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**Sedimentology and Tectonic Implications of the
Pointe la Nim and Campbellton Formations,
Western Chaleur Bay,
Maritime Canada**

By

Charle A. Gamba

**A thesis
presented to the School of Graduate Studies
in partial fulfilment of the
requirements for the degree of
Master of Science
in
the Department of Geology,
University of Ottawa,
Ottawa-Carleton Geoscience Center**



Charle A. Gamba, Ottawa, Canada, 1990



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UNIVERSITÉ D'OTTAWA
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ABSTRACT

The middle to late Emsian clastic succession of the western Chaleur Bay region comprises the newly defined Pointe la Nim Formation and the overlying Campbellton Formation. The type and orientations of the fluvial systems present in the succession lends insight into the larger scale basin configurations and the nature and timing of major allocyclic events. The succession documents a transition from synvolcanic to syntectonic fluvial sedimentation related to a transition from subduction related island arc volcanism to uplift and dissection of the volcanic arc during the early stages of the Acadian Orogeny. The middle Emsian Pointe la Nim Formation is composed of interbedded extrusive volcanics, pyroclastics, and a wide range of fluvial deposits which exhibit a southwestwards to northeastwards proximal to distal trend. Valley fill deposits are transitional northeastwards into gravelly braidplain deposits, thick sequences of which are interbedded with rooted floodplain deposits. This interbedding reflects the northeastwards progradation of the braidplain during periods of relatively intense volcanic activity, followed by southwestwards encroachment of a low energy floodplain environment during periods of quiescence.

The mid to late Emsian Campbellton Formation overlies the Pointe la Nim Formation with local discordance, and can be subdivided into four distinct members: the lacustrine Atholville Member and the fluvial Pointe à la Garde, Pointe à Bourdeau, and Restigouche Members. The deposits of the Pointe à la Garde Member represent a transverse proximal gravelly braidplain which flowed westwards into a northwards flowing, longitudinal sandy braidplain, represented by the deposits of the Pointe à

Bourdeau Member. The deposits of each member are characterized by different scales of cyclic vertical facies assemblages. Small-scale cycles within each of the members are attributed to autocyclic *within* channel processes. The alternation of grouped small-scale cycles and thick sandstone sequences within the Pointe à la Garde Member is attributed to episodic uplift along the eastern margin of the Gaspé Basin.

The fine grained sandy braidplain and floodplain deposits of the Restigouche Member abruptly overlie the proximal gravelly braidplain deposits of the Pointe à la Garde Member, indicating an abrupt termination of uplift in the east.

The onset of dextral strike-slip displacement along the Grand Pabos Fault in early Eifelian time effectively fragmented the Gaspé Basin and uplifted the Aroostook-Percé Anticlinorium, resulting in the creation of an asymmetric half graben in the western Chaleur Bay area. Fluvial styles within the Eifelian Pirate Cove Formation reflect the southwards progradation of alluvial fans in response to episodic faulting activity.

Acknowledgements

I would like to thank my advisor, Brian Rust, for his generosity and unending patience. Thanks also to Geof Eurbidge for his friendship and help during the last two years, and also for his assistance in the field. Office pals Tim deFreitas, Frank Brunton, and Martine Savard, as well as numerous other colleagues at the U of O and Carleton, provided not only numerous defeats at the game of racketball, but also their friendship, for which I am eternally grateful. Thanks to Doris Chin for the motivation and for being there and hanging in during many difficult times.

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CHAPTER 1

INTRODUCTION

1-1 Location and Access

The study area is located within the western Chaleur Bay area, straddling the border between southern Gaspé, Quebec, and northern New Brunswick (Fig. 1-1). The Campbellton Formation forms a northeast to southwest trending outcrop belt located between the town of Atholville, New Brunswick, and Escuminac, P.Q. A small, fault-bounded outlier of the Campbellton Formation occurs to the northeast of the main outcrop belt, near the town of Grand Cascapédia, P.Q. (Fig. 1-1).

The newly defined Point la Nim Formation forms the uppermost portion of the Dalhousie Group, which is extensively exposed within the study area (Fig. 1-1).

Sections were measured primarily from shoreline exposure and from road cuts along highways on either side of Chaleur Bay. Shoreline exposure occurs as high cliffs, the bases of which were fully accessible at low tide. Exposure inland is very poor, due to the dense nature of the vegetation. A total of 26 sections, forming the basis of this study, were measured and described in detail.

1-2 History of Research

The Devonian clastic succession of western Chaleur Bay has had a long history of geological investigation. Gesner

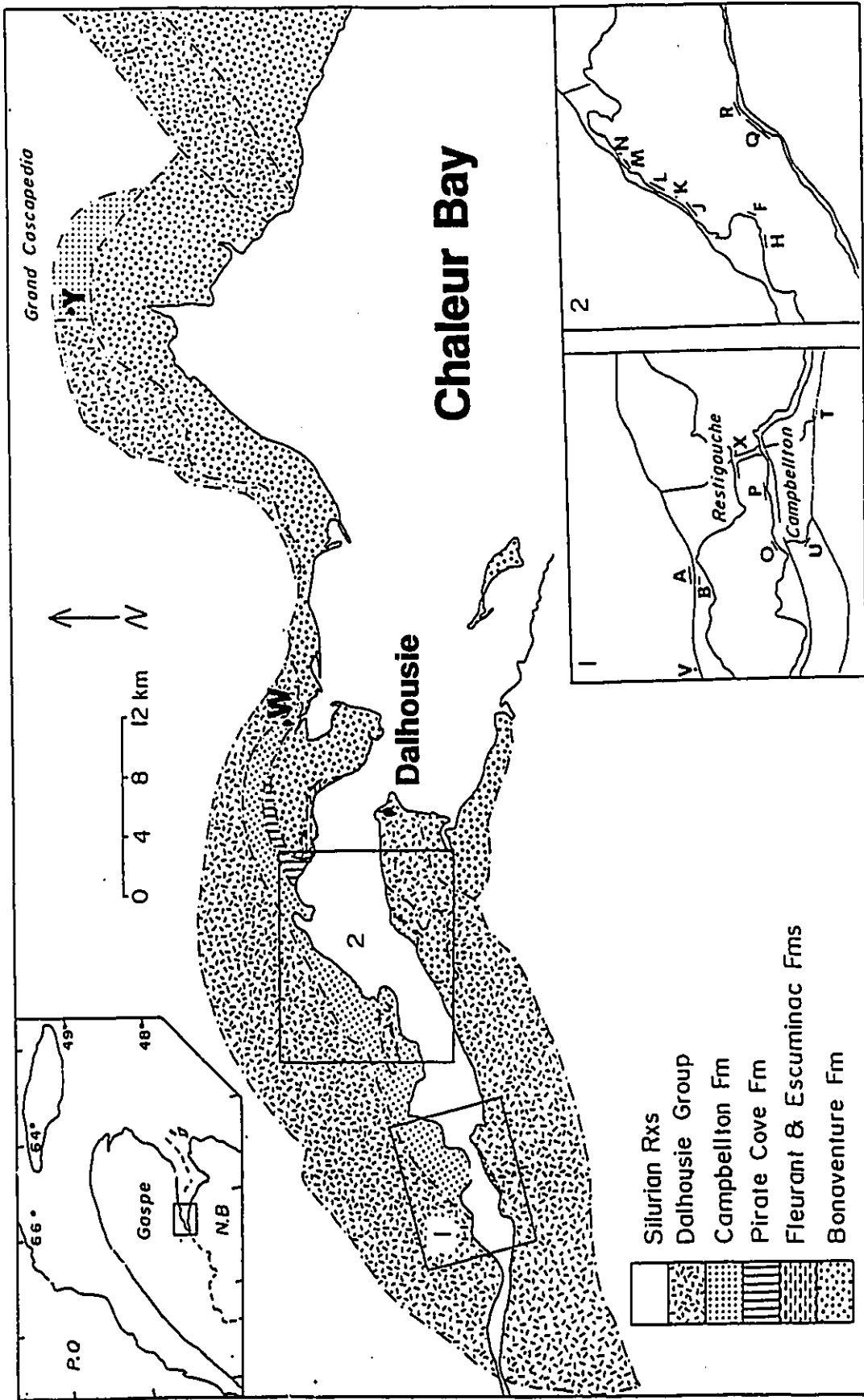


Figure 1-1. Location of sections in the western Chaleur Bay study area.

(1843) was the first to survey the western Chaleur Bay area, assessing mineral resource potential for the New Brunswick Department of Mines. In 1843, Sir William Logan undertook a geological investigation of the Gaspé Peninsula involving a survey of the Chat and Cascapédia Rivers, as well as coastal surveys of Chaleur Bay and eastern Gaspé (Logan, 1846). Logan (1863) divided the post-Ordovician stratigraphy of eastern Gaspé into the Gaspé Limestone (Upper Silurian) and the overlying Gaspé Sandstone (lower - Upper Devonian). Logan (1863) referred briefly to the conglomerates, sandstones, and coal beds of the Gaspé Sandstone exposed along the coasts of Western Chaleur Bay; Campbellton Formation (Ami, 1900), and the La Garde Formation (Dineley and Williams, 1968).

The diverse flora and fish fauna of the Gaspé Sandstones (the Campbellton and La Garde Formations in particular) in western Chaleur Bay drew a great deal of attention from subsequent workers, beginning with W.J. Dawson, who undertook several geological and paleontological investigations in the western Chaleur Bay area from 1850 to 1880. Dawson (1888) divided the Gaspé Sandstones into three biostratigraphic divisions based upon its contained flora, and published detailed reports on the primitive land plants contained within the La Garde Formation (Dawson, 1859, 1888) and later those discovered by Ells (1881) within the Campbellton Formation (Dawson, 1882). Ells (1883) also

reported fish remains within the lower portion of the Gaspé Sandstones of Northern New Brunswick; the fish were studied in detail by Whiteaves (1883). Ami (1900) proposed the name Campbellton Formation for a sequence of fish-bearing shales and buff coloured sandstones and conglomerates of Devonian age outcropping along the coast between Atholville and Campbellton in northern New Brunswick, later termed the Atholville beds by Dineley and Williams (1968).

A formal stratigraphic investigation of the Gaspé Sandstones was undertaken by Kindle from 1925-1930, who proposed a five-fold subdivision of the Gaspé Sandstones in western Chaleur Bay, assigning each subdivision a letter code from A-E. The La Garde Formation was actually not included by Kindle (1930), although subsequent authors (Alcock, 1935) mistakenly interpreted Kindle's (1930) subdivision A as the upper portion of the La Garde Formation. Kindle (1930) described this subdivision as "angular-pebble conglomerates interbedded with chocolate, green and grey argillaceous and sandy shales", overlain unconformably by subdivision B. Kindle was in fact describing the lower portion of the Pirate Cove Formation, which Alcock (1935) mistakenly interpreted as Kindle's subdivision B. Kindle (1930) proposed that subdivisions A-C were the equivalents of the Gaspé Sandstone of eastern Gaspé, and were of Early Devonian age.

Alcock (1935) undertook a reinvestigation of the

geology of the western Chaleur Bay area from 1929 to 1935, formally raising Kindle's (1930) B, C, D, and E subdivisions to formational status as the Pirate Cove Formation (B, C), the Fleurant Formation (D), and the Escuminac Formation (E). Subdivision A, as well as the Campbellton Formation were left within the Gaspé Sandstone Series of Middle Devonian age, separated from the overlying Upper Devonian Pirate Cove Formation by an unobserved unconformity. Alcock (1935) accurately listed the locations and described meticulously the lithology of virtually every outcrop of the Gaspé Sandstone within the area.

Béland (1958) refined the surficial geology and stratigraphy of the Oak Bay area of western Chaleur Bay describing the composition of what he termed the coastal outcrop belt (the present La Garde Formation), and suggesting that it rested unconformably above the underlying volcanics of the Dalhousie Group. Béland (1958) interpreted the La Garde Formation as a beach deposit of Early or Middle Devonian age. However, Béland (1972) revised his interpretation, describing the La Garde Formation as a Lower to Middle Devonian fluvial deposit, which, together with the conformably overlying Pirate Cove Formation, constituted a wedge of molasse deposited after the early phases of the Acadian Orogeny.

Williams and Dineley (1966) and Dineley and Williams (1968) undertook the latest revision of the stratigraphy of

the western Chaleur Bay area. The La Garde Formation was given formational status with a type section (unmeasured and unpublished) located along the coast east of Point a La Garde. A conformable contact with the overlying Pirate Cove Formation was proposed. Dineley and Williams (1968) estimated the thickness of the La Garde Formation at less than 5000 ft, and interpreted the sequence as a fluvial deposit of early Emsian age based on spore identifications by McGregor (1963). The similarity of the Campbellton (Ami, 1900) and La Garde Formations was remarked, although a synonymy was not proposed. Dineley and Williams (1968) also discussed the Atholville 'beds' in some detail, noting the presence of an angular unconformity with the underlying volcanics of the Dalhousie Group. However, the Atholville 'beds' were not deemed of sufficient distinction to merit member or formational status. Dineley and Williams (1968) also suggested that the La Garde Formation was syntectonic in origin, deposited during the initial stages of the Acadian Orogeny.

Grierson and Hueber (1967) as well as Andrews et al. (1973, 1974) studied the primitive macroflora of the Campbellton and La Garde formations. Based upon this Andrews et al. (1974) suggested an early Middle Devonian (Eifelian) age for the Campbellton Formation.

Greiner (1973, 1974) resurveyed the western Chaleur Bay area of northern New Brunswick for the N.B. Department of

Mines, describing the Campbellton Formation as Middle Devonian lacustrine, intermontane fluvial deposits.

Rust (1982) and Rust et al. (1989) interpreted the La Garde as a fluvial deposit of Early Devonian age. McGregor (1989a, 1989b) provided age determinations of mid to late Emsian for the La Garde and Campbellton Formations.

1-3 Early Devonian Stratigraphy of the Western Chaleur Bay Area

The La Garde Formation of southwestern Gaspé and the Campbellton Formation of northern New Brunswick are lithologically and biostratigraphically equivalent. For the sake of simplicity, a synonymy of the two formations is proposed. Following Hedberg (1976), the Campbellton Formation, established by Ami (1900), takes precedence over the La Garde Formation, informally established by Béland (1958) and formally established by Williams and Dineley (1966). A section located along the shoreline 1.5 km east of Pointe à la Garde, Québec (sections J), is erected as the type section of the Campbellton Formation.

On the basis of litho- and biostratigraphy, the Campbellton Formation can be subdivided into three members: the Atholville, Pointe à la Garde, and Restigouche members (Fig. 1-2). The uppermost part of the Dalhousie Group can be given formational status, the Pointe la Nim Formation, which forms a traceable outcrop belt along shoreline and in

				Northern New Brunswick		Southwestern Gaspé	
				W		E	
DEVONIAN	MID	EPELIAN		Pirate Cove Formation		Pirate Cove Formation	
	EARLY		EMSIAN	Late	Campbellton Formation		Restigouche Member
		Mid		Pointe a Bourdeau Member		Pointe a Bourdeau Member	Pointe a la Garde Member
				Atholville Member			
			Dalhousie Group	Pointe la Nim Formation	Pointe la Nim Formation		

Legend

- unconformity
- unknown

Fig. 1-2. Devonian stratigraphy of the western Chaleur Bay area.

road cut. The mid Emsian Pointe la Nim Formation is overlain with local discordance by the Atholville Member of the Campbellton Formation. The Atholville Member is restricted to northern New Brunswick. The mid Emsian Pointe à Bourdeau Member conformably overlies the Atholville Member, and is laterally equivalent in an eastwards direction to the Pointe à la Garde Member. The mid to late Emsian Restigouche Member is restricted to southwestern Gaspé and conformably overlies the Pointe à la Garde and Pointe à Bourdeau members. The Restigouche Member is conformably overlain by the Eifelian Pirate Cove Formation (Bedard, 1958, 1972; Williams and Dineley, 1966; Dineley and Williams, 1968; Zaitlin, 1981; Bourque et al., 1989).

GEOLOGICAL SETTING:INTRODUCTION

1-4 Regional Geology and Tectonic History

The Gaspé Peninsula is located within the northern part of the Appalachian Orogen which extends a distance of approximately 3000 km along the eastern coast of North America. The Appalachians form part of a Paleozoic orogen which includes the Caledonides of the British Isles, Scandinavia, and eastern Greenland; the Mauritanides of Senegal and Mauritania; and the Variscides of Morocco, the Iberian Peninsula, and Brittany. Rocks ranging in age from Precambrian to Carboniferous are exposed in Gaspé, and record a complicated history involving three major orogenic

events.

The Appalachian Orogen has been divided into a number of tectonostratigraphic zones or terranes by Williams (1978, 1979), each composed of pre-Mid Ordovician rocks characterized by unique structural and stratigraphic features. By analogy with the Cordilleran Orogen (Coney et al., 1980), these units have been interpreted as allochthonous or suspect terranes, accreted from east to west onto the passive margin of the Laurentian continent (Williams and Hatcher, 1982, 1983). The terranes are oriented subparallel to the northeast-southwest trending axis of the Appalachian Orogen, and are regionally overlain unconformably or conformably by Middle Ordovician to Upper Devonian rocks. These rocks form three distinct structural and stratigraphical zones in Gaspé: the Connecticut Valley-Gaspé Synclinorium, the Aroostook-Percé Anticlinorium, and the Chaleurs Bay Synclinorium (Bourque et al., in press) (Fig. 1-3).

1-5 The Taconic Orogeny

The Mid-Ordovician Taconic Orogeny had a profound effect upon the paleogeography of the Northern Appalachians, which affected the Silurian to Devonian depositional setting of the area. The orogeny is attributed to a collisional event between Laurentia and a volcanic island-arc along with several micro-continents collectively

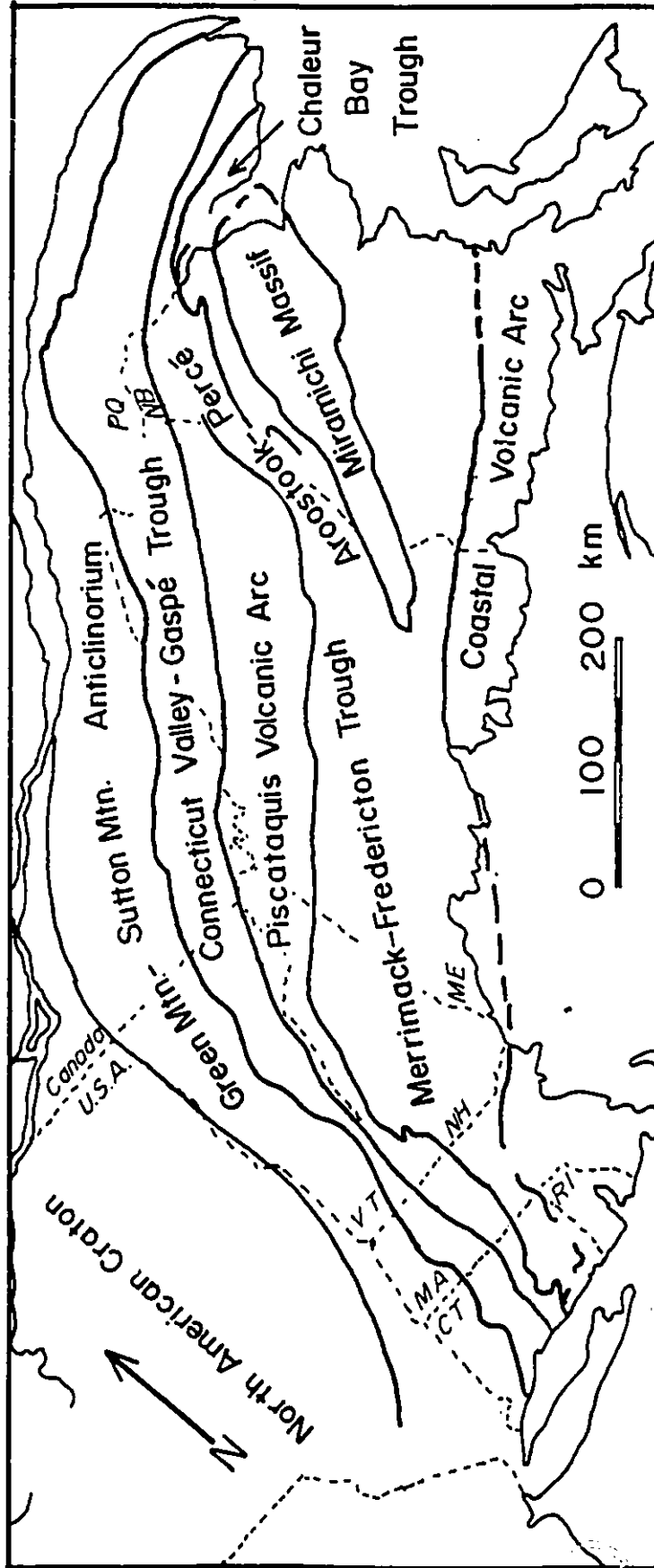


Fig. 1-3. Middle Ordovician to Upper Devonian zones of the northern Appalachian Orogen. Piscataquis Volcanic Arc merges with the Aroostook-Perce and Chaleur Bay Troughs in northern New Brunswick and Quebec (after Bradley, 1983).

referred to as the Central Mobile Belt (CMB) (Poole et al., 1970; Bird and Dewey, 1970; Schenk, 1978; Williams, 1978; Williams and Hatcher, 1982, 1983; Bradley, 1983; Van der Pluigm and van Staal, 1988; Van der Voo, 1988). The CMB was accreted onto the Laurentian margin from east to west above a southeastwards dipping subduction zone.

The northeast to southwest structural and stratigraphic trend of the Precambrian to Mid-Ordovician tectonostratigraphic zones or terranes of the Appalachian Orogen (as defined by Williams, 1978 and subsequent workers) is an artifact of the Taconic Orogeny.

1-6 Upper Ordovician to Upper Devonian Paleogeography and the Acadian Orogeny

Upper Ordovician to Upper Devonian rocks unconformably or locally conformably overlie the Taconic belts. The Upper Ordovician to Upper Devonian rocks of the Northern Appalachians can be divided into several structural belts which trend obliquely to the underlying Taconic zones (Fig. 1-3) (Bradley, 1983; Bourque et al., in press). The Green Mt.-Sutton Mt. Anticlinorium formed a land area during Late Ordovician to Late Devonian time, referred to by Boucot and Johnson (1967) as 'Appalachia' and by Rodgers (1981) as 'Taconia'. The Connecticut Valley-Gaspé Synclinorium is approximately 1200 km in length, and is composed of Mid-Ordovician to Upper Devonian rocks which overlie the pre-Mid

Ordovician Taconic belt with regional unconformity although locally the contact may be conformable (Bourque et al., in press). The Aroostook-Percé Anticlinorium is composed of Mid-Ordovician to Early Silurian rocks, forming a belt which extends from central Gaspé to Maine. The Chaleur Bay Synclinorium is composed of Mid-Ordovician to Upper Devonian rocks, and contains two inliers: the Cambrian to Ordovician Macquereau-Mictaw Inlier and the Ordovician Elmtree Inlier, that were emplaced during the Taconic Orogeny (Keppie, 1985; Fyffe and Fricker, 1987; Bourque et al., in press). The Miramichi Massif is similar in many respects to the much smaller aforementioned Inliers, and is composed of Cambrian to Lower Ordovician rocks emplaced during the Taconic Orogeny. The Miramichi Massif also formed a prominent landmass throughout Mid-Ordovician to Late Devonian time (Keppie, 1985; Fyffe and Fricker, 1987; Bourque et al., in press). The Merrimack and correlative Fredericton Troughs are composed of Silurian to Devonian deep water sediments, and represent an oceanic basin with oceanic crust which closed during Mid Ordovician to Devonian time (McKerrow and Ziegler, 1971; Osberg, 1978; Rodgers, 1981; Bradley, 1983). This oceanic body is commonly referred to as the Iapetus Ocean by various workers (ie. McKerrow and Cocks, 1977), and is believed to have separated Laurentia and its accreted outboard terrains from the Avalonian landmass. The Piscataquis volcanic arc is composed of Silurian to Lower

Devonian volcanics and interbedded sediments, and is interpreted as a subduction related arc (Osberg, 1978; Rodgers, 1981; Bradley, 1983). The Coastal volcanic arc is also interpreted as a subduction related arc which formed upon Avalonia on the opposite side of the Merrimack-Fredericton Trough.

Bourque et al., (in press) suggested that within the Gaspé area, the Connecticut Valley-Gaspé Synclinorium, Aroostook-Percé Anticlinorium, Piscataquis volcanic arc, and the Chaleur Bay Synclinorium formed a single depositional basin from Mid-Ordovician to Late Devonian time, referred to as the Gaspé Basin (Fig. 1-4). This basin extended southwestwards to connect with the Merrimack Trough in central Maine and Connecticut. To the northeast, the Gaspé Basin opened onto the Anticosti Platform, located within the Québec re-entrant. The Gaspé Basin was flanked to the northwest and to the southeast by landmasses, 'Appalachia' or 'Taconia' and the Miramichi Massif respectively (Fig. 1-4). Southeast of the Miramichi Massif, the Fredericton Trough formed part of a wide oceanic basin. Based on a compilation of the stratigraphy of the Gaspé area, Bourque et al., (in press) reconstructed the Mid-Ordovician to Late Devonian paleogeography of the Gaspé area (Fig. 1-5), as well as proposing a series of sea level changes for the basin during the same time (Fig. 1-6).

Tectonic models concerning the Late-Ordovician to Late

SILURIAN PALEOGEOGRAPHY

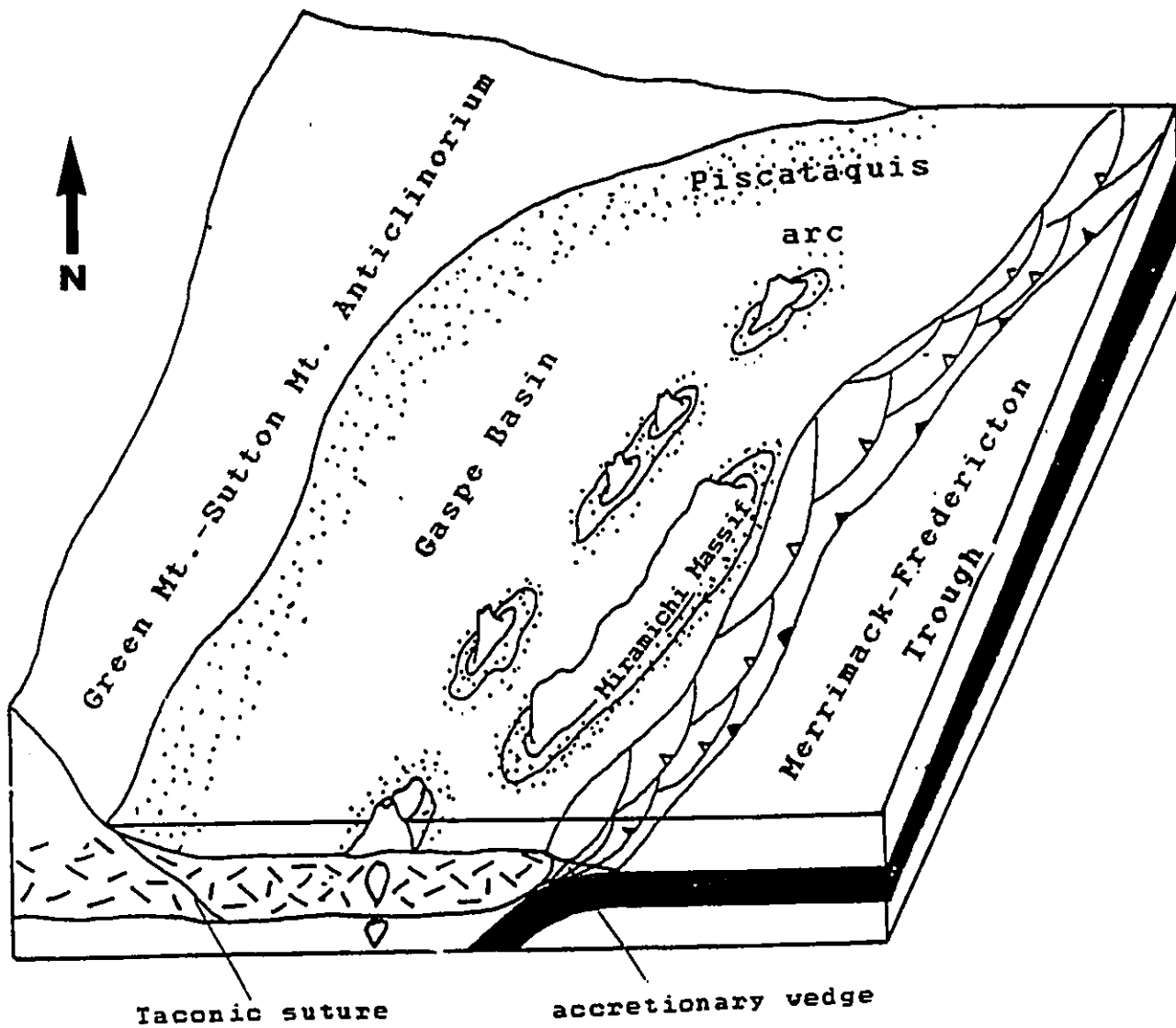
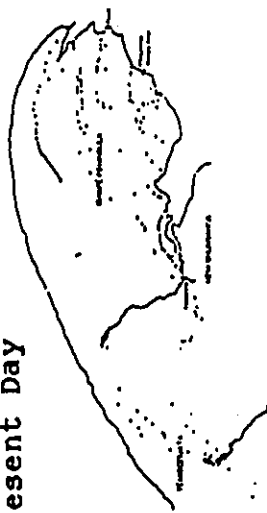
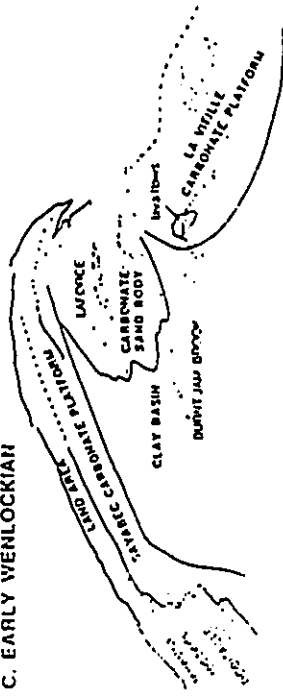


Fig. 1-4. Upper Silurian paleogeographic scenario for the northern Appalachians (after Bradley, 1983).

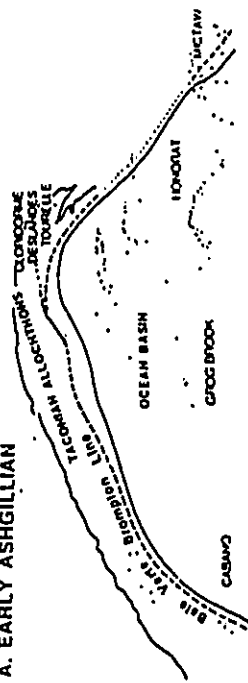
Present Day



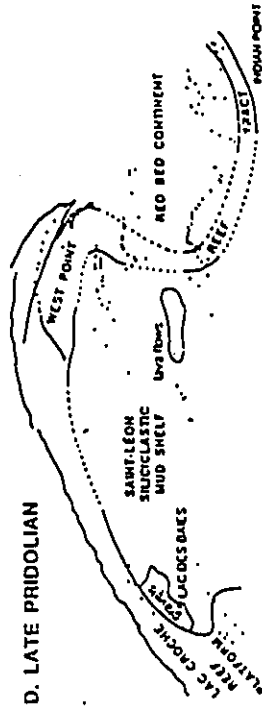
C. EARLY WENLOCKIAN



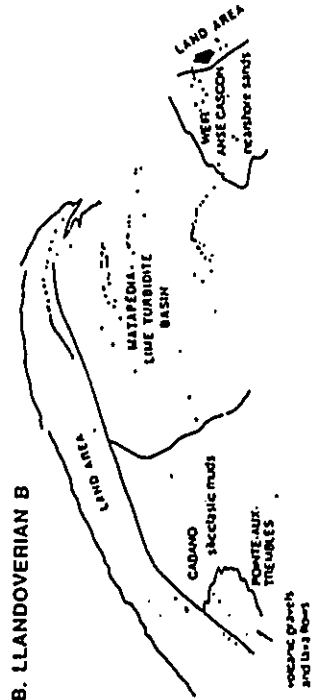
A. EARLY ASHGILLIAN



D. LATE PRIDOLIAN



B. LLANDOVERIAN B



E. LOCHKOVIAN

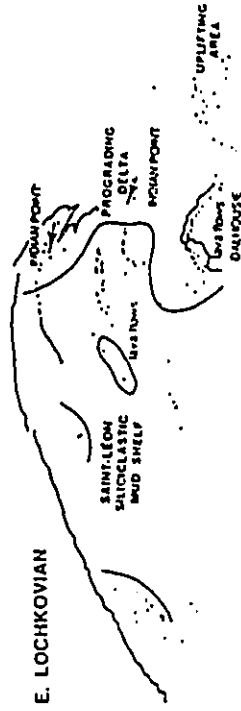


Fig. 1-5. Late Ordovician to Early Devonian paleogeographic reconstructions for the Gaspé Basin. Present day map is illustrated to exhibit the amount of dextral displacement created during the Acadian Orogeny. (After Bourque et al., 1989)

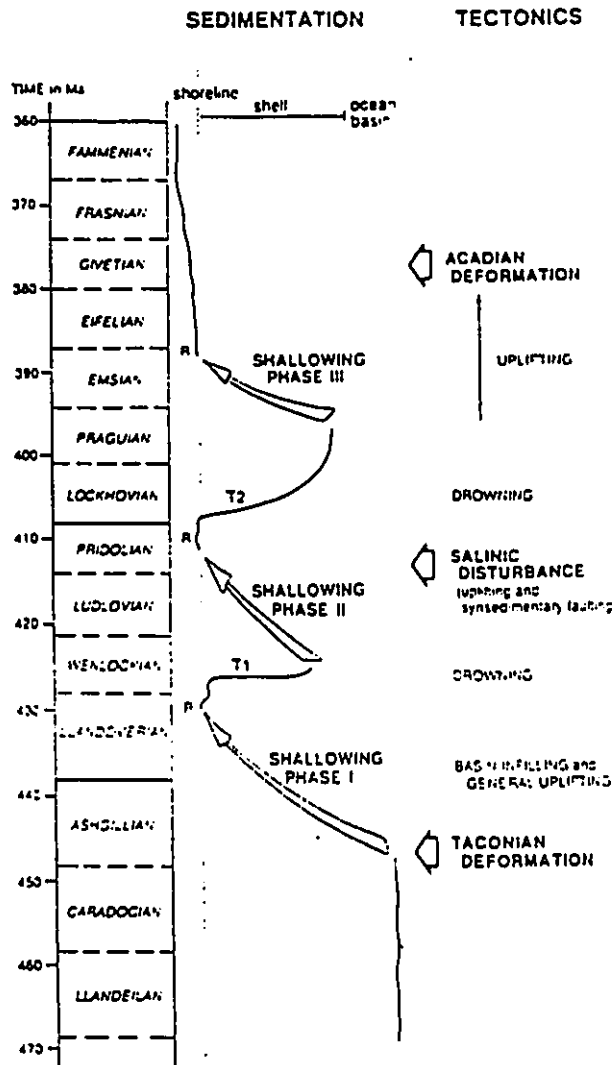


Fig. 1-6. Ordovician to Upper Devonian sequence stratigraphy for the Gaspé Basin (after Bourque et al., 1989).

Devonian of the Northern Appalachians involve some form of convergence between Laurentia and Avalonia. Controversy surrounds the nature of the convergence, with some workers arguing for mainly transcurrent motion (Williams and Hatcher, 1982,1983; Keppie, 1982, 1985; Fyffe and Fricker, 1987; Kent and Keppie, 1988; Stockmal et al., 1986; van der Pluigm and van Staal, 1988; and Bourque et al., in press) and others arguing for almost orthogonal subduction with very little transcurrent motion between the two continental blocks (Bird and Dewey, 1970; McKerrow and Ziegler, 1971; Dewey and Kidd, 1974; Howie and Barss, 1975; McKerrow and Cocks, 1977; Osberg, 1978; Rodgers, 1981; and Bradley, 1983). Most workers concern themselves only with the events immediately preceding the Late Devonian Acadian Orogeny. Few apply their respective models to Silurian and Early Devonian time.

One of the most prominent Silurian to Lower Devonian features within the Gaspé Basin is the Piscataquis volcanic arc, which was active from Silurian to Early Devonian time. The arc is composed of basaltic, andesitic, dacitic, and rhyolitic volcanics, erupted subaqueously to subaerially, with interbedded marine to nonmarine sediments. In the Gaspé area, the arc is represented by the thick volcanic piles of the Chaleur Group and the Dalhousie Group in southwestern Gaspé, and the Mont Alexandre volcanics in central Gaspé. Numerous and conflicting interpretations

concerning the tectonic affinities of the arc-volcanics have been made. Osberg (1978), Hon (1980) , Hon and Roy (1981), Rodgers (1981) and Bradley (1983) suggested that the volcanics were related to northwestwards subduction of oceanic crust of the Merrimack-Fredericton Trough. Laurent and Bélanger (1984) and Bédard (1986) interpreted identical volcanic suites within the Gaspé area as indicative of an anorogenic transpressional and tensional regime respectively. Dostal et al., (1989) suggested that the same suite was related to rifting in a transpressive regime. Rodgers (1981) identified a large accretionary wedge complex within the Merrimack Trough of northeastern Connecticut, which he suggested represented the location of the Silurian trench.

The presence of the oceanic Merrimack-Fredericton (Iapetus) Trough, coupled with flanking volcanic arcs of great lateral extent, and the occurrence of Silurian accretionary wedge complexes, seems to me to suggest that the arc was related to the northwestwards subduction of oceanic crust (Fig. 1-4). The subparallel Coastal volcanic-arc within the Avalon Terrain marks the southeast subduction margin of the Merrimack-Fredericton Trough according to Bradley (1983). The tectonic environment for the northern Appalachians during Silurian time therefore is similar to that proposed by Mckerrow and Ziegler (1971) and Bradley (1983) (Fig. 1-4), with the Gaspé Basin occupying a back-arc

setting. Back-arc basins are usually characterized by extension (Hamilton, 1988), evidence of which occurs within the Connecticut Valley-Gaspé Synclinorium. Lajoie et al., (1968) and Roy (1980) identified two localized Silurian sub-basins characterized by rapid sedimentation rates, the Lac des Baies area and the Mistigougueche sub-basin respectively. Bradley (1983) suggested that these represented small pull-apart strike-slip basins related to a tensional environment. The Late Silurian Salinic Disturbance appears to be related to the first docking event between Laurentia and another continental block. Fyffe and Frischer (1987) suggested that the event was related to the transcurrent emplacement of the Mascarene Terrain in southeastern New Brunswick. This resulted in transpression and uplift of the Miramichi Massif, which shed a coarse clastic wedge northwestwards into the Gaspé Basin (Bourque et al. in press) (Fig. 1-5 d and e, Fig. 1-6).

The docking of continental terrains such as the Mascarene may have marked an end to orthogonal northwest subduction of oceanic crust. Later docking of continental blocks such as the Avalon Terrain occurred by almost purely transcurrent motion or very oblique northwestwards subduction. The Norumbega-Fredericton Fault, which separates the Avalon Terrain from the western blocks and cuts to very deep structural levels is the most likely candidate for the transcurrent fault (Keen et al., 1986).

Paleomagnetic data indicates at least 1500 km of sinistral motion between Laurentia and Avalonia (Kent and Opdyke, 1978). The magnitude of this displacement as well as the sense of motion have been challenged by various workers (Bradley, 1983; Van der Voo, 1988).

Subaerial volcanism persisted within the Gaspé area until mid Emsian time. The abrupt cessation of volcanism preceeded the westwards progradation of a coarse clastic wedge in both southwestern and eastern Gaspé (Campbellton Formation and York River and Battery Point Formations respectively) (Fig. 1-6). This wedge was shed from an unidentified uplift to the east (Bourque et al., in press), created by compression related to the northwards emplacement of the Avalon terrain (Fig. 1-7, Fig. 1-8 b). By Mid to Late Devonian time, the Gaspé Peninsula was the site of dextral east-west directed faulting, again related to increasing pressure created by the northwards emplacement of the Avalon Terrain against the St. Lawrence Promontory (Bourque et al., in press). Cumulative shortening of up to 55 % occurred within the Gaspé region, taken up by approximately 150 km of combined dextral displacement along the Grand Pabos, Grand Riviere, and Riviere Garin Faults. This faulting resulted in the uplift of the Aroostook-Percé Anticlinorium, which effectively segregated the Gaspé Basin into an eastern Gaspé sub-basin, and a southwestern Chaleur Bay sub-basin (Fig. 1-8 c). The Chaleur Bay sub-basin is

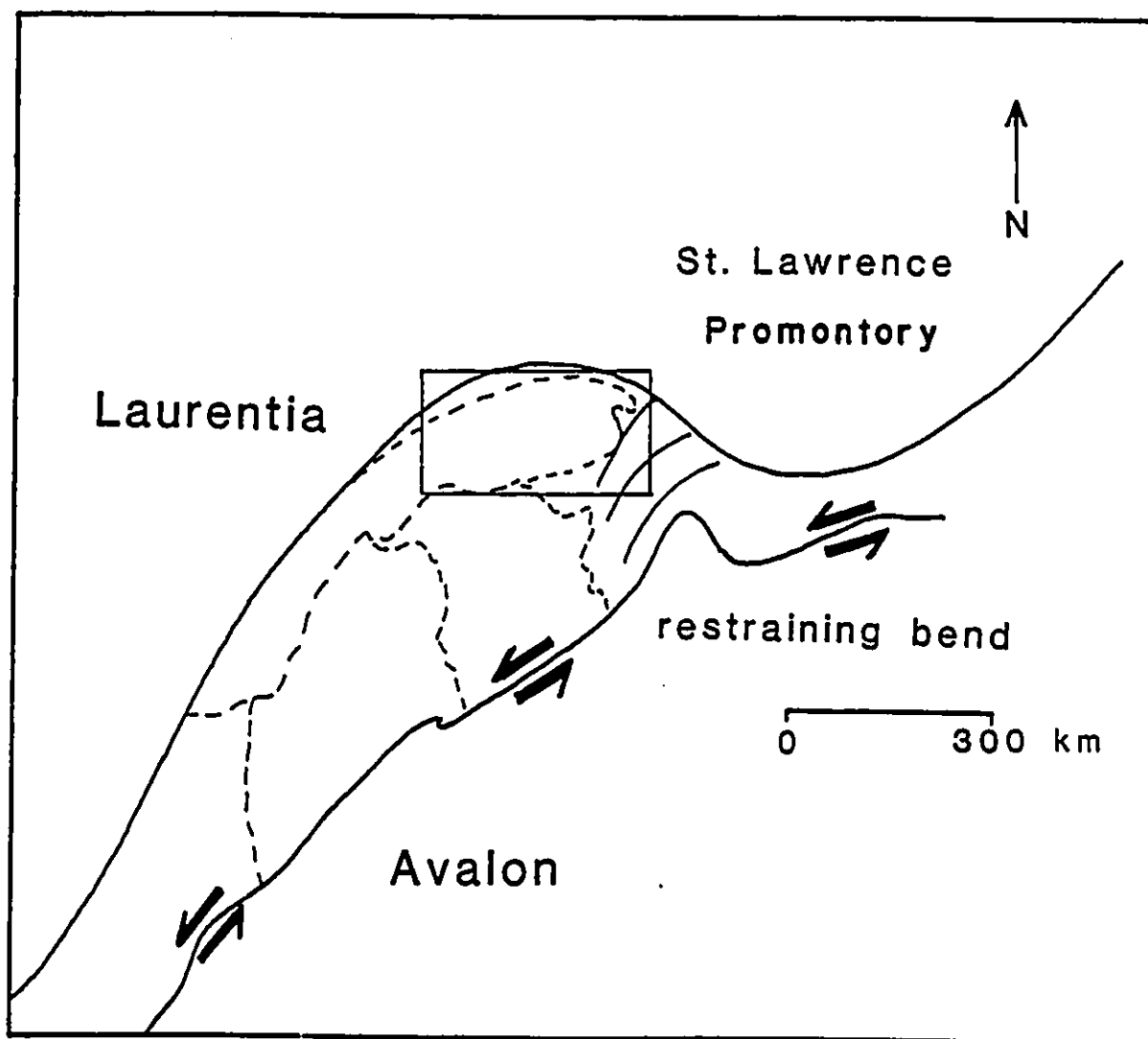


Fig. 1-7. Early to Late Devonian paleogeographic scenario in the northern Appalachian region illustrating transform margin between Laurentian and Avalonian plates. The St. Lawrence Promontory forms a prominent restraining bend, resulting in northeastwards directed compression in the Gaspé area.

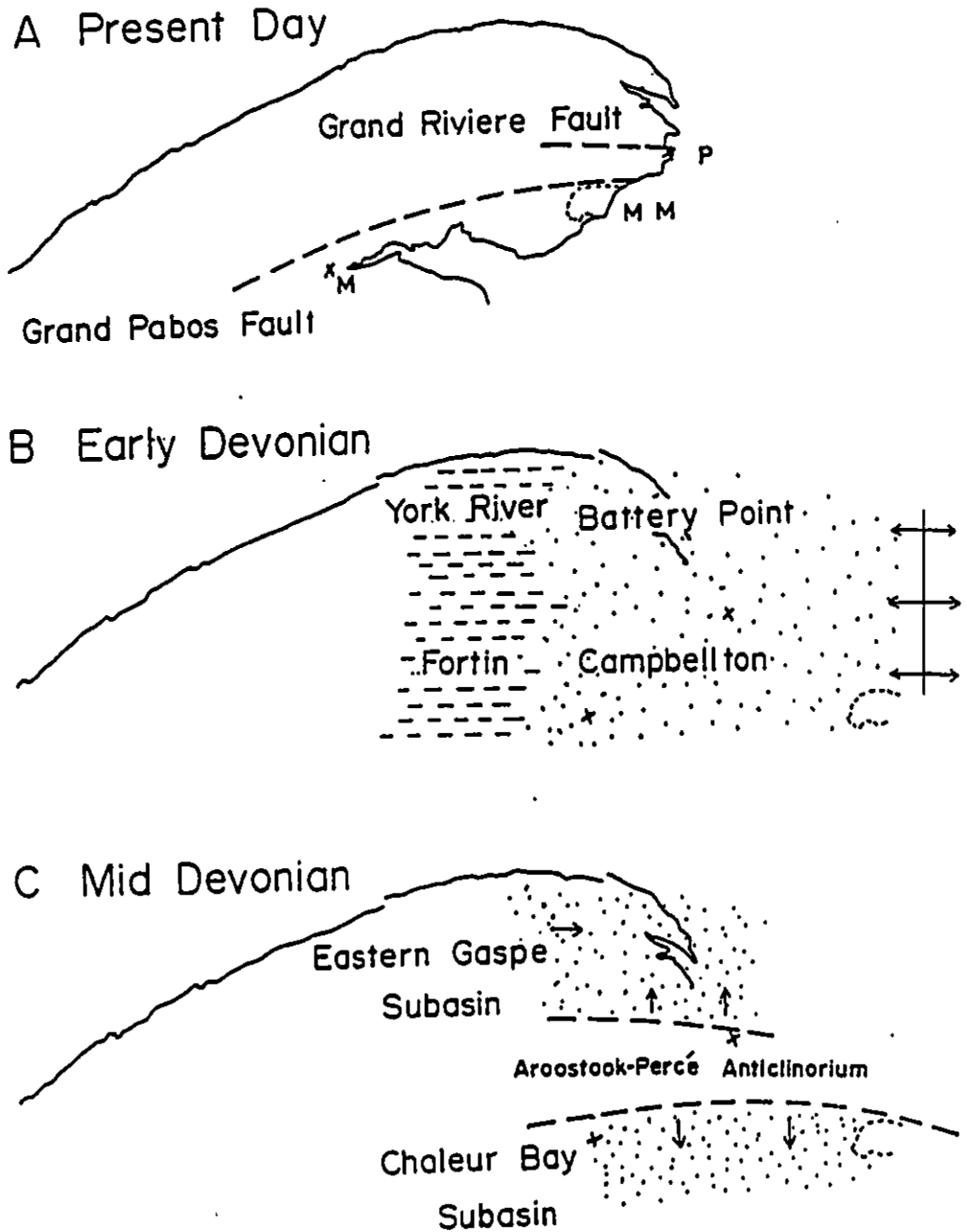


Fig. 1-8. Early to Middle Devonian paleogeographic scenarios for the Gaspé area. A) present day map illustrating the major faults, as well as Percé (P), the Maquereau-Mictaw Inlier (MM), and Matapedia (M). B) palinspastic reconstruction illustrating the westward progradation of the Battery Point / Campbellton terrestrial wedge. C) onset of dextral strike-slip faulting and uplift of the Aroostook-Percé Anticlinorium, resulting in the fragmentation of the Gaspé Basin and the creation of the eastern Gaspé and western Chaleur Bay sub-basins.

interpreted as an asymmetric half-graben by Zaitlin (1982) and Rust et al. (1989). The rising Aroostook-Perce Anticlinorium horst shed fluvial clastic wedges northwards into the eastern Gaspé sub-basin (Battery Point and Malbaie formations) and southwards into the Chaleur Bay sub-basin (Pirate Cove and Fleurant formations).

The Acadian Orogeny peaked in Late Devonian time, and is marked by a regional unconformity between the Devonian fluvial succession and the Carboniferous red-bed succession.

In summary therefore, the Acadian Orogeny is generally attributed to a collisional event between Laurentia and Avalonia, although Kent and Keppie (1988) suggested that Baltica may have also been involved. Whether this collision involved a large subductive component, as advocated by McKerrow and Ziegler (1971), Osberg (1978), Rodgers (1981), and Bradley (1983) (among others), or predominantly transcurrent motion, as advocated by Hatcher and Williams (1982, 1983), Keppie (1985), Fyffe and Fricker (1987), and Keppie and Kent (1988), is at this point controversial. The absence of Acadian aged thrust sheets, ophiolites, and paired high grade metamorphic belts and other features usually associated with orthogonal to oblique collisional events within the northern Appalachian region tends to support the latter hypothesis involving a significant component of transcurrent motion. However, the validity of the paleomagnetic evidence, which indicates up to 1500 km of

sinistral displacement has been challenged by numerous authors (Bradley, 1983; Van der Voo, 1988). In addition, there is general disagreement concerning the sense of motion, with Hamner (1981), Keppie (1985), Kent and Keppie (1988) suggesting that motion was sinistral and Keppie (1982), Mawer and White (1987), and Kusky et al., (1987) suggesting dextral displacement. This hinders wholehearted acceptance of the concept of large transcurrent motion between the Laurentian and Avalonian plates. One potentially valuable clue which might resolve this dilemma would involve a detailed geochemical and isotopic study of the Lower Devonian volcanics of the Piscataquis belt. The three most recent studies concerning the Gaspésian portion of this belt (Laurent and Bélanger, 1984; Bédard, 1986; and Dostal et al., 1989) have all been contradictory.

1-7 Objectives of the Thesis

The main objective of this thesis is a reconstruction of the depositional environments represented by the Emsian Pointe la Nim and Campbellton formations. This will allow for a reconstruction of the Emsian paleogeography of the western Chaleur Bay area. A comparison with the known Emsian and Eifelian paleogeography of the eastern Gaspé region can then be made to delineate the evolution of the Gaspé Basin during the early phases of the Acadian orogeny. This will shed light onto the nature and timing of tectonic events

which affected the Gaspé Basin during Early and Middle Devonian time.

In addition, the sedimentology of fluvial systems within volcanic regimes (Pointe la Nim Formation), and syndeformational regimes (Campbellton Formation) will be investigated.

1-8 Laboratory Methods

Twenty-eight sections through the Pointe la Nim and Campbellton formations were measured and carefully described from road cuts shoreline exposure. Fifty-five thin sections were prepared in order to determine the lithology of the facies scheme used in this study. In addition, pollen samples were collected from muddy and silty facies at various stratigraphic levels within the Pointe la Nim and Campbellton formations and submitted to Colin McGregor of the GSC in Ottawa for analysis. Biostratigraphic information derived from this analysis were used to erect the Emsian stratigraphy proposed in this study for the western Chaleur Bay area. Total organic carbon content from mudstone facies within the Atholville Member were prepared in order to measure thermal maturation above the discordance with the underlying Pointe la Nim Formation. The results of this analysis are pending investigation by Dr. R. Hesse at McGill University.

CHAPTER 2

POINTE LA NIM FORMATION

2-1 Introduction
















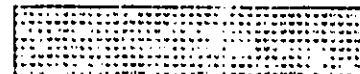



The Pointe la Nim Formation incorporates the uppermost part of the Dalhousie Group, and is composed of interbedded andesitic to rhyolitic volcanics and clastics. McGregor (1989a) dated the Pointe la Nim Formation as mid Emsian (annulatus-sextantii Zone) (Appendix 1), making the uppermost portion of the Dalhousie Group significantly younger than the early Pragian age assigned by Boucot and Johnson (1967) and Bourque and Lachambre (1980).

2-2 Location

Deposits of the Pointe la Nim Formation are exposed primarily on the New Brunswick side of Chaleur Bay. Sections T (Fig. 2-1), U (Fig. 2-2), and V (Fig. 2-3), composed of boulder conglomerates and minor shales interbedded with andesitic volcanics, are exposed along road cuts on either side of Chaleur Bay (Fig. 2-4). Sections Q (Fig. 2-5) and R (Fig. 2-6) are much thicker sections located along the shoreline between Dalhousie Junction and Pointe la Nim, N.B. (Fig. 2-4). This locale is selected as the type section of the Pointe la Nim Formation.

The Pointe la Nim Formation may be divided into two sequences: a proximal sequence (Sections T, U, and V), and a

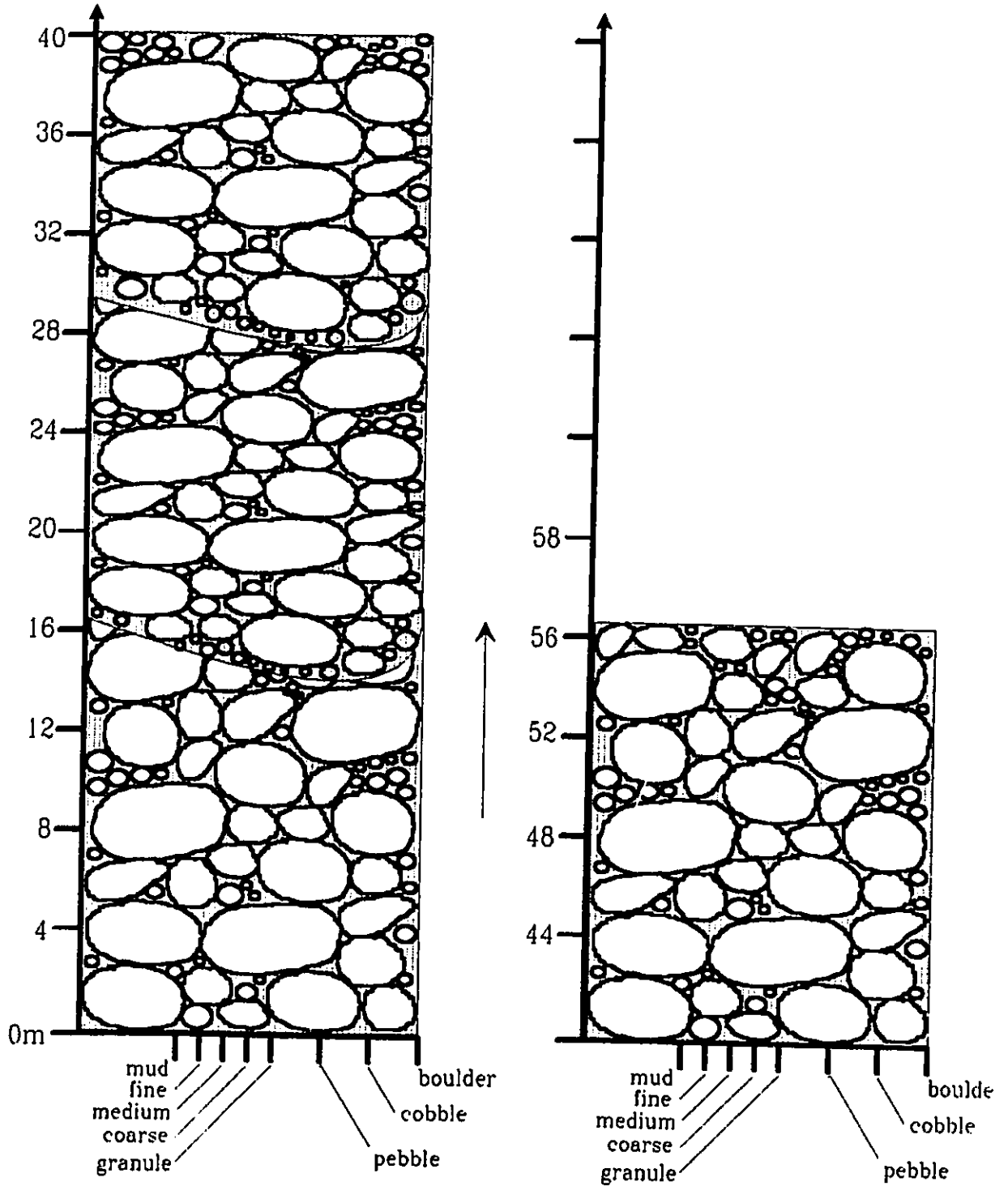
FACIES LEGEND

	Fm		St with pebbles
	Fl (rippled)		Gms
	Fl		Gl
	Sm		Gp
	rooted Sm		Gm oligomictic
	Sh\l		Gm polymictic
	Sr		imbrication
	Sp		sill or volcanics
	Sp with pebbles		
	St		
	coal		

Facies letters after those of Miall (1977, 1978) and Rust (1978). For example, facies Sr corresponds to current rippled sandstone exhibiting cross lamination. Facies Gm exhibiting dark colored clasts (above) represents oligomictic conglomerate. Facies Gm (above) exhibiting uncolored clasts represents polymictic facies Gm.

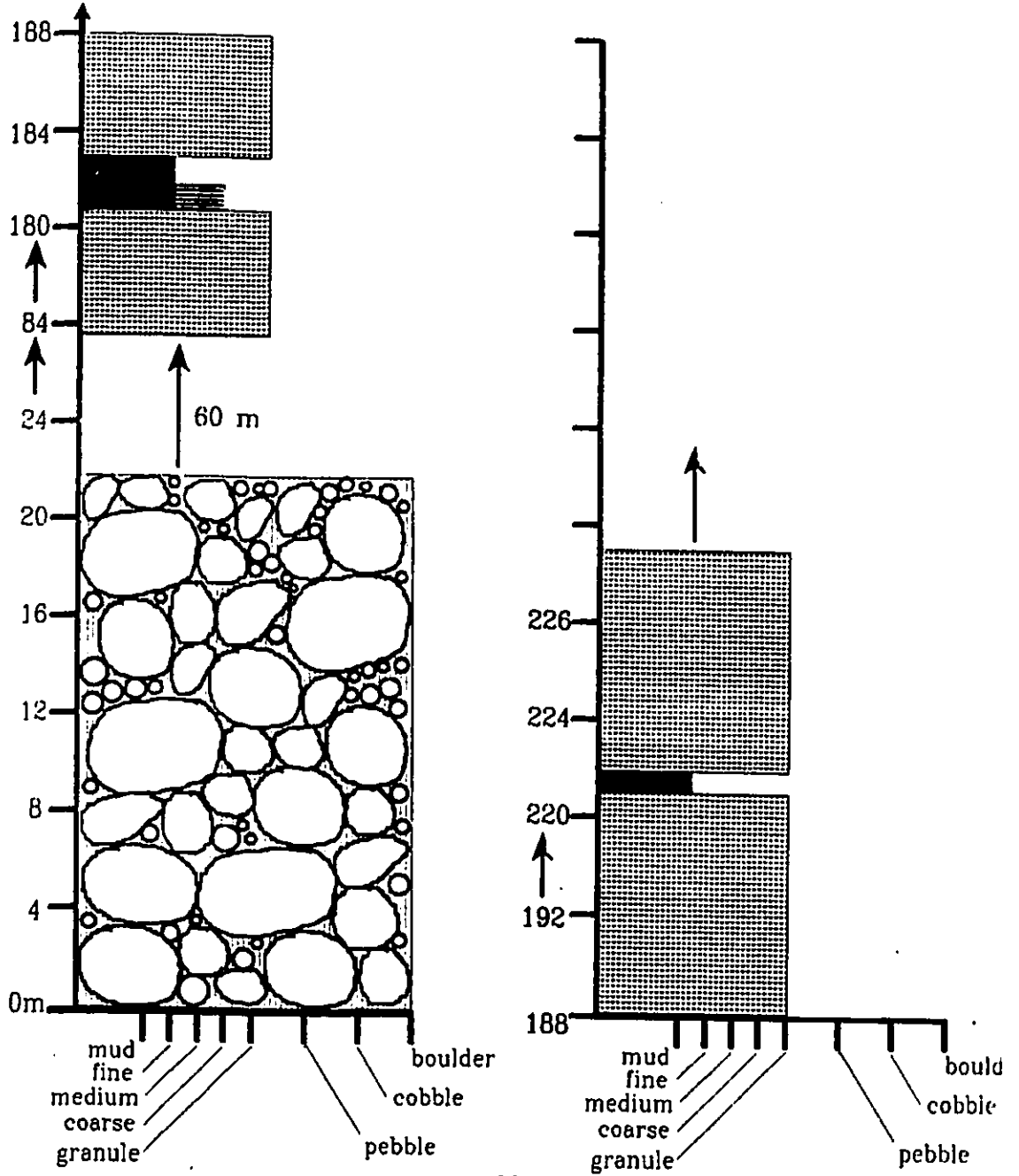
SECTION T

Fig. 2-1



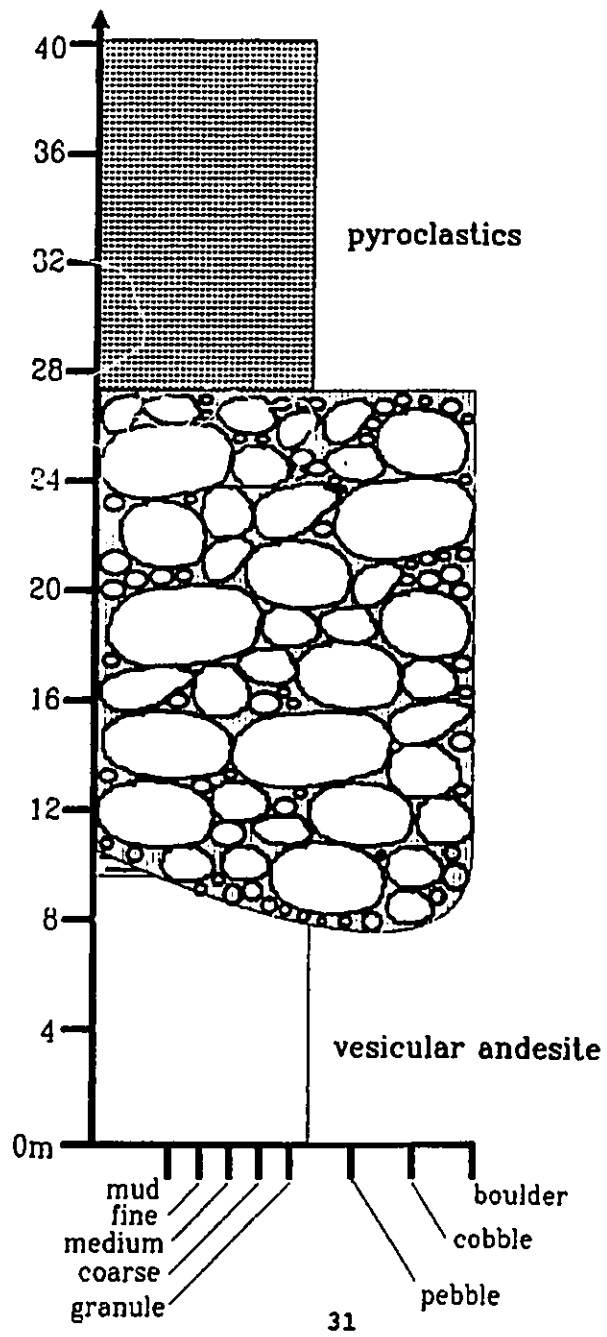
SECTION U

Fig. 2-2



SECTION

V Fig. 2-3



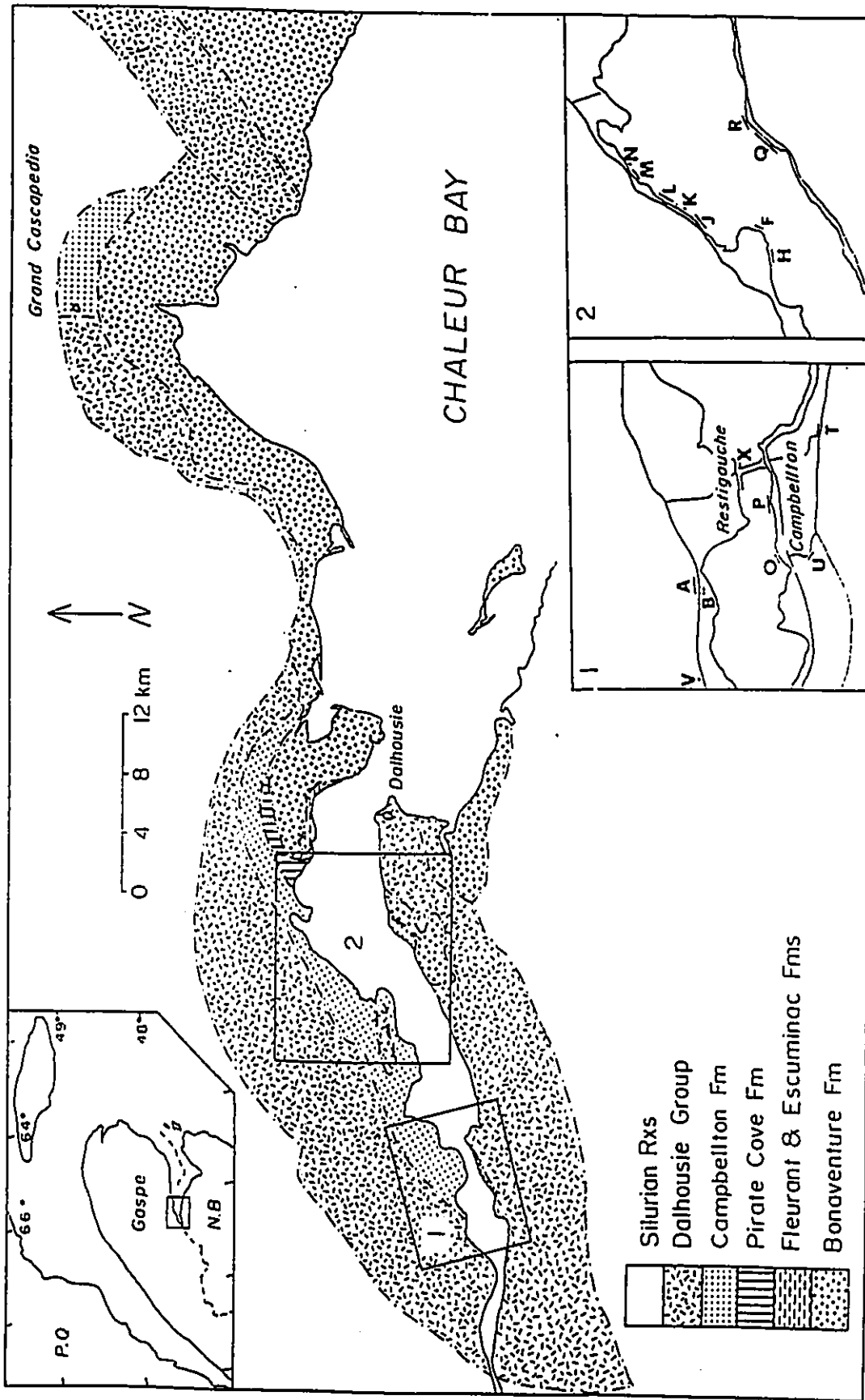
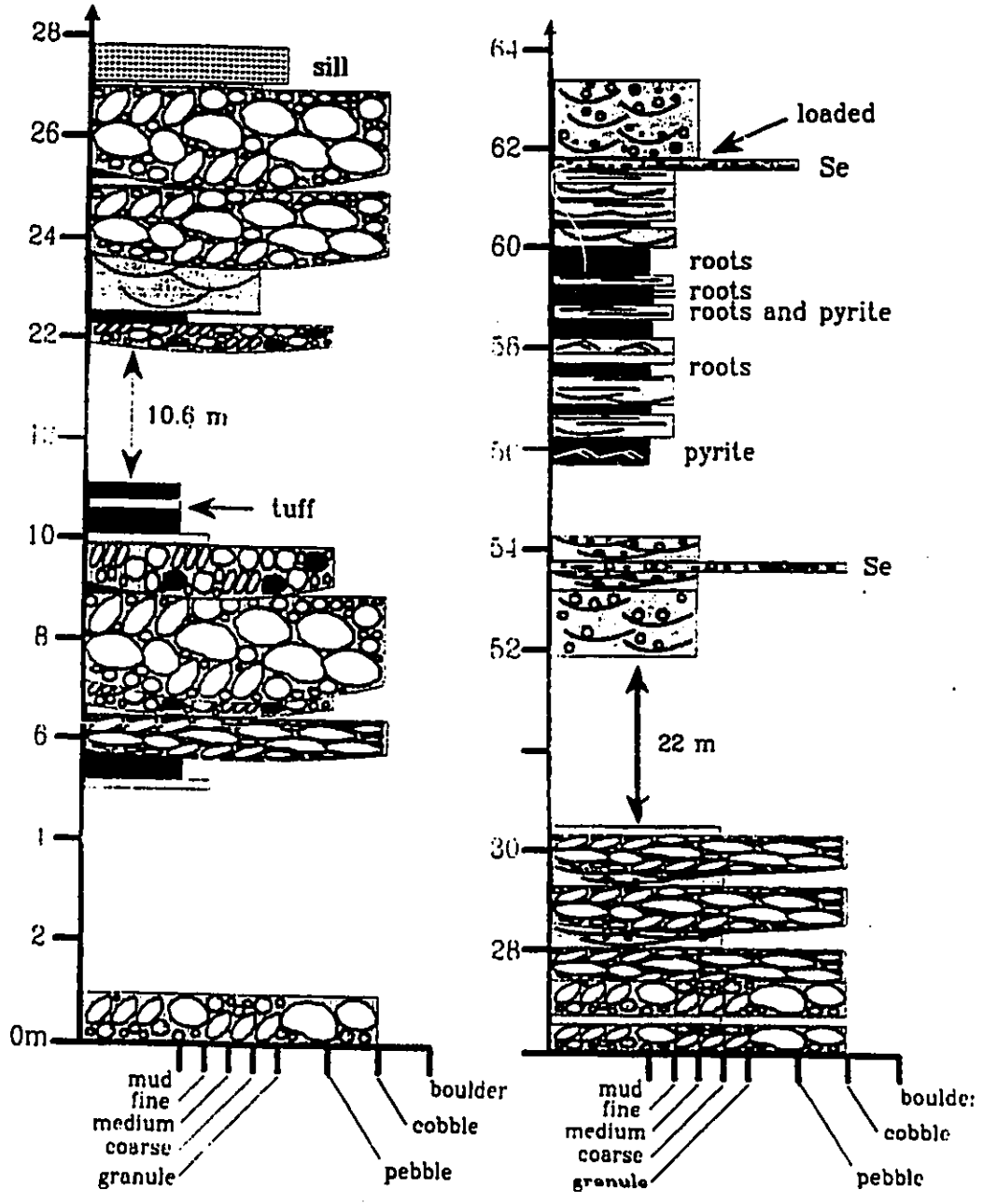


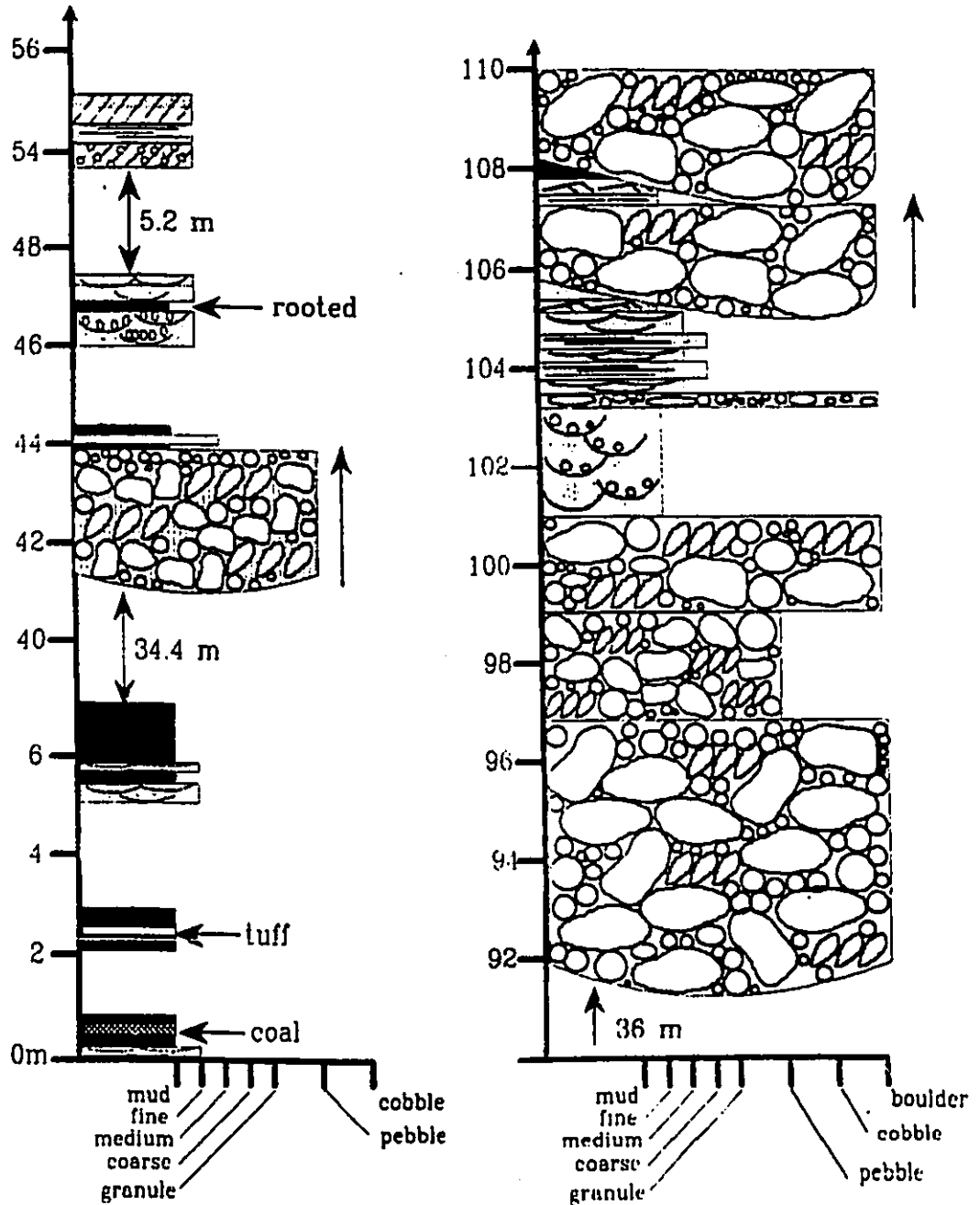
Fig. 2-4 Location of sections in the western Chaleur Bay study area.

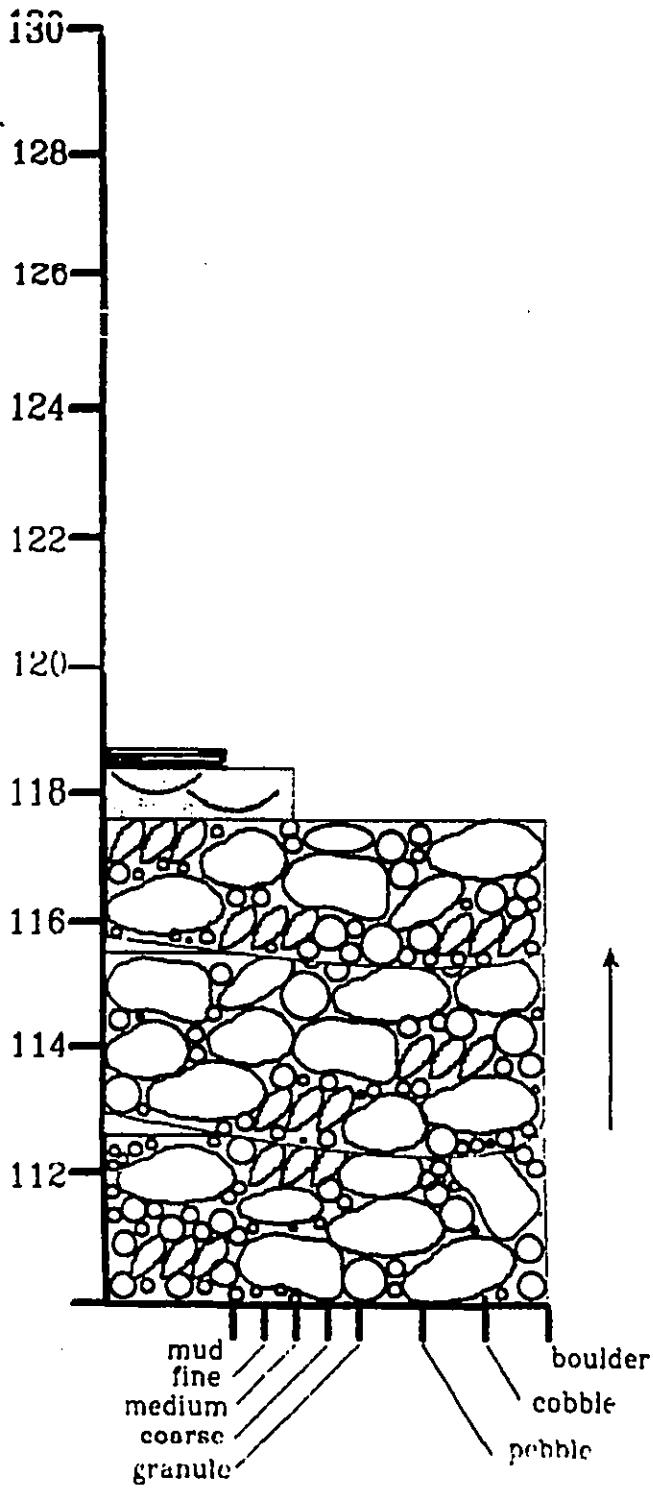
SECTION Q

Fig. 2-5



SECTION R Fig. 2-6





distal sequence (Sections Q and R) (Fig. 2-4). By virtue of their facies assemblages, these two sequences are considered correlative.

2-3 Facies

Facies were designated according to the lithofacies code of Miall (1977, 1978) and Rust (1978).

Gm...dark green coloured cobble to boulder conglomerate, massive, composed exclusively of volcanic lithic fragments, predominantly green porphyritic andesites and red rhyolites. Clasts are moderately to well rounded, poorly to very poorly sorted, exhibiting a strong imbricate fabric. Units exhibit sharp, erosional bases, and may be normally graded.

St...dark green trough cross-bedded sandstone, fine to coarse grained, well to poorly sorted. Lithology exclusively lithic arenite, composed entirely of volcanic fragments. Abundant plant fragments scattered throughout. Solitary or grouped cosets, exhibiting sharp, erosional bases. This facies may contain scattered pebbles or cobbles along foresets or along basal scoured surfaces, sets up to 40 cm.

Sp...planar cross-bedded, lithology and other features same as above, sets up to 25 cm.

Sr...asymmetric current rippled, siltstone to fine grained sandstone, with abundant plant fragments scattered throughout. Lithology that of a lithic greywacke. May be

rooted.

Sh/1...parallel laminated, horizontally to low-angle stratified fine to medium grained lithic arenite, exhibiting current lineations. May be rooted.

Fl...laminated muddy siltstone to mudstone, black to dark purple coloured. Very well indurated, with brittle fracture. Contains abundant plant fragments and is commonly rooted. May contain blebs of botryoidal pyrite along bedding planes.

Fm...massive muddy siltstone to shale, black to dark purple in colour. Very well indurated, with brittle fracture. Pervasively rooted, with rhizomes up to 5 cm in length.

2-4 Description of Sections

2-4-1 Sections T, U, and V

Each of the sections are composed of a single sequence of facies Gm, up to 56 m thick (section T, Fig. 2-1), which are interbedded with volcanic or volcanoclastic rocks.

Each sequence is underlain by volcanics, and exhibits an abrupt scoured base with only minor erosional relief. Facies Gm is composed of framework-supported, poorly indurated very poorly sorted boulder conglomerate. Clasts are up to 3 m in diameter (Figs. 2-7, 2-8), averaging 80-90 cm, and are subangular to predominantly well rounded. The clasts are composed exclusively of volcanics, primarily green porphyritic andesites, with lesser grey porphyries,

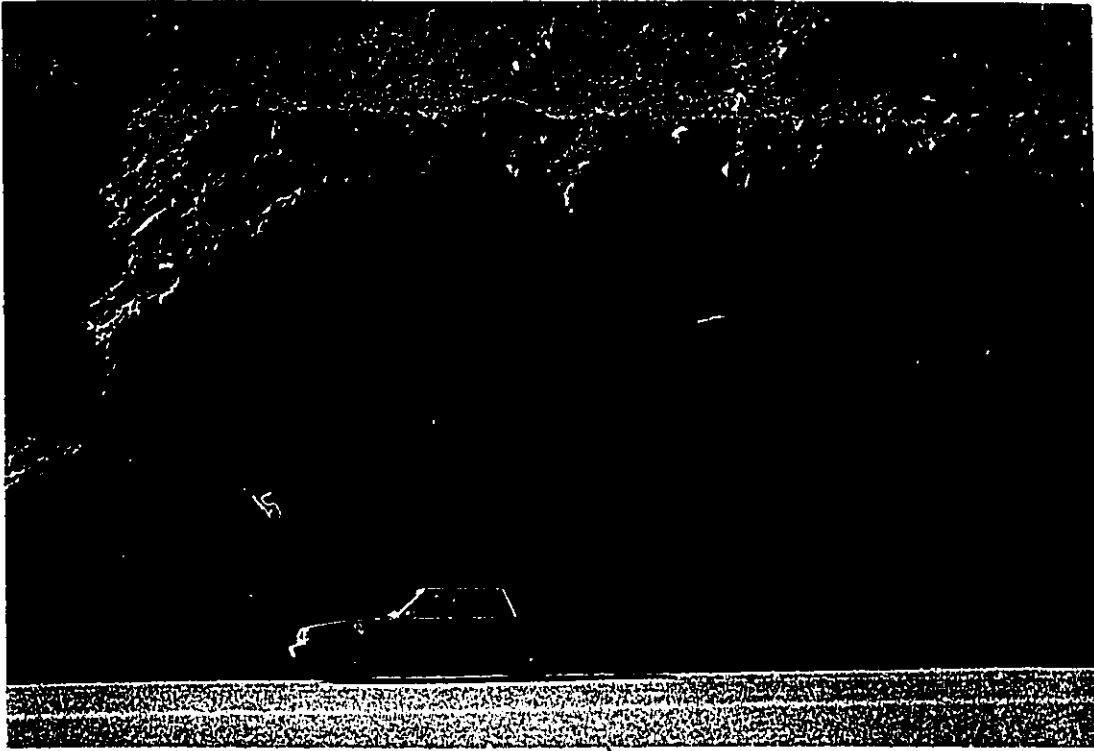


Fig. 2-7. Rounded andesitic clasts up to 3 m in diameter (arrow) within facies Gm at section V. Unit is abruptly overlain by pyroclastics which dip steeply to the right (east).



Fig. 2-8. Facies Gm at section T composed of poorly-sorted, well-rounded volcanic clasts. Beds dip steeply to left (west). Stick 1 m.

red porphyritic rhyolites, and light coloured poorly indurated pyroclastics. Clasts exhibit an imbricate fabric, with the a-axes oriented perpendicular to the dip of the ab plane. The matrix is very poorly sorted, fine grained to pebbly, and composed exclusively of lithic volcanic fragments. Facies Gm is massive, and exhibits very crude normal coarse-tail grading forming poorly defined units up to 17 m thick at section T.

The conglomeratic sequences are abruptly overlain by volcanics (sections T and U, Figs. 2-1, 2-2), or volcanoclastics (section V, Fig. 2-3). Thin units of poorly indurated shale occur interbedded within the green porphyritic andesitic succession 160 m above the boulder conglomerate sequence at Section U (Fig. 2-2).

2-4-1-1 Paleocurrent Trends

Paleocurrent trends from clast imbrication of facies Gm at section T indicate northeastward flow (Table 2-1, Fig. 2-9).

2-4-2 Sections Q and R

Deposits at these sections are the distal equivalent of those at sections T, U, and V. The interbedded volcanics so prominent within sections T, U, and V are absent at Sections Q and R (Figs. 2-5, 2-6). The latter two sections form a succession approximately 150 m thick (Fig. 2-10), composed

TABLE 2-1
 Paleocurrent Trends from the
 Pointe la Nim Formation

Station	Vector Mean	# of clasts measured	Vector Magnitude
T1	37.6	44	0.71
T3	52.7	26	0.87
R	97.1	44	0.81
Q	33.8	34	0.70

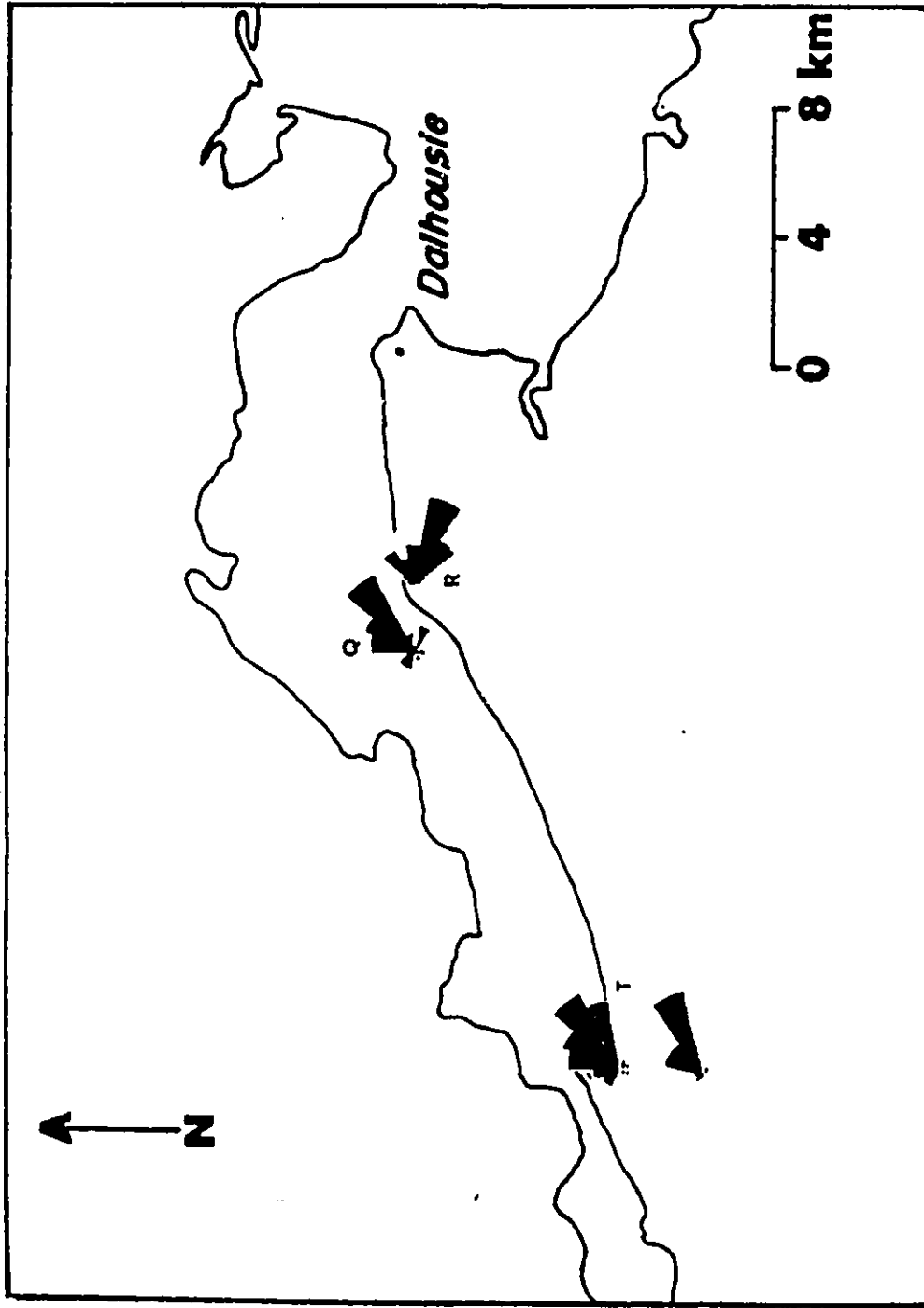


Fig. 2-9 Paleoflow trends from the Pointe la Nim Formation derived from imbrication in facies Gm.

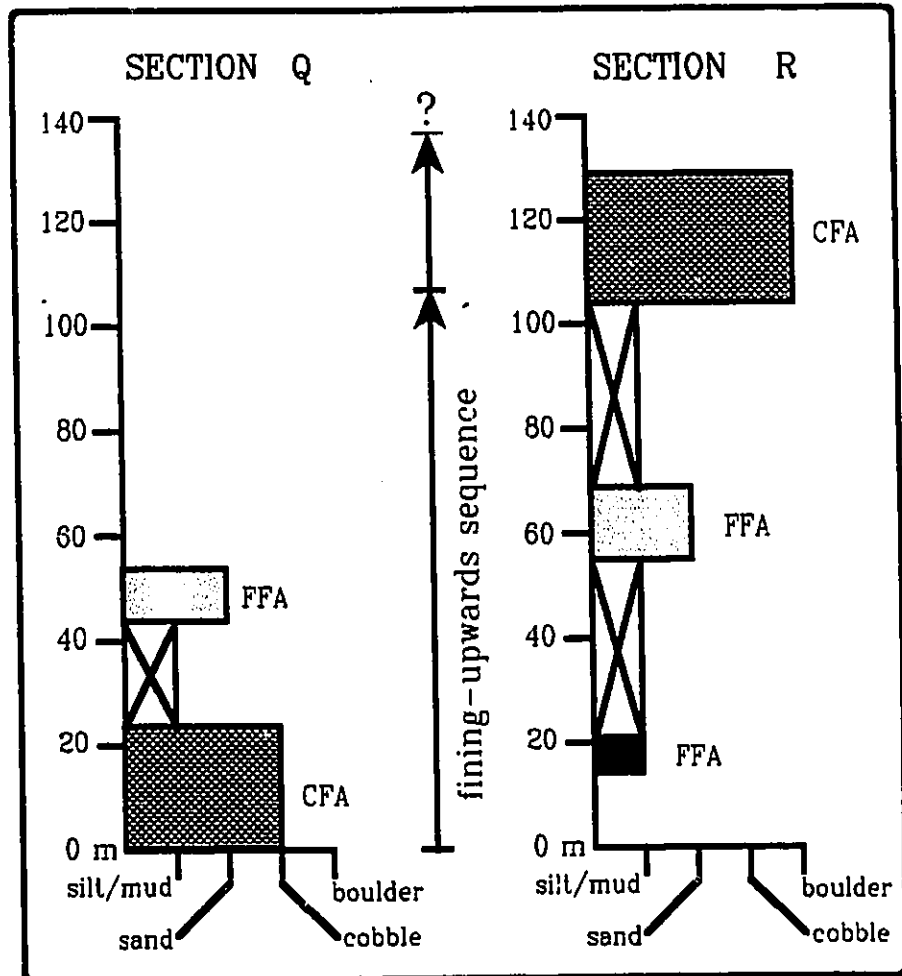


Fig. 2-10. Large-scale fining-upwards sequences within the Pointe la Nim Formation, sections Q and R. CFA- conglomeratic facies assemblage, FFA- fine grained facies assemblage.

of two facies assemblages: a conglomeratic facies assemblage (CFA) and a fine-grained facies assemblage (FFA). The succession exhibits a large-scale fining upwards megasequence 120 m thick, the lower portion composed of conglomeratic facies assemblages and the upper portion composed of the fine grained facies assemblages (Fig. 2-10).

2-4-2-1 Conglomeratic Facies Assemblage

This assemblage is composed of facies Gm interbedded with finer grained facies St, Sr, Sh/1, Fl and Fm, which are generally arranged in fining upwards sequences up to 7 m thick (Fig. 2-6).

Facies Gm is composed of dark green, framework-supported, poorly sorted cobble and boulder conglomerate forming poorly indurated units up to 5 m thick (Section R, Fig. 2-6 and 11). Clasts are subrounded to well-rounded, and are composed exclusively of volcanics, predominantly light to dark green porphyritic andesite with lesser dark green aphanitic andesites and light red coloured rhyolites. Clasts exhibit a strong imbricate fabric, with a-axes perpendicular to the dip of the ab plane. A few large boulder-sized clasts exhibit sand shadows on their lee-sides, composed of crudely laminated, poorly sorted sandstone (Fig. 2-12). Many clasts exhibit red iron-stained poorly indurated rims. The matrix is composed of poorly sorted fine to medium grained sandstone composed exclusively



Fig. 2-11. Typical facies Gm within the conglomeratic facies assemblage at section R. Beds dipping to left (east). Stick 1 m.

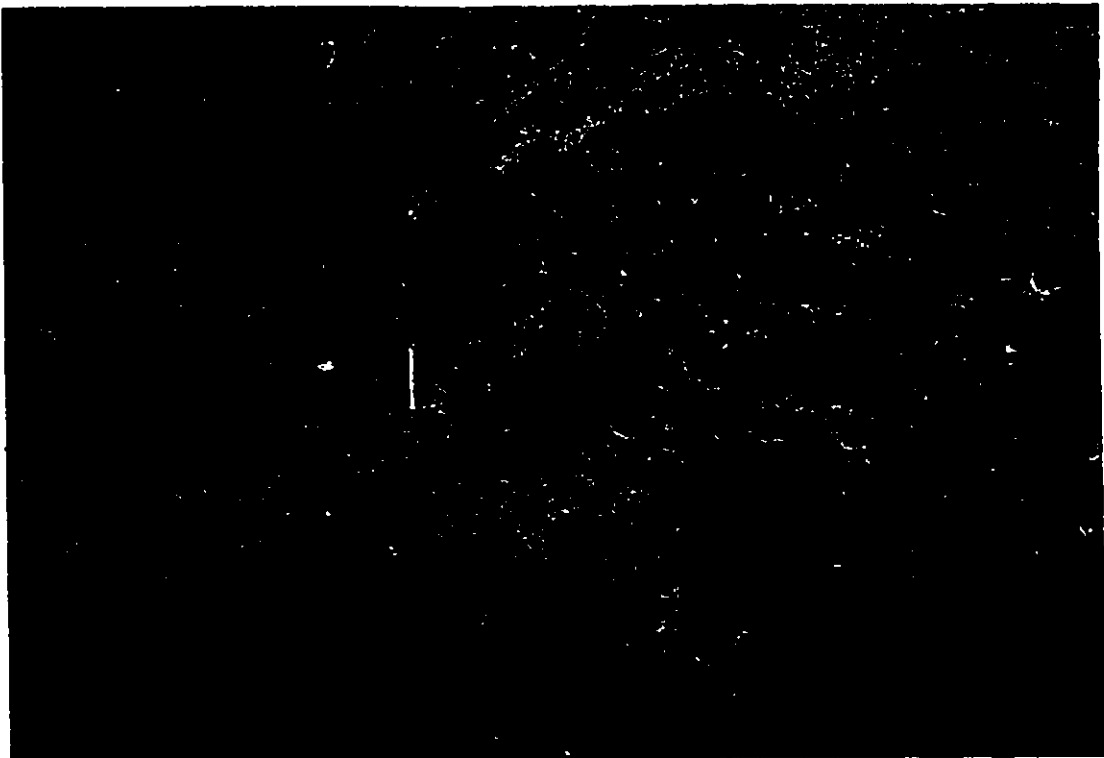


Fig. 2-12. Crudely laminated poorly-sorted sand shadow in the lee side of a well rounded andesite boulder, section R. Flow towards bottom left (northeast). Hammer 30 cm.

of subangular to subrounded lithic fragments, at places containing a significant proportion of green copper-rich cement. Facies Gm forms massive, lenticular units exhibiting normal, coarse-tail grading (Fig. 2-13), with individual units separated by thin interbedded units of facies Sm. Units of facies Gm exhibit a deeply scoured basal contact with up to 2 m of erosional relief, with the lower portion of the unit containing abundant muddy intraclasts up to 40 cm in length, as well as detached layers of facies Fm/F1 peeled upwards into the base. Units of facies Gm are abruptly overlain by finer grained facies, or are erosively overlain by another unit of facies Gm, forming stacked sequences up to 9 m thick (section R, Fig. 2-6).

Units of facies Gm are abruptly overlain either by units composed of interbedded fine grained facies St, Sh/1, Sr, Fm and F1 arranged in a fining upwards sequence (Fig. 2-14) up to 2 m thick, or by units of interbedded facies Sr, F1, and Fm.

The former begins with a unit of sandy facies St or Sh/1. Fine to medium grained pebbly facies St occurs as isolated sets up to 40 cm thick, or rarely as grouped cosets up to 2.2 m thick (section R, Fig. 2-6). The sandy facies grades upwards into finer grained facies F1/Fm with interbedded facies Sr. These facies form very dark coloured, well indurated lenticular units up to 2.5 m thick.

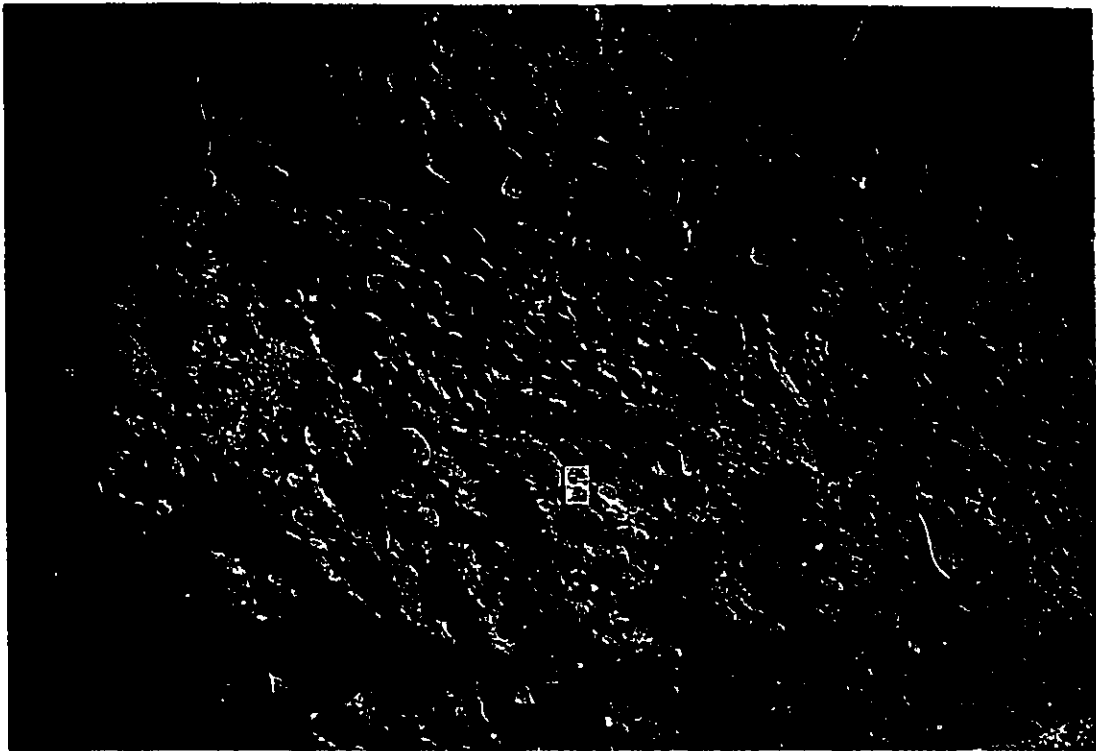


Fig. 2-13. Crude, normal coarse-tail grading within a unit of facies Gm in the conglomeratic facies assemblage at section R. Unit is capped by a lens of poorly sorted cross-stratified sandstone. Book 18 cm.

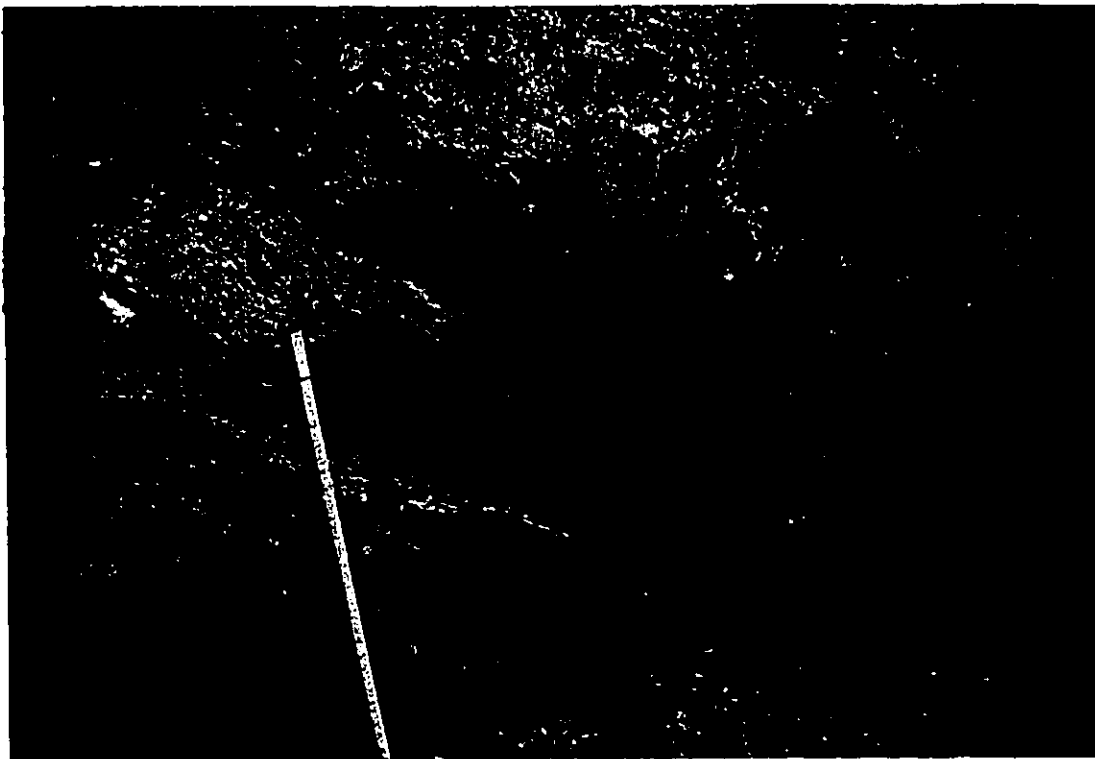


Fig. 2-14. Interbedded sequence composed of facies St, Sr, and F1 within the conglomeratic facies assemblage at section R. Note the two buff coloured tuffs interbedded near the top of the sequence. 10 cm divisions on pogo stick.

Within one such unit at section Q (Fig. 2-5), a very thin, pale light coloured unit of tuff 2 cm thick was observed. Facies Fl, Fm, and Sr do not exhibit any features typical of pedogenic processes, such as roots and caliche, or of subaerial exposure, such as mudcracks or rainprints. The interbedded fine grained units form fining upwards sequences up to 1.3 m thick (section Q, Fig. 2-5), and are erosively overlain by facies Gm.

In a few cases, thick units of facies Gm are abruptly overlain by facies Fl, Fm and Sr, forming thin highly lenticular units 10-20 cm thick. These facies likewise do not exhibit any pedogenic products or features indicative of subaerial exposure. The conglomeratic facies assemblage forms two thick sequences, one 23 m in thickness at the base of Section Q, the other 24.5 m in thickness at the top of Section R (Fig. 2-10). The assemblage at Section Q is composed primarily of cobble conglomerate, whereas that at Section R is composed primarily of boulder conglomerate.

2-4-2-2 Fine Grained Facies Assemblage

This facies assemblage is composed of thinly interbedded facies St, Sp, Sh/l, Sr, Fl, and Fm forming small-scale fining upwards sequences at Section Q (Fig. 2-5) and sequences composed of thickly interbedded sequences of silty argillaceous facies or sandy facies as at Section R (Fig. 2-6).

The thinly interbedded facies form small-scale fining upwards sequences up to 60 cm thick, beginning with sandy facies St or Sp, exhibiting a scoured base, overlain by finer grained silty and muddy facies Sr, Fl, and Fm (as in Section Q, Fig. 2-5). Fine to medium grained facies St and Sp occur as solitary small-scale sets, containing scattered pebble sized muddy intraclasts and lesser extraformational pebbles along foresets and scours. Small plant fragments as well as limb-shaped fragments of Prototaxites logani up to 2.5 m in length occur within these facies (Fig. 2-15). A pervasively rooted, pod-shaped muddy intraclast 40 cm in length was found within the lower portion of a unit of fine grained facies Sp (Fig. 2-16). Units of facies St and Sp are overlain gradationally by thinly interbedded facies Sr and muddy siltstone facies Fl and Fm (Fig. 2-17). Facies Fm exhibits rhizomes up to 8 cm in length. This facies is light grey to pink coloured, and exhibits a high thermal alteration index (McGregor, 1989a).

Units of facies Fl and Fm are up to 60 cm thick, forming thickly interbedded sequences composed primarily of facies Fl, Fm, and Sr with minor sandy facies St and Sp, as at the base of Section R (Fig. 2-6). This particular sequence contains a bed of coal 5 cm thick (Fig. 2-18). In addition, thin beds of pale, light coloured clayey tuffs occur interbedded within these sequences.

Rarely, thick units of facies St occur interbedded

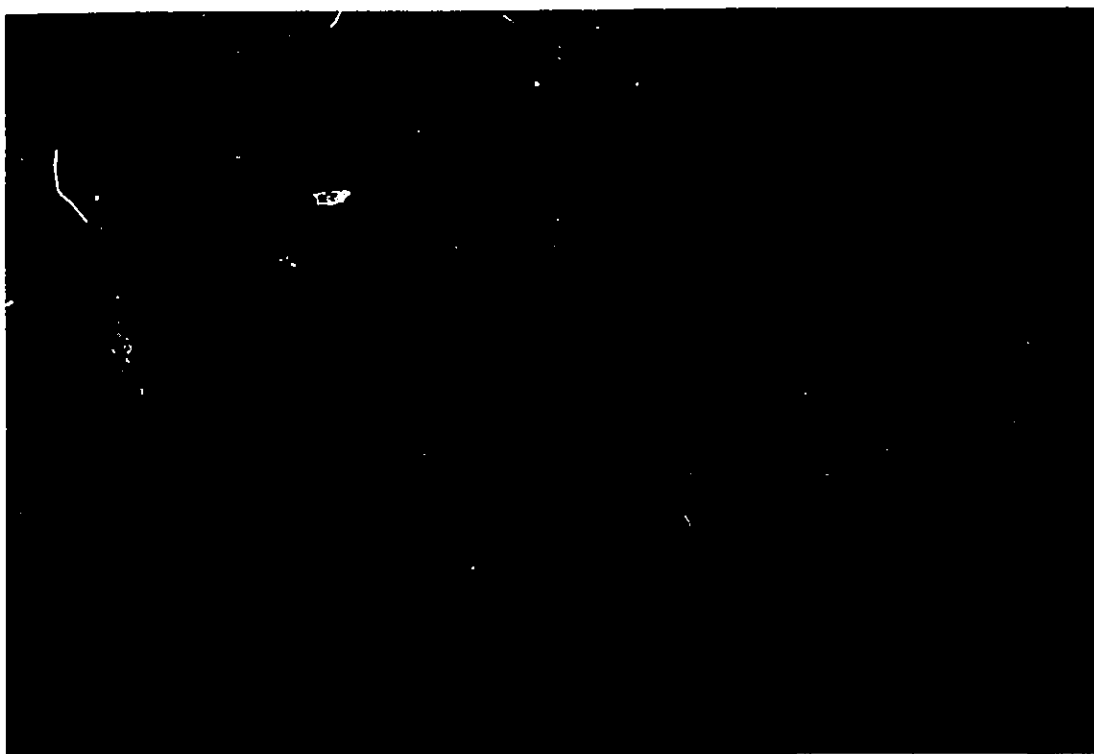


Fig. 2-15. Mould of a limb-shaped fragment of Prototaxites logani on bedding plane within the fine grained facies assemblage at section Q. Stick 1 m.



Fig. 2-16. Bedding plane view of a pod shaped root mat within the FFA at section Q. Note the filamentous rhizomes along the right side of the mat. Lense cap 6 cm.



Fig. 2-17. Sharply interbedded facies Sr (light grey) and facies F1 and Fm (purplish-pink) within the FFA at section Q. Pencil 15 cm long.

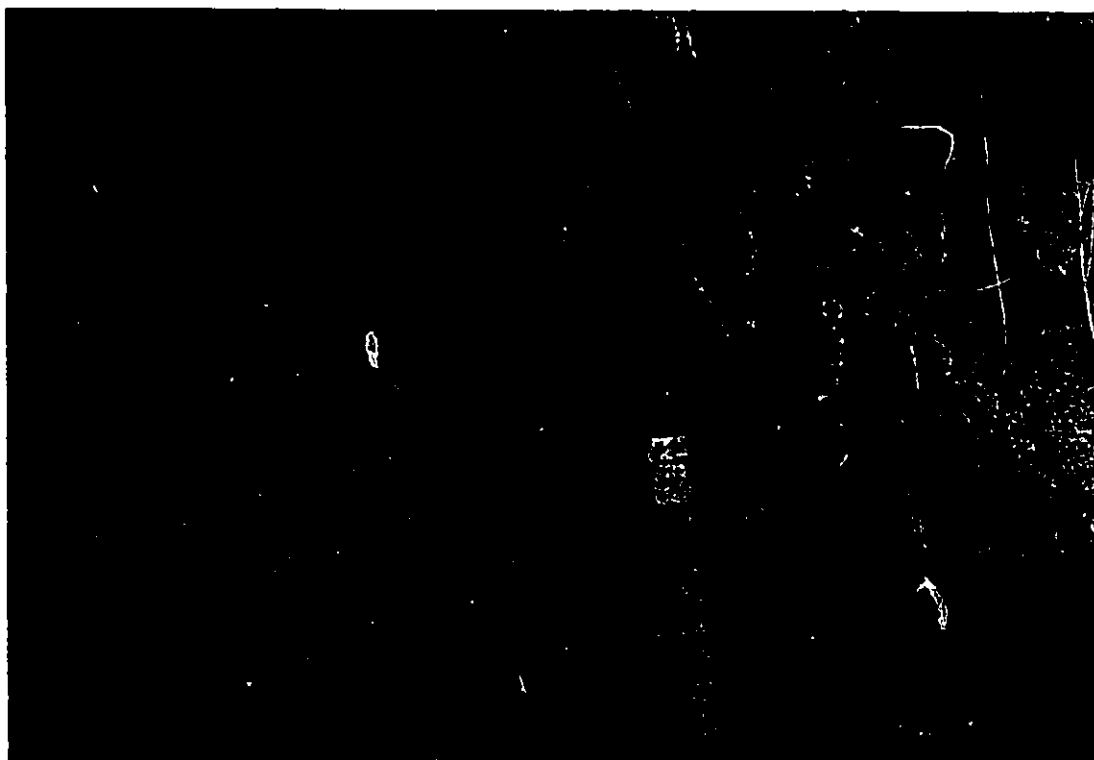


Fig. 2-18. 5 cm thick unit of very low grade coal interbedded within facies Fm at section R. Hammer 30 cm long.

within the fine grained facies assemblage, as at the top of section Q (Fig. 2-5). Facies St occurs as sets up to 40 cm thick, which form units composed of grouped cosets up to 1.5 m thick (Fig. 2-19). These units exhibit a strongly channelized basal contact, with erosional relief up to 1.2 m. Abundant extra- and intraformational pebble and cobble sized clasts occur along foresets and scours. The thick unit of facies St at the top of section Q fines upwards, with sets decreasing in thickness upwards. The emerald green colour of the unit is due to a very high copper content within the matrix.

2-4-2-3 Paleocurrent Trends

Paleocurrent trends from clast imbrication within facies Gm indicates northeastward to eastward flow (Table 2-1, Fig. 2-9).

2-5 Interpretation

2-5-1 Sections T, U, and V

The conglomeratic sequences at Sections T, U, and V exhibit features typical of water laid deposits. These include a clast-supported framework, a strong imbricate fabric with a-axis transverse to flow, and the well rounded nature of the clasts, indicative of abrasion during subaqueous transport. The poorly-sorted nature of the matrix is indicative of rapid deposition (Smith, 1987).

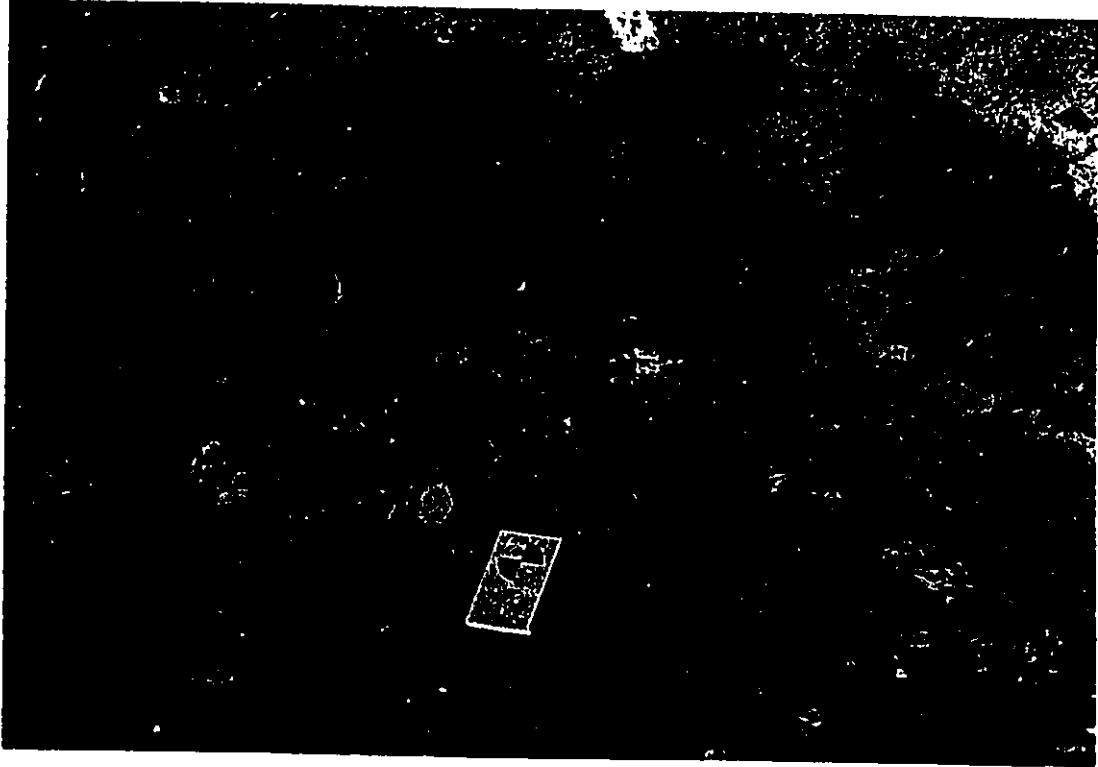


Fig. 2-19. Poorly sorted facies St exhibiting deep basal scour overlain by a pebbly lag at section Q. Dark green colour due to weathering of the malachite cement. Book 18 cm.

Similar conglomeratic sequences have been described from Cenozoic synvolcanic sequences of the western United States (Smith, 1987; Walton, 1986; and Walton and Palmer, 1988). Smith (1987, 1988) described conglomeratic sequences interbedded with debris flow deposits from the Cenozoic of the Cascade Mountains of Washington. The conglomerates are interpreted as the deposits of cohesionless debris flow or hyperconcentrated flood-flow deposits (Smith, 1987, 1988). Walton and Palmer (1988) describe several types of conglomeratic sequences they refer to as lahars from the Mount Dutton Formation of Utah. Lahars and hyperconcentrated flood flows are characterized by a high sediment load (20-70 % by weight), with clasts held in suspension by a combination of dispersive grain pressure and turbulence. The flows are created by the dilution of cohesive debris flows (mudflows) or pyroclastic flows which occurs when the flows encounter an established drainage network. These flows deposit characteristic sequences of conglomerates and sandstones, which are usually interbedded with the deposits of cohesive debris flows. The conglomeratic facies is massive, clast supported, very poorly sorted, normally or inverse to normally graded, and exhibits sharp depositional contacts with other genetically similar units (Smith, 1987, 1988; Walton, 1986; Walton and Palmer, 1988).

The boulder conglomerates at sections T, U, and V are

similar to those discussed above. They differ however in a few significant respects. In hyperconcentrated flood-flow deposits, the a-axis is observed to be perpendicular to flow only for large cobble and boulder sized clasts, whereas pebble sized clasts exhibit a-axes oriented parallel to flow (Smith, 1987, 1988). This is a result of the larger clasts being deposited from traction, while smaller pebble sized clasts are carried in suspension and deposited very rapidly. The very strong imbricate fabric with the a-axis perpendicular to flow is found within a much wider range of clasts sizes (pebble to boulder) within the conglomerates of the Pointe la Nim Formation, indicating deposition from traction, rather than the finer component being deposited from suspension. The absence of interbedded debris flow deposits indicates that sequences within the Pointe la Nim Formation lie more towards the streamflow end of the depositional spectrum.

The conglomeratic facies of sections T, U, and V therefore was deposited within a proximal braidplain environment or within the proximal reaches of a highly energetic braided river. The massive nature of the facies is indicative of deposition upon longitudinal bars (Rust, 1978; Miall, 1977). The absence of interbedded finer grained facies within the conglomeratic sequences of Sections T, U, and V reflects the short duration of the waning flow period following peak flood, with both pebble and cobble fractions

deposited simultaneously, as reflected by the very poor sorting of the matrix. As discharge quickly waned, no finer grained sediment was deposited.

The conglomeratic sequences at Sections T, U, and V are similar to the Scott type model of Miall (1978) and the GII model of Rust (1978), both of which are indicative of distal alluvial fan environments. The absence of associated debris flow or lahar deposits at Sections T, U, and V however argues against deposition upon an alluvial fan. The presence of rounded clasts up to 3 m in diameter reflects the high energy of the fluvial system as well as depositional sites relatively proximal to source. It is rather unlikely that clasts of this size could have been transported an appreciable distance in an unconfined sheetflood. Instead, it is likely that the flow was confined by valley walls, which would have increased the rate of discharge and the carrying capacity of the river, resulting in a much coarser bedload. The conglomeratic successions at sections T, U, and V were deposited within narrow valleys or at the mouths of valleys upon the lower flanks of an active volcano of considerable relief. Sugarloaf Mountain is the neck of a volcano which was active in Early Devonian time (Alcock, 1935), and it was upon the flanks of this volcano that the conglomeratic sequences were deposited.

2-5-2 Sections Q and R

The finer grained nature of the sediments as well as the absence of interbedded extrusive volcanics indicates that the sequences at these localities represent a relatively more distal depositional environment relative to the deposits of sections T, U, and V. The presence of sills and thin tuffs within the sequence indicates some volcanic activity during deposition.

The conglomeratic facies assemblage represents the deposits of a gravelly braidplain environment. Facies Gm was deposited as longitudinal barforms within a low sinuosity channelized system. Rust (1978) suggested that these bedforms undergo active migration up or downstream during initial waning flood stage, and that during high stage, the barforms are in equilibrium with flow. Shallow flow prevented the development of angle of repose slipfaces, and hence the development of cross bedded facies Gt and Gp. The overlying finer grained sandy facies represents deposition within the channel during continued waning flow. The absence of roots and other pedogenic features indicates either that these areas were not subaerially exposed for very long periods of time, or, if soils formed, they were reworked by the following flood event. The exclusively volcanic composition of the clasts, coupled with the northeastward direction of transport, indicates a provenance from the volcanic field to the south and

southwest. Flood events may have been triggered by volcanic-related events, such as the bursting of dammed lakes, or by heavy rainfall on the higher slopes of the volcanoes, which acted as orthographic barriers.

The conglomeratic facies assemblage is similar to the Donjek model of Miall (1978) and the GII model of Rust (1978). The coarse nature of the deposits suggests rather energetic depositional conditions, similar to the proximal reaches of the modern Donjek and Kicking Horse Rivers (Rust, 1974; Hein and Walker, 1978). The pronounced scours at the base of units of facies Gm indicates channelized flow, rather than sheetfloods which are typical of alluvial fan environments (Steel, 1974; Rust, 1984).

The fine-grained facies assemblage (FFA) represents deposition on a low energy floodplain characterized by highly sinuous sandy fluvial systems and large tracts of overbank. At section Q (Fig.2-5), the FFA is composed of thinly interbedded facies St, Sh/l, Fl and Fm interbedded with much rarer thick units of facies St. The thick units of facies St are interpreted as the deposits of the active channel tract. Facies St represents the deposits of sinuous-crested megaripples that migrated downstream within the deeper tracts of the channel, which were at least 1.8 m deep (the maximum thickness of the unit). The thinly interbedded facies are arranged in fining upwards sequences less than 80 cm thick, beginning with a unit of facies St or

Sh/1 followed by facies Fm and Fl. These are interpreted as vertical accretion deposits within abandoned channels. The presence of roots within these sequences indicates that these areas were stable enough to support vegetation.

The FFA is similar to the D1 cyclothems in the Old Red succession of Britain (Steel, 1974). These cyclothems are composed of thin units of channelized facies St interpreted as channel-fill, overlain by relatively thicker sequences of finer grained facies interpreted as overbank deposits. The thinly interbedded finer grained facies within the FFA are also similar to overbank deposits within the floodplain sequences of the Devonian Hornelen Basin of Norway (Steel and Aasheim, 1978). These sequences are composed of thinly bedded fine grained sandstones, siltstones and mudstones arranged in sharp based fining upwards sequences 10's of cm's thick. The absence of caliche within the overbank deposits of Section Q may reflect high sedimentation rates, or a humid climatic setting characterized by a high water table (Rust, 1981).

The presence of fine grained overbank deposits has a stabilizing effect on the channel system (Schumm, 1968), which tends to increase channel sinuosity (Steel, 1974; Jackson, 1978). The FFA therefore represents the deposits of a high sinuosity fluvial system with wide expanses of overbank areas.

At section R, the FFA forming the lower portion of the

succession is composed primarily of silty mudstones, massive to planar and cross laminated, with thinly interbedded coal and tuffs. This sequence is interpreted as a vertical accretion deposit within a very low energy depositional environment, similar to the overbank deposits of meandering fluvial systems (Puigdefabregas and van Vleit, 1978; and Vondra and Burggarf 1978). The thin clay bed is interpreted as an airfall tuff, and is indicative of periods of active volcanism to the south.

The upper portion of the FFA at section R (above 41 m) may be the poorly preserved deposits of a sandy braided fluvial system, as opposed to the high sinuosity fluvial system represented by the lower portion of the FFA at this locale. The thick unit of facies Gm within the sequence indicates that the fluvial system was probably braided. This fluvial system is unrelated to the overbank sequence 34 m below.

2-6 Summary and Conclusions

The Pointe la Nim Formation represents the deposits of a drainage system within an active volcanic range (Fig. 2-20). Sugarloaf Mountain south of Campbellton and Dalhousie Mountain southwest of Dalhousie were both interpreted as volcanic stocks by Alcock (1935), active from Late Silurian to Early Devonian (Emsian) time. The preponderance of Lower Devonian volcanics within the Chaleur Bay area indicates the

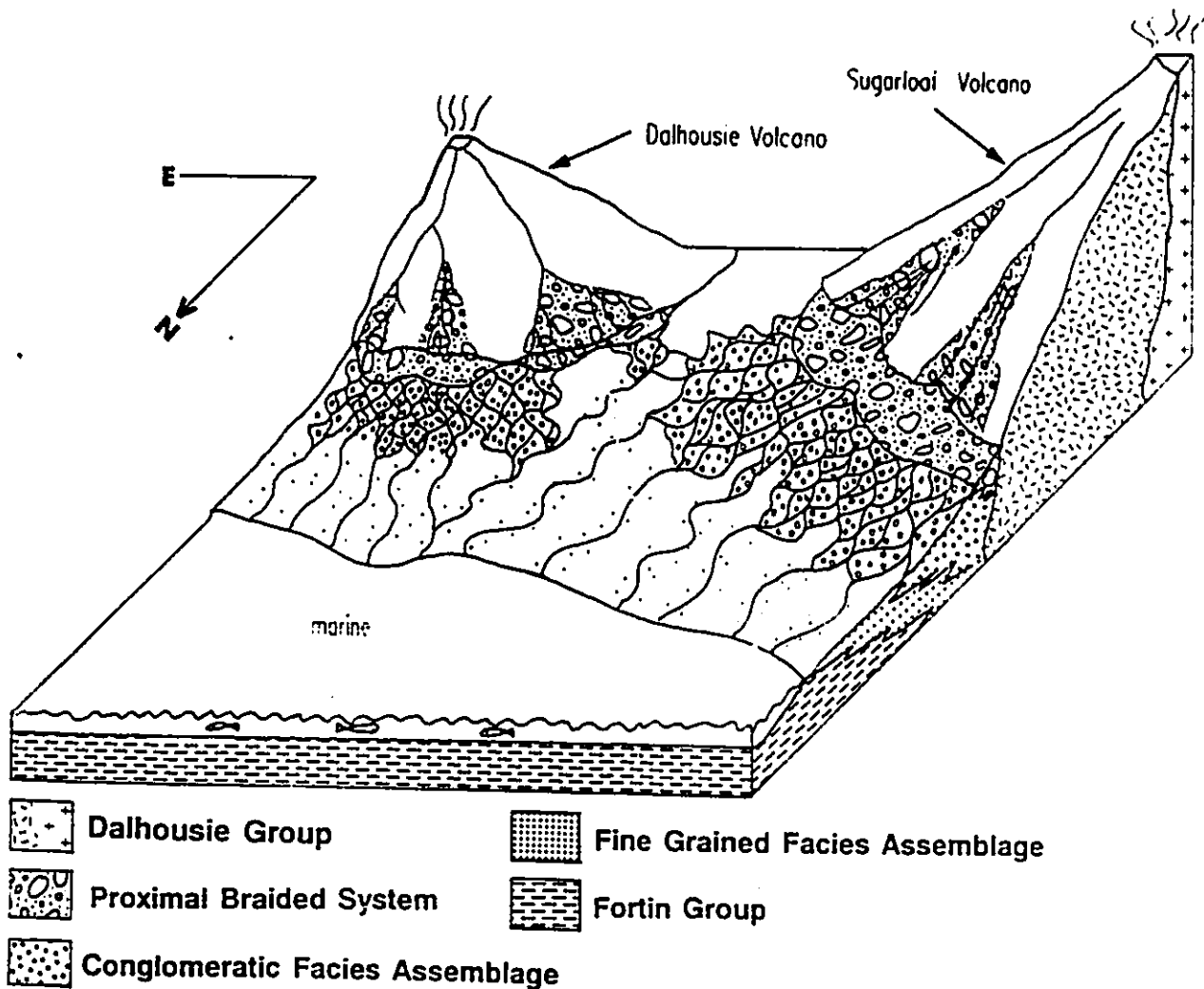


Fig. 2-20. Depositional model for the Pointe la Nim Formation. Fluvial system discharged northeastwards into a marine body represented by the deposits of the Fortin Group, which includes deltaic deposits.

existence of several other volcanoes in the vicinity. The volcanoes of the Chaleur Bay area formed part of the Piscataquis volcanic arc, which extends from northern Maine to central Gaspé (Osberg, 1978; Dostal et al., 1989).

The sedimentary successions at sections T, U, and V are interpreted as proximal gravelly braided deposits located on the lower flanks of the ancient Sugarloaf volcano at canyon mouths (Fig. 2-20). The coarse nature of facies Gm at these localities, with clasts up to 3 m in diameter, indicates that the flanks of the volcano had a steep gradient high topographic relief. The successions at sections Q and R are interpreted as the deposits of gravelly braidplain (CFA) and floodplain (FFA) environments, located relatively distal to the deposits of sections T, U, and V (Fig. 2-20). The CFA of section Q is observed to grade laterally into the FFA of section R, indicating that these two environments coexisted laterally. The northeast trend of paleocurrents within the CFA as well as boulder facies Gm of section T, the exclusive volcanic composition of the deposits, as well as the interbedded tuffs indicate that sedimentary styles were influenced by eruptive events within the volcanic range located to the south.

Megasequences within the distal fluvial succession at sections Q and R record two episodes of northwest progradation and southwards encroachment of a clastic wedge in response to volcanism (Fig. 2-10).

Sections Q and R exhibit vertical transitions from the CFA to the FFA and back again to the CFA (Fig. 2-10). The sharp base of the upper CFA at section R indicates a very abrupt change in depositional environments. Each CFA unit is interpreted as representing the rapid northeastward progradation of a proximal braidplain environment in response to volcanic activity in the south. Periods of active volcanism resulted in the upbuilding of the Sugarloaf volcanic pile, thereby increasing its significance as a sediment source. As volcanic activity decreased, the rate of sediment supply decreased, resulting in the southward encroachment of a floodplain environment, represented by the FFA. Two periods of intense volcanic activity resulting in the northeastward progradation of a clastic wedge are documented within the succession at sections Q and R. Minor interbedded tuffs within the FFA at sections Q and R indicate minor volcanic activity.

The large-scale fining-upwards sequences therefore are attributed to volcanic control. These cycles may also be related to climatic controls. The absence of cyclic color variations within the FFA units interpreted as overbank floodplain deposits however indicates that the climate was relatively stable.

The sedimentary succession within the Dalhousie Group exhibits a gradual upwards shift from shallow marine environments (represented by the deposits of the Lower

Dalhousie Group) to alluvial environments of the Pointe la Nim Formation. This transition from submarine to terrestrial environments is related to the evolution of the volcanic island arc. The deposits of the Fortin Group, which are temporally equivalent to the Pointe la Nim Formation, indicate that the alluvial plain was transitional northwards into a marine environment. Presumably, marine conditions existed towards the south within the Fredericton Trough during Early Devonian time as well.

Interbedded shales of marine origin (McGregor, 1989a) within the volcanic succession above facies Gm at Section T indicate a return to marine conditions near the end of Pointe la Nim time, possibly as a result of eustatic sea level rise or subsidence of the volcanic arc.

CHAPTER 3

ATHOLVILLE MEMBER




















3-1 Introduction

The Atholville Member is dated as mid Emsian (annulatus-sextantii Zone) by McGregor (1977, 1989a, 1989b) (Appendix 1). Dineley and Williams (1968) considered the Atholville 'beds' of the Campbellton Formation insufficiently distinct from the remainder of the formation to warrant member status. The fine grained sediments of the Atholville Member are considered lacustrine in origin, and hence are sufficiently distinct from the remainder of the Campbellton Formation, which is fluvial in origin, to warrant member status.

3-2 Location

The Atholville Member is exposed along the coast of the Restigouche River between Atholville and the CN railyards at Campbellton, New Brunswick (Fig. 2-4). The base of the section is exposed at four minor promontories along the shoreline where the underlying, well indurated volcanics offer resistance to wave erosion. Detailed observations of the contact were made at all exposures, while an incomplete, approximately 57 m section (section O Fig. 3-1) located 16.6 m above the basal breccia assemblage was measured from a location to the east of Atholville (Fig. 3-1). This is the type section of the Atholville Member. A thicker 103 m

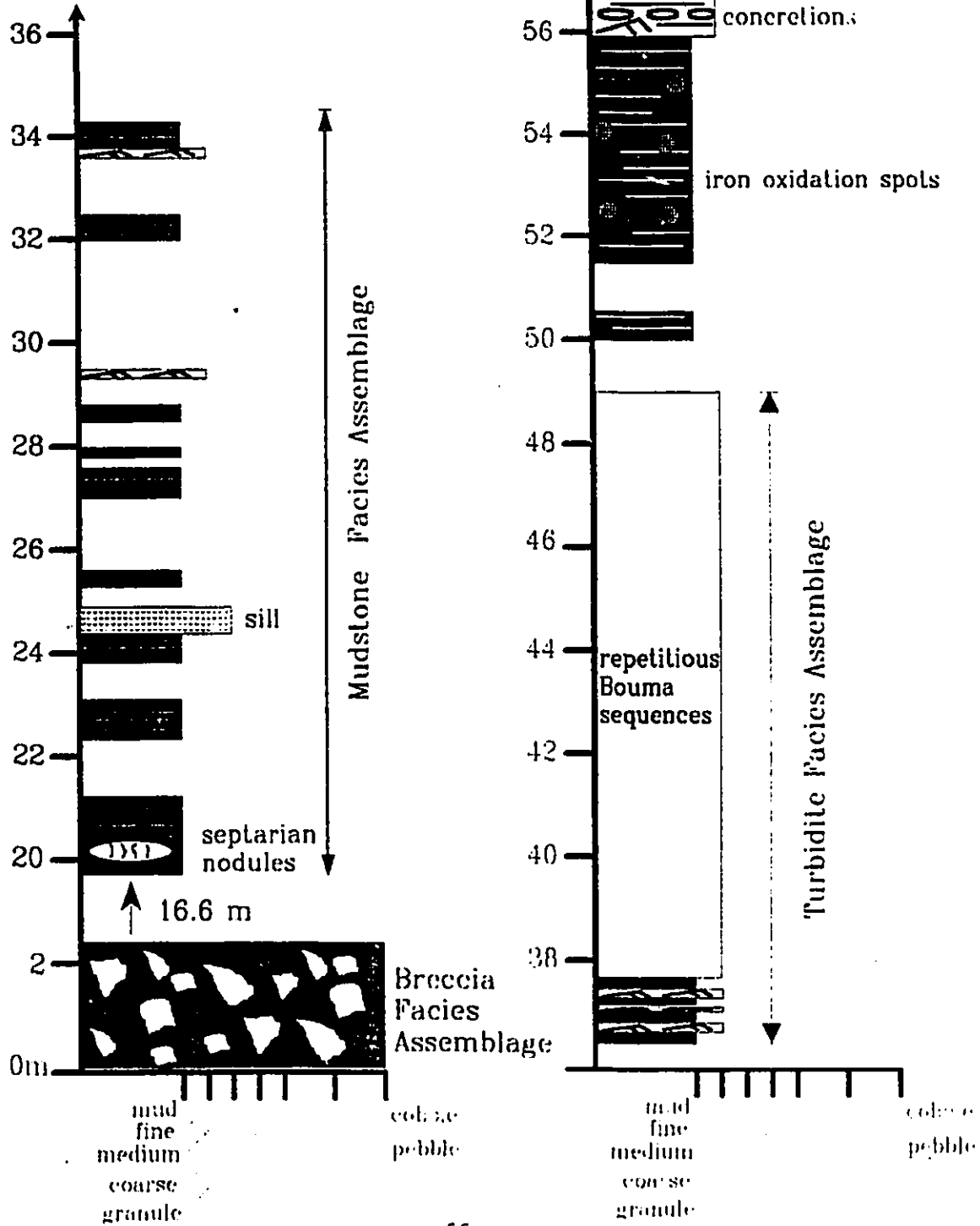
FACIES LEGEND

	Fm		St with pebbles
	Fl (rippled)		Gms
	Fl		Gt
	Sm		Gp
	rooted Sm		Gm oligomictic
	Sh\l		Gm polymictic
	Sr		imbrication
	Sp		sill or volcanics
	Sp with pebbles		
	St		
	coal		

Facies letters after those of Miall (1977, 1978) and Rust (1978). For example, facies Sr corresponds to current rippled sandstone exhibiting cross lamination. Facies Gm exhibiting dark colored clasts (above) represents oligomictic conglomerate. Facies Gm (above) exhibiting uncolored clasts represents polymictic facies Gm.

SECTION 0

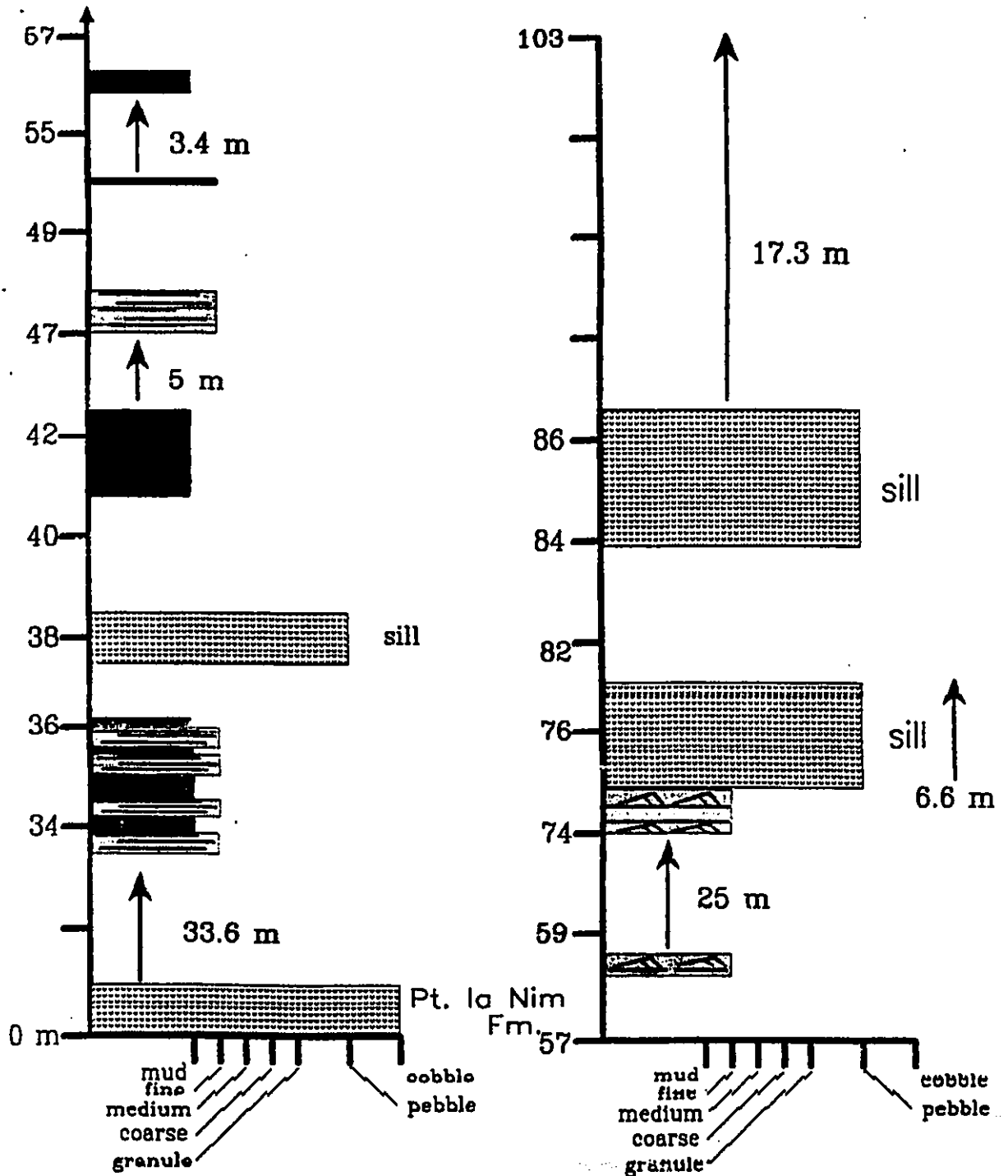
Fig. 3-1



SECTION P

Fig. 3-2

Atholville Member



section (section P, Fig. 3-2) located 33.6 m above the basal contact was measured near the railyards at Campbellton. Exposure here is quite poor, being limited to small beach ridges exposed at low tide.

3-3 Facies

Facies codes are those of Miall (1977, 1978) and Rust (1978).

Fm.....Massive, black to dark grey mudstone and siltstone with scattered fine grains of monocrystalline quartz and feldspar. The facies commonly exhibits normal distribution grading in tabular units up to 8 cm thick. These units have sharp planar bases, and are bioturbated exhibiting both vertical dwelling structures and horizontal locomotion and feeding traces. This facies commonly contains well preserved plant fragments as well as the plates and spines and rarely the entire bodies of fish, together with ostracods and gastropods.

F1.....laminated black to dark grey tabular shales and siltstones, includes alternating light and dark coloured shale and siltstones, forming couplets 1-3 mm in thickness, hereafter referred to as rhythmites. Minor bioturbation is present in the form of vertical dwelling structures and horizontal feeding and locomotion traces.

Sh.....buff, fine grained litharenite, with parallel to low angle laminated, well sorted, angular to subangular grains. This facies exhibits current lineation, with abundant commuted plant fragments along bedding planes. Units are sharp based, with minor erosional relief.

Sr.....buff, very fine to fine litharenite, ripple cross-laminated, commonly climbing, well sorted, angular to subangular. Ripples are symmetrical to strongly asymmetric, with comminuted plant fragments upon foresets.

Sm.....buff, very fine to fine litharenite, massive, moderately sorted, containing angular to subangular mudstone intraclasts and minor comminuted plant fragments, very well indurated, with silica cement. This facies is pervasively bioturbated, with very irregularly shaped burrows containing displacive carbonate cement. The cement occasionally forms nodular concretionary horizons, with individual nodules up to 5 cm in length, elongate parallel to bedding. Contains disseminated pyrite but no plant fragments.

Gms....matrix-supported boulder breccia forming units up to 2.5 m in thickness. Thickness of unit varies laterally. The clasts are angular, up to 1.5 m in length, and very poorly sorted, composed of buff coloured flow banded

rhyolite. Smaller, pebble-sized clasts exhibit a strong fabric, with ab-planes oriented subhorizontally. The mudstone matrix is black, very well indurated compared to recessively weathering volcanic clasts. Contains silt sized grains of quartz, feldspar, and biotite, as well as abundant organic material which occurs as disseminated blebs and agglomerates of spherical particles representative either of spores or bitumen. Mudstones contain well preserved and abundant comminuted plant fragments, fish plates, fish spines, ostracods, and rare gastropods. Small calcite veins, less than 0.5 mm in width pass through both matrix and clasts.

3-4 Description of Sections

3-4-1 Section O

The Atholville Member is divisible into three facies assemblages: a basal breccia assemblage, an overlying mudstone assemblage, and an upper turbidite assemblage (Fig. 3-1).

3-4-1-1 Breccia Facies Assemblage

The breccia facies assemblage is composed exclusively of facies Gms, and rests with angular discordance upon flow banded rhyolites of the Pointe la Nim Formation (Fig. 3-3). The thickness of the assemblage varies along strike from 0 to 2.5 m. The contact is subvertical in outcrop, with the

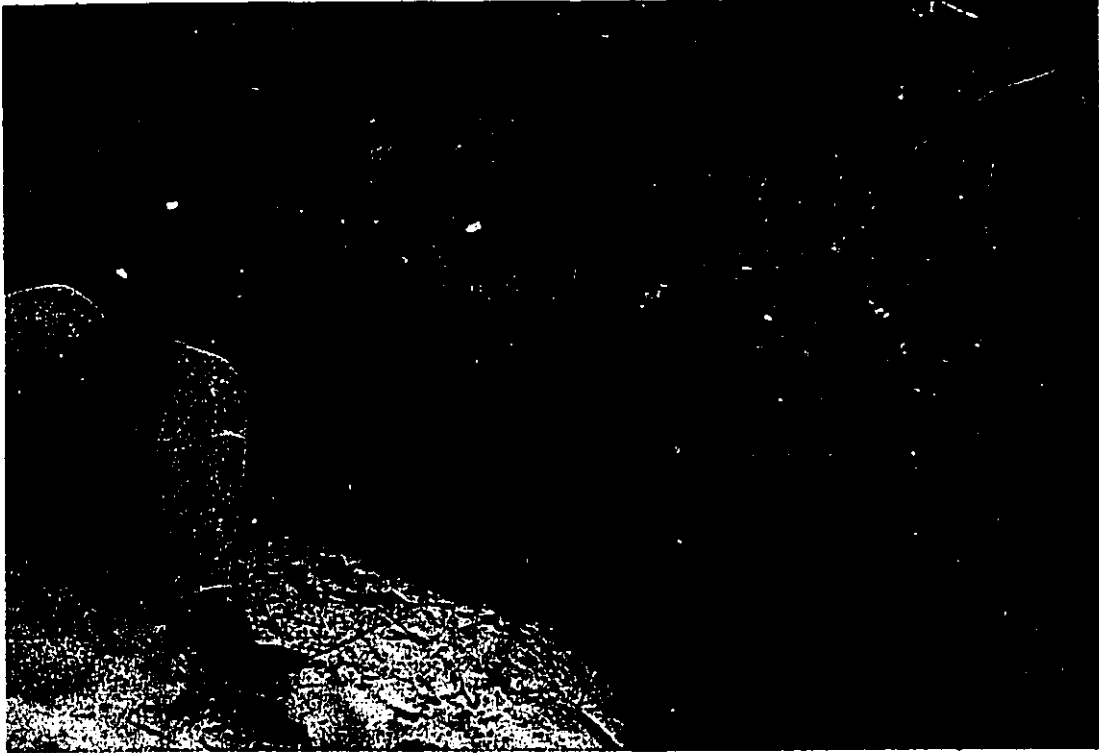


Fig. 3-3. Local discordance between the Atholville Member (left) and the flow-banded rhyolites of the underlying Point la Nim Formation (right) at section O.

rhyolites dipping steeply to the south and the overlying facies Gms offlapping gently to the northwest. The rhyolites exhibit very gentle folding as well as boudinage and minor faulting. At one locality, a 5 m long subvertical fracture up to 0.75 m wide infilled with facies Gms cuts the volcanics (Fig. 3-4). Layering within the rhyolites on either side of the fracture is parallel, suggesting passive infilling of the fracture with facies Gms.

On a regional scale, the Atholville Member is concordant with the underlying upper rhyolitic portion of the Pointe la Nim Formation, suggesting that the observed discordance is of local extent.

Facies Gms is massive and well indurated, with clasts composed exclusively of the underlying, buff coloured rhyolite, up to 1.5 m in length (Fig. 3-5). Clasts exhibit a chaotic fabric in some places, and in others show a preferential subhorizontal orientation. In sharp contrast to the well indurated rhyolite below the contact, rhyolite clasts within facies Gms are relatively soft due to weathering (Fig. 3-5). The muddy matrix of facies Gms however is very well indurated. In thin section, the matrix is non-calcareous and silica-cemented, exhibiting no sign of recrystallization. Facies Gms is internally structureless, aside from the aforementioned subhorizontally oriented fabric of the megaclasts.



Fig. 3-4. Fracture within the flow-banded rhyolites infilled with facies Gms of the breccia facies assemblage of the Atholville Member at section O. Hammer 30 cm long.

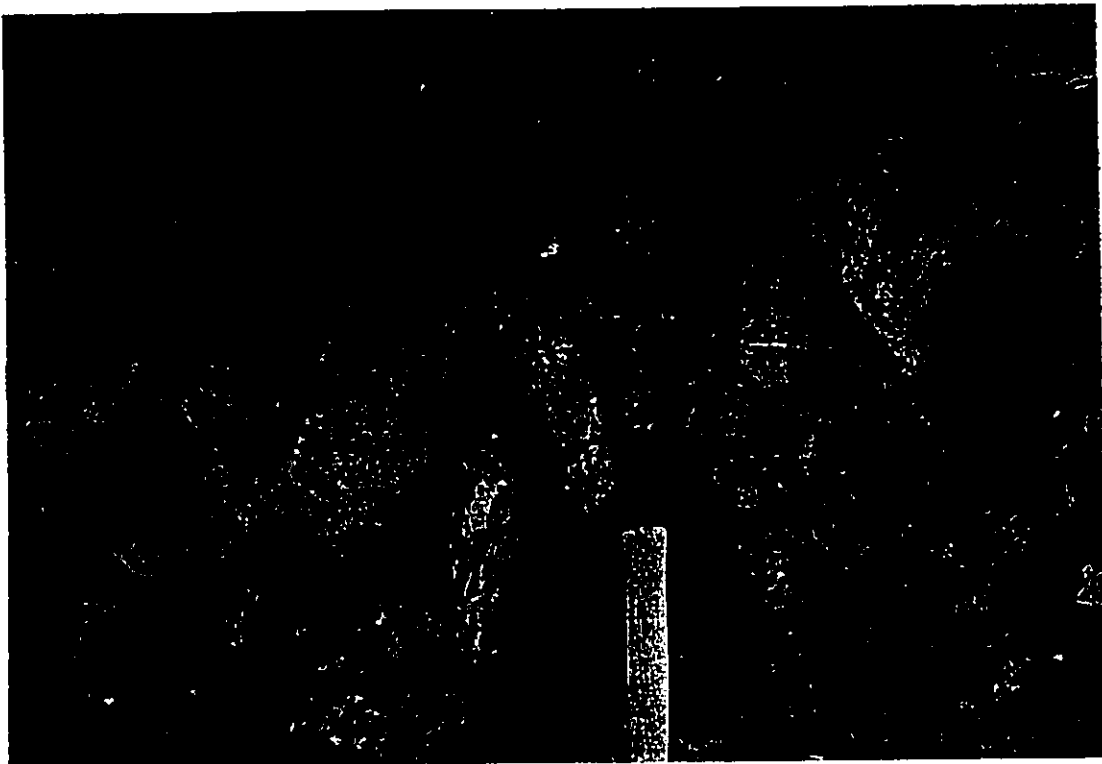


Fig. 3-5. Facies Gms, composed of poorly sorted buff-coloured recessively weathering clasts of flow-banded rhyolite presumably derived from the underlying Point la Nim Formation. Section O.

In outcrop, local relief up to several meters was observed along the contact between the volcanics and facies Gms, but the gross dimensions of the feature are impossible to estimate due to the discontinuous nature of the outcrop.

3-4-1-2 Mudstone Facies Assemblage

Facies Gms of the breccia facies assemblage is abruptly overlain by the mudstone facies assemblage. This assemblage is 18 m thick, and is composed of interbedded, poorly indurated facies F1 and Fm containing several horizons of septarian nodules (Fig. 3-1). The poorly indurated nature of the mudstones accounts for the poor exposure of this assemblage in outcrop.

Facies F1 occurs primarily as mm scale laminated shales or rhythmites. Facies Fm occurs interbedded with facies F1, and is composed of laminated, normally graded silty mudstone forming units several cm's thick (Fig. 3-6). Both facies exhibit bioturbation in the form of horizontal trails and burrows and vertical tunnels up to 5 mm in diameter (Fig. 3-7). Bioturbation within the finely laminated facies F1 is locally intense, completely homogenizing lamination.

The base of the mudstone facies assemblage, resting directly upon facies Gms of the breccia facies assemblage, is marked by a very well indurated unit composed of facies Fm and F1 3.3 m in thickness. The basal 30 cm of this unit

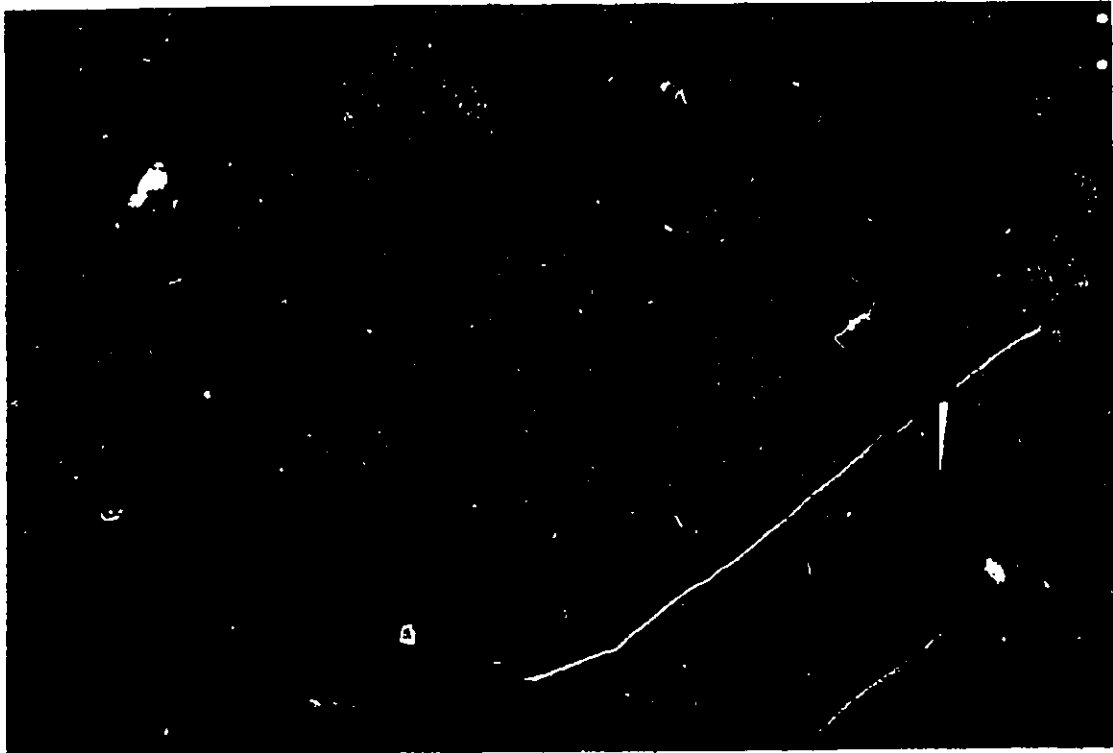


Fig. 3-6. Laminated facies F1 of the mudstone facies assemblage at section O. Note normally graded bioturbated rhythmites (arrow pointing up). Pencil 15 cm long.



Fig. 3-7. Typical bioturbation along bedding plane of facies F1 at section O.

is very well indurated, with the unit becoming gradually less indurated upwards. Within this 3 m sequence occur two horizons of septarian nodules, separated from each other by an interval of 1 m (Figs. 3-1, 3-8). The light grey nodules occur as flattened discs, up to 1 m in diameter, and 15 cm in thickness. The nodules exhibit the vertically tapering polygonal cracks characteristic of septarian nodules. These cracks are filled by two generations of calcite cement. The first generation lines the walls of the cracks, and is composed of fibrous calcite oriented perpendicular to the walls. The second generation infills the remaining void, and is composed of sparry calcite. Primary stratification is poorly preserved within the nodules, with facies F1 forming graded sequences up to 1 cm in thickness composed of a light coloured graded base of silty mudstone passing upwards into dark claystone. There is no evidence of bioturbation.

The remainder of the mudstone facies assemblage is composed primarily of interbedded facies F1 and Fm. A 50 cm thick dacitic sill occurs midway within the assemblage (Fig. 3-1). The adjacent mudstones are well indurated up to a distance of 20 cm on either side of the intrusion. Xenoliths of mudstone occur within the basal portions of the sill.



Fig. 3-8. Septarian nodule within facies Fm of the mudstone facies assemblage, section O. Lense cap 6 cm in diameter.

3-4-1-3 Turbidite Facies Assemblage

The turbidite facies assemblage consists of a 12 m thick sequence of interbedded sandy to silty turbidites and mudstones (Fig. 3-1). The turbidites form silty to fine grained sandy sequences exhibiting a vertical facies arrangement characteristic deposition from waning turbidity currents (Bouma, 1962; Walker, 1984). Facies include Sm, Sh, Sr, and Fl, which are arranged in a fining upwards sequence, from fine sandstone to siltstone and shale. In terms of Walker's (1984) classification, where lithofacies were assigned a letter code (Fig. 3-9), the following turbidite sequences are observed: Tabce, Tbce, Tce, Tace, Tabc, Tbc, and Tac (Figs. 3-1, 3-10, 3-11). The base of each turbidite is abrupt and planar, except where overlain by facies Sm, in which case a minor scour may be present. Sole marks at the base of the turbidites are common, and include flute casts, groove casts, and burrow plugs, where sand has infilled the mouth of a burrow within the underlying Fl facies. The transition between facies within an individual turbidite are generally abrupt and planar (Fig. 3-12). The sandy and silty facies of a turbidite (Sm, Sr, and Sh) are overlain by facies Fl which exhibits bioturbation in the form of horizontally aligned, elliptical burrows similar to those found within Fl of the mudstone facies assemblage. Turbidite sequences attain a maximum thickness of 80 cm, with individual component

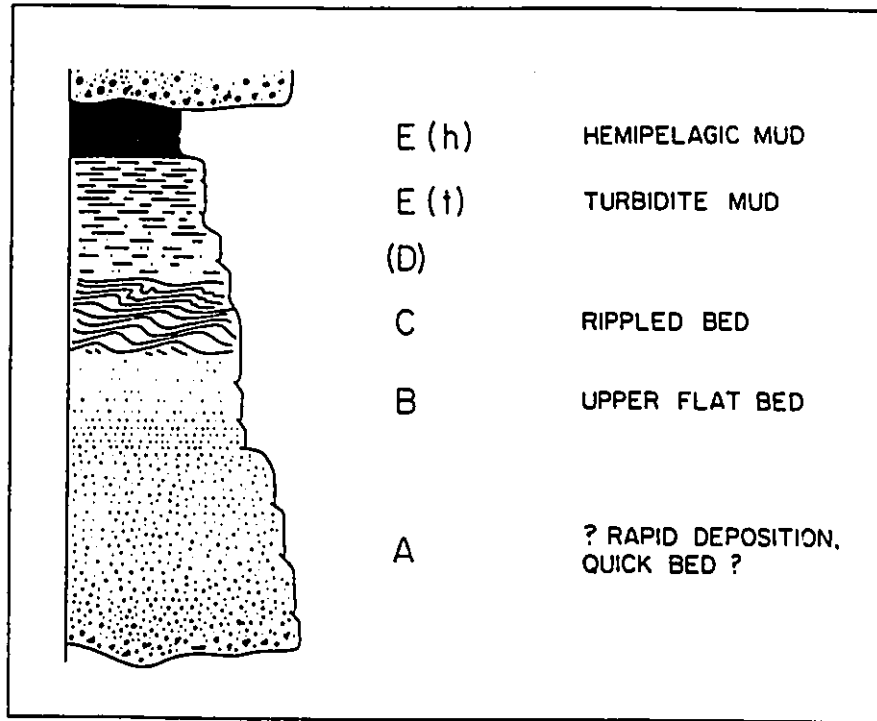


Fig. 3-9 Five divisions of the idealized Bouma sequence: A) massive or graded sandstone, B) parallel laminated sandstone, C) ripple cross laminated sandstone, D) interbedded parallel laminated sandstone and siltstone (not recognized in Atholville Member) and E) (t) turbidite laminated mudstone (h) hemipelagic bioturbated mudstone. (After Walker, 1984)

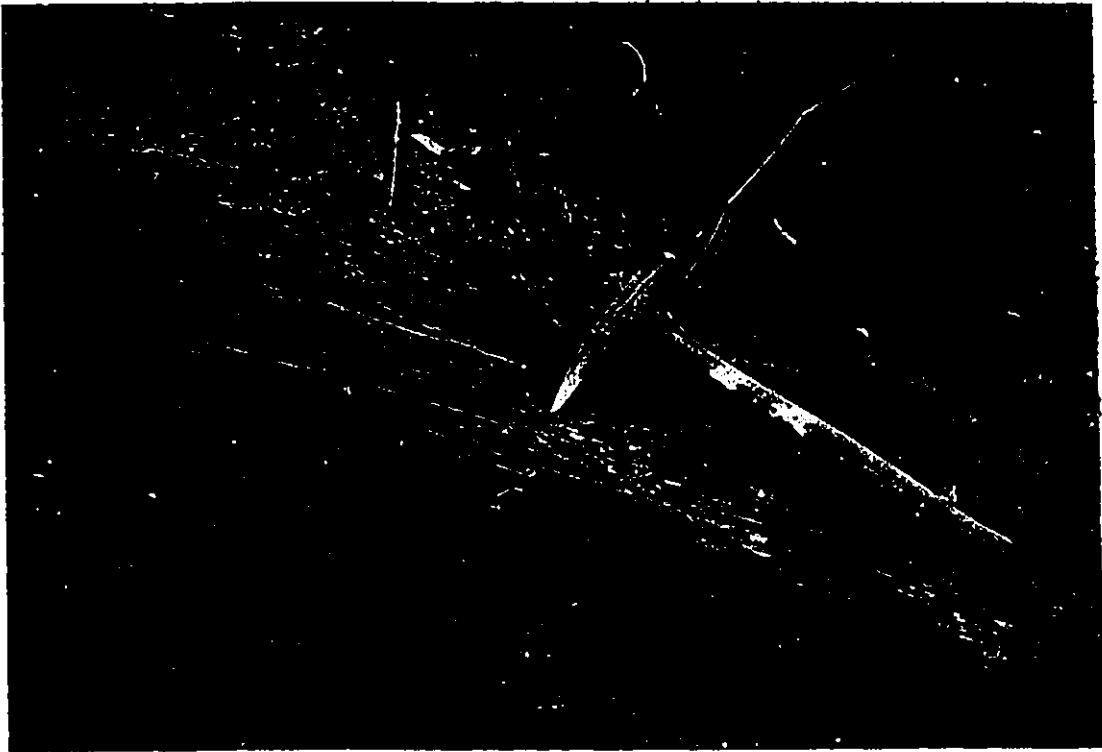


Fig. 3-10. Fine grained facies Sh within the turbidite facies assemblage at section O. Hammer 30 cm long.

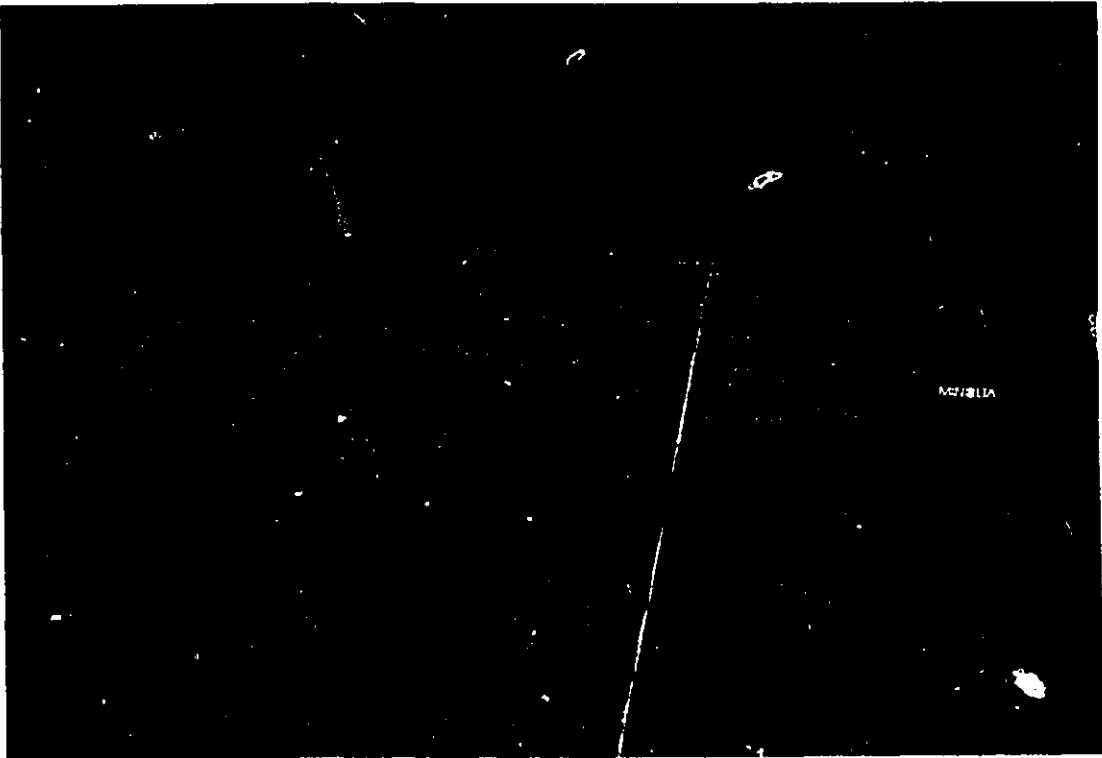


Fig. 3-11. Climbing ripple cross-lamination (facies Sr) within the turbidite facies assemblage at section O.



Fig. 3-12. Typical exposure of the turbidite facies assemblage composed of tabular sandy turbidites interbedded with facies Fm and F1 at section O. Book 18 cm long.

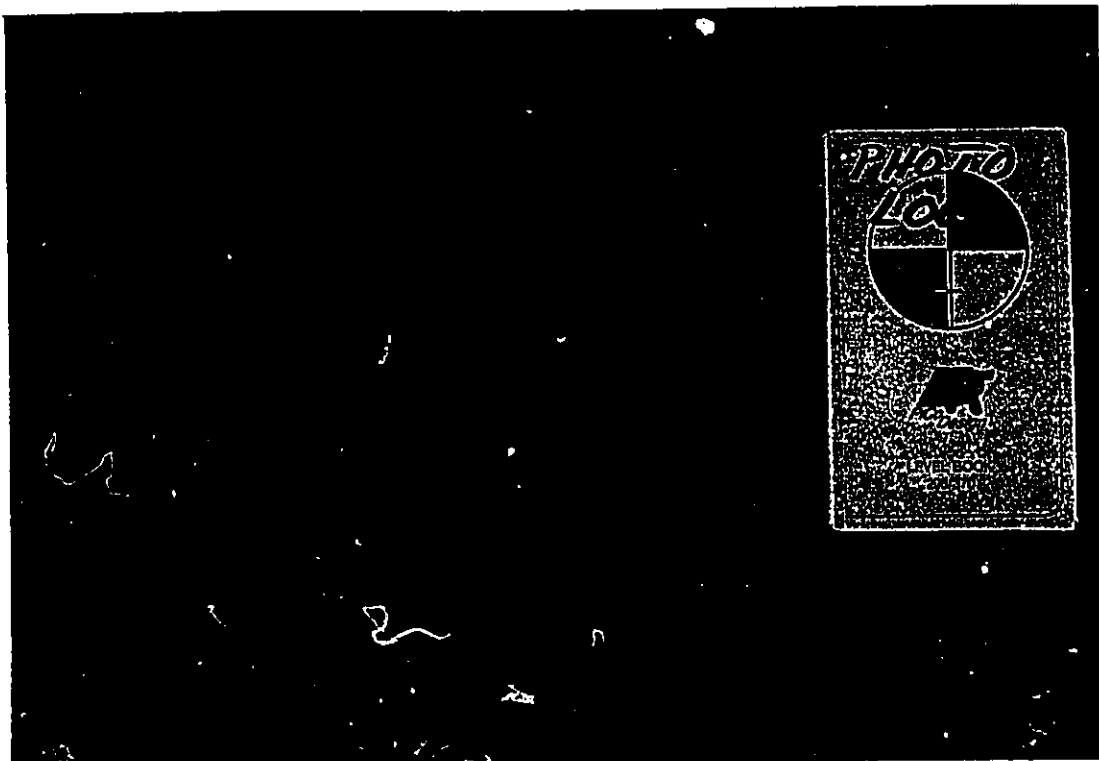


Fig. 3-13. Bedding plane view of irregular-shaped calcareous concretions at section O. Book 18 cm long.

facies rarely exceeding 40 cm.

The turbidite facies assemblage is overlain by 4.3 m of facies F1 and Fm, the basal 3.5 m of which is poorly indurated, the remaining upper 80 cm being very well indurated (Fig. 3-1). The unit exhibits both horizontal and vertically elliptical burrows. Iron oxidation spots are present throughout the unit. Eighty centimeters of buff coloured very fine grained massive sandstone, containing rare scattered mud rip-ups overlies the well indurated, dark coloured unit of facies Fm. This unit is very well indurated, reflecting the silica cemented nature of the sandstone. Planar lamination and starved ripple drift cross-lamination are visible in outcrop, as well as both horizontally and vertically oriented burrows, similar to those discussed above. Scattered calcareous nodules, up to 9 cm in length, form a crude layer within the unit (Fig. 3-13). The nodules possess an irregular, bulbous shape, and are flattened parallel to bedding. A very sharp contact separates the grey, calcite cemented interior of the nodule from the buff coloured, silica cemented host. The ratio of calcite cement to detrital grains is quite high, indicating the calcite cement to be displacive in nature. Small tubular burrows, generally less than 5 mm in diameter, appear as dark coloured features within the nodules, resulting from a lower calcite to clastic grain ratio. In addition, sparry calcite infills voids within the burrows.

The host unit exhibits iron oxidation spotting, which in thin section appear as finely disseminated pyrite. One iron stained cylindrical burrow less than 1 cm in diameter penetrates obliquely to bedding.

Twenty-five centimeters of dark, very well indurated facies F1 caps the section at Atholville (Fig. 3-1). Fe oxidation spots dot the surface of the exposure, indicating the presence of disseminated pyrite within the unit.

3-4-2 Section P

The poorly exposed section at the CN railyards is a repetition of the sequence exposed at Atholville (Fig. 3-2). Although 90 % covered, the mudstone and turbidite facies assemblages are well represented in this section. A 2.5 m thick sequence of interbedded F1 and Fm, located 33.6 m above the base, clearly belongs to the mudstone facies assemblage (section O, Fig. 3-2). Turbidites exhibiting the Tbc and Tce divisions of Bouma (1962) and Walker (1984) are exposed 58 and 83.2 m above the base, clearly representative of the turbidite facies assemblage of section O. Units of facies Fm (e) within the turbidites are heavily bioturbated (Fig. 3-2). One unit contains crude layers of calcareous nodules similar to those observed at the top of the turbidite facies assemblage of the Atholville section. Three dacitic sills intrude the sequence, one measuring 6.6

m in thickness, and all exhibit chilled margins (Fig. 3-2). The host rocks immediately adjacent to the margins of the sills are well indurated up to a distance of 90 cm from the contact, where they become gradually less indurated. The top of the Atholville Member is marked by the first appearance of fluviatile conglomerates (Fig. 3-2), giving the Atholville Member a maximum thickness of 112.8 m.

3-5 Interpretation

Based upon its fine grain size, facies assemblages (particularly the abundance of facies F1), fauna and flora, and the larger scale facies relationships with the remainder of the Campbellton Formation, the Atholville Member is interpreted as a lacustrine deposit.

The regional concordance of the contact between the underlying flow banded rhyolites of the Pointe la Nim Formation and the basal boulder assemblage of the Atholville Member suggests that the discordance at Atholville may be the result of local rhyolitic doming. The well indurated nature of the sediments resting directly above the contact also may be due to the heat generated during the subaqueous extrusion of lava 'baked' the lacustrine mudstones overlying and surrounding the dome, or diagenetic. Facies Gms of the basal boulder assemblage represents the deposit of a subaqueously emplaced cohesive debris flow, which was created during the collapse of the

dome. The poor sorting and angularity of the rhyolitic clasts, along with the absence of internal stratification, are features indicative of cohesive debris flows (Wasson, 1977; Nilsen, 1982). The formation of a cohesive debris flow is favoured by steep slopes, and most importantly, a source of mud (Bull, 1972). The resulting gravity flows travel downslope, with coarse grains supported by both the density and strength of a sediment/water matrix (Lowe, 1979, 1982). Deposition occurs en masse, when shear strength becomes less than the yield strength of the cohesive matrix (Lowe, 1979, 1982). The subhorizontal orientation of megaclasts within the basal boulder assemblage suggests that the cohesive debris flows were relatively more fluid, as would be expected within debris flows emplaced subaqueously. The presence of fish debris, as well as entire fish, gastropods, and ostracods indicates that the debris flows were emplaced subaqueously.

Lacustrine depositional environments have been the object of much recent study: Houbolt and Jonker (1968) (Lake Geneva); Reineck (1974) (Lake Constance); Sturm and Matter (1972, 1978), and Sturm (1975, 1976) (Lake Thun and Lake Brienz). Houbolt and Jonker (1968) recognized numerous depositional environments within Lake Geneva. The eastern margin of the lake is dominated by a subaqueous channel which extends basinwards from the mouth of the Rhône. The channel extends to a depth of 200 m attaining a width in

excess of 200m, and a depth of 15m , and is flanked by well developed levees which terminate below a depth of 200 m where the channel opens onto a fan or depositional lobe resting upon the central plain of the lake. The depositional system therefore comprises a channel-levee complex similar to that of a submarine fan, (Walker, in press) and a central plain which represents the deepest portion of the lake not affected by processes operating within the channel-lévee complex. The channel-levee complex exhibits shallow water deltaic subenvironments, and deeper water sublacustrine fan environments (Fig. 3-14).

Houbolt and Jonker (1968) categorized the deposits of six subenvironments from modern Lake Geneva: central plain, delta foreslope, lateral slopes, channel, levees, and depositional lobe (Fig. 3-14). The central plain is characterized by predominantly clay-rich, finely laminated varves interbedded with thicker, normally graded units. Reineck (1974) recognized an identical facies association on the central plain of Lake Constance. The channel-levee complex can be divided into a deltaic portion and a sublacustrine fan portion. The deltaic foreslope, outside of the channel and fan, consists predominantly of sand with laminated deposits. The sublacustrine fan consists of a main channel, flanking levees, and a depositional lobe or fan. Deposits of the channel consist mainly of fine to medium grained sand, predominantly horizontally laminated,

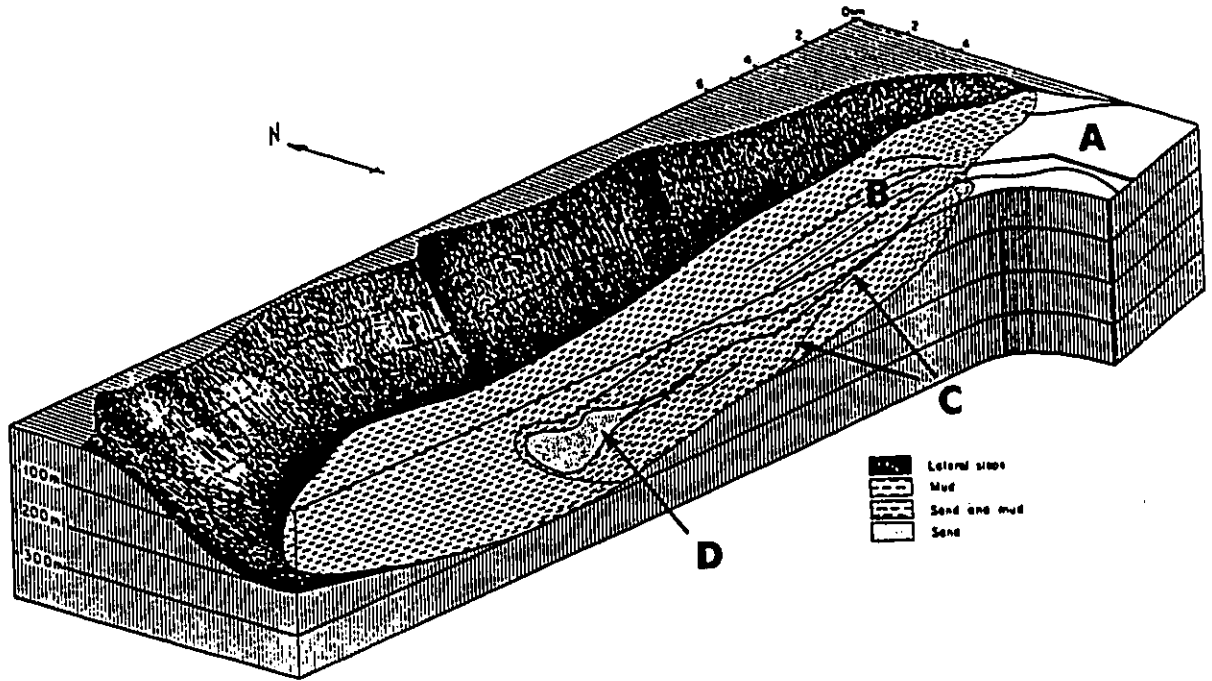


Fig. 3-14 Depositional environments within eastern Lake Geneva. A) Rhone River, B) delta foreslope, C) channel-levee complex, and D) fan depositional lobe. (After Houbolt and Jonker, 1968)

with occasional graded bedding and rare ripple cross-lamination. The fan deposits consist of horizontally bedded finer grained sand, commonly cross-laminated, exhibiting normal grading and lesser horizontal laminations. The levees consist of interbedded sands and silts.

Sturm (1975, 1976) and Sturm and Matter (1978), based upon studies of modern Lake Thun and Brienz, proposed that two main depositional processes operate within lakes. Sediment is generally introduced into a lake via fluvial sources. If the river water and its suspended load is less dense than the cold water of the lake, the river water flows above the seasonally established thermocline as overflows and interflows, with the sediment remaining in suspension. During the summer months, the coarsest fraction settles to the lake bottom, forming a thin, dark lamina. During the autumn and winter months, the thermocline is destroyed, allowing the finer grained fraction to come out of suspension, forming a thin, light coloured lamina. The resulting deposit, comprising a darker coloured, coarser grained lamina and a lighter coloured, finer grained lamina is referred to as a varve (Sturm, 1975, 1976; Sturm and Matter, 1978) or rhythmite (Hesse and Sawh, 1982). This implies that each couplet represents an annual event. Based upon observations from Lake Walense (another Swiss lake), Lambert and Hsu (1979) concluded that up to 5 couplets could be deposited within 1 year, suggesting that a single couplet

does not necessarily represent an annual depositional event.

If inflowing river water has a higher density than the lake water, the flow transforms into a turbulent underflow, which travels down the channel-levee complex and into the basin, being deposited as a turbidite.

The thinly bedded rhythmites of the mudstone facies assemblage are attributed to deposition upon the central plain, mainly from suspension, which is considered representative of normal background sedimentation (Reineck and Singh, 1980). The interbedded, thicker graded units are interpreted as the deposits of underflowing turbidity currents, resulting from unusually high fluvial discharge. Sturm and Matter (1978) suggested that these events are related to catastrophic fluvial discharge, which in Lake Brienz occurs at a rate of 2 per century. These interbedded turbidites, which display the Ta division of Bouma (1962), are interpreted as distal in nature (Walker, in press).

The abrupt transition from the relatively shallow emplacement of facies Gms of basal boulder assemblage to the thinly laminated clayey central plain facies of the mudstone facies assemblage indicates an episode of rapid deepening, likely as a result of the rapidity of dome collapse. The absence of any intermediate shallow water deltaic foreslope deposits indicates that transgression must have been rapid. Very rapid lateral facies changes are known at coincident

lake margins (Allen and Collinson, 1986), implying that an abrupt episode of deepening would create an equally abrupt vertical facies change.

Following the proposed subenvironments of Houbolt and Jonker (1968), the deposits of the turbidite facies assemblage of sections O and P, composed of variably developed thinly bedded sandy turbidites, are interpreted as fan deposits. Houbolt and Jonker (1968) described sediments from this subenvironment as being sandy, horizontally bedded, and primarily ripple cross-laminated, with common normal grading and lesser horizontal lamination. Although Houbolt and Jonker (1968) did not refer to these deposits as turbidites, by analogy to modern submarine fans one would generally expect to find thinly bedded, well developed sandy turbidites upon a depositional lobe (Walker, 1984, in press).

The turbidites of the turbidite facies assemblage exhibit a variety of vertical facies sequences, all of which follow to some degree the idealized, complete vertical facies sequence of Bouma (1962) and Walker (1984) (Fig. 3-9). The displayed vertical sequence of facies is attributed to deposition during the waning or depositional stage of a turbidity current. The completeness of the sequence is dependant upon distance from source (Walker, 1984), with fully developed sequences generally indicative of proximal environments and a Tae sequence generally

indicative of distal environments.

The relatively well developed turbidites within the turbidite facies assemblage are the proximal equivalents of the thinner and finer graded siltstone units interbedded within the varves of the mudstone facies assemblage (Figs. 3-1 and 3-15).

The 4.3 m thick unit of F1 abruptly overlying the thinly bedded turbidites of the turbidite facies assemblage is attributed to much slower deposition, probably from suspension, and is reminiscent of the thinly bedded rhythmites of the mudstone facies assemblage (Fig. 3-1). The abrupt appearance of this unit above the lobe deposits of the turbidite facies assemblage suggests that the lobe was abandoned. Lobe abandonment or switching is a common phenomena of many modern submarine fans (Walker, in press). A topographically lower site becomes the favoured area for deposition and the construction of a new depositional lobe.

The 4.3 m thick unit of F1 is abruptly overlain by a tabular unit of massive, bioturbated silty fine grained sandstone, 80 cm in thickness (Fig. 3-1). This unit exhibits pebble sized muddy intraclasts as well as relict current ripples, and probably represents a highly bioturbated turbidite. The intensity of bioturbation suggests that deposition occurred at shallower depths, although the presence of scattered blebs of pyrite within both this unit and the overlying unit of facies F1 suggests

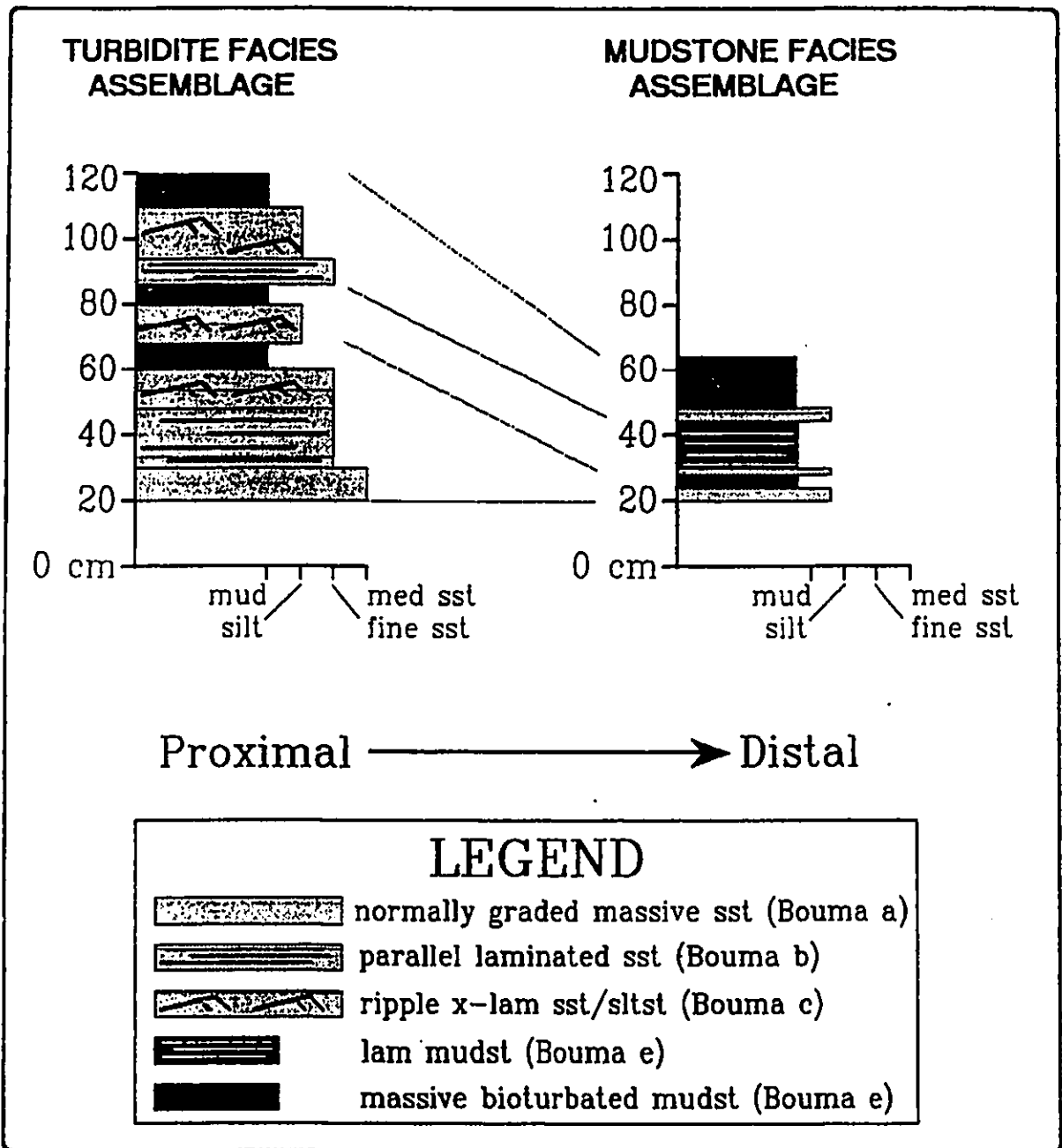


Fig. 3-15. Schematic illustration of the genetic relationship between sequences within the turbidite facies assemblage, deposited within the channel-levee complex, and the mudstone facies assemblage, deposited on the central plain.

deposition under reducing conditions. Basin oxygenation may have fluctuated, perhaps on a yearly basis due to episodic flood events during emplacement of the turbidites. The recurrence of a sandy turbidite sequence suggests the reactivation of deposition upon the lobe.

3-6 Summary and Conclusions

The deposits of the Atholville Member are distinctly different from those of the underlying Pointe la Nim Formation. Deposition of the Atholville Member occurred within a lacustrine basin created by the collapse of a rhyolitic dome. This led to the rapid ponding of drainage, and the creation of a standing, freshwater body. The vertical sequence within the Atholville Member, from central plain to fan deposits, indicates a basinward progradation of the channel-levee complex (Fig. 3-16). The more proximal facies of the channel-levee complex as well as the shallow water deltaic deposits of Houbolt and Jonker (1968) would ideally have capped the sequence. A large covered interval between fluvial sediments of the basal Pointe à Bourdeau Member and deposits of the turbidite facies assemblage at section P may explain the absence of deltaic deposits. These fluvial sediments, which belong to the Pointe à Bourdeau Member of the Campbellton Formation, are interpreted as the deposits of a sandy braidplain which drained northwards into the lake. The braidplain represents

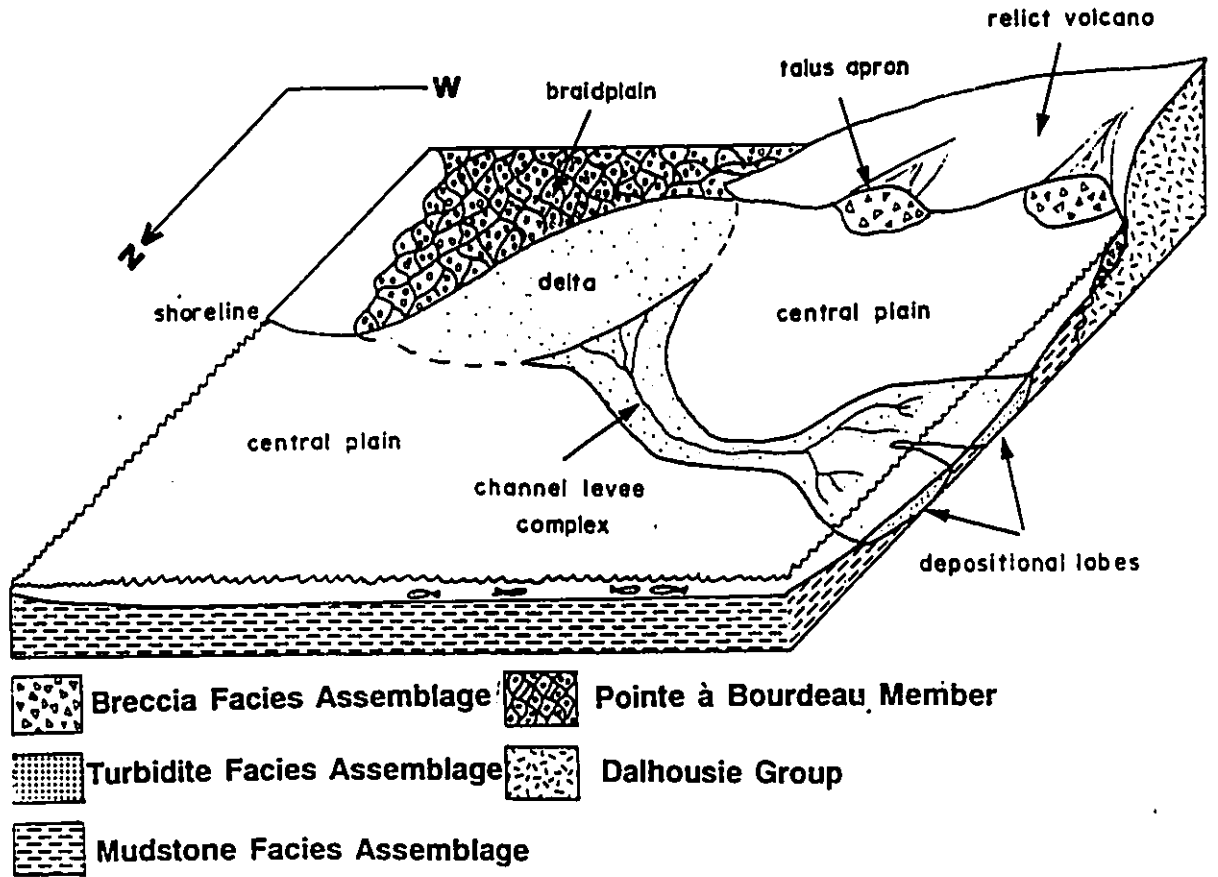


Fig. 3-16. Depositional model for the Atholville Member, exhibiting the east-west trend of the basin axis. The nature of the fluviodeltaic system at the lake margin is unknown. The braidplain located to the south represents the deposits of the Pointe à Bourdeau Member.

a longitudinal drainage network created during compression and subsequent unroofing of the Dalhousie Group towards the east. The genesis of the Pointe à Bourdeau Member will be discussed in greater detail in the next chapter.

The westward direction of transport revealed by paleocurrents within the turbidite facies assemblage is interpreted to represent the trend of the longitudinal axis of the lacustrine basin, along which turbidity currents tend to flow (Klein, 1967). This trend is at right angles to that of the longitudinal fluvial drainage system (Fig. 3-16).

The absence of evaporites indicates that the lake was hydrologically open (Allen and Collinson, 1986).

Finally, the intrusive sills within the Atholville Member indicate that igneous activity continued within the Chaleur Bay area despite the cessation of active volcanism. Diabase dikes within the Emsian York River Formation of central Gaspé indicate that igneous activity affected a large portion of the Gaspé Peninsula during this time.

CHAPTER 4

POINTE A LA GARDE AND POINTE A BOURDEAU MEMBERS

4-1 Introduction

The Pointe à la Garde and Pointe à Bourdeau Members of the Campbellton Formation are interpreted as fluvial deposits which exhibit a marked east to west proximal to distal facies trend over a distance of 74 km. A conservative estimate of the thickness of the two members based upon map patterns and airphoto interpretation is 650 m. Based upon this lateral facies trend, the main body of the Campbellton Formation is subdivided into two laterally equivalent members. The "proximal" Pointe à la Garde Member is highly conglomeratic, and exhibits two scales of cyclic, fining-upward sequences. The "distal" Pointe à Bourdeau Member is sand-rich, and exhibits only small-scale cyclic fining-upward sequences.

4-2 Location

Both members are exposed primarily on the Gaspé Peninsula, with a single occurrence at Campbellton in northern New Brunswick (Fig. 4-1). The members outcrop along a 38 km long belt in southern Gaspé, extending from west of Cross Point to Nouvelle, with a small outlier approximately 10 km in length located 26 km to the east near Grand-Cascapédia, P.Q. (Fig. 4-1). A total of 14 sections

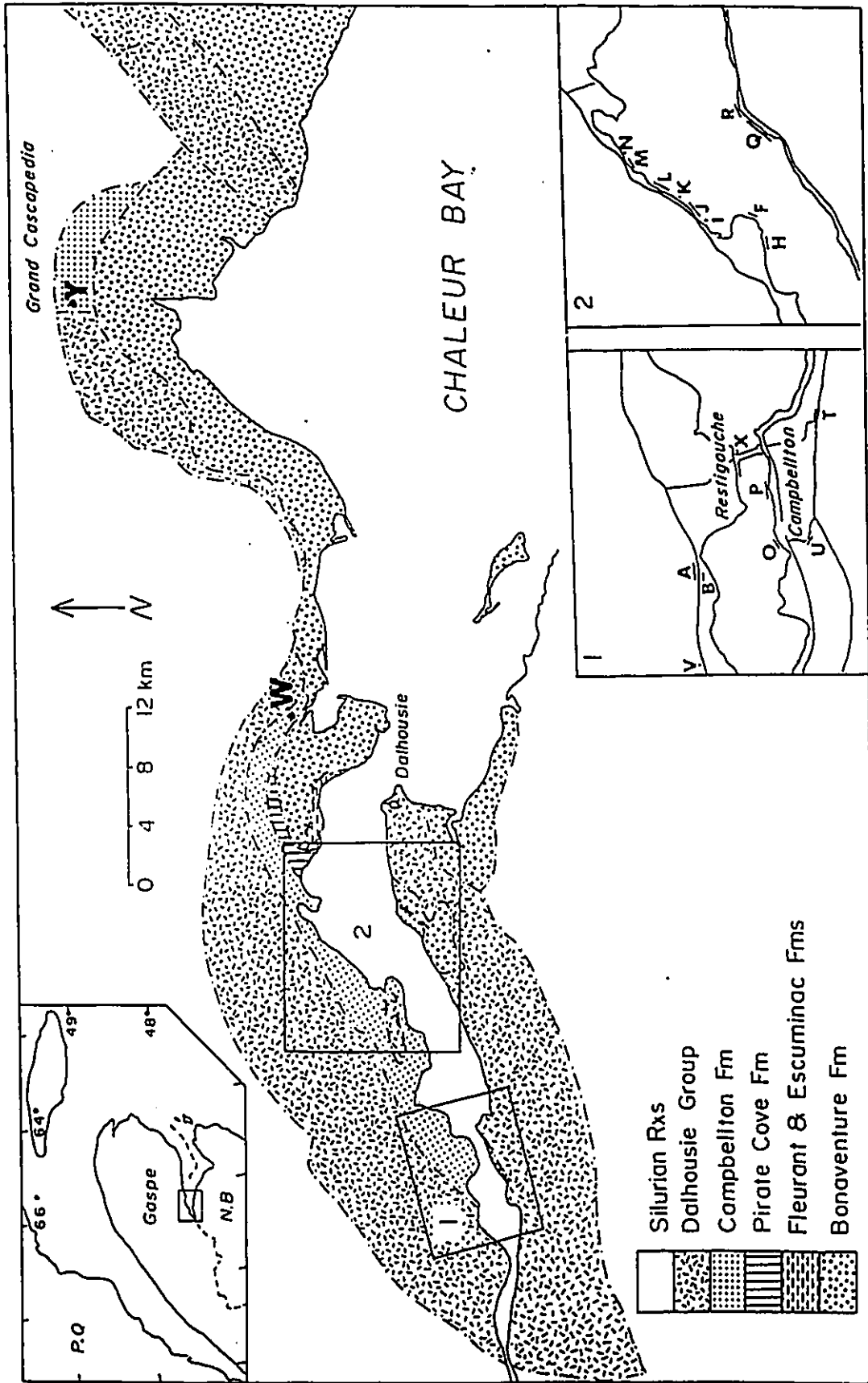


Fig. 4-1 Location of sections in the western Chaleur Bay study area.

were measured from shoreline and roadcut exposure (Fig. 4-1), offering a representative cross-section through the members. Sections F, H, J-N (Figs. 4-2 to 4-8), W (Fig. 4-9), and Y (Fig. 4-10) to the east belong to the Pointe à la Garde Member, while sections A, B, and P to the west belong to the Pointe à Bourdeau Member.

Both members have been dated on the basis of spore data as early to mid Emsian (annulatus-sextantii Zone) by McGregor (1989a) (Appendix 1).







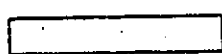








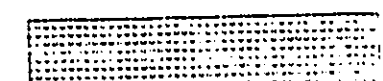



4-3 Facies

Facies are assigned according to the lithofacies code of Miall (1977, and 1978) and Rust (1978).

Gm....massive to crudely stratified framework-supported pebble to boulder conglomerate, poorly sorted, clasts moderately to well rounded, commonly imbricate, with a-b planes dipping upstream, long a axis parallel to flow. Clast composition primarily to exclusively volcanic, with lesser vein quartz, granite, sediments, jasper, and rare limestone. Units up to 4 m thick, exhibiting planar to erosional bases.

Gp....planar cross-bedded pebble to cobble conglomerate, bimodal framework-supported to openwork with calcite cement. Clasts moderately well sorted, moderately to well rounded.

FACIES LEGEND

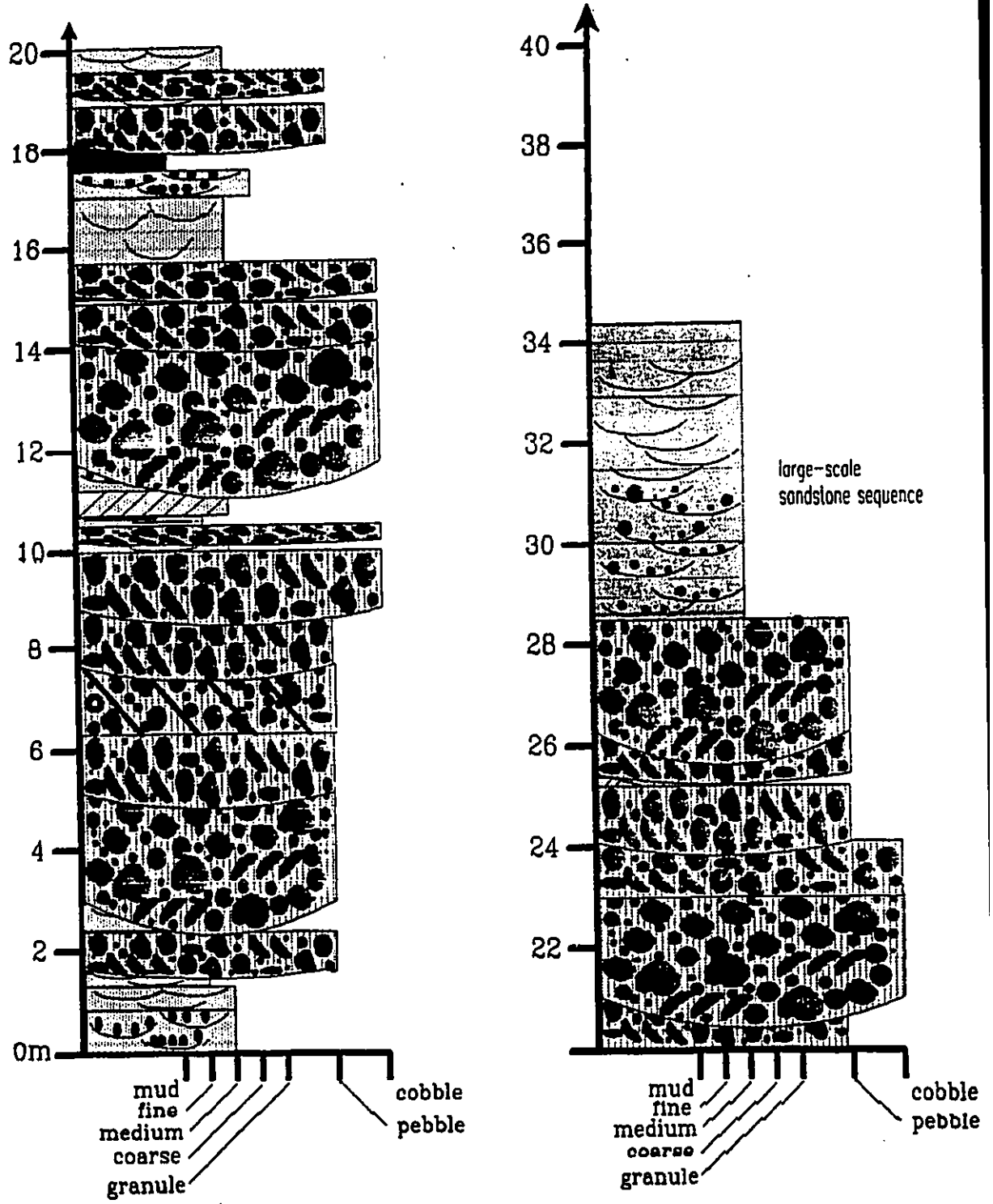
	Fm		St with pebbles
	Fl (rippled)		Gms
	Fl		Gl
	Sm		Gp
	rooted Sm		Gm oligomictic
	Sh\l		Gm polymictic
	Sr		imbrication
	Sp		sill or volcanics
	Sp with pebbles		
	St		
	coal		

Facies letters after those of Miall (1977, 1978) and Rust (1978). For example, facies Sr corresponds to current rippled sandstone exhibiting cross lamination. Facies Gm exhibiting dark colored clasts (above) represents oligomictic conglomerate. Facies Gm (above) exhibiting uncolored clasts represents polymictic facies Gm.

SECTION

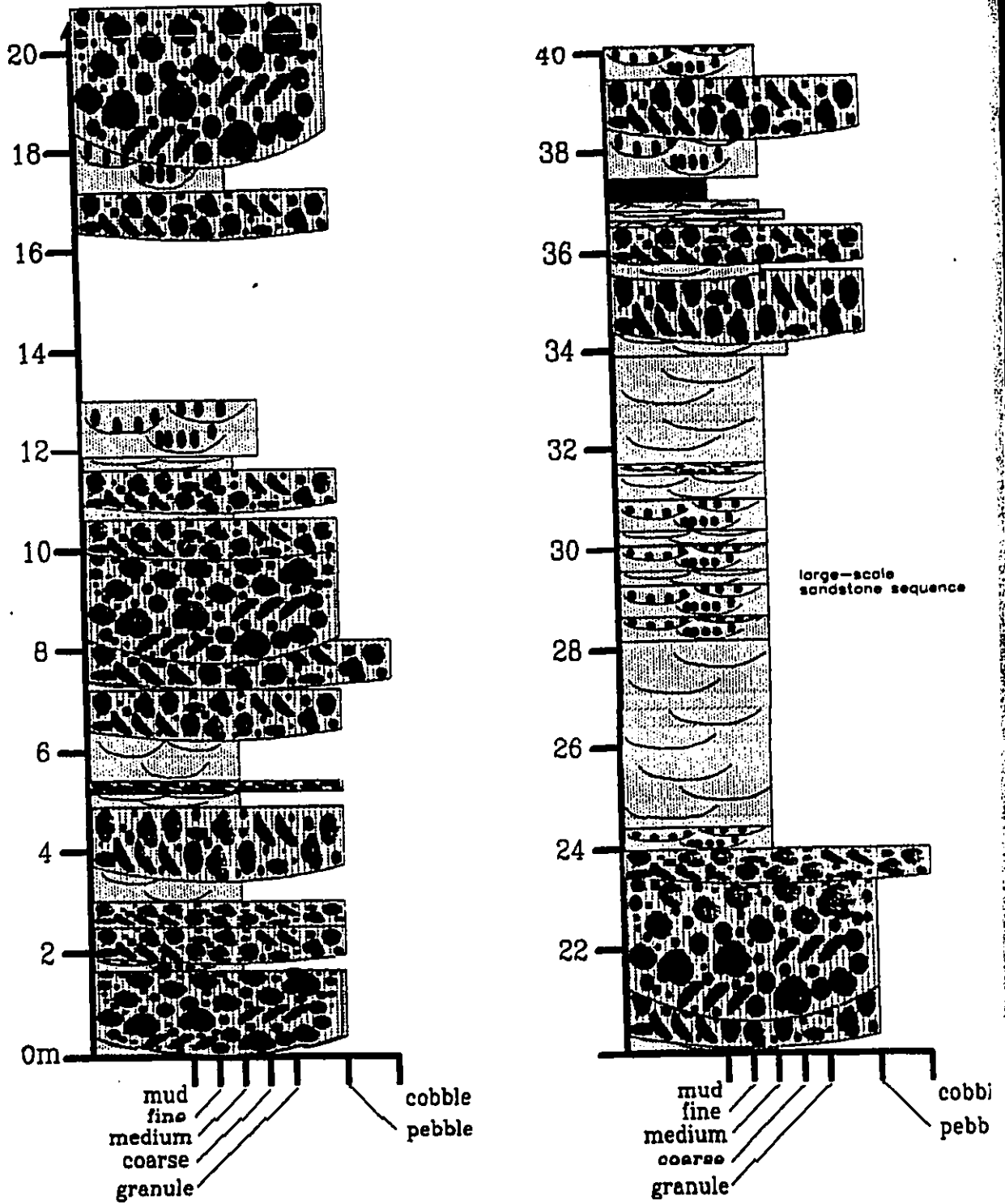
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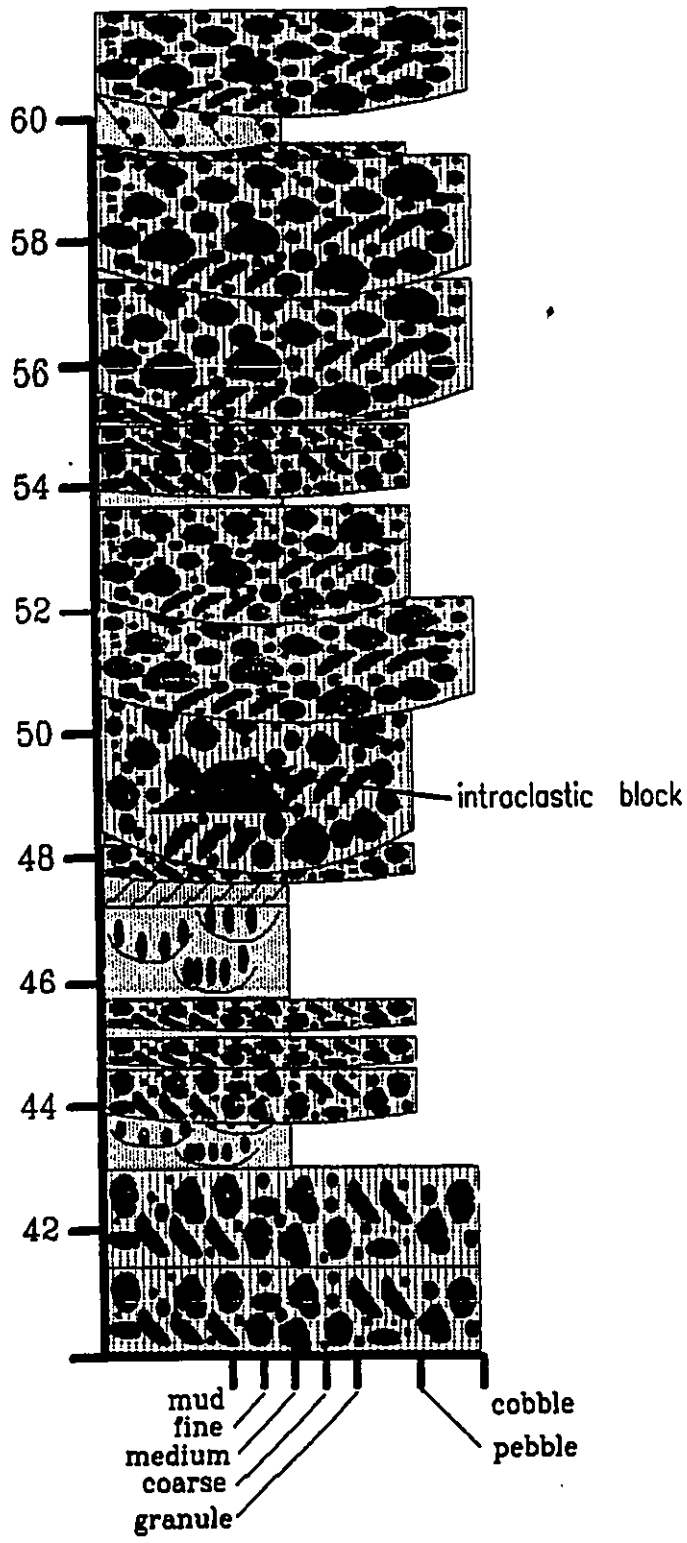
Fig. 4-2



SECTION

H Fig. 4-3





SECTION JA

SECTION JB

SECTION JB

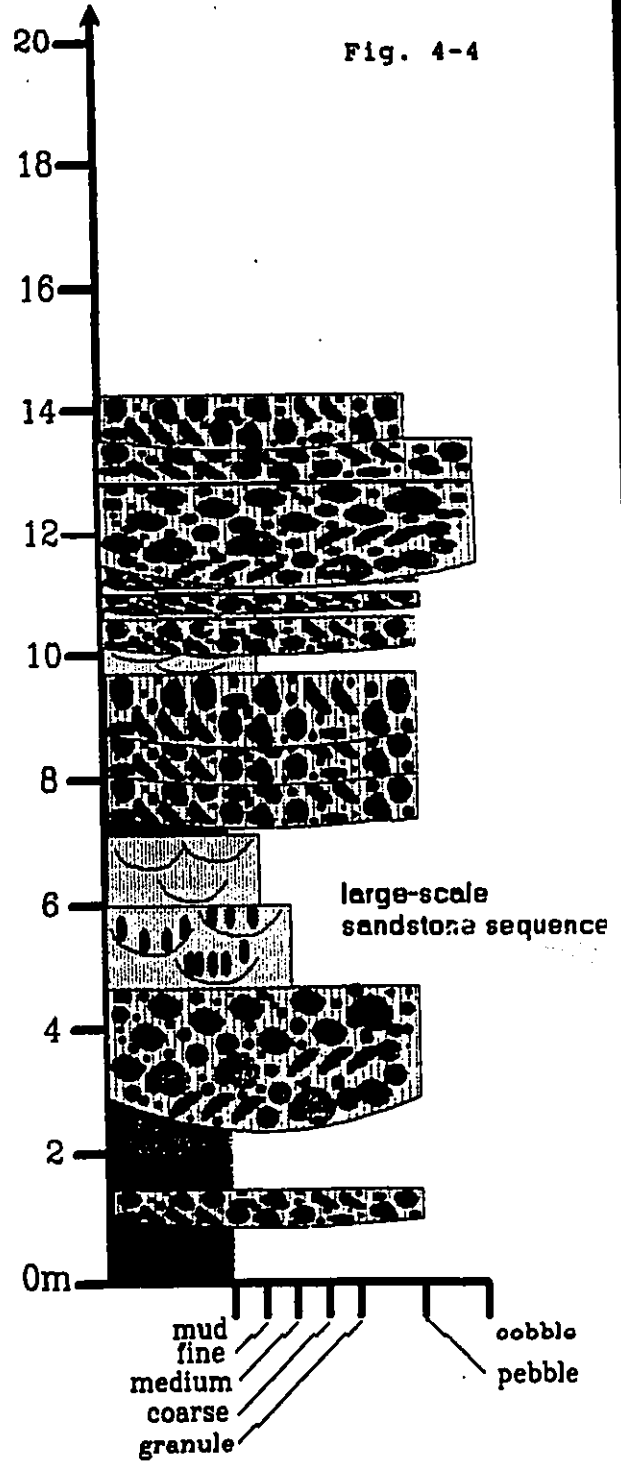
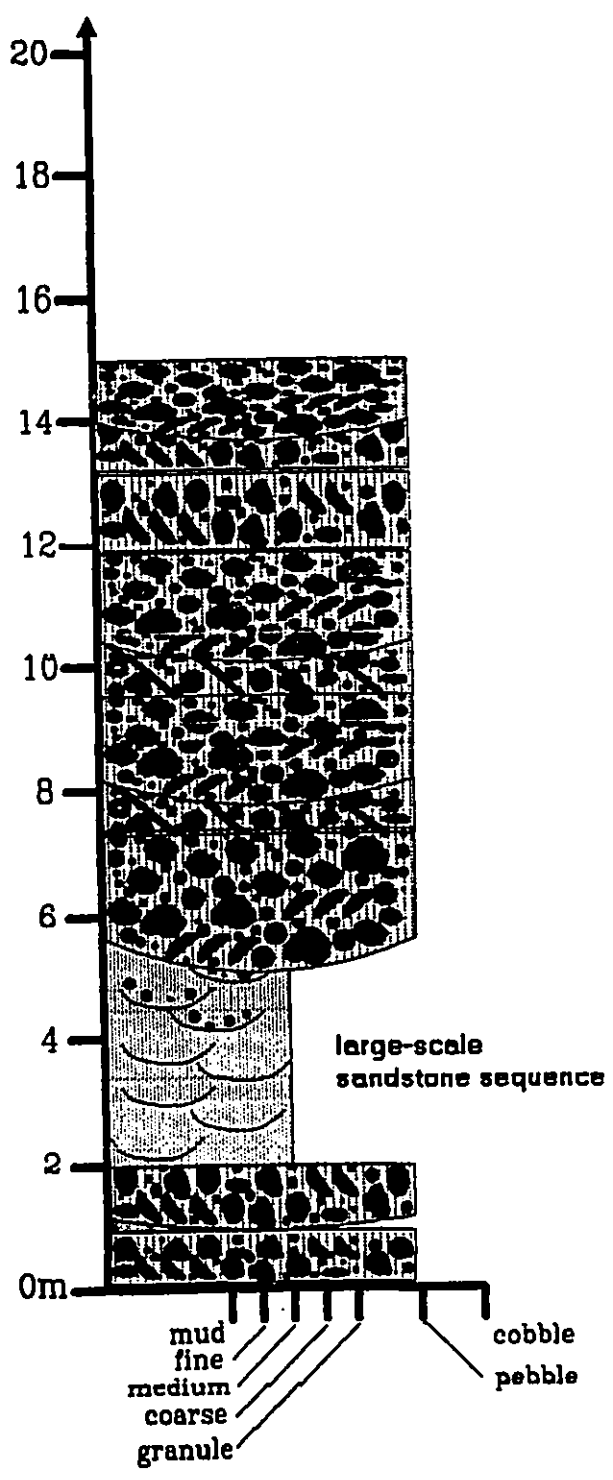
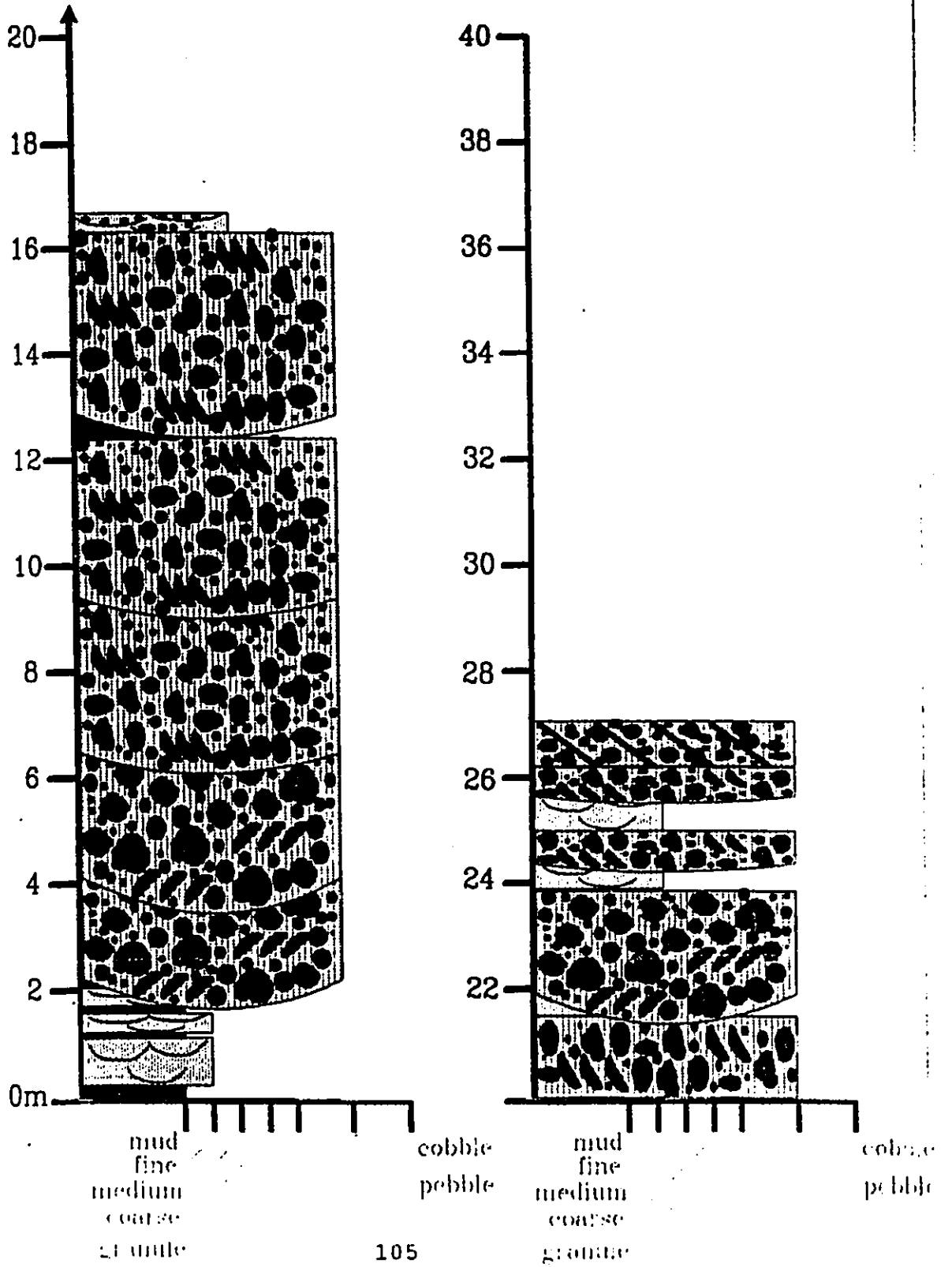


Fig. 4-4

SECTION

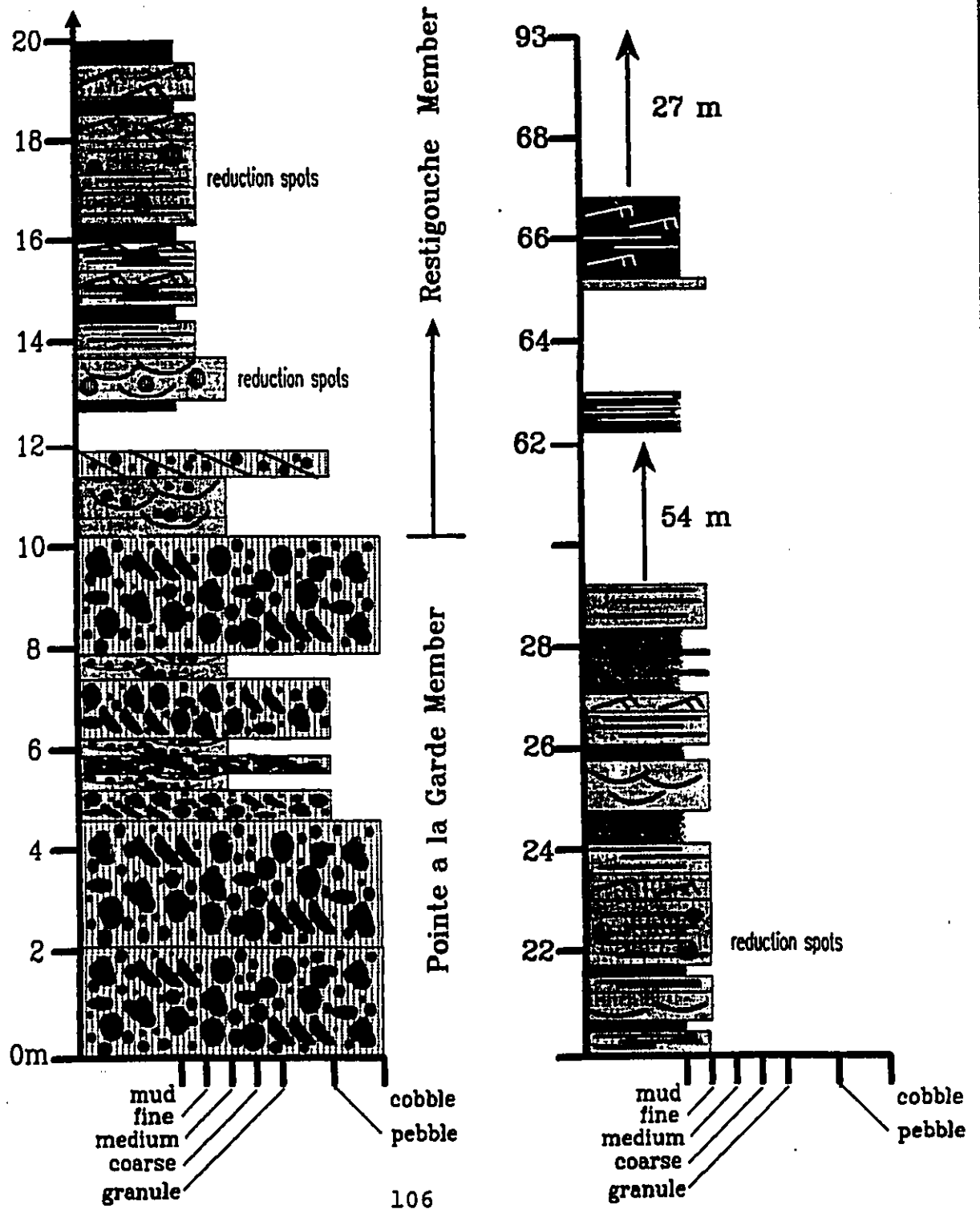
L

Fig. 4-6



SECTION M

Fig. 4-7



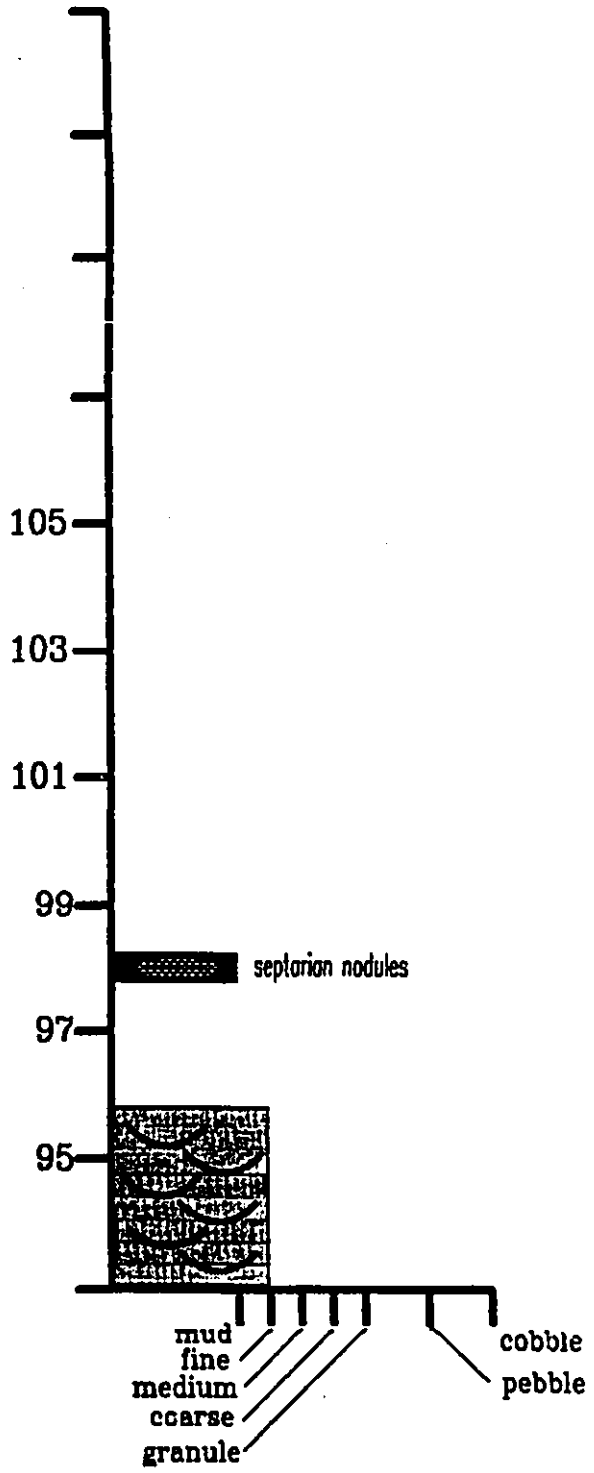


Fig. 4-8

SECTION N

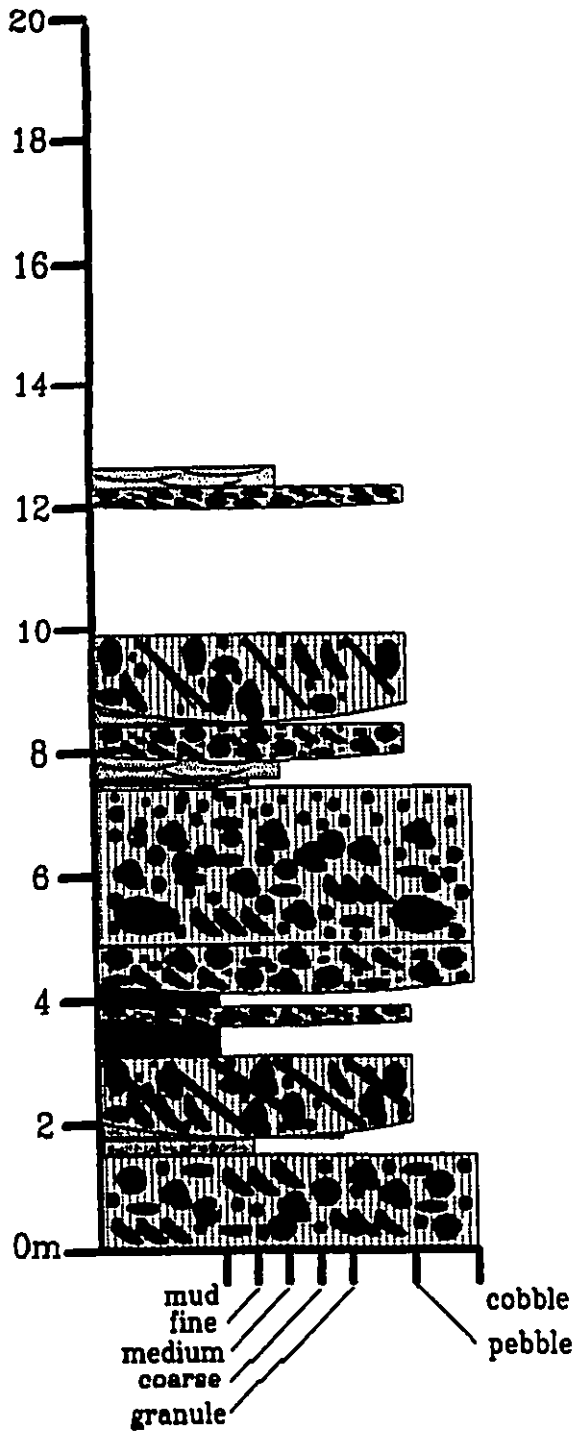
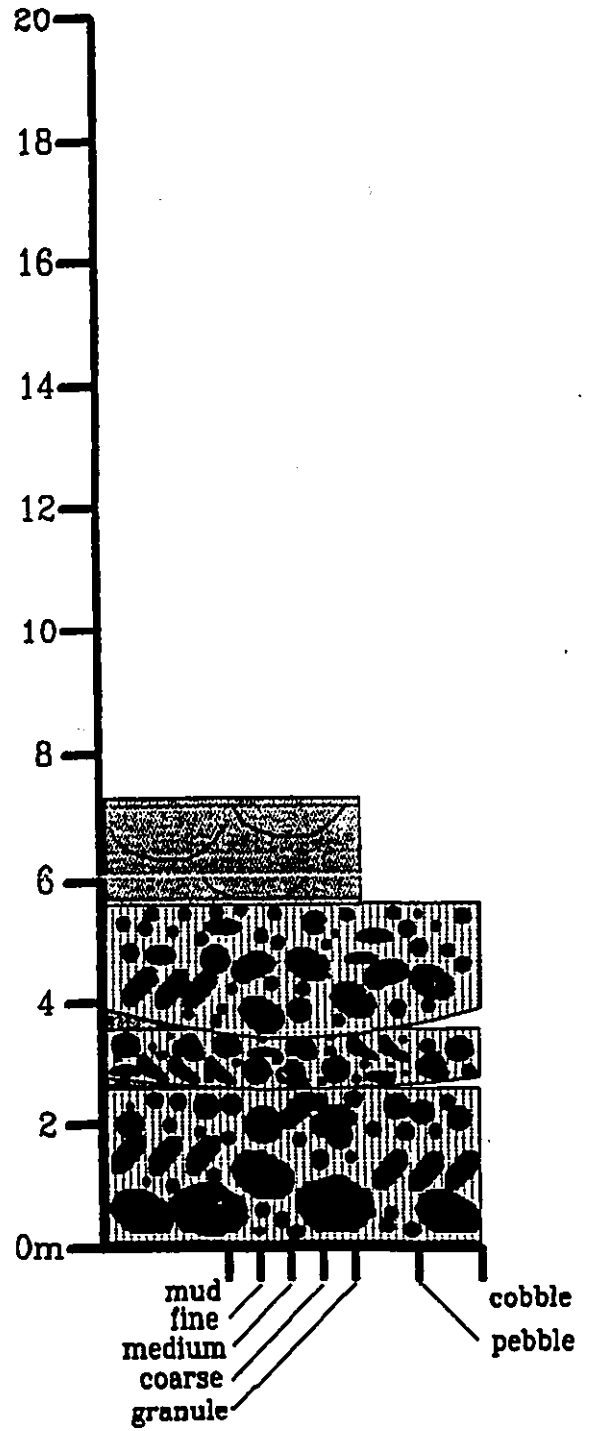


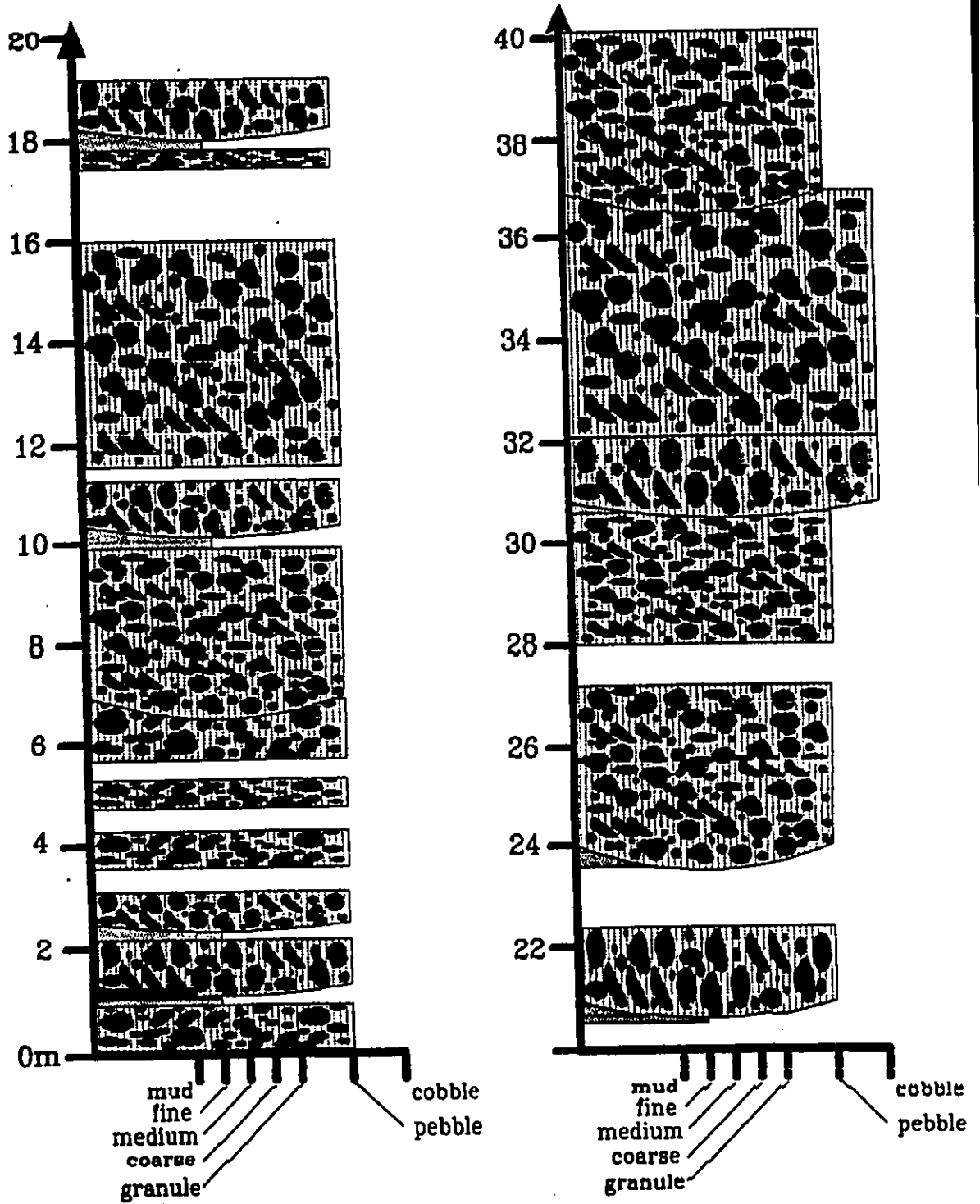
Fig. 4-9

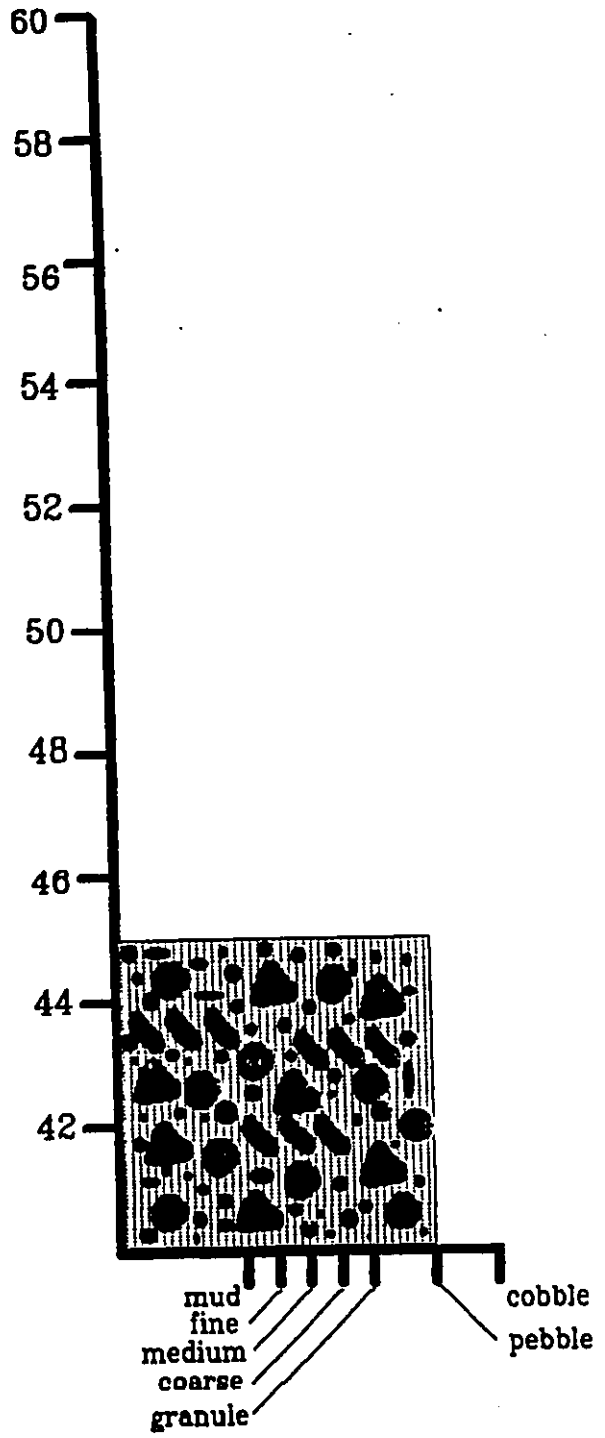
SECTION W



SECTION Y

Fig. 4-10





Sets up to 1.5m in thickness, primarily solitary, exhibiting scoured bases. Foresets exhibit normal grading. Clast composition is similar to that of Gm.

Gt....trough cross-bedded framework cobble to pebble conglomerate. Clasts poorly sorted, moderately to well rounded. Sets up to 2 m thick, solitary or grouped, exhibiting scoured bases. Foresets medium to low angle, exhibiting normal grading. Clasts of similar composition to that of Gm.

St....trough cross-bedded sandstone, pebbly fine to medium grained, moderately well sorted, green to buff coloured lithic arenite. Sets up to 70cm thick, solitary or grouped, medium to high angle, exhibiting scoured bases.

Sp....planar-tabular cross-bedded sandstone, pebbly medium to coarse grained, moderately sorted, green to buff lithic arenite. Sets up to 80 cm thick, primarily solitary, exhibiting a scoured base.

Sh....horizontally bedded sandstone, fine to medium grained, well sorted, green to buff coloured lithic arenite. Bases planar, current lineation on bedding planes, with minor scattered plant fragments.

Sr....ripple cross-laminated sandstone, fine grained, asymmetric, small to large scale current ripples, some lunate, green to buff lithic arenite. Bases planar, with silty flasers and scattered plant fragments.

Se....erosional scour within sandstone. Concave downward basal scour, infilled with poorly sorted sandstone containing abundant muddy intraclasts.

Fm....massive mudstone and siltstone, dark green to black, poorly indurated. Units range in thickness from mm's, representing mud- drapes, to cm's, contains scattered plant fragments.

Fl....laminated shale and siltstone, dark green to black, with scattered plant fragments along bedding planes. Units up to 30 cm in thickness, erosional upper contact.

POINTE A LA GARDE MEMBER

4-4 Description of Sections

Sections were measured at different stratigraphic levels within the Pointe à la Garde Member. The stratigraphically lowermost occurrence of the Pointe à la Garde Member lies less than 10 m above the volcanics of the Dalhousie Group. To the west, the Atholville Member reaches a thickness of 113 m in northern New Brunswick. The absence

of the Atholville Member to the east indicates a rapid eastward thinning (Fig. 1-2). The absence of interbedded volcanics and the presence of a diverse extraformational clast assemblage within the conglomeratic facies at this locality suggests an abrupt, unconformable contact between the Pointe à la Garde Member and the underlying volcanics. Section H is located 127 m above the Dalhousie Group. section F is located approximately 30 m above the top of section H. Sections JA, JB, K, and L are located somewhere within the middle of the member, but precise stratigraphic locations are unknown. Finally, sections M and N are located at the top of the member, and are abruptly overlain by fine grained sediments of the Restigouche Member. Section W occurs at the eastern limit of the main outcrop belt (Fig. 4-1), stratigraphically near the top of the member. Section Y is located within the outlier, north of the village of Grand-Cascapédia and is also located stratigraphically near the top of the member. The Pointe à la Garde Member likely approaches a maximum thickness of 650 m.

4-4-1 Sections F-N

The deposits of sections F-N exhibit two scales of cyclic fining-upward sequences: small-scale (1-6 m), and much larger-scale (10's of m's), which are composed of nested, smaller-scale cycles (Fig. 4-11).

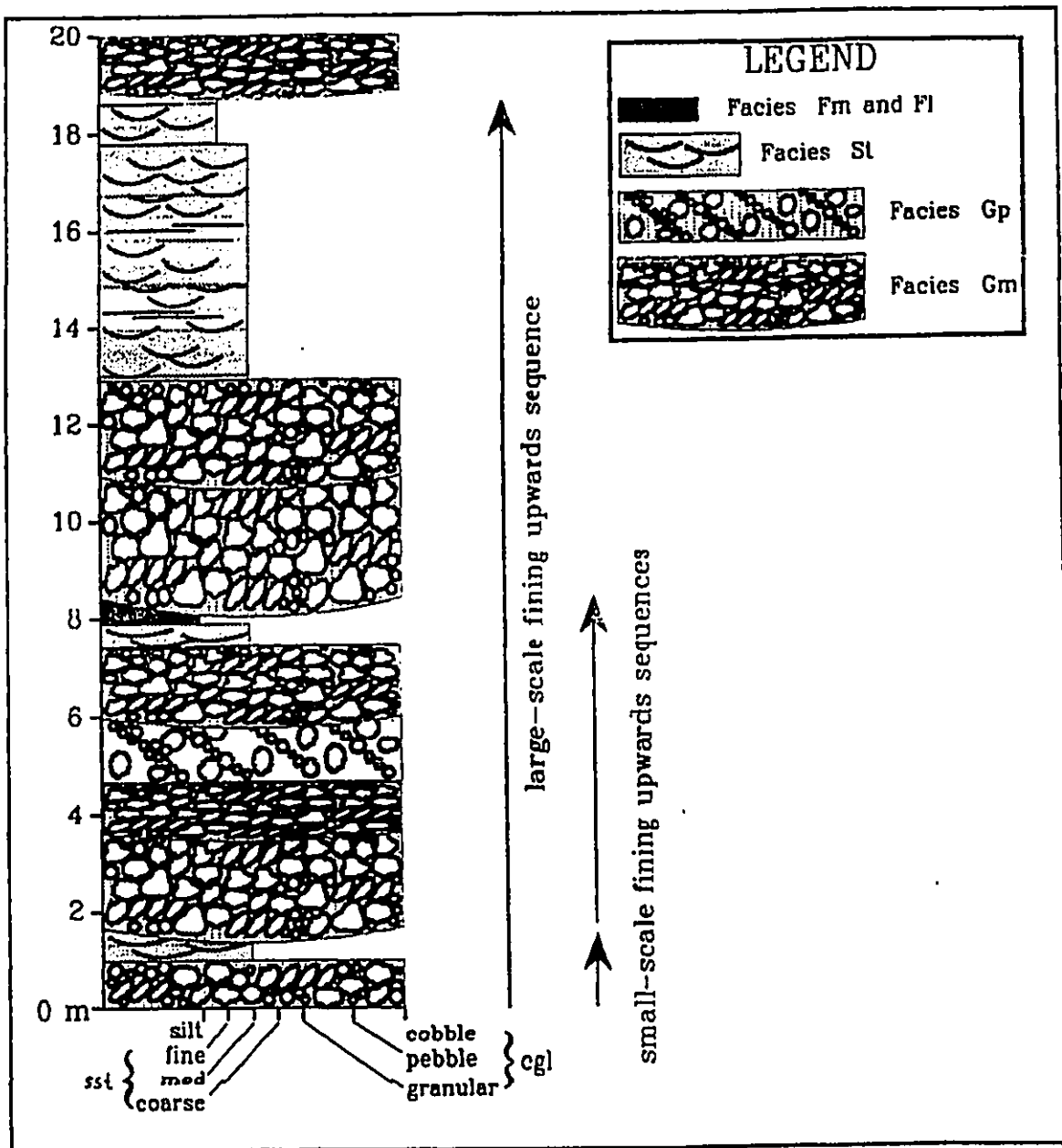


Fig. 4-11 Two scales of fining-upward sequences within an idealized section of the Pointe à la Garde Member. Note the large-scale cross-bedded sandstone sequence near top of section.

A complete small-scale sequence consists of a lower conglomeratic unit composed of facies Gm/Gp, a middle sandstone unit composed of facies St/Sp/Sh/Sl, and an upper argillaceous unit composed of facies Fm/F1 (Fig. 4-2). Complete small-scale fining upward sequences are rare, as the upper fine grained unit is usually absent. Multistorey units of facies Gm are common, forming sequences up to 10 m thick (as at section F and H, Figs. 4-2 and 4-3). Large-scale sequences are much thicker and much more areally extensive. These sequences are composed of a lower portion comprising nested small-scale fining-upward sequences, and an upper portion comprising a thick sandstone sequence.

4-4-1-1 Small-Scale Fining-Upwards Sequences

The small-scale sequences are composed of a lower conglomeratic unit, a middle sandy unit, and an upper argillaceous unit (Fig. 4-11). The sequences are of variable thickness, and variable completeness. The thickest complete fining upward cycle observed was 6.9 m at section F (Fig. 4-2). Multistorey units of facies Gm are common, such as at section JA, where three units of Gm are stacked to form a sequence 10.4 m thick (Fig. 4-4).

Lower Conglomeratic Unit

Description

The lower conglomeratic unit is composed predominantly of facies Gm with rare interbedded facies Gp. The units are broadly lenticular, interfingering laterally with other units of facies Gm or finer grained facies. One unit of facies Gm was traced laterally a distance of approximately 200 m without terminating. The units exhibit an abrupt, slightly scoured base, with local relief up to 1 m. The basal contact may feature gravel-filled, symmetrical gutters 8 to 9 cm deep.

Facies Gm is massive or exhibits crude horizontal stratification (Figs. 4-12 and 4-13). Crude stratification is defined either by thinly interbedded sandstone lenses or by an increase in sandstone content within the matrix, forming parallel horizontal to low-angle dipping beds 10's of centimeters in thickness (Fig. 4-13). Overall, units may exhibit poorly developed coarse-tail normal grading, with disc-shaped clasts showing a strong upstream imbrication. Based upon clast composition, facies Gm may be subdivided into two types; polymictic and oligomictic. Polymictic conglomerate is the most common, and is composed primarily of volcanic clasts, with lesser granites, sedimentary clasts, vein quartz, and jaspers. Polymictic facies Gm occurs as poorly to well sorted pebble or cobble conglomerate. Oligomictic conglomerate is restricted to the



Fig. 4-12. Massive facies Gm, capped abruptly by a lens of medium grained facies St. Section J.

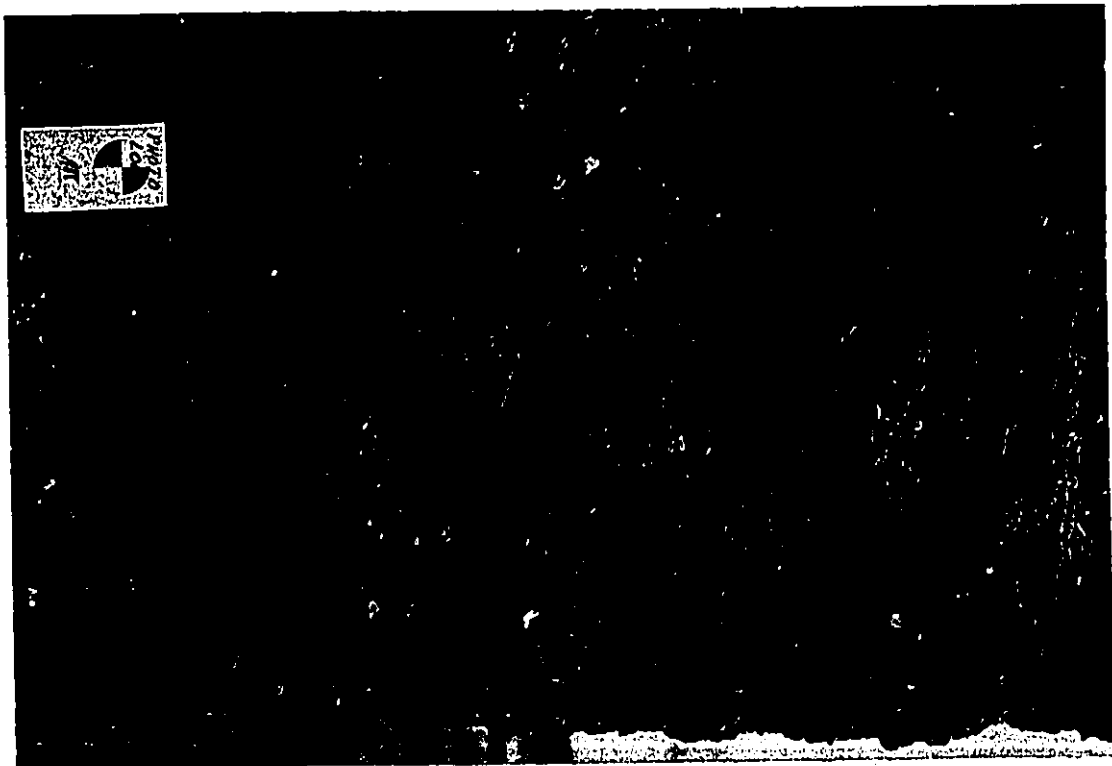


Fig. 4-13. Crude horizontal stratification within facies Gm at section K. Stratification highlighted by interbedded sandstone rich horizons. Book 18 cm long. Arrow points up.

lower portion of the member, occurring as poorly sorted, very dark coloured massive cobble conglomerate (Fig. 4-14). It is composed largely of volcanic clasts, with minor vein quartz. The matrix of the oligomictic conglomerate is poorly sorted, composed exclusively of lithic (volcanic) fragments with minor quartz, and is hematite cemented. Oligomictic units exhibit abrupt scoured basal contacts and abrupt upper contacts, and are overlain by finer grained units of polymictic facies Gm. Facies Gm commonly forms multistorey sequences up to 15 m thick (Fig. 4-15).

Facies Gp occurs as solitary planar tabular sets up to 1.5 m thick that are broadly lenticular. The lenticular units are interbedded with facies Gm, as at section K, where two sets of facies Gp are alternately interbedded with units of facies Gm (Fig. 4-16). Foresets are high angle (up to 27-28 degrees), and exhibit a cyclic alternation between thicker, openwork, well sorted pebble conglomerate and thinner, poorly sorted, framework pebble conglomerate (Fig. 4-17). The openwork portions are calcite cemented, the cement having probably been derived from carbonate clasts within the conglomerate. At section F, a white, very fine powdery clay infills the openwork portions of the foresets, and highlights the high angle dipping foresets of facies Gp, and the low angle dipping parallel surfaces of facies Gm (Fig. 4-18).

Sedimentary intraclasts, composed of facies Fm and Fl,



Fig. 4-14. Bedding plane view of oligomictic facies Gm, composed predominantly of poorly sorted rounded to angular volcanic clasts, with very minor white vein-quartz, section H. Hammer 30 cm long.

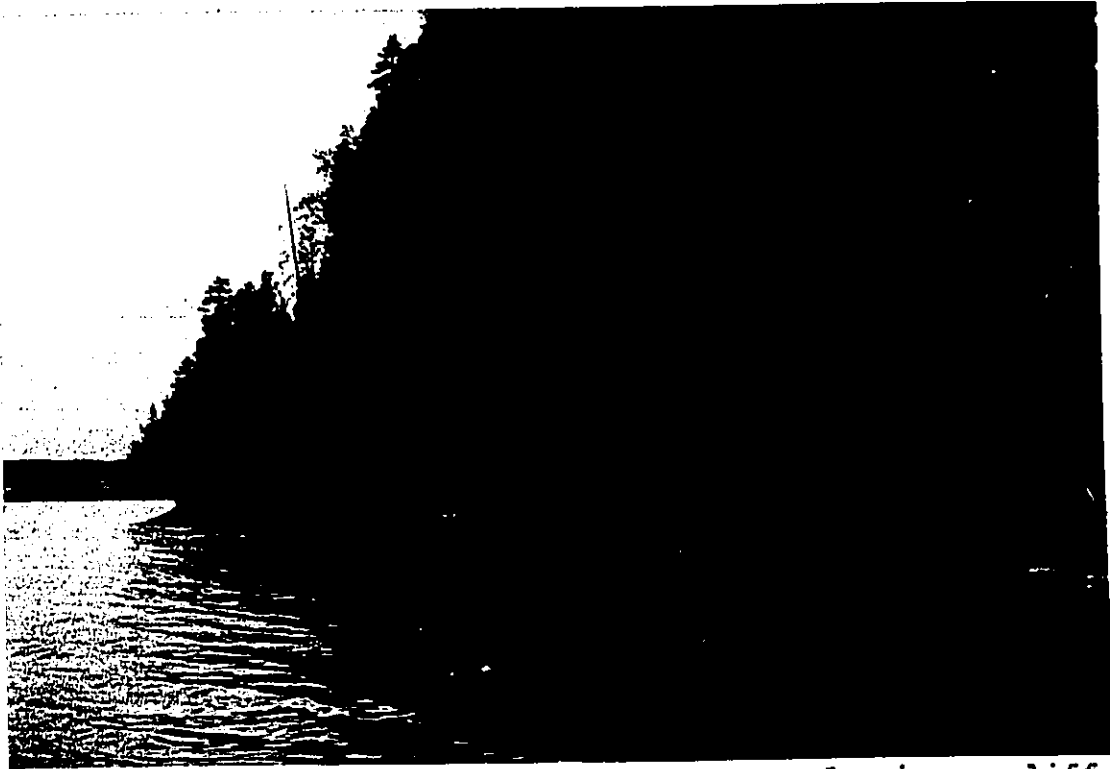


Fig. 4-15. Multistory units of facies Gm, forming a cliff 15 m in height at section F. Overhang to left is the result of wave erosion of a lens of cross stratified sandstone.



Fig. 4-16. High-angle foresets of facies Gp (arrow), 1.5 m high, interbedded with facies Gm. Section K.

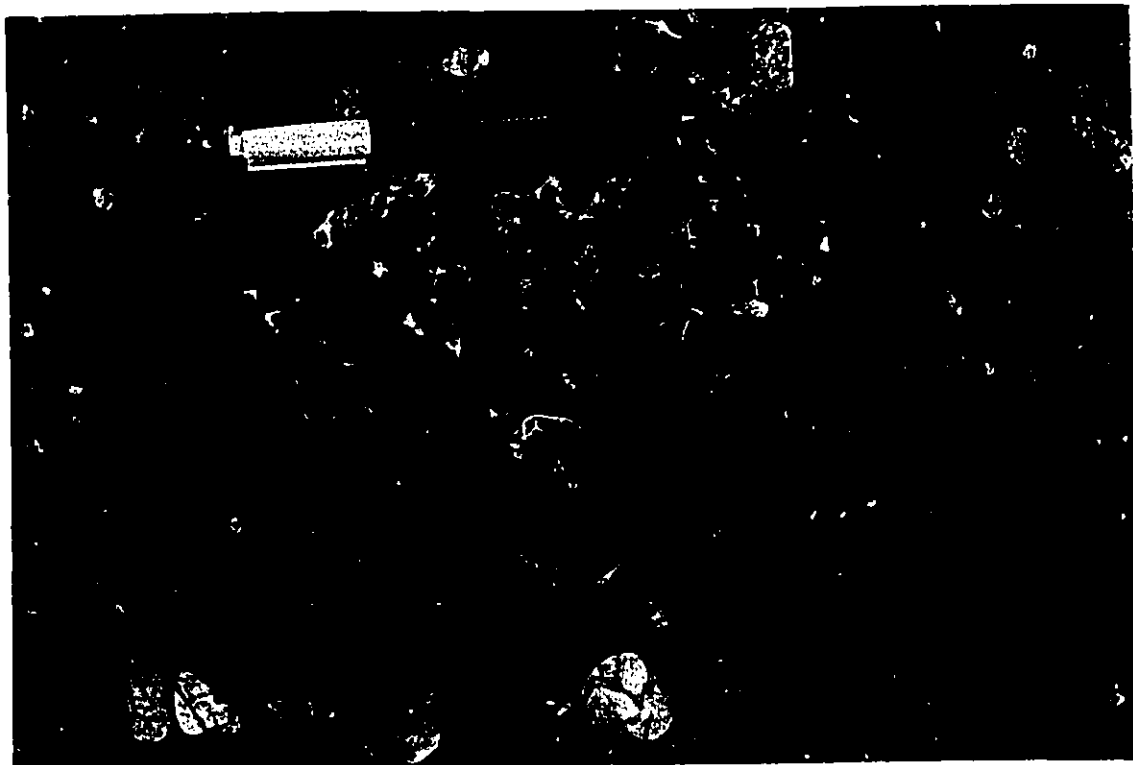


Fig. 4-17. Single foreset of facies Gp, section N. Pen points up. Note the lower openwork calcite-cemented pebble conglomerate grading up to framework granular conglomerate.



Fig. 4-18. Low-angle stratification within facies Gm defined by horizons of very fine white powder (arrows), section K. Stick 1 m long.



Fig. 4-19. Interfingering facies Gm (to right) and finer grained facies Sh/l, Sr, Fl, and Fm (arrows, to left) at section J. Assistant pointing to the base of a single concave-up stringer of facies Gm with prominent gutter casts. Sequence is erosively overlain by facies Gm.

are rare within facies Gm and Gp. A very large angular block up to 1 m in length composed of facies Fl is present at section H (Fig. 4-3). Where facies Gm overlies an upper argillaceous unit, intraclasts are abundant within the lower portion of the conglomeratic unit.

A complex lateral facies transition between a conglomeratic unit composed of facies Gm and an argillaceous unit composed of facies Fm, Fl, and Sr was observed at section JA (Figs. 4-4 and 4-19). Three conglomeratic wedges interfinger with finer grained facies over a distance of 3 m and thicken towards the east, forming a 3.2 m thick unit of facies Gm which exhibits crude horizontal stratification. Similarly, the finer grained wedges, composed of facies Sr, Fl and Fm thicken and amalgamate towards the west forming an argillaceous unit 2.6 m thick. Each wedge of the pebble conglomerate rests abruptly upon an argillaceous unit and exhibits a scoured convex-downward basal contact inclined eastward towards the main body of facies Gm. Each wedge is composed of poorly sorted polymictic pebble conglomerate which grades normally into fine grained interbedded lenses of facies Sl. A parallel series of gutters occurs along the base of the upper two wedges (Fig. 4-19). Thin beds of pebble conglomerate several clasts thick overlie facies Sl. Each wedge is abruptly capped by up to 80 cm of facies Fm/Fl, which pinches out rapidly to the east. The middle

conglomeratic wedge is overlain abruptly by a lens of facies S1 which tapers rapidly towards the west.

Interpretation

Facies Gm is commonly interpreted as the deposits of longitudinal bars (Smith, 1974; Hein and Walker, 1978; Rust, 1978). Longitudinal bars have a rhombic shape in plan view, are elongate parallel to flow, and lack slip faces due to the shallow nature of flow (Rust, 1972). They have gently sloping upstream faces and steeply sloping downstream faces, and an irregular surface with numerous subsidiary channels. Rust (1978) suggested that longitudinal bars are at equilibrium with flow at high flood stage, and migrate upstream or downstream, depending upon flow conditions, while accreting vertically during waning flow. Decreasing flow competency during waning flow results in normal grading. During waning flow, steep flanks are cut into the lateral margins of the bar, around which flow diverges. These flanks become the site of rapid erosion during the next flood event, primarily by undercutting (Rust, 1972).

Horizontal stratification within facies Gm is a result of fluctuations in flow strength during the flood stage, when net deposition is occurring upon the bar surface (Miall, 1970). The low angle inclination of this stratification is related to the upstream or downstream inclination of the bar surface (Rust, 1972). Clasts

deposited upon the bar surface exhibit a marked upstream imbrication of the a-b plane for disc-shaped clasts, and a long axis orientation perpendicular to flow for rod-shaped clasts (Rust, 1972, 1978).

Facies Gp is interpreted as the deposits of downstream migrating slipface bars, with foresets exhibiting a well defined cyclic size sorting (Steel & Thompson, 1983; Rust, 1984). Rust (1984) noted a vertical sequence from framework pebble conglomerates to poorly sorted sandstone overlain by openwork pebble conglomerate with calcite cement within foresets of facies Gp from the Malbaie Formation of eastern Gaspé. Each cycle was interpreted by Rust (1984a) as representing a low rate of avalanching of the poorly-sorted bedload fraction followed by rapid avalanching of well-sorted minor bedforms down the foresets.

The generation of slipfaces was observed to occur during waning flood stage within the Donjek River by William & Rust (1969). Emergence of longitudinal bars resulted in the divergence of flow into adjacent channels and the lateral accretion of gravel onto bar flanks. The occurrence of a lateral facies change from facies Gm to Gp observed within the Malbaie Formation of eastern Gaspé by Rust (1978, 1984a) is explained by this process, as is the occurrence of facies Gp interbedded with facies Gm within the deposits of the Pointe à la Garde Member of the Campbellton Formation.

The basal conglomeratic unit therefore represents deposition of the coarsest fraction of bedload during waning flood stage. Deposition occurred by the aggradation and migration of longitudinal barforms, as indicated by the observed normal coarse-tail grading within facies Gm. The broadly lenticular nature of the lower conglomeratic units indicates that flow was confined within very broad channels, at least several 100 m's in width. Horizontal stratification within facies Gm indicates fluctuations in flow during high stage flood events or a succession of different flood events. The interfingering relationship between facies Gm and Sh, Fm and Fl at section JA indicates that several flood events may be responsible for the deposition of a unit of facies Gm. During the waning stage, flow divergence around the emerging longitudinal bars resulted in the accretion of facies Gp onto the lateral margins of some bars, while undercutting and the creation of steep flanks occurred on other margins, as indicated by the steeply erosional nature of some units of facies Gm. The multistorey nature of thick sequences of facies Gm records the complex depositional and erosional history of numerous longitudinal bars on the braidplain.

Middle Sandstone Unit

Description

Within an idealized small-scale fining-upward sequence, the lower conglomeratic unit is overlain by a sandy unit which comprises facies St, Sh/l, Sp, or Sr. The basal contact of the sandy unit is abrupt and planar, with only minor scour, although some contacts exhibit deep erosional relief (section H, Fig. 4-3). The sandy unit is composed of facies St and Sp, which occurs as solitary sets up to 70 cm thick or as grouped cosets (Figs. 4-3 and 4-4). Facies St is composed of well sorted fine to medium grained sandstone, and may contain abundant well rounded extraformational and angular intraformational pebbles along foresets and basal scours. Facies Sp and Sh/l are often commonly interbedded within the unit. Facies Sp occurs exclusively as solitary sets up to 80 cm thick, composed of well sorted medium grained sandstone, occasionally containing extra and intraformational pebbles along foresets (Fig. 4-20). The foresets of facies Sp are high angle and normally graded. Facies Sh/l occurs directly above the conglomeratic unit in some cases (sections J, F, L, Figs. 4-2, 4, 6), but usually occurs interbedded within grouped cosets of facies St. Only rarely is facies Sr interbedded with cosets of facies St (section K, Fig. 4-5). Some of the units exhibit normal grading (section JB, Fig. 4-4).

The sandy units are of variable thickness, allowing for

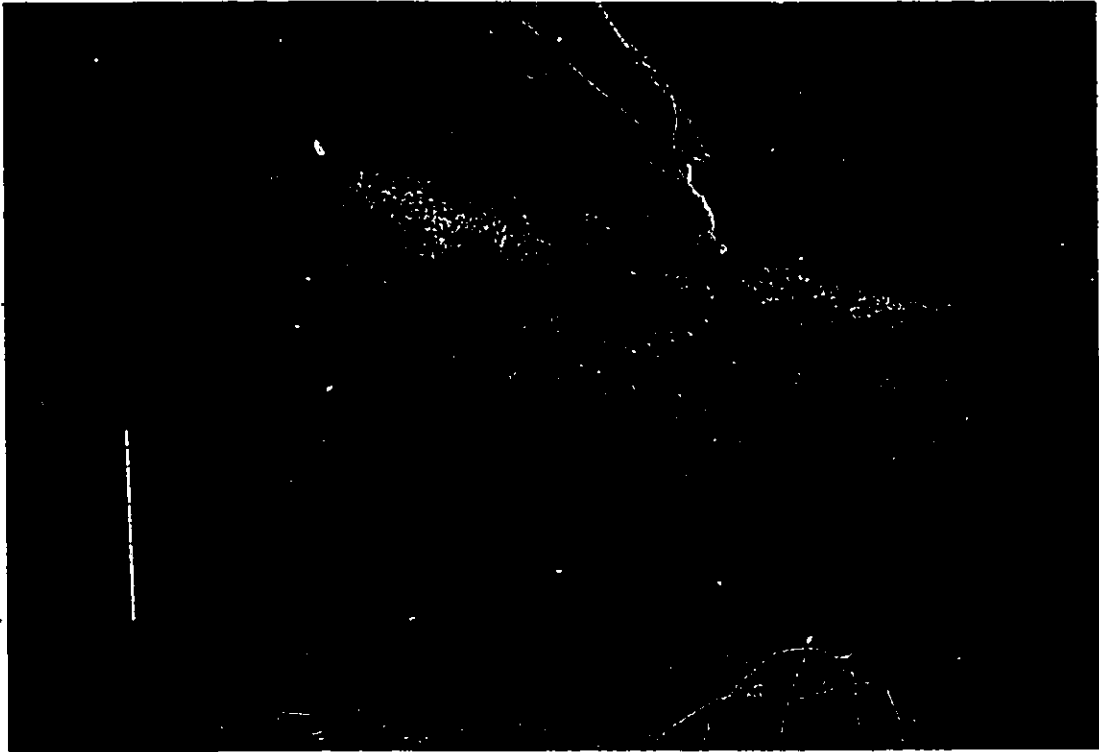


Fig. 4-20. Deeply scoured unit of facies Sp, with recessively weathering muddy intraclasts along foresets at section H. Paleoflow to left (northwest). Facies Sp erosively overlies oligomictic facies Gm, and in turn is overlain by a strongly channelized unit of polymictic facies Gm. Stick 1 m long.

the recognition of two distinctive types: a thin, laterally restricted highly lenticular type (Fig. 4-21), and a thick laterally extensive and broadly lenticular type (Fig. 4-22). The first type is by far the more common, forming units up to 2.0 m thick of limited lateral extent (10's of meters). The latter are rare, up to 10 m in thickness and several 100 m's in width, and will be discussed in more detail in another section.

Interpretation

Facies St represents the downstream migration of sinuous crested megaripples (Harms et al., 1982). Likewise, facies Sp represents the downstream migration of straight-crested megaripples or sandwaves (Harms et al., 1982). Williams & Rust (1969) and Rust (1972) noted that facies Sp was observed only on relatively high terraces within the Donjek River, while large scale trough cross-bedding dominated lower terraces. A similar phenomenon within the sandy Platte River was noted by Smith (1971, 1972). This led Rust (1984a) to conclude that facies St was deposited within relatively deeper portions of a channel than facies Sp. Facies Sh/l with current lineation, represents deposition on a relatively shallow planar surface under upper flow regime conditions (Harms et al., 1982).

The lenticular nature of the sandy units indicates that flow was channelized. The predominance of facies St



Fig. 4-21. Interbedded lens of facies St within facies Gm at section F. Facies St exhibits scoured upper contacts and scattered pebbles along foresets. Hammer 30 cm long.



Fig. 4-22. Thick buff-coloured laterally extensive sandstone sequence composed of grouped cosets of facies St at section F. This sequence is approximately 4 m thick.

within the sandy unit of the fining-upward sequence suggests that flow within the channels was relatively deep (Rust, 1984a), although interbedded facies Sp and Sh/1 suggest that water depth within the channels fluctuated over time due to fluctuating discharge. The middle sandstone unit is interpreted as a deposit characteristic of waning flood or normal stream flow within braided channels.

Upper Argillaceous Unit

Description

The upper argillaceous unit is composed of facies F1 and Fm, and abruptly or gradationally overlies the middle sandy unit. In rare instances, the unit abruptly overlies a unit of facies Gm, as at section N (Fig. 4-8) and section JA (Fig. 4-4). The argillaceous units are composed of facies F1 and Fm and may contain interbedded facies Sr (section I, Fig. 4-23). The units are highly lenticular, up to 2.5 m thick, and exhibit a non-scoured, concave-up basal contact and scoured tops. Pedogenic features such as roots and caliche are absent, as are subaerial exposure features such as mud cracks and rainprints.

Interpretation

Facies F1 of the upper argillaceous unit represents deposition primarily from suspension or from very gentle flows (Miall, 1978). Interbedded facies Sr represents very



Fig. 4-23. Thinly interbedded facies Sr and Fl, abruptly draping a unit of facies Gm with imbricate clasts (flow to left), section L. Lense cap 6 cm in diameter.

slow and shallow flow (Harms et al., 1982). Facies Fm is most likely weathered facies F1, causing the fine laminations to be obscured.

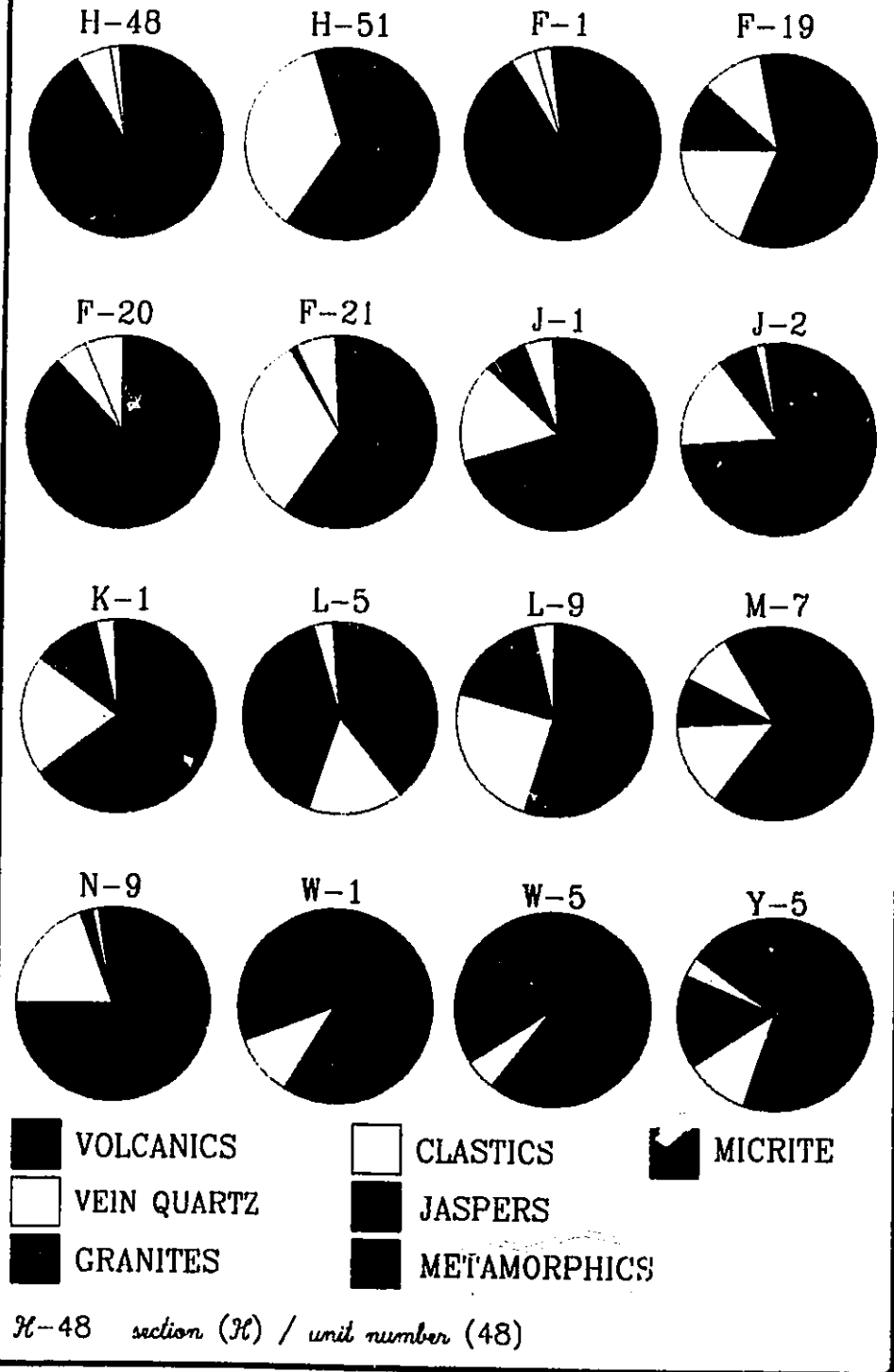
The highly lenticular nature of some of these units and the non-erosive, gradational, concave-up basal contact with the underlying sandstone unit indicate that some of the argillaceous units represent passive infilling or vertical aggradation within a channel, with deposition primarily from suspension and from slow moving flow. Other units are more tabular in nature, and are apparently cut by gravelly channel fills, such as the unit which interfingers with a lower conglomeratic unit at section JA. This indicates that the argillaceous unit was deposited upon the floodplain as overbank material. Deposition in this setting occurred during high flood stage when flow overtopped channels and spread onto the floodplain, depositing sediment from weak flow and from suspension within ponds. The absence of pedogenic features such as roots and caliche, and indications of subaerial exposure such as desiccation cracks and rainprints, suggests that these deposits were not subaerially exposed for extended periods. Although Early Devonian vegetation was very primitive (Schumm, 1968), rooted land plants did exist (Gensel, 1987). The absence of evidence for subaerial exposure coupled with the scarcity of argillaceous units within the Pointe à la Garde Member is indicative of the unstable nature of the braided system.

Channels within braided fluvial systems are prone to migration, accomplishing a great deal of erosion during high magnitude flood events. Fine grained units deposited between flood events are particularly subject to reworking, especially in Early Paleozoic times, when the stabilizing influence of land plants was minimally developed (Schumm, 1968; Cotter, 1978).

4-4-1-1-1 Clast Composition

Pebble counts from facies Gm were performed at several stations at each section within the Pointe à la Garde Member (Fig. 4-24). A 50 x 50 cm box was outlined and all pebbles with apparent long axes greater than 1 cm were measured and categorized according to lithology. The following types, in order of decreasing abundance, were observed: volcanics (intermediate to acidic), milky white vein quartz, granite, metasediments, red jasper, light grey micritic limestone, and schist. Metamorphic clasts are exceedingly rare, with only two being recovered from all of the stations. No systematic trends were observed except for the limestone clasts, which make their first appearance at section M near the top of the member. The oligomictic conglomerate of facies Gm is composed primarily of volcanic clasts (88-89%), lesser vein quartz clasts (5-9%), jaspers (1-2%), and sedimentary intraclasts (1-6%).

Fig. 4-24: Clast Composition Pl. a la Garde Member



4-4-1-1-2 Paleocurrent Trends

Paleocurrent trends from pebble imbrication within facies Gm at sections H-M are presented in Table 4-1 and Fig. 4-25. Vector magnitudes greater than 0.30 are considered significant based upon the Rayleigh test of significance (Curry, 1956). The trends exhibit almost 100 degrees of variability, with a grouped mean of 247.1 degrees. Polymictic and oligomictic facies Gm exhibit similar trends. Paleocurrent trends obtained from gutters at section JA indicate a southwest-northeast direction of flow (Table 4-1).

Paleocurrent trends from section N, located at the top of the member, depart substantially from those lower in the member. Imbrication from facies Gm indicates a south-southeasterly direction of flow (Table 4-1) (Fig. 4-26).

4-4-1-2 Large-Scale Fining-Upwards Sequences

A large-scale sequence comprises a lower portion composed of nested smaller-scale fining-upward conglomeratic sequences and an upper portion composed of a thick sandstone (Fig. 4-11). Proportionally, the lower portion is much thicker, attaining a minimum thickness of 28.5 m. The upper portion approaches a maximum thickness of 10 m (section H, Fig. 4-3), and abruptly overlies the lower coarser grained portion. Although no complete sequence was observed (defined above and below by a thick sandstone

TABLE 4-1

PALEOCURRENT TRENDS FROM POINTE A LA GARDE MEMBER

Clast Imbrication From Facies Gm

Station	Vector Mean	Number of clasts	Vector Magnitude
F*	231.0	33	0.72
F	137.8	30	0.62
F	321.6	30	0.45
H	239.2	30	0.61
H*	233.3	30	0.83
I	198.9	28	0.59
J	231.0	44	0.41
J	264.0	31	0.31
J	295.9	32	0.76
K	226.7	31	0.70
K	318.6	30	0.53
M	330.3	30	0.34
N	169.5	34	0.72
W	131.9	20	0.89
W	158.6	23	0.65

Other

Station	Type	Vector Mean	Number of measurements	Vector Magnitude
J	scours	317.7	3	0.58
J	gutters	254.0	2	1.00
J	facies St	023.8	14	0.66
K	parting			
	lineation	335.3	3	1.00
K	facies St	013.2	8	0.94

* monomictic units

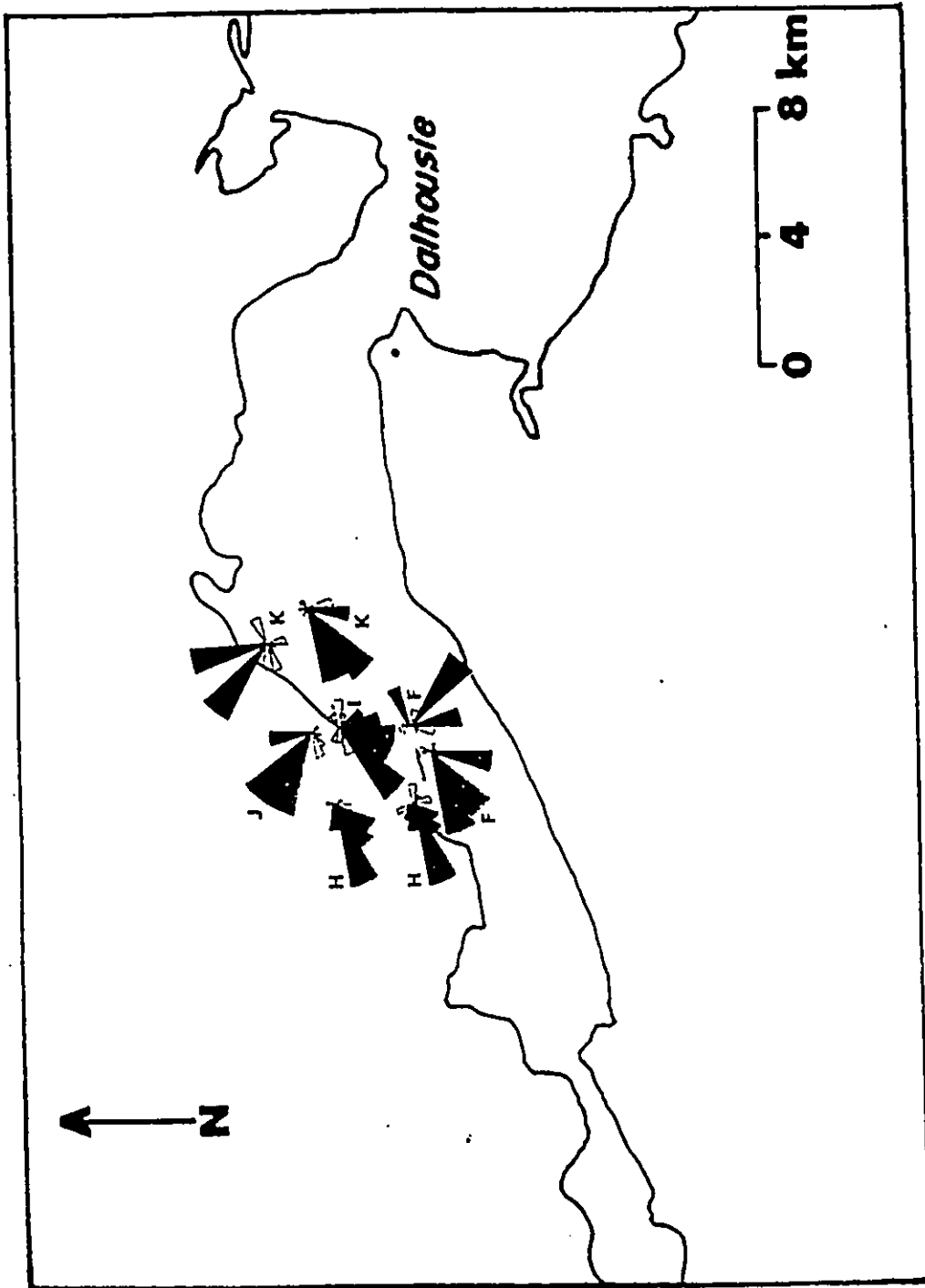


Fig. 4-25 Paleoflow trends within the Pointe à la Garde Member obtained from imbrication of facies Gm (see Table 4-1 for more detail). Upsection direction west to east.

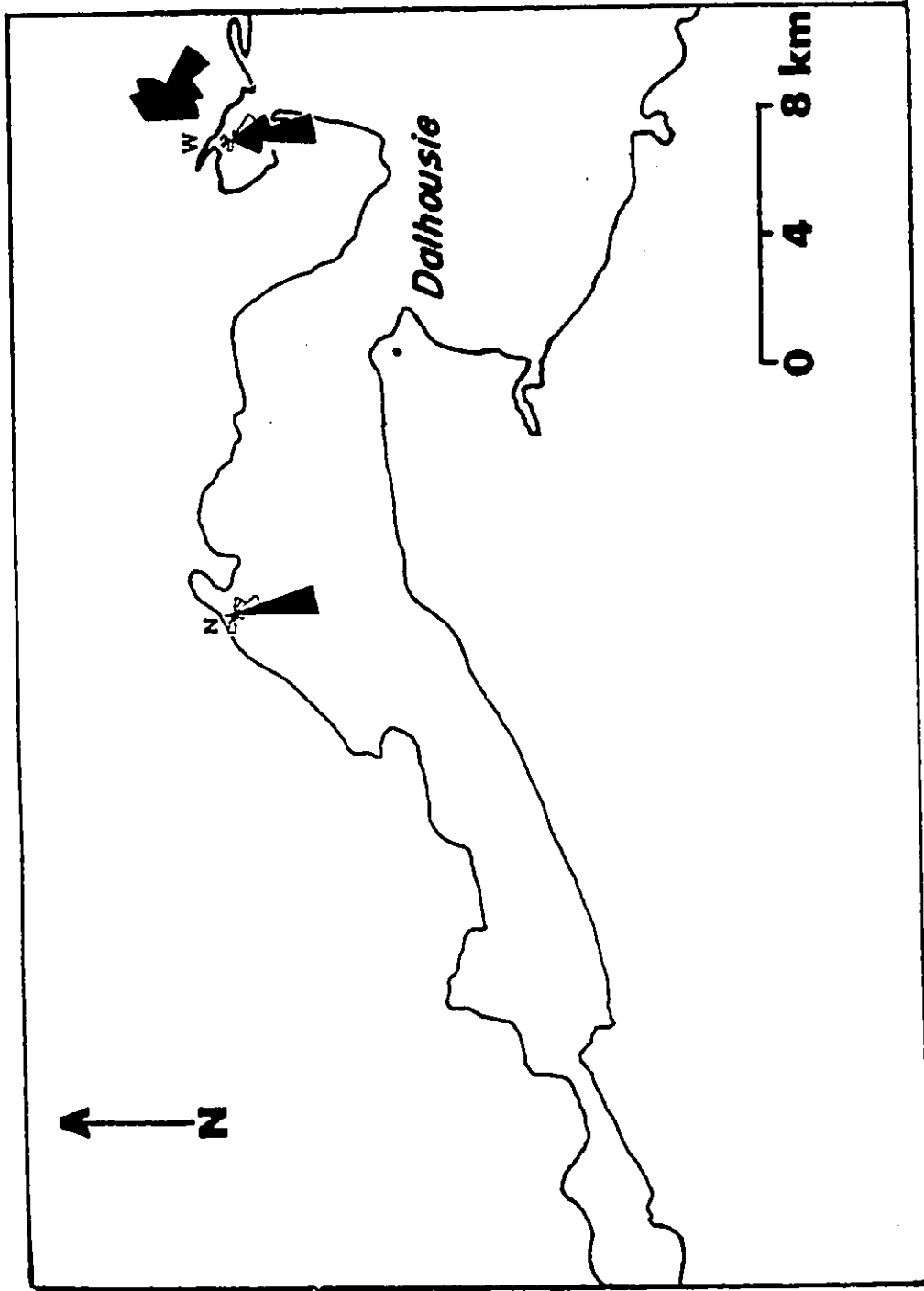


Fig. 4-26 Paleoflow trends within the uppermost part of the Pointe à la Garde Member (sections W and N), obtained from imbrication of facies Gm (see Table 4-1 for more detail).

sequence), a least three such large-scale sequences occur within the Pointe à la Garde Member. The sequence is most easily delineated by the presence of the thick sandstone sequence, which comprises the top of the large-scale fining-upward sequence.

The thick sandstone sequences are composed predominantly of facies St, with lesser facies Sh/1 and Se. Facies St is fine to medium grained sandstone and occurs as grouped cosets, with individual sets up to 50 cm thick (Fig. 4-27 and 4-28). Cosets are bounded by low-angle concave-up erosional surfaces, overlain by up to 2 cm of fine grained, poorly sorted sandstone with abundant plant fragments (Fig. 4-29). Facies Sh/1 is fine to medium grained and occurs as thin lenticular units interbedded with facies St. Three thick sandstone sequences were observed, one each at sections H (Fig. 4-3), F (Fig. 4-2), and JA (Fig. 4-4) to L (Fig. 4-6). The thick sandstone sequence at section H approaches 10 m in thickness. The sequence between sections JA (Fig. 4-4) and L (Fig. 4-6) was traced 250 m laterally, is broadly lenticular, fines upwards, and fines towards the east.

Each thick sandstone sequence is abruptly overlain by facies Gm, which forms the lower conglomeratic unit of a small-scale fining-upward sequence. The minimum thickness of a single large-scale fining-upward sequence therefore is 34 m (section F, Fig. 4-2).



Fig. 4-27. Large sets of facies St within a thick laterally extensive sandstone sequence at section JA. Stick 1 m long.



Fig. 4-28. Grouped cosets of facies St within a thick, laterally extensive sandstone sequence, section J. Paleoflow to upper left (north). Book 18 cm long.



Fig. 4-29. Massive, poorly sorted low-angle concave-up erosion surfaces (arrows) at the base of coSETS facies St within thick, laterally extensive sandstone sequences, section J. Lense cap 6 cm in diameter.

4-4-1-2-1 Paleocurrent Trends

Paleocurrent trends obtained from facies St within the thick sandstone sequences at sections JA and K exhibit a strong north-northeasterly direction of flow (Table 4-1, Fig. 4-30). Trends from current lineation within facies Sh/1 and from the orientation of basal scours of facies Se exhibit northwest-southeast paleoflow.

4-4-2 Section W

Section W is located at the eastern limit of the main Campbellton Formation outcrop belt, south of the town of Nouvelle, P.Q. (Fig. 4-1). The section is 7.5 m thick, and is composed of three small-scale fining-upward sequences of similar character to those described previously, although much coarser grained (Fig. 4-9). The first cycle exhibits a lower conglomeratic unit composed of poorly sorted normally graded facies Gm, 2.6 m in thickness. The unit is polymictic, with scattered rounded to well rounded boulder sized clasts near the base (Fig. 4-31). The remaining two cycles also contain lower units composed of polymictic facies Gm, but lack boulder sized clasts.

A similar sequence located stratigraphically above this section crops out sporadically on a low knoll located 200 m to the north of section W. The sequence is composed of 2.5 m of massively weathering very fine sandstone and siltstone, overlain by 9.6 m of loosely consolidated and poorly exposed

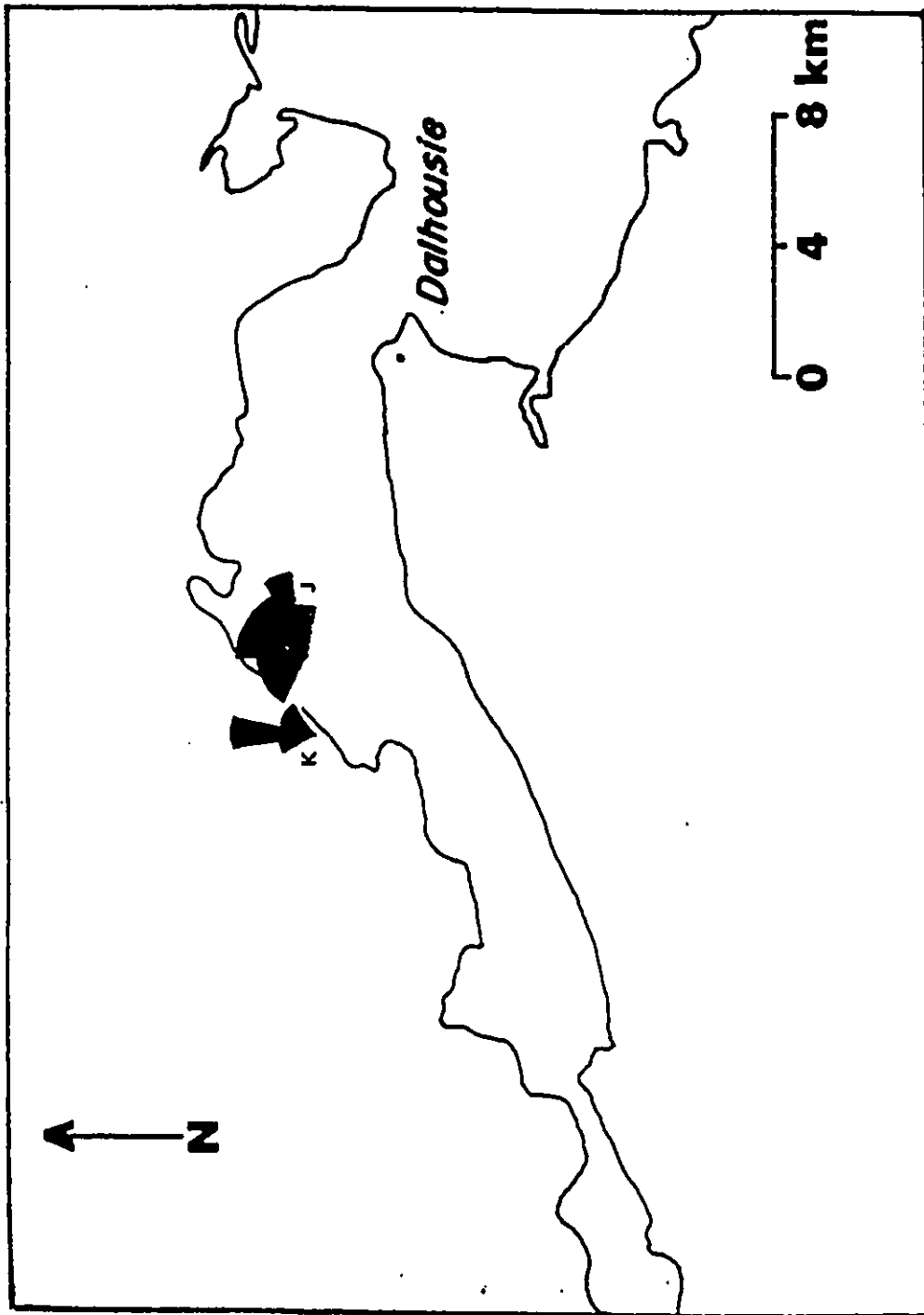


Fig. 4-30 Paleoflow trends within the large-scale sandstone sequences of the Pointe à la Garde Member obtained from facies St (see Table 4-1 for more detail).

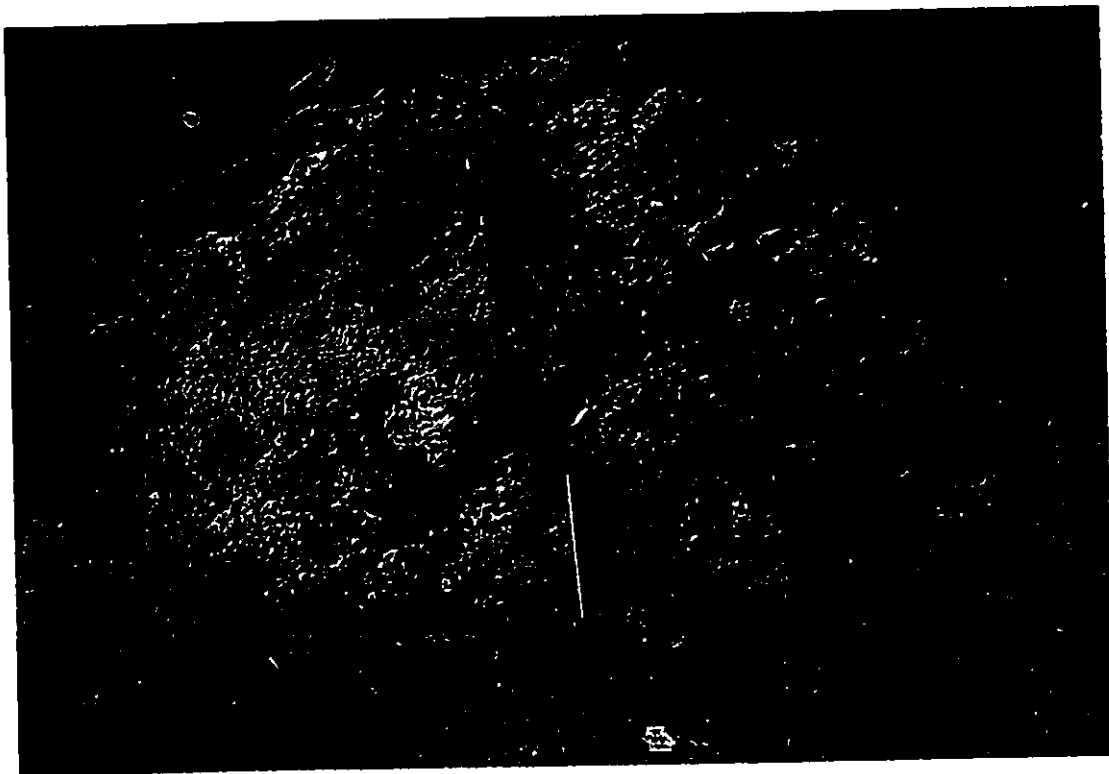


Fig. 4-31. Two small-scale fining-upwards sequences within the Pointe à la Garde Member at section W. Base of the lower sequence exhibits well rounded granitic and limestone boulders (arrow) within a normally graded unit of facies Gm. Pogo 1 m long.

facies Gm, similar in character to the lower unit at the base of section W. The boulder conglomerate is in turn overlain by 3.2 m of poorly exposed pebble conglomerate.

4-4-2-1 Clast Composition

Two stations reveal a significant amount of limestone within facies Gm (Fig. 4-24). The occurrence of limestone clasts suggests stratigraphic equivalence with the highest part of the Pointe à la Garde Member at section H.

4-4-2-2 Paleocurrent Trends

Imbrication within facies Gm exhibits a strong southerly direction of transport (Table 4-1, Fig. 4-26).

4-4-3 Section Y

Section Y is located within the eastern outlier, where it is bounded east and west by faults (Fig. 4-1).

Strata of the Campbellton Formation within the outlier are highly faulted and tend to be vertically dipping. The measured section is 40 m thick, and is composed primarily of facies Gm (94%), with lesser sandy facies St, and very minor facies Fm (Fig. 4-10). The bottom portion of the section is composed of small-scale fining-upward cycles, very similar in character to those discussed previously. The lower units are composed of facies Gm and Gp, cobble to pebble conglomerate, with facies Gp exhibiting calcite-cemented

foresets.

The section is capped by a 15.5 m thick sequence composed of multistorey units of facies Gm (Fig. 4-10). The sequence generally fines upwards from cobble to pebble conglomerate.

4-4-3-1 Clast Composition

Clast composition is very similar to that of sections W and the upper portion of section N, exhibiting a minor amount of micritic carbonate clasts (Fig. 3-24). This suggests a stratigraphic position near the top of the Pointe à la Garde Member.

4-5 Depositional Environments

Braided fluvial deposits commonly display a marked vertical cyclicity. Cycles are generated by autocyclic and allocyclic processes, which may act independently or in combination. Allocyclic processes such as climate and tectonics generally result in the formation of very large scale cycles, such as fining or coarsening upwards sequences 100's of meters in thickness deposited in response to uplift or subsidence. Autocyclic processes tend to form cycles a few meters in thickness, and are reflective of processes acting within the fluvial system, such as point bar accretion, flood events, channel accretion, migration, etc.

Two scales of fining-upward sequences are present within

the deposits of the Pointe à la Garde Member (Fig. 4-11). The small-scale fining-upward sequences are interpreted as reflective of autocyclic processes, while the much larger-scale fining-upwards sequences are attributed to allocyclic processes.

Miall (1977, 1978) and Rust (1978) proposed 6 models for braided fluvial deposits, many of which are composed of cyclic fining upward sequences of various scales, each representing a fixed point within a spectrum of variability.

In terms of these models, the Pointe à la Garde Member of the Campbellton Formation is similar to the Scott and Donjek models of Miall (1978) and the GII model of Rust (1978). Miall (1978, 1980) proposed that each small scale fining-upward cycle was the product of a flood event which resulted in the migration and aggradation of gravelly bars, followed by accretion of the sandy facies. This, however did not lend insight into the generation of much larger (10's of meters) scale fining-upward cycles, which Miall (1977) explained in terms of aggradation of the fluvial system above the surrounding floodplain. Miall (1980, 1981a, 1981b) later attributed these large-scale sequences to allocyclic processes related to tectonic and climatic events.

Rust (1978, 1981) did not formally recognize small-scale fining upward cycles within the GII model, which is based on the proximal reaches of the modern Donjek River (Williams and Rust, 1969; Rust, 1972) and the Lower Devonian

Malbaie Formation of eastern Gaspé (Rust, 1981). The GII model is dominated by facies Gm and Gp, with various sandstone facies forming only a very minor percentage of the deposit. Rust (1978, 1981) interpreted the alternation between conglomeratic and sandstone facies as the product of deposition during waning flood-flow. The scarcity of sandstone within the Malbaie Formation is due to the poor preservation potential of sandy facies, which are subject to erosion during subsequent flood events. Indeed, within the proximal reaches of the Donjek River, finer grained facies are relatively abundant after a flood, but their position upon the floodplain makes them highly susceptible to reworking during the next flood event (Rust, 1972).

Steel (1974) described small-scale fining-upward sequences from the Devonian New Red Sandstone of Scotland, which are very similar to those present in the Pointe à la Garde Member of the Campbellton Formation. Each of Steel's (1974) sequences is composed of a conglomeratic base (facies Gm), overlain by a unit of coarse grained sandstone (facies St/Sp and Sr), which in turn may be overlain by a finer grained sandstone or siltstone unit. Steel (1974) interpreted these sequences as the product of waning flood deposition within relatively well defined channels marked by concave-up erosion surfaces.

According to Miall (1977), there are four main processes acting within fluvial systems which result in net

deposition: cycles of flooding, lateral accretion, channel aggradation, and channel reoccupation. Based on these processes, it is possible to reconstruct the sequence of events which resulted in the creation of both the small and large-scale fining-upward sequences in the Pointe à la Garde Member of the Campbellton Formation.

4-5-1 Small-Scale Fining-Upwards Sequences

Deposition of the Pointe à la Garde Member was characterized by punctuated flood events which resulted in the net erosion of fine grained deposits, followed by deposition during waning flow. The coarsest fraction of bedload was deposited on longitudinal bars, which aggraded vertically and may also have migrated upstream or downstream. The lateral migration of gravel along the flanks of the longitudinal bars during waning flow resulted in the generation of slipfaces, and the formation of facies Gp. As flow velocity and discharge continued to decrease, these bars emerged, resulting in flow diversion and channelization around them. As flow continued to wane, deposition of the sandy fraction occurred within deep channels, primarily in the form of downstream migrating sinuous-crested megaripples. The lenticular nature of the sandy units indicates that flow was relatively more strongly channelized, as opposed to the tabular or broadly lenticular nature of facies Gm, which indicates that the longitudinal

bars were relatively unconfined. The minimum lateral extent of a single unit of facies Gm is nearly 200 m, indicating rather broad channel tracts. Deposition of sandstone occurred on the flanks of the longitudinal bars during normal flow. Facies transitions from St-Sp/Sh indicate that water levels within the channels fluctuated during shallowing of the flow. These channels gradually became infilled, with the deposition of the argillaceous upper unit occurring when flow was very weak and shallow.

Deposits of fine grained material also accumulated on topographically higher reaches of the system and are preserved at section JA. These deposits however had very low preservation potential. During the following flood event, argillaceous and sandy units underwent erosion, with migration of gravelly barforms being reactivated during falling stage. This resulted in the superposition of facies Gm upon older facies Gm, and on abandoned channel deposits, and also accounts for the intraclast-rich nature of the basal portions of some Gm units.

The occurrence of facies Gp within the Pointe à la Garde Member indicates that the longitudinal bars were of relatively higher relief than those of modern braided rivers, where facies Gp is rarely observed. This implies significantly deeper flow which is likely related to climatic factors discussed in more detail later.

The small-scale fining-upward sequences within the

Pointe à la Garde Member therefore are interpreted as waning flood-flow deposits on a proximal braidplain. The relative abundance of sandy and finer grained facies compared to other proximal braidplain deposits such as those found within the Malbaie Formation and the proximal reaches of the Donjek River suggests that the floods during La Garde time were slightly less energetic than those during Malbaie or modern time. This may be due to the La Garde braidplain being relatively unconfined. Rust (1984a) suggested that braided rivers confined within valleys are less likely to maintain extensive floodplain areas where finer grained deposits can accumulate.

4-5-2 Large-Scale Fining-Upward Sequences

The thick sandstone sequences of the Pointe à la Garde Member indicate a change in fluvial style which affected large parts of the braidplain. The sequences within the Pointe à la Garde Member of the Campbellton Formation are similar in nature to the sandstone sequences observed within the Malbaie Formation of eastern Gaspé, which Rust (1984a) interpreted as the deposits of a proximal sandy braidplain. The abundance of facies St indicates relatively deep flow. The broadly lenticular nature of these sequences, as well as the vertical and lateral fining trends are indicative of deposition on a sandy braidplain. Paleocurrents indicate a north-northeasterly flow direction, almost at right angles

to that of the gravelly braidplain.

Palaeomagnetic evidence indicates that the Gaspé Peninsula occupied an equatorial latitude during much of the Early Paleozoic (Van der Voo, 1988). The absence of Fe oxide staining and caliche indicates that the climate was not semi-arid (Williams, 1973). The climate during Pointe à la Garde time therefore was likely hot and humid, with abundant perennial rainfall, resulting in numerous episodic large-scale flood events. Palaeomagnetic evidence indicates latitudinal stability throughout the Devonian, which suggests that no major climatic fluctuations occurred, perhaps indicating that tectonic rather than climatic processes are responsible for the generation of the large-scale fining-upward sequences.

The most important tectonic influence upon sedimentation is the rate of uplift or subsidence. Under rapid rates of subsidence or uplift, large-scale coarsening upwards sequences are generated as an alluvial system progrades rapidly basinwards (Steel et al., 1977; Steel and Aasheim, 1978). In slowly subsiding basins, where the rate of uplift is slower than the rate of erosion, fining-upward sequences are generated (Miall, 1980). Pulses of such uplift or subsidence therefore will create a series of large scale fining-upward sequences, similar to those observed within the Pointe à la Garde Member. That this uplift was the result of compressive folding is suggested by the

absence of alluvial fan deposits, which are indicative of fault controlled basin margins (Rust, 1984; Miall, 1981a). The deposits of alluvial fans should be the coarsest facies present, although it is possible that they are simply not exposed. Pulsating uplift along the eastern margin of the basin caused by compressive folding during the early phases of the Acadian Orogeny led to the westward progradation of a proximal gravelly braidplain represented by the lower portion of the large-scale sequences. During quiescence, a sandy, low-energy braidplain, represented by the deposits of the thick sandstone sequences, encroached eastwards.

The deposits at section Y differ somewhat from those of the remainder of the Pointe à la Garde Member. The sequence is composed primarily of longitudinal bar deposits, indicative of flood dominated deposition. The finer grained sediments deposited during waning and normal flow were removed during the next flood event. This suggests that deposition on the braidplain at locality Y was more energetic than at other localities of the Pointe à la Garde Member. The deposits of section Y are comparable to Miall's (1978) Scott type and Rust's (1978) GII type models. Both of these models are representative of marginal alluvial fan deposition. Whether this sequence was actually deposited upon an alluvial fan is unknown, as no deposits characteristic of proximal fan facies have been identified. Paleocurrent trends within section Y are unknown, however,

it is in a proximal position with respect to the general paleoflow pattern.

The small-scale fining-upward sequences at section W were created in a similar manner to those of the remainder of the Pointe à la Garde Member, except that they are coarser grained. This indicates that section W was located relatively closer to the source or basin margin than section M which, by virtue of its clast composition, is thought to be correlative to section W. The deposits of section W were also deposited in a proximal gravelly braidplain environment.

Based upon the appearance of limestone clasts within the upper portion of the Pointe à la Garde Member, a rough correlation can be made between sections M, W, and Y, all of which contain limestone clasts. Coupled with paleocurrent data, the gross morphology and orientations of the depositional system during the final stages of Pointe à la Garde Member deposition are revealed. The basin was supplied with sediment from the northern margin by a southward trending fluvial system.

The appearance of limestone clasts within the upper part of the member is significant, as it preceded a major change in depositional environments represented by the fine grained Restigouche Member of the Campbellton Formation. Up to that point, sediment was supplied to the basin by uplift and dissection of the volcanics and associated intrusives of

the Dalhousie Group to the east. Granitic and vein quartz clasts originated from associated intrusives similar to those near Bathurst and Val d'Amour in northern New Brunswick (Alcock, 1935). By late Pointe à la Garde Member time, faulting along its northern margin may have altered the basin configuration as well as the morphology of the depositional systems within it. This faulting controlled sedimentation within the Gaspé Basin during the remainder of the Middle Devonian.

POINTE A BOURDEAU MEMBER

4-6 Description and Interpretation of Sections

Exposures of the Pointe à Bourdeau Member occur along highway 132, 2.8 km west of Cross Point, P.Q. (sections A and B, Figs. 4-32 and 4-33), and along the shoreline between Campbellton and Atholville, N.B. (section P, Fig. 4-34, Fig. 4-1). Section P rests conformably upon the Atholville Member, and is located stratigraphically within the lowermost portion of the Pointe à Bourdeau Member. sections A and B occur approximately 103 m above the nearest volcanics of the Pointe la Nim Formation of the Dalhousie Group.

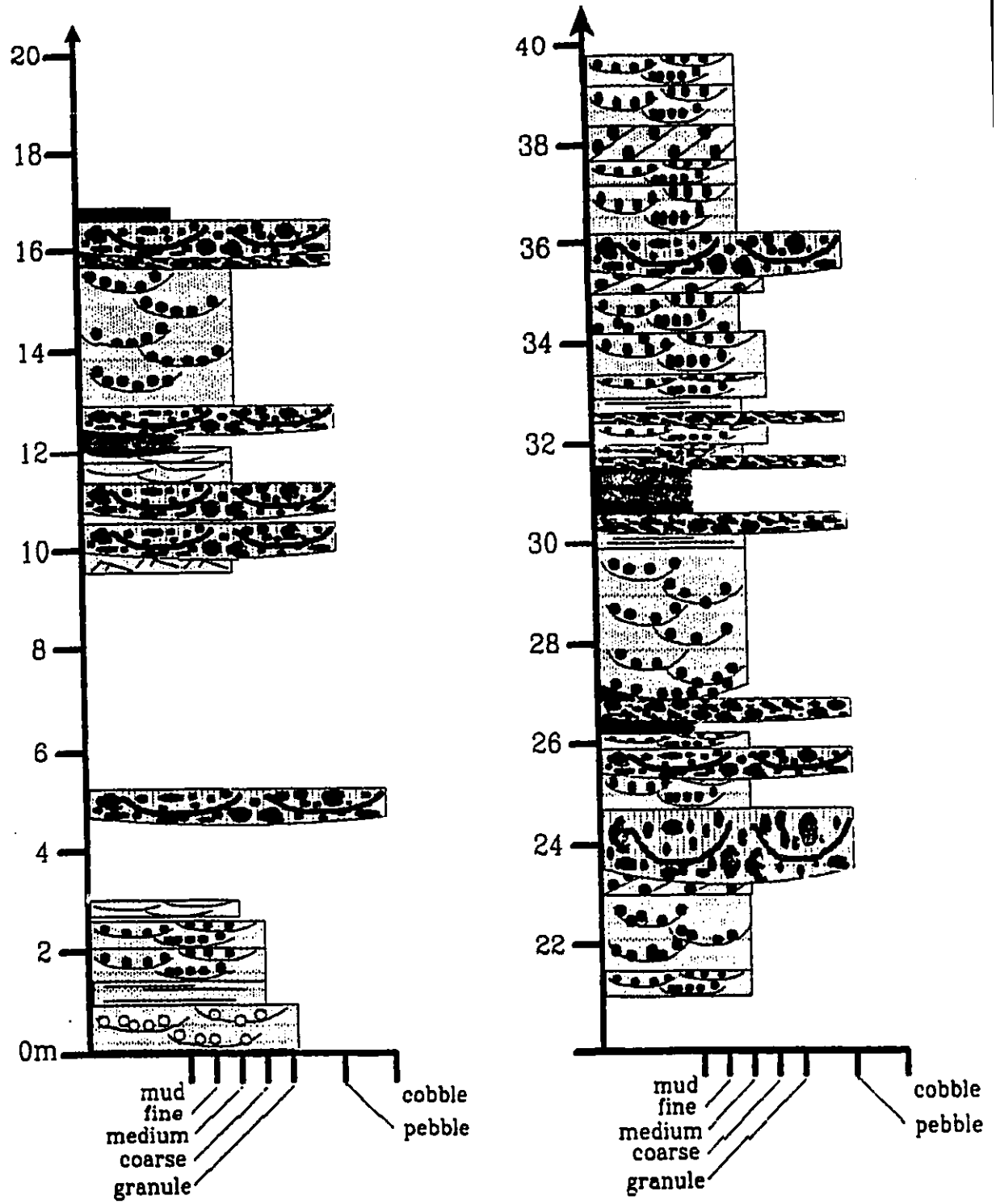
4-6-1 Sections A and B

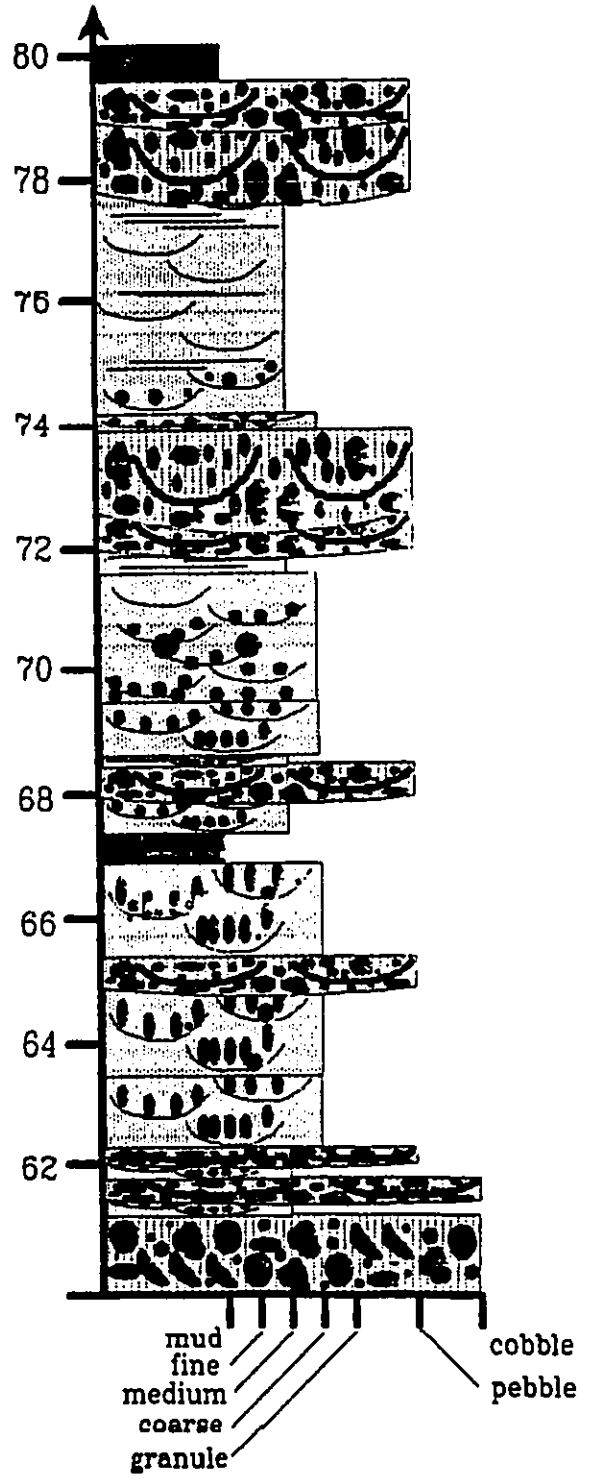
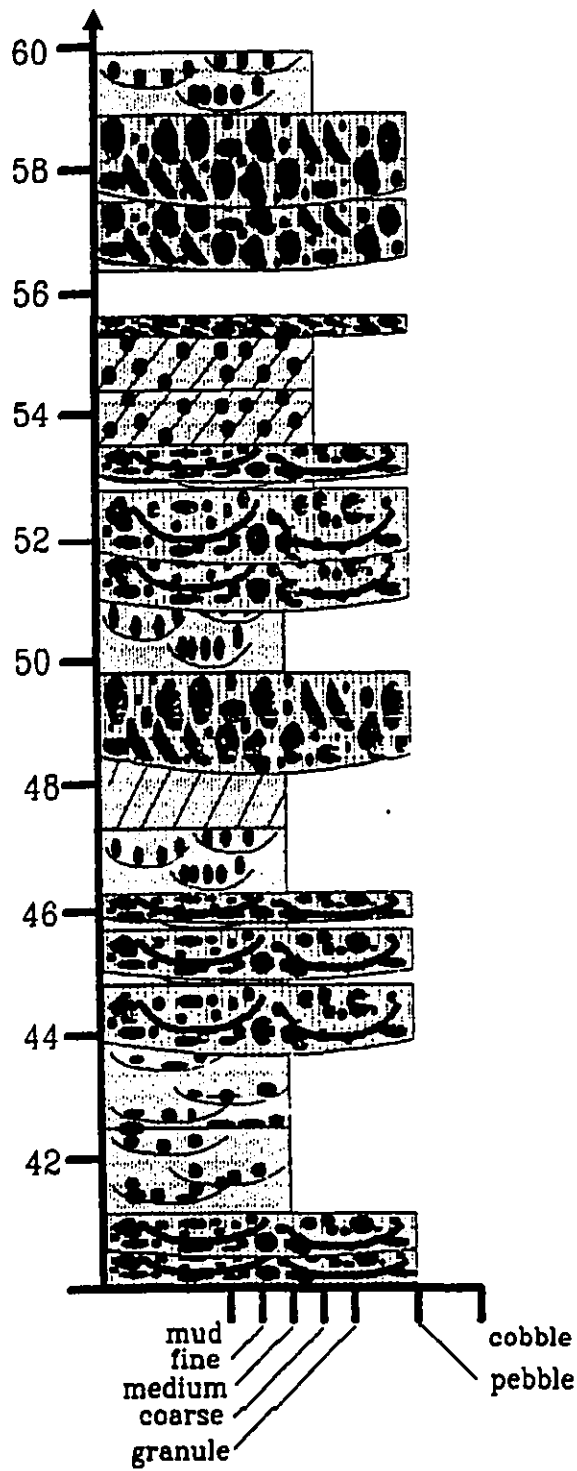
These sections exhibit small-scale cyclic fining upward sequences similar in nature to those of the Pointe à la Garde Member (Fig. 4-35). The fining-upward sequences within the Pointe à Bourdeau Member however differ from those of the Pointe à la Garde Member in three important respects: 1) the lower conglomeratic unit is trough cross-bedded, relatively finer grained, and strongly channelized; 2) the overlying sandstone unit is much thicker and 3) the upper argillaceous units are more common.

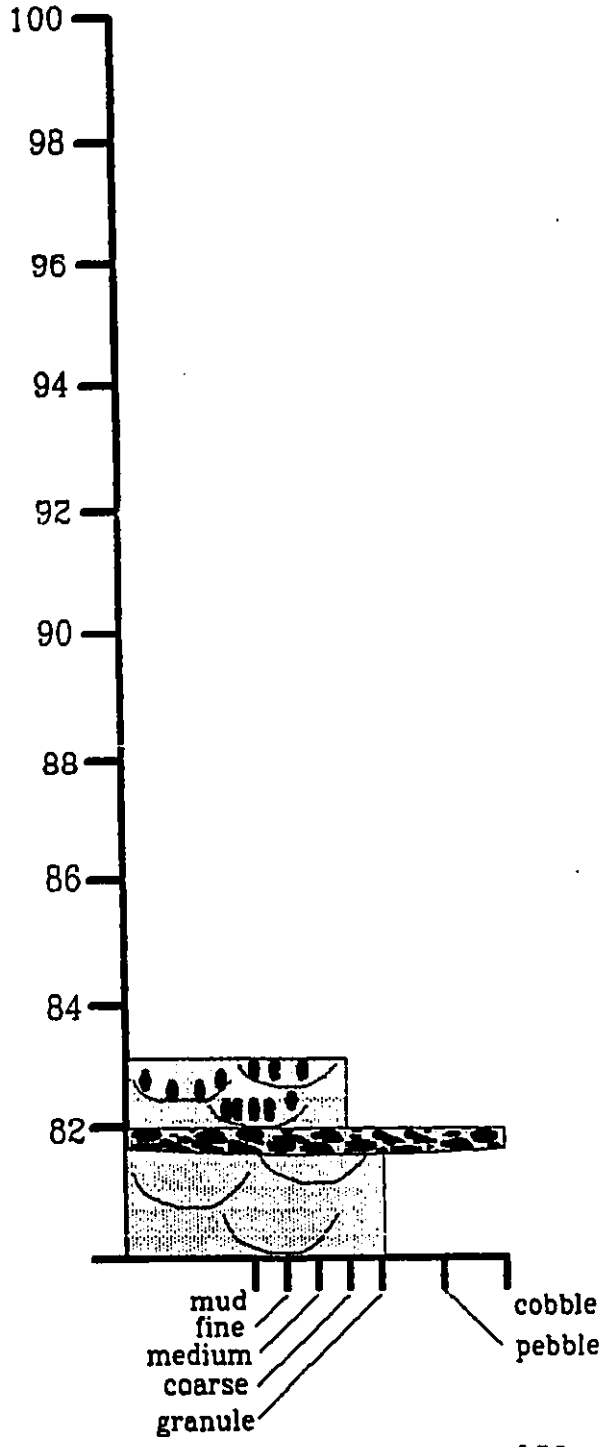
SECTION

A

Fig. 4-32

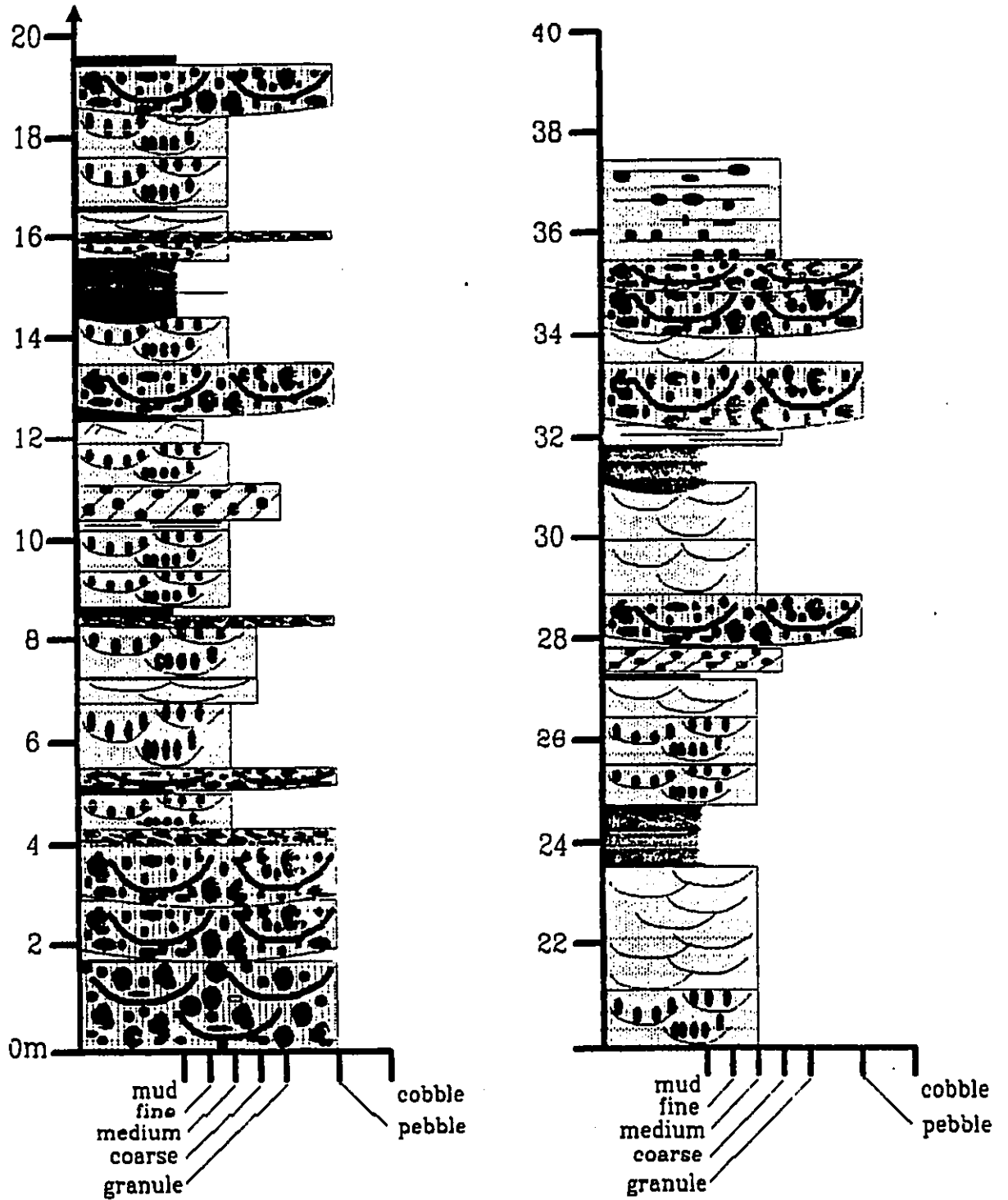






SECTION

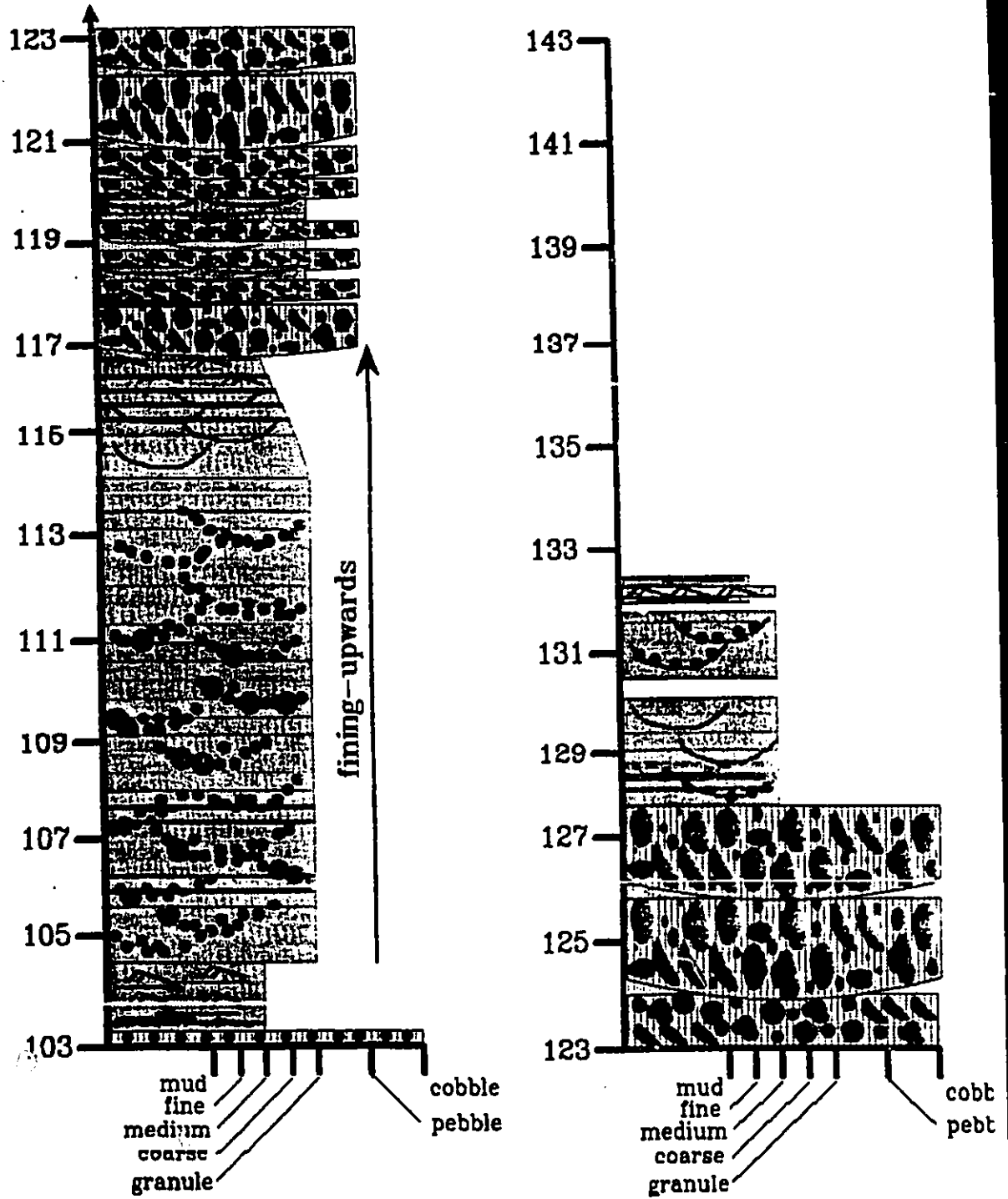
B Fig. 4-33

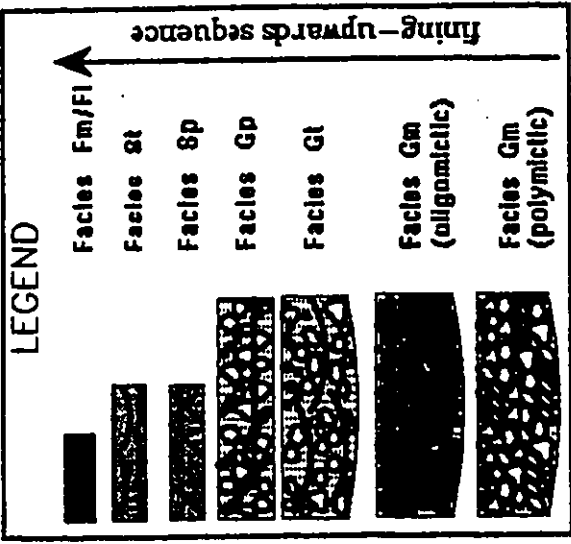


SECTION P

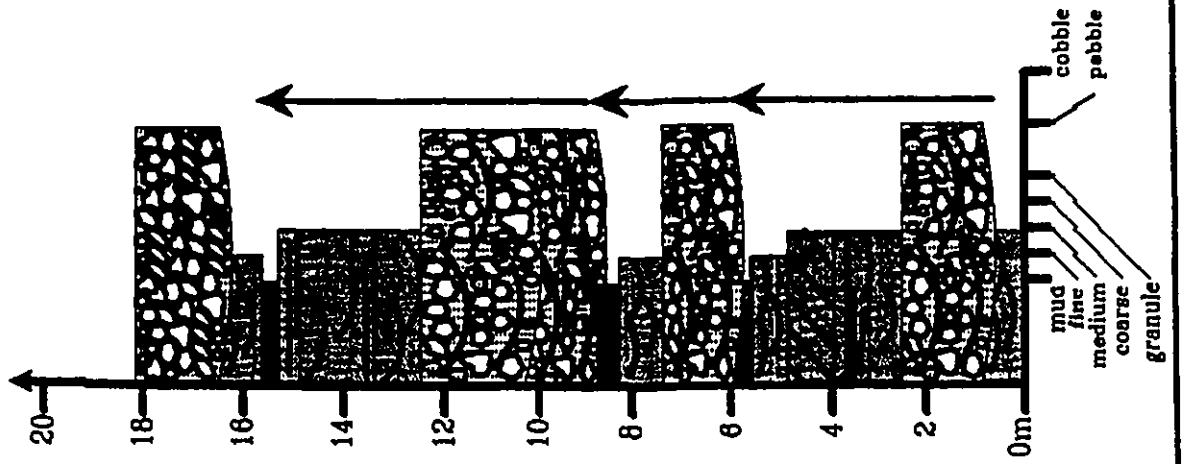
Pointe à Bourdeau Member

Fig. 4-3.





B: Point à Bourdeau Member



A: Point à la Garde Member

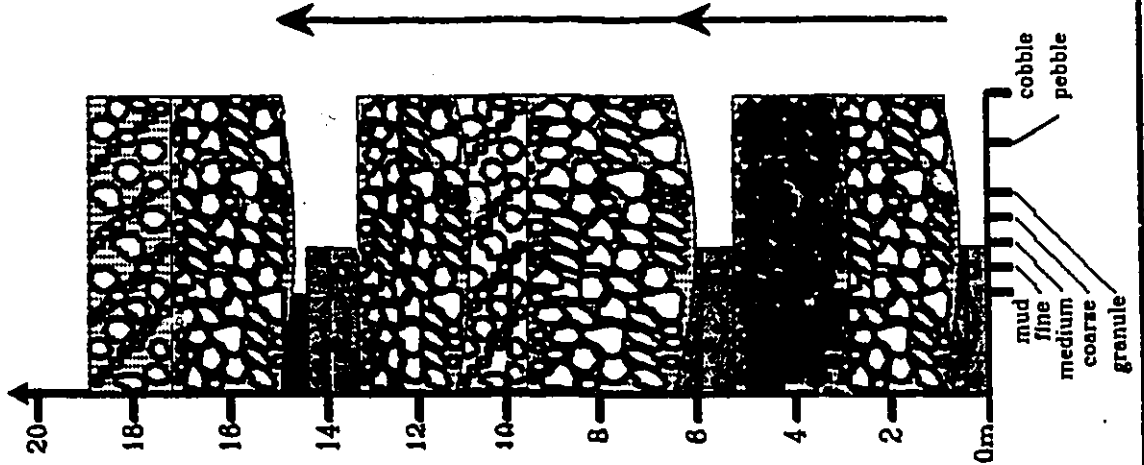


Fig. 4-35. Small-scale fining-upwards sequences within the Pointe à la Garde and Pointe à Bourdeau Members

4-6-1-1 Lower Conglomeratic Unit

The typical fining-upward sequence begins with a lower unit of facies Gt, composed of poorly sorted, framework-supported pebble conglomerate (Fig. 4-36). The basal contact is deeply scoured with erosional relief up to 1.5 m (Fig. 4-37). Where underlain by an argillaceous unit, abundant angular muddy intraclasts are present within facies Gt. Foresets are broad and low angle, and at times are difficult to discern in outcrop due to the poorly indurated nature of the conglomerates. Sets are generally solitary and up to 1.8 m thick. In rare instances, multiple sets occur, separated by very thin lenticular units of facies St and Sm, as at the base of section B (Fig. 4-33).

4-6-1-2 Middle Sandstone Unit

The lower conglomeratic unit is abruptly or gradationally overlain by the middle sandstone unit, composed primarily of grouped cosets of facies St with interbedded solitary sets of facies Sp and facies Sh/l (Fig. 4-38). The middle sandstone units reach a maximum thickness of up to 6 m, as at section A (Fig. 4-32). Sets of facies St are up to 60 cm thick, often exhibiting a pebbly basal scour and scattered pebbles along foresets. Pebbles include well rounded extraformational clasts and angular muddy intraclasts. When abruptly overlying a conglomeratic unit, the contact is scoured and the overlying sets of facies St

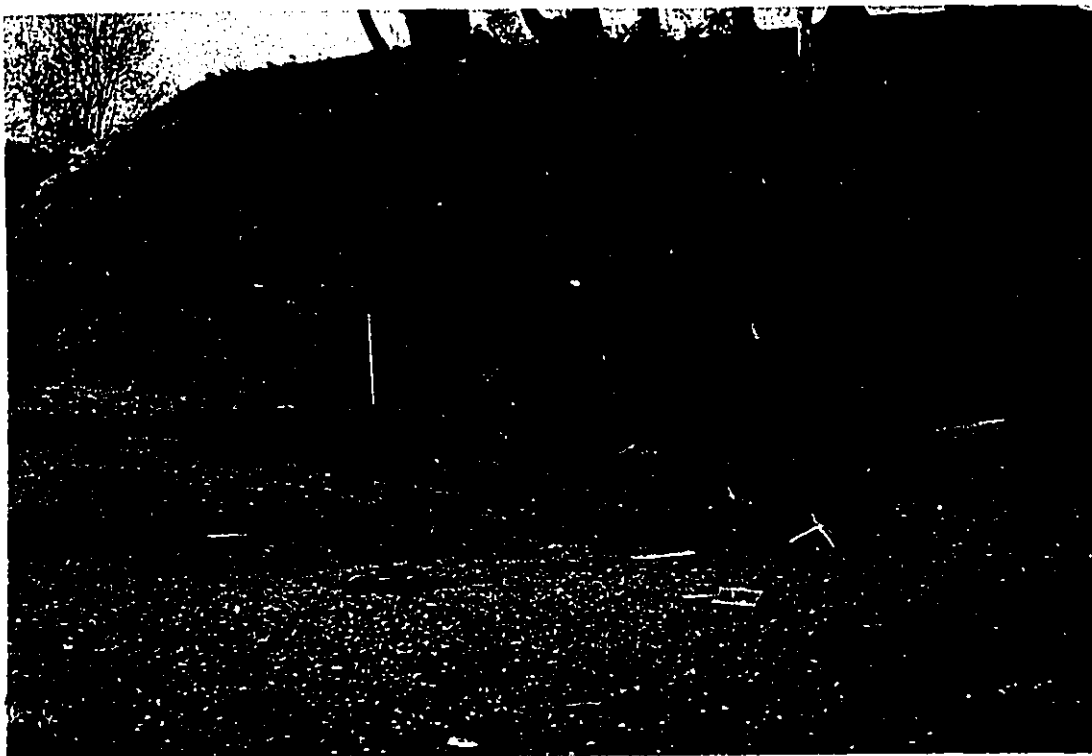


Fig. 4-36. Very large sets of facies Gt within the Pointe à Bourdeau Member. Pogo is 1 m long.



Fig. 4-37. Interbedded facies Gt and cross bedded sandstone, section A. Note the deep scour (arrow) at the base of the unit composed of facies Gt. Pogo is 1 m long.

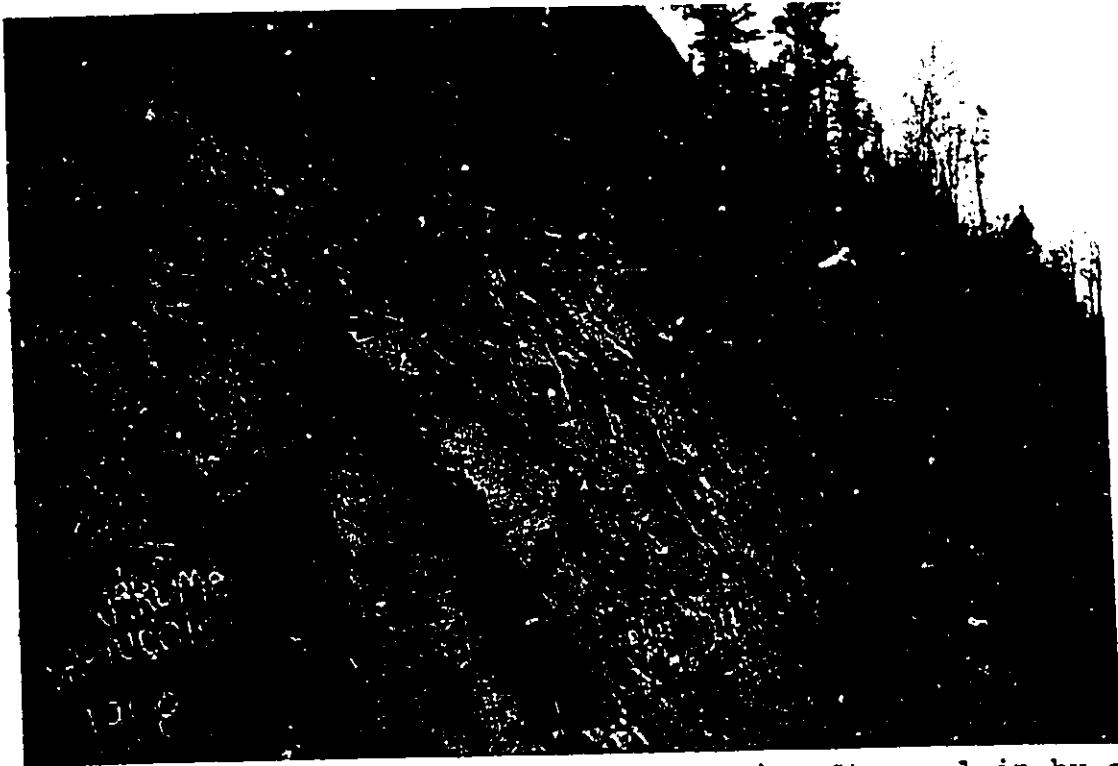


Fig. 4-38. Large grouped cosets of facies St overlain by a thin pebbly lag (arrow), section A. This sequence is in turn overlain by a lenticular unit composed of facies F1 and Fm (adjacent to the field assistant).

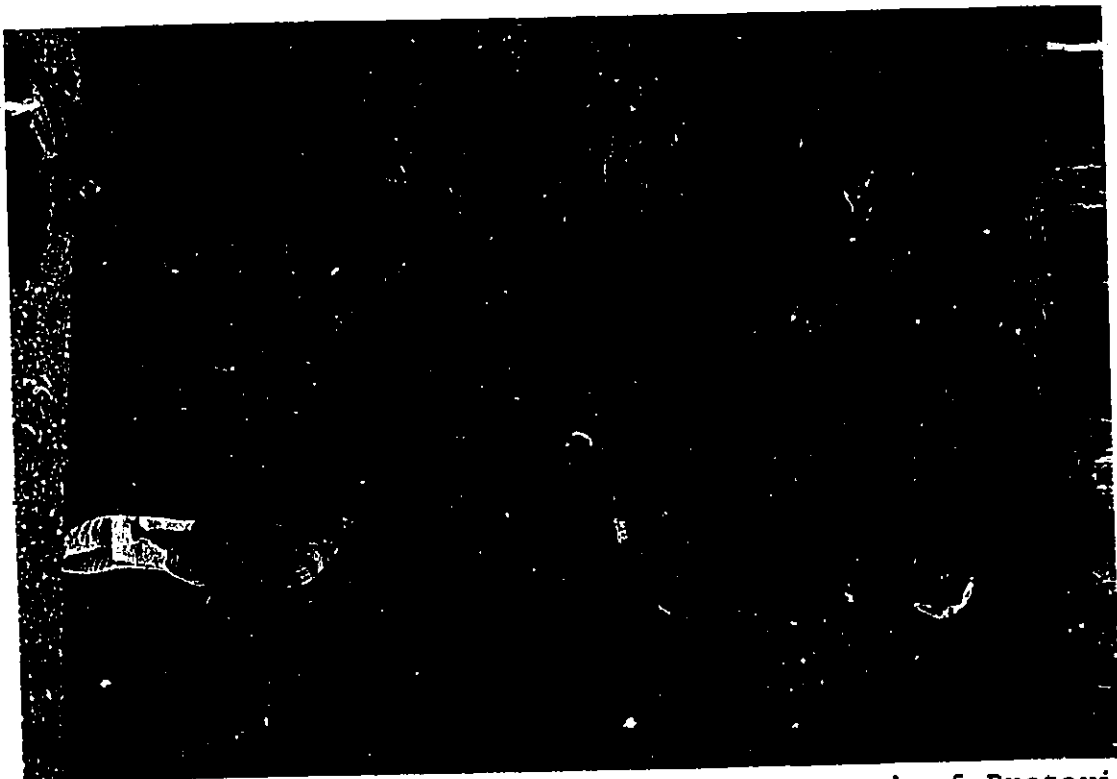


Fig. 4-39. Bedding-plane view of a large trunk of Protaxites logani resting on top of a gravelly channel lag, section A. Note the three-pronged branching fragment at the top of the cliff.

contain few pebbles. Where gradational, the basal sets of facies St are quite pebbly. Facies Sp is coarser than facies St, and occurs as solitary sets up to 70 cm thick, rarely occurring in grouped cosets. Facies Sh/l is composed of fine grained sandstone, and tends to occur near the top of the sandstone unit. Broad scour surfaces marked by a thin pebble layers containing abundant plant fragments and transported trunks of the woody Prototaxites loyani occur within the sandstone units (Fig. 4-39). The units seldom exhibit fining-upward trends.

4-6-1-3 Upper Argillaceous Unit

The argillaceous unit is composed of facies Fm, Fl and Sr. Where gradationally underlain by a sandstone unit, a transition from facies St-Sr-Fm/l may be observed. The argillaceous units are highly lenticular, with a concave-up base and a deeply scoured upper contact. At section B (Fig. 4-33), a unit 1.3 m thick pinches out completely over a lateral distance of 7 m (Fig. 4-40). At section A (Fig. 4-32), the bedding plane of a unit of facies Fl exhibits a parallel series of smooth ridges and grooves, as well as skip marks (Fig. 4-41). The grooves and ridges are interpreted as brush marks created by the dragging of large plant fronds over the depositional surface. Facies Fm and Fl contain abundant plant fragments, but do not exhibit other structures indicative of subaerial exposure such as

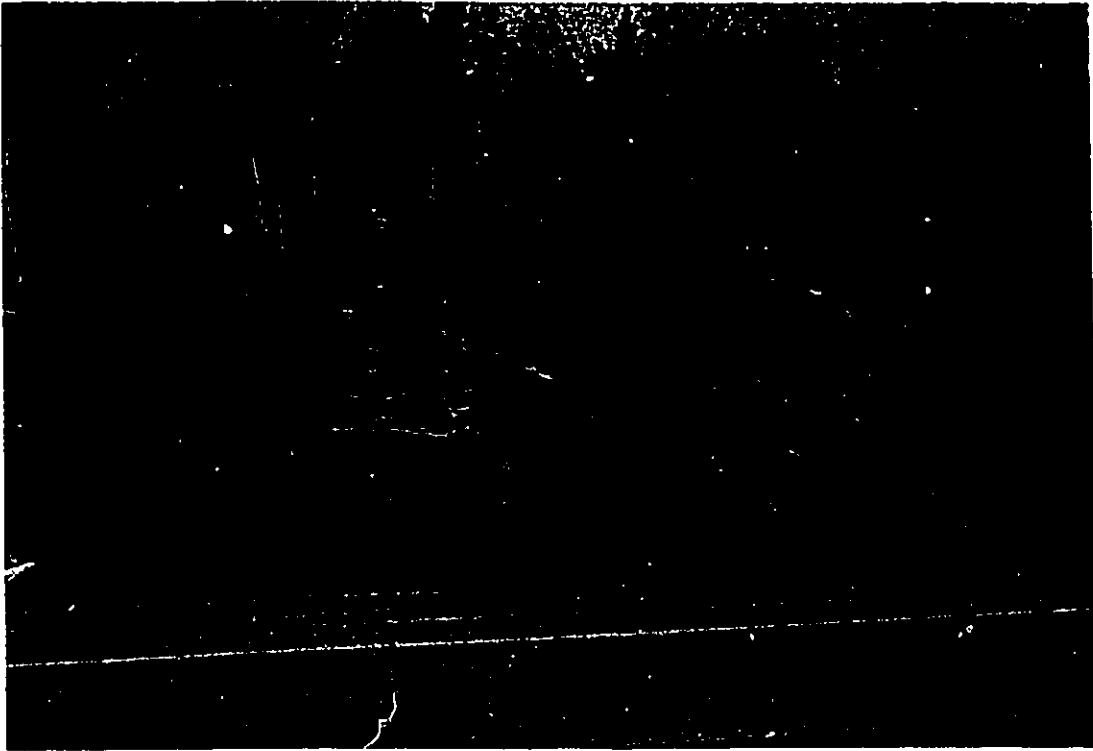


Fig. 4-40. Poorly indurated and lenticular-shaped argillaceous unit pinching out rapidly to the left (east), section B. Unit is erosively overlain by a sequence composed of grouped cosets facies St. Pogo is 1 m long.

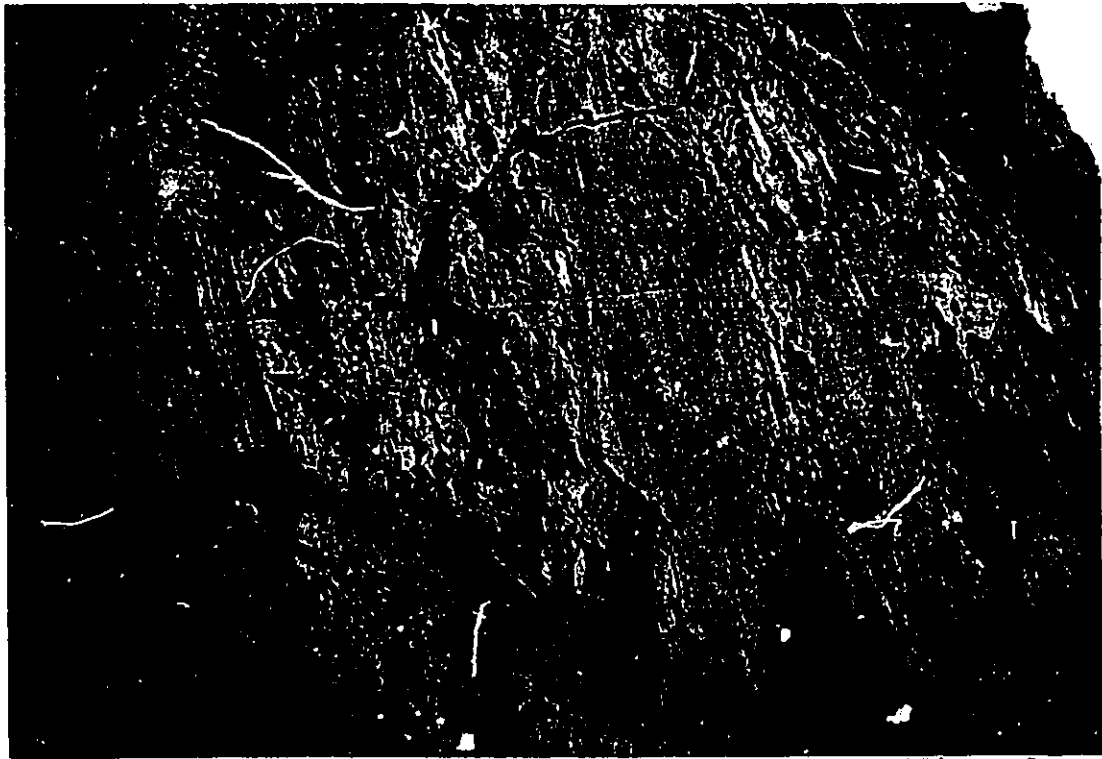


Fig. 4-41. Smooth ridges and grooves upon a bedding plane of facies Fl, likely formed by the dragging action of a frond upon the channel floor, section A. Lense cap 6 cm.

pedogenic features or mudcracks.

The argillaceous unit is abruptly overlain by facies Gt or facies St, which often contain abundant muddy intraclasts. In some instances, layers of facies Fl and Fm have been peeled upwards into the base of the overlying coarser grained facies.

4-6-1-4 Interpretation

Complete fining-upward sequences range in thickness from 1.5 to 3.8 m. The upper argillaceous unit, however, is often absent (Fig. 4-42). Deviations from the idealized fining-upward sequence are common, as at sections A and B, where several thin units of facies Gm are abruptly overlain by facies Fm and Fl. Two fining-upward sequences, consisting of a lower sandy unit and an upper argillaceous unit occur near the top of section B (Fig. 4-33). Across the highway, at section A, the correlative interval exhibits thin units of facies Gt, indicating that the conglomeratic units pinch out rapidly to the south, and are therefore lenticular in external geometry.

Multistorey units of facies Gt are rare, but do occur near the base of section B (Fig. 4-33). Here, very thin lenticular units of facies St and Sm are interbedded within the thick conglomeratic units.

A 2 m thick unit composed of facies Sh exhibiting scattered pebbles along bedding planes occurs at the top of

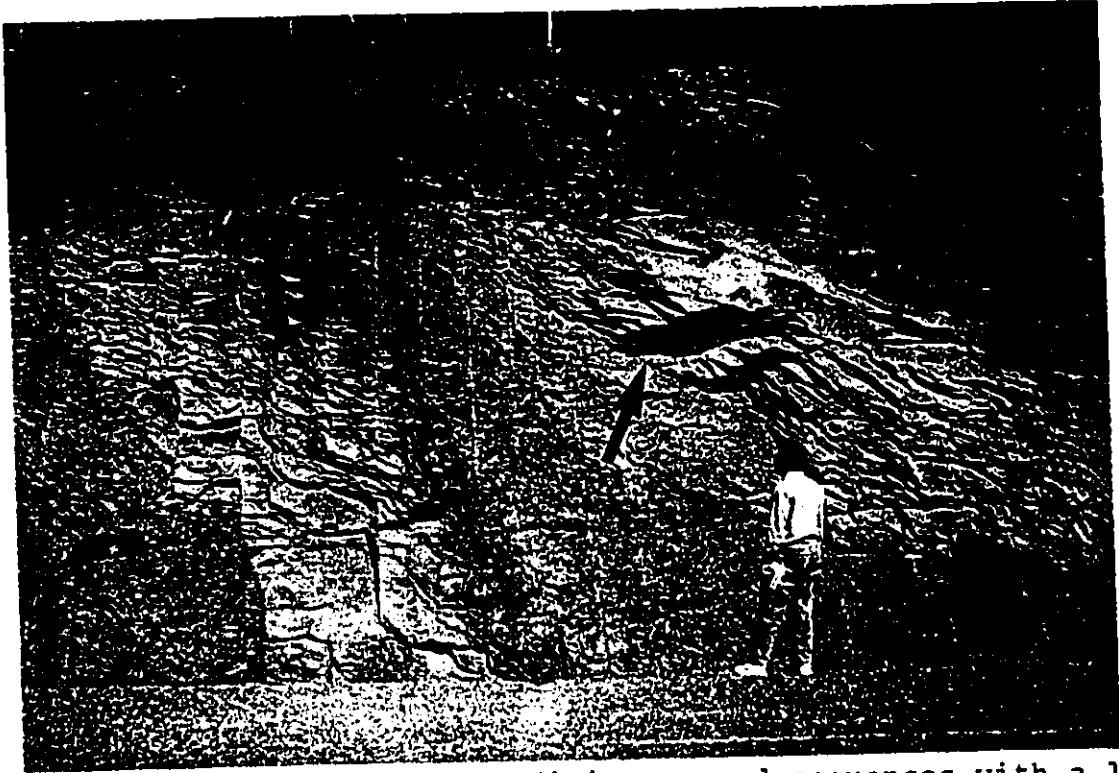


Fig. 4-42. Two incomplete fining-upward sequences with a lower unit composed of facies Gt overlain erosively (arrow) by grouped coSETS of facies St and Sp, section A. Beds dipping steeply to the right.

section B (Fig. 4-33). This represents the only such thick unit of facies Sh within the Pointe à Bourdeau Member.

The fining-upward sequences observed at sections A and B differ from those of the Pointe à la Garde Member in several respects (Fig. 4-35). The lower conglomeratic unit is highly lenticular, indicating that the distal braidplain was more deeply channelized. The trough cross bedded nature of the conglomerate indicates deposition on gravelly bars with crescentic slipfaces. Similar crescentic slipfaces were observed by echosounder within deep reaches of the Knik River by Fahnstock and Bradley (1973), and likely represent dune-like gravelly bedforms (Rust, 1978).

The overlying predominantly trough cross bedded sandstone unit suggests a shallowing of flow and a decrease of total discharge over time. Interbedded sets of facies Sp and Sh/l within the sandstone units indicate periodic fluctuations in these two parameters. The dominance of facies St indicates that flow within the channel was relatively deep (Rust, 1981). The strongly lenticular nature of the overlying argillaceous units indicates that facies Fl, Fm, and Sr accumulated within abandoned channels upon relatively inactive tracts of the floodplain. The absence of pedogenic features and other subaerial exposure features suggests that such areas were unstable and subject to reworking and rapid burial during flood events, as indicated by the abundance of muddy intraclasts within

facies Gt and St. The abundance of plant debris, which includes fragments of the woody Prototaxites logani, indicates that some parts of the floodplain were stable enough to support vegetation. Presumably, more stable floodplains inhabited by stands of P. logani were located upstream.

The fining-upward sequences are therefore interpreted as channel-fills. The conglomeratic and sandstone units are interpreted as deposits of the active tract, while the argillaceous units are interpreted as deposits of the inactive tract located at higher topographic levels upon the floodplain. Discharge within channels fluctuated periodically, as indicated by the interbedded units of facies Sp and Sh/1 within the predominantly trough cross-bedded sandy units. During normal discharge conditions, the channel tract aggraded to a level above that of the surrounding floodplain, at which point the channel became unstable and avulsed to a lower level. The thick unit of facies Sh/1 at the top of section B indicates a period of very shallow flow under upper plain bed conditions within an aggrading channel (Harms et al., 1982). The minor amount of discharge which entered abandoned channels resulted in the deposition of the argillaceous units from gentle flow and from suspension. Sequences composed of thin channelized conglomeratic facies Gm abruptly overlain by facies Fm or Fl indicate that discharge must have been flashy at times.

These sequences were deposited within shallow slough channels on higher levels of the floodplain.

The thickness of each cycle must approach the actual depth of the channel, which reached a maximum of 3.8 m, discounting compaction (section B, Fig. 4-33). Due to the nature of the exposure, the width of individual channels could not be evaluated, prohibiting the calculation of width to depth ratios.

The fining-upward sequences within the Pointe à Bourdeau Member are very similar to those of the GIII model of Rust (1978) and the Donjek model of Miall (1978). Both authors interpreted the cycles in terms of progressive channel aggradation resulting in abandonment, a process which would generate fining-upward sequences. The upper member of the Carboniferous Cannes de Roche Formation of eastern Gaspé is an example of Rust's (1978) GIII model, and exhibits fining-upward sequences comparable in terms of facies assemblages and thickness to those within the Pointe Bourdeau Member of the Campbellton Formation.

Coarse grained fining-upward sequences which exhibit a similar vertical facies sequence to those of the Pointe à Bourdeau Member were documented by Nijman and Puigdefabregas (1978) from the Eocene of Spain. Identification of these sequences as point bar deposits hinged on the recognition of lateral accretion surfaces. The vertical sequences within the Spanish deposits are identical to those of the Donjek

and GIII models of Miall (1978) and Rust (1978) respectively, and would otherwise have been interpreted as rather low sinuosity braided fluvial deposits. As no lateral accretion surfaces were observed within the Pointe à Bourdeau Member, the interpretation of the fining upward sequences as point bar deposits is not favoured.

4-6-1-5 Clast Composition

Conglomeratic facies Gt and Gm are composed primarily of volcanic clasts, with lesser vein quartz, granite, sedimentary, and minor jasper clasts (Fig. 4-43). Clast composition is fairly homogeneous within and between sections.

4-6-1-6 Paleocurrent Trends

Paleocurrent trends obtained from facies St reveal northwesterly to southeasterly flow (Table 4-2, Fig. 4-44), with a mean trend towards the northwest. Paleocurrent trends obtained from facies Sh/l also indicate northwesterly flow (Table 4-2). Paleocurrent trends from facies Gt and Gm reveal north-northeasterly to southwesterly flow (Table 4-2), with a westerly mean direction.

Fig. 4-43. Clast Composition of the Pte. a Bourdeau Member

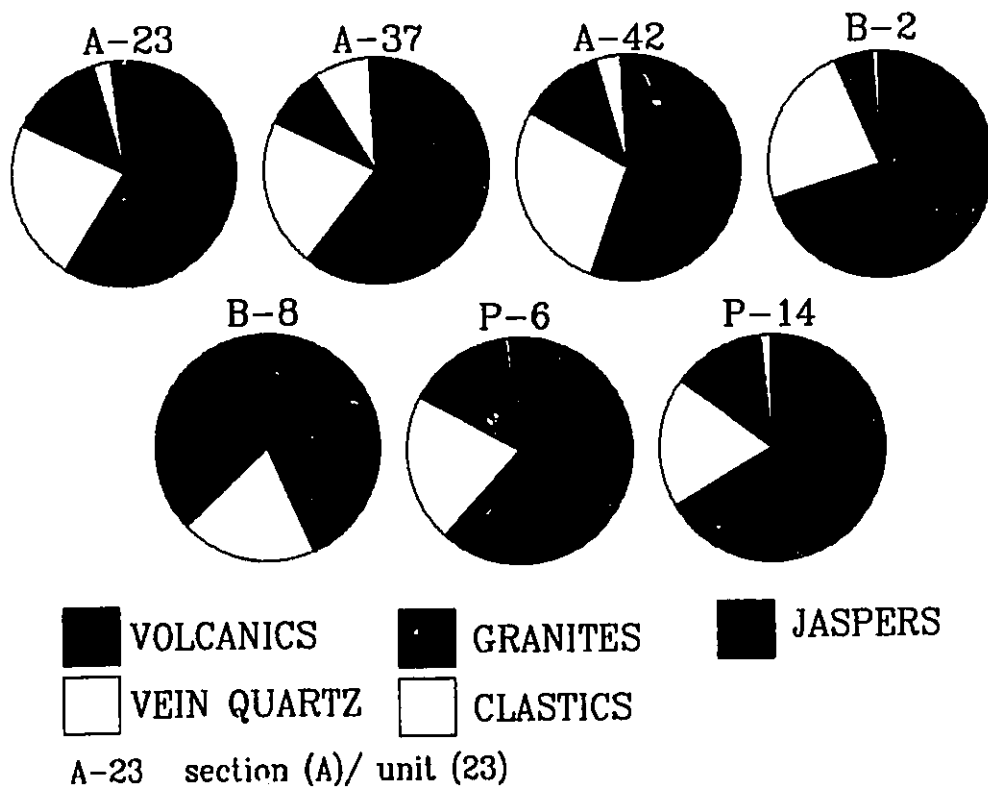


TABLE 4-2

PALEOCURRENT TRENDS FROM THE POINTE A BOURDEAU MEMBER

Station	Type	Vector Mean	Number of Measurements	Vector Magnitude
A	facies St	16.0	24	0.68
B		118.0	3	0.33
A	parting lineation	113.5-293.5	6	0.87
B		82.0-262.0	2	0.90
A	facies Gm	269.0	30	0.92
B		22.7	30	0.55
P	facies St	322.6	22	0.98
P	facies Sr	250.2	20	0.94
P	facies Gm	257.0	35	0.62

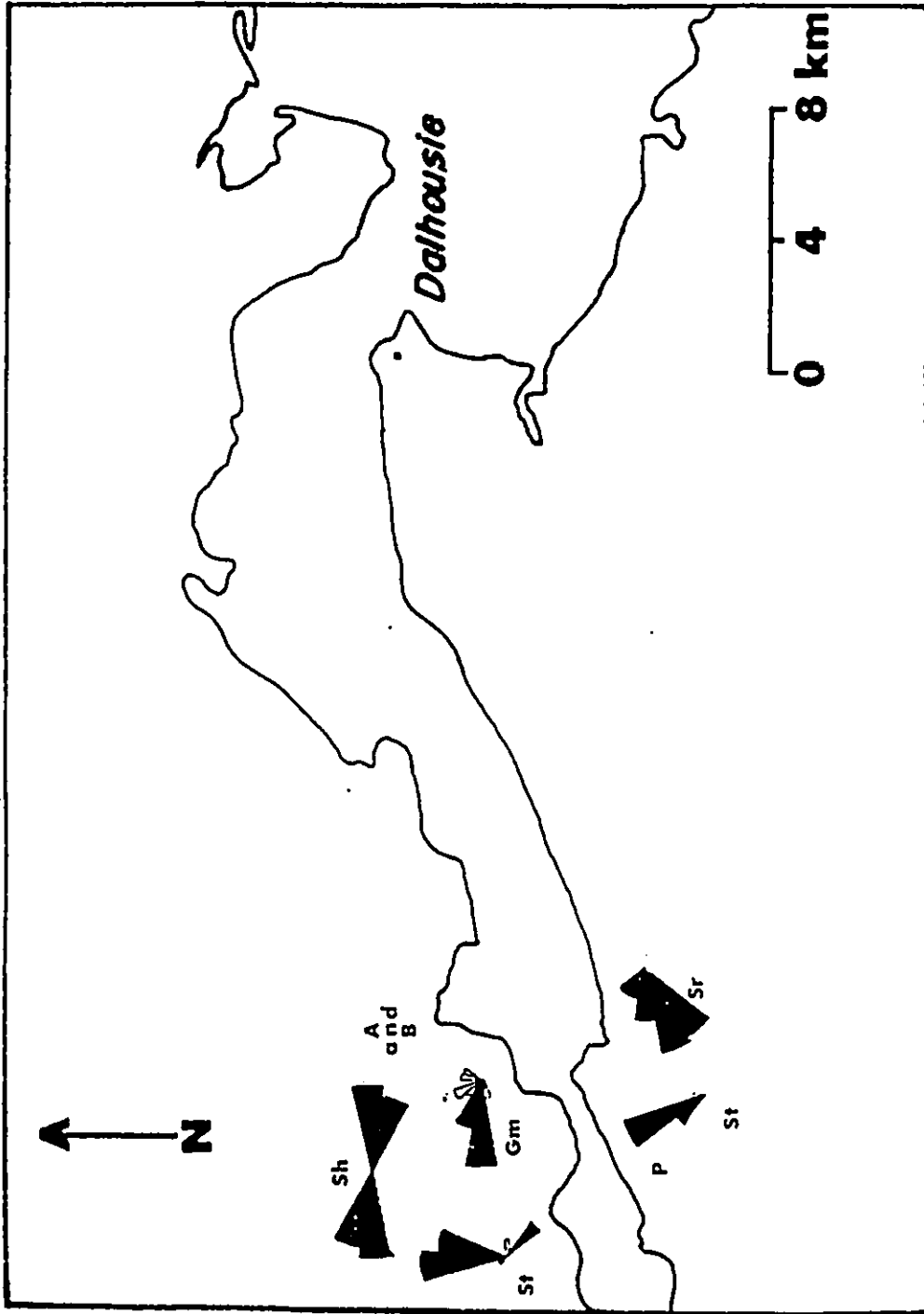


Fig. 4-44. Paleoflow trends within the Pointe à Bourdeau Member (sections A, B, and P) obtained from various facies (see Table 4-2 for more details).

4-6-2 Section P

The deposits at this location are divided into two small-scale fining-upward sequences, separated by a sequence of interbedded facies Gt and St (Fig. 4-34). The base of the section is marked abruptly by a tabular unit of polymictic facies Gm 30 cm thick. A 1.3 m thick sequence of interbedded facies Sr and Sh/l couplets abruptly overlies the conglomerate unit. Thin units of facies Sr gradationally overlie units of facies Sh/l which have abrupt, planar bases, forming couplets up to 40 cm thick.

Abruptly overlying is the first 12.5 m thick fining-upward sequence (Fig. 4-34). This sequence is composed of grouped cosets of pebbly facies St, and becomes progressively less pebbly upwards (Fig. 4-45). Individual sets up to 40 cm thick exhibit pebbly framework supported lags up to 30 cm thick with basal scours. The uppermost 2.8 m of the sequence is composed of grouped cosets of facies St which are pebble free (Fig. 4-34). Facies Sr (lunate ripples) occur at the very top of the sequence, and are confined to thin channelized lenses 30 cm thick and 2 m wide (Fig. 4-46).

Separating the two fining-upward sequences is a 6.4 m thick sequence of interbedded facies Gt and St (Fig. 4-34). These units are very similar to those of the lower portion of the underlying fining-upward sequence, and suggest that the pebbly lags along the basal scour of each set of facies

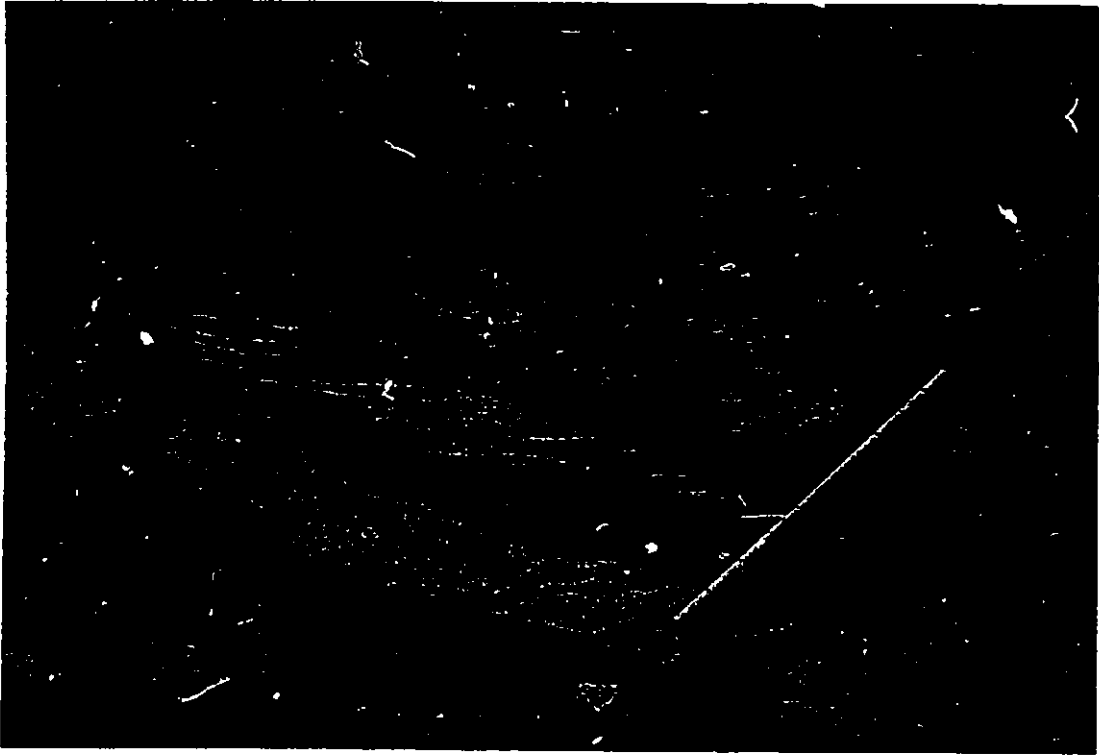


Fig. 4-45. Grouped cosets of facies St, each coset exhibiting a concave-up scoured basal surface overlain by a thin framework pebble lag, section P. Paleoflow to the upper right (north). Pogo is 1 m long.

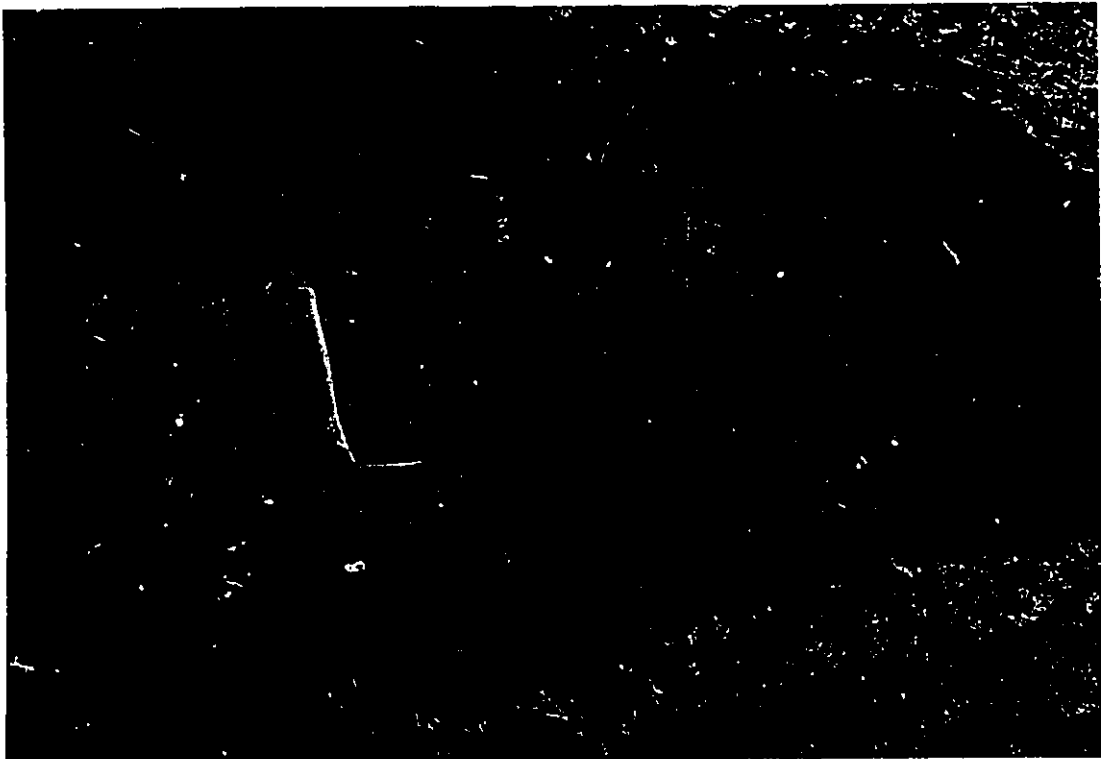


Fig. 4-46. Bedding plane view of lunate ripples (facies Sr) capping the lower fining-upward sequence in section P.

St may represent pebbly lower foresets.

The second fining-upward sequence is composed of a lower multistorey portion of polymictic cobbly facies Gm (Fig. 4-34). Grouped cosets of medium grained facies St overly the conglomerates, and grade upwards into interbedded fine grained units of facies Sh/l and Sr.

4-6-2-1 Clast Composition

Conglomerates of facies Gt and Gm are polymictic, and exhibit compositions similar to those of sections A and B (Fig. 4-43), as well as to those of the polymictic conglomerates of the Pointe à la Garde Member (Fig. 4-43).

4-6-2-2 Paleocurrent Trends

Paleocurrent trends obtained from three dimensional exposures of facies St reveal strongly unidirectional northwesterly flow (Table 4-2, Fig. 4-44). Paleocurrents obtained from imbrication within facies Gm reveal a west-southwesterly direction of flow, as do trends obtained from facies Sr at the top of each fining-upward sequence (Table 4-2, Fig. 4-44).

4-6-3 Interpretation

The coarseness and facies relationships of the fining-upward sequences indicate fluctuating high energy discharge. Each unit of facies St is representative of a distinct flood

event, which resulted in the incision and rapid infilling of small channels on the braidplain, first by deposition of the pebbly fraction as some form of lag or minor bedform, followed by deposition of sand as sinuous-crested megaripples during waning flow. The lenticular nature of this facies indicates deposition within small, shallow channels. Channelized lenses of facies Sr at the top of the sequence indicate minor flow in small, shallow channels. The fining-upwards trend of the lower sequence reflects aggradation of a system of such minor channels on the braidplain.

The intervening sequence of interbedded facies Gt and St is similar to the lower portion of the underlying fining-upwards sequence, except that pebbly transverse bedforms were better preserved, perhaps due to flood events of greater magnitude. Prolonged high-stage flow would allow more time for the development of slipfaces and the downstream migration of pebbly transverse bars. The abruptly overlying unit of facies St was deposited during ensuing waning flow. The repetition of these units is indicative of the variable nature of the discharge.

The upper fining-upward sequence is similar to those within the Pointe à la Garde Member. Facies Gm in the lower portion of the sequence indicates the deposition of cobbles on longitudinal bars, with the multistorey nature of the sequence indicative of a number of flood-related

depositional events. The upper sandy portion of the sequence is indicative of lower energy deposition by sinuous-crested megaripples upon the flanks of the exposed longitudinal bars. Interbedded fine grained facies Sr and Sh/1 at the top of the sequence are indicative of low-energy shallow flow within minor channels.

Deposition at locality P therefore was characterized by periodic flood events, with deposition of gravel as longitudinal and transverse bars as well as pebbly lags during high flood stages, and sand as sinuous-crested megaripples in minor channels during waning flow. Flow was confined to rather small channels on the braidplain, as opposed to the deposits of sections A and B, where large channelforms occur at the base of each fining upwards sequence. Continued aggradation of the braidplain led to the creation of fining-upward cycles, with the interbedded fine-grained rippled and parallel-laminated units indicative of weak shallow flow within minor channels or on the top of bars.

4-7 Depositional Environments

All sections of the Pointe à Bourdeau Member are similar in many respects. Clast compositions of the conglomeratic facies are virtually identical, as are paleocurrent trends from facies St, which indicate a northerly direction of transport. Stratigraphically,

sections A and B are located higher than section P. Sedimentologically, the sequences at each locality are different. Several features within the deposits of section P are indicative of higher energy depositional environments than those of sections A and B. Firstly, the deposits at section P are more conglomeratic and coarser grained than those of sections A and B. Secondly, finer grained deposits such as facies Fm and Fl are absent at section P, but relatively abundant at sections A and B. Thirdly, the channel forms so distinctive at sections A and B are not observed at section P. Finally, while cobble-bearing longitudinal bar deposits occur at section P, they are absent from sections A and B, where transverse barforms or bedforms predominate (Fig. 4-47). Decrease in average clast size downstream is a well documented phenomenon within modern braided fluvial environments (eg. Boothroyd and Nummedal, 1978). Similarly, a downstream transition from longitudinal to transverse barforms has been observed (eg. Hein and Walker, 1978), with longitudinal bars restricted to relatively proximal reaches of modern braided rivers (Rust, 1972; Smith, 1972; Hein and Walker, 1978). These features indicate that deposition at locality P occurred under higher energy conditions in a more proximal setting relative to deposition at localities A and B.

These differences, together with the northerly direction of transport, indicate that a south to north

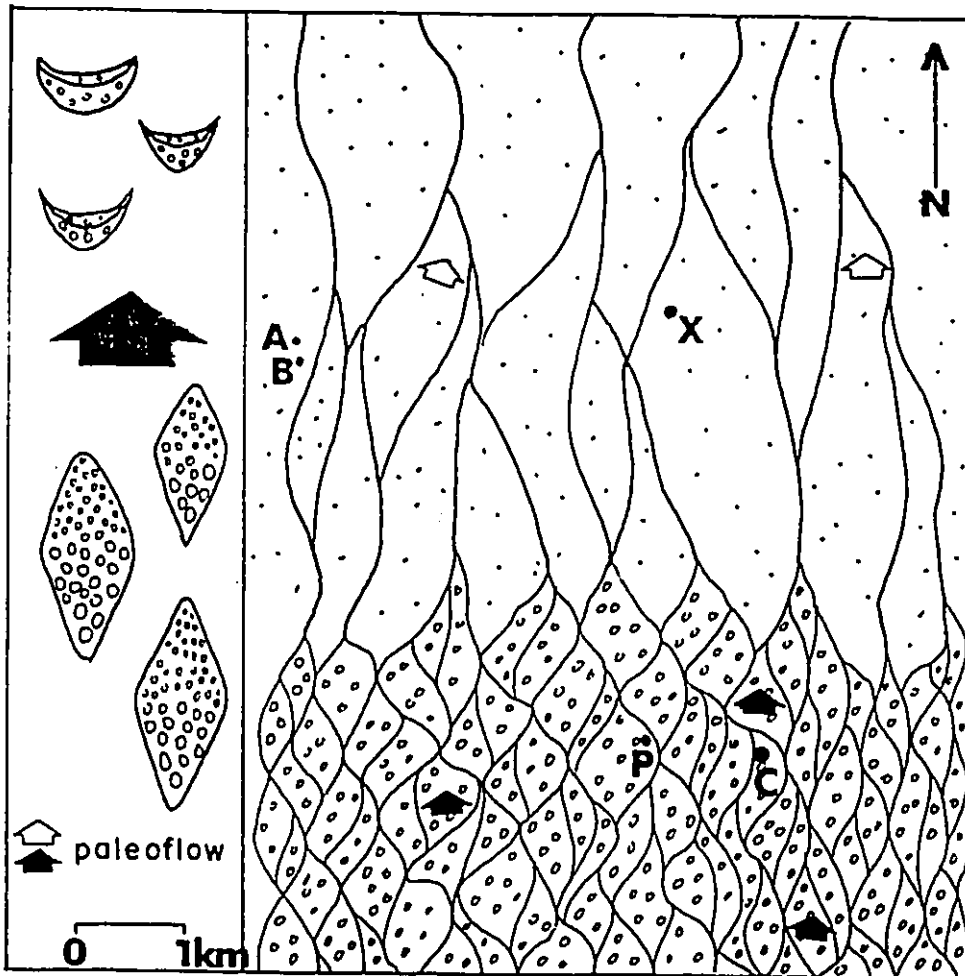


Fig. 4-47 Proximal to distal relationship within the Pointe à Bourdeau Member. Note the transition from longitudinal to transverse barforms downstream, with corresponding increase in channel sinuosity and width, and decrease in grain-size. A, B, and P: section locations, X: Cross Point, C: Campbellton.

proximal to distal relationship exists between section P and sections A and B respectively (Fig. 4-47). Deposition on the Pointe à Bourdeau Member braidplain occurred under conditions of flood-related discharge in a relatively deep channels at localities A and B. Here, channels aggraded vertically over time, resulting in the formation of small-scale fining-upward sequences. Deposition at locality P occurred within relatively shallow channels on steeper slopes, under more energetic flow conditions.

Provenance data indicate that the volcanics and associated plutonics of the Dalhousie Group were the source of sediments. The braidplain prograded rapidly northwards, overrunning the lacustrine environment represented by the Atholville Member. The areal extent of the braidplain is unknown, due to the scarcity of exposure. The absence of interbedded volcanics, pyroclastics, and intrusives indicates that by late middle Emsian time, igneous activity within the western Chaleur Bay area had ceased.

4-8 Summary and Conclusions

Based upon fluvial styles and paleocurrent trends, two distinct depositional systems can be distinguished within the Pointe à la Garde and Pointe à Bourdeau members of the Campbellton Formation (Fig. 4-48). The Pointe à la Garde Member is interpreted as a transverse proximal gravelly braidplain which discharged westwards onto a northward

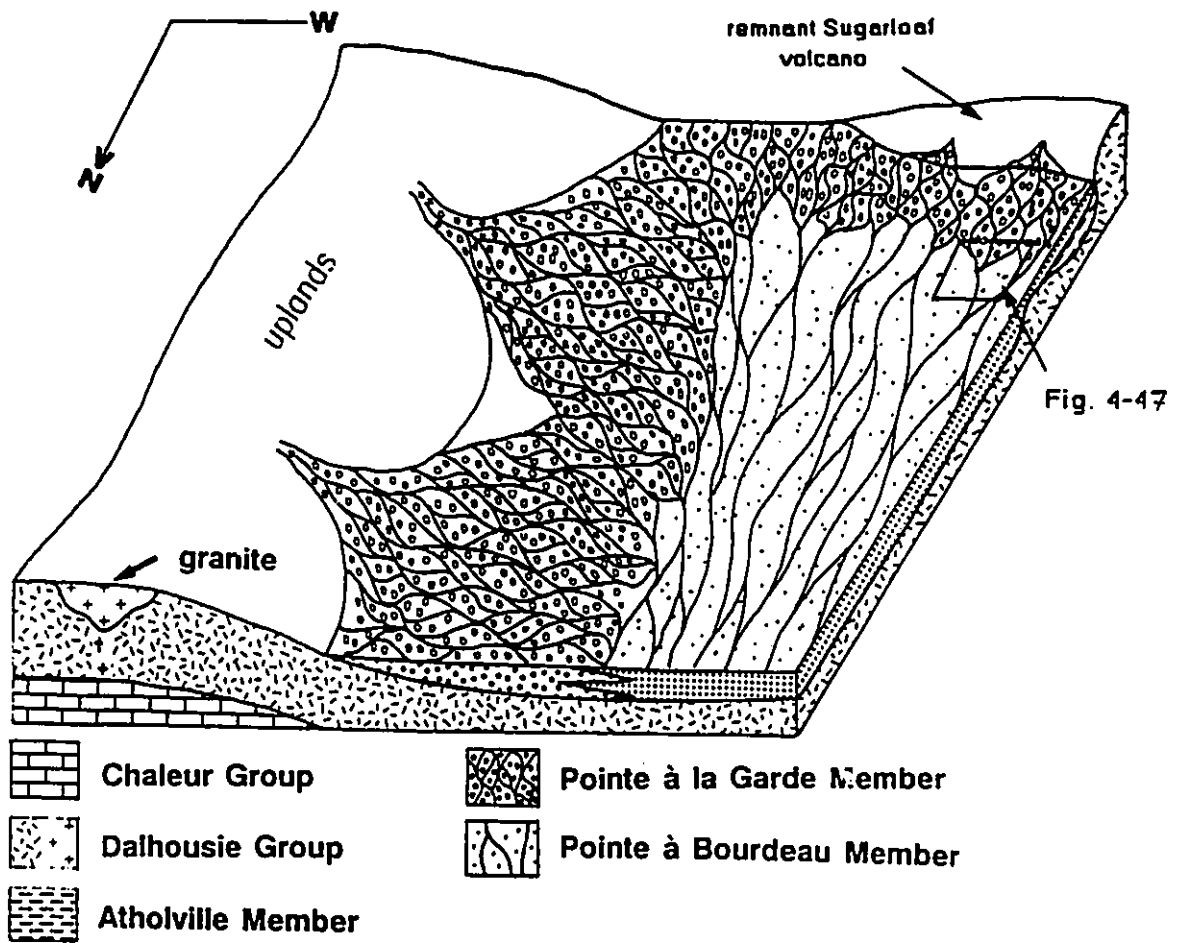


Fig. 4-48. Depositional model for the Pointe à la Garde and Pointe à Bourdeau members. The proximal gravelly braidplain deposits of the Pointe à la Garde Member were shed westwards, from a broad upwarp located to the east, into a longitudinal sandy braided fluvial system represented by the deposits of the Pointe à Bourdeau Member, which flowed northwards.

flowing longitudinal sandy braidplain, represented by the deposits of the Pointe à Bourdeau Member (Fig. 4-48). Several features indicate a proximal to distal relationship between members (Table 4-3). Both the percentage of conglomeratic facies and the average maximum clast size in facies Gm/Gt decrease markedly from east to west between Members. Miall's (1978) and Rust's (1978) models for braided fluvial deposits illustrate a distinct increase in the abundance of conglomeratic facies with proximity to source. Likewise, downstream decreases in maximum clast size have been documented from numerous modern braided fluvial systems (Boothroyd and Nummedal, 1978; Rust 1972; Rust, 1984a).

Gravelly barforms also differ within each Member. The Pointe à la Garde Member is dominated by conglomeratic facies Gm and Gp, attributed to deposition on or beside longitudinal bars, whereas the Pointe à Bourdeau Member is dominated by conglomeratic facies Gt, indicative of deposition on transverse bars. Based upon studies of modern braided fluvial environments Rust (1972), Smith (1974), and Hein and Walker (1978) suggest that longitudinal barforms are restricted to relatively proximal tracts of braided rivers, as these barforms require high flow velocities and discharge volume and shallow water conditions to form. Smith (1974) and Hein and Walker (1978) propose a downstream gradation from longitudinal to transverse

TABLE 4-3

Feature	Pte a la Garde Member	Pte a Bourdeau Member
maximum clast size (cm)	13.8	7.01
% facies Gm/Gt/Gp	74.4	32.8
% vein Qtz and granite	31.37	37.18
monomictic conglomerate	present	absent
gravelly bar type	longitudinal	transverse
channel width-depth ratio	high	low
paleocurrent trends	westwards	northwards

barforms within gravelly braided rivers as a result of these decreasing energy conditions. The apparent width to depth ratio also increases from the Pointe à la Garde to the Pointe à Bourdeau members.

The oligomictic volcanic conglomeratic facies Gm observed within the lower portion of the Pointe à la Garde Member suggests either syndepositional volcanism or multiple sources (all of uplifted volcanics) of sediment for the transverse depositional system. The absence of interbedded volcanics (flows and tuffs) within the Member indicates that volcanism had ceased by this time, and that multiple sources is the most likely explanation for the origin of the oligomictic conglomerates.

The average percentage of vein quartz and granite within the conglomeratic facies is slightly higher within the Pointe à Bourdeau Member. This could be due to the relative hardness of these clasts, which would survive longer distances of transport than the volcanic clasts and hence be more abundant within more distal reaches of the braidplain (Davies et al., 1978).

Finally, the members exhibit paleocurrent trends which are mutually perpendicular. This, coupled with the other sedimentological differences, indicates the existence of two distinct braidplains, one transverse and proximal, the other longitudinal and distal (Fig. 4-48).

According to Miall (1981a), the orientation of

transverse and longitudinal systems are useful in delineating basin geometry. Transverse drainage systems within modern basins are commonly oriented perpendicular to the main structural trends along basin margins, whereas longitudinal systems tend to parallel the main structural trends. The east-west and south-north orientation of the Pointe à la Garde and Pointe à Bourdeau Members respectively indicates that the basin possessed an eastern margin and a north-south trending axis.

The absence of alluvial fan deposits within the Pointe à la Garde Member indicates a lack of steep, fault controlled relief along the eastern margin of the basin. Strike-slip fault-bounded basins such as the Cenozoic basins of California and the Devonian Hornelen Basin of Norway are characterized by alluvial fans adjacent to basin margins, and an extremely thick fluvial succession as basin fill (Howell et al., 1980; Gloppen and Steel, 1981). Instead, the uniformity and areal extent of the Pointe à la Garde Member of the Campbellton Formation indicates that the eastern margin of the basin was likely a broad upwarp. Rust (1984) interpreted the Middle Devonian Malbaie Formation of eastern Gaspé as being deposited within a similar type of basin based upon very similar sedimentological criteria.

Alternatively, the absence of alluvial fan deposits within the Pointe à la Garde Member may be due to lack of sufficient exposure. Alluvial fans may be highly localized

and possess rapid lateral facies changes (Rust, 1982; Boothroyd and Nummedal, 1978). The main structural trends within the Chaleurs Bay Synclitorium are southwest-northeast oriented (Bourque et al., in press, Fig 5). Several north-south trending faults occur between the main outcrop belt and the outlier to the east. The likelihood of these faults controlling sedimentation however is very small, as they are interpreted as Mid to Upper Devonian features (Bourque et al., in press). The large-scale fining-upward sequences observed within the Pointe à la Garde Member are interpreted in terms of periodic uplift along the eastern margin of the basin. This uplift was related to compressive folding during the initial stages of the Acadian Orogeny. No similar fining-upward sequences are observed within the Pointe à Bourdeau Member, indicating that tectonic effects were limited only to the more proximal transverse system, and did not affect the much larger and more distal longitudinal system.

The paleoclimate during Emsian time was humid, and characterized by abundant perennial rainfall.

The abrupt appearance of limestone clasts within the uppermost part of the Pointe à la Garde Member precedes a marked change in depositional styles within the basin, represented by the fine-grained deposits of the Restigouche Member. The deposits at section W indicate that during the latter stages of Pointe à la Garde Member deposition, a

northern source of sediment became prominent within the basin. This source was likely the Silurian and Lower Devonian La Vieille or Westpoint formations. The relative coarseness of the fluvial deposits indicate that the northern margin of the basin was of high relief, possibly due to block faulting (Fig. 1-8).

Thus, the morphology of the basin appears to have undergone a major alteration at the close of Pointe à la Garde Member deposition. This was likely a result of fault activity along the northern margin of the basin, which was to control depositional styles within the basin throughout the Middle Devonian.

CHAPTER 5

RESTIGOUCHE MEMBER

5-1 Introduction

The Restigouche Member of the Campbellton Formation is interpreted as the deposits of sandy braidplain to meandering floodplain environments.

The Restigouche Member is exposed along the shoreline on the north coast of Chaleur Bay at two locations: section X (Fig. 5-1), at Restigouche (Fig. 5-2), Quebec, and sections L and M (Fig. 5-3), 2.5 km east of Pt. a la Garde, Quebec (Fig. 5-2). The sandy deposits of section X form low gently northeastwards dipping cliffs along the shoreline. Several small sections were measured at this locality. The deposits of sections L and M are very poorly exposed, forming low, steeply dipping beach ridges. Sections L and M occur on either flank of a north-south trending anticline. Only section M was measured and described in detail, as it is much better exposed than section L.

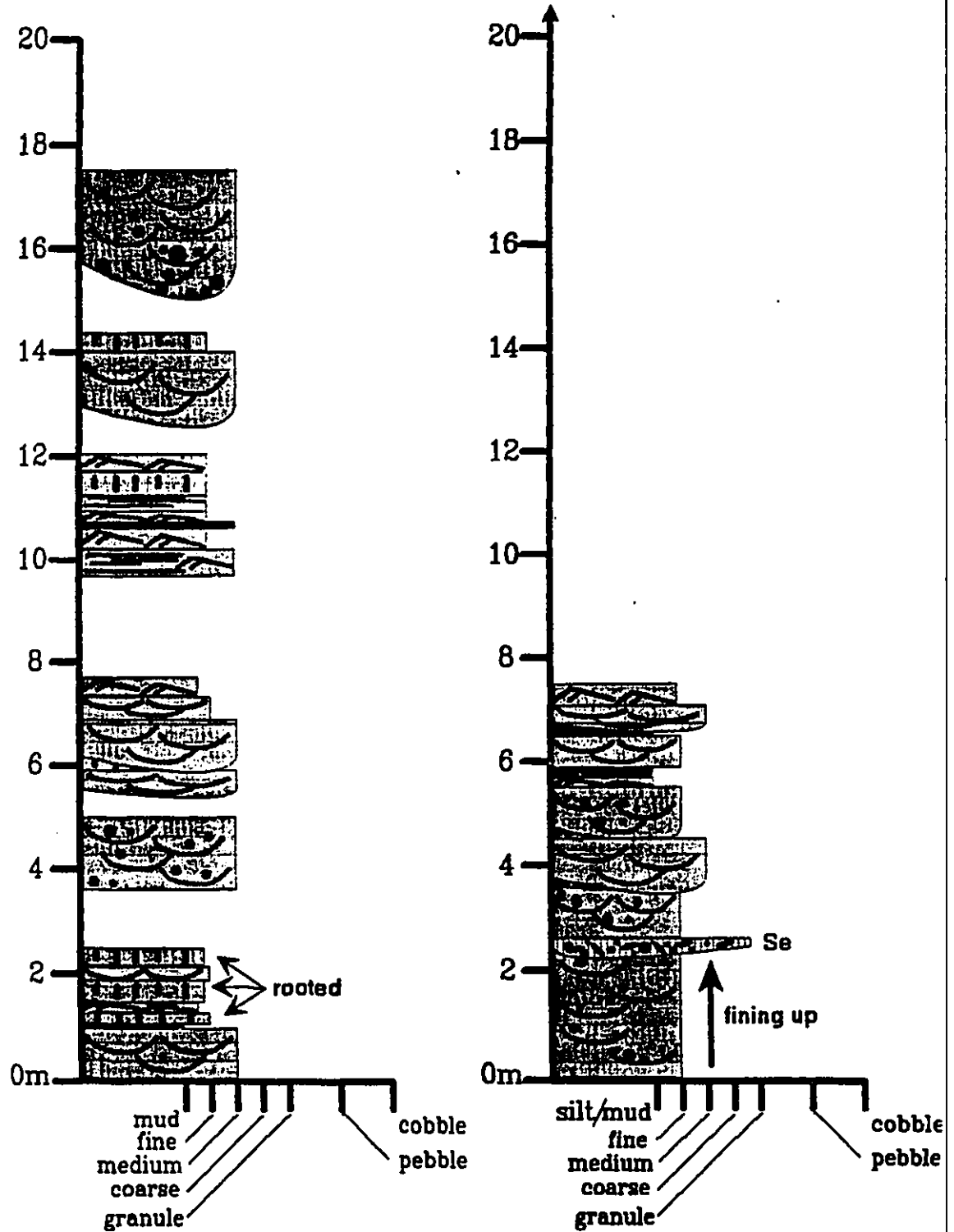
5-2 Biostratigraphy

Based upon pollen samples collected from fine grained facies, McGregor (1989a) determined a late Emsian age for section X and a mid Emsian age for section M (Appendix 1). The two sections therefore are not temporally correlative. Based upon the occurrence of rare acritarchs (Appendix 1), McGregor (1989a) suggested a marginal marine depositional environment for the deposits of section X.

Fig. 5-1

SECTION XA

SECTION XB



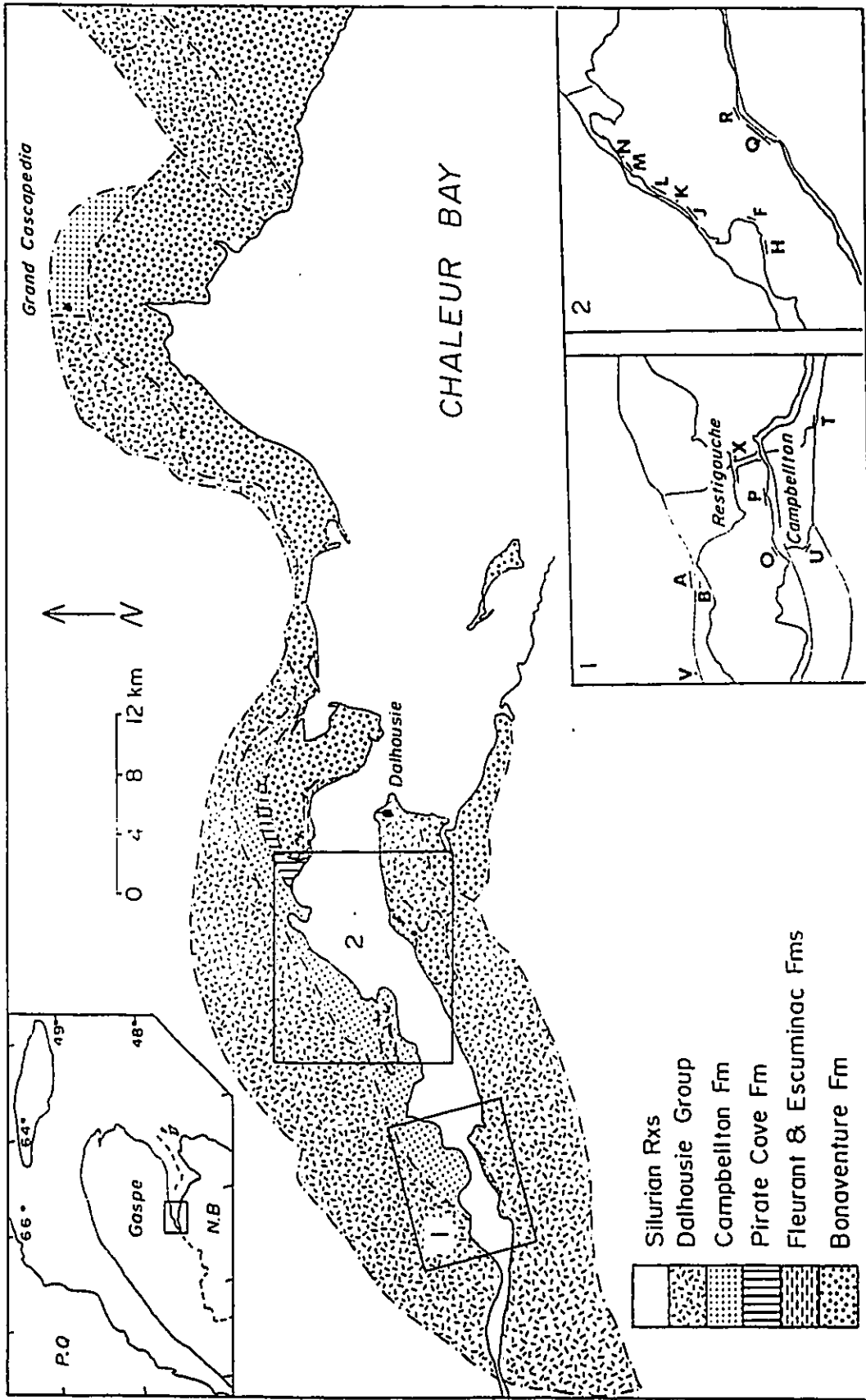
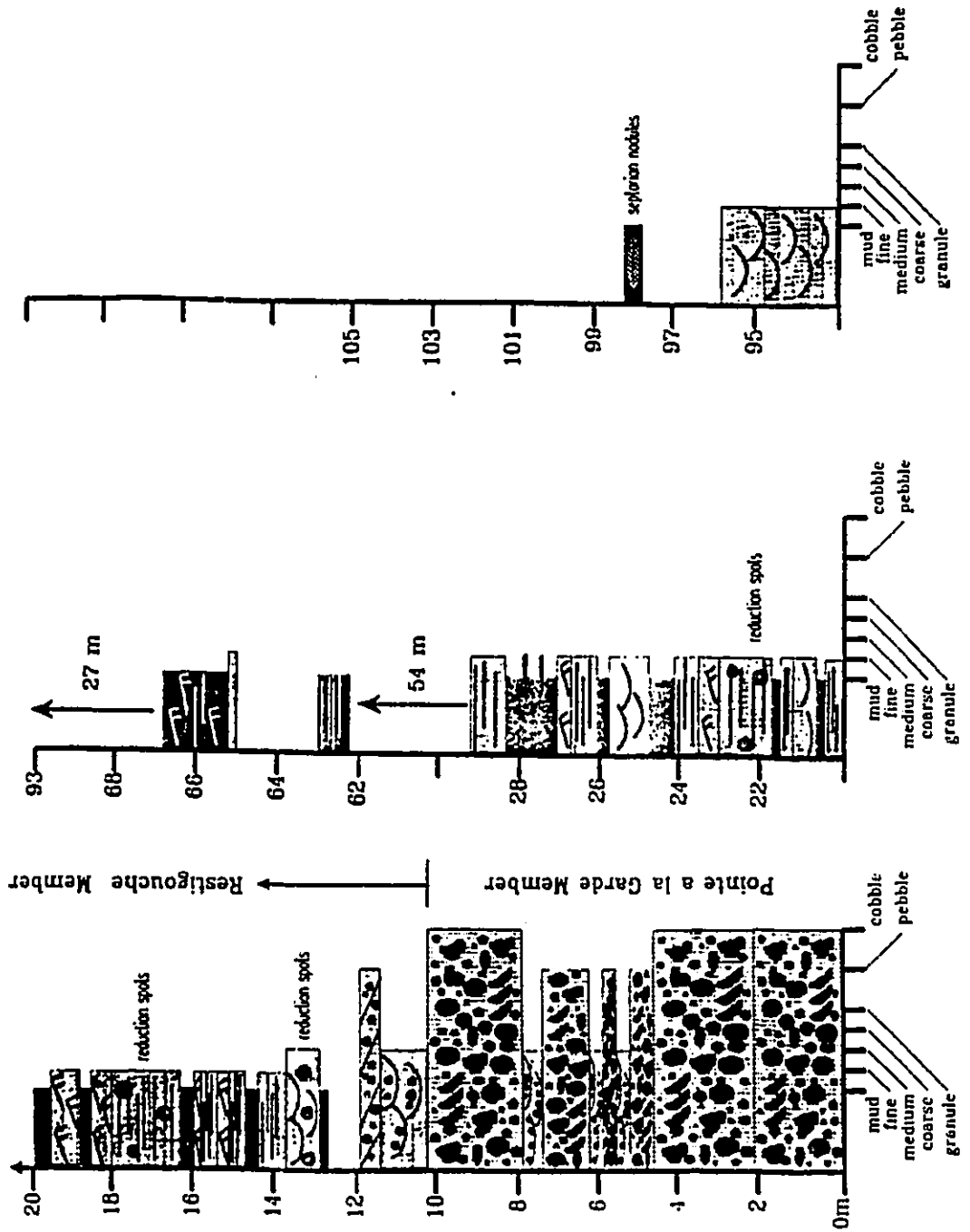


Fig. 5-2. Location of sections in the western Chaleur Bay study area.

SECTION M

Fig. 5-3



5-3 Facies

Facies codes are those of Miall (1977, 1978) and Rust (1978).

St trough cross-bedded, fine to medium grained sandstone, well sorted dark green lithic arenite, occurring as solitary sets up to 40 cm thick, or as grouped cosets. Cosets exhibit a scoured basal contact.

Sh/1 parallel laminated very fine to fine grained dark green lithic arenite, laminae horizontal to low angle inclined containing abundant plant fragments along bedding planes.

Sr ripple drift cross-laminated very fine to fine grained silty lithic greywacke, sets up to 1.5 cm thick, with abundant plant fragments along foresets.

F1 laminated muddy siltstone and silty shale containing abundant plant fragments, may be rooted.

Fm massive siltstone and mudstone containing abundant plant fragments, may be rooted.

5-4 Description and Interpretation of Sections

5-4-1 Section M

The fine grained deposits of section M abruptly and conformably overlie the conglomeratic deposits of the Pointe à la Garde Member (Fig. 5-3). The lower 83 m of section M is composed of interbedded facies Sh/l and Sr, with minor interbedded facies St and Fl. Sandstone petrology indicates that sandy facies are composed of lithic arenite or greywacke. Interbedded facies Sh/l and Sr form tabular units 20 to 150 cm thick, with the lower portion composed of very fine to medium grained facies Sh/l (Fig. 5-4), exhibiting a planar basal contact. Very fine to medium grained silty facies Sr gradationally overlies facies Sh/l, with a slight decrease in grain size (Fig. 5-5). These units may be gradationally overlain by facies Fl or abruptly overlain by another unit composed of facies Sh/l and Sr.

Interbedded units of fine to medium grained facies St occur within the lower 77 m of the section (Fig. 5-3). Facies St forms isolated sets up to 40 cm thick (Fig. 5-6), and rarely forms sequences up to 90 cm thick composed of grouped cosets. Units of facies St exhibit scoured basal contacts, and are either abruptly overlain by sandy facies Sr or Sh/l or gradationally overlain by facies Fl. Facies St is well-sorted, and lacks extraformational or intraformational pebbles. Facies Fl occurs as thinly interbedded tabular units up to 30 cm thick, exhibiting

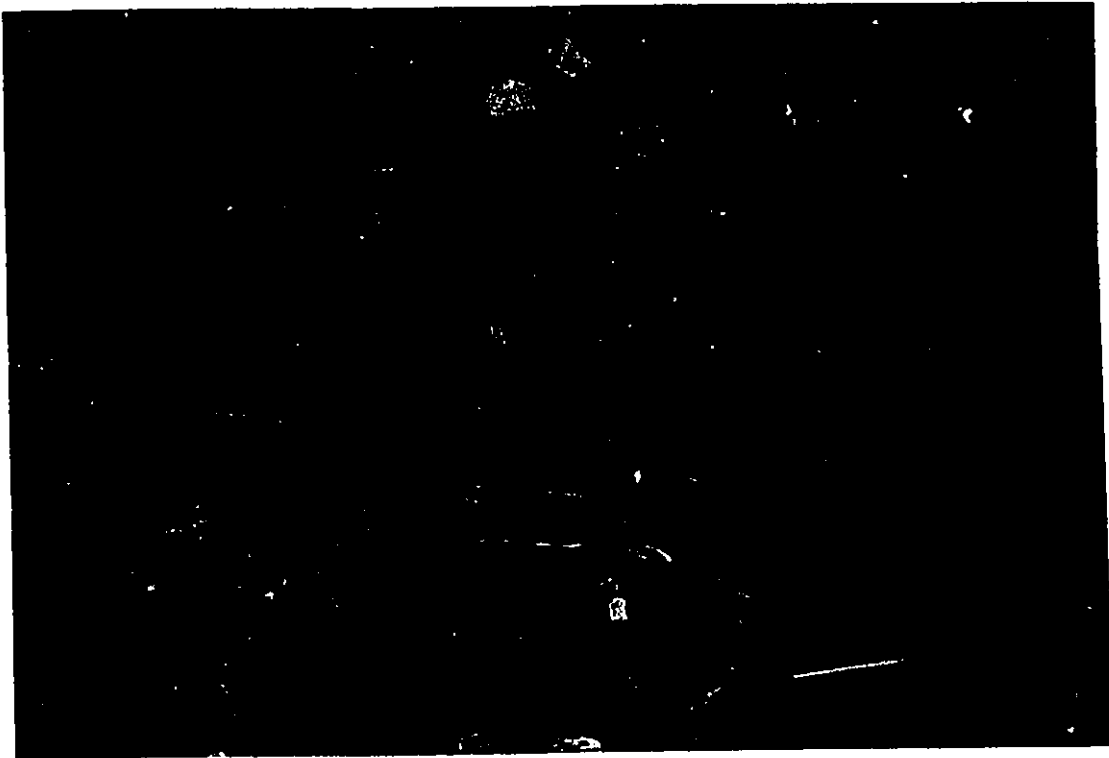


Fig. 5-4. Fine grained facies Sh/1 of the Restigouche Member, section M. Lense cap 6 cm in diameter.

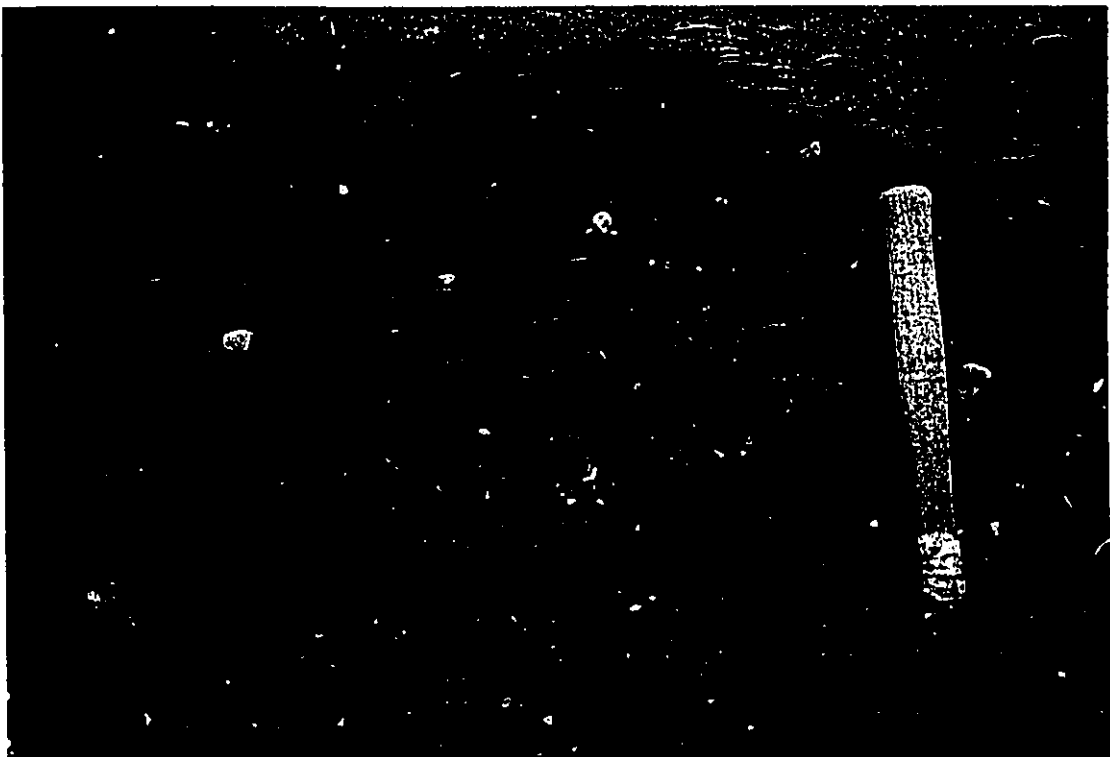


Fig. 5-5. Fine grained current ripple cross lamination (facies Sr) of the Restigouche Member, section M. Hammer 30 cm long.



Fig. 5-6. Solitary set of medium grained cross bedded sandstone (facies St) interbedded with finer grained lithofacies within the Restigouche Member, section M.



Fig. 5-7. Plant fragments within facies Sh/1, presumably oriented parallel to paleoflow, section M. The size of the fragments are unusually large compared to the remainder of the Campbellton Formation. Lense cap 6 cm in diameter.

abrupt scoured upper contacts.

All facies contain abundant plant fragments. The largest occur along the upper surface of units composed of facies Sh/1, and are oriented parallel with respect to each other along bedding planes (Fig. 5-7). Plant fragments within facies F1 are much smaller, however the dark colour of the facies indicates a high carbon content. Roots, caliche, or other pedogenic features are absent from all of the facies. Similarly, no mudcracks or other features indicative of subaerial exposure were observed. Abundant reduction spots occur within the lower portion of the section. The spots are roughly spherical, up to 5 cm in diameter, and have light grey centers with orange to yellow rims.

The upper 6 m of the section is composed of a thick sequence of grouped cosets of medium grained facies St, with minor interbedded facies Sr (Fig. 5-3). Units of facies Sr are convolute, a feature indicative of liquification. A single, 40 cm thick unit of septarian nodules caps the section. The nodules are composed of highly calcareous facies Fm containing abundant plant fragments.

5-4-1-1 Paleocurrents Trends

Two dimensional paleocurrent trends measured from three sets of facies St at various stratigraphic heights within the section indicate northwesterly flow (Fig. 5-8). These

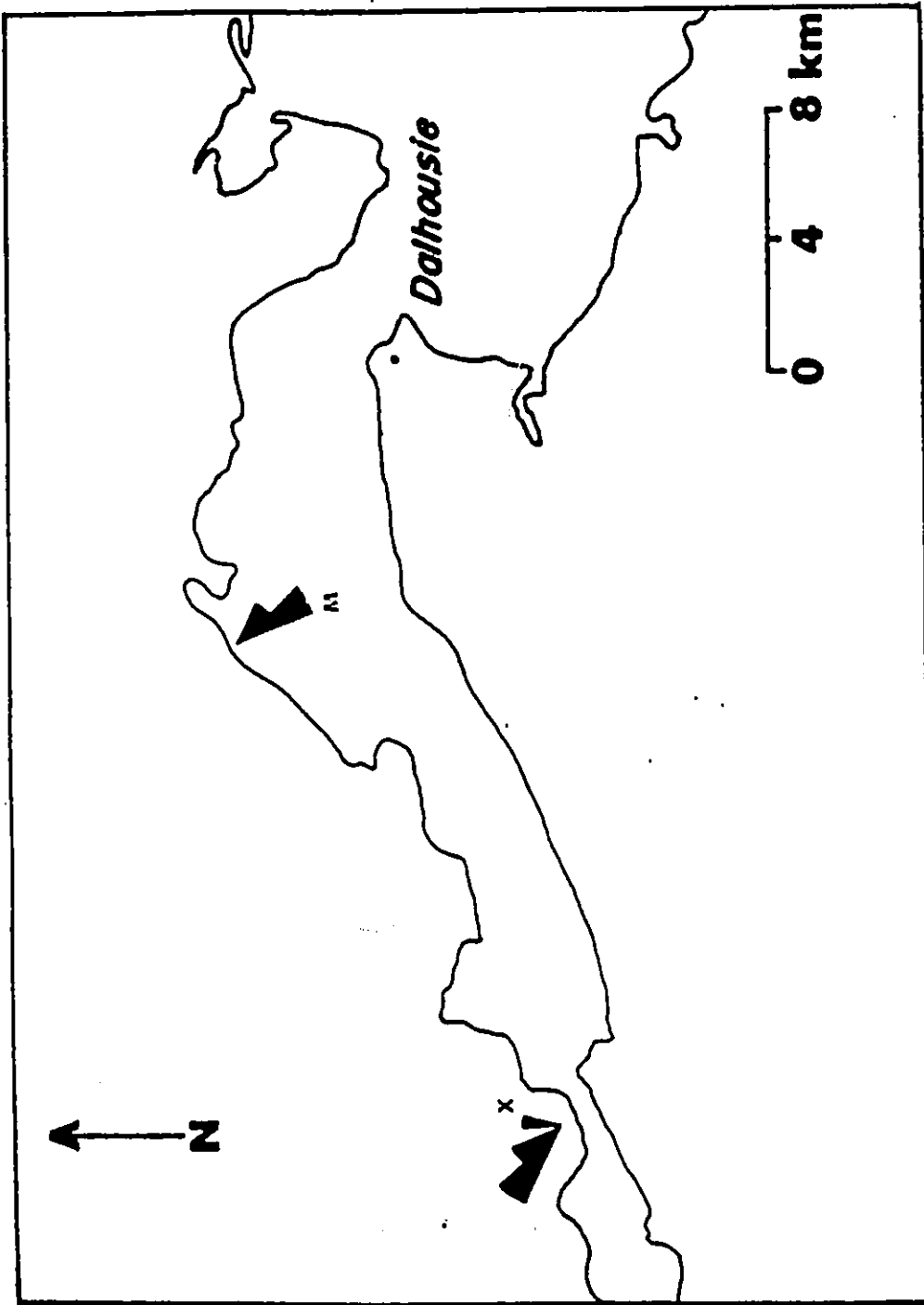


Fig. 5-8 Paleoflow trends within the Restigouche Member obtained from various facies

measurements are equivocal due to the poor, 2-D nature of the exposure. More reliable three dimensional paleocurrent trends from asymmetric ripples measured from one unit of facies Sr indicate southeasterly flow.

5-4-1-2 Interpretation

The succession at section M represents a transition from a sandy braidplain, which forms the lower part of the section, to a floodplain with meandering channels. The occurrence of point bar deposits is impossible to determine due to poor exposure.

Facies Sh/l is attributed to shallow water deposition under upper flow regime conditions (Harms et al., 1982; Reineck and Singh, 1980), with vertical transitions to facies St during waning flow. The tabular nature of these facies suggests that flow upon the braidplain was sheetlike. Facies St was deposited within shallow channels on the braidplain. Finer grained silty to muddy facies F1 and Fm may have been deposited within abandoned channels or on overbank areas. The absence of roots suggests that the former was the most likely depositional environment. The relatively small proportion of facies Fm/F1 relative to sandy facies suggests that inactive channels formed a minor part of the braidplain, and that silt and mud effectively bypassed this portion of the braidplain.

The dark green colour of the deposits and the presence

of reduction spots are indicative of reducing conditions during burial. This is likely due to the presence of a high water table, perhaps due to frequent inundations in a humid climate.

The deposits of the lower portion of section M are very similar in nature to the Bijou Creek model of Miall (1977, 1978). This model is dominated by tabular units of facies Sh, with lesser facies Sr and Sp forming units 15 to 140 cm thick. By analogy with deposits of the Bijou Creek studied by McKee et al. (1967), deposition of the lower part of section M occurred in ephemeral streams under upper flow regime conditions during flood events. Facies Sr was deposited during waning flow, with facies Fl deposited from gentle flow within channels or on overbank areas. Ancient examples include the Sandstone Member of the Peel Sound Formation (Miall, 1970) and the Doko Sandstone of Nigeria (Adeleye 1974).

The upper 6 m of section M consists of a fine grained sequence composed of grouped cosets of facies St passing upwards into facies Fm, which contains a unit of septarian nodules (Fig. 5-3). The sequence of facies St underlying the septarian nodules is interpreted as the deposits of an active channel. Septarian nodules are usually found within marine or lacustrine successions (Boles et al., 1985; Astin, 1986). The formation of the septarian nodules requires a muddy facies and burial within a reducing environment.

Large, stagnant ponds upon the floodplain would provide ideal quiet-water reducing environments suitable for the deposition of mud, with precipitation of calcium carbonate and growth of the nodules beginning immediately after burial.

It is possible therefore that the upper portion of section M represents the avulsion of a meander bend, and the creation of an ox-bow lake, which became the site of quiet-water, low energy deposition.

The abrupt contact between the braidplain deposits of section M and the proximal gravelly braidplain deposits of the Pointe à la Garde Member suggests a significant change in depositional environments. If the Restigouche Member braidplain existed laterally adjacent to the proximal gravelly braidplain of the Pointe à la Garde Member for any length of time, the two deposits should interfinger or exhibit a gradational contact. The abruptness of the contact suggests a fundamental basinwide changes in depositional environments, likely related to an allocyclic, tectonic control. Changes in climatic processes generally encompass a larger timespan relative to tectonic processes. Faulting along the northern margin of the basin, deduced from a northward shift in provenance within the Pointe à la Garde Member, is the most likely explanation for the change in depositional environments within this portion of the basin.

A gradual upwards shift towards lower energy depositional environments occurs within section M. The lower portion is dominated by high energy sheetflood deposits. The presence of septarian nodules at the top of the section indicates the presence of stagnant water-bodies on the floodplain. Large covered intervals near the top of the section could represent poorly indurated silty and muddy facies which weather recessively and are now under cover. The upper portion of section M is therefore interpreted as the deposits of a very low energy floodplain.

5-4-2 Section X

Each of the four sections measured at this locality are composed of facies St and lesser facies Sr, Sh/l, Fm, Fl and Se. Sequences composed primarily of grouped cosets of facies St alternate with sequences composed of interbedded facies Sh/l, Sr, Fl, and Fm (Fig. 5-1). At section XB, a thin unit of facies Se occurs at the base of a thick sequence composed of grouped cosets of facies St. Facies Se is composed of pebble-sized muddy intraclasts and extraformational micritic limestone and volcanic pebbles. The facies forms a thin unit exhibiting a concave-up erosive base, and is gradationally overlain by facies St. Facies St is composed of buff coloured well-sorted fine to medium grained lithic arenite, with sets up to 1.2 m thick, containing scattered intraformational and extraformational

pebbles along foresets and scours. Units composed of grouped cosets of facies St are up to 1.2 m thick (Fig. 5-9), and may fine-upwards (section XA) containing rare interbedded facies Sr.

Thinly interbedded facies Sr, Sh/l, Fl and Fm form sequences up to 2.5 m thick and abruptly overlie sandy cross-bedded units (Fig. 5-10). Fine grained well sorted facies Sh/l exhibits a gradational contact with silty fine grained facies Sr, forming alternating tabular sequences up to 1.5 m thick, as at section XB. Facies Fl and Fm are composed of laminated to massive silty mudstone, forming tabular units. These units are commonly rooted, and contain abundant plant fragments. The fine grained sequences are erosively overlain by units composed of facies St.

5-4-2-1 Paleocurrents Trends

Paleocurrent trends obtained from exposures of facies St located throughout the sections indicate a consistent northwards flow (Fig. 5-8).

5-4-2-2 Interpretation

The succession at section X is interpreted as the deposits of a proximal sandy braidplain. Facies St represents the deposits of sinuous-crested megaripples migrating downstream within active channels. Megaripples of a similar scale were observed within shallow reaches of the

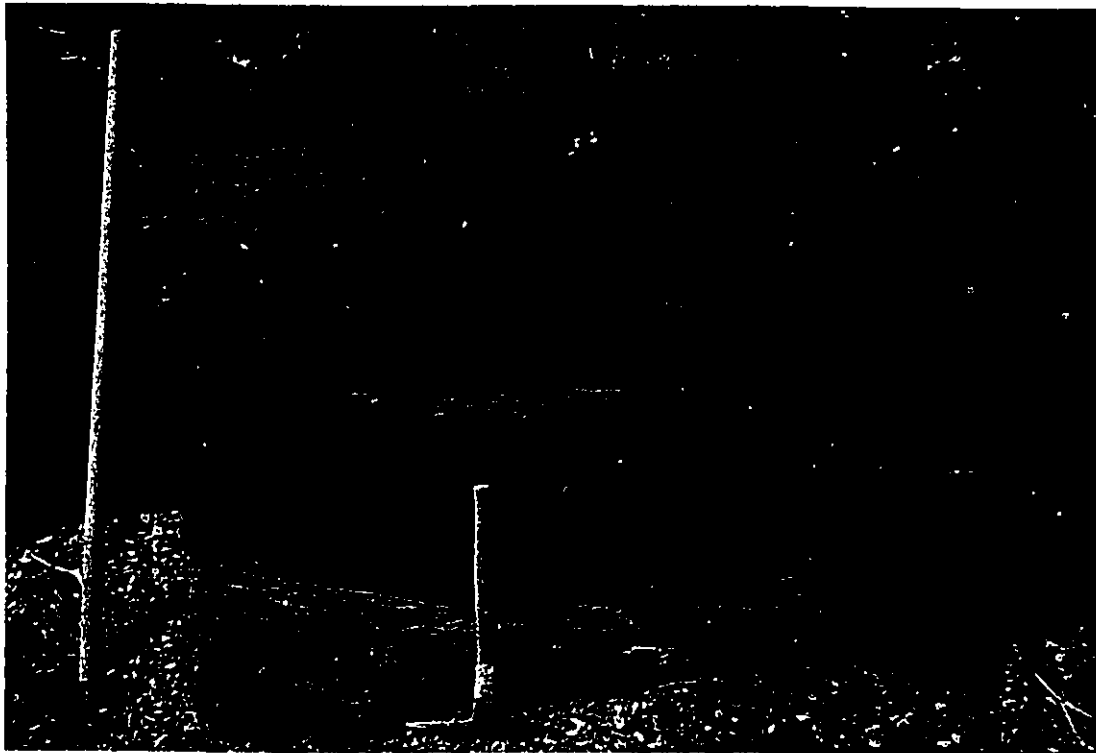


Fig. 5-9. Grouped cosets of medium grained cross bedded facies St within the Restigouche Member at section X. Note large limestone pebbles along the foresets of one unit on either side of the hammer head. Paleoflow trending generally towards the northwest. Stick 1 m long.

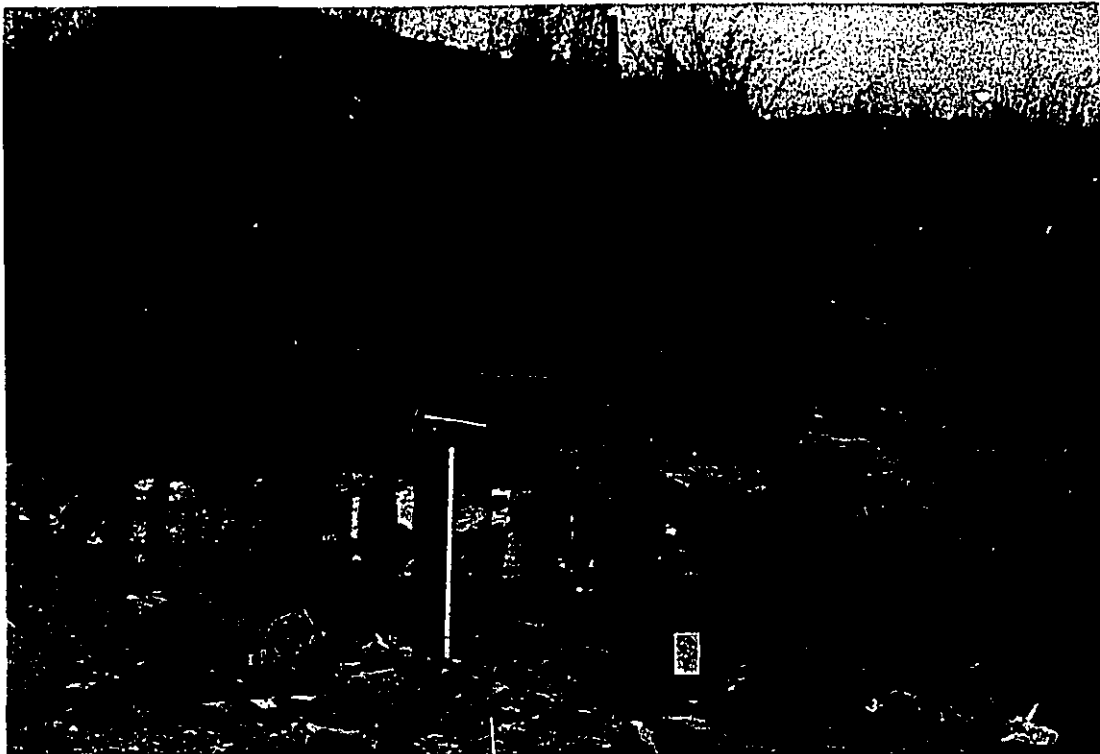


Fig. 5-10. Fining-upwards sequence composed of a lower unit of facies St overlain by a recessively weathering sequence composed of interbedded facies Sr, Sh/l, and Fm and Fl. Pogo is 1 m long.

South Saskatchewan River by Cant (1978). Sequences composed of grouped cosets of facies St at section X therefore represent the deposits of the active channel tract. Each sequence represents the gradual infilling and aggradation of an active channel system. The absence of lateral exposure does not permit an approximation of the lateral dimensions of these channels. Facies Se, which occurs at the base of a sequence composed of grouped cosets of facies St, is interpreted as a scour fill representing the channel lag. Interbedded finer grained sequences composed of facies Sr, Sh/l, Fl and Fm are interpreted either as the deposits of very shallow channel tract or as floodplain deposits. The pervasively rooted nature of the facies within the sequences favours the latter interpretation. Facies Fl and Fm are interpreted as deposited from suspension within inactive channel tracts or depressions on the floodplain. Facies Sr, which occurs interbedded with facies Fm and Fl, was deposited on the floodplain when flow overtopped the banks of a nearby channel during a flood event. At section XB, interbedded facies Sh/l and Sr is indicative of deposition from waning flow, and likely was deposited within shallow partially abandoned channels. Crevasse splay deposits exhibit a similar vertical transition from facies Sh to Sr and are interpreted as the product of flow expansion as flood waters over top the banks of an adjacent channel. Crevasse splay deposits, however, are generally much thicker

than the fine grained sequences at section XB.

The absence of well developed soil profiles within the floodplain deposits can most reasonably be explained in terms of high sedimentation rates. The small percentage of facies Fl and Fm compared to sandy facies Sr suggests that deposition from suspension within low energy pools was not common, and that the floodplain was subjected to frequent inundations during flood events. The absence of caliche, particularly in light of the abundance of available carbonate, is also suggestive of rapid sedimentation rates.

The interbedded nature of active channel deposits, represented by sequences composed of grouped cosets of facies St, and floodplain deposits, represented by interbedded facies Sr, Fm, and Fl, is reminiscent of the South Saskatchewan model of Miall (1977, 1978) and the SII model of Rust (1978). Both are attributed to deposition upon a distal sandy braidplain.

Cant (1978) and Cant and Walker (1976) noted that the active tract of the South Saskatchewan River is dominated by various scales of sinuous-crested megaripples, as well as very large sand flats composed of transverse bar deposits. Inactive tracts of the South Saskatchewan River are dominated by floodplain deposits, primarily those from suspension and from gentle flows created by overbank inundations during flood events. By comparison with the Lower Devonian Battery Point Formation of eastern Gaspé,

Cant (1978) and Cant and Walker (1976) created a facies model for distal sandy braided fluvial systems.

The deposits of section X are similar to the idealized "channel" sequence of the Battery Point Formation in eastern Gaspé (Cant 1978, pg. 632), which is composed of a lower unit of grouped cosets of facies St and an upper portion of interbedded finer grained facies Sr, Sh, Fl, and Fm with no sand-flat deposits. This sequence represents the vertical aggradation of an active channel complex followed by channel switching and the vertical aggradation of floodplain deposits.

The relatively high proportion of floodplain deposits compared to channel deposits within section X is similar to the deposits of a meandering river, which exhibit a similar proportion of floodplain deposits compared to active channel deposits (Jackson, 1978). The absence of lateral accretion deposits at locality X, as well as the absence of crevasse splay deposits within the floodplain sequences argues against a meandering interpretation.

McGregor's (1989a) suggestion that the deposits of section X are marine based on the rare occurrence of acritarchs is unlikely based on the sedimentology of the deposits, which indicate a fluvial depositional environment. In addition, the absence of marine organisms and the presence of numerous rooted horizons argues in favour of a fluvial interpretation. It is likely that the acritarchs

were derived from Silurian micritic limestone grains dissolved during the processing of the palynological samples.

5-5 Summary and Conclusions

The Restigouche Member of the Campbellton Formation contains deposits representative of two distinct depositional environments; a fine grained sandy braidplain to a meandering floodplain (section M), and a proximal sandy braidplain (section X). Both of these systems are temporally and spatially unrelated.

The abrupt and conformable nature of the contact between the Pointe à la Garde Member and the fine grained deposits of the Restigouche Member at locality M is indicative of an abrupt change in basin morphology, attributed to faulting along the northeastern margin of the basin.

The initiation of faulting resulted in the rearrangement of the gravelly proximal braided fluvial system of the Pointe à la Garde Member, from east-west to north-south trending. Rapid infilling of the basin by this system and a cessation of faulting resulted in a decrease in the braidplain gradient. This resulted in the establishment of a lower energy sandy braided fluvial depositional environment, represented by the deposits of the lower part of section M. The southwards directed flow of this system

is based on the orientation of 3-D ripples, and therefore must be viewed with some degree of caution. Continued aggradation and the resulting decrease in gradient resulted in the development of a meandering fluvial system and the creation of small stagnant freshwater bodies or lakes, represented by the upper part of section M (Fig. 5-11). The spatial extent of these floodplain conditions is unknown.

section X represents the deposits of a younger proximal sandy braidplain. The south to north orientation of the system is identical to that of the older Pointe à Bourdeau Member. It is therefore possible that the mid Emsian longitudinal system was maintained until late Emsian time. The shift from a relatively proximal gravelly braidplain to a sandy braidplain is due to a decrease in the rate of basin subsidence or margin relief, related to the progressive unroofing and dissection of the uplifted volcanic-arc remnants to the south. The presence of Silurian limestone clasts within the deposits of section X indicate that by late Emsian time the Upper Silurian to Lower Devonian volcanics of the Dalhousie Group to the south had been completely unroofed in places, exposing the underlying Silurian carbonates of the Chaleurs Group.

The spatial extent of the late Emsian sandy braidplain is unknown, but it is likely to have debouched northwards into a marine body represented by the deposits of the Fortin Group (Fig. 5-12).

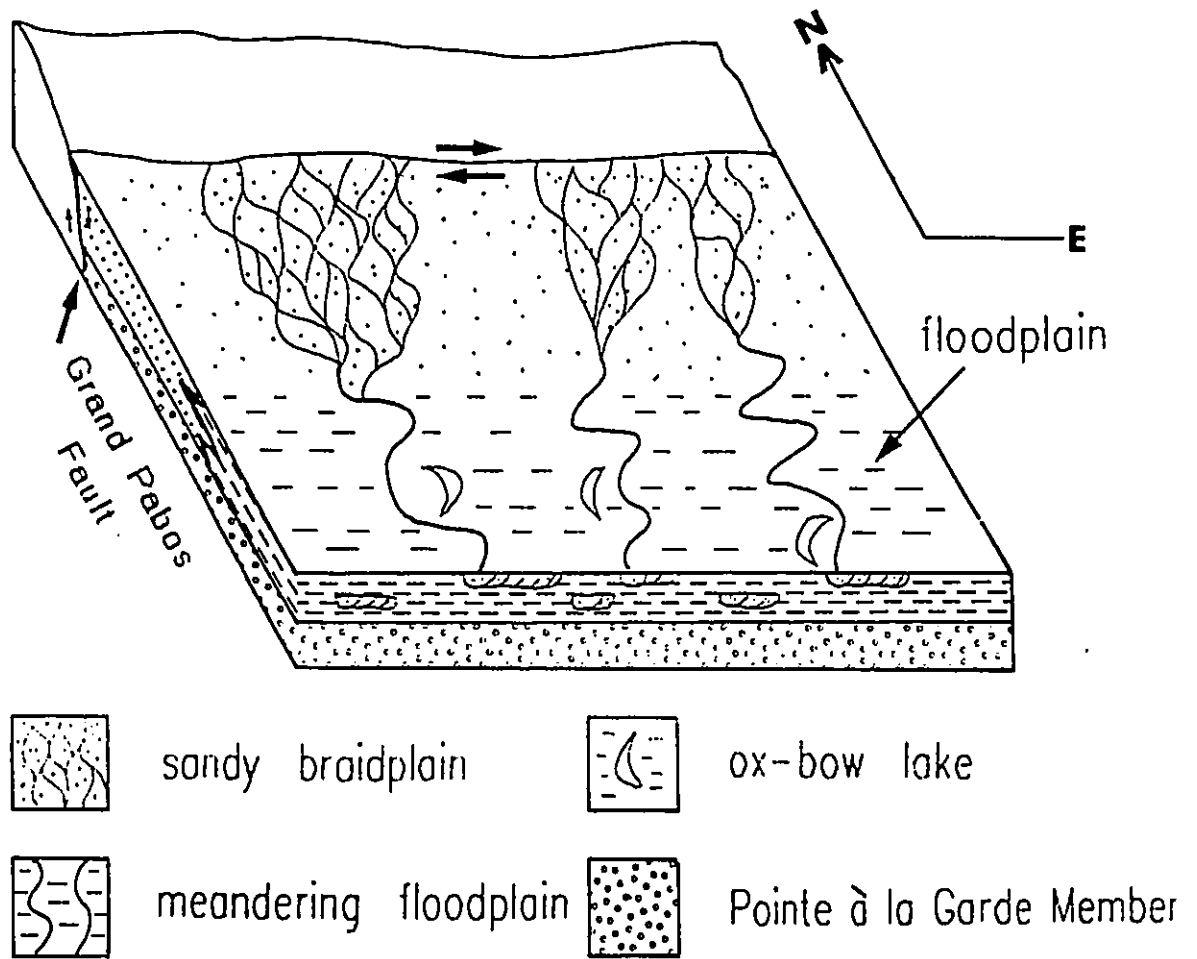


Fig. 5-11 Hypothetical depositional model for deposits of the Restigouche Member at section M. Illustrated orientation of drainage system speculative.

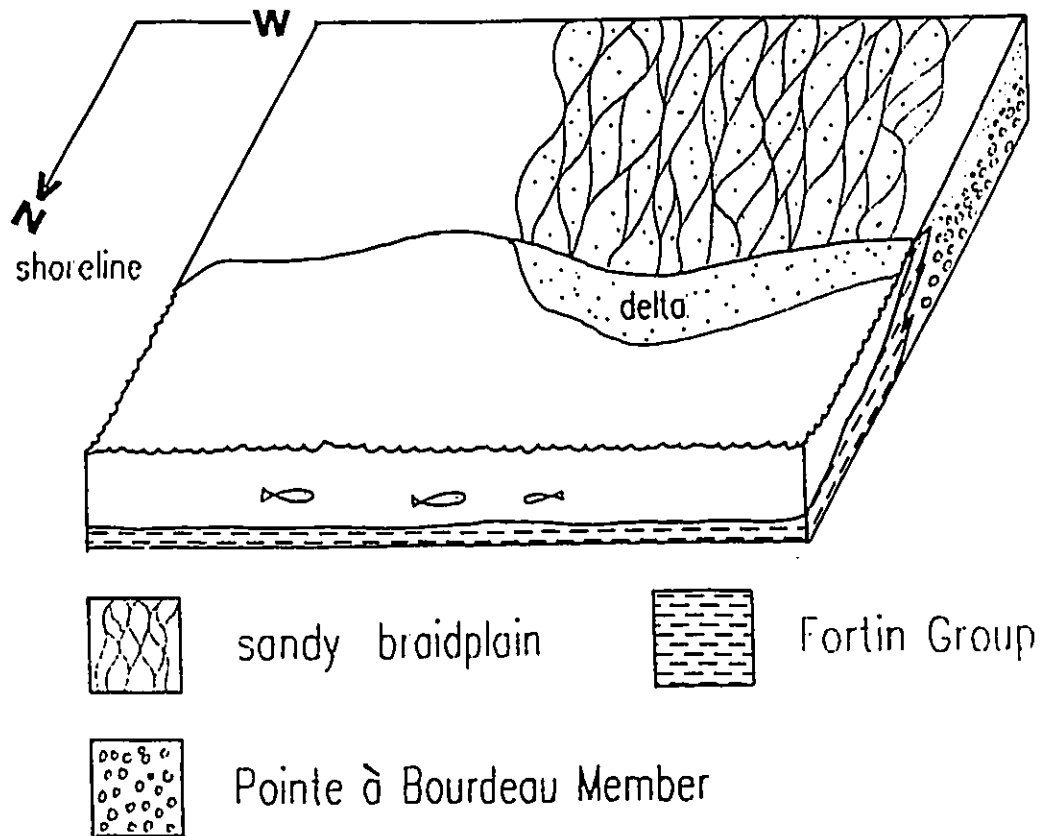


Fig. 5-12 Depositional model for the deposits of the Restigouche Member at section X. Note gradational contact with underlying deposits of the Pointe à Bourdeau Member. The deltaic system to the north at the edge of the marine body (represented by the deposits of the Fortin Group) is hypothetical.

In conclusion, the upper two members of the Campbellton Formation form a large-scale fining-upwards sequence representing a major shift in basin morphology, related to a cessation of uplift and downcutting of the eastern and southern basin margins and the onset of faulting along the northeastern margin of the basin.

The Restigouche Member of the Campbellton Formation is conformably overlain by the Middle Devonian Pirate Cove Formation (Zaitlin, 1981), although the contact is not exposed. The lowermost succession of the Pirate Cove Formation, observed by the author and B. Rust, is interpreted as fine grained floodplain deposits. Sharply lenticular units of limestone breccia, interpreted as channel deposits, occur isolated within a thick sequence of fine grained floodplain deposits, comprising interbedded red and green siltstone and mudstone, exhibiting rooted horizons, caliche, and mudcracks. A gradational transition therefore exists between the low energy floodplain deposits of the Restigouche Member of the Campbellton Formation and the lowermost floodplain deposits of the Pirate Cove Formation.

CHAPTER 6

SUMMARY AND CONCLUSIONS

Sedimentological investigation of the mid to late Emsian Pointe la Nim and Campbellton formations in the western Chaleur Bay area reveals the existence of two distinct drainage systems. These formations exhibit facies assemblages which enable proximity trends to be established, allowing for the reconstruction of basin architecture.

The Point la Nim Formation is interpreted as the deposits of an early to mid Emsian braidplain (Fig. 2-20) situated on the northern flank of an active volcanic range forming part of the Piscataquis volcanic island-arc which extended from central Maine to central Gaspé, a distance of some 1500 km (Fig. 1-3). Volcanism was related either to rifting in a transpressive regime (i.e. continental, Dostal et al., 1989), or island arc related volcanism within a subductive regime (Fig. 1-4) (Bradley, 1983). By mid Emsian time, volcanism had ceased, resulting in the ponding of portions of the drainage network and the creation of a lacustrine body, represented by the Atholville Member (Fig. 3-16).

The Pointe à la Garde, Pointe à Bourdeau and Restigouche Members of the Campbellton Formation are interpreted as the deposits of mid to late Emsian

braidplains situated on the western flank of a broad upwarp created during the early compressional phases of the Acadian Orogeny. Continental collision between Avalonia and Laurentia resulted in compression and crustal shortening, which, in the southwestern Gaspé area, created a broad northward trending upwarp (Fig. 4-48). The extinct Piscataquis arc and the Miramichi Massif acted as rigid blocks which likely controlled the orientation of this upwarp. This resulted in the uplift and dissection of the Late Silurian to Early Devonian volcanic arc represented by the Dalhousie Group. The absence of mid to late Emsian alluvial fan deposits in both the western Chaleur Bay and eastern Gaspé areas argues against fault controlled sedimentation. The Pointe à la Garde Member is interpreted as a proximal gravelly braidplain deposit which formed a broad transverse drainage network flowing westwards down paleoslope (Fig. 4-48). This transverse system debouched into a northward-flowing longitudinal system represented by the deposits of the Pointe à Bourdeau Member (Figs. 4-47, 4-48). The large-scale fining-upwards megasequences within the Pointe à la Garde Member are attributed to episodic uplift along the axis of the upwarp, resulting in the westward progradation of the Pointe à la Garde proximal gravelly braidplain. Periods of tectonic quiescence resulted in eastward encroachment of the longitudinal sandy braidplain.

The Restigouche Member is interpreted as the deposits of a sandy braidplain and meandering floodplain. Deposits located in the eastern part of the study area exhibit a temporal transition from a sandy braidplain to a meandering floodplain (Fig. 5-11). The abrupt nature of the contact between the Pointe à la Garde and Restigouche members in this area indicates a profound change in basin architecture, and is attributed to the initiation of faulting along the Grand Pabos fault located to the north (Fig. 1-8c). Deposits to the west are interpreted as those of a sandy braidplain (Fig. 5-12). Continued northward paleoflow on this braidplain indicates that the longitudinal system initiated in mid Emsian time was maintained until the late Emsian.

The mid to late Emsian basin is interpreted to have extended from Grand Cascapedia, Quebec, to Point a Bourdeau, Quebec, located 2.5 km west of Cross Point Quebec (Fig. 6-1). This basin was likely of much greater lateral extent. The lithological and temporal similarity of Emsian deposits in the western Chaleur Bay and eastern Gaspé areas suggests that both successions were deposited within the same basin, namely the Gaspé Basin of Bourque et al. (in press) (Table 6-1, Figs. 1-5e, 6-1). The Wapaske Formation of Carlton County, southwestern New Brunswick, and the Temiscouta Formation of Madawaska County, western New Brunswick, both contain deposits of Emsian age (Bourque et al., in press),

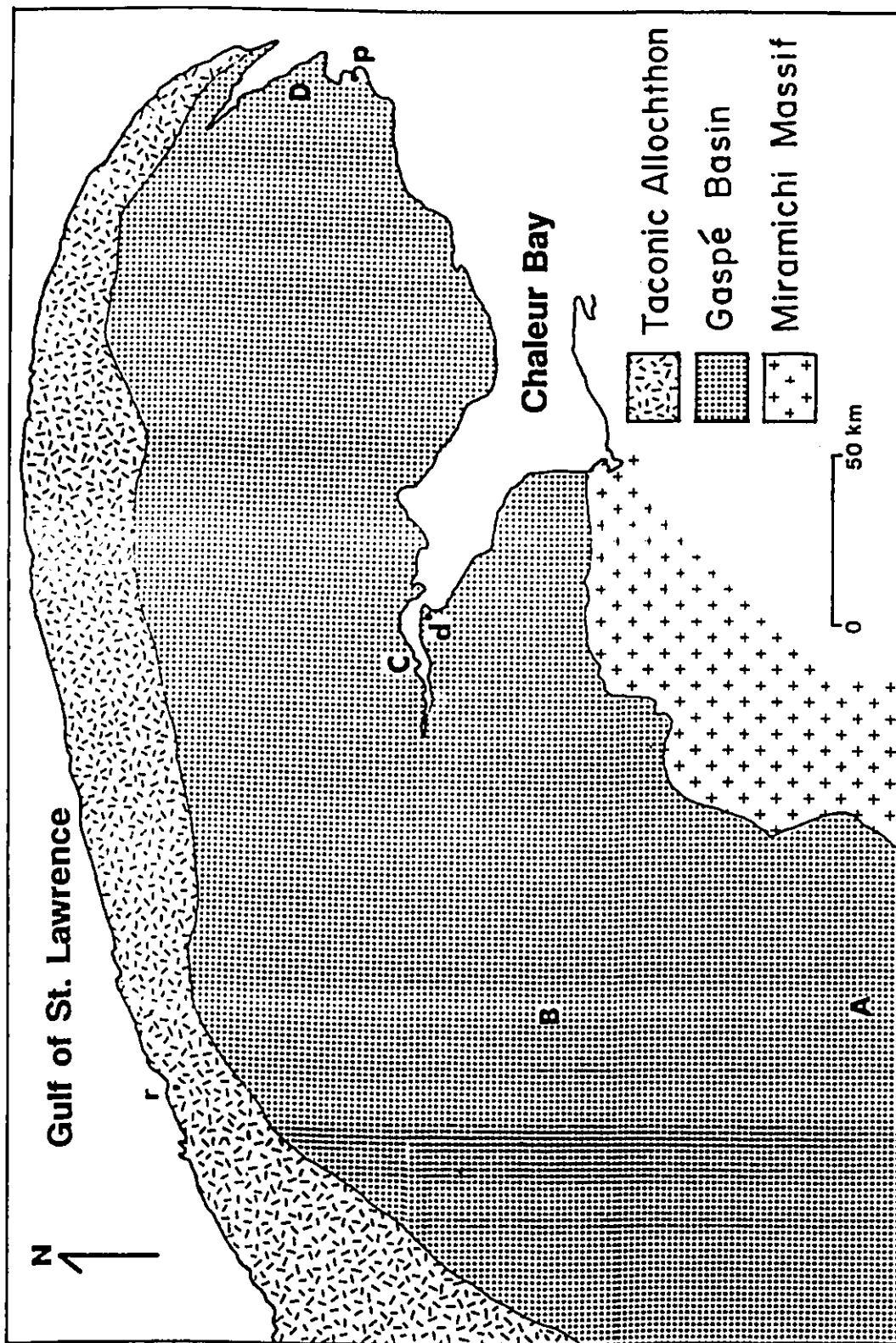


Fig. 6-1. Probable extent of the Gaspé Basin during middle to late Emsian time. Letters A, B, C, and D correspond to the stratigraphic columns illustrated in Table 6-1. p-Percé, r-Rimouski, and d-Dalhousie.

TABLE 6-1

			W		E	
localities (Fig. 6-1) →			A	B	C	D
DEVONIAN	Late	Frasnian		Touladi Fm	Escuminac Fm	
	Middle	Givetian			Fleurant Fm	
		Eifelian			Pirate Cove Fm	
	Early	Emsian	Wapaske Fm	Temiscoula Fm	Campbellton Fm	Battery Point Fm
		Pragian			Dalhousie Group	York River Fm

Legend	
—————	conformable
- - - - -	unconformable
.....	unknown

Devonian Stratigraphy of Western Chaleur Bay and Eastern Gaspé

and are therefore correlative with the Emsian successions of the western Chaleur Bay and eastern Gaspé areas (Table 6-1). The Wapaské Formation is composed of mudstones, shales, coarse sandstones and conglomerates, the latter of late Emsian age (Bourque et al., in press). The coarse sandstones and conglomerates contain clasts of Lower Devonian volcanics derived from the underlying Costigan Formation, a correlative of the Dalhousie Group (Bourque et al., in press), and thus are of similar aspect to the Emsian successions of western Chaleur Bay. Similarly, conglomerates within the correlative Temiscouta Formation to the north may also reflect terrestrial sedimentation. The possible occurrence of Emsian terrestrial deposits within these two formations therefore indicates the great areal extent of the Gaspé Basin during Emsian time (Fig. 6-1).

Dineley and Williams (1968) and most recently Bourque et al. (in press) suggested that, based on lithological and biostratigraphic similarities, the Battery Point and Malbaie formations of eastern Gaspé and the correlative Lagarde (Campbellton) and Pirate Cove formations of western Chaleur Bay were deposited in the same basin (Fig. 1-5e). Bourque et al. (in press) suggested that restoration of the 150 km of Late Devonian dextral displacement between the two areas results in the formation of a northwards trending facies belt which they consider fluvio-deltaic (Fig. 14 f of Bourque et al., in press). Lawrence and Rust (1988) and

Rust et al. (1989) however disagree with this interpretation, largely on the grounds of paleoflow directions within the fluvial deposits of the Battery Point and Malbaie formations, which indicate a northward paleoslope, and those of the Pirate Cove, Fleurant, and Escuminac formations, which indicate a southward mean paleoslope. Based upon these paleoflow trends, as well as the lacustrine nature of the Upper Devonian Escuminac Formation, Lawrence and Rust (1988) and Rust et al. (1989) suggested that the succession in the western Chaleur Bay area was deposited in an intermontane basin located within an 'Acadian Mountain range'.

The results of this study however indicate that until late Emsian-early Eifelian time, the succession in the western Chaleur Bay and eastern Gaspé areas was deposited in the same basin (the Gaspé Basin of Bourque et al., in press) (Fig. 1-8 b). In late Emsian-early Eifelian time, the Gaspé Basin was fragmented by east-west directed dextral faulting related to transpression resulting from collision between Avalonia and Laurentia (Fig. 1-8 c).

Several lines of evidence support this theory: 1) in the early to mid Emsian, shallow marine or transitional conditions existed in the eastern Gaspé area (York River and Battery Point formations) while shallow marine to terrestrial conditions existed in the western Chaleur Bay area (Pointe la Nim Formation of the Dalhousie Group), which

was the site of a northeast to southwest trending volcanic arc. Interbedded volcanics also occur within the York River Formation of central Gaspé (Bourque et al., in press).

2) in the mid to late Emsian, a westward flowing transverse and northwards flowing longitudinal gravelly drainage network existed in the western Chaleur Bay area. In the eastern Gaspé area, paleoflow within the Petite Gaspé and Cap-aux-Os Members of the Battery Point Formation (mid-late Emsian) was predominantly northwestwards, more or less parallel to the main orientation of the longitudinal drainage system within the Pointe à Bourdeau Member of the Campbellton Formation (Figs. 4-47, 4-48). Lawrence and Rust (1988, Figs. 5.2 and 3, p. 56) suggested the existence of a northwards flowing transverse system and a westwards flowing longitudinal system within the two lower members of the Battery Point Formation based primarily upon paleocurrent data. Examination of paleocurrent trends reveals a maximum separation of only 45 degrees between the two systems within the Cap-aux-Os Member (Lawrence and Rust, 1988, Fig. 6, p. 57), which does not necessarily imply a transverse to longitudinal relationship.

3) the late Emsian to early Eifelian Fort Prevel Member of the Battery Point Formation exhibits a reversal in the direction of flow within the longitudinal braided fluvial system from west to east (Lawrence and Rust, 1988, Fig. 5.4, p. 56). The appearance of limestone clasts within both the

Fort Prevel Member and the Restigouche Member of the Campbellton Formation is additional evidence for linkage in late Emsian time. Reversal of drainage patterns within the Battery Point Formation and the abrupt change towards lower energy alluvial depositional environments within the Restigouche Member of the Campbellton Formation are likely related, and may represent the onset of faulting which eventually fragmented the Gaspé Basin. Northward flow of the longitudinal system represented by the westernmost deposits of the Restigouche Member of the Campbellton Formation in late Emsian time parallels that of the transverse system within the Fort Prevel Member, suggesting that faulting did not disrupt the linkage between these two areas until post-late Emsian time.

4) The transverse and longitudinal relationship exhibited by the Pointe à la Garde and Pointe à Bourdeau Members of the Campbellton Formation suggests a large depositional basin, with deposition adjacent to a very broad upwarp.

There are also some notable lithological differences between the Emsian successions of the eastern Gaspé and western Chaleur Bay areas. The Battery Point Formation is composed primarily of sediment derived from metamorphic and granitic source rocks, indicative of a complex source area (Lawrence, 1986). The Campbellton Formation is composed primarily of sediment derived directly from the underlying Dalhousie Group volcanics. Facies assemblages within the

Battery Point Formation are indicative of deposition upon proximal to distal sandy braidplains. Facies assemblages within the Campbellton Formation, on the other hand, are indicative of deposition upon proximal gravelly and sandy braidplains. The contrast in facies assemblages between the two formations may suggest a proximal to distal relationship between the two successions, with petrographic differences related to the localized nature of source rock.

By early Eifelian time, the Gaspé Basin was fragmented by a series of east-west trending dextral strike-slip faults located along the margins of the Aroostook-Percé Anticlinorium (Fig. 6-2). This resulted in the creation of two smaller sub-basins: a half-graben in the western Chaleur Bay area, and a large sized remnant of the Gaspé Basin in eastern Gaspé (Fig. 1-8 c). In Eifelian time, each of the sub-basins was the site of gravelly alluvial deposition; the Malbaie Formation of eastern Gaspé, and the Pirate Cove Formation of western Chaleur Bay. Sedimentologically, several features of the Eifelian successions within each sub-basin attest to fragmentation of the Gaspé Basin. Lithologically, the Malbaie Formation of eastern Gaspé and the Pirate Cove Formation of western Chaleur Bay are similar, being composed predominantly of carbonate clasts derived from the Matapedia and Chaleur Groups. This suggests that each of the successions were derived from the same source area, which was the uplifted Aroostook-

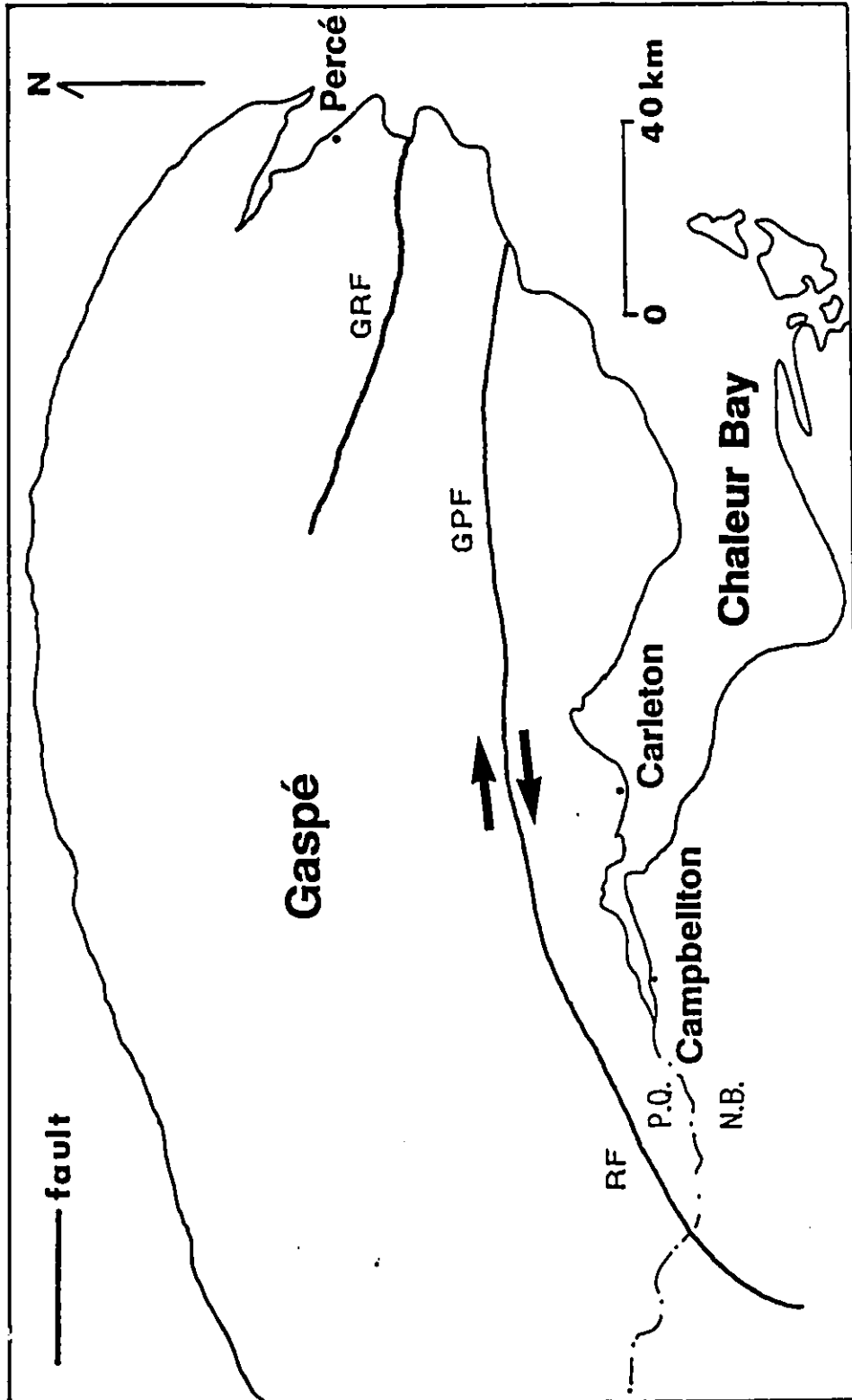


Fig. 6-2 Major strike-slip faults active in the Gaspé area during Eifelian time. S-shaped Grande Pabos Fault (GPF) and its western extension, the Restigouche Fault (RF), forms a prominent restraining bend, resulting in transpression to the north.

Matapedia Anticlinorium separating the two sub-basins (Fig. 1-8 c). As noted by Lawrence and Rust (1988) and Rust et al. (1989), differences in facies assemblages between the two contemporaneous formations indicates that deposition in each basin was controlled by different tectonic processes. Alluvial fan deposits within the Pirate Cove Formation (Zaitlin, 1981) indicate steep fault relief along the northern margin of the western Chaleur Bay basin. Based on this, Zaitlin (1981) proposed that the Pirate Cove and subsequent formations were deposited in a half-graben. The absence of alluvial fan deposits and the lateral uniformity of paleoflow within the Malbaie Formation suggests deposition upon a broad northerly inclined upwarp (Fig. 6-3). Rust (1981), Lawrence and Rust (1988) and Rust et al. (1989) suggested that the upwarp is related to compression and crustal flexure related to the Acadian Orogeny. In light of evidence of faulting in the western Chaleur Bay area however, it is also possible that the coarse gravelly deposits of the Malbaie Formation were deposited on the gently north sloping flank of the footwall block (Fig. 6-4). Dextral displacement along the curved Grand Pabos fault, along which most of the cumulative 155 km of displacement occurred (Fig. 6-3) (Malo and Béland, 1989), resulted in transpression along a restraining bend and subsequent flexure which formed a gentle northwards sloping plain. Transpression at restraining bends is known to create broad

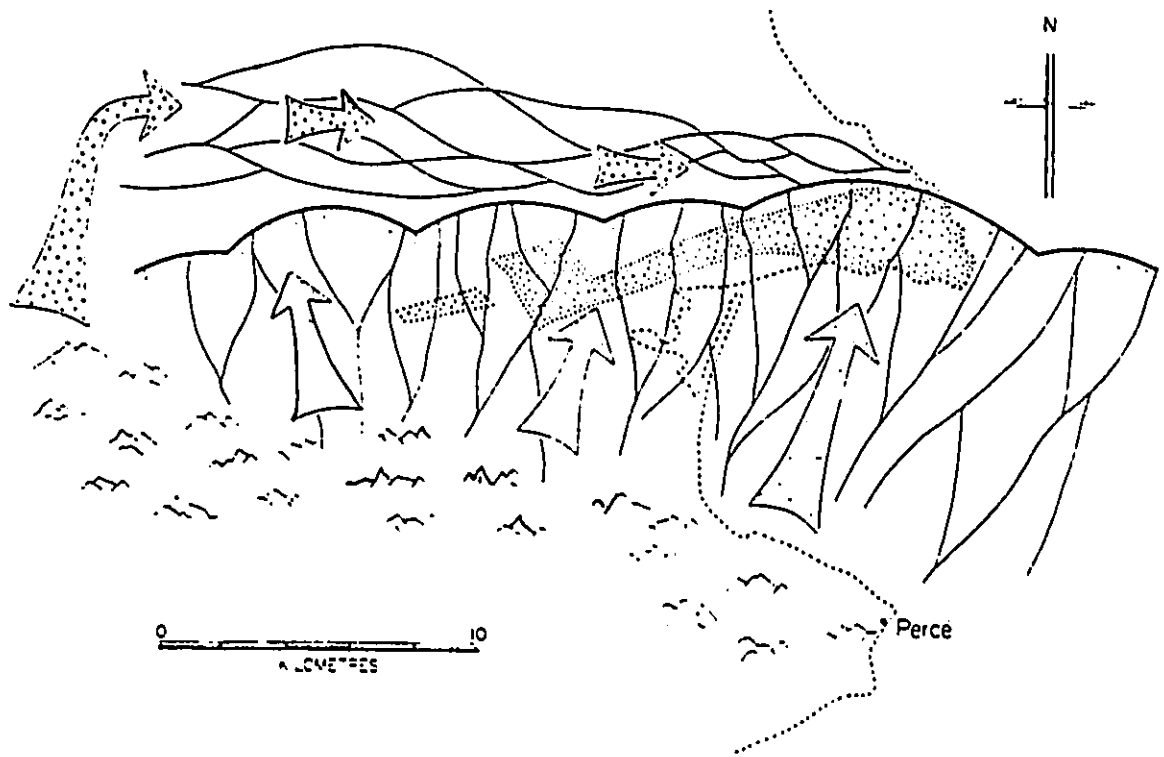


Fig. 6-3 Depositional model for the Eifelian braided fluvial deposits of the Malbaie Formation of Eastern Gaspé (after Rust, 1984a). Lateral uniformity of paleoflow in the proximal gravelly braidplain deposits suggests deposition on a broad upwarp.

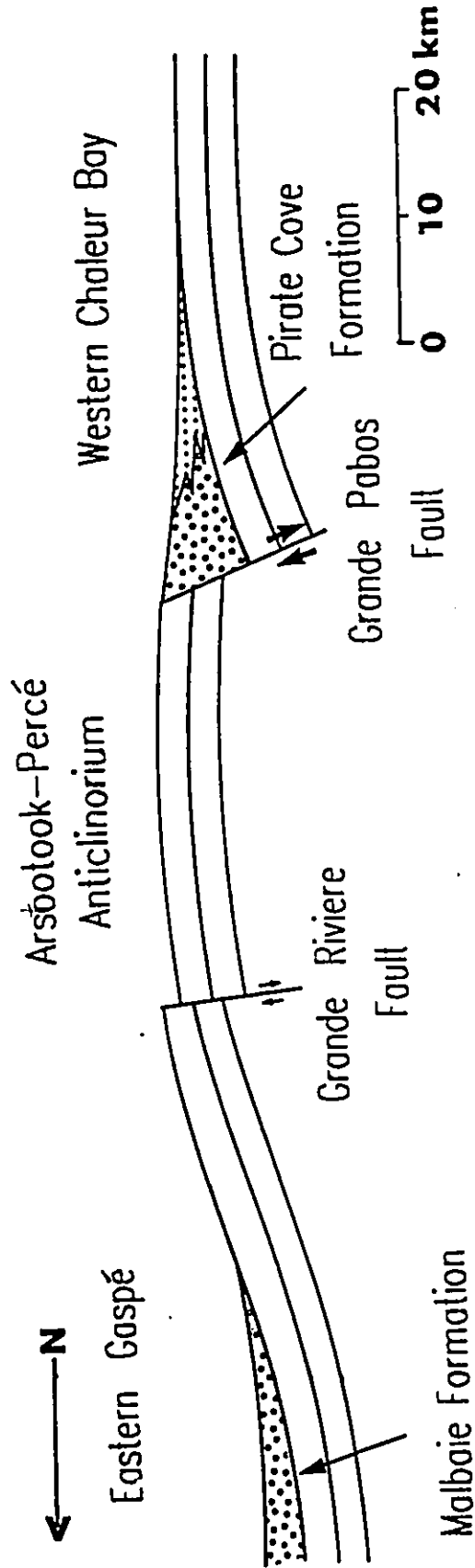


Fig. 6-4 Hypothetical Eifelian tectonic scenario. Initiation of dextral strike-slip faulting, primarily along the Grande Pabos Fault, results in the tilting and compression of blocks and subsequent sedimentation adjacent to areas of high relief, such as fault scarps in Western Chaleur Bay, and on gentle flexures of the footwall block, as in Eastern Gaspé.

and gently inclined upwarps (Reading, 1981). Meanwhile, along the southern fault-bounded margin of this block, alluvial fans of the Pirate Cove Formation prograded southwestwards (Fig. 6-4).

The nature of the overlying Fleurant and Escuminac Formations and the change in paleoflow within the Restigouche Member of the Campbellton Formation in the western Chaleur Bay area also attest to the fragmentation of the Gaspé Basin by Middle to Late Devonian time. The lacustrine deposits of the Escuminac Formation are suggestive of deposition in a small basin (Rust et al., 1989). The shaly and sandy fossiliferous limestone, sandstone, and conglomerate of the Upper Devonian Touladi Formation of Madawaska County in northwest New Brunswick (Bourque et al., in press) indicate that marine conditions existed to the southwest. The relationship between this marine body and the terrestrial environments in western Chaleur Bay and eastern Gaspé is unclear.

The deposits of the Pointe la Nim Formation and the Campbellton Formation indicate a transition from early to mid Emsian synvolcanic sedimentation related to subduction of Avalonian oceanic crust beneath Laurentia to syntectonic sedimentation related to compression during continental collision between Avalonia and Laurentia during mid to late Emsian time. This collision is usually referred to as the Acadian Orogeny. The onset of the Acadian Orogeny resulted

in the westward progradation of a terrestrial clastic wedge, represented by the deposits of the Campbellton Formation and the correlative Battery Point Formation, into the Gaspé Basin. By Eifelian time, dextral faulting related to an east-west oriented compressive regime related to continued collision between Avalonia and Laurentia resulted in the fragmentation of the Gaspé Basin into two distinctive sub-basins. Both sub-basins were the site of coarse alluvial deposition, represented by the deposits of the Pirate Cove and Malbaie Formations, which are reflective of two distinct tectonic environments in an overall strike-slip regime. Based upon the progressively younger ages of clastic wedges to the southwest along the strike of the Appalachian Orogen, Ettensohn (1985) suggested that the timing of continental collision between Laurentia and Avalonia was diachronous in a southwestward direction. In Ettensohn's (1985) model, the progradation of successive clastic wedges is related to collision between Avalonia and various promontories along the Laurentian margin (Fig. 6-5). Southwestward diachroneity implies dextral motion between the two continents. At this stage, paleomagnetic and kinematic indicators yield equivocal interpretations concerning the direction of relative motion between the two continental blocks.

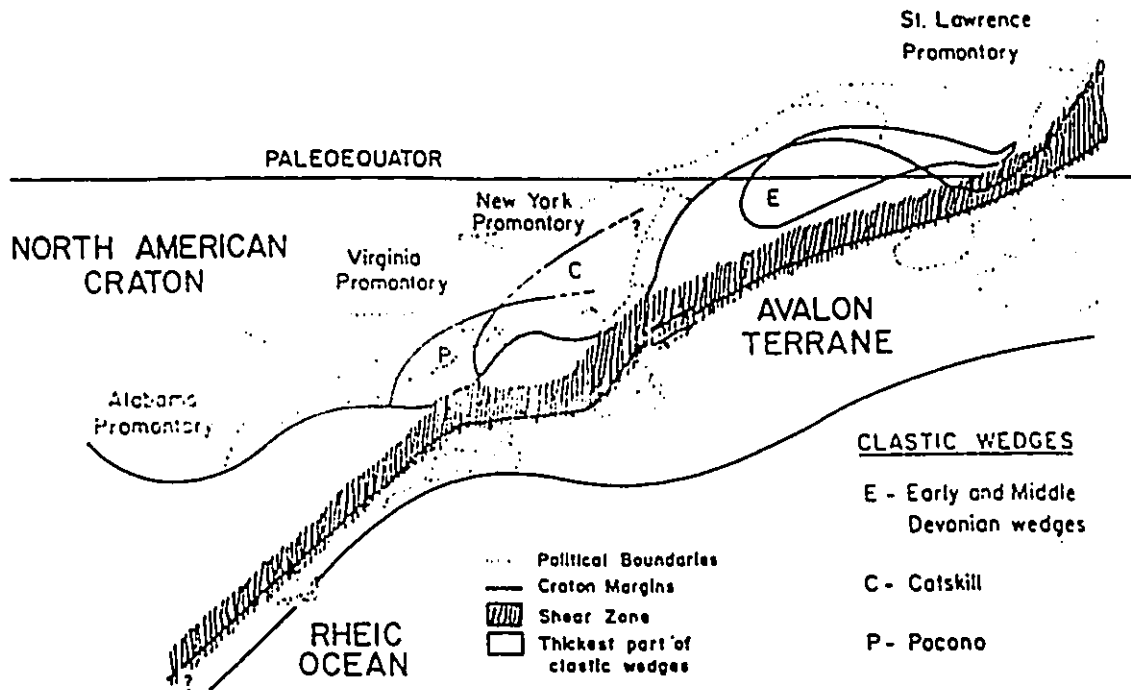


Fig. 6-5 Collision between Laurentia and Avalonia results in the successive progradation of successive clastic wedges away from the various promontories located along the margin of Laurentia (after Ettensohn, 1985).

REFERENCES

- Adeleye, D.R., 1974: Sedimentology of the fluvial Binda Sandstone (Cretaceous), Nigeria. *Sed. Geol.*, v. 12, p. 1-24.
- Alcock, F.J., 1935: Geology of the Chaleur Bay Area. Geological Survey of Canada, Memoir 183, 146 p.
- Allen, P.A., and Collinson, J.D., 1986: Lakes. In Reading, H.R., ed., *Sedimentary Environments and Facies*, 2nd Edition, Blackwell Scientific, p. 63-94.
- Ami, H.M., 1900: Note bearing on the Devonian-Carboniferous problem in Nova Scotia and New Brunswick. *Ottawa Naturalist*, v. 14 (7), p. 121-127.
- Andrews, H.N., Gensel, P.G., and Forbes, W.H., 1974: An apparently heterosporous plant from the Middle Devonian of New Brunswick. *Paleontology*, v. 17, p. 387-408.
- and Kasper, A.E., 1975: A new fossil plant of probable intermediate affinities (Trimerophyte-Progymnosperm). *Can. J. Earth Sci.*, v. 53, p. 1719-1728.
- Astin, T.R., 1986: Septarian crack formation in carbonate concretions from shales and mudstones. *Clay Minerals*, v. 21, p. 617-631.
- Bedard, J.H., 1986: Pre-Acadian magmatic suites of the southeastern Gaspé Peninsula. *GSA Bull.*, v. 97, p. 1177-1191.
- Béland, J., 1958: Preliminary Report on the Oak Bay area, Electoral District of Matapédia and Bonaventure; Que. Dept. of Nat. Res. Prel. Rept. #375.
- , 1972: The La Garde Formation. In P. St Julien and others (eds). *Excursion Guidebook A56-C56*, IAS International Geological Congress 1972, Montreal, p. 90-92.
- Bird, J.M., and Dewey, J.F., 1970: Lithosphere plate-continental margin tectonics and the evolution of the Appalachian Oregon. *GSA Bull.*, v. 81, p. 1031-1060.
- Boles, J.R., Landis, C.A., and Dale, P., 1985: The Moeraki boulders- anatomy of some septarian concretions. *J. of Sed. Petro.*, v. 55 (3), p. 398-406.

Boothroyd, J.C., and Nummedal, D., 1978: Proglacial braided outwash: a model for humid alluvial fan deposits. In Miall, A.D. ed. Fluvial sedimentology, Can. Soc. Pet. Geol. Mem. No. 5, p. 641-668.

Boucot, A.J., and Johnson, J.G., 1967: Paleogeography and correlation of Appalachian Province Lower Devonian sedimentary rocks. Tulsa Geological Society, Digest 35, p. 35-87.

Bourque, P.A., Brisebois, D., and Malo, M., in press: Middle Paleozoic rocks of Quebec and adjacent New Brunswick. In Williams, H., ed., The Appalachian/Caledonian Region: Canada and Greenland. GSA, Decade of North American Geology, v. F-1

----- Hesse, R., and Rust, B.R., 1989: Sedimentology, paleoenvironments and paleogeography of the Taconian to Acadian rock sequence of the Gaspé Peninsula. Geological Association of Canada Field Trip Guide, Excursion B8, Montreal 1989.

-----, and Lachambre, 1980: Stratigraphie du Silurien et du Devonien basal du sud de la Gaspésie. P.Q. Dept. of Energy and Resources, Spec. Paper ES-30, 123p.

Bouma, A.H., 1962: Sedimentology of some flysh deposits. Elsevier, Amsterdam, 168 p.

Bradley, D.C., 1983: Tectonics of the Acadian Orogeny in New England and adjacent Canada. J. of Geology, v. 91, p. 381-400.

Bull, W.B., 1972: Recognition of alluvial fan deposits in the stratigraphic record. In Rigby, J.K., and Hamblin, K., eds., Recognition of Ancient Sedimentary Environments, SEPM Spec. Pub. No. 16, p. 63-83.

Cant, D.J., 1978: Development of a facies model for sandy braided river sedimentation: comparison of the South Saskatchewan River and the Battery Point Formation. In Miall, A.D., ed., Fluvial sedimentology, Can. Soc. Petr. Geol., Mem. No. 5, p. 627-640.

Cant, D.J., and Walker, R.G., 1976: Development of a braided-fluvial facies model for the Devonian Battery Point Sandstone, Quebec. Can. J. Earth Sci., v. 13, p. 102-119.

Coney, P.J., Jones, D.L., and Monger, J.W.H., 1980: Cordilleran suspect terrains. Nature, v. 288, p. 329-333.

- Cotter, E., 1978: The evolution of fluvial style, with special reference to the Central Appalachian Paleozoic. In Miall, A.D., ed., Fluvial sedimentology, Can. Soc. Pet. Geol. Mem. No. 5, p. 361-384.
- Curray, I.J., 1956: Paleocurrent analysis. J. Geol., v. 64, p. 117-131.
- Davies, D.K., Vessell, R.K., Miles, R.C., Foley, M.G., and Bonis, S.B., 1978: Fluvial transport and downstream sediment modification in an active volcanic region. In Miall, A.D., ed., Fluvial sedimentology, Can. Soc. Pet. Geol., Mem. No. 5, p. 61-83.
- Dawson, J.W., 1859: On Fossil Plants from the Devonian of Canada. Quart. J. Geol. Soc. Lond., v. 15, p. 477-488.
- 1882: The Fossil Plants of the Erian (Devonian) and Upper Silurian Formations of Canada, Part II.
- 1888: The Geological History of PLants. D. Appleton and Co., New York, 115 p.
- Dewey, J.F., and Kidd, W.S.F., 1974: Continental collisions in the Appalachian/Caledonide orogenic belt: variations related to complete and incomplete suturing. Geology, v. 2, p. 543-546.
- Dineley, D.L., and Williams, B.P.J., 1968: The Devonian continental rocks of the lower Restigouche River, Quebec. Can. J. Earth Sci., v. 5, p. 945-953.
- Dostal, J., and others, 1989: Geochemistry of Siluro-Devonian Tobique volcanic belt in northern and central New Brunswick (Canada): tectonic implications. CJES, v. 26 (6), p. 1282-1296.
- Elles, R.W., 1881: Report on the geology of northern New Brunswick embracing portions of the counties of Restigouche, Gloucester, and Northumberland. Geol. Surv. of Canada Rept. of Prog. 1879-80.
- 1883: Report on the geology of northern and eastern New Brunswick and the north side of the Bay of Chaleur. Geol. Surv. of Canada, Rept. of Prog. 1880-81-82, pt. D.
- Ettensohn, F.R., 1985: The Catskill delta complex and the Acadian Orogeny: a model. GSA Spec. Paper 201, p.39-49.

- Fahnstock, R.K., and Bradley, W.C., 1973: Knik and Matanuska Rivers, Alaska: a contrast in braiding. In Morisawa, M., ed., Fluvial geomorphology, Proc. 4th Geomorphology Symp. SUNY Binghamton, p. 220-250.
- Fyffe, L.R., and Fricker, A., 1987: Tectonostratigraphic terrane analysis of New Brunswick. *Maritime Sediments and Atlantic Geology*, v. 23, p. 113-122.
- Gensel, P. 1987: Plants of the Devonian. Blackwell Sci., p. 15-32.
- Gesner, A., 1843: Report on the geological survey of the province of New Brunswick, Saint John.
- Gloppen, T.G., and Steel, R.J., 1931: The deposits, internal structure and geometry in six alluvial fan-fan delta bodies (Devonian-Norway)-a study in the significance of bedding sequences in conglomerates. In Ethridge, F.G., and Flores, R.M., eds., Recent and ancient nonmarine depositional environments: models for exploration. SEPM Spec. Pub. No. 31, p. 49-70.
- Greiner, H.R., 1973: Pointe Verte to Tide Head, Chaleur Bay area, New Brunswick. In Rast, N., ed., Geology of New Brunswick; New England Intercollegiate Geological Conference, Field Guide to Excursions, Department of Geology, University of New Brunswick, Fredericton, New Brunswick, p. 58-70.
- 1974: Geology of Campbellton, Oak Bay (east) and Escuminac (west), Restigouche County, New Brunswick. N.B. Dept. of Nat. Res., Plates 74-59, 74-60, 74-61.
- Grierson, J.D., and Hueber, F.M., 1967: Devonian lycopods from northern New Brunswick. In Oswald, D.H., ed., International Symposium on the Devonian System, Calgary, Alberta, 1967. Alberta Society of Petroleum Geologists, v. 2, p. 823-836.
- Hamilton, W.B., 1988: Plate tectonics and island arcs. GSA Bull. v. 100, p. 1503-1527.
- Hamner, S. 1981: Tectonic significance of the northeasterly Gander Zone, Newfoundland: an Acadian ductile shear zone. *Can. J. Earth Sci.*, v. 18, p. 120-135.
- Harms, J.C., Southard, J.B., and Walker, R.G., 1982: Structures and sequences in clastic rocks. SEPM Short Course No. 9.

- Hein, F.J., and Walker, R.G., 1977: Bar evolution and development of stratification in the gravelly, braided Kicking Horse River, British Columbia. C.J.E.S., v 14, p. 562-570.
- Hesse, R. and Sawh, H., 1982: Escuminac Formation. In Hesse, R., and others (eds). Paleozoic continental margin sedimentation in the Quebec Appalachians. IAS 11th International Congress, Hamolton, Excursion Guidebook 7B, p. 72-80.
- Hon, R., 1980: Geology and petrology of igneous bodies within the Katahdin Pluton. In Roy, D.C., and Naylor, R.S., eds., A guidebook to the geology of northeastern Maine and neighbouring New Brunswick. N.E.I.G.C. 72nd Annual Meeting, p. 65-79.
- , and Roy, D.C., 1981: Magmatic tectonic and stratigraphic constraints on Acadian tectonism in southwestern Maine. GSA Abs. with Prog., p. 13, p.138.
- Houbolt, , J.J.H.C., and Jonker, J.B.M., 1968: Recent sediments in the eastern part of the Lake of Geneva (Lac Lemman). Geol. Mij. v. 47, p. 131-148.
- Howell, D.G., Crouch, J.K., Greene, H.G., McCulloch, D.S., and Vedder, J.G., 1981: Basin development along the Late Mesozoic and Cainozoic California margin: a plate tectonic margin of subduction, oblique subduction and transform tectonics. In Ballance, P.F., and Reading, H.R., eds., Sedimentation in oblique-slip mobile zones. IAS Spec. Pub. #4, p. 43-62.
- Howie, R.D., and Barss, M.S., 1975: Paleogeography and sedimentation in the Upper Paleozoic, eastern Canada. In Yorath, C.G., Parker, E.R., and Glass, D.J., eds., Canada's continental margins and offshore petroleum exploration. Can. Soc. Pet. Geol. Mem. No. 4, p. 45-57.
- Jackson II, R.G., 1978: Preliminary evaluation of lithofacies models for meandering alluvial streams. In Miall, A.D., ed., Fluvial sedimentology, Can. Soc. Pet. Geol. Mem. No. 5, p. 543-576.
- Keen, C.E., Keen, M.J., Nichols, B., Reid, I., Stockmal, G.S., Colman-Sadd, S.P., O'Brien, S.J., Miller, H., Quinlan, G., Williams, H., and Wright, J., 1986: Deep seismic reflection profile across the northern Appalachians. Geology, v. 14, p. 141-145.

Kent, D.V., and Keppie, J.D., 1988: Silurian-Permian palaeocontinental reconstructions and circum-Atlantic tectonics. In Harris, A.L., and Fettes, D.J., eds., The Caledonian-Appalachian Orogen. Geological Society Special Publication No. 38, p. 469-480.

-----, and Opdyke, N.D., 1978: Paleomagnetism of the Devonian Catskill red beds: evidence for motion of coastal New England-Canadian Maritime region relative to cratonic North America. J. Geophys. Res., v. 83, p. 4441-4450.

Keppie, J.D., 1985: The Appalachian collage. In Gee, D.G. and Sturt, B.A., eds., The Caledonide Orogen-Scandinavia and Related Areas. Wiley and Sons, New York, p. 1218-1226.

----- 1982: The Minas Geofracture. In St. Julien, P., and Beland, J., eds., Major structural zones and faults of the northern Appalachians. Geol. Ass. of Canada Spec. Paper 24, p. 263-280.

Kindle, E.M., 1930: Stratigraphic relations of the Upper Devonian beds and the Bonaventure Conglomerate, at Escuminac Bay, Quebec. GSC Summ. Rept. for 1928, pt. C, p. 88-89.

Klein, G. de V., 1967: Paleocurrent analysis in relation to modern marine sediment dispersal patterns. AAPG Bull., v. 51, p. 366-382.

Kusky, T.M., Kidd, W.S.F., and Bradley, D.C., 1987: Displacement history of the Northern Arm Fault, and its bearing on the post-Taconic evolution of north-central Newfoundland. J. Geophys. Res., v. 7, p. 105-133.

Lajoie, J., Lesperance, P.J., and Beland, J., 1968: Silurian stratigraphy and paleogeography of the Matapedia-Temisouata region, Quebec. AAPG Bull., v. 52, p. 615-640.

Lambert, A.M., and Hsu, K.J., 1979: Non-annual cycles of varve-like sedimentation in Walensee, Switzerland. Sed., v. 23, p. 453-461.

Laurent, R., and Belanger, J., 1984: Geochemistry of Silurian-Devonian alkaline basalt suites from the Gaspé Peninsula, Quebec Appalachians. Maritime Sediments and Atlantic Geology, v. 20, p. 67-78.

Lawrence, D.A., 1986: Sedimentology of the Lower Devonian Battery Point Formation, eastern Gaspé Peninsula, Quebec, Canada. Ph.D. thesis, University of Bristol.

----- and Rust, B.R., 1988: The Devonian clastic wedge of eastern Gaspé and the Acadian Orogeny. In McMillan, N.J., Embry, A.F., and Gloss, D.J., eds., Devonian of the world, vol. II: Sedimentology. C.S.P.G. Mem. 14, p. 53-64.

Logan, W.E., 1846: On the Geology of The Chat and Cascapedia Rivers, Gaspé, and part of Chaleur Bay. Geol. Surv. of Canada., Rept. Prog. 1884.

----- , 1863: Geology of Canada, Chpt. XVI.

Lowe, D.R., 1979: Sediment gravity flows: their classification and some problems of application to natural flows and deposits. In Doyle, L.J., and Pilkey, O.H. Jr., eds., SEPM Spec. Pub. No. 27, p. 75-82.

----- 1982: Sediment gravity flows II: depositional models with special reference to the deposits of high density turbidity currents. J. Sed. Pet., v. 52, p. 279-297.

Malo, M., and Beland, J., 1989: Acadian strike-slip tectonics on the Gaspé region, Quebec Appalachians. Can. J. Earth Sci., v. 26 (9), p. 1764-1777.

Mawer, C.K., and White, J.C., 1987: Sense of displacement of the Cobequid-Chedabucto fault system, Nova Scotia, Canada. Can. J. Earth Sci., v. 24, p. 217-223.

McGregor, D.C., 1963: Unpublished report submitted to Quebec Department of Mines on spore analysis of samples from Nouvelle and Maria Townships. Geol. Surv. of Canada Rept. F-1-1-1963DCM.

----- 1977: Lower and Middle Devonian spores of eastern Gaspé, Canada. II. Biostratigraphy. Palaeontographica, v. 163 B, p. 111-142.

----- 1989a: Unpublished report submitted to Gamba on spore analysis of samples from Campbellton Formation and Dalhousie Group, P.Q., and northern N.B., Geol. Surv. of Canada Rept.

----- 1989b: Unpublished report submitted by G. Nowlan, ISPG Calgary, on spore analysis from Lower Devonian rock samples from northern New Brunswick, Geol. Surv. of Can. Rept. F1-3-1989-DCM

McKee, E.D., Crosby, E.J., and Berryhill, H.L., 1967: Flood deposits, Bijou Creek, Colorado, June, 1965. J. Sed. Pet., v. 37, p. 829-851.

McKerrow, W.S., and Cocks, L.R.M., 1977: The location of the Iapetus Ocean suture in Newfoundland. *Can. J. of Earth Sci.*, v. 14, p. 488-499.

-----, and Zeigler, A.M., 1971: The Lower Silurian paleogeography of New Brunswick and adjacent areas. *J. Geology*, v. 79, p. 635-646.

Miall, A.D., 1970: Devonian alluvial fans, Prince of Wales Island, Arctic Canada. *J. of Sed. Petro.*, v. 40 (2), p. 556-571.

----- 1977: A review of the braided-river depositional environment. *Earth-Sci. Rev.*, v. 13, p. 1-62.

----- 1978: Lithofacies types and vertical profile models in braided river deposits: a summary. In Miall, A.D., ed., *Fluvial sedimentology*, *Can. Soc. Pet. Geol. Mem. No. 5*, p. 597-604.

----- 1980: Cyclicity and the facies model concept in fluvial deposits. *Bull. Can. Petro. Geol.*, v. 28 (1), p. 59-80.

----- 1981a: Alluvial sedimentary basins: tectonic setting and basin architecture. In Miall, A.D., ed., *Sedimentation and Tectonics in Alluvial Basins*, *Geological Association of Canada Spec. Paper No. 23*, p. 1-34.

----- 1981b: Analysis of fluvial depositional systems. *AAPG Education Course Note Series #20*, 75 p.

Nijman, W., and Puigdefabregas, C., 1978: Coarse-grained point bar structure in a molasse-type fluvial system, Eocene Casticent Sandstone Formation, South Pyrenean Basin. In Miall, A.D., ed., *Fluvial sedimentology*, *Can. Soc. Pet. Geol. Mem. No. 5*, p. 487-510.

Nilsen, T.H., 1982: Alluvial fan deposits. In Scholle, P.A., and Spearing, D.R., eds., *Sandstone depositional environments*. *AAPG Mem. No. 31*, p. 49-86.

Osberg, P.H., 1978: Synthesis of the geology of the northeastern Appalachians, U.S.A. *Geol. Surv. Can. Paper 78-13*, p. 137-147.

Poole, W.H., Sanford, B.V., Williams, H., and Kelley, D.G., 1970: Geology of southeastern Canada. In Douglas, R.J.W., ed., *Geology and Economic Minerals of Canada*. *Econ. Rept. Geol. Surv. of Canada*, v. 1, p. 227-304.

Puigdefabregas, C., and van Vleit, A., 1978: Meandering stream deposits from the Tertiary of the southern Pyrenees. In Miall, A.D., ed., *Fluvial Sedimentology*, Can. Soc. Pet. Geol. Mem. No. 5, p. 469-486.

Reading, H.R., 1981: Characteristic and recognition of strike-slip fault systems. In Ballance, P.F., and Reading, H.R., eds., *Sedimentation in oblique-slip mobile zones*, IAS Spec. Pub. # 4, p. 7-26.

Reineck, H.E., 1974: Schichtgefuge der Ablagerungen im tieferen Seebecken des Bodensees. *Senckenbergiana marit.*, v. 6, p. 47-63.

-----, and Singh, I.B., 1980: *Depositional Sedimentary Environments*, 2nd ed. Springer Verlag, New York, 551 p.

Rodgers, J., 1981: The Merrimack Synclinorium in northeastern Connecticut. *Amer. Jour. Sci.*, v. 281, p. 176-186.

Roy, D.C., 1980: Tectonics and sedimentation in northwestern Maine and adjacent New Brunswick. In Roy, D.C., and Naylor, R.S., eds., *A guidebook to the geology of northeastern Maine and neighbouring New Brunswick*. N.E.I.G.C. 72nd Annual Meeting, p. 1-21.

Rust, B.R., 1972: Structure and process in a braided river. *Sed.* v. 18, p. 221-245.

----- 1978: Depositional models for braided alluvium. In Miall, A.D., ed., *Fluvial sedimentology*, Can. Soc. Pet. Geol. Mem. No. 5, p. 605-626.

----- 1981: Alluvial deposits and tectonic styles: Devonian and Carboniferous successions in eastern Gaspé. In Miall, A.D., ed., *Sedimentation and Tectonics in Alluvial Basins*. Geological Association of Canada Spec. Paper No. 23, p. 49-76.

----- 1982: Significance of alluvial sedimentation for understanding Acadian and Alleghanian Orogenies in the Gaspé region. In Hesse, R., Middleton, G.V., and Rust, B.R., eds., *Paleozoic continental margin sedimentation in the Quebec Appalachians*, IAS Fieldguide 7B, 11th International Congress on Sedimentology, McMaster University, Hamilton, Canada.

----- 1984a: Proximal braidplain deposits in the Middle Devonian Malbaie Formation of eastern Gaspé, Quebec, Canada. *Sed.*, v. 31, p. 675-695.

- 1984b: The Cannes de Roche Formation: Carboniferous alluvial deposits in eastern Gaspé, Canada. Comptes Rendus, 12th International Carboniferous Congress, Urbana, Illinois, p. 72-84.
- Lawrence, D.A., and Zaitlin, B. A., 1989: The sedimentology and tectonic significance of Devonian and Carboniferous terrestrial successions in Gaspé, Quebec. Atlantic Geology, v. 25, p. 1-13.
- Schenk, P.E., 1978: Synthesis of the Canadian Appalachians. In Tozer, E.T., and Schenk, P.E., eds., Caledonian-Appalachian Orogen of the North Atlantic region. Geol. Surv. of Can. Paper 78-13, p. 111-136.
- Schumm, S.A., 1968: Speculations concerning paleohydrologic controls of terrestrial sedimentation. GSA Bull., v. 79, p. 1573-1588.
- Smith, G.A., 1986: Coarse-grained nonmarine volcanoclastic sediment: terminology and depositional process. GSA Bull., v. 97, p. 1-10.
- 1987: Sedimentology of volcanism-induced aggradation in fluvial basins: examples from the Pacific northwest, U.S.A.. In Ethridge, F.G., Flores, R.M., and Harvey, M.D., eds., Recent Developments in Fluvial Sedimentology, SEPM Spec. Pub. 39, p. 217-228.
- 1988: Neogene synvolcanic and syntectonic sedimentation in central Washington. GSA Bull., v. 100, p. 1479-1492.
- Smith, N.D., 1971: Transverse bars and braiding in the lower Platte River, Nebraska. GSA Bull., v. 82, p. 3407-3420.
- 1972: Some sedimentological aspects of planar cross-stratification in a sandy braided river. J. Sed. Petro. v. 42, p. 624-634.
- 1974: Sedimentology and bar formation in the upper Kicking Horse River, a braided outwash stream. J. of Geology, v. 82, p. 205-223.
- Steel, R.J., 1974: New Red Sandstone floodplain and piedmont sedimentation in the Hebridean Province, Scotland. J. of Sed. Petro., v. 44(2), p. 1-19.

----- , and Aasheim, S.M., 1978: Alluvial sand deposition in a rapidly subsiding basin (Devonian, Norway). In Miall, A.D., ed., *Fluvial sedimentology*, Can. Soc. Pet. Geol. Mem. No. 5, p. 385-412.

Steel, R.J., Maehle, S., Nilsen, H., Roe, S.L., and Spinnanger, A., 1977: Coarsening-upwards cycles in the alluvium of Hornelen Basin (Devonian) Norway: sedimentary response to tectonic events. *GSA Bull.*, v. 88, p. 1124-1134.

Steel, R.J., and Thompson, D.B., 1983: Structures and textures in Triassic braided stream conglomerates ('Bunter' Pebble Beds) in the Sherwood Sandstone Group, North Staffordshire, England. *Sed.*, v. 30, p. 341-367.

Stockmal, G.S., Coleman-Sadd, S.P., Keen, C.E., and Quinlan, G., 1986: Collision along an irregular margin: a regional plate tectonic interpretation of the Canadian Appalachians. *C.J.E.S.*, v.24, p. 1098-1107.

Sturm, M., 1975: Depositional and erosional sedimentary features in a turbidity current controlled basin (Lake Brienz). *IXth Int. Cong. Sed.*, Nice, 5, p. 385-390.

----- 1976: Die oberflachensedimente des Brienzersees. *Eclog. geol. Helv.* v. 69, p. 111-123.

Sturm, M., and Matter, A., 1972: Sedimente und sedimentationsvorgange im Thunersee. *Eclogae geol. Helv.*, v. 65, p. 563-590.

----- 1978: Turbidites and varves in Lake Breinz (Switzerland): deposition of clastic detritus by density currents. In Matter, A., and Tucker, M.E., eds., *Modern and ancient lake sediments*. IAS Spec. Pub. No. 2, p. 145-166.

Van der Pluijm, B., and van Stall, C.R., 1988: Characteristics and evolution of the Central Mobile Belt, Canadian Appalachians. *J. of Geology*, v. 96, p. 535-547.

Van der Voo, R., 1988: Paleozoic paleogeography of North America, Gondwana, and intervening displaced terranes: comparisons of paleomagnetism with paleoclimatology and biogeographical patterns. *GSA Bull.*, v. 100, p. 311-324.

Vondra, C.F., and Burggraf Jr, D.R., 1978: Fluvial facies of the Plio-Pleistocene Koobi Fora Formation, Karari Ridge, East Lake Turkana, Kenya. In Miall, A.D., ed., *Fluvial sedimentology*, Can. Soc. Pet. Geol. Mem. No. 5, p. 511-529.

Walker, R.G., 1984: Turbidites and associated coarse clastic deposits. In R.G. Walker, ed. Facies Models, 2nd ed. Geoscience Canada, Reprint Series 1, p. 171-188.

----- in press: Turbidites and turbidity currents: introduction, facies sequence and models. SEPM Short Course.

Walton, A.W., 1986: Effect of Oligocene volcanism on sedimentation in the Trans-Pecos volcanic field of Texas. GSA Bull., v. 97, p. 1192-1207.

-----, and Palmer, B.A., 1988: Lahar facies of the Mount Dutton Formation (Oligocene-Miocene) in the Marysvale Volcanic Field, southwestern Utah. GSA Bull., v. 100, p. 1078-1091.

Wasson, R.J., 1977: Last-glacial alluvial fan sedimentation in the lower Derwent Valey, Tasmania. Sed., v. 24, p. 781-799.

Whiteaves, J.F., 1883: On some fossil fishes, crustacea and mollusca from the Devonian rocks at Campbellton, New Brunswick, with descriptions of five new species. Canadian Naturalist, v. 10, p. 93-101.

Williams, B.P., and Dineley, D.L., 1966: Studies on the Devonian strata of Chaleur Bay, Quebec. Maritime Sediments and Atlantic Geology, v. 2(1), p. 7-10.

Williams, G.E., 1973: Late Quaternary piedmont sedimentation, soil formation and paleoclimates in arid South Australia. Zeitschrift fur Geomorphologie, v. 17, p. 102-125.

Williams, H. 1978: (compiler) Tectonic-Lithofacies Map of the Appalachian Orogen. Memorial University, Newfoundland, Map 1.

-----, 1979: Appalachian Orogen in Canada. Can. J. of Earth Sci., v. 16, p. 792-807.

-----, and Hatcher, R.D. Jr., 1982: Suspect terranes and accretionary history of the Appalachian orogen. Geology, v. 10, p. 530-536.

-----, 1983: Appalachian suspect terranes. GSA Mem. No. 158, p. 33-53.

Williams, P.F., and Rust, B.R., 1969: The sedimentology of a braided river. J. Sed. Pet., v. 39, p. 649-679.

Zaitlin, B.A., 1981: Sedimentology of the Pirate Cove, Fleurant, and Bonaventure Formations of the Western Baie des Chaleurs area, Maritime Canada; A Depositional and Tectonic Model. M. Sc. thesis, University of Ottawa, 188 p.

Appendix 1.

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Palynology of twelve samples of rock from the La Garde and Campbellton Formations, lower Restigouche River region of Quebec and New Brunswick (NTS 21 0/15, 22 A/5, 22 B/1, and 22B/2), submitted for study by C. Gamba, McMaster University.

The relevant parts of any manuscript prepared for publication that paraphrase or quote from this report should be referred to the Ottawa Palaeontology Section for possible revision.

1. GSC locality no. 0-103990.

Field no. A-19.

Locality: Road cut, N side of Hwy 132, 2.5 km W of Cross Pointe, Que.

Collector's comment: La Garde Formation; 17.3 m above base of section; thickness 25 cm; very fine silty sst, massively bedded, mottled, green, with scattered plant material.

Identifications:

Anapiculatisporites cunatus Ravn & Benson
 ?Aneurospora minuta McGregor
Apiculiretusispora plicata (Allen) Streeel
 ?Cirratiradites variverrucatus McGregor
Clivosispora verrucata McGregor var. verrucata
Dibolisporites gibberosus (Kedo) Richardson var. major Kedo
Emphanisporites erraticus (Eisenack) McGregor
E. mcgregorii Cramer
E. orbicularis Turnau
E. rotatus McGregor
E. schultzii McGregor
Gneudnaspota divellomedium (Chibrikova) Balme
Krauselisporites gaspesiensis McGregor
Rhabdosporites mirus Arkhangelskaya
Verrucosisporites polygonalis? Lanninger

Remarks: This is an early to mid Emsian assemblage of the annulatus-sextantii Zone (see Richardson & McGregor, 1986).

2. GSC locality no. 0-103991.

Field no. X-11.

Locality: Shoreline exposure, E of Cross Point, Que.

Collector's comment: La Garde Formation; 10.3 m above bar; thickness 20 cm; siltstone, laminated, some mottling.

Identifications:

Apiculiretusispora plicata (Allen) Streeel
Brochotriletes robustus (Scott & Rouse) McGregor
Dictyotriletes emsiensis (Allen) McGregor
Emphanisporites annulatus McGregor
E. rotatus McGregor
E. schultzii McGregor
Grandispora macrotuberculata? (Arkhangelskaya) McGregor
 G. spp. (2 species)

Rhabdosporites mirus Arkhangelskaya
Tholisporites chulus (Cramer) McGregor var. chulus

Remarks: The spore assemblage is slightly younger than the one from the previous locality, i.e. late Emsian, high in the annulatus-sextantii Zone or low in the douglastownense-eurypterota Zone. The sample also contains rare acritarchs (unicellular palynomorphs of probable marine algal affinity), not included in the above taxon list. The co-occurrence of acritarchs and abundant, well-preserved spores indicates that the depositional site was not far from the terrestrial vegetation that produced the spores, but was nevertheless subject to some marine influence.

3. GSC locality no. O-103992. Field no. F-18.

Locality: Pointe-a-la-Garde Peninsula, Que., SE shoreline exposure.

Collector's comment: La Garde Formation; 19.05 m above base of section; thickness 60 cm; silt-mud, massively bedded, rooted, dark green.

Identifications:

Brochotriletes foveolatus? Naumova
B. robustus (Scott & Rouse) McGregor
B. sp. A. (McGregor, 1973)
Camptonotriletes caperatus McGregor
Clivospora verrucata McGregor var. verrucata
Cf. Dictyotriletes emsiensis (Allen) McGregor
Emphanisporites annulatus McGregor
E. erraticus (Eisenack) McGregor
E. minutus Allen
E. rotatus McGregor
E. schultzii McGregor
Grandispora sp. (McGregor, 1973)
Rhabdosporites mirus Arkhangelskaya
Verrucosisporites polygonalis Lanninger

Remarks: Mid Emsian, annulatus-sextantii Zone.

4. GSC locality no. O-103993 Field no. I-27

Locality: Pointe-a-la-Garde Peninsula, Que., SW shoreline.

Collector's comment: La Garde Formation; 38.35 m above base of section; thickness 25 cm; silt-mud, dark green, abundant plant debris.

Identifications:

Brochotriletes foveolatus? Naumova
Camptonotriletes caperatus McGregor
Clivospora verrucata McGregor var. verrucata
Cymbosporites paulus McGregor & Camfield
Emphanisporites erraticus (Eisenack) McGregor
E. rotatus McGregor
E. schultzii McGregor
Grandispora sp. (McGregor, 1973)
Kraeuselisporites gaspensiensis McGregor

Tholisporites chulus (Cramer) McGregor var. chulus
cf. T. salantaicus (Arkhangelskaya) Turnau

Remarks: Mid Emsian, annulatus-sexantii Zone.

5. GSC locality no. 0-103994.

Field no. 36.

Locality: Shoreline exposure, 1 km E of Pointe-a-la-Garde, Que.

Collector's comment: La Garde Formation: 3.35 m above base of section:
thickness 20 cm: silty mud, massively bedded, abundant plant debris, dark
green.

Identifications:

Acinosporites lindlarensis Riegel var. lindlarensis
Cf. Apiculiretusispora brandtii Streeb
Brochotriletes hudsonii McGregor & Camfield
B. robustus (Scott & House) McGregor
B. sp. (McGregor, 1973)
Gamarozonotriletes sextantii McGregor & Camfield
Cirratriradites variverrucatus McGregor
Clivosispora verrucata McGregor var. verrucata
Dibolisporites wetteldorfensis Lanninger
Dictyotriletes subgranifer? McGregor
Emphanisporites annulatus McGregor
E. sp. cf. microratus Richardson & Lister
E. orbicularis Turnau
E. rotatus McGregor
E. schultzii McGregor
Rhabdosporites mirus Arkhangelskaya

Remarks: Mid Emsian, annulatus-sexantii Zone.

6. GSC locality no. 0-103995.

Field no. M-195.

Locality: Shoreline exposure, 1.5 km W of Escuminac, Que.

Collector's comment: La Garde Formation: 26.15 m above base of formation:
very fine to silty sandstone, massively bedded, fissile, dark green,
containing large plant fragments.

Identifications:

Cf. Anapiculatisporites confertispinosus Ravn & Benson
Brochotriletes foveolatus? Naumova
B. sp. A (McGregor, 1973)
?Camptozonotriletes caperatus McGregor
Clivosispora verrucata McGregor var. verrucata
Emphanisporites annulatus McGregor
Verrucosisporites polygonalis Lanninger

Remarks: The spores are more corroded and broken than those recovered from
the foregoing samples from the La Garde Formation. Nevertheless, enough are
identifiable to date the sample as early or mid Emsian, annulatus-sexantii
Zone.

7. GSC locality no. O-103996

Field no. OD.

Locality: Shoreline exposure between Atholville and Campbellton, NB.

Collector's comment: Campbellton Formation; basal contact; thickness unknown; poorly indurated black shale containing plant fragments and fish.

Identifications:

Apiculatasporites microconus (Richardson) McGregor & Camfield
Apiculiretusispora brandtii Streel
A. gaspiensis? McGregor
A. plicata (Allen) Streel
Camarozonotriletes sextantii McGregor & Camfield
Clivosispora verrucata McGregor var. verrucata
Dibolisporites sp. cf. gibberosus (Kedo) Richardson
Verrucosisporites polygonalis Lanninger

Remarks: The spores indicate mid Emsian age, within the annulatus-sextantii Zone. Like the sample from locality O-103994, this sample contains a few acritarchs. The same comments apply regarding depositional environment.

8. GSC locality no. O-103997.

Field no. Q-57A.

Locality: Shoreline exposure, E of Dalhousie Junction, NB.

Collector's comment: Campbellton Formation; 102 m above base of formation; thickness 40 cm; purple silty sandstone, massively bedded, mottled, rooted.

Remarks: No palynomorphs.

9. GSC locality no. O-103998.

Field no. R-2.

Locality: Shoreline exposure, Pt-a-la-Nim, NB.

Collector's comment: Campbellton Formation; basal unit of section; thickness 15 cm; light grey, massively bedded siltstone.

Remarks: No palynomorphs.

10. GSC locality no. O-103999.

Field no. U-8.

Locality: Road cut, E side of Hwy 134, N of Atholville, NB.

Collector's comment: Campbellton Formation; 125.2 m above base of section; thickness 1.3 m; black siltstone/shale, massively bedded, containing sparse plant fragments.

Identifications:

Acinosporites lindlarensis Riegel var. lindlarensis
A. lindlarensis Riegel var. minor McGregor & Camfield
Apiculiretusispora brandtii Streel
Brochotriletes robustus? (Scott & Rouse) McGregor
Dibolisporites wetteldorfensis Lanninger
Dictyotriletes emsiensis (Allen) McGregor

Emphanisporites rotatus McGregor
E. schultzi McGregor
Kraeuselisporites gaspesiensis McGregor
Rhabdosporites mirus Arkhangelskaya
Tholisporites chulus (Cramer) McGregor var. chulus

Remarks: Same as for locality O-103996.

11. GSC locality no. 104000.

Field no. W-2A.

Locality: Nouvelle, Que.

Collector's comment: La Garde Formation; basal unit; thickness 3.5 m; very fine olive green sandstone, massively bedded.

Remarks: Rare, small, smooth spores of no stratigraphic value were recovered. The sample is no older than Early Silurian. No more precise age determination is possible on this evidence. Abundant Recent angiosperm and gymnosperm pollen contaminants were also present, possibly introduced at the collecting site.

12. GSC locality no. O-104001.

Field no. Y-3.

Locality: Road cut, E side, Grand Cascapedia, Que.

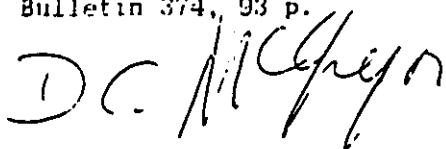
Collector's comment: La Garde Formation; 1 m above base of section; thickness 15 cm; black, massively bedded, fissile siltstone.

Remarks: Most of the organic debris obtained from this sample is strongly corroded and pitted. The palynomorph assemblage consists of abundant and taxonomically diverse acritarchs, and probable chitinozoan fragments. No spores were found. The environment of deposition evidently was holomarine. The diagenetic history of this sample seems to have been rather different from that of the other samples in this lot. This conclusion is supported by both the degradation of the organic debris and the apparently higher degree of its carbonization. The Thermal Alteration Index (TAI; see Utting, 1987, p. 23) of the spores in the other samples is in the range 2+ to 3-; a strictly comparable reading cannot be made on this sample because of the absence of spores, but the level of carbonization seems significantly higher on general inspection.

References:

- McGregor, D.C., 1973, Lower and Middle Devonian spores of eastern Gaspé, Canada, I, Systematics: *Palaeontographica*, Abt. B, v. 142, p. 1-77.
- Richardson, J.B. and McGregor, D.C., 1986, Silurian and Devonian spore zones of the Old Red Sandstone Continent and adjacent regions: Geological Survey of Canada, Bulletin 364, 79 p.

Utting, J.. Palynology of the Lower Carboniferous Windsor Group and Windsor-Canso boundary beds of Nova Scotia, and their equivalents in Quebec, New Brunswick and Newfoundland: Geological Survey of Canada, Bulletin 374, 93 p.



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