Krasnoyarsk (Russia)

Description: The Krasnoyarsk Mining and Chemical Combine near Zheleznogorsk in the Russian Federation housed three graphite-moderated, ADE-type plutonium production reactors and a reprocessing plant in a vast series of underground caverns and tunnels totalling about 7 x 10^6 m^3 (Bradley, 1997). The reactors started operation in 1960 and two of the reactors were shut down in 1992. The reinforced concrete lined caverns housing the reactors were approximately 20 m wide and 53 m high and were excavated at depths of approximately 200 m, Figure 1. Operational temperatures of 61˚C in cavern P-1/P-4 and 45˚C in cavern P-2 have suggested that these caverns may provide analogues for coupled thermo-hydro-mechanical (T-H-M) processes in the excavation disturbed zone (EDZ) adjacent to repositories in strong fractured rock (Gupalo et al., 1998; 1999; 2000a; b).

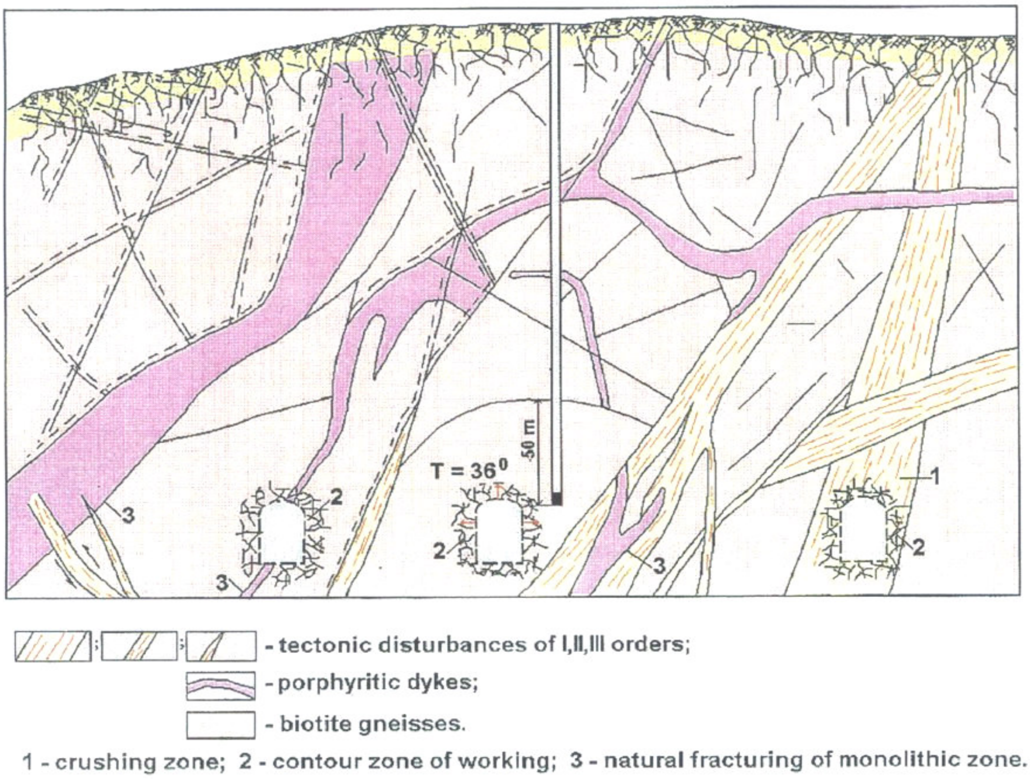

Figure 1. Generalised geological structure of the Krasnoyarsk caverns. From Gupalo et al. (2000b).

The caverns were excavated within a highly tectonised metamorphic complex dominated by biotite plagioclase gneisses cut by deformed basic dykes. Numerous fracture zones are present ranging from 0.01 – 50 m thick and the intact block dimensions range from 0.8 – 1.5 m in less deformed regions to less than 0.1 m in intensely schistose and crush zones (Gupalo, 1999). Variations in intensity of deformation results in uniaxial compressive strengths of intact gneisses varying from 40 – 140 MPa, with bulk values significantly lower at 3.2 – 75.6 MPa (Gupalo et al., 1999).

Many of the fractures are filled by chlorite and/or carbonates (Gupalo et al., 1998) and have low permeabilities (Gupalo et al., 2000b). Water inflow tends to be localised at the contact margins of the dykes and in the schists (Gupalo et al., 2000b). There is evidence for localised groundwater inrushes and rock mass failures in the caverns (Gupalo et al., 1998).

Large-scale geodetic monitoring across major faults at the ground surface and underground has failed to show any facility-induced displacements on these structures (Gupalo et al., 1999).

The thermal signature of the reactors has been measured form boreholes around the caverns and has shown that the thermal anomaly has reached a quasi steady-state and extends for at least 150 m (Gupalo et al., 1999). Comparison with numerical models shows that in areas of structural complexity, heterogeneity in rock mass properties can affect the development of the thermal anomaly (Gupalo et al., 2000a).

Convergence of the cavern walls has been measured; extensiometers placed in boreholes at 10, 20 and 30 m from the cavern walls have been used to monitor absolute and differential movements of the rock mass. In the more structurally complex rock masses rapid changes in displacements have been interpreted in terms of shear displacement on existing fractures (Gupalo et al., 1998). According to Gupalo et al. (1998;1999) there was a 'considerable difference between actual observation results and general geomechanic concepts of deformation process'. Since this is more evident in areas of structural complexity this has been attributed to the greater heterogeneity in these situations.

Relevance: The Krasnoyarsk reactor caverns are relevant to heat-generating HLW and ILW repositories constructed in strong fractured rock. However, the rock mass especially in cavern P-2 is very highly fractured and is perhaps atypical of rock masses likely to be chosen or the construction of a repository. In principle the THM effects are analogues for what might be expected in the EDZ.

Position(s) in the matrix tables: Near-field, mechanical integrity of barriers

Limitations: While the value of the site has been recognised, very little work has been published and it is not clear whether there are sufficient observational data in what is a very heterogeneous and highly fractured rock mass to be able to determine and disentangle the role and magnitude of the various processes that can occur in a coupled T-H-M system.

Quantitative information: Only very limited quantitative information has been published. To make maximum use of this facility it would probably be necessary to re-instrument the monitoring boreholes.

Uncertainties: The lack of published information on these caverns means that it is highly uncertain what analogue messages can be taken from the site. At a very high level it is possible to state that the analogue shows that caverns constructed in highly fractured rock are stable over a 40 year time period even when subjected to a moderate thermal load. Limited data availability and the complexity of the geological structure limit more explicit use of the caverns as analogues.

Time-scale: The relevant time-scale addressed by the study is the human (0 – 100 years) one.

PA/safety case applications: No previous uses of the analogue study in a PA or safety case are known.

Communication applications: No previous uses of the analogue study in communication and dialogue material are known.

References:

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Added value comments: The analogue does have potential for demonstrating the impact of thermal loading on fractured rocks. However, it would probably need to be re-instrumented in order to get maximum value from the analogue.

Potential follow-up work: See above.

Keywords: Krasnoyarsk, EDZ, THM processes, thermal loading.

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