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Low-angle faulting in strike-slip dominated settings: Seismic evidence from the Maritimes Basin, Canada

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ABSTRACT

The Maritimes Basin is an upper Paleozoic sedimentary basin centered in the Gulf of St. Lawrence (Canada). Early phases of basin formation included the development of partly connected sub-basins bounded by high-angle faults, in an overall strike-slip setting. Interpretation of reprocessed seismic reflection data indicates that a low-angle detachment contributed to the formation of a highly asymmetric sub-basin. This detachment was rotated toward a lower angle and succeeded by high-angle faults that sole into the detachment or cut it. This model bears similarities to other highly extended terranes and appears to be applicable to strike-slip and/or transtensional settings.

1. Introduction

Low-angle (< 30°) normal faults have been recognized in many extensional settings worldwide, from both outcrop and seismic reflection data (see review in Colletini, 2011). These faults may record a significant amount of crustal extension and control the formation of supra-detachment sedimentary basins following the late stages of mountain building, accommodating thick clastic sequences derived from the erosion of adjacent reliefs (Fillmore et al., 1994; Vetti and Fossen, 2012). In some cases, steep (> 60°) faults and low-angle detachments occur in the same basin, reflecting a mixed mode of basin formation in space and/or time (Tari et al., 1992; Morley, 2014).

The role of low-angle faults in transtensional settings is far less documented. Traditional models of strike-slip dominated basins (i.e., pull-apart basins) usually show zones of extension between one master fault that form a releasing bend or two parallel high-angle faults with a step-over geometry (Sylvester, 1988; Mann, 2007; Wu et al., 2009). This view masks the inherent complexity of strike-slip and transtensional basins that may exhibit diverse modes of deformation in space and/or time (Ringenbach et al., 1993). The geometry and kinematics of major faults, changes in the strain field, and the re-activation of structures (including low-angle faults), are crucial to explain the diversity of basins in strike-slip settings (Christie-Blick and Biddle, 1985; Crowell, 2003; Allen and Allen, 2013).

In this study, we use reprocessed seismic data in the Gulf of St. Lawrence (Canada) to identify a low-angle detachment associated with the initial phase of formation of the Maritimes Basin, a 'successor basin' classically interpreted as formed in a strike-slip setting, following the late stage of terrane accretion in the Appalachians (Acadian orogeny sensu *lato*).

2. Geological framework

The Maritimes Basin is a large (~250,000 km^2) upper Paleozoic sedimentary basin underlying the Gulf of St. Lawrence, the Cabot Strait, part of the southern Newfoundland continental shelf and adjacent onshore areas in Atlantic Canada; about 75% of the basin area lies offshore (Figs. 1 and 2). The basin developed immediately following the Devonian Acadian orogeny and unconformably overlies all of the NeoProterozoic to middle Paleozoic lithotectonic zones that formed the Canadian Appalachians (Williams, 1979; Marillier et al., 1989; Hibbard et al., 2006; van Staal and Barr, 2012). To the southeast, the Maritimes Basin is overlain by Mesozoic-Cenozoic sedimentary rocks of the Atlantic continental margin.

The composite Maritimes Basin consists of Upper Devonian to Permian continental and subordinate shallow marine strata, with a preserved thickness of approximately 12 km beneath the eastern Gulf of St. Lawrence (Marillier and Verhoef, 1989). At the basin scale, the sedimentary succession records two stages of subsidence. The early stage, from Late Devonian to Early Mississippian, is associated with the development of isolated or partly connected fault bounded depocenters filled with continental deposits of the Horton Group and correlatives

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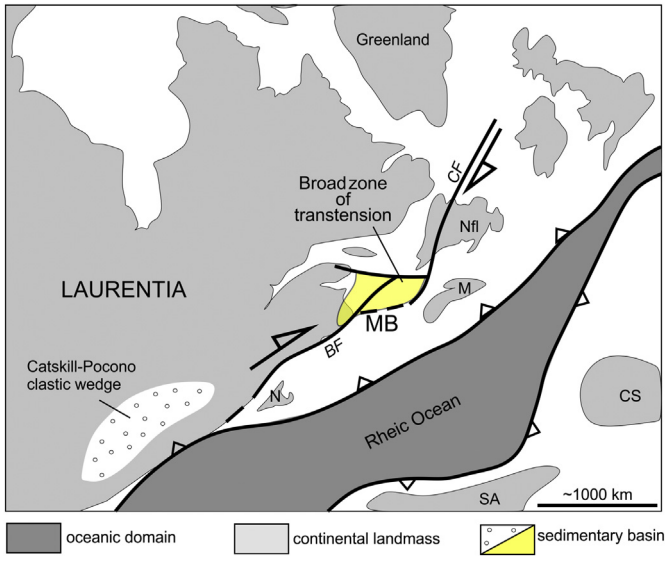

Fig. 1. Geodynamic setting of the Maritimes Basin in the Late Devonian (370 Ma). Modified from Cocks and Torsvik (2011). BF, Belleisle Fault; CF, Cabot Fault; CS, Calabria-Sardinia composite terrane; M, Meguma terrane; MB, Maritime Basin; N, Nashoba terrane; Nfl, Newfoundland; SA, South America affinity terranes.

(Fig. 2, Dietrich et al., 2011). Early subsidence was associated with tholeiitic and bimodal magmatism that continued sporadically through the early Permian (Pe-Piper and Piper, 1998). In southern New Brunswick, Nova Scotia, Prince Edward Island and Newfoundland, depocenters are controlled by high-angle strike-slip faults (Wilson and White, 2006; Waldron et al., 2015) and Horton Group strata exhibit significant lateral thickness and facies variations (St. Peter and Johnson, 2009). Offshore, the base of the Maritimes Basin sedimentary succession has never been reached by drilling. However, the Horton Group was intersected in several wells, including the Bradelle well in the north-central portion of the Gulf of St. Lawrence (Fig. 2) where it corresponds to a thick (> 1500 m) heterogeneous succession of red and grey sandstones and shales (Giles and Utting, 2003, Fig. 3).

The regional extent and shape of the Maritimes Basin was acquired during the second stage of subsidence, from Middle Mississippian to early Permian. This part of the basin succession includes a Visean marine interval (evaporites and carbonates of the Windsor Group, Giles, 2009) overlain by a thick succession of clastic rocks deposited in continental settings (Mabou, Cumberland and Pictou groups; Gibling et al., 2008; Fig. 3). In parts of the Maritimes Basin, including the Bradelle well, Cumberland Group strata are lacking and the Pictou Group rests directly over fine-grained clastics of the Mabou Group (Giles and Utting, 2003). Low-temperature geochronology (Ryan and Zentilli, 1993) indicates that 1 to 4 km of strata have been eroded from the Maritimes Basin area suggesting that the present-day basin was formerly more extensive.

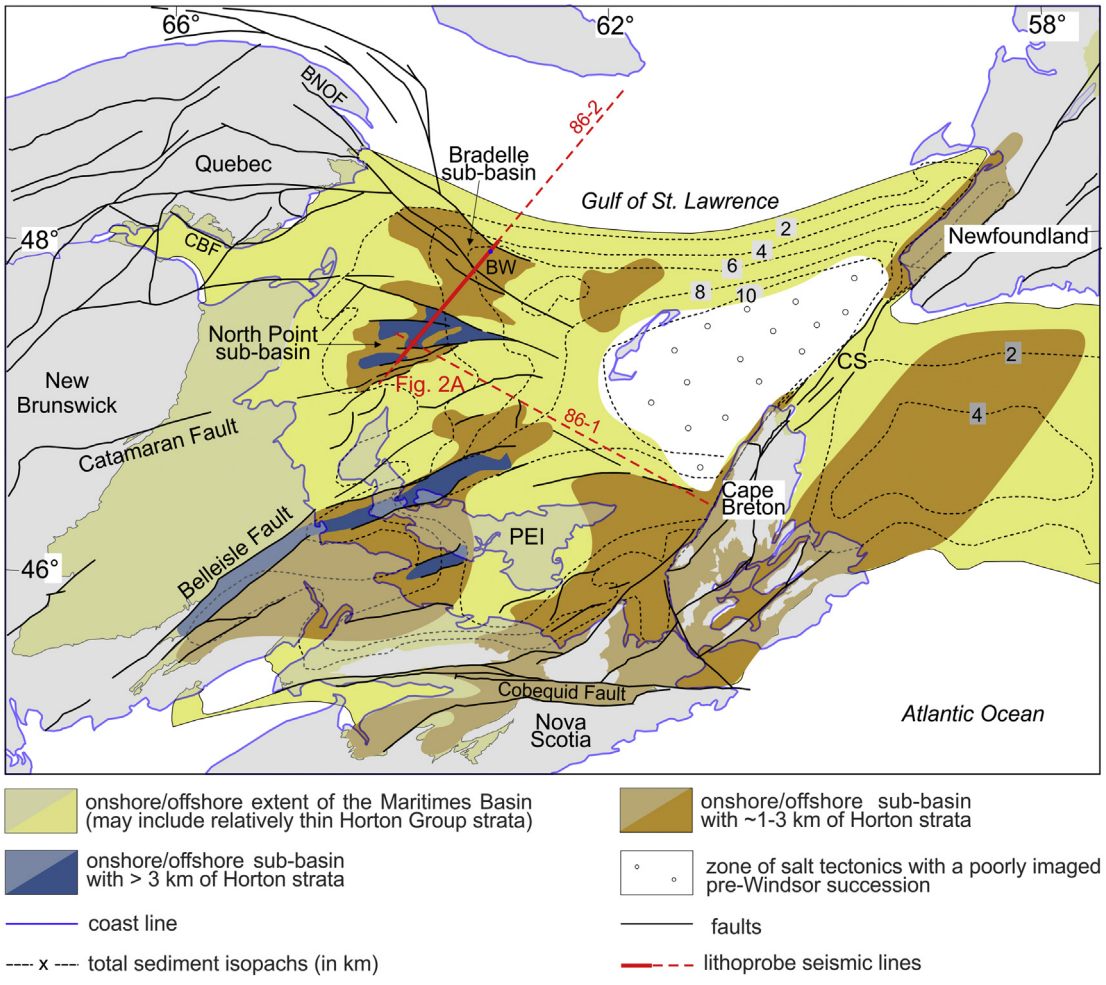

Fig. 2. Geological setting of the Late Devonian to Early Carboniferous sub-basins in the Maritimes Basin. Faults from Durling and Marillier (1990, 1993), Wheeler et al. (1996) and Pinet et al. (2008 and 2012). Sediment isopachs from Lavoie et al. (2009). The thicker segment of the lithoprobe seismic lines corresponds to the segment shown of Fig. 5. BNOF, Bras Nord-Ouest Fault; BW, Bradelle well, CBF, Chaleurs-Bay Fault, CS, Cabot Strait, PEI, Prince Edward Island.