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GEOLOGICAL SURVEY OF CANADA
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Report of activities for Stratigraphic and Tectonic Framework for the Baffin Bay Petroleum Systems

GEM 2 Baffin Bay Project

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Forward

The Geo-mapping for Energy and Minerals (GEM) program is laying the foundation for sustainable economic development in the North. The Program provides modern public geoscience that will set the stage for long-term decision making related to investment in responsible resource development. Geoscience knowledge produced by GEM supports evidence-based exploration for new energy and mineral resources and enables northern communities to make informed decisions about their land, economy and society. Building upon the success of its first five-years, GEM has been renewed until 2020 to continue producing new, publically available, regional-scale geoscience knowledge in Canada's North.

During the summer 2014, GEM's new research program has been launched with 14 activities that include geological, geochemical and geophysical surveying. These activities have been undertaken in collaboration with provincial and territorial governments, northerners and their institutions, academia and the private sector. GEM will continue to work with these key collaborators as the program advances.

Stratigraphic and Tectonic Framework for the Baffin Bay Petroleum Systems: This activity will include the compilation, reprocessing and interpretation of modern and legacy seismic and other geophysical and geological data that will provide the input for a collaborative regional model of the Baffin Bay offshore and adjacent landmasses.

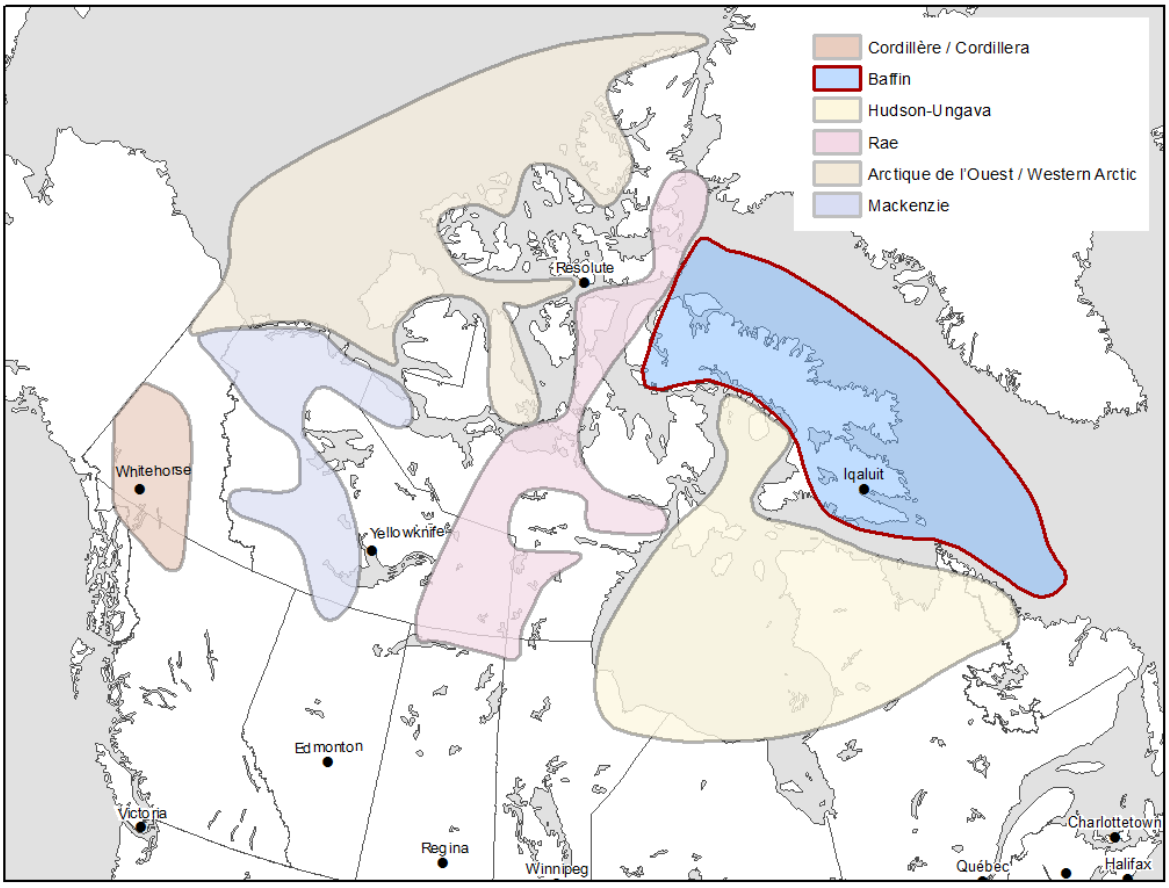


Figure 1: Regional map for the GEM 2 area of interest showing the location of the Baffin Bay Project area.

Introduction

The goal of this activity is to understand the fundamental geologic and tectonic evolution of the sedimentary basins in the Baffin Bay region (Figure 1) and the factors which control the petroleum potential of the area. We do this by mapping the structure and stratigraphy of the sedimentary basins underlying the seafloor to produce maps of sediment thickness and to discover the timing of the key geologic elements needed to produce a complete petroleum system: source rocks (organic content in shales), reservoir (sandstone distribution), seal (shale cap above reservoir) and migration pathways. In order to understand the stratigraphy in the frontier basins of Baffin Bay (where there is little geologic information) we turn to the nearby Labrador margin for information since this margin evolved at the same time and through the similar processes as Baffin Bay, and provides us with a rich dataset of seismic and well data (Figure 2).

This activity aims to address the following key questions:

- What is the nature and age of key stratigraphic surfaces, unconformities and sedimentary packages in Baffin Bay?
- How does the nature of the tectonic setting (extension and/or transform faulting; Figure 2) change along the continental margin from the Labrador Sea into Baffin Bay and how does this influence the stratigraphy?
- What is the impact of tectonic margin segmentation on the stratigraphic succession and petroleum potential in Baffin Bay?

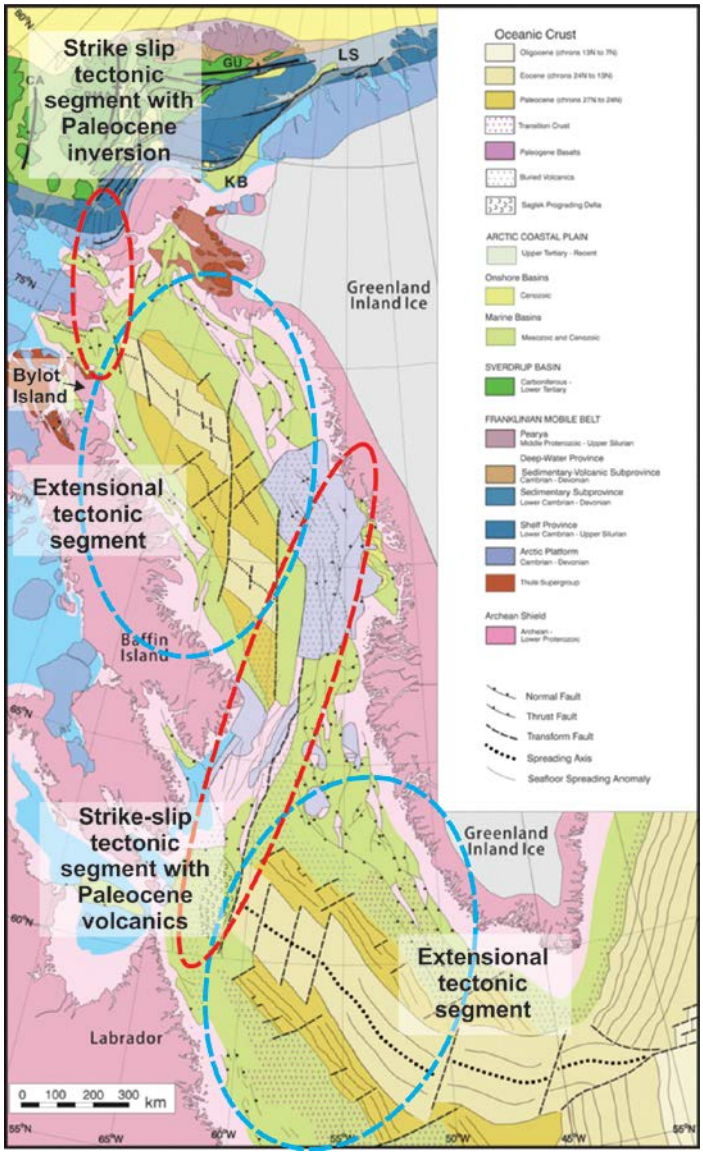


Figure 2: Regional geology map showing development of spreading centers and transform faults from Oakey and Chalmers (2012). The circled areas highlight the extensional margin segments (in blue) and areas of strike slip (in red). As a result of the similarities in the timing and nature of rifting, the extensional margin offshore Labrador can be used as an analogue to the extensional margin segments in Baffin Bay.

We will address these questions by:

1) Integrating well and seismic data from the Labrador margin to develop an analogous and predictive sequence stratigraphic framework that can be applied to seismic studies in Baffin Bay.
2) Characterizing the tectonic segmentation of the Baffin Bay area and its influence on basin development using seismic and geophysical studies.
3) Using the resulting stratigraphic and tectonic frameworks to identify and map the critical elements that govern the nature of the petroleum systems in Baffin Bay.

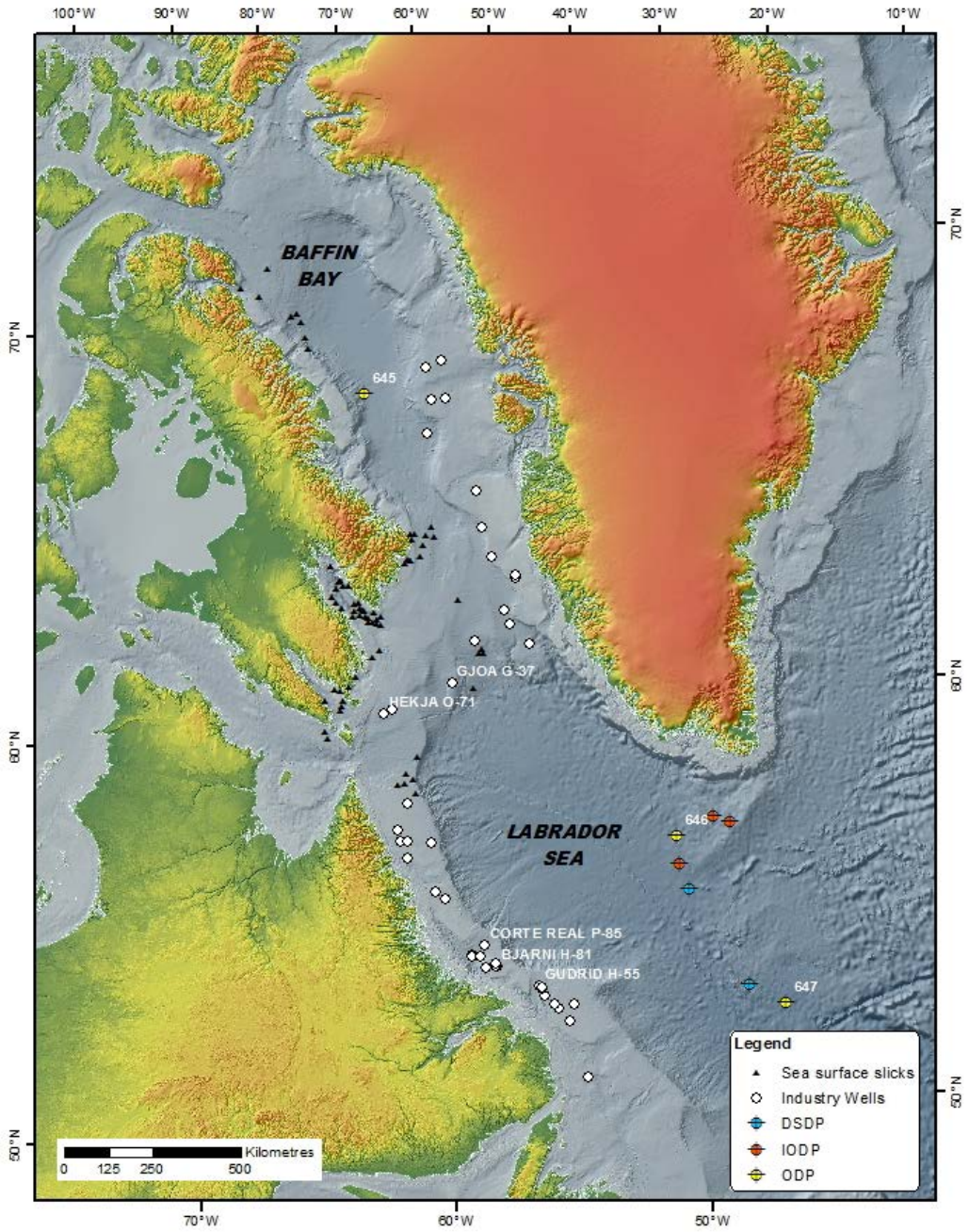


Figure 3: Sample ArcGIS map compilation with sea surface oil slicks and well locations in the Baffin Bay and Labrador Sea.

Methodology
This activity has been built on 5 integrated subactivities that are developed in parallel and are based on the following methodologies:

1) Labrador sequence stratigraphic framework
- Compilation of Labrador Sea seismic data and well data.
- Re-examination of key cores and cuttings with a focus on intervals vital to understanding the stratigraphic framework, paleoenvironments and their influence on petroleum system elements (source, reservoir and seal rocks).
- Modern palynological analysis of core samples and key wells (Corte Real P-85 and Gudrid H-55; Figure 3) for revised biostratigraphic age dating and paleoenvironmental assessments.
- Integration of well and seismic data to build on previous work by developing a robust sequence stratigraphic framework to be used as an analogue for Baffin Bay.

2) Seismic interpretation in Baffin Bay
- Extensive seismic data compilation including: data processing, data conditioning/review, acquisition of new/vintage industry data, registering of scanned seismic data and conversion into SEG-Y format, loading of data, and development of project and master files.
- Establishing time-to-depth functions to convert interpreted seismic time horizons into depth.
- Interpretation of seismic data including: mapping of sediment thickness and basement, extrapolation of regional markers, application of the sequence stratigraphic framework developed for the Labrador basins to the Davis Strait/Baffin Bay region, and regional correlations to the Greenland margin.

3) Tectonic margin segmentation
- Assessment of crustal processes through the analysis of the potential fields (gravity and magnetics) and the existing refraction database.
- Assessment of the variation in seismic character along the Baffin Bay margin with respect to the tectonic margin segmentation models developed from potential fields data and plate reconstruction studies. This will include: relative changes in thickness of seismic stratigraphic packages, depth to basement mapping, identification of fault characteristics and the nature of their corresponding basement structures.

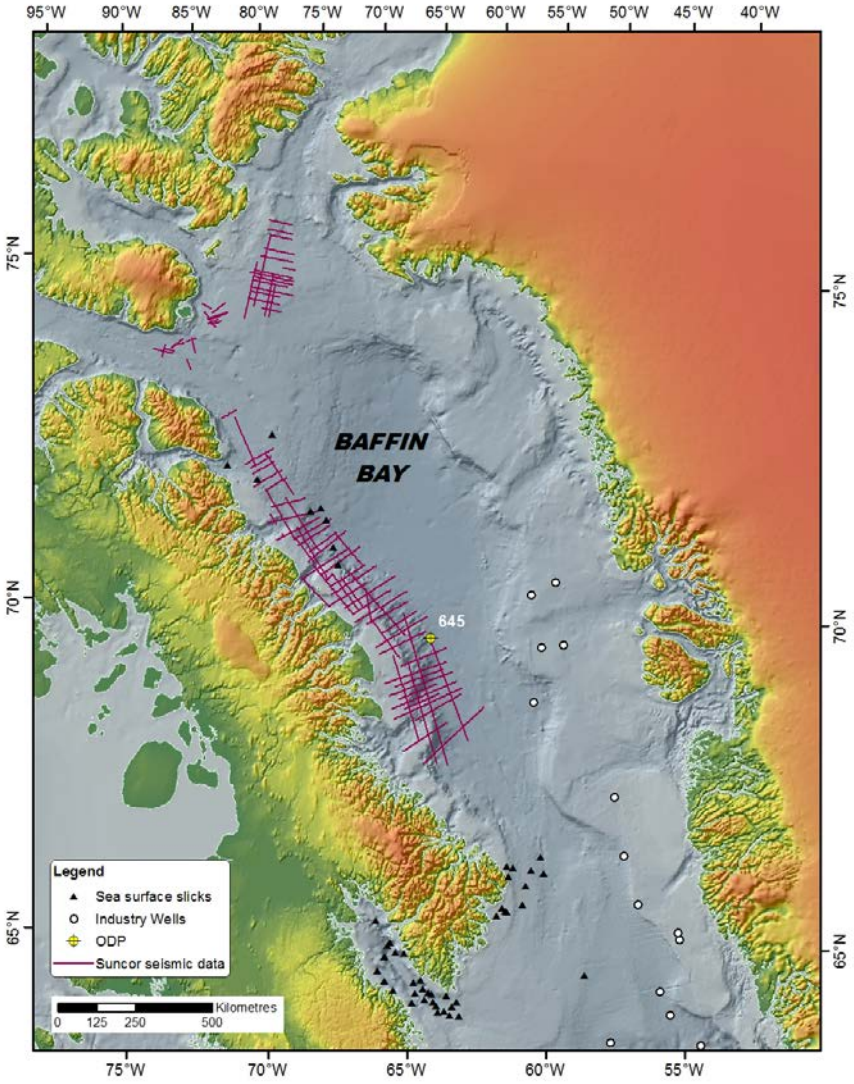
4) Integrated stratigraphic framework for Baffin Bay
- The Labrador sequence stratigraphic framework will be linked to Baffin Bay using the Offshore Drilling Program (ODP) 645, 646 and 647 well data, geological outcrop studies from onshore Bylot Island, previous results from the Baffin Fan, and ongoing research on the Greenland margin done by the Danish geological survey (GEUS).

5) Petroleum systems assessment
- Mapping areas of interest for petroleum systems based on the interpreted tectonic and stratigraphic influences. The variation in sediment thickness, development of major unconformities, development of potential reservoirs and source rock development will be the major factors considered. Additionally, the presence of documented offshore oil slick appearances (Figure 3 and 4) will be considered in the light of this analysis.

Results

Ongoing Progress in this activity includes:

- Key wells offshore Labrador have been identified for modern palynological assessment to improve the biostratigraphic age dating and paleoenvironmental interpretations in both the Cenozoic section and within the Cretaceous graben structures. The Corte Real P-85 well (Figure 3) has been resampled for palynological processing in late 2014. The Gudrid H-55 well (Figure 3) is planned for resampling in the fall of 2014.
- Cores from the Gjoa G-37 and Hekja O-71 wells (Figure 3) have been examined with cores from an additional 15 wells planned for assessment in early October 2014.
- Seismic data compilation is underway including: the loading, migration and assessment of Suncor SEG-Y data (Figure 4). At this point, 16 additional lines have been processed with post-stack migration for use in the interpretation. New and existing SEG-Y data is being organized in project masters for use in seismic interpretation software.



Additional Recently Migrated Data

7810L_mig.sgy
7811L_mig.sgy
7812B_mig.sgy
7812S_mig.sgy
7813L_mig.sgy
7814B_mig.sgy
7816B_mig.sgy
79001A_mig.sgy
79002_mig.sgy
79012_mig.sgy
79013_mig.sgy
79014_mig.sgy
79015A_mig.sgy
79024_mig.sgy
79303_mig.sgy
79328_mig.sgy

Figure 4: Baffin Bay with the portion of the Suncor dataset that has been migrated and loaded.

- A seismic data registration methodology is under development (as a modification of pre-existing work flows for archived single-channel seismic data) to maximize the value of vintage seismic data that comprises much of the available dataset in Baffin Bay.
- Well data is being compiled and loaded into Strater 4 software including well logs, lithology, biostratigraphy and lithostratigraphy (Figure 5). This compilation will serve as the main reference for the sequence stratigraphic framework and includes 30 Labrador Sea wells, ODP 645 and available well data from the Greenland margin (Figure 3).
- The ArcGIS map compilation is ongoing and involves the compilation of base layers for use in map production including: bathymetry, seismic navigation, onshore geology, well locations, and documented oil seep observations (Figures 3, 4 and 6).
- The status of the GSC Atlantic legacy high resolution seismic lines in Baffin Bay and Labrador Sea have been assessed to determine which scanned sections have been converted to SEG-Y (Figure 6). This information was summarized in a KML file and has been incorporated into the GIS project.
- Evaluation of echosounder data from the Canadian Hydrographic Survey (CHS) is underway to enhance the existing bathymetry data for map production and for evaluation of the utility of future airborne gravity surveys.

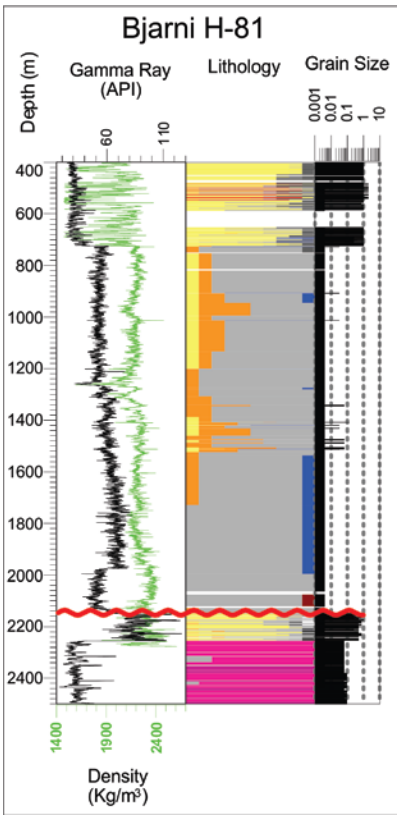


Figure 5: Sample well plot for the Bjarni H-81 well (see figure 3 for location).

Analysis of onshore strata, Bylot Island region (continued from GEM 1):

- Biostratigraphic research of select Bylot Island (Figure 2) and area stratigraphic sections has continued, with the objective of defining principal biostratigraphic zones and interpreting depositional paleoenvironments. Pollen and spores and dinoflagellate cysts provide the most extensive control and demonstrate that non-marine environments are represented in much of the Albian to Paleogene stratigraphic succession. Mollusks and foraminifers are in much less abundance, but have provided important correlation points where available. Inoceramid bivalves from a locality within the Bylot Island formation (informal) indicate a late Santonian to early Campanian age, providing control for palynology zonation; these inoceramid taxa are also known from Nuussuaq Basin in West Greenland, enabling precise correlation with levels in eastern Baffin Bay.
- Detailed review of stratigraphic sections through the Bylot Island succession has continued, and draft composite sections of the entire stratigraphic succession found along the south and southwest coast and in the Twosnout Creek region of Bylot Island have now been compiled. Significant lateral variation in stratigraphic succession and facies can be recognized, demonstrating basin deepening to the northwest during Cretaceous time. Analysis of the structurally more complicated stratigraphic sections preserved in the Maud Bight area of the north coast of Bylot Island continues. It is evident that significant additional fieldwork is required to resolve discrepancies in correlation of the various stratigraphic sections present in the Maud Bight area, as indicated by palynological

biostratigraphy.

- Stable isotope geochemistry of the Twosnout Creek section has been initiated, to assess carbon and oxygen isotopic trends. Isotopic data will be integrated with biostratigraphic data to provide necessary time control on isotopic trends. Stable isotope and organic richness data in the Cretaceous succession will be integrated to assess the presence of strata reflective of oceanic anoxic events.
- Integrated low temperature thermal modelling and structural studies provides insights into the timing, orientation, and magnitude of faulting the Bylot Island area, and will be published in the near future.
- A provenance study of Cretaceous and younger rocks exposed on Bylot Island reflects changes in source area through time related to tectonic events. It will also be published in the near future.

Conclusions

Progress in the *Stratigraphic and Tectonic Framework for the Baffin Bay Petroleum Systems* is ongoing with much of the initial work involving extensive data compilation. Using only vintage seismic data, the compilation phase aims to maximize its value by reprocessing and integration with the other digital datasets.

Short term future work in this activity will include:

- Completion of the seismic data compilation and initiation of seismic interpretation.
- Completion of core logging and initiation of well reports highlighting results from core analyses and sequence stratigraphic interpretations.
- Processing of palynological samples and initiation of palynological interpretations.
- Examination of the single-channel SEG-Y data from the in-house marine geoscience database for possible integration with the multichannel seismic project.
- Updating potential field grids (gravity and magnetics) and compilation of the magnetic anomalies, fracture zones, and spreading centers for the Labrador Sea and Baffin Bay.
- Identification of high priority single-channel surveys for use in interpretation and SEG-Y conversion and registration of selected lines/surveys where needed.
- Assessment of the ArcticNet and CCGS Hudson multibeam coverage in Baffin Bay (including the existence of backscatter information) in order to obtain processed, cleaned, gridded data for inclusion in the GIS project.

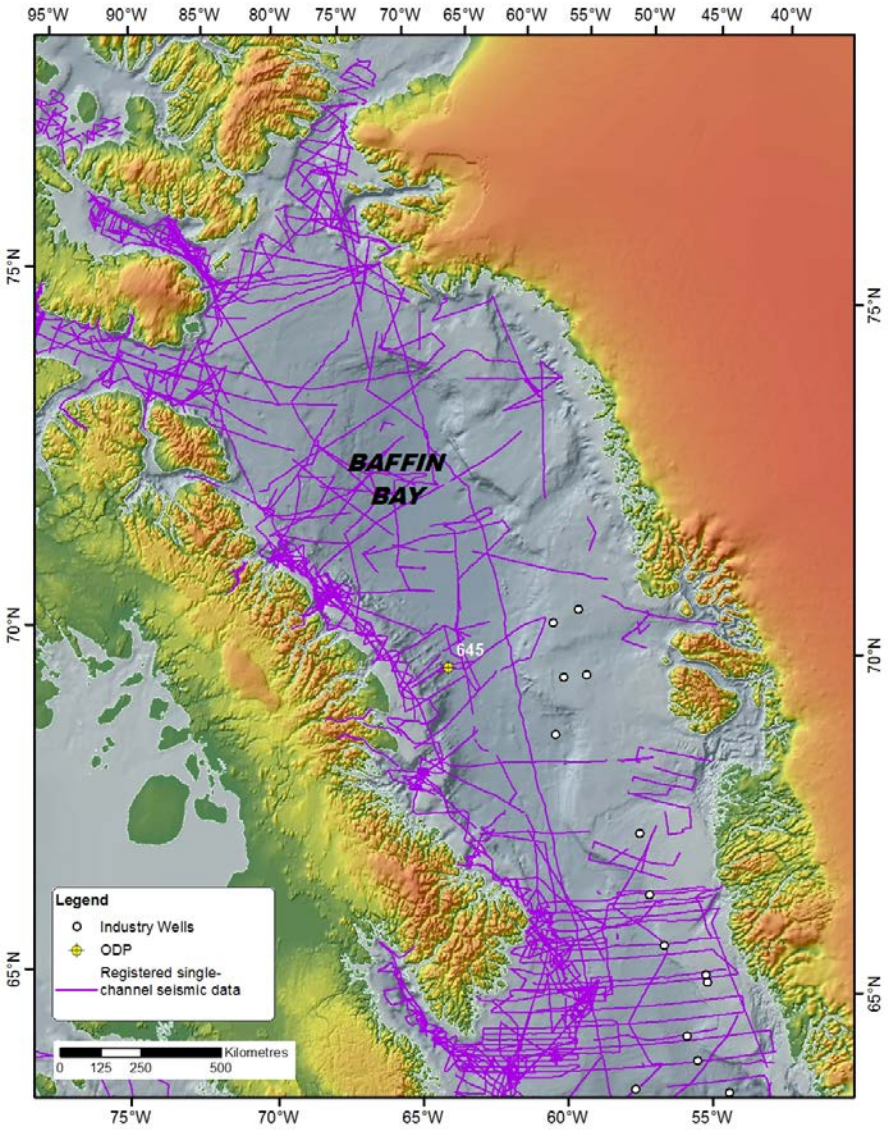


Figure 6: Map of registered (SEG-Y converted) single-channel (high resolution) seismic data in Baffin Bay.

Acknowledgements

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References

Oakey, G.N. and Chalmers, J.A., 2012. A new model for the Paleogene motion of Greenland relative to North America: plate reconstructions of the Davis Strait and Nares Strait regions between Canada and Greenland. Journal of Geophysical Research, 117: B10401.