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Screening the geomechanical stability (thermal and mechanical) of shared multi-user CO_2 storage assets: A simple effective tool applied to the Captain Sandstone Aquifer

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Abstract

Multi-user storage systems are anticipated in the near future to permanently store CO_2 captured at industrial sources to meet emissions reductions targets. Multiple storage permit applications will be required to exploit the immense potential capacity within extensive CO2 storage assets. To retain 99% of the injected CO_2 for 1000 years the geomechanical stability of the sealing strata above the pressurised storage reservoir is a key factor which needs to be included in the geo-engineering design of shared storage assets. The potential for interaction of increased pressure at multiple injection sites needs to be predicted and assessed at a regional scale to assure the integrity at all existing sites before a storage permit is granted. Geomechanical models coupled with the expected fluid pressure response predict the stability of the storage asset during and after injection of CO_2 at multiple injection sites, and can be used as a tool to ensure efficient utilisation of the storage capacity. The geomechanical analysis of the thermal stress as well as local and regional fluid pressure changes requires a detailed numerical evaluation, often at a resolution significantly higher than the data available. Coupling of regional-scale static geological models, dynamic multi-phase flow models and detailed geomechanical models requires extensive computational resources. Such models often produce seemingly detailed results, but are usually only one or two realisations of a system populated by a statistically generated parameter set. Limits on time and computational resources prevent more simulations within fixed time and financial budgets. To enable a more time and cost efficient methodology of assessing the geomechanical stability of potential storage sites we present a four-tier modelling approach with increasing complexity that allows an in-depth evaluation of the geomechanical stability at a regional scale of a multi-user storage asset taking into account the fluid pressure increase and the thermal stress impact on the stability of the strata sealing the CO_2 store. The tiers include: (1) development of a geo-mechanical facies model of the storage system, (2) development of an analytical geomechanical model for the storage site static stress conditions, (3) fitting an empirical multivariable polynomial function to the analytical modal, and (4) conditioning the empirical function using coupled numerical THM modelling for dynamic stress conditions. The result is look up function which gives the maximum possible fluid pressure as a function of location. This approach significantly simplifies the computational requirements and time for the prediction of geomechanical behaviour. In addition to presenting this methodology, using the Captain Sandstone of the North Sea as an example, three key findings are further examined. Firstly, detailed analysis of the stress changes as a result of cold fluid injection suggests that the redistribution of thermal stress can, in some cases, be beneficial to the storage system depending on the stress bridging which occurs. Secondly, pressure plume migration over time in dipping strata, from deeper injection sites to shallower sites, needs to be taken into account. Thirdly, the nature of the strata underlying the storage formation is critical to the pressure increase in response to the fluid injection. The methodology developed in this paper enables a rapid and efficient screening of the dynamic geomechanical stability and facilitates an efficient coupling to diverse discrete multiphase fluid flow models using commonly available computational resources.