Cameco Australia Pty Ltd

# EXPLORATION LICENCE EL 3347

## CADELL – NT

## ANNUAL REPORT FOR THE PERIOD 28 JULY 2003 TO 27 JULY 2004

## CONFIDENTIAL

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**SUMMARY**

Cadell is a uranium exploration project area in northwest Arnhem Land, which is owned and operated by Cameco Australia Pty Ltd (Cameco). Cameco assumed ownership of this project in early 2003 following the dissolution of an unrelated joint venture. Cameco applied for and was granted an extension/renewal in July 2003, whereby the tenement is due to expire on the 27$^{th}$ of July 2005.

Exploration activities carried out during the 2003-2004 reporting period were designed to determine the uranium mineralisation potential of the Steven's Anomaly area in the northwestern corner of the tenement. This consisted of a helicopter assisted drilling program of one diamond drill hole, CDD001 (Table 1). The hole was spudded on the sandstone plateau immediately south of the airborne radiometric anomaly that defines Steven's Anomaly. A total of 339 m was drilled, intersecting 106.35 m of Mamadawerre Sandstone, resting unconformably above 232.65 m of Nimbuwah Complex. No mineralisation was intersected, but a number of geochemical and gamma ray anomalies were encountered in sandstone and basement near the unconformity. A small gouge zone present around 147 m appears to be responsible for a radiometric peak of 700cps. The largest uranium anomaly (18.2 ppm in total digest) is the only one that appears to be associated with significant labile uranium (12900 ppb in U_G950). Further spikes in the gamma log and/or refractory uranium geochemical data in the interval 280-290 m (up to 11.1 ppm) and at the end of hole at 335-339 are interpreted to indicate the presence of younger radiogenic pegmatite or granite dykes. Unfortunately, the vertical extent and geochemical characteristics of the basal >0.6 m thick radiogenic pegmatite interval was not tested because the hole was terminated. Lead isotope data are interpreted to indicate the derivation of lead in the lower 15 m of sandstone and upper 40 m of basement from a dominantly uranium source. $^{207}Pb/^{206}Pb$ is as low as 0.2 and $^{208}Pb/^{206}Pb$ is as low as 0.42.

In terms of diagenesis-, alteration- and weathering-related hydrous mineralogy (as determined by PIMA), the upper 90 m of the Mamadawerre Sandstone appears to have only a small clay component, mainly kaolinite, the concentration of which is vertically stratified. A chlorite-haematite assemblage occurs within the basal 15 m of sandstone above the unconformity, while sericite(illite)-haematite characterises the upper 13 m of the Nimbuwah Complex. A chlorite-sericite assemblage in the remainder of the Nimbuwah Complex is interrupted locally by more sericite-rich zones, which may relate to 'deep seated' alteration associated with faulting or local intrusions of dolerite or granite.

There are a number of lines of evidence supporting the former existence of a hydrothermal system at CDD001 involving transport of uranium through (and rarely introduction into) Mamadawerre Sandstone and Nimbuwah Complex above and below the unconformity, including:

1. narrow low-order labile uranium concentrations;
2. lead isotope data indicating a mainly U source;
3. stratified illite, chlorite and haematite alteration defined by lithology, whole-rock geochemistry and PIMA data;
4. stratified clay alteration and silicification in the Mamadawerre Sandstone, implying the former presence of stacked aquifers and aquicludes;
5. phosphatic lenses near the basal unconformity.

During the reporting period, Cameco undertook re-processing of existing 100 m spaced radiometric data, to resolve older Afmex targets and to define new anomalies for follow-up.

**Table 1 Work summary for EL3347 in 2003-2004**

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# INTRODUCTION

Cadell is a uranium exploration project covering exploration licence EL3347. The project is managed and operated by Cameco Australia Pty Ltd (Cameco). This report details exploration work completed by Cameco during the 2003-2004 licence year, following granting of an extension in July 2003.

The prime objective of the project is to discover economic 'unconformity style' uranium mineralisation within a geological environment similar to the known deposits of the Alligator Rivers Region, Northern Territory, and the concealed high-grade deposits of the Athabasca Region, Saskatchewan, Canada.

The project lands are underlain by a variety of granitic and metamorphic basement units of the Nimbuwah Complex, which are unconformably overlain by a cover sequence of Kombolgie Subgroup sandstone and volcanic units. Basement and cover are intruded by sills and dykes of the Oenpelli Dolerite. Favourable structures and hydrothermal alteration occur in the region. Several uranium occurrences have been identified in the project area, an indication of a favourable mineralising and alteration event.

The exploration activities planned for the 2003 field season were designed to determine the uranium potential of Steven's Anomaly. A drilling target was generated from interpretation of historical and previous AFmeco Mining and EXploration Pty Ltd (Afmex) outcrop sampling, drilling, mapping and airborne geophysical surveys.

## Location and access

EL3347 is located in Western Arnhem Land, Northern Territory on the Millingimbi (SD-5302) 1:250 000 scale topographic map sheet and the Goomadeer (5673) 1:100 000 scale topographic map sheet. The tenement is centred approximately 90 km northeast of Jabiru and 35 km southeast of the now rehabilitated mine site at Nabarlek (Figure 1). Access is either by air to the Nabarlek or Mamadawerre airstrips, or by road via the Arnhem Highway to Jabiru and then via Cahill's Crossing and unsealed roads towards Mamadawerre outstation.

**Figure 1** **Project location map**

The rugged nature of the sandstone, which overlies most of the Cadell tenement, means that access during the current and previous exploration programs was only possible by helicopter or by foot. In 2003, helicopter access was based from a semi-permanent field camp located on Tin Camp Creek, named 'Myra Camp', which was previously operated by Afmeco. Road access to Myra Camp is via the Arnhem Highway to Jabiru and bitumen road to Cahill's Crossing, then by dirt road via Oenpelli and Nabarlek.

## Tenure

The Cadell project Exploration Licence (EL3347) is located in western Arnhem Land (Figure 1). The licence was originally granted on 28th July 1997 for a period of six years. The tenement was explored by a Joint Venture comprising Afmex – operator (19.6%), S.A.E Australia Pty Ltd (19.6%), Kumagai Gumi Co. Ltd (19.6%), Uranerz

Australia Pty Ltd (19.6%), Pasminco Exploration Pty Ltd (formerly Savage Australian Exploration Pty Ltd) (19.6%) and Kunbohwinjgu Land Corporation Pty Ltd (2%). Cameco acquired 98% this project in early 2003 following dissolution of the Joint Venture; 2% remains with the Kunbohwinjgu Land Corporation Pty Ltd (2%). Cameco applied for and was granted a two year extension/renewal in July 2003, whereby the tenement is due to expire on the 27th of July 2005.

EL3347 originally covered an area of 770 $km^2$ and consisted of 230 blocks. Waivers of reduction in area were granted during the third year and another during the fifth year. A 50% reduction in area was carried out in the fourth year of tenure. The licence currently comprises 115 blocks or approximately 384 $km^2$.

The Cadell tenement is located within the Arnhem Land Aboriginal Reserve and is subject to a Consent Deed with the Northern Land Council on behalf of Traditional Owners. Cadell contains two classes of area that are sensitive or have cultural and/or social significance to the Traditional Owners. The most important of these classes is the 'No Go Areas', which are absolutely excluded from exploration access. The other class is 'Restricted Access Areas', where permission from the Traditional Owners must be sought before conducting exploration within the designated areas. As a result of prior arrangements between the earlier Joint Venturers and Traditional Owners, there has been no tenement-wide site clearance for Cadell. Only specific 'target' areas identified by the Joint Venturers were cleared for sites of significance, in an ad hoc manner.

## GEOLOGICAL SETTING

The project area lies in the western portion of the Pine Creek Orogen, roughly on the boundary of the so-called East Alligator and Nimbuwah structural domains (Needham, 1988; Needham and Stuart-Smith, 1980). The oldest rocks exposed in the region are gneiss, migmatite, granite and schist belonging to the Archaean Nanambu Complex. These are overlain by the Palaeoproterozoic Pine Creek Succession, which initiates with the Mount Howship Gneiss and the distinctive Kudjumarndi Quartzite, both belonging to the Kakadu Group. Psammitic rocks of the Kakadu Group are in turn overlain by the Cahill Formation (Mount Partridge Group) that hosts the main uranium ore bodies in the region (e.g. Ranger and Jabiluka). The Lower Cahill Formation consists of a basal calcareous unit that is overlain by a sequence of pelitic schists, meta-arkose and amphibolite. A well-defined amphibolitic unit at the top of the Lower Cahill Formation hosts the Nabarlek uranium deposit. The Upper Cahill Formation and overlying Nourlangie Schist consist of a monotonous sequence of meta-arkose, schist and amphibolite. The Nourlangie Schist is most likely a temporal correlative of the Wildman Siltstone further west and therefore equates to the upper Mount Partridge Group. Thin mafic sills and dykes of the Zamu Dolerite are locally prolific within the Pine Creek Succession.

The sedimentary and igneous rocks of the Pine Creek Succession are structurally complex, having undergone at least three recognisable phases of deformation (Thomas, 2002). They have also undergone high-temperature low-pressure metamorphism, including local migmatisation and remobilisation, during the ~1870 Ma Barramundi Orogeny (Page and Williams, 1988). The intensity of metamorphism varies across the region, however, a broad trend of increasing grade from southwest to northeast is apparent in the Kakadu-East Arnhem region. Distinctions based on metamorphic grade and protolith type have been made on regional maps (Needham, 1988).

1. Greenschist to amphibolite facies metasedimentary rocks is the west can generally be distinguished stratigraphically and are assigned to specific formations and groups.

2. Amphibolite to granulite facies metasedimentary rocks that lie between the Nimbuwah Complex in the east and the areas of better-defined stratigraphy in the west are mapped as Myra Falls Metamorphics. They incorporate outcrop that cannot be distinguished from the Zamu Dolerite and Mount Partridge or South Alligator Groups, but where a sedimentary precursor can be demonstrated (Needham, 1988). Rocks with a likely felsic igneous protolith are assigned to the Nimbuwah Complex (see below).

3. Magmatic rocks (mostly I type granite) and felsic to intermediate migmatite and granulite in the east are distinguished as the Nimbuwah Complex. These rocks have a relatively simple isotopic character (Page and Williams, 1988) that suggests an entirely igneous protolith. However, there is some doubt about this distinction, as much of the mapped Nimbuwah Complex around King River has a sedimentary protolith (e.g. lit par lit zones)

Metamorphic, igneous and sedimentary rocks of the Pine Creek Succession have been intruded by later Palaeoproterozoic 'post-orogenic' granites of the Cullen Batholith, including the Jim Jim, Nabarlek and Tin Camp Creek Granites (Jagodzinski and Wyborn, 1997).

The Pine Creek Succession and Cullen Batholith are locally overlain by felsic volcanic rocks belonging to the Edith River and El Sherana Groups, which are comagmatic with the Cullen Batholith (Jagodzinski, 1992). These units are thickest in the south and are generally absent due to erosion in the north in the Alligator River region.

The various basement units are unconformably overlain by the Kombolgie Subgroup, the basal unit of the late Palaeoproterozoic Katherine River Group, McArthur Basin (Sweet et al., 1999a; Sweet et al., 1999b). This subgroup consists of a series of sandstone formations (Mamadawerre and Gumarrirnbang Sandstones), which are divided by a thin basaltic unit (Nungbalgarri Volcanics). The sandstones form a flat-lying or shallow southeast-dipping strongly-jointed platform, called the Arnhem Land Plateau. The middle to upper part of the Katherine River Group is exposed ~50 km further to the southeast near Mount Marumba.

The Oenpelli Dolerite intrudes various levels of the stratigraphy in the Alligator Rivers region, including the Pine Creek Succession and Kombolgie Subgroup, forming sills, dykes, lopoliths and laccoliths. It is the youngest Precambrian rock unit outcropping in the area.

Deformation since the Katherine River Group includes transpressional movement along steep strike-slip faults of various orientations and possibly some shallow thrusting. However, it is clear that displacements have not been great, because the Arnhem Land Plateau is essentially coherent and offsets along lineaments are generally minor.

Erosional remnants of flat-lying Palaeozoic Arafura Basin and Cretaceous Carpentaria Basin are present as a veneer throughout the coastal zone of the Top End.

## Local geology of Cadell

The geological units present with the tenement are summarised in Table 2. Cadell lies at the southern extremity of the main surface expression of the Nimbuwah Complex, which occupies coastal plains and escarpment country north of the tenement, centred on King River. In this respect, it is a similar geographical and geological setting to the Nabarlek deposit 30 km to the west. Amphibolite to granulite facies gneiss, migmatite and granite of the Nimbuwah Complex crop out in the northwestern corner of the tenement, bounded from the McArthur Basin sedimentary succession to the south by a series of east- and north-east-trending faults, including the Goomadeer Fault (Figure 2).

| ROCK UNIT | THICKNESS | GEOLOGICAL AGE |
|---|---|---|
| Residual sand cover and laterite on tableland, silt and alluvium in valleys | Up to several meters | Cenozoic |
| Undifferentiated Cretaceous-sandstone, siltstone and pebble conglomerate | Remnant outliers 10-50 m | Cretaceous |
| Oenpelli Dolerite – intrusive dolerite sills and dykes | Up to 200 m | Palaeoproterozoic |
| Gumarrirnbang Sandstone – quartz arenite with minor pebble conglomerate | 100-400 m | Palaeoproterozoic |
| Nungbalgarri Volcanics – vesicular and amygdaloidal basalt | 50-130 m | Palaeoproterozoic |
| Mamadawerre Sandstone – quartz arenite, quartzite and conglomerate | 100-250 m | Palaeoproterozoic |
| Nimbuwah Metamorphic Complex – foliated granite and granodiorite; gneiss, migmatite | Unknown | Palaeoproterozoic |

**Table 2 Summary of rock units exposed in Cadell**

**Figure 2 Local geology of Cadell showing drillhole location**

Sedimentary and volcanic rocks of the Palaeoproterozoic lower Kombolgie Subgroup unconformably overlie the majority of the tenement, including the Mamadawerre Sandstone, Nungbalgarri Volcanics and Gumarrirnbang Sandstone (Sweet et al., 1999a). The 100-250 m thick Mamadawerre Sandstone, the oldest formation of the Kombolgie Subgroup, occupies the northwestern third of the tenement, where it forms a deeply dissected plateau surface (Figure 2). This area is composed largely of bare rock with sparse areas of shallow sandy soil supporting Spinifex and scrub. Sandstone is quartzose to lithic and fine- to very coarse-grained with a variety of fluviatile to shallow high-energy marine bedforms, including trough and planar cross-beds (Ojakangas, 1979).

Mamadawerre Sandstone is unconformably overlain by the Nungbalgarri Volcanics. The contact is expressed locally as 100-500 m diameter subcircular depressions ('dome and basins'), with the upper sandstone surface interpreted to represent the palaeotopographic surface of giant lunate current ripples or aeolian sand dunes with the volcanic draped over the top (Nott and Ryan, 1996). It may also represent large dewatering structures formed as a result of hot volcanic rocks draped over water-saturated sediments, which were deposited in estuarine conditions (Needham, 1978). The Nungbalgarri Volcanics consist of multiple vesicular and amygdaloidal basaltic flows. The stratigraphic thickness of the volcanic unit is quite variable between 50 m and 130 m, however, it may also be locally absent (Carson et al., 1999).

The Gumarrirnbang Sandstone, which occupies the southeastern third of the tenement (Figure 2), unconformably overlies the volcanics, comprising fine- to coarse-grained quartz sandstone with scattered pebbly units. Sedimentary structures include planar and trough cross-stratification, ripples and horizontal planar stratification, suggesting a proximal to distal fluvial braided stream and estuarine depositional environment (Sweet et al., 1999b).

Sills and dykes of Oenpelli Dolerite occur within basement in the northwestern corner of the tenement, at Steven's Anomaly, and within the Nungbalgarri Volcanics in the south (Figure 2). However, it has not been intersected within any of the drill holes on the tenement.

Undifferentiated Cretaceous rocks have been mapped in the central part of the tenement (Figure 2). The rocks are exposed as weathered outcrops of lateritised sandstone and siltstone forming resistant mesa-like ridges.

The most visibly obvious structures in the tenement are deeply incised linear features of various orientation and significance, including fractures, joints and small faults (Figure 2). The largest faults, based on perceived displacement, are the: (i) north to north-northwest trending Daniel Fault that has about 30 m vertical throw; (ii) northeast trending Goomadeer Fault where Nimbuwah Complex steeply abuts Mamadawerre Sandstone and; (iii) east to east-southeast trending Steven's Fault, where Nimbuwah Complex and Oenpelli Dolerite steeply abut Mamadawerre Sandstone.

## PREVIOUS EXPLORATION

Previous exploration in Cadell has been carried out by Afmex in the period 1997 to 2002, and is outlined chronologically below and is summarised in Table 3.

**Table 3** **Summary of previous exploration in Cadell from 1997 to 2002**

### 1997-1998

Exploration activities carried out during the first year of the licence included a helicopter-borne magnetic-radiometric geophysical survey, followed up by ground reconnaissance over 67 selected radiometric anomalies.

Five different types of radiometric anomalies were observed over the surveyed area, which are either related to uranium-thorium and or radon/radium sources. The most interesting anomaly, Steven's Anomaly, is located in the northwest part of the project area, where uranium was found associated with gold in altered Oenpelli Dolerite.

**1998-1999**

Five helicopter-supported diamond drill holes totalling 1278.1 m, were drilled on EL3347 during the second year of exploration (Figure 2). The aim of the program was to test the geological nature of the underlying basement, with a strong focus on the major structural zones. No mineralisation was encountered.

During July 1998, Steven's Anomaly was gridded to provide a base for a ground radiometric survey. Radiometric readings were taken every 25 to 50 m, along 100 m spaced north-south grid lines. The mapping and ground radiometrics completed over the area confirmed that the radioactive anomaly is confined to the dolerite close to its faulted contact with the Mamadawerre sandstone. A grab sample collected in talus at the anomaly with a maximum radioactivity of 8000 cps (SPP2) showed yellow uranium oxides in a clay and specular hematite matrix. The grab sample assayed 3.96% U, 1.3% Pb and 2.2% $P_20_5$.

**1999-2000**

Five helicopter-supported drill holes were completed during the third year of exploration, comprising 1359.3 m of diamond drilling (Figure 2). Nimbuwah Complex granitoid forms basement in the area and is overlain by a variable thickness of Kombolgie Formation sandstone. No mineralisation was encountered.

Five NanoTEM ground EM traverses were carried out across the Daniel Fault in the eastern part of the tenement and a test regional gravity line was completed in the west of the tenement. A helicopter supported regional stream sediment survey was also carried out. Results were poor.

**2000-2001**

No exploration work was carried out on the licence during the forth year of tenure due to fundamental changes in the structure of the Joint Venture, as it existed previously and due to budget re-allocation.

**2001-2002**

No exploration work was carried out on the licence during the fifth year due to budget re-allocation and the impending withdrawal of Afmex from the project.

**2002-2003**

No exploration work was carried out on the licence during its sixth and final year of tenure due to budget re-allocation and the withdrawal of Afmex as operator. Work by Cameco Australia during the 2003 field season is reported below.

## EXPLORATION IN 2003-2004 BY CAMECO

Exploration for the first year of a two year extension to EL3347, under Cameco's operatorship, consisted of data review, reprocessing of geophysical survey data and a single helicopter-assisted diamond drill hole at Steven's Anomaly, CDD001 (Table 1). All digital data, which has been acquired by Cameco has been submitted on CD with this report.

### Data review

Data reviewed during the reporting period included: radiometrics, magnetics, gravity, drilling, outcrop observations, downhole and outcrop geochemistry, stream sediment geochemistry, geological mapping and landsat. The results of the review are summarised below:

- A number of discrete radiometric anomalies identified by Afmex had not been followed up in any way and require field investigation;
- Numerous radiometric anomalies that were followed up by Afmex are not adequately explained and require further examination. For example, geochemical analysis of samples from some anomalies showed elevated U and Au values, for which no explanation was provided and no supplementary work was carried out;
- The area near Nei-igmut Creek (Figure 2) has anomalous surface and drillhole geochemical anomalism and has a broad U radiometric response. It requires follow-up ground work to establish the subsurface geology and distribution of radioactive elements, and to generate a discrete U target;
- Most of tenement remains untested for blind U deposits below Kombolgie Subgroup and new remote sensing and geophysical techniques and empirical models need to be employed to generate targets.

### Drilling

Drilling was carried out by Underground Diamond Drilling (UDD) using a helicopter-transportable diamond rig. Location and technical information can be found in Table 4 and Figure 2. The hole was collared 150 m west of KBW1, which had been designed by Afmex to test the same target (Steven's Anomaly), but failed to intersect uranium mineralisation. In the following section, a brief introduction into Cameco sampling techniques and analytical methodology is provided. This is followed by the drilling results, including lithology, alteration and structural logs, gamma logs, geochemical analyses, reflectance spectrometry and petrography.

**Table 4 Drill hole summary for Cadell for 2003-2004**

#### <u>Methodology</u>

##### <u>*Sample processing techniques*</u>

Samples are routinely cut from each row of the core tray and halved using a core saw. One half is described (grain-size, Munsell colour, and magnetic susceptibility, friability) and measured for spectral parameters using the PIMA II spectrometer. These samples are retained within the Cameco storage facility in Darwin. The other half of the sample is used for geochemical analysis. Selected samples were sent for thin sectioning and petrographic description. Logging codes are summarized in Appendix 1.

**Appendix 1 Cameco logging codes**

*Analytical methods*

53 drill core samples from CDD001 were submitted to Northern Territory Environmental Laboratories Pty Ltd (NTEL) for analysis, for multi-element analysis. Sample preparation was carried out at Pine Creek. Four separate methods were used to analyse for 65 elements and four isotopes. The geochemical methods used are detailed in Appendix 2.

**Appendix 2 Standard geochemical methods used by Cameco**

*Major and minor element geochemical interpretation methodology*

The Refractory Uranium Index or 'RUI' (nominally U/Zr*100) is used in this report as a guide to how much uranium is contained in the principal refractory uraniferous silicate phase (zircon) in sandstone, basalt, dolerite and granite (the main rocktypes in the tenement). This ratio is generally consistent in any given homogeneous rock unit, unless uranium is present as: (i) non-refractory magmatic or hydrothermal uranium-bearing minerals (e.g. uraninite, pitchblende, torbernite); (ii) a lattice component of other silicate phases (e.g. allanite, feldspar, apatite, monazite, baddeleyite) or; (iii) compounds or ligands adsorbed to grain boundaries and clays. These accessory minerals are absent or insignificant on most occasions, and RUI is considered a good proxy for U_G950 (weak acid leach or 'labile' uranium) or can be used effectively in conjunction with this analysis type. If a sample exhibits an RUI above background for its particular rock unit, it is deemed anomalous. Importantly, this ratio is essentially unchanged by the partial dissolution of zircon by hydrothermal fluids.

RUI is amenable to vectoring, as it excludes the inherent influence of ubiquitous accessory phases like zircon. Inevitably, a dataset of background values for each rock unit will be compiled and an average value determined. RUI will then be a useful provenance tool. In addition, normalisation factors can be then applied to the RUI, making it a useful correlative tool across various rocktypes and rock units.

Some likely examples from the Alligator Rivers region of rock units with heterogeneous zircon populations with inconsistent or non-systematic U/Zr ratios are:

- Archaean and Palaeoproterozoic metasedimentary complexes (e.g. Nanambu Complex, Myra Falls Metamorphics)
- Magmatically differentiated Palaeoproterozoic granites (pegmatite related to Cullen Batholith or Nimbuwah Complex)

Some likely examples of internally homogeneous rock units are:

- Palaeoproterozoic granites and orthogneiss (e.g. Nimbuwah Complex, Tin Camp Creek Granite, Nabarlek Granite)
- Kombolgie Subgroup sandstones (e.g. Mamadawerre and Gumarrirnbang Sandstones)
- Unmetamorphosed mafic units (Nungbalgarri Volcanics, Oenpelli Dolerite)

Loss on Ignition (LOI), K2O, CaO and Al2O3 are also used as a gauge of the total hydrous aluminosilicate component in the rocks, which enables an accurate assessment of alteration mineralogy and provides quality control for the PIMA data. These geochemical analyses, together with the RUI and PIMA, permit the assessment of the geochemical behaviour of the rock system during deposition and diagenesis. This, in turn, enables the delineation of alteration systems related to uranium mineralisation.

*Lead isotope interpretation methodology*

$^{204}$Pb, $^{206}$Pb, $^{207}$Pb and $^{208}$Pb are routinely determined by Cameco as a means of vectoring uranium transport (Holk et al., 2003). Three of the four common isotopes of lead can be produced by the decay of uranium and thorium. $^{204}$Pb is the only lead isotope not influenced by these radiogenic processes. $^{206}$Pb is the final daughter product of the decay of $^{238}$U whilst $^{207}$Pb is produced during the decay of $^{235}$U. The decay of $^{232}$Th is responsible for production of $^{208}$Pb. For a rock containing uranium and/or thorium, the concentrations of these isotopes are gradually increasing with time while the amount of $^{204}$Pb held within the rock remains constant.

The uranium and thorium isotopes responsible for the gradual increase in the concentrations of radiogenic lead with time have variable decay rates. $^{238}$U has a half-life of 4.47 billion years and $^{235}$U has a half-life of only 0.70 billion years. For thorium, the half-life of $^{232}$Th is 14.01 billion years. These differences in decay rates make it possible to determine fluid history related to radioactive and radiogenic isotopes as follows.

(1) Increasing radiogenic lead concentrations through the decay of uranium- and thorium-bearing minerals (closed-system scenario).

(2) Post-mineralization precipitation of radiogenic lead during interaction with basinal fluids and volatiles that have leached lead from uranium or thorium-rich sources (open-system scenario).

(3) The delineation of exploration vectors that may point toward economic uranium deposits.

The general parameters determined for sandstone analysis are:

**$^{207}$Pb/$^{206}$Pb** – a monitor of the influence of uranium on the system.

- $^{207}$Pb/$^{206}$Pb between 0.95 and 1.15
  Indicates <u>no addition of radiogenic lead from the decay of uranium</u>.

- $^{207}Pb/^{206}Pb$ between 0.80 and 0.95
  Typical range of isotopic ratio for system equilibrated with 'typical' crust.
- $^{207}Pb/^{206}Pb$ between 0.4 and 0.80
  Anomalously low ratio indicates contribution of uranium-source lead to system.
- $^{207}Pb/^{206}Pb < 0.40$
  Extremely low isotopic ratio indicates major addition of lead formed by the radioactive decay of uranium to rock.

**$^{208}Pb/^{206}Pb$** – parameter that determines the relative influence of thorium versus uranium in lead isotopic system

- $^{208}Pb/^{206}Pb > 2.5$
  Th is the dominant element contributing lead to system through radioactive decay.
- $^{208}Pb/^{206}Pb$ between 1.60 and 2.50
  Range of isotopic ratio for system equilibrated with 'typical' crust.
- $^{208}Pb/^{206}Pb$ between 0.5 and 1.60
  Greater contribution of uranium-product lead to system.
- $^{208}Pb/^{206}Pb < 0.50$
  Uranium is the dominant (and probably only) radioactive element contributing to system.

*Reflectance spectroscopy (PIMA)*

Reflectance spectroscopy (PIMA) analysis was completed using the PIMA II short-wave infrared spectrometer on all drill core samples collected. This instrument measures the reflected energy from a sample in the short wave infrared (SWIR) region of the energy spectrum. The sampling area on the rock specimen that is measured is permanently marked. Multiple measurements are occasionally taken, particularly if variations in spectral features are noted. The spectra are converted to an ASCII format and processed using "The Spectral Geologist" (TSG) developed by AusSpec International. TSG is routinely used to process all spectral data. The SWIR spectra, once processed, provide a mineral identification utilising internal software pattern matching algorithms called 'The Spectral Assistant' (TSA).

*Thin-sections and petrography*

Thin sections were prepared by Pontifex and Associates from 13 core samples collected from diamond drill hole CDD001. The samples include two of the sandstone and eleven variably altered granitoids.

## Results and interpretation

*Summary*

Diamond drill hole CDD001 was drilled to a total of 339 m, spudding about 200 m south of the principal radiometric anomaly that defines Steven's Anomaly.

The hole was drilled at 70 degrees to the north to try and intersect the contact between the Oenpelli Dolerite and Nimbuwah Complex, below the Mamadawerre Sandstone unconformity. Instead, the drill hole passed through Mamadawerre Sandstone to 106.35 m, where basement of Nimbuwah Complex was intersected, continuing through to termination depth at 339 m.

The drill hole was collared in fine- to medium-grained bleached to haematitic Mamadawerre Sandstone (Appendix 3; Appendix 4). Many quartz-filled vugs are present on the surface along with drusy quartz-filled tension veins oriented in a north-south direction. Large drusy quartz vugs were encountered at 46.6 m, 59.3 m and a larger cavity was intersected at 76 m downhole. The sandstone grades into a coarser unit at 89 m before becoming very chloritised and haematitic at 90.5 m. A small clay gouge zone at 90.5 m defines this abrupt change and the chlorite-haematite alteration continues until 102.8 m where a change into finer grained silicified sandstone occurs.

**Appendix 3** **Detailed lithology, alteration and structure for drill hole CDD001**

**Appendix 4** **Point structure data for drill hole CDD001**

The unconformity at 106.3 m is represented by massive specular haematite and chlorite and is in contact with sericite-haematite altered granodiorite of the Nimbuwah Complex. The remainder of the hole to 339 m is granodiorite with lesser zones of aplite and pegmatite.

A small gouge zone present around 138 m appears to be responsible for a radiometric peak of 700cps (maximum value in downhole log; Figure 3). A slight intensity increase in sericite alteration appears to be the only visible difference to other zones within the granodiorite.

**Figure 3** **Gamma log (total count) for drill hole CDD001**

*Major and minor element geochemistry*

Geochemical results for drill hole samples from CDD001 can be found in Appendix 5. No uranium anomalies were noted in the results. The highest U value is 18.2 ppm at 125-133 m in the Nimbuwah Complex, which does not coincide with a major spike in the gamma curve (Figure 3; Figure 4; Figure 5). The main gamma spike at 138 m falls within the composite sample 133-142 m, with 5.7 ppm U. Uranium is therefore mildly elevated over an interval exceeding 17 m. A series of small gamma spikes in the basal Mamadawerre Sandstone at 97-106 m coincide with up to 11 ppm U (Figure 4; Figure 5). Otherwise, nearly all elements are within or below expected lithological background values.

**Appendix 5** **Geochemical analyses for drill core in Cadell for 2003-2004**

**Figure 4** **Gamma log (equivalent concentration Uranium) for drill hole CDD001**

**Figure 5** **Downhole geochemical plots for CDD001, including U, RUI, U_G950 and Pb isotopes**

With the exception of the basal 15 m, the Mamadawerre Sandstone is characterised by low uranium, in the range 0.5-1.7 ppm, associated with a fairly constant RUI of 0.6-3.3 (average 1.8) and Zr in the range 27-205 ppm (average 75 ppm). In addition, sandstone has very low LOI (below detection limit of 0.1% in most cases), Al2O3 (0.3-2.5%) and K2O (below 100 ppm detection limit in most cases). These data suggest that the Mamadawerre Sandstone has a very small hydrous component (e.g. clays). Zirconium is generally lower than the expected range for sandstone with a heavy mineral content and could be interpreted two ways: (i) the sandstone is exceptionally mature and contains very few heavy minerals or; (ii) pre-existing detrital zircons have undergone partial dissolution by hydrothermal fluids (along with their contained uranium). At present, petrogenetic studied aimed at distinguishing these two scenarios have not been carried out.

The basal 15 m of the Mamadawerre Sandstone is different to the rest of the formation above, with elevated LOI (3.2-5.1%), Al2O3 (3-21%), K20 (0.3-2.4%), Fe2O3 (5.9-12.5%), Zr (up to 671 ppm) and U (up to 11 ppm). The RUI is mildly elevated in the range 1.1-6 (Figure 5). These data suggest that this interval contains abundant labile detrital materials (clays, feldspar, lithic fragments etc) and heavy mineral placers (mainly zircon), as expected near the basal unconformity of a new basin system. The lowermost sample of this formation has an elevated RUI (6) that is associated with a high U_G950 of 1020 ppb (uranium liberated by a weak acid leach; Figure 5), suggesting the presence of a small but detectable non-refractory uranium phase immediately above the unconformity. The high iron content of the basal sandstone interval also points to strong haematisation at this level.

The majority of the unconformably underlying Nimbuwah Complex granitoid has moderate LOI (0.9-5.6%), Al203 (10.5-15%) and K2O (2.6-6.5%), associated with variable U (0.6-18.2 ppm) and Zr (48-282 ppm). RUI is generally in the range 0.5-2, consistent with no uranium anomalism and a typical weakly-altered granitic lithology. However, there are several specific intervals of elevated U, RUI and U_G950. The profile of the gamma log (Figure 3; Figure 4; Figure 5) does not necessarily correlate exactly with the downhole geochemistry, indicating that the radiogenic intervals are too thin to be resolved using broad composite geochemical sampling.

The uppermost anomalous interval on the gamma log is 125-140 m, which coincides with elevated RUI (up to 23), accompanied by high U (up to 18.2 ppm) and U_G950 (up to 12900 ppb; Figure 4; Figure 5). These data indicate the local presence of non-refractory uranium phases several tens of metres below the unconformity.

Further spikes in the gamma log in the interval 280-290 m coincide in part with elevated RUI (up to 7.8) and high U (up to 11.1 ppm) over the geochemical sampling interval 257-292 m (Figure 4; Figure 5). However, there is no coincident spike in U_G950, indicating that the RUI value accompanies a rock type with high refractory uranium and low labile uranium. This is unlikely to be Nimbuwah Complex granite, but could indicate the presence of younger pegmatite or granite dykes with high RUI. This contention is supported to some extent by the lithological logs (Appendix 3).

Interestingly, high U, RUI and U_G950 (1340 ppb) occur at the end of hole at 335-339 m (Figure 5). This is not reflected in the gamma log (Figure 4), which terminates at 333 m. This anomalous interval includes a >0.6 m thick section of pegmatite at the end of hole from 338.4 to 339 m. Presumably, this pegmatite is responsible for the elevated labile uranium.

*Lead Isotopes*

$^{207}$Pb/$^{206}$Pb and $^{208}$Pb/$^{206}$Pb isotopic ratios for CDD001 follow a similar pattern to each other and indicate differing contribution of uranium to the isotope system at various intervals of the stratigraphy (Figure 5). In the Mamadawerre Sandstone, these ratios are generally in the range consistent with a 'dominant contribution from uranium'. In fact, $^{207}$Pb/$^{206}$Pb is as low as 0.26 immediately above the basal unconformity, consistent with a 'major contribution from uranium'. These two ratios are even lower in the Nimbuwah Complex for ~40 m immediately below the unconformity, with $^{207}$Pb/$^{206}$Pb as low as 0.2 and $^{208}$Pb/$^{206}$Pb as low as 0.42. Lead isotopes therefore suggest fluid phase transport and/or introduction of uranium into sandstone and basement immediately above and below the unconformity.

The low lead isotope ratios bounding the unconformity are in marked contrast to the remainder of the underlying Nimbuwah Complex, which is generally in the range of 'typical crust' or 'minor elevated uranium contribution' (Figure 5). The only exceptions, with depressed $^{207}$Pb/$^{206}$Pb and $^{208}$Pb/$^{206}$Pb isotopic ratios, coincide with the zones of elevated RUI and/or U_G950 discussed in the geochemistry section above (257-292 m and 335-339 m). This supports the conclusion that anomalous uranium occurs within intervals of younger pegmatite or granite in the Nimbuwah Complex (Figure 4). Perhaps the most important interval is the lower one, as the drill hole terminated within it and it's thickness and radiogenic characteristics were not fully assessed.

*Reflectance Spectrometry*

Raw PIMA data for CDD001 are presented in Appendix 6. The upper part of the Mamadawerre Sandstone (0-89 m) has two discrete spectral responses – one that is due to kaolinite-halloysite, and the other set of 'null' values apparently due to a lack of hydrous phases (in agreement with the geochemistry). These are stratified to some degree on a 20 m scale, suggesting either: (i) vertically stacked units of variable facies and mineralogical maturity; or (ii) stacked aquifers and aquicludes that have undergone different diagenetic histories. The latter is favoured because there is no apparent coincidence with major or minor element geochemistry through this interval. The lower 15 m of the Mamadawerre Sandstone (89-105 m) is characterised by illite and chlorite of various composition.

**Appendix 6  PIMA data for CDD001**

PIMA data for the underlying Nimbuwah Complex are also stratified, presumably due to alteration associated with the unconformity uranium mineralising system and/or nearby intrusions. The main components of the Nimbuwah Complex are sericite and chlorite. Sericite is distinguished here as the low-crystallinity variety 'illite' only where it has a distinct water peak at ~1912 nm. Where illite and muscovite (high-crystallinity variety of sericite) occur as a mixture, they are grouped as sericite. Stratified variation in sericite composition is also indicated by the vertical change in the wavelength of the AlOH peak. A summary of downhole variation is as follows:

- 105-118 m – illite with a strong AlOH peak at short wavelength (2198 nm).
- 118-172 m – sericite (70%) with long wavelength AlOH peak (2212 nm; indicating and Fe/Mg component?), plus chlorite (30%) of Mg to intermediate composition.
- 172-267 m – sericite (50%) with short wavelength AlOH peak (2198 nm) and frequent Na-rich paragonitic composition (supported by geochemical data), plus chlorite (50%) with Mg, Fe and intermediate composition, together with minor (<5%) biotite (probably primary magmatic). 172 m may represent the limit of significant unconformity-associated alteration or pre-Kombolgie weathering, as it coincides with the appearance of biotite, an increase in the muscovite/illite and chlorite/sericite ratios, and a dramatic increases in Na and Ca (Appendix 4). The petrology report also supports a gross downward decrease in alteration intensity.
- 267-288 m – sericite (50%) and chlorite (50%) as for the 172-267 m interval, but AlOH peak is notably longer in wavelength (2210 nm).
- 288-339 m – muscovite (70%) with short wavelength AlOH peak (2198 nm), plus chlorite (30%) with mainly Fe composition. This may relate to more 'deep seated' alteration, perhaps associated with local intrusions of dolerite or granite.

*Petrography*

A list of samples and individual descriptions are provided in Appendix 7. A summary of the key observations follows.

**Appendix 7  Petrographic report for Cadell**

Mamadawerre Sandstone samples are comprised of coarse- to very coarse-grained quartz-rich sandstone. Higher up, sandstone has optically continuous quartz overgrowths and is also more weathered, with interstitial limonite-stained clay and scattered voids. Lower down, sandstone contains chlorite-rich to apatite-rich lenses, as well as minor limonite or earthy haematite. This is verified in the whole-rock geochemistry, which indicates the presence of phosphates near the basal unconformity (Appendix 5).

The uppermost Nimbuwah Complex granites are foliated, grading downwards into massive varieties to the end of hole. Two samples of graphic granite occur, at 115.1 m and 134.8 m, with quartz diorite at 126 m, granodiorite at 151.75 m, 165.6 m and 283.9 m and monzogranite at 294.8 m and 330.7 m. Ignoring the graphic granite samples, there is a suggestion of increasing 'fractionation' downhole, with quartz and K-spar both more abundant in the deeper samples. There is also an overall decrease in alteration downhole, with the monzogranite at 298.4 m apparently the least altered of the coarse granitoids.

A probable dyke of microsyenogranite at 330.7 m is even fresher, but seems to have been intruded into incompletely solidified monzogranite, with a transitional contact. This dyke also contains rare garnet, possibly spessartine, and may be more highly fractionated than the other granitoids.

Many of the granitoids contain muscovite and may be hydrous S-types, but one sample of foliated granitoid (at 112.9 m) seems to contain sphene pseudomorphs, which are more typical of I-type granitoids. Rare allanite at 330.7 m may also indicate an I-type affinity, but many of the samples were biotite-only granitoids of uncertain affinity. Zircon was seen in several samples, usually coarse-grained, with maximum grainsizes varying from 0.25 mm to 0.5 mm. Sericite is the main secondary mineral, with chlorite, clays, leucoxene and tourmaline also common, but prehnite was seen only in monzogranite at 330.7 m. Veins were noted in two samples, with sericite veins at 115.1 m and chlorite-carbonate veins at 298.4 m.

**Geophysics**

An airborne radiometric survey was flown by Afmex over the Cadell project in 1997 at 100 m line spacing. This data was utilized in 1998 and 1999 to follow up a total of 81 airborne radiometric anomalies, although 60 additional anomalies were identified but never followed up. Radiometric (256 channel) noise reduction techniques can be instrumental in identifying subtle uranium anomalies. It was for this reason that Afmex applied NASVD (Noise Adjusted Single Value Decomposition) processing in 2002. However, the reprocessed data was never utilised for further anomaly identification (personal communication, A. Bisset, 2003).

In 2003, Cameco observed that the 2002 reprocessing had been poorly applied, with some signal loss. Consequently, Pitt Research Pty Ltd was contracted to reprocess the historical airborne radiometric data including noise reduction. This reprocessed data is considered to be superior to the previous data and has been used to identify new (subtle) airborne radiometric anomalies that might require ground-truthing. Several image processing techniques have been utilised during the analysis including: U; UxU/TH; RGB=U,Th,K; U/Uav (450x450 m) and K/Kav (450x450 m). New anomalies have been prioritised in a qualitative manner (1-high to 3-low), based on the following criteria:

- Amplitude of anomaly
- Dominance of U channel response relative to K and Th

- Presence of the anomaly in multiple images (i.e. robustness)
- Geological parameters, including:
  - Overall prospectivity of the area
  - Contained lithology (e.g. anomalies within cover sandstone generally more highly regarded than in Nungbalgarri Volcanics or Oenpelli Dolerite)
  - Proximity to surface features such as laterite
  - Proximity to faulting

### Expenditure for 2003-2004

Expenditure on EL3347 during the 1st year of licence renewal totalled $146,011.89 (Table 5). For a typical work program, the main expenditure items are: payroll costs including geologists, consultants and field assistants; drilling costs; airborne geophysical survey contractor costs; fuel and air charters; camp costs; NLC administration costs; analytical expenses; equipment; travel; communications. Associated overheads such as office costs are allowable, but have not been included here. Compensation payments made to the NLC and DBIRD property rentals do not constitute reportable exploration costs.

**Table 5 Financial summary for Cadell for 2003-2004**

## CONCLUSIONS

The exploration work completed by Cameco during the 2003-2004 reporting period showed overall poor results. Diamond drill hole CDD001 failed to establish anomalous uranium concentrations in the subsurface at Steven's Anomaly (maximum 18.2 ppm U in total digest and 12900 ppb in weak acid leach) and is interpreted to have been poorly placed to effectively test the target, which is further to the north. However, there are a number of low-order gamma ray peaks, alteration and geochemical patterns that support the 'unconformity model', where fluid flow and uranium transport has taken place in labile-rich lithologies at the basal McArthur Basin unconformity and in the upper 15-80 m of the Nimbuwah Complex. Further, the U potential of narrow radiogenic intrusions in the lower part of the hole was not tested. These may represent a new target style.

## RECOMMENDATIONS

Future work on EL3347 should include further drill testing of Steven's Anomaly, to ascertain the source of the large east-west oriented radiometric anomaly. Drilling should take place to the north of CDD001, closer to the actual anomaly. Instead of testing the basement-sandstone unconformity as previous drill holes have done, future drilling should investigate other possible mineralisation models, perhaps involving the Oenpelli Dolerite. The drill site(s) should be chosen after field investigation of uranium channel anomalies in the reprocessed airborne radiometric survey, and following preliminary prospecting and mapping along the length of Mamadawerre Sandstone-Nimbuwah Complex-Oenpelli Dolerite contacts.

Nei-igmut Creek, in the eastern tenement area along the north-northwest trending Daniel Fault, also requires detailed sampling, ground-based investigations and perhaps drilling, to explain or test a number of ground and drill-hole anomalies from previous explorers.

Other parts of the tenement should also be ground checked to determine if previously recognised geochemical and radiometric anomalies have been incompletely tested. New and subtle anomalies that were generated from the reprocessed geophysics also need be ground tested in the future.

TEMPEST, Hymap and other remote sensing and geophysical tools should also be used to identify blind targets under thick cover of the Mamadawerre Sandstone. Ground follow up should then be undertaken to identify possible leakage of uranium or radon along small structures above the blind anomalies.

## WORK PROGRAM FOR 2004-2005

Work planned for the dry season of 2004 for the Cadell tenement will include up to three helicopter-supported diamond drill holes. Up to two holes are planned at Steven's Anomaly to test geological concepts and to further investigate radiometric and surface geochemical anomalies. The first hole will be spudded on the radiometric anomaly that defines Steven's and will be drilled inclined southward to intersect the contact between Mamadawerre Sandstone and Oenpelli Dolerite or Nimbuwah Complex at ~100 m depth. It will also directly test the subsurface of the anomaly itself. The radiometric results and orientation of the bounding structure determined from this first hole will be used to site a second hole, if warranted, up to 300 m deep.

It is also possible that, pending availability of funds, Cameco will fly a small (12 $km^2$) area of high-resolution aeromagnetics and radiometrics over the Steven's Anomaly. Flying height for the survey will be about 50 m.

Field examination of the Nei-igmut Creek area will also be undertaken, with the view of developing a target for drilling. One tentative ~300 m deep helicopter-supported drill hole is planned for the 2004-2005 reporting period, but this could be postponed until 2005 if a target cannot be determined. A TEMPEST survey is planned for this area (25 $km^2$), dependant on funding, with a flying height of 120 m. This will identify conductive targets along the fault zone.

Cameco will also fly a Hymap hyperspectral survey over the entire tenement during the 2004-2005 reporting period, to help delineate alteration systems developed in the sandstone/basalt plateau above blind unconformity-type uranium deposits. Flying height for the survey will be 2 km.

It is anticipated that expenditures on EL3347 for the next reporting period will be $150 000 to complete the proposed exploration work. Any work planned for this tenement during subsequent years will be dependent upon results.

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