Record of Late Mississippian tectonics in the new Percé Group (Viséan) of eastern Gaspésie, Quebec

Pierre Jutras and Gilbert Prichonnet

Abstract: Viséan clastic units and structures at the northwest margin of the upper Paleozoic Maritimes Basin provide information on tectonic events that are only poorly recorded in more central parts of the basin. These continental units are time equivalent to marine sediments of the Windsor Group of Nova Scotia. They are herein assigned to the new Percé Group, which includes the La Coulée and Bonaventure formations, as well as a new unit, the Cap d'Espoir Formation. The latter unit unconformably underlies the Bonaventure Formation in a small but thick sub-basin of the Ristigouche Basin in eastern Quebec. It is characterized by a succession of sandstone and mudstone rhythmites that contrast with the coarse alluvial fan deposits of the overlying Bonaventure Formation. The Cap d'Espoir Formation was sourced from a broad area of subdued topography occupied by the Viséan La Coulée Formation and underlying units. Erosional remnants of the La Coulée Formation are unconformably overlain by the Bonaventure Formation in marginal parts of the Ristigouche Basin, whereas these units are separated by the Cap d'Espoir Formation in more central areas of the basin. The La Coulée and Cap d'Espoir formations underwent tilting and erosion during a normal faulting event that preceded deposition of the fault-controlled Bonaventure Formation. This series of events is interpreted to represent different steps in the reactivation of a pre-Carboniferous dextral strike-slip system in response to northwest–southeast compression during the Viséan in Gaspésie.

Résumé : Des unités clastiques viséennes et leurs structures intrinsèques dans la marge nord-ouest du bassin des Maritimes (Paléozoique supérieur) illustrent des événements tectoniques qui ne sont que pauvrement enregistrés dans les parties plus centrales du bassin. Ces unités continentales sont chronologiquement équivalentes aux sédiments marins du Groupe de Windsor en Nouvelle-Écosse. Elles sont ici assignées au nouveau Groupe de Percé, lequel inclut les formations de La Coulée et de Bonaventure, ainsi qu'une nouvelle unité, la Formation de Cap d'Espoir. Cette dernière est recouverte en discordance par la Formation de Bonaventure à l'intérieur d'un petit mais relativement épais sous-bassin du Bassin de Ristigouche dans l'est du Québec. Elle est caractérisée par une succession de dépôts rythmiques de grès et de mudstone qui contraste avec les dépôts grossiers de cônes alluviaux de la Formation de Bonaventure sus-jacente. La Formation de Cap d'Espoir est le produit de l'érosion d'une région source de grande étendue et à faible gradient topographique, laquelle était occupée par la Formation de La Coulée et les unités qui lui sont sous-jacentes. Les reliques d'érosion de la Formation de La Coulée sont recouvertes de façon discordante par la Formation de Bonaventure dans les parties marginales du bassin de Ristigouche, alors que ces unités sont séparées par la Formation de Cap d'Espoir dans les parties plus centrales du bassin. Les formations de La Coulée et de Cap d'Espoir ont été basculées et partiellement érodées à l'intérieur d'un événement de fracturation ayant précédé le dépôt de la Formation de Bonaventure, dont les faciès ont été contrôlés par des escarpements de failles. Cette série d'événements est considérée comme étant le résultat de différentes étapes dans la réactivation d'un système de coulissage dextre (pré-Carbonifère) en réponse à des contraintes orientées NW–SE durant le Viséen en Gaspésie.

Introduction

The formation and eventual deformation of the upper Paleozoic Maritimes Basin of eastern Canada (Fig. 1, inset) are increasingly viewed as the results of, respectively, Late Devonian to Tournaisian (Early Mississippian) transtension and Pennsylvanian transpression (Ramsbottom 1973; Arthaud and Matté 1977; McMaster et al. 1980; Fralick and Schenk 1981; Bradley 1982; Keppie 1982; Gibling et al. 1987; Ryan et al. 1988; Pe-Piper et al. 1989; Rust et al. 1989; Reed et al. 1993; Murphy et al. 1995; Koukouvelas et al. 2002; Jutras et al. 2003*a*, 2003*b*). In this scenario, the Viséan (Late Mississippian) is usually considered a time of tectonic quiescence, during which eustatic variations and slow basin subsidence from post-extensional cooling controlled a dominantly marine sedimentation, in contrast with the exclusively continen-

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Fig. 1. Geology and cross-section of the study area in eastern Gaspé, with its location in a regional context shown in the inset. The pre-Carboniferous geology is modified from Kirkwood (1989) and Brisebois et al. (1991). Inset is modified from Gibling et al. (1992). In inset: GRF, Grande-Rivière fault; GPF, Grand-Pabos fault system. In main map: locality 1, the Murphy Creek exposures of La Coulée Calcrete.

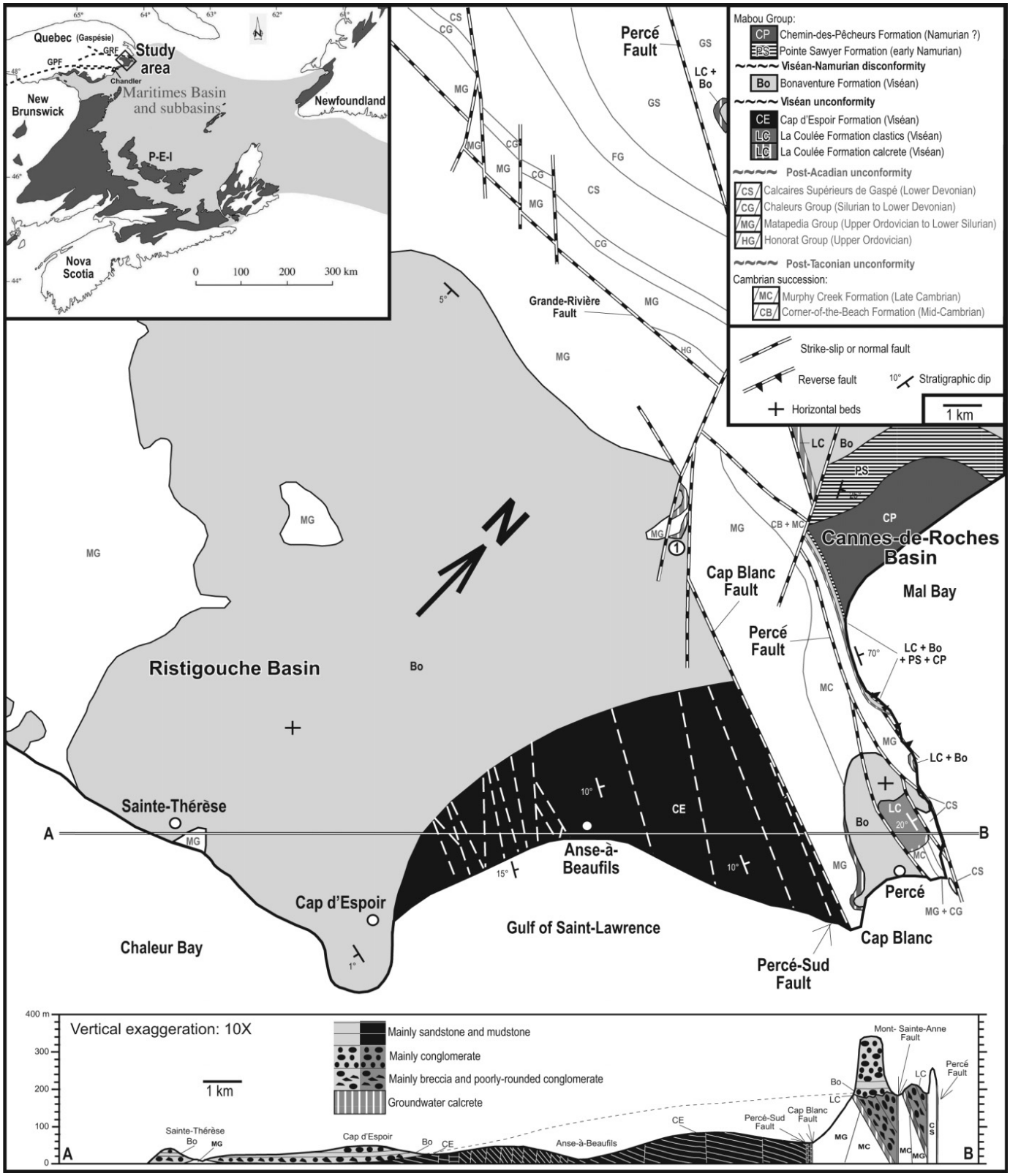
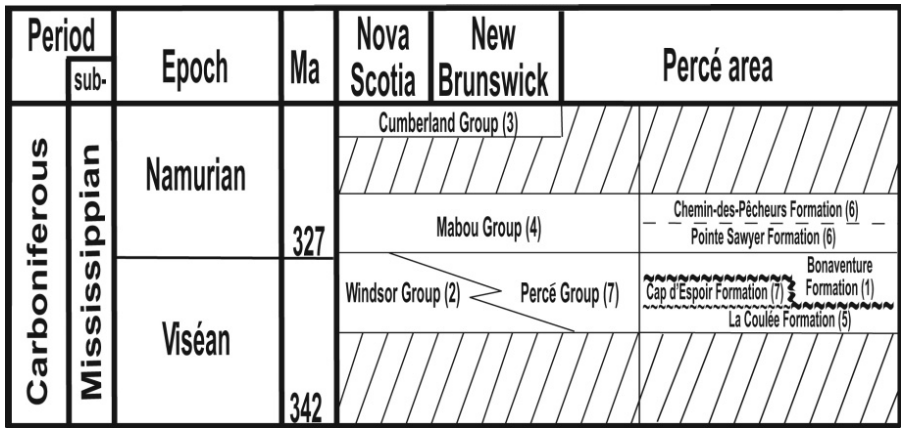


Fig. 2. Proposed stratigraphic framework for the Viséan to Namurian rocks in the Percé area of eastern Quebec, with broad correlations with units of Atlantic Canada. Time scale after Okulitch (1999). Units were first introduced by (1) Logan (1846), (2) Dawson (1873), (3) Bell (1944), (4) Belt (1964), (5) Jutras et al. (1999), (6) Jutras et al. (2001), and (7) this study. Thin wavy lines, disconformities; bold wavy lines, unconformities; full cross-lined areas, major hiatuses.



tal sedimentation that characterizes the rest of the regional upper Paleozoic successions (Howie and Barss 1975; Giles 1981; Bradley 1982; Giles and Boutilier 2000).

Because it records the only marine incursions in the composite Maritimes Basin, the Viséan interval has been studied in detail in central areas of the basin (e.g., Dawson 1873; Bell 1929, 1944; Belt 1965; Kelley 1967; Schenk 1967; Howie and Barss 1975; Geldsetzer 1977, 1978; Giles 1981; Boehner 1985, 1992; Howie 1988; Giles and Boehner 2004). Additional interest for the carbonates, evaporites, and fine-grained clastic rocks of this interval are their association with oil, gas, gypsum, salt, barite, and metallic ore resources. In contrast, Viséan rocks in the Gaspé Peninsula of Quebec, at the northwest margin of the Maritimes Basin (Fig. 1), are exclusively clastic and thus have attracted less exploration interest. They do, however, provide more information about the tectonic events that occurred during the Viséan than time-equivalent units in more central areas of the Maritimes Basin, which may have only experienced an increase or decrease in subsidence and accommodation space during these events. Because the latter processes can be easily confused with eustatic variations from orbital forcing, which are recorded in the entire Windsor Group succession (Giles and Boutilier 2000), the study of clastic deposits and structures in marginal areas of the basin can help distinguish tectonic events from Croll–Milankovitch cycles in the entire basin.

The present paper introduces and describes a new stratigraphic unit, the Cap d'Espoir Formation (Appendix A), which is part of a clastic succession that is time equivalent to the Viséan Windsor Group, but petrographically quite distinct from it. Units of this succession include the La Coulée Formation (Jutras et al. 1999), conformably to disconformably overlain by the Cap d'Espoir Formation (this paper), which is unconformably overlain by the Bonaventure Formation (Logan 1846; Jutras et al. 2001). Because these three units have their type-sections in the Town of Percé, we propose to collectively refer to them as the Percé Group (Appendix B) to differentiate them from both the time-equivalent Windsor Group and the overlying Namurian Mabou Group (Fig. 2).

Seismic reflection data are combined with field data to provide an understanding of the Carboniferous succession and inherent structures in the area between the villages of Percé and Cap d'Espoir (Fig. 1). The new data suggest that post-Acadian and pre-Alleghanian transtensional tectonics were still active during the Viséan at the northwest margin of the Maritimes Basin, adding significantly to the understanding of the tectonic evolution of the basin as a whole during this time frame.

Geological setting

The Carboniferous succession of the Percé area overlies rocks ranging from the Cambrian to the Lower Devonian (Fig. 1) (Kirkwood 1989; Brisebois et al. 1991). The Cambrian Corner-of-the-Beach and Murphy Creek formations were first deformed by the Middle Ordovician Taconian orogeny and are unconformably overlain by an Upper Ordovician to Lower Devonian succession (Honorat, Matapedia, Chaleurs, and Calcaires Supérieurs de Gaspé groups) (St-Julien and Hubert 1975; Kirkwood 1989; Brisebois et al. 1991). The entire pre-Carboniferous succession was deformed by the Middle Devonian Acadian orogeny (Malo and Béland 1989; Malo et al. 1992, 1995; Malo and Kirkwood 1995; Kirkwood et al. 1995).

The Carboniferous successions of eastern Gaspésie were deposited in the east–west-trending Ristigouche Basin (van de Poll 1995), which extends to the south and west of Percé, and in the northwest–southeast-trending Cannes-de-Roches Basin (Jutras et al. 2001) north of Percé (Fig. 1). Both basins include Viséan to Namurian units, but Namurian beds of the Ristigouche Basin are not exposed in the study area.

The oldest post-Acadian rocks in eastern Gaspésie are assigned to the La Coulée Formation (Fig. 2) (Jutras et al. 1999). The latter is a unit of coarse grey fanglomerate affected by thorough groundwater calcretization in its basal 10 m and by partial calcretization in the overlying 20 m.

The La Coulée Formation, which was deposited widely in the Percé area, was tilted, uplifted, and almost entirely eroded prior to deposition of the Bonaventure Formation red beds (Jutras et al. 1999). The latter rest unconformably upon several

Fig. 3. Stratigraphic sections along coastal exposures that extend south of the village of Percé, with localities indicated on the adjoining map (refer to Fig. 1 for legend). Rose diagrams illustrate paleocurrent measurements taken from scour-and-fill trough channels. The symbols "O" and "+" on each side of the Cap Blanc fault refer to lateral movement identified by Jutras et al. (2003*a*).

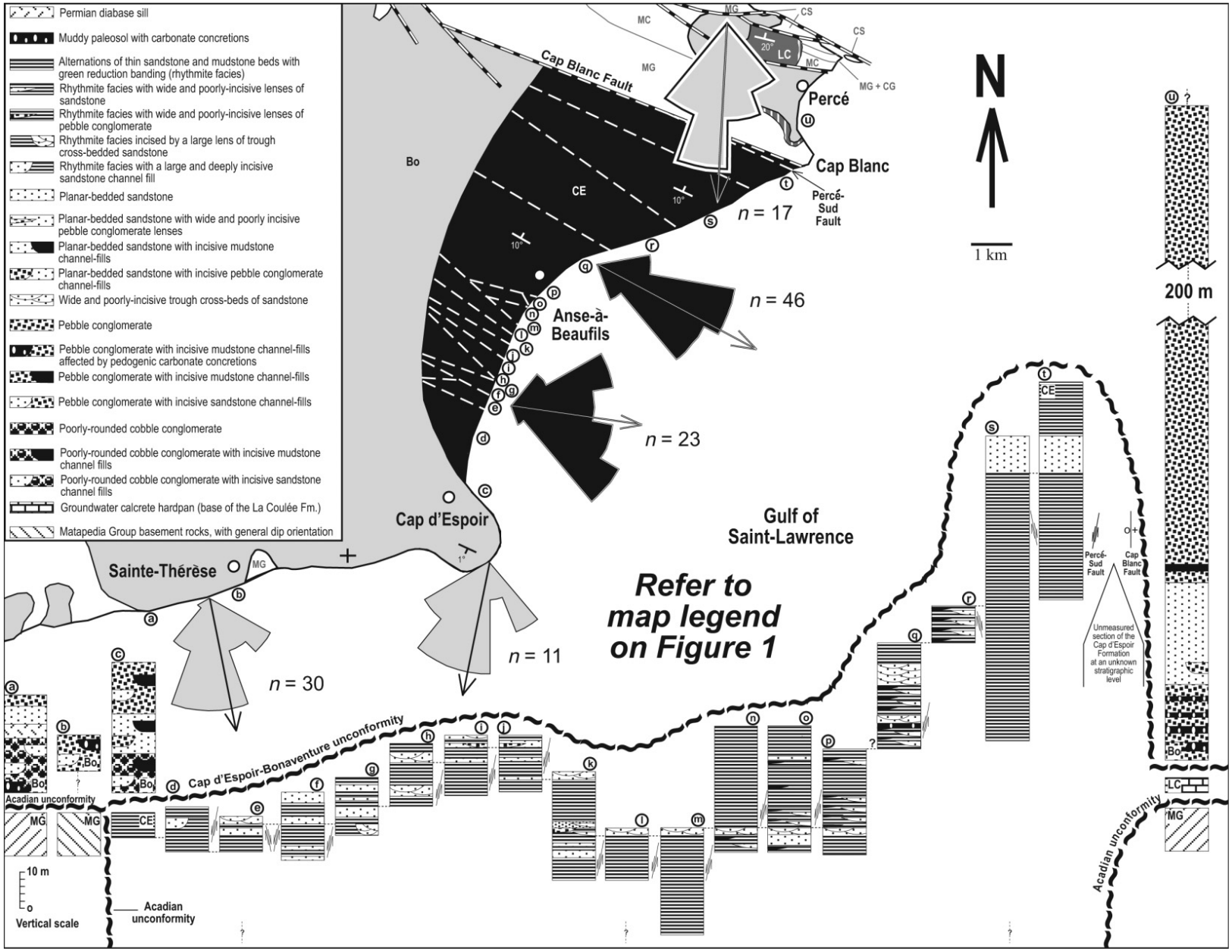
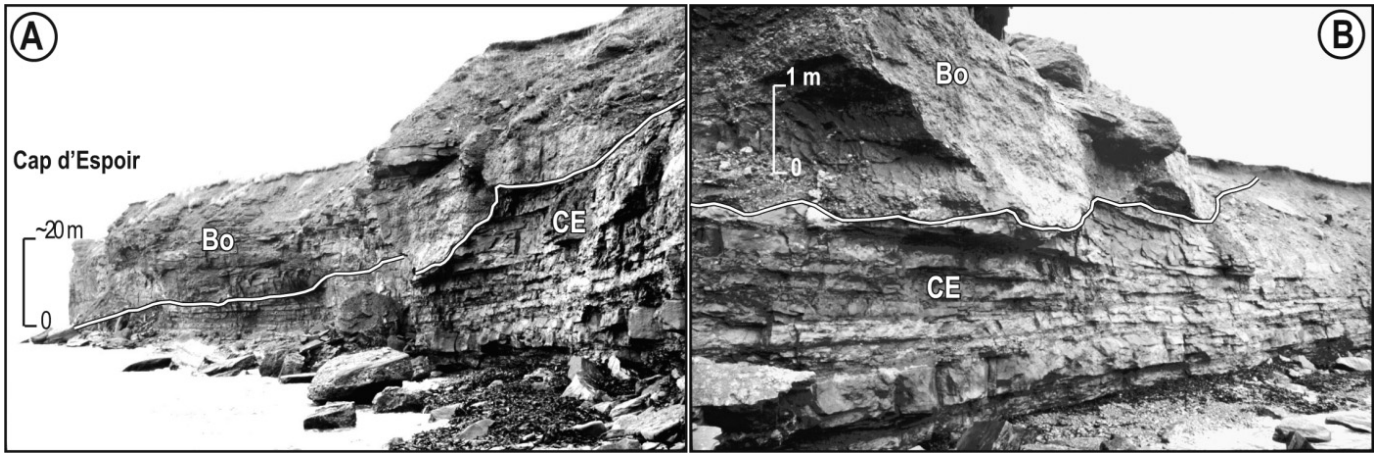


Fig. 4. (A) Southward and (B) northward views of the unconformable contact between the Cap d'Espoir and Bonaventure formations at Cap d'Espoir. Although the exposed contact locally appears to be disconformable, stratigraphic data described in text indicate that the overall contact is a minor angular unconformity.



outliers of the La Coulée Formation (Fig. 1). The thoroughly calcretized basal beds of the La Coulée Formation are more widely preserved than the rest of the succession and are usually the only remnants of this unit unconformably below the Bonaventure Formation (Jutras et al. 2001). However, in the Percé area, a 60-m section of the La Coulée Formation is preserved (Jutras et al. 1999).

In most of Gaspésie, the Bonaventure Formation mainly comprises conglomerate in its lower section and sandstone in its upper section (Jutras et al. 2001; Jutras and Prichonnet 2002). This unit is disconformably overlain by the lower Namurian Pointe Sawyer Formation, which bears a spore assemblage corresponding to that of basal beds in the Mabou Group type-section of Nova Scotia (Jutras et al. 2001). Whereas erosional remnants of Namurian beds in the Ristigouche Basin are limited to the base of the Pointe Sawyer Formation, the Cannes-de-Roches Basin includes the full succession of Pointe Sawyer Formation beds, as well as basal beds from the undated Chemin-des-Pêcheurs Formation (Fig. 2), which gradationally overlies the former unit (Jutras et al. 2001).

The La Coulée Formation overlies a surface interpreted as a paleowave-cut platform in southern Gaspésie (Jutras and Schroeder 1999). The thick and massive groundwater calcrete that marks its base was probably associated genetically with nearby evaporitic basins during its formation (Jutras et al. 1999), based on modern analogs in central Australia (Mann and Horwitz 1979; Arakel and McConchie 1982; Jacobson et al. 1988; Arakel et al. 1989). Because Subzone A carbonates of the lowermost Windsor Group are the only evidence for a marine presence in central New Brunswick during upper Paleozoic times, Jutras et al. (2001) proposed that the groundwater calcrete, and therefore the La Coulée Formation, must have formed during the first transgression–regression cycle of the Windsor Group. Supporting this conclusion, a similar groundwater calcrete occupying the same stratigraphic position is laterally transitional to fossiliferous mounds of the Viséan Parleeville Formation (Windsor Group Subzone A) in central New Brunswick (Johnson and Jutras 2004). It is, therefore, concluded that both the La Coulée and Bonaventure formations are constrained to the Viséan and are, therefore, time equivalent to the Windsor Group of New Brunswick and Nova Scotia, although exclusively composed of continental sediments.

The newly identified fine red beds of the Cap d'Espoir Formation, which strongly contrast with the coarse grey beds of the La Coulée Formation, can be observed along coastal exposures that extend to the south of Percé, between Cap Blanc and Cap d'Espoir (Fig. 1). Its base is not exposed but it is unconformably overlain by the Bonaventure Formation. An ~150-m thick succession of the Cap d'Espoir Formation was measured in the 15-km long coastal exposure that is cut by numerous normal faults.

Stratigraphic and structural relationships

Twenty-one coastal sections of the Percé Group succession were measured in the study area (Fig. 3, sections a–u). In the Percé section (Fig. 3, section u), a 25-m thick sandstone interval is observed in the lower part of a 350-m thick conglomerate succession that directly overlies erosional remnants of the La Coulée Formation (Jutras et al. 1999). This mainly conglomeratic succession is the lateral continuation of the Bonaventure Formation type-section at Bonaventure Island (Logan 1846), 5 km offshore from Percé. The sandstone interval near the base is found at the same stratigraphic position at Sainte-Thérèse in a similar succession of the Bonaventure Formation, which directly overlies pre-Carboniferous basement rocks with no intervening La Coulée Formation remnants (Fig. 3, sections a and b). However, at Cap d'Espoir (Fig. 3, section c), located between the Percé (Fig. 3, section u) and Sainte-Thérèse (Fig. 3, sections a and b) sections, this mainly conglomeratic succession of the Bonaventure Formation unconformably overlies a highly faulted red mudstone and sandstone succession (Fig. 1, cross-section A–B) that was previously included within this unit (Logan 1846; Alcock 1935; Kirkwood 1989; Brisebois et al. 1991; Jutras et al. 1999, 2001, 2003*a*) but which is herein referred to as the Cap d'Espoir Formation (Fig. 4). The latter unit is not observed anywhere west of Cap d'Espoir.

The remnant succession of the Cap d'Espoir Formation dips between 1° and 20° towards the northeast (Fig. 5) and,

Fig. 5. Thin alternations of mudstone and sandstone, the most common facies of the Cap d'Espoir Formation. Note that the strata on the left side of the photo are tilted towards a normal fault that is hidden behind a salient of footwall rocks on the right side.

therefore, thickens in that direction until it abuts the Percé-Sud and Cap Blanc faults, two major structures along which younging is inversed by significant down to the southwest displacements (Fig. 3). Many other northwest–southeast-striking faults (average 121°) with down to the southwest displacements occur between Cap d'Espoir and the Percé-Sud fault, but these faults only work at moderating the northeastward younging caused by the dip of the Cap d'Espoir succession towards the Percé-Sud fault (Fig. 3). As a result of more significant normal displacements along the faults that separate sections j, k, l, and m, the most basal exposures of the Cap d'Espoir Formation between Cap d'Espoir and the Percé-Sud fault are found at the base of section m (Fig. 3).

The faults distributed to the southwest of the Cap Blanc fault (Fig. 3) are characterized by a cataclastic zone of pulverized sandstone and mudstone ranging between a few centimetres to 1 m in width. The footwalls are typically characterized by a smooth surface that is often exposed by coastal erosion, dipping between 50° and 85°. However, none of the fault surfaces provided kinematic indicators apart from the normal displacement of stratigraphic markers, which are not always reliable because of the monotonous and repetitive nature of the Cap d'Espoir Formation succession. Stratigraphic correlations across faults (as presented in Fig. 3) are, therefore, approximate and might be erroneous in some cases.

The estimated intraformational displacements range from 5 to 30 m, except across the Percé-Sud fault, which shows the widest shear zone (1 m) (Fig. 3). There, fine rhythmic alternations of mudstone and sandstone on the southwest block (Fig. 3, top of section t) contrast with thicker alternations of mudstone, sandstone, and conglomerate on the northeast block (Fig. 6). The latter succession, sitting between the Percé-Sud and Cap Blanc faults, cannot be correlated with any of the previous sections and possibly includes the lowermost exposures of the Cap d'Espoir Formation. Because its stratigraphic position is unknown, this section is not presented on Fig. 3.

Neither the true base nor the original top of the Cap d'Espoir Formation succession are exposed. From Cap d'Espoir to the Percé-Sud fault, an estimated 150 m separate the most basal exposures of Cap d'Espoir Formation beds (Fig. 3, base of section m) from their uppermost exposures (Fig. 3, top of section t). This suggests that a vertical displacement of > 150 m may have occurred along the Percé-Sud fault, as its foot-wall succession does not correspond to any part of this 150-m thick succession in the composite hanging-wall block.

Whereas most of the Cap d'Espoir Formation succession is dipping 10° to 15° toward the northeast in a domino-like suite of tilted normal fault blocks (Fig. 1, cross-section A–B), the overlying Bonaventure Formation is nearly flat lying and gently dipping (~1°) in the opposite direction on coastal or near-coast inland exposures (Fig. 1). As a result, the Cap d'Espoir – Bonaventure contact, which is over 200 m above sea level near the Cap Blanc Fault, disappears below sea level at Cap d'Espoir (Fig. 4A), < 15 km to the southwest (Fig. 1). Moreover, no normal faults were observed to cut the Bonaventure Formation southwest of the Cap Blanc Fault, although this unit is exposed for hundreds of metres along brooks of that area (see detailed map by Kirkwood 1989) directly in the path of the northern projection of the faults that cut the Cap d'Espoir Formation at the coast. The Cap d'Espoir – Bonaventure contact southwest of Percé is, therefore, similar to the La Coulée – Bonaventure contact in Percé, where northeastward-tilted beds of the La Coulée Formation are unconformably overlain by nearly flat-lying beds of the Bonaventure Formation (Fig. 1, cross-section A–B) (Jutras et al. 1999).

These observations imply that faulting, tilting, and erosion of both the La Coulée and Cap d'Espoir formations preceded deposition of the Bonaventure Formation. Crustal stretching is necessary to explain the high degree of tilting in such closely spaced fault blocks, which could not be accommodated at that scale by syn-burial growth faulting.

Beds truncated by the Bonaventure Formation conglomerate at Cap d'Espoir (Fig. 3, section c; Fig. 4) sit ~120 m below the top bed of section t (Fig. 3) in the stratigraphy of the Cap d'Espoir Formation. Moreover, the top beds of section t (Fig. 3), which are nearly flat lying in the vicinity of the Percé-Sud fault (Fig. 6), are ~150 m below the contact with the Bonaventure Formation, a position calculated roughly using scarce inland exposures. Hence, erosion of at least 270 m more of the Cap d'Espoir Formation occurred at section 3c rather than at section 3t because of northeastward tilting of the succession prior to deposition of the Bonaventure Formation.

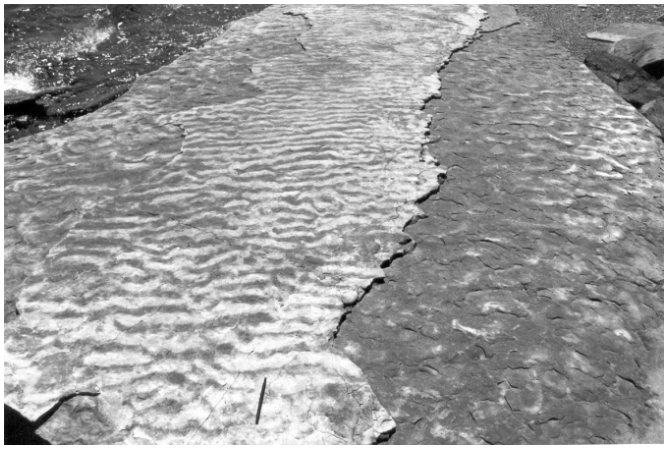
Deep scour-and-fill structures at the Cap d'Espoir – Bonaventure contact (Fig. 7), an absence of red sandstone or mudstone clasts in the Bonaventure Formation conglomerate, and the lack of integrity of the sheared material in the fault zones indicate that the Cap d'Espoir Formation was not significantly lithified when deformation and erosion occurred. Hence, no major hiatus seems to separate the two units although they are separated by an event of deformation and erosion.

Finally, the Percé area forms a horst limited by the Cap Blanc and the Percé faults (Fig. 1). This fault system experienced Pennsylvanian transpression and, therefore, affects the entire Mississippian succession, including the Bonaventure, Pointe Sawyer, and Chemin-des-Pêcheurs formations (Jutras et al. 2003*a*) (Fig. 2). However, beds of the La Coulée Formation were affected by northeastward tilting prior to the latter faulting event, implying that at least some of the faults

Fig. 6. View of the Percé-Sud fault from the east. (A) General view. (B) Close-up view. Metre stick for scale.

Fig. 7. Narrow channel fill of Bonaventure Formation conglomerate, deeply incised into Cap d'Espoir Formation sandstone.

Fig. 8. Ripple marks on a slab of Cap d'Espoir Formation sandstone. Pen for scale.



involved in forming the Pennsylvanian Percé horst had experienced normal displacement during the Viséan (Jutras et al. 1999).

Sedimentary petrography of the Cap d'Espoir Formation

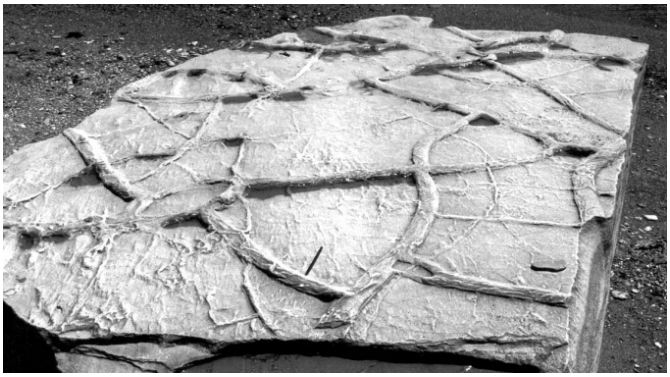
The Cap d'Espoir Formation is mostly a monotonous succession of red mudstone and sandstone rhythmites with green reduction banding (Figs. 3, 5, 6, rhythmite facies). Couplets of specific layer thicknesses and grain sizes tend to repeat themselves stratigraphically on tens of metres, although these attributes vary at different levels of the succession.

The sandy lower portion of each rhythmite is a lithic wacke mainly composed of subrounded to rounded calcareous clasts and quartz grains. It is typically 3–20 cm thick and sharply overlies the previous rhythmite. The muddy upper portion of each rhythmite is typically 2–10 cm thick and gradationally overlies the lower portion. Hydraulic ripple marks (Fig. 8) often form the base of the gradational transition, which ranges from a few millimetres to 1 cm in thickness. Apart for the thin transition zone, no grading is observed within each layer of the rhythmite. Large-scale desiccation cracks are abundant throughout the succession (Fig. 9), indicating periods of prolonged subaerial exposure.

This monotonous rhythmite facies is occasionally cut by poorly incised lenses of trough cross-stratified sandstone, a few metres thick and hundreds of metres wide (Fig. 3, sections e, h–q). More rarely, thinner (~1 m) pebble conglomerate lenses of similar width are also observed (Fig. 3, sections i–k). Some of these sheet-like lenses of conglomerate grade laterally into sandstone. Only two deeply incised channel bodies were identified (sections d and g) in the ~15-km wide exposure of the measured ~150-m thick interval (Fig. 3).

The pebble conglomerate beds include subrounded to rounded clasts from various regionally derived sedimentary and volcanic rock lithologies (90%), roughly 10% quartz pebbles and occasional red jasper clasts. Calcareous clasts are most abundant, reflecting the dominantly calcareous nature of the regional Cambrian to Devonian basement rock succes-

Fig. 9. Sand casts of large desiccation cracks at the base of a sandstone bed. The cracks are common features of the Cap d'Espoir Formation. Pen for scale.



sions. One important component of the Cap d'Espoir Formation conglomerates is the presence of groundwater calcrete clasts. These clasts imply that the Cap d'Espoir Formation is younger than the La Coulée Formation, as the latter is the only unit that bears this lithology in the area. Interestingly, the calcrete clasts include incompletely digested granules and small pebbles of volcanic rocks, which are typical of the La Coulée Formation calcrete in the Cannes-de-Roches Basin (Jutras et al. 2001). In contrast, volcanic clasts are not found within the La Coulée Calcrete in the Ristigouche Basin, which digested an oligomictic limestone conglomerate (Jutras et al. 1999).

Clast lithologies in the Cap d'Espoir Formation are much more varied than in the La Coulée Formation, implying that it was not only sourced from the latter unit, but also from the Cambrian to Devonian basement rocks that are exposed beyond the limits of the Ristigouche Basin. The entire Cap d'Espoir Formation, from mudstones to conglomerates, is rich in calcareous clasts and calcite cement, suggesting hyperarid conditions during deposition.

The Cap d'Espoir Formation is entirely devoid of carbonaceous material. No evidence of root disturbance was observed and only one thin interval shows pedogenic calcrete nodules (Fig. 3, section q). In summary, the Cap d'Espoir Formation can be best distinguished from the unconformably overlying Bonaventure Formation by its finer granulometry, its rhythmicity, a lack of abrupt lateral variations, a paucity of paleosols, and abundant green reduction banding.

Paleocurrent vectors within the Cap d'Espoir and Bonaventure formations

The few wide lenses of trough cross-stratified sandstone in the Cap d'Espoir Formation provide excellent three-dimensional exposures of trough channels. Paleocurrent vectors measured on these channels are summarized in the rose diagrams of Fig. 3. They indicate east–southeast- to southeast-trending paleocurrents in the Cap d'Espoir Formation, which contrast with the south-trending pattern found throughout the alluvial fan deposits of the Bonaventure Formation along the north shore of Chaleur Bay (Jutras et al. 2001), including sections a, b, c, and u as shown in Fig. 3.

As noted earlier in the text, ripple marks are common to the Cap d'Espoir Formation rhythmites (Fig. 8). However, they can best be observed on dislodged rock slabs along the beach because their crests are mostly parallel to the coastline, which makes their in situ observation difficult. Moreover, they are part of beds that lack the mechanical competence that would allow the preservation of overhangs. Hence, ripple marks were not used for paleocurrent measurements.

Seismic reflection profile in the Carboniferous succession that extends to the south of Percé

A seismic reflection profile (line P-5) was produced for the Société Québécoise d'Initiatives Pétrolières (SOQUIP) in 1972 from vibroseis data. The shot point line and resulting section are shown on Fig. 10.

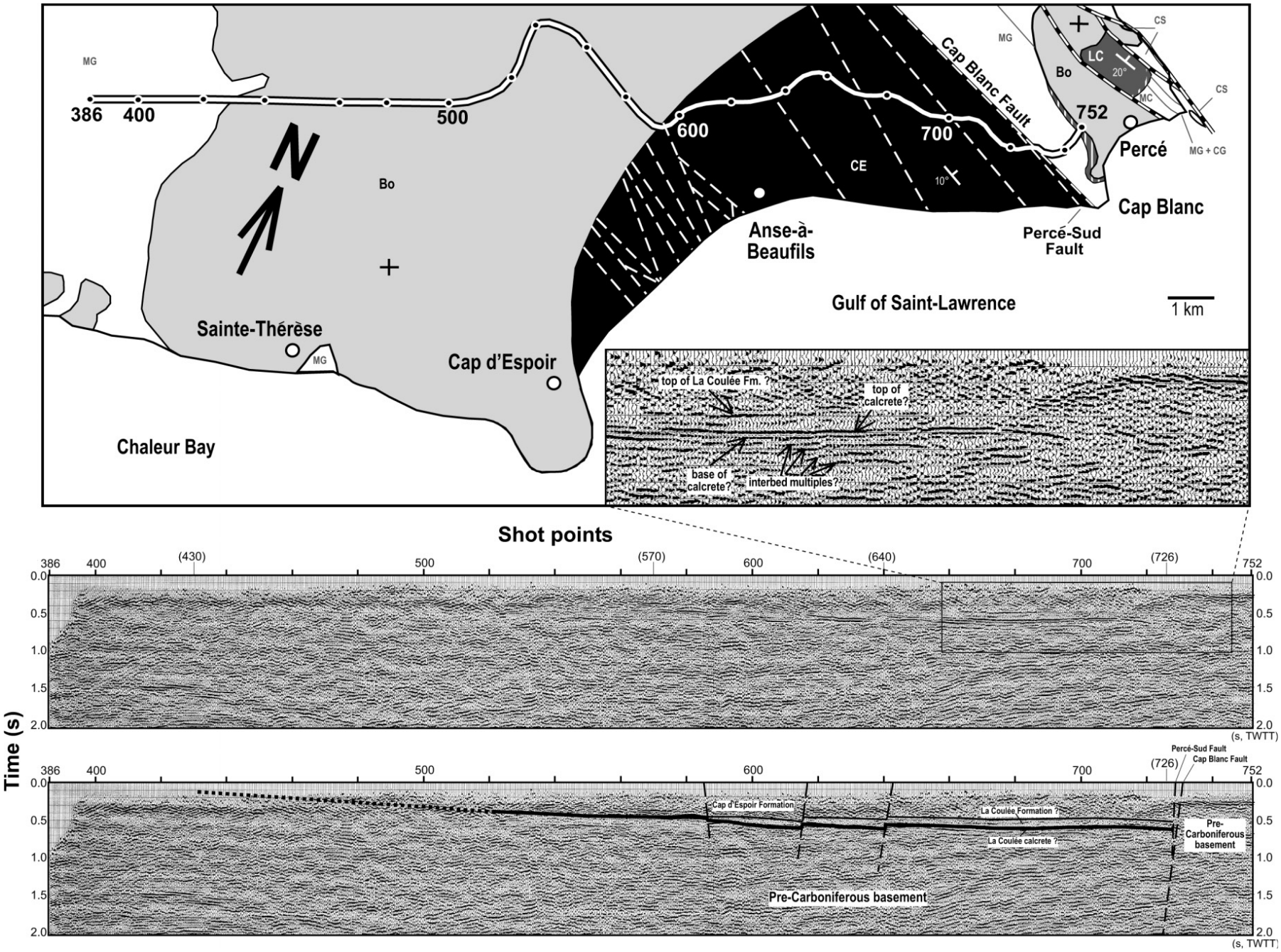
A well-defined couplet of reflections with positive polarities is produced at what is interpreted to be the base of the Carboniferous succession (Fig. 10). These reflections are interpreted to correspond to the top and base of calcretized sediments in the La Coulée Formation, which comprise the basal 30 m of this unit in the Percé area (Jutras et al. 1999). The calcrete would show stronger acoustic impedance than the overlying clastics, but a lower one than that of the underlying basement. Interbed multiples from this postulated calcrete layer can be observed between shot points 650 and 720 (Fig. 10).

Because outcrops of La Coulée Formation calcrete are known to the north of the shot point line (Fig. 1, locality 1), it is probable that remnants of this unit underlie the Cap d'Espoir Formation on the seismic section. It is even conceivable that the entire thickness of the La Coulée Formation may be preserved below central areas of the Cap d'Espoir sub-basin, even though most of it was eroded to the north as it sourced the Cap d'Espoir Formation. Because the La Coulée Formation exhibits coarser material than the Bonaventure Formation in the Percé area (Jutras et al. 1999), it is probably coarser than the Cap d'Espoir Formation as well, which is the most fine grained post-Acadian unit in the area. Hence, the La Coulée – Cap d'Espoir contact should be characterized by a substantial contrast in acoustic impedance. A moderately strong reflector at about 0.5 s (two-way travel time (TWTT)) is observable between shot points 640 and 710 and is interpreted as that contact (Figs. 10, 11).

The well-defined and closely spaced reflectors that represent the basal calcrete are truncated by the Cap Blanc fault, consistent with the observation that Carboniferous red beds are juxtaposed on Lower Silurian limestones of the Matapedia Group in the coastal cliff exposures at Cap Blanc along that major structure (Kirkwood 1989; Jutras et al. 2003*a*) (Figs. 10, 11). Strong diffraction patterns associated with the fault may obscure the exact position of the truncation. The Cap Blanc fault is tentatively positioned at the top flexure point of the diffraction patterns, which is most consistent with a projection of its coastal strike (Fig. 10). The Percé-Sud fault is projected in the exact position of its coastal strike, within the region obscured by diffraction (Fig. 10).

Chaotic seismic pulses in the first 0.3 s (TWTT) of the section probably reflect the entrapment of seismic energy between the bedrock and the surface, in unconsolidated soil

Fig. 10. Seismic reflection and interpretation along line P-5 of SOQUIP (1972), with reference map. TWTT, two-way travel time (in s).



and regolith material. They obscure the westward pinching out of the base of the Carboniferous succession to the west of shot point 570. The contact with pre-Carboniferous basement rocks reaches the surface around shot point 430 according to field data. This corresponds well with extrapolation of the dip of the basal reflector up to the west (Fig. 10).

Seismic velocities were calculated by SOQUIP (1972) for every 0.2 s (TWTT) at shot point 726, which corresponds to the deepest section of Carboniferous rocks, just before its abrupt truncation by the Cap Blanc fault (Fig. 10). Seismic velocities are estimated as 3429 m/s at 0.2 s, 3467 m/s at 0.4 s, 3658 m/s at 0.6 s, and 5353 m/s at 0.8 s (TWTT). The sudden increase in seismic velocity between 0.6 s and 0.8 s (TWTT) is interpreted to mark the transition from poorly consolidated Carboniferous rocks to more competent basement rocks. On the seismic time section, this contact is estimated at 0.675 s (TWTT) below shot point 726, which was surveyed at 90 m above sea level and is estimated to occur 50 m above the top of section t (Fig. 3) in the Cap d'Espoir stratigraphy, based on extrapolations from field data. Assuming a linear trend between seismic velocity measurements, a maximum depth of 870 m was determined for the base of the Carboniferous succession at shot point 726 after corrections related to shot point altitude, datum thickness, and a 170-ms delay in the instrumentation. This depth is considerably greater than the 350-m thickness of the Percé section (Fig. 3, section u), which was the largest estimated thickness to date for Carboniferous successions in Gaspésie.

In summary, of the estimated 870 m of flat-lying Carboniferous rocks at shot point 726, the basal 255 m, between 0.52 s and 0.66 s (TWTT) are interpreted to belong to the La Coulée Formation, whereas the upper 615 m (roughly, 600 m) are interpreted as belonging to the Cap d'Espoir Formation (Fig. 10). Because the stratigraphic position of shot point 726 is estimated as ~100 m below the Cap d'Espoir – Bonaventure contact farther inland (Fig. 10), a maximum thickness of roughly 700 m of Cap d'Espoir Formation beds is inferred in that area. Also, because the stratigraphic position of shot point 726 is estimated as sitting ~200 m above the most basal exposures of Cap d'Espoir Formation beds in section m, ~400 m of Cap d'Espoir Formation beds are only found in the subsurface (Fig. 3). Finally, although stratigraphic correlation from one fault block to the next is complicated by the lack of fully reliable stratigraphic markers within the Cap d'Espoir Formation, the gradual northeastward younging estimated from field data (Fig. 3) is supported by seismic reflection data (Figs. 10, 11).

Stratigraphic synopsis of the Percé Group

Although onshore exposures of the Percé Group succession are patchy and incomplete, a tentative composite section can be drawn from the combined interpretation of field and seismic data (Fig. 12). In areas where the coarse grey clastics of the La Coulée Formation were deposited, the basal 30 m of the succession are thoroughly or partly calcretized (Jutras et al. 1999). However, where this unit was not deposited, calcretization of surface regolith occurred instead (Jutras and Prichonnet 2002). Because the calcretized regolith is always overlain by beds belonging to the Percé Group, we propose to include it within that group and to formally refer to it as the La Coulée Calcrete, a term that can also be used to refer to the calcretized base of the La Coulée Formation (Fig. 12).

If our seismic interpretation is correct, an extra ~200 m of unexposed La Coulée Formation beds may still be present in more central parts of the Ristigouche Basin, conformably overlain by ~400 m of unexposed Cap d'Espoir Formation redbeds (Fig. 12), bearing in mind that eventual drilling in this unexposed ~600-m thick succession would possibly impose a revision of this simple stratigraphic framework. Our current interpretation is that the upper contact of the La Coulée Formation laterally evolves from a conformity with the Cap d'Espoir Formation in central parts of the Ristigouche basin, to a probable disconformity with this unit near the margin of the Cap d'Espoir sub-basin, and finally to an unconformity with the Bonaventure Formation near the margin of the Ristigouche Basin, beyond the limits of the more restricted Cap d'Espoir sub-basin.

In the study area, 450–700 m above its base, the Cap d'Espoir Formation is unconformably overlain by conglomerates of the Bonaventure Formation. The thick sandstone marker located 10–25 m above the conglomeratic base of the latter unit (Figs. 1, 3) is not found in the western parts of the Ristigouche Basin and is therefore only useful in the Percé area. However, the transition between a dominantly conglomeratic lower half to a dominantly sandy upper half is observed in all areas of the Ristigouche and Cannes-de-Roches basins (Jutras et al. 2001; Jutras and Prichonnet 2002). Within the latter basin, the two granulometrically contrasting successions were historically referred to as the lower and middle members of the abandoned Cannes-de-Roches Formation, whereas the Pointe Sawyer Formation was referred to as the upper member of this abandoned unit (Alcock 1935; Rust 1981). In southern New Brunswick, the two successions probably correspond to respectively the Hopewell Cape and Maringouin formations, which are similar in terms of their petrography and stratigraphic position (research in progress). Until solid correlations can be established with other parts of the Maritimes Basin, we propose to informally refer to the coarse and fine successions as respectively the lower and upper members of the Bonaventure Formation (Fig. 12).

Only the coarse lower member of the Bonaventure Formation is exposed in the 350-m thick Percé section (Fig. 3, section u). Because the upper member always comprises at least half of the succession (Jutras et al. 2001; Jutras and Prichonnet 2002), an extra 350 m of finer sediments is added to our composite section (Fig. 12). Because exposure of the lower member is possibly incomplete and the upper member possibly encompassed more than half of the succession, 700 m is inferred as a minimum original thickness for the Bonaventure Formation in Percé. It is therefore predicted that eventual drilling would cross over 1500 m of Percé Group rocks offshore from Percé, where Chaleur Bay enters into the Gulf of Saint Lawrence.

According to exposures located farther west in the Ristigouche Basin, the Bonaventure Formation was disconformably overlain by Namurian grey beds of the Pointe Sawyer Formation (Mabou Group) prior to subsequent erosion (Jutras et al. 2001) (Fig. 12). The original thickness of the Pointe Sawyer

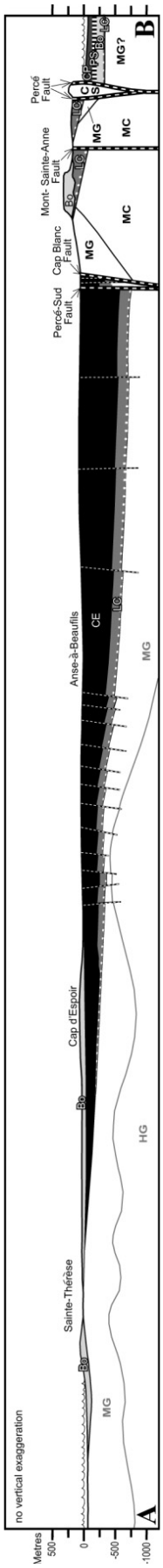


Fig. 11. Subsurface interpretation of cross-section A–B (refer to Fig.1 for transect and legend), combining field and seismic reflection data. The pre-Carboniferous geology is extrapolated from mapping data by Brisebois et al. (1991).

Formation in the Ristigouche Basin is unknown, but it is nearly half of that of the Bonaventure Formation in the thinner Cannes-de-Roches Basin succession (Jutras et al. 2001).

Depositional model for the Cap d'Espoir Formation

Like the Bonaventure Formation (Rust 1981; Zaitlin and Rust 1983; Rust et al. 1989; Jutras et al. 2001), the Cap d'Espoir Formation is interpreted to have evolved under a tropical arid climate, as indicated by deep oxidation of the succession, the absence of plant remains, the paucity of plant traces, and the preservation of abundant carbonate grains. However, the two units differ in sedimentation style. The Bonaventure Formation includes coarse and chaotic fanglomerates with a high lateral variability, which were probably sourced from active fault scarps (Rust 1981; Zaitlin and Rust 1983; Rust et al. 1989; Jutras et al. 2001). In contrast, beds of the Cap d'Espoir Formation were deposited in a relatively uniform energy regime and their characteristics are inconsistent with fault rejuvenation. The few conglomerate beds of the Cap d'Espoir Formation are not incisive, but form thin, sheet-like lenses within the rhythmite succession.

All grain size variations in the Cap d'Espoir Formation can be explained by hydrodynamic flow fluctuations. The unit appears to have evolved in a relatively quiet tectonic environment, with a source area characterized by gentle relief. Abundant evidence for desiccation cracking (Fig. 9) indicates that the basin was often exposed to subaerial conditions. Because only two moderately large channel bodies were identified (Fig. 3, sections d and g), the succession is unlikely related to river overbanking. Lateral continuity, planar bedding, poor incision, and the paucity of cross-beds suggest that the bulk of Cap d'Espoir Formation sediments are sheetflood deposits, such as modern analogs documented in central Australia (Williams 1971).

The most likely sedimentary environment for the Cap d'Espoir Formation is that of an intermittently flooded alluvial plain with an insufficient vegetation cover to generate substantial channeling. The sheetfloods are probably the result of seasonally concentrated precipitation in an otherwise rain-deprived region. Sands were deposited during the invasive stage of each sheetflood, followed by the slow deposition of muds once the entire alluvial plain was covered by water. The basin often remained flooded long enough for reduction, with consequent green banding in the sediment layers.

Rare periods of more evenly distributed precipitation may be responsible for the deposition of wide lenses of trough cross-stratified sandstones and sheet gravels in the alluvial plain at a few stratigraphic levels. Because these wide lenses are directly overlain by rhythmites with a sandstone base, they seem to record times during which the basin was spared from general flooding. The two examples of deeply incised channels (Fig. 3, sections d and g) in the succession may indicate the occasional formation of a meager, but less ephemeral drainage system on the alluvial plain. Finally, the coarser material in the hanging-wall block of the Percé-Sud fault (Fig. 5) suggests that the unexposed lower portion of the Cap d'Espoir Formation may have evolved under a higher energy regime than its upper portion.

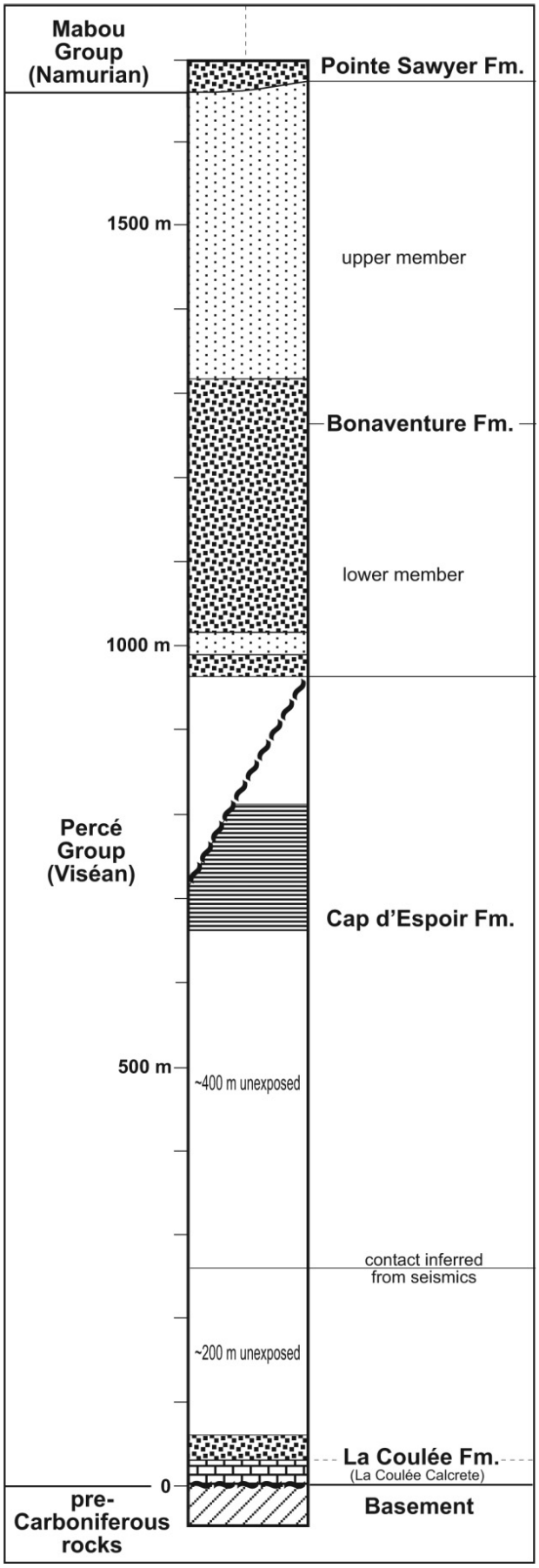


Fig. 12. Composite section of the Percé Group according to data from Jutras et al. (1999, 2001), Jutras and Prichonnet (2002), and this study. Refer to Fig. 1 for legend.

Tectonostratigraphic model for the Viséan succession of eastern Gaspésie

Based on the observation that Late Devonian extension in Atlantic Canada is coeval with mountain building in New England, Jutras et al. (2003*a*) proposed that the opening of the Maritimes Basin resulted from a transtensional response to the lateral migration of compressional stresses during that time period. In this view, the tectonic response in Atlantic Canada may have remained dominantly transtensional as long as an ocean (Theic Ocean or Rheic Ocean, depending on authors) remained between the southern United States and Gondwana, and only became dominantly transpressional during the Pennsylvanian when tectonic environments in the Maritimes Basin became more constrained by the advancing Alleghanian front to the southwest (Jutras et al. 2003*a*). The following Viséan deformation events and associated sedimentation are therefore understood as being the result of far-field stresses related to the ongoing closure of Theic prior to Pennsylvanian continental collision.

Deposition and calcretization of the La Coulée Formation (Fig. 13A)

As noted earlier in the text, the presence of a thick and massive groundwater calcrete in basal fanglomerate beds of the La Coulée Formation is indicative of a circum-evaporitic basin environment (Fig. 13A), which may have formed by sea-arm abandonment after the first Windsor Sea transgression in the middle Viséan (Jutras et al. 1999, 2001). This conclusion is supported by the recent identification of a lateral transition between the La Coulée Calcrete and basal Windsor Group marine limestone in central New Brunswick (Johnson and Jutras 2004). Not much information is available on the nearly completely digested host sediment of the La Coulée Calcrete in the Cannes-de-Roches Basin, but the presence of incompletely digested basalt gravels floating in the calcrete mass indicates that it was a compositionally different conglomerate than that of the La Coulée Formation in the Ristigouche Basin, which is an oligomictic limestone conglomerate (Jutras et al. 2001). A Percé fault-scarp (Jutras et al. 2003*a*) source for the Cannes-de-Roches Basin is inferred from paleocurrent vectors in the overlying Bonaventure Formation (Rust 1981; Jutras et al. 2001) (Fig. 13A).

In the Ristigouche Basin, a scarp associated with activity along the Grande-Rivière fault was inferred as the source of the La Coulée clastics (Jutras et al. 1999). An oblique dextral strike–slip environment was proposed to explain rapid changes of clast lithologies in the stratigraphy of the La Coulée Formation, although normal displacement cannot be ruled out (Jutras et al. 1999). Such movement along that fault is compatible with its pre-Carboniferous history (Malo and Béland 1989; Malo et al. 1992, 1995; Malo and Kirkwood 1995; Kirkwood et al. 1995).

Erosion of the La Coulée Formation and deposition of the Cap d'Espoir Formation (Fig. 13B)

Much of the La Coulée Formation was subsequently eroded and became part of the source of the Cap d'Espoir Formation, which was deposited within a centrally positioned sub-basin of the more extensive Ristigouche Basin (Fig. 13B). Due to the openness of Acadian folds in the immediate source area (Brisebois et al. 1991), the basement geology is locally rather monotonous, and the river system may have been nearly dendritic as a result, showing little structural control on the river paths (Fig. 13B). These poorly incisive rivers provided clastic material to an open alluvial basin that was intermittently flooded by numerous streams issued from the source area (Fig. 13B). Rivers may have connected the Cannes-de-Roches and Ristigouche basins, transporting groundwater calcrete clasts from one basin to the other.

The circum-evaporite calcretization of the La Coulée Formation and its subsequent erosion could represent different steps in one long episode of regression and lowering of base level. However, eustatic variations alone cannot account for the several-hundred-metres thick deposition of Cap d'Espoir Formation beds near the basin margin. Hence, some form of tectonic process had to be involved. As noted earlier in the text, sedimentation style in the Cap d'Espoir Formation does not suggest fault-controlled deposition, but it is also unlikely that relaxation sag could account for so much accommodation in such a limited area. One possible tectonic regime during deposition of the Cap d'Espoir Formation is that of a gentle crustal flexure in response to northwest–southeast compression, with a broad northeast–southwest-striking synclinal sag receiving material from a broad and parallel anticlinal uplift. This hypothesis is supported by the recent observation of an unconformity between a La Coulée Calcrete remnant and the Bonaventure Formation on the New Brunswick side of Chaleur Bay (S. McCutcheon, personal communication, 2004), which may represent the southeast limb of a broad synclinal flexure in which the Cap d'Espoir Formation was deposited.

Pre-Bonaventure tilting and faulting (Fig. 13C)

The suite of southeast-striking normal faults and northeast-tilting fault blocks that offset both the La Coulée (Jutras et al. 1999) and Cap d'Espoir formations (Fig. 1) are perpendicular to the gentle uplift to the northwest that is suggested by the sedimentology of the Cap d'Espoir Formation and therefore cannot be related to syn-burial growth faulting. However, the normal faults are compatible with northwest–southeast compression. In the context of Mississippian transtensional tectonics, they could be related to stepover pull-aparts along east–west dextral shears that were eventually set in motion to accommodate the northwest–southeast-oriented stress (Fig. 13C).

Many east–west striking dextral faults of limited extent are found west of Cap d'Espoir (Brisebois et al. 1991). Fig. 13C hypothesizes on the presence of a right stepover of the Grande-Rivière fault just offshore of Cap d'Espoir, such a fictive fault being compatible with the local onshore geology. However, according to laboratory experiments (Wilcox et al. 1973) and modern analogs (Harding et al. 1985), such an ideal stepover situation is not necessary to generate en echelon normal faulting in a strike-slip system. On average, the normal faults are at a 31° angle with the Grande-Rivière fault and other east–west striking dextral faults of the area, which is compatible with a transtensional setting.

The southeast-striking normal faults of the Percé area are therefore tentatively interpreted as the transtensional response to an early stage of dextral oblique reactivation along the Grande-Rivière fault system (Fig. 13C). The transtensional collapse must have first occurred above base level to justify erosion of the Cap-d'Espoir Formation from the top of resulting southeast-striking fault blocks and to account for the angular unconformity between the Cap d'Espoir and Bonaventure formations.

Pre-Bonaventure erosion of the Cap d'Espoir Formation may also partly explain the pinching out of this unit over a short distance toward the north and the west, going from several hundreds of metres in thickness at the coast to zero near the Grande-Rivière fault and near Sainte-Thérèse, which are < 15 km to the north and the west, respectively, (Fig. 1). Additional erosion of the La Coulée Formation may have occurred during this event as well, although most of this unit may have been eroded prior to its 10° to 20° tilting as indicated by the presence of groundwater calcrete clasts in the Cap d'Espoir Formation, which was seemingly affected by the same faulting and tilting event.

Deposition of the Bonaventure Formation (Fig. 13D)

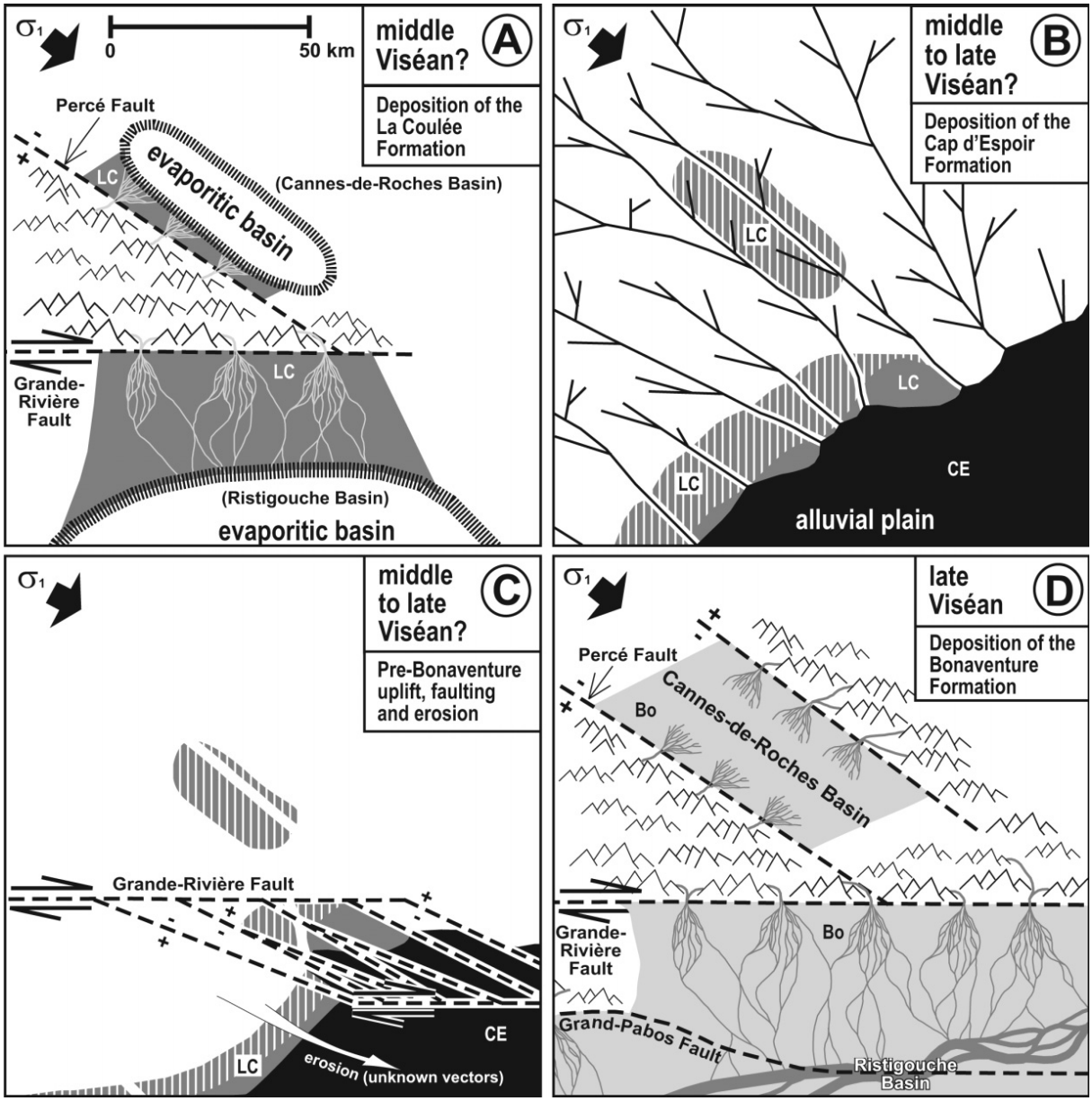
As stress accommodation eventually concentrated along the Grande-Rivière fault weak zone, its southern block rapidly subsided below base level, resulting in the massive deposition of coarse Bonaventure Formation beds in the Ristigouche Basin (Jutras et al. 2001) and burying remnants of the Cap d'Espoir sub-basin (Fig. 13D). Fault activity was either normal or oblique, but the synchronous reactivation of the Ristigouche and Cannes-de-Roches basins, which strike ~45° from each other (Jutras et al. 2001), best conforms to the dynamics of pull-apart tectonics, as pure extension would have resulted in the formation of more or less parallel basins. The most plausible scenario is that of dextral oblique movement along the Grande-Rivière fault and normal movement along the faults that bounded the Cannes-de-Roches Basin, again in response to northwest–southeast compression. A similar scenario is proposed for the La Coulée Formation (Fig. 13A), although more uncertainties remain in the case of this poorly exposed unit.

Post-Viséan deformation (Fig. 13D)

In contrast with Viséan deformation, which mainly shows evidence for transtension, Pennsylvanian strike–slip deformation in the Percé area mainly shows evidence for transpression (Jutras et al. 2003*a*), probably recording far-field stresses from the newly developing Alleghanian orogeny. Pennsylvanian dextral strike–slip movement along the Cap Blanc fault (Jutras et al. 2003*a*) explains the abrupt changes in the Carboniferous stratigraphy on each side of the fault (Fig. 3). The southwestern block shows rocks from deeper in the Ristigouche Basin than the northeastern block, which may have been part of the Cap d'Espoir Formation source area prior to its subsequent lateral displacement.

Some of the normal faults that cut the Cap d'Espoir

Fig. 13. Tectonostratigraphic model for the Viséan of eastern Gaspésie. (A) Deposition of the La Coulée Formation clastics peripheral to evaporitic basins (Jutras et al. 1999). Proximity of the latter led to the formation of a thick and massive groundwater calcrete at the base of the succession. Coarse clastic sedimentation was possibly controlled by oblique dextral strike–slip activity along the Grande-Rivière fault and normal movement along the Percé fault. (B) Gentle uplift to the northwest and alluvial plain sedimentation to the southeast (Cap d'Espoir Formation), fed by a poorly incisive river system in the source area. (C) Normal faulting, tilting, and partial erosion of the Cap d'Espoir Formation, possibly related to reactivation of the regional east–west dextral strike–slip system. (D) Deposition of the coarse clastic detritus of the Bonaventure Formation from the collapse of the southern block of the Grande-Rivière fault (Ristigouche Basin) and the pull-apart reactivation of faults binding the Cannes-de-Roches Basin (modified from Jutras et al. 2001). Refer to Fig. 1 for legend.



Formation may have experienced dextral reactivation during this transpressive event, although no field evidence was found to verify this. Dextral reactivation of the Percé-Sud fault is especially probable because of its proximity to the Cap Blanc fault and due to the greater width of its shear zone (Fig. 7). Hence, the sudden grain-size increase across the Percé-Sud fault may in part be the result of lateral displacements, juxtaposing rocks that were originally closer to the sub-basin margin with rocks from deeper in the sub-basin.

Conclusions

The entire Viséan tectonic history of eastern Gaspésie can be pictured in the context of a northwest–southeast main

principal stress, which would best explain (1) deposition of the La Coulée Formation along northwest–southeast-striking normal faults and east–west-striking oblique dextral faults (Fig. 13A), (2) deposition of the Cap d'Espoir Formation between broad southwest–northeast-striking crustal flexures (Fig. 13B), (3) northwest–southeast-striking normal faulting during early stages in the reactivation of east–west-striking dextral faults (Fig. 13C), and (4) deposition of the Bonaventure Formation along northwest–southeast-striking normal faults and east–west-striking oblique dextral faults (Fig. 13D). In this context, the events that led to the deposition and subsequent deformation of the Cap d'Espoir Formation (Figs. 13B, 13C) may represent a time of readjustment in the regional east–west-striking dextral shear system. We hypothesize that crustal flexure occurred as the dextral strike–slip system was experiencing resistance to shear, perhaps due to its inherited geometry outside of the study area. The complexity of the regional fault systems, which branch out into several segments west of the study area (Brisebois et al. 1991), is compatible with this scenario. The collapse of numerous northwest–southeast-striking normal faults that followed this event of broad flexure may represent a short-lived step in the reorganization of the system on a larger scale, before a return to a similar tectonic setting to that of the La Coulée Formation during deposition of the Bonaventure Formation (Fig. 13D).

Viséan structures and deposits of eastern Gaspésie therefore record different steps within a continuous event of northwest–southeast compression that was for the most part accommodated by a dextral shear system, apart from a temporary episode of broad crustal flexure during a time of resistance to shear within that system. This suite of tectonic events probably occurred as a far-field response to plate readjustments related to the oblique and diachronous closure of oceanic basins during the formation of the Appalachian belt, which spans most of the Paleozoic Era. They occurred near the end of a dominantly transtensional episode that separates the Acadian and Alleghanian events in Atlantic Canada.

In conclusion, although many uncertainties remain, complex tectonic activity is recorded in Viséan clastic sediments and inherent structures of the Percé Group. In contrast, time-equivalent marine rocks of the Windsor Group, occupying more central areas of the Maritimes Basin, offer no such clues, underlying the importance of studying basin margin units and structures to unravel tectonic histories.

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Appendix A

The Cap d'Espoir Formation (Percé Group) Early Carboniferous

Authors: Jutras, P., and Prichonnet, G.

Type locality

The ~150-m thick coastal succession that extends between the towns of Percé (Zone 22A, 5 372 500 m N, 410 000 m E) and Cap d'Espoir (Zone 22A, 5 364 000 m N, 401 500 m E), eastern Gaspésie, Quebec.

Lithology

Red continental clastics dominated by sandstone and mudstone rhythmites, with minor polymict pebble conglomerate that include groundwater calcrete clasts from the Viséan La Coulée Formation, as well as various sedimentary and volcanic clasts issued from lower and middle Paleozoic basement rocks of the area. Desiccation cracks and green reduction banding are common.

Thickness and distribution

The original thickness is unknown because the upper beds of this unit are eroded. Although its basal beds are unexposed, the Cap d'Espoir Formation is at least 700-m thick according to seismic reflection data. To date, this unit was only recognized in the area that extends between the towns of Percé (Zone 22A, 5 372 500 m N, 410 000 m E) and Cap d'Espoir (Zone 22A, 5 364 000 m N, 401 500 m E), eastern Gaspésie, Quebec.

Relation to other units

The Cap d'Espoir Formation is part of the composite upper Paleozoic Maritimes Basin of Atlantic Canada. It is younger than the Viséan La Coulée Formation (Jutras et al. 1999) and was partly sourced by it. It is older than the Viséan Bonaventure Formation, which overlies it unconformably. Due to this pre-Bonaventure deformation and erosion, the thickness of the Cap d'Espoir increases from zero to possibly over 700 m in < 20 km from the southwest to the northeast in the Percé area.

Age justification

The undated Cap d'Espoir Formation is bound from above and below by other undated units of the Percé Group (The Bonaventure and La Coulée formations). As the overlying Bonaventure Formation is disconformably overlain by the earliest Namurian beds of the Pointe Sawyer Formation (base of the Mabou Group) (Jutras et al. 2001), the Cap d'Espoir Formation is probably no younger than the Viséan. The youngest dated unit below the Percé Group succession is the Upper Devonian Miguasha Group (Zaitlin and Rust 1983) of southwest Gaspésie. Because the thick and massive groundwater calcrete that is found at the base of the Percé Group overlies a surface interpreted as a paleowave-cut platform in southern Gaspésie (Jutras and Schroeder 1999) and digests Windsor Group carbonates in central New Brunswick (Johnson and Jutras 2004), the entire Percé Group succession, including the Cap d'Espoir Formation, is probably restricted

to the Viséan. This stratigraphic constraint is based on the observation that marine incursions in the Maritimes Basin are restricted to the Viséan (Howie and Barss 1975; Calder 1998).

History

The Cap d'Espoir beds were previously assigned to the Bonaventure Formation by Logan (1846), Alcock (1935), McGerrigle (1946, 1950), Skidmore (1967), Kirkwood (1989), Brisebois et al. (1991), van de Poll (1995), and Jutras et al. (1999, 2001, 2003*a*).

References

Logan 1846; Alcock 1935; McGerrigle 1946, 1950; Skidmore 1967; Howie and Barss 1975; Zaitlin and Rust 1983; Kirkwood 1989; Brisebois et al. 1991; van de Poll 1995; Calder 1998; Jutras and Schroeder 1999; Jutras et al. 1999, 2001, 2003*a*; Johnson and Jutras 2004.

Appendix B

The Percé Group Early Carboniferous

Authors: Jutras, P., and Prichonnet, G.

Type locality

The Percé area (Zone 22A, 5 372 500 m N, 410 000 m E) of eastern Gaspésie, Quebec.

Lithology

Includes the basal groundwater calcrete and coarse grey continental clastics of the La Coulée Formation, red rhythmitic successions of mainly sandstone and mudstone of the Cap d'Espoir Formation, and red fanglomerate and sandtone of the Bonaventure Formation.

Thickness and distribution

Thickness varies on account of internal unconformities. An original thickness exceeding 1500 m is inferred in the Percé area (Zone 22A, 5 372 500 m N, 410 000 m E) from the combined interpretation of field and seismic data. Rocks of the Percé Group are found in the Cannes-de-Roches Basin of eastern Quebec; the Ristigouche Basin of eastern Quebec and northern New Brunswick; the Plaster Rock, Central, Marysville, Carlisle, and Moncton basins of New Brunswick; and the Cumberland Basin of southern New Brunswick and northwest Nova Scotia.

Relation to other units

The Percé Group unconformably overlies rocks that were deformed by the Middle Devonian Acadian orogeny, except in some areas of southwest Gaspésie, where it is found unconformably above the Upper Devonian Miguasha Group (Zaitlin and Rust 1983) or disconformably overlying the Upper Devonian to Tournaisian Saint-Jules Formation (Jutras and Prichonnet 2002). The group is younger than the Tournaisian Horton (Bell 1929, New Brunswick and Nova Scotia) and Anguille (Baird and Côté 1964, Newfoundland) groups, which are not known in the Chaleur Bay area, and older than the Namurian Mabou Group (Belt 1964), which is represented by the Pointe Sawyer and Chemin-des-Pêcheurs formations in the Percé area (Zone 22A, 5 372 500 m N, 410 000 m E) (Jutras et al. 2001). It is time equivalent and, therefore, laterally transitional to the dominantly marine successions of the Windsor (Bell 1944, New Brunswick and Nova Scotia) and Codroy (Hayes and Johnson 1938, Newfoundland) groups.

Age justification

The Percé Group is disconformably overlain the earliest Namurian beds of the Pointe Sawyer Formation (base of the Mabou Group) (Jutras et al. 2001) and is, therefore, no younger than the Viséan. The youngest dated unit below the Percé Group succession is the Upper Devonian Miguasha Group (Zaitlin and Rust 1983), from which it is separated by a mild post-Acadian unconformity (Jutras and Prichonnet 2002). Because the basal groundwater calcrete of the Percé Group overlies a surface interpreted as a paleowave-cut platform in southern Gaspésie (Jutras and Schroeder 1999) and digests Windsor Group carbonates in central New Brunswick (Johnson and Jutras 2004), the entire Percé Group succession is probably restricted to the Viséan. This stratigraphic constraint is based on the observation that marine incursions in the Maritimes Basin are restricted to the Viséan (Howie and Barss 1975; Calder 1998).

History

The name Percé (formation) was first used in the stratigraphy of eastern Quebec by Ami (1900) to define a Silurian (Wenlock) limestone unit of southern Gaspé that is now referred to as the La Vieille Formation (Schuchert and Dart 1926). The term "Percé Rock beds" was later introduced by Dresser and Dennis (1941) to refer to a Lower Devonian limestone unit that is now correlated with the Forillon Formation of Lespérance (1980). The Percé Group includes the La Coulée (Jutras et al. 1999), Cap d'Espoir (this paper), and Bonaventure (Logan 1846) formations, which were previously unassigned at the group level.

References

Logan 1846; Bell 1929, 1944; Hayes and Johnson 1938; Baird and Côté 1964; Belt 1964; Howie and Barss 1975; Zaitlin and Rust 1983; Calder 1998; Jutras and Schroeder 1999; Jutras et al. 1999, 2001; Jutras and Prichonnet 2002; Johnson and Jutras 2004.