Solid Earth Discussions

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Comment on se-2021-140

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Community comment on "Matrix gas flow through “impermeable” rocks – shales and tight sandstone" by Ernest Rutter et al., Solid Earth Discuss., https://doi.org/10.5194/se-2021-140-CC1, 2021

Review of the paper « Matrix gas flow through ‘impermeable’ rocks – shales and tight sandstone »

by E. Rutter, J. Mecklenburgh and Y. Bashir.

General comments

This is a very interesting paper focusing on the effect of effective pressure on the permeability and the deformation of tight rocks, two shales and one tight sandstone. The pressure sensitivity of the selected rocks were interpreted through poroelasticity theory, and the link with the expected evolution of microstructures in these tight rocks is tentatively given. The authors propose a simple model made of a bundle of capillary tubes with elliptical cross-sections to account for their observations on the permeability decrease with pressure. Another interesting outcome of this work is the discussion on the effective pressure coefficients, with a comparison between the “m” value used in poroelasticity (the so-called Biot coefficient) and the “n” value derived from permeability vs. pressure evolution. It turns out that one of the rocks, the Bowland shale, behaves quite differently compared to the other rocks, and this is explained by strong contrasts in the microstructures and mineralogical content.

Specific comments

When reading the paper, it is clear that the data obtained by the authors are of very high quality. This allowed them to analyze thoroughly their data set on the basis of existing theories or models. The outcome is quite convincing and provides a strong basis for future studies on the transport properties in tight rocks. Nevertheless there are some points which could be clarified to my viewpoint:

- Concerning the velocity anisotropy defined at line 100, I don’t understand how this relates to what the authors call “15.5% axial and 3.1% radial” for the Pennant sandstone.
- When discussing the pressure sensitivity of K_o at line 267, why only providing the law

for quartz? Is the conclusion (i.e. negligible pressure sensitivity) the same for all the other minerals including phyllosilicates?

- In the section 4.1.1 at line 280, the authors check several permeability vs. pressure laws like k vs. P_c (linear) or log k vs. P_c (exponential), but how about log k vs. log P_c (power-law)? The exponential law (i.e. linear fit of log k vs P_c) is relevant for other tight rocks like for the Grimsel granodiorite (benchmark KG²B in which the first author had participated), so the observed non linearity seems to be typical of the shaly rocks tested here.
- There is some confusion I think in the definition of Terzaghi effective pressure. In line 241 the Terzaghi effective pressure is defined as $P_c - P_p$ as it should be, but later several times (e.g. line 306) the Terzaghi effective pressure becomes $P_c - nP_p$. This should be clarified.
- On the same topic, could the authors explain how they estimate the effective pressure coefficient "n" from the permeability data set? Maybe a new figure may help to explain.
- At line 398 the definition of P_{eff} is wrong.
- At line 489, in the definition of hydraulic diffusivity the porosity is missing in the denominator. In the same paragraph, the authors discuss the values of the time constant from the diffusivity, assuming that the pore fluid is either gas or water. However, doing so they assume that the gas permeability that they have measured is the same as the water permeability: can we be sure of that? Again in the KG²B benchmark, a significant difference between permeability values obtained with either gas or liquid as the pore fluid were found for the Grimsel Granodiorite.
- In equations 14 and 15, the denominator should be $1+\alpha^2$
- Equation 16 and the one above should be checked as the units don't match. The product Nc^2d should be dimensionless, but it is not the case because N is defined as a number of tubes per unit surface. As this equation is used to get equation 18, that one is also problematic because 1/Nd should have the unit of m^2.

Technical corrections

At line 63, I wonder if all the digits are significant for the vol%

In Table 1, for Bowland is it correct to read for kaolinite 0.26% +/- 2.6%?

In Table 1 the density of quartz for Pennant is wrong

At line 181, the definition of storativity should be more general, because for the downstream storativity it is not the pore volume that comes in.

At line 536 it should be "in Eq. (15)"