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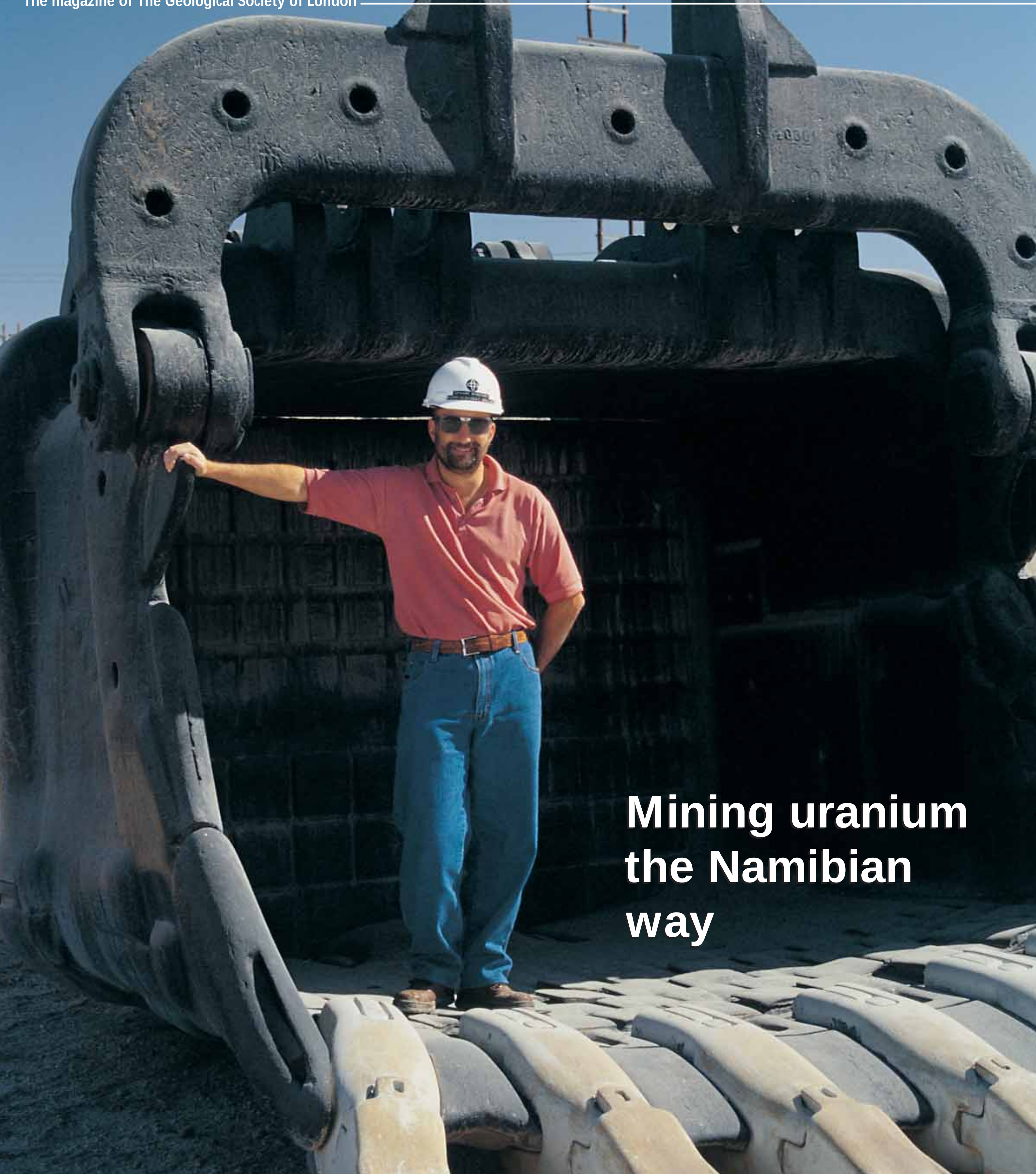

Mining uranium the Namibian way

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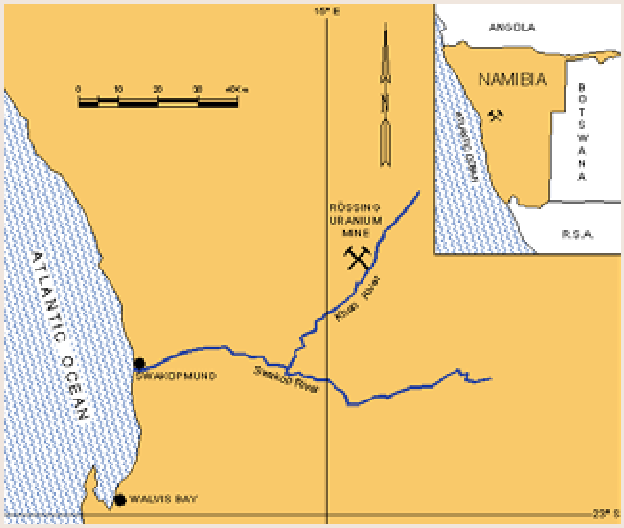
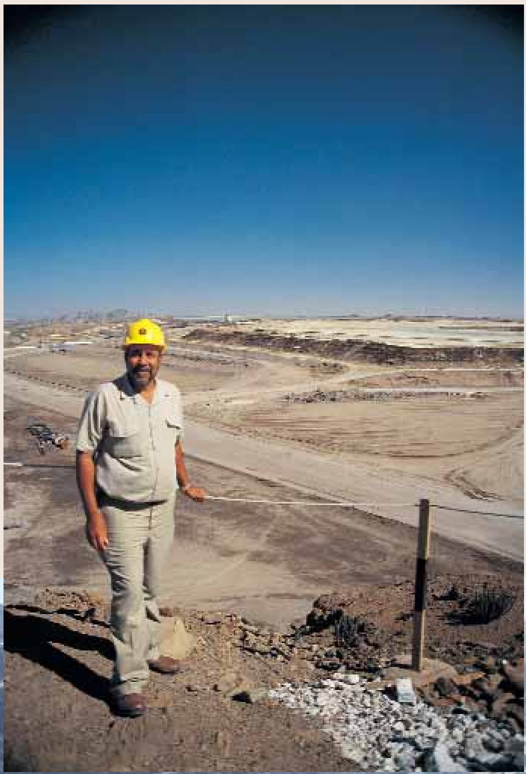


Locality map. Courtesy, Rössing Uranium Ltd



Beyond the

Modern mining geology can help run a profitable uranium mine on an ore of lower grade than some tailings. ***Ted Nield*** *investigates how things have come on since the forked twig…*

"A miner, since he ought to be a good and serious man, should not make use of an enchanted twig, because if he is prudent and skilled in natural signs, he understands that a forked stick is of no use to him, for there are the natural indications of the veins which he can see for himself - without the help of twigs" Agricola De Re Metallica (1556), Trans. HC & LH Hoover (1912)

About 65km inland from the pretty, old colonial clapperboard town of Swakopmund, Namibia, lies one of the largest holes in the ground anywhere in the world. Three kilometres long, 1.5km wide and 320m deep, Rössing Uranium Mine also boasts the world's largest granite-hosted commercial uranium ore.

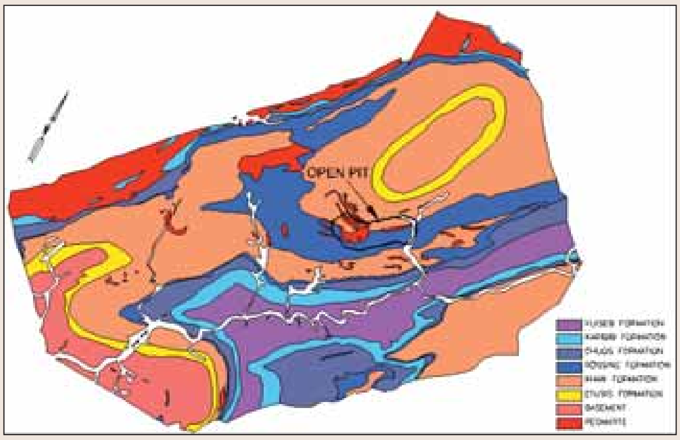
It is also the lowest grade ore-body still producing. Though it has been known to reach 1kg/tonne the mine's average uranium yield is only 0.35kg/tonne. As Achmet Abrahams (picture left), Superintendent Occupational Health and Environmental Management puts it - "Our ore is actually poorer in uranium than some of our competitors' tailings!".

Though the area was known to contain radioactive minerals from 1910, the Rössing Ore Body lay undiscovered amid a wilderness of gravel plains and rocky outcrops until 1928. Then, mineral prospector Captain Peter Louw carried out an autoradiography test on a black mineral that Louw had picked up some 20km west of the present day mine. Captain Louw and others made various unsuccessful attempts to interest mining companies in the deposit he had identified. But it was only in the mid-1960s that a subsidiary of the RTZ Corporation (now Rio Tinto plc) took an option on the prospect and began a long programme of geophysical and geological surveys, drilling and evaluation.

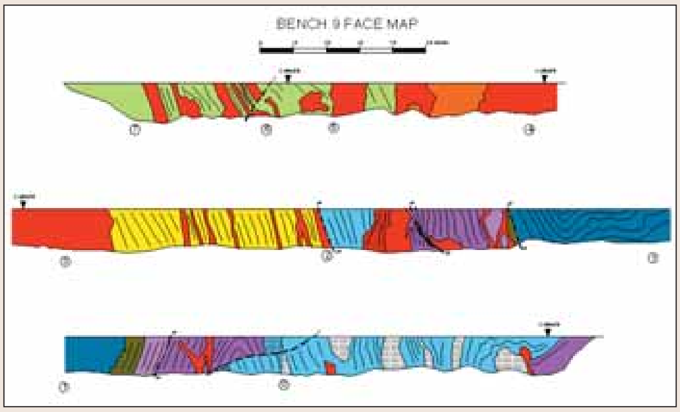
forked twig

The ore body was found to be an enormous low-grade deposit of uranium embedded in tough, abrasive alkali feldspar granite poor in mafic minerals, known as alaskite (Box 2). In 1973, RTZ decided to go ahead; the plant and mine were designed to produce up to 4500 tonnes of uranium oxide per year and began operating in March 1976, reaching full production in 1979.

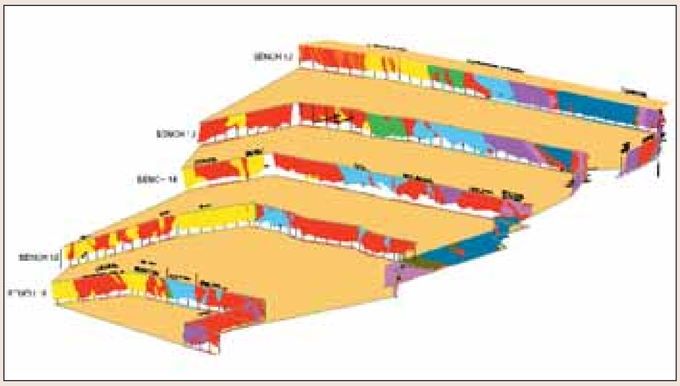
Today, despite the low grade of its ore, Rössing is the fifth largest producer of uranium in the world, accounts for 8% of total world production and for 10% of Namibia's total exports. To succeed in the face of unfavourable economics,



Geological Map of the area around the Rössing Uranium Deposit (modified after Smith 1965) Courtesy, Rössing Uranium Ltd



Typical Geological Face map. Courtesy, Rössing Uranium Ltd


Three dimensional face mapping. Courtesy, Rössing Uranium Ltd

Rössing relies on its large scale, continuous operation, its reputation for quality, reliability and an excellent safety and environmental record. Its policy has been to develop close long-term relationships with its customers around the world. But without state-of-the-art mining geological techniques, those factors alone would count for nothing.

Rössing is situated in the so-called Central Zone of the intracontinental branch of the Damara Orogenic Belt. The DOB itself forms part of the Pan African Mobile Belt that transects the continent and marks the sutures of continental collisions that gave rise to the southern supercontinent, Gondwanaland, in the late Precambrian and early Palaeozoic.

Rössing faces seemingly intractable geological complications. First, there is the alaskite - an extremely hard, abrasive ore body, intruded (in a three-dimensionally complex form) into a highly variable and tectonised sequence of metasediments. Nowhere is it possible to just "mine the ore". Wherever it occurs, the alaskite is intricately mixed with gangue - its host rocks. This is what gives Rössing's geologists their unique challenge: maintaining the grade of the ore delivered to the plant in the face of variable ore and gangue composition.

The various sediments that went to make up the two formations found in the pit (the Khan and Rössing formations -) were subjected, during the late Proterozoic Damara Orogeny, to intense metamorphism and tectonism. The uraniferous alaskites were also intruded at this time. Strong structural control over their geometry demonstrates clearly that they were emplaced syntectonically.

In addition to structural control, the alaskites vary in field habit according to the nature of the country rock they intrude. In the Lower and Upper banded gneisses of the Khan Formation for example, alaskites form regular dykes, parallel to the regional bedding and foliation. In the Rössing Formation, by contrast, they tend to occur in between the amphibole schist and the Upper Marble, replacing much of the original sedimentary thickness.

These complex field conditions - allied to the unfortunate fact that although uranium only occurs in alaskites, not all the alaskites are rich in uranium - make maintaining the ore grade particularly challenging to the geologist. So what's involved?

"The Geological Section provides technical support to two major disciplines: mine planning, and production" says Graham Greenway (cover picture), Superintendent of Geology and a career mining geologist who learnt his trade at the University of Natal, Pietermaritzburg.

"Mine planning is really three disciplines. Long term planning means providing the Long Term Planning Section with ore reserve and geotechnical information adjacent to the proposed pit limit. This information is used to develop mining schedules over five- year and 'life-of-mine' periods.

"Second, in short-term planning detailed grade information (from production blast-holes and so on) is provided for short-term scheduling of the operation. And third, the geological properties of areas to be blasted are used to help design the blast itself." The geological section has to understand the geology of the deposit at all scales - from kilometre to metre.

geological input into Grade Control is vital. It is no exaggeration to say that grade control is the key to making Rössing work.

Greenway splits the geological input to Grade Control into four basic functions.

"First, ore reserve information is needed to create plans for areas where no production blast-holes have been drilled and sampled. Ore reserve estimates of both grade (how much uranium ore) and calc index (how much acid-eating calcareous material) are used to identify and schedule blocks of ground that will be mined out usually more than one month from the first date of the plan."

To build its regional knowledge, Greenway's section makes use of short drilling contracts when information is required for geotechnical and resource requirements (to improve estimation confidence). This, together with mapping the open pit face, gains the team the greater part of its essential structural and lithological data. The two techniques are complementary. Exploratory drilling with oriented core provides knowledge of the deep structure of the ore body, while the most comprehensive view of structural and lithological features is obtained by face mapping - tracing out the different lithologies just as you might the texture and mineralogy of a hand specimen (diagrams, page 5).

"All production and pit limit faces are mapped" Greenway says. "Digital photographs are taken of the faces, which are then spliced together in the computer using *Adobe Photoshop*." Lithology and structure are then interpreted on top of the digital photograph and the interpretation positioned and warped into its true three-dimensional form using surveyed control points - just like wrapping two-dimensional wallpaper around the contours of a room. Only in this case, the "room" is the 3D geometry of the pit wall. With the help of computer technology, all this information can then be collected in one complete three-dimensional model. All interpretation and modelling is computerised using a combination of the commercial programs *AutoCAD* and *Minesight.*

Using *AutoCAD,* the results of the face mapping are used to interpret the geology for the benches showing continuous lithological boundaries, structural axes, shear and fault zones. This allows the creation of plans throughout the deposit to provide rocktype information for areas currently being mined, and aids in the design of future blasts. As a result, the plant receives advance notice of what ore type can be expected for metallurgical processing.

Face mapping is also used in conjunction with borehole data to produce a geological model of lithostratigraphic boundaries on sections. These sections, along with the face mapping, bench interpretations and borehole data, are entered into *Minesight* to allow spectacular three-dimensional visualisation. In a complex structural environment like the Rössing synclinorium this is a powerful tool in obtaining a picture of the general structural geology. Major structural features and secondary features such as small-scale folding and fold axes can also be better understood when they are displayed in 3D. So how does the amassing of this data help the Geology Section ensure that the plant continues to be fed with ore of consistent grade, tonnage and rocktype?

At Rössing, planned ore blend targets are first agreed between the Metallurgical and Mining divisions so as to optimise the mining and metallurgical operations within geological constraints. The heterogeneity of mineralisation and the acid-consuming properties of marble (the plant uses acid leach to extract uranium) means that the

Then, the Geology Section helps design the areas to be blasted and mined. Because of Rössing's incredibly varied geology, each section of bench to be blasted is known as a "composite". "Composites are blocks of ground whose mean grade and calc index have been estimated. They are also divided on the basis of rock type to ensure no problems are encountered in the Processing Plant (you can massage this, as the composites also take rock type into account)" says Greenway. "They provide a practical way of dividing blast patterns into mineable units."

Rössing defines five types of composite, according to mean grade: S1(high), S2(medium), S3(low), Marginal and Waste (sub-economic). Composites are also defined on the basis of average calc index and are denoted as "Low Calc" or "High Calc". These simple categories provide an easy means of characterising the ore properties of mineable units, and each composite is defined in the open pit by boundary tapes and a colour-coded signboard.

The job begins when blast-holes are drilled. Radiometric sampling of the blast-hole cuttings (picture, page 10) defines which areas of the composite are economic and which sub-economic. "Economic" areas are then resampled, and determinations made for grade and calc index. Sampling, blast outline and blast-hole co-ordinate information is then entered into the computer for analysis. An interactive graphics program allows the geologist to attempt any number of configurations of blast until the optimum is reached. Lest this all seem a bit automatic and de-skilled, this process often requires what Greenway refers to as "intuitive input", to fill in any information gaps.

Once a composite has been blasted, tapes are laid out over the broken rock to demarcate its extent. Geologists walk over each blast, checking for anything untoward. "No matter how good the models, Nature can spring a few surprises" says Greenway. Such as, for example, the unexpected presence of marble in composites designated as "Low Calc". As composites are mined the boundary tapes are regularly checked and if necessary moved to minimise dilution and contamination of the ore.

Once loaded by electric shovels that can fill them with one bite (and at a power load of one megawatt each) 180-tonne haultrucks take the ore out of the open pit. As they climb the road, these leviathans switch from diesel power to electricity from overhead cables to which they connect, like trains, by pantograph. This method is both cheaper and more environmentally friendly, reducing the build-up

continued on page 10

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of diesel fumes in the often searing heat of the open pit. At the end of the lift, haultrucks pause for 30 seconds under special scanners that directly sense the uranium content of each load. The truck is then directed either to the ore dump or the waste dump - a relatively recent innovation that has further increased productivity (Box 1).

Rössing ahead

Rössing has just had what Managing Director David Salisbury describes as “one of the most successful years of its operating life”. Yet weak market conditions continued into 2001, and although the spot price increased slightly, it remained stubbornly low at US$10/lb U_3O_8. Rössing’s success, recently more than ever, has been to remain viable against a background of falling prices, while maintaining and improving its widely-admired safety and environmental record.

After a successful cost-cutting programme - and a quarter century in business, which always helps - there is confidence at Rössing. The feeling is that they will ride out the bad market and fully implement their planned closure programme over the next 16 years. One thing is certain: to succeed both in remaining viable and in closing down their operations safely, Rössing will continue to need geological expertise of the highest calibre.

Box 1: Truck scanners

It has long been known that gamma-ray radioactivity, associated with the daughter nuclides of the uranium decay series, provides unique spectral data that can be used as a basis for estimating uranium content. But what works in the lab is one thing; could it be made to work at this largest of all industrial scales?

The answer, fortunately, was yes. At Rössing the technique is now applied to haultrucks, each of which when loaded must pass under a gantry containing gamma ray sensors (pictures). The pilot radiometric ore sorting at Rössing is a first for a uranium mine and construction was completed early in 2001. Greenway says: “The highly erratic nature of mineralisation within the alaskite and metasediments means that internal dilution of the ore is a potentially serious problem. Radiometric analysis of each truck as it leaves the pit provides the geological section with an effective and practical means of discriminating between economic and sub-economic material.” Cost savings achieved since the introduction of truck scanners are large. Estimates vary between 3/4 to 1fi million N$ per month. Four scanner

Box 2: So where did the uranium come from?

From massive xenoliths of country rock whose structural grain shows no deviation from that of the country rock in the intrusion’s walls, it appears that the alaskites were emplaced by passive metasomatism.

The uranium occurs mostly as uraninite (55%), and beta-uranophane (40%), as interstitial grains and crystal inclusions. A refractory mineral, betafite, makes up 5%. Most of these grains are 0.05 to 0.1mm in diameter, though they range from a few microns to 0.3mm. Biotite and zircon seem to be strongly correlated with the uraninite, and pleochroic alteration haloes around the radioactive grains are common.

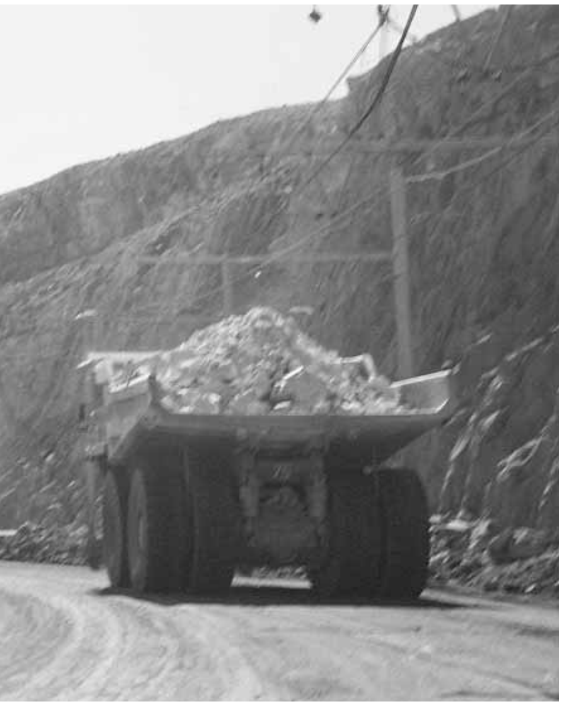
But how did it get there? The answer is till not clear. The alaskite, arriving during a period of extensional rebound between fold phases F3 and F4 of the Damara Orogeny, seems to have infiltrated migmatised country rock along shears, fractures and other structural features.

As replacement of the country rock proceeded by metasomatism, some dykes widened and formed more irregular bodies. From its potassium rich composition, geologists think the alaskite was derived by syntexis of underlying formations, with which it shares some compositional similarities.

units operate within the open pit. Each unit consists of a mobile gantry on which four NaI(T1) detectors are mounted, linked to a trailer containing the counting and communication equipment. The entire scanning operation is controlled from a control station where computers process and store data.

Data received from the scanners form a comprehensive record of the geological characteristics of the ore-body and mean the mine can exert accurate control on the grade of the ore sent for processing. In addition, sophisticated studies of the ore-body are possible with this wealth of sampling data.

This opens up the possibility that the source of the uranium might be the early Precambrian basement, which was extensively eroded in the Proterozoic. Then, during syntexis, these uranium minerals - perhaps already concentrated by sedimentary processes - became further concentrated in the residual melt. The patchiness of the uranium within alaskites probably reflects variations in uranium content of the basement and its cover, with further localisation during emplacement reflecting local geochemistry of the country rock.



Box 3: Rocks of Rössing

The Rössing Open Pit (map) exposes the uranium -rich alaskite intrusion and its country rock formations: the Khan and the younger, originally disconformable, Rössing. While the former comprises banded migmatitic quartzofeldspathic, amphibole-clinopyroxene gneisses and the dominantly clastic Etusis unit, the latter is heterogeneous, vertically and laterally, and consists of marbles, calc-silicate gneisses, pelitic schists and gneisses, quartzites and conglomerates.

To make the mining geologist's job even harder, the originally heterogeneous sediments were subjected to many episodes of tectonism. The main, NE-trending structural grain is due to a phase of intense deformation that has largely overprinted two sets of earlier structures, and their contemporary metamorphism, dated at 665+/- 34Ma. Their existence is in part inferred from large-scale fold interference patterns visible on the map-scale. Of the subsequent, less intense fold episodes, that orientated NNE and manifesting itself as the prominent NNE-trending *Welwitschia* magnetic lineament, is of particular significance to the emplacement of the uraniferous alaskites, with which it is closely associated in space and time (i.e. c.470Ma; Kroner and Hawkesworth 1977).

Acknowledgements

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