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Rare earth element mineralisation in the eastern Arunta Region

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ABSTRACT

This document details rare earth element (REE) mineralisation in the Arunta Region, outlines different styles of REE mineralisation that exist and discusses the potential of the Arunta Region to host additional REE deposits.

The majority of the REE deposits discussed here appear to be small uneconomic prospects, but few have been fully evaluated. REE prospects have been identified on the basis of anomalous exploration rock chip REE geochemistry, or are previously identified locations where REE-bearing minerals are known to occur. Most prospects occur within the Irindina Province and adjacent areas in the southeastern part of the Arunta Region. These REE prospects appear to be related to a holistic model involving REE-enriched pegmatite or granite emplacement, with an associated hydrothermal REE-rich fluid-related event resulting in replacement or vein systems. The timing of these REE deposits appears to be broadly associated with the Palaeozoic Alice Springs Orogeny. The Nolans Bore REE prospect is currently the largest known REE deposit in the Arunta Region with an estimated resource of about 3.8 Mt @ 4 wt% rare earth oxides within 60 m of the surface (Arafura Resources 2003). Although it is spatially separated from REE deposits in the Irindina Province and the timing of mineralisation at Nolan Bore is unknown, broad geochemical similarities suggest that they could be related.

The potential for significant replacement or pegmatite-hosted REE deposits appears to be high, particularly in the southeastern Arunta Region where abundant REE-rich pegmatite swarms occur. Some prospects appear to have considerable REE potential (eg Holsteins) and there is potential for additional REE deposits in nearby areas. There is also some potential for REE mineralisation associated with additional unrecognised carbonatites and alkaline igneous complexes, and for supergene or lateritic enrichment deposits.

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INTRODUCTION

This record is a scoping report that describes REE (rare earth element) mineralisation in the Arunta Region and outlines its REE potential. It aims to provide information on the various types and examples of REE mineralisation found in the Arunta Region and uses this information to outline a possible future work program.

Areas of the Arunta Region that are prospective for REE are discussed. Apart from the Nolans Bore REE prospect, the most prospective area appears to be the southeastern Arunta Region, predominantly in the Irindina Province (**Figure 1**).

Throughout this record, names of 1:250 000 and 100 000 mapsheets are shown in large and small capital letters, respectively, eg HUCKITTA, QUARTZ.

Background and current status

Currently, no REE deposits are mined in the Arunta Region. However, there are several occurrences with significantly elevated REE (**Table 1**). In 1995, while exploring for uranium, PNC Exploration located a REE prospect in the Nolans Bore area in NAPPERBY (Thevissen 1995). This prospect was further explored and sampled by Arafura Resources who dug several costeans and pits. The REE values reported from surface samples at this prospect are high (averaging about 7 wt% total REE; Thevissen 1995, J Goulevitch, Arafura Resources, pers comm 2001) and mostly coincide with fluorapatite, which occurs as veins and forms 53-93% of the rock. The high REE grades and abundance of fluorapatite, along with its apparently large size suggests that a significant economic REE resource may exist at Nolans Bore. This occurrence was further investigated by drilling in 2001 with encouraging results.

Occurrence	REE minerals	Description	General location	Principal references
Nolans Bore	fluorapatite, monazite?, cerianite and unidentified REE phases	hydrothermal veins/pegmatite	NW of Aileron	Thevissen 1995 Arufura Resources 2003
Blueys Foley or Origin Hill	allanite, monazite?	pegmatite/igneous-related	E of Arltunga	Murrell 1988 O'Driscoll 1988 Edser 1991
Mount Finniss	monazite	leucosome or metasomatic pod	S of Mount Finniss	Kojan 1980 Stewart *et al* 1980
Holsteins and Mount Mary	monazite, xenotime, allanite?	hydrothermal veins (pegmatite-related?)	Near Mount Mary in the eastern Harts Range	Joklik 1955 Matheson 1968 Drake-Brockman 1995
Quartz Hill	apatite (fluorapatite?)	metasomatic/pegmatite-related	SE of Mount Denison near Quartz Hill	Davies (1979) Stewart *et al* 1980
Entia pegmatite group	allanite, monazite, samarskite, plus other REE phases	pegmatite-related	Harts Range and Entire Valley regions, Arltunga region, possibly Plenty River mica area	Joklik 1955 Daly and Dyson 1956 Buick 1985 Drake-Brockman 1995 Drake-Brockman *et al* 1996a, b Mawby 2000

Table 1. Significant REE occurrences in the Arunta Province.

Significant REE occurrences have also been found in the Harts Range and Plenty River mica fields within the Irindina Province. Joklik (1955) and Daly and Dyson (1956) provided details of the mica mines and documented numerous minerals associated with the host pegmatites. This area was recently explored for uranium by PNC Exploration (Drake-Brockman 1995, 1996a, b), who documented numerous additional pegmatite, breccia, vein and alteration-hosted REE occurrences. Some of these occurrences appear to be significant and are worthy of further investigation. REE-enriched pegmatites also occur over a large area near Arltunga (Murrell 1988). It is suspected that the latter may be temporal equivalents to nearby REE-enriched pegmatites found in the Irindina Province.

To date, this study has been predominantly literature-based, with minor fieldwork to investigate some representative REE prospects highlighted during the literature search. Existing information on most of the identified REE occurrences and prospects is limited to investigations and sampling during regional exploration programs.

Regional framework

The Arunta Region covers about 200 000 km^2 in central Australia and has undergone a prolonged and complex geological history with several major periods of geological activity concentrated in the Palaeo-Mesoproterozoic and Palaeozoic. It comprises variably deformed, greenschist to granulite facies, metamorphosed sedimentary and igneous rocks.

Recent work in the southeastern part of the Arunta Region has shown that rocks assigned to the Harts Range Group (excluding the Bruna and Entia Gneisses), are at least time equivalents of strata that elsewhere unconformably overlie the Arunta Region. These rocks are part of the newly named Irindina Province. Importantly with respect to this review, REE-rich pegmatites and REE-bearing hydrothermal alteration systems have been identified in this region. REE mineralisation appears to be intimately associated with the tectonic setting and syn- to post-peak metamorphic conditions during the collisional Alice Springs Orogeny.

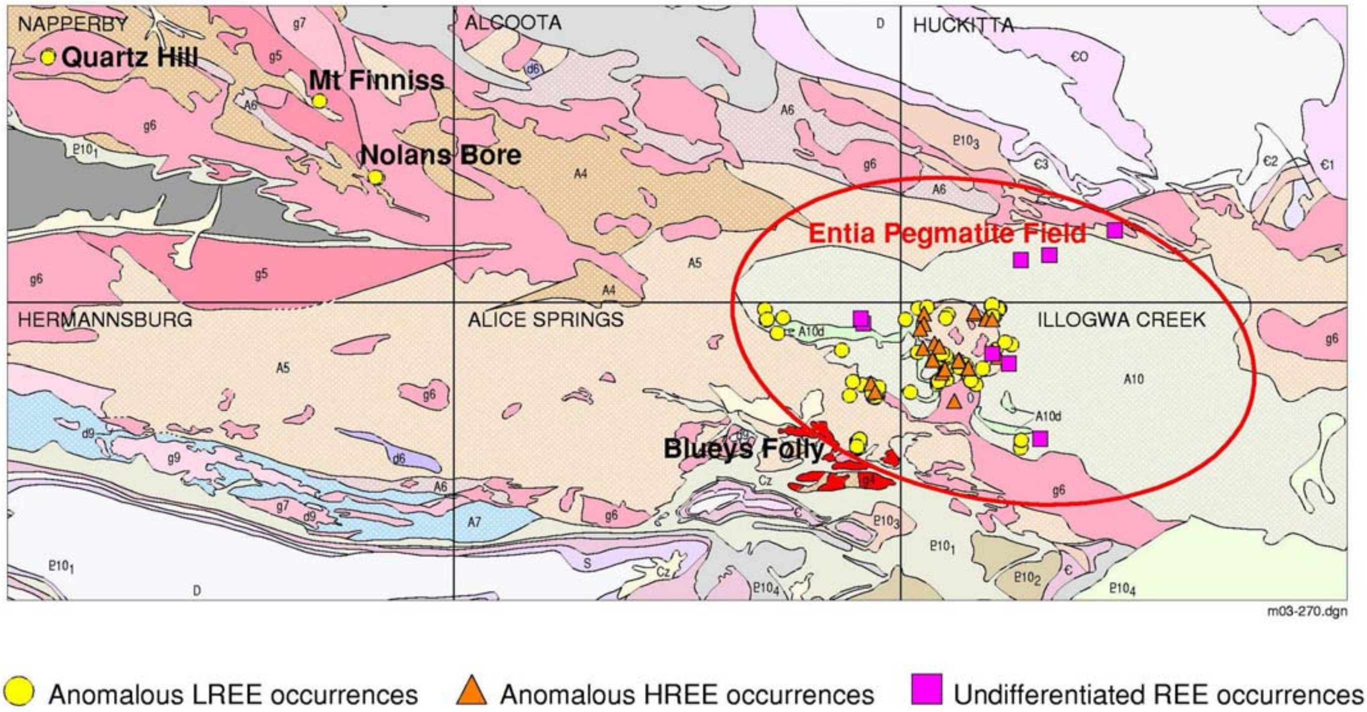

Figure 1. Location of REE prospects.

This account makes no attempt to describe the geology of the Arunta Region in detail, although the contexts of some REE occurrences are discussed. For details on the geology of the Arunta Region, refer to existing geological maps and notes, and to Shaw *et al* (1984), Stewart *et al* (1984), Collins and Shaw (1995), Zhao and Bennett (1995), Miller *et al* (1998), Buick *et al* (1999), Hand *et al* (1999a, b), Mawby *et al* (1999), Collins (2000), Buick *et al* (2001), NTGS (2001, 2002), Scrimgeour and Raith (2001), and references therein.

The southwestern parts of the Arunta Region have been excluded from this review primarily because exploration of this area has been extremely limited and no REE occurrences have been documented. The boundary with the Warumpi Province in the southern Arunta Region therefore serves as a useful limit for this review. It should be noted that allanite-bearing granites have been recognised during recent mapping by NTGS in the Warumpi Province (Dot Close, NTGS, pers comm, 2002).

Due to sparse exposures, very little is known about the REE potential of the northwestern, northernmost and easternmost Arunta Regions. Hence, this review principally concentrates on the central and eastern Arunta Region.

Deposit types

Globally, REE mineralisation typically falls into one the following categories:

- Carbonatites and associated alkaline igneous rocks
- Pegmatites and granitic rocks
- Hydrothermal systems
- Fe oxide-Cu-Au-REE systems
- Mary Kathleen-type U-REE mineralisation
- Lateritic/supergene enrichment
- Heavy mineral sands.

Some of these mineralisation styles overlap and may be genetically related. All of these styles are possible in the Arunta Region. Bajwah (unpublished NTGS manuscript) has recently reviewed the REE occurrences of the Northern Territory and has also described some world-class examples.

REE IN CARBONATITES AND ALKALINE IGNEOUS ROCKS

Carbonatites and alkaline igneous rocks commonly host REE mineralisation. The majority of global REE occurrences are found to be associated with these rock types. It also appears that carbonatite complexes are unusual in that they are generally highly prospective targets; a large percentage of the known examples host some form of economic resource, be it REE, Nb, P, Ti, F, Ba, Sr, Cu, V, Th or vermiculite.

Although the volume of carbonatite in most of these complexes is relatively small (normally <10%), most of the >350 documented carbonatites are associated with alkaline silicate rocks. The co-occurrence of carbonatites and alkaline silicate rocks as flows, plugs, dykes and sills lends strong support to a magmatic origin for all these rock types and it is often difficult to divorce the origin of one from the origin of the other. Carbonatites that are not associated with silicate rocks are few and are invariably rich in dolomite (Bell 1989, 1998). Because of the diversity of silicate rocks associated with carbonatites, it is often difficult to generalise about them. However, Bell (1998) outlined certain groups that are spatially, if not genetically related to carbonatites. These are:

- carbonatite-nephelinite-phonolite, common in East Africa; eg Napak, Uganda; Oldoinyo Lengai, Tanzania; Shombole, Kenya
- carbonatite-melilitolite; eg Oka, Canada; Kovdor, Russia; the Turiy Complex, Russia
- carbonatite-pyroxenite; eg Phalaborwa, South Africa
- carbonatite-syenite; eg Chilwa Island, Malawi; Khibina, Russia; Siilinjarvi, Finland
- carbonatite-lamprophyre; eg Kandalaksha, Russia; Alno, Sweden; northwest Namibia.

Most carbonatite complexes are found in continental crust and on a global scale, carbonatites related to collision-type tectonic activity appear to be scarce. Bell (1989) pointed out that carbonatites also appear to be spatially related to some kimberlites (eg Premier, South Africa).

Carbonatite and alkaline igneous complexes are typically found in rifted continental settings and tend to cluster in both time and space in close proximity to major extensional structures (eg Woolley 1989). A well documented example is the Devonian Alkaline Province in the Kola Peninsula (eg Kramm *et al* 1993, Dunworth and Bell 2001), where numerous complexes have intruded over a short (20-25 Ma) period. In east Africa, at least three distinct episodes of carbonatite and associated alkaline silicate magmatism occur (eg Woolley 1989, Van Straaten 1989). It is interesting to note that one of these periods is coincident with the emplacement age on the Mud Tank carbonatite complex in the Arunta Region.

Carbonatites and associated alkaline silicate rocks are usually strongly enriched in light rare earth elements (LREE). REE concentrations in carbonatites are typically much higher than in most other igneous rocks, with ΣREE ranging from about 500 ppm to >10 000 ppm (Cullers and Graf 1984, Mariano 1989, Hornig-Kjarsgaard 1998). REE mainly reside in the Ca-bearing phases; ie carbonates, apatite, Ca-Nb oxides and Ca-silicates, where they substitute with Sr^{2+} for Ca^{2+}. Fluorapatite is often the major REE host in these rocks and can form at different stages throughout the crystallisation of the host magma. Primary magmatic bastnaesite, on the other hand, often occurs as a late-stage mineral. Late-stage highly fractionated carbonatites such as magnesiocarbonatite or more commonly ferrocarbonatite (cf classification of Woolley 1982), and their associated silicate rocks and fluids are often the most strongly enriched in REE. However, Hornig-Kjarsgaard (1998) pointed out that the variations in distribution of REE are difficult to explain by fractional crystallisation processes and hence are thought to be signatures of the parental melt.

REE can also be found in alteration halos, faults and vein systems associated with the emplacement of carbonatites and alkaline rock types [eg the Mountain Pass district in California (Olsen *et al* 1954) and the Gallinas Mountains F-REE deposits in New Mexico (Williams-Jones *et al* 2000)]. Elevated REE concentrations can also occur in extrusive alkaline volcanic rocks [eg Brockman rare metal deposit in Western Australia (Chalmers 1990)]. REE mineralisation can also occur in secondary REE-bearing phases as supergene enrichment/lateritic deposits developed on carbonatites and or alkaline igneous rocks [eg the Mount Weld (Duncan and Willett 1990) and Cummins Range (Andrew 1990) carbonatites in Western Australia].

The Mud Tank Carbonatite Complex (MTCC) and the Mordor Igneous Complex (MIC) are currently the only known examples of these rock types in the Arunta Region, apart from alkaline pegmatites and associated granitic rocks. The latter are dealt with separately below. At first glance, both the MTCC and MIC appear to be likely candidates for REE mineralisation, with some untested possibilities. A possible carbonatite dyke has been recognised near Mount Bleechmore (Temby 1989), but little is known about this deeply weathered rock.

Mud Tank Carbonatite Complex

The MTCC is portrayed as an example of a solitary carbonatite complex (Bell 1989). However, it seems logical that the presence of an individual carbonatite complex in the Arunta Region would favour the existence of additional complexes emplaced at that time on similar structures. This is because globally: (1) carbonatite complexes tend to cluster in both space and time along suitable structures; and (2) the emplacement of carbonatite and associated silicate igneous complexes appears to be structurally controlled in most cases (eg Woolley 1989). Apart from being buried beneath transported or residual cover, it may simply be a problem of recognising them amongst the complexly deformed and metamorphosed rocks of the Arunta Region. The distribution of lithologies and structural relationships seen in the MTCC clearly demonstrates the problem of recognising these carbonatite complexes in deformed and metamorphosed regions.

Black and Gulson (1978) dated the MTCC at 732 ± 5 Ma using the conventional U-Pb method on zircon separates and also at 735 ± 75 Ma using whole rock Rb-Sr analyses.

The MTCC is deformed and has been stretched into an elongate shape with weakly to strongly developed, steeply northwest-dipping to subvertical foliation/layering (Crohn and Moore 1984, Currie *et al* 1992). This geometry and structural complication is atypical and only a limited number of deformed carbonatite complexes have been reported. It is likely that the MTCC intruded (at mid-crustal? depths) along a prominent east-northeast-trending structure (Currie *et al* 1992), which was subsequently reactivated during later tectonic events. Other workers have suggested a close spatial relationship to the Woolanga lineament (Moore 1979, Crohn and Moore 1984), but this lineament is more than 10 km to the west and is probably not the primary control. Apart from providing a conduit for the MTCC, the east-northeast-trending structure that now deforms the MTCC may also have played an important role during early rift stages associated with the development of the Irindina Sub-basin. The presence of carbonatite and alkaline igneous rocks is compatible with this continental rift setting. Additional complexes might also be found along these structures that now appear to form the faulted margin of the Harts Range Group. Furthermore, it is interesting to note that zircons of the same age as those of the MTCC are present in metasedimentary rocks of the Harts Range Group (cf Buick *et al* 2001).

At least two foliations can be observed in the MTCC. Rb-Sr ages on three different biotite separates from the MTCC are in the range 350-320 Ma (Black and Gulson 1978) and are interpreted as cooling ages related to the Alice Springs Orogeny. These ages probably relate to the overprinting greenschist facies (biotite) crenulation cleavage rather than the amphibolite facies (biotite + actinolitic? amphibole) foliation, although they may be a combination of both. The higher-grade fabric produces the prominent subvertical layering in the complex and also seems to be related to its overall elongate shape. The age of the higher-grade fabric is not clear, as it may form part of a single progressive event associated with the Alice Springs Orogeny. This foliation is most probably about 380 Ma given the recent findings of Ballèvre *et al* (1999, 2000) and Hand *et al* (2001). Alternatively, it is possibly related to a 450-440 Ma event recognised in the nearby Irindina Province (Hand *et al* 2001, Scrimgeour and Raith 2001).

Structural complications observed in the MTCC result in a magnetic expression that is atypical for a carbonatite complex. This therefore makes it rather difficult to discriminate the MTCC from other magnetic units in the Arunta and further suggests that other 'hidden' examples may exist in more intensely deformed areas. The most obvious place to explore is along the extension of the structure that hosts the MTCC.

The MTCC and the surrounding country rocks are not well explored for REE. There is a need for further assessment, although based on currently available data, it would seem to rate as an area of medium to low REE potential. Additional work should involve geochemical studies, particularly of the apatite-rich zones, and further investigation and documentation of the mineral phases. Understanding could also be greatly enhanced by strategic drilling in new areas of the MTCC to explore igneous/metamorphic/structural relationships and possible mineralisation targets.

Preliminary investigations of the MTCC have been disappointing with respect to REE mineralisation and the body is principally regarded as a vermiculite resource. Whole rock geochemical analyses have documented elevated REE levels, but Currie *et al* (1992) pointed out that the REE abundances are lower than world averages for carbonatites. To date, no highly REE-enriched phases have been documented in the MTCC. The apatite is fluorapatite, but its REE content is also low (Currie *et al* 1992). This could indicate that REE were removed from the carbonatitic melt by early crystallising apatite. Hence, early-formed apatite-rich bodies might exist. Alternatively, REE can remain incompatible until the last stages of crystallisation, thus resulting in REE-rich ferrocarbonatites and phoscorites. Hence, the apatite-magnetite-rich parts of the MTCC might host significant REE occurrences. Globally, igneous phoscorites (apatite-magnetite rocks) tend to be the most REE-enriched parts of other carbonatite complexes and they have not been thoroughly tested or explored for in the MTCC. Unfortunately, the amount of apatite seems to be fairly low, based on drilling by Geopeko and NTGS.

Another possibility is that some of the REE may have been stripped by F- and CO_2- or CO_3^{2-}-bearing fluids released during deformation and metamorphism of the complex. Fluids of this composition are capable of transporting significant REE (eg Williams-Jones *et al* 2000). If this is the case, then shear zones and fault systems may have focused and trapped REE sourced from the MTCC, and might provide favourable exploration targets.

A gridded auger-drilling program undertaken by NTGS outlined the shallow subsurface nature and geometry of the carbonatite complex, but geochemistry failed to highlight anomalous REE mineralisation (Moore 1979). This suggests that a lateritic REE-enrichment model (eg Lottermoser 1990, Nasraoui *et al* 2000) does not apply to the MTCC. This is consistent with its current exposure and lack of significant cover. However, the presence of a significant vermiculite resource implies that the rocks have been subjected to significant hydration via surface processes at some time in the past. It is interesting to note that the Cummins Range Carbonatite in Western Australia has both a vermiculite resource and lateritic/supergene REE-enrichment (Andrew 1990). The thin superficial cover and presence of Quaternary? pebble and boulder conglomerates overlying the MTCC suggest that if lateritic/supergene REE occurrences ever existed in the MTCC, they have been stripped.

Based on the above evidence, there appears to be limited potential for REE mineralisation in the MTCC, although is it not well tested. The surrounding country rocks, which host the complex, and apatite-rich parts of the MTCC remain as untested REE possibilities. Large magnetic anomalies that coincide with the MTCC (due to a high magnetite content) would be the targets of highest priority, given that these are candidates for igneous phoscorite-hosted REE deposits.

Syenite inclusions have been recognised in the MTCC (Currie *et al* 1992). An example of this rock type was present as a narrow deformed dyke in the western side of the open cut in 2000-2001, but has since been removed by mining operations. Field relationships suggested that it was closely associated with the carbonatite rather than an incorporated country rock unit. Hence the MTCC might be part of a carbonatite-syenite association (cf Bell 1998), rather than a solitary carbonatite body. This is of interest because rocks in the Khibina region of the Kola Peninsula belong to a carbonatite-syenite association and contain significant apatite-hosted REE occurrences.

Mordor Igneous Complex

The MIC was originally dated at about 1150 Ma by Rb-Sr and Sm-Nd methods (Langworthy and Black 1978, Nelson *et al* 1989) and has been recently dated at 1132 ± 4 Ma using the SHRIMP U-Pb zircon method (Hoatson *et al* 2002). The MIC is significantly older than the MTCC and, contrary to earlier suggestions, they are not related.

The MIC is subcircular in cross-section and, despite being older, has escaped most of the structural complications seen in the MTCC. MIC rocks are virtually undeformed, apart for some minor faulting and shearing, possibly related to the Alice Springs Orogeny.

The MIC is a highly potassic alkaline suite and is considered highly prospective for REE mineralisation. Alkali feldspar syenite–quartz alkali feldspar syenite-shonkinite rocks and surrounding country rocks appear to be the most prospective for REE. These units are typically weathered and, prior to this study, have not been sampled for detailed whole rock geochemistry. Published REE data was limited to a few examples with only La data reported (Langworthy and Black 1978). Results of up to 240 ppm La (about 1000 times chondritic values) were obtained, suggesting they are LREE-enriched.

A suite of syenite-shonkinite rocks was sampled from drill core to assess their whole rock geochemistry and REE potential. As expected, results clearly indicate that these units have elevated LREE contents (**Figure 2**). Several hematite-chlorite-fluorite-pyrite-chalcopyrite alteration zones were encountered in the syenite in drill core. These appear to be related to later fluids migrating along faults. The altered rocks were analysed to investigate bulk chemical changes and mineral potential. Results indicate that LREE are preferentially depleted in these alteration zones as compared to the host syenite rocks (**Figure 2**), suggesting that REE have been stripped by oxidising fluids and deposited elsewhere. A carbonate-fluorite vein with low REE content was also encountered in the syenite (**Figure 2**).

Magmatic- and vein-style deposits analogous to the Mountain Pass district in California (Olson *et al* 1954) and the Gallinas Mountains fluorite-REE deposits in New Mexico (Williams-Jones *et al* 2000) are possible in the vicinity of the MIC. To date, investigations of the MIC have primarily focused on the Cu-Ni-PGE-Au and diamond potential (McCoy *et al* 1997). A barite occurrence has been reported in the northern part of the MIC (Barraclough 1981), but an initial inspection of the mapped location failed to find it. This barite occurrence has potential for Ba-F-REE mineralisation, and the surrounding area should therefore be re-examined to accurately relocate the prospect.

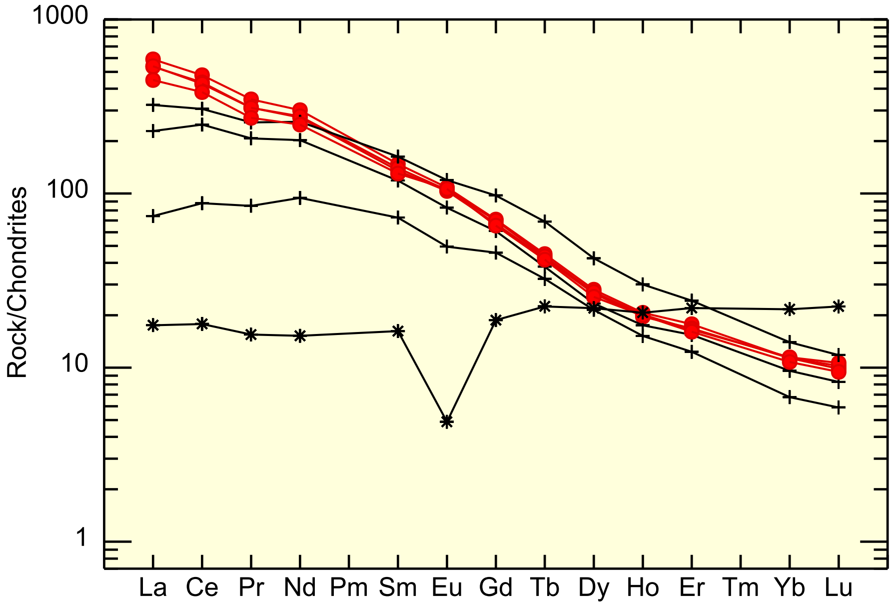

Figure 2. Chondrite-normalised (after Sun and McDonough 1989) REE patterns for various rocks from the Mordor Igneous Complex. Filled circles - unaltered syenite host; crosses – hematite+chlorite altered syenite; stars - hydrothermal carbonate vein.

It is considered highly probable that vein- and magmatic-style REE deposits were associated with the MIC, but these have probably been eroded given the current level of exposure and the close proximity to the unconformably overlying Heavitree Quartzite.

Other carbonatites and associated alkaline igneous complexes

Although no other large obvious carbonatite or alkaline igneous complexes are evident in the Arunta from the regional magnetic data, several untested magnetic bodies do occur close to major structures. It is possible that these might be either alkaline mafic or carbonatitic bodies and, if so, they would be likely candidates for REE mineralisation.

Unpublished CRAE reports document several samples of sövite (carbonatite) collected from fault breccia in the MIC (Barraclough 1975). Carbonatite veins were also initially reported from drillhole MCDDH4 in the MIC (Barraclough 1975). These 'carbonatite' occurrences are now considered to be hydrothermal carbonate veins (Langworthy and Black 1978, Barraclough 1981).

Murrell (1988) reported two carbonatite occurrences near Blueys Folly, east of Arltunga. Deformed forsterite-clinopyroxene marbles were found in this vicinity while on a brief field visit to the site. The so-called carbonatite occurrences are reinterpreted as either rafts of carbonate or calcsilicate rocks in pegmatite, or skarns, rather than carbonatite. This reinterpretation seems to be plausible, since calcsilicate rocks are mapped as part of unit p€x in ALICE SPRINGS.

Possible carbonatite dykes have also been reported near Mount Bleechmore (Temby 1989). These rocks are deeply weathered and are poorly exposed in shallow costeans. Recent drilling by Flinders Diamonds suggests that they are carbonatites similar to those in the MTCC.

PEGMATITES AND GRANITIC ROCKS

Pegmatite swarms are conspicuous in parts of the Arunta Region and different ages are apparent throughout. Potential REE-bearing granite and pegmatite suites have been identified using available data and chemical/petrogenetic models proposed by Černỳ (1991).

Harts Range Region

Joklik (1955) and Daly and Dyson (1956) noted that at least two pegmatite suites are present in the Harts Range region. They recorded mica-poor potassic and mica-rich sodic varieties. The potassic pegmatite suite tends to be hosted mainly within the Entia Gneiss complex, whereas the sodic pegmatites occur in the Irindina and Brady Gneisses. Some potassic pegmatites are known to host accessory REE minerals and examples of centimetre-sized gem-quality monazite are present in some. These pegmatites intrude the Entia Gneiss and Harts Range Group. They are Palaeozoic in age, although it is not clear how many generations of pegmatites are present (Drake-Brockman 1995, Drake-Brockman *et al* 1996a, b, Hand *et al* 1999a, b).

Proterozoic pegmatite swarms and associated granites also occur in the Arunta Region. Some of these appear to have REE potential and will be discussed latter.

The strong peraluminous character of some pegmatites in the Harts Range region, the presence of Be- and Li-rich phases and the overall structural/metamorphic setting, indicate that these pegmatites are probably early melts generated from Harts Range Group metasediments. Be-rich pegmatites may be considered indicative of a marine setting for the source rocks. Using the pegmatite classification scheme of Černỳ (1991) these rocks appear to be analogous to Li, Rb, Cs, Be, Ga, Sn, Nb<Ta (LCT)-type pegmatites and associated granitic suites. Note that these have rare-metal potential, but are not considered candidates for REE mineralisation. Note also that Sn-Ta-W pegmatites and granites are part of this LCT suite and that examples of these occur throughout the northern parts of the Arunta Region.

Other pegmatites in the Harts Range region, informally named the Entia pegmatite field[1], contain REE phases such as samarskite, monazite, allanite, fergusonite, formanite, euxenite, xenotime and others. Muscovite extracted from these pegmatites is of high quality and lacks fluorine and lithium (Joklik 1955). Joklik (1955) and Daly and Dyson (1956) classified these as potassic pegmatites. Descriptions of them appear to be analogous to the Nb>Ta, Y, REE, Sc, Ti, Be, Th, U, F (NYF)-type pegmatite and associated granitic suite of Černỳ (1991), which are considered to be prime candidates for REE mineralisation.

These REE-bearing pegmatites were first documented by Joklik (1955) and Daly and Dyson (1956) as part of an investigation into the Harts Range and Plenty River Mica Fields. Samarskite occurs at the Lone Pine, Painted Canyon and Butcher Bird Mines, and also occurs at the Walter Smiths Mine, along with allanite. Coarse monazite crystals, some of gem quality, occur in the northern workings of the Last Hope Mine, and at the Marenga and Ciccone's North Mines. These observations are consistent with recent work of PNC, who found these and numerous other REE phases at various prospects throughout this region.

PNC prospects which appear to host significant REE are detailed in the appendix and portrayed on **Figure 1**. This prospectivity assessment is based on La, Ce and Y data reported in Drake-Brockman (1995) and Drake-Brockman *et al* (1996a, b). Yttrium has been used as a HREE proxy and has enabled the potential mineralisation to be divided into HREE- and LREE-enriched prospects. Apart from REE, most occurrences are also anomalous in one or more of the following: U, Th, Nb, Ta, P, Ba, Fe, Ti and Zr. Available data clearly indicate that virtually all of the REE prospects show Nb>Ta. This association is

[1] New informal name; encompasses various REE-enriched pegmatite dykes/swarms in the Entire Valley, Harts Range and Plenty River regions.

consistent with that of NYF-type pegmatites (Černỳ 1991), or of fluid systems possibly derived from them (eg Holsteins). Some of these prospects may host significant amounts of REE mineralisation (grab samples locally contain >10% REE). Unfortunately, although the region shows anomalous REE, the amount of REE mineralisation can not be accurately assessed from the PNC grab samples. Systematic costean sampling and drill testing is probably warranted at some of the occurrences.

Assessment of PNC's geochemical data from these prospects suggests that two types of alkaline (NYF-type) pegmatites may exist. Geochemical data indicate that some prospects are enriched in U>Th, Ti, Nb>Ta and Y. These are considered candidates for HREE mineralisation, but sometimes, associated rocks can also have elevated LREE. The majority of the REE prospects have a slightly different geochemical character but still retain this alkaline affinity (NYF-type pegmatite magmatism). This group are typically enriched in Th>U, LREE, P, and sometimes Y, Zr, Ba, Sr and Fe. The distinction between these groups primarily comes down to the Y contents (and by inference HREE) relative to LREE. In most cases, U is high in the HREE-enriched occurrences and low in the LREE-enriched occurrences. Thorium is typically much greater than U in the LREE-enriched occurrences, but U>Th does occur in some.

The pegmatites in the Harts Range region have SHRIMP U-Pb zircon and monazite ages suggesting they are coeval with the Alice Springs Orogeny (eg Drake-Brockman *et al* 1996a, b, Hand *et al* 1999a, b, Mawby 2000), although the number of magmatic events and the genesis of these are unclear. Based on SHRIMP U-Pb monazite dating and P-T constraints, Mawby (2000) suggested that monazites grew from hot REE-bearing fluids that infiltrated post-peak metamorphism. These fluids are thought to be related to the pegmatites.

Buick (1985) suggested that LREE mobilisation occurred during retrograde metamorphism in the Entire Valley and indicated the presence of garnet-epidote skarn systems packed with REE-rich accessory phases. He and his PhD students are currently investigating partial melting, pegmatite genesis and fluids in this area (pers comm 2001). They have found that some pegmatites in the Entire Valley and Harts Range areas have alteration haloes that are REE-enriched. Although Buick did not elaborate further, one of the above PNC prospects is the suspected location.

Holsteins and Mount Mary region

Drake-Brockman (1995) documented late-stage, gossanous, radioactive breccia veins cutting the Brady Gneiss of the Harts Range Group during recent investigations at Holsteins, a previously known REE occurrence. These veins and breccia masses are essentially chalcedony-barite-carbonate-hematite-monazite, with minor to very high REE-Th and insignificant to minor U. Although the amounts vary, REE were found in all samples, reaching a maximum of 12% Ce and 7% La. According to Drake-Brockman (1995), the REE principally reside in monazite and xenotime, although other REE phases could also be expected. Matheson (1968) also reported anomalous Cd and In from this area. The fluids responsible for these occurrences appear to have been oxidised and alkaline, consistent with a fluid derived from the adjacent pegmatite swarms. Associated metasomatism has not been documented, but could be expected in this area. There is no indication of the size and grade of REE mineralisation in this area.

The Ba-Fe oxide-REE association at Holsteins is particularly interesting. It could be viewed as a variant on the fluids responsible for the Fe oxide-REE-Nb mineralisation seen at Bayan Obo in Inner Mongolia, China (cf Drew *et al* 1990, Smith and Chengyu 2000). The elevated P, Ba, Fe oxides and REE is consistent, but Nb is very low in the analysed samples and may therefore discount this analogy. Despite its apparent absence in the grab samples, elevated Nb is expected at Holsteins primarily because the mineralisation may be linked to NYF-type pegmatites. It is possible that a large area in the vicinity of Holsteins and Mount Mary has potential for REE, given the surface samples analysed by Drake-Brockman (1995) and the amount of pegmatite and associated granite indicated in QUARTZ (Shaw *et al* 1990).

Blueys Folly

At Blueys Folly, allanite occurs as a primary igneous mineral in a pegmatite swarm, which has plug-like to lenticular subvertical bodies and sheet-like apophyses that intrude the surrounding amphibolite facies metamorphic rocks (Murrell 1988). Murrell indicated that allanite also occurs as a metamorphic mineral in some amphibolite and marble (calcsilicate?) units adjacent to these pegmatites. This prospect outcrops over an area of about 4 km^2 that consists predominantly of pegmatite and is estimated to contain several million tonnes grading in access of 0.4% allanite (Murrell 1988).

Although uneconomic, this prospect is intriguing and suggests that REE-enriched pegmatite swarms are locally dominant. Although their age is unknown and they are separated spatially by the Illogwa Schist Zone, timing relationships suggest that the REE-rich pegmatites at Blueys Folly could be part of the Entia pegmatite group.

In addition to Blueys Folly, numerous allanite-bearing pegmatites occur between Alice Springs and Ruby Gap (eg allanite bearing pegmatite is present at the Undoolya Quarry). The REE potential of these pegmatite-related mineralisation systems remains untested.

General discussion

The presence of REE-enriched sweats and skarns surrounding all of the above REE-enriched pegmatites suggests a significant potential for REE in the Irindina Province and adjacent regions. The abundance of REE-rich breccia veins and calcsilicate rock units in this area suggests there is significant potential for REE skarns or hydrothermal vein deposits. The inferred timing of these pegmatites suggests there is also a strong possibility that REE-enriched fluids, derived from these systems, may have migrated along major structures to higher crustal levels during the Alice Springs Orogeny. The presence of monazite means that a regional assessment of timing of this REE fluid flow could be achieved via SHRIMP U-Pb dating of monazite in pegmatites, in their alteration halos and in associated shear zones.

Examples that indicate the possibility of these types of fluids may include parts of the Oorabra reefs that outcrop in HUCKITTA (Freeman 1986). The barite-fluorite veins appear to be untested for REE, but are likely candidates for REE mineralisation, because F-rich fluids are capable of transporting REE. If this assumption is correct, then REE vein-style deposits are possible.

It is also interesting to note that in the Arunta, at least several shear zones, which are interpreted as being related to the Alice Springs Orogeny, show elevated Th signatures in radiometric images. Since Th and REE often occur together, it is expected that these shear zones might have been flushed with REE-enriched fluids during the Alice Springs Orogeny. This would provide a mechanism for focusing fluid derived from contemporaneous pegmatite. Prominent examples of shear zones with elevated Th signatures include the Peaked Hill Shear Zone and unnamed shear zones to the south of Pine Hill in NAPPERBY, and the parts of the West Bore Shear Zone in ALICE SPRINGS. Although pegmatites related to the Alice Springs Orogeny are not widely recognised, dating has confirmed that at least some of the pegmatites in the Entia pegmatite field are of this age. The Nolans Bore REE occurrence lies on a major structure and may also be related to these fluids, and REE-enriched pegmatite is present. Apatite veins at Nolans Bore occur in an en echelon arrangement consistent with sinistral strike-slip movement in a brittle environment.

Proterozoic REE pegmatites and associated granite suites

Proterozoic REE-rich, allanite-bearing granites and pegmatites occur in the Arunta Region. Prominent examples include the Gum Tree and Ennugan Mountains Granites. A phase of the Wuluma Granite also contains probable allanite. No known REE mineralisation is associated with these, although the Ennugan Mountains Granite, in particular, is seen as prospective because Otter Exploration found several small U, Th, Ta and Nb occurrences in narrow biotite shears (Kojan 1980, Stewart *et al* 1980). The potential for REE mineralisation in the Gum Tree and Wuluma Granites is considered low, but the presence of minor carbonate and calcsilicate rocks in the surrounding country rocks indicates that REE skarns or hydrothermal systems are possible.

Some phases of the Wangala Granite in northwestern NAPPERBY also contain allanite. This granitic complex hosts the Quartz Hill apatite REE occurrence. This granite appears to be a composite pluton with numerous phases of variably fractionated, crustally contaminated LREE-enriched granodiorite-granite. Stewart *et al* (1980) reported allanite in some phases, suggesting that these phases, at least, are metaluminous rather than peraluminous, as reported.

The Quartz Hill apatite REE occurrence appears to be related to metasomatic/igneous fluids derived from the REE-rich Wangala Granite or its associated pegmatites. According to Davies (1979) and Stewart *et al* (1980), uraniferous REE-rich apatite-mica schists occur in an east-northeast-trending belt over an area of about 2 km^2 within the Wangala Granite. Because of their unusual composition and whole rock chemistry, Davies (1979) and Stewart *et al* (1980) both interpreted these to be metasomatised sedimentary rocks. The schists comprise up to 55% biotite, up to 25% apatite (probably fluorapatite), up to 25% muscovite and up to 55% quartz. Accessory zircon and opaques are present. One sample also contains 5% sillimanite. These prospects were visited in 2001 to compare with the Nolans Bore prospect. Field relationships suggest that the apatite-biotite schists may be hydrothermally altered pegmatite and/or Wangala Granite.

The Wangala Granite is not dated. Stewart *et al* (1980) suggested that it was related to the allanite-hornblende-bearing Ennugan Mountains Granite, recently dated at 1622 Ma (Smith 2000). Young *et al* (1995) suspected that the Wangala Granite (mapped as the Yaloolgarrie Granite by them in MOUNT DOREEN) was older than the 1565 Ma Southwark Granitic suite on structural grounds.

Stewart *et al* (1980) also mapped a hematitic porphyry in the Wangala Granite with 55 ppm Th. The high Th content of this porphyry suggests that it should contain significant REE. The presence of hematite (alteration?) is also of economic interest. It is suspected that this suite (Wangala Granite and possibly also the Ennugan Mountains Granite) may have potential for Fe oxide-Cu-Au-REE mineralisation, if they have not been extensively unroofed. The calcsilicate rocks near the Wangala Granite may also potentially host REE mineralisation (eg Mary Kathleen-style U-REE deposits).

HYDROTHERMAL SYSTEMS

Nolans Bore REE prospect

The Nolans Bore REE prospect is the first of its type to be discovered in the Arunta Region. Understanding of this REE prospect is limited at this early stage to the results of PNC and Arafura Resources exploration programs and poor surface exposures. The REE mainly reside in poorly outcropping fluorapatite veins, or dykes?, with surface samples averaging about 7 wt% total REE (Thevissen 1995, J Goulevitch, Arafura Resources, pers comm 2001). Recent work has also identified abundant cerianite and Arafura Resources, the current holders of the Nolans Bore prospect, have suggested a potential resource of about 3.8 Mt @ >4% rare earth oxide within 60 m of the surface (Arafura Resources 2003). They are currently testing and evaluating the extent and amount of REE mineralisation.

The prospect occurs in two zones over a strike length of about 2 km within variably deformed and altered granitic gneiss and pegmatite, and minor calcsilicate rocks (alteration?). REE mineralisation is not restricted to fluorapatite. It is also present in altered country rock (deformed granite and pegmatite) and occurs in other REE phases, but apart from one region, these appear to be subordinate. The Nolans Bore REE prospect seems to have a close spatial relationship to major Alice Springs Orogeny structures in this region and in this respect, could be interpreted as a pegmatite-related vein system deposited within a high-level shear zone with sinistral offset.

The REE are possibly derived from late-stage hydrothermal fluids and alteration systems related to pegmatite emplacement. Thevissen (1995) suggested that the Nolans Bore fluorapatite was deposited as a low-temperature hydrothermal vein system. The relationship between the fluorapatite and the REE-enriched pegmatite is unclear, although the REE signatures are very similar, suggesting they may be related.

Observations, based on a limited number of thin sections of surface samples collected from Nolans Bore, suggest that brecciation is present and that several generations of fluorapatite are present in these veins. Numerous small mineral inclusions are present in the fluorapatite. Hence, it is apparent that REE might also reside in phases other than fluorapatite. This is consistent with Thevissen (1995) and was also confirmed using the University of Adelaide electron microprobe (**Table 2**). Results indicated bright REE-rich rims surrounding dull-grey REE-bearing fluorapatite, and at least several different phases of bright REE-rich mineral inclusions in the fluorapatite. The REE-rich phases were deposited prior to the deposition of late stage vuggy quartz (dark). Although electron microprobe analyses indicate that the fluorapatite contains significant LREE (**Table 2**), it appears that the variability of REE mineral inclusions within the fluorapatite might be responsible for variations in the reported REE contents and ratios of the veins. On the basis of one surface sample, it also seems possible that localised supergene REE enrichment might be present. Secondary REE-P enrichment is possible and is consistent with calcrete development and surface alteration in the vicinity of Nolans Bore.

Hogarth (1989) indicated that the Mn and Sr compositions of fluorapatite are diagnostic of its host rocks. For the Nolans Bore fluorapatite, Mn is low and Sr is in the middle of typical compositional ranges. Although some of the Nolans Bore apatite compositions are consistent with skarn and carbonatite hosts, others are outside typical compositional fields. The relatively constant Sr content of the apatite at Nolans Bore suggests that either: (1) the amount of Mn in fluid varied during deposition of the fluorapatite; (2) another phase was precipitating Mn synchronous with the deposition of fluorapatite (eg Mn-garnets are common in pegmatite); or (3) Mn is mobile and has been stripped from the fluorapatite.

Hogarth (1989) also pointed out that the Th content of apatite from carbonatites is typically low (<0.13%). The Th content of Nolans Bore fluorapatite is generally much higher than this, ranging from 0.067-0.593% and averaging 0.233% Th (11 analyses). Thevissen (1995) reported a similarly high Th content (averaging 0.483% Th). This high Th content suggests that the Nolans Bore fluorapatite is not related to a carbonatite, or to fluids derived from them, but is more likely to be related to hydrothermal fluids associated with an NYF-type pegmatite. Bea (1996) demonstrated that chondrite-normalised REE patterns for apatite differ between igneous rock types and appears to be controlled by the alkalinity of the rock. However REE patterns for apatite from both peralkaline and carbonatitic rocks (Bea 1996 and Hornig-Kjarsgaard 1998, respectively) are similar to the Nolans Bore apatite-rich rocks. Hence, given the REE similarities, the elevated Th content appears to be more diagnostic and suggests there is probably a connection between sheared/altered pegmatites in the area and the fluorapatite veins.

It follows that this region probably has significant potential for this style of REE mineralisation, particularly if there is widespread fluid flow and suitable 'traps' can be found. Note that REE mineralisation of this style does not necessarily imply a fluorapatite host, as is the case for Nolans Bore.

Mount Finniss REE prospect

The Mount Finniss prospect appears to be an example of REE enrichment related to metamorphism, or possibly to hydrothermal alteration.

The prospect was discovered by Otter Exploration in 1979 and was described as a grossular garnet-monazite pod or lens about one meter in length within the Weldon Metamorphics (Kojan 1980). The host lithologies are granulite facies migmatitic metasediments, predominantly metapelites. Very little is known about this prospect and it has not been relocated since it was discovered.

It was suspected that this pod might be a part of a larger mineralising system. The occurrence of grossular garnet and the unusual whole rock chemistry reported in Kojan (1980) suggested that a hydrothermal or metasomatic alteration (skarn?) system was possible. Hence, it was suspected that hydrothermal alteration and metasomatism related to the 1806 Ma (Vry *et al* 1996) Yaningidjara Orthogneiss might have been responsible for this REE prospect. The Yaningidjara Orthogneiss has produced intensely altered metasedimentary rocks in its contact aureole elsewhere (eg Vry and Cartwright 1994). In addition, Vry and Cartwright (1998) provided rather compelling stable isotope evidence for significant fluid infiltration during contact metamorphism associated with the emplacement of this and related granites.

	1.1 (A) Apatite	1.2 Apatite	1.3 Apatite	2.2 Apatite	2.3 Apatite	3.2 Apatite	4.3 Apatite	5.2 Apatite	6.1 Apatite	6.3 Apatite	2.1 mineral with qtz	2.4 (B) mineral	3.1 (C) mineral with qtz	4.1 (D) prismatic mineral	4.2 mineral	5.1 (E) mineral with qtz	6.2 (E) mineral
Ca	38.966	37.911	38.457	38.326	39.377	38.372	38.617	38.099	37.812	39.353	3.064	3.422	9.289	5.251	3.488	2.935	2.542
Mn	0.011	0.003	0	0.022	0.014	0	0	0	0	0.022	0	0	0.22	0	0	0	0
Sr	0.298	0.29	0.325	0.28	0.314	0.283	0.325	0.346	0.296	0.267	0.312	0.279	0.916	0.301	0.383	0.35	0.247
Mg	0	0	0	0	0	0	0	0	0	0	0	0.018	0	0	0	0.015	0
Fe	0	0.024	0.019	0	0	0	0	0	0	0	0.294	0	0.427	1.261	0.107	0.92	0
La	0.545	0.552	0.612	0.485	0.302	0.591	0.558	0.484	0.656	0.318	23.365	23.713	1.429	6.938	15.523	27.344	25.865
Ce	1.412	1.842	1.83	1.759	1.044	1.71	1.698	1.699	1.857	0.573	0.251	0.851	4.598	25.452	14.19	0.054	0.473
Th	0.172	0.259	0.593	0.067	0.134	0.259	0.288	0.374	0.383	0.183	0	0.319	31.754	0.279	0.661	0	0
Y	0.042	0.126	0.102	0.108	0.06	0.132	0.078	0	0.103	0	0.191	0	0.293	0.336	0.287	0.08	0.04
P	17.295	16.982	16.669	17.391	17.697	16.98	16.764	16.134	15.867	17.991	9.428	9.647	10.951	10.7	9.878	9.562	8.205
O	34.941	34.821	35.285	34.69	34.83	35.274	35.095	35.484	34.64	34.98	28.883	28.681	28.098	27.611	26.742	27.084	26.579
F	2.549	2.411	1.959	2.936	2.579	2.435	2.127	2.245	2.54	2.799	0	0	0.538	1.058	0.473	0	0
Cl	0.014	0.036	0.069	0.019	0	0.014	0.005	0.052	0.04	0.053	0.041	0.05	0.011	0.053	0.057	0.029	0.081
Total	**96.245**	**95.257**	**95.92**	**96.083**	**96.351**	**96.05**	**95.555**	**94.917**	**94.194**	**96.539**	**65.829**	**66.98**	**88.524**	**79.24**	**71.789**	**68.373**	**64.032**

Table 2. Electron microprobe analysis from Nolan Bore REE Prospect. Note that reported totals are low mainly because the only REE to be analysed were La and Ce. A: analysis had C peak; B: analysis had Nd peak equal to La peak; C analysis had medium Nd peak; D analysis had high Nd peak; E analysis had Nd peak about two thirds height of La peak.

However, a field inspection in the vicinity of this prospect has indicated that the garnet is probably pyrope as it occurs in pelitic and psammopelitic rocks and is pink to red. Grossular garnets typically occur in calcsilicate rocks and marble and are atypical in pelitic rocks. Hence, because the rocks are migmatitic metapelites, the Mount Finniss REE prospect may simply be an unusual concentration of monazite in a leucosome, with the garnet misidentified.

Alternatively, since a shear zone attributed to the Alice Springs Orogeny is present in this vicinity, the Mount Finniss prospect might be related to migrating REE fluids.

DISCUSSION

There is potential for carbonatite and associated alkaline igneous complexes in the Arunta Region, in addition to those already discovered. If present, these may have REE potential, but they are likely to be small bodies and/or highly deformed. Since they would probably be buried, they would be prime targets for supergene/lateritic REE enrichment, providing they are not too deep. Of the known examples, it appears that the Mordor Igneous Complex has the most promising REE potential, although the Mud Tank Carbonatite Complex also has untested possibilities.

There is also potential for some of the Proterozoic granites to host Fe oxide-Cu-Au-REE and/or Mary Kathleen U-REE mineralisation.

Most of the remaining REE occurrences within the Arunta Region appear to fall within a holistic/conceptual mineralisation model. It is suggested that large parts of the Arunta Region were subjected to a REE fluid-flushing event (events?) during the Alice Springs Orogeny. This model provides a link between REE-enriched pegmatites in the Harts Range and adjacent regions, Th (+REE)-enriched shear zones and pegmatite-hydrothermal vein systems. The region of highest prospectivity is located in the southeast Arunta Region. Most of the structures related to the Alice Springs Orogeny are considered to have low potential for REE mineralisation, but those that show elevated Th or that have associated pegmatites are of high potential.

The existence of a REE fluid-flushing event is consistent with a proposed hydrothermal alteration/vein-hosted model for the Nolans Bore REE prospect. It is also consistent with recent findings in the Harts Range and Strangways Range regions, where post-peak metamorphic monazite growth has been reported in shear zones (Drake-Brockman 1996a, b, Ballèvre *et al* 1999, Scrimgeour and Raith 2001). It should be noted that monazite growth during prograde metamorphism, other than the breakdown of other REE-bearing phases (eg chlorite), implies the movement of REE fluids. It is possible that monazite enrichment in shear zones could have resulted from REE immobility and volume reduction during deformation. However, the infiltration of REE-bearing fluids probably best explains the monazite enrichment in some Alice Springs Orogeny shear zones. Buick (1985), Murrell (1988), Drake-Brockman (1995), Drake-Brockman *et al* (1996a, b) and Mawby (2000) have all documented the migration of REE-bearing fluids associated with pegmatite emplacement in the Harts Range-Arltunga region. In all of these instances, the growth of REE phases necessitates the infiltration of REE-enriched fluids.

It therefore appears that a regional REE fluid-flushing event occurred in the Arunta during the Alice Springs Orogeny. The question arises as to whether this relates to a single prolonged episode, or to multiple events. The source of the REE is also of interest, as it may highlight prospective regions. Isotopic studies (eg Sm/Nd, Lu/Hf, Pb and O isotopes) may help delineate possible sources. It seems highly possible that the REE mineralisation might be related to mantle metasomatism, given that many of the REE prospects are linked to alkaline igneous activity. It is therefore also possible that Devonian-Carboniferous carbonatites and/or kimberlites might be present in the surrounding regions.

If this hydrothermal model holds true, then it is possible that the fluorapatite veins at Nolans Bore could be related to late-stage hydrothermal fluids from a pegmatite, or possibly an end member analogue of Alpine-type (apatite)-quartz vein systems (cf Wagner and Cook 2000). The latter occur as a late orogenic phase at high crustal levels in a collisional setting.

Because this REE-enriched fluid-flushing event is coeval with the Alice Springs Orogeny, some other interesting questions also arise:

- Is there a temporal/spatial/genetic relationship to low-moderate temperature Au-quartz veins in the Arltunga and Winnecke Goldfields? These appear to have formed during the last stages of the Alice Springs Orogeny.
- Is there a temporal/spatial/genetic relationship to Au-PGE-Cu mineralisation (high? temperature oxidised fluids) in the Harts Range? The timing of shear zones in the Harts Range region also appears to broadly coincide with the REE fluid-flushing event.
- Is U mineralisation in the Amadeus and Ngalia Basins temporally/spatially/genetically related to REE fluid flushing and if so, is there REE potential in these basins?

Proposed follow up work

Most REE occurrences in the Arunta Region are poorly understood. Thus, initial follow-up field investigations should be undertaken to accurately locate and better document these occurrences. These investigations should concentrate on developing a better understanding of the regional setting and genesis of REE occurrences, as well as documenting their petrology and geochemistry. It is envisaged that a REE study would also involve a significant amount of geochemistry and petrology (including electron microprobe analysis and XRD). In addition, some geochronology, and possibly some stable isotope and fluid inclusion studies are needed to gain a better understanding of the host rocks, the proposed regional REE fluid-flushing event and the age(s) of mineralisation.

The first stage of this project should essentially be a location and sampling program, with detailed mapping as warranted. This program would mostly involve targeted sampling for petrology and whole-rock geochemistry. The second stage should comprise follow-up work on significant REE prospects highlighted during the first stage. This should involve additional whole-rock sampling for geochemistry, geochronology, stable isotope and fluid inclusion studies. The project should concentrate on the Irindina Province and also the vicinity of the Nolans Bore and Blueys Folly REE prospects. Some strategic diamond drilling is highly desirable, particularly at Nolans Bore, but also at Holsteins and other prospects in the Entia Pegmatite group.

It seems unlikely that any of the above prospects would be feasible as stand-alone REE mines. This statement is made primarily because it would be very difficult to find a market for these small deposits, given the current oversupply and very large world reserve status (more than 100 Mt of REO, USGS 2001). Despite this, the apparently widespread, regional REE fluid-flushing event during the Alice Springs Orogeny may have been very significant and could have had the potential to produce a significant or world-class REE deposit in the Arunta Region.

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APPENDIX – Summary of all anomalous REE occurrences from Arunta Region. CN = chondrite-normalised (after Sun and McDonough 1989).

Sample	Prospect number	Prospect name	Easting (mE)	Northing (mN)	Anomalous Elements	U	Th	P	Ba	Ce	La	Nb	Y	Ta	(Ce/Y)CN	Comments
5301		Alma	525600	7426000	Th>U, Nb>Ta, LREE, Y, Zr, Ti	80	290	100	80	1680	960	630	1500	50	2.9	chl-epid-fspar-calcite in fault
5302		Alma	525600	7425986	Th>U, Nb>Ta, LREE, Y, Zr, Ti	110	600	75	90	3200	1950	250	1100	35	7.5	epid-fspar rock in fault
1405		Asp	520000	7434225	U>Th, Zr, Y	790	45	380	130	60	40	13	1080	20	0.14	2600 ppm Zr, low LREE, high HREE?
5899		Atnarta Dam	523350	7428650	Th>U, LREE, P, Zr	210	5400	14000	250	20000	10000	100	1800	0	29	allanite in pegmatite, apatite?, 4100 ppm Zr
5900		Black Mountain	520156	7432253	Th>U, LREE	150	6300	3200	370	17000	8400	2	730	0	60	allanite in sheared pegmatite
6850		Black Mountain	520146	7432243	Th>U, LREE, P	1300	18000	54000	340	42000	21000	0	4300	0	25	allanite, 2nd U, amphibolite/pegmatite contact
5223		Blizzard	516759	7432703	Th>U, P, LREE, Zr	6100	12200	11400	140	21500	12600		9800	420	5.6	felsic rock
5318		Brumby	489570	7425400	U>Th, LREE, Y	29500	28000	2		31500	21000	100	4950		16	allanite in felsic gneiss
5556		Brumby	491275	7421472	U>Th, LREE, Y, Zr, P	9000	2600	4900	390	28000	15000	40	8300	0	8.7	minerals in porphyroblastic QF mylonite, 27000 ppm Zr
5561		Brumby	491307	7421879	Th>U, LREE, Zr	1700	2100	3800	200	23000	13000	20	600	0	98	allanite near qtz vein along a fault, 9000 ppm Zr
5562		Brumby	491036	7422415	Th>U, LREE, Zr	260	2000	1900	400	3400	1900	20	140	0	62	biot gneiss contact with qtz mylonite; 3500 ppm Zr
5565		Brumby	490344	7421505	Th>U, LREE, P	290	2800	51000	88	29000	16000	0	900	0	83	allanite block at gabbro/QF mylonite contact
5566		Brumby	491270	7421470	U>Th, LREE, Y, Zr, P	22000	2500	7200	280	18000	9400	0	6000	0	7.7	allanite +2nd U in QF mylonite; 21000 ppm Zr
5567		Brumby	491247	7421454	U>Th, LREE, Y, Zr, P	11000	1500	7800	220	17000	8800	90	5300	20	8.2	allanite +2nd U in QF mylonite; 26000 ppm Zr
5568		Brumby	491203	7421537	Th>U, LREE, P	190	1600	4200	790	10000	6100	0	300	0	86	allanite block on slope
5569		Brumby	490838	7422454	U>Th, LREE, Y, Zr, P	3300	1900	12000	520	28000	17000	0	1000	0	72	allanite, uraninite? 2nd U in QF mylonite; 11000 ppm Zr
5570		Brumby	490836	7422445	U>Th, LREE, Y, Zr	3800	2700	280	310	31000	19000	0	930	0	86	allanite, uraninite? 2nd U in QF mylonite; 11000 ppm Zr
5572		Brumby	489431	7426058	Th>U, LREE, P	130	3000	3300	210	43000	26000	0	770	0	140	allanite-apatite-qtz-epid in QF mylonite
5574		Brumby	491167	7421285	U>Th, LREE, Y, Zr, P	7100	1900	8700	100	14000	8000	20	870	0	41	allanite-thorite?-2nd U in sheared amphibolite; 18000 ppm Zr
5575		Brumby	491192	7422519	Th>U, LREE, Y, Zr, P	850	2600	4200	560	7700	3900	0	1500	0	13	allanite+metamict minerals in pegmatite; 8100 ppm Zr
5577		Brumby	491560	7421913	Th>U, LREE, Y, Zr, P	280	2500	4000	320	13000	7200	0	990	0	34	allanite+metamict minerals in pegmatite; 6300 ppm Zr
5578		Brumby	491863	7422109	Th>U, LREE, Y, Zr, P	2500	7800	18000	280	24000	14000	10	3800	0	16	allanite, uraninite? 2nd U near amph-QF mylonite contact; 7400 ppm Zr
5580		Brumby	491174	7421281	Th>U, LREE, Y, Zr, P	7100	9500	14000	240	19000	11000	10	1000	0	49	allanite- 2nd U blocks near amph-QF mylonite contact; 30000 ppm Zr
5584		Brumby	491095	7421105	Th>U. LREE, P	1400	9900	4700	630	9400	5400	0	390	0	62	allanite- 2nd U blocks near amph inlier; 3700 ppm Zr
5589		Brumby	490693	7421135	Th>U, LREE, P	93	3400	4500	1100	5900	3300	0	620	0	24	pegmatite with allanite; 20 ppm Zr
5596		Brumby	492201	7424920	Th>U, LREE, Y	690	960	470	220	1400	540	210	1100	10	3.7	QF mylonite
5597		Brumby	491086	7421293	Th>U, LREE, P?	500	2400	2400	430	3400	1800	10	230	0	38	qtz mylonite with allanite
5655		Brumby	491192	7421492	U>Th, LREE, P, Zr	2100	2000	4500	370	11000	6300	0	750	0	38	mm-cm veins cutting qtz mylonite; allanite?; 2900 ppm Zr
3374		Desperado	537900	7440500	Th>U, P, LREE, Ca	1030	6600	93100	42	12100	5830	9				pegmatite; musc-qtz-fspar (16.9% Ca, REE-apatite?)
3376		Desperado	537900	7440550	Th>U, P, LREE, Ca	260	4790	34400	27	31900	22000	31				pegmatite from dump, 6.3% Ca, REE-apatite?

Sample	Prospect number	Prospect name	Easting (mE)	Northing (mN)	Anomalous Elements	U	Th	P	Ba	Ce	La	Nb	Y	Ta	(Ce/Y)CN	Comments
5963		Eastern Chief	505885	7454161	Th>U, LREE	150	2500	150	460	18000	12000	0	410	0	110	allanite- kspar block near fault in amphibolite
5600		Florence Creek	483375	7427075	Th>>U, LREE, P	32	2900	5600	1300	8400	4000	0	560	0	38	sheared alkaline granite with biotite + allanite
1406		Holsteins	533300	7453800	Th>U, P, Ba, LREE	80	340	6600	241000	7100	4400	0	300	0	61	barite rock
1453		Holsteins	533100	7453500	Th>>U, Fe, P, Ba, LREE	155	4600	5400	18000	11000	6100	0	100	0	280	gossanous vein
1455		Holsteins	533100	7453500	Th>>U, Fe, P, Ba, LREE	140	6600	12200	208000	6700	4300	5	290	0	59	gossanous vein
1456		Holsteins	533100	7453500	Th>>U, Fe, P, Ba, LREE	330	33000	50000	59000	111000	67000	3	290	0	980	gossanous vein in old pit
2167		Holsteins	533655	7454277	Th>>U, P, Ba, LREE	280	13600	15100	15800	36500	22500	0	220	15	430	Fe-chalcedony-barite-ilmenite rock
2168		Holsteins	533730	7454190	Th>>U, P, Ba, LREE	540	39000	30000	10000	124000	72500	0	520	10	610	hm-ilmenite-xenotime? rock
2169		Holsteins	533630	7453940	Th>>U, Fe, P, Ba, LREE	190	3200	10600	22000	7800	4850	0	230	10	87	brecciated jasper-chalcedony-barite rock
2170		Holsteins	533665	7453615	Th>>U, Fe, P, Ba, LREE	420	29000	11000	3300	11900	6300	0	600	10	51	gossanous rock, barite?
2171		Holsteins	533473	7453956	Th>>U, Fe, P, Ba, LREE	130	4550	3200	14800	3000	1740	0	195	0	39	Fe-ilmenite-hm-kaolin-barite rock
2172		Holsteins	533380	7453934	Th>>U, P, Ba, LREE	135	1760	7500	4700	4950	3450	12	200	0	63	qtz-fspar-epidote rock
6817		Huckitta	532365	7438720	Th>U, Nb>Ta, LREE, P, Zr	150	720	3900	330	1800	640	280	520	40	8.9	altered zone marginal to pegmatite, in E/W fault
2148	14NL01	Jersey	531075	7455000	Th>U, LREE, Y	440	1480	530	350	26000	16800	15	4100	10	16	black rock, float, cerianite?
2149	14NL01	Jersey	531075	7455000	Th=U, LREE	430	370	630	300	46500	29500	0	740	0	160	black rock, partly bladed, vein
2373	14NL01	Jersey	531075	7455000	Th>U, LREE	260	460	850	110	50500	32500	0	630	0	210	
2066		Kong Bore	459400	7450500	Th>U, LREE, P	17.5	4730	6840	854	16400	8110	8				bio-qtz-fspar sweat, monazite?
3385	RECONN	Leprechaun	503200	7423100	Th>U, LREE, P	7880	48100	124000	23	213000	137000	3				monazite xtl
5973		Log Cabin Dam	505640	7437700	U>Th, LREE, P	1800	180	3500	410	18000	14000	0	890	10	52	allanite+samarskite?+2nd U in pegmatite
3205		Moondyke	515600	7427950	Th>U, LREE	680	1100	130	143	2970	1070	10				qtz-plag-allanite-diopside-epidote rock
5313		Ono	453088	7453707	U>Th, Y	633000	5200	1		1000	1000	450	4550		0.56	uraninite from pegmatite
5657		Ono	453610	7449640	Th>>U, LREE, P	18	1500	4800	1100	8800	4200	0	74	0	310	qtz-gt-monazite? sweat in metapelite
5658		Ono	453910	7449925	Th>>U, LREE, P	20	1200	2600	32	4900	2700	0	160	0	79	qtz-gt-monazite? sweat in metapelite
2141	13VB02	Walter Smiths	516075	7451750	U>Th, Y	870	50	200	70	160	100	105	950	0	0.43	qtz-fspar-epidote rock
1214		Yambla	512943	7427728	Th>>U, LREE	25	1080	290	190	4750	3350	5	40	0	310	amphibolite
1226		Yambla	512502	7426401	Th>>U, P, LREE?	105	5400	19300	110	330	85	7	120	0	7.1	white alteration
1298		Yambla	512561	7426519	U>Th,Ti,Nb>Ta,Y,W	365000	39500	1700				1500	1500	200		brannerite?, 190000 ppm Ti, no La, Ce data
1300		Yambla	512518	7426782	U>Th,Ti,Nb>Ta,Y,W	253000	53000	1400				1800	2100	200		brannerite?, 186000 ppm Ti, no La, Ce data
1338		Yambla	512568	7426715	Th>U, LREE	210	3250	490	330	29000	23000	7	165	0	450	dark glassy mineral (allanite?)
1346		Yambla	512944	7427242	U>Th, Nb>Ta, Y	661000	70500	2900				3500	2400	200		uraninite, low Ti
1348		Yambla	512828	7427218	U>Th, Nb>Ta, Y	650000	61000	2100				2200	2200	200		uraninite seam in soil, low Ti
1350		Yambla	512530	7426295	U>Th, Nb>Ta, Y	694000	69000	2200				2100	1800	200		uraninite, low Ti
3215		Yambla	512445	7426623	Th>U, LREE	320	3320	170	383	34700	19700	10				amphibolite
3247		Yambla	512441	7425974	Th>>U, LREE	340	9960	20	451	54500	32500	200				black glassy mineral, allanite?
3455		Yambla	512595	7426745	Th>U, LREE	73	650	260	204	4370	2970	2				felsic layer
3462		Yambla	512769	7427122	Th>U, LREE, Ti	300	5510	10	190	45200	30700	11				pegmatite, allanite-rich; 29000 ppm Ti
3470		Zephyr1	515250	7433500	U>Th, LREE	5580	2260	40	70	2790	1260	45				Ce-poor allanite in pegmatite
1460	16GC51	unnamed	531500	7437150	U>Th, Nb>Ta, Y	1320	75	45	20	7	5	5400	3600	520	0.0050	Nb occurrence, high HREE?
1480	11GC34	unnamed	457470	7444800	Th>U, LREE, P, Zr	85	2200	2250	1820	4950	2650	40	55	0	230	3850 ppm Zr
2088	06HS19	unnamed	528000	7431800	U>Th, Zr,Y, LREE	1980	400	510	420	4050	1920	20	1100	10	9.4	7900 ppm Zr, epidote float
2098	16GC80	unnamed	535650	7441450	U>Th, LREE	1280	85	3650	630	31500	29500	105	660	0	120	black radioactive mineral

Sample	Prospect number	Prospect name	Easting (mE)	Northing (mN)	Anomalous Elements	U	Th	P	Ba	Ce	La	Nb	Y	Ta	(Ce/Y)CN	Comments
2197	06AD05	unnamed	523910	7427380	Th>U, Nb>Ta, LREE	710	5800	25	370	16900	10400	450	1620	55	27	brannerite?, 52000 ppm Ti, rock adjacent to qtz blow
2199	09BW05	unnamed	541140	7405180	Th>U, P, LREE	200	13200	20500	1040	38000	20000	0	530	0	180	pegmatite, 1820 ppm Zr
2397	15GC10	unnamed	522200	7433000	Th>U, P, LREE	65	1760	10300	20	3050	1800	30	820	0	9.5	hotspot on epidote rock
2402	RECONN	unnamed	515700	7435800	Th>U, LREE	82	1060	1130	36	3090	1460	290				mafic rock in fault, some epid
2413	RECONN	unnamed	515280	7436500	Th>U, LREE	5	420	410	250	2040	940	1				qtz-epid rock, allanite?
3218	Heli chk	unnamed	514050	7437250	Th>U, LREE	120	1130	5730	271	7870	3560	780				Bruna Gneiss-amphibolite xenolith contact
3268	RECONN	unnamed	479610	7438490	Th>U, LREE	880	6220	1030	597	4840	2230	8				felsic bio gneiss
3369	6BM1	unnamed	520050	7432340	Th>>U, LREE	640	25600	530	75	81600	38300	6				allanite in pegmatite
3392	6BM1	unnamed	520050	7432340	Th>U, LREE	110	730	1140	258	2730	1240	690				soil, allanite, qtz blow
3472	RECONN	unnamed	508850	7454480	Th>U, LREE	86.5	2300	2800	920	6890	3600	7				felsic gneiss
5593	RECONN	unnamed	490054	7422685	Th>U, LREE, P	410	3400	2900	260	5700	3100	0	210	0	70	qtz-fspar mylonite dyke with allanite
5808	22SN77	unnamed	501500	7449950	Th>U, LREE	68	3100	480	670	8500	5000	0	260	0		allanite in 020 pegmatite
		Kelly	532000	7451000	U>Th, REE											
ILL01K JH003		unnamed	531302	7455282	U>Th, REE?											allanite?
ILL01K JH004		unnamed	531275	7455353	U>Th, REE?											allanite?
		Mount Mary	531400	7451200	LREE?											allanite?
		Nolans Bore East	319270	7501630	Th>>U, LREE, P											fluorapatite, cerianite, monazite
		Nolans Bore West	318470	7501830	Th>>U, LREE, P											fluorapatite, cerianite
		Mount Finniss	298900	7529950	Th>U?, LREE											monazite rock
NAP01 KJH001		Quartz Hill 1	204728	7545472	Th>U?, LREE?											mica-apatite rock
NAP01 KJH002		Quartz Hill 2	204510	7544681	Th>U?, LREE?											mica-apatite rock
S10		Blueys Folley	484800	7402850	Th>>U?, LREE, Ba, Zr		1100	2180	5760	7199	4002		128		140	allanite-pegmatite; apatite with REE filled veins; 2640 ppm Zr
S18		Blueys Folley	485100	7402700	Th>>U?, LREE, P, Ba, Zr		4000	5280	1780	25782	14568		498		130	allanite-epidote-fspar-amph-apatite rock with REE veins; 4692 ppm Zr
S27		Blueys Folley	485000	7402200	Th>>U?, LREE, P, Zr		1740	4540	370	8796	4936		170		130	pegmatite; qtz-fspars-mica-allanite-epidote-zircon-ThO2; 2089 ppm Zr
S36		Blueys Folley	485200	7402550	Th>>U?, LREE, Ba, Zr		855	1048	1530	5406	3093		103		130	pegmatite; allanite; 1348 ppm Zr
S37		Blueys Folley	485100	7402550	Th>>U?, LREE, Zr		831	305		4841	2623		77		160	pegmatite; allanite; 2433 ppm Zr
S46		Blueys Folley	485500	7403900	Th>>U, LREE, Zr	65	1220	349		8147	4993		131		160	pegmatite; allanite; 4556 ppm Zr
S49		Blueys Folley	485800	7403950	Th>>U?, LREE, Zr		1390	305		9231	5231		192		120	pegmatite; allanite; 6612 ppm Zr
S57		Blueys Folley	485800	7404200	Th>>U?, LREE, P, Zr		3960	13880	910	24973	14033		668		96	pegmatite; allanite; 9737 ppm Zr
S60		Blueys Folley	484900	7404700	Th>>U?, LREE, Ba, Zr		4040	1964	2000	29391	17100		350		220	pegmatite; allanite; 3841 ppm Zr
S63		Blueys Folley	485100	7404700	Th>>U?, LREE, Ba, Zr		2080	698	1910	15781	8345		157		260	pegmatite; allanite; 1019 ppm Zr
S64		Blueys Folley	485200	7404700	Th>>U?, LREE, P, Zr		5900	10520		43387	28600		858		130	pegmatite; allanite-epidote-amph-zircon-apatite; 30324 ppm Zr
S66		Blueys Folley	485250	7404700	Th>>U?, LREE, Zr		1190	1746	840	9164	4945		117		200	pegmatite; allanite; 2325 ppm Zr
S67		Blueys Folley	485300	7404700	Th>>U?, LREE, Ba, Zr		837	698	3350	6367	3575		85		190	pegmatite; allanite; 406 ppm Zr
S68		Blueys Folley	485350	7404700	Th>>U?, LREE, P, Zr		5940	10520		45411	29067		838		140	pegmatite; allanite; 7102 ppm Zr
S71		Blueys Folley	485750	7405550	Th>>U?, LREE		637	480	1050	4140	2309		39		270	pegmatite; allanite; 176 ppm Zr

Sample	Prospect number	Prospect name	Easting (mE)	Northing (mN)	Anomalous Elements	U	Th	P	Ba	Ce	La	Nb	Y	Ta	(Ce/Y)CN	Comments
S73		Blueys Folley	485800	7405600	Th>>U?, LREE, Zr		660	3667		43936	26067		520		220	pegmatite; allanite; 3162 ppm Zr
ASP01K		Blueys Folley	484865	7402861	Th>>U, LREE											pegmatite; allanite
JH005																
2906		Asp	519975	7434225	U>Th, Ta>Nb, Y, HREE?, W	26000	1700	2700				190000	147000	213000		pegmatite, 3300 ppm W
5228		Asp	519750	7434000	U>Th, Nb>Ta, Y, HREE?, Zr	85000	9500	480		760	590	191000	83500	103000	0.023	pegmatite
5229		Asp	519700	7434050	U>Th, Nb>Ta, Y, HREE?, Zr	68500	9400	450		1220	175	190000	75500	109000	0.041	pegmatite
5316		Bantam	489600	7425780	U>Th, Y, HREE?, W	464000	89000	1		1500	1000	600	31000		0.12	uraninite, 4100 ppm W
5317		Brumby	491091	7422659	U>Th, Y, W	536000	69000	1		1000	1000	750	35000		0.073	uraninite; 4200 ppm W
3126		Casper	518175	7419130	U>Th, Nb>Ta, Y	26000	3000	1200				49500	8100	4500		xenotime?/uraninite?, 13400 ppm W
5227		Corner	507850	7451400	U>Th, Nb>Ta, Y, HREE?	78000	10500	1300		610	1180	143000	49000	105000	0.032	pegmatite, frags in scree from workings
5237		Cusp	507800	7447550	U>Th, Nb>Ta, Y, HREE?, Zr	97000	13700	175		1240	50	224000	69500	59000	0.046	fergusonite-tantalite? Pegmatite, 4500 ppm Zr
5320		Cusp	506515	7445740	U>Th, Ta>Nb, Y, HREE?	51000	9900	1		2500	1700	112000	63000	144000	0.10	Pegmatite with rhomb shaped xtls; 6200 ppm W
3206		Felspar	522950	7431200	U>Th, Nb, Y?	68000	4780	80	31	510	43	250000				Y-samarskite? In pegmatite
3125		Felspar	523125	7431441	U>Th, Nb>Ta, Y, HREE?, W	75500	5800	400				243000	76000	141000		fergusonite?, float, 6700 ppm W
5169		Felspar	523134	7431436	U>Th, Nb>Ta, Y	780	30	360	55	19	10	3550	1450	820	0.034	pegmatite
5170		Felspar	523134	7431436	U>Th, Nb>Ta, Y	1020	40	380	80	16	13	4050	1540	980	0.027	pegmatite
2917		Garnet	513919	7429708	U>Th, Nb>Ta, Y, Zr, Mn	920	95	2450	110	370	250	2600	4100	650	0.23	pegmatite with gt-bio alteration, 22500 ppm Mn, 12340 ppm Zr
3127		Garnet	513910	7429705	U>Th, Nb>Ta, Y	2700	200	1900				6600	8000	1000		ser-epid-gt rock
3370		Lone Pine	531290	7437350	U>>Th, Nb, Ti	118000	6780	80	51	880	230	285000				Y-fergusonite from pegmatite
5184		Malex	507470	7438565	Th>U, Nb>Ta, Y, Ti	113000	180000	1050	460	240	40	627000	113000	66500	0.0054	2nd U, euxenite, betafite in pegmatite, 74700 ppm Ti, problems with GX Total is wrong
5545		Micks	525504	7451888	U>Th, Nb>Ta, Y, HREE?	200000	8700	160	820	920	200	25000	42000	20000	0.056	pyrochlore in E/W pegmatite
1485		Quartz	533590	7435275	U>Th, Nb>Ta, Y, HREE?	8700	1720	210	180	135	30	38000	29000	2800	0.012	pegmatite, 4900 ppm Zr, high HREE?
1486		Quartz	533590	7435275	U>Th, Nb>Ta, Y, HREE?	7500	1340	145	110	115	25	30000	25000	2350	0.012	pegmatite, 1620 ppm Zr, high HREE?
1487		Quartz	533590	7435275	U>Th, Nb>Ta, Y, HREE?	4100	730	110	120	65	18	18300	14100	1340	0.012	pegmatite, 2650 ppm Zr, high HREE?
1490		Quartz	533590	7435275	U>Th, Nb>Ta, Y, HREE?	9300	1700	200	130	135	25	40000	29000	3600	0.012	pegmatite, 1720 ppm Zr, high HREE?
1491		Quartz	533590	7435275	U>Th, Nb>Ta, Y, HREE?	5900	1020	115	110	80	19	27000	19100	1880	0.011	pegmatite, 220 ppm Zr, high HREE?
5968		Quartz	533300	7435300	U>Th, Nb>Ta, Y, HREE?	550	220	440	6	10	5	3200	2600	250	0.0099	qtz veins + samarskite in pegmatite
1425		Sitting Bull	510865	7434310	U>Th,Nb>Ta,Y, HREE?, Zr	26500	4950	290	1180	940	280	88500	50500	1920	0.048	2450 ppm Zr, High HREE?
1426		Sitting Bull	510800	7434350	U>Th, Nb>Ta, Y	3150	450	75	190	60	14	6200	4550	4250	0.034	brecciated pegmatite
2124	15AT04	unnamed	511375	7440375	U>Th, Nb>Ta, Y, HREE?	39500	4400	1360	130	2650	390	152000	93500	7100	0.073	samarskite? in pegmatite

Sample	Prospect number	Prospect name	Easting (mE)	Northing (mN)	Anomalous Elements	U	Th	P	Ba	Ce	La	Nb	Y	Ta	(Ce/Y)CN	Comments
2128	15AT01	unnamed	513025	7439200	U>Th, Nb>Ta, Y, HREE?	18700	9500	105	520	330	340	91500	40000	48500	0.021	pegmatite in Bruna Gneiss
2441	15NG01/02	unnamed	515050	7431000	U>Th, Ta>Nb, Zr,Y	510	80	1760	60	25	13	930	6000	1700	0.011	pegmatite
5549	22ML09	unnamed	529104	7449417	U>Th, Nb>Ta, Ti, Y, HREE?	64000	4400	1400	320	1200	200	160000	100000	43000	0.031	Xtls in pegmatite
5805	22IN93	unnamed	525325	7452250	U>>Th, Nb>Ta, Ti, Y, HREE?	130000	8500	1900	600	650	180	180000	89000	38000	0.019	pyrochlore? frags in 310 pegmatite dyke
5813	22ML57	unnamed	531300	7449175	U>Th, Nb>Ta, Ti, Y, HREE?	100000	13000	110	10000	550	120	110000	48000	53000	0.029	Xtls in pegmatite
		Butcher Bird	486900	7448600	REE?											samarskite
		Ciccones North	541200	7472200	Th>U?, REE?											monazite
		Last Hope	536900	7433800	U>Th?, Nb>Ta?, LREE?											monazite
		Marenga	551000	7474000	REE?											monazite
		Painted Canyon	486000	7450500	REE?											samarskite
		Lone Pine	531300	7437350	U>Th?, Nb>Ta?, REE?											samarskite
		Black Diamond	547600	7405900	REE?											apatite pegmatite
		unnamed	573600	7483200	REE?											apatite
5321		Janets	?	?	U>Th, Nb>Ta, Ti, Y, W	120000	650	1		1000	1000	76000	1720	20400	1.5	rhomb xtls, 2nd U in pegmatite; 4600 ppm W
5322		Janets	?	?	U>Th, Nb>Ta, Ti, Y, W	46500	100	1		1000	2600	68500	3350	38900	0.77	massive xtls in pegmatite