AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION

A report on the potential of the Granites–Tanami Block for unconformity style Au–Pt–Pd±U mineralisation

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Executive Summary

(1) This report presents the results of a consultancy carried out by Australian Geological Survey Organisation (AGSO) personnel for North Flinders Exploration (NFM) in 1992. The brief was to:

A. " form an opinion based on field and exploration evidence, of the prospectivity of NFM tenements in particular, and the Tanami region in general for unconformity-associated Au-Pt-Pd±U mineralisation"

B. " advise on the exploration indicators (geological, geochemical, geophysical, near surface characteristics, and regional settings) of such mineralisation to be expected in the Tanami Region"

based on AGSO's experience of mineralisation in the Pine Creek Geosyncline and elsewhere.

(2) Our assessment on the prospectivity of the Tanami Region is based partly on a field model by AGSO for the South Alligator Valley, developed during systematic field investigations carried out between 1987 and 1990. It is also based on a more general model developed within the AGSO Precambrian Metallogeny Project which determines the essential ingredients for, and expressions of, all unconformity-style deposits including Alligator Rivers, Westmoreland, Kintyre, Oobagooma and Bigrlyi in Australia and the Athabascan deposits of Canada.

(3) This style of mineralisation is dependent on several distinctive regional geological ingredients. These are

(i) A fracture/fault system controlling fluid circulation through basement and cover sequences, and focussing metal-enriched fluids in structural traps (dilatant zones along faults)

(ii) Low temperature, highly oxidised, low pH, high salinity fluids move down these fault systems

(iii) Chemical traps to induce precipitation of fluids through redox-reactions ie reduced and/or feldspathic and/or calcareous and/or chloritic and/or ferruginous host rocks. Au+Pt+Pd deposits without U are found in feldspar- or carbonate-bearing rocks: U+Au+Pt+Pd is usually only found where carbon-rich shales or chloritic rocks are present.

(4) These deposit types are surrounded by altered rocks that are depleted in Na_2O, CaO, SiO_2, and Th. These same elements have been moved to higher structural levels, and therefore rocks enriched in these elements are considered as possible indicators of Au+Pt+Pd±U mineralisation at depth. The other alteration indicator is high ferrous iron ratios (Fe^{3+}/Fe^{2+}), due to the highly oxidised mineralising fluids.

(5) Correlation of the Tanami Block with the Pine Creek Inlier indicates the two provinces have many geological features in common.

(6) Stratigraphically both contain Early Proterozoic basement sequences of subaqueous basin sediments with local volcanic rocks, which were deposited in intracratonic basins formed by incipient rifting and marginal subsidence of the Archaean crust. Both contain a thick package of chemical sediments which include carbonaceous/graphitic units and cherty ferruginous shales/banded ironstones (Mt Charles Beds, Davidson Beds/Koolpin Formation).

(7) In both areas these basement sequences were multiply deformed and metamorphosed (mainly greenschist facies with local amphibolite grade metamorphism) during the 1870 Ma Barramundi Orogeny, and intruded by pre- and post-orogenic dolerites and high uranium granitoids.

(8) In both areas a series of cover sequences ranging in age from late Early to Middle Proterozoic, Adelaidian and Cambrian were deposited unconformably on the basement. Most of these cover sequences consist of quartz-rich non reactive sediments, although mafic volcanics are prominent in the Cambrian. Minor deformation continued during deposition of all these cover sequences.

(9) The Tanami Block is considered generally prospective for unconformity-style Au+Pt+Pd$\pm$U mineralisation, containing all of the regional parameters recognised as controlling this style of mineralisation.

(10) In the Tanami Block, unconformity-style mineralisation is most likely to occur in basement lithologies. The cover sequences appear to consist of non-reactive rock types, and are thus likely to be barren, unless directly overlying carbonaceous rocks in the basement (eg Athabascan deposits). However, should significant reductant-bearing rock types and/or feldspathic/chloritic rocks (eg. volcanics) be encountered in these cover sequences their prospectivity will increase.

(11) Chemical sediments in the Mount Charles/Davidson Beds (carbonaceous shales, banded ironstones) are similar to those in the Koolpin Formation, which hosts mineralisation in the South Alligator Valley, and provide a reducing environment for precipitation of mineralisation. Other suitable basement lithologies include feldspathic rocks such as volcanics (eg Nanny Goat Creek Beds, Tanami Volcanics), any porphyries that exist, and possibly feldspathic greywackes (only if they contain a high proportion of feldspar). Ferruginous and chloritic sediments are also potential hosts (eg ferruginous sediments and green tuffaceous shale (chloritic?) in the Blake Beds, are associated with elevated Au, U values at Challenger Two).

(12) Preliminary data from the Challenger Prospect suggest structural and stratigraphic controls on mineralisation which are consistent with unconformity-style Au-Pt-Pd±U mineralisation. Element correlations are also consistent with unconformity-style mineralisation.

(13) Further exploration in the Challenger area should consist of delineating major structures (including extension of the fault system at Challenger), and targeting them using costeaning, RAB drilling and geochemical techniques (eg. soil sampling, rock chip analysis, vacuum drilling). U, Th and U^2/Th radiometric anomalies should be followed up, especially where coincident with interpreted structures.

(14) Anomalous radioactivity at Killi Killi Hills is closely associated with the unconformity. AGSO whole rock geochemical data of arkoses previously collected at Killi Killi Hills shows Na_2O and CaO depletion, which is characteristic of alteration associated with unconformity-style mineralisation. The Killi Killi Hills area is therefore considered to have potential for unconformity-style mineralisation. Some samples from the Killi Killi prospects contain Yttrium at wt% values.

(15) An exploration strategy on a regional scale should have 3 fundamental aims:

A) to locate regional structures along which mineralising fluids could have migrated. These structures must affect both the basement and the cover sequences, and could be detected by interpretation of regional magnetic data.

B) to locate alteration zones which surround all known areas of this style of mineralisation which can extend over 1km from the associated fault systems. These could be detected by airborne radiometrics by delineating regions of anomalous U (which may be defined by rations such as U^2/Th). Regional whole rock analysis may also enable definition of zones of depletion of Na_2O, CaO and Th close to the unconformity, and zones of enrichment of Th, P, and SiO_2 in zones in the cover sequence.

C) to locate evidence of reducing rocks which will cause the mineralising fluids to precipitate the metals. Electrical methods may locate buried conductors at depth.

(16) On a regional scale, exploration strategies should not assume that mineralisation will be restricted to

A) the middle/early Proterozoic rocks: it could be located in Palaeozoic or younger rocks.

B) the actual unconformity between the basement units and the Gardiner Sandstone: there is potential for mineralisation both well below and well above the unconformity if the appropriate precipitation mechanisms are present.

C) rock types which contain graphite, as methane-bearing (or similar reduced) fluids generated elsewhere in the basement could cause precipitation on interaction with the more oxidised metal-bearing fluids.

(17) At the prospect scale, exploration strategies should include soil sampling and rockchip sampling on traverses that are perpendicular to the major regional structures. In areas of poor outcrop, RAB drilling may need to be employed.

(18) To locate unexposed deposits buried beneath the Gardiner Sandstone, electromagnetic techniques can be used to locate conductors (graphitic schists) in the basement, or major structures can be targeted using lithochemical techniques developed by Canadians for the Athabascan deposits. These are used to detect alteration in the sandstones above buried deposits.

Objectives

This report records the findings of a consultancy undertaken by the Minerals and Land Use Division of the Australian Geological Survey Organisation on behalf of North Flinders Mines. The two general objectives of this consultancy were

(1) to form an opinion of the prospectivity of the Tanami region (particularly NFM tenements) for unconformity-associated Au-Pt-Pd±U mineralisation

(2) to advise on exploration indicators of such mineralisation to be expected in the Tanami Region.

The achievement of these objectives was based on

(1) AGSO's first hand experience of this style of mineralisation in the South Alligator Valley, Pine Creek Geosyncline during surveys carried out from 1987 to 1990

(2) The AGSO Precambrian Metallogeny Project's work on cataloguing the essential ingredients for, and expressions of, most major Precambrian ore deposit types. The more general model developed accommodates other unconformity-style deposits including Alligator Rivers, Westmoreland, Kintyre, Oobagooma and Bigrlyi in Australia and the Athabascan deposits of Canada

(3) Fieldwork in the Tanami region carried out between 19-24th October 1992, under the guidance of NFM geologists Steve Hogan and Nick Bryce. Fieldwork included

(a) Reconnaissance work to determine whether

- suitable host rocks for this style of mineralisation exist in metasediments of the Tanami Group.
- a suitable cover sequence overlies these metasediments. The Gardiner Sandstone, Pargee Sandstone and Muriel Range Sandstone were considered as potential covers.

(b) A more detailed assessment of the Challenger Two Prospect (NFM tenement EL 2370) and the Killi Killi Hills No.1 prospect

(4) Review of NFM exploration datasets and reports relevant to areas regarded as prospective for mineralisation of this type. This included

(a) Background information on Tanami Group lithologies, metamorphic grade, structure and mineralisation in The Granites region

(b) Familiarisation with processed regional airborne magnetic and radiometric datasets, in order to

- confirm the presence of major (regional scale) fault structures in the Tanami region (based on magnetic data).
- advise on enhancement of radiometric data to emphasize anomalies that may be related to unconformity-style mineralisation and alteration

(c) Detailed inspection of logs, maps and sections from the Challenger 2 Prospect, to determine whether the unconformity model could be apply to this prospect.

Contents of the report

The report is in two parts, with five appendices.

Part 1 summarises the metallogenic model for Au-Pt-Pd±U mineralisation in the South Alligator Valley. The BMR's report to the Resource Assessment Commission (RAC) Inquiry into the Kakadu Conservation Zone (*Wyborn, L.A.I., Valenta, R.K., Needham, R.S., Jagodzinski, E.A., Whitaker, A., and Morse, M.P. 1990. A review of the geological, geophysical and geochemical data of the Kakadu Conservation Zone as a basis for assessing the resource potential. Sections 1 & 2. Unpublished reports*) has been made available to NFM, and provides a more detailed account of the model, and of the South Alligator Valley Mineral Occurrences. A more detailed structural analysis is provided in *Valenta, R.K. 1991. Structural controls on mineralisation of the Coronation Hill Deposit and surrounding Area. BMR Record 1991/107.*

This section includes

- a model for the formation of unconformity-related mineralisation, showing geological features controlling mineralisation in the South Alligator Valley
- a comparison of this style of mineralisation with Alligator Rivers U±Au deposits, unconformity-style deposits of the Athabasca Basin in Canada, and U deposits in the Ngalia Basin, and revision of the South Alligator Valley model to accommodate these deposits.
- indicators of mineralisation (geological features, geochemical signatures and geophysical responses) that can be used as exploration targets
- exploration strategies for locating deposits buried beneath the Gardiner Sandstone

Part 2 determines whether the appropriate conditions exist for unconformity-related mineralisation to occur in the Tanami region. This section includes

- a correlation of stratigraphy and tectonic events between the Tanami region and Pine Creek Inlier
- A general assessment of the prospectivity of the Tanami region for unconformity-related mineralisation, placing Tanami observations in the context of the South Alligator Valley model
- A more detailed assessment of the Challenger Two prospect, to determine whether the known mineralisation can be explained in terms of unconformity model.
- A more detailed assessment of the Killi Kill Hills No. 1 prospect, which may indicate whether the critical ore-forming processes are occurring in the Tanami region.

Appendix 1 contains a mineral deposit database of the South Alligator Valley deposits, which provides a useful summary of information in Appendix 2 of Wyborn et al. (1990). Wyborn et al. (1990) contains a detailed evaluation and description of mines, prospects and mineral occurrences in the South Alligator Valley, compiled from open file and confidential company reports, published literature, and the results of BMR (AGSO) surveys in the area.

Appendix 2 contains details of the airborne radiometric survey carried out by the BMR (AGSO) in the South Alligator Valley. It shows the radiometric signature associated with mineralisation, and how this signature was enhanced.

Appendix 3 contains geochemical analyses of sandstones from the Killi Killi Hills area, from the AGSO Rockchem database.

Appendix 4 contains an unpublished BMR report on the Killi Killi Uranium Prospects in Western Australia (Prichard et al. 1960).

Appendix 5 contains an assessment of exploration carried out by for unconformity-style mineralisation at Brown's Range Dome in the Tanami Block, based on open file company reports

Part 1. A model for the formation of unconformity related Au+Pt+Pd±U mineralisation

1.1 METALLOGENIC MODEL FOR SOUTH ALLIGATOR VALLEY (SAV) STYLE MINERALISATION

In the South Alligator Valley (SAV), Au-Pt-Pd±U mineralisation is formed by a distinct set of structural and geochemical controls (Valenta, 1991; Wyborn et al., 1990; Wyborn, 1990a, 1992). Figure 1 shows a schematic block diagram of the typical geological setting of the mineralisation. In summary, mineral occurrences are characterised by a specific geological environment which combines the following features:

(1) dilatant structures within a strike-slip fault system
(2) distinct host lithologies
(3) proximity to a major unconformity
(4) evidence of highly oxidised mineralising fluids.

In greater detail the controls on and characteristics of mineralisation are as follows:

1.1.1 STRUCTURAL CONTROLS:

(1) All known deposits are close to major fault structures.
Mineralisation is contained within a major northwest-trending dextral strike-slip fault system (Rockhole-Palette-El Sherana fault system). Most deposits are located on the major NW faults, or on minor north and east trending offsets (Figure 2).

(2) Mineralisation is localised around dilatant sites in fault zones. There are two types of deposit geometries, relating to two types of structural control (Figure 3).

(a) Contractional jogs. Strike-slip and reverse fault movement results in build up of compressive stress in the horizontal plane. Rocks extend vertically, causing tensile fracturing and dilation on horizontal planes. Resultant mineralisation occurs in horizontal pipe-like or ribbon-like bodies (eg. Rockhole, Saddle Ridge)

(b) Dilational jogs. Any strike slip movement produces tensile stresses in the horizontal plane perpendicular to maximum principal stress. Fracturing is vertical and mineralisation occurs as subvertical pipes (eg. Coronation Hill, Palette, Skull).

(3) The faults controlling mineralisation were active after deposition of the cover sequence (Kombolgie Formation). They may be reactivated earlier

faults, or younger faults post-dating deposition of the cover sandstones. There is little post-unconformity displacement on these faults.

1.1.2 LITHOLOGICAL CONTROLS: U mineralisation generally occurs in black carbonaceous shales commonly at the contact with iron-rich shales of the Koolpin Formation, and to a lesser extent, in chloritic zones. Au-Pt-Pd mineralisation occurs in a broader range of host rocks, and can occur associated with U in carbonaceous, iron-rich and chloritic shales. In contrast, Au-Pt-Pd mineralisation without U is hosted by feldspathic and calcareous rocks and at Coronation Hill, the host lithologies to the Au-Pt-Pd only mineralisation include quartz-feldspar porphyry, green tuffaceous shale, diorite, dolomite and sedimentary breccias.

1.1.3 THE ROLE OF THE UNCONFORMITY: All known deposits lie within 100m of the unconformity between post-1860 Ma sandstones and felsic volcanics, and pre-1870 Ma highly deformed basement. However, although the deposits are unconformity related, they are in detail structurally controlled. The role of the unconformity is two-fold as follows:

(1) The unconformity represents a chemical contrast between neutral, non-reactive rocks above the unconformity, and chemically reactive rocks below. The ore-forming fluid is largely unaffected by passage through the non-reactive rocks above the unconformity. At the unconformity, mineralising fluids interact chemically with basement lithologies, initiating the precipitation of U-Au-Pt-Pd.

(2) A strain incompatibility between the basement and cover rocks occurs at the unconformity enhances permeability, so that the unconformity acts as a pathway for mineralising fluids.

It follows that 'unconformity' style deposits could also form well below the unconformity in the basement sequence, where there are strong competency contrasts or chemical contrasts. An example is the Koolpin Creek-Monolith area in the SAV, where elevated U-Au-Pt-Pd values are concentrated in a shear at the contact between cherty ferruginous shales and carbonaceous shales in the basement Koolpin Formation. Other U occurrences in the SAV also concentrate at this stratigraphic level (eg El Sherana West). In this case, fluid flow focuses in the cherty ferruginous shale, as this very competent unit becomes brittle and fractures during deformation and is therefore permeable. Mineralisation occurs at the contact between carbonaceous shales and cherty ferruginous shales, where the redox interface induces the precipitation of U-Au-Pt-Pd.

1.1.4 THE ROLE OF THE COVER SEQUENCE:

A thick cover sequence (such as the Kombolgie Formation in the Pine Creek Inlier) plays a dual role in the formation of unconformity-type deposits. Firstly, a thick cover sequence acts as a thermal blanket, such that when the meteoric fluids reach the unconformity, temperatures of approximately 150°C develop would develop: temperatures which are ideal for the transport of Au, Pt and Pd. Secondly, a thick cover sequence, allows prolonged maintenance and concentration of fluids in an oxidised, metal-rich state, before migration into a geochemical environment conducive to progressive reduction. The cover sequence must also be comprised of neutral, non-reactive rocks such as quartz-rich 'clean' sandstones (i.e. containing an insignificant amount of feldspars and clay minerals) to preserve the metal-enriched solutions. If the solutions come into contact with large volumes of carbonaceous material, ferrous iron, carbonate, feldspar or sulphides in the cover sequence, the desired metals will begin to precipitate in disseminated form through the cover sequence, instead of concentrating in a geochemical trap below the unconformity. In the Kakadu region, the Kombolgie Formation sandstones are hematitic, contributing to the oxidation of the ore-forming fluid. The absence of clay in the sandstone matrix allows the cover sequence to maintain permeability, whilst the absence of feldspars maintains low pH conditions in the cover sequence.

1.1.5 CHEMICAL CONTROLS:

Both U-rich and U-poor Au-Pt-Pd mineralisation are formed by descending, low temperature (150-200°C), highly oxidised, slightly acidic, very saline meteoric fluids (Mernagh, 1992; Mernagh et al, 1992). Such solutions allows simultaneous transport of U and Au as chloride complexes, and the chloride-rich, oxidised brines are essential for significant Pt-Pd transport.

In the SAV, both U-rich and U-poor Au-Pt-Pd mineralisation are related to the one geochemical system. The chemical segregation of U from Au-Pt-Pd mineralisation is controlled by fluid-rock interaction in the host rocks. Interaction with feldspathic or carbonate host rocks causes an increase in pH, precipitating Au-Pt-Pd, but not U. Interaction with carbonaceous or chloritic rocks causes a reduction in fO_2, and consequent precipitation of U-Au-Pt-Pd.

1.1.6. AGE OF MINERALISATION: On geological grounds, the mineralisation is young relative to the age of the host rocks as it post-dates deposition of the lower Kombolgie Formation, being controlled by faults that also cut the Kombolgie Formation. U-Pb geochronology on uraninites yielded exceedingly young ages of 500-900 Ma (Cambrian-Adelaidean) (Greenhalgh and Jeffrey, 1959), and hydrothermal zircons give similar ages.

1.1.7 ORE MINERALOGY Primary U mineralisation is in the form of pitchblende veins often associated with chlorite alteration, with only minor late-stage quartz-veining. In contrast Au-Pt-Pd mineralisation at Coronation Hill shows a strong association with quartz-carbonate-chlorite veins.

U mineralisation comprises massive, disseminated and sooty pitchblende, with secondary uranium minerals above the oxidised zone in the weathering profile.

Two types of Au-Pt-Pd mineralisation have been recognised at Coronation Hill (Carville et al., 1990, 1991):

(1) A gold/palladium/platinum/selenide association represented by

- gold in both pure and silver-bearing varieties
- clausthalite (PbSe)
- stibiopalladinite (Pd_5Sb_2)
- rare precious metal phases
- sulphides generally absent

(2) A gold/palladium/platinum/selenide/sulphide association represented by the above mineral phases, but in association with replacive pyrite (some nickel-bearing) and trace marcasite, pyrrhotite, sphalerite, chalcopyrite and galena.

1.1.8 ALTERATION: All known deposits are surrounded by a distinctive alteration zone that may extend over 1 km away from the mineralisation. Alteration is characterised by muscovite (sericite)-chlorite±kaolinite±biotite±hematite (Wyborn et al., 1990; Warren & Kamprad, 1990). Alteration is characterised chemically by loss or gain of SiO_2 (strong desilicification occurs at the unconformity, and silica is redeposited as quartz veins at higher stratigraphic levels), high Fe^{3+}/Fe^{2+} (due to oxidation of nearly all iron present), high U/Th ratios, and almost complete depletion of Na_2O, CaO and Th. U is sometimes enriched in the alteration zone.

1.1.9 INTEGRATED MODEL:

The integrated model for SAV Au-Pt-Pd±U mineralisation is summarised as follows: Meteoric waters circulating in a large aquifer (represented by the cover sandstones) evolve into a highly oxidised, metal-rich fluid, as U-Au-Pt-Pd is scavenged from the basin sediments (and volcanics) by the slightly acidic, oxidised, chloride-rich brine. The cover sequence acts as a thermal blanket, elevating fluid temperatures to ~ 140°C. Oxidation of fluids occurs in the upper part of the cover sequence where interaction with atmosphere occurs, or where fluids come into contact with hematitic sandstones. The mineralising fluids descend along faults into the lower part of the cover sequence, then into the faulted Early Proterozoic basement during reactivation of pre-existing faults or propagation of new faults through the cover sequence sandstone. As there is usually little displacement of the cover sequence along faults, Valenta (1991) evokes a "seismic pumping" model for fluid transfer between cover sequence and basement. In this model, fluids are pumped into the basement (or from basement into the overlying cover sequence) during seismic explosions or earthquake activity along faults. Fluid movement in the less permeable basement is largely restricted to faults and related fractures or to lithological boundaries (eg unconformities). i.e. there is a strong structural control on mineralisation. Chemical precipitation of U-Au-Pt-Pd occurs along the structures where mineralising fluids intersect the appropriate host lithologies, or where the oxidised ore-forming fluids mix with reduced fluids originating from the carbonaceous units in the basement. Fluid interaction with feldspathic or calcareous rocks causes an increase in pH and moderate reduction in fO_2. This may result in the precipitation of significant quantities of Au, Pt and Pd, but most of the U remains in solution. Interaction with carbonaceous rocks or mixing with reduced fluids results in a more efficient reduction in fO_2, and consequent precipitation of U as well as Au, Pt and Pd. Most of the U-Au-Pt-Pd is precipitated upon interaction with carbonaceous and sulphide-bearing parts of the basement. Figure 4 shows the lithological controls on precipitation of U, Au, Pt and Pd.

Mineralisation is surrounded by a distinctive alteration zone characterised by loss of Na_2O, CaO SiO_2, Th and Fe2+ (Figure 4). Alteration is patchy and may extend for over 1 km from the major fault zones. The alteration is most easily recognised in the felsic volcanics by the loss of Na_2O and CaO. The depletion of SiO_2 and Th around the unconformity-related deposits implies that these elements could be precipitated elsewhere. Th enriched areas have been located at higher structural levels, generally associated with high concentrations of rare earth elements and Zr. Zones of Th enrichment and quartz veining may be indicators of unconformity related mineralisation at depth.

1.2 OTHER EXAMPLES OF UNCONFORMITY-STYLE MINERALISATION

1.2.1 Alligator Rivers Uranium Field

The same metallogenic model can be applied to major unconformity-related uranium deposits of the Alligator Rivers Uranium Field (ARUF) to the north (Ranger, Jabiluka, Koongarra, Nabarlek) of the SAV (eg Wilde and Wall, 1987). The main difference between the deposits is their stratigraphic position. With the Alligator Rivers deposits, the host rocks below the unconformity are the carbonate and carbonaceous schists of the Cahill Formation and Myra Falls Metamorphics, and the unit above the unconformity is the Kombolgie Formation. In the SAV deposits, the deposits lie at the Koolpin Formation/El Sherana Group unconformity, which is an older unconformity surface.

The reason that the Alligator Rivers deposits lie at a different stratigraphic position to the SAV deposits (Figure 5), is because the mineralising fluids encounter carbonate and carbonaceous schists immediately below the Kombolgie Formation. In the SAV, the ore-bearing fluids pass through two more neutral, non-reactive cover sequences below the Kombolgie Formation, before encountering the appropriate host lithologies, allowing chemical precipitation of Au-Pt-Pd±U.

Another difference is that the Alligator Rivers deposits are primarily U-Au deposits, with rare Pt, and the U-poor Au-Pt-Pd deposits have not been located in this area. This may be because the main lithologies for separating Au-Pt-Pd from U (feldspathic rocks) do not occur in significant quantities below the Kombolgie Unconformity in the ARUF. However, it must be emphasised that in the limited time exploration was allowed in the area, the prime target was for U-only deposits; the Au-Pt-Pd potential was only realised after exploration activities had been banned.

1.2.2 Kintyre Deposit, Paterson Province

The Kintyre Uranium Deposit is located in the Rudall Region of the Paterson Province, north Western Australia (Rudall 1:250 000 map sheet; 22°20'30''S; 122°04'30''E). The Rudall region consists of a SE to ESE-trending Precambrian basement block of high grade, isoclinally folded metasediments (Rudall Metamorphic Complex) unconformably overlain by Upper Proterozoic sedimentary rocks (Coolbro Sandstone, Yeneena Group) (Jackson and Andrew, 1990). Unlike the SAV, Alligator Rivers and Athabascan deposits, the overlying Coolbro Sandstone has been tightly folded and sheared. Subvertical strike faults are interpreted to be present within the ore zone. The ore zone is locally transected by a NW trending shear which appears to have exerted selective control on remobilisation of uranium ore. The unconformable contact with the overlying Coolbro Sandstone is exposed within 300m of the Kintyre orebody.

Mineralisation is hosted by graphite schists, and chloritic and carbonaceous schists, chert, pelites and psammites in the basement Rudall Metamorphic Complex. Chlorite is the most common alteration mineral. Hematite and carbonates occur immediately around mineralised veins. Mineralisation occurs as colloform pitchblende within dolomitic carbonate veins, with lower grade disseminated pitchblende. Accessory to trace native bismuth, chalcopyrite, bornite, galena and gold are associated with pitchblende. Platinoids have been detected in association with gold.

Thus, Kintyre is an unconformity-related, vein-type uranium deposit similar to those of the East Alligator River Province, with structurally-controlled mineralisation occurring in basement rocks below the unconformity.

1.2.3. Pandanus Creek (Eva) U-Au deposit, Murphy Inlier

In the Murphy Inlier 5 uranium deposit types have been recognised occuring at or near the base of the Westmoreland Conglomerate (Ahmad & Wygralak, 1990) where it unconformably overlies the Cliffdale Volcanics. The contact between the Cliffdale Volcanics and the Westmoreland Conglomerate has been recorded as tectonised (Golden Plateau,1987).

Mineralisation at Pandanus Creek is localised in a series of near vertical shears within a NE trending body of quartz-epidote rocks within the Cliffdale Volcanics, not far from the overlying Westmoreland Conglomerate (Ahmad & Wygralak, 1990; Raymond, 1990). The Westmoreland Conglomerate is the basal unit of the Tawallah group and correlates with the Kombolgie Formation (Plumb et al., 1990). The Cliffdale Volcanics are equivalent in age and composition to the El Sherana Group of the SAV and uraninites from this deposit are also young at 820 and 430 Ma (Hills and Richards, 1972). Thus Pandanus Creek U-Au Deposit closely resembles the Coronation Hill Deposit, in that the mineralisation is hosted by felsic volcanics. Although no Pt or Pd have been recorded in the literature from this deposit, anomalous stream sediment Pt and Pd results have been recorded elsewhere from the area (Golden Plateau,1987).

In another uranium deposit type occur that occurs in the area (Ahmad and Wygralak, 1990), the uranium mineralisation is located in shear zones along the contact with, and in close proximity to altered basic dykes within the Westmoreland Conglomerate. The mineralisation extends well above the unconformity and includes the Northeast Westmoreland, Redtree and Huarabagoo deposits (Hills and Thakur, 1975; Ahmad and Wygralak, 1990; Raymond, 1990).

1.2.4 Athabascan deposits, Saskatchewan

The Athabascan U deposits in Saskatchewan, Canada occupy a tectonic position analogous to the Alligator Rivers deposits. They are also associated with a Middle Proterozoic sandstone overlying metamorphosed and deformed basement, and are similarly structurally and lithologically controlled.

The main difference between them is that in the Alligator Rivers deposits, very little of the ore is hosted by the sandstone cover sequence (Kombolgie Formation) whereas in the Athabascan deposits, a major part of the ore occurs in sandstones of the Athabasca Formation. There are two different theories as to why U precipitates in the Athabascan sandstones.

(1) The first theory considers the reductant to be in the rocks of the cover sequence. That is, the Athabascan sandstones contain solid carbon and Fe^{2+} minerals, so that fluid/rock interaction is the main depositional trap (as with the Alligator Rivers deposits). The Athabasca Formation contains organic material (Gustafson and Curtis, 1983) and is believed to have contained a high proportion of feldspar and mafics prior to diagenetic alteration (Hoeve & Sibbald, 1980). In contrast, the Kombolgie Formation consists of clean, non-reactive mature conglomerates and quartzose sandstones. Quartz:Feldspar:Lithics ratios in the Kombolgie

Formation vary from 100:0:0 to 89:1:10 and it is devoid of organic material. That is, there is no organic or feldspathic material in the Kombolgie Formation to react with the ore-forming fluids and induce precipitation of mineralisation.

(2) The second theory is that the reductant is mobile, consisting of methane, hydrogen sulphide or oil (in younger basins) dissolved in a basement-derived aqueous fluid which has flushed into the cover sequence through fault structures. In this case, fluid mixing is the main trap, with uranium (+Au-Pt-Pd) precipitation upon interaction of oxidised basin waters with the reduced basement fluids.

1.2.5 Bigrlyi Uranium deposit, Ngalia Basin

The Bigrlyi uranium deposit in the Ngalia Basin can be interpreted in terms of the unconformity-deposit model. At Bigrlyi, mineralisation is hosted by organic sandstones in the Devonian to Carboniferous Mount Eclipse Sandstone. The genetic model proposed (Fidler et al, 1990) is that where oxidised basin fluids interact with organic-rich sediments, reduction renders U, V and Cr insoluble, concentrating U at this stratigraphic level. Diagenetic processes eventually result in lower permeability in the sandstones. Late stage faulting and fracturing allows the same chemical processes to continue on a restricted basis, modifying the initial distribution of mineralisation. In the vicinity of faults, oxygenated groundwater causes dissolution of uranium, which is later deposited where reducing conditions still prevail. This results in an eventual reconcentration of U.

The similarity to the of the Bigrlyi deposit to the unconformity-deposit model is immediately clear. Both result from the precipitation of U from mineralised, oxygenated meteoric waters, encountering a reducing environment. However the Bigrlyi deposit occurs in the middle of the sedimentary basin, above an unconformable contact with metamorphosed basement, rather than at the base. This difference is attributed to mineralised, oxygenated meteoric waters encountering reducing conditions (induced by the presence of organic sediments) within the sedimentary basin (cover sequence).

Another example of this Bigrlyi type of deposit is the Oobagooma deposit (West Kimberley). It is hosted by Late Devonian-Early Carboniferous sandstones, within a Phanerozoic basin. Groundwater has migrated along the palaeochannel and formed a broad tongue of oxidised sandstone. Uranium mineralisation was precipitated in and around concentrations of detrital organic matter.

1.3 REVISION OF THE SAV MODEL TO ACCOMMODATE OTHER UNCONFORMITY DEPOSITS

The most important point to note from the above discussion, is that examples of 'unconformity-style' deposits occur at a number of stratigraphic levels, and are not necessarily confined to 'Kombolgie/basement' unconformities. Previously, this unconformity was thought to have a major role in controlling mineralisation. Recent studies however, have shown the unconformity to be a less important control than structural and lithological (chemical) controls. The unconformity may be a first order constraint at the regional scale, but on a local scale the potential exists for 'unconformity-style' mineralisation to occur well above (in cover sequence) or below (in basement) the unconformity if the appropriate structures and host lithologies exist to control mineralisation. Although Alligator Rivers deposits occur at the unconformity below quartz-rich sediments of the Kombolgie Formation, some of the SAV deposits occur below an older unconformity, whereas others occur well below the unconformity in basement structures (eg. Koolpin, Monolith). There is no reason why the cover sequence could not host a deposit if appropriate lithological and/or structural traps existed (eg. Athabascan deposits, Canada, Bigrlyi, Oobagooma). Thus the actual unconformity surface is only one of a potential number of sites for mineralisation. Figure 5 is an integrated model which shows the different stratigraphic positions in which unconformity-style mineralisation could potentially occur within a single basin.

It is also important to note that unconformity-style deposits need not be confined to lower and middle Proterozoic basins, but can occur in younger terrestrial basins.

1.4 THE MODEL AS AN EXPLORATION TOOL

1.4.1 Regional ingredients for mineralisation

Any deposit requires 3 main ingredients: a source of the metals, a fluid to transport the metals and suitable traps either structural, stratigraphic or chemical into which the metals are precipitated. From the model description, the regional ingredients required for Au-Pt-Pd±U mineralisation are:

SOURCE	Average crustal abundances of these elements within a thick cover sequence
FLUID	(i) low T (150-200°C) (ii) oxidised (iii) low pH (iv) high salinity
TRAP-STRUCTURAL	In dilational structures within major fault systems where faults were active during and after deposition of the cover sequence.
TRAP-STRATIGRAPHIC	At unconformities or other stratigraphic boundaries between appropriate lithologies
TRAP-CHEMICAL	(i) reduced (organic, carbon-rich) and/or (ii) feldspathic and/or (iii) ferruginous (Fe^{2+}-rich) and/or (iv) calcareous host rocks

1.4.2 Major expressions of mineralisation

The following geological features therefore, are the most potential expressions of mineralisation:

Proximity to major fault structures	These act as a pathway for transporting mineralised fluids
Presence of appropriate host rocks	U-rich Au-Pt-Pd: graphite-bearing host U-poor Au-Pt-Pd: feldspar, magnetite and/or carbonate-bearing host rocks
Presence of chemical alteration zones	Show where the mineralised fluids have travelled
Proximity to unconformity	Many known deposits are localised at unconformity
Quartz veining/ high Th zones	May indicate mobilisation of Si and Th above buried mineralisation at depth

1.4.3 Using geophysical methods to locate the major indicators of mineralisation

Some of the major indicators listed above can be detected using geophysical methods.

(1) Major structures can be located using the magnetic method by offset of magnetic patterns, or the presence of localised magnetic minerals along linear fractures

(2) Chemical alteration zones and mineralisation can be detected using

(a) Magnetic methods

The oxidised ore-bearing fluids convert magnetite to hematite in the host rocks, resulting in the reduction of magnetic anomaly amplitudes due to demagnetisation of magnetic rocks

(b) Radiometric methods

The radiometric method maps the distribution of K, Th and U. The alteration zones surrounding mineralisation will show a depletion of Th relative to U, whereas Th anomalies alone can indicate mineralisation at depth. If Au-Pt-Pd is associated with weak U mineralisation, U anomalies may indicate mineralised areas.

In the SAV, the alteration zone showed up as a strong anomaly on the U^2/Th radiometric image. The U^2/K image may also be a useful guide to mineralised areas, especially in the Tanami region, where anomalies related to surface drainage patterns could be caused mainly by high K in clays. If this is the case, the U^2/K image will eliminate drainage-related anomalies. Appendix 2 of this report gives details of radiometric image enhancement used in the SAV to locate potential areas of mineralisation.

(3) Graphite-bearing host lithologies can be located using electrical and electromagnetic (EM) methods, due to their conductive nature. In the SAV, El Sherana West, and several smaller prospects were located using the self-potential EM method (Rowston, 1960; Ashley, 1961, 1962).

Lithologies likely to host Au-Pt-Pd only (ie U-poor deposits) are more difficult to delineate geophysically, as the geophysical signature is more complex. These lithologies include feldspar-bearing and carbonate-bearing host rocks.

It is important to note that geophysical techniques located most of the known mineralisation in the South Alligator Valley (Appendix 1). Most mineral discoveries were located by ground or airborne radiometric surveys, although the largest deposit, El Sherana West, was located by a Self Potential survey. However, electrical methods also locate conductors, and not necessarily mineralisation and many other SP anomalies were unsuccessfully drilled in the SAV.

1.4.4 Using geochemical methods to locate the major indicators of mineralisation

(1) Reconnaissance Geochemistry

Stream sediment sampling is typically used as a reconnaissance geochemical technique. Stream sediment sampling techniques for the SAV survey are summarised in Part 3 of Wyborn et al (1990), and statistical handling of stream sediment data is outlined in Appendix 1 of Wyborn et al (1990). Stream sediment results in the SAV suggest that apart from Au-Pt-Pd-U, there are no pathfinder indicators for mineralisation. However, some elements were useful for detecting host lithologies which had the potential to contain mineralisation. For example, high Ni and Cr recorded in stream sediment results were found to relate to altered basaltic rocks associated with mineralisation, such as the green tuffaceous shale, which hosts mineralisation at Coronation Hill. High Ba is associated with feldspathic rocks such as the arkoses of the Coronation Sandstone, and quartz-feldspar porphyries, and high Mn is associated with cherty ferruginous shales of the Koolpin Formation.

(2) Geochemical sampling of specific targets

Once areas have been targeted as having potential for mineralisation by geophysical or geochemical techniques and/or geological mapping, they should be tested geochemically, by such techniques as stream sediment sampling, rock chip or soil sampling, RAB drilling or vacuum drilling. Wyborn et al, 1990 (Part 3; Appendix 1) contains details of geochemical surveys carried out in the SAV by the BMR.

In summary, areas targeted as having potential for mineralisation in the SAV were tested geochemically using stream sediment, rock chip or soil sampling techniques. Soil sampling was used to test 'Greenfield' uranium[2]/thorium anomalies (ie unrelated to areas of known mineralisation). Sampling occurred along traverses 1 km apart, oriented across (perpendicular to) projected geological and structural trends. Each sample consisted of four sub-samples collected over a 25m interval, then combined for final assaying. Rock chip sampling was used at the old mines and prospects, and was also carried out as a series of traverses collecting 5kg of rock per 5m. These traverses targeted geologically significant features related to potential mineralisation, such as shear zones, and were oriented in a series of traverses perpendicular to these features.

The important point to note, is that geochemical surveys should be oriented along a series of traverses perpendicular to the structural/ magnetic/ radiometric/ lithological target. In the SAV, the main indicators of mineralisation are Au-Pt-Pd-U. However, other elements may be used as 'path finders' to detect alteration associated with unconformity-style mineralisation, or appropriate host lithologies. we suggest the following elements should be assayed:

(1) Detecting alteration and mineralisation

Na, Ca and K: These elements should definitely be analysed, as Na and Ca depletion is a distinctive characteristic of alteration, is easily detected in volcanics or feldspathic sediments, which contain 2-3% Na_2O and CaO where fresh, but contain <1% where altered. K_2O also shows some depletion.

Th: Th mobility is also an alteration indicator. Th depletion usually occurs at the unconformity, with Th enrichment in quartz veins above deposits at depth.

V: high V is an indicator of high Fe3+, and a high Fe^{3+}/Fe^{2+} ratio is an indicator of oxidation (alteration is caused by oxidised fluids).

Mg: Mg metasomatism is recorded associated with Alligator Rivers Uranium deposits, and Mg mobility has been detected associated with mineralisation at Challenger Two (Section 2.2).

P: P may be useful, as in the SAV it is found to concentrate in quartz veins above deposits as well as in the ores. At Palette (SAV), U ore had an apatite gangue, and the alteration zone at Jabiluka contains apatite. It should be noted that in the SAV, Coronation Hill, Saddle Ridge South and Sleisbeck are recognised phosphate reserves (Ingram, 1973).

Te: Te is suggested for analysis because in the ARUF, Au mineralisation is associated with Ni and Pb tellurides.

Se: There is an Au-Pt-Pd-selenide association at Coronation Hill.

Ni, Cr and Pb: High Ni and Cr values are common in the Canadian and SAV deposits. In fact, Ni is extracted as a commodity from one of the Canadian deposits. Au is found associated with Ni and Pb tellurides in the ARUF.

Yb, Y and Zr (especially Y): At least one of these high field strength elements is always found associated with U mineralisation. In the Tanami Region, the Kill Killi Hills prospect has Y at wt% levels.

Ag: Minor Ag was mined at El Sherana U-Au mine in SAV.

As: In the SAV, As was found to be very high in deposits above the unconformity (eg Scinto 1), associated with high Au, but not high Pt, Pd. The model for SAV-style mineralisation suggests that oxidised mineralising solutions can become reduced by interaction with sulphides in the basement. They could then change character and start to carry S-bearing species such as As, Cu and Au. So this type of deposit could indicate Au-Pt-Pd mineralisation close by.

Cu: There is a Cu prospect close to Coronation Hill (Callanans). For the same reasons as As, anomalous Cu values could indicate Au-Pt-Pd mineralisation close by.

Hg: High Hg levels have been recorded in the secondaries ores in the SAV (Ryall, 1981) and Hg was recovered from Palette. High mercury was also reported in the Westmoreland deposits by Ahmad and Wygralak (1990).

(2) Detecting favourable host lithologies

Ni and Cr: Ni and Cr can be used to detect one of the host rocks, favourable for mineralisation. Ni and Cr are always high in deposits hosted by 'green tuffaceous shales'.

Ba: In the SAV, high Ba was found in deposits hosted by arkoses of the Coronation Sandstone, or felsic volcanics

Mn: In the SAV, high Mn was found in deposits associated with cherty ferruginous shales of the Koolpin Formation

1.4.5 Reconnaissance exploration for potential areas of mineralisation

On the regional scale, an exploration strategy for this style of mineralisation should involve:

(1) Targeting the unconformity with a clean (or red bed) cover sequence as a regional requirement for mineralisation.

(2) Identification of fundamental regional-scale fractures that had a prolonged history of structural activity during basement and cover sequence deposition. Offsets to these structures should also be targeted. The major structures can be identified using magnetic data, photo-interpretation, remote sensing techniques (particularly band 5) and regional mapping. Any structures that were active after deposition of the cover sequence are potential targets, but the larger structures allow more efficient penetration of the basement.

(3) Targeting areas where the appropriate host lithologies, or major unconformities, intersect these structures.

(4) Targeting radiometric anomalies, especially where they intersect the major structural features and/or the appropriate host lithologies for mineralisation (For example, at Coronation Hill, radiometric and magnetic anomalies are superimposed).

(5) Targeting reduced magnetic anomaly amplitudes along major structures which may be caused by demagnetisation of magnetic rocks during the passage of oxidising mineralisation fluids.

1.4.6 Follow-up work in areas indicating potential

Having identified areas which contain the appropriate geological environment for hosting mineralisation, follow-up work should involve:

(1) Geochemical surveys (see Section 1.5.3 for details).

(2) More detailed surface mapping and if necessary, costeaning and preliminary drilling to obtain a detailed understanding of the structure and stratigraphy in the area of potential.Costeans could be rock-chip sampled at 2kg/2m or 5kg/5m.

1.4.7 Locating Buried Deposits

1. <u>Exploration strategies used in the Athabasca Basin</u>

The above exploration strategies can be applied to areas where basement lithologies and the unconformity with the cover sequence are exposed. If attempting to locate unexposed deposits buried at depth beneath the cover sequence such as the Athabascan deposits in Canada, a different exploration strategy must be applied. The Canadians have devised successful strategies for locating buried deposits which lie beneath several hundred metres of Athabasca Sandstone and have no demonstrable surface expression. Brummer et al (1981) and Sopuck et al (1983) provide excellent summaries of exploration techniques used. In summary, the exploration model used is

"that of a structurally controlled deposit having a well developed alteration halo occurring near to the eroded surface of the underlying metamorphic rocks"

The Canadians use two methods to locate buried targets.

(1) The first methods uses ground electromagnetic surveys to locate basement conductors (graphitic schists which host U mineralisation)

(2) The second method uses lithogeochemical techniques to target the alteration halo associated with mineralisation. The deposits are associated with broad alteration haloes extending vertically into the overlying sandstone, and more restricted haloes in the basement rocks. The haloes in the sandstone are localised around steeply dipping fault structures and form alteration "chimneys" at least 200m wide, extending hundreds of metres above the deposits. The haloes are characterised by intense leaching of hematite and detrital heavy mineral layers and changes in chemistry related to tourmalinisation (dravitization) and clay mineral alteration. The latter involves alteration of kaolinite to illite and chlorite, and deposits are surrounded by a broad, bell-shaped illite envelope.

Lithogeochemical anomalies are characterised by elevated U, V, Zn, Sr, Y, Pb, Th, As and P. Na_2O has a pronounced negative anomaly. The strongest subcropping anomalies are in boron and MgO. A conspicuous effect of alteration is loss of coherence in the sandstones. As silica is leached from the matrix (desilicification), the sandstones become friable. Redeposition of silica in quartz veins above the deposit may occur.

Regional ground surficial geochemical surveys have been found to be largely unsuccessful. These have included track etch, alphameter, soil, lake sediment and water geochemical surveys, and uranium scavenging in bogs. Lithogeochemical techniques described above should be oriented over favourable (basement) structures.

2. Applicability of these strategies to the Tanami Region

It is important to note that the techniques used in the Athabasca basin have never been applied or tested in Australia to date. This is because in the Alligator Rivers Region exploration leases were only granted for a short period of time, and within this period the many basement anomalies located at the surface were of course, the priority targets. (Many of these still remain untested). The only buried deposit in Australia, Jabiluka 2, was discovered by drilling out the extension of the target at Jabiluka 1. In the 1970's, Noranda carried out some exploration for buried targets, using radon cups and track etching over faults to detect leakages of uranium into the cover sequence from the basement. This exploration technique was found to be unsuccessful.

However, it should be possible to apply the techniques used in Canada to the Tanami Region. Lithogeochemical techniques depend on targeting the broad alteration haloes or 'alteration chimneys' in sandstones overlying the deposits. Alteration has been recognised in the clean, quartz-rich sandstones of the Kombolgie Formation up to 300 metres above the Jabiluka deposit (Gustafson & Curtis, 1983). Based on petrographic reports from Challenger (A.Purvis), and regional descriptions of the Gardiner Sandstone in Blake et al. (1979), the Gardiner Sandstone appears to contain chlorite rich, green shales and sandstones, as well as quartz-rich sediments. These chlorite-rich sediments will be more affected by hydrothermal alteration. It is important that any exploration for these alteration halos should always target the major structures, around which alteration 'chimneys' will form. It is also important to note that the alteration signature may be slightly different in the Gardiner Sandstone, as it is dependent on chemical reactions between oxidised fluids and mineralisation, and the initial composition of the Gardiner Sandstone is probably different to the Athabasca Sandstone.

The other exploration technique which could possibly be applied to the Tanami Region is the use of electromagnetic technique to delineate conductors (graphitic horizons) beneath the Gardiner Sandstone. It should be noted that this will target U-rich Au-Pt-Pd mineralisation and after the experience of the SAV where many electrical anomalies were unsuccessfully drilled due to the abundance of graphite and sulphide bearing shales, electrical methods in isolation may not give a definitive answer.

Part 2. Application of the model to the Tanami Region, N.T.

2.1 PROSPECTIVITY OF THE TANAMI REGION FOR UNCONFORMITY-RELATED AU-Pt-Pd±U MINERALISATION

This section discusses the prospectivity of the Tanami region for unconformity-related Au-Pt-Pd±U mineralisation. An assessment of prospectivity is made, based on whether the regional ingredients needed for this style of mineralisation, as determined for the Pine Creek Inlier and outlined in Section 1.5.1, also exist in the Tanami region. In order to be considered prospective for this style of mineralisation, the Tanami Region must contain

(1) The appropriate stratigraphy, including a thick cover sequence to set up the mineralised fluids, and a basement containing the appropriate host rocks
(2) Fundamental crustal-scale fractures (commonly active over a long period of geological time)
(3) Source rocks with high background values of Au-Pt-Pd-U
(4) Evidence of alteration by the oxidised, saline, low-pH fluids, which carry Au-Pt-Pd-U

2.1.1 Correlation of the Tanami region with the Pine Creek Inlier

Studies carried out by the BMR Proterozoic Framework Project have shown that Proterozoic stratigraphic sequences in the northwestern to central parts of northern Australia have a number of common features (ie Pine Creek Inlier, Halls Creek Inlier, Granites-Tanami Block, Tennant Creek Inlier). Figure 6 correlates the stratigraphy and tectonic history of the Pine Creek Inlier and the Tanami Block. This correlation is based on Ding, 1990 and Needham et al, 1988.

It is immediately clear that the Tanami Block has many geological features in common with the Pine Creek Inlier. The most broad and striking similarities are

(1) Each province contains a multiply deformed and metamorphosed (mainly greenschist facies with local amphibolite grade metamorphism) basement sequence, overlain by several mildly deformed cover sequences, the most prominent being the youngest platform sequence (Birrindudu Group/ Katherine River Group).
(2) The basement sequence is comprised mainly of subaqueous basin sediments with local volcanics rocks. Each contains a thick package of chemical sediments containing carbonaceous/graphitic units and cherty ferruginous shales/banded ironstones (Mt Charles Beds, Davidson Beds/Koolpin Formation).
(3) The basement sequence is affected by a major regional tectonic event (Barramundi Orogeny).

As well as this broad correlation between the provinces, the detailed stratigraphy of each is also very similar.

(1) In both cases, the Early Proterozoic sequence was deposited in a geosynclinal basin formed by crustal extension of Archaean basement.

(2) The Pine Creek Geosyncline Sequence is divided into three phases of basin development, a rift phase, a sag phase and a pre-orogenic phase. This same broad division can be applied to the Tanami Complex, and a comparison between depositional environments in each province can be made.

RIFT PHASE:

Pine Creek Geosyncline Sequence: (Namoona Group, Mount Partridge Group). Fluvial fan systems grade distally and vertically into subtidal high energy pelites. These are succeeded by low energy subtidal facies, transitional into intertidal to supratidal carbonates. Localised mafic volcanism accompanies initial rifting.

Tanami Complex: (Blake Beds/Nanny Goat Creek Beds). Deep water shale-turbidite facies, containing fine grained pelites and coarser grained greywackes, with local volcanism along active rift zones (represented by proximal mafic and felsic volcanics)

SAG PHASE:

South Alligator Group; Mount Charles/Davidson Beds. A mixed chemical/pelitic sedimentary sequence deposited under low energy, quiescent conditions. Local volcanism. Chemical sediments include cherty ferruginous shale/banded ironstone (eg Koolpin Formation, Schist Hills Ironstone Member), carbonaceous/graphitic shales (eg Koolpin Formation, Colgate Beds).

PRE-OROGENIC PHASE:

Late South Alligator Group/Finniss River Group, Madigan Beds/Killi Killi Beds. Thick, monotonous sequence of interbedded greywacke and siltstone interpreted to be metaturbidites, representing a deep water, high energy facies.

Variations in depositional environments of the 'Sag' Phase in each province suggest the basins had a slightly different development history, with the Tanami Complex lacking an early fluviatile/shallow marine clastic sequence, possibly due to more rapid initial subsidence during rifting. Alternately, early fluviatile/shallow marine sequence may not be exposed in the Tanami. ie the sag phase has lapped over it. It should also be noted that the precise nature of the Blake Beds is presently unresolved, and some NFM geologists interpret it to be a well sorted, quartz-rich clastic sequence, possibly of shallow water origin

(Giles). Apart from this, basin development is almost identical, and the metasedimentary basement sequence is similar in each province as a result.

From the above comparisons, it can be seen that the appropriate regional stratigraphy for unconformity-style deposits does exist in the Tanami Region. ie The Tanami Block contains both a basement package containing the appropriate host rocks (Tanami Complex, equivalent to the Pine Creek Geosyncline Sequence) and the necessary cover sequence for setting up the mineralised fluids (Gardiner Sandstone, Birrindudu Group, equivalent to the Kombolgie Formation, Katherine River Group).

2 .1.2 Potential host rocks in the Tanami Complex

MT CHARLES/ DAVIDSON BEDS: In the SAV, Au-Pt-Pd-U-rich mineralisation is hosted by chemical sediments (carbonaceous shales, cherty ferruginous shales) of the Koolpin Formation. Therefore, the stratigraphically and lithologically equivalent Mt Charles/Davidson Beds in the Tanami Block have obvious potential to host this style of mineralisation. Both represent a strongly reducing environment which would favour precipitation of Au-Pt-Pd-U. The graphitic schists of the Mt Charles/Davidson Beds also make this unit an attractive exploration target, as they can be readily located using EM surveys. However, mineralisation is not necessarily restricted to the Mt Charles/Davidson Beds. Other basement units are also likely to contain suitable host rocks.

NANNY GOAT CREEK BEDS: The Nanny Goat Creek Beds contain felsic and mafic volcanics which, being feldspathic, could host Au-Pt-Pd mineralisation without uranium.

MADIGAN BEDS: The Madigan/Killi Killi Beds contain thick-bedded, quartz-greywacke with no typical volcanic rocks. This unit is therefore less likely to host unconformity-style mineralisation.

BLAKE BEDS: The Blake Beds are described as a finer-grained variant of the Madigan Beds, and are typically strongly foliated, chloritic/sericitic quartz-rich metasiltstones. However, they have a strong magnetic signature suggesting they carry appreciable magnetite (ie they are iron-rich shales). In this way, they are similar to the mineralised Koolpin Formation of the SAV, which also has a strong magnetic signature. The Blake Beds also contain banded ironstones, observed outcropping near the Challenger 2 prospect.

At Challenger 2, the Blake Beds were found to contain a 'green tuffaceous shale', which may be of basaltic composition. In RAB drill cuttings, this green tuffaceous shale is more radioactive than surrounding shales, and from drill core logs, it can be seen that elevated Au-Pt-Pd-U values concentrate in this lithology. A similar 'green tuffaceous shale also hosts Au+Pt+Pd-U mineralisation at Coronation Hill

It is therefore concluded that the Blake Beds contain potential host rocks for Au-Pt-Pd-U mineralisation.

2.1.3 Potential of the Cover Sequences to host mineralisation

From Figure 6, cover sequences of the Tanami Block include the Gardiner Sandstone (Birrindudu Group), Pargee Sandstone, Supplejack Downs Sandstone and Mt Winnecke Formation. The unconformities which separate any of these units from basement are all potential targets for unconformity-style mineralisation.

Based on current information available for the Tanami region, none of the sedimentary cover sequences are likely to host mineralisation, as they are mainly composed of quartz-rich sediments. However, the discovery of appropriate host lithologies (carbonate- feldspar- Fe^{2+}- or carbon-bearing) in these covers during future exploration would make mineralisation in the cover sequence feasible. The exception would be in fault zones or near the unconformity above carbonaceous lithologies in the underlying basement, if reduced basement fluids flushed into the cover sequence mix with the oxidised basin brines (eg. Athabascan deposits).

Chloritic shales or sandstones within the Gardiner Sandstone are potentially reactive with mineralised fluids, but fluid-rock interaction will depend on the permeability of these horizons (eg if a fault transected a chlorite-rich horizon, sufficient interaction for mineral precipitation may occur). An analogy is the basaltic units in the Kombolgie Formation, Pine Creek Inlier. These basalts have the potential to host mineralisation as they are feldspathic in composition. However, they are impermeable, so it is expected that precipitation of minerals will only occur around favourable fault zones.

The volcanic cover sequences (eg. Mount Winnecke Formation) may represent potential host lithologies. In addition, if the mineralisation event is post-Cambrian in age (Section 2.2.2), the Antrim Plateau Volcanics are also a potential host rock. Again, any mineralisation in these sequences will be confined to structures, or near the unconformity,

2.1.4 Fundamental Structures

An essential criterion for setting up unconformity-style mineralisation is the presence of faults that were active after deposition of the cover sequence. Of these fundamental, crustal-scale fractures with a long-lived history of fault activity are probably the easiest to target. These fractures are usually active during basin development, and provide a 'plumbing' system allowing migrating fluids to permeate through the basin and come into contact with the appropriate reducing host lithologies. Faults reactivated or newly active during deposition of the cover sequences also have an essential role, as they allow mineralised fluids in the cover sequence to focus and migrate downwards into the underlying basement.

In the SAV, these fundamental structures are represented by the major NW-trending strike-slip fault system, which is considered to have been active during deposition of Pine Creek Geosyncline Sediments, and was reactivated to form a wide, shallow graben which was the locus for extrusion and deposition of the El Sherana and Edith River Groups (older cover sequences). There is evidence that the fault system was also active post-deposition of the Kombolgie Formation (Valenta, 1991).

In both the SAV and the ARUF, mineralisation is controlled by reverse faults which post-date deposition of the cover sequence.

In the Tanami Block, Ding (1990) has recognised two sets of fundamental crustal-scale fractures, recognised on a regional scale. He considers the NE trending fractures to be responsible for the original rifting, volcanic activity and sedimentation of the Tanami Complex due to crustal-scale extension. They therefore played an active role during basement formation. Activity along a set of NW trending fundamental fractures post-dates deposition of the cover sequences (Pargee Sandstone, Mount Winnecke Formation), and corresponds with D3 deformation within the Tanami Complex. Strike slip (T3) faults developed as a layer parallel detachment, form a set of WNW trending major faults which have a prolonged history throughout the D3 deformation event.

2.1.5 Source Rocks

There is much debate as to the importance of having elevated values of a particular metal in the vicinity of a major deposit. Most ore deposits form by interaction of a fluid with a volume of rock which is at least one order of magnitude greater than the volume of the deposit. Hence, if the fluid/rock ratio is large, enhanced background values of a particular metal are not considered an essential ingredient for the formation of the deposit, although they may enhance its formation. However, if the fluid/rock ratio is small, then elevated values of particular metals can become increasingly important. The level of importance is often debated, but the fact remains that in the vicinity of most uranium deposits there are high U-source rocks (e.g. Wyborn 1990b) and Au, Pt and Pd have also been found to be above the crustal average in a number of country rocks in the South Alligator Valley Mineral Field, particularly in the black shales and mafic igneous rocks. Au is also elevated above average crustal abundances in the ironstones (cherty ferruginous shales) of the Koolpin Formation. As an alternative, Wilde et al (1989) state having average crustal abundances in a neutral cover sequence is less important than that the presence of PGE elevated source rocks within the cover sequence.

In general, the SAV model developed by AGSO for Au-Pt-Pd±U mineralisation did not require a source enriched in Au, Pt, or Pd as an essential ingredient, although it was recorded that these

elements were in values of 2 to 3 times average crustal abundance in the local area. With the resources available we were unable to quantify the importance of these elevated results.
It may thus be significant that in the Tanami Block, the chemical sediments of the Davidson Beds are considered by NFM geologists to contain elevated Au values. Au-Pt-Pd assays from the Challenger Two prospect show that the Antrim Plateau Volcanics have background Pt-Pd values well above crustal average (2-7 ppb), and other mafic igneous rocks may also be enriched in Au-Pt-Pd.

2.1.6 Setting up an oxidised, mineralised fluid system in the basin

An important regional ingredient for unconformity-style mineralisation is the presence of a thick cover sequence, which allows prolonged maintenance of fluids in an oxidised, metal-rich state, before migration into the basement rocks. The cover sequence must be comprised of neutral, non-reactive rocks such as quartz-rich 'clean' sandstones (i.e. containing an insignificant amount of feldspars and clay minerals) to preserve the metal-enriched solutions. From field observations, the regional observations of Blake et al (1979), petrological reports by A.Purvis, and thin section analysis of samples from the Killi Killi Hills Prospect, the Gardiner Sandstone comprises a thick sequence of quartz-rich, non-reactive clastic sediments, similar in nature to the Kombolgie Formation of the Pine Creek Inlier. It therefore provides an ideal cover sequence for establishing the required mineralising system.

2.1.7 Evidence of Mineralising Fluids of the appropriate composition.

It is very difficult to determine whether the appropriate oxidised, saline, low pH fluids have been active in the Tanami Region, without detailed multielement whole-rock analysis to detect the alteration patterns. However, there is some positive indication that the appropriate fluids may have circulated in the Tanami Region. The best evidence to date comes from the Killi Killi Hills and Challenger Two prospects, where some detailed analyses have been made. AGSO whole-rock geochemical data of arkoses previously collected from Killi Killi Hills, show a depletion in Na_2O and CaO, which is characteristic of the altered feldspar-bearing rocks types in the vicinity of deposits in the SAV. At Challenger Two, initial element correlations for three drillholes show a strong correlation between Au-Pd-Pt and a weaker correlation with U, as observed for the SAV mineralisation, suggesting these elements were carried in the same fluid system. Element correlations and abundances at Challenger 2 are discussed in more detail in Section 2.2.

2.1.8 Summary

In summary, the Tanami Region can be considered prospective for Au-Pt-Pd±U mineralisation on a regional scale. It contains the appropriate stratigraphy, including a thick cover sequence and the appropriate host rocks in the Tanami Complex for precipitating both U-rich Au-Pt-Pd and U-poor Au-Pt-Pd mineralisation. Mineralisation is most likely to occur in the Tanami Complex, and not in the cover sequences, unless overlying carbonaceous units in the basement; in which case mineralisation would occur immediately above the unconformity. The unconformity between any of the cover sequences with Tanami Complex can be used as a potential regional exploration target. Several sets of fundamental crustal-scale fractures can be recognised on airborne magnetic images, remote sensing and from photo-interpretation. The country rocks contain units with above crustal average abundances of Au, Pt and Pd. Finally, there is some indication that the appropriate mineralising fluids existed in the Tanami Region.

2.2 APPLYING THE MODEL TO THE CHALLENGER TWO PROSPECT

2.2.1 Geology of the Challenger Two Prospect

At Challenger Two, basement Tanami Group metasediments (currently interpreted to be Blake Beds) are unconformably overlain by the Middle Proterozoic Gardiner Sandstone (Birrindudu Group). The Cambrian Antrim Plateau Volcanics overlie the Gardiner Sandstone, and locally directly overlie Tanami Group metasediments, suggesting Gardiner Sandstone locally laps out against basement palaeotopography, or was stripped prior to deposition of the volcanics.

Challenger Two lies along the fault-bound southeastern margin of the Antrim Plateau, an extensive subaerial tholeiitic lava flow, extending for over 400 km to the northwest. Preliminary interpretation of the geological setting based on RAB drilling, indicates that mineralisation is located within a NE-trending fault zone at the Antrim Plateau margin, concentrating within an uplifted, basement block bounded by high angle faults/shears (Figure 7). Initial interpretation of the structural setting suggests the uplifted, mineralised basement block is placed in a small north-trending jog within the NE-trending fault system (Figure 7). The NE-trending fault system splays off a north-trending magnetic ridge interpreted to be basement sediments (Blake Beds? Davidson Beds?), so the prospect lies to the side of a magnetic high. In turn, this north-trending magnetic high splays off a major NW-trending linear magnetic anomaly, which extends as far as The Granites area to the south, and represents one of the crustal-scale fundamental faults in the Tanami Region (S.Hogan pers. comm.). To the north of the prospect, the NE-trending fault system at Challenger Two is truncated by a magnetically interpreted, east-west trending shear zone (Figure 8).

2.2.2 Controls on Mineralisation

Figure 9 is a schematic model showing the interpreted controls on mineralisation at Challenger Two. From Figures 7 & 9, the structural and lithological controls on mineralisation are immediately apparent:

- Mineralisation occurs close to the inferred NE-trending fault zones
- Mineralisation is largely confined to the basement Blake Beds, especially in the uplifted fault-bounded basement block
- anomalous Au (±Pd±Pt±U) values are also found at the stratigraphic unconformities.

These observations imply that the circulating mineralised fluids were channelled by fault structures and unconformity surfaces, with precipitation of Au (±Pd±Pt±U) induced by interaction with basement lithologies.

Within the Blake Beds, there is some lithological control on mineralisation. It is largely confined to iron-rich metapelites, some of which also contain chlorite and graphitic material. Other favourable lithologies include a green shale which appears to be tuffaceous in hand specimen (chloritic?, perhaps of basaltic composition), sheared metasediment, and quartz veins. Grey siltstones, sericitised schists and feldspar-rich metapelites are barren. Although mineralisation appears to be controlled by iron content of the shales, iron-rich banded metapelites and siltstones (banded ironstone?) are also barren. This may be due to the impermeability of these chemical sediments.

Anomalous gold mineralisation also occurs within the Antrim Plateau Volcanics at the unconformity. In this case, it is inferred that fluids travelling along the unconformity interacted with the feldspar-rich basalts to precipitate Au (and possibly Pt-Pd: for most drill holes, these elements have not yet been assayed). It is interesting to note that U values are not elevated in the Antrim Plateau Volcanics (although they are sometimes elevated below the unconformity, in the Gardiner Sandstone). According to the model for unconformity-style mineralisation (Section 1.1), feldspathic host rocks will precipitate Au (Pt-Pd) but not uranium. The occurrence of elevated precious metal values within the Cambrian sequence is not at all surprising as elevated Au values have been found elsewhere in Cambrian sequences (AGSO unpublished ROCKCHEM data). Cambrian uraninites and hydrothermal zircons have also been found in the SAV deposits and surrounding areas and palaeoclimactic evidence from detailed studies on Cambrian weathering profiles on phosphatic sediments suggests that extremely oxidising conditions existed at several time intervals (Southgate, 1988). Associated oxidised meteoric groundwaters generated during these time intervals would have the capacity to carry Au + Pt +Pd and could easily move down major fault structures during periods of tectonic instability. The implication for exploration is that the basal Cambrian unconformity may also be prospective.

Anomalous gold mineralisation in the Gardiner Sandstone also occurs at the unconformities, below Antrim Plateau Volcanics and above Blake Beds, and the best intersections are close to the NE-trending structures. Mineralisation is associated with ferruginous or chloritic shales within the Gardiner Sandstone. Away from the unconformity however, these units are barren.

The fact that mineralisation within the Antrim Plateau Volcanics and Gardiner Sandstone occurs at the unconformity and close to major structures, suggests that these units were impermeable at the time mineralisation occurred. This has important implications for future exploration, suggesting mineralisation will be confined to these structural conduits.

The structural, stratigraphic and lithological controls on mineralisation are consistent with the unconformity-style mineralisation model. Further evidence for this style of mineralisation may be found in the geochemical results:

(1) Evidence of alteration.

It has been noted that anomalous intervals within the Gardiner Sandstone are desilicified, resulting in friable sandstones. Desilicification is one of the features distinguishing alteration associated with unconformity-style mineralisation in the Pine Creek Geosyncline, and friable sandstones occur in alteration zones around the Athabascan deposits. Chloritic shales have also been noted in the Gardiner Sandstone, and chlorite alteration often accompanies unconformity-style mineralisation. Further tests for presence of alteration would be useful in establishing the unconformity-style model at Challenger Two, because the alteration pattern is distinctive of this style of mineralisation. Further tests could include

- fluid inclusion studies to determine the temperature, salinity, fO_2, pH of the mineralising fluids
- multielement analysis of host rocks to detect desilicification, Ca, Na, Th depletion, high Fe^{3+}/Fe^{2+} ratios, by controlled sampling of altered rocks and their associated protoliths. Analysis of anomalous Antrim Plateau Volcanics would be particularly useful in establishing Na and Ca depletion, as this is very obvious in volcanic rocks and other feldspar-bearing rocks such as arkoses.

(2) Evidence of Au-Pt-Pd±U mineralisation.

Multi-element correlation has been carried out for samples from three drillholes, C1RB852, 854 855. Results show that a strong correlation exists between Au-Pd-Pt, and to a lesser extent U, as observed for the SAV deposits. The correlation is strongest within the Blake Beds. Association of these elements reflects unconformity-style mineralisation, ie deposition from low temperature, oxidised meteoric waters. In contrast, the Au-As correlation, which would reflect iron formation hosted mineralisation (eg Tennant Creek) is not as strong. If the Au-Pt-Pd±U correlation still holds when more data are available, it will also rule out the possibility that mineralisation is associated with a high temperature epithermal system, a model which should be considered given the close proximity of the Frankenia Granite.

(3) Other element correlations and patterns

- There is an association of Au-Pt-Pd with Te. In the East Alligator deposits, mineralisation is associated with Ni and Pb tellurides. It would be useful to start analysing Se, because there is an Au-Pt-Pd-selenide association at Coronation Hill.
- There is a marked Mg depletion associated with anomalous Au in the Antrim Plateau Volcanics, and an elevation of Mg, U, Au in the Gardiner Sandstone and Blake Beds, indicating Mg has been mobile
- high V associated with mineralisation is one of the indicators of unconformity-style mineralisation especially in Canada, but also typical for sandstone hosted deposits
- Yb is a good indicator of unconformity-style mineralisation, and has a strong correlation with Au-Pt-Pd-U at Challenger Two. In each Australian Proterozoic province, U deposits are found to be high in high field strength elements (HFSE). Elevated Y has been record at Killi Killi

Hills, suggesting this HFSE may serve as an indicator of unconformity-style mineralisation in the Tanami Region. Zr may also be a good indicator.

- There is a strong correlation between Cu values and mineralisation in the Blake Beds. High Cu values may be related to a favourable host lithology for mineralisation, as this correlation is not seen in the Gardiner Sandstone or Antrim Plateau Volcanics. Like u, Au, Pt, Pd, copper is easily transported in oxidised fluids. It should be noted that Coronation Hill is adjacent to a small Cu prospect
- Pb has a strong correlation with U in the Blake Beds. This is often found due to the decay of U to Pb.

In summary, there is geochemical evidence that the unconformity-model is applicable to Challenger Two. Evidence includes desilicification associated with mineralisation, the strong correlation between Au-Pt-Pd±U, mobility of Mg (as observed in Alligator Rivers deposits) and high V (and therefore oxidation) associated with mineralisation.

2.2.3 Further Recommendations for Challenger Two

S.Hogan (1992) suggested that Challenger Two should be viewed as a 'relatively limited, albeit encouraging zone which could be several kilometres away from the eventual target'. Results to date are considered encouraging for potential unconformity-style mineralisation existing in the area, and the prospectivity of the broader area surrounding Challenger One and Two should be evaluated. The following recommendations are made for future exploration.

(1) <u>Target the major structures</u>

- The NE-trending fault system upon which Challenger Two is located, should be targeted for extensions of mineralisation. A better understanding of the structural setting of mineralisation at Challenger Two should enable any extensions of mineralisation along the NE structure to be found. More information about fault controls at Challenger Two can be obtained by costeaning and mapping. A more detailed structural analysis of the region is considered worthwhile in view of the importance of structure in understanding unconformity-style mineralisation in the South Alligator Valley (Valenta 1991).
- Other structures in the Challenger-Rabbit Flat Belt should also be targeted for unconformity-style mineralisation. Linear magnetic anomalies which may represent major fault systems include the north-trending magnetic anomaly and the NW-trending magnetic low.
- To the north of Challenger Two, a magnetic interpreted E-W shear zone truncates the extension of the Challenger Two fault system. Two RAB sections, 16200N and 17800N were drilled in this area. No significant values were obtained in the Antrim Plateau Volcanics in section 16200N, although gold values are elevated at the margin of the Antrim Plateau, probably marking the extension of the Challenger Two fault system. In section 17800N, elevated Pt, Pd and some Au has been detected in the Antrim Plateau

Volcanics. These anomalies occur at the unconformity where exposed in drillcore, and extend into Blake Beds where exposed in drillcore (C1RB871), which may suggest mineralisation in the basement below the Antrim Plateau Volcanics. This mineralisation does not appear to lie upon any extension of structures further south, but section 17800N lies on a major E-W magnetic interpreted shear, whereas 16200N further south does not. This result is encouraging, suggests mineralisation intersected in section 17800N may be associated with the E-W shear. The Blake Beds beneath the Antrim Plateau Volcanics should be targeted along this shear zone.

(2) Multielement analysis and 'pathfinder' elements

Areas targeted as having potential for mineralisation should be tested geochemically, by rock chip or soil sampling, or vacuum drilling. Geochemical surveys should be oriented along a series of traverses perpendicular to the structural/ magnetic/ radiometric/ lithological target. The main indicators of mineralisation are Au-Pt-Pd-U. However, other elements may be used as 'path finders' to detect alteration associated with unconformity-style mineralisation. It is suggested that assays of Mg, As, V, Cu, Ni, Te and Yb should be continued. Other elements which may be useful are Na, Ca, K, Th, P, Se, Y, Zr, Ag, and Cr, for reasons outlines in Section 1.5.3.

(3) Radiometric Anomalies

S.Hogan (1992) states that unenhanced airborne radiometric data identifies U and Th anomalies in the Challenger One and Two areas, and elsewhere in the Challenger-Rabbit Flat Belt. These should be interpreted, and where coincident with major structures, may warrant further consideration.

2.3 THE KILLI KILLI No.1 PROSPECT

The Killi Killi No.1 U prospect is not on ground held by NFM, but was visited during fieldwork to determine its implications for unconformity-style mineralisation in the Tanami Region. The prospect was assessed because alteration in arkosic sandstones, noted in earlier AGSO sampling near the prospect is similar to alteration observed in the South Alligator Valley deposits.

17 samples were collected around costeans and pits at two localities, termed Killi Killi East and Killi Killi West (Figure 10). Appendix 3 contains representative whole rock analyses of sandstone samples collected at Killi Killi Hills, from the AGSO ROCKCHEM database. Appendix 4 contains an unpublished old BMR report on the Killi Killi Hills prospect.

At Killi Killi No1 and No2, anomalous radioactivity of 4 - 8 times background is concentrated in the basal 6m of Gardiner Sandstone. Scintillometer readings taken during recent fieldwork at Killi Killi No.1 showed that radioactivity is confined to a basal pebble conglomerate and coarse sandstones directly above the unconformity. Conglomerate beds higher in the sequence are apparently barren. Anomalous radioactivity is due to uranium contained in xenotime and florencite, but no uranium minerals or ochres are found in the field.

At both the Killi Killi Hills prospects, radioactivity is close to the unconformity between Gardiner Sandstone and steeply dipping, slightly schistose basement shales and greywackes of the Killi Killi Beds. The unconformity does not outcrop between the two prospects, suggesting a higher stratigraphic level, and this area is barren of radioactivity.

Prichard et al (1960) record two local occurrences of radioactivity within basement shales a few feet below the unconformity surface, east of the Killi Killi East anomaly. They interpreted this to be downward leaching from the base of the Gardiner Sandstone. However, in more recent times the BMR has considered the Killi Killi Hills prospects to be potential unconformity-style deposits, and also potential Y deposits.

(1) Applicability of an unconformity-style model to Killi Killi Hills

Arkosic sandstones in the AGSO ROCKCHEM database collected in the Killi Killi Hills area show a strong depletion of Na_2O and CaO, characteristic of unconformity-style alteration (Appendix 4; samples 87496108 & 87496115a). The fact that radioactivity is confined to the basal conglomerates directly above the unconformity also supports the unconformity model.

Further tests for unconformity-style mineralisation are being made. Seventeen samples from Killi Killi No.1 are being assayed for Au-Pt-Pd-U and multi-element analysis. If results are encouraging, the Killi Killi Hills area could be prospective for unconformity-style mineralisation. Figure 10 shows a fault cross cutting Gardiner Sandstone and basement lithologies. Further exploration of the area should target similar structures. Mineralisation is most likely to be confined to appropriate host lithologies in the basement (if they are found to exist in this area), rather than above the unconformity. Some precipitation of U in the basal Gardiner Sandstone may be due to the presence of feldspathic, basaltic or carbonaceous clasts in the conglomerate, or simply due to reduced, basement-derived fluids permeating into the porous conglomerate from the unconformity.

(2) Potential of the Killi Killi Hills prospects for Yttrium mineralisation

At a time when exploration for Y deposits was of interest to manufacturers of superconductors, the BMR considered the Killi Killi Hills prospects to be of interest. The mineralogy of the prospects (xenotime, florencite) indicated there should be high trace element values, particularly Y, and this is seen in representative whole rock analyses in Appendix 3.

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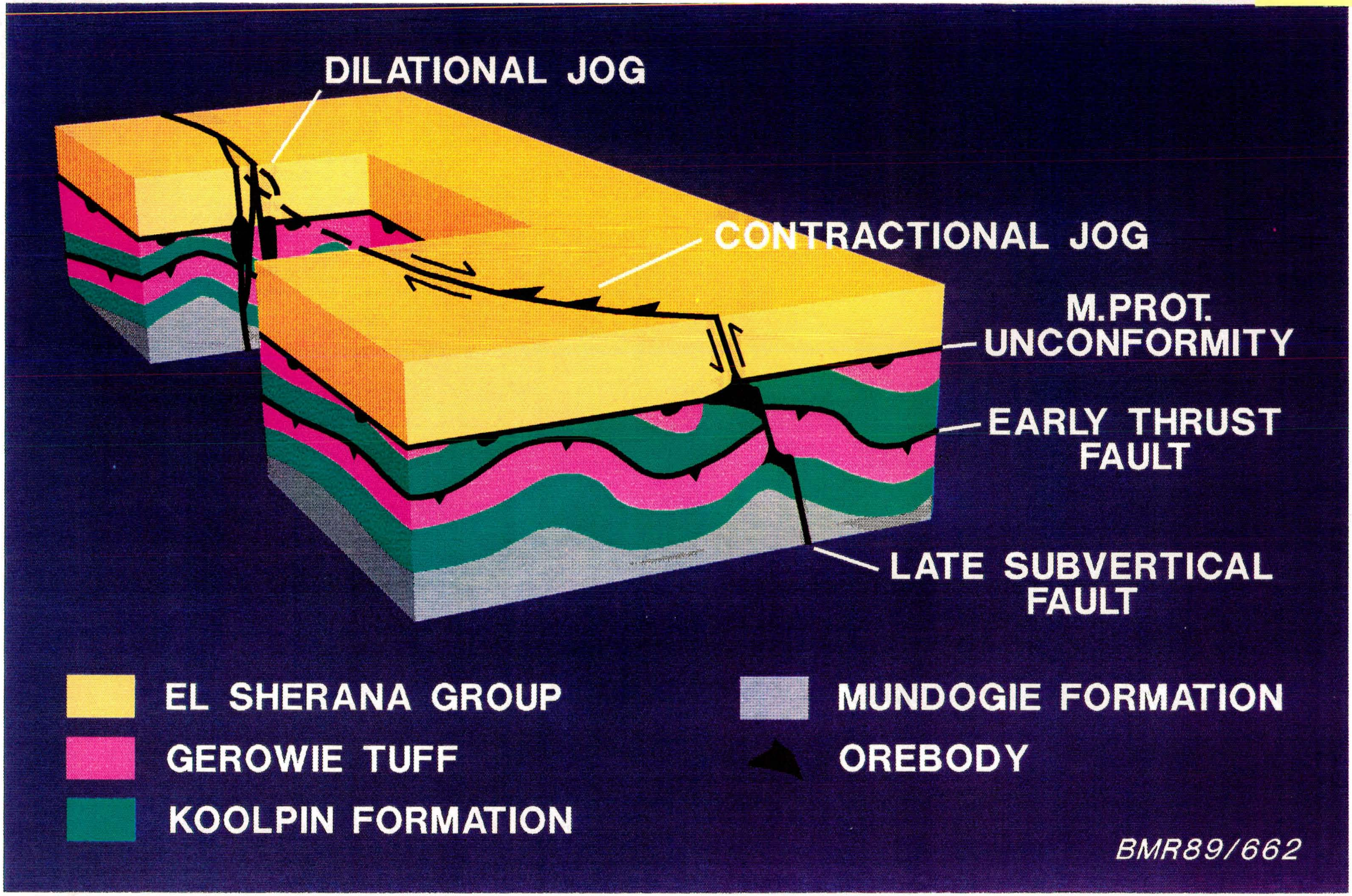
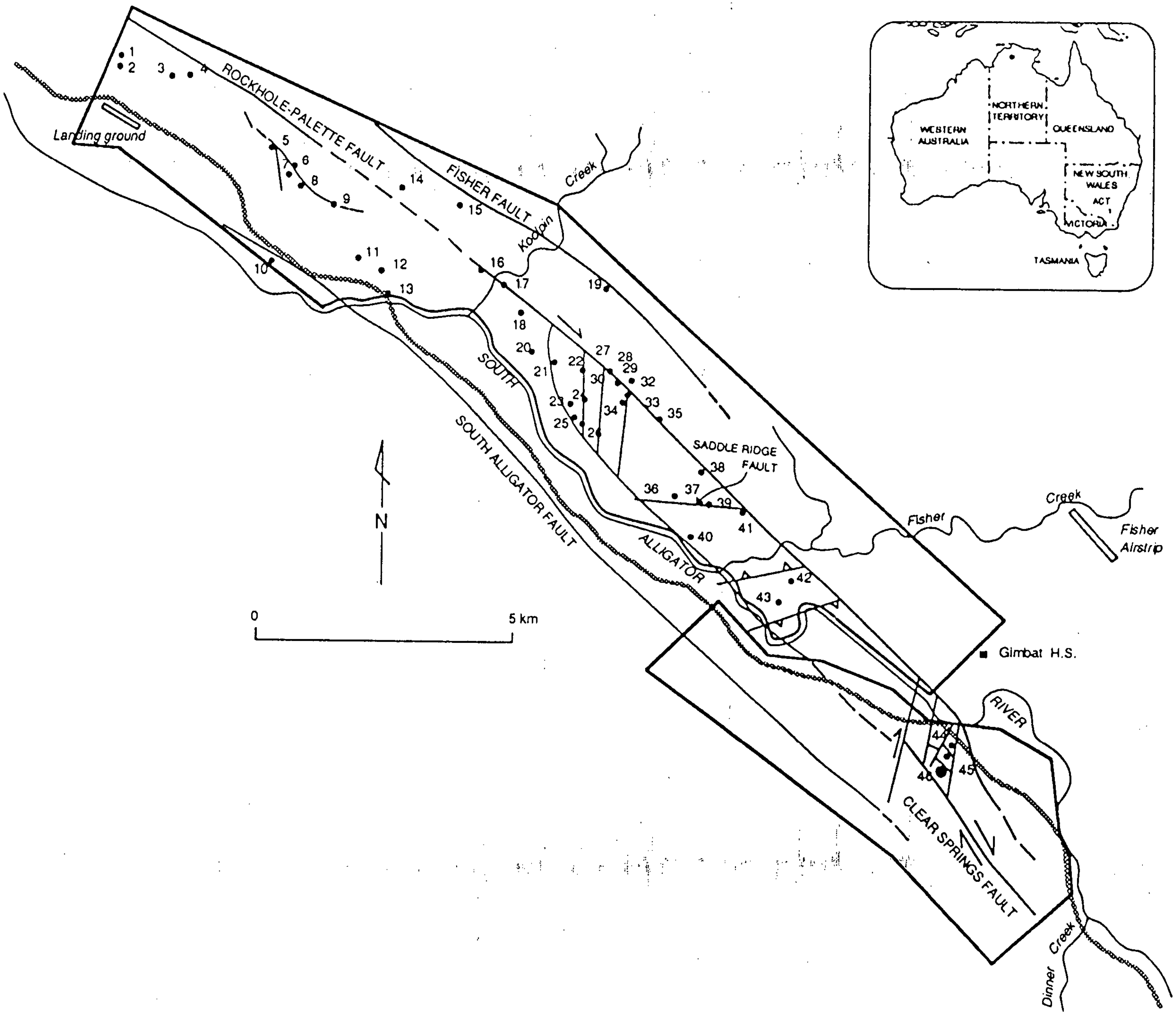
Figure 1: Schematic block diagram showing geological features controlling mineralisation in the South Alligator Valley Mineral Field


DILATIONAL JOG
CONTRACTIONAL JOG
M.PROT. UNCONFORMITY
EARLY THRUST FAULT
LATE SUBVERTICAL FAULT
EL SHERANA GROUP
GEROWIE TUFF
KOOLPIN FORMATION
MUNDOGIE FORMATION
OREBODY
BMR89/662



PROSPECTS

1 - 9600NW
2 - 9200NW
3 - Airstrip
4 - Airstrip Northeast
5 - Stag Creek
6 - El Sherana North
7 - El Sherana West
8 - El Sherana
9 - High Road
10 - South Alligator Fault
11 - Stockpile 1
12 - Stockpile 2
13 - Flying Fox
14 - Charvats
15 - Orchid Gully
16 - Scinto 6
17 - Monolith
18 - Koolpin Creek
19 - Koolpin East
20 - Scinto 5 North
21 - Scinto 5 South
22 - Cliff Face
23 - Scinto 1, No 1 adit
24 - Scinto 1, No 2 adit
25 - Palms
26 - Scinto Camp
27 - Palette 5
28 - Palette 4
29 - Palette 6
30 - Palette 1
31 - Palette 2
32 - Palette 7
33 - Palette 3
34 - Skull 1
35 - Skull 2
36 - Clear Springs
37 - Saddle Ridge
38 - Saddle Ridge NE
39 - Saddle Ridge East
40 - Saddle Ridge South
41 - Saddle Ridge East Extended
42 - Pul Pul Hill North
43 - Pul Pul Hill South
44 - Callanans
45 - Coronation Hill
46 - Coronation Hill SW

Figure 2: Location of deposits in the major NW-trending dextral strike-slip fault system, South Alligator Valley Mineral Field

Figure 3: End member spatial variants in the geometry of dilatant sites.

(a) Steep reverse fault with flat dilatant site (such as an unconformity)

e.g. Rockhole, Saddle Ridge, Sleisbeck (South Alligator Valley).

(b) Steep strike-slip fault with steep dilatant site.

e.g. Coronation Hill, Palette area, Skull.

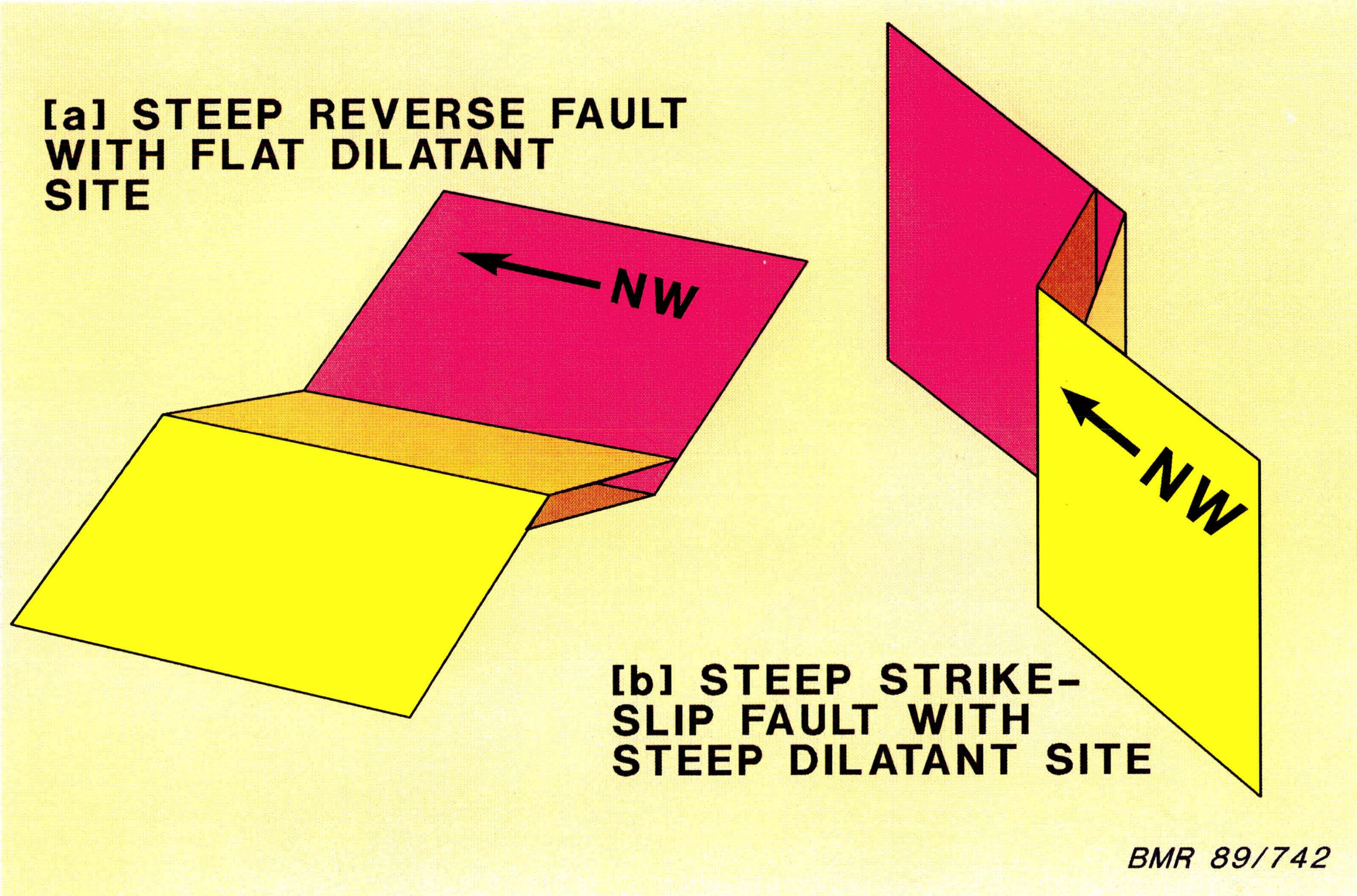
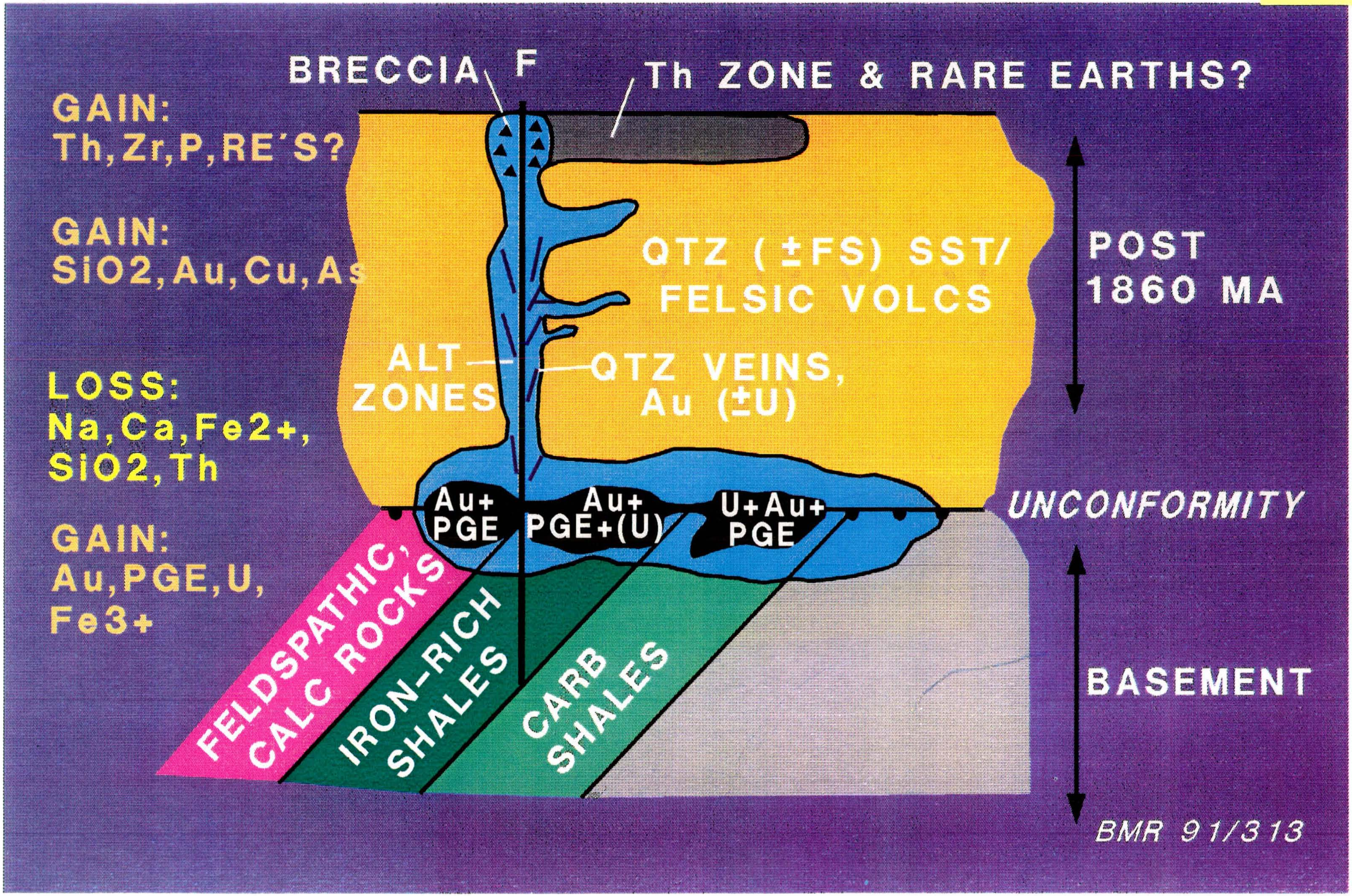

[a] STEEP REVERSE FAULT WITH FLAT DILATANT SITE
NW
NW
[b] STEEP STRIKE-SLIP FAULT WITH STEEP DILATANT SITE
BMR 89/742

Figure 4: Model showing separation of U-rich and U-poor Au-Pt-Pd mineralisation due to lithological controls. The model also shows alteration patterns of desilicification, Na, Ca, Fe^{2+} and Th loss at the deposits, and reprecipitation in quartz veins above the deposits.


BRECCIA
F
Th ZONE & RARE EARTHS?
GAIN:
Th,Zr,P,RE'S?
GAIN:
SiO2,Au,Cu,As
LOSS:
Na,Ca,Fe2+,
SiO2,Th
GAIN:
Au,PGE,U,
Fe3+
QTZ (±FS) SST/
FELSIC VOLCS
ALT
ZONES
QTZ VEINS,
Au (±U)
POST
1860 MA
Au+
PGE
Au+
PGE+(U)
U+Au+
PGE
UNCONFORMITY
FELDSPATHIC,
CALC ROCKS
IRON-RICH
SHALES
CARB
SHALES
BASEMENT
BMR 91/313

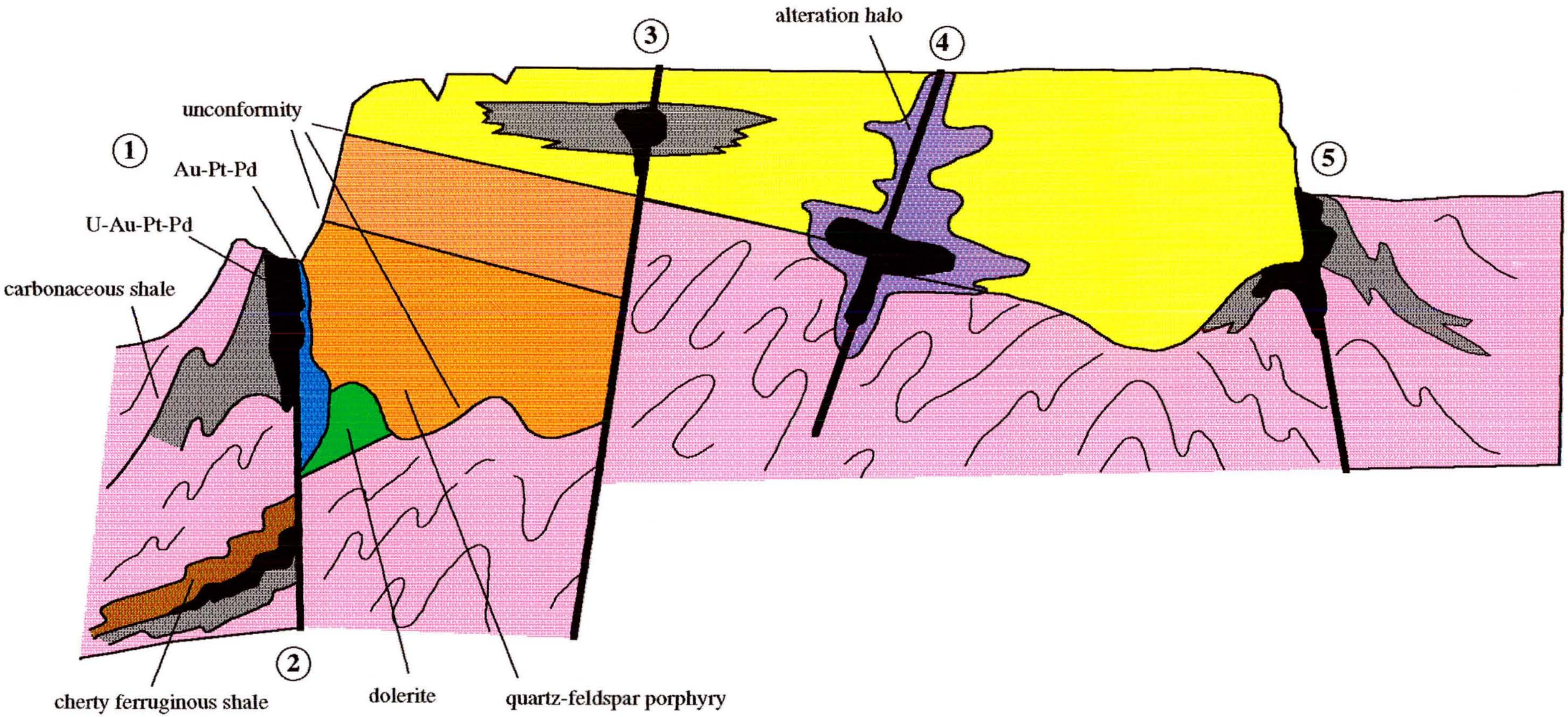
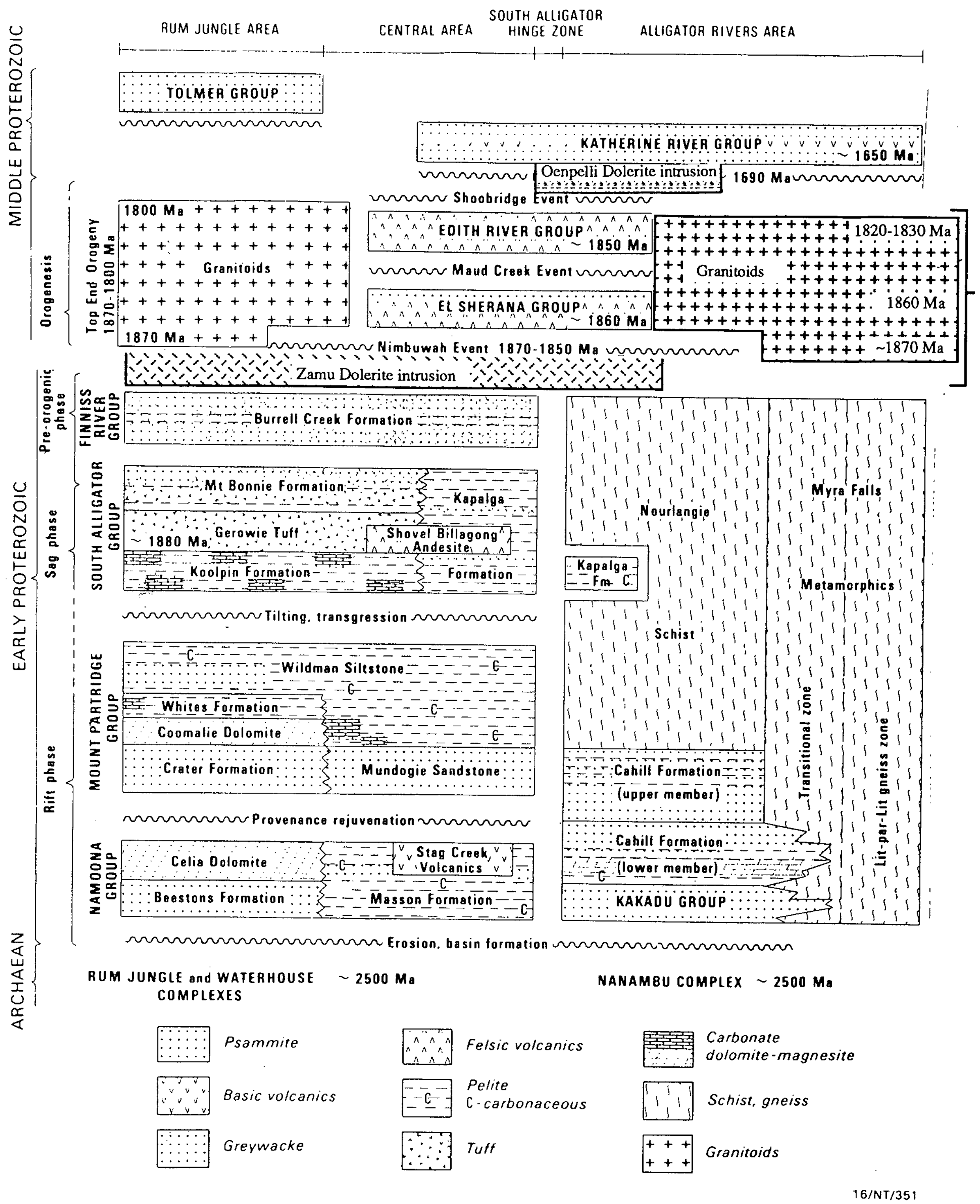


Figure 5: Section showing how different variations of the unconformity-type U-Au-Pt-Pd deposits can be generated within the same basin setting. 1 = South Alligator Valley deposits (eg. Coronation Hill). 2 = South Alligator Valley deposits (eg. Koolpin, Monolith). 3 = Bigrlyi, Oobagooma. 4 = Athabascan deposits. 5 = Alligator Rivers deposits.



PINE CREEK INLIER

TANAMI BLOCK

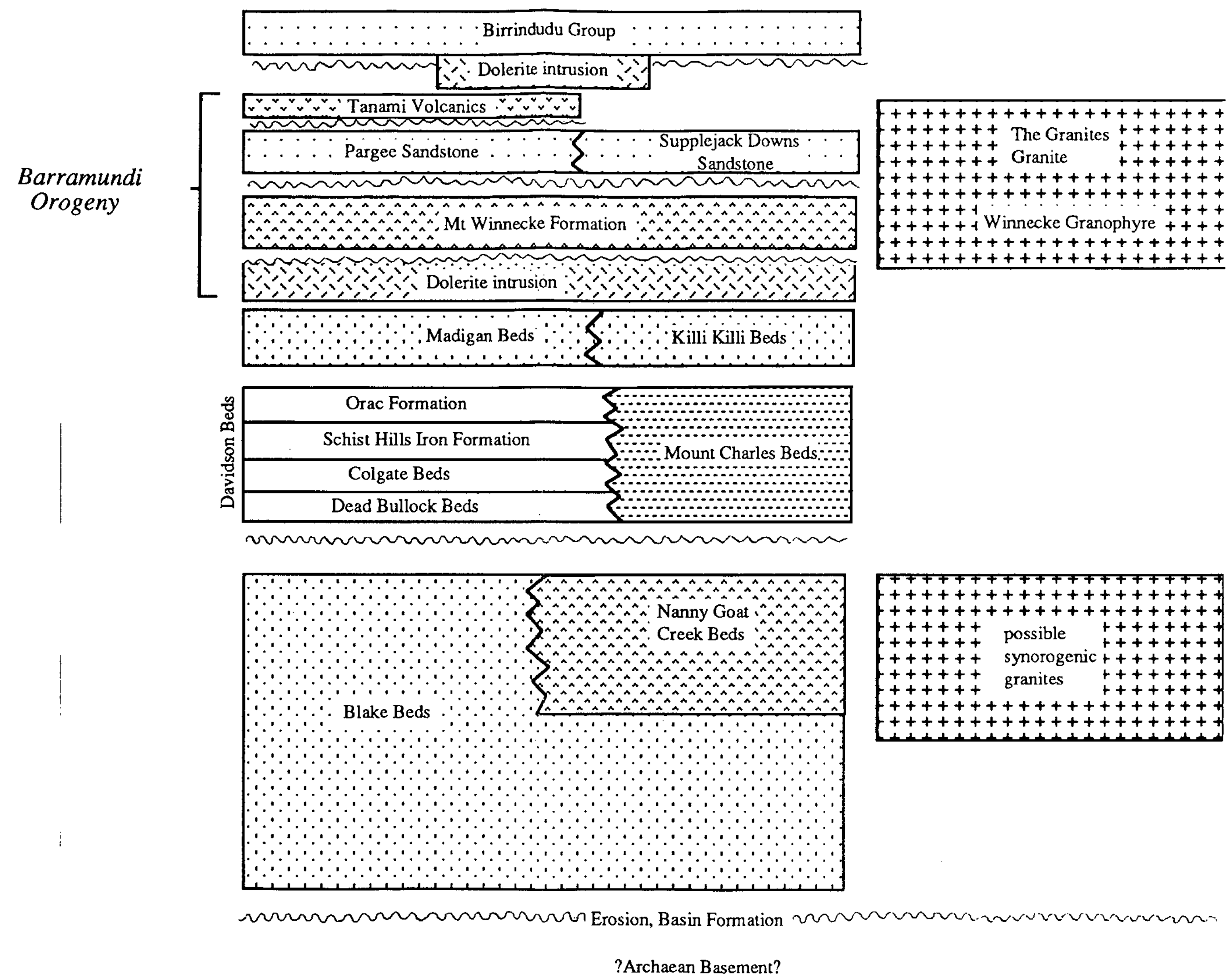


Figure 6: Correlation of the Tanami Block with the Pine Creek Inlier, showing similarities in stratigraphy and tectonic evolution between the two provinces.

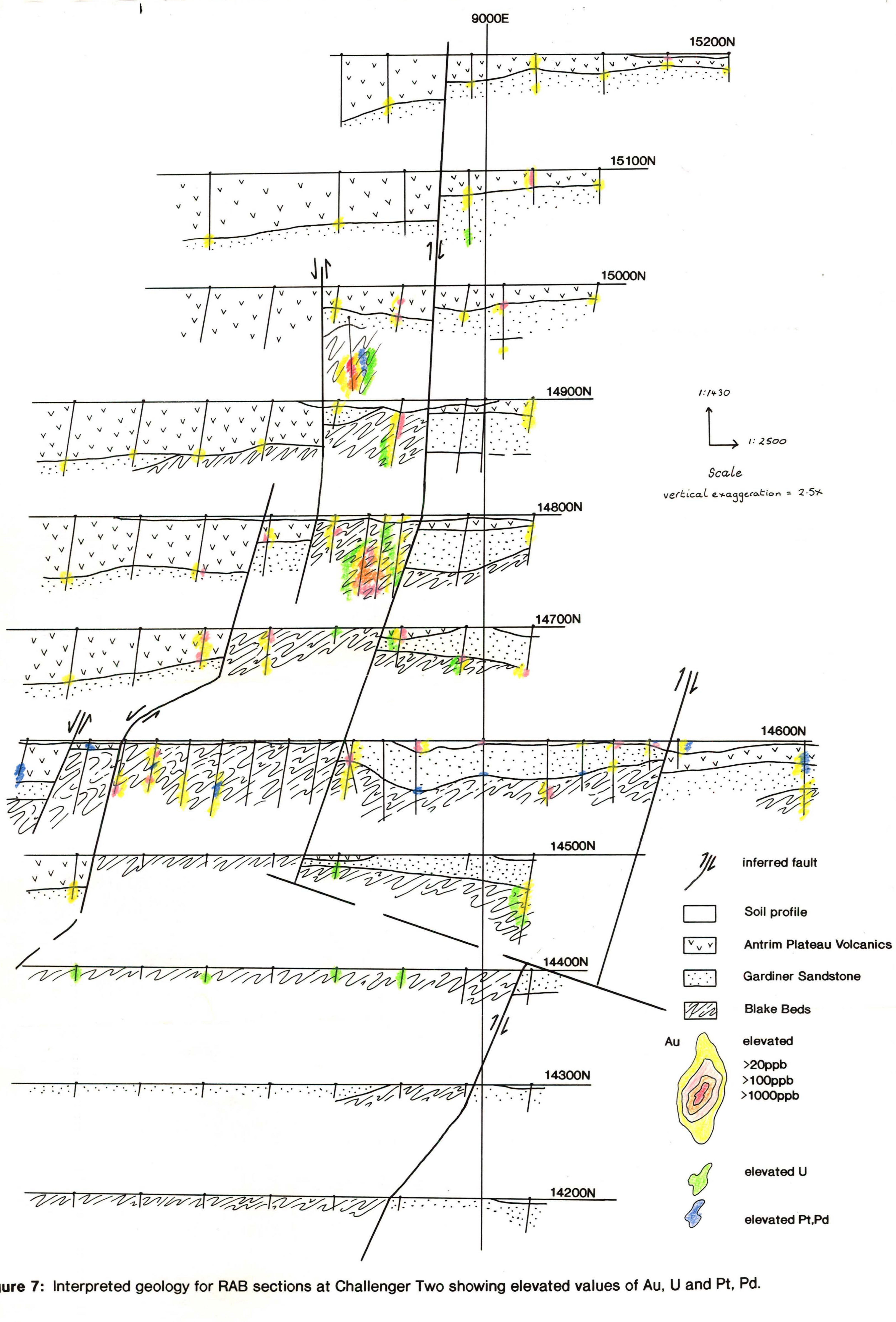


Figure 7: Interpreted geology for RAB sections at Challenger Two showing elevated values of Au, U and Pt, Pd.

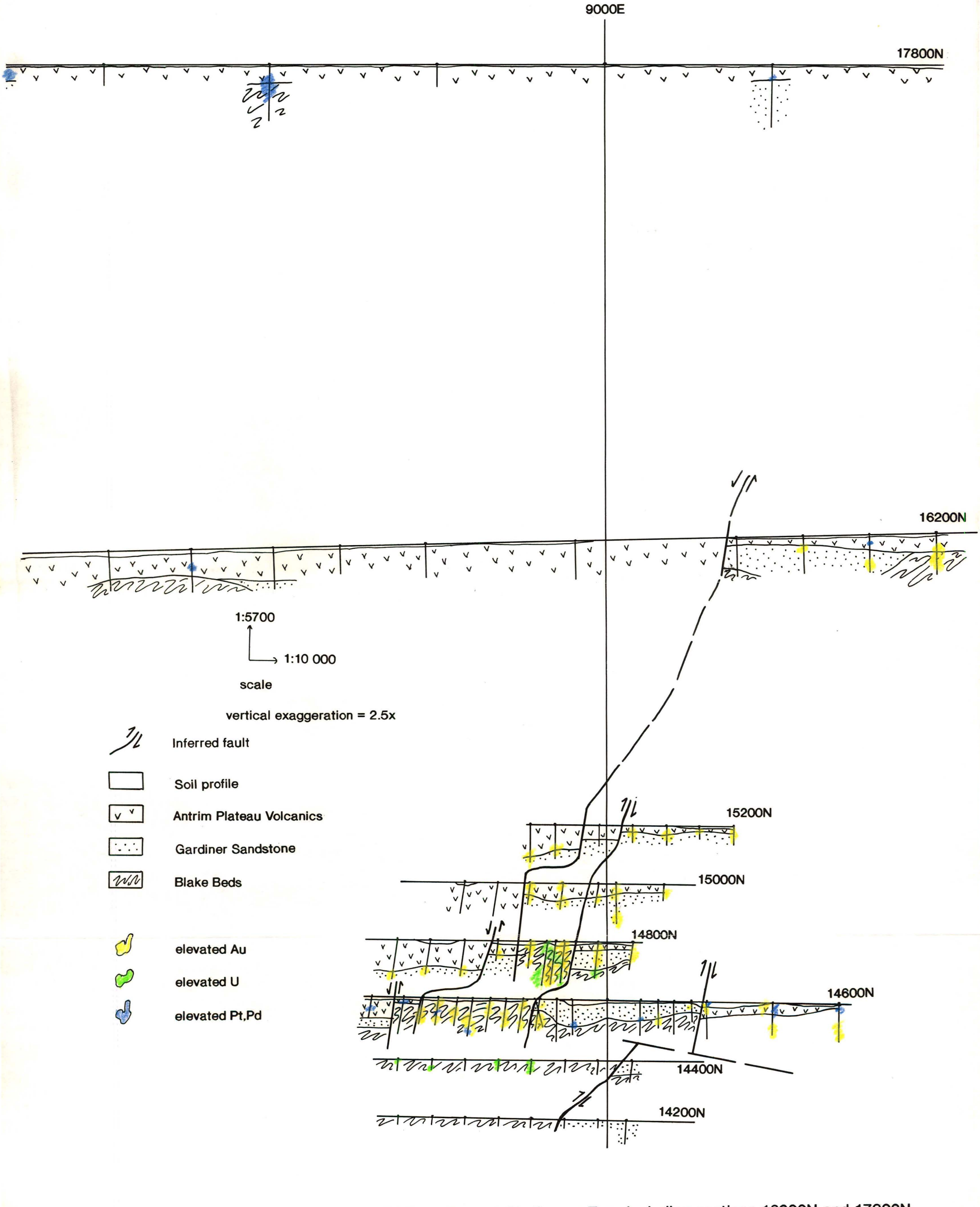


Figure 7: Interpreted geology for RAB sections at Challenger Two, including sections 16200N and 17800N.

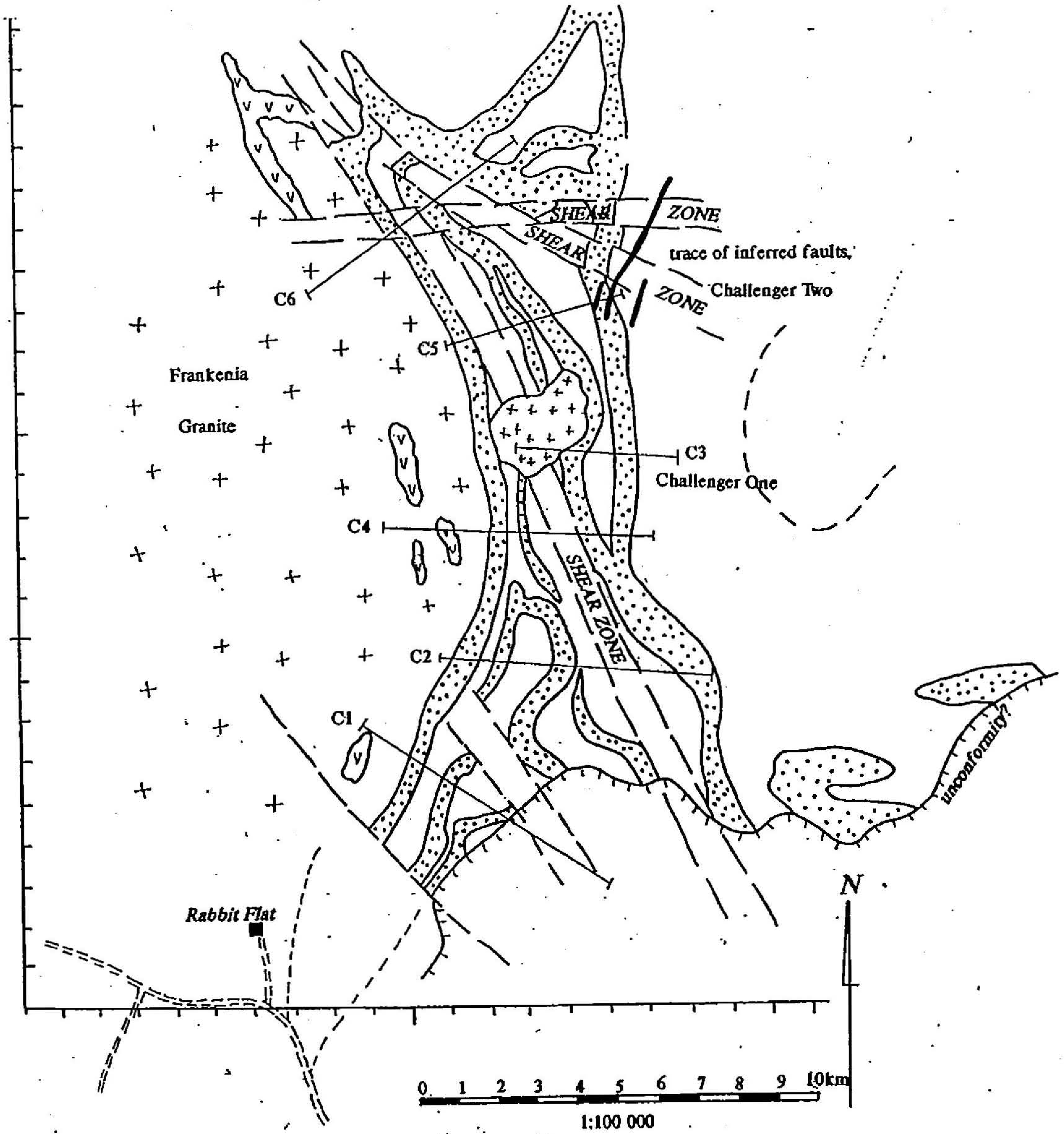
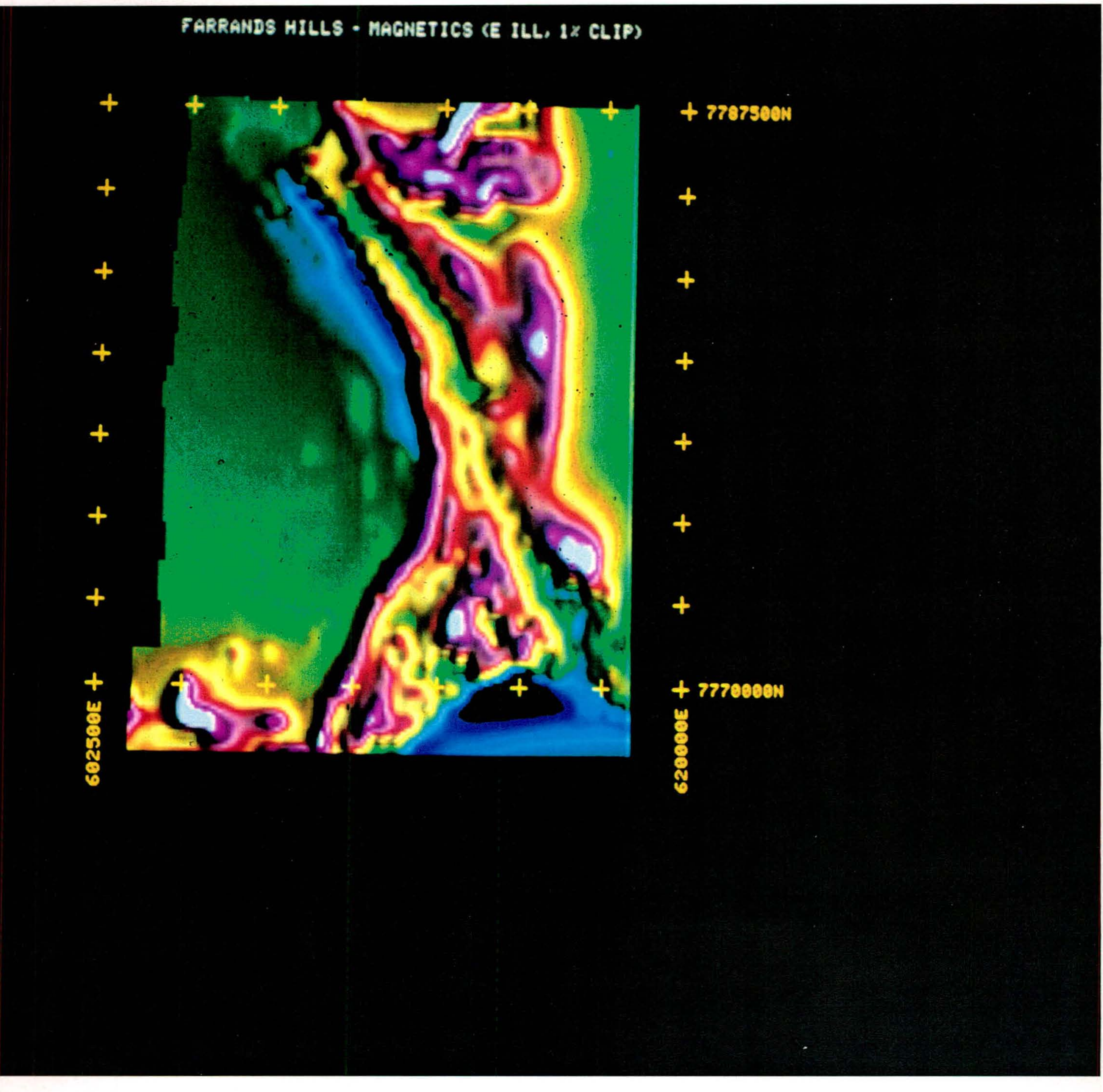
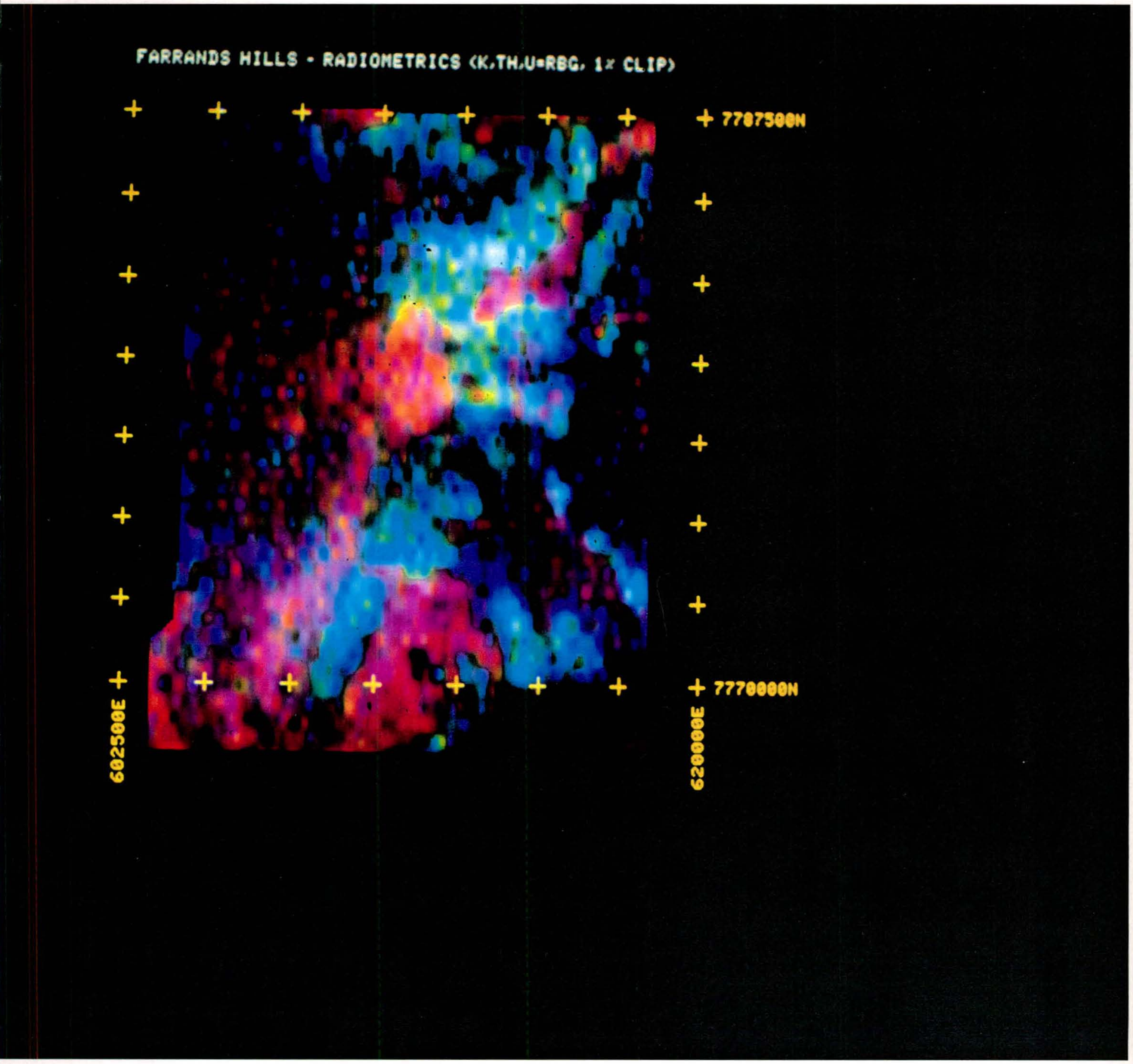
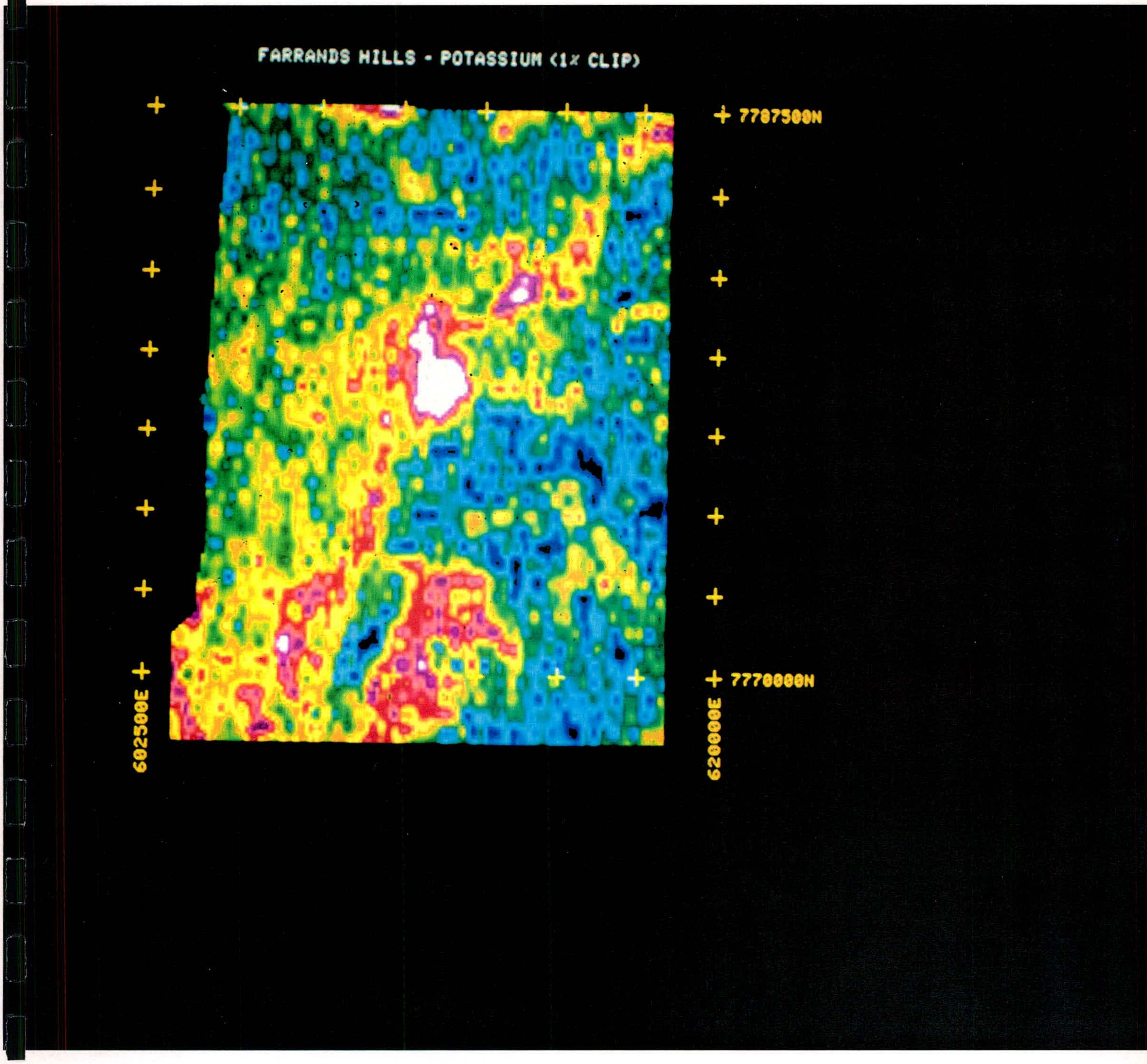


Figure 8: Simplified interpretation of airborne magnetic data (from S.Hogan & N.Bryce, 1992) showing location of the Challenger Two prospect with respect to magnetically interpreted structures.


FARRANDS HILLS - MAGNETICS (E ILL, 1% CLIP)
7787500N
7770000N
602500E
620000E


FARRANDS HILLS - RADIOMETRICS (K,TH,U=RBG, 1% CLIP)
7787500N
7770000N
602500E
620000E


FARRANDS HILLS - POTASSIUM (1% CLIP)
7787500N
7770000N
602500E
620000E

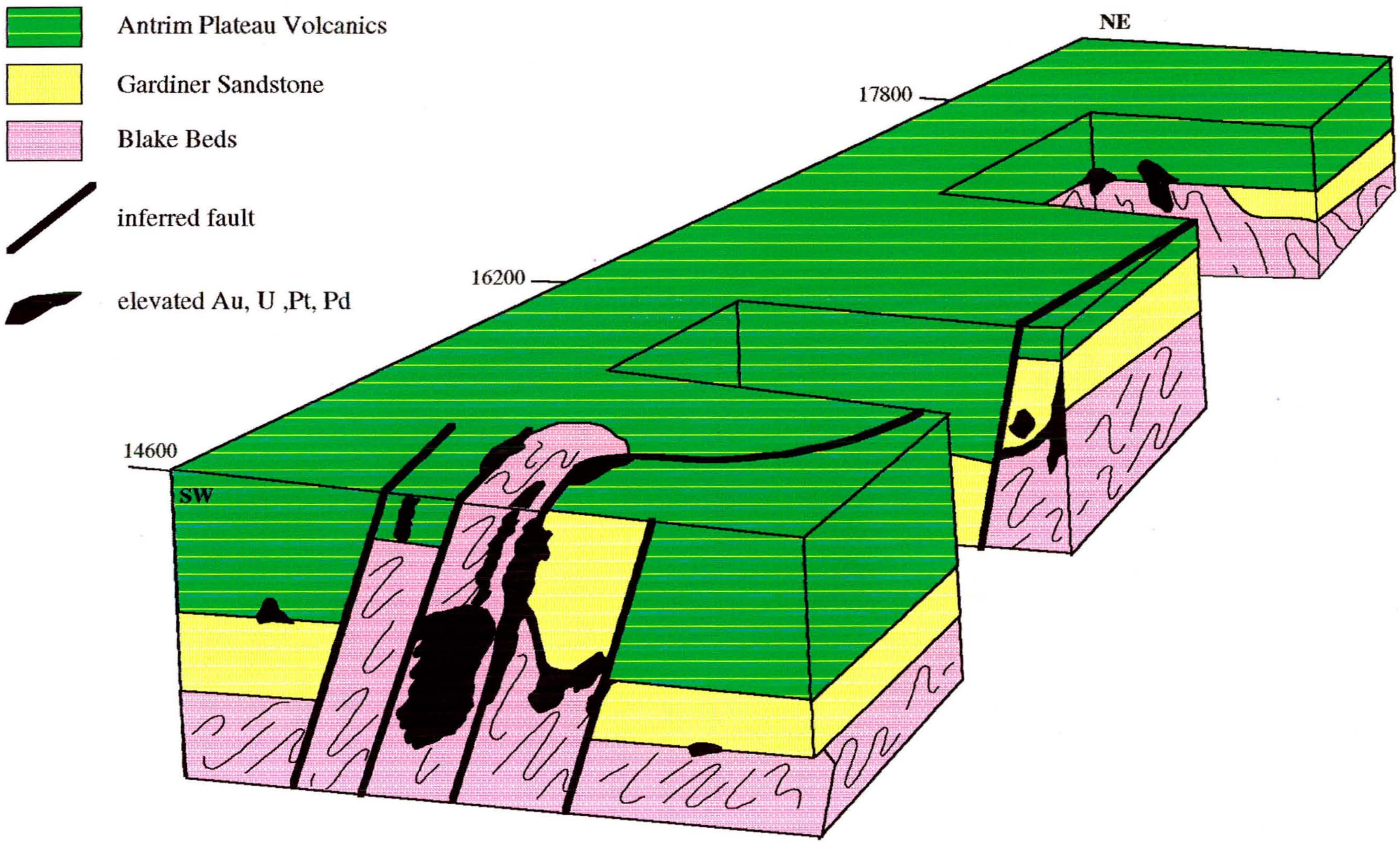
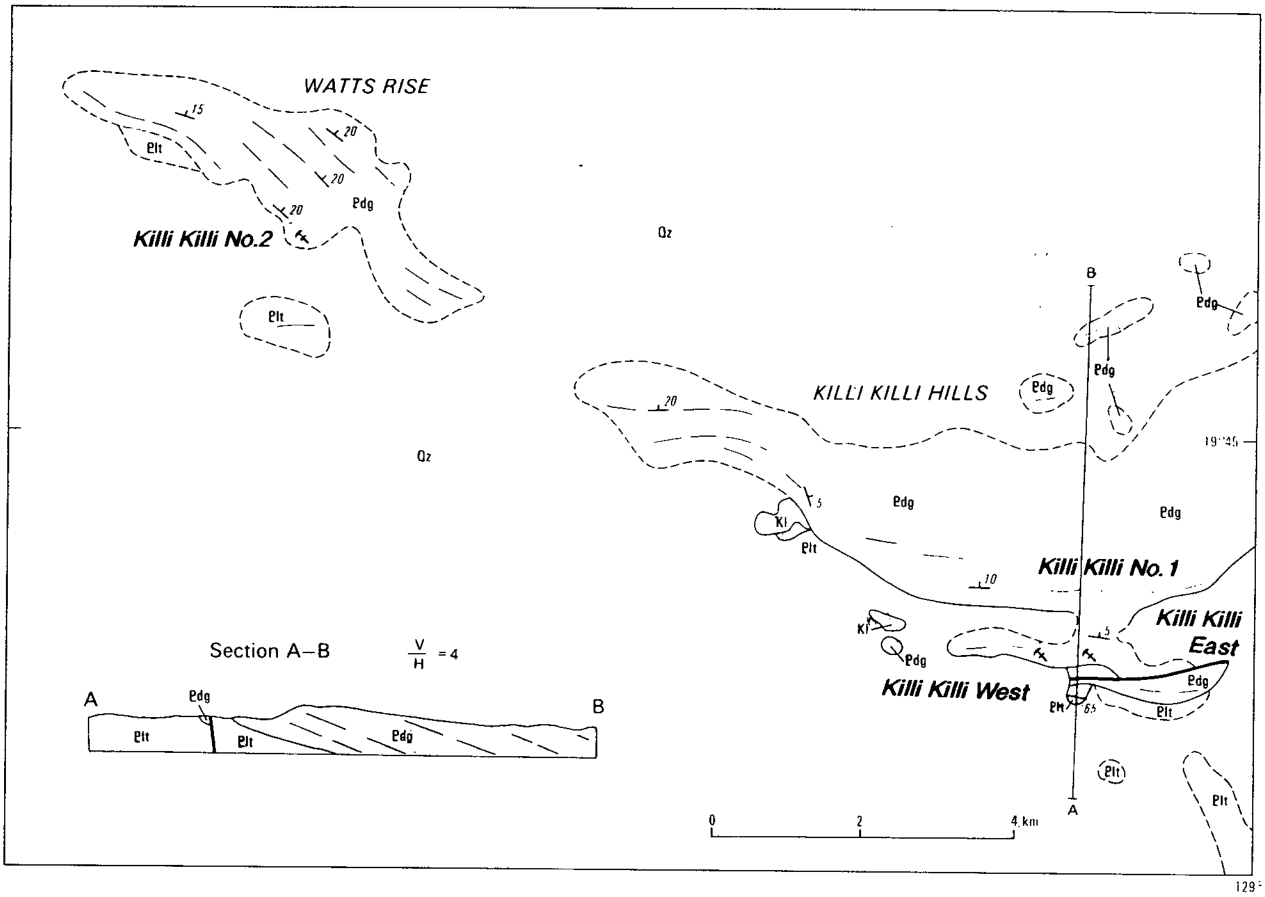


Figure 9: Schematic block diagram modelling geological controls on mineralisation at Challenger Two, based on interpretation of RAB drillhole sections.



Qz	Sand
Kl	Larranganni Beds
Ꞓdg	Gardiner Sandstone
Ꞓlt	Killi Killi Beds

Geological boundary, broken where approximate

Fault

Trend of bedding

Strike and dip of strata

Uranium prospect

Figure 10: Location of the Killi Killi Hills prospects

Appendix 1: Mineral Deposit Database for South Alligator Valley Uranium Field.

1. Commodity/Status/Production/Development
2. Discovery
3. Airborne Radiometric Signatures (BMR 1988 Airborne Geophysical Survey Results)
4. Mineralogy
5. Significant Rock Chip Results
6. Significant Stream Sediment Results
7. Prospect and mine evaluation
8. Mine and Prospect data (Needham, 1987)
9. Mineral production (Needham, 1987)
10. Geological Features of the larger uranium deposits (Needham, 1987)
11. Geological sections through the larger uranium deposits (Needham, 1987)

	Deposit	Commodity	Status	Production	Development
1.	9600NW	U	Prospect		
2.	9200NW	U	Prospect		
3.	Airstrip	U	Prospect		
4.	Airstrip NE anomaly	U	Prospect		
5.	Stag Creek /Stag Creek West	U	Prospect		
6.	El Sherana North No.1	U	Prospect		
7a.	El Sherana West No.1	U, Au,Ag	Mine	185 tonnes U_3O_8 @ 0.82% U_3O_8 0.007 tonnes Au; minor Ag	Open Cut & Underground
7b.	El Sherana West No. 2	U	Prospect		
8a.	El Sherana	U,Au	Mine	225 tonnes of U_3O_8 @ 0.55% U_3O_8 0.33 tonnes Au	Open Cut
8b.	Area north of El Sherana	U	Prospect		
8c.	El Sherana East	U	Prospect		
9.	High Road	U	Prospect		
10.	South Alligator Fault	U	Prospect		
11.	Stockpile No.1	U	Prospect		
12.	Stockpile No.2	U	Prospect		
13.	Flying Fox	U	Prospect		
14.	Charvats	U	Prospect		
15.	Orchid Gully	U	Prospect		
16.	Monolith	U	Prospect		

	Deposit	Commodity	Status	Production	Development
17.	Koolpin Creek	U	Mine	3 tonnes U_3O_8 @ 0.13% U_3O_8	Open Cut
18.	Koolpin East	U	Prospect		
19.	Scinto 6	U	Mine	3 tonnes U_3O_8 @ 0.15% U_3O_8	Open Cut
20.	Scinto 5 North	U	Mine	22 tonnes U_3O_8 @ 0.37% U_3O_8	Open Cut
21.	Scinto 5 South	U	Prospect		
22.	Cliff Face	U	Prospect		
23.	Scinto 1, No.1 Adit	U	Prospect		
24.	Scinto 1, No.2 Adit	U	Prospect		
25.	Palms	U	Prospect		
26.	Scinto Camp	U	Prospect		
27.	Palette No.5 Adit	U,Au	Mine	~ 10 tonnes unknown grade	Underground
28.	Palette No.4 Adit	U	Prospect		
29.	Palette No.6	U	Prospect		
30.	Palette No. 1	U,Au	Mine	124 tonnes U_3O_8 @2.45% U_3O_8 ore averaged 66ppm Au; some Hg	Underground
31.	Palette No. 2	U,Au	Mine	Incorporated in Palette No.1 Figures	Underground
32.	Palette No. 7	U,Au	Mine	Incorporated in Palette No.1 Figures	Underground
33.	Palette No. 3	U	Prospect		
34.	Skull	U,Au	Mine	3 tonnes U_3O_8 @ 0.50% U_3O_8	Underground
35.	Skull 2	U	Prospect		
36.	Clear Springs	U	Prospect		
37.	Saddle Ridge	U	Mine	78 tonnes U_3O_8 @ 0.24% U_3O_8	Open Cut

	Deposit	Commodity	Status	Production	Development
38.	Saddle Ridge Northeast	U	Prospect		
39.	Saddle Ridge East	U	Prospect		
40.	Saddle Ridge South	U	Prospect		
41.	Saddle Ridge East Extended	U	Prospect		
42.	Pul Pul Hill North	U	Prospect		
43.	Pul Pul Hill South	U	Prospect		
44.	Callanans	Cu	Prospect		
45.	Coronation Hill	U,Au	Mine	75 tonnes U_3O_8 @ 0.26% U_3O_8 ; some Au	Open Cut
46.	Coronation Hill Southwest	U	Prospect		

	Deposit	Discovery
1.	9600NW	Radiometric anomaly
2.	9200NW	Discovered during detailed radiometric gridding & mapping carried out at 9600NW
3.	Airstrip	Airborne radiometric anomaly
4.	Airstrip NE anomaly	Shaley rocks in volcanics/sandstones/conglomerates located during sampling program in 1970
5.	Stag Creek /Stag Creek West	Negative Self Potential anomaly
6a.	El Sherana North No.1	Self Potential Anomaly
6b.	El Sherana North No.2	Self Potential & radiometric anomalies
7a.	El Sherana West No.1	Self Potential & radiometric anomalies
7b.	El Sherana West No. 2	Self Potential anomaly
8a.	El Sherana	Radiometric anomaly (ground prospecting)
8b.	Area north of El Sherana	North extension of El Sherana delineated by wagon drilling
8c.	El Sherana East	Self Potential anomaly
9.	High Road	Radiometric anomaly
10.	South Alligator Fault	Strong linear radiometric anomaly
11.	Stockpile No.1	Surface radiometric anomaly
12.	Stockpile No.2	Radiometric anomaly
13.	Flying Fox	Extensive radiometric anomaly
14.	Charvats	Discovered by following up a mineralised float
15.	Orchid Gully	Airborne radiometric anomaly
16.	Monolith	Radiometric anomaly
17.	Koolpin Creek	Radiometric anomaly
18.	Koolpin East	Surface radioactivity was found to be associated with "banded ironstone"
19.	Scinto 6	Radiometric anomaly

	Deposit	Discovery
20.	Scinto 5 North	Ground radiometrics
21.	Scinto 5 South	Weak radioactivity & some uranium mineralisation over ~600m, along strike from Scinto 5 North
22.	Cliff Face	Radiometric anomaly
23.	Scinto 1, No.1 Adit	Following up radioactive boulders at the camp located at the Saddle Ridge & Kooplin Gorge roads
25.	Palms	Following up radioactive boulders at the camp located at the Saddle Ridge & Kooplin Gorge roads
24.	Scinto 1, No.2 Adit	Following up radioactive boulders at the camp located at the Saddle Ridge & Kooplin Gorge roads
26.	Scinto Camp	Investigative adit along the normal fault controlling mineralisation at Palette No.1
27.	Palette No.5 Adit	Adit tested the mineral potential of the fault contact between Coronation Sandstone & basement
28.	Palette No.4 Adit	Adit tested the extension of the fault system in the Palette No.1 area
29.	Palette No.6	Adit tested the extension of the fault system in the Palette No.1 area
30.	Palette No. 1	Ground follow up of radiometric anomaly. Uranium secondaries at the surface.
31.	Palette No. 2	Adit tested at depth, the extension of the mineralised faults in the Palette No.1 area
32.	Palette No. 7	Adit tested at depth, the extension of the mineralised faults in the Palette No.1 area
33.	Palette No. 3	Adit tested a surface showing of secondary mineralisation
34.	Skull	Radiometric anomaly
35.	Skull 2	Self potential anomaly
36.	Clear Springs	High surface radioactivity found
37.	Saddle Ridge	Random radiometric ground traverses with secondary minerals occurring in shallow trenches
38.	Saddle Ridge Northeast	Radiometric anomaly
39.	Saddle Ridge East	Prospect discovered during BMR geological mapping of the area in 1960
40.	Saddle Ridge South	Radiometric anomaly

	Deposit	Discovery
41.	Saddle Ridge East Extended	No details available
42.	Pul Pul Hill North	Small radiometric anomaly
43.	Pul Pul Hill South	Small radiometric anomaly
44.	Callanans	Copper show on a quartz blow
45.	Coronation Hill	Discovered during investigation of the Callanans copper prospect
46.	Coronation Hill Southwest	Discovered by regional mapping

	Deposit	Airborne Radiometric signatures (BMR 1988 Airborne Geophysical Survey Results)
1.	9600NW	Does not show up as a uranium anomaly. Appears as a uranium^2/thoriuim anomaly
2.	9200NW	Shows up as a small uranium anomaly, and a uranium^2/thoriuim anomaly
3.	Airstrip	Significant uranium anomaly, and a uranium^2/thoriuim anomaly
4.	Airstrip NE anomaly	No significant airborne radiometric anomaly
5.	Stag Creek /Stag Creek West	One **uranium** anomaly exists in the Stag Creek West area. Also a **uranium^2/thoriuim** anomaly
6a.	El Sherana North No.1	No significant radiometric anomaly
6b.	El Sherana North No.2	Large **uranium** anomaly enhanced by the old workings
7a.	El Sherana West No.1	Large **thorium** anomaly. Uranium anomaly reflects the old workings
7b.	El Sherana West No. 2	Large **thorium** anomaly. Uranium anomaly reflects the old workings
8a.	El Sherana	Large **thorium** anomaly. Uranium anomaly reflects the old workings
8b.	Area north of El Sherana	Large **thorium** anomaly. Uranium anomaly reflects the old workings
8c.	El Sherana East	**Uranium^2/thoriuim** anomaly
9.	High Road	Part of large **thorium** anomaly covering ridge to the north of El Sherana
10.	South Alligator Fault	No radiometric anomaly
11.	Stockpile No.1	No radiometric anomaly
12.	Stockpile No.2	**Uranium** anomaly and **uranium^2/thoriuim** anomaly
13.	Flying Fox	**Thorium** and **uranium** anomaly
14.	Charvats	Part shows up as a small **uranium** anomaly. The rest is part of a large regional **thorium** high extending from El Sherana
15.	Orchid Gully	No uranium anomaly. Part of regional **thorium** anomaly extending from El Sherana
16.	Monolith	No radiometric anomaly
17.	Koolpin Creek	No radiometric anomaly

	Deposit	Airborne Radiometric signatures (BMR 1988 Airborne Geophysical Survey Results)
18.	Koolpin East	Small **uranium^2/thoriuim** anomaly
19.	Scinto 6	Significant **uranium** anomaly and **uranium^2/thoriuim** anomaly
20.	Scinto 5 North	Prominent **uranium** anomaly which may reflect waste ore dumps. Major **uranium^2/thoriuim** anomaly
21.	Scinto 5 South	**Uranium^2/thoriuim** anomaly
22.	Cliff Face	Significant **uranium** anomaly, possibly reflecting old workings. Also a **uranium^2/thoriuim** anomaly
23.	Scinto 1, No.1 Adit	Prominent **uranium^2/thoriuim** anomaly
24.	Scinto 1, No.2 Adit	Small **uranium^2/thoriuim** anomaly
25.	Palms	No radiometric anomaly
26.	Scinto Camp	Small **uranium^2/thoriuim** anomaly
27.	Palette No.5 Adit	
28.	Palette No.4 Adit	
29.	Palette No.6	
30.	Palette No. 1	The Palette area is a strong radiometric anomaly. This may reflect to some extent the dumps, some of which contain regions of 1000 cps
31.	Palette No. 2	
32.	Palette No. 7	
33.	Palette No. 3	
34.	Skull	**Uranium** anomaly and **uranium^2/thoriuim** anomaly
35.	Skull 2	No radiometric anomaly
36.	Clear Springs	**Thorium** anomaly

	Deposit	Airborne Radiometric signatures (BMR 1988 Airborne Geophysical Survey Results)
37.	Saddle Ridge	Radiometrically anomalous. Prominent **uranium** and **uranium^2/thoriuim** anomaly, mainly reflecting old workings. An area to the west and northwest of the mine shows as a significant **thorium** anomaly
38.	Saddle Ridge Northeast	No radiometric anomaly
39.	Saddle Ridge East	Part of a major radiometric anomaly, high in both **thorium & uranium.** May be on edge of Saddle Ridge mine anomaly
40.	Saddle Ridge South	Significant **uranium** and **uranium^2/thoriuim** anomaly
41.	Saddle Ridge East Extended	No radiometric anomaly
42.	Pul Pul Hill North	Major **thorium** anomaly
43.	Pul Pul Hill South	Major **thorium** anomaly
44.	Callanans	Prospect covered by the large **uranium** anomaly over the old Coronation Hill workings
45.	Coronation Hill	
46.	Coronation Hill Southwest	Part of a large **thorium** anomaly

	Deposit	Mineralogy
1.	9600NW	No visible mineralisation. Abundant limonite & hematite at surface
2.	9200NW	No visible mineralisation. Abundant limonite & hematite in fracture zones at surface
3.	Airstrip	No visible mineralisation at surface
4.	Airstrip NE anomaly	No visible mineralisation at surface
5.	Stag Creek /Stag Creek West	No visible mineralisation at surface
6.	El Sherana North No.1	No significant visible mineralisation at surface
6b.	El Sherana North No.2	No visible mineralisation at surface
7a.	El Sherana West No.1	Ore consists of massive pitchblende with some gold
7b.	El Sherana West No. 2	No visible mineralisation at surface
8a.	El Sherana	Ore = massive segregations, veins & disseminations of pitchblende with cobalt, nickel arsenides, arsenopyrite, pyrite, marcasite, copper sulphate, galena & clausthalite. Native gold occurred in pitchblende. Secondary U minerals at surface
8b.	Area north of El Sherana	No visible outcrop of mineralisation
8c.	El Sherana East	No visible mineralisation at surface
9.	High Road	No visible mineralisation at surface
10.	South Alligator Fault	No visible mineralisation at surface
11.	Stockpile No.1	Secondary uranium mineralisation visible at surface
12.	Stockpile No.2	Secondary uranium mineralisation recorded at surface
13.	Flying Fox	Minor fine-grained pitchblende & secondaries in altered Pul Pul Rhyolite close to a cross fault
14.	Charvats	Some uranium secondaries & hematite observed
15.	Orchid Gully	No visible mineralisation
16.	Monolith	Traces of torbernite at the surface

	Deposit	Mineralogy
17.	Koolpin Creek	Sooty pitchblende & thin stringers of pitchblende in fractures
18.	Koolpin East	Some hematite & limonite at the surface
19.	Scinto 6	Secondary U mineralisation: autunite, torbernite, saleeite. Forms near-surface patches in a shear zone & adjacent joints
20.	Scinto 5 North	Secondary U minerals (mainly torbernite) & minor pitchblende at carbonaceous shale/cherty ferruginous shale contact
21.	Scinto 5 South	Some secondary mineralisation at surface, abundant limonite
22.	Cliff Face	Pods of pitchblende in black, carbonaceous shale surrounded by disseminated halo. Secondary U minerals in fault breccia
23.	Scinto 1, No.1 Adit	Abundant U secondaries in adit & surrounds. Pyrite, phosphate & pitchblende recorded
24.	Scinto 1, No.2 Adit	Some secondary U mineralisation at the surface
25.	Palms	No visible mineralisation at the surface
26.	Scinto Camp	No visible mineralisation at the surface
27.	Palette No.5 Adit	The ore mined was a small pod of pitchblende
28.	Palette No.4 Adit	No economic mineralisation intersected
29.	Palette No.6	No visible mineralisation at the surface
30.	Palette No. 1	Vein & nodular pitchblende, & native Au occurring partially as inclusions in the pitchblende, along shrinkage cracks filled with secondary minerals and forming veins up to several mm in width. Pyrite, chalcopyrite, galena, marcasite, coloradoite & clausthalite (PbSe), anglesite & hematite present. Secondary U minerals include phosphuranylite, uranophane, torbernite & metatorbernite. Gangue = apatite, sericite, hematite & tourmaline
31.	Palette No. 2	As above
32.	Palette No. 7	As above

	Deposit	Mineralogy
33.	Palette No. 3	Some secondary uranium minerals present
34.	Skull	Irregular nodular concentration of pitchblende in shears
35.	Skull 2	No visible mineralisation at the surface
36.	Clear Springs	No visible mineralisation at the surface
37.	Saddle Ridge	Ore chiefly secondary uranium minerals: torbernite & autunite. Pitchblende in deep drill holes. No gold recorded in ore
38.	Saddle Ridge Northeast	Scattered torbernite occurs at the surface
39.	Saddle Ridge East	Secondary U minerals (torbernite) recorded in sandstone and in vesicles in the volcanics
40.	Saddle Ridge South	Secondary U mineralisation at the surface
41.	Saddle Ridge East Extended	No visible mineralisation at the surface
42.	Pul Pul Hill North	No visible mineralisation at the surface
43.	Pul Pul Hill South	No visible mineralisation at the surface
44.	Callanans	Malachite is found on surface outcrops
45.	Coronation Hill	U mineralisation comprised disseminated & patchy sooty pitchblende with minor green secondary minerals at surface. Two types of Au-Pt-Pd mineralisation have been recognised: 1) Au/Pt/Pd/selenide association represented by gold in both pure & silver-bearing varieties; clausthalite (PbSe); Stibiopalladinite (Pd_5Sb_2); rare precious metal phases; sulphides generally absent 2) Au/Pt/Pd/selenide/sulphide association; above mineral phases are associated with replacive pyrite in altered igneous rocks; Sulphide mineral content is generally low with minor pyrite (some nickel-bearing), & trace marcasite, pyrrhotite, sphalerite, chalcopyrite & galena
46.	Coronation Hill Southwest	Autunite & torbernite visible with some wavellite

	Deposit	Maximum Rock Chip Values						
		Au ppb	Pd ppb	Pt ppb	U ppm	As ppm	Cu ppm	Others
1.	9600NW	<10	<10	<10	502		423	
2.	9200NW	<7	<7	<7	131	110	174	
3.	Airstrip	17.6	53.6	16.4	143	94		
4.	Airstrip NE anomaly							P205 = 1.29% depleted Na, Ca
5.	Stag Creek /Stag Creek West	10						Ba =1029ppm Mn = 735ppm
6a.	El Sherana North No.1	n.s.						
6b.	El Sherana North No.2	n.s.						
7a.	El Sherana West No.1	n.s.						
7b.	El Sherana West No. 2	n.s.						
8a.	El Sherana	n.s.						
8b.	Area north of El Sherana	<10	<10	<10				365ppm La, 930ppm Ce, 521ppm Nd,1630ppm Sr, 415ppm Zr, LREE enriched, depleted Na & Ca
8c.	El Sherana East	n.s.						
9.	High Road	214	21.4					
10.	South Alligator Fault	2.1	1.1	1.1		160		
11.	Stockpile No.1				83.8			Na & Ca < 0.17 wt%
12.	Stockpile No.2	22.9		13	269	230	1665	2864 ppm Ba, Na & Ca depletion
13.	Flying Fox	723			30.6	24-47		254 ppm Pb

	Deposit	Maximum Rock Chip Values						
		Au ppb	Pd ppb	Pt ppb	U ppm	As ppm	Cu ppm	Others
14.	Charvats	397.5			2380	37-56		618 ppm Ba, 45.8 & 407 ppm Pb
15.	Orchid Gully							817 ppm Cr
16.	Monolith	44.6	17.2	10.9	111	13-80		359-1434 ppm Ba
17.	Koolpin Creek	111	91.6	27.8	420			1330 ppm Ba
18.	Koolpin East							
19.	Scinto 6	30.5			647			1620 ppm Cr, 1007 ppm Ni, 2089 ppm Mn
20.	Scinto 5 North	n.s.						
21.	Scinto 5 South	60.3	<9.8	<9.8	88.9			1289ppm Cr, 352ppm Ni, 1782ppm Ba, 0.77% P_2O_5
21.	" " " loose boulders	1156-1907			2360-5620	38-80		808-5620 ppb Pb
22.	Cliff Face (shaft)	10975			14800	1300	496	2170 ppm Pb
22.	Cliff Face (bench)	148.5	4.46	2.39	48.1			
22.	Cliff Face (mullock heap)	27.4	17.7	13.7				
23.	Scinto 1, No.1 Adit	410	1.33	1.15	1026	510		401 ppm Pb, low Th (below detection limits)
23.	" " " mullock dump	1327-3523			9730-12100	230-600		1020-1270 ppm Pb
24.	Scinto 1, No.2 Adit							
25.	Palms	193		12.3	36	180		
26.	Scinto Camp	11				28		>4000-7075ppm Ba, 3.76 wt% P_2O_5, high Ca

	Deposit	Maximum Rock Chip Values						
		Au ppb	Pd ppb	Pt ppb	U ppm	As ppm	Cu ppm	Others
27.	Palette No.5 Adit							
28.	Palette No.4 Adit	23.6-25.3	10.1					1261 ppm Ba
29.	Palette No.6	55.1	30.8	30.5				4.61 wt% P_2O_5
30.	Palette No. 1	554.5	63.5	23.6	301			2.36 wt% P_2O_5
31.	Palette No. 2	18.3	181	21.6	467			1675 ppm Cr, 603 ppm Ni, 5060 ppm Pb
32.	Palette No. 7	36.4	26.1					5.22% P_2O_5, 1868ppm Ba 482ppm Cr, 149ppm Ni
33.	Palette No. 3	10.6						
34.	Skull	508.5	190	13.6	182			1.11 wt% P_2O_5 4450 ppm Ba
35.	Skull 2				84.4			5.73 wt% P_2O_5
36.	Clear Springs							Na, Ca & Th depletion
37.	Saddle Ridge				129			2416 ppm Ba
38.	Saddle Ridge Northeast				254			Na, Ca & Th depletion
39.	Saddle Ridge East					62		
40.	Saddle Ridge South							224 ppm Zn
41.	Saddle Ridge East Extended							
42.	Pul Pul Hill North					52	109	1187 ppm Th, 575 ppm Zr
43.	Pul Pul Hill South							
44.	Callanans	n.s.						
45/46.	Coronation Hill/SW	n.s.						

	Deposit	Best Stream Sediment Results								
		BCL (ppb)			Fire Assay (ppb)					Other deposits in drainage basin
		Au	Pd	Pt	Au	Pd	Pt	U ppm	Sampno	
1.	9600NW	0.6	0.32		6.6	0.8			90128001	northern part of 9200NW
2.	9200NW	n.s.								
3.	Airstrip	11	0.2		6.6	2.7	1.14	30.2		
4.	Airstrip NE anomaly	n.s.								
5.	Stag Creek /Stag Creek West	2.7	0.13		3.35	2.16	1.03	14.4	90128121	
6a.	El Sherana North No.1	14.4	0.27		10.9	2.68	1.62		90128011	north of El Sherana pit
6b.	El Sherana North No.2	243	4.7	0.88	195	21.4	8.36		90128127	
7a.	El Sherana West No.1	243	4.7	0.88	195	21.4	8.36		90128127	
7b.	El Sherana West No. 2	243	4.7	0.88	195	21.4	8.36		90128127	
8a.	El Sherana	243	4.7	0.88	195	21.4	8.36		90128127	
8b.	Area north of El Sherana	14.4	0.27		10.9	2.68	1.62		90128011	El Sherana North No.1
8c.	El Sherana East	28.1	1.4	0.25	31	4.72	2.73		90128014	High Road, Stockpile No.1
9.	High Road	28.1	1.4	0.25	31	4.72	2.73		90128014	El Sherana East, Stockpile 1
10.	South Alligator Fault	n.s.								
11.	Stockpile No.1	28.1	1.4	0.25	31	4.72	2.73		90128014	El Sherana East, High Road
12.	Stockpile No.2	n.s.								
13.	Flying Fox	1.5	0.26		2.47	0.89	0.65		90128015	
14.	Charvats	0.55	0.02			0.51			90128119	Orchid Gully
		0.86	0.07		1.71		0.68		90128018	Orchid Gully

	Deposit	Best Stream Sediment Results								
		BCL (ppb)			Fire Assay (ppb)					Other deposits in
		Au	Pd	Pt	Au	Pd	Pt	U ppm	Sampno	drainage basin
15.	Orchid Gully	0.55	0.02			0.51			90128119	Charvats
		0.86	0.07		1.71		0.68		90128018	Charvats
16.	Monolith	1.3	0.24		1.8	2.3	1.72		90128117	
17.	Koolpin Creek			1.31	1.04	0.99				
18.	Koolpin East	1.9	0.24		1.3	1.5	0.77		90128115	
19.	Scinto 6									
20.	Scinto 5 North	30.2	1.3	0.46	30.8	6.5	3.82		90128052	
21.	Scinto 5 South	30.2	1.3	0.46	30.8	6.5	3.82		90128052	
22.	Cliff Face	2.1	0.29		2.46	2.25	1.83		90128114	Palette No.5
23.	Scinto 1, No.1 Adit	30.2	1.3	0.46	30.8	6.5	3.82		90128052	
24.	Scinto 1, No.2 Adit	30.2	1.3	0.46	30.8	6.5	3.82		90128052	
25.	Palms	30.2	1.3	0.46	30.8	6.5	3.82		90128052	
26.	Scinto Camp	30.2	1.3	0.46	30.8	6.5	3.82		90128052	
27.	Palette No.5 Adit	2.1	0.29		2.46	2.25	1.83		90128114	Cliff Face
28.	Palette No.4 Adit									
29.	Palette No.6	2.6	0.16		3.34	0.93	1.01		90128022	Main Palette area, Skull 1&2
30.	Palette No. 1	2.6	0.16		3.34	0.93	1.01		90128022	Main Palette area, Skull 1&2
31.	Palette No. 2	2.6	0.16		3.34	0.93	1.01		90128022	Main Palette area, Skull 1&2
32.	Palette No. 7	2.6	0.16		3.34	0.93	1.01		90128022	Main Palette area, Skull 1&2
33.	Palette No. 3	2.6	0.16		3.34	0.93	1.01		90128022	Main Palette area, Skull 1&2

	Deposit	Best Stream Sediment Results								
		BCL (ppb)			Fire Assay (ppb)					Other deposits in
		Au	Pd	Pt	Au	Pd	Pt	U ppm	Sampno	drainage basin
34.	Skull	2.6	0.16		3.34	0.93	1.01		90128022	Main Palette area, Skull 1&2
35.	Skull 2	2.6	0.16		3.34	0.93	1.01		90128022	Main Palette area, Skull 1&2
36.	Clear Springs	0.21	0.03			0.51			89128013	
37.	Saddle Ridge	1.9	0.11		2.2				90128110	
		1.2	0.03						90128105	north part of Saddle Ridge E
		0.64	0.03		1.17		0.62	82.6	90128104	
38.	Saddle Ridge Northeast	11.1	0.14		23.4	12.6	10.2		90128103	
		0.4	0.03		1.46				90128108	
39.	Saddle Ridge East	1.2	0.03						90128105	northern part of Saddle Ridge
40.	Saddle Ridge South	0.19	0.01						90128106	
41.	Saddle Ridge East Extended	0.42	0.01		1.22				90128107	
42.	Pul Pul Hill North	13.9	0.06		25.7				90128101/90128102	
43.	Pul Pul Hill South	13.9	0.06		25.7				90128101/90128102	
44.	Callanans	n.s.								
45.	Coronation Hill	n.s.								
46.	Coronation Hill Southwest	n.s.								

Prospect	Altered Rocks Present	Main Faults within 150m	Favour-able Host Rocks	Local Shear Zones Present	Uncon-formity within 150m	Elevated Surface Geochem -istry	Gold Intersec-tions	Pre-vious mining
9600NW	✓	✓	✓	✓	✓	✓		
9200NW	✓	✓	✓	✓	✓	✓		
Airstrip	✓	✓	✓	✓	✓	✓		
Airstrip Northeast	✓	✓	✓	✓	✓			
Stag Creek	✓	✓	✓	✓	✓	✓		
El Sherana North	✓	✓	✓	✓	✓	✓	✓	
El Sherana West	✓	✓	✓	✓	✓	✓	✓	✓
El Sherana	✓	✓	✓	✓	✓	✓	✓	✓
El Sherana East	✓	✓	✓	✓	✓	✓		
High Road	✓	✓	✓	✓	✓	✓	✓	
South Alligator Fault	✓	✓	✓	✓				
Stockpile 1	✓	✓	✓	✓				
Stockpile 2	✓	✓	✓	✓		✓		
Flying Fox	✓	✓	✓	✓		✓		
Charvats	✓		✓	✓	✓	✓		
Orchid Gully	✓		✓	✓	✓	✓		
Scinto 6	✓	✓	✓	✓		✓	✓	
Monolith	✓	✓	✓	✓	✓	✓		
Koolpin Creek	✓	✓	✓	✓		✓	✓	✓
Koolpin East	✓	✓	✓	✓	✓	✓	✓	
Scinto 5 North	✓	✓	✓	✓	✓	✓	✓	✓
Scinto 5 South	✓	✓	✓	✓	✓	✓		
Scinto 1, No 1 adit	✓	✓		✓	✓	✓		
Scinto 1, No 2 adit	✓	✓	✓		✓			
Palms	✓	✓	✓	✓	✓	✓		
Scinto Camp	✓	✓	✓	✓	✓	✓		
Cliff Face	✓	✓	✓	✓	✓	✓	✓	✓
Palette 5	✓	✓	✓	✓	✓		✓	✓
Palette 4	✓	✓	✓	✓	✓	✓		
Palette 6	✓	✓	✓	✓	✓	✓		
Palette 1	✓	✓	✓	✓	✓	✓	✓	✓
Palette 2	✓	✓	✓	✓	✓	✓	✓	✓
Palette 7	✓	✓	✓	✓	✓	✓	✓	✓
Palette 3	✓	✓	✓	✓	✓	✓		
Skull 1	✓	✓	✓	✓	✓	✓	✓	✓
Skull 2	✓	✓	✓	✓	✓			
Clear Springs	✓	✓	✓	✓	✓			
Saddle Ridge NE	✓	✓	✓	✓	✓	✓		
Saddle Ridge	✓	✓	✓	✓	✓			✓
Saddle Ridge East	✓	✓	✓	✓	✓			
Saddle Ridge South	✓	✓	✓	✓			✓	
Saddle Ridge E Extend.	✓	✓	✓	✓	✓			
Pul Pul Hill North	✓	✓	✓	✓	✓	✓		
Pul Pul Hill South	✓	✓	✓		✓			
Callanans	✓	✓	✓	✓	✓	✓	✓	
Coronation Hill	✓	✓	✓	✓	✓	✓	✓	✓
Coronation Hill SW	✓	✓	✓	✓	✓			

Table 4.2. Important parameters present at each locality. Headings are explained in section 4.5.

Table 1 Mine and Prospect data for the Conservation Zone

No	Name	Grid reference	Metal(s)	Status, production	Host rocks	Style	Ore mineralogy
1	2J	KF1513	U	prospect <0.98% U_3O_8	Pns altered amygdaloidal basalt,tuff tuffaceous shale	near-surface oxidation lens, nearby minor fault	uranyl phosphate
2	Sandstone (north)	KF1710	U	prospect	Pep sandstone lenses in andesite	near-surface irregular	no visible mineralisation <300ppm U_3O_8,<14ppm at depth
3	Teagues	KF2509	U,Au	152tU_3O_8 @1.1% some gold (included in El Sherana Au production)	Psk,Pec carbonaceous or hematitic chert-banded shale,sandstone	irregular shoots 2cm-2m wide subparallel to Psk/Pec faulted contact,also in joints and shears and forming fine veinlets	pitchblende,near-surface secondaries, accessory pyrite,trace marcasite, chalcopyrite,lead,iron,copper selenides,gold
4	Rockhole No.1	KF2509					
5	Rockhole No.2	KF2509					
6	O'Dwyers	KF2608					
7	Sterrets No.2	KF2608					
8	Sterrets No.1	KF2608	U	prospect	Psk,Pec carbonaceous or hematitic chert-banded shale,sandstone	irregular mass <5cm along faulted Psk/Pec contact	'low-grade pitchblende ore'
9	Sandstone (south)	KF2506	U	prospect	Pep sandstone lenses in andesite	near-surface irregular	no visible mineralisation <300 ppm U_3O_8<14 ppm at depth
10	Airstrip	KF2906	U	prospect	Psk siltstone	near-surface irregular	no visible mineralisation x4 radioactivity
11	El Sherana North	KF3006	U	prospect	Psk ferruginous chert-banded siltstone	anomalous radioactivity	no visible mineralisation
12	El Sherana West	KF3105	U,Au,Ag	185tU_3O_8 @0.8% 0.007tAg	Psk cherty ferruginous siltstone, rare carbonaceous siltstone	irregular mass <20m below Phc unconformity,nearby faulted Psk/Pbc contact	veins,massive segregations(commonly nodular <25 cm) and disseminations of pitchblende cut by gold veinlets an minor galena and anglesite stringers
13	El Sherana	KF3105	U,Au	226tU_3O_8 @0.55% 0.33tAu	Psk cherty ferruginous siltstone, rare carbonaceous siltstone; Phc sandstone	carrot-shaped mass broadening in oxidised zone above unconformity (i.e. in Phc),nearby faulted Psk/Pbc contact	as for El Sherana West,also tail of secondary U minerals in oxidised zone, minor kasolite
14	High Road	KF3104	U	prospect	Psk ferruginous chert-banded siltstone	highly anomalous surface radioactivity	no visible mineralisation
15	Charvats Line	KF3205	U	prospect	Pbp rhyolite	irregular near-surface,nearby minor fault	secondary U minerals
16	Orchid Gully	KF3304	U	prospect			
17	Alligator Fault	KF3104	U	prospect			
18	Stockpile 1 (Boundary)	KF3204	U	prospect	Pbp altered rhyolite	near-surface disseminated; appear to lie close to small cross-faults	minor fine-grained pitchblende, yellow powdery secondaries
19	Stockpile 2 (Boundary)	KF3203	U	prospect			
20	Flying Fox	KF3203	U	prospect			
21	Monolith	KF3403	U	prospect	Psk ferruginous chert-banded siltstone	anomalous radioactivity near minor cross-fault,close to Psk/Pbc unconformity	no visible mineralisation
22	Koolpin	KF3403	U	3tU_3O_8 @0.12%	Psk sheared carbonaceous shale	fracture fillings to 15m depth, minor cross-faults.On possible extension of Palette Fault	sooty and massive pitchblende
23		KF3704	Cu	prospect	Psp shales	patchy near-surface	malachite
24	Scinto 6	KF3503	U	3tU_3O_8 @0.15%	Pbc sheared altered rhyolite	near-surface patches in shear zone and adjacent joints	secondary U minerals (autunite, torbernite,saleeite)
25	Koolpin East	KF3403	U	prospect	Psk ferruginous chert-banded siltstone	on NW extension of Palette Fault	no visible mineralisation
26	Scinto 5 (Daniels)	KF3402	U	22tU_3O_8 @0.4%	Psk bleached white and red ferruginous shale	irregular boundary adjacent to steep sheared contacts with Pbp altered volcanics	U secondaries,minor pitchblende
27	Scinto 5 South	KF3402	U	prospect	Psk ferruginous chert-banded siltstone	patchy mineralisation close to sheared Psk/Pbp contact	U secondaries
28	Cliff Face	KF3502	U	prospect	Psk ferruginous chert-banded siltstone with carbonaceous lenses	on NW fault,higher grades in carbonaceous lenses	pitchblende in carbonaceous lenses, disseminated secondary halo
29	Palette	KF3502	U,Au	124tU_3O_8 @2.5% some gold (included in El Sherana production)	Pbc mottled hematite apatite sandstone with reduction spots, Psk green siltstone and weathered ferruginous chert-banded siltstone	pipe inclined~45,transgresses Phc/Psk contact.Mineralisation in shears and fractures as veins and massive nodules.NW and N faults	vein and nodular pitchblende,veins of gold and minor pyrite,chalcopyrite, galena and marcasite.Phosphuranylite around pitchblende veins in sandstone; clausthalite,coloradoite, pitchblende nodules
30	Skull	KF3601	U	3tU_3O_8 @0.5%	Psk carbonaceous shale	irregular nodular ore in shears; close to flexure in Palette Fault	pitchblende nodules
31	Scinto 1	KF3501	U	prospect	Pbp altered rhyolite	fractures near minor N cross-fault	pitchblende,secondaries
32	Palm	KF3501	U	prospect	Pbp altered rhyolite		no visible mineralisation
33	Scinto Camp	KF3501	U	prospect	Pbp altered rhyolite	radioactive scree	no visible mineralisation
34	Christmas Creek	KF3400	U	prospect	Pbc sandstone,Pek conglomerate	anomalous radioactivity in brecciated Pbc/Pek fault contact	minor U secondaries
35	Clear Springs	KF3600	U	prospect	Pbp altered rhyolite		no visible mineralisation
36		KF3701	U	prospect	Pbc sandstone	talus	
37	Saddle Ridge North	KF3700	U	prospect	Pbc sandstone	anomalous radioactivity in breccia along Palette Fault	no visible mineralisation
38	Saddle Ridge (BMR No.2)	KF3600	U	78tU_3O_8 @0.2%	Psk bleached carbonaceous shales, Pbp rhyolite and tuff	steep tabular boundary on Psk/Pbp cross-fault contact	U secondaries,mainly metatorbenite, minor sooty pitchblende below orebody
39	Saddle Ridge East	KF3700	U	prospect	Pbp vesicular lava	irregular disseminated near-surface; on extension of Saddle Ridge cross-fault	disseminated torbernite,some in vesicles
40	Saddle Ridge South (BMR No.1)	KF3700	U	prospect	Pbs phosphatic hematitic cherty breccia over Psk carbonate	anomalous radioactivity in breccia near-surface,and in red clay pipes with carbonate at depth	no visible mineralisation
41	Saddle Ridge East Extended	KF3700	U	prospect	Psk ferruginous chert-banded siltstone	anomalous radioactivity,near Palette Fault	
42	Callanan's	KE4096	Cu	prospect	Pbc tuff,chert,sandstone	fracture fillings in and near quartz breccia filled cross-fault	malachite
43	Coronation Hill	KE4096	U,Au	75tU_3O_8 @0.3% some gold	Pbc polymictic debris flow conglomerate,altered volcanics	several steep shoots in a 20m cylindrical zone,some shoots of gold only	disseminated and patchy sooty pitchblende native gold disseminations and veinlets
44	Coronation South (Coronation Hill Southwest)	KE4096	U	prospect	Pbc rhyolite,sandstone	fracture fillings in and near N cross-fault~20m above Psk unconformity	minor U secondaries (autunite,torbernite) associated with wavellite
45	Zamu	KE5199	Pb,Ag	20tAg-Pb ore	Pdz dolerite,wedge of Pfb schist	several subparallel W veins in siliceous sheared altered dolerite breccia	argentiferous galena,cerussite
46		KE5690	U?	prospect	Pfb siltstone	tourmaline quartz lode	no visible mineralisation
47	Coirwong	JF9138	Cu	prospect	Psk pyritic siltstone, Pdz dolerite	near-surface irregular	minor surface staining
48	Coirwong Gorge	JF9237	U	prospect	Psk chert-banded hematitic siltstone	minor anomalous surface radioactivity	no visible mineralisation
49	SG	JF8936	U	prospect	Ppm sandstone/Pnm siltstone fault contact	minor anomalous surface radioactivity	no visible mineralisation
50	Gerowie Creek	KF0323	U	prospect	Ppm sandstone/Psk carbonaceous siltstone contact	radon anomalies along contact	no visible mineralisation
51		JF8527	Cu	prospect	Pns altered basalt and tuff	near-surface secondaries in shear	patchy malachite in gossan and weathered
52	Namoona	JF8424	Pb,Zn,Cu	prospect	Pnm carbonaceous pyritic dolomitic shale, siltstone, dolarenite	stratabound disseminated sulphides and massive shoots in veins and breccias	lead and minor zinc sulphides. Galena, cerussite and pyromorphite, visible in gossan
53		JF8126	Pb,Zn	prospect	Pnm shale	patchy surface secondaries in minor shear	minor smithsonite, hydrozincite in gossan
54		JF7729	Pb,Zn	prospect	Pnm shale	patchy surface secondaries in minor shear	minor smithsonite, hydrozincite in gossan

TABLE 2. MINERAL PRODUCTION FROM THE CONSERVATION ZONE

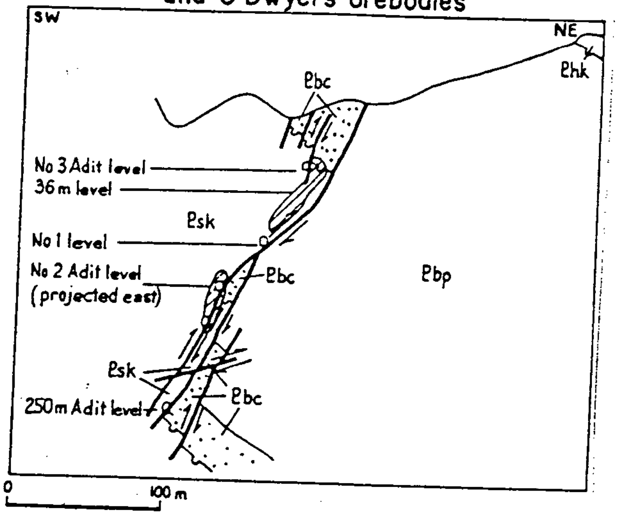
mine	element(s)	tonnes metal	grade
Rockhole Group	U	152t	1.1%
	Au	minor	
El Sherana West	U	185t	0.8%
	Au	0.007t	
	Ag	minor	
El Sherana	U	226t	0.55%
	Au	0.33t	
Koolpin	U	3t	0.12%
Scinto 6	U	3t	0.15%
Scinto 5	U	22t	0.4%
Palette	U	124t	2.5%
	Au	included in El Sherana prodn.	
Skull	U	3t	0.5%
Saddle Ridge	U	78t	0.2%
Coronation Hill	U	75t	0.3%
	Au	minor	
NEARBY MINES			
Sleisbeck	U	3t	0.4%
Zamu	Pb) Ag)	20t high-grade ore	
Minglo	Pb	6.8t	58%
	Ag	0.003t	138g/t

Table 3. *Geological features of* the larger uranium deposits (after Ayres & Eadington, 1975)

	El Sherana	Palette	Rockhole	Coronation Hill	Saddle Ridge	Scinto 6	Skull	Koolpin
Mineralogy	*pitchblende, secondary U minerals;* minor galena-clausthalite, pyrite, marcasite, Co-Ni arsenides, Cu sulphides	*pitchblende, U secondary minerals;* minor galena-clausthalite, coloradoite, pyrite, marcasite, gold	*pitchblende;* minor clausthalite, eskebornite pyrite, marcasite, chalcopyrite, rare U secondary minerals	*pitchblende, U secondary minerals* minor pyrite, Cu sulphides	all 'secondary' uranium minerals trace pyrite	'secondary' uranium minerals only	*pitchblende, secondary U minerals;* minor gold, Cu mineralization	*pitchblende,* secondary ur- nium mineral
Electron microprobe analysis of pitchblende	U Pb Fe Si U/Pb 80.4 7.0 0.4 0.2 11.6 80.9 7.4 0.8 0.3 11.0	U Pb Fe Si U/Pb 77.5 10.7 0.6 0.2 7.3 74.1 11.3 0.3 0.4 6.6						
Gangue	red and grey chert, quartz veinlets	siliceous gangue, apatite, introduced in to host sandstone	siderite	minor quartz veinlets	no introduced gangue, some chalcedony	no introduced gangue	no introduced gangue	no introduced gangue
Host rock	ferruginous siltstone and carbonaceous shale, secondary deposit of open cut in sandstone and rhyolite	sandstone	carbonaceous shale and chert, at higher levels near the unconformity, sandstone host	tuffaceous rocks intimately associated with carbonaceous shale and siltstones	Early Proterozoic siltstone and Middle Proterozoic tuffaceous sandstone and volcanics	rhyolite	sandstone	carbonaceous shale and ferru ginous siltston
Texture	lenticular pitchblende masses in a fault zone enveloped by secondary mineralization, abundant spherical nodules of pitchblende	rich ore shoots along a fault, spherical nodules of pitchblende imperfectly developed	narrow veins of pitchblende similar to Palette	sooty variety of pitchblende, some pitchblende veinlets	secondary U minerals filling joints and fractures	uranium ochres filling joints and fractures	pitchblende veinlets, nodules, sooty pitchblende	sooty pitchblende and sec ondary U minerals in thin stringers occupying fractures
Pitchblende	present	present	present	present	not present	not present	present	present
Carbonaceous shale	present	present	present	present	not present	not present	present	present
Gold	present	present	present	present	not present	not present	present	not present
Fault	present	present	present	present	present	present	present	present
Shape	tabular ore body tapering with depth		ore shoots form a ribbon dipping to west along a fault zone	a number of ore shoots at higher levels, at lower levels ore body is pipe like				
Vertical extent	120 ft (36.6 m)	100 ft (30.5 m)	200 ft (61 m)	180 ft (55 m)	80 ft (24.4 m)	120 ft (36.6 m)	—	50 ft (15.2 m)
Size (tonnes ore)	61200	5100	13260	26520	30600	1734	534	2244
Relation to igneous rocks	rhyolite overlying deposit	rhyolite overlying deposit	rhyolite overlying deposit and in fault contact with host rocks	rhyolite host for part of deposit intimately associated with other host rocks	tuffaceous rocks, host	rhyolite host	rhyolite overlying deposit	Middle Proterozoic rocks removed by erosion

Fig 4. THE ROCKHOLE GROUP

Composite section through Rockhole No 2 and O'Dwyers orebodies



Ehk - Kombolgie Fm
Ebp - Pul Pul Rhyolite
Ebc - Coronation Sst
Esk - Koolpin Fm

Plan

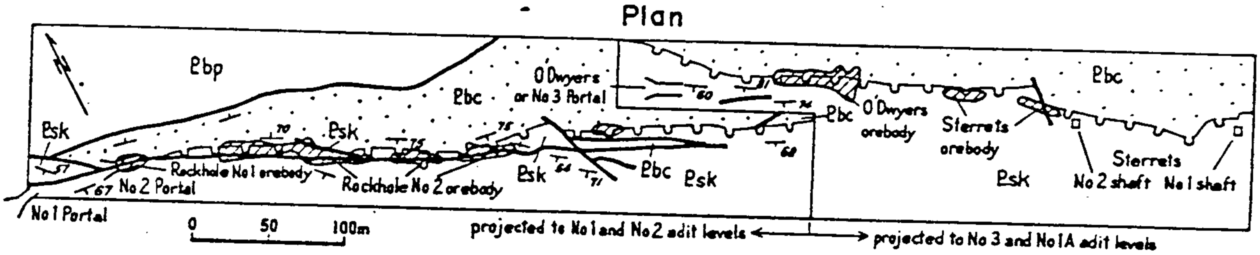
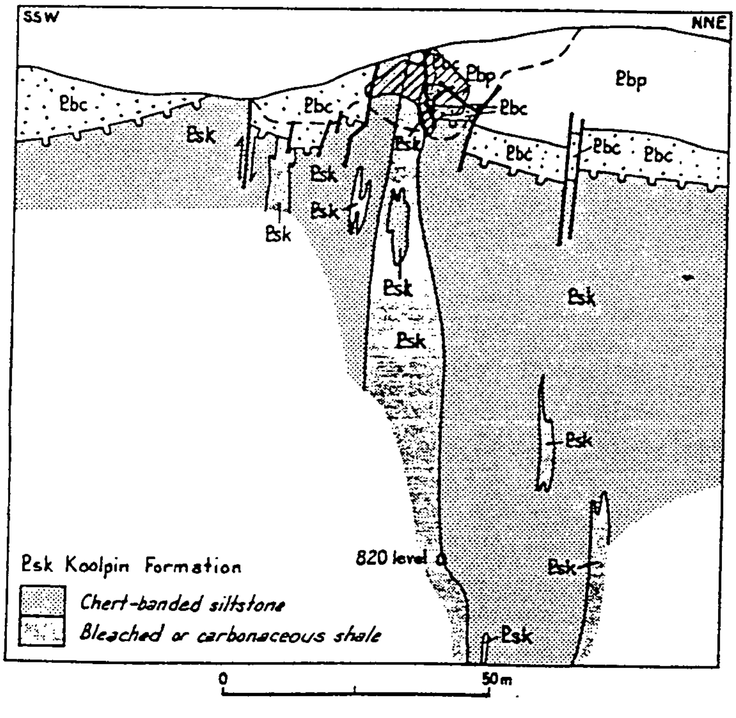


Fig. 5. EL SHERANA

Section EL SHERANA



Plan

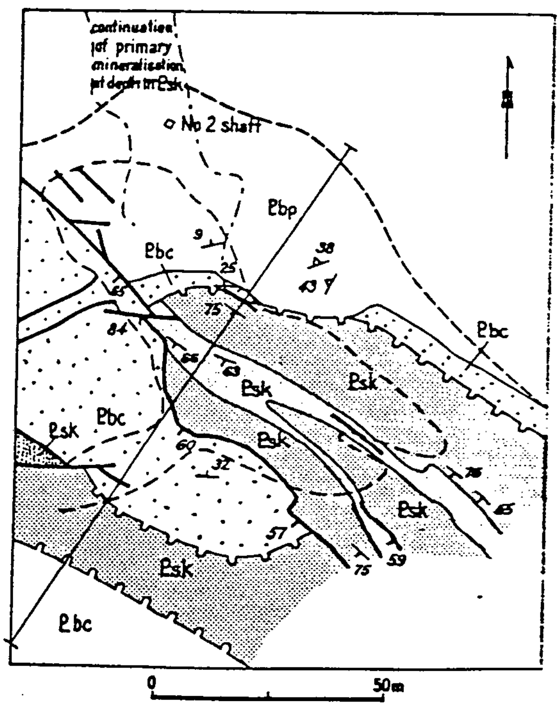


Fig. 6. PALETTE

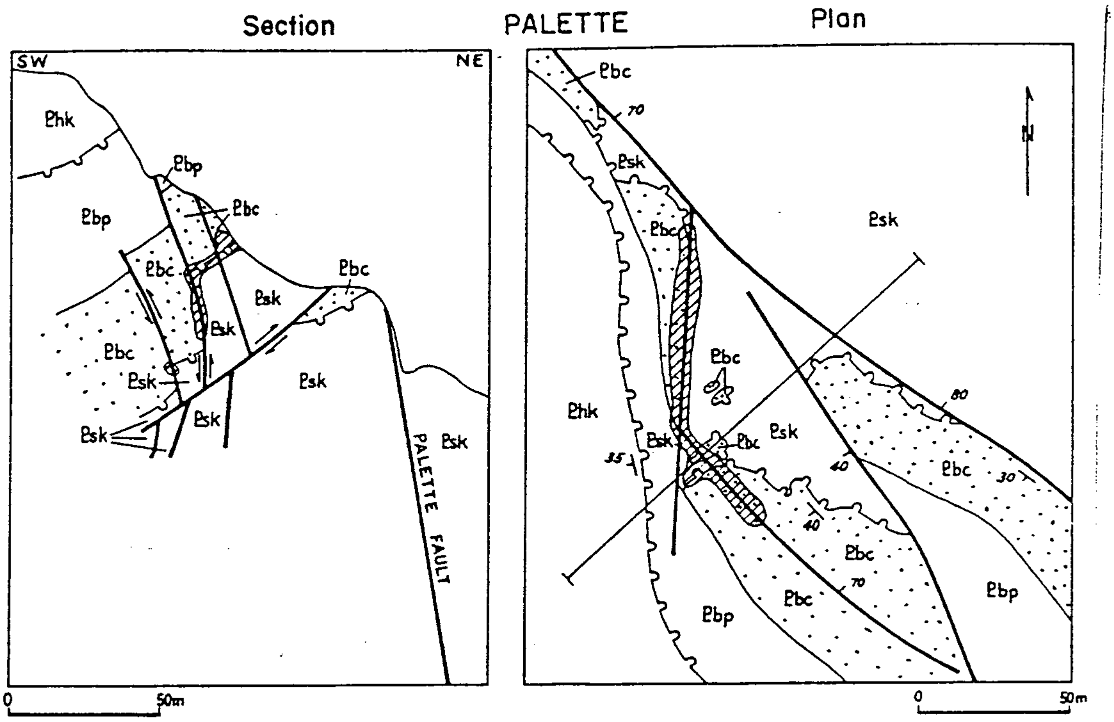


Fig. 7. SADDLE RIDGE

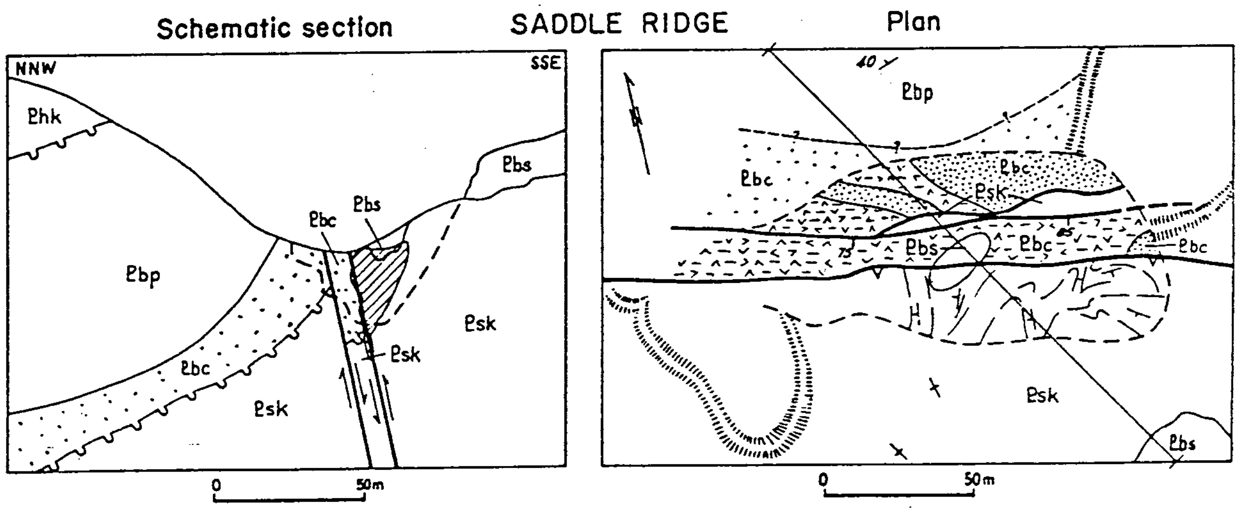
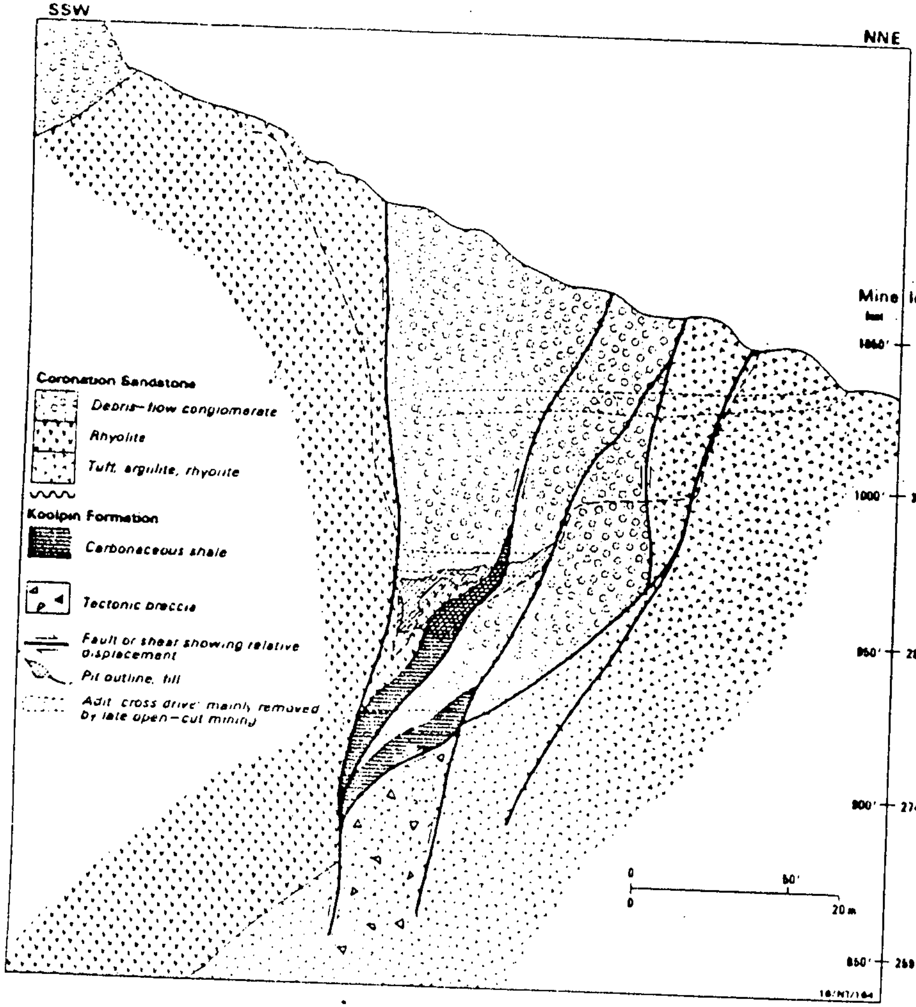


Fig. 8. CORONATION HILL U-Au MINE



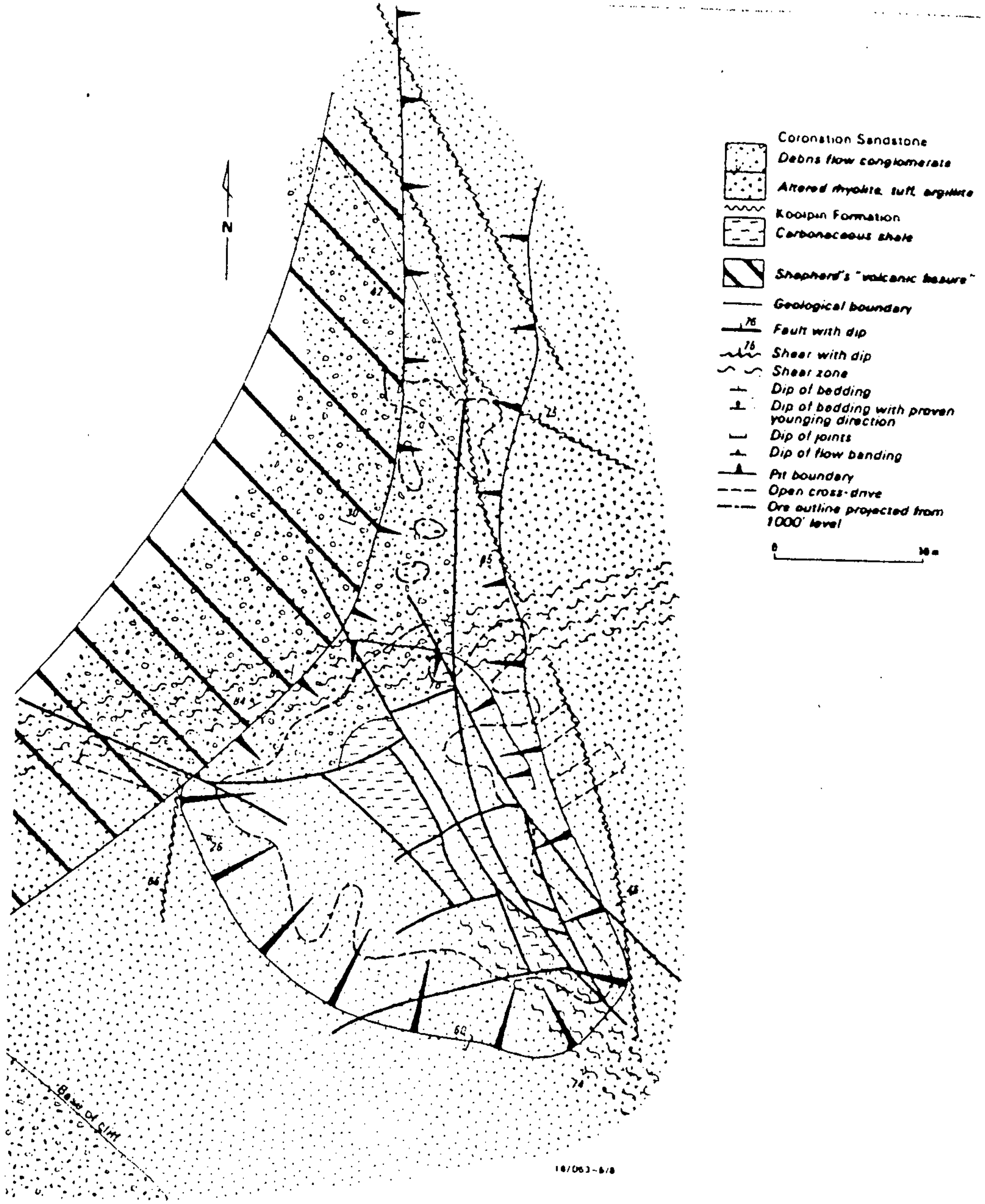
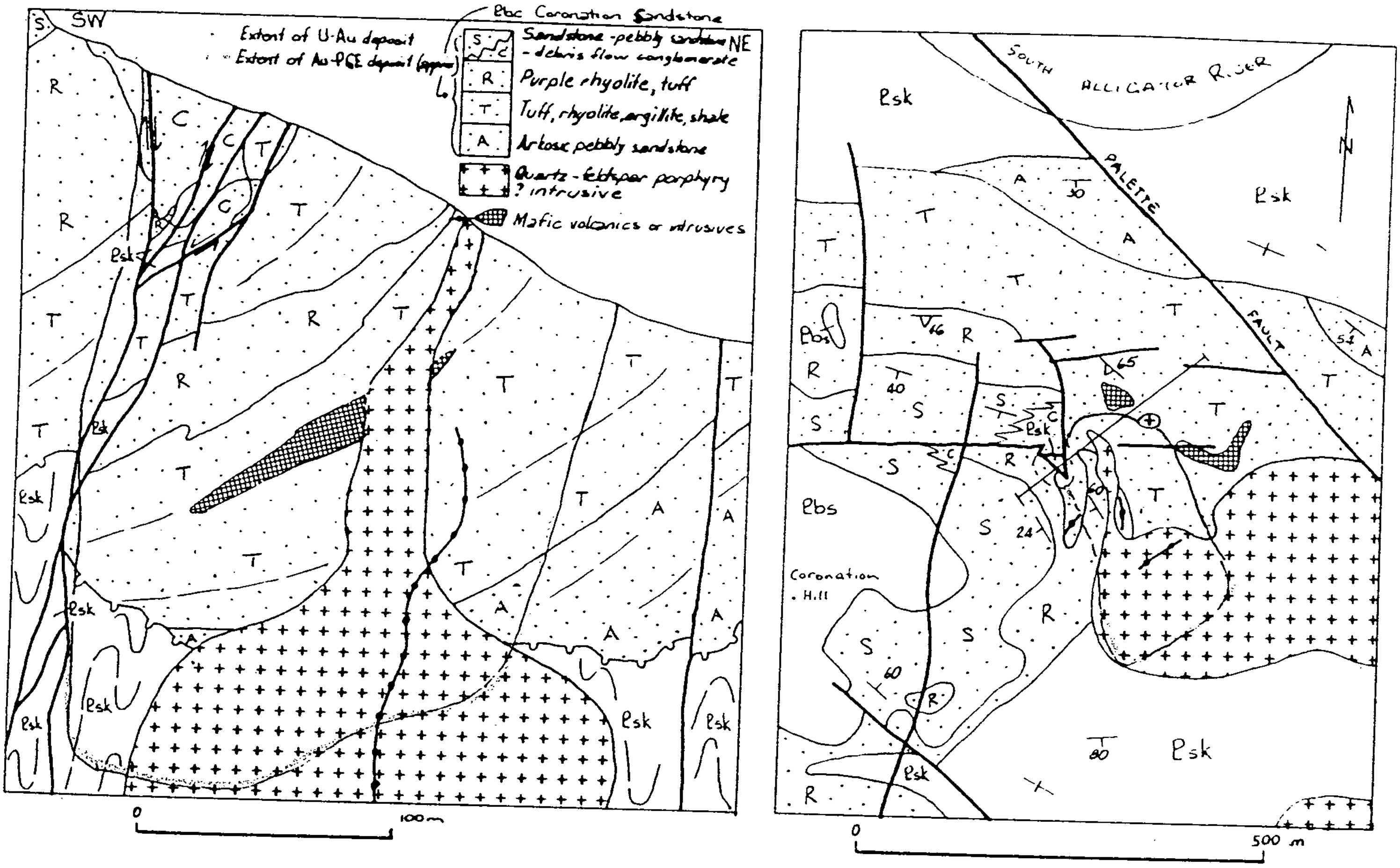


Fig. 9. CORONATION HILL Au-PGE



Appendix 2. Using radiometrics as an exploration tool for unconformity-related Au+Pt+Pd±U mineralisation: A case study from the SAV.

The 1988 BMR Geophysical Survey

During 1988 BMR flew a detailed airborne magnetic and gamma-ray spectrometer survey over the whole of the original Kakadu Conservation Zone, which involved 14,819 line km, at a line spacing of 250m and a nominal ground clearance of about 100m. The crystal size of the collector was 33 litres. The sampling interval was 1.0 sec, which is equivalent to a distance of 55-60m on the ground.

The geophysical sensors on the aircraft included a total field magnetometer and a 4-channel gamma-ray spectrometer. The results from the sensors were digitally recorded together with terrain clearance and flight path recovery information. The spectrometer channels were set for collecting K, U and Th windows, together with a total-count window.

The main survey was flown along lines orientated N25°E, perpendicular to the strike of the geological units. Because of the height of the Arnhem Land escarpment in the central part of the survey area, the actual terrain clearance was highly variable, but approximated 400m over the target stratigraphy. Much of these data were of poor quality. To improve data quality, a second survey, termed the Valley Floor Survey, was flown along the valley floor oriented N115°E. Although this direction is parallel to stratigraphy, which can produce detrimental effects in grids, the Valley Floor Survey achieved the desired ground clearance of 100m (benefits anomaly resolution and consistency in count rates).

Radiometric data for the Tanami Region

Radiometric data held by NFM was obtained as a by product of the airborne magnetic survey (D.Lovett, pers. comm.), during a Geoterrex survey in 1986. Nominal ground clearance was 100m with a line spacing of 500m. Crystal size was 33 litres. The wider line spacing will yield images of lower resolution than those from the SAV. This may be partly compensated for, by stretching data across profiles. One important difference between the Tanami and SAV is that surficial effects due to the degree and depth of weathering are likely to make the images of the Tanami Region more complex than that of the SAV.

Interpreting radiometric data

Radiometric surveys essentially map out the chemical distribution of K, U and Th in the top 35cm of the earth's surface (Minty, 1988). They provide information on distribution of bedrock types, alteration zones, mineralised areas and regolith. Therefore when using radiometrics as an exploration tool, anomalies related to mineralisation will need to be distinguished from anomalies related to bedrock (ie some rock types will have a stronger radiometric signature than others) and regolith. This Appendix outlines image enhancement techniques used in the SAV to remove some of the bedrock and regolith signatures from the radiometric data, and highlight anomalies related to mineralisation and associated alteration.

Individual channel images

In the SAV both individual channel, and multielement channel images were used. The U channel by itself did not discriminate between bedrock and mineralisation/alteration. In particular, the background values of U in both granites and felsic volcanics, at about 2 to 3 times crustal average, were comparable to anomalies associated with mineralisation. Similar values (up to 40 ppm) also occur in granites of the Granites-Tanami Block, and the U image alone will not distinguish between high U that is related to mineralisation, and high U that is of natural occurrence (eg. granites and felsic volcanics).

However, in most felsic igneous rocks, Th is 3 or 4 times more abundant than U, in contrast to the mineralisation and associated alteration. Therefore U^2/Th images will discriminate mineralised areas as being of relative high U^2/Th, whereas granites and volcanics will only have moderate signatures. The U^2/Th image also may prove useful in removing Th related to areas of oxidised weathering or laterite profiles. The U^2/Th not only accentuated U mineralised areas, it also detected the regional alteration zones, where U was preferentially enhanced over Th. Unfortunately areas containing shales, particularly carbonaceous shales, and black soil swamps, may also be enhanced on the U^2/Th image, because these lithologies inevitably have more K and U than Th. Therefore a second useful image is that of the ratio U^2/K, which will eliminate the anomalies due to black soil and carbonaceous shales.

Three band RGB images

One of the most useful images used in the SAV was the Red-Green Blue (RGB) image. RGB images provide a picture of the relative amounts of the three radioactive elements and is therefore a chemical diagram which can be directly related to lithology. In a standard RGB image, the red channel is assigned to K, green to Th and blue to U. At each location on the image, a colour pixel is created where the amount of red is controlled by the amount of K, green is controlled by the amount of Th and blue is controlled by the amount of U. In this way a single image is created which shows the relative amounts of all three elements. The resulting colours are an additive combination such that rocks

- high in all radioactive elements (K, Th, U) will appear white
- with no K, Th or U will appear black
- with equal but intermediate amounts of K, Th, U will appear as a grey colour
- high in K only will appear red
- high in Th only will appear green
- high in U only will appear blue
- high in K(red) and Th (green), but not U, will appear yellow
- high in K (red) and U (blue), but not Th, will appear magenta
- high in Th (green) and U (blue), but not K (red), will appear cyan (eg laterites).

It is important to scale or stretch each of the three channels carefully so that the combined colours are properly balanced. For the SAV data, each channel was stretched individually, relative to the statistical mode.

Interpretation of the SAV Three band (K,Th,U) RGB image

RGB images can be used to delineate rock types and variations within rock types on both a regional and local scale and it has a potential use as a lithological mapping tool. These images have the capacity to map bedrock, altered bedrock and regolith. Radiometric survey results are very sensitive to the development of regolith and other surface processes. In areas where bedrock does not outcrop, it is necessary to discriminate which areas reflect bedrock (or consist of physically broken down bedrock) from areas covered by thick alluvium (drainage areas ore aeolian deposits) or chemically modified regolith (eg laterite profiles). Physical weathering of bedrock does not substantially affect the radiometric signatures. In contrast, chemical weathering will cause preferential leaching of the radioactive minerals. K is usually the most sensitive and is lost quickly in the laterite profiles. Many laterites are a blue green colour, reflecting a set ratio of uranium and thorium, which in turn is controlled by their abundance in resistate minerals such as monazite, sphene and zircon. In extreme laterisation, U can be preferentially leached relative to Th, and in these cases the laterites appear green.

This section describes an interpretation of Figure 1, the RGB image for the southern half of the old Kakadu Conservation Zone, looking at bedrock signatures, effects of weathering and chemical alteration (associated with mineralisation) signatures.

1. Bedrock signatures

The Malone Creek Granite and surrounding felsic volcanics are white (high K, Th, U).

Streams running off the Malone Creek Granite are also white, as they are picking up the detritus from the granite.

The Zamu Dolerite shows up as red as it has some K, and relatively little Th and U.

The Cretaceous and Cainozoic cover shows up as black because they have negligible amounts of K, Th and U.

2. *Weathering effects*

Weathered parts of the Malone Creek Granite and surrounding felsic volcanics show up as yellow due to preferential leaching of U relative to Th.

3. *Identifying the alteration halo associated with unconformity-style mineralisation.*

Radiometrically, the alteration zones associated with mineralisation can be detected in two ways:

(1) depletion of Th, and enrichment of U proximal to areas of mineralisation

(2) enrichment of Th in areas above mineralisation

Figure 2 is an enlargement of the SAV area to the northwest of the Malone Creek Granite, and shows the RGB image superimposed on a Landsat remote sensing image. Figure 3 shows the U anomalies superimposed on the Landsat image. Figure 4 shows the U^2/Th anomalies superimposed on the Landsat image. Figure 5 shows the Th anomalies superimposed on the Landsat image. This area shows the radiometric signature of alteration related to mineralisation.

(1) The first point to note is that in the SAV area surrounding known areas of mineralisation, the felsic volcanic rocks are magenta to blue in colour. This contrasts with felsic volcanics and granite to the southeast which are high in K, Th and U and therefore white in colour (Figure 1), and reflects loss of Th and slight enrichment of U in the alteration halo surrounding mineralisation. This alteration zone extends 1km from mineralisation.

(2) The second point to note is that El Sherana and Pul Pul Hill are Th anomalies (Figure 5) which appear green on the RGB image (Figure 2). They also correspond with topographic highs on the Landsat image. These anomalies represent enrichment of Th structurally or stratigraphically above mineralisation. ie Th anomalies may indicate mineralisation at depth.

(3) The uranium image shows a series of major anomalies which, with few exceptions, are associated with known deposits or prospects (Figure 3). The exceptions occur on Gimbat Ridge and a few scattered anomalies to the west of Coronation Hill.

As Th is depleted and U slightly enriched around areas of mineralisation, the alteration zone can be enhanced by displaying U^2/Th. This image shows a far greater abundance of anomalies, some of which are related to known prospects (Figure 4). The following areas were defined as anomalous on the U^2/Th image, which are not related to known mineralisation and do not appear anomalous on the U image:

(1) the strip of anomalies that trend along the Rockhole-Palette fault between Airstrip Prospect and the High Road Prospect.

(2) the northwestern edge of the Scinto Plateau near the Clear Springs Fault

(3) Saddle Ridge South and Saddle Ridge East area

(4) Gimbat Ridge

(5) Coronation Hill West

(6) Coronation Hill South

(7) Some small anomalies south of Pul Pul Hill

Several of the U^2/Th anomalies were selected for follow up soil sampling, and all returned anomalous values for Au-Pt-Pd.Thus using the U^2/Th images increases the potential target areas for mineralisation. In fact, in delineating 'Greenfield' anomalies, the U^2/Th was more useful than the U image.

Magnetic Interpretation

Figure 6 is an airborne magnetic image over the SAV area. On this image, the alteration zone can be picked up due to the conversion of magnetite to hematite due to interaction with the oxidising mineral fluids. The highly magnetised units in the NNW area (white and red in the image) are due to layers of iron formation within the Koolpin Formation. To the SE, oxidising alteration associated with the mineralisation has variably demagnetised the Koolpin Formation. Some structure is still evident. However equivalent stratigraphy now appears green-yellow in the image.

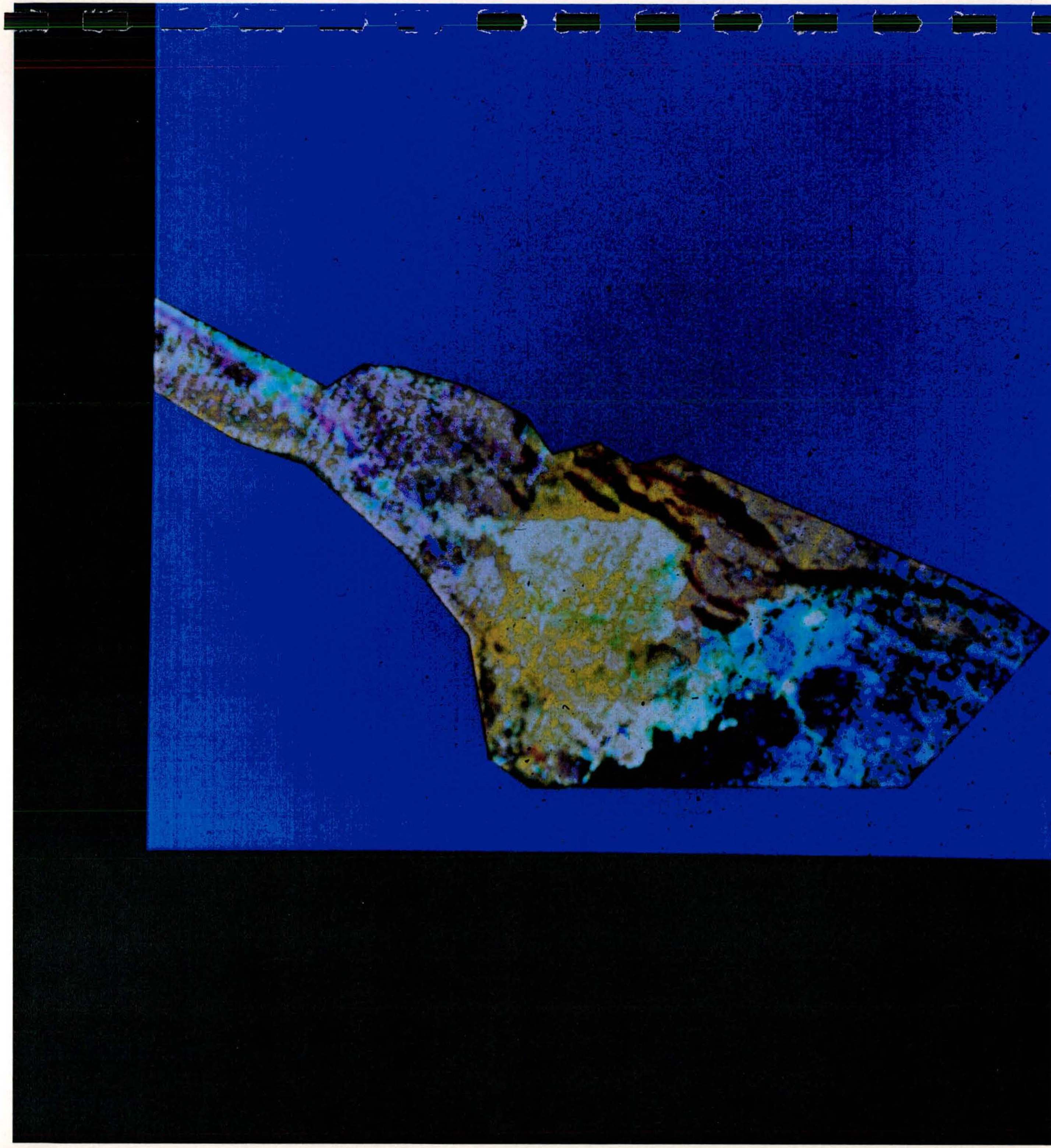
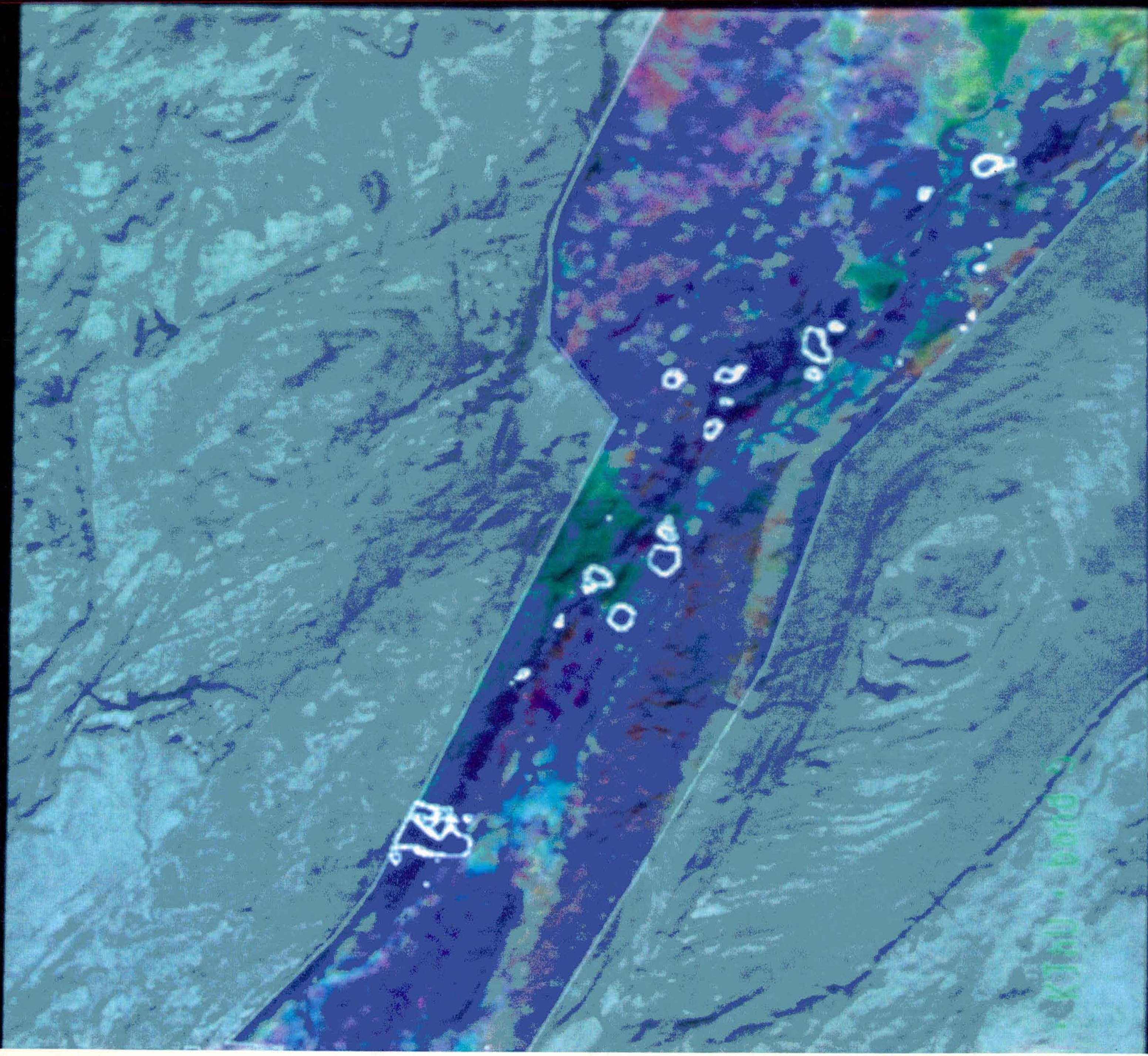


Figure 1.



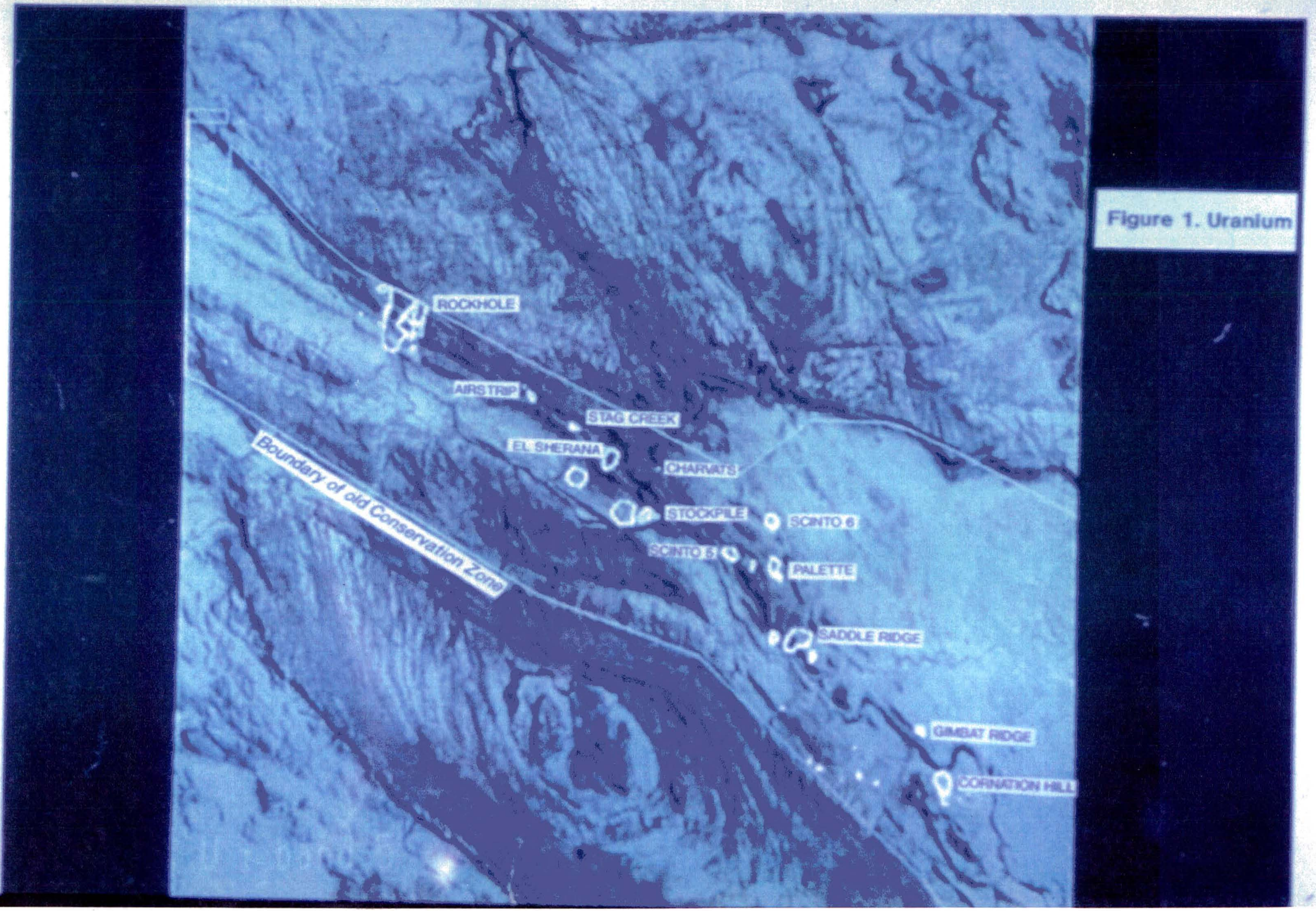


Figure 1. Uranium
ROCKHOLE
AIRSTRIP
STAG CREEK
EL SHERANA
CHARVATS
STOCKPILE
SCINTO 6
SCINTO 5
PALETTE
SADDLE RIDGE
GIMBAT RIDGE
CORNATION HILL
Boundary of old Conservation Zone

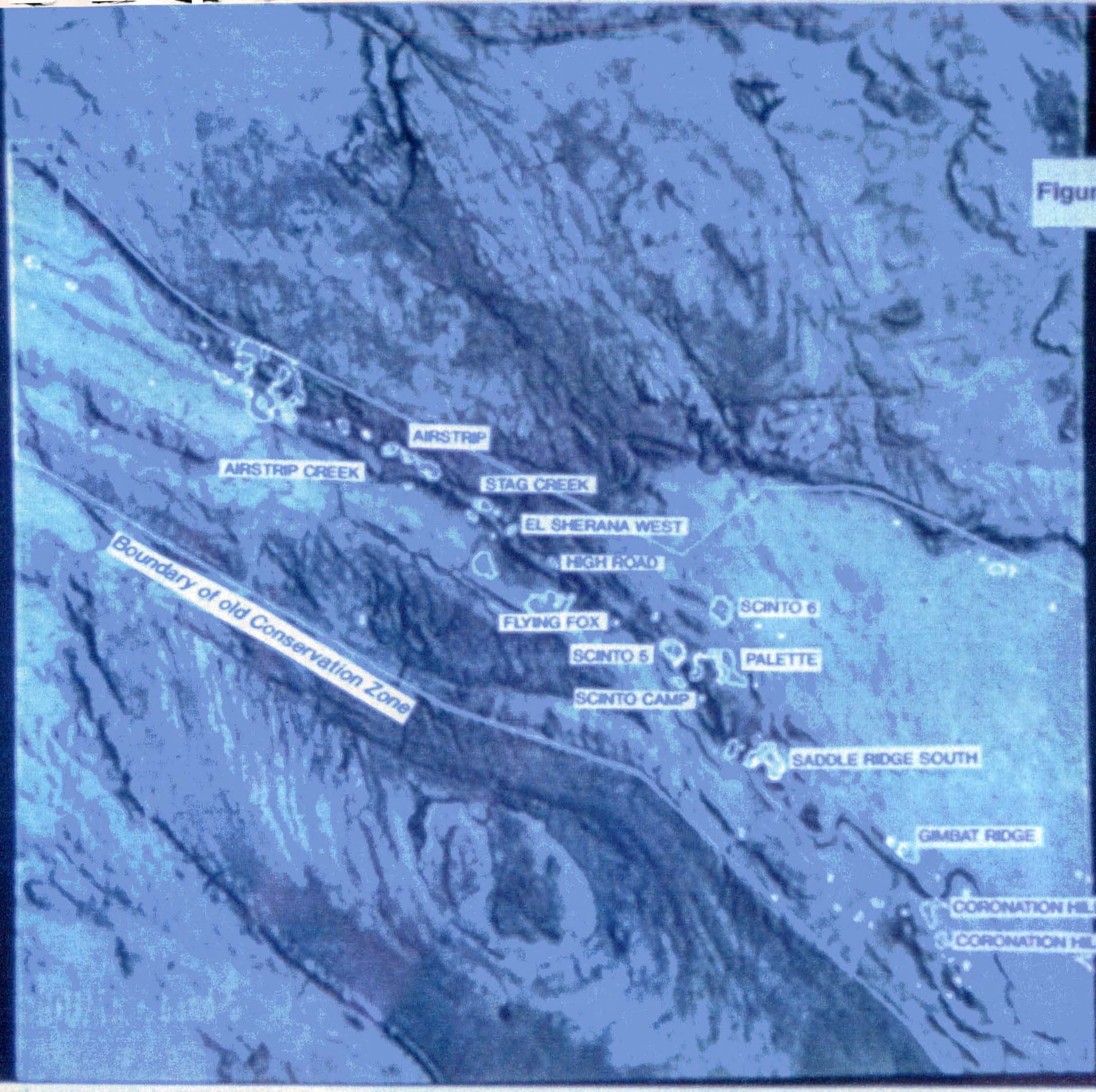


Figure 2. Uranium^2/Thorium

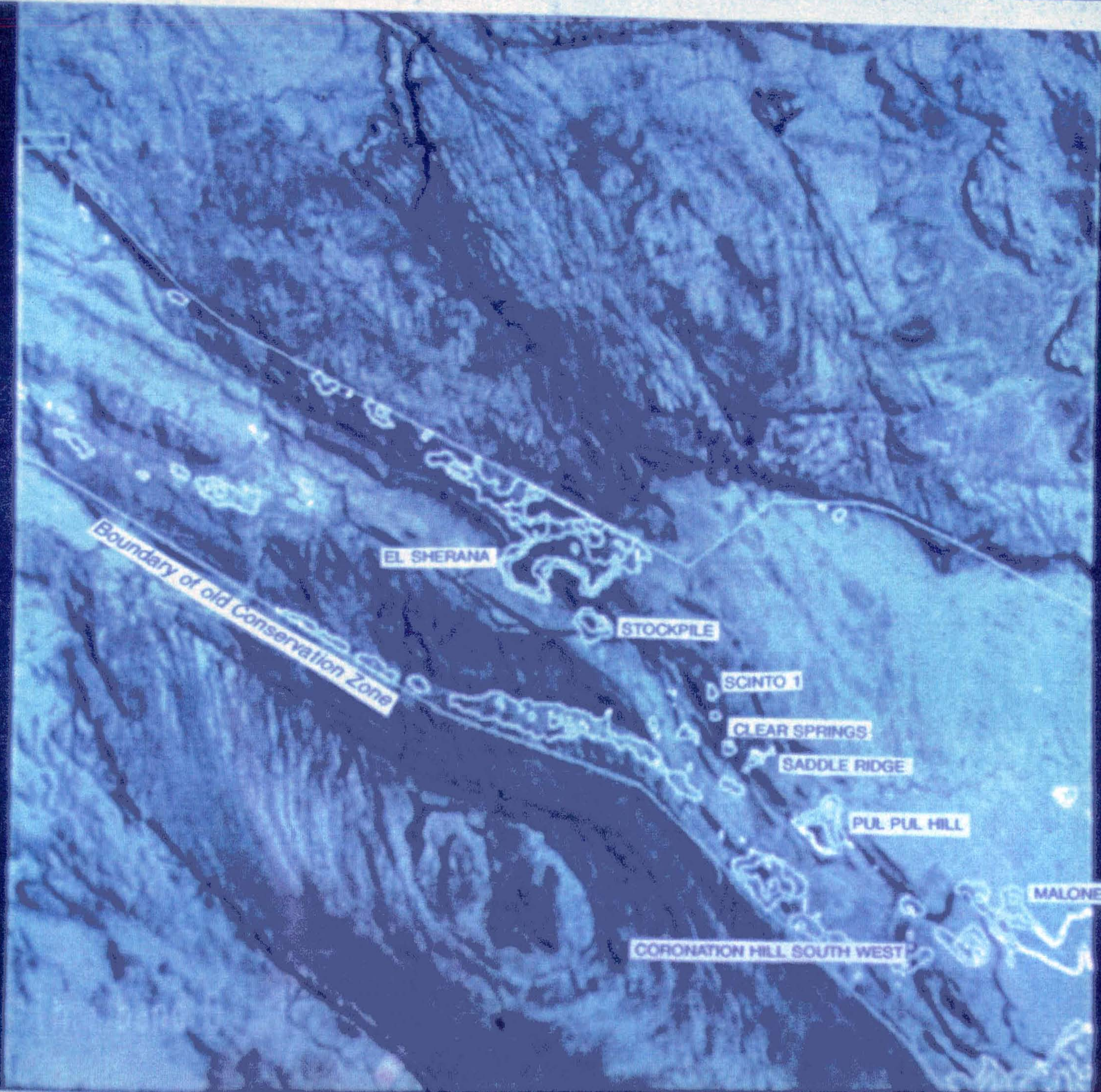
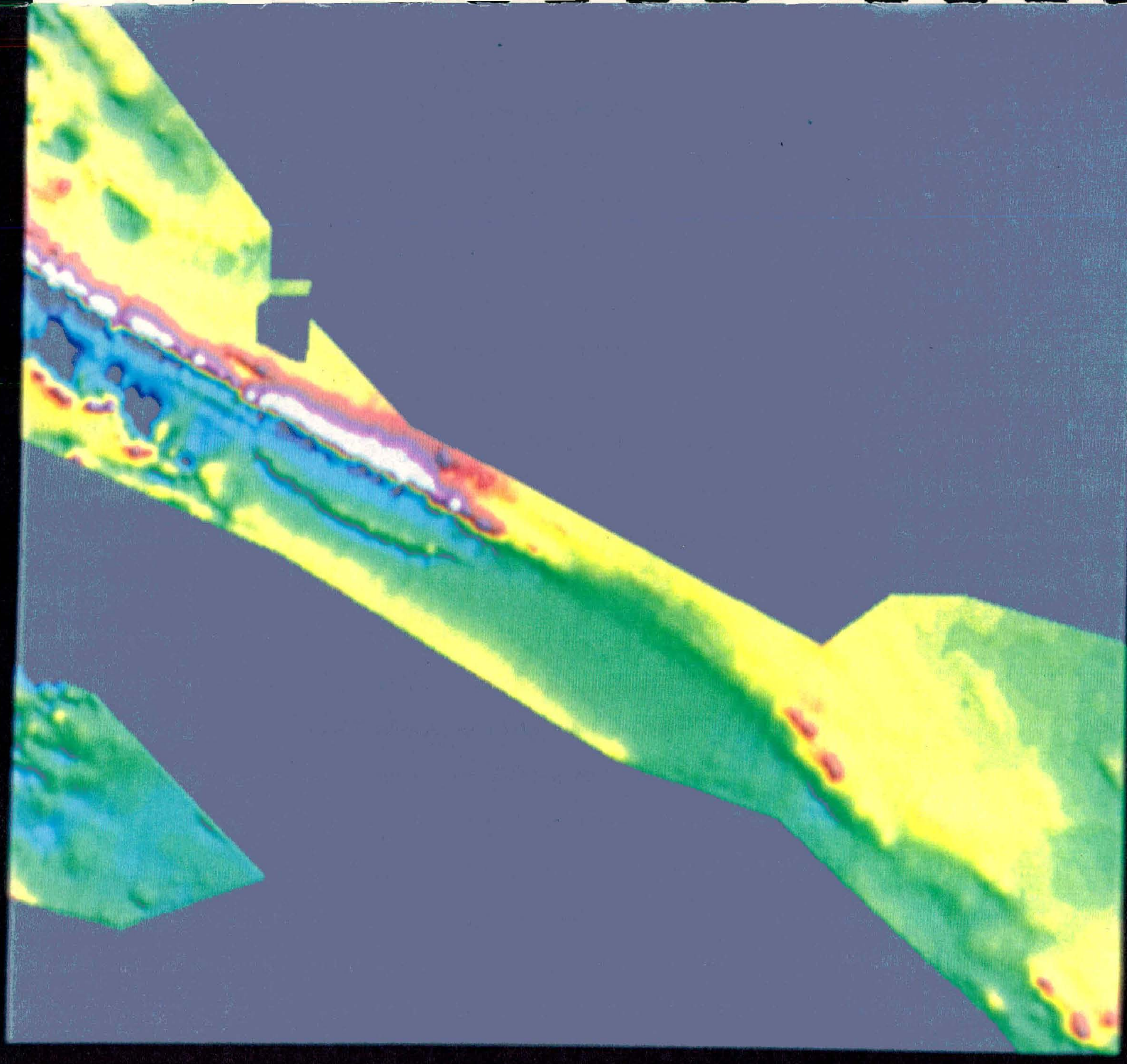


Figure 3. Thorium



Appendix 3: Geochemical Analyses from Killi Killi Hills, from AGSO ROCKCHEM database.

	8749-6105	8749-6106	8749-6107	8749-6108	8749-6115a	8749-6115b	8749-6120	8749-6121	8749-6122	8749-6123
SiO_2	97.53	95.81	94.50	78.49	80.46	97.49	86.09	98.27	94.26	90.40
TiO_2	0.05	0.10	0.12	0.61	0.27	0.07	0.21	0.06	0.09	0.15
Al_2O_3	1.26	1.94	2.41	11.49	11.28	1.46	5.52	0.94	3.09	4.76
Fe_2O_3	0.17	0.59	0.34	3.06	2.21	<0.01	2.65	0.03	1.04	1.18
FeO	0.12	0.13	0.13	0.14	0.13	0.15	0.13	0.12	0.14	0.13
MnO	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01
MgO	0.02	0.06	0.08	0.48	0.28	0.04	0.14	0.01	0.08	0.17
CaO	<0.01	0.02	0.11	0.01	0.02	0.02	0.24	0.01	0.01	0.07
Na_2O	<0.02	<0.02	<0.02	0.05	0.02	<0.02	<0.02	<0.02	<0.02	<0.02
K_2O	0.30	0.48	0.49	3.56	3.28	0.39	1.40	0.17	0.83	1.24
P_2O_5	0.02	0.15	0.64	0.06	0.06	0.03	0.75	0.10	0.13	0.39
S	0.01	0.02	0.08	0.01	0.01	0.01	0.35	0.01	0.01	0.05
BaO										
Cr_2O_3										
NiO										
Rb_2O										
SrO										
ZrO_2										
H_2O^+										
H_2O^-										
CO_2										
TOTAL	99.81	99.88	99.69	99.93	100.15	100.13	99.80	100.07	100.38	99.88
L.O.I.	0.32	0.57	0.78	1.96	2.12	0.46	2.30	0.34	0.69	1.33

	8749-6105	8749-6106	8749-6107	8749-6108	8749-6115a	8749-6115b	8749-6120	8749-6121	8749-6122	8749-6123
T	5	10	13	21	19	12	11	10	9	10
Rb	12	19	22	149	90	15	47	9	28	56
Pb	3	418	3	8	6	2	154	275	4	123
[illegible]	3	9	287	35	10	4	15	6	10	14
Sr	138	435	2435	119	231	151	517	344	495	1329
[illegible]	1.5	32	9.5	3.5	1.0	1.5	14	10	4.0	56
Se	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	0.5	0.5	<0.5	<0.5
C	2	3	2	13	12	1	6	1	3	6
As	1.5	10	4.5	5.5	6.5	4.0	233	5.0	4.5	9.0
V										
[illegible]	<1	2	1	<1	1	<1	3	<1	<1	1
Ge	<0.5	0.5	<0.5	1.5	1.0	<0.5	<0.5	0.5	0.5	1.0
Sn	<2	<2	2	4	2	<2	2	<2	<2	2
b	1	2	1	11	9	1	5	2	2	3
Zr	44	85	116	339	291	87	187	101	80	106
o	<2	2	<2	<2	<2	<2	2	<2	<2	<2
Y	3	15	12	99	22	4	49	7	45	49
Cr	5	33	16	57	20	6	21	8	14	25
a	227	135	183	348	266	139	688	177	294	406
La	14	38	85	35	41	18	49	30	47	29
e	25	113	274	70	79	33	110	67	103	61
Nd	10	98	361	28	22	13	49	38	75	52
r	<3	18	51	10	7	3	12	9	16	9
Cs	<3	<3	<3	8	3	3	5	<3	<3	5
c	<2	3	2	10	5	<2	4	<2	2	3
f	<2	2	3	8	8	3	4	4	2	2
Ta	<2	<2	<2	<2	<2	2	<2	<2	<2	<2
g	<1	1	<1	1	1	<1	1	<1	<1	1
Be	<1	1	1	2	1	<1	1	<1	<1	2
o										
Cr										
u	2	9	1	3	2	3	28	2	2	23
Li	5	4	6	14		2	15	8	8	8
i	2	1	<1	10	4	1	2	1	2	6
n	3	6	4	17	8	4	14	4	5	12

Appendix 4: Prichard et al., 1960: The Killi Killi Uranium Prospects, Western Australia.

THE KILLI KILLI URANIUM PROSPECTS

WESTERN AUSTRALIA

by

C.E. Prichard, W.B. Dallwitz, and W.M.B. Roberts

Record 1960/140

Formerly CONFIDENTIAL RECORD 1960/C.4

SUMMARY

Radioactivity occurs in the basal Upper Proterozoic bed near the border of Western Australia and Northern Territory about Latitude 19°45' South. Radiometric and X-ray spectrographic investigations show that the radio: is due to uranium which is contained in xenotime.

Radioactivity occurs intermittently throughout the 4,000 feet outcrop length of the bed at Killi Killi No. 1 Prospect and again at the next outcrop of the base of the Upper Proterozoic about 7-miles west-north-west at Killi Killi No. 2 Prospect.

Assays of surface specimens from radioactive areas were generally about 0.01% eU_3O_8 and a specimen selected for maximum radioactivity assayed 0.23% U_3O_8 by X-ray spectrograph.

The discovery of radioactivity due to uranium at the base of the Upper Proterozoic at this locality suggests the possibility of other radioactive occurrences in the area. This should be explored by low level airborne scintillograph survey.

INSPECTION REPORT

by

C.E. Prichard

INTRODUCTION

On 12th August, 1960, Mr. J.H. Lord, of New Consolidated Gold Fields (Australasia) Pty. Ltd., reported to the Bureau of Mineral Resources, Darwin, the discovery of radioactive rocks about 50 miles west-north-west of Tanami.

The area was examined on 22nd and 23rd August, 1960, by C.E. Prichard, geologist, and L.V. Skattebol, geophysicist, of the Bureau of Mineral Resources. They were accompanied by A.B. Clark, geologist in charge of the field party from New Consolidated Goldfields.

The Company holds Temporary Reserve No. 1784 in Western Australia and Authority to Prospect No. 769 in the Northern Territory. Two prospects - Killi Killi No. 1 and Killi Killi No. 2 - have been named by the Company; both prospects are probably within Temporary Reserve No. 1784.

LOCATION AND ACCESS

Killi Killi No. 1 prospect is located approximately 129^{o} East 19^{o}45' South. It appears to be about 1-mile west of the border between the Northern Territory and Western Australia. Killi Killi No. 2 prospect is about 7-miles west-north-west of No. 1 prospect.

The prospect area was reached by driving from Gordon Downs Homestead along the Tanami track for 73.6 miles, and then across spinifex sand plain on an approximate course of 220^{o} for 22 miles. This trip takes about six hours travelling by "Landrover".

The nearest known permanent water (Jellabra Rockhole) is about 38-miles from the prospect. It is a half-mile east of the Tanami track 57.5 miles from Gordon Downs.

REGIONAL GEOLOGY

The Billiluna 4-mile sheet, on which the prospects are located, was mapped by J.N. Casey and A.T. Wells in 1956. Additional information was made available by A.B. Clark from his work in 1960.

The oldest rocks seen in the area are steeply dipping slightly schistose, fine-grained, quartz greywacke. These are included in the Halls Creek Metamorphics by Casey and Wells, and are simply referred to as Lower Proterozoic by Clark.

A large granodiorite body intrudes the Lower Proterozoic sediments west of the Prospects. Casey and Wells call this the Lewis Granite and describe it as granite and muscovite granodiorite; Clark considers it is predominantly granodiorite. Both agree that it is Lower Proterozoic. The Upper Proterozoic beds unconformably overlie the Lower Proterozoic rocks.

Clark has recognised three units in the Upper Proterozoic. The lowest unit consists of three members. The basal member contains numerous interlocking lenses of grit, sandstone, and conglomerate; the middle member is thin bedded, fine-grained quartz greywacke; and the top member is current-bedded sandstone and conglomerate.

The middle unit, which crops out poorly, is mainly fine-grained, silty quartz greywacke, but shale is also present.

The top unit consists of quartz sandstone containing conglomerate beds and lenses.

Total thicknesses of between 600-feet and 1,000-feet have been measured by Clark. The Upper Proterozoic in this area has been called Gardiner Beds by Casey and Wells. It is almost certainly the same unit as that 100-miles to the east-north-east which Traves (1955) named Winneckie Sandstone.

THE PROSPECTS

Both prospects occur in the basal member of the lowest unit of the Upper Proterozoic sequence; no radioactive anomalies are known higher in the section.

Killi Killi No. 1 Prospect consists of a number of radioactive anomalies all occurring in the basal 20-feet of the Upper Proterozoic and extending over 4,000-feet along the strike. This is the complete length of the outcrop.

Killi Killi No. 2 Prospect is a single radiometric anomaly about 100-feet long on the same horizon about 7-miles west-north-west of No. 1 Prospect. The base of the Upper Proterozoic does not crop out between the two Prospects.

No other outcrops of this horizon were visited during the inspection. During Clark's reconnaissance of the area no other anomalies were found.

Local Geology

All known anomalies occur within the basal 20-feet of the Upper Proterozoic succession in grit, pebbly grit, or conglomerate with grit matrix. Most anomalies are in the bed directly overlying the Lower Proterozoic. The beds at No. 1 Prospect dip north at 5° to 10°. At No. 2 Prospect the dip is north-north-east at 15° to 20°.

Radioactivity

The Company made the original finds with Phillips Pocket Monitor geiger counters. Harwell 1368A geiger counters were used on the inspection, and readings from them are quoted in this report.

Local background readings on both Upper and Lower Proterozoic rocks were 0.02 mR/Hr and the maximum spot reading obtained was 0.26 mR/Hr.

Maximum radioactivity occurs at the eastern end of No. 1 Prospect. Here an area of 100-feet by 70-feet was gridded. Results are shown on Plate 3, on which the approximate boundary between Upper and Lower Proterozoic is also shown. Scree and rubble from the Upper Proterozoic obscure the boundary and partly overlie the Lower Proterozoic rocks. About 300-square feet is included within the eight times background and 1700-square feet within the four times background isorads.

Two different specimens selected for maximum radioactivity by J.H. Lord assayed 0.18% eU_3O_8 (radiometric, Darwin) and 0.23% U_3O_8 (X-ray spectrographic, Canberra). Both methods indicated that the radioactivity was entirely due to uranium. Typical specimens collected during the inspection from the areas exceeding eight times background gave radiometric assays of 0.1% and 0.11% eU_3O_8.

At the western end of the No. 1 Prospect samples collected from a pebble conglomerate giving field readings of ten times background assayed 0.05% eU_3O_8. This area was not gridded but traverses indicated a maximum width of fifty feet exceeding twice background and about fifteen feet of three times background.

Radioactivity occurs in grit beds and in a pebble conglomerate bed at No. 2 Prospect. Readings are irregular, probably partly because outcrop of the grit is poor. The maximum width of material averaging three times background is about fifty feet. A specimen of grit and another of pebbly grit associated with the conglomerate bed both radiometrically assayed 0.01% eU_3O_8. Both specimens were collected from spots reading about four times background.

Lower Proterozoic rocks near the anomalies were checked for radioactivity. Background readings only were obtained except for one count of twice and one of four times background. These two spots, each very local, occur immediately east of the major anomaly at the east end of No. 1 Prospect. The only stratigraphic or structural feature common to the two spots, which are about 100-feet apart, is that both are within a few feet of the unconformity surface. It is possible that the radioactivity is due to downward leaching from the base of the Upper Proterozoic.

Mineralogy

No uranium minerals or ochres were recognised in the field.

A highly radioactive specimen was examined by W.B. Dallwitz and W.M.B. Roberts in the laboratory. The rock is silicified coarse conglomeratic sandstone or grit. The heaviest mineral fraction consisted of pale buff xenotime containing uranium.

From the perfect (pseudo-cubic) crystal form of a florencite-svanbergite mineral, and the presence of xenotime and a few pseudo-cubic crystals within detrital quartz grains and fragments of siltstone or shale, Dallwitz and Roberts concluded that these minerals were probably epigenetic, although they could be detrital minerals which were recrystallised and partly redistributed during diagenesis or metamorphism.

CONCLUSIONS

The radioactive anomalies are caused by the presence of uranium irregularly distributed in basal rocks of the Upper Proterozoic sequence.

Mineralogy suggests the mineralisation is epigenetic, but the restriction of radioactivity to the basal deposit of the Upper Proterozoic and the absence, so far as is known, of a possible source of mineralisation younger than the host beds suggests a syngenetic origin. If the deposit is syngenetic similar deposits may occur to the north-east and north-west at the base of the Upper Proterozoic.

The two Prospects occur in adjacent outcrops of the same horizon and should be considered as a single new discovery for reward purposes. The discovery is about 200-miles from the nearest known uranium mineralisation near Halls Creek.

RECOMMENDATIONS

The remote locality, the low-grade, and refractory nature of the mineral, suggest that a drilling programme is not warranted at this stage; but a low level scintillograph survey of the Upper Proterozoic rocks in this area should be carried out to determine if other similar prospects are present.

REFERENCE

TRAVES, D.M., 1955 - The geology of the Ord-Victoria Region, Northern Australia. Bur. Min. Resour. Aust., Bull. 27.

6

LABORATORY INVESTIGATION

by

W.B. Dallwitz and W.M.B. Roberts

INTRODUCTION

The specimen examined in the laboratory was taken from the Killi Killi No. 1 Prospect.

In the investigation recorded in this report, Roberts carried out the X-Ray spectrographic and X-Ray diffraction determinations and the acid leachings, and Dallwitz was responsible for the petrographic and optical observations, the separation of a pure mineral sample for X-Ray determination, the speculations as to the identity of one of the minerals, and the speculations as to the origin of the mineral responsible for the radioactivity.

PETROGRAPHY

The specimen is a hard, somewhat porous, reddish brown "grit" or silicified conglomeratic sandstone containing a few fragments which generally measure up to 0.5 cm., but exceptionally up to 2 cm. The rock is strongly cemented, and mostly breaks across the fragments. A freshly cut surface shows patchy pale blue fluorescence under long-wave ultraviolet light; scattered specks fluoresce bright blue, and a small concentration of specks fluoresces dull golden buff. The weathered surface mostly shows no fluorescence, but some patches fluoresce dull golden to pale buff, and specks which fluoresce bright blue are prominent but very scattered. The fluorescence on the cut surface appears to be confined to the matrix.

Radioactivity measured on the cut surface ranged from 400-450 c.p.m. against a background of 80. Maximum radioactivity on a bedding plane or rough joint was 800-850 c.p.m. The instrument used was an "Austronic" ratemeter, Type BGR 1.

In thin section the rock was found to consist of grains of quartz and a few fragments of siltstone, shale, chert, and quartzite in a matrix which amounts to 10-15% of the whole rock. Accessory minerals are hydrated iron oxide, muscovite, zircon, biotite, chlorite, and tourmaline (the last seen in "superpanner" concentrates only - see below); all these occur in extremely small quantity except the hydrated iron oxide, which strongly impregnates the minerals of the matrix.

The quartz grains are mostly well rounded, and some are bordered by a shell of secondary silica which is in optical continuity with that of the original detrital grains. The grains are not well sorted, and their sizes range from 0.1 mm. upwards, the average being about 1 mm. Many of them show strain shadows. Some quartz grains are composite, and have the appearance of vein-material.

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The matrix consists of three minerals which are unevenly distributed, and any one of which may be dominant locally. One of these minerals is quartz. The other two are not readily identifiable; both are fine-grained, and have rather high refractive indices. One of them occurs as perfectly euhedral rhomboid or pseudo-cubic crystals - less commonly as aggregates of anhedral grains - whose size ranges from 7 to 70 microns, and whose average size is about 30 microns. The double refraction of these crystals is less than that of quartz, and their refractive indices range from slightly above 1.660 to above 1.670. Their sign is uniaxial positive. Most of the crystals have a prominent core whose shape conforms exactly to the outlines of the complete crystal, and whose width may range from $\frac{1}{4}$ to $\frac{3}{4}$ of the total width of the crystal; generally, the larger the crystal, the greater the proportion of its width occupied by the core. The core is in optical continuity with the surrounding material, and its refractive index is markedly less than 1.66. In nearly every grain the core is darkened by closely crowded extremely minute specks of a red-brown substance which is most likely hydrated iron oxide; it is not known for certain whether this is an alteration-product or simply included material, but the latter possibility seems the more likely, because cores containing only a few of the dark specks appear to be completely fresh, and, except for lower refractive index, have optical properties identical with those of the shell.

The second of the two fine-grained minerals in the matrix is coloured pale buff, and is commonly strongly impregnated with red-brown, hydrated iron oxide. It generally occurs as aggregates of subhedral to anhedral grains whose size ranges from 3.5 to 35 microns. These grains have high double refraction, and their refractive indices are considerably greater than those of the pseudo-cubic crystals.

Both minerals, but especially the pseudo-cubic one, may occur within the secondary shells of quartz which have been formed round the original detrital grains, and they may, much less commonly, occur within the detrital grains. The mineral with high double refraction is commonly present, and in places extremely plentiful, within the fragments of sedimentary rock; only very rarely is it accompanied by isolated grains of the pseudo-cubic mineral. In one place a veinlet of the pseudo-cubic mineral cuts across the edge of a fragment of siltstone.

The rock is a silicified coarse conglomeratic sandstone.

X-RAY RESULTS

A qualitative X-Ray spectrographic analysis showed that radioactivity is due entirely to uranium, thus confirming the radiometric result obtained in the Darwin office. A quantitative analysis for this element gave 0.23% U_3O_8.

Other elements present, apart from silicon, phosphorus (detected chemically), aluminium, and probably calcium (all of which have too low an atomic weight to be detected by the X-Ray spectrograph), are yttrium, ytterbium, strontium, and iron (in order of decreasing abundance), together with progressively smaller quantities of uranium, dysprosium, erbium, gadolinium, lead, samarium, copper, neodymium, terbium, holmium, cerium, and possibly gold.

Treatment with hot 50% HCl strongly leached uranium from the rock; leaching with 5% H_2SO_4 for 30 minutes also removed uranium, but less strongly. Qualitative X-Ray spectrographic analysis of the leachate from treatment with hot 50% HCl showed that most of the "rare" elements identified in the powdered sample had gone into solution in some degree. A distinct trace of copper was found in the leachate; the presence of this element was somewhat doubtful when the powdered sample was analysed, but copper was apparently strongly leached by the acid, and therefore showed up in solution.

Part of the rock crushed to pass through a 170 - mesh B.S.S. sieve was put over a Haultain "superpanner", and the heaviest fraction was found to consist entirely of granular aggregates of the pale buff mineral with high double-refraction. By means of an X-Ray powder pattern photograph, this mineral was identified as xenotime, and a qualitative X-Ray spectrographic test showed that it contained, among other elements, yttrium, uranium, and strontium. Xenotime is essentially a phosphate of yttrium and erbium, but small amounts of other rare earths, thorium, uranium, iron, aluminium, manganese, beryllium, and the alkaline earths (Ba, Sr, and Ca) may substitute for yttrium and erbium.

PROBLEMATICAL MINERAL

The pseudo-cubic crystals with refractive index about 1.660 to 1.670 have not been satisfactorily identified. However, taking into consideration their distinctive crystal form, their optical properties, and the strong possibility that they contain the phosphate radicle, their identity seems to fall within rather narrow limits. The mineral florencite ($CeAl_3(PO_4)_2(OH)_6$) has properties which appear to fit, more closely than those of any other, the observed properties of these crystals. However, their refractive indices do not correspond sufficiently closely to those of florencite to make the comparison strictly valid, nor does the small quantity of cerium revealed in the X-Ray spectrogram. However, it is stated on page 839 of Dana's System of Mineralogy, Vol. II, Seventh Edition, that "some calcium and yttrium may substitute for the cerium earths in florencite", and that "the distribution of the several rare earths in florencite has not been fully determined". Other minerals whose crystal form is closely similar to that of florencite, and whose chemical formulae may be compared with that of florencite, are

goyazite ($SrAl_3(PO_4)_2(OH)_5H_2O$)

svanbergite ($SrAl_3(PO_4)(SO_4)(OH)_6$)

and woodhouseite ($CaAl_3(PO_4)(SO_4)(OH)_6$).

Florencite identified by X-ray, 1973.

The recorded refractive indices of different specimens of florencite range from 1.670 to 1.705, whereas the mean indices of goyazite, svanbergite, and woodhouseite are about 1.635, 1.64, and 1.64, respectively. All four of these minerals are isostructural. As the measured refractive index of the outer shell of the pseudo-cubic crystals is about 1.665, it is tentatively suggested that they represent a mineral species similar to florencite in which cerium may have been partly replaced by other rare earths and/or strontium and/or calcium. A small quantity of sulphate was detected by A.D. Haldane in the aqueous extract from a sodium carbonate fusion carried out on the rock; this suggests that the mineral is of the svanbergite-woodhouseite type rather than the goyazite-florencite type. The lower refractive index of the cores of the pseudo-cubic crystals shows that their composition is not uniform, and so does the fact that the maximum and minimum refractive indices of the material in the outer shell are inconstant (the range of refractive indices is greater than the double refraction of the shell).

The tentative conclusion from all these observations is that the pseudo-cubic mineral is one whose chemical formula might be represented as follows:

$$(Rare\text{-}earths, Sr, Ca)\ Al_3(PO_4)(SO_4)(OH)_6.$$

CONCLUSIONS

The rock is a silicified coarse conglomeratic sandstone or a silicified "grit". The matrix consists of xenotime, quartz, and a mineral related to florencite and svanbergite. The specimen assays 0.23% U_3O_8, and the uranium is contained in xenotime; this mineral, according to the literature, may contain up to about 5 percent of uranium oxide.

The field and microscopic evidence as to the origin of the uranium-bearing mineral are, on available information, contradictory. The field evidence suggests a syngenetic (detrital) origin, but the perfect crystal form of the florencite-svanbergite mineral and its occurrence with xenotime in detrital quartz grains and in fragments of siltstone suggest an epigenetic origin. Minerals of the goyazite-florencite and svanbergite-woodhouseite types have been variously recorded from several different environments - in veins, in metamorphic rocks, as syngenetic growths, and as detrital fragments.

As it is not recorded in the literature that florencite, goyazite, svanbergite, woodhouseite, or xenotime fluoresce, the rather weak fluorescence which, on a freshly cut surface, appears to be confined to the matrix, can not be explained in terms of present knowledge of the rock.

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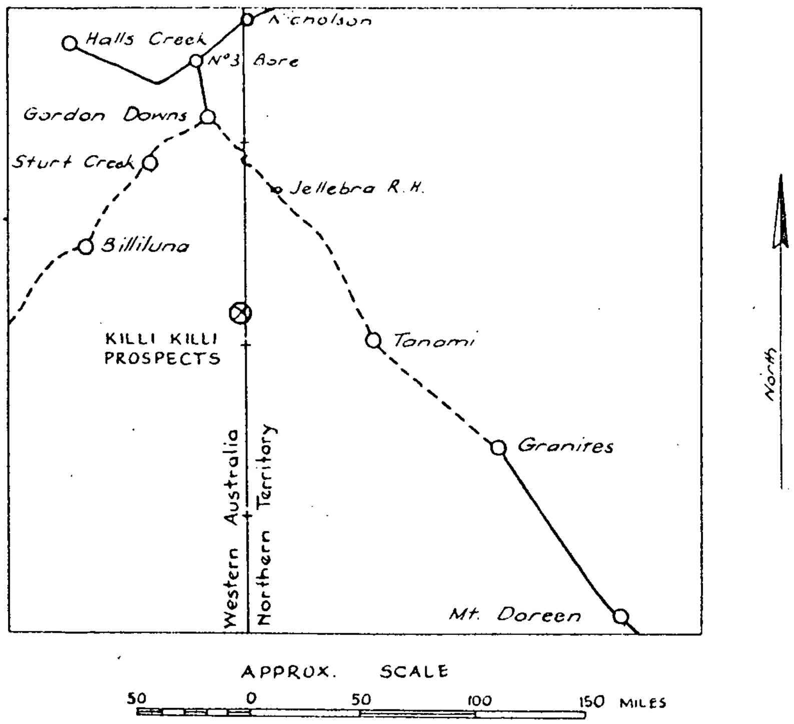

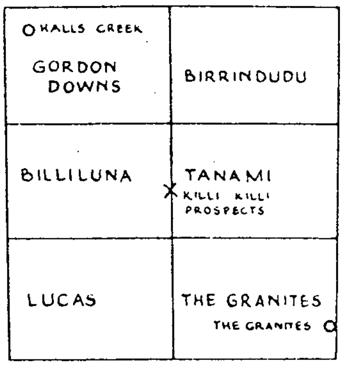

4 MILE GEOLOGICAL SERIES

LOCALITY MAP

KILLI KILLI PROSPECTS

Bureau of Mineral Resources. Geology and Geophysics
Darwin September 1960.

NORTH FLINDERS EXPLORATION

(A Division of North Flinders Mines Limited)
(Incorporated in South Australia)

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THE GRANITES
P.O. Box 3694 Alice Springs 0871
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Facsimile: (007) 1-1-2243
A.C.N. 007 688 093

structural relationships
glacier assoc elements
how to sample

what to look for
how to go about it

2-7 days no bookings.
Jet to Alice
aircraft to granites
morning & afternoon.
monday 11.45 am.
Tue: 9.30
2.30 pm.

Gold in Tanami
① assoc c chem sedst BIFs (granites, eg Bullick sack)
② sheet network veining Kali 9t3-ser schist
③ Au in Tan complex close to U/C Au in basal seds. anomalous U poss Pt Pd (trace) (target)

30th September 1992

Dr. Lynton Jacques
A.G.S.O.
Mineral and land Use Program
GPO Box 378
CANBERRA ACT 2601

Dear Lynton,

CONSULTANCY: UNCONFIRMITY RELATED MINERALISATION

Further to our telephone conversations, and your proposals dated 7th September, 1992, firstly please accept my apology for the delay in responding.

I wish by this letter to accept your proposal, and request your services in relation to our exploration areas in the Tanami Region.

Having regard to the division of responsibilities outlined in your letter, the objectives of the consultancy are as follows:

Based upon consultants' experience of mineralisation in the Pine Creek Geosyncline, and elsewhere,

- OK ✓ to form an opinion based on field and exploration evidence, of the prospectivity of NFM tenements in particular, and the Tanami region in general for unconformity-associated $Au^{+}/\_PGM^{+}/\_U$ mineralisation;

- OK ✓ to advise on the exploration indicators (geological, geochemical, geophysical, nearsurface characteristics, and regional settings) of such mineralisation to be expected in the Tanami Region;

and to report on the above matters.

additionally to discuss these matters with NFM geologists

I shall be happy to discuss the possibility of short courses mentioned in your letter, as the project develops.

Some aspects of these deposits in which we are particularly interested and may seek to discuss include:

COVERED

- geological features: characteristic host rocks, mineralogical and chemical alteration patterns, local and regional structural settings, and other controls of deposit localisation

- geochemical signatures: primary and secondary dispersion, pathfinder elements and other associated trace element assemblages,

- geophysical responses: relevant physical characteristics of deposits and affected halo areas, and radiometric signatures which may be anticipated.

The resources which we would make available to your representatives would include field access to areas which we regard as prospective for mineralisation of this type, exploration datasets and reports relevant to those areas, and insight into regional geological settings as we understand them.

This work is highly confidential, firstly in that a positive outcome would affect future exploration of lands we do not at present control, and secondly in that it draws upon NFM's exploration expertise in the Tanami - a body of knowledge and experience we believe to be substantially ahead of our competitors, and a competetive advantage in the region, acquired at great expense, not lightly to be surrendered to industry generally. While I am sure that the general principle of consultant confidentiality is well understood by your personnel, it is important that they are aware of the particular sensitivity of **all aspects** of this information and their work. No discussion can be countenanced of any of this material apart from that amongst the team involved, and for the purposes of this particular consultancy (e.g. in connection with AGSO/National Mapping Accord work to our south-east) without my specific approval.

The structures we propose for the investigation are as follows:

Field inspection of exposures and drill-defined geological information; discussions with involved geologists Dean Lovett, Steve Hogan Gerard Bosch and Andy Beckwith.

Data familiarisation (geological, geochemical, geophysical) in relation to field investigations to date, with geologists involved, in Adelaide

In these we would be guided by your suggestions of appropriate lines of investigation or documentation, and would make available exploration information as appropriate, to satisfy your inquiries

If this brief is consistent with your expectations, we would anticipate that the field investigation would be undertaken under the guidance of involved exploration geologist(s), over about 1 week in mid-October, followed by the more detailed familiarisation with exploration data, in Adelaide, and report preparation in Adelaide or Canberra as appropriate, during November, with final reporting before the end of the year.

Clearly such a study is open-ended in terms of its scope and detail; I would favour a study which is initially fairly brief, principally placing Tanami observations in the context of Alligator Rivers area experience - perhaps up to 1 week in the field, two weeks in Adelaide, and up to week in final report preparation. Then dependent on any encouragement revealed, follow-up studies in greater depth may be proposed by either of us. I have in mind an overall budget to the point of reporting this initial work, including travel, etc expenses not exceeding $10,000. Analytical and petrological work would be additional to this budget. I would appreciate your comment on these expectations.

In respect of personnel to be involved in the consultancy, you have offered the services of Liz Jagodzinski, supervised by Leslie Wyborn, and supplemented as appropriate by Chris Heinrich, Greg Ewers, and Stewart Needham, the majority of whom are known to me, by reputation at least. Given the fairly general nature of our objectives, and the paucity of available exploration expertise relevant to this suite of deposits, we are happy to follow this course, with the involvement of the last-named three at your discretion.

With regard to invoicing, we are agreeable to the daily rates advised, and to reimbursing expenses incurred, and request that you invoice us monthly, quoting our Order No. 5880.

As the field component is likely to be initiated in the very near future, would you please liaise with Supervising Geologist Dean Lovett regarding details of timing.

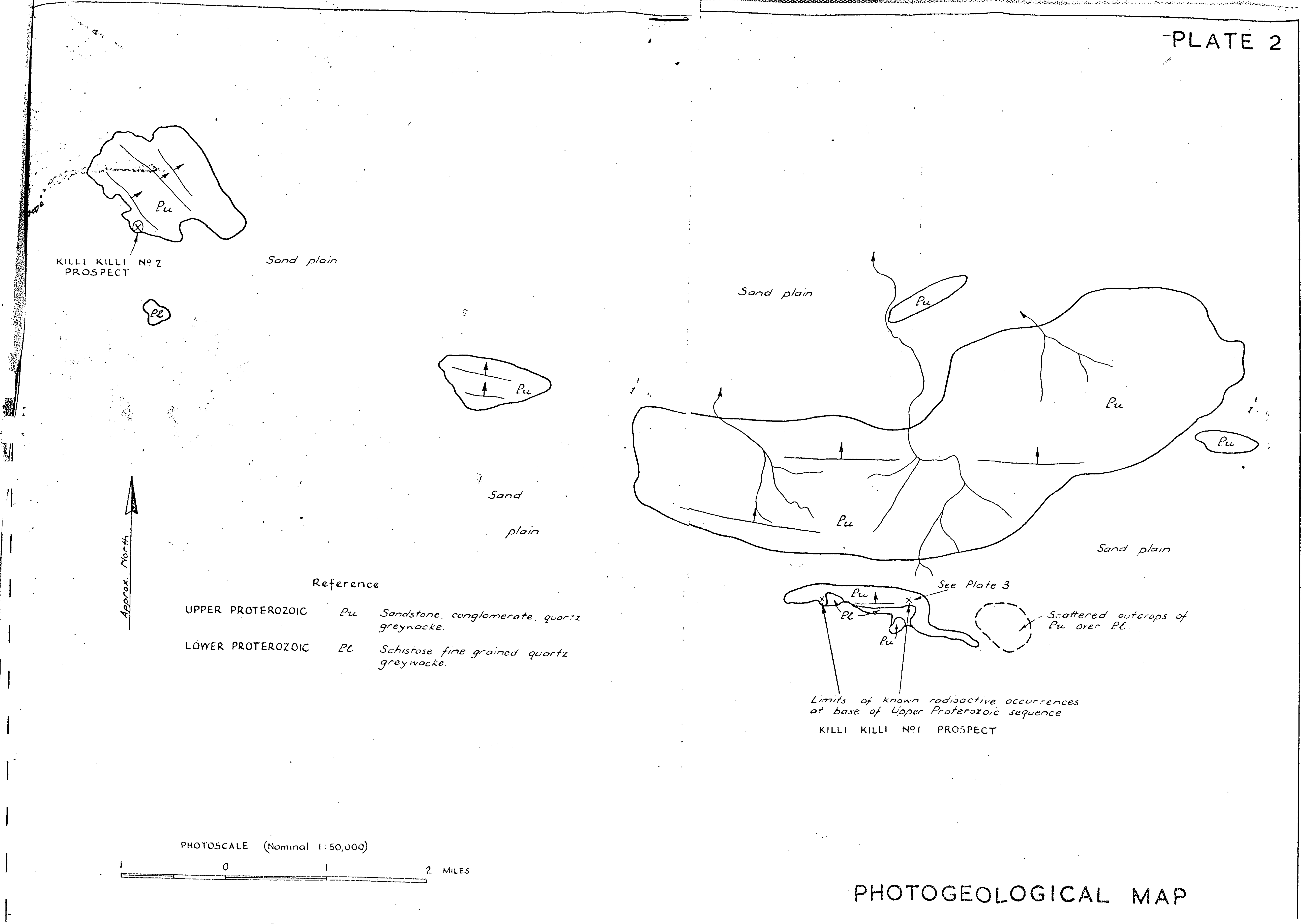
With Thanks

Yours sincerely
NORTH FLINDERS EXPLORATION

Trevor Ireland
EXPLORATION MANAGER

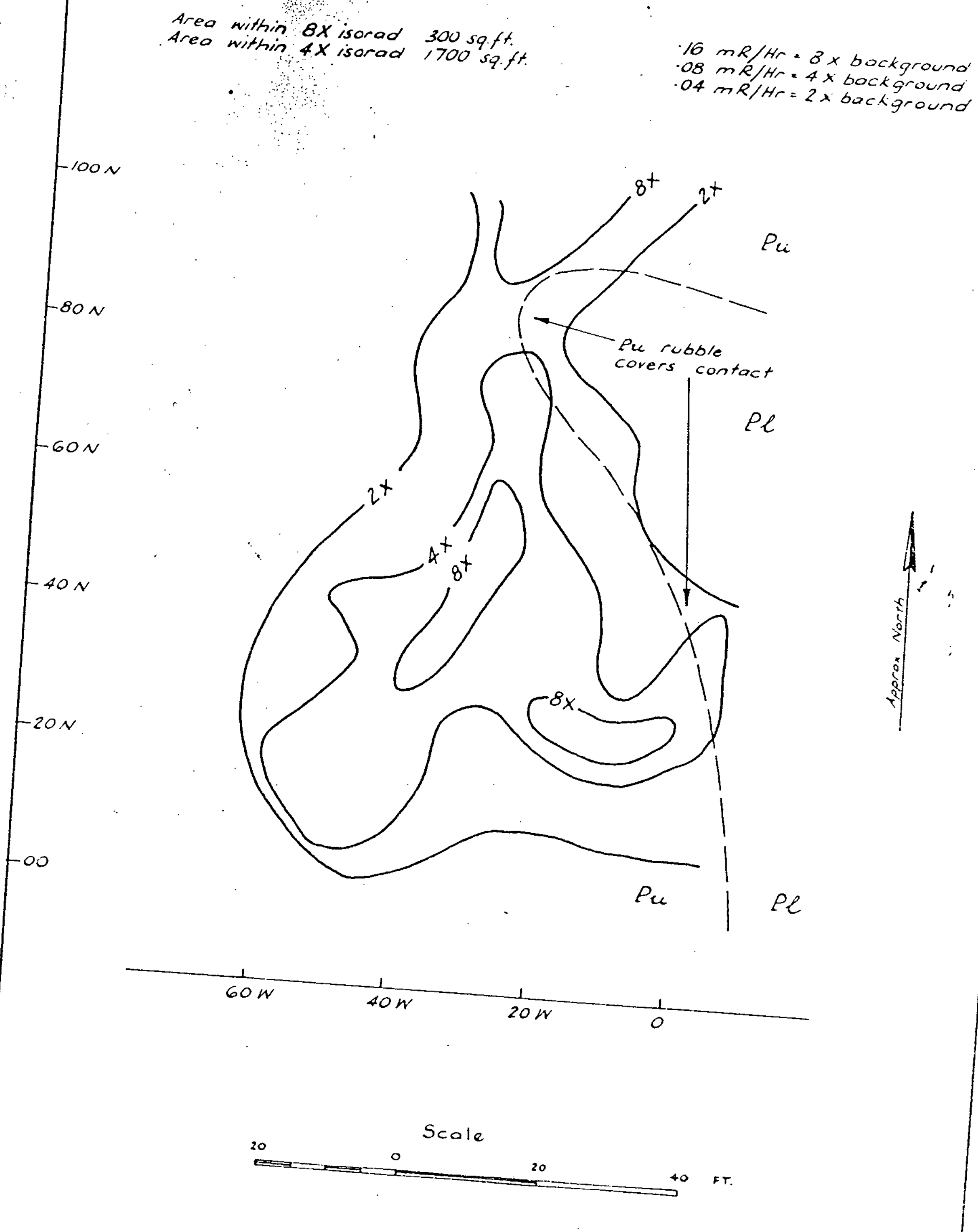
RH:TJI288

PLATE 2



PHOTOGEOLOGICAL MAP

PLATE 3



ISORADS

EAST END KILLI KILLI NO. 1 PROSPECT.

Appendix 5. Review of exploration carried out by PNC and other exploration companies in the Granites-Tanami Block.

(Summary of Relinquishment report on EL 80/693 & EL 80/694 located in western Browns Range Dome, W.A.)

PNC Exploration holds title to four EL's in Western Australia and eight in the Northern Territory, in the Granites-Tanami Block. Exploration is principally concerned with the location of unconformity related uranium mineralisation.

PNC targeted areas where 'extensive Lower Proterozoic geosynclinal/trough sequence, with minor associated associated volcanics and terrestrial to shallow marine shelf sediments partly enclose large uplifted basement features' (such as the Browns Range Dome). That is, they appeared to target the unconformity in areas around what they interpreted to be 'basement features' such as the Browns Range Dome, which they probably considered to be mainly Archaean, and the source for uranium.

Previous Uranium Exploration

1960: New Consolidated Gold Fields (Australasia) Pty. Ltd. discovered uranium in the Killi Killi Hills area.

1970's: Numerous companies were active on the Western Australia and Northern Territory sides of the border, directing exploration towards vein-unconformity type uranium mineralisation based on the Pine Creek Geosyncline and Athabasca Basin models. No deposits of note were located during this period.

1980-1981: The Mineral Reserves Group of Canada undertook a major evaluation of the Granites-Tanami region in the search for Athabasca Basin type uranium mineralisation. Most of this work occurred on tenements in W.A. Of significance was the discovery of polymetallic vein-related uranium, gold, nickel and cobalt mineralisation with associated autunite and meta-torbernite mineralisation at the "Don Uranium Show" in the Gardner Range. The company ceased operations after 1981 without having fully evaluated this occurrence and other areas of interest. Some of the companies tenements were taken up by Canadian Energy Resources Pty. Ltd. in 1982.

1983-1984: Otter Exploration and Cultus Pacific held land but did little work before relinquishment in 1984. Canadian Energy Resources, BHP and CRA Exploration held tenements in the Gardner Range region of W.A., some of which are still current. Details of exploration activities and targets are not known.

Dry Creek Mining N.L. carried out gold exploration over the Killi Killi Beds in the Larranganni Bluff area, W.A. Trace gold was found with a maximum gold content of 2.18ppm in a narrow quartz vein associated with limonitic greywacke country rocks.

PNC became interested in the Granites-Tanami region following research of the regional geology which suggested similarities with the Pine Creek Geosyncline and Athabasca Basin.

1989: The Central Electricity Generating Board of Great Britain carried out an EM survey near the Don Uranium Show in he Gardner Range prior to a short drill program (on tenements held by Canadian Energy Resources).

Apart from tenements now held by BHP and Canadian Energy Resources in the Gardner Range, and Neuman and Associates in the Killi Killi Hills, there are believed to be no other companies actively exploring for uranium in the W.A. sector of the Granites-Tanami.

Summary of work carried out by PNC

- aerial photography at 1:80 000 scale over project area, and 1:25 000 scale over selected areas.

- airborne magnetic and radiometric surveys over all W.A. tenements. Limited ground radiometrics over areas of interest.

- regional geological mapping, geochemical sampling and radiometric surveying of tenement areas.

- 14 RAB holes and 2 diamond holes were drilled.

Results of work carried out by PNC

Geology: Lower Proterozoic metasandstones and thick Middle to Upper Proterozoic sandstone (Gardiner) and extensive Tertiary/Quaternary sand cover. The overlying sandstone may be extensively faulted, the deformation probably associated with the formation of the Browns Range Dome.

Geophysics: generally a uniform geophysical and radiometric response, downgrading the importance of these areas.

Geochemistry: 88 geochemical samples, 7 petrographic samples, 2 geochronology
samples. Elements analysed: U, Th, Y, La, As, Cu, Pb, Zn, Ni, Cr, Ca, Mg, Fe,
As, Yb, Ga, Nb, W.

Only one geochemically and radiometrically anomalous area was located in the relinquished area of EL80/693, northwest of Browns Range Dome (Area 1). A gridded survey showed radiometrics generally between 80-100 cps with a maximum of 550 cps, with 390 ppm Th, 1180 ppm La, 15ppm U, 28 ppm As, 120 ppm Y, 35 ppm Ga. The anomaly is in scattered outcrop of Lower Proterozoic arkose.

Drilling: Drilling was aimed at examining the internal structure of the Browns Range Dome. Two main rock types were intersected: a biotite-quartz-feldspar gneiss with schist bands, and a biotite-quartz-feldspar granite.

Comments

It appears that the PNC exploration model placed emphasis on the source of uranium, and therefore they concentrated exploration programs around the Browns Range and Coomarie Domes, possibly because they believed these structures to contain uranium-rich Archaean basement.