AUSTRALIA’S URANIUM AND THORIUM RESOURCES AND THEIR GLOBAL SIGNIFICANCE

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1. Introduction

This paper summarises Australia’s uranium resources and production in a global context. It observes that there is a strong spatial relationship between uranium mineralisation and uranium enriched igneous rocks, outlines the potential for further uranium discoveries in Australia, summarises future uranium supply and demand scenarios and comments on thorium resources. Finally, it mentions a Federal government led initiative to identify and address impediments to uranium exploration and mining in Australia.

2. Australia’s uranium resources

Approximately 85 significant uranium deposits of various styles have been discovered across Australia [1], including about 20 mined out and partly mined deposits.

The classification scheme used for international reporting of uranium resources\(^1\) comprises two categories that reflect the level of confidence in the quantities reported:
- Reasonable Assured Resources (RAR), and
- Inferred Resources.

These resources are further subdivided into categories based on the cost of production:
- Less than US$40/kg U (less than US$15/lb U\(_3\)O\(_8\));
- Less than US$80/kg U (US$30/lb U\(_3\)O\(_8\)); this includes resources in the <US$40/kg U category; and
- Less than US$130/kg U (US$50/lb U\(_3\)O\(_8\)); this includes resources in both the above categories.

Geoscience Australia’s most recent estimates of Australia’s uranium resources are for December 2005 [2, 3]. RAR recoverable at less than US$40/kg U were estimated at 716,000 t U (843,760 t U\(_3\)O\(_8\)), which represents 36% of world resources in this cost category – by far the largest proportion of any country (Table 1).

The increasing uranium spot price which has been sustained since early 2003 – US$45/lb U\(_3\)O\(_8\) in July 2006 – has raised interest in RAR recoverable at up to US$80/kg U. Australia has the largest share, with approximately 27% of the world total resources in this category (Table 1).

Other countries with major uranium resources are listed in Table 1. In terms of RAR recoverable at <US$80/kg Kazakhstan has approximately 14% of the world total, ahead of Canada (13%), South Africa (7%), Niger (7%), Brazil (6%), Namibia (6%) and the Russian Federation (5%).

Approximately 94% of Australia’s RAR recoverable at <US$80/kg U are within the following seven deposits (Fig. 1):
- Olympic Dam and Beverley (SA),
- Ranger in the Alligator Rivers region (NT),
- Jabiluka, Koongarra (NT) – mining of these requires approval from traditional owners;
- Kintyre and Yeelirrie (WA) – mining of these requires a change in State government policy.

Olympic Dam is the largest known uranium deposit, containing approximately 26% of the world’s total RAR recoverable at <US$40/kg U, and about 21% of global RAR recoverable at <US$80/kg U. Olympic Dam also has major Inferred Resources recoverable at <US$80/kg U, which are growing progressively as exploration drilling continues in the south-eastern part of the deposit; the limits of the mineralisation have not yet been established to the south-east or at depth. While Olympic Dam contains low grades of uranium – averaging 300-400 ppm U – co-production with copper and gold underpins the viability of uranium recovery. Even with the proposed trebling of production, Olympic Dam resources would take over 70 years to mine.

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\(^1\) Uranium resources are reported internationally according to the resource classification scheme of the Uranium Group, a joint initiative of the International Atomic Energy Agency and the OECD/Nuclear Energy Agency. Geoscience Australia represents Australia on the Uranium Group and compiles the national uranium inventory, based on ore reserves and mineral resources for individual deposits as published by mining companies in their annual reports and reports to the Australian Stock Exchange. In general, the national inventory takes a longer term view of what is likely to be economic than does commercial reporting of reserves and resources.
Figure 1. Australia’s main uranium deposits and prospects

Table 1: Reasonably assured resources (t U), 2005

<table>
<thead>
<tr>
<th>Country</th>
<th>&lt;US$40/kg U</th>
<th>&lt;US$80/kg U</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>716,000</td>
<td>732,000</td>
</tr>
<tr>
<td>Brazil</td>
<td>139,900</td>
<td>157,700</td>
</tr>
<tr>
<td>Canada</td>
<td>287,200</td>
<td>345,200</td>
</tr>
<tr>
<td>China</td>
<td>25,795</td>
<td>38,019</td>
</tr>
<tr>
<td>Kazakhstan</td>
<td>278,840</td>
<td>378,290</td>
</tr>
<tr>
<td>Mongolia</td>
<td>7,950</td>
<td>46,200</td>
</tr>
<tr>
<td>Namibia</td>
<td>62,186</td>
<td>151,321</td>
</tr>
<tr>
<td>Niger</td>
<td>172,866</td>
<td>180,466</td>
</tr>
<tr>
<td>Russian Federation</td>
<td>57,530</td>
<td>131,750</td>
</tr>
<tr>
<td>South Africa</td>
<td>88,548</td>
<td>177,147</td>
</tr>
<tr>
<td>Ukraine</td>
<td>28,005</td>
<td>58,498</td>
</tr>
<tr>
<td>United States</td>
<td>Not Reported</td>
<td>102,000</td>
</tr>
<tr>
<td>Uzbekistan</td>
<td>59,743</td>
<td>59,743</td>
</tr>
<tr>
<td>Others</td>
<td>37,820</td>
<td>103,009</td>
</tr>
<tr>
<td><strong>Total adjusted for losses</strong></td>
<td><strong>1,962,383</strong></td>
<td><strong>2,661,343</strong></td>
</tr>
</tbody>
</table>

Sources: Data for Australia compiled by Geoscience Australia; estimates for other countries from OECD–NEA & IAEA (2005).
3. **Australian and global production**

In recent years, the great bulk of uranium mine production has occurred in seven countries: Canada, Australia, Kazakhstan, the Russian Federation, Namibia, Niger and Uzbekistan (Table 2). Estimated world mine production for 2005 was 49,363 t $\text{U}_3\text{O}_8$, an increase of 3% above the previous year [3,4].

Canada was the only country to produce more uranium, with 28% of global production in 2005, down from a high of 34% in 2001. Mine production from Kazakhstan has increased consistently since 1997, and its share of world production has almost doubled from 5% in 2000 (ranked sixth) to 10% in 2005 (third).

<table>
<thead>
<tr>
<th>Country</th>
<th>2005 Mine Production</th>
<th>Share of world total (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canada</td>
<td>13,712</td>
<td>28</td>
</tr>
<tr>
<td>Australia</td>
<td>11,217</td>
<td>23</td>
</tr>
<tr>
<td>Kazakhstan</td>
<td>5,138</td>
<td>10</td>
</tr>
<tr>
<td>Russian Federation</td>
<td>4,046</td>
<td>8</td>
</tr>
<tr>
<td>Namibia</td>
<td>3,711</td>
<td>7</td>
</tr>
<tr>
<td>Niger</td>
<td>3,647</td>
<td>7</td>
</tr>
<tr>
<td>Uzbekistan</td>
<td>2,712</td>
<td>5</td>
</tr>
<tr>
<td>USA</td>
<td>1,225</td>
<td>2</td>
</tr>
<tr>
<td>Ukraine</td>
<td>943</td>
<td>2</td>
</tr>
<tr>
<td>China</td>
<td>884</td>
<td>2</td>
</tr>
<tr>
<td>Others</td>
<td>2,128</td>
<td>6</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>49,363</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>


Australia’s uranium is exported for nuclear power generation in a range of countries, under stringent safeguards arrangements. Tonnages of Australian exports have increased steadily to a record level in 2005 of 12,360 t $\text{U}_3\text{O}_8$, valued at A$573 million (Department of Industry, Tourism and Resources).

4. **Australia’s uranium deposits and felsic igneous rocks**

At regional to local scales, Australia’s uranium deposits and prospects are spatially related to uranium-enriched bedrocks, particularly granitic intrusives and felsic volcanics [5,6]. This is evident from analysis of the national geochemical database OZCHEM (http://www.ga.gov.au/gda/index.jsp). The uranium-enriched felsic igneous rocks (taken here as 10 ppm or more uranium) are mainly highly fractionated and/or have alkaline affinities, and were emplaced during major magmatic events in the late Archaean, the Palaeo-Mesoproterozoic and the Silurian to Permian. Of these intervals, the Proterozoic produced the greatest volumes of “hot” igneous rocks. These are widespread in South Australia, Northern Territory and parts of Western Australia and Queensland, in regions of high geothermal gradients [7,8].

Some of Australia’s uranium deposits appear to have formed during these widespread igneous-thermal events, including the Mesoproterozoic hematite breccia complex mineralisation at Olympic Dam, intrusive style deposits (e.g. Crocker Well in Mesoproterozoic granitoids in South Australia) and volcanic style deposits (e.g. Ben Lomond in Carboniferous rhyolitic tuffs in north-eastern Queensland).

More generally, the uranium mineralisation is considerably younger than the igneous rocks with which they are spatially related. This is the case for calcrete, sandstone and unconformity-related deposits, which appear to have formed as a result of uranium mobilisation from older uranium-enriched source rocks under low temperature oxidising conditions, and precipitation by redox reactions. The grades of mineralisation are likely to reflect the availability of uranium and the efficiency of oxidation-reduction systems.

5. **Uranium potential and significant undeveloped projects in Australia**

Uranium exploration expenditure in Australia increased rapidly to $41 million in 2005. However, this is less than half of the levels of expenditure (in constant $) of the peak years, between the late 1960s and the early
1980s, when most of the significant deposits (except Kintyre) were discovered. From the early 1980s to 2004, when uranium prices were depressed, there was relatively little exploration in Australia and globally.

Given the paucity of systematic modern exploration, there is significant potential for additional uranium deposits in Australia (Fig. 2):

- Unconformity-related deposits – immediately above and below the unconformity – particularly in Arnhem Land in the Northern Territory but also in the Granites-Tanami-Tennant Creek region (Northern Territory-Western Australia), the Paterson Province and Ashburton Basin (Western Australia) and the Gawler Craton (South Australia);
- Hematite breccia complex deposits, particularly in the Gawler and Curnamona cratons of South Australia and the Georgetown and Mount Isa Inliers of Queensland.
- Sandstone type deposits, including in the Frome Embayment (Eyre Basin adjacent to Mt Painter and Willyama/Olary Inliers) and Tertiary palaeochannels overlying the Gawler Craton (South Australia) McArthur Basin (Northern Territory), the Carnarvon, Northern Canning and Gunbarrel Basins (Western Australia), the Money Shoal Basin adjacent to Pine Creek Inlier, the Carpentaria and Karumba Basins adjacent to Mt Isa and Georgetown Inliers, the Eromanga Basin (where concern about impacts on water are likely to limit exploration), the Georgina, Ngalia and Amadeus Basins (Northern Territory), the Murray Darling Basins (Victoria and New South Wales), and the Launceston Basin (Tasmania).
- Calcrete type deposits, particularly in the Yilgarn Craton and Gascoyne block of Western Australia, the Arunta Region (Northern Territory) and the Gawler Craton. Ongoing regolith studies could well identify other regions with calcrete uranium potential.

![Map showing regions with high to medium uranium potential, which were subject to exploration in 2005](image)

Figure 2: Map showing regions with high to medium uranium potential, which were subject to exploration in 2005

In the past, several uranium deposits were subjected to either a comprehensive feasibility study or an Environmental Impact Statement (or both) but have not progressed to mining for various reasons, including
the ramifications of government policies, and low uranium prices and demand at the time. Jabiluka and Yeelirrie have been mentioned above. At Honeymoon, mine development with a production capacity of 400 t U\textsubscript{3}O\textsubscript{8}/year is expected to commence in 2007. Other deposits, which are likely to be reconsidered for mining if there are changes to State policies in the future include Lake Way and Manyinge (WA), and Ben Lomond and Valhalla (Qld).

6. Future global uranium production and demand

Some concern has been expressed in several quarters as to whether there will be sufficient uranium resources to meet demand for nuclear power generation in the longer term. This is comparable to the concerns about resource longevity arising from the Club of Rome in the 1970s [9], which have not come to pass in general because ongoing exploration has resulted in discoveries of new resources to replace depletions through production, and some previously uneconomic mineralisation has become economic through technological advances and metal price increases. The following discussion draws on information provided by governments to the Uranium Group and published by the OECD/NEA and IAEA [3].

Even the most conservative of international scenarios – based on existing and committed plants, refits and closures – imply that nuclear power will be sustained at least at current levels over the next few decades. This requires progressive increases in mine production of uranium, to roughly 40% above current levels by 2020, when it is forecast that secondary supplies (including inventories, highly enriched uranium and reprocessing and re-enrichment of tails) will be much depleted. Secondary supplies have accounted, on average, for 35-50% of annual uranium demand over the past decade.

The more likely scenario of increasing nuclear power generation, as various countries implement evolving strategies to decrease greenhouse emissions, will proportionally increase the demand for uranium. The upper scenario of the World Nuclear Association has uranium demand doubling by 2025 (http://www.world-nuclear.org/).

Significantly increased production has been recently foreshadowed from Australia (particularly through developing a large open pit at Olympic Dam), Canada (mainly through opening of the Cigar Lake mine), and Kazakhstan (developing several new sandstone type deposits). If realised, the planned increases should go a long way towards satisfying demand from 2010 to 2020, filling the potential gap which has been of concern to nuclear agencies and utilities as secondary supplies decline. They will be complemented by the greater efficiencies of new generations of uranium reactors, which will require less primary uranium through operating efficiencies and burning of radioactive waste products.

If perceptions of potential uranium shortfalls continue to grow, increased attention will be given to recovery of uranium from large non-conventional resources, particularly in rock phosphates, and to thorium fuel cycles.

7. Thorium resources

There are no detailed records on Australia’s thorium resources because of the lack of large-scale commercial demand for thorium and a paucity of required data. Similarly, thorium resources are not well quantified for any other countries.

Most of the known thorium resources in Australia are held in the monazite component of heavy mineral sand deposits, which are mined for their ilmenite, rutile, leucoxene and zircon content. Maps and other information on mineral deposits in Australia, including heavy mineral sand deposits can be accessed through Geoscience Australia’s online Mines Atlas at http://www.australianminesatlas.gov.au/.

Prior to 1996, monazite was being produced from heavy mineral sand operations and exported for extraction of rare earths. In current heavy mineral sand operations, the monazite content is not always recorded by mining companies in published reports; the monazite is generally dispersed back through the original host sand (to avoid the concentration of radioactivity) when returning the mine site to an agreed land use.

Australia’s monazite resources are estimated from available information by Geoscience Australia to be of the order of 4.5 million tonnes. As the average thorium content in monazite is about 6%, Australia’s thorium resources could be of the order of 270,000 tonnes, and could exceed 300,000 tonnes if thorium is also included from other heavy mineral sand deposits where companies have not reported the monazite content.
There are also known and potential thorium resources in association with carbonatitic igneous rocks, notably at the Nolan’s Bore prospect in central Australia.

As there is no established large scale demand and associated costing information for thorium, there is insufficient information to determine what proportion of Australia’s thorium resources is economic.

In broad accord with the above, the US Geological Survey (in its annual Mineral Commodity Summaries) has reported 300,000 tonnes of thorium ‘reserves’ for Australia, but has added the qualification that the monazite would probably not be recovered for its thorium content unless there was demand for the rare earth metals in the monazite [or increasing demand for thorium as a nuclear fuel]. A subsequent review by the United Nations Development Program estimated four-fold higher levels of global thorium resources [10].

8. Concluding remarks

It is clear that the international community will be looking increasingly to Australia to sustain its vital role in providing fuels for future nuclear power generation. Acknowledging this, the Australian Government initiated the development of a Uranium Industry Framework aimed at identifying opportunities for, and impediments to the sustainable development of Australia's uranium mining industry. The Framework was developed with industry leadership, involvement of the Federal, South Australian and Northern Territory Governments and indigenous representations. The recommended strategies and actions are being considered by the Australian Government. In another initiative, in August 2006 the Australian Government announced funding for Geoscience Australia to acquire new geoscience data to guide selection of new target areas for uranium exploration.

Available information implies that there are sufficient identified and as yet undiscovered nuclear fuel resources globally to meet energy demands for the foreseeable future, provided there is
• adequate exploration, research and investment to discover and develop new mines in a timely manner,
• resource access through sensitive and responsible approaches to political and social issues, and
• more efficient fuel use through development and deployment of promising new nuclear power generation and recycling technologies, including thorium fuel cycles.

9. References