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Spatial Distribution of Trap Types Relative to the Regional Structural Framework, Baffin Bay, Offshore Greenland

P.W. Bradbury* (TGS) & K. Front (TGS)

SUMMARY

The Baffin Bay area offshore northwest Greenland represents a vast frontier exploration province. The aim of this work has been to create a new structural elements map for the region and assess the spatial distribution of trapping styles within a more detailed framework. The assessment was carried out using a large TGS 2D seismic database (>200,000 km2) acquired between 2007 and 2010 and associated gravity and magnetic data. The main basins in the area are the Melville Bay Basin and Kivioq Basin. In these basins and surrounding areas five distinct trap styles comprise the majority of closures. The trap styles include 1) Tilted fault blocks associated with Cretaceous to Palaeocene rifting. 2) Anticlines formed through differential compaction situated over basement highs. 3) Anticlinal closures formed through regional compression during Palaeogene uplift and localized compression in hangingwall fault blocks. 4) Hangingwall anticlines formed during Palaeogene inversion of normal fault blocks. 5) Stratigraphic traps comprising fans and pinchouts. More than 80 closures have been identified from a high level screening within Cretaceous to Palaeogene levels. The structural style, interpreted age of formation and areal extent of the mapped closures is reviewed.

Introduction

The Baffin Bay area offshore northwest Greenland represents a vast frontier exploration province. The aim of this work has been to create a new structural elements map for the region and assess the spatial distribution of trapping styles within a more detailed framework. Figure 1 shows a structural elements map defining the major basins, structural highs and fault trends present in the area. Figure 2 shows a seismic section orientated approximately NE-SW (location on Fig. 1) through the main structural elements of the northern part of Baffin Bay.

The main basins in the area are the Melville Bay Graben (here referred to here as the Melville Bay Basin, MBB) and Kivioq Basin (KB) with additional smaller associated basins such as the Upernavik Basin to the southeast of the MBB and the Kap York Basin (KYB) to the northwest. The KB is bound to the east by the Melville Bay Ridge and to the west by the Kivioq Ridge in the north. To the south the Kivioq Ridge dies out and the KB widens and links around to the western margin of the Kivioq Ridge. The Upernavik Escarpment defines the southern extent of the major basins and ridges in the Melville Bay area. To the south of the escarpment Cretaceous and Palaeogene strata have undergone extension resulting in down-faulting to the southwest in a series of tilted fault blocks and minor grabens.

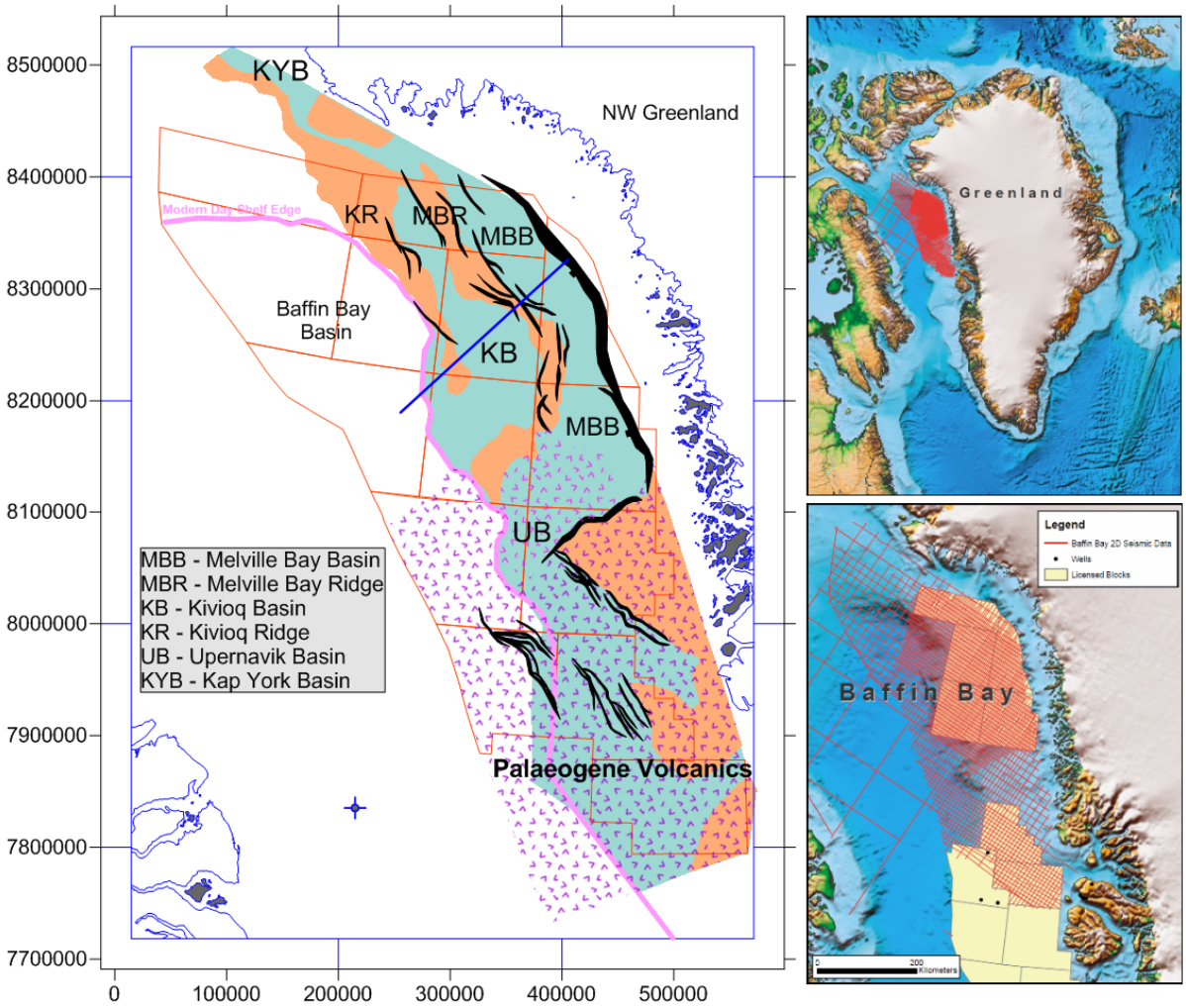

Figure 1 *Structural elements map of offshore Northwest Greenland. Principal basins, ridges and regional faults are shown. Stippled purple V's indicate the approximate outline of the volcanic province. Location of Figure 2 is shown by the blue line.*

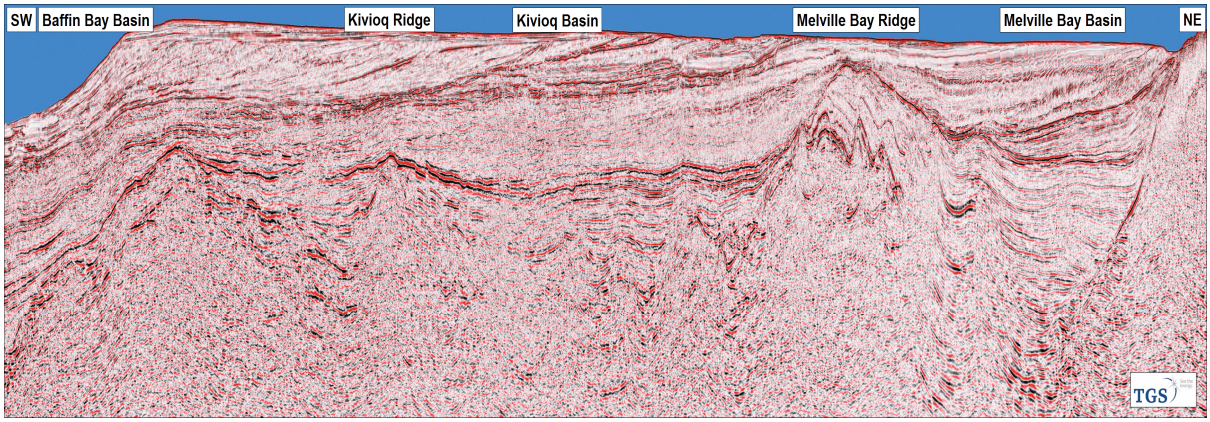

Figure 2 *NE-SW seismic line showing the main structural elements in the Melville Bay area. From northeast to southwest, Melville Bay Basin, Melville Bay Ridge, Kivioq Basin (near the southern extent of the Kivioq Ridge) and Baffin Bay Basin.*

This contribution details the first high level overview of the spatial distribution of closure types and sizes on the Northwest Greenland Margin. The area of interest remains a frontier exploration province with no well control to aid the stratigraphic framework. However, seismic data coverage has increased sufficiently to allow a high level and consistent screening for closure types. The screening conducted has identified structural and stratigraphic closures at all potentially prospective levels in the Baffin Bay region. More than 80 closures have been identified within Cretaceous to Palaeogene levels in close proximity to suggested mature source rocks (Gregersen, 2008) and are often associated with seismic indicators of an active hydrocarbon system. The area presented here approximately corresponds to USGS AU2 predicting minimum – median – maximum values of 1, 60 and 250 undiscovered oil and gas fields in the region (Schenk, 2011).

Schenk (2011) indicates potential source rocks including Cenomanian-Turonian, Campanian and Palaeogene organic-bearing strata that also appear to be regionally extensive. The source rocks are likely to have reached maturity after the development of Cretaceous trapping structures but migration timing relative to later inversion related trap development may prove a critical risk. Reservoir rocks are expected to comprise marginal marine to deep marine slope and fan sandstones of Cretaceous and Palaeogene age (Schenk, 2011, Whittaker, 1997).

Method / Theory

The aim of this work was to define the spatial distribution of closure types and sizes relative to the regional structural framework present in the Baffin Bay area. A 2010 TGS 2D seismic survey in addition to surveys acquired by TGS between 2007-09 and reprocessed in 2011 using new techniques (Bradbury and Woodburn, 2011) were used to improve confidence in geological interpretation especially in sub-volcanic regions. The 2D seismic dataset covers ~200,000 km^2 at a spacing ranging from 3.5 by 8.5km over the shelf to the north of the Upernavik Escarpment and 15 by 15km beyond the shelf and to the northwest.

Closure type distribution and regional structural framework

Five distinct trap styles comprise the majority of closures observed in the Baffin Bay area. The trap styles include 1) Tilted fault blocks associated with Cretaceous to Palaeocene rifting. 2) Anticlines formed through differential compaction situated over basement highs. 3) Anticlinal closures formed through regional compression during Palaeogene uplift and localized compression in hangingwall fault blocks. 4) Hangingwall anticlines formed during Palaeogene inversion of normal fault blocks. 5) Stratigraphic traps comprising fans and pinchouts.

The MBB is bound to the east by a large offset normal fault formed during early Cretaceous rifting. The form of the western boundary to the MBB is more variable. In the north the MBB formed as an early Cretaceous graben but has subsequently undergone significant inversion on the western boundary. On the seismic line (Fig. 2) the MBB forms a half graben with closures present within the tilted fault blocks of the western boundary. To the south where the MBR is oriented N-S there is further evidence of compression inverting the original graben geometry. The areas interpreted to have undergone later Palaeogene compression feature various inversion related closure types including inverted faulted fault blocks and anticlinal closures.

The Kivioq Basin does not contain as much sediment fill as the MBB however source rocks are expected to have reached maturity in deeper kitchen areas of the basin. Updip and adjacent to the kitchen areas the KB contains a variety of trapping styles. Cretaceous sediments are observed in faulted anticlinal closures within the basin with tilted fault block closures present on both the boundary with the MBR in the east and Kivioq Ridge to the west. The KB does not exhibit the same late inversion closure types as seen in the northern and far southern parts of the MBB.

South of the Upernavik escarpment tilted fault blocks are the dominant closure styles. In this region source rocks are expected to comprise the regional Cenomanian-Turonian, Campanian and Palaeogene and potentially additional local hydrocarbon prone shales. Distance from the kitchen areas is greater in this area with migration required from source rocks at greater depth to the southwest.

Example

Figure 3 is an example of the tilted fault block and associated trapping geometries observed in the Cretaceous in the Baffin Bay Area.

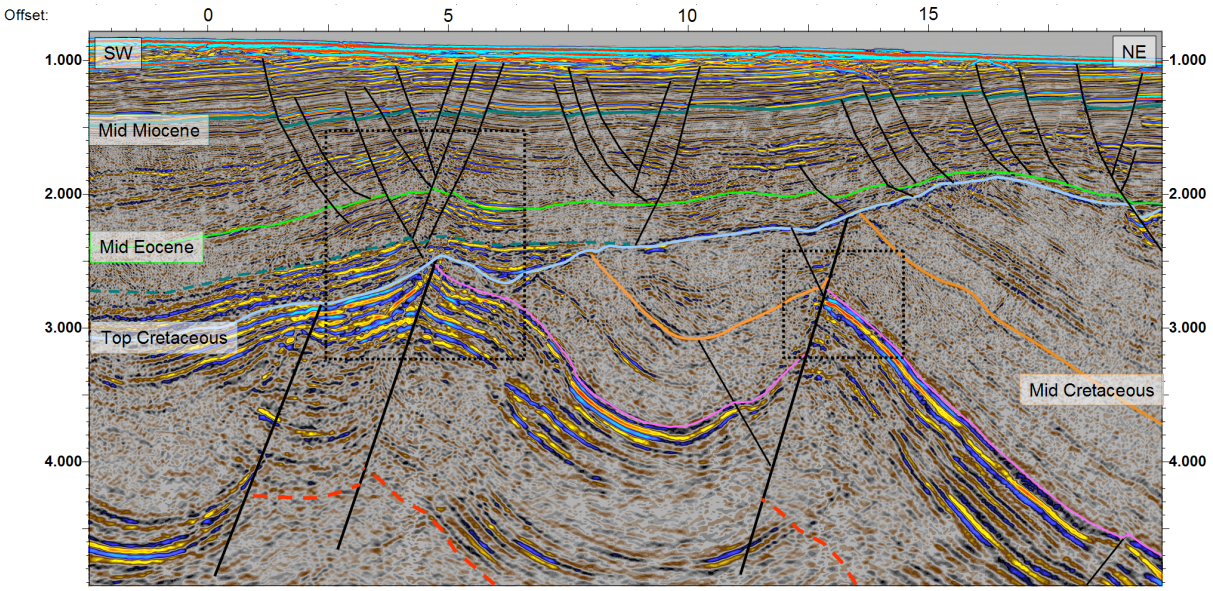

Figure 3 *Seismic line illustrating the presence of tilted fault block closures observed in the Baffin Bay region.*

Mid to lower Cretaceous sheet sands are may be present in the footwall blocks up dip of the potential kitchen area. Source rocks are hypothesized to be lower Cretaceous shales reaching maturity post Eocene times. These closures are considered to be lower risk due to favourable trap development, source maturity and migration timing.

Figure 4 (left) shows the normalized contribution of closure types identified at different ages in Baffin Bay. There are a high percentage of anticlinal closures (40-60%) at all ages which also constitute the

largest cumulative areal closure (Fig. 4, *right*). Tilted fault blocks are the next most significant contributors with 20-40% contribution mostly concentrated in the Cretaceous rifted section and showing the minimum, median and maximum areal extents of 30, 75 and ~300km^2. Inversion related closures comprise a smaller percentage of the total closures mapped reflecting the lesser geographical extent of inversion and are more prevalent within the Cretaceous section. Stratigraphic closures are most commonly identified from the mid Eocene any younger sections.

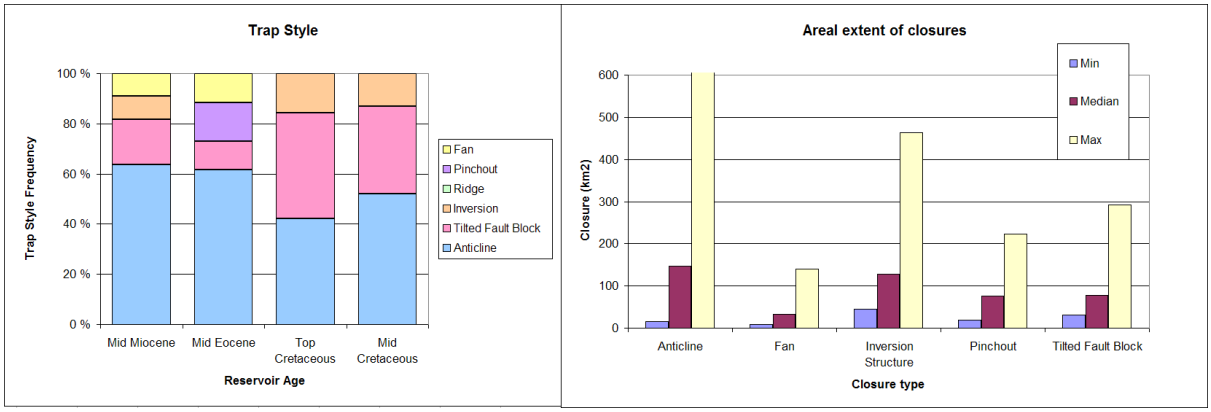

Figure 4 *Shows the distribution of closure types relative to reservoir age (n = 82). Relative areal extent of closure (minimum, median and maximum in km^2) for each closure type (right) and percentage contribution to the total number of closures by each type at each age bracket.*

Conclusions

This contribution has assessed both the spatial distribution and areal extent of the range of closure types observed in the Baffin Bay region. Clear trends in the distribution of closure types and size are seen relative to the regional structural framework. Closures have been observed and mapped in close proximity to seismic indications of an active petroleum system. Phase 2 will be directed towards ranking the closures found in terms of potential reservoir, source, seal and distance from kitchen area. The Baffin Bay region of North West Greenland continues to reveal further potential as geological understanding and mapping increases with the ever expanding geophysical database. Further insight will come as exploration activities increase and geological data is added to the resource.

Acknowledgements

The authors thank TGS-NOPEC for authorization to present this work and in particular Erling Frantzen, Kjell Trommestad, Reidun Myklebust and Kjersti Isrenn.

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