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MINERAL RESOURCES
AND
MINE DEVELOPMENT

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as of May 23, 2015

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Innovative Bausteine der Transportlogistik und ihre Vernetzung
M. Zell, F. Becker
Becker Mining Systems AG, Germany
In modernen Großschachtanlagen der internationalen Untertagebergbaus stellt die gleisgebundene Förderung das Rückgrat des Materialtransports dar. Weltweit ist dabei zu beobachten, dass die Gewichte der Transporteinheiten zunehmen und in den Grubengebäuden höhere Steigungen zu überwinden sind. Ferner wird angestrebt, z.B. beim Schaldausbau des Steinkohlenbergbaus, die Schwertransporte unterbrechungsfrei zwischen Schacht und Betriebspunkt vor Ort durchzuführen.
Zur weiteren Optimierung der logistischen Prozesse werden unter Tage zunehmend WLAN-Netze aufgebaut, mit deren Hilfe über Access-Points und Glasfaserleitungen Informationen aus dem Grubengebäude an eine überörtliche Transportleitwarte übertragen werden können. Damit lassen sich dort die aktuellen Fahrzeugstandorte zwecks Materialverfolgung erfassen, Diagnosewerte der am Transport beteiligten Betriebsmittel verarbeiten und eine bidirektionale Sprechverbindung zu den Fahrzeugführern aufbauen.


Im Vortrag sollen daher der derzeitige Entwicklungsstand zwangsgeführter Transportbahnen, d.h. Einschienenhängebahnen, Schienenflurbahnen und Loko-motiven sowie deren Vernetzungsmöglichkeiten mit funk-und leitungsbasierten Informationssystemen behandelt werden.

Als ein aktuelles Beispiel für innovative Transportlösungen wird schließlich eine neuentwickelte Zahnrad-Lokomotive vorgestellt, die im sogenannten Betrieb auf bergwerkseigenen Schienen fährt und für die Bewältigung von Steigungen im Bereich von 4° bis ca. 30° über ein zuschaltbares Zahnrad verfügt, das formschlüssig in eine in Schienenmitte verlegte Zahnstange eingreift. Die Formgebung der Zahnstange ermöglicht darüber hinaus durch das Eingreifen von Führungslaufrädern in das seitliche Zahnstangenprofil eine Zwangsführung der Lokomotive.

Über den erfolgreichen Ersteinsatz dieser Lokomotive und die dabei im chinesischen Bergwerk Dingji der Huainan-Gruppe gesammelten Betriebserfahrungen wird im Vortrag ebenfalls berichtet.

**OPERATIONAL EXPERIENCES**

-006

**DBE – Expert for Geological Radioactive Waste Repositories**

*T. Lautsch*

Deutsche Gesellschaft zum Bau und Betrieb von Endlagern für Abfallstoffe mbH (DBE), Germany

Geological radioactive waste repositories are a special kind of underground operation. The paper presents the unique features of such a project. Technologies and management processes needed to deal with these unique features are the core competency of DBE, the leading organization within Germany for engineering, procurement, construction and operation of geological radioactive waste repositories. A geological radioactive waste repository has features which are quite different from regular mines.

1. It is a nuclear facility, which follows all regulations of the nuclear industry with regard to radiation protection.
2. Handling of the waste and of all equipment has to follow the "ALARA" principle, as low as reasonably achievable to radiation exposure.
3. Geology and hydrogeology have to be modelled over very long time horizons as the foundation for the longterm safety analysis and therefore of any approval process.
4. It is subject to a complex supervision by the authorities way beyond the requirements of a regular mine or any other industrial complex.
5. Technologies to operate the facility differ from regular extractive mines. Examples are:
   5.1. The main hoisting shaft has to handle large payloads top-down.
   5.2. High quality backfilling is a key part of the operation.
   5.3. Dam structures with extremely low permeability close access roads to storage areas as engineered barriers from potential water flows.
   5.4. All infrastructure underground is built for long-term maintenance free operation of the repository site.
DBE has superb competencies in all of these areas and is the only organization in Germany, which has a 25 year long experience in operating the only one existing repository for radioactive waste in Germany, the final repository for low level radioactive waste Morsleben (ERAM), where decommission (backfilling and sealing) is under preparation. Furthermore since more than 30 years DBE has performed the surface and underground exploration of the Gorleben salt dome as a possible repository for high active radioactive waste. Since 2007 the former iron ore mine Konrad is under construction to erect a repository for low level and low heat generating radioactive waste. These projects are performed by DBE on behalf of the Federal Republic of Germany represented by the Federal Office for Radiation Protection (BfS).

Beside these projects since more than 30 years DBE has carried out various R & D tasks in the field of final disposal. Priorities were set up i. e. for the design and demonstration for the direct disposal of spent nuclear fuel, in-situ tests for sealing constructions in rock salt formations as well as shaft sealing systems etc. Based on this extensive experience DBE with is interdisciplinary teams possess the competency over all projects phases of a final repository for radioactive waste as there are the site exploration, the design phase and generation of documents for any approval process (i. e. due to atomic and mining law), the operation and decommissioning (backfilling and sealing of the repository).

DBE TEC as a fully owned subsidiary of DBE is involved in projects for geological radioactive waste repositories around the world.

DBE – Delivered By Experts!

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The Renaissance of Underground Rail Haulage –

Why Upcoming Mining Projects Focus on this Hidden Champion

A. Merchiers

Schlager Eisenhütte Maschinenfabrik GmbH, Germany

t.b.c.

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I²Mine – Improved Deposit Recovery for Deep Potash Deposits

J. C. Thiele

K+S Aktiengesellschaft, Germany

Within the EU funded 7th framework program the project “I²Mine – Innovative Technologies And Concepts For The Intelligent Deep Mine Of The Future” has been established to cope with the challenges of mining and processing methods in the future. For the various and partly heterogenous scope of work, the whole project is divided into workpackages, tasks and subtasks. In workpackage No 2 “Novel Mining and Underground Processing Methods” conceptual studies for new advanced, intelligent and safe underground mining are being developed technologies in order to gain access to deep mineral resources.

In this workpackage novell, intelligent, safe and economic Methods for deep mines and processing methods including backfill and near to face beneficication have been examined. The objectives being addressed incorporate the development of innovative mining methods for Sublevel caving and -stoping as well as Room And Pillar that are economic reliable at a depth of greater than 1,300 to 1,500 metres, having a 20% higher extraction rate and move at least 20% of the primary processing underground. One of the main focusses in the I²-Mine Project is underground sorting to leave mineral waste from the beginning.
For deep potash deposits K+S is looking for possibilities increasing the extraction rate under existing restrictions and boundaries. Especially for the deep stipping deposits we will give an overview of the possibilities to increase the extraction rate. A validation under economic reliable and sustainable mining conditions followed by an outlook will complete the presentation.

-Stress Direction - An Essential Tool in Coal Mine Planning and Mine Development at Singareni Collieries-

A. Manohar Rao
The Singareni Collieries Co Ltd, India

In underground excavations of coal mining, horizontal stress plays a vital role on the stability of the mine workings. High horizontal stress values have a profound impact on the overall stability of coal mine roadways.

The Singareni Collieries Company Ltd (SCCL) is conducting coal mining operations in Godavari Valley coalfields and is catering to the needs of coal for thermal plants for a large part of south India. SCCL is proposing some new mining blocks with status document with roof hazard zonation maps vis-à-vis stress field, for safe and economic mine design.

Considering the significance and importance of the Stress orientation in mine layout, SCCL has taken up Stress measurement studies through Hydrofracturing studies in advance in some of the mine blocks at Planning stage itself - to help in lay and disposition of panels.

The directional influence of high horizontal stress is observed in mine Development stage in SCCL. Based on the underground Geotechnical mapping conducted in GDK-11 Incline, it is found that after reorientation of dip galleries closer to the mapped minimum principal horizontal stress direction, no bed dilation was observed in the roof strata of the dip galleries, with improvement in working conditions.

Recent overcoring measurements across a graben fault system in a coal mine in Utah showed the occurrence of abnormally high horizontal and vertical stresses. Based on the geological & structural set-up and the nature of the lithic fill, SCCL is termed as Godavari Gondwana Graben. In a S&T project, being a sub-implementing agency, SCCL initiated to take up Stress measurement studies through overcoring method in some of the underground mines.

The knowledge of in-situ stresses is indispensable for safety and suitable support system for coal mines in general and Singareni collieries in specific. Accordingly, SCCL initiated a S&T Project with an object to assess the horizontal stress field in the advance stage of the mines and in the developing mines vis-À-vis roof hazard map, and devise suitable support systems for the coal mining blocks of SCCL.

Roof hazard zonation will be carried out to identify potential weak zones in the mine blocks. Accordingly, a suitable methodology will be developed for devising the support systems or for change in direction of the workings for safer and productive mine workings.
DO's and DON'Ts when Using Orebody Models as Simulation Input

V. Osterholt
Principal Consultant, Osterholt Consulting, Germany

Process simulations can be used to design, analyse, and optimise complex mining operations. One area of application aims at understanding the behaviour of material streams through the mining process. Depending on their scope such simulations require a model of the orebody or an intermediate stockpile as their key input. This input model has to meet the simulation requirements to ensure the study results provide useful information for the related engineering decision. If the model used is not fit-for-purpose, misinformed decisions can lead to adverse financial consequences. Some examples of mining process simulations are used to demonstrate common pitfalls and ways for avoiding them. A scoping tool is described to facilitate communication and alignment between technical stakeholders of a simulation study.

Resource Evaluation Yayaköy Lignite Deposit, Turkey

D. Niggemann, T. Hollenberg, N. Linder
Fichtner Mining & Environment GmbH, Germany

The Turkish company ODAŞ Enerji intends to construct a thermal power plant (TTP) with a capacity of 300 MW(e) near the town of Çan in the Çan District, Çanakkale Province in NW Turkey. Fichtner GmbH & Co. KG has been appointed as Consultant to carry out the planning of this power plant. As a subsidiary of ODAŞ Enerji, Çan Kömür ve İnşaat A.S. has acquired the license of the nearby Yayaköy Lignite Deposit, from which the lignite shall be mined and provided to the TPP. Fichtner Mining & Environment GmbH (FME) has been appointed by ODAŞ to carry out a resource calculation and classification according to the international reporting standard JORC. Furthermore a mining concept has to be developed to ensure the required production rates.

An exploration drilling campaign has been carried out in order to investigate the lignite deposit and to elaborate sufficient underground information for the execution of a resource classification according to the JORC code. In order to improve the understanding of the potential value of the Yayaköy Lignite Deposit, a numerical 3D Geological Model of the entire deposit has been developed by the Consultant using the GEOVIA SurpacTM software package. The lignite occurs as a single seam, with a dip of approx. 25° towards north. Based on this 3D model, the calculated resources of the Yayaköy Lignite Deposit down to a depth of 600 m asl are in the order of approx. 19 Mio. t of lignite.

Additionally four geotechnical drillings have been sunk to receive detailed information for the development of the mining concept and the later mine planning. Two concepts for underground mining have been considered: longwall mining with top coal caving and step room and pillar mining. An open pit mining operation is considered as not feasible, due to an unfavourable overburden/resource ratio.
Recent Developments in Geostatistical Resource Evaluation - Learning from Production Data for Optimized Extraction of Mineral Resources

J. Benndorf

University of Technology - Delft, The Netherlands

The flow of information and consequently the decision making along the chain of mining from exploration to beneficiation typically occurs in a discontinuous fashion over long time spans. In addition, due to the uncertain nature of the knowledge about the deposit and its inherent spatial distribution of material characteristics, actual production performance in terms of produced ore grades, quantity, extraction- and processing efficiency often deviate from expectations.

With the development of modern Information and Communication Technology over the last decade, literally a flood of data about different aspects of the production process is available in a real-time manner. For example, sensor technology enables online characterisation of geochemical, mineralogical and physical material characteristics on conveyer belts or at working faces. The ability to utilise the value of this additional information and feed it back into reserve block models and planning assumptions opens up new opportunities to continuously control the decisions made in production planning to increase resource recovery and process efficiency.

This contribution reviews recent developments in integrated geo-metallurgical modelling and presents a new approach for sequential updating geostatistical resource/reserve models based on production data. It is embedded in a larger framework for Real-Time-Resource Management for optimizing short-term production planning and operations control.

Evaluation of Reserves Using Geostatistical Tools to Assist with Long-Term and Mid-Term Mine Planning

A. Pavlides, D. Hristopoulos, M. Galetakis

Technical University of Crete, Greece

The price of a run-off mine mineral product and mining costs fluctuate through a mine's life. These factors affect the cut-off grade of the mineral deposit and the viability of the project. Consequently, initial reserves estimation in a deposit and long term planning and scheduling of the corresponding mine should be re-evaluated and revised periodically. Several of the mines around the world, like lignite mines, are multi-seam mines and the quality characteristics of certain layers present spatial variability, which further complicates the exploitation. Mine planning is further complicated because the quality parameters of the run-off mine product may fluctuate significantly within broad limits. As a result, the use of mean quality values to represent the whole deposit is suboptimal for mid-term planning and analysis. To address these problems, a spatial profitability index is presented in this project. This index evaluates layer profitability of the different seams at different economic situations based on the quality characteristics or the run-off mine product. Based on this index a theoretical equation is presented that allows a fast and practical estimation of changes in reserves or mine profits for a great range of different economic situations. This equation could be used for different mine sectors or for the whole mine, to predict the changes of reserves or profits due to variations in the exploitation and environmental costs or the expected price of the mine's product. The equation can be used to assist in the reserves estimation and also in the long-term and mid-term mine planning and exploitation of multi-seam or single-seam mines. The use of the profitability index and the theoretic equation is illustrated using a data set from the multi-seam Mavropigi mine (Northern Greece).
The future of mining will surely be subject to increased international competition. In attempting to become more competitive, many mining companies turn to rationalization, looking to both rationalize their production and organization, as well as to optimize their processes. One such rationalization, or way of process optimization, is presented in the concept of Lean Production. Traditionally utilized in industrial settings such as the automotive industry, it has also seen successful implantation in less traditional sectors, such as healthcare. Now, the mining industry is turning their eyes towards the concept as well.

But can Lean Production be implemented in the mining industry? This paper attempts to answer this question. It examines the literature published to date, in regards to Lean Production and mining. However, currently there has not been an excess of research published in regards to this area. Therefore, the examined literature also includes conference proceedings, reports and working papers. The literature is divided into two categories: case studies and theoretical approaches.

From the case studies the paper examines what efforts that have been done to date to introduce Lean Production to the mining industry: what results can be seen; how was the concept implemented and what made it successful; what was not successfully implemented; why did the implementation fail? The paper then discusses what implications the answers to these questions might have.

For the literature with a theoretical approach, the papers adopt another focus. Here, proposed areas of implementation are examined: what areas are currently suitable for the implementation of Lean Production; which areas require a modification of the concept itself or is dependent of further technology development (e.g. continuous miners for metal mines)?

Furthermore, since there are several examples in the literature where the mining industry is compared to traditional manufacturing, an overview is provided regarding the differences and similarities between the mining and other industries. The implications such differences might have for possible implementations are also discussed.
systematic and target-oriented development it is necessary to ensure the adaptation to the changing general conditions.

Occupational health and safety and process efficiency are outstanding action items in this area. As in technology, big development leaps, but also small continuous development steps are required. At first glance, the goals, like risk minimization for the employees and steadily rising productivity, seem to stand in opposition to each other, specifically taking into account the potentially higher risk in underground mining.

History shows that different approaches, for example various management systems have been used to achieve these goals. While the goal of an increasing productivity is an originary contribution interest of the company, work safety is always also under the supervision of various authorities.

Experiences in recent years show that an integrated, systemic approach with close interaction provides even greater efficiency and effectiveness in both areas. Zero accidents and waste-free processes, representing 100 percent added value, are no longer an utopia but targets that can be considered as realistic.

Six related success factors play a main role: A security and improvement culture in which employees assume an proactive approach towards responsibility for themselves and their colleagues, executives who demand this and at the same time show exemplary behavior themselves, the implementation of an efficient organization of continuous improvement, the use of standardized methods and tools, process monitoring and control based on key performance indicators and continuous communication. Achieving these ambitious goals on a permanent basis requires with altered behavior and mind-set of the staff and the management, in connection with a profound change in corporate culture.

How such a corporate cultural change has taken place and is continuously ongoing, is described in this presentation based on the example of the RAG AG.

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**Evaluation of Management Localisation Policy: The Case of the Ghanaian Gold Mining Industry**

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Privatisation of Ghanaian state-owned enterprises has resulted in domination of Western multinational companies (MNCs) in the gold mining industry. Consequently, expatriate managers dominate industry. The Government of Ghana, realising the problem of national managerial gap in industry has made localisation plan (details of expatriate positions, and nationals to understudy these expatriates for eventual takeover, and the time frame involved) a condition for granting of mining lease to MNCs entering the industry as enshrined in the Minerals and Mining Act 703. This paper evaluates the government’s management localisation policy, which takes the form of the localisation plan while its implementation is through local managerial talent development by MNCs operating in industry. Data is predominantly popular and academic literature including mostly the authors’ recent empirical studies on development of local managers in industry, as well as industry publications to evaluating the policy. The evaluation is done by reviewing literature and formulating and discussing two main hypotheses.

H1: The localisation plan is being implemented by MNCs as demanded by law
H2: Management localisation is an effective approach to regain national autonomy over the running of the gold mining industry

Our findings include the following.
H1: It is not proved that MNCs are implementing the policy. Regardless of being precondition for granting of mining lease, most companies have been operating for years without any localisation plan submitted to the Minerals Commission (representing the government) and no local managerial development programme in place.

H2: It is true to an extent as we find that management localisation is not the only challenge facing industry in terms of regaining autonomy over the running of industry.

We conclude that management localisation policy is a commendable step to develop local managerial talent for eventual takeover from expatriates. However, until the government rigorously enforces the implementation of the policy and strengthens her monitoring role, industry will continue to be dominated by Western technical managerial skills as MNCs, left to their volition, would not implement the policy which they consider as unnecessary cost, and would also not be willing to develop local managers to take over their jobs. Even when the management localisation policy is implemented as required and the aim achieved, this cannot fully ‘localise’ industry since there are other two major challenges including inadequate capital and lack of appropriate technology for successful running of industry without outside involvement.

The paper is of value as the first study to evaluate the management localisation policy in terms of the country regaining autonomy over the running of the Ghanaian gold mining industry.

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Investments in Resource Efficiency – An Analytical Assessment Framework and Review of Evidence

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This paper contributes to and reviews the (small, but growing) literature on investments in resource efficiency, and presents two complementary frameworks for assessing and prioritising resource efficiency investments, based on conventional economic theory. This approach is also a criticism of standard commercial investment appraisals, which may not only omit environmental aspects (with potentially negative financial knock-on effects), but also fail to account for crucial barriers to project implementation. A brief introduction offers empirical evidence on material use and productivity patterns in low and middle-income economies (exemplified by Europe, Central Asia, and Northern Africa). It is evident that despite significant increases in commodity price levels and volatility, resource productivity in these countries is trailing behind several developed economies (even when controlling for heterogeneous economic structures). Thus, catching up with more resource efficient peers has the potential of delivering both economic and environmental benefits at a substantial scale. Firstly, in order to conceptualise the potential of closing such an efficiency gap, this paper offers a comprehensive review of the economic, environmental and political costs and benefits of resource efficiency investments relative to inaction. The analysis not only accounts for direct, but also indirect effects. It is concluded that – given certain assumptions – the literature on resource efficiency investments tends to suggest positive net benefits, especially when considering non-monetary dimensions. This paper argues that the proposed cost-benefit framework should be applied systematically to the assessment of specific resource efficiency investments in order to understand their direct and indirect consequences. While such a cost-benefit analysis can potentially identify cost-effective investments, implementation in practice may nevertheless be obstructed by investment barriers, which cause and perpetuate inefficiencies.
Therefore, it is critical to understand the structural causes of inefficient resource use, and how they may affect the success of investments. Thus secondly, a systematic framework for analysing barriers to resource efficiency investments is proposed. Based on the First and Second Fundamental Welfare Theorem, the framework assesses how the theoretical assumptions of perfectly competitive efficient markets are violated in practice. A typology of barriers is presented, distinguishing between information constraints, capacity constraints, financial barriers, uncompetitive market structures, and fiscal mismanagement. Each type of barrier is illustrated with practical evidence and the relevance to resource efficiency investments is highlighted. In this context the paper also discusses how uncertainty and systemic risks (e.g. commodity price volatility) may exacerbate existing investment barriers. Such an analysis of investment barriers is argued to be critical for prioritising action, and achieving sustainable improvements of resource efficiency.

The paper concludes by offering the blueprint for a comprehensive policy strategy, which addresses both the causes and symptoms of resource inefficiency, through both financial and technical support, at both the micro and macro level.

Overall, this paper calls for case specific analyses, which go beyond standard commercial investment appraisals, and take into account the costs of inaction, environmental and social externalities, as well as investment barriers. The analytical foundation of this paper emphasises practical applicability, and is based on an assessment framework for resource efficiency investments, developed at the European Bank for Reconstruction and Development.

MINE PLANNING - EXPLORATION TO OPERATION

-018

Vision Zero - Mission Possible in Mining

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-019

Fairport Mining Strategy, Development and Realization

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K+S Aktiengesellschaft is the leading rock salt producer and one of the leading potash producers in the world. The company headquarter is located in Kassel, Germany and consists of Corporate Center, Business Center and Technical Center. Technical Center provides worldwide support within the K+S Group in the fields of Geology, Mining, Technics / Energy, Research and Development as well as in Environment and Safety.

As an example of developing and coordinating the implementation of a new mining strategy at the Fairport Salt Mine is described. Fairport Salt Mine is located in Ohio, United States as one of six conventional mines of Morton Salt. Morton Salt, a K+S Group company also operates nine solution mining and several evaporation plants.

After Morton Salt entered the K+S Group several production site evaluations were conducted. Regarding the production capacities, the optimization of the mining processes was identified as one of the potentials for production costs reduction. Fairport mine has an excellent location near the markets, sufficient geological conditions but is running two different extraction systems at the same time: Drill and blast and continuous
mining. Based on operation costs of European and North American mines a detailed investigation and comparison of different mining strategies was executed. As a result it was indicated that drill and blast technology with an increased efficient length of 7 m per blast as a single extraction method would be favorable. Due to the fact that the required technology was not available on the American market European machines had to be introduced in the mine. Therefore it was necessary to implement an intensive technology and know transfer. According training programs for operators and especially for maintenance personnel were developed and carried out. Additionally it was necessary to ensure the required local technical service level and support with spare parts.

This presentation outlines the project from the start over implementation and intercontinental teamwork to the actual status of the project.

-020

Managing the Mining Cycle Using GeoVisionary

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Managing the mining cycle from exploration through to evaluation, planning, construction, operation and finally mine closure can involve many datasets in different formats. To be able to visualise all of these different datasets in one environment is important to locate mineral/ore deposits, moderate risks, increase mining efficiency, monitor the impact on the surrounding environment and communicate these factors to stakeholders. Typically, GIS – Geographical Information Systems have been used to manage the life cycle of a mine, however the three dimensional (3D) complexity is lost in these two dimensional (2D) systems. Virtalis alongside the British Geological Survey, have developed the GeoVisionary software which provides the means to manage the life cycle of a mine in a three dimensional environment.

GeoVisionary enables the integration, visualisation and analysis of very large geoscience datasets from multiple sources that include digital elevation models, aerial photography, digital maps, 3D geological models, LiDAR scans, voxels, time-series points and CAD models, some of which cannot be visualised sufficiently 2D GIS. Of these, the datasets that might be most important to a mining operation include volumetric models of ore bodies and LiDAR laser scans. Volume models of ore bodies and their properties can be visualised alongside other geospatial datasets, using real-time isosurfacing and multiple transparencies to see into the core of the data. Point clouds from LiDAR scans of mines, caves and quarries can be visualised and tools have been developed so that distances can be measured accurately, and point clouds can be digitised on for further analysis to monitor change over time. The outputs of which can be directly imported to GIS, which is dynamically linked to GeoVisionary so that the two systems are used in tandem.

4D data and animated sequences can also be integrated into GeoVisionary with the static 2D and 3D datasets to provide scenario analysis, and show how the mining development may develop over time.

The virtual 3D/4D environment that is created from these datasets in GeoVisionary replicates accurately what a user would see in the real world, improving the user’s ability to interpret geoinformation and manage the life cycle of a mining operation more effectively.
Exploration, Initial Mine Planning and Reserve Estimation of the Hanönü Copper Deposit in Northern Turkey

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In the north of Turkey close to the township Hanönü the Turkish company ASYA Madencilik AŞ (ASYA) is holding a license that is part of a copper bearing formation. The property is located in the metallogenic belt of the Central Pontides, which hosts numerous volcanogenic massive sulphide (VMS) deposits. The dominating mineral in the ore is pyrite. Chalcopyrite occurs in small layers. More seldom sphalerite is mineralized. The grain size is small and the mineralization takes place in-between small grain sized quartz and feldspar.

Extensive exploration has been conducted in different phases on the license area since 2007, and since 2012 it is carried out with assistance of DMT as consulting geologists. The exploration revealed substantial Cu-mineralization in the north-western part of the license area.

The mineral exploration activities in the license area covered a broad spectrum of geologic, geochemical and geotechnical investigations. This included geological mapping, drilling of more than 180 boreholes, geophysical well logging and geochemical rock analyses. Based on the acquired data a 3D geological model was created that shows over 130 mineralized blocks. For the 3D block model a total of 128 drill holes (>39,000 m drilled) located in the main mineralized sector in the north-west were used for resource estimation, which revealed substantial VMS-type copper mineralization within the meta-volcanic and meta-sedimentary basement rocks. Detailed inspection of these results yielded an average copper grade of 1.6 wt % in the ore bodies when no cut off is applied, and a total mineral resource of about 20 Mt ore.

Additionally to the resource definition program an intensive geotechnical investigation program was carried for the excavation planning. It included geotechnical core logging, surface mapping of joints and other discontinuities, interpretation of televiewer logs, sampling of rock and drill core and rock mechanical testing. Based on these data a detailed geotechnical characterization of the different main lithologies and a rock mass rating could be performed. The orientation data from core and well logging together with the rock mechanical laboratory results i.e. on the shear parameters were applied for a rock slope stability assessment, which included the calculation of the safety factor of the pit slopes and benches and the probability of failure.

In order to determine the ultimate pit (the most economical pit), a pit optimization was carried out, using NPV Scheduler software. Based on the optimization results an engineered pit was created, which served as basis for the further mine planning and scheduling. These results together with the studies on processing, mining, infrastructure, marketing and economic feasibility will allow an estimate on the copper reserves.

MACHINE TECHNOLOGY AND EQUIPMENT

Reliability of Automation Systems in Mining Machineries; Issues and Challenges

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In most of the mining methods, the mining process is based on the mobile equipment. Not only the reliability and availability but also the effective utilization of the equipment is controlled by many factors. These factors are both mining system dependent as well as machine-and-maintenance dependent. High utilization can be achieved by means of automation. The automation of mobile equipment is one way of minimizing the human
exposure to high-risk areas and undesirable climate in mining. It can also improve the efficiency to compensate the inappropriate production conditions. Generally, there are two main types of failure modes in non-automated mining machineries; electrical and mechanical failures. A new type of failure mode is added to system in automated machineries: failures of automation system. This type of failures is divided into two main categories: software and hardware failures. The software failures in automated mining machineries can be so risky and affect the mine operation safety in a considerable level; therefore, risk-based reliability analysis needs to be considered during the design and operation process of automated machineries.

In this paper, the reliability of the automation systems in mining machineries in general will be discussed. The basic definitions, applied concepts, issues and future challenges of automation systems are discussed. The main sources of failures and unreliability of automated machineries is investigated and also classified. Finally, some guidelines will be presented for reliability analysis and future designs of automated mining machineries.

Keywords: Mining machineries, Automation, Reliability, Failure, Risk

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**Supporting Technology Toolsets for Efficient and Productive Longwall Operation**

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Longwall mining is an expensive undertaking, from the preparation of the site itself to capital investment in the equipment. That’s why longwall owners have extremely high performance expectations—especially in tough economic times when commodity prices are low.

One of the ways longwall mines achieve or exceed their owners’ expectations is through the extensive use of automation. This paper will show how automation technologies are used to meet customer expectations in efficiency and production.

First, the paper will cover the “Advanced Automation Control” package, featuring state-based automation for longwall shearsers. This is the world’s most successful and efficient tool for defining complex automation cycles. It was developed by working closely with key customers, and allows the shearer to precisely match the user’s defined production process—including direction, speed, arm height and ranging arm control modes.

This technology offers the highest levels of horizon control, extraction control and face alignment currently available. The paper will present example data from real operations to explain functionality and provide proof of the system’s high degree of control.

This paper also covers new software and service tools that support mine operations. This includes capability sets from Cat® MineStar, particularly Health for Longwall and Equipment Care Advisor (ECA). The paper will cover in detail how these capabilities benefit longwall operations. It will also show the value and benefit of ECA to customers, dealers and engineers.
A Real-Time Event Driven Data Management Application for Equipment Monitoring in Continuous Surface Mining Operations

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Advances in electronic and data transmission systems allow real-time monitoring of equipment. The challenge, however, is to be able to utilize such information either in real time or at frequent time intervals, e.g., daily, to schedule maintenance, to take preventive or precautionary measures and to monitor system performance. This paper will present the concept of a successful implementation of a real-time event driven data management application, which was developed for the surface lignite mines in northern Greece. These mines operate mainly using a continuous mining system, employing bucket wheel excavators, conveyor belts, spreaders and stackers. At each mine, the equipment operating under the continuous mining system are interlocked and are controlled through a SCADA system. Operations are supervised through a control tower at each mine. Tower personnel interact with both the SCADA system and the new data management system. The new system runs on a separate server and does not interfere with the main control system at each mine. The new data management system has been successfully implemented as the main monitoring tool in three mines for over three years. Mine management utilizes the system on a daily basis to schedule maintenance and to log the operation and productivity of each equipment unit. The paper will also present example reports and charts from these operations.

Development and Initial Operating Results of a New Battery-Electric Monorail Transport System for Hard Coal Mines

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Monorail transport systems with Diesel or Electric propulsion are widely used in hard coal mining, predominantly for material transport in areas close to coal production. Both systems need special measures in the infrastructure such as filling station and fire protected service rooms for diesel- and battery charging station for electric drive. As opposed to diesel drive, electric drive systems are more limited in their range by the battery capacity. Due to explosion hazard no alternative to led batteries are available for underground coal mining at least in the forseeable future. The aim of the development of new battery-electric transport systems therefor is improvement of the efficiency, reduced dead weight as well as energy recovery during braking and down-hill-drive. Material supply to production areas at Ibbenbüren coal mine is only possible by electric drives which are able to cope with long distances, high payloads and steep inclines. As common battery-electric monorail systems could not fulfill all requirements, the development of a new drive system was necessary. After elaboration of a specification book, GTA Maschinensysteme GmbH was appointed to develop a new drive concept. Recent developments in new electric motors and solid state power electronics led to selection of electric motors based on the axial flow principle. This type of motors is characterized by excellent power-to-weight ratio and easy housing into flameproof casings. Also speed and torque control is easy to be realized by power electronics and power recovery is possible to the best extend. After intensive tests of the single components a complete flameproof monorail train was designed and built and put in operation at Ibbenbüren.
mine. The paper describes details of the development and the deployment of the new battery-electric monorail system and it reveals advantages and limits of this particular transport system.

**SUSTAINABILITY AND SAFETY IN MINING**

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**i²Mine - Mobile Rescue Chamber Re-Design to Support Miners Trapped Underground**

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Mobile rescue chambers could be modified and applied to support miners being trapped underground. In contrast, nowadays mobile refuge chambers are usually used as semi-mobile equipment and remain on a fixed location for sometimes several years. They are designed to protect miners for just a few hours during minor incidents like burning mobile equipment. However, the 69-day rescue of 33 miners in Chile 2010 brought the scenario of long-lasting entrapments back on the agenda.

One task of the EU-funded i²Mine project focuses on the scenario of miners being trapped underground in great depths. Regardless of mining method or technology level, road-heading poses a risk of major rockfall blocking the miners' single means of escape. A following long-lasting rescue mission holds new challenges for mine rescue. This study aims to assess innovative mobile rescue chamber concepts in order to provide an appropriate preventive measure for this extreme scenario.

The study compiles today's best practice in rescue chamber technology and guidelines. Furthermore, learnings from comparable fields of human confinements like space flight and Antarctic missions are implemented. Aspects of physical and psychological survival as well as the practicability of a corresponding chamber in the day-to-day work of an underground mine have to be considered.

Findings lead to integrated and innovative concepts for mobile rescue chambers. A re-design of today's technology incorporates “outer” dimensions like mobility and robustness as well as “inner” equipment features supporting nutrition and psychological issues. A further key characteristic of the chamber's application is its dynamic integration into advancing road-heading operations. Thus, re-designed mobile rescue chambers can provide valuable support for miners being trapped underground.

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**Know-how Transfer für einen sicheren Bergbau weltweit**

RAG Mining Solutions GmbH, Germany

In den letzten Jahrzehnten hat die RAG Deutsche Steinkohle viele Prozesse zum Arbeits,- Gesundheits- und Umweltschutz neu gestaltet und entwickelt. So ist es gelungen die Unfallzahlen um mehr als 90 Prozent zu reduzieren.

Mit der Gründung der RAG Mining Solutions wurden die Geschäftsfelder auf die Tauglichkeit ihrer Vermarktung überprüft und für den Weltmarkt angepasst. Der Know-how Transfer aus diesen Feldern und die daraus entwickelten Produkte sind u.a. Thema des Vortrags, genau wie die Herausforderungen und Erfahrungen die damit zusammenhängen.
Safety and Efficiency Benefits of Smart Koepe Winder Rope Handling Systems

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This paper investigates the safety and efficiency benefits derived from the use of "smart" multiple rope handling equipment for Koepe winders.

Multiple rope Koepe winders are used for high capacities, which may be combined with large operating depths of 1500 m and more. Large suspended masses and rope length result in extensive rope maintenance and replacement requirements with high time expenditure. Complex rope installation and changing processes present a challenge for provision of a safe and efficient rope handling system.

The paper describes the system functionality and its components including multi rope clamping and lifting devices, friction winches and auxiliary equipment. It adopts a qualitative approach by describing the reduction in risk during rope handling resulting from factors including increased levels of inherent safety in the equipment, lower levels of reliance on less sophisticated elements within the equipment chain, simultaneous handling of multiple ropes and reduced exposure to human error.

Also considered are the benefits to production resulting from reduced down time during rope installation and changeover processes.

Ensuring Health and Safety in the Face with the marco Digital Mining® Control System

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In the following, we will be looking at safety measures for mechanised faces integrated in the marco Digital Mining control system. In a marco face, every shield is equipped with the requisite sensors and pm32 control units. The new pm32 control unit together with Ethernet standard cables provides a much higher data transfer rate across the face and to the surface. This is a particularly important factor for optimising the use of new technology devices such RFID and video cameras fitted on both face and roadway shields and for visualisation on the underground and surface main computers. The safety features integrated in the marco Digital Mine system allow gas levels and operations in the face to be monitored and controlled and accurate prediction on endogenous fires in the gob to be made.

To ensure the miners safety when working on equipment in the face, person detection (RFID) has been integrated in the marco system enabling the position of a miner to be recognised with an accuracy of 30 cm. Mining operations are automatically prohibited in the area where the miner is detected, for example near the shearer or conveyor.

A gas control system consisting of three calibrated sensors across the face plus additional methane gas sensors in every fifth to tenth shield has been developed. The data are transmitted to the pm32 control unit and underground main computer for monitoring and analysis so that the speed of the shearer and depth of cut
can be reduced if the gas concentration rises above a certain level. Unnecessary interruptions in face production are thus prevented, the mining process is optimised and operational safety is increased.

One indication of an endogenous fire is the appearance of smoke. A method of detecting very fine smoke particles in good time has been developed, in combination with gas sensors - enabling accurate predictions of endogenous fires in the gob. Highly sensitive smoke detectors are positioned at the head and tailgates where the oxygen concentration is at its highest and the data are transmitted to the pm32 control unit and surface main computer for analysis.

The methods described above together with the established seismo-acoustic rock bump forecasting system contribute greatly to improving levels of safety for the miners working in the coal face.

**SIMULATION OF MINING PROCESSES**

- **030**

**Advancing Mining Productivity by Looking to Technology from Other Industries**

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For the last several years there has been a very public conversation amongst mining leaders about the need for significant change in the industry to address systemic productivity and cost control issues. Even with the return to lower, more variable commodity demand, the irony is mining companies would still be realizing near record profits had they invested in productivity initiatives and technologies as other industries do. This is a core reason why the conversation about change has focused on looking at what other industries have implemented.

The presentation will discuss how innovative thinking has transformed other industries and how mining can apply these learnings to deliver enterprise value chain agility across the entire mining lifecycle. Included in the presentation will be an examination of how technologies used by Boeing, Hydro-Québec, FLSmidth, Fujitsu and other diverse companies can be applied in mining to deliver transformational change. It will also look at how best practices from other industries how been incorporated into software to provide solutions to help solve some of the mining industry challenges.

- **031**

**Cost Optimization of Gypsum Mining Operations Using a PLM Simulation Tool**

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As global markets grow tighter, increasing pressure is being placed on mining projects to deliver higher capital efficiency through increased production rates or lower CAPEX and OPEX. Detailed studies need to be implemented to ensure capital efficiency, verify purchasing decisions, do risk management and to optimize mine planning as well as fleet sizes. One possibility to enable better informed decision making throughout the life of a project can be realized by simulation software. The use of simulation as an operational research tool for mining projects is steadily rising. More and more companies have discovered the advantages of computer simulations for themselves. The number of simulators available on the market is huge, but only a few programs meet the requirements to represent the dynamic processes of mining projects.

Most of the simulation tools, particularly designed for mining purposes, are static calculators for fleet optimization and do not allow customized modeling. The Product Lifecycle Management (PLM) software “Plant
Simulation is based on discrete event simulation (DES) and is normally used in logistic planning and in the automotive industry. Plant Simulation has a high level of customization which enables the adaption of the existing modules to specific requirements of each mining project and therefore the simulation of the entire mining supply chain.

Hence, this innovative tool is used by “Knauf Gips KG” not only to simulate processing but also to analyze their mining operations over the entire life of mine. Including practical examples, this paper will provide a brief overview of the development and adaption of a DES model to increase resource efficiency, optimize mine planning and to ensure operating and capital efficiency.

-032

**Longwall Mining Simulation**

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**Background**

In underground mining, mainly in coal mining, longwall systems are used. These consist of shields, a conveyor and a cutting machine (shearer). A longwall system contains up to 250 shields with a total face length of 400 m. Furthermore there is a hydraulic hose line system with up to several kilometers of length. Choosing the appropriate system components and the proper master sequence of shield operation in order to encounter the client needs is a difficult and time consuming task. The main objective is to accomplish a close loop between the system of shields face advance rate and the shearer speed which vary because of coal hardness and other geological conditions. Up to the completion of the project the specification of pump capacity, required hose diameters, obtainable cycle time as well as the resulting face advance rate are results of empirically based pressure drop calculation.

**Project**

For this project Famic Technologies in cooperation with Caterpillar Global Mining developed a method to optimize these aspects. The methodology relies on a simulation tool in which all components have been modelled according to their technical specifications. For this project Automation Studio from Famic Technologies with customized add-ons is used.

**Proceeding**

Once a single shield is modeled and simulated the designers are able to test different valve options to fit the shield performance according to the customer request.

The next stage is the main objective of this project. With the full modelled hydraulic circuit and the new developed tool the whole longwall system can be built with as many shields as the mine needs. Pumps, filters and supply lines are also added.

With the results of the simulation the engineering team is able to optimize pump capacity, hydraulic line diameters and general system layouts to fit the requirements.

Another important aspect is to adjust the longwall master sequence which controls the parameters of each shield cycle. Various scenarios can be tested quickly, compared, analysed and optimized according to different criteria, e.g. flow demand, pressure drop, face advance speed etc.

**Result**

The aim is to have a powerful tool to simulate longwall systems and their dynamic behaviour.
With the results of the simulation the system can be designed according to performance request but also economically advantageous for the customer. The new tool gives the engineering team better results and more opportunities of optimizing future projects.

-033

**Polynomial Algorithms for Ultimate Pit Limit Optimization**

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Ultimate pit limit or final pit shell defines what will be eventually extracted from the ground. Optimizing the open-pit mine limit is a crucial stage in mine planning, since the ultimate pit features directly affect financial and operational parameters including mining cost, revenue, and equipment selection. The ultimate pit limit problem is optimized to achieve the maximum profit under the precedence relations constraint. In the last five decades, several algorithms have been proposed to solve this problem. This paper aims to review the literature of optimization approaches for ultimate pit limit problem. In addition, the current polynomial algorithms which can successfully obtain the optimum pit limits are explained in details. Moreover, the drawbacks of the current solution approaches are discussed.

Keywords: Ultimate Pit Limit, LG Algorithm, Network Flow, Graph Theory

**MINING POLICIES, STRATEGIES AND CONCEPTS**

-034

**Business Plans for Small-Scale Mining in the Democratic Republic of the Congo**

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The Democratic Republic of the Congo (DRC), regarded as one of the richest countries in mineral resources in Africa, depends heavily on its mining sector, representing 56% of its GDP\textsuperscript{(1)}. Among others, it produces in significant amounts columbite-tantalite (coltan), cassiterite, gold, wolframite, or 3T&G. These latter were labelled as conflict minerals\textsuperscript{ii} by the Dodd-Frank Act \textsuperscript{(2)} because their production and trading chain are often illegally taxed from rebel groups and renegade military units, fuelling conflicts in the Great Lakes Region for over fifteen years.

The 3T&G are mainly produced through artisanal and small scale mining (ASM) and constitute an important source of income for the local population, to the point where 10 to 20% of the Congolese population depend on ASM \textsuperscript{(3)}. Mine sites are operated by cooperatives without long term planning and with little to no financing and means.

In order for these cooperatives to attract investors and banks so that they may improve their mining practice and grow into small-sized enterprises, the BGR is conducting trainings in DRC in the drawing up of business plans. These plans should present the cooperatives themselves, their current and past activities, their supposed reserves and resources, the future development of the mine and the corresponding investments that are required. Additionally an economic evaluation of the investment project and the payback scheme for loans and interests is presented.
The long-term objective is to formalize the artisanal activity, improve the safety, health and general working conditions of the miners, limit their social and environmental impact while increasing their productivity and their accessibility to the world market.

(1) BGR (2014), Vorkommen und Produktion mineralischer Rohstoffe ein Ländervergleich
(2) SEC (2010), Dodd-Frank Act Wall Street Reform and Consumer Protection Act, section 1502 (e)(4)
(3) CASM (2009), Share of the population depending on ASM

Mineral Resources and Mine Development in Mongolia – Potentials for Cooperation with German Partners

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Mongolia is one of the world's ten richest countries in terms of raw materials. Its resources include coal, copper, gold, iron, fluor spar, rare earth elements (REE) as well as many other different minerals and ores. The Mongolian government is reliant on the commitment of foreign investors for the exploration and sustainable development of the countries raw material resources. At the same time, it needs to secure a sufficient level of profits to enable the state to reduce poverty and improve infrastructure.

In October 2011, Mongolia and Germany signed the bilateral Mineral Resource Partnership Agreement, aiming at the creation of a win-win situation for both countries in the international commodity market. The partnership entails an intensified cooperation in the field of mining, sustainable resource management as well as technology and knowledge transfer. Its holistic approach closely integrates political, social and economic objectives and invites German investors to support translating Mongolia's mineral wealth into strong, sustainable and balanced economic growth.

At the heart of Germany's political commitment are three projects initiated by the German Federal Ministry of Economic Cooperation And Development (BMZ) and implemented by Gesellschaft Für Technische Zusammenarbeit (GIZ): The “Integrated Mineral Resource Initiative (IMRI)”, the innovative vocational training program “Kooperative Berufsbildung im Rohstoffsektor (KBR)” and the “German-Mongolian Institute for Resources and Technology (GMIT)”.

The presentation gives an overview on Mongolia’s resources, mine development and the actual trade volume with Germany. It will also shed light on how the mentioned development projects support the country’s economy. Against this background, business and investment opportunities in Mongolia are outlined. Additionally, some advice is given on how to enter the Mongolian market.
A Comparison of the Mining Administration System of Germany and Thailand

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The mining industries of Germany and Thailand are differently developed. Their mining administration systems are different but must correspond to national and international policies and regulations. The approaches, regulations, responsibilities and measures in both countries reflect the different fundamentals and values and lead to different procedures and outcomes. Analyzing the similarities and differences of both administration systems and discovering their strengths and weaknesses enables us to improve them, especially taken into account the rising importance of environmental and social issues.

The objective of this paper is to compare the key characteristics of the mining administration system of Germany and those of Thailand. Four main elements of the current administration systems are observed, including objective, structure of the industry, laws and regulations, and concessional and control procedures. They are compared in relation to the ability to secure a sustainable development in the mining industry. Possibilities for improvements are also identified.

Successful Knowledge Transfer in Mining from Germany to Vietnam

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The highly developed German mining industry can offer a lot of knowledge on technology and management useful for emerging mining countries all over the world. Successful knowledge transfer needs a good understanding of cultural differences and long term commitment. Vietnam in Southeast Asia is one prominent example for successful knowledge transfer from Germany in the fields of environmental protection and occupational safety and health for the mining industry. The first example is RAME (Research Association Mining and Environment). This research project started its first activities in Vietnam at the end of 2005 and will be completed in 2015 after nearly 10 years of research to reduce the environmental impacts due to hard coal mining in Quangninh province. Under the funding of the German Federal Ministry of Education and Research, the engagement of universities and companies in Germany, and the close collaboration with the Vietnam National Coal, Minerals Industries Holding Corporation Limited (Vinacomin), environmental concepts for active mines (mine water treatment, dust mitigation, dumping method and environmental monitoring) as well as concepts for a sustainable and economic reclamation of former mining areas (dump stabilization, dump recultivation, treatment of mine leakage) are developed. The second example for knowledge transfer is implemented in the field of risk management and occupational safety and health for Vietnamese coal mines. The project was started by TFH Bochum in collaboration with Hanoi University of Mining and Geology in 2010 and achieved some initiative positive results. The project will continue its capacity development and management consulting activities. The two case studies are analyzed to identify the important aspects of a successful knowledge transfer and develop recommendations for future projects.
GEOTECHNICAL ANALYSIS AND ROCK CLASSIFICATION

-038

**Effect of Water on the Mechanical Properties of Sandstone and Siltstone Rocks**

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For mining and rock engineering projects, air-dry mechanical properties (strength, deformability, etc.) obtained from suggested laboratory tests are generally used for design and classification purposes. For the actual engineering design it is recommended that mechanical properties should also represent environmental conditions (depth, moisture, etc.) as close as possible to those which occur in the field. In this paper, dry and water saturated rock samples (sandstone, siltstone) were tested in the rock mechanics laboratory in order to investigate the potential change in mechanical properties. Uniaxial compressive strength, Brazilian tensile strength, point load strength, deformability and abrasivity tests on dry and water saturated intact sandstone and siltstone rock samples were carried out. The obtained mechanical properties are investigated and evaluated with regards to rock engineering design for various site conditions (depth, environment, etc.).

-039

**Measurements of Dynamic Load Exerted on Support of Workings in Polish Coal Mines**

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Exploitation of hard coal in Upper Silesia Coal Basin (GZW) is conducted in increasingly hard geological and mining conditions, which is caused by increasing depth of mining, and occurrence of numerous signs of former exploitation i.e. edges and residues in the seams above and below. The factors influence the increase in the level of natural hazards, and according to the available statistical data, mining-induced tremors are a serious danger. There were 11,010 tremors in GZW between 2002 and 2012; 9,360 of them had energy of 105 J; 1,471 of 106 J, and 163 of 107 J. There were also 14 tremors of energy of 108 J, and two of energy of 109 J. Hard coal exploitation in areas of occurrence of dynamic events requires considering, at the stage of designing supports of roadways, both static and dynamic load as during tremors there is an increase in the value of load from the rock mass and a properly designed roof support should secure stability of a working and safety of the workplace for the personnel. To know the real load, induced by dynamic phenomena, exerted on supports, it is necessary to make the measurements in situ.

In the paper will be presented the hitherto experience concerning in situ measurements of dynamic load on supports of workings and the latest system devised by Central Mining Institute (GIG) for measuring dynamic load on supports and used in underground measurements. Moreover, the measurements results of the dynamic load exerted on gateroads support will be presented.
The Legnica-Gõgõw Copper Basin is the area where the underground copper mining operations are usually associated with a high seismic activity with high-energy tremors creating a significant roof fall risk for the mine underground infrastructure. For better understanding of this type of phenomena, roof strata failure mechanisms were investigated on the basis of so called safety margins™ 3D distribution around the excavated copper ore body.

The largest risk for the mining operations are created by instabilities encountered within the immediate roof strata composed of sedimentary types of rocks, such as dolomite/anhydrite mainly, of about of 15-20 m in thickness. These categories of competent rocks clearly exhibit the brittle type of failure which occurrence potential has to be related to the safety level value represented by the appropriate safety margin (or safety factor) based on adequate strength hypotheses. Since the most often encountered mechanisms of roof fall events are the slipping type mechanism with the rupture plane, typically the Coulomb-Mohr theory of strength is applied in Polish copper mines for safety level assessment. In the paper however it has been assumed that strength theories based on the complete three principal stresses™ set should serve better as an indicator providing higher correlation between observed and well characterized sedimentary rock strata failure mechanisms and the location of concentration areas of the negative values of margin of safety. Therefore the comparative study of the Mogi™s strength theory based on the â€œtrue™ 3D triaxial compression laboratory tests and the classic Coulomb-Mohr hypothesis based on triaxial tests performed in the Karman™s axially symmetric conditions, has been performed.

Using the appropriate 3D geomechanical models (FEM) which comprised the areas where roof instability has actually occurred, spatial distribution of safety margins values within rock mass during the mining, were effectively investigated using the both mentioned above strength hypotheses. Their practical appropriateness in mining practice have been illustrated using two examples of severe roof fall events occurred in the Lubin and Sieroszowice copper mines.

The Key Factors for the Improvement of Classification Method of Waste Rocks Aimed at the Prevention of Acid Mine Drainage

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Acid Mine Drainage (AMD) is one of the environmental problems caused by the development of resources. This is a serious problem in Indonesia where the development of coal has been expanded with the increase of energy demand triggered by the economic and technique development. Generally, AMD is prevented by cover system in which waste rocks are classified by performing Net Acid Generating (NAG) test in many coal mines in Indonesia. However, it is difficult to classify rocks and to predict AMD only by performing NAG test in some cases. For example, the decrease of pH with AMD disagreed with NAG pH which was obtained in NAG test in this study. Although many studies have been performed to improve the classification method in order to predict...
AMD in the past, a reliable method has not been established due to the many factors which affect to AMD such as the form of elements, physical and chemical weathering of rocks, and the buffering action of carbonate minerals. For the reasons, the sample analysis and experiments such as NAG test, Acid Base Accounting (ABA) analysis, and dissolution test and so on were conducted as the first step of the improvement of the classification method with rock samples obtained in the coal mine in Indonesia in order to understand such effects on AMD.

Based on the experimental results, the decrease of pH caused by the generation of AMD was highly influenced by the form of sulfur in rocks. The rock sample which mainly consists of sulfide minerals caused AMD for a long term while that which mainly consists of sulfate caused AMD in a relatively short time. This result indicates that the form of sulfur is one of the reliable indicators to predict AMD addition to the effects of the buffering action of carbonate in rocks which has been shown in some studies. The effects of disintegration of rocks caused by physical and chemical weathering, additionally, should be considered for the prediction of AMD since the size of waste rocks is larger in mining operation than that used in this experiment: the disintegration of rocks facilitates the chemical reaction through the decrease of size and the increase of surface area. Therefore, the experiment with a larger size of rock sample should be performed to consider such effects on AMD addition to that of the form of sulfur and the buffering action in future research.

FROM MINING ENGINEERING TO SUSTAINABLE MINING OFFICE HAND-OVER OF PROF. MARTENS

-042

Office Hand-Over

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Office Hand-Over

-043

Predicting Acid Mine Drainage: Past, Present, Future

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Total worldwide liability associated the current and future remediation of acid mine drainage (AMD) is approximately US$ 100 billion. Consequences of failing to predict AMD for individual operations and for the mining industry include unplanned spending on remedial measures and reputational damage. Despite these severe risks, predicting the properties and risks of mine wastes is typically not an attribute that is strongly embedded into the development of mineral resources, and examples of failures to predict AMD accurately are plentiful. Accurate AMD prediction allows for significant environmental risk reduction and associated financial liabilities. Currently, a range of chemical static and kinetic tests are used to measure the balance between the acid and neutralising potential of materials, prepare risk assessments and design waste classification schemes for individual mine sites. However, these well-established tests and practices have inherent limitations, and the tests currently used for evaluating AMD risks are riddled with uncertainties that are hard to quantify, or only allow predictions that represent the best estimate of what might happen in the future. Also, today’s AMD and resultant waste classification schemes are far too simple, blinded by chemical data and obsessed with
chemical analyses. The time has come to drastically improve our scientific efforts to forecast the likelihood of AMD accurately.

There is reason for optimism that the required progress is possible. Such optimism is based on the phenomenal advances, which we have achieved since the 1960s, in our ability to predict ore and waste properties as well as AMD processes and impacts. Accurate AMD prediction needs to consider predictive geochemical test data but also mineralogical, textural and geometallurgical rock properties. While the research community needs to establish practical state-of-the-art AMD characterisation tools, industry has to accept and use such tools, if we are to achieve more cost-effective mine closure and reduce environmental liabilities in the long term. Such progress also requires the application of predictive AMD tools at the beginning of life-of-mine. At the earliest stage of mineral resource development, a new architecture of integrative, staged AMD testing should rely on quantitative measurements and integration of scientific tools and data, backed up by field instruments and state-of-the-art laboratories. Such a staged and integrated approach to AMD prediction would allow more cost-effective identification of risks associated with specific rock types during operation and would ultimately lead to less costly mine closure outcomes.

Meeting Mineral Resources and Mine Development Challenges

GC Oldroyd

GC Oldroyd & Associates Pty Ltd, Australia

The mineral resources industry benefited from higher commodity prices during the 2003-2011 cycle but this distracted efforts to achieve improvements in process performance and resource recovery. Volume growth was typically at the expense of value.

The metalliferous mining industry faces major challenges of declining ore grades, declining multi-factor productivity, increased energy demands and reduced exploration discoveries. Innovative approaches are required to grow productivity with a focus on optimising long term value.

The paper outlines some initiatives including work at The Cooperative Research Centre for Optimising Resource Extraction (CRC ORE) where the author is a Non-Executive Director and Chairman of the Board’s Technical Advisory Panel. CRC ORE is pursuing a whole-of-business system approach to transform mining to an advanced manufacturing industry, developing and embedding transformational manufacturing business systems into the extractive culture of mining operations. CRC ORE is supported by the Australian Government, high profile tertiary institutions, major mining industry partners, and the mining equipment, technology and services sector.

From a base of comprehensive ore characterisation, CRC ORE’s research work is focusing on two key initiatives with the potential for significant industry impact: (i) Grade Engineering: a system-based methodology designed to reject low value material early in the extraction value chain and pre-concentrate feed (ii) Integrated Extraction Simulator: simulation of the mineral processing value chain in order to accurately predict, control and optimise the outcomes of Grade Engineering.

The Australian export coal mining industry, in response to a severe margin squeeze in recent years, has attacked costs under its control but further progress is required to offset high labour costs, declining equipment productivities and punitive take-or-pay infrastructure charges. Performance in underground development and surface overburden removal are critical activities to reduce lead times with comments provided on alternative systems. Well-designed benchmarking metrics remain a powerful tool in bridging the gap to required best practice levels.

Learnings from new project mine developments undertaken during the last mining boom which have not met their original planned value objectives (whether due to poor mineral resource estimation or project management reasons) are discussed together with the changes required.
i²Mine - Continuous Cutting Hard Rock Entry Development

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Common to the Rock Header (RH) is the cutting method, which is a combination of two elements. Undercutting weakens the rock by working against its tensile strength of the rock, which means only 10-20% of the energy that other systems use that work against the rock’s compressive strength. Activated cutting means that the picks are moving in a way that they do not have constant contact with the rock but the impact of each pick is enough to release rock chips. The picks not being in contact with the rock all the time and not relying on abrasion rather impact, means they do not heat up as much and wear is reduced significantly. Due to the cutting method the product is a regular grain/particle size versus drill and blast meaning there are additional transport and process plant savings.

Advantages of the Rock Header system include the fact that it is compact and mobile (on tracks) compared to some continuous hard rock mining solutions, yet it still capable to cutting up to 250 MPa and beyond. It also has unique flexibility its design also means that cutting different drift profiles is possible; while the tunnels themselves can be straight, curved, turnouts or even spirals meaning unlike a TBM it can easily be used for cross cuts or declines. The activated undercutting design means that it is a true continuously operating machine, capable of more than a 50% increase of advance rate when compared with drill and blast. This includes continuous cutting, loading and bolting with no delays for scaling or ventilation. It also represents a complete substitution of drill and blast making the use of explosives and everything that this entails from an operational timing, security and safety point of view, redundant. The process of cutting is also fully mechanised and semi automated meaning the operator can be stationed elsewhere in an air conditioned cab.

Gearless Drive Application on Large Conveying Systems

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Gearless drives are known technology in different industrial fields. Using gearless drives on a conveyor installation leads to a more improved overall system. As this solution eliminates the need for big gearboxes (5MW) not only the efficiency of the drive train is increasing but also the availability of the system is much higher. The current state of the art design reduces for example the quantity of bearings to minimum. Also the maintenance time is reduced significantly. In this presentation the technical solution are introduced and the impacted of this drive application to the overall conveyor system is demonstrated.
Intelligente Strebsysteme für den internationalen Steinkohlenbergbau mit Anbindung an nachhaltige Wartensysteme

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Rising Significance of Industrial Minerals in Energy Applications

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The newly published EU report on critical materials now includes seven industrial minerals such as graphite, fluorspar, rare earths and silicon metal. These are specifically consumed in significant amounts by the developing energy markets together with lithium, carbonates, barite and many more. Still more than 80% of Europeâ€™s energy use is based on oil, gas, coal and nuclear power. However, one of the factors for the fast growth of the renewable energy sector are limited resources in fossil fuels, specifically oil, paired with environmental concern.

There are three major areas in which industrial minerals play a critical role with regard to energy issues: energy generation and harvesting, energy storage and transport and energy saving. The search for cheap, safe and clean energy is propelled by scientific and technological research fueled by pressing social and political issues. It will shape the future of energy generation and offer adequate solutions for a growing clean energy, e.g. solar and wind power demand. New developments in decentralized, highly flexible and high power density energy storage solutions are key to ever increasing challenges such as fluctuating energy production and skyrocketing mobile electronic gadgets. This paves the way for a bright future of industrial minerals in Li-ion batteries and fuel cells for which market scenarios predict two-digit CAGRâ€™s with novel storage systems to be implemented at large scale. The presentation pinpoints the new role of industrial minerals in different energy segments, changing processes and specifications. In energy harvesting and generation critical minerals are used in nuclear power and the shale gas / oil industry while becoming even more important in the renewable energy sector. In downstream applications the presentation accents the impact of industrial minerals on modern technologies for energy transport and storage such as the batteries, fuel cell and solar thermal power markets. For saving energy industrial minerals are processed into high tech materials e.g. for the light-emitting diode (LED) which is today one of the most energy-efficient and rapidly-developing lighting technologies. The presentation will give a comprehensive overview on effected markets and their impact for specific industrial minerals, their demand, advanced processing and specifications.
MINING METHOD SELECTION

-049

Assessment of Longwall System Applicability and Development of Alternative Mining Method A Customized Solution for Indian Sub-Continent Coal Deposits

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Underground coal mining technology is in premature stage in India and the complex geo-mining conditions restricted adaptation of the standard global practises. DMT has been requested to review the existing detailed project report and to identify suitable methods for Sitanala coal deposit having prime coking coal quality allocated to Steel Authority of India. The particular coal deposit has complex geological structure with relatively smaller area of 3.21 sq km and overall working depth of 680m, more than 20 coal seams with 15 coal seams identified as suitable for mining, 7 major faults criss-crossing the deposit, steeply dipping coal seams at an angle of 22º to 45º, high gassiness of more than 10cum per tonne of coal and multiple surface constraints like river, railway lines, villages, etc which restricted the initial estimations of overall coal recovery to less than 20%.

This paper concentrates on identifying the customized mining solutions in comparison to the standard longwall and shortwall mining practices for relatively complex deposits such as Sitanala coal block. The mining conditions and resulting requirements are explained and compared for both operations and their influence on the mine layout is discussed. Possible mining hazards and their implication on mine economics are described with recommendations for the further detail investigations for safe and cost effective underground coal extraction.

-050

A Computer Program for Underground Mining Method Selection by Using Topsis and Yageras Method

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Underground mining method selection (UMMS) is one of the most important decisions that mining engineers have to make. Choosing a suitable underground mining method to extract a mineral deposit is very important in terms of economics, safety and productivity of mining operations. In real life, UMMS is one of the Multiple Attribute Decision Making (MADM) problems and decision makers have always some difficulties in making the right decision in the multiple criteria environment. TOPSIS and Yagerâ€™s methods are the MADM tools and can be used for the selection of the best underground mining method by considering the problem criteria.

In this study, a computer program is presented to make a correct decision on underground mining method selection by considering multiple criteria related to the decision process. For this aim, the program provides the decision makers two Multiple Attribute Decision Making methods: TOPSIS and Yagerâ€™s methods and make them easy applicable in their decision processes. The program also provides the decision makers an opportunity to try different what-if scenarios by making them to apply the sensitivity analysis after reaching the end of decision making process. In this way they can observe that how sensitive their final decisions are to the variations in the decision processes.
Chilean Underground Copper Mining, Stoping Methods, Challenges and Trends
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Mining is the largest and the most important industry in Chile. While a variety of minerals are mined, by far the most important is copper ore. Apart of El Teniente, one of the biggest underground mines, several large open pits are very well known worldwide. Although underground mining accounts for less than 20% of copper mined in Chile at present, there are as many as 38 other underground mines of certain importance in operation. The paper briefly describes the typical mining methods used in Chile and identifies the major challenges and trends. This includes both horizontal and vertical development work.

Determination of Development Precedence for Drawpoints in Block-Cave Mining
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Block cave mining has been used since the 19th century and it is getting more popular as ore-bodies going deeper. High rate of production, low operational cost, and using full-automated systems have made block caving attractive to mine owners and mining engineers. Many parameters such as economical, geotechnical and environmental issues should be considered when we are going to make any decision for block-cave operation. Two of the key steps in block-caving operation scheduling are development direction and drawpoint’s precedence determination. An optimum direction for cave development and precedence for drawpoint extraction can add remarkably to the net present value of the mining project. In this paper, a methodology has been introduced in order to find the best direction for development and the best sequence of extraction based on development direction. In the first step, drawpoints are evaluated using adjacent concept to find the best direction of development; the selection is based on the draw economic value (DEV) that has been resulted from the best height of draw (BHOD). In the next step, the best precedence for all drawpoints is determined. Each drawpoint gets its precedence based on the best advancement direction that has been determined in the previous step. The proposed method has been applied for two sets of block-cave mine data. Results show that using this methodology can lead the decision makers to more realistic and near-optimum options in short and long term scheduling.

MINING POLICIES, STRATEGIES AND CONCEPTS

Mineral Safeguarding in the UK: Practice not Perfect
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It has long been recognised in the UK that development pressures on land can sometimes lead to the unnecessary sterilisation of valuable mineral deposits. There is therefore a requirement in the UK land use planning process to avoid sterilisation. However, despite this requirement, new built development has sterilised mineral resources in the UK, which resources may include those of national and international importance. Given the rigorous requirements of the UK planning system, why is this happening. This paper
will describe the history and current process, and, using specific case examples covering a range of mineral and/or development scenarios identify the reasons why sterilisation may happen. The areas for improvement will be identified. The prevention of sterilisation is of European and wider interest and this paper may be of interest to practitioners outside the UK.

-054

**KIC „EIT Raw Materials“**

_B. Sani_

Associazione Trento RISE, Italy

t.b.c.

-055

**Efficiency Developments in Phosphorus Mining over the Last Three Decades**

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⁴CRU

This paper appraises losses and efficiency in phosphorus mining processes. In the theoretical part, first, we discuss the definitions of losses in mining and beneficiation processes, and how their meanings have changed over time. Second, we examine the potential to regain losses in these processes, and we define the proportion of definite losses given they are unlikely to allow for future recovery processes. Last, we discuss the relevance of various existing sustainability frameworks for mining and how they are related to purely economic efficiency measurements. Based on these theoretical considerations, in our analysis, we focus on the dynamic development of efficiency between 1983 and today, addressing both the global and the organizational level: (1) On the global level, we analyze losses and efficiencies in the mining industry (using data from Fertecon/CRU/Zellar-Williams/SRI International) and discuss external factors, which triggered these developments (e.g., technological, economic, and legislative factors); (2) On the company level, we exemplarily investigate organizational implications by taking the case of Potash Corp of Saskatchewan (CAN: POT). We conclude our manuscript by taking a resource conservation approach, first, outlining arguments for a sustainability oriented mining policy which needs to be based on appropriately extracting PR (Phosphate Rock) and critically discussing why a sustainable mining policy is needed – perhaps particularly because Phosphorus represents a finite resource; and, second, discussing the implications of our findings on contemporary policy agendas such as the ‘Resource Efficiency Roadmap’ as outlined by the EC.
A Review of Strategies for Maximizing Benefit of Mineral Development in South Africa

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This paper looks at aspects surrounding the role played by mineral development in the South African economy in relation to benefits accruing there off and steps and strategies that have been attempted or implemented to harness potential of the sector in its contribution to national objectives. The paper starts by looking at the contemporary economic regime and the impact mineral endowment has had on the current disposition of the economy. The study also analyses the different strategies on the dynamics of the economy, the challenges facing the sector, and constraints affecting the contemplated strategies.

Abiding and conflict views of local and international stakeholders in translating from comparative to competitive advantage are looked at, drawing relevance of achievements and shortcomings of the realization of the objectives looking at specific areas like the small scale miners, sustainability issues, monetary and fiscal elements. Much is drawn from existing South African regulatory and policy framework, and the growth path. One question that seeks answers to is how current benefits, if any, can be extrapolated into the future, and where there is shortcomings, how the disparities can be addressed to propagate the economy into a competitive disposition.

The strategy seeks to advance development through the optimization of linkages in the mineral value chain, facilitation of economic diversification, job creation and industrialization. It also aims to expedite progress towards a knowledge based economy and contribute to an incremental Gross Domestic Product (GDP) growth in mineral value addition per capita in line with the vision outlined in the Gross National Product (GNP), National Industrial Policy Framework (NIPF) and the Advanced Manufacturing Technology Strategy (AMTS).

It is understandable that mineral prices are cyclic leading to booms and bursts. Proper planning is needed to ensure maximum benefit is driven from the booms so as to translate the mineral price growth into sustainable life well after mineral resource exhaustion.

MINERAL RESOURCES MANAGEMENT AND SUPPLY SITUATION

The German R&D Program for the Supply of Raw Materials of Strategic Economic Importance

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To secure employment and prosperity, the availability of raw materials of strategic economic importance is crucial for the export-driven industry-based Germany. High-technology metals like the rare earths, platinum group metals, steel refining and electronic metals are mandatory for the development of future emerging technologies and the energy transition to an energy-efficient environmentally-friendly “Green economy”. With
respect to the availability of these primary raw materials, Germany depends almost completely on imports. Besides, many secondary deposits exists, however, environmentally-friendly processing technologies are needed for an economic use. Doubling of the raw materials productivity by 2020 and the decoupling of the economic growth from the raw materials consumption are national sustainability goals.

New technologies are needed to explore and process primary and secondary raw materials. Therefore, the Federal Ministry of Research and Education (BMBF) supports research and development by funding collaborative R&D projects between industry and science. Within the funding activity "r4 – Innovative technologies for resource efficiency – Research for the supply of raw materials with strategic economic importance" BMBF supports for the first time also R&D projects on exploration and extraction of primary and secondary raw materials by mining (ca. 60 million euros between 2015 and 2019). In addition, considerable investment from the industry is expected. An overview of the new collaborative R&D projects will be presented.

Towards a European Raw Materials Intelligence Capacity: Contributions from the Minerals4EU Foresight Study
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The Raw Material Initiative of the European Commission claims reliable and undistorted access to raw materials. In order to support such a sustainable supply of raw materials from European sources, diverse actions have been started like the European Innovation Partnership on Raw Materials (EIP RM). The project Minerals4EU (www.minerals4eu.eu) is an FP7 Coordination and Support Action that contributes fundamentally to the EIP RM by constituting for the first time a pan-European knowledge base on primary and secondary mineral resources in Europe that is interoperable with national databases. 32 European project partners contribute to this activity, including most Geological Surveys of Europe and other key institutions in the field of mineral resources. Main objectives are an operational INSPIRE compliant EU Minerals Knowledge Data Platform, a comprehensive European Minerals Yearbook and a Foresight Study that focuses on the supply and demand of mineral raw materials in Europe. The Foresight Study, striving for a high degree of topical coverage, applies the newly developed knowledge base and combines it with further information sources, thus testing the adequacy, comprehensiveness, and actuality of the structured and unstructured data in this knowledge base. The Foresight Study identifies key factors determining the future supply and demand of mineral resources, and addresses them by selected topics in the areas European Mineral Raw Material Potential, the Legislative, Governmental and Societal Constraints, Recycling, Demand, Resource Efficiency, Market and Technology, and Future Potential. In return, the topics are backed by individual case studies that illustrate specificities. The structure of the Foresight Study supports the abstraction of results from case studies to topics, and from topics to the overall Foresight issue. The Foresight Study will provide useful insights in the contextualisation of diverse factors related to supply and demand of mineral resources in Europe, their interconnectedness, and their temporal/spatial variability. An outlook will be given on the perpetuation of the Foresight Study as essential part of the future EU Raw Materials Intelligence Capacity, and how further tools will be related to these activities.
Australia in Turmoil: A Consequence of the Current International Minerals Market
(October 2014)

F. Leschhorn
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After years of unprecedented boom the international minerals market returned to normal mid-2011. The energy sector is now characterized by falling crude oil and thermal coal prices. Although gas prices remain high in Europe and Asia, energy costs in the USA are falling with increasing shale-gas production. Global demand for thermal coal will further increase primarily in India and in the Asia-pacific region because of coal’s role as the (by far) cheapest energy source. Coal is the basis for about 48% of the world power production. A rising use of regenerative energies and possibly a renaissance of nuclear energy will lower coal’s relative importance but in absolute terms further demand for coal will support consumption growth until an anticipated peak in 2030/2035.

The Anglo-Australian oligopolists Rio Tinto and BHP Billiton dominate the highly competitive market for iron ore and Brazil’s Vale, the world’s largest iron ore producer struggles to serve Asian market due to comparative higher costs. China’s domestic production will determine this market’s supply-demand structure and ultimately decide which new producers will enter and which current producers survive. This is one example of the dominance of Chinese demand in the international minerals trade and the dependence of Australia’s economy on China’s future growth.

In the light of current over-supply in these markets the presentation will look at and analyse the political and corporate actions of competitors seeking to secure profitable sectors.

The author will also review global developments in mining technology that are reducing long-term production cost and enabling miners to find a comfortable position on the supply cost curve.

Concentration Tendencies in the Raw Material Industry

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In studies critical raw material the concentration of mineral production is one of the central points analyzed. Especially when evaluating potential supply bottlenecks, a high share of global production originating from politically unstable countries is regarded as a potential risk. Analyzing these aspects criticality is usually based on annual data and thus only represents the situation for the reference year. These values can change in a relatively short time (e.g. declining political stability) or gradually over decades (e.g. country concentration of production).

An illustrative example are the changes in the country concentration for primary raw material production and in political and economic stability over the last two decades. The developments show that smaller markets (high tech metals) are more prone to large changes over short periods of time, while base metals only show minor changes in concentration.

An increasing country concentration can be observed for example in the cobalt mine production since the end of the 1990s. It reflects the renewed dominance of the DRC on the market. Currently about 50% of the global primary cobalt production originates from the DRC. Critical concentration levels until 1980 are also
representing the Congo’s high share in global production, but on far lower production levels. While other cobalt producing countries were increasing their production capacities in the following years, the Congo’s production was declining as a consequence of the Congo crisis in the 70’s and civil wars in the 90’s. Cobalt-rich nickel laterite deposits were developed in Australia and the South Pacific during the 1990s on, when mining of copper-cobalt deposits in the DRC was restricted due to conflicts and a lack of investment in that country’s mining sector. While the concentration of production was steeply increasing since the 90’s at the same time the concentration of cobalt mining companies was decreasing. In 1998 about half of the global Co production was dominated by state owned companies in Congo and Zambia, Vale Inco and Norilsk Nickel. 10 years later the four major miners (Glencore, Norilsk Nickel, the state of Cuba and Vale) accounted for just about 22% of the global Co production.

**MINE DEVELOPMENT**

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**A Simulation Study to Better Understand the Inherent Constraints of the Roadway Development Process**

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The underground coal mine pillar development cycle consists primarily of three sets of interdependent and synchronised cycles, i.e. the coal cutting cycle by a continuous miner (CM), the support cycle by a roof bolter and the coal transport cycle to the boot end by a shuttle car. Coal cutting by a CM is generally not seen as a constraint as, in almost all cases, the capacity of the CM far exceeds the demand placed on it. Therefore, in essence, the pillar development process can be either transport constrained or support constrained.

Using a discrete simulation model, it was shown that for a case study mine a CM configured with two bolting rigs was support constrained when the distance from the boot end to the face was short. It was suspected that as the distance from the face to the boot end increased the development would change from being support constrained to transport constrained. For this case however, introduction of additional bolting rigs did not change the development rate significantly with an increasing distance from the face to the boot end, thus confirming the initial configuration of the mine was entirely support constrained. Simulation of a bolter-miner configuration with six bolting rigs and concurrent bolting indicated that such a system is a transport constrained. With the introduction of a continuous haulage system (CHS), a bolter-miner configuration with six bolting rigs and concurrent bolting, changed the system to support constrained. This may be explained by the fact that a CHS has a much higher transport capacity than a shuttle car. The simulation results showed an approximate 25% reduction in hours to develop five pillars using a CHS instead of two shuttle cars. It was also inferred from the simulation study that adoption of 150 m cut through centres typically improves average weekly development rates by 5 to 8% (although poor wheeling conditions could rapidly erode potential gains).
Development of Underground Coal Mines in Indonesia Based on Japanese Underground Mining Systems

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Despite the intensifying movement for the global reduction of CO2 discharge, coal is still expected to play an important role as an energy resource in future, and the demand for coal is expected to increase globally, due to a big disaster resulting from the nuclear power station failure caused by big earthquake and tsunami in Fukushima, Japan on March 11, 2011. Japan is the second biggest coal importer in the world, accounting for over 180 million tons, especially from Australia, Indonesia, and Canada etc. Indonesia is currently the world’s fourth largest coal producing country, producing over 400 million tons of coal in 2013. While much of the growth in Indonesia’s coal production is attributable to the expansion of existing operations, new capacity has also contributed to the increase in production with more than many new coal mines having been developed in Indonesia since 1997. To help meet future demand for both domestic and export coal, many Indonesian coal producers are planning to increase output from existing operations. However, optimum surface mining places are limited due to the coal seam conditions. So in order to meet the increased demand for coal, underground coal mines have to be developed in Indonesia.

In Japan, coal mining operations were carried out under complex geological conditions, and so coal mining technology, equipment and systems including those for safety maintenance which had been developed and accumulated by the Japanese coal industry over a long period of time, were considered to be the most advanced in the world before. The mining and safety maintenance technology and systems practiced in the United States and Australia are now considered to be more advanced than those practiced in Japan, and such technical precedence of the coal industry in those two countries is considered to owe much to the extremely favorable geological conditions and their positive attitude towards the development and introduction of various high capacity units of equipment and efficient systems. Thus, in order for the Japanese coal industry to become able to contribute to the coal mining industry in Indonesia and Vietnam through its underground coal mining technology, it is necessary to develop new mining equipment and systems based on its conventional high technical potentiality.

This paper describes the geotechnical problems in Indonesia with which coal mines in Japan were confronted and discusses those matters necessary for introduction to Indonesia of efficient, productive and safe underground mining systems.

Geotechnical and Hydrogeological Issues for Development of Underground Coal Mine from Open Pit Highwall along Sea Coast in Philippines

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Most of coal is produced from open-cut mines in Southeast Asian countries. However, the conditions of their surface mines are worsening each year: The stripping ratio is increasing, approaching economic ratio, the regulation of environmental protection, and poor infrastructure for coal from inland mining areas. To meet the demand for coal in Southeast Asian countries and the rest of the world, underground mines have to be developed in the near future. Under these circumstances, the development of new coal mines from open-cut
Highwalls are being planned in several mines in Southeast Asian countries such as Philippines, Indonesia, Thailand, Vietnam, etc. However, if the conventional mining systems and designs introduced in US, Australia and European countries are applied, several geotechnical issues can be expected due to the mines’ weak geological conditions. Moreover, some of the open pit mines in South-east Asia are located near the sea coast or in Islands and their open-pit final highwalls are constructed along the sea coast. Under these conditions, not only geotechnical measures but also hydrogeotechnical measures, such as the installations of diaphragm wall, dewatering well, sea barrie zone, have to be conducted in order to prevent the intrusion of sea water into the pit and/or final highwall and maintain the stability of final highwall and the development of underground mine.

This paper describes the geotechnical and hydrogeological issues in the open pit mines in Philippine and then discusses the technical measures for development of underground coal mine from the open pit highwall.

Hydromineral Resources - Source of Strategic Rare Earth Metals in Siberia

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Unique kind of natural resources of Siberia are hydro resources. However, the outlook for the integrated use of hydro mineral resources is low, which are mainly associated with the absence of effective and environmentally sound recycling technologies.

The need to address this problem is due to the prospect of integrated development and industrial brines and other unconventional sources of minerals rich in rare earth metals (Li, Sr, Rb, Zs, etc.) For the economic development of Siberia and in Russia in general.

The absolute concentration of these elements in brines above the lower limit "of conditions" (ten times): 20-25 times lithium, 5-10 times rubidium, three times cesium, 10 times strontium.

On the basis of the performed theoretical and experimental studies revealed the conditions of selective extraction of strontium and rubidium of highly concentrated natural brines in the process of ion exchange. There have been processed technological scheme for Hydromineral resources of different composition of iron and diamond deposits in Siberia.

Consequences and Mitigation of Subsidence on Structures and Infrastructures

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The active and abandoned mines may induce subsidence and sinkhole on the surface. These subsidence phenomena concern deep and shallow mines. The risk of the ground movement is the inducing severe damages on the structures and infrastructures. Different mitigation methods can be used to eliminate and/or reduce their consequences.

The objective of the COMEX project is the optimizing mines design and reducing the impact on human environment. In this contribution we present first a state of the art of the existing methods. Second, in the COMEX (EU-RFCS project) project we focus on two types of them: the periphery trench and geotextile. The first method is currently used to reduce the effect of horizontal strain induce by the curvature of the ground and

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the second one is used for reducing the risk of sinkhole. The paper is a theoretical and operational study for using the periphery trench as mitigation method to protect individual houses impacted by the subsidence. The results of numerical and physical models show clearly the main role of those methods to insure the security of existing and future buildings in the area on active and abandoned mines.

Key words: ground movements, mitigation, trench periphery.

-Mining Seismic Instrumental Intensity Scale MSIIS-15 – Verification in Coal Basins

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Deep coal mining in European coal basins in many cases induces seismic activity. The biggest mining seismic events reach magnitudes even bigger than 4 and are thereby causing a substantial hazard to the surface environment. This hazard is manifested mainly with slight damages to buildings and discomfort of inhabitants. The main assumption of the specialist Mining Seismic Instrumental Intensity Scale (MSIIS-15) developed under COMEX project is briefly described in the article.

The MSIIS-15 scale correlates instrumentally measured ground motion parameters (peak horizontal ground velocity, PGVHmax and the duration time of tremor, tHV) with the observed macroseismic impact on buildings, infrastructures and effects on humans. The quality of this correlation was studied and tested using recordings of mining seismic events originating from Polish and German coal basins. The results show strong relationships between chosen instrumental parameters and macroseismic effects. It turned out, that the influence of mining seismic events on buildings depends largely not only on PGVHmax, but also on duration time of vibration exposures and technical condition of structures. According to the seismic and macroseismic data six descriptive intensity degrees were elaborated, ranging from very low and not percept by people up to slight structural damages of buildings. The study shows that the level of PGV=5mm/s is the lower limit of first very slight damages observed in non-construction elements both in the MSIIS-15 scale and in the German DIN-4150 standard.

Key words: induced seismicity, instrumental intensity scale, mining

-Impact of Deep Mining on Shallow Voids Stability and Sinkhole Hazard

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The paper analyze a case in which deep exploitation is carried on below abandoned shallow mines. Between the level of shallow mining and surface, the natural structure of rock mass and its properties are transformed. Within this layer are voids (mining galleries), fractures and beds of crushed rock (caved zones with voids). As a result of deep mining, the subsidence and vibrations (from mining tremors) can change the brittle equilibrium state in near surface layer and activate rock movements or the caving processes over old voids. The aim of this paper is to formulate criteria when such reactivation is likely with special regard to soil vibrations induced by mining tremors.
Free Prior Informed Consent: Benefits & Implications

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Free Prior Informed Consent is the right of a community to grant or withhold consent to projects which will affect them. FPIC is a safeguard placing communities as equal partners with companies during negotiations. It enables companies to demonstrate their social aspects and risk are appropriately managed since the receptors of the impacts agree to them, albeit with conditions. The two principle legal instruments regarding FPIC and Indigenous people are: ILO Convention 169 on Indigenous and Tribal People, and UN Declaration on the Rights of Indigenous People. The latter requiring FPIC “prior to the start of any project”. The trend is towards strengthening the rights of Indigenous people (ICMM 2010). The trend is also for all communities to exercise this right, but may result in a “race to the bottom” as investors seek jurisdictions not requiring such social safeguards. Demographics present challenges as urbanisation and personal wealth increases, placing pressure on mining companies to provide increasing volumes of raw materials at low cost. FPIC thereby becomes a means for projects to not inadvertently result in the irrevocable loss of a traditional culture.

Three key parties: State, Community, Company each have important individual roles in implementing FPIC but will achieve greater success through collaboration. Although Legal and Social Licence to Operate are largely in place, Agreements on Development between State and Communities are not well elaborated, complicating project development. A tripartite Advisory Committee could be set up to establish how mining in a country or region should be developed to provide guidance and address concerns and needs of all parties, including conflict resolution. A paradigm shift in project planning is required to secure and maintain the right to develop a project early in the project cycle in a transparent, participatory and inclusive manner. Exploration and feasibility work needs to be integrated in this approach, not the other way around.

Social Responsibility in Mining Closure, a New Methodology of Assessment

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Social Responsibility is strategic question for the modern mining industry, not only through the life of the mine, but also in its closure period. By the end of the twentieth century, the majority of the active mines in Portugal ceased, in all most of them, in a disorganized and careless process, especially in the subjects related with Social Responsibility. To determine the performance on Social Responsibility, of the mines closed in Portugal, it was necessary to develop an indicator, which takes in account the several human, economic and time constrains, but from which is also able to achieve a quantitative result.

The study case chosen was the closure of the Mina da Urgeirica (uranium), which closure process took place between the years 1992 and 2001. It was developed an indicator called Mining Responsibility for the Society (MRS), which had the ISO 26000 standard as a basis, using its defined themes, questions and actions.
indicator is composed by the result of an inquiry, on 26 selected actions (from the standard ISO 26000), made to a qualified sample, constituted by individual who are considered experts on the subject and followed directly all the closure process of the mine. To each selected action was given a grade according its impact and perpetuity, which is multiplied by the classification obtained from the inquiry. The methodology was applied with great result to the case study, achieving the mine closure a final result of 70 points (in a 0 to 100 scale), being considered the closure as the organization showed interest and was able achieve part of the necessary actions. The easiness, in which this methodology is applied to the majority of the cases, is considered as its biggest advantage. To apply it to a new case, it is just necessary to collect historical, in order to serve as a framework for the inquiry, and obtain a qualified sample, composed by individuals who accompanied the process.

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**Determination of Optimim Coal Mining Policy in Turkey by Using Analitical Network Process**

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There are many problems in coal mining in Turkey. The reasons of current problems in coal mining in Turkey and solutions to these problems are investigated in this study. After clarifying the common problems in coal mining environment, the solutions determined according to the different points of view were gathered. The solution of the problems encountered in coal mining has been considered as Multiple Criteria Decision Making (MCDM) problem. In order to solve this problem, the whole criteria and the alternatives effecting the Decision Making (DM) process are determined. The Analytic Network Process (ANP) one of the important method of MCDM techniques is shortly introduced and then, the solution to the problem was obtained by using the ANP method. A query form was designed to utilize in solving process of the problem and was sent to the experts working at the coal sector and academic medium. After constructing the model by using Super Decisions computer software which has been used for analyzing the ANP models, the solution to the problem was obtained by using the data obtained from the query form. The model outputs obtained from the computer software were evaluated, and the most ideal solution was proposed based on the results after carrying out the sensitivity analyses in which the all solutions were considered.

Keywords: Coal mining; Multiple Attribute Decision Making; Analytic Network Process

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**Sustainable Mining Management in Iran Based on Islam and Iranian Laws and Regulations**

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Sustainable development is an influential ethical concept in modern mining management all around the world. However, a successful realization of strategies and measures of sustainable development in mining cannot be possible without a foundation on the core values of the individual mining country. When applying the concept of sustainable development in Islamic mining countries like Iran, Islamic values build this foundation.
The Islamic Republic of Iran holds 68 types of minerals. With 37 billion tons of proven reserves and more than 57 billion tons of potential reservoirs Iran is ranked among the 15 major mineral rich countries.

To integrate sustainable mining management and Islamic values and Iranian regulations two interrelated issues are analyzed: sustainable development orientated values in Islam based on the Holy Quran as the main reference of Islamic thoughts and national Iranian laws and regulations. It will be shown that nature in general, and its fundamental elements such as water, air, soil, and living organisms are of high value in Islam and there is explicit and implicit emphasis on their conservation. The national constitution and general policies of the government were examined to assess the significance of sustainability in Iranian regulations. It will be shown that the Islamic Republic of Iran has significant attentiveness to social, economic and environmental equality in its laws and regulations. The consideration of religious and regulative obligations facilitates the implementation of a sustainable mining management in Iran for the welfare of the whole country.

RFCS PROJECT - COMEX PART 2

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Performance of Grout Columns as a Mitigation Technique for Longwall Mining

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Mine workings are often located near urban areas. Coal mining using the longwall method typically results in large ground subsidence that might damage buildings and infrastructure. The University of Nottingham, as part of the EU-RFCS project COMEX, is examining the effectiveness of mitigation techniques for reducing building displacements and damage caused by longwall mining. The study involves physical modelling conducted using the University of Nottingham 2m diameter 50g-Tonne geotechnical centrifuge. A series of plane-strain centrifuge tests were conducted on a scaled model of a building and a series of model grout columns buried adjacent to the building within uniform silica sand. The grout columns were replicated in the centrifuge model using miniature piles which give similar behaviour as full-scale grout columns. The sub-surface ground movements in the experiments were measured using digital image analysis and the degree of bending of the model building was measured using strain-gauges. The results from the physical modelling show the grout columns can reduce ground displacements and the magnitude of bending strains in buildings. Further study using numerical modelling will be conducted using FLAC3D in order to provide additional insight into the behaviour of the various components of the system.

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UK Experience of Longwall Mining in Subsideence Damaged Ground above Previously Extracted Workings

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Multiple seam coal mining is common practice in Europe in an aging coal industry and is now becoming more common globally as coalfields mature. Generally it has been the practice to extract the most economic seams first taking the seams sequentially top down to avoid operating within the fractured strata formed by the
subsidence trough above previous worked coal seams. However, as coalfields mature and economics change coal mines are now having to work seams above previously extracted workings. In the 1990’s the UK coal industry found itself at a number of sites having to operate over one or more previously worked seams. This has led to specific geotechnical challenges with respect to maintaining economic, safe and stable rectangular roadways with rockbolted support.

Within this paper the challenges and mitigation strategies adopted to reduce the risks associated with working above old mine workings are reviewed following the completion of a European Commission funded project on this subject in 2010. Further case histories are examined in this paper of mining in subsidence damaged ground in the UK, outlining the planning and support processes. This is for a mine operating at a depth of approximately 700 m where 4 longwall panels have recently been extracted and a further longwall has been recently developed above previously worked longwalls some 35 – 40 m below. This paper also details the numerical modelling that has been used to aid layout and support design at this site and its application is discussed.

Deformations and Stability of a Surface Lignite Mine – A Challenging Case Study

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Greece is constantly placed among the leading lignite producers in Europe. In addition to the mining-technology related issues, the Greek surface lignite mines often pose significant challenges in terms of geotechnical perspective. A very interesting case study, in terms of slope stability problems and ground deformations, has been the Mavropigi lignite mine in northern Greece. In the present paper, the major causes that triggered significant geotechnical problems and produced kinematically unstable wedges are discussed. These were the local geological conditions with steep inclined faults, the presence of near horizontal unfavorably dipping thin clay seem with a very low residual shear strength and the adverse excavation geometry due to expropriation limitations. Following, the basic elements of a 2D finite element model (FEM) that has been used to numerically simulate the excavation and further investigate the geotechnical aspects of the problem are presented. Preliminary results of the simulations are discussed and future steps of research are outlined.

MACHINE TECHNOLOGY AND EQUIPMENT

Continuous Cutting Hard Rock Mining System - CAT Rock Straight System

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Caterpillar has developed a longwall mining system for the extraction of tabular hard rock deposits, the Cat Rock Straight System. The vision was to take the longwall concept as it exists in coal and take it into hard rock areas, with all the advantages that entails in terms of continuous operation, safety and performance. Rock Straight is a hard rock longwall system, with all the components that would be expected in a longwall including
roof supports, an AFC (Armoured Face Conveyor) with a mining machine instead of a shearer, which applies Caterpillarâ€™s Activated Undercutting technology which is a combination of two elements. Undercutting weakens the rock by working against its tensile strength of the rock, using only 10-20% of the energy that other systems use that work against the rockâ€™s compressive strength. Activated cutting means that the picks are moving in a way that they do not have constant contact with the rock but the impact of each pick is enough to release rock chips. The picks not being in constant contact with the rock and not relying on abrasion rather impact, means they do not heat up as much and wear is reduced significantly. The maximum face length of Rock Straight System is 100m, but the panel length is effectively unlimited, and as with a coal panel, it is controlled by the nature of the deposit along with the mine layout. A key advantage of the Rock Straight is its ability to cut from 2 m heights down to low heights of 1.3 m effectively and thus avoiding dilution, a major factor for customers extracting high value tabular deposits. Hardness being cut in a Polish Copper Mine is up to 150 MPa but the machine has the ability to cut harder material than this. Operations are completely remote controlled, with the operator back at the tailgate in a climate controlled cabin. Cuts are made as part of an automated cycle, with no operator required to follow the mining machine. The Rock Straight system is under trial at the KGHM Polkowice-Sieroszowice mine, KGHM is the development partner for the Rock Straight System.

Management of Enterprise Assets with Use of RFID System

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KOMAG Institute of Mining Technology in collaboration with ELSTA Group worked on information systems supporting the management of assets in mining plants, for many years. In 2005, consortium consisting of KOMAG, Silesian University of Technology and ELSTA Group started to work on a system for identification of powered roof supportâ€™s components, with recording the time and conditions of their use, on the basis of RFID (Radio Frequency Identification) technology. Experience from implementation of developed solutions induces an improvement of the author systems for evidence of components of mining machines as well as adaptation of solutions to the current needs of users. Increase of interest in state-of-the-art, resistant to environmental conditions systems for management of: machines, equipment, fixed assets and transportation means, which are used in hard coal mines, was the reason to develop a complex, modular identification system - iRIS. Each module of the iRIS system is presented. The system enables quick identification of main sub-systems of mining machines in underground and surface conditions, capital assets and equipment of offices as well as means of transportation by marking them with RFID transponders or barcodes. Destination, functionality and method of integration of modules in a complex system are described. Main assumptions of the modified system and possibilities of its cooperation with state-of-the-art hardware solutions are presented.
Mining after Mining: New Heavy Metal XRF-CPT Probe as Efficient In-Situ High-Resolution Mine-Tailings Characterization Tool

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The more and more difficult exploration challenges turn the attention on mine tailings not only for environmental related problem owner but as valuable secondary sources for raw materials as well. Seen in the past as either not economically exploitable or simply not interesting, the industry developments push the mine tailing through a re-evaluation process. Traditionally, extensive, time consuming and costly soil sampling followed by standard lab analytics provided the only viable choice to acquire the required amount and volume of data needed for interpolation, evaluation and forecast models. The innovative approach of combining the X-ray fluorescence (XRF) technology with a cone penetration test (CPT) probe allows for simultaneous in-situ detection and quantification of heavy metals, soil classification, electrical conductivity and dynamic porewater pressure. As real-time tool for a minimal-invasive in-situ site characterization, the new probe provides an economically efficient acquisition of various datasets in one single push and gives a basis for reliable site assessment and management. The probe further proved its ability to mitigate the Health & Safety related risks with respect to mercury and arsenic during several field campaigns. Different praxis based advantages in comparison to the existing approaches are taken into account, further application fields are highlighted.

Improved Particle Liberation from a New, High-Velocity Impact Crusher - The VeRo Liberator

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Crushing and grinding make up the biggest cost factors in the communication of primary ores, processing slags, waste-incineration slags, recycled concrete, other secondary mineral resources and metal-containing urban waste such as waste electrical and electronic equipment (WEEE). A significant reduction in communication energy is thus required from any new crushing and/or grinding machine. Besides the reduction of the particle size, the liberation of the various constituents and the separation of the commodity particles from waste particles is a requirement in efficient communication. Incomplete particle liberation is a major challenge for subsequent extraction techniques, e.g. direct heap leach or tank leach, or the classic separation techniques such as froth flotation. Currently, incomplete particle liberation of complexly intergrown and extremely finely intergrown raw materials is dealt with by ultra-fine grinding, which increases the energy consumption drastically and, in many cases, leads also to overgrinding.

The newly developed VeRo Liberator is a high-velocity impact crusher with a vertical rotation axes or rather several with each other rotating axes with several levels of hammer tools (up to 75 in total). The VeRo Liberator combines very low energy consumption with highly efficient comminution, i.e. commonly from an input particle size of 120mm to d90 < 1mm in a single pass, e.g. massive sulphide ore from Pyhäsalmi, Finland. Additionally, the VeRo Liberator liberates the commodity particles from barren waste particles in a highly efficient way with separation primarily along particle boundaries. The liberation along particle
boundaries is apparently due to the differential particle behavior, which is characterized by the material-specific elasticity \( (\varepsilon_E) \) and compressibility \( (\varepsilon_K) \) moduli.

Compared with traditional ball mills or other types of comminution equipment, the VeRo Liberator combines low energy consumption with rapid particle size reduction and particularly efficient particle liberation.

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