MAJOR RESERVOIRS OF THE NORTH SEA

British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

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Dr Oliver Wakefield
Sedimentologist

Environmental Science Centre, Keyworth
Nottingham NG12 3DL, United Kingdom
Direct Line +44(0) 115 936 3169
Mobile +44(0)770 212 8629
www.bgs.ac.uk Email: oliverw@bgs.ac.uk

MAJOR RESERVOIRS OF THE NORTH SEA

BGS short-course

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Overview

Early Palaeozoic times the North Sea belonged to the Proterzoic terrane known as Eastern Avalonia. By Ordovician times this land mass lay at a palaeolattitude of between 40° and 60° south of the equator. Concurrently, Scotland belonged to the Laurentian Precambrian shield situated in equatorial latitudes thousands of kilometres away across the Iapetus Sea. Scandinavia lay within a portion of the Baltic shield, seperated from the Eastern Avalonia by the Tornquist Sea (an arm of the Iapetus Ocean until it closed late in the Ordovician).

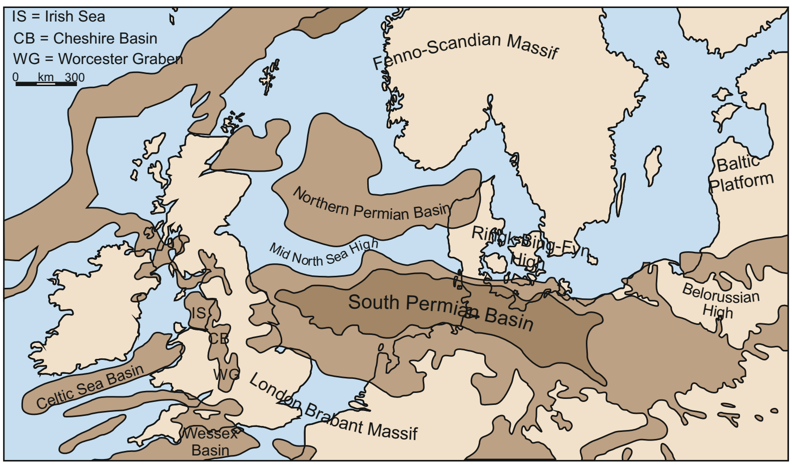
The closure of the Iapetus Ocean resulted from the subsequent collision of the Avalonia, Lauraentia and Baltic shield landmasses during the Caledonian orogeny (Ordovician to Devonian). Though subject to variable climatic conditions the general area of the modern day North Sea formed at the culmination of the Caledonian orgogeny. Subsequent uplift in large parts of the North Sea resulted in an general absence of Devonian aged sediments from the Basin.

During the Carboniferous the North Sea sat at equatorial latitudes at the margin of the coalescing supercontinental landmass of Pangaea. The formation of a number of graben and half-grabens during this time were infilled by a range of deepwater and deltaic sediments. By late Palaeozoic times the Formation of Pangaea as a result of the Variscan Orogeny created the Variscan mountains that stretched from southern England through to east Europe. The Southern North Sea formed a foreland area next to this mountain chain. Subsequent uplift and erosion of source sediment ranges led to large-scale erosion and reworking of substantial (up to 1.5 km thick) amount of Carboniferous sediments. The formation of the Pangaean landmass also greatly impacted global circulatory systems and as a result resulted in periods of relatively extreme and variable climatic conditions.

The Early Permian saw the cessation of the Variscan orogeny. Most of the north Sea belonged to the postorogenic-collapse basin which extended from eastern England through to Germany and Poland. The Pennine High became a positive feature for the first time during the Early Permian and separated the large north European Basin from the East Irish Sea. The mid North Sea High formed its northern boundary also during this time. Sedimentation during the Permian and Early Triassic was almost exclusively continental dryland (combinations of aeolian, fluvial and sabkha environments). By mid-Triassic times the uplift of sediment sources areas lead to the rapid deposition of the Bunter Sandstone formation across much of the North Sea. The Upper Triassic successions of the North Sea by comparison to the underlying are generally of argillaceous composition.

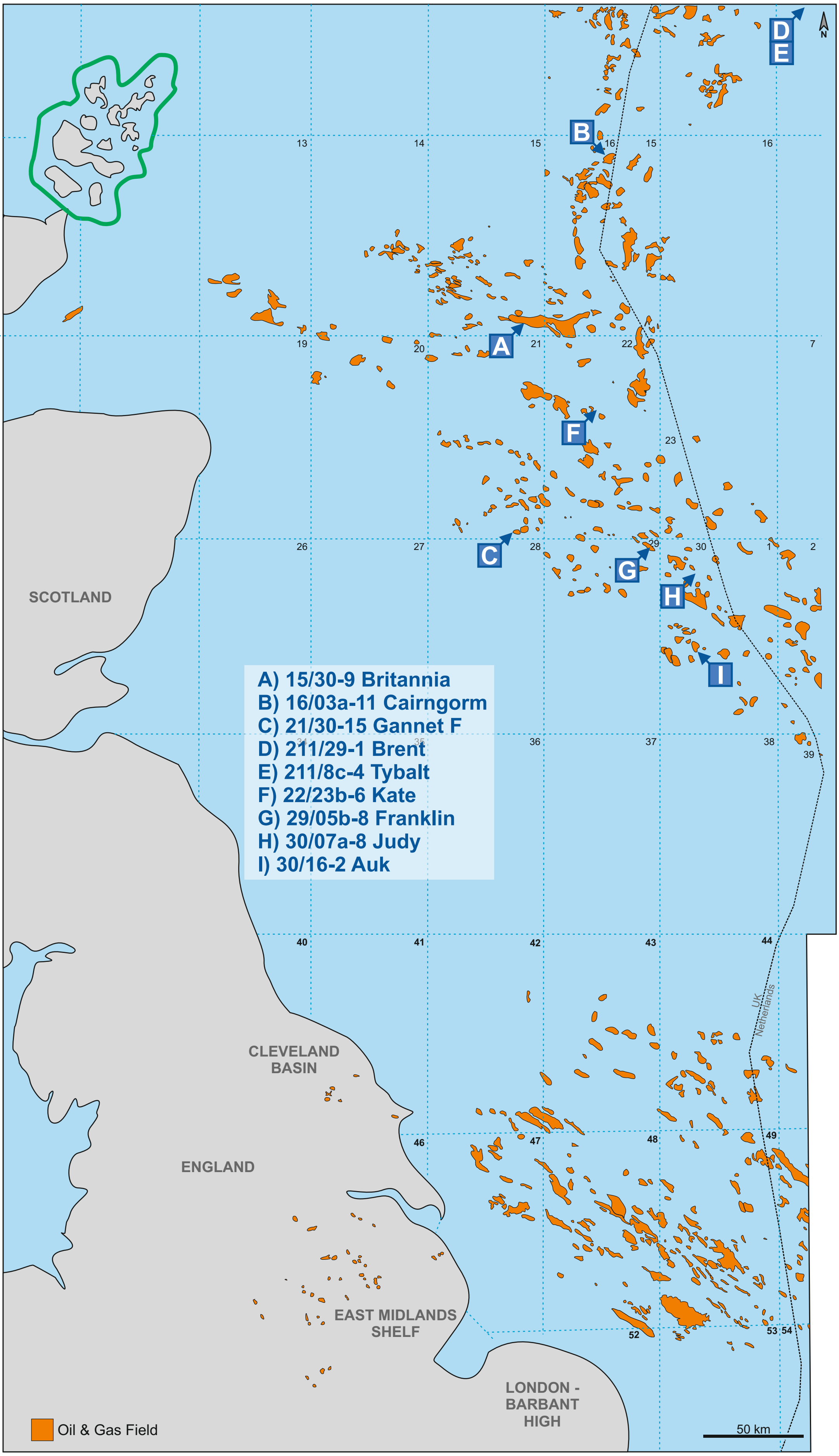
By the end of the Triassic fully open marine condition where established, as crustal extension along the central axis of the North Sea allowed the Tethys ocean to link with the Boreal Ocean. By Late Jurassic times regional doming along the central axis of the North Sea was superseded by renewed rifting and rapid subsidence. Lithospheric extension and localised rifting on the central axis of the North Sea finally ceased around the middle Cretaceous. A coeval rise in global sea-level allowed pelagic carbonate sedimentation to extend over large parts of the North Sea. During the Late Cretaceous, inversion of parts of the North Sea occurred as a result of compression reactivating basinal faults.

Tertiary to Quaternary tectonic activity has been dominated by broad synclinal downwarping towards a depositional axis that extends from the Viking Graben to the Central Graben towards the Netherlands. As a result, the depocentres for the major Cenozoic sedimentary units, especially in the Southern North Sea are situated in Dutch Territorial waters.



Permian (Rotliegend Group) palaeogeography of NW Europe showing distribution of major non-marine sedimentary basins.

The North Sea

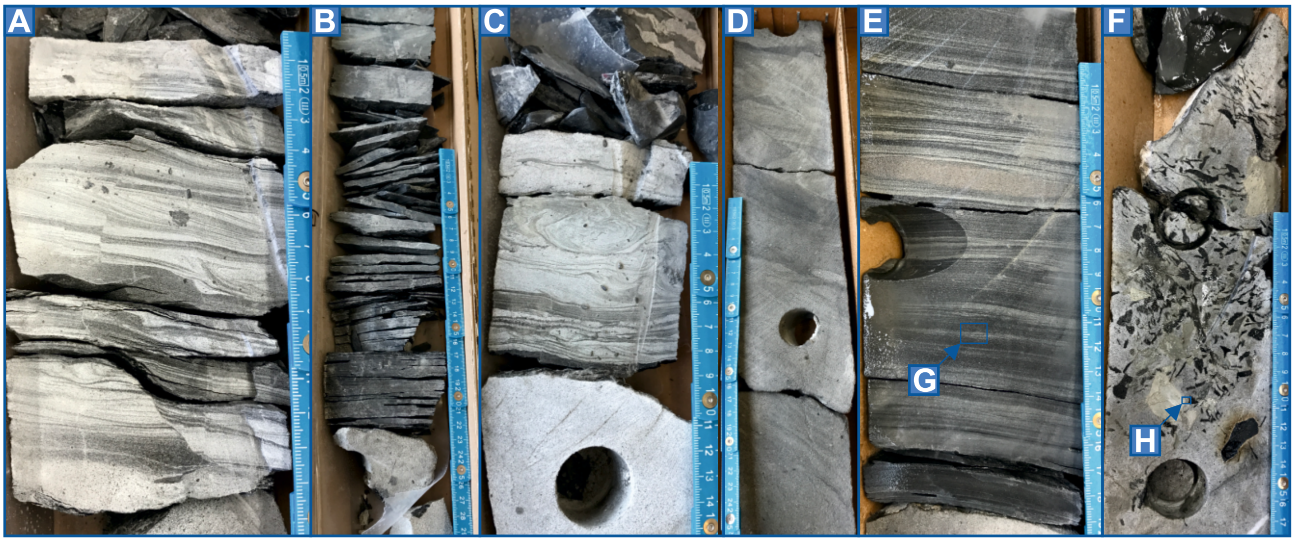


Field Britania

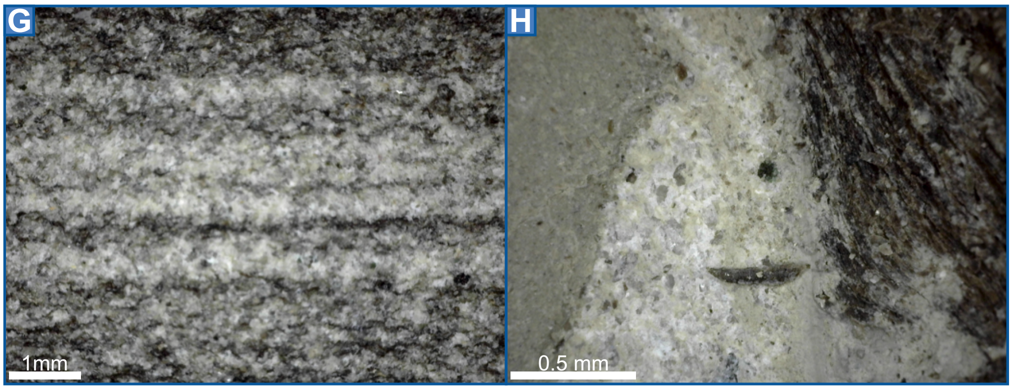
Formation Britania Formation

Borehole viewed 15/30-9 *(depth: 13308' - 13414')*

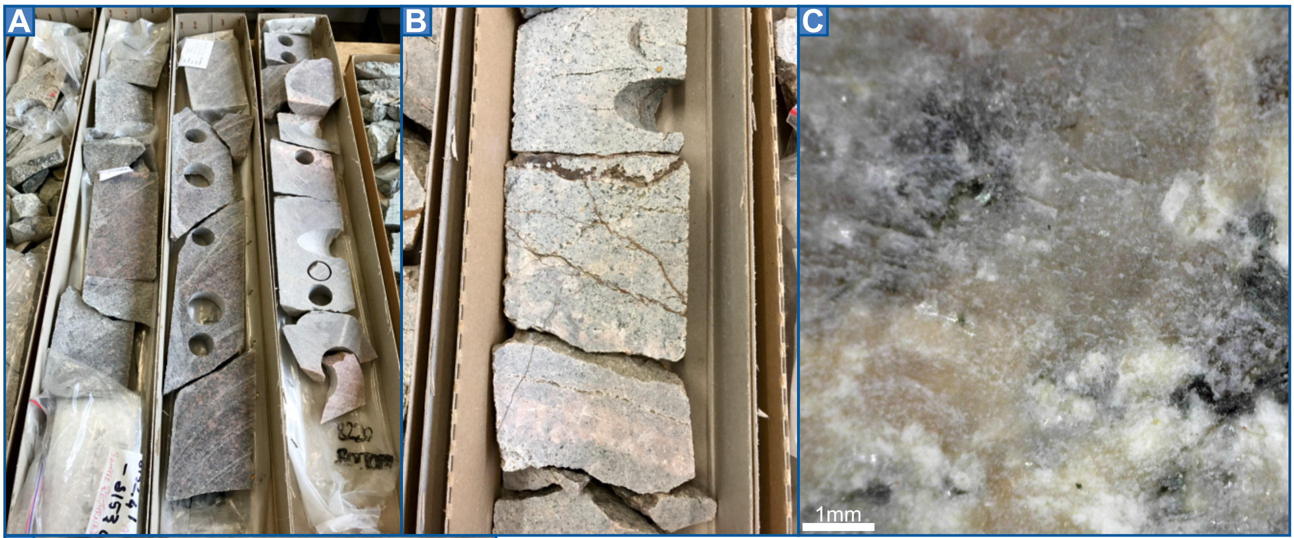
Summary Deep water Lower Cretaceous (Aptian) succession. Reservoir units include clean high-density turbidite sandstones and finer-grained gravity driven deformed (slurried) sandstones. Slurried sandstones can contain a high proportion of mud material.

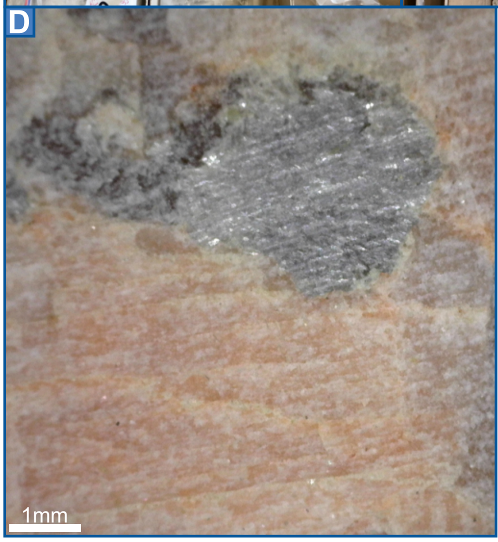


A) Horizontal lamination and small rippleforms, note the series of syn-sedimentary faulting (13308'). B) Succession of finely laminated mudrocks and basal sandstone unit (13345'). C) Mildly deformed sandstone unit (13332'). D) Larger deformed sandstone unit (13323'). E) Heterolithic succession of v.f. sandstones and mudstones (13316'). F) Sandstone succession containing locally derived rip-ups of dark and light mudstone (13409'). G) Horizontal lamination comprised of sand and mud sized material (see 'E' for location). H) Quartz-rich sandstone with rip-up clasts of laminated dark mudstone and amorphous lighter mudstone (see 'H' for location).



Field Cairngorm
Formation [igneous basement]
Borehole viewed 16/03a-11 *(depth: 7916' - 8220')*
Summary Uniquely in the North Sea, the Cairngorm field reservoir is weathered and fractured basement rocks underlying a major unconformity. Basement rock is comprised of Granodiorites, Monzogranites and plutonic intrusions, Late Silurian to Early Devonian in age.





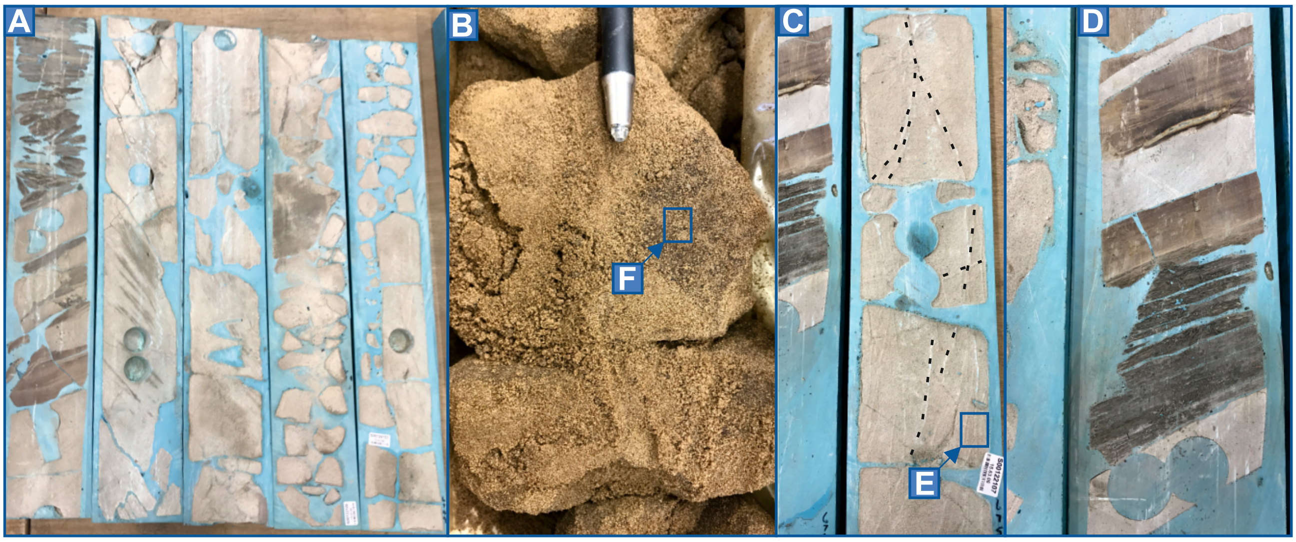
A) Example of the general character of the reservoir unit (8152' - 8220').
B) Example of the fracture pattern within the basement rock. Note that these fractures provide the secondary porosity that holds the hydrocarbons (7925').
C) & D) High-resolution examples of the crystalline structure of the basement rocks.

Field Gannet F

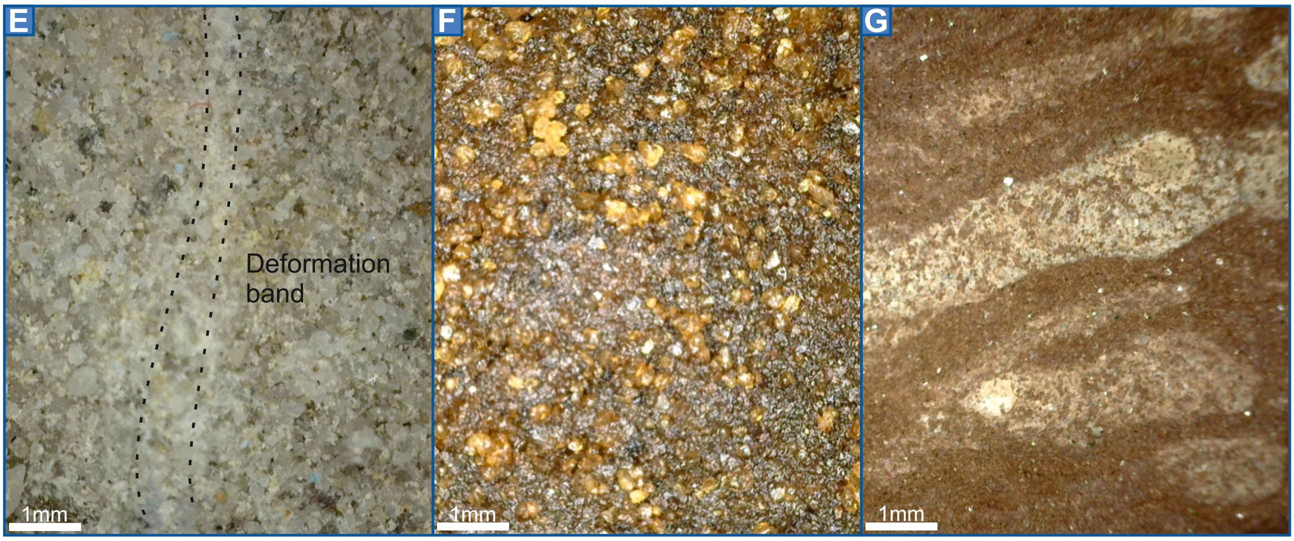
Formation Tay Sandstone

Borehole viewed 21/30-15 *(depth: 6602' - 6632'; 6692' - 6760.4')*

Summary Oligocene succession predominantly composed of sandstones with minor mudstones. The Tay Sandstone belongs to the Horda Formation which in contrast is a succession of mudstone with subordinate sandstones. The Tay Sandstone is believed to represent deep water channel-fan complexes.



A) Example of 'cleaner' sandstone succession (6734'-6749'). B) Oil saturated sandstone (6621'). C) Cataclastic (deformation) band within cleaner sandstone (6751'). D) Heterolithic succession of cleaner light sandstones and darker laminated mudstones (6760'). E) Zoomed image of a deformation band (see 'C' for location). F) Zoomed image of sandstone with oil staining (see 'B' for location). G) Sand filled horizontal burrows within a predominantly muddy facies (6629').

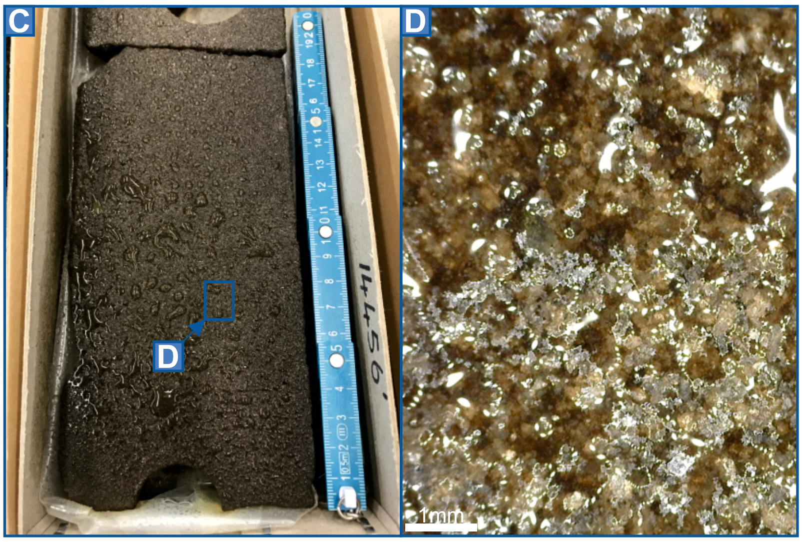


Field Kate

Formation Heather Sandstone Member

Borehole viewed 22/23b-6 *(depth: 14441' - 14537')*

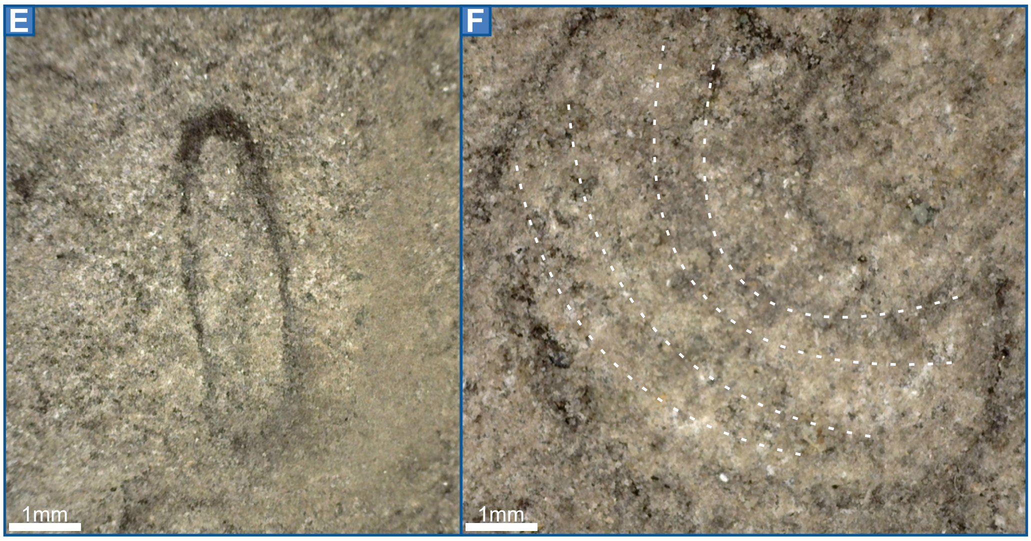
Summary Late to Mid Jurassic, marine to deep marine-mudstone dominated succession with sandstones and siltstones. Sandier units are predominantly the product of up-slope mass-flow events.



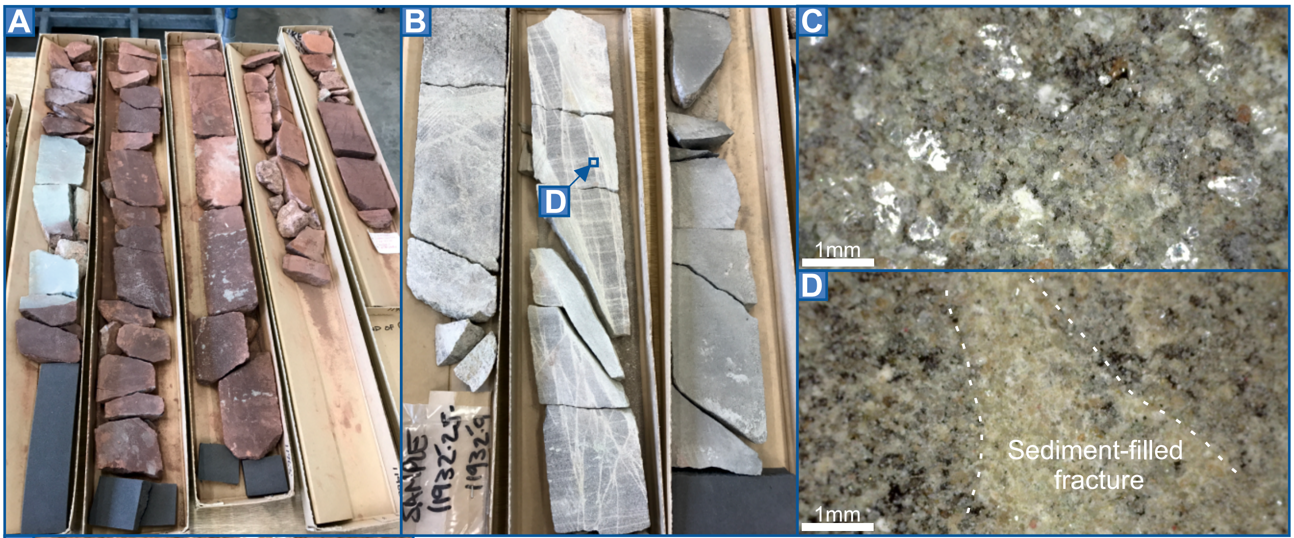
A) Large succession of the Heather Sandstone Member, note the lighter coarser sandstones to the left of the image and the transition to darker mudstone to the right. (14438'-14456').
B) Boundary between heterolithic grey unit above and coarse, cleaner sandstone below. (114455').
C) Oil saturated sandstone, note darker colour and hydrophobic property (14459').
D) Zoomed image of oil saturated sandstones, note water is not penetrating the sandstone due to the presence of hydrocarbons (see 'C' for location).

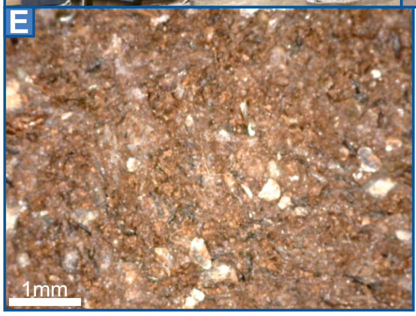
Field Franklin
Formation Heather Sandstone & Fulmer Formation
Borehole viewed 29/05b-8 *(depth: 18451' - 18535')*
Summary Marine shoreface sandstones. Bioturbated throughout, with ichnofacies assemblages being key in determining upper, middle and lower shoreface palaeoenvironmental position. Variations in shoreface position are driven by allogenic relative sea-level fluctuations.

A) Highly bioturbated horizon. Relatively few trace-fossils evident as biogenic reworking is extensive (18510'). B) Moderately bioturbated horizon. Trace-fossils are predominantly sand-rich burrows with mudstone linings (18461'). C) Moderately to highly bioturbated horizon (18463'). D) Minor to moderately bioturbated horizon. (18455'). E) Zoomed image of an *Ophiomorpha nodosa(?)* burrow (see 'D' for location). F) Zoomed image of a concentric filled burrow, oblique cut through *Diplocraterion parallelum*(?) (see 'D' for location).



Field Joanne / Judy
Formation Joanne Sandstone
Borehole viewed 30/07a-8 *(depth: 11873.1' - 11968')*
Summary Triassic continental dryland fluvial succession. The Joanne Sandstone (Skagerrak Formation) is a sandstone dominated succession representing largely non-channelised (pervasive) sheetflood deposits.

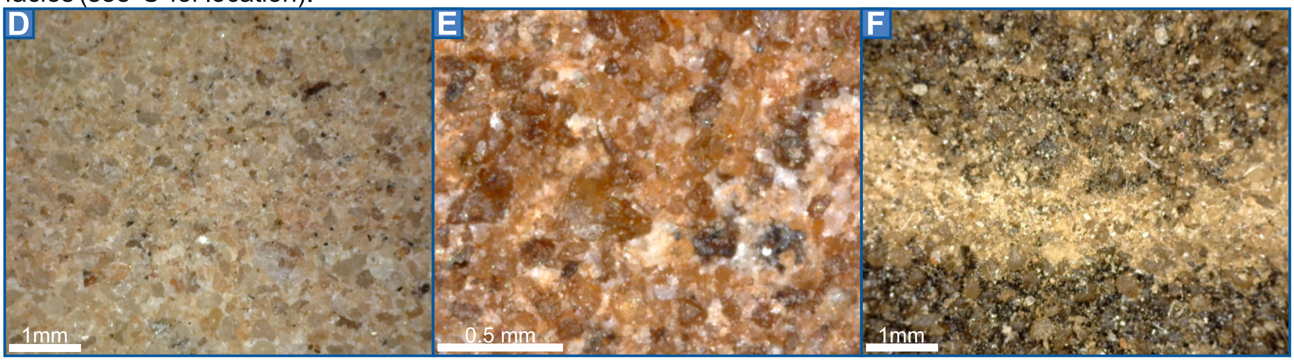




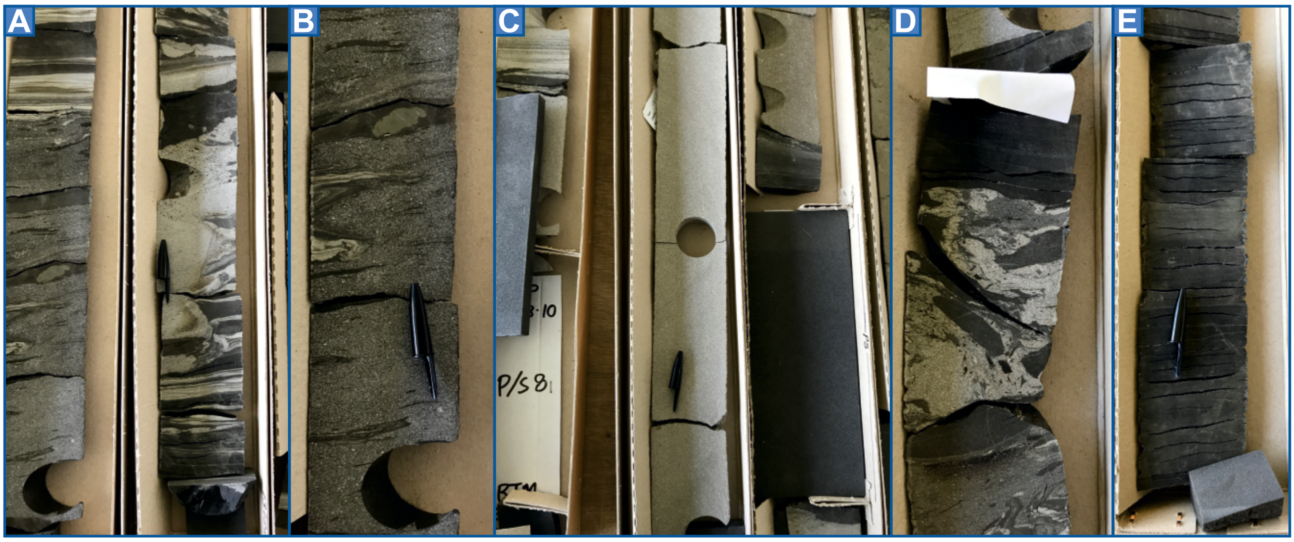
A) Example character for well. Note the reduction grey-green colouring in places (11954-11968').
B) Reduced grey-green coloured succession with sediment-filled fractures (11934').
C) Highly micaceous sandstone (11915').
D) Sediment-filled fracture (see 'B' for location).
E) Zoomed image of fine-grained sandstone. Note the polymineralic composition of the unit (11965').

Field	Auk
Formation	Auk Formation
Borehole viewed	30/16-2 *(depth: 7635' - 7814.6')*
Summary	Permian aeolian succession dominated by large migratory duneforms with slipfaces and interleaving interdunes. Some minor amounts of fluvial facies are present. These fluvial facies are as a result of incursions in to the aeolian dunefield by episodic flood waters.

A) Example of the character of the well. Areas of reduction colouring occur following the bimodal grain structure (7635-7647'). B) Interdune bounding surface between two duneforms (7734'). C) Aeolian grainfall and grainflow facies, note that the slight permeability differences are expressed with grainflow facies being hydrocarbon stained (7756'). D) Example of the generally rounded grains of aeolian facies types (see 'A' for location). E) Aeolian grains with frosted coatings (see 'B' for location). F) Oil stained grainflow facies and cleaner grainfall facies (see 'C' for location).

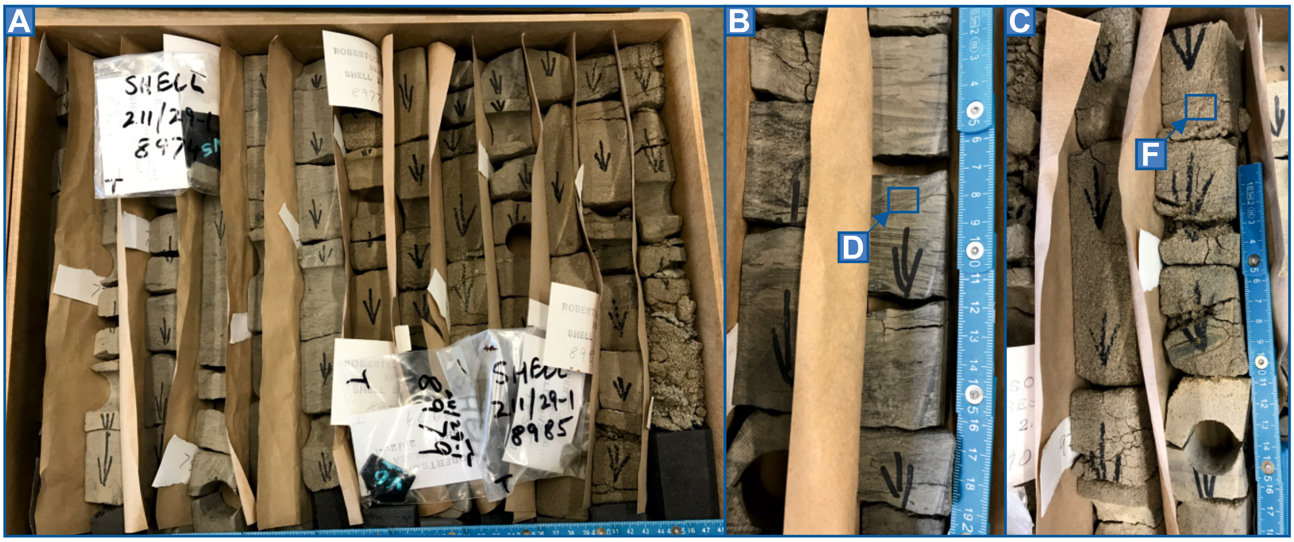


Field Tybalt
Formation Magnus Sandstone
Borehole viewed 211/08c-4 *(depth: 13040' - 13137')*
Summary Jurassic deep water succession consisting of dark laminated mudstones and sandstone bodies. Sandstone units were deposited largely by high density turbidity currents, that formed a series of laterally and vertically stacked lobe deposits.



A) Series of gravity flows, variations in resultant texture relate to flow kinematics, larger between turbid or laminar flow (13123'). B) Heterolithic mass-flow (13121'). C) Succession of clean homogeneous sandstone (13111'). D) Deformed sandstone overlain by dark laminated mudstone (background sedimentation) (13090'). E) Thicker succession of finely laminated mudstones (13045').

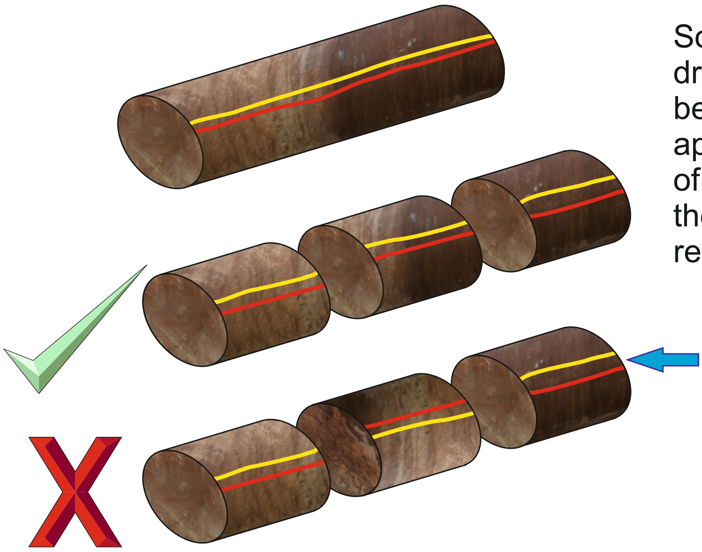
Field Brent
Formation Upper and Middle Jurassic
Borehole viewed 211/29-1 *(depth: 8650' - 9000')*
Summary Jurassic aged succession of sediments deposited in a littoral to shallow marine environment. The Brent Group is sub-divided at formation level based upon this transition from coastal to shallow-marine palaeoenvironment.



A) Example of the character of the well (8970-8988'). B) Deformed horizontal lamination in heterolithic succession, possible examples of 'crude' bioturbation (8997'). C) Poorly cemented coarse sandstone to sandy gritstone (8992'). D) Poorly laminated sandstone with some mica (see 'B' for location). E) Sandy mudstone (8681'). F) Well-rounded to sub-rounded gritstone clasts (see 'C' for location)

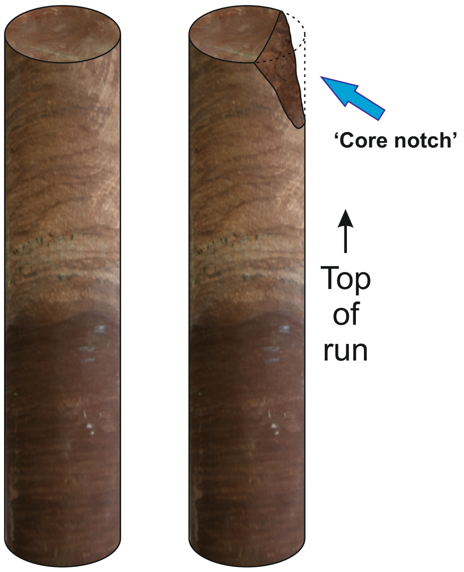
Appendix

Core material



Some core will have coloured lines draw along its length. These lines can be of variable colour and are usually applied soon after drilling. The addition of the lines is used to prevent pieces of the core being put upside-down in relation to the rest of the core.

Note that the middle piece is orientated incorrectly to the other pieces (indicated by the coloured lines).



The coring process can sometimes lead to the upper parts of a core-run having a 'notch' at the top. The damage occurs when the drill is replaced in the hole after the subsequent core has been retrieved. As such, the identification of this damage can sometimes be used to orientate the top of individual core runs in the absence of other information.

All boreholes are catalogued in the National Geological Repository using a barcode system. This includes labels on the borehole boxes. This commonly indicates the depth range for the core box (top and bottom), but may also include information on:

- The top of the core.
- Whether the measurements in imperial or metric (dennoted by a 'm' or 'I').

Additional depth information is sometimes written on the insides of the core box.

Notes