Department
of Energy &
Climate Change

Prospectivity in the UKCS north of 62°N

Promote
United Kingdom 2014

Introduction

North of 62° N remains a frontier exploration area for the UKCS. This is due in part to the ubiquitous presence of Paleogene volcanics (and the difficulty of imaging beneath them) and in part to the extreme water depth in the far north.

The study undertaken covers an area of 22,000 km² or 156 blocks and part-blocks. Of these, only 38 blocks and part-blocks are either currently licensed or are awaiting licence award following the recent 27th Offshore Licensing Round. This study is based on a reconnaissance interpretation of 14,000 line-km of 2D seismic data available north of 62° N.

The most promising hydrocarbon potential occurs in several broad areas, although the unproven nature of source rocks and their maturation remains a caveat in all areas. Gas is proven immediately south of the study area (214/4-1), but analysis of mudstones from well 219/21-1 showed the Upper Cretaceous to be over-mature (presumably due to the presence of high heat flow on the Brendan Dome).

There are areas which are considered to have a low chance of success for hydrocarbon potential. These correspond to areas of thick volcanics, thick, monotonous post-volcanic mudstone successions and areas which lack favourable structuration. In the absence of 3D seismic data or a dense grid of 2D data, it has not been feasible to confidently identify and map stratigraphic traps.

Mobilisation of mud, possibly facilitated by the presence of gas, occurs over a large area centred on the 'Pilot Whale Anticline'. Disrupted shallow sediments and mud vents on the sea floor have also been mapped.

The only proven play in the vicinity of the study area is the mid-Eocene Caledonia Fan Play, but structures and sandstones have still to be validated north of 62° N. The Paleocene and Upper Cretaceous sections provide the primary and secondary targets for leads in the area. Several leads can be delineated on structure contours on the top Paleogene volcanics reflector, which mirrors the structure of deeper, potentially prospective prospective horizons.

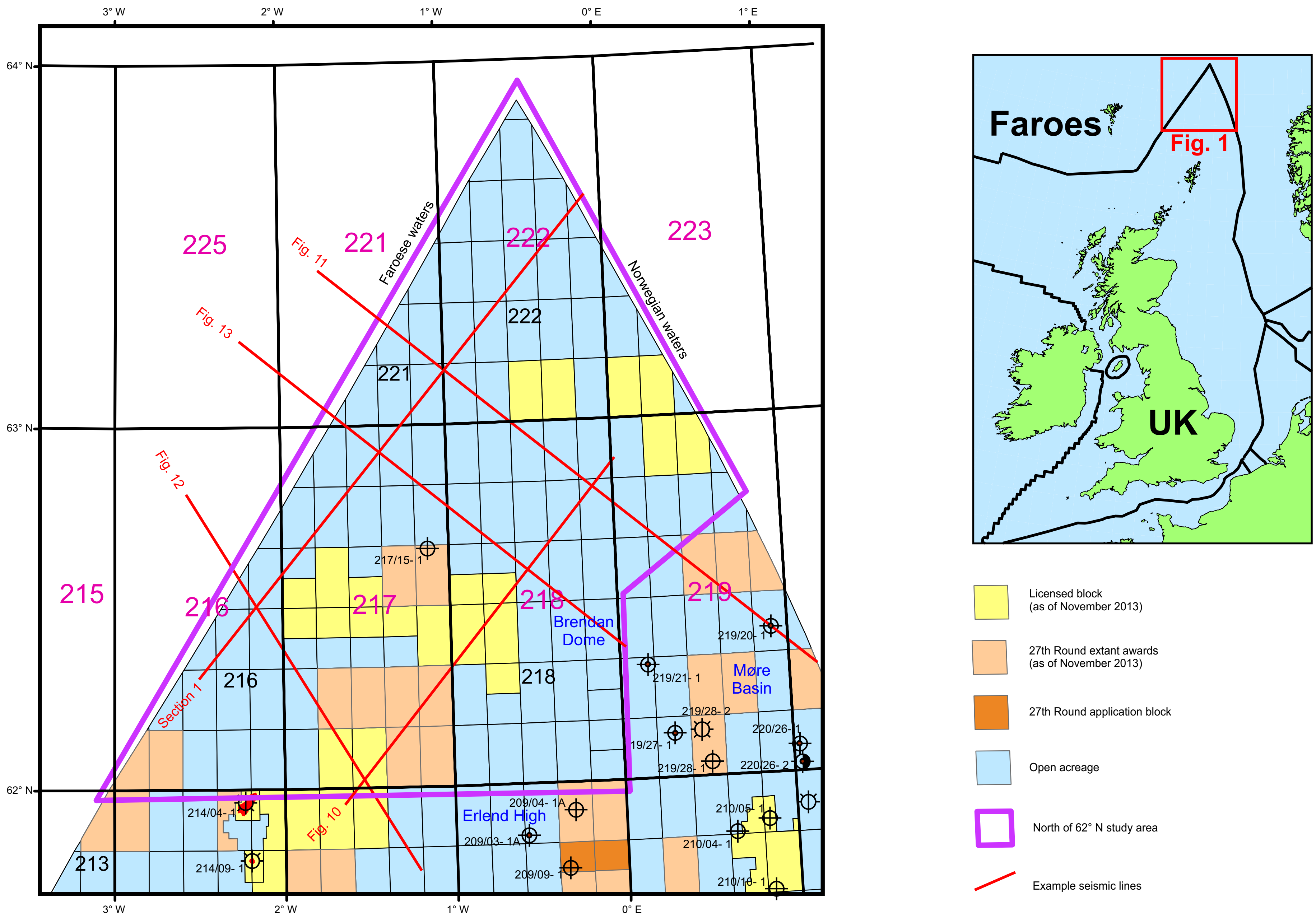


Fig. 1 Location of the study area, licenced acreage and example seismic lines, north of 62° North

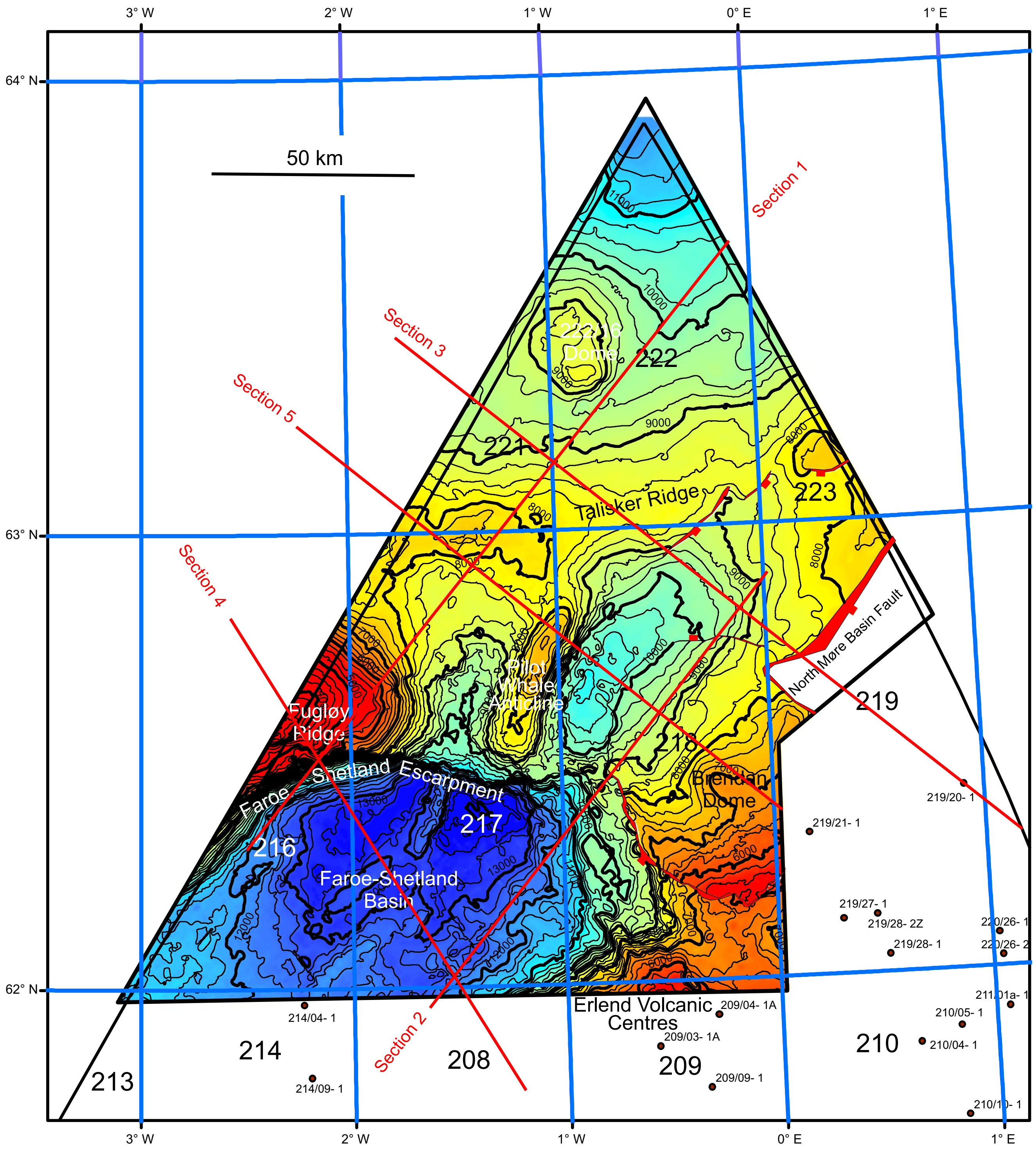


Fig. 2 Top Paleogene volcanics structural framework. Contours are in feet sub-sea.

Faroe-Shetland Basin

The Faroe-Shetland Basin extends from the south into Quadrants 216 and 217 and the south-western corner of Quadrant 218. Its northern limit is marked by the Faroe-Shetland Escarpment.

The thick Eocene and younger strata that fill this basin (up to 8,800 ft) are floored by Paleocene lavas, which are largely impenetrable to seismic energy. These strata are affected by Cenozoic compressional/transpressional deformation, which has produced a series of anticlines and monoclines (Johnson et al. 2005).

Two of the three Eocene fans of the Caledonian Play Fairway extend from the south only into the southernmost blocks of Quadrant 216.

Faroe-Shetland Escarpment

The Faroe-Shetland Escarpment marks the limit of a thick basaltic shield volcano phase of the Faroe-Shetland Volcanic Series. The escarpment, which runs broadly west-east across the centre of Quadrants 216 and 217, is in parts 3,000 ft high. The escarpment is flanked to the east by the Brendan Dome and Erlend Volcanic Centres.

Brendan Dome

The Brendan 'Dome' appears to be a fault-controlled feature lying above a buried volcanic centre of presumed ?Early Cretaceous age (Smythe et al. 1983) although the 'old volcanic centre' model of Smythe et al. (1983) has been questioned. In the study area the shallow structure of the feature is dominated by a thick, sill-intruded Upper Cretaceous section and a large down to the south-west fault, which is thought to be controlled by the Magnus Transfer Zone.

Part of the Brendan Dome was drilled in 2003 by the 219/21-1 well. Based on this well, Rohrman (2007) postulated that the intrusion of the igneous pluton (and related uplift) took place 60-65 Ma (in the Danian) with later flood basalts (58-59 Ma) and early Eocene sill intrusion (55-56 Ma). The latter two ages are based on Ar-Ar dating from well 219/21-1 samples (Rohrman 2007).

Northern area

The area north of the Faroe-Shetland Escarpment, Brendan Dome and the north Møre Basin fault is dominated by volcanics. The area has been termed the Møre Platform and contains a number of distinct features based on the top volcanics structure map.

(a) A nose of the Fugløy Ridge extends into UK waters in the north-east of Quadrant 216. The water depth shallows in this area and a top Volcanics reflector approaches the sea floor.
(b) Pilot Whale Anticline (or Lagavulin High) culminating in block 217/10.
(c) Rim-syncline basins to the west and east of the Pilot Whale Anticline.
(d) A west-east ridge, here termed the Talisker Ridge, extending from 217/2, across the Talisker lead and then through 222/28 towards the ENE.
(e) 222/16 Dome. A circular volcanic high.
(f) Seaward-dipping wedge of lava reflectors in the far NW (mainly in Faroese waters).

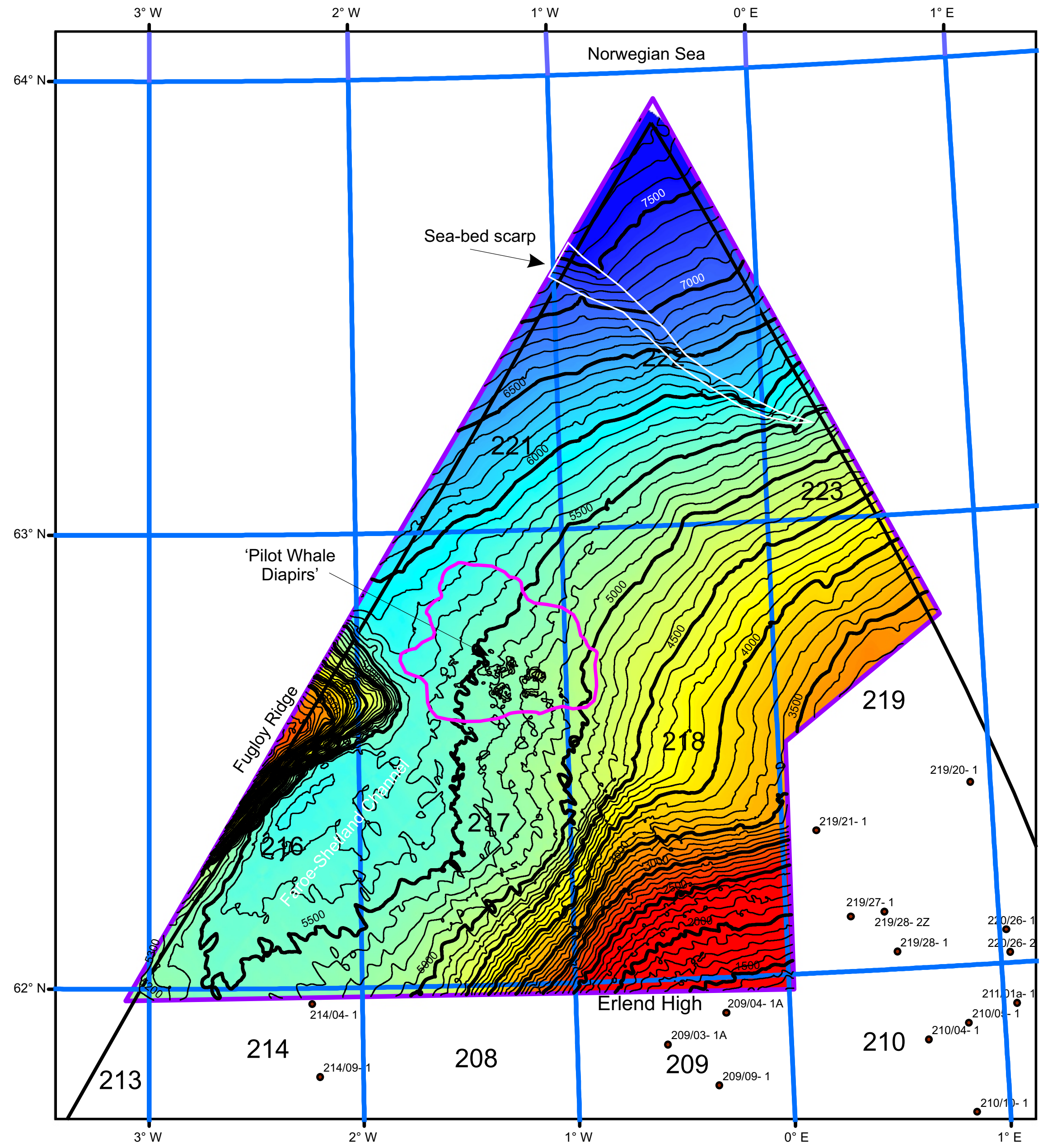


Fig. 3 Contours of depth to sea bed (feet)

Sea bed topography

North of 62° N, the water depth ranges from 1,500 ft in the far south-east to a maximum of 7,900 ft in the extreme north. Prominent sea-bed features in the study area include the Fugløy Ridge, the Faroe-Shetland Channel, the Erlend High, the 'Pilot Whale Diapirs' and a NW-SE trending scarp in Quadrant 222. The area to the north is known as the Norwegian Sea.

To date, the well drilled in the deepest water is 214/4-1 (5,317 ft water depth). Well 219/21-1 was drilled in a water depth of 2,987 ft.

'Pilot Whale Diapirs'

A series of sea-bed topographic mounds is located in the northern half of Quadrant 217 and have been informally termed the 'Pilot Whale Diapirs'. The mounds were first described by Haflidason *et al.* (1996). Multibeam, swath bathymetry survey coverage shows the largest could measure 3x5 km and reach a height of 360 ft (120 m) above the adjacent sea bed (Holmes *et al.* 2003). The larger mounds cover an extensive area of 20x22 km within five blocks. However, a wider area containing only smaller mounds measures 40x60 km (Holmes *et al.* 2003).

Sediment sampling on one of these mounds found evidence for strata of pre-Oligocene age being involved in the diapirism and now occurring at sea bed (Holmes *et al.* 2003).

The mounds have been tentatively interpreted as tectonically-triggered mud volcanoes, diapirs and associated intrusions that formed due to the upward migration of muddy fluids, which seismic evidence suggests were probably derived from the Eocene-Oligocene succession (Ritchie *et al.* 2003). Overpressuring of these older sediments is considered a possible cause (Long *et al.* 2003).

The mud volcanoes could be vent deposits linked to gas venting from deeper, potentially gas-bearing anticlines. This has yet to be proven.

McDougall (2003), in a study of sediment hydrocarbons in this part of SEA4, notes that although some recent low-level petroleum hydrocarbons are present around the diapirs, but otherwise the samples are not anomalous.

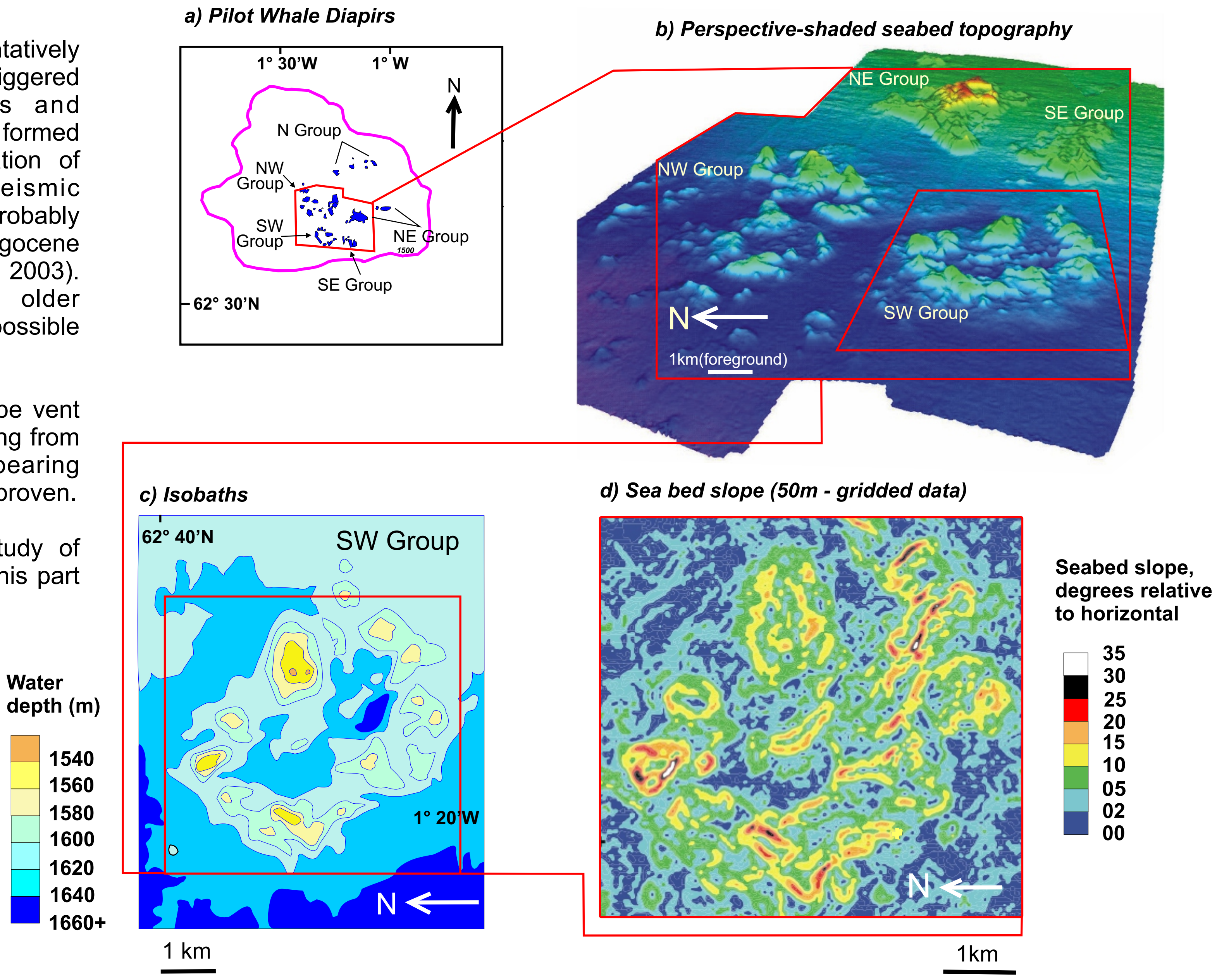


Fig. 4 Geomorphology of the Pilot Whale Diapirs (from Holmes *et al.* 2003)

Potential reservoirs and source rocks

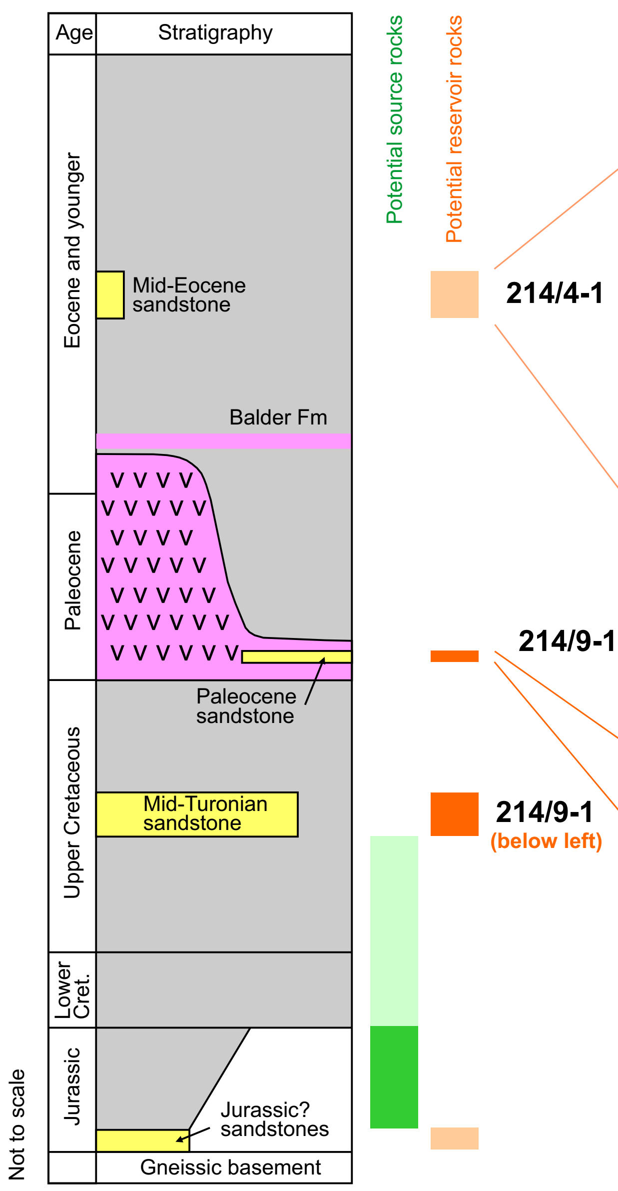
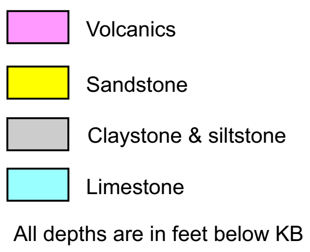
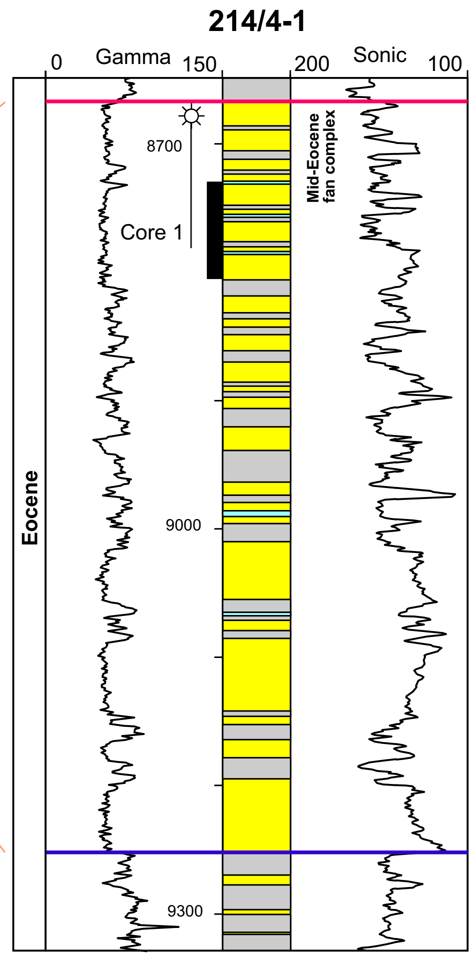


Fig. 5 Prognosed stratigraphic column north of 62° N based on nearby wells





The nearest working hydrocarbon play to the study area comprises the mid-Eocene Caledonia Play as tested by well 214/4-1 (Tobermory). Although these fan sandstones may extend into the southern fringe of the study area, they are not present in any viable closures.

The mid-Eocene fan section in 214/4-1 contains an excellent reservoir section:

Gross sandstone thickness: 585 ft
Net:Gross: 0.84
Porosity: 30-37%
Hydrocarbon saturation: 93%

Fig. 6 Well log across the mid-Eocene fan complex in Tobermory discovery well 214/4-1

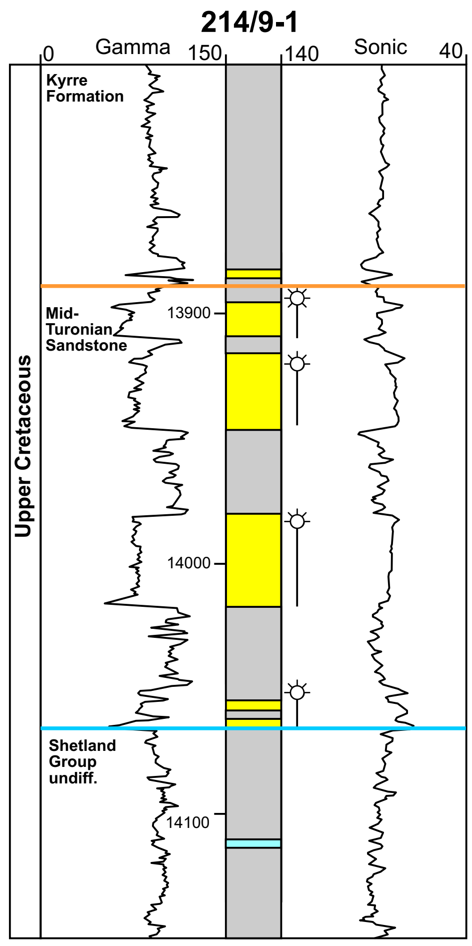


Fig. 7 Well log across mid-Turonian sandstones in well 214/9-1

In the Faroe-Shetland Basin, well 214/9-1 drilled *c.* 100 ft of mid-Turonian sandstones. These were gas-bearing with 10-15% porosity, but were reported as 'tight'.

Some 5,000 ft of Upper Cretaceous mudstones are present beneath the Paleogene volcanics. They are typically intruded by sill complexes and sandstones are locally developed.

In the Norwegian Vøring Basin, there are several Upper Cretaceous sandstones units which were derived from both the north-west and south-east (Kjennerud & Vergara 2005). Average porosities within the Lysing sandstone are 14-18% and in the Nise sandstone are 15-27%.

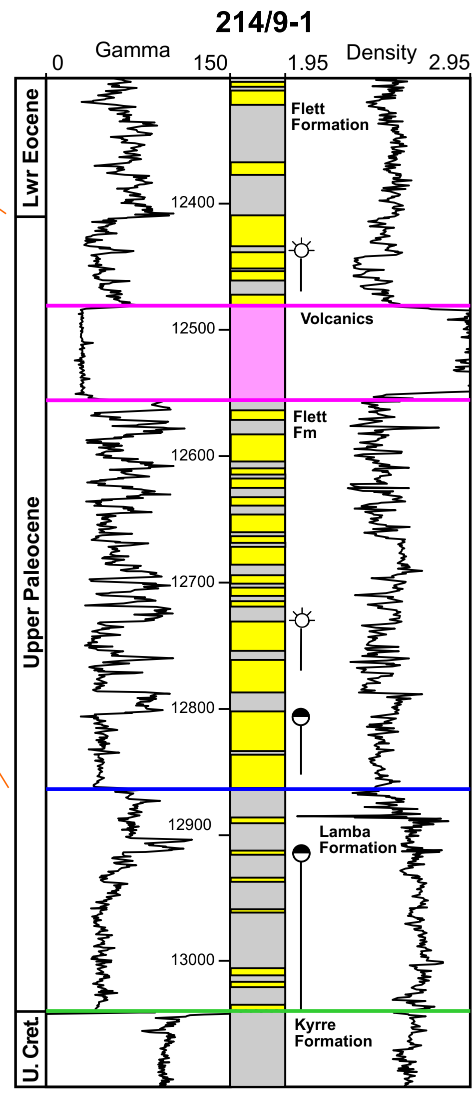


Fig. 8 Well log across Paleocene sandstones in well 214/9-1

In well 214/9-1, Paleocene sediments occur above and below a 75 ft-thick lava, with sandstones correlated with the Flett Sandstone Formation of the Faroe-Shetland Basin.

Analogous sequences occur in the Norwegian offshore and onshore Greenland where intra-basalt and base-basalt sandstones are the main targets within the Paleocene. These are of shallow marine and deeper marine origin respectively.

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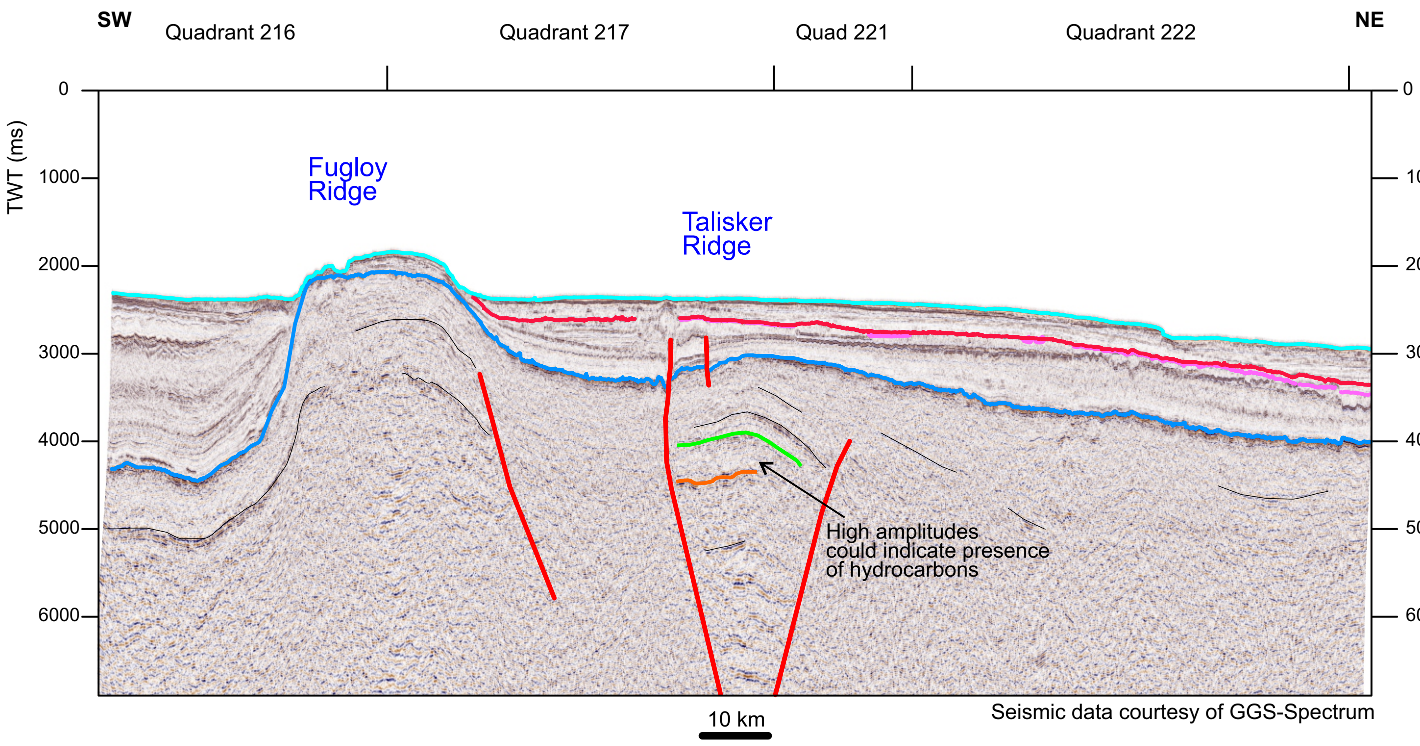

Fig. 9: From the Faroe-Shetland Basin, Faroe-Shetland Escarpment and Fugloy Ridge, this SW-NE seismic section crosses the Talisker Ridge before reaching deeper water (7200 feet) at a latitude of 63° 45'N. High amplitudes beneath the Paleogene volcanics mirror the overlying structure of the Talisker Ridge in what may be sandstones of Paleocene or Upper Cretaceous age.

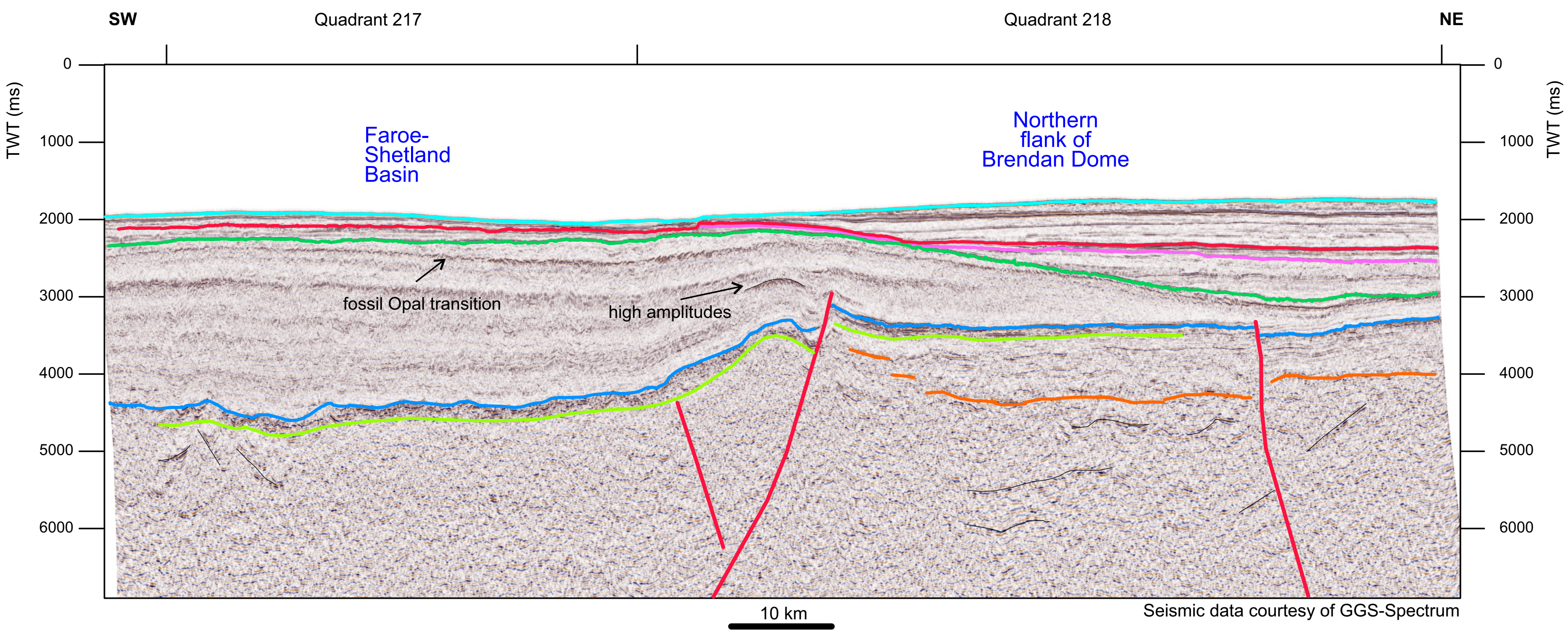

Fig. 10: The thick Eocene and younger sediments of the Faroe-Shetland Basin are replaced by an expanded younger sequence to the north-east over the flanks of the Brendan Dome. Beneath a volcanic covering, anticlinal forms are mapped in the sill-intruded Upper Cretaceous mudstones. A fossilized opal A-CT diagenetic event or opal transition zone occurs across the basin (Davies & Cartwright 2002).

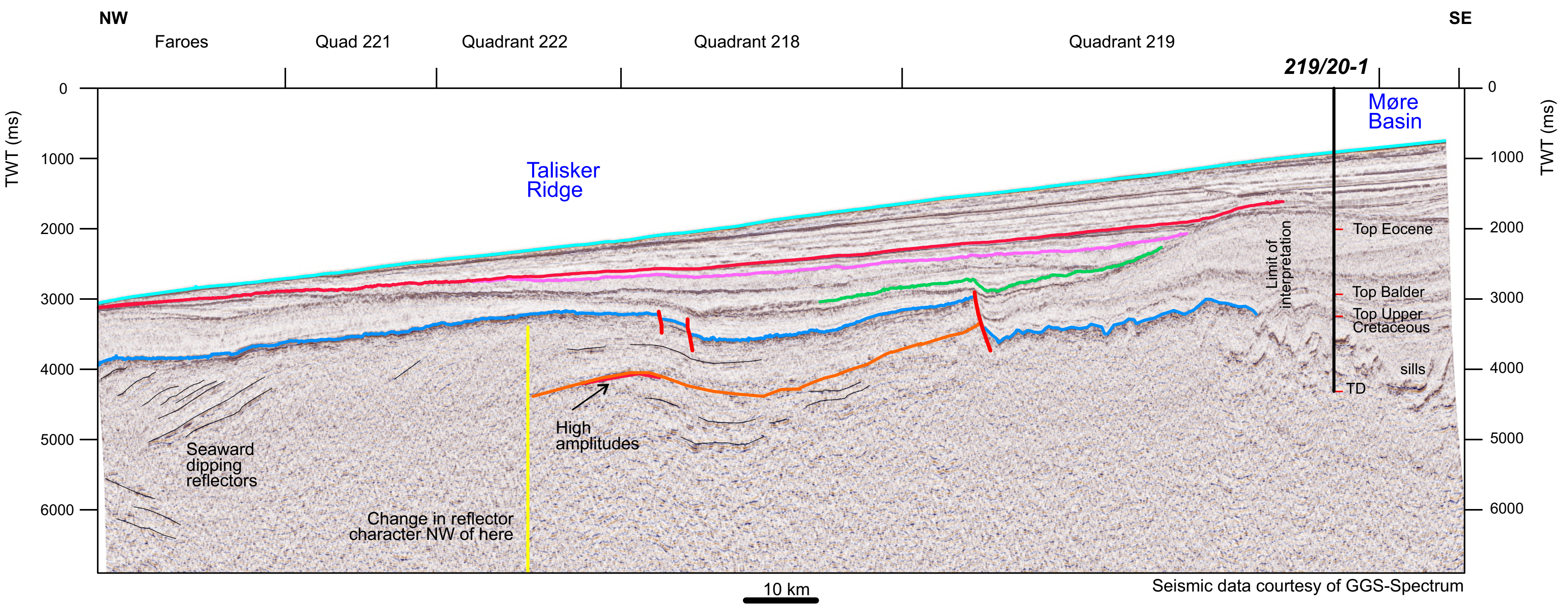

Fig. 11: Seaward-dipping reflectors, largely in Faroese waters at the NW end of this line, mark the limit of continental crust. The SE end of this seismic section crosses the Møre Basin, beyond the limit of thick Paleogene volcanics.

Sea-bed
Reflector B2
Reflector A
Reflector B
Reflector C
Top Volcanics
?Base Volcanics
?Base Tertiary

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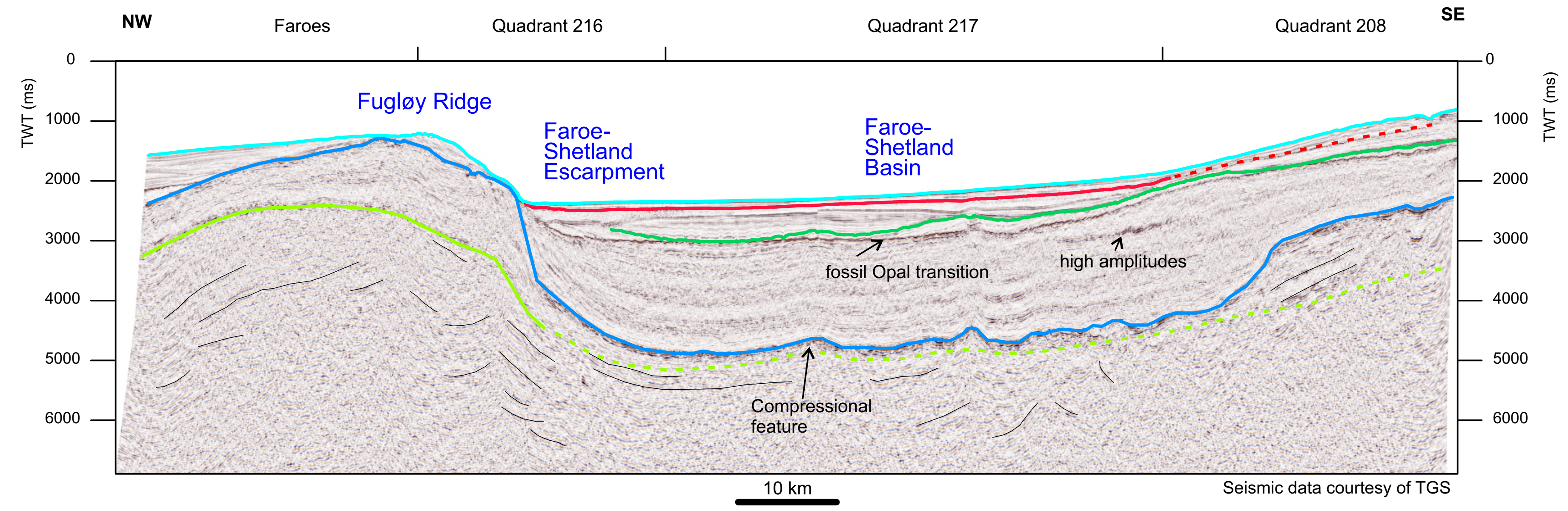

Fig. 12: The Faroe-Shetland Escarpment, defining the south-eastern limit of the Fugloy Ridge, and here extenuated by later uplift, is a major feature north of 62° N. The Faroe-Shetland Basin is infilled with up to 8,800 ft of Eocene and younger mudstones and is floored by Paleocene lavas. These strata are affected by Cenozoic compressional/ transpressional deformation, which has produced a series of anticlines and monoclines.

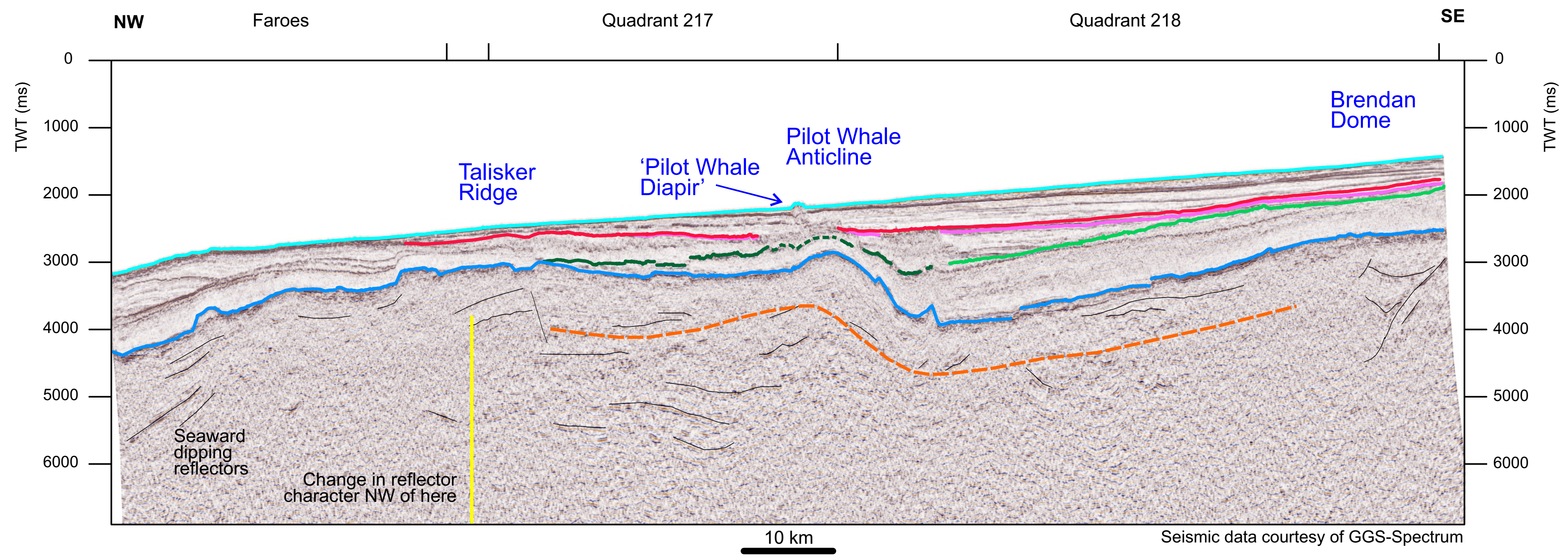

Fig. 13: This section crosses the Pilot Whale Anticline, a compressional feature within Paleogene sediments and volcanics. Potential resrevoirs are prognosed in the Paleocene and Upper Cretaceous. In this area the sea bed is scattered with mud mounds, the so-called 'Pilot Whale Diapirs'.

Sea-bed
Reflector B2
Reflector A
Reflector B
Reflector C
Top Volcanics
?Base Volcanics
?Base Tertiary

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Summary

- Some of the last remaining regional highs on the UKCS are yet to be tested
- Viable source and reservoir rocks in Jurassic and Cretaceous strata may be present
- High amplitudes beneath volcanics may indicate the presence of hydrocarbons

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