Three Segments of the Arctic Continental Margin, Beaufort Sea, Canada: Deep Seismic Profiles of Crustal Architecture

James Helwig*, Naresh Kumar, Pete Emmet
Consultants, ION BasinSPAN Programs, Houston, Texas, USA
jim.helwig@iongeo.com

and

Menno G. Dinkelman
Chief Geologist, ION BasinSPAN Programs, Houston, Texas, USA

Summary

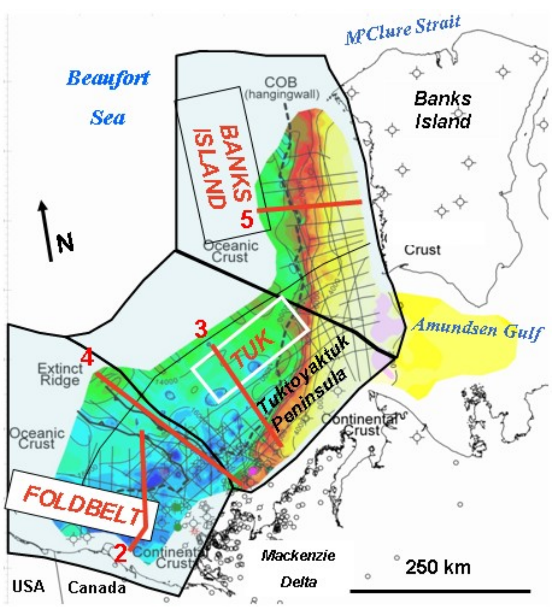
The thick clastic sedimentary prism deposited on the continental margin of the Beaufort Sea was largely derived from the Mackenzie River; this river and its Mackenzie Delta depocentre were localized by both the initial Mesozoic rifting of the Canada Basin and the much younger Tertiary deformation of the easternmost Arctic Alaska Terrane (AAT). Utilizing over 16,000 km of 2D, 40 km-deep, PSDM marine seismic data from surveys made in 2006-2008 for a multi-client industry group, we interpret the crustal-scale geology of the Beaufort Sea portion of the Canadian Arctic Passive Margin (CAPM) from the US border east and north to Banks Island.

Introduction

The passive margin of the Beaufort Sea in Canada is divided into 3 distinctly oriented segments (Figure 1) that reflect their distinct crustal structure and history in seismic and gravity profiles:

1. The Beaufort Foldbelt segment trends east from the US border to the Mackenzie Delta and manifests Tertiary propagation of the AAT compression north into the passive margin prism.
2. The Tuk segment strikes NE parallel to the Tuktoyaktuk Peninsula and shows transtensional structure including strike-slip movements during both breakup and later Oligocene reactivation.
3. The Banks Island segment trends north from Amundsen Gulf and displays a simple rift-extensional passive margin style throughout its Meso-Cenozoic depositional history.

Figure 1: Tectonic segments of Canadian Beaufort Sea showing location of profiles in figures 2 - 5.



Tectonic Development of the Three Segments of the Margin

The Beaufort Foldbelt segment is a unique marine compressional foldbelt characterized by linkage to the Tertiary deformation of the NE Brooks Range - Yukon salient of the Cordillera. The foldbelt is characterized by 5-km amplitude growth folds detached in deep mobile Cretaceous shales at depths of 12-15 km (Figure 2; Helwig et al, 2009). Hence the basin is an unusual hybrid basin, both passive margin and foreland. The basement of the foldbelt includes both continental crust of the Arctic Alaska Terrane that was rifted from the Tuk and Banks Island segments in Early Cretaceous time as well as oceanic crust. The continent-ocean boundary (COB) is defined principally by steep gravity gradient rather than seismic reflectors because the fold belt obscures the image of the 15 km deep sub-detachment crust. Slightly oblique to the frontal zone of folding, a Miocene inversion feature, the Tulluk High, is in apparent continuity with the linear regional gravity low of the deep Canada Basin; and hence it is interpreted as an inversion of the extinct spreading centre.

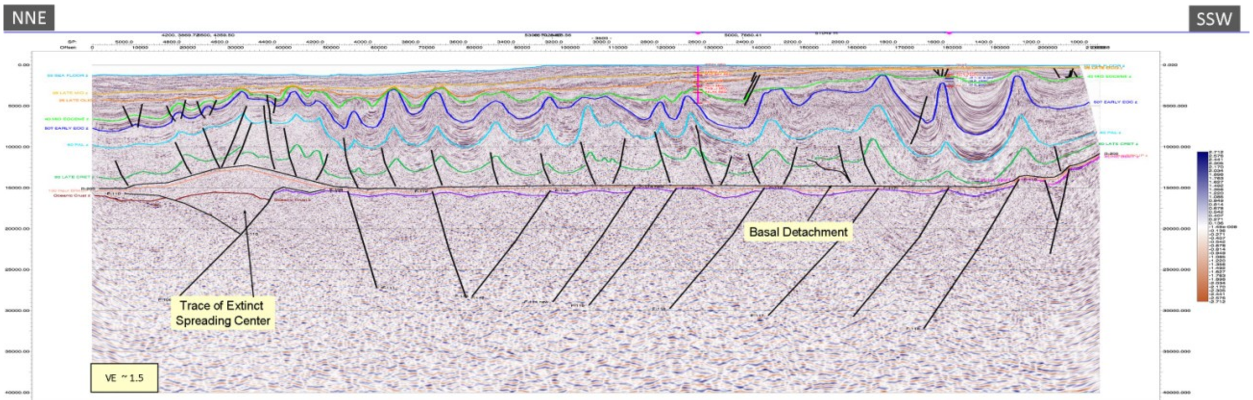


Figure 2: Seismic profile of the Beaufort Foldbelt showing detached folds of Cretaceous through Miocene age overlying the breakup unconformity and inferred basement faults. The outboard (NNE) end shows the Tulluk High. Line is 200 km long and 40 km deep.

The Tuk segment is identified as a transform-extensional margin to the east of the foldbelt. The sinistral Tuk Transform fault forms the COB and is kinematically required to accommodate the extension of the more northerly oriented Banks Island margin (Figure 1). A seismic profile crossing the center of the Tuk segment (Figure 3) illuminates the Tuk fault at the COB and the rifted oceanic crust and fracture zones overlain by Jura - Cretaceous syn-rift sediments and capped by the ~136 Ma breakup unconformity. The overlying undeformed passive margin prism achieves 15 km thickness. In the post-sea-floor spreading history, the nearshore and onshore continental parts of the Tuk segment are affected by an Oligocene episode of fault reactivation including extensional and dextral strike-slip faults, most notably in the Oligocene Amauligak half-graben / pull-apart basin (Figure 4). This structural basin interacts with the diffuse transitional boundary of the Foldbelt in a quite complex 3D growth geometry.

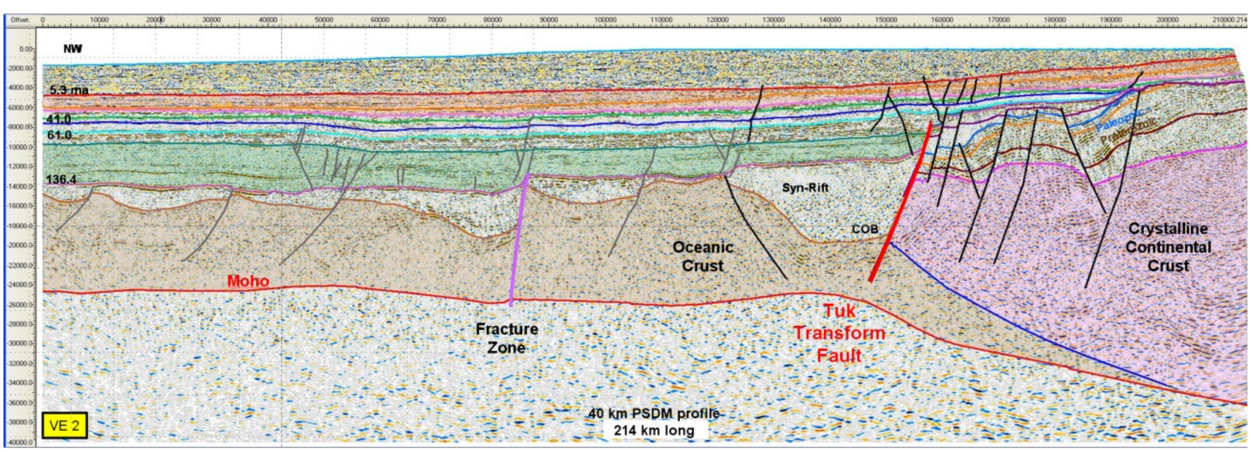


Figure 3: Seismic profile of the Tuk segment showing the abrupt COB marked by the Tuk Transform fault (TT). Note the 8 km thick syn-rift graben at the COB, and the fracture zone.

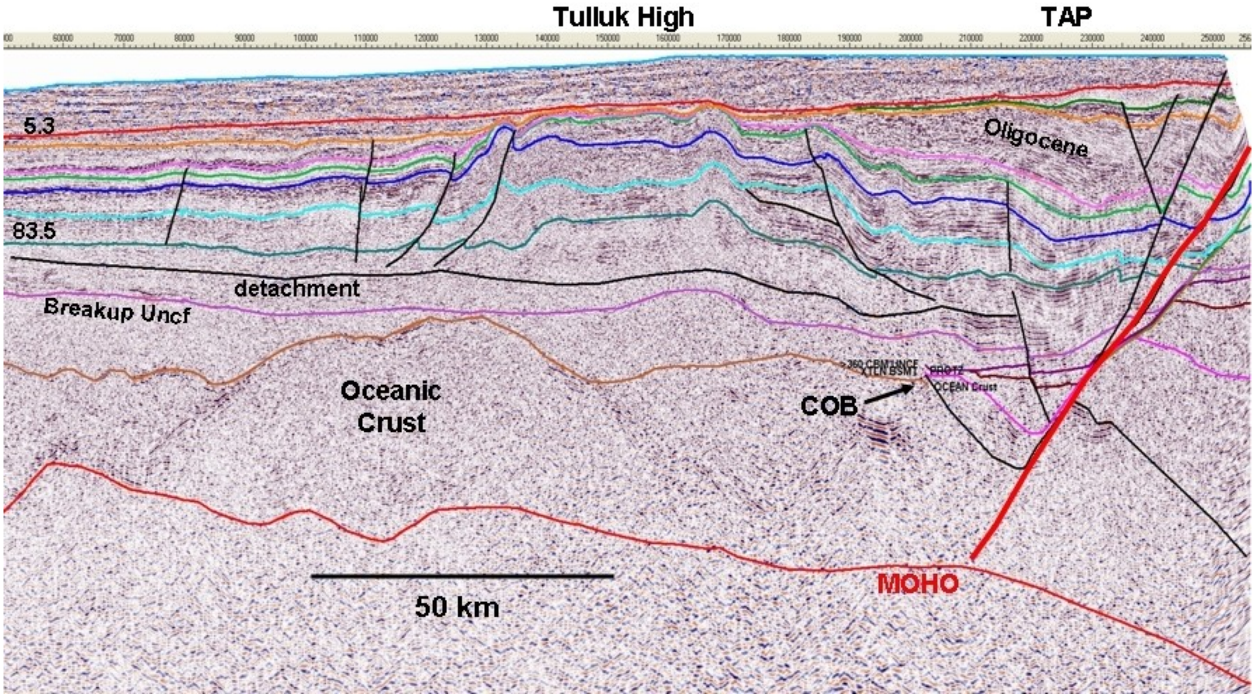


Figure 4: NW oriented seismic profile showing continental and oceanic crustal architecture at the transitional boundary of the Foldbelt (near strike-oriented) and Tuk segments of the margin. The red fault marks the edge of the Tarsiut-Amauligak pull-apart half-graben filled with Oligocene Kugmallit Formation growth strata (Enachescu, 1990).

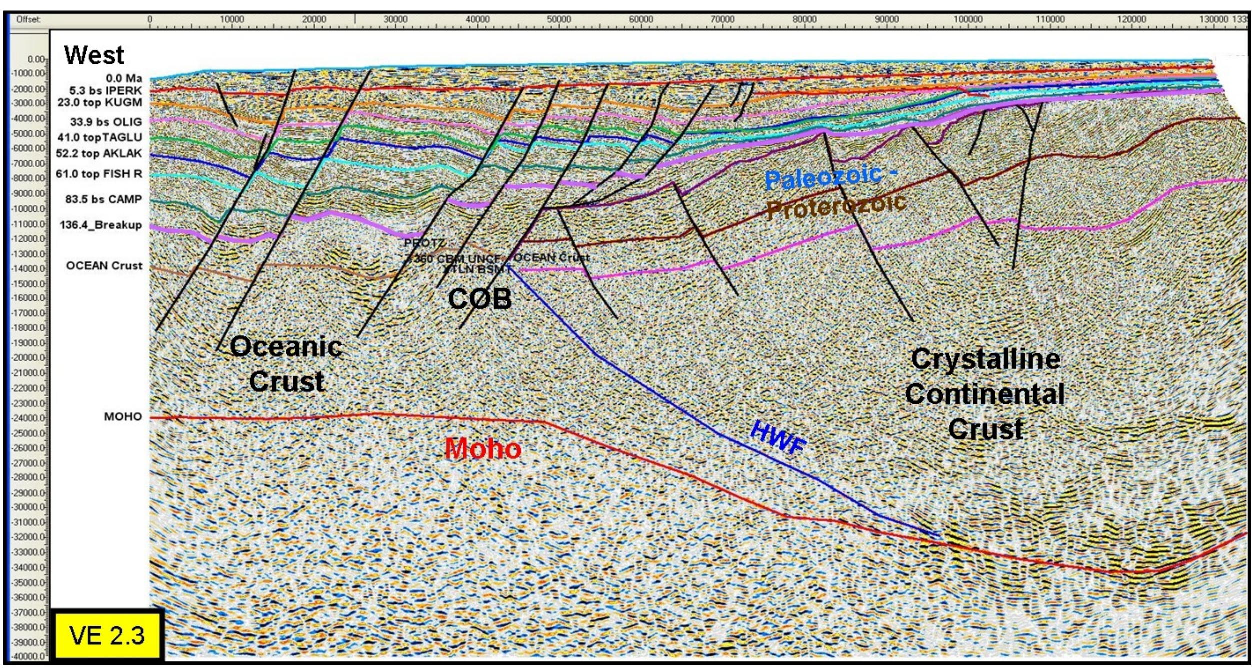


Figure 5: Seismic profile of the Banks Island segment (132 km long). Note the antithetic faults in the continental crust, synthetic faults in the post-breakup (orchid horizon) prism, and inferred reactivation of faults in oceanic crust. HWF – hanging wall fault of crustal attenuation.

Lastly, the Banks Island segment of the margin trends north-south and is marked by a well-developed Paleozoic subcrop and normal faulting throughout its long Meso-Cenozoic history. The seismic data are very limited in their seaward extent, but suggestive of a hanging-wall style continental margin which is supported by gravity observations (Figure 5; Kumar et al, 2010).

Conclusions and Discussion

The contrasting architecture of the three segments of the Beaufort Sea margin reflects their distinct origins and roles in the opening of the Canada Basin and in the overprint of younger Cordilleran deformation. Our analysis shows that the continuation of the Canada Basin gravity low, identified by many workers as the spreading axis of the Canada Basin (Grantz et al, 2007), if logically continued under the Beaufort Sea Margin, is in fact revealed by the Miocene oblique inversion structure (Tulluk High) affecting the Beaufort Foldbelt. The resulting continental margin architecture at time of rifting is consistent with the separation of the Arctic Alaska Terrane (AAT) from the North American Plate (NAM) in Late Jurassic to Early Cretaceous time with a pole of rotation located in the Blow River Trough, just west and south of the Mackenzie Delta (Dixon, 1996). In this setting, the structure and stratigraphy of the Banks Island margin and Alaskan Beaufort coastal margin, including the Beaufort Foldbelt Segment of Canada, are compatible with origin as conjugate rifted margins. The corner of the Arctic Alaska Plate that separated from North America by extension and sinistral transform motion along the Tuk Transform fault could correspond to the Beaufort Foldbelt segment or areas to the south on the west flank of the inverted Blow River Trough in the Yukon. The difficulty of analyzing and reconstructing the crustal structure of the pivotal region of the opening of the Canada Basin is not surprising, given the Tertiary overprinting of contraction and trans-tension, and it will continue to be a challenge (Lane, 2002; Dinkelman et al, 2008, 2010).

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