Variations in crustal structure across the Nova Scotia continental margin and its conjugate

Ka Wai Helen Lau [1]**; Keith E. Louden** [2]**; M. Nedimovic** [3]

(1) Dept. of Oceanography, Dalhousie University, Halifax, NS, B3H 4J1, Canada; kwhlau@dal.ca
(2) Dept. of Oceanography, Dalhousie University, Halifax, NS, B3H 4J1, Canada; Keith.Louden@dal.ca
(3) Dept. of Earth Sciences, Dalhousie University, Halifax, NS, B3H 4J1, Canada; mladen@dal.ca

ABSTRACT

The East Coast Magnetic Anomaly and associated seaward dipping reflectors, both suggesting volcanism, are observed on the south-western Nova Scotia margin but quickly reduce in magnitude to the northeast. A comparison of seismic observations across three previous refraction profiles (from NE to SW: SMART-1,2,3) also shows a parallel decrease in syn-rift volcanism as the margin becomes non-volcanic near the central line (SMART-2). A velocity model from a new profile northeast of SMART-1 suggests continuation of non-volcanic features, such as serpentinized mantle and thin oceanic crust, to the north-eastern end of the margin. Being conjugated to SISMAR-4 on the Moroccan margin, this new profile facilitates a better constrained kinematic reconstruction of the rifting and breakup of the complete Nova Scotia-Morocco conjugate margins.

KEYWORDS: Nova Scotia, Morocco, Atlantic, Conjugates.

1. Introduction

The Nova Scotia rifted continental margin lies in a transitional segment between the volcanic US East Coast margin to the south and the non-volcanic Newfoundland margin to the north. The East Coast Magnetic Anomaly (ECMA) and the associated seaward dipping reflectors (SDR), both well-known volcanic margin phenomena, are observed off Georges Bank on the south-western part of the margin, but they quickly reduce in magnitude to the northeast (FIG.1). A comparison of seismic observations across different parts of the margin also shows a parallel decrease in syn-rift volcanism as defined by three previous cross-margin refraction profiles (SMART-1,2,3). The margin changes from volcanic to non-volcanic between the southern line (SMART-3; Dehler *et al.*, 2004) and the central line (SMART-2; Wu *et al.*, 2006).

In addition to the lack of evidence for syn-rift volcanism, there is another feature that uniquely defines the non-volcanic part of the margin. Existing data between the central and the northern line (SMART-1; Funck *et al.*, 2004) show a wide continent-ocean-transition (COT) zone characterized by a pervasive layer with velocities of 7.3–7.9 km/s, intermediate between crust and mantle, that we interpret as partially serpentinized mantle (FIG.1, 2b & c). The nature of the crust overlying the partially serpentinized layer is, however, difficult to define as it was under-sampled due to sparse receiver spacing. Furthermore, there is a lack of a conjugate pair profile with the SISMAR-4 profile on the Moroccan margin. Therefore, new data acquisition was necessary to reduce the uncertainties in crustal interpretations and conjugate margin reconstructions.

In November 2009, a new refraction profile was acquired by the Offshore Energy and Technical Research (OETR) Association of Nova Scotia along a coincident deep reflection profile (GXT line 2000) to the northeast of SMART-1 (FIG.1). The profile was obtained using 100 ocean-bottom seismometers and with particularly dense spacing (2.5 km) within the COT that gives greatly improved resolution in this region. It also extends 125 km seaward of the reflection profile to better constrain the oceanic crust. Please refer to Makris *et al.* (in section Nova Scotia, this conference) for details on data acquisition and velocity modelling. In this paper, we present our interpretation of this new velocity model and integration with other observed refraction and coincident multi-channel reflection profiles in the study area. This comparison clearly demonstrates a northeastward continuation of the non-volcanic structures. A comparison of conjugate margin structures confirms a marked asymmetry with a much narrower COT off Morocco.

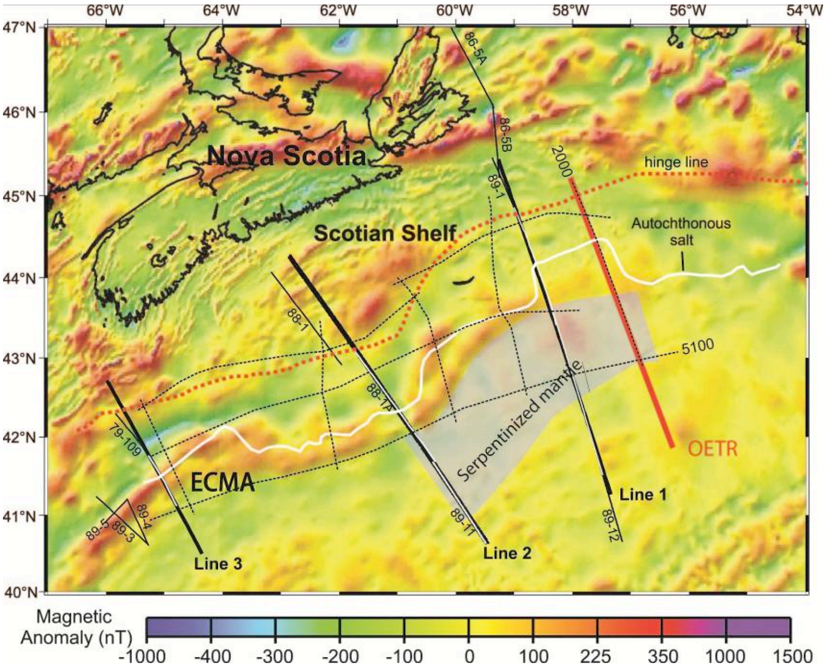

FIG.1 – Magnetic anomaly map of Nova Scotia margin. [CAN YOU DESCRIBE THE SEISMIC LINES? PEOPLE WON'T KNOW THAT LINES 1, 2 AND 3 ARE SMART LINES 1, 2 AND 3, ETC.]

2. Structural variations

FIG. 2a shows the velocity model of the OETR profile. This simple model shows structures very similar to those determined for SMART-1 (FIG.2a & b). This comparison indicates similar non-volcanic characteristics of the three major crustal zones, namely continental, transitional and oceanic. Firstly, the continental crust in the NW of profile OETR thins over a relatively wide zone (> 180 km). Even wider rifts are observed on the SMART-1 and SMART-2 profiles. Secondly, the oceanic crust composed of layers 2 and 3, is found to be thinner than average. In the SE of profile OETR, oceanic crust is 4–5 km thick, which is similar to SMART-1, while for SMART-2, it increases only slightly to ~ 6 km. Thirdly, there is a wide transitional zone (COT) on all profiles that cannot be explained by either a continental or oceanic crustal model. The COT is modeled on profiles OETR and SMART-1 as two layers above normal mantle. The lower layer, interpreted as partially serpentinized mantle, has velocities of 7.2–7.6 km/s and a thickness of ~ 6 km. A similar layer is observed on profile SMART-2 but with higher velocities (7.6–7.8 km/s) and smaller thicknesses, suggesting lower degree of serpentinization.

The upper layer of the COT is the most variable crustal feature along the margin and its crustal origin is least constrained due to its small thickness and large depth. According to profile OETR, this layer has a velocity of ~ 5.3 km/s and an overall seaward decrease in thickness (from 4 to 2 km). It is best interpreted as oceanic layer 2 as it is continuous with this layer on the seaward end. On SMART-1, a thin layer, with similar velocities, is interpreted as exhumed mantle for the seaward half of the COT. Since we do not see evidence for exhumed mantle on profile OETR and SMART-2, we reinterpret this layer to be ultra-thin oceanic crust. As oceanic layers 2 and 3 are interpreted for the seaward part of the COT on SMART-2, we observe a southward trend of more fully developed oceanic crust above serpentinized mantle.

On the landward part of the COT, the upper layer is interpreted as continental crust on

SMART-1 and -2. On SMART-2, it is observed as rotated fault blocks with fanning syn-rift sediment layers in the reflection data. Therefore, on profile OETR, continental crust may possibly extend beyond the seemingly abrupt thinning at ~ 170 km.

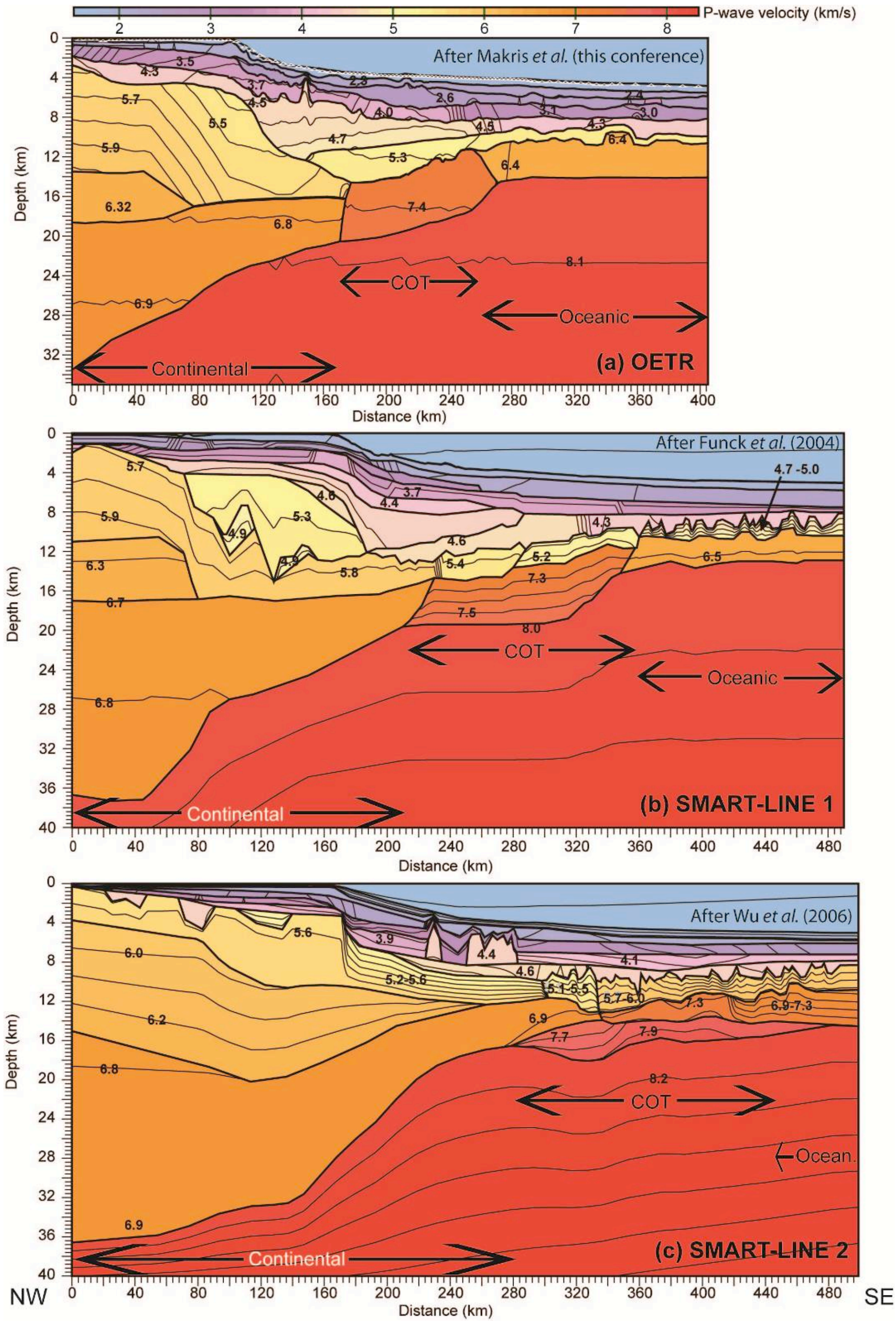

FIG.2 – P-wave velocity models across the NE Nova Scotia margin.

A mapping of the COT zone (FIG.1) shows close correlation with the hinge line of the rift basin, implying a common regional scale forcing behind its formation. Within this zone, a strong crustal reflection (W) is observed on reflection profile NovaSPAN 5100 (FIG.3) at about the depth of the top of the interpreted serpentinized mantle, suggesting an abrupt velocity contrast across the boundary. Therefore, a mapping of the 3-D geometry of this reflection would help to discriminate between the different crustal models of the transitional upper crust.

A kinematic reconstruction of the rifting and breakup of the complete Nova Scotia-Morocco conjugate margins will be presented using these new results. After plate reconstruction, a dramatic asymmetry in all three crustal zones (i.e. width of continental thinning, nature of the COT and oceanic crustal thickness) is clearly observed on the Moroccan margin along profile SISMAR-4, which is nearly conjugate to NovaSPAN 2000 (Contrucci *et al.*, 2004). Either a ridge jump or post-spreading volcanism may be required to explain such asymmetry.

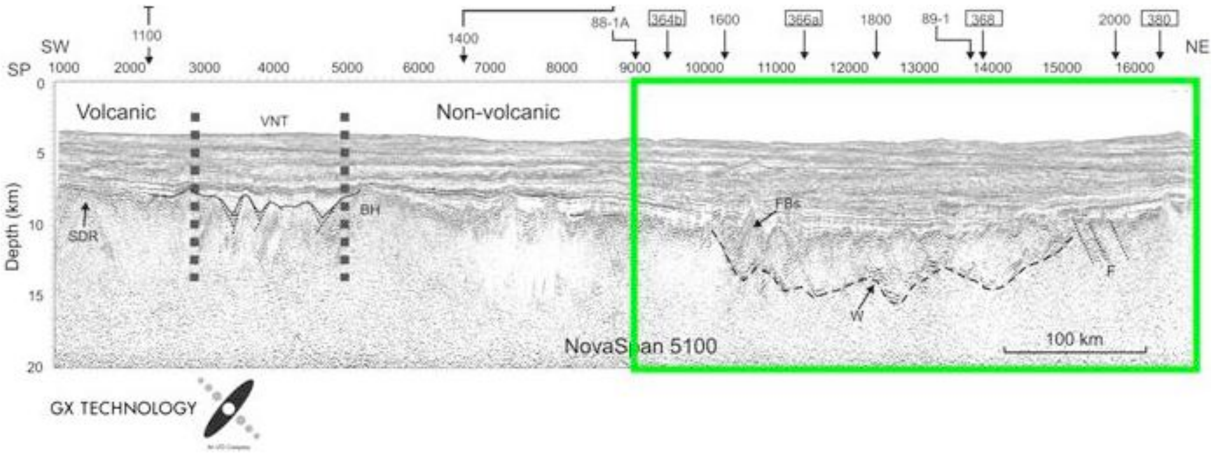

FIG.3 Prestack depth migrated section of NovaSpan 5100.

4. Future work

We will refine existing models targeting detailed velocity structures of the upper transitional crustal layer. For line OETR, the close spacing of OBS receivers should allow a refined model with unprecedented level of detail for the structures already identified. We will also map in 3-D the strong reflection within the OCT using newly reprocessed MCS data.

Acknowledgements

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