Errata 2011-10

SKB TR-10-48

Geosphere process report for the safety assessment SR-Site

In the earlier distributed report, there are errors that have now been corrected. The corrected pages 75 and 107 are enclosed. The changed text is marked with a vertical line in the page margin. An updated pdf version of the report, dated 2011-10, can be found at www.skb.se/publications.

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First, it is difficult in practice to determine the capillary pressure and relative permeability functions on the scale needed for field-scale numerical modelling for a fracture network.

Secondly, there may be important features of the flow, particularly small-scale features that are not captured by the two-phase flow equations. Gas transport as discrete bubbles that are small compared to the numerical discretisation (which will always be the case for field-scale modelling) is not properly captured by these equations. Gas migration may also exhibit instabilities of various forms: viscous and gravitational instabilities which lead to "fingering" of gas flow and accelerated advance through the fracture network; and instabilities concerned with the creation and collapse of gas flow channels through the fracture network. The latter may be significant as an effect on water movement that is not captured by the large-scale application of the porous medium flow equations.

These issues are discussed in more detail by /Rodwell et al. 1999/ (see also the summary in /RETROCK 2004/).

There is an implied assumption in the two-phase flow equations that when a gas phase is present it is connected, so that the viscous pressure gradient in the gas phase is well defined. Where flowing gas breaks up into bubbles, this is no longer the case.

Although there are some difficulties in the quantitative application of the general two-phase flow equations to a fractured rock geosphere, the understanding that is available of the mechanisms of gas migration should allow simple arguments to be developed to adequately bound the capacity of the geosphere to transport a free gas phase from the repository to the surface. Except possibly in an exceptionally low permeability rock, it is expected that free gas generated from spent fuel wastes will easily be able to disperse through the geosphere. Calculations within SR-Can /Hartley et al. 2006a, Section 5.2/ found that a single fracture intersecting each deposition tunnel with an aperture of $15 \cdot 10^{-6}$m (equivalent to a transmissivity c. 10^{-9} m^2/s) was sufficient to carry the estimated upper bound for gas generation from a defective canister to the surface, and concluded such conditions were met by the fracture network at Forsmark.

The two-phase flow around the repository excavations during operations is of a somewhat different nature to that of a gas migrating through an initially saturated fracture network after repository closure. During the operational phase, the gas in the unsaturated zone is connected to the air in the repository at atmospheric pressure, and it is a good approximation to assume that the gas pressure in the unsaturated zone is constant at this value. This leads to simplified equations for water movement and the variation of gas saturation in the unsaturated zone during operations. However, issues connected with the presence of gas in the geosphere are only likely to be of significance after the repository has resaturated.

Gas that is dissolved in the groundwater is transported along with the groundwater in the same way as any other solute. Transport may occur both by advection and by dispersion/diffusion. The only additional issue arising in the case of gas is, as already mentioned, that gas might come out of solution if the water pressure is reduced sufficiently, usually as the water moves towards the surface. This phenomenon will give rise to a two phase flow situation.

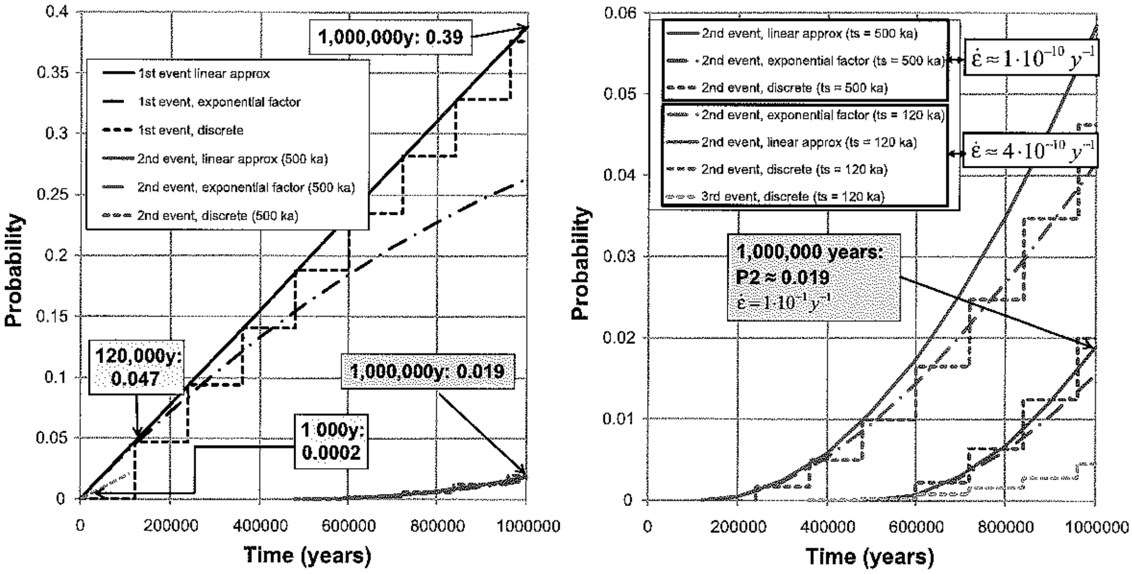

Figure 4-6. *Left: Probabilities used in SR-Site. Right: Sensitivity of probabilities of a second earthquake to the duration t_s of the period of local stability following a large strain energy release. Results for two values of t_s are shown; 120 ka and 500 ka. Corresponding strain rates are $4 \cdot 10^{-10} \cdot y^{-1}$ and $1 \cdot 10^{-10} \cdot y^{-1}$, respectively.*

of magnitude 5 or larger. Results are provided for different ways of approximating the probability evolution: using Equation 4-1, Equation 4-2 or the discrete step approach for P1, and Equation 4-4, Equation 4-5 or the discrete step approach for P2. Estimates in yellow boxes indicate the probabilities established as relevant for use in SR-Site (assessment of the number of canisters sheared 0.05 m or more) of one earthquake. The 1,000-year probability is set at a value that is intermediate to the probabilities obtained using the linear approximation (Equation 4-1) and the discrete step relation which allows for large earthquakes only during periods of endglacial instability. The estimate in the pink box shows the probability of a second earthquake established as relevant for use in SR-Site. The right part of the figure shows the sensitivity to the time required to restore stresses after a large earthquake. Assuming the time to be short enough for a large earthquake to occur at Forsmark at the end of all glacial cycles (i.e. every 120 ka) gives a modest increase of the probability of a second large earthquake within the 1 million year assessment period; a factor between two and three. For this to be a real possibility, the strain rate effective for restoring the stresses between glacial cycles would have to be $\dot{\varepsilon} = 4 \cdot 10^{-10} \cdot y^{-1}$, i.e. almost on par with the highest strain rates suggested for the large-scale tectonic compression of the Fennoscandian Shield. This would mean that there would be almost no aseismic strain energy release in large regional deformation zones at any time.

Therefore the value 0.019 suggested here for $P2(10^6)$ based on a lower strain rate ($\dot{\varepsilon} = 1 \cdot 10^{-10} \cdot y^{-1}$) is judged to be a relevant estimate.

If the stability time t_s does not cover three cycles (as the case shown in Table 4-4), there will be a non-zero probability $P3(10^6)$ of a third large earthquake within the one million year assessment time frame. The green discrete step relation in Figure 4-6 (right) shows the probability P3(t) for the worst case; unstable conditions at the end of all future glaciations, i.e. $t_s = 120{,}000$ years which requires a strain rate $\dot{\varepsilon} \geq 4 \cdot 10^{-10}\ y^{-1}$. At the end of the 1 million assessment period, the worst case probability P3 is less than 0.005.

Because of the low probability and the high strain rates required for a third earthquake, the possibility of a third large earthquake is not considered in SR-Site, i.e. in the assessment of the number of canisters sheared 0.05 m or more during the one million year assessment time frame. Additional reasons for not considering the possibility of more than two large earthquakes are listed below.

- The effects on the buffer-canister system of three (or more) small low-velocity slip events distributed over hundreds of thousands of years will be very different from those of one fast displacement that takes place in one single pulse of movement. Note that slip velocity scales with slip magnitude /Fälth et al. 2010/, meaning that the slip velocity effective for a displacement