A discrete element model (DEM) for swelling behavior of clay

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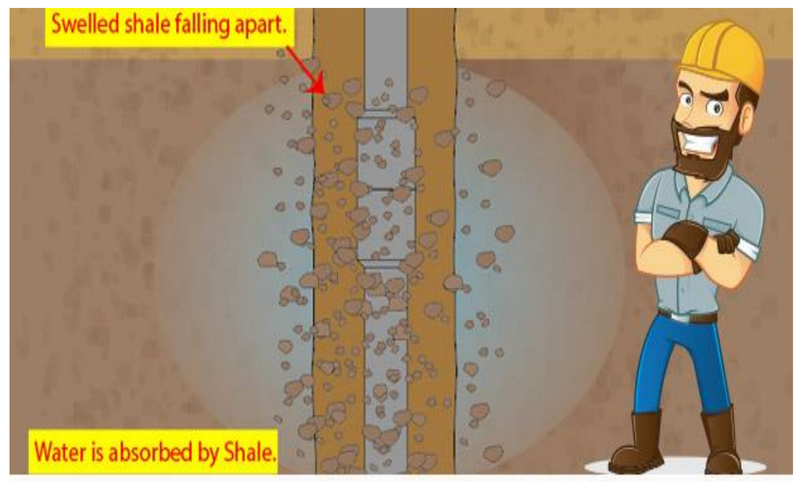
Abstract

Swelling of Shale-rocks create several problems [1] during underground drilling operations, such as stuck-pipe/drill-bit. The field experience reveals that some shale-rocks are good candidate for swelling and some are not. It is believed that, amount of clay is the most important factor for shale-swelling. There are several other parameters that can influence the swelling behavior, such as- porosity, quartz contents, clay-cluster distribution, stress difference between field and drilling zone etc. Therefore, to plan a safe and efficient drilling through shale-rocks, we should understand the swelling mechanism of clay.

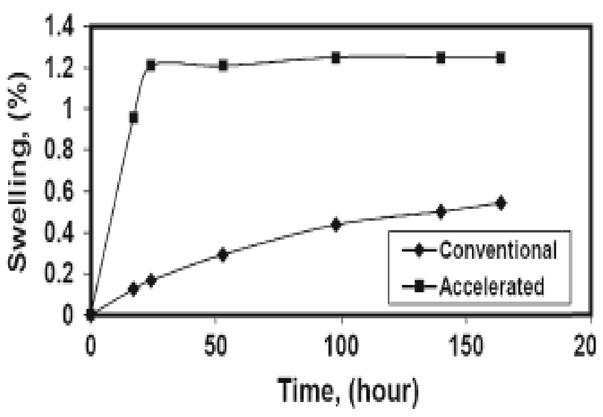
To investigate swelling of clay, we have introduced a discrete element model (DEM), based on Monte-Carlo technique. We define a probability of swelling for all the clay grains in the shale-rock sample that includes the effect of stress-difference, porosity, temperature etc. The time evolution of grain swelling results in bulk swelling behavior of the sample and the simulation result qualitatively matches [2] with the observations of shale/clay swelling experiments [3,4]. The Monte-Carlo based DEM code has been studied [5] for the entire parameter space by varying several important inputs like porosity, clay-quartz contents, stress difference, temperature etc. In addition, the mass-transport phenomenon has been implemented by considering clay grain movement through fractures (flow channels).

The problem

- Stuck pipe due to shale swelling
- Clay management in port areas
- Swelling does not happen always
- Self healing can prevent leakage

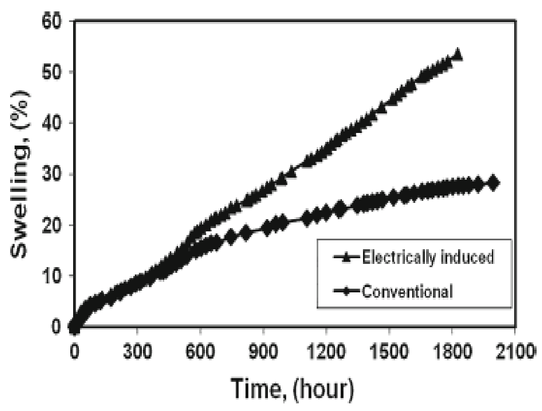


Experimental Results



Kaolinite Clay

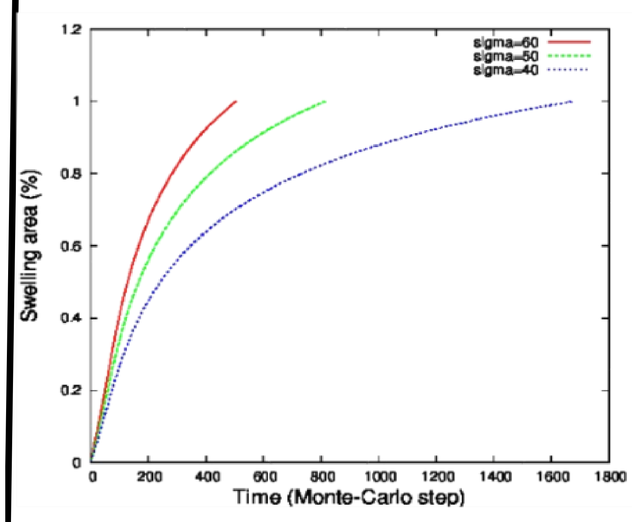
Clay

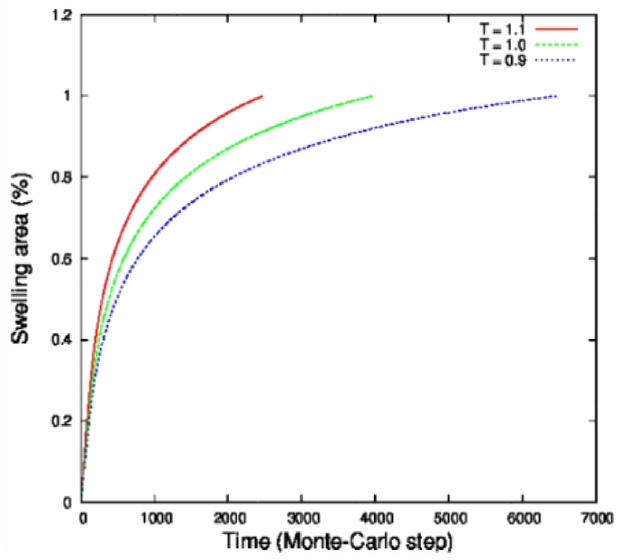


Bentonite Clay

M. Deriszadeh and R.C.K. Wong Transp. Porous Med (2014)

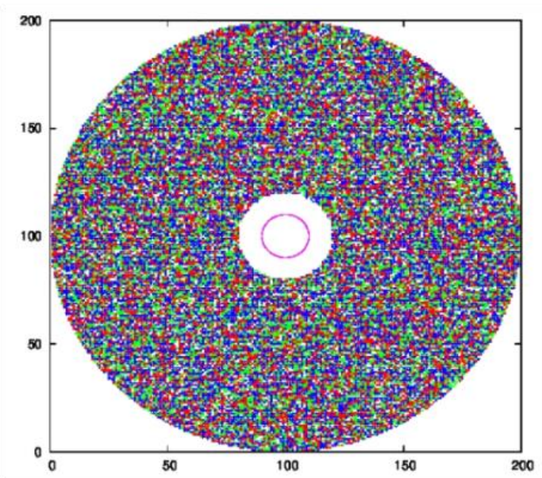
Numerical Results



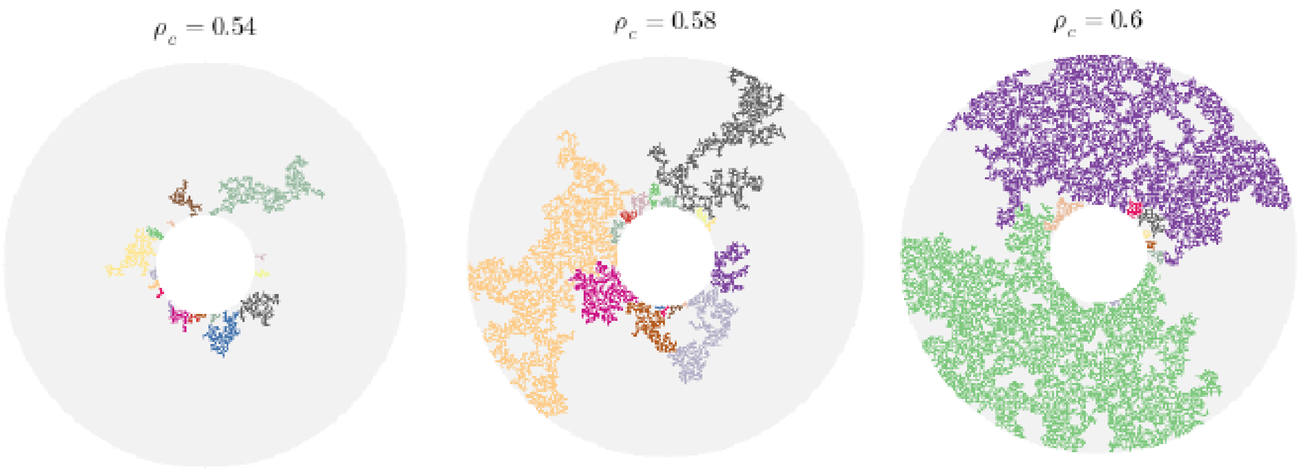


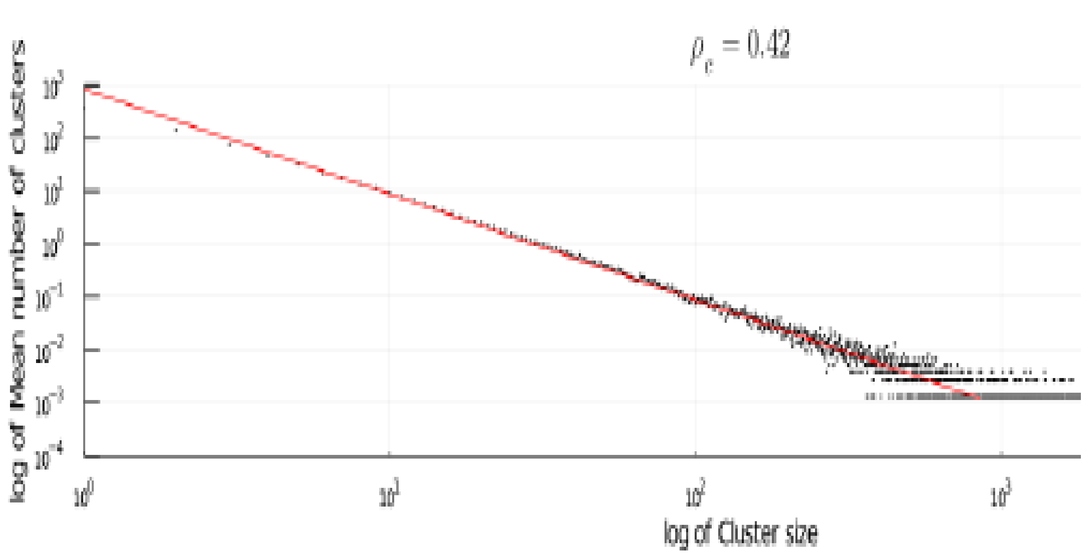
Numerical methods

- Define the swelling probability of a grain: $P_s = f(sigma, T, r)$
- Use Monte-Carlo. Take grains of different type (clay, quartz) & size (radius distribution)
- Stop simulation when total swelling area reaches the area of the annulus



Clay-Cluster Analysis





References:

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3. M. Deriszadeh and R.C.K. Wong, Transp Porous Med (2014) 101:35–52 DOI 10.1007/s11242-013-0229-8.
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Next step:

- Link clay chemistry to swelling probability
- Develop a theory for simple distributions
- Include mass transport

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