Alleghanian deformation in the eastern Gaspé Peninsula of Quebec, Canada

Pierre Jutras†
Department of Geology, Saint Mary's University, Halifax, Nova Scotia B3H 3C3, Canada

Gilbert Prichonnet
GEOTERAP, Département des Sciences de la Terre et de l'Atmosphère, Université du Quebec à Montréal, C.P. 8888, Succursale Centre-Ville, Montréal, Quebec H3C 3P8, Canada

Steven McCutcheon
New Brunswick Department of Natural Resources and Energy, P.O. Box 50, Bathurst, New Brunswick E2A 3Z1, Canada

ABSTRACT

Juxtaposition of the Mississippian Ristigouche and Cannes-de-Roches Basins, which are subbasins of the composite late Paleozoic Maritimes Basin, occurred through dextral movement along the northwest-striking Percé Fault system in the eastern Gaspé Peninsula of Quebec. The northwest-striking faults are truncated by small north-northwest–striking dextral strike-slip faults, which probably developed as regional stress gradually rotated clockwise from north-northwest–south-southeast to northeast-southwest. This study provides the first evidence in eastern Quebec for significant post-Acadian block displacement other than normal faulting and indicates that Alleghanian deformation extended much farther north than previously thought. Identification of these structures formed during the Alleghanian orogeny but more than 1000 km away from areas of peak Alleghanian metamorphism in the southeastern United States underlines the far-reaching effects of continental collisions. It also casts doubt on the age attribution of brittle strike-slip faults elsewhere in the Gaspé Peninsula, away from Mississippian exposures. Such brittle faults were previously associated with late stages of the Acadian orogeny but could in fact be considerably younger.

Keywords: Alleghanian orogeny, structural geology, Gaspé Peninsula, Ristigouche Basin, Cannes-de-Roches Basin, Carboniferous, strike-slip faults.

INTRODUCTION

Transpressive deformations associated with peripheral effects of the Carboniferous to Permian Alleghanian orogeny are well documented in Atlantic Canada (Fralick and Schenk, 1981; Piqué, 1981; Bradley, 1982; Keppie, 1982; Ruitenberg and McCutcheon, 1982; Nance and Warner, 1986; Gibling et al., 1987, 2002; McCutcheon and Robinson, 1987; Nance, 1987; Yeo and Ruixiang, 1987; Reed et al., 1993; Murphy et al., 1995; Pascucci et al., 2000). However, until now, it was thought that the Alleghanian fault system that affects Carboniferous rocks of the Maritime Provinces did not extend as far north as the Gaspé Peninsula of Quebec (Fig. 1), a large segment of the Canadian Appalachians. Prior to a study by Faure et al. (1996a), post-Acadian deformation in the rocks of the Gaspé Peninsula was thought to be limited to Carboniferous synsedimentary dip-slip faulting (Rust et al., 1989) and to minor postsedimentary normal-fault readjustments (Alcock, 1935; St-Julien and Hubert, 1975; Bernard and St-Julien, 1986; Kirkwood, 1989; Bourque et al., 1993; Peulvast et al., 1996). Faure et al. (1996a) documented evidence for post-Acadian compressive paleostresses from slickenfibers on mesoscopic brittle fault planes in southern Quebec, including the Gaspé Peninsula, but no significant displacement was noted.

Described here are large transcurrent faults and associated compressive features, such as reverse faults and drag folds, which were recognized for the first time in Mississippian rocks of the Gaspé Peninsula. We argue herein that these structures are related to the Alleghanian orogeny and were responsible for the postsedimentary juxtaposition of two Mississippian depocenters, namely, the Ristigouche (van de Poll, 1995) and Cannes-de-Roches (Jutras et al., 2001) Basins (Fig. 1). These depocenters are subbasins of the large late Paleozoic Maritimes Basin, which extends throughout most of Atlantic Canada (Fig. 1A).

Identification of post-Acadian transpressive structures in the Gaspé Peninsula indicates that the tectonic impact of the Alleghanian orogeny affected rocks much farther north than previously thought, thus adding significantly to our understanding of late Paleozoic tectonics in the northern Appalachians. The identification also underlines a need to reevaluate the age attribution of all brittle strike-slip faults in the Gaspé Peninsula, which were previously attributed to late stages of the Acadian orogeny (Kirkwood et al., 1995; Malo and Kirkwood, 1995).

POST-ACADIAN TECTONIC HISTORY OF SOUTHEASTERN CANADA

The Middle Devonian Acadian orogeny brought together Laurentia, Baltica, and Gondwana, and during Late Devonian and Mississippian time, southeastern Canada mainly was subjected to extension and graben formation (Howie and Barss, 1975; Arthaud and Matté, 1977; Fralick and Schenk, 1981; Bradley, 1982; Keppie, 1982, 1993; Ruitenberg and McCutcheon, 1982; Fyffe and Barr, 1986; Gibling et al., 1987, 2002; McCutcheon and Robinson, 1987; Rust et al., 1989; Pe-Piper et al., 1991; Durling and Marillier, 1993; Reed

†E-mail: pierre.justras@smu.ca.

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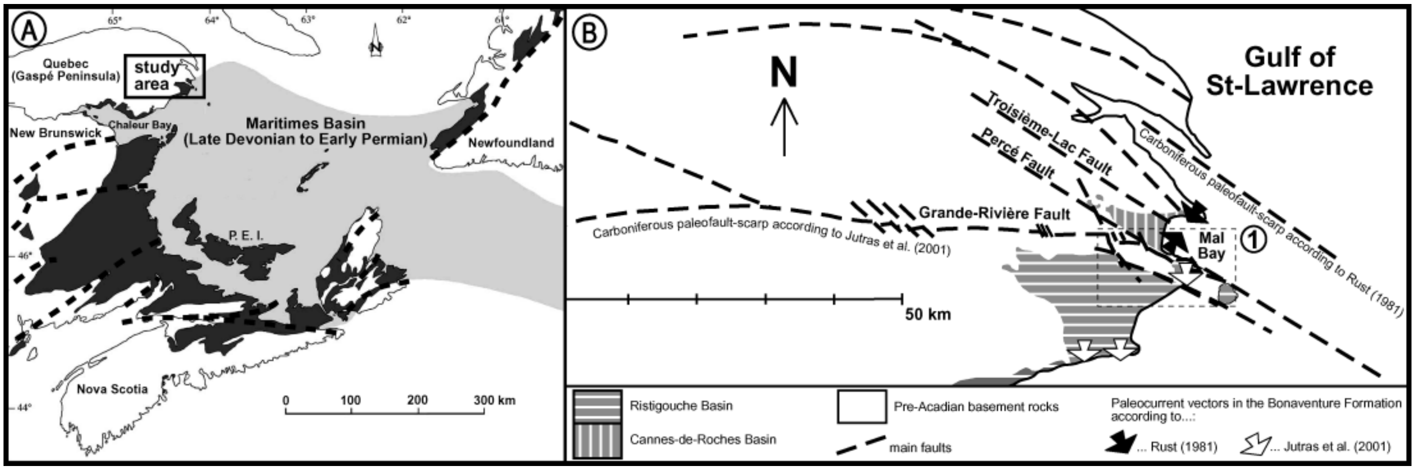

Figure 1. (A) Location of the study area within the late Paleozoic Maritimes Basin (light shading where its deposits are currently below sea level and dark shading where they are on land; modified from Gibling et al., 1992). (B) Simplified geology of the eastern Gaspé Peninsula (modified from Brisebois et al., 1992), showing only post-Acadian (Middle Devonian) relationships. Box in the vicinity of Mal Bay shows map area of Figure 3.

et al., 1993; Murphy et al., 1995; Pascucci et al., 2000). Onset of this extension was coeval with orogenic uplift in New England, source area of the uppermost Devonian Catskill clastic wedge (Rust et al., 1989). Within the Lower to Middle Devonian clastic wedge of the eastern Gaspé Peninsula, observation of a gradual displacement of source areas from the southeast to the southwest led Rust et al. (1989) to propose a model that correlates this succession with the Upper Devonian Catskill clastic wedge within one continuous wrench tectonic event. This Devonian migration of stress and foreland-basin development toward the southwest was accommodated by the gradual closing of the Theic (or ‘‘Rheic’’, for some authors) Ocean (Fig. 2A), which culminated with the Pennsylvanian to Early Permian Alleghanian orogeny and the formation of Pangea (Fig. 2B) (Arthaud and Matté, 1977; Piqué, 1981; Lefort and van der Voo, 1981; Russell and Smythe, 1983; Haszeldine, 1984; Kent and Opdyke, 1985; Lefort et al., 1988; Kent and Keppie, 1988; Rodgers, 1988; Sacks and Secor, 1990; Piqué and Skehan, 1992; Keppie, 1993; Faure et al., 1996a).

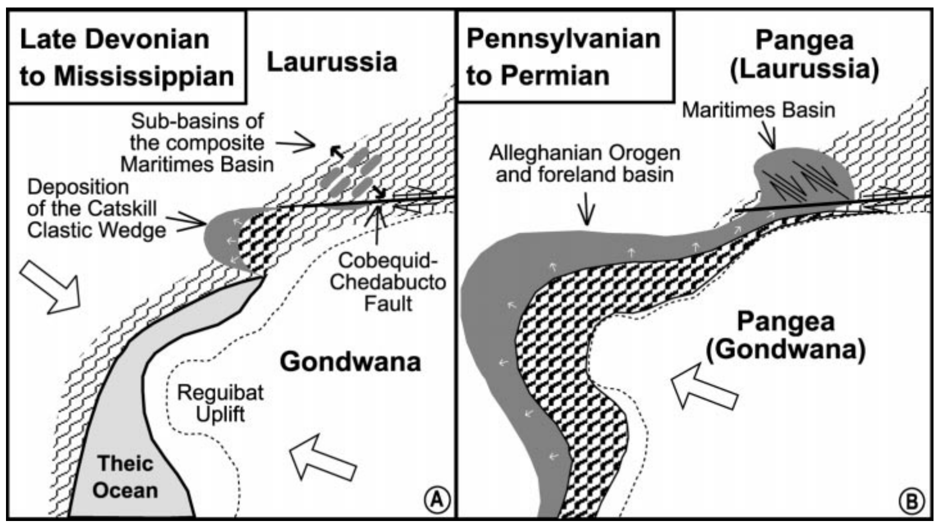

Figure 2. Tectonic model for the formation and deformation of the Maritimes Basin in the context of Theic Ocean closure. Dotted line represents the contour of the Precambrian West African craton within Gondwana. Light wavy lines represent areas affected by penetrative early to middle Paleozoic (pre–Late Devonian) deformation. Thick wavy lines represent areas that were then affected by penetrative deformation. Dark gray shading represents areas of active continental clastic sedimentation; white arrows represent inferred paleocurrent trends.

As the West African craton converged with southern North America (Lefort and van der Voo, 1981; Sacks and Secor, 1990; Piqué and Skehan, 1992), Gondwana rotated counterclockwise with respect to the assembled Euramerican landmass (Laurussia), causing dextral shear from central Europe to northeastern North America (Kent and Keppie, 1988) (Fig. 2A). Within this general context, the Cobequid-Chedabucto Fault, which separates a Gondwanan terrane (Meguma) from Iapetan terranes in Nova Scotia (Keppie, 1982), may have accommodated much of these plate readjustments, generating pull-apart extension in most of southeastern Canada as the main stress vectors migrated toward New England (Fig. 2A). In favor of the pull-apart model, Late Devonian and Mississippian magmatism along the Cobequid-Chedabucto Fault evolved under a transpressive regime (Koukouvelas et al., 2002), while the rest of southeastern Canada was undergoing general extension. The Mississippian Ristigouche and Cannes-de-Roches Basins of eastern Quebec are among the grabens that developed in southeastern Canada during the Late Devonian and the Mississippian; altogether the grabens formed the composite Maritimes Basin (Fig. 2A).

The Reguibat uplift, a well-defined promontory on the West African craton margin, acted as a rigid indenter when Gondwana and southeastern North America started colliding in Pennsylvanian time, and much of the compression concentrated around it (Lefort and van der Voo, 1981; Sacks and Secor, 1990; Piqué and Skehan, 1992; Faure et al., 1996a) (Fig. 2B). Peripheral areas, such as the Maritimes Basin, mainly were subjected to transpressive accommodation of this indentation, while being simultaneously buried by sediments coming from the Alleghanian orogen, which was being constructed to the southwest (Thomas and Schenk, 1988; Gibling et al., 1992; Keppie, 1993) (Fig. 2B).

POST-ACADIAN TECTONOSTRATIGRAPHY OF THE EASTERN GASPÉ PENINSULA

The pre-Carboniferous basement in the eastern Gaspé Peninsula comprises late Precambrian to Ordovician rocks deformed by the Middle Ordovician Taconic orogeny and Late Ordovician to Middle Devonian rocks deformed by the Middle Devonian Acadian orogeny (Kirkwood, 1989). The oldest post-Acadian unit in the eastern Gaspé Peninsula is the undated La Coulée Formation, a gray clastic succession that unconformably underlies the also-undated red clastic rocks of the Bonaventure Formation (Jutras et al., 1999) (Fig. 3). Thick and massive groundwater calcrete forms the base of the La Coulée Formation and is often the only remnant of this unit, which was uplifted and almost entirely eroded prior to sedimentation of the Bonaventure Formation.

The La Coulée (Jutras et al., 1999) and Bonaventure (Rust et al., 1989) Formations are interpreted as fault-controlled sedimentary units. These two units are locally in fault contact with one another, which implies that fault activity also occurred after deposition of the Bonaventure Formation (Jutras et al., 1999).

Renewed fault activity is thought to have controlled sedimentation of the Pointe Sawyer Formation, which overlies the Bonaventure Formation and was dated as late Viséan to early Namurian (Late Mississippian) (Jutras et al., 2001) from a spore assemblage (the SM Zone of Utting, 1987) that is now considered to be exclusively Namurian (J. Utting, 2002, personal commun.). The conformably overlying Chemin-des-Pêcheurs Formation, consisting of undated sandstones, marks the onset of sedimentation from distal sources (Jutras et al., 2001).

Faure et al. (1996a) recorded evidence within Late Devonian plutons of southern Quebec and within Mississippian rocks of the Gaspé Peninsula for three minor paleostress orientations involving no significant displacement. Prior to the present study, large strike-slip faults affecting Silurian–Devonian rocks in the Gaspé Peninsula, whether ductile or brittle, were assigned to late stages of the Acadian orogeny (Malo and Béland, 1989; Malo et al., 1992, 1995; Kirkwood et al., 1995; Malo and Kirkwood, 1995) and had not been recognized within Mississippian rocks.

PROBLEMS RAISED BY THE REGIONAL STRATIGRAPHIC RECORD

Paleocurrent, provenance, and facies-distribution data indicate that the Mississippian successions of the Mal Bay and Chaleur Bay areas were deposited in two different basins that are referred to as the Cannes-de-Roches (Jutras et al., 2001) and Ristigouche (van de Poll, 1995) Basins, respectively (Fig. 1). In the Cannes-de-Roches Basin, red clastic rocks that were previously assigned to the lower and middle members of the abandoned Cannes-de-Roches Formation (Alcock, 1935) are now included in the Bonaventure Formation (Jutras et al., 2001). Correlation of the Bonaventure and Cannes-de-Roches red beds is based on facies equivalence and stratigraphic position, both successions being unconformably underlain by the La Coulée Formation and disconformably overlain by gray beds of the Pointe Sawyer Formation.

The just-mentioned correlation raises a problem because the Bonaventure Formation is less than 50 m thick in the Cannes-de-Roches Cove section (Figs. 3, 4E) of the Cannes-de-Roches Basin, but at least 350 m thick in the incomplete Percé section (Figs. 3, 4C, 4D) of the Ristigouche Basin, 500 m away. In fact, if the subvertically tilted strata of the Cannes-de-Roches Cove section (Fig. 4E) were to be restored to horizontal, they would literally touch rocks of the much thicker Percé section (Fig. 4C, 4D), which only includes the coarse lithofacies that corresponds to the lower half of the Bonaventure Formation (Jutras et al., 2001). The residual 350 m, which are seven times thicker than the full Cannes-de-Roches Cove section, may therefore represent less than half of the original thickness of the Bonaventure Formation in the Percé section. Moreover, paleocurrent indicators in the two successions show opposing trends (Fig. 1), and clast compositions indicate that they were not fed by the same local source area (Jutras et al., 2001). Clast compositions in Bonaventure Formation beds of the Cannes-de-Roches Basin (Cannes-de-Roches Cove section) are mainly characterized by Lower Devonian siliceous limestones of the Forillon, Shiphead, and Indian Cove Formations (encompassing the abandoned Grande-Grève Formation) (Rust, 1981). These units are now absent from the inferred source area for the Bonaventure Formation detritus in the Cannes-de-Roches Cove section, which is to the southwest according to paleocurrent vectors (Fig. 1) (Rust, 1981) and which is now in part underlain by Bonaventure beds of the Ristigouche Basin or by older basement rocks (Fig. 3). Likewise, paleocurrent vectors measured in Bonaventure beds of the Ristigouche Basin in the Percé area indicate a source area to the north (Jutras et al., 2001), where Bonaventure beds of the Cannes-de-Roches Basin are now located (Fig. 1). In other words, the two basins had to be separated by a source area during deposition of the Bonaventure Formation, but that source area is no longer present.

The present distribution of Mississippian rocks in the eastern Gaspé Peninsula implies that a significant lateral displacement has occurred between the two basins. The fault system along which this took place is exposed in the Percé area (Figs. 3, 4). The main fault is here referred to as the ''Percé Fault'' (new name), although Kirkwood (1989) referred to the same fracture as the ''Troisième-Lac Fault.'' The new name is proposed because this fracture zone is not coincident with the Troisième-Lac Fault as defined by Béland (1980) (Fig. 1).

The Percé Fault and other faults of the eastern Gaspé Peninsula are described in the following section. Structures within pre-Mississippian basement rocks were studied by Kirkwood (1989). The focus of this paper is on structures that affect Mississippian rocks, which exhibit brittle fabrics of strongly cataclastic material but which contain only scarce kinematic indicators. Subordinate Riedel structures and reverse faults locally bear slickensided surfaces with calcite fibers that provide diagnostic kinematic indicators through their asymmetric shape. These data are compiled in Table DR1.[1]

POST-MISSISSIPPIAN STRUCTURES OF THE PERCÉ AREA (EASTERN GASPÉ)

The Percé Fault

The Percé Fault system separates Mississippian rocks of the Ristigouche Basin from those of the Cannes-de-Roches Basin. Along transect A–B, the Percé Fault separates the

[1]GSA Data Repository item 2003xxx, the numerical data used for plots in Figure 3, is available on the Web at http://www.geosociety.org/pubs/ft2003.htm. Requests may also be sent to editing@geosociety.org.

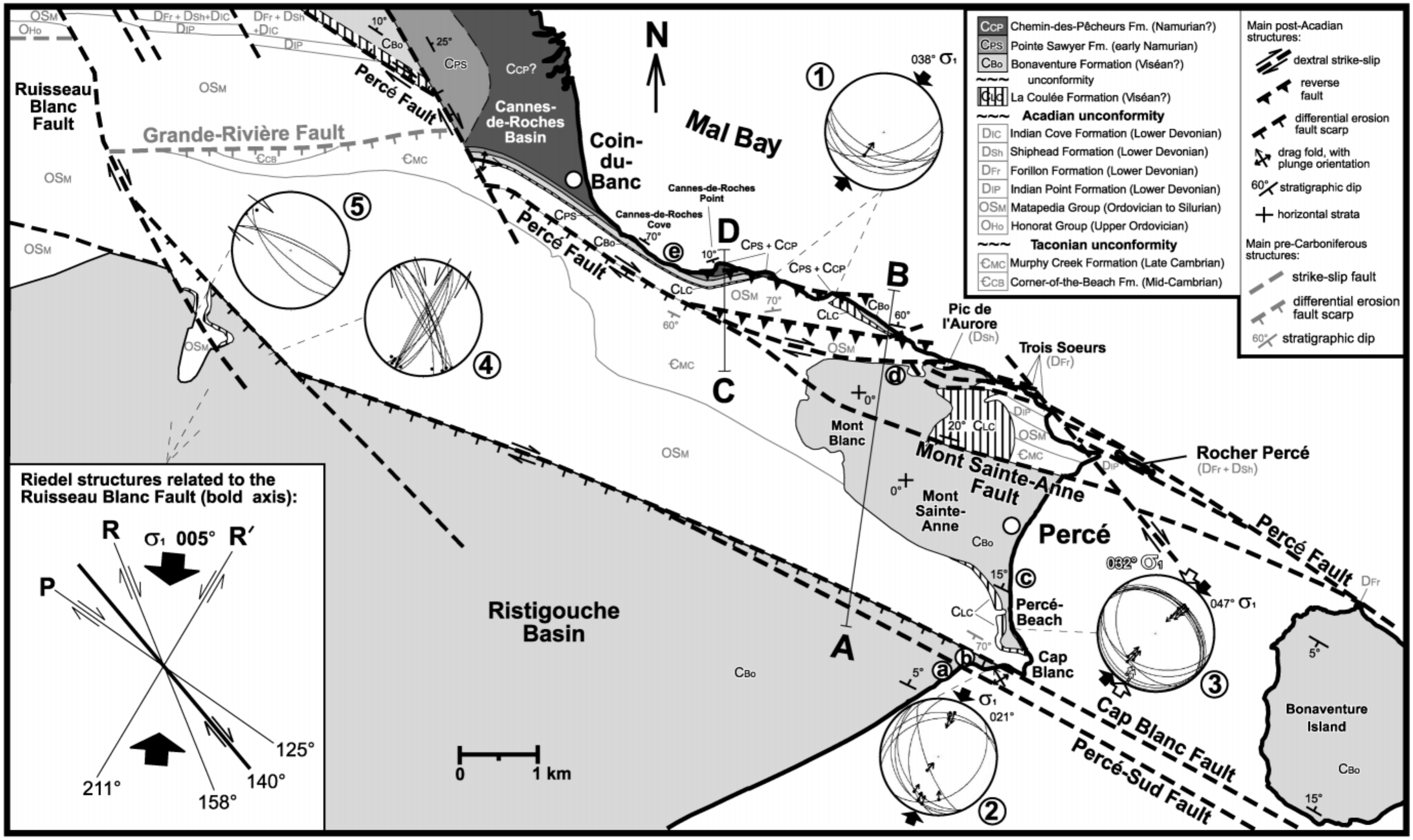

Figure 3. Geology of the Percé area, with fault-plane (great circles) and slickenfiber (dots and dotted arrows) orientations in (1) the strike-slip duplex of the Percé Fault at Cannes-de-Roches Point, (2) the deformation corridor at Cap Blanc, (3) the La Coulée Formation groundwater calcrete at Percé-Beach, (4) the roadside outcrop near the Ruisseau Blanc Fault, and (5) the La Coulée Formation groundwater calcrete on the side of Murphy Creek. Geology of pre-Mississippian units is by Kirkwood (1989). Composite columns of localities a–e and the cross section of transect A–B are shown in Figure 4. The cross section of transect C–D is shown in Figure 9. Interpretation of the three groups of secondary structures recorded in the vicinity of the Ruisseau Blanc Fault is shown in inset.

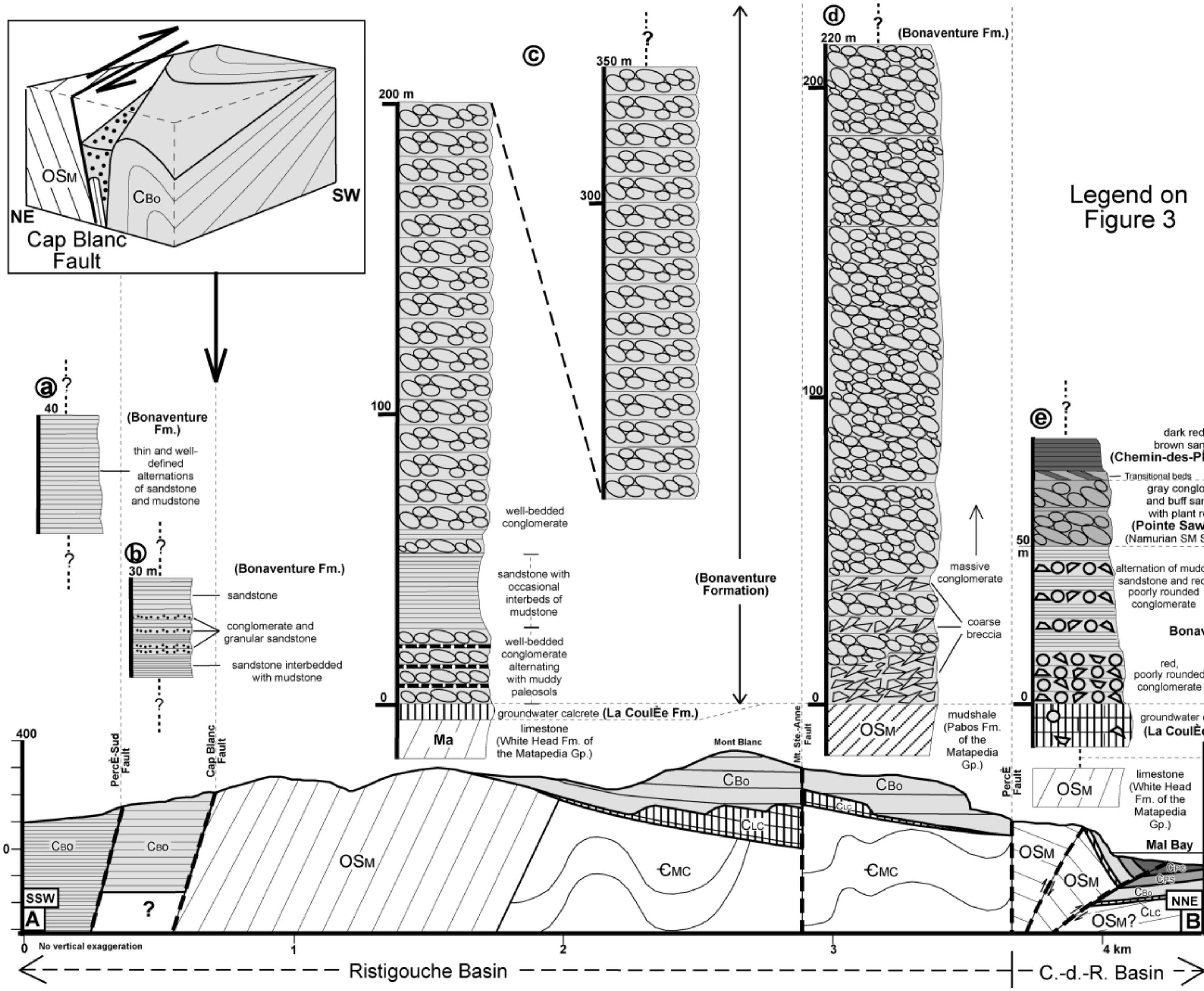

Figure 4. Stratigraphic columns a to e and cross section A–B, showing the main structures and stratigraphic units of the Percé area (legend, localities, and transect are shown in Fig. 3). A sketch of the open drag fold adjacent to the Cap Blanc Fault is shown in inset. C.-d.-R Basin—Cannes-de-Roches Basin.

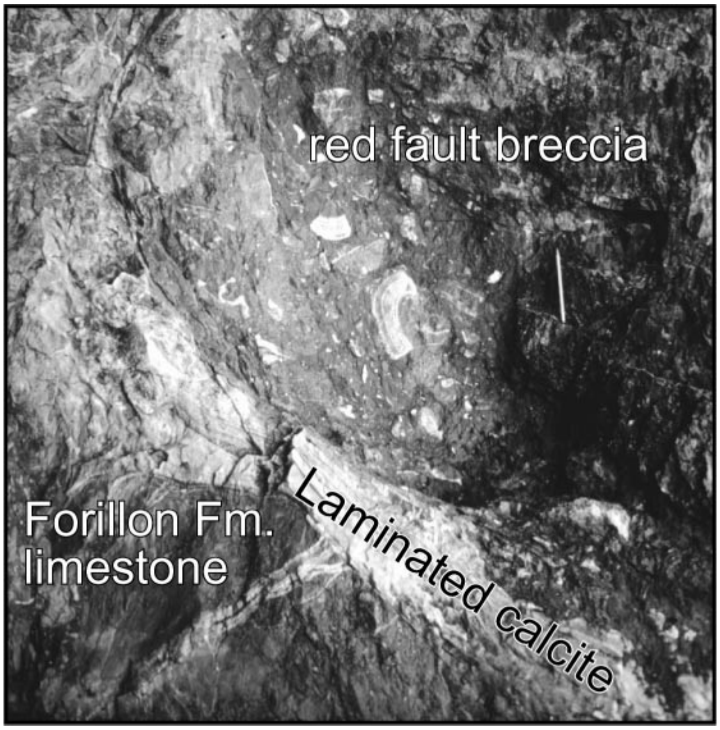

Figure 5. Large limestone blocks of the Forillon Formation and red fault breccia in multiepisodic, laminated calcite veins within the deformation corridor of the Percé Fault. Pen is 15 cm long.

thin and steeply dipping Cannes-de-Roches Cove succession (Fig. 4E) from the thick flat-lying Percé succession (Fig. 4C, 4D) to the south (Fig. 3). The fault corridor includes the northernmost tip of Bonaventure Island (southeast corner in Fig. 3), which is characterized by red fault breccia (Fig. 5) plastered against flat-lying Bonaventure Formation conglomerate and sandstone. The breccia comprises a mixture of pulverized Bonaventure Formation detritus and angular limestone clasts of the Devonian Forillon Formation. Large blocks (1 to 10 m^3) of red fault breccia and limestone of the Forillon Formation are enclosed within laminated calcite veins. The blocks are also invaded by older but similar calcite veins, indicating that this section of the deformation corridor was affected by several hydrothermal episodes.

The northwest-striking deformation corridor is exposed for several kilometers on the coastal cliffs of Percé, where a series of 100-m-scale rock slabs can be observed, including Rocher Percé, the Trois Soeurs, and Pic de l'Aurore (located in the eastern half of Fig. 3). The fault slabs stand in the local landscape as differential-erosion monoliths. All these slabs are composed of vertical beds of Forillon Formation limestones and Shiphead Formation sandstones (Early Devonian) (Kirkwood, 1989), which are reddened and contain numerous laminated calcite veins and which are oriented at high angle to the structural trend of the pre-Carboniferous basement.

The Trois Soeurs and Pic de l'Aurore are separated from pre-Carboniferous basement rocks by red fault breccia. This cataclastic material can be best observed within large blocks fallen on the beach from the 2–3-m-thick in situ fault breccia that plasters the northern flank of Pic de l'Aurore (Fig. 6). Red fault breccia is also observed on the southern flank of Pic de l'Aurore, separating horizontal beds of the Bonaventure Formation from vertical beds of the Shiphead Formation, which constitute the fault slab (Fig. 7). Randomly oriented patches of fissile structures, absence of sedimentary structures, higher compaction, and more angular clasts clearly differentiate this breccia from the flat-lying sedimentary breccia of the Bonaventure Formation, which constitutes part of Pic de l'Aurore (Figs. 8A, 8B).

The Percé Fault turns inland in an east strike at the westernmost end of Pic de l'Aurore (Fig. 3) and resumes a southeast strike ~2 km to the west. The sharp bend in the fault trajectory at Pic de l'Aurore may have caused the reverse fault to offset rocks of the Mississippian succession parallel to the bend, a few hundred meters to the north of the main fault near Cannes-de-Roches Point (transect C–D in Figs. 3 and 9). Measured reverse-fault planes are oriented east-west on average, but can be subdivided in two groups, one striking east-northeast and the other striking east-southeast (Fig. 3, stereonet 1; Table DR1 [see footnote 1]). One of the east-northeast–striking fault planes shows slickenfibers plunging 60° with a 218° trend, indicating thrusting toward 038°.

The orientations of reverse-fault slickenfibers, reported here and elsewhere in this paper, are interpreted as reflecting the main principal stress (σ_1) that controlled their formation, but not necessarily that of the paleostress that controlled formation of the fault itself (see subsequent discussion). In some cases, the observed slickenfibers may only reflect the last movements in the history of a fault plane that may have been subjected to paleostresses having different trends. In friable clastic rocks, kinematic indicators of early fault movement are unlikely to be preserved after reactivation of the fault under a different trend. Only re-

Figure 6. Fallen slab of compact red fault breccia near Pic de l'Aurore.

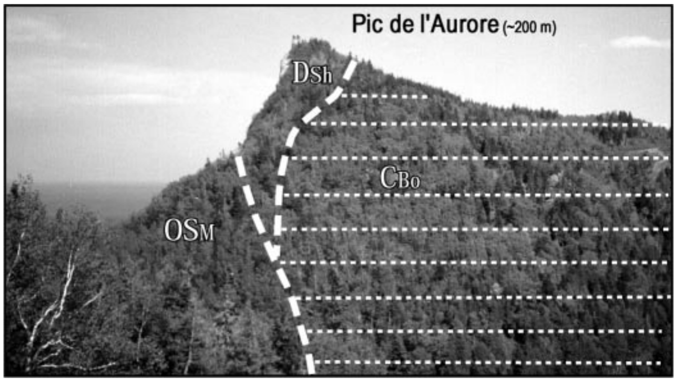

Figure 7. View of ~200-m-high Pic de l'Aurore from the west with superimposed mapping data. A large fault slab of the Shiphead Formation (DSh) is caught between rocks of the Matapedia Group (OSM) and subhorizontal beds of the Bonaventure Formation (CBo; light dashed lines). Breccia is concentrated along heavy dashed lines.

verse faults that strike approximately perpendicular to their slickenfibers are assumed in this study to have undergone a single deformation event.

The thrust block near Cannes-de-Roches Point is interpreted as a ''strike-slip duplex'' (sensu Woodcock and Fischer, 1986) within a positive flower structure. The Mississippian succession on the hanging wall of the reverse fault is steeply dipping (Figs. 8A, 8B), whereas the same units on the footwall of this fault, exposed at Cannes-de-Roches Point, are nearly horizontal (Fig. 9). In the western exposures of the reverse fault, Matapedia Group rocks (Ordovician to Silurian) thrust over Mississippian rocks of the Pointe Sawyer and Chemin-des-Pêcheurs Formations (east of transect C–D in Fig. 3). These contractional features associated with a left bend suggest that movement of the Percé Fault was dextral (Woodcock and Fischer, 1986).

Although only fault planes directly involving Mississippian strata are represented on the stereonets of Figure 3, east-striking reverse faults affecting pre-Carboniferous strata are also abundant near Pic de l'Aurore. Of 29 measurements made by Kirkwood (1989) on these thrusts, the average strike is 086°. From these structures and the conjugated secondary strike-slip faults affecting Matapedia Group rocks, movement along the Troisième-Lac Fault (Percé Fault in this paper) was interpreted as dextral by Kirkwood (1989), which corroborates with our data.

Northwest of Mont Blanc, the Percé Fault resumes a northwest strike, with Mississippian beds of the Cannes-de-Roches Cove succession tilting 70° perpendicular to the fault (center of Fig. 3). Farther to the northwest, the trace of the Percé Fault makes another bend into a west-northwest strike (west of the village of Coin-du-Banc in Fig. 3) and is adjacent to a tight anticlinal drag fold (plunge 30°, trend 105°) affecting strata of the La Coulée and Bonaventure Formations on the north side of the fault (Fig. 10). This drag fold is the northernmost evidence for compressive stress affecting Mississippian rocks in this area, but continuation of the Percé Fault farther north is suggested by the sharp stratigraphic break between Matapedia Group rocks and Mississippian rocks (northwest quadrant of Fig. 3).

The path of the Percé Fault is offset by two small north-northwest–striking dextral faults, near Coin-du-Banc and near Percé (Fig. 3), one of which is adjacent to the drag fold shown in Figure 10. The west-northwest–striking fold and the north-northwest–striking

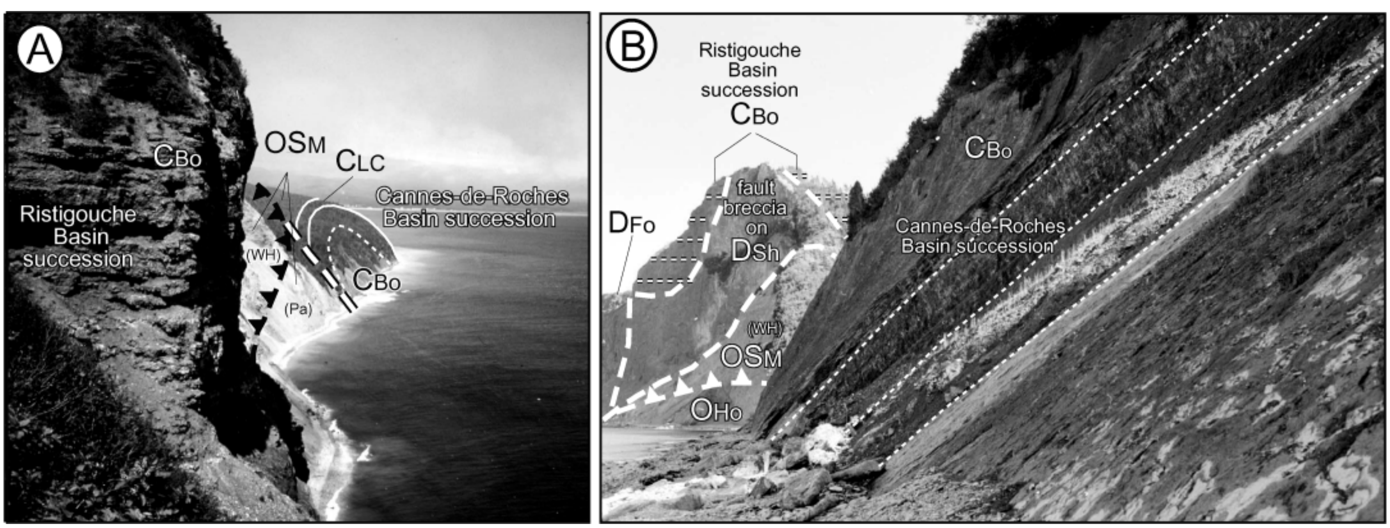

Figure 8. (A) View from the southeast side of the 200-m-high Pic de l'Aurore. The thick, flat-lying succession of Bonaventure Formation beds within the Ristigouche Basin contrasts with that succession's thin and steeply dipping equivalent within the Cannes-de-Roches Cove succession, in the background. (B) Opposite view. A major post-Acadian strike-slip fault separates the Cannes-de-Roches Basin succession from the Ristigouche Basin succession. The heavy dashed lines are fault contacts, thin full lines are interformational stratigraphic contacts, and thin dashed lines are intraformational contacts. OHo—Honorat Group; OSM (Pa)—Pabos Formation (lower Matapedia Group); OSM (WH)—White Head Formation (upper Matapedia Group); DFo—Forillon Formation; DSh—Shiphead Formation; CLC—La Coulée Formation; and CBo—Bonaventure Formation (refer to legend in Fig. 3). The pre-Carboniferous geology is by Kirkwood (1989).

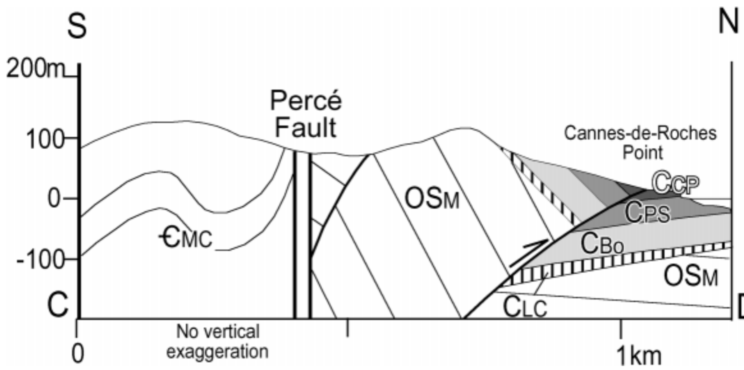

Figure 9. Unnamed reverse fault creating an offset within the Cannes-de-Roches Point succession (from transect C–D of Fig. 3; the legend is also in Fig. 3).

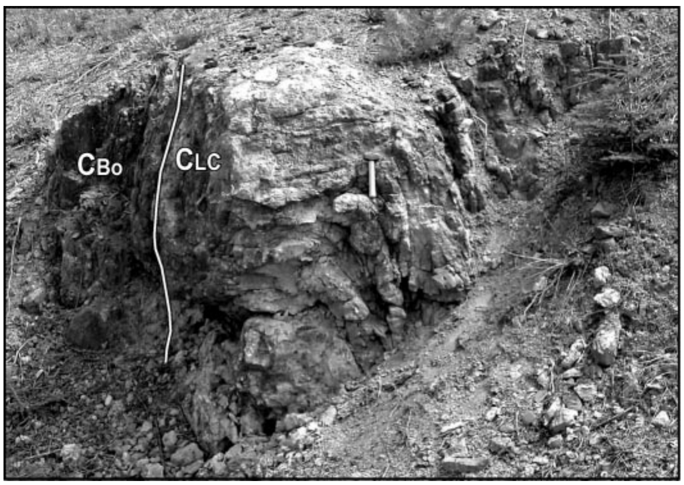

Figure 10. Drag fold in the La Coulée Formation groundwater calcrete (CLC) and Bonaventure Formation (CBo) near the village of Coin-du-Banc (location shown in Fig. 3). The photograph is oriented toward the southeast.

fault are compatible with a north-northeast–south-southwest main principal stress (Wilcox et al., 1973). North-northwest–striking faults, with usually <1 km offset, are found throughout the eastern Gaspé Peninsula (Fig. 1) and were considered to be late Acadian structures by Kirkwood (1989), who also included larger northwest-striking faults within the same system. From the observed offset of stratigraphic breaks, it is here concluded that the northwest-striking fault system is truncated by the north-northwest–striking fault system and that both systems produced lateral offsets in Mississippian rocks.

The Mont-Sainte-Anne Fault

The Mont-Sainte-Anne Fault (southeast quadrant of Fig. 3), which merges with the Percé Fault at both ends and was inferred by Jutras et al. (1999) to coincide with a line of abrupt stratigraphic breaks, is clearly observable on aerial photographs but is not exposed. Although kinematic indicators are lacking, it is postulated that this fault is part of the flower structure associated with the left bend in the Percé Fault system at Pic de l'Aurore.

The Cap Blanc Fault

The Cap Blanc Fault parallels the Percé Fault and separates the Matapedia Group from the Bonaventure Formation on the south side of Cap Blanc (southeast quadrant in Fig. 3). It was interpreted as a normal fault by Alcock (1935) and Kirkwood (1989). According to Jutras et al. (1999), the Cap Blanc Fault may have acted as a normal fault prior to Bonaventure Formation deposition to account for the 20° tilting of La Coulée Formation beds away from the fault, below flat-lying Bonaventure beds (between km 2 and km 3 on cross section A–B of Fig. 4). However, this pre-Bonaventure normal movement is opposite to the present stratigraphic offset observed along that fault.

Basement rocks are vertically offset by at least 200 m at the level of the Cap Blanc Fault, according to thickness extrapolations for the Bonaventure Formation on the coastline. Along the 15 km of coastline southwest of Percé, several normal faults parallel to the Cap Blanc Fault have offset the Bonaventure Formation by tens of meters. The largest normal fault is designated the Percé-Sud Fault (Fig. 4 and southeast quadrant in Fig. 3).

The 25-m-wide deformation corridor of the Cap Blanc Fault (Figs. 11A, 11B) includes a 2-m-thick slab of vertically dipping Matapedia Group limestone and a 20-m-wide anticlinal drag fold (plunge ~45°, trend 330°) developed within the Bonaventure Formation (Fig. 4, inset). To be compatible with the observed drag-fold geometry, normal or reverse movement would imply that the northeast block collapsed with respect to the southwest block, which is contrary to the observed stratigraphic displacement. The fold is open and plunging toward the north-northwest, suggesting that it may be related to lateral dragging from dextral strike-slip motion along the 115°-striking Cap Blanc Fault (cf. Biddle and Christie-Blick, 1985).

Rocks in the deformation corridor are also cut by minor reverse faults with slickensided surfaces bearing calcite fibers indicating thrusting toward the north-northeast (~021°) and the south-southwest (~201°) (Fig. 3, stereonet 2; Table DR1 [see footnote 1]). On the northeast side of the Cap Blanc fault, in the groundwater calcrete of the La Coulée Formation at Percé-Beach, three low-dipping thrusts (<10°) with slickenfibers indicating thrusting toward the north-northeast (~032°) are truncated by steeper (~35°) reverse faults with slickenfibers indicating thrusting toward the northeast (~047°) and the southwest (~227°) (Fig. 3, stereonet 3; Table DR1 [see footnote 1]).

The orientation of slickenfibers on these subsidiary reverse faults is interpreted to reflect the main principal stress vector (σ_1) that led to their formation, which seemingly rotated clockwise from north-northeast to northeast. On both sides of the Cap Blanc Fault, these slickenfibers are nearly perpendicular to the main fault trace, which precludes their being related to strike-slip movement on that fault. The slickenfibers are oblique to the hinge line of the drag fold, which makes them

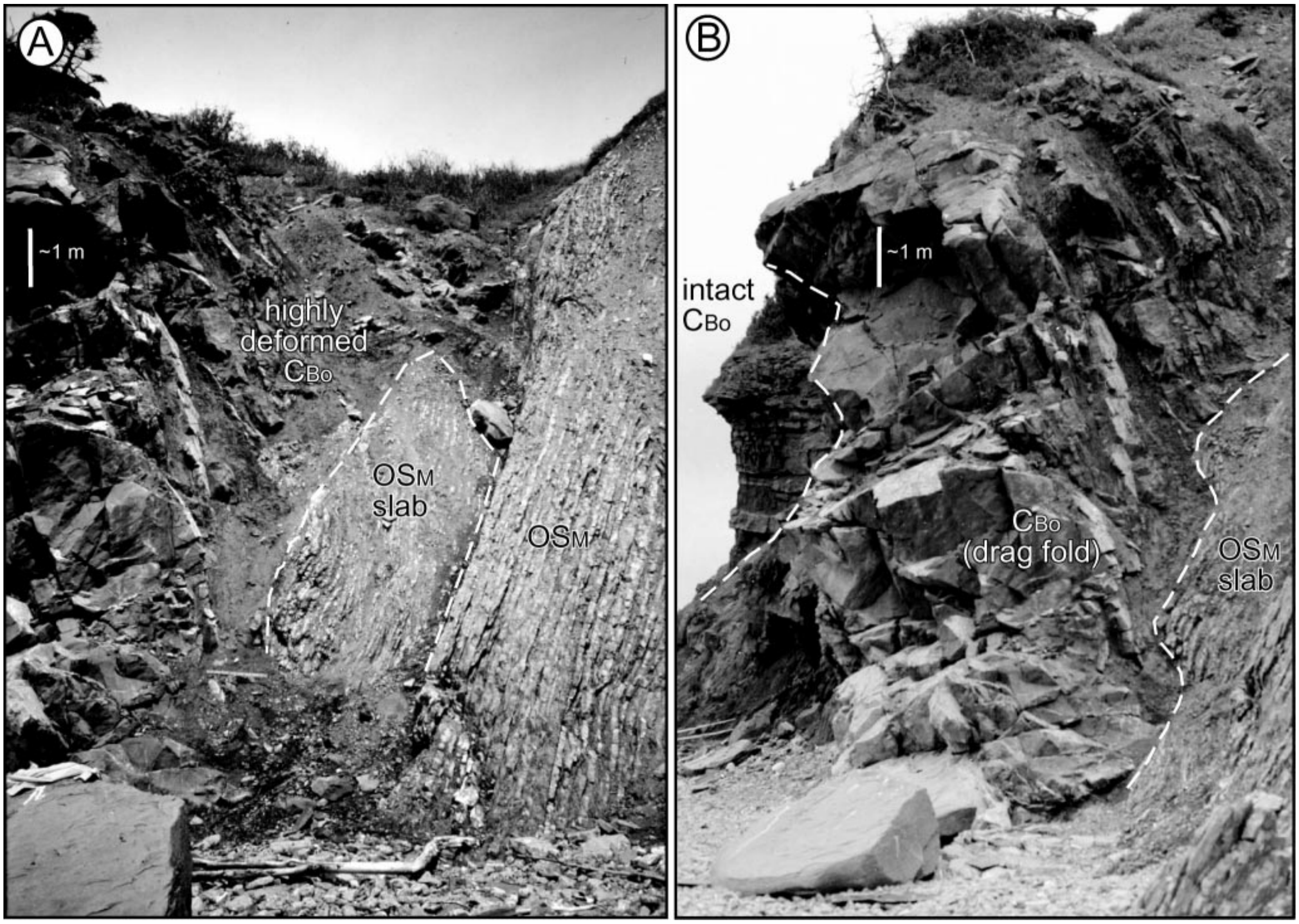

Figure 11. The Cap-Blanc Fault. (A) Coastal outcrop of the fault zone, with an over 10 m long fault slab containing Matapedia Group limestone (OSM) and highly deformed Bonaventure Formation sandstone (CBo). The photograph is oriented toward the northwest. (B) View of the northeast limb of a 20-m-wide drag fold and of the undeformed Bonaventure Formation beds that extend away from it. The photograph is oriented toward the west.

incompatible with that structure as well. As the reverse faults are overprinted in the fold, they are interpreted as being related to a subsequent north-northeast– to northeast-trending compression event, which may be responsible for the 15° tilting of Mississippian strata away from the fault on the northeast block. This 15° dip of Mississippian beds, away from the Cap Blanc Fault, is also observed at the southern end of Bonaventure Island (southeast corner in Fig. 3). The Cap Blanc Fault may have been the site of minor reverse movement in the process, but the dominant vertical displacement along that fault is normal, as older rocks compose the footwall (Fig. 4). In conclusion, although secondary structures mainly indicate reverse movement along the Cap Blanc Fault, such kinematics can only represent a minor reactivation of a fault that mainly supported normal and transcurrent movement earlier in its history.

The Ruisseau Blanc Fault

In a roadside outcrop of Bonaventure Formation conglomerate (Fig. 3, locality 4), minor subvertical fault planes forming a conjugate set are plastered with thick calcite slickenfibers that cumulatively indicate several meters of displacement (Fig. 12). Dextral faults striking north-northwest are conjugate to sinistral faults striking north-northeast (Fig. 3, stereonet 4; Table DR1 [see footnote 1]). Less than 1 km to the northwest, on a brookside exposure (Murphy Creek), subvertical northwest-striking fault planes cut the basal calcrete of the La Coulée Formation and bear dextral slickenfibers (Fig. 3, stereonet 5; Table DR1 [see footnote 1]). The average 53° angle that separates the strikes of dextral faults from those of sinistral faults on stereonet 5 and the average 86° angle that separates the latter from the strikes of dextral faults on stereonet 4 suggest that they are respectively R, R′, and P structures of a main dextral fault with an ~320° strike (Fig. 3; inset). The main principal stress (σ_1) responsible for motion along these structures is inferred to bisect the average R and R’ structures, giving a north-north-east (005°) strike (Fig. 3; inset).

The fault orientations and proposed kinematics can be attributed to the nearby Ruisseau Blanc Fault, one of several north-northwest–striking dextral fractures truncating the east-striking Grande-Rivière Fault (Kirkwood, 1989) (Fig. 1). Although the Ruisseau Blanc Fault on Kirkwood’s map is shown as buried under the Bonaventure Formation to the south, lineaments on aerial photographs indicate that the fault cuts this poorly exposed unit.

The Ruisseau Blanc Fault apparently truncates the Cap Blanc Fault (western half of Fig. 3), whose location can be approximately deduced from stratigraphic breaks and scarp de-

Figure 12. Thick dextral slickenfibers plastered on Bonaventure Formation conglomerates in the area of the Ruisseau Blanc Fault (Fig. 3, locality 4). The photograph is oriented toward the east.

velopment from the coast to the inferred intersection with the Ruisseau-Blanc Fault. However, scarcity of exposure on land makes it difficult to trace faults accurately.

DISCUSSION

Synopsis and interpretation of Alleghanian structures in the eastern Gaspé Peninsula

The absence of observed paleostress indicators within Mississippian units of the Gaspé Peninsula led many authors to conclude that these rocks were not affected by the brittle strike-slip motion that affected older rocks (Alcock, 1935; St-Julien and Hubert, 1975; Bernard and St-Julien, 1986; Kirkwood, 1989; Bourque et al., 1993; Malo and Kirkwood, 1995; Kirkwood et al., 1995). Subsequently, however, Faure et al. (1996a) demonstrated that such indicators exist, although they are scarce.

The paucity of paleostress indicators within Mississippian rocks of the Gaspé Peninsula area can be explained by the nature of the material, which is dominated by poorly consolidated coarse-grained clastic rocks. Such rocks are not good materials for recording paleostress indicators compared to more massive and competent rocks. For example, subordinate structures in Mississippian rocks of the Percé area are best recorded in the massive and competent La Coulée Formation groundwater calcrete (drag fold in Fig. 10, and slickenfiber-bearing fault planes plotted in stereonets 3 and 5 of Fig. 3), although this lithology has very limited exposure.

Interpretation of structures affecting the Mississippian clastic succession of the Gaspé Peninsula area is further complicated by the scarcity of inland exposures and by the chaotic, cataclastic nature of the main faults. Moreover, the flat-lying Mississippian continental clastic rocks, which are characterized by high lateral variability, do not provide tight constraints on stratigraphic displacements.

The main structure affecting Mississippian rocks in the Percé area is the northwest-striking Percé Fault, but kinematic indicators from secondary structures along this fault are especially limited within these rocks, as opposed to those provided by the local basement rocks (Kirkwood, 1989). The overall orientation of reverse faults cutting Mississippian rocks near Cannes-de-Roches Point (Fig. 3, stereonet 1) is compatible with dextral movement along the northwest-striking Percé Fault, which would imply a north-northwest–south-southeast to north-south main principal stress. However, the only observed slickenfibers on these reverse-fault planes are oriented at a 90° angle with the main fault trace, which casts doubt on this inferred north-northwest–south-southeast to north-south stress direction and instead indicates a north-northeast–south-southwest main principal stress. Moreover, structural data presented by Kirkwood (1989) for this fault collectively indicate a north-northeast–south-southwest main principal stress, which is nearly perpendicular to the observed fault trace, thereby raising questions about the dextral strike-slip interpretation presented in that paper as well. However, such movement is necessary to explain the present distribution of Mississippian strata in the area. Neither normal nor reverse movement can explain the juxtaposition of time-equivalent units with such a significant difference in thickness, opposite paleocurrent trends, and nonmatching provenance.

At the time of deposition, the petromict fanglomerates of the Bonaventure Formation that are now near Pic de l'Aurore in the Cannes-de-Roches Basin are interpreted to have been located north of the Grande-Rivière Fault (Fig. 3), which forms the northern boundary of the Ristigouche Basin (Jutras et al., 2001), to allow the presence of an intervening source area between the two basins at the time of deposition. In support of this interpretation, pre-Carboniferous rocks exposed north of the Grande-Rivière Fault (Fig. 3) correspond well with the clast compositions of Bonaventure beds in the Cannes-de-Roches Cove section, which are dominated by Lower Devonian siliceous limestones of the Forillon, Shiphead, and Indian Cove Formations (Rust, 1981). These units are only present in the form of fault slabs in the source area indicated by paleocurrent vectors determined from alluvial-fan deposits in the Cannes-de-Roches Cove section (Rust, 1981) (Fig. 3).

At least 10 km of lateral displacement along the Percé Fault, away from contemporaneous Ristigouche Basin rocks, is necessary to return these northeast-trending alluvial-fan deposits to the outcrop area of basement rock corresponding to the clast compositions in the alluvial-fan deposits and to reconstruct a plausible pre-displacement paleogeography (Fig. 13). Even more displacement is necessary to allow space for the significant source area that would have been needed to provide the southward-trending coarse-grained alluvial-fan deposits of the Ristigouche Basin in the Percé area, away from contemporaneous Cannes-de-Roches Basin rocks (Fig. 13). Hence, although displacement values based solely on basin reconstruction cannot be precise, a post-Mississippian displacement in the order of 10 to 20 km along the Percé Fault is considered probable.

As the Cap Blanc Fault is parallel and adjacent to the Percé Fault, it probably has a similar tectonic history. The Cap Blanc Fault provides evidence for successive normal, dextral strike-slip, and reverse motion. The dextral strike-slip component, which would indicate a north-northwest–south-southeast to north-south main principal stress, is suggested by the presence of an open drag fold plunging ∼45° on the southwest block of the Cap Blanc Fault (Fig. 4, inset).

In summary, the Percé Fault system structurally bounded the Cannes-de-Roches Basin during deposition of the Bonaventure Formation (Fig. 13A), in accordance with the paleogeography proposed by Rust (1981), and was

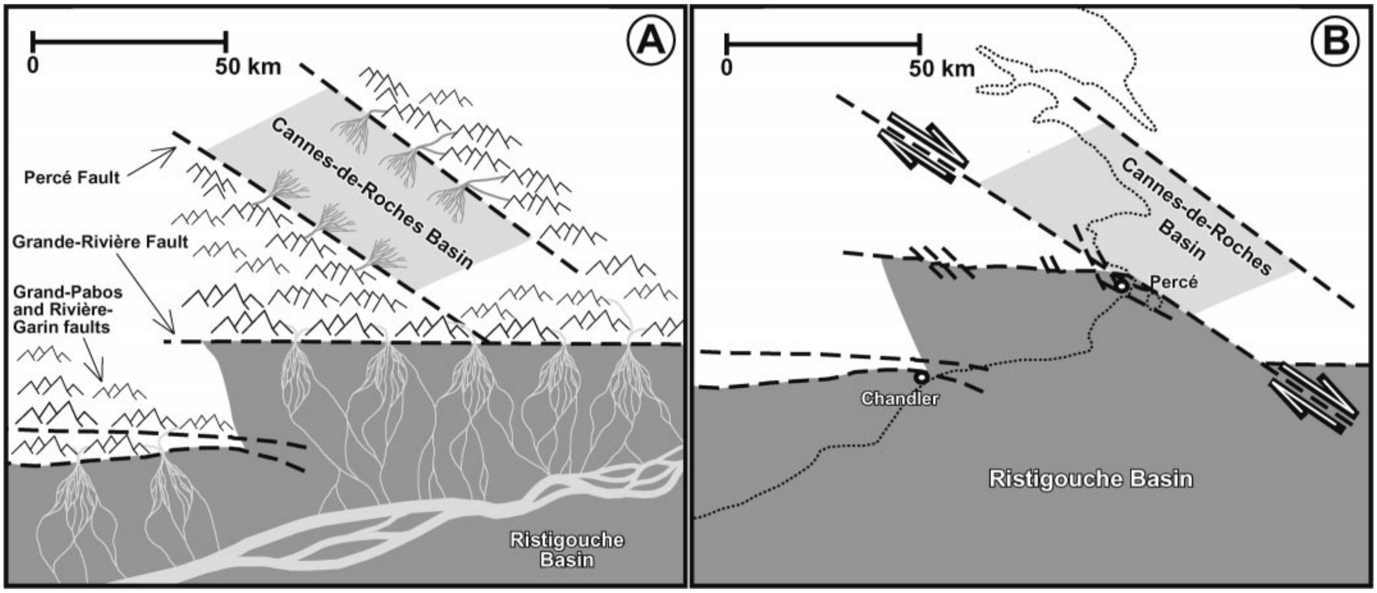

Figure 13. (A) Paleogeography of the Bonaventure Formation in the Cannes-de-Roches Basin (Rust, 1981) and Ristigouche Basin (Jutras et al., 2001). The thin Cannes-de-Roches succession of Bonaventure Formation beds (lower and middle members of the abandoned Cannes-de-Roches Formation) is characterized by fanglomerates and alluvial plain deposits only (Rust (1981), whereas alluvial fans in the Ristigouche Basin connected with west- to west-southwest–flowing trunk rivers (Jutras et al., 2001). (B) Model for the juxtaposition of the two basins by strike-slip faulting.

subsequently involved in juxtaposing the Cannes-de-Roches and Ristigouche Basins (Fig. 13B). Most of this displacement occurred along the Percé and Cap Blanc fault system, whereas only minor displacement seems to have occurred along the north-northwest–striking fault system that truncates this system, even though secondary structures associated with the latter are best represented. According to the observed displacement of Ordovician and Silurian units, only ~1 km of dextral displacement occurred on the Ruisseau Blanc Fault (Kirkwood, 1989), the main north-northwest–striking fault in the Percé area.

It is here argued that clockwise rotation of σ_1—evolving from north-northwest–south-southeast to northeast-southwest—and gradual reduction of its intensity may have occurred in the eastern Gaspé Peninsula during post-Mississippian time. Evidence for this clockwise rotation of paleostress is given by the truncation of thrust planes that indicate an ~032°–212° σ_1 orientation by reverse-fault planes that indicate an ~047°–227° σ_1 orientation in the calcrete of Percé-Beach (Fig. 3, stereonet 3). The 005°–185° σ_1 orientation estimated from Riedel structures of the Ruisseau Blanc Fault (Fig. 3, stereonets 4 and 5) and the 021°–201° σ_1 orientation estimated from reverse-fault slickenfibers in the Cap Blanc Fault corridor (Fig. 3, stereonet 2) add to this array of main principal stress vectors determined in Mississippian rocks of the Percé area.

Further evidence in support of this stress-rotation hypothesis is the attitude of reverse faults in the Cap Blanc Fault corridor, which does not correspond well with the orientation of their slickenfibers (Fig. 3, stereonet 2). None of these reverse faults strike east-northeast, which would be expected under a north-northeast–south-southwest σ1, but three reverse faults out of eight strike east-southeast and are therefore compatible with north-northwest–south-southeast compression. The slickenfibers may correspond to late movement on the fault planes and possibly formed under a slightly different stress regime than that prevailing when the fracture was originally formed.

Similarly, the only slickenfibers that were measured on reverse-fault planes associated with the Percé Fault are oblique to the strike of the one fault plane that hosts them (Fig. 3, stereonet 1; Table DR1 [see footnote 1]). Although orientation of this particular fault plane would indicate a stress regime involving north-northwest–south-southeast compression, the fault plane's slickenfibers indicate a north-northeast–south-southwest main principal stress. Here again, the slickenfibers may only reflect the last movement on that fault plane and are possibly not indicative of the cumulative history of that fault.

In their study of post-Acadian paleostresses in southern Quebec, Faure et al. (1996a) also inferred a gradual clockwise rotation of σ_1 from north-northwest–south-southeast to north-northeast–south-southwest, although none of their estimated σ_1 vectors are as clearly northeast-southwest as that suggested by the youngest reverse faults at Percé-Beach. These authors tentatively associated this paleostress rotation with the gradual indentation of Gondwana's Reguibat uplift into Laurentia during the Carboniferous (Fig. 2) (Lefort et al., 1988; Vauchez et al., 1987; Piqué and Skehan, 1992).

In most cases, objectively dividing structures related to one trend from those of the other can be a difficult task, as structures related to different episodes of deformation may intermingle. Because Kirkwood (1989) considered northwest- and north-northwest–striking fault planes to lie within the same fault system, contrasting paleostress trends presented by Kirkwood average out to north-northeast, but may in fact reflect this clockwise rotation of paleostresses from north-northwest–south-southeast to northeast-southwest.

The proposed scenario to explain the array of structural data collected in Mississippian rocks of the Gaspé Peninsula is as follows:

1. Dextral motion along the northwest-

striking Percé and Cap Blanc Faults occurred in response to a strong initial north-northwest–south-southeast paleostress, resulting in the displacement of Carboniferous units by more than 10 km. Subordinate structures associated with those faults are the Cap Blanc drag fold (Fig. 4; inset) and the east-northeast– to east-striking reverse faults at Cannes-de-Roches Point (Fig. 3, stereonet 1) and Cap Blanc (Fig. 3, stereonet 2).

2. As σ_1 gradually rotated clockwise and as compressive stress diminished in intensity, the drag fold at Cap Blanc and the preexisting subsidiary reverse faults were reactivated accordingly, new ones were formed, and the main faults were eventually truncated by newly developed north-northwest–striking dextral faults. Associated with this north-northeast–south-southwest to northeast-southwest compression are the drag fold near the village of Coin-du-Banc (Figs. 3, 10), the 70° tilting of Mississippian strata perpendicular to the Percé Fault in the Cannes-de-Roches Cove (center of Fig. 3), the 15° tilting of Mississippian strata on the northeast block of the Cap Blanc Fault (southeast quadrant in Fig. 3), the slickenfibers and west-northwest– to northwest-striking reverse faults at Cannes-de-Roches Point (Fig. 3, stereonet 1), Cap Blanc (Fig. 3, stereonet 2), and Percé-Beach (Fig. 3, stereonet 3), and various Riedel structures associated with the Ruisseau Blanc Fault (Fig. 3, stereonets 4 and 5).

Regional perspective and timing constraints

Details on the post-Acadian tectonic history of the Gaspé Peninsula remain elusive on account of the complexity of paleostress trends, as defined by Faure et al. (1996a), paired with the nonpenetrative nature of the deformations, which left most of the host rocks undisturbed. However, on the basis of the present data, it must be emphasized that all the strictly brittle strike-slip structures that have been previously recognized in the Gaspé Peninsula and that Malo and Kirkwood (1995) and Kirkwood et al. (1995) associated with the ''Acadian Phase III'' are possibly post-Acadian. As the Mississippian beds in the Gaspé Peninsula overlie a mature, almost peneplain surface that truncates Acadian folds (Peulvast et al., 1996; Jutras and Schroeder, 1999), substantial postorogenic uplift and erosion necessarily separate the exposed Acadian ductile-brittle deformation from strictly brittle exposed structures related to Carboniferous or younger deformation events.

Only Quaternary sediments overlap post-Acadian structures, giving a very poorly constrained upper age limit for them, whereas their lower age limit is constrained to the Namurian, which is the age of the Pointe Sawyer Formation. It is postulated that all deformations affecting Mississippian rocks of the Gaspé Peninsula are distal manifestations of the Hercynian-Alleghanian orogeny, which ended in the Permian, although later compressive features related to oceanic plate readjustments were also registered within Cretaceous rocks of southern Quebec, but indicate that σ_1 was northeast-southwest (Saull and Williams, 1974; Gélard et al., 1992; Faure et al., 1996b).

As post-Acadian structures in the Gaspé Peninsula affect rocks that are as young as Namurian, they are possibly related to the deformation event that took place during the Westphalian B, which corresponds to the most important Alleghanian phase to have affected the Maritimes (Piqué, 1981; Ruitenberg and McCutcheon, 1982; Nance, 1987; Nance and Warner, 1986; Gibling et al., 1987; Yeo and Ruixiang, 1987; Ryan et al., 1988; Thomas and Schenk, 1988; Keppie, 1993; Reed et al., 1993). The presence of seemingly undisturbed Westphalian C to Stephanian beds of the Clifton Formation on the south shore of Chaleur Bay, unconformably overlying Mississippian rocks, supports this hypothesis (Alcock, 1935; Ball et al., 1981; Legun and Rust, 1982).

Transpressive deformations in the Maritimes Basin are also reported for the end of the Namurian (Piqué, 1981; Waldron et al., 1989; Pe-Piper et al., 1991; St. Peter, 1993) and for the Pennsylvanian-Permian boundary (Donkin episode; Pascucci et al., 2000; Gibling et al., 2002), but are less widespread. To conclude on the subject of potential timing, it should be noted that some faults in the Maritimes Basin are thought to have remained intermittently active until the Triassic (Donohoe and Wallace, 1988; St. Peter, 1993; Withjack et al., 1995).

The transpressive deformation features recorded in Carboniferous rocks of the Gaspé Peninsula, more than 1000 km away from areas of peak Alleghanian metamorphism in the southeastern United States, put in perspective the far-reaching effects of rigid indenters during continental collision. As a modern analogue, Tapponnier et al. (1982) associated transpressive accommodation occurring in Southeast Asia with the prograding Indian craton, which acts as a rigid indenter, more than 1000 km away in the Himalayas. A parallel between the Alleghanian and Himalayan orogenies was also observed by Gibling et al. (1992), from similarities in the drainage patterns that convey sediments along the tectonic grain and into passive basins that are located laterally behind the main orogenic front. However, whereas the Himalayan orogeny involves the collision of a small continent with a large one, the Alleghanian orogeny involved the collision of two major continental masses, which restrained the indentation to some degree.

CONCLUSION

Post-Acadian deformation involving significant lateral displacement is demonstrated for the first time in the Gaspé Peninsula along the Percé Fault system, which has juxtaposed the Mississippian Cannes-de-Roches and Ristigouche Basins in post–early Namurian time under a transpressive regime. Although the flat-lying Carboniferous succession does not provide precise stratigraphic markers, significant lateral displacement on the Percé Fault is necessary to justify the absence of a source-rock area between the juxtaposed strata of the Cannes-de-Roches and Ristigouche Basins in the Percé area. From these new data, age determination should be reconsidered for the strictly brittle strike slips of the peninsula, many of which could be post-Acadian and related to phases of the Alleghanian deformation in Carboniferous to Permian time.

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REFERENCES CITED

Alcock, F.J., 1935, Geology of the Chaleur Bay region: Geological Survey of Canada Memoir 183, 146 p.

Arthaud, F., and Matté, P., 1977, Late-Paleozoic strike-slip faulting in southern Europe and northern Africa: Result of a right lateral shear zone between the Appalachians and the Urals: Geological Society of America Bulletin, v. 88, p. 1305–1320.

Ball, F.D., Sullivan, R.M., and Peach, A.R., 1981, Carboniferous drilling project: New Brunswick Department of Natural Resources, Report of Investigations 18, 109 p.

Béland, J., 1980, Faille du bassin Nord-Ouest et faille du Troisième-Lac dans la partie est de la Gaspésie: Ministère de l'Énergie et des Ressources de la Province de Québec, no. DP-740, 20 p.

Bernard, D., and St-Julien, P., 1986, Analyse structurale du Siluro–Dévonien du centre de la Gaspésie et du Carbonifère du sud et de l'est de la Gaspésie: ère de l'Énergie et des Ressources de la Province de Quebec, no. MB 86–36, 78 p.

Biddle, K.T., and Christie-Blick, N., 1985, Glossary- Strike-slip deformation, basin formation and sedimentation, *in* Biddle, K.T., and Christie-Blick, N., eds., Strike-slip deformation, basin formation and sedimentation:

Society of Economic Paleontologists and Mineralogists Special Publication 37, p. 375–386.

Bourque, P.A., Gosselin, C., Kirkwood, D., Malo, M., and St-Julien, P., 1993, Le Silurien du segment appalachien Gaspésie-Matapédia-Témiscouata: Stratigraphie, géologie structurale et paléogéographie: Ministère de l'Énergie et des Ressources de la Province de Quebec, no. MB 93–25, 115 p.

Bradley, D.C., 1982, Subsidence of late Paleozoic basins in the northern Appalachians: Tectonics, v. 1, p. 107–123.

Brisebois, D., Lachambre, G., and Piché, G., 1992, Carte géologique: Péninsule de la Gaspésie: Ministère de l'Énergie et des Ressources de la Province de Quebec, no. DV 91–21, scale 1:250,000, 1 sheet.

Donohoe, H.V., Jr., and Wallace, P.I., 1988, Movement history of the Cobequid Fault zone, Cobequid Highlands, northern Nova Scotia: Atlantic Geology, v. 24, p. 191.

Durling, P.W., and Marillier, F., 1993, Tectonic setting of Middle Devonian to Lower Carboniferous rocks in the Magdalen Basin: Atlantic Geology, v. 29, p. 199–217.

Faure, S., Tremblay, A., and Angelier, J., 1996a, Alleghanian paleostress reconstruction in the northern Appalachians: Intraplate deformation between Laurentia and Gondwana: Geological Society of America Bulletin, v. 108, p. 1467–1480.

Faure, S., Tremblay, A., and Angelier, J., 1996b, State of intraplate stress and tectonism of northeastern America since Cretaceous times, with particular emphasis on the New England–Quebec igneous province: Tectonophysics, v. 255, p. 111–134.

Fralick, P.W., and Schenk, P.E., 1981, Molasse deposition and basin evolution in a wrench tectonic setting: The late Paleozoic, eastern Cumberland Basin, Maritime Canada, *in* Miall, A.D., ed., Sedimentation and tectonics in alluvial basins: Geological Association of Canada Special Paper 23, p. 77–97.

Fyffe, L.R., and Barr, S.M., 1986, Petrochemistry and tectonic significance of Carboniferous volcanic rocks in New Brunswick: Canadian Journal of Earth Sciences, v. 23, p. 1243–1256.

Gélard, J.P., Jébrak, M., and Prichonnet, G., 1992, Les contraintes phanérozoïques dans la plate-forme du Saint-Laurent, région de Montréal, Quebec: Canadian Journal of Earth Sciences, v. 29, p. 499–505.

Gibling, M.R., Boehner, R.C., and Rust, B.R., 1987, The Sydney Basin of Atlantic Canada: An upper Paleozoic strike-slip basin in a collisional setting, *in* Beaumont, C., and Tankard, A.J., eds., Sedimentary basins and basin-forming mechanisms: Canadian Society of Petroleum Geologists Memoir 12, p. 269–285.

Gibling, M.R., Calder, J.H., Ryan, R., Van de Poll, H.W., and Yeo, G.M., 1992, Late Carboniferous and Early Permian drainage patterns in Atlantic Canada: Canadian Journal of Earth Sciences, v. 29, p. 338–352.

Gibling, M.R., Langenberg, W., Kalkreuth, W.D., Waldron, J.W.F., Courtney, R., Paul, J., and Grist, A.M., 2002, Deformation of Upper Carboniferous coal measures in the Sydney Basin: Evidence for late Alleghanian tectonism in Atlantic Canada: Canadian Journal of Earth Sciences, v. 39, p. 79–93.

Haszeldine, R.S., 1984, Carboniferous North Atlantic paleogeography: Stratigraphic evidence for rifting, not megashear or subduction: Geological Magazine, v. 121, p. 443–463.

Howie, R.D., and Barss, M.S., 1975, Upper Paleozoic rocks of the Atlantic provinces, Gulf of St.-Lawrence and adjacent continental shelf: Geological Survey of Canada Paper 74–30, v. 2, p. 35–50.

Jutras, P., and Schroeder, J., 1999, Geomorphology of an exhumed Carboniferous paleosurface in the southern Gaspé Peninsula, Quebec: Paleoenvironmental and tectonic implications: Géographie Physique et Quaternaire, v. 53, p. 249–263.

Jutras, P., Prichonnet, G., and von Bitter, P., 1999, The La Coulée Formation, a new post-Acadian stratigraphic unit bearing groundwater calcretes, Gaspé Peninsula, Quebec: Atlantic Geology, v. 35, p. 139–156.

Jutras, P., Prichonnet, G., and Utting, J., 2001, Newly identified Carboniferous units (The Pointe Sawyer and Chemin-des-Pêcheurs Formations) in the Gaspé Peninsula, Quebec: Implications regarding the evolution of the northwestern sector of the Maritimes Basin: Canadian Journal of Earth Sciences, v. 38, p. 1–19.

Kent, D.V., and Keppie, J.D., 1988, Silurian–Permian paleocontinental reconstructions and circum-Atlantic tectonics, *in* Harris, A.L., and Fettes, D.J., eds., The Caledonian-Appalachian orogen: Geological Society [London] Special Publication 38, p. 469–480.

Kent, D.V., and Opdyke, N., 1985, Multicomponent magnetizations from the Mississippian Mauch Chunk Formation of the central Appalachians and their tectonic implications: Journal of Geophysical Research, v. 90, p. 5371–5383.

Keppie, J.D., 1982, The Minas Geofracture, *in* St-Julien, P., and Béland, J., eds., Major structural zones and faults of the northern Appalachians: Geological Association of Canada Special Paper 24, p. 263–280.

Keppie, J.D., 1993, Synthesis of Paleozoic deformational events and terrane accretion in the Canadian Appalachians: Geologische Rundschau, v. 82, p. 381–431.

Kirkwood, D., 1989, Géologie structurale de la région de Percé: Ministère de l'Énergie et des Ressources de la Province de Quebec, no. ET 87–17, 42 p.

Kirkwood, D., Malo, M., St-Julien, P., and Thérrien, M., 1995, Vertical and fold-axis parallel extension within a slate belt in a transpressive setting, northern Appalachians: Journal of Structural Geology, v. 17, p. 329–343.

Koukouvelas, I., Pe-Piper, G., and Piper, D.J.W., 2002, The role of dextral transpression faulting in the evolution of an Early Carboniferous (Mississippian) mafic-felsic plutonic and volcanic complex: Cobequid Highlands, Nova Scotia, Canada: Tectonophysics, v. 348, p. 219–246.

Lefort, J.P., and van der Voo, R., 1981, A kinematic model for the collision and complete suturing between Gondwanaland and Laurussia in the Carboniferous: Journal of Geology, v. 89, p. 537–550.

Lefort, J.P., Max, M.D., and Roussel, J., 1988, Geophysical evidence for the location of the NW boundary of Gondwanaland and its relationship with two older satellite sutures, *in* Harris, A.L., and Fettes, D.J., eds., The Caledonian-Appalachian orogen: Geological Society [London] Special Publication 38, p. 49–60.

Legun, A.S., and Rust, B.R., 1982, The Upper Carboniferous Clifton Formation of northern New Brunswick: Coal-bearing deposits of a semi-arid alluvial plain: Canadian Journal of Earth Sciences, v. 19, p. 1775–1785.

Malo, M., and Béland, J., 1989, Acadian strike-slip tectonics in the Gaspé region, Quebec Appalachians: Canadian Journal of Earth Sciences, v. 26, p. 1764–1777.

Malo, M., and Kirkwood, D., 1995, Faulting and progressive strain history of the Gaspé Peninsula in post-Taconian time: A review, *in* Hibbard, J.P., van Staal, C.R., and Cawood, P.A., eds., Current perspectives in the Appalachian-Caledonian orogen: Geological Association of Canada Special Paper 41, p. 267–282.

Malo, M., Kirkwood, D., de Broucker, G., and St-Julien, P., 1992, A re-evaluation of the position of the Baie Verte–Brompton Line in the Quebec Appalachians: The influence of Middle Devonian strike-slip faulting in the Gaspé Peninsula: Canadian Journal of Earth Sciences, v. 29, p. 1265–1273.

Malo, M., Tremblay, A., Kirkwood, D., and Cousineau, P., 1995, Along-strike Acadian structural variations in the Quebec Appalachians: Consuccession of a collision along an irregular margin: Tectonics, v. 14, p. 1327–1338.

McCutcheon, S.R., and Robinson, P.T., 1987, Geological constraints on the genesis of the Maritimes Basin, Atlantic Canada, *in* Beaumont, C., and Tankard, A.J., eds., Sedimentary basins and basin-forming mechanisms: Canadian Society of Petroleum Geologists Memoir 12, p. 287–297.

Murphy, J.B., Rice, R.J., Stokes, T.R., and Keppie, D.F., 1995, St. Mary's Basin, central mainland Nova Scotia, late Paleozoic basin formation and deformation along the Avalon-Meguma terrane boundary, Canadian Appalachians, *in* Hibbard, J.P., van Staal, C.R., and Cawood, P.A., eds., Current perspectives in the Appalachian-Caledonian orogen: Geological Association of Canada Special Paper 41, p. 409–420.

Nance, R.D., 1987, Dextral transpression and Late Carboniferous sedimentation in the Fundy coastal zone of southern New Brunswick, *in* Beaumont, C., and Tankard, A.J., eds., Sedimentary basins and basin-forming mechanisms: Canadian Society of Petroleum Geologists Memoir 12, p. 363–377.

Nance, R.D., and Warner, J.B., 1986, Variscan tectonostratigraphy of the Mispec Group, southern New Brunswick: Structural geometry and deformational history: Geological Survey of Canada Paper 86-1A, p. 351–358.

Pascucci, V., Gibling, M.R., and Williamson, M.A., 2000, Late Paleozoic to Cenozoic history of the offshore Sydney Basin, Atlantic Canada: Canadian Journal of Earth Sciences, v. 37, p. 1143–1165.

Pe-Piper, G., Piper, D.J.W., and Clerk, S.B., 1991, Persistent mafic igneous activity in an A-type granite pluton, Cobequid Highlands, Nova Scotia: Canadian Journal of Earth Sciences, v. 28, p. 1058–1072.

Peulvast, J.-P., Bouchard, M., Jolicoeur, S., Pierre, G., and Schroeder, J., 1996, Paleotopographies and post-orogenic morphotectonic evolution around the Baie-des-Chaleurs (eastern Canada): Geomorphology, v. 16, p. 5–32.

Piqué, A., 1981, Northwestern Africa and the Avalonian plate: Relations during late Precambrian and late Paleozoic times: Geology, v. 9, p. 319–322.

Piqué, A., and Skehan, J.W., 1992, Late Paleozoic orogenies in western Africa and eastern North America: The diachronous closure of Theic Ocean: Tectonics, v. 11, p. 393–404.

Reed, B.C., Nance, R.D., Calder, J.H., and Murphy, J.B., 1993, The Athol syncline: Tectonic evolution of a Westphalien A-B depocenter in the Maritimes Basin, Nova Scotia: Atlantic Geology, v. 29, p. 179–186.

Rodgers, J., 1988, Fourth time-slice: Mid-Devonian to Permian synthesis, *in* Harris, A.L., and Fettes, D.J., eds., The Caledonian-Appalachian orogen: Geological Society [London] Special Publication 38, p. 621–626.

Ruitenberg, A.A., and McCutcheon, S.R., 1982, Acadian and Hercynian structural evolution of southern New Brunswick, *in* St-Julien, P., and Béland, J., eds., Major structural zones and faults of the northern Appalachians: Geological Association of Canada Special Paper 24, p. 131–148.

Russell, M.J., and Smythe, D.K., 1983, Origin of the Oslo graben in relation to the Hercynian–Alleghanian orogeny and lithospheric rifting in the North Atlantic: Tectonophysics, v. 94, p. 457–472.

Rust, B.R., 1981, Alluvial deposits and tectonic style: Devonian and Carboniferous successions in eastern Gaspé, *in* Miall, A.D., ed., Sedimentation and tectonics in alluvial basins: Geological Association of Canada Special Paper 23, p. 49–76.

Rust, B.R., Lawrence, D.A., and Zaitlin, B.A., 1989, The sedimentation and tectonic significance of Devonian and Carboniferous terrestrial successions in Gaspé, Quebec: Atlantic Geology, v. 25, p. 1–13.

Ryan, R.J., Donohoe, H.V., Jr., and Boehner, R.C., 1988, Sedimentation, tectonics and Carboniferous basin evolution adjacent to the Cobequid Highlands massif, northern Nova Scotia: Maritimes sediments and Atlantic Geology, v. 24, p. 211.

Sacks, P., and Secor, D.T., Jr., 1990, Kinematics of late Paleozoic continental collision between Laurentia and Gondwana: Science, v. 250, p. 1702–1705.

Saull, V.A., and Williams, D.A., 1974, Evidence for recent deformation in the Montréal area: Canadian Journal of Earth Sciences, v. 11, p. 1621–1624.

St-Julien, P., and Hubert, C., 1975, Evolution of the Taconian orogen in the Quebec Appalachians: American Journal of Science, v. 275-A, p. 337–362.

St. Peter, C., 1993, Maritimes Basin evolution: Key geologic and seismic evidence from the Moncton Subbasin of New Brunswick: Atlantic Geology, v. 29, p. 233–270.

Tapponnier, P., Peltzer, G., Le Dain, A.Y., Armijo, R., and Cobbold, P., 1982, Propagating extrusion tectonics in Asia: New insights from simple experiments with plasticine: Geology, v. 10, p. 611–616.

Thomas, W.A., and Schenk, P.E., 1988, Late Paleozoic sedimentation along the Appalachian orogen, *in* Harris, A.L., and Fettes, D.J., eds., The Caledonian-Appalachian orogen: Geological Society [London] Special Publication 38, p. 515–530.

Utting, J., 1987, Palynology of the Lower Carboniferous Windsor Group and Windsor-Canso boundary beds of Nova Scotia, and their equivalents in Quebec, New Brunswick and Newfoundland: Geological Survey of Canada Bulletin 374, 34 p.

van de Poll, H.W., 1995, Upper Paleozoic rocks: New-Brunswick, Prince-Edward-Island and Îles-de-la-Madeleine, *in* Williams, H., ed., Geology of the Appalachian/Caledonian orogen in Canada and Greenland: Geological Survey of Canada, Geology of Canada, v. 6, p. 455–492.

Vauchez, A., Kessler, S.F., Lécorché, J.P., and Villeneuve, M., 1987, Southward extrusion tectonics during the Carboniferous Africa–North America collision: Tectonophysics, v. 142, p. 317–322.

Waldron, J.W.F., Piper, D.J.W., and Pe-Piper, G., 1989, Deformation of the Cape Chignecto pluton, Cobequid Highlands, Nova Scotia: Thrusting at the Meguma-Avalon boundary: Atlantic Geology, v. 25, p. 51–62.

Wilcox, R.E., Harding, T.P., and Seeley, D.R., 1973, Basic wrench tectonics: American Association of Petroleum Geologists Bulletin, v. 57, p. 74–96.

Withjack, M.O., Olsen, P.E., and Schlische, R.W., 1995, Tectonic evolution of the Fundy rift basin, Canada: Evidence of extension and shortening during passive margin development: Tectonics, v. 14, p. 390–405.

Woodcock, N.J., and Fischer, M., 1986, Strike-slip duplexes: Journal of Structural Geology, v. 8, p. 725–735.

Yeo, G.M., and Ruixiang, G., 1987, Stellarton Basin, a pull-apart basin, *in* Beaumont, C., and Tankard, A.J., eds., Sedimentary basins and basin-forming mechanisms: Canadian Society of Petroleum Geologists Memoir 12, p. 298–309.

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