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Britannia Field, UK North Sea: Influence of the Regional Geologic Setting on Field Properties.

The Britannia Gas Condensate Field in the, Outer Moray Firth area of the, UKCS is located 225 kilometres northeast of Aberdeen at the triple junction of the South Viking, Witch Ground and Central Grabens. Hydrocarbons are trapped in Early Cretaceous (Late Barremian - Late Aptian) deepwater, marine turbidite sandstones in a combination stratigraphic/structural trap.

The Britannia Field was discovered in 1975 and production began in August 1998. The ultimate recovery from the field is estimated to be 3.1 TCF of gas together with 117 MMBO of condensate. These hydrocarbons are being developed by pressure depletion through a 36-slot platform and a 14-slot sub-sea manifold. The field is expected to have a life of 30 years.

The Britannia Field is over 35km long and straddles four UKCS blocks. It has a gas column of 420m and an oil leg up to 44m thick. Reservoir parameters and hydrocarbons vary markedly from west to east across the field. Much of this variation is a result of the large-scale regional complexity rather than local stratigraphic and sedimentological facies variation.

Doming of the crust commenced at the North Sea rift triple junction in the Late Toarcian (185 Ma) and this became emergent in the Bajocian (170 Ma). Associated with this doming was a phase of extensive volcanism with up to 1500m of Bathonian / Callovian (160 - 155 Ma) extrusive alkali basalt and tuffs encountered on the Rattray High to the south of the field.

The subsequent gradual deflation of the dome was accompanied by a pulsed marine transgression that progressively flooded the area depositing, the Humber Group shales. The Britannia area remained emergent throughout the Middle Jurassic to Late Oxfordian period. Flooding was accelerated in the earliest late Oxfordian (150 Ma), by the onset of a major extensional rifting phase. This extension led to the development of a series of deep grabens and half-grabens, separated by high standing horsts and tilted fault blocks. These high areas underwent rapid erosion with the deposition of shallow marine shoreface sands on the flanks, (Piper Formation) and submarine turbiditic sands in the basins.

Structural realignment of the Moray Firth had largely ceased by the Late Volgian (147 Ma) and was followed by a period of relative quiescence with broad regional subsidence and rising relative sea levels. The Late Jurassic - Earliest Cretaceous Kimmeridge Clay source rock and the subsequent Early Cretaceous Valhall Formation marls and shales filled the rapidly expanding accommodation space and onlapped the basin flanks. This period of pelagic sedimentation was punctuated by two major tectonic events. The first occurred in the earliest Late Valanginian, with the deposition of the Scapa basin floor fans (in the Witch Ground Graben) and the Punt Sandstone (in the Inner Moray Firth). Coarse clastics were shed off the Halibut Horst into the adjacent basins, initially as locally sourced conglomerates followed by more distal sand-rich turbidites.

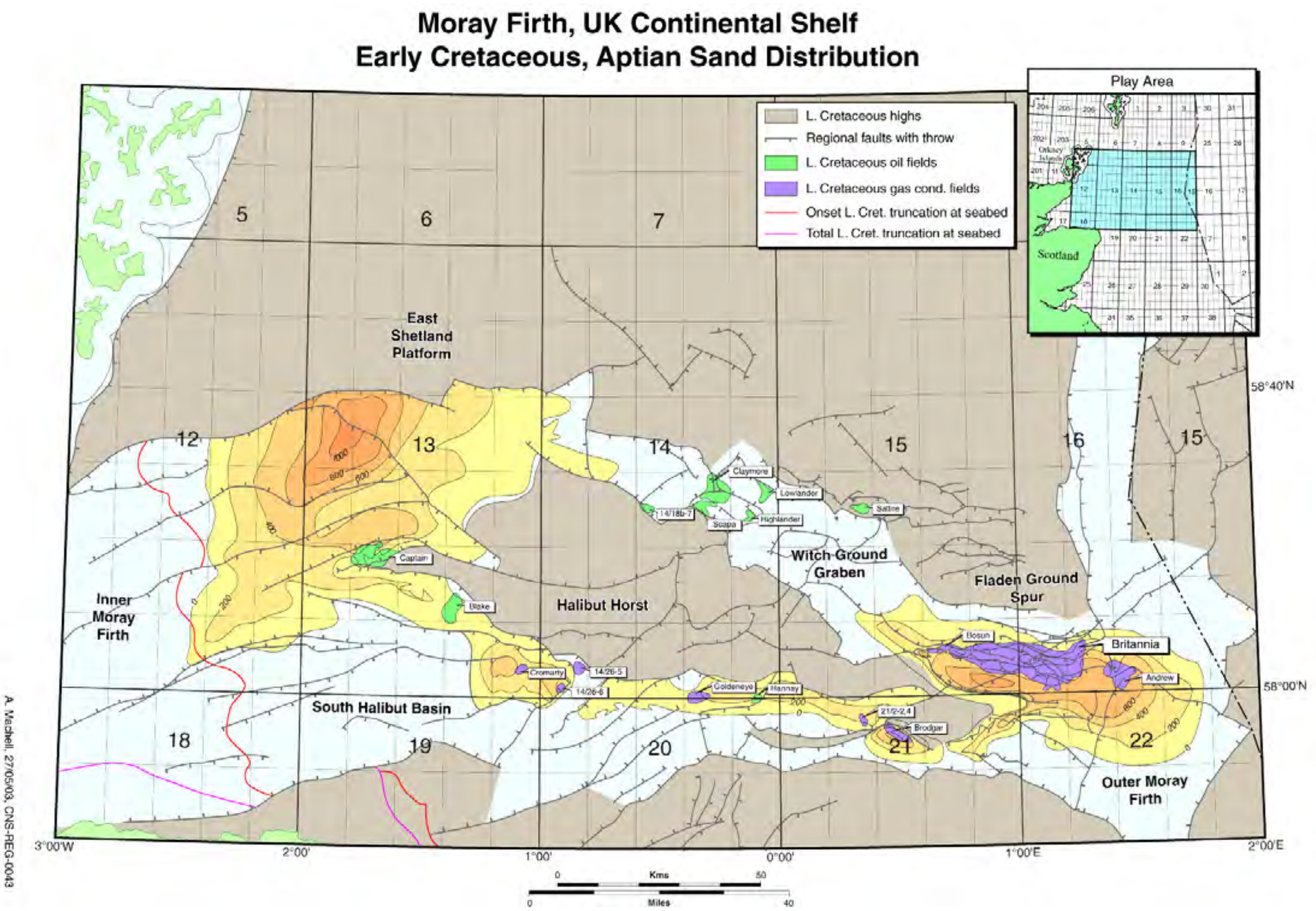
By the Late Barremian - Early Aptian, the surrounding landmasses had been eroded, the climate was more arid and fluvial run off into the basin had decreased. Samarium - Neodymium age dating of these Early Cretaceous Aptian sands in the Outer Moray Firth has revealed a provenance area with an age of 1800-2500Ma. Rocks of this age are found in the Archaen from west of the Moine Thrust (North West Highlands, Outer Hebrides) and not from the adjacent Caledonian (<1600 Ma) basement.

The second, and regionally more important tectonic episode occurred in the earliest Late Aptian Austrian orogenic phase (115 Ma). This event is a correlative datum throughout the area and is seen both locally and regionally as a major erosive event. Regionally sedimentation switched from calcareous to argillaceous hemi-pelagic shales at the Sola / Valhall Formation lithostratigraphic boundary. This tectonic activity was accompanied by turbidite sandstone deposition of, the Britannia Sandstone Formation, of which the thickest and most extensive sands are the Late Aptian intra-Sola (Kilda member) sands.

The Inner and Outer Moray Firth was connected by two narrow depositional fairways flanking the Halibut Horst: the Witch Ground Graben to the north, and the South Halibut basin to the south. Both fairways have an asymmetric north to south bathymetric profile, deepest adjacent to the Horst. The South Halibut fairway consists of a series of discrete sub basins separated from each other by high standing basin rims. It is at its widest (100 km) in the Inner Moray Firth and narrows to a width of 15 km in the Outer Moray Firth. The Witch Ground Graben plunges steadily to the southeast, reaching its maximum width (25km) and depth in the vicinity of the Britannia Field.

Sand deposition in the Inner Moray Firth was continuous from the Kimmeridgian through to the Early Albian, where 1630m of Early Cretaceous arenaceous sediments have been encountered. The Outer Moray Firth was largely starved of these sands. Within the Britannia area, regional subsidence allowed free water circulation and the deposition of several thousand metres of pelagic, dark grey, calcareous, silty shales and limestones in the basin depocentres. The flanking structural highs were onlapped by progressively younger Valhall and Sola sediments.

Turbiditic sandstones first appear in the Britannia area during the Late Barremian, attesting to a degree of instability that pre-dates the main Austrian tectonic event. This Late Barremian to Early Aptian sand, the Valhall Formation -



Lapworth & Sloop members, is limited in occurrence to the Witch Ground Graben and the Outer Moray Firth. The main phase of sandstone deposition occurred within the Sola Formation of the Late Aptian.

Renewed tectonic activity resulted in instability of the massive sand piles in the Inner Moray Firth transporting the sand down the basin axis as a series of turbidite flows. Deposition of the "Britannia sands" in the South Halibut basin was controlled by the local sub-basin geometries, sediments progressively filled these sea floor depressions as laterally extensive sheets. Once the available accommodation space was filled, the sediments spilled into the next basin leading to an easterly progradation down slope in a simple "fill and spill" model. Sand deposition was a balance between the available clastic input from subsequent turbidite flows and differential compaction.

The Britannia sands are limited in the Witch Ground Graben to the lowest point of the graben where over 250m of sand was deposited. They are shelf sourced, but the origin is uncertain. An Inner Moray Firth sediment source seems more likely as Late Jurassic shales covered the Fladen Ground Spur. The inherited Base Cretaceous structure controlled the distribution of the sands. Seven different "structural regions" can be recognised in the Britannia field, each area having differing Britannia sand properties (stratigraphic position, quality and hydrocarbons).

As tectonic activity increased, turbidite flows became more frequent. The sands became mixed with Late Jurassic argillaceous material slumping off the still exposed highs, or ripped up during transport. Sand input was episodic; hemi-pelagic shales overlie the various sand pulses. As the clastic supply waned in the Late Aptian, the turbidite flows became less extensive, retreating back up the basin towards the shelf. The last vestiges of sand deposition in the Britannia area are the Bosun sands, which are found to the west of the field.

The biggest difference between the sands in the two fairways is their clay content. The South Halibut fairway is characterised by very clean sands with vertical net to gross ratios in excess of 95% sand. In the Britannia field the equivalent net to gross ratio is much lower at 37%, 17% in the west of the field, rising to 65% in the east. The sands in both fairways contain green detrital mud as a major rock constituent (20%), occurring as both discrete clasts and as a micro porous clay matrix. The clay matrix helps to preserve porosity by inhibiting quartz cementation. Where the clay matrix content is low, quartz overgrowths form the predominant cement, preserving the original high depositional permeability. A very well defined regional porosity / depth and porosity / permeability relationship, has been established for the Aptian sands.

The Aptian sands of the South Halibut fairway are normally pressured, at 1.48 psi/m (SG 1.04, 8.7ppg), from outcrop in the Inner Moray Firth to depths in excess of 3000m in the Outer Moray Firth. Reservoir pressures in the Witch Ground basin are transitional from this normally pressured trend in the subsea area of Britannia to a maximum reservoir pressure of 1.8 psi/m (SG 1.26, 10.5 ppg) in Block 22/4. These higher pressures are associated with the poorer quality reservoir sands.

Britannia has a hydrodynamically tilted hydrocarbon water contact (HWC) a common gas pressure gradient, but variable parallel water pressure gradients. The gas fluid contact rises from a flat gas oil contact of (-4014m) in block 15/30 to a gas water contact of approximately (-3870m) in the far northeast of the field. The shallowest gas water contact proven by development drilling is at (-3907m). The gradient of this northeast to southwesterly tilt of the HWC is 30m/Km.

The ability to maintain a tilted HWC requires an active hydrodynamic environment. There are a number of possible mechanisms, all of which are present in the Britannia Field, to explain a hydrodynamic aquifer, meteoric (artesian) drive, burial compaction (mechanical and chemical), dehydration of smectite, kerogen conversion to oil, aquathermal expansion, convection drive, thermal generation of gas, salinity variation and pressure drive.

An alternative explanation relates back to the original depositional model of the Early Cretaceous passively infilling and onlapping the Base Cretaceous relict topography. In the north east of Britannia, the normally pressured (6000 psi) Early Cretaceous reservoir sands lie directly on the over pressured (12,000 psi) Late Jurassic. It is probable that this pressure difference, either alone or in combination with the other mechanisms, is responsible for allowing water to move and maintain a tilted gas fluid contact.

The 35° API oil leg in Britannia is not in equilibrium. There is a marked variability in the thickness and pressure gradients observed within the oil leg across the field. In addition to maintaining the tilt of the gas, the water strips out the more mobile oil phase in areas of the greatest tilt greatest water movement, leaving a gas water contact on the eastern side of the field. The oil is moved to areas where the aquifer movement is more limited.

Further evidence for the contact being hydrodynamically controlled is given by the temperature distribution over the field. At the top of the reservoir the temperature increases as the HWC becomes shallower. At the gas fluid contact, however, the temperature is constant across the field.

A thorough understanding of the regional geologic model has enabled the apparent local intra field differences to be put into context for the optimum development of the field.