A spectrum of alluvial deposits in the Lower Carboniferous Bonaventure Formation of western Chaleur Bay area, Gaspé and New Brunswick, Canada[1]

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Received October 5, 1982
Revision accepted February 9, 1983

The Lower Carboniferous Bonaventure Formation of western Chaleur Bay, Gaspé and New Brunswick, is a terrestrial redbed succession with abundant calcretes, deposited in a semi-arid paleoclimate. Facies can be grouped into three associations, conglomeratic, sandstone, and mud-dominated, within two 100–150 m upward-fining megasequences. The megasequences are attributed to alluvial fan progradation due to tectonic rejuvenation.

Vertical facies relationships and internal structures indicate that varied alluvial environments are represented. Alluvial fans formed on steep slopes adjacent to fault scarps and are dominated by deposits of the conglomeratic association. Lateral and downslope coalescence of fans into a braid plain is represented by transition from the conglomeratic to the sandstone facies association. Distally, the braid plain is transitional into deposits of the mud-dominated association.

Paleocurrents and clast compositions show that sediment in the Gaspé outcrops was derived from the northwest, and that in New Brunswick from the southwest. This indicates that Chaleur Bay is an exhumed Carboniferous paleovalley, with axial drainage to the east.

La formation de Bonaventure du Carbonifère inférieur dans le secteur ouest de la baie des Chaleurs, à Gaspé et au Nouveau-Brunswick est une succession de couches rouges terrigènes incluant de fréquents encroûtements calcaires et sédimentés sous un paléoclimat semi-aride. Les faciès peuvent être regroupés selon trois types d'associations, conglomératique, gréseuse et à prédominance argileuse, dans deux mégaséquences de 100–150 m à texture progressivement plus fine vers le toit. Les mégaséquences sont attribuées à une progression des cônes de déjection occasionnée par des rajeunissements tectoniques.

Les changements verticaux dans les faciès et les structures internes révèlent que des milieux d'alluvionnement différents sont représentés. Les cônes de déjection se sont formés sur des pentes raides adjacentes aux escarpements de faille, et où prédominent des sédiments de l'association conglomératique. Le rassemblement de cônes, latéralement et au bas des pentes, formant une plaine anastomosée, est représenté par la transition du faciès d'association conglomératique à celui d'association gréseuse. En s'éloignant, la plaine anastomosée devient beaucoup plus argileuse.

Les paléocourants et les compositions des fragments démontrent que les matériaux sédimentaires dans les affleurements à Gaspé proviennent du nord-est, et ceux du Nouveau-Brunswick du sud-ouest. Ceci indique que la baie des Chaleurs est une paléovallée carbonifère désensevelié, avec un drainage axial vers l'est.

[Traduit par le journal]

Can. J. Earth Sci. **20**, 1098–1110 (1983)

Introduction

The Lower Carboniferous Bonaventure Formation outcrops along the Chaleur Bay coasts of southern Gaspé and northern New Brunswick, extending eastward as far as Bonaventure Island at the eastern end of the Gaspé Peninsula (Fig. 1). The Bonaventure is a coarse clastic redbed deposit, up to 250 m thick, which unconformably overlies, or is in fault contact with, Silurian to Devonian carbonate and clastic rocks (Alcock 1935; Dineley and Williams 1968*a*,*b*).

Portions of the Bonaventure Formation along the eastern and southern Gaspé coasts were investigated by Logan (1846), and the formation was mapped by Kindle (1930) and Alcock (1935). The Bonaventure was briefly discussed by McGerrigle (1950), Sanschagrin (1963), Ayrton (1961, 1967), and Dineley and Williams (1968*a*,*b*).

The only detailed sedimentological study of the Bonaventure Formation is that by Zaitlin (1981*a*,*b*), who attributed it to deposition in a variety of alluvial environments. The present paper examines the lithofacies distribution and depositional environments of the Bonaventure in relation to the braided fluvial depositional models of Miall (1977, 1978) and Rust (1978).

Facies description

Facies in the Bonaventure Formature were defined according to the scheme proposed by Miall (1978, Table 1, p. 598), and grouped into three associations.

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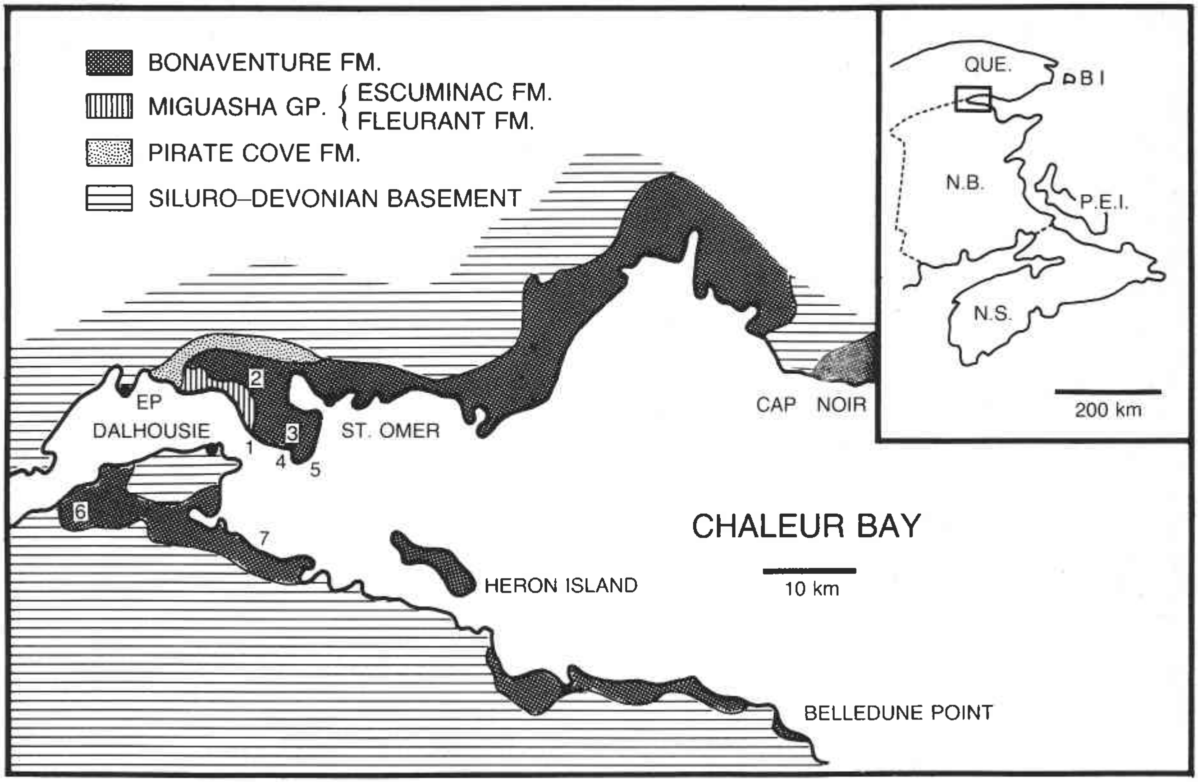

FIG. 1. Simplified geologic map of the Chaleur Bay area (after Dineley and Williams 1968*a*,*b*) with locations of measured sections: (1) Yacta Point; (2) Hugh Miller Cliffs; (3) Miguasha Road; (4) Anse aux Corbeaux; (5) Pointe aux Corbeaux; (6) Dalhousie Junction; (7) Charlo. EP = Escuminac Point. Inset relates study area to Gaspé Peninsula, Quebec (Que.) and northern New Brunswick (N.B.). BI = Bonaventure Island.

Conglomeratic facies association

Gm: massive to horizontally bedded conglomerate

This facies has a clast-supported framework of pebbles and boulders with a medium- to coarse-grained pebbly sandstone matrix. Clasts are poorly to moderately sorted, angular to moderately rounded, and in places exhibit well developed imbrication. Horizontal stratification is apparent in large outcrops, but cannot be discerned in some small outcrops, in which the facies has a massive appearance. Gm occurs as both cyclic and non-cyclic successions within both fining- and coarsening-upward cycles. Minor amounts of planar cross-bedded and trough cross-bedded conglomerate are included within Gm where their percentage is less than 5%.

Gms: massive, matrix-supported conglomerate

This facies contains pebble- to boulder-size clasts set in a muddy siltstone to fine sandstone matrix. These deposits apparently lack internal structure and fabric, irrespective of outcrop size.

Gp: planar cross-stratified framework-supported conglomerate

This facies is moderately sorted, with clasts that are rounder and smaller (pebble to cobble size) than those of facies Gm, but set in a similar matrix. The planar cross-stratal sets average 0.75 m in thickness and are up to 1.25 m thick. Calcite cement fills void spaces, which are much more common than in facies Gm.

Gt: trough cross-stratified framework-supported conglomerate

The clasts in this facies are pebble to cobble size, moderately to well sorted and rounded, and show moderate sphericity. Facies Gt is characterized by large-scale trough cross-beds with single sets up to 1.5 m thick, and occurs within Gm- or Gp-based fining-upward cycles associated with channel fills.

Sandstone facies association

Sr: ripple cross-laminated sandstone

Facies Sr comprises fine- to medium-grained sandstone with small- to medium-scale current ripples and ripple drift cross-lamination in 0.1–0.4 m thick sets, with composite sets reaching 2 m. The facies is present with either abrupt or erosional lower contacts in both fining- and coarsening-upward cycles in which it is transitional to facies St.

St: trough cross-stratified sandstone

This facies comprises medium-grained to pebbly sandstone in solitary or grouped sets of medium- to high-angle trough cross-strata. The sets range in thickness from 0.1 to 0.3 m, with composite sets up to 1 m. Facies St is commonly transitional into facies Sp and Sr.

Sp: planar cross-stratified sandstone

Facies Sp consists of fine-grained to pebbly sandstone in moderate- to high-angle solitary to multiple sets of planar cross-strata. Set thickness varies from 0.1 to 0.5 m.

Sh: horizontally stratified sandstone

This facies comprises medium- to coarse-grained sandstone in sets up to 1.2 m thick, commonly showing well developed current lineation. A variant of this facies, which is also lineated and contains planar laminated sandstone dipping at low angles (<10°) to the original horizontal, is incorporated into Sh as Sh/l.

Fine-grained facies association

Fm: massive siltstone and mudstone

Facies Fm occurs in units that vary in thickness from a few millimetres (representing mud drapes) to several metres (representing overbank deposits). Internal features include desiccation cracks, plant chaff, rootlets, calcrete, reduction spots, and isolated rippled units, too thin to be recognized as a separate facies. Facies Fm commonly occurs at the top of fining-upward sequences and varies from red to dark grey in colour.

Fl: laminated siltstone to fine sandstone

Units of facies Fl range in thickness from 0.25 to 3 m, and can be transitional to Fm or any of the sandstone facies, particularly Sr. The predominant structure is horizontal to low-angle (<10°) planar lamination; other features include ripple cross-lamination and ripple drift, desiccation cracks, calcrete nodules, and occasional intraclasts.

Calcrete

This facies is present mainly in facies Fm and Fl, but also to a lesser extent in the associated facies Sh/l, Sp, and St. Calcrete commonly occurs as rhizoliths, calcareous encrustations around roots (Klappa 1980), but is also present as isolated nodules, "honeycomb" texture, crusts, and continuous hardpans. In the order listed, these represent progressively more mature calcareous paleosols (Leeder 1975).

Vertical facies distribution

Stratigraphic relationships of measured sections

The locations of the measured sections through the Bonaventure Formation are presented in Fig. 1. The Bonaventure Formation in this area is composed of two 100–150 m thick, fining-upward megasequences. The sections at Yacta Point, Charlo, Dalhousie Junction, lower Anse aux Corbeaux, and lower Pointe aux Corbeaux form portions of the lower megasequence. The Hugh Miller Cliffs, Miguasha Road, upper Anse aux Corbeaux, and upper Pointe aux Corbeaux sections are thought to be correlative parts of an upper megasequence. The scale of both sequences suggests that they arose as a result of tectonic rejuvenation. Details of the measured sections are given below.

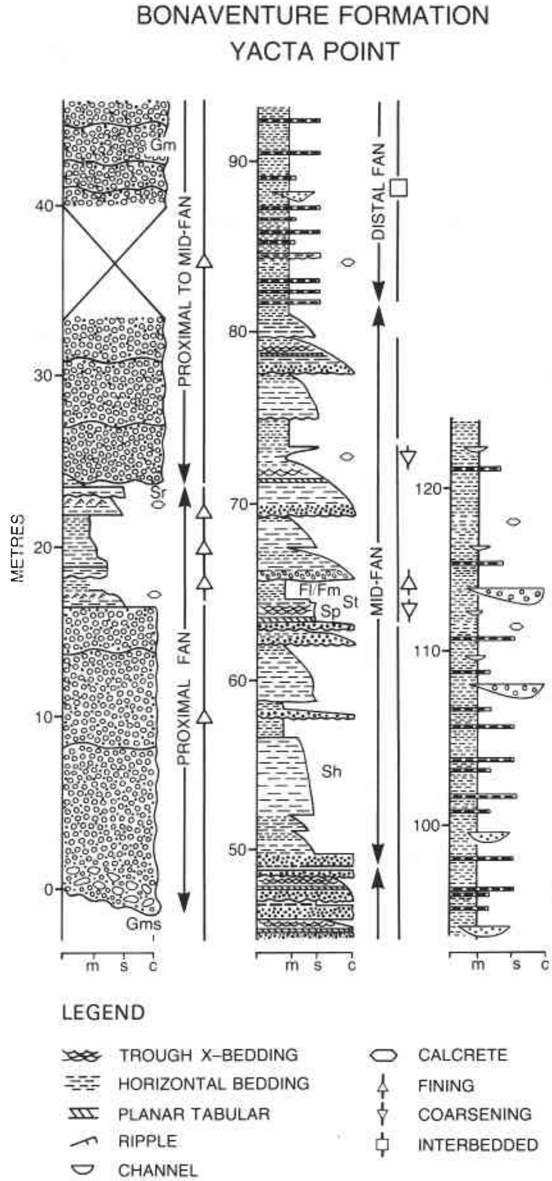

FIG. 2. Yacta Point section (see Fig. 1 for location); m = mudstone/siltstone; s = sandstone; c = conglomerate.

Yacta Point

The Yacta Point section (Fig. 2), which starts approximately ½ km east of Miguasha Wharf, offers the most complete and continuous section of the Bonaven-

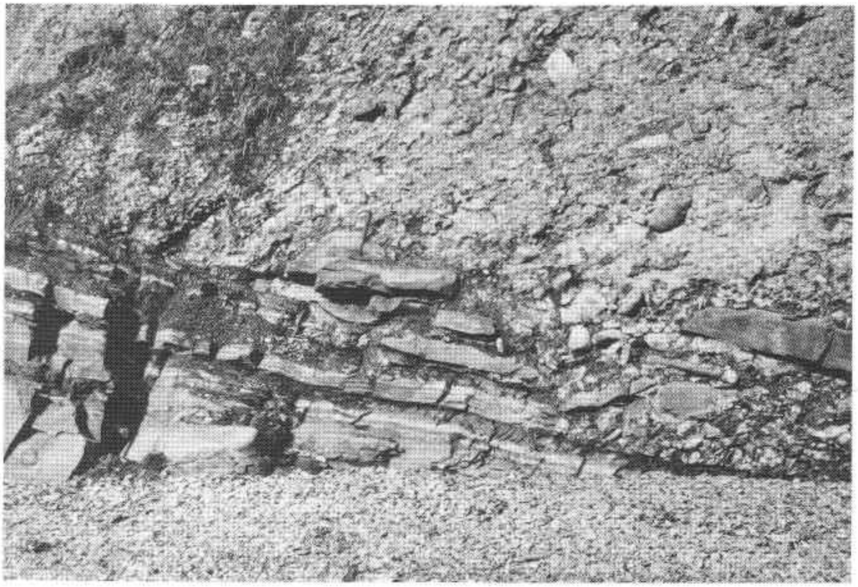

FIG. 3. Unconformity between the Escuminac (Devonian) and Bonaventure formations. Note stepped relief and Escuminac blocks set in a silty conglomeratic matrix in center right of photo. Hammer 30 cm long.

ture Formation in the study area (approximately the basal 125 m). The base of the section rests with pronounced angular unconformity on the Upper Devonian Escuminac Formation (Fig. 3). The unconformity is sharp and erosional, displaying up to 10 m of stepped topographic relief, with Escuminac blocks up to 1.3 m long incorporated into the lowest portions of the Bonaventure. The contact exhibits a 15–20° dip, which quickly shallows up-section to approximately 3°. The dip at the contact is assumed to be close to depositional dip, representing the original paleotopography during deposition, which probably indicates rapid accumulation during or after source uplift.

The Yacta Point section is divisible into three distinct successions (Fig. 2): (1) a lower succession (0–48 m) dominated by facies Gm, with minor Gms near the base; (2) a middle succession (48–83 m) in which the dominant facies combination is Sh fining upward to Fl; and (3) an upper succession (83–124 m) dominated by facies Fl and Fm with minor sandstone and conglomerate units.

The lower succession (0–48 m) contains two conglomerate-dominated fining-upward sequences, separated by minor fining-upward medium- to coarse-grained sandstone and siltstone. The lower conglomerate is dominated by facies Gm, with pods or lenses of Gms near the base. These lenses contain the large subhorizontal blocks shown in Fig. 3, which are considered to be part of a talus accumulation. The transport of the large blocks is attributed to grain and (or) cohesive debris flow (Lowe 1976, 1979). Upward dispersive pressure in this type of mass flow caused the blocks to assume an orientation subparallel to the original paleotopographic surface. Flows of this type occur in areas of steep slope, commonly adjacent to scarps. The sequence is therefore interpreted as a talus accumulation, transitional upward to proximal alluvial fan deposits formed adjacent to the apex of a fan complex. Paleocurrent data, chiefly from imbrication studies, indicate that the scarp from which the clasts were derived was located to the north of the exposed section (Fig. 4).

The upper conglomerate in the lower succession is also dominated by Gm, but contains indistinct fining-upward cycles of boulder to cobble conglomerate. Minor amounts of imbricate Gm and Gt with minor Sh transitional to Sr are present up-section. This sequence is also attributed to alluvial fan deposition, but in a less proximal position than the lower conglomerate and subject to fluvial rather than mass flow sedimentation.

The interval between the two conglomerate sequences is composed of granule-bearing medium-grained sandstones (Sh and Sh/l) in repetitive fining-upward cycles capped by Fm and Fl (Fig. 2). The relatively thick Fm and Fl deposits contain incipient calcrete. These deposits are thought to have been deposited under high-energy ephemeral conditions (Tunbridge 1981). The sandstones may have accumulated either on an interlobe area that was not receiving coarse detritus, or during an interval between two syndepositional uplifts.

The middle succession (48–83 m) of the Yacta Point section is characterized by repeated fining-upward cycles, 1–5 m thick, that are dominated by transitions from facies Sh to Fl, but also contain minor Sr, Sp, and St (Fig. 2). The cycles rest on minor erosional surfaces,

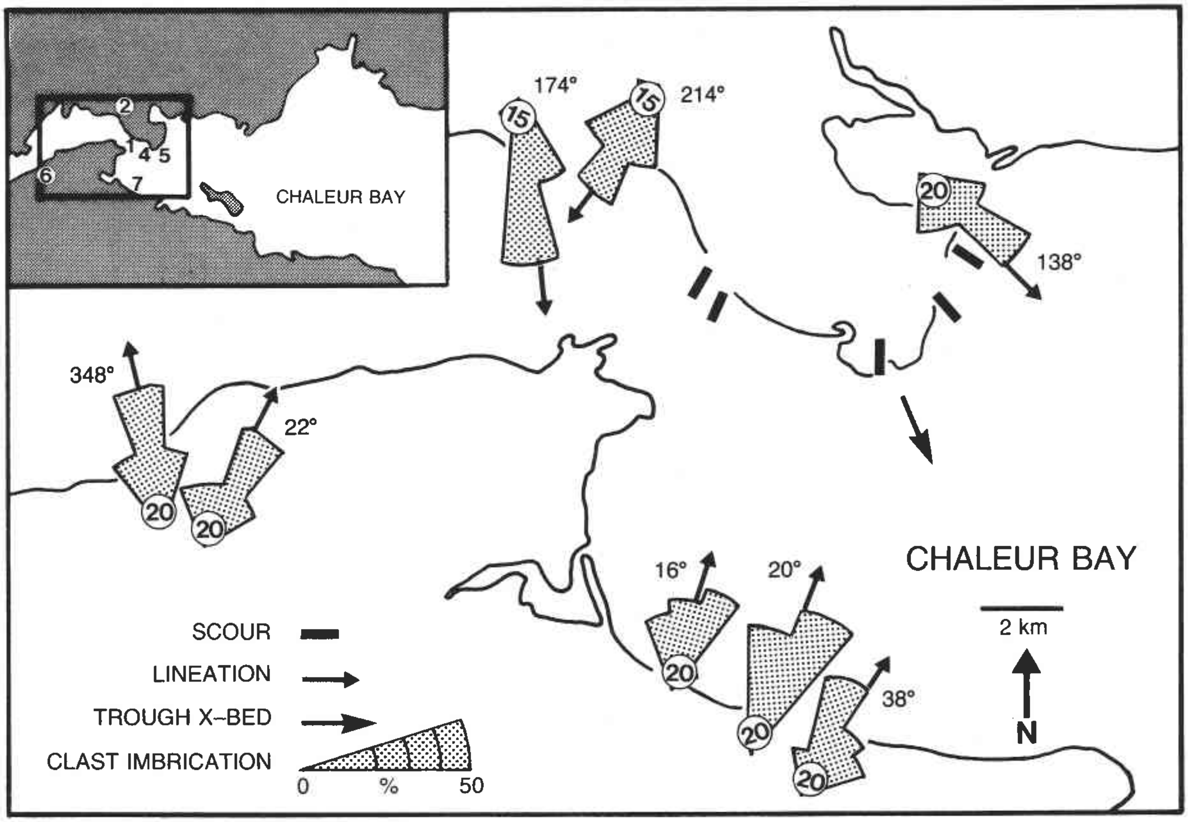

FIG. 4. Paleocurrent data, Bonaventure Formation, in the western Chaleur Bay area. Inset numbers refer to measured sections (see Fig. 1). Numbers 20 and 15 refer to number of measurements per station.

and many contain incipient calcrete in the finer grained lithofacies. In the lower part of this succession the sandstone bodies are laterally extensive sheets, some of which incorporate rip-up clasts at the base. The cycles are attributed to autocyclic causes, chiefly the waning of flood events. A few channel-fill sandstones and coarsening-upward crevasse-splay or levee deposits are also present towards the top of the middle succession. Because of inaccessibility, channel dimensions cannot be measured, but are estimated to average 1 m in depth and 25 m in width. Large-scale desiccation cracks containing nodular calcrete are present in the crevasse-splay and overbank deposits (Fig. 5).

The predominance of facies Sh (and Sh/Sr) in the middle succession is attributed to deposition by shallow, high-velocity flow during flash floods (McKee *et al.* 1967; Tunbridge 1981). The presence of channel-fill, sheetflood sandstones, and crevasse-splay deposits towards the top of the succession probably indicates deeper flow under more continuous pluvial conditions.

The upper succession (83–123 m) of the Yacta Point section is dominated by the facies Fl and Fm, with thin units of facies Sh or Sh/l (Fig. 2). Conglomerate-filled channels, isolated in the mainly mudstone succession, have high depth/width ratios, averaging 1.5 m in depth and varying from 3 to 5 m in width. They increase in abundance up-section, as does the abundance of calcrete in the fine-grained facies. At their base some of the channels have sinuous, bifurcating scours 3–10 cm deep that are longitudinally continuous for up to 4 m (Fig. 6). They are filled with coarse-granule to small-cobble conglomerate, lacking any apparent internal structure, and spaced at 20–40 cm intervals, depending on the size of the channel. These structures resemble gutter marks, attributed to scour by a water–sediment mixture flowing in helices with horizontal axes (Whitaker 1973). A slightly different, alternative interpretation is that they are harrow or kolking structures, indicative of high-energy turbulent scours and infills in ephemeral channels (Harvey 1980; Karcz 1967).

Discussion

In broad terms the Yacta Point succession can be related to the alluvial facies models of Miall (1977, 1978) and Rust (1978). The lower succession is interpreted as a transition from deposits of proximal to middle reaches of an alluvial fan complex (Fig. 2), corresponding to a transition from Miall's Trollheim to

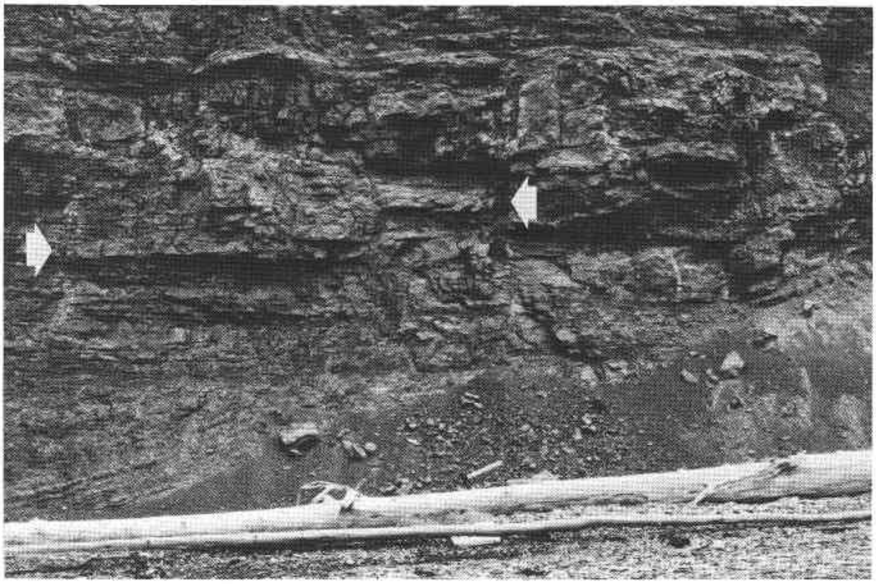

FIG. 5. Calcrete-filled desiccation cracks (arrowed) within crevasse-splay and sheetflood sandstones, middle succession of Yacta Point section. Hammer 30 cm long.

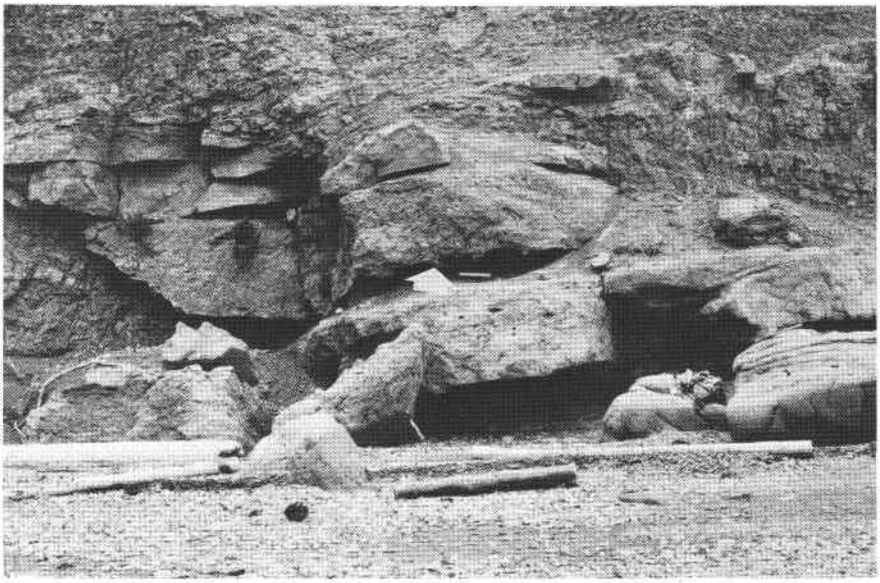

FIG. 6. Stacked pebbly channel sandstones in upper succession of Yacta Point section. Note scour structures (arrowed) above hammer, interpreted as harrow, kolking, or gutter mark structures. The channels are surrounded by mudstone (facies Fm) with calcrete. Hammer 30 cm long.

Scott models. The middle succession is similar to the Bijou Creek model of Miall (1978), and is attributed to deposition on sand-dominated middle reaches of the alluvial fan complex. The upper succession represents a transition from mid-fan to mud-dominated distal fan or alluvial plain. The abundance of mudrocks and the lack of cyclicity suggest correspondence with the silt-dominated braided alluvial systems discussed by Rust (1978). However, the contrast between the fine grain size of the dominant facies and the conglomeratic channel fills in the Bonaventure indicates that a direct comparison is invalid. The high depth/width ratios are characteristic of meandering channels (Schumm 1977), but the restricted lateral extent indicates that the streams

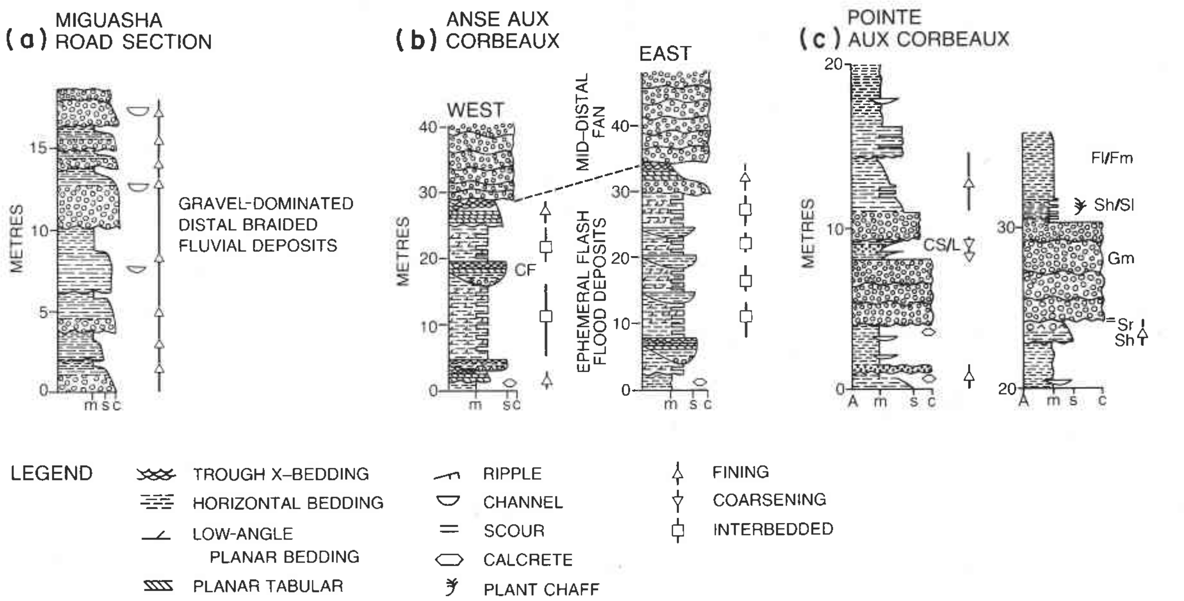

FIG. 7. Measured sections at (*a*) Miguasha Road, (*b*) Anse aux Corbeaux—east and west, and (*c*) Pointe aux Corbeaux. Refer to Fig. 1 for locations. CF = channel fill; CS/L = crevasse-splay or levee deposit.

did not meander. Lateral restriction was probably due to incision of channels on the distal region of the fan complex as a result of a change in hydrologic regime, or, more probably, rejuvenation of the alluvial system after downfaulting of the basin. The limited vertical extent of the channels suggests that they did not remain incised indefinitely at any one location, but relocated by avulsion, which probably occurred on higher reaches of the fan complex. The thin units of facies Sh or Sh/l are interpreted as sheetflood or crevasse-splay sandstones; their abundance implies that frequent flood events covered the alluvial plain between the incised channels, probably originating by overbank flooding from more proximal settings where channels were not incised.

Hugh Miller Cliffs

The Hugh Miller Cliffs expose a composite 46 m section divisible into a lower, Gm-dominated unit and an upper, repetitively fining-upward unit. Because of inaccessibility, it was not possible to determine detailed facies relationships. Despite this drawback, the location is significant because it is stratigraphically above the Yacta Point section and represents part of a second fining-upward megasequence. The lower unit (approximately 12 m thick) is composed dominantly of cobble- to pebble-size, well imbricated, horizontally bedded Gm units. Indistinct fining-upward cycles (from 0.5 to 1.5 m thick) contain abundant internal erosional surfaces and minor Sp–St channel-fill sandstones. The proportion of sandstone increases up-section. Some Gm zones are massive and ill sorted, displaying a matrix-supported framework that approaches Gms. These latter deposits may represent the most distal portion of debris-flow deposits. Elsewhere, however, well developed clast imbrication within facies Gm indicates flood reworking by unchannelized flow or in broad, shallow channels (Bull 1972, 1977; Koster 1977). The facies association of the lower part of the Hugh Miller Cliffs resembles the Scott depositional model of Miall (1978), suggesting deposition on the proximal to middle reaches of the fan complex.

The upper portion of the cliff section (34 m approximately) comprises repetitive fining-upward conglomerate–sandstone units. Cycles range from 0.25 to 1.5 m thick and contain local erosional surfaces, laterally persistent conglomerate sheets, and well imbricated Gm units. The sheetlike nature, abundant erosional surfaces, and fining-upward cycles suggest deposition on coalescing longitudinal and (or) transverse bar sheets below the intersection point of a fan complex (Hooke 1967; Church and Gilbert 1975).

Miguasha Road section

The Miguasha Road section (Fig. 7*a*) is a 17.5 m thick pebble to small-cobble conglomerate – sandstone succession composed of 0.75–3.25 m thick repetitive fining-upward cycles, many of which are erosionally based. They include fining-upward Gm, Gm–Sh–Fl, Gm–Gp–Sp/St, St–Sp and Fl deposits that are not cyclic, and minor units of facies Sh/Fl and Fl.

The abundance of facies Sh and of fining-upward cycles is an important characteristic of the Miguasha Road section, resembling the middle succession at Yacta Point (Fig. 2). This suggests a similar deposi-

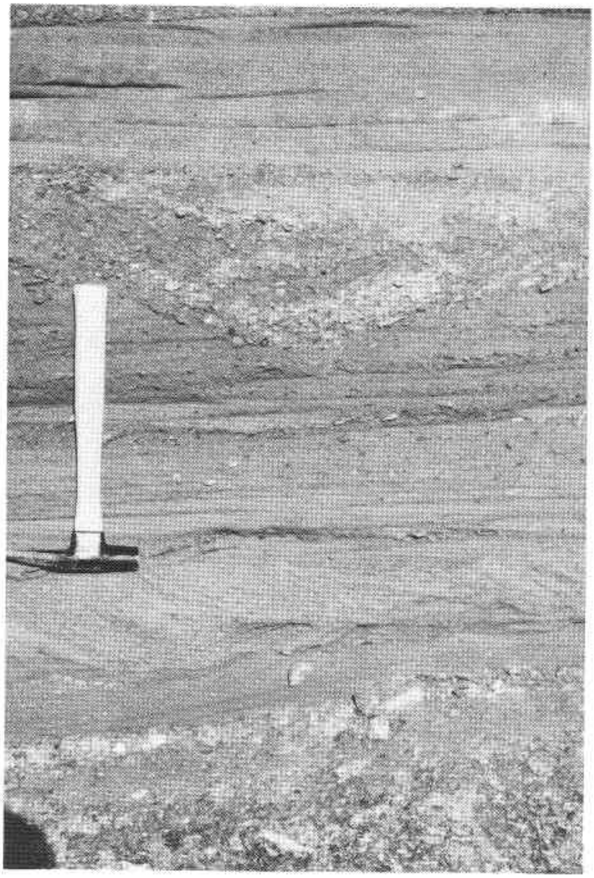

FIG. 8. Asymmetric scour fill of pebbly sandstone cut into Sh sandstone, overlain and underlain by fine-grained Gm deposits (Anse aux Corbeaux section). Hammer 30 cm long.

tional mode: shallow ephemeral floods on the middle reaches of the fan complex (Tunbridge 1981).

Anse aux Corbeaux—east and west

The Anse aux Corbeaux sections (Fig. 7*b*) are on the east and west limbs of a gentle, open anticline, and are divisible into two distinct successions: (1) a lower sandstone-dominated succession with minor sheetflood and channel-fill deposits; and (2) an upper small-boulder to cobble conglomerate succession containing massive to sheeted Gm deposits.

The lower succession ranges in thickness from 28 to 35 m and is composed predominantly of fining-upward cycles of Sh/Sl–Sh/Sp–Fl high-energy deposits, with subordinate sheetflood and channel-fill sandstones (Fig. 8). Erosional surfaces are abundant, as are low-angle planar cross-bedded and single pebble horizons, and the repetitive interbedding of Sh and Sl with minor amounts of Sp/St (Fig. 9). Grey–green reduction spots indicate the presence of disseminated plant material. Figure 10 shows an imbricate mud-chip conglomerate with facies Sh and single pebble horizons.

The laterally extensive sheetflood sandstones have abrupt lower contacts. Channel-fill bodies, with width/depth ratios of the order of 100:1, are erosionally based and contain Gm–Sh–Sp–St–Fl or Gm–Gp–St fining-upward cycles. The top and bottom of the section contain calcrete associated with Fl and Fm deposits. These features indicate an ephemeral, sand-dominated, braided fluvial deposit of the Bijou Creek type (McKee *et al.* 1967; Miall 1978).

The upper succession is a thicker, fining-upward sequence of massive to horizontally bedded Gm (>70%), with minor amounts of facies Gp, Gt, Sh, Sp, and St. The contact between the lower and upper successions is sharp and occurs above a calcrete horizon, indicating a time lapse between the deposition of the two successions. The massive to horizontally bedded Gm deposits contain indistinct fining-upward cycles as channel fills. In many regards this portion of the Anse aux Corbeaux section is similar to the upper conglomerate in the lower succession of the Yacta Point section, and is attributed to deposition on the middle reaches of an alluvial fan complex, above the intersection point (Hooke 1967). Up-section the conglomerate becomes more sheetlike and fines become rarer, probably due to unconfined flow at the toe of the fan or the proximal braid plain below the intersection point.

Pointe aux Corbeaux

The Pointe aux Corbeaux section (Fig. 7*c*) is a 36 m continuous succession of sandstone and conglomerate that exhibits two (and part of a third) fining-upward cycles, approximately 15 m thick. The cycles start with massive, well imbricated, fining-upward Gm deposits that contain gutter marks at the base. The Gm (and minor Gp) facies are overlain by Sh or interbedded Sh/Fl units, grading upward into relatively thick Fl deposits with disseminated plant and calcrete material. The middle and upper portions of some cycles contain sheetflood sandstones that include zones of pebble and rip-up clasts and large-scale dune cross-stratification.

The cycles in the Pointe aux Corbeaux section are attributed to deposition near the toe of the alluvial fan complex or on the proximal part of a braid plain. The internal truncation within the Sh and Fl units indicates successive depositional events, probably with short recurrence intervals. Cycles of similar thickness (15 m) have been observed in alluvial fan successions by Steel *et al.* (1977) and Steel and Aasheim (1978), but are mostly of the coarsening-upward type, with some cycles coarsening then fining. Steel *et al.* (1977) attributed the cyclic behaviour to tectonic rejuvenation, generating upward coarsening by progradation of coarse proximal sediments over finer distal deposits. In the present case,

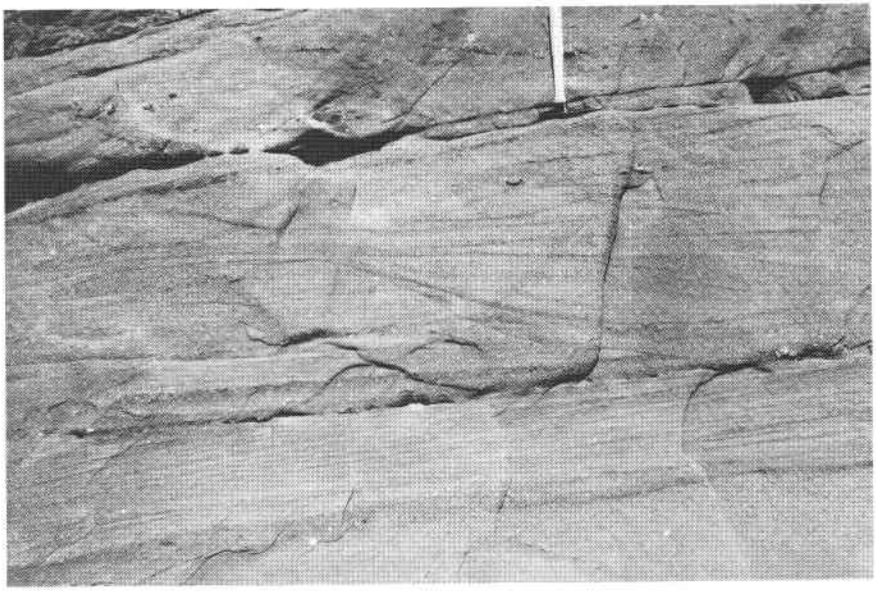

FIG. 9. Typical example of facies Sh/l at Anse aux Corbeaux. White spots are reduction spheres. Hammer 30 cm long.

FIG. 10. Mud-chip conglomerate at base of facies Sh/l in Anse aux Corbeaux section. Lens cap diameter 4 cm.

the fining-upward cycles may be due to particularly rapid uplift that caused the depositional site to be flooded by coarse proximal detritus, which fined upward as the system subsequently adjusted to relative quiescence.

In terms of existing models, the Pointe aux Corbeaux succession most closely resembles the Donjek model of Miall (1978) or G_{III} of Rust (1978). However, both of these models relate to distal braid plains, several tens of kilometres from the influence of alluvial fans. Their cyclicity is attributed to autocyclic processes: lateral migration of areas within the braid plain, characterized by certain facies assemblages. However, an interpretation of the Anse aux Corbeaux succession based directly on the models is misleading because the depositional environment was much closer to the source area and because in this case cyclicity is attributed to tectonic (allocyclic) causes.

Dalhousie Junction

The Dalhousie Junction section (Fig. 11*b*), located approximately 11 km west-southwest of Dalhousie, New Brunswick, consists of an 11.5 m quarry exposure

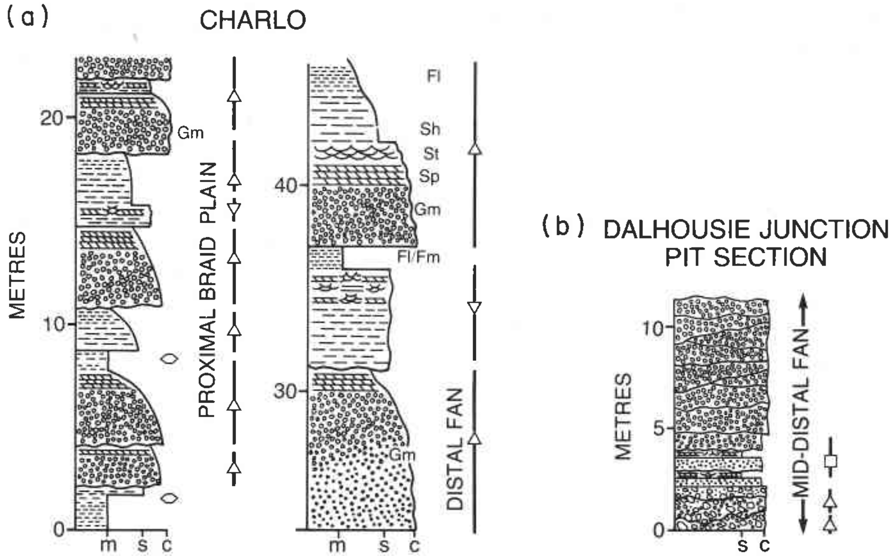

FIG. 11. Measured sections at (*a*) Charlo and (*b*) Dalhousie Junction (see Fig. 1 for location; Figs. 2 and 7 for legend).

of Gm- (and Gms-) dominated Bonaventure Formation. The section can be subdivided into: (1) a lower 4 m composed of ill sorted, massive, matrix-supported Gms deposits fining upward into Gm, Gp, or Sp units; and (2) an upper 7 m with massive to horizontally bedded, well imbricated Gm with minor amounts of Sp and St.

Facies Gms in the lower part of the section locally contains a muddy matrix, and is attributed to debris-flow deposition. The upper part of the section is composed of massive to horizontally bedded and well imbricated Gm units. These units have abundant internal erosional surfaces and minor amounts of facies Gp and Sp–St channel-fill sandstones. The *A–B* planes dip upstream and the *A*-axes are transverse to paleoflow direction, a fabric typical of fluvial transport (Rust 1972, 1978). The association of facies resembles deposits of coalesced longitudinal bars in a proximal braided fluvial tract, as typified by the G_{II} model of Rust (1978).

Like other Bonaventure sections in New Brunswick, that at Dalhousie Junction is thinner than the sections in Gaspé. This is thought to be due to lower relief of the source terrane in New Brunswick, which was probably reflected in a somewhat smaller alluvial fan complex on the southern side of the paleovalley. The Dalhousie Junction section is attributed to transition from the proximal region of the fan complex, on which debris flows were active, to a more distal braided tract, on which streamflow processes were dominant.

Charlo

The Charlo section (Fig. 11*a*), located along a 2 km stretch of coast at Charlo, New Brunswick, is a gently dipping (<3°) 46 m succession similar to that at Pointe aux Corbeaux. The section consists of fining-upward cycles of Gm–Sp, Gm–Sp–St, Sh–Fl, and Fl/Fm deposits.

Facies Gm is a well imbricated cobble to pebble conglomerate with minor interbedded Gp and Gt facies. Gm units are laterally extensive and show rapid vertical and horizontal facies changes to Sp and St, attributed to deposition on longitudinal bars with marginal cross-stratal deposits. The finer units (Sh–Fl and Fl/Fm) are attributed to overbank deposition; the scattered coarsening-upward successions may be due to crevasse-splay or levee formation. In general, the section corresponds to a gravelly braid plain deposit, closely corresponding to the G_{III} model of Rust (1978).

Paleogeographic interpretation

The measured sections and local interpretations discussed above are assembled into an overall paleogeographic interpretation for the Bonaventure Formation of the Chaleur Bay region in Fig. 12. Three depositional environments have been recognized, each transitional into the adjacent environment or environments: (1) alluvial fan complex; (2) gravelly braid plain; and (3) sandy (to locally silty) braid plain. The facies associations on which these interpretations are based are summarized in Fig. 13.

The only continuous section is at Yacta Point, but the other sections provide specific depositional information. Proximal alluvial fan deposits containing debris-flow units are present at Yacta Point and Dalhousie Junction. Proximal gravel-dominated braided fluvial deposits representing mid- to distal fan to proximal braid plain (i.e., containing longitudinal bar deposits) are present at Yacta Point, lower Hugh Miller Cliffs, upper Anse aux Corbeaux, and the Dalhousie Junction sections. Areas of more distal gravel-dominated braided fluvial environments that have deposits of both dissected longitudinal and traverse bars are the upper portion of the Hugh

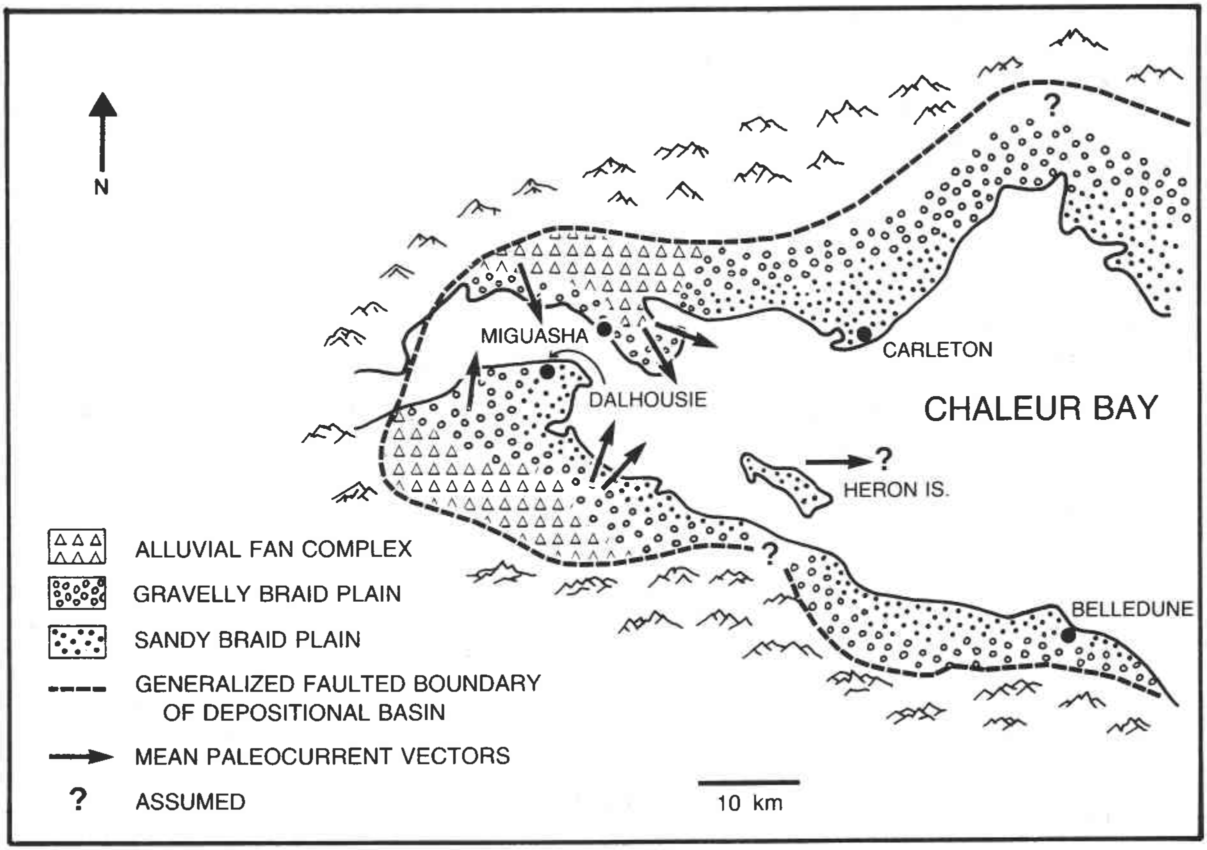

FIG. 12. Paleogeographic reconstruction for the Bonaventure Formation in the western Chaleur Bay region.

<table>
<tr><th colspan="2">MODEL</th><th colspan="4">LITHOFACIES</th><th rowspan="3">DEPOSITIONAL ENVIRONMENT</th><th colspan="4">BONAVENTURE FORMATION EXAMPLES</th></tr>
<tr><th rowspan="2">RUST</th><th rowspan="2">MIALL</th><th colspan="2">RUST</th><th colspan="2">MIALL</th><th colspan="2" rowspan="2">RUST</th><th colspan="2" rowspan="2">MIALL</th></tr>
<tr><th>MAJOR</th><th>MINOR</th><th>MAJOR</th><th>MINOR</th></tr>
<tr><td>G_I</td><td>Trollheim</td><td>Gms, Gm</td><td>St, Sp Fl Fm</td><td>Gms, Gm</td><td>St, Sp, Fl Fm</td><td>proximal braided rivers, alluvial fans subject to debris flows</td><td rowspan="3">L. Yacta Point
Charlo
U. Anse aux Corbeaux
L. Yacta Point
U. Hugh Miller Cliffs</td><td rowspan="3">L. Hugh Miller Cliffs
Dalhousie Junction
Pointe aux Corbeaux
Miguasha Road Sec.</td><td>L. Yacta Point</td><td rowspan="3">Dalhousie Junction
Pointe aux Corbeaux
Charlo</td></tr>
<tr><td>G_{II}</td><td>Scott</td><td>Gm</td><td>Gp, Sp Sh</td><td>Gm</td><td>Gp, Gt, Sp St, Sr Fl, Fm</td><td>proximal braided rivers (incl. alluvial fans) subject to stream flow</td><td rowspan="2">L. Yacta Point
L. Hugh Miller Cliffs
U. Anse aux Corbeaux
U. Hugh Miller Cliffs
Miguasha Road</td></tr>
<tr><td>G_{III}</td><td>Donjek (cyclic)</td><td>Gt, Gm St</td><td>Sh, Fl</td><td>Gt, Gm St</td><td>Gp, Sh, Sr</td><td>distal gravelly rivers</td></tr>
<tr><td>S_I (Bijou)
S_I (Malbaie)</td><td>Bijou Creek</td><td>Sh
Se, Sl</td><td>Sp, Sr
St</td><td>Sh, Sl</td><td>Sp, Sr</td><td>proximal sandy rivers on braid plains</td><td rowspan="2">L. Middle Yacta Point
L. Anse aux Corbeaux
M. Yacta Point
U. Yacta Point</td><td rowspan="2"></td><td rowspan="2">L. Anse aux Carbeaux
M. Yacta Point
U. Yacta Point</td><td rowspan="2"></td></tr>
<tr><td>S_{II}</td><td>South Sask. (cyclic)
Platt (non cyclic)</td><td>Se, St, Sp</td><td>Sr Fl Fm</td><td>St
St, Sp</td><td>Sp, Se, Sr Sh, Ss, Sl Gm, Fl, Fm
Sh, Sr, Ss Gm, Fl, Fm</td><td>distal sandy rivers on braid plain</td></tr>
</table>

FIG. 13. Braided fluvial models after Rust (1978) and Miall (1978) shown in relation to this study.

Miller Cliffs and the Miguasha Road and Pointe aux Corbeaux sections. The remaining sections are interpreted as sand–silt deposits formed distally on an alluvial fan complex (the upper part of the Yacta Point section) or on inactive parts of a braid plain. Successions transitional to meandering fluvial deposits were not observed in the study area, but probably occur downvalley, now submerged by Chaleur Bay. In all sections investigated, evidence for wide discharge fluctuation suggests an ephemeral hydrologic regime. The prevalence of redbeds and well developed calcretes indicates that the Bonaventure was deposited under semi-arid climatic conditions.

The paleocurrent measurements obtained from the

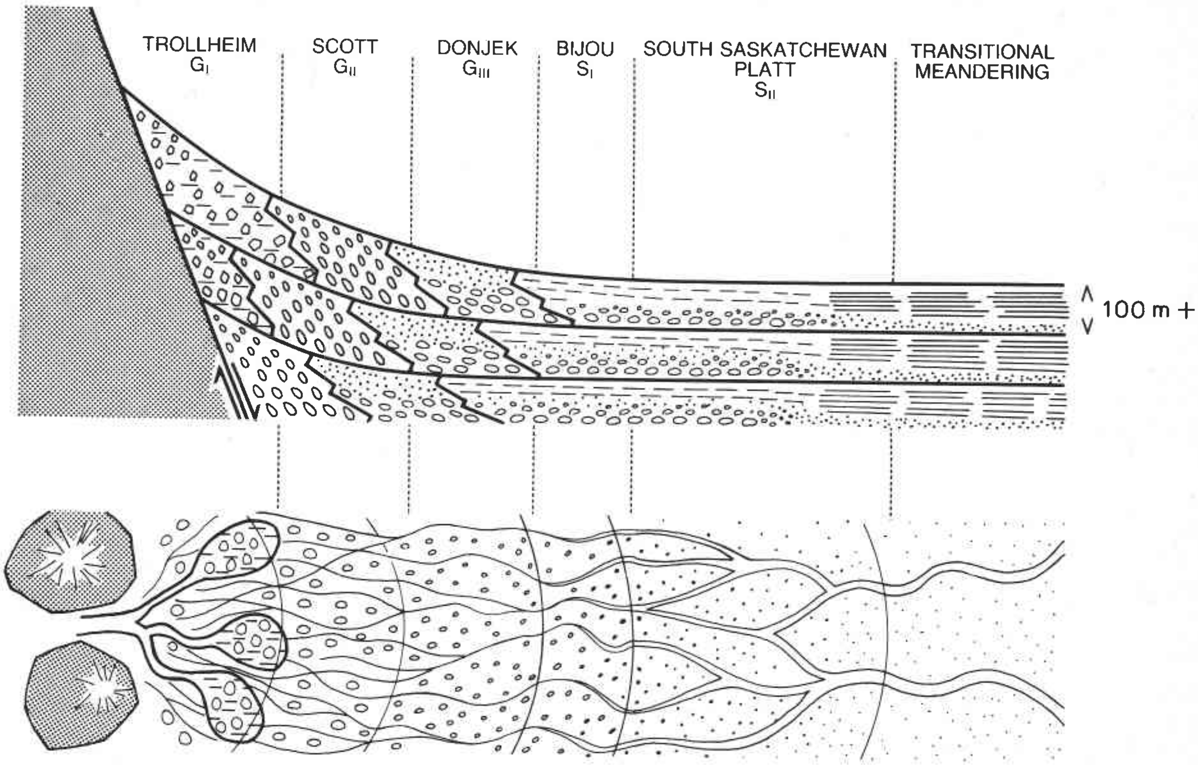

FIG. 14. Plan and cross-sectional diagrams for alluvial facies transitions observed in the Bonaventure Formation in the western Chaleur Bay area.

Bonaventure Formation are summarized in Fig. 4. The data from the Quebec portion of Chaleur Bay show a south to southeastward transport direction. The values obtained from New Brunswick show a north to northeastward paleocurrent direction. These opposed directions strongly suggest that the Bonaventure occupied a paleovalley, and it is reasonable to interpret the eastward dip of the Bonaventure on Heron Island as the original paleoslope direction, suggesting a west to east paleodrainage direction down the axis of Chaleur Bay. Figure 12 shows the proposed model of paleodrainage during the deposition of the Bonaventure Formation. This east to west trending paleovalley is now exhumed and forms the present Chaleur Bay. East of a line joining Belledune Point and Cap Noir (Fig. 1) the Bonaventure paleovalley may have opened out onto the New Brunswick Platform.

The major source areas for the western Chaleur Bay region were to the north, west, and south. Clast counts and petrographic analysis indicate that the carbonates in conglomerates of the southern Gaspé coast were derived from the Restigouche and (or) Matapedia groups and the volcanics in northern New Brunswick were derived from the Tetagouche Group (Zaitlin 1981*b*).

In general terms, this study shows that the models proposed by Miall (1977, 1978) and Rust (1978) are helpful in interpreting the paleogeography of an ancient alluvial deposit such as the Bonaventure Formation (Fig. 13). It is important to note, however, that the models have several limitations. They represent arbitrary points chosen from within the continuously variable spectrum of alluvial systems (Fig. 14). They were developed from detailed study of specific examples and it is not surprising to find cases in which an interpretation falls between proposed models. In addition, the geographic names of Miall's models imply a specific climatic, tectonic, and geographic setting, whereas in fact they represent a specific set of hydrologic, provenance, and gradient parameters that define processes controlling alluvial sedimentation.

Depositional models necessarily are simplifications, which cannot take into account all possible sources of variation in the natural environment. This is well illustrated by the upper part of the Yacta Point section, in which the predominance of fine-grained facies suggests similarity to the silt-dominated braided systems of Rust (1978). However, the narrow channels with conglomeratic fill can only be explained by an additional environmental factor: channel incision due to tectonic rejuvenation of the whole alluvial system.

Acknowledgments

This paper is derived from part of the M.Sc. thesis completed by B.A.Z. under the direction of B.R.R. at the University of Ottawa. We wish to thank A. D. Miall and R. G. Walker for comments on the manuscript and M. M. Lerand and G. Nadon for critically reading an earlier version. Special thanks goes to Karen Mahowich and Julie Hayes for typing, Cathy Work for drafting, and Gulf Canada Resources and Edward Hearn for photographic assistance. Logistic support was provided by the Natural Sciences and Engineering Research Council of Canada.

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