

Institution: University of Southampton
Unit of Assessment: 07 Earth Systems and Environmental Sciences
Title of case study: 07-13 Stimulating new exploration strategies for copper mining in Africa
<p>1. Summary of the impact</p> <p>The Zambian Copperbelt is the largest known repository of copper on Earth. Research at the University of Southampton has transformed the exploration landscape in the region, providing the world's mining companies with new opportunities for mineral exploration in Zambia and other sedimentary basins in Africa. This inward investment has contributed to rapid economic growth in Zambia and boosted local employment. Southampton's research model has contributed to the discovery of two world class copper deposits, impacted on the earnings of global mining companies, as well as ensuring a flow of highly skilled geologists from academia to industry.</p>
<p>2. Underpinning research</p> <p>Ore deposits represent the culmination of rare and complex geological processes. Sediment-hosted copper deposits are recognised as some of the world's most high-quality sources of copper and cobalt, making them much sought-after exploration targets. Southampton's research focused on developing new insights into these large-scale hydrothermal systems and generating new models to explain how deposits were formed and preserved, with the aim of identifying new areas for exploration.</p> <p>Zambia is the seventh largest copper producer in the world. The 100km-long Central African Copperbelt that cuts through the north of Zambia contains world-class copper and cobalt deposits thought to be in excess of two billion tonnes. Yet it wasn't until 1999, following a 25-year gap in exploiting the resource under the influence of the Soviet Union, that the Zambian government de-nationalised the country's mines, reigniting overseas-led development of its copper mining sector. It provided an opportunity for the University of Southampton's Professor Steve Roberts to lead investigations into the formation of copper deposits in the region. Over the past 14 years, Roberts, supported by Ross McGowan, post-doctoral research fellow (2004) and PhD student (1999-2003), and PhD students Robin Bernau (2003-2007) and James Nowecki (2009-2012), has carried out a series of geological studies into the origins of Copper-Cobalt mineralisation in the Zambian Copperbelt. There have also been numerous projects undertaken by Masters students.</p> <p>In the early 2000s Roberts led field studies at Zambia's Nchanga mine, one of the largest open cast mines in the world. Researchers used a combination of structural mapping and geochemical techniques, including major, trace and radiogenic isotope analyses carried out at the National Oceanography Centre Southampton, to challenge the long-accepted assertion that ore Cu-Co deposits formed at the same time as the sediments in which they were found. They showed, for the first time, that ore formation – and crucially location – is controlled by geological processes that occurred much later in the evolution of the basin than previously accepted [3.1, 3.2]. Roberts' team found that within the 800-million-year-old basin, ore formation had occurred over a 300-million-year period as a result of the thermochemical reduction of sulphate and metal enriched hydrothermal fluids introduced during basin inversion. This new evidence expanded the applicable exploration criteria to include additional, substantive structures that developed within the basin during its evolution [3.3].</p> <p>The team extended their studies to the Cu-Co deposits of the Lumwana Mine, in Zambia's Domes Region, through the PhD studies of Bernau (2003-2007) and Nowecki (2009-2012). The origin of these deposits had been the subject of much debate. However, Southampton firmly established that copper was located within basement rocks of the Zambia Copperbelt, and developed along basement shear zones [3.4]. This work amplified the results of the earlier Southampton studies, further developing the role of tectonics in the origins of mineralization and broadening further potential exploration targets in the region.</p>

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Taken together, the new studies showed that successful base metal exploration within the Zambian Basin requires an understanding of the contrasting styles and timing of mineralization. This knowledge opens significant new regions for exploration previously dismissed by scientists and the mining industry.

3. References to the research (the best 3 illustrating quality of research are starred)

- *[3.1] (2003) McGowan R., Roberts S., Foster R.P., Boyce A.J. & Coller D. Origin of the copper-cobalt deposits of the Zambia Copperbelt: An epigenetic view from Nchanga. *Geology*, **31**, 497-500.
- *[3.2] (2006) McGowan R., Roberts S. & Boyce A. Origin of the Nchanga Copper-Cobalt Deposits of the Zambian Copperbelt *Mineralium Deposita*, **40**, 617-638. Awarded "SGA Best Paper" published in *Mineralium Deposita* for 2005 – 2006.
- [3.3] (2009) Roberts S., Palmer M., Cooper M., Buchaus P., Sargent D. REE and Sr isotope characteristics of carbonate within the Cu-Co mineralized sedimentary sequence of the Nchanga Mine, Zambian Copperbelt. *Mineralium Deposita*, **44**, 881-891.
- *[3.4] (2012) Bernau R., Roberts S., Richards M., Nesbitt B., Boyce A.J., Nowecki J. The Geology and Geochemistry of the Lumwana Cu (\pm Co \pm U) deposits, NW Zambia. *Mineralium Deposita*, **v48**, 137-153.

Funding:

- 2011 NERC-Stable Isotope Support– Zambian Copperbelt (IP-1241-0511) £55K
- 2000 NERC PhD award (NE/H524922/1) £65K
- 2007 Equinox Resources. Copperbelt Uranium £10K
- 2005 NERC-Stable Isotope Support – Zambia Copperbelt (IP/890/1105) £24K
- 2006 NERC PhD CASE Award – (Equinox Resources) (NER/S/A/2003) £55K
- 2003 Anglo American PLC – Geochemistry of the Copperbelt £140K
- 2002 Anglo American PLC – Geochemical Exploration Vectors in the Copperbelt £20K
- 2002 NERC-Stable Isotope Support – Zambia Copperbelt (IP/755/0302) £19K
- 1999 Geological Society London - Fermor PhD award. Towards a new genetic model for pre-Cambrian sediment-hosted copper deposits £55K

Plus "In Kind" Support from: Anglo American, Equinox Resources, Vale, First Quantum. During a 10 year period this includes all transport and accommodation costs in Zambia and the costs of sample shipment. Estimated value in excess of £100K.

4. Details of the impact

The de-nationalisation of its copper mines has powered economic growth in Zambia over the last decade [5.1]. *The Economist* ranks Zambia as one of the world's fastest-growing economies over this period and since 2000 average income per capita has risen more than 40 per cent. Copper accounts for 80 per cent of Zambia's export earnings, which were 9 billion US dollars for 2011.

Research at Southampton that successfully challenged conventional wisdom on the formation of copper deposits in Zambia, is credited with playing a key role in furthering the development of the Central African Copperbelt. Prior to studies led by Roberts, the Zambian Copperbelt was regarded as a mature exploration terrane, with limited opportunities for new ore discoveries. Southampton's intervention was timely as the renascent mining industry in Zambia was attracting substantial incoming investment from the world's mining giants. Insights published by Roberts et al gave mining companies the licence to be more creative in generating new targets and allowed them to

manage risk more effectively. On behalf of Anglo American, Graham Brown [5.2], Group Head of Geosciences, comments that research at Southampton *“changed our exploration targeting methodologies and, by encouraging us to think about the process of formation, opened up the whole (copper) package, and made regions prospective that weren’t prospective previously.”*

The lessening of risk was crucial. The new Southampton research model gave several mining companies, including Anglo American, Equinox/Barrick, First Quantum, Vale and Rio Tinto, the confidence to launch new exploration programs in the knowledge that viable Cu-Co deposits existed outside the regions explored under the traditional research paradigm. The published research provided these companies with the geochemical tools and theoretical modelling to find them. It has been impossible to obtain commercially confidential figures detailing the amount of investment global mining companies have poured into these programs. In 2012 Rio Tinto used the new Southampton model to shift its exploration focus to a relatively unexplored area south of the Domes region, committing a substantive exploration budget. Adam Duffin [5.3], Chief Geoscientist at Rio Tinto, said: *“Rio Tinto has invested considerable resources in copper exploration in Zambia over the past two years based on the new understanding of the geology of the copperbelt and its mineral resources and enjoys a strong relationship with The University of Southampton group led by Steve Roberts which it has drawn on in developing our exploration strategy.”* World-leading exploration consultant Richard Sillitoe [5.4] notes: *“The University of Southampton group led by Steve Roberts has played a key role in an ongoing reinterpretation of the geology of the Zambian Copperbelt. This fresh vision is stimulating exploration activity in the region, impacting on the strategies that companies are employing and leading to increased expenditure.”*

One of the most significant outcomes of this expanded exploration activity in Zambia was the opening, by Australian miners Equinox, of a new mine in Lumwana, in the Domes region, in January 2009, an asset that partly motivated Barrick’s takeover of Equinox for £4.5 billion in July 2011. The population of Manyama, the nearest settlement to the mine has increased five-fold over the last ten years. The opening of the mine has offered employment (directly and indirectly) to around 3000 Zambians in the region and improved local infrastructure [5.5]. Mike Richards [5.6], former Chief Geologist at Barrick, said: *“The decade-long collaboration between Steve Roberts’s team and our geology team in Zambia to reinterpret the geology of the Zambian Copperbelt has been an integral part of our exploration efforts in Zambia. It has had a profound influence on our exploration strategies, expenditure and success in the region.”*

The impact of the research has extended beyond Zambia. Mining companies have applied the Southampton model to similar environments in Gabon and Democratic Republic of Congo (DRC). Canada’s Ivanplats led the discovery of the Kamoia mine near Lubumbashi, the mining capital of DRC, in 2011. DRC produces more than three per cent of the world’s copper and half its cobalt. Kamoia ranks as the world’s largest undeveloped high-grade copper discovery, with 739 million tonnes grading 2.67% copper. In Gabon another Canadian firm Armada Exploration is investing more than \$5 million in exploration for copper in a region with a similar formation history to the Zambian Copperbelt [5.7].

Through research led by Roberts, a number of highly skilled scientists that trained at Southampton have filled high-profile industry posts. PhD students McGowan and Bernau are CEO at Armada Exploration and Project Geologist at Micon International respectively. McGowan was actively involved in the discovery of the Kamoia Deposit in DRC. Masters student Adam Burley (1996-2000) was, until July 2013, President of Kennecott Eagle Minerals Co. and is now managing strategy, growth and innovation for copper at Rio Tinto.

Roberts has also actively shared his expertise and research findings with industry, as is demonstrated by his pivotal role in a recent workshop. In June 2013 Roberts organised and delivered a capacity-building workshop, *African Metallogeny II – Base Metals in Basins* in Kitwe, Zambia. The aim of this workshop, supported by UNESCO, *“is to train young African geoscientists in the specific field of metallogeny, i.e. practical aspects of the genesis of ore deposits that can be*

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applied in the formulation of future exploration strategies” [5.8]. The course was attended by over 50 delegates from 14 countries and twenty mining companies such as Rio Tinto, First Quantum and Barrick. Feedback from delegates was very positive, particularly praising the link between theory and practical exposure to example rocks. Delegate feedback included: “The workshop structure was fantastic with the right balance between lectures, mine visits and core viewing. I personally enjoyed that while looking at the core you guys assigned tasks that made our observation of the rocks, alteration and mineralization styles and discussion about stratigraphic positioning much more objective.”, “The workshop was one of the best that I’ve ever participated in 10 years of professional life. I believe that you guys had found the right structure for future events” and “Thanks for organising an excellent workshop. The Barrick team really appreciated the effort and time you put into organising the workshop and the seamless execution” [5.9].

5. Sources to corroborate the impact

[5.1] <http://www.economist.com/blogs/baobab/2013/05/development-africa>

[5.2] Group Head of Geosciences, Anglo American.

[5.3] Chief Geoscientist, Rio Tinto.

[5.4] Exploration Consultant.

[5.5] <http://barrickbeyondborders.com/2012/12/managing-in-migration-at-lumwana/> and <http://www.eib.org/infocentre/press/news/stories/2010-august-02/lumwana-stimulates-economic-growth-in-zambia.htm>

[5.6] Chief Geologist, Barrick.

[5.7] Chief Executive Officer, Armada Exploration Limited.

[5.8] Industry workshop: *African Metallogeny II – Base Metals in Basins*, Kitwe, Zambia, June 2013 <http://www.meetingpoints-mining.net/2013/02/2nd-sga-seq-unesco-iugs-short-course-on-african-metallogeny/>

[5.9] Report for SGA Council Meeting (draft).