Thunderbirds are go! Sheffield Resources WA zircon deposit

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- Thunderbird deposit can fulfil 8% of global zircon demand
- Zircon suitable for ceramic sector, ilmenite for welding
- Metallurgical testwork confirms high quality using conventional process

Sheffield Resources Ltd is a mineral sands-focused explorer and developer, headquartered in Perth, Western Australia. The company is targeting first production from its flagship Thunderbird heavy mineral sands (HMS) project, near Derby in northern Western Australia, in 2017.

“The Thunderbird deposit is one of the largest and highest grade mineral sands discoveries in the last 30 years. Once in production, Thunderbird has the potential to supply approximately 8% and 4% of the world’s zircon and ilmenite, respectively over an initial 32 year mine life,” managing director Bruce McQuitty said.

In addition to Thunderbird, the company is also evaluating the Eneabba and McCall’s mineral sands projects, located in the established North Perth Basin mineral sands province in WA’s mid-west region. These projects have substantial mineral resources and are well located with respect to existing infrastructure.

The Thunderbird deposit is located on the Dampier Peninsula about 60km west of Derby, and 25km north of the sealed Great Northern highway joining Derby and Broome (Figure 1).

As noted in March 2014 by McQuitty, “The Thunderbird deposit is one of the largest accumulations of zircon in the world. The contained zircon of the total resource stands at 14.3m tonnes. The deposit also contains a globally significant quantity of ilmenite. The key to the deposit is the extensive high grade zone which features exceptionally high in-situ grades of 0.92% zircon and 3.4% ilmenite (Table 1). Furthermore, the mineralisation at Thunderbird remains open in all directions (Figure 6). Sheffield’s next drilling campaign will target extensions to the deposit.”

Thunderbird has total mineral resources (measured, indicated and inferred) of 2.62bn tonnes at 6.5% heavy minerals (HM) for 170m tonnes of contained HM, including a high grade component of 740m tonnes at 12.1% HM with 0.92% zircon and 3.4% ilmenite grades (Table 1).

At a 3% HM cut-off, the HM assemblage of the resource is 8.4% zircon, 2.8% high-titanium (HiTi) leucoxene, 3.0% leucoxene and 28% ilmenite for a total valuable heavy mineral (VHM) component of 42%. Process testwork has shown that the VHM can be recovered using standard mineral sands processing techniques and that Thunderbird will generate high quality marketable products.

Product quality assessment demonstrates that Thunderbird zircon is premium grade and suitable for the ceramic sector, while the primary ilmenite is suitable for sulphate TiO2 pigment manufacture and sulphate or chloride slag. Secondary ilmenite, rutile and high TiO2 leucoxene products are suitable for the welding electrode sector.

The Thunderbird scoping study, released on 14 April 2014, showed the project has the potential to generate consistently strong cash margins from globally significant levels of production over an initial 32-year mine life (Table 2).

“The large scale and favourable geometry of the deposit are conducive to significant production expansions. The strong life of mine (LOM) cash flows are supported by a 30% higher cash flow in the first 10 years of operations, advantaging estimated capital payback and project financing,” McQuitty said.

The company has commenced its pre-feasibility study.

Sheffield recently expanded its Dampier project tenure to 2,521km2 by applying for a further three exploration licences.

Geology

The Thunderbird deposit is hosted by deeply weathered Cretaceous-aged formations. Its areal extent, thickness, grain size, excellent grade and geological continuity are thought to indicate an off-shore, sub-wave base depositional environment. Sheffield geologists have defined five stratigraphic units which are referred to locally as the Fraser Beds, Reeves, Mellogio, Thunderbird and Jowlaenga formations. Of these, the Thunderbird formation is the main mineralised unit.

<table>
<thead>
<tr>
<th>Table 1. Thunderbird measured, indicated and inferred resources with India</th>
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<tr>
<td>3% HM Cut-off</td>
</tr>
<tr>
<td>Resource</td>
</tr>
<tr>
<td>m tonne</td>
</tr>
<tr>
<td>2.620</td>
</tr>
<tr>
<td>7.5% HM Cut-off</td>
</tr>
<tr>
<td>Resource</td>
</tr>
<tr>
<td>m tonne</td>
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<tr>
<td>740</td>
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<table>
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<th>Table 2. Scoping study results – key metrics</th>
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<tr>
<td>Average Mining Rate</td>
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<tr>
<td>Mine Life</td>
</tr>
<tr>
<td>HMC Produced</td>
</tr>
<tr>
<td>Production - Zircon</td>
</tr>
<tr>
<td>Production - HiTi80</td>
</tr>
<tr>
<td>Production - Ilmenite</td>
</tr>
<tr>
<td>Strip Ratio (LoM)</td>
</tr>
<tr>
<td>Strip Ratio (first 10 years)</td>
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</table>
The Thunderbird formation comprises fine to very fine well-sorted loose sands; it is over 90m thick and is rich in heavy minerals (up to 40% HM). Within the formation are occasional thin and discontinuous layers of iron-cemented sandstone, interpreted to have formed by post-depositional processes involving water table movements.

Within the Thunderbird Formation is a continuous zone of very high grade HM (>7.5%) named the “GT Zone”. The GT Zone is up to 29 metres thick (average 15 metres) over an area at least 7km by 3.5km, strikes approximately north-south, follows the dip of the Thunderbird formation and is open along strike. The GT Zone is interpreted to have formed in off-shore higher wave energy shoals.

Geological exploration
Drilling was at a nominal spacing of 250 metres by 500 metres with four areas drilled at nominal 60 metre hole spacing for bulk sample collection and geostatistical data analysis. Drilling was industry-standard NQ and HQ diameter aircore (Figure 2) to generate 2-3kg samples at 1.5 metre intervals down-hole.

Every drill sample was washed and panned (Figure 3), then geologically logged on site in 1.5 metre intervals recording primary, secondary and oversize lithology, qualitative hardness, grainsize, rounding, sorting and washability, with visual estimates of HM percentage, slimes percentage and oversize percentage as well as water table depth. All drill samples were deslimed, screened for oversize and the -1mm +38μm fraction subjected to heavy liquid separation at 2.96g/ml SG in lab conditions.

Figure 1. Location of the Thunderbird deposit within Sheffield Resources tenements, Western Australia.

Figure 2. Wallis Drilling ‘Mantis 100’ aircore rig drilling at Thunderbird. This specialised rig includes drill rod clamps, hydraulic rod bins and hydraulic height adjustment of the cyclone.

Figure 3. Panning a drill sample on site, 2012.
Mineral resource

The updated mineral resource reported in March 2014 is based on data from Sheffield’s 2012 and 2013 aircore drilling programmes which together comprise 441 holes for 25,953 metres. The mineralisation occurs as a thick north-westerly striking sheet-like body, extending from surface to a maximum modelled depth of 153 metres (Figures 5, 6 and 7).

Thunderbird has an estimated total mineral resource of 2.62bn tonnes at 6.5% HM (measured, indicated and inferred, at 3% HM cut-off), containing 14.3m tonnes of zircon, 47.9m tonnes of ilmenite, 5.2m tonnes of leucoxene and 4.7m tonnes of HiTi leucoxene. The resource has a coherent higher grade component of 740m tonnes at 12.1% HM (measured, indicated and inferred, at 7.5% HM cut-off) containing 6.8m tonnes of zircon, 2.1m tonnes of HiTi leucoxene, 1.9m tonnes of leucoxene and 25m tonnes of ilmenite. As noted by McQuitty at Diggers & Dealers conference in Kalgoorlie this year, the Thunderbird deposit is a “Tier one project, amongst the world’s largest and highest grade deposits” (Figure 8).

At 3% HM cut-off the resource covers an area which is 8km long and between 2.5km and 5.5km wide and remains open in all directions. The average depth to the top of mineralisation is 21 metres and the average mineralised thickness is 47 metres. At 7.5% HM cut-off the resource covers an area about 7km long by 2.5km to 4.5km wide, and remains open to the north and south. This higher grade mineralisation is enclosed within the 3% cut-off resource envelope and extends from a metre below surface to a maximum modelled depth of 112 meters. The average depth to the top of the high-grade mineralisation is 36 metres, the average mineralised thickness is 15 metres and approximately one quarter of the >7.5% HM resource area is within 15 metres of surface.

The updated resource includes the results of 459 HM concentrate composites created from 234 holes through 9,848.5 metres from the 2013 drilling program which were analysed to determine the HM assemblage. The test method was developed following mineralogical trials guided by earlier bulk sample metallurgical testwork, and used a combination of screening, magnetic separation, QEMSCAN and XRF. The 2013 mineralogical data was also supplemented with the average mineralogy of a six tonne bulk sample, sourced from the 2012 ‘cross’ of 60 metre spaced drilling.

As described above, HM concentrates were produced from drill samples using heavy liquid Tetrabromoethane (TBE). The heavy mineral concentrate (HMC) were then screened at 106μm and each fraction weighed Thunderbird HM with grainsize >106μm does not contain significant amounts of valuable heavy mineral...
The -106m fraction was then magnetically separated into highly-susceptible (H/S), magnetic one, magnetic two and non-magnetic fractions, with each fraction weighed. The magnetic one and magnetic two fractions were combined and analysed by QEMSCAN™ for mineral determination as follows:

- **Ilmenite**: 40-70% TiO$_2$ >90% liberation
- **Leucoxene**: 70-94% TiO$_2$ >90% liberation
- **HiTi Leucoxene**: >94% TiO$_2$ >90% liberation
- **Zircon**: 66.7% ZrO$_2$+HfO$_2$/0.667

The non-magnetic fraction was submitted for XRF analysis and minerals determined as follows:

- **Zircon**: ZrO$_2$,HfO$_2$/0.94
- **HiTi Leucoxene**: TiO$_2$/0.94

The mineral resource has been classified according to the JORC 2012 code, taking into account data quality, data density, geological continuity, grade continuity and confidence in estimation of heavy mineral content and mineral assemblage. In plan, polygons were used to define zones of different classification.

Measured resources are restricted to the four separate ‘crosses’ of close-spaced drilling, where drill spacing is 60 metres along strike and 60 metres across strike (Figure 6). Indicated resources are defined where drilling is at 500 metre centres along strike, by 250 metre or better. Inferred resources are defined around the margins of indicated resource, where the drill spacing is reduced to 500 metre by 500 metres.

**Metallurgy and products**

A processing flow-sheet has been developed on the basis of metallurgical process flow diagrams produced by test programmes on two bulk samples totalling 11 tonnes, collected from drill samples. The test programmes were conducted by Robbins Metallurgical Pty Ltd and comprised feed preparation screening and scrubbing, wet concentrate spiral tests, concentrate upgrading and mineral separation testwork to design ilmenite, HiTi leucoxene and zircon circuits.

Engineers RJ Robbins and Associates developed engineering process flow diagrams from the metallurgical work to design conceptual mining, feed preparation, wet concentrate, concentrate upgrade and mineral separation plants, a process water system and product load-out plants.

Metallurgical testwork confirms Thunderbird will generate high quality marketable products using conventional processing technology. Sizing analyses data indicate heavy mineral to be fine to medium grained with a median diameter (d50) of 75-90 microns (Figure 4).

The Thunderbird deposit has moderate slimes content, averaging 17% slimes at the 3% HM cutoff and 16% slimes at the 7.5% HM cutoff. The slimes have a low clay content, and exhibit high settling rates at low flocculant dosages of 20-30 grams per tonne.

Product quality assessment by TZ Minerals International (TZMI) confirmed that Thunderbird zircon is premium grade and suitable for the ceramic sector (Table 3). The primary ilmenite is suitable for sulphate TiO$_2$ pigment manufacture and sulphate or chloride slag. The low levels of alkalis and chromium in the primary ilmenite make it an attractive feedstock for blending with ilmenite with higher levels of these contaminants. Secondary ilmenite, rutile and high TiO$_2$ leucoxene products are suitable for the welding electrode sector. These products may be combined into a single HiTi product.

Results of a tile opacity test on Thunderbird primary zircon were received and have physically confirmed that Thunderbird zircon is suitable for the premium ceramic market. The testwork was undertaken by Ferro Corp. (Australia) and involved milling the zircon to flour followed by firing to make a test tile. This test indicated a firing whiteness suitable for ceramic use and is

Table 3. Typical Thunderbird product specifications

<table>
<thead>
<tr>
<th></th>
<th>ZrO$_2$</th>
<th>TiO$_2$</th>
<th>Fe$_2$O$_3$</th>
<th>FeO</th>
<th>SiO$_2$</th>
<th>Al$_2$O$_3$</th>
<th>P$_2$O$_5$</th>
<th>Cr$_2$O$_3$</th>
<th>MgO</th>
<th>CaO</th>
<th>MnO</th>
<th>V2O5</th>
<th>Nb$_2$O$_5$</th>
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<tbody>
<tr>
<td>Zircon</td>
<td>66.2</td>
<td>0.09</td>
<td>0.05</td>
<td>0.1</td>
<td>0.14</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Primary ilmenite</td>
<td>&lt;0.01</td>
<td>50.1</td>
<td>36.4</td>
<td>8</td>
<td>1.6</td>
<td>0.3</td>
<td>0.05</td>
<td>0.2</td>
<td>0</td>
<td>0.01</td>
<td>1.5</td>
<td></td>
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</tr>
<tr>
<td>Secondary ilmenite</td>
<td>0.2</td>
<td>60.1</td>
<td>33.9</td>
<td>2</td>
<td>0.4</td>
<td>0.06</td>
<td>0.15</td>
<td>0.1</td>
<td>0.01</td>
<td>0.03</td>
<td>0.2</td>
<td></td>
<td></td>
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<tr>
<td>Hi-TiO$_2$ leucoxene</td>
<td>2.5</td>
<td>91.9</td>
<td>1.2</td>
<td>2.2</td>
<td>0.2</td>
<td>0.09</td>
<td>0.08</td>
<td>&lt;0.01</td>
<td>0</td>
<td>0.03</td>
<td>0.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rutile</td>
<td>1.5</td>
<td>94.6</td>
<td>0.5</td>
<td>1.8</td>
<td>0.2</td>
<td>0.03</td>
<td>0.09</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>0.01</td>
<td>0.3</td>
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</tbody>
</table>

![Figure 6. Thunderbird resource classification and 32 years LOM pit shell](image-url)
Resources update

comparable with premium zircon currently in the marketplace.

Mining and processing

The scoping study assumes dry mining of the Thunderbird deposit at a rate of 2,500 tph using large dozers and scrapers. Ore will be screened and pumped as a slurry from relocatable skid-mounted mining unit plants (MUP) for further screening, scrubbing and desliming at the wet concentrator plant (WCP). Deslimed ore will be pumped to a conventional wet concentrator circuit. Processing water for slurrying and the WCP will be supplied by a bore field accessing the shallow fresh water aquifer underlying the deposit. HMC from the WCP will be transported to a concentrate upgrade plant (CUP), whilst thickened slimes, sand tails and oversize from the WCP will be co-disposed in the mine void.

At the CUP, magnetic and gravity circuits will separate magnetic (ilmenite-bearing) from non-magnetic (HiTi 80 and zircon-bearing) concentrates. Separate ilmenite and non-magnetic circuits within a conventional mineral separation plant (MSP) will produce final products of ilmenite, zircon and HiTi 80 leucoxene for transport to port.

Further work

Drilling during 2014 will target extensions to shallow high-grade mineralisation open up-dip, with the aim of expanding the current resource and improving the project’s already outstanding economics.

In addition, infill drilling will target those areas of the resource which are currently classified as Inferred and were therefore excluded from consideration for the current scoping study pit optimisation. Positive results from this drilling could enable a resource upgrade and potentially enhance the project’s economics and mine life.

Infill drilling in the up-dip portion of the deposit will also be undertaken to assist with the optimisation of mining schedules in early production years. Sample material from both infill and extension drilling will be collected for enhancing metallurgical testwork during feasibility.

A programme of geotechnical drilling using sonic coring has commenced. The purpose of this drilling is to obtain sufficient geotechnical information for pit slope stability analyses and pit design, assessment of the excavatability of the mineralised zone and other materials (soils and overburden) in the modelled pit shell, and in-situ density measurements.

In addition, a programme of hydrogeological test bores has commenced. This program will provide information on the aquifer underlying the Thunderbird deposit and allow the effects of potential processing water abstraction to be modelled.

Acknowledgements

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Figure 8. Comparison of Thunderbird with other mineral sands deposits. Only deposits of more than 100 Mt shown. Data compiled by Sheffield Resources from open file sources and excludes Rio Tinto deposits.