EXPLORATION LICENCES 6155-6157, 6250

(PANDANUS CREEK AREA)

FINAL REPORT PERIOD 1988-1990

CALVERT HILLS 1:250,000 SHEET SE 53-8

Licensee:  Kratos Exploration Pty Ltd
Operator:  Kratos Exploration Pty Ltd

J R Stewart
Kratos Exploration Pty Ltd
June 1990
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Metre Conglomerate

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KRATOS EXPLORATION PROGRAMME 1986-1987

1986 Programme

1987 Programme

Bulk Stream Sediment Sampling

Rock Chip Sampling

Core Sampling

Stream Sediment Sampling

Metre Conglomerate Bulk Sample

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INTRODUCTION

Kratos Exploration Pty Limited (Kratos) has explored actively in the Pandanus Creek region since 1975.

The three Exploration Licences originally granted to Kratos were:

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<td>1016</td>
<td>10.5.76</td>
<td>Surrendered 14.4.82</td>
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<tr>
<td>1074</td>
<td>8.8.78</td>
<td>Surrendered 8.8.79</td>
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On 30 June 1982, three new Exploration Licences were granted to Kratos over the same ground as had been held immediately previously as EL 1016. Details were as follows (Fig 1):

<table>
<thead>
<tr>
<th>Exploration Licence No.</th>
<th>Approx Area (sq km)</th>
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<tr>
<td></td>
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<tr>
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<td>3.26</td>
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<tr>
<td>3626</td>
<td>35.90</td>
<td>16.30</td>
</tr>
<tr>
<td>3627</td>
<td>29.38</td>
<td>16.30</td>
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<tr>
<td></td>
<td>68.54</td>
<td>35.86</td>
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On expiration of ELs 3625–3627, two Exploration Retention Leases and four Exploration Licences were granted as follows (Fig 2):
Fig 2
Locality Map:
ERLs 81, 82
ELs 6155-6157, 6250
Two separate reports have been prepared, viz
1) this report, which covers Exploration Licences 6155-57 and 6250, and

2) a report covering Exploration Retention Leases 81 and 82

PREVIOUS JOINT VENTURE ARRANGEMENTS

For completeness, the following summary of the joint venture arrangements which applied prior to the granting of ELs 6155-57 and 6250 is given.

On 19 April 1971, Kratos' parent company (Kratos Uranium NL) entered into a Co-operative Exploration Agreement (PKW Agreement) with Pechiney (Australia) Exploration Pty Limited (a wholly owned subsidiary of Compagnie Pechiney of France) and Wyoming Mineral Corporation (a wholly owned subsidiary of Westinghouse Electric Corporation of USA) to search for uranium in the Northern Territory.

Following initial exploration work by Kratos in ELs 1017 and 1016 in 1975-1976, these titles were brought under the PKW Agreement by a Deed of Continuation dated 31 March 1977. As Pechiney (Australia) Exploration Pty Limited had in the meantime changed its name to Minatome Australia Pty Limited, this Deed of Continuation was referred to as the MKW Agreement.
By Agreement dated 23 September 1981, Wyoming Mineral Corporation sold its interest in the MKW Agreement to Kratos and Bridge Oil Limited was admitted as a new partner (MKB Agreement).

By Deed dated 21 May 1984 Minatome Australia Pty Limited (which had in the meantime changed its name to Total Mining Australia Pty Limited) withdrew from the joint venture, leaving Kratos and Bridge Oil Limited as the remaining partners.

In June 1984, Kratos and Bridge entered into an agreement with Stockdale Prospecting Ltd covering exploration for diamonds only within the Exploration Licences area. After completion of a reconnaissance test programme, Stockdale withdrew in September 1985.

Earlier, in February 1984, Central Electricity Generating Board Exploration (Australia) Pty Ltd (CEGBEA) approached Kratos and Bridge with a view to entering into the joint venture to continue the search for uranium in the area. A formal joint venture agreement was not signed, but CEGBEA took over as operator for the uranium search programme in the area from mid-1984, and continued until its withdrawal in November 1987.

Originally it had been intended that CEGBEA would earn a 50% equity interest in the joint venture by matching previous expenditure by Kratos and its partners. In August 1986 this was revised to allow CEGBEA to earn up to a 50% interest in the rights to uranium only for a reduced expenditure. The rights to all other minerals reverted to Kratos and Bridge and Kratos carried out field programmes exploring for gold, platinum group elements and diamonds in 1986 and 1987 (concurrently with the CEGBEA uranium programme).

Except for the programmes carried out by CEGBEA and Stockdale, Kratos was at all times Operator for the various programmes of exploration in the area.

Bridge Oil Limited indicated its intention to withdraw from the joint venture in mid-1988 (formalised in October 1989) and
exploration within the new titles (ELs 6155-57, 6250) was therefore carried out by Kratos alone.

BIBLIOGRAPHY OF REPORTS

Details of the work carried out by Kratos in ELs 1016, 1017 and 1074 are contained in the following Company reports lodged with the Department of Mines and Energy:

Exploration Report and Analysis of Results EL 1017, Pandanus Creek Area, N.T., 1975 March 1976

Uranium Exploration Programme, Pandanus Creek Area, N.T., EL's 1016 and 1017, 1976 May 1977

Stratigraphy of the Westmoreland Conglomerate, EL's 1016 and 1017, N.T. L.R. Hall December 1977

Uranium Exploration Programme, Pandanus Creek Area, N.T., EL's 1016 and 1017, 1977 February 1978

Uranium Exploration Programme, Pandanus Creek Area, N.T., EL's 1016, 1017 and 1074, 1978 March 1979

Uranium Exploration Programme, Pandanus Creek Area, N.T., EL's 1016 and 1017 March 1980

Uranium Exploration Programme, Pandanus Creek Area, N.T., EL 1016 April 1981

Uranium Exploration Programme, Pandanus Creek Area, N.T., EL 1016 May 1982


Details of the work carried out in ELs 3625-3627 by Kratos and by the two other Operators who carried out programmes during parts
of the period of tenure of these tenements, are set out in the following reports lodged with the Department of Mines and Energy:

Uranium Exploration Programme, Pandanus Creek Area, N.T., 1982, EL's 3625, 3626 and 3627 (Kratos). June 1983


Geophysical Data EL's 3625, 3626 and 3627, Pandanus Creek Area, Calvert Hills 1° x 1.5° Quadrangle, Northern Territory: Initial Interpretation. CEGBEA Report 1984/1 (L.J. Starkey July 1984).


Exploration Licences 3625, 3626, 3627 held by Kratos Exploration Pty Ltd in the Calvert Hills 1° x 1.5° Quadrangle. Annual Report to the NT Department of Mines and Energy for the Year Ending 29 June 1985. CEGBEA Report 1985/7 (P.W. Pritchard 31 July 1985).


Test Seismic Refraction and Reflection Survey JN and Turkey Creek Geophysical Grids, North East Pandanus Creek. CEGBEA Report 1986/6 (L.J. Starkey 26 February 1986).


Annual Report Exploration Licences 3625-3627

Pandanus Creek Area Exploration Licences 3625-3627:

Details of the work carried out by Kratos in ELs 6155-57 and 6250 are contained in the following report lodged with the Department of Mines and Energy:


LOCATION AND ACCESS

The locations of the various titles, all of which lie within Wollogorang Pastoral Lease, are shown in Figs 1 and 2.

Ground access to the area may be achieved either through Mount Isa and Doomadgee Mission in Queensland, or via Borroloola in the Northern Territory.

The area is affected by monsoonal rains during the summer period. Present access roads are impassable during this period and hence field work can only be carried out during the winter dry season.
REGIONAL GEOLOGY

The Pandanus Creek-Westmoreland province lies at the southern extremity of the Wearyan Shelf of the McArthur Basin and is separated from the Lawn Hill Platform of the South Nicholson Basin by the Murphy Tectonic Ridge (Figs 3 and 4).

The geology of the area is shown in generalised form in Fig 5. A more detailed geological map of the area of the tenements showing prospect locations is included as Fig 6. It should be noted that some of the unit identification symbols used in Fig 6, which is based on the original Calvert Hills 1:250,000 Geological Series map sheet, have now been changed.

The Early Proterozoic basement rocks of the Murphy Tectonic Ridge (Murphy Inlier) are overlain unconformably by the lowest units of the Middle Proterozoic Tawallah Group, the basal group of the McArthur Basin sequence.

The Murphy Inlier trends east-north-east and is composed of three units, viz Murphy Metamorphics, Cliffdale Volcanics and Nicholson Granite Complex (Sweet and Slater 1975).

Murphy Metamorphics

The Murphy Metamorphics (Plm) are the oldest rocks in the region; they are at least 1,900 m.y., and possibly 2,100 m.y. old (Plumb and Derrick 1975). They are intruded by all members of the Nicholson Granite Complex and are overlain by the Cliffdale Volcanics in the Fish River area. As the Metamorphics have undergone regional deformation which has not affected the Cliffdale Volcanics it is inferred that the relationship is unconformable.
Fig 3

Principal Tectonic Elements, McArthur Basin/Mount Isa Orogen.

After Plumb et al, 1980.
Fig 4

Tectonic Units in Pandanus Creek/Westmoreland Province. (From B.M.R. Record 1975-88).
Fig 5  Generalised Geology
In the Fish River area, exposures comprise greenschist facies (muscovite-epidote-) quartz-albite-biotite-chlorite schists. Eastwards, the schists grade into massive, medium to coarse grained, granite-veined, muscovite gneiss. The textural and compositional differences between the schists and gneiss, and the gneissic banding, probably reflect primary sedimentary banding (Gardner 1978).

The dominant structure in the Murphy Metamorphics is a west to north-west trending foliation; the plane of schistosity is vertical or near-vertical. The linear form of the intruding Nicholson Granite Complex is east-north-east, i.e oblique to the foliation in the Murphy Metamorphics. However, secondary foliations in the Metamorphics are parallel to the main east-north-east trends in the granites.

The Murphy Metamorphics are similar in lithology and metamorphic grade to the Yaringa Metamorphics, the oldest rocks in the Mt Isa Block and, on a broader regional scale, both have been correlated with basement inliers in eastern Arnhem Land and the Pine Creek Geosyncline (Plumb and Derrick 1975).

**Nicholson Granite Complex**

Gardner (op cit) subdivided the Nicholson Granite Complex (Pgn) into seven pahses, mainly on lithological and chemical, rather than geochronological, grounds as age relationships, particularly among the small intrusions, are uncertain.

The subdivisions are:

- **Pgn₁** White, coarse grained, porphyritic, hornblende-biotite-microcline-albite granite, distinctive by virtue of its high proportion of mafic minerals and the euhedral nature of its K-feldspar phenocrysts. Pgn₁ is probably overlain by the Cliffdale Volcanics and is at least 1,840 m.y. old.
Pgn$_2$ Porphyritic, albite-microcline granite, younger and more fractionated than Pgn$_1$ - the groundmass minerals are even-grained and not recrystallised to mono-mineralic aggregates as in Pgn$_1$. Pgn$_2$ apparently intrudes Clifftdale Volcanics along one of its contacts, but may include granite of a range of ages, some of which may be older than the Clifftdale Volcanics. The texture of Pgn$_2$ is similar to Pgn$_1$, viz euhedral K-feldspar phenocrysts set in a hypidiomorphic granular groundmass of albite, quartz and mafic minerals.

Pgn$_{3-4}$ This is a grouping of lithologically and chemically identical hornblende granodiorites of different ages. Red, coarse grained granodiorites occur as ring dykes along margins of plutons, and are cut by smaller, fine grained melanocratic granodiorite dykes. The best-exposed dyke intrudes the Murphy Metamorphics, and is intruded by Pgn$_1$. Other dykes intrude Pgn$_2$, Pgn$_5$, Pgn$_6$ and the Clifftdale Volcanics, indicating that granodiorite ring dyke intrusion continued to at least 1,770 m y. Pgn$_{3-4}$ is petrographically similar to Pgn$_1$, but is less fractionated.

The group Pgn$_5$-Pgn$_8$ is distinguished from the group Pgn$_1$-Pgn$_{3-4}$ by its more fractionated chemistry and absence of phenocrystic K-feldspar. The K-feldspar present is intergrown with the other minerals. The four units in the group are coeval with, or younger than, the Clifftdale Volcanics.

Pgn$_5$ Red, even grained, biotite-albite-microcline granite

Pgn$_6$ Red, even grained, albite-microcline leucogranite
Pgn$_7$ Microgranite

Pgn$_8$ White, aplitic, muscovite-bearing, microcline-albite granite

The common occurrence of greisen and aplite dykes associated with Pgn$_5$, Pgn$_6$ and Pgn$_8$ indicates high-level crystallisation of these younger granites. Muscovite pegmatites occur within Pgn$_8$.

Pgn$_1$ is the most "basic" granite. The later phases of the Complex are characterised by successively lower plagioclase/total feldspar and hornblende/biotite ratios, lower mafic content, change from green to brown biotite paralleling increasing oxidation state of iron, gradual aggregation of mafic minerals, and replacement of calcic accessories by opaque oxides.

Pgn$_1$ intrudes regionally metamorphosed rocks along contacts which are partly concordant and locally migmatitic. This relation implies relatively deep seated intrusion but the absence of large scale gneissic or flow structures, the presence of xenoliths, the low metamorphic grade of the country rock and the development of a contact aureole indicate that Pgn$_1$ migrated some distance from its site of melt formation before it crystallised.

Pgn$_2$ apparently crystallised at slightly shallower depth than Pgn$_1$ as discordant contacts do not show metamorphism of the intruded country rock.

Clear red feldspars are characteristic of Pgn$_3$-$4$. Iron was incorporated in such feldspars in solid solution during crystallisation and the red colouration is due to exsolution of the iron with time to form submicroscopic grains of hematite along crystallographic planes of the host feldspar. The amount of iron in solid solution increases with increasing temperature. Hence, the intensity of red colouration in the resulting rock is a measure of temperature of formation, ie red feldspar granites crystallised at higher temperatures than white feldspar granites.
Pgn₅ and Pgn₆ show evidence of having crystallised under minimal cover-rock pressure from a relatively hot magma. The intrusives contain no cognate xenoliths and a variety of hypabyssal rocks – including granodioritic ring dykes, quartz-feldspar porphyry dykes, aplites and microgranites – are associated with them.

Pgn₈ is distinguished from the other granites by its generally finer and more even grain size, the presence of muscovite rather than biotite or hornblende, and its higher quartz content. The presence of muscovite, and the association of this unit with greisen, suggest a high-level, late-stage, residual-melt origin. Pgn₈ represents the last stage of intrusive activity as it intrudes Pgn₂, Pgn₅ and Pgn₆. Several samples of Pgn₈ have been dated by the whole-rock Rb-Sr method at 1,773 ± 56 m.y. (Webb 1975).

The intrusions within the Nicholson Granite Complex conform to a pattern observed in many igneous complexes, viz a series of related intrusions emplaced at successively higher crustal levels with time.

Buddington (1959) defined three levels of placement:

Catazone Zone of upper amphibolite and granulite facies metamorphism. Anatetic granite melts generated in this zone may crystallise in situ or migrate to higher levels in the crust before solidifying.

Mesozone Corresponds to the zones of greenschist and lower amphibolite facies metamorphism. Mesozone granites are not associated with metamorphic rocks from the source area of the granites, nor with volcanic or subvolcanic rocks.
Epizone Lies above the level of greenschist facies metamorphism. Melts which reach the epizone initially produce volcanics. The accompanying sudden release of pressure causes the remaining magma to crystallise rapidly. This produces subvolcanic discordant circular intrusions surrounded by narrow contact aureoles and accompanying porphyry dykes, ring dykes and granophyres.

$Pgn_1$, $Pgn_2$ and the older granodiorite stocks of $Pgn_{3-4}$ are the oldest exposed rocks of the Nicholson Granite Complex and show features characteristic of mesozonal intrusions.

$Pgn_5$, $Pgn_6$ and $Pgn_8$ are high-level epizonal granites, preceded and accompanied by emplacement of quartz-feldspar porphyry dykes and the younger granodiorite ring dykes of $Pgn_{3-4}$.

Gardner (op cit) postulates that the source material for the granites was sediments and volcanics from the base of the sequence now represented by the Murphy Metamorphics.

On the basis of their chemistry, he suggested that the Nicholson Granite Complex was generated and emplaced between about 10 and 7 km depth, the younger granites having been formed within the zone of emplacement of the older granites.

Dyke rocks within the granites include:

(Quartz) - feldspar porphyry. These dykes fall into two groups, viz granite types with phenocrysts of quartz and K-feldspar which cut $Pgn_2$ and granodiorite types with no quartz phenocrysts which cut all units of the Cliffe Dale Volcanics and $Pgn_5$.

Aplite and microgranite. Microgranite is abundant as chill zones within $Pgn_5$ and as dykes and chilled margins, mainly near contacts. Aplite dykes occur throughout the Complex, but more commonly in $Pgn_2$, $Pgn_5$ and $Pgn_6$. 
Dolerite and basalt. These may belong to the same basic igneous activity which produced the Seigal Volcanics.

Greisen. Greisen is present as greisenised granite (produced by pneumatolytic fluid); greisen dykes filling faults and joints; and a large apophysis, not related to granite fissuring, at Crystal Hill.

Quartz. Quartz is the most abundant dyke rock, occurring as silicification along faults as well as massive veins, probably not controlled by faulting. Although occurring in all orientations, most fault-controlled quartz veins occur in north-south tensional zones. Associated with the quartz veins are goethite, limonite, hematite and, rarely, minor copper mineralisation.

Major element chemical variation trends of granites younger than the Clifffdale Volcanics are indistinguishable from those of the older granites. Trace elements show wide variations in both groups. Thus the chemical data are inconclusive as to whether all the granites of the Complex are comagmatic. Regardless of the source of the major intrusions, the granodiorite dykes emplaced at various times throughout the history of the Complex show similar major and minor element chemistry and would thus appear to have been all derived from the same magma source.

The older granite, Pgn₁, and the Clifffdale Volcanics fall almost coincidentally within the range of intermediate to high initial \( \text{Sr}^{87}/\text{Sr}^{86} \) ratios. This coincidence, combined with the chemical similarity between the two units, strongly suggests that they are cogenetic, derived by anatexis of predominantly crustal material. (Upper mantle basaltic material has lower initial \( \text{Sr}^{87}/\text{Sr}^{86} \) ratios as the crust has with time become enriched in Rb). The highly fractionated chemistry and higher initial \( \text{Sr}^{87}/\text{Sr}^{86} \) ratios of the younger granites suggest that they are, at least partly, the products of remelted, previously fractionated material, viz remelted Pgn₁. The suggested process is one of reactive assimilation of Pgn₁ by granitic magma at high crustal levels.
Uranium values are high in the granites and the greisen dykes relative to average granites (Taylor 1965) and are even higher in the volcanics of similar SiO₂ content. Thus uranium may have migrated from the granite into the volcanics.

At the Eva mine, uranium occurs in shear zones in altered volcanics adjacent to their contacts with the Westmoreland Conglomerate and a small pod of granite.

Both granite and Cliffdale Volcanics are cut by Cu-bearing quartz veins. It is suggested that the Cu mineralisation is due to the migration of Cu, along with late-stage greisening fluids, into low-pressure zones, ie tensional structures formed by intersecting trends.

"In summary, mineralisation appears to be restricted to granite/volcanic contacts or to late-crystallising rocks emplaced in north-south tensional zones. If, as seems likely from the high-level nature of the younger granites, there had been widespread mineralisation throughout the original upper levels of the complex, it has been removed by the extensive erosion that has taken place before and since the deposition of the Westmoreland Conglomerate and equivalents".

The Nicholson Granite Complex was extensively eroded before the Westmoreland Conglomerate was deposited.

**Cliffdale Volcanics**

The Cliffdale Volcanics (Pcc) are a sequence of rhyolitic to andesitic ignimbrites, flow-banded rhyolitic lavas, and acid tuffs which form part of the Murphy Tectonic Ridge. They form a belt of nearly continuous outcrop between 7 and 18 km wide and 48 km long which is more or less bisected by the Queensland/Northern Territory border.
The Cliffdale Volcanics were erupted as a series of extensive flat-lying pyroclastic and lava flows onto a probably irregular land surface. They are still predominantly flat-lying, although they dip more steeply adjacent to some faults and intrusive granite contacts.

Intrusion of granite Pgn₅ south-west and south-east of Billicumidji Waterhole produced the basin-like structure where the oldest known volcanic units (Pcc₁, Pcc₂, Pcc₃) are preserved. The basin is about 5 km in diameter, and the volcanics around its margin dip inwards at up to 20°.

Rocks of the Cliffdale Volcanics commonly have a primary foliation resulting from the flattening of pumice fragments and welding of glass shards soon after the flows were extruded. Contorted flow banding in rhyolite lavas formed at the time of extrusion.

Minor folding is apparent at the south-eastern margin of the tectonic basin, where several open folds plunge gently to the north-west. These folds are probably related to the intrusion of adjacent granite Pgn₂.

Two possible eruptive centres for some of the acid volcanics have been found. These are occurrences of rhyolitic breccia.

The high level granites of the Nicholson Granite Complex, particularly phases Pgn₅, Pgn₆ and Pgn₈, were probably comagmatic with the Cliffdale Volcanics, and their locations may indicate the position(s) of magma chamber(s) which were the immediate sources for the volcanics. The swarms of acid porphyry dykes intruding the volcanics are closely related spatially to the granites, and are considered to be a final magmatic phase. They are not the main feeders to the volcanics.
The Volcanics define the base of the Carpentarian System, and have been dated at 1,770 m.y. Acid volcanics of similar age in other parts of Northern Australia include the Edith River Volcanics of the Alligator Rivers area of the Pine Creek Geosyncline.

The greatest known thickness of the Cliffdale Volcanics - more than 4,000 m - occurs near the Queensland/Northern Territory border, but the base of the succession is not exposed. They are generally flat-lying or shallow-dipping and form gently undulating terrain.

Five major units have been recognised (Mitchell 1976); two of these have several sub-units. The three oldest $Pcc_1$, $Pcc_2$ and $Pcc_3$ consist of ignimbrites in a small tectonic basin surrounded by younger granites on the Queensland side of the border.

$Pcc_4$ is a sequence of ignimbrites and minor lavas and $Pcc_5$ (named the Billicumidji Rhyolite Member) consists of lavas and subordinate ignimbrites. These two units are much more extensive than the older units.

$Pcc_4$ consists of numerous ignimbrites, tuffs and lava flows, many of which have been mapped as separate sub-units. Each sub-unit is at least 100 m thick, and $Pcc_4$ as a whole has a thickness of at least 2,000 m. It is intruded by granite and its base is not exposed.

The Cliffdale Volcanics have not been regionally metamorphosed, but show effects of thermal metamorphism, such as the development of chlorite, epidote, albite, biotite and actinolite, near granite intrusions.

$Pcc_4$ and $Pcc_5$ both occur on the Northern Territory side of the border. $Pcc_4$ is represented by the three sub-units $Pcc_4a$, $Pcc_4c$ and $Pcc_4d$; $Pcc_4b$ is minor (Fig 7).
Fig 7  Distribution of Units of Cliffdale Volcanics
In summary, these units are:

Pcc₅ (Billicumidji Rhyolite Member); At least five flow-banded and massive red rhyolitic lava flows with minor intercalations of tuff and ignimbrite.

Pcc₄d Blue-black ignimbrite. Basal, thin-banded, graded-bedded tuff, in part conglomeratic.

Pcc₄c Red to pink, massive and flow-banded rhyolite lava.

Pcc₄a Red-brown ignimbrite.

The colour of the ignimbrites depends on the concentration and state of oxidation of opaque minerals in the groundmass which is, in many cases, devitrified glass.

Pcc₄a

The Pcc₄a red-brown ignimbrites show thin banding, highlighted by differential weathering. They contain small phenocrysts of white plagioclase, pink alkali feldspar, and quartz, volcanic rock fragments of mostly lapilli size, flattened pumice fragments, and minor small aggregates of biotite - chlorite and opaque minerals. The ignimbrites are cut by veins up to 3 mm wide consisting of quartz and epidote in a pale red, partly streaky, microcrystalline groundmass.

The plagioclase phenocrysts are up to 3 mm across, form up to 30 per cent of the rock, and are highly altered to sericite, clay and chlorite. The alkali feldspar phenocrysts (up to 15 per cent of the rock) are partly cloudy and contain dusty opaques and minor chlorite and calcite. Phenocrysts of quartz (up to 5 per cent of the rock) are embayed, and contain inclusions of devitrified groundmass, which also forms veinlets and fracture
fillings. Mafic minerals are uncommon, but up to 2 per cent occur in some specimens; they are represented by bleached and altered biotite flakes largely replaced by opaque minerals, sphene and chlorite. Some of the flakes are wrapped around phenocrysts, and some in the groundmass are bent. There are also scattered opaque grains.

The volcanic rock fragments closely resemble the host rock. The pumice fragments contain chlorite flakes and fine magnetite or hematite grains. Their quartzo-feldspathic groundmass is coarser grained than that of the host rock.

The groundmass of the red-brown ignimbrites is devitrified glass, and consists of quartz, feldspar, and minor sericite, chlorite, sphene and other secondary minerals. The red-brown colouration is due to minute grains of hematite in the groundmass. The devitrification has resulted in a micrographic fabric, but this has not completely obliterated the eutaxitic structure. Some of the flattened glass shards form pressure tails around phenocrysts; the resulting banding is discontinuous and lenticular, distinguishing it from flow banding found in rhyolite lavas. A common feature in the groundmass is the presence of small irregular fragments of quartz, some of which are flattened and form lenticular plates.

\[ \text{Pcc}_4\text{c} \]

Sub-unit \text{Pcc}_4\text{c} consists of red to pink rhyolite lava which is massive and flow-banded.

The massive part is microporphyritic, with pink potash feldspar laths up to 2 mm long forming up to 5 percent, and small aggregates of biotite-chlorite, nearly 1 mm across, forming about 1 percent of the rock. Some of the biotite-chlorite aggregates are aligned, and impart a streaky appearance to the rock. The groundmass is pale red and cryptocrystalline.
The flow-banded part of the rhyolite is also microporphyritic, but the pink and white feldspar phenocrysts are not obvious on weathered surfaces. Some of the flow banding consists of overlapping lenticular streaks of material which resembles flattened pumice fragments. However, most of the flow banding is marked by thin, continuous layers of quartz, feldspar, and devitrified glass. Some of the banding is convolute. Spherulites and vesicles lined with chalcedony are present locally.

\[ \text{Pcc}_{4d} \]

\[ \text{Pcc}_{4d} \] consists of blue-black to grey ignimbrite, which commonly forms hills covered with blocky rubble.

The ignimbrite contains phenocrysts of plagioclase and fragments of acid volcanic rocks and pumice enclosed in a light grey, cryptocrystalline groundmass. Two specimens were also found to contain both unaltered and partly chloritised augite phenocrysts.

The phenocrysts of plagioclase are about 3 mm long, and constitute up to 20 per cent of the rock; they are heavily sericitized, especially the cores, and their composition cannot be determined optically. Minor alkali feldspar, quartz, and actinolite phenocrysts are present. The ignimbrite also contains up to 1 per cent of chloritic pseudomorphs after biotite. Elongate fragments of porphyritic volcanic rocks form about 10 per cent, and flattened pumice fragments up to 10 per cent. Rock and pumice fragments are less abundant on the Northern Territory side of the border.

Relict perlitic cracks are present in the devitrified glassy groundmass, which now consists of quartz, feldspar and minor chlorite, epidote, clay, opaques and, in the Northern Territory, biotite, actinolite and sphene. Some of the groundmass is fluidal, owing to compression and welding of shards. A granular
fabric is locally developed adjacent to intrusive granite contacts, where fresh biotite and actinolite are probably metamorphic rather than magmatic. Three of the Northern Territory side blue-black ignimbrites have been chemically analysed: they range in composition from andesite to dacite.

Pcc₄ Undivided

The reference area for Pcc₄ undivided lies 3-7 km inside Queensland, where there is a succession of red-brown ignimbrites, blue-black ignimbrites, rhyolite lavas and minor tuffs. There are at least 16 individual flows and the succession is over 2,000 m thick, the base of the unit being intruded by granite.

Pcc₅ Billicumidji Rhyolite Member

As stated above, this unit consists, in the reference section, of at least five flow-banded and massive red rhyolitic lava flows with minor intercalations of tuff and ignimbrite.

The reference section is in Queensland immediately adjacent to the border. Here "a thickness of at least 2,000 m is indicated... using the average dip of 30° as shown by four uniformly dipping layers of ignimbrite". The highly viscous nature of the rhyolitic lavas is indicated by convolute flow-banding.

The reference section contains four tuffs, 1-10 m thick, separating the five rhyolites.

It is generally not possible to distinguish between the five rhyolite lavas in or away from the reference section.

Convolute and regular flow banding, including small basins and domes up to 10 m across, are present in all of the rhyolites, which are resistant to weathering and erosion and characteristically form hills and cappings.
The Member is cut by numerous faults, many of which are quartz-filled, and is intruded by several dykes of acid porphyry and at least two of dolerite.

The rhyolite lavas are red to pale pink. Although mainly flow-banded, some of the rhyolite is massive, and contains vugs which are lined or, more rarely, filled with quartz accompanied by chlorite, epidote, calcite, or clay minerals.

Angular fragments of rhyolite and quartz near the base of some lavas may represent flow-base breccias. Other breccia-like textures in rhyolites appear to have resulted from the infilling of vugs and voids by secondary minerals, especially quartz and chlorite.

Microphenocrysts of pink alkali feldspar and white plagioclase up to 2 mm long form up to three per cent of the lava. Some of the phenocrysts are aligned parallel to, and some distort, the flow banding.

The Clifdale Volcanics are cut by many small dykes which appear to be older than the overlying Westmoreland Conglomerate. Most of the dykes are of acid porphyry and contain phenocrysts of feldspar (either alkali feldspar or plagioclase, or both) and commonly quartz. Mafic phenocrysts are absent or rare. Some of the thicker dykes have chilled margins and commonly show a vertical flow foliation. A few dykes are basaltic, and show subophitic textures.

Many of the dykes occur in north and east trending swarms. They are most abundant where there are high-level phases of granite, eg Pgn5, nearby. The dykes are probably comagmatic with such granite phases, representing the final phase of magmatic activity.
Fig 8  Andesite Body in Cliffordale Volcanics
Acid dykes cutting the Billicumidji Rhyolite Member trend north-east, in contrast to the north and east trends of acid dykes intruding older units. Some can be traced up to 3 km, but many are offset or truncated by north-west and north-east trending faults.

Basic dykes cutting the Volcanics and the Granite Complex generally trend east-north-east, in contrast to the general west-north-west and north-north-east trends of the acid dykes. They may be related to the basic dykes known to intrude the Westmoreland Conglomerate. They are definitely younger than the acid dykes as proved by an outcrop showing a cross-cutting relationship.

Andesite

A saucer-like body of porphyritic, fine grained and medium grained andesite forms a roughly circular outcrop, about 3 km across, 4 km west of Lagoon Creek (Fig 8). The andesite body is probably an intrusion, but it appears to be concordant with the underlying pink ignimbrite and rhyolite of Unit Pcc4. Banding in the country rock at the base of the intrusion outlines a basin-shaped depression with inward dips of 5° to 30° around the margins. The upper part of the intrusion has been removed by erosion. The andesite, which has not been affected by contact metamorphism, forms massive to blocky exposures.

The outer part of the intrusion is formed of fine grained andesite consisting of small phenocrysts of augite, chlorite pseudomorphs, and plagioclase up to 3 mm long set in a grey, microcrystalline groundmass which locally shows flow banding. In some rocks, the phenocrysts show a preferred orientation. The augite phenocrysts occur separately or with chlorite, and make up 5 to 10 per cent of the rock. They are colourless in thin section and unzoned. A thin rim of hornblende(?) was noted in one section; otherwise the augite is unaltered. Euhedral, tabular chlorite (penninite) pseudomorphs make up 5 to 10 per cent of the rock, and are accompanied by minor magnetite and epidote. Some of the pseudomorphs show 6- and 8- sided cross
sections, and some interpenetration twins are present. Plagioclase phenocrysts make up 5 to 15 per cent of the rock, and are extensively altered to sericite and minor epidote and chlorite. The groundmass consists of a granular to intergranular microcrystalline assemblage of euhedral plagioclase, equant augite, patches and veinlets of chlorite, pale brown alkali feldspar which has altered to clay minerals, and opaque granules. A subtrachytic fabric is developed in places. Interstitial quartz is commonly present. Secondary minerals present are epidote, sericite, actinolite and clay. At least part of the groundmass is probably devitrified glass.

The inner part of the intrusion consists of medium grained andesite which is similar mineralogically to the fine grained andesite, although it has a higher phenocryst content. The plagioclase phenocrysts are extensively replaced by granular epidote and sericite, and some of the augite phenocrysts are zoned.

Mineralisation

High grade pitchblende/secondary uranium mineralisation occurs at the Eva mine. The ore was emplaced in en-echelon shear zones up to 2 m wide in intensely altered volcanic host rocks which are unconformably overlain by the Westmoreland Conglomerate. A medium-grained biotite granite outcrops nearby.

Geological History

Pelitic and quartzofeldspathic sediments were deposited in a geosyncline, probably trending roughly east-west. Subsequent folding, accompanied by regional metamorphism, compressed the sediments along their geosynclinal axis.

Towards the close of orogenic activity, about 1,860 m.y, the basin was domed and intruded by magma generated by anatexis at the base of the pile, at a depth of about 10 km.
The Pgn₁ magma intruded along tensional zones which opened in response to the arching of the rocks in the geosyncline. The east north east fault system thus initiated remained active throughout most of the history of the Granite Complex, especially along its northern side.

Because it was derived by anatexis of geosynclinal sediments, the Pgn₁ magma would have been relatively hydrous (Harris et al 1970) and would not have risen far in the crust before starting to crystallise. Fractional crystallisation of the Pgn₁ magma left a residual melt, which was subsequently extruded as a series of ignimbrites and lavas - the Cliffordale Volcanics.

The release of volatiles accompanying extrusion resulted in decreased pH₂O in the magma chamber, enabling the remaining melt to rise further in the crust before solidifying as Pgn₂. In response to the volatile release accompanying crystallisation, there was a shift to subvolcanic activity, with the intrusion of quartz feldspar porphyry dykes and the fractionated high-level granites Pgn₅, Pgn₆ and Pgn₇.

Volcanic activity was in its closing stages by the time muscovite granite, probably derived from the metasediments, was emplaced as Pgn₈ at about 1,750 m.y. Late stage fluids from the source region had been circulating since intrusion of Pgn₂, causing the growth of K-feldspar phenocrysts and deposition of secondary silica soon after crystallisation of the various granites. As the fluids moved to higher levels, alteration became localised in zones of structural weakness, and was accompanied by emplacement of greisen dykes.

Further uplift and tilting was accompanied by block faulting along the northern side of the Murphy Tectonic Ridge. A 50-100 m.y period of erosion separated magmatic activity on the Murphy Tectonic Ridge from the commencement of deposition of sediments in the basins on its northern and southern margins.
Westmoreland Conglomerate

The Westmoreland Conglomerate (Ptw), the oldest formation of the Middle Proterozoic McArthur Basin, is exposed in an east-north-east-trending belt, 140 km long and up to 20 km wide, along the northern margin of the Early Proterozoic Murphy Inlier (Fig 5). The general strike of the beds is parallel to the trend of the Murphy Inlier and dips are 5-10° toward the north-west, except in the vicinity of some faults and the zone of flexuring in the eastern part of the area named the Tin Hole Hinge Line. The Westmoreland Conglomerate unconformably overlies the Early Proterozoic Murphy Metamorphics in the west, the Nicholson Granite Complex in the central area and the Cliffdale Volcanics in the east.

The Westmoreland Conglomerate is up to 1,800 m thick. In its programme of regional mapping and stratigraphic section measurement carried out in 1977, Kratos adopted a subdivision of the Westmoreland Conglomerate into four units numbered 1-4. Sweet et al (1981) also used this subdivision.

Wygralak et al (1988) divided the Westmoreland Conglomerate into five sedimentary units. This subdivision differs from the earlier one in two respects, viz

Unit 2 is divided into two separate units, and

the boundary between Units 3 and 4 is raised to the base of the conglomerate beds in the previous Unit 4 (although this does not appear to have been done in the El Hussen area).

With these modifications, each stratigraphic unit represents a major fining-upward cycle of sedimentation. In general, the average grain size within each unit decreases upward. Taking the whole sequence, the average grain size increases up to Unit 3 and then quickly decreases. Such a pattern suggests that periodic tectonic rejuvenation of the area (uplift of the source or subsidence of the basin) reached a maximum during deposition of Unit 3 and rapidly decreased thereafter.
During each cycle, sedimentation started in the proximal parts of rivers and was succeeded by deposition in more distal and sandy braided rivers. Within some cycles, a similar sequence can be followed down the direction of paleotransport.

A diagrammatic section through the Westmoreland Conglomerate, showing these major cycles, is given in Fig 9.

Wygralak et al (op cit) used the unit identification $Ptw_{1-5}$. In this report, the later unit identification system adopted by Ahmad and Wygralak (1989) is preferred, viz $Ptw_1$, $Ptw_{2a}$, $Ptw_{2b}$, $Ptw_3$ and $Ptw_4$. It is felt that this is less confusing.

Early sedimentation of the Westmoreland Conglomerate was controlled by local paleotopography. Around paleohills talus deposits developed, represented by poorly sorted, angular boulder conglomerate and breccia, consisting of angular clasts of acid volcanics.

In other places red, micaceous, laminated and ripple-marked silts were deposited in lakes which filled paleodepressions. Similar siltstones were developed locally on the very top of the Westmoreland Conglomerate sequence.

Sediments display a wide range of variation in sorting and rounding, and commonly contain a mixture of well-rounded and angular grains, pointing to a multiple source. Rounded grains are probably recycled.

Most of the sediments contain more that 5% matrix and are texturally immature. Sorting ranges from very poor in debris-flow conglomerates and some greywackes to very good in some quartz sandstones and quartz wackes. In a few samples (especially in Unit 4), sediments with a high matrix content are well sorted and rounded. This textural inversion indicates mixed products of two energy levels and is a result of recycling of older sediments, the products of this recycling being incorporated into the final deposit.
Fig 9 Stratigraphic Sections of the Westmoreland Conglomerate
<table>
<thead>
<tr>
<th>Unit</th>
<th>Thickness (m)</th>
<th>Lithology</th>
<th>Sedimentary Structures</th>
<th>Depositional Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>0-20</td>
<td>Lithic greywacke, quartzwacke and quartz arenite: medium grained, well-sorted, rounded grains of quartz, acid volcanics, muscovite and chert; sericitic and hematitic matrix. Locally red, calcareous siltstone on the top.</td>
<td>Medium to large-scale planar cross-bedding, some ripple marks</td>
<td>Distal gravelly rivers, sandy braided rivers. Cyclic deposits</td>
</tr>
<tr>
<td>20-130</td>
<td></td>
<td>Sublitharenite and lithic greywacke: coarse grained with scattered pebbles, moderately sorted, subrounded grains of quartz, acid volcanics and chert; sericitic and hematitic matrix.</td>
<td>Medium scale-trough cross-bedding</td>
<td></td>
</tr>
<tr>
<td>10-20</td>
<td></td>
<td>Cobble conglomerate and conglomeratic sandstone: mostly matrix-supported clasts of quartz, sandstone and acid volcanics up to 20 cm in size; interbeds of poorly sorted, medium grained, subangular to subrounded greywacke and lithic arenite; near the top a 0.2-2.0 m thick clast-supported conglomerate (Metre Conglomerate), maximum clast size 0.5 m.</td>
<td>Medium-scale trough cross-bedding</td>
<td></td>
</tr>
</tbody>
</table>
0-180 Lithic greywacke and quartzwacke: medium to coarse grained, well-sorted, subangular to rounded grains of quartz, acid volcanics and chert; sericitic matrix

Mega-scale planar cross-bedding

Proximal rivers: predominantly alluvial fans subject to debris flows and stream flows; distal gravelly rivers; sandy braided rivers. Cyclic deposits

0-100 Lithic arenite: very coarse grained to granular, poorly sorted, subangular to well-rounded grains of quartz, acid volcanics, chert and sandstone; sericitic matrix with some hematite

Medium to large-scale trough cross-bedding

0-550 Lithic greywacke: coarse grained to granular, poorly sorted, subangular to subrounded grains of quartz, acid volcanics, muscovite, chert and locally feldspar; sericitic and often ferruginous matrix; thin pebble interbeds; lenses of matrix-supported conglomerate near the top

Small to medium-scale trough cross-bedding

0-130 Boulder and cobble conglomerate: matrix-supported, extremely poorly sorted, angular to well-rounded clasts of silicified sandstone, acid volcanics and quartz, up to 0.5 m in size; matrix of coarse, angular sandstone, often hematitic

Inverse grading
<table>
<thead>
<tr>
<th>Interval</th>
<th>Lithic arenite: medium grained, well-sorted, well-rounded grains of quartz, acid volcanics and feldspar; sericitic matrix</th>
<th>Small-scale planar cross-bedding</th>
<th>Proximal rivers: predominantly alluvial fans subject to debris flows; sandy braided rivers. Cyclic and non-cyclic deposits</th>
</tr>
</thead>
<tbody>
<tr>
<td>100-740</td>
<td>Lithic greywacke: medium grained to granular, moderately sorted, subangular to subrounded grains of quartz, acid volcanics, muscovite and locally feldspar; pebble beds in upper part</td>
<td>Small to medium-scale trough cross-bedding</td>
<td></td>
</tr>
<tr>
<td>15-300</td>
<td>Boulder to cobble conglomerate: mostly matrix-supported, poorly sorted, angular to well-rounded clasts of silicified sandstone and acid volcanics; matrix of coarse sandstone and sericite, locally contains lenses of feldspathic greywacke</td>
<td>Inverse grading, occasional small-scale trough cross-bedding in matrix</td>
<td></td>
</tr>
<tr>
<td>2a 100-500</td>
<td>Lithic greywacke, sublitharenite, minor greywacke: medium to very coarse grained, moderately sorted, angular to rounded grains of quartz, acid volcanics, muscovite and chert; scattered 1-2 cm pebbles of quartz, silicified sandstone and black chert; sericitic matrix</td>
<td>Rip-up siltstone clasts near the top, small-scale trough cross-bedding</td>
<td>Proximal rivers including alluvial fans and sandy braided rivers. Cyclic deposits.</td>
</tr>
</tbody>
</table>
0-80  *Pebble and cobble conglomerate:* matrix or clast-supported, moderately sorted, well-rounded clasts of quartz, sandstone, siltstone, acid volcanics and chert, up to 20 cm in size; matrix of clayey sandstone; interbeds of sublitharenite and lithic greywacke; common silicification

Small-scale trough cross-bedding in matrix

1  60-180  *Quartz arenite, minor sublitharenite and lithic greywacke:* fine to medium grained, well to moderately sorted, subangular to rounded grains of quartz; small amount of sericitic matrix; commonly silicified

Small to medium-scale low-angle planar cross-bedding, rare small scale trough cross-bedding, lamination                  Proximal rivers including alluvial fans and sandy braided rivers

50-150  *Sublitharenite, lithic greywacke, quartzwacke and minor quartz arenite:* fine to coarse grained, poorly sorted, angular to subrounded grains of quartz, acid volcanics and chert; sericitic, often ferruginous matrix; granular and pebbly interbeds

Medium-scale trough and planar cross-bedding

0-30  *Micaceous siltstone*

Wave ripple marks, lamination
0-30  *Talus breccia:* angular clasts of acid volcanics, tuff, chert and sandstone up to 1 m in size

Note: The classification used for the thickness of cross-bedded sets is: small (<0.25 m), medium (0.25 - 1 m), large (1 - 3 m) and mega scale (>3 m).
The Westmoreland Conglomerate was probably derived from a northerly extension of the Mt Isa orogen, which formed highlands north-east of the McArthur Basin. Repetitive uplifts, probably along fault-bounded escarpments, produced alluvial and braided-stream deposits, which now constitute the Westmoreland Conglomerate. The formation was probably deposited in a west-south-west-trending trough about 25 km wide, flanked to the south by the Murphy Tectonic Ridge and to the north by granitic uplands.

In Queensland, angular unconformities have been identified between Units 2a and 2b and between Units 2b and 3, but on the Northern Territory side of the border, these surfaces are merely disconformities, the breaks in sedimentation being indicated by the presence in the younger units of pebbles derived from older units.

A description of each of the units, together with its suggested depositional environment is given in Table 1 (after Wygralak et al). It should be noted that the grain size and lithological terms refer to the predominant grain size and lithology over sections up to several metres thick, rather than each bed.

The several lithofacies of the Westmoreland Conglomerate reflect the results of depositional processes which acted in various parts of an alluvial fan and braided river system.

A study of 1,250 measurements of dip of cross-bedding by Wygralak et al showed a strongly unidirectional, generally south-westerly, direction of paleo-transport (Fig 10). There is no appreciable difference in the general direction of paleo-transport between the different Units of the Westmoreland Conglomerate. However, considerable local variation in Units 1 and 2 north-east of the Calvert Fault probably indicates a local influx of sediments from the Murphy Inlier in addition to the main north-easterly source.
Fig 10  Paleotransport Directions in the Westmoreland Conglomerate
Except for the basal conglomerate and talus breccia of Unit 1, where the clast content is strongly influenced by the composition of the local basement, the clast content of all five units of the Westmoreland Conglomerate is uniform. The most frequent components of the framework of conglomerates are well-rounded clasts of white vein quartz. Other clasts in order of decreasing abundance are fine to coarse, often silicified, sandstones, acid volcanics and tuffs derived from the Clifffdale Volcanics, metasediments derived from the Murphy Metamorphics and less frequently chert and siltstone. All material appears to be of local origin.

Some clasts in younger units consist of material derived from the older units; for example, clasts of pink silicified sandstone of Unit 1 are present in conglomerates of Unit 2b. Clasts of the Nicholson Granite are noticeably absent. Details of the clast composition of each unit are given in Table 1.

Clast lithologies suggest that the composition of the source area was similar to the currently exposed rocks of the Murphy Inlier.

Quartz is the dominant mineral present in the sandstones and occurs in five different forms, viz

| Crystal Form      | Type                        | Origin                  |
|-------------------|-----------------------------|                        |
| Monocrystalline   | Clear xenomorphic           | Plutonic                |
|                   | Cloudy xenomorphic          | Hydrothermal            |
|                   | Clear idiomorphic           | Volcanic                |
| Polycrystalline   | Aggregates, mosaic extinction | Metamorphic, non-shearing stress |
|                   | Stretched grains, undulose extinction | Metamorphic, shearing stress |

Chert, lithic fragments and feldspar are minor constituents. Muscovite, biotite, hematite, cassiterite, zircon and tourmaline are rare.
The matrix is generally fine grained, clayey and turbid; sericite, chlorite and opaque minerals are common.

Diagenetic quartz is a common feature of the Westmoreland Conglomerate and constitutes up to 25% (commonly 5-9%) of the rock. Silicification has taken place selectively, e.g. the strongly silicified sandstone sequence of Unit 1 interbedded with non-silicified sediments. Many of the quartz grains have two silica rims separated by bands of iron oxides, reflecting two stages of silicification.

Seigal Volcanics

The Seigal Volcanics (Pts) conformably overlie the Westmoreland Conglomerate. They are probably not thicker than 1,600 m and consist predominantly of basic lavas with minor tuff interbeds.

Numerous thin interbeds of siltstone and fine sandstone are also present and one sandstone interbed, the Carolina Sandstone Member, is up to 20 m thick. In the north-east this Member is about 800 m above the base of the Seigal Volcanics; in the type section it is about 200 m above; and in an outlier of the unit it is only 50 m above the base.

The lava flows, generally less than 20 m thick, are reasonably well exposed. The tops of the flows are finer grained than the centres and contain abundant vesicles filled with quartz, chalcedony, hematite and celadonite. Below the Carolina Sandstone Member, the Seigal Volcanics are generally more massive and are dominated by basaltic flows; above it, the Volcanics consist of amygdaloidal basalt, tuffaceous siltstone, micaceous siltstone and agglomerate (Roberts et al 1963).

Darby (1986) described the Volcanics as being derived from the mantle and having tholeiitic affinities.
In thin section, the lavas have ophitic to subophitic texture with laths of plagioclase (An50-An70) partly included in augite. The groundmass is altered and consists of varying proportions of chlorite, sercite, opaques, plagioclase and rarely quartz and alkali feldspar. Aggregates of antigorite, probably after olivine, were also noted. They are basalt or trachybasalt.

Dolerite dykes which intrude the Murphy Inlier sequence and the Westmoreland Conglomerate are considered to be related to the Seigal Volcanics. The plug of rhyolite breccia near Cobar II may be related to volcanics higher in the stratigraphic sequence.

The Seigal Volcanics below the Carolina Sandstone Member appear to have been deposited predominantly under subaerial conditions. The Carolina Sandstone Member is probably a marine deposit. The presence of tuff, siltstone and agglomerate in the upper part of the Seigal Volcanics suggests an increasingly sub-aqueous environment.

Mullaman Beds

The Late Jurassic - Early Cretaceous Mullaman Beds (Kl), up to 70 m thick in the area, are part of an extensive belt of fluvial and shallow marine sandstone and siltstone covering vast areas of the Northern Territory and western Queensland. They form dissected plateaux and isolated mesas capping older rocks.

ABORIGINAL ASPECTS

Inspection Visit by Aboriginal Party

In May 1978, Kratos approached the Northern Land Council with a view to discussing with Aborigines with an interest in the area the locations of any sites of special significance to ensure that they were not disturbed by the Company's proposed activities.
Fig 11. Aboriginal Consultation
Map Shows:

(1) Position of present ELs
   (6155-6157 & 6250) in
   relation to area covered by
   Consultation (former ELs
   1016 & 1017)

(2) Localities determined to be of
   Aboriginal interest (Three)
| Table 2 | Genealogical Tree - Last Nimeringi |

Bundiyanyi  
(His country Bidida)  

Dina  
(Their country Nicholson R, Fish R, Gorge Ck)  

Wargardi  

Gundawarri  
(King George)  

Boodoomoongooji  
(His country Dunbilar and "all up around Crocodile Waterhole")  
Last Nimeringi of Upper Westmoreland Valley.  
Died at Turnoff Lagoon, Queensland.  

Linda  

Lorna  
First husband Bob.  
Then stolen by Jack Riversleigh. Perished near Mellish Park with small child.  

Alice  

Ben Steel  

Eva  
Sent to Palm Is  

Son (deceased)  

Daughter Sent to Palm Is  

Daughter Sent to Palm Is
Table 3  Genealogical Tree - Principal Jungeye

Boorajala
(Nellie)
(Her country Upper Settlement Creek)

Jininja (alt Wooragaga)
(His country Seigals Creek)

Gnawoonyi
(Death Adder Dreaming)
(Her country Westmoreland Valley, ie Lagoon Creek)

King Pedro
Bunjudburri
Nulyaga
(Annie)
No children

Gundawarri Gagamunda
(King George)
(His country Nicholson R, Fish R, Gorge Ck)

Nadayoo
(Dinny Pedro)
No children

Wagagi
(Jack Pedro)
No children

Yaboongoo
(Cubbie Pedro)

Wilajiji
(Daisy)

Lagoon Creek area, Queensland

Alma Howard Len Son

Note. King Pedro (His country undetermined) was a full member of the Wanyi tribe of the Northern Territory, but was appointed King of Lawn Hill in Queensland. He stole Gnawoonyi, youngest wife of Jininja (Wooragaga), and took her to Lawn Hill. Nadayoo (Dinny Pedro) is the Principal Jungeye for the Upper Westmoreland Valley area.
The Council put the Company in touch with Mr John Dymock, one of its Field Officers, and an Aboriginal inspection visit took place on 8-9 July 1978. At the time of this visit, Kratos held Exploration Licences 1016 and 1017, which covered a considerably larger area than the present Exploration Licences (6155-6157, 6250) and Exploration Retention Leases (81, 82). See Fig 11.

The general background to Aboriginal occupation of the area, as known to the Northern Land Council, is as follows.

The area, which comprises the Upper Westmoreland Valley and adjoining areas, was originally inhabited by the Rumbaria, whose language and tribal group appears to have been Garawa, but who also had cultural and matrimonial affiliations with the Wanyi tribe to the south, and an ill defined group called the Gnyunga to the north. Little is known of the last named group - possibly because of the massacre at Mungaburra (Massacre Inlet) in the middle of their territory.

It is known that punitive expeditions were sent out from Westmoreland Station in Queensland and Wollogorang Station in the Northern Territory during the period from the late 1880s into the early years of this century and details of excesses at the time are preserved in oral tradition amongst present day Aborigines.

On the basis of the background outlined above, and discussions with Aboriginals having knowledge of the area, Mr Dymock concluded that there are no surviving Nimeringi (Primary Traditional Owners) for the area. Table 2 shows the genealogical tree of the last known Nimeringi, Boodoomoongooji, who had no children.

It was thus necessary to determine the Principal Jungeye, ie the person with the highest level of Secondary Ownership, and other persons with more distant relationships to the area. Table 3 shows the genealogical tree of the Principal Jungeye, viz Dinny Pedro, eldest son of King Pedro of Lawn Hill and Gnawoniyi, who
was stolen from her husband and taken to Lawn Hill by King Pedro. Gnawoonyi's daughter by her original husband in the Northern Territory, Gagamunda, married Gundawarri (King George), first cousin to Linda, wife of Boodoomoongooji, the last known Nimeringi.

The inspection party, which was accompanied by Mr Dymock, comprised the following Aboriginal people, being those most closely associated with the area:

**DINNY PEDRO:** Principal Jungeye and Son of King Pedro of Lawn Hill

**ECHO PETER:** Secondary Jungeye, Son of King Peter of Westmoreland and Chairman of Culture Council, Doomadgee

**TOBY CHARLIE:** Secondary Jungeye

**ARCHIE ROCKLANDS:** Secondary Jungeye

**ROGER CHARLIE:** Knowledgeable regarding area

Dinny Pedro and Echo Peter were living at Doomadgee Mission; Toby Charlie, who had been crippled by a fall from a horse, lived at Burketown; Archie Rocklands, a fencing contractor, was working at the time on Lawn Hill station; Roger Charlie, the only Northern Territory resident, was working on Brunette Downs station, but often lived at Borroloola. Dinny Pedro and Echo Peter were both elderly men; the other three were much younger.

The Aboriginal Party, after inspecting the whole of the area covered by Exploration Licences 1016 and 1017, determined that there were only three localities of interest from an Aboriginal point of view. They specifically declared clear of significant sites the prospect areas within the current tenements known as El Hussen, White Horse, Chinamans Garden, McGuinness, Kings Ransom,
Cobar II, Old Parr and North East Westmoreland. At the conclusion of the visit, an Agreement was signed by all five members of the Aboriginal Party and by Mr Dymock. This Agreement, and a complementary statement drafted by Mr Dymock and signed by Kratos, are reproduced in Appendix 1.

Of the three localities of interest indentified by the Aboriginal Inspection Party (Fig 11), two (Chinamans Garden and Poisonous White Rocks) lie within EL 6155 and one (Death Adder Dreaming) lies outside the area covered by the present tenements.

Chinamans Garden — Gooyalina. In the early years of this century (ca 1910-1915), a Chinaman known as "Straight-Fingered Jimmy" erected a humpy and formed a garden at this location to supply miners working small copper mines (Dianna and others) in the area. Although Straight-Fingered Jimmy lived alone, a Post-European Folk Tradition amongst Aboriginal Stockmen was that Jimmy cohabited with a female Galajala or Rock Country Spirit. These spirits are variously described, but their dominant qualities are that they are thin, secretive, semi-malevolent, and capable of driving people insane. Aboriginal Stockmen even claimed that the Galajala had a female child to Jimmy and that the child, which she carried on her shoulders, had a Chinese face. It is said that, some years after Jimmy left the area, the woman Galajalas left also and "got married somewhere else". (In discussion with the Aboriginal party, it was mentioned that Galajalas are very difficult to see as they are always hiding behind something, eg a tree or rock. When you move to the other side of the object, they also move, so as always to be on the opposite side to you).

In deference to this Post-European Folk Tradition, the Aboriginal Party requested Kratos not to drill in the Spring itself or in the immediate vicinity of the location of the Chinaman's humpy; it was, however, quite in order to explore/drill in the remainder of the general area. The precise location of the Chinaman's humpy is not known, but presumably it was fairly close to the Spring.
Poisonous White Rocks - Gamoongooro or Gamoogooro. This locality is a taboo area associated with a potent and much feared white poison of the same name. It is centered about 1.5 km due east of Old Parr and is comprised of Cretaceous cap rocks.

The Aboriginal Party felt that it was in Kratos' interest that none of its personnel go into the area, otherwise "something bad would happen" as it was a "dangerous place".

Death Adder Dreaming - Gardijiwarra (Wanyi) or Boorooodjin (Garawa). Echo Peter advised that his Father-in-Law, a long dead Garawa (Woodalia Semi Moiety) man named Locket, told him that this locality, which is outside the area currently held under title by Kratos, was associated with Boorooodjin, the Death Adder, which left its excrement Mageera, or white clay, at the place.

Locket had a wide reputation as a Winyagi or Magicman, who on one occasion was seen by a group of people to be bitten by a King Brown snake, "died", giving all the external appearances of death, but came back to life next day after being wrapped in a blanket.

Dinny Pedro, whose mother Gnawoonyi was born at Gnawoonyi waterhole on Lagoon Creek (in Queensland), stated that his mother had the Death Adder as her dreaming.

Sacred Sites Authority

In July 1982, following granting of Exploration Licences 3625-3627, Kratos contacted the Aboriginal Sacred Sites Authority regarding the area. The Authority advised that there were no registered sites within the area and that it had no further information to add to Mr Dymock's 1978 report.
PREVIOUS EXPLORATION

In order to place in perspective the work carried out in 1988-1990 in ELs 6155-57 and 6250, it is necessary to review the work carried out previously by Kratos in the area. (Details of earlier work in the area by North Australian Uranium Corporation NL, BHP Co Limited, United Uranium NL and others are given in Kratos' 1978 Programme Report).

The following comprehensive summary is arranged in chronological order to show the progression of ideas on the occurrence of mineralisation in the area, and the development of exploration programmes to test those ideas.

A. 1975-1981: ELs 1017, 1016 & 1074

SUMMARY

Kratos carried out initial orientation work in EL 1017 in 1975. In the following two years, after granting of EL 1016, systematic exploration of the whole area was carried out. Grids were laid out over known prospect areas and geological, geophysical and geochemical surveys were carried out. Detailed geological mapping, especially of the Westmoreland Conglomerate, was undertaken and reconnaissance radiometric/geochemical traverses were carried out over the northern, soil-covered parts of the area. Preliminary reconnaissance drilling commenced at El Hussen late in the 1977 field season.

In 1978, a major percussion/diamond drilling programme totalling 9,483 metres was carried out. This comprised four widely-spaced stratigraphic diamond holes, and percussion profiles across the mineralised fault zones at NE Westmoreland, Cobar II and El Hussen. The aim of the programme was to test for stratiform uranium orebodies comparable to those straddling the Redtree Fault across the border in Queensland. No presently economic bodies of this type were encountered. Intersections of possible interest were, on the contrary, closely associated with faults and/or quartz veining.
Geological/radiometric grid coverage of the exposed Seigal Volcanics/Westmoreland Conglomerate contact from NE Westmoreland to El Hussen (20 km) was completed. A number of prospects were located but none of these showed surface mineralisation approaching that found at the three main prospect areas (NE Westmoreland, Cobar II and El Hussen).

Drilling continued at NE Westmoreland in 1980 (1,634 m), the best holes being:

WPD 60 3 m @ 40 lb U₃O₈/ long ton
        4 m @  4.7 g Au/tonne

WPD 45 11 m @ 1.8 lb U₃O₈/ long ton
        4 m @  6.8 g Au/tonne

Hole WPD 60 was drilled near the NT/Queensland border in a zone which was later unilaterally annexed by Queensland.

Radiometric gridding of the main prospects on the southern side of the Main Range at NE Westmoreland (Southern Comfort, Jim Beam, Jacksons Pit and Jacques) was undertaken as a prerequisite to drilling.

Drilling in 1981 was at NE Westmoreland (6,972 m), the southern prospects (2,558 m) and Waterfall Creek (198 m). A number of the holes gave uranium intersections in the 0.5 - 2 lb U₃O₈/ long ton range, some with anomalous gold also, but none of the mineralisation encountered was of clear economic potential. The highest grade intersection was 0.5 m @ 6.1 lb U₃O₈/ long ton and 11.2 g Au/tonne (WDD 105).

In addition to geological and radiometric mapping at a number of prospects, ROAC radon and soil mercury surveys were also undertaken during the 1981 field programme.
1975 PROGRAMME

The only Exploration Licence held by Kratos in 1975 was EL 1017, to the north of the main prospective area.

Reconnaissance testing was carried out by way of a systematic combined track etch/radiometric/geochemical soil sampling survey together with preliminary examination of two previously known occurrences of secondary uranium mineralisation near the southern boundary of the Licence area (McGuinness and White Horse prospects).

The work carried out in 1975 can be regarded as a large scale orientation survey which was aimed at testing the methods of exploration to be used later in a full-scale programme in the area. Various graphical and mathematical techniques were used to analyse the results obtained.

Briefly, the methods used highlighted anomalous areas around the two known prospects and suggested that there could be geochemically anomalous zones in the soil covered parts of the area.

1976 PROGRAMME

In 1976, after the granting of EL 1016, geological mapping of the eastern part of this Exploration Licence area was carried out at 1:25,000 scale using a helicopter and a map of the remainder of the area was prepared at the same scale using photointerpretation combined with ground observations.

An extensive grid (JN Grid) was laid out over the JN Fault at NE Westmoreland, which was known to contain pitchblende mineralisation. Radiometric readings, geochemical soil sampling, VLF measurements, track etch and emanometry measurements and some magnetic measurements were carried out over this Grid.
Geological, geophysical and geochemical surveys were carried out also over smaller grids at the Calvert South and Calvert North prospects, and several geophysical test surveys were run over the Cobar II mine area.

A programme of reconnaissance radiometric/geochemical traverses over the northern, soil-covered parts of the area was commenced.

As expected, geophysical and geochemical anomalies were outlined in the three prospect areas gridded.

1977 PROGRAMME

Detailed stratigraphic and structural mapping of the Westmoreland Conglomerate was undertaken in 1977. This work included the measurement of 26 stratigraphic sections in various parts of the area, and preparation of a generalised composite section. Mapping of the Cliffdale Volcanics was also undertaken.

Detailed geological, geophysical and geochemical surveys were carried out over extensive grids at the three main prospect areas (NE Westmoreland, El Hussen and Cobar II). Similar surveys were carried out over smaller grids at three other prospects showing less extensive surface uranium mineralisation, viz McGuinness, Kings Ransom and Maniws.

Preliminary reconnaissance drilling (three percussion holes) was undertaken at the end of the season at the El Hussen prospect. Two vertical holes (150 and 136.5 metres respectively) were drilled into the sedimentary sequence on the north-eastern side of the El Hussen Fault. The third hole was angled at 60 degrees to intersect the Fault but it had to be stopped at 94.5 metres due to excessive inflow of water.
The programme of reconnaissance traverses over the northern, soil-covered parts of the area was continued and a complete radiometric grid coverage of the Seigal Volcanics/Westmoreland Conglomerate (Pts/Ptw) contact from NE Westmoreland to El Hussen (20km) was commenced.

1978 PROGRAMME

During the 1978 field season, a major percussion/diamond drilling programme totalling 9,483 metres was carried out.

Of the total, 7,773 metres was drilled by percussion using a Foxmobile dual-purpose rig and, for a short period, a Gryphon percussion rig. An Airtrac rig was used to drill 986 metres of shallow percussion holes in locations which the larger rigs could not reach. The 724 metres of NQ diamond coring undertaken was drilled by the Foxmobile rig.

Four stratigraphic diamond holes (two at NE Westmoreland and one each at Cobar II and El Hussen) were designed to provide detailed information on the lithologies and thicknesses of the geological units intersected. Diamond coring was also undertaken in three other holes at NE Westmoreland to test the JN Fault and a mineralised intersection obtained in a percussion hole.

The percussion drilling was planned as a series of vertical hole profiles across the mineralised fault zones at NE Westmoreland and Cobar II and across the El Hussen Fault and Westmoreland Conglomerate/Seigal Volcanics contact at El Hussen. Each profile comprised three or four holes, spaced about 150 metres apart. The distance between the profiles varied from 200 to 675 metres.

The reconnaissance Airtrac drilling was carried out on the Westmoreland Conglomerate dip slope at NE Westmoreland, at Cobar II and at the Calvert North and Calvert South prospects.
Fig 12 shows the locations of all the holes drilled in EL 1016 during the period 1977-1981 in relation to the boundaries of ELS 3625-3627. See also Figs 13, 14 and 15.

Details of the drilling undertaken at each prospect in 1978 are set out below:

<table>
<thead>
<tr>
<th>Prospect</th>
<th>No. of Holes</th>
<th>Drilling (m)</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Diamond</td>
<td>Percussion</td>
<td>Airtrac</td>
<td>Total</td>
</tr>
<tr>
<td>NE Westmoreland</td>
<td>47</td>
<td>493</td>
<td>4,049</td>
<td>320</td>
<td>4,862</td>
</tr>
<tr>
<td>Cobar II</td>
<td>14</td>
<td>108</td>
<td>1,479</td>
<td>33</td>
<td>1,620</td>
</tr>
<tr>
<td>El Hussan</td>
<td>16</td>
<td>123</td>
<td>2,245</td>
<td></td>
<td>2,368</td>
</tr>
<tr>
<td>Calvert North</td>
<td>6</td>
<td></td>
<td>328</td>
<td></td>
<td>328</td>
</tr>
<tr>
<td>Calvert South</td>
<td>8</td>
<td></td>
<td>305</td>
<td></td>
<td>305</td>
</tr>
<tr>
<td>---------------</td>
<td>--------------</td>
<td>--------------</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td></td>
<td>91</td>
<td>724</td>
<td>7,773</td>
<td>986</td>
<td>9,483</td>
</tr>
</tbody>
</table>

The aim of the drilling programme was to test for stratiform uranium orebodies comparable to the Jack, Garee and Langi Lenses straddling the Red Tree Fault across the border in Queensland. The holes drilled did not intersect any presently economic mineralisation of this type in the prospect areas tested.

Where present, the siltstone unit (later named the Mageera Siltstone) at the top of Unit 4 of the Westmoreland Conglomerate was found to contain low uranium values, especially at NE Westmoreland. It was concluded that it was doubtful if this unit could host an orebody, but that economic concentrations could possibly be developed in the underlying sandstones if physico-chemical conditions were favourable.

Intersections of interest obtained in 1978 were, in every case, associated with fault structures and/or quartz veining.
1979 PROGRAMME

During 1979, a three-part programme was undertaken, viz:

(1) Radiometric and geological gridding of the exposed contact between the Westmoreland Conglomerate and the overlying Seigal Volcanics from NE Westmoreland to El Hussen (Contact Survey) was completed.

(2) Reconnaissance radiometric and geological gridding was carried out over the photointerpreted southern extension of the Southern Comfort Lineament into the Clifdale Volcanics to the south of NE Westmoreland.

(3) Exhaustive analysis of all data on the area was undertaken with a view to determining whether any drilling targets in addition to the known prospects existed in the area.

The Contact Survey accurately positioned several previously reported uranium occurrences, and located three previously unknown occurrences. Although none of these showed surface mineralisation approaching that found at the three main prospect areas (NE Westmoreland, Cobar II and El Hussen), it was recommended that, because several of them were associated with prominent faulting, at least one should be tested by drilling.

The Contact Survey demonstrated clearly that the Seigal Volcanics/Westmoreland Conglomerate contact is not uniformly mineralised. It appears to contain anomalous uranium values only in close proximity to fault structures which themselves are mineralised.

No anomalous radioactivity was recorded over the postulated southern extension of the Southern Comfort Lineament, a previously unknown mineralised fault parallel to the JN Fault at NE Westmoreland, which was discovered during detailed gridding of the Main Range.
1980 PROGRAMME

Following the complete reassessment of the area carried out in 1979, a forward programme comprising four main elements was proposed, viz:

(1) Continued testing of the JN Fault by systematic reconnaissance drilling (JN Grid)

(2) Detailed radiometric gridding, followed by drilling, of the more important prospects on the southern side of the Main Range at NE Westmoreland, ie Southern Comfort, Jim Beam, Jacques and Jacksons Pit

(3) Drilling of a stratigraphic hole to determine the depth to basement, and the nature of the basement rocks, in the Jim Beam/Jacques area

(4) Follow-up detailed radiometric gridding of the anomalous areas defined by the Contact Survey.

In the event, work in 1980 was restricted to Items (1), (2) and (4) above and, in each case, portion only of the proposed programme could be completed. The drilling programme had to be severely curtailed due to late arrival of the drill rig, and its inability to negotiate the access road to the prospects on the southern side of the Main Range.

Continued drilling of the JN Grid was restricted to 24 vertical percussion holes totalling 1,634 metres. It was not possible to drill any angled holes through the JN Fault as the rig used was only capable of drilling vertical holes. The locations of the holes drilled in the NE Westmoreland area prospects during the period 1978-1981 are shown in Fig 13. Typical JN Grid drillhole profiles are shown in Figs 15 and 15.
All but four of the holes drilled in 1980 were put down in that part of the JN Grid where the prospective Westmoreland Conglomerate rocks are overlain by a relatively thin cover of Seigal Volcanics – arbitrarily taken as the zone from the exposed Pts/Ptw contact to JN 2000N, where the depth of cover is about 55-60 metres.

Of the 20 holes drilled in this zone, nine intersected 1 metre intervals assaying in excess of 150 ppm U. Of these, 5 holes gave intersections assaying in excess of 1 lb U₃O₈/long ton (approx 380 ppm U).

Hole WPD-45 (JN 1725N Profile) gave an average grade of 1.8 lb U₃O₈/long ton (approx 680 ppm U) over 11 metres from 47-58 metres and 6.8 g Au/tonne (AAS assay) over 4 metres from 53-57 metres.

In the second part of the 1980 drilling programme on the JN Grid, it had been intended to continue testing from JN 2000N to the most north-easterly profile drilled during 1978 (JN 2500). Due to reduced drilling time, three holes only were drilled, all on Profile JN 2325N.

In Hole WPD-59 the 5-metre interval 60-65 metres averaged 1 lb U₃O₈/long ton, including two 1-metre sections grading 1.64 and 1.27 lb U₃O₈/long ton respectively.

In the third part of the planned 1980 drilling programme on the JN Grid, it had been intended to test whether the dip of the Pts/Ptw contact remained constant further to the north-east of JN 2500N and, at the same time, to test anomalies defined by the 1976 track etch survey along the JN Baseline. Due to the onset of heavy wet season rains, only one hole (WPD-60 on Profile JN 3400N) was completed. The nearest previous drillhole to WPD-60 was 900 metres to the south-west along the strike of the JN Fault.
Hole WPD-60 intersected a 3-metre interval at 115-118 metres depth assaying of the order of 40 lb U₃O₈/long ton (approx 15 kg U/tonne). In addition, the 4-metre interval 116-120 metres gave 4.7 g Au/tonne by AAS assay. A check fire assay of a bulk split from the interval 117-118 metres returned 6.9 g Au/t.

In the surface programme carried out in 1980, radiometric grids were completed at the four main southern prospects at NE Westmoreland, ie Southern Comfort, Jim Beam, Jacksons Pit and Jacques. This work allowed planning for drilling of these prospects to proceed during the wet season.

A radiometric grid was also completed at the Rocky Creek prospect (Contact Survey).

**1981 PROGRAMME**

The programme carried out during the 1981 dry season comprised:

(1) Continued testing along the JN Fault at NE Westmoreland by drilling

(2) Drilling of the southern prospects at NE Westmoreland ie Southern Comfort, Jim Beam and Jacksons Pit

(3) Soil radon surveys to trace known and postulated fault zones in areas of soil cover at the Southern Comfort and Waterfall Creek prospects

(4) Detailed follow-up radiometric gridding of prospects defined by the Contact Survey, with initial drilling of one (Waterfall Creek).

Total drilling was 9,728 metres, comprising 8,319 metres of percussion drilling and 1,409 metres of diamond drilling. Fig 13 shows the locations of the holes drilled. Typical JN Grid drillhole profiles are shown in Figs 14 and 15; Jacksons Pit and Jim Beam drillhole profiles are shown in Fig 16.
A summary of the drilling undertaken at each prospect is set out below:

<table>
<thead>
<tr>
<th>Prospect</th>
<th>No. of Holes</th>
<th>Drilling (m)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Diamond</td>
<td>Percussion</td>
</tr>
<tr>
<td>NE Westmoreland</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>JN Grid</td>
<td>54</td>
<td>826</td>
<td>6,146</td>
</tr>
<tr>
<td>Southern Comfort</td>
<td>13</td>
<td>463</td>
<td>976</td>
</tr>
<tr>
<td>Jim Beam</td>
<td>5</td>
<td>120</td>
<td>573</td>
</tr>
<tr>
<td>Jacksons Pit</td>
<td>3</td>
<td></td>
<td>426</td>
</tr>
<tr>
<td>Contact Survey</td>
<td></td>
<td></td>
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As a result of the work carried out in 1981 and earlier years, the JN Grid was divided into three zones for ease of reference. Two of these (Mageera and Oogoodoo) are considered to warrant further testing.

The Mageera Zone (JN 1600-2500N), adjacent to outcropping Westmoreland Conglomerate and therefore having the shallowest cover of Seigal Volcanics, includes the mineralisation centered on Hole WPD-45.

The Oogoodoo Zone (JN 3100-4040N) is furthest from outcropping Westmoreland Conglomerate and therefore has the thickest cover of Seigal Volcanics. It includes the mineralisation centered on Hole WPD-60.

The Intermediate Zone (JN 2500-3100N) lies between the other two zones and appears to have less potential for economic mineralisation.
Of the 13 holes drilled in the Mageera Zone, 5 (WDDs 96 and 98, WPDs 66, 67 and 71) gave intersections close to, or better than 1 metre at 1 lb U$_3$O$_8$/long ton (approx 380 ppm U). One of these, WPD-98, gave 3 metres averaging 1.17 lb U$_3$O$_8$/long ton (approx 445 ppm U).

Of the 31 holes collared in the Oogoodoo Zone, 28 were completed, 2 were precollared by percussion but not completed, and 1 collapsed at shallow depth. Eight (WDDs 97, 99 and 105, WPDs 82, 88, 100, 104 and 107) gave intersections close to, or better than, 1 metre at 1 lb U$_3$O$_8$/long ton (approx 380 ppm U).

The best intersections were:

**WPD-88**

122-142 m 664 ppm U  (1.75 lb U$_3$O$_8$/long ton)

*including* 125-126 m 1,550 ppm U (4.10 lb U$_3$O$_8$/long ton)

**WDD-105**

177-178 m 540 ppm U  (1.42 lb U$_3$O$_8$/long ton)

183.5-184 m 2,300 ppm U,  11.2 ppm Au, 4 ppm Ag  (6.08 lb U$_3$O$_8$/long ton),

184-184.5 m 520 ppm U  (1.37 lb U$_3$O$_8$/long ton)

**WDD-99**

129-131.5 m 854 ppm U  (2.25 lb U$_3$O$_8$/long ton)

*including* 130-130.5 m 1,700 ppm U (4.49 lb U$_3$O$_8$/long ton)

**WPD-82**

101-103 m 700 ppm U  (1.85 lb U$_3$O$_8$/long ton)

108-110 m 390 ppm U  (1.03 lb U$_3$O$_8$/long ton)

Of the 10 holes drilled in the Intermediate Zone, none gave an intersection close to, or better than, 1 metre at 1 lb U$_3$O$_8$/long ton (approx 380 ppm U).

The 13 holes drilled into the Southern Comfort Lineament gave elevated uranium and copper values, but not of ore grade. The Lineament proved difficult to detect in percussion chips.
The best intersections were:

**SCPDD-1**
86-88 m 290 ppm U, 3,500 ppm Cu  
(0.77 lb U₃O₈/long ton)

**SCDD-1**
108-110 m 1,800 ppm Cu
121-122 m 290 ppm U  
(0.77 lb U₃O₈/long ton)

**SCDD-4**
38-39 m 360 ppm U, 2,900 ppm Cu  
(0.95 lb U₃O₈/long ton)

Three of the five holes drilled at the Jim Beam prospect gave elevated uranium and copper values but these were not of ore grade:

**JBDD-1**
44-46 m 100 ppm U, 0.1 ppm Au  
(0.26 lb U₃O₈/long ton)

**JBPD-1**
54-55 m 220 ppm U, 0.2 ppm Au  
(0.58 lb U₃O₈/long ton)

**JBPD-3**
1-2 m 160 ppm U, 0.1 ppm Au, 1,000 ppm Cu  
(0.42 lb U₃O₈/long ton)
10-11 m 100 ppm U, 0.65 ppm Au  
(0.26 lb U₃O₈/long ton)
26-27 m 150 ppm U, 0.15 ppm Au  
(0.40 lb U₃O₈/long ton)

The three holes drilled at Jacksons Pit did not intersect any mineralisation of significance, the highest assay value being 150 ppm U (0.4 lb U₃O₈/long ton) at 52-54m in JPPD-3.
The two holes drilled as an initial test of the Waterfall Creek prospect returned low uranium values only, the highest assay being 90 ppm U (0.24 lb U₃O₈/long ton) over the interval 12-13m in WCPD-1. A sample taken from a pit gave 0.3 ppm Au and 1 ppm Ag.

During the course of the 1981 field programme, geological mapping was carried out at six prospects, with radiometric surveys at five of these; ROAC radon surveys were undertaken on the Southern Comfort North Grid, and at Waterfall Creek. Soil mercury traverses were run on the Southern Comfort North and JN Grids to assess the usefulness of this method as a prospecting tool in the area.

B. 1982-1987: ELs 3625-3627

SUMMARY

After granting of ELs 3625-3627 in June 1982, Kratos proceeded with a programme of testing a number of geophysical techniques thought capable of detecting and delineating target structures in areas masked by soil/Seigal Volcanics cover.

This work was carried out in two main areas, viz Southern Comfort North (SCN) and Cobar II (CT). The techniques employed included ground magnetics, EM conductivity and dc resistivity depth soundings.

Two radiometric traverses were run along prominent structural features in EL 3625, soil samples from the SCN Grid were analysed for mercury (Hg) and a further analysis of the Landsat data for the area was undertaken.

In 1983, Kratos continued and expanded the ground geophysical surveys of selected areas commenced in 1982.
Results obtained confirmed that ground magnetic and conductivity surveys can be used to trace fault structures, which carry the mineralisation in the area, in areas of soil/Seigal Volcanics cover. When used in association with an appropriate geochemical survey method (ROAC and/or Hg), such ground geophysical surveys would appear to be valuable in selecting drilling targets.

An attempt to commence collection and processing of bulk stream sediment samples for diamonds, gold and other heavy minerals was unsuccessful due to mechanical problems.

Following conclusion of the joint venture arrangement with CEGBEA in February 1984, that Company took over as operator for the uranium search programme within the three ELs.

Its programme within ELs 3625-3627 was part of a much wider uranium search programme in the Pandanus Creek - Westmoreland province, particularly its joint venture with Uranerz Australia Pty Limited, work carried out to the north of ELs 3625-3627 and work carried out across the border in Queensland.

In the period to June 1985, CEGBEA undertook re-examination of all Kratos data, including re-interpretation of Kratos' geophysical data, and processing of the results of an airborne magnetic and radiometric survey carried out by Geoterrex for Uranerz. It also noted an unexplained botanical feature north-west of the JN Grid at NE Westmoreland.

In 1985-86, it continued its exploration programme by carrying out radiometric, magnetic, gravity, seismic reflection and geochemical surveys over the JN and Turkey Creek areas, and by re-examining the geophysics and geochemistry of the Cobar II area.

In 1987, it drilled two diamond holes at Cobar II without result.
Under the terms of the separate joint venture agreement covering the diamond potential only of the ELs, Stockdale Prospecting Limited took three drainage samples in 1984 and tested them for diamonds and diamond indicator minerals. No minerals of interest were found.

Concurrently with the CEGBEA uranium exploration programme, Kratos undertook exploration for gold, platinum group elements and diamonds.

Bulk stream sediment sampling was commenced in 1986 and continued in 1987 until all drainages in the area of the three ELs had been tested by way of samples 3-4 tonnes in size treated through a Kimberley-type diamond pan. Two samples showed fine grained gold; no diamonds or platinum group metals were detected.

With the realisation, based on earlier mineragraphic study of the gold mineralisation intersected in Hole WPD 60 and, particularly, on the recently reported Coronation Hill mineralisation, that gold and platinum group metals could well be present in a grain size range which would not have responded to the gravity separation method used on the bulk stream sediment samples, further reconnaissance sampling was carried out.

This sampling took the form of widely-spaced, reconnaissance rock chip sampling grids over the known mineralised areas in the ELs, and limited fine sediment stream sediment sampling. The results of this work showed that follow-up was required. Hence applications were lodged for further exploration titles in the area.
KRATOS GEOPHYSICAL PROGRAMME 1982-1983

Introduction

The extensive data obtained prior to the granting of ELs 3625-3627 had shown the close association of uranium mineralisation with fault structures.

Prospective fault structures can usually be traced relatively easily through Westmoreland Conglomerate outcrop, but become obscured where they pass into Seigal Volcanics, particularly if the volcanic rocks are wholly or partly soil covered. This is especially true of the mineralised Southern Comfort Lineament.

It was therefore decided to select several prospective structures and try and trace them through soil cover using geophysical techniques. The zones of interest selected for testing were Southern Comfort North and Cobar II.

In addition, further test work was carried out along the JN Fault and an initial test was made of the two main fault structures in the Douglas Creek area. The Landsat image of the area was analysed in detail and selected drill core was re-logged.

1982 Programme

The 1982 field programme comprised the following elements:

JN Grid:
Oogoodoo Zone (mostly unilaterally annexed by Queensland) - ROAC and soil mercury survey
Mageera Zone - Magnetic traverses and soil mercury survey

Southern Comfort North:
Soil mercury, magnetic and conductivity surveys and resistivity depth soundings
Hole WDD-1:
Core re-logged, with particular attention to the possibility of a volcanic component in the sediments of the topmost part of the Westmoreland Conglomerate

Dyke Intersections:
Dyke intersections in JN Grid drillholes WDD-96 and WDD-97 were re-logged in detail

Landsat:
A study of two Landsat images of the area was carried out, including the use of computer enhancement techniques.

Survey Techniques

The magnetic surveys were made with a Geometrics G816 proton magnetometer, with the sensor mounted on a 3 metre staff. A standard survey station spacing of 5 metres was used, with infill readings at 1 metre intervals in areas of high magnetic gradient. Both base station and looping back to magnetically levelled baseline methods were used to take account of diurnal variation. Measurements had to be repeated over part of the area surveyed due to a magnetic storm.

Conductivity measurements were made using a Geonics EM34-3 transient EM system. Vertical co-planar coils were used with a separation of 40 metres.

The resistivity method used employed a Schlumberger array electrode configuration for vertical electrical soundings (VES). The measurements were made with an ABEM Terrameter instrument.

As in previous years, radiometric readings were made with SRAT SPP2 scintillometers and close attention was paid to maintaining consistency of data from year to year.
JN Grid - Oogoodoo Zone

As stated above, the Oogoodoo Zone of the JN Fault extends from 3100N to 4040N (Fig 13). It had been previously tested by surface radiometry, VLF, emanometry and track etch (baseline only) to 3600N in 1976. In 1980, one hole (WPD-60) was drilled on a track etch anomaly and intersected high grade mineralisation. In 1981, a further 31 holes were drilled without outlining any significant body of mineralisation.

As the high grade mineralisation intersected in hole WPD-60 seemed to be related to a surface track etch anomaly, it was considered appropriate to use a radon detection method to search for targets for further testing. The method selected was ROAC (Radon on Activated Charcoal), which offered the promise of results comparable to those obtained by track etch, but at reduced cost. As the mineralisation was known to comprise gold as well as uranium, it was decided to run an orientation soil mercury traverse over the best mineralisation known (line 3400N).

For the ROAC survey, nine cross lines were laid normal to the JN baseline in the interval 3050N to 4000N. Line lengths varied from 390 to 960m and a station spacing of 30m was used on the cross lines. As part of the Company's evaluation of the ROAC system, two sets of cartridges - one of new, unused cartridges and one of cartridges used 12 months previously in areas showing background radon levels only - were laid on cross line 3400N using closely spaced pairs of holes.

Some problems were experienced with the ROAC results, especially the occurrence of negative values. There are several possible explanations for such values, ie values ostensibly less than the background of the cartridges. However, in practical exploration terms, such values merely indicate that the contribution of radon absorbed from the soil air is low, ie the cartridge concerned was not located at a site of significant soil radon concentration.
The ROAC results appeared to show two distinct populations - one in "gilgai" soil and one in normal soil, the former giving rise to lower absolute values.

An anomalous trend was found to run from 3050N/90W to 3850N/240W with discontinuity between 3320N and 3520N. The previously drilled hole WPD-92, which did not give encouraging results (maximum assay 170 ppm U over 1m), lies almost directly on this trend. Hole WPD-60 is located about 55m off the trend, but so also are holes WPD-81, WPD-82, WPD-86 and WPD-104. None of the latter made intersections of interest.

The results from the trial soil mercury traverse (line 3400N) show low absolute values, but what appear to be definite anomalies against background over known mineralisation. Soil samples were collected from the bottom of all ROAC holes for later mercury analysis.

In view of the lack of potential revealed by previous drilling, and the fact that over three quarters of the anomalous ROAC trend lay in the zone annexed by Queensland, no further work was undertaken.

JN Grid - Mageera Zone

The Mageera Zone of the JN Fault extends from 1600N to 2500N (Fig 13). In early exploration in this area, United Uranium NL drilled six holes.

As stated previously, Kratos tested the area by surface radiometry, magnetics, soil geochemistry (U, Th, Bi, Cu, Pb, Zn, Fe and Mn), VLF, emanometry and track etch (baseline only) in 1976. This surface work was followed by the drilling of 21 holes in 1978, 23 holes in 1980 and 13 holes in 1981. One of the 1980 holes, viz WPD-45, intersected 11m (47-58m) @ 680 ppm U (1.8 lb U₃O₈/long ton) and 4m (53-57m) @ 6.8 g/t Au (AAS assay).
In 1982, two magnetic traverses were run across the JN Fault, in normal to the grid baseline, and a study was made of the relationship between mercury levels and gold mineralisation in hole WPD-45.

The magnetic traverses were run primarily to determine whether the "step" in the top surface of the Westmoreland Conglomerate caused by the JN Fault has a distinctive magnetic signature which can be detected at the surface. The traverse lines were extended sufficiently far to the west to cross the postulated position of the northern extension of the Southern Comfort Lineament.

The two traverses were carried out on lines 1500N (00E to 900W) and 1600N (350E to 1000W). Station spacing was normally 5m, but this was reduced to 1m in areas with a high magnetic gradient (the earlier survey had been carried out at 10m spacing). All data was corrected relative to a datum.

The most obvious feature of both traverses was a very noisy zone between approximately 150W and 500W corresponding to outcropping Seigal Volcanics on elevated ground. A three-point moving average smoothing process was applied to the raw data and this removed much of the high frequency noise.

The residual curves show a number of features. The most prominent is a N-S low (1500N/260W and 1600N/370W) with a calculated depth reasonably close to the depth of the Westmoreland Conglomerate/Seigal Volcanics contact. A subtle lineation corresponding to this magnetic feature is visible on the airphoto of the area.

The peak/trough feature on line 1600N (peak 65E; trough 25W) probably represents the step caused by the JN Fault.

In the western part of the area tested, the peak at 1600N/545W appears to correlate with the feature at the edge of the noisy zone on line 1500N (555W). These two features lie almost directly on the projected strike of the Southern Comfort Lineament.
Although anomalous gold had been recorded in a number of drillholes, assays for gold had, in general, only been carried out where there was evidence of uranium mineralisation. Because of the high cost of assaying large numbers of drillhole, rock chip and soil samples for gold, it was decided to investigate the possibility of using mercury as a pathfinder for gold. Work carried out by CSIRO had shown that mercury levels were higher in samples containing gold.

As an initial test, a number of samples from drillhole WPD-45 were analysed for mercury. The results were inconclusive as only one sample had a significant gold content but elevated mercury appeared to be associated with elevated uranium content.

A surface soil sampling traverse was then run over drillhole WPD-45 on line 1725N. The results showed a broad zone of higher Hg values over the JN Fault but the traverse did not extend sufficiently far to establish the background level unequivocally.

Southern Comfort North

Southern Comfort North is the name given to the postulated extension of the Southern Comfort Lineament north-eastwards from the gutter marking the presence of the Lineament in the outcropping Westmoreland Conglomerate sandstone dip slope at NE Westmoreland. The area concerned is soil covered Seigal Volcanics (Fig 13).

Early work at Southern Comfort North included radiometric gridding, costeaming and shallow percussion drilling by United Uranium NL in the area close to the Seigal Volcanics/Westmoreland Conglomerate contact.

Kratos radiometrically surveyed the same part of the area in 1976-77, drilled 10 holes in 1978 and a further 6 holes in 1980 (two of the latter holes could also be regarded as lying within the Mageera Zone of the JN Fault.)
In 1981, Kratos covered the area with a systematic gamma radioactivity and ROAC survey and an orientation soil mercury survey. One angled percussion hole was drilled to try and intersect the Southern Comfort Lineament but it was not clear whether or not this hole accomplished its purpose.

In 1982, the same grid (SCN Grid), which had been laid out sub-parallel to the Seigal Volcanics/Westmoreland Conglomerate contact, was used for a systematic soil mercury survey (Fig 17). The results showed two clusters of anomalous values. One, in the area of outcropping Seigal Volcanics where the SCN and JN Grids overlap, could be divided into N-S and E-W trends, the former corresponding quite closely to the trend defined by the magnetic lows on the two magnetic traverses undertaken as part of the work in the Mageera Zone of the JN Grid (see before). The other anomalous area comprised two roughly parallel trends about 100m apart striking about 40° compared with a strike of 50° for the projection of the trace of the Southern Comfort Lineament. However, the Southern Comfort Lineament is kinked towards its southern end within the area of outcrop of the Seigal Volcanics, with the southern portion trending closer to 40°. It is therefore possible that this southern portion correlates with the mercury anomaly trend, which also correlates with the trend defined by the earlier ROAC survey, the mercury trend lying approximately 70m to the west of the ROAC trend.

It was necessary to establish a second grid in 1982 parallel to the projected strike of the Southern Comfort Lineament. This grid (Southern Comfort North Geophysical Grid - SCNG Grid) was needed for geophysical measurements which, unlike geochemical values, are strike dependent.

The SCNG Grid baseline was laid on a bearing of 37°, parallel to the anomalous trend defined by the ROAC and soil mercury surveys. The surveys conducted on this grid in 1982 were magnetic, transient EM conductivity and resistivity depth soundings (Fig 17).
During the course of this work, a small outcrop of weathered dyke material was found at 620N/15E.

Thirteen magnetic traverses were undertaken between 00N and 600N. These varied in length to up to 215m east of the baseline and 500m west of the baseline.

Transient EM conductivity readings were made on seven cross lines between 150S and 600N, along the baseline, and along line 100W between 00N and 600N.

The results showed that the area could be divided into two distinct zones by a line roughly perpendicular to the baseline between lines 200N and 300N.

The northern, more resistive, zone gave conductivity measurements generally below 40 millimho/m, ie the resistivity was >25 ohm-m. These values are in line with those expected in basaltic rock types.

Within the northern part of this northern, more resistive, zone there is a distinct resistive axis from approximately 400N/25W through to 600N/65E. This axis correlates closely with an anomalous zone defined by the ROAC and soil mercury results, and also passes close to the outcrop of dyke material referred to above.

The survey coverage in the southern, more conductive, zone was not as detailed as in the northern zone. However a conductive axis in excess of 60 millimho/m (ie <16.6 ohm-m resistivity) coincides with the grid baseline. A slightly less conductive axis branches from this main conductive axis and turns through 150N/60E into the resistive zone to 400N/180E.

Resistive responses at the eastern ends of several of the traverses are due to their proximity to Westmoreland Conglomerate sandstone outcrop.
Fourteen resistivity depth soundings were undertaken on the Grid. Trial soundings were carried out initially on line 150N. The results showed good agreement with the drillhole data for this line.

Sounding VES-18 at 600N/00E, about 460m distant from the exposed Seigal Volcanics/Westmoreland Conglomerate contact, gave an interpreted depth to the top of the Mageera Siltstone of approximately 77m. Assuming no surface relief, this would indicate an apparent dip of about 9½° for the Pts/Ptw contact. This is in reasonable agreement with the known dip of the contact in this area.

The form of the two resistivity curves on line 500N (VES-13 and 14) indicates that there is a vertical electrical discontinuity between the two sounding sites which is likely to be a fault with either a vertical offset or dyke infilling. The position of this discontinuity is roughly coincident with the Grid baseline, and a soil mercury anomaly.

The overall coincidence of features indicated by the various methods described above highlighted a reasonably narrow linear zone in the Southern Comfort North area, which appeared to lie on the projected trend of the Southern Comfort Lineament.

Cobar II

Early work included mining of high grade ore from Cobar II (or Blackwells) workings.

Kratos (see before) carried out a trial geophysical survey in 1976, followed by radiometric gridding, VLF and multi-element soil geochemistry in 1977 (Fig 18). In 1978, drilling comprised a stratigraphic diamond hole and four drill profiles spaced over 800m of the strike length of the northerly trending Old Parr-Cobar II Shear Zone.
The previous geophysical testing did not adequately cover the projected trend of the Old Parr-Cobar II Shear Zone to the north, an area of relatively flat soil cover. A second grid, the Cobar II Geophysical Grid (CTG Grid) was therefore established in this area to facilitate the use of several geophysical methods on a trial basis (Fig 18).

Four resistivity depth soundings on line CTG 250N showed three layers with differing resistivity – probably representing, in downward order, soil and alluvium, weathered volcanics and the top of the Westmoreland Conglomerate. There would appear to be a vertical offset in the bottom layer between 00E and 50W. This feature corresponds closely to an apparent NNE magnetic trend indicated by the magnetic survey carried out over the Grid.

The most prominent feature evident in the contoured magnetic data is a magnetic low which crosses the baseline at approximately 175-200N. This low appears to be comprised of two elements, one striking NE (150N/50W - 225N/50E) and one striking NW (175N/100E - 225N/50E). The second trend (NW) is parallel to the trends of magnetic highs to the NE and SW. To the N and NW of the magnetic low feature, the regional strike of magnetic features is roughly parallel to the first element of the low.

The low probably indicates two faults, striking NE and NW respectively, which intersect about 225N/50E.

The conductivity survey carried out over the Grid largely confirmed the NE regional geophysical strike indicated by the magnetic data. The interpretation of the data was tentative due to insufficient density of measurements. However, at the northern extremity of the Grid, a conductive axis corresponds closely with several of the magnetic trends in this part of the Grid.

The trend in the SE corner of the Grid is roughly perpendicular to the general trend and is thus roughly coincident with the second element of the magnetic low discussed above.
As with the previous geophysical testing, the previous geochemical and radiometric testing did not extend sufficiently far to test the projected trend of the Old Parr-Cobar II Shear Zone to the north.

The previous work showed an anomalous area, open to the east, to the north of the old mine workings. Although this anomaly was positioned largely over the old ore dump area, it did lie directly along strike from the Old Parr-Cobar II Shear Zone and it appeared to extend uphill away from the ore dump site. Radiometric gridding and soil mercury geochemistry were therefore undertaken on an extension of the original grid in order to close off the anomaly concerned.

After statistical analysis, the radiometric contour felt to be most appropriate to show anomalous radiation due to mineralisation (as distinct from contamination due to previous mining operations) broadly outlined a N-S trend coinciding with the projection of the Old Parr-Cobar II Shear Zone.

At its northern extremity this trend gives way to two trends, striking 300° and 40° respectively, which intersect about 375N/200W, the location of the historic ore pad. However, these trends are reasonably linear and cross topographic features. This would indicate that they are unlikely to be due to contamination from previous mining activity. Further, the intersection point coincides with a significant magnetic feature at CTG 100N/50W and the 40° element lies roughly on the projected trend of the NE strike of the magnetic low in this area and also coincides with a resistive axis indicated at the western end of the line CTG 100N conductivity traverse.

Douglas Creek

In EL 3625 (Douglas Creek), airphoto and Landsat interpretation was followed by geological and radiometric traversing.
A previously unrecorded minor occurrence of uranium mineralisation in a joint in Westmoreland Conglomerate sandstone near its contact with Seigal Volcanics was found in a portion of the contact which had been shown to be radiometrically anomalous during the earlier Contact Survey.

Two traverses undertaken in 1982 followed the two most prominent eroded joints ("gutters") identifiable on the Westmoreland Conglomerate dip slope. The only anomalous radiometric values recorded were at the Westmoreland Conglomerate/Seigal Volcanics contact. Soil samples were also collected.

Landsat

Two Landsat images of the region were available but the usefulness of the more recent one was limited by the effects of a bushfire.

The lineaments visible on the clearer image were plotted, digitised, and their distribution analysed.

For the lineament distribution analysis, the Landsat scene was divided into four areas. For each sub-area, rose diagrams were constructed using 5° class intervals for number of lineaments per class and average length per class.

This analysis confirmed the already known structural trends in the area, ie NW, N-S, NE and E-W.

1983 Programme

The geophysical programme commenced in 1982 was continued in 1983 in the JN Grid (Mageera Zone), Southern Comfort North and Cobar II areas. Basically, the same instruments and techniques were used except that two Geometrics G856 memory magnetometers and an HP-85 portable computer were used in addition to a Geometrics G816 manual magnetometer.
JN Grid - Mageera Zone

A magnetic traverse was run on line 1400N between 100E and 1000W because the two 1982 traverses showed noisy zones associated with the hill of outcropping Seigal Volcanics in the area.

In general, the results were similar to those of the two earlier traverses, but the noisy zone was less pronounced. Of particular interest was the presence of a feature at 825W, which lined up with similar features at 800W on line 1500N and 775W on line 1600N, to produce a trend parallel to the JN Fault and on the strike projection of the Southern Comfort Lineament.

So that the data from the 1976 magnetic survey in the southern part of the JN Grid could be integrated with the 1982 and 1983 data, three stations used in the first survey were re-read.

Southern Comfort North

The baseline and cross lines of the Southern Comfort North Geophysical Grid (SCNG Grid) were extended in 1983 to follow and further define the features highlighted during the 1982 programme. Magnetic and EM conductivity measurements were made.

During the course of this work, a number of outcrops of dyke material were located at the western edge of the extended grid in the vicinity of 300-400N. These occurrences strike roughly 70°, are near vertical, and range from a few centimetres to a metre or so in thickness. The dyke material is generally very weathered and light orange-pink in colour. It is similar to that found the previous year at 650N/00E.

These dykes found in 1983 lie roughly along strike from the magnetic and conductivity features noted at the western ends of lines 400, 500 and 600N in 1982.
Cobar II

Further magnetic and EM conductivity surveying was carried out on the Cobar II Geophysical Grid (CTG Grid) in 1983 to fill in and extend the surveys undertaken in 1982.

In the conductivity data, the most significant feature was a NE trending conductive axis almost directly along strike from the Old Parr-Cobar II Shear Zone. This trend is not parallel to the expected strike of layering within the Seigal Volcanics.

Diamond Exploration

In 1983, it was intended to make a start on collecting and processing bulk (1-2 tonne) samples from drainages in the area to check for the presence of diamonds, gold and other heavy minerals. The processing plant comprised a trommel and single cell Yuba jig with riffle box and amalgam box scavenger circuit.

Due to mechanical problems this part of the programme had to be suspended. No results of interest were obtained.

CEGBEA URANIUM EXPLORATION PROGRAMME 1984-1987

Introduction

CEGBEA recognised that surface prospecting for uranium in the area had been thorough and comprehensive. It hypothesised that the hydrothermal mineralisation in the province (uranium, gold, base metals, tin and tungsten) might occur in stratigraphic traps as well as in and around fractures. Such stratigraphic traps could occur within the Westmoreland Conglomerate as well as at the Seigal Volcanics/Westmoreland Conglomerate contact. It was felt that geophysics, in which CEGBEA had particular expertise, should be useful in locating such traps (Fig 19).
In its initial structural analysis of the province, CEGBEA recognised five main directions of faulting, viz

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<td>Calvert Fault</td>
<td>WNW</td>
<td>El Hussen?</td>
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<td>Main Range</td>
<td>E-W</td>
<td>Southern Comfort, Jim Beam, Jacques, Glen Grant,</td>
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<td>Zig Zag, Jacksons, Red Rock</td>
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<td>NE</td>
<td>Red Tree, Tjuambi, JN, Southern Comfort</td>
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<td>JE</td>
<td>NW</td>
<td>Conjugate to Red Tree Set - mineralisation best</td>
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<td>developed at intersection of both types eg Mageera Zone of JN Fault</td>
</tr>
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<td>Cobar II</td>
<td>N-S</td>
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Re-evaluation of Kratos' Geophysical Data

CEGBEA carried out an initial re-interpretation of all available geophysical data on the Pandanus Creek area in the first half of 1984.

This data comprised:

1) The ground radiometric, magnetic and VLF surveys carried out at NE Westmoreland and Cobar II and the ground radiometric survey undertaken along the Seigal Volcanics/Westmoreland Conglomerate contact by Kratos during the currency of the previous Exploration Licence held in the area (EL 1016)

2) The ground magnetics and EM conductivity surveys and dc resistivity depth soundings carried out at Southern Comfort North and Cobar II in 1982 (see above)
3) The data from the 1983 airborne radiometric and magnetic survey carried out over Kratos' ground by Uranerz Australia Pty Ltd.

SCN Grid (Fig 17)

On the basis of Kratos' data, the sequence was interpreted to be folded and possibly faulted, with the layering in the Seigal Volcanics generally about 20m thick and the magnetic susceptibility varying between normal and reversed. Three interpreted faults trend NW and intersect NE trending structures.

CEGBEA endorsed the three-layered interpretation of the conductivity results. It considered that regions of high conductivity indicated deeper electrical basement, ie greater depth to Westmoreland Conglomerate (as confirmed by drilling), because the basement appears to have a lower conductivity than the overlying rocks. Further, the conductivity results indicate that the depth to the top of the Westmoreland Conglomerate is probably fault controlled. Five NE trending faults could occur.

CEGBEA noted that the soil mercury results show nine anomalies; all except one of which could be associated with faults. It suggested that the Southern Comfort Gutter could be down faulted by a cross shear and thereby lose surface recognition at 150N.

Cobar II Grid (Fig 18)

The magnetic pattern was found to be similar to that at Southern Comfort North, ie the sequence shows magnetic layering and is folded and faulted. A WNW fault dislocates the magnetic continuity. The two zones of low magnetic intensity present could indicate alteration.
As in the case of Southern Comfort North, the conductivity results show a three-layered electrical section and CEGBEA again considered that the major effect on conductivity values is the depth to electrical basement. The contacts between high and low conductivity zones are therefore possible faults. The indicated NNE trending fault through drillhole CPD-10 was considered important. A pronounced radiometric anomaly parallels this feature, but is offset to the west by 100m.

Examination of the VLF data suggested four possible fault zones.

Interpretation of the airborne magnetic data shows nine regional NE trending magnetic lineaments intersect the Westmoreland Conglomerate/Seigal Volcanics contact.

The airborne radiometric data indicates a large number of NE and NW trending lineaments. Fifty six slightly above background uranium anomalies are present.

**Interpretation of Uranerz Airborne Magnetic and Radiometric Survey**

**Initial Data Interpretation**

CEGBEA made an initial interpretation of the results of the airborne magnetic and radiometric survey carried out by Uranerz in 1983.

The regional magnetic contour plan showed a pronounced ENE trending semi-regional magnetic low cross-cutting the Main Range Fault west of Southern Comfort. It was felt that this could have been due to either the presence of granite at shallow depth, or to thinning of the Clifftdale Volcanics.
The structure of the basement below the Westmoreland Conglomerate and Seigal Volcanics suggested a granite, as indicated by a positive magnetic anomaly. The high and low magnetic zones in the transition area to this basement could have been produced by Cliffdale Volcanics and Murphy Metamorphics.

A similar possible basement dome below Seigal Volcanics was apparent in the north-west of the area.

In view of the promising results of the initial interpretation of the airborne data, CEGBEA obtained all the survey data in digital form.

By means of spectral analysis, the magnetic field data was divided into short wavelength and long wavelength components. Both were then reduced to pole (RTP) to position anomalies more accurately and to remove false negative anomalies produced by the dip of the Earth's magnetic field, eg a magnetic low in the vicinity of Maniw's was removed in this way. Remaining negative anomalies are therefore remnant magnetic features, areas of low magnetic susceptibility or dip anomalies due to the dip of the magnetic body (Figs 20, 21, 22 and 23).

The regional (long wave) component characterises the basement rocks below the Westmoreland Conglomerate. It shows that they can be divided into three units (Fig 24).

Unit 2 is located below the Cliffdale Volcanics outcrop and trends NW below the Westmoreland Conglomerate. It represents an upfaulted block of Cliffdale Volcanics over granite basement which plunges to the north-west. It is comprised of ENE trending zones of varying magnetic susceptibility (andesitic to rhyolitic composition). In the vicinity of the Lagoon Creek Fault, the basement is granite.
Unit 3, a magnetic low with local anomalies trending N-S is located to the south of Unit 2, ie south of the Dingo Creek Fault and its continuation to the north-west. It is considered to indicate a zone of increased depth to Cliffdale Volcanics over a granite basement.

Unit 1 is located to the north of Unit 2, ie north of the Main Range Fault, where there is also an increased depth to magnetic basement, which could be Cliffdale Volcanics intruded by granite, or possibly Murphy Metamorphics.

The circular pattern below the Seigal Volcanics of Unit 1 could indicate a granite basement uplift which would bring the Murphy Metamorphics or Cliffdale Volcanics closer to the surface.

The near surface magnetic field is complex and outlines the Seigal and Cliffdale Volcanics. Its pattern is controlled by variations in near surface magnetic susceptibility which result from low magnetite content, weathering, faulting and magnetite layering in basalts.

A depth analysis (depth to magnetic contact) was carried out using a five point Werner deconvolution filter. As several of the magnetic trends correlated with geological features it was possible to separate out such features extending to depth.

A study of the depth data suggested circular features, which may indicate areas of magnetic zoning due to hydrothermal alteration of magnetite, eg White Heather/Kings Ransom area.

Relative magnetic susceptibility contrasts were plotted and a dip analysis plan was also prepared.

The airborne radiometric results were produced as stacked profiles for Th, U, K and total count. The Seigal Volcanics were found to be potassium rich and a potassium contour plan was produced. Uranium to thorium ratio plots were also prepared.
Radiometric anomalies were located at Old Parr and the Cobar II mine dumps and at a number of other localities outside Kratos' then current ELs (Tourist Creek, El Hussen, White Horse South, Margaret, Lagoon Creek Fault, Lagoon Creek SW, Milliways SE and SW, and Turkey Creek).

Initially, the airborne survey yielded 165 total count or uranium anomalies worthy of checking. On follow up in the area held by it, Uranerz located 53 anomalies on the ground, of which 12 were recommended for further work.

Models

The following model types were considered:

Olympic Dam. A coincident regional gravity high and magnetic high were found at Olympic Dam. The gravity profile across the Cliffdale Volcanics shows a 40 gravity unit gravity high. The interpretation suggests that the basement to the Seigal Volcanics is granite and that an increase in thickness of the Cliffdale Volcanics produces the gravity and magnetic high. Nevertheless, further information on densities in the Cliffdale Volcanics is required before dismissing the possibility of mineralisation similar to that at Olympic Dam. Geophysical N-S cross-sections through Southern Comfort are shown in Figs 25 and 26.

East Pine Creek. It has been postulated that the two circular magnetic features in the area of outcrop of the Seigal Volcanics could be basement domes and that the narrow bounding magnetic zones could be vertically faulted Murphy Metamorphics and Cliffdale Volcanics, which could constitute a target for vein type uranium mineralisation.

Red Tree Model. The magnetic trends cross cutting the Westmoreland Conglomerate/Seigal Volcanics contact could be narrow intrusive basic dykes and, as such, could have uranium mineralisation associated with them.
NORTH-SOUTH GEOPHYSICAL SECTION
Through Southern Comfort Prospect

LEGEND

- Seigal volcanics
- Westmoreland conglomerate
- Rhyolite
- Clifdale volcanics
- Andesite
- Granite

Calculated gravity anomaly for magnetic model
Area A-B
Density 2.91 volcanic
2.67 granite

Scale 1:25 000

Fig 25
North South Geophysical Section
Gravity & RTP Mag.
Through Southern Comfort

LEGEND
- ○ Regional RTP (dipole) mag.
- ··· Gravity survey
- — Topography

Fig 26
Ben Lomond Model. South of the Lagoon Creek Fault (outside Kratos' ELs), an interpreted intrusive feature could as well indicate a basement volcanic caldera which could contain uranium mineralisation in the zone surrounding the vent.

Shear Zones. Numerous linear magnetic features cross cut the volcanic units and could indicate shear zones which may contain mineralisation, cf Jim Beam.

Conclusions

The following were CEGBEA's conclusions following its study of all the geophysical data on the area:

1) The three negative magnetic features located along the Seigal Volcanics/Westmoreland Conglomerate contact should be investigated for hydrothermal alteration by magnetic and ROAC surveys (Fig 20)

2) The computer processing outlined 34 magnetic features, including the JN Fault, which cut the Seigal Volcanics/Westmoreland Conglomerate contact. The majority of the known uranium prospects are associated with these magnetic linear's which are most likely to be either narrow basic dykes which invade both the sedimentary and volcanic rocks, or magnetic susceptibility contacts, ie faults.

The accuracy of the magnetic linear's should be tested by field geological investigation, ground magnetics and ROAC

3) The structure of the Cliffdale Volcanics, with coincident gravity and magnetic profiles, should be investigated by deep electrical soundings to determine a drilling target based on the Olympic Dam model (Figs 25 and 26)
4) Twenty seven linear magnetic zones within the Cliffdale Volcanics could have mineralisation concentrated in intrusive basic dykes, or in the contact zones of wide basic intrusives. A number of these linearals also cross the Cliffdale Volcanics/Westmoreland Conglomerate contact

5) There could be mineralisation associated with possible basement rocks mapped by the regional magnetic analysis below the Seigal Volcanics. This should be investigated by seismic and deep electrical soundings to develop a vein-type uranium target.

6) A coincident magnetic and radiometric anomaly SE of Milliways (outside Kratos' ELs) could represent uranium mineralisation associated with a basic intrusive.

7) There is a distinctive RTP magnetic low over the Westmoreland Conglomerate south of the Lagoon Creek Fault (outside Kratos' ELs). This could be due to an acid intrusive which may have mineralisation associated with it. This should be investigated by gravity to confirm that the magnetic anomaly is produced by an intrusive body.

Seismic Surveys

Prior to CEGBEA's 1985 seismic survey, two seismic surveys had been conducted on the Queensland side of the border by Compagnie General de Geophysique (CGG) in 1969.

The first of these was conducted over the Red Tree Dyke area. It was thought that buried channels on top of the Westmoreland Conglomerate could indicate fractures which high velocity zones could identify as dolerite intrusions. However, interpretation proved difficult due to lower than hard rock seismic velocities, thought to be due to weathering. (The same effect could also have been caused by deuterionic or hydrothermal alteration).
The second survey, conducted in conjunction with resistivity and magnetic surveys, was carried out east of the Buck Hill Fault. The survey was designed to locate troughs in the seismic basement which could indicate the presence of fracture zones similar to the Red Tree Fracture. Fifty four seismic anomalies with E-W and NE trends were detected and five were chosen for follow-up drilling.

After having established grids at JN (different from Kratos' JN Grid) and Turkey Creek (area referred to by Kratos as Douglas Creek), Fig 27, CEGBEA carried out seismic reflection surveys as follows:

- Red Tree Fracture - 1 traverse in Huarabagoo Zone
- JN Fault - 4 traverses
- Turkey Creek Area - 1 traverse.

The aim of this work was to provide an interpretation of the stratigraphy and structure of the Seigal Volcanics and Westmoreland Conglomerate at depth beneath the RTP magnetic features outlined in the latter two areas (Figs 20, 21, 22, 28 and 29) with a view to identifying stratigraphic and/or structural traps for uranium mineralisation.

It was recognised that interpretation of the seismic records would be a complex task without drillhole control. However, the survey produced excellent seismic records from the surface to 500m and, in places, to 1,000m and more. It indicated the presence of a variety of possible traps for mineralisation in both the JN and Turkey Creek areas.

In the JN area, the seismic survey showed layering within both Formations and several faults dipping at moderate angles to the north. One of the faults lies at approximately the northern edge of the botanical feature.

Basement doming has occurred in the Mageera and Oogoodoo Zones of the JN Fault, and in the Huarabagoo Zone of the Red Tree Fault.
GEOLOGY

- Quartz vein
- Lithological boundary
- Fault

GEOPHYSICS

- Lithological boundary
- \( \gamma \) Radiation anomaly
- Magnetic low (R.T.P. data)

Fig 29
LINE 10000E (SOUTH OF BASELINE)
LOOKING EAST

N

S

9700N 9600N 9500N 9400N

0m
500m
1000m
1500m

Reflection Horizon

Fig 30

1985 CEGBEA Seismic Reflection Survey.

CEGB EXPLORATION (AUSTRALIA)
WESTMORELAND PROVINCE
JN AREA SEISMIC SECTION
LINE 10000E

ORIGINATOR: LJS  REPORT NO: 1986/6
DRAWN BY: MAPGRAPHICS  FIGURE NO: 1308/390
DATE: FEB 1986  PLAN NO: 1308/390
An unusual flat lying reflector was found in the Mageera Zone. The explanation for this feature is not known - it could be a flat lying intrusion, a stratigraphic horizon, a fracture zone (possibly in Cliffdale Volcanics), or, indeed, the base of the domed layer (Fig 30).

In the Turkey Creek area, the survey also showed layering similar to that at JN, and several faults which, in contrast to those in the JN area, dip at moderate angles to the south, i.e. parallel to the Main Range Fault.

The possibility of a granite at depth in the JN - Turkey Creek area inferred from the regional RTP magnetic anomaly may be correlated with an apparent thickening of the Westmoreland Conglomerate shown by the seismic data.

On the basis of the seismic results, it was recommended that:

- a hole up to 300m deep should be drilled at around 9610N on line 10000E, JN Grid to determine the stratigraphy and structure at depth in this area (Hole WPD-41 drilled previously by Kratos in this area was completed at 112m)

- a hole should be drilled at 9580N on line 9800E, Turkey Creek Grid to define the structure of this area at depth.

Geological/Geochemical/Ground Geophysical Programme

Concurrently with its programme of analysis of geophysical data, CEGBEA commenced ground geological, geochemical and geophysical surveys in the area.
Background Geological Studies

Twenty six thin sections held by Kratos were submitted to MacKay & Schnellmann Pty Limited for re-examination. All but two of these were cut from diamond drill core covering the main prospect areas, viz NE Westmoreland, Southern Comfort, Cobar II and El Hussen.

The sediments intersected were mainly described as orthoquartzite, with intraformational conglomerate recognised in one hole at NE Westmoreland. The orthoquartzite consists of sub-rounded to rounded quartz grains with good sphericity set in silica cement, with 10% or less sericitic matrix. Occasional rounded grains of felsic porphyry are also present.

Dyke filling from the JN Fault Zone (Hole WDD-98) was described as a strongly carbonated and ferruginised dolerite/basalt; dyke filling from the Southern Comfort Fault Zone was described as altered olivine dolerite (outcrop sample) and altered obsidian? (Hole SCDD-1). The radioactively anomalous boulder found at Waterfall Creek was described as a kaolinised basalt?

An unusual rock type from Hole WDD-86 was described as a metasomatised welded tuff.

A further 9 samples taken from Kratos diamond drill core (Jim Beam and JN) by CEGBEA, and 29 outcrop samples collected by CEGBEA from various prospect areas were then examined petrographically by MacKay & Schnellmann.

Four of the five surface samples from Jim Beam were described as altered andesites - variously silicified, chloritised, sericitised and albitised; the remaining sample was classed as a rhyodacite. Two of the drillhole samples were described as volcanic breccia, one as altered tuff, one as rhyolitic ash-flow lapilli tuff and the fifth as a devitrified amygdaloidal obsidian.
Three drill core samples from JN Hole WDD-98 were highly altered andesite (2) and rhyolitic and andesitic volcanic breccia (1). In the latter rock, the clasts consist of fluidal, devitrified rhyolite and carbonated, ferruginised, fine grained ?andesite. The other drillhole sample was of Westmoreland Conglomerate orthoquartzite similar to the other samples described above. A surface sample of Seigal Volcanics was sericitised basalt.

Two of the four samples from the Milestone Breccia Pipe were composed of clasts of completely ferruginised basalt set in a matrix of quartz veins. The original felspar laths of the basalt are now totally replaced by fine crystalline quartz, and the matrix consists of hematite. Relic amygdales are filled with fine quartz. It is possible that this breccia resulted from explosive activity which preceded the intrusion of the ?trachyte described below.

The ?trachyte was seen in thin section to be composed of extremely fine grained, subradially fibrous, somewhat kaolinised alkali felspar. Quartz is accessory. This material is in sharp but very irregular contact with enclosed fragments of strongly ferruginised basalt. The latter comprise hematite enclosing limonite-stained relics of plagioclase laths, which now consist of partly silicified kaolin.

The fourth sample from Milestone was a dark reddish-brown ferruginised basalt. The original texture of fine grained, randomly oriented plagioclase laths and prismatic pyroxenes is still evident although both the plagioclase and pyroxene have been replaced by limonite-stained clay minerals.

Of the four samples from the Dianna Copper Mine area, two were ferruginised, amygdaloidal basalt. In thin section, only a relic texture indicates the original nature of the rock - sparse plagioclase microphenocrysts in a very fine grained groundmass of
subradially oriented, feathery microlites of plagioclase immersed in a matrix of glass. The rock now consists of limonite and probable clay minerals. The amygdales commonly have a thin outer zone of pale green chlorite enclosing quartz, which becomes strongly limonitic towards the centre.

One of the two samples from the mine site proved to be a tuffisite (intrusive tuff, ie intrusive explosion microbreccia) consisting of clasts of completely altered basalt in an extremely fine grained matrix of limonite-stained felsitic material.

The other, of ore from the mine shaft, was a trachyty breccia comprised of clasts of strongly kaolinsied trachyty material in a matrix of hematite (probably derived from magnetite) with intergrown veinlets of quartz and malachite. This rock appears to represent a further stage in the process of brecciation (and mineralisation) compared with the Milestone breccia, in that the trachyty material itself is now brecciated.

As a general comment, MacKay & Schnellmann felt that the breccias present in the Cliffdale Volcanics were associated with the volcanism. The Westmoreland Conglomerate and Seigal Volcanics, on the other hand, have been affected by an explosive, brecciating process that seems to have been highly volatile and possibly associated with the emplacement of trachyty (syenitic) magma.

The three samples from El Hussen were a basaltic tuff from the base of the Seigal Volcanics; a sericitic and chloritic quartz sandstone, with a matrix which may well have been introduced, which shows incipient brecciation, from the Westmoreland Conglomerate; and a green (chloritic) chert.
Two samples of Westmoreland Conglomerate quartz sandstone from near the contact with Seigal Volcanics at McGuinness had chloritic and sericitic matrices. A sample further away from the contact was described as an orthoquartzite, but differing from those described previously in that this rock has a cement of fine, intergrown grains of chalcedonic silica rather than quartz overgrowths on grains.

Of four samples from the Eva Mine area, two were devitrified, partly silicified rhyolite; one was a metaquartzite explosion breccia close to a tuffisite (cf Dianna Copper Mine sample); and one was a brecciated Westmoreland Conglomerate orthoquartzite.

A sample of Carolina Sandstone was described as a felspathic orthoquartzite. The alkali felspar occurs as rounded grains of microcline and tabular grains of ?sanidine. The latter suggests nearby vulcanicity at the time of deposition. Nearby samples of Seigal Volcanics (from the hill south of Uranerz' helicopter pad) were basalt, ferruginised amygdaoidal basalt, impure water-laid basaltic tuff (ash-fall tuff deposited in an immature silty sediment) and tuffaceous siltstone with basaltic lapilli.

Examination of airphotos and the Landsat image, and field observation, led to the recognition of a botanically unusual zone to the north-west of the JN Fault. Above average soil base metal values evident in the Mageera Zone of the JN Fault were found to continue into the botanical feature.

B G Bourke, who carried out much of CEGBEA's geological programme, held the view (not accepted by Kratos) that the opportunity for discovery of fault related economic mineralisation in the Pandanus Creek area was limited due to the paucity of rock units having reducing properties (CEGBEA Report 1986/3). Therefore CEGBEA's programme was directed towards "uranium and gold occurrences from hydrothermal sources beneath the sandstones and volcanics" and "reverse fault structures where mineralisation would naturally occur".
As reported above, CEGBEA's detailed analysis of the airborne magnetic data revealed three subtle, previously unrecognised, lows in the residual component of the Earth's magnetic field along the contact between the Seigal Volcanics and the Westmoreland Conglomerate. These zones were interpreted as possible hydrothermal alteration zones produced by intrusive bodies of Middle to Upper Proterozoic age.

Two of these three anomalous areas were selected for initial further study, viz JN and Turkey Creek (see Fig 27). Figs 21 and 22 show the RTP (Returned to Pole) magnetic anomalies in these two areas.

Field examination of these two areas showed at least three different basalt flows, which vary in both mineralogy and texture. The lowermost unit, lying immediately above the Westmoreland Conglomerate, is a hard, dark, fine grained chloritic (35-40% chlorite) basalt, which was shown in the laboratory to have a low magnetic response. The hills to the north of this unit are composed of a different unit of the Seigal Volcanics, which has a much higher magnetic response.

The RTP lows at JN and Turkey Creek could be due to the near surface occurrence of these chloritised basalts. The question then is whether this chloritisation is inherent in the basalt lava, or is the result of hydrothermal alteration.

Four samples of unmineralised Westmoreland Conglomerate sandstones (at Pts/Ptw contact and at 100, 200 and 300m away from the contact), and one mineralised sample from the Pts/Ptw contact near the JN Fault, were examined petrographically and by SEM (scanning electron microscope).

The four unmineralised samples were broadly similar, but differed from the description given by Hills and Thakur (1975) in that they were consistently cemented by overgrowth quartz, resulting in an impervious quartzite. This epitaxial silica cementation is common in older sandstones where it is usually regarded as a diagenetic product. The pervasion of uranium mineralisation in
the cement of the mineralised sample suggests that there must be a relationship between the two. It seems unlikely that a previously silicified sandstone could be permeated by epigenetic solutions unless it was heavily fractured. There was no evidence for such fracturing in the thin sections studied.

Further support for a non-diagenetic origin of the silica cement is the evidence of silicification of mica and the growth of idiomorphic quartz in the mineralised pores. The uranium mineralisation was found to be comparable with that reported previously except that the vanadium species was not carnotite.

In the unmineralised samples studied, the predominant clasts, ie the primary quartz grains, are often well rounded and have a grain size range between 0.1 and 0.6mm. The silica overgrowths are essentially epitaxial and can exceed 25% of the rock. The resulting texture is entirely impervious. The other clasts do not exceed 5% and are of similar dimensions, and rounded. The negligible accessory heavy minerals include zircon, thorium-bearing monazite, tourmaline, florencite (cerium calcium aluminium phosphate) and pyrite.

Apart from the silica cement, the other main matrix constituents are iron oxides (probably a mixture of hematite and geothite) and mica.

The mineralised sample was similar, but slightly coarser (quartz grains 0.1-1.0mm) and with more iron staining of the mica seen in thin section. The widespread uranium mineralisation was identified as pitchblende and torbernite. The pitchblende occurs in veinlets and in disseminations in the iron and iron titanium oxides; the torbernite is more restricted.

Seven samples of Seigal Volcanics (six from the JN area and one from the Turkey Creek area) were examined petrographically and by SEM. This showed that the classification of these rocks is difficult. They are two felspar-clinopyroxene-olivine amygdaloidal coarse lavas. The available evidence suggests that
the original plagioclase has been modified to albite and that the K-feldspar is original. This would place them in the field of hawaiite, a type of alkali rich basalt/dolerite. They may therefore represent some form of differentiated dolerite.

These rocks are usually relatively coarse grained, but chilled phases occur in places. A chilled contact between lava and siltstone in the Turkey Creek area showed potash metasomatism of the immediate contact zone.

Three of the samples from the JN area showed varying degrees of chloritisation. A polished section of one sample showed chalcopyrite and pyrite.

A sample of mineralised rock (location not stated) was described as a chlorite-hematite-sericite "schist" - a secondary rock such as forms in a contact or shear zone. This process occurred prior to the deposition of uranium. In reflected light, the main opaque was hematite, which occurred as clusters of lath like crystals linked to an irregular pattern of fine trails of the same mineral. The uranium occurs as pitchblende veins, rarely wider than 25 microns, which commonly cross the hematite trails, but not carbonate (CaMn siderite) veins also present in the rock.

The 1985 CEGBEA JN Grid (which, as stated above, differs from the Kratos JN Grid) was designed to cover both the RTP magnetic anomaly zone and the JN Fault. It was later extended northwards to cover the botanical feature, and probable NW and NE trending faults.

Fig 27 shows the locations of the JN and Turkey Creek Grids.

JN Grid

A ground magnetics survey (total magnetic field) was carried out over the whole grid at 20m station interval using a Scintrex MP-3 magnetometer. No base station was used but base station repeat measurements were carried out whenever possible.
The data clearly showed the marked differences in the magnetic susceptibilities of the Seigal Volcanics units. The low magnetic susceptibility of the basal unit was confirmed. Regional and residual maps were produced and computer generated magnetic depths were also plotted.

Following specific gravity measurements on nine fresh, representative rock samples, and comparison with similar measurements made by Uranerz, a gravity survey was carried out using a Lacoste and Romberg Gravity Meter.

Repeat measurements were carried out at the base station at approximately 2 hr intervals to establish instrument drift. Readings were taken at 100m intervals with infill readings on selected lines at 50m intervals. The Bouguer gravity values were calculated using a density of 2.67g/cm\(^3\) and regional, residual and depth maps were produced.

The gravity results showed low gradients over the JN Grid. Four zones were evident from the regional gravity map, viz:

1) The expected increase over the Seigal Volcanics was not present; instead there was a localised low intensity high (0.2 gravity units) over outcropping Westmoreland Conglomerate corresponding to a zone of fracturing, jointing and alteration

2) The gravity data showed an E-W trending low (0.2 gravity units) which coincided with the RTP magnetic low and chloritised basalt unit

3) A localised, NE trending gravity high (0.5 gravity units) in the north-east part of the grid

4) A gravity gradient decrease (0.04 gravity units/km) to the north-west in the north-west part of the grid.
The residual gravity map showed comparable results to the regional gravity map, but led to the recognition of localised, N-S trending lows which were not evident on the magnetic or regional gravity plots. These lows are collinear with visible joints in the outcropping Westmoreland Conglomerate and probably reflect hydrothermal alteration of the sandstones. On this interpretation, the joints were the conduits for mineralising fluids post-dating the Seigal Volcanics. That is, the mineralising event(s) post-dated the creation of the redox boundary at the Seigal Volcanics/Westmoreland Conglomerate interface.

As stated previously, Kratos, on the basis of its drilling programmes, recognised three zones along the JN Fault, viz the Mageera and Oogoodoo Zones, which showed mineralisation of possible economic interest, and the Intermediate Zone, which showed very little mineralisation. The geophysical data shows localised jointing and fracturing in the Mageera and Oogoodoo Zones but both the magnetic and gravity results show little structure in the Intermediate Zone. Furthermore, the Intermediate Zone has no collinear joints in the outcropping Westmoreland Conglomerate to the south.

The jointing pattern in the outcropping Westmoreland Conglomerate sandstones is associated with both a magnetic and a gravity high and is considered to have been caused by a denser, uppermost unit of the Cliffdale Volcanics which has been caught up in the reverse faulting and thrusting which formed the Main Range at NE Westmoreland. (The source is not a granite as this would have given both a magnetic and a gravity low).

Following deposition and lithification of the complete sequence, tectonism produced particularly north-east trending fractures, which were reactivated at later times and infilled with dyke material and/or quartz. The main mineralising event is believed to have been the later Main Range faulting event, which produced reverse faults and overthrusting.
Soil geochemical sampling was carried out by CEGBEA over selected lines of its JN Grid to expand the geochemical data obtained previously by Kratos and to test the geobotanically anomalous area to the north. Samples were taken from the bottom of 10cm auger holes and sieved to -4mm. Analyses were carried out on the +80 and -80 mesh fractions.

The sampling was carried out on lines 200m apart, with samples taken generally at 100m intervals (50m in about one third of the area covered). Although this sample spacing is too wide for detailed analysis, the copper and zinc values seem to form a broad crudely banded pattern which may reflect the differing compositions of different basalt layers in the Seigal Volcanics. The uranium values are low and the occasional higher values (maximum 3ppm U) do not form any recognisable pattern. Lead forms a more definite high (maximum 305ppm) north-west of the Mageera Zone of the JN Fault (between the JN Fault and the geobotanical anomaly).

Radiometric readings at 20m spacing were carried out by CEGBEA over their JN Grid using a SRAT SPP2 Scintillometer (the same instrument as used by Kratos in its earlier surveys).

Only one markedly anomalous zone was located. This was at the Seigal Volcanics/Westmoreland Conglomerate contact in an area where there is strong hematisation of the sandstone. A thin section (see before) showed torbernite and pitchblende, the latter being present in veinlets and in disseminations in the iron and iron titanium oxides.

A second, less intense, anomaly was recorded over the Mageera Zone of the JN Fault.

In the latter part of the 1986 field season, it was decided to assess the usefulness of the GEM 8 electromagnetic system and ROAC (Radon on Activated Carbon) in the JN area.
The two test surveys were carried out on Line 10,000E, which was selected because it crossed the central part of the JN Fault and considerable data for comparison was available from work in 1985 and earlier years.

The EM survey showed two significant anomalies - one at 9300N which was interpreted as the Seigal Volcanics/Westmoreland Conglomerate contact, and the second between 10800N and 10900N, which was interpreted as a near surface fault in Seigal Volcanics, which may extend into the Westmoreland Conglomerate. The JN Fault and a zone between 10300N and 10400N also showed up as small EM anomalies.

Overall, there was good correlation of the EM data with the magnetic, gravity, seismic and ROAC data.

The ROAC survey was carried out, over the Seigal Volcanics portion of Line 10,000E only, at 50m station spacing. The cartridges were buried in augered holes 30cm deep, left for 5 days, removed and counted. The results showed only one strongly anomalous zone - between 10600N and 10800N - which correlates approximately with magnetic and gravity features. The ROAC data was, however, somewhat noisy, the mean background value being 110 units compared with the highest value of 300 units at 10700N.

The anomalous zone between 10600N and 10900N on Line 10000E defined by the EM and ROAC data falls broadly within the area of minor structural features interpreted from the seismic, gravity and ground magnetic data. In the area concerned, there is no outcrop or surface expression of underlying structure. CEGBEA felt that, although not considered significant in terms of its prospectivity for uranium mineralisation, the area warranted further examination, particularly in the vicinity of 10700N. (The area is some 400-600m NW of Kratos' JN Grid drilling).
Integrating the airborne and ground data, processing of the airborne magnetics data defined a subtle magnetic low along the Seigal Volcanics/Westmoreland Conglomerate contact where the basal basalt unit of the Seigal Volcanics is highly chloritised. This was interpreted as a hydrothermal alteration area, the hydrothermal fluids having been sourced from an intrusive body at depth.

To the south of the magnetic low zone, the regional magnetic and gravity data both showed a localised high over outcropping Westmoreland Conglomerate sandstone which was attributed to an uppermost, denser unit of the Cliffdale Volcanics which had been caught up in the reverse faulting and thrusting which formed the Main Range at NE Westmoreland.

CEGBEA believed that the mineralisation in the JN Fault area is linked to the Main Range Fault event and that it is likely that the joints and fissures which are visible in the outcropping Westmoreland Conglomerate, and evident in the gravity data continuing into the Seigal Volcanics, were the conduits for the mineralising fluids. This interpretation suggests possible target areas and would explain the intermittent nature of the mineralisation along the JN Fault Zone, ie the barren Intermediate Zone, where there appear to be few joints and fissures, between the mineralised Mageera and Oogoodoo Zones which are along strike from visible joints and fissures in the outcropping Westmoreland Conglomerate.

CEGBEA commented that the mineralisation was usually precipitated at the Seigal Volcanics/Westmoreland Conglomerate redox boundary.
Turkey Creek Grid

This area was considered prospective for the following reasons:

1) The location of four about 4x background radiometric anomalies by earlier work along the Seigal Volcanics/Westmoreland Conglomerate contact in this area

2) The presence of an E-W trending magnetic low similar to that in the JN area

3) A structural pattern of major jointing and fracturing in the outcropping Westmoreland Conglomerate suggestive of updoming due to an underlying intrusive body, probably associated with the Main Range Fault event.

A 1.4 x 0.8km grid was surveyed in over the Seigal Volcanics/Westmoreland Conglomerate contact zone. Magnetic and radiometric readings were taken at 20m spacing and gravity readings at 100m spacing. Only a small number of soil and rock chip samples were taken as two thirds of the surveyed area comprised outcropping Westmoreland Conglomerate sandstone.

The regional magnetic map shows clearly the different response of the Seigal Volcanics and the Westmoreland Conglomerate, the latter having a low magnetic response.

The residual (filtered) magnetics show a broad magnetic high over the sandstones and a low over the Seigal Volcanics.

The regional gravity contours show that the gravity field increases in intensity in a north easterly direction. This trend is broken by a pronounced gravity low centered around 9450N, 9950E (see Fig 31). This low, of about 15 gravity units, was considered to be significant because:

1) it occurs in Westmoreland Conglomerate sandstones where there is evidence of fracturing and alteration
2) it coincides with the RTP magnetic low apparent from processing of the airborne magnetic data (see before)

3) the four localised radiometric anomalies referred to above occur in strongly hematised sandstone near the Seigal Volcanics/Westmoreland Conglomerate contact

4) there is evidence of doming, which could indicate the presence of an intrusive body, in the area of the gravity low.

CEGBEA's ground radiometric survey did not reveal any anomalies other than the four localised radiometric anomalies referred to above.

The limited geochemical soil sampling carried out in the grid area gave no significant uranium anomaly, the highest value being 2ppm U. Copper and zinc were both low for the first 200m out into the Seigal Volcanics from the Seigal Volcanics/Westmoreland Conglomerate contact, and then increased markedly. Lead followed a similar pattern, but was also low westwards.

A rock chip sample was taken of a mineralised alteration zone 240m out from the contact. This gave:

ppm

<table>
<thead>
<tr>
<th>Element</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cu</td>
<td>2,000</td>
</tr>
<tr>
<td>Zn</td>
<td>5,420</td>
</tr>
<tr>
<td>Pb</td>
<td>288</td>
</tr>
</tbody>
</table>

However, this alteration/veining was fairly localised.

To summarise, the Turkey Creek area was considered of interest because of the presence of a distinctive RTP magnetic low after processing of the airborne magnetic results. The gravity results defined a localised low corresponding with a low in the RTP magnetic contours. Jointing, minor quartz/chert veining, surface alteration and evidence of doming are present in the same area.
These results suggest an intrusive body relatively close to surface beneath the sandstones which gave rise to mineralising hydrothermal fluids. CEGBEA felt that the lack of detectable uranium mineralisation at the surface may be due to the lack of Seigal Volcanics cover, and hence absence of a redox boundary to precipitate uranium.

Cobar II Grid

CEGBEA assayed soil samples collected by Kratos on the Cobar II Geophysical (CTG) Grid. The results showed maximum values of gold (15ppb), copper (280ppm), lead (55ppm) and zinc (90ppm) in the eastern part of the grid. A low intensity uranium anomaly (maximum 6ppm U) appeared to be aligned along the trace of a northerly trending photolineament east of the northerly trending photolineament on which Cobar II lies.

CEGBEA (later overruled by CEGB, London - see below) concluded that there was no basis for carrying out any additional detailed work for uranium exploration in the Cobar II area. The gold and base metal results would, however, appear to be of interest (Fig 32).

1987 CEGBEA Programme

Introduction

Following an assessment of the results of its work in ELs 3625-3627, CEGBEA recommended, in April 1986, that four holes be drilled in the JN area and one in the Turkey Creek area. These holes were sited on the basis of the magnetic, gravity and seismic results. Fig 33 shows the four proposed holes in the JN
Exploration target based on seismic, gravity and magnetic data.

DH 1 Proposed drillhole

Reference:
- Geometrical Zone
- Sandstone
- Westmoreland Sandstone
- Basalt
- Trachyandesite
- Altered Basalt
- Quartzite Dike
- Joints/Fractures
- Fracture/Fault
- Hydrothermal Alteration Zone
- Copper

OCGR Exploration (Australia)
WESTMORELAND PROVINCE
JN Fracture - 3 Quadrangle
GEOLOGY

Fig 33 CEGBEA Recommended Drillholes/Geology
ZFX Exploration target based on seismic, gravity and magnetic data.

DH 1 Proposed drillhole

LEGEND
- Diamond Drill Holes
- Percussion Drill Holes
- Percussion/Diamond Drill Holes
- United Drilling Drill Holes

DRILLHOLE LOCATIONS
COMPILED FROM KRATOS REPORTS 1979-1981
AND FIELD ASSESSMENT 1985

Fig 34
CEGBEA Recommended Drillholes/Previous Drilling
area in relation to the geology of the area and Fig 34 shows them in relation to the holes drilled previously by Kratos. Later, in June 1986, the recommended number of holes was reduced to two (in the JN area) in response to perceived programme approval and budget difficulties.

The recommendations of CEGBEA were subsequently overruled by the CEGB Head Office in London, which decided that two holes would be drilled at Cobar II to further test the known mineralised Shear Zone.

Cobar II

Two diamond holes (each with a short percussion precollar) were drilled at the Cobar II prospect in 1987. The purpose of the first hole was to reconnoitre down pitch from the known Cobar II uranium mineralisation. The other, located 100m south of the first, was to test between the two known occurrences of mineralisation at Cobar II and Old Parr. Both holes were to have intersected the Old Parr–Cobar II Shear Zone in Westmoreland Conglomerate sediments about 45m below the Seigal Volcanics/Westmoreland Conglomerate contact.

The elevation of the first hole collar was too low to achieve a satisfactory intersection of the Shear Zone, ie within 30m of the Seigal Volcanics/Westmoreland Conglomerate contact. The highest uranium value was 65ppm over 1m and the highest gold value 18ppb over 0.5m.

The second hole was abandoned prior to reaching the Shear Zone due to very slow drilling and exhaustion of the water supply. The highest uranium value was 30ppm over 0.5m and the highest gold values 37ppb over 0.5m and 23ppb over 1m.

It should be noted that a sample of dump material from the Cobar II mine is reported to have assayed 5ppm Au.
Dyke Material

A sample of dyke material from 105m depth in Kratos drillhole WDD-98 at NE Westmoreland was assayed and examined petrographically. The rock is anomalous in uranium (80ppm) and boron (237ppm). Its gold content is 27ppb. It may be referred to as an altered potassic intrusive in which the K-felspar may be metasomatic.

Metre Conglomerate

CEGBEA collected a sample of Metre Conglomerate and had it assayed for a wide range of elements. The gold content of the sample was <5ppb.

STOCKDALE DIAMOND EXPLORATION PROGRAMME 1984-1985

In 1984, Stockdale took three reconnaissance samples from major drainages in the area. After processing, the concentrates were examined in the company's laboratory but no diamonds or kimberlite indicator minerals were recovered.

KRATOS EXPLORATION PROGRAMME 1986-1987

1986 Programme

Prior to commencement of the 1986 field season, desirable bulk stream sediment sample sites were selected to provide coverage of all drainages in the area of ELs 3625-3627. To minimise the need to construct access tracks, these sites were selected as near as possible to existing tracks. In each case, the precise sampling location was determined on site.
A traxcavator was used to collect 3-4 tonnes of material from each sampling site. The samples were transported to a central processing site on Cobar II Creek approximately 2km north of Sandy Hollow campsite.

Due to breakdown of the traxcavator, only 11 of the proposed 22 sample sites could be sampled. Three drainages covering a further six of the proposed sites were sampled by hand by taking about 200kg of material from suitable trap sites.

A 1.8m diameter Kimberley-type diamond pan was used to treat the samples. However, because of the onset of heavy rains, which severely hampered vehicular movements, only 3 of the 11 bulk samples collected could be treated.

The concentrates from the diamond pan were sieved into four size fractions. The three coarser fractions (+6.3mm, -6.3 to +3.1mm, -3.1 to +1mm) were jigged on the sieves and examined by eye. The finest fraction (-1mm) was passed over a mobile grease table. The concentrates amounted to 120-130kg per sample, about half falling in the -1mm size range.

In the case of the 8 bulk samples which could not be processed through the diamond pan, a sub sample (130-190kg) was sieved into three size fractions (+6.3mm, -6.3 to +2.8mm and -2.8mm). The coarse fraction was hand picked for any grains of interest. The middle fraction was subjected to attrition grinding to remove clay and any grain coatings prior to hand picking. The finest fraction was passed over the mobile grease table.

The grease table unit incorporates a 0.5mm aperture desilting screen. In all cases, the underflow from this screen was collected and panned by hand.

After removal of magnetic material with a hand magnet, these pan concentrates and the material retained on the grease were further concentrated using heavy liquid (bromoform SG 2.89) separation.
The "sinks" from the heavy liquid separations (27 samples) were examined under a binocular microscope and then dispatched to Amdel for more detailed examination.

Amdel scanned the grease table heavy fractions directly and the pan concentrates heavy fractions after sieving at 0.2mm (72 mesh) for mineral grains of interest, which were removed and prepared in polished section form for quantitative analysis by JEOL Superprobe.

Garnet, generally pale in colour, was present only in trace amounts in a few of the samples. Green, possibly chromium-bearing, clinopyroxene grains were found abundantly in some samples and were conspicuous by their absence in others. A number of grains of possible picroilmenite and chrome spinel (which lies between spinel proper and chromite) were also picked for analysis.

The clinopyroxenes proved to have compositions which placed them in the augite field rather than the diopside field. They are nevertheless of similar composition to pyroxenes analysed from a number of eclogitic kimberlites.

The analyses of the ilmenite grains showed that they were all low in magnesium and unlikely to be related to kimberlites/lamproites.

The chrome spinels were found to fall into three groups, but all three types showed significant compositional differences from typical kimberlites and lamproites. For example, those with high chromium content were lower in magnesium content than the published analyses of diamond associated rocks.

Thus Amdel concluded that the samples examined did not contain indicator minerals definitely characteristic of kimberlites and associated xenoliths, or of lamproites.
Kratos' preliminary examination of the heavy liquid concentrates sent to Amdel had shown several small grains thought to be possible microdiamonds and a number of grains of gold. Amdel did not identify any microdiamonds, possibly because the grains concerned may have been smaller than 72 mesh, and only noted one grain of gold.

1987 Programme

Bulk Stream Sediment Sampling

A comprehensive programme of bulk stream sediment sampling was carried out during 1987 (Fig 35). Samples of 3-4 tonnes each were obtained from suitable deposition sites using a front end loader. As in 1986, the samples were processed by Kimberley diamond pan, grease table and heavy liquid separation.

No diamonds were noted in any of the concentrates. Clinopyroxene and ilmenite/chromite/chrome spinel grains similar to those recovered in 1986 were present in a number of concentrate samples. These minerals must be considered as characteristic of the background host lithology of the area rather than as from an atypical source within the background lithology.

Gold grains, <0.5mm in size, were noted in two samples in the vicinity of EL 3625. Apart from follow up of these two samples, it was concluded that there is unlikely to be a significant source of coarse gold mineralisation (ie visible grainsize range) anywhere in the drainage areas tested.

Rock Chip Sampling

A rock chip sampling programme was carried out as an initial test for the presence of fine grained gold and/or platinum group elements within the ELs. Samples were collected, at fairly wide spacing, from reconnaissance grids established over six prospect areas where the presence of uranium mineralisation had been established previously (Fig 35).
It was realised that gold and platinum group mineralisation need not necessarily be found in close juxtaposition to uranium mineralisation, but it was felt that testing of the main known uranium prospect areas should reveal some evidence of elevated gold and platinum group values if such mineralisation is present in the region.

The samples were analysed for Au, Pt and Pd by fire assay. In general, the assay results were low, with many values below the limit of detection. Even the higher values could perhaps, on a strictly mathematical basis, be held to lie within expected statistical variation. However, within each individual grid area there are clusters of higher values for one or other (sometimes several) of the elements analysed. Thus the results, which are summarised below, were thought to be of significance.

1) Jim Beam: Three elevated gold values (highest 0.08ppm) occur in the vicinity of the surface radiometric anomaly. All Pt values are <5ppb; 4 Pd values are 1ppb, the remainder <1ppb.

2) Cobar II: On the relatively small CTG grid, elevated values (maxima Au 0.01ppm, Pt 10ppb and Pd 13ppb) tend to cluster around Cobar II Creek in the vicinity of drillhole CPD-3 on the projected strike of the mineralised Old Parr-Cobar II Shear Zone.

Further to the north-east, in the second area gridded in the general Cobar II locality, results confirm a zone of elevated Au soil geochemical values highlighted by an earlier survey. Maxima are Au 0.02ppm, Pt 10ppb, Pd 9ppb.

3) Southern Comfort North: Only one Au value (0.01ppm) and two Pt values (both 5ppb) are above the respective limits of detection. Pd values are more varied, the highest being 10ppb. There is no particular pattern to the higher values.
4) North East Westmoreland: This grid covers part of the Mageera Zone of the original JN Grid in the vicinity of the high grade U and Au intersections made in WPD-45. Elevated Au (0.01ppm) and Pt (maximum 10ppb) values are evident in the samples overlying the area of known U/Au mineralisation at depth. An isolated high Au value (0.04ppm) occurs at the SW end of the grid.

5) Kings Ransom: The two highest Au values (both 0.02ppm) both lie to the east of the old shaft. A second zone of slightly higher Au values (0.01ppm) is located at the southern end of the grid. The highest Pt value (10ppb), on the other hand, occurs to the north of the old shaft close to the highest Pd value (18ppb).

6) Milestone: Although all values are relatively low, the northern side of Milestone has consistently higher Au and Pt values than elsewhere on the grid.

Core Sampling

Selected core from previous drilling at Jim Beam and NE Westmoreland was split and sampled for gold and platinum group analysis. The sample interval was approximately 1m in most cases.

Jim Beam. The geological setting of the Jim Beam prospect would appear to be similar to that of the Coronation Hill deposit. In particular, immediately to the north of the area drilled previously, there is a brick red felspar porphyry identical in hand specimen to the one at Coronation Hill which carries most of the platinum/palladium mineralisation. Further, drillhole JBDD-1 intersected some 55m of volcanoclastic (?) breccia which would appear, in hand specimen, virtually identical to the "mass debris flow conglomerate" which occurs at Coronation Hill.
Drillhole JBDD-1 was precollared by percussion to 52m and then drilled to completion at 171.1m by diamond coring. Only the zone 42-46m of the percussion precollar was assayed for Au, with the interval 42-43m giving 0.08ppm Au and the interval 44-46m giving 0.6ppm Ag. Only five samples from the cored section of the hole (each representing 0.5m) were assayed for Au, each giving 0.01ppm.

Samples from the percussion holes drilled at Jim Beam gave maximum values as follows:

<table>
<thead>
<tr>
<th>Sample</th>
<th>Au (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>JBPD-1</td>
<td>0.20</td>
</tr>
<tr>
<td>JBPD-3</td>
<td>0.65</td>
</tr>
</tbody>
</table>

Again, only a relatively small number of samples were assayed for gold.

Later, the NT Geological Survey reported that a surface sample of "altered tuff" from Jim Beam assayed 10.1ppm Au and a surface sample held in Kratos' Sydney office was found to assay 3.1ppm Au.

No percussion chips remained, but the diamond core from JBDD-1 was available. A further selected suite of samples from this core was therefore taken. Each variation in rock type was sampled and seven samples were taken at roughly equal intervals from the main breccia unit which extended from 116.81m to 150.03m.

The results show three zones of elevated gold values - around 56m, 109-121m and 158-172m. None of the values approach ore grade, but they are clearly anomalous. Pt and Pd values are low throughout. These results are incomplete because selected intervals only were assayed.
NE Westmoreland. To test further for the possibility of Witwatersrand-type placer gold in the Westmoreland Conglomerate, two samples of Westmoreland Conglomerate Unit Ptw 3 conglomerate were taken from the core from drillhole WDD-1, a stratigraphic diamond hole drilled near the NT/Queensland border at NE Westmoreland.

The two samples gave low values for all three elements.

Stream Sediment Sampling

A sample of fine grained clayey material was collected at each bulk stream sediment sampling site to test for the presence of fine gold, as distinct from gold of a grain size which would be recovered in the diamond pan.

These samples were collected carefully, in most cases from the top several centimetres of a clay layer underlying a cobble/boulder train. The clay adhering to each cobble/boulder was carefully brushed off and retained in the sample. The sampling technique was based on the assumption that the hydraulic conditions in which fine gold would settle would be those in which clay particles could settle to form a clay layer. Cobbles/boulders would act as an additional trapping mechanism.

About 7 kg (rather than the 40 kg originally intended) was collected from each site and a subsample was sent to Comlabs for AAS analysis. The only results which appeared to be of significance were the values (8 and 10 ppb respectively) at two sample sites, which indicated a possible trail of interest in the Milestone/Kings Ransom area.

Similar stream sediment sampling was carried out in two other areas, viz in the vicinity of EL 3625 and in the Cliffdale Volcanics Window (Jim Beam area). See Fig 35.
The sampling in the EL 3625 area was carried out to follow up the identification of gold in the -0.5 mm concentrate fraction of two of the samples collected during the bulk stream sediment sampling programme (see above). It is interesting to note that the corresponding fine fraction stream sediment samples collected at the same localities gave values of only 4 and <2 ppb.

In the follow up sampling, the western sample trail (proceeding upstream) gave values of <5, <5, 5, <5, 10, <5 and <5 ppb. The highest value (10 ppb) was recorded in the vicinity of the intersection of the two major faults in this Exploration Licence area. This value warrants follow-up.

In the case of the eastern sample trail, all values were <5ppb.

The values recorded in the Jim Beam area were significantly higher than those encountered elsewhere in the sampling programme. The highest value (40 ppb) was recorded in the stream draining the large andesitic intrusive within the area of outcrop of the Clifftdale Volcanics. The second highest value (15 ppb) was recorded from a stream draining the Clifftdale Volcanics/Westmoreland Conglomerate unconformity in the vicinity of Southern Comfort. This latter drainage is largely outside EL 3626.

Metre Conglomerate Bulk Sample

A bulk sample (230kg) was taken from Metre Conglomerate outcrop in the hillside immediately west of Sandy Hollow campsite. The unit was sampled systematically from top to bottom and the sandstone surface underlying the conglomerate was brushed clean with a broom at the conclusion of the sampling.
After rejection of cleaned cobbles (approximately 60% of the original sample), the remaining material was crushed by hand in a steel bowl using a hammer. The crushed material was sieved and panned. No minerals or fragments of interest were present. The NT Geological Survey recovered three gold grains from a much smaller sample from this sample locality, but the Survey used a more refined test technique — their sample was crushed and jigged in the laboratory prior to examination.

Analysis of High Grade Grab Samples

Prior to the field programme, 12 high grade grab samples (including several drillhole core samples) were assayed for U, Au, Pt and Pd to try and assess the possible potential of the area for these elements.

The results were, in general, relatively low considering the very high uranium content of some of the samples. This could, of course, be due to gold and/or platinum group mineralisation being spatially separated from high grade uranium mineralisation.

The highest gold value was 3.1 ppm in the sample from Jim Beam. The highest platinum value was 11 ppb in the sample from Jacques and the highest palladium value was 15 ppb in the sample from Waterfall Creek.

EXPLORATION 1988–90: ELs 6155–57 & 6250

1988 Programme

In 1987, as described above, rock chip sampling for fine gold/platinoids was carried out, at fairly wide spacing, over reconnaissance grids, and limited sampling of fine stream sediments for gold was carried out to follow-up gold recorded during the bulk stream sediment sampling programme.
Prior to commencement of the 1989 field programme, samples obtained from the sites of previous bulk sampling for diamond/indicator minerals were assayed for their gold content. This was done initially by Classic Comlabs in Adelaide by AAS using a 50 g charge after mixermill preparation of the entire sample. The remainder of each sample was subsequently despatched to ALS, Orange for BLEG (bulk leach extractable gold) analysis for Au, Pt and Pd. Unfortunately, due to a mix up in the latter laboratory, the original sample numbers were not recorded and it is therefore not possible to interpret the BLEG results.

The results of the AAS assaying (Table 4) indicated the presence of anomalous gold at several sample sites at which coarse gold was not observed during the examination of the heavy mineral concentrates.

Late in 1988, further rock chip and stream sediment samples were collected and assessed as a precursor to planning the 1989 dry season programme.
Table 4  Bulk Sample Sites: AAS Assays

<table>
<thead>
<tr>
<th>Locality</th>
<th>Sample (PC30)</th>
<th>Au (ppb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kings Ransom</td>
<td>04</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>05</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>06</td>
<td>10</td>
</tr>
<tr>
<td>Cobar II</td>
<td>07</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>09</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>22</td>
<td>&lt;2</td>
</tr>
<tr>
<td>Turkey Creek</td>
<td>12</td>
<td>&lt;2</td>
</tr>
<tr>
<td></td>
<td>13</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>14</td>
<td>4</td>
</tr>
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<td></td>
<td>15</td>
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<td>16</td>
<td>&lt;2</td>
</tr>
<tr>
<td></td>
<td>17</td>
<td>&lt;2</td>
</tr>
<tr>
<td></td>
<td>23</td>
<td>&lt;2</td>
</tr>
</tbody>
</table>

(For sample locations see Fig 35)

Larger size stream sediment samples were collected for analysis for both gold and platinoids using the BLEG method. In contrast to 1987, the rock chip samples were selected on the basis of the local geology of each area sampled.

The twelve stream sediment samples (Fig 36) were assayed by Australian Assay Laboratories Group (AAL), Perth. The higher values are shown in Table 5.
Table 5: BLEG Stream Sediment Sampling: Higher Values

<table>
<thead>
<tr>
<th>Locality</th>
<th>Sample No</th>
<th>Gold (ppb)</th>
<th>Silver (ppb)</th>
<th>Copper (ppb)</th>
<th>Lead (ppb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cobar II</td>
<td>001</td>
<td>5.4</td>
<td>0.59</td>
<td>0.32</td>
<td>1.0</td>
</tr>
<tr>
<td>Kings Ransom</td>
<td>004</td>
<td>0.9</td>
<td>1.40</td>
<td>2.00</td>
<td>4.3</td>
</tr>
<tr>
<td>EL Hussen</td>
<td>006</td>
<td>2.0</td>
<td>0.08</td>
<td>0.34</td>
<td>2.0</td>
</tr>
<tr>
<td></td>
<td>008</td>
<td>0.8</td>
<td>0.50</td>
<td>1.70</td>
<td>6.2</td>
</tr>
<tr>
<td>Turkey Creek</td>
<td>010</td>
<td>0.9</td>
<td>1.20</td>
<td>1.70</td>
<td>7.8</td>
</tr>
<tr>
<td></td>
<td>011</td>
<td>0.7</td>
<td>1.30</td>
<td>1.60</td>
<td>4.2</td>
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<tr>
<td></td>
<td>012</td>
<td>29.8</td>
<td>0.70</td>
<td>1.60</td>
<td>2.2</td>
</tr>
</tbody>
</table>

(For sample locations see Fig 36)

Thirty five rock chip samples were collected from different geological environments as shown in Fig 36. These were assayed by Analabs, Perth, with limits of detection of 5, 5 and 50 ppb for Au, Pd and Pt respectively.

As can be seen from Table 6, the results were, in general, relatively low in absolute terms, but there appeared to be significant clustering, especially in the case of gold values at El Hussen, Dianna and Cobar II. Because of the high detection limit for Pt, all Pt values were below the limit of detection.
Table 6: Rock Chip Sampling: Higher Values

<table>
<thead>
<tr>
<th>Prospect</th>
<th>Sample No</th>
<th>Sample Details</th>
<th>Assay Values (ppb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cobar II</td>
<td>5</td>
<td>Basic volcanics-mullock from Old Parr shaft</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>Basic volcanics-mullock from Cobar II No 1 shaft</td>
<td>22</td>
</tr>
<tr>
<td>Kings Ransom</td>
<td>20</td>
<td>Mullock from costean north of shaft</td>
<td>9</td>
</tr>
<tr>
<td>El Hussen</td>
<td>24</td>
<td>Main El Hussen workings</td>
<td>35</td>
</tr>
<tr>
<td></td>
<td>25</td>
<td>Basic volcanics adjacent to El Hussen Fault</td>
<td>100</td>
</tr>
</tbody>
</table>


26 Basic volcanics
    adjacent to El
    Hussan Fault  256  14

27 Mullock from adit  49  6

30 Cuttings from hole  13  7

Dianna  34 Brecciated quartz
        porphyry from
        cosetean  17  11

35 Cu-bearing porphyry
    in mullock  145  78

(For sample locations see Fig 36)

As gold mineralisation up to potential ore grade is known from
drilling in the Mageera Zone of the JN Fault at NE Westmoreland,
some of the gold values were considered to be of possible
significance.

1989 Programme

Using a helicopter, BLEG stream sediment samples were collected
from 54 sites in the area (Fig 36). Samples were collected from
the "active channel" and, in general, from a trap or semi-trap
site. The -6 mm fractions of the samples were assayed by AAL,
Townsville for Au, Pt and Pd.
Resampling of the 4 previous sample sites was undertaken as part of the 54 sample programme. There was no noticeable systematic correlation between the two data sets other than an apparent order of magnitude variation between the AAS results and the BLEG results.

A statistical analysis was carried out and appropriate threshold levels determined for Au, Pt and Pd. Using these thresholds, 7 sample sites were regarded as "anomalous".

Statistical analysis of the assay data showed a general lack of correlation between Au and the Pt group metals. Thus, if these values were due to mineralisation as distinct from being background values, it could be postulated that the presence of the two types of mineralisation was not necessarily the result of the same mineralising event/mechanism. However, it seems likely that the results quoted represent only statistical variation in background levels.

Of the 7 "anomalous" values, 3 were in the El Hussen area, 3 in the McGuinness/Dianna area and one in the Cobar II area.

In order to further assess background levels of Au, Pt and Pd, drill core samples were taken for analysis from available cores. In general, samples were taken from all cored intervals through Seigal Volcanics into the uppermost Westmoreland Conglomerate lithologies. These samples were analysed by AAL, Townsville.

In general, the only elevated results correlate with elevated uranium values. There was no significant enrichment in Au, Pt or Pd in any of the sections of Seigal Volcanics sampled. The background levels for Pt and Pd in the Seigal Volcanics were found to be slightly higher than the background level for Au.
### Table 7: Stream Sediment Sampling: Check Assaying

<table>
<thead>
<tr>
<th>Sample No</th>
<th>Comlabs</th>
<th>Assay Results (ppb)</th>
<th>SGS</th>
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<tbody>
<tr>
<td></td>
<td>Au</td>
<td>Au</td>
<td>As</td>
</tr>
<tr>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td><strong>Jim Beam Area</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>871001</td>
<td>40</td>
<td>&lt;2</td>
<td>3.5</td>
</tr>
<tr>
<td>871002</td>
<td>10</td>
<td>&lt;2</td>
<td>6.5</td>
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<tr>
<td>871003</td>
<td>15</td>
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<td></td>
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<td></td>
</tr>
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<td>&lt;5</td>
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<tr>
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<td>D5/50</td>
<td>D2(d)</td>
</tr>
<tr>
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<td>-------</td>
<td>-------</td>
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<td></td>
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</tr>
<tr>
<td>871024</td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

(For sample locations see Fig 35)
The drill core samples did not offer encouragement that economic mineralisation would be discovered in the near-surface environment of either Cobar II or El Hussen.

On the basis of the considerable amount of work carried out over the period from 1976, it appeared that the chance of locating a uranium, gold or PGM ore deposit having a surface expression recognisable using existing exploration techniques was remote.

Late in 1989, it was decided to reassay the stream sediment samples taken from the Turkey Creek and Jim Beam areas to check the values obtained previously, especially the 40 ppb Au result to the south of Jim Beam. This work was carried out at SGS Australia Pty Ltd, Perth. The results, shown in Table 7, throw serious doubt on the initial results obtained by Comlabs, Adelaide.

1990 Programme

As a basis for a programme of work in 1990, the conceptual framework set out in Appendix 2 was adopted.

Due to financial constraints, the Company was unable to carry out this programme and, despite its best endeavours, was unable to find a joint venture partner. The titles were therefore surrendered.
CONCLUSIONS

The potential for the discovery of economic near-surface U/Au/PGM orebodies in the Pandanus Creek area using existing exploration methods has, in practical terms, been exhausted.

There remains the possibility of unconformity-related type orebodies located at depth, but exploration for these will be difficult and expensive. Although it is believed that such exploration is certainly justified on technical grounds, it proved beyond the financial resources of the present titleholders.
REFERENCES


"Geochronology and evolution of the Late Archaean basement and Proterozoic rocks in the Alligator Rivers uranium field, Northern Territory, Australia." International Uranium Symposium on the Pine Creek Geosyncline, June 1979, IAEA Vienna.

Plumb K A & Derrick G M 1975

Wall V J, Johnston JD & Koul S L 1985
"The plumbing systems of unconformity-related uranium deposits" International Conference on Concentration Mechanisms of Uranium in Geological Environments, Nancy, France.
APPENDIX 1

AGREEMENTS WITH ABORIGINES
In compliance with the provisions of the N.T. Mining Ordinance, the undersigned inspected the area covered by Katoa Exploration Pty Ltd's Exploration License Nos. 1016 and 1017 on 8-9th July, 1978 to determine if there are any sites of Aboriginal significance in the area in general, and in particular in those parts of the area where Katoa plans to drill.

We have determined that the area known as Gamoongooroo and Gardijwara (Wanyi) or Cooroodjin (Garawa) should be avoided. These areas have been farmed out to Katoa representatives. We have also agreed with Katoa that the Company will not drill in Chinaman's Garden, Spring or in the area once occupied by the Chinaman's house.

Apart from the area listed above and Beach Creek Gorge, which lies immediately to the north of E1 1017, there are no other sites of significance known to us. In particular the areas known as Colby South, Colby North, The Horse, White Horse, Chinaman's Garden, McQuinn's, Kings Reckoning, Colby II, Old Pool, North East West and Moreen and Crippled Horse are quite clear of significance to sites. Also the strip of country along the bedstone/volcanic contact from Colby south to the Queensland border is free of sites of significance as is the country to the south of N.E. West and Moreen.

DINNY PEDRO

ECHO PETE CAID BIRD

FRED CHARLIE

ARCHIE RANKLANDS

ROGER CHARLIE

JOHN DYMOCK, FIELD OFFICER FOR NORTHERN LAND COUNCIL
In compliance with the provisions of the N.T. Mining Ordinance, we, the undersigned, have made the necessary inspection of our E.I.s Nos. 016 and 1017 in company with an organised party consisting of five Aboriginal men and one N.C. Field Officer. There being no known NIMERINGI (or Primary Traditional owners) to the area in question, the Aboriginal party, appropriately consisted of the Principal JUNG/EYE or "Aboriginal Manager" - Danny Pedro, whom mother originally came from the area, including that covered by our E.I.s. The remaining 4 Aboriginal men were considered the most appropriate for conducting the inspection of proposed drilling sites. By reason of their traditional knowledge, degree of guardianship and traditional attachment to adjacent areas of land, we have fully satisfied the wishes of the Aboriginal party mentioned above by complying with their advice concerning sacred sites, and areas of significance as was mentioned and practiced out to us, and we undertake to uphold, and in the event of discovery or new knowledge, promote and enhance those interests. The N.C. Field Officer John Dymock who has advised the party of Aboriginal men of their rights, responsibilities, and privileges, concerning sacred sites, areas of significance, and other matters, is also fully satisfied that Aboriginal interests will be fully
To promote that understanding and accord he has advised us of Aboriginal traditional attachments to their land, in general and of Aboriginal Cultural values so that we are aware and mindful of our responsibilities whilst in this area.

1. In agreeing to avoid the immediate area known as GAMOON GOOROO - Poison Dreaming, and the general area known to the GARAWA (tribe) as BOOROODJIN, alternately known to the WANYI (tribe) as GARDINDARRA or Death Adder Dreaming and 2 also of not drilling in the G Spring or in very close proximity to the site of the Chinamans House at Chinamans Gardens - we have obtained the approval and permission to proceed with our drilling operations from the aforementioned inspection party.

4. Further we have agreed to inform the Northern Land Council of the discovery of any Aboriginal Art or Artifacts that may be located within the area of our EIS.

5. We have also agreed to produce a small pamphlet advising Kratos Staff, Contractual workers and Visitors to Kratos EIS of their responsibilities concerning respect for Aboriginal Artifacts and in general areas of significance.

6. We will send to each member of the inspection party including the NILC a copy of the pamphlet.

7. We will advise the Archive Rockland and the NILC.
of any Rud. Ochre deposits in the southern area of our E.I.s.

8. Finally and upon our own initiative we have offered (and the offer has been most readily agreed to) to name our drill site locations after significant names associated with the RUMBARRA people who originally inhabited the Westmorland Valley - land of which our E.I.s form a part.

[Signature]
DIRECTOR, KRATOS EXPLORATION PTY LIMITED
APPENDIX 2

PANDANUS CREEK AREA: CONCEPTUAL FRAMEWORK
PANDANUS CREEK AREA: CONCEPTUAL FRAMEWORK

Kratos Exploration Pty Limited and its partners have spent approximately $A 3 million exploring the near-surface environment in the Pandanus Creek area for uranium, gold, platinoids and diamonds.

Mineralisation is widespread and, in some small pockets, very high grade. For example, the Cobar II mine shipped 72.7 tonnes of ore grading 8.92% U over 2,000 km by road to Rum Jungle for treatment; and one Kratos drillhole in the Oogoodoo Zone of the JN Fault at NE Westmoreland assayed 3 metres at 1.35% U and 4 m at 4.7 g Au/t.

The geology of the area can be regarded as the mirror image of the Alligator Rivers area geology on the opposite side of the McArthur Basin. See, for example, Plumb and Derrick 1975. A Comparative Age Table is presented as Table 1. This Table is based on the more detailed dating information set out in Attachment 1.

The main difference between the two areas is that the present land surface in the Pandanus Creek area is at a higher stratigraphic level - there is very little exposure of the Murphy Metamorphics basement.

The mineralisation in the Pandanus Creek area is identical with that of the Alligator Rivers area orebodies, viz pitchblende/gold with identical minor elements such as platinoids, selenium, tellurium and mercury.
Although the work done to date has significantly reduced the possibility of finding an economic size, near-surface orebody detectable by present exploration methods, the potential at depth must be rated highly.

Based on the extensive exploration carried out, over a period of many years, in both the Pandanus Creek and adjoining Westmoreland (Queensland) districts, the following genetic model is proposed.

Uranium was concentrated in favourable horizons within the Westmoreland Conglomerate by surficial processes. Later, as a result of groundwater movement, uranium was leached out of these horizons and re-deposited in favourable traps, especially dyke-filled faults.

It is suggested that this process is well illustrated in drill cross-sections of the NE Westmoreland prospect area (see Fig 14, Main Text). The Mageera Siltstone, the uppermost unit of the Westmoreland Conglomerate, is a fine-grained, probably lacustrine-type, deposit with a large tuffaceous component. In the general NE Westmoreland area, i.e., not in fault/dyke zones, this unit always exhibits anomalous radioactivity, and has a uranium content varying from 10 ppm U up to about 1,000 ppm U, with values commonly in the range 50-700 ppm U. The uranium content of the Mageera Siltstone may thus be regarded as protore.

Drillhole data shows that the Mageera Siltstone is present right across the Pandanus Creek area from NE Westmoreland through Cobar II to El Hassan. It is also present in drill cores from the Lagoon Creek - Junagunna area on the Queensland side of the border. It is not preserved in the Redtree area due to removal of the top surface of the Westmoreland Conglomerate by erosion.
The discovery of the Yeelirrie uranium deposit in 1971 led to the recognition of the importance of surface phenomena in concentrating uranium. Since that time, many uranium deposits of surficial type have been studied around the world (IAEA 1984).

Uranium is believed to have concentrated in the Mageera Siltstone in much the same way as the Yeelirrie deposit was formed. Later, after burial, this uranium was transported by groundwater to the fault zones where it is now concentrated. The groundwater involved was probably heated by the faulting, which would be especially true of reverse faults, and/or dyke emplacement.

The same origin is proposed for the uranium deposits of the Alligator Rivers region. The essential prerequisite was a surficial zone already enriched in uranium which retained sufficient permeability after burial to allow subsequent movement of uranium into suitable trap sites.

This hypothesis fits well with that proposed by Wall et al (1985). They pointed out that the high grade uranium mineralisation of the Alligator Rivers region is localised in reverse fault zones, which "preferentially follow schistose basement units, transform along the unconformity to form flats and ramp steeply through the massive sandstone forming narrow zones within it". The essential role of the unconformity is that it marks the boundary between the contrasting rheology and fracture-related permeability of the basement and cover rocks.

Pervasive, transient, dilatant hydrofracturing of the schistose basement in the vicinity of the fault zones greatly increased the permeability of the basement in contrast to the sandstone cap, the permeability of which had been reduced by diagenetic processes. The breccia zones and the mineralisation are most extensive where faults are subparallel to the basement foliation.
The mineralising fluids, which were part of major regional hydrothermal systems operating during burial at 4-5 km, were focussed into zones of reverse faulting, and consequent enhanced permeability. Episodic rejuvenation of faulting/permeability would account for the complex paragenesis of alteration/mineralisation and the 500 m y spread of radiogenic ages.

The genetic model put forward in these notes differs from that of Wall et al only by the addition of an intermediate concentration step between the original source rocks and the final deposit.

It should be pointed out that recent work in the Alligator Rivers area has shown that, at least in the northern part of the area, there is a uranium-enriched bed at the base of the Kombolgie Formation which can be compared with the Mageera Siltstone, even to the extent of having the same general range of uranium content. This bed was not recognised previously because it is, where seen to date, only about 0.5 m thick. It is suggested that it has provided the uranium to form the Nabarlek orebody.

The mobility of uranium in groundwater, and even in rainwater, has been known since the earliest days of uranium exploration in the tropical climatic environment of Northern Australia.

There is a clear example of re-concentration of uranium by groundwater movement, confirmed by drilling, in the Nabarlek area. At the locality concerned, uranium-bearing groundwater has moved down a gentle slope to a position where it has deposited uranium upon being ponded against a body of Zamu Dolerite.

Another example is the prominent down-slope dispersion "tail" of secondary uranium mineralisation away from the Koongarra orebody.
Turning to the question of the original source of the uranium, Hochman and Ypma (1984) established, by 800 thermoluminescence measurements, that the whole of the Westmoreland Conglomerate has suffered radiation damage caused by at least 10 ppm U over one billion years. They attributed this high uranium content to derivation from the uranium-rich Clifffdale Volcanics and associated Nicholson Granite.

Later work by geologists of the NT Geological Survey, comprising some 1,250 measurements of cross-bedding at 164 sites (see Ahmad and Wygralak 1989), has shown that the provenance of the Westmoreland Conglomerate sediments was to the north-east. Nevertheless, "clast lithologies suggest that the composition of the source area was similar to the presently exposed rocks of the Murphy Inlier", i.e. Murphy Metamorphics, Nicholson Granite Complex and Clifffdale Volcanics.

The background uranium content of the Westmoreland Conglomerate sandstones is still 4-6 ppm U (Schindlmayr and Beerbaum 1984).

In contrast to the Westmoreland Conglomerate, thermoluminescence measurements on 200 samples from the Corunna Conglomerate in South Australia, which occupies a similar stratigraphic position to the Westmoreland Conglomerate, showed no widespread radiation damage. In this case, "radiation damage was only observed along the Middle Proterozoic unconformity surface and ... associated with some shear zones." (Hochman and Ypma, op cit). This lack of radiation damage in the Corunna Conglomerate is attributed to its derivation from uranium-poor metasediments, with only local input from radiogenic granites.
Hochman and Ypma concluded that the "precontained uranium within the Westmoreland Conglomerate was remobilised by intrusion of dolerite dykes and circulated by means of a convective cell system to be precipitated in suitable reducing environments near to overlying basaltic volcanics and along the margins of the intrusive dolerite dykes".

A small suite of samples (21) from the chlorite injection zone at the base of the Kombolgie Formation overlying the Jabiluka orebody in the Alligator Rivers region all showed major radiation damage. In the absence of any background samples, Hochman and Ypma concluded that "at this stage, it is not known if this is indicative of the whole formation, caused by upward leakage of uranium or caused by protore movement close to the base of the Kombolgie Formation".

The genetic models put forward by Hochman and Ypma and Wall et al are basically compatible and, as was the case with the genetic model put forward by Wall et al, the present genetic model differs from that of Hochman and Ypma only by the introduction of an intermediate concentration step between the Westmoreland Conglomerate and the ultimate orebodies.

Any satisfactory model must take account of the fact that almost all the occurrences of mineralisation in the Pandanus Creek area are situated at the contact of the Westmoreland Conglomerate with rocks having more reducing lithologies, viz Cliffdale Volcanics blue-black ignimbrite and PccA andesite, PgnA granite and Seigal Volcanics/dyke rocks.
On a more general note, although unconformity-related uranium deposits constitute a very significant proportion of the world's uranium reserves, they are found only in rocks which were formed within a relatively limited time period. This is thought to be related to the change in the earth's atmosphere from reducing to oxidising conditions during the same time period.

It may well be that the changeover to an oxidising atmosphere initiated leaching of uranium from pre-existing igneous and sedimentary terrains and the deposition of uranium in environments which were still reducing, i.e. which had not yet been oxidised by the action of oxidising ground water.

Thus, the time correlations between the rock units of the Alligator Rivers and Pandanus Creek regions are considered very important.

It is also thought that the extensive regolith which was developed in the Alligator Rivers region before the deposition of the Kombolgie Formation is of importance in that:

1) it indicates a long period of quiescence and associated weathering, and

2) it constitutes a permeable pathway for uranium-bearing groundwater.

The extent of regolith development on the Murphy Metamorphics basement in the Pandanus Creek area is not known at this stage, but it is assumed that, because there was the same long period of erosion as in the Alligator Rivers region, it should be comparable.
It is quite likely that there may be similar regolith development at the top of the Clifftale Volcanics prior to deposition of the Westmoreland Conglomerate.

It is predicted that bodies of uranium mineralisation will be repeated at vertical intervals where suitable source beds intersect fault zones. For example, Fig 1, which is a copy of a BHP - Afmeco section showing the geology of the Westmoreland area in Queensland, shows repetition of uranium concentration at four different stratigraphic levels.

On the basis of the known unconformity-related uranium deposits in the Alligator Rivers and Athabasca (Canada) regions, the most favourable position for major orebodies of this type in the Pandanus Creek area would be at the unconformity surface between the Murphy Metamorphics and the overlying rocks. The relative merits of a cap rock of Clifftale Volcanics as against Westmoreland Conglomerate must remain an open question at this stage. However, it is suggested that the majority of the units forming the Clifftale Volcanics may well have been no more permeable than the Westmoreland Formation/Kombolgie Formation. On this aspect, it is interesting to note that the Edith River Volcanics (which are very similar to the Clifftale Volcanics) form the base of the upper succession at the Coronation Hill, El Sherana and Rockhole mines in the Alligator Rivers area.

At El Hussen, which is located on a reverse fault, secondary uranium mineralisation occurs at the surface over a strike length of 1.6 km. Thus, assuming there is uranium enrichment, and probably also regolith development, at the top of the Murphy Metamorphics, and perhaps also at the top of the Clifftale Volcanics, uranium deposition can be expected against the fault at these positions also.
Secondary uranium mineralisation is also present along the Main Range Fault, also a reverse fault, at NE Westmoreland. However, because the Cliffdale Volcanics are thin or absent, and much of the Westmoreland Formation succession has been removed by faulting, it is considered that El Hussen would be the best place to site an initial test hole.

As a first pass programme to test the model proposed, it is suggested that at least two diamond holes be drilled to basement - one in the El Hussen area and the other in the Main Range area at NE Westmoreland. These would be sited with the aims of:

1) intersecting mineralisation and/or evidence of rock alteration indicative of mineralisation,

2) determining the depth to basement and the nature of the basement rocks, including the presence of a regolith and/or a uranium-enriched surficial horizon, and

3) providing samples for measuring the properties of the rocks intersected for geophysical interpretation purposes.

It may be of assistance in siting these two reconnaissance holes if some ground geophysical work were carried out first.

On the basis of geophysical measurements in the Main Range area, and general comparison with the volcanic units of the Alligator Rivers area, it is believed that the depth to basement is probably not more than 500 metres, and perhaps less in the El Hussen area.
Table 1: Comparative Age Table

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<th>Pandanus Creek Area</th>
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<td><strong>Age (my)</strong></td>
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<tr>
<td>Chlorite Alteration Haloes</td>
<td>Upper Tawallah Group Aquarium Formation (glaucnite)</td>
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<tr>
<td>920</td>
<td>$\not\sim$ 1,590</td>
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<tr>
<td>1,600</td>
<td>Packsaddle Microgranite $\sim$ 1,600</td>
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<td>Kombolgie Formation Nungbalgarri Volcanic Member</td>
<td>Westmoreland Formation</td>
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<tr>
<td>1,648</td>
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<td>Oenpelli Dolerite</td>
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<td>$\sim$ 1,750</td>
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<td>Regional Metamorphism and Deformation 1,800</td>
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</table>

Nimbuwah Complex 1,886-1,866

Ranger 1 "Footwall Sequence"  Murphy Metamorphics $\not\sim$ 1,900
(Lower Proterozoic metasediments) 2,000-2,200 (est)

Nanambu Complex 2,470
ATTACHMENT 1: DETAILED AGE DATA

The Comparative Age Table (Table 1) is based on the following age data (all figures in m y):

**Alligator Rivers Region**

Page, Compston & Needham (1980)

Nabarlek - younger alteration episode
and pitchblende age

\[ \leq 920 \]

Main episode of chloritisation
at Nabarlek and Ranger 1

\[ \text{ca } 1,600 \]

Nungbalgarri Volcanic Member
(in middle of Kombolgie Formation)

\[ 1,648 \pm 29 \]

Oenpelli Dolerite

\[ 1,688 \pm 13 \]

Post-tectonic Middle Proterozoic
(Carpentarian) granites - Jim Jim, Tin Camp
and Nabarlek

\[ 1,730-1,780 \]

Principal regional metamorphism

\[ 1,800 \]

Nimbuwah Complex - granitoids
and charnockitic granulites

\[ 1,886-1,866 \]

Ranger 1 "Footwall Sequence"
(Lower Proterozoic metasediments)

\[ 2,000-2,200 \text{ (est)} \]

Nanambu Complex - granitic basement

\[ 2,470 \]

Compston & Arriens (1968)

Edith River Volcanics

\[ \text{ca } 1,750 \]

* Malone Creek Granite

\[ \text{ca } 1,750 \]

* Grace Creek Granite

\[ 1,710 \]

* May be significantly younger
Pandanus Creek Area

Ahmad & Wygralak (1989)

Uranium mineralisation

Namalangi, Cobar II & Eva deposits (1972)

Namalangi (1985)

Hobblechaine Rhyolite

Packsaddle Microgranite

Crystal Hill greisen

Cliffdale Volcanics

Nicholson Granite

Pgna

Pgnb

McDougall et al (1965)

Aquarium Formation

Plumb and Derrick (1975)

Murphy Metamorphics

Gardner (1978)

Nicholson Granite Complex

Bimodal distribution of values; peaks at 1,770 and 1,830

(some phases of the granite are definitely older than the Cliffdale Volcanics; some are coeval with, or younger than, the Volcanics)