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NOTES ON CROYDON, NORTH QUEENSLAND, FIELDWORK JULY/AUGUST 1988 AND RESULTS OF K/Ar DATING OF SERICITIC ALTERATION

by

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ABSTRACT

Age determinations carried out on sericite in two granite samples from the Croydon Goldfield and two greisen samples from the nearby Mt Cassiterite Tinfield show apparent Palaeozoic ages of alteration for the Middle Proterozoic Esmeralda and Nonda Granites. Owing to the wide range of the results, 293 to 549.m.y., they are considered unlikely to reflect true ages of alteration. They are interpreted instead as representing either Permo-Carboniferous alteration and mineralisation or a Permo-Carboniferous thermal event superimposed on earlier Precambrian alteration and mineralisation. The latter is most likely for the greisens if not the gold vein-related alteration. A small intrusion of granite or quartz syenite, unlike the surrounding Precambrian granites and comagmatic Croydon Volcanic Group in composition, was discovered during the course of further investigations of the geology of Croydon area. Other investigations generally confirm conclusions reached after the 1980 BMR fieldwork with respect to stratigraphic interpretation, relationships between coarse and fine-grained granite types, and the origin of graphite in the granites and volcanics. Observations of relationships between formations southeast of Tabletop area indicates the need for some revision of the extent of formations in that area.

INTRODUCTION

As a result of discussions between the Bureau of Mineral Resources and the joint venture companies in the Croydon Goldfield operations, Barrack Mines Ltd and Pancontinental Mining Ltd, a program of field work was carried out by BMR in July/August 1988. The main purpose of the work was to collect samples of the altered granite and volcanics associated with the gold mineralisation, and also the greisen hosting the tin mineralisation to the south of the goldfield, for age determination of the sericite in the altered rock. It was also agreed that further work to help elucidate various aspects of the stratigraphy and structure of the goldfield area should be done at the same time. The importance of the sericite age determinations was because Pancontinental had obtained, and revealed at the time in confidence to BMR, a hitherto unsuspected Carboniferous age on a single drill core sample of altered granite adjacent to one of the gold-bearing quartz reefs. Age determinations previously had indicated a Proterozoic age for the unaltered granite and volcanics (see Doutch, 1977), and the mineralisation was assumed to be Proterozoic also.

Accommodation during the fieldwork was provided by Barrack Mines at their mining operations camp 7km northwest of Croydon. The author used a BMR vehicle for transport. The isotopic age determinations were carried out by contract and funded jointly by Barrack Mines and Pancontinental Mining.

The aims of the project, as listed before commencing fieldwork, were:

1. Investigate possible further subdivision of the Croydon Volcanic Group, particularly the Carron Rhyolite and dacite at the base of the Idalia Rhyolite and top of the Parrot Camp Rhyolite.

2. Differentiate any volcanics and intrusions younger than, or distinct from, the Croydon Volanic Group and Esmeralda Granite by sampling for chemical analysis and age determination.

3. Look for possible specific source rocks of local anomalous concentrations in stream sediments of elements such as copper, lead and arsenic within Croydon Goldfield shown up by 1980 stream sediment sampling program.

4. Sample sericitic alteration adjacent to gold/quartz reefs in volcanics, and tin greisen in granites, for age determination.

5. Differentiate true alteration zones in volcanics from apparent alteration zones from previous air-photo interpretation that may, especially in elevated areas, be remnants of a Mesozoic deep weathering profile. Collect appropriate samples for isotopic dating.

6. Investigate significance of preferred directions of altered rhyolite dykes in many areas, the nature of other lineations and structures and the relationship of dykes and other structures to alteration and mineralisation.

7. Map areas of medium and fine-grained granite not previously differentiated from the coarse Esmeralda Granite in the contact zone between the Esmeralda Granite and Croydon Volcanic Group, and determine age relationships between adjacent granite types.

8. Sample graphite-rich zones in granite with sericitic alteration.

9. Attempt to determine nature of major faults, whether normal or reverse, and to trace northern and southern continuations of Mount Angus and Tabletop Faults.

10. Investigate possible extent of Democrat Rhyolite beyond mapped area and evaluate possibility that it is merely a hornfels effect.

FIELDWORK

Investigations carried out in the field relating to the specific work program are outlined below.

1. Areas examined for possible subdivision of the Carron Rhyolite included a locally restricted zone of outcrop of a more basic, dacitic rock at the top of the formation 3km northeast of Croydon, and possible dacite at the base of the formation immediately above the Parrot Camp Rhyolite 3km east-southeast of Tabletop homestead. The dacite 3km northeast of Croydon appeared to be no more extensive than the small area indicated by the darker soil evident on the air-photo; a sample was taken for chemical analysis (sample 88300005, Appendix 2). No dacite or other rock of composition different from either the Parrot Camp or Carron Rhyolites was found in the area southeast of Tabletop homestead.

2. Some areas of medium and fine-grained granite were examined near the contact of the Esmeralda Granite and the Croydon Volcanic Group between 7 and 12km east of Croydon. In most places the medium and fine-grained granite did not appear to differ very greatly in composition from the bulk of the Esmeralda Granite, and locally was observed to be intimately mixed with the coarse granite. However one outcrop of fine-grained granite immediately west of the Tabletop Fault is a distinctive dark pink and appears to be richer in mafic minerals than any of the other granites. A sample of the granite was taken for thin section and chemical analysis on which further discussion is given below (p. 7).

Apart from examining and discounting the likelihood that the dacite 3km northeast of Croydon, referred to above, is a younger volcanic rock, no other volcanic rocks were found in any of the areas examined which did not appear to be part of the Croydon Volcanic Group.

3. No specific investigations were done to look for possible source rocks of base-metal stream sediment geochemical anomalies. Most of these anomalies are downstream from known gold/quartz reefs, although it is possible in some places that other sources are involved where no major reefs are known to occur in the catchments of the streams.

4. Two altered Carron Rhyolite samples were taken from pits not being worked at the time of the fieldwork, one from the Glencoe and the other from the Jubilee pit. In the absence of observable sericite in decomposed rock immediately adjacent to quartz veins the samples were taken from typical altered rocks from within the pits.

Two altered granite samples were collected from about 10km east of Croydon, one from a natural outcrop at some distance from any known gold/quartz reefs, and the other from a waste dump beside the old Problem mine-shaft in the Boomerang group of mines.

Three greisen samples were collected from the Mt Cassiterite area, one from a greisen outcrop within the Mt Cassiterite group of mines, one from a waste dump, and a third from a greisen outcrop about 4km to the west of Mt Cassiterite.

5. A small area about 5km northeast of Croydon was examined in detail to compare actual alteration zones to those previously interpreted from the air-photos. The alteration in this particular area was found to be not quite as extensive as it appeared on the air-photo. However in this and other areas it would appear that, while boundaries of alteration zones may be different in detail from those shown on the maps, the general areas of alteration are reliable.

6. The greisen zones east of Mt Cassiterite were followed east-southeast along their strike and found to grade into dyke-like bodies of altered Democrat Rhyolite at the contact between granite and volcanics. Generally the greisen and altered rhyolite 'dykes' in the granite and immediately adjacent volcanics at Mt Cassiterite, and in the southern part of the Croydon Goldfield, strike in northwest or north-northwest directions, whereas the altered rhyolite 'dykes' farther to the north strike northeast. The significance of these preferred directions in each area is unclear except that together they form a conjugate set which is probably related to compressive movements associated with the more marked tilting, folding and faulting of the volcanics in the northwestern part of the Croydon Volcanic Group as a whole. Both sets of greisen and dykes are vertical or steeply dipping, as distinct from the graphite-rich zones of alteration in the granite close to the contact with the volcanics near Croydon which dip at shallow angles to the northeast.

7. An attempt was made to differentiate areas of medium and fine-grained granite from the normal coarse Esmeralda Granite near the contact of granite and volcanics 7 to 12km east of Croydon. However, even in the areas of relatively abundant outcrop near the contact it was difficult to map a precise boundary. This was because of the mixtures of coarse, medium and fine granite in many outcrops. Farther to the south, where outcrops are much sparser, it was not possible to determine whether or not an isolated outcrop of fine-grained granite represented a much larger body of such granite.

8. No altered granite samples were taken from very graphite-rich zones. The white, altered granite 'matrix' in these zones appeared to be similar to altered granite in the waste dumps where graphite was less in evidence.

9. No direct evidence on the ground could be obtained for the attitudes of major faults in the areas examined along the Tabletop and Mt Angus Faults east of Croydon, or seemed likely elsewhere. The exact positions of possible extensions of the major faults where they pass under superficial deposits to the north, and into areas of poor granite outcrop to the south, remains conjectural, although the calculated amount of displacement on these faults suggests that they must continue for some kilometres at least in each direction.

10. The distinction between the Democrat and Idalia Rhyolite could not be seen with confidence in two areas examined, one near the main road east of Croydon and the other east of Mt Cassiterite. Therefore no attempt was made to map a possible northern or northwestern extension of the Democrat Rhyolite. Possibly the boundary of the Democrat Rhyolite as mapped encompasses restricted zones of rhyolite with the characteristically purple-coloured quartz. The otherwise similar, or even identical, compositions of the Idalia and Democrat Rhyolites, and the proximity of the Democrat Rhyolite to the Esmeralda Granite, suggests that the coloured quartz in the Democrat Rhyolite is more likely to be a hornfels effect of the granite than indicative of a separate volcanic formation. The sinuous contact between the granite and parts of the Democrat Rhyolite is in accord with observations in the vicinity of Stanhills to the south that much of the granite-volcanics contact is sub-horizontal in this area. Hence outcrops of Democrat Rhyolite not immediately adjacent to the granite nevertheless could be underlain by granite at shallow depth and within range of contact metamorphism.

AGE DETERMINATIONS

Four samples, two from altered granite bordering the volcanics east of Croydon township and two from the greisen zones in the Mt Cassiterite area, were judged the most suitable, after thin section examination, for sericite K/Ar age determination. The determinations were carried out by AMDEL (see Appendix 1 for AMDEL report). Three samples of altered Carron Rhyolite collected were unsuitable for dating because the sericite in them was too fine-grained to extract successfully. The locations from which the altered granite and greisen samples were collected are shown in Figure 1.

As detailed in the AMDEL report (Appendix 1) the four age determinations carried out on the extracted sericite each gave a different result ranging from 293 ± 2 m.y. for one of the altered granite samples (88300009) to 549 ± 3 m.y. for one of the greisen samples (88300011). The two altered granite samples (88300007 and 88300009) and the two greisen samples (88300011 and 88300014) give ages relatively close to each other. However there is still a wide divergence between each of the results. This possibly has something to do, in each case, with the nature of the material analysed, and is certainly related to the nature of the mica content (see AMDEL report and notes on thin sections below). Sample 88300007 was from a surface outcrop of moderately altered granite, whereas sample 88300009 was extremely leached and altered granite, sampled at the surface beside an old mine pit, but originally from some unknown depth within the pit. The greisen samples were both taken from surface outcrops. However, one (88300011) was from a moderately weathered outcrop with very abundant white mica evident in hand specimen, whereas the other (88300014) was from a fresher silicified greisen with less abundant mica.

Leaving aside possible factors relating to the sources of the samples at least two interpretations can be made of the age data.

1. They accurately reflect the ages of primary alteration and hence mineralisation.

2. They represent mixed ages resulting from partial resetting of Precambrian wallrock during a possible Permo-Carboniferous event related to the Permian volcanism in the Gilbert River area to the east.

The first possibility is very unlikely as it would imply four separate periods of alteration and mineralisation for which there is no evidence elsewhere in the region. Late Cambrian or early Ordovician ages are particularly unlikely for the greisens because they are spatially related to the Nonda Granite which is geochemically linked to the Precambrian Esmeralda Granite and Croydon Volcanic Group. No igneous rocks of Cambrian or Ordovician age are known within 200km.

The second possibility presents two alternatives.

a) The primary alteration and mineralisation is Permo-Carboniferous.

b) The Permian event is superimposed on older, possibly Precambrian alteration and mineralisation.

It is pertinent at this stage to go back to the thin sections and record some observations further to those made by AMDEL. They are as follows.

88300009: Shows obvious weathering. Two distinct phyllosilicate populations - (1) coarse, commonly deformed muscovite, mostly after primary biotite; (2) very fine clay mineral (sericite-like) replacing feldspars and along grain boundaries and fractures. Also evidence of deformation and recrystallisation.

88300007: Less altered than 88300009. Some relict <u>biotite</u>. About 1% coarse muscovite after biotite; about 5% fine muscovite/sericite replacing feldspar; about 1-2% clay(?) in altered K-feldspar. Possible early-generation (immed. subsolidus) muscovite; evidence of recrystallisation/alteration of early muscovite.

88300014: Greisen, with 2 mica populations: medium to medium-coarse, commonly in sheaf-like clumps; partly overprinted by very fine aggregate.

88300011: Greisen, with trace primary feldspar. 2 mica populations - (1) coarse, undeformed with no evidence of recrystallisation; (2) medium-fine, possibly overprinting coarse muscovite(?), or even vice-versa.

These observations, taken together with AMDEL'S petrography, XRD, and K/Ar dates suggest that an earlier alteration event (sericitisation -> greisenisation, of variable intensity) has been overprinted to various degrees in the four samples by a later (Permo-Carboniferous), lower-temperature hydro(?)thermal event. Sample 88300009 has been most affected by this later event and the others less so. Sample 88300009 may have suffered some argon loss due to weathering, and hence the age determined <u>may be</u> too young, especially in the light of the 322±2 Ma age obtained from Pancontinental's sample (Appendix 3).

Returning to the two alternatives (a) and (b) above, the interpretation of the results may be concluded as follows. The first alternative is the simpler, and perhaps to be preferred for the altered granite samples associated with the gold-bearing veins. It is consistent with an interpretation that the principal structural complexity in the Goldfield, manifest as a series of west-facing concentric normal faults, is unrelated to the middle Proterozoic (Croydon) volcano-tectonic processes and may be of late Palaeozoic age.

The second alternative would be favoured if the structural complexity could be demonstrated to be related to the Croydon volcano-tectonic event. Early hydrothermal fluids associated with that event would have exploited existing fault/fracture systems and altered the wallrocks. Any subsequent hydrothermal event during late Palaeozoic time would be likely to preferentially affect these altered zones, effectively updating their isotopic clocks. These effects would be likely to be uneven in their distribution and therefore result in various degrees of resetting of sericite ages. This is consistent with the observed range of ages but not the only possible explanation. It is perhaps the most likely explanation for the apparent early Palaeozoic ages for the greisens.

DISCUSSION OF OTHER TOPICS

<u>Subdivision of the Granites</u>

The Proterozoic granite which intrudes, and is regarded as comagmatic with, the Croydon Volcanic Group may be divided into two types. One is blue-grey, coarse-grained, porphyritic Esmeralda Granite which forms very large boulders and joint-bounded blocks, and the other is a darker, finer-grained rock of generally similar composition forming more subdued outcrops. These two types correspond with the 'coarse muscovite granite' and 'aplitic granite' of Clappison (1940), who also differentiated 'mixed granite' - an intimate mixture of the above two types , 'greisenised granite' and 'fine-grained aplitic dykes'. The fine-grained granite is named the Nonda Granite to the southeast of the area shown in Figure 1 (Mackenzie & others, 1985).

Known areas of fine-grained or 'mixed' granite are indicated in Figure 1 as Nonda Granite, derived from Clappison's map and from more recent fieldwork. An apparent tendency for the finer-grained granite to occur close to the boundary with volcanics may be partly due to the greater amount of outcrop in these areas, and because more extensive areas of little or no outcrop are mapped as Esmeralda Granite for want of evidence to the contrary. Some small areas shown in Figure 1 as Nonda Granite are derived from spot observations during fieldwork by BMR in 1980, and more widespread outcrop could be present. The intimate mixing in places of the fine and coarse granite indicates that they are different phases of the same intrusive event. The mixing takes the form of tors and boulders made up partly of fine, and partly of coarse, granite. Boundaries between the two types on rock surfaces may be either sharp or diffuse. In some places patches of fine granite appears to form inclusioons within coarse granite; in others the fine granite is represented as dykes.

The fine-grained, Nonda-type granite may be either the 'chilled' roof zone of the Esmeralda Granite, or represent later injection into the roof zone of less differentiated magma from deeper in the magma chamber in response to magma withdrawal during eruption of Croydon Volcanic Group.

A granite of somewhat different composition occurs in one small area immediately west of the Tabletop Fault. This granite is dark pink, with prominent mafic minerals which are more abundant than in the Esmeralda or Nonda Granites, and include clinopyroxene, which is absent in both the Esmeralda and Nonda Granites. A chemical analysis of this rock (sample 88300006, Appendix 2) and thin section examination indicates a composition verging on quartz monzonite rather than granite. This granite is shown as ?Palaeozoic granite on Figure 1, although no evidence exists at this stage for its age other than its possibly greater chemical similarity to Permian igneous rocks in the Gilbert River area to the east of Croydon than to the Precambrian rocks around Croydon. Its chemical affinities, however, are debatable. The silica content is comparable with some of the Permian rocks, but the rock is relatively high in K_2O and differs in the proportions of other elements. Also the rock is extremely altered, and this has probably affected its chemistry. The secondary minerals include prehnite, quartz, chlorite, calcite and clay(s).

Subdivision of the Volcanics

The Croydon Volcanic Group has been divided into a number of formations and sub-units as shown in Mackenzie & others (1985) and in Figure 1. Similarities between units at different levels in the sequence, combined with faulting and locally complex folding, create doubts in interpretation in some places. Little structural information indicating the attitude of formations is available in most places and where pumice foliation or flow banding is present, for example in the Carron Rhyolite, it is commonly folded or slumped in unpredictable attitudes so that the true prevailing dip cannot be ascertained.

In a few places contacts between formations are well-exposed, one such place being in the north-central part of Figure 1 where, as a result of recent fieldwork, the superposition of two units has been reversed. Some of the rocks in this area originally interpreted as Parrot Camp Rhyolite are now interpreted to be the similar-looking Idalia Rhyolite. It would seem that a major, previously unnamed fault, now shown as the Dead Horse Fault in Figure 1, forms the southwestern limit of the Parrot Camp Rhyolite in this area. The problem has not been solved beyond doubt however. Figure 2, which shows some of the contact between the Carron Rhyolite and reinterpreted Idalia Rhyolite, indicates progressive overturning of the contact from east to west. This assumes that the eastern part of the contact is the right way up. Bedded tuff up to 10m thick separates the two units where bedding is shown in Figure 2.

Outcrops of sparsely porphyritic lava(?) with steeply-dipping flow banding about 3km northeast of Croydon, originally included in the Carron Rhyolite, proved upon petrographic examination and chemical analysis (sample 88300005, Appendix 2) to be of dacitic composition. The rock has sharp boundaries with the remainder of the Carron Rhyolite, at least in part, and appears to be of limited extent. A polymictic volcanic breccia, the origin of which is possibly related to that of the dacite, is developed immediately to the east, along the contact with the Idalia Rhyolite.

Major Faults

The major faults in terms of displacement are the Mt Angus, Tabletop, Basket Creek and Dead Horse Faults, plus one or two other faults shown in Figure 1. As a result of the reinterpretation of part of the area in and around Figure 2 as Idalia Rhyolite rather than Parrot Camp Rhyolite, the Tabletop Fault has now been extended along a photo-lineament to the west of Tabletop homestead. It is possible to suggest likely extensions of the major faults beneath Cainozoic deposits to the north, and into the Esmeralda Granite to the south, but evidence on the ground for their exact positions is lacking. The Tabletop Fault, at least, in view of its obvious large displacement of the Esmeralda Granite, must almost certainly extend much farther to north and south than shown.

Alteration of Granites and Volcanics

Extensive areas of sericitic alteration of the Croydon Volcanic Group, particularly the Carron Rhyolite, occur within and around the area of the Croydon Goldfield. In the other units the alteration is commonly confined to dyke-like bodies which show marked preferred orientations. The areas of alteration shown in the published 1:250 000 and 1:100 000 scale geological maps of the Croydon region (Mackenzie & others, 1985; Henderson and others, 1982) have been mostly photo-interpreted. Observations on the ground in one or two of these areas suggest that the alteration may not perhaps be quite as extensive or pervasive as shown, but not to the extent that the map is misleading. It is not clear from photo-interpretation whether or not the dyke-like altered bodies are true dykes - i. e. intruded later. Field observation suggests that most, if not all, of them are narrow zones of alteration localised by the joint pattern. The texture of many of them is identical to that of the adjacent unaltered rock.

Similarly in the granites the grainsize in the greisen reflects the grainsize in the adjacent unaltered granite. Where the numerous greisen zones at Mt Cassiterite extend east-southeast into volcanic units, the greisens grade into altered rhyolite.

Graphite in Granite and Volcanics

Graphite, generally as rounded aggregates up to a few mm in diameter, is widespread and abundant both in the Esmeralda and other granites, and in the volcanics. Further evidence that the graphite is derived from carbonacous sedimentary rocks (c.f. Mackenzie, 1988) was observed during the present study.

Although the graphite in most places forms only a minor proportion of the total rock mass, it is much more abundant in the granite immediately adjacent to contacts with the volcanics, particularly in the goldfield area. There it occurs in zones of varying width within altered granite. The various sized graphite inclusions, commonly up to several centimetres in diameter, constitute up to 50% of the rock mass. But, even there, the inclusions are generally amorphous and of uncertain parentage. However in at least one place the graphitic inclusions consist of small blocky slabs, clearly resembling a carbonaceous sedimentary rock rather than pure graphite. The locality (GR 415882) is almost due east of Croydon township, a few hundred metres to the northwest of where sample 88300009 was taken (Figure 1), and was brought to the attention of the author by M. van Eck of Barrack Mines.

Another locality about 4km to the southeast (GR 435862) shows a variety of inclusions ranging in size from small, golf-ball-sized graphite to large slabs of metamorphosed carbonaceous sedimentary rock up to 0.6m in diameter.

Further discussion of the origin of the graphite, and also its relationship to the gold mineralisation is given in Mackenzie (1988).

Structural Synthesis

Figure 3 shows the main elements of the structure of the Croydon area; they are the major faults, the altered rhyolite `dykes`, the quartz reefs and the greisen. Geological boundaries between the granite and volcanics, and between the different volcanic units are also shown. This is because in many places the strike, and in some places at least the dip, of the reefs appears to reflect the strike and dip of the volcanic formations, or the strike of the granite/volcanics contact. The altered rhyolite `dykes` show a conjugate pattern, with northwest and northeast trends, although the northeast trend is clearly dominant. The greisen zones in the Mt Cassiterite area strike west-northwest.

It is possible that the major north-trending faults extend north and south in such a way as to define a set of concentric normal faults, west side down, centred west of Croydon on a postulated fault along the western side of the Esmeralda Granite. The age of this faulting is not known, but it appears to postdate all volcanic activity and subsequent folding. It is probably also later than the gold and tin mineralising events because the faults truncate quartz reefs and alteration 'dykes'.

CONCLUSIONS

1. Age determinations on sericite give a wide scatter of Palaeozoic ages, none of which are necessarily indicative of the age of gold and tin mineralisation. Taking regional geological factors into account, the age of alteration and mineralisation is either late Carboniferous - earliest Permian, or a late Carboniferous - earliest Permian event has partly reset Precambrian ages.

2. A small intrusion of granite or quartz syenite east of Croydon is chemically and petrographically different from the Precambrian Croydon Volcanic Group and comagmatic intrusives such as the Esmeralda Granite. It is probably of Palaeozoic, possibly Permian, age.

3. The Nonda Granite is penecontemporaneous with the Esmeralda Granite and differs only in grainsize.

4. Although small areas of local variation occur within the units of the Croydon Volcanic Group, and some outcrops may have been assigned to the wrong formation in the Tabletop area, no major amendments to the interpretation of the stratigraphy are indicated.

5. Very detailed mapping would be needed to define the areas of alteration more accurately. The areas of alteration interpreted from airphotos and limited fieldwork are generally reliable.

6. Graphite in the granites and volcanics is of sedimentary origin.

7. The structural pattern involves well-defined faults, conjugate sets of 'dykes' of alteration and gold/quartz reefs. The attitudes of the reefs in many places are governed either by the dip of the host formation or the dip of the contact between granite and volcanics.

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APPENDIX 1

K-Ar DATING OF c.-2μm AUTHIGENIC SERICITE FRACTIONS OF FOUR SAMPLES FROM CROYDON, QUEENSLAND

by

AMDEL

K-Ar DATING OF c.-2 μm AUTHIGENIC SERICITE FRACTIONS OF FOUR SAMPLES FROM CROYDON, QUEENSLAND

1. INTRODUCTION

Four samples were received from Dr Mel Jones Exploration Division, Pancontinental Mining Limited with a request for K-Ar dating of the -2 μm authigenic sericite fraction. The samples come from Croydon, Queensland and the work is part of a joint investigation between Pancontinental Mining, Barrack Mines and the Bureau of Mineral Resources.

2. PROCEDURES

The samples were crushed with a jaw crusher then pulverised for 10 seconds. Clay fractions were separated by a series of static sedimentations in a column of ultra-pure water then accumulated by centrifuging at high speed for c.30 minutes. Through repetitive static sedimentations and centrifuging sufficient clay size material was obtained for dating.

Prior to final evaporation of excess water the clay fraction of each sample was agitated and a small volume removed for the XRD determinations. The clays were oven dried at 50°C and stored in a desiccator.

The dispersed clay fractions obtained were examined by plummet balance to determine their solids contents and then used to produce oriented clay preparations on ceramic plates. Two plates were prepared per sample, both being saturated with Mg^{++} ions, and one in addition being treated with glycerol. When air-dry, these were examined in the X-ray diffractometer.

Standard procedures were used to determine the K contents in duplicate and for the extraction and isotopic analysis of the Ar.

3. PETROGRAPHY

All four samples are similar in mineralogy and texture. They all consist of coarse grained quartz and feldspar with lesser primary mica (? muscovite), and all have been extensively hydrothermally altered giving rise to secondary sericite and clays and in some cases quartz veining. Samples 88300007 and 88300009 are not as extensively altered and some relict primary igneous feldspar is present. The amount of secondary sericite is not as great in these two samples. Sample 88300011 contains significant amounts of coarse grained muscovite that may be a relict igneous phase. Secondary sericite is also present. Sample 88300014 also contains some relict igneous muscovite, but is dominated by a high proportion of the secondary sericite. Little feldspar remains in this sample.

4. RESULTS

4.1 X-RAY DIFFRACTION RESULTS

The results of the XRD study are given in Table 1, which lists the minerals found in approximate order of decreasing abundance using the semiquantitative abbreviations given. The -2 μm fractions of samples 88300011 and 88300014 are dominated by muscovite with a significant amounts of quartz. Sample 88300007 is also dominated by muscovite but there are also significant amounts of smectite and K feldspar. Smectite is the dominant phase in 88300009 with sub-dominant kaolinite and muscovite.

Whilst the XRD results are not ideal, the results for 88300011 and 8300014 suggest that these two clay fractions are likely to yield K-Ar ages that reflect the timing of the sericite formation. The results for 88300007 and 88300009 indicate a heterogeneous mixture and although likely to yield spurious K-Ar ages it was decided to analyse these samples in order to provide further information on the K-Ar systematics of the hydrothermal alteration of these granitoids. In particular to asses the ages obtained on the two purer sericite fractions.

4.2 K-Ar RESULTS

The K-Ar data are given as Table 2. All four samples contain high radiogenic Ar contents. The K contents however, are lower than would normally be expected for a muscovite, though this is consistent with an apparent dilution in K content due to the presence of impurities as identified by XRD. There is a wide range in calculated K-Ar ages, the two more impure samples giving Carboniferous and Permian calculated ages whilst 88300011 and 88300014 give Early Cambrian and Early Ordovician calculated ages respectively. This wide range in calculated ages precludes any simple explanation or interpretation of the data other than to suggest that the inhomogeneous nature of the -2 μm fractions gives rise to mixed K-Ar systematics. A more detailed discussion of the results may be possible from a detailed knowledge of their geological setting and inter-relationships.

TABLE 1: SUMMARY OF X-RAY DIFFRACTION RESULTS

88300007		88300009		88300011		88300014	
M	D	Sm	D	M	D	M	D
Sm	A-SD	K	SD	Q	SD	Q	SD
FF'	A-SD	M	SD	Unk	Tr-A		
Q	A	F'F	A	K	Tr		
		Q	A				
		Unk	Tr-A				

Key

- F Feldspar (plag.)
- F' K feldspar
- K Kaolinite
- M Mica (well-crystalline $2M_1$ muscovite)
- Q Quartz
- Sm Smectite
- Unk Unknown phase, ?possibly alunite family

SEMIQUANTITATIVE ABBREVIATIONS:

D = Dominant. Used for the component apparently most abundant, regardless of its probable percentage level.

SD = Sub-dominant. The next most abundant component(s) providing its percentage level is judged above about 20.

A = Accessory. Components judged to be present between the levels of roughly 5 and 20%.

Tr = Trace. Components judged to be below about 5%.

TABLE 2: POTASSIUM-ARGON RESULTS FOR -2 μm FRACTIONS

Sample	%K	$^{40}Ar^*$($x10^{-10}$moles/g)	$^{40}Ar^*/^{40}Ar_{Total}$	Age†
88300007	5.90 5.71	39.21	0.905	353±7
88300009	5.35 5.30	29.41	0.860	293±2
88300011	5.49 5.46	60.99	0.773	549±3
88300014	6.64 6.49	64.70	0.801	494±7

* Denotes radiogenic ^{40}Ar.

† Age in Ma with error limits given for the analytical uncertainty at one standard deviation.

Constants: ^{40}K = 0.01167 atom %

λ_β = $4.962 \times 10^{-10} y^{-1}$

λ_e = $0.581 \times 10^{-10} y^{-1}$

APPENDIX 2

CHEMICAL ANALYSES OF TWO ROCK SAMPLES FROM CROYDON, QUEENSLAND

by

BMR Geochemical Laboratory

REG. NO.	88300005	88300006
SiO_2	68.87	63.16
TiO_2	0.66	0.81
Al_2O_3	13.14	15.82
Fe_2O_3	1.49	1.76
FeO	4.33	2.92
MnO	0.10	0.08
MgO	0.37	1.20
CaO	1.71	2.42
Na_2O	2.06	4.64
K_2O	5.02	4.27
P_2O_5	0.14	0.22
S	0.01	0.03
TOTAL	99.60	99.48
Th	32	19
Rb	268	142
Pb	69	32
Y	76	65
Sr	101	257
U	10	3
Se	<0.5	<0.5
Ga	24	27
As	2.5	2.5
W	7	5
Bi	<1	2
Ge	2	1
Sn	6	7
Nb	23	25
Zr	415	701
Mo	4	4
S	98	263
Cl	37	105
V	19	50
Cr	3	6
Ba	1211	1482
La	69	99
Ce	144	200
Nd	62	84
Pr	15	22
Cs	14	13
Sc	21	14
Hf	11	16
Ta	<2	<2
Ag	2	2
Be	5	4
Co	5	8
Cu	6	6
Li	34	30
Ni	<2	2
Zn	158	98

88300005: Dacite/dacitic ignimbrite from 3km northeast of Croydon.

88300006: Granite/quartz monzonite from immediately west of Tabletop Fault.

APPENDIX 3

K-Ar DATING OF SERICITE IN DRILL CORE SAMPLE FROM GOLDEN BUTTERFLY DEPOSIT, CROYDON, QUEENSLAND

by

AMDEL

amdel

K-Ar AGE DETERMINATION ON SERICITE

1. INTRODUCTION

One sample of drill core, GBD-1 was received from Mel Jones, Pancontinental Mining Limited Exploration Division, with a request for K-Ar dating of sericite if satisfactory.

2. PROCEDURE

A standard thin section was prepared and examined with respect to suitability of the sericite for K-Ar dating. Results of the evaluation were discussed with Dr. Mel Jones and it was decided to proceed with K-Ar dating using the statically sedimented sericite.

The sample was crushed with a jaw crusher then siebed for 20 seconds. Approximately 15 grams of sample were shaken then stirred in a cylinder of ultra pure water. The solution was allowed to sediment statically then -2 μm and -4 μm "clay" fractions were pipetted off and analysed by X-ray diffraction (XRD). The results of the XRD are given below. They confirm that a fine 2M muscovite (sericite) dominates both the -4 μm and -2 μm fractions and through repetitive sedimentations and centrifuging sufficient sericite was obtained for K-Ar analysis.

Standard procedures were used to detemine the potassium content in duplicate and for the extraction and isotopic analysis of the argon. The results are given in the Table and discussed below.

3. PETROGRAPHY

Sample GDB-1: TS46484

ALTERED GRANITOID

This is a coarse grained, plutonic, acid igneous rock that has been highly altered. It principally consists of coarse grained feldspar, and its alteration products, and quartz. There are medium grained ?graphic intergrowths of quartz and feldspar. Remnant coarse flakes of muscovite have been recrystallised and ?crenulated but suggest that muscovite was a primary igneous phase. The feldspars have been intensely altered to sericite. The sericite alteration event appears to have been associated with a brittle deformation, with conjugate fractures often highlighted by secondary iron staining and opaques, and some fine granulation of the quartz and feldspar.

A K-Ar age determination on the finer muscovite/sericite would yield a minimum age for the alteration.

amdel

4. X-RAY DIFFRACTION RESULTS

The -2 μm and -4 μm sedimented fractions are indistinguishable when analysed semi-quantitatively by XRD scans. Both fractions consist dominantly of well crystalline, 2M, mica-like material identified as muscovite type. There are trace to accessory amounts of quartz and K-feldspar (?microcline) and traces of kaolinite.

5. K-Ar RESULTS

The results of the K-Ar analysis are given in the Table. The sericite has a high K content consistent with a normal muscovite, hence any dilution due to quartz, feldspar and kaolinite impurities appears to have been negligible. The radiogenic argon content is high and the calculated age of 322±2 Ma is considered to reflect the time of sericite formation.

TABLE: POTASSIUM-ARGON RESULTS

Sample	%K	$^{40}Ar^*(x10^{-10}moles/g)$	$^{40}Ar^*/^{40}Ar_{Total}$	Age†
GDB-1 "Sericite"	7.90 7.86	48.11	0.971	322±2

* Denotes radiogenic ^{40}Ar.

† Age in Ma with error limits given for the analytical uncertainty at one standard deviation.

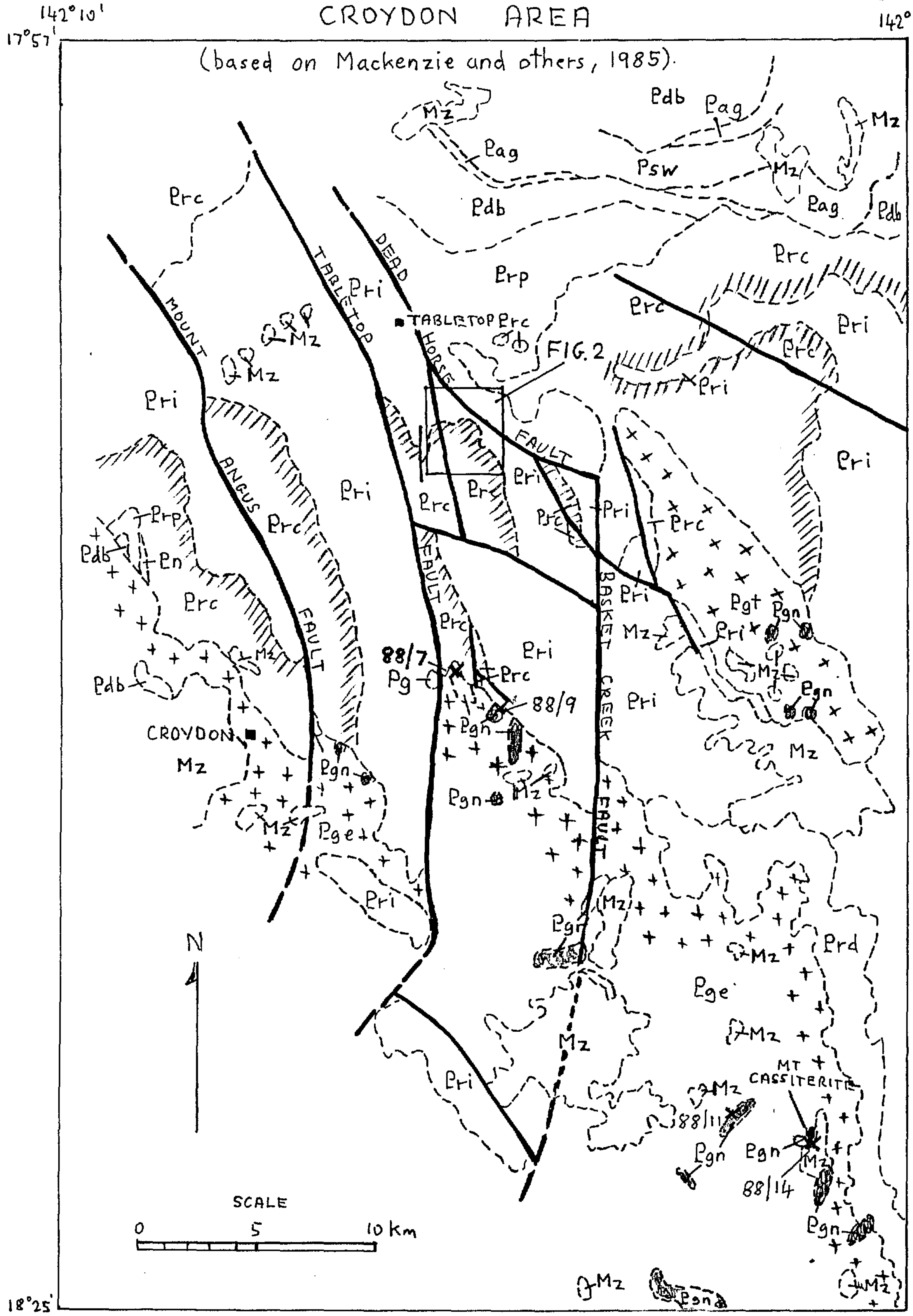
Constants: ^{40}K = 0.01167 atom %

λ_β = $4.962 \times 10^{-10}y^{-1}$

λ_ϵ = $0.581 \times 10^{-10}y^{-1}$

GEOLOGICAL SKETCH MAP OF CROYDON AREA

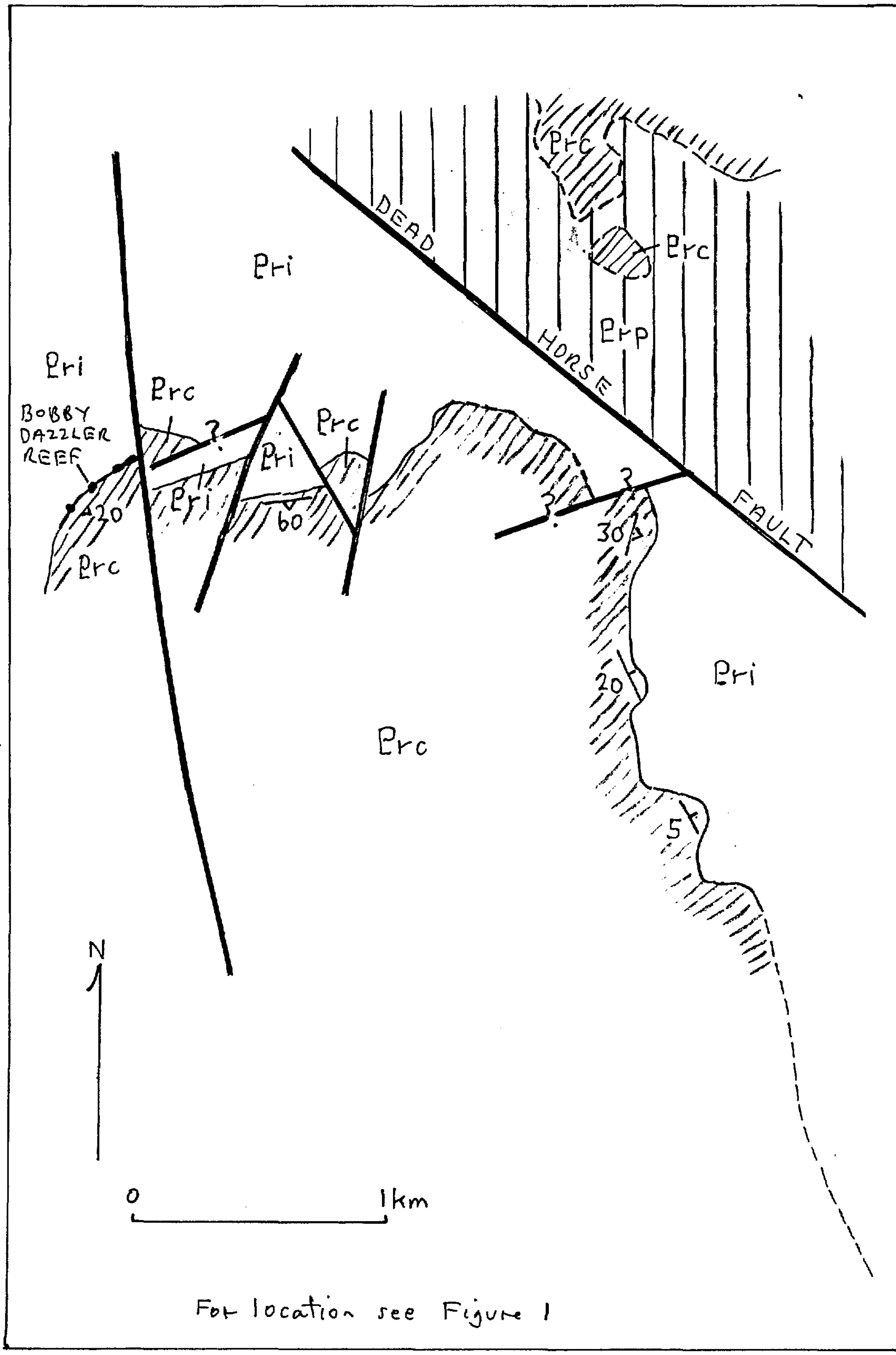
Fig. 1



Mz	Mesozoic sediments
Pg	?Palaeozoic granite
Pgn	Nonda Granite
Pgt×	Mooremount Granite
Pge+	Esmeralda Granite
Pri	Idalia Rhyolite
Prd	Democrat Rhyolite Mbr.
Prc	Carron Rhyolite
Pn	Nancy Lee Sandstone Mbr.
Prp	Parrot Camp Rhyolite
Pdb	B Creek Rhyolite
Pag	Goat Creek Andesite
Psw	Wallabadah Siltstone
-----	Geological boundary
——	Fault (dashed where approx.)
× 88/7	Age determination sample locality with abbrev. reference number

Cainozoic units omitted

GEOLOGICAL SKETCH MAP OF SMALL AREA SOUTHEAST OF "TABLETOP" Fig. 2



Geological boundary, accurate

Geological boundary, approximate

Fault

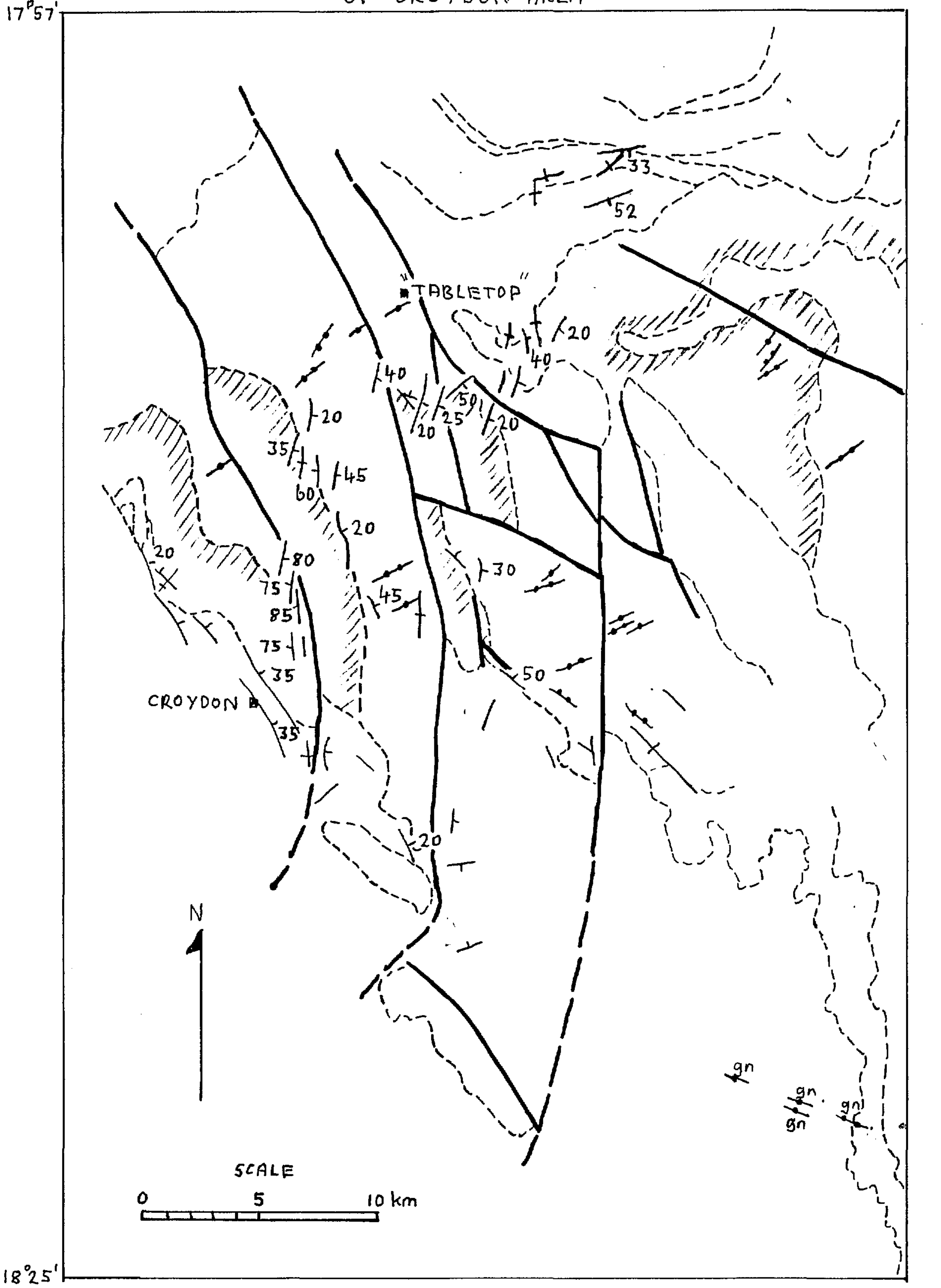
20 Strike and dip of bedding

20 Strike and dip of banding

Letter symbols as in Figure 1

Fig. 3

STRUCTURAL SKETCH
OF CROYDON AREA



Geological boundary
Fault (dashed where approximate)
35 Quartz reef showing dip
Vertical quartz reef
Quartz reef, attitude unknown
Altered rhyolite
gn Greisen

Quartz reefs generalised from Clappison & Dickinson, 1937