RESOURCE CHARACTERISATION

Strategy and vision (**will be included in part 1 of the roadmap**, should include: state of the art, key drivers, needs, assumptions, vision = mutual and ultimate goal, 300-400 words, now 531 words)

Geological, geochemical, geophysical, rock mechanical, geometallurgical and environmental data are generally collected at mining operations, and corresponding models are established. Novel analysis techniques exist in all these areas.

Geological methods for resource characterisation include both lithological and mineralogical analysis techniques. Lithological data can be obtained in a non-subjective way by e.g. digital photogrammetry, optical borehole imaging (OBI), and X-ray fluorescence and hyperspectral methods. These techniques are currently available, but they are only at a very slow rate being adopted by the mines. *Mineralogical* analysis techniques focus on mineral chemistry and mineral textures. Most mining companies analyse only base and precious metals, since the content and distribution of associated trace metals and low-grade by-products has not been economical. Several commodities listed by EU as critical raw materials (e.g. graphite, Co, PGM, Ga, In, REE, Ge, Sb and W) have a good potential for extraction in present and future Swedish mines. There is, however, a need to better establish the analytical chain of characterisation techniques needed in order to obtain this detailed information of ore, waste rock and waste material produced in the most efficient way. The principal advantage with existing techniques is the high spatial resolution and consequent facility for analysing individual mineral grains, which becomes more and more important when finer grained and more complex and lower-grade ore bodies are mined, and the need to identify and extract raw materials present in small quantities in ore and waste products is pronounced. For a proper prediction and prevention of potential *environmental* impact and for sustainable mine waste and water management a detailed characterisation is needed already during the exploration phase. This require expanded quantitative mineralogical analysis that includes mineral and elements of concern for the environment.

Geophysical methods are widely used in exploration but only to a limited extent in production (e.g. gamma-gamma log) even though they offer a huge potential. In *rock mechanics*, both geological and geophysical methods are used (e.g. petrophysical analysis) but the measurements of intact rock strength, fracture properties and stress state require techniques of their own. Continuous measurement techniques are available (such as CSIRO HI, doorstopper and MWD) but the mining industry is slow to adopt them.

In *geometallurgy*, mineralogical methods are used to map the mineralogical variation (modal mineralogy and textures) and interpret the metallurgical response from this data through small-scale laboratory tests. The spatial ore data with forecasted metallurgical response is integrated and used in production design, planning and management. In recent years there has been a strong development in utilising mineralogical information in geometallurgy also at Swedish mines. The quantification of mineral textures is challenging and the use of image analysis tools on different kinds of images (optical, hyperspectral, X-ray) of macroscopic and microscopic specimens are the focus of much research around the world. Another challenge in geometallurgy is how to use the deposit information to reliably forecast how the ore will behave in processing. Since geometallurgical tests are lacking in several areas a more promising route is to link the mineralogical information with mineral processing. This requires good quality and detailed mineralogical information on both the ore and the process streams. Such integrated systems dealing with the whole geometallurgical data are virtually lacking.

Summary/purpose of the thematic area (razor-sharp summary of the thematic areas role in the strategy: What are we doing? Why are we doing it? Main challenges and objectives, what we hope to achieve with our research and how it pushes us towards the vision. The essence of everything that is important, 300

words, now 345 words)

A sound knowledge of a resource serves as a basis for effective extraction and utilisation of an ore body. Besides geological knowledge of geometry and commodity grade, spatial information should be available on how the rock unit (ore type, rock mass) behaves during mining production, minerals processing, and waste disposal/remediation. This knowledge should preferably be acquired in an early stage of the primary mineral resource value chain.

Knowledge of the resources in mining operations is currently in many ways incomplete. Gaps exist in data collection, subjective characterisation and between different disciplines. Cross-thematic and multi-disciplinary usage of data is limited. For example, geological and rock mechanical models are separate and use very little data from each other. In addition, some of the relevant data is underused or is lost during data processing. In mining operations in general, the data collection and usage are ineffective and subjective. It is not uncommon for drill core logging to be done twice: first for geological purposes and then for rock mechanical measurements.

In order to avoid subjective characterisation, automatic, online and less time-consuming methods are needed in tunnel mapping and for characterisation of drill cores and chips. With our research, we aim to achieve:

- Resource characterisation that results in a mathematical and physical (property based) copy of the rock mass, i.e. a detailed description of all parameters (rock material, joints, faults, mineralogy, microstructure, geometallurgy etc.) of the rock mass.
- Resource characterisation that results in the detection of new value-added minerals, e.g. high-tech and critical raw materials.
- Resource characterisation that results in identification and quantification of minerals and elements of concern for environmental studies, as well as potential industrial minerals suitable for innovative products.
- A geometallurgical approach that captures variability within the ore body significant for mineral processing plants (e.g. mineralogy and ore textures implemented in comminution models) and production management (e.g. traceability of ore from mining face through concentrator).
- In-situ mining and process development aiming to zero footprint in future resource development
- Energy-efficient and environmental-conscious process development in the concept of geometallurgy and 4D-geomodelling.

Objectives and KPI (former vision and beyond vision, 150 words, now 134 words)

For the agenda area *Resource Characterisation*, the long-term vision for 2030 and beyond is to improve the competitiveness of the Swedish mining companies with high-quality knowledge of ore bodies and rock mass, high resource efficiency and reliable systems for predicting and managing production from mine to mill. This will help to reach the goals for zero accidents, no human exposure at the production face, greater energy savings, reduced CO_2 emissions and lower ore losses, effective water and waste management. For these targets the following key performance indicators are defined:

- Increased use of automated and on-line systems
- Reduction of energy and related CO2 emissions
- Reduction of ore losses
- Reduce dilution
- Increase of new value-added products from ore and waste
- Reduce the amount wastes by resource efficiency and development of innovative product

- Increase of water circulation

Research and innovation needs, and strategies and actions (350 words, now 247 words)

In order to mine Swedish deposits at increasing depths as well as near the surface with good resource efficiency, minimised environmental impact and increased productivity and safety, the research should be focused on optimising the methods providing reliable data in the design-, operational-, and closure stages. The research should focus on the following main areas:

Short- to medium-term

Apply new and existing resource characterisation techniques for online and in-situ measurement of geological, mineralogical, rock mechanical and metallurgical properties.

Facilitate the use of new monitoring methods for rock mechanics by adapting the use of existing sensor techniques.

Develop new resource management tools, which enable real-time data integration, effective data visualisation, production planning and scenario analysis.

Develop a tool for resource efficiency assessment and sustainability evaluation of existing and planned mining operations.

Long-term

Facilitate the use of new online analysis tools, sensing methods and management tools, all integrated in a geometallurgical model and resource management system.

Facilitate the use of micro-analytical tools for incorporating detailed resource information in long term production planning.

Develop interdisciplinary tools for rock mass characterisation. A common visualisation platform based on an open source Virtual Reality technique could possibly be used.

Develop and implement novel resource characterisation techniques and methodologies for identification of innovation-critical metals as by-products.

Develop MWD and AWD (measurement while drilling and assay while drilling) technology to deliver data for online process design, optimisation, prediction and planning for ore delineation, rock mechanics, drilling, continuous mechanical excavation, blasting, crushing and grinding or milling.

Expected impact (200 words, now 113 words)

Technical

Increased resource efficiency by automation.

Reduction of ore losses.

Optimised mine-to-mill processes.

Enhanced prediction of downstream processing performance.

Effective mass handling and transport.

Economical

More cost-effective production.

New value-added products.

Providing income to local communities.

Promoting environmental mindfulness through early-stage rehabilitation programs
Generating revenue for the local government thereby directly contributing to its economy.
Promoting a more efficient use of energy.

Environmental
Reduced energy consumption.
Reduction of the amount of wastes.
Efficient use of wastes as secondary raw material.
Decrease in harmful emissions.
Reduced CO_2.

Social
Improved working environment.
Increased job satisfaction.
Equal gender employment.
Effective and systematic community engagement.
Safe workplaces.
Sustainable and suitable approach for community dislocation and amenity loss.