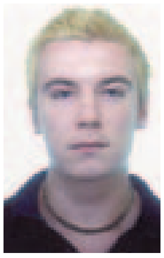
David Middleditch* looks at the ore recovery process of Rössing, one of the largest and most efficient open cast uranium mines in the world



Dave Middleditch

The Rössing Uranium mine is situated 65 km to the northeast of Swakopmund in the notoriously arid Namib Desert. The fifth largest producer of primary uranium in the world, Rössing accounts for approximately 8% of the world's uranium oxide production, which is exported for use by electricity generating utilities.

A bit of history…

The discovery of the Rössing orebody has been attributed to the late mineral prospector Captain Peter Louw during the 1920s. Although Captain Louw and his partners made various attempts to interest mining companies in the deposit, it was only in the mid 1960s that a subsidiary of the RTZ Corporation (now Rio Tinto) took an option on the prospect and commenced a long programme of geophysical and geological surveys, drilling and evaluation.

Rössing turned out to be a huge low-grade ore body contained within tough granite known as Alaskite. The final decision to mine the ore body was made back in 1973 when Namibia was still part of the old South Africa and the operation was officially opened in 1976. In 1979 the mine reached full-scale production with an average of 4,500 t/y of uranium oxide.

Geology

The Rössing orebody is unique as it is the largest known granite hosted uranium deposit of economic significance and viability. Its geological past dates back 1,000 million years to when the sea covered the Namib Desert. Over long periods of time, layers of sedimentary rock were deposited in the shallow waters of this prehistoric sea. Due to seabed subsidence additional deposition of the accumulated solids sank deep into the earth's crust where they were exposed to extremely high temperatures and pressures. These conditions resulted in the complex folding of the sediments and caused

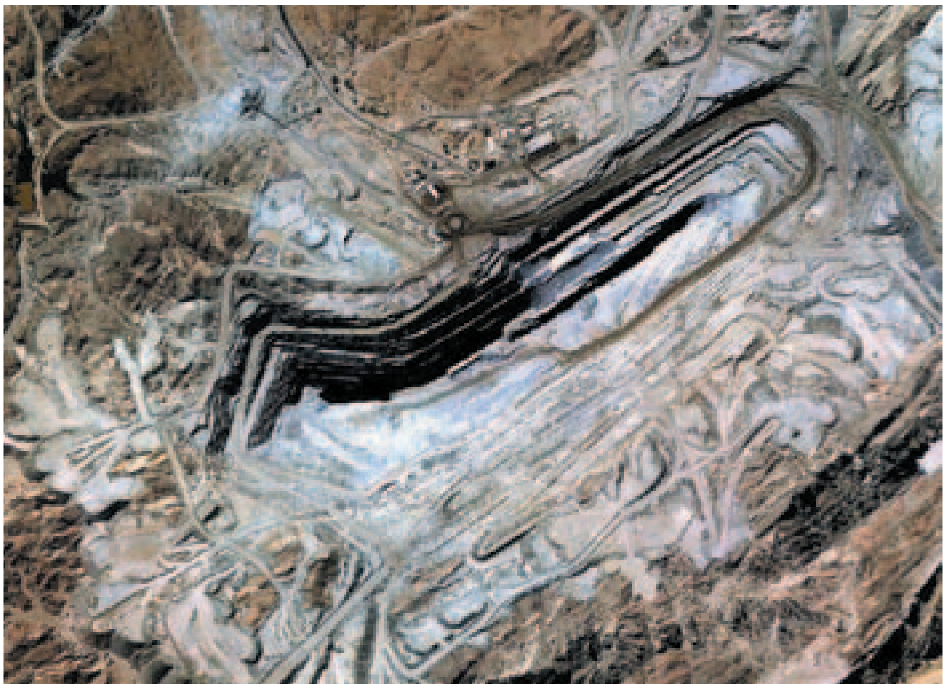
The Rössing open pit mine is currently 3 km long, 1.5 km wide and 330 m deep. Photo courtesy of Rössing Uranium

Energy from the

the sub layer of molten granite to intrude and become embedded in the sedimentary rock. The granitic alaskite host rock contains the uranium bearing minerals in two forms as either microscopic crystals of uraninite (the dominant primary radioactive mineral) or visible crystals of beta-uranophane.

MINE FACTS

Mine Name	Rössing Uranium
Location	65 Km northeast of Swakopmund, Namibia
Ownership	68.6% Rio Tinto, rest Namibian Government
Start Up	March 1976, reaching full capacity of 4,500 t/y uranium oxide in 1979
Mining Method	Conventional open pit; drill and blast, loading and hauling
Ore Treatment	Leaching-solvent extraction
Reserves	27.1 Mt at 3.9 ct/t (diluted) from four ore bodies called A154S, A154N, A418, and A21
Production:	Uranium oxide produced (2002) 2,778 t



An aerial view of the Rössing open pit. Photo courtesy of Rössing Uranium

Mining operations

Rossing is a low grade, high throughput operation with 2,643 t of uranium oxide barrelled in 2001 from approximately 21.1 Mt mined. Uranium is mined from an open pit by conventional means using drilling, blasting, loading and hauling equipment.

The loading equipment consists of two Marion 201M rope shovels, one P&H 2100 rope shovel and a Demag H485 hydraulic excavator. Haulage is by a fleet of 11 of the 180 t Haulpak trucks, and this task is conducted by an all-female driving team.

Early in 2002 Rössing recruited a number of female haul truck drivers and after initial training as equipment operators, they progressed quickly to driving safely and efficiently. One of Rössing's policies is to encourage the placement of women in all positions.

Plant operations

As a visitor to Rössing, the first things you are likely to notice are the two huge ore stockpiles that pierce the horizon almost as dramatically as the nearby Rössing mountain from which the mine takes its name.

The coarse ore stockpile is fed by the two 54" Allis-Chalmers gyratory crushers situated in close proximity to the open pit. The primary crushers operate with a closed side setting of 150 mm and the coarse ore stockpile has a total capacity of 400,000 t of which 70,000 t is live.

The coarse ore is then conveyed to the secondary crushers, which are situated somewhat closer to the milling and extraction areas of the plant. Symons-Nordberg crushers are used to reduce the ore to minus 65 mm and the ore is screened on Pegson Vibro-King double deck vibrating screens fitted with 50 mm and 19 mm apertures.

The oversize is sent to the tertiary crushers for further size reduction. The undersize from both screens and crushers is screened at 850 micron, where the subsize particles are conveyed directly to the fine ore stockpile. Ore is discharged onto the stockpile via two discharge points at the apex. The ore is then conveyed to the rod mill section where the next stage of comminution is carried out. A corrugated roof to prevent the fines being carried away by the strong east wind conditions covers the fine ore stockpile.

Grinding is by four Marcy rod mills running in parallel open circuit. The dimensions of each of the four mills is 4.4 m x 6.1 m which is characteristic of the medium diameter, long length mills employed in South African operations. Charged with 100 mm diameter steel rods, they are capable of grinding 500 t/h of ore per mill. Typically a pulp density of 75–76% solids is used for grinding. The mills are set up to grind to 32% +20 mesh (0.85 mm) and have a rod consumption of about 0.43 kg/t. Return Dam Solution (RDS) is used as feed water to the rod mills.

Ground pulp is discharged over a circular Trommel screen attached to the discharge end of each mill. These serve the purpose of screening out any tramp oversize material, which would cause problems in the leach tanks. The discharge is pumped to the leach tanks by two 8 x 6 Warman pumps.

desert

Leaching process/ Extraction & reagents

The extraction area of the plant consists of a conventional leaching-Solvent Extraction-Continuous Ion exchange arrangement with thickeners, rotoscoops and hydrocyclones being used as slimes and sands washing stages respectively. The leaching process is carried out in two leach tank modules both containing six leach tanks each. Leach tank No1 has a capacity of 290 m^3 and leach tanks 2-6 have a capacity of 1,450 m^3. The tanks are constructed from mild steel plate and are completely rubber lined. To increase the mixing of the reagents the first tank in each module is considerably smaller than the other five. Therefore, the five tanks provide the required retention time of about 9-11 hours for the extraction to take place under agitation. The following reagents are added to the leach tanks:

Ferric iron – This oxidises the uranium into a soluble hexavalent state in association with 93% sulphuric acid. The acid is shipped in from overseas via the acid store in nearby Walvis Bay.

Manganese oxide – This oxidises the ferrous back to ferric and is delivered as a finely ground pyrolusite slurry obtained from crushing, grinding and thickening plant adjacent to the leach modules. The uranium is 55% of the uraninite form and 40% of the beta-uranophane form. The other 5% is insoluble and is therefore unextractable. The leach process typically consumes ±18 kg/t of acid and ±1.40 kg/t of manganese. However, acid consumption may vary considerably with differing calc indexes.

The washing circuit is comprised of two distinct areas, referred to as sands washing and slimes washing. It is in this stage that the pregnant uranium bearing solution is separated from the coarse sands fraction.

The leach pulp is diluted using the first stage rotoscoop overflow and the slimes/sands split is achieved by ten 660 mm diameter hydrocylones with the slimes reporting to the hydrocyclone overflow and the sands to the underflow. The overflow slimes are pumped directly to the counter current decantation (CCD) circuit, whereas the underflow coarse sands fraction reports to one of the ten primary rotoscoops.

A 180 t capacity Haulpack truck dumping its load at the primary crusher. Photo courtesy of Rössing Uranium

There are 20 rotoscoops in each module arranged in ten pairs. These pairs form a two-stage washing circuit consisting of primary and secondary units. The rotoscoops utilise barren solution from CIX as the washing medium. The rotoscoop works by providing conditions for the settlement of coarse solids from the barren wash solution. The solids are picked up by ploughs attached to the underside of a rotating table and discharged down a chute onto the next processing stage. The solution and the fines from the first stage are returned to the hydrocyclone feed. The sands are diluted with barren solution from CIX and are fed to the second stage rotoscoops. The washed sands are discharged and are conveyed to the tailings dam via the recently installed sands conveyor belt.

The slimes from the hydrocyclone overflow are sent to the CCD circuit where washing is undertaken in a five-stage thickener process.

ViCorr GRATING BEATS THE RAIN

StonCor Africa's ViCorr – a durable and widely used grating system exclusive to the company's Fibergrate division – has been installed at Rössing Uranium for the refurbishment of the plant's acid stock area where large quantities of highly concentrated sulphuric acid are stored.

ViCorr, a corrosion-resistant vinyl ester resin system, was developed to perform reliably in harsh environments, offering outstanding resistance to a wide range of highly corrosive situations ranging from caustic to acidic.

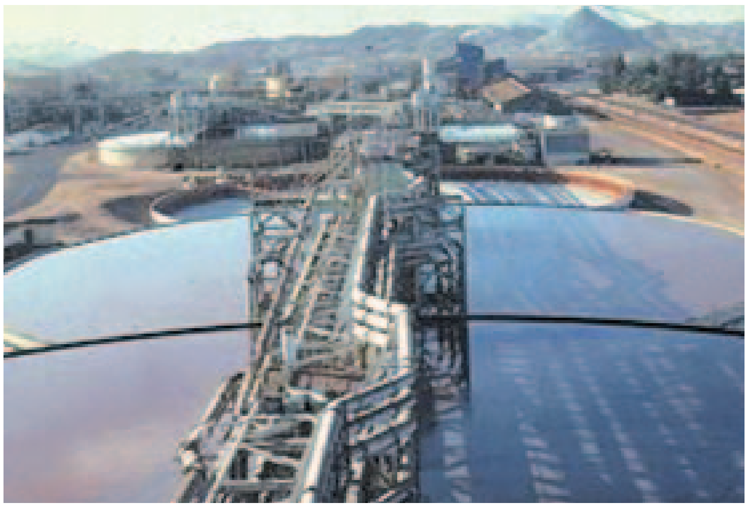
At Rössing, where a total of 130 m^2 of the system was installed, a resin sealant (the same resin used in the manufacture of the system) was applied to finish and seal panel edges in instances where it had been necessary to cut them to fit.

Above: StonCor Africa's red ViCorr grating system from its Fibergrate stable in place at Rössing Uranium

The first stage of this process is comprised of four Eimco thickeners all with a diameter of 42.7 m. The feed for these thickeners consists of the leached pulp, which is diluted with the second-stage thickener overflow. The settling rate of the fine particles is greatly improved by the addition of a non-ionic polyacrylamide flocculent. Floerger 4040 was in use during the author's visit but alternative reagents were being researched.

The combined overflow from the four first-stage thickeners is fed to two more thickeners, which are used as clarifiers. The overflow fed to the clarifiers is the 'pregnant overflow' and contains about 140 ppm uranium, compared to the feed grade of about 3 ppm. The pregnant overflow is sent to the CIX plant. The combined underflows are sent to the second-stage thickener.

The second to fifth-stage thickeners are larger 68.6 m diameter Dorr-Oliver units of the centre pier type. These thickeners work in series with the underflow moving towards the fifth-stage and the overflow moving towards the first-stage thickeners. Basically, the thickeners consist of the flow of underflow slimes losing uranium going one way and the overflow picking up uranium moving the other way, hence 'Counter Current Decantation'.



The thickeners or Counter Current Decantation tanks. Photo courtesy of Rössing Uranium

The pregnant solution from the thickener overflow is pumped to the pregnant solution storage tank adjacent to the CIX plant. There are four pumps that discharge the pregnant solution into four lines of CIX contactors. Each of the four lines has six contactors, giving a total of 24 contactors.

The Porter CIX plant is relatively large with a total solution flowrate of about 3,600 m^3/h passing through it. The upward flow of pregnant solution is used to fluidise a bed of resin in successive upflow contactors with the barren solution leaving the last contactor. The resin beds are moved from one contactor to the other by means of airlifts in a direction counter current to the pregnant solution. Loaded resin from the first contactor is transferred to one of the three-elution columns. Barren solution discharged from the sixth contactor is sent to the barren storage tank

MINE MANAGER OF THE MONTH

David Salisbury (David, 52) joined Rössing Uranium in October 2000. He has been managing director/general manager operations since March 2001. David's experience spans a period of 27 years of significant involvement in underground and surface coal mining as well as open pit gold mining. Besides Rössing, David has held a range of executive positions with strategic business responsibilities in a number of organisations, including: The Coteau Properties Company, Energy Resources Company, Al Hamilton Contracting Company, Cordero Mining Company and Kennecott Ridgeway Mining Company.

When asked about the major challenges at Rössing, David says: "Rössing operates in a very aggressive global market with significantly lower ore grades than our competitors. Increasing the cost efficiency of the operation has been a constant focus. We have changed the focus from cost cutting to that of spending wisely to generate greater returns. We are continually improving our productivity, both in terms of people and equipment and critical process efficiency. Most importantly we have improved our safety performance."

For David, safety is the first and foremost focus: "If an injury occurs, it means that I have failed in my duty to provide a safe work environment. A safe mine will operate efficiently and at low cost. Since 2000 we have been able to reduce the LTIFR by 250% to a level of 0.24, but we will not be satisfied until we have an accident-free environment."

David is very proud of his team, with which he maintains an open and through communication. "Rössing is producing with 800 employees today what years back required more than double the number of people. It is the determination and hard work of our people that has set us apart from other mines."

And the future? "Rössing's future depends on developing a value-adding business case that supports a large investment to extend the life of the mine through 2017. This will require a significant pushback to open up additional ore," says David, explaining that the plan will be completed, and approval for the investment sought in September 2004.

David says: "Within the uranium industry many voices have long predicted the end of Rössing. But we are still here and are working hard to secure a long-term future for our people and prove the critics wrong."

where it is distributed to the CCD circuit and rotoscoops sections accordingly.

There are three elution columns per line, which take the form of rubber lined, mild steel pressure vessels, with 10% sulphuric acid as the eluate. This strips the uranium from the resin beads as it is pumped through the columns. Stripped resin is returned to the contactors and the uranium rich concentrate is pumped to solvent extraction. The concentrate has a uranium tenor of 3 to 5 g/l, whereas the barren has a uranium tenor of 0.005 to 0.12 g/l. The resin used is NCP Duolite A101-Du.

The concentrate from CIX is pumped to SX as the aqueous phase. The organic phase is Shellsol, which contains alamine 336 and isodecanol. Transfer of the uranium from the aqueous to the organic phase is carried out using banks of Davy Powergas mixer settler units. It employs five extraction, two scrubbing, four strip and one solvent generation stage.

After extraction, the loaded solvent is passed through the two unit clean water scrubbing stage before entering a four unit stripping stage where the organic solvent is mixed with 7% aqueous ammonium sulphate solution under pH control with aqueous ammonium hydroxide. At this stage a chemical reaction and phase change occurs whereby uranium in the form of ammonium diuranate returns to the aqueous phase and is pumped to the final product recovery plant as OK liquor. The OK liquor has a concentration varying between 8 and 20 g/l uranium.

Sustainable mining

The Namib is one of the world's oldest deserts and the natural habitat of a number of extremely rare species of flora and fauna. Local and international scientific conservation communities closely monitor the eco-system.

Rössing Uranium is well aware of its responsibility and has responded proactively to concerns about mining and the environment following not only its own strategies through the EMS (Environmental Management System), but also by strictly adhering to the principles laid down by the Rio Tinto board.

The main environmental factors that Rössing has to take into account are water management, dust, noise pollution, radiation, gases, fumes and chemicals.

Although in its past the area was submerged by the sea, its present conditions could not be more in contrast; it has a desert climate, it is extremely arid and has an average annual rainfall of only 30 mm. Temperatures range from a relatively cold 10° C during the night to extreme highs of 40° C during the day, leading to a very unforgiving environment.

In 2003, the one billionth tonne of rock was removed from the open pit since operations started in 1976. Photo courtesy of Rössing Uranium

Water

Water is a valuable and essential commodity. At Rössing, the CCD thickeners are huge consumers of water. Saline water is also used in large quantities to suppress dust particles in the open pit.

Water is pumped from the underground aquifers in the estuaries of the Kuiseb and Omaruru Rivers. Due to the climate and an average annual rainfall of only 30 mm, it is vitally important to use water responsibly and to conserve reserves. Rössing has been able to reduce its percentage of fresh water usage from 100% in 1997 to 26% in 2003. This has been achieved by recycling water from RDS (Return Dam Solution)

Although the annual target in 2003 for fresh water usage has been exceeded, the overall fresh water consumption has been reduced from about 10 M m^3/y in 1979 to about 2.4 M m^3/y in 2003.

Rössing has implemented an ongoing programme in the Khan River Valley to monitor the stress on vegetation due to the drawing of water from the surrounding area. The mine is limited to a water table draw down of 15 m below the surface. This is closely monitored and the programme has not noted any adverse effects on the vegetation due to mine activity.

* *David Middleditch (d.j.middleditch@ex.ac.uk) is a Minerals Engineering student at the Camborne School of Mines, UK. This article is based on David's two-month, assessed industrial work placement at Rössing. David says: "Working at Rössing was a thoroughly enjoyable experience that provided a valuable insight into working in a successful extraction plant."*