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THE GEOLOGY OF THE DUCHESS-TREKELANO AREA, NORTH WESTERN QUEENSLAND.

by

K.R. Walker

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SUMMARY

Ninety square miles of Precambrian rocks in the Duchess-Trekelano area, 60 miles south-west of Cloncurry, were mapped on a scale of 2 inches to 1 mile. The area is extensively mineralized and contains the Duchess and Trekelano copper-gold deposits. The rocks belong to the Corella Formation, which is mainly a calcareous succession. They are extensively metamorphosed and metasomatized, and are intruded by granitic and basic igneous rocks, each of two ages; thus the rocks of the area form a metamorphic and igneous complex. Various metamorphic and igneous units which form mappable rock units have been recognised. These units include metasomatic rocks such as hornfelsic or granulitic rocks, ortho-amphibolites, "red rocks", and aplitic-and pegmatitic-looking rocks.

Folding is intricate, strata having been plastically deformed, and dips are invariably steep. The general strike of the strata is slightly west of north and faults break the strata in north and north-east directions.

The few large copper deposits appear to be structurally controlled, whereas the much more numerous smaller deposits cannot readily be related to known structures. Mineralization is everywhere related to a general hydrothermal alteration that followed the emplacement of the basic igneous rocks, the early igneous granite and attendant chlorine and soda metasomatism, but was probably accompanied by the metasomatic formation of granite. Calcite deposits are quarried for flux, but known supplies are nearing exhaustion.

Geophysical and geochemical investigations in the Trekelano mine area both located roughly coincident anomalies.

It seems unlikely that new outcropping copper deposits will be found, as the area has been thoroughly prospected, and disseminated deposits are unknown. Consequently, the use of geophysical and geochemical methods will be necessary in the search for ore in future.

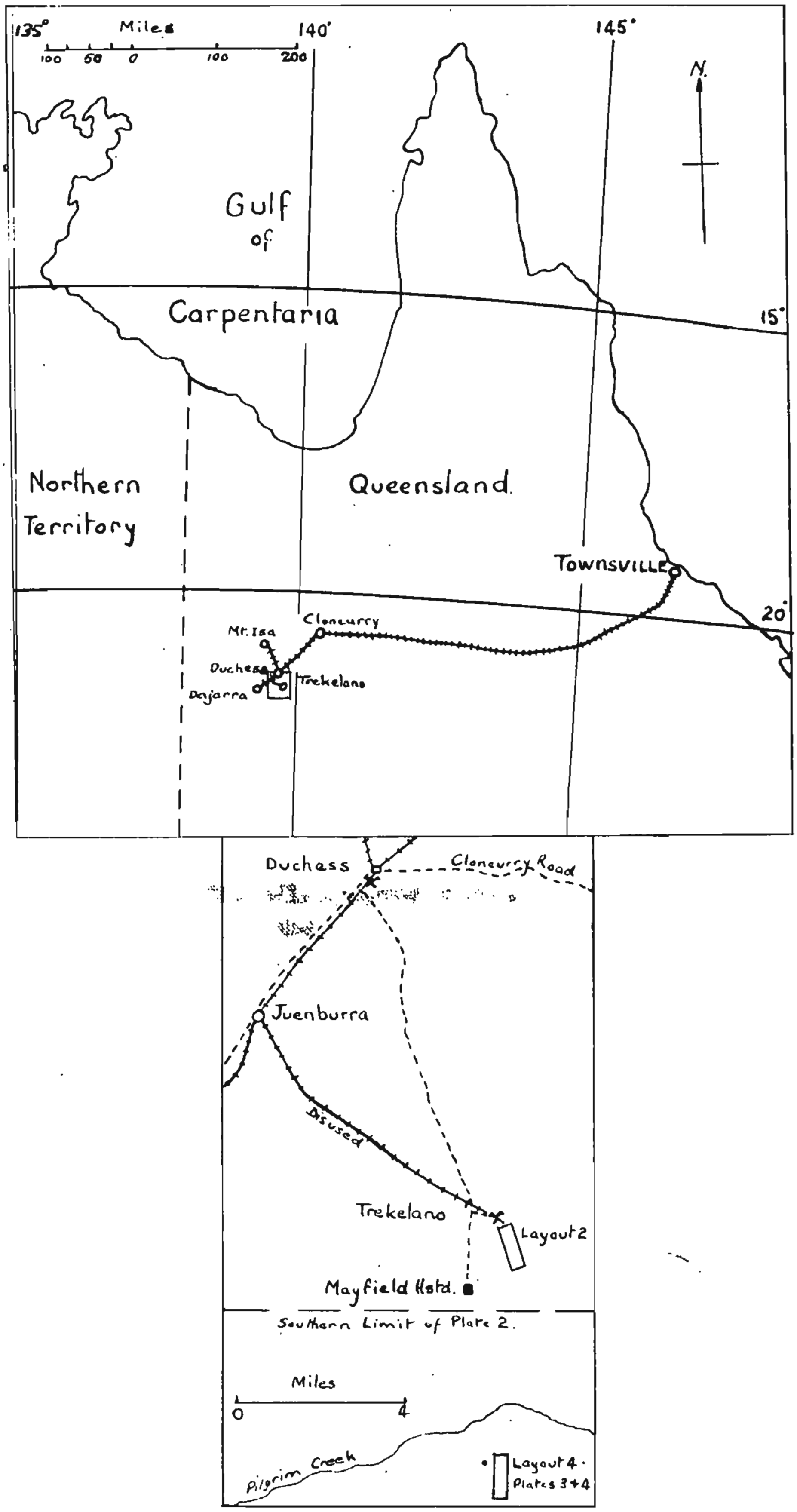


Plate 1 - Locality Maps Showing the Duchess - Trekelano Area.

INTRODUCTION

Geological mapping of an area between the Duchess and Trekelano copper mines was undertaken during July and August, 1957 by two geologists, one from the Bureau of Mineral Resources (K.R. Walker) and the other from Enterprise Exploration Company Pty. Ltd. (B. G. Riseley).

The area comprises approximately 90 square miles of Precambrian rocks bounded by outcropping Cambrian sediments to the east, Precambrian granite to the west and a soil covered plain to the south; mapping to the north was not extended beyond the latitude of Duchess. The area forms the southern half of area 3, authority to prospect 92M, Duchess area, held at the time by Enterprise Exploration Company Pty. Ltd. Area 3 is 25 miles by 6 miles.

The purpose of the survey was to map the area in greater detail than previously as an aid to further prospecting. As known economic copper deposits are exhausted in the area, any areas of potential mineralization located were to receive further investigation.

Location and access:

Duchess is 60 miles south-west of Cloncurry and 50 miles south-south-east of Mt. Isa, and Trekelano is 9½ miles south-south-east of Duchess. Both of these mines occur in the Mount Isa Gold and Mineral Field.

Access to Duchess is by graded gravel road and by rail from Mt. Isa and Cloncurry. The main road continues on to Dajarra and Trekelano is reached by a side-road from Duchess and also by a track that follows the disused railway line from Juenburra siding. This siding is 5 miles south-west of Duchess. Numerous other side-tracks connect Juenburra siding with both operating and depleted calcite mines which are mostly to the east of the siding. Duchess is a railway junction where the Mt. Isa line branches from the Cloncurry-Dajarra line.

Previous Investigations:

Previous investigations have been mainly concerned with the economic deposits in the area, particularly the Duchess mine environs and the Trekelano mine. However, the area was included in the regional mapping of the Precambrian Mineral Belt of North-western Queensland on a scale of 4 miles to 1 inch, undertaken jointly by the Bureau of Mineral Resources and the Queensland Geological Survey during 1950 to 1953.

In 1936, an area of 2 square miles around the Trekelano mine was mapped, in conjunction with a geophysical survey by E. O. Rayner for the Aerial Geological and Geophysical Survey of Northern Australia. Rayner also mapped an area of half a square mile, covering a number of old leases, 6 miles south of Trekelano.

S.R.L. Shepherd (1936, 1940 and 1953) reported for the Queensland Geological Survey on the Trekelano mine and mapped an area of half a square mile around it. Similarly, A. K. Denmead (1940) reported on this mine. Blanchard, Hall and McDonald (1941) submitted a report on the Trekelano mine to the Anglo Queensland Mining Co. Most of their work consisted of underground examination and mapping. Four diamond drill holes were subsequently put down by Broken Hill South Ltd., to intersect the Trekelano lode at depth, and an investigation of the mine was made by this company in 1949.

In 1952, E. Broadhurst (vide also 1953) mapped about 20 square miles around the Duchess mine for Broken Hill South Ltd. His map was used later by Edwards and Baker (1954) in their study of the "Scapolitization in the Cloncurry District of North-western Queensland". This investigation involved a detailed petrological study of the scapolite-bearing rocks from the Duchess and the Trekelano mine areas. It followed previous investigations of specimens collected by E. Broadhurst from the Duchess area and by P. B. Nye from the Trekelano mine, and from the cores of the four holes drilled by Broken Hill South Ltd., which were submitted to C.S.I.R.O. Mineragraphic Investigations for description. Some of these specimens formed the subject of mineragraphic reports Nos. 412 and 424, in 1949.

Mapping Method:

The R.A.A.F. aerial photographs (scale : 1-1/3 inches to 1 mile) were enlarged to a scale of 4 inches to 1 mile and field observations were plotted directly. An outcrop map was compiled on a scale of 4 inches to 1 mile using a slotted template layout controlled by astrofixes. This corresponds in part with the layout used in the compilation of the Duchess 4-mile sheet. The map (Plate 2) accompanying this report has been photo-reduced to a scale of 2 inches to 1 mile. Many of the boundaries on the map are approximate as they are commonly soil covered or are gradational between rocks which are products of metasomatism.

PHYSIOGRAPHY

The central north-south belt of the area forms a low-lying gently undulating plain; it roughly coincides with the part of the area mapped (Plate 2) as "Complex" rocks. Equidimensional outcrops of basic and acid igneous rocks form low rounded hills in this plain. Duchess is at the northern end and is 1190 feet above sea level (Plate 5, Fig.1).

South of the old Juenburra-Trekelano railway line, the central plain opens out into an extensive, soil-covered plain over the entire width of the area. A few hills, consisting of granite, aplite and quartzite, have low relief above the plain. The Trekelano mine workings were established in the northern part of this plain.

The central belt is bounded by prominent hills of para-amphibolites and "red-rocks" on the east and mainly by para-amphibolites on the west. The hills to the west are up to half a mile wide, and north of the Duchess-Dajarra Road they stand out prominently; but the country between these hills and the western border of the area mapped is low lying with only a few low hills that rise above the soil and rubble of the plain.

East of the central belt, the hills are highest in the west and grade into plain country to the east. This plain passes into undulating country to the south and into a series of north-south quartz-filled fault ridges to the east. These define the eastern margin of the area and separate it from the outcropping Cambrian sediments further east.

Silicified faults, which are commonly scree covered, strike roughly north-south and form prominent ridges. An example is the Juenburra Fault which extends three miles south-south-west from Duchess.

Drainage in the hilly country runs mainly a little south of east or west, cutting across the general north-south grain of the country. It feeds watercourses in the plain country which, except in the extreme north of the area, flow south into Pilgrim Creek and thence south-east. Streams only flow after rain during the wet season in the summer months.

As a result of mining calcite from veins, numerous cavities exist east of Juenburra siding which contain water fairly permanently.

ROCK UNITS

In terms of the regional geology of North-western Queensland, only strata of the Corella Formation and intrusive igneous rocks crop out in the area mapped (See Carter and Brooks, 1960). Further sub-division of this formation has not been possible, as the area is structurally complex and widely affected by igneous and metasomatic activity. The rock units described, therefore, are mainly those of metasomatic and igneous origin which are sufficiently widespread to form mappable units; however, much of the area is an igneous and metamorphic complex, and, where details of this complex were unresolved by mapping, the areas concerned are shown in Plate 2 as "complex" rocks. The boundaries of the metamorphic rock units do not necessarily conform to the original stratification, and are mostly discordant, irregular or gradational; the rocks of a unit may, however, contain relict bedding and a mineral assemblage indicating the type of pre-existing strata in the Corella Formation. The igneous rocks are grouped into basic and acid types; the groups contain rocks of several ages.

Metamorphic rocks include many metasomatic types that were derived from the thinly bedded, originally lime-magnesia sediments of the Corella Formation, and which have typically hornfelsic mineralogical and textural features, but are not true hornfelses, as they are mostly products of both metamorphism and metasomatism and not necessarily of contact metamorphism. Edwards & Baker (1954) have described many of these rocks as granulites. In this paper they are referred to as calcite, hornblende or pyroxene-rich calc-silicate hornfelses (Holmes, 1920, p.52).

Calcite-rich calc-silicate hornfels:

The calcite-rich calc-silicate hornfelses crop out in the north-east and the south-west corners, and on the western side, of the area; they are separated from the central "complex" by a band of pyroxene-rich calc-silicate hornfels (Plate 6, Fig. 8). The rocks one mile east of Duchess are also calcite-rich calc-silicate hornfels. Many of the outcrops contain patches of "red rock" (vide Edwards & Baker, 1954, pp 15 and 23, and this report, p. 6). Calcite segregations are common and the larger ones have been quarried for smelter flux.

The hand specimens are equigranular, medium-grained rocks in which calcite forms conspicuous grains and small segregations of grains throughout. The freshly broken rock has an uneven fracture and is grey. The light rock-forming minerals are probably feldspar and scapolite, and the dark mineral is mostly dark green hornblende. The weathered surface is generally pitted and may be iron-stained.

Thin sections show that the rocks are granoblastic and consist of equidimensional grains of calcite, scapolite and hornblende. Plagioclase and quartz occur in small amounts and pyroxene occurs in some rocks. Sphene, apatite, and opaque iron minerals are accessories. Grainsize is generally fairly even, though it may range from 0.1 to 1 mm.

Pyroxene-rich calc-silicate hornfels:

The pyroxene-rich calc-silicate hornfels borders the western margin of the central "complex". It also is the main rock of the hills west and south-east of Duchess, where it contains some horizons of sedimentary breccia whose fragments and matrix are also the same hornfelsic type.

Two varieties are recognizable in hand specimen. The first is a finely banded grey rock; the bands range from cream or pinkish white to dark green. The banding reflects original bedding; the light bands, composed mainly of plagioclase and some scapolite, alternate with the dark bands, which are mostly pyroxene-rich. The thin sections of the banded rocks contain mostly equidimensional grains up to 0.7 mm. across. Though grainsize is variable between rocks, individual thin sections are generally even-grained. The light bands consist of scapolite and plagioclase, and may contain quartz and microcline in lesser amounts. Grains of ferromagnesian minerals also occur, but these minerals mostly form the darker bands that are composed of pale green pyroxene and medium green hornblende. Accessory minerals are opaque iron mineral, sphene, and apatite.

The second variety is generally more homogeneous and is the product of more intense alteration than the first. Where metasomatism has strongly influenced alteration, the rock is gabbroic-looking but may retain indistinct patches of relict bedding. This type is more like the basified rocks described below (p. 6), and in thin section it is composed mainly of pyroxene, plagioclase, and scapolite with subordinate hornblende. Apatite, sphene, and less commonly, opaque iron mineral, are accessories. The rock has a granular texture, and although some rocks are even-grained, equidimensional grains measured in a number of thin sections ranged from 0.1 to 1 mm.

Hornblende-rich calc-silicate hornfels :

Although the hornblende-rich calc-silicate hornfels is probably a fairly common type it is difficult to map systematically, as it is closely associated with both the calcite and pyroxene-rich varieties. The rock lacks conspicuous calcite and shows insufficient metasomatic alteration to be pyroxene-rich. It, therefore, occurs mostly in areas of moderate grade alteration.

Hand specimens are mostly dark grey and are fine-to medium-grained. Hornblende is the most conspicuous mineral, but light grains, probably of plagioclase with some scapolite, occur in lesser numbers.

Biotite and hornblende schists:

Basic schists are widespread, and the largest outcrops occur along the western margin of the area. They form valley floors. Small patches of schists occur in the areas of outcrop of the other rock units mapped, particularly in the "complex". Some are also to be found on the eastern side of the area in "red rock" (p. 6) where they are most noticeable near faults.

The large exposures of schists in the west are mostly biotite schist that may contain some hornblende or muscovite. The colour of the schist darkens with increasing biotite content. The rocks are schistose in hand specimen and between the abundant biotite flakes, finely granular plagioclase and quartz can be recognised. Some rocks, particularly the muscovite-biotite schists, contain porphyroblasts of muscovite which appear to have partially replaced aggregates of plagioclase crystals. The thin sections show that the rocks are schistose and contain biotite, and some muscovite. Microcline, and some plagioclase and quartz, occur between the oriented mica flakes. Opaque iron mineral and scapolite, though accessory minerals, are common. Other accessory minerals are tourmaline and apatite. Biotite flakes measure up to 0.5mm long and the other mineral grains are mostly between 0.1 and 0.5mm. in diameter. The porphyroblastic aggregates measure up to 10 mm. across.

The hornblende schists occur where the various calc-silicate hornfelses have been sheared, and like the biotite schists, small patches of them are widely distributed. They are well developed in the Trekelano mine area and along the western border of the central "complex". The rocks are schistose, and biotite flakes, in addition to hornblende grains, can be recognized in freshly broken surfaces parallel to the schistosity. In thin section, numerous small quartz inclusions can be seen in the hornblende forming sieve structure. Between these oriented minerals are granular plagioclase and potash feldspar, and some scapolite and quartz. Accessory minerals are ilmenite, tourmaline, and apatite.

Muscovite Schist :

Muscovite schists crop out 3 miles north-north-east of the Trekelano mine and 1½ miles east of Duchess. At the southern end and on the eastern margin of the first-mentioned occurrence, pink aplitic and porphyritic rocks appear to grade into these schists. East of Duchess the schists have developed with quartzitic-looking rock at the northern end of a north-south striking fault that extends as far south as the Trekelano mine. The alternation of sericite schist with pale pink aplitic rocks can also be seen 3¼ miles south-east of Duchess. Only small scattered outcrops of muscovite schist occur west of the central "complex"; one exposure has been dissected by the Railway Fault, which has displaced the southern portion 1¼ miles further south-west from Duchess than the northern one.

As with the biotite schists, the muscovite schists crop out in areas of low relief. In hand specimen the schists have moderate to abundant muscovite flakes between which finely granular quartz and feldspar occur. They are typically schistose. In thin section muscovite preponderates over biotite, and granular quartz is the main mineral between the mica flakes. Small amounts of feldspar are also present.

Basified Rocks:

The basified rocks are para-amphibolites that consist almost completely of ferromagnesian minerals. It is believed that they were derived from the hornfelses, described above, by addition of basic material, possibly as a result of action by a basic front. (vide p. 12)

The outcrops of these rocks are generally small and widely distributed. However, a large outcrop occurs east of Juenburra railway siding; possibly a continuation of it appears $1\frac{1}{4}$ miles north-east, on the northern side of the Railway Fault. Rocks from these outcrops are hornblende-rich. Examples of pyroxene-rich rocks include the hill south of the Ivanhoe lode at Duchess, and numerous small round hills which form prominences above the plain about 2 and 5 miles south of the Duchess-Cloncurry Road, 3 miles east of Duchess. "Red rocks" invariably occur near the basified rocks.

Amongst the hornblende-rich type are schistose bands carrying biotite. The massive hornblende-rich type is dark green-black to black, fine-grained and spotted with sporadically-distributed aggregates and porphyroblasts of cream feldspar. Outcrops are shiny and massive or exfoliated. In thin section the rocks are fairly even-grained and consist mostly of hornblende; grains are equidimensional and measure up to 0.5 mm. A few pale green pyroxene grains incorporate smaller hornblende grains. Scapolite and plagioclase are evenly distributed between the ferromagnesian minerals but occur in much smaller amounts. The feldspathic aggregates show heavy turbid alteration and appear to be a potash variety. Small grains of opaque iron mineral and sphene are scattered throughout.

The pyroxene-rich rock is a more basic variety of the pyroxene-rich calc-silicate hornfels described on p. 4 . It has dark, massive outcrops, which are commonly gabbroid-looking. Thin sections show granular texture and contain mainly pale green pyroxene or pyroxene with some medium green hornblende, between which scapolite occurs. Grainsize is variable, even within a single thin section. Grains are equidimensional and up to 1mm. across. Accessory minerals are ilmenite, sphene, and apatite.

"Red Rocks":

A group of unusual rocks that are commonly brick red have been referred to previously by Edwards & Baker (1954, p.15 & 25) as "red rocks". These rocks were analysed and described by them. They are believed to have been formed from calc-silicate rocks during the general hydrothermal alteration in the area (see p. 22). The "red rocks" occur throughout the area and are the predominant type east of the central "complex". Further east, on the plain, rubble of "red rock" in the soil indicates that "red rock" is concealed beneath the plain. The occurrence of "red rock" west of the central "complex" is donfined mostly to outcrops north and south of the Dajarra railway line, about 3 miles south-west of Duchess. Another manifestation of the general hydrothermal alteration is the numerous veins and replacement dykes which are widely distributed in most of the country rocks (Plate 9, Fig. 1).

The "red rocks" have massive or jointed outcrops. Relict bedding can be seen on many of the brick red rock surfaces. Moreover, where the banded calc-silicate hornfelses are cut by replacement veins of red soda feldspar, the relict bedding remains undisturbed, (Plate 9, Fig. 1) The "red rocks" are fine and mostly even-grained. They consist mainly of red soda feldspar, secondary quartz, and of scapolite and residual ferromagnesian minerals (mostly pyroxene but also hornblende) in lesser amounts. Other minerals, which are evenly distributed in various amounts, are epidote and, not infrequently, actinolite, calcite, and hematite; any of these minerals may form segregations in the "red rock" country. Thus, there are a wide variety of "red rock" types. A thin section of one specimen shows it is granoblastic with a range in grainsize from 0.1 to 0.3mm. It consists mainly of oligoclase and of some residual pyroxene and rare hornblende. The plagioclase has a red colouration owing to impregnation with finely divided hematite. Accessory minerals are apatite, calcite, sericite, and opaque iron mineral.

Quartzitic rocks :

The main outcrops of quartzitic rock are at the northern end of the north-south striking fault that appears to pass through the Trekelano mine, and adjacent to the same fault about 2¾ miles south-east of Duchess. Other small occurrences are found in the south-west and north-east corners of the area. The rocks of these outcrops are granular and quartzitic and were probably produced by silicification of the country rock.

The quartzitic rocks include epidote-bearing varieties which are generally found in association with "red rock" or with calcite-bearing calc-silicate hornfels. These occur south of the Cloncurry Road, 2¼ miles east of Duchess; two other outcrops are 2 miles and 3½ miles farther south. They consist of alternating bands of epidote quartzite and hornblende-biotite schist. If these outcrops originally belonged to the same belt, then much of it has been altered to "red rock". Other epidote-bearing quartzites have been mapped midway between Juenburra siding and the Trekelano mine and also 1¼ miles north-north-west of the mine. Rubble of epidote bearing quartzitic rocks occurs in the soil of the low-lying country west of the fault ridges in the south-west corner of the area.

The epidote quartzite is fine-grained and green, and consists mainly of quartz with epidote in various amounts.

The "Complex" rocks :

The "complex" rocks occur in the central part of the area and extend from the northern border south to the old Juenburra-Trekelano line, where they pass beneath the soil of the southern plain. A small outcrop occurs 2½ miles south-west of Duchess.

The "complex" rocks are a conglomeration of metamorphic and metasomatic rocks into which igneous rocks of several ages have been intruded, forming, in some cases, composite bodies. (Plate 6, Fig. 2). The metamorphic rocks recognised are mostly hornblende-biotite schist and para -and ortho-amphibolites. Intrusive granitic rocks and silicification are widespread. Moreover, granitized country rocks and migmatites are fairly uncommon and are accompanied by pegmatitic and aplitic types. Two ages of basic igneous rocks are represented, the older rocks being the ortho-amphibolites. The large igneous intrusives are shown on the map.

Granitic rocks :

Although the granitic rocks are widespread, they occur mainly in the "complex " where their outcrops form low rounded hills; an example may be seen 5 miles south of Duchess. They also crop out in the "red rocks" 3½ miles south-south-east of Duchess. Scattered granitic outcrops, with which pegmatitic and aplitic types are associated, occur in the plain south of the disused Juenburra-Trekelano railway line. Two miles north-west of the Trekelano mine aplitic types grade into medium-grained granite on their northern and eastern margins. Another medium-grained granitic rock crops out 1 mile south-south-east of Duchess; a northern exposure of this granite is foliated, and its foliation conforms with the bedding in the adjacent pyroxene-rich calc-silicate hornfels.

Among these examples are both igneous and metasomatic types, but the genesis of the granites cannot always be determined from their outcrop. Conformity between the foliation in the granitic rocks and the schistosity in the country rocks, though only one example is cited, is of common occurrence, and in the Duchess area small and large patches of country rock apparently have been made over, in situ. to granite. This granitic type formed at a late stage in the sequence of geological events and was probably preceded by an earlier igneous granite (p.12) that may be seen as small stock-like bodies and dykes cutting the country rocks; examples occur at the foot of the western hills, adjacent to Duchess, where they contain abundant xenoliths. Veins of granite cut many of the microgabbro dykes and stocks (Plate 7, Fig.2), which are the youngest basic intrusives in the area. But the igneous granite has not been seen to invade the foliated granitic rocks.

The igneous granite is the more massive of the two types and is fine-or medium-grained. Cream feldspar, quartz and hornblende can be recognised in hand specimen. Thin sections show that the rock is allotriomorphic granular and that it consists mostly of microcline, quartz, and plagioclase. Both feldspars are extensively altered and are turbid brown. The plagioclase appears to be oligoclase. Accessory minerals are opaque iron mineral and zircon and rarely apatite, pyroxene, tourmaline, rutile, and sphene also occur. Grainsize mostly ranges between 0.1 and 3mm; microcline and quartz form the larger grains, some of which measure 5 mm across.

The metasomatic granite is probably the most abundant granitic type in the area. It is commonly foliated, is from fine to medium-grained and its colour is largely determined by the biotite content and the colour of the feldspar; it is generally pink. It tends to be somewhat porphyritic and consists mostly of pink potassic feldspar, quartz, and biotite in lesser amounts. Some of the biotite has been chloritized. Soda plagioclase occurs only in small amounts. Microcline is fresh whereas other feldspars may be altered and reddish brown. Sphene is a rare accessory.

Pegmatitic rocks :

Pegmatitic rocks are widely distributed in the "complex" rocks and are closely associated with the "red rocks". They occur amongst the granitic rocks exposed in the plain south of the Juenburra-Trekelano line where they apparently formed during the development of granitic rocks accompanying the general hydrothermal alteration (p.12) For example, 2 miles north-north-east of Trekelano mine the pegmatitic rocks occur amongst aplitic types, whereas farther south they are associated with "red rocks". Moreover, this close association with "red rocks" and porphyroblastic aplitic types is commonly found adjacent to major north-south striking fractures in the area. Examples of pegmatitic rocks within "red rock" may be seen $1\frac{1}{2}$ miles east-south-east of Duchess and about 2 miles farther south of this point; at these localities "red rock" grades into an amphibole-free pegmatitic rock. An example of a pegmatite associated with foliated granite occurs 1 mile south-south-east of Duchess where a large pegmatitic dyke, containing calcite and quartz with extremely coarse pink microcline, extends northwards from the granitic rock into pyroxene-rich calc-silicate hornfels.

Aplitic rocks :

The aplitic rocks occur mainly to the east of the central "complex" and are found (1) adjacent to, or in, "red rocks"; (2) adjacent to major north-south fractures; (3) Rarely as apparently isolated occurrences, in which case they commonly retain relict bedding or foliation. Their field relations indicate that they are metasomatic rather than igneous rocks.

Aplitic rocks occur at numerous points along the series of north-south faults that border the eastern margin of the "complex". Some scattered outcrops of aplitic rocks at the northern end of this line of faults contain relict bedding.

At a point 2 miles north-west of the Trekelano mine small outcrops of pink aplitic and porphyritic rocks occur amongst the pyroxene-rich calc-silicate hornfels. The aplitic rock appears to retain original bedding planes; thus planar structures, including foliation, are conformable with bedding in the adjacent country rocks. At the northern end of the outcrops, aplitic rocks are more abundant and grade into pink granitic rocks. In this part the hornfels is medium-grained and massive, consisting of dark green hornblende with feldspar and quartz in lesser amounts. However, at the southern end transgressive contact relations are seen, and scattered outcrops of the aplitic rocks extend to within $\frac{3}{4}$ mile of the Trekelano mine. Another outcrop occurs 1 mile north of the mine.

Similar relict bedding and para-amphibolites occur on the western margin of pink aplitic rocks that crop out adjacent to pyroxene-rich calc-silicate hornfels, 2 and $3\frac{1}{2}$ miles south-south-east of Duchess.

The aplitic rocks contain pink, and less commonly white, feldspar with quartz. They are fine-grained and granoblastic. Some of them have phenocrysts or porphyroblasts of microcline and microcline - perthite. Small amounts of altered biotite and magnetite are evenly distributed through some specimens.

Porphyritic or porphyroblastic rocks :

Closely associated with the aplitic rocks are rocks which are either porphyritic or porphyroblastic. These rocks crop out 2 miles north-north-east of the Trekelano mine, and also about 1 mile north of this point there are scattered outcrops that have bedding or foliation plans which conform with the schistosity in the adjacent muscovite schist in the west and with relict bedding in "red rock" in the east. They occur in the north-east corner and form rubble in the soil-covered plain surrounding the outcrops.

These rocks consist of flesh-coloured feldspar and clear quartz grains set in a red-brown aphanitic groundmass.

Basic Igneous rocks :

Two ages of basic igneous activity are represented in the area.

Many of the rocks of the first event are ortho-amphibolites metamorphosed during regional folding and metasomatized subsequently by soda and chlorine. The rocks of the second event are microgabbro which, compared with the earlier basic rocks show little deformation and alteration. They have incipient joints along which some scapolitization and hydrothermal alteration took place. This alteration caused distinctive bands to develop in them (Plate 8, Fig. 2).

The basic igneous rocks are widespread. The earlier intrusives are mostly dykes and small irregular-shaped bodies. The dykes are up to 50 feet wide and up to about ½ mile long. A dyke swarm occurs in the calc-silicate hornfelses and schists, 3 miles south-west of Duchess. Amphibolitic dykes occur in the environs of Duchess and cut the pyroxene-rich calc-silicate hornfels at ¾ mile west and also ¾ mile south-east of Duchess. They have been observed at numerous points in the central "complex" and in the calcite-rich calc-silicate hornfels east of Juenburra siding.

The basic rocks of the first event are ortho-amphibolites, and it is difficult to distinguish them in the field from the para-amphibolites; they may be schistose, migmatitic or massive and granoblastic. Some dyke outcrops are short jointed (Plate 8, Fig. 1). The hand specimens have a dark basic appearance and break with an uneven fracture. Thin sections show that the rocks are either schistose amphibolites or, more commonly, granular (Plate 10, Fig. 1), as they consist mainly of equidimensional granoblastic grains of pyroxene or amphibole or both, plagioclase, scapolite, and quartz. Accessory minerals are opaque iron mineral, apatite, and sphene. Grainsize is fairly even and ranges from 0.5 to 1mm.

The later basic rocks mostly form stocks and irregular-shaped bodies. The stocks measure up to 1 mile in diameter and some of them may be composite bodies. These are well-represented in the Duchess mine area and form numerous outcrops of low rounded hills in the "complex" rocks to the south of Duchess (Plate 5, Fig. 2). Hydrothermally altered rocks of this event crop out 2 miles and 5 miles south of a point 3 miles from Duchess on the Cloncurry Road.

The basic rocks of the second event are slightly altered dolerite and microgabbro. Their outcrops are block jointed or of rounded boulders (Plate 8, Fig. 1). Hand specimens are dark grey and break with a sub-conchoidal fracture. In thin section the rocks can be seen to consist mainly of augite, hypersthene, and labradorite. Pigeonite, biotite, opaque iron mineral, and quartz may occur in small amounts. The texture is ophitic, porphyritic or intergranular (Plate 9, Fig. 2) Grainsize ranges from 0.2 to 3mm. Alteration is slight, being mainly uralitization of pyroxene and scapolitization of feldspar, particularly along incipient joints. A few rocks show low to moderate-grade thermal metamorphism (Plate 10, Fig. 2).

In the Duchess area a number of more basic varieties crop out. These rocks are gabbroid and contain olivine in conjunction with more basic plagioclase and more abundant pyroxene. They are probably accumulative types derived from the microgabbre.

STRUCTURE.

Folding :

The rocks of the Corella Formation were mainly calcareous, but included argillaceous bands. In the Duchess area, these rocks have been altered to para-amphibolites and various calc-silicate and micaceous schists. Folding in these rocks is complex, and, in the case of the originally calcareous sediments, intricate folding resulted from plastic deformation; igneous and metasomatic activity have disrupted structural features further.

Mapping on the present scale did not permit structural analysis; the impression was gained that minor structures are not always a guide to the character of major structure. If this is correct, disordered folding probably was the result of plastic deformation. Measured strikes and dips (Plate 2.) show that the grain of the country strikes slightly west of north, and that dips are generally steep. Most folds plunge north.

Faulting:

Two sets of Precambrian faults have been recognized; members of the first range from 350° to 355° (magnetic) and those of the second range from 025° to 045° (magnetic). The faults of the first set, and their walls, are silicified, and form weathered ridges that have a quartzitic appearance. Examples border the eastern boundary of the area. Faults of the second set are younger and contain white, crystalline, vein quartz, or calcite including some red soda feldspar; some have weathered, iron-stained, jaspery outcrops and others are mostly concealed by soil. These faults are not as conspicuous as those of the first set, though their linear/ments can be seen in the aerial photographs.

The faults immediately east of the central "complex" belong to the first set; they are siliceous and have served as access channels for solutions of the general hydrothermal activity (p. 12). One of these, passes into muscovite schist at its northern end, has breccia associated with it four miles south-east of Duchess, and may pass through the Trekelano mine at its southern end. (See p. 17).

Another fault of this set meets the Duchess-Dajarra railway line about $2\frac{5}{8}$ miles from Duchess where, it has been displaced by the younger Railway Fault. The northern part is indicated by a quartzitic-looking ridge, whereas the southern part, which is displaced south-west, is less siliceous.

The Railway Fault is an important fault of the second set as it has displaced faults of the first set. Whereas the older faults are high angle longitudinal faults, the younger ones are high angle transverse faults; these obviously caused considerable lateral movement, sufficient, in the case of the Railway Fault, to displace the southern block a mile and a half. The rock sequence to the north of the Duchess-Dajarra railway line is thus repeated south of the line farther south-west.

Other faults striking 030° occur west of the eastern boundary fault-ridges and also $2\frac{1}{2}$ miles to the north-east of this occurrence. The displacement on the more easterly of these faults is similar to that of the Railway Fault, provided the calcite-rich calc-silicate hornfels to the south originally coincide/d with similar rocks, that are partly converted to "red rock", to the north.

The dis/placement of the Juenburra Fault is shown by outcrops at its southern end, and is about one quarter of a mile, the south-eastern block having moved south-west.

The ages of faulting may now be approximately established. A fault of the first set that intersects the Duchess-Dajarra railway line $2\frac{5}{8}$ miles from Duchess has been displaced by the younger Railway Fault. Faults of both sets have been exploited during the general hydrothermal activity, which deposited "red rocks" products in them; thus this event followed the main epoch of faulting in the area. Faulted "red rocks" have not been observed anywhere. However, disruption of the Cambrian strata demonstrates renewed fault activity at a later date, but probably this involved mostly the re-opening of old fractures in the underlying strata. For example, where the Duchess-Cloncurry Road crosses a post-Cambrian fault that marks the eastern boundary of the area, an extensive fault breccia is exposed. Moreover, drag folds and contortions have developed in the Cambrian sediments.

As faults of the second set are younger than those of the first, the latter faults probably re-opened during the formation of the former, together forming a fault system, which probably also helped the relief of late stress in the area. In the absence of sufficient structural and stratigraphical detail, however, the displacement in most faults has not been determined and the direction of forces causing the faults are, therefore, unknown.

GEOLOGICAL PROCESSES AND SEQUENCE OF EVENTS.

Geological events in the area were initiated by the deposition of the Corella Formation, a succession of finely inter bedded calcareous slightly calcareous and non calcareous shale bands, dolomitic bands may also have been deposited.

These beds were intruded by basic rocks following which regional metamorphism and faulting took place; the strata were plastically deformed. Regional metamorphism accompanied folding, and though generally low grade, it reached the amphibolite facies in places.

Some igneous granite was emplaced at this stage, causing contact metamorphism. Late phases of this acid igneous event were probably soda rich, as a regional soda and chlorine metasomatism appears to accompany them. The metamorphosed calcareous strata, and the basic igneous rocks of the first event, were metasomatically altered to various scapolite-bearing para-and ortho-amphibolites. The deformation, had caused internal fracturing of these rocks, which assisted the migration of metasomatic solution through them.

Another basic igneous event followed the main diastrophic episode and probably the regional metasomatism. The rocks of this event are massive and typically impermeable igneous rocks, which are unaffected by regional metamorphism, but are slightly scapolitized. Scapolitization occurred only along incipient joint planes. Granite, however, veins the younger basic igneous rocks also (Plate 7, fig. 1), suggesting another still younger acid igneous event. It contact metamorphosed these basic rocks in places; in general, however, their alteration is slight or negligible.

The general hydrothermal alteration followed the main igneous events, and, with it, the attendant formation of metasomatic granite took place. This alteration resulted in many of the hornfelsic and granulitic rocks being converted to "red rock", which is one of the main, and most distinctive, products of it. Edwards & Baker (1954, p.1) believe that the formation of "red rock" resulted from leaching of MgO and some of the CaO and FeO from the calc-silicate rocks, as well as from some of the igneous rocks within them; part of the iron was redistributed in a finely divided state as hematite, giving the rocks their typical opaque, red colouration. The attendant process involved mainly potash metasomatism, but granitization of the calc-silicate rocks would also have required additions of SiO_2 and Al_2O_3. As these hydrothermal and granitization processes were so intense, it is possible that some of the regional metasomatic products in the affected country rocks were decomposed, and, as a result, further minor scapolitization took place, as shown by alteration along the incipient joints in basic igneous rocks of the second event.

That granitization was a late event, is shown by its effect on previously scapolitized country rocks. Furthermore, pegmatitic and aplitic-looking rocks developed in conjunction with the "red rocks" and together these formed massive rock bodies and replacement veins, many of which are in the proximity of north-south fractures that the solutions used for access to the country rocks. Mineralization is also associated with the general hydrothermal alteration, and thus the Duchess lode occurs in sheared granitic and basic igneous rocks. This fact, and the fact that igneous granite has not been seen invading the foliated granite, suggest that the igneous granite was intruded before granitization.

ECONOMIC GEOLOGY

Copper and calcite have been mined in the area. At present, however, only small amounts of calcite are being extracted to use as flux in the Mt.Isa Mines smelter. Copper has been obtained principally from the Duchess and Trekelano Mines: only small tonnages have been produced from the numerous other old workings.

Duchess Mine :

Little information is available on the details of the Duchess mine and its workings; the mine was worked until 1920. Ore reserves were exhausted and the mine workings are now inaccessible. Details of the mine and its setting have been briefly summarized by Nye and Rayner (1940). The mine produced 24,747 tons of copper from ore averaging 12.3 percent. The lode occupied a shear zone in mica and quartz-mica schist and gneiss which strikes roughly north-south and dips steeply east. Ore was mined over a maximum length of 700 feet and an average width of 5 feet. It consisted of bornite, chalcopyrite, pyrite, quartz and carbonate but was mainly bornite with smaller amounts of chalcopyrite in a gangue of pinkish carbonate. Quartz was not common near the surface but was plentiful below the 500 feet level; below the 850 feet level, the level the mine was worked to, carbonates gave way entirely to sheared country rock partially replaced by glassy quartz and with small amounts of copper and iron sulphides. The oxidized ore does not appear to have been particularly important.

In the map (Plate 2) a zone around the mine is outlined with a broken line. This roughly delineates the zone of wall rock alteration surrounding the Duchess lode. Within this zone, country rocks including para- and ortho-amphibolites and granitic rocks, have been sheared and strongly leached. The rocks are now decomposed and are transected by a complicated network of travertine-like veins (Plate 7, Fig.2). Material from these veins is white and easily powdered; it decomposes in dilute hydrochloric acid leaving a few silica grains as a residual.

Only small amounts of rock and mineral discharged from the mine remain in dumps. The dumps indicate that some of the wall rock was hornblende-biotite schist which contained veins and patches of "red rock" in addition to calcite with bornite and chalcopyrite.

Trekelano mine :

Information on the Trekelano mine has been accumulated by a number of workers (vide References p.19) many of whom have inspected the underground workings before they became inaccessible. Little information can be obtained from surface inspection as the mine occurs beneath a soil covered plain with little outcrop. The mine was discovered in 1907 and the main period of production was from 1928-1943. It was closed mainly because of labour difficulties. Lack of mining development at the time means potential ore reserves are unknown.

The ore occurred within a zone of shearing in hornblende-biotite schist; the shearing has a general north-south strike and dips at 60° to 75° west. The mined zone is 300 to 400 feet long and 110 feet wide. According to Shepherd (1940) the ore is concentrated in three subordinate fissures within this zone. Blanchard, Hall and McDonald (1941) believe that the ore was localized in the foot wall of an overthrust fault.

Secondary ore was more common than at Duchess and extended to a depth of 200 feet. Primary ore was worked to 800 feet and was of uniform grade, averaging a little more than 10 percent copper and 1.5 dwt of gold per ton. The mine produced 20,141 tons of copper. The ore consisted essentially of chalcopyrite in a calcite gangue and occurred mainly as a dissemination, either uniform or erratic, in the schist. The calcite also formed stringers and tongues and, in a few places, lenses up to 40 feet long and 10 feet across; chalcopyrite mainly occurred around the fringes of these. Less important gangue minerals are augite, magnetite, garnet, epidote and a small amount of quartz. Quartz was mainly limited to a few cross fractures.

Inspection of the dumps and open cut south-east of the shaft showed that the country rock was mostly hornblende-biotite schist. Small patches and veins of "red rock" and calcite containing chalcopyrite are common in this schist. Edwards & Baker (1954) examined bore cores from holes put down by Broken Hill South Ltd. and found that the cores were composed predominantly of hornblende-biotite schist with alternating bands of pyroxene-rich granulite and that small red soda feldspar veins cut the foliation of the schists.

Although outcrop is poor in the mine environs, it is evident that much "red rock" and associated pegmatitic rocks occur in the area. The mineralization appears to be related to the general hydrothermal alteration which followed the regional metasomatism and metamorphism.

Small Copper Deposits :

Numerous small copper deposits have been mined in addition to the deposits described above. Examples are St. George and Maude A. mines In some cases excavation was extensive in comparison to the amount of ore obtained. Most of the small deposits were in narrow fissure veins or shear zones; they have been mined to less than 25 feet deep. Only a few tons of ore were mined from each mine, except for the St.George mine (101 tons).

Calcite deposits :

Most of the calcite produced in the area has been quarried from concentrations in the calcite-rich calc-silicate hornfels east and north-east of Juenburra siding. Many of the workings, however, are exhausted. The calcite is carted from the few remaining quarries to Juenburra siding and railed to Mt. Isa for smelter flux. Over 122,000 tons have been quarried from this area.

Calcite mainly occurs in fissures but is also concentrated in the crests and troughs of some folds. The quarried veins strike roughly north-south. Smaller calcite veins occupy joints that strike between 025° and 065°.

An examination of the quarries show that products of the general hydrothermal alteration are intimately associated with the calcite and that disseminated chalcopyrite is commonly concentrated at the fringe of the calcite segregations. Other associated hydrothermal products within, or adjacent to, calcite are concentrations, or disseminations of, red soda feldspar, epidote, amphibole, pyroxene, and hematite.

GEOPHYSICAL & GEOCHEMICAL PROSPECTING

Geophysical Investigations:

Because of the extensive soil cover in the vicinity of the Trekelano mine, the Aerial Geological and Geophysical Survey of Northern Australia conducted an electro-magnetic survey around the mine and followed this up by self-potential, potential ratio, resistivity and magnetic methods to check the more promising anomalies. Over the Trekelano mine all the electrical anomalies coincided closely with the known ore deposit, but the known weakly mineralized portions registered as strongly as the high grade portions. A number of other electro-magnetic anomalies, (See Rayner, Nye & Horvath, 1936, plate 1), away from the Trekelano mine, was indicated but several were not confirmed by the self-potential method. About half of the moderate to strong anomalies were tested by costeaning, drilling, or shaft sinking, but without success. Rayner et.al. (op. cit) noted that the strong electro-magnetic anomalies occurred in narrow schist embayments surrounded by granite, and that the anomalies were probably due to minor shearing, pyritization, or some other condition, along the granite-schist contact, not necessarily related to important chalcopyrite deposition. Furthermore, by using the electro-magnetic method the problem arises as to how to distinguish between an electro-magnetic anomaly produced by a solid conductor and one produced by a liquid conductor; in the case of the present area any of the ore-deposits under the plains, or soil covered country, might be expected to be associated with basic schist. Thus, owing to the porous nature of the schist and the pyrite mineralization sometimes found in it, it is probable that many electro-magnetic anomalies would be caused by conductive mineralized waters in the schist.

Geochemical Investigation :

During the preparation of an outcrop map of the Duchess-Trekelano area, some of the stronger geophysical anomalies detected by A.G.G.S.N.A. were tested geochemically. Further testing was carried out during 1958. The areas concerned occurs $1\frac{1}{4}$ miles south-south-east and 6 miles south of the Trekelano mine.

The geophysical anomalies are shown in Plates 1 and 8, layout 2 and 4 of Rayner & Nye, 1936 and in Plates 3 and 4 of this report. Plate 3 shows the results of the 1957 work and Plate 4 those for 1958. The samples collected in 1957 were analysed for copper by A.H. Debnam, and in 1958 the samples were collected and analysed by A. McClure. From Plates 3 and 4 it can be seen that work undertaken during 1958 was a continuation of the work in 1957, following the promising results obtained. The 1957 work was repeated using a different sampling method. During 1957 samples were taken from one particular horizon in the soil profile, regardless of depth, whereas during 1958 samples were collected uniformally 15 inches beneath the ground surface. This duplication has enabled the copper concentrations in soil samples from constant depth to be compared with those from a particular horizon. This resulted in overall lower copper concentration being found in 1958.

The samples obtained are mostly from soil overlying the stronger geophysical anomalies shown in layout 4, an area which is essentially a soil covered plain prospected only by a few shallow shafts. Although an attempt was made to use the same base line in 1957 and 1958, corresponding holes put down each year are probably only within 25 feet of each other. The holes were planned to coincide with the grid established for the geophysical survey and directly overlie the geophysical anomalies, by using base peg ML. 1079 for control in layout 4, and 2 costeans about 350 feet east of the A.G.G.S.N.A. base line in layout 2.

Each year the traverses were made at 200 feet intervals, samples being taken along these at 50 feet intervals and at depths ranging from 1 to 10 feet. A hand soil auger was used and in 1957 one hole per traverse went to bed-rock. In 1957, 133 samples were collected from layout 4 and 30 from layout 2, and in 1958, about 450 samples were tested from layout 4.

Analyses of the soil samples for copper showed that the geochemical anomalies coincide with the geophysical anomalies shown in layout 4 (Plates 3 and 4). The analyses made of samples collected during 1957 (Plate 3) indicate that 18 samples contain more than 300 p.p.m. copper whereas surrounding samples yield less than 200 p.p.m. copper and mostly less than 100 p.p.m. Later work by McClure (Plate 4) which extended the geochemical investigation farther south to cover the geophysical anomalies located in the environs of ML 1080 showed that the copper content of the soil is generally lower, being above 240 p.p.m. at only 30 points; these points also coincided with the known geophysical anomalies. The 1958 samples analysed from the soil surrounding the anomalies mostly showed less than 100 p.p.m. copper. The overall lower copper values obtained by McClure probably resulted, as mentioned, from his different sampling method.

In layout 2 nothing of geochemical significance was obtained from soil samples collected over the geophysical anomalies. The distribution of trace copper is sporadic and, except for 2 samples, copper is less than 50 p.p.m., which agrees roughly with the background trace copper distribution found in the soil away from the anomalies shown in layout 4.

The geochemical work has shown that poor copper anomalies coincide with the geo physical anomalies in layout 4, that is, that the concentration of copper in the soil plain is greatest above the geophysical anomalies, and therefore that the area is mineralized. However, the significance of this mineralization cannot be ascertained without further investigation by other methods, for example, drilling.

Soils :

The soil profile commonly encountered in the northern half of layout 4 (Plate 3) consisted of top soil from 1 to 5 feet thick; this is brown to chocolate-brown and is probably partly ferruginous. It generally has a lumpy texture, particularly where clay is present; however, some fine-textured top soils are present. Quartz grains and white mica flakes occur and, in places, increase in abundance with depth Limey fragments are rare, they also become more abundant with depth giving the soil a lighter colour.

The marker horizon from which the samples were taken during 1957 forms a $4\frac{1}{2}$ to 6 inches layer beneath the top soil. It is generally from light brown to fawn or buff but in places is buff-green, yellow or brown-green. By contrast with the top soil it contains more limey material and thus is a lighter colour. It rarely contains clay, and possibly the increase in lime is accompanied by a decrease in iron content. Its texture ranges from fine and granular to smooth and powdery. Quartz grains, rock fragments and mica flakes are fairly common; the rock fragments are generally quartz-feldspar-mica (biotite or sericite) schist. Where amphibolitic rock fragments, or their decayed products, predominate, the soil has a green colouration.

In most cases the soil beyond the limey marker horizon was derived mainly from decomposed bed-rock, forming one or more sub-horizons of bedrock soils. The number of sub-horizons developed increase with increasing soil thicknesses; holes reached bedrock from 2 to 8 feet below their collar. Soil colour in this part of the soil profile mostly varies from light rusty yellow-brown to fawn or buff, but some soils are green or green-grey.

Sandy soils containing mica flakes have formed above biotite-feldspar-quartz schist whereas micaceous soils are found above quartz-sericite schist; the latter soils have a silky or talcy texture. Above decomposed amphibolitic bed-rock, the soil has a green colouration and contains biotite flakes, feldspar and decomposition products of ferromagnesian minerals.

The bedrock soils generally contain many rock fragments and red soda feldspar has been seen flecking or veining some of these. In this area, and also at Trekelano, the products of general hydrothermal alteration also may be found; these include "red rock" and other granitic-looking material. Lime that commonly concentrated near the marker horizon becomes less abundant and may be absent from the bedrock soil.

Plate 3 shows an interpretation of the rock-types beneath the soil-covered plain, as indicated by the rock fragments found in the holes. The country rock is mainly biotite-feldspar-quartz schist but amphibolite, pyroxene-plagioclase granulite, and muscovite schist occur in lesser amounts. Outcrops are rare. However, half a mile south of the ML 1079 corner peg, quartz rubble, "red rock", and hematitic rocks occur in the vicinity of a silicified shear that appears to be in quartz-sericite schist, and amphibolitic rocks with cleavage strike 030° and dip 70°W.

Only a small number of soil samples was collected from the area shown in layout 2 (Rayner & Nye, 1936), and although these were useful for a preliminary geochemical check [illegible] there were insufficient of them to construct isochemical contours. None of the holes in this northernmost survey reached bedrock, although they ranged from 2 to 9 feet deep. The soils encountered differed in some respects from those found in the layout 4 area. The top soil has a finer texture and ranges in colour from red-brown to light-brown; it commonly contains some limey material, as well as quartz and "red rock" fragments. In some cases it is a fine powdery dust. Horizons beneath the top soil vary considerably in colour, ranging mostly from light brown to fawn, but buff with a grey or green colouration, or cream with a pink, mauve or mauve-brown colouration, may be found. These soils have a soft powdery texture, a condition caused by fairly abundant limey material which appears to increase in amount with depth, and consequently with the change to lighter soil colours. A few rock fragments found amongst the soils suggest amphibolite as well as "red rock" and associated granitic types occur in the vicinity.

DISTRIBUTION AND CONTROL OF MINERALIZATION

Some ideas on the control of mineralization can be obtained from the field and petrological observations, though these are limited as much of the area comprises an unresolved igneous and metamorphic complex. The location of the larger copper deposits, on the other hand, may have some important structural aspects with implications on ore control.

The two major copper deposits appear to be located at the junction of early and late Precambrian faults. Broadhurst (1953) observed that the Duchess mine occurs at the intersection of the Juenburra Fault and the Railway Fault, which, by projection, would cut each other at about 25°. In the case of the Trekelano mine, the present mapping shows that the mine occurs at a point which could be the intersection of a north-south striking fault and a 025° striking fault. The projection of these faults, which apparently pass beneath the soil covered plain, would however be deflected slightly and intersect at about 40°. Another point of structural interest is that the lodes of both mines occupy shears that strike approximately north-south.

There are many smaller occurrences of copper mineralization in the area and although these occupy structural traps such as small fissures, a regular structural setting has not been recognized for them. Small concentrations of copper apparently formed radomly whereas in the case of the larger deposits a particular set of structural conditions was probably an important factor determining the size of the deposit.

Wherever deposits have been examined, they show, without exception, the intimate association of copper with products of the general hydrothermal alteration. These products are calcite, quartz, red soda feldspar, epidote, hornblende, augite, hematite and magnetite. They form the gangue of both the major and minor mineralized assemblages; Duchess and Trekelano mines are examples. These minerals are commonly concentrated into large and small fractures, particularly calcite which is one of the more abundant. Furthermore, a strongly leached zone surrounds lodes, and again Duchess is a good example.

Edwards & Baker (1954, p.32) have also noted the close association between mineralization and the general hydrothermal alteration at Trekelano. They observed that the ore veins, and veins of red soda feldspar, cut across the foliation of the granulites, and that the adjacent granulites have been converted to "red rock". They concluded, therefore, that mineralization occurred after the soda and chlorine metasomatism.

Mineralization occurred after the major faults developed and after all the basic igneous activity and some of the granitic activity. However, some metasomatic granite developed as an attendant process of the general hydrothermal alteration, and probably, therefore, some granite accompanied mineralization. Granite of the type concerned includes the aplitic and pegmatitic types accompanying the "red rocks" and is well developed in the Trekelano area. The writer considers that much of the granite mapped by Rayner and Nye (1936) is this "red rock" granitic type. Moreover, mapping (Plate 2) shows that the products of the general hydrothermal alteration occur abundantly in the vicinity of north-south shears and fractures. These pre-existing fractures, and also some of the younger Precambrian faults have, therefore, served as access channels for the hydrothermal solutions.

Speculation on the mechanism of mineral concentration is an interesting one. As mentioned, p.14, where calcite has been quarried for flux, copper, with other products of the general hydrothermal alteration, may be disseminated, or may fringe, the calcite segregations. The segregation, which are large enough for quarrying, only occur in the calcite-rich calc-silicate hornfels, suggesting that the calcite was culled from the surrounding lime-rich rocks and concentrated in nearby traps. Possibly copper was also gathered and concentrated this way. Undoubtedly the various hydrothermal solutions freely permeated the country rocks, mineral concentrations accumulating only where suitable structural traps existed. The association of the products of mineralization, and general hydrothermal alteration, with fractures, indicates a structural environment where such fractures could develop.

During the course of mapping two altered zones similar to that surrounding the Duchess lode were encountered. One occurs $\frac{3}{4}$ mile north-north-east of the Duchess mine and could be an extension of the mine alteration zone. The other is $3\frac{1}{4}$ miles south of the Duchess mine in the "complex" rocks. These zones appear to invite further prospecting. Geochemical or geophysical testing would be an advantage. The discovery of future ore will require the use of such techniques to investigate zones with promising geological settings.

REFERENCES

BLANCHARD, R., HALL, G., and McDONALD, F.T., 1941 - Trekelano mine, north-western Queensland: Report to Anglo-Queensland Mining Pty. Ltd. (unpubl.).

BROKEN HILL SOUTH LTD., 1949 - Trekelano area. Field investigation department. (unpubl.).

BROADHURST, E., 1953 - Duchess copper mine. In Geology of Australian ore deposits, Fifth Emp. Min. Metall. Congr., 1, 398-403.

____________ and DUTTON, A.H., 1952- Report on work under authority to prospect Duchess area. Gold Mines of Australia Ltd. (unpubl.).

CARTER, E.K. and BROOKS, J.H., 1960 in The Geology of Queensland. Geol. Soc. Aust. J. Vol. 6, pt. 2.

DENMEAD, A.K., 1940 - Trekelano copper mine. Geol. Surv. Qld. (unpubl.).

EDWARDS, A.B. and BAKER, G., 1954 - Scapolitization in the Cloncurry district of north-western Queensland. Geol. Soc. Aust. J., 1, 1-33.

HOLMES, A., 1920 - The nomenclature of petrology, Thomas Murby, London.

NYE, P.B. and RAYNER, E.O., 1940 - the Cloncurry copper deposits with special reference to the gold-copper ratios of the area. Aer. Surv. N.Aust. Rep. Qld. 35.

RAYNER, J.M., and NYE, P.B., 1936 - Geophysical report on the Trekelano area, Cloncurry district. Aer. Surv. N.Aust. Rep. Qld. 5.

____________________, 1937 - Geophysical report on the Trekelano area, Cloncurry district (Supplementary to Rep. Qld. 5). Ibid, Qld. 17.

SHEPHERD, R.S.L., 1936 - Trekelano copper mine, North-western Queensland. Qld. Govt. Min. J., 37, 372-375.

____________, 1940 - Trekelano copper mine. Ibid, 41, 236-238.

____________, 1953 - Trekelano copper mine. In Geology of Australian ore deposits, Fifth Emp. Min. Metall. Congr., 384-390.

STILLWELL, F.L., 1949a - Rocks from the Duchess area, Cloncurry district, Queensland. Comm. Sci. Ind. Res. Org. Minerogr. Inv. Rep. 412.

____________, 1949b - Scapolite granulite from No. 1 drill core, Trekelano, Cloncurry district, Queensland. Ibid. 424.

GEOLOGICAL MAP OF THE DUCHESS-TREKELANO AREA

PLATE 2

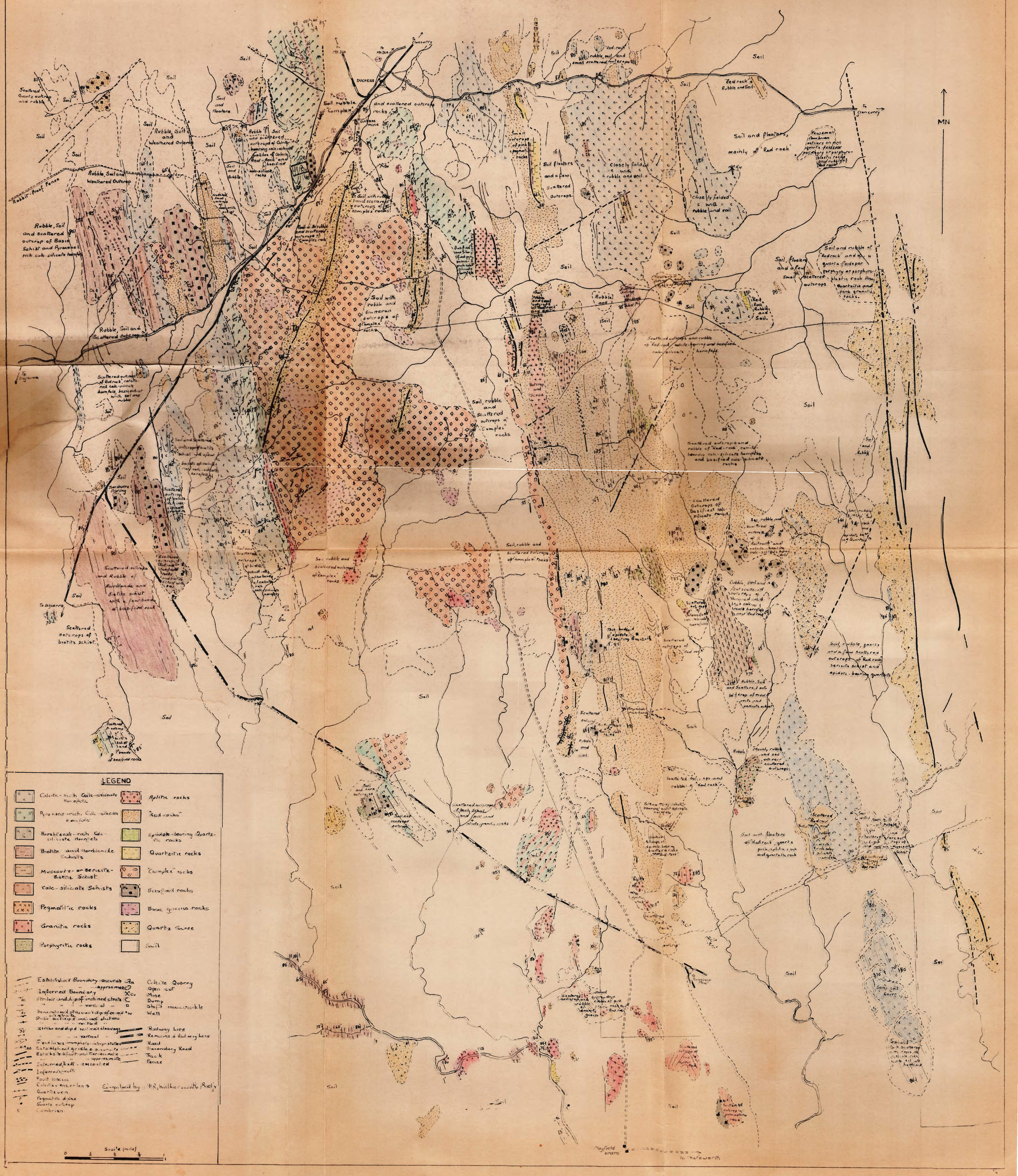
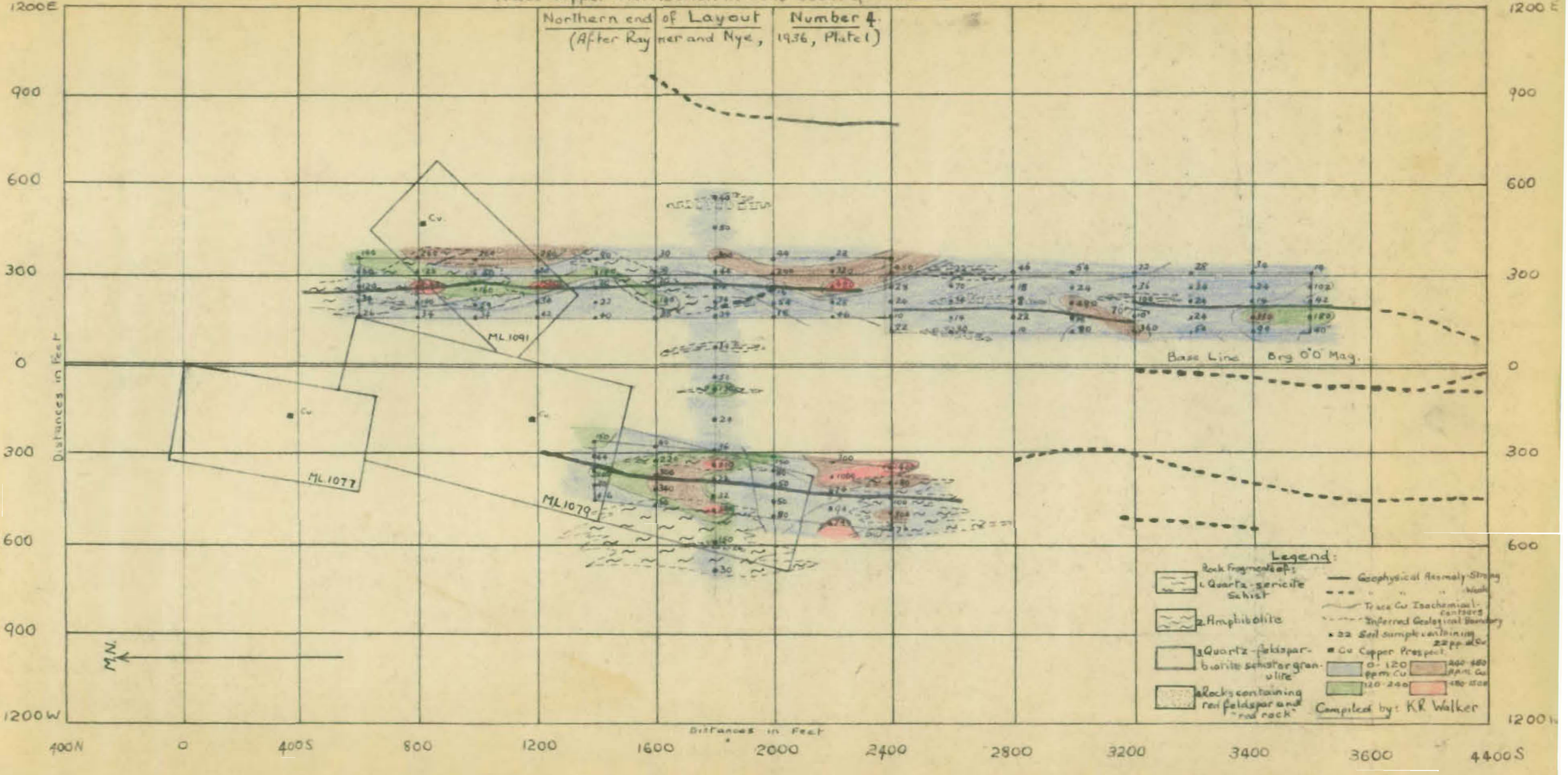


PLATE 3

Trace Copper Distribution in Soils South of Tickelano



Geochemical Survey, Trekelano N.W. Queensland

PLATE 4

Distribution of Copper in soils

Compiled from Plate 8 of A.G.G.S.N.A. Report Queensland No 5, 1936.

PLATE 5.

Figure 1: Duchess from the Ivanhoe lode showing the township and mine sites at the northern end of the central plain.

Figure 2: Hilly country about three miles S.S.W. of Duchess showing low rounded hills, most of which are gabbro stocks.

PLATE 6

Figure 1: Outcrops of thinly bedded calcite-rich calc-silicate hornfels, one and a half miles east of Juenburra Siding.

Figure 2: Outcrops from which vegetation has been burnt, three and a half miles south of Duchess showing different phases of acid igneous rock and the "complex" rocks.

PLATE 7.

Figure 1: Microgabbro at Duchess intruded by veins of granitic rock.

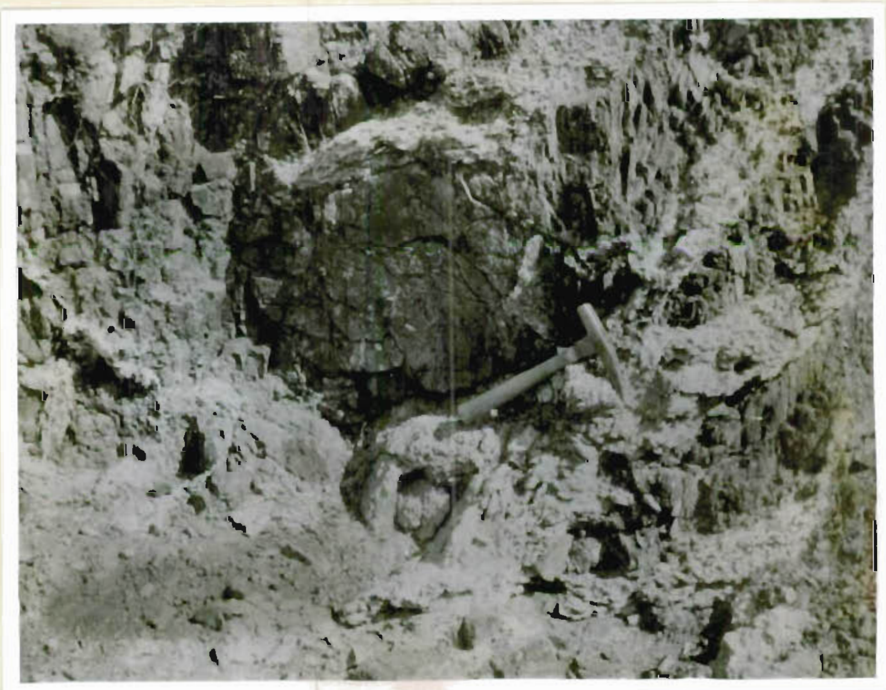


Figure 2: Extensively altered rocks, in the leached zone surrounding the Duchess lode, which are cut by veins of limey material.

PLATE 8.

Figure 1: Jointing in a dolerite dyke three-quarters of a mile west of Duchess.

Figure 2: Microgabbro, three and a half miles south of Duchess, showing fine intersecting bands.

PLATE 9.

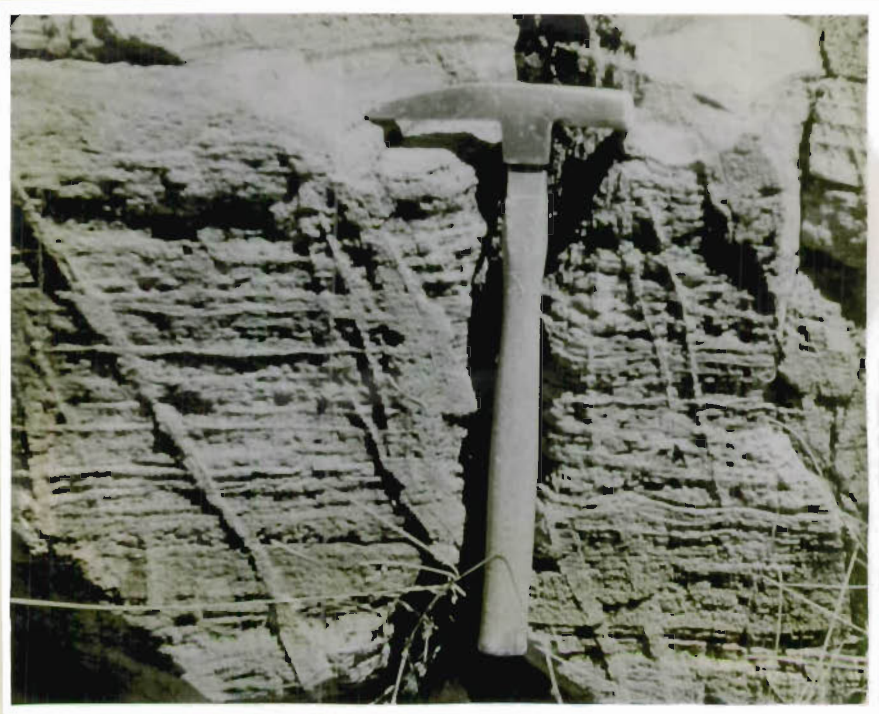


Figure 1: Red soda feldspar replacement veins cutting finely banded calc-silicate hornfels about four miles north of the Trekelano mine.

Figure 2: Duchess - Thin section of microgabbro showing feldspar laths, with numerous parallel trains of fine inclusions, ophitically intergrown with partly uralitized pyroxene. Scapolite, biotite, and opaque iron mineral occur in small amounts. (x 27).

PLATE 10.

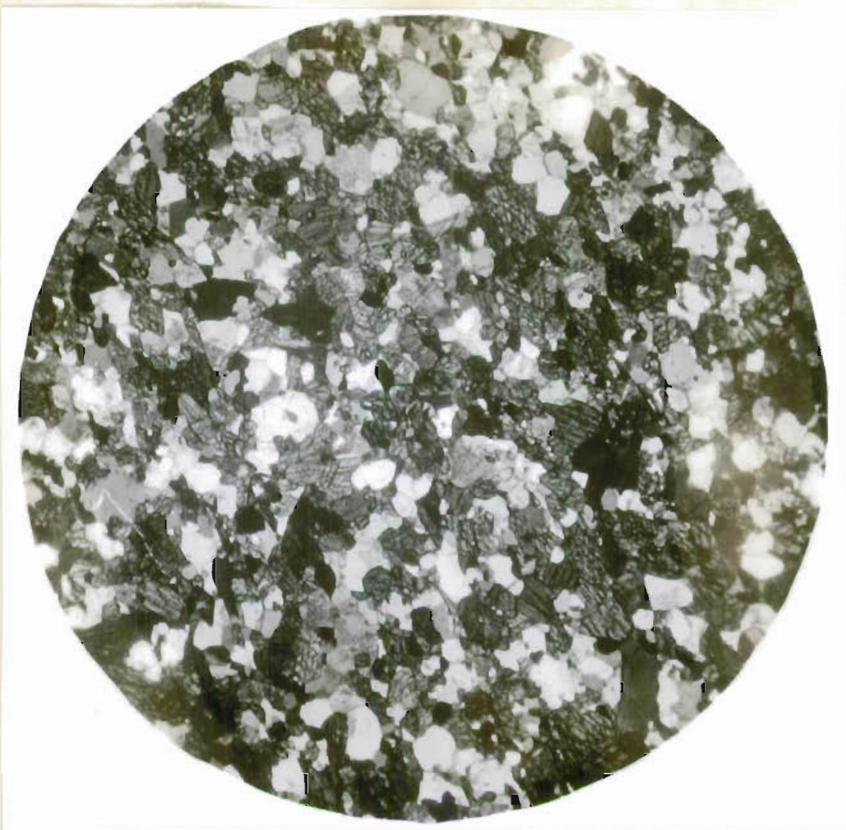


Figure 1: Duchess - Thin section of a scapolite-plagioclase amphibolite, showing xenoblastic equidimensional grains of amphibole and plagioclase. Quartz and opaque iron mineral are accessory. (x 27).

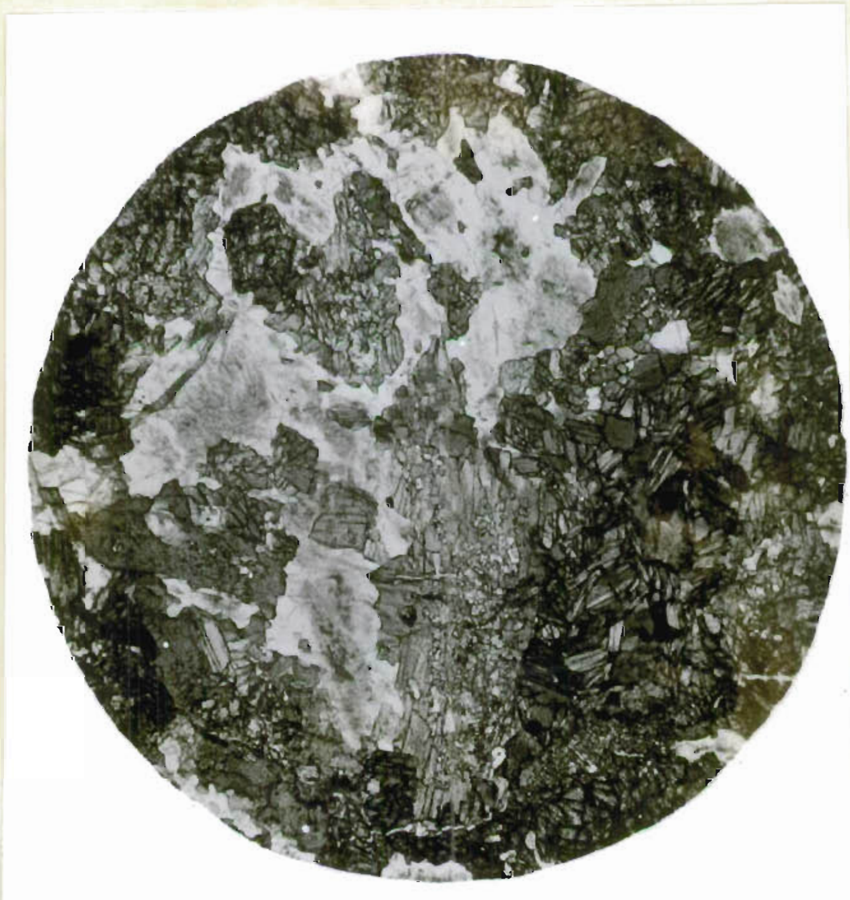


Figure 2: Duchess - Thin section of a thermally metamorphosed microgabbro containing clouded feldspar laths, amphibole grains with sieve structure and pyroxene cores, and clots of biotite flakes surrounding opaque iron mineral grains. (x 27).