Iluka Resources Limited

Mineral Sands Technical Presentation 3 May 2011

Edited Transcript

Robert Porter, General Manager, Investor Relations

The context on the three presenters today: Peter Benjamin who is a General Manager of Exploration and Geology. He has been with the company for just under 10 years. Peter has responsibility for Iluka's overall exploration effort. Grant Huggins is the mine manager at Kulwin in the Murray Basin. Kulwin, as you probably appreciate, is the first of the northern Murray Basic deposits that we are now in the process of mining. Dan McGrath is the Manager of Mid-West Operations. Dan's been with the company for 17 years.

Peter Benjamin, General Manager, Exploration and Geology

[Slide 2] Thank you Rob. I'm going to talk to you about strategies and some definitions and then we'll go into what is mineral sands and what makes mineral sands deposit valuable or not valuable, and things for you to look for. I think you've heard this mantra coming out very consistently from anyone you've heard in Iluka, but everything we are looking for has got to be long life and high value. We are principally focusing on rutile and zircon because they are the highest value commodities. So that is our target for our exploration strategy.

[Slide 3] What are heavy minerals? A very simple definition is anything which has an SG (specific gravity) greater than or equal to 2.9. So if they are higher than that they are a heavy metal, if they are not they are light heavies, or lights. You hear people talk about bulk tonnages of metal, so for example, you have a volume or ore, you multiple it by the grade and you get X tonnes of copper, or you get X grams of gold or ounces of gold. It is the same thing with the mineral sands deposit. You get a bulk commodity of sand, you multiply it by the grade and you get a total amount of metal in the ground which we call heavy mineral.

That's not what we get paid for. It's called VHM or valuable heavy minerals, so it's that component of the heavy mineral, which you actually can recover and get paid for. It is the rutile component, the zircon component and the various types of ilmenite.

What I've actually shown there on the presentation is a range of titanium products. So you see from the very high rutile, which is nearly titanium dioxide, all the way down to ilmenite, and you'll see ilmenite ranges from about 35% up to about 65%. The material we target is material usually in excess of 55% TiO_2. It's known as an altered ilmenite; it's been partly weathered, partly eroded and what actually happens is the TiO content increases in nature, eventually it goes all the way up until you get to leucoxene, which is at 90% and rust is given off, which is FeO.

If you are looking at other commodities, or other mineral sands companies, make sure that are you looking at something more than 55% TiO_2. Zirconia - zirconia is simply a silicate and we also get a by-product, monazite, which we stockpile and that contains various elements.

When you add up our assemblages, you will see it never comes to 100% in our resources statements because it contains other minerals such as kyanite, staurolite, garnet, magnetite and others.

[Slide 4] Now again, harping on VHM, if you have a look at the triangle, where we want to be is in the top right-hand side. So then we've got rutile and then we've got zircon. You can see Douglas, it's down in the bottom left, it's an ilmenite dominated site, until we get all the way up towards Euston, which is just east of Mildura, and you can see it's has got quite an abundance of rutile and zircon. So in other words, the value in ground of this material is much, much higher for the same percentage of what you see at say, Douglas.

The key thing here though is the products. The have to be recoverable, and they have to be marketable. You can have zircon in the ground which is irrecoverable because it's too fine. In other words, that SG, the SG difference is so small between the grain and other grains that the water in the spirals cannot actually separate it effectively. So while someone may actually quote a very large proportion zircon if you cannot separate it effectively it isn't worth very much.

The other issue is, often zircon, or certainly ilmenite contain some inherent nasties. One of them is uranium and thorium, and you measure it as U + Th. So if you have something, for example, U + Th in excess of 1,000 parts per million, well you can't transport it. You'd have difficulty transporting it, you'd certainly have difficulties getting it into the US and other countries. So I will harp on it again, it needs to be recoverable, it needs to be marketable and you need to understand how much R and Z is in there, and that's what you will see as a valuable heavy component.

[Slide 5] I'm going to talk about mineral sand deposit formation. All the ones we generally look for are sedimentary deposits, so there is the sediment, they occur in sands.

If you go down to the beach, and I've seen them in Sydney because I'm an old Sydney boy myself, you will see little strains of black sand, especially after storms. That's actually the sort of stuff we've been looking for. The entire East Coast, or most of the East Coast of northern New South Wales, has been mined for mineral sands in the past. There's quite a bit left under Surfer's Paradise and I don't think anyone will be trying to mine it any time soon.

So certainly what happens is you've got hard rock hinterland, you've got a granitic mountain, and it erodes and the sand gets washed down the river and it gets into the sea there and it's affected by wind, waves, alongshore drift and the principle then that really affects it most is water, the action of water that really can move quite a lot of sand. Wind does play a part and I'll talk about that later.

[Slide 6] Here's a typical sort of cross-section, this is how it actually forms. So basically you've got a sand-dune and it's got a natural background component of about half a percent HM, that's fairly typical, and then you get some big storm events. Sometimes you have a massive storm, a cyclonic storm and it erodes that area and what it does is exactly what you do when you are panning for gold. You are washing all the lights over the top and in the end you've got left a heavy mineral register usually with some heavy minerals at the bottom. [Slide 7]

The wave and the wind action actually does this work and does it naturally. So take the lighter minerals, that's just the quartz, out to sea, the finer minerals out to sea and it actually concentrates the heavier quartz and minerals, and what you wind up with is then a period of beach building over the top of that, and it leaves this heavy mineral placer, very commonly about 10%, maybe 20% of the sand mass is actually in that red zone there [Slide 8] but it's buried, and eventually the sea regresses, in other words it goes out and you will be left with is this hidden, fossilised beach, and they are the targets we primarily seek in our exploration programme.

[Slide 10] And what I've got here is a digital terrain model. What you see are areas with blue which are the shallowest areas, or the deepest areas, areas of red and up to white they are the highest areas. So you can see basically the shape of the basin three to five million years ago when the basin formed, dropped, the sea came in and it actually created a series of beach ridges, an old shore line, and you can see them just north of Horsham, they are the old coast lines.

Also though in the middle here, we've actually got hidden deposits. For example you have West Balranald, certainly Kulwin is under a band of 10, 15 metres of overburden. Douglas was actually almost at surface, or under a couple of metres.

[Slide 11] There are really two types of heavy mineral deposits. The first one is the strand, it's really just a fossilised or buried beach, that's what I've been talking about, and this is the Douglas strand and what you see there is a series of ribbons. Typically they have very sharp, very well-defined edges, they are only just a few metres and then you are out of them. They can be quite long. Sometimes they are up to 20 kilometres, but normally a few kilometres long, up to 300 metres wide and a thickness of just a few metres.

The one thing they do have is they generally are very high grade, and some of the highest grade mineral sand deposits you can find. For example West Balranald has an in situ grade of about 32%. That's very high, but they also contain high portions of valuable heavy minerals.

[Slide 12] At the other end of the spectrum is what we call the dunals. An example here is North Stradbroke Island, but if any of you are familiar with Richard Bay, Richard's Bay in South Africa, is a dunal deposit. These are very, very large deposits, and they are principally grown as a consequence of wind action. So just like the water winnows it out on the beach, the wind can actually blow the lighter sand further away leaving a progressive out-graded higher grade zone of VHM. So they wind up being very deep. They are often tens of kilometres long, the width can be a few kilometres and the thickness can be up to 100 metres.

At North Stradbroke, they are mining dune thickness there of about 130 metres when they are in the high kick zones. But on the flipside they tend to be fairly low grade, about half a percent to about .7% HM. They can be very big, so you can have them up to 200 million tonnes or more, but because they are not very sharp-edged, because they look like an onion skin, gradational boundaries, they are quite amenable to bulk mining.

[Slide 13] I thought I'd put this one up because this one is actually a cross-section through Jacinth in the Eucla Basin, and it's the discovery section. What it shows is a classic onion skin. This is a really a combination deposit, so it's the best of both worlds. What we've actually got is the high grade strand, which you see in red, which is basically anything better than 20% HM, and then you see the concentric onion rings around it. So not only can this actually benefit from selective mining, but if we look for lower and lower bulk mining opportunities, or even the opportunity as prices increase, between some of the areas of yellow edges, and particularly the blue this is the, I wouldn't call it the perfect deposit.

[Slide 14] I'm going to talk about exploration techniques, and all this simply is a stylised cross-section, talking about ages.

[Slide 15] So we look for ones which have limited or no rock, which are very easy to open pit mine. This is a study we did a couple of years ago and we looked at all the different types of mineral sand deposits, be they hard rock, soft rock, or otherwise in the world. We see revenue on the left-hand side, so in situ value versus size and tonnes. Basically we came to the conclusion that the ones we've been targeting, you can see West Balranald in the big blue dot and the little Jacinth-Ambrosia under it - these are areas where we have got very high value in-ground. They are not particularly big, but they are some of the biggest strand style deposits you can find. That's what we are principally targeting.

If you go to the bottom, you'll actually see there's a big yellow zone, and you'll see things like RBM. Now they are more dunal deposits and basically they are low value, you can see the relative value there, they are probably half or a third of the value of the material we've been looking at. I will point out this slide is now two years out of date and is not based on the new prices which you see touted, but the relativities remain the same.

So we actually are focusing on the blue style, these high grade strand deposits, but we are also keeping our eye open for any of the dunals, because they can have a considerable mine life.

[Slide 16] Just a snapshot, currently we've got about 83,000 square kilometres of exploration tenements. I think we are probably one of the biggest tenement holders by area in Australia, we've got about 450 tenements and we are looking to increase that number.

[Slide 17] A little more on exploration techniques, and I think one of the things that makes us different and more successful than some others. What we tend to do is we look for an exploration model, we create an exploration model and then we test it, and then we modify. Now if we don't believe it's any good we move on to the next, and we move on to the next after that, otherwise we continue going until we have explained the anomaly or tested that exploration model. And you'll see the people here, they are sitting with digital terrain models, trying to work out where an old shore line might be, where a new target zone might be.

[Slide 18] We also have this very extensive database, and it's got every known deposit that we have ever come across throughout the world as well as every operating mine.

[Slide 19] Now some of the other techniques, I'm a geologist and the only way to find these things is to get out in the field. So what you see there is a surface auger, and it's quite typical for us to go out, pan for mineral sands on the surface, actually get a streak and make a discovery. That's pretty much how we found Typhoon, which is a brown field discovery announced last year, to the east of Jacinth-Ambrosia. We often use helicopters.

The other thing we look for visual evidence for mineral sands, or the presence of mineral sands. On the left you'll see a little pen mark and you'll see the dark grey slicks, and you see the same things on the beaches around Sydney, that's good evidence that there is some mineral sand around. Is it concentrated enough? Have we got a trap site? The other most important thing is that you've got the right host material and we are dealing with sediment. We do have some very, very good sedimentologists working for us who understand, 'if you put a drill hole down here then which way is the beach?' We have to find the right sort of host rock.

[Slide 19] This is a digital terrain model, and you can actually see the occurrences of Capel and the Yoganup shore lines, and you can see the old shore line going up along here.

[Slide 20] This is an example of radiometrics, basically what happens is you have a low level plane flying over and it measures the uranium, potassium and thorium response, and we did it to the east of Jacinth-Ambrosia, so this is data that has been modelled and you'll see what you think, if you really squint hard and look at JA, you can just see this little, tiny, light blue anomaly. It's very small, but we were looking and we said 'okay, what else can we find?' These little white dots here, which initially attracted attention, they are ground outcrops, they are hard rock. This area here is a lake, it's a clay lake and it's quite typical to have elevated uranium and thorium in those sorts of lakes. But this area here, and you'll see this little line of dots, it actually did turn out to be a mineral sands deposit discovery. So we've still got to do some work on that, but it did get picked up. Unfortunately with radiometric, it doesn't work everywhere, it works some places, it doesn't work in others and the signal can be attenuated very, very quickly by as little as about five centimetres of cover. So unless you get some daylight, unless you get something there which is leading you with high uranium or thorium, you are going to be hard-pressed to find something.

[Slide 23] Some of the other things we use are magnetics and we do some extensive and quite sophisticated modelling. If you look very hard you'll see a series of little black lines running all through there and we've named those lines with various numbers. This was done about four years ago. We subsequently tested each one of those anomalies and they are sitting at between 30 and 100 metres below the surface and every one of them is a mineral sand strand. What you see here is a strand claim. Unfortunately some of them are quite deep, and as yet may not be amenable because they are too small or too deep, but every one of them actually is a mineral sand occurrence. Some of them are actually quite high grade, some of have also got very god VHM. So you can get make it work in some places.

[Slide 24] This is what we use almost exclusively as our best test of all the exploration modelling. It's an Iluka Mantis rig and it's a simple fixed wheel drive Toyota, it will drill down between 70 and 100 metres, drill a hole the size of a beer can, very, very little environmental impact, and operated by two people. We often have another support, you'll see the support truck behind it, but there's usually a logging truck with two geologists or a geologist and an off-sider there helping. [Slide 25/26] The next thing they do is of course every sample is panned. There are all in bags so that we can work out the vectors to mineralisation, and of course simply you've got all these bags that are going to go through our mineral laboratories. We've got our own laboratories in the Murray Basin as well as at Narngulu, and you'll see in the bottom right-hand corner where we work out the amount of HM, what you see here, but we also work out the mineral component, how much rutile, ilmenite, zircon is there.

[Slide 27] This is the Douglas site, where we have done extensive resource drilling campaign, so we model it, we do some very sophisticated modelling in-house. It is usually audited and checked using external consultants, and what you see here, this is part of the JA deposit [Slide 28], a typical cross-section, and of course here is the facsimile of what the model looks like in solid form. That's then passed over to people such as Grant and his mining engineers, which they then decide how they are going to mine it, how much is it going to cost? Is it going to make a profit? And what techniques they are going to use to extract the ore.

[Slide 29] This is a slide of our mineral resources. This is actually taken out of the, page 75 of our annual report, and basically you will see, if you take the Eucla Basic for example, just how you read this chart, we've got nearly 294 million tonnes of sand, that's what that means, we've got nearly 14 million tonnes of metal or HM in the ground, the average grade is just under 5% HM, and here's the interesting thing, there's the HM assemblage. We've got 40% ilmenite, 39% zircon and 4% rutile, which all adds up to about 83% of the VHM, the other remaining material is not VHM, it's what we consider as having potential value,.

[Slide 30] Probably the last and not by least is just challenges, what really the greatest challenge is for us is making sure we get there first, that we've got a model. We go to places where other people haven't been looking, and we get out footprint over the new tenements, sometimes we do a joint venture, sometimes we buy a tenement.

I think access and environmental approvals are very fundamental to us and very important. You've got to make sure all the stakeholders are happy. One of the things we've just managed to accommodate is working in South Australia, we've got that big area of the Eucla Basin, it's about 50,000 square kilometres of tenement, and there's some pretty challenging environment-, it's a very pristine environment. So we've been working with PIRSA, which is the local mineral resources department and the environmental department, and we've developed in conjunction with them, a thing called PEPR, which is a programme for environmental protection and rehabilitation, and instead of every time we do an exploration programme, or an adjunct to that programme, we'd always have to put in a programme of works and seek individual approval to go in and do what we have to do, we were able to convince PIRSA and the environmental authorities that we've done a very good job up until now, we created a set of procedures and protocols to follow so that they have now given us basically blanket approval to go in as long as we follow those approvals and protocols. It actually streamlines that whole process to a degree, and also gives PIRSA a tick in the box for Iluka that we are very environmentally responsible.

Those protocols are actually going to be followed by everybody working, whether it's mineral sands or base metals or gold, in that particular environment. It certainly streamlines the process.

Grant Huggins, Mine Manager, Kulwin, Murray Basin, Victoria

My presentation today is really just going to give you a helicopter view of mineral sands mining, just to try and cover the basic aspects of it. Our number one objective is always to keep the costs as low as possible. Our objective in Iluka is to deliver value for shareholders and being the largest, or one of the largest cost bases within the business, we are always attempting to find new ways, simple ways of mining mineral bodies and getting a better return.

So I wanted to talk to you, I'll briefly just firstly run you through each stage of mining, and just add some pictures really just to give you an idea of the type of machinery that we use. Then to drill a little bit more into the mining method selection and cover some of these aspects in a bit more detail, and some of the more interesting things that we come across in mineral sands mining.

Costs are very much a focus for us and after Peter delivers the resource model we turn it into a reserve. It's an iterative process, and as costs change over time, you know at the end of 2008, 2007 mining costs were pushing higher and we went through the GFC which certainly improved that situation for Iluka and we've been able to manage to sustain that through to now.

Sustaining mining is a large part of what we do. We need to be able to have a good relationship with our stakeholders and we certainly need a licence to operate within our region so that we can continue to do what we do.

The general mining sequence in reasonable simple at first glance. We have to separate and stockpile topsoil and subsoil, simply just most of the land that we operate in is agricultural and following that overburden, stripping the ore block comes out, and generally we discharge our tail-ends component back into the pit from where we took it out. Now that sounds all well and simple, but logically for a mineral sands mine, keeping our unit costs down means keeping the amount of void that we have open as small as possible, and utilising as much of the space that we have in the pit as best we can.

Topsoil and topsoil removal, typically and usually to protect topsoil to get the best yield back out of crops when it's put back in the ground, land claims just give us the best cut, best opportunity, usually 12 to 14 cubic metre buckets on those.

Overburden stripping is just typically mining equipment. These are 650, 7G scrapers. This is the Douglas Mine in the Murray Basin. One of the Bondi East strands, one of the larger sort of massive deposits with an ore sequence of sort of three to four metres and this operation is really just stripping and taking to stockpile. Same pit, just a different mode of stripping, 992G, 777 trucks. So I mean depending what unit rate we can get, we use any type of equipment.

This is Kulwin, deeper deposits, long strand, 14 kilometre strand, two 200 tonne diggers, three to five trucks, and the real game here is to make sure that we maximise the void as best as possible. So minimal ore exposed at any one time, minimal overburden haul. Logistically it is a scheduling and a planning task to make sure that these are minimised at every turn so that we really pick everything up once and put it back into its final resting place the first time, making obviously a big difference to our cost base.

Ore mining again at Douglas, one of the Bondi East streams, some of the finer detail on these things, the bottom of the pit here is just untrafficable with the trucks, so these things aren't really known until we get there, until they are tried and tested. Usually low risk is always another way to do it, but typically. Ore mining at Kulwin, we have a mining unit, which is the primary, it removes the rock component out of the ore feed to the concentrator. It's a wet mine, it's one of the few wet mines that we have. We just simply dewater with external bores, pump that to an infiltration basin.

This is another good example of trying to minimise costs. So basically mining the ore in situ and dozing it straight into the trap.

Again, another ore mining example, and again completely different. Two of our mines in the Murray Basin just completely different mining methods. This is a just a very large, flat tabular three metre thick, beautiful high grade zircon, large grade zircon ore. And again, this is CRL, not with us any more, but just an example of the different types of mining styles that we cover.

An important part of our process, and this is again the logistics chain that we see in mining, extract the ore, right behind it we generally try and backfill tailings, and basically fill that void, but there's usually some sort of factoring of the way that we place them, so we end up with a higher topography when we have finished. And this is part of our tailings process, which is essentially a modified co-disposal with a flocculent that allows us to displace clay, fines and sand material back into the pit at the same time without segregation and it means that we can have quite a good stand up on our tailings, which gives us the ability basically to tail above pit crests at any point, which just gives us more real estate to work in.

This is just a wall, this is the Douglas mine wall separating the pit, and this is one of the main, the Bondi main pits and tailing into the back-fill here, which will be recaptured with overburden and then subsoil and topsoil placed back on top. The ore that is extracted here and taken straight to the mining unit. We try and put a fixed plant directly next to the ore body where possible, and you would have seen in Peter's presentation the Bondi main, or the Bondi East strands going up, and there were sort of 10 kilometres away at times from the plant where we use a HaulMax truck, which is a Cat product that was made in Tasmania, and that was very successful for us, because basically it was more economic to do that than move our mining unit.

Rehabilitation, just a slide in there to show you what the final result looks like. This is just a cereal crop and basically just on top of that pit there. So that's basically 18 months later. So the sooner as we can rehabilitate it, the sooner our cost base goes down.

Strip ratios, obviously depth isn't the only thing. It's about strip ratios, the wall angles, the more incompetent the material that we are mining, the steeper the walls have to be, more overburden moving. Just to give you an idea of the strip ratios that we mine in Murray Basin and the Eucla Basin, Kulwin has one to five strip ratio, that's walls to overburden. Jacinth, which is a complete reversal, just a massive ore body with not a lot of overburden. The Bondi East deposit classically about five metres of overburden and four metres of ore, and Echo, which is a different strand again, which is about 37 kilometres from Douglas, which is truck in the ore, it's generally say a four to one strip ratio.

Hardness is a very important thing for us, because it increases our cost base market if we get that wrong, so we have two methods of defining that. We pan the drill strings which basically test our ore body, and anything about two ml, we basically put that into our block model and it describes for us, those drill cuttings, if there is rock in it, the percentage of that gives us a good idea of what we are going to see and the abrasiveness of it. We also have a measure which is more a, what's the word I'm looking for? Anyway, complete blank sorry, but basically the geologist decides on the spot, so depending of the geologist you've got, they basically describe the hardness of the pit. The drill team rejects basically hardness five, and it just pushes through without any hesitation at the one, so it's more a subjective, that's the word I'm looking for, view of the world.

With us, if we get that wrong and you basically get down there and it's hard, and you can't mine it, that's a big issue. So we put a lot of time in to make sure we can understand before we dig.

So just looking at Kulwin, which is being mined at the moment, it finishes at Christmas and then we move on to the WRP strand, which is about 20 kilometres west. JA, Douglas generally above the water table. Kulwin, below the water table. We pump about 50 litres a second at Kulwin to an infiltration basin. Basically bore pumps along the edge of the pit, spaced about every 100, 200 metres, depending on how much water is, and what type of topography we are going through at the time, and we just simply put it back into a void, it infiltrates naturally and we rehabilitate later.

Ore body geometry, it has a big effect. You can see the different styles of machinery that we employ in the Murray Basin, scrapers are generally good for short haul, trucks for longer hauls, diggers for more bulk earth-moving, and the bigger digger generally gives us the better return and the lower unit cost for what we are generally chasing.

Geometry, just talking about strand lengths, this is one that Peter showed earlier, but just a simpler view.

So just some interesting dynamics that we get when we are doing ore body mining selection and how we decide the size of the fleet. So generally we find that there is some upside in our geological models, but this is just an example of how we would arrive at those, and again, this is the termination of each strand, and this is the point which we actually manage to find, to demonstrate that.

Now if we are drilling 10 metres apart in the strands, so this being one drill hole and another one's out here, we basically just cut off halfway with some of the tricky nuts bits, and if your pit is only 30 metres wide and you've got basically in-fill drilling, it's very important in these types of strands to make sure that we actually get the best reserve to mine when we make a decision about how we are going to extract it.

Ore body geometry, just continuing on. This is an aerial photo take by the Department of Primary Industries just after the rain event in January to give us an idea of what we looked like and they were kind enough to pass it on, but it gives you a bird's eye view of the geometry that we are dealing with, it's not your classic top down, large bulk commodity, we have to come up an innovative solution to keep our cost base down. It's also a good look at how much water was lying around in the Mallee after the rainfall, it was quite extraordinary.

The second thing in mine planning, we basically spend a lot of time working with our mining engineers to make sure that we get the best result from a cost point of view, and we feed back our mining costs into our reserve models continuously to make sure that we are actually can, or whether or not we can bring more material into the reserve model and actually have a larger reserve base.

Continuous improvement opportunities, there is a whole list of these types of things, which gives an example, this is an oversize crushing campaign, so this is the material that comes out of the mining unit, which generally we slide past back into the pit, discover that there were traces of mineral on it, so we employed a very simple financial model, starting a crushing campaign, and now it's the status quo. So out of a small pile of oversize we generate 5,000 tonnes of HMC, just from crushing the product which liberates some of the material in there, that you might actually get out from washing or other types of methods as well, but just simply by putting it through that crusher and screen we get a return on that as well. So these are the types of things that go on that add value within the business all the time, that certainly aren't sometimes self-evident when you start a project.

Dan McGrath, Mid West Operations Manager

Simplistically processing begins at the mine site and the first function of a processing plant is to remove the rock. There are three geological components - the rock component, clay and sand. A simple mining unit involves screening the rock out and you are left with the sand and clay fractions. A more complex mining unit is when heavy minerals may be distributed within clay and sand agglomerates, which then needs to be liberated. As such a higher energy input is required, so some beneficiation separate the sand and the clay into there separate components. The technical considerations in mining unit design, relate to the clay characterisation, the clay is the most variable in nature and affects the behaviour of material most significantly. The oversize as Grant talked about before, and the way it is liberated from the heavy mineral from the oversize is a matter for consideration in mining unit design. The slurry handling systems, the question earlier, where the mobility of the mining unit is offset by the pumping distance and the energy input for pumping. Obviously in terms of recovery beneficiation, the assumption in the design basis is that you recover 100% of the heavy mineral and the valuable heavy mineral. Therefore the mining unit design is important to ensure that outcome. Obviously with the high fixed costs in downstream processing, you want to maximise your recovery.

After the rock has been screened out or the heavy minerals, and the sand and the clays into their discrete components, the clay is separated from the sand using generally hydro-cyclones. The sand fraction is then separated from the light fractions. Generally, heavy minerals from quartz in most cases, is by gravity separation. The concentrator may contain magnetic separation circuits. If ilmenite is low value such that the cost of hauling it and processing it is less than the value recovered from it, the concentrator design can separate it at the mining stage, which is the process Iluka employs at its Kulwin operation in the Murray Basin. The concentrator design is based on achieving the highest utilisation possible and generally because it's static, stationary and the mining units can be mobile, certain concepts like pre-concentrators or rougher head stockpiles are employed to maximise utilisation and maximise capital efficiency of the mining unit.

Heavy minerals, as Peter talked about heavy minerals ain't heavy minerals. It's all about the sizing of the heavy mineral in relation to the gangue or the waste, what the upgrade ratio is, how many stages, the need for magnetic separation, process water conditions and both front source and equilibrium and potentially surface conditioning like attrition scrubbing circuits in the process. And re-agents used can often interact with the flocculants. And if all elements are not managed carefully they could adversely affect operating costs. Slurry handling systems need to be robust enough to be able to handle a wide range in duty or distance.

Imperfect design can really either make or break your margins. VHM recovery or HM recovery is the most significant NPV driver of any project. So any negative estimate or understatement of recovery or overstatement of recovery will drastically affect project economics. And again low product grade; the concentrates have to deliver a suitable product grade for downstream processing. Processing units are dependent upon grade and it also affects the cost of transport from the concentrator to the downstream processing plant.

Generally heavy mineral concentrate, the rutile, the zircon, the ilmenite and some gangue is carted to a mineral separation plant or in the case of Iluka's Jacinth-Ambrosia operation shipped, to the mineral processing plant. The purpose of feed prep circuit, which is generally the front end of most mineral separation plants, is to ensure that the surface of the mineral is suitably conditioned for separation. So things like attrition scrubbers, removing the clays and any other surface coatings from the mineral are important as is removing dissolved salts from the moisture contained in the HMC. In terms of mineral separation plants, the engine room is the electrostatics, mainly because the magnetic separation is relatively simple. It's about removing ilmenite and other minor trash minerals from the non magnetic mineral, such as rutile and zircon. And as I've shown in this diagram with the dashed lines, these circuit configurations are quite variable and they depend upon the heavily mineral assemblage of the feed stock. So, for example, a low ilmenite deposit wouldn't have the magnetic separation circuit, ilmenite would be recovered from the rutile circuit magnetic separation stage.

The important feature is that the circuit design has to be matched to the mineral assemblage so that output is unconstrained. You don't want, for example, your rutile circuit inhibiting your production of zircon because it's at a bottleneck. Technical considerations of the mineral separation plant. It's all about the surface condition; the technology for separation is primarily electrostatic separation, so the separation based on the conductivity differential between the minerals. Alumina silica coatings, either bound or unbound have a very deleterious effect on electrostatic response. So the importance of the feed preparation circuit upstream. Iron based coatings on zircon affect the conductivity differential between zircon and the TiO2 species. And salts, including salts that have been dried onto the surface, affect the electrostatic response under varying atmospheric conditions. Managing atmospheric conditions in a mineral separation plant is one of the most important process control steps.

The ilmenite and the alteration profile of the ilmenite, it's important for how ilmenite is treated and how it's recovered, but it also determines its suitability or eligibility for different markets, whether it be a sulphate pigment market, chloride market or whether it's upgraded into synthetic rutile. And the mineralogy, morphology, size, shape, elemental composition, the question before about what other elements are important, almost all of them are important. For zircon for example, we talked about uranium and thorium and it's about shipping and waste disposal, but also with ilmenite the non TiO2 components and their quantity affect its marketability, in which destination, in which market it can be supplied. Almost all of the elements are important in terms of the intrinsic quality. So with the ilmenite, for example, we've recovered the rutile and zircon, the ilmenite maybe suitable for upgrading to synthetic rutile. From around anywhere between a 56%, 58%, 60% titanium dioxide content, anywhere up to 95%. The process that Iluka employs, the Becher process, which is a carbothermic reduction of the iron and the ilmenite at about 1100 degrees. The reduced ilmenite is the product. The iron metal or the metallised iron is then leached away from the titanium using a catalysed oxidation reaction called aeration, the remaining chloride accelerates the rusting process, residual iron and manganese are leached from the TiO2 using generally sulphuric acid. Plant configurations can vary; I've shown a box for the waste heap system and one of our largest kilns in the business actually has a waste heap recovery plant. So basically a boiler, a turbine, a power generation plant as opposed to heat exchange or heat recovery for other reaction processes.

Key technical considerations with the Becher process, it's all about ilmenite quality, whether it be the TiO2 grade or whether it be the contaminants, some of them contain contaminant, some of them affect the amount of iron that can be removed and some of them affect the marketability depending on size and other characteristics and how the chlorinators generally perform. And again the product specification or which market is targeted - Iluka generally targets TiO2 into the pigment market being a high grade producer. But there are step changes in TiO2 grade produced, depending on which technology is employed. A standard grade product is anywhere from 85% to 88% titanium dioxide, premium products between 89% and 92% and the SREP or the synthetic rutile enhancement process is up to 95%. The three different products generally employ slightly different technologies. For example, the standard grade product has very little acid leaching, the premium grade has sulphur addition into the kiln and very high intensity acid leaching. The SREP has a flux addition into the kiln, acid leaching plus caustic washing, so each of those have vastly different cost profiles and product grades.

The two markets or the two downstream processes from taking our TiO2 products to pigment are the sulphate process and the chloride process. The chloride process is employed by the large producers and the high quality pigment producers, the DuPont, Huntsman, Kronos, Tronox and Cristal, etc. The sulphate process is an older technology, although still viable depending on feedstock for the production of TiO2 pigment. The reason for that, the chloride processing route, the main reason that it’s been used, apart from the fact that it’s a cheaper operating cost is that just about all feed stocks are eligible for conversion to pigment via the chloride technology. The sulphate processing has a very narrow suite of feed stocks that are eligible for upgrading via that process. As I said, just about everything is suitable for chloride production; there are technical constraints around which feed stocks are suitable for pigment via the sulphate route.

TiO2 grade is the key driver of chloride process and profitability, generally because the chlorinators operate on either a chloride constraint or a chlorination constraint, so hence the more TiO2 you put in the front end the more output you're going to get per tonne of feed. Again and lower production costs, everything that’s not TiO2 is basically a cost driver for the chloride processing either in waste disposal, lost chlorine or neutralisation costs. The operability as well with a higher grade feed stock is generally more stable in composition and the trace elements, for example, the lower boiling point chlorides, calcium magnesium they cause operational difficulties, so again the less abundant they are the more operable the chlorinator is. And again waste disposal - the less non TiO2 the less waste it has to be disposed of.

Feed stocks for the chloride process and production of pigment: chloride ilmenite, synthetic rutile, rutile or upgraded slag. And I guess it’s the industry preference. Again being a natural product it’s in limited supply.

I’ll flick through sulphate pigment. The value of higher grade feedstock is limited, so the advantage of say sulphate slag over ilmenite is limited in terms of the amount of TiO2 that can be produced, because the reaction rate of the slag is a lot lower than the ilmenite. The high grade feed however does reduce the production costs, it might avoid the cost of scrap iron for reducing the ferric and ferrous sulphate and that’s neutralisation chemicals. No real difference in operability, but again the major difference is around waste and how much it costs and where it can be stored and what the critical volumes are with the sulphate process. Traditional feeds, ilmenite between 48% and 56% TiO2, obviously they prefer around 56%. However they want to maximise the amount of ferrous iron and minimise the ferric iron. Basically if it’s present it has to be removed and if there’s no market for copper it becomes a very high cost.

The sulphate slag, less iron, less waste, it needs to contain certain amounts of magnesium, to ensure that TiO2 phases are in soluble form, but it does require higher acid concentration, which reduces the ability to recycle acid. Feedstock interchangeability is a question. The lower the TiO2 it does reduce the pigment production in the range between 54% and 56% in sulphate plants. Most plants can convert from, for example, ilmenite to slag, but it’s very hard to go the other way, because it requires additional infrastructure and equipment. The chloride plants, the only ones that can take chloride ilmenite are DuPont’s. But most of them operate on a feed blend and some of them actually rely on Iluka’s high grade product to dilute other lower grade products and maximise their output. And those that are used to the higher grade feeds, synthetic rutile, chloride slag or natural rutile, if you reduce the TiO2 input then it reduces their output.

Natural rutile is a substitute. Natural rutile is less reactive than the slags and synthetic rutile, so it will slow the reaction rate of the chlorinators down and it may constrain their output also and obviously some of them have relied on Iluka for that grade boost and with us restricting our output that has put pressure on the price of the high grade feedstocks. For the chloride producers to modify their plant it’s very capital intensive and generally it has to be a whole new train, very little expansion within the train itself. And there’s fairly low surety around the supply of these high grade TiO2 feedstocks and hence some of the pressure on pricing of our customers.