From Deep Mineral Exploration to Mine Closure: Why Groundwater Matters?

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Extended Abstract

Groundwater plays a critical yet often overlooked role in the lifecycle of mineral resource development, from exploration to mine closure. As global demand for minerals intensifies, deeper and more complex deposits are being targeted, and the sustainable management of groundwater resources has become a pivotal factor in successful operations. This work highlights the importance of groundwater investigation at the earliest stage of the mining project life cycle and the need to integrate groundwater management into every mining stage, emphasizing its influence on environmental stewardship and operational success. Addressing deep mineral exploration challenges, we bring the idea of miniaturized robotic tools for deep exploration of inland mineral deposits closer, with a particular focus on groundwater challenges. Early hydrogeological exploration can minimize environmental risks, reduce costs, and ensure the long-term viability of mining projects. This is crucial as the industry faces increasing scrutiny from regulatory bodies and local communities.

Based on the MINOTAUR EU-funded project approach (MINOTAUR, 2024), we present a novel concept of a miniaturized robotic exploration tool for deep land deposits (Fig. 1) that will support developing an integrated hydrogeological framework combining advanced geophysical surveys, hydrogeochemical information, and long-term monitoring data to assess groundwater conditions at each stage of mining project life and to plan effective and sustainable mine water management.

The implementation of the Logging-While-Drilling (LWD) and Measure-While-Drilling (MWD) approach by integrating novel sensors and technologies into the MINOTAUR robotic tool (Fig. 2) is expected to allow for direct identification and measurement mainly of rock geochemical and geomechanical properties but also of groundwater basic parameters like pressure, temperature or electric conductivity. This information is often lacking at the stage of early mineral exploration. However, it is crucial for future mine operation planning, e.g., drainage design, mineral processing design, or mine closure design.

The key applications of our work include improving risk assessments and mine planning, enhancing regulatory compliance, and providing tools for effectively monitoring groundwater throughout the mining process. Our integrated framework supports decision-makers in designing more resilient and environmentally responsible mining operations. The implications of our findings are particularly relevant for developing sustainable mineral resource extraction practices in a world increasingly focused on climate change and water security, ensuring that groundwater is protected and utilized efficiently across the entire mining lifecycle.

Acknowledgements

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References

MINOTAUR – Miniaturized Robotic Systems for Autonomous In-Situ Exploration of Critical Raw Materials In Deep Land Deposits – project proposal, 2024, DOI: https://doi.org/10.3030/101178775

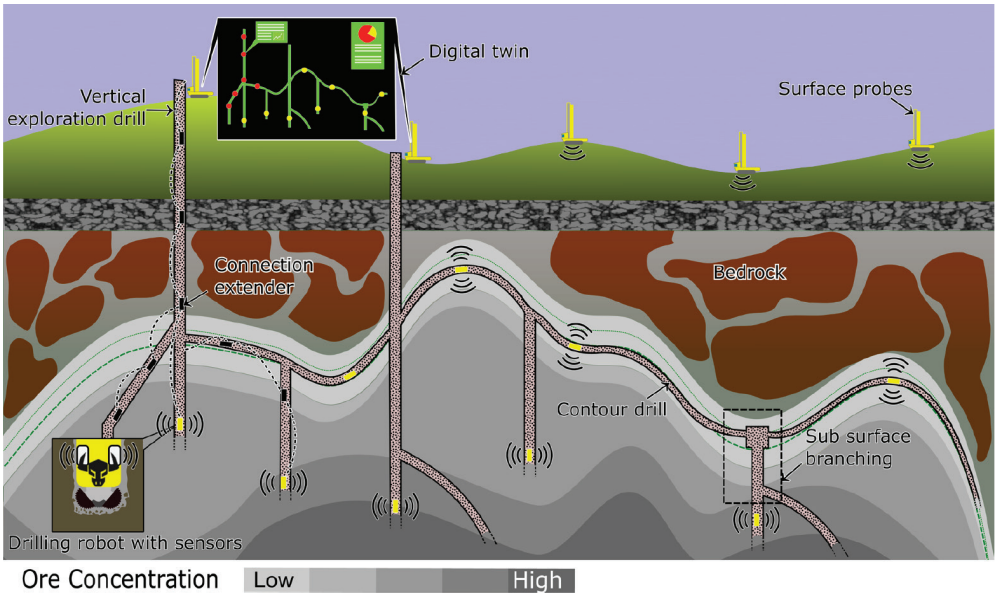

Figure 1 *Minotaur concept for exploratory drilling, with novel technologies, such as robotized drilling machines, autonomous contour drilling and ore-tracking, in-situ sensing and AI based resource characterization and geo-modelling. (MINOTAUR, 2024).*

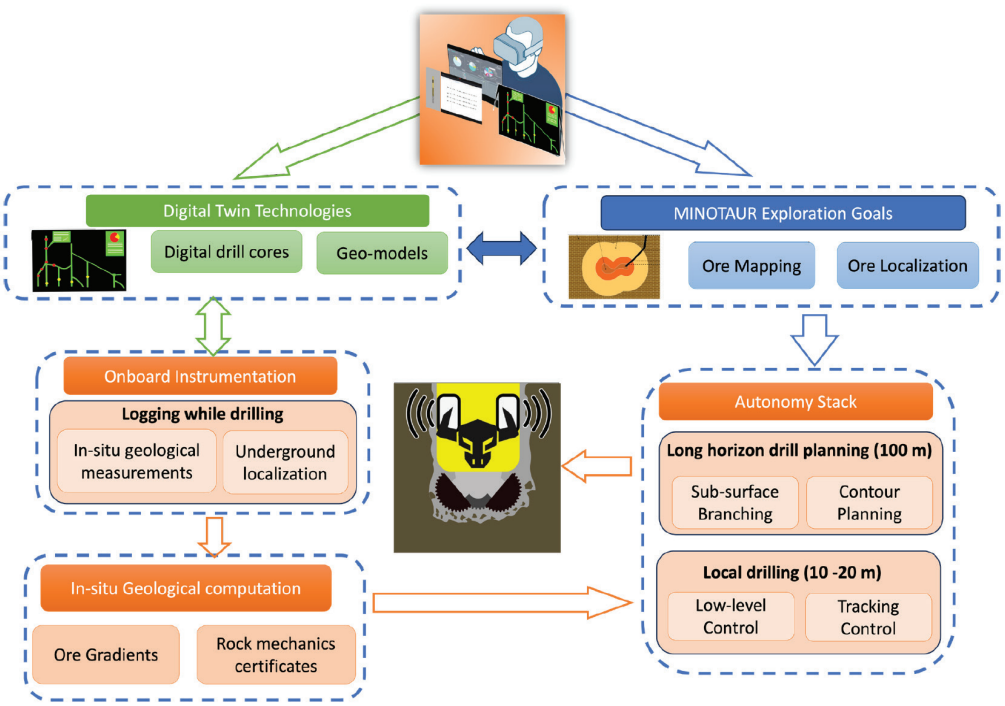

Figure 2 *A workflow diagram of the conceptual MINOTAUR system. (MINOTAUR, 2024).*