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Reappraisal of Fulmar Formation Correlation and Impact on Reservoir Quality Distribution: Elgin and Franklin Fields, UK Central North Sea

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Overview

A range of stratigraphic techniques have been used to improve correlation of the Fulmar Formation reservoir in the Elgin and Franklin fields of the Central North Sea. Through these approaches, an important intra-reservoir erosive event has been recognised which will significantly impact the way in which the field is modelled. In addition, two markedly different reservoir rocks are recognised which have significantly different porosity-permeability relationships. The first is dominated by primary porosity, the latter by secondary porosity. The main controls on porosity evolution appear to be the distribution of sponge spicules, feldspar and shaliness. These factors can, in turn, be placed in a stratigraphic context, allowing a more realistic distribution of reservoir quality parameters.

The HP/HT Elgin and Franklin Fields

The Elgin and Franklin fields are currently in a late phase of development following production start up during 2001. They are located 240 km east of Aberdeen in Blocks 22/30c, 22/30b and 29/5b of the Central North Sea (see fig. 1).

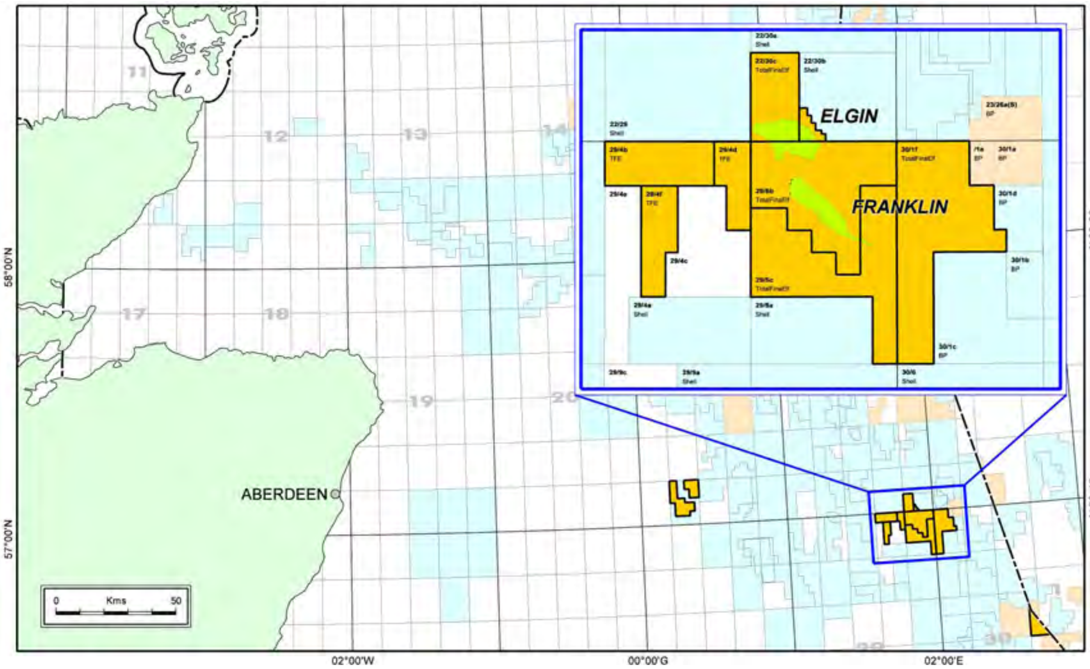

Figure 1. Field location, UK Central North Sea.

The fields have posed a considerable development challenge due to their high pressure/high temperature reservoir conditions: 1100 bars formation pressure (2.02 sg EMW), and 190ºC reservoir temperature. The fields are structural traps, the main reservoir being the shallow marine Fulmar Formation (locally called Franklin Sands) of Upper Jurassic age sealed by the overlying Heather and Kimmeridge shales. Minor production also comes from the underlying Pentland Formation, a fluvial reservoir of Middle Jurassic age.

Structural Setting

Figure 2 shows a West-East traverse over Elgin field demonstrating the structural context of the area. The deepest observable seismic event is the Permian Top Rotliegendes which is at approximately 7 km depth (over 5s TWT). The predominant basement faults trend NNW-SSE with a secondary fault direction of ENE-WSW. The Top Zechstein Salt pick indicates that there is a marked detachment between the pre- and post-salt. Salt movement has created sediment ‘pods’ infilled by Triassic and Jurassic age strata. Both salt movement (swelling, withdrawal) and grounding of pods on the underlying Rotliegendes fault blocks have had impacts on the development of the Jurassic reservoirs sands. The current structural arrangements of the reservoir reflect a phase of late Jurassic extension when thick Kimmeridge Clay successions were developed in the hanging wall basins.

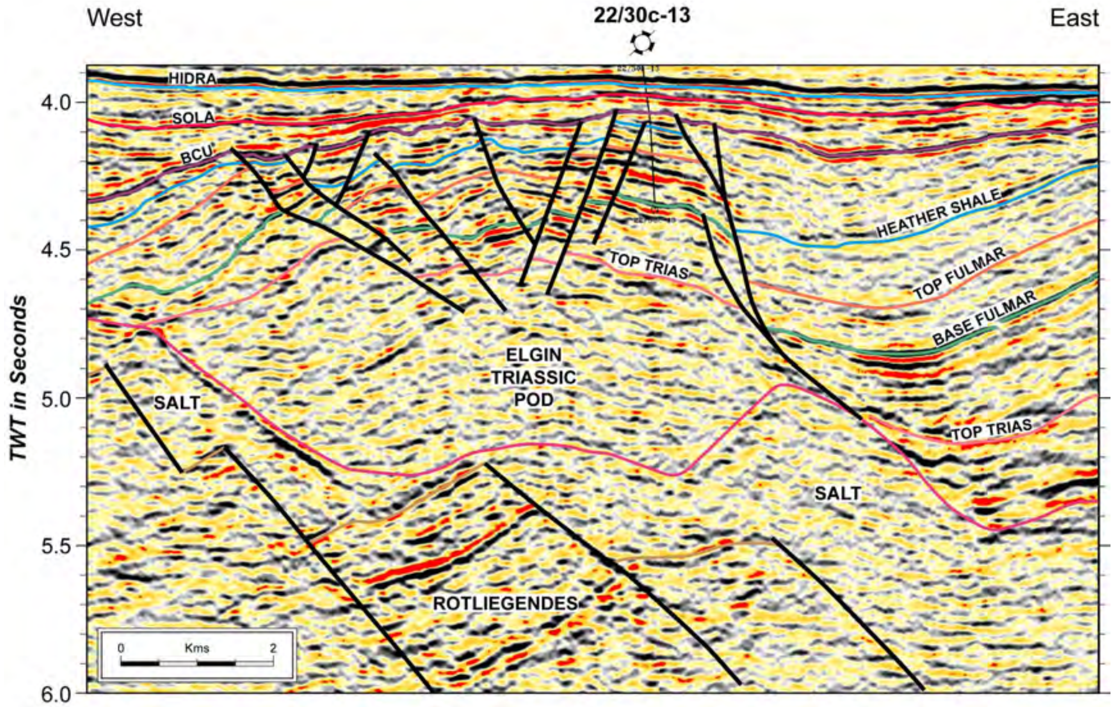

Figure 2. Seismic section showing key structural features.

The Franklin Sands Reservoir

The Franklin Sands net reservoir thickness averages 200m and consists of a succession of fine to medium grained sandstone which is largely bioturbated or unstructured in appearance. Where sedimentary structures are seen, the presence of cross-bedding and winnowed shell lags suggests a shallow marine setting with mixed wave and tidal current influence. The sands are subarkosic arenites with average porosity of 17% and average permeability of 25 mD. Secondary porosity evolution has been enhanced through the dissolution of feldspar and sponge spicules. Early compactional effects have been lessened as a result of the growth of early authigenic minerals (microquartz and dolomite) which helped provide a rigid grain framework. During burial, the development of increasingly high overpressure within the reservoir helped to minimize further compactional effects, as evidenced by the general lack of significant pressure solution. Compaction tends to be higher in the shalier reservoir facies where secondary porosity predominates.

Stratigraphic Approach

Lack of vertical seismic resolution at more than 5 km depth (18-20 Hz dominant frequency) makes intra-reservoir surfaces difficult to pick in a consistent manner. In addition, the homogenous character of the reservoir has led to a number of different sedimentology-based correlations being generated, each with significant uncertainty attached to it. Given the wealth of core data available across the field, efforts have been made to improve intra-reservoir correlation using a combined analysis of wireline logs, core sedimentology (especially trace fossil analysis), core chemostratigraphy, spectral gamma ray logs and point-counted petrographic data.

A genetic sequence stratigraphic approach was used to recognise multiple phases of progradation and retrogradation within the Franklin Sands. However, due to the lack of grainsize differentiation and the low shale content it is often difficult to be sure that the cycles are being correctly correlated, particularly where wells are spaced more than 500m apart.

The presence of two horizons in the upper part of the Fulmar Sands showing the development of erosive lags overlain by pebble and oyster coquina material has been recognised since the field appraisal stage (see fig. 3).

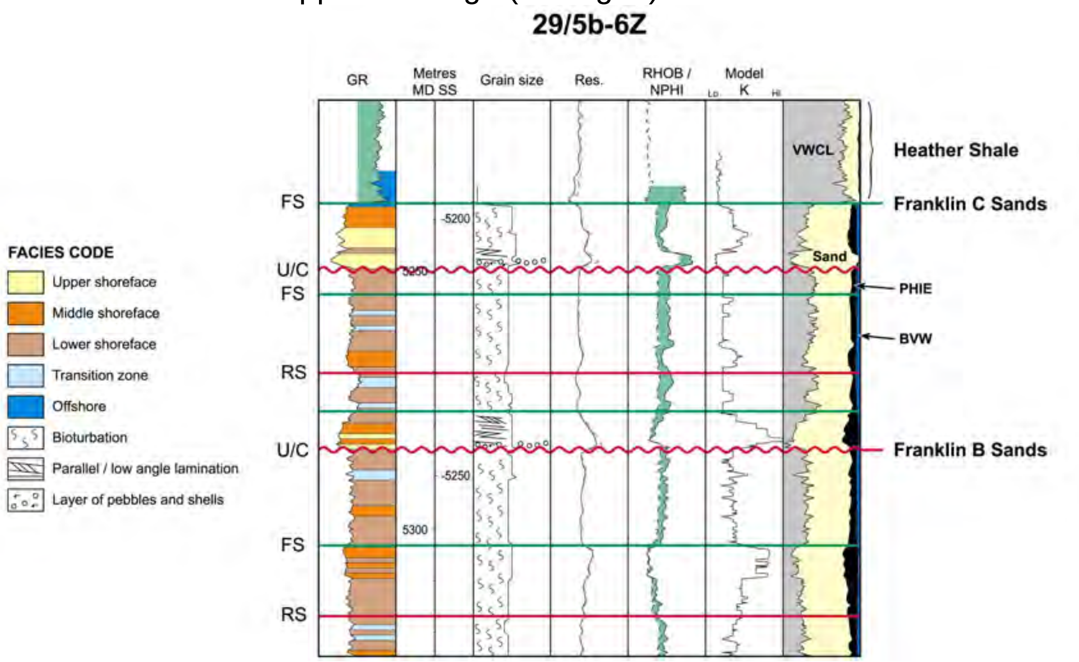

Figure 3: Erosive unconformity horizons in well 29/5b-6Z well.

The potential significance of these horizons has been difficult to quantify previously. However, with the benefit of more wells and the recent stratigraphic studies (notably trace fossils analysis), it can be demonstrated that the lower of these two surfaces represents a considerable erosive unconformity which reflects the dynamic interaction of salt movement and sediment loading in the area. The Franklin Sands which lie above the unconformity surface show different thickness trends to those below due to the increased activity of a zone of salt upwelling between the Elgin and Franklin fields. Figure 4 shows a possible mechanism for relating the structural evolution to the deposition and subsequent erosion in the area.

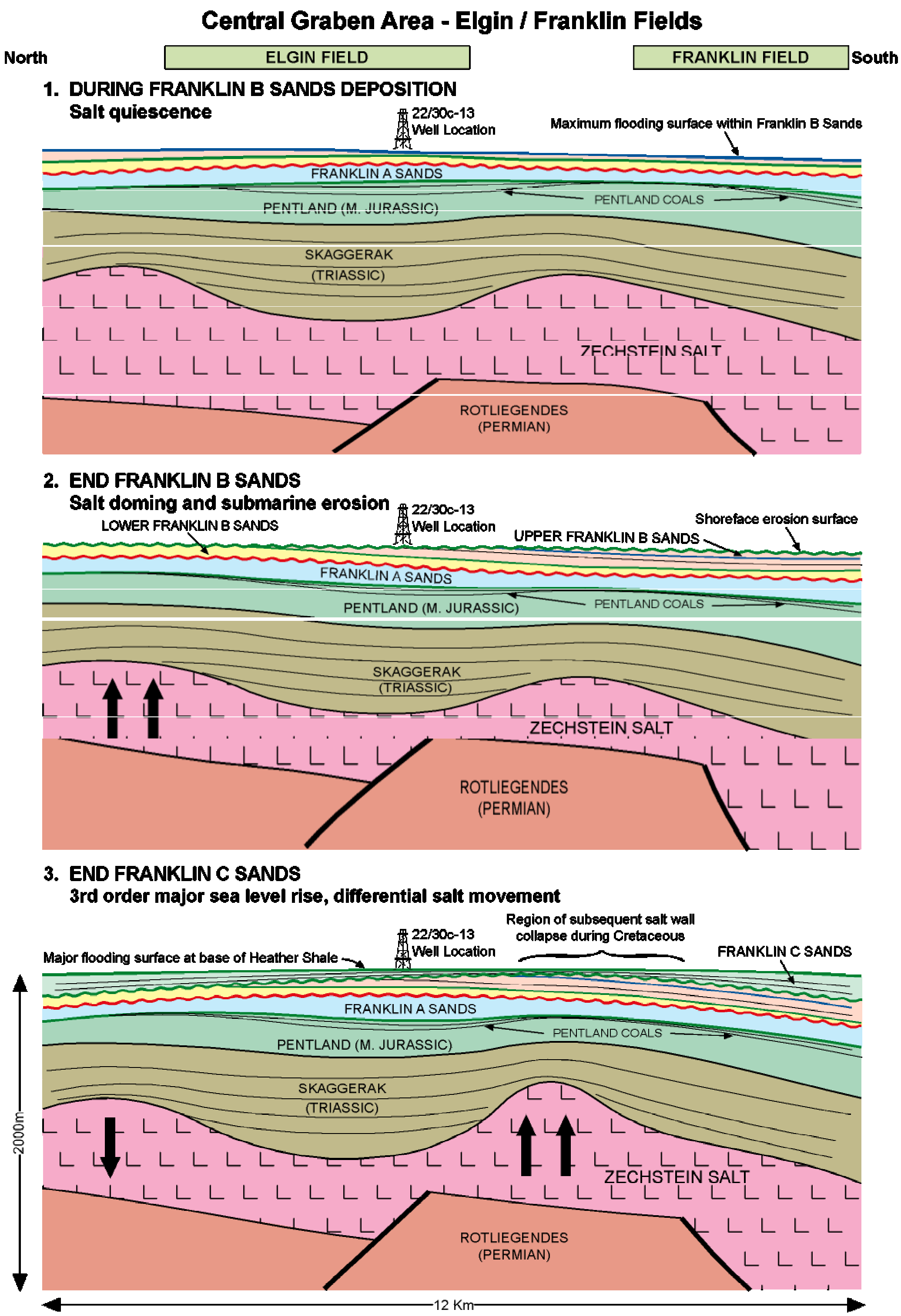

Figure 4. Halokinetic model for origin of the Top Franklin B Sands erosion surface over the Elgin and Franklin fields.

Thickness trends in the upper part of the Franklin Sands are more similar to those in the overlying Heather Shale Formation as shown in Figure 5.

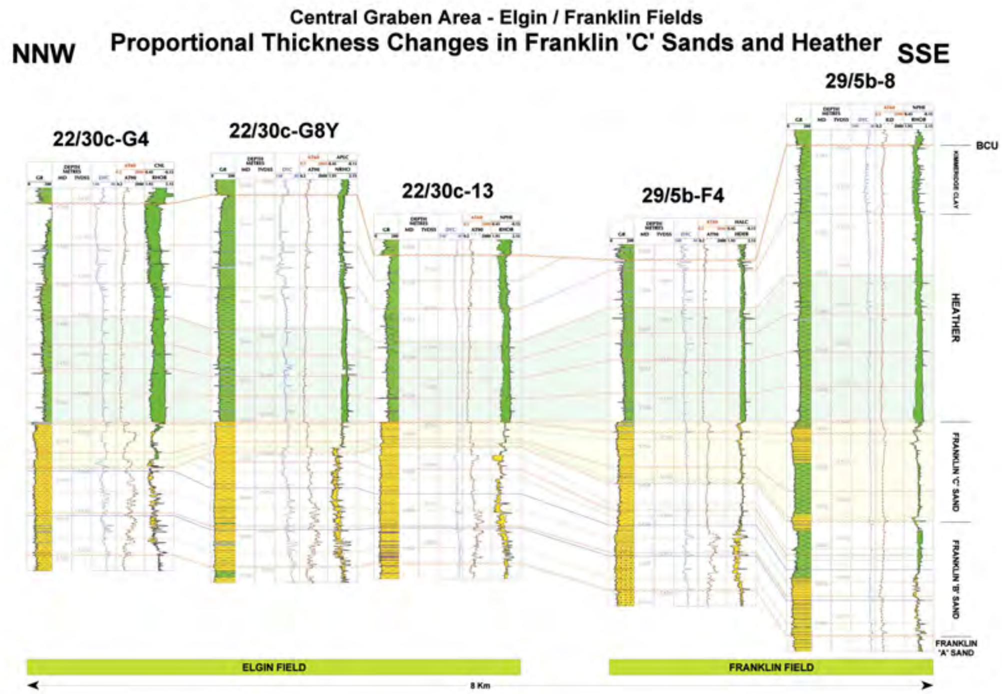

Figure 5. Proportionality of Franklin C Sand and Heather thickness.

<u>Control on Reservoir Quality</u>

The unconformity surface at the top of the Franklin B Sands locally erodes a significant thickness of the Franklin B Sands over the Elgin field. This is significant since this unit is the most important reservoir across both fields. The erosion results in pronounced thickness variations of a distinctive sandstone unit referred to as the Upper B Sands. This unit was deposited during a long term retrogradational phase. The Lower B Sand was deposited during the preceding progradational phase. The Upper B Sand originally contained a high proportion of sponge spicule bioclasts, now represented in the rock as secondary porosity (see fig. 6).

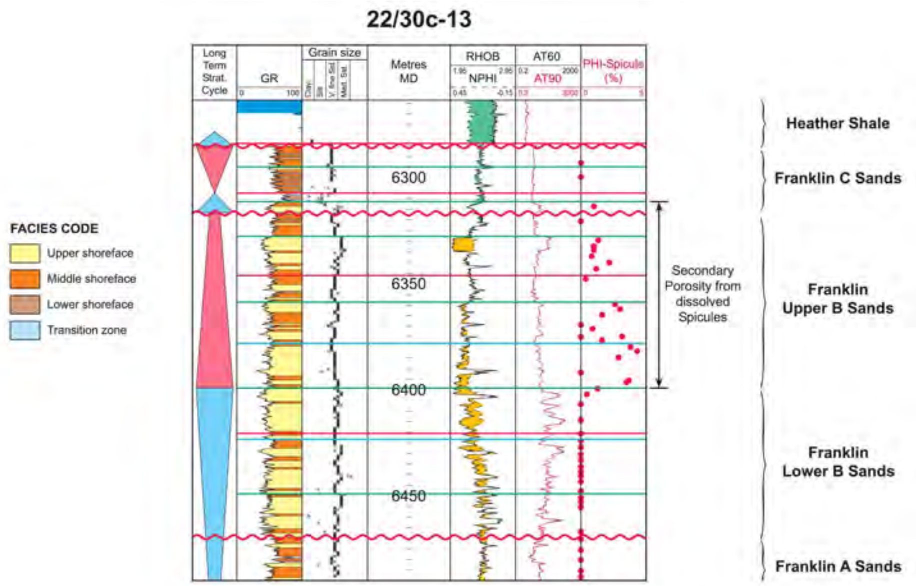

Figure 6. Secondary porosity development related to sponge spicule dissolution in the Franklin Sands.

Presence of spicule grains within the Upper B Sands may have been due to slower rates of deposition during the retrogradational phase of depositon. Cross-plots of porosity and permeability emphasise a marked change in the relationship of these two parameters between the Lower and the Upper B Sands (see fig. 7).

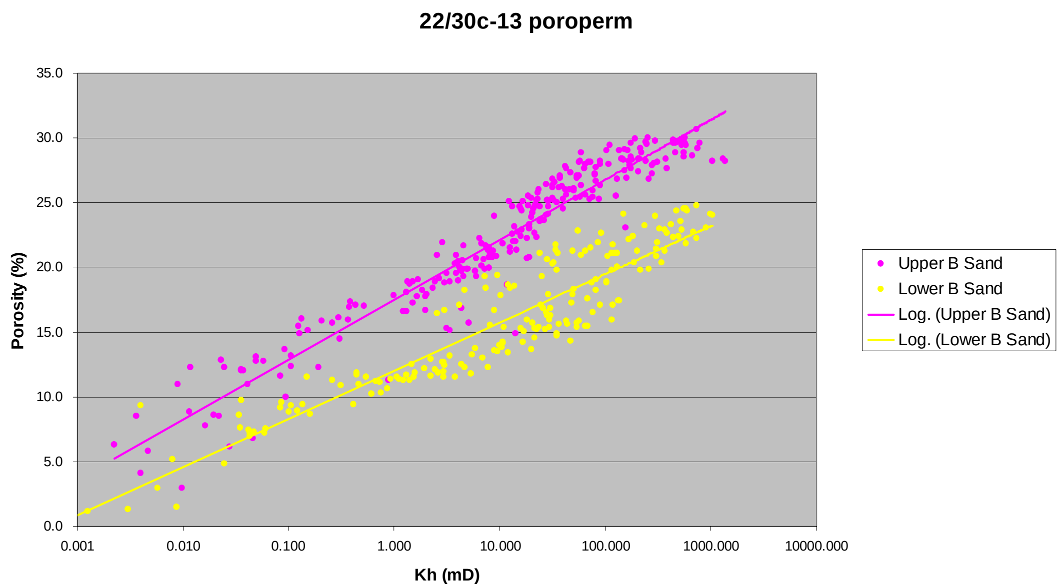

Figure 7. Poroperm relationship of Upper and Lower B Sand in Well 22/30c-13

The difference in reservoir quality is due to a dominance of secondary porosity over primary porosity in the Upper B Sands. Although overall porosity can be higher, pore spaces remain poorly connected so that permeability is not improved. Spicule presence within the Upper B Sands exerts a significant influence on porosity: (1) by lessening compactional effects due to the growth of authigenic microquartz derived from spicules,

(2) by inhibiting the development of syntaxial quartz overgrowths, and (3) by generating secondary porosity through spicule dissolution.

Implications of the Study

Improved correlation within the reservoir through the application of new stratigraphic techniques has resulted in the need for a re-evaluation of how the seismic data can be used to help characterise the reservoir. High-resolution stochastic impedance inversion has been attempted to improve the vertical resolution of the seismic and initial results suggest that while the direct well-to-well correlations seem valid, spatial interpretation remains quite difficult due to the poor quality of the seismic in some of the field area.

As far as 3D reservoir modelling is concerned, the mapping of intra-reservoir surfaces will have to rely to a greater extent than previously on thickness maps based mainly on well picks. Most importantly, the new stratigraphic scheme has allowed the improved modelling of proximal-distal facies trends. These are the main control on reservoir quality and, together with changes to the structural model, are one of the factors most likely to influence field volumetrics.