Evaluating Current Plate Tectonic Models in the Light of Newly Acquired Geophysical Data in the Amerasian Basin

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Summary

Tectono-stratigraphic interpretations of recent deep seismic and gravity data in conjunction with deformable plate tectonic reconstructions have helped us advance the anti-clockwise rotational model for the evolution of the Canada Basin. The interpretation of the Canadian margin of the Beaufort Sea supports an anti-clockwise rotational model for development of the Canada Basin, with the addition of an initial stage of oblique separation. While our work supports the anti-clockwise rotational model for development of the Canada Basin, further modeling and plate reconstructions have shown that this model appears inadequate to explain the origin and evolution of the Amerasian Basin beyond Banks Island to the Lomonosov Ridge.

Introduction

In this study deformable plate reconstructions were used to develop a model for the tectonic development of the Amerasian Basin. More than 16,000 km of newly acquired deep (40 km) 2-D seismic PSDM data in the Canadian Beaufort Sea (Figure 1) provided input into the model by enabling us to more accurately define and constrain the Continent-Ocean Boundary (COB), and measure Beta factors. Once the Beta factors were applied to the deformable plate margins in order to remove the extensional effects of rifting prior to break-up, incremental plate reconstructions from 145 Ma to present day were created using published poles of rotation. The poles of rotation were iteratively adjusted to achieve the best fit and geological and geophysical data were used on each side of the conjugate deformable plate margins to provide constraints for the model. Tectono-stratigraphic interpretations of the deep seismic and gravity data (Helwig et al, 2010) also helped in the development of the model and in defining the timing of break-up and rifting.

Our model, supported by deep seismic and gravity interpretations, refines the anti-clockwise rotational plate tectonic model for the opening of the Canada Basin proposed by Embry (1990); Lawver et al (2002); Grantz et al (2007); and others. The anti-clockwise rotational model is also widely believed as the most likely model for the opening of the entire Amerasian Basin and this study sought to evaluate the model in this part of the Basin. In contrast to the Canada Basin, the Amerasian Basin from Banks Island to the Lomonosov Ridge is a vast, relatively unstudied area with poor data coverage and lacking definitive sea-floor magnetic anomaly and paleomagnetic data.

Beaufort Sea Evidence for a Two-Phase Model for Opening of Canada Basin

We arrived at a plate model for the Canada Basin that clearly demonstrates a two phase opening of the Basin. The first phase (145-136Ma) was characterized by extension and thinning of continental crust along the Banks Island margin, strike-slip movement or transtension along the Tuk Transform Fault, thought to be due primarily to the geometry of the plate boundaries, and initial sea-floor spreading

(Figure 2). The model also showed considerable anti-clockwise rotation of individual fault blocks in the hinge zone between the Alaska North Slope and the Mackenzie Delta. Phase II of the opening of this part of the Basin began to occur at around 136 Ma when the Tuktoyaktuk margin was separated from the Alaska Arctic Terrane by anti-clockwise rotation and inferred asymmetrical fan-shaped sea-floor spreading (Figure 3). Sea-floor spreading was assumed to have ended by 125-120 Ma. The pole of rotation for our model lies approximately on the axis of the Mackenzie Valley near the hinge zone between the eastern Brooks Range and the Mackenzie Delta.

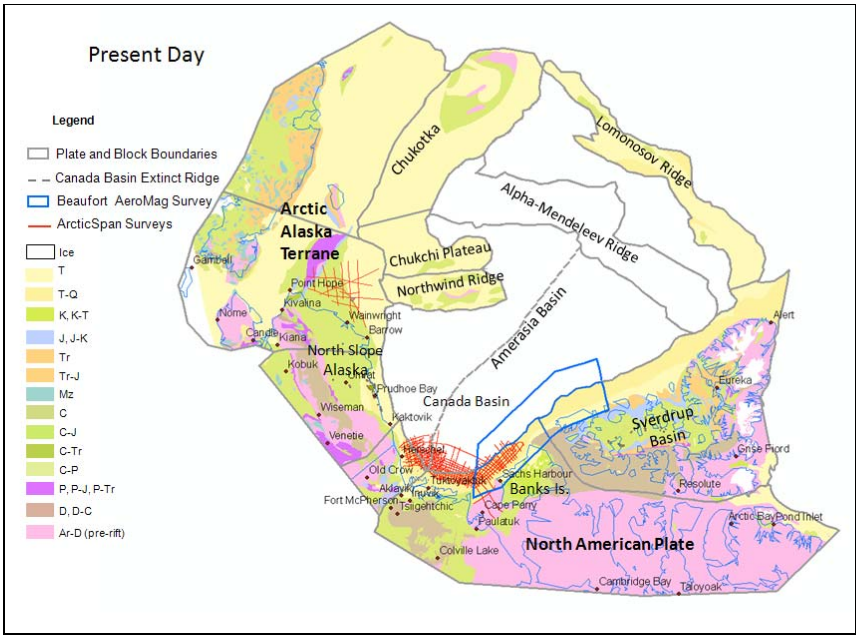

Figure 1: Present Day configuration of the Amerasian Basin and related tectonic elements

We verified the model against recent deep seismic and gravity interpretations. Helwig et al. (2010) divide the southern and southeastern Canada Basin margin into three distinct segments. While the Beaufort Sea margins are extensional as a whole, the Tuktoyaktuk Peninsula defines a NE-trending segment of the passive margin interpreted as a sinistral transform-extensional COB, along which the Phase 1 strike-slip movement predicted by the model occurred. The central Canada Basin Gravity Low marks the position of the extinct ridge of the spreading centre (Figure 1). The Banks Island segment trends north from Amundsen Gulf and displays a simple rift-extensional passive margin style throughout its Meso-Cenozoic depositional history consistent with the preliminary plate tectonic model. Mapped seismic horizons are consistent with a first phase of rifting and initial sea-floor spreading from late Jurassic to Valanginian time, and a second phase of sea-floor spreading from Valanginian to Barremian or earliest Aptian time (Helwig et al, 2010). The onshore pre-Mesozoic paleo-geology and Mesozoic onlap geology, not discussed here, also support the reconstructions shown in Figures 2 and 3.

Evaluating the Anti-Clockwise Rotational Model beyond Banks Island

We evaluated the applicability of the anti-clockwise rotational model beyond an inferred transform zone in the eastern part of the Canada Basin to encompass the entire Amerasian Basin (Figures 2 and 3). We used the most accurate COB and Beta factors from published interpretations and gravity data and made the assumption that the Alpha-Mendeleev Ridge is over-thickened oceanic crust and the Northwind Ridge and Chukchi Plateau are extended continental crust. The Northwind Ridge and Chukchi Plateau were rotated clockwise away from Chukotka during the final stages of opening (Grantz et al 2007).

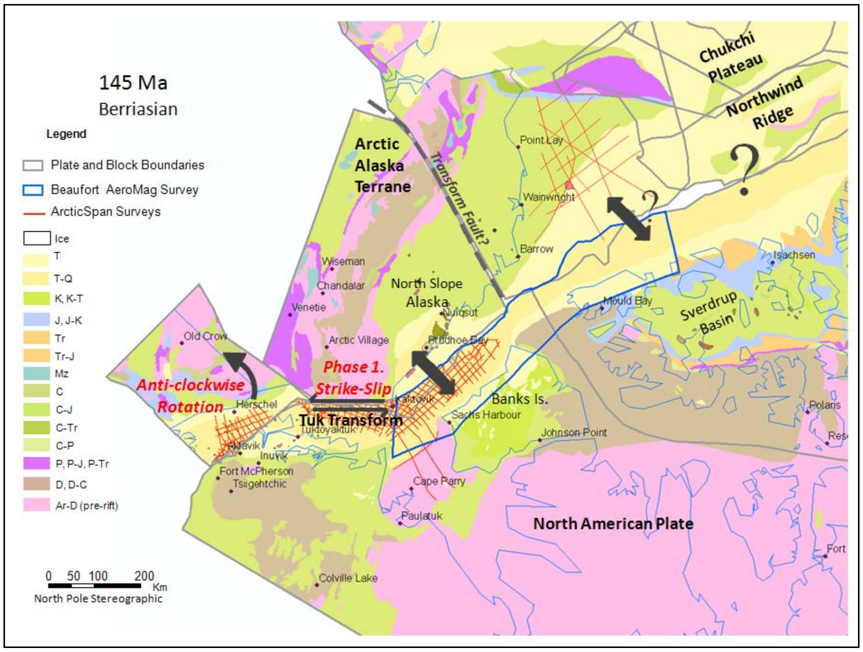

Figure 2: 145 Ma pre-rift reconstruction of the Canada Basin

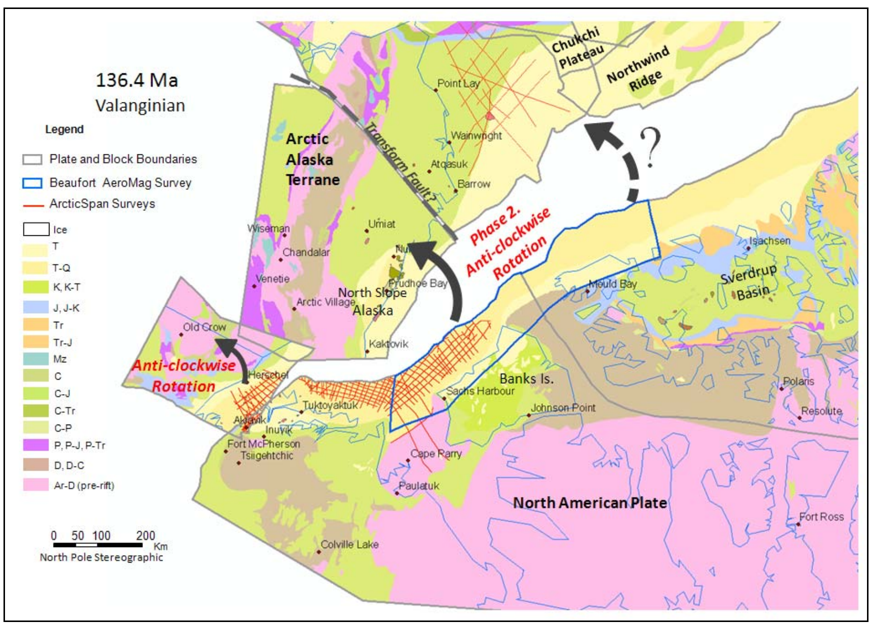

Figure 3: 136 Ma reconstruction of the Canada Basin

We found that, even with removal of pre-rift extension, a good fit for the remainder of the Amerasian Basin could not be obtained using the anti-clockwise rotational model. There was considerable overlap and under-fit in the Northwind Ridge - Sverdrup Basin area and along the Lomonosov Ridge. To improve the fit, based on scant geological and potential field evidence, we cut the Amerasian margin into several segments separated by inferred transform zones, each with separate poles of rotation and rates of spreading. This resulted in an improved fit, but still with measurable overlap along the Lomonosov Ridge. Implied in the modified model was major extension and compression along the transform zones to compensate for the overlap and under-fit, which does not appear to be supported by field evidence. As a result, we conclude that a different model is required to explain the development of the Amerasian Basin beyond Banks Island to the Lomonosov Ridge.

Conclusion and Discussion

A seismic-reflection based geological interpretation of the Canadian margin of the Beaufort Sea supports an anti-clockwise rotational model for development of the Canada Basin, with the addition of an initial stage of oblique separation. However, the anti-clockwise rotational model appears inadequate to explain the origin and evolution of the Amerasian Basin beyond Banks Island. Recent work (for example Miller, 2009) suggests that a later phase of Cretaceous rifting occurred in the Amerasian Basin beyond Banks Island causing Wrangel Island, Chukotka and the Alaska Arctic Terranes and Chukotka microplate to move away by clockwise rotation from the Lomonosov Ridge. Hutchinson (pers. com, 2009) interprets a prominent graben feature caused by extensional faulting approximately 300 km offshore from Prince Patrick Island on UNCLOS seismic data acquired by the USGS and GSC in 2007-2009 (Hutchinson, 2009). This graben can be traced on gravity data and the anomaly runs parallel to the Sverdrup Basin coastline for several hundred kilometers. This faulting may be related to onshore Cretaceous rifting with the same trend, interpreted on seismic data in the Banks Island-Prince Patrick Island area.

Development of a plate model for the Amerasian Basin is hampered by sparse data coverage and an absence of definitive sea-floor magnetic anomalies and paleomagnetic data. However, over the past several years there has been renewed interest in the area resulting in new scientific research and data acquisition. Future work applying deformable plate reconstruction techniques and interpretation of industry deep seismic and high-resolution gravity and magnetic data should help in the development of a plate model for the development of the Amerasian Basin.

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