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BUREAU OF MINERAL RESOURCES GEOLOGY AND GEOPHYSICS.

RECORDS:

1963/129

THE TENNANT CREEK GOLD AND COPPER FIELD

by

P. W. Crohn

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Records 1963/129

1. Senior Resident Geologist, Northern Territory Administration, Darwin.

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Introduction

The Tennant Creek gold and copper field occupies an area of approximately 30 by 40 miles in the arid interior of Northern Australia, at latitude 19°30' south, longitude 134°15' east, about 640 miles from the nearest port of Darwin, and over 300 miles from the nearest rail-heads of Alice Springs to the south and Larrimah to the north. With an average annual rainfall of only about 12 inches, there are no permanent streams, and vegetation consists largely of spinifex with open stands of eucslypts and mulga.

The maximum relief is of the order of 300 feet, with the higher ranges consisting partly of flat-topped hills, representing remnants of a ?Tertiary land surface, and partly of tors in areas of igneous rocks or razor-back ridges developed on major quartz reefs or ironstone lodes. Most of the low-lying areas are occupied by alluvium, creek gravels and wind-borne material, locally known as bull-dust. The thickness of these deposits only exceptionally exceeds 25 feet.

During the ten years which have elapsed since the publication of the first edition of "The Geology of Australian Ore Deposits" (Sullivan and Ivanac, 1953), the character of this field has undergone several major changes. With the emergence of Peko as the largest single operating mine, copper has replaced gold as the major product of the field. At the same time, the number of operating mines has steadily decreased and exploration for new ore bodies has increasingly become the function of the larger mining companies and Government organisations, which alone have the resources to carry out extensive geological and geophysical surveys and to follow up their indications by diamond drilling programmes. This has also resulted in increasing emphasis on regional studies to complement the detailed investigation of individual prospects.

The total recorded production of the field to June, 30, 1962, amounts to about 885,000 ounces of gold and 48,000 tons of copper, of which about two thirds of the gold and practically all the copper have been won since 1952.

General Geology

Archaean. A complex of quartz-feldspar-garnet gneisses, amphibolites, granitic and gabbroic intrusives and magnetite-rich rocks have been encountered in diamond drill holes put down by Australian Development N.L. in an area known as B.M.R. 3, some 20 miles west-south-west of Tennant Creek township.

These rocks are overlain by up to 80 feet of poorly consolidated grits and sandstones and are not known in outcrop. They give rise to pronounced magnetic anomalies, but these are due to the presence of magnetite-rich bands within the gneiss complexes, and not to defined quartz-magnetite lodes of the type occurring within the Warramunga Group. Although no absolute age determinations are available, these rocks are regarded as part of an Archaean basement.

Warramunga Group. As pointed out by previous workers (Ivanac, 1954; Sullivan and Ivanac, 1953), all the known mineral deposits of the field occur in rocks of the Warramunga Group, consisting of greywacke, siltstone and shales of Lower Proterozoic age, with minor grits and pebble beds. These beds show commonly graded bedding and small-scale slump structures, and are thought to be due, at least in part, to deposition by turbidity currents in moderately deep water.

Attempts to sub-divide the Warramunga Group have only been partially successful, owing to the complexity of structures and the absence of marker beds. However, in the vicinity of Mount Cleland, it is possible to distinguish a succession consisting of approximately 2,500 feet of shales and siltstones, overlain by at least the same thickness of interbedded greywackes and shales. Within this greywacke shale assemblage, a very distinctive bed of hematite shale, from a few inches to about 20 feet thick, can be used as a local marker bed, and has been traced with only minor interruptions for a distance of about three miles in the Mount Samuel - Eldorado area, and for more than eight miles in the Burnt Shirt - Lone Star - Mammoth - New Moon area. It is also known to occur, among other localities, at the Northern Star and Blue Moon mines.

Massive sandstones occur in the Warramunga Group near the margins of the field, e.g. near the New Hope and Last Chance mines, and may represent a lateral variation of the greywacke facies.

Rocks exceptionally rich in chlorite, sericite and talc, are also very widespread. They appear to be derived from shales of the normal Warramunga type by recrystallisation under strong shearing stresses, probably in association with hydrothermal activity related to the igneous intrusions and mineralisation of the area.

Structurally, the Warramunga rocks are divisible into two main units, separated roughly by a major north-west trending shear zone, the line of which is marked by a prominent group of quartz reefs, especially in the Quartz Hill and Rocky Range areas. To the south and west of this line, the dominant structural features are folds with roughly east-west axes. Dips average about 60 degrees, but occasionally reach 90 degrees. Pitches may be either to the east or to the west, generally at angles of 10 to 20 degrees. To the east and north of the Quartz Hill - Rocky Range shear zone, folding is generally more open and dips are most commonly in the range 30 to 45 degrees.

The regional strike of the cleavage is generally about 80 degrees, with predominantly steep northerly dips.

Shearing and faulting are very widespread and fall into several well-defined sets. The most prominent of these has a north-westerly trend and includes the above-mentioned Quartz Hill - Rocky Range structure, which has been traced intermittently for about 30 miles, and which has an

apparent throw of about one and a half miles, east block north, measured by the displacement of the hematite shale marker bed at the Mammoth mine and the granite contact in the Seven Mile area. Complementary north-east trending shear zones are also known and are also occupied by major quartz reefs.

Structures which are occupied by ironstone lodes, and in some cases by gold and sulphide ore bodies, tend to be distinct from this. The most numerous of these are shears striking between 50 and 100 degrees, although most of them can only be traced for short distances. Shears trending 105 to 110 degrees are less numerous, but they include some very large structures, such as the Mary Lane - Mary Ann shear with its probable extension to the vicinity of the Lone Star mine. East-north-easterly trending shears (average strike 60 to 75 degrees) also become important in the New Hope, Gibbet, Pinnacles and Golden Forty areas, and there are also some local developments of shears trending north-north-east (20 to 30 degrees) and north-north-west (320 to 340 degrees).

Igneous Rocks. Of the igneous rocks intruding the sediments of the Warramunga Group, by far the most important are a pene-contemporaneous consanguinous series ranging from massive and foliated granite and adamellite complexes through granite porphyry and quartz-feldspar porphyry dykes and plugs to ignimbrites filling volcanic pipes. The presence of ignimbrites in this series shows that these were high-level intrusions, and this is borne out by the relatively slight contact metamorphism which most of them have produced.

Of the granitic rocks, the best examples are the Quartz Hill - White Hill complex (area about fifteen by eight miles) in the centre of the field, and the Cabbage Gum complex (area at least fifty square miles) near its southern margin. Both of these consist of several rock types, including gneissic, porphyritic, medium-grained and aplitic phases, and are cut by quartz veins and dolerite dykes. They also contain numerous small xenoliths and some infaulted wedges of sedimentary material.

By contrast, the porphyries generally occupy smaller areas with a maximum extent of about three by one miles, as in the Curlew, Jubilee, Wheal Doria, Red Terror, Peko and New Hope areas. Most of them are elongated east-west, parallel to the dominant strike of the Warramunga sediment, and many of them also show shearing parallel to this direction. Both the granites and porphyries are thus conformable to the surrounding sediments on a large scale, although they commonly transgress the bedding on a small scale.

Undoubted ignimbrites, identified by the presence of shards of volcanic glass, are only known from the vicinity of the Wheal Doria and Bernborough mines to date, but related pipe fillings are also thought to occur in the Black Angel area, where porphyries with unusually large, strongly corroded quartz phenocrysts have been noted.

Other igneous rocks recorded from the Tennant Creek field comprise uralitised diorites from the Mary Lane and Golden Forty areas, a small occurrence of serpentine in the Caroline area, dolerite dykes in the Quartz Hill and Cabbage Gum granite complexes and a large number of lamprophyre plugs and dykes throughout the area. None of these are thought to be genetically related to the economic mineral deposits of the area, and at least some of the lamprophyres can be shown to post-date the mineralised ironstone lodes, e.g. at the Caroline mine.

Post-Warramunga Rocks. Rocks of the Warramunga Group are overlain to the north by the Ashburton Sandstone and to the south by the Hatches Creek Group. Both of these consist of considerable thicknesses (possibly as much as 20,000 feet) of dominantly arenaceous rocks which show open folding and are intruded by both acid and basic igneous rocks. They carry some mineralisation, e.g. the Hatches Creek wolfram lodes, but this is of quite a different type from that occurring in rocks of the Warramunga Group.

Smith et al. (1961) have shown an angular unconformity between the Warramunga and Hatches Creek Groups, but Ivanac (1954) recorded a conformable passage between the Warramunga Group and the Ashburton Sandstone. However, on general lithological and structural grounds, the Ashburton Sandstone is thought to be equivalent to the Hatches Creek Group, at least in part, and it is still thought possible that detailed mapping would reveal an unconformity between the Ashburton and Warramunga rocks.

Next in age, - possibly Upper Proterozoic, - is the Rising Sun Formation, which occupies an area of about six miles by a quarter of a mile to the south of the Nobles Nob, Rising Sun and Red Terror mines. This is composed largely of conglomerates, quartzites and grits in its lower portion, followed by a succession of sandstones, siltstones and mudstones. The maximum exposed thickness of the whole formation is about 200 feet. Structurally it occupies an assymetric syncline with its southern limb faulted out in places, and it is cut by numerous quartz veins and at least one lamprophrye dyke, but to the south of the Red Terror mine it unconformably overlies a quartz-feldspar porphyry body which is intruded into sediments of the Warramunga Group.

Other post-mineralisation formations comprise the Helen Springs Volcanics, consisting of rhyolites, amygdaloidal basalts, tuffs and agglomerates, and the Middle Cambrian Gum Ridge Formation, consisting of siliceous shales, cherts and siliceous limestones. Both of these are essentially flat-lying, free from quartz reefs or igneous intrusions, and attain maximum observed thicknesses of the order of 40 feet each.

Depth of Oxidation. Because of the great depth of water table - generally of the order of 200 to 250 feet, - and the relatively stable history of the area since Cambrian times, the depth and degree of oxidation are unusually great. In general, sediments and ironstones appear to be substantially fresh at depths of 150 to 200 feet, but the oxidation of sulphide bodies and breccia zones extends to an average depth of 300 to 350 feet. At Orlando, oxidation of a major shear zone with a high sulphide content is still appreciable at a depth of 600 feet.

Ironstone Lodes, Jaspers and Quartz Reefs. As noted by previous workers, the wide-spread presence of ironstone lodes is one of the outstanding features of the Tennant Creek field, and is of considerable economic importance as most of the known gold and copper ore bodies occur within or in close association with these lodes. These ironstones are mostly quartz-magnetite bodies below the water table, but supergene alteration has produced a partial or complete change to hematite in the oxidized zone, which generally extends to a depth of about 200 feet.

Most of these ironstones are lenticular or tabular in shape with widths from a few inches to about 40 feet and lengths up to several hundred yards. Occasionally, however, irregular shapes result from the preferential replacement of favourable beds, especially in the axial regions of folds. On the other hand, the Peko ironstone, which will be considered more fully in a subsequent

section, has a steeply plunging pipe-like shape.

The great majority of these ironstones occupy faults or shear zones, and many of them are localised at the intersections of these zones with favourable beds, such as the hematite shale. This type of occurrence is favoured by conditions in which bedding and shearing of the sediments tend towards parallelism, i.e., in areas of steep dips, but it does not follow that the best development of these ironstones is necessarily in the largest shear zones. In fact, some of the largest ironstones, e.g. at Eldorado, are associated with shears of only local significance. Many of these lodes are also faulted themselves, indicating that the area was affected by renewed movements subsequent to their emplacement.

A second group of ironstones, often approaching jaspers in composition, are replacements of unsheared or only slightly sheared favourable beds, of which the hematite shale is again the outstanding example. The lodes at Metallic Hill and the Golden Mile are of this type.

A third group are developed at the margins of some of the larger porphyry intrusions, especially at concordant contacts. These lodes also tend to be jaspery and always conform closely to the bedding of the host rocks. The best examples of this type occur in the Jubilee and New Hope areas.

Because of the close association of many of these ironstones with the hematite shale, it was at one stage thought possible that the lodes might be the products of mobilisation and concentration of iron oxides originally disseminated in the sediments, but a number of spectrochemical determinations of trace elements showed that the disseminated iron oxides in the hematite shale contained significant Cr, Mn, V, Ba and Ag, indicating a probable syngenetic origin, while the ironstones were relatively rich in Bi, W, Ge and Mo, which are elements typically associated with epithermal deposits. (Oldershaw, 1960).

The area also contains jasper beds and breccias, which are replacement bodies, similar in many ways to the ironstones, but composed mainly or entirely of cryptocrystalline silica, generally coloured red by minor amounts of iron oxides. Where relations are observable, they are found to occur closer to the margins of porphyry intrusions and to have been formed earlier than the ironstones.

Quartz veins, ranging from mere stringers to massive bodies up to 30 or 40 feet wide, are very widely distributed, as already described, and cut all rocks older than the Helen Springs Volcanics. Veins of more than one age are probably present in many parts of the field, but except for those cutting the Rising Sun Formation, it is not possible to distinguish the various groups.

Gold and Copper Deposits

The known gold and copper deposits of the Tennant Creek field occur in a variety of structural and lithological environments, ranging from massive quartz-hematite and quartz-magnetite lodes to brecciated zones in sediments, generally mudstones, which may carry only very minor amounts of iron oxides.

Most of the gold deposits worked in the early days of the field were associated with the more massive ironstones, although the best gold values were frequently found in the brecciated sediments immediately adjoining the ironstones, rather than in the ironstones themselves. However, there is also evidence of a stratigraphic control of ore emplacement, as there is a very marked concentration of the more productive mines in the immediate vicinity of the hematite shale. Thus, although only about a quarter of the known ironstones of the field occur in the immediate vicinity of hematite shale outcrops, this group contains three quarters of the mines which had produced more than 1,000 ozs. of gold up to the end of 1961, including four out of five of those which have produced more than 10,000 ounces (Blue Moon, Eldorado, Nobles Nob, and Whippet).

There are fewer known copper deposits, so that statistical generalisations are more difficult, but a greater variety of environments appears to be represented with major shear zones as the most important single control. The outstanding producer to date is the Peko mine, in which the central portion of a massive quartz-magnetite pipe has been replaced by almost massive sulphides (essentially pyrite, pyrrhotite and chalcopyrite). This quartz-magnetite differs in shape from the typical tabular lodes on the field and Elliston (1960) has suggested that it is due to the replacement of an original slump conglomerate in the Warramunga beds. However, known examples of such conglomerates have a fine-grained impervious matrix and do not appear intrinsically favourable for replacement. It is therefore thought to be more likely that the structural control at Peko is the intersection of a steeply dipping north-east trending shear zone with a zone of favourable beds or a shear-zone sub-parallel to the bedding, which here trends roughly east-west. This is supported by the pattern of the aerial magnetic map, and the airphotos of this area, and by the presence in the mine workings of chlorite schist, suggestive of intense shearing. A detailed account of this ore body is the subject of a separate article.

A few tons of oxidised copper ore have also been won from two other mines, Pinnacles and Shamrock; which are situated on shear zones not closely associated with major ironstone bodies and remote from any outcrops of hematite shale. No primary ore has been encountered at these mines to date, but a diamond drilling programme by the Mines Branch, N.T. Administration, is now in progress at the Pinnacles mine to test the downward extension of this shoot.

Some copper mineralisation has also been encountered in the course of exploratory diamond drilling and development work at a number of minor deposits which have only been worked for gold to date. These include the Northern Star, Lone Star and Cats Whiskers Mines, where copper has been encountered dominantly in massive ironstones, and the Golden Forty and Golden Forty North prospects (the latter also known as the Golden Kangaroo) where copper occurs in sheared sedimentary rocks.

Individual Mines

Nobles Nob Mine. Among the gold mines of the field, Nobles Nob is the outstanding producer. From the beginning of operations in 1949 to June, 1962, this mine has produced a total of over 580,000 ounces of gold from about 343,000 tons of ore, and production is continuing at an approximate rate of 3,600 ounces of gold per four-weekly period.

Two large hematite bodies outcrop at the mine. The western body forms a lens 320 feet long with a maximum width of 90 feet. The eastern hematite mass comprises two lenses, each about 80 feet long and 30 feet wide, which may be a fault repetition of part of the western body.

The sediments in this vicinity have a general east-west strike and dip southerly at 50 to 70 degrees. Cleavage with a strike of 110 degrees and northerly dips from 80 degrees to vertical, is well developed/and in places obscures the bedding.

The position and attitude of the ironstone bodies are apparently controlled by the intersection of a zone of intense cleavage, and possibly some shearing, with a group of predominantly argillaceous beds lying between more arenaceous beds (see section, Fig. 3). A minor pitch reversal in a local flexure of the beds may be an additional control, at least in the upper portion of the mine.

The cleavage control gives an almost vertical attitude to the south wall of the ironstone mass, but the northern boundary is more irregular, due to the introduction of iron along some mudstone beds for short distances from the main zone.

Reverse bedding-plane faulting and renewal of movement on the main shear zone fractured much of the ironstone subsequent to its emplacement and this fractured ironstone acted as a favourable host rock to the hydrothermal solutions responsible for the existing ore shoots, which now appear essentially as auriferous sericite - hematite crush zones. The distribution of gold is therefore very irregular, but assay plans and sections clearly outline the position of faults and highly cleaved zones, along which hydrothermal activity was concentrated. The best ore is generally fairly friable, due to the high sericite content , and the fractured nature of the ironstone, but gold is rarely visible in the hand-specimen.

Minor amounts of bismuth minerals are closely associated with the gold, and minor copper mineralisation has been noted below the 215 foot level. The deepest production workings to date are 305 feet below the Main Shaft collar.

Orlando Mine. In spite of intensive exploration and reports of encouraging indications from several prospects, only one new mine has come into production on the field in the past ten years. This is the Orlando mine, (a subsidiary of Peko), which is situated about twenty miles north-west of Tennant Creek township, and which commenced production during 1962 at a rate of 100 tons per day. The average grade of the body, based on the results of exploratory diamond drilling, development headings and the treatment of several trial parcels at the Government Battery, is expected to be about 11 dwts. of gold per ton and 1.5 percent copper. The structural control of the ore body is a very large west-north-west trending shear zone, but owing to the exceptional depth of oxidation of this lode, there is so far little information on the composition of the primary ore, although exploration has extended to more than 800 feet below the surface.

Ivanhoe Mine. The discovery of another new ore body, to be known as the Ivanhoe, has recently been announced by Peko Mines N.L. This is situated some ten miles north-west of Tennant Creek township, close to the projected intersection of the Mary Lane - Mary Ann shear zone with a north-east trending quartz-filled shear zone. Some 250,000 tons of ore, averaging 5 percent copper are reported to have been proved and about 70,000 tons of this are reported also to carry about 10 dwts. of gold per ton.

Other Mines. None of the other mines on the field are in regular production at the present time, although several of them are being intermittently worked on a small scale by individual prospectors and local syndicates.

Apart from Peko and Nobles Nob, some production has been recorded from about 115 mines and prospects on the field of which 19 have produced more than 1,000 ounces of gold. Of these, Eldorado with a recorded production of 105,000 ounces of gold from 146,000 tons of ore was the most important. This mine has been worked to a depth of 400 feet, and had several prospective blocks of ore which still required testing at the time of closure, but owing to the unsafe state of the workings, re-opening would now involve an extensive rehabilitation programme.

Other mines which were formerly of importance include the Whippet (18,000 ounces from 16,000 tons of ore), Blue Moon (12,000 ounces from 3,600 tons), Northern Star (9,600 ounces), Rising Sun (8,000 ounces) and Enterprise (6,600 ounces). As previously mentioned, practically all these mines are associated with quartz-hematite and quartz-magnetite lodes, the richest shoots occurring either in the sheared and brecciated sediments on the flanks of the ironstones, or in shear zones or fractures within the ironstones themselves. The gold is not usually visible to the naked eye, but the presence of bismuth minerals and of sericite are generally regarded as favourable indications.

Except for the Eldorado Mine, none of the workings on these mines have reached a depth of more than 300 feet. This is in part due to the limited vertical extent of the individual ironstone bodies and to the increasing cost of mining at greater depth, but there has also been a very marked falling-off of the average grade below the water table at some of the richest mines on the field, e.g. Noble's Nob, Whippet and Blue Moon, strongly suggestive of the occurrence of secondary enrichment. This possibility is also supported by the reported occurrence of flaky gold and occasional nuggets within the oxidized zone of several mines, but not below it (Ivanac, 1955, p.54.).

Owing to the unfavourable topography and the fine grain-size of most of the gold, alluvial deposits are practically unknown on the field.

Current Exploration.

At the time of writing - June 1963 - diamond drilling in the search for new ore bodies is being carried out by the two operating companies on the field - Peko and Australian Development N.L. - as well as by several other companies and syndicates and by the Mines Branch, N.T. Administration.

These programmes involve work in the Black Angel, Red Bluff, Golden Forty, Mary Lane, Lone Star and Cat's Whiskers areas, but none of them have as yet reached the stage where the presence of mineable ore bodies has been demonstrated. In most of these areas, the targets are magnetic anomalies, many of which were originally delineated by the air-borne magnetic surveys carried out by the Bureau of Mineral Resources, as described below.

Origin of Ore-bearing Solutions

The origin of the solutions responsible for the emplacement of the gold and sulphide ore bodies of the Tennant Creek field is not yet conclusively established. At the Aerodrome, a few specks of sulphides (pyrite and chalcopyrite) have been found in massive quartz-feldspar porphyry, and at several other localities, notably three quarters of a mile south of the Pinnacles mine, the weathered porphyries contain limonite-coated cavities which are regarded, at least in part, as box-works due to the leaching of sulphide minerals. This is thought to support the theory that the ore-bearing solutions were derived from or associated with the porphyry intrusions.

Mineragraphic evidence has shown that at Peko the emplacement of the ironstone was essentially complete before the introduction of the gold and sulphide minerals (Edwards, 1955), and it has already been shown that in other areas the occurrence of massive ironstone bodies and of gold and/or uslphide ore bodies need not necessarily be closely associated. It is therefore considered, that, for future exploration, shear zones not carrying major amounts of iron oxides may warrant increased attention. Such zones are likely to be soft formations, whose outcrops are easily obscured, and which will thus escape attention unless copper concentrations at the surface give rise to obvious indications of mineralisation. Geochemical and geophysical surveys, especially by methods with great depth penetration, such as I.P., may be of value in detecting and tracing such zones carrying sulphides at depth.

Geophysical and Geochemical Surveys.

Ground magnetometer surveys have been the main method of prospecting for non-outcropping ironstone bodies on the Tennant Creek field since the pioneer work of the Aerial Geological and Geophysical Survey of Northern Australia in 1935 - 1937 (Daly, 1957). In addition, air-borne magnetic surveys of the entire field were carried out by the Bureau of Mineral Resources in 1957 and 1961, and these indicated a very pronounced pattern of regional anomalies, reflecting major shear zones with east-south-easterly and north-north-easterly trends, as well as numerous local anomalies due to individual ironstone bodies. Most exploration effort in recent years has been concentrated on drilling the most intense of these local anomalies, and the two ore bodies recently opened up (Orlando and Ivanhoe) were both found by this technique.

However, these surveys, together with work by private companies, have now covered the greater part of the areas where potential gold and base metal lodes might be expected, and attention has lately been directed to other geophysical methods, notably I.P. surveys, which may have the large depth penetration required to overcome the great depth of oxidation commonly encountered on this field.

The Bureau has also undertaken geochemical surveys of part of the field, which succeeded in delineating several areas containing abnormal copper concentrations, both in ironstone lodes and in areas of sedimentary rocks (McMillan and Debnam, 1961). Orlando, Cat's Whiskers and Golden Forty North are three areas in which such concentrations were detected and have since been confirmed by diamond drilling and other development work.

More recently, the Bureau has been experimenting with deep auger sampling and spectrographic analyses as a geochemical technique at Tennant Creek, and the preliminary results are sufficiently encouraging to warrant further development of this work. The regional background for copper in particular appears to be very low, and initial orientation studies suggest that anomalous concentrations of as little as 50 parts per million of copper may be significant.

Minerals Other than Gold and Copper.

Apart from copper, gold and by-product silver, the only mineral of value on the Tennant Creek field is bismuth. A small plant was set up in 1963 at the Jubilee mine to treat a limited amount of ore containing between one and two percent of bismuth, mostly in the form of oxide and carbonate; occurrences of bismuth-rich material are also known from several other mines.

The total quantity of iron oxides present in the known ironstone bodies of the field is estimated to amount to some tens of millions of tons, but owing to the isolation of the field, the scattered distribution of the ironstones and the variation in grade, this is not likely to be an economic source of iron ore in the foreseeable future.

Acknowledgements

The description and cross-section of the Nobles Nob mine and data on the occurrence of Archaean rocks in the B.M.R. 3 area have been provided by Mr. C. Wegener, Chief Geologist of Australian Development N.L. They are included by permission of the Company, which is gratefully acknowledged.

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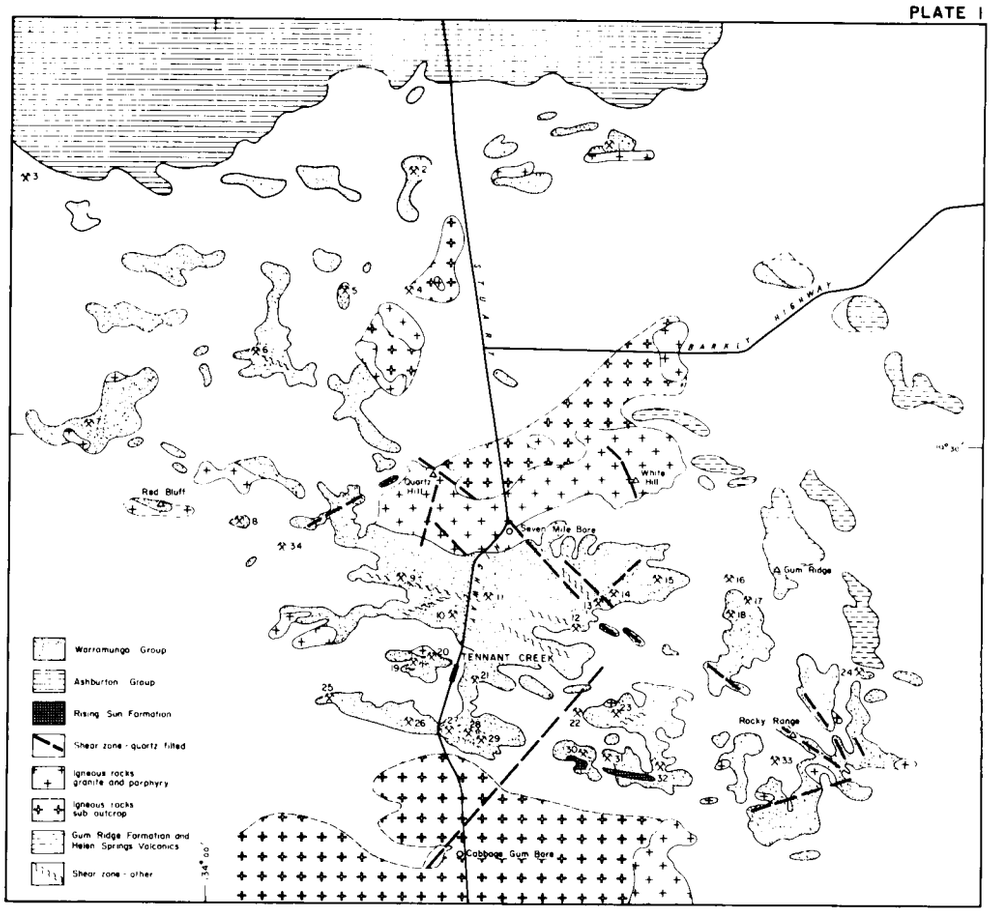
PLATE I



1 Whippet
2 Northern Star
3 Last Hope
4 Bernborough
5 Queen of Sheba
6 Orlando
7 Black Angel
8 Curlew
9 Mary Lane
10 Shamrock
11 Mary Ann
12 Lone Star
13 Memschib
14 Mammoth
15 Black Cat
16 Gigantic
17 Blue Moon
18 Metallic Hill
19 Gibbet
20 Wheal Darra
21 Pinnacles
22 Peko
23 Golden Forty
24 Golden Mee
25 Skipper
26 Mount Samuel
27 Enterprise
28 Eldorado
29 Cat's Whiskers
30 Noble's Nob
31 Rising Sun
32 Red Terror
33 New Hope
34 Ivanhoe

TENNANT CREEK AREA, N. T.
GENERALIZED GEOLOGY

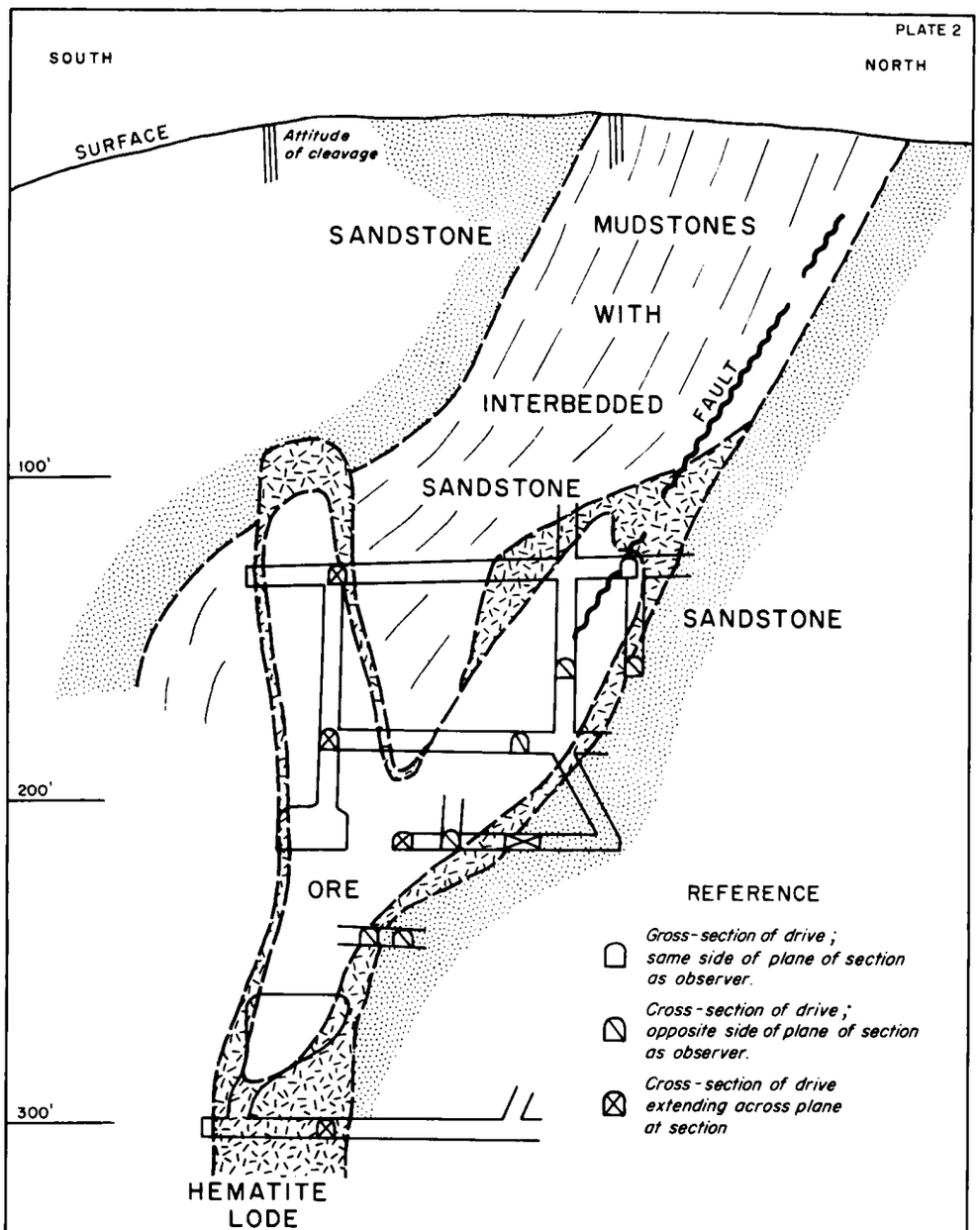
SCALE IN MILES
4 0 4 8 12

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

To accompany Record No 1963/129

E53/14/20
SEPTEMBER 1963

PLATE 2



NOBLE'S NOB GOLD MINE

AUSTRALIAN DEVELOPMENT N.L. TENNANT CREEK N.T.

SECTION ON 5150 E SHOWING MAIN ORE CONTROLS

20 0 20 40 60 80 100 FEET

VERT. AND HORIZ. SCALE

To accompany Record No 1963/129

Bureau of Mineral Resources, Geology and Geophysics. September 1963

E 53/A14/19 JK