Mineral potential mapper
A GEOSCIENCE AUSTRALIA CASE STUDY

Box 1 Executive Summary

Key findings

The Mineral Potential Mapper (MPM) project represents a significant step forward in identifying new mineral provinces in Australia. The project demonstrated that the apparent under-representation of giant Ni Cu-PGE sulfide resources in Australia was a consequence of concealment of mineral deposits by sediments, basins and regolith (cover) which has hindered exploration success, rather than a lack of geological endowment. The project focused on the identification of prospective regions considered worthy of more detailed work (by exploration companies). The availability of new digital datasets at continental scale enabled the work which predicted a high potential for Ni-Cu-PGE sulfide deposits in a wide range of geological regions across Australia.

The project delivered the following outputs:

- a technical report providing the first continental-scale assessment of Ni-Cu-PGE mineral potential of Australia applying knowledge-driven geographic information system (GIS)-based prospectivity analysis methods
- a series of Geodatabase digital maps (included in the report)
- primary digital data and programming script used in the GIS analysis
- a workshop delivered in Perth to industry on the 12 June 2016
- a world first National mineral potential map for Ni Cu-PGE sulfide deposits.

The MPM materials have generated considerable industry interest. Chalice Mining Limited (Chalice) (formerly Chalice Gold Mines Limited) notes the MPM "*… provided valuable input into Chalice's regional targeting, particularly when applied to frontier areas"* (and that) *"… recent success at Julimar validates the work by Geoscience Australia (GA) and shows the impact that pre-competitive data can have when applied to greenfields exploration."*

Chalice's Julimar discovery is the world's largest deposit of its type discovered in 20 years and one of four Tier one deposits discovered in the world in the last five years. It has spurred a significant uptake in tenements by explorers across a green field region and further significant finds are likely. The project has also generated considerable international government interest, sparking the Critical Minerals Mapping Initiative. The United States of America and Canada are both applying similar innovative mineral systems-based assessment methodologies to undertake precompetitive prospectivity mapping at a national scale.

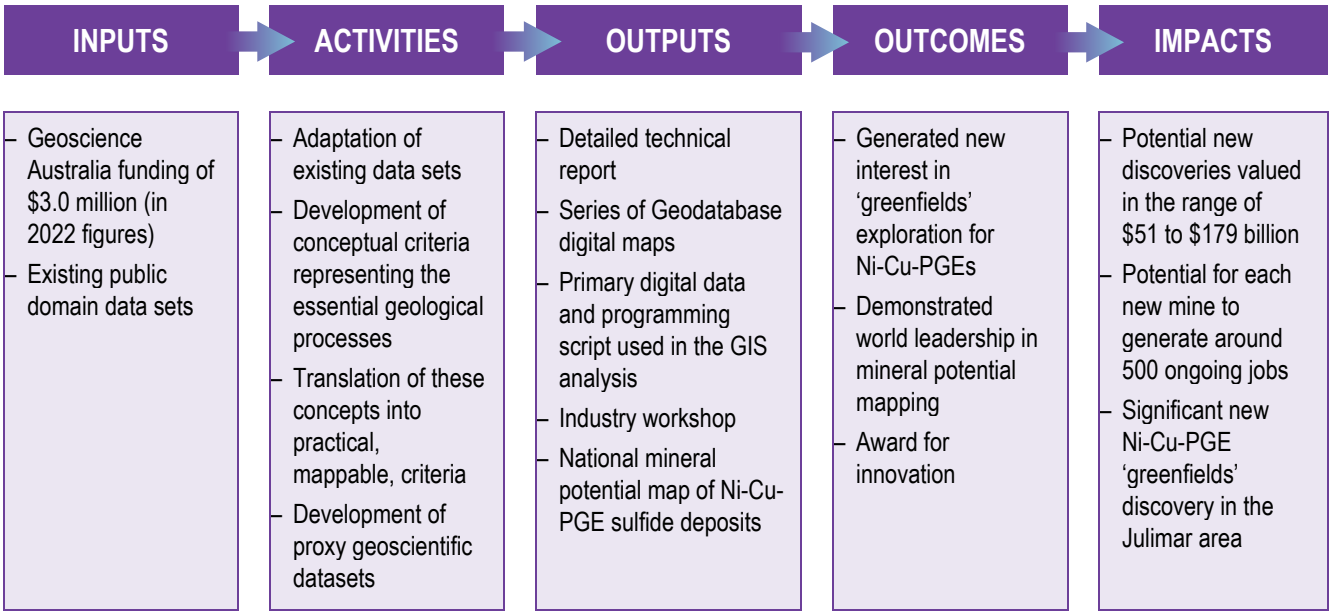
Given the impact of the MPM project will only be fully appreciated with the realisation of new mines, ACIL Allen has considered two hypothetical mine development scenarios: development of the Gonneville deposit based on Chalice's (Australian Securities Exchange) ASX report of 8 July 2022, and a second case with an expansion of the Gonneville deposit (to 500Mt), coupled with a more spectacular discovery (double the size of the Gonneville deposit). Both success case scenarios were modelled using a conservative set of assumptions drawn from Chalice's ASX reporting, prevailing market figures and industry norms.

Based on those assumptions, ACIL Allen estimates that the development scenarios could generate an overall benefit to the Australian economy of between $3.48 billion and $4.57 billion and between $1.21 billion and $1.56 billion in net benefits to the Commonwealth in terms of taxation.[1] GA's investment in the project ($3.0 million) enabled the creation of these benefits. Indeed, every dollar invested in this project by the Commonwealth through GA could generate between $1,176 and $1,546 in additional benefits to the economy. The estimated benefit-cost ratio (BCR) for the Commonwealth Government is between 409 and 526 for the 'success cases'. This is a substantial step up from the initial assessment conduct 12 months ago prior to the availability of resource figures for the Gonneville deposit (with a small and a large mine delivering an overall benefit of between $441 million and $869 million, with a BCR between 65 and 127).

[1] All figures are in present value terms in 2022 using a 7 per cent real discount rate and in 2022 prices.

This case study uses an evaluation framework that ACIL Allen has used to evaluate the impact and value of research done by a large number of scientific organisations.[2] The results of applying that framework to the Mineral Potential Mapper (MPM) case study are summarised in Figure 1.

Figure 1 Mineral Potential Mapper Case Study – Impact Framework Diagram



Source: ACIL Allen

1. Purpose and audience for case study

This case study considers the economic and social benefits arising from the MPM project. The evaluation assesses the positive impacts arising from several projects undertaken by Geoscience Australia. This case study can be read as a standalone report or aggregated with other case studies to substantiate the impact and value of GA's work in supporting minerals exploration more broadly and to estimate the return on the investment from the funds spent on these activities.

2. Background

Global demand for key metals such as nickel (Ni), copper (Cu) and the platinum-group elements (PGEs) (Ni-Cu-PGEs) continues apace driven by their greater use in everyday products and appliances utilising stainless steel, vehicle pollution controls and high-tech electronic devices. With the transition to renewable energy technologies the demand for these metals and associated cobalt (Co) is expected to grow substantially over the next few decades. A recent World Bank report predicts "*… more than 3Bt of metals will be needed to underpin the clean energies necessary to achieve a sustainable environmental future*"[3] by 2050 (which translates to 500 per cent growth in Co demand; 213 per cent growth in Cu demand and 76 per cent growth in Ni demand). Changes in working patterns, lifestyles and consumer expectations in relation to climate action will result in greater demand for these types of goods.

GA aims to maximise the value from Australia's abundant mineral resources through stimulating mineral exploration investment to open up new provinces. Australia has benefited greatly from its natural endowment in mineral resources. However, the maintenance of the Australian resource base requires continual replenishment through new discoveries to ensure a continuous pipeline of new projects to maintain Australia's preeminent position in key global supply chains. While

[2] The approach is based on that outlined in the CSIRO Impact Evaluation Guide. The most recent version of the guide can be seen at: https://www.csiro.au/en/About/Our-impact/Evaluating-our-impact .

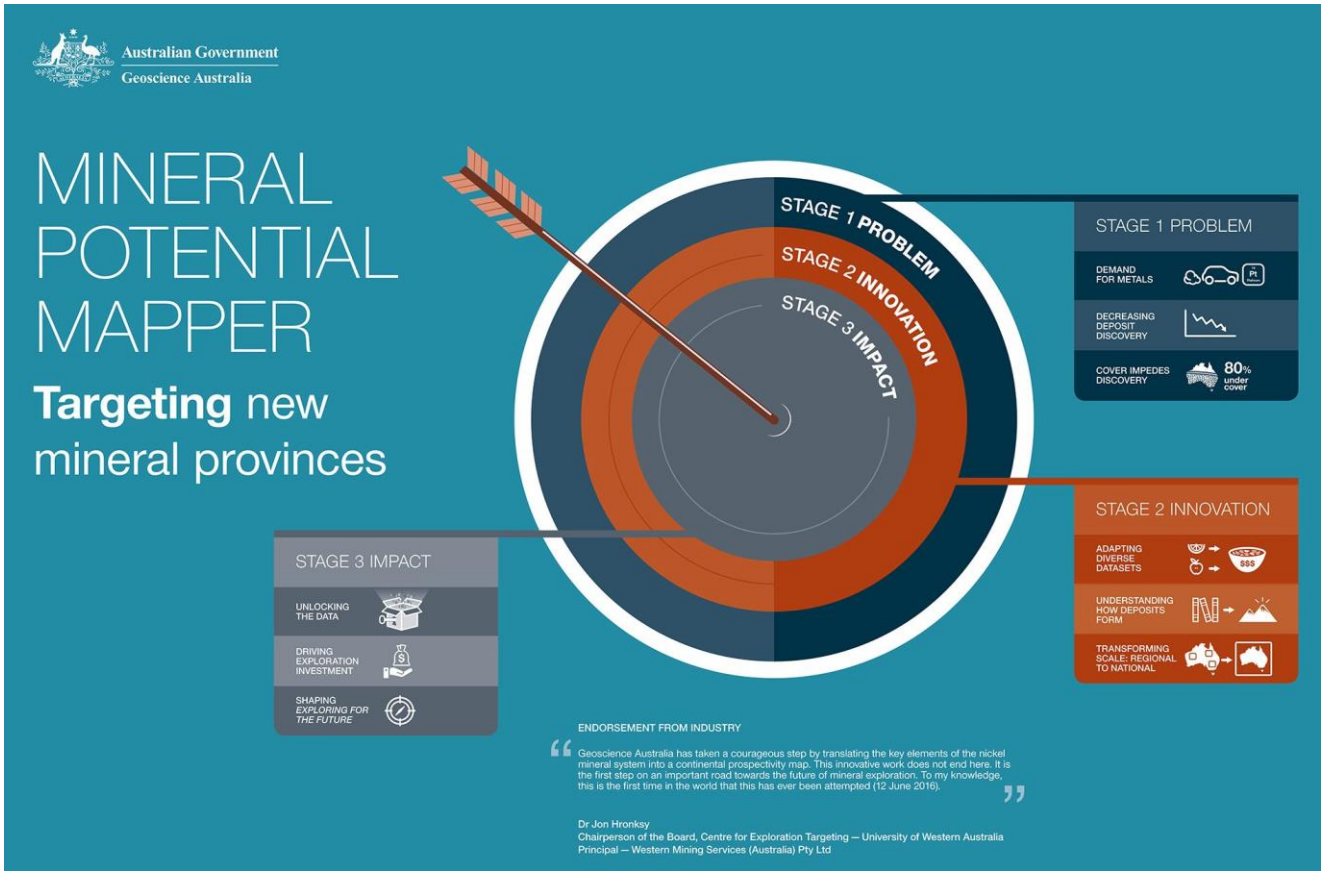
[3] The World Bank group, 2020; *Minerals for Climate Action: The Mineral Intensity of the Clean Energy Transition* accessed 10 June 2020 http://pubdocs.worldbank.org/en/961711588875536384/Minerals-for-Climate-Action-The-Mineral-Intensity-of-the-Clean-Energy-Transition.pdf

the demand for Australian minerals remains strong, and despite relatively high levels of exploration expenditure, according to AMIRA's *Unlocking Australia's Hidden Potential: An industry roadmap* for the UNCOVER initiative[4]:

> *"Reversing the decline in mineral discovery in Australia, transforming modern exploration and re-setting the country's exploration maturity clock is now urgent.*
>
> *Re-setting and turning back Australia's exploration maturity clock is possible by moving into the new frontier 'under cover' areas representing over 70% of Australia's landmass. Post-mineralisation cover represents a major technical barrier for the discovery of new mineral deposits. The conventional tool-kit and way of exploration have been adequate in the past but these are not adequate in areas beneath cover. New technologies, data, information and business models are now required."*

Figure 2 captures Geoscience Australia's approach to addressing this issue through the MPM project.

Figure 2 The Mineral Potential Mapper Approach



Source: Geoscience Australia

The majority of Australian minerals discoveries and mines occur in areas with outcropping host/basement rocks or where the 'cover' of sediments and weathered rock is thin. However, only about 30 per cent of Australia's prospective basement rocks have thin layers of cover. The depth of cover in other areas is a significant impediment to minerals exploration. Focussing on ways to support minerals exploration activity in the remaining 70 per cent of the area that is under cover will be essential to Australia's future prosperity. Such efforts have a public good attribute given that the level of exploration

[4] AMIRA International, September 2017; *Unlocking Australia's Hidden Potential: An industry roadmap*. https://www.uncoveraustralia.org.au/wp-content/uploads/2019/02/UNCOVER-Roadmap-Unlocking-Australias-Hidden-Potential.pdf accessed 3 June 2020

activity that would be generated in a pure private market would be sub-optimal, given the high degree of uncertainty.[5] As ACIL Allen noted in a 2015 report, these issues have long been globally recognised.[6]

There are also specific questions regarding Australia's Ni-Cu-PGEs potential. Magmatic mineral deposits of this group are formed by the immiscible separation and concentration of Ni-Cu-PGE-rich sulfide liquids from magmas of mantle origin. An important sub-type of these deposits is the tholeiitic intrusion-hosted Ni-Cu-PGE sulfide deposit class, typified by the giant Noril'sk (Russia), Voisey's Bay (Canada) and Jinchuan (China) deposits. These deposits contribute significant proportions of the world's production and represent some of the most valuable global mineral deposits. For instance, the Noril'sk deposit in Russia, with proven and probable ore reserves totalling 478.7Mt (containing 6.27Mt of nickel, 9.37Mt of copper, 62.2Moz of palladium (Pd) and 16Moz of platinum (Pt))[7] has an estimated value of approximately $US 1 trillion.

However, there are very few known tholeiitic intrusion-hosted Ni-Cu-PGE sulfide deposits in Australia, and these are mostly uneconomic due to their small size, low grade and/or remoteness. Accordingly, given Australia's favourable geology, GA holds the view that:

> *"… potential exists for discovery of new, very large, intrusion-hosted Ni-Cu-PGE deposits."*[8]

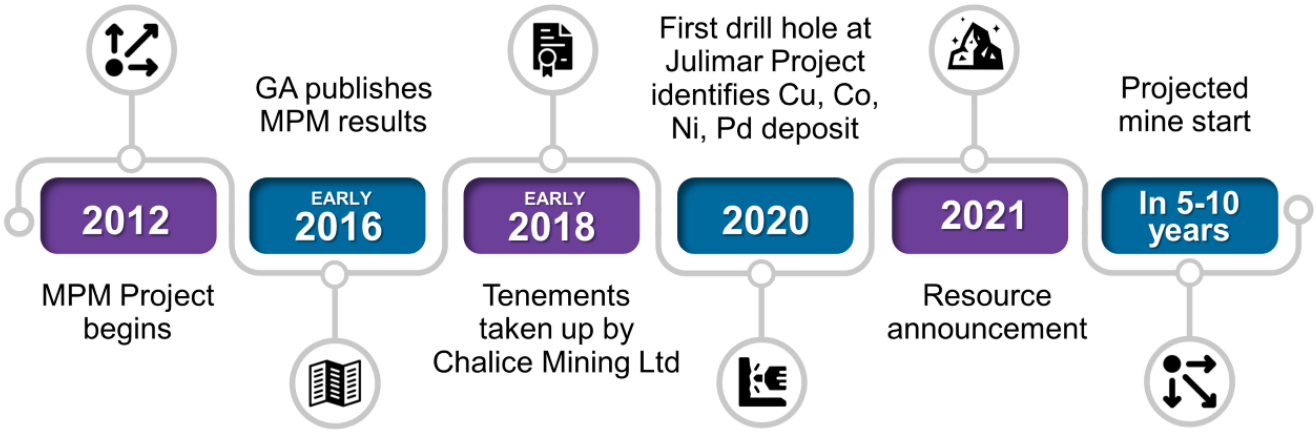
Given these systems are of potentially world-class size and value, they may be of major economic importance for Australia. Global geo-political tensions add to the value of new critical minerals discoveries (such as Co and PGEs).

3. Impact Pathway

3.1 Project Timelines

Figure 3 provides a timeline of the MPM project culminating in the potential development of the Gonneville deposit to commence in 2026. The case study maps out the steps to realising this outcome.

Figure 3 MPM Project timeline



Note: At the time of tenement uptake and initial drilling Chalice Mining Limited was known was Chalice Gold Mines Limited

Source: ACIL Allen

[5] Exploration driven by a pure private market will generate too much brown field exploration and too little green field exploration.

[6] ACIL Allen Consulting (2015), *Exploration incentive scheme, economic impact study*: Geological Survey of Western Australia. http://dmpbookshop.eruditetechnologies.com.au/product/exploration-incentive-scheme-economic-impact-study.do

[7] https://www.mining-technology.com/projects/norilsk/ accessed 11 May 2020

[8] Geoscience Australia website, accessed 25 May 2020; https://www.ga.gov.au/scientific-topics/minerals/mineral-potential-mapper

3.2 Project inputs

The total nominal cost for the MPM project was about $1.5 million in cash and in-kind contributions (see Table 1). GA contributed the full amount, the vast majority of which went towards its direct costs (contractor costs were only $30,000).

Table 1 Support for the project

Contributor / type of support	Year 1 (2012/13) ($)	Year 2 (2013/14) ($)	Year 3 (2014/15) ($)	Year 4 (2015/16) ($)	Total
Cash and in-kind					
GA direct/contractor costs	282,983	291,473	473,220	456,516	1,504,192
In-kind contributions	-	-	-	-	-
Total	282,983	291,473	473,220	456,516	**1,504,192**

Source: Geoscience Australia

The MPM project drew heavily on a range of existing/new digital datasets at continental scale and information including:

- the Mafic-Ultramafic Magmatic Events of Australia GIS dataset[9]
- the AuSREM model of seismic tomography[10]
- Major Crustal Boundaries of Australia[11]
- a Geochemical Classification of Mafic and Ultramafic rocks in Australia[12]
- national variably reduce to pole total magnetic intensity grid and national Bouguer gravity anomaly coverage.[13] [14]

3.2 Project activities

A key objective of the study was to identify new mineral provinces in Australia with previously unrecognised potential for giant or major Ni-Cu-PGE sulfide deposits, focussing on tholeiitic intrusion-hosted Ni-Cu-PGE sulfide ore-forming systems.

The project set out to answer the question of whether the apparent under-representation of giant Ni-Cu-PGE sulfide resources in Australia is due to a:

> *"…lack of geological endowment or is a consequence of concealment of mineral deposits by sediments, basins and regolith (cover) which has hindered exploration success."*[15]

The project adopted a continental scale of analysis given that giant Ni-Cu-PGE sulfide deposits are expressions of tectonic plate-scale ore-forming geological systems. The scale of such systems is sufficiently large that some features of the geological settings are expected to be recognisable in continental-scale geological, geophysical and geochemical datasets.

[9] Thorne, J.P., Highet, L.M., Cooper, M., Claoue-Long, J.C., Hoatson, D.M., Jaireth, S., Huston, D.L., and Gallagher, R., 2014. The Australian Mafic-Ultramafic Magmatic Events GIS Dataset: Archean, Proterozoic and Phanerozoic Magmatic Events. Geoscience Australia, Canberra. http://dx.doi.org/10.4225/25/54125552CDA7C

[10] Kennett, B.L.N., Fichtner, A., Fyshwick, S., and Yoshizawa, K., 2013a. Australian Seismological Reference Model (AuSREM): mantle components. Geophysical Journal International, 192(2), 871-887.

[11] Korsch, R.J., and Doublier, M.P., 2014. *Major crustal boundaries of Australia*. 1st Edition. Scale 1:2,500,000. Geoscience Australia, Canberra

[12] Champion, D.C., and Dulfer, H., 2015. *Geochemical Classification of Mafic to Ultramafic rocks in Australia GIS Dataset*. Geoscience Australia, Canberra. http://dx.doi.org/10.4225/25/552B4B786431D

[13] Nakamura, A. ; Milligan, P.R. (2015): Total Magnetic Intensity (TMI) Grid of Australia with Variable Reduction to Pole (VRTP) - sixth edition. Geoscience Australia.dataset. http://pid.geoscience.gov.au/dataset/ga/89596

[14] Bacchin, M., 2009. Bouguer Anomaly Gravity Grid, onshore only. Geoscience Australia. Canberra.

[15] Dulfer, H., Skirrow, R.G., Champion, D.C., Highet, L.M., Czarnota, K., Coghlan, R. & Milligan, P.R. 2016. *Potential for intrusion-hosted Ni-Cu-PGE sulfide deposits in Australia: A continental-scale analysis of mineral system prospectivity*. Record 2016/01. Geoscience Australia, Canberra. http://dx.doi.org/10.11636/Record.2016.001 .

The scope of the MPM project did not extend to identification of individual prospective intrusions or parts of intrusions hosting ore deposits. Rather, it focused on the identification of prospective regions, considered worthy of more detailed work (by exploration companies and others) to determine the economic value of any resources that may be discovered.

The recent availability of a suite of new digital datasets at continental scale (such as those outlined at Section 3.1 above) provided the opportunity to attempt such a study at the continental scale. GA modelled the spatial patterns of mineral potential using ESRI Arc GIS tools and knowledge-driven fuzzy logic-based methods. The prospectivity analysis used a wide range of geological, geophysical and geochemical datasets (with several building on earlier work by GA and academia) as proxies for fundamentally important geological features in the Ni-Cu-PGE ore-forming systems.

A mineral systems approach was used to identify new provinces as well as extensions to known provinces with potential to host major Ni-Cu-PGE sulfide deposits. The ore-forming processes of such deposits require the following four components of the mineral systems to have operated efficiently:

— energy sources or drivers of the ore-forming system

— crustal and mantle lithospheric architecture

— sources of ore metals (i.e., Ni, Cu, PGEs)

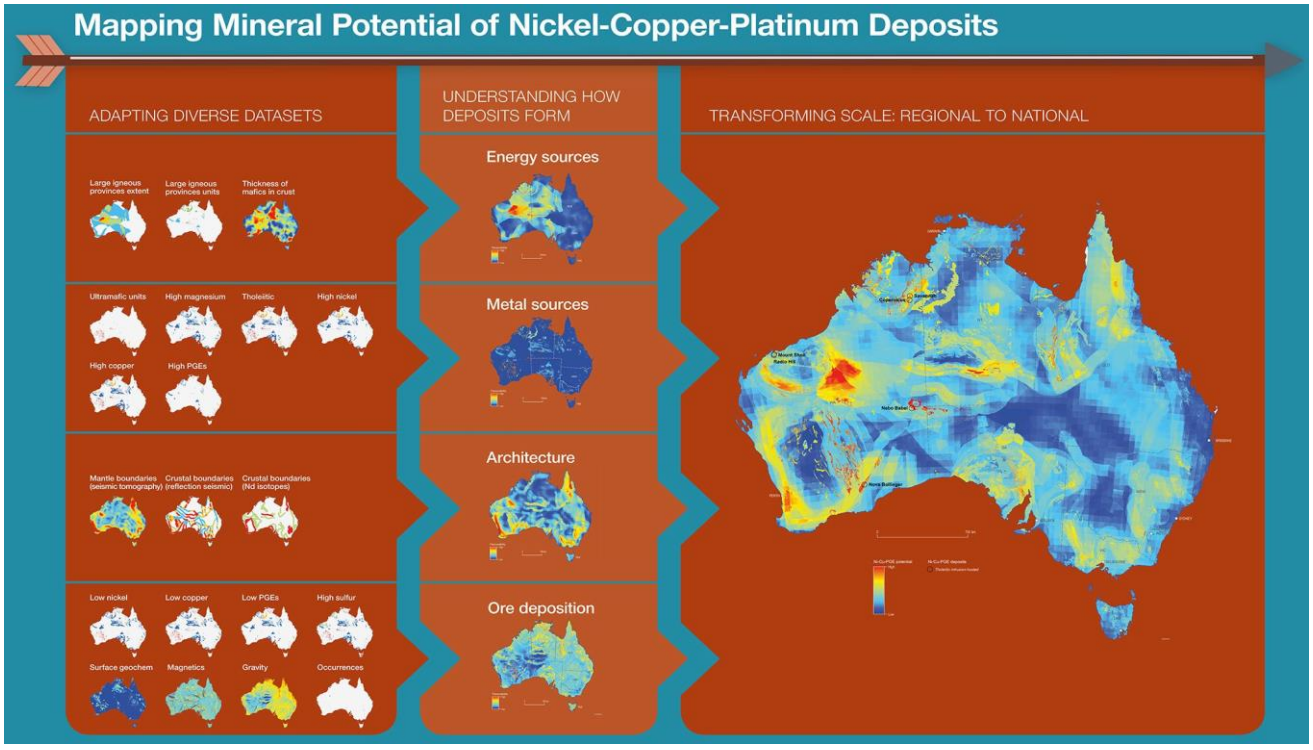
— gradients in ore depositional physico-chemical parameters.

Conceptual criteria were developed representing the essential geological processes involved in each components which were translated into practical, mappable, criteria for which proxy geoscientific datasets were developed.

3.3 Project outputs

Maps of 'favourability' were constructed for each of the four components of the ore forming process as outlined above using input overlays, and then weighted according to the perceived importance, applicability and confidence levels (see Figure 4). The results for the four maps were allowed to contribute equally to the final mineral potential map so that the areas of highest potential represent targets where all four mineral system components combine most favourably.

Figure 4 The identification of potential Ni-Cu-PGE deposits



Source: Geoscience Australia

Through combining the adapted, pre-existing data sets with the 'favourability' maps, GA was able to generate national scale mapping of potential Ni Cu PGE sulfide deposits as shown in Figure 4.

The outcome predicts a high potential for Ni-Cu-PGE sulfide deposits in a wide range of geological regions across Australia, including both those of known prospectivity and several with previously unrecognised potential. Importantly, as shown in Figure 5, the assessment successfully predicted the locations of the few known major Ni-Cu-PGE deposits as having high potential, despite this data not being included as inputs in the modelling (to validate results and avoid bias).

In considering the project outcomes it is necessary to recognise a number of limitations and caveats as follows:

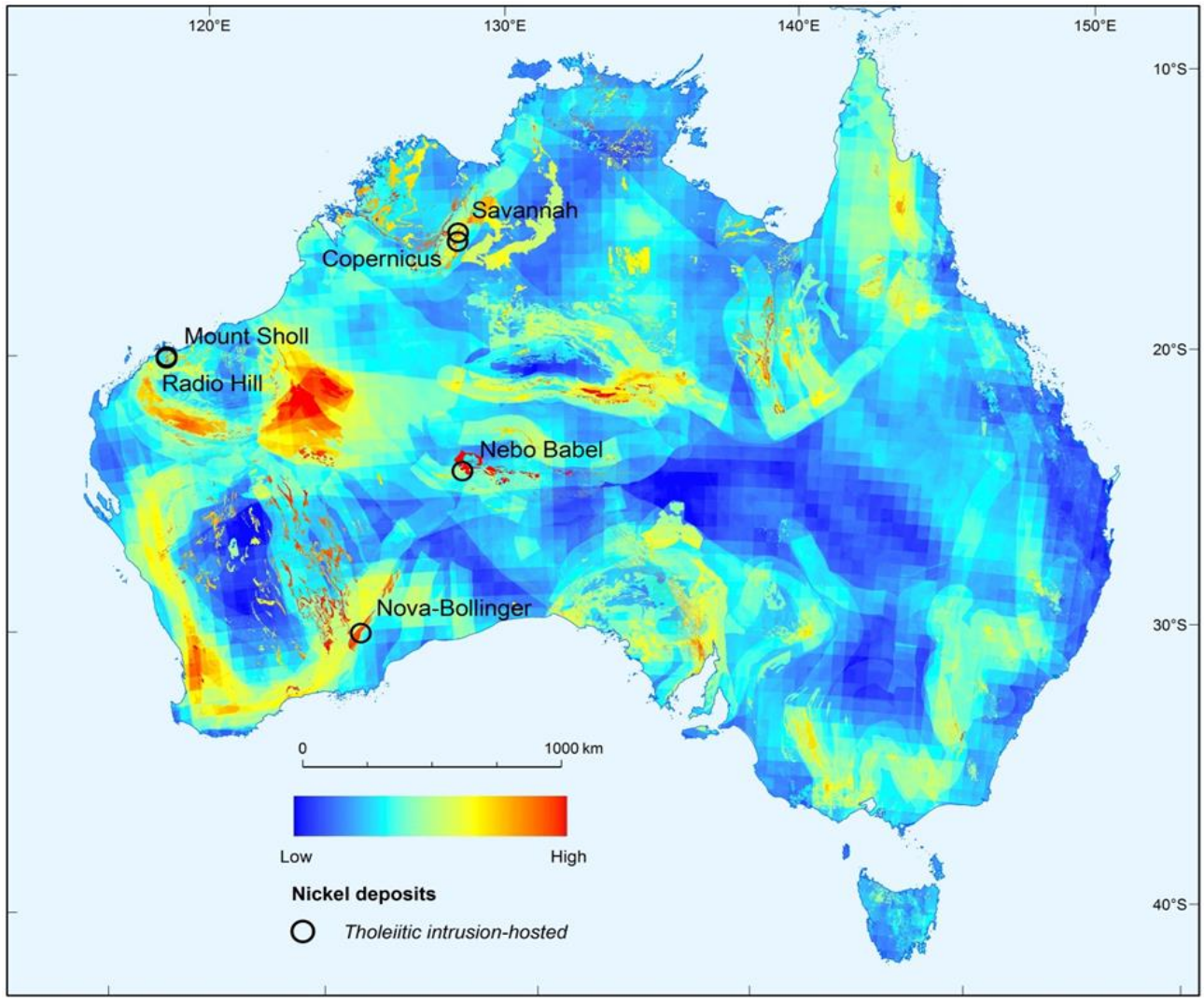
— the higher modelled prospectivity of some areas is partly due to a greater spatial density of data, particularly geochemical data, and therefore the assessment may not identify all possible areas of high mineral potential (due to data limitations)

— further areas of elevated prospectivity are expected to emerge if and when new data become available

— false-positives may arise due to spatial overlaps of mineral system components that may be temporally unrelated

— the lack of inclusion of sulfur-bearing wall rocks in relevant components of the mineral system (as appropriate datasets were not available at the national scale) further limit the mineral potential modelling.

Figure 5 Areas of high or moderate potential for large Ni-Cu-PGE mineralisation



Source: Geoscience Australia

The GA Record 2016/01 notes that "*Notwithstanding these limitations and caveats, the mineral potential modelling has successfully identified all of the magmatic provinces hosting known major deposits of tholeiitic intrusion-hosted Ni-Cu-PGE sulfide mineralisation in Australia, and importantly has also highlighted the potential of several other areas in 'greenfields' regions.*"[16]

Given the caveats and limitations outlined above, the assessment represents the minimum areas of potential. Additional detail in relation to the 12 areas identified as having high or moderate potential are available from GA.[17]

The MPM project was completed in early 2016 with the release of a technical report and digital map products, together with a delivery workshop to industry in June 2016.

Publications

The technical report captures the outcomes of the project – the report was described as the

> *"… first continental-scale assessment of Ni-Cu-PGE mineral potential of Australia to apply a knowledge-driven GIS-based prospectivity analysis method … (in which a) … mineral systems approach is used to identify new mineral provinces as well as extensions to known provinces with potential to host major Ni-Cu-PGE sulfide deposits."*

The report is available from the GA website at https://www.ga.gov.au/scientific-topics/minerals/mineral-potential-mapper.[18]

Presentation/Workshops

GA presented the results of the MPM project at a workshop for industry held in Perth on 12 June 2016. Further promotion occurred at the 13th International Nickel-Copper-PGE Symposium, also in Perth on 5-9 September 2016. GA ran these workshops specifically for industry. GA has promoted the MPM at various industry conferences and events since its launch.

Models or tools

In addition to the above technical report, the results of the project are available as a series of Geodatabase digital maps (rasters) representing the input datasets; four mineral system components (including mapping); and the final prospectivity for tholeiitic intrusion-hosted Ni-Cu-PGE sulfide deposits (mapped at a continental scale).

The Python programming script used in the GIS analysis is also available. The primary digital data used to create the input datasets for the modelling are also available on-line for users' own purposes. An analytical online tool has also been developed allowing users to repeat the assessment and vary the inputs. The tool is available through the Exploring for the Future Data Discovery and Delivery Portal (https://portal.ga.gov.au/).

Awards

On 27 July 2016, the MPM project was announced as the winner of one of four categories ('Engaging with the Edge') in the Public Sector Innovation Awards. In making the award the "*judges considered (that) this is a new and well-articulated approach to applying data analytics with demonstrable economic benefit.*"

Innovation

The MPM project was innovative in the following ways:

- In adapting and integrating diverse datasets to unlock the value of fundamental and extensive geoscientific databases at GA and in the public domain through innovative 'data mining' across multiple geoscientific databases and diverse datasets, yielding new insights on the nation's mineral potential. Many of the datasets had not been used previously in such studies and required innovative adaptation to be useful in mapping prospectivity.
- In understanding how deposits form and developing a decision support system to integrate the datasets within a robust knowledge framework, based on a geological understanding of how Ni-Cu-PGEs are concentrated into ore deposits.

[16] Ibid.

[17] Ibid.

[18] Ibid.

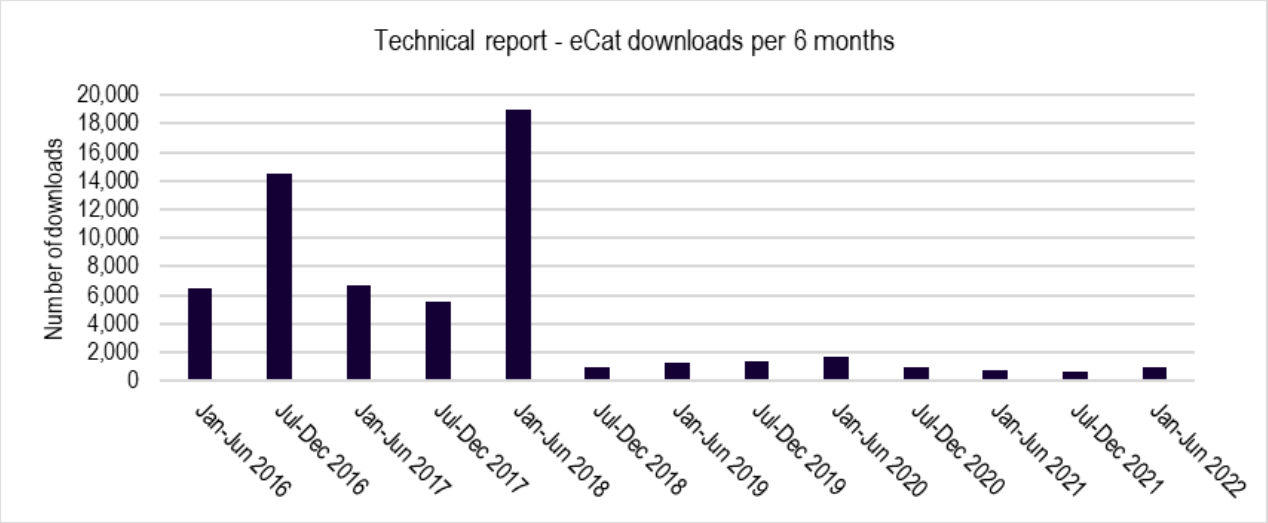
- In transforming scale from regional to national this project is the first of its type in the world to be conducted at the continental scale. It shows the way forward for mapping of the nation's mineral potential, not only for Ni-Cu-PGEs but also in the future for other metals such as gold, zinc, lead, uranium, rare-earth elements, and other types of copper deposits and associated critical minerals such as cobalt.
- Through new computer programming of the geographic information system (GIS) processing the project lead to improved efficiency of the workflow and allowed the testing of multiple scenarios.

In effect the project pioneered a new approach to the development of pre-competitive mineral resource data that can be developed for a range of valuable mineral resources at a continental scale. It is an important tool in informing greenfields exploration and facilitating better targeted exploration efforts by the minerals industry. As such it provides a stimulus to greater private sector exploration effort and expenditure.

3.4 Project Outcomes

Release of the Ni-Cu-PGE sulfides prospectivity map and associated data bases/tools sparked considerable interest. The technical report, *Potential for intrusion-hosted Ni-Cu-PGE sulfide deposits in Australia: A continental-scale analysis of mineral system prospectivity*, has been downloaded more than 60,000 times. While initial download numbers were high following release and promotion of the report, interest remains strong (see Figure 6). This is further evidenced by hits on the Mineral Potential Mapper web service which received 472,573 requests during the period 1 January 2021 to 18 July 2022.

Figure 6 Technical report downloads



Source: ACIL Allen based on Geoscience Australia data

The availability of the new pre-competitive data/mapping with regard to Ni-Cu-PGE sulfide deposit prospectivity is vital to driving new greenfields exploration and investment. As noted by Dr Jon Hronsky OAM, Western Mining Services Pty Ltd:

> *"… in 2019, Australia showed the largest percentage increase in exploration expenditure of any country in the world to take the global number one spot. … a very important part of the reason for this has been the efforts to develop the world-leading geoscientific infrastructure (both data and concepts) to support mineral exploration. Geoscience Australia has played a key role in leading this process and its Mineral Potential Mapping project represents the most recent iteration of an ongoing effort to add value to, and help market the value of, our geoscientific infrastructure."*

The MPM project was a major contributing factor in the significant Julimar Ni-Cu-PGEs discovery in Western Australia (WA) early in 2020. As noted by Alex Dorsch, Managing Director, Chalice Mining:

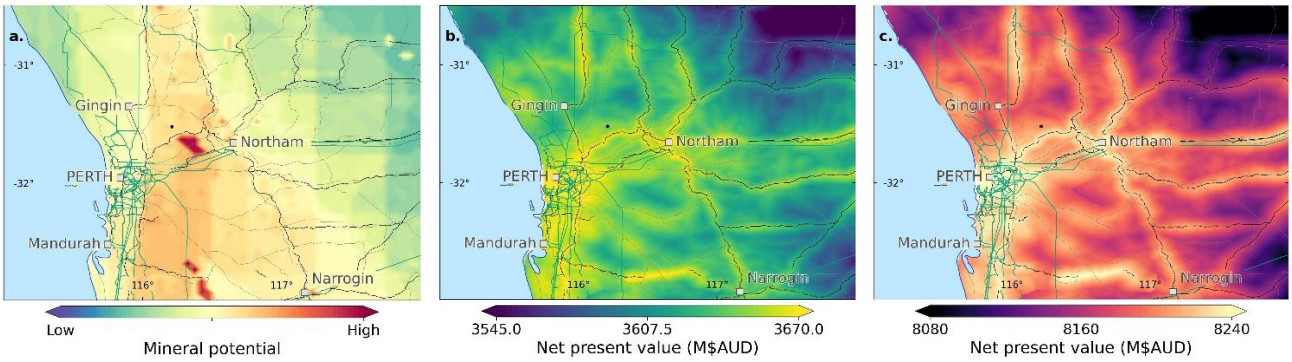
> *"The Mineral Potential Mapper Project published in 2016 provided valuable input into Chalice's regional targeting, particularly when applied to frontier areas. The work by GA … provided the catalyst for the Company to acquire prospective ground holdings in both of these districts. Our recent success at Julimar validates the work by GA and shows the impact that pre-competitive data can have … ".*

The initial success of Julimar gave rise to significant further exploration activity in the immediate term in an area previously overlooked. As reported in MiningNews on 29 June 2020:[19]

> *"Aside from Chalice Gold itself, new activity in the SW Yilgarn in coming months will include exploration efforts from (in no particular order) Impact Minerals, Anson Resources, Cassini Resources, Australian Vanadium, Liontown Resources, DevEx Resources, Mandrake Resources and Anglo American."*

Figure 7 shows the mineral potential for the region around Julimar. At Section 3.6, two hypothetical mine developments located in the Julimar area are considered, the first is for the development of the Gonneville discovery (350 Mt indicated and inferred resources), the second based on an expansion of the Gonneville deposit to 500Mt, coupled with a more spectacular discovery (double the size of the Gonneville deposit). Figure 7, maps b and c, show the NPVs for these resources computed from Geoscience Australia's Economic Fairways Tool for each scenario (discussed further in Section 5).

Figure 7 Mineral potential of the Julimar region



Note: Maps show: (a) mineral potential for Ni Cu-PGE sulfide deposits in the region around the Julimar discovery (red dot); (b) NPV for Scenario 1; and (c) NPV for Scenario 2. NPV is computed from Geoscience Australia's Economic Fairways Tool.

Source: Geoscience Australia:

Chalice's ongoing exploration results (as reported to the ASX) have spurred continuing interest in the Julimar Complex, approximately 70 km north east of Perth. Figure 8 depicts the extent of exploration leases exploring for Ni-Cu-PGE deposits in the southwest minerals province pre (yellow) and post (pink) June 2016 (MPM released June 2016). The pre-existing yellow tenement holders were in effect early movers that have subsequently acknowledged the Julimar discovery as part of the rationale underpinning their ongoing (reinvigorated) strategy for working the region. Since June 2016, over 200 tenements are linked to the MPM (as of July 2022). The maps clearly highlight a key outcome of the project, namely the increased tenement uptake, following the release of the MPM.

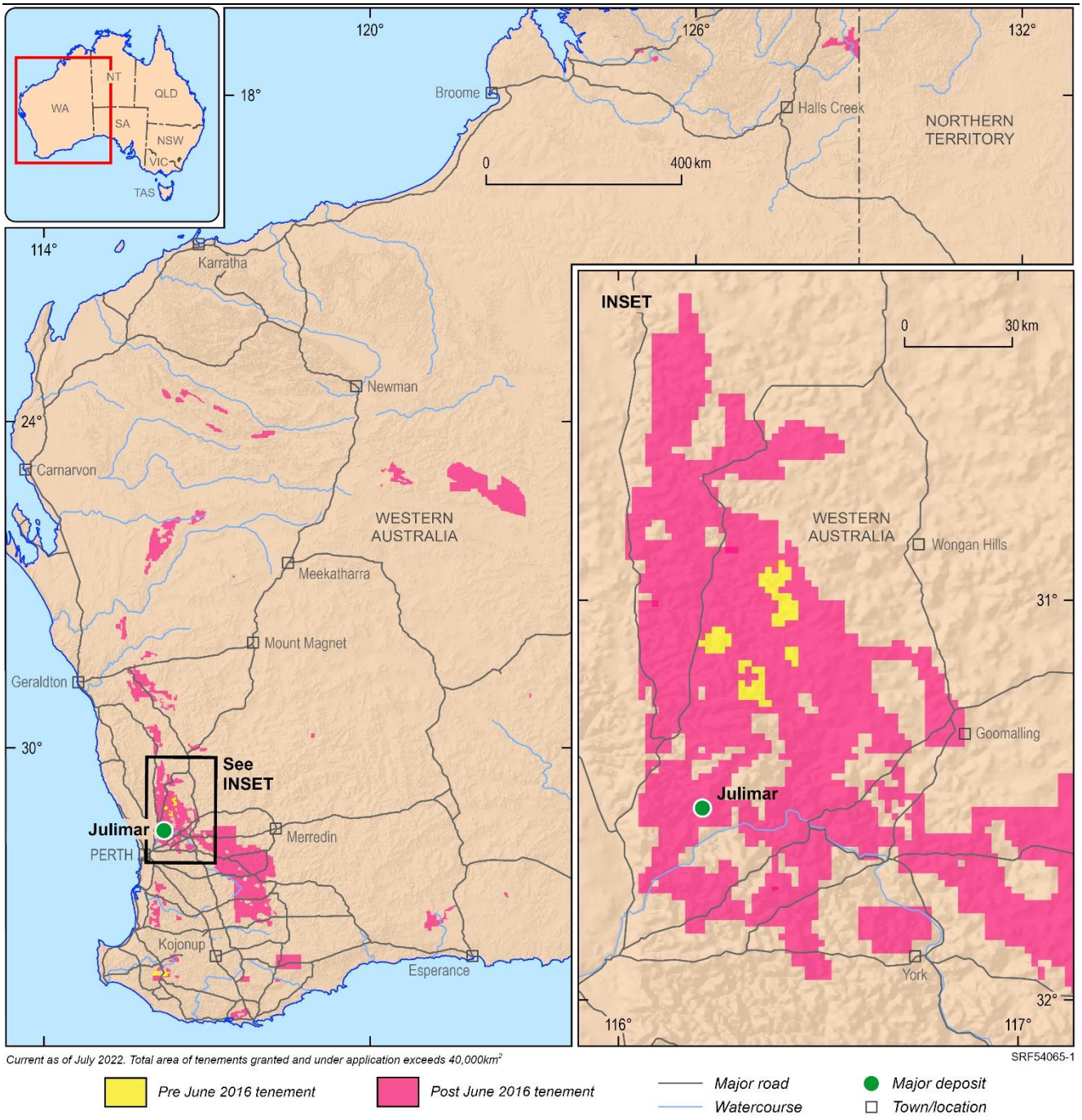
Figure 9 shows the MPM has stimulated tenement uptake exceeding 40,000 square kilometres. The map clearly highlights the significant tenement uptake linked to the MPM. While a considerable number of these exploration leases are adjacent to the Chalice discovery, there is also significant interest and activity across the entire Julimar complex and across the state.

The majority of the tenements have been taken up following the release of the MPM project (more than 200 individual tenements since June 2016). All of the 28 companies shown in Figure 9 (including 17 companies operating proximal to the Chalice discovery) cite the MPM and/or the Chalice/Julimar discovery as a key rationale driving exploration investment decision making in their public and ASX reporting (and in personal communications). Eight companies (in addition to Chalice) cite the MPM as a major factor, while a further 20 indicate the Chalice (Julimar) discovery was a significant factor in their taking up tenements and initiating new exploration. While there are further companies operating in the area, these are not included as they do cite either the MPM or Chalice discovery (only those which clearly link their activities to the MPM precompetitive geoscience are included).

[19] MiningNews 29 June 2020; https://www.miningnews.net/strictly-boardroom/opinion/1389811/julimar-nearologists-play-game-of-thrones accessed 2 July 2020

Since the release of the MPM, exploration expenditure in the Julimar Complex has exceeded $47 million (reported/committed)[20] over the past 2-3 years. Future expenditure is likely to significantly increase given most companies, including Chalice, are just ramping up). This exploration expenditure is likely to be primarily 'new' money, although there may have been some reprioritisation/redirection of existing exploration dollars by some companies. Nevertheless, the employment impacts are an important consideration and could translate to around 100+ jobs to date.[21] While the investment required for exploration is orders of magnitude less than that required for resource development/production, it can still be significant.

Figure 8 Ni-Cu-PGE exploration tenements in the Julimar Complex and across the state stimulated by the MPM

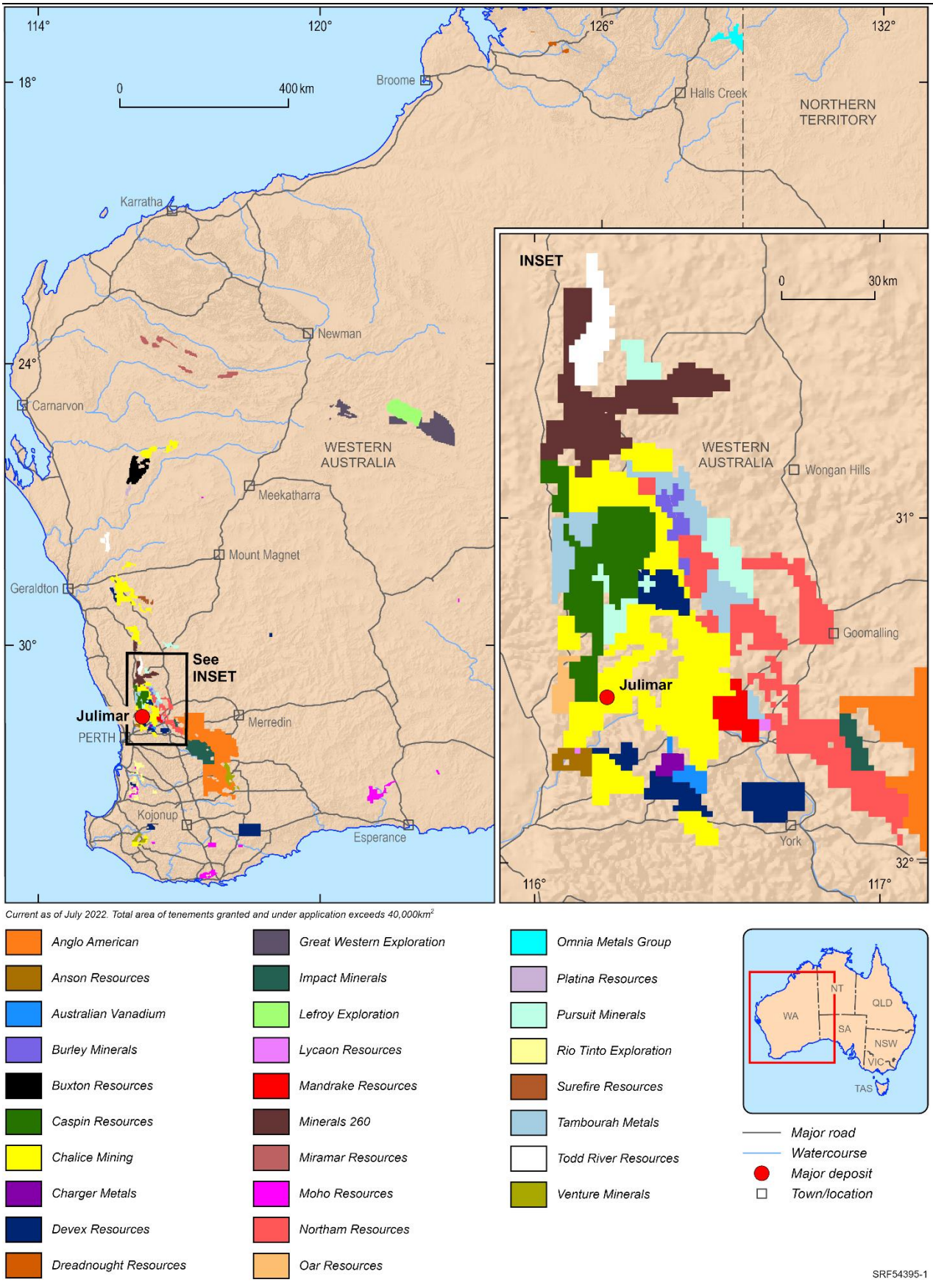


Source: Geoscience Australia

[20] Reported or inferred expenditure derived from public and ASX reporting documents.

[21] Analysis based on WA Department of Mines, Industry Regulation and Safety Resources Statistics, 2021-22

Figure 9 New mineral tenements stimulated by the MPM and Julimar discovery



Note: Map shows companies with tenements (as of July 2022) exploring for Ni Cu-PGE sulfide deposits in the region around the Julimar discovery (red dot) and further afield in MPM 'hotspots' which cite the MPM and/or the Chalice/Julimar discovery as a key rationale driving exploration investment.

Source: Geoscience Australia

3.5 Adoption

Following initial exploration, on 23 March 2020, Chalice announced to the market that its first drill hole at the Julimar project intersected 19 metres of high-grade nickel, copper, cobalt and palladium mineralisation (cobalt is often found in association with nickel deposits). The ore bearing layered mafic-ultramafic rocks that host magmatic sulfides, intersected at 48 metres, were under 'cover' in an area that had not been previously drilled.

The May 2020 edition of the Australian Mining Monthly noted that:

> *"Geoscience Australia's publication in 2016 … was a world first and even noted an unusual new hot spot just to the east of Perth that flew in the face of industry thinking at the time.*
>
> *"We had been looking all around WA and actually the rest of the world for new opportunities in nickel sulfide, which are very rare," Dorsch said. "From that we quickly realised we had to look more conceptually and look at frontier areas. Julimar is the first we have put a drillhole into and tested a concept, and it has been a nice surprise – a spectacular result."*
>
> *"However, the Julimar discovery has even bigger implications. It proves the GA's prospectivity mapping works, which is a big deal for exploration in this country."*

On 9 November 2021 Chalice formally announced[22] its:

> *"… maiden Mineral Resource Estimate (Resource) for the Gonneville deposit (deposit), the first discovery at its 100%-owned Julimar Nickel-Copper-Platinum Group Element (PGE) Project."*
>
> *"The Resource confirms that Gonneville is the largest nickel sulphide discovery globally in over two decades, and the largest PGE discovery in Australia's history – a remarkable achievement considering that this is the first discovery in what we consider to be an entirely new district, Julimar, within a new nickel-copper-PGE province, the West Yilgarn."*

The report notes that the deposit remains open to the north and at depth, demonstrating the potential for material growth with ongoing drilling. On 2 March 2022 Chalice reported initial results from its continuing exploration as follows:

> *"Recent step-out drilling at Gonneville has again highlighted the outstanding growth potential of the tier-1 scale resource, and the opportunity for significant growth of the deposit to support future underground mining said Dorsch."*

Chalice released updated resource details to the ASX on 8 July 2022[23], with Dorsch noting that:

> *"The work we have completed since publishing our maiden Resource in November last year continues to demonstrate the world-class endowment, scale and quality of the Gonneville Deposit. Apart from further increasing the contained metal, this Resource update has resulted in a significant increase in the higher-confidence Indicated Resource – which now represents ~70% of the total. Importantly, 90% of the resource above a depth of 250m is now classified as Indicated, which represents a major de-risking step for the Project."*
>
> *"Updated Indicated and Inferred, open-pit and underground mineral resource estimate are 350Mt @ 0.96g/t 3E1, 0.16% Ni, 0.10% Cu, 0.015% Co (~0.58% NiEq2 or ~1.8g/t PdEq3); containing 11Moz 3E, 560kt Ni, 360kt Cu, 54kt Co (~2.0Mt NiEq or ~20Moz PdEq)."*

International recognition/initiatives

As a world first, the MPM project attracted considerable international interest from other governments (as well as being of significant interest to Australia mining and exploration companies). Both the United States of America (USA) and Canadian Governments have moved to apply a similar innovative mineral systems based assessment methodology to undertake precompetitive prospectivity mapping at national scale. Collaboration between GA and the United States Geological Survey (USGS) and also with the Geological Survey of Canada (GSC) has been formalised through the following agreements:

[22] Chalice Mining Ltd. ASX announcement 9 November 2021: https://chalicemining.com/sites/default/files/asx-announcements/61061655.pdf

[23] Chalice Mining Ltd. ASX announcement 8 July 2022: https://chalicemining.com/sites/default/files/asx-announcements/61098901.pdf

- On 19 November 2019, GA and the USGS signed the project agreement to improve each nation's understanding and supply of critical minerals focused on *"… joint critical mineral potential mapping and quantitative mineral assessments; determining geological controls on critical mineral distribution; and developing data analytics capability to understand supply and demand scenarios for developing the critical minerals pipeline."*[24]
- In March 2020, GA established an agreement with the GSC to "*work together to better understand our respective geological resource potential.*"[25] Applying the approach pioneered by the MPM, Canada has developed its own Ni mineral potential map.[26]

Jointly, the USGS, GSC and GA established the Critical Minerals Mapping Initiative (CMMI)[27] which was sparked by the success of the MPM project. This tri-nation project is focused on building a diversified critical minerals industry in Australia, Canada, and the United States through developing a better understanding of:

- known critical mineral resources
- geologic controls on critical mineral distribution for deposits currently producing by-products
- how to infer new sources of supply through critical mineral potential mapping and quantitative mineral assessments.

The CMMI published its Australia/Canada/US mineral potential modelling in February 2022.[28] The CMMI Portal (the primary data delivery platform for the CMMI) merges and delivers mineral resource information of the three organisations. New outputs from the collaboration are added to the portal as they become available.

Furthermore, GA is using its internationally recognised technical expertise to assist the Geological Survey of India (GSI) in becoming a world-class geoscience organisation. Through a Memorandum of Understanding, GA is building the capacity and technological capability of GSI to assess the potential for minerals deep underground. It has held 'train the trainer' workshops in India, inspecting equipment and facilities, and seconding Indian officers to work inside GA.

3.6 Impacts

Chalice notes that[29]:

> "The Resource is considered to have reasonable prospects for eventual economic extraction (RPEEE) on the following basis:
>
> – *The deposit is located in a favourable mining jurisdiction, with no known impediments to land access and tenure status;*
> – *The volume, orientation and grade of the Mineral Resource is amenable to mining extraction via traditional open pit mining methodologies;*
> – *Available metallurgical test work indicates that the Mineral Resource is amenable to metallurgical extraction via flotation and/or leaching."*

While mining developments are capital intensive and often involve long lead times (the time from discovery to production varies considerably, with 5-10 years being the norm) Chalice has already initiated work focused on moving to production. "*The next major milestone for the Julimar Project is the Gonneville Scoping Study, which is targeted for completion in Q3 2022. The Company continues to progress development studies for the Gonneville Deposit in parallel to initial exploration activities across the*

[24] Geoscience Australia, *US-Australia partnership on critical minerals*; 19 November 2019: https://www.ga.gov.au/news-events/news/latest-news/us-australia-partnership-on-critical-minerals

[25] Minister Pitt media release linked to PDAC, 4 March 2020: https://www.minister.industry.gov.au/ministers/pitt/media-releases/new-data-shows-dramatic-increases-critical-minerals

[26] Lawley, C.J.M., Tschirhart, V., Smith, J.W., Pehrsson, S.J., Schetselaar, E.M., Schaeffer, A.J., Houlé M.G., Eglingtond, B.M.; *Prospectivity modelling of Canadian magmatic Ni (±Cu ± Co ± PGE) sulphide mineral systems*; Ore Geology Reviews, Volume 132, May 2021

[27] CMMI Website; fact sheets; ESO article: https://portal.ga.gov.au/persona/cmmi; https://eos.org/science-updates/geological-surveys-unite-to-improve-critical-mineral-security

[28] Lawley, C.J.M., McCafferty, A.E., Graham, G.E., Huston, D.L., Kelley, K.D., Czarnota, K., Paradis, S., Peter, J.M., Hayward, N., Barlow, M., Emsbo, P., Coyan, J., San Juan, C.A., Gadd, M, G,. *Data–driven prospectivity modelling of sediment–hosted Zn–Pb mineral systems and their critical raw materials*; Ore Geology Reviews Volume 141, February 2022

[29] Chalice Mining Ltd. ASX announcement 8 July 2022: https://chalicemining.com/sites/default/files/asx-announcements/61098901.pdf

>*30km long Julimar Complex."*[30] Chalice's Julimar discovery is the world's largest deposit of its type discovered in 20 years and one of four Tier one deposit discovered in the world in the last five years.

Economic viability at the project level involves a wide range of factors which make it difficult to quantify impacts at this stage. While the MPM project has delivered essential pre-competitive data, it is effectively only the first step on a long 'move to production' pipeline and its ultimate impact will only be fully appreciated with the realisation of new mines. Nevertheless, potential economic and social impacts are identifiable.

Production of new Ni-Cu-PGE sulfide deposits will deliver corporate tax and royalty income streams for governments; provide employment and industry development opportunities; deliver upgraded infrastructure and services to remote locations; generate export earnings; and support Australia's transition to a green economy. Production will also provide opportunities for indigenous communities where native title/access to indigenous land is a consideration.

To assess the impact of the project ACIL Allen has considered two scenarios:

- **Scenario 1 – Production of the Gonneville deposit** based on the indicated and inferred resources reported to the ASX on 8 July 2022. That is 350Mt @ 0.96g/t 3E[31], 0.16% Ni, 0.10% Cu, 0.015% Co (~0.58% NiEq2 or ~1.8g/t PdEq3); containing 11Moz 3E, 560kt Ni, 360kt Cu, 54kt Co (~2.0Mt NiEq or ~20Moz PdEq). The resource valuation approach is set out at Section 5.1 below with metals price forecasts based on those used by Chalice in the ASX report.

  Based on Chalice's ongoing exploration results, production based on 350Mt is considered a reasonable assumption. The estimated gross value of the Gonneville deposit is $51.4 billion.

- **Scenario 2 – an increase in the Gonneville deposit (to 500Mt), coupled with a more spectacular discovery** (double the size of the Gonneville deposit) (indicated and inferred resources); that is a 500Mt Gonneville+ deposit plus a second mine (XYZ deposit, a new discovery) of 700Mt. Assuming the same mineral composition, the Gonneville+ deposit would contain 15.5Moz 3E, 883kt Ni, 500kt Cu and 80kt Co, while the XYZ deposit would contain 21.5Moz 3E, 1,120kt Ni, 720kt Cu and 108kt Co. The estimated gross value of the combined discoveries is $179.1 billion.

Confirmed discoveries of this magnitude that proceed to operational mines would strongly position Australia in comparison to the giant discoveries overseas (i.e. Noril'sk (Russia) with ore reserves of 478.7Mt; Jinchuan deposit (China) with over 500Mt; and Voisey's Bay (Canada) at ≈50Mt).

Given the level of success, Chalice's assay results for Julimar, and the significant upturn in exploration activity in the region, there is a reasonable likelihood of the second scenario being realised, and the returns could even be significantly higher given the size of known world giants.

Employment

The mining industry is a major source of employment, especially in regional and remote areas. Employment growth has been strong in recent years. For instance, WA's "*mining, mineral exploration and petroleum industries employed an average of 156,238 on-site personnel or 123,132 in full-time-equivalent (FTE) terms during 2021, representing another record for a single calendar or financial year*".[32]

While it is too early to assess the employment impacts of the MPM project, the employment associated with IGO's Nova operations (around 460 employees)[33], and Voisey's Bay mine in Canada (approximately 500 people support mining operations with an estimated additional 400 employees required when underground mining begins)[34] provides an indication

[30] ibid

[31] 3E minerals is a collective reference for palladium (Pd), platinum (Pt) and gold (Au). The average in-situ ratio of ~4.8:1:0.18 (Pd:Pt:Au).

[32] WA Department of Mines, Industry Regulation and Safety; Industry activity indicators accessed 1 July 2022 https://www.dmp.wa.gov.au/About-Us-Careers/Latest-Resources-Investment-4083.aspx#:~:text=activity%20review%202021-,Employment,single%20calendar%20or%20financial%20year

[33] Independence Group NL (IGO); Nova Site Visit August 2018 https://www.igo.com.au/site/PDF/481314ea-9ce4-41f3-9b10-e17665f22bb8/NovaSiteVisitPresentation accessed 28 May 2020

[34] Vale Canada Ltd; Voisey's Bay Snapshot of Operations http://www.vale.com/canada/EN/aboutvale/communities/voiseysbay/Pages/default.aspx accessed 28 May 2020

of the likely scale of direct jobs that might be created. Deloitte Access Economics estimates that in addition to this direct economic contribution mining also makes an indirect contribution to employment with a 1.35 multiplier.[35]

Each discovery will generate its own employment needs, highly dependent on the location, the nature of the deposit and the scale of operation/processing technologies deployed (and whether it is an open cut or underground operation). However, it can be reasonably assumed (based on the figures above) that Scenario 1 could generate almost 500 ongoing new jobs per annum, while Scenario 2 above could generate at least two to three times that many (over a longer mine life). Employment will peak during the mine and processing plant construction phase. A ratio of 1.25 FTE per million dollars of capital expenditure per year is used to generalise an estimate of the labour effort (based on a number of case study mines examined by ACIL Allen).On this basis Scenario 1 may involve a construction workforce of around 1,900, while Scenario 2 could be in the order of 4,800 FTEs spread over several years.

The WA Government is committed to the development of the state's future battery and critical minerals industries. The Future Battery Industry Strategy launched in January 2019, seeks to position the State as a leading global supplier of battery and critical minerals and to realise investment opportunities across WA's battery and critical minerals value chains. The Government is seeking to realise this vision through mining and processing projects that will enable the State to expand its contribution to the global battery supply chain and created local jobs. Development of critical minerals resources (such as the Gonneville deposit) are essential to underpin this vision and drive opportunities.

4. Clarifying the Impacts

4.1 Counterfactual

There are no other scientific groups in Australia which had the skills necessary to undertake the development of the national-scale pre-competitive data sets and models underlying the MPM project. The data sets would not exist without the development efforts of GA. As noted by Alex Dorsch, Managing Director, Chalice Mining, the data sets were a key consideration in the exploration efforts that led to the Julimar find.

4.2 Attribution

At this stage there is limited quantifiable benefit from the MPM project, but it is clear that the MPM products are stimulating exploration activity (as are similar GA projects e.g. the Tennant Creek to Mount Isa (TISA) dataset[36]). Given the project was developed and funded entirely by GA, 100 per cent of the potential benefits have been attributed to GA. However, it should be noted that in part, the project drew upon state data sets as well as academia data (funded through AuScope)[37] to develop the 'favourability' maps.

As discussed above, the availability of quality pre-competitive data is but the initial step in a lengthy and capital intensive minerals development process. Initial (lower-level) benefits will begin to flow with increased exploration activity, while the significant benefits only being realised once projects go into production. However, early benefits are being realised (e.g. Chalice has spent ~$0.5 M in the community, with its contractors having spent ~$1.5 M.[38]) Ultimately, commercial players will have to undertake major investments to realise the benefits which may flow from development of any discovered new resources.

[35] Deloitte Access Economics, 2017; *Mining and METS: engines of economic growth and prosperity for Australians Report prepared for the Minerals Council of Australia* https://www2.deloitte.com/au/en/pages/economics/articles/mining-mets-economic-growth-prosperity-engines.html accessed 3 June 2020

[36] Geoscience Australia, May 2020; *Exploring for the Future Case Studies: New Exploration in the East Tennant Area* https://www.ga.gov.au/eftf/data-and-publications/case-studies/latest-case-studies/new-exploration-in-the-east-tennant-area accessed 2 July 2020

[37] AuScope, 17 November 2021; AuScope underpins Julimar polymetallic minerals discovery; accessed 5 July 2022 https://www.auscope.org.au/impact-posts/auscope-underpins-julimar-polymetallic-minerals-discovery

[38] Chalice Mining Ltd, *Annual Report 2021*; Annual Report to Shareholders 23 Sep 2021 accessed 28 July 2022

https://chalicemining.com/sites/default/files/asx-announcements/61051779.pdf

5. Evaluating the Impacts

5.1 Cost-Benefit Analysis

Costs

The nominal costs of the project are shown at Table 1. GA was responsible for the total budget of $1.5 million (equivalent to $1.8 million in 2022 prices[39]). The present value (PV) in 2022 of these costs using a seven per cent real discount rate is $3.0 million (in 2022 dollars).

Benefits

Resource valuation

The assumptions adopted to derive the resource valuations for each scenario are set out in Table 2. Metals prices are based on the prices adopted in Chalice's ASX report of 8 July 2022.[40] An exchange rate of AUD$1 = US$0.75 is used.

Table 2 Gross resource valuations

Metal	Mineral mass		Commodity price (US$)	Gross value (US$M)	Gross value (AUD$M)
Scenario 1: 350Mt indicated and inferred resource (Gonneville deposit)					
Nickel (Ni)	560,000t		$22,000/t	$12,320	$16,427
Copper (Cu)	360,000t		$10,500/t	$3,780	$5,040
Cobalt (Co)	54,000t		$75,000/t	$4,050	$5,400
Palladium (Pd)	8.6Moz		$1,800/oz	$15,480	$20,640
Platinum (Pt)	1.8Moz		$1,300/oz	$2,340	$3,120
Gold (Au)	0.33Moz		$1,800/oz	$594	$792
			Total	$38,564	$51,419
Scenario 2: Two deposits (Gonneville+ and XYZ deposits)- 500Mt + 700Mt					
	Gonneville+ deposit	**XYZ deposit**			
Nickel (Ni)	883,000t	1,120,000t	$22,000/t	$44,066	$58,755
Copper (Cu)	500,000t	720,000t	$10,500/t	$12,831	$17,108
Cobalt (Co)	80,000t	108,000t	$75,000/t	$14,100	$18,800
Palladium (Pd)	12.1Moz	17.2Moz	$1,800/oz	$52,740	$70,320
Platinum (Pt)	3Moz	3.6Moz	$1,300/oz	$8,580	$11,440
Gold (Au)	0.47Moz	0.66Moz	$1,800/oz	$2,034	$2,712
			Total	$134,351	$179,135

Note: Metals prices are based on Chalice's ASX report of 8 July 2022 (the resource is reported within a pit shell and within underground MSO shapes using metal price assumptions and is reported above a 0.4% NiEq cut-off grade in-pit and within selective mining shapes underground); an exchange rate of AUD$1 = US$0.75

Source ACIL Allen

[39] All figures for the CBA analysis have been converted into constant 2022 dollars using an inflation rate of 2.5 per cent per annum. All present value calculations of impacts refer to present values in the year 2022 calculated using a 7 per cent real discount rate.

[40] The Chalice metal prices used were determined from long-term consensus analyst estimates from S&P Global Market Intelligence (typically for 2025), selecting a rounded figure within the P20-P30 range of the distribution (i.e., 20-30% of the distribution of consensus analyst estimated metal prices were above the selected figures). Chalice and Cube believe this is a reasonable approach, considering the potential mine life and considerations for reporting Mineral Resources in accordance with the JORC Code. See https://chalicemining.com/sites/default/files/asx-announcements/61098901.pdf

Exploration benefits

While there are no doubt short-term benefits due to an upturn in economic activity as a result of increased exploration activity, the major long-term benefits will not accrue until mine production commences. The benefits arising from exploration activity have not been incorporated in the CBA modelling below given exploration expenditure is generally written off as a project cost. It is also likely to represent a combination of new investment and the reprioritisation/redirection of existing exploration dollars. However, since 2016 (when the MPM was released) Australia's share of global exploration has increased significantly and a 20 year decline has been averted.[41]

As outlined the exploration employment impacts to date could translate to around 100+ person years. Exploration activity can generate a ROI to Government through income tax revenues. As detailed in Section 3.4,100 'new' exploration person years could be expected to generate an income tax receipt in the order of $2.5 million (based on average WA mining salary figures).

MPM project 'success cases'

Given the lack of clear quantifiable benefits (as there are no Australian mining operations in production that can be causally linked to the project), any cost benefit analysis of the MPM project must necessarily rely on a range of assumptions. As discussed above, benefits arising from exploration activity have not been incorporated in the modelling. Nevertheless, the MPM project and state and academic data bases have been instrumental in maintaining Australia's position as a desirable exploration investment location.

ACIL Allen has estimated the benefits based on the projected revenues that will be generated by Ni-Cu-Co-Pd-Pt production. Two 'success case' scenarios have been adopted to generate conservative estimates of benefits. Given the high degree of uncertainty in relation to Scenario 2, the following assumptions are applied:

- two discovery scenarios used as central cases (as outlined in Section 3.6):
- Scenario 1: development of the 350Mt Gonneville deposit with indicated and inferred resources of 11Moz 3E, 560kt Ni, 360kt Cu, 54kt Co (with the indicated resource representing ~70 per cent of the total)
- Scenario 2: development of and expanded (500Mt) Gonneville+ deposit plus a second 700Mt XYZ deposit (twice the size of the current Gonneville deposit) with total indicated and inferred resources of 37Moz 3E, 2,003kt Ni, 1,220kt Cu and 188kt Co
- early exploration success enables rapid mine start-up with production of the Gonneville deposit to commence in 2026, and production of the XYZ deposit resources (Scenario 2) beginning 3 years later (2029)
- while this is a relatively fast start-up given the need to prove the resource; develop approved production plans; secure project financing; and to establish the necessary production/processing facilities and related infrastructure, it is in alignment with Chalice's forward plans
- given both scenarios are based on 'indicated and inferred resource' figures; the modelling assumes 100 per cent resource recovery
- given industry interest in the MPM project data, relatively bullish assumptions are applied with regard to mine success rates (that is the likelihood of an economic resource discovery that is taken through to full production) – in part informed by the recent exploration successes
- for Scenario 1 a success rate of 80 per cent is applied
- for Scenario 2 a success rate of 60 per cent is used for the Gonneville+ deposit (reflecting it builds on the Scenario 1 deposit and given positive exploration outcomes to date) and 10 per cent is applied for the XYZ deposit
- for Scenario 2 it is assumed the larger Gonneville+ deposit is developed by Chalice – that is it in effect increases both production and mine life as compared to Scenario 1, while the XYZ mine is developed independently at a more remote location and with more challenging conditions (i.e. greater depth of overburden, an orebody dip angle of 20 degrees)

[41] Schodde R., *Assessing Long Term Exploration and Discovery Performance for Key Minerals in Australia*; Presentation to the International Mining and Resources Conference, 27th November 2020, Melbourne

- mine life of 24 years for Scenario 1; 27 years for the larger Gonneville+ deposit under Scenario 2; and 30 years for the XYZ deposit mine
- royalties payable 2.5 per cent ad valorem value of the metal (as per Western Australia)
- an exchange rate of AUD$1 = US$0.75; a corporate tax rate of 30 per cent of profit ex royalty
- mine production economics, derived using the Economic Fairways Mapper Tool, based on the Blue Cap code[42,43], are based on the following assumptions/modelled parameters
  - idealised mine-valuations based on:
    (a) description of the hypothetical orebody (e.g. grade, geometry, depth of cover and location) and additional input parameters governing the mine economics (e.g. commodity prices)
    (b) appropriate mining systems based on the geometry and cover, with production rates estimated using a modified form of Taylor's rule
    (c) processing systems based on the type of mineral mined with processing capacity estimated from the amount of ore produced
    (d) general and administrative costs – 14 per cent of the mining and processing costs
    (e) infrastructure requirements/costs including power, transportation and water costs based on mine location and its energy and water requirements.

Benefits from Scenario 1 and Scenario 2

The 'success case' assumptions, parameters and impact analysis outcomes for both scenarios are shown in Table 3.[44]

It is estimated that, under the two scenarios, the project generates (in present value terms in 2022 at 2022 constant prices):

- $9,555 million in benefits for Scenario 1 or $11,140 million in Scenario 2
- $6,075 million in costs for Scenario 1 or $6,565 million in Scenario 2
- $1,209 million in Commonwealth tax receipts in Scenario 1 or $1,556 million in Scenario 2
- $509 million in state government royalty returns in Scenario 1 or $594 million in Scenario 2

In net present value (NPV) terms, the overall benefit of the mine project in 2022, using a seven per cent real discount rate, is $3,480 million for Scenario 1 and $4,574 million for Scenario 2 (in 2022 dollars). Given that the analysis in this section takes into account of a range of different factors (such as the probability of success and different mine start timeframes), the NPV figures do not relate directly to the NPV values in Figure 7 shown at Section 3.4 earlier.

The benefit-cost ratio (BCR) of the project from the Commonwealth Government's perspective, obtained by dividing the present value of Commonwealth tax benefits by the present value of GA's project costs, is estimated to be 409 under Scenario 1 or 526 under Scenario 2. Furthermore, the analysis shows that every dollar invested in this project by the Commonwealth Government through GA could enable between $1,176 and $1,546 in net benefit.

[42] The Economic Fairways Mapper is a multi-criteria decision support tool to identify regions that are economically viable. The tool generates a heat map and a report for a user defined region. The commodity of interest and the economic variables are selected by the user. The tool and documentation on how the Economic Fairways Mapper algorithm works is available at https://portal.ga.gov.au/ under *Assessment Tools.*

[43] Walsh S.D.C., Northey S. A., Huston D., Yellishetty M., Czarnota K.; 2020; *Bluecap: A geospatial model to assess regional economic-viability for mineral resource development;* Resources Policy Volume 66, June 2020, 101598 available at https://doi.org/10.1016/j.resourpol.2020.101598

[44] Notably, the analysis for this report was undertaken using a Cost Benefit Analysis (CBA) framework, which differs from the financial appraisal (FA) of a project (a method used to evaluate the financial viability of a proposed project to, for instance, raise capital). While both CBAs and FAs require quantifying the stream of costs and benefits into the future and discounting these to obtain a NPV, and they typically cover the same analysis period, FAs and CBAs differ in respect to the scope and the basis for valuation of the costs and benefits included in the analysis, and the discount rate used. As a result, the results presented in this report are not comparable with financial figures typically disclosed by mining companies. Additional information about the difference between CBAs and FAs can be found in the NSW Government Guide to Cost Benefit Analysis.

Table 3 Impact analysis - central case

	Units	Scenario 1: Gonneville deposit	Scenario 2: two mines	
			Gonneville+ deposit	XYZ deposit
Parameters				
Mine life	Years	24	27	30
Probability of success	%	80%	60%	10%
Commodity prices (2022 prices) [a]				
Nickel (Ni)	US$/tonne	$22,000	$22,000	$22,000
Copper (Cu)	US$/tonne	$10,500	$10,500	$10,500
Cobalt (Co)	US$/tonne	$75,000	$75,000	$75,000
Palladium (Pd) [a]	US$/oz	$1,714	$1,714	$1,714
Platinum (Pt) [a]	US$/oz	$1,714	$1,714	$1,714
Gold (Au)	US$/oz	$1,800	$1,800	$1,800
Impacts				
PV of benefits in 2022	AUD$M (2022 prices)	$9,554.7	$11,139.5	
PV of costs in 2022 [b]	AUD$M (2022 prices)	$6,074.6	$6,565.3	
PV GA's project costs	AUD$M (2022 prices)	$3.0	$3.0	
PV of Commonwealth income tax receipts	AUD$M (2022 prices)	$1,208.5	$1,555.9	
PV of royalties	AUD$M (2022 prices)	$508.5	$594.4	
NPV (mine project)	AUD$M (2022 prices)	$3,480.1	$4,574.2	
NPV (Commonwealth)	AUD$M (2022 prices)	$1,205.5	$1,552.9	
Average annual employment [c]	502	543	585	
Benefit cost ratio				
BCR (Commonwealth)	Ratio	409	526	
BCR (mine project)	Ratio	1.6	1.7	
Net total benefits delivered for every $ invested by GA [d]	Ratio	1,176	1,546	

[a] All commodity prices are taken from Chalice's ASX report of 12 November 2021. A PGE price has been used for Palladium (Pd) and Platinum (Pt) to meet the input requirements of the Economic Fairways Mapper Tool.

[b] Excludes royalties and Commonwealth income taxes as in a cost benefit analysis framework these are not considered a resource cost, but a transfer.

[c] Average annual employment figures based on the Economic Fairways Mapper Tool and data from Resources and Energy Major Projects List: 2015, 2018

[d] Derived by dividing the project NPV by the PV of GA's project costs ($3.0 million).

Note: All present value calculations refer to present values in the year 2022 calculated using a 7 per cent real discount rate. Some numerical differences may occur due to rounding to one significant figure.

Source: ACIL Allen

5.2 Sensitivity analysis

ACIL Allen has tested the BCR outcome by varying assumptions with regard to commodity prices (plus/minus 20 per cent) and modelling a delay in mine commencement of five years. The shaded cells in Table 4 show where the commodity price assumptions have been changed relative to the central case scenario as part of the sensitivity analysis.

Table 4 Impact analysis - sensitivities

	Units	Default prices		Low prices		High prices		Default prices with 5 year delay	
		Scenario 1	Scenario 2	Scenario 1	Scenario 2	Scenario 1	Scenario 2	Scenario 1	Scenario 2
Parameters									
Mine life	Years	23	27,31	23	27,31	23	27,31	23	27,31
Probability of success	%	80%	60%,10%	80%	60%,10%	80%	60%,10%	80%	60%,10%
Commodity prices (2022 prices)									
Nickel (Ni)	US$/tonne	$22,000	$22,000	$17,600	$17,600	$26,400	$26,400	$22,000	$22,000
Copper (Cu)	US$/tonne	$10,500	$10,500	$8,400	$8,400	$12,600	$12,600	$10,500	$10,500
Cobalt (Co)	US$/tonne	$75,000	$75,000	$60,000	$60,000	$90,000	$90,000	$75,000	$75,000
Palladium (Pd)	US$/oz	$1,714	$1,714	$1,371	$1,371	$2,057	$2,057	$1,714	$1,714
Platinum (Pt)	US$/oz	$1,714	$1,714	$1,371	$1,371	$2,057	$2,057	$1,714	$1,714
Gold (Au)		$1,800	$1,800	$1,440	$1,440	$2,160	$2,160	$1,800	$1,800
Impacts									
PV of benefits in 2022	AUD$M (2022 prices)	$9,554.7	$11,139.5	$7,643.8	$8,911.6	$11,465.7	$13,367.4	$6,812.4	$7,942.3
PV of costs in 2022	AUD$M (2022 prices)	$6,074.6	$6,565.3	$6,074.6	$6,565.3	$6,074.6	$6,565.3	$4,331.1	$4,681.0
PV GA's project costs	AUD$M (2022 prices)	$3.0	$3.0	$3.0	$3.0	$3.0	$3.0	$3.0	$3.0
PV of Commonwealth income tax receipts	AUD$M (2022 prices)	$1,208.5	$1,555.9	$732.3	$1,001.7	$1,846.5	$2,300.3	$861.6	$1,109.3
PV of royalties	AUD$M (2022 prices)	$508.5	$594.4	$191.1	$222.8	$286.6	$334.2	$362.5	$423.8
NPV (mine project)	AUD$M (2022 prices)	$3,480.1	$4,574.2	$1,569.1	$2,346.3	$5,391.0	$6,802.1	$2,481.3	$3,261.3
NPV (Commonwealth)	AUD$M (2022 prices)	$1,205.5	$1,552.9	$729.4	$998.7	$1,843.5	$2,297.3	$858.7	$1,106.4
Benefit cost ratio									
BCR (Commonwealth)	Ratio	409	526	248	339	624	778	291	375
BCR (mine project)	Ratio	1.6	1.7	1.3	1.4	1.9	2.0	1.6	1.7
Net total benefits delivered for every $ invested by GA	Ratio	1,176	1,546	530	792	1,822	2,299	838	1,102

Note: All present value calculations refer to present values in the year 2022 calculated using a 7 per cent real discount rate. Some numerical differences may occur due to rounding to one significant figure. Commodity prices based on Chalice's ASX report of 8 July 2022 (PGE price used for Palladium and Platinum for input into Economic Fairways Mapper Tool).

Source: ACIL Allen - based on information produced using Geoscience Australia's Economic Fairways Tool.

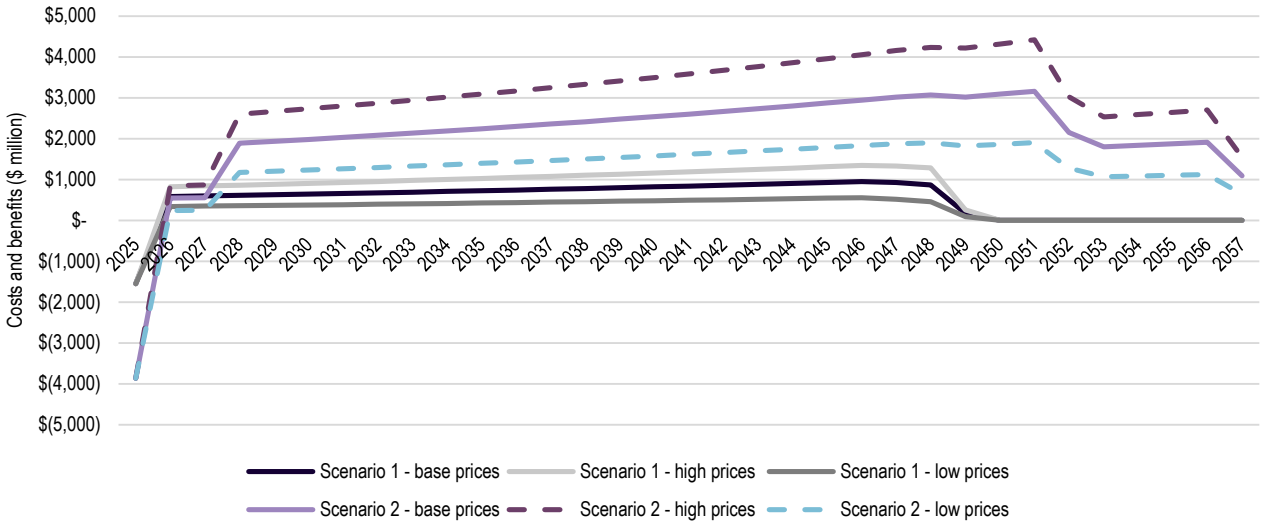
The two central case scenarios assume the default commodity prices as outlined in Table 3. If the commodity prices are increased by 20 per cent (as per Table 4), then the BCR from the Commonwealth Government's perspective increases from 409 (Scenario 1) and 526 (Scenario 2) to 624 and 778 respectively (with the project BCR's increasing from 1.6 and 1.7 to 1.9 and 2.0 respectively). In contrast, if the commodity prices are decreased by 20 per cent, then the BCR from the

Commonwealth Government's perspective falls from 409 (Scenario 1) and 526 (Scenario 2) to 248 and 339 respectively (with the projects' BCR's decreasing from 1.6 and 1.7 to 1.3 and 1.4 respectively).

In line with 'normal' practice, both positive and negative changes in commodity prices have been modelled. Given nickel and palladium constitute the bulk of the mines' value, the weight of probability favours the more positive of the two sensitivities (given current and anticipate global demand). Table 4 also shows the impacts of developing all mines later with first production delayed by five years, compared to the central case.

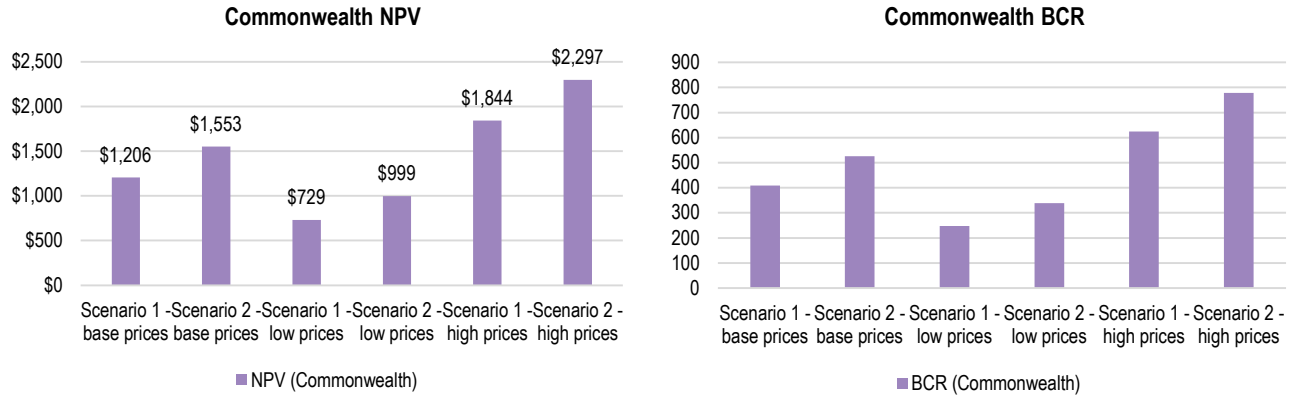
Figure 10 shows the undiscounted net cashflows of the project for each scenario, while the impact of varying the assumptions on NPVs and the BCR is summarised in Figure 11. In addition, the impact of these sensitivities on the Commonwealth NPVs and BCRs are summarised in Figure 11.

Figure 10 Net project cashflows under different scenarios



Source: ACIL Allen - based on information produced using Geoscience Australia's Economic Fairways Tool.

Figure 11 Commonwealth Government NPV and BCR under different assumptions



Note: All present value calculations refer to present values in the year 2022 calculated using a 7 per cent real discount rate.

Source: ACIL Allen - based on information produced using Geoscience Australia's Economic Fairways Tool.

5.3 Potential future impacts

ACIL Allen conducted an initial assessment of the impact of the MPM program 12 months ago prior to the release of the resource figures for the Gonneville deposit (that is, before the ASX reports of 9 November 2021 and 8 July 2022). Two

scenarios were modelled - a small mine at a discovery of 10Mt and a more spectacular discovery of 50Mt. Development 'success cases' were modelled using similar assumptions to those above (with commodity prices pegged to those prevailing at the time). It was estimated that the development scenarios could generate an overall benefit to the Australian economy of between $441 million and $869 million and between $131 million and $258 million in net benefits to the Commonwealth in terms of taxation. Every dollar invested in the MPM project by the Commonwealth through GA was estimated to generate between $215 and $425 in additional benefits to the economy. The estimated BCR for the Government was between 65 and 127 for the 'success cases'.

In contrast, the updated Chalice reporting provides for a more robust assessment and far stronger economic outcomes. Scenario 1 delivers around $3.48 billion to the Australian economy, more than four times that estimated for the large mine in the original assessment, with $1.21 billion in net benefits to the Commonwealth in terms of taxation (compared to $258 for the large mine). The estimated BCR for the Commonwealth Government is between 409 and 526 for the 'success cases'. This is a substantial step up from the initial assessment with the mines having a BCR of 65 and 127, respectively).

The Scenario 1 analysis above is based around a single potential discovery. The MPM Project has identified 12 locations as having high or moderate potential prospectivity for Ni-Cu-PGEs. Exploration success followed by mine development and production at any of these locations has the potential to generate benefits along the lines of those estimated for the scenarios above (albeit more than two major discoveries in the same province are not considered highly likely).