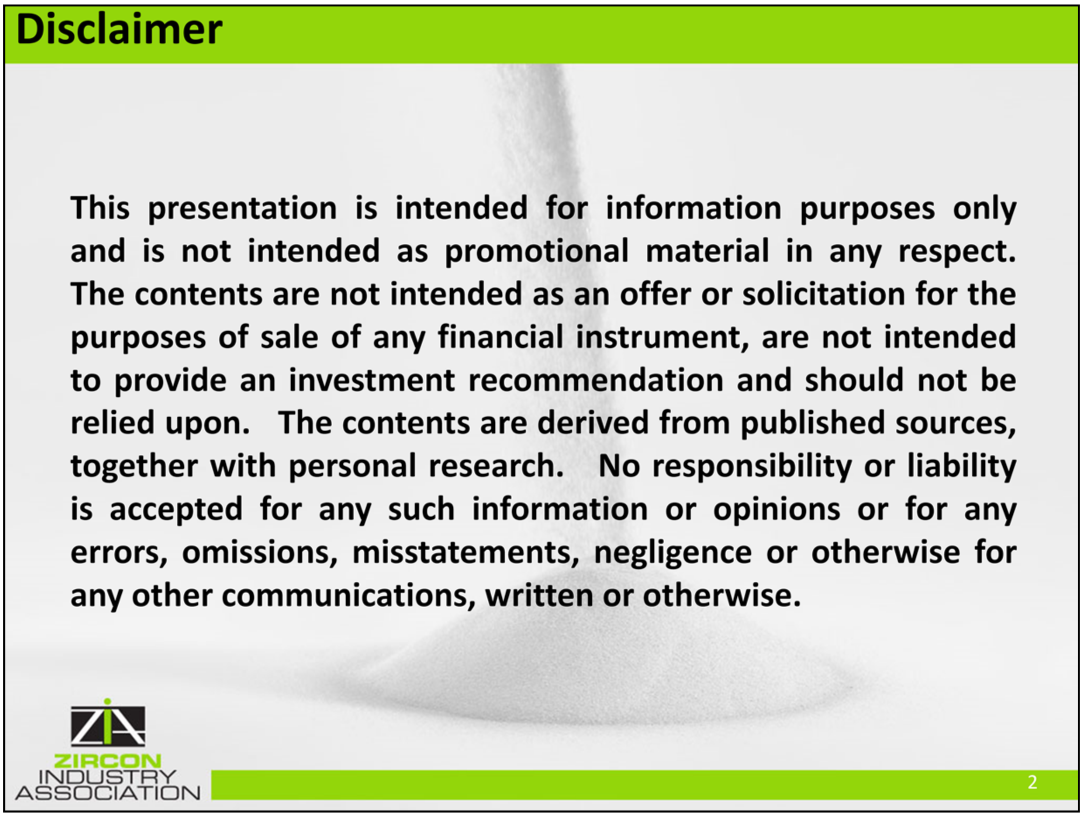
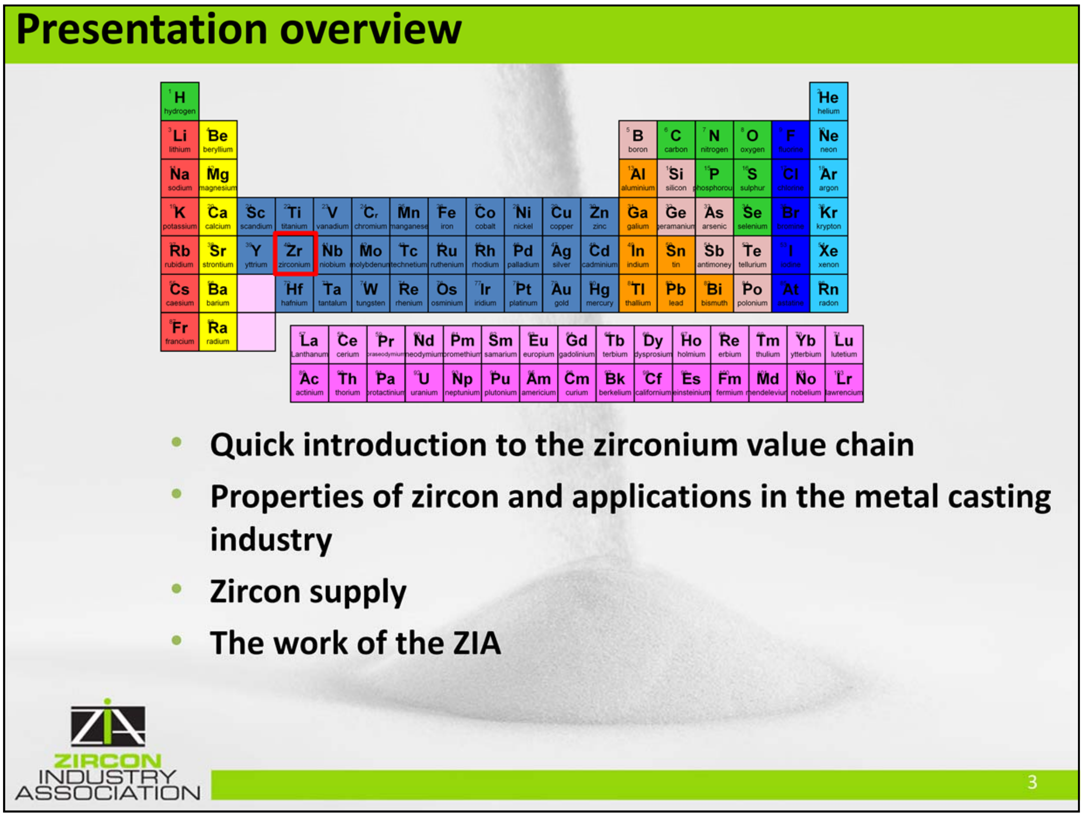
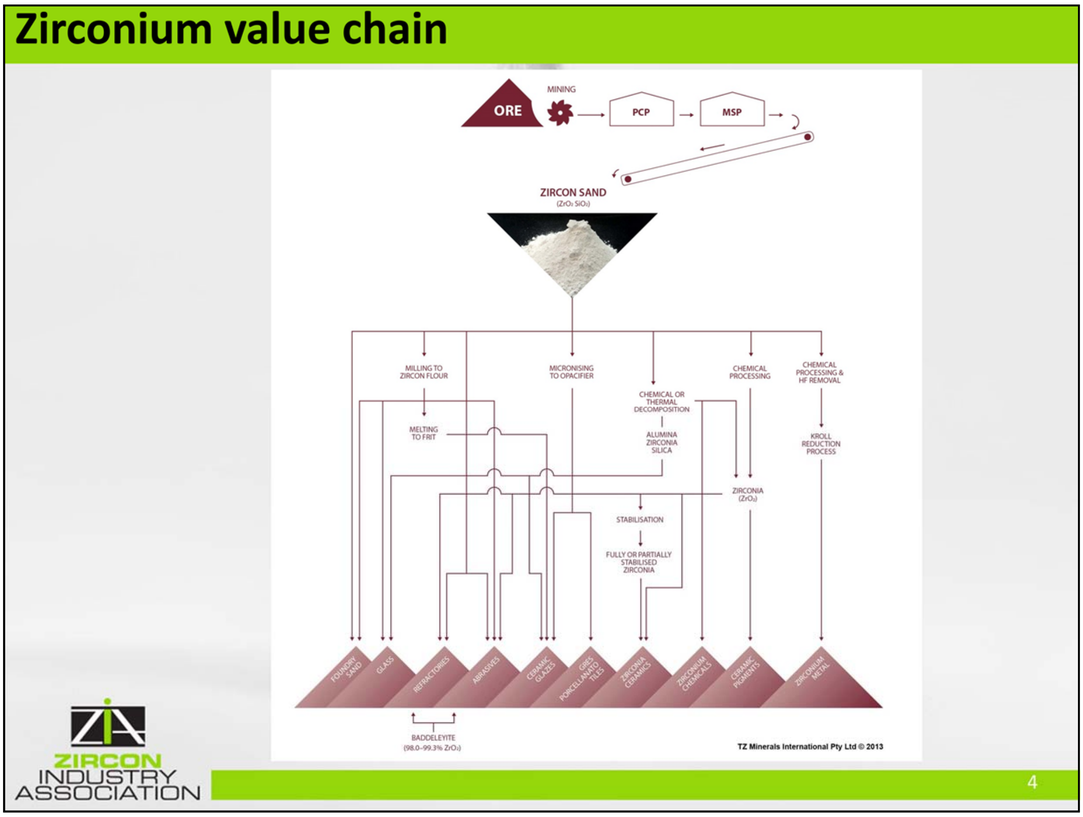
First of all, thanks to IMformed for having invited ZIA to present at this forum.



Secondly, the usual disclaimer - in essence, don’t bet your life savings on the basis of anything that you see or hear during this presentation.



The content of my presentation is as per this slide ……



I am indebted to TZMI for this chart, depicting the zirconium value chain, from mining through to downstream users - although not down to the ultimate end users - zircon and its derivatives can be found in many aspects of our daily lives.

Zircon is found in so-called mineral sands, containing mainly the titanium minerals ilmenite and rutile, and zircon. Mineral sands undergo two main stages of beneficiation - first production of a heavy mineral concentrate and secondly separation into the various constituent minerals.

Zircon can be used directly in sand form, as a milled product down to micron sizes and as feedstock for a wide range of oxides and chemicals for eventual use in a wide variety of end uses.

Properties of zircon

High refractive index	important in ceramics where zircon acts as an opacifier and enhances whiteness
High hardness	important in ceramics giving resistance to scratching and mechanical damage
High melting point	Important in the refractory industry [and by extension the metal casting industry]
High spatial and thermal stability at elevated temperatures	important in the metal casting and refractory industries
Low coefficient of linear expansion - good resistance to thermal shock	important in the metal casting and refractory industries
Moderate to high thermal conductivity	important in the metal casting and refractory industries
Low wettability by molten metal	important in the metal casting and refractory industries
Chemical stability	Important in many applications, including metal casting
Low solubility in molten silica or silicates	important for glass refractories
Clean and round grains, which can be bonded at little cost and with little material	important in the metal casting and refractory industries
Binding ability with all organic and inorganic moulding sand binders	important in the metal casting and refractory industries
Good dielectric properties	important for technical and advanced ceramics

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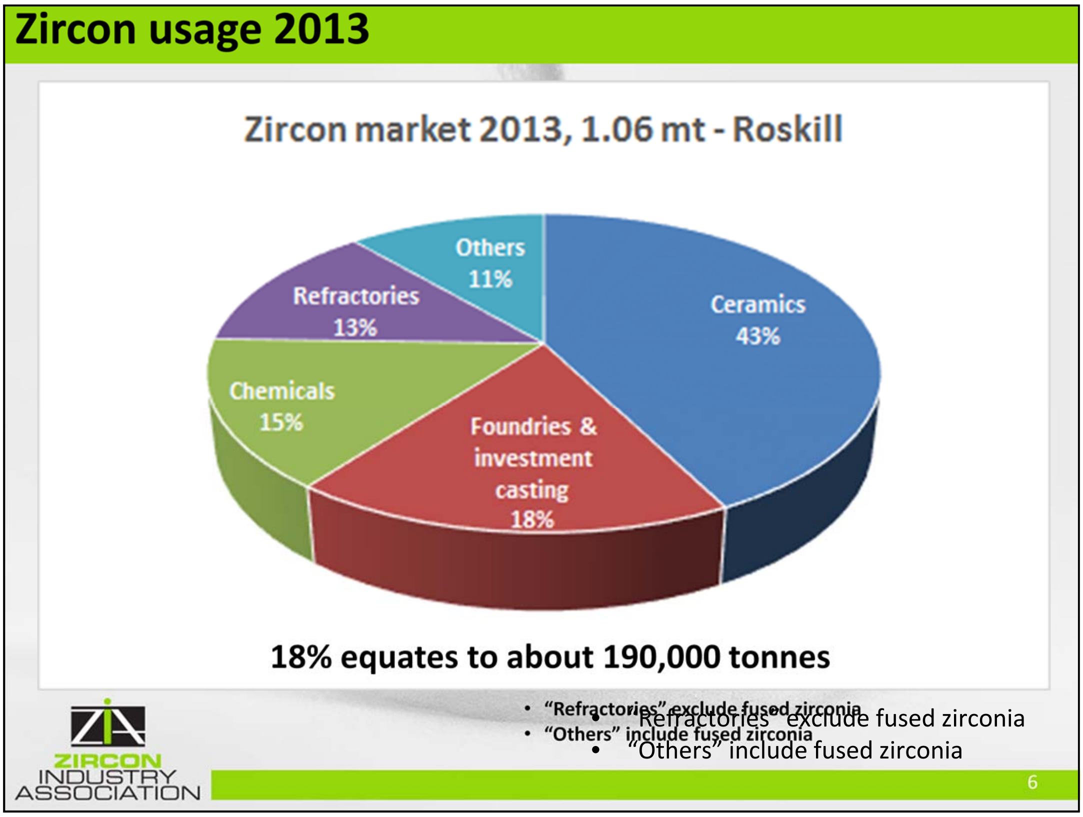
Zircon has a unique set of properties which make it the preferred feedstock for a number of applications.   These properties are summarised here - those in red relate to the metal casting industry - I won't talk in detail to this slide, but will refer to some of the properties in the forthcoming slides.



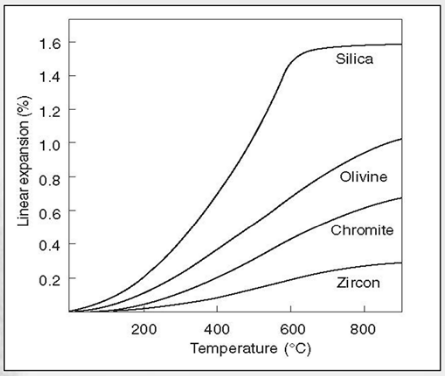
This chart is a broad representation of the global zircon market in 2013, based on data from Roskill's latest report – thanks to Roskill for allowing me to show these data. A couple of detailed footnotes are shown at the bottom right.

As ever, ceramics accounts for the single largest market share with 43% of the 1.06 mt market in 2013. This number is lower than the corresponding 49% from TZMI's 2014 report – but Roskill and TZMI have very similar views about the size of the total market in 2013, i.e. just over 1 million tonnes.

The 18% share of foundries and investment casting equates to about 190,000 tonnes.

Sand casting - benefits of zircon

- **Clean and round grains, allowing easy bonding together + high ability to bind with all organic and inorganic sand binders**
- **Low thermal expansion coefficient + high spatial stability at elevated temperatures = no expansion defects**
- **High thermal conductivity = faster cooling than with silica sand**
- **Chilling effect of zircon can be used to produce favourable thermal gradients for directional solidification and sounder castings.**
- **Zircon does not react with iron oxide = sand burn-on defects can be avoided**



Source: Foseco Ferrous Foundryman's Handbook

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Now let's turn to the various metal casting applications, first of all sand casting. Here are the main properties of zircon which make it suitable for this application …….

Sand casting - use of zircon

- **Used with chemical binders for high quality steel castings and critical iron castings:**
  - **high temperature applications + larger castings = higher zircon usage**
- **Zircon has low acid demand and can be used with all chemical binder systems.**
- **The relatively high cost of zircon has led to significant substitution by chromite and ceramic beads:**
  - **chromite has higher chilling effect than zircon, but higher acid demand**
  - **chromite is less easy to reclaim than zircon**
  - **per Roskill, the use of chromite in foundry sands increased by an estimated 7% py between 2003 and 2013, compared to 1.4% py for zircon sand over the same period.**

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Zircon is the preferred material for steel castings, especially for high temperature applications and larger castings.

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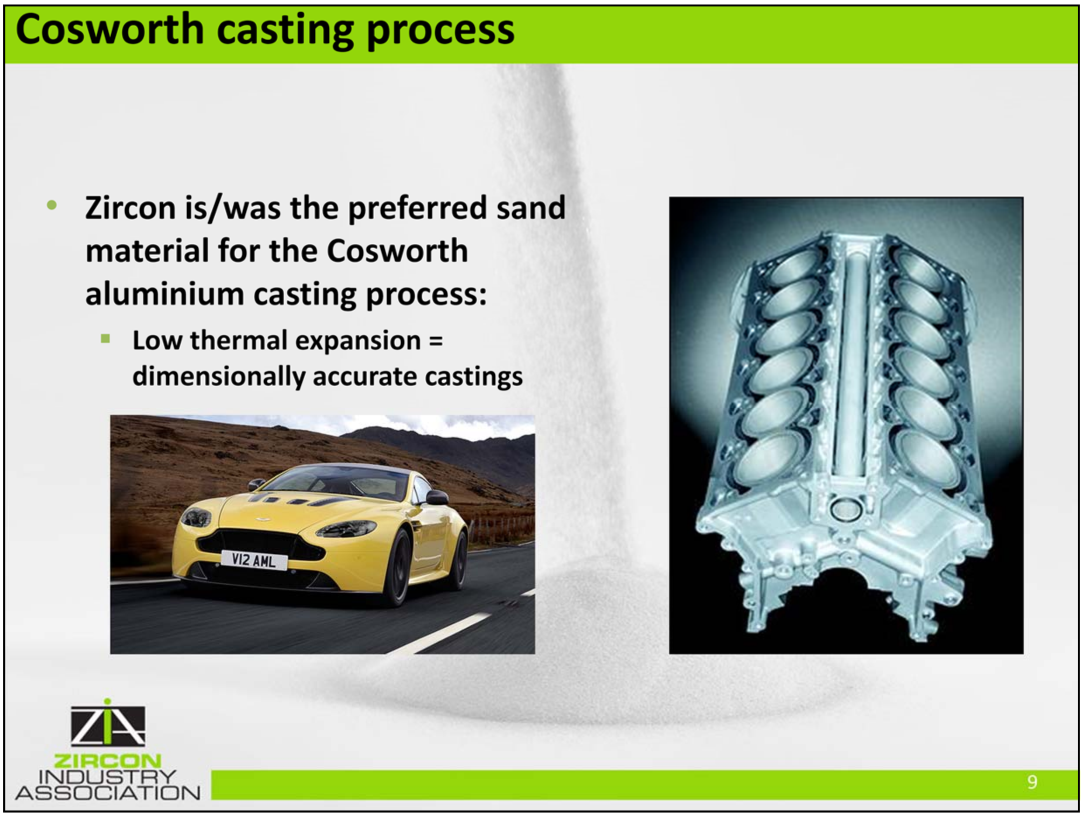

Allow my some nostalgia with this slide - in the days of Raw Material Solutions, our mineral distribution business, now part of Prince Minerals, Cosworth Technology was one of our main customers.   It's proprietary, counter-gravity casting process for production of aluminium alloy castings uses only zircon, due to its low thermal expansion which enables dimensionally accurate castings.   Sadly, most of the Cosworth process foundries have been closed, but a couple are still operating in the UK as far as I know, serving the Formula 1 market.

One of the company's clients was Aston Martin and Cosworth produced its V12 cylinder block.   I always thought that a scrap block would make a wonderful wine rack, but could never get hold of one!

Coatings

- Coatings are used to eliminate casting defects and improve surface finish of castings. They also prevent metal/mould reaction, influence metallurgical properties, increase the temperature stability of the mould material and restrict/redirect possible gas defects.
- The mineral filler system in coatings is key and is the main barrier in resisting heat transfer from the molten metal to the sand mould or core.
- The choice of filler material is critical in achieving a good quality casting:
  - by not melting or breaking down under high temperature/pressure
  - by insulating the mould/core from thermal shock by molten metal

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Now turning to refractory coatings …..

Coatings - use of zircon

- Zircon is used in the form of flour, typically 200-300 mesh.
- Zircon enables coatings to provide a heat resistant barrier that protects sand moulds and cores from molten metal leaving a defect free, smooth casting finish.
- Zircon imparts high refractoriness to coatings, as well as a high melting point and thermal stability at elevated temperatures.
- Suitable for the high pour temperatures of iron and steel, exceeding 1600^{o}C.
- Good chilling characteristics for aluminium castings.

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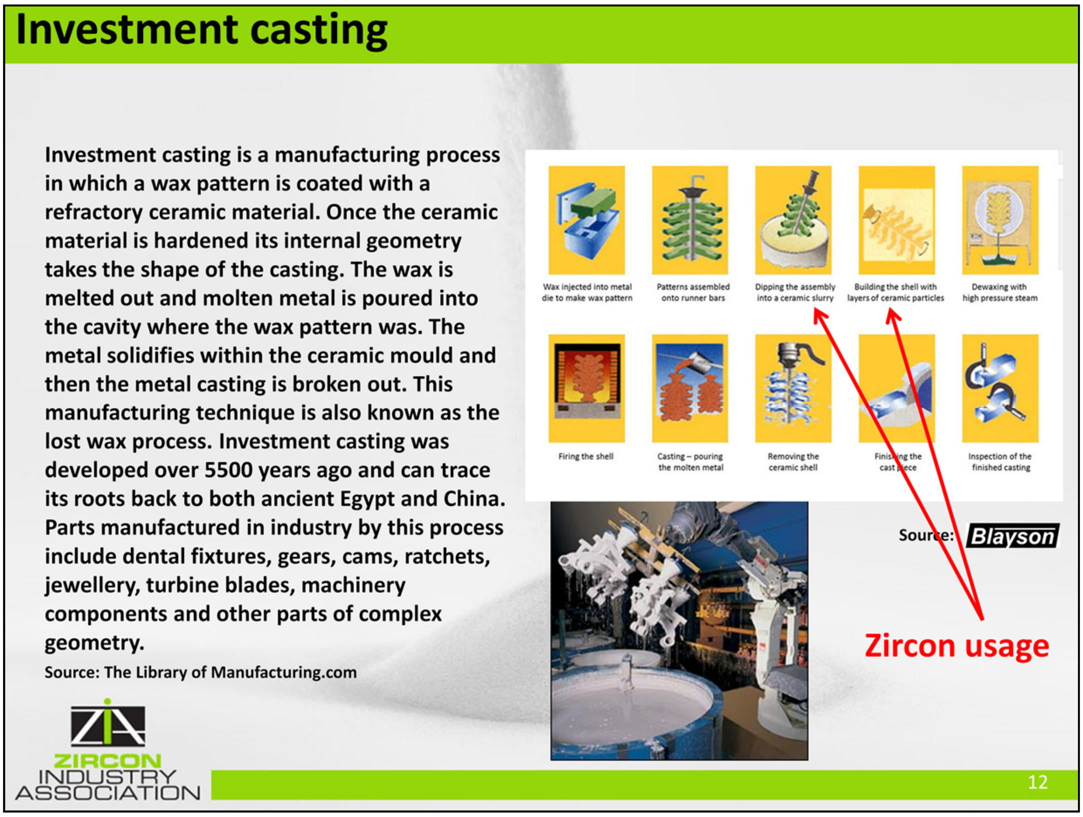
In coatings …….



I suspect that most here are familiar with the investment casting process - for those that are not, the text on the left is a summary I found on the internet. The graphic on the right is a good pictorial representation. It is in the ceramic shell which covers the wax patterns that zircon is used.

The ceramic shell, known as the *investment*, is produced by three repeating steps: coating, stuccoing, and hardening. The first step involves dipping the cluster of patterns into a slurry of fine refractory material and then letting any excess drain off, so a uniform surface finish is produced. This fine material enables a smooth surface finish and reproduction of fine details. In the second step, the cluster is *stuccoed* with a coarse ceramic particle, by dipping it into a fluidised bed, placing it in a rainfall-sander, or by manual application. Finally, the shell is allowed to harden.

Investment casting - use of zircon

- Zircon is used in the form of both sand and flour [typically 200 mesh], both calcined and uncalcined.
- Zircon is used in the primary coat which controls the quality of the casting surface and initiates the alloy solidification process. Lime-stabilised zirconia is also used in the primary coat, mainly for titanium alloys.
- Key properties of zircon are high refractoriness, chemical inertness (i.e. no or low reactivity with the molten alloy), low coefficient of thermal expansion.
- Since the cast metal does not stick to the mould even at high casting temperatures, easy separation is achieved with the casting needing minimal secondary finishing.

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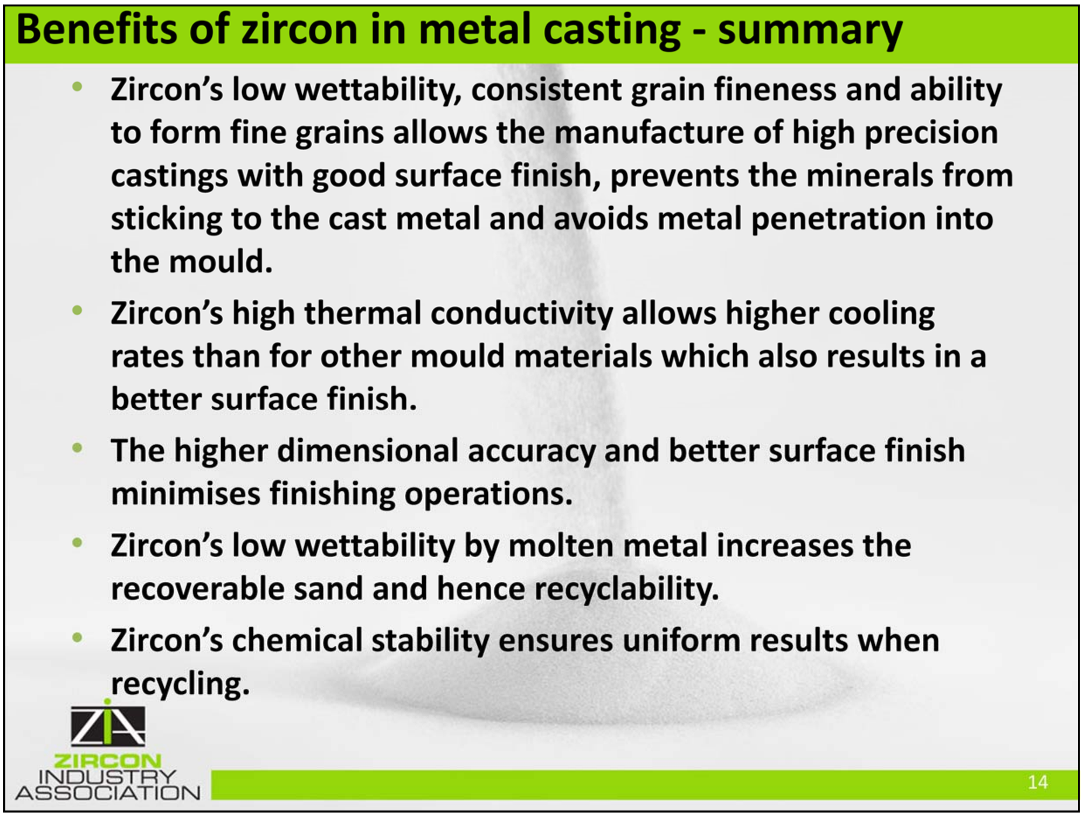
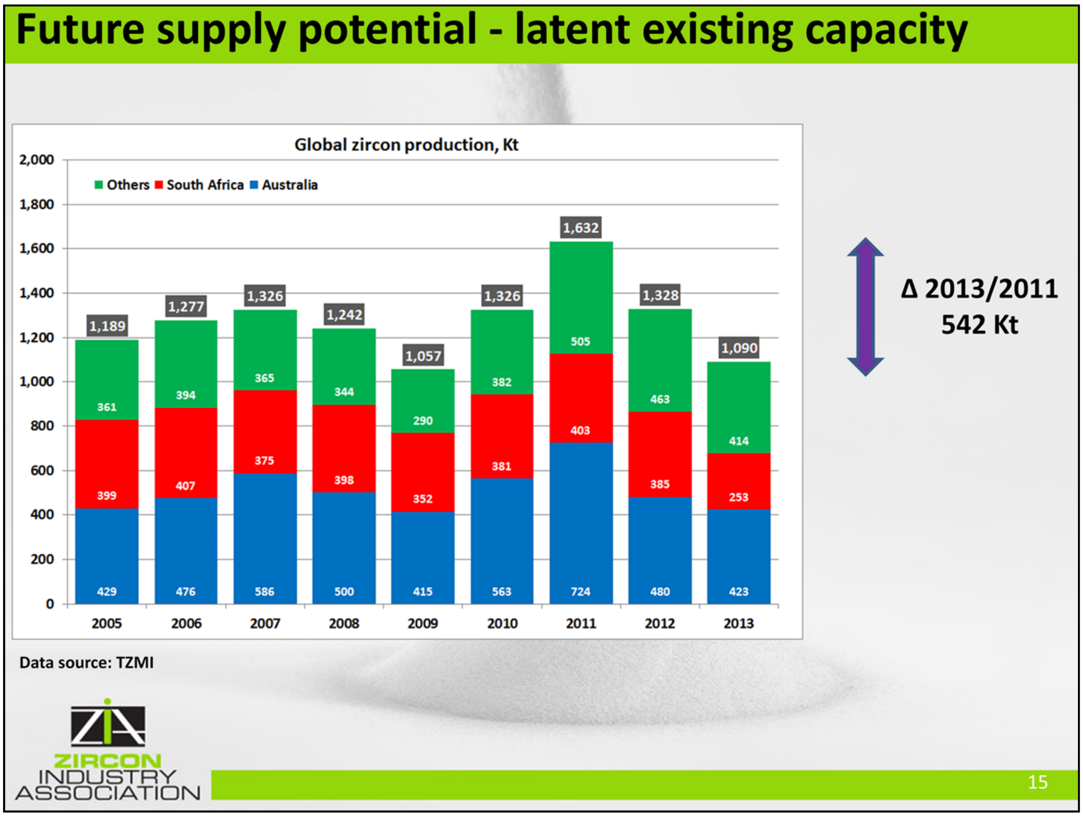


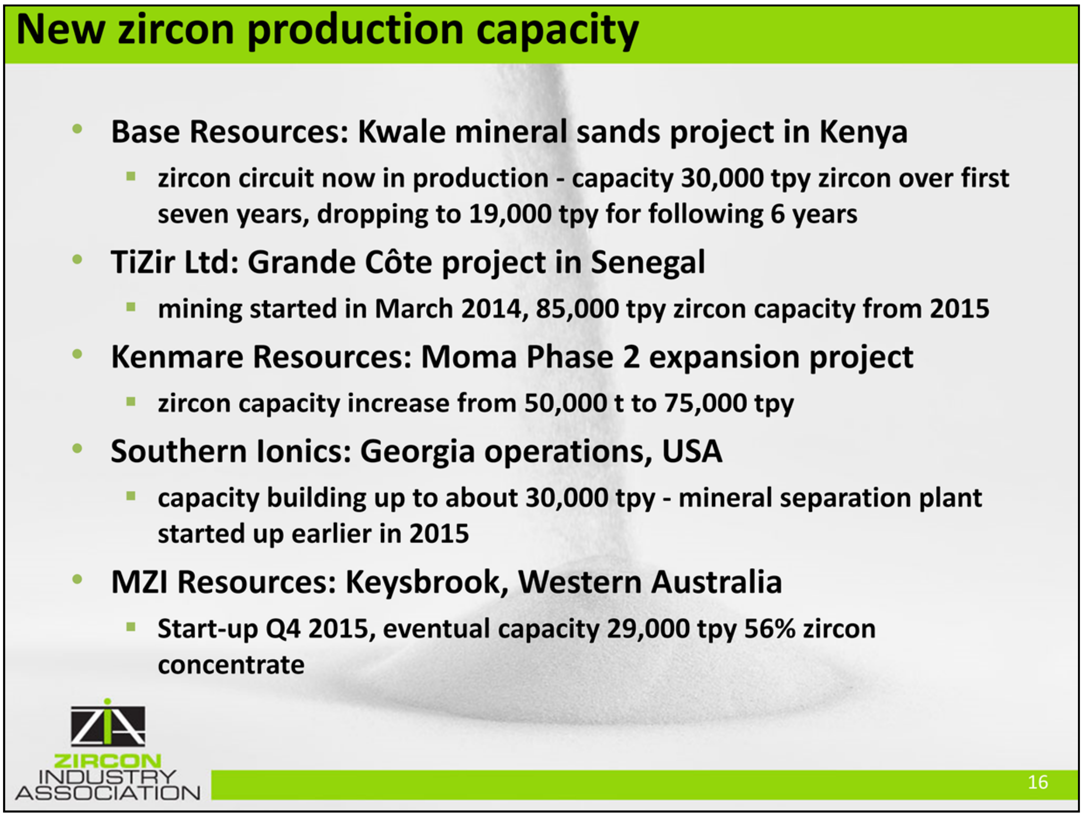
So, to summarise ……



One of the messages that we want to convey to the R&D community and developers of new applications is that, contrary to some articles and reports, supply of zircon should not be a constraint to their activities for the foreseeable future.

As can be seen from this chart, the main sources of zircon are Australia and South Africa. Others include Mozambique, Senegal, India, Vietnam, China and Indonesia. As can be seen, the peak production level was in 2011 with more than 1.6 million tonnes. Production fell dramatically over the next couple of years, to just over one million tonnes in 2013.

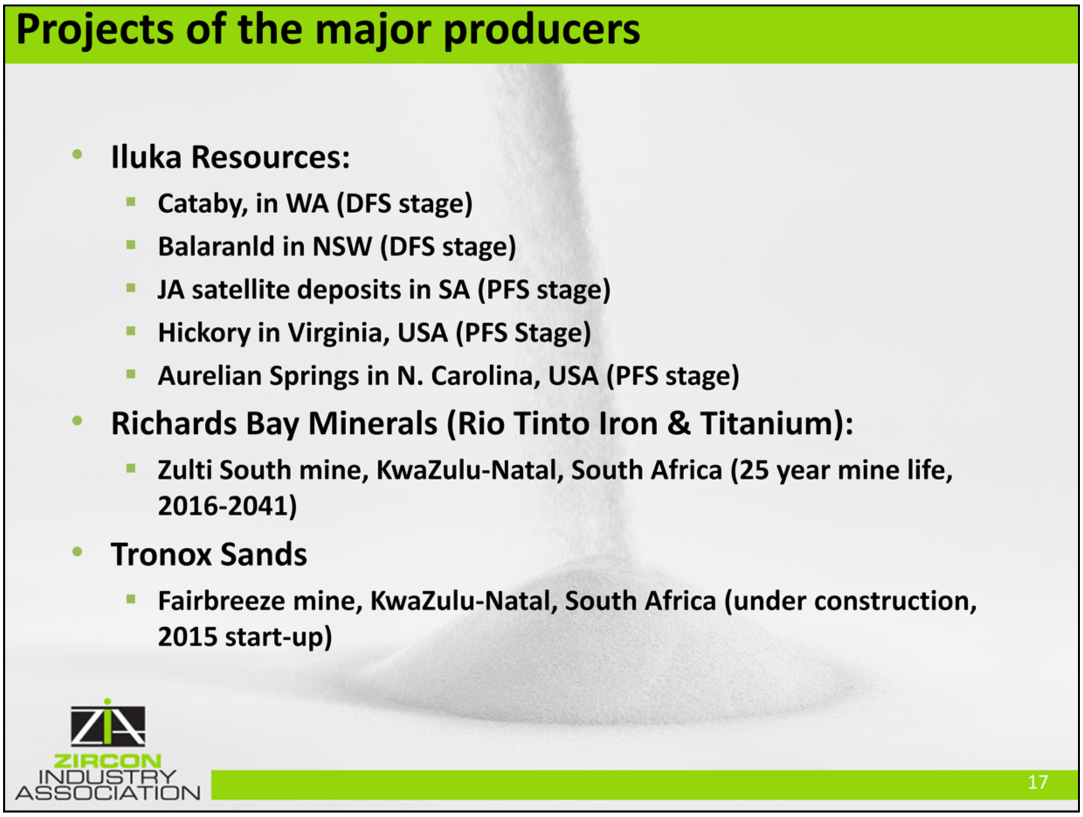
It can be implied from this chart is that there is considerable latent capacity out there - → the delta between the high of 2011 and the low of 2013 was about 540,000 tonnes. However, it should be said that the top slice of the production in 2011 was induced by the strength of demand which allowed prices to rise very rapidly - some of this incremental production might not be economic at today's less stratospheric price levels. It is also arguable that the rapid increase in prices incentivised some buyers to go long in anticipation of further price rises - considering some of the price forecasts being made by analysts at the time, such a strategy was not unreasonable. It is probably also fair to say that there is still some residual excess inventory at various points along the supply chain.



There were several new entrants to the market and some capacity expansions last year and one new project is scheduled for later this year:

Read from the slide.

In conclusion it seems reasonable to say that existing capacity is adequate for the foreseeable future, whatever that is, let's say 5-10 years. As we go out further into the future, price levels will have to be such as to support the development of new sources.

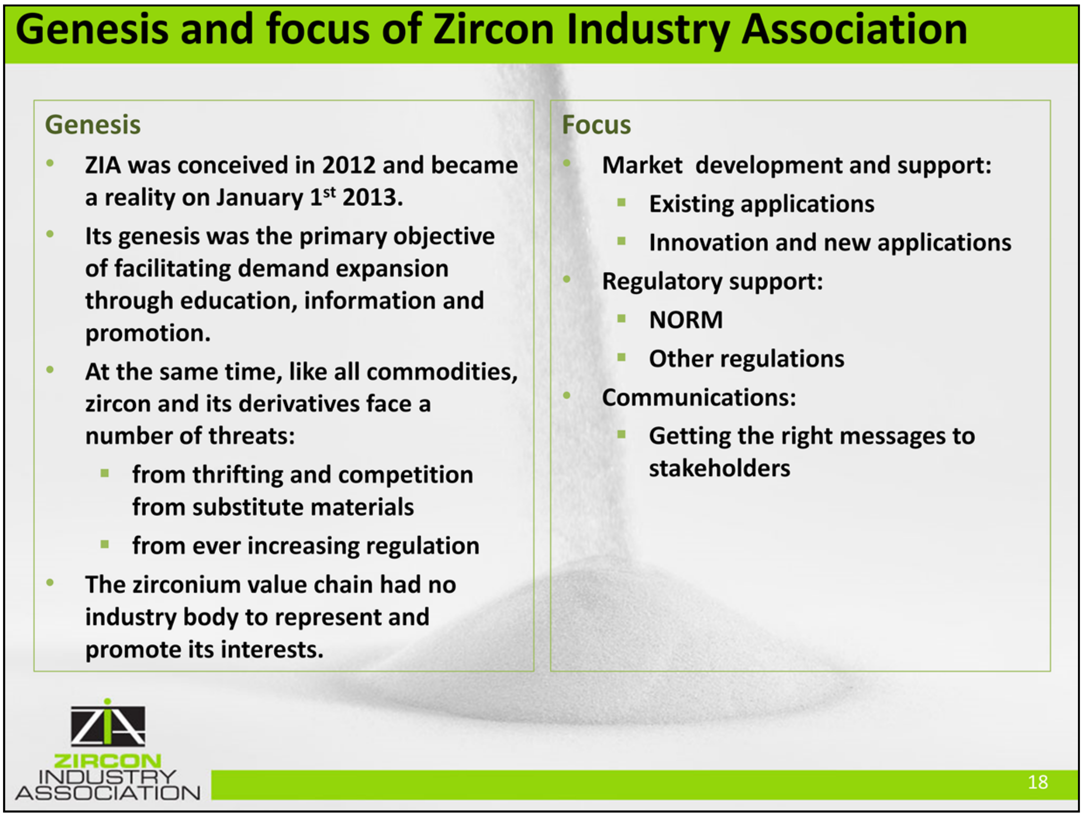


One should not forget that the existing mineral sands mines are at varying stages of maturity and that production from some of them can be expected to decline in the years ahead, meaning that new, replacement capacity will be needed to support existing and incremental demand.

The three major zircon producers, Iluka Resources, Richards Bay Minerals and Tronox Sands all have projects at various stages of development. The most advanced projects are listed on this slide and represent sustaining as well as potentially expansionary capital investment.

There are many other projects out there with the potential to add to the zircon supply. In this context, there is an obvious caveat: that is that market prices must be adequate to support them.

One more caveat: the zircon content in the mineral assemblages of many of the new projects is not as high as for some of the mines operating today. The implication of this is that for such projects, demand and pricing for TiO_2 feedstock is likely to be a more important driver than demand for zircon itself.



→ As said here, the Zircon Industry Association was conceived during the course of 2012 and was born on January 1st 2013. Its genesis was a proactive move, aimed at facilitating demand expansion through education, information and promotion to stakeholders, both present and future.

At the same time, this strategy would enable the industry to respond to some of the threats common to many commodities, for example thrifting and competition from substitute materials and an increasingly regulated industrial and consumer environment.

Market support and development are vital for the sustainable growth of any industry and individual companies' activities in this area can be enhanced by an industry approach. In the regulatory space, regulators generally prefer to deal with industry associations rather than individual companies.

The industry had no representative body, hence the ZIA and our goal is ambitious - to be the voice of the entire zirconium value chain. So far, we have made good progress, but there is still some way to go.

→ As shown by the box on the right side, our activities are now focussed on the three pillars of market development and support, regulatory support and communications.

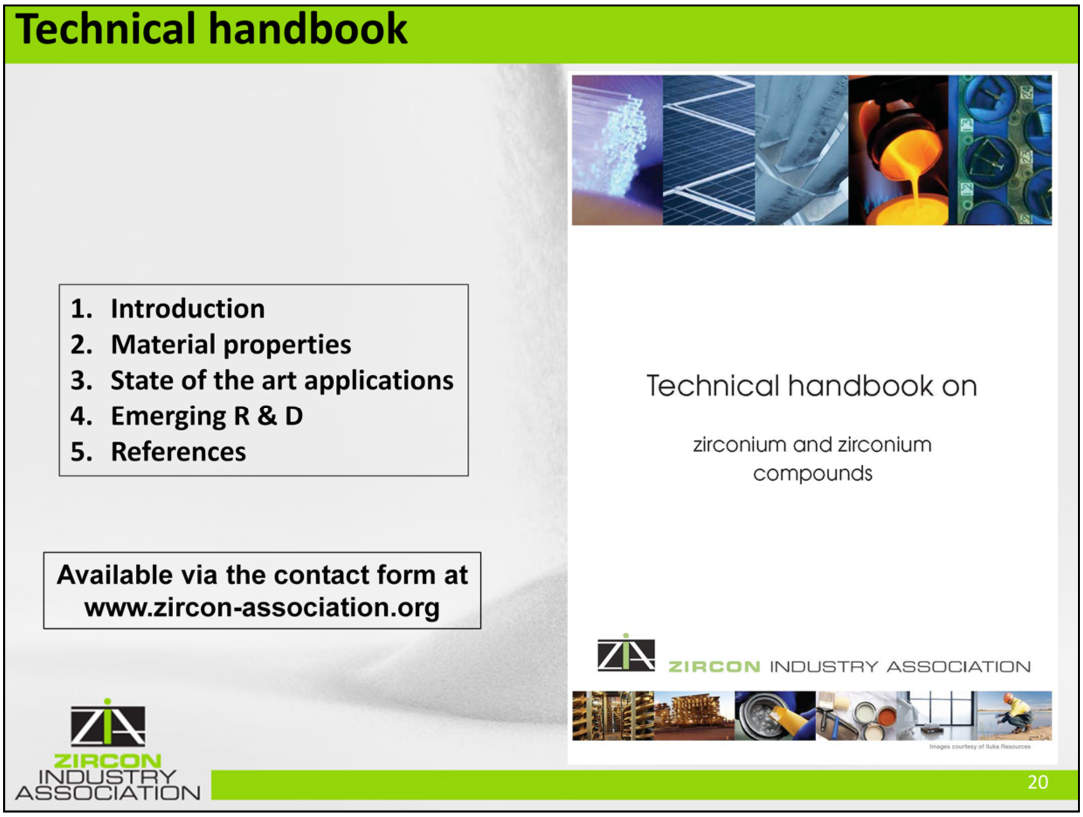
Talking of regulation, zircon is a NORM. Movement of NORM is governed by the Transport regulations, but on arrival at destination the regulatory regime switches to the Exemption regulations.

→ However, there are grey areas at the transition point, for example when the material is in storage. Under the transport regulations, zircon is in effect exempt, but this is not the case for the exemption regulations where the threshold is 1 $Bq.g^{-1}$. There are differences in application of these regulations from one jurisdiction to another and sometimes even within a single jurisdiction.

→ For a new cross-border movement especially, provision of activity data in advance to the regulators in the destination country, as well as to new carriers, should facilitate the process. Inclusion of a suitably worded SDS in the shipping documents is also a good idea.

→ ZIA does intend to produce guidance to facilitate cross border movements.

Regulations are a moving target - they are evolving all the time and what is important is to anticipate changes - once a new regulation comes into effect, it’s too late! Thus an important part of ZIA’s work is to keep abreast of regulatory developments. Our membership of the International Council of Mining and Metals, with its product stewardship and chemicals regulation programmes, in an important benefit in that respect.



An important first project for us was the production of our Technical Handbook on zirconium and zirconium compounds, published in November 2013. We commissioned this from a team led by Professor Julian Allwood in the Engineering Department of Cambridge University.

The handbook has four main chapters as shown as well as a list of references and is available to anyone who wants it, by application through the contact form on our website.

We are in the process of updating this and the second edition should be available in Q4 this year.

Finally, I'd like to include a plug for the Zircon Conference that we are organising on October 4th/5th this year in Florence - we will soon be announcing details, so please keep an eye on our website!