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2024 MinEx CRC Annual Report

1 July 2023 - 30 June 2024

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1.1 Executive summary

During the past year, MinEx CRC operated safely and responsibly, with no recordable injuries and a focus on equality, diversity and inclusivity in all our activities. Risk management is a critical governance function, and the MinEx CRC Board provides oversight, *inter alia,* into risks that may impact MinEx CRC 's ability to achieve our vision and goals. OHSE remains the top risk for MinEx, primarily because of the potential consequence of an incident.

MinEx CRC had a strong year in 2023/24 in retaining all 23 Participants. MinEx CRC revenue and expenditure were according to budget, with a budgeted deficit of $1.1M. The MinEx CRC life-to-date surplus of $9.2M will be reduced to nil over the remaining life of the CRC. During FY24, the National Drilling Initiative (NDI) drilling campaigns reduced the cash balance by $3.9M and project expenses were $6.4M.

During the past year, in our large team of 165 (67 FTE) we achieved 355 of our 367 Phase 2 quarterly project milestones, with cumulative progress against all Phase 2 project milestones at 79.3% compared to a target of 77.6%. Of the four Opportunity Fund projects, we achieved 29 of 31 milestones. MinEx CRC remains on target to achieve all Phase 2 milestones by end-2024 and complete all eleven Commonwealth Milestones.

In the past year, MinEx CRC staff had 61 publications, comprising scientific publications, internal publications, technical reports, conference abstracts, and made numerous external presentations. One hundred and thirty people attended the MinEx CRC in-house conference in November 2023.

Significant progress has been made in the past year towards MinEx CRC 's target of 50 postgraduate completions, with six postgraduate students completing their studies, bringing the total completions to 15. A total of 55 postgraduate research students have now registered.

Planning meetings at our Mid-year Science Review proved important for defining desired commercialisation outcomes and shaping the Phase 3 research agenda. Draft Project Agreements for Phase 3 of MinEx CRC (2025-2027) were completed for all core projects and circulated for review by Participants. The Phase 3 draft projects emphasise commercialisation and bringing products to market. The MinEx CRC business plan includes preparation for wind-up in June 2028.

The move towards the commercialisation of technologies continues, in line with the MinEx CRC strategy, with four commercialisation agreements executed in the past year. These were the lease-for-purchase contract for the CT500 Coil Tube (CT) system (including personnel), LogAR visualisation, Hobby drill management, and the AutoDrill rig automation system. Two provisional patent applications were also lodged, one for our unique downhole EM sensor system and the second for our drill hole geochemical logging system using in-situ Laser-Induced Breakdown Spectroscopy (LIBS).

Combined with the MinEx CRC CT drilling platform the downhole EM and LIBS geochemical tools are technologies that can contribute to an overarching stretch target of MinEx CRC - to log and characterize buried geology whilst drilling, and use those data to steer toward off-hole targets. These technologies, spanning multiple research projects, exemplify the portfolio nature of MinEx CRC research.

Two NDI campaigns were undertaken in the past year for the Geological Survey of Western Australia (GSWA). The 'Nifty' campaign commenced in August 2023. We achieved 758m of drilling in three holes, with two holes completed to depth. The program was cut short due to a mechanical failure and the rig was returned to Adelaide for repairs. The CT platform was then deployed to the 'Moonera' campaign where we completed a 501m hole in challenging drilling conditions.

Samples from the 2022 and 2023 NDI 'Delamerian' and 'Delamerian Margins' campaigns were the subject of multiple geological and geochemical analyses, including novel isotopic techniques designed to characterize and date key components of the mineral system. This work has led to a reappraisal of the history, tectonic setting and mineral potential of the Delamerian Orogen and helped to inform our web-based user-guides for emerging exploration techniques and technologies.

WA NDI drill site in collaboration with GSWA.

1.2 Achievements

AWARDS

- Former Postgraduate Student Dr Fernando F. Fontana was awarded the 2023 UniSA Norton Jackson Material Science and Engineering Medal.
- MinEx CRC Director Peter Rossdeutscher was awarded Member (AM) Of the Order of Australia in the 2024 Kings Birthday Honours.
- Internal MinEx CRC awards were presented at the Annual Conference as follows:
  - MinEx CRC 2023 Publications Award: Mark Lindsay (CSIRO), Agnieszka Piechocka (CSIRO), Mark Jessell (UWA), Richard Scalzo (University of Sydney), Jeremie Giraud (UWA), Guillaume Pirot (UWA) and Edward Cripps (UWA) for "Assessing the impact of conceptual mineral systems uncertainty on prospectivity predictions."
  - MinEx CRC Team Player Award 2023: Adrienne Brotodewo, Project 7.5 Leader (UniSA).

PARTICIPANTS AND AFFILIATES

- 23 sponsoring Participant organisations
- 20 sponsoring Affiliate organisations

One new Affiliate (AngloGold Ashanti) joined during the reporting period. A complete list of Participant and Affiliate sponsors is included in Appendix A.

EQUITY, DIVERSITY, AND INCLUSION (EDI)

MinEx CRC is committed to growing and supporting an equitable, diverse, and inclusive environment where everyone feels safe, valued, supported, and treated fairly with dignity and respect.
The following EDI actions were undertaken during the reporting period:

- The MinEx CRC Board (excluding the CEO) comprises eight members, 50% male and 50% female.
- The MinEx CRC Executive Management Committee, including the CEO, comprises eight members, 62.5% male and 37.5% female.
- Research Leads for the nine primary programs are 78% male and 22% female.

EDUCATION AND TRAINING (E&T)

- As of June 30 2024, MinEx CRC had 55 registered postgraduate students, 15 students graduated and 35 students currently enrolled.
- Six MinEx CRC postgraduate students completed during the reporting period. The completing students are employed as follows:
  - Alex De Vries Van Leeuwen (PhD): MinEx CRC embedded researcher, University of Adelaide (embedded with the GSSA).
  - Mahtab Rashidifard (PhD): Geophysicist, GSWA
  - Jie Yu (PhD): Research Associated, Curtin University
  - Elizabeth Bruce (Masters by research): Undertaking a PhD project at UWA with MinEx CRC Project 6
  - Naina (PhD): CSIRO
  - Victor Santos (PhD): Rotating Equipment Engineer, ERM Consulting
- The MinEx CRC Mid-Year Postgraduate Day was held online on 15 and 18 July with 82 attendees.
- Seven video conferences were held throughout the reporting period to engage students and ensure they feel supported within the CRC environment.
- Eight students presented TEDx-style talks at the Annual Conference held in November 2023.
- Two students undertaking 'Company Sponsored Projects' have continued their research directly affiliated with MinEx CRC industry partners and are complimentary to the broader MinEx CRC

research agenda. These projects are concentrated on case study areas of the industry partner. Partners include AIC Mines, Encounter Resources, Inca Minerals, Lodestone Mines, Middle Island Resources and Strategic Energy Resources.

COMMUNICATIONS AND EVENTS

- Two press releases were distributed during the reporting period titled:
  - 'Augmented Reality Core Logging a Step Closer Under New Commercial Deal'
  - 'Australian-designed Drilling Tech Set to Revolutionise Exploration via DIG CT Commercialisation Deal'
  - One Ministerial Press Release was distributed in collaboration with Tom Koutsantonis, MP Minister for Energy and Mining, South Australia, titled 'Strong Mining Sector Sets Pace for Growth'.
- A suite of 'pre-commercial product brochures' to act as a go-to document for those seeking more technical context around MinEx CRC research was created, titled as below:
  - Pre-commercial Product Brochure: LIBS Downhole Geochemistry Tool
  - Pre-commercial Product Brochure: Downhole Swept Frequency EM Tool
  - Pre-commercial Product Brochure: RoXplorer® CT Drilling System. These brochures are included as Appendix F.
- Nine videos were published on MinEx CRC TV, and the total YouTube views now exceed 14K.
- Three episodes of the MinEx CRC vNews on significant research outcomes were published on MinEx CRC TV.
- There were 39k visitors to the MinEx CRC website, with 80k page views.
- The ‘2023 Year in Review' summary document was released and is included as Appendix B.
- The MinEx CRC Open Day was held on June 4 in Perth, with 127 attendees, spanning 32 organisations.
- The annual Mid-Year Science Review was held on June 5 in Perth, with 103 attendees, spanning 22 organisations.
- MinEx CRC 's fifth Annual Conference: Frontier Exploration was held on 15-16 November at the Tradewinds Hotel, Fremantle. Over 155 delegates attended the 2-day conference spanning 28 organisations.
- A session at PDAC 2024 in collaboration with Australia Minerals was facilitated by Andrew Bailey (CEO), David Giles (CSO) and Cameron Jackson (Drilling Operations and Commercial Manager).
- A VIP industry delegation toured the CT drilling platform stationed in the Great Sandy Desert (WA) for our NDI project in collaboration with GSWA.
- Research outcomes were featured in prominent industry publications such as Australia's Mining Monthly, Australasian Drilling Magazine, miningnews.net and the Precompetitive Review.
- In collaboration with Geoscience Australia, CT drilling platform and NDI Drilling Campaign were featured in a 7 News Exclusive.

SME ENGAGEMENT

- MinEx CRC maintained its relationship with OMNI GeoX to coordinate and manage aspects of the WA NDI campaign in collaboration with GSWA.
- Participant Imdex Limited provided significant in-kind contributions of people and equipment to research projects and logging equipment for the NDI drilling program. The equipment was a valuable aid to the Project and provided Imdex with important feedback on using and developing recently released products.

INTERNATIONAL COLLABORATION

Cooperation is ongoing with European-based METS companies Sandvik, Epiroc, LKAB Wassara and AnTech.

SAFE OPERATION

MinEx CRC achieved another year of safe and responsible operational performance. No recordable injuries were sustained, and there continued to be focus on the people of MinEx, with equality, diversity and inclusivity considered in all our activities.

During the first six months of the past year, an operational drill crew of eight employees were active in the field and workshop, significantly raising the operations' risk profile. Risk management was considered for all aspects of MinEx CRC operations, with MinEx CRC also achieving a year with no other significant risk, personnel, research or insurance issues.

OPERATIONAL ACHIEVEMENTS

MinEx continue to operate a field crew for operation of the CT Rig for the first 7 months of the past year. During this time the rig was utilised in South Australia and Western Australia, and underwent a significant maintenance period and mast rebuild towards the end of the period. During this period the CT Rig continued to perform safely but a major mechanical failure of the primary shaft on the mast led to significant down-time at the end of the period.

MinEx projects conducted extensive field operations, including the following:

- Project 1 undertook field and laboratory testing of drilling equipment and processes, with both real-world and simulated drilling operations.
- Project 2 modified and tested aspects of the CT1000 drill rig under workshop settings and under field conditions at Kapunda in South Australia.
- Project 3 undertook the first field trial of the LIBS down-hole tool, utilising a test facility at Neerabup in WA.
- Project 4 tested down-hole EM arrays and configurations in the Curtin University deep test-hole and in a range of outdoor simulation environments.
- Project 5 undertook various field trials of seismic equipment, including at the Curtin deep test-hole and at Otway in Victoria
- Project 7 researchers conducted extensive sampling, analysis and core logging at various localities and core yards of partner Geological Surveys.

MinEx CRC downhole LIBS tool.

RESEARCH MANAGEMENT

MinEx CRC primary aim is to research and commercialise topics of relevance to participants, which can be commercialised or utilised in the pursuit of improved exploration outcomes. Significant achievements in the 2023/2024 reporting period are as follows:

- We are on target to achieve all Phase 2 milestones by end-2024 and complete all eleven Commonwealth Milestones due June 30 2025.
- On June 30, 2024, we achieved 355 of the 367 Phase 2 quarterly project milestones due. We were behind schedule on 12 milestones and ahead of schedule on 25. The 12 milestones behind schedule are expected to be complete by the end of Phase 2. Cumulative progress against all Phase 2 core project milestones was 79.3% compared to a target of 77.6%.
- Of the four active Opportunity Fund projects during the reporting period, we achieved 29 of 31 quarterly milestones. We were behind schedule on two milestones, expected to be completed by the end of Phase 2.
- Draft Project Agreements for Phase 3 of MinEx CRC (2025-2027 inclusive) were completed for all core projects by June 30 as planned and circulated for review by Participants. Planning meetings at our Mid-year Science Review (June 4-5 in Perth) proved important for defining desired commercialisation outcomes and shaping the Phase 3 research agenda accordingly.

RESEARCH HIGHLIGHTS

Drilling optimisation and automation

- During the reporting period, we implemented a series of upgrades and developed alternate versions within our family of *iFluid* drilling fluid management systems. This includes *CTiFluid,* which has been in near continuous use with the MinEx CRC CT drilling platform during the reporting period, and two versions of *DiFluid* designed as standalone systems for integration with diamond drill rigs. One version, *'Unforgiven',* utilises a conventional hydraulic control system compatible with most drill rigs in the current market. The other version, *'Hobby'*, incorporates an electric-over-hydraulic control system compatible with younger generation rigs. Both versions will be ready for a planned trial deployment to Chile in Q1 2025 in collaboration with Participant Geotec Boyles. This deployment was initially planned for 2024 but has been postponed to 2025 at the request of Geotec Boyles.
- We are now well advanced in our program of single-impact percussion drilling experiments using the custom-designed *'Woody'* apparatus. The experimental platform performed well so far and delivered high-quality data. By isolating each individual interaction between drill bit and rock, we can isolate the effect of weight-on-bit and impact energy on rate-of-penetration in percussion drilling. We can model multiple real-world drilling scenarios by modifying the experimental setup and using different bits and rocks with a range of mechanical properties. During Phase 3, we will work closely with MinEx CRC Participant Sandvik to execute a systematic program of experiments from which we will build a library of percussion bit-rock interactions that could be used to assess drilling performance and/or model rock mechanical properties during drilling operations.

Coiled Tubing (CT) drilling

- Much of our CT drilling research during the reporting period has been devoted to our ambition to achieve accurate downhole positioning, logging and steering-while-drilling for our CT1000 drilling platform. This has involved testing multiple alternative technologies as follows:
  - In Q3 2023, we deployed the CT1000 drill rig (and a hastily assembled but effective substitute fluid handling system) for field trials at the EnviroCopper site at Kapunda, about an hour north of Adelaide. The trial involved re-entering a 290m deep hole we drilled in September 2021. We successfully tested and collected logging-while-drilling (LWD) data from the MinEx CRC SMART bottom hole assembly (BHA) during short drilling runs. The SMART BHA includes a total counts gamma sensor module developed by MinEx CRC, integrated with a modified version of a commercial survey module developed by MinEx CRC

Participant Wassara. The SMART BHA communicates to the surface via an optic fibre cable deployed within the non-rotating drill string – a significant advantage for downhole communications enabled by CT drilling.

- The Kapunda deployment also included a successful optic fibre distributed acoustic sensing (DAS) technology trial, utilising the drill string optic fibre cable as a seismic receiver during drilling. Seismic-while-drilling offers the potential to characterise the rock volume around (and between) drill holes. Deployment of DAS on the CT drill rig requires an optic fibre' slip ring' to accommodate connection to the rotating drill spool. During the trial, we deployed a newly designed slip ring and successfully collected seismic data using surface shots (static logging during drilling) and the downhole drill hammer (true logging-while-drilling) as seismic sources.
- Our primary strategy to achieve steering-while-drilling is via a collaboration with UK drilling technology company AnTech Limited. The UniSA-based CT drilling team entered into an agreement with AnTech in Q4 2023, in which AnTech will build the steering tool (miniaturising an existing commercial tool) and deliver it to Australia for integration with the CT1000 drill rig and drilling trials starting in Q4 2024. The tool's Major components are complete and being shipped to Australia due to arrive in late October 2024. In the meantime, our Project 2 team have been making preparations for integration of the AnTech tool with the CT1000, including i) installation of a cased shallow hole 'test cylinder' at UniSA for preliminary load testing of the AnTech BHA, ii) manufacture of a bespoke downhole motor compatible with the AnTech BHA, iii) vibration testing of the CT1000 motor and percussion BHA (without the AnTech module) within the test cylinder to establish likely operating parameters during the trials, and iv) installation of communications cable within 1000m of coiled tubing and spooling onto the CT1000.
- Between April and June 2024, we conducted successful hardware and operating procedures trials to 'kick-off' from an existing drill hole, creating the potential for multiple deviations from the same collar location. The trials were conducted in soft formations (at UniSA Mawson Lakes Campus) and hard formations (at Kapunda in collaboration with MinEx CRC Affiliate EnviroCopper). The procedure involves setting a casing wedge at the required depth and drilling a pilot hole using a full-face bit, and reamer developed in collaboration with Hardcore Diamond Products. To demonstrate the viability of the 'kick-off', we re-entered the drill hole with a diamond coring bottom hole assembly. We collected three meters of drill core from the new trajectory. This is a passive approach to achieving an outcome comparable to steering-while-drilling, namely that the driller can control the drilling trajectory in response to geological and geophysical data while the hole is being drilled.

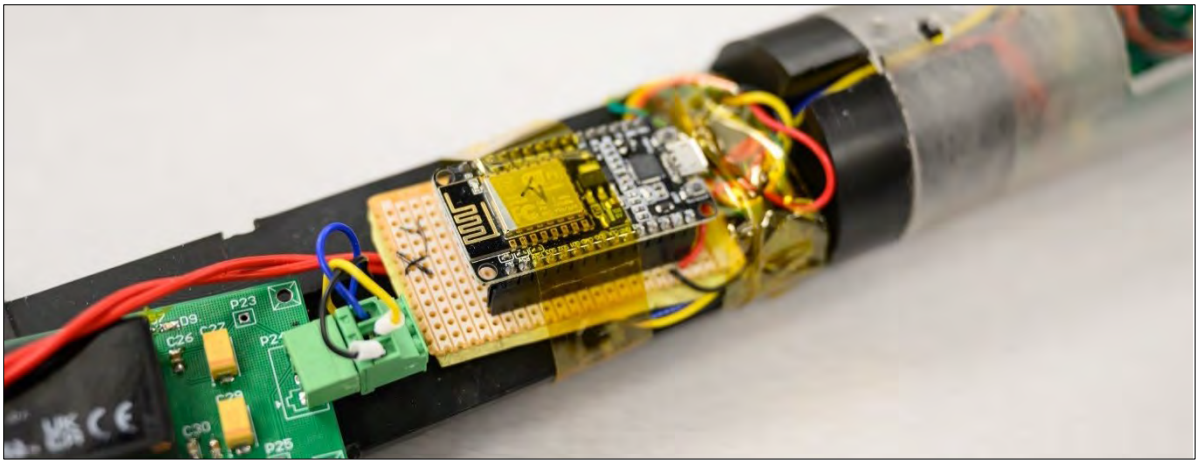
Downhole Assay

- In October 2023, we filed a provisional patent based on our prototype downhole LIBS system, which incorporates a high-powered, variable-focus laser and optics and spectrometers capable of detecting all elements on the periodic table to part per million levels.
- In June 2024, with the support of MinEx CRC Participant Imdex Limited, we conducted our first within-hole trials of the prototype downhole LIBS tool, collecting over 220 logging meters in shallow drill holes at the Australian Automation and Robotics Precinct (AARP) in Perth. Multiple logging runs were conducted in the same drill hole with varying parameters (wet vs dry walls, with and without the autofocus mechanism; with and without air jets for cleaning) and specific intervals within the drill hole were doped with elevated concentrations of target elements Cu and Li. The tool returned geologically sensible data under various operating parameters and could detect and measure Cu and Li concentrations in the doped intervals. We are using the results to refine the tool design, including redesigning the optical front end and deployment process to make it an attractive commercial proposition for a service provider such as Imdex.

- In preparation for the downhole LIBS field trial, we completed a series of experiments that provided background data for physics-informed modelling of LIBS spectra, including temperature control and the characterisation of all four spectrometers with a calibrated light source. This allowed us to produce the first physics-informed forward models of LIBS spectra for the expected mineralogy at the AARP field trial site and common Cu minerals.
- Progress was also made in understanding sampling error and the optimal number of LIBS shots for predictive modelling. The sampling rate downhole was investigated from a geostatistical perspective using a compiled test dataset of drill core geochemical data to estimate the impact of irregular grain size distributions ("nugget" effect) on data quality. Work on sampling statistics for two-way sampling and uncertainty estimations was used to inform deployment for the AARP trial.

Logging-while-drilling petrophysics

- In November 2023, we filed a provisional patent based on our prototype downhole swept frequency EM tool, which incorporates coil and control circuit design, generation of multiple 'swept' source frequencies and data processing methods to extract multiple petrophysical parameters from the signal response.
- During the reporting period, we progressed the downhole Swept Frequency EM tool from a laboratory prototype (TRL4) to a field-tested prototype (TRL6), with the successful acquisition of data from a 900m deep drill hole located at Curtin University. In parallel, we have been conducting controlled experiments in environments with high but well-constrained conductivity contrast (i.e. the shallow waters of the Swan River) designed to understand the temperature-dependent response of the tool. These data will help us create calibration procedures vital to collecting reliable, high-quality data. We have now built three prototype versions of the tool, each with subtle design variations. These will be subjected to similar field trials to determine the most appropriate tool design for various potential commercial applications.
- We have also progressed our efforts to develop a novel downhole Time Domain EM (TDEM) tool. The TDEM tool will be a downhole equivalent to conventional surface TDEM methods, with a similar waveform, that can be integrated with surface measurements for improving resolution and confidence in subsurface modelling. The TDEM tool will deliver greater depth penetration (tens of meters) than the swept frequency tool, which offers the potential to locate and model off-hole conductors. Critical to the performance of the TDEM tool is a rapid turn-off (micro-seconds) of the source waveform, which has been demonstrated in the laboratory version of the TDEM tool. We have now commenced work on a comparably fast sampling receiver system.



MinEx CRC downhole Swept Frequency EM tool.

- Results from the combined Gamma logging-while-drilling and distributed acoustic sensing (DAS) while drilling field trials at Kapunda SA (conducted in Q3 2023) confirmed the function and performance of the optic fibre slip ring (commissioned as part of our parallel opportunity fund project OP04) which allows DAS data to be streamed from the hole, via the rotating CT reel, while drilling.

Seismic in the drilling workflow

- During the 2023/2024 reporting period, we maintained our focus on optic fibre DAS seismic systems, which we consider has the best potential for flexible deployment options (including downhole deployment) and cost efficiency whilst delivering high-quality data. This work included:
  - Design and build a prototype electromagnetic three-component (3C) source ideal for borehole seismic applications. We tested a prototype version of the 3C source with an optic fibre DAS receiver deployed within the Curtin University research borehole. Results of the Curtin trial have been used to inform the design of a field-deployable 3C source.
  - Trial of a high-frequency sparker seismic source within the Curtin research borehole.
  - Comprehensive performance tests on several fibre optic interrogators, including the new generation of Treble Gen 3 (Terra15 Technologies Pty Ltd) and OptoDAS (ASN Inc.) interrogators. The tests were conducted in conditions that simulate potential DAS field deployment on various cables. The tests identified the pros and cons of the various interrogators for several scenarios, including sensitivity in the low-frequency (below 20 Hz) and high-frequency (>200 Hz) range and potential for deployment of long cables (> 10 km). The OptoDAS interrogator, designed to maximise the transmitted optical energy per pulse, demonstrated exceptional data quality at small gauge lengths (the parameter allows the record of high frequencies properly) and with very long fibre optic cables, up to 100 km in length. This is a significant improvement compared to interrogators we have used. It offers the potential to lay-out a large and complex DAS survey geometry (e.g. surface array + tens of drill holes) in a single connected array across an entire mine-site.
  - We tested two machine learning approaches for denoising DAS data (traditional supervised methodology and noise-to-noise) on seismic-while-drilling DAS data. The two methods were evaluated on numerous field datasets acquired with different seismic sources (borehole and surface), passive data for event detection, and seismic-while-drilling data for subsurface characterisation. Both neural networks are effective in attenuating the noise on field data examples. Tests demonstrated the increase of signal-to-noise of the DAS data, specifically for data acquired with low-power sources. This leads to further application of a combination of DAS with small seismic sources, bringing the cost of seismic acquisition down. It also enhanced data with high-frequency sources, which opened the application of new seismic approaches for mineral exploration.

Automated 3D modelling

- We have developed QGIS plugins for many of the 3D modelling software modules developed by MinEx CRC. QGIS is a free, open-source geographic information systems package that will allow access to our 'Loop' suite of software, including the dh2loop, map2loop, loop 3D modelling and Tomofast geophysical inversion capabilities without the need for third-party licensing.

National Drilling Initiative (NDI) campaigns

- The MinEx CRC drill crew and CT drilling infrastructure were mobilised to Nifty in August 2023 to commence the Paterson NDI campaign in collaboration with GSWA. The Nifty Campaign was challenging from the outset with the loss of our most experienced driller for family reasons, resulting in a reduction to single-shift operations and requiring training of a new driller. Nonetheless, we achieved 580m of drilling in two holes across 15 shifts during the first stint.

From that point, we were frustrated by mechanical issues with the rig, compounded by the remote location and lack of access to a qualified fitter to assess and address the problem. This resulted in very slow, stop-start drilling during the second stint. Part of the problem was identified and redressed on return for the third stint, followed by one productive shift before a critical mechanical failure (bearings and shaft on the CT spool). The rig was returned to Adelaide for repairs and maintenance, having drilled 758m across three holes, and two holes were completed.

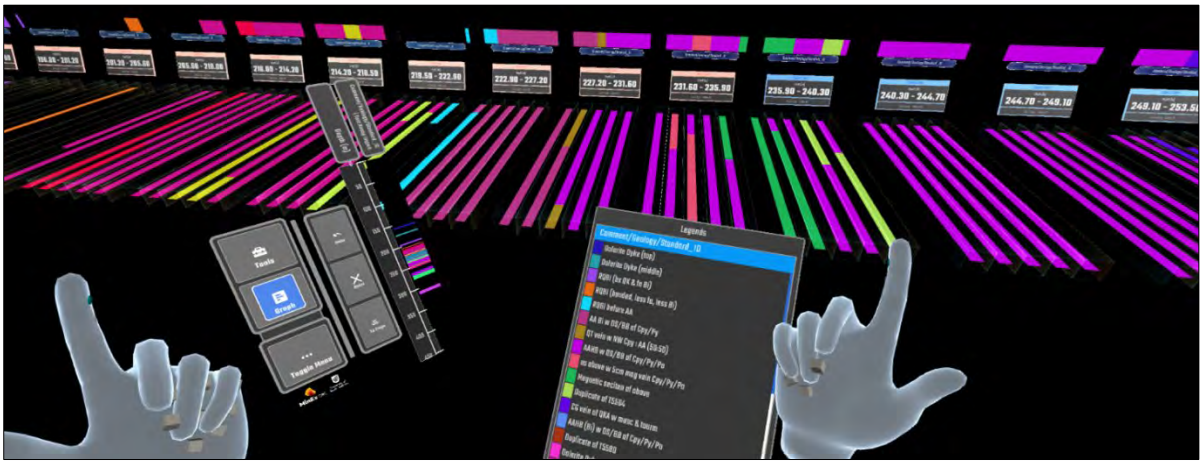
- Following repairs and maintenance in Adelaide Dig CT, the CT500 rig was deployed to the Moonera drilling campaign in collaboration with the GSWA in Q2 2024. The Moonera campaign was designed to test the performance of the CT platform in the challenging ground conditions of the Eucla Basin, which have thwarted previous exploration campaigns that utilise conventional drilling technology. The campaign design allowed three attempts to complete and take quality samples from a single ~500m drill hole into basement rocks. The Campaign can be considered a partial success. Ground conditions were extremely challenging, with significant fluid losses throughout drilling, very high water consumption and little to no recovery of cuttings samples. In the face of these challenges, Dig CT and GSWA devised and executed a plan to recover the drill core at regular depth intervals to provide reference sample material and a stratigraphic log. By applying these methods we could complete a 501m hole, utilising the full-depth capability of the CT500 platform.

NDI sampling and analysis

- A sampling workshop providing access to drill core and cuttings sampled in the Delamerian Margins NDI campaign (completed during the previous reporting period) was held at the GSNSW Londonderry core library in October 2023. Seventeen attendees were from Geoscience Australia, GSNSW, GSSA, UNSW, UniSA and the University of Adelaide. The Delamerian Margins samples have now been the subject of multiple geological and geochemical analyses, including downhole geophysical logging (natural gamma, magnetic properties, acoustic imaging, electrical resistivity and conductivity), field-based portable XRF and infrared spectroscopy, laboratory whole rock and isotope geochemical data, U-Pb zircon geochronology, Ar/Ar thermochronology. Much of the data and resulting interpretations are available via the Geoscience Australia Exploring for the Future website, and we expect publications to continue to flow from this work well into 2025.
- The Delamerian Margins NDI campaign has complemented and added to the previous Delamerian NDI campaign (in collaboration with the GSSA), leading to a reappraisal of the history, tectonic setting and mineral potential of this vast region. Samples taken during the Delamerian NDI programs reveal ~500 million years of Earth history, beginning with rifting ca. 830 Ma and break-up of the Rodinian supercontinent, forming a long-lived passive margin ca. 800 to 530 Ma. This developed into a convergent margin ca. 530 to 490 Ma that the mid-to-late Cambrian Delamerian Orogeny terminated. The orogen was later impacted by episodic shortening and extension during Ordovician, Silurian and Devonian times up until ca 350 Ma. Significant first results of the Delamerian Margins NDI campaign reveal the existence of a corridor of Siluro-Devonian igneous rocks flanked by Cambrian igneous rocks within the Loch Lilly-Kars Belt, possibly related to an episode of rifting or extension, with potential for rift-related and magmatic-hydrothermal mineral systems of that age.
- We have made significant progress on the web-hosted Wiki User Guides for mineral exploration technologies. The five user guides cover key technologies being used and developed by MinEx CRC, including mineral systems analysis, exploration geophysics, isotope geochemistry, isotope geochronology and regolith exploration. Each user guide references work completed within the NDI, including analytical outputs from NDI drilling campaigns and using everyday language developed as part of the Mineral Systems Vocabulary.
- We completed version 1 of our long-awaited Mineral Systems Vocabulary (MSV) document, an example of its application to knowledge graphs. We circulated it to Participant Geological Survey

Organisations for feedback. The MSV is intended to be a live document, subject to constant revision by end-users, with application as a guide (rather than definitive reference work) for communicating mineral systems research and exploration strategies between diverse stakeholders and for multiple mineral systems.

- We have developed automated cover interface detection workflows from drill-site geochemical (pXRF) and mineralogical (ASD and TIR) analyses – using the Delamerian Margins NDI campaign as a case study. The workflow has been embedded in a web application, *'Lithobound',* which offers a user-friendly means of importing and analysing self-generated or precompetitive drilling data.
- Our work on novel airborne electromagnetic (AEM) inversions and regolith interface identification from bore hole data has revealed a tantalising correlation between detailed AEM inversions and regolith interfaces identified by the *Lithobound* web application. The two techniques, operating independently, tend to identify interfaces at comparable depth intervals, demonstrating a link between petrophysical and geochemical/mineralogical properties in cover materials for which the measurement of petrophysical properties is notoriously difficult. This raises the potential to i) use drill hole geochemical/mineralogical data as proxies for petrophysical properties and/or ii) use inversions of regional geophysical data to map geochemical/mineralogical interfaces between widely spaced drill holes. The work highlights the benefits of integrating disparate datasets (airborne geophysics and borehole mineralogy) with the potential for unexpected results.
- We have investigated joint inversion of seismic and AEM data for improved detection and mapping of cover boundaries, including the base of cover. This work's underlying philosophy is comparable to integrating Lithobound with AEM inversion, i.e., using seismic horizons or discontinuities to help constrain and sharpen boundaries within the AEM inversion.
- The multi-disciplinary and multi-scale characterisation of the Nifty deposit and surrounds has progressed by utilising legacy data – based on sampling conducted during the Nifty workshop at the GSWA core library in Q2. This includes a compilation of rock property datasets within the Nifty NDI area. Public releases of petrophysics have been ongoing throughout the Paterson province work program. These have already been used to refine the mineral system's relevant lithological groups for Nifty and provide a foundation for predicting physical properties from chip samples.



MinEx CRC LogAR data simulation.

- We have continued to support the development of in-situ same mass radiogenic isotope measurement and techniques at both the University of Adelaide and Curtin University. We aim to increase the number of mineral phases amenable to in-situ dating techniques '(particularly mineral phases associated with ore deposits or hydrothermal alteration). We have now published methodologies and research papers on three radiogenic isotope pairs applied to multiple mineral phases as follows: Rb-Sr dating of whole rocks, feldspars, micas and clays; Lu-Hf dating of carbonates, apatite, epidote and garnet and Re-Os dating of sulphide minerals (especially molybdenite).

COMMERCILISATION PROGRESS

Commercialisation in MinEx CRC is proceeding per the MinEx CRC Business Plan. Commercialisation opportunities in MinEx CRC have resulted from historical agreements and new projects.
The historical agreements assigned by DET CRC to MinEx CRC in 2018 comprise seven agreements and a matrix of 22 parties. In FY24, $51k was earned from royalties from the DET CRC agreements. In 2024, the MinEx CRC Board endorsed a decision not to renew certain patents while vigorously pursuing two new patent applications.

During the past year, four commercial licence assignments were completed successfully,

- Hobby: A system to achieve fluid automation for drilling mud systems, supported by Curtin University and the Federal Trailblazer program.
- Auto-drill, also through Curtin University and Trailblazer, is a high-tech early-stage drilling rig automation system that facilitates a step change in drilling optimisation using data. Curtin University has committed significant funding to support Auto-drill and Hobby by funding a Drilling Analytics Research Centre (DARC).
- LogAR (CSIRO) augmented reality platform and practical tool for geological logging tasks.
- The MinEx CRC CT500 drill rig and its associated IP are being leased to a start-up company (DIG CT) undertaking CT drilling on behalf of MinEx CRC. DIG CT is endeavouring to expand the demand for, and use of, MinEx CRC CT drilling technology through safely and actively utilising the current equipment and by stimulating demand and facilitating or placing orders for the manufacture of additional CT Rigs.

Undertaking MinEx CRC research at Geoscience Australia laboratories.

1.3 Research Case Study

MinEx CRC drill hole sensor technologies move toward commercialisation

MinEx CRC and its participant organisations are investing in novel sensing technologies to be deployed in the borehole during drilling operations. Our aim is to deliver near real-time exploration data for more efficient drilling and timely decision making. In combination with downhole steering and multilateral drilling techniques currently under development in our CT drilling project, these technologies will enable explorers to modify drill targets and alter the trajectory of drilling 'on-the-fly'. This will decrease the cost of drilling (fewer holes and less meters drilled) and increase the chances of intercepting target mineralisation.
Following advice from our end-user mining companies and mining, equipment, technology and service provider (METS) companies we have focussed our downhole sensing research on electromagnetic (EM) and geochemical logging tools aimed at developing functionality not available in the current market.

Next generation driller deployable EM tools

Borehole EM sensors have been part of the mineral exploration toolkit for decades however they are only used in a small percentage of drillholes, typically deployed by wireline (requiring a separate deployment by specialist logging crew) and have functionality limited by the single, or sometimes dual, frequency settings of the source EM field. The MinEx CRC research team, based at Curtin University, has developed a unique downhole "Swept Frequency" EM sensor system which cycles through hundreds of source frequencies at each measurement location. The tool has been designed for small diameter mineral exploration drillholes and can be deployed by wireline or as part of the drilling bottom hole assembly. The latter is a critical aspect of the MinEx CRC approach as it enables the options of logging-while-tripping or logging-while-drilling – removing the requirement for a separate logging deployment and significantly reducing the risk of hole collapse between drilling and logging.

The frequency dependent response from the surrounding geological formation delivers an exceptionally rich data stream which is ripe can be used to derive multiple physical properties (conductivity, induced polarisation, magnetic susceptibility) and characterise the geophysical response meters from the drillhole.

During the 2023/2024 reporting period we have progressed the downhole Swept Frequency EM tool from a laboratory prototype (TRL4) to field-tested prototype (TRL6), with successful acquisition of data from a 900m deep drillhole located at Curtin University. In parallel we have been conducting controlled experiments in environments with high, but well-constrained, conductivity contrast (i.e. the shallow waters of the Swan River) designed to understand the temperature dependent response of the tool. These data will help us create calibration procedures vital to the collection of reliable, high-quality data. We have now built three prototype versions of the tool, each with subtle design variations, which will be subjected to similar field trials to determine the most appropriate tool design for various potential commercial applications.

In November 2023 we filed a provisional patent based on our prototype downhole swept frequency EM tool which incorporates coil and control circuit design, generation of multiple 'swept' source frequencies and data processing methods to extract multiple petrophysical parameters from the signal response.

Our plan is to progress the Swept Frequency EM tool to TRL7 during 2025, the first year of our market-focussed third phase of research and work closely with our METS Participants to plot a course toward commercialisation of the tool within the time frame of MinEx CRC.
At the same time, our petrophysical logging research team will step up their efforts to develop a novel downhole Time Domain EM (TDEM) tool. The TDEM tool will be a downhole equivalent to conventional surface TDEM methods, with similar wave form, that can be integrated with surface measurements for improving resolution and confidence in subsurface modelling. The TDEM tool will deliver greater depth penetration (tens of meters) than the swept frequency tool which offers the potential to locate and model off-hole conductors, for example massive sulphide mineralisation, to inform drilling decisions (including trajectory control or kick-off for multilateral drilling from the same drill hole).

Drillhole geochemical logging with Laser Induced Breakdown Spectroscopy (LIBS)

If achievable, in-situ geochemical logging of the drill hole has the potential to dramatically change our approach to mineral exploration in three ways. Firstly, by reducing our reliance on high-quality sample recovery (thus permitting more cost-efficient drilling techniques), secondly by generating an objective, multidimensional data stream for automated multiparameter geological logging and thirdly by bringing real-time decision making to the drill site.

Currently available drill hole geochemical logging tools include Prompt Gamma Neutron Activation Analysis (PGNAA) and X-Ray Fluorescence (XRF) sensors. PGNAA is an active-source technique which measures a volume (typically ~1m^3) around the drill hole and is suitable for major element analyses with detection limits between 100ppm and 1% for most elements of interest. Large diameter PGNAA tools are currently used to measure concentrations of percent-level elements in hydrocarbon exploration and iron-ore grade control operations where fractions of percent detection limits are tolerable, drill holes are wide enough to accommodate the large diameter tools and management of active-sources represents an acceptable risk. However, they are not optimised for agile, unpredictable mineral exploration drilling with narrow drill holes and a requirement for detection limits of <10ppm for many commodity and pathfinder elements. Such detection limits are possible for many relevant elements with drill hole XRF technology however they rapidly increase for elements with atomic mass below 30 (including Si, Al and Mg) and analyses are not possible for elements with atomic mass below 22 (including Na, F and Li). Additional challenges for drill hole XRF include:

- Drilling muds and/or fine-grained drill cuttings which coat the drill hole wall will contaminate or completely obscure the in-situ analysis due to the non-destructive and shallow penetrating nature of the X-ray source.

MinEx CRC researchers on site during downhole LIBS field trials.

- Water both attenuates and interferes with the in-situ x-ray response reducing analytical quality.
- Each analysis, giving an average response over an ~1cm^2 area, takes minutes to complete. A time-efficient logging strategy (< minutes per meter) can only be achieved with a series of spot-analyses (≤ one per meter) which are not representative of the bulk-rock composition nor heterogeneity within the sample interval.

LIBS has inherent advantages over alternate downhole geochemical techniques in that:

- It can measure the entire periodic table at detection limits relevant to mineral exploration (< 10ppm)
- Multiple pulses of the high-energy laser source can be used to dry or clean the drill hole wall prior to analysis.
- Each analysis is very rapid so that a time-efficient logging strategy can deliver hundreds of analyses per meter. These can be integrated to provide a bulk-rock composition at user-defined intervals or used as input into geochemical and spatial analytics software. The data are particularly conducive for clustering and domaining techniques used for automated drill hole logging.
- Each analysis covers a small area (tens of microns in diameter) with the ability to resolve single mineral grains (and simple mixtures of mineral grains). This enables data processing techniques which can be used to determine quantitative mineralogy, mineral chemistry and proxies for mineral texture (e.g. grain size distribution).

If we can solve the various challenges in design, deployment and data processing of a downhole LIBS system we will be able to deliver an extremely rich dataset for rapid, objective, quantitative geological logging of drill holes.

Since commencement of MinEx CRC our LIBS research team based at CSIRO and UniSA have progressed our downhole LIBS tool from a concept (TRL1) to a field-deployable prototype (TRL5). In consultation with end-user and service provider Participants we have chosen to defer research on our original stretch target – downhole LIBS analyses in flooded drillholes – so that we can focus on delivering a market-ready tool for air-filled drillholes within the timeframe of MinEx CRC . This has involved design and build of multiple versions of the tool coupled with laboratory testing focussing on key technical challenges including: 1) Optics and spectrometer design to fit within the constrained space of a borehole. 2) Ruggedised housing to survive drill hole conditions. 3) Requirement to collect analyses while the tool is in motion, at a velocity which is practical for drill hole logging. 4) Likelihood that the drill hole wall will be uneven at millimetre to centimetre scale. 5) Likelihood that the drill hole wall will be wet (with water and drilling fluid) and dirty (with drill cuttings and dried drilling fluid).

In parallel with tool design and testing we are developing novel calibration and data processing algorithms designed to achieve high-quality, repeatable data with detection limits in the part per million range for multiple elements from the same LIBS spectra. In turn, from those data we are working on algorithms to generate user-defined derived data including data clustering, automated boundary detection, integrated 'bulk-rock' analyses, quantitative mineralogy, mineral chemistry and proxies for texture.

In October 2023 we filed a provisional patent based on our prototype downhole LIBS system which incorporates a high-powered, variable-focus laser and optics, and spectrometers capable of detecting all elements on the periodic table to part per million levels.

The tool has a ruggedised chassis with a diameter of 75mm, which fits within most mineral exploration drill holes (all drillholes larger or equal to NQ diameter). In-hole stabilisers protect the tool from being damaged by the drill hole wall and position the laser at an optimum distance from the wall during analysis. The prototype tool is deployed by wireline (although future versions are intended to be driller deployable) with a winch system controlled by bespoke software that allows user-controlled logging velocity and sampling rates. The system also includes an in-field calibration module and additional sensors for monitoring instrument performance.

In June 2024, with the support of MinEx CRC Participant Imdex Limited, we conducted our first within-hole trials of the prototype tool collecting over 220 logging meters in shallow drill holes at the Australian Automation and Robotics Precinct (AARP) in Perth. Multiple logging runs were conducted in the same drill hole with varying parameters (wet vs dry walls; with and without the autofocus mechanism; with and without air jets for cleaning) and specific intervals within the drill hole were doped with elevated concentrations of target elements Cu and Li. The tool returned geologically sensible data under a range of operating parameters and was able to detect and measure Cu and Li concentrations in the doped intervals. Our we are using the results to refine the tool design, including a redesign of the optical front end, and deployment process so that it is a more attractive commercial proposition for a service provider such as Imdex.

Our plan is to progress the downhole LIBS tool to TRL7 during MinEx CRC Phase 3. Working in parallel with potential commercialisers to ensure that the final product is both technically sound (robust and delivering high quality data) and commercially viable (delivering useful data within an affordable and profitable business model).

Towards logging-while-drilling and real-time trajectory control

The MinEx CRC downhole EM tools and downhole LIBS geochemical tool are enabling technologies which can contribute to an overarching stretch target of MinEx CRC which spans multiple research projects and exemplifies the portfolio nature of MinEx CRC research:
To deliver logging-while-drilling and real-time trajectory control within a safe, environmentally friendly and cost-effective CT drilling platform.

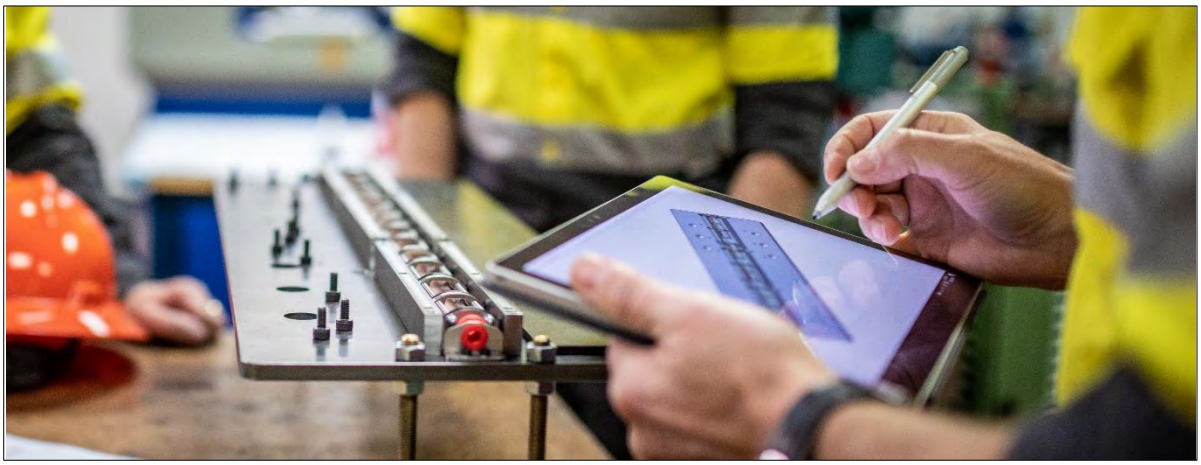
There remain technical hurdles to overcome if we are to achieve this vision. Any tool intended to operate during active drilling will have to withstand the extreme conditions encountered in deep flooded drillholes – high pressures, abrasion (both from drilling fluids and cuttings and from physical contact with the drill hole wall) and severe vibrations caused by the drilling process. These challenges will be easier to overcome for the EM tools (which have relatively high tolerance for physical stress and are designed to operate underwater) than for the downhole LIBS tool (which is currently designed for use above the water table and relies on finely tuned mirrors and lasers that are prone to disruption by physical stress). To mitigate the risks involved in attaining our stretch target, each of our down hole tools have been designed to offer commercialisation potential as standalone products, with the option of being deployed by wireline or as logging-while-tripping tools. Logging-while-tripping is attractive option in many drilling scenarios, allowing the driller to collect end-of-shift or end-of-hole data for within-program decision making without requiring a separate wireline deployment.

Equally important to our vision of real-time trajectory control is the ability to accurately locate and steer the drill bit while drilling. This is the subject of ongoing research for our CT drilling engineers who are working in collaboration with UK-based drilling technology provider AnTech Limited. Our strategy is to miniaturise a bottom hole steering assembly, the larger version of which is proven

technology in the oil and gas sector. The bulk of our bottom hole steering research was planned to occur during Phase 3 however additional resources were provided by MinEx CRC Participants to bring the build of a field prototype forward into 2024. This will culminate in a series of field trials planned for late 2024 and early 2025 which, if successful, will allow us time to plot a pathway toward commercialisation within the timeframe of MinEx CRC.

If steering while drilling proves not to be viable we will revert to our fall-back strategy (agreed by MinEx CRC CT Project Participants in late-2022) to deliver multiparameter drillhole logging (ie downhole EM and LIBS) combined with accurate location of the drill bit and the ability to drill multiple deviations from the same drill hole. Between April and June 2024 our UniSA-based drilling engineers conducted successful trials of hardware and operating procedures to 'kick-off' from an existing drill hole, creating the potential for multiple deviations from the same collar location. The trials were conducted in both soft formations (at UniSA Mawson Lakes Campus) and hard formations (at Kapunda in collaboration with MinEx CRC Affiliate EnviroCopper). The procedure involves setting a casing wedge at the required depth and drilling a pilot hole using a full-face bit and reamer developed in collaboration with Hardcore Diamond Products. To demonstrate viability of the 'kick-off' we re-entered the drill hole with a diamond coring bottom hole assembly and collected three metres of drill core from the new trajectory.

This is a passive approach to achieving an outcome comparable to steering while drilling, namely that the driller can control the drilling trajectory in response to geological and geophysical data while the hole is being drilled. The component technologies to enable this vision have now been designed and built by MinEx CRC and are at various stages of field testing. Each has standalone commercialisation potential and in combination they have the potential to deliver a profound improvement in drilling functionality, cost and success – measured by meters drilled per discovery.



Program 1 experiments at the UniSA Mawson Lakes Campus.

1.4 Risks & Impediments

Risk management is an important governance task and management function. The MinEx CRC Board Audit and Risk Committee provides oversight on risks that may impact MinEx CRC 's ability to achieve our vision and goals.

Risks are summarised and addressed in the attached table, with the following notes:

- The change to a model of sub-contracting out-of-field work involving the CT Rig, commencing in February 2024, has significantly decreased risk exposure to MinEx.
- OHSE remains the top risk for MinEx, primarily because the consequence of an incident may be extreme (fatality-level), with a rare chance of occurrence still resulting in a mitigated risk of 'High'.
- The focus of MinEx CRC is changing from primarily research to commercialisation of research; hence, the risk landscape is evolving, reflecting this.

Note that impediments to MinEx CRC are viewed as risks and are included in MinEx CRC risk mitigation.

The three highest risks faced are as follows. The strategies adopted to address the risks are listed as controls that are in place and mitigating factors that exist.

Risk Issue	Controls in Place	Mitigating Factors
OHSE Performance Failure to develop policies and achieve satisfactory OHSE performance and comply with Client specific and/or legal obligations	* OHSE Policy in place * OHSE reporting regime in place * Detailed OHSE Risk Assessments * Specific mitigation steps in place, eg journey management, whistleblower policy, sexual harassment awareness	* Reduced MinEx CRC drilling Campaigns * Most CRC activities are relatively low risk * Risk assessment completed for each Campaign and implemented on site. * CT Drilling subcontracted to Dig CT
Staff Retention and Diversity Failure to achieve satisfactory Staff retention and diversity of HO Management	* Active diversity and inclusion strategy * Market based employment conditions * Monitoring of staff turnover and diversity	* MinEx CRC track record and reputation established * Depth of experience of pool of candidates increasing * Management focus in these areas
Research Portfolio Failure to: a) Meet industry requirements b) Maximise outcomes from Opportunity Fund c) Address industry research requirements in Phase 3	* Project agreements with Milestones & budgets * Ongoing Project reporting & tracking * Project Review Panels include Participants	* Diversification of research portfolio across sectors, we and participants * Track record of efficient Opportunity Fund leverage * Phase 3 negotiations in final stages

The following significant risks are also recognised:

Risk Issue	Controls in Place	Mitigating Factors
Crisis Management * Business Continuity and crisis management * Failure to develop and implement suitable strategies	* Risk Register process and Management controls * Approved Crisis plan * Detailed plans and procedures in place including communication	* Experienced Board and Management Team * Crisis Management Plan
Failure to Execute Drilling Projects a) Reliability of required drilling equipment, spare parts and support by sub-contractors b) Community and Land access issues c) Integration of the Drilling Campaign with the Research Projects	* CT Drill equipment outsourced to specialised drilling company * Proactive approach adopted for ground access * Expert drilling advice being utilised * Structure and process in place to maximise integration * Detailed Plan in place	* Experienced personnel and learnings between states, including Drilling Manager * Process has commenced in a timely manner and regularly monitored * Alternative drilling techniques available * Closely managed relationship between research, subcontractor and execution teams * Track record of successful completion of campaigns
Cash Management and Fraud a) Loss of funds or income due to fraud b) Loss of funds or income due to poor debtor management c) Loss of funds or income due to poor investment returns	* Best practice fraud prevention in place * Low-risk investment policy * Rigorous debtor management and small number of Debtors & Invoices	* Spread of funds across accounts & low risk Banks * Conservative investment policy
Commercialisation Outcome Failure to achieve commercialisation outcomes of the CT System	* Clear commercialisation mandate in place for CT500 Rig and HPS including non-exclusive contracts * Commercialisation committee consideration and support	* Understanding by key personnel of Commercialisation pathways * Commercial METS partners * Successful field trials * Dedicated personnel * Commercialisation agreement with specialised drilling company * Contract in place for 8 months to date
Unsatisfactory Performance at a Management Level by: a) Executive & E&T Committee b) Science Advisory Committee c) Research Project Leaders and Committees	* Regular review of Management performance by the Board * Ongoing reporting, feedback and monitoring processes by CEO * Well-defined business plans and objectives	* Experienced management team and Board with over 6 years of stable team and satisfactory outcomes

1.5 Education and Training

The MinEx CRC primary education goals are to support vocational training in drilling and mineral exploration and to achieve an ambitious target of 50 postgraduate completions. The CRC is making substantial progress toward both objectives.

Vocational Education and Training

The vocational education and training (VET) component of the MinEx CRC E&T program has focused on two main areas. The first has been the ongoing training of drillers and drill crews to support the NDI drilling campaigns. This training has been conducted progressively and in-house using formal driller training schedules. The second focus has been on developing a virtual-reality (VR)-based feasibility demonstrator to validate the VR approach for training specific competencies for drill rig operators and drill crews. The initial phase of this project created a highly realistic, navigable VR virtual drill site featuring the RoXplorer® CT drill rig and the associated HPS system. Augmented reality and 3D-printed versions were developed concurrently with the VR platform.

In the second phase of the VR project functionalities were enhanced to include multiple users in the same scene, represented by customisable avatars. The digital twin can be used with or without VR headsets and operates over the internet on multiple computers, effectively creating an immersive virtual meeting room (e.g., for example, individuals can be trained in Perth from a room in Adelaide). The platform includes basic rig articulations and animations, representations of the sampling process, and visualisations of the fluid path between the CT rig and HPS truck using colored animations, labels, graphics, and videos to aid in understanding. It also features safety warnings and visualisations to highlight site hazards. This development was supported by two workshops held in September and October 2023, attended by Program 1 engineers, sampling experts, E&T committee representatives, and drillers experienced with the RoXplorer® rig. A field trip in September 2023 allowed the digital twin team to observe the RoXplorer® in operation at Kapunda. The digital twin was showcased at the 2023 Annual Conference and the 2023 GSWA Open Day.

Postgraduate experiments undertaken at the University of Adelaide.

Higher Degree by Research (HDR) Program

MinEx CRC tracks the progress of student enrolments, progression and completions against its target of 50 postgraduate student completions through a student pipeline developed under the Postgraduate Education Business Plan. As of June 30 2024, MinEx CRC had achieved 15 completions including four Masters by Research and 11 PhD students. At 30 June 2024 there were four Masters by Research and 31 PhD students registered and actively participating in the MinEx CRC postgraduate program. All but four of these student projects have received a MinEx CRC bursary, with the remaining projects being supported by surplus funds from other student bursaries. Two Honours and 10 Masters by coursework students completed their studies on MinEx CRC -related research projects during the reporting period.

The final round of new postgraduate projects was developed during the reporting period. These projects were advertised online through various channels, including the MinEx CRC website, SEEK job listings, university websites, social media and professional societies. The online promotion generated significant interest, helping to secure the last round of enrolments sought through this reporting period.

A detailed register of all active students and project information as of June 30 2024 is provided in Appendix C.

MinEx CRC support for HDR students

The MinEx CRC E&T Committee maintains oversight of the HDR program, including development of new projects, monitoring student progress and providing support to the HDR cohort. High-risk students are a specific agenda item at quarterly E&T Committee meetings. Supervisors and the students monitor student progress towards completion, and factors including difficulty with experimentation, analysis and impacts of Covid-19 are considered. Students listed as high-risk are contacted regularly to offer support as appropriate and are further supported by their supervisors and the student cohort through monthly online video conference sessions.
Recognising the challenging environment for student retention due to strong industry demand for mineral exploration and mining graduates, the MinEx CRC E&T Committee has implemented the following strategies to attract, support, retain and ensure timely completion of postgraduate students:

- **A $20,000 per annum bursary for each HDR student** (three years x $20,000 = $60,000 for PhD students, two years x $20,000 = $40,000 for Masters by research students). This funding is provided irrespective of whether the student holds other scholarships or stipends. The funding is intended to support the student and their Project depending on the individual needs of each student as determined by the supervisory panel. Common uses of the bursary include scholarship support, scholarship top-up, project operational expenditure (travel and analyses) and conference support.
- **A completion bonus** of $3,000 for PhD students and $2,000 for Masters by Research students.
- **Financial support for Honours and Masters by coursework students** undertaking MinEx CRC-related research activities and who may go on to undertake a MinEx CRC postgraduate research project. This strategy raises the profile of MinEx CRC with undergraduate students and allows advertising of projects across multiple universities. The initiative has attracted three high-quality students to the MinEx CRC postgraduate program. Two Honours and ten Masters by coursework students completed their projects during the reporting period and there are ten Masters by coursework students currently enrolled. Research topics are summarised in Appendix C.

- **MinEx postgraduate students are invited and encouraged to be part of CRC's Equity, Diversity and Inclusion Committee**. Four postgraduate students sat on the committee during the reporting period.
- **HDR candidates are deeply connected to government, mining industry and METS Partners.** All MinEx CRC postgraduate students are required to have a MinEx CRC Participant or Affiliate industry co-supervisor. This process requires sign-off from a MinEx CRC Participant or Affiliate industry representative with whom the project aims and objectives have been co-developed with academic supervisors. Industry/end-user co-supervisors include staff from AIC Mines, Anglo American, BHP, CSIRO, Department of Energy and Mining/GSSA, Encounter Resources, GSNSW, GSV, GSWA, Geoscience Australia, Inca Resources, Lodestone Mines, McKay Drilling, Middle Island Resources, Northern Territory Geological Survey, South32 and Strategic Energy Resources.

Three students undertook 'Company Sponsored Projects' during the reporting period. The students have continued their research that is directly affiliated with MinEx CRC industry partners and that is complimentary to the broader MinEx CRC research agenda. These projects are concentrated on case study areas of the industry partner. Partners involved include AIC Mines, Lodestone Mines, and Strategic Energy Resources.

Students interact with end-users through various channels. They maintain regular engagement with industry co-supervisors via ongoing project meetings. Where appropriate, students also participate in and present at quarterly Project Review Panel meetings and workshops organised for MinEx CRC Participants and Affiliates. For instance, PhD students from Project 3 attended and presented at all Project Review Panel meetings throughout the reporting period.

Students are encouraged to pursue internship opportunities with MinEx CRC Participants and Affiliates. During this reporting period, two students were supported by end-users CSIRO, GSWA and GSSA in internship programs that added significant value to their postgraduate experience and skillset.

MinEx CRC 's student pipeline

Institution	2019					2020					2021					2022					2023				
	Y1 students	Y2 students	Y3 students	Y3.5 students	COMPLETIONS	Y1 students	Y2 students	Y3 students	Y3.5 students	COMPLETIONS	Y1 students	Y2 students	Y3 students	Y3.5 students	COMPLETIONS	Y1 students	Y2 students	Y3 students	Y3.5 students	COMPLETIONS	Y1 students	Y2 students	Y3 students	Y3.5 students	COMPLETIONS
Australian National University	1						1						1						1						1
Curtin University	4					3	4				3	3	4			4	3	3	4		4	4	3	3	4
University of Adelaide	5						5				0		5			1			5		2	1			5
University of Newcastle						3					1	3					1	3					1	3	
University of New South Wales						1						1						1			1			1	
University of South Australia	2					3	2				3	3	2			3	3	3	2		3	3	3	3	2
Unversity of Western Australia	1					1	1				1	1	1			1	1	1	1		1	1	1	1	1
CRC TOTAL	**13**	**0**	**0**	**0**	**0**	**11**	**13**	**0**	**0**	**0**	**8**	**11**	**13**	**0**	**0**	**9**	**8**	**11**	**13**	**0**	**11**	**9**	**8**	**11**	**13**

Institution	2024					2025					2026					2027					2028 (to 30 June)				
	Y1 students	Y2 students	Y3 students	Y3.5 students	COMPLETIONS	Y1 students	Y2 students	Y3 students	Y3.5 students	COMPLETIONS	Y1 students	Y2 students	Y3 students	Y3.5 students	COMPLETIONS	Y1 students	Y2 students	Y3 students	Y3.5 students	COMPLETIONS	Y1 students	Y2 students	Y3 students	Y3.5 students	COMPLETIONS
Australian National University																									
Curtin University	3	4	4	3	3		3	4	4	3			3	4	4				3	4					3
University of Adelaide	1	2	1	0	0		1	2	1				1	2	1				1	2					1
University of Newcastle	1			1	3		1			1			1						1						1
University of New South Wales		1			1			1						1						1					
University of South Australia	4	3	3	3	3		4	3	3	3			4	3	3				4	3					4
Unversity of Western Australia		1	1	1	1			1	1	1				1	1					1					
CRC TOTAL	**9**	**11**	**9**	**8**	**24**	**0**	**9**	**11**	**9**	**32**	**0**	**0**	**9**	**11**	**41**	**0**	**0**	**0**	**9**	**52**	**0**	**0**	**0**	**0**	**61**

- Years refer to calendar years, except for 2028 which is to 30 June (end of MinEx CRC)
- Pipeline assumes 60 PhD student starts, each of which take 3.5 years to complete. The pipeline does not account for any Masters by Research starts, who will be expected to complete within 2 years.
- Numbers in each cell are respectively the numbers of first, second, third, fourth (to 3.5 years since commencement) and completed postgraduate students
- Colours indicate the progress of a year cohort.
- Non-completions are not accounted for within the pipeline. MinEx CRC aims to complete 50 students from 60 starts (83% completion rate).
- The pipeline allows for student commencments at each university as per the allocation based on the Particpant universities overall involvement.

- **HDR candidates are strongly connected to core MinEx CRC research programs.** The approval process for MinEx CRC postgraduate student projects requires sign-off by a MinEx CRC Project Leader, Program Leader, Industry Co-supervisor(s), E&T Committee Coordinator and the CSO. All projects are tightly integrated with MinEx CRC's research agenda.

  Student research is regularly featured in all forms of MinEx CRC reporting and is particularly significant in MinEx CRC meeting its milestones in the following areas:
  - Project 1: Curtin university students are undertaking research on drilling fluid control and automation, cuttings transport, rock-bit interactions, impregnated diamond bits and down-hole percussive drilling. (Eu Lim Kean, Hing Hao Chan, Joao Victor Borges dos Santos, Maryam Abdollahi, Rui Huang, Snehal Jayakumar, Su Kwong Lee)
  - Project 3: University of South Australia students investigating machine learning algorithms to generate synthetic data to train predictive models for automated interpretation of LIBS Spectra. (Ivan Gutierrez Agramont)
  - Project 4: Curtin University student research in using geophysics for drilling trajectory control. (Aruni Rajanayake)
  - Project 5: Students at Curtin University and University of South Australia conducting a range of projects including using artificial intelligence for seismic data processing, inversion and interpretation; development of borehole seismic imaging techniques; and linking geophysics and geology through borehole data. (Emad Al-Hemyari, Mosayeb Khademi Zahedi, Mikhail Vorobev, Nikita Beloborodov)
  - Project 6: University of Western Australia students developing methods for easier geological interpretation and building of automated multi-scale 3D geological models and associated uncertainty predictions from geophysical data. (Lizzie Bruce, Mahtab Rashidifard, Nuwan Suriyaarachchi, Ranee Joshi)
  - Program 3: Students at multiple MinEx CRC affiliated universities undertaking various projects on signatures of alteration, basin analysis, thermochronology, geochronology, petrophysics, geophysics, critical element mobility, biogeochemistry and microbial diversity and genetics in basement and cover sequence materials for understanding metal fertility and prospectivity in buried terranes as well as understanding social acceptance of mineral exploration. (Alejandra Bedoya Meija, Alex van Leeuwen, Andreas Bjork, Andres Sifuentes, Bianca Palombi, David Yanyi-Ankfur, Elnaz Khazaie, Himanshu Sekhar Bal, Jie Yu, Joe Shifano, Justine Flahaut, Lucy Mathieson, Luke Tylkowski, Naina, Oliver Pring, Rory Carter, Stacey Curtis, Yoli Wu, Zara Woolston, Zhufu Shao)
  - Company sponsored projects: Students at each of Universities of Adelaide and South Australia are undertaking geoscience-related projects that are not affiliated with one of the seven core MinEx CRC projects but are concentrated on a company exploration tenement with research being complimentary to the broader MinEx CRC research agenda. (Hamid Bizhanikalatehahmad, Ruiqi Zheng, Travis Batch)

- **There are dedicated HDR sessions at MinEx CRC conferences and events** and HDR students are provided financial support to travel and participate in these events.

  The 2023 Annual Conference was attended by 24 of the 36 students actively enrolled at that time attending. The students took part in a communications workshop led by Gavin Buckley (Human Orchard Consulting) and Rob Lines (Curator, TEDx Kings Park). The workshop also included MinEx CRC we and industry representatives, providing valuable networking opportunities through the interactive workshop sessions. Eight students were selected to give the presentation had developed during the workshop as the last session of the main conference. A $1,500 prize for research or professional development was awarded to PhD student, Hing Hao Chan for the best presentation. Thirty-four students showcased their work by

presenting 'graphical-abstract'-style posters at the conference. Students also engaged with industry and government representatives during the conference social events.

The 2023 Mid-year Postgraduate Day was held online in July, centered around the theme of 'Celebrating Milestones'. The event honored students at various stages of their research projects, from those just starting to those who had recently completed their confirmation of confirmation of candidature or major review, submitted a paper, were approaching completion, or had finished their degree. Throughout the day, 22 students presented in three sessions. Additionally, a PhD student from the University of London, external to MinEx CRC, shared her research findings on the process of mineral exploration in Australia, using MinEx CRC as a case study.

Students were also invited to the 2024 MinEx CRC Open Day and Mid-year Science Review, held in Perth in June 2024. Although attendance was not mandatory, 10 MinEx CRC postgraduate students participated. These students also attended the networking dinner held in conjunction with the event, which provided a valuable opportunity for them to connect with peers, MinEx CRC we, and industry and government representatives.

Nine videoconference sessions were conducted during the reporting period to engage students and provide support within the CRC environment. Sessions were dedicated to discussion on student involvement with MinEx CRC events, preparation for the 2023 Annual Conference and the 2024 Mid-Year Postgraduate Day (held in July 2024 after this reporting period). In response to student requests, the 2023 sessions featured speakers addressing the theme of 'Strategic Career Planning' and included presentations from three members of the MinEx CRC Board of Directors. The 2024 sessions shifted focus to personal development, covering topics such as communication, stress management, and insights from two recent MinEx CRC graduates on their postgraduate journeys. Three industry representatives provided brief overviews of their organisation's involvement in MinEx CRC during these sessions.

Postgraduate students undertaking experiments at the Australian National University.

Graduate destinations

There were six postgraduate completions during this reporting period. Four of these students are now employed with MinEx CRC Participants or Research Participants and one of the graduates has returned to MinEx CRC to pursue a PhD project. The completing students are now employed as follows:

- Alexander De Vries Van Leeuwen (PhD): MinEx CRC Embedded Researcher, University of Adelaide/GSSA.
- Mahtab Rashidifard (PhD): Geophysicist, Rio Tinto.
- Jie Yu (PhD): Postdoctoral Researcher, Curtin University.
- Lizzie Bruce (Masters): MinEx CRC PhD student, University of Western Australia.
- Naina (PhD): Research Scientist, CSIRO.
- Joao Victor Borges dos Santos (PhD): Rotating Equipment Engineer, ERM Consulting.

Postgraduate students undertaking experiments at the Australian National University.

1.6 Intellectual Property Management

The following principles are applied in MinEx CRC under the guidance of a board sub-committee:

- IP resulting from MinEx CRC research is legally owned by MinEx CRC and beneficially owned according to project shares defined in individual Project Agreements for the five primary projects of MinEx.
- For the single project (Project 6), where open-source software is being developed, the IP is legally and beneficially owned by MinEx CRC.
- Opportunity Fund projects recommended to the Board by the Science Advisory Committee (SAC) have IP legally and beneficially owned by MinEx CRC.
- IP rights can be sought by MinEx CRC participants by expressing an interest and using a MinEx CRC proforma. Opportunities are highlighted at Project Review meetings and SAC meetings.
- IP is to be diffused into the METS supplier sector as rapidly as possible, as enhanced technology and/or services are available to mining companies, with the companies that sponsor MinEx CRC having preferential terms of access.

MinEx CRC currently holds:

- Ninety-six properties across nine patent families. Of these, 12 are Australian.
- Eleven properties across three design families and three trademark registrations. Of these, six are Australian.
- A total of 26 Licences/Options/Assignments (LOAs) are active.
- Two Australian provisional patents are in preparation.

During the past year, four licence assignments were executed, as follows:

- Hobby: A modular system composed of different fluid automation components (hardware, software, and its Universal Drilling Fluid) that, by whole or through its components, can achieve fluid automation for drilling mud systems. The funding will fast-track development, de-risk technology and commercialise the high-tech modular components to facilitate a step change in drilling optimisation using data-driven automation.
- Through Curtin University, Auto-drill fast-tracks development, de-risk technology, and commercialisation of a high-tech early-stage drilling rig automation system to facilitate a step change in drilling optimisation using data. Curtin University has committed significant funding to support Auto-drill and Hobby by funding a Drilling Analytics Research Centre (DARC).
- LogAR (CSIRO) is an augmented reality platform and practical tool for core, chip, and sample logging tasks.
- The MinEx CRC CT500 drill rig and its associated IP are being leased to a start-up company (DIG CT) that will undertake CT drilling, utilising the equipment, methodologies and personnel currently under the management of MinEx CRC . DIG CT is endeavouring to expand the demand for and use of MinEx CRC CT drilling technology by safely and actively utilising the current equipment, stimulating demand, and facilitating or placing orders to manufacture additional CT rigs.

A list of Registered IP (patents, trademarks, designs) held by MinEx CRC is included in the MDQ and as Appendix D. Note that most Intellectual Property patents and families listed above originated in the DET CRC and were deeded to MinEx CRC on the termination of DET CRC in 2018.

1.7 CRC Future Plans and Transition Arrangements

The MinEx CRC Board held a strategy session in May 2023 to discuss future plans and transition arrangements. The MinEx CRC Strategy and underlying business plan for 2023/2024 reflect the 2023 strategy session. The business plan identified and commenced with the following tasks in preparation for wind-up in June 2028:

- The seven major project plans for Phase 3 have been drafted and are currently out for signature with Project participants. Each project emphasises commercialisation and bringing products to market.
- The projected achievement of all Commonwealth Milestones is being closely monitored and mapped, with Phase 3 projects structured to enable the achievement of the Commonwealth Milestones.
- The projected life-of-centre budget position has been updated, and the range of financial outcomes projected for 2028 is narrowing. Outcomes include consideration of both staffing and budget requirements for wind-up.
- Consideration of commercial achievements to date, as outlined separately in this report, and an evaluation of the prospect of further commercial achievements are being carefully considered. The commercial outcomes achieved to date and the predicted outcomes materially affect the planning and projected budget outcomes for 2028 and future plans.
- A program has commenced to simplify the numerous royalty agreements ceded from DET CRC to MinEx CRC in 2018. The aim is to terminate or consolidate agreements to reduce the complexity of legal and IP costs.

The 2025 Q1 Board Strategy session will consider the above factors, which will result in the first draft of the MinEx CRC closure and transition plan.

To aid in achieving the commercialisation goals of MinEx CRC, which are vital to closure planning, a change in board members was also undertaken in 2024. As outlined in this report, a new director with recent and deep commercialisation experience has been recruited to the Board.

1.8 Financial Management

MinEx CRC commenced operations on April 12, 2018. The financial tables provided below compare the current FY24, with all previous years back to FY19 (includes the period from April to June 2018).

REF	TITLE
Table 1	Revenue and Expenditure by Financial Year to date Including Cumulative Total
Table 2	Statement of Financial Position by Financial Year to date
Table 3	Cash Report by Financial Year to date Including Cumulative Total

The following key points provide an overview of the financial performance of the CRC during FY24.

Cash Balance and Surplus
The CRC had a deficit for FY24 of $1.1M, with the CRC Life to date restricted surplus reducing to $9.2M. With some Participant funds being received in advance in FY19 and FY20, the CRC generated a significant surplus, which will gradually reduce to nil over the 10 year life of the CRC.

The cash balance at June 30 24 was $9.1M compared to June 30 23 of $10.7M and June 30 22 $13.1M. All of these funds are committed to future research programs, drilling campaigns, E&T activities and management of operational activities.

The NDI drilling campaigns which commenced in September 2020, and CT Drilling field trials which commenced in May 2021 have reduced the cash balance by approximately $8.6M in FY21, $4.6M in FY22 and $6.4M in FY23. During FY24 the NDI drilling campaigns have reduced the cash balance by a further $3.9M.

Participant Contributions
Revenue from participant & affiliate contributions was $3.8M for FY24 ($6.6M in FY23 and $5.8M in FY22). This exceeded the Commonwealth Agreement Budget in FY24 by approximately $0.9M, primarily due to additional contributions received/receivable for the year compared to the Agreement.

Research Projects
Phase 1 of the research projects came to completion in December 2021. Phase 2 projects commenced January 2022 and are due to finish at December 31 2024 when Phase 3 will commence. Payment to research institutions is made quarterly in arrears based on actual expenditure. Project expenses were $6.4M for FY24 ($5.8M in FY23 and $5.8M in FY22).

Interest Income
Cash balances are being invested in a mixture of short- and medium-term cash deposits appropriate for cash flow requirements. No interest income was included in the original CAB. Total interest income earned to date is $1.4M. Interest rates dropped during and subsequent to COVID but have risen substantially over FY23 and FY24 and are currently stable.

CRC Contributions
Cash payments from the Commonwealth were $5.5M (GST exclusive) in the period ($5.5M for FY23 and $5.5M for FY22). Payments from the Commonwealth are paid quarterly in arrears, following completion of the quarterly CRC Report.

National Drilling Initiative (NDI) Campaigns

Drilling commenced at Nifty Copper Mine on behalf of GSWA on ground held by Cyprium Metals in late July 23 for the Paterson Campaign. This drilling was halted temporarily in October 23 due to equipment maintenance requirements with the subsequent GSWA Moonera campaign undertaken on the Nullarbor in February 24 and completed in June 24. The final drilling for the GSWA Paterson Campaign at Nifty was then recommenced.

Financial Tables

Table 1 - Revenue & Expenditure ($'000)	FY24	FY23	FY22	FY21	FY20	FY19	Cumulative Total
Revenue							
Commonwealth Funding	5,500.0	5,500.0	5,500.0	5,798.5	6,597.0	2,729.5	31,625.0
Other Government Grants	425.0	28.0	-	-	-	-	453.0
Participant Contributions	3,540.0	6,421.1	5,600.0	7,023.0	4,811.8	12,067.5	39,463.4
Affiliates Contributions	295.0	215.0	210.0	185.1	285.0	150.0	1,340.1
DET CRC Unspent Participant Contributions	-	-	-	-	-	113.6	113.6
Non-financial asset acquired for Nil Consideration	-	-	-	-	850.0	-	850.0
Gain on Sale of CT System to DIG CT Pty Ltd	1,301.0	-	-	-	-	-	1,301.0
Interest Income - Finance Lease CT System	20.5	-	-	-	-	-	20.5
Interest Income	465.8	365.3	70.1	112.9	300.5	124.0	1,438.6
Royalty Income	280.0	127.4	52.1	34.1	-	-	493.6
Other Income	123.7	18.1	79.8	9.6	122.2	30.8	384.2
Total Revenue	**11,951.0**	**12,674.9**	**11,512.0**	**13,163.2**	**12,966.5**	**15,215.4**	**77,483.0**
Expenditure							
Research Program Expenditure							
- Program 1	2,047.8	1,871.9	1,905.5	2,576.7	2,121.4	486.1	11,009.4
- Program 2	1,392.6	1,361.1	1,292.8	1,610.1	1,524.6	544.8	7,726.0
- Program 3	4,838.1	6,866.8	5,686.0	10,405.2	1,859.8	653.5	30,309.4
- Opportunity Fund & Other Projects	993.0	759.8	580.2	204.8	-	-	2,537.8
Total Research Program Expenditure	**9,271.5**	**10,859.6**	**9,464.5**	**14,796.8**	**5,505.8**	**1,684.4**	**51,582.6**
Education & Training	552.8	575.4	432.3	504.4	384.5	200.0	2,649.4
Management Expenses	845.7	841.3	717.2	418.2	492.3	503.8	3,818.5
Royalty Expense	104.2	85.5	28.7	22.0	-	-	240.4
Salaries & Wages - Drill Crew	1,099.2	1,372.3	987.8	97.2	-	-	3,556.5
Salaries & Wages - Head Office (incl Directors Fees)	1,218.1	1,167.4	1,049.8	1,046.7	996.9	1,005.3	6,484.2
	3,820.0	**4,041.9**	**3,215.8**	**2,088.5**	**1,873.7**	**1,709.1**	**16,749.0**
Total Expenditure	**13,091.5**	**14,901.5**	**12,680.3**	**16,885.3**	**7,379.5**	**3,393.5**	**68,331.6**
Restricted (Deficit)/ Surplus	**(1,140.5)**	**(2,226.6)**	**(1,168.3)**	**(3,722.1)**	**5,587.0**	**11,821.9**	**9,151.4**

Table 2 - Statement of Financial Position ($'000)	30-Jun-24	30-Jun-23	30-Jun-22	30-Jun-21	30-Jun-20	30-Jun-19
Assets						
Cash at Bank	9,142.7	10,728.5	13,148.8	14,794.8	18,167.3	13,688.1
Trade Receivables	313.5	271.6	596.2	369.8	-	255.0
Other Receivables	522.0	632.9	395.2	442.2	396.6	166.4
Prepayments & Accrued Income	386.4	267.5	135.7	101.8	84.3	100.4
Mining Exploration Bonds	20.0	130.0	-	39.9	-	-
Property Plant & Equipment	-	1,172.5	962.2	1,251.6	1,031.2	9.2
Net Investment in Lease CT System	1,723.7	-	-	-	-	-
Total Assets	**12,108.3**	**13,203.0**	**15,238.1**	**17,000.1**	**19,679.4**	**14,219.1**
Liabilities						
Trade Payables & Accruals	2,652.0	2,634.0	2,544.4	3,081.2	2,205.6	2,366.2
Employee Provisions	304.9	271.3	165.0	97.8	59.7	21.3
Lease Liability - Premises	-	5.8	10.2	134.3	5.2	9.7
Total Liabilities	**2,956.9**	**2,911.1**	**2,719.6**	**3,313.3**	**2,270.5**	**2,397.2**
Net Assets	**9,151.4**	**10,291.9**	**12,518.5**	**13,686.9**	**17,408.9**	**11,821.8**
Current Year Restricted (Deficit)/ Surplus	(1,140.5)	(2,226.6)	(1,168.3)	(3,722.1)	5,587.0	**11,821.9**
Retained Restricted Surplus	**10,291.9**	**12,518.5**	**13,686.8**	**17,408.9**	**11,821.9**	-
Equity	**9,151.4**	**10,291.9**	**12,518.5**	**13,686.8**	**17,408.9**	**11,821.9**

Table 3 - Cumulative Cash Report ($'000)	FY24	FY23	FY22	FY21	FY20	FY19	Cumulative Total
Cash flows from operating activities (inclusive of GST where applicable)							
Government grants	6,050.0	6,050.0	6,050.0	6,378.4	7,256.7	3,002.4	34,787.5
Participant contributions	4,353.3	7,546.2	6,170.0	7,551.0	5,754.6	13,097.2	44,472.3
Other income	378.8	90.0	54.0	50.0	63.9	131.4	768.1
Royalties received	119.9	104.1	32.3	4.7	-	-	261.0
Interest received - finance lease receivable	20.5	-	-	-	-	-	20.5
Interest received	543.8	217.5	51.8	142.4	303.1	74.5	1,333.1
Interest paid	(0.4)	(1.0)	(8.1)	(1.6)	(1.0)	(1.4)	(13.5)
Royalties paid	(89.6)	(39.3)	(16.9)	(2.6)	-	-	(148.4)
Payments to suppliers and employees	(13,540.4)	(15,976.7)	(13,846.1)	(17,259.9)	(8,656.4)	(2,611.9)	(71,891.4)
Net cash (used in)/ provided by operating activities	**(2,164.1)**	**(2,009.2)**	**(1,513.0)**	**(3,137.6)**	**4,720.9**	**13,692.2**	**9,589.2**
Cash flows from investing activities							
Payments for plant and equipment	(2.9)	(336.8)	(18.1)	(215.0)	(237.0)	-	(809.8)
Payments for motor vehicles	-	(69.1)	-	-	-	-	(69.1)
Proceeds from repayment of lease receivable	587.4	-	-	-	-	-	587.4
Net cash used in investing activities	**584.5**	**(405.9)**	**(18.1)**	**(215.0)**	**(237.0)**	**-**	**(291.5)**
Cash flows from financing activities							
Repayment of lease liability	(6.2)	(5.2)	(114.9)	(19.9)	(4.7)	(4.1)	(155.0)
Net cash used in financing activities	**(6.2)**	**(5.2)**	**(114.9)**	**(19.9)**	**(4.7)**	**(4.1)**	**(155.0)**
Net change in cash and cash equivalents	**(1,585.8)**	**(2,420.3)**	**(1,646.0)**	**(3,372.5)**	**4,479.2**	**13,688.1**	**9,142.7**
Cash and cash equivalents at the beginning of the year	10,728.5	13,148.8	14,794.8	18,167.3	13,688.1	-	-
Cash and cash equivalents at the end of the year	**9,142.7**	**10,728.5**	**13,148.8**	**14,794.8**	**18,167.3**	**13,688.1**	**9,142.7**

MinEx CRC Limited
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ABN: 66 625 533 913

Appendix A
Sponsors

MinEx CRC Limited
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ABN: 66 625 533 913

Partners – FY23/24

List of Participants during the reporting period

Participant's Name	ABN or ACN	Organisation Type	Category
Anglo American Technical & Sustainability Serv Ltd	81 629 813 216	Industry	Large Miner
Australian National University	52 234 063 906	Research	University
BHP Billiton Iron Ore Pty Ltd	46 008 700 981	Industry	Large Miner
Commonwealth Scientific and Industrial Research Organisation (CSIRO)	41 687 119 230	Government Body	Statutory Body
Curtin University	99 143 842 569	Research	University
Epiroc Rock Drills AB	N/A (International)	Industry	METS
Geological Survey of New South Wales	38 755 709 681	Government Body	Geo Survey
Geological Survey of South Australia	83 768 683 934	Government Body	Geo Survey
Geological Survey of Western Australia	69 410 335 356	Government Body	Geo Survey
Geoscience Australia	80 091 799 039	Government Body	Geo Survey
Geotec Boyles Bros SA	N/A (International)	Industry	METS
Imdex Ltd	78 008 947 813	Industry	METS
LKAB Wassara AB	N/A (International)	Industry	METS
McKay Drilling Pty Ltd	21 009 392 625	Industry	METS
Minerals Research Institute of Western Australia	86 779 457 072	Government Body	Statutory Body
Rio Tinto	12 002 183 557	Industry	Large Miner
Sandvik Mining and Construction Oy	N/A (International)	Industry	METS
South 32 Ltd	74 601 343 202	Industry	Large Miner
The University of Adelaide	61 249 878 937	Research	University
University of Newcastle	52 234 063 906	Research	University
University of New South Wales	57 195 873 179	Research	University
University of South Australia	37 191 313 308	Research	University
University of Western Australia	37 882 817 280	Research	University

List of Affiliates during the reporting period

Affiliate's Name	ABN or ACN	Organisation Type	Category
AIC Mines Ltd (prev Demetallica)	11 060 156 452	Industry	Junior Explorer
AngloGold Ashanti	42 008 737 424	Industry	Large Miner
AuScope	33 125 908 376	Government Body	Statutory Body
Datacode	N/A (International)	Industry	METS
Encounter Resources Limited	47 109 815 796	Industry	Junior Miner
EnviroCopper Ltd	19 635 434 721	Industry	Junior Miner
Evident	N/A (International)	Industry	METS
Geological Survey of Queensland	59 020 847 551	Government Body	Geo Survey
Geological Survey of Victoria	83 295 188 244	Government Body	Geo Survey

HiSeis Pty Ltd	83 136 507 429	Industry	METS
Lodestone Mines Limited	67 150 740 613	Industry	Junior Miner
Matsa Resources	88 613 060 352	Industry	Junior Miner
Middle Island Resources	70 142 361 608	Industry	Junior Explorer
Veracio (formerly Minalyze AB)	N/A (International)	Industry	METS
Mineral Resources Tasmania	36 388 980 563	Government Body	Geo Survey
Monash University	12 377 614 012	Research	University
Northern Territory Geological Survey	84 085 734 992	Government Body	Geo Survey
Santos QNT Pty Ltd	80 007 50 923	Industry	Large Miner
Strategic Energy Resources Ltd	14 051 212 429	Industry	Junior Explorer
University of Tasmania	30 764 374 782	Research	University

Changes to Affiliates & Participants during the reporting period

Affiliate's Name	Retiring, Withdrawing or New	Department Approval
AngloGold Ahanti	New	Yes
Encounter Resources	Withdrawn	n/a
Evident	Withdrawn	n/a
Lodestone	Withdrawn	n/a
Middle Island	Withdrawn	n/a

- AngloGold Ashanti joined MinEx CRC as new Affiliate as of 1/7/2023 and was approved by the Board.
- Evident, Lodestone and Middle Island withdrew as Affiliates as of 30/06/2024
- Encounter Resources withdrew as an Affiliate as of 31/12/2023

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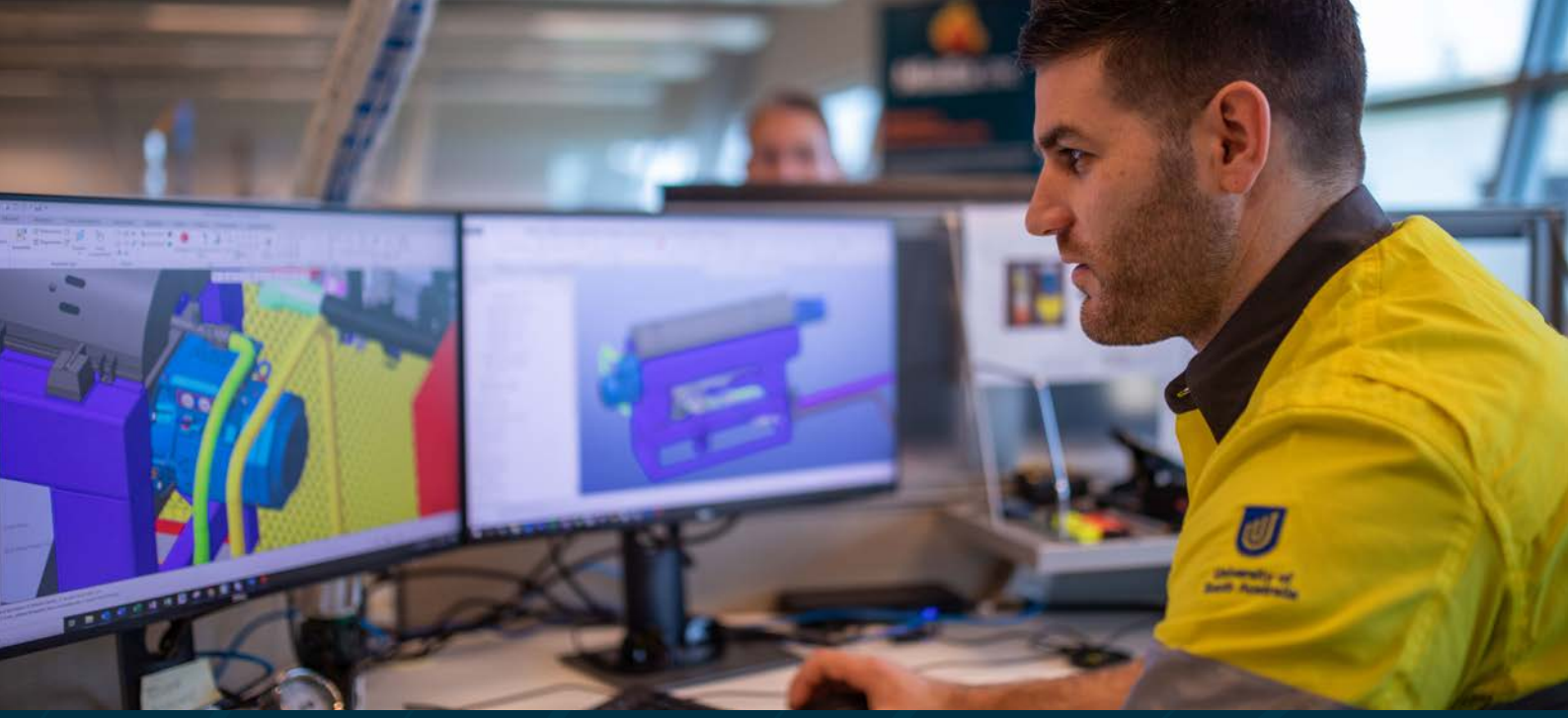
Appendix B
2023 Year in Review



MinEx CRC

2023 YEAR IN REVIEW

Australian Government
Department of Industry, Science and Resources

AusIndustry
Cooperative Research Centres Program

CHEAPER, FASTER, CLEANER MINERAL EXPLORATION TECHNOLOGY

KEY NUMBERS

$4.4M
Ahead of Commonwealth Agreement budget

55
Peer-reviewed scientific publications

51
Postgraduate enrolments to date (on target for 60)

57%-43%
Pro-female gender split on MinEx CRC Board of Directors (excluding CEO)

24
Participant Sponsors

9
Postgraduate completions to date (on target for 50)

198/216
Phase 2 quarterly milestones met. 38 milestones progressing ahead of schedule

700m
Deepest hole yet drilled with the MinEx CT platform

25
Affiliate Sponsors

1/8TH
Water consumption compared to conventional drilling in Anglo American CT drilling campaign

1/5TH
CO_2 emissions compared to conventional drilling in Anglo American CT drilling campaign

TWO
New Opportunity Fund Projects commenced

1/1
Commonwealth Milestone met

7954m
Drilled over 23 holes in the Anglo American and Delamerian Margins NDI drilling campaigns

ADVANCING TECHNOLOGY

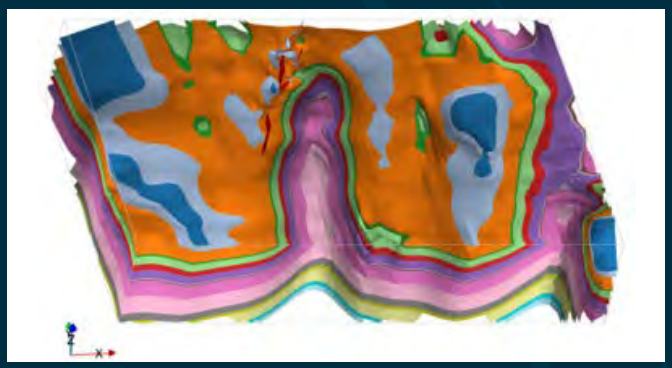
Program 1: Drilling

- Data from the "Woody" single impact percussion drilling experimental device is being used to develop a percussion drilling 'sweet spot seeking' algorithm.
- Our drill rig measurement and monitoring system for RC drilling (RC DTrol) has been updated to enable two-way digital communication with the drill rig, not only receiving data but also transmitting control commands. This is an important step on the pathway to drilling automation.
- Researchers commissioned a new LiqiCTrol production plant with 1 tonne/day capacity (ten times our previous production method) the plant can service between 6 and 10 field-deployed i-fluid systems.
- Researchers drilled a 700m hole (our deepest coiled tubing drill hole to date) with the prototype CT 1000m drill rig. Despite difficult ground conditions the hole was drilled without incident, with good sample recovery at an average 'all-in' drilling production rate of >40m per shift.
- The CT 500m drill rig and HPS were deployed at the Anglo American 'Diamantina Project' in outback Queensland between August and December 2022 and in the Delamerian Margins NDI campaign between March and June 2023. Researchers drilled 22 holes for a total of 7,254m.

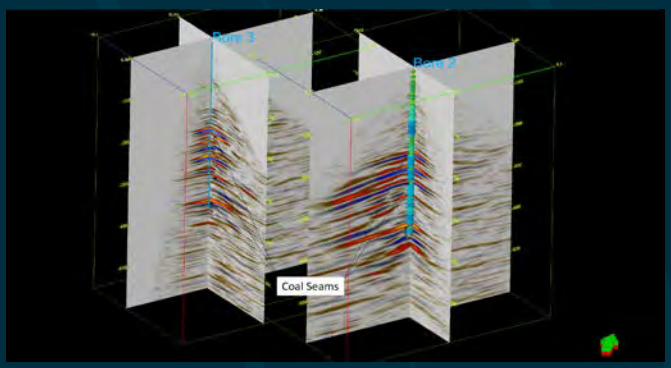
MinEx CRC drill rig on site during the Paterson Region National Drilling Initiative Campaign, West Australia.

Program 2: Data From Drilling

- Our prototype LIBS downhole geochemistry tool has been upgraded (including redesign of the optics, addition of an auto-focus mechanism and temperature sensors and updating of the GeoLIBS software) in preparation for downhole trials planned for 2024.
- Our prototype downhole swept frequency EM tool has been tested in a borehole to a depth of 450m. The sensor proved highly sensitive over a wide frequency range with logging results that compare favourably against commercial systems.
- Researchers have implemented a noise-to-noise approach for denoising of DAS seismic data which is remarkably effective at minimising noise and highlighting the seismic response of the near hole formation in borehole DAS data.
- Researchers have developed QGIS plugins, enabling free access to MinEx-developed 3D modelling software on standard personal computers.



Automated 3D geological model generated from map and drill hole data.



Seismic reflection data collected using borehole and surface deployed optic fibre distributed sensing (DAS).

Program 3: National Drilling Initiative

- Researchers have developed a semi-automated workflow to generate pseudo-logs and deliver near real-time identification of regolith/basement interfaces from downhole geophysical logs, pXRF and portable radio-spectrometer data from drilling samples.
- Enhanced detection of cover interfaces using novel airborne electro-magnetic inversion techniques has been favourably tested in the vicinity of NDI boreholes in the Delamarian Margins NDI campaign.
- 3D modelling and geophysical inversion in the southern Cobar Basin has highlighted elements of the regional architecture that control the localisation of known mineral deposits and has identified prospective, under-explored parts of the basin.
- A select group of 'downstream' analytical techniques are emerging as the most useful for delivering exploration relevant data from the NDI drilling campaigns. These include U-Pb dating coupled with multi-element analysis of zircon and monazite; Ar/Ar thermochronology; in-situ Rb-Sr, Lu-Hf and Re-Os dating of ore, gangue and alteration phases; Cu-isotopes, and; apatite chemistry for characterising mineral systems.

Dr Hamid Zekri and Dr Indrani Mukherjee (both UNSW) undertaking experiments at the School of Biological, Earth and Environmental Sciences, UNSW.

RESEARCH FOCUS

MinEx CRC remains focused on delivering 1) cheaper, faster, safer and cleaner mineral exploration technology, 2) in-field sensing and data science to enable informed decisions while drilling, and 3) pre-competitive geoscience data to de-risk exploration in frontier mineral provinces, delivered by the National Drilling Initiative.

RESEARCH ENGAGEMENT

- MinEx CRC-designed measurement, monitoring and control systems ("DTrol") have been installed on two drill rigs, a Reverse Circulation percussion drill rig and a Diamond drill rig, operated by MinEx CRC Participant McKay Drilling.
- MinEx CRC maintained its relationship with OMNI GeoX to coordinate and manage aspects of the Delamerian South NDI campaign.
- Participant Imdex Limited provided significant in-kind contributions of people and equipment to research projects and logging equipment for the NDI drilling program. The equipment was a valuable aid to the project and provided Imdex with important feedback on the use and development of recently released products.
- MinEx CRC's seismic research project conducted field trials at Anglo American and BHP field sites.
- Cooperation is ongoing with European-based METS companies Sandvik, Epiroc, LKAB Wassara and Sercel. Staff from the Anglo American London office have become involved with the pull-through of MinEx CRC CT drilling technology, which has prompted discussions with international companies interested in the commercial manufacture of the CT platform.
- Chilean-based drilling company Geotec Boyles remains an active participant in Project 1, with field trials in South America is being planned for the calendar year 2024.
- MinEx CRC and Schramm (a subsidiary of Epiroc) have agreed upon a commercialisation agreement to build the CT rig and associated Hydraulic Processing System. Subject to orders for CT Systems being placed, Schramm will manufacture all CT rigs in Adelaide, South Australia.

EDUCATION

- As at June 30th 2023 MinEx CRC had 37 active postgraduate students enrolled, with 51 postgraduate enrolments to date.
- There were seven MinEx CRC postgraduate completions during the reporting period, bringing the total number of completions to nine.
- Seven video conferences were held throughout the reporting period to engage students and ensure they are supported within the CRC environment.
- Four students presented at the Annual Conference held in November 2022.
- A fully immersive VR digital twin of the RoXplorer® CT drilling platform in collaboration with the Australian Research Centre for Interactive and Virtual Environments at UniSA. The digital twin will be used to optimise engineering and user workflows of the drill site, train drillers on the new platform, and act as a technology showcase for stakeholder engagement and commercialisation.

COMMUNICATIONS

119
press articles generated

37K
website visitors

2.2K+
YouTube views

- Three quarterly episodes of the MinEx CRC vNews were published on MinEx CRC TV (the MinEx CRC Annual Conference serves as the Q4 update for researchers and sponsors).
- Two press releases were distributed during the reporting period titled:
  - New Tech Promises Smaller Carbon Footprint in South Australian Drilling Campaign (October 2022).
  - MinEx CRC Clean and Green Drilling Tech: A Step Closer Following Trial in Collaboration With Anglo American (February 2023)
- 7 videos were published on MinEx CRC TV, with two thousand views.
- 119 press articles generated.
- 37k visitors to the MinEx CRC website, with 74k page views in total.

SPONSORS

Majors, METs & Survey Participants

Research Participants & Affiliates



REVENUE & EXPENDITURE

Revenue ($'000)	FY23	FY22	FY21	FY20	FY19	Total
Commonwealth Funding	5,500.0	5,500.0	5,798.5	6,597.0	2,729.5	26,125.0
Other Government Grants	28.0	-	-	-	-	28.0
Participant Contributions	6,421.1	5,600.0	7,023.0	4,811.8	12,067.5	35,923.4
Affiliates Contributions	215.0	210.0	185.1	285.0	150.0	1,045.1
DET CRC Unspent Participant Contributions	-	-	-	-	113.6	113.6
Non-financial asset acquired for Nil Consideration	-	-	-	850.0	-	850.0
Interest Income	365.3	70.1	112.9	300.5	124.0	972.8
Royalty Income	127.4	52.1	34.1	-	-	213.6
Other Income	18.1	79.8	9.6	122.2	30.8	260.5
Total Revenue	**12,674.9**	**11,512.0**	**13,163.2**	**12,966.5**	**15,215.4**	**65,532.0**

Expenditure ($'000)						
Research Program Expenditure						
- Program 1	1,871.9	1,905.5	2,576.7	2,121.4	486.1	8,961.6
- Program 2	1,361.1	1,292.8	1,610.1	1,524.6	544.8	6,333.4
- Program 3	6,866.8	5,686.0	10,405.2	1,859.8	653.5	25,471.3
- Opportunity Fund & Other Projects	759.8	580.2	204.8	-	-	1,544.8
Total Research Program Expenditure	**10,859.6**	**9,464.5**	**14,796.8**	**5,505.8**	**1,684.4**	**42,311.1**
Education & Training	575.4	432.3	504.4	384.5	200.0	2,096.6
Management Expenses	841.3	717.2	418.2	492.3	503.8	2,972.8
Royalty Expense	85.5	28.7	22.0	-	-	136.2
Salaries & Wages - Drill Crew	1,149.1	987.8	97.2	-	-	2,234.1
Salaries & Wages - Head Office (incl Directors Fees)	1,390.6	1,049.8	1,046.7	996.9	1,005.3	5,489.3
	4,041.9	**3,215.8**	**2,088.5**	**1,873.7**	**1,709.1**	**12,929.0**
Total Expenditure	**14,901.5**	**12,680.3**	**16,885.3**	**7,379.5**	**3,393.5**	**55,240.1**
Restricted (Deficit)/ Surplus	**(2,226.6)**	**(1,168.3)**	**(3,722.1)**	**5,587.0**	**11,821.9**	**10,291.9**

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Department of Industry, Science and Resources

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Appendix C
Student Register

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Student Register

Postgraduate students

#	Student	University	Supervisor	Industry co-supervisor	Degree	Project title	Project	Start Date	Finish date	Date registered
1	Alejandra Bedoya Meija	University of Adelaide	Stijn Glorie	David Kelsey (GSWA)	PhD	Thermochronology of the margins of 'The Gap', Western Australia	7	20/12/2021	19/12/2024	27/01/2022
2	Andreas Bjork	University of South Australia	David Giles	James Austin (CSIRO)	PhD	Application of the multi-sensor core logger for petrophysical analysis and geophysical modelling	7	18/04/2022	17/04/2025	2/06/2022
3	Andres Sifuentes Chamochumbi	UniSA	Caroline Tiddy	Benjamin Zammit (SA Dept. Energy & Mining)	PhD	Impacts of technology development on social and governance frameworks in the context of mineral exploration	7	9/08/2022	9/08/2025	12/08/2022
4	Aruni Rajanayake	Curtin University	Brett Harris	Fiona Best (South32)	PhD	Innovative geophysics for drilling trajectory control	4	01/02/2021	1/02/2021	16/02/2021
5	Bianca Palombi	University of Newcastle	Brett Neilan	Chris Folkes (GSNSW), Nathan Reid (CSIRO)	PhD	Microbial diversity and their genetic basis for heavy metal resistance in regolith	7	1/03/2022	1/03/2025	23/03/2022
6	David Yanyi-Akfur	Monash	Pete Betts	Philip Skladzien (GSV)	PhD	Predicting gold mineralisation: Using geophysics and petrophysical characteristics to map prospective structures under cover	7	1/01/2023	1/02/2027	22/03/2023
7	Elnaz Khazaie	UoA	Alan Collins	Peter Haines (GSWA)	PhD	Novel Isotope Techniques for Basin Exploration: Chrono and Chemostratigraphy of the Officer Basin	7	4/03/2024	4/09/2027	15/04/2024
8	Emad Al-Hemyari	Curtin University	Andrej Bona	Tim Dean (Anglo American)	PhD	Seismic data processing and inversion with distributed acoustic sensing and artificial intelligence	5	9/05/2022	9/05/2025	3/06/2022
9	Eu Lim Kean	Curtin	Masood Mostofi	Alton Grabsch (CSIRO)	PhD	Non-Newtonian fluid flow in naturally fractured rocks with application in fluid loss control	1	1/04/2022	1/04/2024	22/08/2022

#	Student	University	Supervisor	Industry co-supervisor	Degree	Project title	Project	Start Date	Finish date	Date registered
10	Hamid Bizhanikalatehahmad	UoA	Graham Heinson	David DeTata, Chris Yeates (Strategic Energy Resources)	PhD	Investigating Crustal Anomalies in the Curnamona-Mundi Mundi Region using an Integrated Geophysical Approach	Company	20/06/2023	19/06/2026	11/09/2023
11	Himanshu Sekhar Bal	Curtin	Chris Clark	David Kelsey (GSWA)	PhD	Extracting petrological information from low sample volumes	7	1/01/2024	31/12/2026	5/10/2023
12	Hing Hao Chan - PhD	Curtin	Masood Mostofi	Yevhen Kovalyshen (CSIRO)	PhD	Effect of wear on drilling response of an impregnated diamond bit	1	1/09/2022	1/09/2026	2/09/2022
13	Ivan Gutierrez Agramont	University of South Australia	Caroline Tiddy	Neil Francis, Yulia Uvarova (CSIRO)	PhD	Generating synthetic data for training predictive spectroscopic models	3	12/07/2021	12/07/2024	12/07/2021
14	Joe Shifano	University of New South Wales	David Cohen	Chris Folkes (GSNSW)	PhD	Regional biogeochemical mapping (and associated regolith studies) of the Cobar Basin for mineral exploration at regional to local scales	7	1/03/2019	1/07/2021	18/04/2019
15	Justine Flahaut	UniSA	Justin Payne	Claire Wade (GSSA)	PhD	New approaches for rapid analysis and tracing of fluids and their ligands in regional mineral systems	7	14/11/2022	14/11/2025	7/12/2022
16	Lizzie Bruce - PhD	UWA	Vitaliy Orgarko	Richard Chopping (GSWA)	PhD	Tomofast-x Gravity-Magnetic Inversion to Map Greenstone Belts in Archean and Paleoproterozoic Terrains	6	1/04/2024	1/04/2027	29/04/2023
17	Lucy Mathieson	Curtin University	Chris Kirkland	Klaus Gessner (GSWA)	PhD	Mapping radiogenic Pb loss in space and time: a new tool to track fluid rock interaction	7	7/03/2022	6/03/2026	21/03/2022
18	Luke Tylkowski	University of South Australia	Caroline Tiddy	Ross Cayley (GSV), Rob Thorn (CSIRO)	PhD	Resistate indicator minerals as an exploration tool for orogenic gold mineralisation: a case study from the Murray Basin, southeastern Australia	7	1/3/2021	1/03/2024	4/03/2021
19	Maryam Abdollahi	Curtin University	Masood Mostofi	Yevhen Kovalyshen (CSIRO)	PhD	Design and evaluation of shape memory polymers composite (SMPC) to control lost circulation of water-based mud	1	2/05/2023	2/05/2026	13/06/2023

#	Student	University	Supervisor	Industry co-supervisor	Degree	Project title	Project	Start Date	Finish date	Date registered
20	Mikhail Vorobev	Curtin University	Konstantin Tertyshnikov	Tim Dean (Anglo American)	PhD	Passive seismic imaging and monitoring	5	10/01/2024	11/01/2027	11/12/2023
21	Mosayeb Khademi Zahedi	University of South Australia	Dave Giles	Teagan Blaikie (CSIRO)	PhD	Linking geophysics and geology through borehole data	5	8/2/2021	8/02/2024	18/02/2021
22	Nikita Beloborodov	Curtin University	Rman Pevzner	Ilnur Minniakhmetov (BHP)	PhD	Seismic imaging and monitoring using low-power and ambient sources	5	1/10/2023	2/10/2026	13/09/2023
23	Nuwan Suriyaarachchi	University of Western Australia	Mark Jessell	Lachlan Hennessey (Anglo American), Richard Chopping (GSWA)	PhD	Integrated passive seismic/EM characterisation of cover as constraints on drilling	6	21/10/2019	20/10/2022	3/12/2019
24	Oliver Pring	UoA	Lucy McGee	Phillip Blevin (GSNSW)	PhD	Tracing the movement of metals through the mantle and crust using Cu isotopes	7	14/03/2022	14/09/2025	24/10/2022
25	Ranee Joshi	University of Western Australia	Mark Jessell	Tim Ivanic (GSWA)	PhD	Multi-scale 3D geological modelling of the Yalgoo-Singleton Greenstone Belt using the Loop Platform	6	22/01/2019	22/01/2022	26/02/2019
26	Rory Carter	UNSW	Ian Graham	Brenainn Simpson, Chris Folkes (GSNSW)	PhD	Rare earth element (REE) geochemistry, mineralogy, and mobility in the Cobar Basin - from potential primary granite sources to the surface environment	7	12/02/2024	6/02/2028	11/12/2023
27	Rui Huang (Eric)	Curtin University	Masood Mostofi	Yevhen Kovalyshen (CSIRO)	PhD	Fundamentals of rock fragmentation of impregnated diamond bits	1	1/04/2020	1/12/2023	22/06/2020
28	Ruiqi Zheng	University of Adelaide	Juraj Farkas	Erick Ramanaidou (CSIRO)	PhD	Geological and geochemical constraints on the origin and diagenetic history of Neoproterozoic Breamar ironstones (SA) based on new metal isotope (Fe, Cr) and REE proxies	Company	31/01/2022	30/01/2025	25/03/2022

#	Student	University	Supervisor	Industry co-supervisor	Degree	Project title	Project	Start Date	Finish date	Date registered
29	Snehal Jayakumar	Curtin University	Masood Mostofi	Yevhen Kovalyshen (CSIRO)	PhD	Cutting transport in RC drilling using compressible fluids	1	15/06/2020	15/06/2023	7/09/2020
30	Stacey Curtis	University of South Australia	Justin Payne	Mark Pawley (GSSA)	PhD	Integrated framework for the magmatic evolution of the greater Delamerian Orogen	7	10/02/2020	9/02/2023	1/04/2020
31	Su (Joel) Kwong Lee	Curtin	Thomas Richard	Yevhen Kovalyshen (CSIRO)	Masters	Experimental setup for a single diamond cutter drill test	1	1/06/2022	1/06/2024	22/08/2022
32	Travis Batch	University of South Australia	Caroline Tiddy	Michael Taylor, Vaclav Metelka (AIC Mines)	PhD	Magnetite and monazite chemistry for iron oxide-copper-gold exploration	Company	30/09/2021	30/09/2024	5/10/2021
33	Yoli Wu	ANU	Marnie Foster	David Kelsey (GSWA)	Masters	Application of argon geochronology to constrain shear zone movement and exhumation of the northern and eastern margins of the West Australian craton	7	30/09/2022	30/09/2024	24/10/2022
34	Zara Woolston	University of Adelaide	Juraj Farkas	Anna Petts, Alicia Caruso (GSSA), Phil Gilmore, John Greenfield (GSNSW)	PhD	Tracing subsurface ore deposits through the isotope analysis of regolith/cover in Australia: Coupled Cu and S isotope approach applied to a rock-soil-water-plant system	7	1/3/2021	1/03/2025	7/04/2021
35	Zhufu Shao	University of Adelaide	Juraj Farkas	Charles Verdel (NTGS)	PhD	Novel isotope techniques for basin exploration: In-situ dating and metal isotope analysis of glauconite/apatite from the Georgina Basin	7	29/11/2021	29/11/2024	21/02/2022

Completed students

#	Student	University	Supervisor	Co-supervisors	Industry co-supervisor	Degree	Project title	Finish date	Graduation Destination
1	Alexander De Vries Van Leeuwen	UniSA	Tom Raimondo	Laura Morrissey (UniSA), Martin Hand (UoA)	Rian Dutch (GSSA), Joel Fitzherbert (GSNSW)	PhD	Petrochronological framework of the Curnamona Province and the role of radiogenic heating	8/08/2023	MinEx CRC Embedded Researcher, University of Adelaide/Geological Survey of South Australia
2	Mahtab Rashidifard	UWA	Mark Lindsay	Mark Jessell, Jeremie Giraud, Vitaliy Ogarko, Guillaume Pirot (UWA)	Neil Godber (Anglo American), Richard Chopping (GSWA)	PhD	The integration of regional reflection seismic profiles and gravity datasets with different spatial coverage associated with geological models	23/08/2023	Geophysicist, Rio Tinto
3	Jie Yu	UoA	Martin Hand	Justin Payne, Laura Morrissey (UniSA)	Rian Dutch (GSSA)	PhD	The early Mesoproterozoic tectonic systems and IOCG mineralisation in the northern Gawler Craton	31/12/2023	Postdoctoral Researcher, Curtin University
4	Lizzie Bruce	UWA	Mark Jessell	Vitaliy Ogarko (UWA)	Richard Chopping (GSWA)	Masters	Tomofast-x gravity inversion to analyse the upper crustal structure of Archean Greenstone Belts	8/01/2024	PhD with Mark Jessell at UWA
5	Naina	ANU	Greg Yaxley	Dorrit Jacob (ANU)	Anthony Reid (GSSA), Geoff Fraser (GA)	PhD	Missing pieces in the deformation and thermal history along the Cambro-Ordovician Delamerian Orogen, South Australia: Revelation of 100My of post-Delamerian tectonic history through 40Ar/39Ar geochronology	3/04/2024	Research Scientist, CSIRO
6	Joao Victor Borges dos Santos	Curtin	Thomas Richard	Masood Mostofi (Curtin)	Bevan Eagle (McKay Drilling)	PhD	Experimental study of down-the-hole percussive drilling	28/03/2024	Rotating Equipment Engineer, ERM Consulting.

Honours-Masters by Coursework Students

Student	Affiliation	Degree	Project Title	Primary Supervisor	Co-Supervisor(s) & Affiliation(s)
Jarred Tilby	University of Adelaide	Honours	Metal concentrating mechanisms at active volcanoes: Whakaari (White Island)	Dr Lucy McGee	A/Prof Justin Payne (UniSA), Prof Simon Turner (Macquarie University)
Lesley Edwards	University of Adelaide	Honours	Life in 1.4 billion years old Northern Territory Seas	Prof Alan Collins	Dr Morgan Blades (UoA)
Chloe Zou	UniSA/University College London	Masters by Coursework	Investigate the chemistry of pyrite to provide information on the changing physiochemical conditions of the fluid from which it precipitated from and their association with mineralizing events	Dr Adrienne Brotodewo	A/Prof Caroline Tiddy (UniSA)
Constantin Goeschl	UniSA/University College London	Masters by Coursework	Investigate the chemistry of pyrite to provide information on the changing physiochemical conditions of the fluid from which it precipitated from and their association with mineralizing events	Dr Adrienne Brotodewo	A/Prof Caroline Tiddy (UniSA)
Hetal Bhatia	UniSA/University College London	Masters by Coursework	Investigation of the economics of ISR for the Kapunda region	A/Prof Caroline Tiddy	Dr Adrienne Brotodewo (UniSA)
Kubra Akbulut	UWA	Masters by Coursework	Cost and value analysis of data collection scenarios to reduce geological uncertainty	Dr Guillaume Pirot	Prof Mark Jessell (UWA)
Leonardo Marchetti	UniSA/University College London	Masters by Coursework	Investigation of the economics of ISR for the Kapunda region	A/Prof Caroline Tiddy	Dr Adrienne Brotodewo (UniSA)
Oscar Clausen	UniSA/University College London	Masters by Coursework	Investigation of the economics of ISR for the Kapunda region	A/Prof Caroline Tiddy	Dr Adrienne Brotodewo (UniSA)
Ozgur Yedek	UWA	Masters by Coursework	Constraining the 3D geology of the Hamersely Province	Prof Mark Jessell	Dr Vitaliy Ogarko (UWA)
Shiyue Zhang	UniSA/University College London	Masters by Coursework	Investigate the chemistry of pyrite to provide information on the changing physiochemical conditions of the fluid from which it precipitated from and their association with mineralizing events	Dr Adrienne Brotodewo	A/Prof Caroline Tiddy (UniSA)
Tolga Mercan	UWA	Masters by Coursework	Hyperspectral imaging in hydrothermal alteration patterns related to Cu-Au mineralisation	Dr Weronika Gorcyzk	Prof Mark Jessell, Prof Franco Pirajno (UWA)
Zeyu Zhang	UniSA/University College London	Masters by Coursework	Investigation of the economics of ISR for the Kapunda region	A/Prof Caroline Tiddy	Dr Adrienne Brotodewo (UniSA)

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Appendix D
Registered IP (Patents, Trademarks, Designs)

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Registered IP (Patents, Trademarks, Designs)

Patents

PATENT FAMILY	RELATES TO	COUNTRY	APPLICATION NO.	FILING DATE	STATUS	MANAGEMENT
Borehole Logging Methods an Apparatus	AutoSonde	International	2013904475	19 Nov '13	Patent applications lodged in numerous countries by Boart Longyear	Boart Longyear
Sampling and Analysis System and Method for use in Exploration Drilling	Lab-at-Rig®	International	2014904646	19 Nov '14	Patent applications lodged in numerous countries by Imdex	Imdex
Drying apparatus and related method	Lab-at-Rig®	International	2014904649	19 Nov '14	Patent applications lodged in numerous countries by Imdex	Imdex
Capture of drilling fluid returns	Lab-at-Rig®	International	2015903272	Aug '15	Patent applications lodged in numerous countries by Imdex	Imdex
Mobile Coiled Tubing Drilling Apparatus	CT Rig	International	2017050508	30 May '17	Patent applications filed in numerous countries by POF on behalf of MinEx	POF (MinEx)
High Speed Downhole Coring System	CT Rig	Australia	2017101088	10 Aug '17	Innovation Patent Granted, 8 years Next renewal 10 Aug '22	POF (MinEx)
Sample Collection System and Parts Thereof	CT Rig, LAR for CT	International	2018050938	31 Aug '18	Patent applications filed in numerous countries by POF on behalf of MinEx	POF (MinEx)
Rotary Drill Head for Coiled Tubing Drilling Apparatus	CT Rig	International	2017051098	11 Oct '17	Patent applications filed in numerous countries by POF on behalf of MinEx	POF (MinEx)
Drilling Fluids and Uses Thereof	CTrol, CT Rig	International	2019050486	21 May '19	Patent applications filed in numerous countries by POF on behalf of MinEx	POF (MinEx)

Registered Designs

DESIGNS	COUNTRY	APPLICATION NO.	FILING DATE	STATUS	MANAGEMENT
Fluids Capture Apparatus	Australia	AU201514172	14 Aug ‘15	Registered, 10 years, expiry due 14 Aug’ 2025	Imdex
Mobile Coiled Tubing Drilling Apparatus	International	AU201710287	18 Jan ‘17	Registered various countries on behalf of MinEx	POF (MinEx)
A Cone Member for a Cone Splitter	Australia	AU201715232	1 Sep ‘17	Registered, 10 years, renewal required at 5 yrs	POF (MinEx)

Trademarks

TRADEMARK	COUNTRY	APPLICATION NO.	CLASSES	FILING DATE	STATUS	MANAGEMENT
Lab-at-Rig®	Australia	1581982	7, 9, 37 & 42	23 Sep ‘13	Registered, 10 years	Imdex
RoXplorer®	Australia	1664080	7,37	11 Dec ‘14	Registered, 10 years	POF (MinEx)
CTrol®	Australia	1827061	1	21 Feb ‘17	Registered, 10 years	POF (MinEx)

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Appendix E
Publications

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Publications

Scientific Publications (26)

1. **Bedoya, A., Glorie, S., Hand, M., Kirkland, C., Kelsey, D., Nixon, A.** and Fraser, G. (2024). Apatite triple dating (Lu–Hf, U–Pb, FT) constrains deformation and cooling in the Coompana and Madura Provinces, Western Australia. Lithosphere, Volume 2023 (Special 14), March 2024.
2. **Bockmann M.J., Payne J.L., Hand M., Morrissey L.J.** and Belperio A.P. (2023). Linking the Gawler Craton and Mount Isa Province through hydrothermal systems in the Peake and Denison Domain, northeastern Gawler Craton. Geoscience Frontiers, Volume 14/5, article 101596, September 2023.
3. Brown, D. A., Reid, A., Jagodzinski, E. A., Williams, M., Simpson, A., Pawley, M., Kirkland, C., **Wade, C., De Vries Van Leeuwen, A. T. and Glorie, S.** (2024) Testing in-situ apatite Lu–Hf dating in polymetamorphic mafic rocks: a case study from Palaeoproterozoic southern Australia. Contributions to Mineral and Petrology, Volume 179, article 46, May 2024.
4. **Clark C.,** Kelsey D.E., Kohanpour F., **Kirkland C.L.**, Rankenburg K. and Makin S. (2023). A comparison of fast pulse and conventional LA-ICP-MS detrital zircon geochronology: A large n detrital zircon study from the Centralian Superbasin, northwestern Australia. Precambrian Research, Volume 393, Article 107103, August 2023.
5. Fox D.C.M., **McGee L.E., Farkaš J., Payne J.L.,** Spinks S.C., Barham M. and Aspandiar M. (2023). Copper isotope fractionation in Archean hydrothermal systems: Evidence from the Mesoarchean Carlow Castle Cu-Co-Au deposit. Geochemistry, Geophysics, Geosystems, Volume 24/9, article e2023GC011019, September 2023.
6. **Giraud, J.,** Caumon, G., Grose, L., **Ogarko, V**. and Cupillard P. (2024). Integration of automatic implicit geological modelling in deterministic geophysical inversion. Solid Earth, Volume 15/1, p. 63 - 89, February 2024.
7. **Glorie, S.**, Mulder, J., **Hand, M., Fabris, A., Simpson, A.** and Gilbert, S. (2023) Laser ablation (in situ) Lu-Hf dating of magmatic fluorite and hydrothermal fluorite-bearing veins. Geoscience Frontiers, Volume 14/6, article 101629, November 2023.
8. Guo, J., Xu, X., Wang, L., Wang, X., Wu, L., **Jessell, M., Ogarko, V.,** Liu, Z. and Zheng, Y. (2024). GeoPDNN 1.0: a semi-supervised deep learning neural network using pseudo-labels for three-dimensional shallow strata modelling and uncertainty analysis in urban areas from borehole data. Geoscientific Model Development, Volume 17/3, p. 957 - 973, February 2024.
9. **Hong, W., Fabris, A.**, Gilbert, S., **Wade, B., Collins, A., Wise, T.** and Reid A. (2024) Using zircon and apatite chemistry to fingerprint porphyry Cu – Mo ± Au mineralization in the Delamerian Orogen, South Australia. Mineralium Deposita, Article 07 June 2024
10. **Hong, W., Fabris, A., Wise, T., Collins, A.,** Gilbert, S., Selby, D., **Curtis, S.** and and Reid, A. (2023) Metallogenic setting and temporal evolution of porphyry Cu – Mo ± Au mineralization and alteration in the Delamerian Orogen, South Australia: Insights from zircon U-Pb, Molybdenite Re-Os and in-situ white mica Rb-Sr geochronology. Economic Geology, Volume 118/6, p. 1291-1318, September 2023

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1. **Batch, T., Tiddy, C., Brotodewo, A., Giles, D., Cayley, R.** and **Thorne, R.** (2024) Apatite chemistry and geochronology recording orogenic gold events in the eastern Bendigo Zone, Victoria, Australia. Geochemistry of Mineral Deposits, Gordon Research Conference: Geochemistry of Ore Deposits for a Low Carbon Society, 23-28 June 2024, Maine USA
2. **Batch, T., Tiddy, C., Brotodewo, A.** and **Giles, D.** (2023) Assessing REE-phosphate mineral chemistry for ISCG exploration. 17th Biennial Meeting of the Society for Geology Applied to Mineral Deposits (SGA) on Mineral Resources in a Changing World Zurich, Switzerland, 28 August – 1 September 2023. Volume 1, pp. 339-342
3. **Batch, T., Tiddy, C., Brotodewo, A.** and **Giles, D.** (2023) Developing a tool for ISCG exploration using REE-bearing phosphate chemistry. South Australian Exploration and Mining Conference 2023, 1 December 2023, SAEMC Poster Presentation, Poster 7
4. **Collet O.,** Gu X., **Tertyshnikov K. and Pevzner R.** (2023). DAS Denoising: Using Deep Learning to Remove Instrumental Noise. 3rd EAGE Workshop on Fiber Optic Sensing for Energy Applications, Chengdu, Article 22, November 2023.
5. **Flahaut, J.** (2023) UniSA / MinEx CRC PhD mineral systems research. South Australian Exploration and Mining Conference 2023, 1 December 2023, SAEMC Poster Presentation, Poster 1
6. **Gutierrez Agramont, I., van der Hoek, B., Tiddy, C.**, Zhang, L., **Francis, N.** and **Tassios, S.** (2023) Sensitivity analysis of Data Driven Machine Learning algorithms for Laser Induced Breakdown Spectroscopy (LIBS) data. South Australian Exploration and Mining Conference 2023, 1 December 2023, SAEMC Poster Presentation, Poster 2
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8. **Ogarko, V.**, Frankcombe, K., Liu, T., **Giraud, J.**, Martin, R. and **Jessell, M.** (2023) Tomofast-x 2.0: an open-source parallel code for inversion of potential field data, to recover density, susceptibility and magnetisation vector, with topography and wavelet compression. EGUsphere 2023 – 2243
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18. **Tylkowski, L., Tiddy, C., Brotodewo, A., Giles, D., Cayley, R.** and **Thorne, R.** (2024) Decoding apatite geochemistry to find signals of gold mineralization. University of South Australia, Future Industries Institute HDR Student Seminar Series May 2024
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1. **Bailey, A., Giles, D.** and **Porter, A.** (2023) MinEx CRC 2023 Year in Review. MinEx CRC Booklet, 5pp (November 2023)

2. **Forster, M.** (2024) Argon Geochronology data for events in the North Queensland Project. ANU Argon Facility Technical Report: ANU01-2024, For the Anglo Gold Ashanti for MinEx CRC OP8.1 Barcoding Metallogenesis, Research School of Earth Sciences, 91pp (January 2024)

3. **Forster, M.** (2024) MinEx CRC Opportunity Fund Op8 “Getting the most out of your date”. Timing and character of the East Yilgarn region, Western Australia. ANU Argon Facility Technical Report: ANU01-2023, For Geological Survey of Western Australia MinEx CRC Opportunity Fund, Research School of Earth Sciences, 89pp (January 2024)

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7. **Hill, J., Stromberg, J., Laukamp, C., Rodger, A.** and **Bradley, S.** (2023) Project OP9: Fast Logging with HyLogger Data. MinEx CRC Technical Report / Final Project Report 2023/34, 16pp (August 2023)

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9. **Porter, A.** (2024) Media Release: Australian-designed drilling tech set to revolutionise exploration via Dig CT commercialisation deal. News & Events: MinEx CRC Media Press Release (14 February 2024)

10. **Tiddy, C.** (2023) Postgraduate Completions. Education and Training Commonwealth Milestone Report 4.2.3. MinEx CRC Report 2023/32

11. **Tiddy, C., Soe, S., Giles, D., Fox, S.** and **van der Hoek, B.** (2023) Vocation training modules designed in collaboration with Partners and VET sector providers completed. Education and Training Commonwealth Milestone Report 4.1.1. MinEx CRC Report 2023/31

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Appendix F
Pre-commercial Product Brochures

MinEx CRC

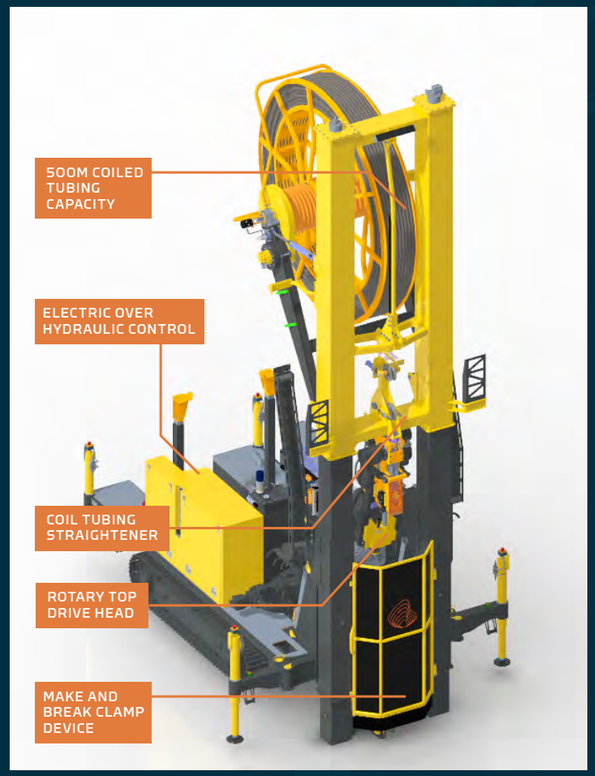
Australian Government
Department of Industry, Science and Resources

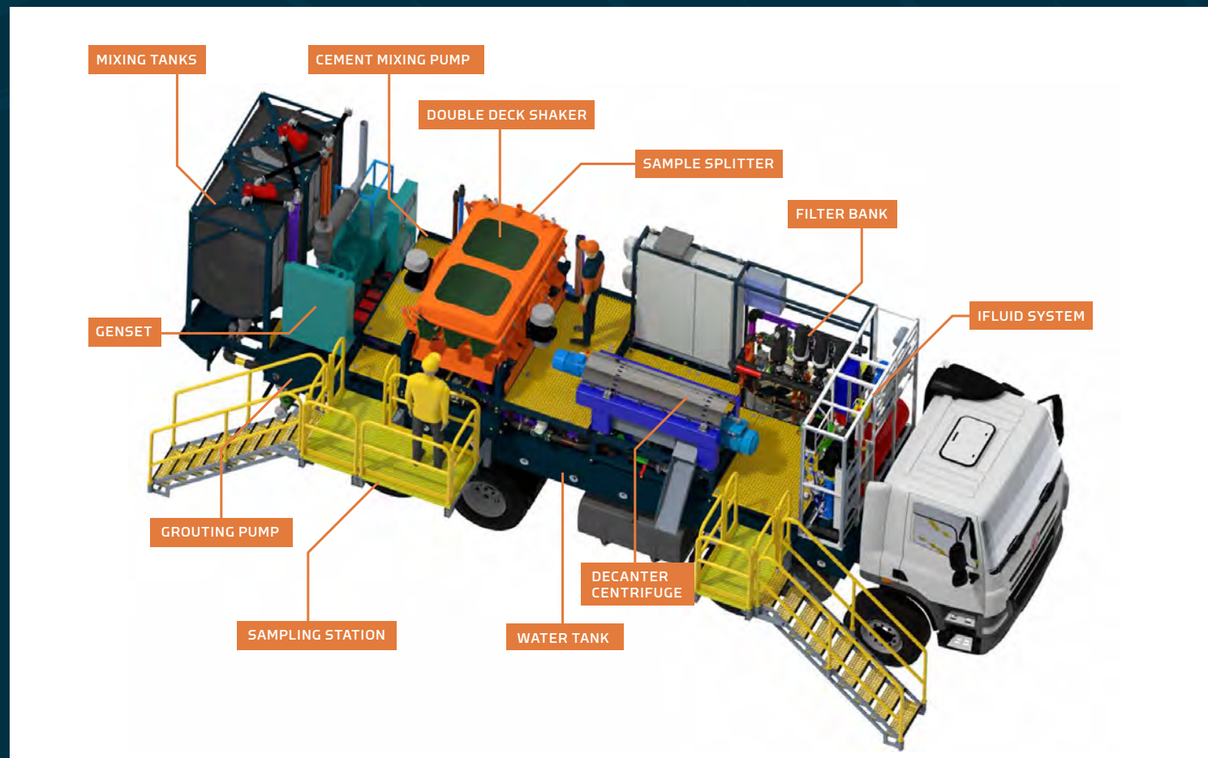
AusIndustry
Cooperative Research Centres Program

ROXPLORER® CT DRILLING SYSTEM

COILED TUBING DRILLING AND SAMPLING FOR GREENFIELDS MINERAL EXPLORATION

The RoXplorer® is a unique coiled tubing (CT) drilling platform that delivers the safety, environmental and productivity benefits of CT drilling in a light weight, agile and robust platform suitable for mineral exploration drilling. RoXplorer® is designed to drill unconsolidated cover and hard rock formations delivering high-quality samples of drill cuttings and core to depths of 500m.





Innovative

The key feature of RoXplorer® CT drill rig is the patented mast design and over-the-hole positioning of the coil reel with multiple benefits including:

- Increased coil life
- Seamless transition between CT and conventional top-drive drilling
- Rapid loading and unloading of tooling
- Drill string incorporated on the rig for ease of set up, pack down and transport

Fluid management for the RoXplorer® CT drilling platform is provided by a purpose-built Hydraulic Processing System (HPS), coupled with a universal polymer fluid additive, LiqiCTrol. The HPS and LiqiCTrol deliver benefits over-and-above conventional mud systems including:

- Reduced fluid management costs
- Real-time and remote monitoring
- Automated dosing
- Multifactor performance optimisation (cuttings transport, sample quality, fluid cleaning, bore hole integrity)
- Agile response to changed or adverse conditions (e.g. to mitigate fluid loss events)
- Reduced wear on downhole tools

Functional simplicity

The RoXplorer® CT platform has been designed to deliver priority drilling functions (safety, efficiency, productivity, high quality sampling) with minimal infrastructure and streamlined operating processes.

The RoXplorer® drill rig features a compact and reliable design with a diesel deck engine, hydraulic system and drill coil incorporated on the track-mounted platform weighing 16 tonnes. (use total weight including coil).

The electric-over-hydraulic control system and drillers console with ergonomic graphic user interface delivers constant feedback to the driller enabling informed decision making. The operator console can be positioned to give maximum comfort to the driller in changeable environmental conditions.

The HPS incorporates all fluid management functions (cleaning, additive preparation and dosing, monitoring) and cuttings sampling onto a single, truck-mounted platform. The RoXplorer® CT system is completed by attaching hoses between the drill collar, HPS and drill coil to close the fluid circuit.

Sensors on the drill rig and HPS provide continuous measurement of drilling and fluid parameters and allow for remote monitoring and automated adjustment of the drilling and fluid parameters according to drilling conditions.

Safe

While drilling in CT mode there are no rod connections and no spinning drill rods on surface, effectively removing two of the most significant safety hazards on the drill site.

Energy and water efficient

The RoXplorer® CT drilling platform has low energy and water consumption compared to top-drive rotary and pneumatic percussion drilling systems.

No energy is used spinning drill rods and less energy is required to drive downhole motors and hammers using non-compressible fluids compared to pneumatic drilling systems.

All drilling fluids are recirculated through the HPS to the drilling operation removing the need for fluid sumps on the drill site and reducing the risk of surface spills.

Continuous fluid monitoring and dosing with LiqiCTrol mitigates fluid loses to the formation and helps maintain hole integrity.

Agile

The RoXplorer® CT drilling platform and all support vehicles can be accommodated within an area of less than 20 x 20 meters.

Mobilisation to remote locations can be achieved with three vehicles (excluding a water truck) with set-up to drill within three hours of arrival at the drill site.

The RoXplorer® offers wireless tramming and set up functions for added safety and mobility on the drill site. Tramming (at 6km/h) provides an alternative transport mechanism over short distances or in areas with poor road access.

High quality sampling

The dynamics of fluid and cuttings transport within the drill hole and through the RoXplorer® and HPS are predictable and can be managed to deliver high quality cuttings samples that are representative of the interval drilled.

The HPS includes a cuttings sampling system which can be tuned by the user to a chosen sample volume and particle size threshold (with minimum mesh size of 150µ).

Cuttings sample quality and depth fidelity have been benchmarked by twinning rotary mud/diamond and RC drill holes in multiple drilling scenarios and ground conditions.

Cuttings samples are well-suited to in-field analysis (e.g. pXRF, hyperspectral scanning) for real time generation of geological data.

The ability to collect drill core delivers a key benefit for mineral exploration end-users who place high value on rock texture and structural information collected from the bore hole.

Productive

Removal of rod connections from the drilling operation increases the effective drilling time (bit-on-bottom) delivering consistent and predictable drilling productivity.

Rapid tripping (~20m per minute) allows bit changes and alterations to the bottom hole assembly (BHA) to be made safely and with little impact on productivity.

Fit-for-purpose of bottom hole tools consistently deliver penetration rates of >10m per hour when drilling ahead in CT mode with blade, drag or percussion bits.

Versatile

RoXplorer® offers multiple modes of CT drilling to suit ground conditions and drilling purpose. Downhole motors coupled with blade or drag bits deliver best performance in unconsolidated cover materials. Hammers and percussion bits penetrate rapidly through hard rock. Intervals of 43.9mm diameter core (equivalent to NQ) up to 3m in length can be taken by drilling with the Selective Coring Interval BHA.

Industry Participants:

AngloAmerican · BHP · Epiroc · SOUTH32 · wassara · mriwa

Research Participants:

Curtin University · CSIRO · University of South Australia

TECHNICAL SPECIFICATIONS

RoXplorer®

Dimensions	Metric	Imperial
Length	8.3 m	27.2 ft
Width	2.5 m	8.2 ft
Height, Mast Down	3.3 m	10.8 ft
Weight	16 tons	26k lbs

Hydraulic Processing System (HPS)

Dimensions	Metric	Imperial
Length	11.3 m	37.1 ft
Width	2.5 m	8.2 ft
Height	4.3 m	14.1 ft
Weight, Empty	23 tons	46k lbs

RoXplorer®	Description	Metric	Imperial
Injector	Thrust	3500 kgf	7716 lbf
	Pullback	7000 kgf	15430 lbs
	Max ROP	1500 mm/min	5 ft/min
	Max Tripping Speed	20 m/min	65 ft/min
Coil Tubing	Reel Capacity	500 m	1640 ft
	Tubing Size	44.45 mm OD x 4.8 mm WT	1.75" OD x 0.19" WT
	Estimated Life	Up to 935 cycles	Up to 935 cycles
Mast	Telescopic Stroke	3.35 m	11 ft
	Max Tooling Length	4.2m	13.8 ft
Water Pump	Max Flow	240 L/min	63.4 gpm
	Max Pressure	280 Bar	4060 psi
Crawler	Max Speed	5 km/hr	3 mph
	Max Approach	15°	15°

Hydraulic Processing System (HPS)	Description	Metric	Imperial
Tanks	Fresh Water (in frame)	8000 L	2113 gal
	Ctrol Storage	4000 L	1056 gal
	Shaker Tank	300 L	79 gal
	Centrate Tank	50 L	13 gal
Gen Set		150kVA	150 kVA
Shaker	Double Check	150µ screen	0.002" screen
Centrifuge	CDNX200		
Grout Pump		12.24 l/hr up to 16 bar	0.05 gpm up to 232 psi

RoXplorer® (CT) Information – Casing Installation

Max Rotary drilling bit diameter	121.0 mm	4.75”
Max PQ casing installation depth	60 m	200 ft
Max HQ casing installation depth	250 m	800 ft

RoXplorer® (CT) Information – Coil tube drilling

Max drilling bit diameter	95 mm	3.74"
Min drilling bit diameter	60 mm	2.36"

RoXplorer® (CT) Information –Selective coring

Hole Diameter	60 mm		2.36"
Core Diameter	43.9 mm		1.73"
Core Length	1500mm or	3000mm	59" or 118"

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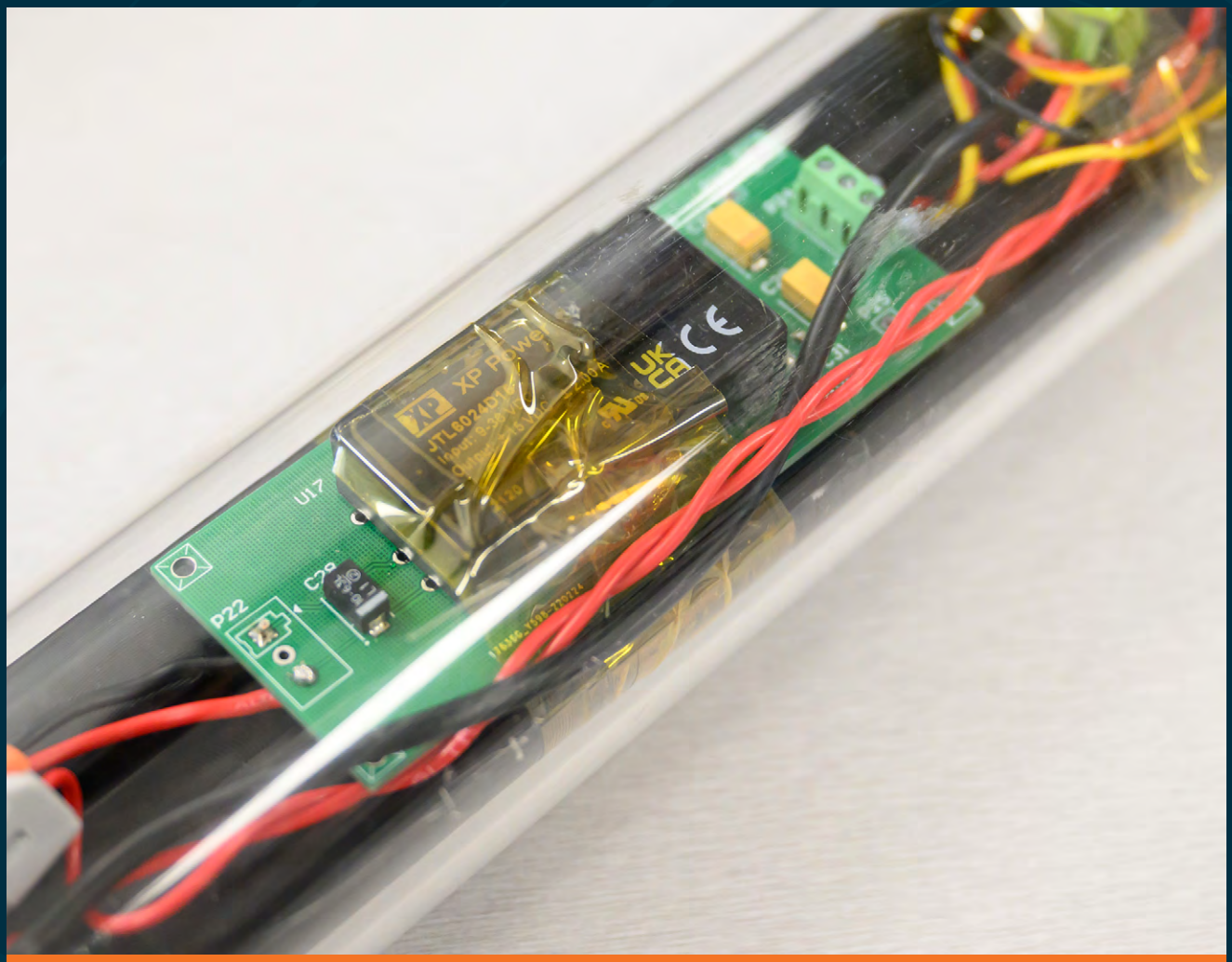


DOWNHOLE SWEPT FREQUENCY EM TOOL

BRINGING NEW EXPLORATION TECHNOLOGY TO MARKET

RELIABLE, SENSITIVE DOWNHOLE EM FOR FREQUENCY DEPENDENT CONDUCTIVITY AND MAGNETIC SUSCEPTIBILITY

MinEx CRC are developing a downhole swept frequency electro-magnetic (EM) tool. The technology is documented in a confidential patent application. The tool incorporates an electromagnetic sensor system, that facilitates rapid cycling across frequency ranges between ~1000 to 100,000Hz, with multiple advantages over single or dual frequency tools. The prototype tool fits within NQ diameter boreholes and can be deployed by wireline or fitted to the drill string for logging-while-tripping or logging-while-drilling applications.

Exploration value of downhole EM

Borehole electro-magnetic (EM) tools have proven value in mineral exploration due to their potential to 'see' variations in electrical conductivity in the rocks surrounding a borehole. Rocks with high conductivity include many orebody types, particularly those containing a high proportion of sulphide minerals. These include critical minerals that underpin modern life.

The distance that EM tools can 'see' around the borehole (known as the radius of investigation, ROI) has a dependence on the transmitted frequency and the conductivity distribution in the formation. Conventional EM tools with single or dual frequency are limited to delivering averaged conductivity estimates of the material within relatively narrow ROIs. Tools of specific frequency need to be carefully chosen to match target characteristics and ground conditions.

In contrast, the MinEx CRC broad bandwidth swept frequency tool delivers rich EM information content, with enhanced ROI at each frequency sweep. The MinEx CRC system has numerous advantages over single or dual frequency tools.

Advantages of the swept frequency EM

Swept frequency EM has a number of advantages:

- Wide range of penetration depths (ROI)
- Broad application across different target characteristics and ground conditions
- Enhanced potential to detect off-hole features
- Signal-to-noise is readily optimised for targeted geo-electrical settings
- Rich, multidimensional EM data with potential to apply ML techniques

MinEx CRC Downhole Swept Frequency EM Tool

MinEx CRC are developing a first-of-a-kind downhole Swept Frequency EM Tool intended to deliver the benefits of broad bandwidth EM in a robust, driller operated tool suitable for deployment by traditional wireline or attached to the drill string.

Several prototype tools have been fabricated and successfully trialled in Curtin's deep research borehole, to a depth of 900m.

MinEx CRC Researcher, Hoang Nguyen (Curtin University).

MinEx CRC Communications Manager, Anna Porter.

Fit for purpose

The sensor system is small, light (less than 1kg), with independent power, independent data storage and a wireless communications system.

When assembled in its housing, the prototype tool has a length of ~1.7m and weight <5kgs making the prototype Swept Frequency tool lightweight, independent and easy to transport.

The assembled prototype has an outer diameter of 60mm. Significant further miniaturisation for future version of the tool is readily achievable.

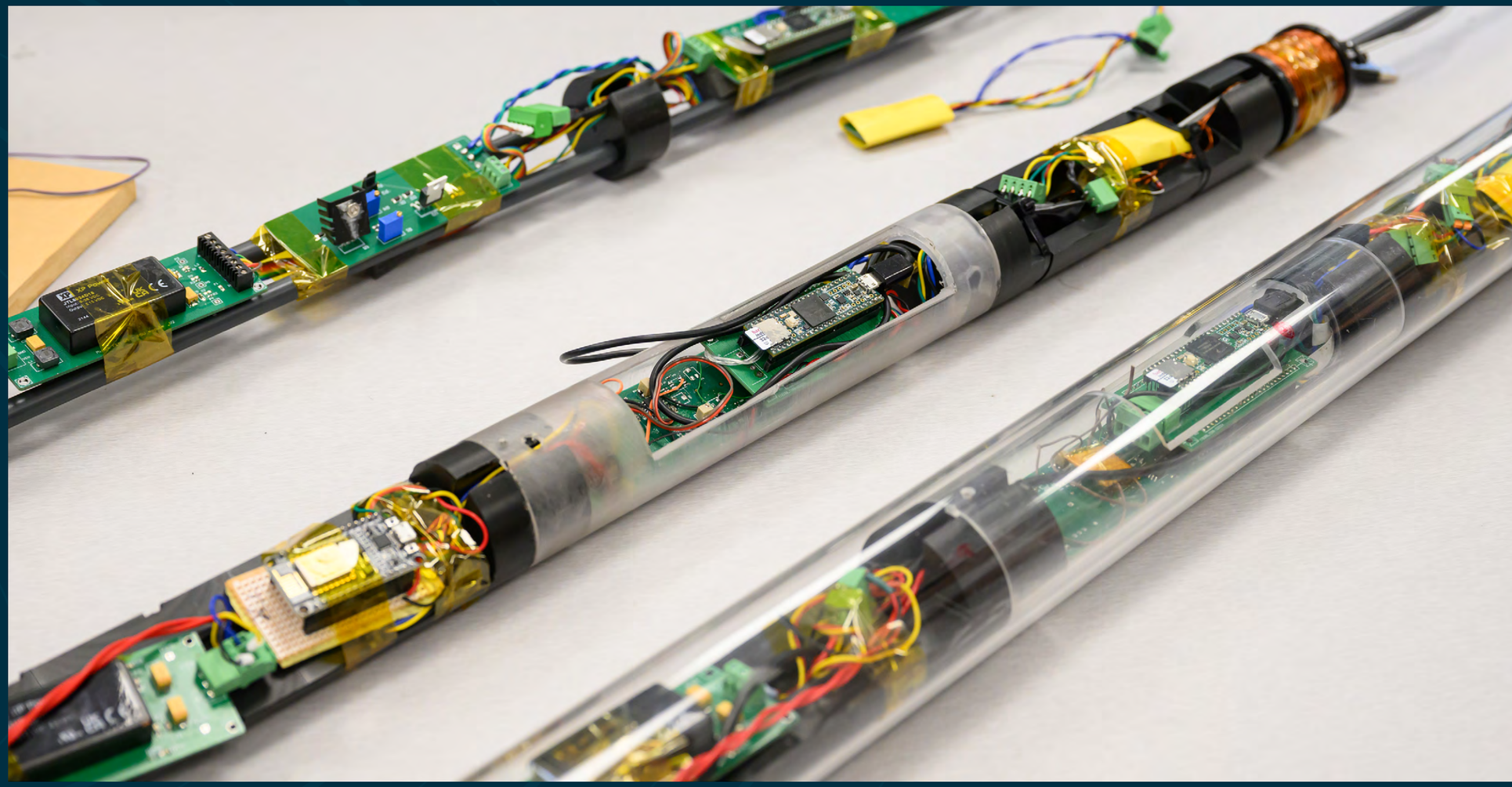
The tool will be driller deployable; either by wireline or by attachment to the drill string bottom hole assembly for logging-while-tripping applications.

Logging can be conducted in parallel with complimentary survey and geophysical logging techniques with little to no additional time penalty.

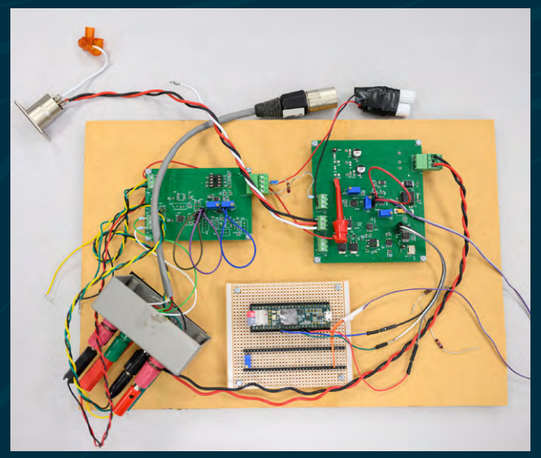
Reliable, quantified analyses

Test results and calibration of the MinEx CRC downhole swept frequency tool are underway. Several comparisons of the sensor response with conventional induction logging tool have been completed.

Ultimately standardised calibration procedures and processing methods will be provided to users to ensure accurate, precise analyse.



Prototype evolution of the downhole swept Frequency EM tool.



Rudimentary design stages of the downhole swept Frequency EM tool.

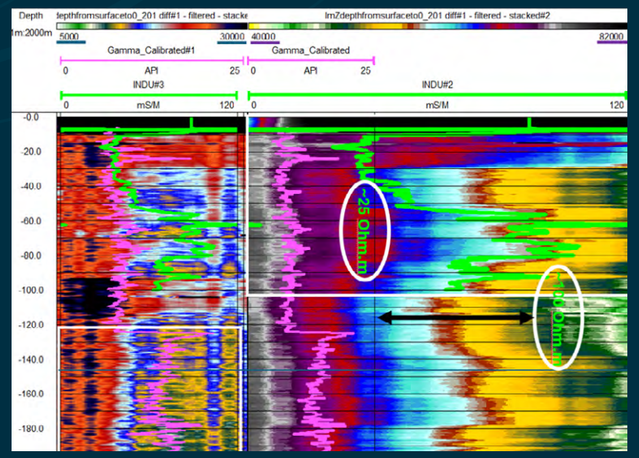


Image representations of uncalibrated data generated by the MinEx CRC swept frequency tool compared to single channel conventional gamma and induction wireline logs (the current swept frequency prototype swept frequency sensors generates 400 channels of data at each depth measurement).

TOOL OPERATIONAL SPECIFICATIONS

Physical	
Length	100 to 150cm (depending on tool configuration)
Diameter	60mm
Weight	4 to 6 kg (depending on tool configuration)
Pressure rating	10MPa (suitable for 1000m borehole)
Temperature rating	100ºC (suitable for all minerals drilling)

Technique	
Conveyance	Wireline or rig deployed on BHA (enables logging-while-tripping)
Data capture	Memory or uphole comms link depending on deployment method
Logging speed	Up to 10 m/min (logs 500m hole in 50 minutes)

* These numbers are based on our existing advanced prototype tools. However ultimate design of the sensor is flexible allowing it to be incorporated into a range of tools with physical specifications and deployment options optimised for the intended function.

PROJECT PARTICIPANTS

Project Industry Participants

IMDEX™

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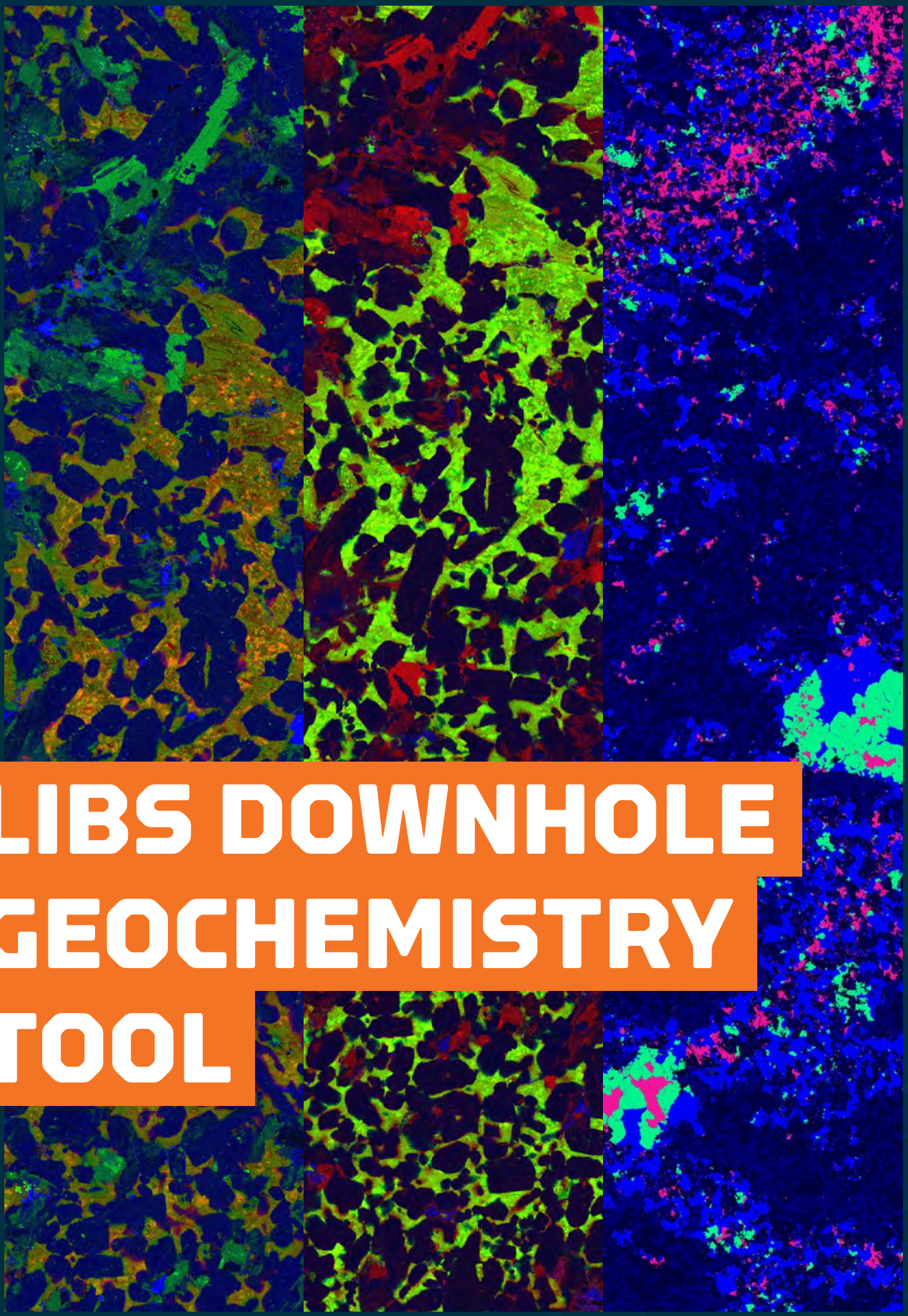


LIBS DOWNHOLE GEOCHEMISTRY TOOL

QUANTITATIVE, HIGH-RESOLUTION DOWNHOLE GEOCHEMISTRY FOR MINERAL EXPLORATION AND RESOURCE DRILLING

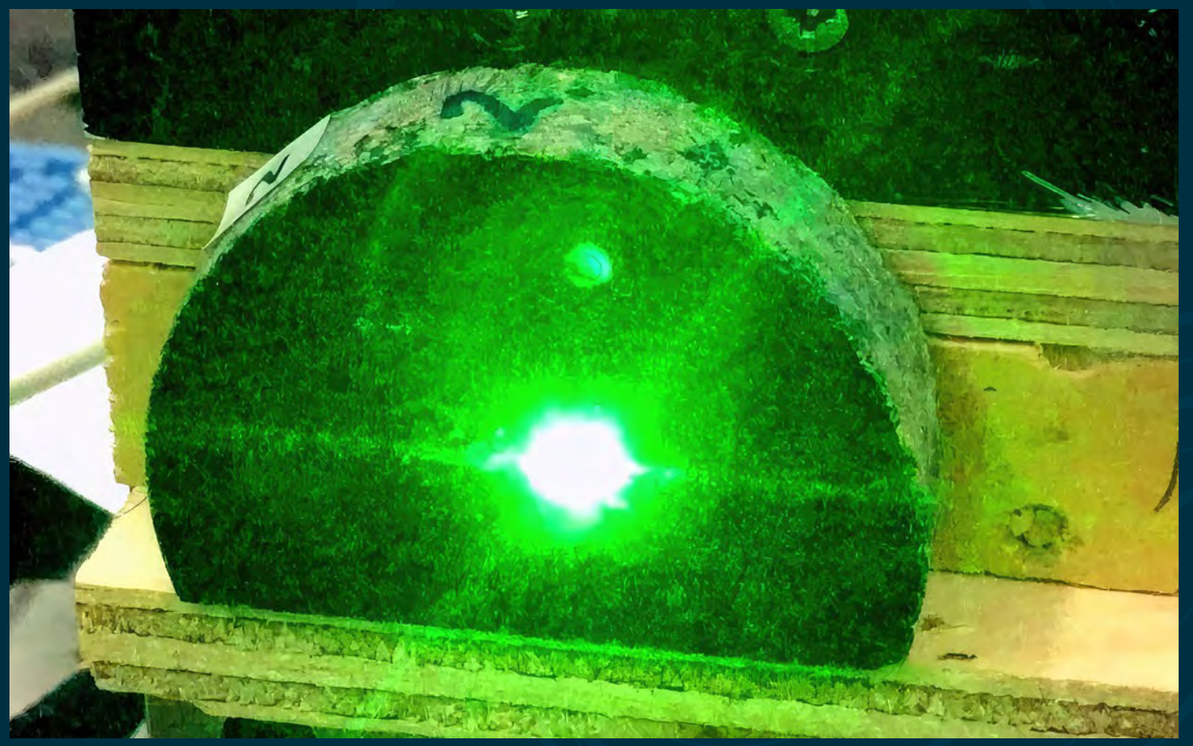
MinEx CRC is developing a downhole geochemical tool utilising Laser-induced Breakdown Spectroscopy (LIBS). The tool incorporates a high-powered, variable-focus laser and optics, and spectrometers capable of detecting all elements on the periodic table to part per million levels. The prototype tool fits within NQ diameter boreholes and can be deployed by wireline.

Introducing LIBS

Laser-induced Breakdown Spectroscopy utilises a rapid pulsed laser focussed on the analyte to generate a high-temperature plasma containing ionised material from the analyte. As the plasma cools all elements within it emit light at discrete, measurable wavelengths between ~200 and 900 nm (similar to the visible range for the human eye). The resulting spectral signature is a quantifiable fingerprint of the analyte composition.

LIBS analysers comprise a laser responsible for generating the plasma, optics for capturing and delivering the light signal, spectrometers for detecting the spectra, and back-end processing (e.g. deconvolution, multivariate analyses, calibration) for elemental identification and quantification.

The LIBS technique has had wide application in materials classification and quantification including in deep sea and extra-terrestrial settings. In the last decade handheld LIBS analysers have been commercially available to the mineral exploration community and more recently 2D LIBS scanning tools for detailed chemical and textural mapping have entered the market.



LIBS plasma

Advantages of the LIBS technique

LIBS has a number of advantages over other potential in-field, real-time analytical techniques including:

- It can be applied to solids, liquids or gasses
- Little or no sample preparation is required
- It can detect all elements in every pulse, including light elements (e.g. helium, lithium, nitrogen, oxygen, carbon) that are not easy to measure with other in-field techniques
- It is effectively non-destructive due to the very small analytical area

MinEx CRC Downhole LIBS tool

MinEx CRC are developing a first-of-a-kind downhole LIBS tool intended to leverage the benefits of the LIBS technique to solve the challenge of obtaining real-time, in-hole geochemistry during a drilling campaign.

The all-in-one prototype tool has been fabricated and successfully trialled in simulated borehole conditions in the laboratory. Field trials are scheduled in 2024.

Prototype downhole tool

Safe

The downhole LIBS tool does not contain a permanent source of harmful radiation.

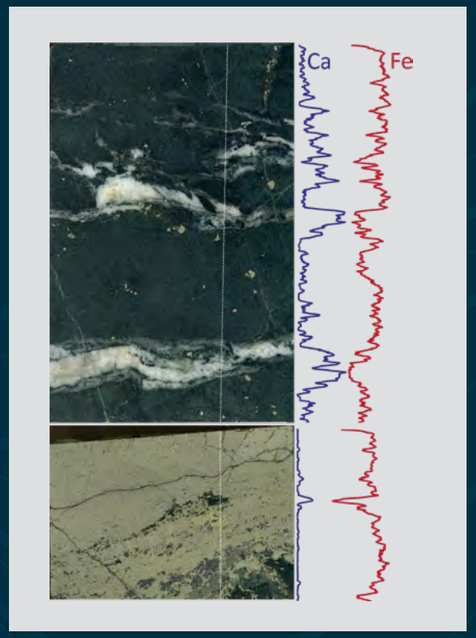
The in-built laser is switchable and can be configured to operate only when deployed in the borehole.

Fit for purpose

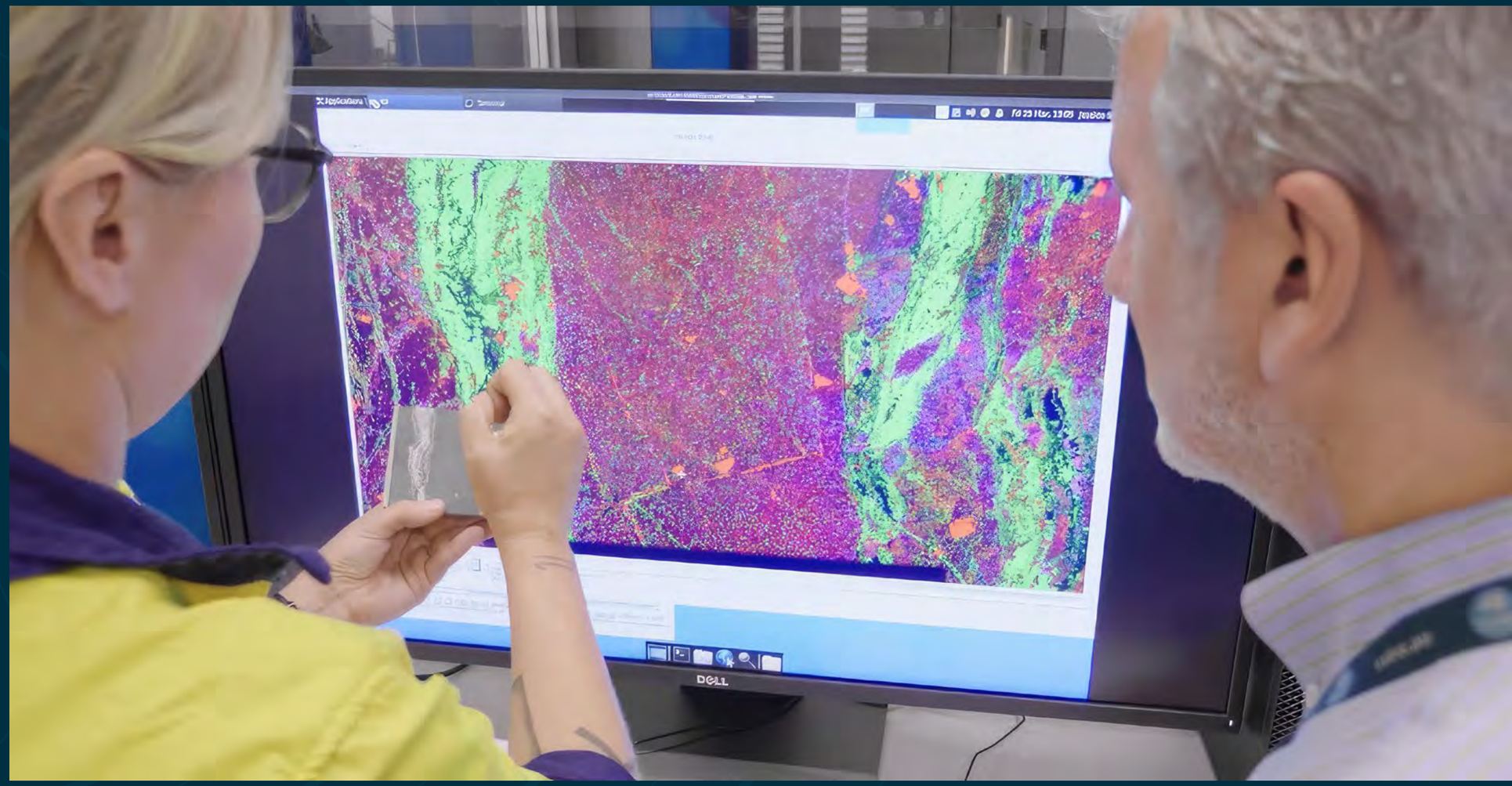
With a length of ~1.7 m and weight of <5 kgs the LIBS prototype tool is lightweight and easy to transport.

The prototype tool has outer diameter of 75 mm, designed to fit within NQ boreholes. Further miniaturisation will be explored in future versions of the tool.

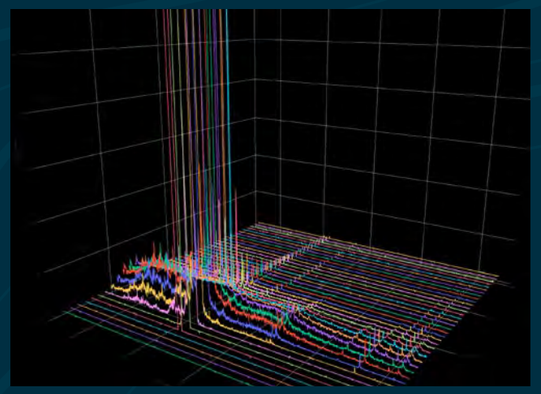
The tool will be driller deployable by wireline and geochemical logging can be conducted in parallel with complimentary survey and geophysical logging techniques with little to no additional time penalty.



Grain-scale analytical signal



Calibration against real rocks



High quality spectra

Scalable data

At logging rates of 2 to 10 m/min and typical sampling rates of 10 Hz the LIBS tool will deliver 60 to 300 individual analyses per meter.

Each LIBS analysis represents an area of <100 µm – at mineral grain-scale for most geological materials. As a result, the output from a LIBS traverse of the borehole wall is highly scalable. It can be broken down into individual mineral (and mixed mineral) observations or bulked out over hand-specimen (decimeter) or mining-scales (meter) depending on geological or engineering parameters.

Reliable, quantified analyses

Preliminary results from the prototype MinEx CRC LIBS downhole tool indicate that analytical precision and detection limits will be comparable to commercially available hand-held LIBS analysers. Detection limits are expected to be at part per million levels for most elements.

Standardised calibration procedures and analytical standards will be provided to users in order to ensure accurate and precise analyses.

DOWNHOLE PROTOTYPE SPECIFICATIONS

Physical	
Length	1.7 m
Diameter	75 mm
Weight	~4 kg
Power	24 V

Technique	Laser Induced Breakdown Spectroscopy (LIBS)
Focal length	Active focus system 20-150 mm
Deployment type	Wireline
Deployment speed	10 m/min
Deployment conditions	Dry and open borehole

Data	
Spectral resolution	<0.2 nm
Data processing	Physics-Informed Machine Learning Model
Elements	All of them

TRL	
Focal length	4 – Component validation in laboratory environment. Preparing for validation in relevant environment/field trial (TRL 5)
Software	2-3 – Technology concept formulated TO Analytical and experimental critical function proof-of-concept

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