CSIR FUTURE PRODUCTION: MINING

The research and innovation partner of choice for the mining industry and its stakeholders

science & innovation
Department:
Science and Innovation
REPUBLIC OF SOUTH AFRICA

CSIR
Touching lives through innovation

Artificial intelligence application of sensing, data analytics and artificial intelligence for **improved decision making**

Innovative solutions for **sustainable economic growth**

Safer environments through automaton and robotics

Sustainable **post-mining rehabilitation solutions**

ABOUT THE CSIR

The Council for Scientific and Industrial Research (CSIR) is a leading scientific and technology research organisation that researches and develops transformative technologies to accelerate socioeconomic prosperity in South Africa.

The organisation's work contributes to industrial development and supports a capable state. The CSIR is an entity of the Department of Science and Innovation.

The organisation plays a key role in supporting the public and private sectors through directed research that is aligned with the country's priorities, the organisation's mandate and its science, engineering and technology competences.

The nine high-impact sectors identified by the CSIR to achieve its aims are:

Industry advancement clusters

- Advanced Agriculture and Food
- NextGen Health
- Future Production: Chemicals
- Future Production: Mining
- Future Production: Manufacturing
- Defence and Security

Industry and society enabling clusters

- Smart Places
- Smart Mobility
- NextGen Enterprises and Institutions

ABOUT CSIR FUTURE PRODUCTION: MINING

The CSIR's Mining cluster

CSIR Future Production: Mining aims to partner with industry and support the revitalisation of the growth of the industry through:

- Innovations in processes and technologies aimed at improving safety, health and environment for the mining industry;
- The diffusion of appropriate innovative solutions to drive efficiency and improvements in productivity;
- The development of relevant capabilities to support sustainable economic growth of the mining Industry; and
- The improvement of socioeconomic development conditions in the mining industry and communities.

The CSIR's Future Production: Mining cluster builds strategic relationships with industry partners and, together, agree on and identify opportunities to innovate, localise and diffuse transformative technologies in South African mining.

With a track record of more than 75 years of scientific research, the CSIR is a research partner of choice – one that has made significant contributions to the sector. This includes pioneering rock engineering research in South Africa in the 1950s, amassing technical expertise over decades and honing a thorough understanding of mining processes and methodologies, including access to unique, independent, International Organisation for Standardisation-certified (ISO), testing and verification services, training and other infrastructure and tools required for safe and efficient mining operations.

The CSIR places emphasis on continuously remaining at the cutting edge of innovation and technological advances, performing critical technology roadmaps and undertaking foresight exercises to prepare the sector for the future.

Clients also benefit from blended skills from the CSIR's multidisciplinary science and engineering base. These include fourth industrial revolution technologies and the expertise of environmentalists; physicists; chemists; mathematicians; digital innovators; radar, photonic and optronic experts; robotics and simulation specialists; and enterprise and systems engineers – to name but a few – all with access to the necessary infrastructure and tools for their trades.

The technical experts within CSIR Future Production: Mining apply their skills in two impact areas, namely Mining Testing and Training, and Mining Minerals Resources.

CSIR FUTURE PRODUCTION: MINING **IMPACT AREAS**

MINING TESTING AND TRAINING IMPACT AREA

Many factors contribute to safety risks in mining – fall of ground, transportation and handling of powerful machinery, to name a few. Over decades, the South African mining industry has been able to improve mine safety and reduce fatal incidents. However, the goal remains zero harm.

The CSIR is geared to provide quality, independent testing and verification services, targeted training, relevant research outcomes and competent technical advice in support of the industry-wide goal of Zero Harm. These include:

- Annual monitoring and legislated performance acceptance testing of existing and new self-contained self-rescuer designs/models;
- Proof-load, destructive and other mechanical testing of mining components, such as mine support, hoisting and lifting gear;
- Monitoring and analysis of workplace air pollution to minimise human exposure;
- Mine fire and explosion safety awareness training seminars;
- Testing and evaluation of fire and explosion suppression products and systems; and
- Conducting mining health and safety related research and providing specialist technical advice.

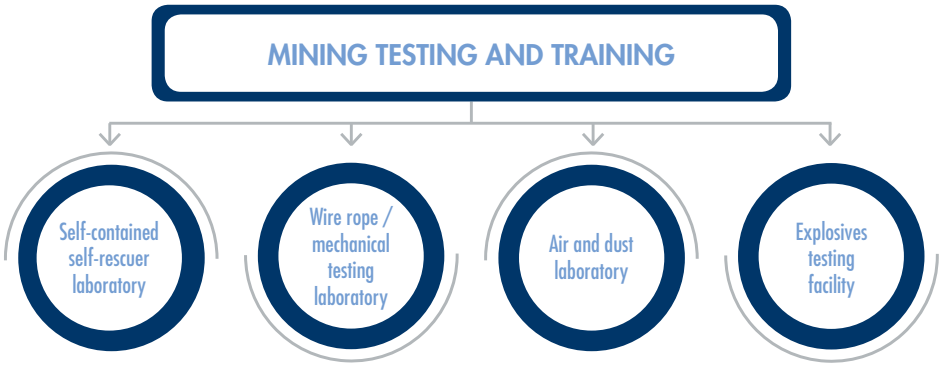


Figure 1: Mining Testing and Training Impact Area structure

CSIR FUTURE PRODUCTION: MINING **IMPACT AREAS**

CSIR SELF-CONTAINED SELF-RESCUER LABORATORY (COTTESLOE)

The CSIR established a self-contained self-rescuer (SCSR) laboratory and an industry-wide monitoring programme to detect any unacceptable deterioration in the functional performance of the SCSRs used by mines. The CSIR is the only approved testing authority in South Africa mandated by the Department of Mineral Resources and Energy to monitor the functional performance of these devices.

ITS OFFERINGS INCLUDE:

- Functional performance testing of SCSRs on the breathing simulator machine and practical performance tests, namely laboratory treadmill, underground field trials and mine training gallery as part of acceptance/approval testing of new SCSR designs/models;
- Product development testing for SCSR Original Equipment Manufacturers;
- Development of SCSR technologies; and
- An annual monitoring programme – sampling from all SCSR users in mining and construction across South Africa.

The CSIR serves on the Mine Health and Safety Council Tripartite Technical Committee for self-contained self-rescuers to provide technical advice on, for example, product quality issues, and participates in SCSR incident investigations. The CSIR also serves on the South African Bureau of Standards Technical Committee (TC94/SC15, Personal protective equipment – Respiratory equipment) and contributed significantly to the development of SANS 1737 on which the CSIR frequently provides consultation to local and international clients specifically about the application of SANS 1737 during research and development testing.

Over the years, the CSIR has invented and patented some critical components of SCSRs. The inventions include:

- Mouthpieces;
- Canister gas seals;
- Protective housing for chemical canisters;
- Training devices (Experiential trainer);
- Flexi-systems; and
- Patented nose clips which, together with novel mouthpieces, are extensively used by equipment manufacturers that supply the South African mining industry.

CSIR MECHANICAL AND ROPE TESTING LABORATORIES (COTTESLOE)

The CSIR mechanical testing laboratory, which was established in 1935, houses two of the largest mechanical testing machines in South Africa, which accommodates large-load test specimens such as mine support products, hoisting equipment and lifting gear. Tests are performed in compliance with legislative standards and to promote the general safety of workers in mining, manufacturing and construction.

ITS OFFERINGS INCLUDE:

- Proof load testing within a 10 kN to 15 MN force range;
- Destructive testing in tension and compression;
- Load comparison testing/force calibration;
- Destructive tensile testing of steel wire ropes;
- Tensile testing of conveyor belt splices; and
- Rope failure inspections and investigations.

The rope testing laboratory is accredited by the South African National Accreditation System (SANAS) for compliance with the ISO 17025 standard, ensuring testing at international benchmark standards.

CSIR AIR AND DUST LABORATORY (PRETORIA)

The CSIR air and dust laboratory undertakes analysis of environmental air quality through, for example, the occupational hygiene filters of mine employees. The laboratory was the first of its kind to obtain SANAS accreditation for the NIOSH 5040 method and the direct-on-filter analysis using X-ray powder diffraction according to international method MDHS 101.

ITS OFFERINGS INCLUDE:

- Analysis of airborne pollutant samples such as respirable dust (the cause of silicosis) and diesel particulate matter;
- Monitoring and analysis of industrial air pollution such as stack sampling, and collection and analysis of fallout dust;
- Development of analytical methods; and
- Research in the field of human exposure to airborne pollutants.

FIRES AND EXPLOSION RESEARCH, TESTING AND TRAINING FACILITY (KLOPPERSBOS)

The CSIR-managed fires and explosion testing and training facility at Kloppersbos is located approximately 40 km north of Pretoria. The size and location of the facility allows controlled large-scale coal dust/methane explosions as live demonstrations when training mine workers.

SERVICES INCLUDE:

- Mine fire and explosion safety awareness training seminars;
- Fire and explosion suppression/mitigation product testing and evaluation;
- Conveyor belt fire retardant property testing;
- Explosibility testing of coal dust and industrial dusts such as those in the pharmaceutical, food and chemicals sector; and
- Evaluation of mine ventilation products and systems.

MINING AND MINERAL RESOURCES IMPACT AREA

CSIR areas of competence in this area include rock engineering, geotechnical engineering, geophysics and mining engineering

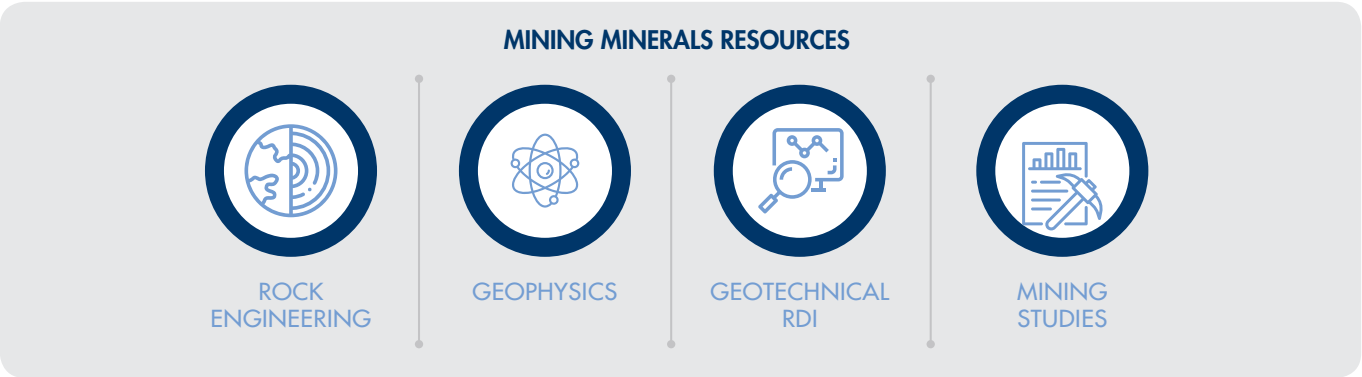


Figure 2: Mining Minerals Resources Impact Area Structure

ROCK ENGINEERING/GEOTECHNICAL ENGINEERING

The CSIR's rock engineering/geotechnical specialists have the technical knowhow and experience to improve the safety and economic viability of mines through efficient data acquisition, underground mine layout and support design, underground mine design optimisation, and open pit slope stability assessments and feasibility studies.

MINING ENGINEERING

The CSIR's mining engineering expertise and project portfolio encompasses an array of sub-disciplines that include mining performance improvement studies, occupational health and safety, ventilation and occupational environmental engineering, socioeconomics, ergonomics and fatigue management.

GEOPHYSICS

The CSIR's geophysics team uses high-resolution geophysical tools, such as 3D and 2D ground-penetrating radar, borehole radar and electrical resistance tomography to address a range of pertinent mining challenges. The applications include orebody delineation, structural mapping to identify reef disruptions, seismic hazard assessments, determination of hanging wall integrity, hazard mapping (such as cavities, potholes and utilities), water pollution mapping, and the effectiveness of rehabilitation processes on previously mined-out areas at open pits. Expertise in this domain has, among others, led to the development of a geophysics textbook, which contributes to human capacity development and knowledge dissemination in the industry.

MINE MODERNISATION

The mining sector remains the backbone of the South African economy. However, the conventional underground gold and platinum group metals mines have been struggling to remain profitable due to a number of challenges, such as increasing operating costs, fluctuating commodity prices, increasing mining depth and poor occupational health and safety performance. Modernisation of the South African mining sector offers an opportunity to improve the viability of the sector (through improved productivity, mining efficiencies and occupational health and safety), stimulate economic growth and create employment opportunities. Therefore, it is the aim of the mining sector to forecast and adopt technological innovations, understand the associated impacts (particularly on skills supply and demand) and develop applicable measures.

To this end, the Mining Qualifications Authority contracted the CSIR to conduct research to investigate the envisaged extent of technological innovation and associated impacts in the mining sector.

The following priorities were determined for the medium and longer terms:

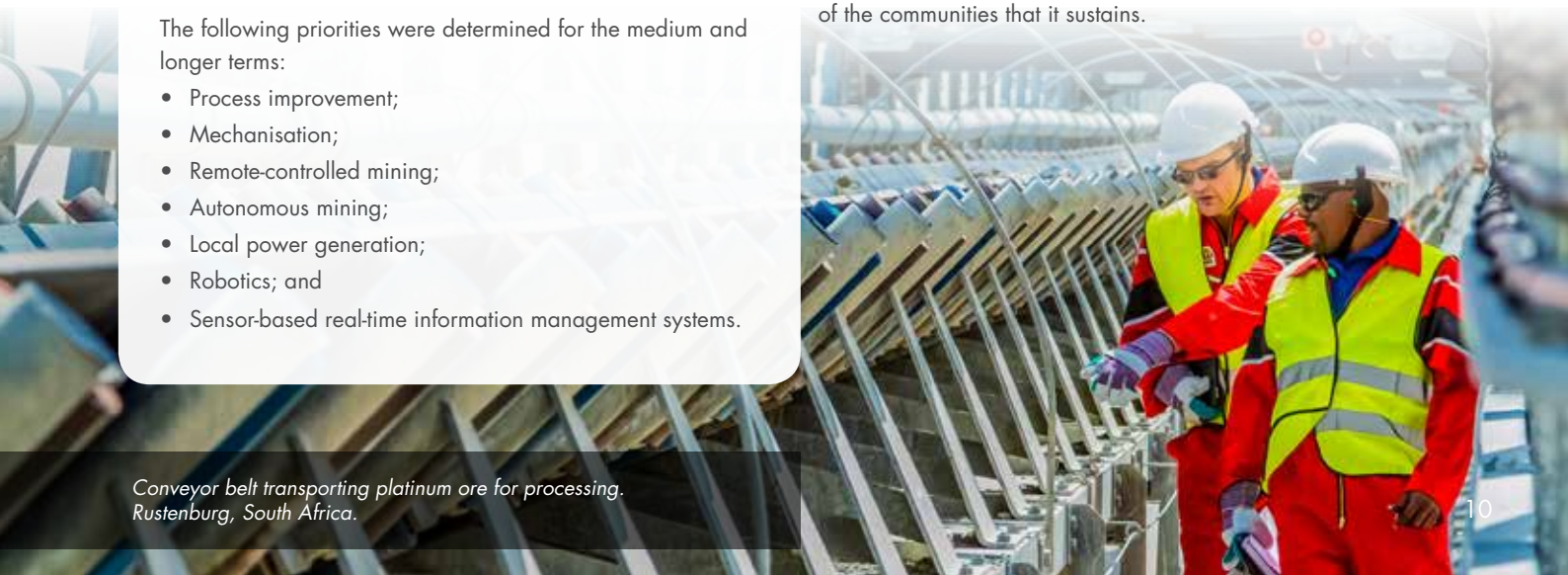
- Process improvement;
- Mechanisation;
- Remote-controlled mining;
- Autonomous mining;
- Local power generation;
- Robotics; and
- Sensor-based real-time information management systems.

There are also critical challenges, namely lack of skills, funding, proper change management, strategic visioning in planning and adopting improved systems thinking approaches.

Sustainable modernisation requires collaboration between all key stakeholders in the mining sector and interventions and incentives from government – particularly in terms of policies on labour, education and training.

The key role that innovation plays in mining modernisation cannot be over-emphasised. It ensures the evolution of safety, health and environmental responsibility through, for example, the design of new processes and technologies. Innovative interventions, if appropriate and efficiently diffused, can drive operational efficiency and productivity to higher levels. This includes the development of relevant and strategic capabilities (skills, expertise and infrastructure).

It is the responsibility of the mining industry to find pathways to positively impact on the socioeconomic standing and conditions of the communities that it sustains.



Conveyor belt transporting platinum ore for processing. Rustenburg, South Africa.

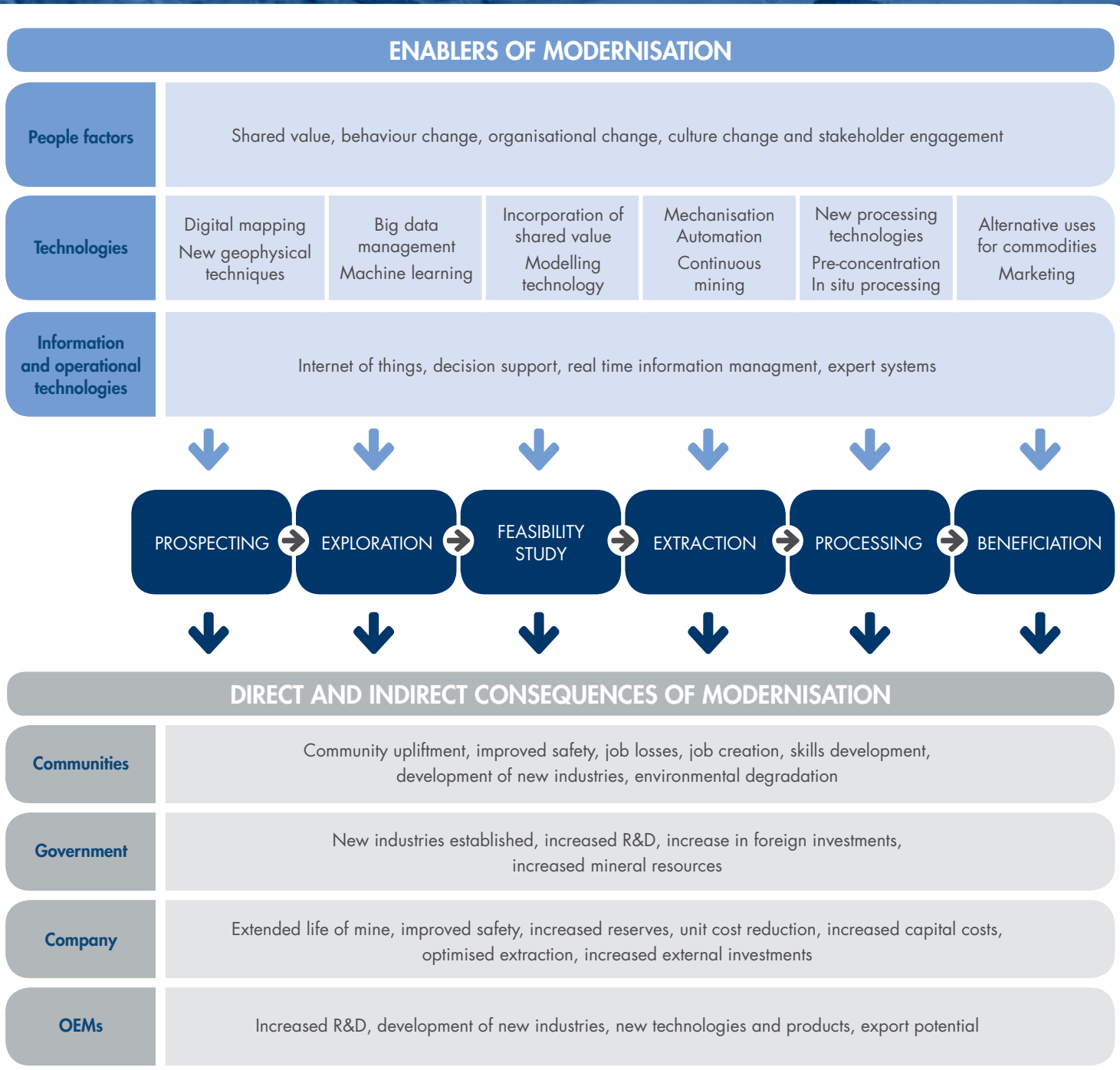


Figure 3: Enabling activities for modernisation components across the mine value chain and potential direct and indirect consequences of modernisation (Ngobese, 2019)

MINING DEVELOPMENT AND OPERATIONS PROGRAMME

The CSIR focuses on processes that ensure efficiency so that mines can maximise the recovery of mineral wealth in a safe and sustainable manner. It also focuses on input resource optimisation, modernised mining engineering and non-explosive rock breaking. CSIR Future Production: Mining is building on current programmes in geophysics and rock engineering, mining engineering, sensor development and robotics and automation. The cluster's priorities include the optimisation of current mining, advanced orebody knowledge, mechanised mining and real-time information management systems.

IMPORTANT ASSOCIATIONS

The CSIR has made a commitment to champion engagements with its various stakeholders from associations and individual mining houses, to key role-players within the public sector and research institutions. This is in recognition of the importance of mutually beneficial partnerships in the interest of a robust and well-supported sector.

MINE HEALTH AND SAFETY COUNCIL

For a number of years, the CSIR has been a strategic research partner of the Mine Health and Safety Council (MHSC). The CSIR is also a proud research partner for the MHSC's Centre of Excellence for occupational health and safety research in the South African mining sector. The R&D undertaken for the MHSC aims to improve conditions in the South African mining industry, in terms of occupational health and safety, thus contributing to the overall industry goal of attainment of Zero Harm.

In addition to its work with national and international organisations and mining companies, the CSIR has a track record of supporting small, medium and micro enterprises. This includes collaborations in the development of mining products to both mining and non-mining sectors, where it is critical to meet relevant safety standards and end user requirements.

THE MANDELA MINING PRECINCT

The Mandela Mining Precinct is a public-private collaboration between the Department of Higher Education, Science and Innovation, and the Minerals Council of South Africa, and is managed by the CSIR. The main objective of this entity, which was launched in 2018, is the implementation of the South African Mining Extraction, Research, Development and Innovation (SAMERDI) strategy, which drives collaborative and sustainable research, development, innovation and implementation of mining technologies in a socially, environmentally and financially responsible manner. The SAMERDI strategy includes the following research programmes: Longevity of Current Mines, Mechanised Mining Systems, Non-explosive Rock Breaking, Advanced Orebody Knowledge, Successful Applications of Technologies Centred around People and Real-time Information Management Systems.

The ultimate benefits of these efforts are renewed vigour in the quality of mining RD&I, the wellbeing of local communities and a competitive industry that contributes positively to the national economy.

PROJECT SHOWCASE

GEOTECHNICAL DATA ACQUISITION

Geotechnical consulting services have been deployed for international and local projects and included:

- Geotechnical data acquisition – Core logging, scanline mapping, rock sampling;
- Rock mass characterisation – rock mass classification systems, analysis of rock strength testing, discontinuity analysis; and
- Training and quality assurance quality control on geotechnical data acquisition.

Geotechnical core logging

Core samples

Measuring of structure on core sample

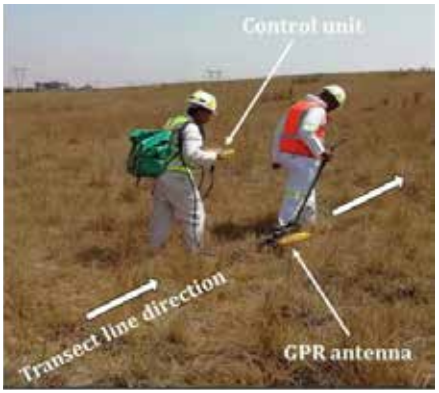
GEOPHYSICAL SURVEYS TO IMPROVE SOIL CHARACTERISATION

The CSIR and the Agricultural Research Council collaborated in a Coaltech funded project to improve the characterisation and assessment of rehabilitated opencast coalmine soils in South Africa, with the aim of using ground-penetrating radar (GPR) to study rehabilitated soils at several sites on opencast coal mines.

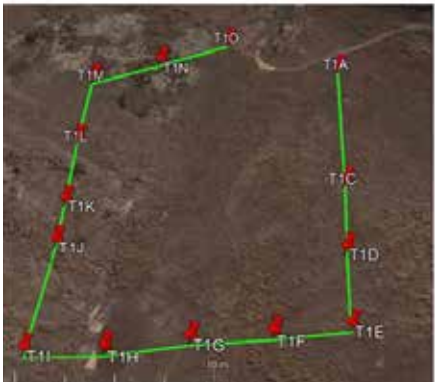
SPECIFIC AIMS OF THIS COALTECH PROJECT INCLUDED:

- Assessing the correlation between GPR results and ground-truthing by soil auger regarding the depth limiting layer of rehab soils – variables studied included seasonal differences (wet summer conditions vs dry winter conditions), soil/spoil interface variability and different GPR antennas (500 MHz vs 1 GHz);
- Obtaining an indication of the spatial variability and occurrence of rehab soils of varying depth classes; and
- Determining the cost and time implications of using GPR for rapid field assessment of rehab sites on opencast coal mines.

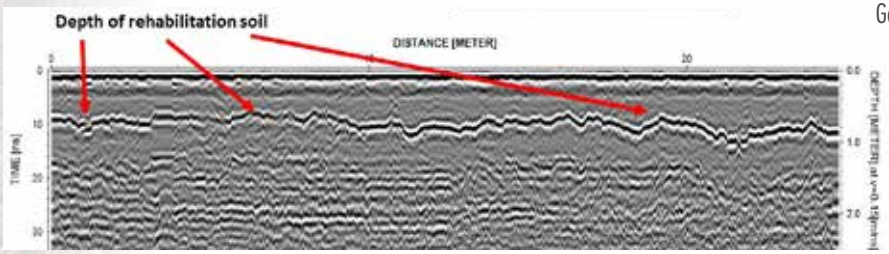
It was found that the success of GPR in determining the depth of the rehabilitation soils is very dependent on the quality of the rehabilitation process. However, the results suggested that the technique can make a significant contribution to accurately and cost-effectively tracking the continuity and undulation of the boundary layer.



Team undertaking the survey



Google map showing survey lines on rehabilitated area at a coal mine

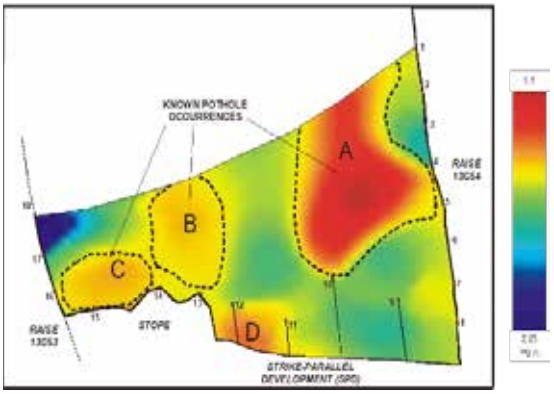


GPR radargram showing the clear transition from rehabilitation soil to underlaying spoil/coal

PROJECTS UNDERTAKEN AND LED BY THE CSIR THROUGH THE SAMERDI ADVANCED OREBODY KNOWLEDGE PROGRAMME

The CSIR has a niche integrated in-mine geophysics offering. An integrated or geophysical toolbox approach includes the following applications or use cases, which are currently being researched and developed:

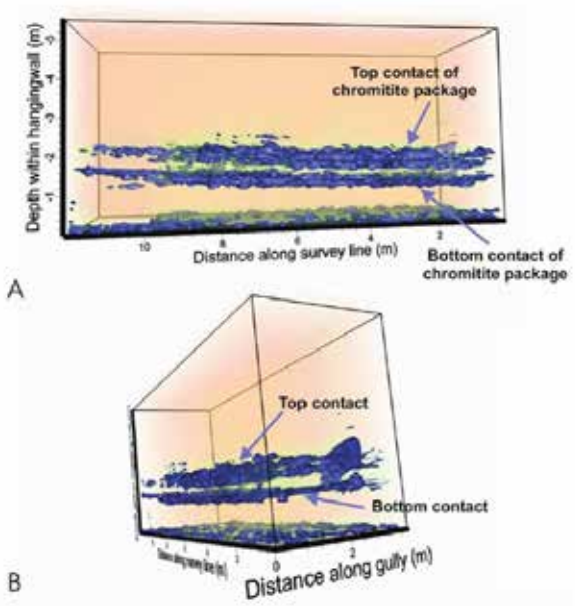
- Ground-penetrating radar surveys (both 2D and 3D) for assessing hanging-wall integrity; and
- Electrical resistance tomography surveys to track reef continuity and delineate reef disruptions.



In-mine geophysics: ERT mapping of platinum potholes

GPR sidewall

Hangingwall



GPR visualisation of hangingwall structures

Training is offered in these areas. The figure below shows a potential use case for the integrated use of the geophysical toolbox to optimise extraction and ensure safe mining. The versatility of the geophysical tools makes it applicable to sectors outside of mining, e.g. hydrogeophysics, environmental studies and civil engineering.

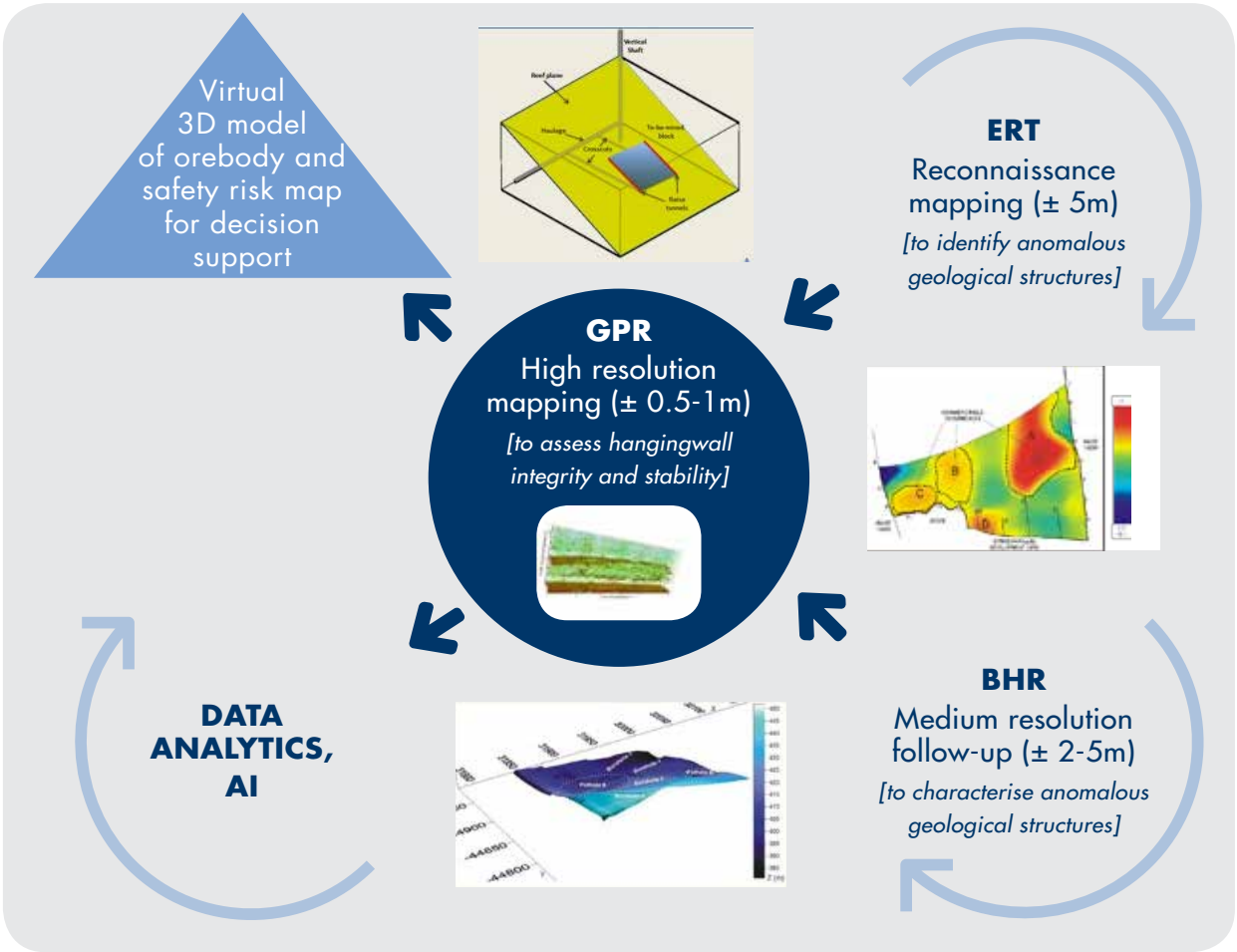


Figure 7: Integrated use of the "geophysical toolbox" to optimise extraction and ensure safe mining

SAMERDI LONGEVITY OF CURRENT MINES PROGRAMME: OPTIMISATION OF SHIFT CYCLES

The CSIR, in collaboration with the University of Johannesburg, developed a draft framework for optimising shift cycles to maximise productivity, while ensuring optimal health and safety outcomes in South African mining operations. Deeper and more expansive gold and platinum mines means workers spend more time to travel from surface to the work place and less working time at the face. This project aims to maximise time at the rock face. Benefits of the framework include considerations of ancillary activities that have an impact on available time spent working at the rock face, and alternate shift cycles, which could lead to improved health, safety and productivity.

SAMERDI SUCCESSFUL APPLICATION OF TECHNOLOGY CENTRED AROUND PEOPLE PROGRAMME

The CSIR, in collaboration with the University of Pretoria and WITS University, participates in the SATCAP programme that focuses on understanding people in the process of mining modernisation. One such project aimed to develop a globally benchmarked strategy for the engagement of workers in the development of equipment by original equipment manufacturers. The research outcomes indicated that human-centred design is necessary, and participatory programmes should be adapted to suit specific contexts. Factors to be considered include management commitment, the creation of multidisciplinary teams, shared understanding of needs, training and development, communication, and evaluation, along with changes to work structures, systems, processes, leadership and trust. The involvement of workers in all phases of equipment design and development was recommended, as the benefits include improved product quality, user acceptance and ownership of the technology.

EXTERNAL FACTORS:

- Workplace culture, communication, leadership and trust
- Work systems and structure

Figure 8: Draft strategy for engaging workers in equipment design

LOOKING **FORWARD**

The CSIR continues to review its impact and its competences to ensure that it has the optimal posture to support a modern mining industry that has adapted to the demand of the fourth industrial revolution, a journey it is undertaking with its clients and stakeholders.

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