Application of performance data from evaporite mines to salt nuclear waste repository design

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Summary

Data on the performance of operating mines in rock salt and potash from United States and British sources is reviewed. A design validation scheme for nuclear waste repositories is proposed, based on back analysis of the response of operating evaporite mines.

Keywords: Evaporite mine; nuclear waste repository; rock creep; rock mechanics; salt dome.

Introduction

Considerable effort and expense have been expended in selecting candidate sites and in conceptually designing a nuclear waste repository in salt. Candidate sites and horizons have been selected on the basis of reported physical properties. These physical properties have been determined from testing core samples recovered through drilling programs. A key input to repository design, be it site selection or response modelling, should be data from field observations from operating mines.

The size of repository excavations will be modest with respect to salt mine openings. Eleven metre (36 ft) wide openings are considerably less than the 60 m (200 ft) at the Winsford Mine or less than half the 23 m (75 ft) wide rooms at the Jefferson Island Mine. The planned depths do not exceed current rock salt and potash mining operations. The planned 600 m (2000 ft) to 900 m (3000 ft) depths are greater than the majority of salt and potash mines. However, the Cane Creek Mine is at 940 m (3100 ft), the Boulby Mine is in excess of 1070 m (3500 ft) deep and the El Perdon Mine is nearly 1500 m (4900 ft) deep. The 20–35% extraction which may be required for a repository is at the low end of the evaporite mine extractions, which range from 92% in retreat panels at the Mississippi Chemical Corporation Mine to 27% in the IMC Mine in Saskatchewan.

Thermally driven creep of rock salt is unique to repository design. Deep potash mines may be uncomfortably warm, over 32° C (100° F) rock temperature at Boulby, but the temperature...
does not increase with time as in the repository case. It should be remembered that manned access to areas of the repository which are undergoing, or have undergone, temperature rises will only be necessary to retrieve stored waste. The increasing creep rate resulting from increasing temperature after waste emplacement and withdrawal of personnel from a particular storage room should speed natural closure and sealing. Delayed retrieval of waste from backfilled storage rooms will, if necessary, be a difficult and expensive mining operation in a thermally hostile environment.

**Creep model validation**

The most basic problem facing investigators attempting to predict radioactive waste repository response in rock salt is the validation of specimen-derived rheological models. Subsidiary problems relate to the determination of whether primary or secondary creep models best fit full-scale real-world conditions. Such validation can be achieved, in part by acquiring data from operating salt and evaporite mines and by instituting a multi-mine multi-salt physical testing and measurement (instrumentation) programme.

The development of a data base for operating salt and potash mines presents a method of partially validating the predictive creep models presently available. Data on in-mine and mine-to-mine variations in creep deformations were presented by Hedley (1967), and are plotted on Fig. 1. Part of the impressive scatter in convergence rates shown is probably caused by different time intervals between initial excavation and the start and duration of the period of reading and different ambient temperatures at the mines. Table 1 presents a different data set obtained from published literature and statements by operating personnel.

The limited data presented on Fig. 1 and in Table 1 demonstrates a rough apparent increase in convergence rate with depth. However, the contradictions between the closure rates and depths in Table 1 and convergence rates and estimated pillar stress (average) on Fig. 1 indicate a much more complex set of controlling criteria.

The deeper, more completely extracted and higher rooms in the Rocanville Mine did not result in a higher closure rate than that measured in the Kerr–McGee Mine. One of the Kerr–McGee staff stated, 'that within the Carlsbad district there are differences in ore strength – at IMC the ore’s compressive strength is 4000 psi and at Kerr–McGee it is 2000 psi'. Physical testing across the full height of the cycle 7 potash bed at the Mississippi Chemical Corp. mine near Carlsbad, New Mexico showed a range of specimen unconfined compression strengths from 11.1 MPa (1610 psi) to 34.1 MPa (4950 psi). These same unconfined specimens strained between 0.3% and 7.0% before failure. Obviously there is a lot of variation across this particular potash bed.

It would appear that the evaporite sedimentation sequence could also influence the measured convergence rates in mined openings. The mining horizon at Rocanville lies within a greater than 33 m (110 ft) thick salt and potash bed, and a 7½–10 cm (3–4 in) thick clay bed occurs about 0.68 m (27 in) above the 'upper sylvite'. A less than 2.5 cm (1 in) thick clay parting occurs at the top of the 'upper sylvite' at the Kerr–McGee Mine. In addition, a 2.5–5 cm (1–2 in) thick clay bed is present at about the midpoint of the ‘lower sylvite’ at the Kerr–McGee Mine. A paper-thin clay parting is locally present approximately 0.5 m (1.5 ft) below the roof of the cycle.