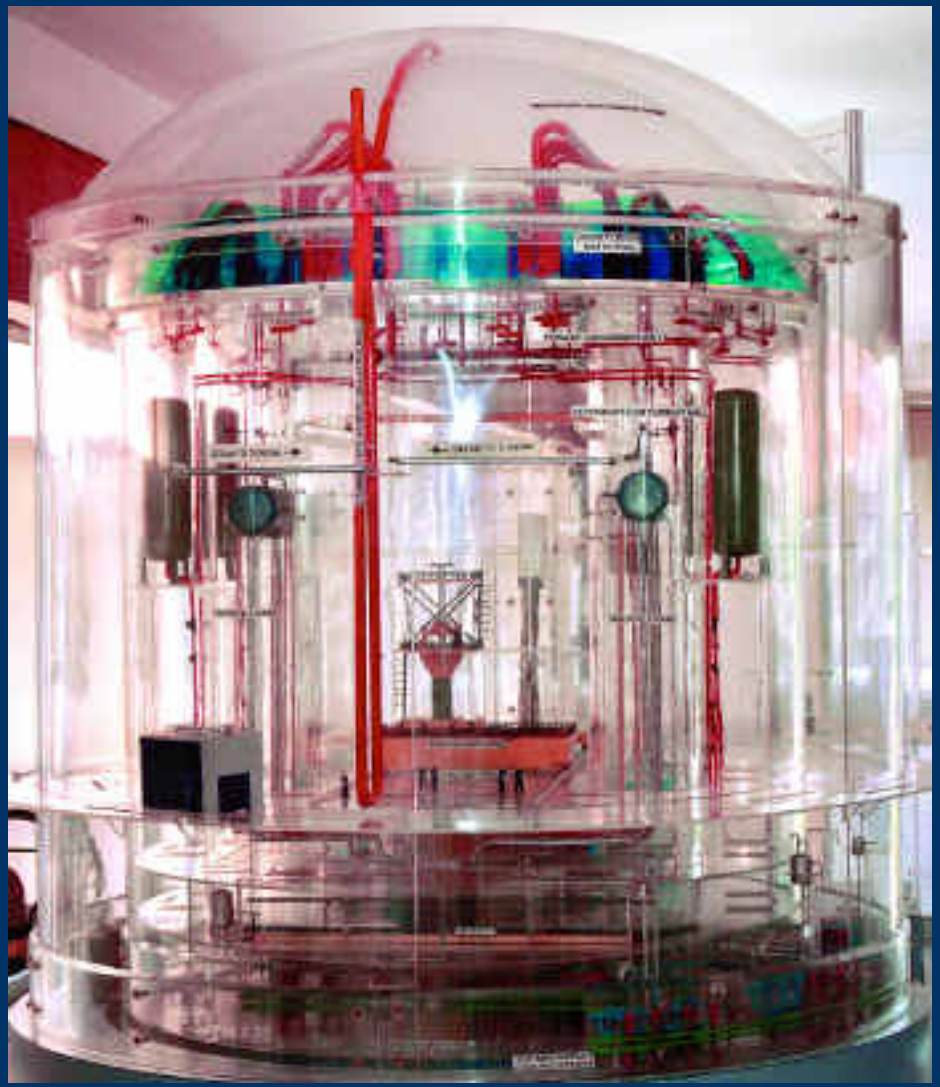
AUSTRALIA'S THORIUM RESOURCES – Current Developments, Likely Overseas Demand

Yanis Miezitis and Terry Mernagh



A model of the thorium fuelled 300MWe Advanced Heavy Water Reactor ('technology demonstration plant') at Bhabha Atomic Research Centre, India.

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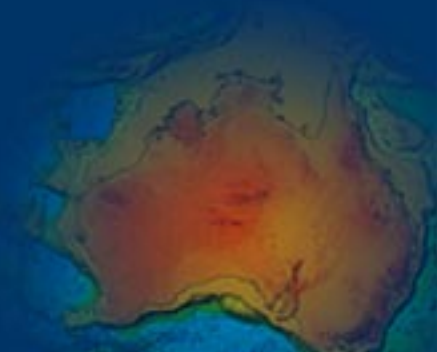
THORIUM RESOURCES

OUTLINE OF PRESENTATION

- *Current status in U fuelled nuclear power generation*
- *Thorium fuel, current developments, demand*
- *Types of thorium deposits*
- *Australia's thorium resources*
- *Further work*

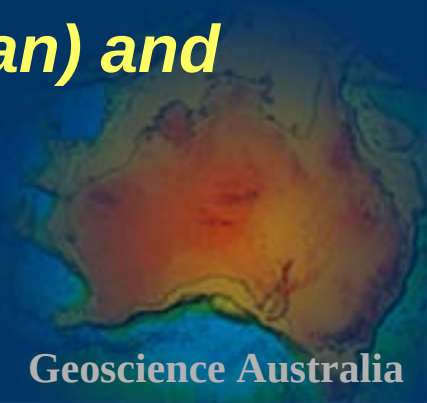


THORIUM RESOURCES

WHY INTEREST IN THORIUM? –

First reason is concern over U SUPPLY

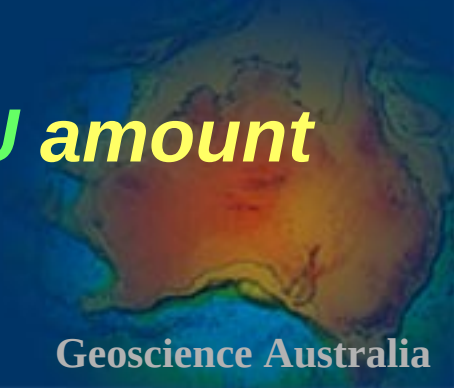
- *Relentless increases in demand for energy in face of concerns for climate change*
- *Nuclear power generation seen by some as a possible solution in generating energy with minimal greenhouse gas emissions*
- *Current U power profile*
  - *There are 437 U fuelled reactors accounting for 16% of world's energy requirements*
  - *Another 30 under construction*
  - *Further 74 being planned (23 China, 11 Japan) and*
  - *another 182 proposed*
  - *Mounting concerns on the supply side of U*



THORIUM RESOURCES

CURRENT - FUTURE DEMAND FOR U RESOURCES

- *437 nuclear reactors producing 370,040 MWe required 66,529t of U (mine & secondary sources)*
- *Another 104 reactors (under construction & planned) to generate 103,999 MWe will need another 23920 t U (230 t U per 1000 MWe)*
- *Total U resources (RAR+Inf) recoverable at <US$80/kg U = 6.55 million t U*
- *Could last about 70 yrs at an annual rate of consumption ~90K U*
- *The proposed 182 reactors (151,345 MWe) would reduce this to about 50 yrs*
- *U resources recoverable at <US$130/kg U amount to another 4.74 million t*



THORIUM RESOURCES

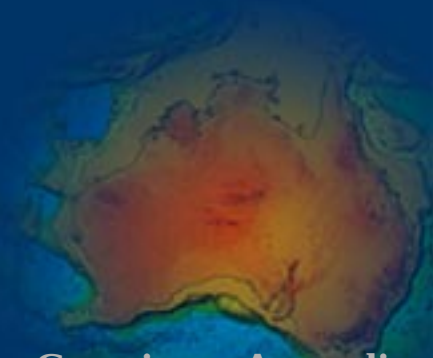
CURRENT - FUTURE DEMAND FOR U RESOURCES

These projections are subject to

- ***Reprocessing of spent U fuel***
- ***Improvements in efficiency of U reactors***
- ***New U discoveries***

All of which will lead to significant extensions in U resources

HOWEVER



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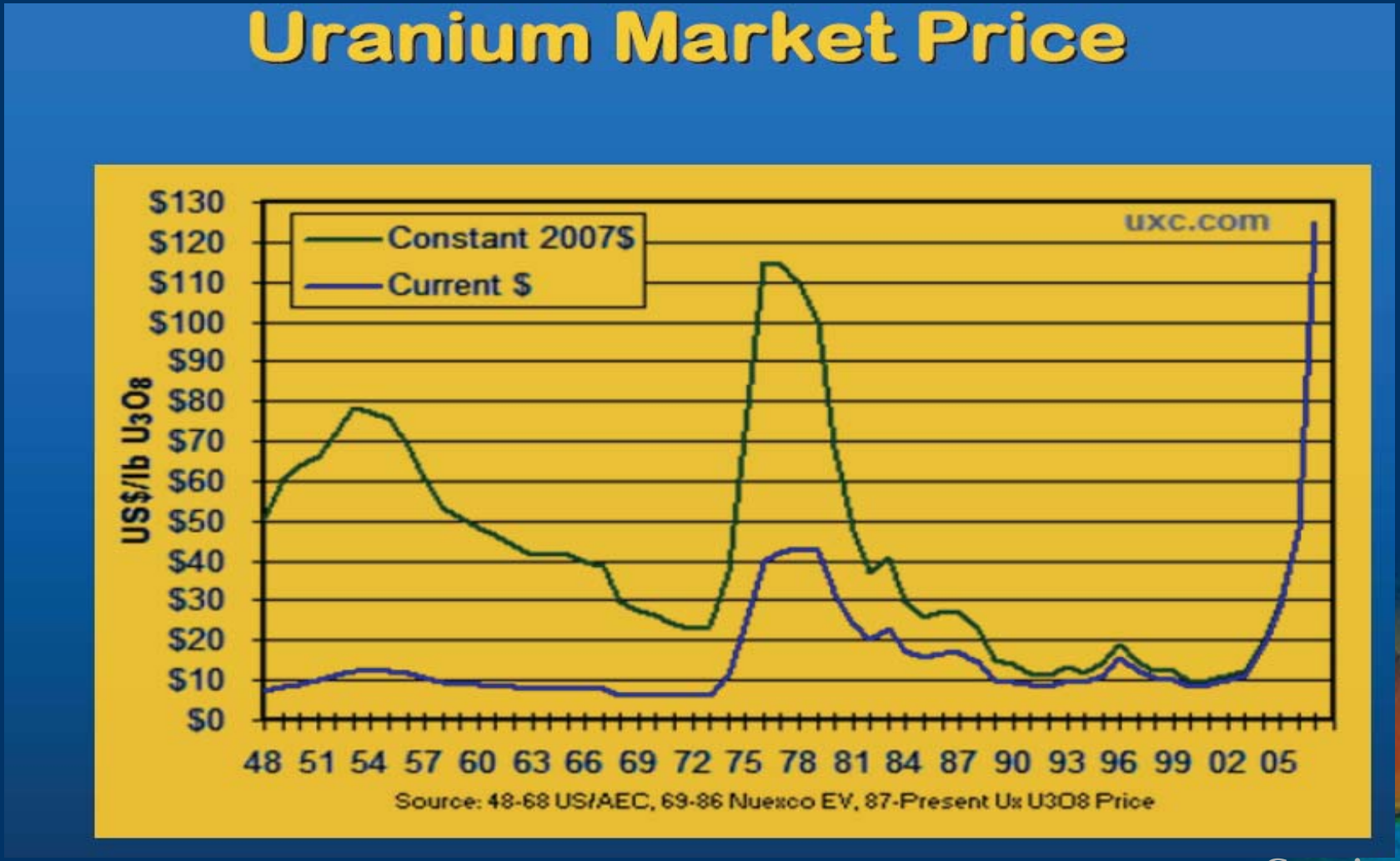
CURRENT - FUTURE DEMAND cont'

- ***Short term market reaction to perceived U shortages, interruptions to U mine operations has led to sharp increase in U spot price***

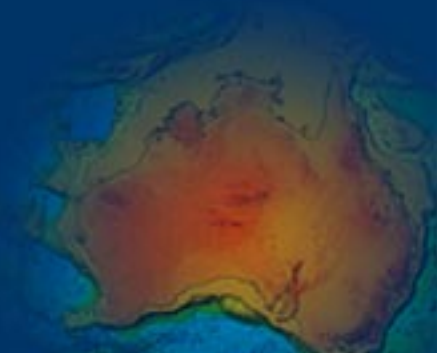


THORIUM RESOURCES

CURRENT - FUTURE DEMAND cont'

So the big question is –

Is thorium a possible alternative nuclear fuel ?



THORIUM RESOURCES

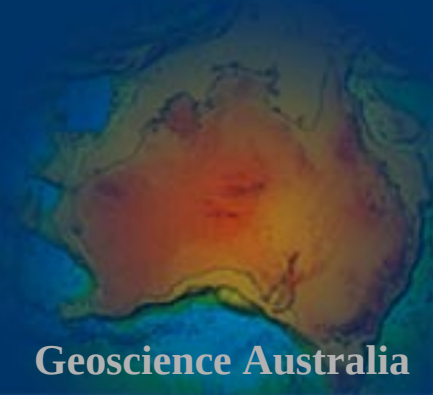
THORIUM AS A NUCLEAR FUEL – a few basics

- *Th is 3-5 more abundant in the Earth's crust than uranium*
- *More than 99.99% of natural Th is Th^{232}, the rest is Th^{230} and Th^{228}*
- *Th^{232} decays very slowly (its half-life is about three times the age of the earth)*
- *Virtually all of the Th (ie Th^{232}) is potentially useable in a reactor, compared with the 0.7% (U^{235}) of natural uranium*
- *Although not fissile itself, Th^{232} will absorb slow neutrons to produce U^{233}, which is fissile. Hence like U^{238}, Th^{232} is fertile (U^{238} transmutes to Pu^{239})*

THORIUM RESOURCES

DIFFERENCES BETWEEN U AND TH RESOURCES

- ***Because all (99.9%) of the Th is potentially useable in a reactor, compared with the 0.7% (U^{235}) of natural uranium – this means that***
  - ***Of Australia's total (RAR + Inferred) U resources amounting to 1.244 million t U, only 8,708 t are useable fissile U^{235} uranium fuel (not counting U^{238} going to Pu^{239})***
  - ***Australia also has an (indicated + inferred) thorium resource of 420,000t of which 99.99% is useable fertile Th^{232}***



THORIUM RESOURCES

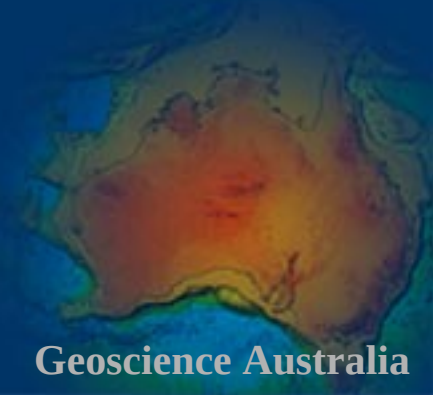
CURRENT DEVELOPMENTS IN THORIUM REACTORS – NO CURRENT COMMERCIAL Th REACTORS

- *Few commercial scale Th-fuelled nuclear reactors trialled in Germany and USA in the 1970s-1980s - shut down in late 1980s*
- *Two current developments of most interest are in*
  - *Russia, in a joint program with a US company (Thorium Power) and US government funding, is developing a Th-U fuel for existing Russian VVER-1000 reactors, partly to burn up stocks of plutonium, possible fuel licensing in 6 years,*
  - *A major attraction of this approach is that Th fuel can be used in current light water U reactors,*
  - *ie no need to build a Th reactor*

THORIUM RESOURCES

CURRENT DEVELOPMENTS cont'

- *Thorium Power claim that because Th fuel remains in reactor for up to 9 yrs highly radioactive actinides are 'burnt' and Th fuel will decay to background levels in 100 yrs*
- *Thus when Th-fuel cycle is used, much less plutonium and other transuranic elements are produced, compared with uranium fuel cycles*
- *This is the second reason for interest in Th fuels*

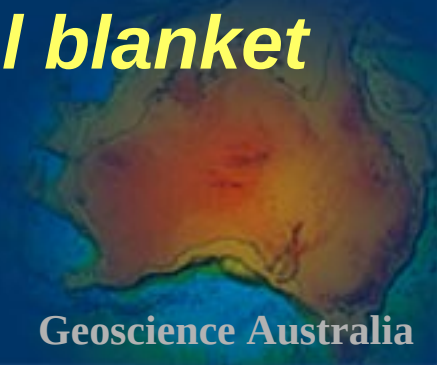


THORIUM RESOURCES

CURRENT DEVELOPMENTS cont'

The second development of interest is in

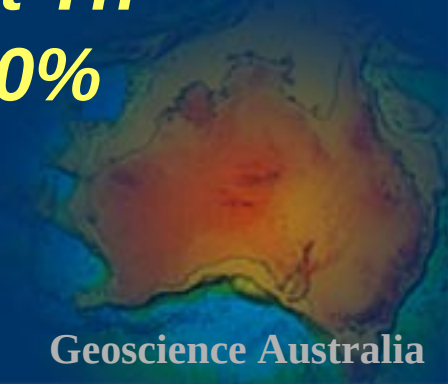
- ***India is currently testing components for a 300 MWe technology demonstrator Th-fuelled reactor, completion in 2020?***
- ***The development of a full scale Th-fuelled commercial thorium reactors 'Stage 3' in India possibly in 2030s***
- ***In the meantime India is also building a 470MWe fast breeder reactor that will use a Th fuel blanket - anticipated completion in 2010***



THORIUM RESOURCES

LIKELY DEMAND FOR THORIUM FUEL - (do we need look for more Th?)

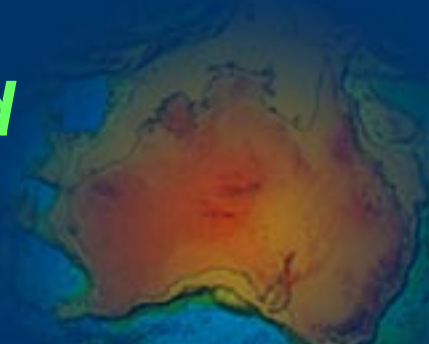
- *Difficult to assess demand for Th-fuel as there are no commercial Th-fuelled reactors*
- *It is claimed that one unit mass of natural thorium could contain about 40 times the amount of energy available in the same amount of natural uranium (ie U^{238}+ U^{235})*
- *1970s data indicated that a 1000 MWe Th fuel reactor required an initial loading of ~40 t Th and ~10 t of highly enriched uranium (~90% U^{235}) and annual reloading of ~10 t Th*



THORIUM RESOURCES

LIKELY DEMAND FOR THORIUM FUEL -

- ***Thus in a hypothetical scenario of 500 Th-fuelled 1000 MWe nuclear reactors may have an annual demand of about 5000 t of Th-fuel compared to about 67,000 t of natural uranium for 440 U-fuelled reactors <500MWe to over 1500MWe in size***
- ***Total world Th resources amount to about 2.5 Mt, see table next slide***
- ***Presumably enough to last 500 Th-fuelled reactors 500yrs***



THORIUM RESOURCES

Estimated thorium resources by country

Country	Total Identified Thorium Resources ('000 t Th) <USD 80/kg Th	
		%
Australia	420	17
United States	400	16
Turkey	344	14
India	319	13
Venezuela	300	12
Brazil	221	9
Norway	132	5
Egypt	100	4
Russian Federation	75	3
Greenland	54	2
Canada	44	2
South Africa	18	1
Others	33	1
TOTAL	**2460**	

Sources: Data for Australia compiled by Geoscience Australia; estimates for all other countries are from: OECD, 2006: Red Book Retrospective. A review of Uranium Resources, Production and Demand from 1965 to 2003.

THORIUM RESOURCES

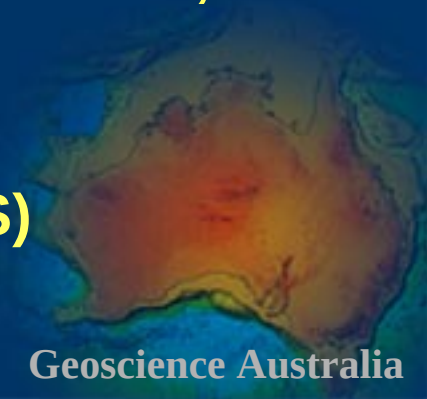
MAJOR TYPES OF THORIUM DEPOSITS

PLACERS

- ***Shoreline heavy mineral sand (HMS)* deposits (Australia, India)**
- ***Alluvial placers* (North and South Carolina, US)**
- ***Ancient metamorphosed placers* (Blind River, Canada)**

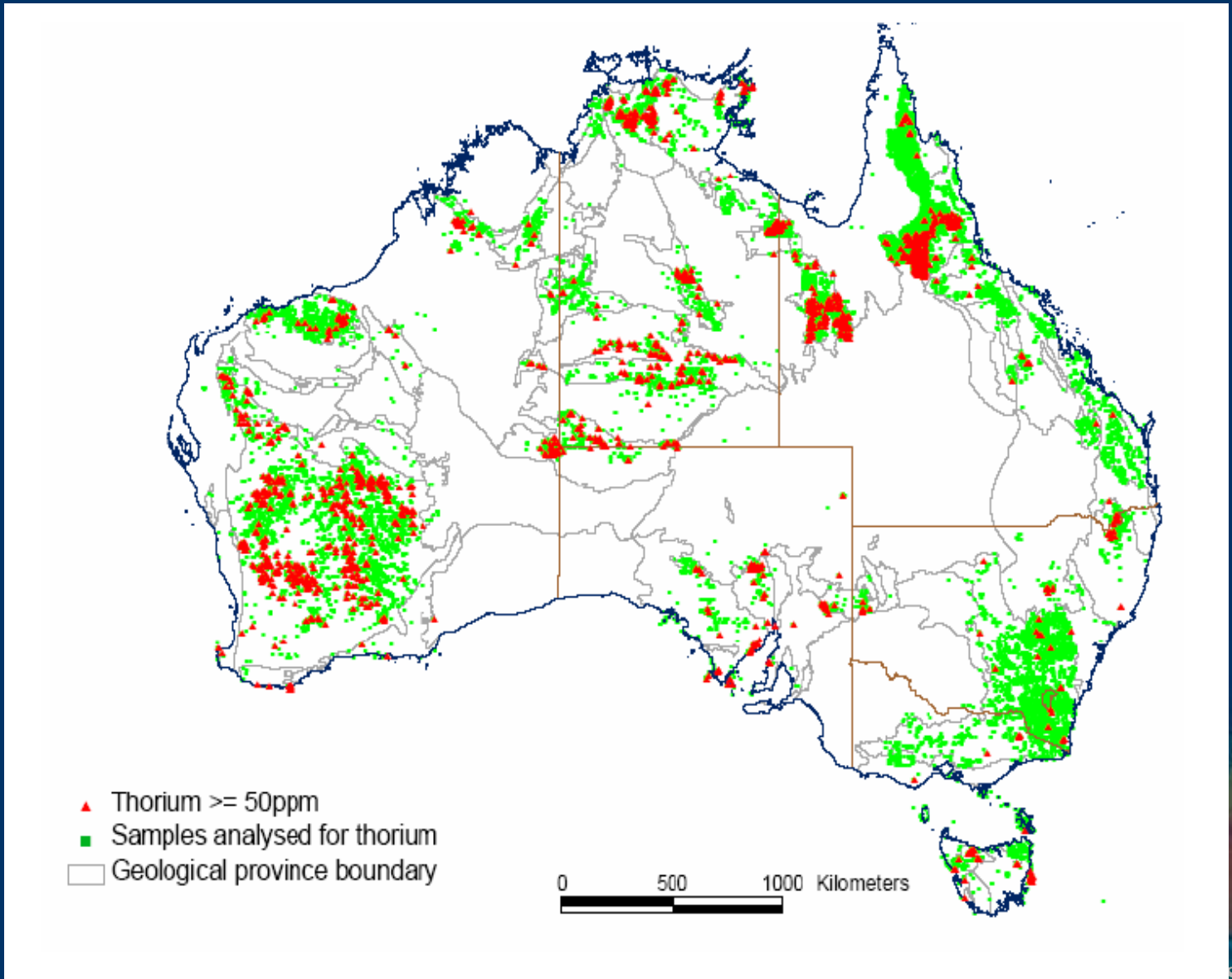
MAGMATIC

- ***Carbonatites* (Araxa, Brazil; Palaborwa, South Africa)**
- ***Alkaline rocks*, eg nepheline syenite (Ilimaussaq, Greenland; Ulug Tansek, Russian Federation)**
- ***Granites, pegmatite* (Bancroft, Canada)**
- ***Hydrothermal veins* (Wet Mountains, Powderhorn, US)**



THORIUM RESOURCES

Distribution of >50ppm Th in rocks and soils in Australia as recorded in GA OZCHEM database

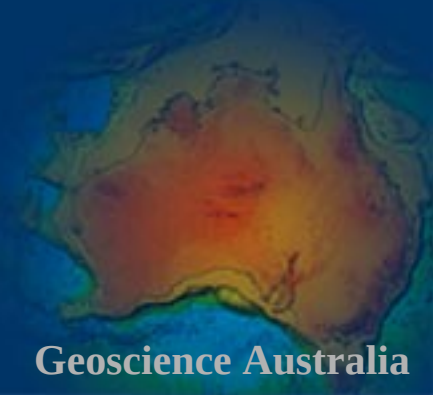


THORIUM RESOURCES

AUSTRALIA'S THORIUM RESOURCES

- ***Most of Th resources in Australia are in the monazite component, a rare-earth Th phosphate ($(CeLaTh)PO_4$), of heavy mineral sand deposits (HMS), which are mined for their ilmenite, rutile, leucoxene and zircon content***

- ***Australia's monazite resources are estimated by GA from individual HMS deposits to be of the order of 5.2 Mt***



THORIUM RESOURCES

AUSTRALIA'S THORIUM RESOURCES

The problem is that the assessment of the Th in HMS is based on assumptions

- *Assuming an average Th content in monazite of 7%, Australia's Th resources in HMS deposits could amount to about 364,000 t*
- *only a few deposits have analyses of monazite and none for Th content*
- *the monazite contents in GA estimates are often extrapolated from limited regional data*
- *The resources in the HMS are inferred resources*

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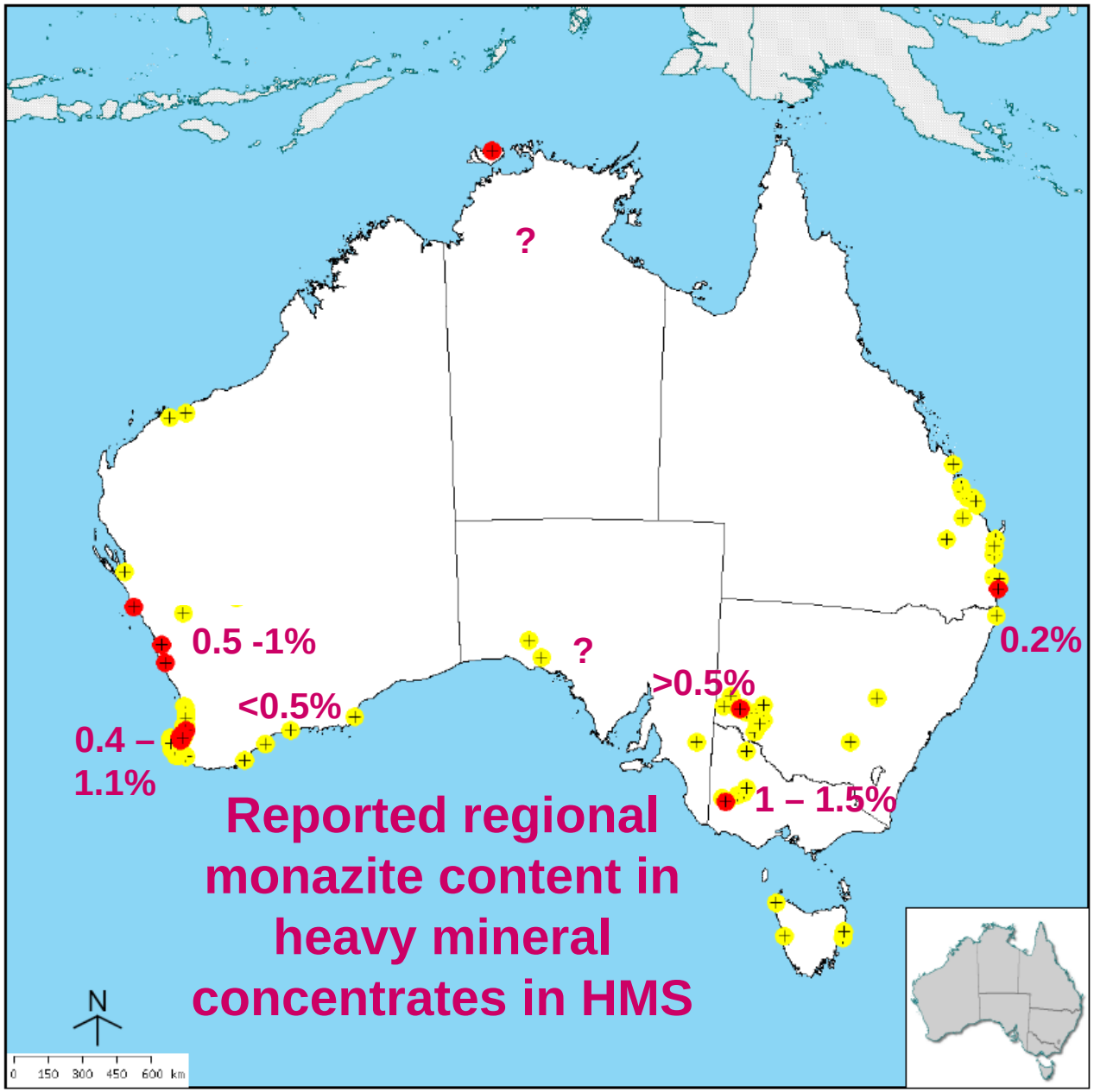
Heavy Mineral Sand Deposits



Projection: Lambert Conformal Conic (Central meridian:134; Standard parallels:-18,-36; Datum:WGS84) Map centre: 132.944°E, 26.168°S

Operating mine

Mineral deposit

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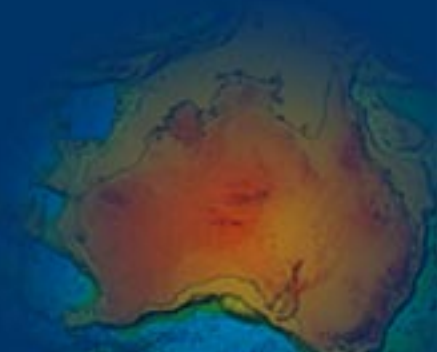
THORIUM RESOURCES

AUSTRALIA'S THORIUM RESOURCES cont'

Apart from HMS deposits

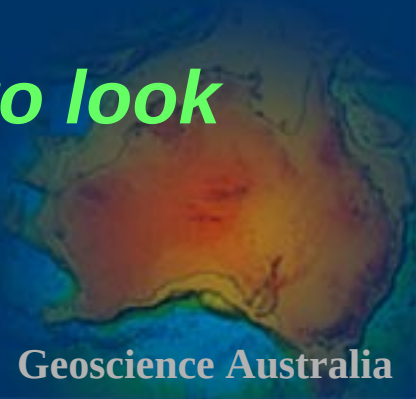
- ***A significant proportion of Australia's Th resources (53,300 t Th) are present in the Nolans Bore rare earth-phosphate-uranium deposit, in NT, which is in fluorapatite veins and dykes hosted within a granitic gneiss.***



THORIUM RESOURCES

AUSTRALIA'S THORIUM RESOURCES cont'

- *In current heavy mineral sand operations the monazite is dispersed back in the original host sand to avoid the concentration of radioactivity*
- *thus eliminating monazite as a resource for both thorium and rare earths*
- *The mining costs of Th for both HMS deposits and probably at Nolans Bore could be carried by other commodities*
- *The main point is that there is little need to look for more Th resources*



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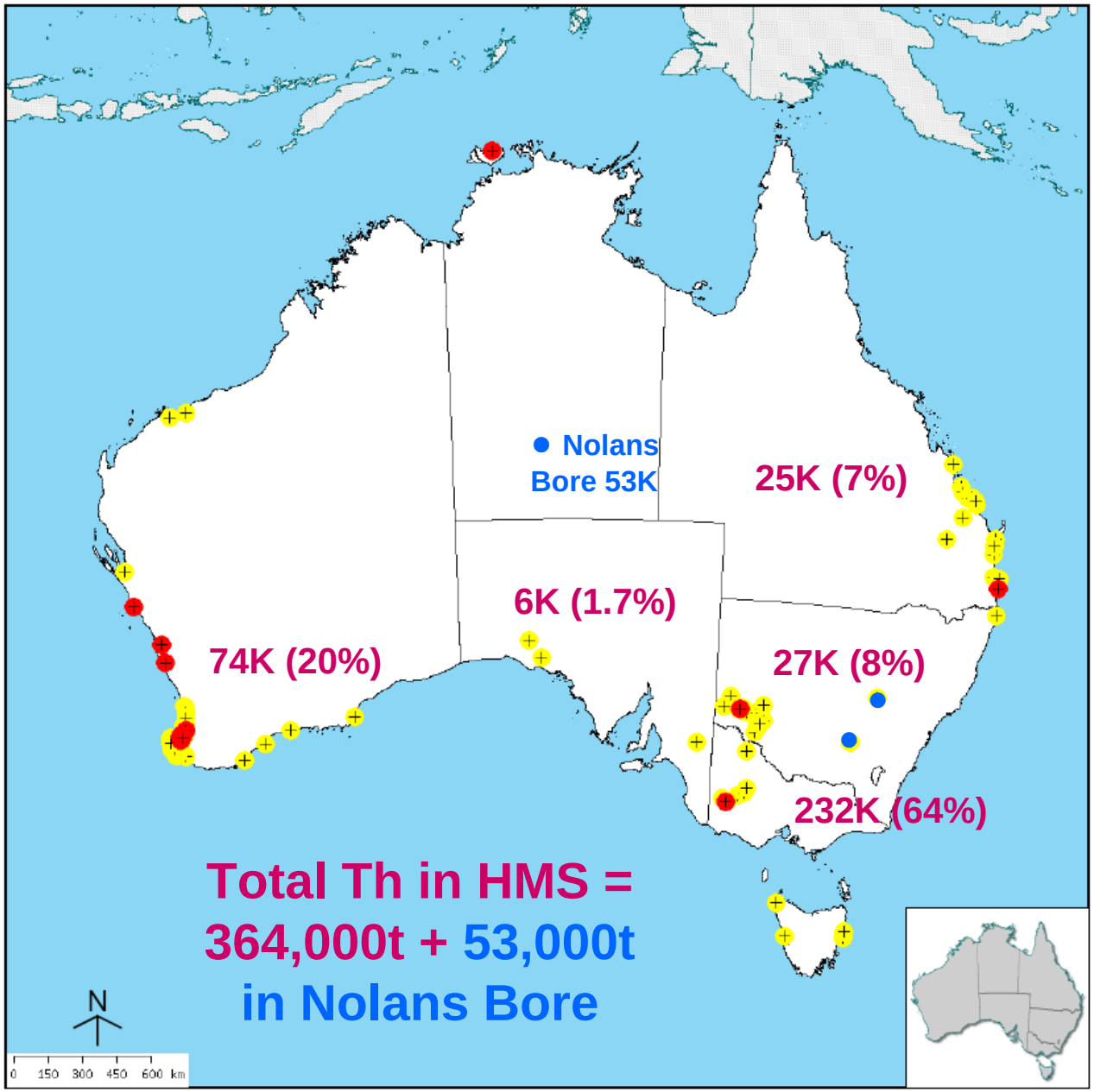
Heavy Mineral Sand Deposits



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Operating mine

Mineral deposit

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Summary of main points

- *Two main factors generating interest in Th are*
  - *Perceived shortage in cheap U resources – no urgency likely in development of Th reactors if cheap U available*
  - *Reduced length of time required for storing radioactive waste from Th fuel*
- *Most likely scenario is increasing use of Th in existing light water U reactors within the next decade*
- *India most serious about commercial Th reactors*
- *'Technical demonstration' AHWR may be built by 2020 but full scale 'Stage 3' roll-out of commercial Th reactors not likely until 2030*

THORIUM RESOURCES

Summary of main points cont'

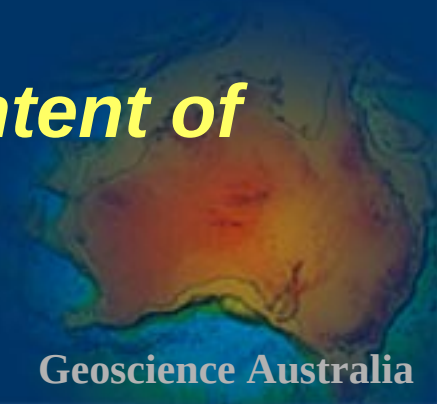
- *Little need to look for more Th deposits as multi commodity operations in HMS and Nolans Bore would pay for extraction of Th*
- *In case of monazite in HMS, rare earth elements would be an additional co-product*

THORIUM RESOURCES

WHAT WILL GA DO?

Upgrade current data on monazite/thorium in HMS deposits as follows

- *Approach companies, State/Territory agencies for data on monazite, thorium content of HMS deposits/regions,*
- *If no data, collect minimal number of representative samples of selected deposits from HMS deposits to*
  - *Establish indicative monazite content in the deposit/region*
  - *Determine the Th (and rare earth?) content of the monazite*



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WHAT WILL GA DO? Cont'

Other types of Th deposits

- ***Need to be aware** of geochemical/geological environments for Th deposits, enhance our capability to recognise such environments*
- ***Assess/acquire** readily available data on known alkaline/carbonatite complexes, identify geological settings where there could be undiscovered complexes, acquire data on Th content*
- ***Assess** what further work needs to be done on Th resources*

THANK YOU!