Plenary Lectures of General Interest for all Conference Participants (as of 07.04.2017)

Monday, June 26, 2017; 9.30 am
Dr. *Thomas Bünger*, Aurubis AG, Germany:
Metals for Progress – Challenges of Base Metals Industry in Future

Monday, June 26, 2017; 10.00 am
Professor *Rodney T. Jones*, Mintek, South Africa
Current status of the primary and secondary smelting industries in South Africa

---

Tuesday, June 27, 2017; 9.00 am
Juan Rayo, Chile
Mining in South America – Trends and Innovations

Tuesday, June 27, 2017; 9.30 am
David H. DeYoung, Ph.D., Alcoa Technical Center, USA
The Smelting of Primary Aluminum – Past, Present, and Future

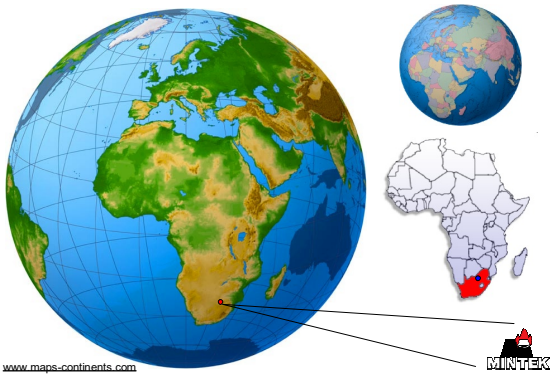
Tuesday, June 27, 2017; 10.00 am
Professor *Shuji Owada*, Waseda University, Japan
Technical and Process Innovation in Resources Recycling by Applying Intelligent Comminution and Physical Separation

---

Wednesday, June 28, 2017; 9.00 am
Liu Cheng, China ENFI Engineering Corporation, China
Development of Lead and Zinc Industry in China

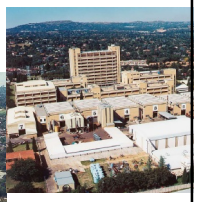
Wednesday, June 28, 2017; 9.30 am
Dr. *Christian Hagelücken*, Umicore AG & Co KG, Germany
The EU Circular Economy Package – an opportunity to improve metals recycling

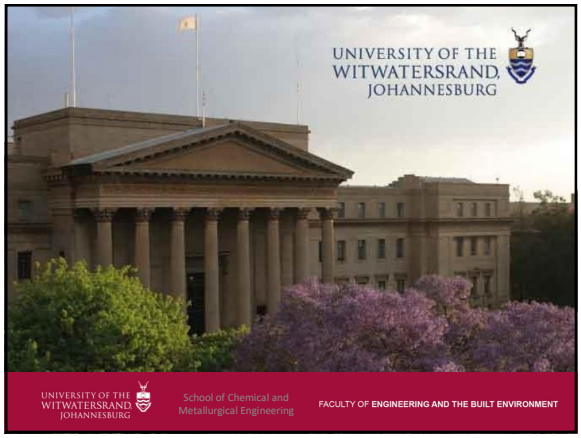
Mintek, Randburg, Johannesburg, South Africa



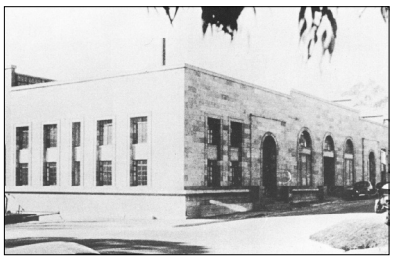
Mintek (Established 1934)

- Government-owned minerals research organization
- Employs ~750 people (250 professionals)
- Annual budget of ~R500m (Euro 35m)
- State & corporate funding (50:50)





Minerals Research Laboratory (1934-1944)

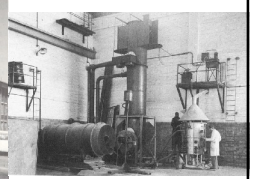


Wits University campus (1935-1948)

MINTEK

Government Metallurgical Laboratory (1944-1966)

National Institute for Metallurgy (NIM) (1966-1981)



Yale Road, Milner Park (1946-1976)

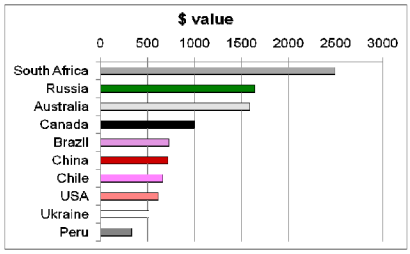
MINTEK

Council for Mineral Technology (1981 →)

Randburg (1976→)

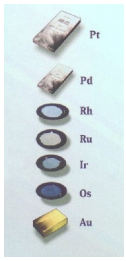
Mineral wealth of South Africa

- Southern Africa is particularly well endowed with a host of minerals. A study by Citibank in 2010 concluded that South Africa, of all the world's mining countries, had the highest value of mineral (non-oil) reserves in the ground. The combined contained value of South Africa's minerals was estimated as US $2.5 trillion at then-current prices, more than Russia and Australia, each at about $1.6 trillion.

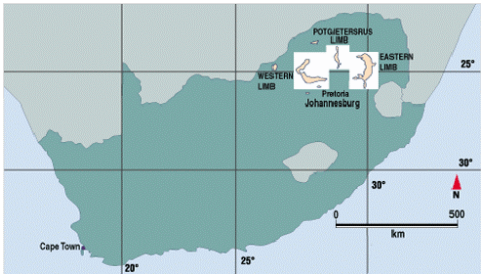


Mineral wealth of South Africa

- South Africa has over 90% of the world's reserves of platinum group metals, the world's largest chromite reserves, as well as significant quantities of manganese, vanadium, and titanium, amongst other metals
- Southern Africa has a relatively long history of small-scale mining and smelting, and a more recent but highly prominent history of smelting on an industrial scale
- It should be remembered that electric smelting is just over 100 years old



Bushveld Complex



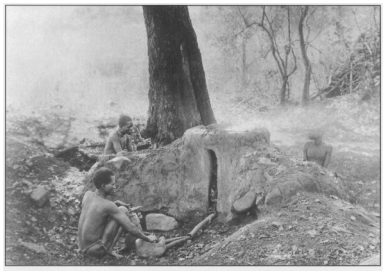
Largest known layered igneous complex of its type in the world:
350 km west to east; 250 km north to south

South Africa's production and reserves (DMR & USGS)

	Annual Production	Production % of global	SA Reserves % of global
PGMs	262 t	51.4 (1st)	**95.3 (1st)** (320y)
Cr	14.8 Mt	49.2 (1st)	**35.8 (1st)**
Mn	13.9 Mt	34.4 (1st)	**32.0 (1st)** (>30y)
V	17 kt	15.8	18.4
Cr alloys	3497 kt	30.8	-
Mn alloys	366 kt	8.9	-
Ti (ilmenite)	2511 kt	22.2	8.2
Ti (rutile)		8.7	13.9
Gold	142 t	4.6 (7th)	10.6 (3rd) (40y)
Coal	253 Mt	3.7 (9th)	3.4 (210y)
Iron	66 Mt	1.9	0.6 (<20y)
Nickel	49 kt	2.2	4.7
Copper	64 kt	0.3	0.2

40% of South Africa's copper production is a by-product of the PGM industry

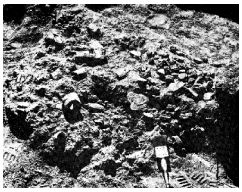
Early smelting in South Africa



'Makaties iron foundry ... east of the Spelonken'. This remarkable photograph, taken in 1888 by H. Gros, shows a typical Venda iron-smelting furnace in operation. The operators are each using two bellows made of hide. Straightened antelope horns channel the air blast through three clay tuyères to the charge in the furnace (Africana Library, Johannesburg)

Early smelting of iron in South Africa

- Mason (1974) produced evidence from Broederstroom (near what is now Johanesburg) for the production of iron and copper, the farming of cattle and sheep, and the construction of large villages, from at least AD 460 onwards
- *Earliest traces of iron smelting in the Transvaal. Tuyeres, iron slag, and iron ore, dated AD 460.*



- Low-shaft bloomery furnaces of the Iron Age were found at Melville Koppies (dated to ~1400 AD) and other sites in the vicinity of Johannesburg.

Early smelting of tin in South Africa

- Remnants of 'ancient' Iron Age tin workings, including small slag heaps, tuyeres, and pottery sherds, have been found at Rooiberg in the Waterberg area
- Some tin was found with a purity of approximately 95%
- Tin mining (of high-grade cassiterite) in this area goes back to at least the mid 1400s, based on radiocarbon dating of a piece of mining timber found in an ancient shaft. Dating of tin smelting furnaces is less certain, as only the bottoms of furnaces remain (containing slag and prills of tin). (Friede & Steel, 1976)
- It has been suggested that the original tin miners were contemporaries of the ancient gold miners of Zimbabwe who had moved south prospecting for gold and copper (from Phalaborwa and Messina)
- Friede (1980) suggests that ancient mining in the Transvaal ended around the middle of the 1800s, probably as a result of Nguni raids, and the emergence of three powerful kingdoms (Zulu, Matabele, and Sotho) from the succession of wars when many smaller tribes were displaced or destroyed

Diamonds and Gold

- Discovery of diamonds in Kimberley in 1867, and the discovery of gold, especially around Johannesburg in 1886, changed South Africa's economy from being based on agriculture to being based on mining
- The legacy of colonialism dates back to this period
- Mines required expensive machinery, and the consolidation of small claims, thereby ushering in the era of large capital and the mining magnates
- The money accrued from diamond mining in Kimberley provided capital for opening up the new goldfield

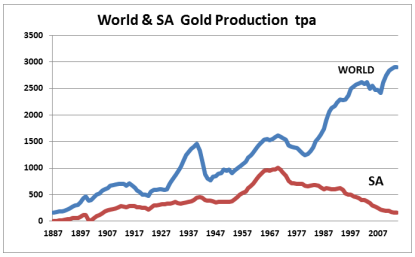
MINTEK

Perspective on South African gold

- The Witwatersrand gold basin is unique, being the most immense gold resource with the poorest grade
- It has yielded almost one third of all the gold ever mined in the world. More than 1.5 billion ounces of gold has been extracted.
- South Africa still has more gold underground than has been mined

MINTEK

Declining gold production in South Africa



Peak SA production was 1000 t in 1970
Production in 2016 was 141 t

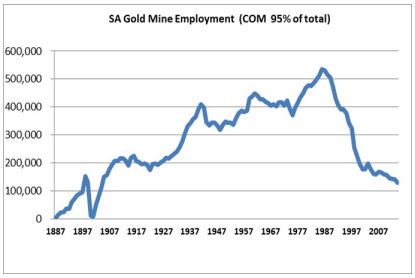
MINTEK

Decline in South African gold production

- South Africa was the largest producer until 2006 (300 t), even though no longer at its peak from 1970 (1000 t)
- Ten years later (200 t), it had fallen to seventh place, behind China, Australia, Russia, USA, Canada, and Peru
- The last shaft sinking to initiate a major gold mine in SA was in 1981 (Mponeng)

MINTEK

Employment has dropped by 400 000 gold miners



State of the South African gold industry

- "Today, it takes an average of 18 years from discovery of gold to first production, compared to 10 years a decade ago. While the grade of gold has fallen 3% per year since 2000 and prices are dropping, cost inflation is ever-present. Governments and communities are demanding greater benefits, and incidents of clashes with local communities have risen 22% per year over the past 10 years."

Drawing up a blueprint for the gold mine of the future
by Nick Holland, 4 November 2015

http://www.bdlive.co.za/opinion/2015/11/04/drawing-up-a-blueprint-for-the-gold-mine-of-the-future

Ancient history of copper smelting

- Smelting history goes back at least 6000 years to the copper smelters of the Timna valley near Eilat in Israel
- Copper is the world's oldest metal and was used in Africa more than 5000 years ago for water plumbing in the Pyramid of Cheops in Egypt. The Egyptians obtained their copper from Israel and from Cyprus.
- Copper artefacts found in sub-Saharan Africa date back to 4000 BC
- Ancient sites in present day Zambia and DRC date back to 400 AD

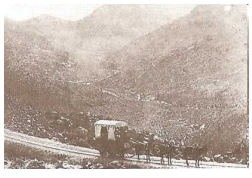
Ancient mining tools

Copper smelting – O'okiep, Messina, Palabora

- Industrial-scale smelting began in South Africa in the 1850s or 1860s when copper was produced by the O'okiep Copper Company in cupola furnaces
- Messina Copper Mine was producing a high-grade matte by 1914
- (Copper smelting started in the Zambian copper belt in 1931, with two reverberatory furnaces and two Peirce-Smith converters at Nkana)
- In 1966, Palabora Mining Company started smelting copper in a coal-fired reverberatory furnace and three Peirce-Smith converters

O'okiep Copper Company

- Simon van der Stel 'discovered' the 'Copper Mountain' at Springbok in 1685
- The first South African mining company was formed there in 1852 to mine the copper deposits. Other notable firsts for this mining district include the first South African geological report and geological map.
- In the 1860s, Okiep became the most important mine of the Cape Copper Company. In 1866, a narrow-gauge railway line was built to Port Nolloth on the coast. This line was primarily used to convey the partially smelted copper matte to the coast from where it was exported for further refining in South Wales. Because there was an insufficient supply of water to operate steam locomotives on this line, the service was pulled by mules until as late as 1890.



The mule train between O'okiep Mine & Port Nolloth, ~1880

O'okiep Copper Company

- Copper miners preparing to go underground at O'okiep, ~1890. Note the candles attached with clay to their helmets. (Cape Archives, Digging Deep)

O'okiep Copper Company

- Cupola furnaces were in place at the smelter
- Production by the Cape Copper Company ceased in 1919 as a result of the post-war economic slump, and Okiep soon became a ghost town
- The O'okiep Copper Company was floated on the New York stock exchange during the 1940s
- In the 1960s, O'okiep Copper Company paid the highest dividend ever on the NYSE for that period

O'okiep Mine ore dressing floors, ~1890

A Cornish Beam Engine House on the site of Okiep Mine

MINTEK

O'okiep Copper Company

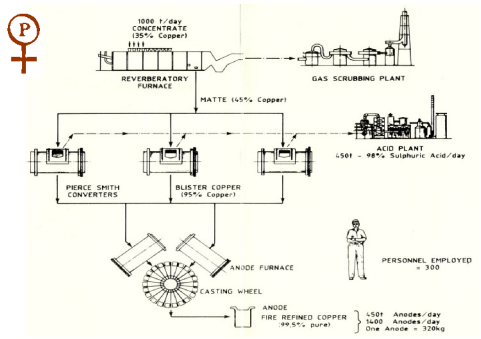
- In 1984, Newmont sold the Okiep Copper Company to Goldfields of South Africa
- Assets from the O'okiep Copper Company were acquired by Metorex in 1998. Reprocessing of the slag dump over a seven-year period by flotation methods started in 2002. Metorex managed the mine and smelter, sourced concentrate feed for the smelter, and marketed the resulting blister copper. O'okiep smelted its own concentrate, as well as concentrate from Maranda and Chibuluma. Concentrate was converted to blister copper at the smelter, and the product was exported, with the metal being refined in Europe.
- The O'okiep smelter consisted of a pulverised coal-fired reverbatory furnace and a converter, dating back to 1937.
- Today, Okiep (its modern spelling) is a small ex-mining town that is going through tough times, despite having been, at the turn of the previous century, arguably the richest copper mining area in the world.

MINTEK

Palabora Mining – Phalaborwa, South Africa

- The Palabora smelter commenced in 1966, and consists of a single coal-fired reverberatory furnace, three Peirce–Smith converters, two anode refining furnaces, a holding / scrap melting furnace and an anode casting wheel, and a sulfuric acid plant
- The smelter nameplate capacity was originally 80 kt/a, but was improved and upgraded to 120 kt/a by 1972
- Underground mining commenced 2001; open pit was closed end 2003
- In 2004, the smelter feed was supplemented with imported concentrates
- Originally a joint venture between Rio Tinto and Anglo-American, the facility is now operated by a new consortium comprising South African and Chinese interests
- Nominal copper capacity at Palabora is 160 kt/a

Palabora Mining Company – Smelter Flow Diagram



MINTEK

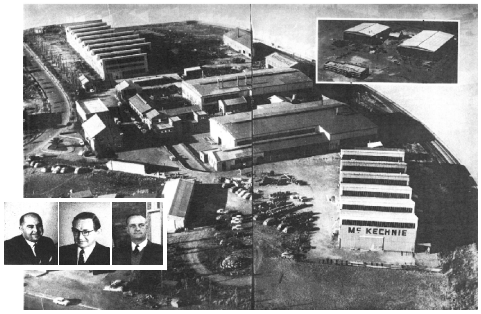
Palabora Mining Company

A mine, smelter, and wildlife sanctuary (adjacent to Kruger Park)

MINTEK

Copalcor – Germiston, South Africa

- Founded in 1949 as McKechnie Brothers SA (Pty) Ltd
- Photograph shows growth over first 10 years (1949-1959)



Copalcor – Germiston, South Africa

- South Africa's largest secondary copper smelter
- Scrap-melting induction furnaces supply molten metal for slab casting, hot rolling, and extrusion of copper and brass
- Three furnaces provide capacity to smelt over 400 tons per month, roughly 5 kt/a
- Copalcor also manufactures various furnace components, including busbars, contact shoes, furnace side-wall coolers, tap-blocks and launders


Furnace


Slab Casting


Hot Rolling

World mine production of copper in 2016, kt/a

Chile	5500	28%
Peru	2300	12%
China	1740	9%
DRC + Zambia	**1650**	**8%**
USA	1410	7%
Australia	970	5%
Canada	720	4%
Russia	710	4%
Mexico	620	3%
Other	3800	20%
TOTAL	**19 400**	**100%**

U.S. Geological Survey, Mineral Commodity Summaries, January 2017

Southern African Copper Smelters in operation

Smelter	Location	Copper capacity	
Kansanshi	Solwezi, Zambia	300 kt/a	IsaSmelt
KCM (Konkola Copper Mines)	Nchanga, Chingola, Zambia	300 kt/a	Flash
Chambishi (China Nonferrous Metal Mining Group)	Chambishi, Zambia	250 kt/a	IsaSmelt
Mopani	Mufulira, Zambia	185 kt/a	IsaSmelt
Palabora	Phalaborwa, South Africa	160 kt/a	Reverb
Dundee Precious Metals	Tsumeb, Namibia	45 kt/a	Ausmelt
BCL Ni-Cu smelter	Selebi Phikwe, Botswana	30 kt/a	(Flash)
Rubamin	Likasi, DRC	20 kt/a	
Copalcor	Germiston, South Africa	5 kt/a	
TOTAL		**1295 kt/a**	

Argent Silver Mine

- In 1891, silver was first produced at the Argent Mine near Delmas, in two reverberatory roasting furnaces and two blast furnaces
- An almost forgotten chapter in South Africa's smelting history
- Currently being studied by an industrial archaeologist

Argent Silver Mine

Foundations

•Rectangular foundations of a reverberatory furnace

•Circular foundations of a roaster

Argent Silver Mine

Blast furnace remnants

Argent Silver Mine

•Slag dump is extensive, and highly ordered

Early lead smelting

- In South Africa, lead was first discovered at the Maitland River in 1782, and was worked for a short period early in the 19th century (Snodgrass, 1986). Before the introduction of breech-loading arms, lead was smelted in the Transvaal for use in the Boer Republics. The lead deposits that were exploited were mainly in the Transvaal near Argent station, where a smelter was erected between 1889 and 1893. Between 1922 and 1925, the Argent Mines and Smelter were operated by Transvaal Silver & Base Metals Limited, which produced about 360 t of crude lead per month from a blast furnace for refining overseas.
- These Argent deposits were mined intermittently until 1957, when they finally closed down, the most productive periods being between 1882 and 1893, 1922 and 1925, and 1951 and 1957. A total of 16 250 t of metallic lead was produced.

Secondary lead smelting at Fry's Metals

- Fry's Metals and Castle Lead Works are members of the Zimco Group of Companies
- Castle Lead began manufacturing lead products near Cape Town Castle in 1933, and now has branches in Krugersdorp, South Africa, and in Kitwe, Zambia
- Fry's Metals began in Wadeville, Germiston ~1947
- Uses rotary furnaces to smelt recycled lead-acid batteries as well as lead concentrates. Refines lead, antimony, and tin alloys.
- Produces ~55 kt/a of lead and lead alloys for the battery and electrical cable industries

Iron and steel

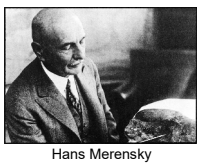
- Iron was first smelted on a large scale in South Africa in 1901, near Pietermaritzburg, in a primitive blast furnace. The Union Steel Corporation electrically melted steel scrap in 1911. The first industrial-scale smelting of iron ore began in Pretoria in 1918, in a blast furnace constructed by Professor George Stanley.

- The Iron and Steel Corporation of South Africa (Iscor) was formed in 1928.
- Iscor was later taken over by what is now Arcelor Mittal

Platinum and PGM smelting

- Platinum in the Bushveld Complex was first documented by William Bettel (the first President of what has become SAIMM) in 1906 (Cawthorn, 2007)
- The great geologist, PA Wagner, concluded in 1923 "that it would never pay to work the chromite rock for that metal (platinum) alone"
- Dr Hans Merensky (1871–1952) is regarded as the father of the platinum industry in South Africa, having discovered economic deposits

William Bettel



Hans Merensky

Platinum and PGM smelting

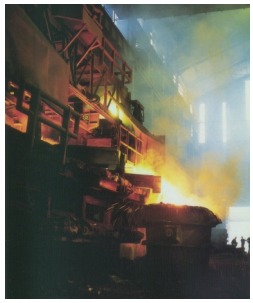
- Platinum Group Metals (PGMs) have been mined in South Africa since 1923
- The platinum smelting industry began in 1937 with a blast furnace and converter at Rustenburg Platinum Mines. This was replaced by a six-in-line electrical furnace in 1969. Subsequent furnaces have all been electrical.

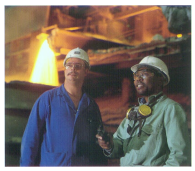
Anglo Platinum

Mortimer Smelter
Union Section

Waterval Smelter
Rustenburg Section

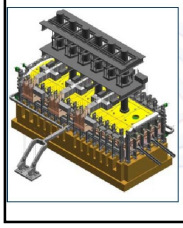
Anglo Platinum – Waterval Smelter





Anglo Platinum – Polokwane smelter

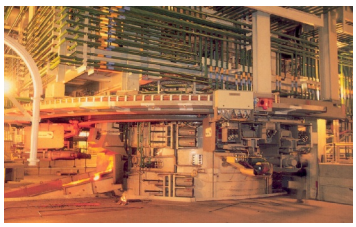
- High-power 68 MW six-in-line rectangular furnace switched on in 2003
- Furnace matte is sent to the Waterval smelter for centralised converting



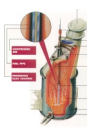
- Capacity :
  - 650,000 t/a (87 tph)
- Power :
  - 68 MW (168MVA)
- Power density :
  - 250 kW/m^2
- Matte temperature :
  - 1,550^{o}C
- Slag temperature :
  - 1,600^{o}C

Anglo Platinum – Waterval Smelter (Old converting)

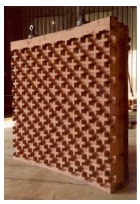
Anglo Platinum – ACP plant, Rustenburg

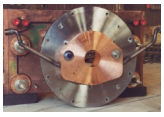


•Developed by Anglo Platinum, based on Ausmelt technology

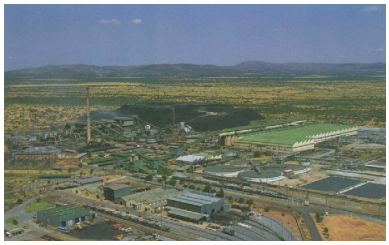


Anglo Platinum – Slag cleaning furnace, Rustenburg





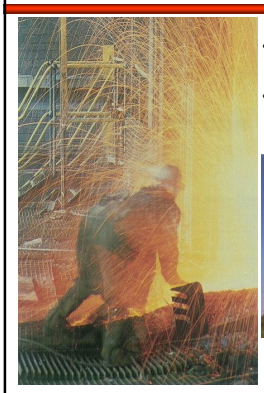
Impala Platinum (1969)



- Large integrated smelter using older established technology (six-in-line furnaces and Peirce-Smith converters)
- Toll treatment of a range of concentrates
- Previous deal with A1 to co-smelt autocatalysts

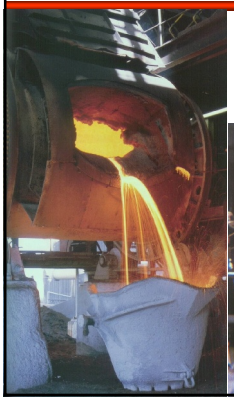
Impala Platinum – Converting

Lonmin Platinum (1971)

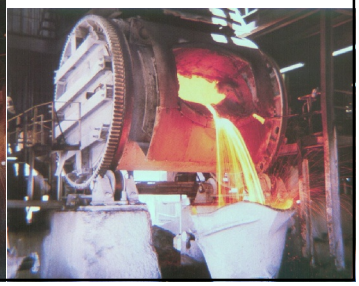


- Uses rectangular and circular furnaces
- First to smelt high quantities of UG2 ore (high Cr) concentrates

Lonmin Platinum – Converting

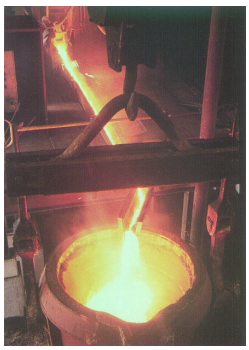


•Peirce-Smith converters



Northam Platinum (1992)

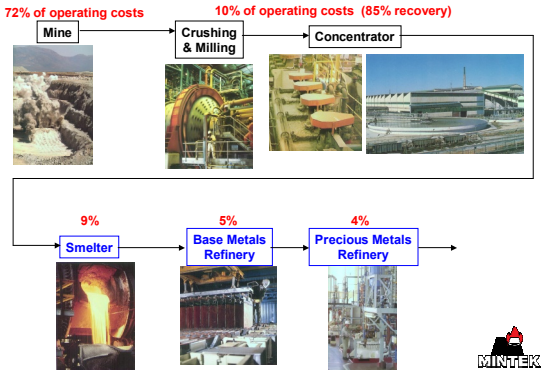
- One six-in-line rectangular furnace, built in 1992
- Peirce-Smith converters



New PGM smelting furnace at Northam (2017)

- Northam Platinum is constructing a new circular furnace. It will be able to accommodate reducing conditions (using carbon) to control the chromite content introduced by UG2 concentrates from their Booysendal mine

Operating costs of PGM production



Tin smelting

- Modern mining of tin in South Africa began in about 1904
- The two major producers of tin, Rooiberg Tin and Zaaiplaats Tin, both commenced operations in 1908, and a few smaller operations were started around 1907
- A tin smelter was installed at Rooiberg Tin in 1979

Tin smelting

- Smelting of cassiterite is done by using carbon to reduce SnO_2 to metallic tin. The conditions required for the process also reduce sulfides and oxides of most other base metals, so a high-grade tin concentrate is required as a feed material, in order to minimize impurities.
- South African concentrates typically contain 60–70% Sn and 3–15% Fe. A two-stage smelting process can be used to treat this material. The first stage (gentle reduction) leaves a slag containing ~20% Sn. A second stage (stronger reduction) forms a tin-iron alloy (known as hardhead) that is recycled to the primary smelting furnace, and a low-grade slag is rejected. Ferrosilicon (75% Si) can be used as a reducing agent in the secondary smelt, and the iron is rejected as a low-grade FeSi product, and metallic tin is produced instead of the hardhead tin-iron alloy.
- Rooiberg used two 550 kVA submerged-arc electric furnaces with a production capacity of ~2 kt of metallic tin per year. Three 10 t electric refining kettles are used to produce a tin product with a purity of more than 99.9%.

Tin smelting

- A smaller smelter at Iscor, Vanderbijlpark, with a capacity of less than 1 kt of metallic tin per year, was based on one 350 kVA submerged-arc electric furnace (Uys, 1977).
- The Zaaiplaats smelter used gas-fired reverberatory furnaces.

Ilmenite smelting to produce titania slag

- Ilmenite smelting to produce titania slag and pig iron started in 1977/1978 with two AC open-arc six-in-line furnaces at Richards Bay Minerals. Two more six-in-line furnaces were added later.
- Anglo American and the forerunner of Exxaro built four DC arc furnaces between 1994 and 2003.

Ilmenite smelting (DC arc furnaces)

- 25MW DC furnace at Namakwa Sands in 1994
- 35MW DC furnace followed in 1998


- Two further 36MW DC furnaces at Ticor near Empangeni were commissioned in 2003

- A 30MW furnace was commissioned for CYMG in China in 2009

Chromite smelting to produce ferrochromium

- The first ferrochromium plant in Africa is claimed to be Zimbabwe Alloys which was founded in 1949 in Gwelo (now Gweru)
- However, African Metals Corporation, near Vereeniging, commenced production in 1942 and made FeMn, FeSi, and high-carbon FeCr
- Rand Mines (RMB Alloys) started smelting chromite to produce the first low-carbon ferrochromium in South Africa at Samancor and Middelburg Steel and Alloys in 1964, even though chromite mining in South Africa had begun in 1921
- The first South African stainless steel was produced in 1943 by Amcor in Vereeniging (who had earlier, in 1939) produced small quantities of FeMn

Abundant power drove growth

- Abundant and cheap electricity in the 1960s and 1970s provided the impetus for a rapid expansion of industrial smelting capacity.

Chromite smelting – DC arc furnaces

- A major breakthrough in the treatment of chromite fines occurred with the first industrial application, at Palmiet Ferrochrome, of a 12 MW (16 MVA) DC arc furnace for the production of ferrochromium in 1984


- Over the next 25 years, the largest individual DC furnace capacity increased to 60 MW in South Africa (two in place)

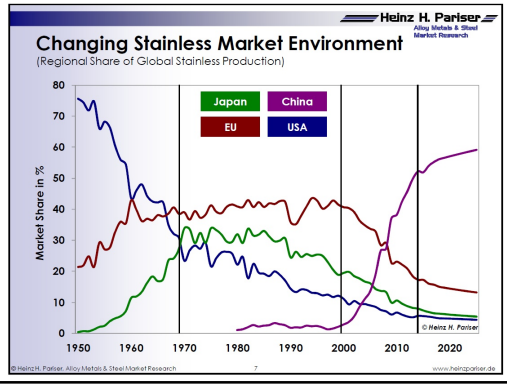
- In 2013, four 72 MW DC arc furnaces for chromite smelting were built in Kazakhstan

Production of FeCr in South Africa and China

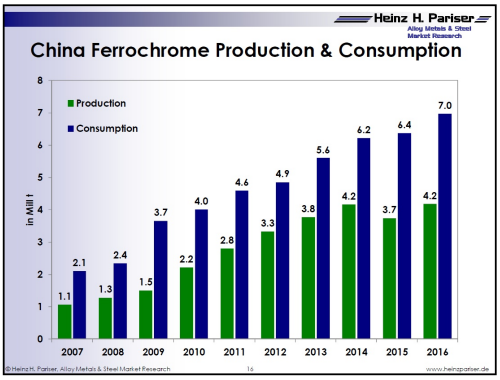
- Ten years ago, 90% of the chromite that South Africa produced was converted to ferrochromium (FeCr) in the country, which made SA by far the world's largest producer of this ferro-alloy. China, by comparison, has very little chromite, and has either to import it (much of it from South Africa) to produce FeCr, or to import the FeCr necessary for its stainless steel production. Thirty years ago, China was in 7th place for FeCr production, producing only 120 kt/a. By 2006, China's FeCr production had grown to 1.0 Mt/a, and they had moved up to 3rd place (after South Africa with 3.0 Mt/a, and Kazakhstan with 1.2 Mt/a). China continued to grow rapidly, and South Africa's production of FeCr declined as a result of power shortages and higher costs. China overtook South Africa as the world's leading producer of ferrochromium in 2012.

Stainless steel production in China

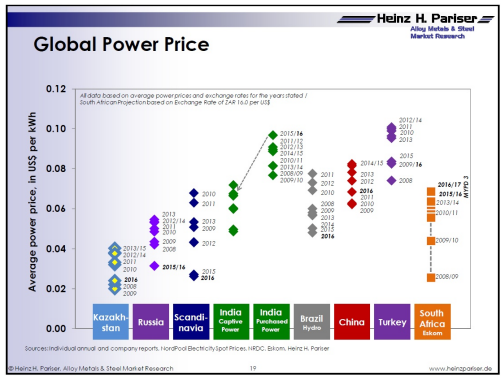
China's increasing share of stainless market



China's production of ferrochromium



Power price comparison



Chromite production is affected by policy

- World production of chromite is dominated by South Africa; Kazakhstan stands in second place. As much as chromite production depends significantly on what is in the ground, it is also affected by policies and infrastructure development within a country, as can be seen by the significant increase in chromite production in Turkey, and the significant decline in chromite production in Zimbabwe during the past decade.

Chromite smelting: Improved processes

- One of the important questions being examined in South Africa is how to ensure that the minerals in the ground contribute as much as possible to the prosperity of the country's people
- One way to do this is to optimize the costs of production by considering the mineral processing and smelting processes holistically and not in isolation
- For example, mineral processing circuits remove silica to improve grade, but smelters add silica as a flux. A cost-saving simplification can be made here.

Power shortage in South Africa – a major failure

- Electricity demand grew faster than supply (South Africa has ~40 GW of power generating capacity)
- Load-shedding crisis in 2008
- Electricity price tripled in next six years (25% increase each year)
- Mining industry uses ~15% of the country's electricity (~6 GW), with over 4 GW smelting capacity

Latest developments

- Renewable power now at ~2 GW
- No load shedding for past 20 months
- Demand for electricity has decreased
- In March 2016, Eskom generated 4.3% less power than the previous year (Stats SA)
- Evraz Highveld and Tata Steel in liquidation
- ArcelorMittal operating at < 80% capacity
- Anglo Platinum: R12.2 bn loss a year ago
- Impala: R4.1 bn loss a year ago
- Lonmin: R1.2 bn loss a year ago
- Strike of 2014 (5 months) cost SA R38 bn
- Number of foundries in SA: 270 → 170 since 2003

FeCr industry constrained by lack of power

- Lack of power capacity is a major factor that prevented South Africa from benefiting from the minerals boom of the past decade (driven primarily by the urbanization of China)
- Many ferro-alloy smelters are currently shut, and some are paid by Eskom to not use electricity to make it available to others
- Much South African chromite ore is now being sold to China (to make FeCr for stainless steel)
- News reports said that China overtook South Africa as the world's leading FeCr producer in 2012

Challenges

Infrastructure problems:

- Electricity
- Rail
- Rolling stock
- Harbours / ports

Factors discouraging investment:

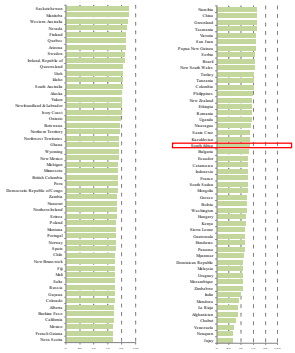
- Power cost
- Labour unrest
- Political policy
- Skills shortage

On the brighter side

- Great mineral deposits
- Experienced pyro engineering companies
- Good processes
- Energy savings
- Pyrometallurgy remains essential as long as metals are required

- Electric smelting continues to have a large part to play in the South African economy
- Electricity prices are increasing rapidly, and smelting processes will have to increase their energy efficiencies

Investment Attractiveness Index (Fraser Institute)



•The Fraser Institute rated South Africa 74th out of 104 mining jurisdictions (and 13th out of 18 African countries) for investment attractiveness

Major concerns from industry

- Capital investment
  South Africa's mining industry makes up just 4.4% of global mining stocks, down from 18% in 2000, and 47% in 1980, according to a presentation by Jim Rutherford, a non-executive director of Anglo American at the Joburg Indaba in October 2015
- Metal prices (R / $) and Demand
- Mining costs
  The cost of mining dominates operating costs, e.g., over 70% for PGM production.
  Lower-grade or more complex ores (UG2 and Platreef) will need to be processed.
- High operating costs
  Electricity price tripled in the six years following the load-shedding crisis of 2008 (25% increase each year)
- Availability of water and power
- Social licence to operate
- Government regulations
  Safety stoppages; Uncertainties and cost of BEE; Environmental requirements
- Labour and community relations
  HIV / AIDS

Mining is the essential core of the SA economy

- Provides 1 million jobs (500 000 direct & 500 000 indirect)
- SA Mining Industry direct employment: 457 874
  - PGMs 172 000
  - Gold 116 000
  - Coal 77 000
- Mining income for 2015/16 contributed R286 bn to GDP (just over 7% of total GDP of R4014 bn), with another 10% indirect & induced contribution
- As a consequence of the low profitability of the mining industry, the tax revenue from mining amounts to only 1.8% of total tax revenue of R1.07 trillion for 2015/16
- Critical earner of foreign exchange >50%.
- Accounts for 18% of investment (9% direct).
- 15% of electricity demand

Primary mineral revenue (total sales 2016)

• Coal	R110bn	26%	78%
• PGMs	R97bn	24%	
• Gold	R76bn	18%	
• Iron ore	R42bn	10%	
• Diamonds	R21bn	5%	
• Mn ore	R17bn	4%	
• Cr ore	R16bn	4%	
• Nickel	R7bn		
• Copper	R4bn		

By contrast, the world's top 40 mining companies earned 83% of their revenue from Copper, Coal, Gold, and Iron ore in 2015 (PWC, 2016)

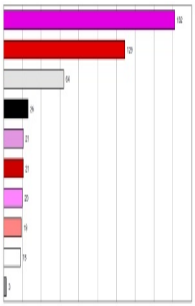
South Africa's economy

- South Africa's economy is officially in recession (two quarters of economic decline) (StatsSA GDP data, 6 June 2017)
- According to a survey (IRR, 21 June 2017), there are officially more South African beneficiaries of social grants than there are people working
- In 2016, there were 15.5 million people with jobs in South Africa, while 17.1 million beneficiaries of social grants
- By comparison, in 2001, there were 12.5 million people employed, and 4.0 million receiving social grants. This equates to a 328% increase in grant beneficiaries, while jobs increased by only 24%
- Official unemployment rate is 28%, but the value of the expanded definition (including non-searching unemployed) is 36%, with 6.2 million (or 9.3 million by the expanded definition) people unemployed when they should be economically active

Top ten mining countries (Baxter, 2011)

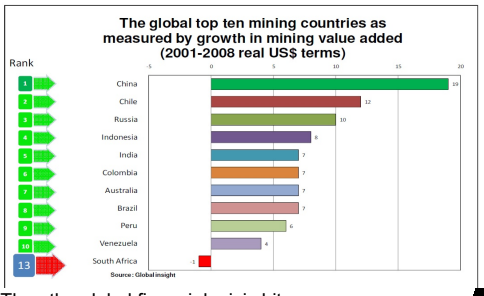
- SA has the world's fifth largest mining sector, as measured by Mining GDP (US $ billion)

1	China	182
2	USA	129
3	Australia	64
4	Brazil	26
5	South Africa	21
6	Canada	21
7	Russia	20
8	India	19
9	Chile	18
10	Colombia	3



SA performed poorly during commodity boom

- A missed opportunity, largely because of infrastructural constraints (electricity, rail, etc.) and poor policy decisions



- Then the global financial crisis hit

"Slower, lower, weaker, … but not defeated"

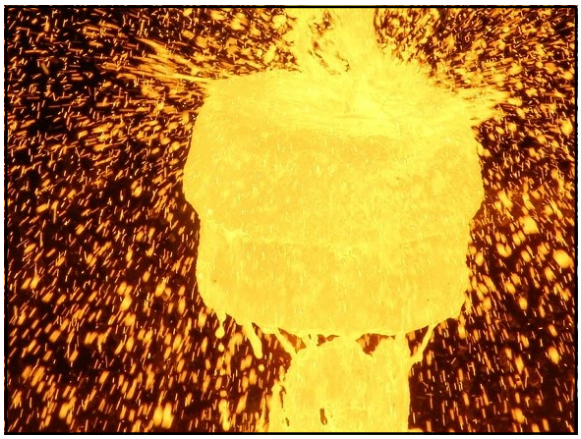
- The PWC Annual Mining Report for 2016 showed that the top 40 global mining companies collectively experienced a net loss (US $27 bn) for the first time
- This has effectively wiped out the gains made during the commodity super cycle
- "Whilst the industry continues to face significant economic headwinds, there is still a long term positive outlook"

Export of technology: DC Nickel laterite smelting

- Two 80MW twin-electrode DC furnaces constructed by Glencore Nickel for the Koniambo FeNi smelter in New Caledonia, were started up in 2013 and 2014
- DC arc smelting technology was developed at Mintek and licensed to Glencore for Koniambo Nickel

Acknowledgement

- Mintek
- University of the Witwatersrand
- Thanks to the National Research Foundation of South Africa for travel support



Mintek's DC furnaces

http://www.mintek.co.za/Pyromet/