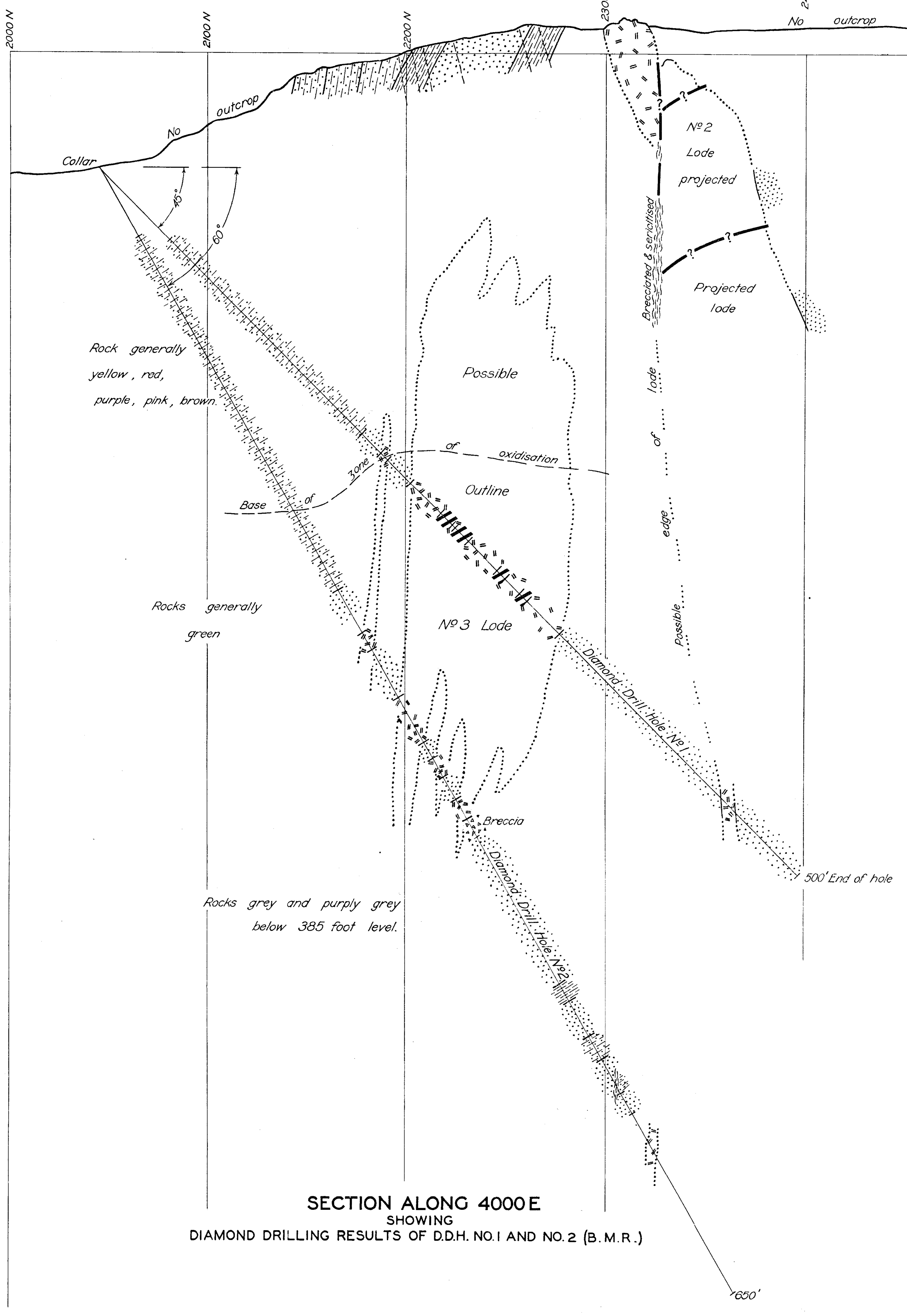
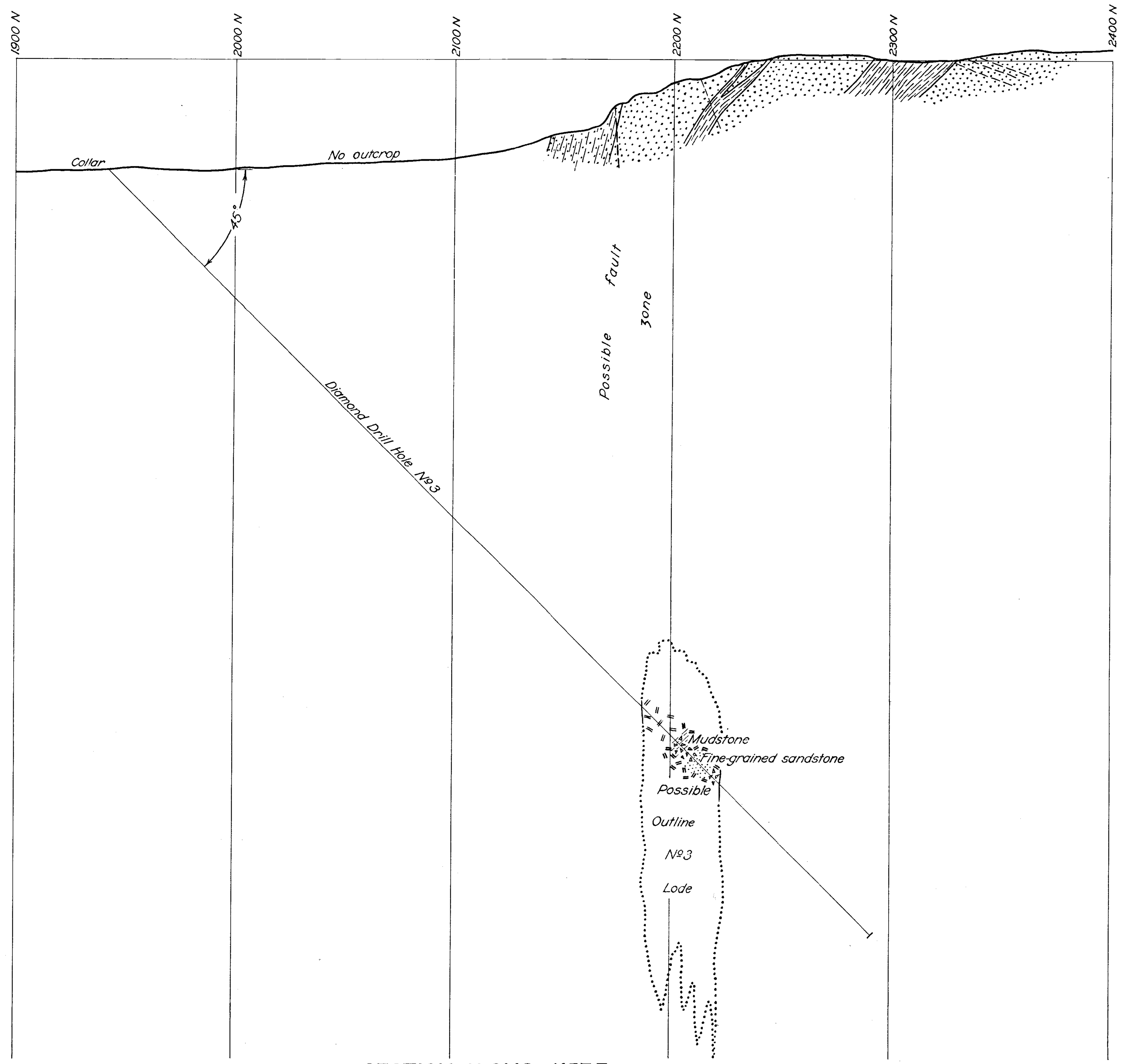

SURFACE GEOLOGY
NOBLE'S NOB GOLD MINE
TENNANT CREEK GOLD-FIELD
NORTHERN TERRITORY
40 0 40 80 120 160 FEET
REFERENCE
Quartz Hematite
Silicified Hematite Shale
Mudstone and Claystone
Interbedded Shale silty Claystone fine grained Sandstone
Tuffaceous, med.- fine grained and argillaceous Sandstone
Quartzitic Sandstone
Breccia
Quartz veins
Strike and dip
Strike, dip and pitch
Strike and dip of cleavage
Vertical cleavage
Indeterminable cleavage
Cleavage, & pitch of bedding on cleavage
Section
D.D. Diamond drill hole
Shaft, accessible
Shaft, inaccessible
True
Magnetic
Creek
Road
Interbedded Sandstone and Mudstone
Mudstone
Tuffaceous Sandstone
Sandstone lenses
Sandstone
Quartzite
Fine grained Sandstone
Scattered outcrops of Sandstone and Shale
Silicified in part
Interbedded Sandstone with some Mudstone
Probable Bedding
Light Brecciation
Hematite Rubble
Interbedded Sandstone and Slate
No.3 Shaft
No.2 Shaft
No.4 Shaft
No.5 Shaft
Main Shaft
Partly silicified and kaolinized
Mostly talus covered
Outcrops partly covered with talus
Interbedded fine grained Sandstone and Shale
Isolated Outcrops
MESS
OFFICE
No outcrop
Axis of Pitch Change
Suggested
Isolated Sandstone outcrops
MINE BUILDINGS AND EQUIPMENT
Battery
Possible fault zone
Interbedded fine grained facies
Fine tuffaceous Sandstone
Scattered Mudstone and fine grained Sandstone
Sedimentary Gradation
Mudstone lenses
Massive
Mostly tuffaceous Sandstone with narrow Mudstone lenses
Siltstone, very cherty in part
¼" Siltstone lens
Tuffaceous Sandstone
Tailings Dump
DD. No.1
DD. No.2
DD. No.3
SECTION 3750 E
SECTION 4157 E
SECTION
Bureau of Mineral Resources, Geology and Geophysics, Feb 1951
NT AD-1 ASt.


PLATE 18
LEVEL PLANS
NOBLES NOB GOLD MINE
TENNANT CREEK GOLD-FIELD
NORTHERN TERRITORY
SCALE
20 0 20 40 60 FEET
70 FT. LEVEL
N°5 SHAFT
132 FT. LEVEL
N°5 SHAFT
86 FT. LEVEL
N°2 SHAFT
135 FT. LEVEL
183 FT. LEVEL
215 FT. LEVEL
REFERENCE
Quartz hematite
Crush zone
Breccia
Sandstone
Cherty slate
Limit of ore
Stoped ore
Main shaft (showing number of compartments)
Shaft - extending above and below level
Shaft - inaccessible
Rise or winze - extending through level
Head of rise or winze
Foot of rise or winze
Open cut
Established boundary - position approximate
Joint
Vertical joint
Strike and dip of bedding
Plunge or pitch
Fault with dip
Minor fault or shear with dip
Established fault - position approximate
Strike and dip of foliation
Sectionline
BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS. APRIL 1952.
NT I AD 3



SECTION ALONG 4000 E
SHOWING
DIAMOND DRILLING RESULTS OF D.D.H. NO.1 AND NO.2 (B.M.R.)



SECTION ALONG 4157 E
SHOWING
DIAMOND DRILLING RESULTS OF D.D.H. NO.3 (B.M.R.)

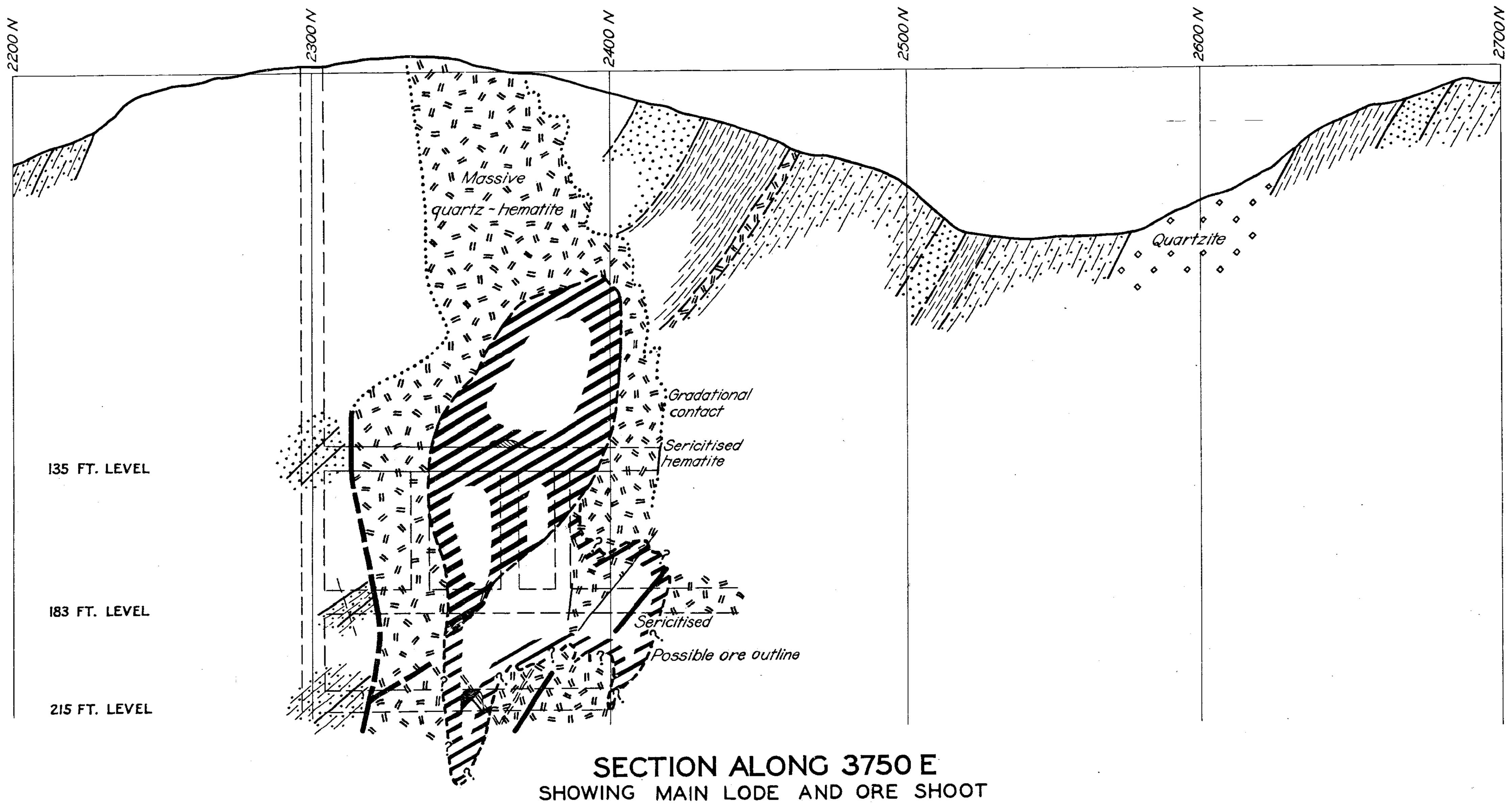
NOBLES NOB GOLD MINE

TENNANT CREEK GOLD-FIELD

NORTHERN TERRITORY

SCALE

FEET 40 30 20 10 0 40 80 120 160 FEET



SECTION ALONG 3750 E
SHOWING MAIN LODE AND ORE SHOOT

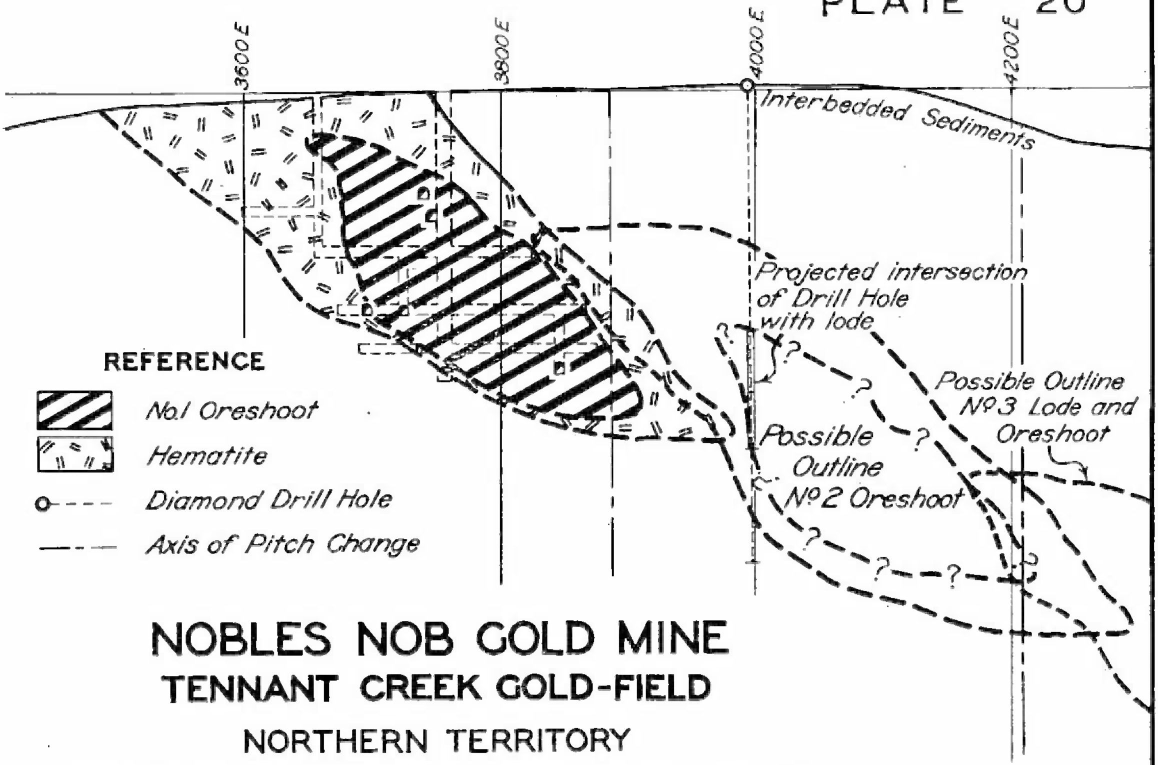
REFERENCE

- Hematite-rich brecciated country rock.
- Quartz hematite
- Interbedded shale silty claystone fine grained sandstone
- Tuffaceous medium fine grained and argillaceous sandstone.
- Mudstone and claystone
- Ore
- Fault
- Minor fault
- Inferred fault
- Fault zone
- Cleavage
- Drive approaching & receding from observer
- Projected shaft and drive
- Ore boundary
- Possible ore boundary

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS. DECEMBER 1951.

NT I AD 2
A.J.S.

PLATE 20



NOBLES NOB GOLD MINE

TENNANT CREEK GOLD-FIELD

NORTHERN TERRITORY

COMPOSITE LONGITUDINAL PROJECTION SHOWING No.1 ORESHOOT, POSSIBLE OUTLINE No.2 ORESHOOT AND POSSIBLE POSITION No.3 ORESHOOT

HOR. AND VERT. SCALE OF FEET

160 80 0 160 320

NT1AD-4 A.J.S.

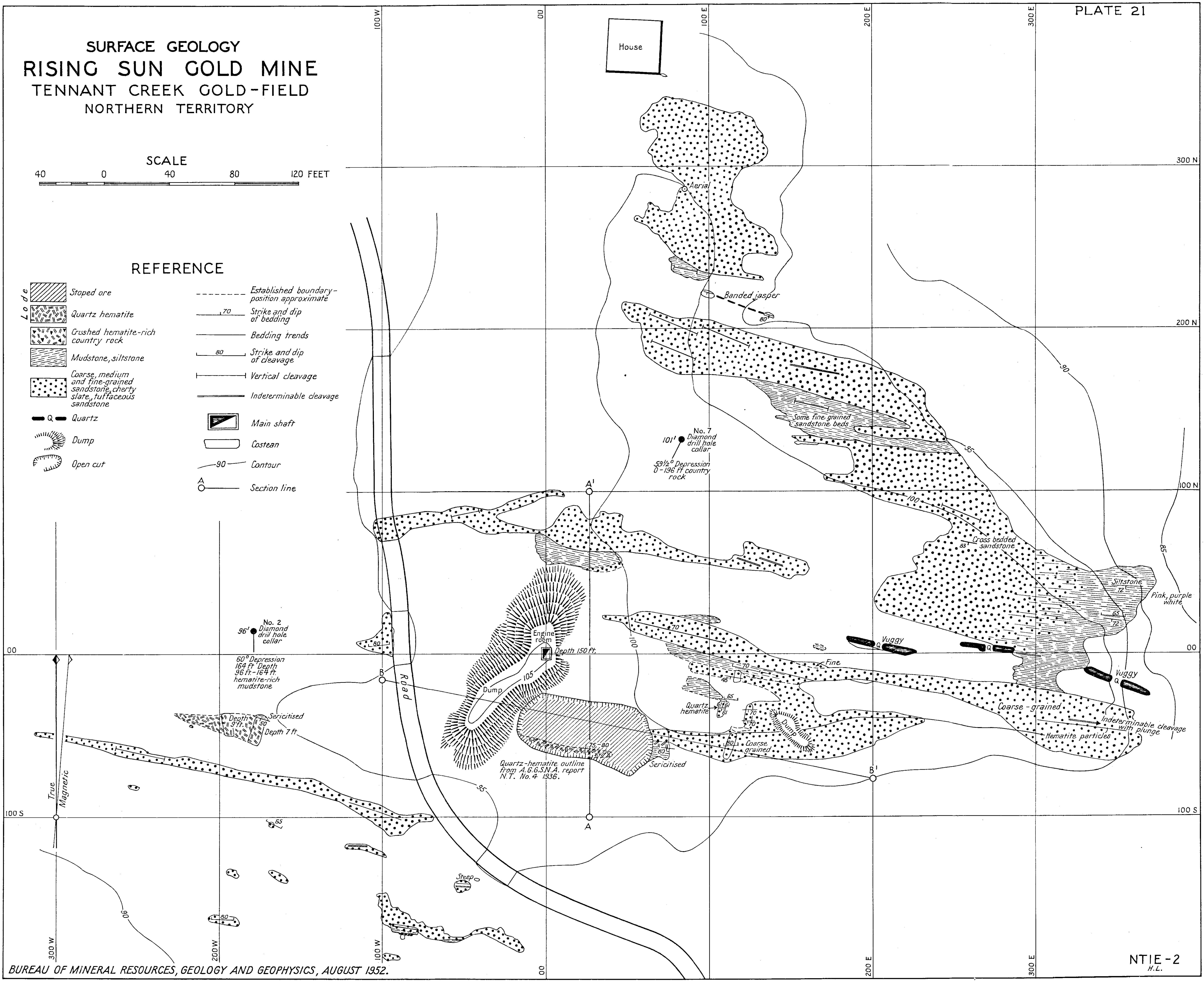


PLATE 21
SURFACE GEOLOGY
RISING SUN GOLD MINE
TENNANT CREEK GOLD-FIELD
NORTHERN TERRITORY
SCALE
40 0 40 80 120 FEET
REFERENCE
Lode
Stoped ore
Quartz hematite
Crushed hematite-rich country rock
Mudstone, siltstone
Coarse, medium and fine-grained sandstone, cherty slate, tuffaceous sandstone
Quartz
Dump
Open cut
Established boundary - position approximate
Strike and dip of bedding
Bedding trends
Strike and dip of cleavage
Vertical cleavage
Indeterminable cleavage
Main shaft
Costean
Contour
Section line
House
Aerial
Banded jasper
Some fine grained sandstone beds
No. 7 Diamond drill hole collar
101'
59½° Depression 0-196 ft country rock
Cross bedded sandstone
Siltstone
Pink, purple white
Vuggy
Fine
Coarse - grained
Indeterminable cleavage with plunge
Hematite particles
Coarse grained
Quartz hematite
Dump
Engine room
Depth 150 ft.
No. 2 Diamond drill hole collar
96'
60° Depression 164 ft Depth 96 ft-164 ft. hematite-rich mudstone
Sericitised
Depth 3 ft.
Depth 7 ft.
Road
Quartz-hematite outline from A.G.G.S.N.A. report N.T. No. 4 1936.
Sericitised
Steep
True
Magnetic
300 N
200 N
100 N
00
100 S
300 W
200 W
100 W
00
100 E
200 E
300 E
BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS, AUGUST 1952.
NTIE-2
H.L.

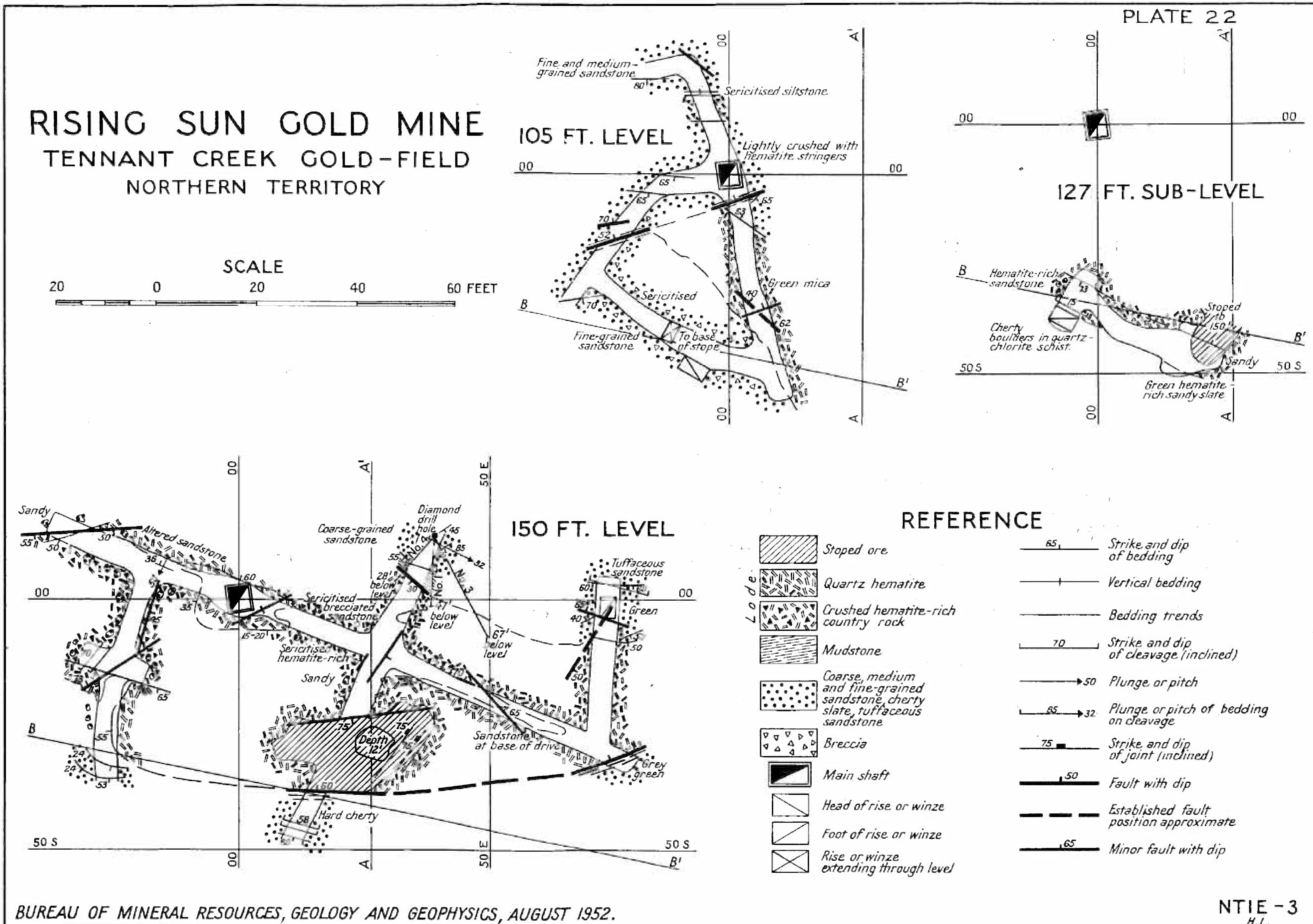


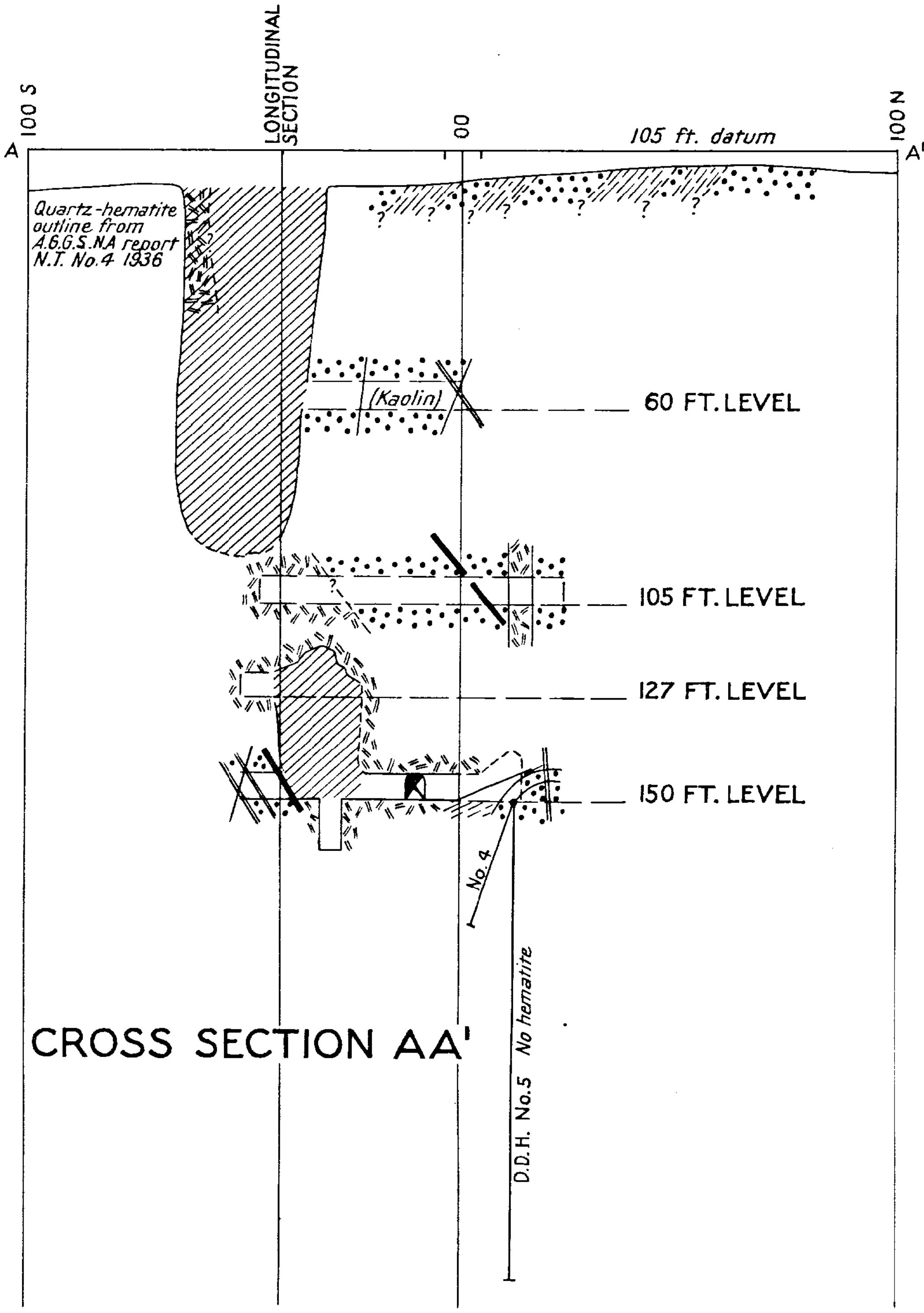
PLATE 22
RISING SUN GOLD MINE
TENNANT CREEK GOLD-FIELD
NORTHERN TERRITORY
SCALE
20 0 20 40 60 FEET
105 FT. LEVEL
Fine and medium-grained sandstone
Sericitised siltstone
Lightly crushed with hematite stringers
Green mica
Sericitised
Fine-grained sandstone
To base of stope
127 FT. SUB-LEVEL
Hematite-rich sandstone
Cherty boulders in quartz-chlorite schist
Stoped to 150'
Sandy
Green hematite-rich sandy slate
150 FT. LEVEL
Sandy
Altered sandstone
Coarse-grained sandstone
Diamond drill hole
Sericitised brecciated sandstone
Sericitised hematite-rich
28' below level
77' below level
67' below level
Tuffaceous sandstone
Green
Sandy
Depth 12'
Sandstone at base of drive
Grey green
Hard cherty
REFERENCE
Lode
Stoped ore
Quartz hematite
Crushed hematite-rich country rock
Mudstone
Coarse, medium and fine-grained sandstone, cherty slate, tuffaceous sandstone
Breccia
Main shaft
Head of rise or winze
Foot of rise or winze
Rise or winze extending through level
Strike and dip of bedding
Vertical bedding
Bedding trends
Strike and dip of cleavage (inclined)
Plunge or pitch
Plunge or pitch of bedding on cleavage
Strike and dip of joint (inclined)
Fault with dip
Established fault position approximate
Minor fault with dip
BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS, AUGUST 1952.
NTIE-3
H.L.

PLATE 23

RISING SUN GOLD MINE
TENNANT CREEK GOLD-FIELD
NORTHERN TERRITORY

SCALE

40 0 40 80 120 FEET



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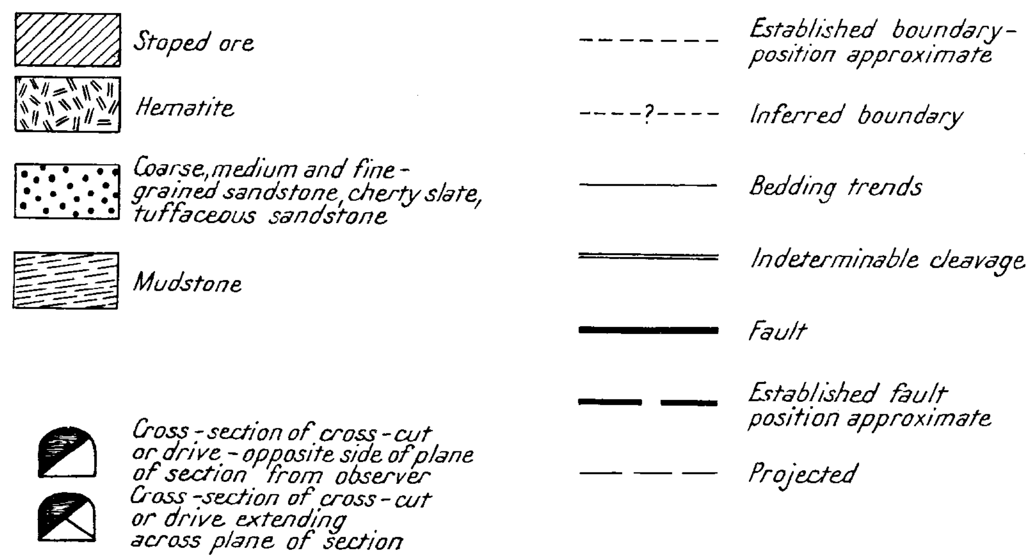
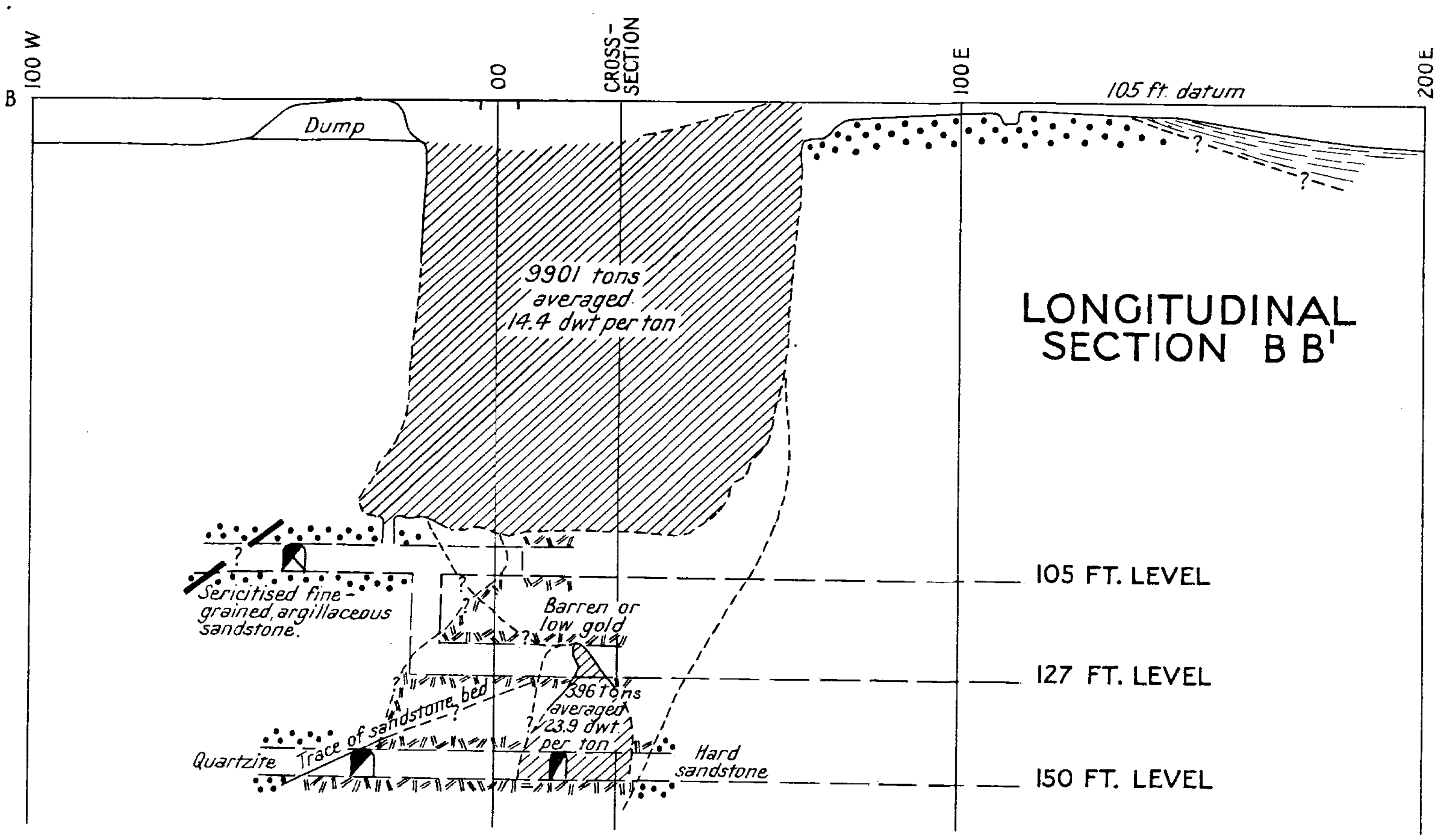




BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS, AUGUST 1952.

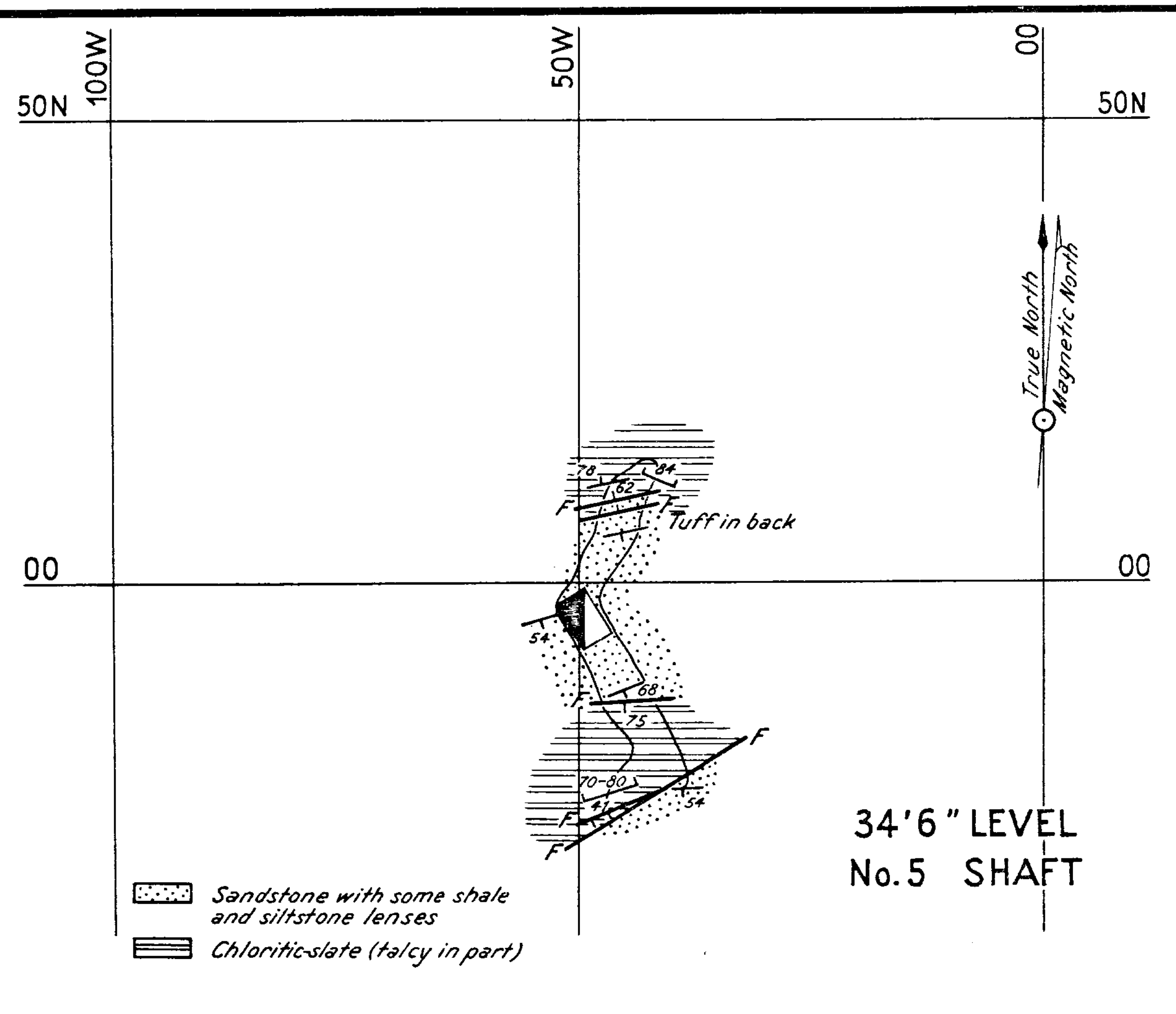
NTIE-4
H.L.

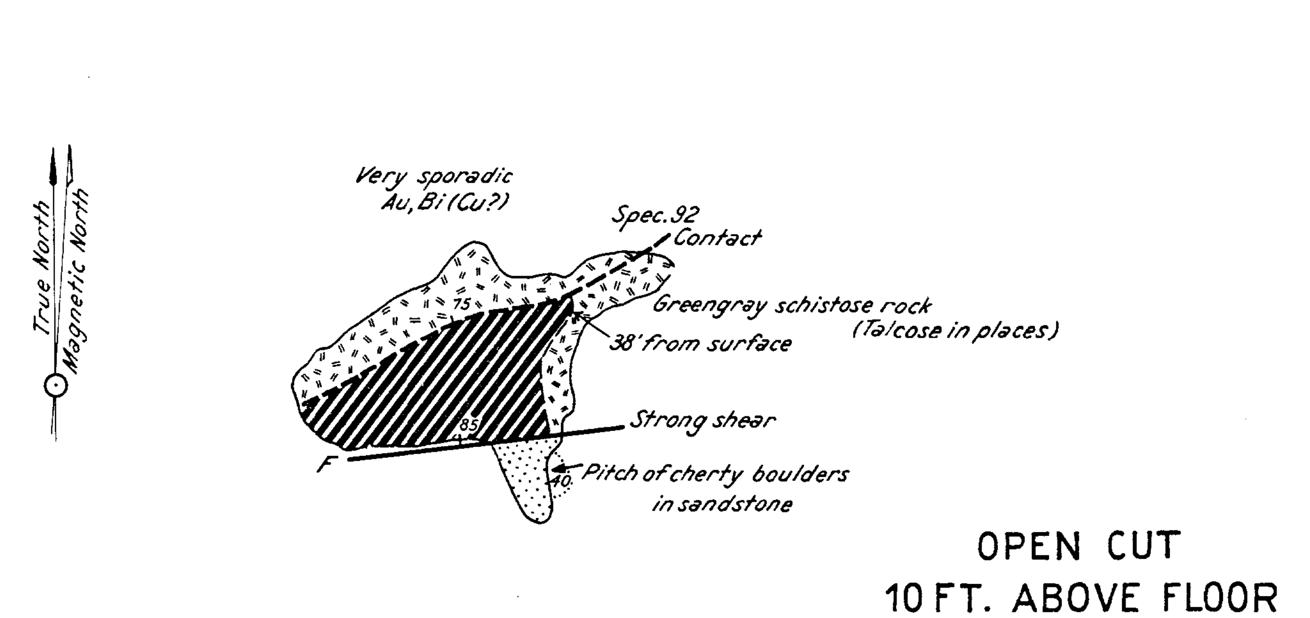
PLATE 24

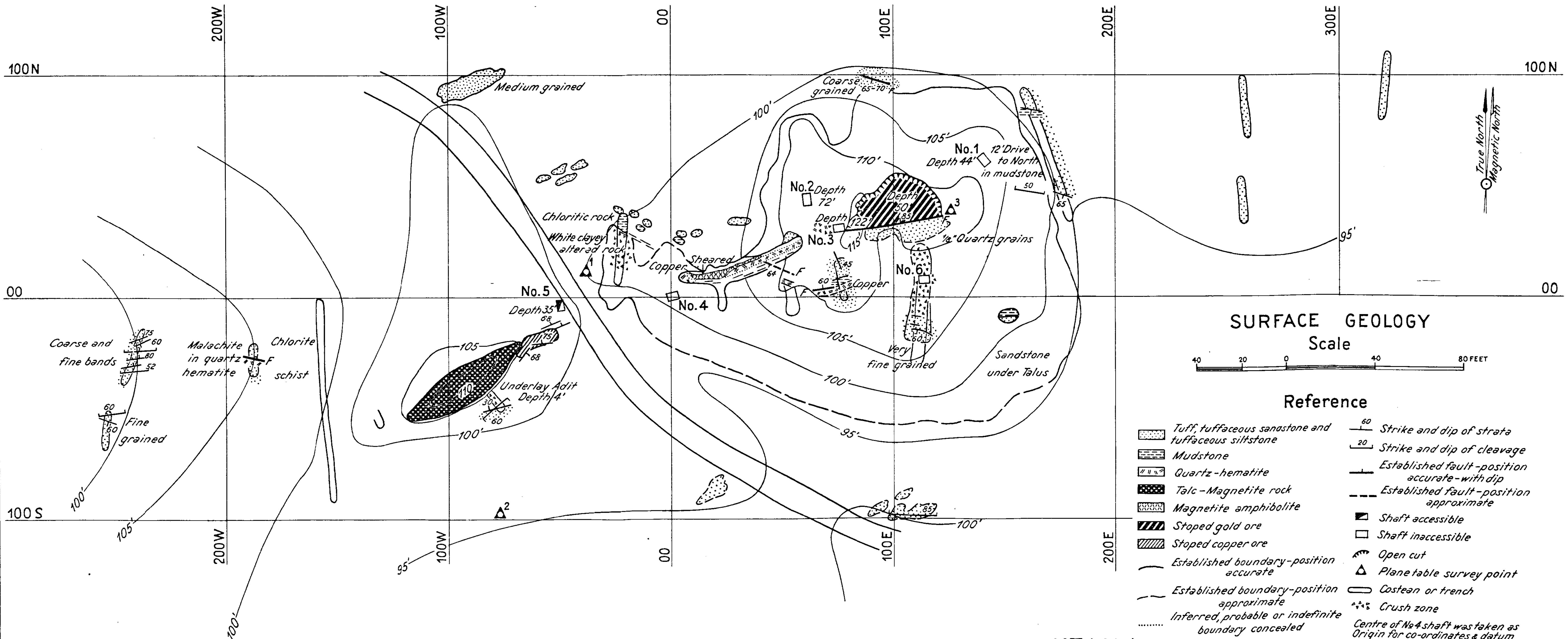
PINNACLES GOLD MINE

TENNANT CREEK GOLD-FIELD

NORTHERN TERRITORY

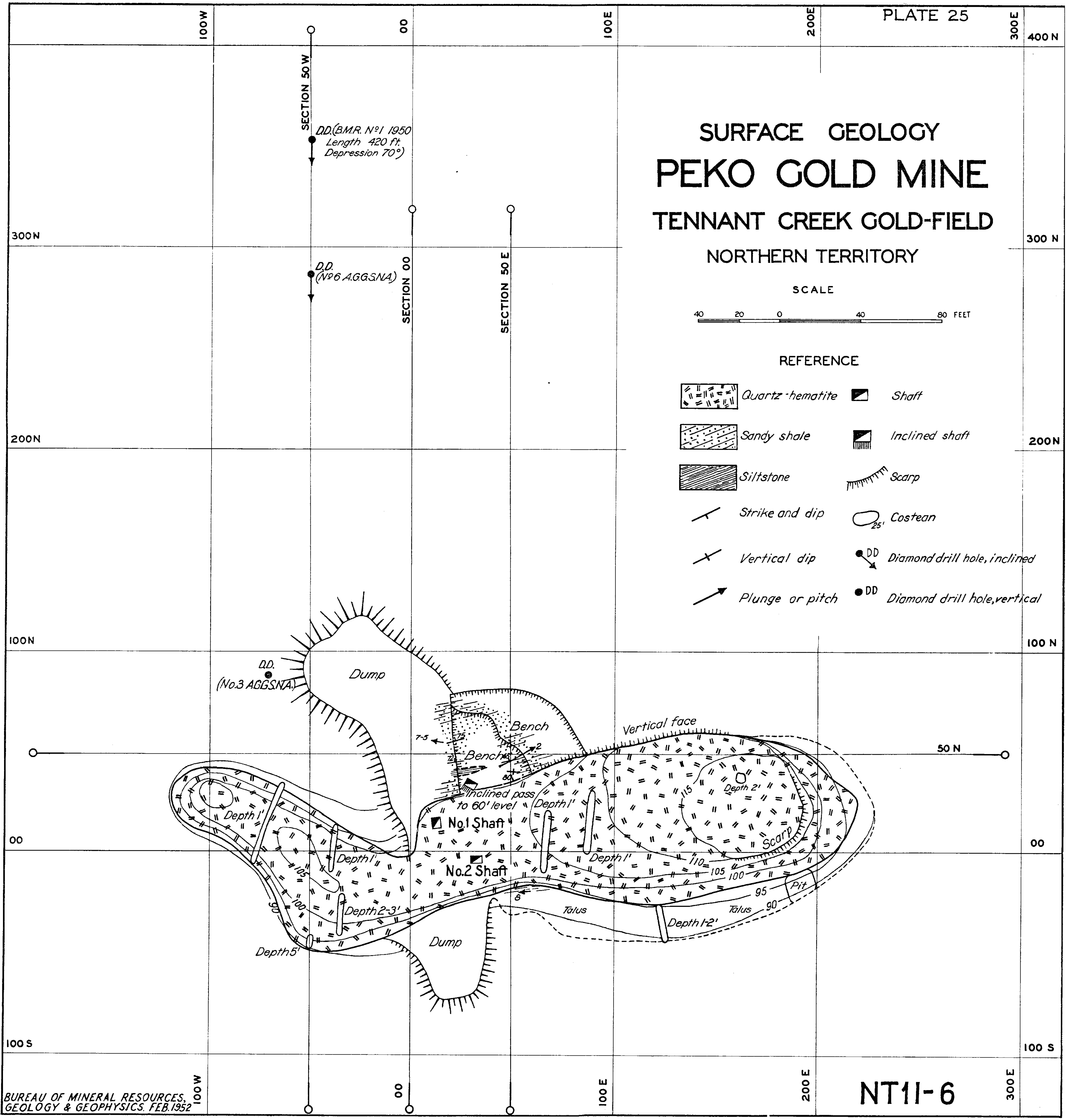






BUREAU OF MINERAL RESOURCES, GEOLOGY & GEOPHYSICS, FEBRUARY 1952

NT1Aj-1



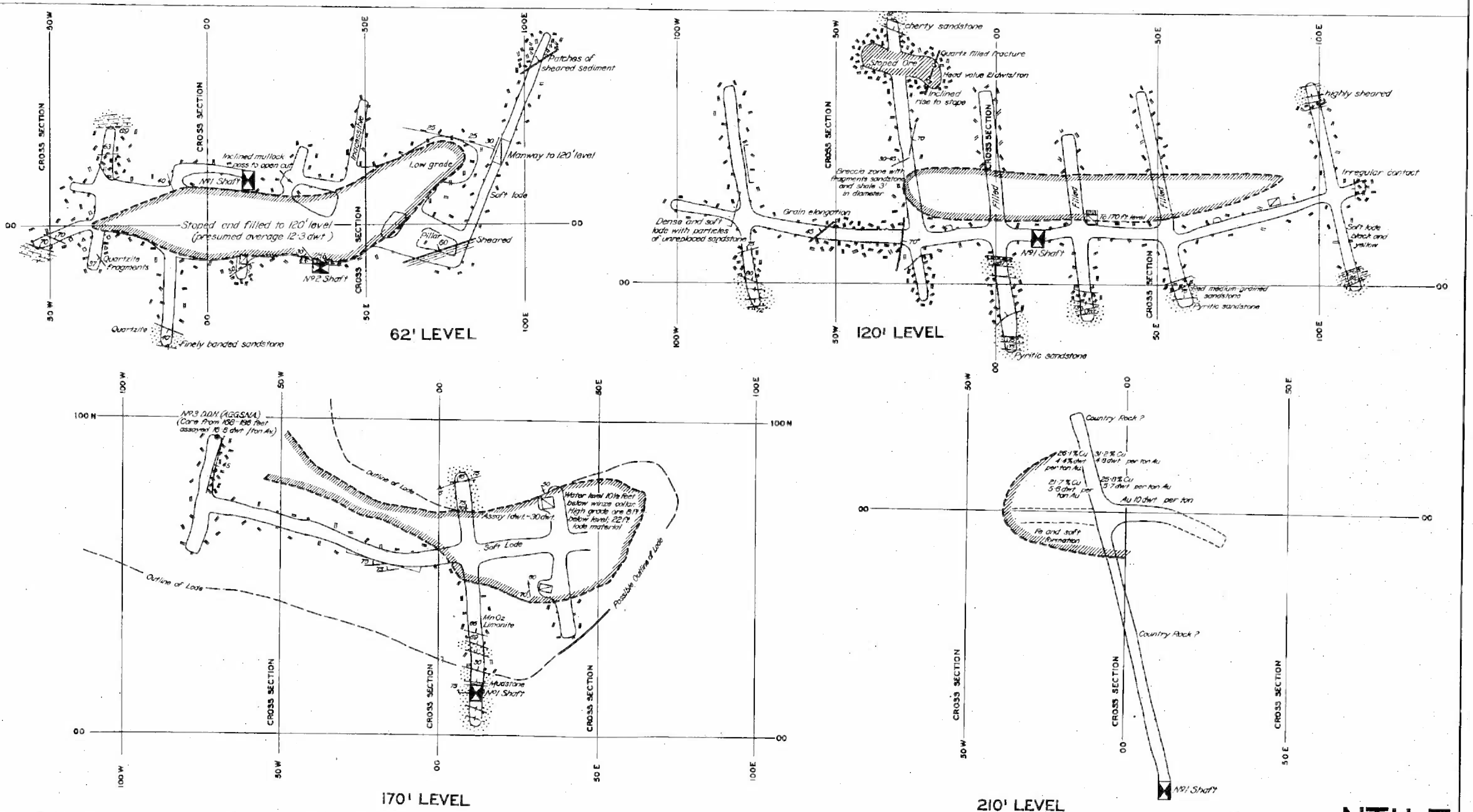
BUREAU OF MINERAL RESOURCES, GEOLOGY & GEOPHYSICS. FEB. 1952

LEVEL PLANS
PEKO GOLD MINE
TENNANT CREEK GOLD-FIELD
NORTHERN TERRITORY

40 0 40 80 FEET

REFERENCE

- Shaft - extending above and below level
- Head of rise or winze
- Foot of rise or winze
- Head of inclined winze
- D.D. Diamond drill hole
- Inclined bedding
- Vertical bedding
- Inclined cleavage
- Inclined joint
- Fault with dip
- Quartz - hematite
- Crushed hematite
- Sandstone
- Sandstone and shale
- Quartz vein
- Economic ore boundary
- Stoped ore



BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS. FEB 1952

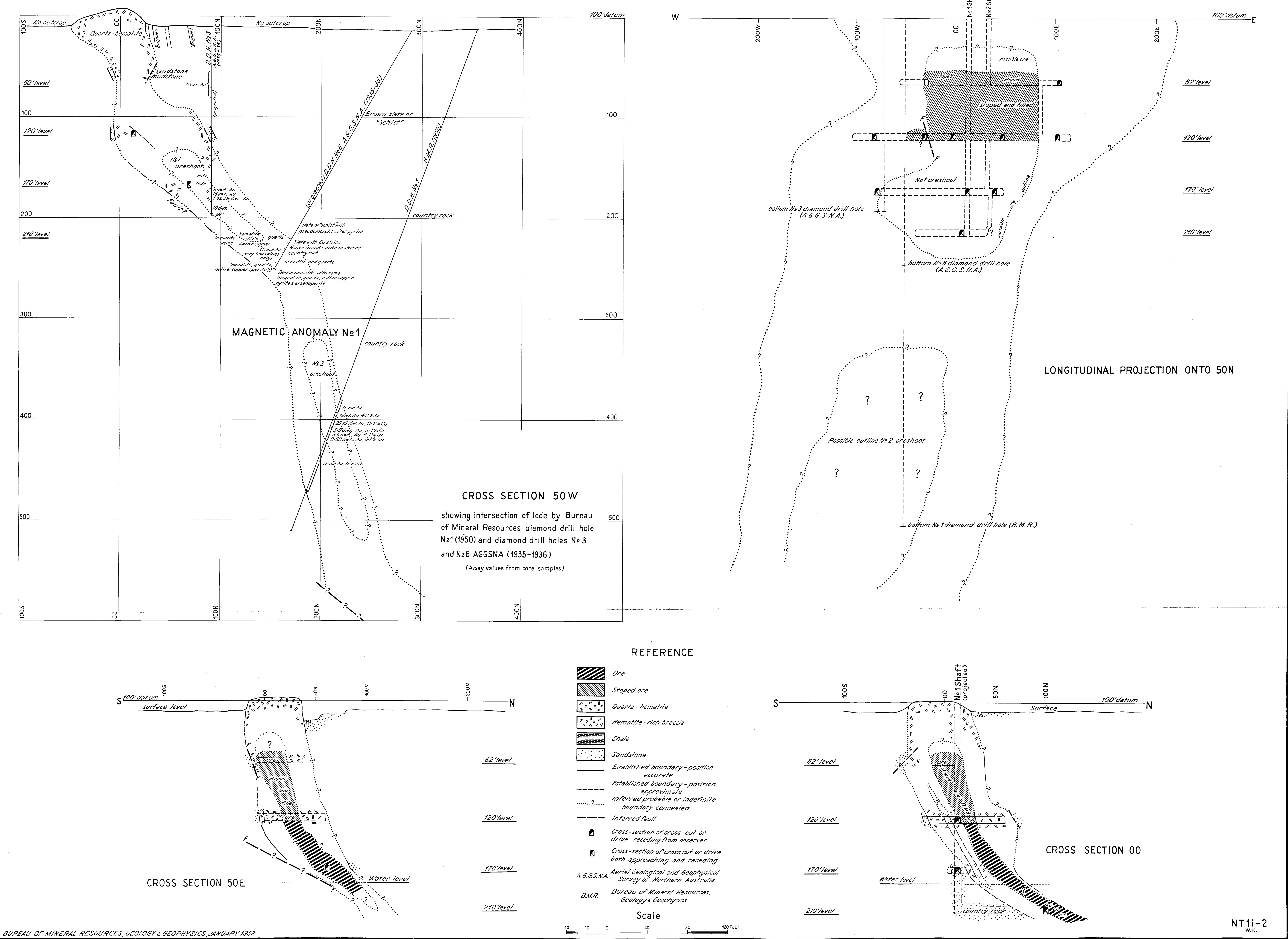
NT11-7

PLATE 27

PEKO GOLD MINE

TENNANT CREEK GOLD-FIELD

NORTHERN TERRITORY

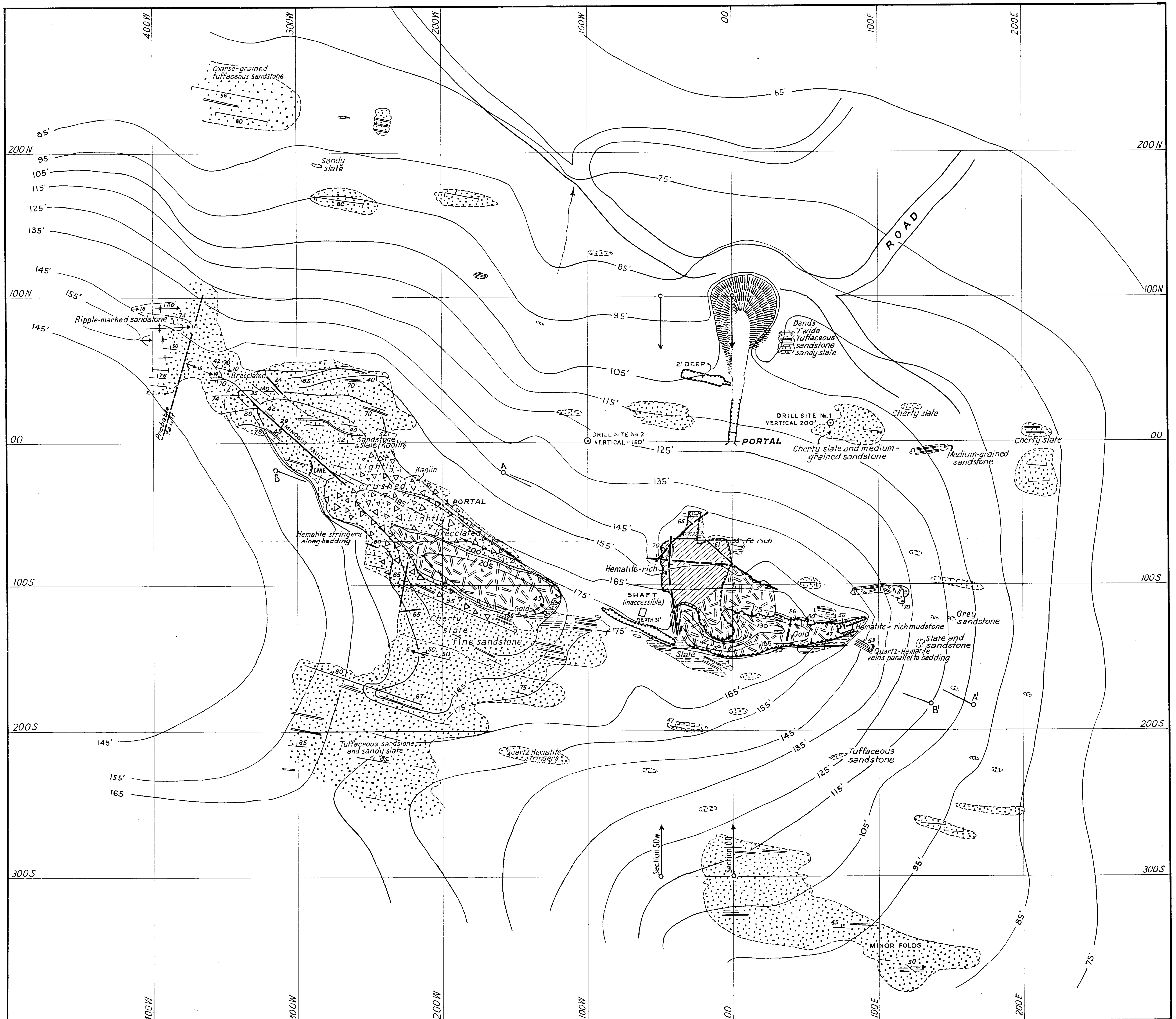


BUREAU OF MINERAL RESOURCES, GEOLOGY & GEOPHYSICS, JANUARY 1952

NT1i-2
W.K.

LONE STAR GOLD MINE
TENNANT CREEK GOLD-FIELD
NORTHERN TERRITORY

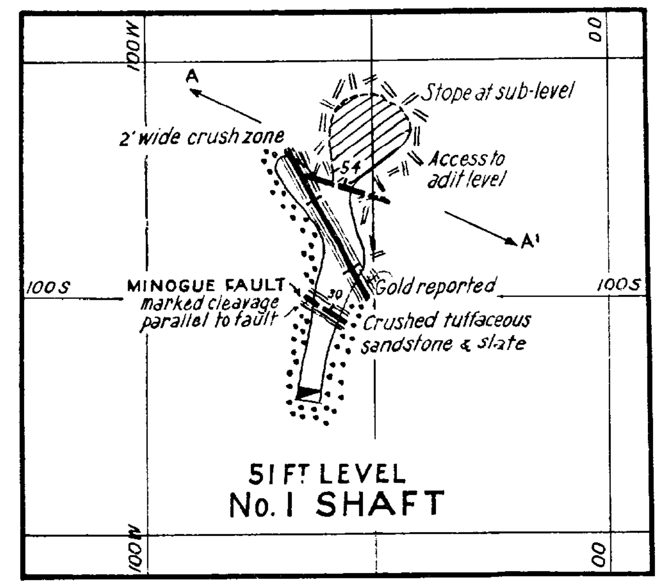
SCALE
40 20 0 40 80 120 FEET



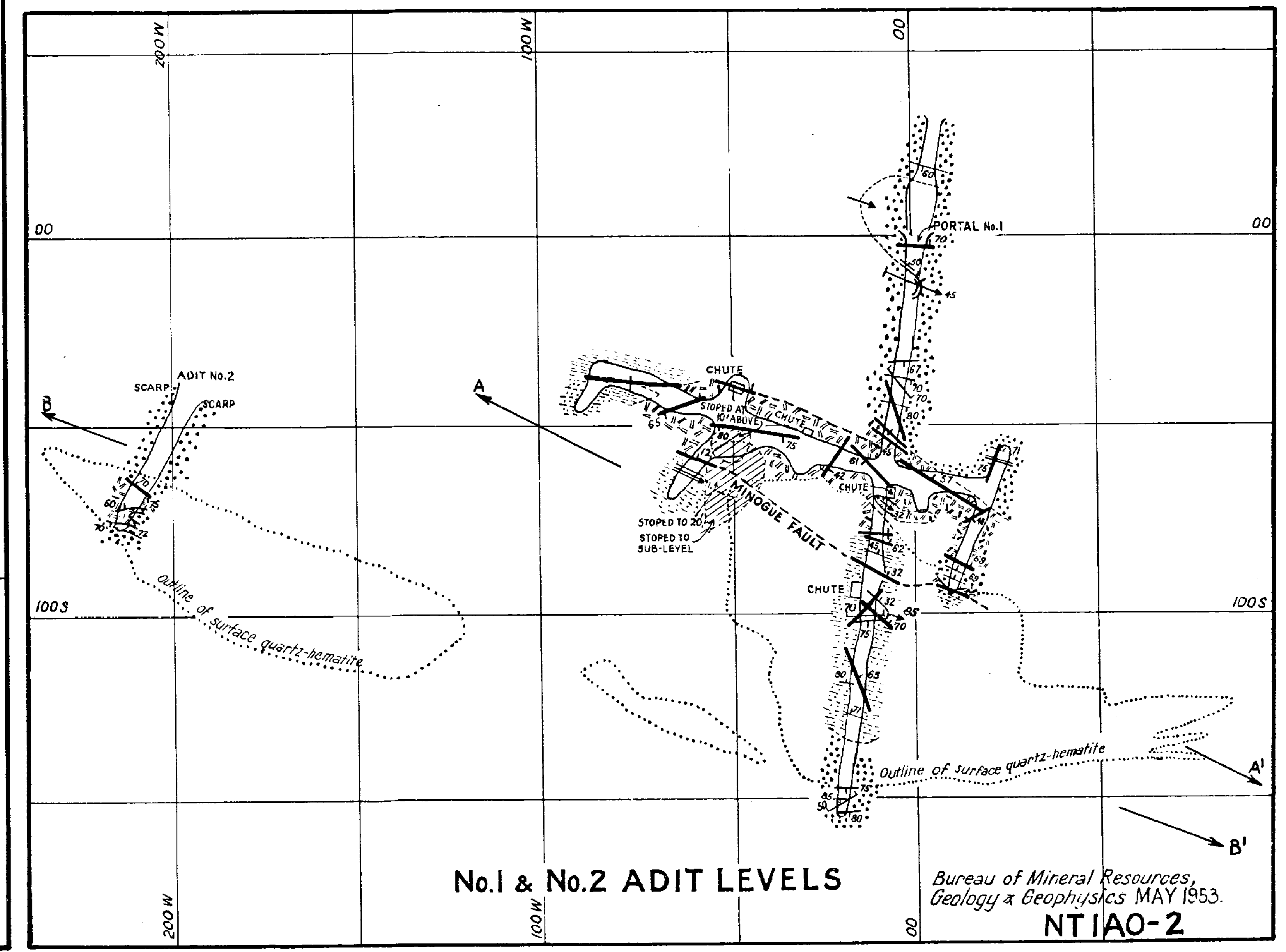
Reference

- Quartz-hematite
- Medium and fine-grained sandstone
- Silty claystone (mudstone)
- Talcose slate
- Breccia
- Stoped ore
- Established boundary - position accurate
- Established boundary - position approximate
- Strike and dip of bedding
- Bedding vertical
- Strike and dip of joint
- Strike and dip of cleavage - inclined
- Strike of cleavage - vertical
- Strike of cleavage - dip indeterminable
- Plunge or pitch of bedding on cleavage
- Plunge or pitch
- Strike and plunge or pitch of dragfold
- Plunge or pitch of minor anticline
- Plunge and pitch of minor syncline
- Established anticlinal crest
- Established synclinal trough
- Established fault - with dip
- Established fault - vertical
- Established fault - position approximate
- Ore chute
- Contour
- Open cut
- Section lines
- Dump

TRUE
MAG



51 FT. LEVEL
No. 1 SHAFT



No.1 & No.2 ADIT LEVELS

Bureau of Mineral Resources, Geology & Geophysics MAY 1953.
NT1AO-2

LONE STAR GOLD MINE

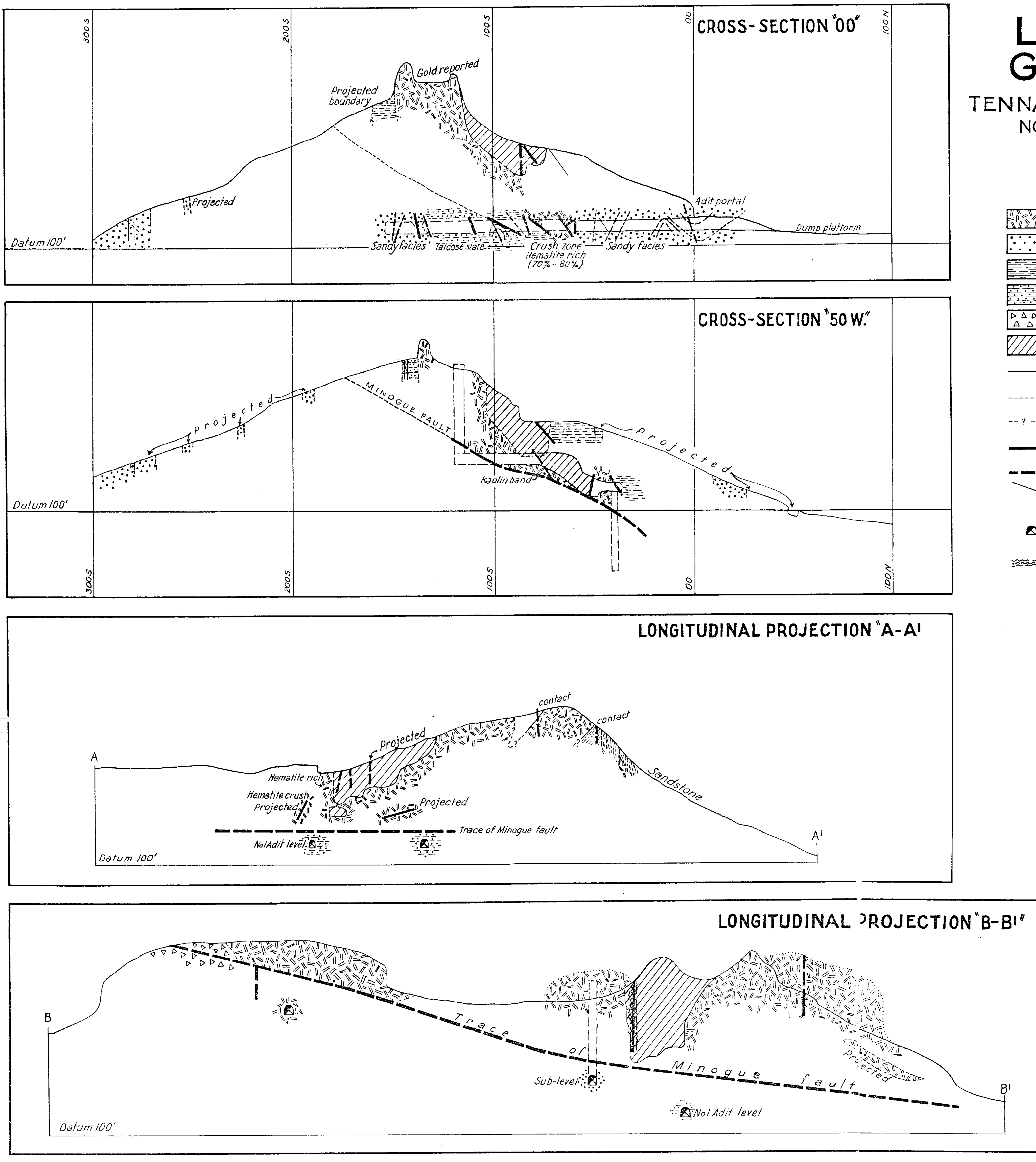
TENNANT CREEK GOLD-FIELD
NORTHERN TERRITORY

SCALE

40 20 0 40 80 FEET

Reference

- Quartz-hematite
- Medium and fine-grained sandstone
- Silty claystone (mudstone)
- Talcose slate
- Breccia
- Stoped ore
- Established boundary - position accurate
- Established boundary - position approximate
- Inferred or probable boundary
- Established fault - position accurate
- Established fault - position approximate
- Cleavage
- Bedding
- Cross-section of cross-cut or drive - extending across plane of section
- Crush zone

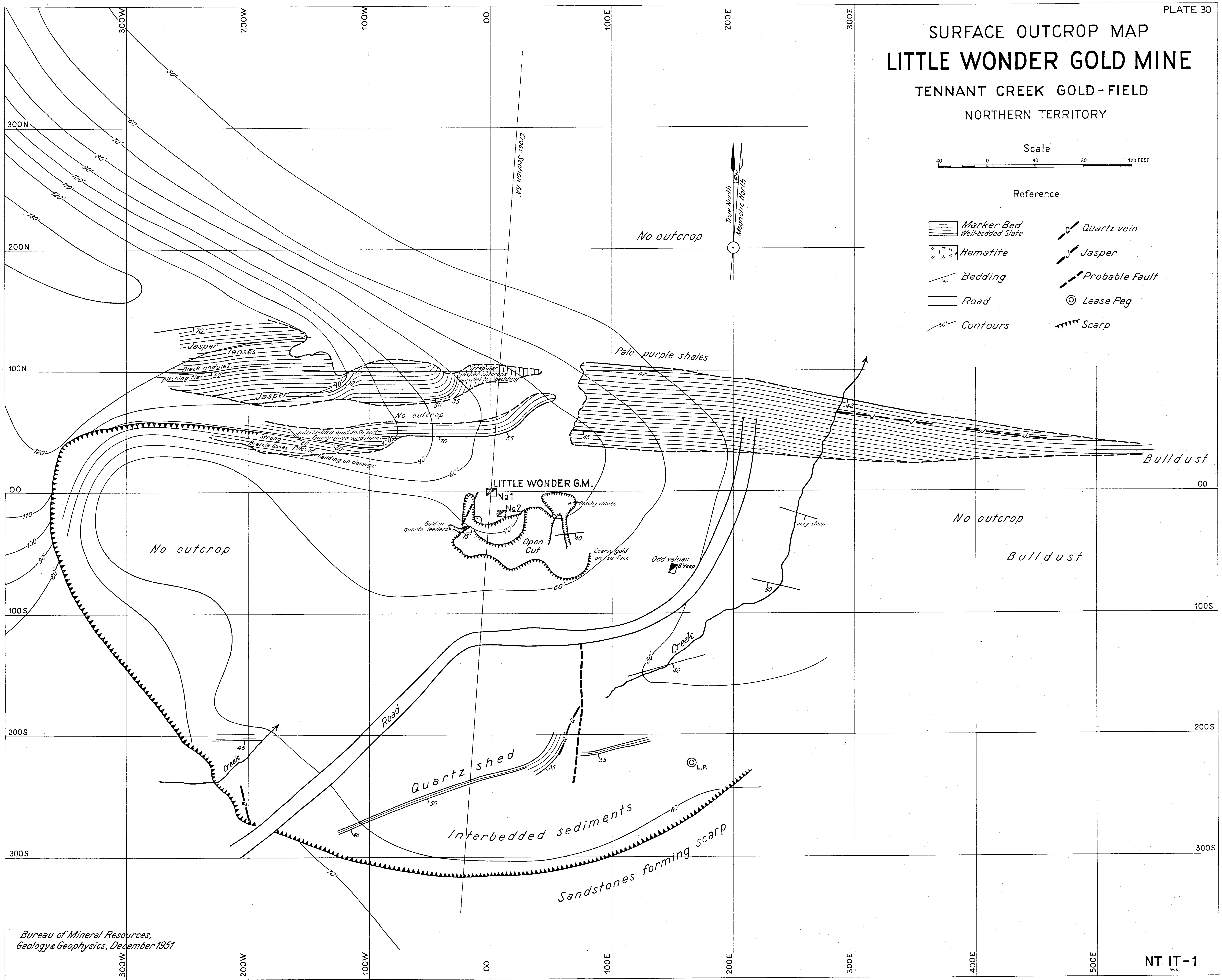


Bureau of Mineral Resources
Geology and Geophysics MAY 1953

NT 1AO-1

PLATE 30

SURFACE OUTCROP MAP
LITTLE WONDER GOLD MINE
TENNANT CREEK GOLD-FIELD
NORTHERN TERRITORY



Bureau of Mineral Resources, Geology & Geophysics, December 1951

NT IT-1

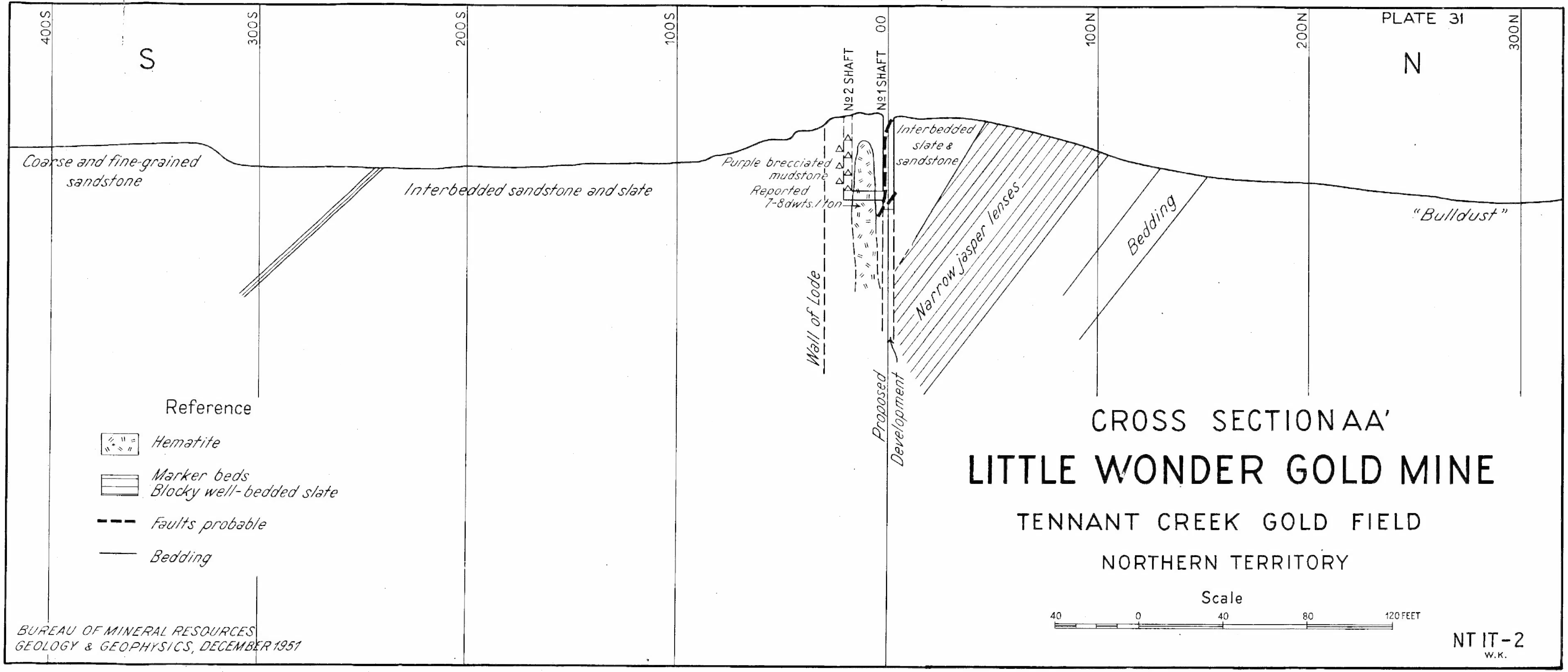
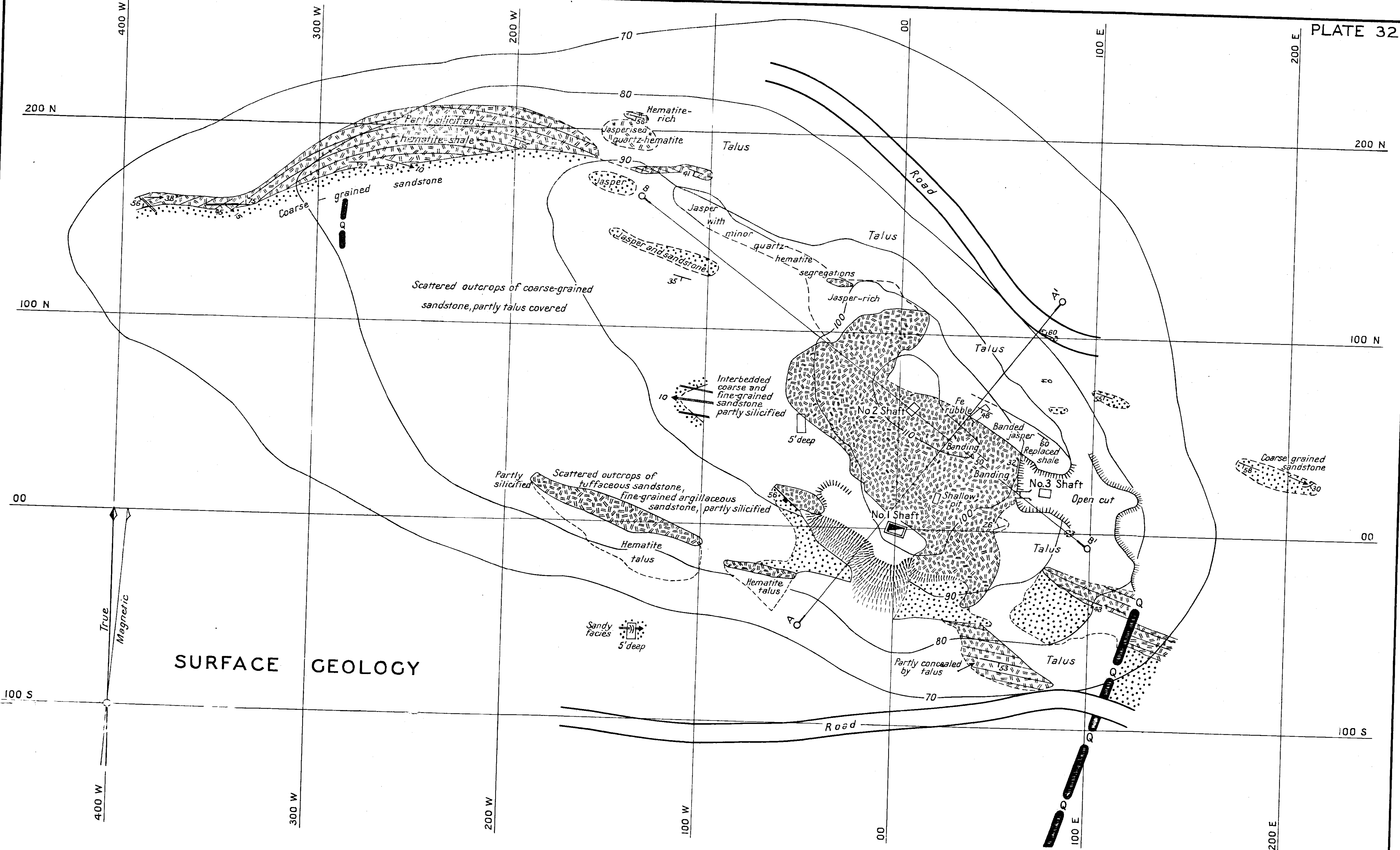


PLATE 31
400S
300S
200S
100S
00
100N
200N
300N
S
N
№2 SHAFT
№1 SHAFT
Coarse and fine-grained sandstone
Interbedded sandstone and slate
Purple brecciated mudstone
Reported 7-8dwts./ton
Interbedded slate & sandstone
Narrow jasper lenses
Bedding
"Bulldust"
Wall of Lode
Proposed Development
Reference
Hematite
Marker beds
Blocky well-bedded slate
Faults probable
Bedding
CROSS SECTION AA'
LITTLE WONDER GOLD MINE
TENNANT CREEK GOLD FIELD
NORTHERN TERRITORY
Scale
40
0
40
80
120 FEET
BUREAU OF MINERAL RESOURCES
GEOLOGY & GEOPHYSICS, DECEMBER 1951
NT IT-2
W.K.



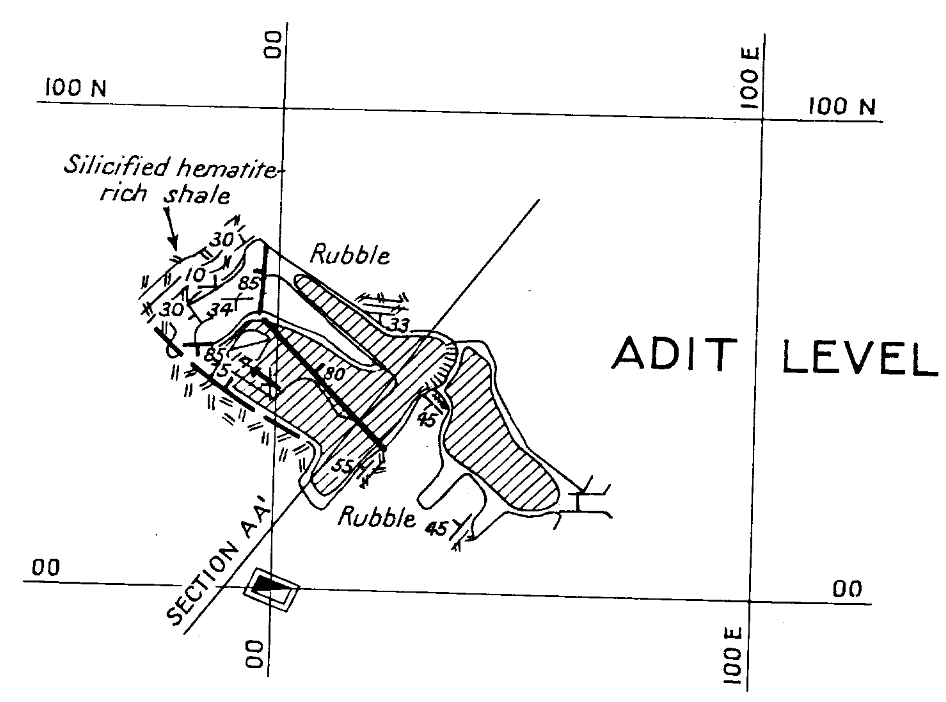
BLACK CAT GOLD MINE

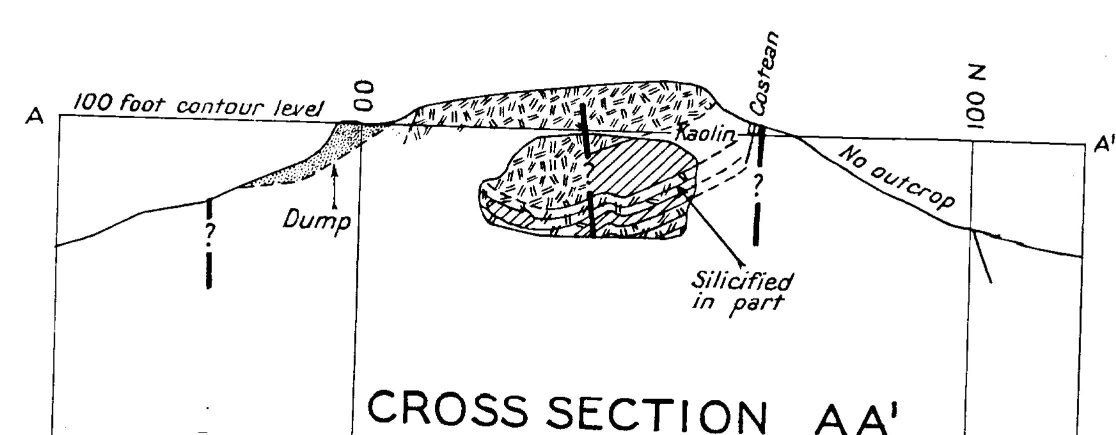
TENNANT CREEK GOLD-FIELD

NORTHERN TERRITORY

SCALE

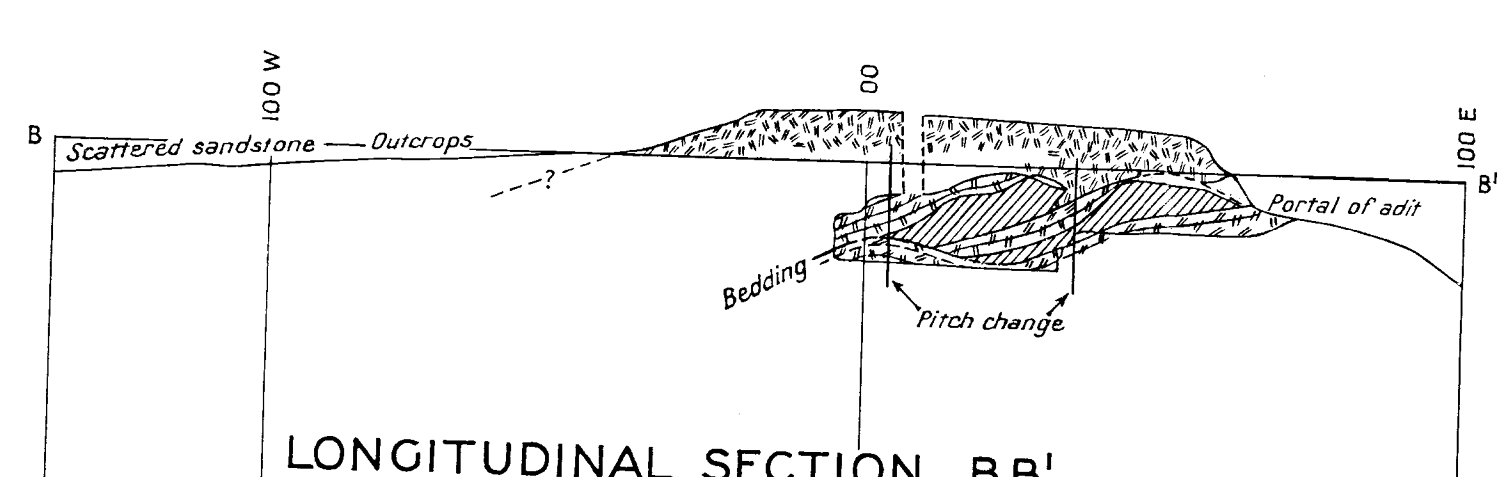
40 0 40 80 120 FEET



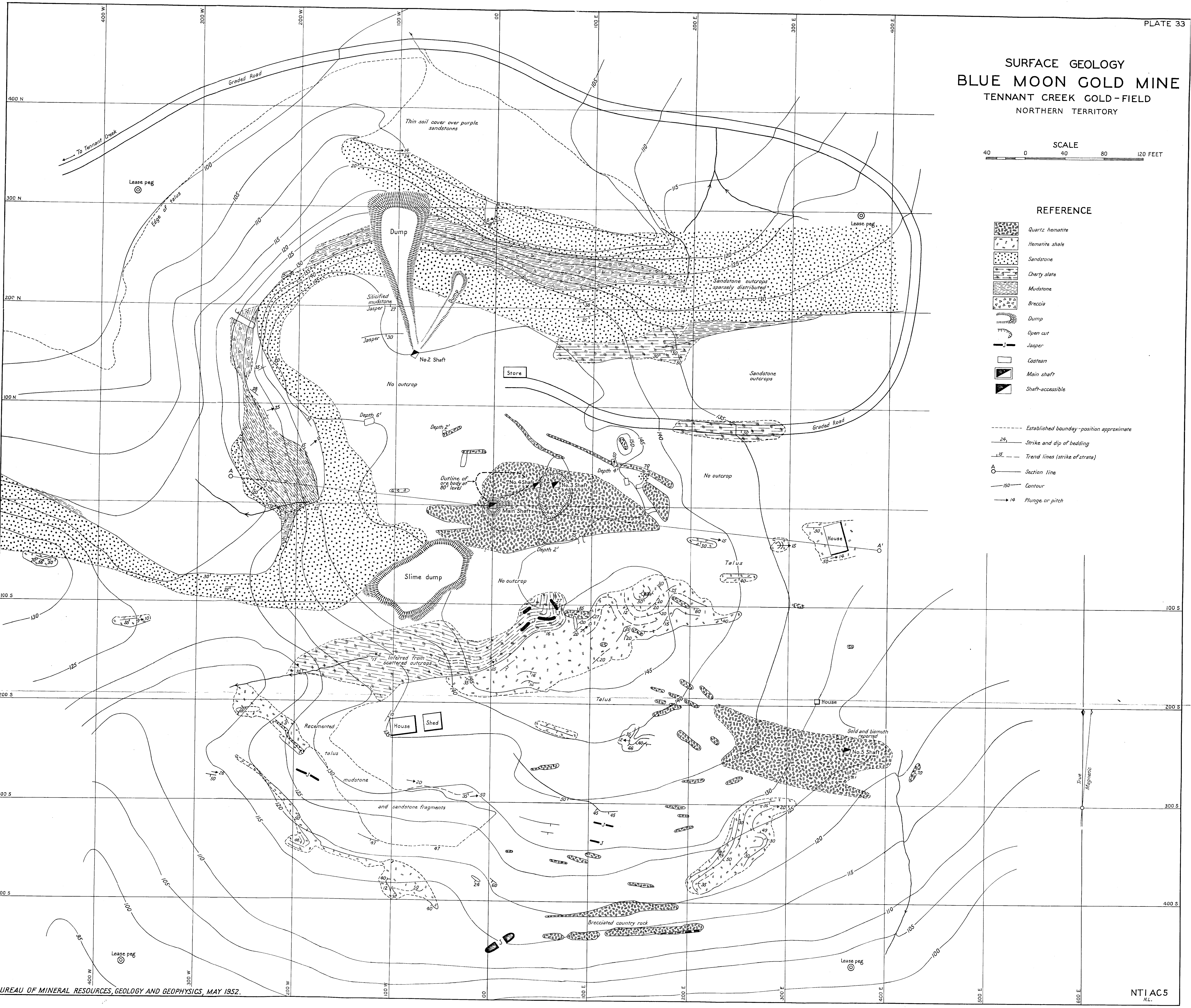


REFERENCE

- Quartz-hematite
- Hematite-shale
- Sandstone
- Stoped ore
- Main shaft
- Shaft-inaccessible
- Dump
- Quartz veins
- Costean
- Established boundary-position approximate
- Inferred boundary
- Strike and dip of bedding
- Indeterminable cleavage
- Plunge or pitch
- Inclined joint
- Fault with dip
- Inferred fault
- Established minor fault with dip
- Section
- Contour
- Portal of adit



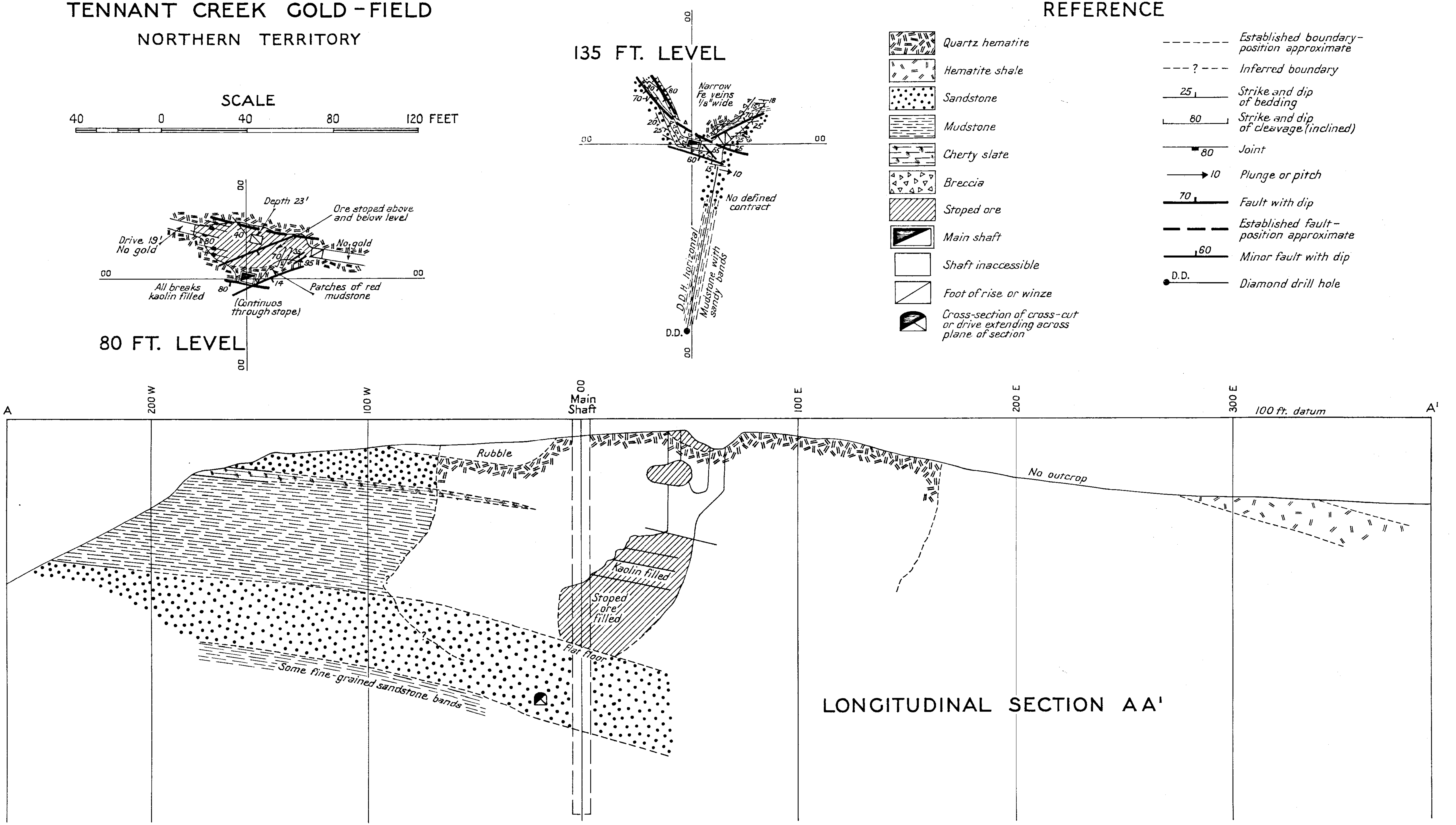
BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS, FEBRUARY 1952.


SURFACE GEOLOGY
BLUE MOON GOLD MINE
TENNANT CREEK GOLD-FIELD
NORTHERN TERRITORY
SCALE
40 0 40 80 120 FEET
REFERENCE
Quartz hematite
Hematite shale
Sandstone
Cherty slate
Mudstone
Breccia
Dump
Open cut
Jasper
Costean
Main shaft
Shaft-accessible
Established bounday-position approximate
Strike and dip of bedding
Trend lines (strike of strata)
Section line
Contour
Plunge or pitch
Graded Road
To Tennant Creek
Thin soil cover over purple sandstones
Lease peg
Edge of talus
Dump
Silicified mudstone
Jasper
No 2 Shaft
Sandstone outcrops sparsely distributed
Sandstone outcrops
Store
No outcrop
Depth 6'
Depth 2'
Depth 4'
Outline of ore body at 80' level
No 4 Shaft
No 3 Shaft
Main Shaft
House
Talus
Slime dump
No outcrop
Inferred from scattered outcrops
Recemented talus mudstone and sandstone fragments
House
Shed
Gold and bismuth reported
No 5 Shaft
True
Magnetic
Brecciated country rock
NT1AC5
H.L.

BLUE MOON GOLD MINE

TENNANT CREEK GOLD-FIELD

NORTHERN TERRITORY



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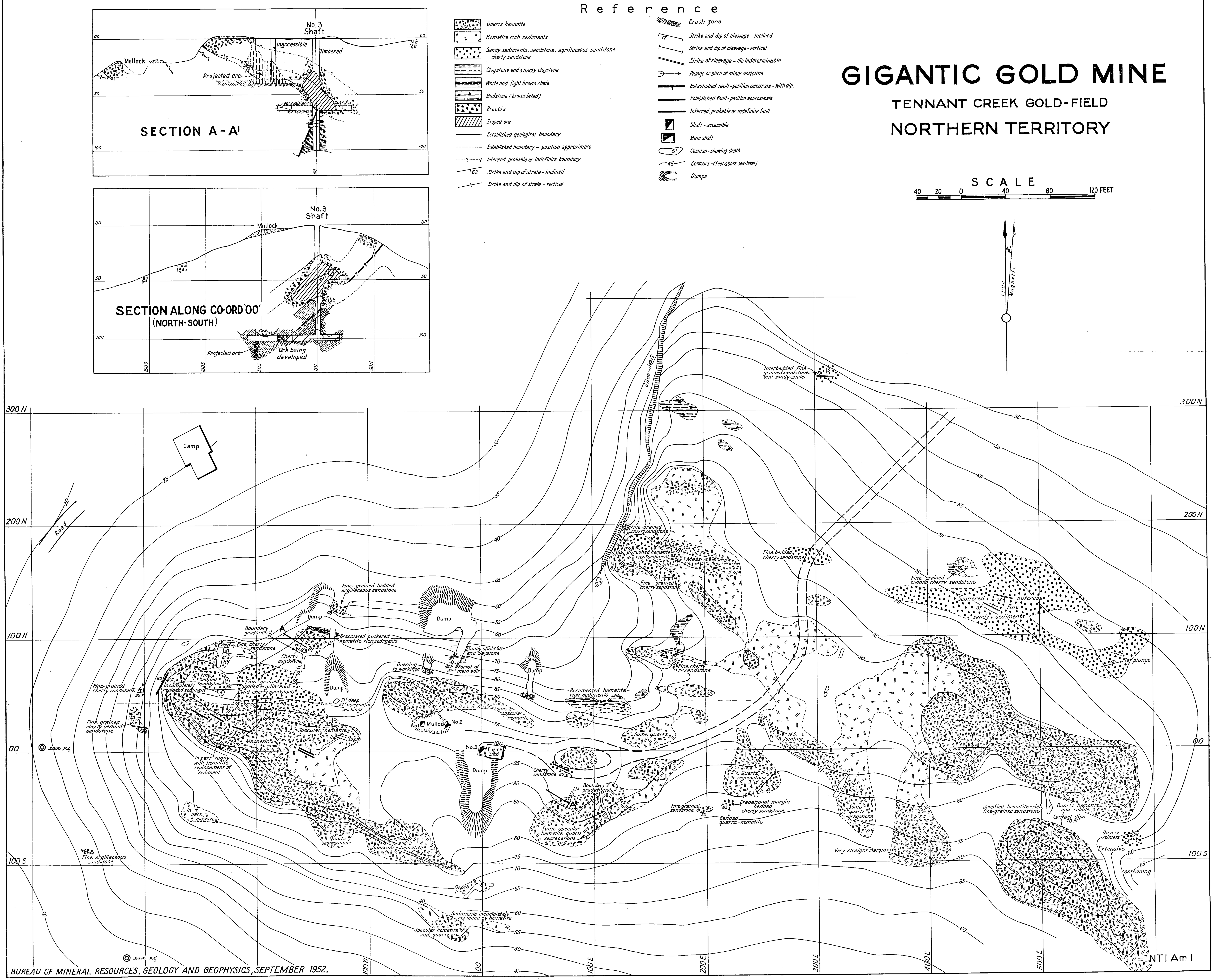
NTI AC 6

H.L.


GIGANTIC GOLD MINE
TENNANT CREEK GOLD-FIELD
NORTHERN TERRITORY
Reference
Quartz hematite
Hematite rich sediments
Sandy sediments, sandstone, agrillaceous sandstone cherty sandstone.
Claystone and sandy claystone
White and light brown shale.
Mudstone (brecciated)
Breccia
Stoped ore
Established geological boundary
Established boundary - position approximate
Inferred, probable or indefinite boundary
Strike and dip of strata - inclined
Strike and dip of strata - vertical
Crush zone
Strike and dip of cleavage - inclined
Strike and dip of cleavage - vertical
Strike of cleavage - dip indeterminable
Plunge or pitch of minor anticline
Established fault - position accurate - with dip.
Established fault - position approximate
Inferred, probable or indefinite fault
Shaft - accessible
Main shaft
Costean - showing depth
Contours - (feet above sea-level)
Dumps
SCALE
40 20 0 40 80 120 FEET
True
Magnetic
SECTION A - A'
No. 3 Shaft
Mullock
Inaccessible
Timbered
Projected ore
SECTION ALONG CO-ORD '00' (NORTH-SOUTH)
Ore being developed
Camp
Road
Lease peg
Steep scarp
Dump
No. 3
Engine Shed
Mullock
Massive
Specular hematite
Fine-grained cherty sandstone
Recemented hematite-rich sediments
Scattered outcrops of fine sandy sediments
Flat plunge
Quartz veinlets
Extensive costeaning
Very straight margin
N.S. Jointing
NT1 Am 1
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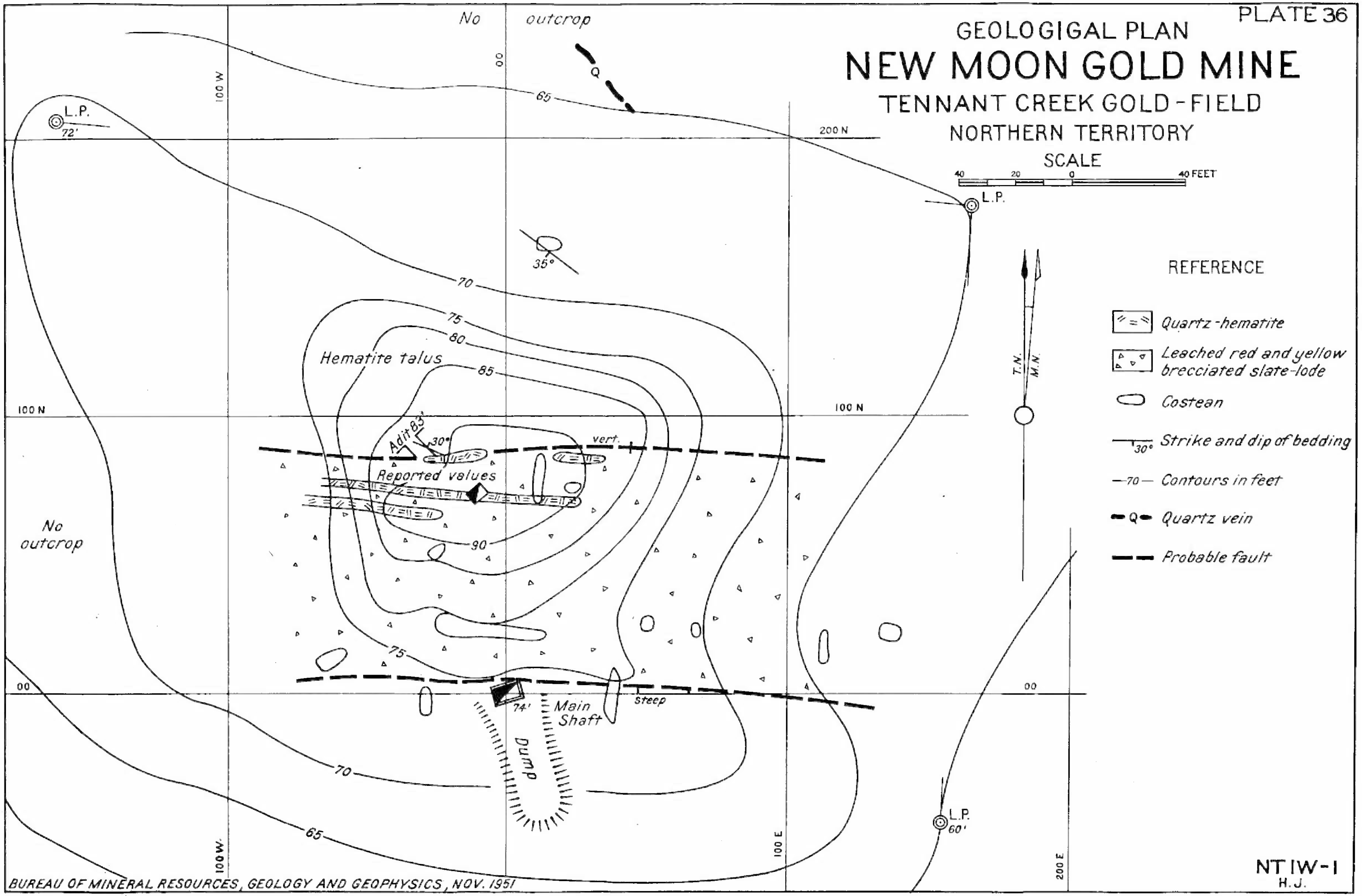

PLATE 36
GEOLOGIGAL PLAN
NEW MOON GOLD MINE
TENNANT CREEK GOLD-FIELD
NORTHERN TERRITORY
SCALE
40 20 0 40 FEET
REFERENCE
Quartz-hematite
Leached red and yellow brecciated slate-lode
Costean
Strike and dip of bedding
Contours in feet
Quartz vein
Probable fault
No outcrop
Hematite talus
Reported values
Adit 83'
vert.
Main Shaft
Dump
Steep
L.P.
72'
60'
T.N.
M.N.
100 W
00
100 E
200 E
200 N
100 N
65
70
75
80
85
90
35°
30°
74'
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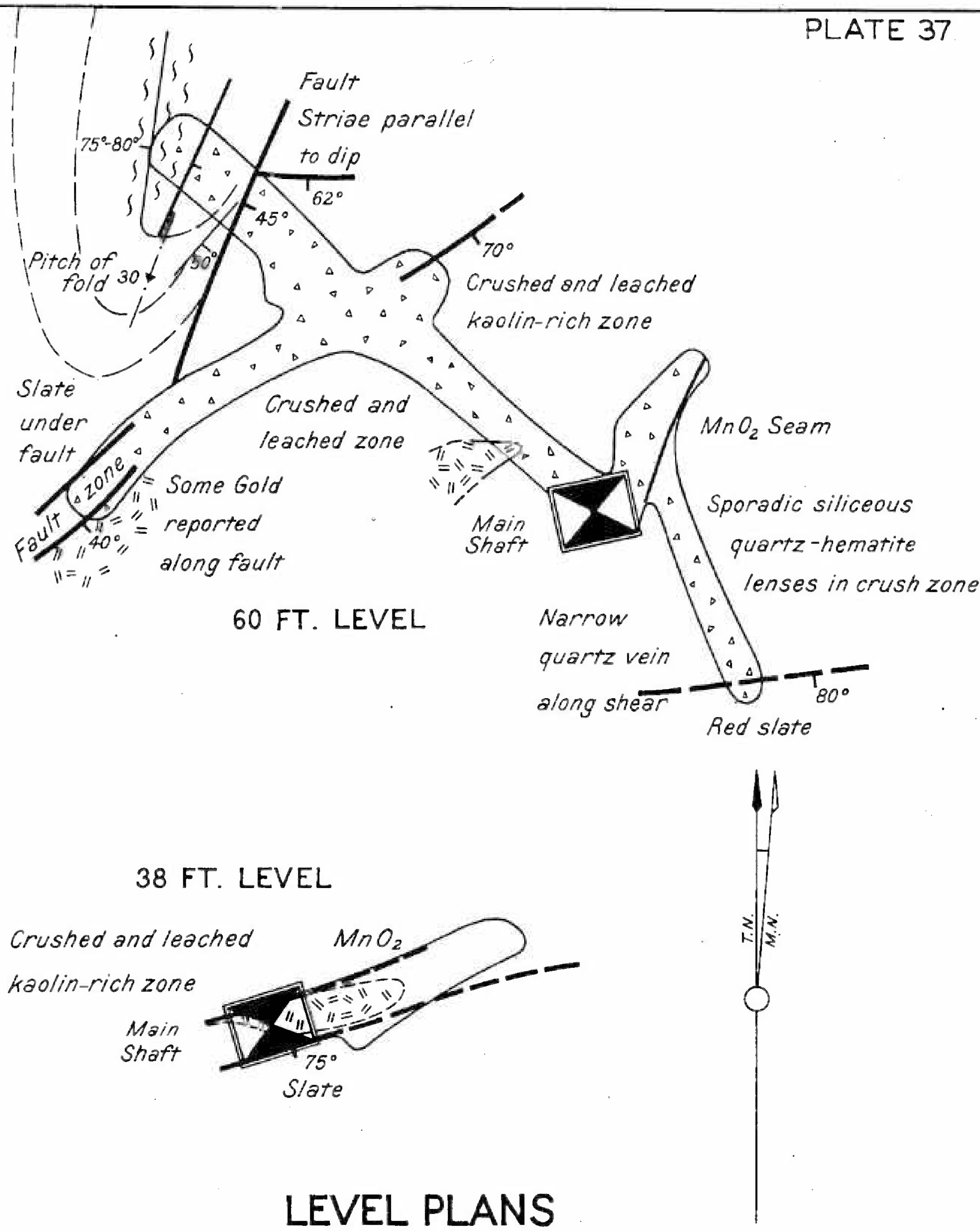
NT IW-1
H.J.

PLATE 37



LEVEL PLANS

NEW MOON GOLD MINE

TENNANT CREEK GOLD-FIELD

NORTHERN TERRITORY

SCALE

10 5 0 10 20 30 FEET

REFERENCE

- Quartz-hematite
- Well-banded slate
- Leached red and yellow brecciated slate } lode
- Fault with dip (62°)
- Probable fault (80°)
- Minor fault
- Strike and dip of bedding
- Probable bedding

NT IW-2
H. J.

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PLATE 38

SURFACE GEOLOGY
CRUSADER, BLACK ANGEL AND WHITE DEVIL LEASES
TENNANT CREEK GOLD-FIELD
NORTHERN TERRITORY

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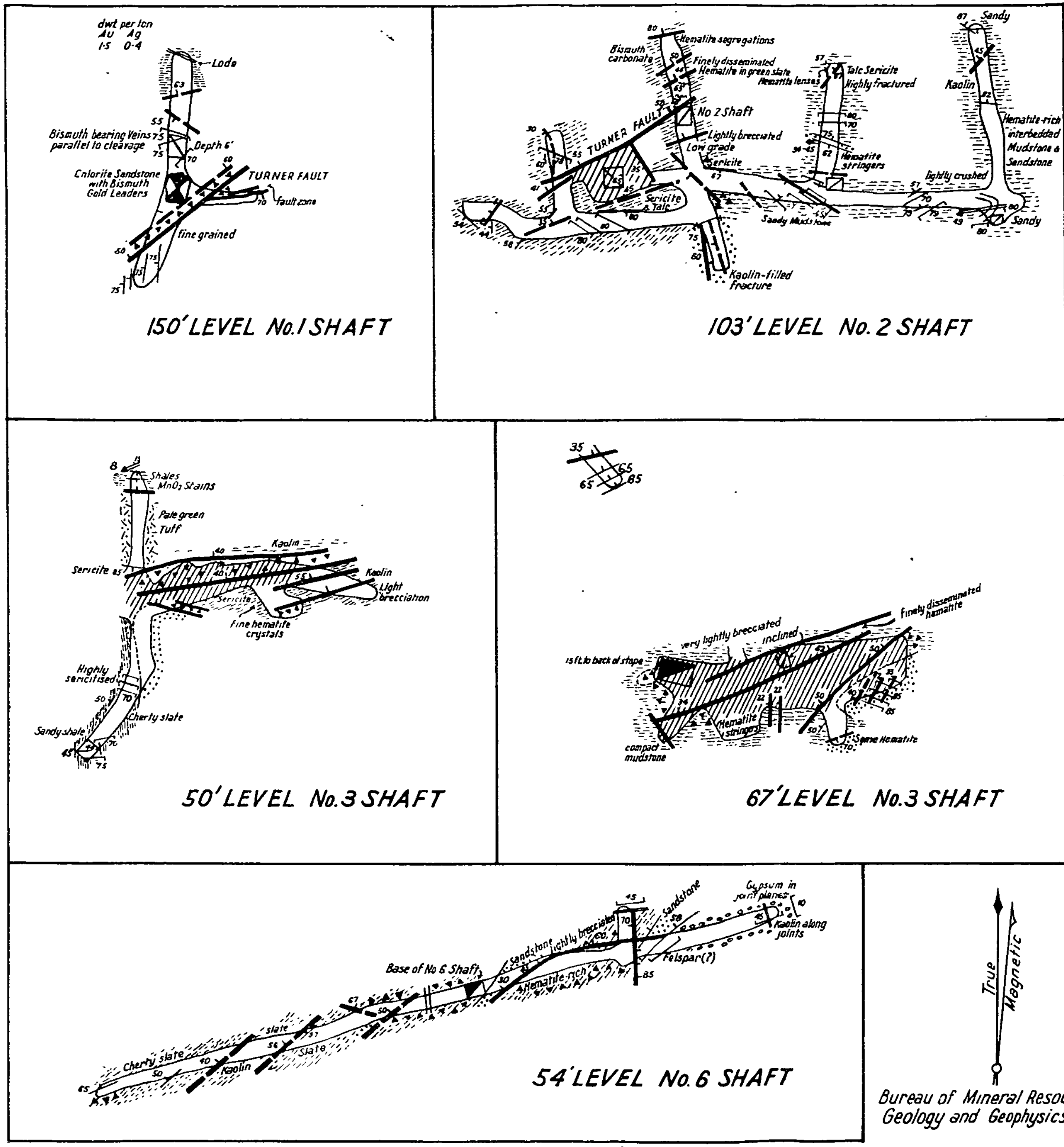
NT1A1-1

BLACK ANGEL GOLD MINE

TENNANT CREEK, N.T.



SCALE

40 20 0 FEET 40

Reference

- Medium grained sandstone
- Tuffaceous sandstone
- Mudstone
- Breccia
- Conglomerate
- Established boundaries - position accurate
- Established boundaries - position approximate
- Strike and dip of strata - inclined
- - vertical
- Generalised strike and dip of crumpled or undulating strata
- Strike and dip of cleavage
- Strike of cleavage - dip indeterminable
- Plunge or pitch of bedding on cleavage
- Established fault - position accurate - with dip
- Established fault - position approximate
- Stoped ore.
- Shaft - accessible
- Shaft - extending above and below level
- Head of rise or winze
- Foot of rise or winze

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NT 1AL-2

NORTHERN STAR
PLATE 40
(SHEET 1)
SURFACE GEOLOGY
NORTHERN STAR GOLD MINE
TENNANT CREEK GOLD-FIELD
NORTHERN TERRITORY
SCALE
80 0 80 160 240 320 FEET
REFERENCE
Lode
Quartz hematite
Lozenge shaped boxwork-ribwork in hematite
Dense massive quartz hematite
Quartz jasper hematite mainly jasper
Botryoidal or mammillary hematite
Hematite shale
Sandy shale
Jasper-silicified sediments
Sandy facies.(Ripple marked sandstone. Fine grained sandstone. Cherty slate.)
Silty claystone.(mudstone)
Principal zones of magnetic anomaly. (From plate 4. Third report on magnetic prospecting at Tennant Creek 1937)
Main shaft
Shaft accessible
Quartz
Costean
Dump
Open cut
Established boundary position approximate
Inferred boundary
Strike and dip of bedding
Vertical bedding
Bedding trends
Strike and dip of cleavage (inclined)
Strike of cleavage-dip indeterminable
Plunge or pitch of bedding on cleavage
Plunge or pitch
Strike and dip of joint (inclined)
Vertical joint
Fault with dip
Vertical fault
Established fault position approximate
Contour
Sectionline
No outcrop
Shale
Talus
Ripple marked sandstone
Fine argillaceous sandstone
Cherty slate
Fine grained argillaceous sandstone
Road
Hematite shale
Banded silicified
Medium-grained sandstone
Fine grained
Cave
Fine argillaceous sandstone partly concealed by talus
Massive hematite lenses in partly replaced sediments with some banded ironstone
Crush zone with breccia fragments (silicified mudstone)
Mudstone
(Soft crumbly)
Medium-grained tuffaceous sandstone and fine banded sandstone
Rubble
Limonite kaolin
(Soft)
To 50 ft. level
(Crumbly)
Massive
Depth 3 ft.
Main Shaft
Depth 1 ft.
Sandy shale and claystone
Depth 4 ft.
Fine argillaceous sandstone
Sandy shale
(MnO₂ Stains)
Bedding and cleavage parallel
Mudstone and sandy shale
Quartz stringers
MINE BUILDINGS
No outcrop
BATTERY AND TREATMENT PLANT
Mine Office
Store
Oil
Silicified fine-grained sandstone
Scattered outcrops well cleaved, argillaceous sandstone partly by talus
Intense polygonal cleavage
Subhorizontal slickensides
Strongly jointed
Argillaceous sandstone
Partly hematised sandy shale
Platform
Talus and recemented material
Lightly hematised sandy shale
Joins sheet 2
100 W
00
200 E
300 E
400 E
300 N
200 N
100 N
00
100 S
200 S
NT IP 18A

NORTHERN STAR
PLATE 40
(SHEET 2)

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NT IP 18B

PLATE 41
NORTHERN STAR GOLD MINE
TENNANT CREEK GOLD-FIELD, N.T.
SCALE
40 20 0 40 80 120
REFERENCE
Lode
Quartz hematite
B Dense massive quartz hematite
C Quartz jasper hematite - mainly jasper
Mudstone
Medium and coarse-grained sandstone
Stoped ore
Unstoped ore
Sandy shale
Limit of ore
Shear zone
Ore chute
Head of rise or winze
Foot of rise or winze
Cross-section of cross-cut or drive - opposite side of plane of section from observer
Cross-section of cross-cut or drive extending across plane of section.
Established boundary
Established boundary - position approximate
Inferred, probable or indefinite boundary
Strike and dip of bedding - inclined
Strike and dip of bedding - vertical
Strike and dip of cleavage - inclined
Strike and dip of cleavage - vertical
Strike and dip of joints - inclined
Strike and dip of joints - vertical
Plunge or pitch
Fault with dip
Established fault - position approximate
Fault showing horizontal movement
Minor fault
Prevailing dip of strata (undisturbed or gently inclined strata showing inconstant strike and dip).
W
E
200W
100W
00
100E
200E
300E
indicated ore
filled
50 ft. level
100 ft. level
150 ft level
200 ft level
235 ft level
possible lode outline
possible top of unfavourable sandstone
Possible continuation of lode to be tested by underground development or diamond drilling.
LONGITUDINAL PROJECTION ALONG '00' (EAST & WEST)
100S
00
100N
no outcrop
interpreted
Higgins fault
possible lode outline
Possible ore-shoot to be tested by underground development or diamond drilling
possible top of unfavourable sandstone
CROSS SECTION ALONG 50'W
replaced fine-grained sandstone
soft lode
Higgins fault trace
crushed hematite very micaceous
Water table level
CROSS SECTION ALONG '00'
50' LEVEL
100' LEVEL
150' LEVEL
235' LEVEL
No.1 SHAFT
True
Mag
NT1P 19
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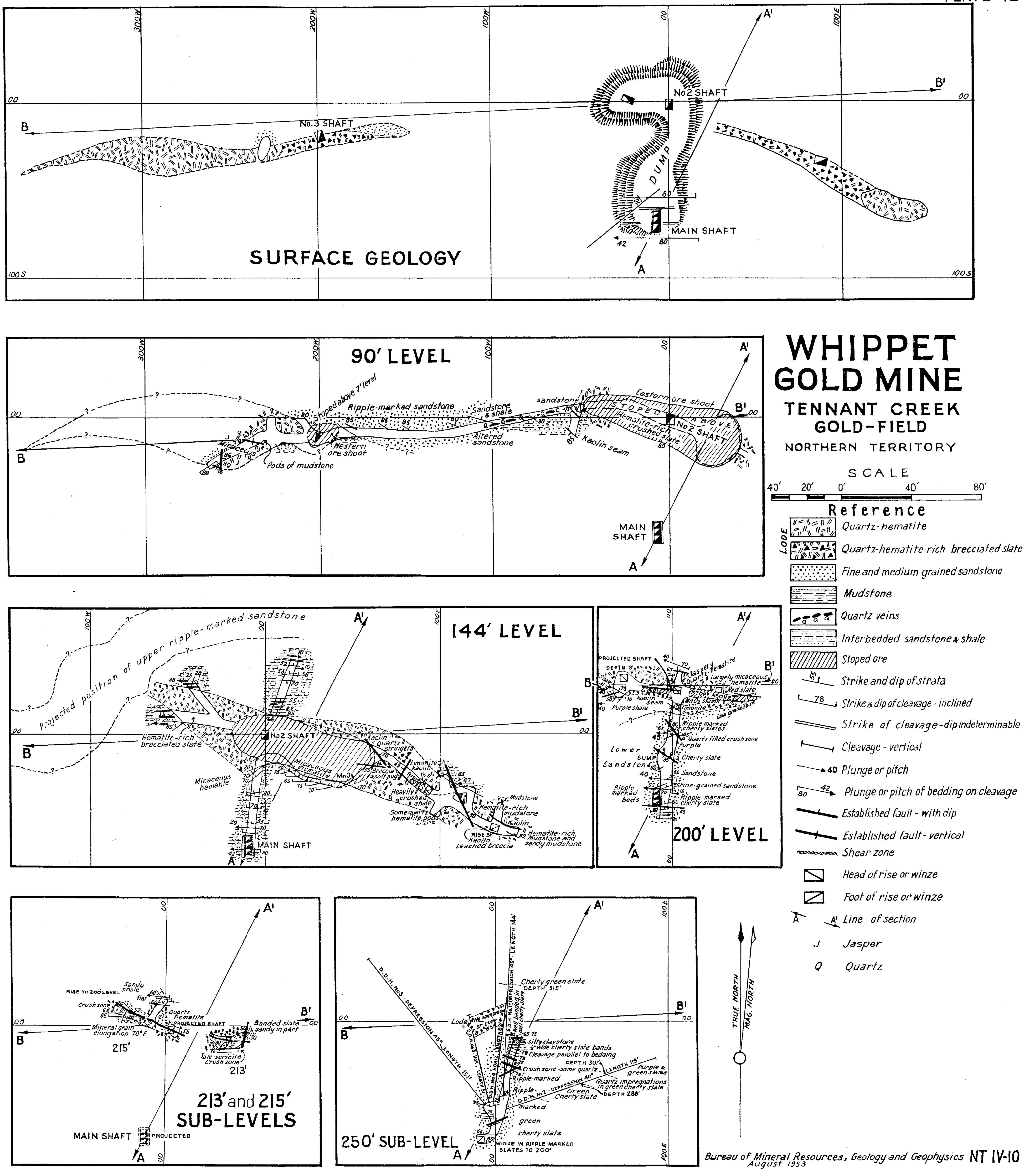

SURFACE GEOLOGY
No.3 SHAFT
No2 SHAFT
DUMP
MAIN SHAFT
90' LEVEL
Ripple-marked sandstone
Eastern ore shoot
STOPED ABOVE
Hematite-rich crushed slate
Kaolin seam
Western ore shoot
Pods of mudstone
Altered sandstone
144' LEVEL
Projected position of upper ripple-marked sandstone
Hematite-rich brecciated slate
Micaceous hematite
200' LEVEL
213' and 215' SUB-LEVELS
250' SUB-LEVEL
WHIPPET GOLD MINE
TENNANT CREEK GOLD-FIELD
NORTHERN TERRITORY
SCALE
40' 20' 0' 40' 80'
Reference
LODE
Quartz-hematite
Quartz-hematite-rich brecciated slate
Fine and medium grained sandstone
Mudstone
Quartz veins
Interbedded sandstone & shale
Stoped ore
Strike and dip of strata
Strike & dip of cleavage - inclined
Strike of cleavage - dip indeterminable
Cleavage - vertical
Plunge or pitch
Plunge or pitch of bedding on cleavage
Established fault - with dip
Established fault - vertical
Shear zone
Head of rise or winze
Foot of rise or winze
Line of section
J Jasper
Q Quartz
TRUE NORTH
MAG. NORTH
Bureau of Mineral Resources, Geology and Geophysics
August 1953
NT IV-10

WHIPPET GOLD MINE

TENNANT CREEK GOLD-FIELD
NORTHERN TERRITORY

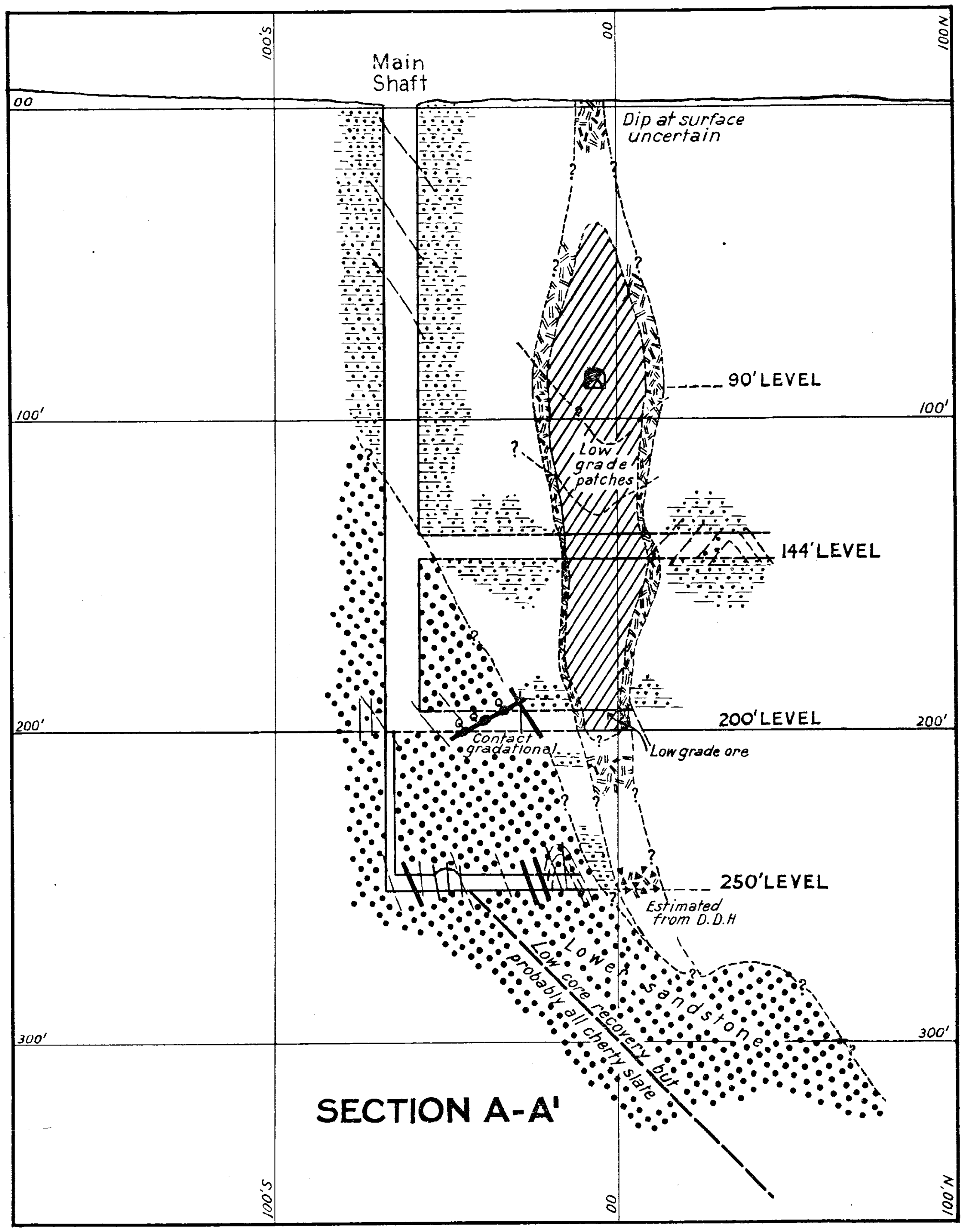
SCALE

40 20 0 40 80 120 FEET

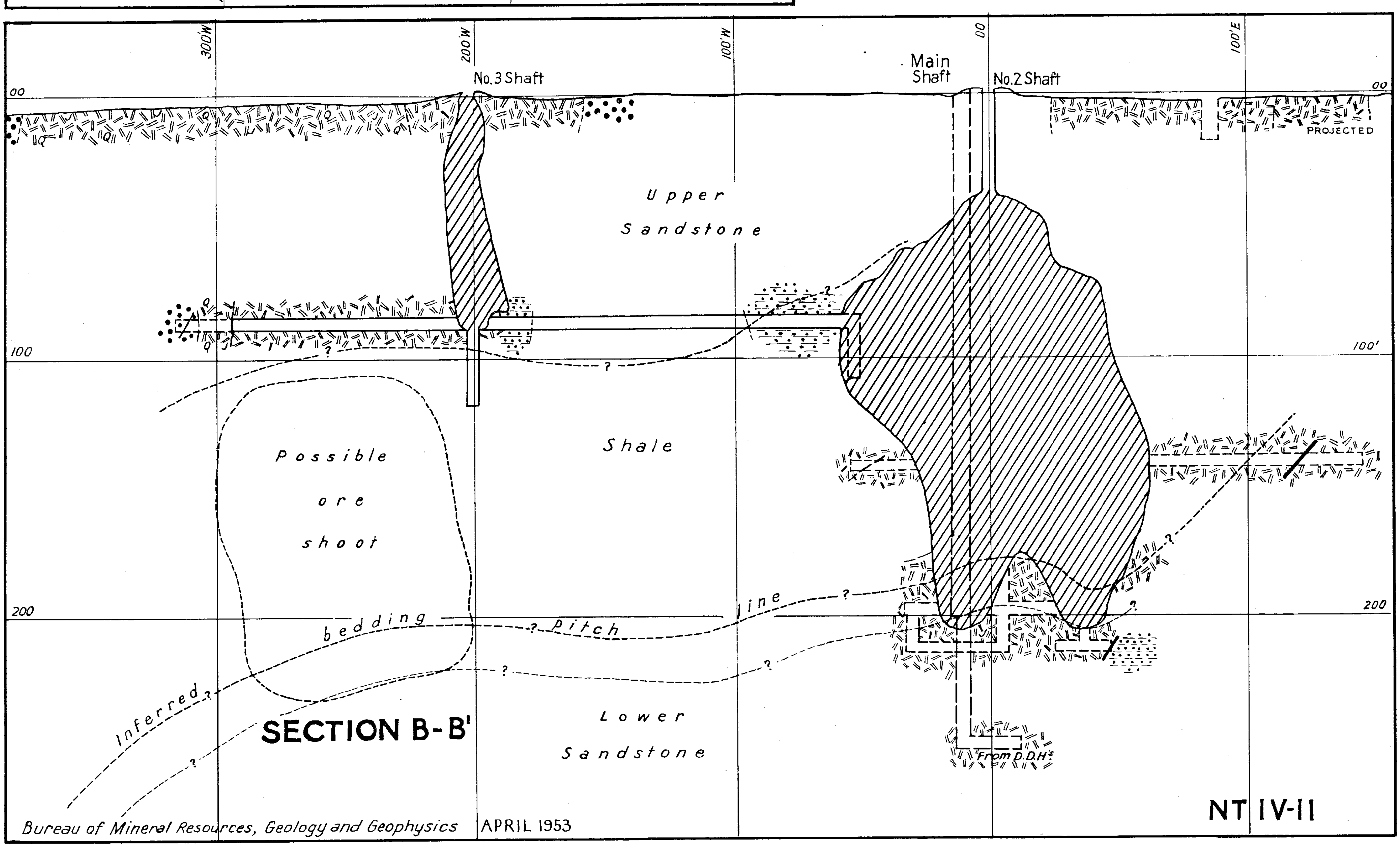
Reference

LODE
- Quartz-hematite
- Quartz-hematite-rich brecciated slate

- Fine and medium grained sandstone
- Interbedded sandstonstone and shale
- Quartz veins
- Stoped ore
- Established geological boundary-position approximate
- Inferred geological boundary
- Fault
- Minor fault
- Bedding
- Cleavage
- Cross section of cross-cut or drive - extending across plane of section.
- Q Quartz
- J Jasper

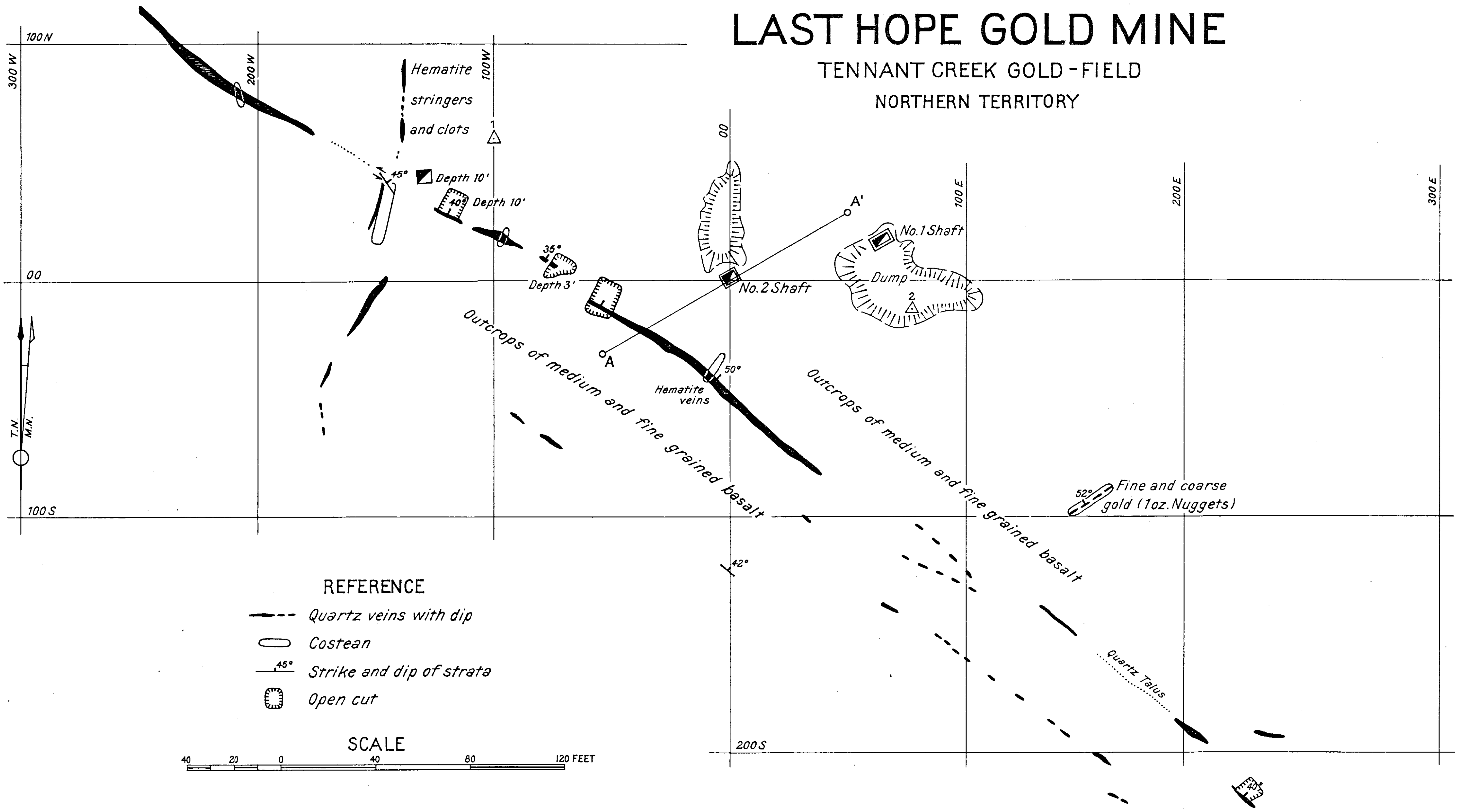


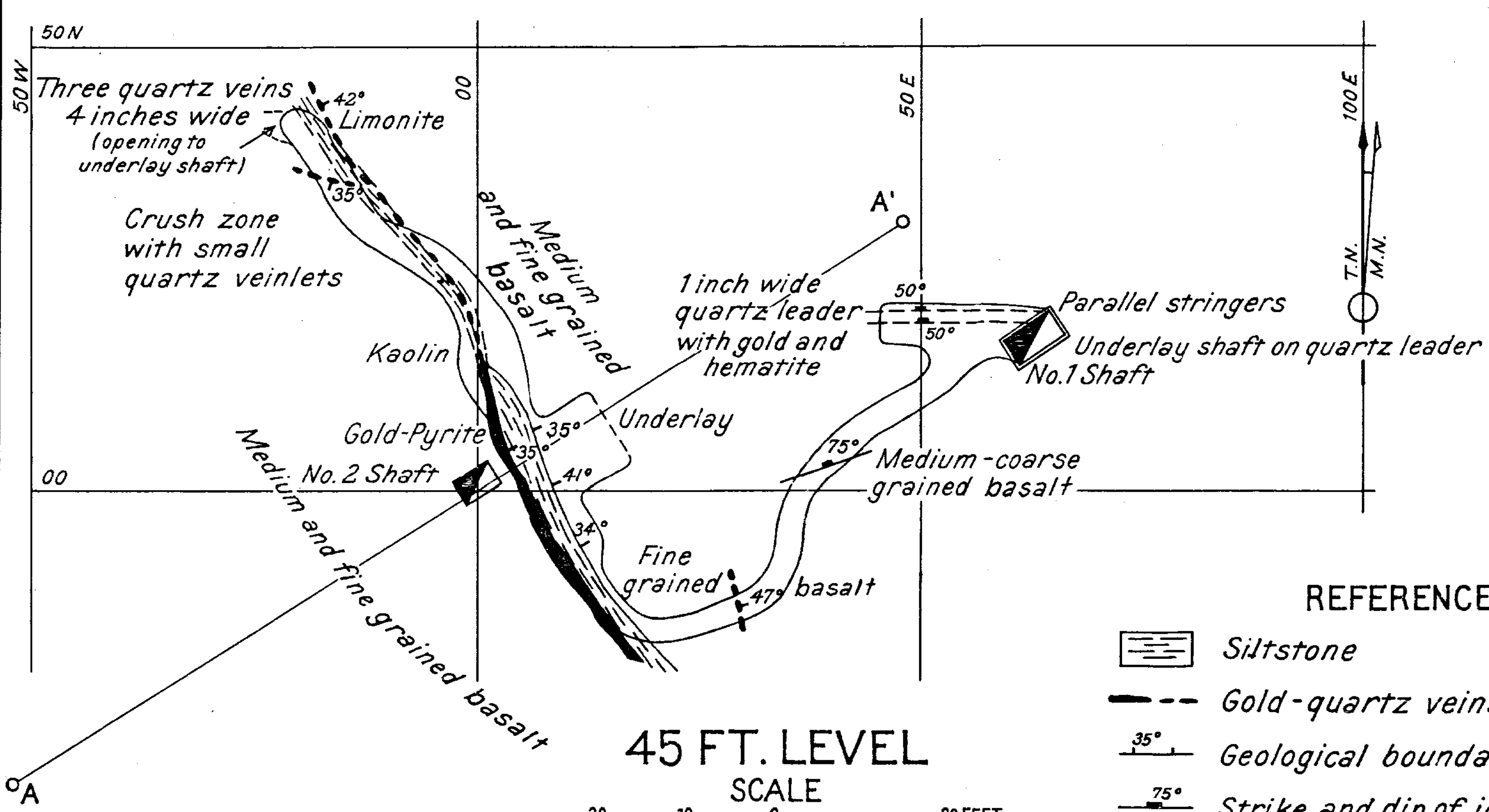
SECTION A-A'



SECTION B-B'

GEOLOGICAL PLAN
LAST HOPE GOLD MINE
TENNANT CREEK GOLD-FIELD
NORTHERN TERRITORY

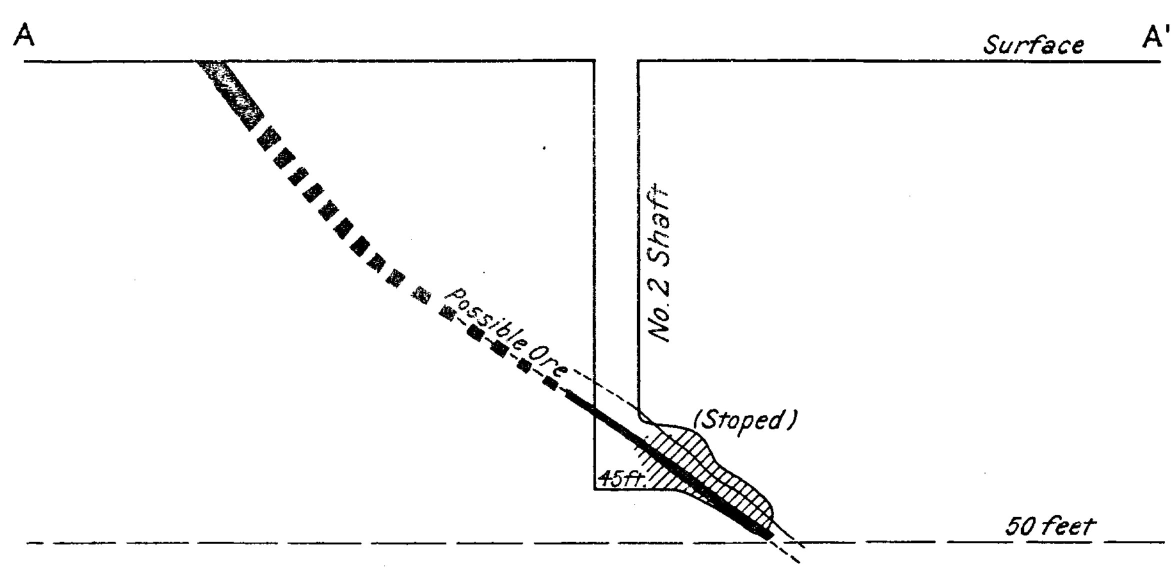




45 FT. LEVEL

SCALE
20 10 0 20 FEET

REFERENCE
- Siltstone
- Gold-quartz veins with dip
- Geological boundary with dip
- Strike and dip of joints



CROSS SECTION AA'

SCALE
20 10 0 20 FEET

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NT1-Af-1
H.J.