DISTAL FOOTPRINTS (RP04-063) CASE STUDY 1

BOX 1 EXECUTIVE SUMMARY

Key findings

The main areas of benefit that may arise for the distal footprints project are:

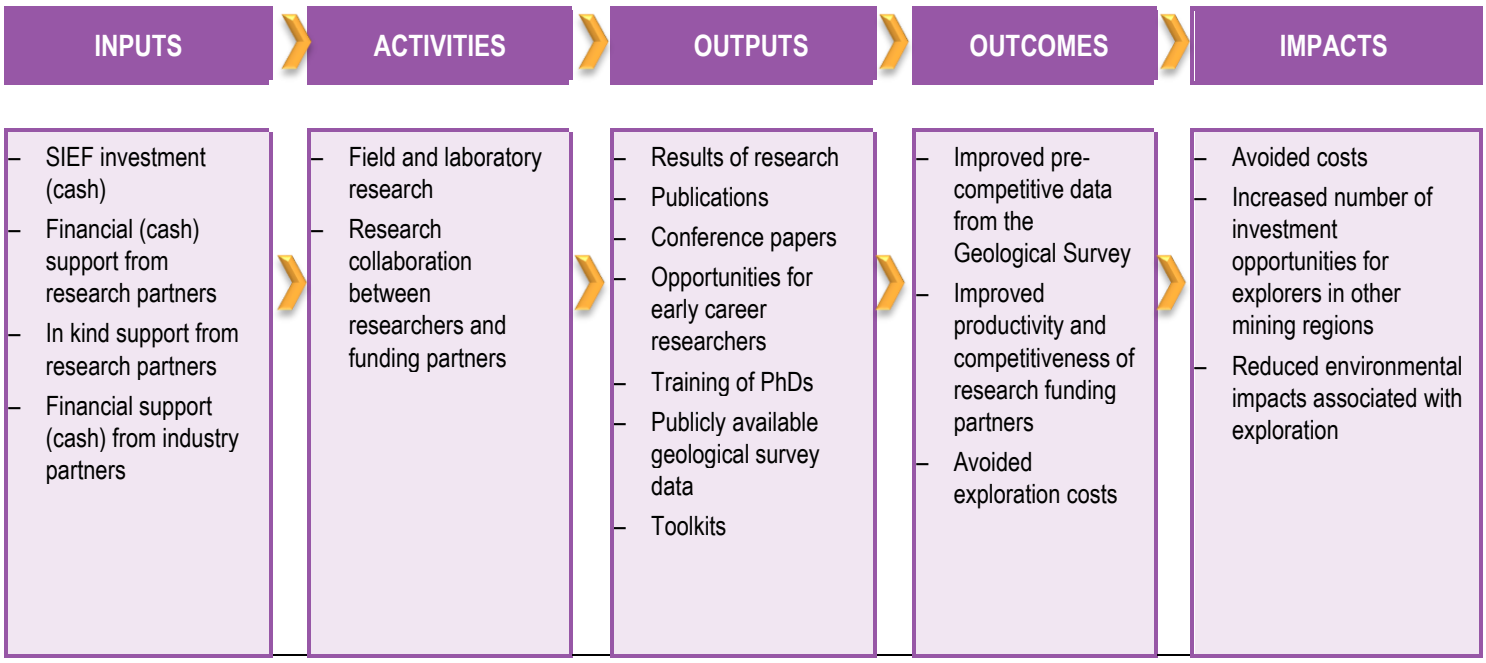
- Information that can provide a catalyst for mineral exploration in unexplored areas by providing precompetitive (basic) geoscientific data.
- Information that can allow future explorers to apply new techniques and technologies to areas where mineral detection and extraction has previously been deemed too technically difficult or not cost effective enough to warrant investment.
- Access to new information and techniques is providing investment opportunities for explorers in other mining regions.

Innovation impact

The distal footprints project has developed an innovative approach that could allow resource discovery rates to increase significantly even in areas where the cover over the top of the potential source is relatively deep. It has also supported the further development of a research concentration in Perth that is leading to additional investment in Western Australia's geological research community.

This case study uses the evaluation framework outlined in the CSIRO Impact Evaluation Guide. The results of applying that framework to the Distal Footprints case study are summarised in **Figure 1.1**.

FIGURE 1.1 DISTAL FOOTPRINTS CASE STUDY—IMPACT FRAMEWORK DIAGRAM



SOURCE: ACIL ALLEN

1.1 Purpose and audience for case study

This case study describes the economic, environmental and social benefits arising from the Science and Industry Endowment Fund (SIEF) research project "The Distal Footprints of Giant Ore Systems: UNCOVER Australia Project (RP04-063)". The stated objectives of the Distal Footprints project are to:

- *Build on current knowledge to deliver improved understanding of the evolution and controls on mineral systems in the Capricorn region, with generic learnings that can be applied elsewhere to boost exploration discovery success in covered terrains in Australia.*
- *Provide a framework for establishing and applying an exploration 'toolkit' for the detection of distal footprints associated with mineral systems under cover. The toolkit will include a first order approach to cover, delineating its thickness, sampling the cover and revealing its complexity. It will include an understanding of the deeper crustal architecture in the region and the metallogenic potential of the broader mineral system in the crust and finally a mineralogical analysis approach within the toolkit that might detect a distal footprint of the expression of a potentially mineralised mineral system and better understanding of what anomalism means against the regional background.*
- *Develop an Exploration Guide to the Capricorn region of Western Australia as a product for Junior Exploration companies and geologists.*
- *Develop a set of integrated large scale geological and geophysical datasets that assist with providing constraints on crustal whole lithosphere architecture and tectonic evolution.*

Funding Agreement between SIEF and the CSIRO, the University of Western Australia, Curtin University and the Geological Survey of Western Australia, 2013, Section B.3.

This case study provides information for accountability, communication and continual improvement purposes. Its considers the impact of the Distal Footprints project from two perspectives: 1) against the objectives set for project; 2) the other or unintended benefits that may have been generated from the project's inputs, activities, outputs and outcomes. The audiences for this case study may include Members of Parliament, Government Departments, SIEF, CSIRO and the general public.

1.2 Background

Most large Australian ore deposits that are being mined today were discovered via their direct surface expression, and mostly in the last century. However, much of its remaining mineral endowment is obscured under the thick cover of weathered rock, sediment and soil materials that extends over two thirds of the continent. This represents both an opportunity and challenge for explorers and the nation as the industry currently lacks the fundamental data, scientific knowledge and technological tools needed to discover new, world-class ore deposits buried beneath this cover.[1]

To replace the resources being extracted and to provide long-term mineral wealth for Australia, this trend needs to be reversed. New discoveries will sustain and drive export revenue, regional development, employment, royalty and taxation returns and a thriving mineral industry for the benefit of all Australians. Australia's global leadership in the development and export of exploration technologies and services will also be protected and indeed grow as a proportion of the export economy.

The technical risk associated with mineral exploration due to this cover is reducing investment in Australia by major mining companies. At the same time, the difficulty in obtaining capital to finance exploration coupled with low levels of IPO activity for junior explorers means a reduced discovery success rate.

The key to the discovery of new high grade mineral deposits is the ability to detect and recognise the distal footprints ore bodies. The Federal government has called for a National Exploration Strategy to reverse the decline in greenfield exploration in Australia and drive improved discovery rates for new resources. The existing non-bulk mining resource base in Australia has a relatively short future lifespan and yet new mineral resources are not found to replenish those being depleted. The Academy

[1] Distal Footprints 2018, 'Final Supplementary Report on SIEF Research Projects', January

of Science High Flyers Think Tank and UNCOVER initiative has highlighted this and is encouraging exploration geoscientists to collaborate to tackle this national challenge with focussed research programs that will provide the science and toolkit to assist the industry.[2]

The Distal Footprints project aims to develop a toolkit with a workflow to identify such footprints within the hosting mineral system and thereby address a fundamental limitation in current exploration methodologies.

1.3 Impact Pathway

1.3.1 Project Inputs

Table 1.1 shows the cash and in-kind support provided for the Distal Footprints project by the various contributors to the research. SIEF was the major cash contributor to the project with a total of $4 million. The project received strong support from the Geological Survey of Western Australia (GWSA), which contribute $2.5 million.[3] Industry also provided cash support of $900,000 for the research. Total cash support was $7.4 million.

In-kind support (provided by CSIRO, Curtin University and the University of Western Australia) totalled just over $6.1 million.

Note that the cash and in-kind support listed in **Table 1.1** was used to fund work streams 1, 2 and 3.

TABLE 1.1 CASH AND IN-KIND SUPPORT FOR THE DISTAL FOOTPRINTS PROJECT

Contributor / type of support	2012-13	2013-14	2014-15	2016-17	2017-18	2016-17	Total
Cash							
SIEF	$256,031	$928,407	$995,355	$1,007,020	$405,567	$407,620	$4,000,000
GSWA		$1,500,000	$500,000	$500,000			$2,500,000
Industry		$225,000	$225,000	$225,000			$900,000
Total							**$7,400,000**
In-kind							
Curtin	$105,145	$482,052	$502,240	$523,437	$242,239	$243,466	$2,098,579
UWA	$201,289	$362,489	$427,026	$447,269	$233,671	$234,854	$1,906,598
CSIRO	$143,492	$553,879	$587,096	$571,905	$113,350	$113,925	$2,143,440
Total							**$6,148,617**
Total Investment	**$13,548,617**						

Note: GSWA—Geological Survey of Western Australia

SOURCE: CSIRO

1.3.2 Project activities

The core activities of the Distal Footprints project fall into one of six work streams. Themes 1, 2 and 3 commenced in 2013 following the project's successful application for SIEF grant funding. These themes comprised the following research activities:

1. Theme 1—Mineral Systems. This theme is aiming to examine the whole mineral system. It is studying the region at a very large scale and trying to build an image what is present at deep to intermediate depths. Researchers are using passive seismic techniques and magnetotellurics[4] to better understand

[2] The UNCOVER initiative identified the Distal Footprints project as "a flagship research exemplar"

[3] The funding from GSWA was used to carry out an airborne geomagnetic survey of the Capricorn region.

[4] Magnetotellurics is an electromagnetic geophysical method for inferring the earth's subsurface electrical conductivity from measurements of natural geomagnetic and geoelectric field variation at the Earth's surface.

the Capricorn mineral system in the context of the 4D evolution of the region.[5] [6] The work on this theme provides the framework that underpins the research on all the other themes.

2. Theme 2—Characterising the cover in the Capricorn region. The researchers in this theme are using the results of the airborne survey to build a map of the approximately top 300 meters of the cover. This effectively provides a map of the subsurface and allows the researches to identify where the cover is depositing or eroding. This in turn helps to determine the significance of what is detected at the surface. In other words, is the signature seen at the surface from below or from a more distant region?
3. Theme 3—Mineral hosts as Distal Footprints. This theme is seeking to answer the question—what are the distal footprints associated with mineral deposits? The project will develop a 'distal footprints toolbox', to be applied to exploration in the Capricorn region. To do this the researchers are developing a better understanding of how key indicator trace elements can be associated with different ore deposit types at different distances from the sampling site. The research for this theme is applying techniques that have never before been used for mineral exploration.

Following the successful progress of these themes against the milestones established by SIEF and the project's funding partners, three additional research themes were adopted to build on the work already done. Work on these new themes was funded by the Minerals Research Institute of WA (MERIWA), the research partners and the Geological Survey of WA.[7] These themes were:

4. Theme 4—The hydrogeochemistry of the Capricorn. This theme seeks to map the hydrogeochemistry of specified areas within or adjacent to the Capricorn region and determine background concentrations of elements with exploration importance for different mineral types. The research will also examine the detection of different isotopes in groundwater or can be used to analyse the prospectivity of an area
5. Theme 5—Geochemical Mapping for Lithospheric Evolution, Metal Reservoirs & Predictive Targeting. This theme seeks to undertake:
   - Zircon separation (SELFRAG LAB) using selective fragmentation and recovery of morphologically intact zircon
   - Zircon characterisation using SEM analysis and CL imaging
   - LASS-ICPMS analysis using simultaneous U-Th-Pband trace element abundances.
6. Theme 6—Developing a Digital Model using virtual environments for data integration and visualisation. This theme seeks to provide a standardised approach to data management (i.e. sample data, analysis data) to make it easier to both disseminate data to end users and to provide end users with analytical and visualisation tools to enable them to more easily make use of the data.

ACIL Allen's consultations with project leaders made it clear that, while themes 4—6 are not formally funded by SIEF, there is a high level of interaction between all the research themes under the Distal Footprints project. That is, the learnings and data generated from one research theme influences the activities of the other research themes.

1.3.3 3.3 Project outputs

Research outputs

The Distal Footprints' core research team have been actively seeking to publish their research findings and contribute to the growth of the stock of knowledge about exploration methodologies and techniques. The table below provides a selection of publications (and submissions) by Distal Footprints-supported researchers since 2014.

[5] Orogens develop when a continental plate is crumpled and is pushed upwards to form mountain ranges. The geological processes involved are collectively called orogenesis.

[6] The choice of the Capricornia region was driven by a number of factors. These included that GSWA had recently conducted a seismic study of the region, the region was surrounded by some good infrastructure and that the region was of interest to a number of smaller explorers.

[7] SIEF did not provide any funding support for research themes four, five and six.

TABLE 1.2 PUBLICATIONS ASSOCIATED WITH THE DISTAL FOOTPRINTS PROJECT

Year	Authors	Title	Journal	Status
2017	Lampinen, H., Laukamp, C., Occhipiniti, S.A., Metelka, V., Spinks, S.	Delineating Alteration Footprints from Field and ASTER SWIR Spectra, Geochemistry and Gamma-Ray Spectrometry above Regolith Covered Base Metal Deposits - an example from Abra, Western Australia.	Economic Geology 112, 1977-2003.	Published
2015	Devaraju A., Klump J., Cox S. J. D., and Golodoni uc P	The Internet of Samples: Representing and publishing physical sample descriptions	Computers & Geosciences doi:10.1016/j.cageo.2016.07.018.	Published
2014	White, A.J.R., Smith, R.E., Nadoll, P., leGras, M	Regional scale metasomatism in the Fortescue Group volcanics, Hamersley Basin, Western Australia: Implications for hydrothermal ore systems.	Journal of Petrology 55, 977-1009	Published
2018	ilerook, H.K.H., Sheppard, S., Johnson, S.P., Occhipiniti, S.A., Reddy, S.M., Clark, C., Fletcher, I.R., Rasmussen, B., Zi, J.W., Pirajno, F., LaFlamme, C., Donaldson, J.A., Ware, Blandthorn, E., Lindsay, M., Lu, Y.-J., Crossley, R.J., Erickson, T.M.,	Constraints on extensional episodes in the Paeoproterozoic Capricorn Orogen, Western Australia, revealed by petrogenesis and geochronology of mafic-ultramafic rocks.	Precambrian Research 306, 22-40.	Published
2017	Pina-Varas, P. and Dentith, M.	Magnetotelluric data from the Southeastern Capricorn Orogen,Western Australia: an example of widespread out-of-quadrant phase responses associated with strong 3-D resistivity contrasts.	Geophysical Journal International, 212, 1022-1032.	Published

SOURCE: DISTAL FOOTPRINTS PR3 PROGRESS REPORT TO SIEF

In addition, the Distal Footprints project researchers have been active in the dissemination of research findings at national forums. Over the past two years key Distal Footprints researchers have given over 20 conference presentations. Five are listed below:

1. White, A.J.R., Pearce, M.A., Meadows, H.R., Treacy, J., Robinson, J. Geochemical background: A statistical approach to anomaly detection. Society of Economic Geologists, Hobart, Australia, September 2015.
2. Banaszczyk, S., Annetts, D., Dentith, M. 2016, Towards resolving dipping contacts undercover in the Capricorn Orogen using AEM. ASEG Extended Abstracts Adelaide 2016, 1-8.
3. Occhipiniti, S.A., Methods of targeting across all scales - toolbox from the Capricorn Distal Footprints study, In: Wyche, S., Witt, W. (Eds.), TARGET 2017. Geological Survey of Western Australia, Perth, Australia, pp. 117-119.
4. Golodoniuc P., Devaraju A., and Klump J., 2016, The implementation of IGSN in the context of Australian mineral exploration: Geophysical Research Abstracts, Vol. 18, pp. EGU2016-1562, Copernicus Society, Vienna, Austria.
5. Lampinen, H., Laukamp, C., Occhipiniti, S.A., Metelka, V., Spinks, S., 2017. Ground truthing remote sensing maps - mineralogical composition of regolith and its implications to hydrothermal alteration, In: Wyche, S., Witt, W. (Eds.), Target 2017. Geological Survey of Western Australia, Perth, Australia, pp. 81-84.

Research training and early career development

Distal footprints has provided career development and research training opportunities for a number of researchers in Western Australia. Each of these researchers have made a positive contribution to the

research output of the project and/or progress towards the completion of their doctorates. Details of the postdoctoral researchers and doctoral students directly funded by SIEF are provided in **Table 1.3**.

TABLE 1.3 EARLY CAREER AND DOCTORAL STUDENTS DIRECTLY SUPPORTED BY SIEF

Postdoctoral or research fellows	Research discipline/focus	Doctoral candidate	Research discipline
Dr Alistair White	Research scientist with the CSIRO Mineral Resources Flagship	Sasha Banaszczyk	PhD candidate working on a geophysical component of the Footprints project—University of Western Australia
Dr Sam Spinks	Research geologist with experience in economic geology and Precambrian geological research	Vikraman Selvaraja	PhD candidate focusing on the mineralisation in the orogen and its relationship to the evolution of the orogeny in a spatial and temporal sense— University of Western Australia
Dr Diana Plavsa	Research Associate examining the tectonic evolution of the Capricorn Orogen—Curtin University	Holly Meadows	PhD candidate focusing on multi-stage ore formation
Dr Sandra Occhipinti	Senior Research Fellow Exploration Targeting—University of Western Australia	Inalee Jahn	PhD candidate in the Department of Applied Geology—Curtin University

SOURCE: DISTAL FOOTPRINTS PR3 PROGRESS REPORT TO SIEF

Publicly available exploration data

Where and when mineral exploration occurs depends on the perceptions of a region's geologic potential and the overall climate for the medium-to-large scale investment usually required to fund exploration activities. Perceptions of geologic potential are influenced by a number of factors, including:[8]

— First, perceptions reflect the knowledge about the region's geology obtained from previous activities, which can include previous exploration and mining, as well as non-mining activities such as road building and assessment of geological hazards.

— Second, the results of geoscientific research and information from publicly available geological surveys often play a critical role in attracting exploration to a relatively unexplored region, such as the Capricorn.

A key feature of the Distal Footprints project is that it contributes to the stock of precompetitive research results and data on the Capricorn region. These data can be described as a form of public good – that is, they are goods which are likely to be undersupplied by the market because they benefit the entire industry.

The information generated by the Distal Footprints project can provide a catalyst for mineral exploration in unexplored areas by providing precompetitive (basic) geoscientific data. That information can provide exploration companies with important signals that can point to the geological potential of the Capricorn. These signals can also be applied to other regions that display similar geological characteristics/formations.

The availably of the precompetitive data on the geology of the region generated from the Distal Footprints project also allows different explorers (using different techniques) to explore areas of the Capricorn which may have been previously examined and deemed unsuitable for development. History is littered with examples of deposits that have been discovered only after several exploration attempts have been made in the same area.

[8] Roderick G. Eggert, Mineral Exploration Development: Risk and Reward, May 2010, http://www.miningnorth.com/_rsc/site-content/library/education/Mineral_Exploration_&_Development_Roderick_Eggert_Eng.pdf

Furthermore, the availability of these data allow future explorers to apply new techniques and technologies to areas where mineral detection and extraction has previously been deemed too technically difficult or not cost effective enough to warrant investment.

Finally, a better understanding of the mineralisation could also inform decisions on how best to develop any resource that might be found.

Toolbox

A toolbox for industry has been developed as part of the research effort. This toolbox offers new ways of integrating geophysical datasets that image the upper crust to within the mantle have been used in order to map the 3D crustal architecture of the Capricorn Orogen. These, when used in conjunction with geochronological data and isotopic maps of Lu/Hf and Sm/Nd across the region can be used to help explorers understand the tectonic evolution of the region through time.[9]

Geological mapping, and geophysical-geological interpretations throughout the region has led to an improved synthesis of the tectonic development of the region. 3-D geological/geophysical models have been developed for the Yerrida Basin, enabling better interpretation of the stratigraphy of this region 'under cover'. Geophysical data collected for this project provide 3-D information for the region that can be further analysed, interpolated or inverted. Within the scope of this study data and interpretations a first pass mineral systems analysis has been made, and construction of prospectivity models accompanied by a prospectivity tool can be used to aid in area selection for exploration programs.[10]

Further work, within tenement blocks involving regolith land-form mapping that has benefited from analysis of regional scale electromagnetic (EM) data has been useful in a bid to target and understand results from regolith and hydrogeochemical sampling programs. Trace element geochemistry in rutile and titanite from a range of rock types across the area appears to highlight regions of relatively higher Au prospectivity.[11]

Innovation / commercialisation

A Western Australia firm (Lab West) that has been helping the research team with the analysis of samples have used their involvement in the project to drive a significant improvement in the efficiency of their operations—in particular, their exploration/sampling techniques.

Awards

One CSIRO staff member has been granted a CSIRO early career research award for his work on the project.

1.3.4 Project Outcomes

Given the relatively short time since this project began it is likely to be some time before the outputs of the research generate outcomes. Nonetheless the early signs are encouraging, with one of the minor explorers, Marindi Metals, participating in the project pegging an area in the Capricornia region based on the information delivered to date by the research effort.

We also note that the results from the Distal Footprints project have provided Geological Survey of Western Australia (GSWA) with the confidence to decide to carry our airborne magnetic surveys in other parts of Northern Australia. The information gained from this and other surveys will be a long term national asset that can be repeatedly examined and analysed as the technology available to do so changes and improves.

Direct economic benefits of the Distal Footprints project will flow from the potentially increased economic activity generated by additional exploration activity that might result from the information generated by Distal Footprints project. Additional exploration is more likely to be seen from those companies which have supported the SIEF funded research as they have exclusive access to the

[9] T. Munday and S. Occhipinti 2018, 'RP04-063/M436 Distal Footprints: UNCOVER Australia', Report on the Distal Footprints project.
[10] T. Munday and S. Occhipinti 2018, 'RP04-063/M436 Distal Footprints: UNCOVER Australia', Report on the Distal Footprints project.
[11] T. Munday and S. Occhipinti 2018, 'RP04-063/M436 Distal Footprints: UNCOVER Australia', Report on the Distal Footprints project.

research results for a period of time. However, other exploration industry players will also ultimately benefit from the publicly available knowledge generated by the research.

In essence, these benefits are the positive commercial outcomes that accrue to the exploration industry. They can take the form of increased chances of exploration activity that leads to the identification of new deposits that are economic to develop. There is also the prospects of improvements in the efficiency of exploration activities as companies get a better picture of the risks and opportunities of exploration in a particular region. The benefits could be reflected in avoided costs of exploration activities that do not reveal a commercially viable deposit.

There are also broader potential environmental benefits from improved characterisation of the Capricorn region. For example, improved characterisation provides important insights about the way mineral deposits form within a region and waste or hazardous materials below the earth's surface are distributed over a long term timeframe.

The results from Theme 2 of the research are also expected to be useful for water discovery.

Additional detail about the impacts (or benefits) generated from these outcomes is provided in Section 1.3.6.

1.3.5 Adoption

It has now been approximately four years since the commencement of Theme 1. It is still very early in the life of this project and therefore there has not been a great deal of adoption of the results of the research. However there are a number of extremely promising early signs that the benefits of this project will be considerable. They include:

- The decision by MERIWA to extend the scope of the project by providing significant funding for themes 4 to 6 of the project.
- The decision by Marindi Metals to take up a mining tenement in the Capricornia region after receiving the early results of the analysis carried out.
  - Marindi Metals have reported that their tenement activity has doubled following their involvement in the Distal Footprints project.
- Another firm is reportedly also considering acting on the information provided by the project.
- The Deep Exploration Technologies CRC has announced their intention to use the outputs of the project.

There are few, if any, barriers to the adoption of the technologies being developed. ACIL Allen is therefore confident that if the exploration results from early adopter firms like Marindi Metals are successful then the adoption rate of the technology among the rest of the industry is likely to be very rapid.

1.3.6 Impacts

The project's impact lies in its influence over renewed exploration activity and its ability to support end users in the discovery of new Australian resources. This influence generates benefit in royalties, tax collection, jobs, exports and social in terms of regional development, jobs in communities, new communities. The project's impact on a range of end users is outlined below. Owing to the long term and uncertain nature of minerals exploration in the Capricorn region and elsewhere (i.e. where the research will be applied on the ground) the impacts are appropriately divided amongst current and potential future impacts.

Impact on Geological Surveys

At the launch of the Proceedings of the Australian Academy of Science's Theo Murphy Think Tank, Searching the deep earth: the future of Australian resource discovery and utilisation in 2010, the Federal Minister Martin Ferguson commented: "What is needed now is the next generation of maps. Industry needs the information these next-generation maps will provide to uncover the deposits that will underpin our future resource prosperity."

Since then, the project has worked closely with Geological Survey of Western Australia (GSWA) to support the creation of new maps (a key part of their role in UNCOVER). The commitment to, collection and release of geological data across the Capricorn by the GSWA, as well as the acquisition of passive seismic and MT data, have been important outcomes of the collaboration.

CSIRO and its Distal Footprints research partners also intend to develop new tools and knowledge that support the surveys and provide industry with better understanding and access to pre-competitive data. These tools and knowledge will be used in regional assessment and targeting, particularly in greenfield terrains, and drive investment in mineral exploration. The planned impact is therefore likely to be a series of 'new pre-competitive geoscience products that support mineral exploration in Australia', and which value-add to their established geological and mineral deposit map products.[12]

Impact on Junior, Mid-Tier and Major Mining Companies

The Distal Footprints project has generated some commercial benefits for the businesses which have supported the project, however, these benefits can be more accurately characterised as future rather than current benefits.

The project has attracted industry sponsors are from a range of different classes of mineral exploration companies, including junior, mid-tier and major mining companies. For these sponsors, the project has provided a 'toolkit' that has been used on active exploration tenements in the Capricorn region. The early adoption of elements of 'the distal footprints toolkit' by these sponsors has revealed new discoveries, which are the key short and medium term impacts of the project.

For example, one sponsor has reported to ACIL Allen that the data and insights from the project have assisted identifying a large Capricorn-based deposit that may not have otherwise been discovered. Without the research the company reported that it would not have explored the tenement.

The same company also identified that the data and learnings from ongoing sponsorship of the Distal Footprints project has given it confidence to explore other regions with similar technical challenges in Australia. This company has reported to ACIL Allen that the application of Distal Footprints' knowhow to another tenement has led to a recent discovery, with the company now securing new external investment to support the exploration activities. This investment is estimated to be approximately $1 million worth of additional capital funding. If the exploration activities yield success over the longer term, the benefit to the company is estimated to be in the order of billions of dollars.

The Distal Footprints project has also led to one-on-one interactions between researchers and other mining industry companies. For example, one researcher approached a WA-based mining company (Montezuma Mining Ltd) for permission to work on their Butcherbird manganese deposit tenement. This deposit is the largest undeveloped manganese deposit in Australia. As the discussions between researchers and the company evolved and the collaboration deepened, researchers were able to help the company overcome technical barriers related to the processing the manganese ore for the purposes of processing high-value products that could be used in lithium batteries. The first stage of the research involved a collaborative co-funded pilot project testing a new type of ore processing that could extract more of the desired manganese product. The results positive results from this research, led to a stage 2 project which aimed to fully test the viability of the technique and move towards commercialisation.[13]

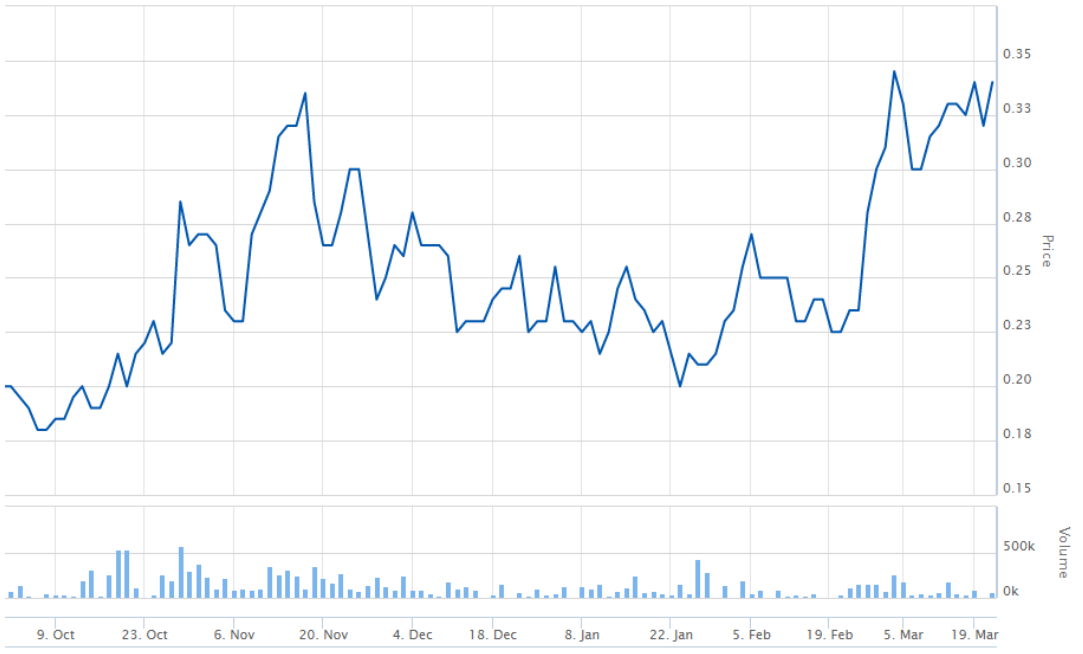
The positive outcomes to emerge from the research was a key factor in Montezuma Mining Ltd publicly announcing a revised resource estimate as part of its reporting obligations to the ASX in late October 2017. **Figure 1.2** identifies the stock price for Montezuma Mining since that announcement. It shows that the stock price rose sharply in the two months following the announcement, declined during January and February 2018, and has risen thereafter.

While this is not definitive evidence of the Distal Footprints' value, it is illustrative of how investment in the research can generate benefits to companies operating in the Capricorn region and elsewhere. It is also likely that this impact will extend well beyond the life of the SIEF agreement and the current sponsor-base. Ongoing communication and technology transfer (in the form of industry interactions and research engagement, training programs, and media communications) that is likely to be driven

[12] Distal Footprints 2018, 'Final Supplementary Report on SIEF Research Projects', January
[13] Based on consultations with the research team and Montezuma Mining's press releases.

by the researchers involved in the Distal Footprints project will ensure uptake of the research results over the longer term.

FIGURE 1.2 STOCK PRICE OF A DISTAL FOOTPRINTS INDUSTRY PARTNER (OCT 2017-MAR 2018)



SOURCE:
TTPS://WWW.ASX.COM.AU/PRICES/CHARTING/?CODE=MZM&COMPARECODE=&CHARTTYPE=&PRICEMOVINGAVERAGE1=&PRICEMOVINGAVERAGE2=&VOLUMEINDICATOR=&VOLUMEMOVINGAVERAGE=&TIMEFRAME=

Impact on the research capability of the National Geoscience Community

This project has significantly boosted the research capability of Australia's exploration geoscience community. It has done this by identifying and creating the next generation of researchers who now have exposure to the challenges and operating environments of industry. As a consequence, the project has supported the development of several early career researchers who have gained exposure to industry's need for the rapid technology transfer of research outputs and outcomes, and can work with industry in a collaborative or embedded way.[14]

The project has also exposed the research team to the importance of training of industry geologists in the newly-developed approaches and technologies. This exposure has helped the researchers involved in Distal Footprints to improve their communication and training skills and ultimately their ability to extend the research outputs and outcomes from the project. This new capability helps to boost the nation's capability in exploration geoscience research by generating a 'hub of researchers in Perth' who have industry experience and can link this experience to other research groups in Queensland, New South Wales, the Northern Territory and South Australia.

Potential to reduce unnecessary exploration costs

Mineral exploration and development are, by definition, speculative activities. The rewards for successful exploration can be significant if a mineral deposit is discovered and developed into a commercial mining operation. For an exploration and mining company, successful exploration can lead to increased profits. For a State Government, successful exploration can lead to jobs that otherwise would not have existed; to investment in local infrastructure (e.g. roads and power generation), and to increased government revenues.

But mineral exploration also carries with it risks and potentially high costs. Mining companies invest in exploration in the expectation that future revenues will be sufficient to cover the upfront costs of

[14] Distal Footprints 2018, 'Final Supplementary Report on SIEF Research Projects', January

exploration and deliver an acceptable profit to shareholders in the future. The level and location of investment are determined by expected revenues and costs, adjusted for time and risk. For example, the higher the expected revenues or the lower the expected costs, the more attractive an investment opportunity is.

The factors that influence expected revenues, costs, and risks in the mining sector have been grouped into four categories by US academic Roderick G. Eggert:[15]

— *Geologic Factors*—Does a mineral resource exist in a region, in what quantities, and of what quality? Geologic risk can be conceptualised as the likelihood and degree to which actual mineralisation (its quantity and quality) differs from what is anticipated at the point a decision is made to undertake exploration.

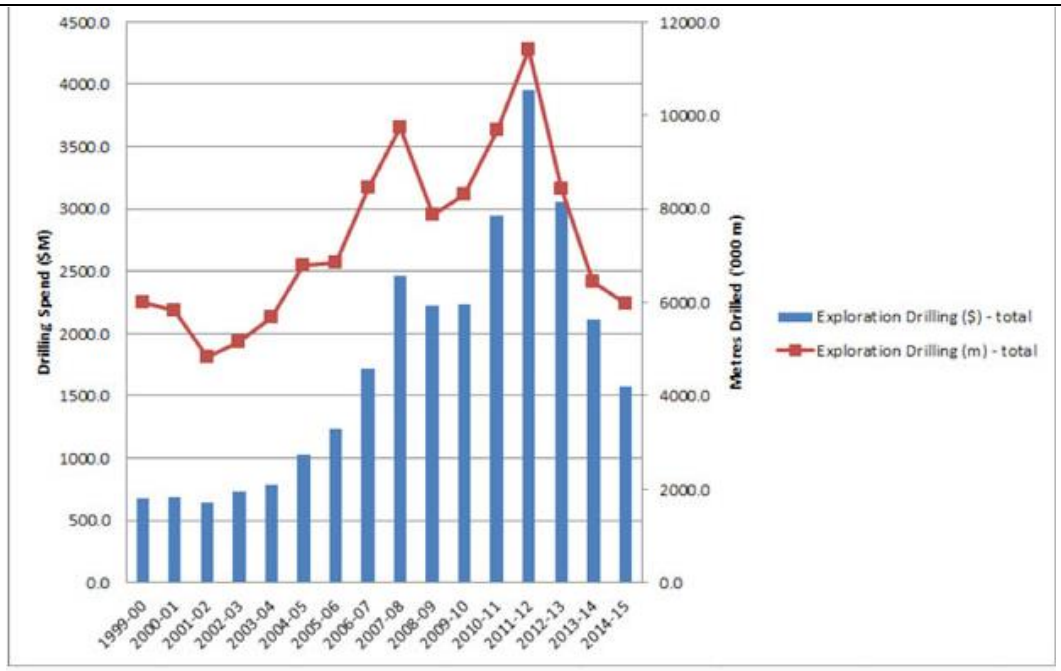
— *Technical Factors*—Can a known resource be extracted and processed with existing or likely future technologies? Technical risk can be conceptualised as the likelihood and degree to which actual recovery of a mineral during mining and processing differs from what was anticipated.

— *Environmental, Social, and Political Factors*—Can a resource be extracted in ways that are consistent with a nation's preferences and policies for environmental protection?

— *Economic Factors*—Overall, can a mineral resource be extracted at a profit? Economic risk can be conceptualised as the degree to which actual revenues and costs differ from what was anticipated at the time of investment? Economic risk reflects the three other categories of risk cited above.

ABS data shows there has been a continuing decline in minerals exploration in Australia. While there has been a small recent upturn in the overall level of exploration activity and expenditure, the long term data shows current activity is at levels last seen in the mid-2000s (see **Figure 1.3** below). It is clear from the consultations undertaken for this case study that this decline is both a function of the perceived risks of exploration activity in Australia (and in particular in previously unexplored or very lightly explored regions, such as the Capricorn), and the high costs of exploration activity.

FIGURE 1.3 ANNUAL AUSTRALIAN EXPLORATION ACTIVITY (EXPENDITURE AND METERS DRILLED)



Note: Based on ABS data

SOURCE: MINERALS COUNCIL OF AUSTRALIA, HTTP://WWW.MINERALS.ORG.AU/POLICY_FOCUS/EXPLORATION/

[15] Roderick G. Eggert, Mineral Exploration Development: Risk and Reward, May 2010, http://www.miningnorth.com/_rsc/site-content/library/education/Mineral_Exploration_&_Development_Roderick_Eggert_Eng.pdf

Australia requires an expanded exploration effort to improve its standing as a destination for investment and to ensure the ongoing development of mining projects, which generally have a gestation period of around ten years and a productive lifetime of ten-to-fifteen years.

Data produced by the Mineral's Council of Australia (MCA) shows that over the past 20 years Australia's share of economically significant mineral discoveries has declined significantly. These data show that Australia's share of global exploration for non-fuel mineral commodities has declined from 17.6 per cent in 2002 to 12 per cent in 2014.[16]

These data further show that exploration expenditure continues to be in sharp decline. Exploration expenditure fell 25.3 per cent in 2014-15 to total $1.575 billion, which is a decline of 48.5 per cent from 2012-13 and down 60.2 per cent from 2011-12. Western Australia continues to account for the largest share of total exploration expenditure (about 58 per cent) followed by Queensland (almost 20 per cent). However, these data also indicates that Australia's attractiveness as a destination for mining investment is declining with it falling further behind major competitors Canada and the United States.

The information, techniques and technologies generated by the Distal Footprints project is anticipated to provide the knowledge required to de-risk exploration and, over time, reduce the costs of exploration. The six research themes of the Distal Footprints research project is leading to advances and expertise in detection technologies, mineral systems, resource characterisation and data analysis. This in turn supports more cost effective exploration and discovery of new mineral resources in the, to date relatively lightly explored, Capricorn region.

Analysis by ACIL Allen in 2015 for the Western Australian Government identified some key parameters that can help us to estimate the potential value of exploration.[17] The analysis considered drilling data between January 2012 and November 2014 for Western Australia. These data show that there were 40,187 mineral exploration holes drilled across the State with a combined distance of approximately 4 million meters of drilling. Based on analysis of ABS data (catalogue 8412) ACIL Allen estimated that the average cost of drilling for a new deposit to be $382 per meter.

Based on these calculations, any improvement to the accuracy and effectiveness of exploration would reduce the economic burden of exploration by the value of the avoided meters of drilling. If even a small proportion of the 4 million meters drilled between 2012 and 2014 were avoided, say for example, 1 per cent (i.e. 40,000 meters), this would generate an economic benefit (through avoided costs) of $15.28 million.[18]

1.3.7 Counterfactual

A research project of this scale and scope would not have been possible without the funding and support of SIEF.

Prior to SIEF, the University of Western Australia, Curtin University and the CSIRO had collaborated on a number of occasions. However, these collaborations were often at the researcher level and commensurate to the size of the research funding opportunities available through the competitive grants system, or through small-scale state government, industry or university-supported funding programs. Funding for these projects was often piece meal, short term and not of sufficient scale to adequately fund a multi-year, multi-institutional project to deliver the human capital and research infrastructure needed to deliver the SIEF project objectives.

So, while some useful research outputs and outcomes were generated through these earlier collaborations, the scale of the effort needed to effectively examine the Distal Footprints of the Capricorn region and deliver the research outputs needed to improve exploration in the region would have been impossible without access to the SIEF funding.

Consultations with the project's research leaders undertaken confirmed the central role of SIEF in establishing the project. SIEF provided the level of funding necessary to encourage CSIRO, the University of Western Australia and Curtin University to enter into discussions about a large scale

[16] http://www.minerals.org.au/policy_focus/exploration/
[17] *Exploration Incentive Scheme: Economic Impact Study*, Report to the Geological Survey of Western Australia, ACIL Allen, 2015.
[18] ACIL Allen 2015, 'Exploration Incentive Scheme: Economic Impact Study', Report to the Geological Survey of Western Australia.

collaboration in geoscience research in Western Australia. Importantly, the funding also provided an incentive for the State Government to not only participate in, but also to contribute significant financial and in-kind support to the research effort.

Participating research institutions were also able to more effectively demonstrate their commitment to a large scale research project that would deliver benefits to industry. The presence of SIEF funding made the prospect of a research project 'more attractive' by increasing the likelihood that industry partners would receive 'actual' as opposed to 'promised' benefits from their financial support.

1.3.8 Attribution

Consultations undertaken for this case study suggest that the attribution of Distal Footprints' benefits to SIEF should be high. This is because the participants in the project are firmly of the view that a project with the scope and scale of Distal Footprints would not have been possible in the absence of SIEF funding support. In ACIL Allen's professional opinion a high level of attribution may be appropriate for those benefits (and beneficiaries) that are more closely aligned to the research effort and outputs.

Other beneficiaries (such as non-participating industry end-users of open source data from the Distal Footprint project) may be subject to a range of other factors which are beyond the reasonable influence of SIEF. Hence, it may be appropriate to attribute any benefits they receive to SIEF at a lower rate.

Generally, a conservative attribution rate of 50 per cent has been adopted for this case study to ensure the benefits generated by SIEF's support for the Distal Footprints project is not overstated.

1.4 Evaluating the Impacts

1.4.1 Cost-Benefit Analysis

Costs

SIEF funding for the project was: $0.741 million (2011-12), $1.425 million (2012-13), $1.397 million (2013-14), $1.444 million (2014-15), $0.393 million (2015-16) and $0.600 million (2016-17).

Benefits

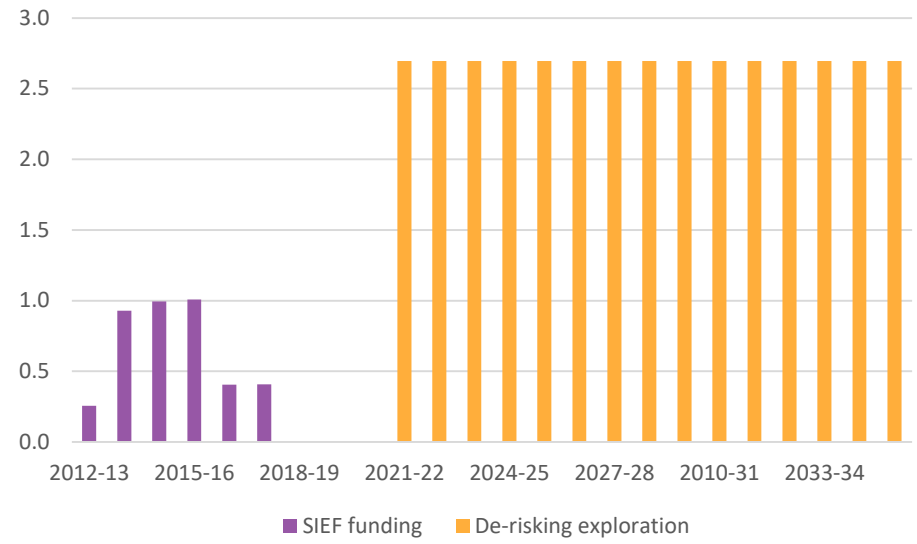
In the period from early 2012 to late 2014, on average approximately 1,411 million metres of mineral exploration holes were drilled in Western Australia every year. The average cost of this drilling was $382 per metre.

It is assumed that the SIEF-funded research results in miners having access to information that allows them to more accurately target their drilling activities and that this results in a 1 per cent reduction in the distance drilled per year from 2021-22 onwards, and that 50 per cent of these benefits are attributable to SIEF.

Assessment of benefits against costs

The costs and benefits of the project to 2036-37 are shown in **Figure 1.4**.

FIGURE 1.4 DISTAL FOOTPRINTS COSTS AND BENEFITS BY YEAR TO 2035-36 ($M, 2016-17 DOLLARS)



SOURCE: ACIL ALLEN

The present value of SIEF funding is $4.69 million in 2017-18 dollars under a 7 per cent real discount rate. The present value of project benefits attributable to SIEF is $19.43 million in 2017-18 dollars under the same discount rate.

The net present value (NPV) of the project is therefore $14.74 million in 2016-17 dollars under a 7 per cent real discount rate. The benefit-cost ratio (BCR) of the project is 4.14.

Sensitivity analysis

In the central case of the cost-benefit analysis, it is conservatively assumed that the Distal Footprints project is able to reduce the annual distance drilled in WA for mineral exploration by 1 per cent. The BCR of the project increases to 20.71 if the SIEF-funded research enables a 5 per cent reduction in drilling distance per year in that state.

A 7 per cent real discount rate is used in the central case of the cost-benefit analysis. The BCR is 6.01 and 2.92 under a 4 per cent real discount rate and a 10 per cent real discount rate respectively.

1.4.2 Potential future impacts

While the results of the distal footprints project will initially be applied in Western Australia, there is the potential for them to over time be applied across parts of Australia. There is some evidence of this, with a project sponsor receiving $1 million of capital from an overseas investor to undertake drilling activities in another region.

1.4.3 The project's role as an innovation catalyst

The Distal Footprints project is an innovative approach that could allow resource discovery rates to increase significantly even in areas where the cover over the top of the potential source is relatively deep.

In addition, the project has helped to further develop the concept of a research hub in Western Australia. The project's partners (including those located in the National Resource Sciences Precinct) will seek further funding beyond SIEF to support ongoing research and ongoing development of the project's outcomes.

Through the UNCOVER roadmap, project partners are currently planning the next steps for the future research activities for UNCOVER. This would see project partners further their research outputs into other mining regions.

Furthermore, the project's partners are submitting an expression of interest (in collaboration with Macquarie University and Adelaide University) for an ARC Centre of Excellence to build upon the UNCOVER vision and some of the outputs of this SIEF program. This will continue and expand the collaboration of the SIEF research team.

The Minex CRC proposal, a bid for a new cooperative research centre in mineral exploration research, involves the three research partners at its core, plus the GSWA as a sponsor. The team created here and the research impact would be further built upon in the Minex CRC if it is successful. The bid outcomes will be known in 2018 with a potential start for the CRC in late 2018, early 2019.

1.4.4 Distribution effects on users

The main beneficiaries of this research are likely to be mining firms and the research geological community in Western Australia and elsewhere.

1.4.5 Externalities or other flow-on effects on non-users

There may be some environmental benefits as a result of being better able to manage the drilling process, and overtime drilling less holes. A more targeted drilling process also means less local level environmental damage associated with transporting drilling equipment between sites which may not yield any return. This reduction in environmental impact is real but difficult to calculate due to the unavailability of data that would allow a quantification of the reduction benefits.