Presentation of the ISRM mine closure state of the art report

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Presentation of the ISRM mine closure state-of-the-art report.

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ABSTRACT

In 2005, Prof. Nielen Van der Merwe, at that time President of the ISRM, initiated a commission to facilitate the constitution of an international network of experts involved in mine closure and post-mining management. Eight experts coming from different countries have been deeply involved in this ISRM "mine closure commission", for four years.

Closure of mining operations does not lead to the complete elimination of risks likely to affect the surface above old mine workings. Therefore, disorders potentially harmful for people and goods may develop, sometimes just after the closure but also, in some cases, after a long time.

The first mandate of the commission has been dedicated to the production of a state-of-the-art report presenting, at an international scale, the mine closure problem (context, main risks of disorders, major hazard assessment methods and treatment techniques). The present paper presents an outline of this ISRM report that members may download on the ISRM website.

1 INTRODUCTION

1.1 Commission constitution and objectives

The mine closure Commission has been appointed with two main objectives. The first one was to facilitate contacts between experts in rock mechanics from different countries concerned with post mining management in order to create opportunities to exchange experiences, case studies and scientific data.

The second objective of the commission was to produce a reference document, presenting the international "state-of-the-art" for existing techniques and methods enabling identification, characterisation and management of geotechnical hazards related to mine closure processes (Didier et al., 2008).

An expert panel has thus been constituted to produce the document. All the members that joined the commission got involved on a strictly voluntary basis and gave considerably of their time and their expertise to the benefit of the commission work. They are listed below:

- Christophe DIDIER, INERIS, Verneuil-en-Halatte, France. President of the Commission.
- Nielen Van der MERWE, Stable Strata Consulting, South-Africa. Past President of the ISRM.
- Ömer AYDAN, Tokaï University, Shizuoka, Japan.
- Marc BÉTOURNAY, CANMET, Mining and Mineral Sciences Laboratories, Ottawa, Canada.
- Jean-Pierre JOSIEN, GEODERIS, Metz, France.
- Andrej KOTYRBA, Central Mining Institute, Katowice, Poland.
- Mark MAINZ, IHS (Ingenieurbüro Heitfeld-Schetelig), Aachen, Germany.
- Won-Kyong SONG, Korea Instit. of Geoscience and Min. Resources, Daejeon, Korea.

1.2 Content of the report

The mine closure state-of-the-art report is dedicated to both experts and non experts that may be concern by mine closure process and/or post-mining management. It thus covers a large panel of topics, including general context, potential disorder description, hazard identification methods and treatment techniques in order to constitute a reference document useful for future readers interested by international experience on the particular subject.

The document contains 7 sections and 3 appendices. After a brief presentation of the mine closure context, at an international scale, the document describes precisely the most frequent geomechanical hazards that may develop above an abandoned mine. In addition to the description of consequences and potential effects on people and surface structures, the basic mechanisms that may initiate the failure are discussed.

The commonly used hazard assessment methods are then described, with particular attention to the key factors that have to be taken into account in the assessment process. Classical post-mining risk management methods are then discussed: voids treatment, monitoring methods and land use management. Specific references are included at the end of each section and a large recommended additional literature is also given.

Numerous figures/photographs illustrate the document to make it clear and understandable, for both mining experts and non specialists.

2 NATURE OF GEOMECHANICAL HAZARDS

Many kinds of disorders may affect an abandoned mine, some of them specific to underground mine workings, others to abandoned open pit mines. The report describes all those phenomena, describing for each one, which kind of mechanism may be the generator one (depending on the geological and mining context). As an illustration, three typical phenomena that can develop above underground mine workings are presented below.

2.1 Continuous subsidence

Continuous subsidence is characterised by a usually slow, smooth and flexible re-adjustment of surface. In most cases, the maximum amplitudes observed in the centre of the depression are decimetric to metric (Kratzsch, 1983; Peng, 1996).

Generally, it is not so much vertical displacements which affect surface buildings and infrastructures, but ground deformation (NCB, 1975). Depending on its position in the subsidence depression (Figure 1), differential horizontal displacement may take the form of shortening (compression zone - inside depression) or extension (tensile zones - outside depression).

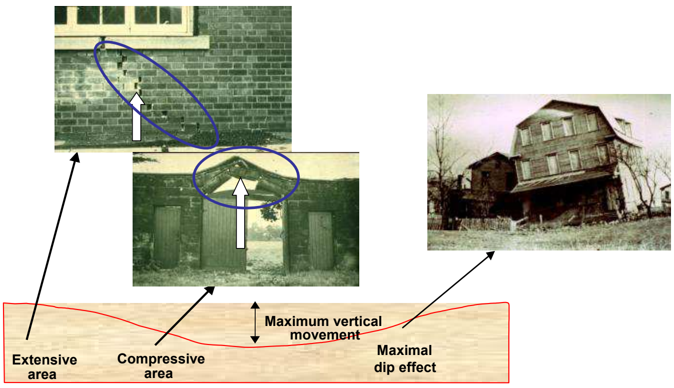

Figure 1: Effects of continuous subsidence on structures.

Continuous subsidence classically develops during mining extraction above panels mined by total extraction methods (e.g. longwall methods). It may also affect areas mined by partial extraction methods (e.g. room and abandoned pillars), when the mine workings fail after closure.

2.2 Sinkholes

A sinkhole is characterised by a sudden appearance of a collapse crater at surface (Piggott and Eynon, 1978). The instability extent varies usually from a few metres to several tens of metres in diameter.

The dimensions of the crater and suddenness of its development on surface make sinkholes potentially dangerous events, particularly when they develop in or close to urban sectors or infrastructures (Figure 2).

Figure 2: Sinkhole having caused a fatality within a French urban area (source CETE/MEEDDAT)..

Sinkholes develop above mining sectors where residual voids are present underground. This phenomenon is generally restricted to shallow mine workings (often less than 50 m deep even if there are exceptions).

Sinkholes result in the progressive failure of the hanging-wall, a dome-shape propagating towards the surface if there are no resistant layers to stop the mechanism.

2.3 Massive discontinuous subsidence

Massive discontinuous subsidence events are caused by dynamic failure of all or part of the mine workings. They may affect surface stability over several hectares. On the opposite of continuous subsidence, in a discontinuous event, the central trough is edged with open, sub-vertical cracks, marking out "steps", which can generate severe damage to people and property

Figure 3: Massive discontinuous subsidence associated with vertical cracks above a French chalk mine.

Those kinds of events (Figure 3) denote a general instability of the mining works, usually due to an excessive extraction. Fortunately, these events are very rare but the consequences are potentially serious.

Contrary to sinkholes, massive discontinuous subsidence events may concern relatively deep mines. Their occurrence also requires adequate horizontal extension relative to their depth.

3 HAZARD ASSESSMENT METHODS

A hazard is defined by the probability of occurrence and foreseeable magnitude of an event at a specific location. The probability of occurrence, reflecting the site's sensitivity subject to an instability, is generally more difficult to quantify than the magnitude. No matter what type of events are feared, the complexity of the mechanisms involved, the heterogeneous environment and the incomplete available data often make it very difficult to assess quantitative probabilities.

Priority is therefore often given to qualitative “predisposition” of a site subject to a particular damage. Evaluation of this predisposition depends on the combination of different factors, which are favourable or unfavourable to the initiation and development of a given mechanism.

Some mine closure context specifies may strongly influence the choice of the best adapted hazard assessment method. Experts have to face the “collective memory loss syndrome” which contributes to the difficulty of data collection and to the choice of assessment methods adapted to very partial knowledge of the mining context as well as the environment (e.g. geology, hydrogeology).

3.1 Selection of adapted hazard assessment methods

A large variety of methods can contribute to evaluate, characterise and describe post-mining hazards (Bétournay, 2004; INERIS, 2006; Deutsche Gesellschaft für Geotechnik, 2004). Some of them are explicit, others implicit; some combine qualitative data, others require qualitative values. The choice of the best adapted method will depend on several parameters, some of them being discussed below.

- Economic consideration

  The future surface utilisation is usually the most important parameter in the choice of the assessment method. Important investments to collect data (investigation) and use precise quantitative assessment method (e.g. numerical modelling) are generally restricted to dense surface occupation areas.
- Typology of phenomenon

  The type of suspected phenomenon may influence the assessment method. For sinkhole prediction, simple analytical approaches are recommended. For risk evaluation of massive collapses, large scale numerical models are, on the contrary, often needed.
- Amount of available data

  When few data are available, qualitative methods may be used, taking benefit of expert judgement. On the contrary, when lot of data are available (very large mining field with different mining methods and contexts), one will consider the application of the decision-making aid methods.

3.2 Principal stages of a hazard assessment process

The first (if not the only) stage of the assessment is a desk study. This step aims to gather existing data and applicable knowledge from which pertinent engineering information can be extracted and used in order to identify and evaluate the hazard. The aim is to locate and review, in detail, potential impacts of the abandoned mine, to identify the potential hazards. At this stage the information that are required but missing should be identified.

Complementary to the desk study, a detailed inspection of the mining site is generally strongly recommended. Whatever the accessibility of the mine workings, the knowledge and understanding of the site and its history provide to experts a satisfactory degree of accuracy for the hazard assessment process.

In the case of very old mine workings (serious lack of data), if the surface occupation is very sensitive to potential disorders (urban environment, important infrastructure), complementary information may be necessary. Field complementary investigation works have then to be performed. Numerous investigation techniques exist; the most suitable ones will depend on the objectives, the kind of requested data as well as the time and budget available.

Among the most classical investigation techniques used, one may quote: drilling (diamond or destructive, with possible geophysical survey) and geophysical methods (gravimetric, seismic, electro-resistivity, electromagnetic).

A specific appendix of the report is dedicated to the main geophysical methods adapted to locate disused mine workings (Figure 4).

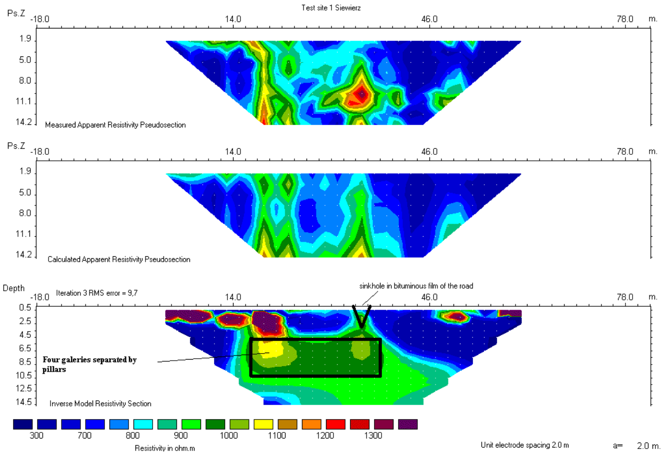

Figure 4: Models of resistivity distribution over abandoned silver mine galleries in Poland.

3.3 Factors influencing hazard predisposition

The rock mass failure that induces instabilities on surface may be affected by several influences.

- Influence of time

  Time is a fundamental factor, which must be integrated in the hazard assessment process (Van der Merwe, 2003). The phenomena observed nowadays often occur for mine workings having several tens of years of existence, and sometimes more than one century. Several mechanisms must thus be taken into account to evaluate the effect of time on mechanical stability (creep effect, ageing effect, long term evolution of fracturing).

- Influence of water

  Mine closure is very frequently accompanied by a progressive flooding of underground mine workings. The effect of water on rock mass is difficult to quantify because there are plausible arguments for both beneficial and damaging effects. The balance of these effects determines whether flooding is stabilising or detrimental in a given condition (e.g. nature of rocks, mining methods). Among those effects, one may quote: strength drop (water sensitive rocks) and stress modification (effect of water pressure).

- Influence of geology and mining methods

  Geological configuration of the deposit (e.g. sedimentary flat layers, vein deposits) as well as rock mass properties may strongly influence the nature and the magnitude of the potential surface disorders. The presence of a “stiff” horizon in the hanging-wall may for example contribute to increased risk of violent collapse of the overburden (Didier and Josien, 2003).

  The nature of potential disorders is also strongly related to the mining configuration. Mining methods ensuring a systematic treatment of the mining voids and mining methods leaving behind large residual voids will evolve very differently in time, the most severe disorders being specific to the partial extraction methods.

4 HAZARD MANAGEMENT METHODS

When hazard has been assessed and located, depending on the type of surface occupation, several kinds of management methods may be considered. Among the numerous ones developed in the ISRM report, three of them will be briefly presented below.

4.1 Backfilling

Quite often, where harmful consequences of subsidence are expected on surface in inhabited areas, the most efficient and sustainable protection is assured by backfilling of underground works (Figure 5). Different backfilling methods may be used (Hydraulic, Pneumatic, hand packing, both from underground or from the surface). The choice of the most adapted process will depend on the site context.


Figure 5: Injected paste in an abandoned Slovenian Mercury mine (By courtesy of Bojan Rezùn).

4.2 Land use Management and Regulation

When, for technical or economical reasons, it appears irrelevant to treat existing mine workings by backfilling or grouting, it is of major importance to properly manage land use of undermined sectors. Two approaches may then be complementary: a preventive one that consists in defining regulatory measures to avoid or reduce risky situations and a curative approach that consists in managing existing goods subjected to high risk (evacuation, reinforcement).

As an example of land use regulation procedure, the ISRM report presents an overview of the French “Mining Risk Prevention Plans”. The scope of MRPP is to identify post-mining risk exposed zones and to elaborate instructions to be applied for existing and future property and activities in those areas (Didier and Daupley, 2007).

4.3 *Monitoring*

When serious hazards have been identified in areas where sensitive structures are already located on surface, if voids treatment is technically difficult and/or too expensive, monitoring may be an interesting alternative.

Monitoring does not eliminate risk. It is designed and implemented to manage the risk in collecting "early-warning data" that enables one to take decisions before the mine workings failure. The main objective is thus to avoid accidents in taking appropriate measures in advance (treatment, evacuation).

There are many kinds of monitoring processes; the best adopted one depending on the site characteristics. The most simple and classical monitoring consists in regular visual monitoring performed by experts visiting accessible mine workings. To collect more quantitative data (including kinetics evolution), one may use instrumental monitoring. This consists in installing sensors (e.g. extensometers, inclinometers) in potentially unstable mining sectors in order to monitor ground movements and their evolution in time.

Some innovative monitoring techniques have been developed to enable "large scale" monitoring. The objective is to allow detection of early-warning signals within a large rock mass volume and a limited number of sensors. Among those promising techniques, one may quote: micro-seismic monitoring (Figure 6), Time Domain Reflectometry (TDR) monitoring, Interferometric Synthetic Aperture Radar (InSAR) Technique.

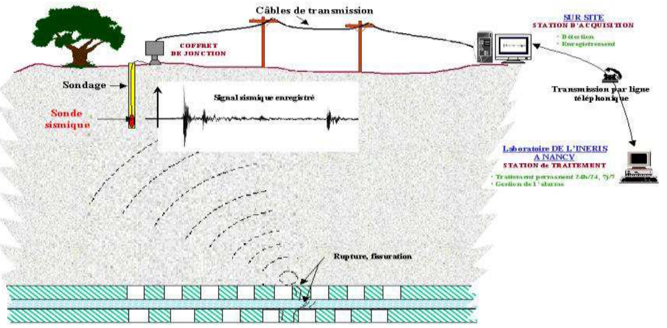

Figure 6. Illustration of a microseismic monitoring network managed by INERIS above an abandoned mine.

5 PERSPECTIVES

The mine closure and post-mining management state-of-the-art report concludes the first step of on-going work of the mine closure commission. The "version 1" of the report is now available through the ISRM website (www.isrm.net).

The document will be completed. The ISRM members are thus strongly encouraged to download the report and transmit to the president or members of the commission, their suggestions to improve the document. The contributions will be welcome (e.g. complementary references, technical modifications, illustrations) and will be considered in a further edition of the document.

The members of the mine closure commission are motivated to continue and finalise the work already accomplished. The commission will thus probably be re-appointed for a second mandate. The objective is to prepare a reference publication that will enlarge and complete the report available.

This will notably consist in the extension of the international post mining context to major mining countries that have not yet been represented in the commission (e.g. Australia, China, India, United States; Russia, Brasil). It will also include a compilation of several well documented "case studies" of successful mine closure examples, properly managed in different contexts (e.g. countries, type of mining methods, treatment or monitoring).

An enlargement of the commission to the previously listed countries is thus envisaged in the coming months. The commission plans to finalise the publication for the XIIth International Congress of the ISRM that will be held in 2011 in Beijing.

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