COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

REPORT No. 45

# Geology of the Gold Prospects at Union Reefs, Northern Territory

BY

J. W. SHIELDS, D. A. WHITE, and J. F. IVANAC



*Issued under the Authority of the Hon. David Fairbairn,*
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MINISTER: THE HON. DAVID FAIRBAIRN, D.F.C., M.P.

SECRETARY: R. W. BOSWELL, O.B.E.

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PLATES (at back of Report)

## SUMMARY

This Report sets out the results of detailed geological mapping and drilling of the gold-quartz lodes at Union Reefs near Pine Creek, Northern Territory, which were carried out in 1963 and 1964 by the Bureau of Mineral Resources as part of the Special Mineral Survey Programme planned at the request of the Department of Territories.

An area 10,400 feet long and 1500 feet wide was mapped by plane table at a scale of 1 inch to 40 feet. The Union Reefs area lies on a major strike-shear zone, known as the Pine Creek Shear, and consists of a succession of near-vertical Precambrian tuffaceous greywacke and slate which occupies an embayment in the Cullen Granite. The sediments are intruded by the granite and minor amphibolite dykes.

Most of the gold lodes are located in two intense near-vertical shear-zones, which trend about 335°, and are separated by 550 feet at the southern end and 750 feet at the northern end. The lodes are lenticular and arranged en echelon along the trend of the shear-zones. The western line of lodes is known as the Union and the eastern line as the Lady Alice. Both lines occupy ridges and generally coincide with discontinuous outcrops of barren quartz reefs.

The diamond drilling programme consisted of 13 holes totalling 6204 feet and was designed to test the lodes below the water table at three localities known as Millars, Crosscourse, and Prospecting Claim. The drilling showed that the gold values persisted below the water table, and that the gold-quartz lodes are pipe-like and extend at least 700 feet below the surface. The sulphides present in the lode consist of pyrite, arsenopyrite, chalcopyrite, galena, and marcasite, in a quartz gangue with minor carbonate veinlets.

From drill intersections at the Crosscourse inferred ore reserves are 18,000 tons of 21.6 dwt/ton Au and 9.5 dwt/ton Ag. This ore-shoot could be mined from the existing Government Shaft. The drilling results at Prospecting Claim and Millars are also encouraging and warrant underground testing.

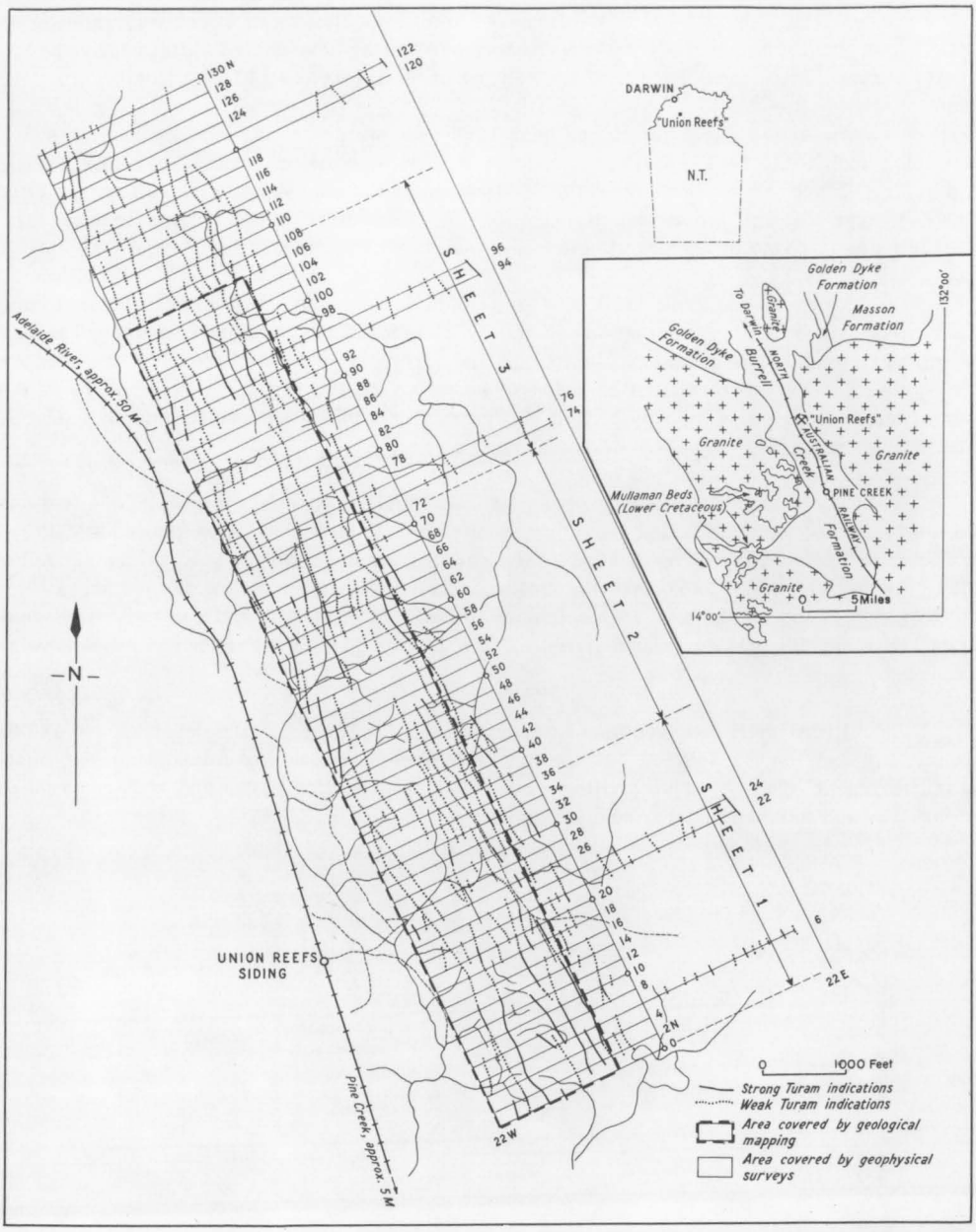


Fig. 1. Area covered by geopogical and geophysical survey.

## INTRODUCTION

Union Reefs, in the Agicondi Goldfield of the Northern Territory, was selected for detailed examination as part of a special mineral survey programme carried out by the Bureau of Mineral Resources at the request of the Commonwealth Department of Territories. As part of the same programme the Geophysical Branch of the Bureau undertook an elecro-magnetic and potential ratio survey of the area (Fig. 1). It was hoped that sufficient information on size and grade of selected gold deposits could be obtained to induce a mining company or prospecting syndicate to develop the mineral deposits.

Messrs D.A. White, J.W. Shields, J.F. Ivanac, C.E. Prichard, and R.G. Dodson participated in the work. Detailed mapping was carried out by White and Shields from 25th April to 25th July 1963. Cores were assayed by J. Edwards, Manager of Government Battery, Tennant Creek, and by Australian Mineral Development Laboratories, Adelaide.

The area was mapped at a scale of 40 feet to 1 inch and contoured at intervals of 20 feet. Control survey stations were laid out by theodolite and their height above sea level deduced by ties to reference stations on the adjacent North Australian Railway line. Subsidiary stations and heights were fixed by plane table and telescopic alidade. Compass and tape were used to outline outcrops and the size and shape of the workings.

A rectangular area 10,400 feet by 1500 feet was mapped. Geophysical surveys covered an area 10,800 feet by 2200 feet. Associated Diamond Drillers started diamond drilling on 25th July 1963 and completed the contract of 6204 feet in July 1964. In October 1964, United Uranium N.L. put down 1113 feet of waggon drilling for the Bureau of Mineral Resources.

The gold prospects were untenanted except for GML59A. At the request of the Bureau of Mineral Resources, the Administrator of the Northern Territory declared a reserve over the whole of the rest of the Union Reefs area until the investigations by the Bureau were completed.

### Situation and Access

The auriferous deposits at Union Reefs are situated 140 miles south of Darwin, the capital of the Northern Territory and the port for the region, and adjacent to a small siding on the North Australian Railway (3'6" gauge).

The deposits can be reached by a bush track which leaves the Stuart Highway 145 miles south of Darwin. Part of this 6-mile track, where it crosses the headwaters of the McKinley River, is inaccessible during the monsoon season from November to March. Poorly graded tracks lead to most of the numerous mine workings.

A township and an airstrip licensed for light aircraft are situated at Pine Creek, 9 miles due south of Union Reefs. A sealed emergency airstrip, Macdonald airstrip, is situated at the turnoff from the Stuart Highway to the Union Reefs. A Government Battery at Mount Wells, 17 miles by road north of Union Reefs, is available for treatment of custom ores.

## History

### Previous Investigations

Hossfeld (1936) gives a general historical appraisal of the area, and the reader is referred to his report. The position of diamond drill holes drilled in the period 1905 to 1914 is shown on Plate 1, Sheets 1 and 2. Generally spot assays of the core were made, although in a few places stated lengths of core were assayed. The true position of core assayed is not known, as none of the holes were surveyed for inclination and probably they deviated from their collar inclination: the holes drilled in 1963-64 deviated by as much as $30^{o}$ in 600 feet. A summary of the results follows.

DDH 1 (Brown, 1906). Drilled in 1905. Total depth 861 feet.

At 753 feet: Quartz assaying 9 dwt 19 grains Au/ton
At 758 feet: Quartz containing visible gold

DDH 2 (Brown, 1907). Drilled in 1906. Total depth 1052 feet.

| | | | | | |
|---|---|---|---|---|---|
| At 47 feet: | Quartz | containing | 8 dwt | 18 grains | Au/ton |
| At 70 feet: | Quartz | " | 4 | 2 | " |
| At 482 feet: | ? | " | 6 | 12 | " |
| At 484 feet: | ? | " | 19 | 12 | " |
| At 509 feet: | ? | " | 9 | 3 | " |
| At 510 feet: | ? | " | 2 | 16 | " |
| At 724 feet: | ? | " | 5 | 21 | " |
| At 756 feet: | ? | " | 3 | 20 | " |
| At 758 feet: | ? | " | 5 | 10 | " |
| At 771 feet: | ? | " | 4 | 21 | " |
| At 945 feet: | Small vein containing 2oz 9 dwt 16 grains Au/ton | | | | |

DDH 3 (Jensen, 1915). Drilled in 1913. Total depth 450 feet 7 in.

At 379'6" to 394'2": Traces to 16 grains gold per ton, 3 dwt to 3 oz silver per ton, heavily mineralised with galena, marcasite, and pyrite.

At 430' to 436': Gold trace, silver 2oz 18 dwt per ton, lead 10.2%, copper trace.

DDH 4 (Jensen, 1915). Drilled in 1914. Total depth 480 feet.

At 350' to 350'6" 2dwt 22 grains gold/ton.

DDH 5 (Jensen, 1915). Drilled in 1914. Total depth 417 feet.

No value, only very broken quartz

DDH 6 (Jensen, 1915). Drilled in 1914. Total depth 407 feet.

At 331 to 336 feet: 1 dwt 7 grains of gold/ton
At 394 to 398 feet: 1 dwt gold/ton.

The Union Reefs area lies within the Pine Creek 1:250,000 Sheet area, which has been mapped by the Bureau of Mineral Resources and described by Malone (1962). He shows that the gold-quartz veins are localised along a major shear-zone trending north-west and referred to in this Report as the Pine Creek Shear-Zone.

## Workings

The Union Reefs lodes were worked extensively between 1880 and 1910, mostly by Chinese. More than 1600 pits, shafts, and open cuts were recorded during the 1963 mapping and their outlines and depths in feet are shown on Plate 1. More workings are present to the north and, to a lesser extent, to the south of the area mapped.

The workings are grouped in two zones trending about 335 degrees, which are separated by 550 feet at the southern end and 750 feet at the northern end. The eastern zone is known as the Lady Alice line, and the western zone as the Union line. Another zone in the central part of the area trends across these two zones at an angle of approximately $10^{o}$ and is known as the Crosscourse (Hossfeld, 1936).

Vertical and inclined shafts are common throughout the area. All inclined shafts slope at a shallow angle to the north, which suggests that they were designed either to follow richer shoots which were pitching northwards, or, more probably, to provide walking access for miners. The deepest vertical shafts are found at Millars and Crosscourse, which are both 200 feet deep. At Millars, a winze was sunk to the 240-foot level, and driving was begun from the shaft at the 60 and 80-foot levels (see Plate 3).

The longest adit in the area mapped connects the Crosscourse area to the tramway on the eastern side of the Lady Alice line and is over 600 feet long; most of it is inaccessible. Of the three adits in the Prospecting Claim area, one was used to tram ore from the Prospecting Claim open cut, and the two others were evidently made to test the lode; but little driving or stoping was attempted from them. Other adits were driven into the Lady Alice line from the east, and connected to the surface by shafts which were used for ventilation and as ore-passes.

Open cuts range in size from small prospecting pits a foot or so in diameter to a pit at the Crosscourse lode which is 350 feet long and a maximum of 20 feet wide. The Crosscourse open pit was worked from the surface to about 20 feet then stoped from below to about 100 feet below ground level.

Other underground workings occur at Millars, Prospecting Claim, Ping Quees, and Crosscourse Lodes, but no maps exist to show their extent and underground mapping is not feasible at the present time because of collapsed ground. Nevertheless, most of the adits and some of the shafts could be rehabilitated without much difficulty.

## Production and Grade

Recorded production (Hossfeld, 1936) for the area is 58,232 tons of ore treated by amalgamation for a return of 48,187 oz of gold, an average yield of 16.5 dwt of gold per ton; and 3900 tons cyanided to yield 474 oz of gold, an average of 2.4 dwt gold per ton. These are minimum figures only and are very incomplete; for instance, the quantity of gold won from numerous eluvial workings, mostly by Chinese miners, is not known.

Gold yields from individual leases are also listed by Hossfeld, but the record is incomplete. The lease containing Crosscourse lodes yielded at least 2939 oz 8 dwt of gold from 2502 tons of ore. Production from the Prospecting Claim was at least 1446 oz 13 dwt of gold from 800 tons of ore.

## Water Supply

Union Reefs is located in the 40-50-inch rainfall belt, and during the wet season, abundant supplies of potable water are available. The McKinley River is parallel to the line of lode three-quarters of a mile to the west, and generally flows from November to June. Permanent water is available from two billabongs situated along the river half to three-quarters of a mile west of Union Reefs railway siding. The water level drops in one of these during the dry season, but in the other, the more northerly, it remains at approximately the same level throughout the year: it was used as a water supply during diamond drilling, and the water level did not drop.

Most of the deeper shafts at Union Reefs are partly filled with water and could provide a useful source at the start of any mining operation.

## Topography and Geomorphology

The Union Reefs area is situated near the divide between the Mary River System, which flows north, and the Daly River System, which flows south and west. The lodes occupy the crests and flanks of two north-trending ridges which are steep-sided and deeply incised, particularly along the Union Line. The range of relief is about 260 feet; the highest point is 800 feet above mean sea level, Darwin. Minor alluvial flats exist along some of the creeks and small areas of eluvial cover drape the flanks of the hills.

# GENERAL GEOLOGY

Quartz lodes in the Union Reefs area occur in the Burrell Creek Formation, which is preserved in an embayment in the Cullen Granite in the central southern portion of the Pine Creek Geosyncline (Malone, 1962). The embayment is 4 miles wide and extends for 18 miles to the south-east. The Burrell Creek Formation is of Lower Proterozoic age and has been intruded by Cullen Granite, amphibolite, and albite dolerite.

Remnants of Mesozoic sediments crop out 1 mile and 4 miles south-west of Union Reefs. Minor Quaternary gravels, silts, and ferricrete in and on the edges of streams flank the hills at Union Reefs.

## Burrell Creek Formation

The Burrell Creek Formation (Malone, 1962) is 8000 feet thick and in the west of the Pine Creek Sheet consists of greywacke, siltstone, greywacke-siltstone locally metamorphosed to andalusite-mica schist, and mica schist. In the Union Reefs area it comprises tuffaceous greywacke and tuffaceous slate in approximately equal proportions. At the surface the rocks are bright ochre-red, grey-brown, and pale buff; in the unoxidised zone they are grey-green, dark grey-green, and greenish black.

The slate is homogeneous and consists of fine-grained sericite with lesser amounts of clay. Grains of sericite are oriented parallel to the bedding. Opaque minerals and finely divided crystalline quartz lie along cleavage planes oblique to the bedding.

The greywacke is predominantly medium to fine-grained, with minor quantities of coarse-grained material and rock fragments of heterogeneous composition randomly oriented in a matrix of sericite, chlorite, clay, and fine equivalents of coarser components. Wisps of sericite in the groundmass are foliated.

Lenses of slate in greywacke and greywacke in slate are common on a mesoscopic and regional scale. Minor cut-and-fill structures were noted in the drill core. In hand specimen the slate/greywacke interface appears planar, but in thin section one merges into the other, which suggests continuous deposition or partial reworking of tuffaceous sediments. The greatest thickness of greywacke encountered in diamond drilling is approximately 100 feet; maximum thickness of slate beds was 30 feet.

A sheared cobble conglomerate crops out along the Union and Lady Alice lines. The outcrops are lenticular. Along the Union line the conglomerate occurs between 80N and 95N and is interbedded with greywacke between two well defined bands of slate. Near the Lady Alice line the conglomerate crops out between 79N and 80N, but its relationship to greywacke and slate is not seen.

The strike of the beds ranges from $330^{\circ}$ to $340^{\circ}$ parallel to the direction of the Pine Creek Shear. Dip ranges from steep east to steep west and may change over a few feet. In many places strong shearing has transposed the bedding parallel to the regional cleavage; minor dragfolds are rare; and tectonic fish (Turner & Weiss, 1965) and rhombohedral cleavage fragments were noted on the eastern side of the Lady Alice line.

Amphibolite Rocks

Basic rocks were mapped in three places in the area. (i) Amphibolites occur in the north-eastern part of the area and appear to be interlayered with the Burrell Creek Formation, but the relationship is not clear.

(ii) At grid-coordinate 120N 23W unweathered medium-grained basic rock containing accessory pyrite and chalcopyrite appears to intrude the Burrell Creek Formation. In thin section it is seen to comprise biotite, albite, pyroxene, accessory tremolite, calcite, apatite, and quartz, and magnetite, pyrite, chalcopyrite, and chalcocite. It is an albite dolerite and because it contains sulphides it could be the source of sulphide mineralisation. However, pink feldspar veins up to 5 mm wide intrude the dolerite, contain minor sulphides on their edges, and may have introduced the main mineralisation.

(iii) Weathered amphibolite dykes crop out sporadically along the Lady Alice line and in several other places in the area. The dykes occurring between 53N and 66N strike $345^{\circ}$ - $355^{\circ}$ and are parallel to the strike of one of the major fracture directions in the area.

Cullen Granite

The Cullen Granite (Malone, 1962) intruded the central and southern portion of the Pine Creek Geosyncline. It ranges from granite to adamellite and is generally coarse-

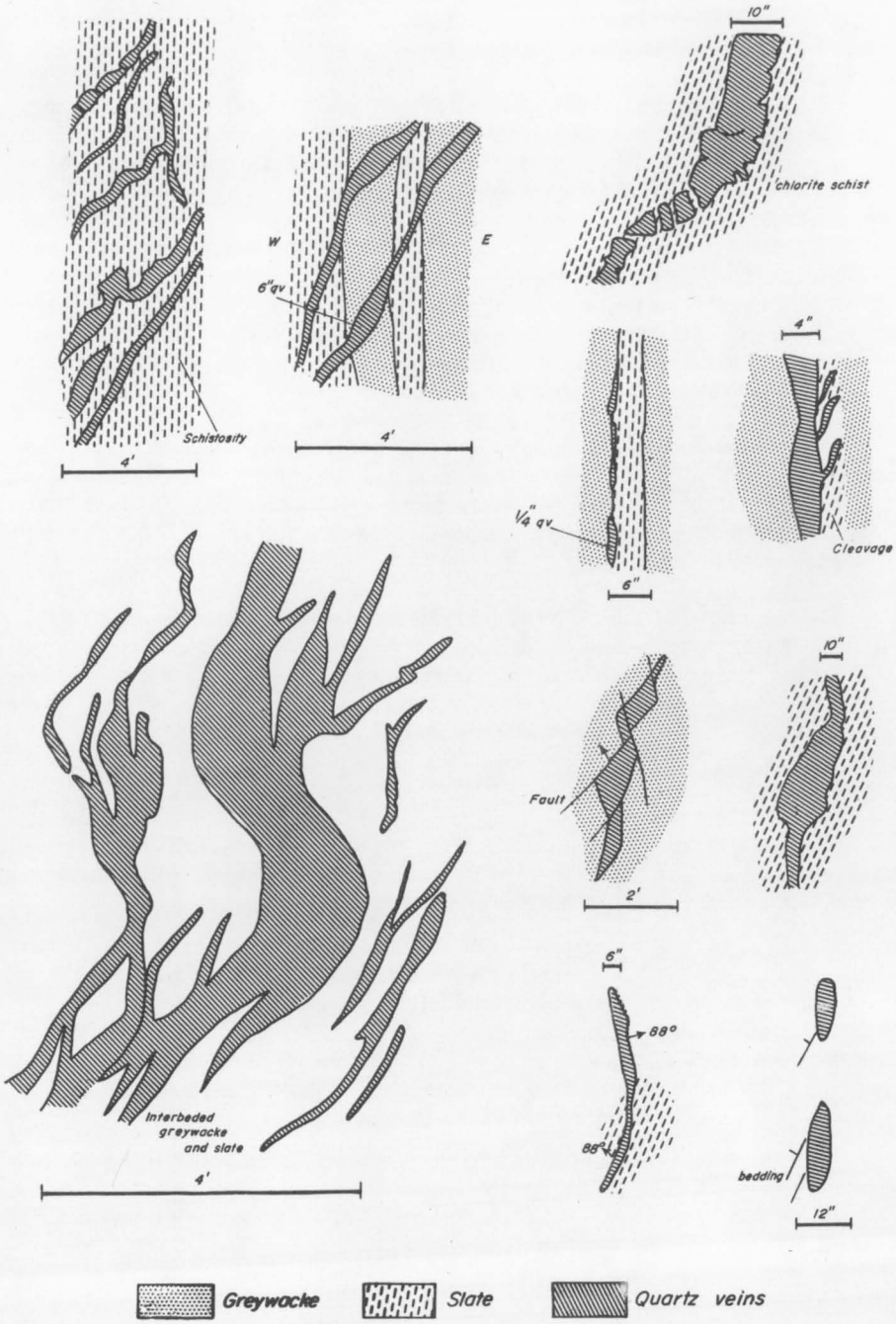


Fig. 2. Shape of typical quartz veins.

grained grey to pinkish grey or red. It may be massive or gneissic. Quartz veins are common in the granite. A well defined contact metamorphic aureole up to half a mile wide was noted in the Union Reef area. The isotopic age of the granite was determined by Hurley et al. (1961):

| | | |
|---|---|---|
| K/Ar | - biotite | 1695 million years |
| Rb/Sr | - biotite | 1765 $\pm$ 90 million years |

The granite has been strongly sheared, and the pattern of shearing corresponds to a broad rhomb with axes parallel to major lineaments mapped in the Pine Creek 1:250,000 Sheet.

Pegmatite Dykes

Pegmatite dykes crop out 2½ miles west of Union Reefs railway siding. Their relationship to the Burrell Creek Formation was not seen.

Quartz Lodes

At least two generations of quartz lodes were mapped in the Union Reefs area. The most prominent of these are lenses of white barren quartz several feet thick, which have been strongly sheared and fractured and appear to have been introduced before the gold-bearing quartz veins, which are described below.

## ECONOMIC GEOLOGY

### Quartz Lodes

Distribution. The gold-bearing quartz lodes mostly crop out as lenses and are confined to a major fault or shear-zone trending north-north-west. The zone contains shears most of which trend in one of three directions: 330° - the most persistent -,355°, and 10°. Millars lode and Prospecting Claim lode occur in shear-zones trending 330°, and the Crosscourse lode lies in a shear-zone striking 355°. These shear-zones are nearly vertical. At Millars the zone dips 85° west; and at Crosscourse and Prospecting Claim the zone dips vertically or 85° east.

Shape and Size. The shape and size of the quartz lodes can be inferred from surface workings, the results of previous investigations, and diamond drilling.

The lodes are lenticular, of the pinch and swell type, and in places they have the appearance of boudins. Ramifying and discrete veinlets and stringers are common. Some typical shapes are shown in Figure 2. In places the unusual shape of pits shows the shape of the lodes worked; in others, it reflects the outline of the exploration shaft or pit. The pits are shown in red in Plate 1.

The largest open cut is the Crosscourse, 350 feet long and up to 20 feet wide. The open cut at Millars is 250 feet long and has a maximum width of 40 feet: cross-sections (Jensen, 1915) suggest that the orebody which was worked at the surface lenses out horizontally and vertically and another lens parallel to it does not reach the surface. The open cut at Prospecting is 100 feet long and has a maximum width of 30 feet.

The deepest intersection of a diamond drill hole with a lode was at a depth of 600 feet under Millars open cut in DDH 13. This intersection shows that the lode is pipe-like. The lode material encountered at this depth is similar to that near the surface and is about the same width.

Mineralogy

The lodes consist of quartz ranging in colour from dull white to milky; they are reddish brown where stained by iron oxides. Occasional cavities are probably due to the leaching of sulphides and contained sedimentary fragments. Some cavities are cubic and clean; others contain limonite after pyrite. Vugs filled with quartz crystals were noted. Diamond drilling has shown that the lodes consist of alternations of quartz, slate, and greywacke.

In hand specimen pyrite and arsenopyrite are seen as irregular particles and aggregates, with traces of galena, chalcopyrite, and native gold in quartz veins or disseminated through country rock. Isolated cubes and blebs of pyrite are widely dispersed through the country rock.

In thin section carbonate veinlets were identified by Pontifex (1964) as calcite and dolomite; some are associated with quartz. Pyrite, arsenopyrite, galena, chalcopyrite, fluorite, sphalerite, marcasite, ilmenite, gold, and silver occur in the veins.

Arsenopyrite generally forms large crystals and more commonly occurs in greywacke within the lode than in quartz-carbonate-pyrite veinlets. It forms a significant part of quartz lodes immediately north of the area mapped.

Oxidation and Enrichment. Union Reefs area could well have been land since the Precambrian, except for a short period of submergence during the Cretaceous (Skwarko, 1966), and hence subjected to a long period of weathering, which may have enriched the gold values near the surface. In several places eluvial gold has accumulated by the mechanical weathering of lodes and these areas have been worked out. Mechanical weathering may have been responsible for secondary enrichment by attrition in the oxidized portion of the lodes, although some chemical weathering may also have taken place.

At Prospecting Claim lode oxidation in country rock extends to a depth of 120 feet and within the lode to a depth of 200 feet: the lode occurs in an intense shear-zone which allows water to circulate, thus causing oxidation to a greater depth. The same conditions occur at Crosscourse and Millars.

Assays of diamond drill core in the sulphide zone suggest that gold values are generally lower in the sulphide zone than near the surface as recorded in earlier mining reports.

## STRUCTURAL GEOLOGY

Major Structures

The major structure of the Union Reefs Goldfield is a shear-zone, referred to here as the 'Pine Creek Shear-Zone', which trends through the Union Reefs area at

about 330°. The shear-zone extends north-west for at least 120 miles and south-east for about 30 miles to the Edith River and Fergusson River Railway Sidings area. Its width is not known precisely, but it may include the whole of the embayment of sediments in the Cullen Granite in the Union Reefs area, with the most intense part at Union Reefs (Fig. 3). This intense zone of shearing and fracturing coincides with a line of quartz reefs.

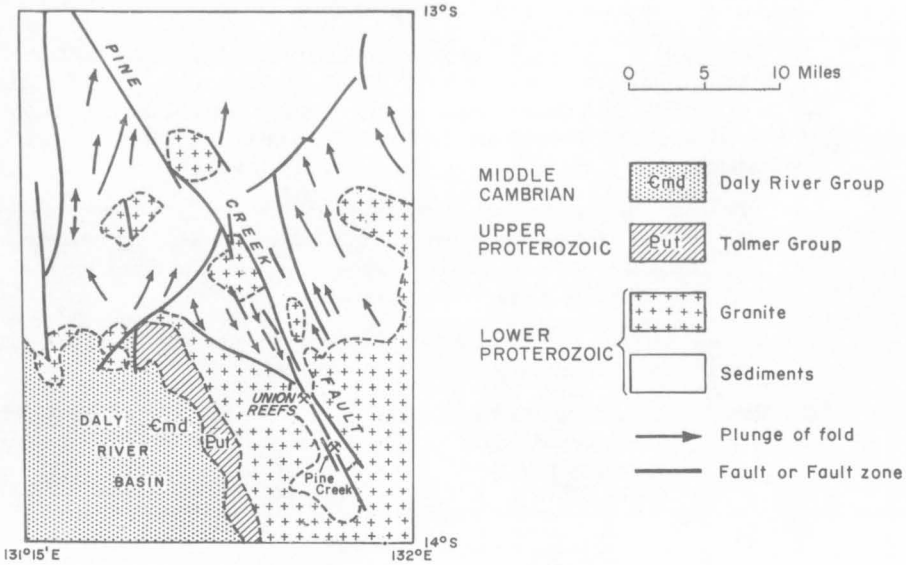


Fig. 3. Structural sketch-map showing regional setting of Union Reefs.

The Pine Creek Shear-Zone is probably a fundamental fault (de Sitter, 1956, p.175) in the tectonics of the Katherine-Darwin area. Regionally it is located on a hinge-zone separating south-east pitching sediments to the east. Another important fault is found where the north-eastern boundary of the Cullen Granite abuts Lower Proterozoic sediments. If projected south-east, this fault intersects the Pine Creek Shear-Zone in the general area of the Union Reefs Goldfield.

Shears of Union Reefs trend in three main directions: 330°, 355°, and 010°. Movements on the three shears appear to have been mostly horizontal; as a result of them the outcrops in the Union Reefs area are elongated lenses which are arranged en echelon along the general trend of the beds.

It is difficult to determine the degree and type of folding because of the intense shearing. The dip of the beds ranges from 65° to vertical, and generally is to the east in the area south of the Crosscourse, and to the west north of the Crosscourse. The relationship between bedding and fracture cleavage in outcrops about 150 feet north of Millars open cut at the southern end of the Lady Alice line of lode suggests that here the beds are overturned 70° to the east. Although folds are not common, this evidence suggests that the style of folding is isoclinal.

The only marker bed in the greywacke and slate succession at Union Reefs is a greywacke pebble conglomerate which is exposed in two places adjacent to each other, one in the northern end of the Lady Alice line at 80N and the other along the Union Line at 85N. These two exposures suggest that the Union and Lady Alice lines may coincide with the limbs of a fold.

Control of Mineralisation

Structures which have controlled mineralisation are:

(i) The shears: Although the relationship and relative importance of the three trends have not been studied in detail, the shears trending 330° appear to be the oldest and those trending 010° the youngest. Quartz lodes occupy shears of all three trends, and in the centre of the Lady Alice Line a shear-zone trending 010° contains an altered amphibolite dyke.

(ii) Difference in competency: Isoclinal folding and subsequent shearing have resulted in large-scale movements between competent greywacke beds and less competent shales; in some places the contact is brecciated and has provided a favourable locus for ore localisation.

(iii) Strike changes: Mineralisation has been found where shears change strike on passing through beds of different competency.

(iv) Thickness: Mineralisation appears to be concentrated in areas where the beds of greywacke and slate are interbedded and of about equal thickness, ranging from 6 inches to 3 feet. Very thick beds of greywacke or slate alone without any interbeds of slate or greywacke appear to be unfavourable for ore localisation.

## DIAMOND DRILLING

Three groups of lodes, Millars, Crosscourse, and Prospecting Claim, were tested by diamond drilling. The central and northern parts of the Lady Alice lines of lode were selected for testing initially, but were deferred because of the difficult access and the need for rehabilitation, mapping, and sampling of underground workings before a diamond drilling campaign is planned.

Plate 1, Sheets 1, 2, and 3, show the locations of the holes drilled. Drilling was carried out under contract by Associated Diamond Drillers Pty Ltd of Melbourne, between July 1963 and July 1964. A total of 6204 feet was drilled. The shortest hole drilled was No.3, which was stopped at 163 feet 6 inches because of the likelihood of intersecting old workings, and the longest hole was No.13, which was stopped at 861 feet.

Diamond drill holes were surveyed with either a Tropari surveying instrument or a hydrofluoric acid tube. Holes lifted considerably; the greatest lift was in DDH 6, which lifted from 66° at the collar to 36° at 600 feet. The holes showed only minor deviations in azimuth; the maximum was 1°. From the surface to 40 feet core recovery averaged 70 percent; below this depth recovery averaged 90 percent.

The entire core from mineralised sections was ground, split, and assayed. This procedure was introduced after it was observed that a split of core from one hole contained gold in one half and not in the other.

Core sizes were NX near the surface and BX and BMS at depth. The core is stored in the Bureau of Mineral Resources store at Winnellie, Darwin, N.T. It was assayed by Australian Mineral Deveopment Laboratories, Adelaide.

Millars Lode

Production. Hossfeld (1936) reported that Millars lode produced at least 1072 oz 11 dwt of gold from 209 tons of ore.

Workings. The main surface workings are at the southern end of the Lady Alice line of lode and consist of an open cut 250 feet long, 40 feet wide (maximum), and about 15 feet deep. Forty feet south of this cut is the main shaft, 210 feet deep. Immediately south of the main shaft mine spoil fills an old stope which extended 80 feet below the present surface. The underground workings are inaccessible, but an old mine section reproduced on Plate 2 shows the extent of stoping.

Geology. The Burrell Creek Formation in the Millars area consists of intensely folded and sheared tuffaceous slate and greywacke striking 330° and dipping 68° east to 85° west. The 330° shear direction is paralleled by the gold-bearing quartz veins, faulting, brecciation, cleavage, axes of minor folds, and bedding. The plunge of minor folds ranges from 25° at the southern end of the lode to 41° at the northern end. Cleavage/bedding intersections suggest that, in places, the plunge is horizontal. Fracture cleavage is vertical and is better developed in slates than in tuffaceous greywacke; movement along cleavage planes and isoclinal folding have led to the development of transposed bedding. The 335° shear is more prominent away from the lodes and is represented by vertically-dipping fracture cleavage. Minor quartz stringers are parallel to this direction. The 010° shear is shown by minor warps pitching 20° south-south-west on the bedding planes. In addition, on the western edge of the open cut minor vertical shears and horizontal rolls, with crests 6 to 12 inches apart, on shear planes trend 295°.

Millars Lode strikes 330° and dips 85° west; it pitches vertically to steep north parallel to the intersection of 330° and 295° shears.

Drilling Summary (Plate 2). Complete details of rock types intersected during the drilling of Millars Lode and results of assays of quartz veins are shown in Plate 2. Five diamond drill holes were put down, with a total footage of 2962 feet. DDH 3 was abandoned at 163 feet 6 inches when an old plan was discovered showing underground workings close to the path of the drill hole.

The sulphides in the lode are pyrite, arsenopyrite, chalcopyrite, galena, and marcasite. Pyrite is the most common sulphide found, and in some places it grades into marcasite. The sulphides are in a quartz-carbonate gangue with chloritized slate and greywacke. In DDH 6 arsenopyrite occurs in greywacke without quartz mineralisation as disseminated fine to medium-sized crystals. The percentage of sulphides, nine-tenths of which is pyrite, in the quartz carbonate gangue is approximately 1 to 2 percent.

DDH 11 intersected small lodes 400 feet below the collar of Millars main shaft, which contained low gold values.

DDH 13 intersected several non-auriferous lode formations before reaching the main lode at 700 feet below Millars open cut. The lode formation was 30 feet wide and was more sheared on the west side than on the east. The gold tends to be in the centre of the lode.

Crosscourse Lode (Plate 3)

Production. Hossfeld (1936) reported that at least 2501 tons 15 cwt of ore yielding 2939 oz 8 dwt of gold came from the two leases which enclose the Crosscourse lodes.

Workings. The open cut developed to mine the Crosscourse lode is the largest in the area; it is 350 feet long and 20 feet wide. The lode was stoped to about 100 feet. Thirty-five feet west of the southern end of this open cut is the Government Shaft, which has been sunk to a depth of 200 feet; this shaft was put down under government subsidy in 1907. No assay results exist from the Government Shaft or associated workings. DDH 9, sited north of the Government Shaft, penetrated a cavity at the same reduced level as the bottom of the shaft, so it is possible that a northerly drive was put in.

Another large open cut is situated 300 feet west of the Crosscourse lode. It is 240 feet long and has a maximum width of 12 feet and depth of 40 feet. Fifty feet to the north a shaft was sunk to a depth of 100 feet and stoping may have been carried out to this depth.

The shape and size of the workings closely reflect the original outlines of the lodes containing gold-bearing quartz veins.

Geology. The Crosscourse lode is lenticular and replaces sheared interbedded slate and greywacke. It consists of vuggy quartz veins with minor pyrite and arsenopyrite. It is 350 feet long and has a maximum width of 20 feet; in the diamond drill holes the width of lode ranges from a few inches to 14 feet. Down pitch the lode is known to extend 500 feet below the surface.

Bedding in the area strikes 335$^{o}$ and is parallel to the long axis of the lode and to the Pine Creek Shear-Zone. Cleavage ranges in dip from steep west to vertical. Crenulations or rolls in the walls of the open cut pitch 40$^{o}$ south; lineation pitches 80-85$^{o}$ south and reflects the pitch of the lode. Subparallel gash veins or parallel lodes have been intersected by drilling.

Drilling Summary. Three diamond drill holes, Nos 1, 2, and 9, were put down to test the lodes below the main Crosscourse open cut. DDH No.7 (Pl. 3) was drilled to test a parallel lode 300 feet west of Crosscourse lode.

DDH 1 intersected lode material containing 5 to 10 percent of sulphides between 180 and 200 feet beneath the surface; pyrite is the main constituent and minor chalcopyrite is confined to a small section of the lode. DDH 9 encountered pyrite and arsenopyrite in approximately equal proportions; the pyrite is associated with quartz, and arsenopyrite forms crystals up to 6 mm across and occurs mainly in greywacke. Sphalerite was also present in this lode. In DDH 7, which was drilled beneath the Crosscourse open cut, arsenopyrite is associated with greywacke rather than with the quartz veins. In this hole the chalcopyrite appears to have been introduced at the same time as a second generation of quartz (Pontifex, 1964).

Lode material intersected in DDH 9 from 304 feet to 314 feet was the richest discovered during the drilling programme and assayed:

| | | | | | | |
|---|---|---|---|---|---|---|
| 304 feet to 306 feet 5 inches | 3.0 | dwt/ton | Au | 4.0 | dwt/ton | Ag |
| 306.5 feet to 309 feet | 186.0 | " | " | 74.0 | " | " |
| Check assay | 122.9 | " | " | 37.4 | " | " |
| 309 feet to 311.5 feet | 0.4 | " | " | 2.0 | " | " |
| 311.5 feet to 314 feet | 0.5 | " | " | 5.0 | " | " |

The host rock is quartz with minor pyrite and arsenopyrite, grading into greywacke with blebs of pyrite and arsenopyrite.

DDH 1 intersected the same vein and assayed 16.6 dwt/ton Au and 16 dwt/ton Ag over 2.5 feet from 184 to 186.5 feet. The spread of values was higher in this hole; from 184 to 193 feet the average was 6.8 dwt/ton Au and 6.5 dwt/ton Ag.

Estimates of ore reserves based on these two drill intersections, assuming an average true width of 6 feet over 200 feet length and 210 feet depth, give inferred reserves of 18,000 tons averaging 21.6 dwt/ton Au and 9.5 dwt/ton Ag.

Two veins were intersected by DDH 7. The lodes probably dip 80° east and may reverse to 85° west in places. From 412 to 414 feet 6 inches the western lode assayed 8.1 dwt/ton Au and trace Ag; in the eastern lode the gold content ranged from 0.3 to 3.2 dwt/ton over a width of 2 feet 6 inches. Waggon drill hole No.3 (see p. ) intersected the western lode over an inclined width of 35 feet; from 70 to 75 feet the lode assayed 8.6 dwt/ton Au and from 85 to 90 feet 13.6 dwt/ton Au. The lode consisted of vuggy quartz with minor chalcopyrite, galena, arsenopyrite, and free gold.

Prospecting Claim Lode (Plate 4)

Production. Total gold production is unknown. Hossfeld (1936) reports that recorded total gold production from Prospecting Claim area was 8400 ounces, but early records are incomplete and the actual production is probably much greater. Gold was won from eluvial sources as well as from lodes.

Workings. The main surface working on the Prospecting Claim lode is a lenticular open cut which trends about 350° and is about 100 feet long, up to 30 feet wide, and 40 feet deep. About 150 feet to the north of the open cut several pits and trenches trending 335° are found; 50 feet to the south similar workings trend 340°. Shafts near the open cut are more than 100 feet deep and an adit 85 feet long connects with the bottom of the open cut. The extent and condition of workings under the open cut are not known; diamond and waggon drilling encountered cavities beneath the open cut which are assumed to be mine workings.

Two other adits, one 130 feet long and the other 300 feet long, have intersected the lode to the north of the open cut. Drives from these adits do not extend very far.

Geology. Prospecting Claim lode occupies a shear-zone in the crest of a tight anticline in interbedded slate and greywacke. The axial plane of the fold is probably vertical, parallel to the dip of the lode. On the eastern side of the open cut sediments strike 330° and dip 75° west; on the western side they strike 355° and dip either vertically or steeply west. Dips of bedding measured from diamond drill core range from 70° east to 70° west, but most dips are about vertical. Cleavage strikes 330° and dips vertically.

The lode strikes 355° and changes abruptly to approximately 330° at the northern and southern ends of the open cut. These strike changes occur near the intersection of two major shears and have played an important part in localising the lode. The dip of the lode is irregular and may be influenced by the competency of the rocks. Diamond drill intersections show that the lode dips vertically to 85° and pitches 85° north.

Drilling Summary. Four holes totalling 1584 feet 6 inches were drilled to test the Prospecting Claim lode beneath the main open cut. The results are displayed in Plate 4.

Mineragraphic investigation of core from DDH 4 shows that sulphides in the Prospecting Claim lode make up approximately 5 percent of the lode in volume. Pyrite is

the main sulphide, followed by galena, arsenopyrite, and minor chalcopyrite. Galena surrounds and embays arsenopyrite that is possibly sheared (Pontifex, 1964).

The main lode was intersected in all holes and ranges from 6 feet thick in DDH 10 to 30 feet thick in DDH 4. It is made up of vuggy quartz veins and stringers in chloritic slate and greywacke with pyrite, arsenopyrite, galena, and chalcopyrite as accessory minerals. Carbonate veinlets were noted.

The most significant assay results were obtained in DDH 4, 5, and 10.

| Diamond Drill Hole | From | To | Au dwt/ton | Ag dwt/ton |
|---|---|---|---|---|
| 4 | 192½ (feet) | 195 | 8.0 | 4.0 |
| | 195 | 197½ | 3.7 | 1.6 |
| 5 | 186½ | 191½ | 22.5 | 10.1 |
| 10 | 345½ | 348 | 13.3 | 13.0 |

Gold distribution is spotty; this is demonstrated by assay results of opposite halves of the core from 184 feet to 186 feet 6 inches in DDH 5: one side assayed 44.6 dwt/ton, the other 10.8 dwt/ton, and the bulk 24.0 dwt/ton.

All these drill holes intersected the main lode, and DDH 10 in addition intersected a subsidiary gash vein or a parallel lode.

## WAGGON DRILLING

United Uranium N.L. co-operated with the Bureau in an experimental waggon drilling programme and provided, at cost, drill crews, a Gardner Denver Airtrac waggon drill, a 900 c.f.m. compressor, and a cyclone dust collector.

Seven waggon drill holes ranging in depth from 115 to 185 feet were drilled at Prospecting Claim and Crosscourse lodes. The main object was to test a cheap method of prospecting many of the numerous quartz lenses and veins that have been mined at the surface. Wherever possible, holes were drilled alongside and parallel to diamond drill holes to provide a check on the results.

The most significant waggon drill hole results are as follows:

| W.D.H. | Depression | Length (feet) | Interval (feet) | Dwt/ton Au |
|---|---|---|---|---|
| 1 | 60° | 185 | 110 - 115 | 6.7 |
| 2 | 60° | 175 | 165 - 170 | 3.3 |
| | | | 170 - 175 | 4.2 |
| 3 | 60° | 115 | 70 - 75 | 8.6 |
| | | | 85 - 90 | 13.6 |
| 4 | 50° | 180 | - | - |
| 5 | 50° | 108 | 105 - 108 | 0.3 |
| 6 | 60° | 195 | 160 - 165 | 0.3 |
| 7 | 55° | 155 | 150 - 155 | 0.5 |

The drilling results show that most of the lodes have been worked out to the water table. Samples can be collected from above the water table by drilling between stopes and the assay results should provide a useful guide to further exploration. Below the water table the cuttings form a slurry and pack the sides of the hole, and the return of cuttings is poor.

## ELUVIAL AND ALLUVIAL DEPOSITS

Eluvial gold placers have been worked extensively on the eastern and western flanks of the Union Reefs line of ridges.

Alluviated areas containing gold prospects have been noted along McKinley River and immediately north-north-west of the area mapped. The profile in both areas consists of alluvium, overlying sediments with well developed cleavage and amphibolite. The area along the McKinley River is parallel to the Union Reefs area and is three quarters to one mile to the west. The alluvial plain is about 200 yards wide and 4000 yards long. Alluvium is up to 10 feet thick.

The other alluvial plain is situated along a creek which trends north-south and drains the northern and eastern parts of the Union Reefs area, 1 mile north of the Prospecting Claim lode. The plain is approximately 300 yards wide and 2500 yards long, and up to 6 feet deep. Eight hand auger holes were put down across the plain during 1963 and panning showed that in two of the holes the alluvium contained gold.

Both areas should be tested for alluvial gold which could have been trapped in river gravels and in cleavages of Burrell Creek Formation, which may have acted in the same way as riffles in gold boxes. Further areas may be found downstream from Union Reefs.

## ORIGIN OF MINERALISATION

The mineralisation at Union Reefs can be ascribed to two possible sources, the granitic rocks or the intrusive amphibolites. The mineralisation appears to be spatially related to both, although amphibolites are geographically closer. Quartz veins intersect all rock types and may be end-stage derivatives of granitic intrusives, but equally they could be derived from fractionation of basic intrusives. The writers have no evidence which could substantiate a preference for the source.

## CONCLUSIONS AND RECOMMENDATIONS

The quartz veins have been emplaced in a broad shear-zone - Pine Creek Shear-Zone - which strikes 330$^{\circ}$ and parallels a fundamental lineament in the Precambrian shield of the continent.

The Pine Creek Shear has provided favourable zones for ore localisation, and repeated movements along the shear have given rise to progressive development of fractures subsequently filled by quartz lodes.

Mining at Union Reefs was largely confined to the oxidised portions of lodes, where secondary enrichment took place either by solution and redeposition of gold in the lodes or by weathering of quartz and concentration of the gold in situ. How much chemical enrichment took place can only be guessed, but development in the sulphide zone would show the percentage of gold bonded with sulphide minerals and provide a clue. Detailed mineragraphic studies of concentrates could also assist to resolve this problem.

The sulphide zones were neglected by miners, either because of treatment difficulties caused by sulphides in the ore and bonding of gold with sulphide minerals, or because cost of extraction below water table level may have made the operation difficult or uneconomic.

Diamond drilling in 1963 and 1964 has shown that gold-quartz lodes probably extend to a considerable depth and may increase in size with depth. At Millars, for example, lodes intersected between 300 feet and 700 feet below the surface are wider than lodes at the surface.

At Crosscourse and Prospecting Claim areas gold distribution is irregular, but assay results are encouraging and underground testing is warranted. Crosscourse lode was intersected below the main open cut and inferred ore reserves of 18,000 tons of 21.6 dwt/ton Au and 9.5 dwt/ton Ag have been calculated from cores recovered from DDH 1 and 9. Dewatering of the Government Shaft, which appears to be in good condition, is recommended. In addition the development programme should include crosscutting 100 feet to the line of lode, driving 400 feet along the line of lode, rising 300 feet and winzing 300 feet. Ore recovered could be sent to Mount Wells Battery to determine feasibility of recovery as a concentrate; representative samples should also be sent to AMDL for beneficiation studies.

Prospecting Claim lode dips vertically and continues down-dip for at least 400 feet. Gold assays from DDH 4 and 5 suggest that the mine should be reopened and underground exploration carried out. At the same time the parallel lode discovered by DDH 10 could be tested.

It is recommended that adequate facilities for gold assay should be established on the field if exploration is begun.

Because gold distribution is irregular, the true grade of the lode can probably only be determined by underground operations. Therefore further diamond drilling to outline oreshoots is not recommended until the results of the 1963-64 programme are assessed by underground development. However, diamond drilling will always be a useful tool to provide the stratigraphy and the general distribution of the lodes.

Alluviated areas near Union Reefs should be tested for gold. It is thought that gold could be trapped in the gravels, and in the cleavages of slates and greywackes of the Burrell Creek Formation. Pits dug through gravels into the slates for at least 2 feet would test this. The slates can be easily broken by rippers and hauled by Tournapullers to a treatment plant.

An interesting problem to be resolved is the depth to granite in the embayment in the Union Reefs area. The contact metamorphic aureole on the margin of the Cullen Granite may be magnetic, or there may be sufficient magnetic contrast between the sediments and Cullen Granite to make magnetic surveys useful and provide more information to guide exploration at depth.

## ACKNOWLEDGMENT

We wish to thank the General Manager, United Uranium N.L., Mr J. Fisher, who supplied his company's waggon drill and crew for drilling at Union Reefs.

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PLATE 1 SHEET 3

# UNION REEFS, AGICONDI GOLDFIELD N.T., GEOLOGY AND MINERAL DEPOSITS

THEODOLITE AND PLANE TABLE SURVEY BY D.A. WHITE AND J.W. SHIELDS

## REFERENCE

- Greywacke, tuffaceous, medium grained
- Slate, consisting of fine grained sericite with minor chlorite and clay
- Interbedded greywacke and slate
- Amphibolite, weathered
- Pebble conglomerate
- Quartz vein
- Quartz vein less than 3 feet
- Zone of brecciation, silicification, with or without quartz veining
- F Fault
- Shear zone
- 85° Measured strike and dip of beds
- 85° Measured strike and dip of cleavage
- Measured strike of cleavage, dip vertical or near vertical
- T20 Survey control point marked by iron stake
- Iron stake marking geophysical base line
- Telephone line
- Topographic contour with height above Mean Sea Level, Darwin, N.T.
- Vehicle track
- Disused railway embankment
- DD2(1963) 45° Diamond drill hole showing projection in horizontal plane, range of inclinations and year drilled
- WD11(1963) 45° Waggon drill hole showing projection in horizontal plane, inclination and year drilled
- A—A Section line
- 5' Prospecting pit showing depth in feet
- 6' Open cut showing average depth in feet
- Shaft, inaccessible
- 30' 45° Inclined shaft showing depth and inclination
- Mine dump
- Trench 6' Drainage or alluvial trench
- Creeks

Note: The grid used on this map is that used for the contract geophysical survey by A.B.E.M., 1963.

SCALE

100 75 50 25 0 100 200 300 400 500 FEET

Compiled and drawn 1963-65 by M.E.Nancarrow and J.Kopras

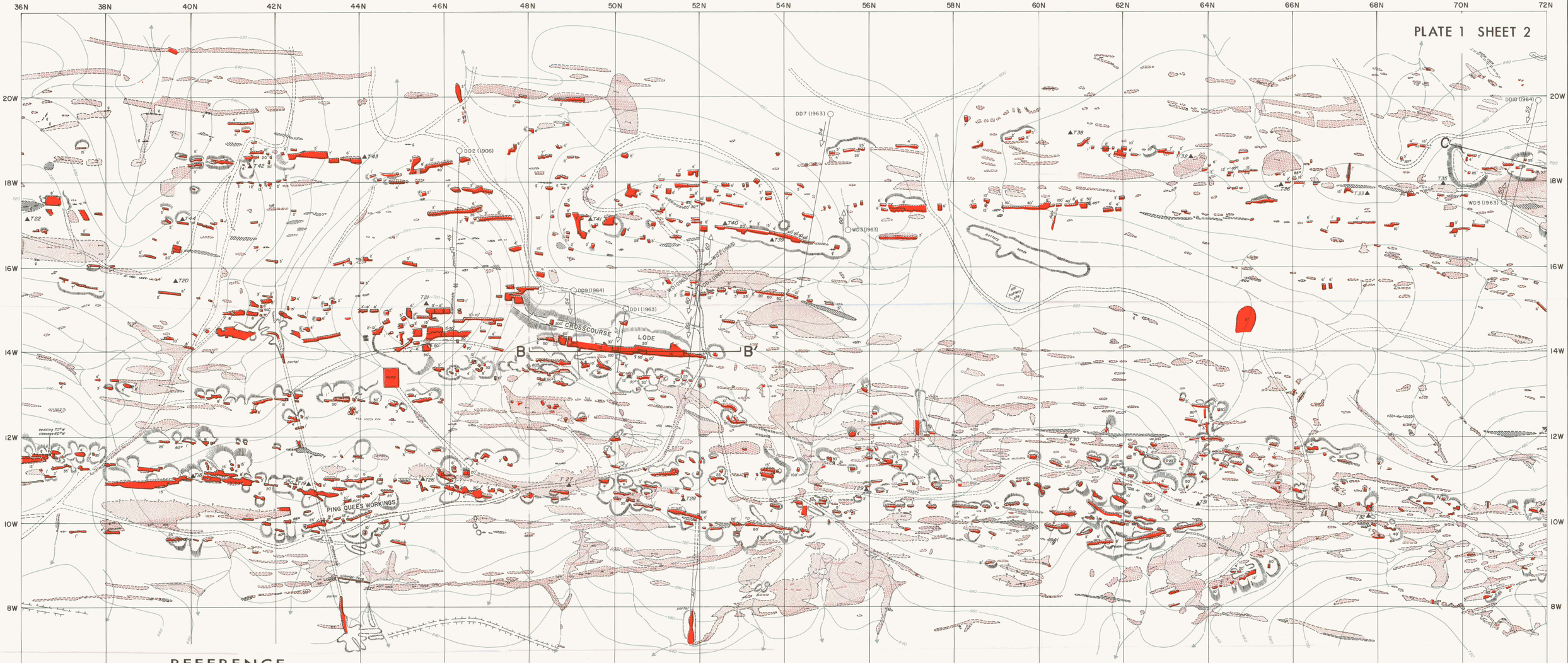
| SHEET 1 | SHEET 2 | SHEET 3 |
|---|---|---|

TRUE MAGNETIC

MAGNETIC DECLINATION 3°50' EAST (1963)
ANNUAL CHANGE 4' EAST

Bureau of Mineral Resources, Geology and Geophysics, October 1965
To accompany Report 45 and Record 1965/201

D52/A8/164




## REFERENCE

- Greywacke, tuffaceous, medium grained
- Slate, consisting of fine grained sericite with minor chlorite and clay
- Interbedded greywacke and slate
- Amphibolite, weathered
- Pebble conglomerate
- Quartz vein
- Quartz vein less than 3 feet
- Zone of brecciation, silicification, with or without quartz veining
- F Fault
- Shear zone
- 85° Measured strike and dip of beds
- 85° Measured strike and dip of cleavage
- Measured strike of cleavage, dip vertical or near vertical
- T20 Survey control point marked by iron stake
- Iron stake marking geophysical base line
- Telephone line
- 620 Topographic contour with height above Mean Sea Level, Darwin, N.T.
- Vehicle track
- Disused railway embankment
- DD2 (1963) 45° Diamond drill hole showing projection in horizontal plane, range of inclinations and year drilled
- WD1 (1963) 45° Waggon drill hole showing projection in horizontal plane, inclination and year drilled
- A—B Section line
- 5' Prospecting pit showing depth in feet
- 6' Open cut showing average depth in feet
- Shaft, inaccessible
- 30' 45° Inclined shaft showing depth and inclination
- Mine dump
- Trench Drainage or alluvial trench
- Creeks

Note: The grid used on this map is that used for the contract geophysical survey by A.B.E.M., 1963.

# UNION REEFS, AGICONDI GOLDFIELD N.T., GEOLOGY AND MINERAL DEPOSITS

THEODOLITE AND PLANE TABLE SURVEY BY D.A. WHITE AND J.W. SHIELDS

SCALE

100 75 50 25 0 100 200 300 400 500 FEET

Compiled and drawn 1963-65 by M.E.Nancarrow and J.Kopras

| SHEET 1 | SHEET 2 | SHEET 3 |
|---|---|---|

TRUE
MAGNETIC

MAGNETIC DECLINATION 3°50' EAST (1963)
ANNUAL CHANGE 4' EAST

Bureau of Mineral Resources, Geology and Geophysics, October 1965
To accompany Report 45 and Record 1965/201

D52/A8/163

PLATE 1 SHEET 1

# UNION REEFS, AGICONDI GOLDFIELD N.T., GEOLOGY AND MINERAL DEPOSITS

THEODOLITE AND PLANE TABLE SURVEY BY D.A. WHITE AND J.W. SHIELDS

## REFERENCE

- Greywacke, tuffaceous, medium grained
- Slate, consisting of fine grained sericite with minor chlorite and clay
- Interbedded greywacke and slate
- Amphibolite, weathered
- Pebble conglomerate
- Quartz vein
- Quartz vein less than 3 feet
- Zone of brecciation, silicification, with or without quartz veining
- F Fault
- Shear zone
- 85° Measured strike and dip of beds
- 85° Measured strike and dip of cleavage
- Measured strike of cleavage, dip vertical or near vertical
- ▲T20 Survey control point marked by iron stake
- Iron stake marking geophysical base line
- Telephone line
- 620 Topographic contour with height above Mean Sea Level, Darwin, N.T.
- Vehicle track
- Disused railway embankment
- DD2(1965) 45° Diamond drill hole showing projection in horizontal plane, range of inclinations and year drilled
- WD1(1963) 45° Waggon drill hole showing projection in horizontal plane, inclination and year drilled
- A—A' Section line
- 4' Prospecting pit showing depth in feet
- 6' Open cut showing average depth in feet
- Shaft, inaccessible
- 30' 45° Inclined shaft showing depth and inclination
- Mine dump
- Trench 6' Drainage or alluvial trench
- Creeks

Note: The grid used on this map is that used for the contract geophysical survey by A.B.E.M., 1963.

SCALE

100 75 50 25 0 100 200 300 400 500 FEET

Compiled and drawn 1963-65 by M.E. Nancarrow and J. Kopras

| SHEET 1 | SHEET 2 | SHEET 3 |
|---|---|---|

TRUE
MAGNETIC

MAGNETIC DECLINATION 3°50' EAST (1963)
ANNUAL CHANGE 4' EAST

Bureau of Mineral Resources, Geology and Geophysics, October 1965
To accompany Report 45 and Record 1965/201

D 52/A8/162

## CROSS SECTION
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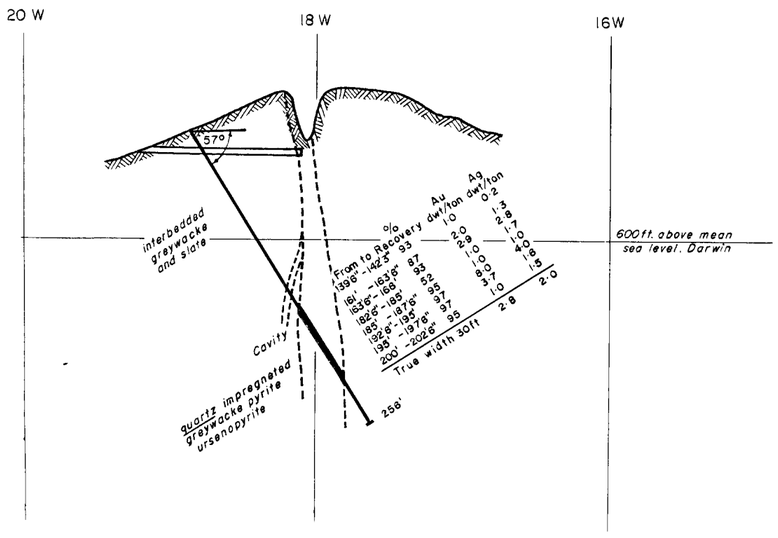


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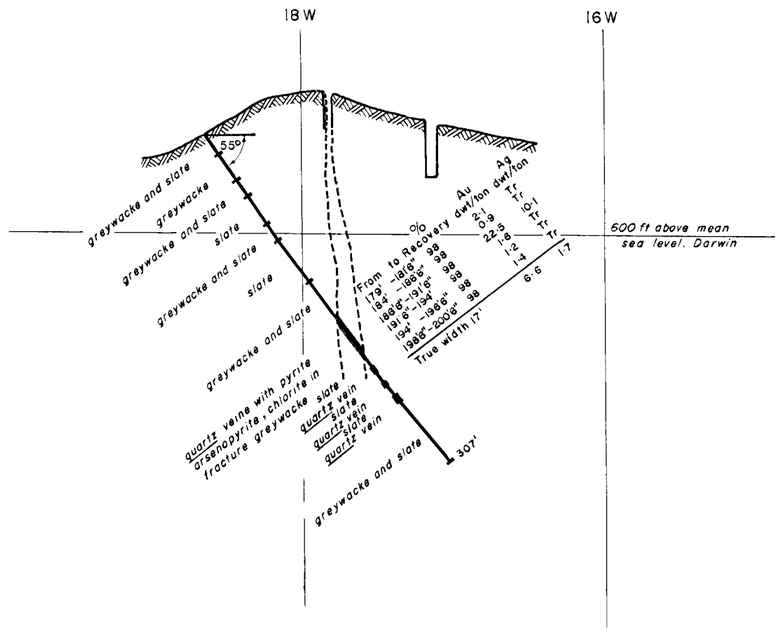


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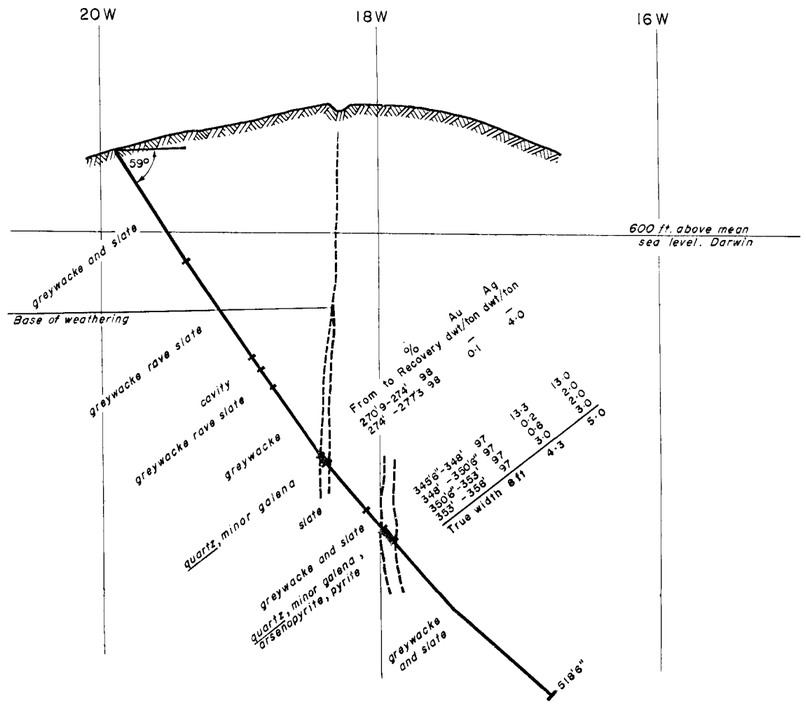


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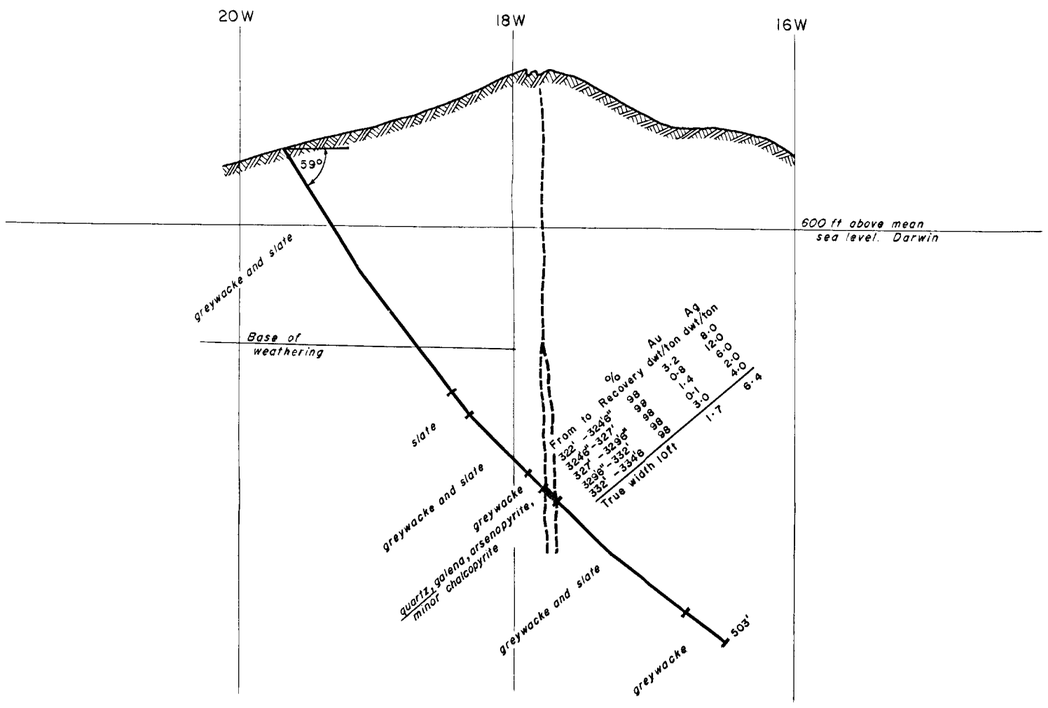
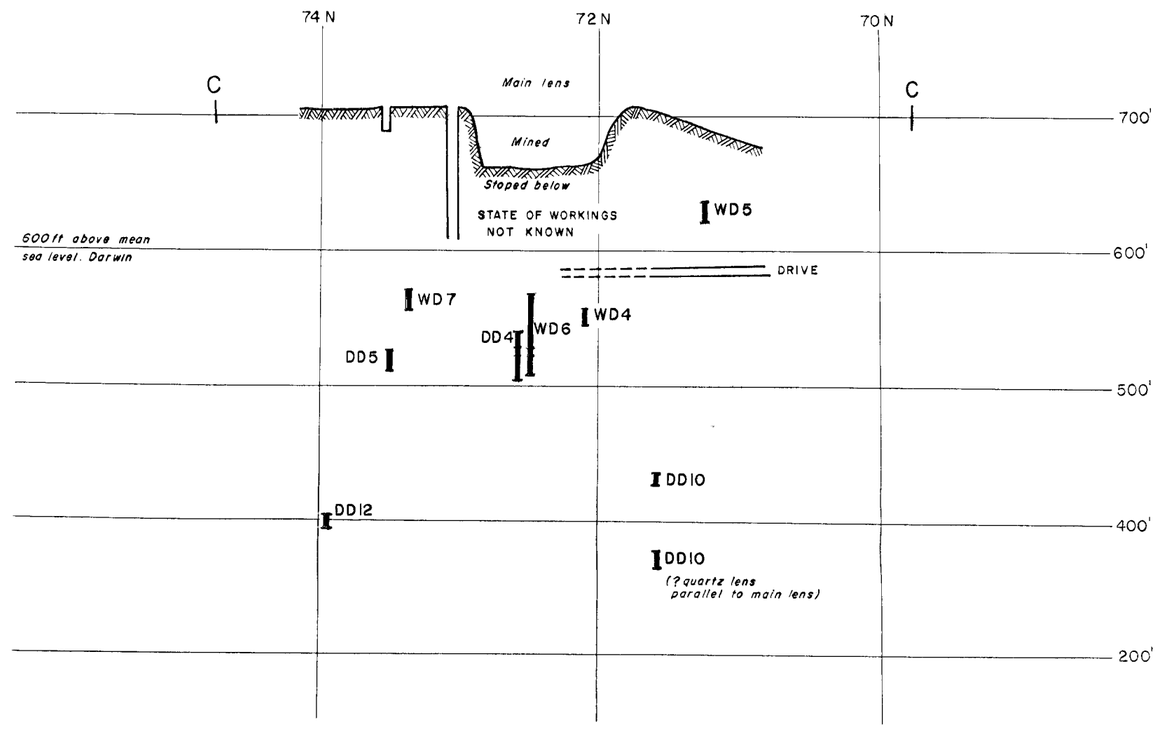
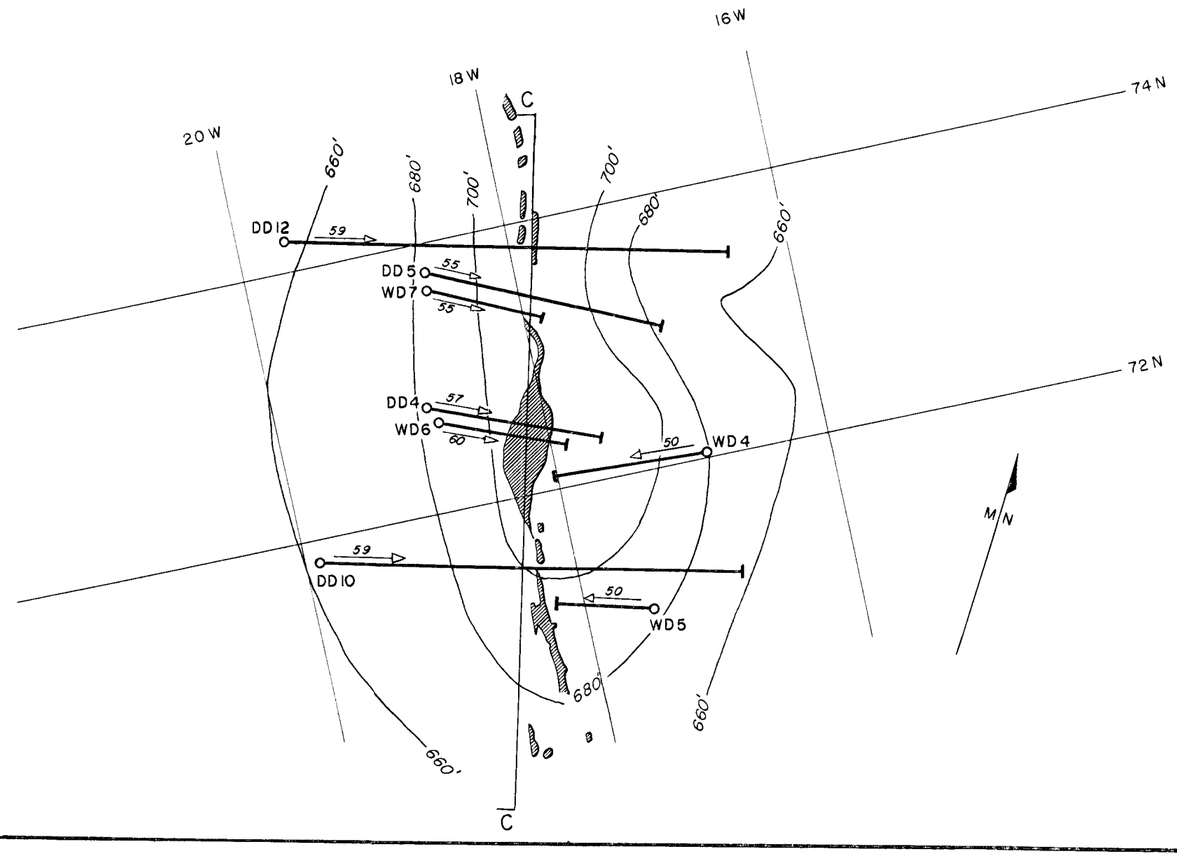



## LONGITUDINAL PROJECTION C-C




## PLAN SHOWING DD 4,5,10,12 AND WD 4,5,6,7




0 100 200 300 Feet

**I** Lode, quartz vein

Open cut, pit or stope

DD4 55 — Diamond drill hole showing projection in horizontal plane and inclination.

WD5 50 — Waggon drill hole showing projection in horizontal plane and inclination

700 — Topographic contours with height above M.S.L. Darwin, N.T.

(Assays by Government Assayer, Tennant Creek and Australian Mineral Development Laboratories, Adelaide.)

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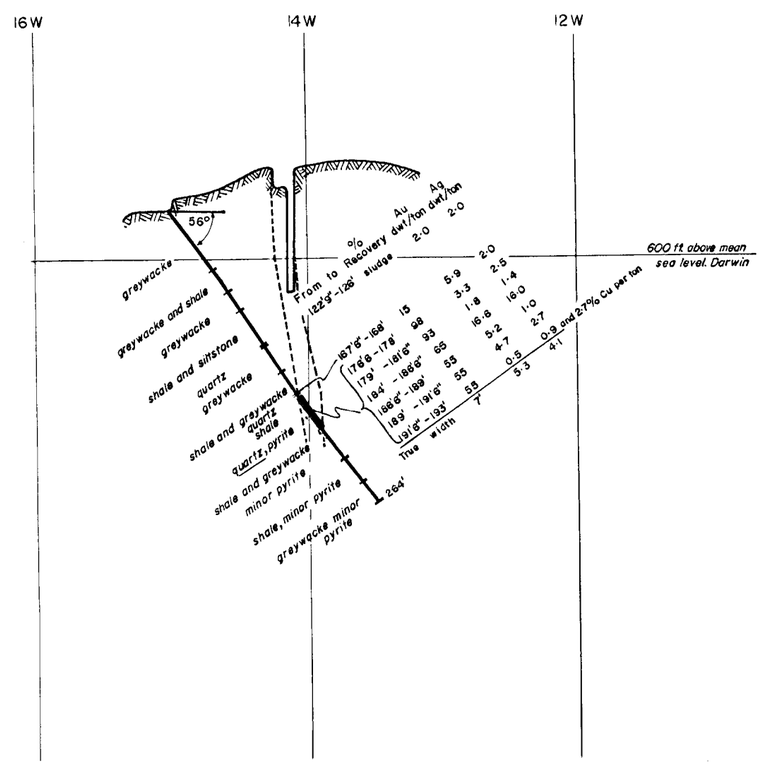


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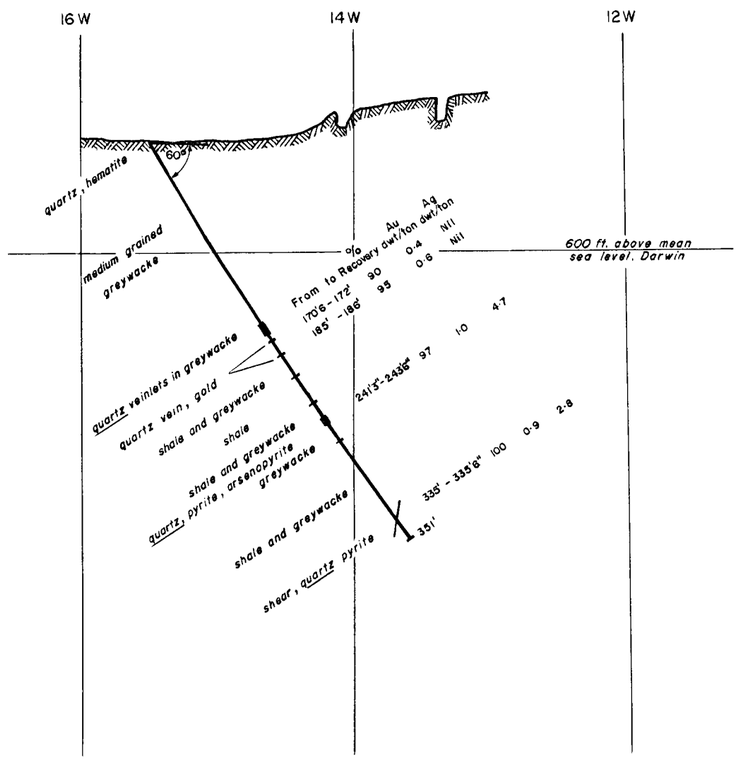


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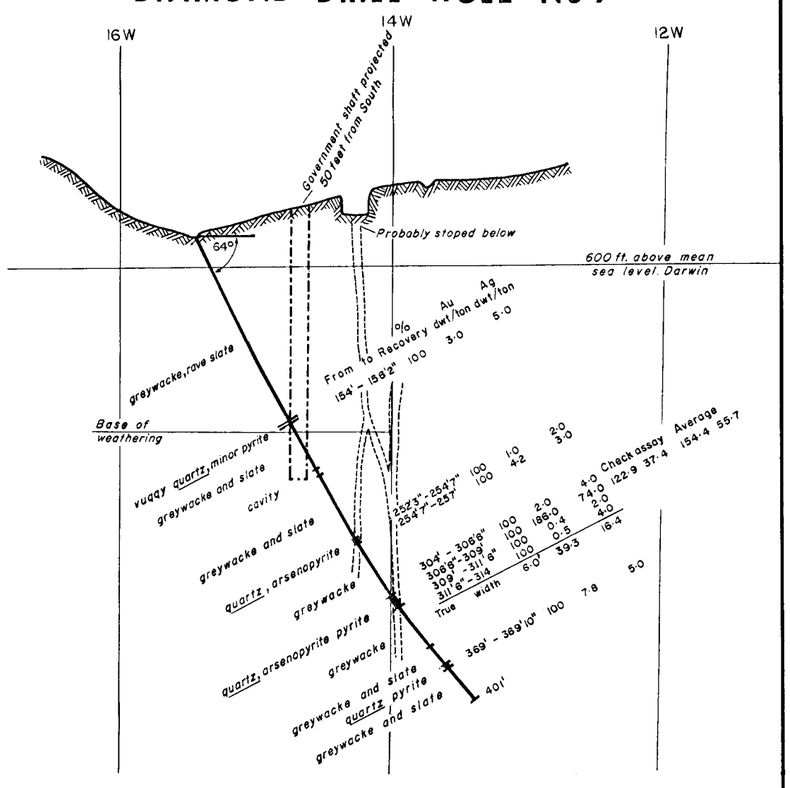


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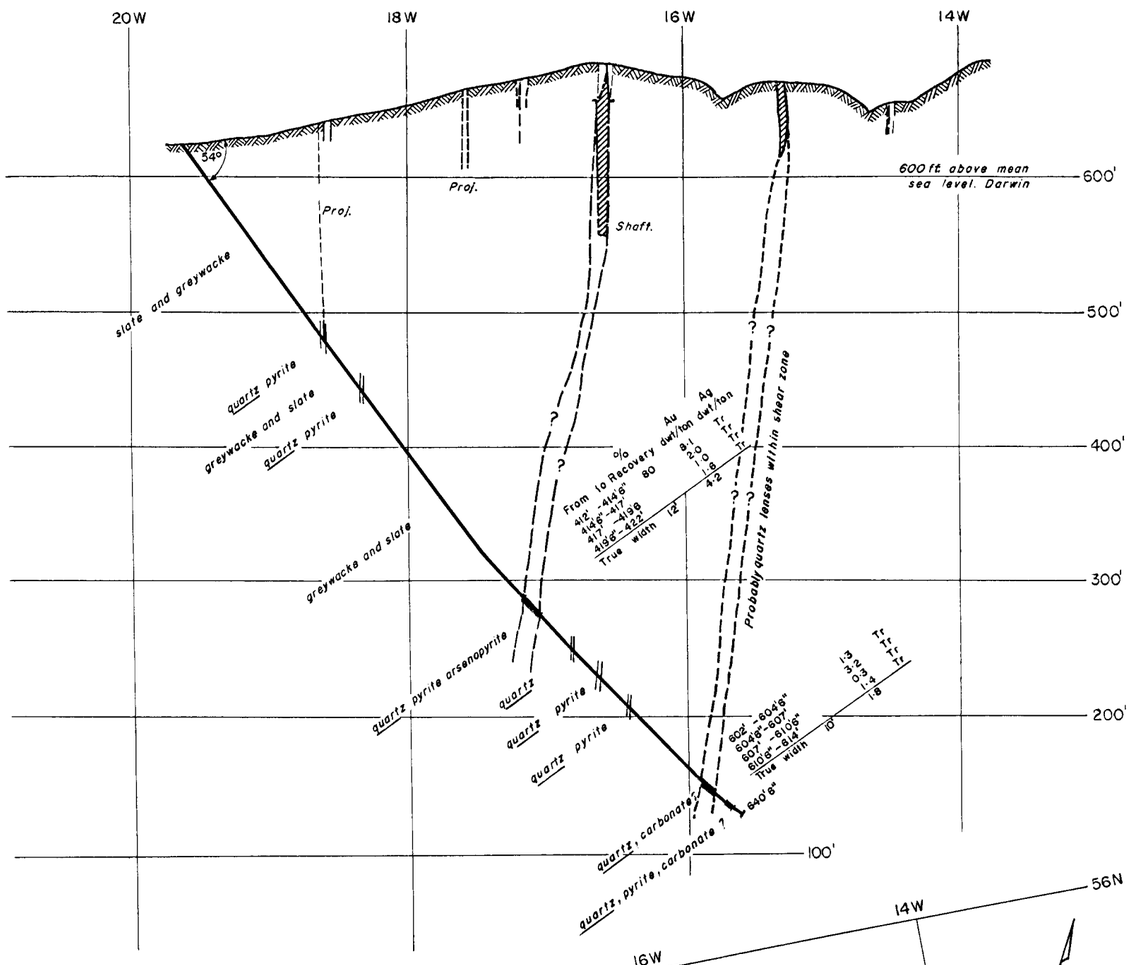


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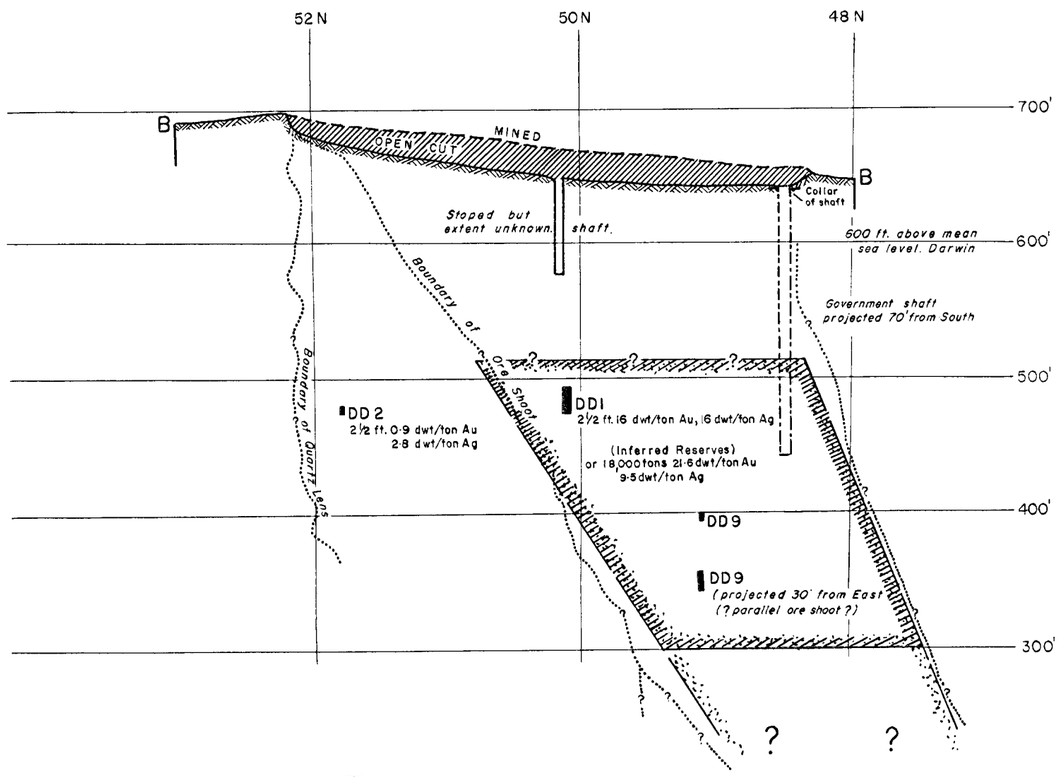
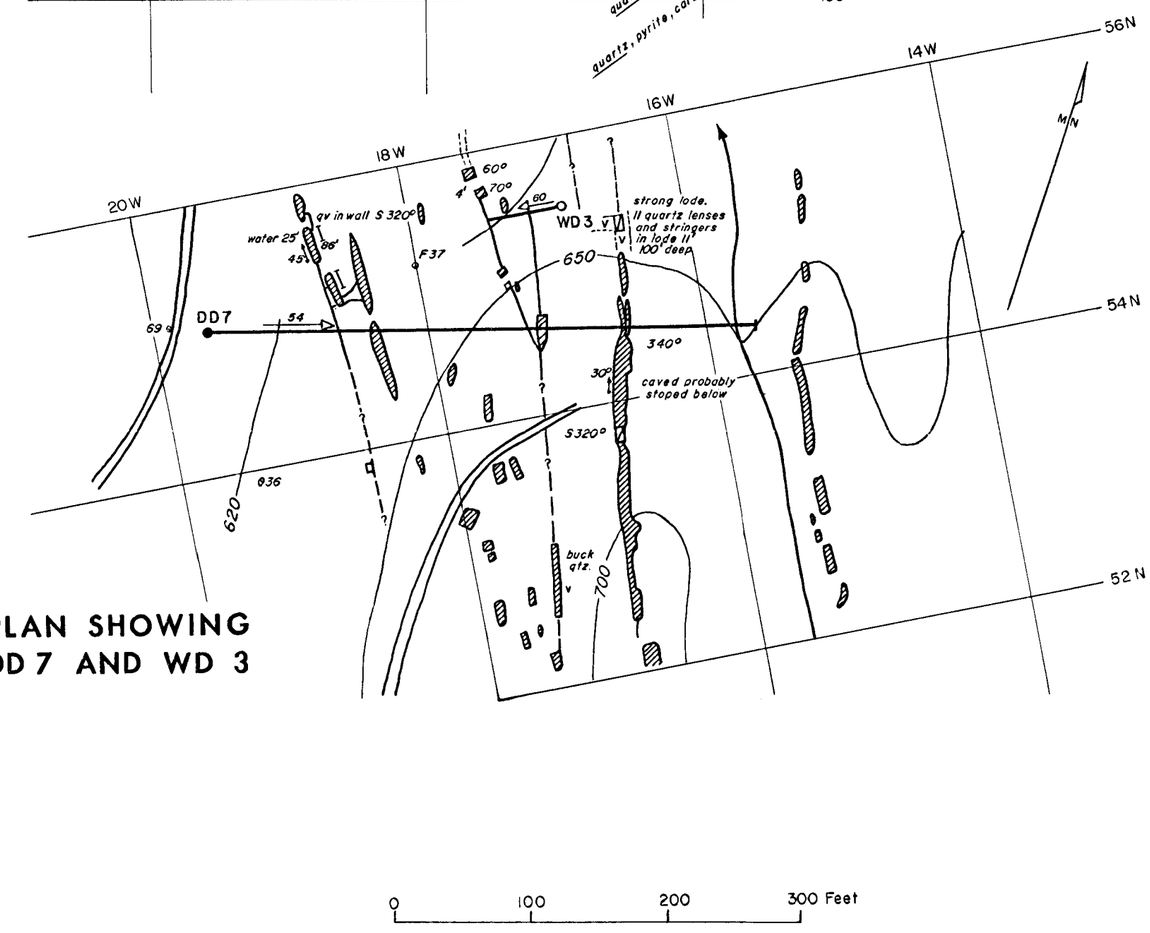
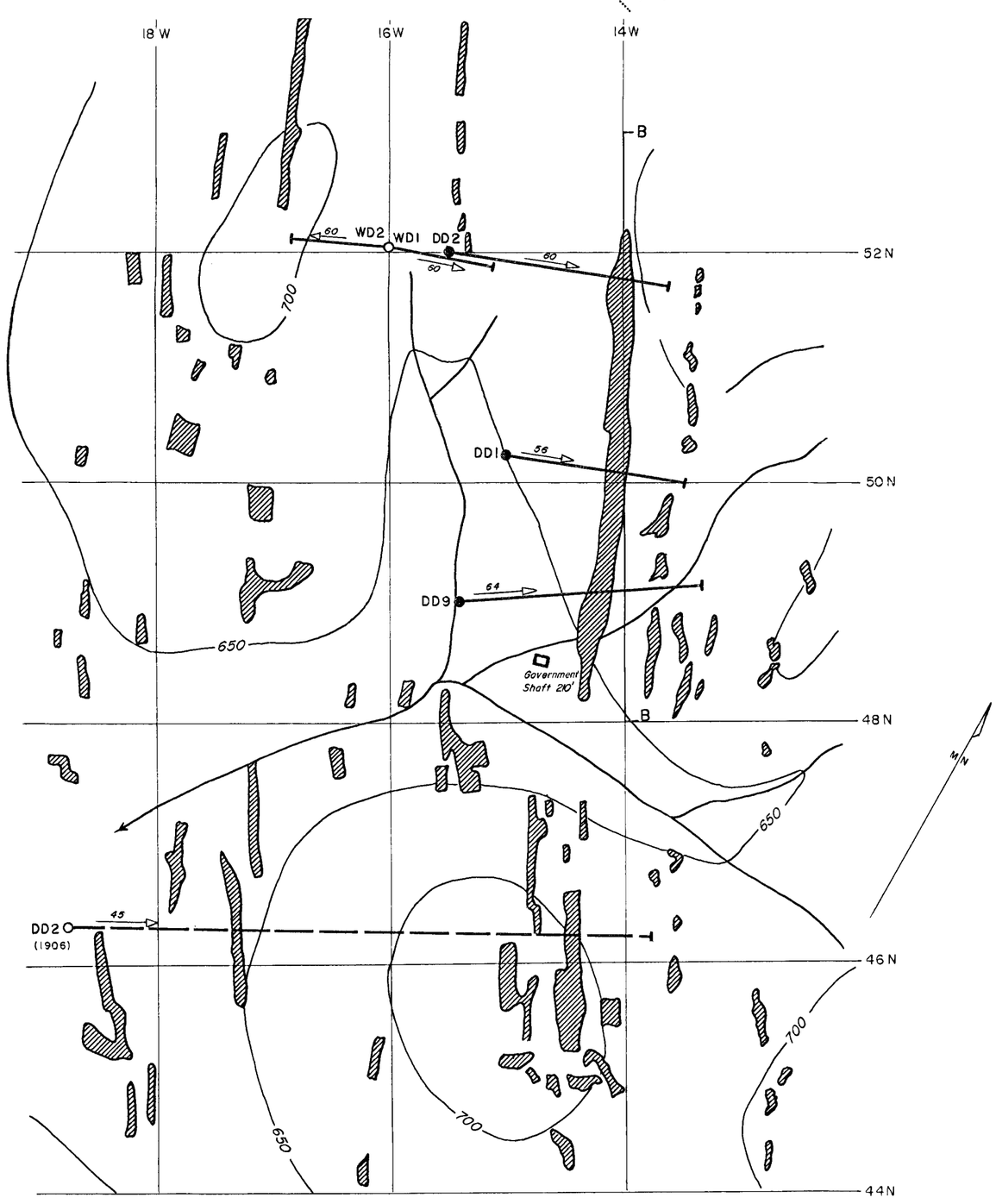



## PLAN SHOWING DD 7 AND WD 3




## PLAN SHOWING DD 1,2,9 AND WD 1,2

0 100 200 300 Feet

Lode – quartz vein

Open cut

Shaft inaccessible

Boundary of ore shoot (possible)

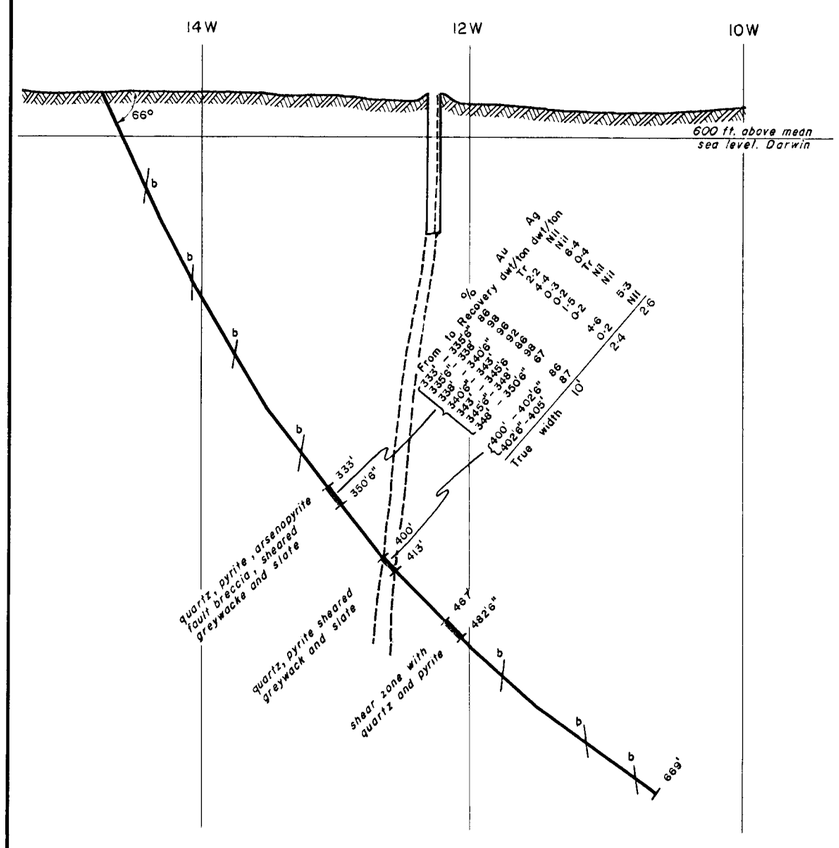
Outline of block (calculated, inferred)

DD7 54 — Diamond drill hole showing projection in horizontal plane and range of inclination

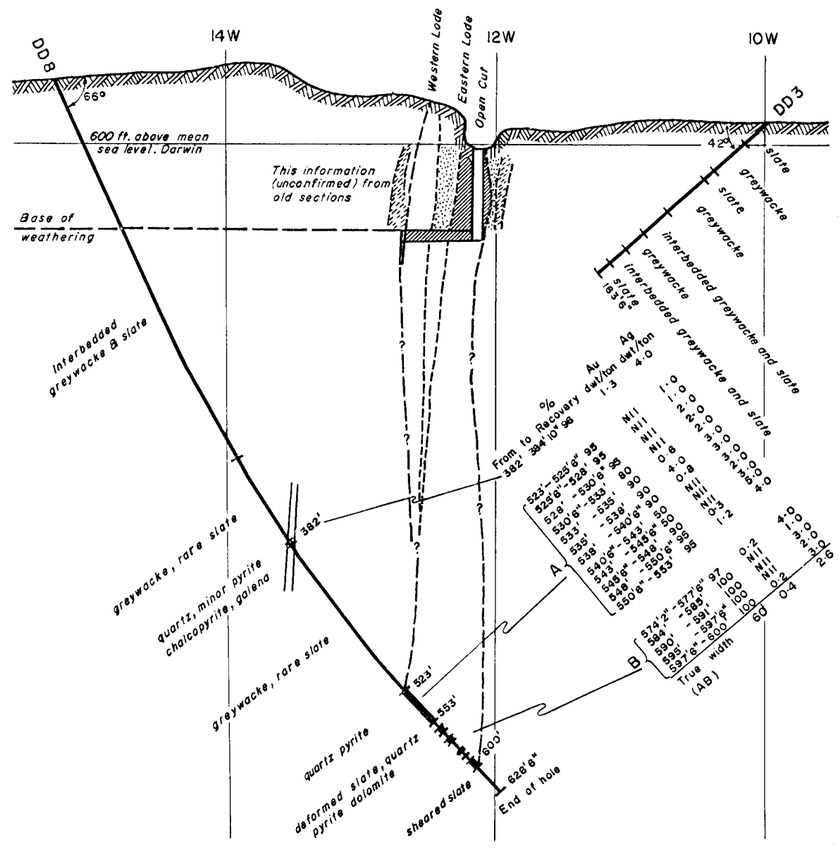
WD2 60 — Waggon drill hole showing projection in horizontal plane and inclination

(Assays by Government Assayer, Tennant Creek and Australian Mineral Development Laboratories, Adelaide)

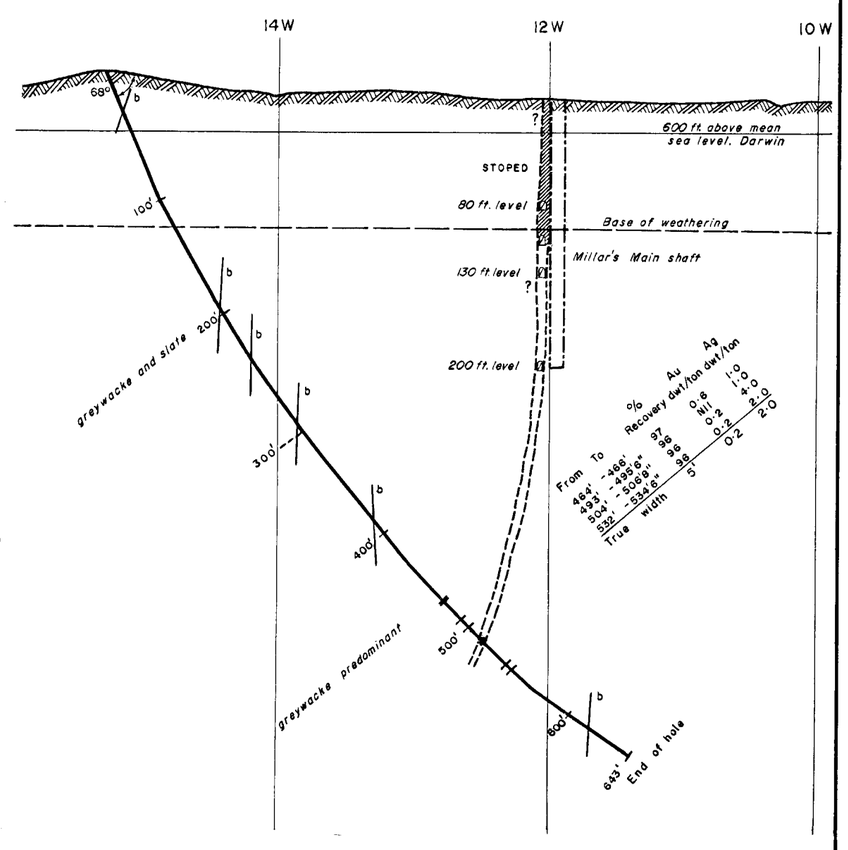
## CROSS SECTION
## DIAMOND DRILL HOLE No 6



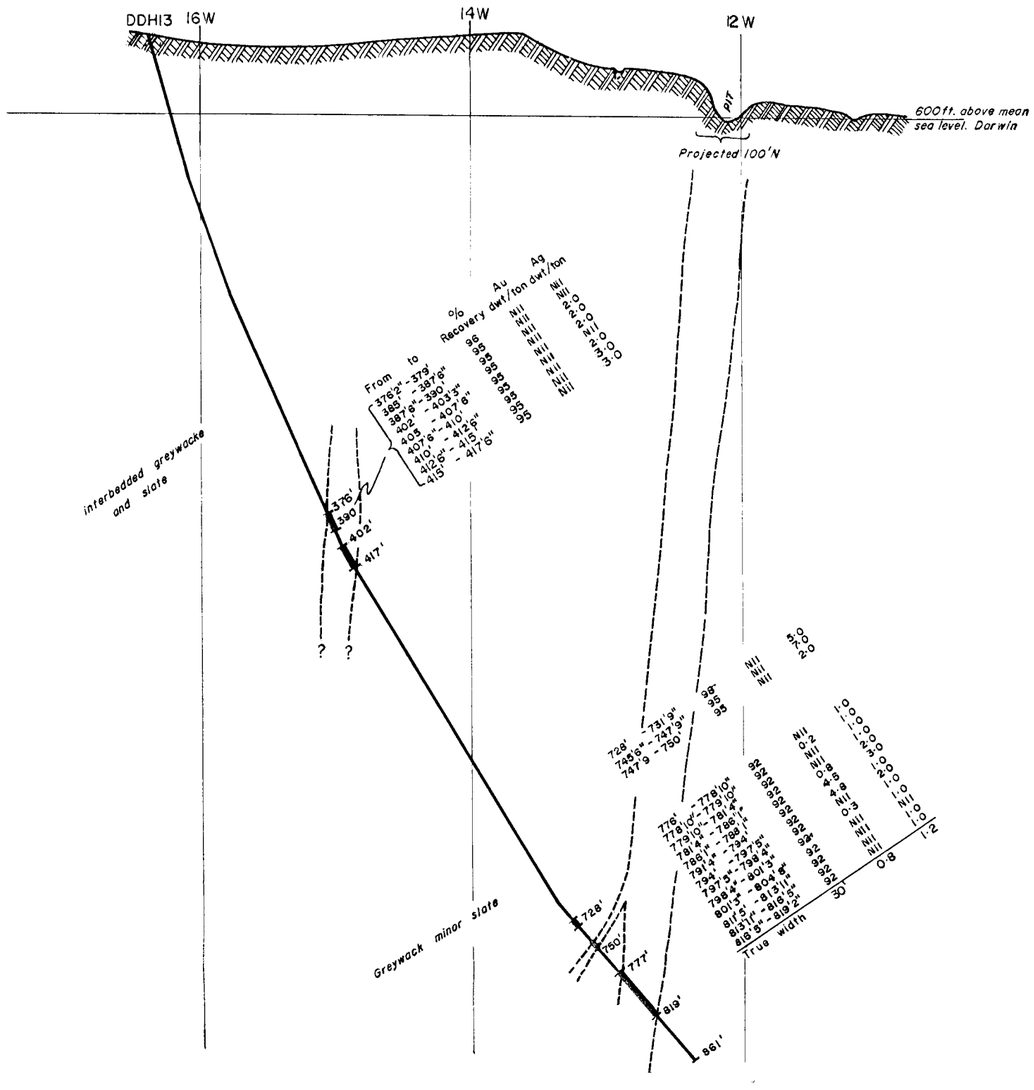

## CROSS SECTION
## DIAMOND DRILL HOLES No 8 AND 3



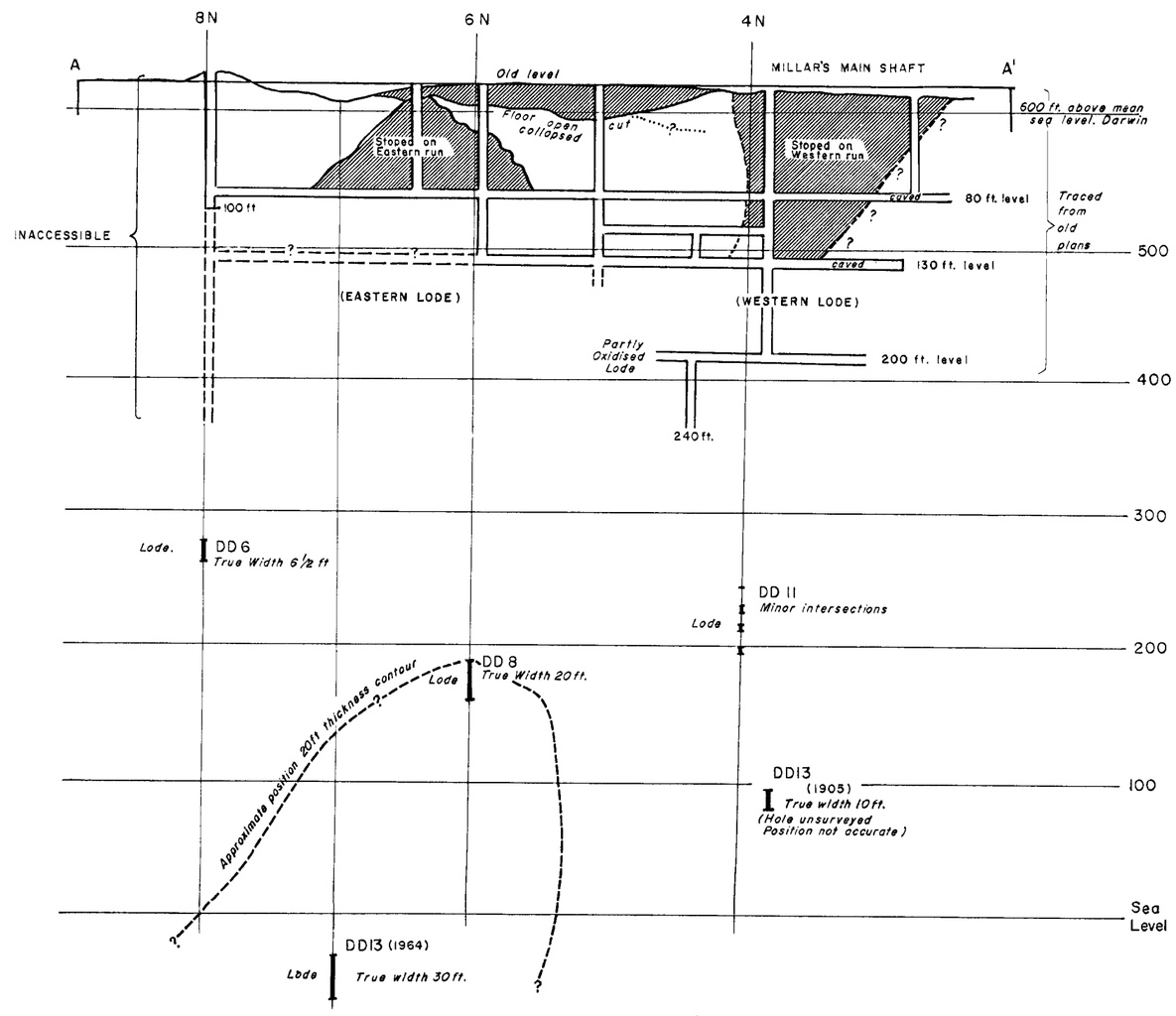

## CROSS SECTION
## DIAMOND DRILL HOLE No 11



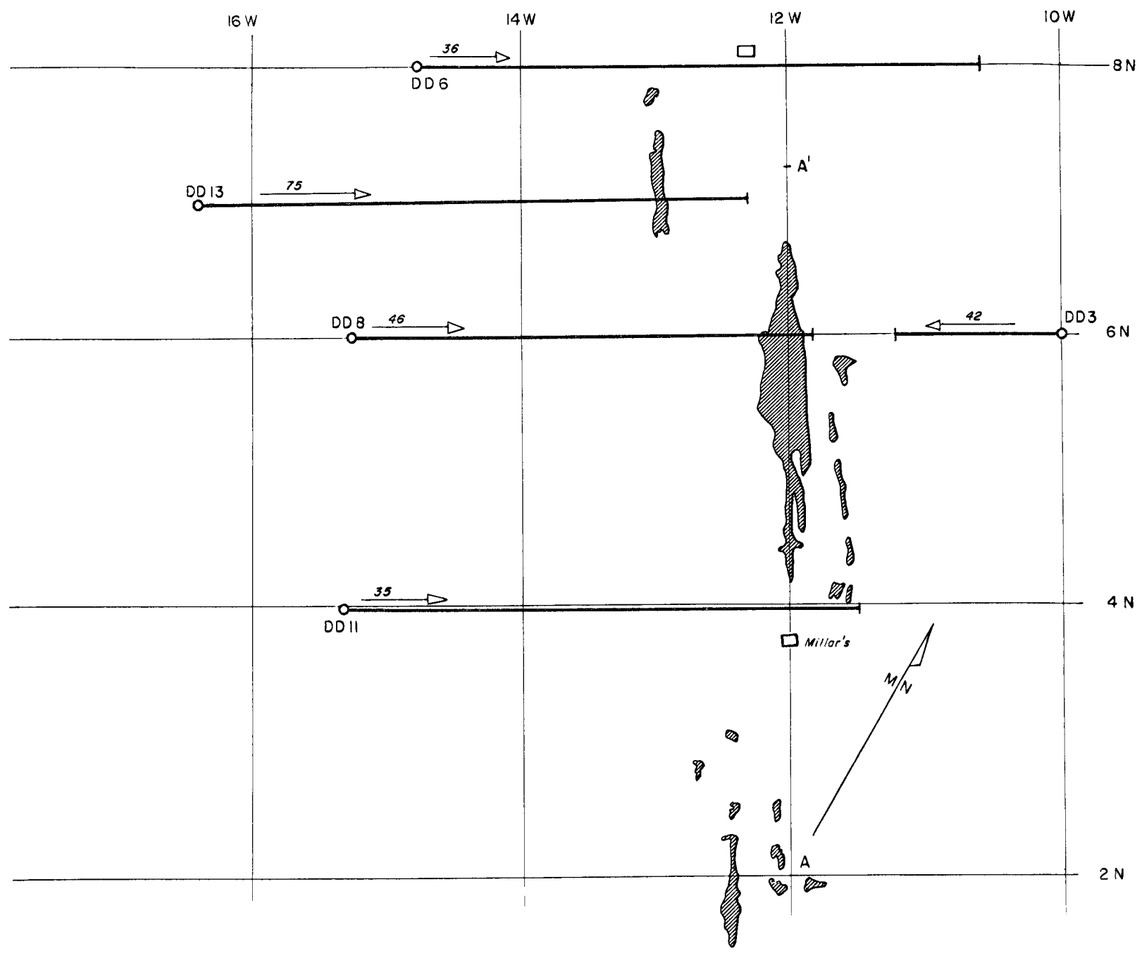

## CROSS SECTION
## DIAMOND DRILL HOLE No 13




## LONGITUDINAL PROJECTION - MILLAR'S LODE




## PLAN SHOWING DD 3,6,8,11, 13.




0 100 200 300 Feet

- Lode, quartz vein
- Open cut, pit or stope
- Greywacke
- Shale
- Bedding
- Projected - in front plane of Section
- Projected - behind plane of Section
- Diamond drill hole showing projection in horizontal plane and inclination (DD 3)

(Assays by Goverment Assayer, Tennant Creek and Australian Mineral Development Laboratories, Adelaide)