CO_2 Migration and Storage: seismic velocity heterogeneity in a CO_2 layer at Sleipner

Co-Investigator: **R. A. Chadwick**
Key researchers: R. A. Chadwick; G.A. Williams
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Project overview

To ensure the safe operation of an underground CO_2 storage site, it is important to understand where and at what speed the CO_2 is migrating through the storage reservoir. This is often a function of rock heterogeneities, which act to control the distribution of CO_2 from the pore scale to the whole reservoir. Seismic imaging is an important tool that can be used to measure the distribution of the CO_2. Seismic velocity changes caused by CO_2 in the rock pores can be measured and combined with laboratory data to assess the CO_2 saturation distribution within the reservoir (Fig. 1). This research uses high resolution seismic data from Sleipner to map velocity heterogeneity at the top of an active CO_2 plume.

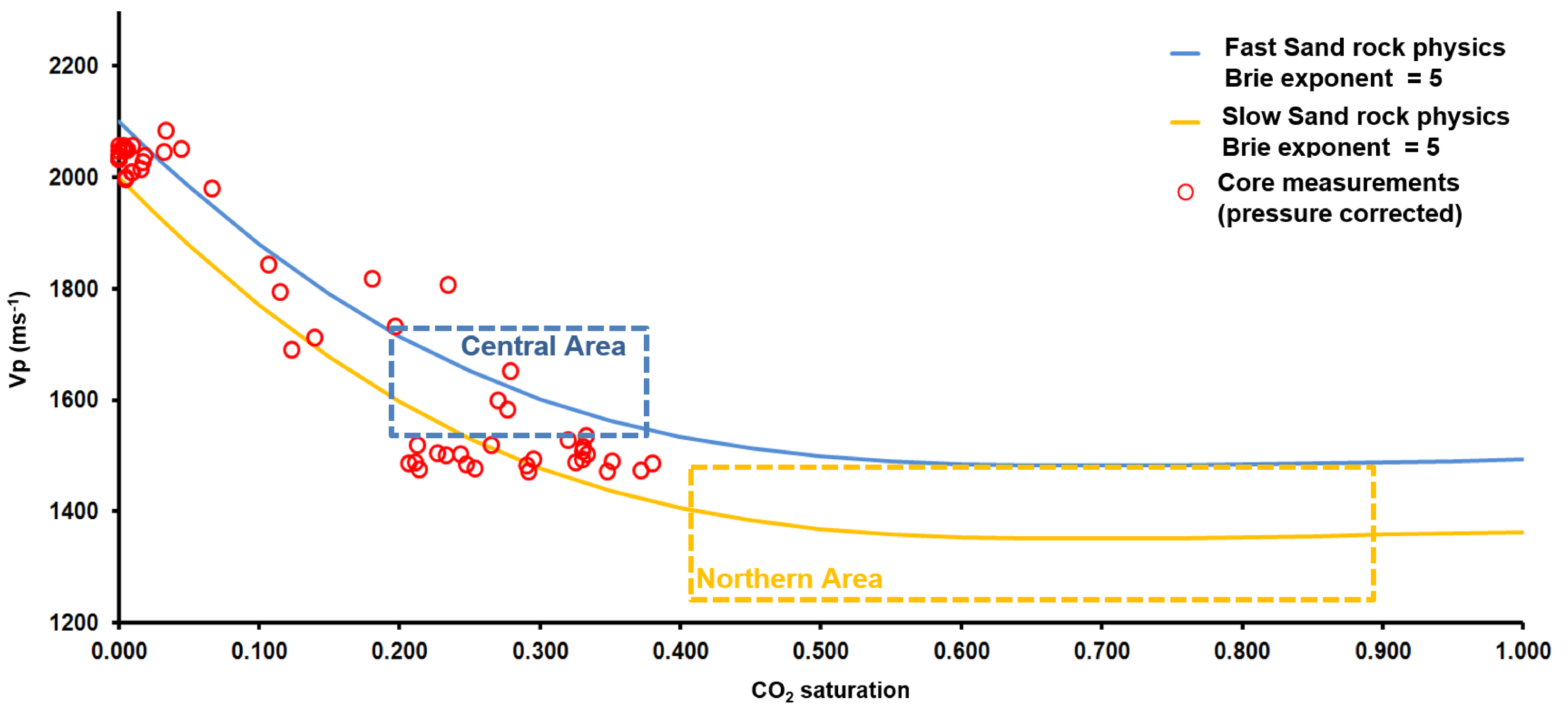

Fig. 1 Laboratory velocity-saturation measurements for Utsira Sandstone (Falcon-Suarez et al., 2018)

Key objectives:

1) Map the horizontal variability in seismic velocity at the top of the Sleipner CO_2 plume.
2) Combine the measured velocity data with laboratory rock physics measurements to derive the spatial CO_2 saturation distribution at the top of the plume.
3) Use the resulting saturation distribution to provide new insights into reservoir heterogeneity at Sleipner.

Research highlights

1) An individual thin layer of sequestered carbon dioxide has been explicitly resolved by 3D seismic for the first time at Sleipner.
2) Spatial seismic velocity variation within this layer of sequestered carbon dioxide has been mapped for the first time.
3) Seismic velocity variation within this layer can be related to reservoir channelling and permeability heterogeneity.

Emerging findings

1) Layer velocities calculated from a high resolution seismic dataset range from around 1200 ms^{-1} to 1800 ms^{-1}.
2) Two spatially distinct 'velocity regions' can be mapped at Sleipner: a Northern Area with layer velocities around 1372 ms^{-1} and a Central Area with higher velocities of c. 1632 ms^{-1} (Fig. 2a and Fig. 1).
3) A channel feature interpreted in the topmost reservoir sand body on baseline seismic data correlates almost perfectly with the low velocity sands of the Northern Area (Fig. 2b).
4) Incorporating this high permeability channel into reservoir models of the topmost sand layer greatly improves the predictive capabilities of these models (Fig 2c).

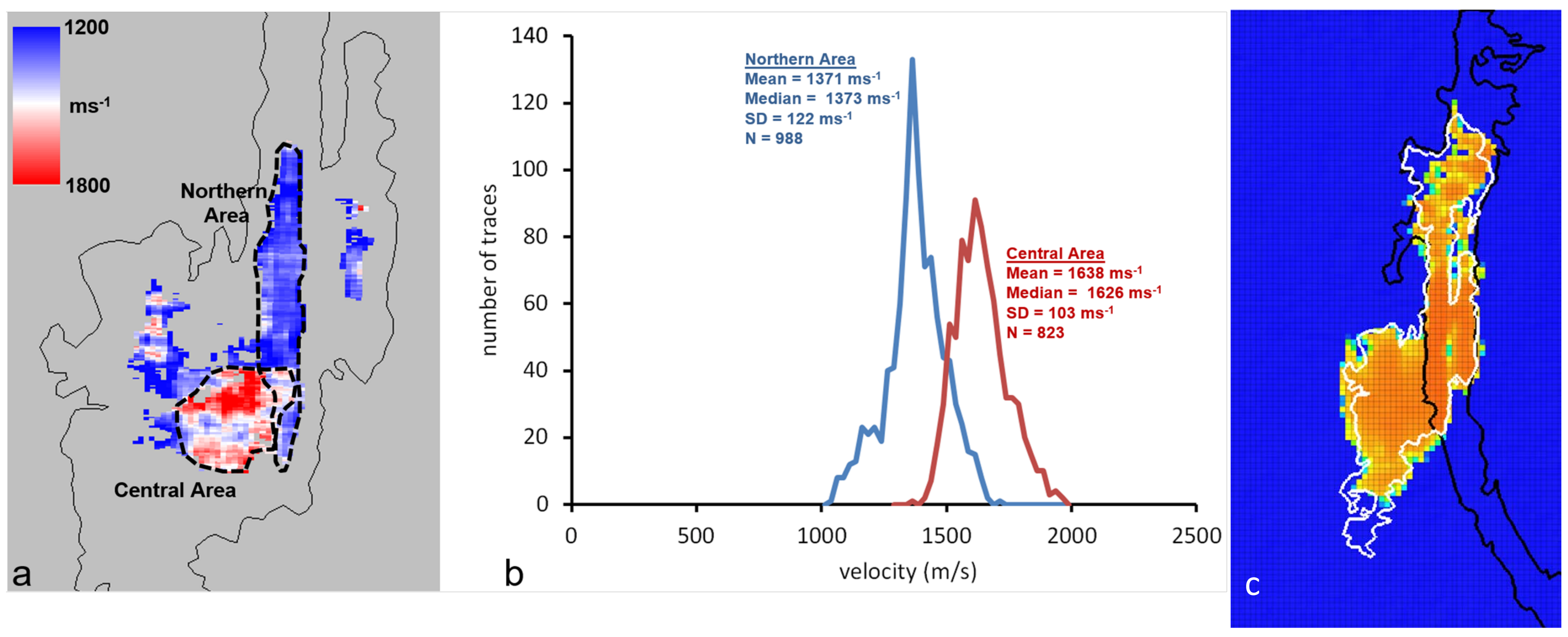

Fig. 2 Velocity analysis for two selected areas in the topmost CO_2 layer. a) Extracted velocities with areas marked. b) Velocity histograms for the two areas. c) Results of incorporating an high permeability channel into a reservoir model of the Sleipner site (white line shows CO_2-water contact observed on seismic data; black line high permeability channel).

Next steps

Explore the robustness of the velocity estimation by applying the same technique to later vintages of time lapse seismic data, in which the vertical thickness and lateral extents of the top CO_2 layer will have increased in response to continued CO_2 injection.

Acknowledgements

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References

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