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# THE GEOLOGY OF THE TENNANT CREEK GOLD AND COPPER FIELD



Progress Report on the work of the
1958 field season.

by

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## Table of Contents

## Table of Contents (Continued)



## Plates

# THE GEOLOGY OF THE TENNANT CREEK GOLD AND COPPER FIELD.

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## SUMMARY

The aim of the 1958 work at Tennant Creek was to supplement previous surveys by re-mapping part of the field in greater detail than had previously been possible.

The rock types mapped during this programme comprised sediments of the Warramunga Group, quartz-felspar porphyries, quartz-magnetite and quartz-hematite lodes, jasper lenses, quartz reefs, lamprophyre dykes, the Rising Sun Conglomerate and Recent superficial deposits.

The origin of the gold and sulphide orebodies of this field are discussed in the light of the latest available data, and an attempt is made to assess the significance of recent geochemical and geophysical work in the area.

# INTRODUCTION

The aim of the 1958 work at Tennant Creek was to supplement previous surveys by re-mapping part of the field at a scale of 1 inch - 1,000 feet. Air photos of this scale, made available by Peko Mines N.L., were used as the basis for this work. An area of about 115 square miles was covered, lying between grid lines 2,527,000 and 2,544,000 north and between 185,000 and 213,000 east on the Tennant Creek One-Mile map. Further work is to be carried out on the Field in 1959, and this account should therfore be regarded as a progress report only.

In order to avoid unnecessary duplication, frequent reference is made in this report to previous investigations, and only those aspects of our work are discussed in detail in which the present conclusions differ from those of previous workers.

## Previous Work

The most important previous investigation of the field was by Ivanac (1954), who also summarises the results of other geological work in this area prior to 1952.

In 1957, the Bureau of Mineral Resources produced a set of maps on a scale of one mile to the inch, showing total magnetic intensity as measured by an air-borne magnetometer. In the same year, a geochemical party from the Bureau carried out extensive outcrop sampling on the field to determine the relation of trace copper in soil and surface rock exposures to the presence of economic concentrations of copper at depth (McMillan and Debnam, 1957).

Other reports on the field which will be referred to in this discussion are as follows:

C.S.I.R.O. Mineragraphic Reports No. 524, 571, 592, 618, 626, 653, 655 and 724 deal mostly with the mineral assemblages of specimens and drill cores from various mines, especially Peko.

Edwards (1955) gives a very full account of the Peko ore body, with special emphasis on its mineral composition.

Daly (1957) summarises the results of magnetic prospecting by the A.G.G.S.N.A. in this area during 1935 - 1937, and discusses the results of this work in the light of subsequent developments.

Finally, an editorial contribution in the Chemical Engineering and Mining Review (1958) summarises recent developments at the Peko Mine.

## History of Mining and Production

The early history of the field, up to 1952, is fully discussed by Ivanac (1954), and will not be recapitulated here.

However, a number of important developments have taken place since then. In 1954, Peko began the regular production of copper concentrate and became the most important mine on the field in terms of tonnage mined and value of minerals produced. During the following years, a number of prospects on the field were tested by various companies, but although several encouraging results are reported to have been obtained, only one of these prospects appears likely to be developed in the immediate future. This is the Orlando - One-Oh-One area, where exploratory drilling by Peko Mines has resulted in a number of rich gold intersections which it is proposed to develop by means of an exploratory shaft and associated underground workings (Chem. Eng. & Mining Review, 1958).

At the end of the current survey (October 1958), only two established mines were in production on the field. For the twelve months ending 30/6/58, Peko Mines N.L. mined 110,000 tons of ore, containign 7,500 tons of copper and 13,000 ozs. of gold. For the same period, Australian Development N.L. (Noble's Nob) mined 32,000 tons of ore, containing 51,000 ozs. of gold. The Eldorado Mine ceased production in July 1958, and is now on a maintainance basis.

In addition to these mines, a number of prospectors and syndicates were active in the area. Most of these were depending on the Government Battery (re-opened October 1958), for crushing their ore, and many had broken up to several hundred tons of ore in anticipation of this re-opening.

In October 1958, the following mines and prospects were being worked on a small scale by such prospectors and syndicates, many of them on a part-time basis:

Ace High.
Burnt Shirt.
Caroline.
Great Northern.
Joker.
Kathleen.
Lone Star.
Maple Leaf.
Pinnacles.
Pup.
Shamrock.
Susan.
Trump.
Wheal Doria.

The total recorded production of the field to June 30, 1958, amounts to about 625,000 ozs. of gold and 19,000 tons of copper, of which about sixty per cent of the gold and practically all the copper have been won since 1952.

The following table lists all the mines on the field with a recorded production of more than 1,000 ozs. of gold:

| | Tons ore. | Ozs. gold. | Tons copper. |
|---|---|---|---|
| Black Angel & White Devil | 6,400 | 3,020 | |
| Black Cat | 2,200 | 1,020 | |
| Blue Moon | 3,500 | 12,200 | |
| Burnt Shirt | 2,600 | 2,340 | |
| Edna Beryl | 2,600 | 4.240 | |
| Eldorado | 144,000 | 104,680 | |
| Enterprise | 10,000 | 6,600 | |
| Golden Chance | 400 | 1,260 | |
| Hammerjack | 5,900 | 5,520 | |
| Lone Star | 7,500 | 3,850 | |
| Mount Samuel | 2,600 | 4,000 | |
| Noble's Nob | 185,000 | 382,700 | |
| Northern Star | 29,000 | 9,660 | |
| Patties | 1,650 | 1,530 | |
| Peko | 232,000 | 35,520 | 18,920 |
| Red Terror | 600 | 1,310 | |
| Rising Sun | 10,300 | 8,000 | |
| Skipper Extended | 2,100 | 4,250 | |
| Wheal Doria | 2,600 | 2,890 | |
| Whippet | 16,000 | 17,960 | |

Those underlined are situated in the Area examined in 1958.

Physiography

Physiographically, the area consists of groups of flat-topped ridges, generally with an east-south-easterly trend, separated by low-lying areas up to two or three miles across. The maximum relief is of the order of 300 feet, the highest point being Mount Samuel, 1,429 feet above sea level. These ridges are essentially remnants of an old land surface, characterised by a zone of iron enrichment, up to 15 feet thick, underlain by a considerably thicker leached zone. However, no true laterite is present. The characteristic steep-sided profiles of the ridges are due to the undercutting of this iron enriched zone during the current cycle of erosion.

The remnants of this old land surface now commonly slope at angles of one to two degrees. This can be accounted for either on the assumption of an old peneplain, locally upwarped or block-faulted and tilted in geologically recent times, or on the assumption of an originally undulating surface with a relief of at least 300 feet, followed by a change in climatic conditions resulting in pedimentation cutting into the slopes of the former hills.

Typical scenery at Tennant Creek, showing sloping remnants of old land surface. Vicinity of Red Terror Mine.

The resultant pediments now occupy areas up to several square miles on the flanks of some of these ridges and in the headwater areas of major creeks rising within the ranges. The extensive gently undulating areas on the north flank of the Honeymoon Ranges in the vicinity of 940425, (2,542,500 north, 194,000 east), are excellent examples. The present creeks are incised into these pediments to a depth of several feet.

The low-lying areas between the ridges are now largely occupied by "bull-dust", which is essentially wind-borne material of silt-particle size. The maximum thickness of this material seen to date is of the order of six feet, but may of course be appreciably more than this in places.

There are also more restricted areas of true alluvium and poorly sorted creek gravels. At least five feet of locally strongly cemented gravel occur in the vicinity of 955420, and other examples are known from the Mount Rugged area, from the vicinity of the Arizona Mine, and from other localities. The present creeks are generally incised into these deposits to a depth of several feet.

The depth of oxidation is known only from mine workings and from diamond drill holes. In general, the sediments and ironstones appear to be substantially fresh at depths of 150 to 200 feet, but the oxidation of sulphide bodies and of breccia zones often extends to depths of 300 to 350 feet. At Peko, Edwards (1955) believes that the original zone of secondary enrichment in the copper orebody was formed with the water table standing at about 210 feet below the present surface. This zone was subsequently exposed to oxidation by a drop in water table to 260 feet below the present surface, but the water table now stands at 170 feet below the surface.

## GENERAL GEOLOGY

The major rock units occurring in the gold field have been described by previous workers, notably Ivanac. The following table is adapted from Ivanac (page 19) with minor modifications:

| | | |
|---|---|---|
| Tertiary to Recent. | Alluvium, creek gravels and "bull-dust". | |
| Lower middle Cambrian. | Gum Ridge Formation. | Calcareous sandstone, shale and chert. |
| ? Lower Cambrian. | Helen Springs Volcanics. | Lavas and pyroclastic rocks. |
| ? Proterozoic. | Rising Sun Conglomerate. | Conglomerate, sandstone and quartzite. |
| Igneous activity and mineralisation. | | Granite, porphyry, quartz-hematite lodes, quartz veins, gold and sulphide ore bodies. |
| ? Proterozoic. | Ashburton Sandstone. | Sandstone, conglomerate and quartzite. |
| ? Lower Proterozoic. | Warramunga Group. | Greywackes, siltstones and shales, minor grits & pebble beds. |

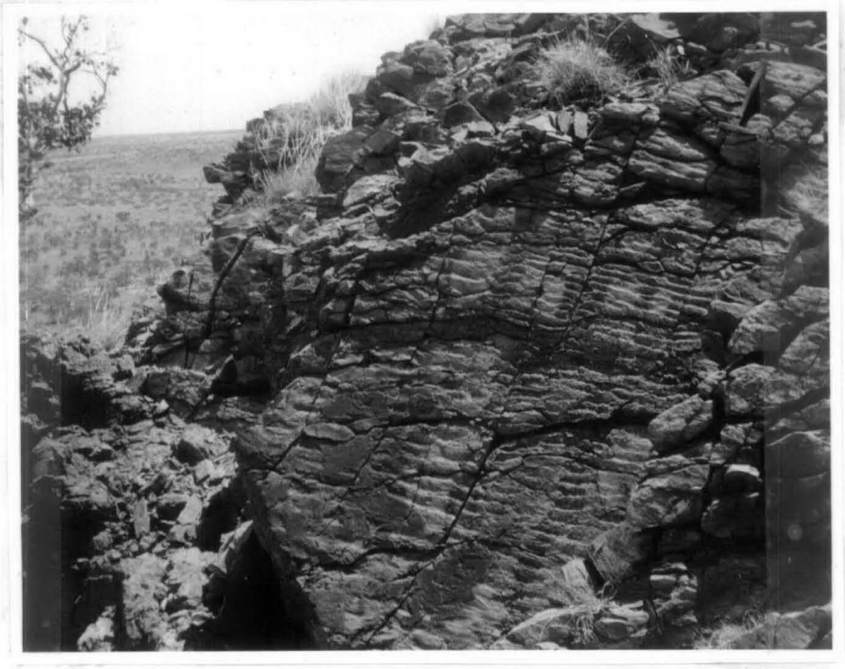
### Warramunga Group

The basement over most of the gold field consists of sediments of the Warramunga Group, comprising greywackes, siltstones and shales with subordinate pebble beds. The thickness of individual beds rarely exceeds 15 or 20 feet and grading bedding is

very commonly developed. Slump structures on a small scale are also very wide-spread and include mud-pellets, balled structures and sole markings. Probably the pebble beds are also the products of slumping on a larger scale.


Minor slump and graded bedding in coarse-grained sandstone of Warramunga Group. Noble's Nob area.

All these features can be accounted for on the assumption that most of the deposition of these sediments took place in moderately deep water and that at least some of the detrital material was carried into its present position by turbidity currents. There are a few occurrences of cross-bedding, indicating that the depth of water was not too great to show the effects of occasional current action, but it is suggested that all previous reports of ripple marks in these sediments should be discounted. These so-called ripple marks are believed to be in part load casts and sole markings and in part structures resulting from the intersection of bedding and cleavage at low angles.



? Ripple marks in Warramunga sediments, half a mile north-east of Red Terror Mine.

The most wide-spread rocks of the normal Warramunga succession comprise a complete range from greywackes through siltstones to shales, but in the field it is only possible to distinguish two main groups, based on joint and cleavage patterns. All the greywackes and some of the coarser sandy siltstones have developed joint patterns composed of two or more sets of joints, generally developed symmetrically to the bedding planes and varying in attitude from bed to bed. The shales and most of the siltstones, on the other hand, have developed fracture cleavage, the trend of which is almost entirely controlled by regional factors and therefore remains almost constant over large areas.

Very few fresh specimens are available for the study of the mineral composition of these rocks, and most of these come from mines, where the rocks are likely to have been affected by metamorphic or metasomatic processes, due to the proximity of ironstone bodies and gold and sulphide orebodies. However, two specimens from the 300-foot level of the Eldorado Mine indicated that quartz and fragments of pre-existing shale are the dominant constituents of the coarser-grained types, while sericitic and chloritic aggregates make up the bulk of the finer-grained ones. Grains of sericitised felspar are probably present in minor amounts, but are difficult to identify with certainty. Both rocks carry relatively abundant magnetite, frequently as euhedral crystals, indicating epigenetic origin or at least recrystallisation after the consolidation of the rock. This, however, may be a local effect, as pointed out above.

Ivanac (p. 20) suggests that a shale facies in the central portion of the goldfield grades into a sandy facies near the margins, but in the more limited area so far mapped during the current investigation, no changes in facies have been observed.

A very distinctive horizon of thin-bedded hematite-rich shales, often with minutely crenulated bedding planes and a peculiar blocky type of outcrop, occurs in the Mount Samuel - Eldorado area, in the vicinity of the Burnt Shirt and Lone Star Mines and at a number of other localities, including, probably, the immediate vicinity of the Northern Star Mine. The thickness of this shale bed varies from a few inches to about 20 feet. To the west of the Eldorado Mine, two bands of hematite shale appear to be present, separated by up to 20 feet of "normal" sandstone and shale, and to the east of the Burnt Shirt two horizons of this hematite shale have been mapped about 250 feet apart. In the Mount Samuel - Eldorado area, this horizon has been traced with only minor interruptions for a distance of more than three miles along the strike, and in the vicinity of the Burnt Shirt Mine for at least two miles. The deposition of these hematite shales is believed to mark a temporary decrease in the supply of detrital matter and to be probably due, at least in part, to the precipitation of iron by chemical or possibly bacterial action. It is probable, however, that the present hematite contents of these rocks represents an alteration product of magnetite, which itself may be a product of metamorphism, derived from hydrated iron oxides or primary hematite. The correlation of the various occurrences of this hematite shale is only tentative at this stage.

There are also a number of isolated occurrences of thin-banded shales, again sometimes with crenulated bedding planes, which lack the high hematite contents of typical members of this group, although they are comparable in all other respects. Such rocks are especially prominent near the eastern extremity of the Burnt Shirt line of outcrops, and they are tentatively regarded as the leached equivalents of the hematite shales.

The pebble beds in the Warramunga Group have so far been

recorded from only three localities. Between 870420 and 880420, a bed with a maximum thickness of some 50 feet has been traced along the strike for more than 2,000 feet. This bed, thickest at the western end and gradually tapering to the east, consists largely of boulders and angular fragments up to two feet in diameter in a matrix of sandy siltstone or shale. Most of these boulders are similar in composition to the typical greywackes, siltstones and shales of the Warramunga Group, suggesting that they were derived by pene-contemporaneous erosion from lower parts of the succession, but a few of them appear to be cut by quartz veins, which is difficult to explain on this hypothesis.

At 115345, a 50-foot section of otherwise normal well-bedded siltstones and fine-grained greywackes contains sporadic pebbles, up to three inches in diameter, of slightly indurated greywacke and shale. Where two such pebbles have been brought into contact by the compaction of the matrix normal to the bedding planes, they show flattening at the interface, indicating that they were still plastic at the time of deposition. A similar occurrence, containing a slightly higher proportion of pebbles, also occurs at 105295. These occurrences are therefore consistent with a picture of extensive transport of material by turbidity currents, the original derivation of the material being by slumping or by intermittent erosion, e.g. by seasonal flood conditions.

Rocks exceptionally rich in chlorite, sericite and sometimes talc have been recorded from several localities, including the 980-foot level at the Peko Mine, the Shamrock Mine, and the contact zone of the large porphyry mass about half a mile south of the Pinnacles Mine. Some of these rocks contain disseminated euhedral magnetite crystals and many of them show sufficiently strong parallelism of the constituent minerals to warrant the names of chlorite schist, talc schist, etc. All the occurrences seen to date appear to be derived from shales of the normal Warramunga type by recrystallisation under strong shearing stresses, possibly in association with hydrothermal activity accompanying the emplacement of the porphyries and ironstones or the gold and sulphide ore bodies.

At Mount Samuel, Eldorado, Noble's Nob, Red Terror and in the vicinity of the Gibbet Mine, a number of beds in the Warramunga Group contain concentrations of ovoid bodies which were at one stage thought to be of organic origin. The occurrences in the Mount Samuel - Eldorado area appear to be restricted to two or possibly three beds, situated only about 20 feet stratigraphically below the hematite shale, but at Noble's Nob and Red Terror the relation is less close. At the Gibbet Mine, this "fossil" horizon is not associated with any hematite shale, and there are also numerous occurrences of hematite shale which are not associated with any "fossil" beds.

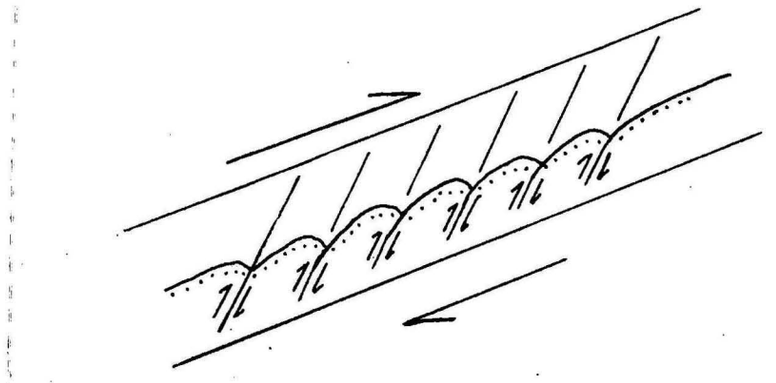
At all these localities, these bodies appear to lie on the fine-grained upper layers of greywacke beds. The individual bodies are ovoid dome-shaped forms, having an apical depression which is probably the outlet of some duct or pipe. The ovoids are mostly one to two inches long, but range up to four inches and down to a quarter of an inch. Their width is usually about two thirds of their length, but this ratio varies considerably, depending apparently on the amount of deformation undergone by the rock, as the elongation is always parallel to the trend of near-by fold axes. The height of the bodies is generally about one quarter of their length.

Thin sections of several of these structures have shown an internal stratification parallel to the domed upper

surface. A central pipe, leading to the apical depression, is composed of relatively coarse grains, while the average size of the particles in the stratified portion of the ovoid decreases from the centre outward. The stratification appears to continue into the surrounding rock, suggesting an origin similar to "sand volcanoes", but their distribution in well-defined horizons requires explanation.

"Fossils" from 100 yards south of Red Ned Mine, near Mount Samuel. Scale shown by match-box.

The minor structures described as ripple marks by previous workers are now thought to be accounted for either as pene-contemporaneous features, such as load casts and sole markings, or as the effects of minor disturbance of the bedding planes by movement on closely spaced shear and cleavage planes cutting the bedding at low angles. The latter type of structure may be comparable to drag-folding on a small scale, except that the movements are localised on cleavage planes instead of being continuously distributed.

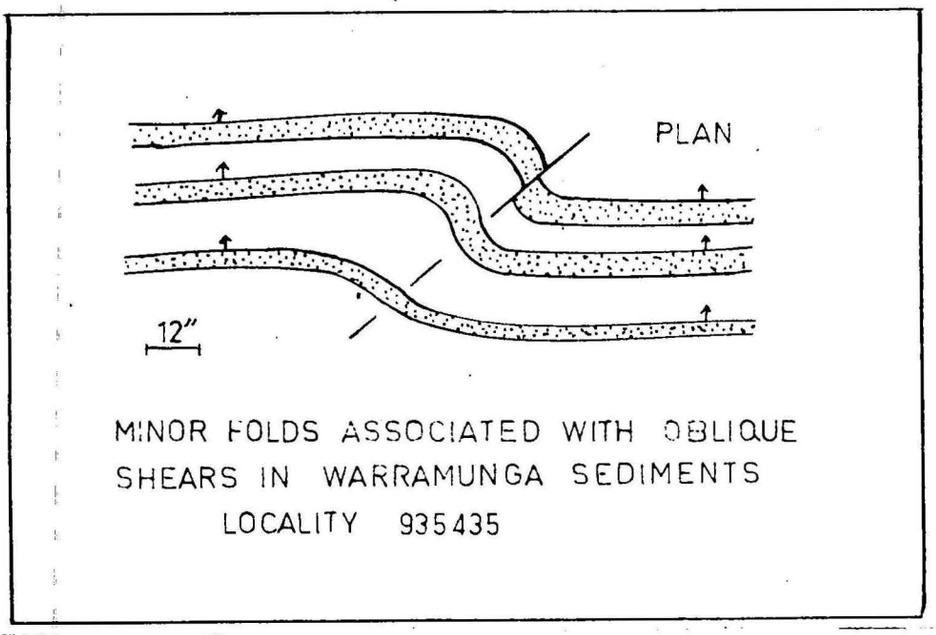



PSEUDO RIPPLE MARKS DUE TO ACUTE ANGLE INTERSECTION OF CLEAVAGE AND BEDDING PLANES. (DIAGRAMMATIC).

The dominant structural features in the Warramunga sediments are folds with roughly east - west axes. Dips average about 60 degrees, but occasionally reach 90 degrees, and in a few instances by reference to the bedding - cleavage relationship and to graded bedding, were found to be overturned. Most of the folds are roughly symmetrical, except in the Mount Samuel - Eldorado area, where a major monoclinal structure in an area of dominantly gentle dips has produced a local steepening of dips to the north.

Pitches are dominantly to the east at angles of up to 20 degrees in the Mount Samuel - Eldorado area, and to the west at angles of up to 30 degrees in the Honeymoon Ranges and the Peko - Golden Forty area. Other areas show more variable pitches, often with rapid reversals.

In some areas, two periods of deformation are indicated by the presence of minor folds pitching down the dip of the limbs of the major folds. These often take the form of "bruch-falten", associated with oblique shears, and can sometimes actually be traced into clean breaks along the strike of the shears.




MINOR FOLDS ASSOCIATED WITH OBLIQUE SHEARS IN WARRAMUNGA SEDIMENTS LOCALITY 935435

The cleavage throughout this area tends to strike about 080 degrees and to dip about 80 degrees north. It does not appear to be influenced to any great extent by changes in the strike and pitch of the beds or the near-by fold axes.

Shearing and faulting are very wide-spread in the Warramunga beds. They range from clean breaks to zones of brecciation and mylonitisation more than a hundred feet wide, and the resultant displacement may be anything from a fraction of an inch to several hundred feet. Many of them have subsequently been infilled or replaced by quartz reefs or quartz-hematite lodes.

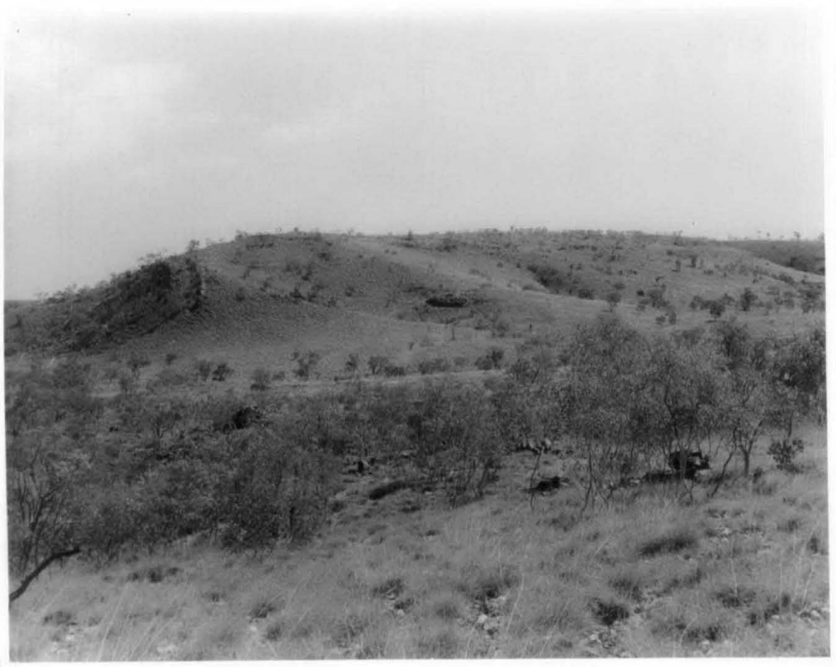
They fall into several sets, which are unequally developed in different parts of the area. The most wide-spread of these sets strikes between 090 and 100 degrees and accounts for nearly half of all the shears observed. To the north-east of the Lone Star Mine, a major zone of disturbance (the Quartz Hill - Rocky Range fault system) trends about 120 degrees, and numerous minor shears have developed parallel to this direction in this vicinity. To a lesser degree, this trend is also represented in the Honeymoon Ranges and in the vicinity of the Eldorado Mine. Shears striking east-north-easterly (average 060 to 070 degrees) form a subordinate but significant set in the Honeymoon Ranges, around the Government Battery, and in the Caroline, Gibbet and Peko - Golden Forty areas. In addition, mary areas show subordinate sets striking north-north-east (average 020 to 030 degrees) and north-north-west (320 to 340 degrees). These also reach a maximum in the Red Terror and Peko - Golden Forty areas.

Ashburton Sandstone

The Ashburton Sandstone does not occur within the area mapped in detail in 1958. Reconnaissance trips to the area north and north-east of the Last Hope Mine tended to confirm Ivanac's suggestion that the Warramunga sediments in this area pass conformably up into the Ashburton Sandstone. There is undoubtedly a steady increase in the proportion of sandstone to shale as this boundary is approached, and these sandstones become more siliceous, better sorted and more strongly cross-bedded. Nevertheless, the shape of the Warramunga - Ashburton contact as shown on Ivanac's map suggests an unconformity, and the question will only be satisfactorily resolved by detailed mapping of several miles of this boundary.

Rising Sun Conglomerate

As far as it has been mapped to date, this formation covers an area of approximately six miles by a quarter of a mile, elongated in a general east-south-easterly direction, to the south of Noble's Nob, the Rising Sun and the Red Terror Mines. It is composed largely of conglomerates, quartzites and grits, and rests on an eroded surface of porphyry and Warramunga sediments. Structurally, it forms a syncline with its axis parallel to the long dimension of the outcrop, but the southern margin of the occurrence is strongly faulted and in places the entire southern limb appears to have been faulted out. Dips are of the order of 20 to 30 degrees in the northern limb of the syncline, but those in the southern limb are much less regular and are locally overturned. The maximum exposed thickness is of the order of 600 feet, but the original thickness may of course have been very much greater than this.



Rising Sun Conglomerate unconformably overlying porphyry and Warramunga sediments. South-west of Red Terror Mine, looking south-west.

The pebbles in the conglomerate range up to about 18 inches in diameter and are largely sandstones and quartzites, often with a strong lithological resemblance to the Ashburton and Davenport Range Formations. The formation is cut by a number of quartz veins, especially in its faulted southern portion, but is not intruded by any of the igneous rocks of the area. The basal pebble bed of the Rising Sun Formation with a thickness of up to ten feet had been regarded as "porphyritised" by a number of previous workers because its matrix consists largely of quartz and felspar grains derived from the underlying porphyry, probably without very much transport. However, careful examination always discloses a sharp boundary against the porphyry itself.

The folding of this formation and its invasion by quartz veins must therefore be attributed to a much later period than that responsible for the major phase of folding and intrusion of the Warramunga sediments.

Granite and Porphyry

Within the area mapped in detail, the Warramunga sediments are intruded by numerous quartz-felspar porphyry bodies occupying areas up to two miles by half a mile, notably in the vicinity of the Aerodrome, south of the Red Terror Mine and to the east and south-east of Peko. These rocks are commonly strongly sheared, and in the hand-specimen are not always distinguishable from the grits of the Warramunga Group. In the field, however, they can usually be identified by their uniform appearance over much greater widths than the maximum thickness of individual beds of the Warramunga Group and by their transgressive contacts.

Nearly all these masses are elongated east - west, parallel to the dominant strike of the Warramunga sediments, and the direction of shearing is generally also parallel to this direction. The transgressive relations of these bodies are usually most obvious at the east and west tips, where the sediments have been forced apart and often shattered to some extent.

Some of the larger masses have been sheared only in their marginal portions, leaving a relatively fresh core of bluish-grey or greenish-grey rock studded with glassy quartz and white or flesh-coloured felspar. The sheared phases are generally more strongly weathered and are reddish-brown in colour.

Petrologically, the occurrence to the south of the Red Terror Mine has been examined in greatest detail. This consists largely of quartz, microcline and oligoclase-andesine phenocrysts, all up to a quarter of an inch in diameter, in a matrix of irregular quartz granules, sericite flakes, epidote and magnetite dust.

An unusual phase occurs in the vicinity of the Black Angel Mine, some 25 miles north-west of Tennant Creek township. Here, several bands of porphyry, up to 100 feet wide, trend roughly north-west, parallel to the locally dominant trend of the Warramunga sediments. These porphyry bands are characterised by the presence of rounded clots of quartz phenocrysts (? glomero-porphyritic texture), and were mapped as conglomerates by Ivanac (p. 123), although their true nature had been recognised by Owen (1942).

The contact metamorphic effects of most of these intrusions are restricted to the silicification of a few favourable beds and breccia zones, which have given rise to prominent jasper bars, sometimes extending for up to a quarter of a mile from the nearest porphyry outcrop. Apart from this silicification, however, the sediments rarely show any alteration visible to the naked eye, even within a few inches of the contacts. The same applies to xenoliths, which are very common in some areas, e.g. at 060350.

A few specimens from the central, unsheared portion of the Aerodrome porphyry were found to contain specks of disseminated sulphides (chalcopyrite and pyrite), and at several other localities, notably about three quarters of a mile south of the Pinnacles Mine, the weathered porphyries contain cavities partly filled by limonite, which may be, at least in part, residual after the leaching of sulphide minerals. The possible significance of this will be more fully discussed in a later section.

Outside the area mapped in 1958, the Warramunga sediments are intruded by adamellite at the Old Telegraph Station, about seven miles north of the town, by granite at the Cabbage Gum bore, about ten miles south of the town, and by granodiorite to the south-east of Noble's Nob. In general appearance and degree of

shearing, the granite and adamellite are comparable to the porphyry, but the granodiorite appears rather fresher and less deformed.

The adamellite - porphyry relations may be discernible in the vicinity of the Bernborough Mine, where Ivanac's mapping shows outcrops of the two types in close proximity, but the relations of the two southerly occurrences are not likely to be directly observable.

A number of igneous rocks also occur in the vicinity of the Last Hope Mine, about 30 miles north-west of Tennant Creek. At the mine itself, Ivanac (p. 143) records a series of lavas or tuffs occurring within the transition zone from the Warramunga beds to the Ashburton sandstone. Some three miles east of this mine, several bodies of igneous rock occupy areas of up to half a mile by a quarter of a mile, but are so deeply weathered and iron-stained that their characteristics and relations to the surrounding sediments could not be established. Residual mineral grains and textures suggest that they may have been medium-grained acid or intermediate rocks, possibly related to the porphyries. Similar rocks also occur within the Ashburton Sandstones themselves, about 30 miles north of the township.

Lamprophyres

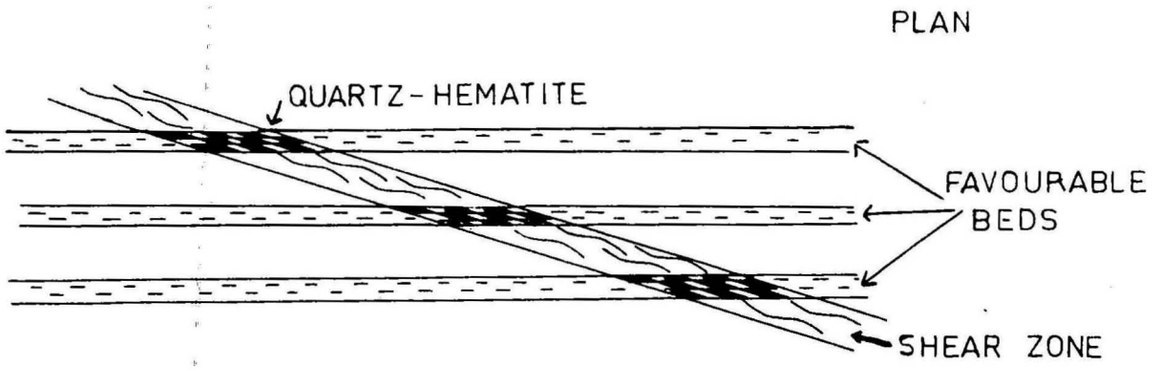
The Warramunga sediments are also intruded by a number of fine - to medium-grained intermediate and basic rocks, tentatively grouped as lamprophyres. These usually occur as irregular bodies not more than 200 feet by 200 feet in extent, and are generally deeply weathered. An exceptionally large member of this group occurs in the vicinity of 910420, where it has been traced intermittently for more than half a mile with an average width of 100 to 150 feet, apparently following a major fault or shear zone. Others occur as flat-lying sheets, up to 20 feet thick, again presumably following joints or shear zones. At the Caroline Mine, at least one such sheet cuts across the quartz-hematite lodes, which are exposed in shafts, adits and costeans. At the southern flank of the Aerodrome porphyry, one of these lamprophyres occurs within a few feet of the porphyry, but the contact relationships are obscured by shearing.

The petrology of these rocks has not been investigated in detail, but they appear to include amphibolites and pyroxenites, as well as biotite-rich types. The outcrops of these rocks are commonly marked by a strong development of travertine, which may be regarded as almost diagnostic of this group.

Ironstones

The general term ironstones is retained for the quartz-hematite and quartz-magnetite bodies of this area. As a rule, the iron oxide is hematite at the surface and magnetite below the water table, but some occurrences still carry significant amounts of magnetite even in the oxidised zone.

They range from a few inches to more than forty feet in width and up to several hundred yards in length. Some of them have developed in shear zones, while others replace favourable beds, and many of them are controlled by a combination of these two features, i.e. they are located at the intersection of a major shear zone with favourable beds, generally mudstones. A pattern of right-hand echelon repetition tends to be developed under these circumstances, as most of the shears responsible for this type of intersection strike east-south-east, compared to a general east - west strike for the bedding.



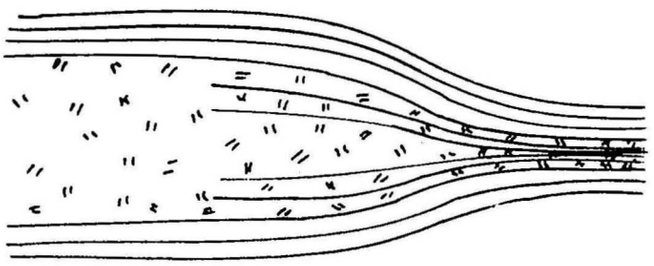

QUARTZ-HEMATITE LOCALISED BY INTERSECTION OF SHEAR ZONE AND FAVOURABLE BEDS IN THE WARRAMUNGA GROUP. (DIAGRAMMATIC).

Most of the ironstones are tabular or lenticular in shape, but some are irregular and one (at 006400) was found to have the shape of an inverted saddle reef. The elongation for the great majority of them is east - west, parallel to the regional strike of the bedding and cleavage and the accompanying set of strike faults and shears. However, minor sets, striking about 070 degrees are fairly wide-spread, generally in response to a set of shear-zones with that trend, and strikes of 130 degrees, parallel to the Quartz Hill - Rocky Range fault system, become important in the vicinity of the Lone Star Mine and in parts of the Honeymoon Ranges. There is also a minor set striking 040 degrees, best developed in the vicinity of the Government Battery and in the Peko - Golden Forty area. The Peko orebody itself, which has the shape of a steeply plunging pipe, is exceptional and will be discussed in detail in a later section.

The contacts of these ironstones with the surrounding sediments may be either sharp or gradational. In the latter case, a transition zone consisting of country rock traversed by a large number of very small hematite veinlets, may reach a width from one or two inches to several feet. In general, sharp smooth contacts appear to be the rule whenever replacement terminated against a well-defined major shear plane, and gradational contacts whenever replacement was limited by a change of lithology or a gradual decrease in intensity of shearing. Transitions from one type to the other can sometimes be observed along the strike of an individual quartz-hematite body.

Differential replacement of very thin laminae of the country rock is comparatively rare. A good example occurs at 938432, where certain laminae of a minor drag-fold have been selectively replaced. Along the strike, this occurrence passes into a massive quartz-hematite body occupying a shear zone.

The fact that the quartz-hematite bodies have not only replaced the pre-existing sediments volume for volume, but have also pushed them apart bodily is well shown by a small exposure at 053271, where the banding of the sediments can be traced into and around a small quartz-hematite lens.




WARRAMUNGA SHALES APPARENTLY PASSING LATERALY INTO IRONSTONE AND INCREASING IN VOLUME.
LOCALITY 053271

Many of the quartz-hematite bodies are themselves sheared or faulted, indicating that major movements have affected the area subsequent to their emplacement. Almost all mines have encountered such faults in their workings, the largest having displacements of the order of a hundred feet or more, and a number of others became apparent during the regional mapping, e.g. in the vicinity of the Burnt Shirt, Kathleen and Plain Jane Mines.

The proportion of quartz to iron oxides (hematite and/or magnetite) varies widely, even within a single body, and many of the lodes are themselves cut by younger quartz veins free from iron oxides. In general, long narrow bodies of ironstone, which follow the bedding closely, tend to carry less quartz than the more lenticular bodies associated with shear zones. The two types are well contrasted in the vicinity of the Queen of Sheba Mine, about 20 miles north of the township, where the quartz-rich phase appears to be the younger of the two.

Mineragraphic evidence indicates that the hematite of these lodes is derived from magnetite, but the degree of oxidation varies considerably and some magnetite is often preserved even at the surface. Many grains of iron oxide from these lodes show the crystal form of magnetite and are attracted by a hand magnet but give a hematite streak, suggesting that partial pseudomorphous replacement has taken place.

Theoretically, the oxidation of magnetite to hematite can be accomplished either by hydrothermal or by supergene solutions. In this area, the evidence of magnetometer surveys, deep drilling and mine development all indicate a very abrupt increase in the hematite contents of the ironstones above water level, showing that supergene solutions have been responsible at least for a large proportion of the hematite. On the other hand, the presence of bladed hematite intergrown with quartz, talc and chlorite in many of the occurrences indicates that hydrothermal effects have also played a part. The relative importance of the two factors thus has to be evaluated for each occurrence, largely on the basis of mineralogical studies.

Origin of iron now contained in quartz-hematite and quartz-magnetite lodes. A very rough estimate suggests that ironstone lodes and lenses occupy areas of the order of 10,000 to 50,000 square feet per square mile in various parts of the area mapped during 1958. This is equivalent to about 0.04 to 0.20 per cent of the country rock by volume or 0.08 to 0.40 per cent by weight. If the iron oxides now contained in some of the major shear zones are included, this figure might have to be increased by a factor of two or three, but would even then be no more than 0.2 to 1.0 per cent by weight.

Examination of the heavy mineral fraction of two specimens of Warramunga sediments from the Eldorado Mine revealed the presence of 0.7 per cent by weight of magnetite in a sandstone and 1.0 per cent in a sandy shale. These may not be truly representative of the sediments of the area, as they may have undergone some enrichment in iron associated with the introduction of the near-by massive ironstone bodies. However, these figures show that at least some of the sediments in the area carry as much as one per cent of magnetite as disseminated grains, so that the total amount of iron present in defined lodes and heavily impregnated shear zones may be no greater than that present in the sediments themselves.

If all this iron is regarded as being largely or entirely derived from a magmatic source, it is necessary to assume a very complete penetration of the Warramunga sediments by the iron-bearing solutions. Alternatively, if the iron is thought to be merely re-distributed by percolating solutions, it is only necessary to assume the concentration of one half of the iron originally present in the sediments to account for all the ironstones and iron-impregnated shear-zones now observed on the field. It may of course be that both of these processes have been active in this area.

Relation of ironstone bodies to hematite shale beds. In the Mount Samuel - Eldorado area, there is a very close association of major ironstone bodies with the bed of hematite shale. This could be due either to the fact that the hematite shale and immediately adjoining beds provided the source of the iron which was concentrated into these ironstones, or that these beds were especially favourable for replacement by iron by reason of their physical or chemical constitution.

The same association of hematite shale with ironstone bodies has been observed in the Burnt Shirt area, near the Lone Star and Great Bear Mines, and possibly at the Northern Star Mine. On the other hand, there are several occurrences of hematite shale not associated with ironstones, as in the area half a mile north of the Burnt Shirt Mine, and there are of course very many ironstones in areas where no hematite shale is as yet known. Further mapping in adjoining parts of the field may throw some additional light on this problem.

Jasper Beds and Breccias

These are replacement bodies similar in many ways to the ironstones, but composed mainly or entirely of crypto-crystalline silica, generally coloured red by minor amounts of iron oxides. They are best developed in the vicinity of the Aerodrome and at East Peko, and generally occur within a few hundred feet of one or other of the larger porphyry bodies. Their dimensions are comparable to those of the ironstones and some of them pass along the strike into rock types indistinguishable from typical quartz-hematites, while others contain minor coatings of hematite on joint planes.

The inference drawn from these relations is that the jaspers are the result of the silicification of favourable beds and shear zones in the Warramunga sediments by solutions emanating from the porphyries, and that the ironstone bodies are the results of similar replacements by more iron-rich solutions at greater distances from the porphyry contacts. Occasional inclusions of jasper fragments in quartz-hematite lodes indicate that the jaspers were the earlier formed of the two.

The jasper breccias consist essentially of angular fragments of jasper re-cemented by white vein quartz, indicating that the emplacement of these jaspers was followed by a second period of deformation, which resulted in the shattering of some of them, and by a second period of silica introduction, this time as vein quartz.

Quartz Veins

Quartz veins with only subordinate amounts of iron oxides appear to have been the last phase of mineralisation affecting this area. They cut all other rocks, including the ironstone lodes, the jasper bodies, the porphyry and adamellite intrusions, the Ashburton Sandstone and the Rising Sun Conglomerate. They range in size from veinlets a fraction of an inch in width to massive bodies up to thirty or forty feet wide and intermittently traceable for many miles, as in the Quartz Hill - Rocky Range fault zone. Strikes of 090 degrees predominate, but important minor sets strike 060 to 070 degrees (especially in the vicinity of Peko), 030 to 040 degrees (Honeymoon Ranges), 340 degrees (Eldorado area) and 120 degrees (Lone Star area).

In the vicinity of Mount Rugged and in the Gibbet area, a number of them contain minor amounts of tourmaline, but otherwise they are singularly free from associated minerals.

## ECONOMIC GEOLOGY

### Gold Deposits

The workable gold deposits in this area 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 individual mines and prospects on the field have been described in detail by Ivanac, and these descriptions will not be duplicated here.

Since the completion of Ivanac's survey, only one potentially important discovery of new gold-bearing material has been made on the field. This is in the Orlando - One-Oh-One area, mentioned in an earlier section, where five diamond drill holes by Peko have given results of up to 26 dwts. of gold per ton over 22 feet of inclined depth (Chem. Eng. & Min. Rev., Nov. '58).

However, increased exploration has now indicated the presence of sulphides at several mines where development or drilling had not previously penetrated below water level, and it therefore seems increasingly likely that all the gold deposits of the field were originally associated with at least some sulphides. As these sulphides have now been entirely removed from the shoots being worked in all mines except Peko, this would tend to suggest that the gold must also have undergone some re-distribution and possibly secondary enrichment. The structural and lithological factors controlling the distribution of gold in shallow workings may thus be controls for enrichment rather than for original deposition.

This applies especially to the concentration of values in the brecciated sediments immediately adjoining some ironstone bodies and in shear zones and pure seams intersecting them. It is tentatively suggested that most if not all of these occurrences are due to the secondary concentration of gold originally present in the massive quartz-hematite bodies or uniformly distributed through the adjoining sediments.

Sulphide Deposits

With the emergence of Peko as the largest mine on the field, interest in the exploration for copper is now equalling or surpassing that for gold. However, since none of the other mines has so far exposed any primary ore, it is difficult at this stage to generalise on the factors responsible for the localisation of copper orebodies.

At Peko, massive sulphides, (essentially pyrite, pyrrhotite and chalcopyrite), replace the central portion of a quartz-magnetite pipe (Edwards, 1955). This quartz-magnetite differs in shape from the typical tabular bodies of the field and J. Elliston (personal communication) has suggested that it is due to the replacement of an original slump conglomerate, similar to that mapped as a "pebble bed" from the vicinity of the Caroline Mine. However, the Caroline pebble bed has a fine-grained impervious matrix, and does not appear intrinsically favourable for replacement. An alternative suggestion for the controlling influence of the Peko orebody would be the intersection of a steeply dipping shear zone striking 030 degrees with a zone of favourable beds or a shear-zone sub-parallel to the bedding, which here trends roughly easterly. The sediments adjoining the orebody are reported by Elliston to show only moderate disturbance, but the presence of chlorite schist on the 980-foot level suggests fairly intense shearing, and the presence of two sets of linear structures is strongly suggested by the pattern of the aerial magnetic map of this area.

Low-grade lead and zinc mineralisation is recorded from the footwall sediments of the copper orebody at Peko (Edwards, 1955), but little is so far known about its extent and relation to structural or lithological controls.

At several other mines and prospects, disseminated sulphides have been recorded from diamond drill holes in sheared or brecciated sediments, associated with varying amounts of quartz and hematite or magnetite. The most important of these occurrences are as follows:

Northern Star: 4.05 per cent copper between 967 and 977 feet inclined depth in Peko Mines Ltd's diamond drill hole (Chem. Eng. and Min. Rev., June 1957).

Orlando: 9.1 per cent copper between 348 and 353 feet inclined depth in Peko Mines Ltd's diamond drill hole No. 3 (Chem. Eng. and Min. Rev., Nov. 1958).

Wheal Doria: Disseminated sulphides with hematite and magnetite in chloritic slate between 157 and 170 feet in hole No. 4, and between 167 and 183 feet in hole No. 4 A, both vertical (A.G.G.S.N.A. Report, N.T., No. 41).

Eldorado No. 3 Anomaly: Five assays averaging 0.48 per cent copper in sheared rocks with quartz and magnetite between 413 and 452 feet vertical depth in hole No. 2 (A.G.G.S.N.A., Report, N.T., No. 41).

Peko No. 2 Anomaly (East Peko): Specks of sulphides in slate and dense magnetite between 264 and 280 feet vertical depth in hole No. 5 (A.G.G.S.N.A., Report, N.T., No. 41).

Noble's Nob: Minor amounts of pyrite and chalcopyrite in quartz-hematite and brecciated sediments between 268 and 278 feet and between 321 and 331 feet inclined depth in hole No. 2, Bureau of Mineral Resources (Ivanac, 1954).

Golden Forty Mine: Average assay of 1.5 per cent copper over 41 feet of chlorite schist in hole drilled by National Lead Co. of U.S.A. (personal communication, R.D. Ellett, quoted by J. McMillan, 1957).

In addition, secondary copper minerals have been worked in sheared and brecciated sediments at the Pinnacles and Shamrock Mines. None of the workings at these mines have so far encountered primary ore, but it seems likely that this would consist of disseminated sulphides, similar to those recorded from some of the diamond drill holes listed above, with a strong possibility of the presence of a secondarily enriched zone at or near the water table.

At the Aerodrome, a few specks of sulphides (chalcopyrite and pyrite) were found in massive quartz-felspar porphyry. At several other localities, notably about three quarters of a mile south of the Pinnacles Mine, the weathered porphyry contains cavities partly filled with limonite, which are regarded, at least in part, as box-works due to the leaching of sulphide minerals. Spectrographic analyses of the limonite of two of these specimens have confirmed the presence of small amounts of copper and further tests are in progress. If the presence of traces of copper in these porphyries proves to be wide-spread, a geochemical programme of testing may indicate areas warranting more detailed examination by geophysical resistivity or self-potential methods and by diamond drilling.

The presence of copper in these porphyries strengthens the suggestion that the copper now occurring in the ironstones and Warramunga sediments was also derived from the porphyries in the first instance, especially as all known occurrences lie within about three miles of one of the major porphyry intrusions. This raises the question of the relation of the gold- and sulphide-bearing solutions to those responsible for the emplacement of the ironstones. At Peko, mineragraphic evidence indicates that the emplacement of the ironstone was essentially complete before the introduction of the gold and sulphides (Edwards, 1955). In areas of disseminated magnetite-sulphide occurrences, as at Wheal Doria and Eldorado No. 3 Anomaly, relations are not as clear-cut, but it still appears improbable that solutions should be capable of simultaneously depositing significant quantities of iron oxides and sulphides.

If the two phases of activity were distinct, it follows that the present occurrence of gold and sulphides in close association with ironstone is not necessarily universal, being due only to the fact that generally the same channels tended to control the flow of both sets of solutions. Numerous ironstones are of course known which do not carry gold or sulphides, but there are very few examples to date of gold or sulphide deposits not associated with ironstone. The intersection of 41 feet of chlorite schist, carrying an average of 1.5 per cent copper without significant amounts of iron oxides in a diamond drill hole at the Golden Forty Mine (McMillan, 1957), is one example of such an occurrence, and the occurrences of secondary copper minerals at the Shamrock and Pinnacles Mines may also be derived from such bodies. In general, shear zones not carrying significant amounts

of iron oxides 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. Geophysical methods, such as resistivity and self-potential surveys, may be of value in detecting and tracing such shear-zones carrying sulphides at depth. Relations at the Wheal Doria, Pinnacles, Joker and Red Terror Mines suggest that shear zones striking 060 to 070 degrees may be especially favourable for such mineralisation.

Magnetic Anomalies

On the aerial magnetic map of the area mapped in 1958, a pattern of regional anomalies with east-south-easterly trends is combined with local anomalies due to individual ironstone bodies. These east-south-east trends appear to be made up of elements parallel to the prevailing strike of the sediments (090 degrees), and to two of the dominant directions of shearing (100 and 120 degrees). A second set of linear features, striking about 030 degrees, probably also related to faults or shear-zones, is present in the Peko - Golden Forty area.

Areas of low magnetic relief, as in the vicinity of the Aerodrome and between Peko and Eldorado, correspond to areas where igneous rocks are exposed at the surface or are believed to underlie it at relatively shallow depths.

A very sharp break in the pattern is apparent at the line of the Quartz Hill - Rocky Range fault zone. To the north-east of this line, magnetic relief is very low, although outcrops of Warramunga sediments, complete with ironstones, etc., persist, especially in the Golden Mile and New Moon areas. One possible explanation is that igneous rocks underlie this area at a depth not far below water-level, so that only the oxidised zone of the Warramunga sediments is represented, which does not give rise to significant magnetic anomalies. Alternatively, the pattern could be explained by much greater depth of oxidation on the north-east side of the fault zone, or by a change in the magnetite contents of the sediments themselves. Detailed mapping of the area north-east of the fault zone will probably indicate the correct explanation.

At the northern edge of the gold field, a very distinctive pattern is developed in the area occupied by the Ashburton Sandstone. This consists of strong linear anomalies parallel to the Ashburton - Warramunga contact and to the trends of the Ashburton Sandstones themselves. The geological interpretation of this pattern is not possible at this stage, due to lack of detailed mapping in this area.

Of the anomalies due to individual ironstones, only the larger ones, such as the Peko, Golden Forty and Eldorado No. 1, are obvious on the aerial map, and some of these, such as Golden Forty, can be divided into several smaller anomalies on the basis of ground surveys. However, ground magnetic surveys by A.G.G.S.N.A., the Bureau of Mineral Resources and private companies have by now covered a very large proportion of the areas on the field where potential gold or base-metal lodes might be expected, and more than fifty separate anomalies are now known. Of these, many are related to outcropping ironstone bodies, but others show no relation to any outcropping features.

There are at present no reliable criteria for distinguishing anomalies due to non-outcropping gold- or copper-bearing quartz-magnetite lodes from those due to barren bodies.

Unfortunately, the only orebody which is adequately exposed below water level (Peko), is not typical of the ironstone bodies of this field in that it has a pipe-like rather than a tabular shape. Disregarding the question of whether this is due to tectonic factors, such as the intersection of two shear zones, or to the shape of the original sedimentary unit now replaced by the orebody, it may be that the shape of the original quartz-magnetite body was an essential factor in determining its subsequent replacement by the gold-sulphide mineral association. In this case, prospecting on this field would be reduced to the search for similar steeply pitching pipe-like bodies. Alternatively, it may be that the shape of the ironstone body was not a critical factor, in which case the chances of finding significant gold-sulphide mineralisation in any quartz-magnetite body are about the same as those of finding payable shoots of gold in the corresponding quartz-hematite surface outcrops. This chance is thought to be of the order of one in ten. On this theory, the average size of ore shoots at depth would be expected to be of the same order as those on the surface. In the area mapped in 1958, about 360 lenses of ironstone were encountered, of which about 50 have been recorded as producing some gold. Of these, 13 have produced less than 100 ozs., 21 between 100 and 1,000 ozs., 10 between 1,000 and 10,000 ozs., and three more than 10,000 ozs. However, an ore shoot capable of producing 10,000 ozs. is equivalent to a body of 10-dwt. material measuring only 10 ft. by 100 ft. by 150 ft., so that exploration at depth for targets of this size will be a matter of some difficulty. Moreover, a shoot of these dimensions, although an attractive proposition at the surface, may not be economically mineable at a depth of several hundred feet, so that the proportion of quartz-magnetite bodies containing actually payable shoots of primary ore may be nearer one in a hundred than one in ten.

Geochemical Results

A geochemical prospecting campaign for copper was carried out by a Bureau of Mineral Resources party under J. McMillan in 1957. Essentially, it consisted of the analysis of numerous surface and near-surface samples, both of soil and of bed-rock, for trace amounts of copper. A concentration of 10 parts per million of copper in sediments and 30 parts per million in ironstones was regarded as background for the area, and concentrations significantly higher than this (more than twice background) were thought to indicate the presence of significant amounts of epigenetic copper in the vicinity of the sample.

Such anomalously high concentrations could be due either to residual copper remaining in an originally mineralised rock after oxidation and partial leaching, or to copper introduced from near-by mineralised formations by circulating ground waters. The search for the source of these copper concentrations would thus have to be guided in each case by geological considerations.

The areas listed by McMillan for further testing on the basis of this geochemical prospecting campaign were as follows (with comments on recent exploration and development work):

Cat's Whiskers: The major magnetic anomaly on this prospect is currently being drilled by Eldorado Tennant Creek Ltd. (November 1958).

Pinnacles: Some rich secondary copper ore has been worked to a depth of about 20 feet. The prospect is currently being re-opened as a gold mine, but no exploration below water level has been carried out to date. No major magnetic anomalies are known from this area.

Peko: This mine is being adequately developed and explored.

East Peko: This prospect has been drilled by the A.G.G.S.N.A. and by Peko Mines N.L., but only minor amounts of gold and copper were encountered (A.G.G.S.N.A. Report No. 41 and J. Elliston, personal communication).

Golden Kangaroo (= Golden Forty North): Two holes drilled by the National Lead Co. of U.S.A. on a combined geochemical and magnetic anomaly failed to encounter either sulphides or any magnetic material (McMillan, 1957).

North Star: 4.05 per cent of copper was encountered at an inclined depth of 967 to 977 feet in a diamond drill hole put down by Peko Mines N.L., but the discovery has not been followed up (Chem. Eng. & Min. Rev., June 1957).

Queen of Sheba: The mine has been worked for gold only and no testing at depth has been carried out to date.

Orlando: Two magnetic anomalies on this line were drilled by Peko Mines N.L. One intersection of 9.1 per cent copper was obtained over an inclined depth of five feet, but it is proposed to open the prospect primarily as a gold mine (Chem. Eng. & Min. Rev., Nov. 1958).

It will thus be seen that out of the eight targets listed by McMillan, two are being actively developed (Peko and Orlando), three have been tested and discarded (East Peko, Golden Kangaroo and North Star), one is being tested at present (Cat's Whiskers), and two still require testing at depth (Pinnacles and Queen of Sheba).

For future geochemical work in the area, it is suggested that attention be transferred from the ironstones to shear-zones of the Pinnacles, Shamrock and Wheal Doria type, and to outcrop areas of porphyry, especially where these contain limonite-filled cavities which might be interpreted as box-works.

Note on Maps

Two main maps have been drawn to accompany this report. One emphasises rock types, including ironstones and quartz veins, but shows only generalised trend lines of the Warramunga sediments. The other shows all dips and strikes recorded in the Warramunga sediments, as well as fold axes, but omits details of igneous rocks, veins and lodes.

## REGIONAL GEOLOGY

For descriptive purposes, the area has been divided into eleven regions, based largely on continuity of outcrop and named after prominent mines or natural features. An attempt has been made to outline the outstanding characteristics of each region, but in order to avoid unnecessary duplication, relationships which hold throughout the goldfield and which have already been referred to in the previous sections will not be repeated. The order of discussion is based largely on convenience, so that areas with least specialised features are discussed before those with unusual relationships.

The regions, in order of discussion, are:

Honeymoon Ranges.
Mary Ann.
Government Battery.
Peko - Golden Forty.
Lone Star.
Caroline.
Gibbet - Aerodrome.
Eldorado.
Mount Samuel.
Noble's Nob.
Red Terror - Joker.

Honeymoon Ranges

This area lies roughly between 39,000 and 42,000 north and between 92,500 and 00,000 east, and contains the largest continuous extent of outcrops on the whole field. The Honeymoon Ranges themselves are a series of flat-topped hills rising up to 200 feet above the surrounding plains in the south-western part of the area.

The rocks are typical Warramunga shales and greywackes and rare grits, with dips averaging 60 to 70 degrees. To the west of 97,000 east, the major structure is a west-pitching anticline with axis at about 41,000 north. To the east of 97,000 east, several other fold axes can be traced to the south of this main anticlinal structure, and the westerly pitches locally steepen to as much as 45 degrees.

The hematite shale can be traced for about two miles on the southern limb and for over one mile on the northern limb of the main anticline and a group of major north-south trending faults can be mapped by the displacements of this marker horizon. Other shear zones are dominantly sub-parallel to the strike of the bedding, but one major zone with a trend of about 110 degrees has been intermittently traced from 963413 to 010397.

The area contains only minor occurrences of igneous rocks. Several dyke-like bodies of porphyry with east - west elongations occur in the vicinity of 930415. The largest of them has an extent of about 1,000 by 200 feet. A very strongly sheared and weathered outcrop of porphyry also occurs about a quarter of a mile south of the Kathleen Mine, and a few smaller bodies have been noted in the eastern part of the area. Only two very minor occurrences of lamprophyre are known from the area, both apparently as flat-dipping sheets, not more than 20 feet thick.

Ironstones occur throughout the area, but the greatest concentration is found between 39,000 and 40,500 north and between 93,500 and 96,500 east, where two major easterly trending zones, about 1,000 feet apart, may each contain up to three sub-parallel ironstone lodes. Several lenses up to 200 by 20 feet occur in this group, and one at 935403, has dimensions of about 800 by 20 feet. The trends are domirantly easterly, except in the vicinity of major transcurrent faults, as at the Ace High Mine. At 005400, an ironstone body with the shape of an inverted saddle reef was noted, apparently following the trend of a favourable bed.

In the southern foot-hills of the Honeymoon Ranges, a number of prominent jasper bars occur at 950388 and at 961385. These are probably associated with an extensive body of porphyry, which however is only exposed at one point, about half-way between the two jasper localities.

Quartz veins are fairly uniformly scattered throughout the area, with trends of 080 to 090 degrees and 030 to 040 degrees about equally represented.

The only mines of any importance occur in the south-western part of the area, where the Burnt Shirt, Ace High and Kathleen Mines are now being worked on a small scale. These are all in massive ironstone and are worked for gold only, no sulphides having been so far encountered in any of the workings. The Burnt Shirt, with a total recorded production of 2,340 ozs. to June 1958, is the most important of this group. Recorded production of the Ace High is 100 ozs. and of the Kathleen 360 ozs. A magnetic anomaly of about 150 gamma has been located by the 1937 A.G.G.S.N.A. survey half-way between the Burnt Shirt and Ace High workings and is interpreted by Daly (1957) as due to a magnetic body centred at a depth of at least 400 feet. No attempt has so far been made to test this anomaly.

Mary Ann Area

This comprises the low-lying, level to gently undulating area between 42,000 and 44,000 north and between 92,500 and 97,000 east. Bed-rock is exposed over most of this area, and it is regarded as a pediment into which the present creeks are incised to a depth varying from 2 to 20 feet.

The Warramunga sediments in this area are generally similar to those of the Honeymoon Ranges, except for the occurrence of a considerable thickness (? 500 feet) of shale and fine-grained siltstone, free from any coarser-grained beds, at 950429. Dips are dominantly to the north, but there are many minor fold axes trending easterly, generally without any pronounced pitch. However, in the vicinity of 935435, there is a development of minor folds which pitch steeply down the limbs of the major structures, indicating a second period of deformation under the action of differently orientated stresses.

Faulting and shearing are not very prominently developed, but the Mary Ann Mine is situated on a shear zone, and the line of quartz reefs and breccias passing about 100 yards north of this mine probably also follows such a zone. This line, trending about 100 degrees, has been followed intermittently for nearly one mile.

Only minor porphyry occurrences have been noted in this area, generally elongated parallel to the strike of the surrounding sediments, and strongly sheared. Three occurrences of lamprophyre are known, the largest occupying an area of about 300 by 50 feet, but all are too weathered for detailed petrological examination.

Only very minor ironstone occurrences are known from this area. Of these, the most interesting is that at 938432, where a massive ironstone lens passes along the strike into a zone in which individual laminae of the country rock have been selectively replaced by iron oxides.

Quartz veins are very wide-spread, and, apart from those following the previously described shear zone north of the Mary Ann Mine, show a pronounced predominance of trends of 030 to 040 degrees.

The Mary Ann Mine is the only one which has been worked in this area. It is situated on an iron-impregnated shear-zone trending 100 degrees, and is recorded as having produced 180 ozs. of gold up to June 1958.

Government Battery Area

This area extends roughly between 35,000 and 38,000 north and between 92,500 and 00,000 east. The best exposures are found in a line of flat-topped hills which extends for about two miles to the east-south-east of the Battery, and in a less regular group of hills between the Pinnacles, Pup and Southern Star Mines, about one mile south-west of the Battery.

The Warramunga sediments of this area are generally similar to those of the Honeymoon Ranges, and often show very pronounced graded bedding. Several fold axes have been mapped, trending roughly easterly. They pitch gently east in the western part of the area, and are nearly horizontal in the eastern part. In the northern part of the area, a few originally south-dipping beds are now overturned.

Shearing is not very pronounced. Most shears trend easterly, parallel to the regional strike of the bedding, and a minor set, as at the Pinnacles Mine, trends 050 to 060 degrees.

About one and a half miles south of the Battery, a porphyry mass with an extent of at least half a mile by a quarter of a mile forms a group of low hills. It is moderately sheared and rather strongly weathered, and its northern portion is cut by a network of quartz veins up to two feet wide. It also contains a number of inclusions of sheared Warramunga sediments, now represented by chlorite-magnetite schists. The quartz veins within the porphyry carry some gold and have been worked at the Pup Mine. The porphyry itself contains numerous limonite-filled cavities, at least some of which are thought to be boxworks, due to the leaching of original sulphides.

An isolated occurrence of lamprophyre was found about half a mile east of the Southern Star Mine.

Ironstones are distributed throughout this area, but the greatest concentration occurs at the Southern Star Mine, where an area of approximately 2,000 by 500 feet contains about twenty separate lodes and lenses, the largest measuring about 400 by 15 feet. The strikes are generally easterly or a few degrees north of east.

About two fifths of a mile south of the Pinnacles Mine, three jasper lenses up to 100 by 15 feet trend north-east and lie in an echelon formation. They locally grade into hematite-rich phases indistinguishable from typical ironstones and are probably related to the porphyry mass outcropping at the near-by Pup Mine. At the Pinnacles Mine, silicification has also affected some bands of rock within and close to the mineralised shear zone, but these lack the red colour and very fine-grained texture of the typical jasper occurrences.

Quartz veins are very abundant throughout this area, and the majority trend east or east-north-east.

The main mines of the area are the Southern Star with a recorded production of 120 ozs. of gold, the Pinnacles with a recorded production of 920 ozs. of gold and an estimated 5 tons of copper in hand-picked ore, and the Susan without any recorded production but with an estimated 300 tons of ore awaiting crushing at the time of the survey. In addition, some workings about 250 yards west of the Pinnacles are referred to by Ivanac as the Ajax Mine (recorded production 4 ozs.), although they are shown as the Western Chief Mine on the A.G.G.S.N.A. 1937 plan. The Fassifern Mine (recorded production 110 ozs.) is believed, by

interpolation from Ivanac's regional map, to be situated at 939374, and the International (recorded production 2 ozs.) is situated a quarter of a mile south-east of the Susan.

Of these mines, the Pinnacles, Ajax and International are located on major shear zones associated with minor ironstones, while the remainder appear to be substantially developed in massive ironstones. Copper mineralisation is present at the Pinnacles Mine, as described in a previous section, and to a lesser extent also at the Ajax Mine.

Only the immediate vicinity of the Pinnacles and the Pup Mines are covered by ground magnetic surveys. Daly (1954) interprets the results at the Pinnacles as indicating the absence of any major type anomalies, but at the Pup (referred to in his report as the Pinnacles Alluvial) he records a weak anomaly in a position roughly coincident with the porphyry contact.

For future work in this area, the need for further prospecting for copper mineralisation on the Pinnacles shear zone and in the porphyry south of the Pup Mine has already been referred to in a previous section.

Peko - Golden Forty area

This area extends from 32,000 to 37,000 north and from 00,000 to 13,000 east. Its eastern portion includes a number of deeply dissected ridges, culminating in Mount Rugged, but in its western portion, around the Peko Mine, outcrops are more limited.

The area contains a number of minor easterly trending fold axes, generally with westerly pitches of up to 30 degrees, and a major anticline passes through 31,500 north, just to the south of this area.

Lithologically, the Warramunga sediments are similar to those described from other areas, e.g. the Honeymoon Ranges. The hematite shale has not been recognised in this area, but at 116344, a 50-foot succession of otherwise typical Warramunga shales and greywackes contains scattered pebbles up to three inches in diameter. These pebbles are composed largely of sedimentary rock types similar to those of the Warramunga Group itself.

The intensity of shearing is greatest in the central part of the area, around the Golden Forty workings, where many shear zones are heavily impregnated with iron oxides. Trends of 080 degrees and 100 degrees are commonest. In addition, an east-west trending zone of about two miles by a quarter of a mile, passing through the Kia Ora Mine at the northern edge of the area, shows very well developed fracture cleavage which almost obliterates the bedding in both shales and greywackes. This must indicate intense local stresses, but is not accompanied by any marked increase in the number of defined shear zones.

Porphyry crops out very prominently in the area between Peko and Golden Forty, including both sheared and massive phases. Some of these masses are associated with prominent jasper bars, but others have given rise to no discernible contact effects at all. At 060350, one of these masses is crowded with irregular xenoliths, from a few inches to ten feet in diameter, but these have suffered no metamorphism except for slight induration.

No lamprophyres have been encountered in this area.

The ironstones of this area are concentrated in two main localities around East Peko and Golden Forty. The East Peko bodies

are largely massive lenses, up to 200 by 40 feet, most commonly striking 070 degrees and similar in general appearance to the outcrop at Peko itself. The Golden Forty occurrences, on the other hand, are mostly groups of small lenses associated with iron-impregnated shear zones. They frequently show en echelon grouping and most commonly strike 090 degrees.

Quartz veins are very prominently developed throughout the area, especially to the east of the Kia Ora Mine, where a number of blows up to 200 by 20 feet have been observed. Two sets, respectively striking 070 and 090 degrees are almost equally developed.

Peko is the only mine now operating in this area. This orebody has been described at length by previous workers, especially Edwards (1955), and its structural relations have been discussed in a previous section. Its ore reserves are currently estimated at 1,000,000 tons, representing a life of about nine years at present production rates.

The Golden Forty, Great Eastern and several unnamed mines have all worked iron-impregnated shear-zones containing lenses of massive quartz-hematite. Recorded production is 500 ozs. for the Golden Forty and 280 ozs. for the Great Eastern. The Golden Kangaroo (recorded production 50 ozs.) is situated on a group of lenticular quartz and quartz-hematite bodies with vuggy and gossanous outcrops, between half and three quarters of a mile north of the Golden Forty. McMillan (1957), referring to it as the Golden Forty North, records two diamond drill holes by the National Lead Co. of U.S.A., which were intended to test a combined geochemical and magnetic anomaly on this line, but which encountered neither sulphides nor magnetite.

About one mile south-east of Mount Rugged, the Tunnel Mine (recorded production 20 ozs.) consists of two adits and irregular stopes in sheared and brecciated sediments associated with small quartz-hematite lenses. In the northern part of the area, the Kia Ora Mine has a recorded production of 520 ozs. from a zone of brecciated sediments re-cemented by quartz and hematite. No massive ironstones are associated with this zone.

The area contains a large number of magnetic anomalies of the type normally associated with concealed quartz-magnetite bodies. These include the major anomaly at Peko itself.

At East Peko, a group of four anomalies has been tested by A.G.G.S.N.A. diamond drill hole No. 5 and by several holes put down by Peko Mines N.L. (Daly, 1957). The full results are not available, but were apparently not sufficiently encouraging to warrant further work on any of the bodies.

At Golden Forty, four anomalies are arranged in a roughly ring-shaped pattern. Two of these have been drilled by Kia Ora Gold Corporation and Australian Development N.L. (Daly, 1957), and a hole by the National Lead Co. of U.S.A. is reported to have intersected 41 feet of talc schist, averaging 1.5 per cent copper (McMillan, 1957, quoting R. Ellett, personal communication).

Two anomalies of lesser intensity are also known from the vicinity of the Great Eastern Mine, but have not been tested to date. The anomaly in the Golden Kangaroo area has already been referred to.

Another very large anomaly is situated about one mile west of Peko. This is interpreted by Daly (1957) as analogous

to a magnetic body of about 480 feet radius, centred at a depth of about 2,140 feet. It has not been tested to date, but owing to the large indicated size of the ironstone body and its proximity to the rich Peko orebody, it is regarded as an attractive target by Peko Mines N.L., who hold the area under lease (November 1958).

Lone Star Area

This area extends from 41,000 to 43,000 north and from 99,000 to 07,000 east. It consists of a group of well dissected ridges in its western portion, tailing away to more isolated outcrops to the east.

The Warramunga sediments of this area show no features of special interest. Outcrops of hematite shale are known intermittently from the True Blue Mine at 995418 to the Great Bear Mine at 063410. Possibly more than one horizon may be present. The beds are fairly tightly folded with vertical dips at a number of localities. Pitches are variable, dominantly to the east at low angles.

Shearing is very pronounced, with a predominance of east-south-easterly trends, apparently associated with the proximity of the Quartz Hill - Rocky Range shear zone, which forms the north-east limit of the area.

No outcrops of porphyry have been noted in this area, but there are three or four small occurrences of basic igneous rocks (? lamprophyres), indicated by patches of travertine at the surface.

The ironstones of this area include massive lenses up to 300 by 50 feet, as at the Arizona Mine, and some strongly jasperoid types, as at the Trump Mine. At the True Blue Mine, a peculiar type of spotted lode consists of blebs of hematite, averaging half an inch in diameter, enclosed in quartz. At the Lone Star Mine, the ironstones are themselves extensively sheared, and at the Plain Jane Mine a north-south fault has displaced portion of the lode by about sixty feet horizontally.

The dominant trend of the quartz-hematites throughout the area is still easterly, but two distinct minor sets, respectively striking 060 degrees and 120 degrees are apparent in a number of localities.

Quartz veins are present throughout the area, but in the eastern portion they reach a maximum development in channels forming part of the Quartz Hill - Rocky Range shear zone Several lines of quartz reefs and quartz breccias with remnants of sediments in various stages of replacement by silica attain widths of 20 to 30 feet and can be traced with minor interruptions for distances of at least one mile. They generally trend between 110 and 130 degrees and are often offset by minor north-east striking faults.

Among the mines of this area, the Lone Star with a recorded production of 3,850 ozs. is the most important. The Trump and Maple Leaf are currently being worked on a very limited scale, but there are no records of production. Others which have produced some gold in the past are the Arizona (22 ozs.), Plain Jane (675 ozs.) and Great Bear (180 ozs.). In most of these mines, gold values have been obtained both in massive ironstones and in brecciated iron-impregnated sediments on their flanks. Traces of secondary copper minerals are apparent in the ore currently being won from the Lone Star Mine.

A magnetic anomaly of about 300 gamma has been located about 300 yards north-west of this mine, but has not been tested to

date. As the quartz-hematite in the mine is reported to be cut off at depth by a thrust fault dipping gently to the north (Ivanac, 1954, p. 105), this anomaly may conceivably be related to the displaced lower portion of the ore body.

Caroline Area

This area is situated between 40,000 and 44,000 north and between 85,000 and 92,500 east. The eastern portion forms an extension of the Honeymoon Ranges and shows very closely spaced exposures, which gradually decrease in frequency to the west.

The sediments are typical representatives of the Warramunga Group, except for a pebble bed between 870420 and 880420, as previously described. No occurrences of hematite shale are known from the area.

There are at least 15 fold axes, spaced at an average distance of ten to fifteen chains. Pitches are predominantly to the west in the eastern part of the area, but the fold axes are roughly horizontal in the western part. The beds are strongly sheared at many localities, especially in a zone extending from 870414 to 900424. This zone, with an average trend of 070 degrees, is marked by a concentration of quartz reefs, breccias, lenses of sheared porphyry, jasper bars and minor quartz-hematite bodies. Another major line of weakness is marked by a zone of lamprophyre intrusions up to 150 feet wide, which extends from 910420 to 908428, with an average trend of 340 degrees.

There are several small porphyry outcrops in the southern and western parts of the area, most of them associated with zones of intense shearing, as described above. These comparatively small occurrences tend to be associated with relatively large jasper bars, and there are also a few occurrences of jasper and silicified sediments in areas where no porphyry is exposed at the surface, as between 890400 and 900400. It is probable, therefore, that the northern extension of the Aerodrome porphyry underlies much of the southern part of the area at relatively shallow depth.

Lamprophyres are well represented in this area. In addition to the occurrences associated with the major shear zone already described, there are outcrops in the vicinity of the Caroline Mine and to the east of the Shamrock Mine. Several of those at the Caroline Mine are flat-lying sheets, and at least one of them intersects the main ironstone body at that mine.

Ironstones aresporadically distributed throughout the area, but reach a maximum development in the vicinity of the Caroline Mine, where several of them attain dimensions of 15 by 100 feet. Between 895416 and 903416, several ironstone lenses outcrop prominently on steep-sided ridges, but terminate at shallow depths, generally above the level of the surrounding plains. East - west trends again predominate. The presence of jasper bars and breccias has already been referred to. They commonly grade into less strongly silicified sediments, and are generally distinct from the quartz-hematite lodes. Quartz veins, except for a few occurrences associated with major shear zones, are not very prominent.

Among the mines of the area, there are only three with any recorded production. The Shamrock has produced 20 ozs. of gold and 6 tons of copper from a zone of sheared and brecciated sediments, now converted in part to chlorite- and sericite-schists. The Caroline has produced 280 ozs. from massive quartz-hematite lodes and associated sheared sediments, and the Great Northern 450 ozs. from an iron-impregnated shear zone in Warramunga sediments.

The only parts of this area covered by ground magnetometer surveys are the immediate environs of the Shamrock and Great Northern Mines. The area around the Shamrock gave no indication of the presence of any magnetite bodies at all, and that around the Great Northern indicated a number of small bodies at relatively shallow depths only (Daly, 1957).

Gibbet - Aerodrome Area

This area lies between 36,000 and 39,000 north and between 87,000 and 92,000 east. A central line of hills extends roughly east - west, flanked to the north and south by lower-lying ground with less continuous exposures.

This central portion of the area is largely occupied by normal sediments of the Warramunga Group. Hematite shale occurs at 888372 and at 901379. Specimens from these localities, in addition to the finely divided iron oxides typical of this rock, contain disseminated octahedral crystals, probably of martite (hematite pseudomorphs after magnetite), up to one hundredth inch diameter. Two or possibly three beds containing spheroidal bodies of the type thought to be possibly of organic origin occur at 893370. The most prominent structural features of the area are a group of tight west-pitching folds in the vicinity of the Wheal Doria Mine and an open dome-like structure centred about half a mile south-east of the Gibbet Mine. In the vicinity of the Wheal Doria Mine, a strong set of shears trends 070 degrees, and the alignment of ironstone lenses at the Gibbet Mine suggests an extension of these structures into that vicinity.

Almost the entire northern portion of this area is occupied by a group of porphyry bodies, the largest of which has an extent of approximately one mile by half a mile, elongated east-west. This body is of interest in having a very massive and relatively fresh central portion, surrounded by a more strongly sheared and weathered zone from a hundred to several hundred yards wide. It is intersected by a number of major north-east trending quartz reefs, and is surrounded to the south and south-west by an unusually strong zone of silicification, including a number of prominent jasper bars. An isolated small occurrence of porphyry has also been noted at 900363, in the southern part of the area.

A small body of lamprophyre, probably in the form of a flat-lying sheet, underlies the quartz-hematite at the Gibbet Mine, and a few specimens have also been found in spoil from a shallow shaft three quarters of a mile east-south-east of this mine.

The main occurrences of ironstone in this area are on the Wheal Doria - Big Ben line, and in the immediate vicinity of the Gibbet Mine. They range up to forty feet in width and are largely associated with shears trending 070 degrees. The occurrences at the Gibbet Mine are cut off at about five feet below the surface, and adits driven underneath them have encountered either crush breccia or lamprophyre. They are therefore thought to have been displaced by flat-lying faults, now marked by these breccia zones, along which the lamprophyres were subsequently intruded. Quartz veins, except for those associated with the major porphyry occurrences, are not very strongly developed in this area. At 895366, some of them contain aggregates of small needles of dark green tourmaline.

The main mines of the area are the Wheal Doria (recorded production 2,900 ozs.), Peter Pan (70 ozs.), Big Ben (7 ozs.), and Gibbet (no record). Of these, the first three have mostly worked sheared and brecciated sediments impregnated with varying

amounts of iron oxides, and locally with minor amounts of copper, bismuth and manganese minerals. These shear zones strike about 070 degrees and dip north at about 60 degrees. Massive ironstone bodies also outcrop on all these leases, but have apparently yielded only very minor amounts of gold. The Gibbet workings are in massive ironstones and in crush breccias intersecting them.

A relatively large part of this area has been covered by detailed magnetometer surveys. Four anomalies are recorded from the Wheal Doria - Bi., Ben line, and a test of the strongest of these by two diamond drill holes (A.G.G.S.N.A. holes No. 4 and 4 A), encountered disseminated hematite, magnetite, calcite, pyrite and chalcopyrite in chloritic slate between 157 and 170 feet in hole No. 4 and between 159 and 183 feet in hole No. 4 A. However, only low gold and copper values were obtained.

In the southern part of the area, two very prominent anomalies are apparent on the aerial magnetic map. The more westerly of these (locally referred to as the West Gibbet) has been further investigated by ground magnetometer surveys by Peko Mines N.L., but no drilling has been attempted to date.

Eldorado Area

This area extends from 30,000 to 33,000 north and from 91,000 to 99,000 east. It includes a group of rather abrupt ridges extending from the Enterprise to the Cat's Whiskers Mine, and a number of gentler hillocks to the east and north-east.

The Warramunga sediments of this area show no unusual characteristics. The hematite shale is well developed and can be traced almost continuously from 910320 to 940310, with minor occurrences about two miles north-east of the latter point. Two "fossil" beds are also present, occurring stratigraphically just below the hematite shale.

Structurally, the main features are an open anticline just south of the Enterprise - Cat's Whiskers line of lodes, and a syncline just north of this line. Pitches are to the east in the western part of the area and to the west in the eastern part, generally at angles of less than 15 degrees. Shearing is not very prominently developed, except for a few localities near the Enterprise and Cat's Whiskers Mines, where the dominant sets trend 100 to 120 degrees, and a few quartz breccias in the eastern part of the area, generally striking 340 to 360 degrees.

No igneous rocks have been encountered in this area, except for a few very small lenses of sheared porphyry about a quarter of a mile south-east of the Cat's Whiskers Mine.

Ironstones are very well developed, but are confined entirely to the western part of the area, where they occupy a belt extending from 910320 to 940312. This belt, with an average width of some 500 feet trends roughly east between the Enterprise and Eldorado Mines and 120 degrees between the Eldorado and Cat's Whiskers Mines. The individual ironstones within this belt range from massive lenses of 200 by 60 feet, as at the main shaft of the Eldorado Mine, to bedded formations only a fraction of an inch wide. They almost invariably strike close to 090 degrees, except for one completely irregular body about ten chains south-east of the Eldorado Mine. There is a very close coincidence between this belt of ironstones and the outcrop of the hematite shale, but the significance of this, as pointed out in an earlier section, is not fully understood yet. The belt also appears to coincide with the zone of steepest northerly dips in the area.

Quartz veins are more abundant in the eastern portion of the area, where two main sets strike 090 degrees and 340 to 360 degrees respectively.

The mines of the area are confined to the belt of ironstones extending from the Enterprise to the Cat's Whiskers Mine. From west to east, the main ones are the Enterprise (recorded production 6,600 ozs.), Patties (1,530 ozs.), Eldorado (105,000 ozs.), The Mount (no recorded production), and Cat's Whiskers (100 ozs.). At the Enterprise and Patties Mines, most of the ore came from a zone of brecciated iron-impregnated sediments in the foot-wall (south side) of the massive ironstone lenses. At the Eldorado Mine, the bulk of the ore consisted of brecciated zones in the ironstone itself. At all three mines, there were indications that much of the gold was secondary. At The Mount, workings are largely in iron-impregnated sediments, and at the Cat's Whiskers in massive quartz-hematite and adjoining crush zones.

Five major magnetic anomalies are known from the area to the north and east of the Eldorado Mine. Anomaly No. 1, to the north of the mine, was tested by A.G.G.S.N.A. diamond drill hole No. 1, which intersected massive ironstone from 223 feet to the bottom of the hole at 235 feet, but encountered only low gold and copper values. Ironstone has also been encountered in this vicinity by Eldorado diamond drill holes S.3, 300-4 and 300-5. Anomaly No. 2 may be due to the lower portion of the Eldorado ore-body, and ironstone has been cut close to its calculated position by Eldorado diamond drill holes S.1. and S.2. Anomaly No. 3 has been tested by A.G.G.S.N.A. hole No. 2, which encountered sheared sediments with disseminated magnetite, chalcopyrite and pyrite between 413 feet and the bottom of the hole at 452 feet, including a body of massive magnetite between 435 and 441 feet. Copper values over this 39-foot section averaged 0.42 per cent, with a maximum of 0.88 per cent for the bottom seven feet.

In the area occupied by No. 4 anomaly (Cat's Whiskers), evidence of two diamond drill holes was seen on the surface, but no record of these is available. At the conclusion of the 1958 season, another hole had been begun in this area by Eldorado Tennant Creek Co. Ltd. but no results are available as yet. No. 5 anomaly has never been tested.

There is also an anomaly about three miles east-south-east of the Eldorado Mine, locally known as the "Bulldust Anomaly", which was tested by the National Led Co. of U.S.A. by means of two diamond drill holes. According to McMillan (1957), neither of these holes encountered ironstone or sulphide concentrations of any importance.

Mount Samuel Area

This extends from 31,500 to 34,000 north and from 86,500 to 90,500 east. The best exposures within this area are restricted to a group of ridges extending in an east-south-easterly direction from Mount Samuel to the Hammerjack Mine.

The Warramunga sediments in this area show very similar features to those of the Eldorado area. The hematite shale can be traced intermittently for about a mile and a half, and at least two "fossil" horizons are again present, occuring stratigraphically just below the hematite shale. Structurally, the main features are two open east-trending anticlinoria en echelon, one situated to the south of the Red Ned - Hammerjack line of lode, and the other immediately west of Mount Samuel. A major syncline lies on the north flank of each of these anticlinoria. Dips throughout the area are gentle, generally less than 45 degrees,

except in the immediate vicinity of the Red Ned - Hammerjack line of lode, where steep northerly dips of up to 70 degrees occur. Pitches are to the east at angles of 10 to 20 degrees over most of the area, with a local reversal to 20 degrees west half a mile south-east of Mount Samuel. One unexpected feature is that the hematite shale has only been found on the north flanks of the anticlinoria, although the "fossil" beds occur on both flanks.

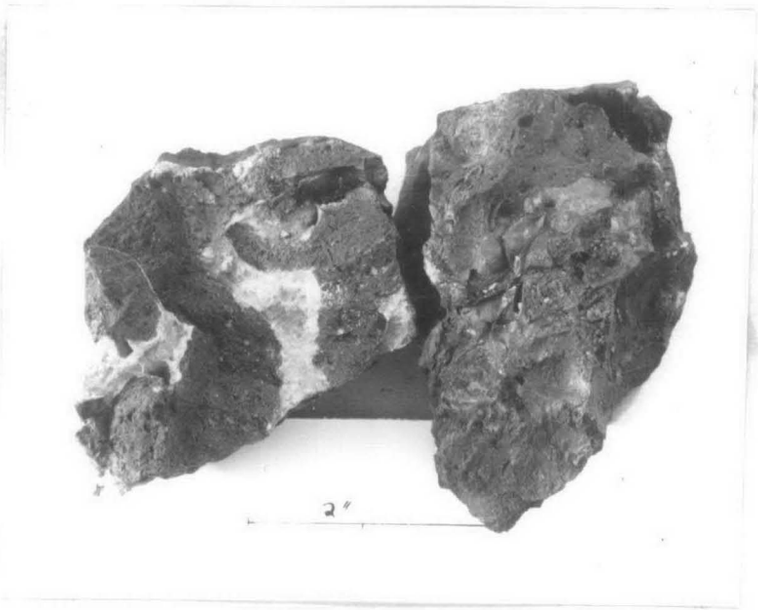
Shearing is not very obvious over most of the area, but individual ironstone bodies are commonly surrounded by zones of brecciation up to ten feet wide. There are also a number of topographic features, such as the alignment of minor scarps and gullies, suggestive of meridional faulting in this area. Cleavage is commonly well developed in the finer-grained sediments. It is roughly vertical and strikes 080 to 090 degrees.

No igneous rocks were seen in this area during the current survey, but Owen (1942) records that porphyry was encountered at a depth of 60 feet in a bore at the south-west foot of Mount Samuel.

The ironstones of the area are confined almost entirely to a belt about 500 feet wide, which trends 120 degrees at the Southern Cross workings, swings to 135 degrees at Mount Samuel and continues at 100 degrees between the Outlaw and Hammerjack Mines. The greater part of this belt coincides closely with the outcrop of the hematite shale, and its eastern portion also coincides with the zone of steepest northerly dips in the area, comparable with the relations observed in the Eldorado area. Several of the individual lenses attain horizontal dimensions of the order of 200 by 500 feet, but as these bodies are largely flat-lying sheets, the actual volumes of these lenses are no greater than those of other areas. They are generally very dense and compact, and many of them are still strongly magnetic, even in exposed portions at the surface.

Quartz reefs do not attain any significance in this area.

The main mines of the area, from west to east, are the Southern Cross (recorded production 300 ozs.), Mount Samuel (4,000 ozs.), Outlaw and Red Ned (no recorded production), and Hammerjack (5,500 ozs.). At all these mines, workings are partly in massive ironstone and partly in sheared and brecciated sediments close to the ironstones, but much of the richest ore appears to have been a porous granular or botryoidal limonitic material with ramifying solution pipes up to two inches in diameter. It is not possible to decide from the available evidence whether this material is the product of leaching of massive sulphides in situ, or is due to the re-precipitation of iron oxides transported by supergene solutions. However, comparison with other areas on the field would favour the latter origin.



Solution pipes and botryoidal texture in limonite. Hammerjack Mine.

At the Hammerjack Mine, the main ironstone bodies dip north at an average angle of about 30 degrees, roughly parallel to the dip of the adjoining sediments, and are cut off to the north by a breccia zone, probably representing a major fault. No extension of these bodies to the north of this breccia zone is known to date.

At Mount Samuel, a group of ironstone bodies occupies areas of up to 500 feet by 200 feet, but all of them bottom at depths of 70 to 90 feet. The underlying sediments, which are approximately horizontal, show slight brecciation, so that the base of the ironstone bodies may be controlled either by a change in lithology or by a shear zone parallel to the bedding. Brecciated sediments also flank these ironstones on the north side, which may thus be another faulted contact.

At the Red Ned and Outlaw Mines, the ironstone bodies dip north more steeply, again roughly in conformity with the surrounding sediments. At the Southern Cross Mine, the dips of the sediments are predominantly to the south at low angles, but the ironstones are flat-lying bodies similar to those of Mount Samuel.

Throughout this area and the adjoining Eldorado area, there appears to be a tendency for major mines (Mount Samuel, Enterprise, Eldorado and possibly Hammerjack) to be situated at points where the general ironstone-rich belt undergoes a change in direction. These changes in direction are probably reflections of pitch changes, which may be the underlying controlling factors.

Traces of chalcopyrite and secondary copper minerals have been encountered in several ironstones of this group, but none of these are of economic significance.

Three magnetic anomalies are known from this area. One is situated vertically below the outcrop of the Red Ned ironstone and another in a position down dip from the outcrop of the Outlaw ironstone. Both of these are undoubtedly due to the extensions of the outcropping bodies below water level. The third anomaly is situated about one thousand feet north of the Outlaw workings and according to Daly (1957) is due to a much more deeply buried body than either of the others. None of these anomalies have been tested as yet.

Noble's Nob area

This area lies between 28,500 and 31,500 north and between 01,000 and 06,000 east. It includes a group of flat-topped ridges with good outcrops in its central portion, decreasing in height towards the margins.

Most of this area is occupied by Warramunga sediments of normal lithology. Minor occurrences of hematite shale were seen at 046290, and just to the south of the Noble's Nob Mine. Two or possibly three "fossil" horizons have been traced intermittently for about a mile to the west of this mine, where they are repeatedly offset by minor faults.

Dips in the Warramunga sediments are generally to the south at angles of 60 to 80 degrees, except near the northern margin of the area, where a few minor folds occur. A major anticlinal axis passes just north of the most northerly outcrops of the area. Pitches are generally to the west at gentle or moderate angles.

In the scuthern portion of the area, an occurrence of Rising Sun Conglomerate outcrops intermittently over an area of about two miles by half a mile. These beds generally dip to the south, and the occurrence is bounded on the south side by a group of major faults.

The dominant faults and shears in the area, including those affecting the Rising Sun Conglomerate, trend 070 degrees, locally swinging to 050 degrees, and are commonly marked by zones of silicification or iron-impregnation. A minor set strikes 330 degrees.

No igneous rocks are known from the area.

Quartz-hematite lodes are best developed in the immediate vicinity of the Rising Sun and Noble's Nob Mines, and show the usual east - west elongation. Quartz veins are fairly widely distributed and most commonly trend 100 to 120 degrees.

The two principal mines in the area are Noble's Nob, with a recorded production of 383,000 ozs. of gold, and Rising Sun (8,000 ozs.). At Noble's Nob, Ivanac (1954) records two outcropping quartz-hematite lodes, respectively 300 by 80 feet and 80 by 30 feet in size, and a third body, 90 feet wide, has been intersected by diamond drill holes. The massive quartz-hematite is reported to contain average values of up to one ounce of gold per ton, while parts of the adjoining sheared and brecciated sediments carry erratic values of up to 300 ozs. per ton. Traces of pyrite and chalcopyrite have also been encountered in diamond drill holes.

At the Rising Sun, a zone of brecciated sediments with minor lenses of hematite has been mined over a length of 125 feet and to a maximum width of 50 feet, mostly by means of a large open cut. Other prospects in the area include the Archangel, Bee's Knees and Weaber's Find, all of which are situated on small ironstone lenses. On the A.G.G.S.N.A. 1937 plan, the Bee's Knees area is referred to as the Two Blues, for which Ivanac (1954) records a production of 550 ozs., although he does not show it by this name on his own plan.

A rather feeble magnetic anomaly occurs roughly in the position of the ironstone intersected in the B.M.R. diamond drill hole at Noble's Nob, and Daly (1957) also interprets the magnetic contours to the east of this mine as indicating the

presence of a very large feature at a depth of 1,500 feet or more. This is more likely to be due to rock magnetism or disseminated magnetite than to a defined ironstone body and no attempt has been made to test it to date.

Red Terror - Joker Area

This area extends from 27,000 to 32,000 north and from 06,000 to 13,000 east. Several groups of the typical flat-topped, steep-sided ridges are developed in the Warramunga sediments, reaching their best development in the immediate vicinity of the Red Terror Mine. In addition, an east-trending group of more rounded ridges is developed in the Rising Sun Conglomerate in the southern part of the area. The greater part of Warramunga sediments are the usual greywackes, siltstones and shales. An occurrence of hematite shale has been traced for about three quarters of a mile between 076290 and 089290, and several isolated occurrences of "fossils" have been found between this point and the Red Terror Mine. Immediately west of this mine, an outcrop of pebble beds, about 15 feet thick, offset by a number of faults, has been traced for nearly a mile. It is very similar to the occurrence already described from the area north-east of Mount Rugged.

Minor slump structures are wide-spread, and a few specimens from various localities contain nodules and structures resembling worm-tubes. Pyrite casts up to an eighth of an inch in diameter occur in shales about a quarter of a mile north-west of the Red Terror Mine.


Minor slump structures at base of coarse-grained greywacke in Warramunga Group. Near Red Terror Mine.

The main structural feature of the area is a major easterly trending anticline at 31,300 north approximately. This pitches to the west at average angles of 10 to 20 degrees. Faulting and shearing are wide-spread. Two very prominent sets of faults strike 330 degrees and 030 degrees respectively, and there is also a set of mineralised shears, including those worked at the Red Terror and Joker Mines, which strikes 070 degrees.

The Rising Sun Conglomerate in this area occupies an east-west belt with an average width of a quarter to half a mile, continuous with that in the southern portion of the Noble's Nob area. Its lithology and main structural features have already been referred to in a previous section.

To the south and south-west of the Red Terror Mine, a porphyry intrusion occupies an area of approximately three miles by half a mile, elongated east-west. As in all other occurrences on the field, most of the outcrops are deeply weathered. On the northern flank of this porphyry mass, a few occurrences of graded greywacke show a superficial resemblance to the porphyry in hand-specimen, and some of the quartz grains in them show lobate outlines, reminiscent of those of the porphyry itself. This has given rise to the impression among other investigators that these rocks have undergone "porphyritisation" (e.g. J. Elliston, personal communication). Under the microscope, however, they are invariably found to contain fragments of pre-existing fine-grained sediments, which distinguish them from the porphyry itself.

At its south-eastern margin, the porphyry is surrounded by a strong zone of silicification, including a number of prominent jasper bars, and is intersected by several quartz reefs with north-north-westerly trends. To the south and south-west, the porphyry is overlain by the Rising Sun Conglomerate with contact relations which have been fully described in a previous section.

A second occurrence of porphyry occupies an area of about ten by ten chains, about one mile west-north-west of the Red Terror Mine. This shows highly irregular boundaries and encloses numerous xenoliths of Warramunga sediments.

At 115285, a group of lamprophyric igneous rocks outcrops in close proximity to the Red Terror porphyry, but separated from it by a major shear zone.

Ironstones are not very well represented in this area. Within the area half a mile north and north-west of the Red Terror Mine, a few have been tested by shallow workings, but no production is recorded from any of these. Quartz veins, on the other hand, are strongly developed, with a general predominance of north-south trends.

The only two mines of this area with any recorded production are the Joker (715 ozs.) and the Red Terror (1,300 ozs.) Both of these have worked steeply dipping iron-impregnated shear zones trending 070 degrees. The Joker Mine has recently been re-opened and is now working on a small scale.

The areas surrounding the Red Terror and Joker Mines have been covered by ground magnetometer surveys, but no major magnetic anomalies have been located.

## Acknowledgements

The authors gratefully acknowledge the assistance and co-operation received during this work from the management and staff of the mining companies operating on the Tennant Creek field. They are especially obliged to Mr. J. Elliston of Peko Mines N.L. for assistance in the early stages of the work and for many stimulating discussions.

Addendum. (March 1959).

The following developments on the Tennant Creek field have taken place since the completion of field work in October 1958:

A crushing of 500 tons from the Lone Star Mine has yielded 700 ozs. of gold (Chem. Eng. & Min. Rev., Feb. 1959).

New Merloo Gold Mines N.L. has tested and abandoned the Enterprise Mine and is currently testing the Skipper Extended, Outlaw, Red Ned, Patties, Memsahib and Kathleen Mines. A crushing of 141 tons of development ore from the Kathleen Mine has yielded 100 ozs. of gold (Indust. & Min. Standard, 5/3/1959).

Australian Development N.L. has tested and abandoned the Archangel Mine. It is currently testing Weaber's Find and is preparing to test the New Moon Mine. (Indust. & Min. Standard, 5/3/1959).

## Bibliography


A.G.G.S.N.A. Report, N.T. No. 4. Rayner, J.M. and Nye, P.B. Report on Magnetic Prospecting at Tennant Creek, 1936.

" " Report, N.T. No. 23. Richardson, L.A., Rayner, J.M. and Nye, P.B. Second Report on Magnetic Prospecting at Tennant Creek, 1936.

" " Report, N.T. No. 41. Richardson, L.A. and Rayner, J.M. Third Report on Magnetic Prospecting at Tennant Creek, 1937.

Chem. Eng. & Min. Rev., 51 (2), p. 47. Nov. 1958. Editorial Contribution. Peko Mine, Tennant Creek.

C.S.I.R.O. Mineragraphic Report No. 89. Cores from No. 2 diamond drill hole, Eldorado No. 3 Anomaly.

" " No. 193. Specimens from Joker Mine.

" " No. 499. Specimens from Peko, Eldorado, Enterprise, etc

" " No. 462. Cores from Peko Mine.

" " No. 524. Specimens from Peko Mine.

" " No. 571. Specimens from Peko Mine.

" " No. 592. Specimens from Peko Mine.

" " No. 618. Specimens from Peko No. 2 diamond drill hole.

" " No. 626. Specimens from Peko diamond drill holes.

" " No. 653. Specimens from Peko No. 3 diamond drill hole.

" " No. 655. Examination of copper concentrate from Peko Mine.

" " No. 724. Specimens from Peko Mine.

Daly, J. 1957. Magnetic Prospecting at Tennant Creek, 1935-37. Bur. Min. Res. Aust., Bull. 44.

Edwards, A.B. 1955. Composition of the Peko Copper Orebody. Proc. A.I.M.M., N.S., NO. 175, p.55.

Hills, E. S. & Thomas, D. E. 1953. Turbidity Currents and the Graptolite Facies in Victoria. J. Geol. Soc. Aust., I, pp. 119-133.

Ivanac, J. F. 1954. Geology and Mineral Deposits of the Tennant Creek Gold Field, Northern Territory. Bur. Min. Res. Aust., Bull. 22.

Kuenen, Ph. H. 1948. Turbidity Currents of High Density. Rep. 18 Int. Geol. Cong., London, VIII, pp. 44-52.

" " 1953. Origin and Classification of Submarine Canyons. Bull. Geol. Soc. Am., 64, pp. 1295 - 1314.

" " 1956. The Difference between Sliding and Turbidity Flow. Deep Sea Research, 3, pp. 134 - 139.

Kuenen, Ph. H. & Menard, H.W. 1952. Turbidity Currents, Graded and Non-graded Deposits. J. Sed. Pet., 22 (2), pp. 83 - 96.

McKeown, M.R. 1942. The Tennant Creek Gold Field. Proc. A.I.M.M., N.S., No. 128, p. 177.

McMillan, N.J. & Debnam, A.H. 1957. Geochemical Prospecting at Tennant Creek. Bur. Min. Res. Aust., Records, 1957. (IN MANUSCRIPT ONLY).

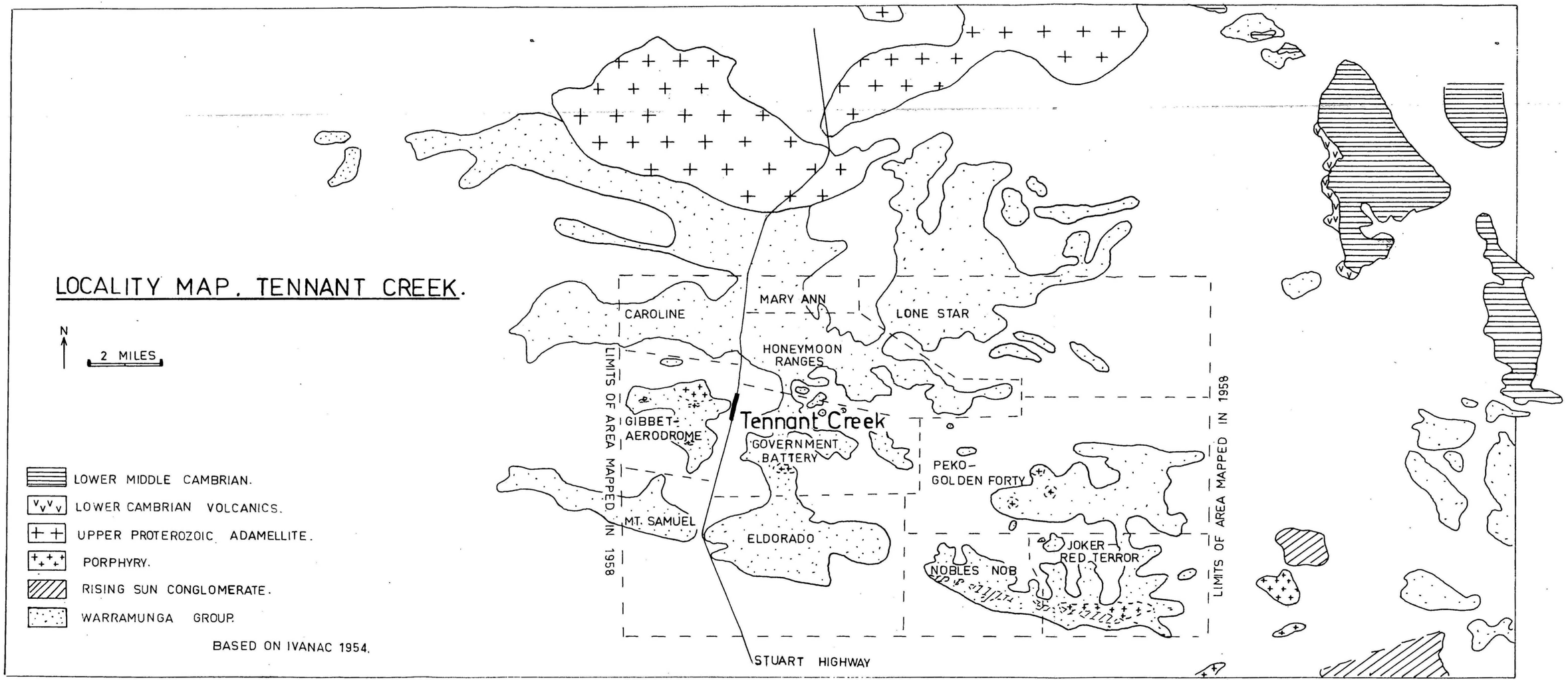
Owen, H.B. 1942. Report on Tennant Creek Gold Field. Geol. Br., Dept, of Int., Aust. (Unpub.).

Rankin, R.I. 1949. Tennant Creek Gold Field. Chem. Eng. & Min. Rev., 42 (3), p. 83.

Ryan, G.R. 1958. A Geological Examination of the Eldorado Mine, Tennant Creek, N.T. Bur. Min. Res. Aust., Records, 1958/76.

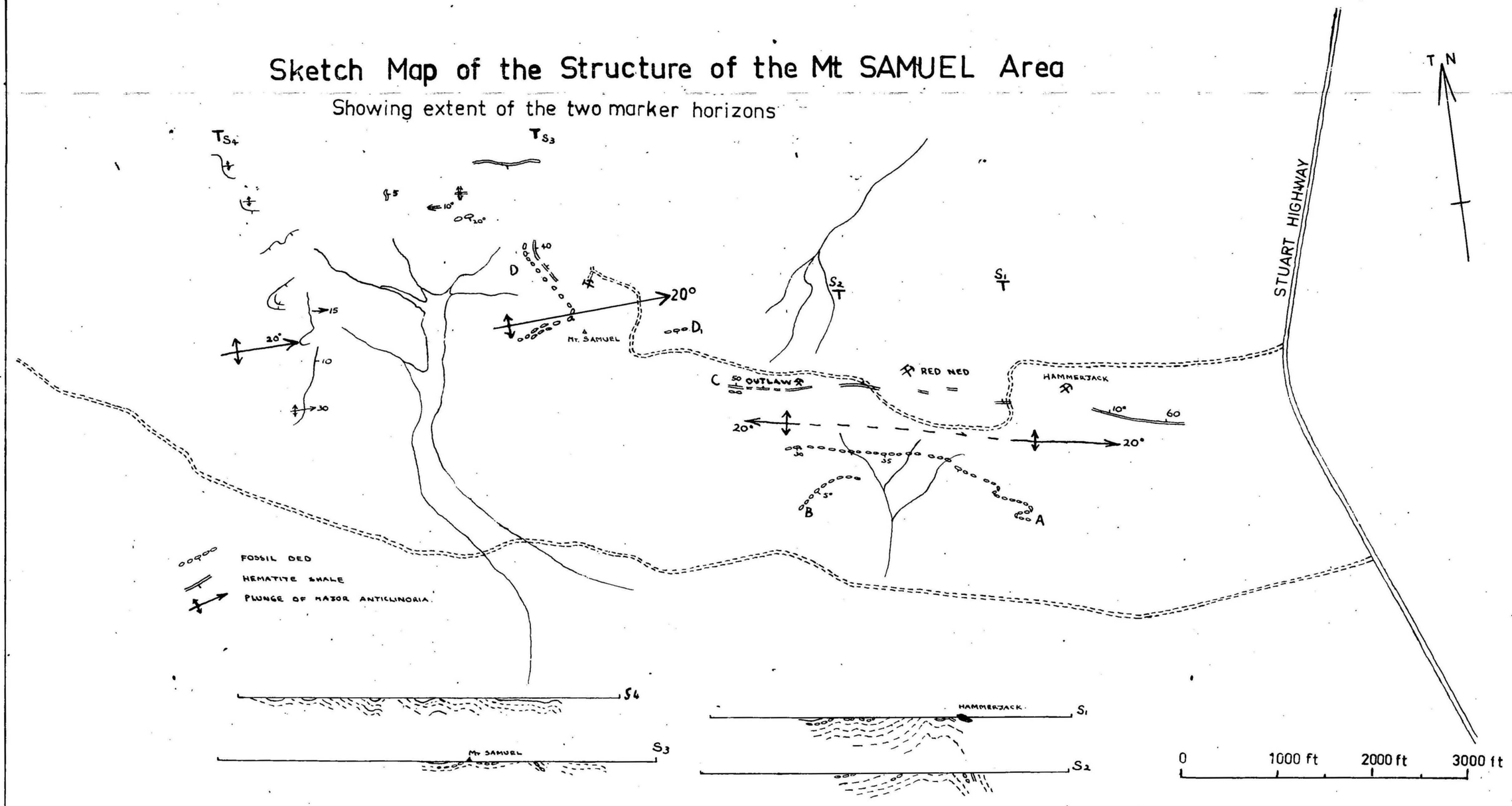
Stillwell, F.L. & Edwards, A.B. 1942. Mineral Association of Tennant Creek Gold Ores. Proc. A.I.M.M., N.S., No. 126, p. 139.

Woolnough, W.G. 1936. Report on the Tennant Creek Gold Field. Bull. N.T. Aust., No. 22.


LOCALITY MAP. TENNANT CREEK.
N
2 MILES
LOWER MIDDLE CAMBRIAN.
LOWER CAMBRIAN VOLCANICS.
UPPER PROTEROZOIC ADAMELLITE.
PORPHYRY.
RISING SUN CONGLOMERATE.
WARRAMUNGA GROUP.
BASED ON IVANAC 1954.
CAROLINE
MARY ANN
LONE STAR
HONEYMOON RANGES
GIBBET-AERODROME
Tennant Creek
GOVERNMENT BATTERY
PEKO-GOLDEN FORTY
MT. SAMUEL
ELDORADO
JOKER-RED TERROR
NOBLES NOB
LIMITS OF AREA MAPPED IN 1958
LIMITS OF AREA MAPPED IN 1958
STUART HIGHWAY

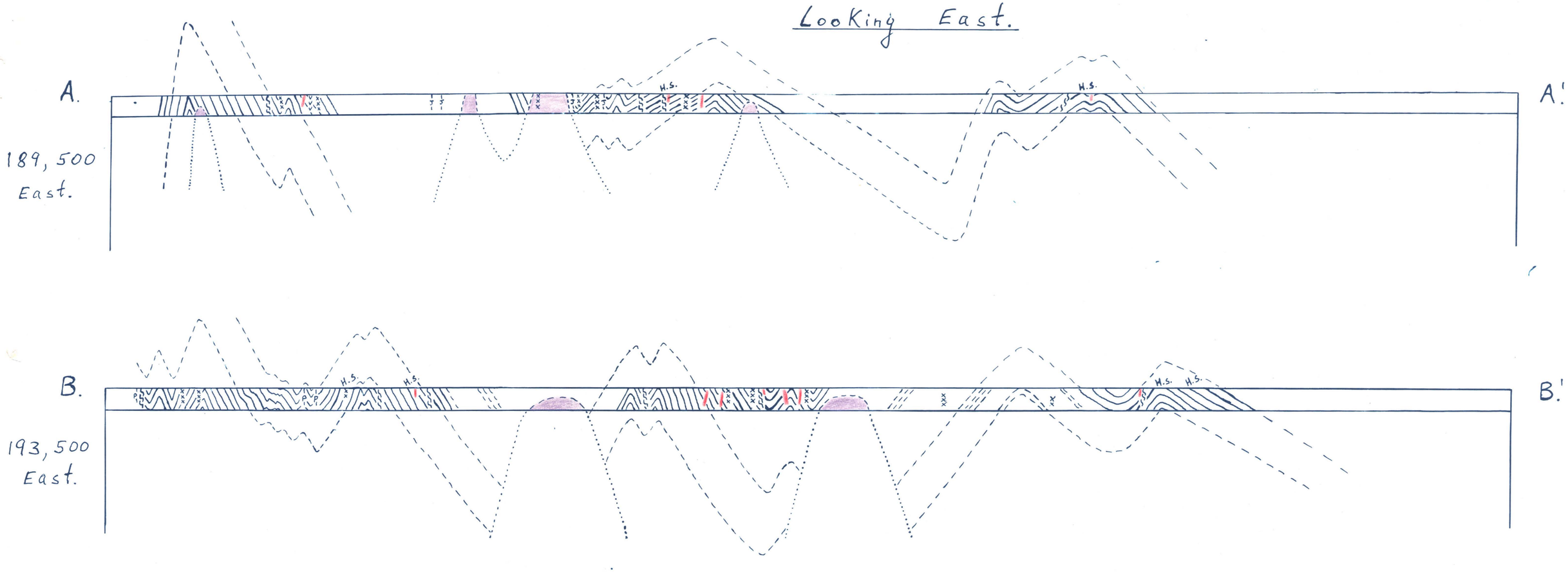
# Sketch Map of the Structure of the Mt SAMUEL Area

Showing extent of the two marker horizons



# Cross-Sections.

## Looking East.



# TENNANT CREEK

WARRAMUNGA GROUP:-

DIP & STRIKE

HEMATITE SHALE

PEBBLE BED

FAULT

ANTICLINE

SYNCLINE

SHEAR ZONE

PORPHYRY

RISING SUN CONGLOMERATE

MINE

0 2000 4000 6000 8000 Feet

0 ½ 1 2 Miles

187,000 190,000 195,000 200,000 205,000 210,000 214,000

A A' B B' C C' D D'

2544,000 2540,000 2535,000 2530,000 2527,000

GREAT NORTHERN

MARY ANN

CAROLINE

SHAMROCK

TRUE BLUE

MAPLE LEAF

ARIZONA STAR

TRUMP

PLAIN JANE

LONE STAR

GREAT BEAR

ACE HIGH

BURNT SHIRT

KATHLEEN

TENNANT CREEK

WHEAL DORIA

GIBBET

GOVERNMENT BATTERY

PINNACLES

SUSAN

SOUTHERN STAR

PUP

KIA ORA MINE

PEKO

GOLDEN FORTY

Mt. RUGGED

GREAT EASTERN

Mt. SAMUEL

HAMMER JACK

ENTERPRISE

ELDORADO

CATS WHISKERS

JOKER

NOBLES NOB

RISING SUN

RED TERROR

N

187,000 A 190,000 B 195,000 200,000 C 205,000 210,000 D 214,000

2544,000

2540,000

2535,000

2530,000

2527,000

CAROLINE
MARY ANN
GREAT NORTHERN
SHAMROCK
TRUE BLUE
MAPLE LEAF
ARIZONA STAR
TRUMP
PLAIN JANE
LONE STAR
GREAT BEAR
ACE HIGH
BURNT SHIRT
KATHLEEN
TENNANT CREEK
WHEAL DORIA
GIBBET
GOVERNMENT BATTERY
PINNACLES
SUSAN
SOUTHERN STAR
PUP
KIA ORA MINE
PEKO
GOLDEN FORTY
Mt. RUGGED
GREAT EASTERN
Mt. SAMUEL
HAMMER JACK
ELDORADO
ENTERPRISE
CATS WHISKERS
JOKER
NOBLES NOB
RISING SUN
RED TERROR

N

## TENNANT CREEK

WARRAMUNGA GROUP:-
TREND LINE
PEBBLE BED
PORPHYRY &—P—
RISING SUN CONGLOMERATE
IRONSTONE
QUARTZ VEIN xxxx
LAMPROPHYRE vvvv
JASPER —J—
FAULT or SHEAR ZONE
MINE

0 1000 2000 3000 4000 Feet
0 ½ Miles 1 1½

187,000 A' 190,000 B' 195,000 200,000 C' 205,000 210,000 D' 214,000