Revisiting the Subsurface Geology of Sabine Peninsula (Melville British Columbia, Canada Island, Western Arctic) Through Geostatistically-Steered Data Processing and Interpretation*

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Abstract

The Drake and Hecla gas fields that occur on the Sabine Peninsula of Melville Island are the two largest conventional natural gas fields in Canada and are estimated to contain a combined 8.9 trillion cubic feet of recoverable gas. Modern processing and interpretation methods guided by geostatistical models were applied to more than 3400 line-kilometres of legacy seismic data from onshore Sabine Peninsula. The success of the reprocessing improved the imaging and hence the interpretation of the Devonian through Cretaceous succession. Faults were active repeatedly and control many of the Permian and younger structures. Regional subsurface mapping has identified a number of unconformities and better constrained the relationships between units. The existing discoveries in the region along with the improved understanding of the subsurface lead to the identification of new hydrocarbon plays.

Introduction

The Sabine Peninsula of Melville Island is located on the fringe of the Sverdrup Basin in the Queen Elizabeth Islands of the Western Arctic (Figure 1). The legacy data re-examined in the present study date from initial round of exploration from 1961-1985 when more than 190 wells were drilled and more than 30 000 line-km of various quality 2D seismic data were collected across the Western Arctic. The Sabine Peninsula represents an area with the highest density of data coverage in the Western Arctic (Figure 1). Because of the early exploration boom, three separate gas fields were discovered near northern Sabine Peninsula: Drake Point, Hecla and Roche Point (Waylett, 1990). Feasibility studies for the development of the gas fields were conducted in the 1980s; however, the price of gas and an existing abundant gas supply led to reduced interest in the Arctic (Harrison, 1995). The study of the Sabine Peninsula was undertaken as part of the Geological Survey of Canada's Geo-mapping for Energy and Minerals (GEM) program. Given the cost of data acquisition in frontier areas, vintage datasets still possess a strong value. This study utilizes modern geoscientific processing and interpretation methods applied to a suite of vintage data. The focus of the project was on the subsurface of Sabine Peninsula and improves the existing seismic stratigraphy in order to develop play concepts that were not identified during the initial round of exploration.

Geological Setting

The Sverdrup basin of the western Arctic Islands spans >1,000 km and measures as much as 350 km in width containing a thickness of strata greater than 13 km (Embry and Beauchamp, 2008). The Sverdrup basin is separated from the underlying Franklinian basin by a sub-Carboniferous unconformity. The Franklinian basin was superseded by widespread rifting and re-organization following the Late Devonian-earliest Carboniferous Ellesmerian Orogeny. Because of rifting, the consequential structural depression acted as a major depocentre from the Carboniferous through the Paleogene (Embry and Beauchamp, 2008). The surficial geology of Melville Island is dominated by strata of the Franklinian basin. The Sabine Peninsula is an exception and the exposed rocks are part of the Sverdrup basin. On Sabine Peninsula, the Franklinian basin is present only in the subsurface.

The Sverdrup succession was affected by the Eurekan Orogeny early in the Cenozoic and consequently much of the Paleogene and Neogene succession is absent. The geology of the Sabine Peninsula consists of slightly deformed Late Carboniferous to Quaternary aged sandstone, siltstone, shale, and minor amounts of carbonate. Additionally, evaporitic rocks are exposed in two piercement diapirs on northern Sabine Peninsula – the Barrow and Colquhoun domes that consist of deformed anhydrite and gypsum. The strata of the Sverdrup basin succession on Melville Island are affected by a series of folds including the Murry Harbour Syncline in the north of the peninsula and the Drake Point Anticline and the Marryatt Point Syncline to the south.

Seismic Dataset

Data access was obtained through a Memorandum of Understanding signed in 1997 by the Geological Survey of Canada (GSC), Panarctic Oils, the Arctic Islands Exploration Group and the Offshore Arctic Exploration Group joint ventures parties. The processing strategy consisted of five steps: 1) Unfiltered stack sections were input into the processing software, 2) Principal component decomposition was used to remove both coherent and random noise, 3) Data were migrated following the principals of Kirchhoff migration through the use of velocity models built using the geostatistical method of kriging with an external drift (Duchesne et al., 2012), 4) Seismic bandwidth extension was conducted in order to increase vertical resolution and finally 5) The resultant reprocessed section was output to be used for seismic interpretation.

Building upon the success of the seismic reprocessing and the improved vertical resolution and signal-to-noise ratios, seismic lines were loaded into IHS-Seismic Micro-Technology's Kingdom seismic and geological interpretation software. Reflections representing key seismic horizons were chosen based on formation top information at well intersections and manually correlated. Time-structure grids of the key seismic horizons were computed using a universal kriging algorithm. The resultant time-structure maps were used to investigate the overall subsurface morphology of Sabine Peninsula.

Subsurface Interpretation

The subsurface of the Sabine Peninsula can be divided into the Franklinian and Sverdrup successions (Figure 2). The older Franklinian Succession was better imaged in the south and presumably continues to the north beneath the overlying basinward thickening Sverdrup succession. Seismic reflection profiles reveal that the Franklinian succession consists of parallel, continuous to chaotic seismic reflections with an overall folded morphology. In contrast, the overlying Sverdrup succession consists of stacked, parallel continuous seismic reflections with an overall draped morphology.

The best control on the Franklinian succession was at the southern limit of the Sabine Peninsula where the overlying Sverdrup succession was thinnest and formation top data was available. The succession was interpreted to be both folded and faulted, thus the extent of interpretation was limited. The Franklinian succession is host to the Blue Fiord carbonate reef front, the limits of which were refined throughout the course of this study. Through seismic interpretation and formation top re-evaluation, we inferred that the reef edge and any connection to Bent Horn oil field of Cameron Island would be located further to the south.

The seismic stratigraphy of the Sverdrup succession appears to have an inherited topography based on the underlying Franklinian succession. The Sverdrup succession is much better imaged than the underlying succession and a number of features were interpreted including 6 sets of intrusions, fault controlled patch reefs, changes in reflection continuity and reflectivity that indicate the interfingering between Mid Permian units, and several instances of clinoforms. Interpreted features were placed in a seismic facies context and contribute to the improved the understanding of the subsurface of Sabine Peninsula. Throughout the course of the seismic interpretation the extent of potential source and reservoir units of the Franklinian succession (Cape Phillips and the Thumb Mountain formations) were better defined. Additionally a number of potential reservoir units suggested by Embry and Beauchamp (2008) to be sufficiently porous to act as potential reservoirs were investigated and a number of trapping configurations identified. The presence of both source and reservoir units combined with the presence of migration pathways indicate that clinoforms and carbonate reefs could both represent potential play concepts in the subsurface of Sabine Peninsula. In addition to the investigation of seismic facies, 9 time-structure maps were created for the Great Bear Cape, Sabine Bay, Degerbols, Roche Point, Grosvenor Island, Sandy Point, Awingak, and Christopher Formations. Rendering the regional extent of these markers allowed for the investigation of subtle changes in morphology throughout the overall succession.

Conclusions

The success of the reprocessing and reinterpretation effort has improved the understanding of the Devonian through Cretaceous evolution of the Sabine Peninsula. Regional subsurface mapping has refined the extent and better constrained the relationships between units. The improved seismic stratigraphic context and the recognition of numerous potential source and reservoir units have aided in the development of new clinoform and carbonate reef play concepts in this area of the Western Arctic.

Acknowledgements

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References Cited

Duchesne, M.J., M. Claprood, and E. Gloaguen, 2012, Improving velocity estimation for 2-D postack time migration of regional seismic data using kriging with an external drift: The Leading Edge, v. 31, p. 1156-1166.

Embry, A., and B. Beauchamp, 2008, Sverdrup Basin: In Sedimentary Basins of the World, K.J. Hsü (ed.), v. 5, p. 451-471.

Harrison, J.C., 1995, Melville Island's salt-based fold belt, Arctic Canada: Geological Survey of Canada Bulletin 472, 344 p.

Waylett, D.C., 1990, Drake Point gas field, Canadian Arctic Islands: In Structural Traps I, Tectonic Fold Traps, AAPG Treatise of Petroleum Geology, Atlas of Oil and Gas Fields, p. 77-102.

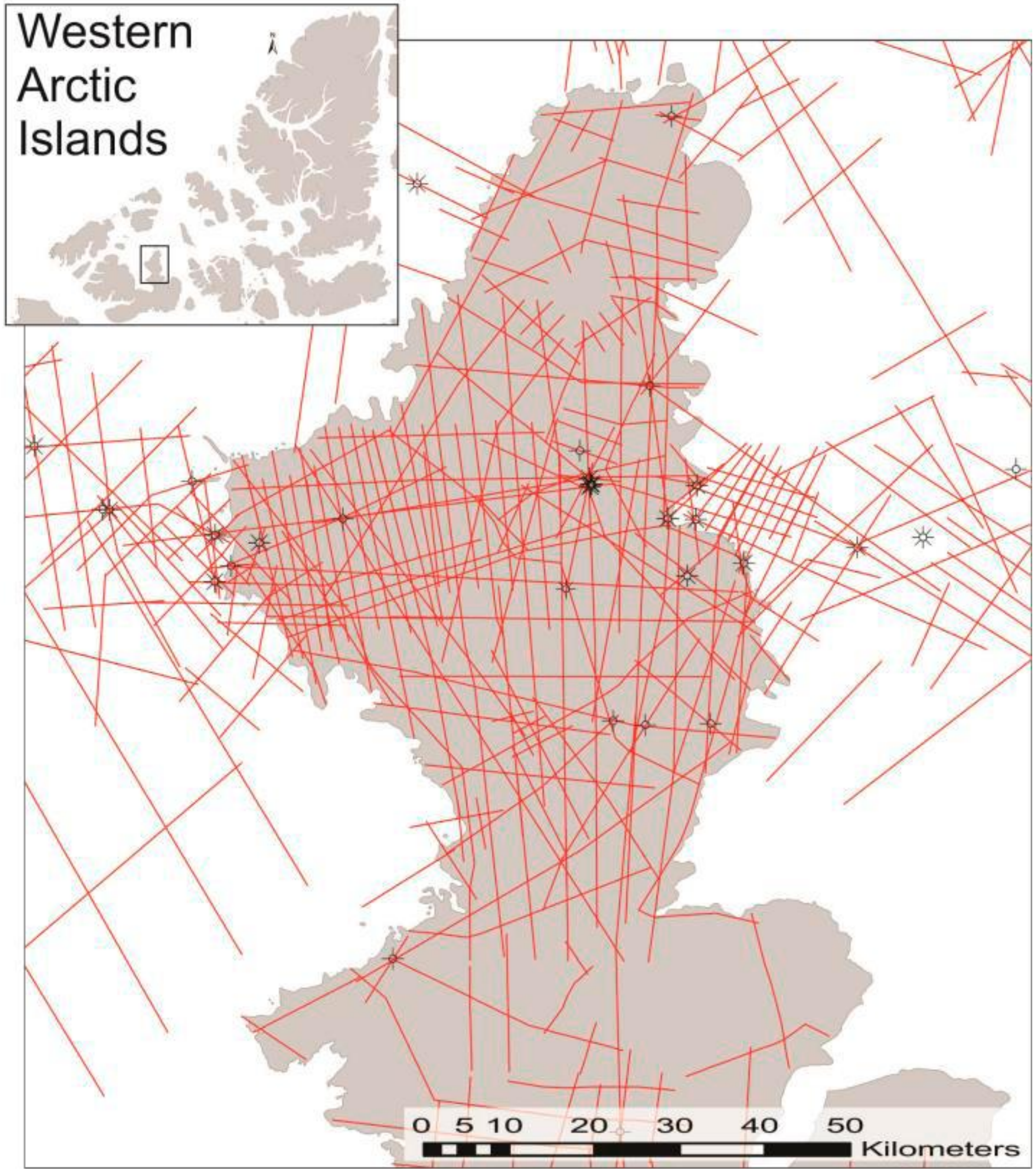

Figure 1. Location of the Sabine Peninsula of Melville Island, Queen Elizabeth Islands, Canadian Western Arctic with existing well and 2D seismic data displayed.

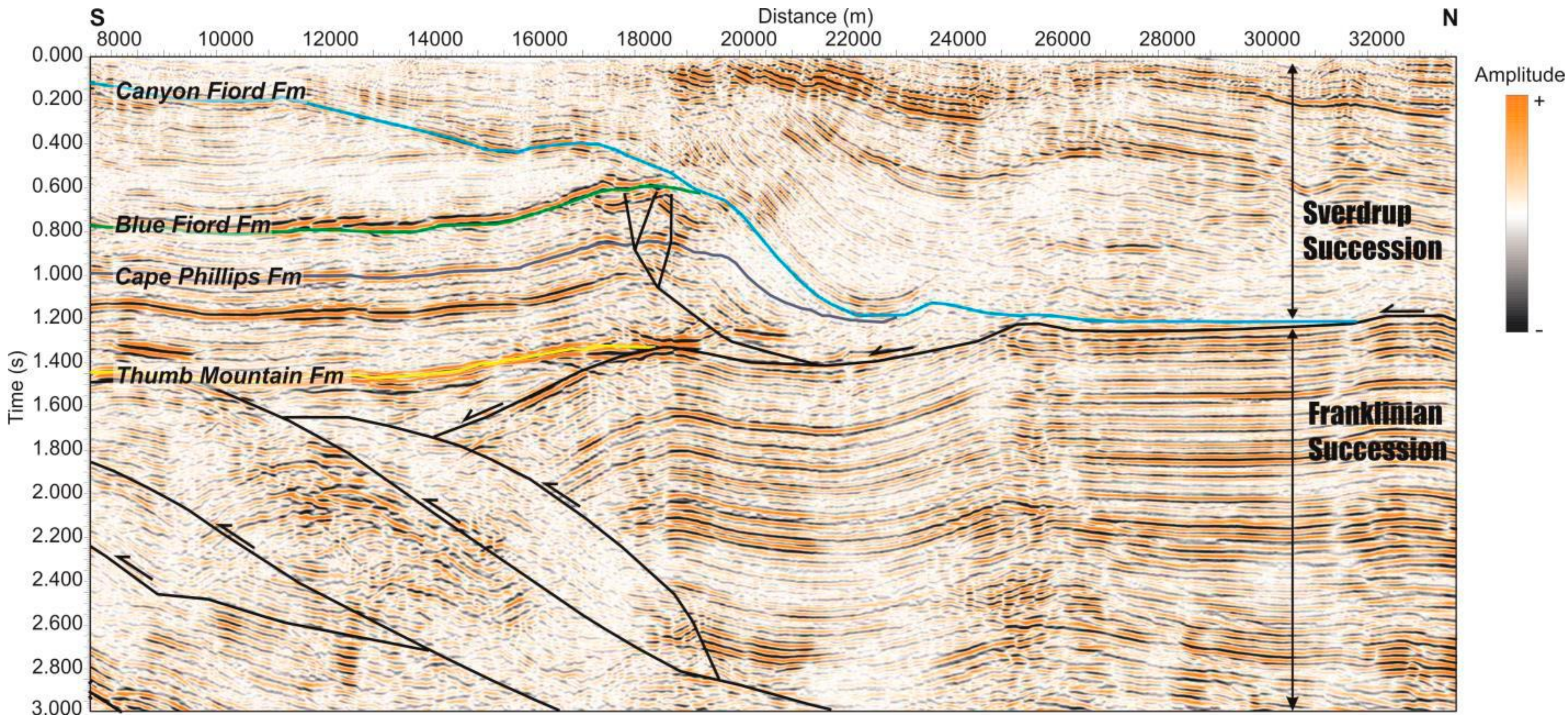

Figure 2. Line showing the geometrical relationship between the Franklinian (Lower Ordovician to Upper Devonian) Basin and the Sverdrup (Lower Carboniferous to present) Basin. Structural interpretation is inspired from Harrison (1995).