MEASURING PRESSURE PERFORMANCE OF A LARGE SALINE AQUIFER DURING INDUSTRIAL-SCALE CO_2 INJECTION: THE UTSIRA SAND

R.A. Chadwick, J.D.O. Williams & D.J. Noy
rach@bgs.ac.uk

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Text (500-1000 words - maximum 2 pages, font 12)

The pressure response of a saline aquifer to large-scale CO_2 injection is a key determinant of dynamic storage performance: the ability to accept large injected volumes at the input rates required to receive CO_2 from power-station emissions. A number of papers have highlighted the importance of pressure buildup in storage aquifers but these are based largely on numerical modelling: as yet there is little field experience of large-scale aquifer injection.

The Sleipner injection project has now stored more than 12 Mt of CO_2 in the Utsira Sand and so provides a unique opportunity to monitor the pressure response of a large saline aquifer to industrial-scale CO_2 injection. There is no downhole pressure monitoring at Sleipner. Pressure measurements on the injection wellhead show little evidence of systematic increase, but these cannot be related directly to reservoir pressure due to possible changes of CO_2 density in the wellbore with time. Some other method of pressure monitoring is required therefore. Time-lapse seismic is a potentially powerful indicator of reservoir pressure change, because seismic velocities vary with effective stress. The comprehensive 4D seismic monitoring programme at Sleipner provides an opportunity to test this. An empirical velocity - stress relationship for sandstones, calibrated against Vp and Vs data from the Utsira Sand, indicates that a pressure increase of 1 MPa would induce a Vp reduction of around 30 ms^{-1}. For typical thicknesses of the Utsira Sand reservoir around Sleipner (200 to 300 m), this would correspond to systematic two-way travel-time reductions through the reservoir of around 3 to 4 milliseconds (ms) which should be easily measureable. The 3D time-lapse surveys from 1994 (prior to injection), 2001 and 2006 were used to assess travel-time changes through the Utsira reservoir by accurately mapping the top and base of the reservoir on successive repeat surveys. The mapping covered an area between 0.5 and 3.5 km from the injection point, essentially corresponding to the area of the 4D datasets but outside of the plume saturation footprint (Figure 1a). Measured travel-time changes are of the order of a very few ms, with significant scatter about a mean value (Figure 1b). This is because the data are not noise free: the picked events at top and base reservoir show small trace-to-trace mismatches or ‘jitter’ between successive repeat surveys. This ‘jitter’, due to non-perfect repeatability of the time-lapse surveys, has a high spatial frequency and is essentially random. It therefore gives rise to a roughly symmetrical distribution about the mean and provides a powerful statistical tool for determining the mean. The observed mean values of travel-time change through the Utsira Sand were 0.097 ms in 2001 and 0.175 ms in 2006. These correspond to estimated mean pressure increases of less than 0.1 MPa (Figure 1b).

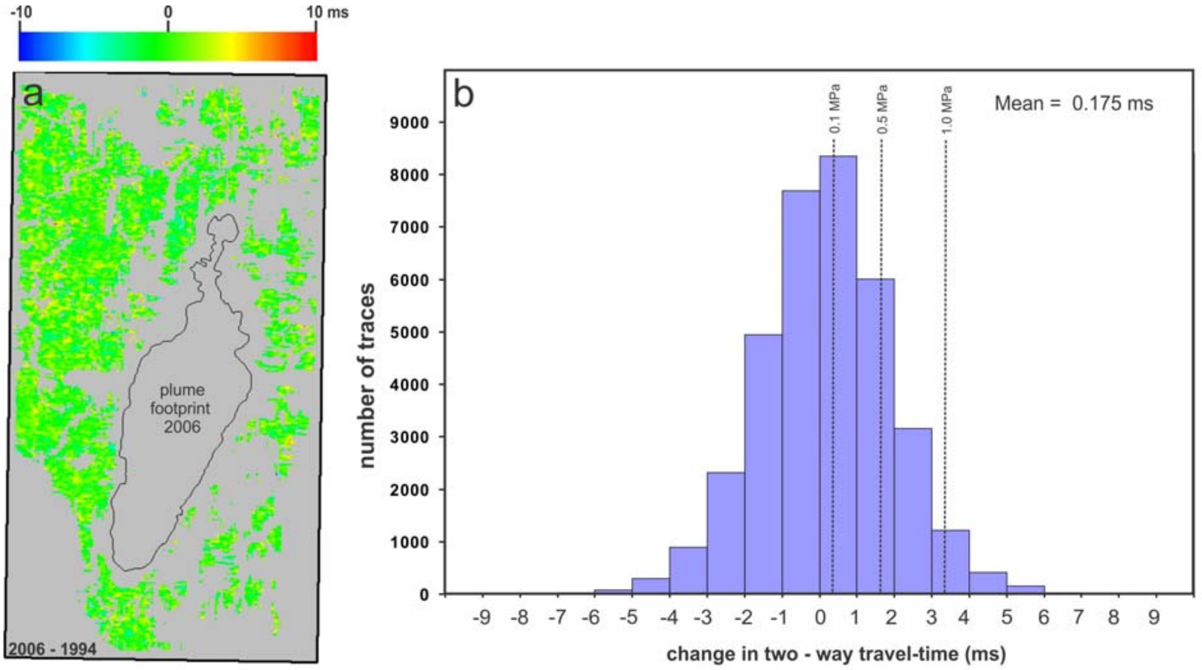

Figure 1: a) Map of travel-time changes from 1999 – 2006 through the Utsira Sand around the Sleipner plume. Mapping restricted to areas of high quality coherent seismic signal. b) Histogram of the travel-time changes showing the relationship to increases in reservoir pressure (for a notional 250m thick reservoir).

Numerical flow simulations based on the Sleipner injection history indicate that this small pressure change is consistent with a storage reservoir whose lateral boundaries are 40 km or more from the injection point, similar in distance to the actual stratigraphical limits of the Utsira Sand. The small pressure change is not consistent with a significantly smaller, or hydraulically compartmentalized reservoir, which would lead to significantly larger pressure increases. The indications are, therefore, that the Utsira Sand does not contain any significant internal barriers to lateral fluid flow, a contention supported by the observed lack of any structures other than very small-scale faulting in the reservoir. It is concluded that major saline aquifers similar to the Utsira Sand (which occur widely in the post-rift successions of the Central and Northern North Sea basins), are likely to show internal flow characteristics which are suitable for large-scale CO_2 injection.