GFS

A STRUCTURAL AND METAMORPHIC ASSESSMENT OF THE SUTTON'S-WELL TREE AREA WITH REFERENCE TO URANIUM MINERALISATION

REPORT SUBMITTED TO

MOBIL ENERGY MINERALS AUSTRALIA

B.W.NISBET, B.Sc., Ph.D.

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TABLE OF CONTENTS

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TABLE OF CONTENTS

I - INTRODUCTION

This report details work performed during the period 8.9.80 to 31.10.80 on Exploration Licences 1597 (Chilling Creek), E.L. 1965 (Twin Peaks), E.L. 1599 (Elizabeth Downs), E.L. 1356 (Litchfield), and E.L. 1359 (Noltenius), collectively referred to as the SUTTON's AREAS, and E.L. 1731 (Well Tree).

The purpose of the work was to assess the structural, metamorphic and stratigraphic relationships between rocks units in these areas, concentrating upon the lower Proterozoic and Archean (?) rocks.

Table 1 shows a break down of time spent on the project, and it is apparent that a large portion of the field time was spent in Twin Peaks E.L.

Mapping was carried out on 1:100,000 scale topographic maps, using black and white R.C.9 aerial photography at a scale of about 1:88,000 as a mapping aid.

A Localities Visited/Fact Geology Map is presented at 1:100,000 scale in Enclosure 1, and an Interpretation Map at the same scale in Enclosure 2.

203 rock samples were collected during the study and these were forwarded to Dr. M.A. Etheridge of Monash University for holding. Forty seven thin sections have been cut from 46 of the samples. These were examined at Monash University by the writer during the period 28.9.80 to 30.9.80. A further 13 samples were submitted for thin sectioning on 30.9.80. It has been proposed that a detailed examination of all these thin sections will be conducted over a two week period in late February, 1981, and a detailed petrographic report will be made available at the end of this period.

66 colour slides were taken during the study to illustrate features of note. A copy of each slide, with a written description, is presented in Appendix.

DATE	DETAILS	N° of days
8.9	Discussion in Melbourne. M.E.M.A.	1
11.9	Flew Melbourne-Darwin	1
12.9 to 13.9	Compilation. M.E.M.A. Darwin office	2
14.9 to 19.9	Visited tenements with field personnel	6
20.9 to 24.9	Compilation. M.E.M.A. Darwin office	5
25.9 to 3.10	Field work. Twin Peaks	9
5.10	" " . Noltenius	1
6.10	" " . Litchfield	1
7.10	" " . Elizabeth Downs	1
8.10	" " . Twin Peaks, Chilling Creek	1
9.10 to 10.10	Field inspection with M.E.M.A. personnel	2
11.10 to 12.10	Field work. Noltenius	2
13.10	Visited George Creek, Adelaide River Mines	1
14.10	Sorting samples. Darwin M.E.M.A. office	1
15.10	Flew Darwin-Sydney	1
17.10	Compilation. Report preparation, Sydney	1
20.10 to 24.10	Compilation. Report preparation, Sydney	5
27.10	Discussion. M.E.M.A. personnel, Melbourne	1
28.10 to 30.10	Examination of thin sections, Monash	3
31.10	Discussions. M.E.M.A. personnel, Melbourne	1
1.11 to 2.11	Report preparation, Sydney	2

TABLE 1 : Breakdown of time spent on Sutton's Areas/Well Tree Project.

II - PREVIOUS WORK

A detailed review of previous work is not presented here. Published material referred to includes : Morgan etal, 1972 (Ref. 5), Pontifex etal, 1972 (Ref. 7), Sweet, 1977 (Ref.11), *Solid Geology of the Pine Creek Geosyncline,* 1979, (Ref.10), Riley, 1980 (Ref. 8), and Fergusson etal, 1980 (Ref. 2).

Extensive use was made of unpublished M.E.M.A. company reports, especially those of Thomas, 1979 (Ref.12), Cotton, 1979 Ref.1), and Rose, 1980 (Ref. 9). In the Well Tree area, Drawing N^o NS231 supplied by Urangesellschaft Australia Pty. Ltd. at a scale of 1:25,000 was used as a base.

Petrographic reports C.M.S. 80/6/4, 80/7/12, 80/8/21, 80/8/60 and 80/8/22 by Central Mineralogical Service were examined and their findings are incorporated in this report.

III - LITHOLOGIES

1. Chilling Sandstone.

This rock type is most common in the Chilling Creek and southeastern Twin Peaks E.L.'s, where it generally occurs as a fine layered clean sandstone with rounded quartz grains up to a few mm in diameter. It is commonly cross bedded and ripple marked. Typical examples of this rock type are shown in slides 12 and 13.

2. Berinka Volcanics.

These rocks outcrop extensively in Chilling Creek E.L.and south-west Twin Peaks E.L. where they are interlayered with and intrude the Chilling quartzite (see slide 62).

The most commonly occurring lithology is a red-brown to green prophyritic rock with phenocrysts of feldspar and quartz up to a few mm in diameter in a fine grained altered ground mass. This rock is rarely layered or foliated. Some fine grained purple to dark green shaly rocks are interlayered with the porphyries.

In the vicinity of locality 26-9-21, the porphyritic rocks appear fresher and flinty in nature. In thin section metamorphic pyroxene has been identified and feldspar phenocrysts are myrmeckitic around their edges. It is considered that these rocks have been hornfelsed to pyroxene hornfels facies at this locality.

3. Granitic Rocks.

Granitic rocks outcrop extensively in the tenements and four main types were recognized :

Pgx : Inclusion rich biotite granodiorite

Pgp : Inclusion poor, pegmatite rich biotite granodiorite

Pgt : Microgranites, porphyries, intrusive breccias

Pgh : Hornblende granodiorite.

Pgx : This outcrops in the southern and central portions of Twin Peaks E.L. It is typically a coarse grained (up to 4mm) biotite granodiorite with from 10 to 90 % of the rock occupied by xenoliths of biotite schist, quartzite, and fine grained biotite rich granitic rocks (e.g. slides 10, 31,32,35,36). Most xenoliths are identical to rock types elsewhere in the Hermit Creek Metamorphics (e.g. slides 36,37,38).

In many outcrops garnet as equant crystals up to 2 cm in diameter constitutes up to 20 % of the rock (e.g. localities 17-9-6, 25-9-8, see slide 32). Cordierite has also been described from this lithology.

Occasional blebs of coarse vein quartz occur but the rock type is notable for its general lack of a coarse pegmatitic phase.

The lithology is generally unlayered, but commonly possesses a weak to strong cleavage. In some localities a general layered aspect is apparent however (localities 2-10-5, 2-10-14, 3-10-2, slides 46,51,52), and the rock is migmatitic in character. At locality 2-10-14, abundant sillimanite occurs. Migmatites define a horizon along the Pgx-HCg contact as shown in Enclosure 2.

Pgp : Pgp granitic rocks are very similar to Pgx, with the following differences

a) They are similar in composition, but commonly porphyritic, with large orthoclase crystals up to a few cm. long in a medium to coarse grained groundmass (slides 53,54,58,59). Both biotite and muscovite were identified.

b) Although xenoliths of rock types identical to those found in Pgx were described, they generally constitute less than 10 % of the rock.

c) A spectacular difference is the common occurrence of thick quartz-feldspar-biotite pegmatite veins cross cutting the rock (slides 56,57).

d) Although garnet was described it is quite uncommon compared to Pgx.

Pgt : These lithologies are uncommon and are made up of micrograniitic rocks, quartz-feldspar porphyries and intrusive breccias intruding other rock types. They are thought to be associated with Pgp lithology.

Microgranitic rocks are best seen at localities 29-9-11 and 29-9-3 and differ from typical Pgp only in grain size.

Porphyries were observed at locality 6-10-1 (slide 55). Here the rocks are composed of feldspar and quartz phenocrysts up to 1-2 mm long in a fine grained, pink, layered groundmass.

Intrusive breccias are best seen at localities 25-9-2 and 25-9-4 (slides 27 to 30), and usually take the form of veins up to 20 cm wide with pink granitic as well as country rock fragments in a coarse granitic matrix.

Pgh : This rock was only seen at locality 26-9-13 and is distinguished from all other granitic rocks by the absence of micas and presence (10 %) of dark green hornblende. The rock is inclusion free and appears granodioritic in composition.

4. Basic Rocks.

A sequence of massive basic rocks, which have been correlated with the Zamu dolerite of the Pine Creek Geosyncline by previous workers, outcrops in the southern Twin Peaks area.

The rocks are generally medium to coarse grained and, from petrographic descriptions, are composed dominantly of labradorite and augite with minor hypersthene. The rocks are commonly uralitised. Ophitic and sub-ophitic textures are described and the rocks are probably gabbros.

These rocks are rarely layered or foliated on a mesoscopic scale but layering does occur on a macroscopic scale (see enclosure 2). Two rock types were delineated :

Pd_1 : the most common type consisting of medium grained (few mm) homogeneous dolerite with occasional plagioclase veinlets up to a few mm in width.

Pd_2 : a rock composed of angular to rounded fragments of fine grained dolerite up to 10-20 cm in diameter in a coarse grained pyroxene-plagioclase matrix (slides 24,25). In places, no fragments occur.

5. Burrell Creek / Noltenius Formation (Pu).

These lithologies are made up of quartz-muscovite-graphite schists and quartzites, quartz muscovite meta-arenites and conglomerates. To the west of Noltenius prospect the rocks are extensively intruded by hornblende-plagioclase-epidote amphibolites.

The presence of cross bedding, graded bedding, slump structures and channel-fill structures indicate that this is a turbidite sequence. Two formations have been previously recognized, the Burrell Creek Formation, which is predominantly fine grained (distal facies) and the Noltenenius Formation, which is composed mostly of coarser material (proximal).

Andalusite and tourmaline are common constituents of the rocks, particularly in carbonaceous layers. Two types of andalusite were observed :

a) Large (1 cm long) prismatic crystals occasionally with a weak preferred orientation in foliation planes (locality 15-9-6, slides 1 and 2).

b) Very large (3-4 cm) prismatic blades with random orientation in proximity to granitic intrusives (e.g. locality 9-10-2).

Tourmaline occurs in a form which can be easily mistaken for andalusite and may constitute up to 30 % of carbonaceous layers (see slides 65 and 66).

6. Hermit Creek Metamorphics

The distribution of these lithologies is shown in Enclosure 2 and a range of rock types and metamorphic grades are encompassed by the term. The unit outcrops most widely in the Twin Peaks E.L., although rocks at Well Tree and Elizabeth Downs are very similar. The unit is broken into various sub-units, defined partly on lithology and partly metamorphic grade.

a) Low Grade Units :

- Quartz Mica Schists (HCs) : This unit outcrops in the central and southern part of Twin Peaks E.L. and is composed dominantly of pelitic rocks, most often strongly foliated quartz muscovite sericite schists (slides 39,40). This schist is usually iron stained and buff coloured, with a thin lenticular layering parallel to foliation. The iron staining and coloration may be due to weathering of chlorite in fresh rock. Commonly, knots of white sericite/muscovite up to 2 mm in diameter occur, the foliation wrapping around them. The knots possibly represent retrograde products after higher grade minerals.

Quartz-rich variants occur , with quartzite layers up to 10 m thick. These rocks are always strongly recrystallised, and conclusive sedimentary structures could not be demonstrated.

In the north-west corner of Chilling Creek E.L. (localities 1-10-9,10,11 ; 8-10-3) large cordierate crystals up to a few cm in diameter with andalusite cores overprint earlier features in the rock. The rock appears hornfelsic in nature.

- Meta-basalts (HCb) : In the Buffalo Fly Hill area, fine grained amphibolites are interlayered with mica schist of HCs. Limited petrography indicates that these rocks are composed of hornblende, plagioclase and epidote. Pillow structures have been identified at locality 17-9-4 (slides 17,18,19) and the rocks probably represent extrusive basalts.

- Carbonaceous Schists : At locality 17-9-15 and in contact with the above-mentioned pillow basalts is an outcrop of strongly foliated carbonaceous schists. The rocks are quite ferruginous, with abundant limonite veining and staining and some fine (less than 1 mm) pseudo-morphs after pyrite.

Experience in the East Alligator Region has shown that weathered carbonaceous rocks are often quite difficult to recognize as such, and this lithology may be more widespread in the region.

b) High Grade Units :

- Pelitic Rocks - schists and gneisses (HCg) : Quartz-feldspar-biotite-muscovite schists, quartzites and gneisses are common in the central Twin Peaks E.L. and similar rocks are seen at Elizabeth Downs and Well Tree. These rocks are usually layered, with alternating quartz rich/quartz-poor layers up to a few cm thick (slides 46 to 50).

Commonly sillimanite needles or sericite clusters after sillimanite were seen in pelitic layers, and sillimanite and garnet have been described from these rocks in thin section.

- Amphibolites (HCa) : Extensive areas of dark green amphibolite ranging from massive to layered and foliated in nature occur in northern Twin Peaks E.L., Well Tree, and Elizabeth Downs. Examples of these rocks are shown in slides 43 and 44. No structures which could not be described as original igneous/sedimentary were seen in these rocks, although at Well Tree a breccia was found which is possibly an original structure (slide 26).

From limited petrography, these rocks are composed mainly of plagioclase and hornblende, with large garnet porphyroblasts common at Well Tree. Prograde poikiloblastic diopside and hypersthene with minor hornblende and labradorite has been described from samples in the northern Twin Peaks E.L.

These basic rocks contain lenses and layers of pelitic schists and gneiss.

- Ultramafic Rocks (HCum) : Within the above unit (HCa) at both Well Tree and northern Twin Peaks, a number of rock types with possible ultramafic assemblages occur. Three types were found :

(1) most common is a chlorite-actinolite rock, massive or foliated, in bands up to a few 100 m thick (localities 29-9-5,10-10-5).

(2) thin bands of anthophyllite-tremolite rock (Well Tree ; locality 9-10-2).

(3) thinly banded actinolite-chlorite rock (locality 2-10-7).

Limited geochemistry (R. Beeson, personal communication) shows these rocks are MgO rich (around 27 %), and contain in the order of 2000ppm Cr and 1000ppm Ni. This strongly indicates that these are metamorphosed ultramafic igneous rocks rather than metasediments.

IV - STRUCTURE

1. Breccias

Breccias are very common and have the following characteristics :

a) They occur in steeply dipping bands up to 10-50 m thick, with long strike extent (usually greater than 100 m). Bands can usually be traced intermittently for a number of kilometers.

b) They most commonly consist of angular to rounded fragments of quartzite (rarely micaceous quartzite) in a coarse grained white quartz matrix.

c) Quartz veins are quite common in the rock, and most veins are parallel to the dip and strike of the breccia band.

d) The rock is commonly iron stained and ferruginous.

e) Bands may separate rocks with quite different lithologies and metamorphic grade (e.g. granitic rocks and quartz-muscovite schists), or be contained within one lithology (e.g. Chilling quartzite, biotite granodiorite).

f) Commonly, rocks adjacent to the breccias are cleaved, with the cleavage parallel to the breccia bands.

Examples of these rocks occur at localities 18-9-5 and 28-9-12, and are illustrated in slides 20 to 23, 41 and 42.

These rocks are interpreted as fault breccias formed in zones of high fluid pressures. Deformation was concentrated in these zones but is manifest in adjacent lithologies as a cleavage subparallel to the breccia bands.

2. Chilling Sandstone, Berinka Volcanics

These rocks are not strongly deformed, although dips as steep as 70° occur adjacent to the Giants Reef Fault zone. To the east and southeast away from the fault zone dips flatten to 10-15°. Deformation takes the form of :

a) brecciation in fault zones described previously,

b) some large flexure type folds with moderate south-easterly plunges and steeply dipping axial surface (slides 60,61). These folds are usually asymmetric, with dislocation on the short limb. It is thought these folds are fault-related.

c) fairly rare examples of a penetrative cleavage developed adjacent to breccia zones and paralleling them, e.g. localities 26-9-7,8.

These rocks appear to have suffered no major penetrative deformation, and any deformation seen is probably fault-related.

3. Granitic Rocks

Granitic rocks are often affected by a strong penetrative cleavage, which cross-cuts xenoliths as well as pegmatite veins. Examples are shown in slides 10, 35 to 38, 51 to 58. Xenoliths are commonly flattened in the cleavage plane, and often a strong lineation defined by flattened xenoliths, quartz crystals, or prismatic feldspar phenocrysts exist (see slides 51 to 59).

It is considered that this cleavage is not a flow cleavage formed during intrusion of the granites but a tectonic cleavage imparted to the rocks.

Figure 1 is a plot of cleavage and stretching lineations in the Twin Peaks E.L. The cleavage is quite variable in orientation but generally dips steeply. However, as shown in Enclosure 1, cleavage is generally strongest adjacent to a breccia zone or fault and strikes parellel to these features.

The plot of stretching lineations shows steeply plunging lineations are associated with N.S. striking foliations, shallow plunging lineations with E.W. striking foliations.

4. Xenoliths

The following features were observed in xenoliths within the granitic rocks :

a) Schistose rocks usually possess a strong foliation which is commonly overprinted by the granitic cleavage (slide 36).

b) In psammitic rocks folds with poorly developed axial surface foliation were observed (e.g. slides 37.38).

Similar structures were observed in the high grade pelitic rocks.

5. Basic Rocks

The basic rocks referred to as Pd on Enclosure 2 are generally undeformed, although very local deformation has affected them. This takes the form of :

a) rarely developed "shear" zones (locality 18-9-1),

b) a locally developed penetrative cleavage at locality 30-9-4.

These features are developed adjacent to a quartz breccia and are probably fault-related.

6. Burrell Creek / Noltenius Formation

These rocks are strongly folded and foliated, and the following structural sequence has been identified :

a) B1 Folds.

Minor intrafolial folds with a strong axial-surface foliation parallel to layering were identified at NPD5 prospect. These folds are similar in style to B2 folds and may be present at macroscopic scales.

b) B2 Folds.

These are the dominant fold generation seen in the region and are developed on all scales. They are generally tight to isoclinal with a strong axial-surface foliation. Examples are shown in slides 65 and 66.

Commonly a strong "down dip" lineation is seen in the foliation, defined by elongated pebbles, elongate quartz or feldspar grains in arenites, or prismatic andalusite or tournaline grains. Thin sections indicate that the former probably grew during deformation (i.e. are syntectonic).

Figure 2 shows a plot of layering and B2 axial-surface foliation (S2) from these rocks. Poles show a strong preferred orientation and define a vertical, north-south trending plane, illustrating well the tight nature of B2 folding. B2 folds axes and bedding/cleavage lineations shown in Figure 3 lie in this plane and are quite variable in plunge on a regional scale. B2 plunges appear to be quite consistent on a prospect scale, however (e.g. NPD5, Noltenius).

c) B3 Folds.

B3 folds are best seen in schistose pelitic rocks and generally take the form of a crenulation cleavage or kinks crenulating S2. Most plunge at moderate angles and have N.W./S.E. trending axial surface dipping at moderate angles to the N.E.

B3 folds crenulate and kink muscovites but no significant mineral growth is associated with them. Large knots of sericite in schists folded by B3 may represent retrogressed andalusite.

7. Hermit Creek Metamorphics

a) Low Grade units - HCs, HCb

The low grade pelitic rocks of the Hermit Creek Metamorphics characteristically possess a strong schistosity with a well developed "down-dip" lineation. Layering is not common, but when present, is usually isoclinally folded or transposed into parallelism with schistosity. At many localities an earlier schistosity is overprinted and crenulated by the later, dominant one.

The later schistosity is itself crenulated by small kinks, though these were never witnessed on a large scale. The later dominant foliation and the kinks are illustrated in slide 40.

The metabasalts in this unit, in contrast to the metapelites, are unfoliated and only slightly deformed even though metapelites in contact with these rocks may be strongly foliated (e.g. localities 17-9-14,15). It is probable that the metabasalts/schist contacts represent thrusts.

b) High Grade units

The following structural sequence was observed in the pelitic gneiss from the high grade rocks :

- Early Folding.

Early folds are generally tight to isoclinal with a strong axial-surface foliation. Often coarse quartz segregations up to 1 cm in width are parallel to the axial surfaces of these folds. Examples of early folds are shown in slides 48, 49 and 50.

- Late Folds.

Late folds are the dominant type observed in these rocks, and consist of open to tight folds with no axial-surface foliation. Only scant orientation data was collected from these folds, but in north-central Twin Peaks E.L. late folds plunge steeply to the N.N.E., with approximately vertical axial surfaces.

Basic and ultramafic amphibolites from the high grade units are commonly foliated and lineated (see slides 43,44) but no mesoscopic folding was observed. It is probable that the prominent foliation is equivalent to the early foliation in the pelitic rocks.

LEGEND FOR ORIENTATION DIAGRAMS

Pole to layering

Early fold plunge

Pole to early fold axial surface

Pole to foliation

Plunge-crenulation

Pole crenulation cleavage

Plunge-kink

Pole-kink axial surface

Bedding/cleavage intersection

Down dip lineation

All data plotted on an equal area projection.

Plots referred to magnetic north.

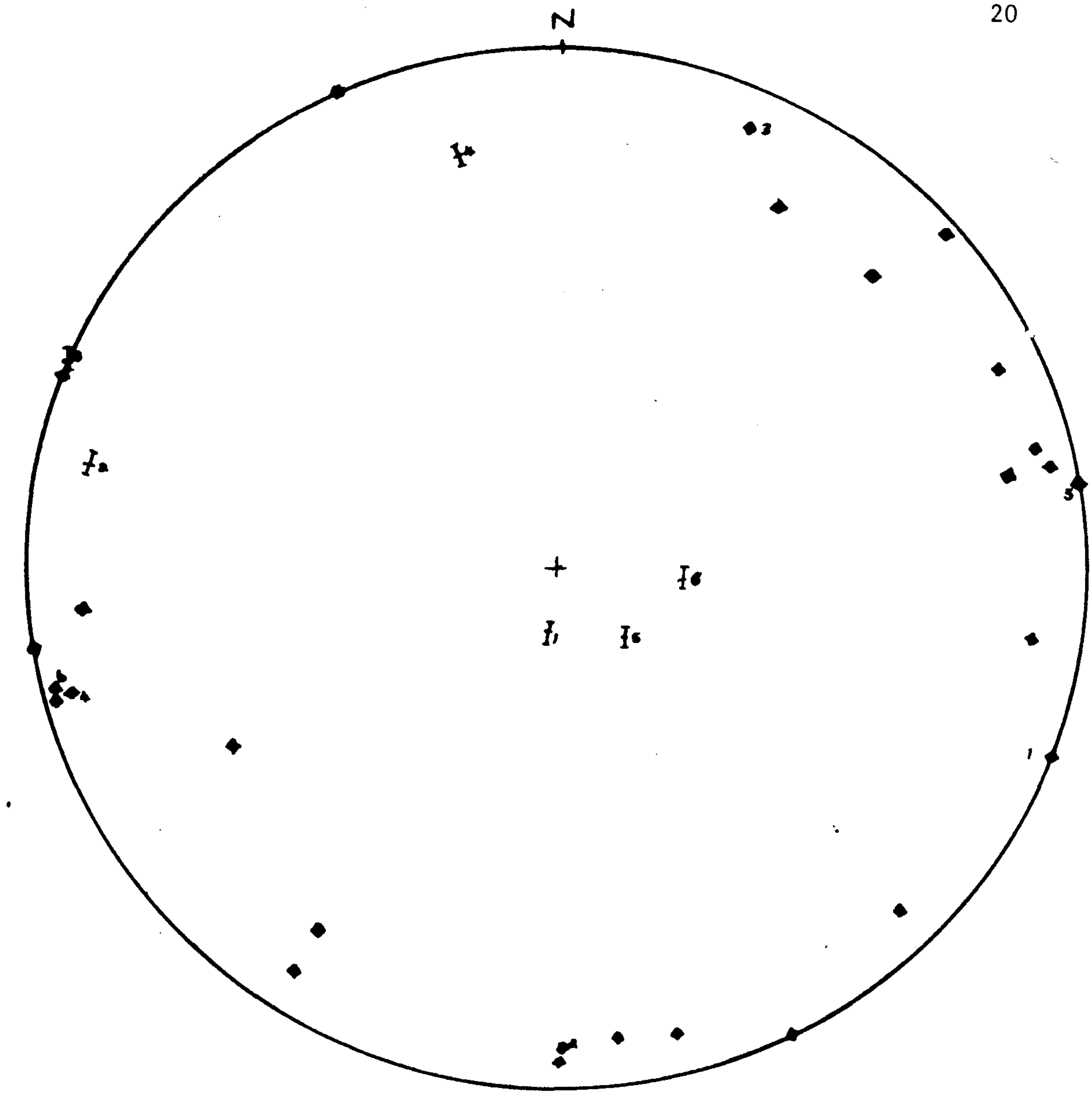

FIGURE 1 : Orientation Data for granitic rocks.

Down-dip lineation N°1 refers to foliation N°1, etc.

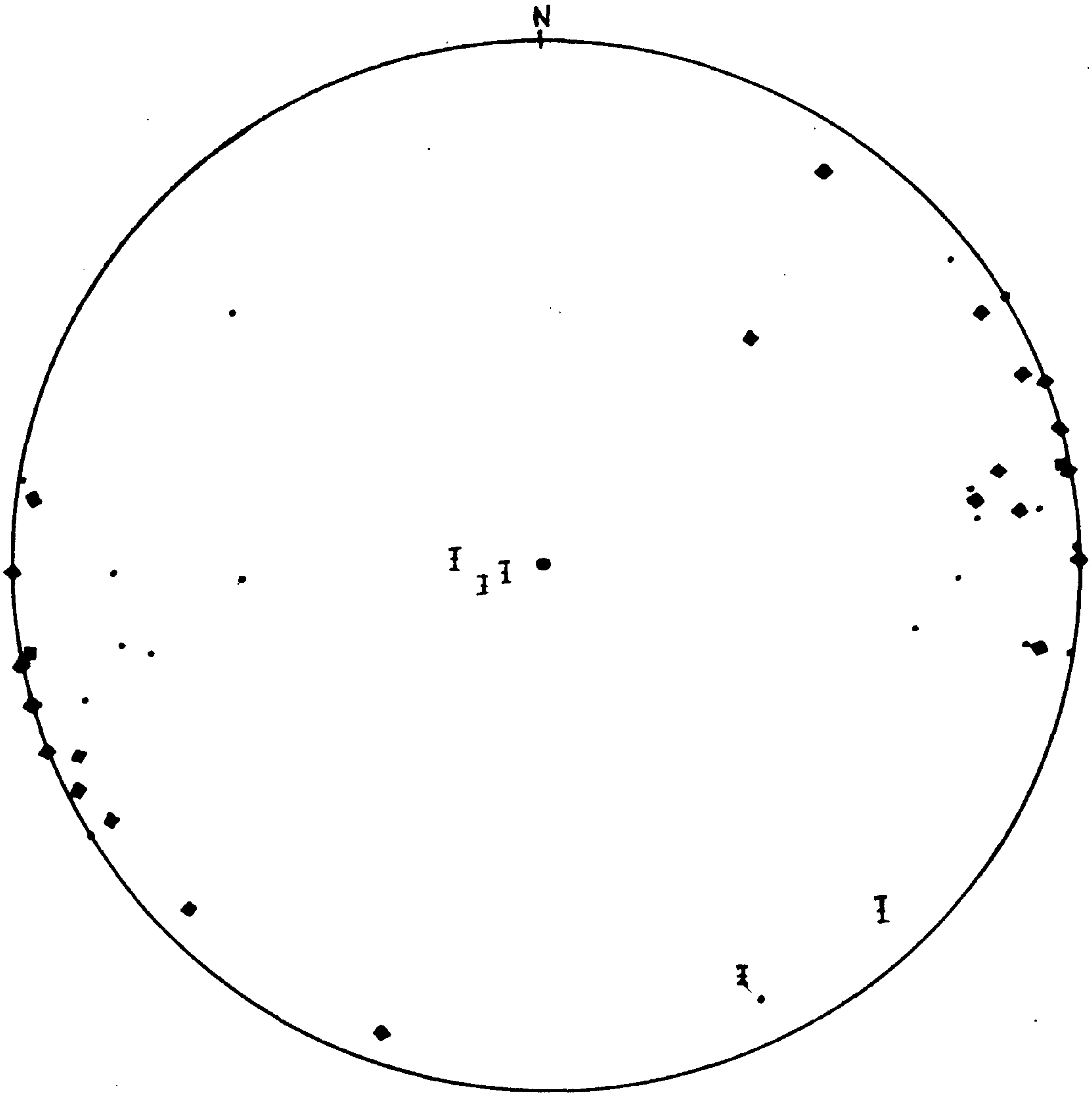

FIGURE 2 : Layering, foliation, and mineral lineation orientation data for the Burrell Creek and Noltenius Formations.

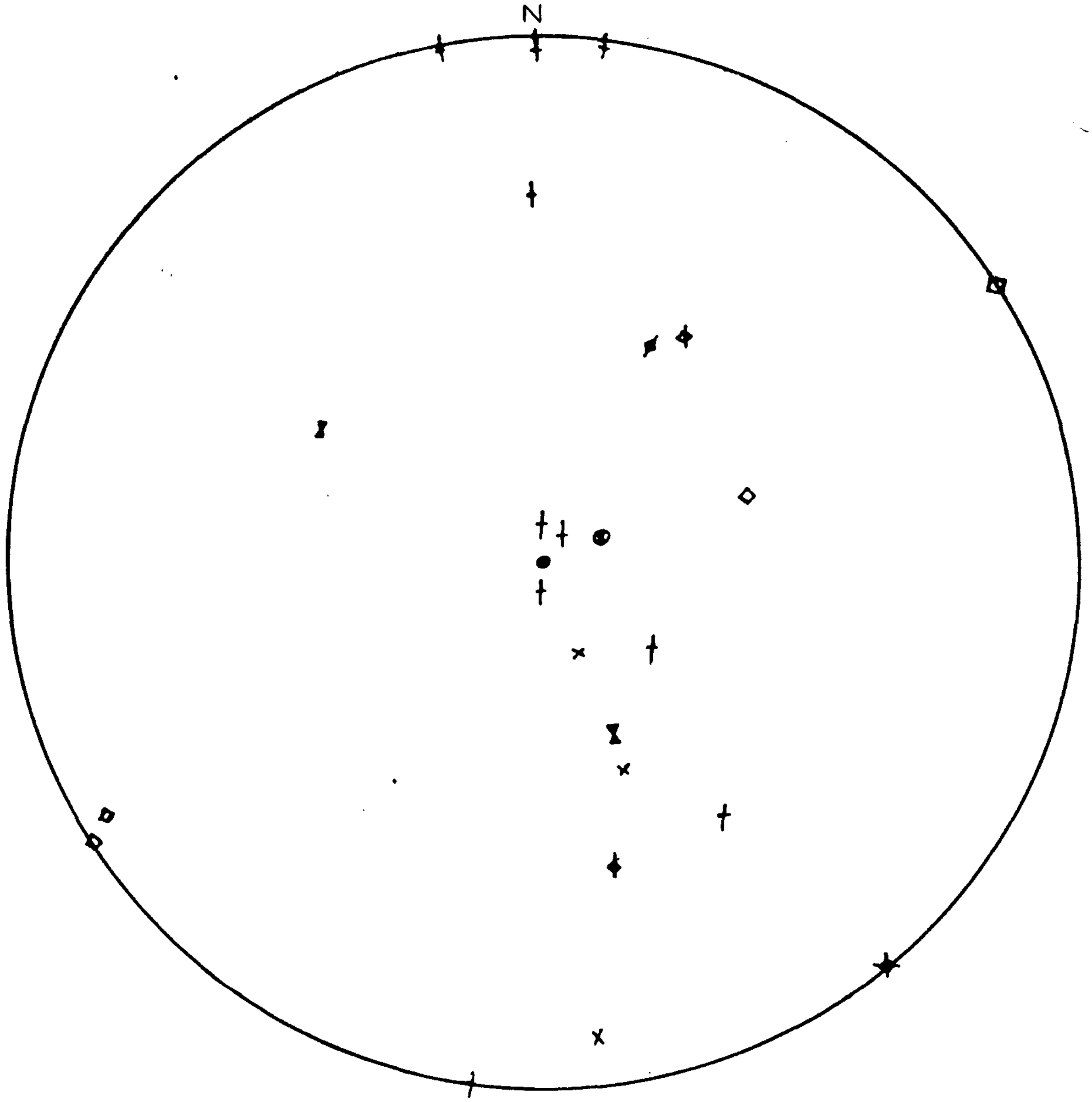

FIGURE 3 : Fold orientation data for the Burrell Creek and Noltenius Formations.

V - METAMORPHISM AND MAGMATISM

1. Regional Prograde Metamorphism

a) Greenschist Facies :

Greenschist Facies Metamorphism is most widespread in the Burrell Creek lithologies and is characterised by quartz, muscovite and chlorite in pelitic rocks, and chlorite-albite-calcite in basic intrusives (C.M.S. Report 80/8/21).

Greenschist facies assemblages are also typical of HCs unit in the southern Twin Peaks area. This is further discussed in a later section on retrogression.

b) Amphibolite Facies, Granulite Facies :

Amphibolite Facies rocks in the area typically contain quartz-feldspar-biotite-sillimanite in pelitic rocks and plagioclase-blue-green hornblende in basic rocks. Units exhibiting these assemblages are HCg, HCa and HCcs. In the north-west part of Twin Peaks E.L. basic rocks exhibit brown hornblende-plagioclase-hypersthene-augite assemblages typical of upper amphibolite/lower granulite facies metamorphism.

Prograde andalusite in schists of the Burrell Creek Formation were also observed, but their distribution is presently uncertain.

2. Thermal Metamorphism

Thermal prograde effects were noted in the following areas :

a) Buffalo Fly Hill (Enclosure 2)

In the west of this area pelitic quartzites contain spherical, inclusion-rich bodies of cordierite up to 1cm in diameter with andalusite cores.

b) Basic rocks in this same area (locations 17-9-8,14) contain hornblende-plagioclase assemblages and are unfoliated.

*c) Berinka Volcanics at locality 26-9-21 show metamorphism to Pyroxene-Hornfels Facies at the contact with Pgh.

d) Basic rocks near locality 29-9-3 contain an epidote-quartz-plagioclase-horblende assemblage which appears to be a retrograde product of a coarse-grained amphibolite.

e) Percussion chips west of Noltenius Prospect exhibit thermal effects of greenschist and hornblende-hornfels facies in basic and pelitic rocks (C.M.S. Report 80/8/21).

3. Retrograde Metamorphism

Two types of retrograde metamorphism were identified in the area :

a) In the HCg unit, randomly oriented clusters of sericite almost ubiquitously replace coarse-grained muscovite and sillimanite. This probably represents a static retrogressive event which may have occurred during weathering of the rocks.

b) In the HCs unit knots up to 5mm in diameter comprised of sericite and quartz are common. Foliation planes anastomose around the knots or cut them, and knots may be equidimensional or elongate parallel to the foliation. This retrogressive phase is probably a dynamic event associated with formation of the foliation.

4. Granitic Rocks

a) Xenolith-rich Granite (Pgx) : Pgx granites contain abundant garnet and numerous xenoliths with amphibolite facies assemblages. A zone of migmatites as shown in Enclosure 2 is also present. These rocks fit the criteria for "S" type granites as described by Ferguson etal (Ref. 2). It is thought that these granites are the result of anatexis of Hermit Creek metasediments during a regional metamorphic event which produced as high as Granulite Facies assemblages in basic rocks. The abundant xenoliths, garnet and cordierite found in these rocks are probably relicts from the metamorphism. At locality 2-10-11, a cordierite-biotite-quartz-sillimanite-garnet rock possibly represents a "Restite" or residual rock left after partial melting of the metasediments.

b) Porphyritic Granites (Pgp) : These rocks are very similar to Pgx in composition and in the presence of xenoliths.However, their porphyritic nature, lower xenolith content, and presence of pegmatites and more differentiated phases suggest they represent a more differentiated phase of Pgx. These rocks cause thermal metamorphic effects in places (e.g. localities 29-9-3,4), intrude Pgx and the metasediments (see Enclosure 2) and contain rafts of metasediment (Elizabeth Downs, N.E. Twin Peaks, Well Tree).

c) Hornblende Granite(Pgh) : This rock type is different from all other granitic rocks in the region because of its absence of micas and presence of hornblende. It hornfelses the Berinka Volcanics at locality 26-9-21 and appears younger than Pgx or Pgp. It has the characters of an "I" type granite (Ferguson etal, Ref. 2).

5. Discussion

The minerals identified (andalusite-cordierite-sillimanite), metamorphic grades (Greenschists, Amphibolite and Granulite Facies), and presence of associated granites and migmatites suggest that this belt of rocks represent a Low-Pressure Type metamorphic terrane as described by Miyashiro (1976, Ref. 4) similar to the East Alligator region of the Northern Territory and the Cooma region of New South Wales.

VI - DISCUSSION OF ROCK RELATIONSHIPS

The following features need to be considered before discussing the evolution of the area.

The Hermit Creek Metamorphics probably represent a sequence of shales, carbonaceous shales, quartzites, basalts, pillow lavas, gabbros and ultramafic igneous rocks. The basic and ultrabasic rocks may be comparable to the Archean greenstones of Western Australia or represent intrusives as postulated in the Victoria River Region Sweet, Ref.11). The age of these rocks is uncertain. They may represent Archean rocks similar to the Rum Jungle and Nanambu Complexes or they may be Lower Proterozoic in age. Pgx granites intrude these rocks and place a lower limit of about 1740m.y. (J.Rose, personal communication) on the rocks.

The amphibolite-ultramafics-pillow basalt assemblage probably does not correlate to the Zamu Dolerite of the Pine Creek Geosyncline but may be a Stag Creek Volcanics equivalent.

The Hcs unit of the southern Twin Peaks area is considered not to be a Burrell Creek Fmn. correlative, even though rock types in the two units are similar. Reasons for this are as follows :

a) no ultramafics or pillow basalts have been described from the Burrell Creek/Noltenius Formations.

b) HCs unit seems to have had a more complicated structural and metamorphic history than the Burrell Creek/Noltenius rocks. Whereas original bedding features and relict sedimentary can often be identified in the latter, HCs unit is completely recrystallised and no relicts are observable.)

It is considered that the Noltenius/Burrell Creek rocks are younger than the Hermit Creek Metamorphics.

The Chilling Sandstone/Berinka Volcanics lithologies are essentially unmetamorphosed and only weakly deformed. They are younger than the Hermit Creek Metamorphics and the Burrel Creek/Noltenius rocks. The Berinka Volcanics are intruded and metamorphosed by Pgh lithology.

Basic rocks designated $Pd_{1/2}$ on Enclosure 2 are unmetamorphosed and only weakly deformed. Their relationship to other units is unclear at this time but it is probable that they are of similar age to the Berinka Volcanics.

Although deformation in Chilling Creek/Berinka Volcanics is generally not intense, the units can be quite strongly deformed adjacent to faults. In some areas, slivers of fault bounded material (e.g. area A in south Twin Peaks) possess strong foliation parallel to fault boundaries and contain retrograde mineral assemblages. The foliation also occurs in the granites to the north of the zone. It is considered that the foliation and retrogression are caused by deformation and associated high fluid pressures during faulting.

VII - GEOLOGIC EVOLUTION

1. Deposition of shales, quartzites, carbonaceous shales with volcanics including basalts, pillow basalts, gabbros and ultramafics. These rocks may be Archean or Lower Proterozoic in age.

2. Deposition of a sequence of distal and proximal turbidites of the Burrell Creek and Noltenius Formations. These rocks are probably Lower Proterozoic in age and unconformably overlie the Hermit Creek rocks.

3. Metamorphism and deformation, producing a complex structural/metamorphic overprint on the rocks. Metamorphism was more intense in the Hermit Creek rocks, causing partial melting and migmatisation in suitable lithologies. Deformation was probably associated with thrusting.

4. Granitic material thus generated migrated and differentiated and in some cases intruded and hornfelsed older granites and metamorphics.

5. Deposition of Chilling Sandstone unconformably above this sequence.

6. Intrusion (and extrusion) of Berinka Volcanics. Another phase of this activity is possibly $Pd_{1/2}$. Pgh intrudes these rocks and may be an even later phase of this activity.

7. Extensive faulting in the Giants Reefs Fault Zone. This faulting is quite complex in detail and a number of fault generations are present. Some slivers of high-grade metamorphics incorporated in the fault zone suffered penetrative deformation and retrogression associated with high fluid pressures.

8. Deposition of Adelaidean and younger units.

VIII - MINERALISATION - TARGET CONCEPT

In a recent study of the Pine Creek Geosyncline, Nisbet (1980, Ref. 6) considers the following characteristics of East-Alligator types mineralisation to be most significant in an exploration sense :

a) Host rocks are Lower Proterozoic carbonaceous pelitic schists with associated carbonates.

b) These rocks are in close proximity to radiometrically anomalous rocks with Archean ages.

c) Mineralisation in found in tabular, steeply dipping, highly strained zones in which the schists have been retrogressed from amphibolite to greenschist facies.

d) Mineralisation is associated with abundant chlorite.

e) Activity in the mineralised zones occured over a long time span, with faulting and chloritisation affecting Carpentarian cover rocks (e.g. Kombolgie Fmn.- equivalent to the Chilling Sandstone).

In the Suttons-Well Tree area, it is considered that all of these characteristics can be identified in the sequence and that the chances of finding mineralisation in the Lower Proterozoic rocks are high.

IX - DISCUSSION OF EXISTING PROSPECTS

Rocks at Noltenius and N.P.D.5 Prospects are in the Burrell Creek/Noltenius Formations and have been metamorphosed to Greenschist Facies. No evidence for retrograde/high strain zones were seen at the properties, although mineralisation at Noltenius seems to be located in a thin fault zone. At both prospects rocks are isoclinally folded with a strong S2 foliation sub-parallel to layering. B2 folds plunge steeply to the north at Noltenius and at shallow angles to the north at N.P.D.5.

A visit to Georges Creek and Adelaide River Mines showed rock types identical to those seen at Noltenius and N.P.D.5. It is likely that the mineral occurrences are very similar in all four cases.

1. Drill Hole L.P.D.5, Noltenius.

Drill hole L.P.D.5 was logged with John Rose on 11-10-80, emphasising structural features such as bedding/cleavage relationships, angles between bedding, cleavage and core axis, and facing directions (see Laing, 1977, Ref. 3). Hole L.P.D.4, which encountered mineralisation, was unsuitable for this exercise as it was drilled straight down-dip.

Results are plotted in Figure 4, and it is shown that a previously unrecognised isoclinal fold hinge was found. These techniques will prove very useful during further exploration in the region.

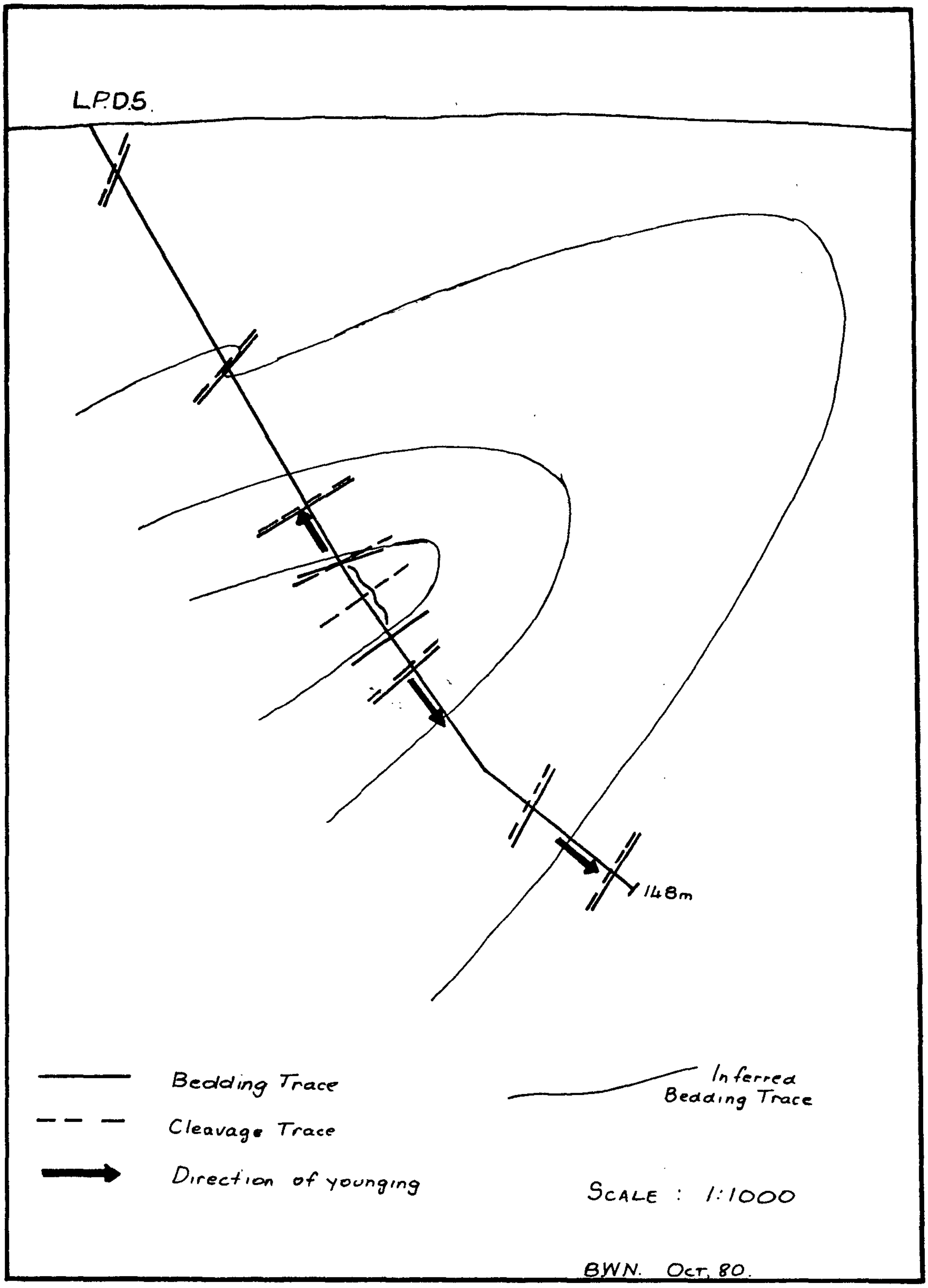

FIGURE 4 : Interpretation of structure in LPD5, Noltenius Prospect based on bedding/cleavage relationships to core axis and facing directions.

2. Section along Holes N.P.D.74, 75, N.P.D.5 Prospect.

Figure 5 is a cross section at a scale of 1:1000 incorporating Holes N.P.D.74 and 75 at N.P.D.5 Prospect. Areas of anomalous count in the down-hole survey and a surface radiometric anomaly are shown.

The anomalous radioactivity seems to be confined to a distinct horizon. In drilling to date this horizon has only been intersected in the weathered zone and it is recommended that a 45 degree angled hole situated 60m east of N.P.D.75 be drilled to test the horizon in fresh rock. This hole will also intersect a siliceous "fault" zone which is radiometrically anomalous at the surface and was possibly intersected in N.P.D.74 and 75.

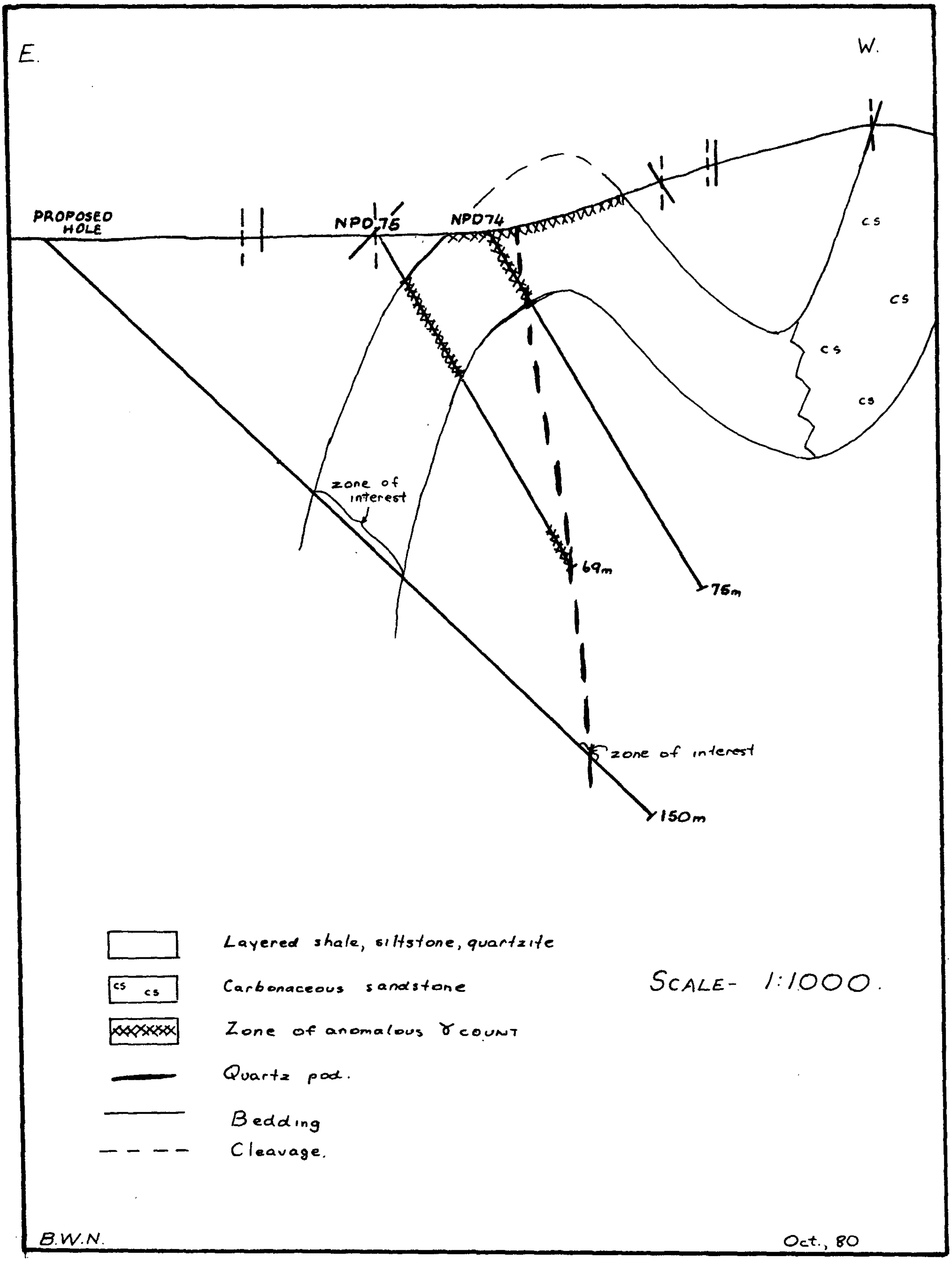

FIGURE 5 : Cross section at NPD5 Prospect showing structural interpretation and proposed hole.

X - RECOMMENDATIONS FOR FURTHER WORK

1. Buffalo Fly Hill Area

This area contains an E-N.E. trending sliver of metabasalts, schists and carbonaceous schists with a strong N.-S. oriented retrogressive foliation. A zone extending south from locality 17-9-15 to the scarp is strongly ferruginised and is anomalous in lead near the scarp (R. Beeson, personal communication).

Detailed mapping and geochemistry is recommended with follow up drilling.

2. Area A (Enclosure 2)

The zone of interest in this area is the fault bounded sliver of HCs lithology shown in Enclosure 2. This material has a strong retrogressive foliation and may possibly be chloritic below the weathered zone.

No radiometric or geochemical anomalies have so far been detected, but it is possible that leaching has removed mineralisation from the surface zone.

A programme of mapping, geochemistry, and a track-etch survey in conjunction with stratigraphic drilling is recommended to further assess this area. Sites for some stratigraphic drillholes have been indicated to M. Binns.

3. Alligator Lagoon (Enclosure 2)

Rocks in this area outcrop very poorly but ferruginous retrograde schists have been identified at localities 2-10-9, 2-10-10 and 2-10-11.

The zone from 2-10-10 to 18-9-10 is associated with a magnetic anomaly and a radiometric high (L. Starkey, personal communication).

This area should be tested by mapping, geochemistry and magnetic/radiometric surveys, followed by drilling.

4. General

Outcrop is poor in the low-land parts of the Sutton's and Well Tree areas, Recent cover is extensive, and weathering is intense. It is considered likely that airborne radiometric surveys could have missed leached or buried zones of mineralisation.

It is recommended that the area be mapped, preferably at a scale of 1:25,000, using coloured aerial photographs, with a view to defining highly foliated retrograde schist zones. Many of the zones already defined are ferruginous and would stand out well on colour photographs. This should be done in conjunction with a re-interpretation of all geophysical data in the hope of defining subtle anomalies.

B.W.NISBET, 2.11.1980

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APPENDIX

COLOUR SLIDES WITH DESCRIPTIONS

SLIDE Nº	LOCALITY	DESCRIPTION
1	15-9-6	Andalusite schist in Burrell Creek Fmn. Looking down foliation.
2	"	Same rock, close up.
3	16-9-1	Glaciated pavement NPD7 (Hayward Ck).
4	"	" " "
5	"	Glaciated pavement with overlying tillite.
6	"	" " "
7	16-9-3	Vertical fracture in Adelaidean sandstone filled with iron oxide veins.
8	"	Same feature. Note brecciation.
9	17-9-5	Outcrop of "S" granite.
10	"	Strongly foliated "S" granite with mafic xenolith.
11	17-9-10	Fault breccia with Chilling sandstone fragments.
12	17-9-11	Layered Chilling sandstone.
13	"	" "
14	17-9-12	Looking west from scarp to where it swings N.W.
15	17-9-12	Looking N.W. from scarp.
16	"	Looking N along scarp at Chilling sandstone and Berinka volcanics.
17	17-9-14	Pillow basalts.
18	"	" "
19	"	" "
20	18-9-4	Foliated and quartz veined fault breccia.
21	18-9-5	Siliceous fault breccia with shallow dipping fractures.
22	18-9-11	Fault breccia.
23	"	" "
24	25-9-12	Breccia with fine grained dolerite in coarser grained gabbro.

SLIDE N°	LOCALITY	DESCRIPTION
25	25-9-12	Breccia with fine frained dolerite in coarser grained gabbro.
26	19-9-7 Well Tree	Breccia with fine grained amphibolite in coarse amphibolite matrix.
27	25-9-2	Fine layered quartz muscovite biotite gneiss.
28	"	Intrusive breccia in layered gneiss.
29	"	" " " "
30	25-9-4	Intrusive Breccia.
31	25-9-9	Biotite granodiorite with biotite rich inclusions and garnets.
32	25-9-9	Biotite granodiorite. Note garnets.
33	1-10-9	Granite intruding gneiss and schist.
34	"	" " " "
35	28-9-3	Biotite granodiorite with elongate biotite rich and clear quartz inclusions.
36	28-9-3	Biotite granodiorite with inclusions. Note biotite-rich rim. Foliation in inclusion not necessarily parallel to granite foliation.
37	28-9-5	Granodiorite with quartz gneiss xenolith. Note fold.
38	28-9-5	" " " "
39	28-9-5	Typical quartz muscovite schist of Hermit Creek Metamorphics.
40	30-9-5	Quartz muscovite schist, Hermit Creek Metamorphics Note strong foliation, lenticular layering.
41	28-9-7	Quartz breccia.
42	"	" "
43	29-9-4	Foliated and lineated coarse amphibolite. Note layering.
44	"	" " " "
45	2-10-11	M5 coarse grained biotite-quartz-cordierite-sillimanite rock. (Restite ?).

SLIDE N°	LOCALITY	DESCRIPTION
46	2-10-5	Irregularly layered schistose migmatitic gneiss
47	3-10-5	"Late" folds (Pl. 67 → 030, A.S.86 → 118) in layered schistose gneiss.
48	3-10-5	Early tight folds with axial surface foliation refolded by later folds (as in 47).
49	3-10-5	Similar
50	"	"
51	3-10-10	Granite gneiss / migmatite.
52	"	" " "
53	6-10-2 Litchfield	Coarse grained porphyritic biotite granodiorite. Note foliation.
54	"	" " "
55	"	Layered porphyritic rock (rhyolite).
56	"	Foliated granodiorite cut by coarser pegmatitic veins. Foliation cuts veins as well.
57	6-10-5	Foliated pegmatite vein cutting granodiorite.
58	6-10-10	Porphyritic granodiorite.
59	"	" " . Note lineation.
60	8-10-A	Fold in Chilling quartzite on scarp, probably associated with faulting.
61	8-10-B	" " "
62	8-10-C	Berinka volcanics "intruding" Chilling quartzite.
63	12-10-1	Conglomerate in Burrell Creek Fmn, looking along foliation.
64	"	" - looking perpendicular to foliation.
65	12-10-7	Isoclinal folds in quartzite layers in Burrell Creek. Can see cross bedding in some layers.
66	"	Similar.