Structure and Isopach Maps of the Jeanne d'Arc Basin, Grand Banks of Newfoundland

T. Edwards, P. Moir and K.Coflin

Geological Survey of Canada (Atlantic)

P.O. Box 1006, Dartmouth, Nova Scotia, Canada, B2Y 4A2

GSC Open File Report # D3755
December 2000

Structure and Isopach Maps of the Jeanne d'Arc Basin, Grand Banks of Newfoundland

Introduction

Over the past 30 years, tens of thousands of kilometers of reflection seismic profiles have been acquired by the petroleum industry to assist in their exploration for hydrocarbons in the Jeanne d'Arc basin offshore eastern Canada. The Geological Survey of Canada undertook to systematically interpret these data, create regional maps of subsurface geology and provide a framework for increased understanding of the basin as assistance to further exploration and development. These maps are a subset (covering only the Jeanne d'Arc Basin) of the large scale maps that will be included in the Grand Banks Basin Atlas, one of series of Basin Atlases published by the Geological Survey of Canada (Atlantic).

The original interpretation and mapping was performed by Tony Edwards in the late 1980's. The maps included in this open file were later digitized (from the manual contours) on a GIS and edited by Phil Moir.

The seismic data that form the basis of these maps were taken from a large reflection seismic data base made available to the Geological Survey of Canada (Atlantic) through agencies regulating offshore exploration in eastern Canada (Canada-Newfoundland Offshore Petroleum Board). All the data used are now in the public domain and only regionally extensive and high quality data were used in the preparation of these maps. The primary data set used is the regionally extensive Parex reflection data grid.

The identification of the reflectors and assignment of stratigraphic significance was performed by tying to wells using the stratigraphic nomenclature (Figure 1) described in McAlpine (1990). Example of interpreted profiles can be found in Edwards (1990).

List of Maps

Tectonic Elements Map
I: Depth to Near Base Tertiary Map
II: Depth to Petrel Marker Map
III: Depth to Near Base Upper Cretaceous Map
IV: Depth to Near Base Cretaceous Map
V: Depth to Near Pre-Mesozoic Basement- Map
VI: Isopach of Tertiary Map
VII: Isopach of Base Tertiary to Petrel Map
VIII: Isopach of Early Cretaceous Map
IX: Isopach of Jurassic and Late Triassic Map
X: Depth to “B” Marker Map

Depth Conversion

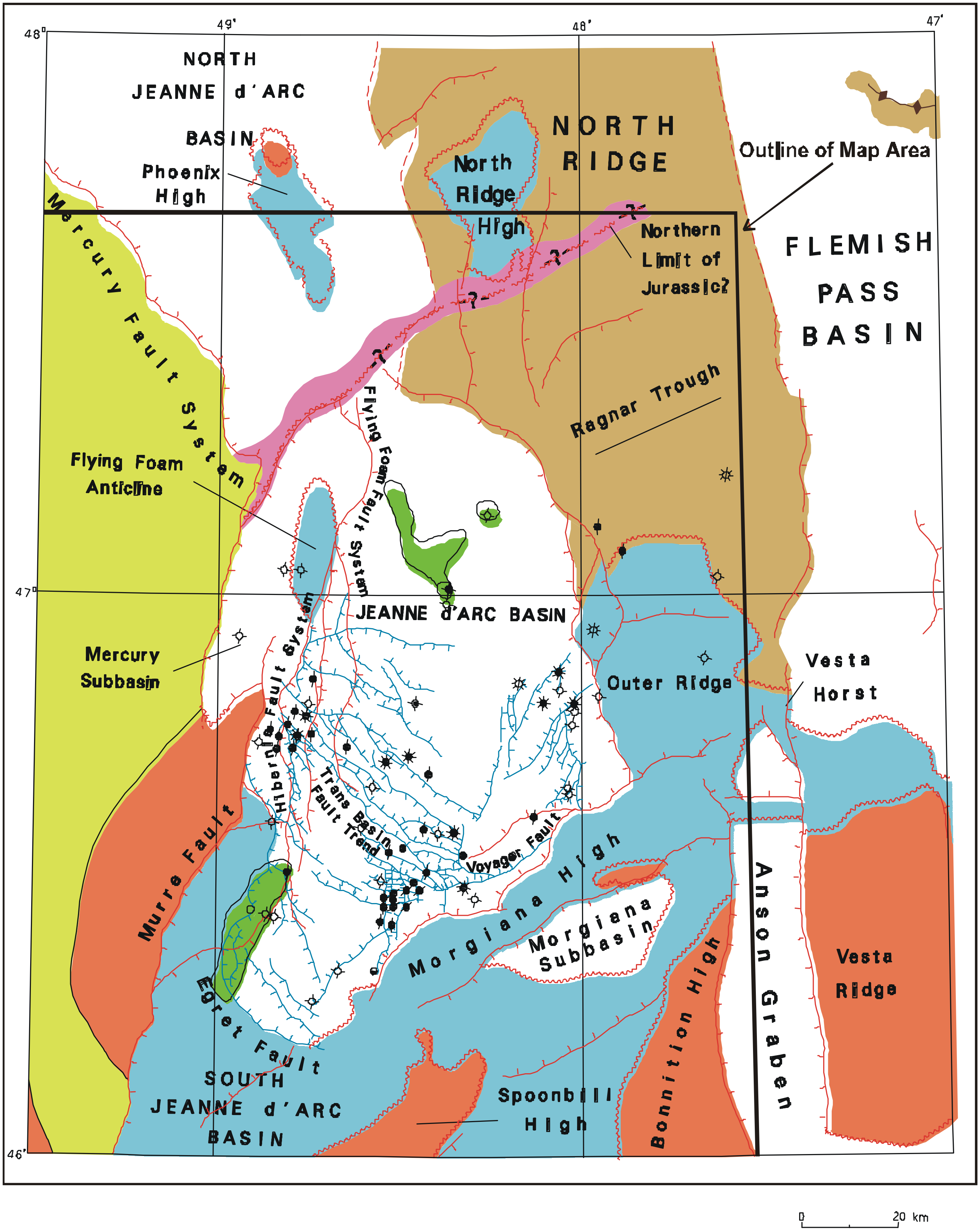
Depth conversions for all seismic structural depth maps and isopachs were derived in the same manner. The root mean square seismic stacking velocities were converted through the Dix formula into interval velocities and then into time/depth functions. Seismic stacking velocities were taken from section header information. The time/depth functions were then sampled at 500 ms intervals to provide equal time average velocity slices down to 16 s TWT. These average velocities were then gridded (at a quarter degree interval) and smoothed to produce the final iso-time average velocity fields. Depth conversion was then a simple matter of linear interpolation between iso-velocity slices. Seismic stacking velocities were used because they are the only means to determine the regional distribution of velocity, as most wells were drilled in small areas of concentrated coverage.

Tectonic Elements Map.

The Jeanne d'Arc Basin is the deepest of the Grand Banks basins, with over 20 km of Mesozoic sediment preserved (Keen et. al., 1987). It is bound on the east by a chain of prominent ridges, the Outer Ridge, and the North Ridge and, on the west by the Bonavista Platform (Avalon Uplift) (Jansa and Wade, 1975). The ridges to the east are deformed Jurassic strata, with block faulting and salt cored anticlines being the most predominant structural forms. They separate the Jeanne d'Arc Basin from the Flemish Pass Basin. The Bonavista Platform to the west is characterized by small basins that preserved deformed Jurassic strata beneath a peneplain surface above which the Early Cretaceous strata are absent.

Within the Jeanne d’Arc Basin, deformation styles vary but halokinesis plays a major role given the large volumes of Late Triassic and Early Jurassic salt. These thick salt layers have been extremely mobile and have formed salt ridges with shallow diaparic structures. Within the post-salt cover, the southern part of the Jeanne d'Arc Basin shows extensive fault deformation. Here the NW-SE oriented Trans Basin Fault Trend is dominant. The faults that form this trend are typically listric growth faults which were active from Avalon Formation times. These faults sole at depths either near the top of the salt or higher within Jurassic shales.

Tectonic Elements Map



I: Depth to Near Base Tertiary Map

The Base of Tertiary is represented by a strong seismic marker over much of the Grand Banks. This interface is either a primary change in depositional style or a strongly erosive surface. In general this seismic event is unstructured with few faults.

II: Depth to Petrel Marker Map

The Petrel Marker is another prominent seismic reflector. It is normally generated from the Petrel Member of the Dawson Canyon Formation, a limestone of late Cretaceous age (McAlpine 1990). It also is relatively undeformed and is used as a key marker event throughout the basin.

III: Depth to Near Base Upper Cretaceous Map

Within the basin, the unconformable nature of the Near Base Upper Cretaceous event is seen only on the flanks of the Bonavista Platform. In the central portion, this event becomes conformable or paraconformable. This event is mappable south of the Adolphus salt features, but to the north of this area, the event is weak and difficult to correlate.. This surface shows little significant tectonism and few faults cut its surface. The most prominent of these are the Murre and Mercury faults outlining the Jeanne d'Arc Basin.

IV: Depth to Near Base Cretaceous Map

The depth to the near Base Cretaceous event can extend to over eleven kilometres. In the deeper parts of the basin, the Base Cretaceous is penetrated by diapirs of Triassic salt. This is particularly marked in the Adolphus region where a large salt wall produces stocks of salt that pierce almost to the seafloor. This map also demonstrates the complex nature of extensional faulting present in the Jeanne d'Arc Basin. In areas where this horizon is not mapped, the Cretaceous may be absent or is too thin to be resolved seismically.

V: Depth to Near Pre-Mesozoic Basement Map

The pre-Mesozoic Basement depth map represents a number of significant deep seismic events rather than a single mappable event. The events picked were chosen to illustrate the depth of basement subsidence achieved in various parts of the region. The greatest depth to basement seen is in the northern part of the Jeanne d'Arc Basin where basement is observed to be at a present depth of greater than 20 kilometres.

Structure at the basement level is generally simpler than that observed within the Mesozoic section. Much of the deformation is related to the large basin bounding and intra-basin ridge bounding faults.

VI: Isopach of Tertiary Map

The post Cretaceous isopach represents the Tertiary passive margin wedge of sediments that generally progrades from the mainland to the oceanic basins. Over the Bonavista Platform, this isopach is generally very thin, less than one kilometre.

VII: Isopach of Base Tertiary to Petrel Map

This interval represents a series of post rift passive wedges that build from the Avalon Uplift eastward over the Jeanne d'Arc Basin and southward over the basins of the southern Grand Banks.

VIII: Isopach of Early Cretaceous Map

This is the isopach between the mid-Cretaceous unconformity and the near Base of Cretaceous. In areas where the mid-Cretaceous unconformity has not been mapped, it represents the isopach between the Base of Tertiary and the near Base of Cretaceous marker. On the map this is seen as the area north of the red line that cross cuts the contours near 47^{o} 15' N.

From this map, the early Cretaceous strata are seen to be areally restricted. The greatest development of Early Cretaceous strata is found in the north-central part of the Jeanne d'Arc Basin where in excess of five kilometres of sediment is preserved.

<u>IX: Isopach of Late Triassic and Jurassic Map</u>

This is the isopach between the Near Pre-Mesozoic basement reflector and near Base of Cretaceous reflector. A thick section of Triassic and Jurassic strata is present in the northern part of the basin, with over nine kilometres of sediment preserved. In general, over the rest of the area, preservation is only on the order of five to six kilometres.

The map indicates that the earlier rift and epeiric basin stage sediments are entirely restricted to the basinal areas. The degree of erosion exhibited by these sediments due to later unconformities indicates that the presently preserved volume of sediment is only a fraction of that originally deposited. The basement reflector has only been mapped over a limited area, due to the often poor nature of this seismic event. For reference, a red line has been plotted on the southwestern portion of the map to indicate the southern extent of the overlying Early Cretaceous sediments.

<u>X: Depth to “B”-Marker Map</u>

One of the most prominent Mesozoic seismic markers in the Jeanne d'Arc Basin is referred to as the "B" marker. The reflection is generated from limestone beds of early Valanginian age, lithostratigraphically referred to as the "B" Marker (McAlpine 1990). The reflector is well developed around the southern and western margins of the basin. To the north and east, reflection strength is lost, due to a facies change into the basin axis, where limestone grade into distal basinal shales.

The "B"-Marker is heavily cut by growth faults of the Trans Basin Fault Trend (Grant et al., 1989), the most dominant structural trend within the basin. The Trans Basin Trend is oriented NW-SE between the Nautilus Fault in the north and the Trinity Fault in the south (Sinclair 1988).

Faults in the zone throw both to the north and to the south forming horst and graben structures. Other prominent fault trends are also recognizable. In the east, a set of faults conjugate to the Trans Basin Trend can be seen; these are oriented SW-NE. The SW-NE Amethyst Fault Trend is dominant between the Whiterose structure and the eastern arm of the Trinity Fault. The third, and weaker, orientation of faulting is a north south trend. This trend is dominant in the axis of the basin and in the Terra Nova area and is sub-parallel to the faulting marking the western edge of the Outer Ridge.

REFERENCES

Edwards, A., 1990. The western Margin of the Jeanne d'Arc Basin Offshore Newfoundland (Eastern Canada); in The Potential of Deep Seismic Profiling for Hydrocarbon Exploration, B. Pinet and C. Bois, eds. Editions Technip., Paris, pp 161-173.

Grant, A.C., L.F.Jansa, K.D.McAlpine, A.Edwards, 1989. Mesozoic-Cenozoic geology of the eastern margin of the Grand Banks and its relation to Galicia Bank; in Proc. ODP. Sci. Results, 103, G.Boillot, E.Winterer and A.Meyer, eds., Ocean Drilling Program, College Station, Texas, p. 787-808.

Jansa, L.F. and J.A.Wade, 1975. Geology of the continental margin off Nova Scotia and Newfoundland; in W.J.M. van der Linden and J.A.Wade, eds., Offshore Geology of Eastern Canada, v.2, Regional Geology: Geological Survey of Canada Paper 74-30, p. 51-105.

McAlpine, K.D., 1990. Mesozoic stratigraphy, sedimentary evolution, and petroleum potential of the Jeanne d'Arc Basin, Grand Banks of Newfoundland. Geological Survey of Canada Paper 89-17. 50p.

Keen, C.E., R.Boutilier, B.de Voogd, B.Mudford and M.E.Enachescu, 1987. Crustal Geometry and models of the evolution of the rift basin on the Grand Banks of eastern Canada: constraints from deep seismic data; in Sedimentary Basins and Basin-Forming Mechanisms, ed. C.Beaumont and A.J.Tankard; Canadian Society of Petroleum Geologists, Memoir 12, p. 101-115.

Sinclair, I.K., 1988. Evolution of Mesozoic-Cenozoic sedimentary basins in the Grand Banks area of Newfoundland and comparison with Falvey's (1974) rift model; Bulletin of Canadian Petroleum Geology, v.36, p.255-273.