# An Assessment of $CO_2$ Storage Potential within Carboniferous Aquifers of the Onshore Clare Basin, West Ireland – a Case Study for Pre-feasibility appraisal of Storage Sites

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The Irish Environmental Protection Agency (EPA) commissioned an international group led by Aurum Exploration Services, DMT GmbH & Co. KG and TNO Built Environment and Geosciences to conduct a pre-feasibility study to assess the $CO_2$ storage potential in the vicinity of Ireland's largest single point emitter at Moneypoint Power Station (current emission rate 3.95 Mt $CO_2$ per annum).

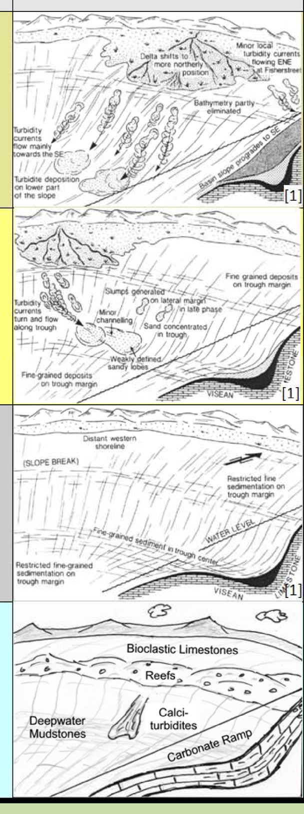
Potential storage reservoirs and seals belong to the Carboniferous Clare Basin, West Ireland (Fig. 1).

In order to allow an early judgement of the Clare Basin's principal storage feasibility, the study focuses on the assessment of main geological criteria such as:

- ***Reservoir depth***
- ***Reservoir size (storage capacity)***
- ***Trap style and size***
- ***Presence of faults / Compartmentalization***
- ***Permeability and formation thickness***
- ***Transmissibility***
- ***Seal integrity***

Owing to very limited subsurface information from three deep boreholes and historical 2D seismic data (1962) over the western part of the basin, it was necessary to conduct extensive data compilation exercise. All surface and drill hole data were digitized from heterogeneous sources and integrated into a 3D geological model. An initial model served to define two additional new borehole locations (GSI 09/04 and GSI 09/05) which provided wireline log data and core samples.

| System | Stage | Lithostratigraphy | Maximum Thickness (m) | Depositional Environment | | Lithofacies | | Assessment scope for $CO_2$ storage |
|---|---|---|---|---|---|---|---|---|
| Carboniferous | Namurian | Central Clare Group | 900 | | cycles of prograding deltas | mudstone sheets, delta mouth bars, and distributary channels | | none (burial depth too shallow) |
| | | Gull Island Formation | 600 | [1] | unstable basin slope | slumps, mudstone sheets, subordinated channels | | Seal |
| | | Ross Sandstone Formation | 450 | [1] | turbidite sequences | lobes, channels, slumps, and mudstone sheets | [2] | Primary Reservoir |
| | | Clare Shale Formation | 275 | [1] | tranquil deepwater | entirely composed of dark grey shale | | Seal |
| | Tournaisian and Viséan | Dinantian Limestones | 2000 | | carbonate ramp (shelf to deepwater), reefs | entire range of carbonate grain sizes, reefs, oolites | [3] | Secondary Reservoir |



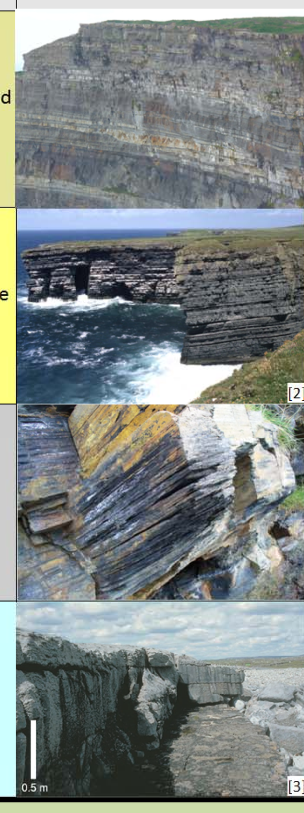




Fig. 1 Stratigraphy and facies development of the Carboniferous Clare Basin

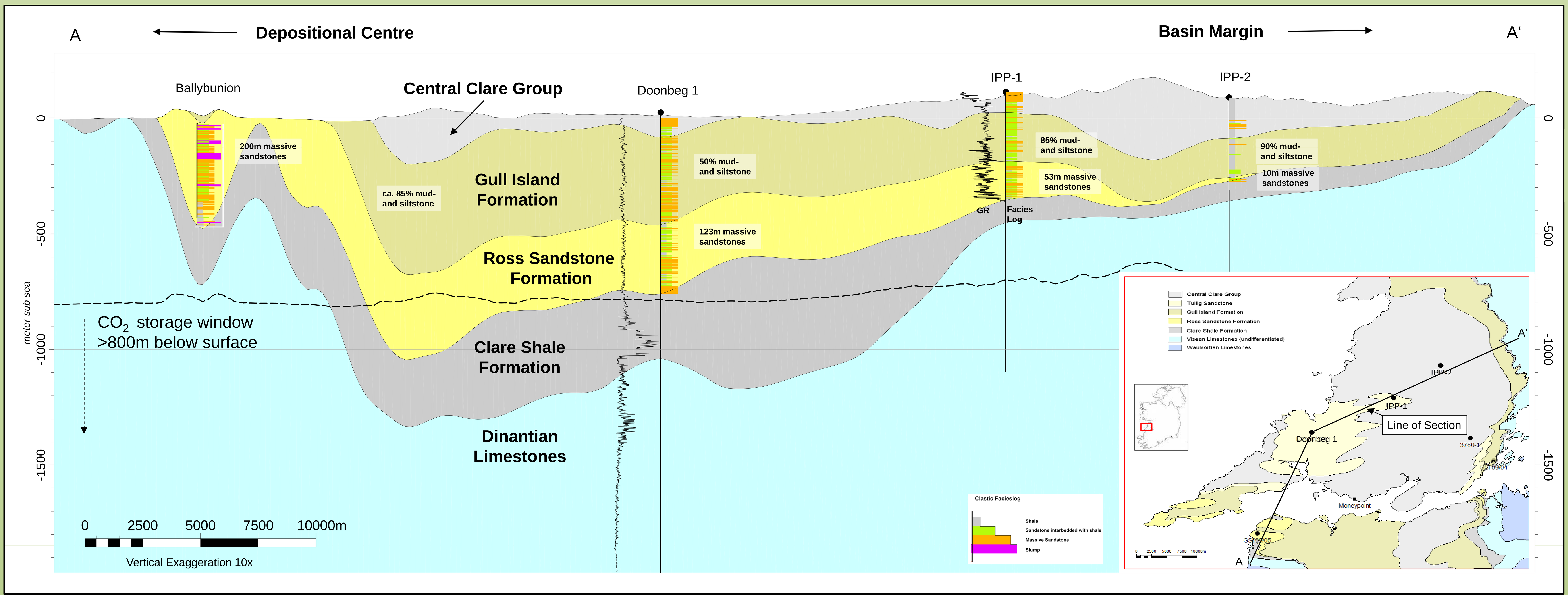



Fig. 2 Cross section through the Clare Basin

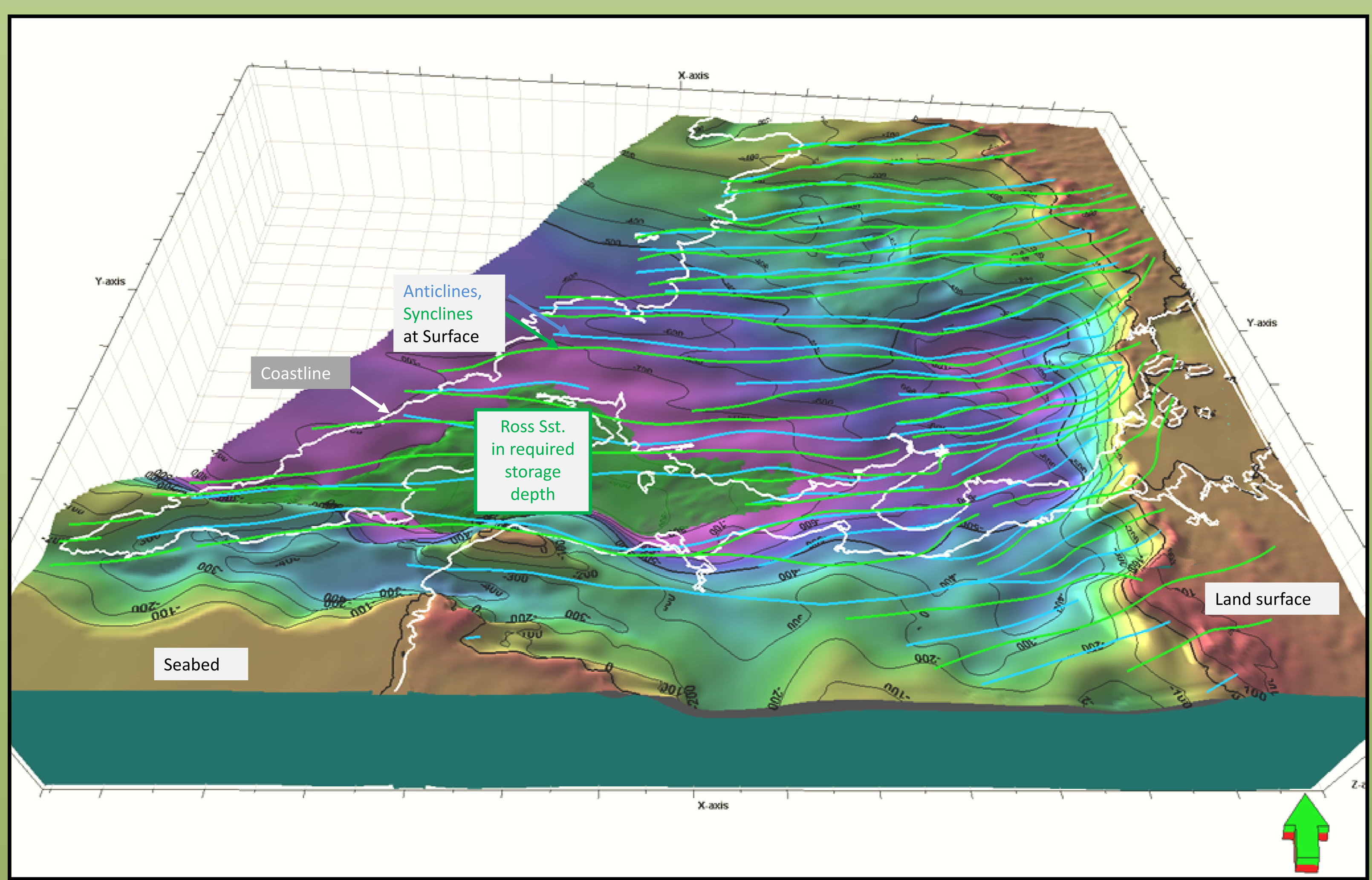



Fig. 3 3D view of surface at Base Ross Sandstone Fm./Top Clare Shale Fm.

The resultant data was assimilated into a final 3D subsurface model which provides a description of the structural setting (Fig. 3) and the spatial reservoir/seal property distribution.

Potential trapping structures are related to Variscan folding. These are mostly of open symmetrical geometry (Fig.4).

The principal structures within the Dinantian Limestones are relatively broad, simple anticlines and synclines. Within the sandstone to siltstone dominant sequences of the Namurian clastics fold wavelengths and amplitudes decrease. Commonly, trap widths are in a range from two to three kilometres. Fold heights are frequently between 75 and 130m, locally they can reach a maximum of up to 300m.

The study demonstrates that the onshore part of the Clare Basin is unsuitable for the storage of substantial volumes of $CO_2$.

Several geological factors are unfavourable:

- **The subsidence history of the sedimentary basin produced an overall trough geometry, under which the formation of structural traps is very limited (Fig. 5);**
- **The post depositional tectonics amplified this adverse configuration. With the exception of a restricted central area, all possible anticlinal traps plunge into the basin centre and produce spill points towards the western and eastern margins (Fig. 6);**
- **Possible remaining traps are relatively small in size and would require many gas injection wells (Fig. 6);**
- **Observed brittle tectonics such as thrusts, strike-slip and normal faults may further compartmentalize potential reservoirs;**
- **A risk for gas spill exists also towards the South and North (Fig. 6);**
- **All possible reservoirs and seals subcrop at today's surface and could provide pathways for $CO_2$ migration into the biosphere;**
- **Porosity and permeability on core samples show very poor properties in the order of less than 1.5% porosity and 0.025mD permeability (Fig. 7).**

| *Parameter* | Hypothetical Required Parameter | Actual Situation | | Sleipner |
|---|---|---|---|---|
| | 80m thick reservoir | **Ross Sandstone Fm.** | **Dinantian Limestones** | Utsira Formation |
| ***Reservoir depth*** | >800 m | **upper section with higher sand content not or only partly in depth window** | **largely achieved** | 800-1000 m |
| ***Bulk reservoir size (storage capacity)*** | 90 km² | **215 km²** | **>835 km²** | 26,000 km² |
| ***Trap style and size*** | Large domal anticlines | **possible small scale traps, cumulative 1.5 km³ estimated from surface structures** | **two structures of moderate size (total 4km³) identified on seismic** | flat lying reservoir |
| ***Compartmentalization*** | no faulting to large fault blocks | **minor faulting, but strike slip-faults and thrusts developed** | **unknown, brittle deformation likely due to rock rheology** | none? |
| ***Porosity*** | >20% | **0.1-1.7%** | **0.2-1.5%** | 30-40% |
| ***Permeability*** | >200 mD | **0.003-0.025 mD** | **0.003-0.009 mD** | >500 mD |
| ***Seal integrity*** | Tested impermeability | **Gull Island Fm: risk that locally high portions of permeable silt- and sandstones are developed, disturbance of layering by soft slide and slump deformation** | **Clare Shale Fm: thickness 70-280 m, considered as good seal, but not tested** | Caprock Thickness 250 m |

Table 1: Hypothetical required parameter to store $CO_2$ emissions from Moneypoint power plant in comparison with the actual situation and Sleipner site

For comparative purposes, the project results are placed in context against a 'hypothetical situation', whereby carbon storage in the Clare Basin would be permissible (Table 1). The "required parameters" for the hypothetical scenario are those considered necessary to store the $CO_2$ emissions during a lifetime of a power plant at Moneypoint (total injectivity 200 Mt, injection rate 5 Mt/a).

Further assumptions for the hypothetical case are:

- **Net reservoir thickness: 80 m**
- **Storage capacity: in the order of 2% of the aquifer pore volume**
- **Filling capacity of individual traps: 40% of trapped pore volume**
- **Porosity: 20%**
- **Permeability: >200 mD to ensure required injection rates**

**The comparison reveals that the actual geological properties for the Clare Basin are far below the necessary thresholds for successful storage of $CO_2$ in a saline aquifer.**

**References:**
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[2] Elliott, T. (2000): Depositional architecture of a sand-rich, channelized turbidite system: the upper Carboniferous Ross Sandstone Formation, western Ireland. In: Weimer, P., Slatt, R.M., Coleman, Rossen, N.C., Nelson, H., Bouma, A.H., Styzen, M.J., Lawrence, D.T. (Eds.), Deep-Water Reservoirs of the World, Gulf Coast Section-SEPM Special Publication, 342-373.
[3] Martinsen, O.J. & Collinson, J.D. (2002): The Western Irish Namurian Basin reassessed: a discussion. Basin Research 14(4), 523.

Fig. 4 Monoclinal fold forming a natural arch at Ross Bay

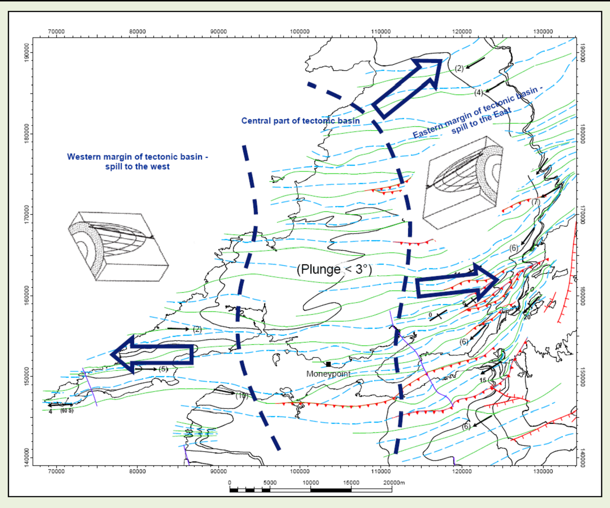

Fig. 5 Orientation of fold axes

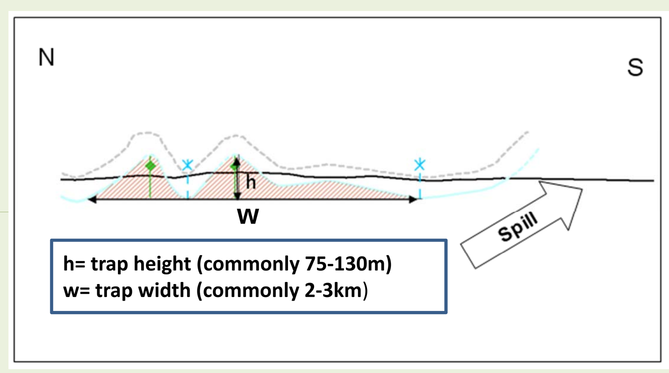


Fig. 6 Principal trap configuration

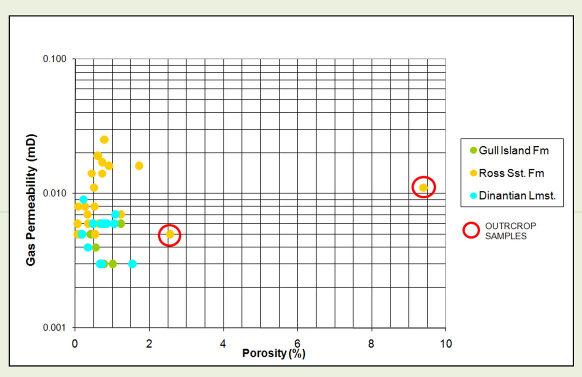


Fig. 7 Porosity-Permeability Cross-plot from Core Samples