New insights into petroleum potential from multi-disciplinary data integration for the Carson Basin, Grand Banks of Newfoundland

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ABSTRACT

The bulk of exploration on the Grand Banks has been focused in the Jeanne d' Arc Basin, leaving potentially prospective basins farther south virtually untested. We take a fresh look at some of the existing data for the Carson Basin (Figure 1). Potential-field data maps combined with a tectonic elements map provide a framework for understanding the structural geometry of the basin. Seismic interpretation, tied to a well section with new biostratigraphic data (Figure 7), shows the complexity of the basin. Although no drill stem tests were run, nor any shows reported, there appear to be some hydrocarbons in the system in the form of bitumen extracted from cuttings from Skua E-41, St George J-55 and Bonnition H-32. Source rock potential has not been identified, apart from a few hints, but this is hardly surprising considering that all four wells were drilled along the landward-most margin of the basin. The seismic and geological sections show that Tertiary, Cretaceous and Jurassic rocks are present, and that many of the structures are due to salt kinematics. The timing of the salt movement in relation to hydrocarbon generation will determine whether structural traps were filled.

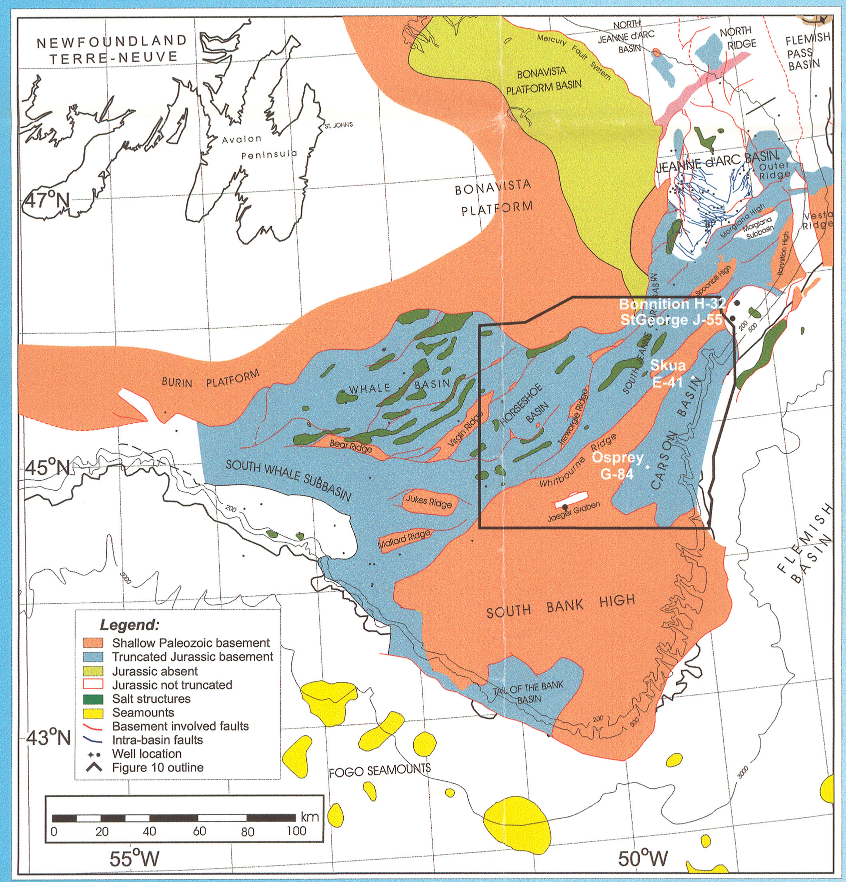


Figure 1: Tectonic elements

This map is based on seismic analysis and shows the major basins and structural features. The outlines of the basins and salt structures have been overlain on Figures 2 to 5.

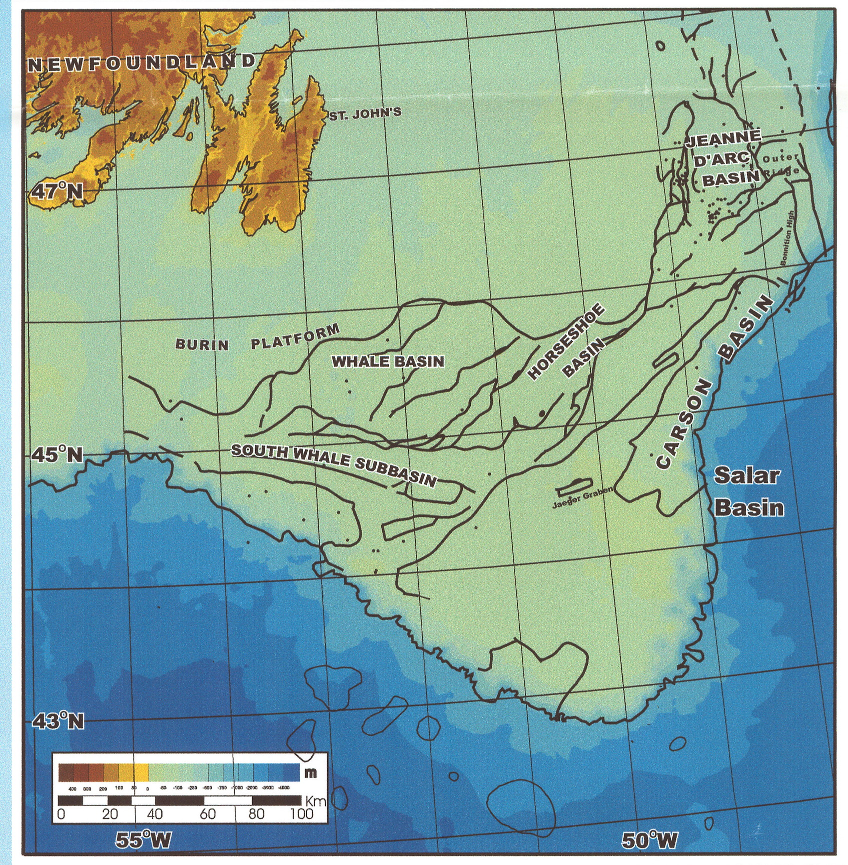


Figure 2: Bathymetry

This image (Oakey, 1999) is derived from hydrographic surveys. It shows the waterdepths to the basins and the edge of the shelf. At the crustal scale, the Jeanne d'Arc, Whale, and Horseshoe Basins are "intercratonic"; Carson Basin is a shelf edge-slope basin. Note that neither the presence of basins nor the seamounts are reflected on the seafloor.

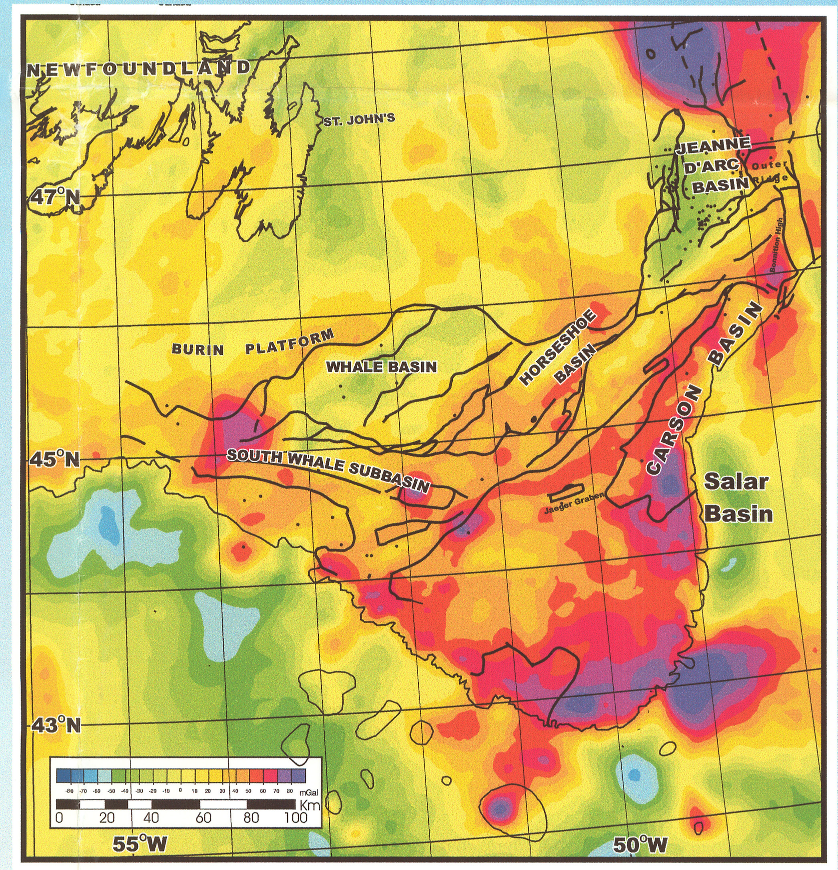


Figure 3: Gravity

This free-air gravity map incorporates all publicly available data (Dehler & Roest, 1998). Basins with thick sediments tend to produce negative anomalies (-10 to -70 mGal). Overlain are selected outlines from Figure 1, showing general correspondence. Sediment thickness in the Whale Basin appears comparable to the Jeanne d' Arc Basin, while the Horseshoe, South Whale and Tail of the Bank basins appear thinner. Carson Basin appears thin, but this is caused largely by the steep gradient of the modern bathymetric slope. Reds and purples manifest granitic intrusions and volcanic rocks, but the seamounts are hardly visible. The large red-purple mass south of the Salar Basin is likely a granitic intrusion, as interpreted from seismic. The anomaly just NE from 44°N and 54°W was drilled and is volcanic. Note that the Salar Basin is a slope basin with sediment thicknesses apparently exceeding those in the Jeanne d' Arc Basin.

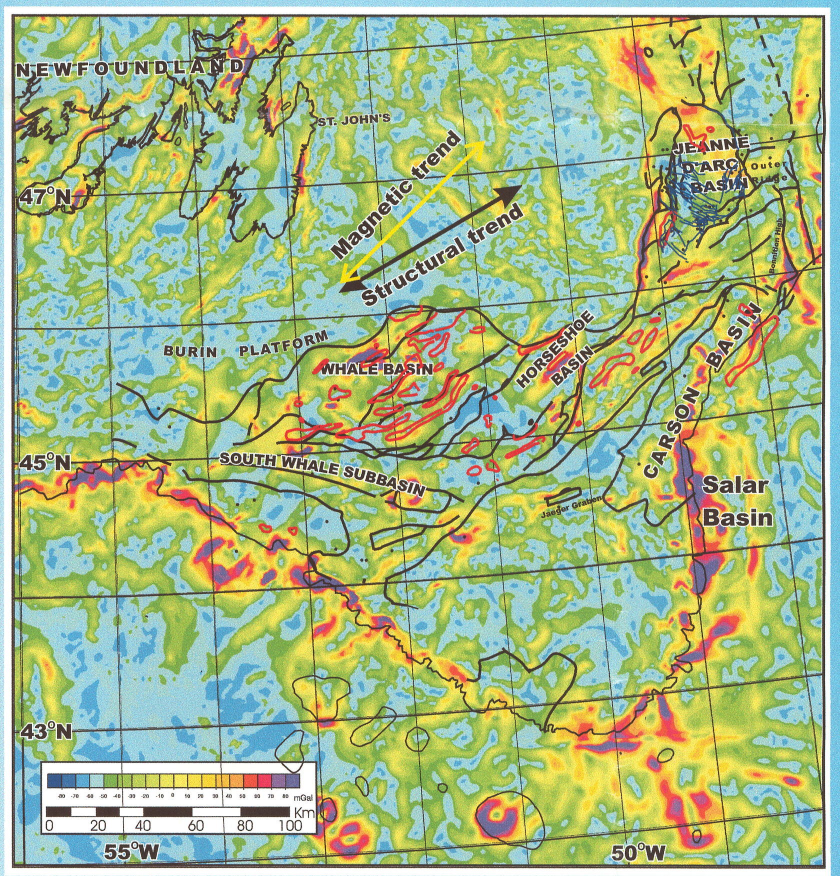


Figure 4: Gravity Gradient

The horizontal gradient is very useful to outline the edge of the shelf and the structural grain of the area. The seamounts show a little better than on the gravity map. The major salt bodies are outlined in red and are visible in the gradient to some extent. Note also how well those salt bodies follow the structural grain of the area (black arrow). The image shows that the grain in the Jeanne d'Arc Basin is different, i.e. has a more circular trend, from the area to the south. The intensive NW-SE faulting is the likely related to the cause of this difference.

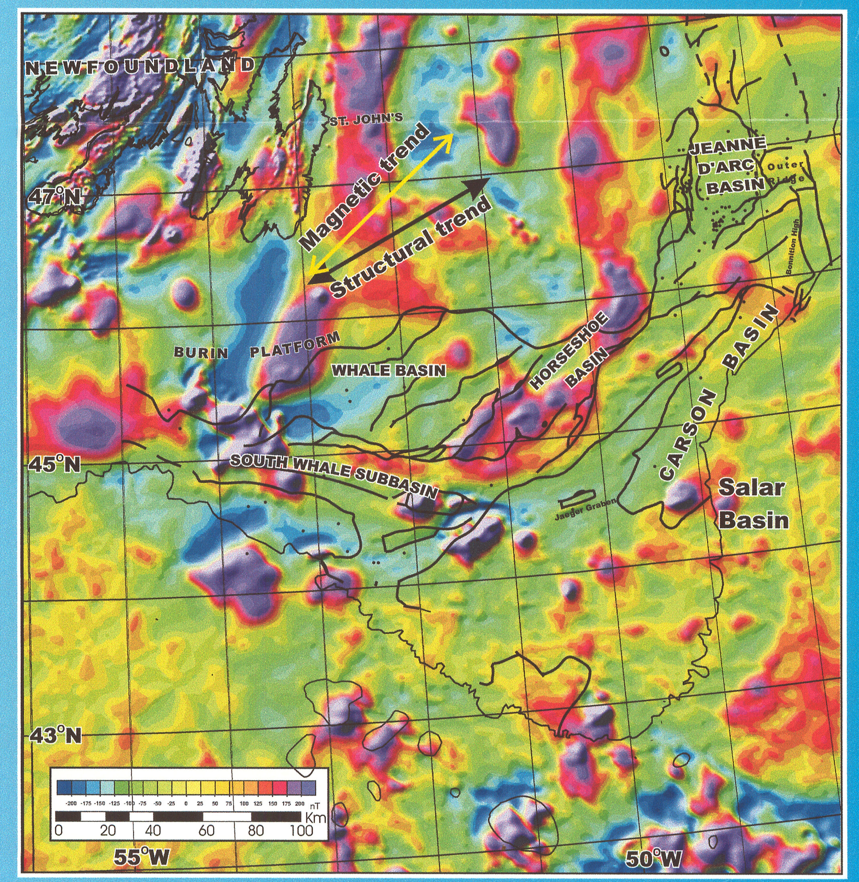


Figure 5: Magnetic Anomalies

The magnetic anomalies (Oakey & Dehler, 1998) reflect in part the basin outlines, and also volcanic rocks such as in the seamounts. Volcanic rocks under the shelf follow a trend that has a slight angle to that shown on the gravity gradient map (yellow arrow). This trend reflects possibly a rejuvenation of Carboniferous or older weakness zones.

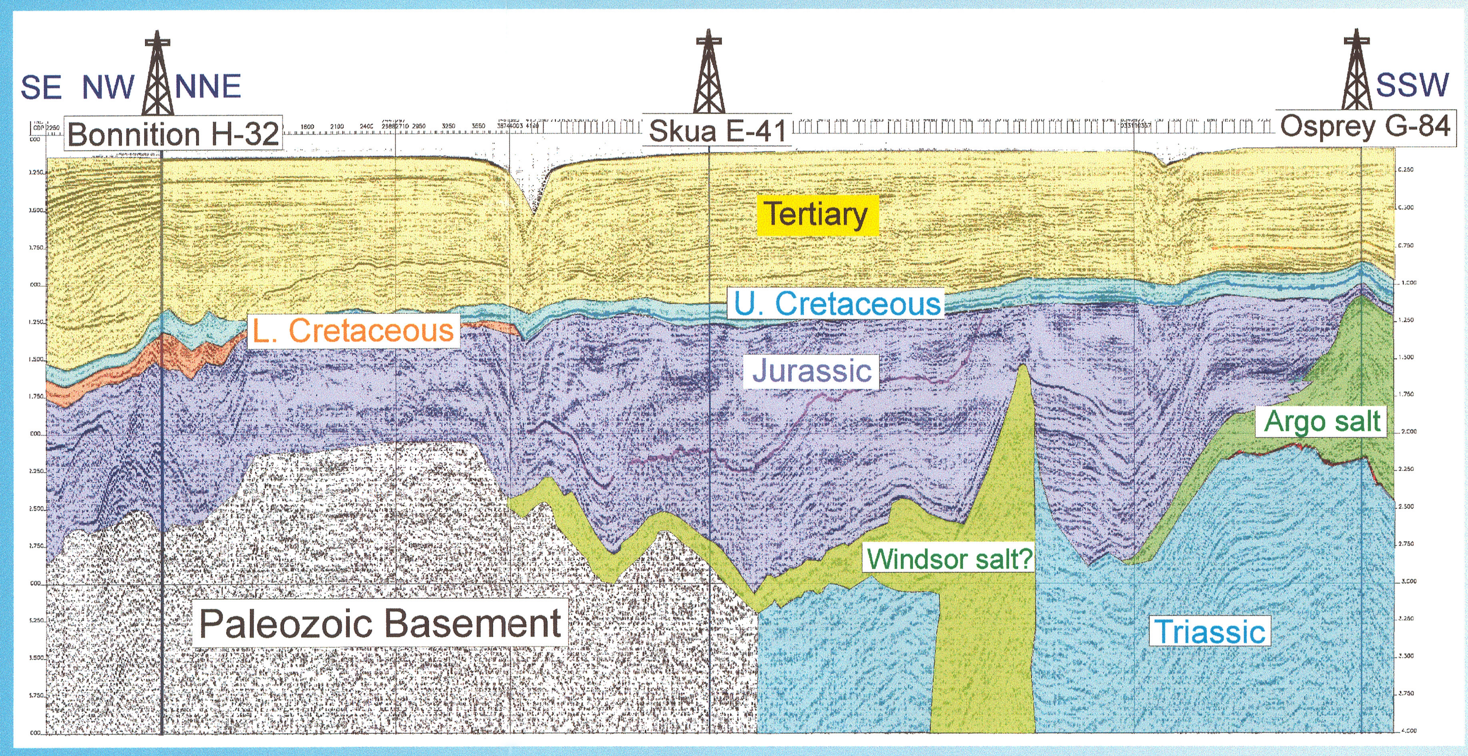


Figure 6: Seismic strike lines in Carson Basin

The seismic composite (lines PCP-81071A, 6307, 6307A, 6307D, 6307C, shown in red lines on Figure 10) shows three of the Carson Basin wells. Note that the line changes direction at Bonnition H-32. The Tertiary consists of one formation, the Banquereau, which contains megasequences, unconformities and hiati. Detailed study of this formation is under way because it contains potential reservoirs and source rocks. During its deposition, many events crucial to the petroleum system happened. It is underlain by thin, continuous Upper Cretaceous which contains the widespread Petrel Limestone marker. The marker is absent from Bonnition H-32 and St. George J-55. The Petrel time surface is shown in Figures 10 and 11. Locally, there is Lower Cretaceous present above a thick, complex Jurassic section that may contain, in distal settings, equivalents to the Egret source rock. Salt tectonism is responsible for most of the structures. The salt is possibly of two ages, the Carboniferous Windsor and the Jurassic Argo salt. The seismic suggests a deep source for the "Windsor". The geometries on this line suggest the salt moved primarily during the Jurassic. The nature of the Paleozoic basement is unknown but it contains granitic intrusions that have been drilled e.g. in Twillick G-49.

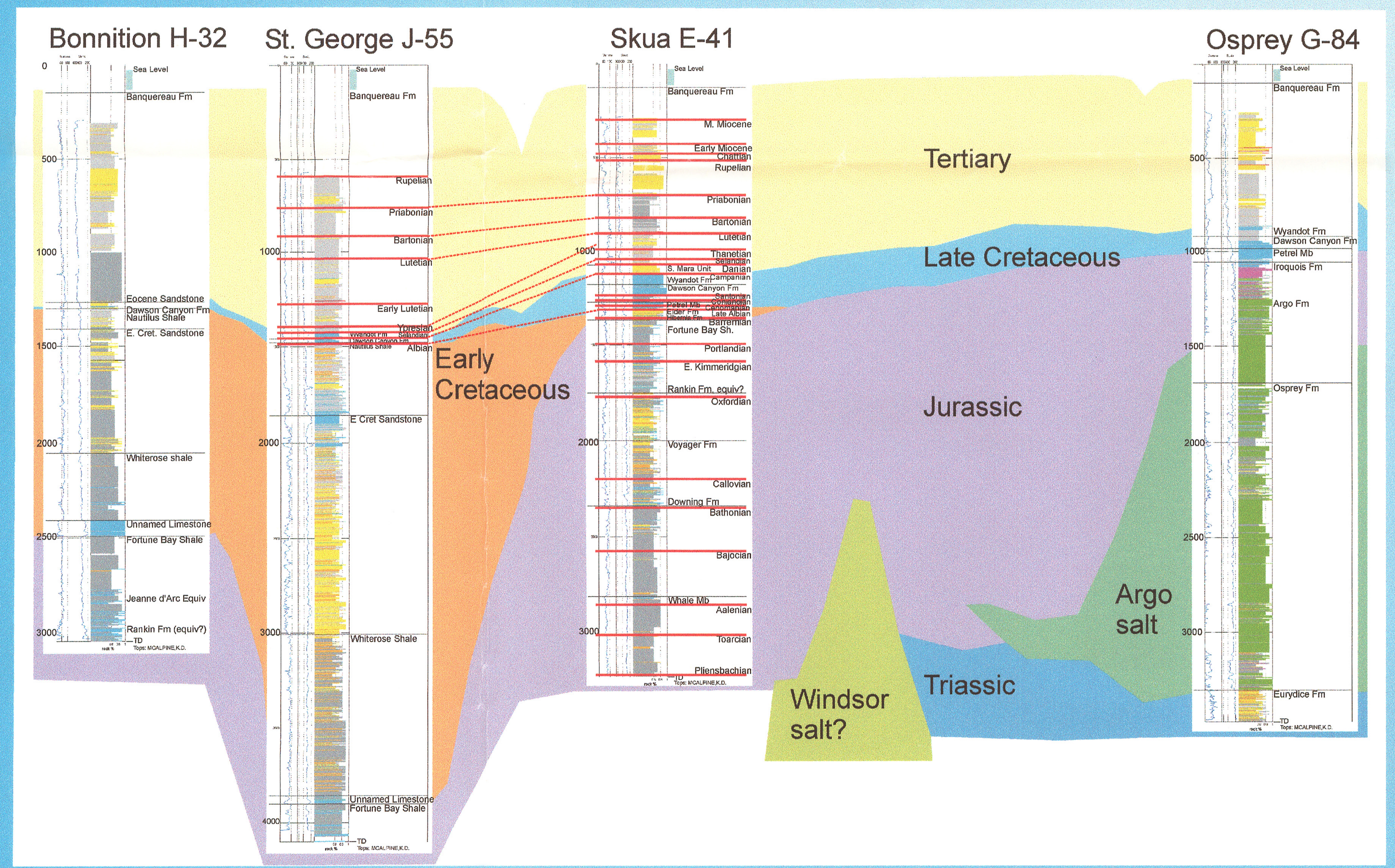
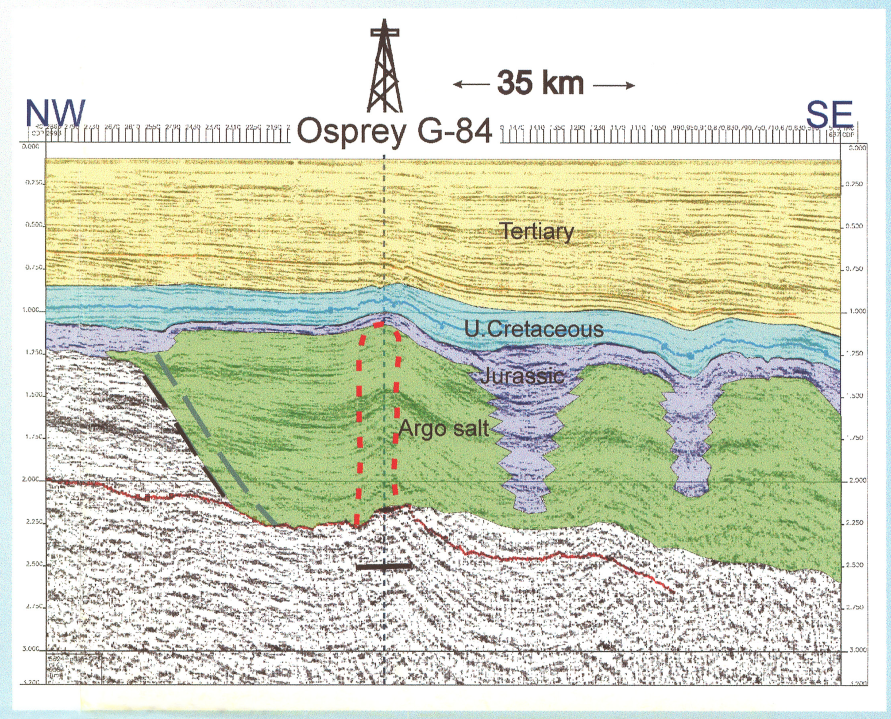


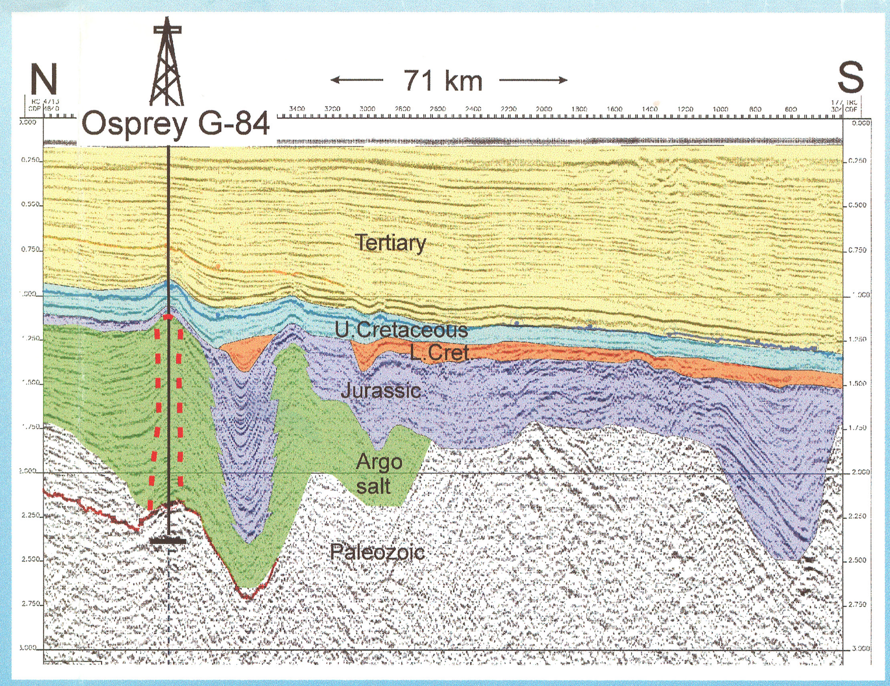
Figure 7: Structural cross section parallel to the seismic strike line, through the four wells.

St George J-55 (which is not located on an available seismic line) was drilled on a collapsed Jurassic section, is also shown. The wells show gamma and sonic logs, lithology, formation picks and in red biostratigraphic ages. The correlation is based on the strike line above. Biostratigraphy shows a complex pattern for the Tertiary. The Upper Cretaceous is present in all wells in reasonably consistent thickness. The thin Petrel marker lies within this interval. The Lower Cretaceous is quite thick in St. George, perhaps as a result of salt withdrawal. Skua E-41 tested a rollover on a fault block and penetrated much Jurassic, but no source rocks were found. This is not surprising, because the well location is close to the oxygenated edge of the basin. The Windsor salt is inferred from the structural relationships on several seismic lines. Osprey G-84 drilled a thick section of salt in an anticline, and many shale layers lie within the section. The top of the salt is Argo, the bottom is Osprey, and there are compositional differences between the salts, e.g. bromine content is below 60 ppm in Osprey and up to 120 ppm in the Argo (Holser et al, 1988). Bonnition H-32 tested Lower Cretaceous sands against a major fault. Extracts of cuttings showed bitumens 241, 141 and a range from 145-2369 ppm, in Skua E-41, St George J-55 and Bonnition H32, respectively. The bitumens are in formations from Banquereau to Whiterose Shale. They show there is some hydrocarbon in the system.

Figures 8 and 9: Strike and dip lines through Osprey G-84

The strike and dip lines through Osprey G-84 show many internally consistent reflectors within the salt. The chemical and lithological differences between Argo and Osprey salt, the consistency of the shale layer and the configuration of the structure appear to indicate that this is not a diapir, but the remnant of salt withdrawal away from the well. That implies that the thickness of 2000 m represents the original thickness of the Jurassic salt. If true, the amount of salt precipitated here is staggering. Away from the well, the withdrawal is evident on both lines. They show that the salt moved from Jurassic through Early Tertiary times, and the largest movement was prior to Late Cretaceous. An alternate interpretation for the salt at Osprey is a diapir.
If this is true, it is fairly narrow, as shown in red dashed lines. Such an interpretation does not explain the continuing reflections, but is consistent with the onlapping geometries of several reflections within the green package. The withdrawal model does not explain what appear to be on-lap relations in the salt north of Osprey G-84. The dip line gives an impression of the deepening of the basin to the southeast, and the thickening wedge of Tertiary sediments. This indicates that deep-water clastic rocks can be expected on the slope. Also, in a deepening setting of slope sedimentation, units like the Petrel coccolithic Limestone Member may distally shale out and become good source rocks.





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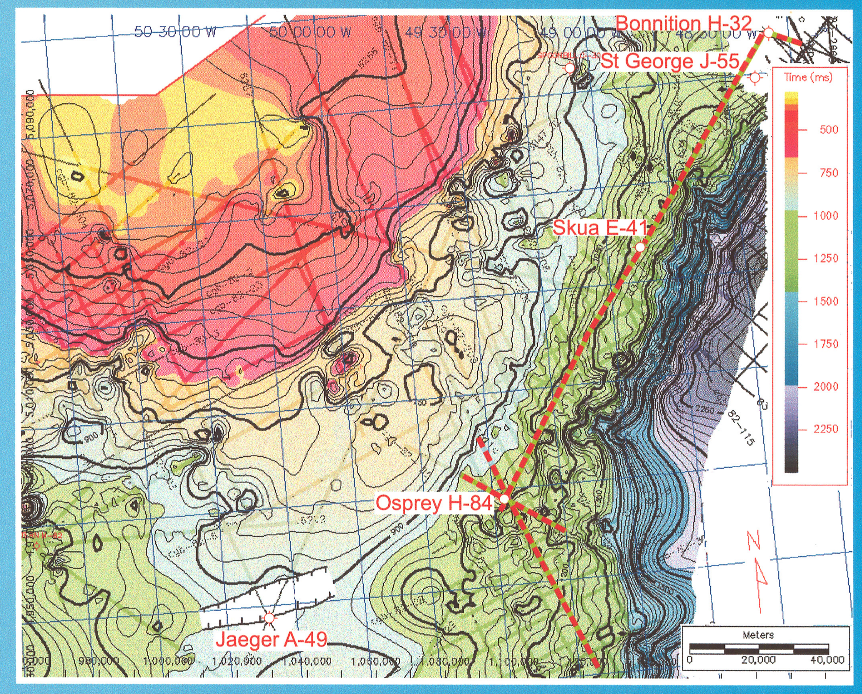

Figure 10: Petrel 2D surface

The map shows the seismic coverage used, and the two-way time surface of the Upper Cretaceous Petrel Limestone marker. The Petrel is widespread, and loses seismic character only on the slope, likely due to facies change into shale, or possibly erosion. The coccolithic organisms can become excellent source rock under anoxic conditions. Red-green dashed lines show locations of Figs 7-9.

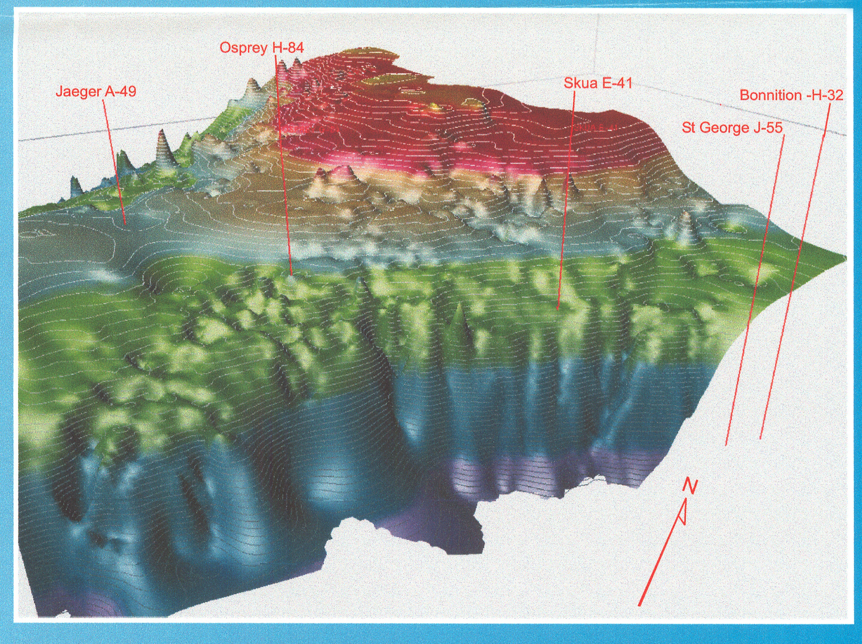

Figure 11: Petrel 3D surface

The two-way time surface shows quite well how steeply the Petrel marker deepens into the slope. This resembles some Gulf of Mexico slope images, and evokes the deep-water clastic rocks that form the prolific reservoirs there. Several potential feeder canyons are visible for these turbidites.