REVIEWS

Disposal of Hazardous Waste in Underground Mines

Edited by V. Popov and R. Push
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This book contains a collection of articles aimed at presenting the current experience in the utilization of underground mines for the safe storage of hazardous waste and forecasts future developments related to this topic. This collection is based upon the results of an international collaborative research project sponsored by the European Commission. The articles are assembled in a coherent manner, so that all the main aspects are covered. The content of the book partially duplicates other environmental collections, particularly those related to the safe disposal of low-level radioactive wastes. However, this book is not a repetition of previously published materials because the editors made sure that other hazardous wastes, such as alkaline batteries, pesticides, consumer goods and products containing dioxins, furans, etc., are included. More importantly, the economic and legal aspects of waste disposal are treated in a comprehensive manner, so legislators, businessmen or environmentalists willing to acquire a practical knowledge of the subject can use parts of this book to their advantage.

The book has 6 chapters and an appendix spread over 260 pages. The first chapter examines hazardous waste generation and management in Europe. Statistical data are shown about the amount of waste generated per person, the main waste streams and emission trends, and expectations up to the year 2010. At the end of the chapter a brief but informative overview regarding the wastes of concern, such as heavy metals and persistent organic pollutants, is presented.

The second chapter reviews the need and potential for underground disposal and provides an overview of underground mines in Europe. This chapter is helpful for a general reader, because it presents the fundamentals of the problem and discusses the two principal standing points of this technology, namely the availability of underground storage space in industrialized countries and the advantages of underground disposal compared to surface disposal.

The third chapter reviews the criteria for selecting repository mines. Different scenarios are analyzed such as mines in crystalline rocks, argillaceous rocks, salt rocks and other rock types. The favourable and unfavourable conditions dictated by the rock structure, hydrology and stress conditions are presented in a concise way. Although the significance of rock properties is discussed in more detail in the next chapters, the empirically deduced criteria and sound sense presented in this chapter should be sufficient for non-academic readers to grasp the basic principles of site assessment.

The fourth chapter deals with engineering barriers most commonly used in underground mines. The emphasis is on the application of clay materials for isolation, because of the cost effectiveness and good isolation properties of clays. The basic manipulations and processing of clays are discussed using as an example two brands of clay, namely MX–80 and Friedland Ton. Properties of the clays such as rate of hydration, chemical interactions between smectite and cement, and conversion of the smectite to non-expandable minerals (illitization) are examined quantitatively. At the end of the chapter, important remarks about the cost of disposal of given amounts of batteries and pesticides are given.

The fifth chapter is devoted to the mechanical integrity of the mines. The rock mechanic properties are discussed with respect to the Coulomb failure criterion. The suggestions for modelling of stress conditions offered in this chapter are illustrated with 3D diagrams from particular mines. The modelling is based on the boundary-element method and it is applied using specially customized software (GiD, [http://gid.cimne.ups.es]). The nature of the customization and the principles of the calculation methodology are not discussed in detail. In general, the treatment of the problems in this chapter is rather brief, and some important details regarding the connection of the model to a particular geological environment are missing, as well as the theoretical justification for choosing a particular model. In other words, although the models described in this chapter may be of significant value, it is unlikely that the reader can use them unless he or she is a specialist in this subject.

The sixth chapter is the longest (pp. 151-207) and theoretically most complex, because it deals with risk assessment of underground repositories using numerical modelling of flow and transport in porous and fractured rocks. The chapter begins with

an overview of the theoretical problem, with emphasis on the differences in approach to modelling for the near-field and far-field zones around underground openings. Next, the governing equations for flow in porous and fractured rock media are discussed, which are needed for the development of flow models. This is followed by general discussion of the boundary-element method. In the second half of this chapter, the models are applied to particular tunnel geometries for migrants such as dichlorvos and zinc.

The appendix contains a list of inactive and active mines in Belgium, Denmark, Finland, France, Greece, Ireland, Italy, Luxemburg, Portugal, Spain, Sweden, Nederland and the United Kingdom. The list provides data about the mine operator and the annual mine capacity in cubic tonnes of mined material.

In general, the first three chapters of the book contain a variety of data that can be used by non-specialists to acquaint themselves with the problems associated with underground storage of hazardous wastes. The last chapters treat stress and flow models and are relevant to qualified engineers who have previous experience in hydraulics calculations and applications of numerical models. The book is richly illustrated but some of the illustrations are detached from their context in the book. Little is said about data collection procedures and the availability of data needed for building the numerical models. My personal opinion is that this book contains a good introduction to the procedures and practices of hazardous waste storage but it is most suitable for qualified geo-engineers rather than students.

Magnetic Fabric: Methods and Applications

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The history of a rock's formation and deformation is recorded, in part, by the alignment of its constituent minerals. Petrofabric, the study of the preferred alignment of minerals and rocks, is used as a proxy measurement for paleocurrent directions in sedimentary rocks, emplacement flow directions in igneous rocks, and strain directions in deformed and metamorphosed rocks. These proxies do not necessarily mimic their targets, so a great deal of clever field work, lab work and analysis must be done to determine their applicability.

Most techniques used to measure petrofabric (pebble long-axis counts, universal stage optical microscope measurements of oriented thin sections, and x-ray or neutron goniometry) are tedious and time consuming and only account for the orientations of small numbers of grains. In contrast, measurement of anisotropy of magnetic susceptibility (AMS) is a rapid and sensitive petrofabric tool. It takes less than 3 minutes a sample, and integrates the fabric of all the grains in a core specimen.

Application of magnetic anisotropy is often complicated because the relationship between magnetic fabric and petrofabric is not direct. In rocks that host ferromagnetic minerals, such as magnetite, the magnetic fabric signature is dominated by those grains. Iron oxides and sulfides are sensitive to the primary, metamorphic and environmental history of the rocks, leading to both the strength but also the complexity of the method. In rocks lacking a ferromagnetic component, the alignment of paramagnetic (mostly silicates) and diamagnetic (mostly carbonates and quartz) minerals is observed. Usually the major axis of the AMS ellipsoid is parallel to crystal lineation, and the minimum axis is perpendicular to foliation. The magnitudes of the ellipsoid axes, however, depend, in a complex way, with the alignment forces such as finite strain magnitude.

In 1954, John Graham published "*Magnetic Susceptibility Anisotropy, an Unexploited Petrofabric Element*". On the golden anniversary of that trail-blazing publication, the Geological Society of London published its Special Publication No. 238 on "*Magnetic Fabric: Methods and Applications*". This book reveals the development of this research field over the last 5 decades. There are papers on the history of the method, its physical foundations, instrumental aspects, and current examples of how anisotropy results can be applied to many areas in the earth sciences. The papers do not shy away from presenting important limitations and unresolved problems.

Based on special sessions in 2003 at the Joint Assembly of the EGS-AGU-EUG in Nice and the AGU Fall Meeting in San Francisco, this volume is more than a collection of unrelated current research papers. Several reviews are featured, including the fine overview by the editors. The centrepiece is Borradaile and Jackson's 62 page review of "Anisotropy of magnetic susceptibility (AMS): magnetic petrofabrics of deformed rocks", including an extremely useful 3 page glossary. This paper is rigorous but fully readable. It also introduces a clever new polar plot to display fabric data.

The book is divided into 5 sections. The first, "Magnetic Fabric Characterization Methods and Mineral Sources" (6 papers), includes reviews on laboratory methods (Potter) and statistical methods (Jezek and Hrouda). The second section, *Sedimentary Fabrics*, features 6 case studies. Unfortunately, only one of these deals with the important application of depositional flow directions (Matasova and Kazansky's