



**British
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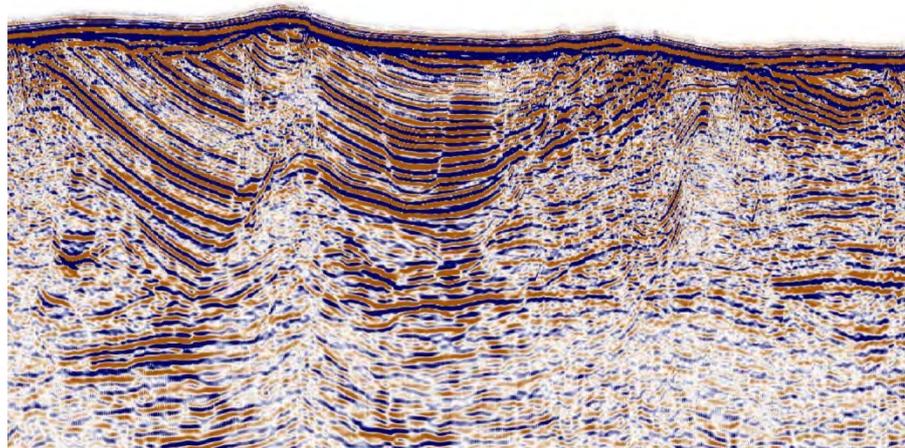
NATURAL ENVIRONMENT RESEARCH COUNCIL

A geological interpretation of the nearshore area between Belfast Lough and Cushendun, Northern Ireland, utilising a newly acquired 2D seismic dataset to explore for salt layers for possible gas storage within man-made caverns.

Marine Geoscience Programme

Commissioned Report CR/10/069

Volume 2



Department of
Enterprise, Trade
and Investment

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**Geological Survey
of Northern Ireland**

BRITISH GEOLOGICAL SURVEY

MARINE GEOSCIENCE PROGRAMME

COMMISSIONED REPORT CR/10/069

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Keywords

Gas storage, salt caverns, Northern Ireland.

National Grid Reference

SW corner 999999,999999
Centre point 999999,999999
NE corner 999999,999999

Map

Sheet 999, 1:99 000 scale, Map name

Front cover

Detail from newly acquired high resolution 2D seismic profile.

Bibliographical reference

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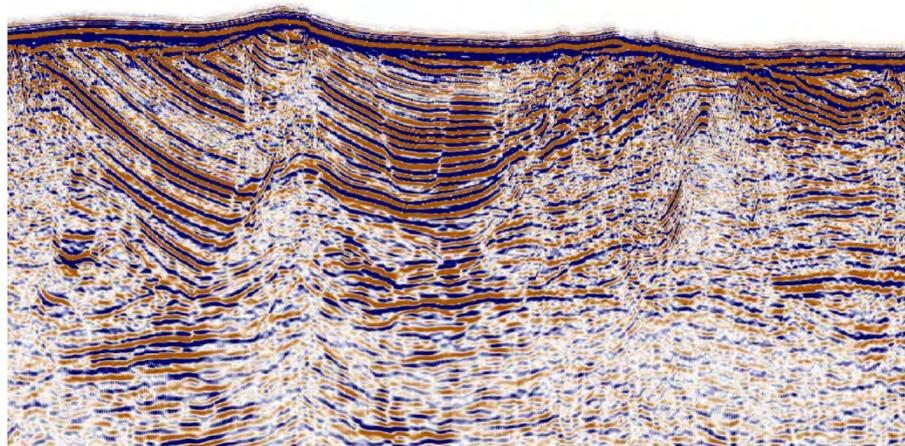
A geological interpretation of the nearshore area between Belfast Lough and Cushendun, Northern Ireland, utilising a newly acquired 2D seismic dataset to explore for salt layers for possible gas storage within man-made caverns.

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VOLUME 2

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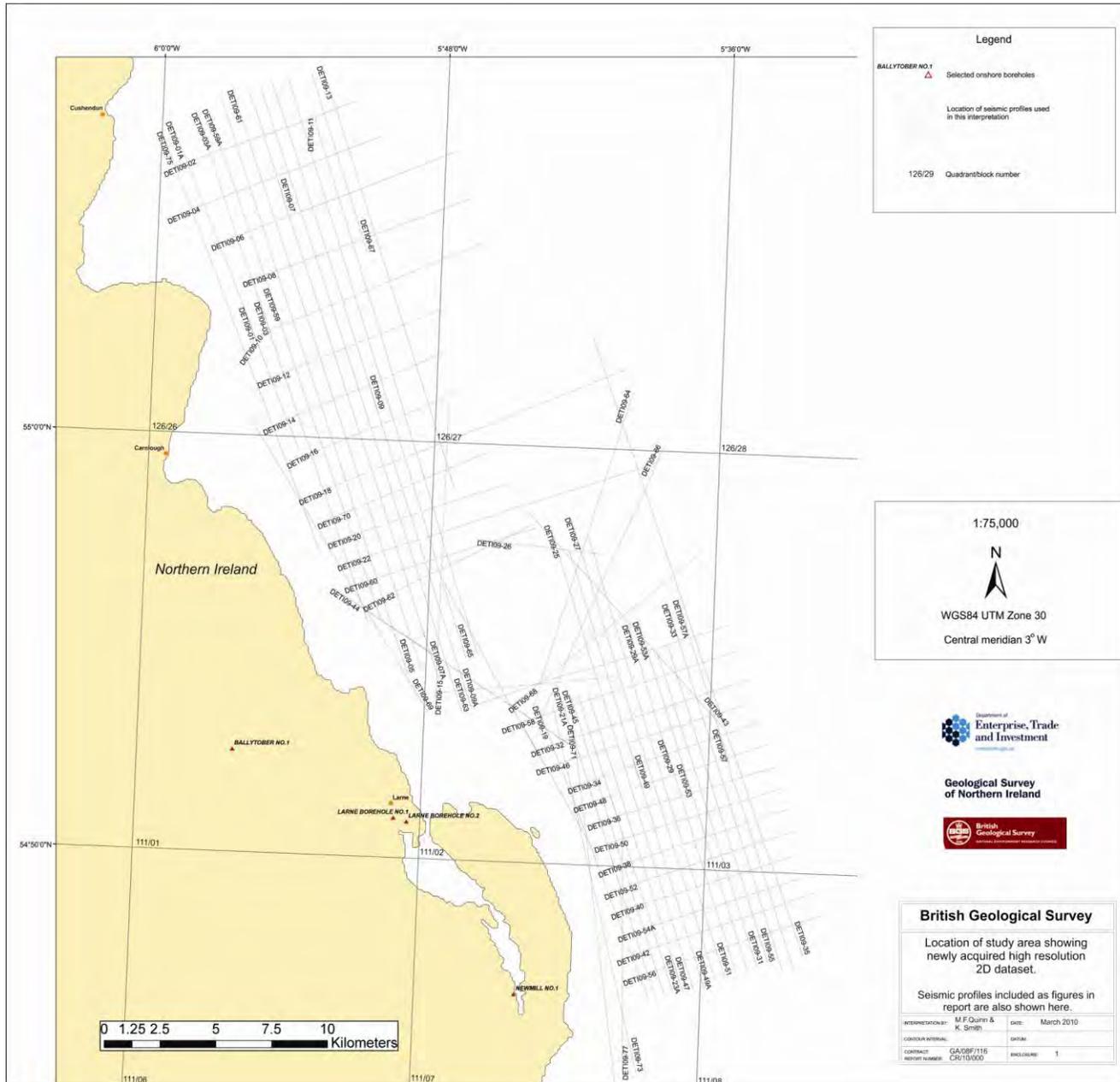
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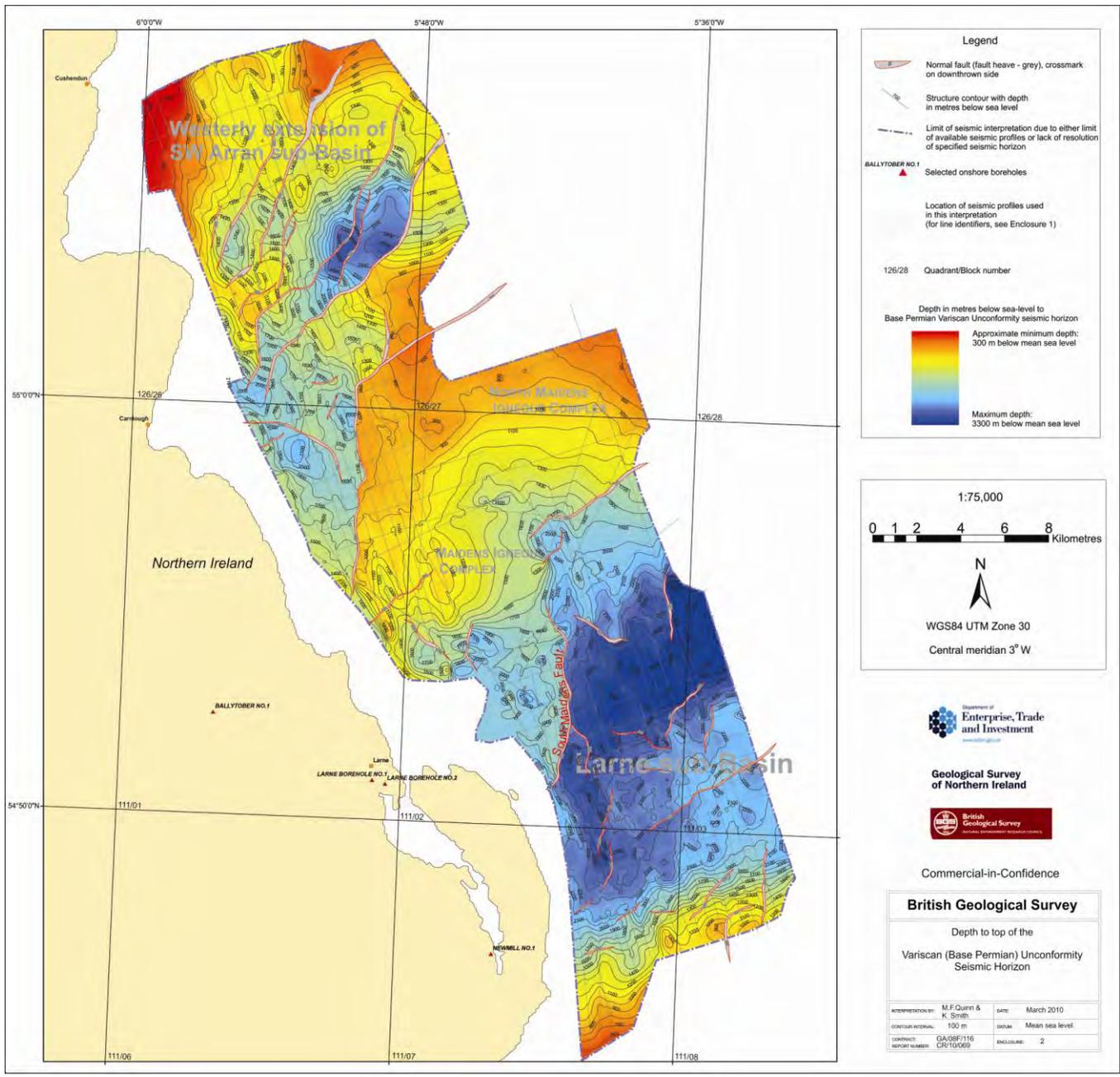
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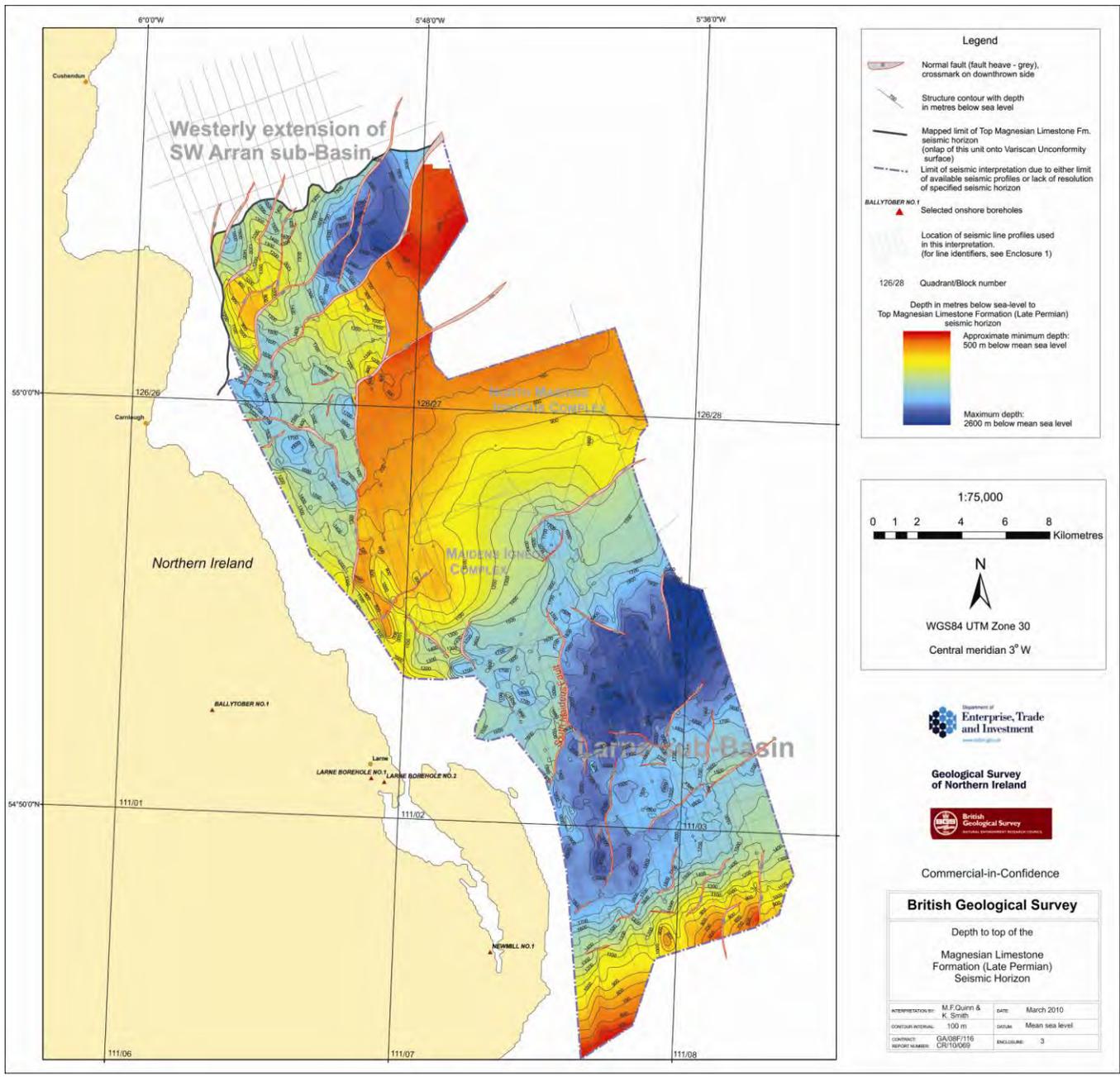
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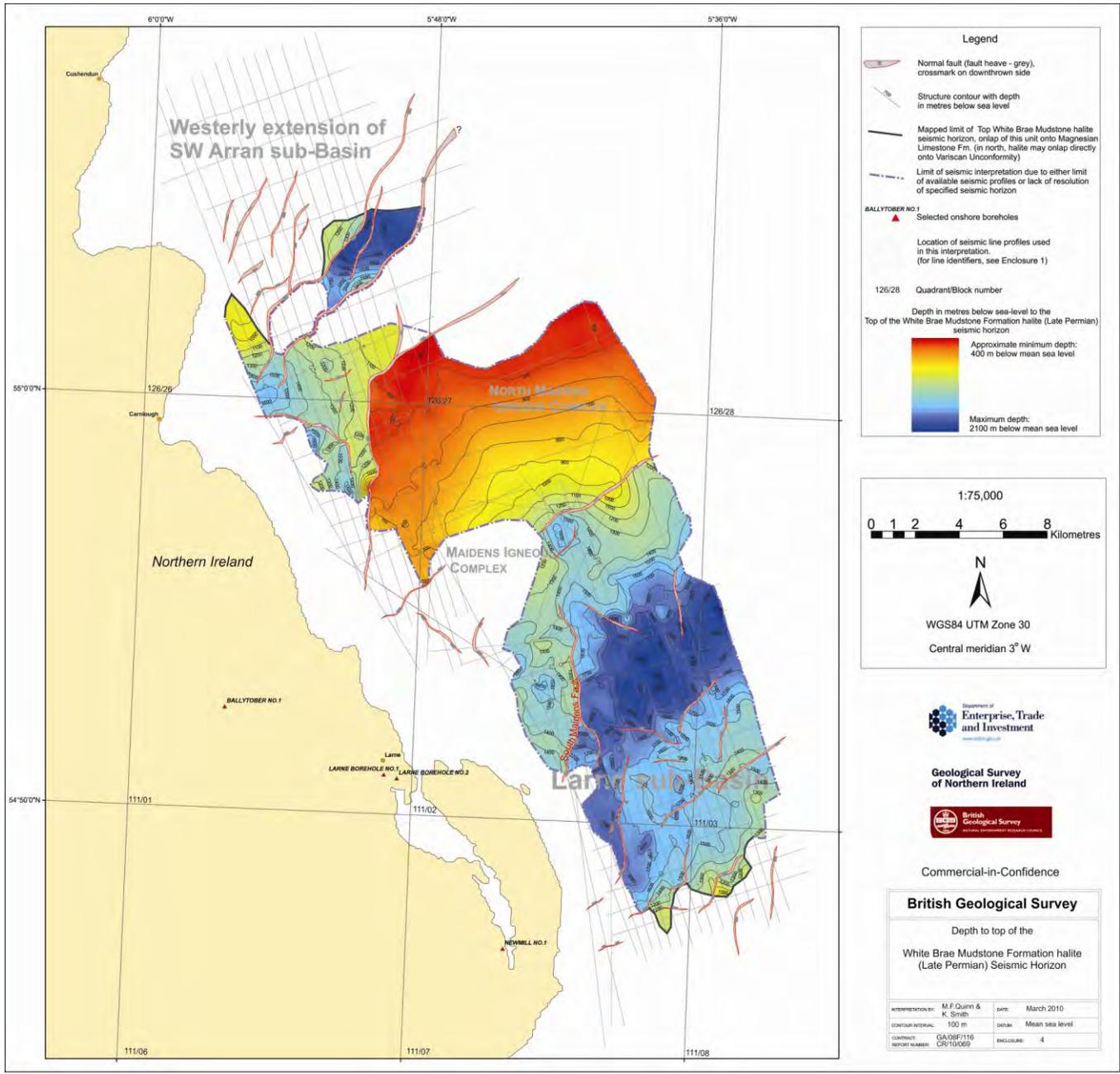
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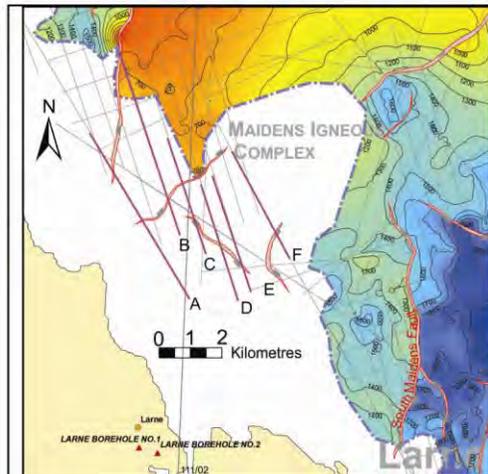


Enclosure 3. Depth to Top Magnesian Limestone Formation in metres below mean sea level.



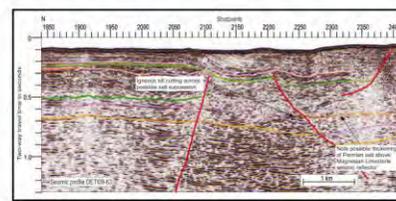
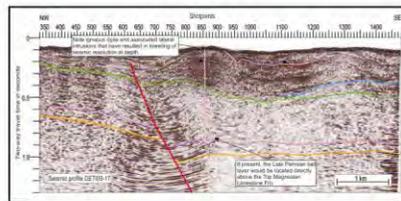
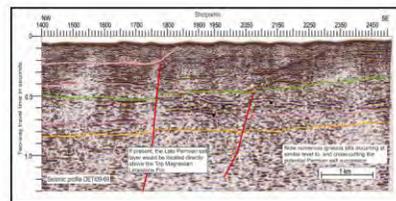
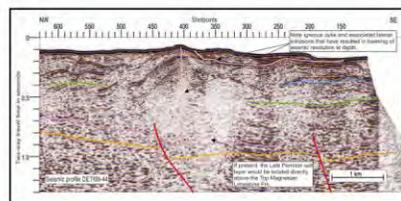
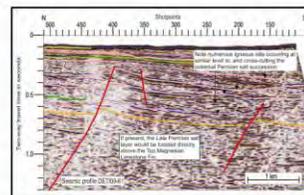
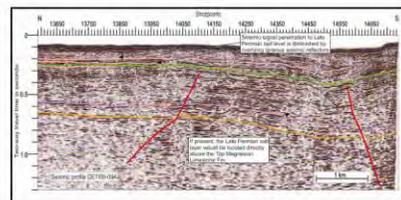
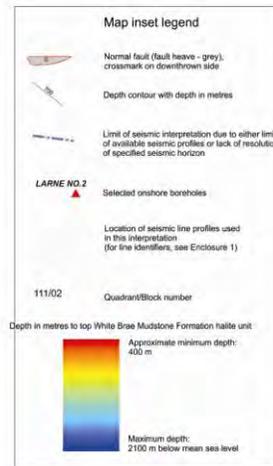
Enclosure 4. Depth to White Brae Mudstone Formation halite in metres below mean sea level.

Enclosure 5. Examples of the quality of seismic profiles at the level of Top White Brae Mudstone Fm. halite unit in the area south-west of the Maidens Igneous Complex.



Location of illustrated seismic profiles, superimposed on detail of map showing depth in metres to the top of the White Brae Mudstone halite unit.

The top of the White Brae Mudstone Formation halite unit immediately south-west of the Maidens Igneous Complex could not be mapped with any confidence due principally to the high concentration of igneous sills and dykes. These intrusions tend to deflect the seismic signal and reduce the amount of energy penetrating to deeper levels. Most of the seismic examples set out illustrate the masking effect of the igneous intrusions.



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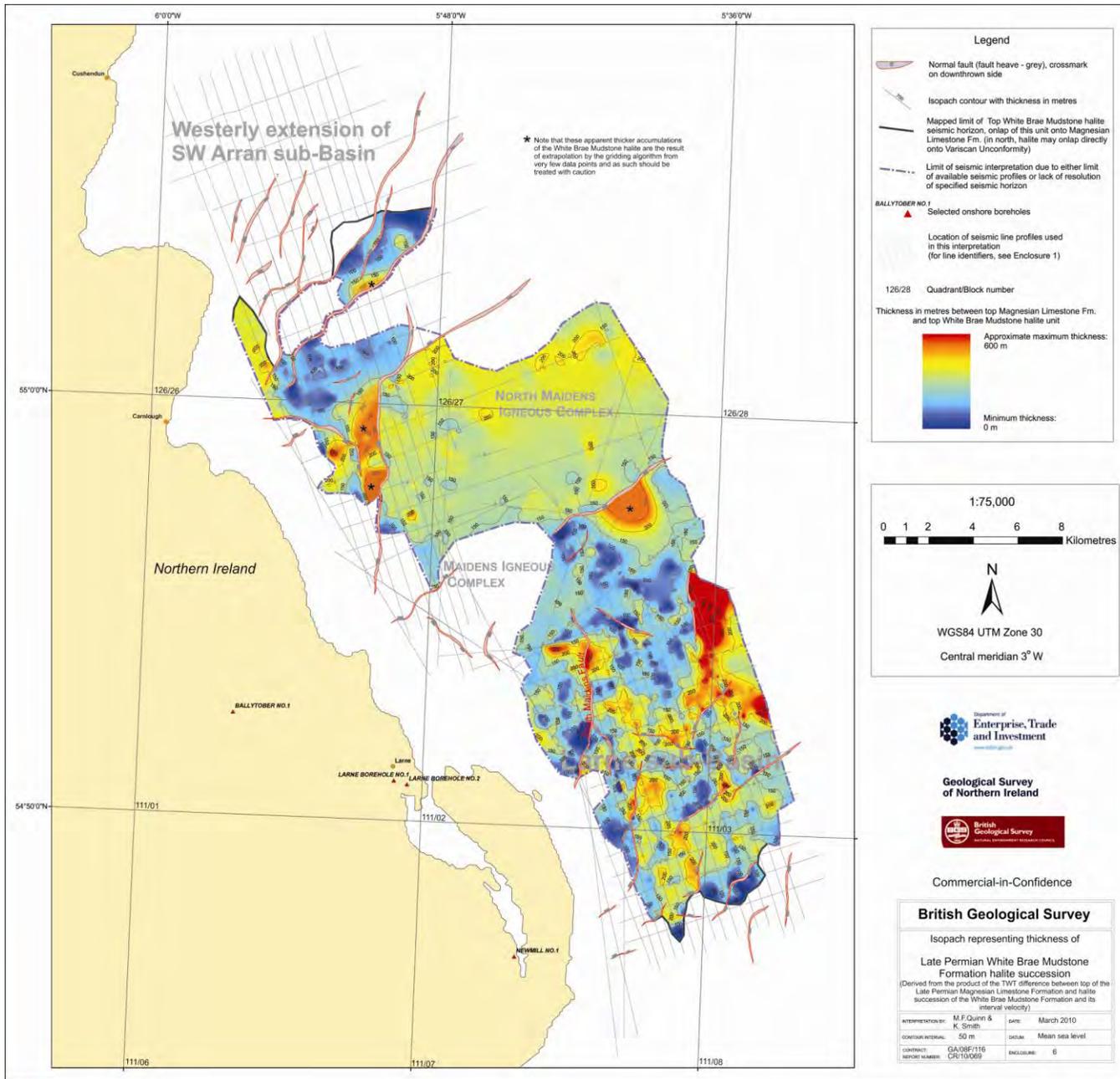
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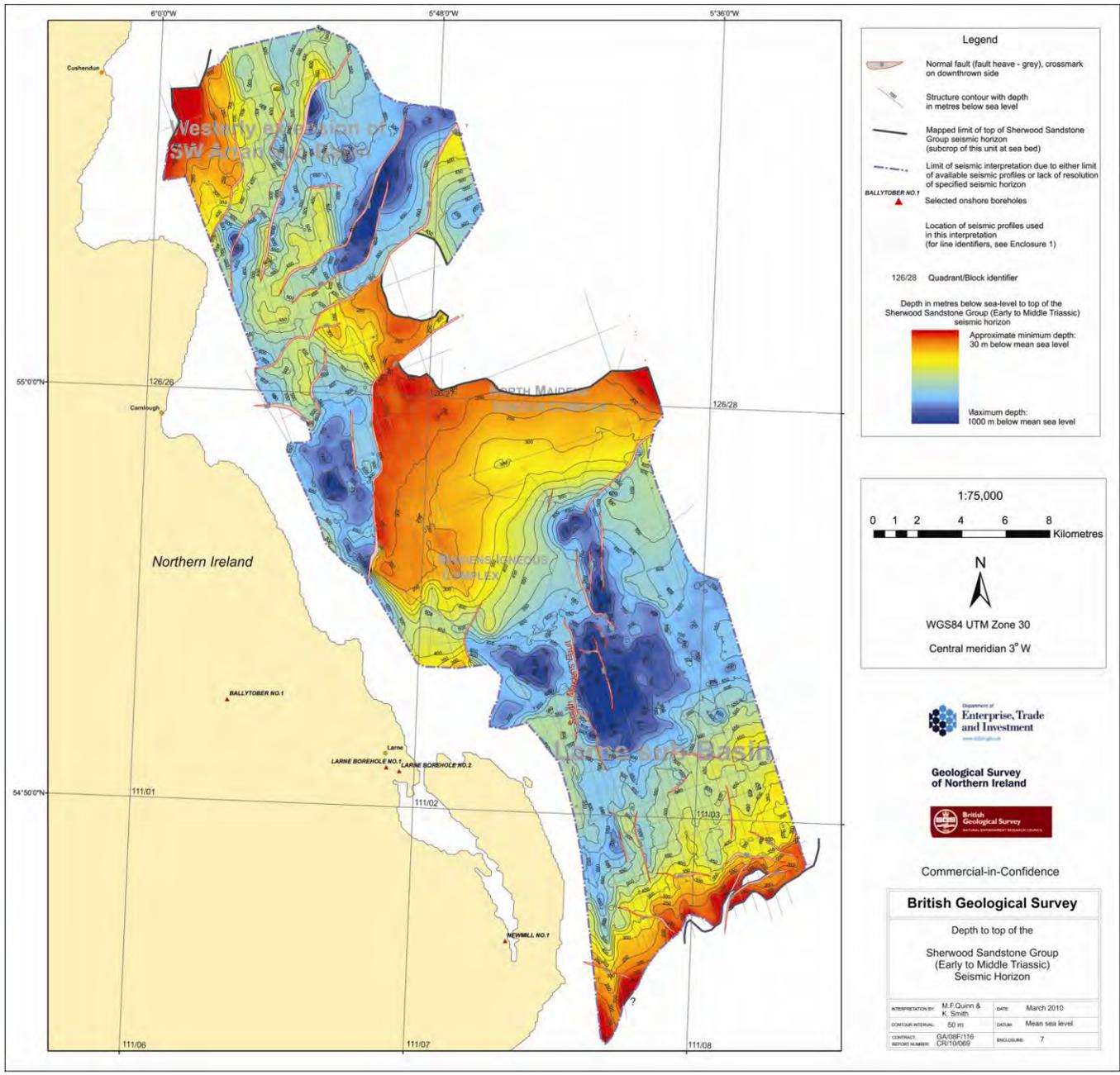
British Geological Survey

Examples of the quality of seismic profiles at the level of Top White Brae Mudstone Fm. halite unit in the area south-west of the Maidens Igneous Complex

INTERPRETED BY: M.F. Quinn & K. Smith	DATE: March 2010
CONTOUR INTERVAL: 100 m	datum: Mean sea level
COPYRIGHT: GSA/BNIP/116	ENCLOSURE: 5
REPORT NUMBER: CR/10/069	

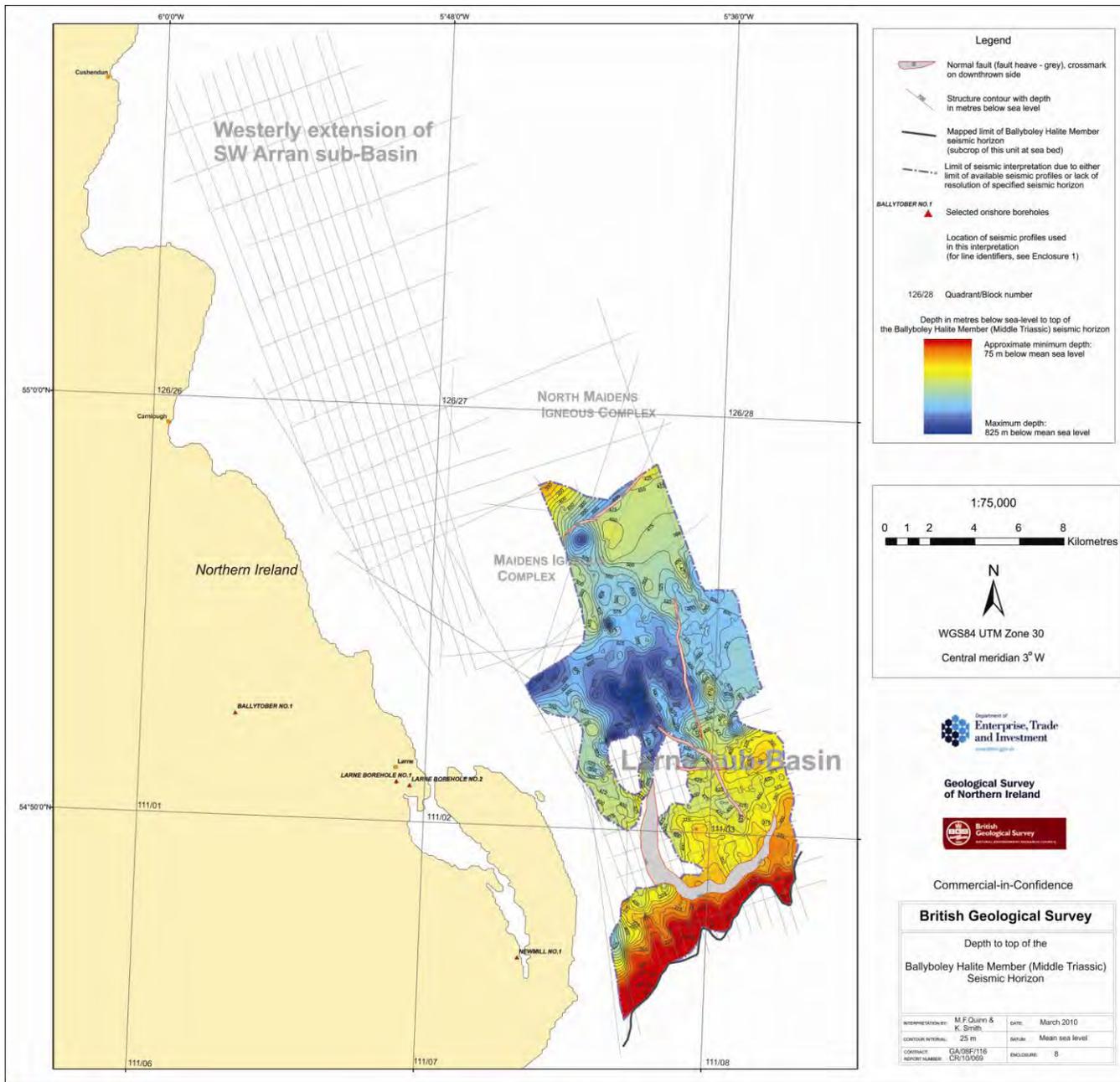
Enclosure 6. Thickness of White Brae Mudstone Formation halite in metres.

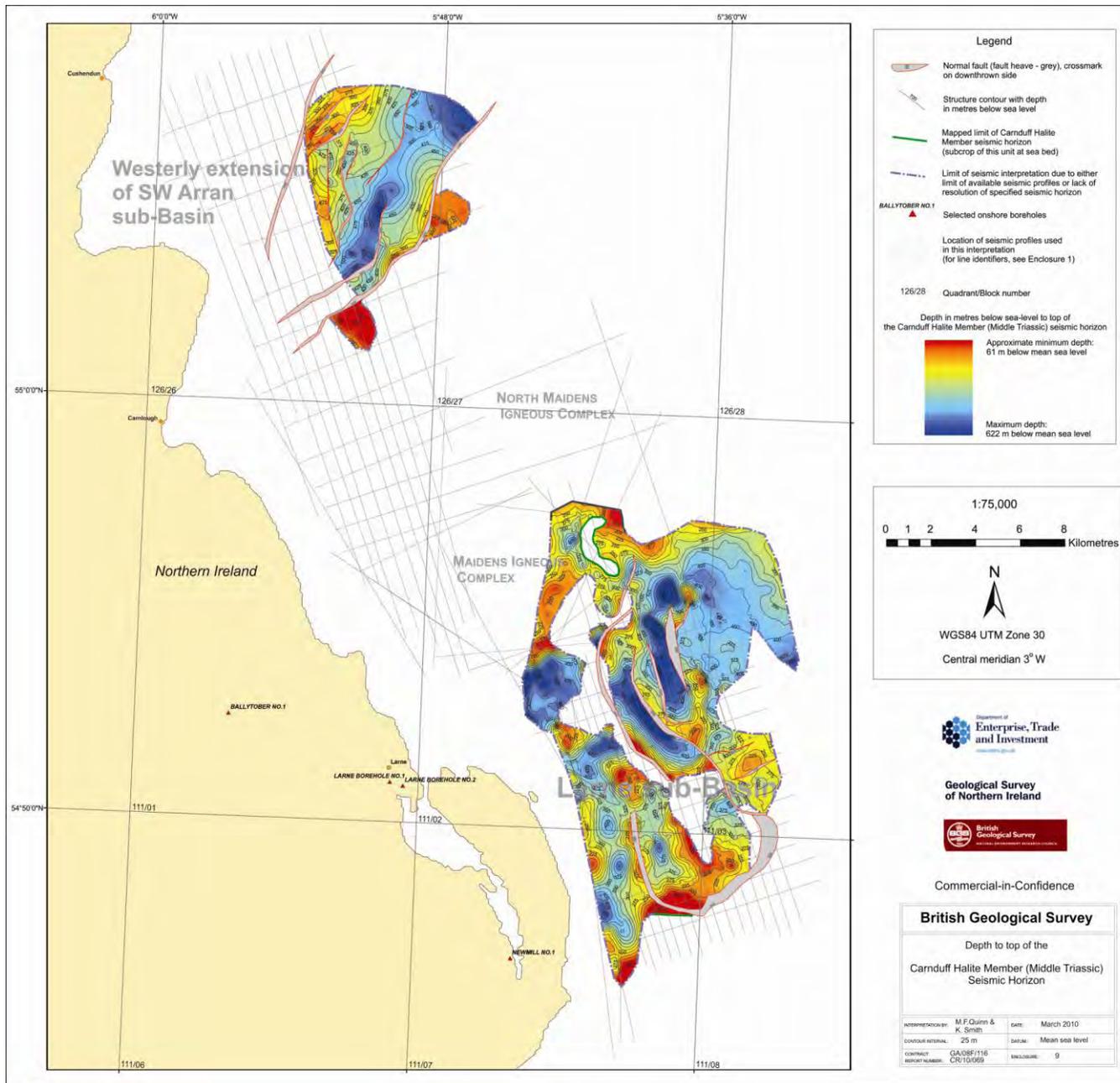




Enclosure 7. Depth to top Sherwood Sandstone Group in metres below mean sea level.

Enclosure 8. Depth to top Ballyboley Halite Member in metres below mean sea level.

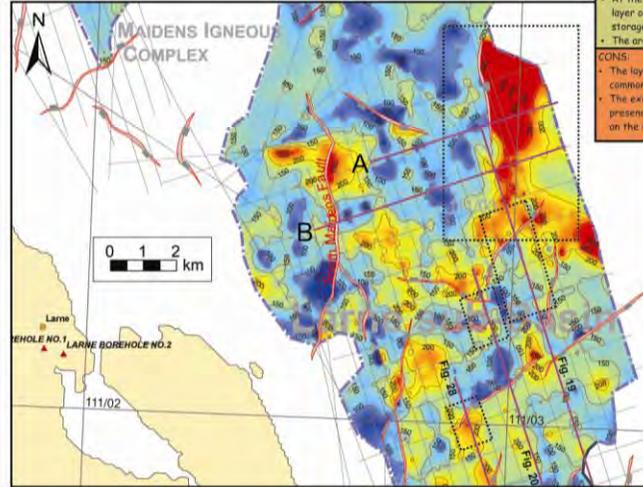




Enclosure 9. Depth to Carnduff Halite Member in metres below mean sea level.

Enclosure 10. Location 1, increased depositional thickness in eastern part of Larne sub-basin. White Brae Mudstone Fm. halite unit.

Location of illustrated seismic profiles, superimposed on detail of map showing thickness in metres of WhiteBrae Mudstone halite.



- PROS:**
- At all locations, igneous intrusions appear to be less frequent at Late Permian salt level;
 - The salt is interpreted to attain thicknesses amenable to cavern construction;
 - The Late Permian salt succession in Larne Borehole No. 2 was relatively pure;
 - At the three areas highlighted in Figures 19, 20 and 28, the Late Permian salt layer occurs at depths most commonly developed at salt covers for gas storage;
 - The area highlighted on Figure 28 is 6 km from nearest landfall.
- CONS:**
- The layer of thickened Late Permian salt lies at depths greater than that commonly used in salt caverns;
 - The existence of a Late Permian salt layer offshore is based upon its presence onshore, palaeogeographical reconstruction and limited indications on the seismic profiles.

Location 1 is defined where the White Brae Mudstone Formation halite succession is interpreted to thicken eastwards to more than 300 m, twice that seen in Larne No. 2 Borehole. Although a maximum value of 500 m is shown on the thickness map, interpretation of the top of this halite unit is uncertain and absolute values should be used with caution.

Increase in thickness is interpreted to be due to availability of additional accommodation space within Larne sub-Basin and is predominantly depositional with little mobilisation of the expected halite layers.

In addition three areas are highlighted where thickening of salt has been interpreted on individual seismic lines (Figures 19, 20 and 28). The salt is interpreted to vary in thickness between 150 and 250 m and occur at a depth of approximately 1500 m bmsl. Water depth varies from 100 m in the west to 130 m in the east.

Map inset legend

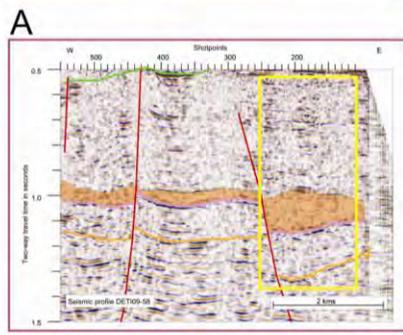
- Boundaries of Location 1 and three additional areas of interpreted thickened Late Permian salt
- Normal fault (fault heave - grey); crossmark on downthrown side
- Isopach contour with thickness in metres
- Mapped limit of White Brae Mudstone Fm. halite seismic horizon (onlap of this unit onto Magnesian Limestone Fm.)
- Limit of seismic interpretation due to either limit of available seismic profiles or lack of resolution of specified seismic horizon
- LARNE NO.2 Selected onshore boreholes
- Location of seismic line profiles used in this interpretation (for line identifiers, see Enclosure 1)
- 111/02 Quadrant/Block number

Thickness in metres between Top Magnesian Limestone Fm. and top White Brae Mudstone halite unit

Approximate maximum thickness: 600 m
Minimum thickness: 0 m

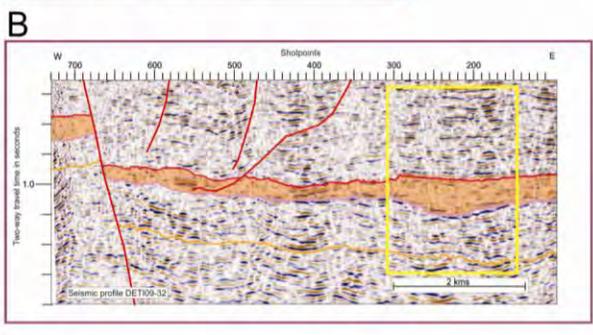
Seismic line inset legend

- Top Sherwood Sandstone Group
- Top White Brae Mudstone Fm. halite section
- Top Magnesian Limestone Fm.
- Variscan (Base Permian) Unconformity
- Normal fault
- Area in subsurface where salt of enhanced thickness expected



Key parameters within yellow box from seismic line DET109-58

Width: 1.8 km.
Depth: 2000 m (bmsl) to top of White Brae Mudstone Fm. halite.
Thickness: 400 - 500 m of White Brae Mudstone Fm. halite.
Water depth: 150 m.
Distance from port of Larne: 15 km.



Key parameters within yellow box from seismic line DET109-32

Width: 2 km
Depth: 2000 m (bmsl) to top of White Brae Mudstone Fm. halite
Thickness: 300-400 m of White Brae Mudstone Fm. halite
Water depth: 145 m.
Distance from port of Larne: 15 km.



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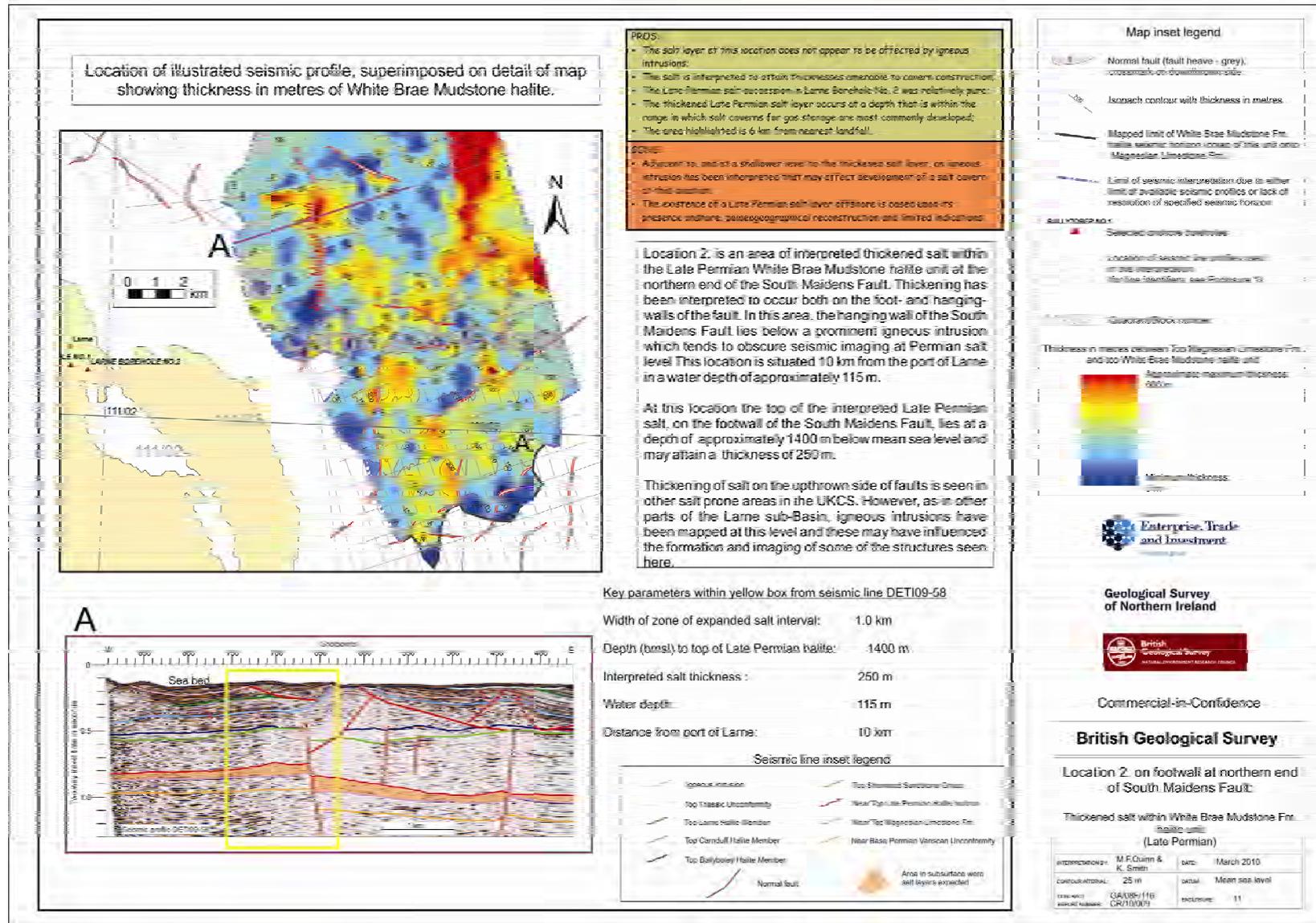
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Location 1, increased depositional thickness in eastern part of Larne sub-Basin

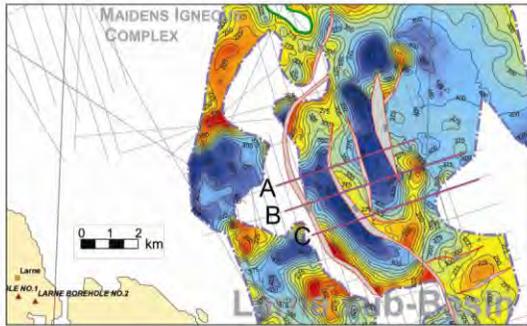
White Brae Mudstone Fm. halite unit (Late Permian)

INTERPRETER(S):	M.F. Quinn & K. Smith	DATE:	March 2010
COURTAGE INTERVAL:	50 m	DATE:	Mean sea level
CONTRACT NUMBER:	GA/08F/716	ENCLOSURE:	10
REPORT NUMBER:	CR/10/069		



Enclosure 11. Location 2, on footwall at northern end of South Maidens Fault: Thickened salt within White Brae Mudstone Fm. halite uni

Location of illustrated seismic profiles, superimposed on detail of map showing depth in metres below mean sea level of near Top Carduff Halite Member.



PROS:

- The salt is interpreted to attain thicknesses amenable to cavern construction.
- There are examples of caverns in bedded salt at depth between 500-650 m in depth. The thickened salt identified here is interpreted to lie between 280 - 620 m in depth with the older Ballyboley halite more likely to be at the greater depth.

CONS:

- Igneous intrusions, both sills and dykes, are present within the Triassic succession and may present a risk to cavern construction if located within the thickened salt succession.
- There is uncertainty regarding the purity of the Triassic salt members.

Location 3, is a NNW-trending high between two NNW-trending down-faulted blocks situated 12.5 kms from the port of Larne in a water depth of approximately 120 m.

This high exhibits updoming within the deeper part of the section that could indicate the mobilisation and migration of Mercia Mudstone Group salt.

At this location the depth to the interpreted Middle Triassic salt is approximately 300 m and thickness 320 m.

The structures interpreted here are similar to those seen in other basins where mobilised salt has been proved by drilling. However, igneous intrusions have been mapped in the area at this level and these may have influenced the formation and imaging some of the structures seen here.

Map inset legend

- Normal fault (fault heave - grey), crossmark on downthrown side
- Structure contour with depth in metres below sea level
- Mapped limit of Carduff Halite Member seismic horizon (subcrop of this unit at sea bed)
- Limit of seismic interpretation due to either limit of available seismic profiles or lack of resolution of specified seismic horizon

BALLYBOLEY NO. 1

- Selected onshore boreholes

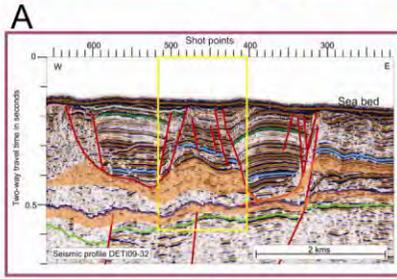
Location of seismic line profiles used in this interpretation (for line identifiers, see Enclosure 1)

111/02 Quadrant/Block number

Depth in metres below sea-level to top of the Carduff Halite Member (Middle Triassic) seismic horizon

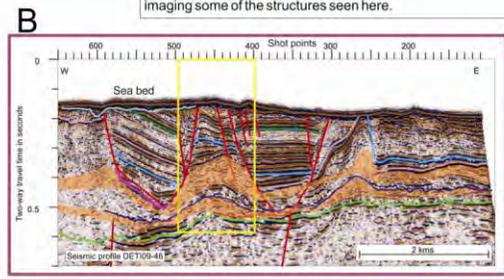
Approximate minimum depth: 51 m below mean sea level

Maximum depth: 622 m below mean sea level



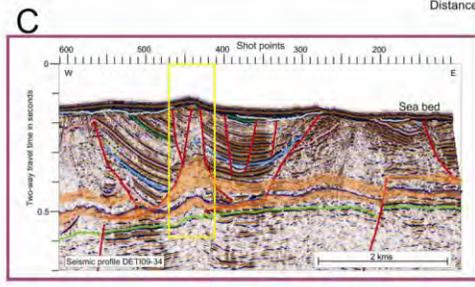
Key parameters within yellow box from seismic line DET109-32

- Width of zone of expanded salt interval: 1.3 km
- Depth (bmsl) to top of Carduff Member: 320 m
- Depth (bmsl) to top of Ballyboley Halite Mbr: 660 m
- Interpreted salt thickness: 340 m
- Water depth: 110 m
- Distance from port of Larne: 12.5 km



Key parameters within yellow box from seismic line DET109-46

- Width of zone of expanded salt interval: 1.1 km
- Depth (bmsl) to top of Carduff Member: 280 m
- Depth (bmsl) to top of Ballyboley Halite Mbr: 620 m
- Interpreted salt thickness: 340 m
- Water depth: 115 m
- Distance from port of Larne: 12.5 km



Key parameters within yellow box from seismic line DET109-34

- Width of zone of expanded salt interval: 0.7 km
- Depth (bmsl) to top of Carduff Member: 270 m
- Depth (bmsl) to top of Ballyboley Halite Mbr: 580 m
- Interpreted salt thickness: 310 m
- Water depth: 100 m
- Distance from port of Larne: 12.5 km

Seismic line inset legend

- Igneous intrusion
- Top Triassic Unconformity
- Top Larne Halite Member
- Top Carduff Halite Member
- Top Ballyboley Halite Member
- Top Shanewood Sandstone Group
- Normal fault
- Area in subsurface where salt layers expected



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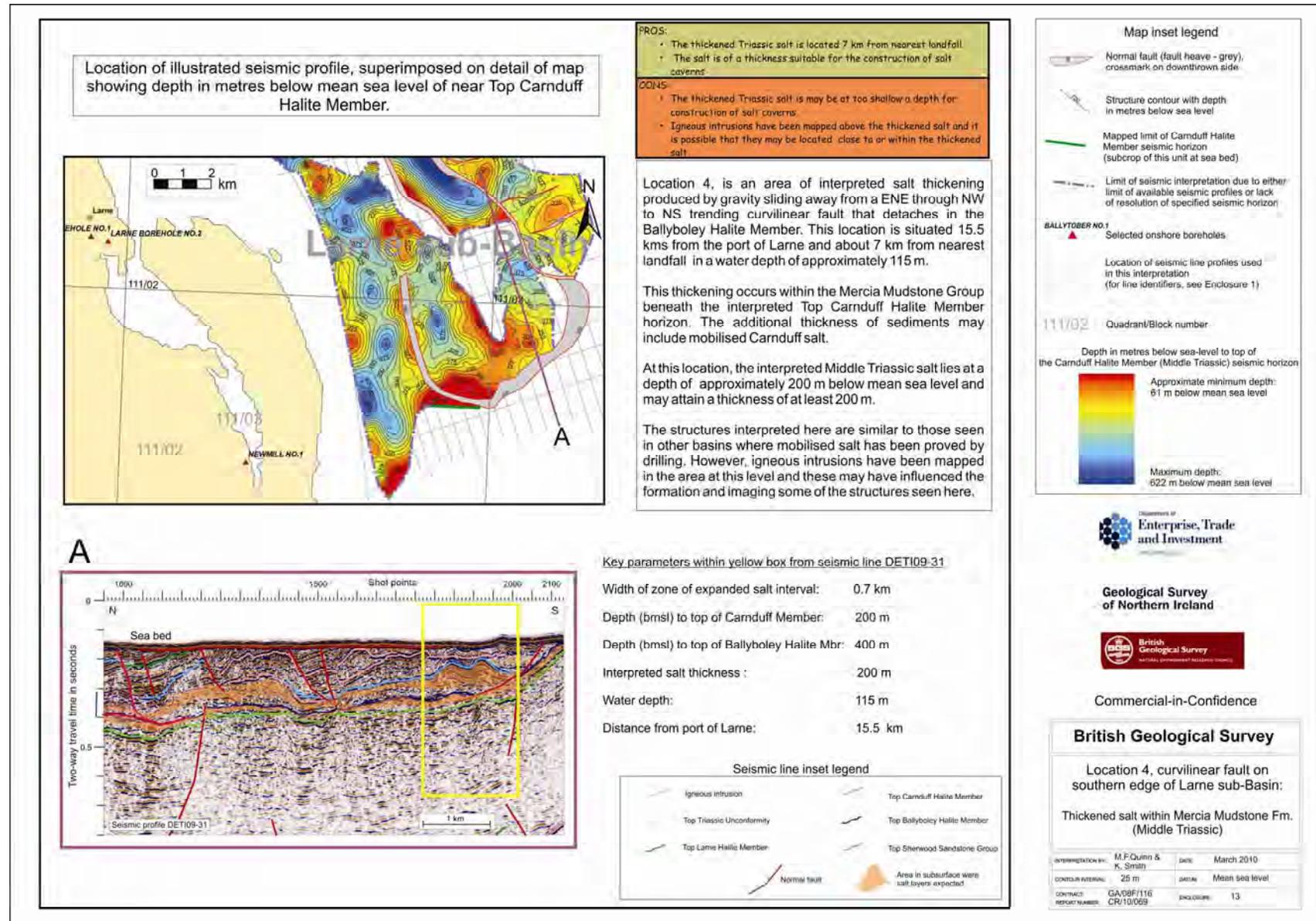
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Location 3, NNW-trending high in Block 111/02:

Thickened salt within Mercia Mudstone Fm. (Middle Triassic)

INTERPRETER:	M F CLARKE & K. SMITH	DATE:	March 2010
CONTOUR INTERVAL:	25 m	DATE:	Mean sea level
CONTRACT REPORT NUMBER:	GA/08/F116 CR/10/069	ENCLOSURE:	12



Enclosure 13. Location 4, curvilinear fault on southern edge of Larne sub-basin: Thickened salt within Mercia Mudstone Fm.