Northern Territory Government

DEPARTMENT OF **MINES AND ENERGY**

MLN 1 - Report Cover Sheet

Tenure:	MLN 1
Title:	MLN 1 Annual Report 1 – August 2014 to August 2015
Period:	12th August 2014 to 11th August 2015
Project Name:	MLN 1
Title Holder:	Energy Resources of Australia Ltd.
Title Operator:	Energy Resources of Australia Ltd.
Personal Author:	Greg Rogers
Report Type:	Annual
250K Mapsheet/s:	Alligator River SD5301
100K Mapsheet/s:	East Alligator 5473, Cahill 5472
Geological Province:	Pine Creek Orogen
Stratigraphic Name:	Cahill Formation, Kombolgie Formation, Nanambu Complex
Keywords:	Uranium, MLN1
Commodity:	Uranium
Drilling:	Nil
Geochem Sampling:	Nil
Geophysics:	Nil
Work Done:	No exploration or evaluation work was carried out on the MLN1 lease in the reporting period.
Results:	Nothing to report
Conclusions:	MLN1 and the Jabiluka mineral resource remain under the Jabiluka Long Term Care and Maintenance Agreement between ERA, traditional owners and the Northern Land Council dated 25 February 2005 (LTCMA). Under the terms of the LTCMA ERA has agreed not to undertake any mining development or apply for any authorisation to undertake mining development on MLN1 without the approval of traditional owners. Based on the current circumstances, ERA has not undertaken any exploration on the MLN1 lease during the period to which this report applies.

Energy Resources of Australia Ltd

MLN1 – Exploration Report - 2015

Alligator River SD53-01, Northern Territory
Alligator Rivers Uranium Field

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Date:	October 2015
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Submitted:	Greg Rogers
Distribution:	ERA Darwin Office

Exploration Report No: ERA_EXPL002

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1 LOCATION MAP

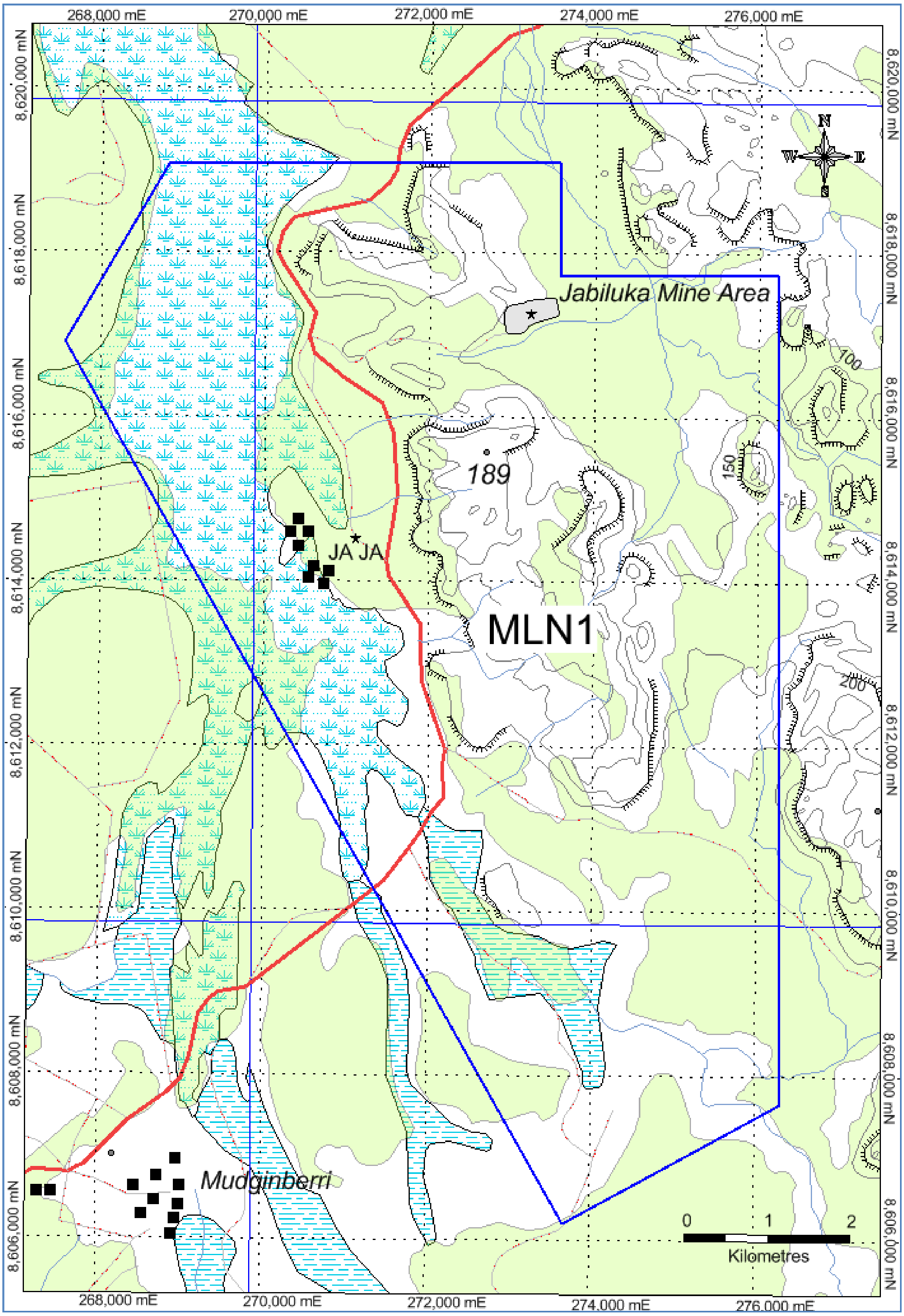


Figure 1 – Map showing the location of MLN 1 – Northern Territory Australia.

Map shown in MGA Zone 53.

2 REGIONAL GEOLOGY

2.1 Regional Geological Correlation

The majority of the rocks that make up the wasterock stockpiles at Ranger Uranium Mine (RUM) are derived from a sequence of what are largely metasedimentary rocks, known as the Cahill Formation. The Cahill sequence forms a continuous folded belt approximately 5km wide, covering an area of some 15000 square kilometres geographically. The ribbon like, V-shaped occurrence stretches roughly north-south from approximately the entrances of the South Alligator and East Alligator rivers in the north to the escarpment of the Arnhem Land Plateau near Mount Partridge Range in the south (see fig 3.1).

Regionally the Cahill Formation is situated within the eastern limits of an extensive synclinal geological formation known as the Pine Creek Geosyncline (PCG) of which it is part of. The PCG extends at the surface in an approximate triangle, covering some 66,000 square kilometres south and east of Darwin. The region within its geographic bounds consists of Proterozoic metasediments, dolerite and granite interspersed with minor granitoid Archaean basement domes (Needham et al, 1980). It is surrounded on all sides by sediments of Middle Proterozoic to Mesozoic in age which overlie it with marked regional unconformity (see fig 3.1(top)).

Exposure of the PCG, including the Cahill Formation, is moderate to sparse as deposition of Cainozoic cover sequences and deep weathering has occurred extensively in the region. Likewise in the vicinity of RUM insitu and reworked weathering products (nodules, pisoliths, Fe concretions and mottled clays), unconsolidated sands, mud, silt and clay of the Tertiary to Quaternary (estimated ages only from Needham, 1988) conceals most of the geology. However interpretations from shallow stratigraphic drilling reveals the north-south trending Cahill formation at Ranger is banked by the granite, gneissic rocks of the Nanambu Complex and the Nourlangie Schist on the west and east respectively (see fig 3.1). The nearest exposed rocks are the Nanambu Complex 11km to the west, the plateau forming Kombolgie Formation 15km to the east, the Cahill Formation and Nourlangie Schist 5km to the north and more Cahill Formation at the base of Mount Brockman (Kombolgie Formation) less than 3km to the south (Needham, 1988).

2.2 Regional Stratigraphy

At its simplest, the PCG consists of a stack of clastic, organic and chemical sediments with minor volcanics overlaying a granitic basement. Both have been significantly metamorphosed and then eroded before being overlayed by a large platform cover of shallow marine, fluviatile and colluvial sediments, also with interspersed volcanics. During deposition the basin was perhaps as large as 100,000 square km (Needham et al, 1980) and so obviously what are equivalent sedimentary units in stratigraphic time can vary in type from one side of the basin to the other, depending upon their relative environment of deposition. Conformity of the sedimentary units with interbedded tuff units across the basin indicates the chronostratigraphic nature of the geosynclinal pile (Needham et al, 1980). For this reason emphasis will be placed on those rocks more relevant to the Ranger side of the basin.

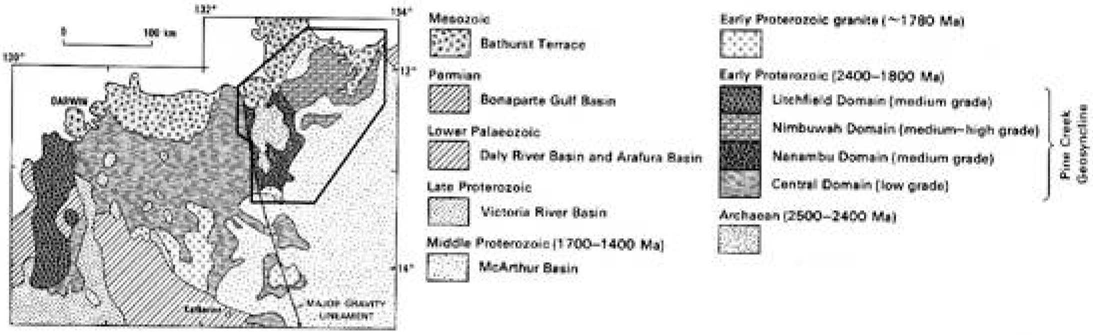
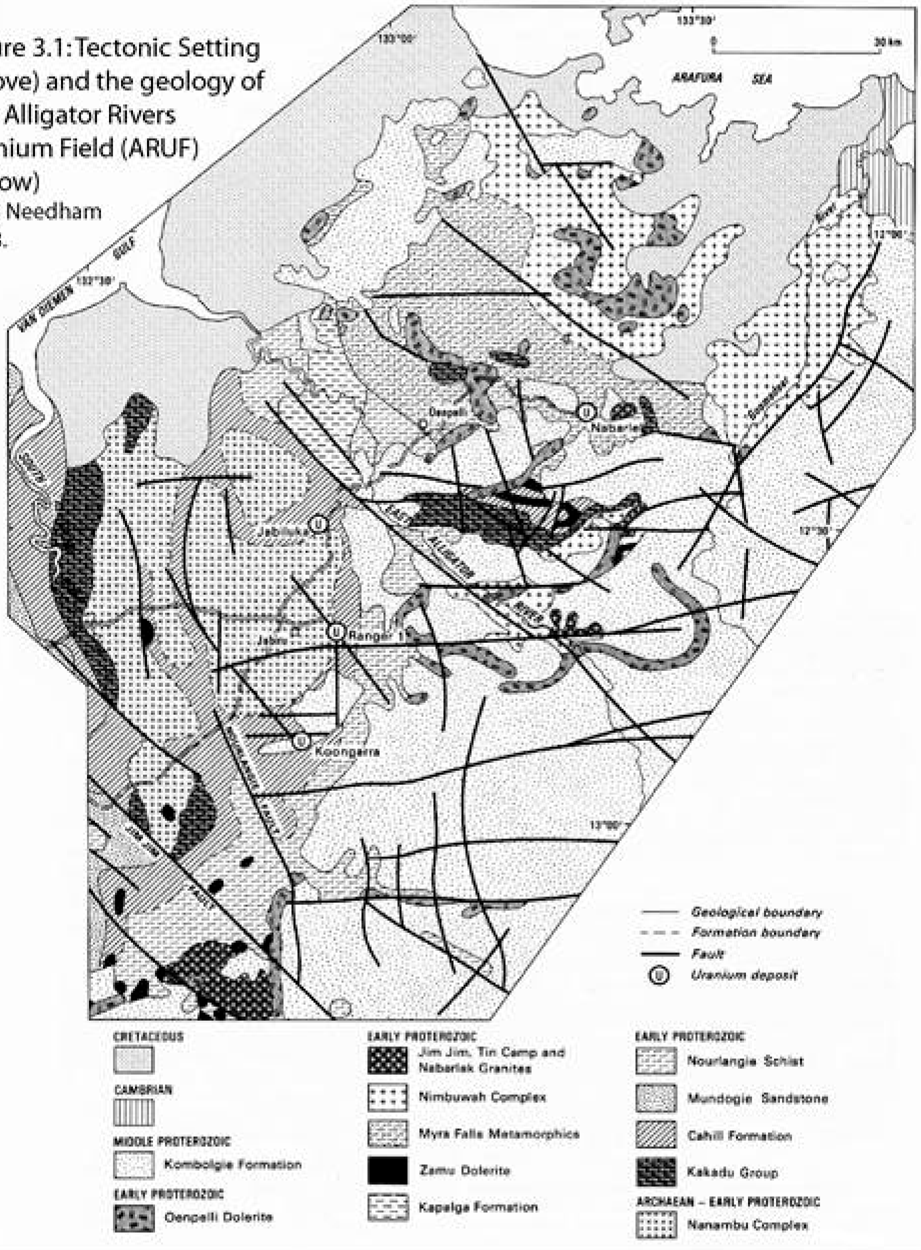


Figure 3.1: Tectonic Setting (above) and the geology of the Alligator Rivers Uranium Field (ARUF) (below) from Needham 1988.



Comprehensive summaries of regional stratigraphy along with detailed discussions of the rocks of the PCG have been presented by Needham et al (1980), Needham et al (1988), Needham and Stuart-Smith (1976, 1985) and Needham (1988). For a more detailed understanding of regional geological stratigraphy these publications are recommended. The following provides a summary of the PCG stratigraphy relative to Ranger whilst Fig 3.2 represents a simplified stratigraphic correlation of the PCG from west to east.

2.3 Basement Complexes

The granitoids of the PCG can be split into two groups; those emplaced before regional peak metamorphism (approx 1800Ma), thus undergoing deformation, and those emplaced after. The latter have been commonly interpreted as high level diapiric granitoids (ages of 1780 to 1710m.y.), having intruded the overlying metasediments and in some cases, creating hornfelsic aureoles up to 5km wide around them (Ferguson et al, 1980; Riley, 1980).

Of the five major granitoid complexes emplaced before peak metamorphism, only the Nanambu complex underlying Ranger in the east, and the Rum Jungle and Waterhouse complexes in the west are definitive PCG Archaean basement. Whole rock Sr-Rb isochron and U-Pb zircon studies have determined Archaean ages (2500Ma ± 100m.y.) for all three (Page, 1976 in Ferguson et al, 1980; Richards and Rhodes, 1967; Page et al, 1980). Predating even these however, are metasediments, some granitised, banded iron formation, volcanics and metabasics which are contained within and engulfed by these three granitic complexes (Ferguson et al, 1980; Needham et al, 1980; Needham, 1988). It has been suggested that the three basement complexes have features in common with mantled gneiss domes, the doming being produced by polyphase folding (Ruxton and Shields, 1962 in Ferguson et al, 1980; Needham et al, 1980; Needham, 1988).

Rocks of the Nanambu complex, basement to the Ranger orebodies, have been subdivided on the basis of age and lithology into: unmetamorphosed Archaean two-mica granite; metamorphosed Archaean granite (now predominantly augen gneiss); and Early Proterozoic pegmatoid leucogneiss, schist and migmatite. This latter subgrouping is thought to represent a portion of Lower Proterozoic basal arkosic rocks which were accreted onto the Archaean granitoids during peak metamorphism around 1800Ma (Needham et al, 1980; Page et al, 1980). However due to the sparse nature of exposure within the PCG geological subdivision has been limited and thus large areas are mapped as undivided Nanambu Complex (Needham, 1988).

Figure 3.2: Simplified regional stratigraphy of the PCG correlated from west to east across the basin

WEST OF THE SOUTH ALLIGATOR RIVER/JIM JIM CREEK		*ALLIGATOR RIVERS URANIUM FIELD*	
Burrell Creek Formation (greywacke, siltstone)			Myra Falls Metamorphics
Mount Bonnie Formation (chert-banded ferruginous siltstone, tuff, greywacke, minor shale, carbonate)	Kapalga Formation (chert-banded ferruginous siltstone, greywacke, shale, minor arkose)	Kapalga Formation?	
Gerowie Tuff (tuff, tuffaceous siltstone, argillite, shale, rare chert nodules, banded iron formation)			
Koolpin Formation (chert-banded ferruginous siltstone, carbonaceous shale, carbonate, banded iron formation)			
Coomalie Dolomite (carbonate)	Wildman Siltstone (interbanded siltstone and carbonaceous shale, minor quartzite)	Nourlangie Schist	
Crater Formation (conglomerate, sandstone, minor shale)	Mundogie Sandstone (sandstone, conglomerate, siltstone, phyllite)	Cahill Formation (upper member)	
Celia Dolomite (carbonate)	Masson Formation (carbonaceous shale, calcarenite, carbonate, sandstone)	Cahill Formation (lower member)	
Beestons Formation (feldspathic sandstone, arkose)		Kakadu Group	

2.4 The Pine Creek Geosyncline and the Cahill Formation

The Ranger ore bodies occur in the lower member of the Cahill Formation, the second major sequence of sedimentation within the PCG. Deposition of the PCG pile began some time after 2400Ma (the age of the youngest basement rocks) and finished prior to 1870Ma (the age of pre-metamorphic granadiorites in the northeast) (Needham et al, 1980). It has been suggested by Needham et al (1988) that the 10km, maybe 14 km, of supracrustals more likely accumulated in less than 20 million years around 1900Ma.

The Cahill Formation conformably overlies a group of quartzofeldspathic gneisses (Mount Basedow and Mount Howship Gneiss) and quartzites (Kudjumarndi Quartzite) formally known as the Kakadu Group. The arkosic parents of the Mount Basedow Gneiss unconformably overlay the basement Nanambu Complex, hence they can be regarded as the oldest known sediments of the eastern PCG (Needham, 1988). To the west these rocks correlate with similar arkosic rocks of the Beestons Formation, part of the Bachelor Group, and unconformably overlying other Archaean basement (Rum Jungle and Waterhouse Complexes). Rocks of the Mount Basedow Gneiss are radioactive with up to 0.3% U_3O_8 in the vicinity of the uranium fields of the Alligator Rivers region. Frequently preserved bedding and compositional banding (mainly bands of different grain size in quartzites) with rare cross bedding can be found throughout the sequence. It is thought that this initial deposition in the PCG occurred in proximal marine or fluviatile conditions (Needham, 1988).

The Cahill Formation has been separated into two groups, a lower carbonaceous sequence and an upper more psammitic member. The lower member is some 300 to 600 metres thick and consists of carbonaceous schist, marble, calc-silicate rock, para-amphibolite and dolostone, and schist and quartzite. The upper member conformably overlies the lower member and consists of interlayered feldspathic quartz schist, feldspathic schist, feldspathic quartzite, and minor mica schist and quartzofeldspathic gneiss. At Koongarra this member has an apparent thickness of some 2500 metres due to repeated faulting and folding (Needham, 1988). The lower member corresponds to the Masson Formation (part of the Namoona Group) in the Rum Jungle area to the west, a sequence of carbonaceous shales, calcarenite, carbonate and sandstone (Needham, 1988; Needham et al, 1980). Together, the lower Cahill Formation and the Masson Formation are host to much of the uranium deposits and other mineralisation in the entire PCG.

A significant interpretation of these rocks is the identification of evaporitic parentage for some of the metamorphic carbonate sequences, indicating a transition from subtidal, low energy marine to intertidal and supratidal evaporitic facies. Evidence suggests that in the west these evaporites formed in thick continuous stromatolitic algal mats where as in the east they formed lens shaped masses up to 250 metres thick (now calcitic dolomite to magnesite marble) within the partly carbonaceous and calcareous sediments of the lower Cahill Formation. Importantly the thickest lenses of the latter are adjacent to or partly within the major uranium orebodies and have thus been used as a possible Mg source for the medium to high Mg-chlorites which are common to all the major uranium deposits.

Overlying the Cahill Formation is the Mount Partridge Group, comprising the Mundogie Sandstone (sandstones, conglomerate, siltstone and phyllite) conformably overlain by the Wildman siltstone (interbedded siltstone and carbonaceous shale and quartzite). The Mondogie sandstone overlies lithologies similar to those of the lower Cahill Formation and so it is thought that it may be a coarser grained and lower grade metamorphic equivalent of the Upper Cahill Formation (Needham, 1988). West of the Alligator Rivers region an extensive unconformity exists at the base of the Mundogie Sandstone. Pebbles of silicified carbonate from the Mundogie sandstone conglomerate, allegedly derived from the Cahill Formation, imply a period of palaeo-weathering for the corresponding hiatus (Needham, 1988). Also further west in lower grades of metamorphism, ripple-drifts can be found in the banded siltstone and carbonaceous shales of the Wildman Siltstone (Needham, 1988).

Closer to Ranger, interpretation of the Jabiru drill traverse (Needham and Stuart Smith, 1976) revealed that the Upper Cahill Formation appears to be overlain, in some places conformably and in others unconformably, by the Nourlangie Schist. It is thought that this is simply a high grade metamorphic equivalent of the relatively homogenous Wildman Siltstone, which overlays Upper Cahill Formation equivalents elsewhere as stated above. In fact east of the Nanambu Complex the stratigraphic succession of the PCG becomes a monotonous combination of schists and gneiss corresponding to an increase in metamorphic grade away from a central PCG trough. Further to the east of Ranger, the Nourlangie Schist grades into metamorphically differentiated schist and gneiss of the Myra Falls Metamorphics. Parent lithologies are mostly unrecognisable in this group however resisters are present, which indicate remnant Kakadu Group and Cahill Formation lithologies. The presence of the Cahill formation may be further supported by the hosting of the Nabarlek Uranium deposit in these metamorphics.

The South Alligator Group rests unconformably on the Wildman Siltstone; in fact a basal ferruginous sandy quartz breccia with rare quartz pebbles at the contact in places could be interpreted as a regolith (Needham et al, 1988). The group basically consists of Fe-rich sediments, carbonate, and tuff and represents a period of mature sedimentation (the Koolpin Formation) followed by episodic felsic volcanism (Gerowie Tuff and Mount Bonnie Formation). Where this sequence is found in the uranium fields closer to Ranger, tuff and argillite are absent making subdivision difficult, hence the entire sequence has been named as a single unit, the Kapalga Formation. The youngest group of sediments in the PCG, a monotonous sequence of interbedded greywacke and siltstone with deep water high energy characteristics, called the Finness River Group is not found in the east of the basin near Ranger.

2.5 Cover Rocks

New light has been shed on the plateau forming cover rocks of the PCG by the Arnhem Land section of the National Geoscience Mapping Accord (NGMA), a combined mapping project between AGSO and the NTGS. Previous studies (Walpole et al, 1968 and Roberts and Plumb, 1965 in Sweet et al, 1999; Needham and Stuart-Smith, 1985) have separated the massive cover of sandstone with interbedded volcanics known as the Kombolgie Formation and the underlying accumulation of felsic volcanics and associated sediments, known as the El Sherana and Edith River Groups, with a marked regional unconformity. The new evidence from dating and examination of differences within the Kombolgie Formation itself suggests the hiatus may be as short as a few million years and that in fact the sandstones of the lower Kombolgie Formation are of the same tectonic regime as those of the El Sherana and Edith River Groups. A major regional unconformity was recognised within the Kombolgie Formation which effectively separates the lower from the upper sandstone sequences. The Kombolgie Formation has been renamed the Kombolgie Subgroup (as that of the greater Katherine River Group) and is possibly 100 million years older than previously thought (Sweet et al, 1999). If the new dates are correct then the proposition that these rocks are the most north westerly preserved extent of the McArthur Basin, as has been presumed in the past (Needham et al, 1980; Needham, 1988), cannot be true. More importantly for Ranger, the new 1822-1720Ma age constraints mean that primary uranium mineralisation of Ranger ore at 1737 ± 20 Ma (for Orebody No. 3) (Ludwig et al, 1985, 1987) now fit well within a post-Kambolgie mineralisation model as proposed by Maas and McCulloch (1987) for Jabiluka, Koongarra and Nabarlek. Previous ages for the Kombolgie Sub-group were based on a basement ridge forming dolerite (Oenpelli Dolerite) being dated at c.1690 Ma and one of the volcanic members within it being dated as 1645 Ma (Page et al, 1980 in Needham, 1988).

The El Sherana and Edith River Groups occur mainly to the south of the uranium fields, as far south as Katherine (Needham, 1988). However small pockets of porphyritic rhyolite at Mount Basedow and tuff scattered elsewhere correspond to this rift dominated sedimentary regime, the former probably corresponding to the Pul Pul Rhyolite member of the El Sherana Group. Directly east of the Ranger 1 ore body isolated lenses of valley fill tuff unconformably overly the Nourlangie Schist (or Myra Falls Metamorphics – unresolved). It is thought to represent distal volcanic activity and has an apparent conformable relationship with the overlying lower unit of the Kombolgie Subgroup, the Mamadawerre Sandstone (Needham, 1988).

Due to the lack of El Sherana and Edith River rocks around the Alligator Rivers region, the Kombolgie Subgroup directly overlies PCG rocks in most places with a marked regional unconformity. The unconformity surface is not unlike that of the present surface of the northern plains with a common local relief of around 20 metres, but with sandstone units thinning and pinching out against isolated basement highs of up to 250 metres. Ten percent of the sporadically distributed basal conglomerate consists of blades of PCG schist. Cross-bedding and ripple marks are widespread throughout the sandstone units, their types suggesting shallow-water origin (Needham, 1988). Evidence from recent mapping suggests that the lower unit (Mamadawerre Sandstone) and the units associated with the unconformities (Gumarrimbang and Marlgowa Sandstones) represent braided stream environments punctuated by brief marine incursions whilst the upper most unit (McKay Sandstone) is predominantly marine (Sweet et al, 1999).

Two notable volcanic members exist conformably within the subgroup, the regionally continuous Nungbalgarri Member overlying the Mamadawerre Sandstone, and the intermittent Gilruth Member, overlying the Gumarrimbang Sandstone in places. The Nungbalgarri Member is composed largely of massive basalt through trachybasalt and dacite to rhyodacite with local cherty rhyolite and ignimbrite whilst the Gilruth Member is a thin sequence of tuffaceous siltstone, banded quartz-jasper rock and amygdaloidal and vesicular basalt. The basalt in the former member contains up to 4ppm U and 12ppm Th, anomalous to average basalt concentrations (according to Taylor, 1964 in Needham, 1988).

Some one billion years separates the depositional stratigraphic record above the Kombolgie Subgroup. In the far north east of Arnhem Land, below the escarpment at Junction Bay, a sequence of Middle Cambrian sandstone and shale (Wessel Group) has been preserved, the basal unit containing the trace fossil Skilithos (Plumb et al, 1976). Also preserved in pockets of Arnhem Land are the Mesozoic Bathurst Island Formation and even rarer, upon the plateau, the Mesozoic Petrel Formation. The former consists of a sequence of fossiliferous paralic sediments palynologically dated from Neocomian to Cenomanian (Early to Late Cretaceous) in age. The Petrel Formation occurs as low mesas of white and purple claystone and medium to course friable sandstone up to 25metres thick. It is lateritised completely and only rare fragments of indeterminant plant fossils can be found. Both of these sequences have been examined in more detail using oil exploration drill holes to the north (see Needham, 1988).

Throughout most of the lowlands including the areas directly surrounding Ranger, an overlying assortment of unconsolidated to weekly cemented coarse quartz sands and minor conglomerate, commonly with an Fe-oxide and clay matrix, dominate the surface. In places these are up to 75 metres thick as a single package and as such were named the Koolpinyah Surface by Williams (1969 in Needham, 1988), to represent the remnants of a Tertiary sand plain. They are most probably locally derived from the Mesozoic and Proterozoic strata; large sub-angular and sub-rounded pebbles (up to 5cm in diameter) of Fe-stained Quartz and schistose material can be found in some ferricretes directly to the north of Ranger (North Magela Creek), most probably Fe-cemented slope lags (personal observations).

Other Later Tertiary to Quaternary deposits can be found overlying this Koolpinya surface. Large talus slopes are widespread against the escarpment of the Kombolgie Formation. Alluvial sands are found in the rivers and streams and large sand outwash deposits are frequent over the flood plains. The current channels in theses flood plains are incised by abandoned river silts and muds. Clay and silt deposits can be found in isolated depressions, suggested to be ‘swallow holes’ developed by solution or collapse of the mottled and/or pallid zones of the underlying clayey sands. It seems these have been preferentially ferruginised further to the west of the region (personal observations).

At present the coastal flood plains are inundated with brackish water conditions during the wet season leaving behind sediments of both well drained silts and clays to poorly drained black soil plains and mud flats adjacent to channels. These deposits are no greater than 6 metres thick and contain various intertidal fauna and wood fragments. Coastal beach ridges are found parallel to and within 2km of the current coastline, the innermost ridge corresponding to a 7000 B.P. shoreline (correlated to dated ridges 65km to the west of the region).

2.6 Igneous Intrusions

An extensive combination of sills, dykes, volcanic plugs and granites have intruded the PCG and its cover sequences, the rocks of Ranger not isolated from some of these events. Due to differences in metamorphic grade across the region, those intruded before peak metamorphism now host a range of different metamorphic lithologies. The Zamu Dolerite includes several geographical groupings of similar dolerite throughout the PCG but closer to Ranger it is metamorphosed to strongly foliated amphibolite. It outcrops as lensoids up to 2km long which are aligned parallel to the dominant foliation in the surrounding Cahill Formation or Nourlangie Schist, narrow dykes transgressing (apparent) the foliation of paragneiss in the Nanambu Complex and a 167m thick sill-like amphibolite intersected by drilling beneath the Jabiluka No. 1 Orebody (Needham, 1988). Amphibolites within the Ranger deposits have also been suggested to be part of the Zamu Dolerite although alternative origins are possible (see later) (Reynolds and Miezitis, 1985). U-Pb zircon studies of a dacite intruded by the Zamu dolerite provide a maximum age of 1884 $\pm$ 3 Ma (Page pers. comm. 1984 in Needham, 1988) for the dolerite whilst regional metamorphism at 1800Ma provides a minimum age. Geochronological studies of the dolerite itself constrain the age to 1914 $\pm$ 170 Ma (Page pers. comm. 1984 in Needham, 1988).

The Nimbuwah Complex represents a 2600km^2 semi-circular body of mesocratic to leucocratic granitoid migmatite between Aurari Bay and Nabarlek and melanocratic migmatite and tonalite in the Caramal East and Beatrice Inliers. It is the only other major pre-metamorphic igneous intrusion, having a primary magmatic crystallisation age of 1886 $\pm$ 5 to 1866 $\pm$ 8 Ma being determined by Page et al (1980).

Four major igneous intrusions are thought to have occurred after metamorphism but before the deposition of the overlying Kombolgie Formation. The Nabarlek Granite and Tin Camp Granite are both enriched in U and have been dated at 1780 Ma (at least) and 1755 ± 15 respectively (Page et al, 1980). Neither are found near Ranger, being near and beneath Nabarlek (Nabarlek Granite) and in inliers of the Kombolgie Formation (Nabarlek and Tin Camp Granites) and both have been pervasively altered. The Jim Jim Granite is an approximate circular pluton of granite and leucogranite which extends into the south of the Alligator Rivers Uranium Field. A Rb-Sr age of 1732 ± 11 Ma has been appointed to the granite by Page et al (1980). Near Jim Jim falls (southwest of Ranger) this granite is clearly intruded by the Oenpelli Dolerite with ferromagnesian metasomatism of the surrounding granite accompanying the intrusion.

The Oenpelli Dolerite occurs as three ellipsoidal lopoliths, scattered exposures of dolerite north of Oenpelli, rare subvertical, possibly stringer dykes around 1 metre wide and as an isolated exposure of dolerite in the west of the Alligator Rivers Uranium Field (Needham, 1988). Doleritic dykes within the Ranger Orebodies have been postulated to be Oenpelli Dolerite however dating of a similar rock adjacent to Orebody No. 1 suggests that they are unrelated chronologically (see below). The lopoliths crop out as arcuate ridges up to 100 metres high and 1km wide in the centre and south of the region, one extending south into the Kombolgie Formation where it forms discontinuous inliers (Needham, 1988). They transgress all rock unit boundaries and foliations within the Early Proterozoic PCG and are unconformably overlain by the Kombolgie Formation often forming hornfels in surrounding rocks (Needham, 1988). The lopoliths basically consist of roughly differentiated layered sheets of olivine dolerite, all of which have been at least slightly altered to chlorite, prehnite, epidote and calcite (Needham, 1988). Page et al (1980) proposed a pooled Rb-Sr isochron age of 1688 ± 13 Ma for the intrusions.

Another phase of igneous intrusion seems to occur with the Mudginberri and Maningkorrirr Phonolite dyke swarms, the former dated by Page et al (1980) as 1316 ± 40 Ma (Rb-Sr). The Mudginberri Phonolite outcrops around the Mudginberri Homestead, only 10km NNE of Ranger and Granite Hill around 4km south of Jabiluka, intruding granitoid of the Nanambu complex in the latter area (Needham, 1988). The Maningkorrirr Phonolite occurs further to the NE near the Goomadeer River in Arnhem land. Also in this age bracket is the K-Ar pyroxene age of 1370 ± 30 Ma for an altered dolerite intersected by drilling directly east of the Ranger No.1 Orebody (Page et al, 1980). It is possible this corresponds with a dolerite dyke occupying the Ranger fault, which trends eastward through the Ranger 1 deposit.

The only other evidence of igneous intrusions occurs far from the Ranger vicinity. A doleritic plug (Wurugoij Dolerite) K-Ar pyroxene dated at 1200 ± 40 Ma intrudes the Kombolgie Sandstone in the NE of Arnhem Land (Needham, 1988). Even later a small vertical porphyritic olivine basalt cuts the Nungbalgarri Volcanic member of the Kombolgie Formation, K-Ar dated at 522 Ma (Needham, 1988).

3 LOCAL GEOLOGY

The rock and mineralogical descriptions presented here have been grouped according to major rock type instead of the mine sequence groupings given earlier. It should be noted that some sources used to formulate these descriptions are copies of company reports, which are void of publication dates.

SCHISTS

Schists are probably the most common type of wasterock judging from their abundant distribution within the mines and from observations of the wasterock piles. Most of them have been chloritised although the degree of chloritisation varies. For those that are heavily chloritised, two phases have been recognised. Ewers and Ferguson (1980) observe that it is an earlier distorted period of muscovite and chlorite growth, which defines the schistosity, with later undeformed flakes superimposed on foliation. Segregation banding is also a common characteristic of the schists with any one of the major minerals dominating each band. In many of the quartz-chlorite schists thin quartz veins and rarer carbonate veins (± quartz ± sulfides) occur discordantly or concordantly to the schistosity. Six different types of schist have been recognised.

UMS Quartz-chlorite schist

Dominated by the quartz and chlorite, this schist is found closer to and within the mineralised zone of the UMS, having altered from a quartz-feldspar-biotite schist (Kendall, 1990) with biotite and/or phlogopite still evident in places (Colville, 1974). Extremely fine sericite is also present according to Colville (1974), at least in Orebody No.3, occurring in thin continuous bands. Earlier publications suggest that muscovite is also a dominant mineral in the UMS schist (Ewers and Ferguson, 1980; Nash and Frishman, 1983), however these may be simply referring to the sericitisation phase. Colville (1974) identifies both a light green and dark green variety of chlorite and suggests that the light green is a Ti rich variety. The UMS schist is the main host to uranium mineralisation at RUM.

LMS Sericite- chlorite-quartz schist (Lenticle Schist)

A prominent band in the LMS also called Lenticle schist due to the chlorite occurring as aligned, lenticular nodules (Kendall, 1990) or 'micro-augen' as described by Reynolds and Miezitis (1985). It has been suggested that these chlorites reflect the alteration of staurolite or similar minerals (Kendall, 1990). Once again earlier publications state muscovite as another dominant mineral in this schist but sericite/muscovite is probably a better term (see above). Nash and Frishman (1983) actually define two schists in the LMS, a Lenticle schist and a Quartz-chlorite-muscovite schist. Either way quartz, chlorite and sericite/muscovite are the dominant phases.

HWS schists

These rocks are not mineralised and of little use for construction materials therefore most of that mined would have been placed on the wasterock piles. Their mineralogy is a little confusing due to seemingly conflicting descriptions in published material. Needham (1988) identifies two different rocks, a Quartz-feldspar schist +- sericite+-biotite+-garnet and a coarse sericitised chloritised mica and quartz schist +-feldspar, amphibole, garnet, pyrite and magnetite in both the Ranger and Koongarra deposits. Colville (1974) also notes the existence of chloritisation in HWS schists for the No. 3. Orebody, in fact describing no schists without it. He describes the HWS as Quartz-chlorite-muscovite schists with interbedded Quartz-chlorite schists, the latter possibly representing amphibolite units due to the existence of chloritised amphibole needles in many. Whilst others also note the existence of interbedded amphibolite units (Kendall, 1990; Reynolds and Miezitis, 1985), few describe the schists with chlorite inclusive. For example Kendall (1990) describes the unit as micaceous quartz-feldspar schists with local garnetiferous horizons. It is probable that Needham's description is more precise as it is difficult to believe that the 'zone of chloritisation' does not extend, at least partly, into the HWS. However that being said it is clear that some units (possibly upper) have negligible chlorite due to description of units of this nature in most publications. Ground magnetic surveys from a 1987 exploration program suggest that the magnetite in these rocks is concentrated in the basal 50 metres of the HWS (Kendall, 1990).

UMS Quartz-feldspar-biotite schist

This is the main constituent of the UMS away from the ore zone, where it has altered to the quartz-chlorite schist described above. It is unknown exactly how far the chloritisation within this rock extends laterally, although estimates of 300metres (see above) suggest that little of this rock would be present without chlorite within the mine area. There still may be at least some of this rock in the wasterock piles because if it does exist within the mined area, it would be unmineralised (chlorite-ore relationship described above).

FWS Quartz-biotite schist

The Quartz-biotite schist of the FWS is well foliated, non banded and composed of approximately 70% biotite and 30% milky granular quartz. It is also partially chloritised (Colville, 1974).

It is important to include here some notes on the FWS rocks. Drill logs have noted biotite schist, augen gneiss, leucogneiss and granite within the FWS of Orebody No.3 (Reynolds and Meizitis, 1985). Quartzites and Pegmatites have also been noted (Reynolds and Meizitis, 1985; Colville 1974). Drill core from the No.1. Orebody reveal schist, gneiss, microgneiss and granitic rock (Kendall, 1990). Importantly however, Nash and Frishman (1983) identify only gneiss and schists and Reynolds and Meizitis (1985) state that there has been no true Archaean granite recorded in the entire mine area. Colville (1974) interprets the FWS into only two significant lithologies, Feldspathic Augen Gneiss and Quartz-biotite schist, which is the FWS interpretation accepted here.

UMS Carbonaceous-chlorite schist

This chloritised schist is confined to the base of the UMS schists and it contains fine grained and platey carbonaceous material, thought to be mainly graphite, which occurs as thin bands parallel to schistosity or as coatings on shear planes (Ewers and Ferguson, 1980). The unit is commonly brecciated and retextured and often contains fragments of UMS schist and LMS chert and carbonate. Pyrite mineralisation has also been noted within this zone (Colville, 1974). It is important to note that this unit is only 1 to 3 metres thick in Orebody no.3 (Colville, 1974) and that which occurs within the central disturbed zone is host to high-grade uranium mineralisation (Kendall, 1990). Therefore the Carbonaceous-chlorite schist is probably not in the wasterock piles or at least accounts for very little.

MASSIVE CARBONATES

Massive carbonates dominate the LMS and hold no significant mineralisation except deep in orebody No.3 (refer to fig 3.4), hence these rocks will be abundant in the wasterock stockpiles. A number of interpretations of the carbonates have been made. Kendall (1990) separates the carbonates into a lower magnesian marble and an upper impure dolomite separated by the Lenticle schist. Colville (1974) prefers three types, a pink chloritic carbonate, a recrystallised carbonate and a banded carbonate, whilst Nash and Frishman have identified marble and a chloritic marble. Needham (1988) tends to group all of them together into the “most prevalent carbonate rock in the Cahill formation”, that of massive crystalline marble, which can vary from calcitic dolomite to magnesite often interbedded with various impurities. The difference between the interpretations seems to be simply differences in detail and so all of them are probably correct and if taken together, explain the massive carbonate of the LMS and its variety. Colville’s (1974) interpretations of Orebody No.3 tend to be the most descriptive and preferred here due to similarities noticed during brief observations of the surface of the southern wasterock dump.

Pink coloured carbonate

The rock consists of fine hypidiomorphic granular pink magnesian intergrowths with haematite finely dispersed between grains and on mineral cleavage plains being responsible for its colour. Fine wavy discontinuous concordant bands of dark green chlorite are found throughout this type.

Recrystallised carbonate

This marble like carbonate is more pure and course grained with subiodiomorphic intergrowths of dolomitic carbonate. Angular blobs and fine wispy disseminations of dark green chlorite still occur throughout but much less frequent than in the other carbonates. At depth in the mine the purity of the carbonate decreases with chlorite content increasing. Vughs containing rhombic crystals and fine well developed pyrite are common. Personal observations of rocks on the SWP confirm this with large calcite crystals present with pyrite, quartz and haematite developed on quartz within the vughs. The magnesite in the marble at Ranger has inclusions of anhydrite, which is another key piece of evidence to its original sedimentary origin (see Crick and Muir 1980 for further details). It should also be noted that brief inspection of large carbonate boulders on the southern wasterock dump revealed large splay aggregations (up to 10cm diameter) of white to translucent grey tremolite consistent with tremolite found in equivalent marble in the Myra Falls Inlier to the east (Needham, 1988) and with a paragenesis of metamorphosed impure dolomite (see Deer et al, 1992).

Banded carbonate

The Banded carbonate is beneath and within the recrystallised carbonate within the mine and consists of white, greyish and pinkish slightly calcareous fine carbonate in alternating bands up to 5 cm thick. The banding becomes almost gneissic in nature in places and thin wispy dark green chlorite bands occur throughout.

CHERT

The chert has been mapped locally in the past as 'Jasperoidal chert' and so is often referenced with this name (Kendall, 1990; Nash and Frishman, 1983). It is a fine, vaguely banded, recrystallised chalcedonic silica rock, white to greenish pink in colour depending on the chlorite and haematite content respectively (Colville, 1974). It replaces the carbonate closer to the ore zone but this is not as prevalent in Orebody No.3. Pyrite and minor chalcopyrite are common accessory minerals (Colville, 1974). Whilst the chert is found closer to the orebody it does not seem to be intimately associated with the ore zones (see fig 3.5) so a reasonable amount of this material may have been placed on the wasterock and VLG stockpiles.

MASSIVE CHLORITE ROCK

Massive chlorite rock which intrudes the UMS and LMS (Colville, 1974; Reynolds and Miezitis, 1985) seems to have an intimate association with uranium mineralisation, at least in some places, according to Colville (1974), Needham (1988) and the cross section of Orebody No.1 in FIGURE 3.5 (Kendall, 1990) despite Kendall making no mention of this fact. Thus a significant portion of this material must have been included in higher grade stock piles, however rocks fitting drill core descriptions of this rock were found in abundance in places upon the surface of the southern wasterock pile (personal observations). It consists of dark green chlorite and light olive green soapy chlorite in a banded but contorted texture (Johnson, DDH No.S1/56, 1971; Kitto and Eupene DDH No.S1/55, 1971). In many places it contains fine disseminated red haematite zones and fine disseminated leucoxene (Colville 1974; Johnson, DDH No.S1/56, 1971; Kitto and Eupene, DDH No.S1/55 1971). It is characteristically disrupted, fractured, talcose soft along joint planes and fractures with a serpentiferous texture (Kitto, DDH No.S1/54, 1971).

PEGMATITE

All of the pegmatite is barren and therefore will be an important constituent of the wasterock piles. Once again descriptions are a little confusing. Kendall (1990) subdivides them into four different types, dark green quartz rich and quartz poor as well as light green quartz rich and quartz poor varieties. He suggests the dark green varieties to represent insitu digestates of LMS rocks and the others to be intrusive. Colville (1974) on the other hand identifies two varieties with chloritisation or lack of it, being the differentiating feature. Brief observations favour Colville's interpretation but quartz content may be a factor. Basically, apart from differences in chlorite content and hence colour, pegmatites at Ranger consist of coarse grained intergrowths of microcline feldspar with quartz, muscovite and tourmaline (Colville, 1974). Their paragenisis is an issue that does not need to be dealt with here.

DOLERITE (DIABASE)

Dolerite dykes are more common in the No.1 Orebody than in No.3. There is only one known occurrence of economic primary mineralisation in diabase rock which, incidentally, corresponds to intense chloritisation (Kendall, 1990). Hence almost all of this rock will be found in the waste and VLG stockpiles. Few descriptions exist of these rocks however some characteristics can be pieced together. They can be classified as Olivine Dolerite dykes often heavily chloritised, therefore greenish in colour (Reynolds and Miezitis, 1985). It is mostly a massive, homogenous rock with aphanitic textures although it can develop rosettes of light green crystals in a darker groundmass (Kitto, DDH No.S1/54, 1971). On the wasterock stockpiles it is characteristically exfoliated insitu. Personal observations of hand specimens of this rock show veinlets of haematite are quite common. A classic unaltered olivine dolerite mineralogy should be dominated by pyroxene and plagioclase with interspersed olivine (Best, 1982) and so it is probable that in the less altered rocks the plagioclase and pyroxene may still be at least partly tact.

GNEISS

The gneissic textured rocks are limited to the FWS and for further discussion of this sequence one should refer to the FWS schist description above. The definitive description of the FWS gneiss is from Colville (1974).

Feldspathic Augen Gneiss

The Feldspathic Augen Gneiss has a typical gneissic texture with white elongated augen of feldspar in a matrix of finely intergrown biotite, muscovite and granular milky quartz. It has also been partially chloritised.

WEATHERED MATERIALS

According to Ruddock (1981) the depth of weathering at RUM varies from 3 to 30 metres below the surface at orebody No.3 and the limit of oxidation, defined in geological logs as the base of iron staining on joint and foliation surfaces, ranges from 20 to 90 metres.

In 1974 Colville stated that 15% of the U mineralisation in the No. 3 orebody is contained within the oxidised zone. While these figures are old and possibly out of date it still gives a clear indication that there is a proportion of the overlying weathering profile that will not be contained within the wasterock or VLG stockpiles. Even less of the weathering profile above Orebody No. 1 should have been dumped as wasterock because in contrast to No.3, Orebody No. 1 contained “a large tonnage of lateritic ore” (Ruddock, 1981). A brief inspection of early geological cross-sections of both orebodies shows these differences (figure 3.5).

Combined with this, the cross-sections reveal which types of rocks have been weathered. Whilst mineralogical and geochemical characteristics will obviously be markedly different towards the more weathered surface within the lithologies, it gives a good indication of what type of transitional material may be present in the stockpiles.

Using the information in figure 3.5 above, it is clear that there is still a considerable proportion of the weathering profile that will not be included as ore. Hence a significant amount of rocks and materials entering the wasterock and VLG stockpiles at Ranger are already weathered to some degree. These materials are not distributed evenly throughout the dumps due to their separation on classification by degree of weathering into transitional or laterite materials (see introduction).

If figure 3.5 is a reasonably accurate representation then it can be used as an indication of the types of lithologies that have been effected by weathering. Whilst the upper weathering profile will have markedly different mineralogy the transitional material should include partially weathered pegmatite, HWS schists, UMS schists and LMS chert from orebody No.1 and HWS schists, UMS schists and pegmatite from orebody No.3.

Milnes (1988) described minerals in the weathering profile of Pit 1 to consist mainly of fine-grained haematite, goethite and residual quartz as well as the dominant clays illite, kaolinite and smectite, which had replaced the primary minerals chlorite and muscovite. Von Gunten et al (1996) found that the weathering at depth (below ~6metres) in the Ranger area consisted of quartz, chlorite/vermiculite, goethite, kaolinite and mica. It should also be noted that secondary uranium minerals (mostly uranophosphates) have been observed both on and within the wasterock stockpiles in weathered samples, although such observations are not common.

4 TENEMENT HISTORY

On 15th March, 1971 Authority to Prospect (AtP) 2013 was acquired by Pancontinental from Air Navigators Pty Ltd (Figure 1). In October 1971 a Joint Venture (JV) deal was signed between Pancontinental (65%) and Getty Oil (Texaco) (35%). AtP 2013 was converted to an exploration license – EL12 – on 17th March, 1972 under the Northern Territory Mining Ordinance. The holder of the title was transferred from Air Navigators to Pancontinental at this time. EL12 covered an area of approximately 186km^2. Thereafter EL12 was renewed annually until its expiry on 17th March, 1977 (Pancontinental, 1979).

In each year from 1974 the area of EL12 was reduced by 50% as required by the Northern Territory Mining Ordinance. In 1974, however, the area was effectively reduced by some 75% because the renewal application of that year was not granted in respect of ~60km^2 on the grounds that such area fell within the proposed Kakadu National Park.

An application was made on 13th October, 1973 over an area of ~31km^2 for a Special Mining Lease (SML 61) to cover the Jabiluka 1 and Jabiluka 2 deposits.

On 24th November, 1974 an application was made in the Hades Flat area for a further Special Mining Lease (SML64) covering an area of ~6km^2.

Several Gold Mining Leases (GMLs) were pegged and applied for on 29th July, 1975 to cover gold deposits which were discovered within the Jabiluka 2 deposit.

A series of Mineral Leases (MLs) was pegged and applied for on 14th December, 1975 over an area within SML61 of ~5.5km^2.

On 24th November, 1976 a further series of MLs was pegged and applied for over an area of ~6.8km^2 also partly within SML61.

Four MLs were pegged and applied for on 15th June, 1976 in the Granite Hill area to provide aggregate material for the Jabiluka Project.

Two applications were made on 24th November and 14th December, 1976 for residential leases (RL) to cover the Company's camp at Ja Ja.

On 6th September, 1977 Pancontinental applied for block mineral leases covering the entire area within the Jabiluka Project Area not already covered by mineral lease applications – other than the lease applications in respect of aggregate material.

The Northern Territory Government granted Mining Lease Northern 1 (MLN1) as replacement title for these applications on 12th August, 1982 for a period of 42 years.

In 1991, the Jabiluka project was sold by Pancontinental to ERA. Since then ERA has become part of the Rio Tinto Group through the acquisition of the North Group.

5 EXPLORATION HISTORY

In 1970, the BMR (now Geoscience Australia) flew a fixed wing airborne magnetic/radiometric survey over the area. No radiometric anomalies were detected from this survey.

In 1971, Pancontinental conducted a helicopter borne radiometric survey that didn't detect either Jabiluka 1 or 2. The survey did, however, detect a number of other anomalies that were subsequently followed up. In the 1971 dry season a hand held radiometric survey detected two small anomalies at Anomaly 7e (Jabiluka 1). This anomaly was given a low ranking but a detailed radiometric grid survey was conducted over Anomaly 7e. (Apparently one of the anthills in the area had a very high radiometric count which provided sufficient encouragement to warrant follow up). Costeans were dug after the radiometric survey and secondary uranium mineralisation at Jabiluka 1 was intersected.

In the period 1971/1973 diamond and percussion drilling was conducted at Jabiluka 1 which delineated a resource of 3,500t U_3O_8

Another prospect within the Jabiluka lease was discovered in 1971 – Hades Flat. A series of auger, diamond and percussion drilling programs were conducted in the Hades Flat area covering three prospects between 1971 and 1976. A resource of 800t U_3O_8 was delineated.

Scout drilling to the east and west of Jabiluka 1 along the strike of mineralisation led to the discovery of the Jabiluka 2 mineralisation. In the period 1973/1976, percussion and diamond drilling at Jabiluka 2 defined a resource of 230,000t U_3O_8. In November 1976, Pancontinental formed the Jabiluka Division to handle the development of the deposit. During 1977/1979, further diamond drilling and resource assessment was conducted on Jabiluka 2. An Environmental Impact Statement was lodged as a precursor to granting of permits to develop the project.

In 1991, Pancontinental sold the Jabiluka Project to ERA. Subsequent to the sale of the project, ERA conducted a drilling program on Jabiluka 2 in 1992/1993 (resource definition and geotechnical) and underground diamond drilling in 1998/1999 as part of the development of the exploration decline.

In 2000, a new resource for Jabiluka 2 was calculated based on an updated geological model. The results of the underground drilling and mapping of underground exposures were the basis of this new model for the Jabiluka mineralisation. A resource of approximately 156,000t U_3O_8 (Measured, Indicated & Inferred was calculated - Hellman & Schofield, 2000) was defined.

In summary, no "recent" exploration work has been conducted on the Jabiluka Project. The exploration potential of MLN1 is highlighted by the lack of systematic work east of the Jabiluka 2 deposit and north of Hades Flat containing the favourable stratigraphy that hosts both the Ranger and Jabiluka deposits.

6 WORK COMPLETED

No Exploration work has been carried out on the MLN1 lease.

MLN1 and the Jabiluka mineral resource remain under the Jabiluka Long Term Care and Maintenance Agreement between ERA, traditional owners and the Northern Land Council dated 25 February 2005 (LTCMA). Under the terms of the LTCMA ERA has agreed not to undertake any mining development or apply for any authorisation to undertake mining development on MLN1 without the approval of traditional owners. Based on the current circumstances, ERA has not undertaken any exploration on the MLN1 lease during the period to which this report applies.

7 CONCLUSIONS AND RECOMMENDATIONS

No ground work is planned since the project remains under long term care and maintenance.