Institution: University of Leicester

Unit of Assessment: 7 Geology

Title of case study:
New geological approaches drive exploration strategies and accelerate economic growth in the minerals industry

Period when the underpinning research was undertaken: 2009 - present

Details of staff conducting the underpinning research from the submitting unit:

Name(s):	Role(s) (e.g. job title):	Period(s) employed by submitting HEI:
Dr David Holwell	Associate Professor in Applied and Environmental Geology	August 10 2009 - present

Period when the claimed impact occurred:
January 2015 – December 2020.

Is this case study continued from a case study submitted in 2014? N

1. Summary of the impact

Dr David Holwell's research led to new, geologically targeted ore-exploration strategies and mining procedures for four mining and exploration companies in the UK, Greenland, and Zambia. This research contributed a total GVA of GBP408,804,900 to these companies and to regional economies by enabling mergers, accelerated productivity, and reduced capital expenditure; by leveraging regional investment; and through the creation of c. 500 jobs in an economically deprived region of Zambia.
In particular, the research facilitated the closed Munali Nickel Mine, Zambia, to reopen in 2019, producing 3,600 tonnes of nickel annually by December 2020, worth GBP37,546,750. It enabled ASX-listed Conico to purchase Longland Resources, Greenland, in October 2020, worth GBP1,760,000.

2. Underpinning research

Since 2009, Dr David Holwell's research has focused on developing new, strategic, geological search methodologies for reducing economic and energy costs in the mining industry. Mineral exploration is essentially a search-area-reduction exercise, with the aim of discovering a mineral resource. Making exploration more efficient in terms of generating targets, and reducing the search space in this 'needle-in-a-haystack' exercise saves the minerals industry millions of dollars (a typical exploration drilling programme is c. USD1,000,000 – 2,000,000). Through collaboration with industry at every stage, Holwell has applied a multi-technique approach that utilises a classic 'source-pathway-sink' scientific framework. Predicting where to explore for the 'sink' (ore deposits) relies on understanding the processes of source and pathway and being able to fingerprint them [**R1-R5**].

In Greenland, the publication of work on newly discovered mineralisation and the identification of high potential for discovery of new copper-palladium and gold ore deposits [**R1**, **R2**] illustrates this multi-technique approach. The publication [**R1**] outlines the 'fingerprints' of a pathway, with confirmation that many of the source characteristics are

there, and thus provides strong evidence of a sink (deposit). In addition, the discovery of the first gold mineralisation in east Greenland [**R2**] has generated an exploration strategy to develop this deposit. Longland Resources (now Conico), set up on the basis of these findings [**R1**, **R2**], is currently actively exploring the area for such deposits.

Holwell's research at the Munali mine in Zambia [**R3**-**R5**] revealed that different parts of the orebody have varying metallurgical characteristics, including a copper-rich zone [**R5**]. Howell's methodology has developed a new **mineral exploration technique** for nickel deposits [**R7**]. Magnetite is a common mineral in many rock types, including those that host nickel deposits. But Holwell's research showed that magnetite associated with nickel sulfide deposits is chemically distinct from other sources [**R7**]. Thus, Holwell discovered that magnetite in soils can be used to trace the possible presence of *hidden* nickel deposits. Holwell's novel research process defined a new exploration 'fertility indicator' for nickel mineralisation that can be picked up from *surface soil*. The results instigated a regional soil-sampling programme by Consolidated Nickel Mines (CNM) around the Munali Mine, Zambia (2015-present), which in one are identified magnetite with strong fertility indicators.

The application of automated mineralogy to informing mineral processing [**R6**] has been applied at the Kitumba Copper Project in Zambia, where ongoing research since 2018 with ZEISS and CMI is providing key new information on the nature of a copper orebody that had been discovered, but had yet to be exploited.

3. References to the research

[R1]. **Holwell, D.A**., Abraham-James, T.H., Keays, R.R. and Boyce, A.J. 2012. "The nature and genesis of marginal Cu- PGE-Au sulphide mineralisation in Palaeogene Macrodykes of the Kangerlussuaq region, east Greenland". *Mineralium Deposita*, 47, 3–21. DOI: https://doi.org/10.1007/s00126-010-0325-4

[R2]. **Holwell, D.A.**, Jenkin, GRT, Butterworth, KG, et al. 2013. "Orogenic gold mineralisation hosted by Archaean basement rocks at Sortekap, Kangerlussuaq area, east Greenland". *Mineralium Deposita*, 48, 453-466. DOI: https://doi.org/10.1007/s00126-012-0434-3

[R3]. **Holwell, D.A**., Michell, C.L., Howe, G.A., et al. 2017. "The Munali Ni sulfide deposit, southern Zambia: A multi-stage, mafic-ultramafic, magmatic sulfide-magnetite-apatite-carbonate megabreccia". *Ore Geology Reviews*, 90, 553-575. DOI: https://doi.org/10.1016/j.oregeorev.2017.02.034

[R4]. Blanks, D.E., **Holwell, D.A**. and Barnes, S.J. 2017. "Magmatic sulphide mineralisation of the Munali nickel deposit: evidence for immiscible sulphide-carbonate-phosphate-silicate melts?" *Proceedings of the 13th Biennial Society for Geology Applied to Mineral Deposits Meeting 2017*, Quebec City, Canada, Volume 2, 415-418. http://hdl.handle.net/102.100.100/88107?index=1

[R5]. Blanks, D.E., **Holwell, D.A.**, and Barnes, S.J. 2018. "Carbonate-rich magmatic Ni-Cu-PGE mineralisation at Munali: a new style of magmatic sulfide deposit?" Abstract volume, 13th International Platinum Symposium, Polokwane, South Africa.

[R6]. **Holwell, D.A.**, Adeyemi, Z, Ward, L.A. Ward, et al, 2017. "Low temperature alteration of magmatic Ni-Cu-PGE sulfides as a source for hydrothermal Ni and PGE ores: A quantitative approach using automated mineralogy". *Ore Geology Reviews*, 91, 718-740, DOI: https://doi.org/10.1016/j.oregeorev.2017.08.025

[R7]. Ward, L.A., **Holwell, D.A.**, Barry, T.L., et al, 2018. The use of magnetite as a geochemical indicator in the exploration for magmatic Ni-Cu-PGE sulfide deposits: a case study from Munali, Zambia. *Journal of Geochemical Exploration*, 188, 172–184. DOI: https://doi.org/10.1016/j.gexplo.2018.01.018

4. Details of the impact

Legacy mineral *exploration* techniques and extraction methods require significant resource, time, and cost. Dr David Holwell's research methodologies [**R1**-**R7**] informed new exploration strategies and mining procedures in Greenland and Zambia, directly and indirectly contributing GVA GBP408,804,900 to four mining and exploration companies in the UK, Greenland, and Africa; and to local economies in Zambia through investment and c. 500 jobs [**E1-E5**].

Transforming business strategies worth GBP3,300,000 in Greenland

Holwell's research methodologies [**R1-R5**, **R7**] changed exploration and mining strategies for two companies: Longland Resources (Longland – now Conico), Greenland. Holwell's accurate geological predictive geological capability contributed to GBP3,300,000 in economic growth for both companies through leveraged investment, accelerated productivity lead-time through strategic, surface-level exploration, and company mergers [**E1**, **E2**].

The Mineral Systems Approach (MSA) methodology increased the value of the Ryberg exploration project, Greenland, by GBP1,750,000 following their purchase by ASX-listed Conico [**E2**]. Holwell's MSA research in Greenland (2008-2014) [**R1**] identified indicators of mineral resources, and pinpointed likely targets within a vast region. Longland Founder/Director and now Conico CEO (TAJ) confirmed that Holwell's research "*highlighted significant potential for the discovery of a large nickel, copper and palladium deposit, which provided the basis for the decision… to set up the company* [and] *increase the licence area from 299km² to 3,889km²*" [**E1**]. Furthermore, the discovery of gold reported in [**R2**] is of particular interest to Conico, who are currently exploring the site [**E1**].

Holwell's methodology [**R1**] equipped Longland with the research evidence and strategic viability required to raise GBP1,580,000 investment [**E1**] for exploration for both copper-palladium, and gold deposits in summer 2020. Longland applied Holwell's strategic, targeting methods [**R1**] to apply electromagnetic geophysical surveys, in order to generate focused targets to reduce drilling time and costs [**E1**].

Howell's "*significant research contributions . . . resulted in* [Longland's] *credibility to gain the interest of an acquirer*" – CEO Conico [**E1**]. In October 2020, Australian ASX-listed company, Conico, merged with Longland, which increased trading share prices by 11.5% by 4 November 2020 [**E2**]. This acquisition was *"The most significant and tangible measure of the impact* [from Holwell's] *research, with the result that Longland has increased its value by GBP1,750,000"* [**E1**].

Transforming mining and employment in Zambia worth c. USD540,000,000
(c. GBP405,504,900 21 December 2020)

Resurrecting the Munali Nickel Mine
The Munali Nickel Mine in Southern Province, Zambia (Munali) was placed on care and maintenance in 2011 by then-operator Albidon, in part due to "*using the wrong geological model, hence the wrong mining method . . . leading to uneconomic operations*" [**E5**]. The mine was taken over by Consolidated Nickel Mines (CNM), who approached Holwell (2015-present) to help develop their geological and metallurgic understanding [**R2**], leading to the Munali Mine Mineralisation Model (MMMM) [**E3**]. Holwell's MMMM and strategic protocols for understanding ore nature and continuity; and ore zone predictability [**R3**, **R4**] improved Munali's exploration indicators and their core logging, data gathering, mineralisation classification protocol [**E3**]. Munali specifically used Howell's magnetite research [**R7**] as an exploration indicator to define their exploration drill targets, and to contribute to better understanding of an orebody's predictable 'shoots' of nickel, copper, cobalt and platinum group elements [**R3**, **R4**, **E3**]. The former CNM CEO (2013-2020) confirmed that, by applying strategies informed by Holwell's research [**R2**-**R4**], CNM were able to extend the viability of the mine to target Munali's resources. He stated: *"By changing understanding in this way, CNM have been able to redesign the mining operations and brought the mine back into production in 2019"*, and exports of nickel and platinum concentrates began in May 2020. [**E4**]. He further stated: *"With the assistance of Dr Holwell's research, Munali was able to begin producing nickel and platinum concentrates in April 2020, producing an annual 3,600* [tonnes] *rising to 4,800 tonnes per annum of nickel in concentrate, valued, depending on nickel price,* [at] *USD40,000,000 – 60,000,000 per annum"* (04-2020, c. GBP37,546,750 12-2020) [**E4**, **E5**].

Munali's Superintendent of Geological Services stated that Holwell's research was *"of phenomenal importance to our understanding of the Geology of Munali Mine"* [**E3**]. Munali is now able to give *"much needed assurance to investors"* by providing *"improved mining services, consistent feed to the processing plant* [and] *better understanding of the variability of the resource model"* [**E3**]. *"Dr Holwell's work* [also potentially] *increased the Life of Mine (LOM) of about 20 to 30 percent"* [**E3**]. The former CNM CEO further stated: *"The increased capacity from Holwell's research directly impacted on jobs at Munali Mine, which now employs more than 400 people with a 99% Zambian workforce"* [**E4**, **E5**].

Transformed processing strategies for significant capital savings at Kitumba
Holwell's research [**R6**]—which he has applied since 2018 at The Kitumba Copper Project, Kitumba, Zambia, and in partnership with CMI and ZEISS—has changed CMI's understanding of ore processing techniques, leading to significant economic benefits for CMI [**E4**]. This research highlighted a critical misidentification in the mineralogy from previous work on the deposit. The results of the research enabled CMI to design and optimise their mineral processing strategy for the ores to minimise mining costs and maximise revenue from the copper resource. By confirming this feasibility, Holwell's research reinforced CMI's plans to develop the project, and changed CMI's proposed processing technique. CMI's CEO stated that Holwell's research showed that *"the ore will respond much more favourably to the extraction technique (acid leaching) than previously thought. This change in practice equates to a reduction in the capital costs required to develop the project from c. USD450million to a more financeable USD220million",* saving the company 51% in capital costs worth USD230M (12-2020) [**E4**].

Economic impact in a deprived region of Zambia

CMI's CEO stated: *"The increased capacity and production that Holwell's research enabled at both Munali and Kitumba* [**R1**-**R7**] *has brought more than USD60million in investment into Zambia, with a further USD220million planned in 2021 from the UK and China"* (12-2020) [**E4**]. As of December 2020, CMI has brought both direct and indirect employment for c.500 people in the economically deprived Southern and Central provinces region of Zambia. Furthermore, CMI has worked with the Zambian and British governments to bring an additional USD100million (12-2020) in investments into Zambian SMEs as part of its contribution to its sustainable development goals [**E4**].

5. Sources to corroborate the impact

[E1]. Testimonial letters from Founder/Director of Longland relating to Longland / Mount Ridley Mines / Conico, February and November 2020.

[E2]. Compiled Longland/MRM/Conico merger news and market reports.

[E3]. Testimonial letter from Mabiza Resources Superintendent of Geological Services, Munali Nickel Mines.

[E4]. Testimonial letter from CEO of CMI/CNM, 14 December 2020.

[E5]. Compiled Consolidated Nickel Mines/Munali materials: CNM Brochure, April 2019; CNM Factsheet, February 2020; *Mining Technology News* feature; Munali Nickel Mines website.