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Jacinth-Ambrosia heavy mineral sands mine: discovery to production

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Introduction

Iluka Resources Limited's Jacinth-Ambrosia heavy mineral (HM) sands mine is located on the margin of the Eucla Basin in the state's Far West, ~200 km NW of Ceduna (Fig. 1). Production commenced on 17 November 2009, a mere five years after discovery of the mineral sands deposits in November and December 2004. The Premier, Hon Mike Rann MP, officially opened the mine on 9 February 2010.

The project has the capacity to supply ~25% of the global zircon demand, and will cement Iluka's position as the largest global supplier of zircon — which is used in ceramic, foundry, refractory and chemical applications, with China now the major global consumer.

From discovery to commissioning in five years represents a great achievement. This 'best in class' result is the culmination of a successful collaboration between Iluka Resources and the South Australian Government to make Jacinth-Ambrosia the fastest established mining venture in the state.

The project was delivered ahead of schedule and within budget, and was completed without a lost time injury and in full compliance with its environmental obligations. Final capital expenditure for the project was \$390m, compared with an approved budget of \$420m.

Support from the local community was also a key factor that enabled such successful delivery. Iluka's collaboration with the community from an early stage has established a strong partnership in the long term.

Discovery

The recognition that Ooldea and Barton sand ranges were remnants of coastal deposits formed along the Eucla Basin

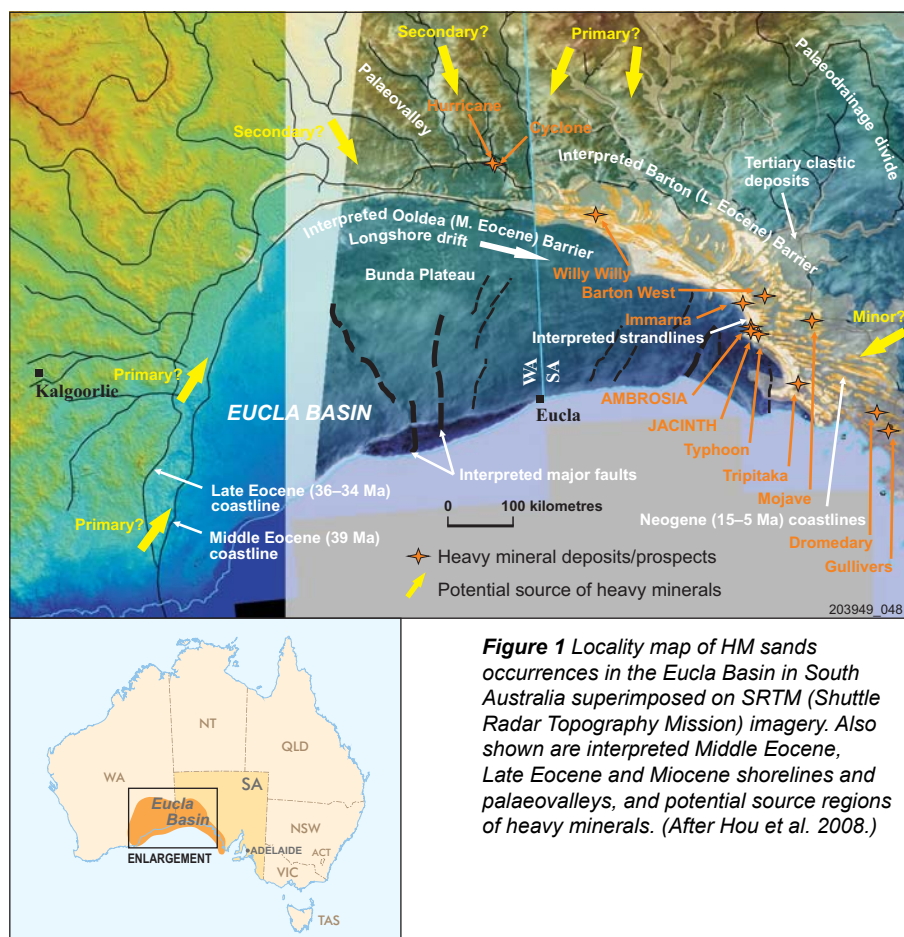


Figure 1 Locality map of HM sands occurrences in the Eucla Basin in South Australia superimposed on SRTM (Shuttle Radar Topography Mission) imagery. Also shown are interpreted Middle Eocene, Late Eocene and Miocene shorelines and palaeovalleys, and potential source regions of heavy minerals. (After Hou et al. 2008.)

margin (Benbow 1990) stimulated resource companies to explore the region for HM. Reconnaissance drilling during the late 1980s to early 1990s produced limited successes, locating thin HM zones, with low rutile content, beneath thick overburden. Iluka was attracted to the area by intercepts recording zircon dominant over titanium minerals and new models for HM accumulation based on reinterpretation of the dune stratigraphy (Hou et al. 2003). Within three weeks of drilling commencement, the Iluka exploration team had discovered Jacinth and Ambrosia. Tripitaka followed in November 2005. The deposits represent a source of high-grade, world-class HM with zircon dominant over titanium. They provide the opportunity to

decouple zircon from titanium mineral production, of particular significance at a time when zircon prices are increasing, while titanium pigment prices remain low. Iluka has made further HM discoveries that are yet to be fully evaluated (Table 1; Fig. 1).

Jacinth and Ambrosia were named by the exploration teams who discovered them. Jacinth is after the striking yellow gemstone variety of zircon; zircon forms ~50% of the deposit's ore assemblage. Ambrosia is named after Australian racing car driver Marcos Ambrose as an ironic reminder of the slow journey out to the drill site from the camp each day. Because of the condition of the track, it took the exploration team almost an hour to travel the short 5 km to the drill site.

Table 1 *Iluka's exploration and development activity in the Eucla Basin, 2004–10*

Date	Activity
Nov. 2004	Jacinth high-grade zircon mineral sands discovered in the Ooldea Barrier complex.
Dec. 2004	Ambrosia mineral sands discovered, 3 km north of Jacinth.
Early 2005	Prefeasibility study for a mineral sands mining operation in the Eucla Basin commenced.
Nov. 2005	Tripitaka mineral sands discovered on the boundary of Iluka's Exploration Licences 2232 and 3316 (operated under the Colona JV with Adelaide Resources NL).
Apr. 2006	Gullivers mineral sands discovered, 60 km east of Ceduna.
June 2007	Definitive feasibility study for Jacinth-Ambrosia commenced.
July 2007	Typhoon mineral sands discovered, 5.5 km SE of Jacinth-Ambrosia.
Dec. 2007	Dromedary mineral sands discovered, 45 km NE of Ceduna — a PACE-funded project.
May 2008	Jacinth-Ambrosia development approved by the Iluka Board with project capital expenditure to \$420m.
July 2008	Mineral lease and two miscellaneous purpose leases granted for the Jacinth-Ambrosia development.
Oct 2008	Iluka acquired Adelaide Resources' interest in tenements held under the Colona JV.
Nov. 2008	Mojave mineral sands discovered — Iluka's first success in the Barton Barrier system, 100 km north of Penong.
Nov. 2008	Construction phase of the mining and rehabilitation program (MARF) for Jacinth-Ambrosia approved.
May 2009	Operation phase of MARF approved.
Nov. 2009	Production of HM concentrate commenced from Jacinth — project ahead of time and within budget.
Dec. 2009	First full shipment of HM concentrate dispatched from Port Thevenard to Iluka's Narngulu mineral separation plant in Western Australia.
Feb. 2010	Jacinth-Ambrosia Mine officially opened by Premier Mike Rann.

Geological setting

The Eucla Basin in southern Australia is one of the world's largest onshore extents of Cenozoic marine sediments. Early Cenozoic coastal deposits remain largely intact and can be traced along a 2000 km basin margin that extends up to 380 km inland of the present day coastline. This includes over 650 km of coastal dune complexes along the northeastern basin margin that have been modified by aeolian processes to form the Ooldea and Barton sand ranges. Sand deposited along this coastline is the result of interaction between a dominant westerly wind, driving westerly longshore drift and building coastal dunes, and sea level change during Eocene to Miocene times. Marine transgressions during the late Middle Eocene (39–36 Ma), Late Eocene (36–34 Ma), and Neogene (15–2 Ma) reworked beach and backshore dune deposits to concentrate HM in suitable trap sites (Hou et al. 2008; Hou and Keeling 2008). Studies of the zircon age population in sediments indicate the dominant source is from the Musgrave Province, with minor contribution from the Albany–Fraser Orogen to the west (Reid and Hou 2006). The high zircon content reflects a combination of sorting during transport in fluvial and coastal environments over long distance, with possible recycling through Palaeozoic sandstones of the Officer Basin.

Deposit geology

Jacinth and Ambrosia formed on the western, basinward side, of the Ooldea barrier system with HM concentrated on a prograding beach complex that developed in a 'J-shaped' bay. A prominent headland at the southern end of the bay is the result of sand accumulation on shallow crystalline basement of Palaeoproterozoic metagranite, part of the Fowler Domain of the western Gawler Craton. The Jacinth deposit is ~3.2 km long and 0.9 km wide. The orebody has an overall N–S orientation and is slightly curved in plan view (Hou and Warland 2005).

A high-grade core of >20% HM, between 2 and 10 m thick, is present at 5–10 m above the bedrock contact and extends across the full width of the deposit. This is interpreted as aggradations of beach swash zone deposits that extend basinward over surf zone sands and are partly reworked into overlying younger beach deposits

or aeolian backshore dunes (Ruperto et al. 2006). Concentration of HM in the swash zone increases from north to south. The top of the high-grade zone is an unconformity marked by patchy and generally weak silicification and a narrow zone of bioturbation in the form of intensive burrowing. This is overlain by up to 20 m thickness of iron-stained quartz sand that contains 3–5% HM. Average ore zone thickness is 20 m at 1.0% HM cutoff; overburden thickness averages 7 m. Contained in situ HM content is estimated at 6.4 Mt (Table 2).

The Ambrosia deposit is 3 km to the north of Jacinth and is ~2.2 km long by 0.7 km wide. The orebody is elongate NW–SE. Heavy mineral content is more patchily distributed than for Jacinth and overall grade is lower. High-grade zones of >10% HM are associated with beach swash zone aggradations, typically <3 m thick, with lower HM grades present in overlying sands that include backshore dunes and backshore wash-over sand facies. Ore zone

Table 2 *Iluka's Eucla Basin HM deposits with resource estimates (December 2008)*

Deposit	Resource			Mineralogy		
	Quantity (Mt)	HM grade (%)	In situ HM (Mt)	Zircon (%)	Ilmenite* (%)	Rutile (%)
Jacinth	124.3	5.2	6.4	47	30	5
Ambrosia	114.8	2.7	3.0	50	21	5
Tripitaka	42.0	2.4	1.0	65	9	5
Total	281.1		10.4			

* Ilmenite includes hydrated ilmenite (Ti/Ti + Fe = 0.5–0.6), pseudorutile (Ti/Ti + Fe = 0.6–0.7) and leucoxene (Ti/Ti + Fe = 0.7–0.9).

Source: Company information releases to the Australian Securities Exchange to December 2008.

thickness, at 1% HM cutoff, averages 12 m, and overburden thickness is an average 8 m. Contained total HM content is estimated at 3 Mt (Table 2).

Both deposits are above the watertable in unconsolidated, moderately to well-sorted, fine sand (typically between 0.1 and 0.2 mm). Grains are subrounded to well rounded and rarely exceed 1 mm diameter. Silt and clay 'fines' content ($<53\ \mu\text{m}$ fraction) averages 11% at Jacinth and 14% at Ambrosia. Fines content is lowest in the high-grade ore zones and increases to a maximum of ~30% in the upper portion of barrier/dune deposits. The upper sands are typically orange-brown in color due to iron-oxide-stained clay coating on grain surfaces.

Heavy mineral concentrates average 82% valuable HM at Jacinth and 76% at Ambrosia. Zircon proportion is high for both deposits at ~50% of total HM, with a zircon to titanium dioxide ratio of ~2.6, which is around 10 times the industry production average. Ilmenite content is ~30% for Jacinth and 20% for Ambrosia, mostly as altered ilmenite with a high average TiO_2 content of 64% and $\text{Ti}/(\text{Ti} + \text{Fe})$ equal to 0.66, making the dominant mineral phase pseudorutile (Pownceby, Sparrow and Fisher-White 2008). Combined rutile-anatase content is ~5%. Other minerals present in the HM fraction include tourmaline, spinel, staurolite, monazite and chromite, with minor iron-oxide-coated quartz contributed mainly from the upper ore zone. Monazite and chromite content in the HM concentrate is typically low at ~0.2% each.

The approvals challenge

The approval process for mining the Jacinth-Ambrosia site began in 2007. This presented one of the toughest challenges for the Jacinth-Ambrosia Alliance, an integrated team formed between Iluka and environment and design engineering firm Parsons Brinckerhoff. Jacinth-Ambrosia is within the bounds of the Yellabinnia Regional Reserve, a dual proclamation reserve open to both conservation and mining activities.

This was uncharted territory for both Iluka and the state government, as approval was required from both the Minister for Environment and

Conservation and the Minister for Mineral Resources Development. A dedicated task force was formed early in the approvals phase, with representatives from Iluka, Department for Environment and Heritage and PIRSA.

The streamlined process meant that the mining lease and associated mining and rehabilitation plan (MARF) was approved in stages over an 18-month period, making Jacinth-Ambrosia the first mining lease approval granted in a regional reserve.

Mining and processing

Mining is by open pit, dozer-trap method. Soil and overburden are stripped and stockpiled separately. Sand containing HM is pushed by dozer to the mining unit plant located within the pit (Fig. 2). Oversize particles ($>2.4\ \text{mm}$) are rejected using a rotating trommel and undersize is mixed with water and pumped to the

wet concentrator plant. Every 20–30 days, the mining unit plant is moved to maintain an economic dozer push distance.

Slurry pumped from the pit to the wet concentrator is deslimed using cyclones to remove fines ($<53\ \mu\text{m}$) which are thickened before being discharged to tailings storage or pit infill. Recovered water is recycled back into the process. Sands are distributed to banks of spiral separators and are cycled through several stages to produce a HM concentrate by gravity separation. The wet concentrator installed at Jacinth-Ambrosia was relocated from Iluka's Georgia operations in the United States (Fig. 3). Production is rated at ~1650 tpd HM concentrate.

Water for the project is groundwater pumped from a borefield, 32 km west of the mine site. Highly saline, 35 000 – 50 000 mg/L, water is drawn from Middle to Early Eocene sands infilling a broad palaeochannel below Nullarbor



Figure 2 Sand containing HM is pushed by dozer to the mining unit plant located within the pit. (Photo 407878)



Figure 3 Wet concentrator plant — this was relocated from Iluka's operations in the United States. (Courtesy of Iluka Resources; photo 407879)

Limestone. A proportion of the supply is treated in a reverse osmosis plant for potable water requirements at the mine and site village.

HM concentrate is transported by road in B-triples, 270 km to Port Thevenard (Fig. 4). At Thevenard, the concentrate is loaded into 25 kt payload vessels and shipped to Geraldton, Western Australia, for mineral separation and processing at Iluka's Narngulu Plant. Planned production is for ~300 ktpa zircon, ~45 ktpa rutile and ~170 ktpa ilmenite. Jacinth-Ambrosia produces a premium-grade zircon, with high opacifier qualities, suitable for ceramic applications.

Environmental management and rehabilitation

With the approval to mine came a range of requirements under the MARP for the management and rehabilitation of the fragile arid environment. Initially a research partnership was formed with the University of Adelaide, Botanic Gardens of Adelaide and Department for Environment and Heritage to investigate seed ecology issues for key vegetation species. This has been followed with a growing suite of site-based and external institution research and development collaborations (Fig. 5). The program aims to improve the understanding of the Jacinth-

Ambrosia ecosystem, its components and the interactions between these components, to inform the overall rehabilitation program.

The current research and development program addresses a range of issues, including re-establishment of soil crusts for ecosystem stability and function and the use of capillary breaks in the rehabilitation of tailings pits.

The local Indigenous community of Yalata has been involved in the collection of native seeds and weed control as part of the rehabilitation program, which is integral to the effective and ongoing management of the land. Working with the team from Yalata adds a wider dimension to this work — their local and traditional knowledge enhances any activity and as a result of their involvement they have opportunities to develop their skills and gain employment in land management.

Indigenous community partnerships

The Jacinth-Ambrosia site is located on the Far West Coast Native Title Claim area, incorporating the communities of Ceduna, Scotdesco, Yalata and Oak Valley. In December 2007 a Native Title Agreement was signed between the Far West Coast Native Title Claimant Group and Iluka, to allow mining to occur. A liaison committee was formed initially to lead the negotiations on

behalf of the traditional owners, to ensure the agreement will benefit their communities well into the future. Now, during the mining operations phase, the committee is responsible for executing the terms of the agreement, working in partnership with Iluka.

The committee's focus is on local community development, including education, training and employment. Part of the agreement includes a scholarship program, which aims to support students from the Far West Coast in furthering their education. A business development program has also been included in the agreement, and looks to foster the growth of locally based Indigenous enterprise to create sustainable employment in the community long after Jacinth-Ambrosia closes its operations.

The Ceduna community

Iluka has appreciated the strong support it has received from the local Ceduna community since the launch of the project. The community was invited to become involved very early on in the process, which was important for the construction and operations teams alike. Iluka recognised from the beginning that the local community had a big stake in the project and wanted them to be a part of the process. This ranged from discussing local supply and employment, to transport routes out to Port Thevenard and road safety.



(Left) **Figure 4**
Loading HM concentrate for trucking to Port Thevenard.
(Photo 407881)

(Right) **Figure 5**
Site-based and external research and development collaborations are helping to inform the overall rehabilitation of the arid environment at Jacinth Ambrosia. (Courtesy of Iluka Resources; photo 407880)

Part of this relationship includes a Road Train Safety Program, run in collaboration with Kalari, Iluka's concentrate haulage contractor. The program was run with the schools in Ceduna with great success in 2009, and will be rolled out again in 2010 in the surrounding Aboriginal communities. The program talks to school children about being safe around passing road trains, and explains how blind spots and the size of the truck have to be considered.

Local business and employment

Transport is only one of the industries boosted by the development of Jacinth-Ambrosia. During project development, ~75% of project expenditure was committed in South Australia. Now during operations, of the 64 Iluka employees, 35% are drawn from the Eyre Peninsula, in particular the Ceduna area (Fig. 6).

Iluka is committed to the development and implementation of on-site training and skills development of Indigenous employees. The Jacinth-Ambrosia operation has fourteen Indigenous employees in a variety of positions, including equipment operators, administration officers and a shift coordinator. This level of Indigenous employment matches the goal Iluka set of a 20% Indigenous workforce. Iluka's mining contractor, Exact Mining, and Kalari, are also aiming to achieve the same goal for Indigenous employment.

Exploration and Iluka's future in the Eucla Basin

With Jacinth-Ambrosia successfully up and running (Fig. 7), Iluka are continuing to explore in the Eucla Basin. They currently hold 50 000 km² of tenements, with a significant portion of the exploration budget being spent in the search for 'the next Jacinth-Ambrosia.' The company is seeking to increase its resource position through a combination of greenfield exploration, as well as brownfield exploration attempting to tie-in additional mineral resources to the infrastructure at the existing Jacinth-Ambrosia site. While the mine life of Jacinth-Ambrosia is currently 10 years, Iluka aims to remain in the region for a long time to come.



Figure 6 The Jacinth-Ambrosia Mine currently operates with 64 employees — 35% are from the Eyre Peninsula and 20% are Indigenous. (Courtesy of Iluka Resources; photo 407882)

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For further information on Iluka's operations visit their website <www.iluka.com>.



Figure 7 Aerial view of Jacinth-Ambrosia Mine. (Courtesy of Iluka Resources; photo 407883)