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Structural and Stratigraphic Interpretation of a Frontier Exploration Region, Offshore Labrador, Canada

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Summary

The Chidley Basin is an unexplored sedimentary basin encompassing the shelf to deep water of the Labrador Sea. Over 33,000 line kms of long offset 2D seismic data has been acquired since 2011 and is revealing elements of the basin extent and geometry. The lack of wells in the basin requires a combination of detailed seismic interpretation, AVO rock physics work and seafloor coring to define the potential petroleum system. Immature Paleocene source intervals with high TOC have been encountered on the shelf and can be mapped into the slope and deep water. These could provide an actively generating source in a deeper burial setting. Undrilled synrift packages exist within the Chidley basin that could provide additional reservoir and source rock intervals. Regional AVO scoping work is helping to constrain the play fairways throughout the Paleogene section. The identified AVO anomalies are commonly associated with large structural closures within a listric fault system and overlying BSRs. These early insights are indicating that exploration potential in the slope and deepwater Labrador region is high.

Introduction

The Chidley Basin is a recently described slope and deepwater depocentre (Carter et al., 2013), recognized locally in earlier work (Balkwill et al., 1990; Enachescu, 2006) outboard of the shelfal Hopedale Basin and located central to the coast of Labrador, Canada (Figure 1). Covering an area of 83,000 km^2 this unexplored hydrocarbon region consists of thick Cenozoic clastic pro-deltaic to deep water fan sequences underlain by localized syn-rift to early-drift Cretaceous clastic deposits.

Prior to the acquisition of long offset 2D seismic data that began in 2011, the basin was not fully imaged. Coverage was limited to a handful of lines and the basin extent, fill and geometry were largely unknown. Post-2015 acquisition, over 33,000 line km's 2D seismic data is revealing elements of the basin geometry including potential petroleum system insights and prospective reservoir intervals that exist in this emerging frontier exploration region.

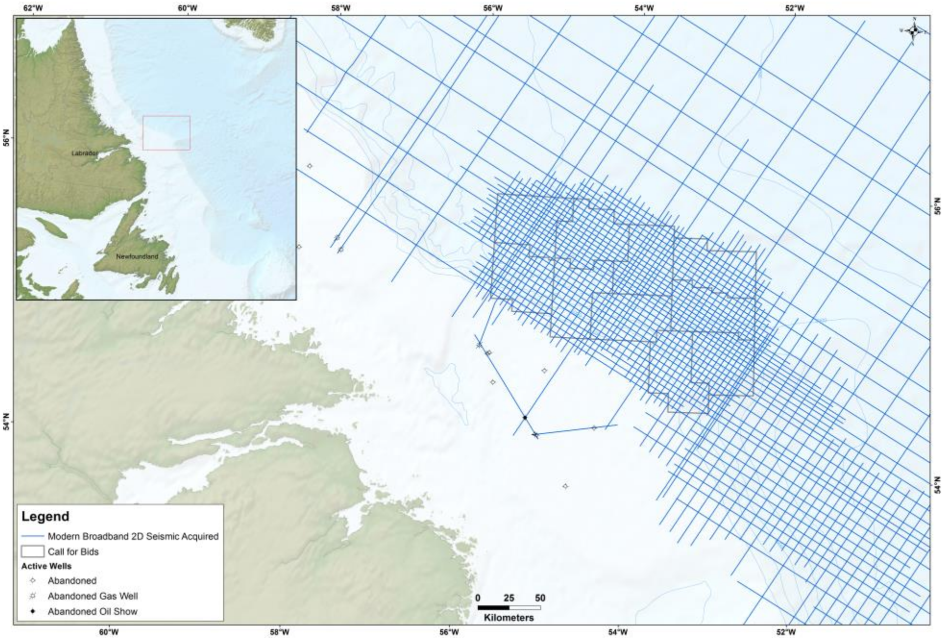

Figure 1 *Labrador margin illustrating shelfal well distribution and recent 2D seismic data. 2017 licence round area (grey outline) and bathymetric profile.*

Rifting and Sedimentation

Greenland-Labrador rifting began in early Cretaceous (Barremian time) with the opening of the Labrador Sea (Balkwill and McMillan, 1984; McWhae, 1986). The onset of rifting is characterized locally by the emplacement of the alkali volcanic rocks of the Alexis Formation and the development of NW-SE trending half grabens within which syn-rift sedimentary rocks were deposited (Balkwill and McMillan, 1984; Dickie et. al, 2011). Rifting likely continued through the Cretaceous; however, the timing of rift to drift transition is one of debate, ranging from Late Cretaceous (Roest and Srivastava, 1989; Balkwill and McMillan, 1990), Maastrictian (Chian et. al., 1995) to Mid Paleocene (Chalmers, 1991; Chalmers and Laursen, 1995).

Evidence of the Continental-Oceanic crustal boundary can be seen in the outboard ridge complexes that elevated the top of early drift section (Figure 2). When overlain with the regional magnetic map (data courtesy of the GSC c.1988), the chrons 25, 26 and 27 align with these ridges (Roest and Srivastava, 1989). The termination of these ridges denotes the boundary between rifted continental/transitional crust, and oceanic crust.

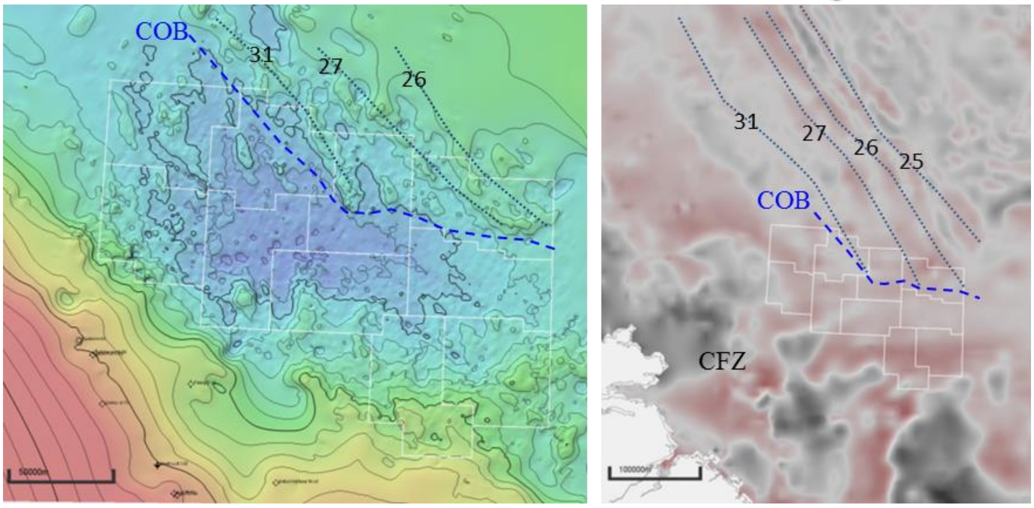

Figure 2 *Structure map of top early-drift sequence (left – data courtesy of TGS and PGS) and regional magnetic profile (right – GSC showing alignment of magnetic anomalies with basement ridges in northern portion of 2017 Labrador AOI (white outline)*

Syn-rift sedimentation can be found west of this boundary with both early rift Bjarni Formation equivalent section, as well as late-rift to early-drift late Cretaceous Markland Formation equivalent. This allows for source rock preservation for both the known Bjarni Formation equivalent (Hopedale Basin source), as well as the possibility of a late-Cretaceous Cenomanian-Turonian interval as described offshore West Greenland (Bojesen-Koefoed et al., 1999; Bojesen-Koefoed et al., 2004). A key observation regarding Cretaceous source on the Labrador Margin is that, when targeting structural prospects over the shelfal regions in the 1970's and early 1980's, the crestal targets failed to encountered full mid- to late-Cretaceous section. This is observed at the North Bjarni structure where the well encountered a thin Maastrictian to Campanian section, while in the flanking depocentres older sections of Late Cretaceous fill are preserved and onlap against the drilled early-rift Bjarni Formation and local basement highs

Since base Paleocene time, during the early drift phase of the Labrador Sea opening, the paleo Churchill River system has fed the margin with sediment leading to stacked sequences of progradational, aggradational, and retrogradational deltaic and prodeltaic section over 4km in thickness. This sediment loading caused the development of a gravity driven, large listric fault system and associated toe thrust zone, which are clearly imaged on the 2D seismic dataset and lead to multiple areas with large structural closures.

Evidence for hydrocarbons

There are currently no wells drilled in the Chidley Basin; however, nearby discoveries (Bjarni H-81, Gudrid H-55) are evidence of an active petroleum system in the nearby Hopedale Basin. The lack of drilling in this area requires a combination of seismic interpretation, AVO/Rock Physics work, and seafloor coring projects to identify potential for an active petroleum system outboard of the proven system encountered on the shelf.

The high quality 2D data shows numerous anomalies in the region that are commonly related to DHI's (Sheriff and Geldart, 1995; Wright et. al., 2013), including gas chimneys, shallow bright reflectors and bottom simulating reflectors. The Paleogene listric fault system's decollement surface (approximately 54 Ma) consists of an interval that, while immature on the shelf, has TOC and HI values that could provide an actively generating source in a deeper burial setting. Additional source could be generated from the underlying Cretaceous synrift package, with the proven Bjarni Formation as well as the potential for some Late Cretaceous source rocks equivalent in age to the oil prone intervals of West Greenland. The burial depths and geothermal gradients estimated over the slope and deep water of the study area allow for a possible mixed and gas prone source rock in the region.

Regional AVO scoping work is giving insights that are helping to de-risk prospectivity (Figure 4) and constrain several of the identified play fairways within the Paleogene section. The Gradient Envelope (GrenV) was calculated via angle stacks from regional 2D datasets and the results were subsequently gridded as a 3D cube (pseudo 3D) throughout the 2017 AOI. Applying the GrenV workflow allows for the identification areas with significant gradient responses. Once combined with regional rock physics modeling, the results will be one of the methods used to high grade areas of greatest prospectivity. In particular, time slicing of the pseudo 3D GrenV dataset allows for trend mapping between lines. Preliminary results are showing clear, fault-bounded structural trends that have AVO signatures consistent with hydrocarbon presence.

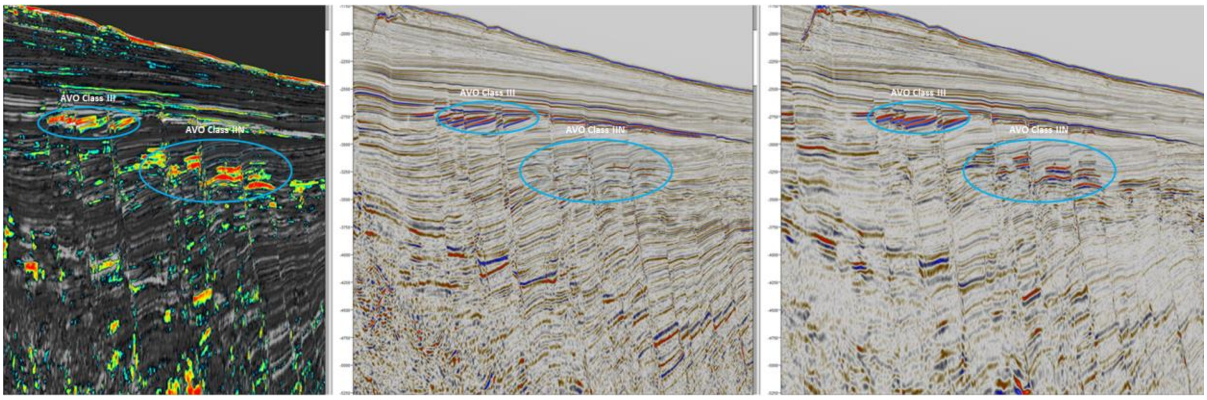

***Figure 4**: Dip section illustrating GrenV (Left) Near Angle Depth Seg Y (middle) and Far Angle Depth Seg Y (right). Amplitude blooming parallel to the shelf break and regional fault trends are showing type II and III AVO responses. In the example above Class III AVO anomalies are pinching out against an unconformity. These anomalies are underlain by structurally conforming amplitude anomalies pinching out against faults with associated Class II responses. Data courtesy of TGS and PGS*

Multiple play types exist in the 2017 license area, including combination structural-stratigraphic traps within the synrift Cretaceous section, large listric fault traps and associated toe thrusts within the Paleogene and Neogene sediments and possible large scale basin floor fans in the more distal areas (Figure 5).

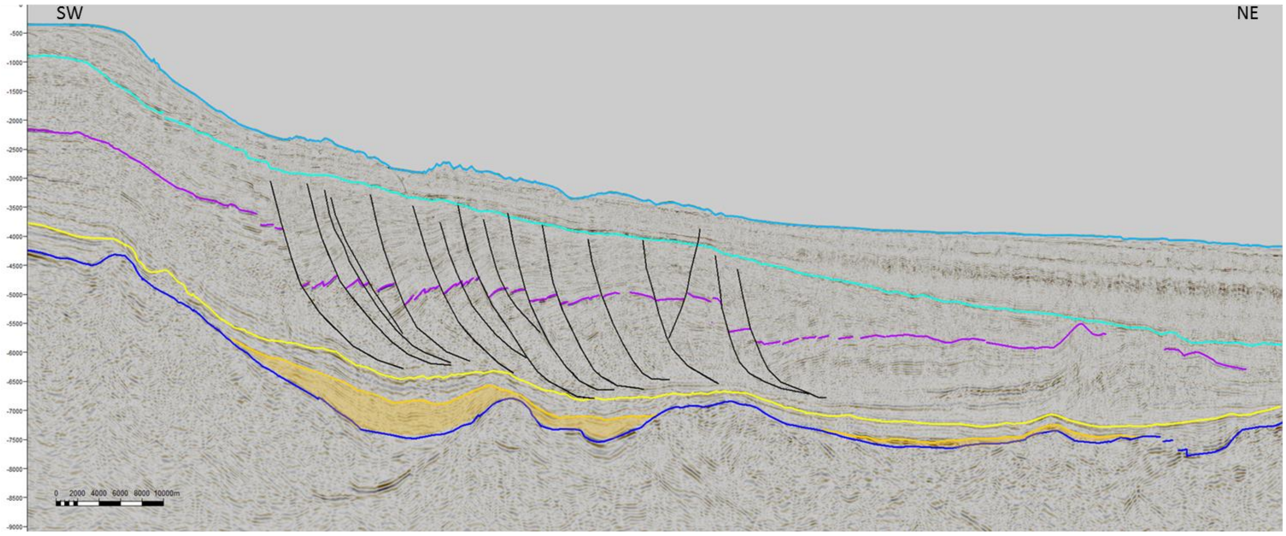

***Figure 5** Dip section through 2017 licence round showing multiple play types and local syn-rift depocentres with preserved Cretaceous section (orange fill intervals). Data courtesy of TGS and PGS*

Conclusions

A proven petroleum system exists over the Labrador shelf, with multiple discoveries related to previous exploration efforts of the 1970s and 1980s. The detailed 2D seismic grid over the 2017 slope and deepwater license round area allows for a detailed study of a never-explored region adjacent to the prolific Hopedale Basin. Interpretation efforts have identified the presence and distribution of the elements required for an active petroleum system. Mesozoic syn-rift and Paleocene drift sections provide source, reservoir and seal potential. Large listric faulted terranes produce numerous structural features, some having an associated AVO response consistent with the presence of hydrocarbons. These AVO anomalies, coupled with overlying BSR's, provide evidence of potential migration of hydrocarbons into these features.

While further work will require a detailed review of the rock physics parameters over the identified leads and an incorporation of a recent surficial geochemistry survey that has sampled the sea floor, these early insights are indicating that exploration potential in the slope and deepwater Labrador region is high.

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