A Geostatistical Study in Support of CO_2 Storage in Deep Saline Aquifers of the Shenhua CCS Project, Ordos Basin, China

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Overview

The critical need for advancing CCUS technology has recently been reaffirmed in the US-China Joint Announcement on Climate Change. The Ordos Basin ranks first in China in its coal, coalbed methane, and natural gas reserves, and ranks fourth in its oil reserves. The coal deposits in this basin account for 39% of Chinese coal resources, and six of the thirteen largest coal mines in China are in this basin. We have built upon previous research that created layer-cake, homogeneous framework simulation models for 3 years of CO2 injection into low-permeability saline aquifers at Shenhua Group site in the Ordos basin. Carbon dioxide injection commenced in 2010 at this site. As of January 2014, approximately 155,000 tons of supercritical CO2 has been injected into a Triassic-to-Ordovician siliciclastic reservoir at 1,690–2,453 m depths. Despite CO2 emplacement, only limited pressure increase was observed at the wellhead of the injector. After 3 years, seismic VSP data and 4 short-duration CO2 injection tests suggest that almost 80% of the CO2 has migrated into the Liujiagou sandstone formation at the top of the reservoir. Because both surface reservoir analogs and well logs from the injection and monitoring wells suggest strong reservoir heterogeneity, we developed a detailed geocellular model using seismic, well logs, and core data while accounting for facies and sub-facies heterogeneity.

Methods

In an attempt to better capture uncertainty in reservoir geology, multiple-point geostatistical methods were used to integrate all data with which alternative facies scenarios, each with its own corresponding property models, were generated (Figure 1). The geocellular model was scaled up to create a flow simulation model. To accurately capture flow dynamics, the simulation grid is refined at the injector. To validate CO2 storage at this site, the Eclipse compositional simulator was used to model CO2 injection for 10 years. This model was first history-matched to the 3-year production data provided by the Shenhua Group, before it was used to explain the observed pressure response at the injector and to history match the CO2 plume movement inferred from the VSP data. Each facies scenario was also tested during the flow simulation, and model fitness was ranked to determine a best-fit facies model. Finally, a parallel effort for the Shenhua site simulation study was undertaken using the Finite Element Heat and Mass Transfer (FEHM) simulator to incorporate geomechanic responses including enhanced porosity and permeability to explain the observed small-to-medium pressure buildup that resulted from CO2 injection.

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Preliminary Results

A detailed geologic model consisting of roughly 7 million cells was created over an area of 5x5 (km). The initial facies model represents the fact that the site is characterized with sandstone alternating with mudstone and shale (baffle facies) except for the Majiagou formation at the bottom. Porosity and permeability populations were conditioned to log data distribution and facies using cutoff values. Due to the low porosity and permeability log values, many cells have pore volume below E-10 (m3) and were turned inactive during the simulations. A tartan simulation grid was built to refine the area around the injection wellbore and while keeping the far-field at more coarse resolution (Figure 2). The new mesh reduces the number of cells to 1.2 million. Simulations were performed to replicate the pressure response. . Initial results of injected CO2 saturations are shown in Figure 3. The history matched simulations are used to develop a code comparison between FEHM and Eclipse. Results from coupled stress/flow calculations using FEHM are presented to explore feedbacks including permeability increases with reduction in effective stress.

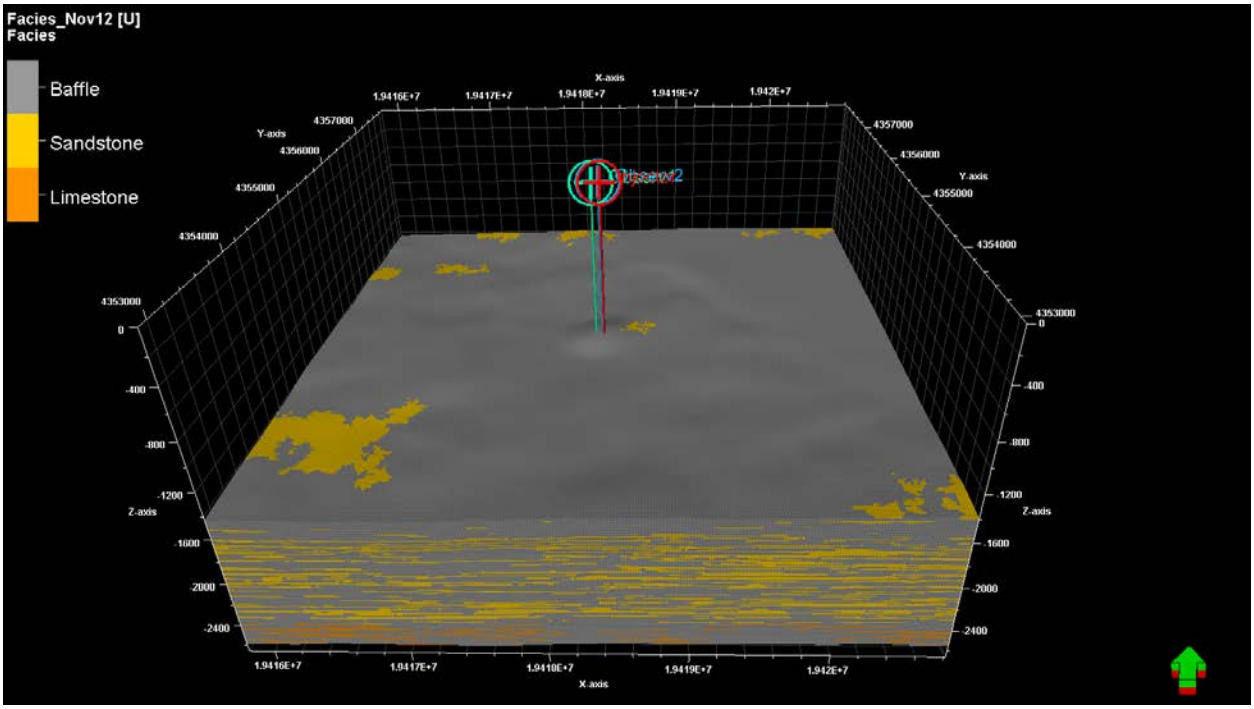

Figure 1. Initial facies model of the Shenhua injection site from log data of 3 wells including 1 injector in the middle and 2 observation wells. This model represents the fact that the site is characterized with sandstone alternating with mudstone and shale (baffle facies) except for the Majiagou formation at the bottom.

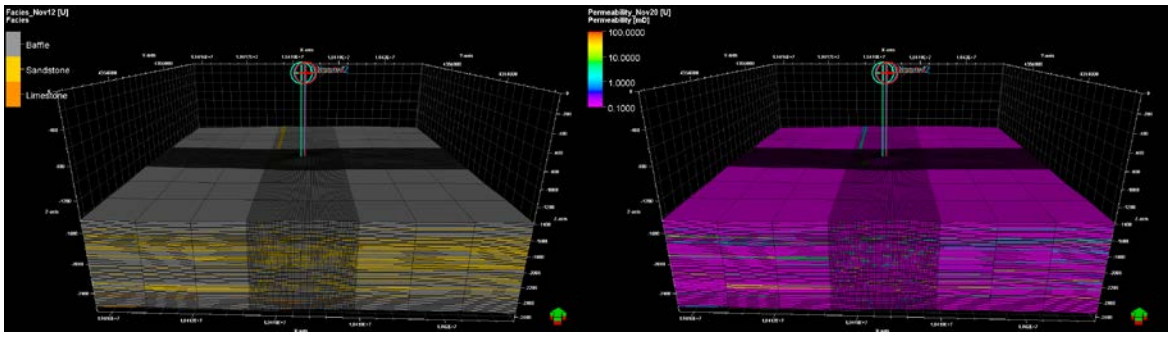

Figure 2. Upscaled Tartan grid for simulation. Due to the nature of CO2 injection, only the area around wellbore is concerned the most and therefore is kept refined to capture CO2 plume movement.

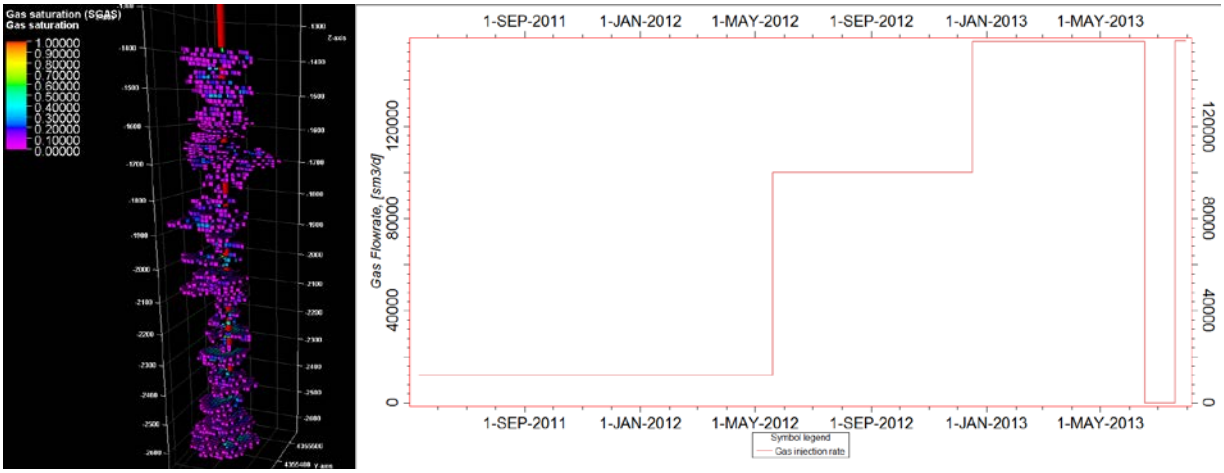

Figure 3. Initial simulation results including gas saturation after 3 years of injection and gas injection rates.