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Comment on egusphere-2022-987

Anonymous Referee #2

Referee comment on "Impact of permeability evolution in igneous sills on hydrothermal flow and hydrocarbon transport in volcanic sedimentary basins" by Ole Rabbel et al., EGUsphere, https://doi.org/10.5194/egusphere-2022-987-RC2, 2022

Impact of permeability evolution in igneous sills on hydrothermal flow and hydrocarbon transport in volcanic sedimentary basins

The authors investigate the intrusion of magmatic sills into carbon-rich sedimentary basins that drive the production and transport of hydrocarbon-bearing fluids. They review field observations from the Neuquén Basin, Argentina, that reveal highly fractured sills containing bitumen- and calcite-bearing veins. Raman spectroscopy on the vein-filling material reveals graphitization, from which temperatures are estimated to be ~350-500 C. Based on these observations, they suggest that thermal fracturing of the sill during cooling allows the transport of pressurized hydrocarbons through the sill, which they point out is counter to the existing models that treat sills as impermeable boundaries. To investigate how the development of fractures during cooling influences the production and transport of hydrocarbons, they construct numerical models for coupled heat and fluid transport for the case of an instantaneously emplaced sill within a carbon-bearing shale host rock.

The primary results of the modeling work are the identification of three stages of flow: 1) an early-phase contact-parallel flow regime while the sill is still hot and impermeable; 2) the development of permeability within the sill leading to vertical flow of fluids through the sill "flushing"; and 3) late-stage, slow backflow of fluids into the sill from the tip region inward. The authors show a few examples of how flow patterns differ with different sill thickness and intrusion depths constrained by the field data.

The primary conclusion is that the development of permeability in cooling sills drastically alters the flow paths and accumulation of hydrocarbons produced by heat from the sills. In a general sense this result is significant and the work should be shared with the community. However, the analysis falls short of addressing many potentially rich complexities in any kind of quantitative way. After reading this manuscript, I certainly had a greater appreciation for the number of coupled physical processes involved in these systems: cooling and fracturing of the sill, heating and maturation of the source rock, and porous and fracture-dominated fluid flow. However, I am not sure I learned a substantial amount about how these processes interact to give rise to the observed phenomena. Part of the reason for this could be the open-ended and somewhat exploratory nature of the modeling – the question of "how does permeability development influence hydrothermal flow" is too open-ended. If there were a clearly-defined question or testable hypothesis, then the modeling inputs/outputs could be analyzed in a more systematic way to address the question. For example, the authors could potentially use the model to address the following questions: Under what conditions (combinations of sill thickness, depth, initial temperatures, source rock chemistries) do we expect the development of through-going bitumen deposits in the sill? How does the accumulation of bitumen in the sill change over time and space as a function of the key parameters? (Can this then be used to compare with the field distributions?)

Putting aside the open-endedness of the study and generally qualitative analysis of the modeling results, I still had a few questions about the treatment of permeability in the sill. I suggest that the authors address these questions prior to final publication:

Given poor constraints on the permeability of fractured media, how do assumptions about temperature-permeability relationships influence the results?

Flow through fractures is a different transport mechanism than porous flow, especially given the potential for development of permeability anisotropy related to fracture orientations. How does the treatment of fracture-dominated flow as porous flow potentially influence the flow pattern results? Would backflow be possible if fractures are vertically oriented?