結合壓溶作用與熱水力化耦合模型評估岩石滲透率演變

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摘要

由於放射性廢棄物所產生的放射性物質會對人體造成危害，目前國際上認為最佳的處置方式為深地層處置。然而，放射性廢棄物在地底埋藏處置，需要考量放射性廢棄物本身特性與相關地質的特性，以免放射性核種以及廢熱外洩。本研究透過開發熱水力化模型(THMC Model)，模擬由純石英組成之多孔沉積岩長期之滲透率變化，模型考慮了由高壓應力造成壓力溶解的壓溶作用(Pressure Solution)所造成滲透率變化，並根據室內試驗所得資料進行擬合以率定並驗證模型。隨後利用日本核燃料循環開發研究所（Japan Nuclear Cycle Development Institute, JNC）建立之概念模型以及相關參數，進行深地層高放射性廢棄物的埋藏數值模擬，模擬岩石滲透率的長期演變。模擬結果顯示，當不考慮壓溶作用的影響下，滲透率隨著時間的變化較小；當考慮壓溶作用的影響下，在距離放射性廢棄物處置處較近之區域，其岩石滲透率在 10^4 年內減少了一個數量級。

關鍵字： 岩石滲透率、熱水力化耦合模型、礦物溶解、壓溶作用。

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Coupled thermo-hydro-mechanical-chemical modeling by incorporating pressure solution for estimating the evolution of rock permeability

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ABSTRACT

A coupled THMC numerical model has been developed to examine the long-term change in permeability of the porous sedimentary rocks that are assumed to be composed purely of quartz. Specifically, the chemo-mechanical process of the pressure solution was incorporated into the model. The developed model was validated by replicating the existing experimental measurements of the porosity reduction and the evolving silica concentration. Subsequently, by simulating the burial of high-level radioactive wastes in the deep subsurface, namely, by applying the simulated confining pressure and temperature conditions, the long-term evolution of the rock permeability was predicted. The model predictions clearly showed a significant influence of the pressure dissolution on the change in permeability with time. The predicted permeability of the rocks close to the wastes decreased by one order of magnitude in 10^4 years when considering the pressure dissolution, while the permeability changed little during the same period when the pressure dissolution was not considered. This reduction should delay the dispersion of the radioactive materials dissolved in the groundwater.