Headwaters Project
(EL25220)

Annual Technical Report
For the Period 22/04/09 - 21/04/10

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EXECUTIVE SUMMARY

Uranium Equities Limited ("UEL") was granted EL25220 for a six year term, expiring 21st April 2015. UEL believes the tenement has the potential to host significant uranium mineralisation.

Early work has concentrated on desktop analysis involving compilation of previous exploration and targeting. In house reviews are being supported by external structural and alteration studies.

While there was no field work undertaken during the 2009 field season due to a period of instability in global financial markets. Planning for the 2010 field season is well advanced.

Reviews and targeting resulted in a submission to the NT government as part of its "Bringing Forward Discovery" program for co-funding exploration. UEL believes that geological environment at its Headwaters Project holds similarities to the style of uranium mineralisation present at Westmoreland in north-west Queensland.
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1. INTRODUCTION

1.1 Location and Tenure

EL25220 lies in the northeast of the Headwaters Project and covers an area of 391.5km$^2$ (Figure 1). The exploration license is held by GE Resources Pty Ltd, a wholly owned subsidiary of UEL. EL25220 was granted for a period of six years, expiring on 21st April 2015.

UEL has a joint venture with Vale Exploration Pty Ltd, a wholly owned Australian subsidiary of Vale S.A. whereby Vale can earn up to 75% equity in the Headwaters Project.

![Figure 1: Location Map](image-url)
The history of the licence application is detailed below in Table 1.

**Table 1: EL25220 tenement progress**

<table>
<thead>
<tr>
<th>EL25220 Activity</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Licence Application for area of 448.7km²</td>
<td>6/03/2006</td>
</tr>
<tr>
<td>Exploration proposal submitted to NLC</td>
<td>25/09/2006</td>
</tr>
<tr>
<td>Five year moratorium from original application area (ELA27153) commences</td>
<td>13/11/2008</td>
</tr>
<tr>
<td>NLC consent to grant</td>
<td>18/11/2008</td>
</tr>
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<td>Ministerial consent to grant</td>
<td>31/12/2008</td>
</tr>
<tr>
<td>Exploration Agreement with NLC signed</td>
<td>12/02/2009</td>
</tr>
<tr>
<td>Exploration JV Agreement signed with Vale</td>
<td>12/03/2009</td>
</tr>
<tr>
<td>EL25220 granted for area of 391.54km²</td>
<td>20/04/2009</td>
</tr>
<tr>
<td>Work program meeting-work proposal accepted</td>
<td>26/03/2010</td>
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</table>

1.2 Access

EL25220 is located 60km east of the township of Jabiru. Access is difficult as there is no ground access to the exploration licence. UEL is proposing to use helicopter assistance for the ongoing field programs from the existing field camp based on the Nabarlek Mineral Lease.

1.3 Heritage

The tenements are located on Aboriginal Freehold land, and therefore require access approval of the traditional owners. Exploration agreements have been signed with the NLC who represent the traditional owners.

A Work Program Meeting was held on the 26th March 2010 with the traditional owners being supportive of reconnaissance exploration within EL25220. The likelihood of a heli-supported drill program was discussed and approved.
2. **GEOLOGY**

2.1 **Regional Geology**

The regional geology is characterised by intensely deformed and metamorphosed sedimentary successions of the Pine Creek Basin, notably the Palaeoproterozoic age Nimbuwah Complex Metamorphics and Myra Falls Metamorphics. These basement rocks are host to the major unconformity related uranium deposits of the Alligator Rivers region. Deformation and metamorphism is attributed to the Barramundi Orogeny (~1880 – 1850Ma).

Undeformed fluvial sediments and intraformational volcanics of the Kombolgie Subgroup (~1822 – 1720Ma) unconformably overlie the basement rocks and represent the basal portion of the McArthur Basin. The platform sediment thickness is poorly known, but progressively thickens to the southeast, probably reaching depths in excess of 1000 metres in the southeast of the project area.

2.2 **Project Geology**

The geology of EL25220 is dominated by platform sequences of the Kombolgie Subgroup sediments, with a general succession of formations towards the south-east (Figure 2). The lowermost unit, the Mamadawerre Sandstone and the overlying Nungbalgarri Volcanics do not outcrop within the project area but are present immediately to the north.

The lowermost unit exposed on the project is the Gumarrimbang Sandstone, consisting of fine to very coarse grained, medium to thickly bedded quartz arenite. Deposition of the Gumarrimbang Sandstone is interpreted to have been in a braided fluvial system with an overall upwards trend to more finer-grained and better-sorted sands in the upper portions of the formation.

The Gilruth Volcanic Member is a thin mafic volcanic horizon which conformably overlies the Gumarrimbang Sandstone. The Gilruth Volcanics are generally recessive in outcrop, forming lateritised terraces of ferruginous debris and are clearly recognisable in the radiometric imagery.

Conformably overlying the Gilruth Volcanics is the Marlgowa Sandstone, a fine grained to granular, thickly bedded quartz arenite deposited in a braided fluvial to shallow marine, tidal environment.

While not exposed on the licence area, dolerite dykes and sills of the Oenpelli Dolerite are visible in the magnetic imagery. It is possible that the Oenpelli Dolerite could be the feeder dykes to the Nungbalgarri or Gilruth Volcanics basaltic units.

Major structures occur through the region with the NW – SE trending regionally significant Bulman Fault present within EL25220.
2.3 Mineralisation

Uranium mineralisation is well known in the region, with the Ranger, Jabiluka, Koongarra, Coronation Hill and Naborlek Deposits being the most significant. These deposits are typically associated with the unconformity at the base of McArthur Basin sediments.

There are various mechanisms that have been proposed to explain the source, transport and formation of these deposits, but it is widely noted that there is a lack of extensive mineralisation in the cover (Kombolgie Subgroup) rocks.

However, there are several known uranium occurrences within Kombolgie Subgroup to the immediate south of EL25220, as defined by previous explorers from radiometric anomalies and surface geochemistry (Figure 3). The most significant of these is the Flying Ghost Prospect. These are documented within the MODAT mineral occurrences as being secondary uranium mineralisation associated with clays within zones of intense fracturing in the Kombolgie Subgroup sediments.
Figure 3: Regional geology, uranium deposits and occurrences
3. WORK COMPLETED

3.1 PREVIOUS EXPLORATION COMPILATION

An analysis of previous exploration was completed during the reporting period. Due to its inaccessible nature, the Headwaters Project area was largely unexplored until Cameco Australia Ltd began evaluating the area in 1996. Their approach to exploration was heavily influenced by geophysics and clearly focused on targeting unconformity-style uranium deposits at the base of the Kombolgie Subgroup.

Cameco completed the following activities over four field seasons between 2002 and 2005:

- 208 lithogeochemical rock chip samples (2x2km grid with 68 elements, with infill sampling providing higher density in anomalous areas)
- airborne magnetic – radiometric – DTM survey (200m line spacing, flying height 60m)
- airborne electromagnetic survey (TEMPEST) on 200m line spacing
- airborne hyperspectral survey (HYMAP MkI)

A compilation of the previous exploration is shown in Figure 4. Uranium anomalism in the rock chips returned values up to 68.1ppm at surface, associated with ferruginised sandstone in the Bulman Fault Zone and elevated gold (up to 896ppb gold) and platinum group elements (PGE's). The TEMPEST survey mapped a conductive layer at about 200m depth, which is likely to be the Nungbalgarri Volcanic Member of the Kombolgie Subgroup. The HYMAP hyperspectral scanner mapped the distribution of clays, which appeared to be largely controlled by stratigraphy.

Cameco concluded that the highest uranium geochemistry values are associated with the Gilruth Volcanic Member, which downgraded their significance with respect to unconformity related deposits. Furthermore, the geophysics was unable to identify any targets underneath the Kombolgie Subgroup, and thus the ground was relinquished.

Cameco’s exploration to the south of EL25220 discovered uranium occurrences at the Banshee – Casper Prospects and Flying Ghost Prospect (Figure 3). Limited drilling was undertaken at these prospects, and the results were again disappointing in light of their target model. Nevertheless, the results are very interesting to UEL as they prove the application of the Westmoreland model is valid, with significant anomalism present within and adjacent to the mafic units.

A more comprehensive and regional analysis of the previous exploration is provided in Appendix I, which was compiled by Helen Wood as part of a Masters Project sponsored by UEL.
3.2 TARGET GENERATION

In contrast to previous explorers, UEL is targeting Westmoreland-style deposits (eg. Redtree) in Arnhem Land. These deposits occur within conglomerate, sandstone and mafic volcanic rocks within the McArthur Basin succession more than one kilometre above the unconformity as well as in the basement. They have some features in common with sandstone–hosted, vein-type and unconformity-related deposits and are associated with redox boundaries near the contacts between different lithologies, in a variety of geological settings.

Higher grade mineralisation in the Westmoreland model is spatially associated with north-east trending mafic dykes emplaced along steep trending fault systems. Extensive, shallow dipping, stratabound mineralised zones are also associated with the fault interaction zones. The same features are observed in the Headwaters Project. Figure 5 shows the comparison between the two areas.
A significant feature of this style of mineralisation is that the target footprint is relatively large, with the vertical dykes likely to be in the order of 10 – 20m thick, and stratabound mineralisation possibly up to 600m away.

Areas of interest based on Westmoreland-style mineralisation have been identified and are shown in Figure 6. The presence of dolerite dykes, Gilruth Volcanics, structural complexity, radiometric anomalies (particularly adjacent to Gilruth) and rock chip geochemistry have been used to generate these targets.

An application was submitted to the "Bringing Forward Discovery" initiative of the NT government for co-funding to test the Westmoreland targets on EL25220.
Figure 6: EL25220 target compilation, showing historical surface geochemistry with background image of TMI aeromagnetics merged with radiometrics. Gilruth Volcanics and fault interpretation as mapped from NTGS 1:250,000 Mt Evelyn Sheet

3.3 DESKTOP STUDIES

UEL commissioned the University Of Queensland to undertake a structural study of the Headwaters Project, of which EL25220 is the NE portion. Significant results of the study included the recognition of four major orientations of lineaments, striking NW-SE (300°-330°), E-W (075°-085°), NE-SW (025°-045°) and N-S (340°-000°). Also, mineralised zones are predominantly focused along reactivated NW and E-trending structures. Further details are provided in Appendix I.
4. FURTHER WORK

A field program has been outlined, commencing in the 2010 dry season, as follows:

Stage 1: Field checking of the target areas. Detailed mapping and surface sampling will be considered if exposure is reasonable in the areas of interest.

Stage 2: Radon emanometry. Uranium Equities intends to use E-PERM or Lucas Cell Radon Detectors over areas of interest. It is hoped that this technique will detect radon gas being emitted from near surface mineralisation and thus provide a vector for drill targeting.

Stage 3: Drilling. Using the empirical data from rock chip sampling and radon emanometry, combined with the geological and geophysical data, the broad targets currently defined will be refined into specific drilling targets.

In additional, the ongoing collaboration with the Queensland University will see work continue on alteration and geochemical studies, to understand vectors towards mineralisation.
Preliminary Report for Headwaters Masters Project

by

Helen Wood
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Introduction

The Headwaters Project is located 260 kilometres east of Darwin in Arnhem Land, Northern Territory. Exploration licenses 27513, 27514, 27515, 24711, 24712, 24713 and 25220 cover an area of approximately 5,300 square kilometres on the Arnhem Plateau of the McArthur Basin. Sediments within the tenements are comprised mostly of the Katherine River Supergroup. The Kombolgie subgroup covers most of the project area and ranges from 300 metres thick in the west to over 1450 metres thick in the east (Otto, 2002 #123).

Uranium mineralisation is known to occur in areas around the Headwaters tenements such as the Alligator Rivers uranium province (Jabiluka, Ranger, Narbalek, Koongarra) and South Alligator Valley (Coronation Hills). Exploration within the Headwaters Project is focussed on locating deposits similar to the unconformity-style deposits found in the Athabasca Basin in Saskatchewan, Canada, which is geologically similar to the area within the tenements.

Previous exploration in the area has been conducted since 1969 with very little success. Normanby Exploration focussed on commodities such as diamonds, zinc, lead, copper and silver with no significant results. Cameco Australia searched for uranium deposits similar to those found in the Athabasca Basin and located uranium several anomalies within its Deaf Adder Project. However, due to the expenses associated with further exploration in the area, Cameco relinquished their leases.

This report involves a short preliminary evaluation of data received from Cameco Australia followed by a detailed summary of all reports for previous exploration conducted within the Headwater tenements.
Cameco’s data – Preliminary evaluation

Geochemistry collected from Evelyn rock chips and outcrops in the different tenements show that the majority of anomalous uranium readings occur within sandstone units. These units included:

- Gumarrirnbang Sandstone
- McKay Sandstone
- Marlgowa Sandstone

Other units which contained only a few high uranium readings include:

- Oenpelli Dolerite
- Gilruth Volcanic Member

Samples were generally unaltered. However, in some samples silicification, bleaching, limonite, hematite, and ferruginised weathering were evident. In some cases, secondary uranium minerals accompanied hematite and secondary silicification alterations.

Figure 1 shows the uranium values in the Headwaters tenements. High values generally occur in areas around current prospects. There are some higher readings in other areas but they are not clumped together and, therefore, may not represent an economical prospect.

Figure 2 shows that most of the uranium anomalies occur along or close to structures in the area. This would suggest that mineralisation is structurally controlled. However, elongated dykes are common in the area and a more thorough investigation would be needed to determine the origin of the structures within the area.

Elevated uranium values that occur along structures do not necessarily show that uranium has been transported along fault lines or with dykes. Faults may be indicated by depressions in the area which may collect water and deposit uranium from sources nearby including radioactive volcanic and other prospects.
Figure 1: Uranium anomalies within the Headwaters tenements.
Figure 2: Uranium anomalies and associated structures in different areas of the Headwaters tenements; A – part of EL 25220, B – part of EL 27513, C – part of EL 27514, D – part of EL 24712 (Google Earth, 2009b).
Previous Reports

Previous reports on exploration in the Headwaters tenements were studied to determine what mineralisation, if any, has been found to date. This included looking at reports based on exploration for commodities other than uranium to determine if alteration in the area was similar to alteration that is known to occur in relation to uranium mineralisation. Exploration has occurred to varying extents in all but one of the Headwaters tenements. The northern part of Exploration License 27,513 was classed as a No Go Zone, which was defined by the Northern Land Council on behalf of the Traditional Owners.

Liverpool River Project

In 1969, a joint venture to search for uranium in the Northern Territory was undertaken by Peko Mines N. L., Electrolytic Zinc Company of A/asia LTD and Newmont Pty. Ltd. Dyke-like structures occurring in sandstones in the Liverpool Project area bore a resemblance to those in the area in which the Westmoreland deposit was found. This made the Liverpool Project area prospective for similar uranium deposits (Maynard, 1971).

A small section of the Liverpool River Project area covers the majority of exploration license 25220 and part of exploration license 27,513 in the Headwaters tenements (Figure 3).

Figure 3: Location of Liverpool River Project in relation to the Headwater tenements (from Maynard, 1971).
Early exploration in the Liverpool area was limited to photo-interpretation of the area along with an airborne radiometric and magnetic survey over a small sample portion of the area. The photo-interpretation was of little use apart from confirming the lack of suitable outcrops through the Kombolgie Sandstone cover in likely “window” areas. The radiometric spectrometer did not reveal any significant uranium anomalies but did indicate the presence of long, buried dykes (Maynard, 1971).

A study into the “window” areas was conducted with geological maps and aerial photos. It was concluded that the “windows” more than likely did not extend to basement. Despite this, an airborne radiometric survey was undertaken that revealed only one uranium anomaly in the project area. A considerable number of uranium readings were recorded that were considered to be higher than normal. However, most of these higher readings may represent rock types with higher activity as opposed to a uranium deposit (Maynard, 1971).

Exploration in the nearby Waterhouse River area revealed that the one anomaly seen in the Liverpool area, termed a “mud patch” anomaly, could be an indication of a uranium deposit upstream. This was not proven and it was determined that if water transporting the uranium originated from springs, the possible uranium deposits may be buried beneath cover rocks and difficult to find (Maynard, 1971).

In September 1971, it was concluded that no further work was warranted in the area and the area was relinquished without any further exploration (Maynard, 1971).

**EL’s 260, 264 and EL’s 243, 244, and 245**

EL 260 is located just to the north of the Headwaters tenements. The location of the other exploration licenses is yet to be determined. In 1972, Queensland Mines Limited was granted Exploration Licenses 260 and 264 for a period of nine months. Both exploration licenses formed part of Authority to Prospect 2221. An annual report by Queensland Mines for AP 2221 will be sought from the Northern Territory Geological Survey.

The object of the exploration program was to examine, reinterpret and convert results from previous exploration in AP 2221, identify gaps in the data and design an exploration program to fill any gaps found. Geological maps were compiled from aerial photographs and existing geological maps. Studies of previous radiometric data showed minor anomalies in both areas that were determined to be due to volcanic rocks (Queensland Mines Ltd, 1972a; Queensland Mines Ltd,
1972b). Limited field investigations were carried out in EL 260 during 1972 to confirm geological features previously interpreted and collect samples for analysis (Queensland Mines Ltd, 1972a).

In 1973, photogeological interpretation was carried out and new geological maps from the previous year were studied to determine if any areas within the two exploration licenses warranted any further attention. One area of geological interest was located in EL 264 and several areas were located in EL 260 (Queensland Mines Ltd, 1974a; Queensland Mines Ltd, 1974b).

Notes on ground exploration for both exploration licenses were included in a separate report that also contained information on other exploration licenses in the area. A geochemical stream sediment survey was carried out for EL 260 along with three other exploration licenses. No stream sediments were tested in EL 264. Both reports have been outlined below.

**Notes on ground reconnaissance**

Nine localities, named W1 to W9, plus an addition locality named the Magella Creek Window within exploration licenses 244, 260, 261 and 264, were selected for ground reconnaissance based on the presence of volcanic or metamorphic units. General geology was recorded, in particular the presence of Myra Falls Metamorphics, the lowest Kombolgie Formation, and alteration of the Kombolgie or intrusive rocks in the area. Samples were collected for analysis and levels of radioactivity were recorded (Swingler, 1973).

**Magella Creek Window (EL260)**

Two outcrops of Myra Falls Metamorphics were reported, one of which was a highly altered haematitic-quartz-schist. Alteration was due to contact metamorphism from intrusive dolerites. The other outcrop, containing mostly quartz schist, was strongly contorted and cross cut by quartz veins. A TV1 traverse resulted in several channel 1 readings ranging from 1000 to 4000 cpm with T2/T3 ratios ranging from less than four to six (Swingler, 1973).

**W1**

The two dominant units in this area were the Kombolgie Sandstone and a Gneissic Complex which unconformably underlies the Kombolgie. The Gneissic Complex consists of a radioactive granite (TV1 of up to 7000 cpm on channel 1) and a biotite granite. There was no alteration observed and there were no other significant TV1 readings in the area (Swingler, 1973).

**W2 (EL260)**

This area consisted of intrusive dolerite and the Kombolgie Sandstone. There appeared to be no alteration at the contact between the two despite the fact that the dolerite was thought to be an
intrusive sill. No alteration was observed and no significant TV1 readings occurred in the W2 area (Swingler, 1973).

**W3 (EL260)**
The W3 area consisted of volcanics and sediments of the Kombolgie Formation. The sediments contained haematitic-limonitic cement bands and cross cutting coxcombed quartz veins were recorded. These veins were thought to be the result of surface resilicification. The volcanic unit consisted of vesicular and amygdaloidal andesite and microdiorite which showed evidence of metasomatism. TV1 readings in the area are shown in Table 1 (Swingler, 1973).

| Table 1: TV1 readings taken from different units in area W3. |
|-----------------|-----------|----------|-----------|
| Unit            | Channel 1 | Channel 2 | Channel 3 |
| Sediments       | 400       | 25       | 5         |
| Sediments       | 700       | 15       | 5-15      |
| Volcanics       | 2000      | 80       | 40        |
| Volcanics       | 3000      | 150      | 25        |

**W4 and W5 (EL 260)**
The only unit seen in either area was the Kombolgie Formation. There were several thick laterite outcrops that were though to represent lateritised Kombolgie Volcanics. The highest TV1 reading was 2000 cpm on channel 1 (Swingler, 1973).

**W6 (EL264) and W7**
These areas contained Kombolgie sediments and volcanics. The volcanics were seen to be a thin layer of buckshot and laterite over sandstone, the laterite assumed to be a result of weathering. TV1 channel 1 readings taken from the laterite returned results of 2500 and 3500 cpm (Swingler, 1973).

**W8**
The W8 area consisted of a valley of Ophitic Dolerite and Granophyric Dolerite bounded by walls made of Kombolgie Formation. No chloritisation was observed in the area. TV1 readings taken from the area are shown in Table 2 (Swingler, 1973).

| Table 2: TV1 readings taken from different units in area W8. |
|-----------------|-----------|----------|-----------|
| Unit            | Channel 1 | channel 2 | Channel 3 |
| Kombolgie       | 600       | 30       | 15        |
| Kombolgie       | 500       | 35       | 15        |
| Ophitic Dolerite| 600       | 30       | 10        |
| Granophyric Dolerite | 1000   | 30       | 10        |
| Granophyric Dolerite | 800   | 70       | 15        |
| Granophyric Dolerite | 400   | 40       | 15        |
**W9**

Area W8 consisted of narrow bands of dolerite, meta-siltstone, black quartzites and cherts from the South Alligator Group. No Kombolgie Formation was seen in the area and chloritsation was not observed. TV1 readings taken from different rocks types in the area are shown in Table 3 (Swingler, 1973).

<table>
<thead>
<tr>
<th>Rock type</th>
<th>Channel 1</th>
<th>Channel 2</th>
<th>Channel 3</th>
</tr>
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<tbody>
<tr>
<td>Phyllite</td>
<td>3000</td>
<td>70</td>
<td>40</td>
</tr>
<tr>
<td>Phyllite</td>
<td>2500</td>
<td>150</td>
<td>20</td>
</tr>
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</tr>
<tr>
<td>Dolerite</td>
<td>500</td>
<td>25</td>
<td>10</td>
</tr>
</tbody>
</table>

Swingler (1973) concluded that further exploration including mapping, geochemical sampling and radioactive mapping was warranted given the presence of the Myra Falls Metamorphics, Gneissic Complex and Intrusive Dolerites. The dolerites in several areas were petrologically similar to those found at Narbalek where economic uranium deposits have been found.

**Geochemical stream sediment survey**

Within EL’s 243, 244, 245 and 260, mineralisation is already known to occur at five locations. These are the Narbalek Orebody, Gorrunghar Prospect, Caramal Prospect, G4 Prospect and Beatrice Prospect. At Narbarlek, a tabular pitchblende orebody that is structurally controlled has an average grade of 2.37% U3O8. The Caramal Prospect contains a very large body of primary uranium mineralisation in a deformation zone within chloritic schists. The Gorrunghar, G4 and Beatrice Prospects consist of secondary mineralisation that is also structurally controlled. The G4 prospect was found by investigations driven by geochemical stream sediment results (Swingler, 1974).

The aim of the stream sediment survey was to determine other areas of possible uranium mineralisation in the exploration licenses using trace elements such as uranium, lead, zinc and copper. Approximately 4000 samples were collected with a spacing of 400 metres and analysed for the aforementioned elements. Water samples were collected during an orientation survey and analysed for uranium. However, due to the expense associated with a helicopter the water sampling part of the survey was rejected (Swingler, 1974).

Overall, 110 anomalies were located. Several of the anomalies were associated with previously known mineralisation and will not be described in this report. Other anomalies were associated with
possible uranium mineralisation where as some had only minor potential. Lithological anomalies were also determined (Swingler, 1974).

Geochemical anomalies possibly associated with uranium mineralisation

Some anomalies occurring within the Myra Falls Creek area mentioned above consisted of high uranium and lead values. The area consists of gneisses cut by several major faults that coincide with some of the anomalies. Anomalies in the transitional zones of the Nimbuwah Complex are considered to be primary due to high uranium and/or lead values. Three anomalies in close proximity to the Gorrungah and Gurrigarry Prospects consist of broad areas of moderate to high uranium values. One other anomaly which is considered to be primary due to its high uranium values occurs to the west of the Caramal Prospect (Swingler, 1974).

Geochemical anomalies of minor potential

Anomalies taken from granites near a major fault zone north of the Horn window returned high uranium values. These values were considered significant since they are higher than background values in the granite. Anomalies occurring at dolerite margins were only slightly anomalous but were investigated due to the fact that the mineralisation at the Caramal Prospect envelopes the Oenpelli Dolerite. Hypotheses for the mineralisation were groundwater from surface sources moving over weathered dolerites; and alteration of chlorite in dolerite by deuteric or meteoric solution reduce the iron and possibly create an environment where uranium from subsurface mineralisation could be “fixed” (Swingler, 1974).

Lithological anomalies

Lithological anomalies were located in several different lithologies. High values were recorded in the Oenpelli Dolerite or Amphibolites where creeks drain from other dolerite anomalies. The margins of the Anatectic Granite recorded anomalies that were slightly lower but widely dispersed. Black soils with high uranium values were most likely enriched by scavenging or evaporation of uranium rich waters. Sandstone close to volcanics in the Kombolgie Formation also returned high readings (Swingler, 1974).

Swingler (1974) concluded that several areas were highly prospective for uranium mineralisation and would warrant further investigation, although in some areas uranium was detrital as opposed to “fixed” by sediments. He also showed that a close sample density is important as known uranium mineralisation would have been missed by the sediment sampling survey. It was suggested that a stream water survey would have been more productive. However, this would have been problematic due to ground access restrictions and a limited wet season.
Bulman/Mainoru Project

The Bulman/Mainoru project covered a number of exploration licences including 6352, 6353, 6354, 6355 and 8436. Most of EL6354 and part of EL6352 are now part of the Headwaters project exploration licenses 27,515; 24,715; and 24,712 (Figure 4).

Figure 4: Location of Bulman/Mainoru project exploration licences in relation to the headwaters project tenements (from Warren, 1997).

Exploration in the Bulman/Mainoru project area was for commodities including diamonds, zinc, lead, copper and silver. Although uranium was not listed as one of the commodities, by looking at alteration and mineral assemblages it may be possible to determine if uranium mineralisation is likely to occur within the project area.

In 1995, Normanby Exploration began regional reconnaissance sampling programs to determine if diamonds, gold and/or base metals were present within the exploration licenses (Price, 1996). Heavy mineral drainage samples were taken along major drainages and their tributaries. Heavy mineral loam and geochemical samples were collect from features of interest that were identified from air-photos. Rock chip samples were also taken from various sites within the exploration licences (Price, 1996).
The results of the sampling showed that one diamond chip and numerous chromite grains with kimberlitic affinities had been found. Four anomalies within the exploration licenses had been defined but more sampling was needed to test the anomalies (Price, 1996). No mention was made of any alteration or mineral assemblages in the area.

In 1997, an aeromagnetic survey (Figure 5) was flown over three known anomalies in the area to confirm the presence of the anomalies and to determine if any more existed in the area. Thirty three anomalies were defined in total (Warren, 1997).

High uranium readings in the area do not appear to be related to areas of high magnetic intensity. However, the areas of high magnetic intensity in the lower part of Figure 5 may extend to where the high uranium readings occur in the lower left (Figure 5 - circled).

As only a small number of samples were collected in the Bulman/Mainoru Project area and no previous exploration for uranium had been undertaken, it is difficult to determine if any prospective uranium deposits occur in the project area. Further field work, including sampling and airborne radiometrics, would be required.
Death Adder Project

First year of exploration

In 1997, Cameco Australia PTY LTD conducted a field program in exploration licenses 5061 and 5062. Those licenses cover all or parts of tenements in the Headwaters project, including 24711, 24712, 24713, 27513 and 27514 (Figure 6).

![Figure 6: Location of Death Adder project exploration licences in relation to the Headwaters tenements (from Drever and Marlatt, 2000).](image)

The focus of the field program was to discover high grade unconformity-related uranium deposits similar to those found in Saskatchewan, Canada and the Alligator Rivers region in the Northern Territory. The program consisted of an airborne magnetic spectrometric survey, radiometric prospecting, PIMA analysis of sandstone samples and lithogeochemical studies. Detailed work, such as geological mapping, radiometric surveys, rock chip sampling and stream sediment sampling, was carried out on the Flying Ghost prospect (Drever et al., 1998).

The results of the airborne radiometrics are shown in Figure 7. It shows that there are several areas that contain anomalies, 28 of which were chosen for field checking. The anomalies were divided into black soil swamp and lateritised surfaces within the Kombolgie Sandstone. The latter was divided
further into anomalous radioactivity due to laterite and areas where the anomaly is also associated with sandstone. In the second areas, fracturing, bleaching, and silicification are associated with hotspots up to 26,500cps (Drever et al., 1998). These areas were classed as prospects and given names (Figure 7).

Figure 7: Airborne radiometrics in the Deaf Adder project with areas of high total radiometric counts (circled) and current prospects (from Drever et al., 1998).

Flying Ghost Prospect

The Flying Ghost anomaly covers an area of 450 by 125 metres. It has strong fracture-related control, patchy surface enrichment and secondary dispersion. The majority of uranium anomalies were found in a creek bed with exposed sandstone and along fractures within the prospect. The main uranium minerals are green and yellow secondary uranium minerals and a trace of Threadgoldite (Al(UO2)2(PO4)2(OH)•8(H2O)) was also found (Drever et al., 1998).
Autoradiography confirmed that uranium mineralisation is weakly disseminated and, in the high radioactive zones, fracture controlled. It was also determined that uranium can occur within goethite and as well as within clean sandstone. Gold was also discovered to be associated with uranium in goethite with values of 350 to 1,760 ppb occurring with uranium values of 430 ppm to 1.32% (Drever et al., 1998).

Alteration in the associated with the Flying Ghost prospect can be seen in fractures lined with quartz veins which on occasion contain drusy quartz. Blotches of black or purple goethite are present in areas that contain the most intense radioactivity and strong bleaching of goethite has occurred along fractures. Unlike the blotches of goethite, the bleached goethite is not generally associated with high radioactivity (Drever et al., 1998).

**Banshee Prospect**

The Banshee Prospect contains the most intense area of fracture related uranium anomalies. The area is 50 by 300 metres and is characterised by brecciation and strong silicification. Secondary uranium minerals occur in goethite filled fractures and at fracture intersections within mottled goethitic sandstone. Uranium values ranging from 1,400ppm to 1,500 have been recorded along with Th values ranging from three to four ppm. Anomalous gold values up to 1,893ppb were also recorded (Drever et al., 1998).

**Casper Prospect**

The Casper prospect covers an area of around fifty square metres. The main radioactivity is related to yellow-green secondary uranium minerals that were present along fractures in mottles goethite sandstone which was also seen in the Banshee prospect. Gold was also found in association with goethite in the fractures with a value of 236,550ppb recorded from significant fracture-related native gold. (Drever et al., 1998)

**Phantom Prospect**

Hotspot anomalies in the Phantom prospect were mostly associated with soft clay-like minerals found in fractures beneath a goethitic crust. These hotspots occur in flat goethitic sandstone outcrops that have broad areas of uranium with an average of around 1,000cps. The hotspots had values up to 9,000cps. Radioactivity within the clay itself reached 16,300cps (Drever et al., 1998).

The Phantom prospect is also characterised by elevated B, moderately elevated Zr, Al, Mg and Ti. Samples of lateritic grey soil from areas outside the prospect which are also anomalous in these elements are geochemically similar to basaltic tuff. This suggests that grey soil within the prospect may be of volcanic origin which could be a possible source of uranium (Drever et al., 1998).
**Stretch Prospect**

The Stretch prospect occurs at the intersection of two structures. There is a structure at 340°, which is defined by a boron anomaly, and a structure at 075° which is where the mineralisation occurs. The 075° structure is a lateritic grey clay filled valley that has a brecciated, silicified and quartz veined margin. Radioactivity associated with the valley has been recorded up to 15,000 cps and the highest uranium reading was recorded at 12.5ppm. A possible dyke is coincident with the valley and a kandite (halloysite-kaolinite) anomaly is associated with the radioactive anomalies (Drever et al., 1998).

Drever et al., (1998) concluded that two areas, the Flying Ghost prospect and the combined Casper-Banshee anomaly, contain sandstone hosted secondary uranium mineralisation which was associated with elevated gold values. They found that uranium was associated with clays in fractured zones of the Kombolgie Sandstone which could be the result of leakage from a primary uranium source underground. However, the uranium may also be related to volcanic units in the area.

**Second year of exploration**

In 1998, a diamond drilling program was undertaken at the Flying Ghost prospect to determine if radioactivity extended below the surface. Airborne radiometrics and consequent anomalies from the 1997 work program were followed-up and processing continued using new techniques. Airborne geophysics and air photography were undertaken over known prospects to aid in geological mapping, further outline mineralisation and generate new targets. Geological mapping and outcrop sampling concluded the 1998 work program (Drever et al., 1999).

The drilling program consisted of five drill holes in a 400 by 900 metre area over the mineralisation and radioactivity found at the Flying Ghost project. Samples were collected from each core and used for lithogeochemical analysis. The deepest hole, DDH DAD-002, at a depth of 792 metres, did not reach the basement. In most of the wells, radioactivity and alteration occurred at the contacts with the Gilruth and Nungbalgarri volcanic members and the Kombolgie Sandstone. Facies variations within the Kombolgie also showed elevated geochemistry. Radioactive anomalies located on the surface were not shown to continue at depth (Drever et al., 1999).

During the airborne radiometrics and anomaly follow-up, Minimum Noise Fraction (MNF) and Noise Adjusted Singular Value Decomposition (NASVD) were used to remove noise from by extracting principle components in the data. As a result, lateritic and organic-related radioactivities were able to be screened from zones of brecciation and structure that are more likely to indicate mineralisation underground. Subsequently, two more prospects, Spectre and Writer (Figure 8), were found (Drever et al., 1999).
The geophysics and air photography carried out over the Flying Ghost and Casper-Banshee prospects resulted in radiometric and magnetic figures which showed good agreement with known geology in the area and assisted with the construction of geological base maps. These base maps were used in the interpretation of clay, geochemical and geophysical data in the prospect areas as previous geological maps were very basic and outdated (Drever et al., 1999).

Detailed outcrop sampling was completed in the Flying Ghost-Phantom area, the Casper-Banshee area and at the new Writer and Spectre prospects. 510 samples were collected in total (Drever et al., 1999). Figures showing gold and uranium (partial) geochemistry along with a geological interpretation of the prospect areas are shown in Appendix 1.

The results of the sampling varied between the different areas. In the Flying Ghost-Phantom area, uranium and gold were shown to be elevated in the “K4” lithofacies in the Kombolgie Sandstone (see appendix 1 for description). The dikite horizon was shown to be extensive throughout the area. In the Casper-Banshee area, the uranium and gold values occur in a north-south trending zone which widens where two structures meet. Possible hydrothermal illite exists in the area but more work was needed to determine this (Drever et al., 1999). In the Spectre area, uranium secondaries were
discovered within the “K6” lithofacies of the Kombolgie Sandstone. Gold and uranium values did not show any sort of trend in the prospect. The Writer area was interpreted to be within the “M1” unit of the McKay Sandstone which exhibited sheared and foliated fabric. Elevated uranium values were found within the sandstone which was dominated by muscovite, illite and halloysite.

**Third year of exploration**

In 1999, two more holes were drilled in the southern part of the exploration licenses in an attempt to reach the basement. Detailed airborne geophysics was also undertaken in the southern section of the project area. A gravity survey was completed to better define structure and lithology around structures of interest, and collection and analysis of samples from the most recent anomalies was completed (Drever et al., 2000).

The two drill holes were located within the Spectre prospect with a total combined depth of 2,260 metres. The basement was not intersected in either hole due to limitations of the drilling equipment. Uranium mineralisation at depth could not be established although elevated uranium was located at contacts between the Kombolgie Sandstone and volcanics. This confirms reports from drilling in previous years (Drever et al., 2000).

The airborne geophysics survey resulted in the identification of the Slimer prospect (Figure 9) and over 300 new radiometric anomalies. A total of 605 samples were collected from 298 of the new anomalies in the hopes of defining characteristics that indicate why elevated uranium appears in these areas. The majority of the elevated readings were explained by the presence of black soils, laterite or variations in topography. The remaining samples were determined to be anomalous with one taken from near the Slimer prospect having 1000ppm uranium (Drever et al., 2000).

![Figure 9: Location of Slimer prospect (modified from Otto et al., 2001).](image-url)
Drever et al., (2000) concluded that the Kombolgie Sandstone is potentially difficult and expensive to explore due to its thickness. They were also still unable to determine the role of the two volcanic units in the area. It was proposed that the volcanics were not barriers to fluid flow but may have scavenged uranium from solutions originating deeper underground. This may have prevented expressions of uranium on the surface.

**Fourth year of exploration**

Two more diamond drill holes (Figure 10 - circled) were completed during the exploration program in 2000. One new hole, DAD-0008, was drilled in the western part of EL 5062 and a previous hole, DAD-0006, was deepened in an effort to reach basement. Outcrop sampling from fractures at anomalous sites were collected and analysed, and an Airborne Multispectral Scanner (AMS) survey was conducted over the project area to identify alteration associated with uranium mineralisation (Otto et al., 2001).

A total of 228 samples were collected from various sites in the project area. The results were disappointing with only two samples showing elevated uranium values. Over 1100ppb uranium was recorded and accompanied by metal contents over 4300ppb. The uranium in one of the samples was thought to have originated from a brinal evaporitic environment. The other sample was in close proximity to the Gilruth Volcanic Member which may be a source of uranium (Otto et al., 2001).
Of the two holes drilled during the fourth year of exploration, only DAD-0008 reached the unconformity at a depth of 993.45 metres. Drill hole DAD-0006 was terminated at a depth of 1436.4 metres without reaching the unconformity. Immediately below the unconformity in DAD-0008 is a fine grained, green clay-like layer. The basement rocks consist of gneisses and schists that contain narrow quartz veins and thin quartz ribbons. Metavolcanic rocks are interbedded with the basement rocks which show hematite alteration to a depth of two metres below the contact (Otto et al., 2001).

The sandstone above the unconformity, the Mamadawerre Sandstone, contained chloritic alteration in the lower portion of the unit. The alteration appeared to be structurally controlled and chlorite haloes were found to be surrounding zones that had structural displacement and some fracturing (Otto et al., 2001).

Analysis of samples taken from the drill cores was did not return any high uranium readings. Results of the AMS survey were not available for submission in the 2000 report so were included in the final report. Uranium results were disappointing but exploration during the fourth year did determine that the sandstone cover in the Deaf Adder prospect is quite thick in the east but thins towards the north-western part of the prospect (Otto et al., 2001).

**Fifth year of exploration**

Exploration during 2001 consisted mostly of fracture, quartz vein and breccia sampling along with following-up anomalous radioactive areas. The results of the AMS survey from the previous years exploration program was also included in the 2001 annual report (Otto et al., 2002).

The sampling was undertaken with the hypothesis that alteration fluids may not be able to penetrate the volcanic units in the area unless using fluid flow conduits such as fractures, veins and hydraulic brecciation. It was hoped that the sample might display geochemical anomalies that indicate alteration and uranium leakage from a deposit at the unconformity. Occasional outcrop samples were also taken from areas near where fracture samples were collected. A total of 165 samples were taken altogether (Otto et al., 2002).

The results from the fracture sampling only returned two high uranium readings from the Slimer prospect. The samples also had elevated gold, platinum, REE’s and palladium. The sampling results from northwest of Spectre (Table 4) indicate a trend of anomalous radioactive values parallel to the Spectre fault. This trend extends for approximately 1.5 kilometres from the Spectre prospect into the South Alligator River Valley (Otto et al., 2002).
Table 4: 2002 Uranium values above 5ppm in the Deaf Adder project area.

<table>
<thead>
<tr>
<th>Sample Number</th>
<th>U(t) (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DA01C10262</td>
<td>561.67</td>
</tr>
<tr>
<td>DA01H10063</td>
<td>418.05</td>
</tr>
<tr>
<td>DA01H20065</td>
<td>315.7</td>
</tr>
<tr>
<td>DA01H10065</td>
<td>281.56</td>
</tr>
<tr>
<td>DA01H20063</td>
<td>277.69</td>
</tr>
<tr>
<td>DA01H20064</td>
<td>223.29</td>
</tr>
<tr>
<td>DA01H10064</td>
<td>81.74</td>
</tr>
<tr>
<td>DA01H20066</td>
<td>30.86</td>
</tr>
<tr>
<td>DA01H10066</td>
<td>22.53</td>
</tr>
<tr>
<td>DA01C20262</td>
<td>11.3</td>
</tr>
<tr>
<td>DA01C30262</td>
<td>5.38</td>
</tr>
</tbody>
</table>

The highest uranium values came from samples taken at the Slimer prospect. Readings of 418ppm uranium with 213ppm metals, and 281ppm uranium with 148ppm metals were recorded. Breccias and drusy quartz veining in the vicinity of the samples did not appear to be associated with a structural event. Therefore, the origin of the uranium is difficult to determine (Otto et al., 2002).
The AMS survey was conducted to determine if alteration haloes existed around known uranium occurrences. The results showed that there was no evidence to show hydrothermal alteration and no strong clay readings. This may be due to poor outcrops in the area or due to the relation of occurrences to stratigraphic units. The Writer anomaly is interpreted as an anomaly associated with phosphates in a stromatalytic unit which would not be expected to have a major hydrothermal alteration halo (Otto et al., 2002).

The lack of alteration haloes around uranium anomalies was taken to suggest that either the uranium mineralisation in the Deaf Adder project is the result of surface enrichment or the alteration haloes do not reach the surface due to inhibition by volcanics. Either way, it was determined that depth of the unconformity severely diminished the prospectivity of the exploration licenses and the licenses were surrendered in June 2002 (Otto et al., 2002).

**East Alligator Project**

In 2002 and 2003 Cameco Australia PTY LTD commenced exploration for uranium within exploration license 23522 (Figure 12) which is now classed as exploration license 25220 in the Headwaters tenements. An airborne hyperspectral survey, airborne magnetics, radiometrics and a digital terrain model along with outcrop sampling were undertaken to determine if an unconformity-style uranium deposit occurred in the project area (Carter and Beckitt, 2003).

![Figure 12: Location of East Alligator project exploration licence in relation to the Headwaters tenements (from Carter and Otto, 2006).](image-url)
The airborne hyperspectral survey was conducted to determine if alteration patterns (namely clays) associated with unconformity-style uranium deposits were present within the project area. In the interpretation of the hyperspectral data, Zaluski (2003) determined that the main control on the distribution of clays appeared to be stratigraphic which may make identification of hydrothermal alteration difficult. However, Zaluski (2003) was able to determine that the most prospective area in the East Alligator Project was a large area of illitic clays in the north-western corner. The area was heavily dissected by fracturing and a number of cross structures and coincided with the lowest stratigraphy, the Gumarrinbang Sandstone.

The airborne radiometrics for uranium (Figure 13) showed numerous uranium anomalies within the East Alligator Project area. The majority of these anomalies correspond with exposures of the Gilruth Volcanics shown in Figure 14. Weaker anomalies were less common and were generally related to features and dykes within the Gumarrinbang and Marlgow sandstones.

Figure 13: Airborne radiometrics for uranium and high uranium readings (pink dots) from sample geochemistry (from Carter and Beckitt, 2003).
In 2003, 121 sandstone outcrop samples were collected including 104 samples collected from a grid and 17 rock samples collected as a follow up to anomalies shown in the airborne radiometric survey. Geochemical analysis was performed on the samples and the results showing uranium values greater than two parts per million are listed in Table 5 on the next page (Carter and Beckitt, 2003).

The four best samples containing more than 27ppm uranium were samples taken from anomalies previously identified by radiometrics. They all had U/Th ratios less than two which suggests that the uranium in the area is not associated with detrital silicate minerals. It was also determined that higher uranium values were strongly associated with gold and platinum group elements (Carter and Beckitt, 2003).

Table 5: 2003 uranium values above 2ppm in the East Alligator Project area.

<table>
<thead>
<tr>
<th>Sample number</th>
<th>U(t) ppm</th>
</tr>
</thead>
<tbody>
<tr>
<td>EA03C10207</td>
<td>110</td>
</tr>
<tr>
<td>EA03C10211</td>
<td>75.5</td>
</tr>
<tr>
<td>EA03C10210</td>
<td>34.3</td>
</tr>
<tr>
<td>EA03C10214</td>
<td>27</td>
</tr>
<tr>
<td>EA03C10213</td>
<td>8.5</td>
</tr>
<tr>
<td>EA03C10212</td>
<td>7.81</td>
</tr>
<tr>
<td>EA03C10220</td>
<td>4.98</td>
</tr>
</tbody>
</table>
The majority of samples that contained uranium levels above two parts per million were found to have a northwest trend that parallels the Bulman Fault Zone (Figure 15). The figure also shows that three or four high uranium readings are clustered near where the Bulman Fault Zone intersects the Sawcut Fault Zone that trends east-west (Carter and Beckitt, 2003).

Two other high readings that do not fall along this north-west trend do correspond to a north-east trending structure in the project area (Figure 15 – circled in orange). However, it is unknown whether this structure is a fault or dyke.

Carter and Beckitt (2003) also determined during sampling in the project area that the majority of higher uranium values were found in the Gumarrirnbang Sandstone. In the overlying Marlgowa Sandstone, only one value higher than two parts per million was recorded.

<table>
<thead>
<tr>
<th>Sample Code</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>EA03C10217</td>
<td>4.92</td>
</tr>
<tr>
<td>EA03C10221</td>
<td>3.78</td>
</tr>
<tr>
<td>EA03C10209</td>
<td>2.64</td>
</tr>
<tr>
<td>EA03C10216</td>
<td>2.37</td>
</tr>
<tr>
<td>EA03C20207</td>
<td>2.09</td>
</tr>
<tr>
<td>EA03B10140</td>
<td>2.06</td>
</tr>
</tbody>
</table>

Figure 15: Anomalous uranium readings and associated faults in the East Alligator Project area (Google Earth, 2009a).
From February 2004 to February 2005, Cameco Australia PTY LTD followed up exploration from the previous year by collecting more samples from the anomalous area around the Bulman Fault Zone. Previously unchecked radiometric anomalies were also targeted. Eight samples returned uranium values above two parts per million as shown in Table 6 (Carter, 2005).

### Table 6: 2004 uranium values greater than 2ppm in the East Alligator Project area.

<table>
<thead>
<tr>
<th>Sample Number</th>
<th>Lithology</th>
<th>U_ppm_G400</th>
</tr>
</thead>
<tbody>
<tr>
<td>EA04C20020</td>
<td>sandstone</td>
<td>68.1</td>
</tr>
<tr>
<td>EA04C10020</td>
<td>sandstone</td>
<td>43.9</td>
</tr>
<tr>
<td>EA04C20070</td>
<td>sandstone + laterite (volcanic)</td>
<td>23.2</td>
</tr>
<tr>
<td>EA04C10042</td>
<td>sandstone + laterite</td>
<td>13.5</td>
</tr>
<tr>
<td>EA04C20023</td>
<td>sandstone + ?volcanic material</td>
<td>8.07</td>
</tr>
<tr>
<td>EA04C30020</td>
<td>sandstone</td>
<td>4.48</td>
</tr>
<tr>
<td>EA04C10011</td>
<td>sandstone</td>
<td>2.27</td>
</tr>
<tr>
<td>EA04C20011</td>
<td>sandstone</td>
<td>2.06</td>
</tr>
</tbody>
</table>

The two highest values and one of the lower values were taken from the same area. The samples with the highest values also returned high U/Th ratios and were associated with elevated Au-PGE’s, Se, Be, REE’s and V. High V values generally suggest a volcanic influence, therefore the uranium and metal content was determined to be inherited from the Gilruth Volcanics and not related to deformation (Carter, 2005). The Gilruth Volcanics were mapped only 500 metres away from the zone containing high uranium readings. Dune-like features observed in the sandstone near some of the samples are recognised as an indicator of the top of the Gumarrirnbang which is believed to be the depositional surface of the Gilruth Volcanics (Carson et al., 1999).

During the third year of exploration, Cameco Australia PTY LTD conducted sampling to determine the prospect of the intersection of the Bulman and Sawcut Fault. The clay distribution appeared anomalous and some right lateral movement along the Sawcut fault had been suggested by magnetic imagery. A TEMPEST (airborne electromagnetic) survey was flown over the site to determine any possible alteration and the depth to the unconformity in the area (Carter and Otto, 2006).

The samples taken did not return any significant uranium values. The TEMPEST survey determined that there were no features of interest and that the unconformity was at depths greater than 400 metres within the exploration license (Carter and Otto, 2006).

Cameco concluded that there was no evidence suggesting a relationship between elevated uranium values and deformation along the Bulman Fault. Anomalous uranium values were related to
scavenging, inheritance and surficial enrichment from the Gilruth Volcanics. As such, analysis of surface samples would not help in determining basement targets within the East Alligator Project and drilling to a depth of up to 450 metres would be high risk and expensive (Carter and Otto, 2006).

Summary

Previous reports on exploration in and around the Headwaters tenements have located several uranium prospects. The majority of prospects, including Flying Ghost, Phantom, Stretch, Slimer and writer, are located in the central part of the Headwaters projects. The Banshee and Casper prospects lie further north and the Spectre prospect is located in the south.

The majority of the prospects and other areas of high uranium appear to be structurally controlled in that most of the high uranium readings were in or around fault lines. However, in some areas the uranium is most likely detrital with a stratigraphic source of uranium nearby and was only concentrated in structures due to transport by water. Other areas, and most prospects, show a potential deeper source for uranium, possibly from an unconformity-type deposit. However, due to drilling restrictions the unconformity was only penetrated in one drill hole in the east of the tenements and no anomalous uranium was located.

Although alteration was always seen in samples that contained high uranium values, alteration that is generally associated with uranium deposits can be found in areas surrounding elevated uranium readings. Hydrothermal alteration in the form of clays can be seen in most of the prospects. High uranium readings do not always accompany alteration but this may be due to alteration haloes not penetrating to the surface.

In order to determine if an unconformity-type deposit is present within the Headwaters project, further drilling would need to be conducted down to the unconformity in areas surrounding known prospects.
References


Drever, G. and Marlatt, J., 2000. EL 5061 and EL 5062, Deaf Adder Project, 2000 proposed work program. Cameco Australia Pty LTD.


Appendix 1 – Uranium and gold values for prospects in the Deaf Adder Project.
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28 August 2009

Structural Geology of the Headwaters project area

Summary
- The aim of this report is to provide a first-order synthesis of the structural architecture and tectonic history of the Headwaters project area.
- The report summarises results of a preliminary desktop study, focusing on the relative timing of faulting and the potential structural control on uranium mineralisation.
- Based on the interpretation of aerial images, four major orientations of lineaments were recognised striking NW-SE (300°-330°), E-W (075°-085°), NE-SW (025°-045°) and N-S (340°-000°).
- Overprinting relationships indicate two major generations of deformation:
  o an early ~E-W extension accompanied by E-W reverse faulting and dextral strike-slip faulting along the NW-trending Bulman fault; and
  o a late N-S extension accompanied by fault reactivation of NW-SW-trending and E-W-trending structures, as well as development of NE-SW dextral (extensional) features.
- Strong positive magnetic anomalies along NW- and NE-trending lineaments suggest that these structures may have provided pathways for dykes.
- Mineralised zones are predominantly focused along (reactivated) NW- and E-trending structures.
- The pattern of mineralisation is promising and should be investigated in the future using field structural mapping, geochemical work on uranium alteration and remote sensing.
- Further fieldwork is recommended in the area north of the Spectre Fault. This area includes a relatively large concentration of uranium prospects, which seem to be associated with major structures.
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1. Introduction
The Headwaters area is located in the Arnhem Land Plateau at the northwestern margin of the Palaeoproterozoic McArthur Basin (Figure 1). This area hosts large volumes of uranium mineralised zones that occur predominantly at the proximity of the unconformity between the deformed and metamorphosed basement rocks and the overlying volcano-sedimentary package of the McArthur Basin (Kombolgie Subgroup) (Needham & Stuart-Smith 1980, Wilde et al. 1989, Holk et al. 2003). All rocks in the project area belong to the overlying volcano-sedimentary cover, making direct exploration targeting complicated. Accordingly, following earlier exploration efforts by Cameco, it has been concluded that potential prospectivity is not cost effective (Carter & Otto 2006).

An alternative approach for exploration is that uranium mineralisation is not restricted to the actual unconformity but is also structurally controlled (e.g. Polito et al. 2005). Rocks in the area are strongly fractured, and there is evidence for multiple generations of faulting and fault reactivation. The architecture of faulting and fracturing, when combined with the relative timing of deformation and fault reactivation, could provide vectors towards discoveries of future uranium deposits.

Figure 1. Location map of the Headwaters project.
The aim of this report is to provide a first-order synthesis of the structural architecture and tectonic history of the Headwaters project area. The scope of this preliminary work was limited to a desktop study involving map and image interpretation on GIS platforms (MapInfo and Google Earth Pro) and literature review (predominantly unpublished reports). The construction of a more robust structural model would require additional constraints from a field-based structural study and geophysical data.

2. Geological setting

The project area is located in the western part of Arnhem Land and east of Kakadu National Park (Figure 2). Rocks in the area belong to the northwestern part of the Palaeoproterozoic McArthur Basin, which together with cover sequences of the Mt Isa and Georgetown inliers, form a series of volcano-sedimentary basins, approximately 1300 km in length (Giles et al. 2002). These rocks were deposited between 1.8 and 1.6 Ga (Figure 3) on a deformed and metamorphosed Palaeoproterozoic basement. Basement rocks are exposed immediately to the east of the project area and belong to the metamorphosed sedimentary succession of the Pine Creek Basin (Needham et al. 1980).

Figure 2. Tectonic map of the McArthur Basin – Mt Isa inlier region (after Rawlings 1999). The location of the project area is shown in red.
The development of the McArthur basin is commonly considered to be associated with a widespread and prolonged rifting event that possibly occurred in a far-field continental back-arc setting (Giles et al. 2002). In this tectonic framework, individual basins were subjected to intermittent extension, transient shortening and episodes of elevated heat flow and magmatism (Giles et al. 2002). The multiple generations of faulting and folding are expressed in the current crustal architecture.

A key element in the tectonic evolution of the Palaeoproterozoic basins in northern Australia is the role of fault reactivation. Many of the basin faults are considered to represent reactivated deep-seated structures, which had formed during the earlier (1890-1870 Ma, Page & Williams 1988) Barramundi orogenic event (Plumb 1979). According to Etheridge et al. (1987), these earlier faults were predominantly oriented northwest, north-northwest and northeast. Further reactivation has occurred during subsequent deformational phases, leading to the inversion of rift-related structures (Lindsay 2001) and possible remobilization of ore-bearing fluids (Southgate et al. 2000). Identifying reworked structures could therefore be crucial for targeting structurally-controlled mineralised zones.

3. Stratigraphy
Rocks in the project area belong to the Katherine River Group, which comprises of a thick sandstone sequence intercalated by a few thin volcanic layers. These Paleoproterozoic rocks are the lowermost basin-related sediments deposited directly on the unconformity. The sandstone package is flat lying and show general younging and thickening from northwest to southeast (Drever et al. 1999, Carter & Otto 2006). The exact depth of the unconformity is unknown, except of one locality (DAD0008) where a drill hole intersected the basement at depth of 993 m (Otto et al. 2000). Further south and east, the unconformity is possibly deeper. The relatively deep (1436 m) drill hole DAW0006 has not reached the basement (Otto et al. 2000).

The lowest part of the cover sequence is the Kombolgie Subgroup, which comprises of massive cross bedded and ripple-marked quartz sandstone, quartz greywacke, minor siltstone and pebble conglomerate (Needham & others 1981). The
basal unit is a sandstone unit (Mamdawerre Sandstone) comprising of an alluvial fan to braided stream facies. It is overlain by a volcanic layer (Nunbalgarri Volcanics in the north and Birdie Creek Volcanic Member in the south). The Mamdawerre Sandstone and the Birdie Creek Volcanic Member outcrop in the southwestern corner of the tenement. A small outcrop of the Nunbalgarri Volcanics exists at the northernmost part of the tenement, along the Bulman Fault. The overlying sandstone unit, the Gumarrimbang Sandstone, outcrops in the northwestern and southwestern parts of the tenement. It consists of fine to very coarse grained, medium to thickly bedded quartz arenite, with an overall fining upward trend (Carson & others 1997, Carter & Otto 2006). The unit is overlain by the Gilruth volcanic Member, comprising of amygdaloidal basalt, tuff, tuffaceous siltstone and banded jasperite rubble (Needham & others 1981). The sub-horizontal marker of the Gilruth volcanic Member is up to 14 m thick (Otto et al. 2000) and is recognized in aerial photographs by its purple laterite colour. However, according to Drever et al. (1999), ground exposures are limited to few weathered outcrops. The sandstone unit above the Gilruth volcanic Member, the Marlgowa Sandstone, is a fine grained to granular, thickly bedded quartz arenite (Carson & others 1997, Carter & Otto 2006).

The Kombolgie is overlain by the McKay Formation (Drever et al. 1999), which consists of marine facies glauconitic sandstone, shale and siltstone. This unit, according to Otto et al. (2000), is now incorporated as a member within the Marlgowa Sandstone. Two occurrences of dolerite intrusions (Oenpelli Dolerite) in the McKay Formation have been reported by Drever et al. (1999). The age of this mafic intrusion has been dated at 1720 Ma (Holk et al. 2003).

4. Structure

Based on image interpretation, at least four systems of lineaments are recognized in the Headwaters project area. In a map-view image all lineaments appear as straight lines, even when crossing the topography, indicating that they most likely represent steeply dipping or sub-vertical faults. The discussion below focuses on the strike-slip separation along these faults based on recognized offsets of stratigraphic markers and displaced lineaments. An exact determination of the net slip (e.g. using the piercing point technique) would require additional data on the dip and dip direction of displaced markers and/or slickenlines.

The two most prominent structures in the areas are the Bulman Fault in the northeastern part of the tenement, and the splaying NW-oriented (300°-330°) faults in the southwestern part (including the 300°-trending Spectre Fault). Both Bulman and Spectre Faults are responsible for marked stratigraphic discontinuities.

4.1. NW-SE lineaments

300°-330° lineaments are the most penetrative features in the northern and central parts of the project area, and appear as a penetrative fabric every few meters (or less) (Figure 4). A moderate folding of this fabric is recognized, possibly due to fault drag along the 075° Sawcut Fault (Figure 5). The 300°-330° fabrics are parallel to the orientation of the Bulman Fault, and are particularly penetrative in distance of less than 30 km away from the fault zone. As the fabric is relatively homogenous, it is difficult to determine whether it was affected by later faulting.
Figure 4. An array of 330° lineaments in the northern part of the project area (UTM 304915E 8577081N).

Figure 5. Folding of 300°-330° lineaments in the northern part of the project area (UTM 304099E 8577210N), probably as a result of sinistral faulting along the Sawcut Fault.
Closer to the Bulman Fault, another set of NW-SE penetrative fabric is recognized, striking 290°-300°, parallel to the axial plane of (possible) local folds (Figure 6). If these structures represent the axial plane of fault-related folds, their orientation is consistent with dextral strike-slip movement on the Bulman Fault.

The 310°-320° Bulman Fault itself passes through the northeastern corner of the tenement. It seems to appear in two major sub-parallel faults, although the northern one may be the one on which most dextral displacement have occurred. Both faults are displaced by later faulting, forming segments 2-7 km long. Apart from the possible fault-related folds (see above), there are a few lines of evidence suggesting that the Bulman Fault accommodated dextral strike-slip movement.

Figure 7 shows a dextral offset of 2 km of the Nunbalgarri Volcanics, as well as associated fault drag. At a larger scale, a dextral strike-slip movement of ~20 km is inferred based on the offset of the basement outcrop (Figure 8). In contrast with these observations, Carter and Otto (2006) suggested based on results of an airborne electromagnetic geophysical survey (TEMPEST), that the Bulman Fault may have also accommodated an apparent sinistral offset. The Bulman Fault, therefore, has possible experienced multiple generations of reactivation.

Figure 6. 290°-300° lineaments in the proximity of the 320°-trending Bulman Fault. The lineaments are oriented parallel to local folds, consistently with the strain associated with dextral strike-slip on the Bulman Fault (UTM 316766E 8586817N).
**Figure 7.** Dextral offset of the Nunbalgarri Volcanics along the Bulman Fault. The strike-slip separation is ~2 km (UTM 318019E 8594235N).

**Figure 8.** Map showing possible dextral offset of basement outcrop (grey) along the Bulman Fault.
Other important NW-SE faults are found in the southern part of the project area. The NW-trending (300°) Spectre Fault is responsible for marked stratigraphic discontinuity and is associated with large-scale brecciation and silicification (Drever et al. 1999, Drever et al. 2000). The regional geology suggests 14 km of sinistral strike-slip movement, based on the separation of the contact between the Kombolgie Formation and the McKay Sandstone (Drever et al. 1999). A sinistral kinematics is supported by the existence of drag folds (Figure 9). The Spectre Fault was mapped here over a length of ~40 km. Its continuation towards the NW and SE is not clear. In the area north of the Spectre Fault, a number of NW-oriented (300°) lineaments have been mapped. However, the kinematics and slip along these structures remain unresolved.

![Figure 9. Fault related sinistral drag along the 300°-trending Spectre Fault (UTM 297455E 8479325N).](image)

### 4.2. E-W lineaments
A second set of faults, oriented ~E-W (075°-085°), appear as regionally important structures that can be traced for great distances (>150 km). One of these faults, crossing the study area in the northern part, is the ~E-W-oriented (075°) sinistral Sawcut Fault (Figure 5). The fault spacing of the ~E-W faults generally increases from north to south. Both the relative timing and the sense of movement along the E-W faults are ambiguous, indicating that they could represent large structures that have been reactivated a number of times. North of the tenement, the Bulman Fault is displaced 5.5 km by a sinistral E-W-trending (090°) Fault (Figure 10). In contrast, Figure 11 shows dextral offset of NE-SW (025°-045°) lineaments, which seem to postdate both NW-SE and (early sinistral) E-W fault systems. Evidence for dextral movement was also interpreted by Carter and Otto (2006) based on magnetic imagery of the Sawcut Fault. All these observations suggest that the ~E-W faults were first active as sinistral structures and only later reactivated as dextral structures.
South of the Spectre Fault, deformation is very much dominated by abundant E-W-trending (075°-085°) lineaments. This network of faults and fractures is relatively dense with characteristic fault spacing of 400-1000 m. Here, some of these structures are parallel to the axial plane of local folds (Figure 12).

Figure 10. Sinistral offset of the Bulman Fault along an E-W fault (UTM 309570E 8599165N).

Figure 11. Dextral offset with separation of 1.2 km of a NE-SW lineament along an E-W fault (UTM 313185E 8561260N).
Figure 12. (a) A dense network of 070-trending lineaments running parallel to the axial plane of local folds (UTM 306584E 8458936N); (b) A possible larger scale fold structure with an axial plane that runs parallel to the ~E-W-trending (070°) fabric.
4.3. NE-SW lineaments
Lineaments oriented 025°-045° are dominant in the northern area and are characterized by fault spacing of 2-5 km. Such structures are less abundant in the central part of the project area and are almost absent south of the Spectre Fault.

The Bulman Fault is offset by these structures (Figure 13), indicating that they represent a later generation of faulting. The strike-slip movement along the 025°-045° structures is mostly dextral, indicated by the separation of Bulman Fault segments (Figure 13), and the development of dilation sites in a right step-over (Figure 14).

Figure 13. NE-SW-oriented (040°) dextral faults offsetting the Bulman Fault with a strike-slip separation of 1.3km (UTM 322775E 8587954N).
4.4. N-S lineaments

A fourth set of lineaments in the northern area are oriented N-S (340°-000°). Fault spacing is characteristically 3-5 km. The N-S faults seem to overprint all earlier structures. The Bulman Fault and the NE-SW (025°-045°) structures are displaced by the N-S faults, and the strike-slip separation is sinistral (Figure 15 and Figure 16). West of the tenement, there is evidence for an E-W-trending (080°) fault (Deaf Adder Fault) that is offset by a N-S structure, here with a dextral strike-slip separation (Figure 17). In the central part of the area, NW-SE to N-S (330°-000°) lineaments become more penetrative. They are characterized by only minor strike-slip separation and sometime appear in an orientation that is axial planar to local folds (Figure 18).
Figure 15. Sinistral offset of the Bulman Fault by N-S structures (UTM 337567E 8569489N).

Figure 16. Sinistral offset of a NE-SW lineament along a NNW-SSE (345°) fault (UTM 333450E 8566751N).
Figure 17. Offset of the Dead Adder Fault (Red) by a ~N-S structure showing dextral strike-slip separation. Note that the penetrative appearance of the N-S structures in the southern part (UTM 293573E 8549901N).

Figure 18. A dense network of 335°-trending lineaments which are oriented parallel to the axial plane of a local fold (UTM 316752E 8506317N).
5. Geophysics
The scope of this study did now allow detailed interpretations of geophysical data. However, based on the available images, a number of conclusions can be made.

Images of magnetic intensities (Figure 19) show a large positive magnetic anomaly at the northeastern part of the area, possibly associated with an igneous body that is located northeast of the Bulman Fault. The Bulman Fault itself is also characterised by a positive anomaly, suggesting that it provided a pathway for dyke intrusions. Linear positive magnetic anomalies are also recognized along the array of NE-SW (025°-045°) lineaments in the northern part of the area (Figure 19 and Figure 20). Structures oriented E-W (070°-080°) are also recognised in Figure 19, especially in the southern part of the project area; however, the intensity of the positive magnetic anomaly along E-W structures is somewhat lower than the NE-SW structures further north.

Figure 19. Magnetic intensity images showing coincidence between linear magnetic anomalies and NE-SW faults in the northern part of the project area. (a) TM1_i_GA706; (b) TM2_i_GA706.
Figure 20. Enlargement of the magnetic intensity image (TM1_i_GA706) in the northern part of the project area, and locations of mapped structures based on surface geology. Coloured lines indicate faults mapped during this study; black lines are faults mapped by earlier workers (MapInfo file).

One possible explanation for the pattern of magnetic anomalies is that mafic dykes preferably intruded through the pre-existing Bulman Fault and the network of (transtensional?) NE-SW structures. Since the latter appear as relatively late structures (see section 4.3 and next section), it is probable that such intrusions took place during a relatively late stage of fault reactivation.
6. Structural synthesis
Based on the structural constraints described above, I will attempt to provide a preliminary structural model. It should be emphasised, however, that at this stage, this model could only be used as a working hypothesis and must be tested against further data on the geometry and kinematics of specific faults.

6.1. Early E-W extension
The earliest and most significant structures in the project area seem to be the NW-SE Bulman Fault and the network of E-W faults. The Bulman Fault is a relatively deep structure which coincides with major geophysical anomalies and the general NW-SE trend of the McArthur Basin. Therefore, it is probable that the Bulman Fault was an important structure associated with the basin architecture. It was possibly inherited from the earlier Barramundi orogeny, and certainly reactivated during subsequent deformational episodes.

Based on overprinting relationships, it appears that dextral strike-slip movement along the Bulman Fault occurred relatively early in the deformation history. This style of deformation could correspond to strain configuration in which the maximum extension is oriented E-W (Figure 22a). Deformation was accompanied by N-S shortening accommodated by folds with axial planes ranging from NW-SE (300º) in the north to ENE-WSW (070º) in the south. In this strain regime, structures oriented ENE-WSW (070º), such as the Sawcut Fault were probably active as a sinistral reverse faults. Some of the N-S planar features could have been active as normal faults or Mode 1 tensional fractures; however, direct evidence supporting these extensional structures is lacking.

It seems that in the south, the expression of ~N-S contractional deformation was more pronounced, giving rise to a large (50 km scale) anticline and dense ~E-W-oriented (070º-080º) axial plane fabric (Figure 21). This could result due to the left bend in the South Alligator Fault. The latter seems to be a dextral strike-slip fault when striking NW-SE (310º-320º) based on the inferred offset of the basement outcrop (Figure 21), but would become a reverse fault at its E-W segment. As a result, the whole area south of this E-W segment was subjected to transpressional deformation.

6.1. Late N-S extension
The second generation of deformation involved reactivation of the Bulman Fault as a sinistral strike-slip fault and sinistral movement along the Spectre Fault. The strain associated with this deformation was characterised by maximum extension in the N-S direction (Figure 22b). In this strain regime, reverse E-W faults were likely reactivated as normal faults, accommodating a component of dextral movement. Dextral movement with an element of dilation was also accommodated along NE-SW (025º-045º) faults. In contrast, structures oriented ~N-S accommodated shortening, as supported by axial plane orientations of local folds (Figure 18).

The lack of NE-SW dextral structures in the southern part of the project area may suggest that this zone, south of the Spectre Fault, was protected from reworked deformation. This could be due to the location of this area south of the basement block (originally displaced by the South Alligator Fault), which acted as a buttress and protected the area from E-W shortening.
Figure 21. Structural interpretation map showing outcrops of basement rocks (grey) and mapped faults. B, Bulman Fault; R, Ranger Fault; SA, South Alligator Fault; Sp, Spectre Fault.
Figure 22. Simplified diagrams showing the possible strain during (a) an early generation of deformation; and (b) a late generation of deformation. The sense of kinematics on reverse and normal faults is arbitrary.
7. Mineralisation

Previous exploration reports by Cameco stated that mineralised structures in Arnhem Land are second order reverse faults that form dilation zones in conjunction with strike-slip faults (Drever et al. 1999). The conclusion of the exploration efforts, however, stated that clear evidence between localised deformation and uranium mineralisation had not been found (Carter & Otto 2006).

The spatial distribution of uranium mineralised zones clearly suggests that mineralisation is structurally controlled (Figure 23 and Table 1). The majority of the mineralised structures occur along ~E-W lineaments. These structures were interpreted here (see Section 6) as early reverse faults that reactivated as extensional features (normal faults and/or Mode 1 fractures). Mineralised zones, including Spectre, Wisp and (possibly) Spirit also seem to coincide with the splaying network of NW-SE faults in the southern part of the area. The Banshee and Casper prospects appear on a (minor?) N-S fault (Drever et al. 1999). None of the mineralised zones coincide with NE-SW structures.

Table 1. Relationships between mapped structures and mineralised zones.

<table>
<thead>
<tr>
<th>E-W lineaments</th>
<th>N-S lineaments</th>
<th>NW-SE lineaments</th>
<th>NE-SW lineaments</th>
<th>Unknown</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phantom</td>
<td>Banshee &amp; Casper</td>
<td>Spectre</td>
<td></td>
<td>Slime</td>
</tr>
<tr>
<td>Flying Ghost</td>
<td>Spirit?</td>
<td>Wisp</td>
<td></td>
<td>DAD002</td>
</tr>
<tr>
<td>DAD050 &amp; DAD052</td>
<td></td>
<td>Writer</td>
<td></td>
<td>Anomaly 28</td>
</tr>
<tr>
<td>DAD034, DAD036 &amp; DAD060</td>
<td></td>
<td></td>
<td></td>
<td>Anomaly 16</td>
</tr>
<tr>
<td>Stretch &amp; DAD015</td>
<td></td>
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<tr>
<td>DAD014</td>
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<tr>
<td>Waif</td>
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</tbody>
</table>

The regional scale distribution of uranium deposits and prospects (Figure 1) confirms the suggestion that the most important structural control on mineralisation occurred along E-W and NW-SE faults. NW-trending mineralized zones occur along the South Alligator Fault (including Coronation Hill and Sleisbeck), Nouralangie Fault and Bulman Fault (e.g. Beatrice). Large concentrations of uranium mineralisation also occur along the western continuation of the ~E-W Sawcut Fault (Koongarra) and Ranger Fault (Ranger).
8. Recommendations for further work

The structural model presented here remains speculative unless tested against field data. Fieldwork should be aimed to establish better control on the geometry and kinematics of faulting, including direct observations of fault planes, slickenlines and displaced markers.

Within the consent areas (Figure 1), the best area to conduct fieldwork would be north of the Spectre Fault, including the Writer, Slime and Stretch prospects. This area seems to have a relatively good representation of the major structures and includes individual mappable stratigraphic markers. The area also has relatively large concentration of uranium prospects, which seem to be structurally controlled.

Future geochemical work, already underway by Helen Wood, would be most beneficial for establishing possible links between the structural architecture and the alteration zones. This could be complemented by remote sensing mapping of alteration zones (e.g. Rajesh 2008).
References


