NABARLEK WEST PROJECT

EL28245 Nabarlek West C

Annual and Final report for the period

27 September 2010 to 24 October 2012

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This report details activities for the Nabarlek West tenement, EL28245 for the period to 26 October 2012. The Nabarlek West tenement is subject to a Joint Venture agreement between UXA Resources Limited 51% and RIL (Australia) Pty Ltd 49% where UXA has been appointed as the project operator. The tenement is considered prospective for unconformity style uranium mineralisation analogous to known unconformity related uranium deposits located throughout the Alligator Rivers Uranium Field. During the third year of tenure no exploration activities took place.

The Nabarlek West C tenement is considered prospective for unconformity style uranium mineralisation since it comprises similar tectonic setting, lithology and structure to known deposits within the region, but no exploration was carried out and the tenement will be relinquished.
Executive Summary

This report details exploration activities for the Nabarlek West C tenement, EL28245 for the period from 26 September 2011 to 26 October 2012. The Nabarlek West C tenement is subject to a Joint Venture agreement between UXA Resources Limited 51% and RIL (Australia) Pty Ltd 49% where UXA has been appointed as the project operator.

The tenement is considered prospective for unconformity style uranium mineralisation analogous to known unconformity related uranium deposits located throughout the Alligator Rivers Uranium Field.

Key criteria for uranium mineralisation within the region include reduced basement lithologies in unconformable contact with overlying oxidized, quartz-rich sandstones that provide an ideal environment for the accumulation and transportation of uranium-bearing fluids.

Within the Nabarlek West C tenement, Neoproterozoic Kombolgie Subgroup sandstone provides a suitable cover sequence, while the most prospective basement lithologies include reducing units within Lower Cahill Formation, Myra Falls Metamorphics (lit-par-lit gneiss zone) and possibly Zamu dolerite, Oenpelli Dolerite and Nungbulgarri Volcanic member.

Palaeoproterozoic basement sequences within the Nabarlek West tenements are mostly concealed either by sandstone, volcanics and conglomerate of the Kombolgie Formation or Tertiary and Quaternary laterite, silt and sand.

During the third year of tenure, no exploration activities were conducted and the tenement will be relinquished.
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1 Introduction

This report encompasses the Nabarlek West C tenement, EL28245, for the period 27 September 2011 to 26 October 2012. The report is prepared on behalf of the joint venture collaboration between UXA Resources Limited and RIL (Australia) Pty Ltd. The tenement is still considered prospective for unconformity-style uranium mineralisation analogous to the Ranger, Jabiluka and Nabarlek deposits.

2 Tenure

The Nabarlek West C tenement was issued to UXA Resources Limited on 27 September 2010 for an initial period of 6 years. Subsequently, 49% ownership of the tenements was transferred to RIL (Australia) Pty Ltd on 31 March 2011 and UXA remains the nominated tenement operator (Table 1). EL28245 was surrendered on 24 October 2012.

Table 1: Tenement Details

<table>
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<tr>
<th>EL No/Name</th>
<th>Registered Holder</th>
<th>Area (km²)/blocks</th>
<th>Grant Date</th>
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<td>UXA 51% RILA 49%</td>
<td>3 (5 blocks)</td>
<td>27/09/2010</td>
<td>24/09/2012</td>
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2.1 Location and Access

The Nabarlek West C tenement is located approximately 250km east of Darwin and approximately 60km northeast of Jabiru (Figure 1) and occurs within the Arnhem Land Aboriginal Land Trust.

Access to the tenement is via sealed Arnhem Highway from Darwin to Jabiru, then sealed/unsealed road from Jabiru via Oenpelli. The principal access to EL24564 is via the Nabarlek mine road however access within this tenement is limited due to rugged and incised topography.

2.2 Climate and Physiography

The wet season lasts from November through to March, and is responsible for virtually all the 1,350mm mean annual rainfall received in the region. The dry season lasts from May through to September, during which grass fires are prevalent (Needham, 1984).

The Nabarlek region is dominated by the Arnhem Land Plateau, undulating sandy plains and coastal and estuarine plains. The Arnhem Land Plateau comprises spectacular sandstone escarpments typically 200-300m above sea level, and up to ~500m. The surface of the Plateau is typically dominated by bare rock or shallow sandy soils which support spinifex and low scrub. Woodland and rainforest can dominate over well developed soil profiles associated with interbedded volcanic units, or within gorges and areas where there are permanent springs (Needham, 1984). Previous explorers have noted the difficulties in navigating this terrane using vehicles, with a lot of work required to be conducted on foot.

The undulating sandy plains are the most extensive topographic unit, supporting woodland to tall forest with tall grasses. The sandy plains form over many different rock types ranging from recent
Tertiary sediments to Archaean and Palaeoproterozoic granite and gneiss. The coastal and estuarine plains typically occur between the sandy plains and the coast, and are mainly developed on estuarine sediments deposited in former drowned river valleys (Needham, 1984).

3 Historic exploration

Mineral exploration in the Alligator Rivers Uranium Field (ARUF) has focused almost exclusively on uranium (and associated gold mineralisation, ie Jabiluka 2), with minor lead-zinc mineralisation documented in quartz-breccia-filled faults in the Nanambu Complex and minor alluvial tin associated with the Tin Camp Granite.

Uranium exploration within the ARUF commenced in 1969 following the release of geochronological data from the Nanambu Complex and mapping work by the Bureau of Mineral Resources. The majority of available exploration licences were taken up by four companies; Geopeko Ltd, Pancontinental Ltd, Noranda Ltd and Queensland Mines Ltd. Regional radiometric surveys conducted by each company and subsequent follow-up work led to the discovery of Ranger 1 (Geopeko), Jabiluka 1 (Pancontinental), Koongarra (Noranda) and Nabarlek (Queensland Mines Ltd). By 1972, resources had been defined at Ranger, Nabarlek and Koongarra, with the resource at Jabiluka defined in 1973. Mining at Nabarlek took place in 1979 over a 5 month period, with the stockpiled ore processed between 1980 and 1988. Mining at Ranger 1 commenced in 1980 and is on-going, with recent delineation of the Ranger 3 Deeps ore body (~34,000t contained U₃O₈) likely to extend the mine life by several years.

Exploration work conducted on historical exploration licences relevant to the Nabarlek West tenements is summarised below.

3.1 EL 2508 (Afmeco & Queensland Mines Ltd)

EL 2508 was granted on 29th June 1988 to a joint venture comprising Queensland Mines Ltd and Afmeco Mining and Exploration Pty Ltd. The exploration licence covered an area of 580km² encompassing EL24564 and was considered prospective for unconformity style uranium mineralisation analogous to the Ranger, Jabiluka and Nabarlek deposits. Initial exploration activities during the first two years of tenure defined a total of 49 anomalies which were ranked and systematically followed up with work including geological mapping, soil and rock chip sampling, surveying and gridding, ground radiometrics, trenching, radon track etch surveys and drilling (RAB, >1580 holes for >30,000m; RC and diamond, >73 holes for >8,800m). Of these 49 anomalies, three occur within 5km of EL24564 (Q4, S21 & U11). Following 10 years of systematic follow-up, the majority of EL 2508 was relinquished in 1998 with the exception of three prospects (N147, 5MLB & U65) which were retained under Exploration Retention Licences ERL 150, ERL 151 and ERL 152.

3.2 EL 3419 (Afmeco & Cameco)

EL 3419 was located within the current boundaries of EL 24564 and was explored by Afmeco and Cameco between 1997 and 2003. Exploration activities included 9 diamond drill holes (KUN001-KUN009), a helicopter-borne radiometric and magnetic survey, an airborne multispectral scanner survey, logging of drill core using PIMA II spectrometer and rock chip sampling. The aim of the exploration work was to test the geological nature of the basement beneath the sandstone cover and major structural zones.
A helicopter radiometric and magnetic survey was carried out in 1997, covering 651 line kilometres at 100m line spacing with a sensor height of 30m. No significant radiometric anomalies were identified from this survey.

Five diamond holes were completed in 1997 (KUN001-KUN005) and a further 4 completed in 1998 (KUN006-KUN009) targeting the unconformity between the Kombolgie sandstone and basement lithologies however no significant mineralisation was identified.

3.3 ERL 150 (Afmeco)

ERL 150 was one of three ERL’s retained by Afmeco when EL 2508 was relinquished in 1998. It covers an area of 21.45km² and is located on the southern margin of EL 24868. The ERL was retained due to the discovery of uranium mineralisation in the SML Boundary (SMLB) area in 1992 during blind drilling of the interpreted extension of the Nabarlek Shear. The mineralised zone is associated with a northwest striking fault known as the Boundary Fault.

Exploration work carried out between 1999 and 2004 on ERL 150 included RC/diamond drilling of 9 holes for a total of 2,467m, airborne magnetic/radiometric and electromagnetic (TEMPEST) surveys and ground electromagnetic (EM) and induced polarization (IP) surveys.

During the first year of tenure, ground NanoTEM and Tensor IP (TIP) surveys were carried out over ERL 150, along with a microgravity survey. The NanoTEM method was employed to map the thickness of the Kombolgie Sandstone and help determine vertical movement in faults through the sandstone. Unfortunately due to the rugged terrane, the lines were too short to produce useable data. The TIP survey collected readings at 500m intervals and produced unexplained anomalous resistivity and phase responses in the central part of the survey area. The microgravity survey was employed to determine if this method could be used to detect mineralisation and/or alteration haloes and structures in sandstone covered areas. The results of this work suggested this method could be successful in mapping structures and lithological variations.

A detailed airborne magnetic/radiometric survey was flown in 2001 over ERL 150, focused on a structural corridor considered prospective for uranium mineralisation in order to provide detailed information on the structural features. Unfortunately it failed to resolve structural information beneath the sandstone, and produced several weak radiometric anomalies. The airborne EM (TEMPEST) survey flown in 2001 was a trial to test the effectiveness of the method in resolving depth to the unconformity, highlighting basement conductors and elevated conductivity in hydrothermally altered sandstone. The resulting conductivity depth image produced a narrow conductive horizon interpreted to represent hydrothermal alteration around the unconformity.

Drilling was conducted using both dual purpose truck mounted rigs (RC/DD) and helicopter supported drilling, comprising 9 holes for a total of 2,467m.

4 Geological Setting

The Nabarlek West tenement is situated within the north-western portion of the Pine Creek Orogen and fall within the Alligator Rivers Uranium Field (ARUF). The following summary is drawn from Lally & Bajwah (2006), Needham (1984), Sweet et al (1999), Wilde & Noakes (1990) and Wilde & Wall (1987) and detailed geology is shown on 1:100,000 Special Geology Publication “Geology of the Nabarlek Region”.
Nabarlek area comprises Archaean to Mesoproterozoic Nanambu Complex which has been subdivided based on age and lithology, comprising un-metamorphosed Archaean granite, metamorphosed Archaean granite (now mainly gneiss) and Mesoproterozoic metamorphics.

The un-metamorphosed granite is white to light grey, medium-coarse grained and comprises quartz, microcline, plagioclase and biotite with accessory muscovite and opaques. Outcrops form mainly scattered domes and pavements on the eastern side of the South Alligator River floodplain. The granite has been dated at 2504 ± 22Ma. The metamorphosed Archaean granite is strongly foliated and comprises quartz, feldspar (mostly potash) and biotite. They typically comprise granuloblastic texture characteristic of almandine-amphibolite facies.

The Mesoproterozoic metamorphics comprise pegmatoidal leucocratic paragneiss, schist and migmate dated around 1800Ma and appears to be consistent with the timing of late Mesoproterozoic regional metamorphism. Isotopic ratio work has suggested a meta-sedimentary origin for this sequence of rocks.

Kakadu Group units overlie the Nanambu Complex gneiss and comprise the Mount Howship Gneiss and Kudjumarndi Quartzite. The Mount Howship Gneiss (potentially up to 1000m thick) is coarse, granular quartzofeldspathic gneiss which is typically massive to faintly foliated. Quartz forms 30-75% of the rock, with microcline, plagioclase and muscovite (up to 10% of the rock) with subordinate biotite and accessory apatite and monazite.

Kudjumarndi Quartzite (up to 150m thick) comprises an ortho-quartzite which ranges in composition from monomineralic to muscovite-biotite-hornblende, biotite-muscovite and feldspathic gneiss. It can be distinguished from the underlying Mount Howship Gneiss by its higher quartz content (>75%).

Cahill Formation units conformably overlie the Kakadu Group units and comprise a lower member (carbonate and carbonaceous schist) passing transitionally into a more psammitic upper member. The Cahill Formation is for the most part poorly exposed, confined mostly to a belt 5km wide surrounding and folded into the Nanambu Complex, as well as within the Myra Falls Inlier. The poor exposure tends to be due to the typically micaceous nature of many of the rock units, making them less resistant and friable, with silicified dolomite ridges providing the best outcrop. The lower member of the Cahill Formation is interpreted to be between 300-600m thick.

The upper member of the Cahill Formation comprises a sequence of interlayered feldspathic quartz schist, feldspathic schist and feldspathic quartzite, with minor mica schist and quartzofeldspathic gneiss. It conformably overlies and grades vertically into the lower member, and in the Koongarra area it is interpreted as being up to 2500m thick (this thickness is probably a result of repetition by folding and faulting).

The Nourlangie Schist is believed to overlie the Cahill Formation and is probably a metamorphosed stratigraphic equivalent of the Wildman Siltstone, which occurs elsewhere in the Pine Creek Geosyncline overlying correlatives of the Cahill Formation. It comprises amphibolite facies rocks in the north, upper Greenschist facies rocks through the southern portion of the ALLIGATOR RIVER map sheet to lower Greenschist facies rocks, mostly within the adjoining MOUNT EVELYN 1:250,000 map sheet.

To the east of the East Alligator River, the Nourlangie Schist grades into the Myra Falls Metamorphics, a sequence of differentiated gneiss and schist formed by progressive
metamorphism and migmatisation during the Top End Orogeny (~1800Ma). The sequence has been divided into two zones, the Transitional Zone and the Lit-par-lit Gneiss Zone. The rocks of the Lit-par-lit Gneiss Zone are predominantly gneiss, although granuloblastic amphibolites are widespread and are typically retrogressively metamorphosed to an assemblage of radiating fibrous aggregates of actinolite, tremolite and chlorite. In some cases, relict ophitic texture of hornblende and plagioclase with accessory sphene, magnetite, granular quartz, apatite, garnet porphyroblasts and orthopyroxene are preserved. This relict texture and mineral assemblage suggests that these rocks are ortho-amphibolites derived via metamorphism from Zamu dolerite.

The Zamu Dolerite is comprised of a series of tholeiitic sills which intruded the Palaeoproterozoic sediment pile prior to regional deformation and metamorphism. The unit ranges from metadolerite in the west of the ALLIGATOR RIVER map sheet to amphibolite with occasional metadolerite cores in the east of the map sheet area, with an interpreted age of approximately 1884 ±3Ma.

The Nimbuwah Complex forms a large, roughly semi-circular body approximately 2600km² in the Nabarlek region, comprised of mesocratic to leucocratic granitoid migmatite with melanocratic migmatite and tonalite. The complex can be broadly divided into a northern group and a southern group as described below.

The northern group of the Nimbuwah Complex is present predominantly to the north of the Nabarlek project area and is consisting of migmatite and porphyroblastic granite.

The southern group of the Nimbuwah Complex is present predominantly within the Caramal and Beatrice Inliers, approximately 25km and 40km south of the Nabarlek project area respectively. These areas contain the most mafic rock types of the Nimbuwah Complex, including melanocratic migmatite and tonalite.

The Tin Camp Granite and Nabarlek Granite within the ALLIGATOR RIVER map sheet are members of the late Palaeoproterozoic Jim Jim Suite, which is present throughout the eastern portion of Pine Creek Inlier and appears to be coeval with the Cullen Supersuite (~1825Ma). The Tin Camp Granite is present within the Caramal and Beatrice inliers approximately 25km and 40km south of the Nabarlek project area respectively. It intrudes the Nimbuwah Complex, is faulted against the Oenpelli Dolerite and appears to intrude the Myra Falls Metamorphics.

The Nabarlek Granite has been mapped approximately 7km east of the Nabarlek deposit, and has also been documented to occur below the Nabarlek ore body. In outcrop, the granite is cut by numerous quartz breccia-filled fault zones and is extensively altered.

Oenpelli Dolerite occurs throughout the eastern portion of the Pine Creek Orogen and is mapped predominantly in the eastern half of the ALLIGATOR RIVER map sheet in the vicinity of the Nabarlek West project areas. Regionally, the Oenpelli Dolerite forms large lopoliths up to 250m thick, as is the case below the Nabarlek ore body.

The Kombolgie Formation is a thick, predominantly sandstone sequence which unconformably overlies Archaean to Mesoproterozoic basement rocks within the Pine Creek Orogen. It is divided into upper and lower sandstones, each containing a distinctive volcanic unit (the Gilruth and Nungbalgarri volcanic members respectively). The entire sequence of sandstone and associated
volcanic units forms part of the Katherine River Group. Recent work has constrained the age of the Kombolgie Subgroup to between 1822Ma and ~1730Ma.

Sporadic outcrops of the Late Jurassic Petrel Formation occur throughout the ALLIGATOR RIVER map sheet, and have a limited presence in the northeast corner of ELA 24868. This sequence comprises coarse sandstone, conglomerate, minor siltstone and claystone and sits unconformably on older rocks. Cainozoic sediments include laterite, late Tertiary sand, silt and sandstone, talus, Quaternary continental deposits and coastal sediments.

Refer to Figures 2 and 3 for the ALLIGATOR RIVER geology overlain with the Nabarlek EL’s and stratigraphic column/map units.

4.1 Structure

Palaeoproterozoic deformation took place primarily during the Top End Orogeny (~1880-1800Ma), with the basement units divided into two main structural/metamorphic terrains. The Nimbuwah Domain, east of the East Alligator River, comprises gneissic and schistose, medium to high grade rocks with shallow dipping (<35°) foliation and flat lying, west-verging recumbent folds. To the west of the East Alligator River, The Nanambu Domain, medium grade schist with steeply dipping foliation predominate with folds ranging from recumbent to steeply inclined, facing both east and west. At least four phases of deformation are attributed to the Top End Orogeny.
4.2 Mineralisation

The Alligator Rivers Uranium Field (ARUF) contains over 60 known uranium occurrences, including the Ranger, Jabiluka, Koongarra and the historic Nabarlek uranium mine (Figure 4).

These uranium deposits and occurrences are related to fracture, fault and breccia zones within Palaeoproterozoic basement rocks, and proximal to an unconformable contact with overlying Neoproterozoic sediments.
4.2.1 Nabarlek

The Nabarlek uranium deposit was discovered in 1970 by Queensland Mines Ltd while investigating a significant airborne radiometric anomaly. Mineralisation is hosted within chlorite schist, biotite-muscovite-quartz-feldspar gneiss and amphibolite within the Myra Falls Metamorphics. These rocks are faulted against Palaeoproterozoic Nabarlek Granite and are intruded by a thick (~220-250m) discordant sheet of Oenpelli Dolerite (Figure 5). The ore body was approximately 250m in length, 7m wide and tapered to a maximum depth of 85m where it was truncated by an Oenpelli Dolerite sill. Mineralisation is intimately associated with the Nabarlek Fault breccia, which contains the high grade core (>1% U₃O₈) surrounded by a lower grade (0.1% U₃O₈) envelope, extending up to several metres into the country rock. The primary ore mineral is uraninite (with rare brannerite), with secondary ore minerals comprising coffinite and yellow-green phosphate phases. Minor sulphide phases (including chalcopyrite, galena with rare pyrite, chalcocite and bornite) are present, typically comprising less than 1% by volume of the ore assemblage.

![Nabarlek Cross-section](image)

**Figure 5: Cross section of the Nabarlek deposit. After Lally & Bajwah (2006)**

4.2.2 Ranger

The Ranger Uranium Mine is located approximately 55km southwest of the Nabarlek West and includes the Ranger 1 and No 3 ore bodies (Figure 6). Mineralisation is hosted within the Lower Cahill Formation and comprises a total of 148,082t contained U₃O₈ at an average grade of 0.25% U₃O₈. Mineralisation is characterised by intense chloritisation, sericitisation and hematite alteration, which in some cases completely obliterates primary mineral fabrics. Several periods of brecciation with associated chloritisation and uranium mineralisation are described within the ore zone. The primary ore assemblage comprises uraninite, with minor brannerite and amorphous
mixtures of pitchblende with titanium and phosphates. Pyrite, chalcopyrite and galena (predominantly radiogenic) are associated with pitchblende mineralisation.

Figure 6: Cross section of the Ranger 1 No 3 ore body (after Lally & Bajwah 2006).

4.2.3 Jabiluka

The Jabiluka deposit is located approximately 24km southwest of the Nabarlek West project area and comprises two separate ore bodies, Jabiluka 1 and 2, which contain a combined uranium resource of 166,250t contained U\textsubscript{3}O\textsubscript{8} at an average grade of 0.39% U\textsubscript{3}O\textsubscript{8}. Uranium mineralisation is hosted by Lower Cahill Formation schists. The bulk of the mineralisation (163,000t contained U\textsubscript{3}O\textsubscript{8}) at a grade of 0.53% U\textsubscript{3}O\textsubscript{8} is contained within the Jabiluka 2 ore body (Figure 7). Uranium mineralisation is typically confined to zones of brecciation within graphitic schist and commonly associated with chloritisation, sericitisation and hematite alteration. The primary ore mineralogy comprises predominantly uraninite with minor brannerite, coffinite and organo-uranium minerals. Sulphides present include pyrite with lesser galena and chalcopyrite. Economic gold mineralisation is also reported within graphite horizons from the Jabiluka 2 ore body.
4.2.4 Koongarra

The Koongarra uranium deposit is located approximately 70km southwest of the Nabarlek West project area. The deposit comprises two discrete ore bodies, separated by ~100m in plan (Figure 8), and contains an estimated resource of ~16,541t contained U₃O₈. Uranium mineralisation is hosted by Lower Cahill Formation schists. The Koongarra 1 ore body extends ~450m along strike and to ~100m depth, with a secondary mineralisation zone present within the weathered schists overlying the main ore body. The Koongarra 2 ore body has a strike length of ~100m and occurs between 50-250m depth. Primary uranium mineralisation is hosted predominantly by quartz-chlorite schist. Primary ore comprises crystalline uraninite veins and veinlets, with sooty amorphous uraninite masses present within host schists, while secondary mineralisation includes sklodowskite, kasolite, renardite, metatorbernite, saleeite and curite.
4.2.5 Other Occurrences

The Ranger 68 deposit is located approximately 44km west-southwest of the Nabarlek project area and contains resources of approximately 5000t contained U$_3$O$_8$ with an average ore grade of 0.35% U$_3$O$_8$. The geology is broadly similar to that at the main Ranger deposit, with mineralisation hosted by chloritised breccia and to a lesser extent quartz-sericite-chlorite schist within the Lower Cahill Formation.

Hades Flat uranium prospect is located ~42km southwest of EL24868 and comprises an estimated resource of 726t contained U$_3$O$_8$. Mineralisation is found within the Lower Cahill Formation and is comprised predominantly of pitchblende, which occurs both within fractures and breccia in chlorite-feldspar schist.

Caramel prospect is located ~22 south of the Nabarlek mine site and contains an unconfirmed estimated resource of 2500t contained U$_3$O$_8$. Primary uranium mineralisation occurs within a ~80m wide elongate zone within altered metasedimentary schist and carbonate rocks of the Myra Falls Metamorphics.
A number of uranium occurrences have been reported proximal to the Nabarlek West C tenement (Figure 4), including:

- **U40** (200m south of EL24868), currently being evaluated by Cameco in joint venture with Uranium Equities Limited.
- **Tadpole** (~12km north of EL 24564), described as a vein occurrence.
- **Mordijimuk** (~2km east of EL 24564), described as “surficial enrichment”.
- **Gorrunghar** (~2km south of EL 24564), described as “unconformity-related”.
- **Gurrigarri** (~4.5km southeast of EL 24564), described as “unconformity related”.
- **Anomaly N84** (~2.3km east of EL 24564), described as “surficial enrichment”.
- **Anomaly N7** (~6km southwest of EL 24868), described as “surficial enrichment”.
- **Stevens** (~15.5km southeast of EL 24868), described as “vein gold, platinum, palladium, uranium”.
- **King River** (~12km west of EL 24868), described as “unconformity-related”.
- **00128** (~7km east of EL 24564), described as “surficial enrichment”.

**5 Exploration Rationale**

The model proposed for unconformity-style uranium deposits in the Alligator Rivers area comprises an intracratonic basin setting, where a thick, oxidized and quartz-rich cover sequence unconformably overlies metamorphic basement containing suitable reductants. Fluids produced during basin diagenesis transport uranium along basement penetrating faults where they may come into contact with reducing lithologies that precipitate uranium minerals. Key criteria for a deposit of this type are:

- A thick, oxidized quartz-rich sandstone cover sequence, preferably free of organic matter, which can facilitate the transport of uranium bearing fluids.
- Basement rocks comprising suitable reducing lithologies such as graphitic schists, carbonates (marble etc), hydrocarbons or inorganic reductants (eg sulphides or ferric Fe2+ iron rich rocks).
- Burial of the basin accompanied by diagenesis creating a moderate temperature (~150-200°C) with oxidizing saline fluid capable of transporting uranium.
- A leachable source of uranium which could include uranium-rich felsic rocks either rimming or underlying the sedimentary basin, lithic fragments of felsic rocks (including volcanic ash) within aquifers or leachable detrital U-rich minerals such as zircon, monazite, allanite and apatite within the sandstone sequence.
- Significant fault structures which penetrate both the cover sequence and basement rocks form pathways for fluids. Structures within the basement (particularly those associated with reducing lithologies) provide further conduits for mineralising fluids and form depositional sites.
The characteristics of unconformity style uranium deposits in the Northern Territory can be summarised as follows (after Mernagh et al, 1998 & Beaufort et al, 2005):

- Typically an oxidized, thick cover sequence of quartz-rich sandstone overlying reduced basement lithologies.
- Significant fault/structural feature bisecting both the covering sequence and basement rocks, to allow passage of fluids.
- Clay alteration (kaolinite-illite) in covering sandstones proximal to the fault structure.
- Elevated Th in stratigraphic units above the unconformity (areas of high Th but low U/K may indicate mineralization at depth).
- Phosphatic breccias above the unconformity and areas of silicification proximal to the fault structure at higher stratigraphic levels with strong desilicification at the unconformity.

Previous exploration in and around the Nabarlek West tenements suggests the Kombolgie Formation sandstone has been subjected to diagenetic processes with illite alteration commonly reported and silicification and chlorite-hematite alteration also suggestive of fluid flow.

The most prospective basement lithologies in the Nabarlek project area include the Lower Cahill Formation (host to the Ranger, Jabiluka and Koongarra deposits) and the Myra Falls Metamorphics (in particular the lit-par-lit gneiss).

6 Previous UXA exploration

In 2011, during the first year of tenure exploration activities comprised a desk top review of historical works completed by previous explorers and research on known uranium deposits within the region, a 1,395.4 line kilometre fixed wing airborne GEOTEM electromagnetic survey and a hyperspectral remote sensing survey.

Results from the airborne EM survey were non-conclusive in delineating the unconformable contact, highlighting conductors and delineating detailed structure. The hyperspectral survey failed to identify any zones of significant chlorite alteration or intense argillic alteration considered as strong indicators of potential mineralisation.

7 Exploration Activities for the period ending 26 October 2012

During the second year of tenure no exploration activities were carried out.

8 Environmental Management Activities

Environmental rehabilitation was unnecessary as no ground was disturbed.
9 Expenditure Statement

An expenditure statement for the reporting period was submitted to the Northern Territory Department of Resources on 29 October 2012.

Table 3 summarises expenditure for the Nabarlek West C tenement.

Table 3: Summary of Expenditure during the Reporting Period

<table>
<thead>
<tr>
<th>EL #</th>
<th>Covenant</th>
<th>Expenditure</th>
</tr>
</thead>
<tbody>
<tr>
<td>EL28245</td>
<td>$5,000</td>
<td>$5,180</td>
</tr>
</tbody>
</table>

10 Conclusions and Recommendations

The Nabarlek West C tenement is considered prospective for unconformity style uranium mineralisation since they comprise similar tectonic setting, lithology and structure to known deposits within the region, but as no exploration was carried out the tenement will be relinquished.

11 References


APPENDIX 1

AEM Survey Report
Nabarlek, Northern Territory
GEOTEM
Geophysical Survey

Acquisition and Processing Report
for
Uranium Exploration Australia Ltd

Prepared by :   A. Carbone
                L. Stenning

Authorised for release by :   ........................................
                               ........................................

Survey flown: October 2010

by

Fugro Airborne Surveys
435 Scarborough Beach Road, Osborne Park WA 6017, Australia
Tel: (61-8) 9273 6400    Fax: (61-8) 9273 6466

FAS JOB # 2160
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1. SURVEY OPERATIONS AND LOGISTICS

1.1 Introduction

Between the 11th of October 2010 and the 14th October 2010, Fugro Airborne Surveys Pty. Ltd. (FAS) undertook an airborne GEOTEMDEEP® electromagnetic and magnetic survey for Uranium Exploration Australia Ltd, over the Nabarlek Project area in the Northern Territory. The survey consisted of two areas. Total coverage of the survey areas amounted to 1927.1 line kilometres flown in 5 flights.

The survey employed the GEOTEMDEEP® electromagnetic system, operating at a base frequency of 25Hz. Ancillary equipment consisted of a magnetometer, radar altimeter, video camera, analogue and digital recorders and an electronic navigation system. The instrumentation was installed in a CASA C212-200 Turbo Prop survey aircraft registration VH-TEM. The aircraft was flown at an average speed of 235 km/h with an EM bird receiver height of 80 m. This report summarises the procedures and equipment used by FAS in the acquisition, verification and processing of the airborne geophysical data.

1.2 Survey Base

The survey was based out of Jabiru, Northern Territory. The survey aircraft was operated from the Jabiru Airstrip with the aircraft fuel brought in. A temporary office was set up at the Lake View Lodge, Jabiru, where all survey operations were run and the post-flight data verification was performed.

1.3 Survey Personnel

The following personnel were involved in this project:

<table>
<thead>
<tr>
<th>Role</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Supervision - Acquisition</td>
<td>Bart Anderson</td>
</tr>
<tr>
<td>Project Supervision - Processing</td>
<td>Denis Cowey</td>
</tr>
<tr>
<td>On-site Crew Leader</td>
<td>Ben Riggs</td>
</tr>
<tr>
<td>Pilot/s</td>
<td>Peter Hiskins, Mel Cote, Tymon Dyer</td>
</tr>
<tr>
<td>System Operator/s</td>
<td>Ben Riggs</td>
</tr>
<tr>
<td>Aircraft Engineer</td>
<td>Richard Carden</td>
</tr>
<tr>
<td>Field Data Processing</td>
<td>Adam Carbone</td>
</tr>
<tr>
<td>Office Data Processing</td>
<td>Adam Carbone</td>
</tr>
</tbody>
</table>
1.4 Area Map
1.5 General Disclaimer

It is Fugro Airborne Survey's understanding that the data and report provided to the client is to be used for the purpose agreed between the parties. That purpose was a significant factor in determining the scope and level of the Services being offered to the Client. Should the purpose for which the data and report is used change, the data and report may no longer be valid or appropriate and any further use of, or reliance upon, the data and report in those circumstances by the Client without Fugro Airborne Survey's review and advice shall be at the Client's own or sole risk.

The Services were performed by Fugro Airborne Survey exclusively for the purposes of the Client. Should the data and report be made available in whole or part to any third party, and such party relies thereon, that party does so wholly at its own and sole risk and Fugro Airborne Survey disclaims any liability to such party.

Where the Services have involved Fugro Airborne Survey's use of any information provided by the Client or third parties, upon which Fugro Airborne Survey was reasonably entitled to rely, then the Services are limited by the accuracy of such information. Fugro Airborne Survey is not liable for any inaccuracies (including any incompleteness) in the said information, save as otherwise provided in the terms of the contract between the Client and Fugro Airborne Survey.
2. SURVEY SPECIFICATIONS AND PARAMETERS

2.1 Area Co-ordinates

The survey area was located within GDA94 MGA Zone 53S, Central Meridian = 135
(Note - Co-ordinates in WGS84/UTM Zone 53S)

AREA 1

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<td>8637773</td>
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<td>306069</td>
<td>8637785</td>
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2.2 Survey Area Parameters

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<tr>
<td>Survey Company</td>
<td>Fugro Airborne Surveys Pty Ltd</td>
</tr>
<tr>
<td>Date Flown</td>
<td>11th October 2010 – 14th October 2010</td>
</tr>
<tr>
<td>Client</td>
<td>Uranium Exploration Australia Ltd</td>
</tr>
<tr>
<td>EM System</td>
<td>GEOTEMDEEP®</td>
</tr>
<tr>
<td>Navigation</td>
<td>Real-time differential GPS</td>
</tr>
<tr>
<td>Datum</td>
<td>GDA94</td>
</tr>
<tr>
<td>Projection</td>
<td>MGA Zone 53S</td>
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<tr>
<td>Project Name</td>
<td>Nabarlek, Northern Territory</td>
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<tr>
<td>Area Names</td>
<td>1 and 2</td>
</tr>
<tr>
<td>Nominal Terrain Clearance</td>
<td>120 m</td>
</tr>
<tr>
<td>Traverse Line Spacing</td>
<td>200 m</td>
</tr>
<tr>
<td>Traverse Line Direction</td>
<td>090 – 270 degrees</td>
</tr>
<tr>
<td>Traverse Line Numbers</td>
<td>1001 – 1057, 2001 – 2066</td>
</tr>
<tr>
<td>Tie Line Spacing</td>
<td>1920m EL24868, 2200m EL24564</td>
</tr>
<tr>
<td>Tie Line Direction</td>
<td>000 – 180 degrees</td>
</tr>
<tr>
<td>Tie Line Numbers</td>
<td>1701 – 1705, 2701-2717</td>
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<tr>
<td>Area 1 Line Kilometres</td>
<td>531.7 km</td>
</tr>
<tr>
<td>Area 2 Line Kilometres</td>
<td>1395.4 km</td>
</tr>
<tr>
<td>Total Survey Kilometers</td>
<td>1927.1 km</td>
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</table>

2.3 Data Sample Intervals

Nominal data sample intervals.

<table>
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<tr>
<th>Instrument</th>
<th>Sample Interval</th>
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</thead>
<tbody>
<tr>
<td>Magnetometer</td>
<td>70 m (@1 Hz)</td>
</tr>
<tr>
<td>Electromagnetics</td>
<td>17 m (@4 Hz)</td>
</tr>
<tr>
<td>Radar altimeter</td>
<td>70 m (@1 Hz)</td>
</tr>
<tr>
<td>Barometric altimeter</td>
<td>70 m (@1 Hz)</td>
</tr>
<tr>
<td>GPS</td>
<td>70 m (@1 Hz)</td>
</tr>
</tbody>
</table>

2.4 Survey Reflight Specifications

As specified in the contract, the following tolerances were used.

- If electronic navigation data are not available.

- Where the actual flight path deviates from the flight plan by more than 50% of the nominal spacing over a continuous distance exceeding 3 km or where lines cross. The line spacing measurements to be used in determining such reflights will be made from the field flight path recovery.

- If the terrain clearance continuously exceeds the nominal terrain clearance by +/- 20 m over a distance of 3 km or more unless to do so would, in the sole opinion of the pilot, jeopardise the safety of the aircraft or the crew or the equipment or would be in contravention of the Aviation Authority regulations such as those pertaining to built up areas.

- GEOTEM X or Z data is not interpretable. Where the dB/dt RMS noise calculated over 3 km of the raw digital data in the last off-time channel at 25 Hz exceeds 5 nT/s (or 10 pT for B-field) in resistive areas devoid of any external interference (eg. Cultural sources etc.), for a distance greater than 3kms. Also, the FAS field geophysicist will examine all anomalous regions on the analogues to determine if the character and shape of the significant geophysical anomalies can be properly separated from the noise, and re-fly any sections of lines where the noise levels irreparably distort the significant geophysical anomalies.
- The magnetometer noise envelope of ± 1.0 nT is exceeded intermittently over a cumulative total of 10% or more of any flight line or continuously over 2 km or more.

- The departure of the diurnal magnetic field from a straight line chord, 10 minutes in length, exceeds 10 nT.

2.5 Job Safety Plan

A Job Safety Plan was prepared and implemented in accordance with the Fugro Airborne Surveys Occupational Safety & Health Management System.
3. GEOTEM SYSTEM AND SURVEY EQUIPMENT

3.1 The GEOTEMDEEP® Multi-Coil System

GEOTEMDEEP® is a time domain towed bird electromagnetic system incorporating a high speed EM receiver. The primary electromagnetic pulses are created by a series of discontinuous half-sine current pulses fed into a multi turn transmitting loop surrounding the aircraft and fixed to the nose, tail and wing tips. The pulse repetition rate is 25 Hz (50 bipolar pulses per second).

The EM sensor is an orthogonal set of coils mounted in a "bird", towed behind the aircraft on a cable. The cable is demagnetised to reduce noise levels. Three coil orientations are available. The X component has a horizontal axis in the direction of flight. The Y component has a lateral horizontal component. The Z component has a vertical axis, which is coplanar with the transmitter coil.

Time-domain airborne electromagnetic systems have historically measured the in-line horizontal (X) component using a coaxial receiver coil. New versions of the electromagnetic systems are designed to collect two additional components (the vertical component (Z) and the lateral horizontal component (Y)) to provide greater diagnostic information. The three components, X, Y and Z can be combined to give the “energy envelope” of the response. Due to asymmetry in the transmitter and receiver coil geometry, the shapes of the component profiles depend on flight direction, the most sensitive component being X component.

In areas where lithological strike is near horizontal, the Z component response provides greater signal-to-noise due to greater coupling. In comparison, the X coils couple best with vertical structures striking perpendicular to the flight direction. In a laterally symmetric environment, the symmetry implies that the Y component will be zero; hence a non-zero y-component indicates lateral inhomogeneity.

In the interpretation of discrete conductors, the Z component data may be used to ascertain the dip and depth to the conductor using simple rules of thumb. The response of the Y component can be used to ascertain the strike direction and lateral offset of the target respectively.

Having the Y and Z component data increases the total response when the profile line has not traversed the target. This increases the possibility of detecting a target located between adjacent flight lines or beyond a survey area.

Each primary current pulse may induce eddy currents in subsurface conductors that decay following cessation of each pulse. Any decaying earth currents can induce voltages in the receiver coils that are proportional to the electromagnetic field. These voltages are sampled over 20 time gates. The centres and widths of these gates are variable and may be placed anywhere within or outside the transmitter pulse.

The time varying EM signals received at the sensor pass through anti-aliasing filters and are then digitised with an A/D converter. The digital data stream from the A/D converter passes into an array processor where all the numerically intensive processing tasks are carried out. The array processor is under control of a multi-tasking minicomputer. The on-board processing sequence is as follows:

**Transient Analysis**: Transient analysis enables the separation of noise from signal in real time.

**Digital Stacking**: The stacking of transients to produce 1 recorded reading, of which 4 are recorded every second.

**Windowing of Data**: The transient is initially sampled into 384 time windows that are then binned to form 20 channels.
Table 1: Airborne Equipment Specifications

<table>
<thead>
<tr>
<th>System Parameters</th>
<th>GEOTEM&lt;sub&gt;DEEP&lt;/sub&gt;® Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Navigation</strong></td>
<td>Real time Differential GPS</td>
</tr>
<tr>
<td>Nominal aircraft speed (m/s)</td>
<td>65</td>
</tr>
<tr>
<td><strong>Geometry</strong></td>
<td></td>
</tr>
<tr>
<td>Transmitter height</td>
<td>120</td>
</tr>
<tr>
<td>Above ground level (m agl) (Nominal terrain clearance)</td>
<td></td>
</tr>
<tr>
<td>Receiver Bird Height (agl, m)</td>
<td>80 m</td>
</tr>
<tr>
<td>Tx-Rx horizontal separation (m)</td>
<td>136 m</td>
</tr>
<tr>
<td>Tx-Rx vertical separation (m)</td>
<td>38 m</td>
</tr>
<tr>
<td><strong>Transmitter</strong></td>
<td></td>
</tr>
<tr>
<td>Coil Axis</td>
<td>Vertical</td>
</tr>
<tr>
<td>Signal</td>
<td>Half sine wave current pulse</td>
</tr>
<tr>
<td>Base frequency (Hz)</td>
<td>25</td>
</tr>
<tr>
<td>Repetition rate (pulses per second)</td>
<td>50</td>
</tr>
<tr>
<td>Pulse width (microseconds)</td>
<td>4108</td>
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<tr>
<td>Loop area (square metres)</td>
<td>231</td>
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<tr>
<td>Number of turns</td>
<td>6</td>
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<tr>
<td>Peak Current (amps)</td>
<td>650</td>
</tr>
<tr>
<td>Tx loop dipole moment (Am&lt;sup&gt;2&lt;/sup&gt;)</td>
<td>9.009 x 10&lt;sup&gt;5&lt;/sup&gt;</td>
</tr>
<tr>
<td><strong>Receiver</strong></td>
<td></td>
</tr>
<tr>
<td>Coil Axes</td>
<td>X, Y and Z</td>
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<td>Sample Interval (seconds)</td>
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<tr>
<td>Channel times</td>
<td>see Table 2</td>
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### Table 2: Receiver Channel Positions

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<td>384</td>
<td>54</td>
<td>17188</td>
<td>20000</td>
<td>18594</td>
</tr>
</tbody>
</table>

### 3.2 Electromagnetic Acquisition System

The Digital Acquisition System (GEODAS) is a computer-based software system using a Pentium field PC. It runs multiple DOS programs in a multi-tasking environment. The modular design of the GEODAS allows for re-configuring of the system to record different types of surveys by adding, removing or changing task modules.

The GEODAS is currently installed on a rugged, totally enclosed, moisture and dust-proof system, originally designed for military use. The GEODAS currently uses a Pentium CPU on a plug-in module card that can be upgraded.

The following are recorded digitally using the GEODAS:

- **Each second:** Flight number, Navigation data, Total magnetic field, Fiducial number (time in seconds), Altitude (radar and barometer)
- **Each 0.25 secs:** 20 X, Y, & Z component dB/dt \text{GEOTEM_{DEEP}} channels, 20 X, Y, & Z component B-field \text{GEOTEM_{DEEP}} channels, X, Y, & Z component transmitter primary field
Power line (50Hz) monitor (X, Y, & Z component)  
Earth field monitor (X, Y, & Z component)

3.3 Magnetometers

3.3.1 Survey Magnetometer

Model: Cesium vapour optical absorption magnetometer sensor  
Mounting: Tail stinger  
Sample period: 50 milliseconds  
Sample interval: 1.0 seconds *  
Sensitivity: 0.01 nanoTeslas (nT)

* To operate both the GEOTEMDEEP<sup>®</sup> system and the magnetometer system simultaneously, the transmitter is switched off for a period of 200 milliseconds every second to allow for a noise free magnetometer reading.

3.4 Altimeter System

3.4.1 Radar Altimeter

Model: Sperry Stars RT-220 radio altimeter system  
Sample interval: 1.0 second  
Accuracy: +/- 1.5 % of indicated altitude.

The Sperry radio altimeter is a high quality instrument whose output is factory calibrated. It is fitted with a test function which checks the calibration of a terrain clearance of 100 feet, and altitudes which are multiples of 100 feet. The aircraft radio altitude is recorded onto digital tape as well as displayed on the aircraft chart recorder. The recorded value is the average of the altimeters output during the previous second.

3.4.2 Barometric Altimeter

Output of a Digiquartz 215A-101 pressure transducer is used for calculating the barometric altitude of the aircraft. The atmospheric pressure is taken from a gimbal-mounted probe projecting 0.5 metres from the wing tip of the aircraft and fed to the transducer mounted in the aircraft wingtip.

3.5 Video Tracking System

The video tape recorded by a PAL VHS colour video system is synchronised with the geophysical record by a digital fiducial display, which is recorded along with GPS latitude and longitude information and survey line number.

3.6 Electronic Navigation

A Picodas PNAV 2001 Navigation Computer is used for real-time navigation. The PNAV computer loads a pre-programmed flight plan from disk which contains boundary co-ordinates, line start and end co-ordinates, local co-ordinate system parameters, line spacing, and cross track definitions. The WGS-84 latitude and longitude positional data received from the Novatel GPScard contained in the SURVEY computer is transformed to the local co-ordinate system for calculation of the cross track and distance to go values. This information, along with ground heading and ground speed, is displayed to the pilot numerically and graphically on a two line LCD display, and on an analog HSI indicator. It is also presented on a LCD screen in conjunction with a pictorial representation of the survey area, survey lines, and ongoing flight path.
The PNAV is interlocked to the SURVEY computer for auto selection and verification of the line to be flown. The GPS information passed to the PNAV 2001 navigation computer is corrected using the received real time differential data, enabling the aircraft to fly as close to the intended track as possible.

### 3.7 Analogue Recorder

- **Model:** RMS GR33 Thermal Dot Matrix Printer
- **Chart speed:** 11 cm/minute; time increases from left to right
- **Event marks:** 20 second marks are recorded on the bottom of the chart with the associated fiducial numbers being printed at the base of the chart.

**GEOTEM\textsuperscript{DEEP}® Traces:** The scales for the GEOTEM\textsuperscript{DEEP}® traces are displayed on the analogue charts.

The zero line for each channel is separated by 0.5 cm with the latest channel always being plotted closest to the bottom of the page.

**Synchronisation:** A lag of approximately 5.0 seconds occurs between the GEOTEM\textsuperscript{DEEP}® channels and the magnetometer and altimeter traces.

**Channels Displayed:**
- Channel 16 noise monitors (X, Y and Z)
- Primary field monitor (X and Z)
- Earth field monitors (X, Y and Z)
- Total magnetic field - fine and coarse scale
- Terrain clearance - radar
- Barometer
- Selected GEOTEM\textsuperscript{DEEP}® X and Z channels
- Powerline monitor
4. EQUIPMENT TESTS AND CALIBRATIONS

4.1 GEOTEM\textsuperscript{DEEP} \textsuperscript{®} Daily Calibration

All checks and adjustments are performed at high altitude at the start of each flight to allow for automatic compensation and calibration at survey altitude. The calibrations and compensations are as follows:

4.1.1 Compensation

At the beginning of the flight data is acquired at high altitude (in excess of 600m). These data are used by the airborne operator to determine if:

a) the system noise level is acceptable

b) the response had not varied significantly from previous flights, and

c) the sferics level is acceptable,

This calibration system produces a reference waveform (or series of coefficients) which is used to establish the compensation algorithm within the GEOTEM receiver itself. This therefore allows automatic compensation to take place at survey altitude. Zero levels of the GEOTEM channels are verified at the beginning and end of each flight.

Following this aircraft manoeuvres (swoops) are performed before and after each sortie to ensure that the system operates correctly when the relative position of the towed sensor is varied relative to the aircraft.

4.2 Lag Tests

4.2.1 Electromagnetic Lag Test

An electromagnetic lag check is routinely carried out to determine the lag of the GEOTEM\textsuperscript{DEEP} \textsuperscript{®} system. The check is conducted by flying in two different directions over a known target with a particular electromagnetic signature. The value calculated by the electromagnetic test is used in the processing of the GEOTEM\textsuperscript{DEEP} \textsuperscript{®} electromagnetic data.

A lag check was completed over a known conductive feature near Mandurah, Western Australia. The results showed that the lag for the electromagnetic data was 16 samples (4 seconds).

4.2.2 Magnetometer Lag Test

The lag of the magnetics can be calculated by flying the aircraft in opposite directions over a sharp magnetic anomaly with the navigation system and magnetometer operating. The position of the magnetic high is determined from the navigation system for each line direction. The numerical difference in position is the 2-way or total lag. The lag to be applied to each direction is this value divided by two. Varying lag due to varying ground speed will be compensated for in the processing. However, for this survey the lag was calculated using grids of the magnetics data from the survey. The results showed that there was a lag of 2.25 seconds.
5. GROUND DATA ACQUISITION EQUIPMENT

5.1 Magnetic Base Station

Two CF1 magnetometer's were used to measure the daily variations of the Earth’s magnetic field. The base stations were established in an area of low gradient, away from cultural influences. The base stations were run continuously throughout the survey flying period with a sampling interval of 1 second at a sensitivity of 0.1 nT. The magnetometer base stations were set up north of the base airstrip approximately 50 m apart.

5.2 GPS Base Station

A GPS base logging station integrated with the CF1 unit was used throughout the survey, setup at the base airstrips as described above.

The GPS base station position was calculated by logging data continuously at the base position over a period of approximately 24 hours. Data were then averaged to obtain the position of the base station using GrafNav software.

The calculated GPS base position at Jigalong Airstrip was (in GDA94):
- Lat: -19° 42' 27" S
- Long: 135° 49' 08" E
- Height: 76 m. (ellipsoidal height). Sensor approximately 2m above ground surface.
6. PRODUCTS AND PROCESSING

Raw \text{GEOTEM}^{\text{DEEP}}\textsuperscript{\textregistered} data collected on the aircraft GEODAS is read onto a Pentium IV laptop computer where proprietary Fugro software is then used to further process the data.

Processed data is displayed as profiles and plans in the field. Displays are produced of flight path plots, magnetic and EM channel amplitudes. The field processor / geophysicist uses these displays and other QC procedures to analyse the quality of the data collected, and decide on any reflights.

Field Processing System

Hardware: Laptop PC operating on a Windows XP platform
           HP Laser Printer

Software: Fugro Airborne Surveys developed GMAPS \text{GEOTEM}^{\text{DEEP}}\textsuperscript{\textregistered} processing software
          OASIS Montaj geophysical processing software
          GRAFNAV GPS processing software

Office Processing System

Hardware: PC network and peripherals operating on a Windows XP platform
           Ricoh DVD+R/RW CD/DVD burner
           HP 1055 Design-jet Plotters

Software: Fugro Airborne Surveys developed ATLAS \text{GEOTEM}^{\text{DEEP}}\textsuperscript{\textregistered} processing software
          OASIS Montaj geophysical processing software

6.1 Electromagnetics

6.1.1 Levelling

Since the \text{GEOTEM}^{\text{DEEP}}\textsuperscript{\textregistered} receiver constantly normalises and calibrates during data acquisition there is normally minimal levelling of data required at the post-survey processing stage. However, some low amplitude noise and microlevelling is generally applied to adjust small line to line level busts and improve the cosmetic appearance of the gridded data.

6.1.2 Synchronisation Lag

All \text{GEOTEM}^{\text{DEEP}}\textsuperscript{\textregistered} and auxiliary geophysical data have been synchronised with navigation data so that there is no "peak position" offset between the responses obtained from lines flown in opposite directions over a narrow vertical conductor (see also section 4.2.1)

6.1.3 Noise Reduction

Noise reduction in the digital data is accomplished by identification of the noise type (atmospheric, system or cultural), analysis of the spectral content of the entire signal (geological + noise) and selective filtering.
6.1.3.1 Atmospheric Noise

The first stage of processing is atmospheric (spheric) noise removal which is achieved by using a method based loosely on cross correlation and non-linear filtering, since most spheric events are single reading (impulse response) features which cannot be properly removed by linear filtering.

6.1.3.2 Cultural noise

Cultural noise (which includes sources such as 50 Hz powerlines, electric fences, cathodic protected metal structures) is measured by the 50 Hz monitor. Normally cultural noise is not removed during processing.

6.1.3.3 System noise

System noise is removed by filtering using strict amplitude and wavelength thresholds to correctly isolate noise from geological signal. The filter shape and amplitude thresholds are determined on a flight by flight basis from raw data plots of at least 2 flight lines flown in opposite directions at the beginning and end of the flight. This allows customised filtering for directional, diurnal and flight noise, ensuring that the minimal amount of filtering is performed so that real signal is not degraded by using a "lowest common denominator" philosophy of applying one filter (usually the maximum) for all noise conditions.

6.2 Magnetics

6.2.1 Diurnal Levelling

Base station data is edited so that all significant spikes, level shifts and null data are eliminated. The data is re-sampled and synchronised to the airborne fiducial system prior to subtraction from airborne magnetic readings. A diurnal base value was then added.

<table>
<thead>
<tr>
<th>Area</th>
<th>Base Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nabarlek 1 &amp; 2</td>
<td>46167 nT</td>
</tr>
</tbody>
</table>

6.2.2 Synchronisation Lag

A lag was applied to synchronise the magnetic data with the navigation data (see section 4.2.2).

6.2.3 IGRF Removal

The International Geomagnetic Reference Field (IGRF) 2000 model (updated for secular variation 20010.8) was removed from the levelled total field magnetics. An IGRF base value was then added to the data.

<table>
<thead>
<tr>
<th>Area</th>
<th>Base Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nabarlek 1 &amp; 2</td>
<td>45889 nT</td>
</tr>
</tbody>
</table>

6.2.4 Levelling

A Fugro proprietary micro-levelling process was applied in order to more subtly level the data. This process removes sub-gamma pulls evident only under image enhancement algorithms.
6.3 Digital Terrain Model

Where necessary, spike corrections to the raw radar altimeter data are carried out and undefined values interpolated. The data is then co-ordinated with post-processed GPS data. The aircraft’s height above ground is subtracted from the aircraft’s height above the WGS84 ellipsoid.

The accuracy of the elevation calculation is directly dependent on the accuracy of the two input parameters, radar altitude and GPS altitude. The radar altitude value may be erroneous in areas of heavy tree cover, where the altimeter reflects the distance to the tree canopy rather than the ground. The GPS altitude value is primarily dependent on the number of available satellites. Although post-processing of GPS data will yield X and Y accuracies in the order of 1-2 metres, the accuracy of the altitude value is usually much less, sometimes in the ±5 metre range. Further inaccuracies may be introduced during the interpolation and gridding process. Because of the inherent inaccuracies of this method, no guarantee is made or implied that the information displayed is a true representation of the height above sea level. Although this product may be of some use as a general reference, THIS PRODUCT MUST NOT BE USED FOR NAVIGATION PURPOSES.

6.4 Flight Path Recovery

A GPS receiver mounted in the survey aircraft uses 3D triangulation of satellite signals to calculate both the position of the aircraft in real time and to provide pilots with steering information. GPS data are read into the field computer and plotted on a daily basis to ensure data quality control and determine any re-flights. Positioning data are stored digitally as Latitudes and Longitudes and later converted to Universal Transverse Mercator coordinates using the appropriate datum. Raw GPS data are corrected with post differential corrections improving the accuracy of the recorded position.

The integrated aircraft track is plotted on a daily basis using the differential GPS data. Plots are analysed to ensure data quality and to determine any re-flights.

6.5 Survey Products

6.5.1 Multi-Parameter Profile Plots

Final GEOTEM<sub>DEEP</sub><sup>®</sup> data is presented as multi-parameter profiles after final processing in the Fugro Airborne Surveys office in Perth. The processed geophysical data are plotted at suitable scales from top to bottom. The x-axes of alternate sections of each plot are annotated with fiducial numbers or grid coordinates. The scales for the GEOTEM<sub>DEEP</sub><sup>®</sup> traces vary according to the channel, to allow resolution in late channels whilst keeping early channels on scale. The base level for each channel is separated by 0.5 cm with the latest channel always being plotted closest to the bottom of the page. Each plot has a title containing line number, job number, area name, transmitter frequency and average northing or easting.

6.5.2 Hardcopy Products

- Acquisition and processing report

6.5.3 Digital Products

- Located Data - EM window data and auxiliary data as ASCII and Geosoft GDB
- Acquisition and Processing Report
- Flight Path
- CDI plots for dB/dt and Bfield (X and Z channels 1-20, multiplots as PDF files)
- Gridded Data – ERMapper grids of EM channels and auxiliary data (TMI, TMI1VD, DEM, 16 X and Z channels for both dB/dt and Bfield data)
• Waveform files calculated from high alt cal lines pre and post flight.
# APPENDIX I – Weekly Acquisition Reports

<table>
<thead>
<tr>
<th>Date</th>
<th>F/H, Pilot Initials</th>
<th>On board Initials</th>
<th>Production Time</th>
<th>FAS Scrub</th>
<th>Time</th>
<th>Engine Hours</th>
<th>Job Hrs</th>
<th>Prod. Hrs</th>
<th>Stdby Days</th>
<th>Activity</th>
<th>Activity</th>
<th>Comments</th>
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<tr>
<td>11-Oct</td>
<td>1 PH, MC BR</td>
<td>554.900</td>
<td>6:29:00</td>
<td>10:50:00</td>
<td>4.4</td>
<td>1.00 P</td>
<td>P</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
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<td>2 PH, MC BR</td>
<td>944.000</td>
<td>6:12:00</td>
<td>10:48:00</td>
<td>4.6</td>
<td>0.50 P</td>
<td>P</td>
<td></td>
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<td>186.500</td>
<td>11:44:00</td>
<td>14:01:00</td>
<td>2.3</td>
<td>0.50 P</td>
<td>P</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14-Oct</td>
<td>4 PH, MC BR</td>
<td>480.200</td>
<td>5:58:00</td>
<td>10:20:00</td>
<td>4.4</td>
<td>0.50 P &amp; S</td>
<td>Bird problems</td>
<td></td>
<td></td>
<td></td>
<td>0.50 E</td>
<td>Bird suspension failed, replaced bird with</td>
</tr>
<tr>
<td>15-Oct</td>
<td>5 PH, MC BR</td>
<td>331.700</td>
<td>5:56:00</td>
<td>10:38:00</td>
<td>4.7</td>
<td>0.50 P &amp; R</td>
<td>Production with spare bird</td>
<td></td>
<td></td>
<td></td>
<td>0.50 TF</td>
<td>TD check flight.</td>
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<tr>
<td>16-Oct</td>
<td>6 PH, TD</td>
<td>12:05:00</td>
<td>12:55:00</td>
<td>0.8</td>
<td></td>
<td></td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>17-Oct</td>
<td></td>
<td>74.8</td>
<td>25.2</td>
<td>1927.100</td>
<td>480.200</td>
<td>1.00 SETUP</td>
<td>Job Packup</td>
<td></td>
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<tr>
<td>18-Oct</td>
<td></td>
<td>74.8</td>
<td>25.2</td>
<td>1927.100</td>
<td>480.200</td>
<td>1.00 MO</td>
<td>Demob back to Perth</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>19-Oct</td>
<td></td>
<td>8:00:00</td>
<td>14:00:00</td>
<td>6.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>20-Oct</td>
<td></td>
<td>8:00:00</td>
<td>11:30:00</td>
<td>3.5</td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

**Totals This Week:** 1927.100 480.200 30.6 0.50 A/C Hrs to Next Service 7.00

**Week Hours:** 30.6
NABARLEK AREA 2
COMM JOB NUMBER: 2160
COMM AREA NUMBER: 2
COMM SURVEY COMPANY: Fugro Airborne Surveys Pty Ltd
COMM CLIENT: Uranium Exploration Australia Ltd
COMM SURVEY TYPE: 25Hz GEOTEM Survey
COMM AREA NAME: Nabarlek
COMM STATE: NT
COMM COUNTRY: Australia
COMM SURVEY FLOWN: October, 2010
COMM LOCATED DATA CREATED: November, 2010
COMM DATUM: GDA94
COMM PROJECTION: MGA
COMM ZONE: 53

COMM SURVEY SPECIFICATIONS
COMM TRAVERSE LINE SPACING: 200 m
COMM TRAVERSE LINE DIRECTION: 90 deg
COMM TIE LINE SPACING: 2200 m
COMM TIE LINE DIRECTION: 180 deg
COMM NOMINAL TERRAIN CLEARANCE: 120 m
COMM FINAL LINE KILOMETRES: 1395.4 km

COMM LINE NUMBERING
COMM TRAVERSE LINE NUMBERS: 2001 - 2066
COMM TIE LINE NUMBERS: 2701 - 2717

COMM AREA BOUNDARY (WGS84, UTM53S)
COMM EASTING NORTHING
COMM 307882 8637797
COMM 307894 8635954
COMM 307906 8634110
COMM 307918 8632266
COMM 306578 8632257
COMM 306106 8632254
COMM 306118 8630410
COMM 306130 8628566
COMM 304318 8628554
COMM 302506 8628542
COMM 300693 8628529
COMM 298881 8628517
COMM 29868 8630361
COMM 298855 8632205
COMM 298842 8634049
COMM 298830 8635892
COMM 298817 8637736
COMM 298804 8639580
COMM 30617 8639593
COMM 302359 8639605
COMM 302430 8639605
COMM 302433 8639243
COMM 302443 8637761
COMM 304256 8637773
COMM 306069 8637785

COMM SURVEY EQUIPMENT
COMM AIRCRAFT: CASA C212 Turbo Prop, VH-TEM
COMM
COMM MAGNETOMETER: Scintrex Cs-2 Cesium Vapour
COMM INSTALLATION: stinger mount
COMM RESOLUTION: 0.001 nT
COMM RECORDING INTERVAL: 1.0 s
COMM
COMM ELECTROMAGNETIC SYSTEM: 25Hz GEOTEM
COMM INSTALLATION: Transmitter loop mounted on the aircraft
COMM Coil Orientation: X,Y,Z
COMM RECORDING INTERVAL: 0.25 s
COMM SYSTEM GEOMETRY:
COMM RECEIVER DISTANCE BEHIND THE TRANSMITTER: 136 m
COMM RECEIVER DISTANCE BELOW THE TRANSMITTER: 38 m
COMM
COMM RADAR ALTIMETER: Sperry RT-220
COMM RECORDING INTERVAL: 1 s
COMM
COMM NAVIGATION: real-time differential GPS
COMM RECORDING INTERVAL: 1.0 s
COMM
COMM ACQUISITION SYSTEM: GEODAS
COMM
COMM DATA PROCESSING
COMM
COMM MAGNETIC DATA
COMM DIURNAL CORRECTION APPLIED base value 46167 nT
COMM PARALLAX CORRECTION APPLIED 2.25 seconds
COMM IGRF CORRECTION APPLIED base value 45889 nT
COMM IGRF MODEL 2010 EXTRAPOLATED TO 2010.8
COMM DATA HAVE BEEN MICROLEVELLED
COMM
COMM ELECTROMAGNETIC DATA
COMM SYSTEM PARALLAX REMOVED, AS follows
COMM X-COMPONENT EM DATA 4.0 s
COMM Y-COMPONENT EM DATA 4.0 s
COMM Z-COMPONENT EM DATA 4.0 s
COMM DATA CORRECTED FOR COIL MOVEMENT
COMM DATA HAVE BEEN MICROLEVELLED
COMM
COMM CONDUCTIVITY DEPTH INVERSION CALCULATED EMFlow V5.10
COMM
COMM DIGITAL TERRAIN DATA
COMM PARALLAX CORRECTION APPLIED TO RADAR ALTIMETER DATA 0 seconds
COMM PARALLAX CORRECTION APPLIED TO GPS ALTIMETER DATA 0 seconds
COMM DTM CALCULATED [DTM = GPS ALTITUDE - RADAR ALTITUDE]
COMM DATA HAVE BEEN MICROLEVELLED
COMM
COMM DISCLAIMER
COMM
COMM DISCLAIMER
COMM It is Fugro Airborne Survey’s understanding that the data provided to
COMM the client is to be used for the purpose agreed between the parties.
COMM That purpose was a significant factor in determining the scope and
COMM level of the Services being offered to the Client. Should the purpose
COMM for which the data is used change, the data may no longer be valid or
COMM appropriate and any further use of, or reliance upon, the data in
COMM those circumstances by the Client without Fugro Airborne Survey’s
COMM review and advice shall be at the Client’s own or sole risk.
COMM
COMM The Services were performed by Fugro Airborne Survey exclusively for
COMM the purposes of the Client. Should the data be made available in whole
COMM or part to any third party, and such party relies thereon, that party
COMM does so wholly at its own and sole risk and Fugro Airborne Survey
COMM disclaims any liability to such party.
COMM Where the Services have involved Fugro Airborne Survey's use of any
COMM information provided by the Client or third parties, upon which
COMM Fugro Airborne Survey was reasonably entitled to rely, then the
COMM Services are limited by the accuracy of such information. Fugro
COMM Airborne Survey is not liable for any inaccuracies (including any
COMM incompleteness) in the said information, save as otherwise provided
COMM in the terms of the contract between the Client and Fugro Airborne
COMM Survey.
COMM With regard to DIGITAL TERRAIN DATA, the accuracy of the elevation
COMM calculation is directly dependent on the accuracy of the two input
COMM parameters laser altitude and GPS altitude. The laser and radar
COMM altitude value may be erroneous in areas of heavy tree cover, where
COMM the altimeters reflect the distance to the tree canopy rather than the
COMM ground. The GPS altitude value is primarily dependent on the number of
COMM available satellites. Although post-processing of GPS data will yield
COMM X and Y accuracies in the order of 1-2 metres, the accuracy of the
COMM altitude value is usually much less, sometimes in the ±5 metre range.
COMM Further inaccuracies may be introduced during the interpolation and
COMM gridding process.
COMM Because of the inherent inaccuracies of this method, no guarantee is
COMM made or implied that the information displayed is a true
COMM representation of the height above sea level. Although this product
COMM may be of some use as a general reference,
COMM
COMM THIS PRODUCT MUST NOT BE USED FOR NAVIGATION PURPOSES.
COMM -----------------------------------------------------------------------------
COMM
COMM ELECTROMAGNETIC SYSTEM
COMM
COMM GEOTEMdeep IS A TIME-DOMAIN HALF SINE-WAVE SYSTEM,
COMM TRANSMITTING AT A BASE FREQUENCY OF 25Hz,
COMM WITH 3 ORTHOGONAL-AXIS RECEIVER COILS IN A TOWED BIRD.
COMM FINAL EM OUTPUT IS RECORDED 4 TIMES PER SECOND.
COMM THE TIMES (IN MILLISECONDS) FOR THE 20 WINDOWS ARE:
COMM
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COMM 2  0.625        1.719      1.172  | "on-time"
COMM 3  1.719        2.969      2.344  | windows
COMM 4  2.969        4.531      3.750  |
COMM 5  4.531        4.688      4.609  |
COMM 6  4.688        4.844      4.766  |
COMM 7  4.844        5.000      4.922  |
COMM 8  5.000        5.313      5.156  |
COMM 9  5.313        5.625      5.469  |
COMM 10 5.625        6.094      5.859  |
COMM 11 6.094        6.563      6.328  |
COMM 12 6.563        7.188      6.875  | "off-time"
COMM 13 7.188        7.969      7.578  | windows
COMM 14 7.969        8.906      8.438  |
COMM 15 8.906        10.000     9.453  |
COMM 16 10.000       11.250     10.625  |
COMM 17 11.250       12.813     12.031  |
COMM 18 12.813       14.688     13.750  |
COMM 19 14.688       17.188     15.938  |
COMM 20 17.188       20.000     18.594  |}

COMM PULSE WIDTH 4.108 ms
COMM
COMM WAVEFORM FILE HAS BEEN PROVIDED WITH DATA (T0031210003.out)
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APPENDIX IV – List of all Supplied Data and Products

Final Located Data

2160_[1-2]_final.des  -  header file describing the contents of...
2160_[1-2]_final.asc  -  flat ascii file containing located magnetic, EM and digital terrain data
2160_[1-2]_final.gdb  -  Geosoft database file containing located magnetic, EM and digital terrain data

Final Gridded Products (delivered in ERMapper format GDA94 MGA53S)

- Total Magnetic Intensity
- First Vertical Derivative TMI
- Digital Terrain Model
- EM Channels (dB/dt & B-Field, X and Z)

Final Digital Products

- Flight Path map
- Multiplots & Stacked sections

Final Acquisition and Processing Report

Delivered as hardcopy and digitally
APPENDIX 2

Hyperspectral Survey Report
HyMap SURVEY AND PROCESSING REPORT

Arnhem Land Blocks A & B
Northern Territory

CUSTOMER: Uranium Exploration Australia Limited

CONTACT:

SURVEY DATE: October 2010

REPORT DATE: 15/11/2010

WRITTEN

Dr M C Hussey

EDITED

P Cocks

ISSUED

NOVEMBER 2010

Disclaimer: No warranty is given for the accuracy or of any of the products or statements made regarding the HyMap data or derived results, however all processing was done to the best of the author’s knowledge.
Executive Summary

HyVista Corporation was contracted by Uranium Exploration Australia Limited to acquire and process HyMap airborne hyperspectral scanner imagery from 2 survey blocks to the NE of Jabiru, NT. The data acquisition occurred between on between the 11th and 19th October, 2010.

This report describes the processing that has been applied to the HyMap data to produce a number of image products including overview colour composites, minimum noise fraction (MNF) colour composites, mineral maps (produced from unmixing and logical operator processing) and illite (white mica) wavelength shift images (that map Al content of illites-white micas) To produce these products the raw data has had a series of processes applied to it that converts it into reflectance imagery which is then geometrically corrected and radiometrically levelled to produce seamless mosaic images. These seamless images are used for all further processing.

Three (3) “Classes” of imagery have been produced:

1. Overview colour composites and MNF images can be used for photo-interpretation to delineate geological units and structural features. They do not provide information on the mineralogy of geological formations i.e. the same colour may map different rock types in these images.

2. Mineral maps where information is extracted by applying endmember unmixing and logical operator processing to the reflectance image mosaic. This requires several procedures that are carried out separately on the Short Wave InfraRed bands (SWIR: 2.00 microns to 2.43 microns) and the Visible Near InfraRed bands (VNIR: 0.488 microns to 1.12 microns). Processing of the SWIR bands maps the distribution of clay minerals, mica’s and carbonates and the VNIR bands the iron oxides.

3. Mineral chemistry mapping where a polynomial function is applied to a specific wavelength range of the reflectance data that maps the change in minima of a spectral absorption feature that shifts in position in response to changes in the chemical composition of a specific mineral.

All mineral identification is based on analysis of the spectra and since this is a subjective procedure it requires field confirmation. Some minerals, particularly those characterised by Mg-OH / carbonate absorption (~2.30 microns) have very similar spectra.

For each mineral the output products are a greyscale, greyscale thresholded and rainbow coloured images where the tone or colour depicts the abundance of the mineral mapped (i.e. increasing abundance from dark to light or from blue to red).

For the SWIR minerals RGB colour composite image maps have been produced by assigning differing mineral abundance images to the red, green and blue image bands. Other combinations are possible.

Rule Classification Images have also been produced in which up to 5 minerals are displayed,

The output images are written ENVI, ECW, and Geotiff formats. The geo-correction applied to the data results in image maps in the UTM/WGS 84 (Zone 53 SOUTH) map projection.

The Level 1 strip data (reflectance and geocorrection) and delivery image products are supplied to the customer on external USB2 disk drives.

A brief assessment of the results based on the observed mineralogy suggests several areas of hydrothermal alteration have been detected. Whilst it is possible the pyrophyllite is of detrital origin, typically this mineral is stable in relatively high temperature and relatively acid environments, and is a good indicator to hydrothermally altered regions.

Note the intermediate products are not intended to be used by the customer they are provided for future reference by HyVista staff.
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INTRODUCTION

HyVista Corporation was contracted by Uranium Exploration Australia Limited to acquire and process HyMap airborne hyperspectral scanner imagery from 2 survey blocks to the NE of Jabiru, NT. The data acquisition occurred between the 11th and 19th October, 2010.

![Figure 1: UXA Arnhem Land Survey Areas locations.](image)

The HyMap is an airborne hyperspectral scanner delivering 126 bands (approx 18 nm width per band) of imagery over the 450nm to 2500nm spectral interval. The HyMap data pre-processing is carried out on a strip by strip basis, to produce radiance and apparent reflectance, and GLT files for later geometric rectification / mosaicing. The reflectance images are cross track and level corrected, (i.e. solar illumination corrected). These reflectance images are then geo-corrected to position each individual pixel in its accurate geo-location in the UTM/WGS 84 map projection. The corrected strips are then mosaiced to produce a seamless, homogeneous data (map) cube for the whole survey area, level 1C processing. This data-cube is then processed to produce the various images Level 2 and 3 products detailed below.

Figures 2a & b show an example image produced from the cross-track illumination and level corrected reflectance data for each survey block (not same scale); this is a colour composite in which bands 109, 28, 03 are displayed in red, green, and blue respectively. For colour composite images the order of band numbers, wavelengths or mineral names in the file name is always red, green and blue.

![Figure 2a: Overview False Colour Composite (RGB Bands 109, 28, 3 – equivalent to Landsat 7, 4, 2 colour composite image) of block A.](image)
This document outlines the pre-processing (Level 1) and details the Level 2 and Level 3 processing applied to HyMap data. Further information on the sensor specification, survey planning and data pre-processing is available upon request. A summary of the flight line planning supporting this survey is provided in Appendix 2.

DATA PROCESSING

Three levels of process have been applied to the data for this project and the initial products are stored as intermediate images. These intermediate are analysed, scaled, thresholded, masked and overlain onto background images as required to produce the delivery product images:

**LEVEL 1 A&B**
Raw and Pre-processed data

**LEVEL 1C**
Cross track corrected mosaiced reflectance image (Data-Cube)

**LEVEL 2**
Colour composites, true and false colour
SWIR MNF Image from which a colour composite of bands 2-3-4 has been produced

**LEVEL 3**
Mineral Mapping from unsupervised statistical based end-member unmixing and logical operator supervised classifications to produce:

- Mineral abundance images presented as:
  - Thresholded greyscale images
  - Rainbow coloured threshold images
  - Mineral colour composites of thresholded images
  - Rule classified Images of thresholded images

Wavelength Shift for Illite (White Mica) Al-OH content presented as:
**MAP PRODUCTS**

The delivered map products are precision geo-rectified 53 South.

**LEVEL 1 / PRE-PROCESSING OF DATA**

The HyMap scanner data is collected and stored on a DLT flight tape and converted to ENVI-compatible image files (16-bit integer, BIL data file with an ASCII header file) during pre-processing of the data. The HyMap stores the intensity of light reflected from the surface of the earth as digital numbers (DN). The intensity recorded is the net effect of the wavelength-dependent atmospheric absorption and scattering, solar irradiance, light scattered back from the earth surface, and background voltages from the scanner electronics. Pre-processing involves two corrections.

**Dark Current Subtraction**

This correction removes the “zero light” spectrum in all image pixels. The DN values for subtraction are obtained from the scanner while imaging a non-reflecting surface. It represents system voltages and electronic noise. It is additive and band-dependent.

**Calibration – Radiometric, Spectral and Scaling**

The scanner is calibrated using a standard light source so the response of each detector is known. Every pixel of each band has been scaled by this band constant and a multiplier has been applied so that the data is stored as a 16-bit integer.

**Data Units**

When the pre-processing corrections described above have been applied, the data are in radiance units of microwatts/cm²/steradian/nm before the multiplier of 1000 is applied to convert it to a 16-bit integer.

**Atmospheric Correction**

Whilst the HyMap’s radiance data is spectrally and radiometrically calibrated, the spectra are distorted by atmospheric absorption and scattering. The data has been processed using the HyCorr program that determines a model of a subset of atmospheric properties that are appropriate for the time (UTC), date, latitude/longitude and acquisition height (AGL) for HyMap data that has been radiance corrected. HyCorr uses radiative transfer calculations and the calibrated hyperspectral data (with artefact suppression) to remove and reduce atmospheric and solar illumination effects. The output of HyCorr is an apparent surface reflectance image from which spectra can be compared to relative reflectance library spectra, i.e. the atmospheric over-print has been removed and mineral absorption features are now recognisable. HyCorr output is apparent surface reflectance. Reflectance imagery is unit-less.

**Cross Track Correction and Strip Levelling**

Prior to geometric correction each strip is processed to remove the effect of bi-directional reflectance that results from non uniform illumination across the image when the azimuth is to the side of the flight line. This results in the images being brighter on one side than the other. The levelling correction adjusts each data strip to the same data ranges. These corrections improve processing and ensure that the final mosaic images are seamless.

**Geometric Correction**

Variations in the aircraft orientation, speed and altitude during image acquisition result in spatial distortions of the images, even though the scanner is mounted in a tri-axial, gyro-stabilised platform that compensates for some of these motion effects. An IMU/GPS unit is attached to the scanner and it provides data that can be used remove these distortions which would otherwise result in positional errors of several hundred metres. Using these data with the appropriate software permits geo-correction to be completed without the need for control point picking and, depending on terrain variation; this can reduce positional errors to below 20m.
Software developed by HyVista is used for to produce a ray traced image (.glt) file from combining the output from the IMU/GPS with a DEM (SRTM 90m image). The glt file is then used to georectify the image products produced to the UTM/WGS84 map projection using proprietary HyVista software.

Level 1C Product

In this survey the cross track corrected and levelled reflectance data have been mosaiced into data cubes for the SWIR and VNIR bands and subsequent Level 2/3 processing has been carried out using these images. Prior to applying the additional processing image masks are generated that remove areas of abundant green/dry vegetation, water, shadow, bright spots due to fires and cultural features such as highly reflective steel roofs as these features can affect the statistical processes applied.

LEVEL 2 PROCESSING

Colour Composite Mosaics

Overview Colour Composites

Two colour composite images have been produced from the reflectance data consisting of:

Landsat TM 742 equivalent: RGB = 2.206um/0.851um/0.488um (HyMap bands 109, 28, 03 respectively)
True Colour: RGB=0.664um/0.577um/0.488um (HyMap bands 15, 09, 03 respectively)

The contrast in these colour composites has been enhanced by applying the ENVI contrast stretches to the images.

Note all colour composite images (MNF and Mineral Map) have a naming convention where band numbers or mineral names are given in order Red, Green and Blue the same as they are displayed.

MNF Transform

For the SWIR, MNF transforms have been applied to the reflectance data and from these images a colour composite has been produced (MNF bands RGB 2, 3, 4). This band combination shows the greatest variation in surface materials producing images that highlight geological and regolith variation within the area.

LEVEL 3 PROCESSING

Mineral Mapping

Hyperspectral remote sensing is essentially a mineral mapping technology. Its fundamental principles are based on spectroscopy, so an understanding of the spectral signatures of surface materials is required for its application. Briefly, each pixel of a hyperspectral image contains a spectrum which forms the basis for determining the materials present in a scene. Surface mineralogy and other components are mapped using algorithms which either de-convolve a scene into component endmember signatures (unsupervised unmixing) or specifically target spectral signatures of known materials (supervised match filtering). A recently developed refinement to the band depth ratio process (logical operators) has also been utilised. A combination of these approaches has been applied in the project.

Spectral Endmember Un-mixing

Linear spectral unmixing is the process of deriving the abundances of component materials in a scene from the individual pixel spectra, given the endmember spectral signatures. To give perfect unmixing results, the signatures for all endmembers present in a scene would need to be known. However, in practice, unmixing algorithms map the distribution of automatically scene derived endmember materials. These are especially useful for analysis where signatures of the target(s) are not known and for general geological and regolith mapping.
Unmixing methods output a set of endmember spectra with corresponding un-mixed images which are, in effect, mineral maps. There are several programs that can be used for this type of processing. ENVI has a selection of mapping methods which generate abundance images notably Matched Filtering and Matched Tuned Filtering. However, HyVista has several proprietary unmixing programs that can be applied to mosaiced reflectance imagery (as in this case) or allows for the selection of endmember data from multiple strips without the need to mosaic them. Thus, when they are un-mixed, the distribution of endmembers matches across images strip boundaries. This software produces mineral maps that can be used for geological and regolith interpretation where there is no a priori knowledge of the minerals present in the area. In these survey data unsupervised unmixing worked well and applying the supervised techniques did not improve overall mineral mapping results though this may be required to detect specific minerals in sub-scene area during more advanced analysis (Level 4 processing).

Prior to applying the unmixing algorithm, the data are processed to remove pixels that are of shadow, anomalously bright areas (such as active fires and metal roofs), and surface water, green and dry vegetation. These are effectively noise pixels and affect the image statistics. These pixels are masked out (i.e. set to zero).

Running the un-mixing algorithm produces two outputs; an endmember library that contains the spectra for each spectral endmember detected within the data, including minerals, and a series of abundance images (one for each flight line) each band of which maps the distribution of a spectral end member. The program is run several times, with differing parameters, to determine the optimum output in terms of minerals mapped and is run separately on the Visible Near Infra Red bands (VNIR 0.5 microns to 1.12 microns) for iron oxides and Short Wave Infrared bands (SWIR 1.95 microns to 2.45 microns) for phyllosilicates, carbonates and other minerals with cation OH bonds (e.g. amphiboles).

The spectral libraries are examined and endmembers recognised as minerals are determined and then mineral species identified. Non mineral spectra may include those from noisy spectra, residual vegetation, spectrally featureless areas and multiple mixed spectra that cannot be identified. The program uses a statistical technique to match each pixel to a spectral endmember and creates the abundance images such that each pixel has a value that is proportional to its closeness of fit to the spectra in question, the higher the value the better the match. In percentage terms, pixels with 0% have no match and the values of 100% have a perfect match and would be “pure” spectra but these will be quite rare within an image as most pixels will contain several different materials.

**Logical Operators**

In this process where mineral spectra have several absorption features the presence of which, their relative depths and width of the feature at half of its depth are used to identify which mineral a spectrum identifies by applying logical rules based on these criteria. Logical Operators have been established for:

- Alunite (Al), Amphibole(Am), Apatite(Ap), Biotite(Bi), Buddingtonite (Bu), Calcite (Ca), Carbonate-Chalcedony(Op), Chlorite mixture (ChCa), Chlorite (Ch), Dickite(Di), Dolomite(Do), Epidote(Ep), FeOx-Goethite(Go)*, FeOx-Hematite(He)*, Gibbsite (Gi), Gypsum(Gy), Jarosite(Jr), Kaolinite (Ka), Muscovite(Ms)**, Montmorillonite(Mo), Nontronite(No), Paragonite(Pa)**, Phengite(Ph)**, Phengite2(Ph2)**, Pyrophyllite(Py), Serpentine (Se), Talc(Ta), Topaz(To), Tourmaline(Tu), Trona(Tn)

*Iron oxides may be a mixture of hematite and goethite and dominant type mapped is assessed from examining the wavelength position of the broad absorption feature between 0.86 and 1.00 microns.

** The white micas or illites main absorption feature shifts its minima from 2.185 microns to >2.225 microns depending on its Al content, the shorter the wavelength the higher the Al content. These minerals can also be named as Illite (III) with the location of the absorption feature appended thus:

Paragonite – III2185 toll2190
Muscovite –~ III2205
Phengite – III2211
Phengite2 – III2220 or III2225
Thresholding

In probability terms pixels in percentage range above 85% have a significant content of the spectral endmember (mineral). Examining the spectra of areas highlighted above 85% using an interactive linear stretch (Figure 3) determines the minimum value in the image where spectra of interest are present (abundant). Pixels below this value are set to zero and those above to the scaled from 0 to 1 (i.e. real data), a thresholded image. The values for this thresholding are recorded and shown in table 3. Thresholding is also applied to LO Index images.

![Figure 3: Thresholding, image left has no threshold applied and the image to the right has been thresholded at greater than 85% using the interactive stretch function in ENVI.](image)

Processing Sequence

In this case the following processing sequence was applied to the masked reflectance image:

**SWIR**

*Unmixing and Logical Operators*

The logical operator functions were run first and where mineral were detected threshold values were determined and applied after examining the spectra to validate the mineral identification. Unmixing processing was then applied and the endmember images that were mapping minerals were similarly assessed, thresholded and stored. The thresholded mineral abundance images from the differing processes were then compared and those considered to be the most robust were selected. After final thresholding the greyscale mineral map images have a rainbow colour look up table applied to them (ENVI rainbow) such that blue pixels indicate a less perfect match, possibly due to dilution effects, grading through green, yellow and red being the best match. This image is also saved in jpg, tiff, ecw and img (ENVI bil with ERMapper header) formats and has the identifier “rainbow” in the file name.

While the unmixing is set to resolve up to 22 unique minerals (VNIR+SWIR) or mineral mixtures and the logical operator tests for the presence at least 30 minerals, only a small number of minerals were detected in these survey blocks (Table 1.). After checking the images produced from the unmixing and logical operator processing those that display coherent spatial patterns are selected and thresholded to produce BW and RAINBOW mineral maps.

Using the rainbow coloured abundance images to locate the highest abundance (purest areas) of the mineral mapped, A characteristic spectrum is selected from these mineral maps, displayed with the continuum removed (CR) and stored as jpeg images. These spectra are shown in Table 3 below.
The selected mineral map images are also combined as RGB colour composites, that is, different endmembers combined in red, green and blue, with the relatively small number of endmembers detected, one RGB colour composite have been produced. Colour triangle legends as jpeg images are included with these images.

ENVI has a Rule Class function which permits the combination of the thresholded greyscale images into colour coded mineral maps, one has also been produced and Rule Class Legends have been produced as jpeg images.

**Wavelength Shift**

Using a polynomial fitting program the change in absorption minima between 2.180um and 2.225um has been mapped. The resultant image is scaled so that the grey scale values map the absorption from 2.18um shortwave absorbing illite or white mica (Al rich muscovite: paragonite) to 2.227um long-wavelength absorbing white mica (Al poor muscovite: phengite). The confusing effects of kaolinite which also has an absorption minimum within this wavelength range are minimised by identifying pixels containing kaolinite and masking those pixels.

Usually, a rainbow colour table is then applied to colour the image so that the absorption at 2.180um is mapped in blue through to the 2.227um in red i.e. cool colours represent paragonite, intermediate colours (green-yellow) muscovite and warm colours phengite. However, the white mica / illite wavelength absorption minima range observed in these survey data is relatively restricted and indicates most are the short wavelength / relatively Al rich variety. A rainbow colour table has been applied to colour the image so that the absorption at 2.180um is mapped in blue through to the 2.195um in red i.e. the white mica species is probably paragonite and colour variation maps subtle changes in its Al content (Plate 8).

The advanced argillic minerals alunite and pyrophyllite are spectrally distinctive with absorption minima between 2.165 and 2.175um. By selecting a slightly different wavelength range to the white mica image and inverting the table used to colour the data, it is possible to highlight areas of potential advanced argillic alteration (Figure 4).

![Figure 4: Wavelength Shift Image scaled from 2.165um to 2.195um. Inverted rainbow coloured, highlights (red / yellow) areas of potential advanced argillic minerals such as pyrophyllite. Example from Block B, western edge of the survey.](image-url)
IMAGE PROCESSING PRODUCTS

The intermediate products are not intended to be used by the customer and are provided in ENVI format only, for future reference by HyVista staff.

Tables 1 and 2 list the abbreviations used in the image file names including mineral names.

Table 3 lists all of the files produced in the Level 2 and Level 3 processing and final delivery images and the spectra of the various minerals mapped.

Examples of the images products are presented in Appendix I.

All the presentations of Mineral Maps (greyscale thresholded, rainbow, colour composite, rule class and wavelength shift) show areas devoid of minerals with distinct and classifiable spectra in black (0). It is possible to overlay these mineral maps products onto a greyscale background image. However, this can distract from the pattern of mineral distribution and also make overlaying these images with other data in a GIS package less effective.

If the customer requires such background versions of the Mineral Maps they can be requested and produced. Alternatively the customer can produce them by overlaying the required mineral map onto the first band of the overview colour composite (OCC15-9-3_rgb) selected from the tiff image in their GIS software.

ANALYSIS

The terrain imaged in both survey blocks by the HyMap data is characterised by three minerals; kaolinite, a white mica / illite and pyrophyllite. These minerals are observed as coherent spatial patterns and as pure examples and as mixtures. The unmixing derived mineral maps (MM_AB#) probably best depict this mineralogy.

Kaolinite is widespread. This is not unexpected as it is a common component of the regolith developed under tropical weathering. The spectral expression varies greatly suggesting mineral crystallinity also varies. When in spatial association with pyrophyllite; dickite rather than kaolinite is suspected. However, it is spectrally difficult to separate these minerals.

White mica / illite is also relatively widespread. Whilst it is characterised by shifts in its wavelength, these shifts are minor and indicate that all white mica /illite observed in both survey blocks is relatively Al rich perhaps paragonite. Generally, this mineral forms in relative high temperature and relatively acid environments.

Pyrophyllite is observed at a small number of locations within the survey blocks (Examples: Block A in the south west & Block B western edge). This mineral typically depicts advanced argillic style hydrothermal alteration and is stable in high temperature and strongly acid environments. The lower image depicted in Figure 5 is an example on one occurrence of this mineral (Block B). The red hues highlight the presence of pyrophyllite. The slightly more mauve hues suggest a kaolinite group mineral (perhaps dickite) is mixed with the pyrophyllite.
Figure 5: The lower image is an unmixing Mineral Map Colour Composite, RGB, Pyrophyllite-Kaolinite, WM2187-2206 and Kaolinite abundance image. The upper image is an overview colour composite of the same area for comparison.

DATA DELIVERY

The processed data are supplied an external disk with the following directory structure:
//UXA SURVEYS OCT 2010
//UXAARNHEM

// LEVEL 1 A & B [Strip data with raw, radiance, reflectance and geocorrection images-glit images]

//UXAARNHEM Ancillary Data and Location

//UXAARNHEM Intermediate Processing
//UXAARNHEM (A, B) Processing
  LEVEL 1C [Reflectance data cubes]
  LEVEL 2
    //Masking
    //MNF Colour Composites
    //Overview Colour Composites
  LEVEL 3
    //Index Images (Logical Operator)
    //Mineral Maps Greyscale TH (Thresholded)
    // Mineral Maps Colour Composites
    //Mineral Maps Selected
    //Mineral Maps rainbow [Coloured]
    //Rule Classification [Mineral Maps]
    //Unmixing
    //Wavelength Shift White Mica
    //Spectra

//UXAARNHEM Delivery Products
//UXAARNHEM (A, B) Delivery Products
  // Mineral Maps Colour Composites
  //Mineral Maps Thresholded Selected
  //Mineral Maps rainbow [Coloured]
  //MNF Colour Composites
  //Overview Colour Composites
  //Rule Classified [Mineral Maps]
  // Wavelength Shift White Mica
  //Spectra

Mineral File Naming and Table 1

The naming convention in the delivery products gives the survey name, block, data source and process from which mineral derived, mineral name and processes applied to the mineral maps as follows:

Mineral Maps Thresholded BW and RAINBOW

The file named: uxaarnhem_A_ref_MM_FPL_AB#06_WM2187-2205_bw_TH;

Is a black / white (wm) white mica image (WM) that has been thresholded (TH). Original processed data being UXA Arnhem Land Block A and derived from reflectance (ref) data. This mineral map (MM) image was selected from endmember unmixing set to find 13 endmembers of which the 6th band (AB#06) is a relatively Al rich white mica / illite (perhaps paragonite). The numbers 2187 / 2205 are the HyMap band centres in nm.

A similar endmember image has been derived from the use of the logical operator (LO) technique which is based on band depth-position of an absorption feature. MM_AB#xx is replaced by LO_MM in the file name.

These black & white mineral map images can be rainbow coloured by applying an ENVI colour lookup table. In the file name BW is replaced by rainbow.

See table 2 for file name abbreviations.
Colour Composites

These images have been derived from stack image that has had all of the separate thresholded mineral maps combined.

The file name: uxaarnhem_A_ref_mmcc_ab#070608_KaPy-WM-Kaolinite_rgb_th;

Is a colour composite of unmixing derived mineral maps listed (MMCC); display in red, green and blue respectively i.e. KaPy (Kaolinite-Pyrophyllite mixture) in red, WM (short wavelength white mica / illite) in green and Kaolinite in blue).

Table 1 Names of Minerals Mapped and Abbreviations Used

<table>
<thead>
<tr>
<th>Mineral</th>
<th>Abbreviation</th>
<th>Pure or Mineral Mixture</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pyrophyllite</td>
<td>Py</td>
<td>Both</td>
<td>Indicates passage of hot (&gt;250°C) acid (pH&lt;4) fluids, often accompanied by kaolinite/ dickite, hydrothermal alteration</td>
</tr>
<tr>
<td>Dickite/Kaolinite</td>
<td>Di</td>
<td>Mixture</td>
<td>Difficult to spectrally discriminate between dickite and kaolinite. In these survey blocks there is a kaolinite group mineral mixed with the pyrophyllite.</td>
</tr>
<tr>
<td>Hematite</td>
<td>He</td>
<td>Pure</td>
<td>Defines the tracks / roads in block a and adjacent maintenance pits. Not detected in block b.</td>
</tr>
<tr>
<td>Kaolinite</td>
<td>Ka</td>
<td>Both</td>
<td>Commonly supergene / weathering but also in lower temperature late stage hydrothermal overprints. Acid conditions. Spectral expression varies with crystallinity, regolith position, transport, etc...</td>
</tr>
<tr>
<td>Muscovite (or Illite)</td>
<td>WM</td>
<td>Both</td>
<td>The wavelength minima observed in HyMap data of both block a &amp; b suggest an Al rich white mica perhaps paragonite. Suggests relatively high temperatures and relatively acid conditions</td>
</tr>
<tr>
<td>Nontronite?</td>
<td>No</td>
<td></td>
<td>Generally spotty spatial distribution. Nontronite is a Fe rich phyllosilicate usually a weathering product of mafic rocks. It is possible the mineral maybe talc or an amphibole such as actinolite.</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Description</td>
<td></td>
<td></td>
</tr>
<tr>
<td>--------------</td>
<td>-------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AB#</td>
<td>Abundance Band Number Of Unmixing Image</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AAM</td>
<td>Modified white mica wavelength absorption minima images displaying potential advanced argillic minerals in warm hues</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BG</td>
<td>Background Image – colour image overlain on background image</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CC</td>
<td>Colour Composite</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DB</td>
<td>Band Depth - Index image that maps the relative depth of a specified absorption feature, identifies classes rather than individual minerals</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DCS</td>
<td>Decorrelation Stretch Image</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DVeg</td>
<td>Dry Vegetation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EQUALISE OR HE</td>
<td>Histogram Equalize contrast stretch</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GEO</td>
<td>Geo-Corrected Data using a HyMap glt (geometric lookup table) file</td>
<td></td>
<td></td>
</tr>
<tr>
<td>G</td>
<td>Gaussian contrast filter applied to image to reduced contrast effects of bright &amp; dark areas</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GVeg</td>
<td>Green Vegetation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>INDEX</td>
<td>Logical operator derived image based on presence and Band Depth of defining absorption features</td>
<td></td>
<td></td>
</tr>
<tr>
<td>INVERTED</td>
<td>Negative Image</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MF</td>
<td>Match Filter Unmixed Abundance Output</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MNF</td>
<td>Minimum Noise Fraction Transform Image</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MOS</td>
<td>Mosaic of all survey strips that have been cross track corrected and leveled</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MM</td>
<td>Mineral Map Produced from unmixing – Factorisation (# Number is number of endmember in unmixing image)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MMAM#</td>
<td>Mineral map produced from Unmixing Absorption Band Mapping (# Number is number of endmember in unmixing image)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LOMM</td>
<td>Mineral map produced from Logical Operators</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MMCC</td>
<td>Mineral Map Colour Composite</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OCC</td>
<td>Overview Colour Composite</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PL</td>
<td>Unmixed Output</td>
<td></td>
<td></td>
</tr>
<tr>
<td>REF</td>
<td>Reflectance Data – Atmospherically Corrected</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RC</td>
<td>Rule Classified Image - mineral maps combined into 1 image with each mineral mapped to a unique colour</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RGB</td>
<td>Red, Green, Blue - following band numbers or mineral names displayed in these colours respectively</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SCALED</td>
<td>Linear Contrast Stretch</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SGA</td>
<td>Unmixed Output</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SR</td>
<td>Square Root Contrast Stretch</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SWIR</td>
<td>Shortwave Infra Red Bands from 2.00um to 2.45um image of these bands derived for processing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Th</td>
<td>Images thresholded &gt;85% to &gt; 99.5%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VNIR</td>
<td>Visible Near Infra Red Wavelengths from 0.45um to 1.13um image of these band derived for processing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>W</td>
<td>Wallis contrast filter applied to reduce contrast effects of bright and dark areas</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WM</td>
<td>White Mica mineralogically same as illite</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WM WVL</td>
<td>Map of White Mica main absorption from 2.18 to 2.205um i.e. Al Rich To Al Poor</td>
<td></td>
<td></td>
</tr>
<tr>
<td>X_ab</td>
<td>Mineral Abundance file where x is number of endmembers derived from unmixing software</td>
<td></td>
<td></td>
</tr>
<tr>
<td>XTR</td>
<td>X-Track (BRDF) corrected results (removing illumination variations common to one survey strip)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BLOCK B</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>----------------</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mineral Map Colour Composites</td>
<td>See Selected Minerals below</td>
<td>See Selected Minerals below</td>
<td></td>
</tr>
<tr>
<td>uxaaarnhem_B_ref_MM_FPL_RGB_(ab#080907)_Pyrophyllite-WM-Kaolinite</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>uxaaarnhem_B_ref_MM_FPL_RGB_(ab#080907)_Pyrophyllite-WM-Kaolinite_median</td>
<td>Median Filter applied to removed scattered pixels.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mineral Maps Greyscale TH</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>uxaaarnhem_B_ref_MM_FPL_FPL_ab#07_Kaolinite_bw_TH</td>
<td><img src="image1.png" alt="Spectral Profile" /></td>
<td>0.189-0.422</td>
<td></td>
</tr>
<tr>
<td>uxaaarnhem_B_ref_MM_FPL_ab#08_Pyrophyllite-Kaolinite_bw_TH</td>
<td><img src="image2.png" alt="Spectral Profile" /></td>
<td>0.117-0.393</td>
<td></td>
</tr>
<tr>
<td>Sample Description</td>
<td>Reflectance Range</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-----------------------------------------------------------------------------------</td>
<td>-------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>uxaarnhem_B_ref_MM_FPL_ab#09_WM2187-2206_bw_TH</td>
<td>0.119-0.387</td>
<td></td>
<td></td>
</tr>
<tr>
<td>uxaarnhem_B_ref_LO_MM_Dickite-Kaolinite_bw_TH</td>
<td>0.193-0.320</td>
<td></td>
<td></td>
</tr>
<tr>
<td>uxaarnhem_B_ref_LO_MM_Kaolinite_bw_TH</td>
<td>0.171-0.364</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sample</td>
<td>Reflectance (nm)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>---------------------------------------------</td>
<td>------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>uxaarnhem_B_ref_LO_MM_Kaolinite-WM2187_bw_TH</td>
<td>0.105-0.207</td>
<td></td>
<td></td>
</tr>
<tr>
<td>uxaarnhem_B_ref_LO_MM_Nontronite_bw_TH</td>
<td>0.022-0.077</td>
<td></td>
<td></td>
</tr>
<tr>
<td>uxaarnhem_B_ref_LO_MM_Pyrophylite_bw_TH</td>
<td>0.120-0.456</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Possible but probably talc or an amphibole such as actinolite.
<table>
<thead>
<tr>
<th>uxaarnhem_B_ref_cc_MNF_RGB_2_3_4_G</th>
</tr>
</thead>
</table>

**Overview Colour Composites**

uxaarnhem_B_ref_OCC_15-09-03_G  
uxaarnhem_B_ref_OCC_28-15-03_G  
uxaarnhem_B_ref_OCC_109-28-03_G

**Rule Classification**

uxaarnhem_B_ref_LO_MM_Stacked_5-Minerals_RC_rgb

**Wavelength Shift White Mica**

uxaarnhem_B_ref_WM_wvl_masked_rainbow_TH  
uxaarnhem_B_ref_AAM_wvl_masked_inverted_rainbow_TH  

*(Colour Tables Inverted)*  

2.179um – 2.195um  

2.165um – 2.195um
APPENDIX I
EXAMPLE IMAGE GALLERY BLOCK B

Plate 1: Overview Colour Composite Image–Natural Colour Bands15, 09, 03 (RGB)
Plate 2: MNF Colour Composite Bands2-3-4 (RGB)
Plate 3: Greyscale Thresholded: Pyrophyllite-Kaolinite unmixing derived mineral abundance image.
Plate 5: Mineral Map greyscale rainbow coloured Pyrophyllite-Kaolinite unmixing derived mineral abundance image.
Plate 6: Unmixing Mineral Map Colour Composite, RGB, Pyrophyllite-Kaolinite, WM2187-2206 and Kaolinite abundance image
Plate 7: White Mica Wavelength Shift Image scaled from 2.179μm to 2.195μm rainbow coloured.
Plate 8: Wavelength Shift Image scaled from 2.165um to 2.205um inverted rainbow coloured, highlights (red) potential advanced argillic minerals such as pyrophyllite.
APPENDIX 3
SURVEY FLIGHTLINE SPECIFICATIONS

Site Name: NT – UXA ARNHEM
Project name: AUS2010B
Project number: NT – UXA ARNHEM

Footprint across: 1649.00
Sidelap: 20.0
Flying height agl: 1400 m
Field of view: 61

TOTAL QUANTITIES
Totals for runs + strips
Total lines: 17
Total length (km): 269 km
Total length (nm): 145 nm

Coordinate system: UTM coordinate system
Projection: Transverse Mercator
Ellipsoid: wgs-84

Strips
Total strips: 17
Total length (km): 269 km
Total length (nm): 145 nm

Strip number: 1
WGS84 Start: -12 08.191 / 133 15.856
WGS84 End: -12 08.248 / 133 25.242
UTM WGS84 Start: [53] 311119 / 8657748
UTM WGS84 End: [53] 328146 / 8657748

Strip number: 2
WGS84 Start: -12 08.936 / 133 15.851
WGS84 End: -12 09.092 / 133 25.237
UTM WGS84 Start: [53] 311119 / 8656376
UTM WGS84 End: [53] 328146 / 8656376

Strip number: 3
WGS84 Start: -12 09.677 / 133 15.847
WGS84 End: -12 09.813 / 133 25.233
UTM WGS84 Start: [53] 311119 / 8655009
UTM WGS84 End: [53] 328146 / 8655009

Strip number: 4
WGS84 Start: -12 10.433 / 133 17.774
WGS84 End: -12 10.477 / 133 25.223
UTM WGS84 Start: [53] 314624 / 8653637
UTM WGS84 End: [53] 328135 / 8653637

Strip number: 5
WGS84 Start: -12 11.174 / 133 17.769
WGS84 End: -12 11.241 / 133 29.222

Strip number: 6
WGS84 Start: -12 11.918 / 133 17.764
WGS84 End: -12 11.985 / 133 29.217
UTM WGS84 Start: [53] 314624 / 8650899
UTM WGS84 End: [53] 335396 / 8650899

Strip number: 7
WGS84 Start: -12 12.659 / 133 17.760
WGS84 End: -12 12.726 / 133 29.213
UTM WGS84 Start: [53] 314624 / 8649532
UTM WGS84 End: [53] 335396 / 8649532

Strip number: 8
WGS84 Start: -12 13.400 / 133 17.755
WGS84 End: -12 13.445 / 133 25.205
UTM WGS84 Start: [53] 314624 / 8648166
UTM WGS84 End: [53] 335396 / 8648166

Strip number: 9
WGS84 Start: -12 14.107 / 133 17.817
WGS84 End: -12 14.190 / 133 25.207
UTM WGS84 Start: [53] 303864 / 8646793
UTM WGS84 End: [53] 328146 / 8646793

Strip number: 10
WGS84 Start: -12 14.848 / 133 17.812
WGS84 End: -12 14.930 / 133 25.202
UTM WGS84 Start: [53] 303864 / 8645427
UTM WGS84 End: [53] 328146 / 8645427

Strip number: 11
WGS84 Start: -12 17.913 / 133 09.297
WGS84 End: -12 17.913 / 133 09.297
UTM WGS84 End: [53] 299341 / 8639744
UTM WGS84 Start: [53] 299341 / 8628314

Strip number: 12
WGS84 Start: -12 17.918 / 133 10.054
WGS84 End: -12 17.918 / 133 10.054
UTM WGS84 Start: [53] 300714 / 8639744
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<th>WGS84 Start</th>
<th>WGS84 End</th>
<th>UTM WGS84 Start</th>
<th>UTM WGS84 End</th>
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</thead>
<tbody>
<tr>
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<td></td>
<td></td>
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<td>UTM WGS84 Start: [53] 302080 / 8639744</td>
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<tr>
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<td>UTM WGS84 End: [53] 302080 / 8628314</td>
</tr>
<tr>
<td>14</td>
<td>-12 17.928 / 133 11.561</td>
<td>-12 24.127 / 133 11.519</td>
<td>[53] 303447 / 8639744</td>
<td></td>
</tr>
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<td></td>
<td>UTM WGS84 Start: [53] 304819 / 8639744</td>
</tr>
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<td></td>
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<td></td>
<td>UTM WGS84 End: [53] 304819 / 8628314</td>
</tr>
<tr>
<td>15</td>
<td>-12 17.933 / 133 12.318</td>
<td>-12 24.132 / 133 12.276</td>
<td>[53] 306185 / 8639744</td>
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</tr>
<tr>
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<td></td>
<td>UTM WGS84 Start: [53] 306185 / 8639744</td>
</tr>
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<td></td>
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<td></td>
<td>UTM WGS84 End: [53] 306185 / 8628314</td>
</tr>
<tr>
<td>16</td>
<td>-12 17.938 / 133 13.071</td>
<td>-12 24.137 / 133 13.029</td>
<td>[53] 307557 / 8639744</td>
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<tr>
<td></td>
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<td>UTM WGS84 Start: [53] 307557 / 8639744</td>
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