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STRATIGRAPHY, SEDIMENTOLOGY, TECTONICS, AND RESOURCE POTENTIAL OF THE LOWER CARBONIFEROUS MABOU GROUP, NOVA SCOTIA

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Cover illustration
Small natural arch eroded through middle Carboniferous red channel sandstone, with Bay of Fundy at low tide in background (Joggins area, Nova Scotia). GSC 4720-1

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Abstract

The upper Lower Carboniferous Mabou Group of Nova Scotia was deposited as the final sedimentary fill into the nearly replete subbasins of a large, intracontinental rift system during the waning stages of tectonic subsidence. Deposition occurred immediately after the short-lived marine carbonate and evaporite realm of the underlying Windsor Group receded. These subbasins lay at a paleolatitude of about 15° S in a warm, semiarid, seasonally wet climate. Sedimentation occurred in distensive, fault-bounded subbasins characterized by large total depositional area, and near-vertical stacking of laterally intertonguing formations of moderate thickness. Deposition was influenced primarily by gentle subsidence, and fault-bounded margins were generally located outside the study area. Most detritus was derived from previous sedimentary cover (Horton and Windsor groups). Extraformational pebbles are present in only a few outcrops located close to interpreted subbasin margins.

The Mabou Group consists of two lithostratigraphic formations: the lower Hastings Formation, and the upper Pomquet Formation. However, Mabou deposition comprises a single, but internally complex, overall third-order coarsening-upward succession about 500 m thick. This succession begins with shallow-lacustrine muddy deposits (Hastings Formation), which intertongue upward with red, subaerial playa-mudflat-floodplain deposits (Pomquet Formation), which gradually become dominant.

The Hastings Formation (of late Viséan–early Namurian age) comprises thin-bedded grey mudstone with interbedded sandstone and limestone of shallow-lacustrine origin. These lithologies are arranged into fourth- and fifth-order, asymmetrical, transgressive-regressive shallowing-upward sequences, deposited in broad, shallow lakes (150 to 200 km long by 100+ km wide in size). Four facies assemblages, which reflect a distal-proximal continuum, are identified in this lacustrine system: dark grey mudstone and sandstone and minor limestone (open lacustrine), grey, very fine- to fine-grained sandstone (lacustrine nearshore and shoreline), minor, red, pedogenic siltstone (subaerial coastal floodplain), and minor, thick, scour-based, very fine- to medium-grained sandstone (high-sinuosity fluvial channel). The intertonguing and overlying Pomquet Formation (of early Namurian age) comprises thin-bedded red siltstone and fine- to medium-grained sandstone, with abundant evidence of vertisol and calcisol pedogenesis. The strata are of subaerial playa-mudflat-floodplain-floodout origin and were deposited as the final fill of the rift subbasins. Four facies assemblages, which reflect a distal-proximal continuum, are identified in this floodplain system: minor thin grey mudstone (very shallow lacustrine); red, massive, pedogenic siltstone (subaerial playa-floodplain-floodout); thick, red, very fine- to medium-grained sandstone (high-sinuosity fluvial channel); and minor, thin, quartz-pebble conglomerate to pebbly sandstone (alluvial fan-braidplain).

In comparison to similar deposits of the earlier Horton Group, the Mabou was deposited in less well-defined subbasins that were less dominated by fault-bound subsidence, where carbonate deposition and frequent exposure were more important in the very shallow-lacustrine phase, and fine-grained deposition and pedogenesis were more important in the subaerial phase. Although little direct evidence was found in this study for economic potential, there are some clues suggesting potential for hydrocarbon and redbed copper deposits in the Mabou Group, warranting further investigation.

Résumé

En Nouvelle-Écosse, le Groupe de Mabou de la partie supérieure du Carbonifère inférieur s'est déposé sous forme de remblai sédimentaire ultime dans des sous-bassins presque comblés dans un vaste rift intracontinental au cours des dernières phases de subsidence tectonique. La sédimentation a eu lieu juste après le retrait du domaine des roches carbonatées et des évaporites marines de courte durée du Groupe de Windsor sous-jacent. Les sous-bassins se trouvaient à environ 15° de paléolatitude sud, dans une région à climat chaud, semi-aride et temporairement humide. La sédimentation a eu lieu dans des sous-bassins de distention limités par des failles et caractérisés par une vaste aire de sédimentation totale et un empilement

presque vertical de formations latéralement interdigitées, d'épaisseur moyenne. Elle a été influencée principalement par une faible subsidence; les bordures limitées par des failles se trouvaient en général à l'extérieur de la région à l'étude. Le matériel détritique provenait essentiellement de la couverture sédimentaire antérieure (groupes de Horton et de Windsor). Des cailloux extraformationnels se rencontrent uniquement dans quelques affleurements situés à proximité des bordures interprétées des sous-bassins.

Le Groupe de Mabou se compose de deux formations lithostratigraphiques, soit la Formation de Hastings inférieure et la Formation de Pomquet supérieure. Toutefois, les dépôts du Groupe de Mabou comportent une seule succession complexe de troisième ordre, à granoclassement inverse, dont l'épaisseur est d'environ 500 m. Cette succession comporte d'abord des dépôts boueux de lac peu profond (Formation de Hastings), qui sont interdigités avec des dépôts rouges de playa subaérienne, de slikke et de plaine d'inondation (Formation de Pomquet), qui deviennent prédominants vers le haut de la coupe.

La Formation de Hastings (Viséen tardif-Namurien précoce) comprend du mudstone gris finement lité ainsi que du grès et du calcaire interstratifiés de milieu lacustre peu profond. Ces lithotypes sont disposés en séquences transgressives-régressives asymétriques de quatrième et de cinquième ordre, qui témoignent d'une diminution de la profondeur d'eau vers le haut et qui ont été déposées dans de grands (de 150 à 200 km sur 100+ km) lacs de très faible profondeur. Quatre assemblages de faciès, qui traduisent un continuum distal-proximal, ont été mis en évidence dans ce système lacustre : mudstone et grès gris foncé et un peu de calcaire (milieu lacustre ouvert); grès gris à grain très fin à moyen (littoral et ligne de rivage lacustres); petite quantité de siltstone rouge pédogénétique (plaine d'inondation côtière subaérienne); et un peu de grès à grain très fin à moyen, de forte épaisseur, dont la base est affouillée (chenal fluviatile très sinueux). La formation interdigitée et sus-jacente de Pomquet (Namurien précoce) comprend du siltstone rouge finement lité et du grès à grain fin à moyen; elle présente d'abondantes indications de pédogenèse de vertisol et de calcisol. Les strates proviennent de playa subaérienne, de slikke, de plaine d'inondation et d'aire inondé; elles se sont déposées comme remblai ultime des sous-bassins du rift. Quatre assemblages de faciès, indicateurs d'un continuum distal-proximal, sont reconnus dans ces dépôts de plaine d'inondation : petite quantité de mudstone gris de faible épaisseur (milieu lacustre très peu profond); siltstone pédogénétique massif rouge (playa subaérienne, plaine d'inondation et aire inondée); grès rouge épais à grain très fin à moyen (chenal fluviatile très sinueux); et, accessoirement, conglomérat à galets de quartz passant à du grès caillouteux de faible épaisseur (cône alluvial et plaine anastomosée).

Par comparaison avec des dépôts similaires du Groupe de Horton plus ancien, le Groupe de Mabou s'est accumulé dans des sous-bassins moins bien définis qui n'ont pas été aussi touchés par la subsidence limitée par des failles et dans lesquels l'accumulation des roches carbonatées et l'exposition fréquente étaient plus importantes dans la phase lacustre de très faible profondeur et le dépôt de sédiments à grain fin et la pédogenèse étaient plus importants dans la phase subaérienne. Bien que l'on ait trouvé très peu d'indications directes de potentiel économique dans le cadre de cette étude, certains indices laissent supposer que le Groupe de Mabou renferme un potentiel en hydrocarbures et en gisements de cuivre de type redbeds, ce qui justifie une étude plus poussée.

Summary

To more fully understand the regional stratigraphy, sedimentology, and resource potential of the upper Lower Carboniferous Mabou Group, a series of outcrop measured sections from northern, central, and western Nova Scotia was studied. Because the Mabou Group has received little attention since the early 1960s, part of this report synthesizes the previous, scattered literature, providing a solid framework for the interpretations that follow. This study attempts to a) present the regional stratigraphic architecture, lithofacies, sedimentological interpretations, and tectonic vs. climatic signatures inherent in the Mabou deposits; b) complete the portrayal of the tectonic evolution of the Lower Carboniferous rift-wrench system; c) elucidate the character of the Alleghanian unconformity, which terminated Mabou deposition; and d) investigate, in a preliminary way, the economic potential of these strata.

As a result of the mid-Late Devonian Acadian Orogeny, previously separate tectonostratigraphic zones were assembled into a single, intracontinental area where a subsequent series of postorogenic basins actively subsided. This system of interrelated successor basins is collectively referred to as the Maritimes Basin. The late Early Carboniferous portion of the Maritimes Basin represented the waning stages of the previously developed Late Devonian–Early Carboniferous Fundy Basin Rift, which postdated Acadian compression and predated Alleghanian transpression. Deposits of the Horton, Windsor, and Mabou groups make up the Kaskaskia Sequence. The upper Viséan to lower Namurian Mabou Group of Nova Scotia was deposited into widening, but nearly-replete, extensional subbasins as the final fill of that large, intracontinental rift system, which had been initiated with deposition of the Horton Group. Mabou sedimentation occurred during the waning stages of regional tectonic subsidence, after the short-lived marine carbonate-evaporite realm of the underlying Windsor Group receded. These partly linked subbasins lay at a paleolatitude of about 15° S in a warm, semiarid, seasonlly wet climate. Deposition was terminated by a mid-Carboniferous compressional (oblique-slip) event, the “Maritimes Disturbance” or Alleghanian Orogeny, in this area expressed as a mid-Namurian unconformity that separates the Mabou from overlying deposits of the Absaroka Sequence.

The Maritimes Basin consists of an Upper Devonian–Permian, first-order basin-fill succession that includes four, unconformity-bounded second-order basin-fill successions. The second of these can be further subdivided into two conformable third-order sequences. The latter of these, the Mabou Group, comprises in places as much as 1000 m of clastic deposits, arranged in an overall coarsening-upward succession. It includes the Hastings Formation, composed primarily of grey shale with thin sandstone and limestone beds, and the overlying Pomquet Formation, consisting mostly of interbedded red siltstone and sandstone. Sedimentation occurred in distensive fault-bounded subbasins characterized by a large total depositional area, and near-vertical stacking of laterally intertonguing formations of moderate thickness. Deposition was primarily influenced by mild subsidence, and fault-bounded margins were mostly located outside the present study area. Most detritus was derived from previous sedimentary cover; extraformational pebbles are present in only a few outcrops located close to interpreted subbasin margins. Mabou Group deposition generally comprises about 500 m of shallow-lacustrine, muddy deposits, which intertongue with red, subaerial playa-mudflat-floodplain deposits that become dominant upward.

The Hastings Formation (upper Viséan–lower Namurian) comprises several hundred metres of thin-bedded, grey mudstone with interbedded sandstone and limestone of shallow-lacustrine to marginal-lacustrine origin. These lithologies are arranged into fourth- and fifth-order asymmetrical, transgressive-regressive, shallowing-upward sequences, which were deposited in broad, shallow lakes (150 to 200 km long by 100+ km wide in size). The lack of marine fossils and an abundant nonmarine palynoflora suggest deposition in a lacustrine, rather than marine, setting. Clastic input was limited, thick shoreline sandstone is rare, large areas of the shorelines were characterized by carbonate sedimentation, and desiccation was common. The bulk of sediment was deposited offshore below wave base, as mud, silt, and density underflow sand, although no great depth is implied. Four facies assemblages, which reflect a distal-proximal continuum, can be identified in this lacustrine system: dark grey mudstone and sandstone, and minor limestone (open lacustrine); grey, very fine- to fine-grained sandstone (lacustrine nearshore and shoreline); minor, red, pedogenic siltstone (subaerial coastal floodplain); and minor, thick, scour-based, very fine- to medium-grained sandstone (high-sinuosity fluvial channel). Paleocurrent data suggest that trends of symmetrical ripple crests approximate lacustrine shoreline trends, and flow directions of ripple crosslamination indicate offshore and obliquely alongshore transport. This range of facies is identical to those of the coeval Rocky Brook Formation of Newfoundland, except that no oil shales have yet been discovered in the Hastings.

The intertonguing and overlying Pomquet Formation (early Namurian) comprises several hundred metres of thin-bedded red siltstone and fine- to medium-grained sandstone, with abundant evidence of vertisol and calcisol pedogenesis. These lithologies are arranged into fourth- and fifth-order asymmetrical, coarsening-upward terrestrial chronosequences. These strata, gradationally overlying the Hastings Formation, are of subaerial playa-mudflat-floodplain-floodout origins and were deposited as the final fill of the rift subbasins. The lack of marine fossils, presence of nonmarine palynoflora, red colour, and ubiquitous pedogenic features suggest deposition in subaerial settings. The bulk of the deposits comprises red, pedogenically altered floodplain-playa siltstone, deposited slowly over a considerable span of time in a warm, semiarid climate. These deposits are characterized by distinct pedogenic features such as blocky texture, colour mottling, desiccation cracks, evaporite crystals, horizons of caliche glaebules, vertical fractures with slickensides, and columnar peds. Four facies assemblages, which also reflect a distal-proximal continuum, are identified in this floodplain system: minor, thin, grey mudstone (shallow lacustrine); red, massive, pedogenic siltstone (subaerial playa-floodplain-floodout); thick, red, very fine- to medium-grained sandstone (high-sinuosity fluvial channel); and minor, thin, quartz-pebble conglomerate to pebbly sandstone (alluvial fan-braidplain). Paleocurrent data suggest that fluvial flow indicators are generally oriented approximately perpendicular to subbasin margins and lacustrine shorelines.

Initial dominance of shallow-lacustrine deposition evolved from the former marine setting of the Windsor Group, but gave way to subaerial, low-slope, floodplain-fluvial deposition as the rate of subsidence and creation of accommodation space decreased. The enclosed formations are interpreted as tectonically controlled, three-dimensional depositional systems with diachronous boundaries that represent the final phases of evolution of the Lower Carboniferous Fundy Rift. Because of the progressive widening of the subbasins of the rift system, the influence of fault-bounded subbasin margins became less obvious through time, signaling the gradual demise of the Fundy Rift. Subsequent reorientation of the regional tectonic stress regime is represented by the compressional Alleghanian Orogeny, and the mid-Namurian disconformity. The Mabou Group deposits are similar to those of the earlier Horton Group, but lack initial volcanic strata, and were deposited in less well-defined subbasins that were less dominated by fault-bounded subsidence, where carbonate deposition and frequent exposure were more important in the very shallow-lacustrine phase, and fine-grained deposition and pedogenesis were more important in the subaerial phase.

Although little direct evidence was found in this study for economic potential, there are some clues suggesting undiscovered potential for hydrocarbon and redbed copper deposits in the Mabou Group, warranting further investigation. Sampled Hastings Formation rocks at surface have modest quantities of gas-prone organic matter that is currently within the oil window or at the low end of the gas window. The Hastings Formation is correlative to known oil source rocks and oil shales of Newfoundland. Sandstones with potential reservoir quality are present. In deeper and offshore areas of the Maritimes Basin, the Mabou Group may harbour significant hydrocarbon potential. Solution-front redbed copper deposits, typical of thick, nonmarine, reddened sequences overlying evaporative successions, may be expected in association with Pomquet Formation facies. A small copper showing was noted in a thick, red channel sandstone at one outcrop in this study. More systematic analysis of these possibilities is required to properly evaluate the economic potential of the Mabou Group.

Sommaire

Afin de mieux comprendre la stratigraphie régionale, la sédimentologie et le potentiel en ressources du Groupe de Mabou de la partie supérieure du Carbonifère inférieur, on a étudié des coupes mesurées d'affleurements dans le nord, le centre et l'ouest de la Nouvelle-Écosse. Puisque le Groupe de Mabou a été peu étudié depuis le début des années 1960, une partie de ce bulletin présente une synthèse des documents épars sur le sujet, fournissant ainsi un cadre rigoureux aux interprétations qui suivront. La présente étude a pour buts (a) de présenter l'architecture stratigraphique régionale, les lithofaciès, les interprétations sédimentologiques et les signatures tectoniques et climatiques inhérentes aux dépôts du Groupe de Mabou; (b) de décrire l'évolution tectonique du rift/décrochement du Carbonifère inférieur; (c) de tirer au clair la nature de la discordance alléghanienne, qui a mis fin à la sédimentation du Groupe de Mabou; et d) de faire une étude préliminaire du potentiel économique de ces strates.

L'orogénèse acadienne du milieu du Dévonien tardif a réuni des zones tectonostratigraphiques anciennement distinctes en une seule zone intracontinentale dans laquelle il y a eu subsidence d'une série de bassins postorogéniques. Ce système d'épieugéosynclinaux étroitement reliés entre eux est appelé collectivement «Bassin des Maritimes». La partie du Bassin des Maritimes qui remonte à fin du Carbonifère précoce représente les dernières phases du rift de Fundy du Dévonien tardif-Carbonifère précoce, qui s'était formé antérieurement, après la compression acadienne mais avant la transpression alléghanienne. Les dépôts des groupes de Horton, de Windsor et de Mabou forment la Séquence de Kaskasia. Le Groupe de Mabou (Viséen supérieur-Namurien inférieur) de la Nouvelle-Écosse s'est accumulé dans des sous-bassins de distension en voie d'élargissement mais presque comblés; il représente le remblai ultime du vaste rift intracontinental, qui avait commencé à se remplir avec le début de l'accumulation du Groupe de Horton. Le Groupe de Mabou s'est accumulé au cours des dernières phases de la subsidence tectonique régionale, après

le retrait du domaine des roches carbonatées et des évaporites marines de courte durée de vie du Groupe de Windsor sous-jacent. Ces sous-bassins en partie reliés entre eux se trouvaient à environ 15° de paléolatitude sud, dans une région à climat chaud, semi-aride et temporairement humide. Une phase de compression (rejet oblique) au Carbonifère moyen a mis fin à cette sédimentation; cet événement, connu sous la désignation de «perturbation des Maritimes» ou d'«orogenèse alléghanienne», est représenté dans la région par une discordance du Namurien moyen qui sépare le Groupe de Mabou des dépôts sus-jacents de la Séquence d'Absaroka.

Le Bassin des Maritimes comprend une séquence de remplissage de bassin de premier ordre du Dévonien supérieur-Permien qui comprend quatre successions de remplissage de bassin de deuxième ordre limitées par une discordance. La deuxième de ces successions peut être subdivisée en deux séquences concordantes de troisième ordre. La dernière de ces séquences, le Groupe de Mabou, renferme par endroits jusqu'à 1 000 m de dépôts clastiques, disposés en une succession essentiellement à granoclassement inverse. Elle comprend la Formation de Hastings, composée essentiellement de shale gris accompagné de lits de grès et de calcaire de faible épaisseur, ainsi que la Formation de Pomquet sus-jacente, comportant principalement du siltstone et du grès rouges interstratifiés. La sédimentation s'est produite dans des sous-bassins de distension limités par des failles et caractérisés par une vaste aire de sédimentation totale et un empilement presque vertical de formations latéralement interdigitées, d'épaisseur moyenne. Elle a été influencée principalement par une faible subsidence; les bordures limitées par des failles se trouvaient en grande partie à l'extérieur de la présente région d'étude. Le matériel détritique provenait essentiellement de la couverture sédimentaire antérieure; des cailloux extraformationnels se rencontrent uniquement dans quelques affleurements situés à proximité des bordures interprétées des sous-bassins. Le Groupe de Mabou comporte en général environ 500 m de dépôts boueux lacustres d'eau peu profonde qui sont interdigités avec des dépôts rouges de playa subaérienne, de slikke et de plaine d'inondation, qui deviennent prédominants vers le haut de la coupe.

La Formation de Hastings (Viséen supérieur-Namurien inférieur) se compose de plusieurs centaines de mètres de mudstone gris finement lité avec du grès et du calcaire interstratifiés accumulés dans un milieu allant d'un lac peu profond à un milieu margino-lacustre. Ces lithotypes sont disposés en séquences transgressives-régressives asymétriques de quatrième et de cinquième ordre, qui témoignent d'une diminution de la profondeur d'eau vers le haut et qui ont été déposées dans de grands (de 150 à 200 km sur 100+ km) lacs de très faible profondeur. L'absence de fossiles marins et la présence d'une palynoflore non marine abondante portent à croire que ces sédiments se sont accumulés dans un milieu lacustre plutôt que marin. L'apport de matériel clastique était limité, les grandes épaisseurs de grès de ligne de rivage sont rares, de vastes zones de lignes de rivage étaient caractérisées par une sédimentation carbonatée et des périodes de sécheresse étaient fréquentes. La plupart des sédiments se sont déposés au large sous le niveau de base des vagues, sous forme de boue, de silt et de sable de courant de densité, mais pas forcément à une forte profondeur. Quatre assemblages de faciès, qui traduisent un continuum distal et proximal, ont été mis en évidence dans ce système lacustre : mudstone et grès gris foncé et un peu de calcaire (milieu lacustre ouvert); grès gris à grain très fin à fin (milieu lacustre littoral et ligne de rivage); petit quantité de siltstone rouge pédogénétique (plaine d'inondation côtière subaérienne); et un peu de grès à grain très fin à moyen, de forte épaisseur, dont la base est affouillée (chenal fluviatile très sinueux). Les données sur les paléocourants permettent de supposer que les directions des crêtes de rides symétriques sont à peu près les mêmes que celles de la ligne de rivage lacustre et que les directions d'écoulement indiquées par la stratification croisée de rides sont indicatives d'un transport extracôtier et littoral oblique. L'éventail des faciès est identique à celui de la Formation de Rocky Brook contemporaine de Terre-Neuve, si ce n'est que l'on a pas encore découvert des schistes bitumineux dans la Formation de Hastings.

La formation sus-jacente et interdigitée de Pomquet (Namurien précoce) comprend plusieurs centaines de mètres de siltstone rouge finement lité et de grès à grain fin à moyen et présente d'abondantes indications d'une importante pédogenèse de vertisol et de calcisol. Ces lithotypes sont disposés en chronoséquences terrestres asymétriques de quatrième et de cinquième ordre à granoclassement inverse. Ces strates, qui recouvrent progressivement la Formation de Hastings, sont d'origines diverses : playa subaérienne, slikke, plaine d'inondation et aire inondée; elles ont été déposées comme remblai ultime des sous-bassins du rift. L'absence de fossiles marins, la présence de palynoflore non marine, la couleur rouge et la présence répandue d'éléments pédogénétiques laissent supposer que l'accumulation a eu lieu dans des milieux subaériens. La plupart des dépôts se composent de siltstone rouge de playa et de plaine d'inondation, altéré par la pédogenèse, qui s'est accumulé lentement au cours d'une très longue période dans un climat chaud et semi-aride. Ils se caractérisent par des éléments pédogénétiques distincts tels que structure polyédrique, marbrure de couleur, fentes de dessiccation, cristaux d'évaporite, horizons de glébules de caliche, fractures verticales avec miroirs de faille et agrégats en colonnes. Quatre assemblages de faciès, traduisant également un continuum distal et proximal, ont été reconnus dans ces dépôts de plaine d'inondation : petite quantité de mudstone gris de faible épaisseur (lac peu profond); siltstone pédogénétique massif rouge (playa subaérienne, plaine d'inondation et aire inondée); grès rouge épais à grain très fin à moyen (chenal fluviatile très sinueux); et, accessoirement, conglomérat à galets de quartz passant à du grès caillouteux de faible épaisseur (cône alluvial et plaine anastomosée). Les données sur les paléocourants permettent de supposer que les indicateurs d'écoulement fluvial sont en général orientés presque perpendiculairement aux bordures des sous-bassins et aux lignes de rivage lacustres.

La sédimentation en milieu marin du Groupe de Windsor a cédé la place à la sédimentation dans un milieu d'abord essentiellement lacustre et peu profond puis, avec la baisse du taux de sédimentation et le ralentissement de la création de l'espace disponible, dans un milieu de cours d'eau et et de plaine d'inondation subaérienne à pente faible. Les formations incluses sont interprétées comme étant des systèmes de sédimentation tridimensionnels contrôlés par la tectonique et dont les bordures diachrones représentent les phases finales de l'évolution du rift de Fundy du Carbonifère inférieur. En raison de l'élargissement progressif des sous-bassins du rift, l'influence des bordures des sous-bassins limitées par des failles est devenue moins évidente avec le temps, signalant la fin du rift de Fundy. La réorientation ultérieure du régime régional de contrainte tectonique est représentée par l'orogenèse alléghanienne de compression et la discordance du Namurien moyen.

Les dépôts du Groupe de Mabou sont semblables à ceux du Groupe de Horton plus ancien, mais sont dépourvus de strates volcaniques initiales. Ils se sont accumulés dans des sous-bassins moins bien définis qui étaient moins touchés par la subsidence limitée par des failles et dans lesquels l'accumulation des roches carbonatées et l'exposition fréquente étaient beaucoup plus importantes dans la phase d'eau lacustre de très faible profondeur et le dépôt de sédiments à grain fin et la pédogenèse étaient plus importants dans la phase subaérienne.

Bien que l'on ait reconnu peu d'indications directes de potentiel économique au cours de l'étude, un certain nombre d'indices laissent supposer que le Groupe de Mabou renferme un potentiel non encore découvert de gisements d'hydrocarbures et de cuivre de type redbeds, ce qui justifie une étude plus poussée. Des échantillons de roches de la Formation de Hastings prélevés à la surface renferment de petites quantités de matière organique susceptible de donner du gaz qui se trouve actuellement dans la fenêtre à huile ou à la base de la fenêtre à gaz. On a établi une corrélation entre la Formation de Hastings et les roches mères du pétrole et les schistes bitumineux de Terre-Neuve. Du grès susceptible de constituer un réservoir est présent. Dans les zones plus profondes et les zones extracôtières du Bassin des Maritimes, le Groupe de Mabou pourrait contenir un potentiel d'hydrocarbures considérable. Des gisements de cuivre de type redbeds de front de dissolution, typiques des séquences rougeoyantes non marines épaisses qui reposent sur des successions évaporatives, pourraient être associés aux faciès de la Formation de Pomquet. Un petit indice de cuivre a été rencontré dans du grès rouge épais de chenal à un des affleurements examiné lors de cette étude. Une analyse systématique de ces possibilités est requise afin d'effectuer une évaluation fiable du potentiel économique du Groupe de Mabou.

INTRODUCTION

Study area, sections, and samples

In order to more fully understand the regional stratigraphy and sedimentology of the long-ignored mid-Carboniferous (probably upper Viséan–lower Namurian) Mabou Group, a modest but wide-ranging field program was initiated. Seventeen outcrop measured sections were studied in several areas of northern, central, and western Nova Scotia (Fig. 1; see Appendix 1 for detailed locations). Standard field techniques were used and detailed sedimentological observations recorded. Paleocurrent indicators were measured and corrected on a bed-by-bed basis for local structural deformation. A number of palynological and organic geochemical samples were also submitted for analysis.

Four sections are located in northeastern Cape Breton Island, seven in southwestern Cape Breton Island, three in the Antigonish area, and three in the Joggins-Parrsboro area. Together they represent a total of 2800 m of measured section, each section ranging from 20–500 m in thickness. Although the Mabou Group can be mapped over considerable areas of Nova Scotia (Fig. 1), outcrop quality is good only in coastal exposures; inland and stream outcrops are generally very poor for stratigraphic and sedimentological work. Twelve sections include rocks of the Hastings Formation (and equivalents) and ten include rocks of the Pomquet Formation (and equivalents). Only the Broad Cove outcrop, in western Cape Breton, comprises a complete section of the Mabou Group.

A significant body of paleocurrent data was collected during this study, the first such set from rocks of the Mabou Group in Nova Scotia (see Appendix 1 for raw data). These data proved useful in delineating sediment source areas and dispersal patterns, and in interpreting the characteristics of the depositional subbasins. A total of 693 measurements were taken from the 17 outcrop sections measured. Nearly 400 measurements were from the Hastings Formation and equivalents (12 outcrops), and nearly 300 from the Pomquet (10 outcrops). Of these, about two thirds represent data from ripples, the most common sedimentary structure in the Mabou Group. The rest are primarily from trough crossbedding, with minor sole marks, scours, and channels.

Twenty-six palynological and geochemical samples were collected from Mabou strata (see Appendices 2 and 3). The palynological samples were analyzed by J. Utting (GSC Calgary) as part of a larger study of the middle Carboniferous rocks of Nova Scotia, Newfoundland and New Brunswick (see Utting et al., 1999). The geochemical samples were analyzed by M. Fowler (GSC Calgary) as a reconnaissance evaluation of the source rock potential of the Hastings Formation, and to compare with previous work performed on the correlative Rocky Brook Formation of west-central Newfoundland (see Hamblin et al., 1997).

Objectives

Rocks of late Viséan to early Namurian age are widely distributed in the Maritimes Basin but represent one of the last poorly known stratigraphic units in the Gulf of St. Lawrence region. The Mabou Group has received little attention in local areas, and no comprehensive regional synthesis since Belt (1964, 1965). Because so little work has been directed specifically toward the Mabou Group, a considerable portion of this report consists of a necessary effort to synthesize the scattered previous literature and concepts for this unit within one reference publication. Regional analysis of this thick succession will help to complete our understanding of the tectonic evolution of the Lower Carboniferous rift system, which was transformed into a wrench system during the Alleghanian event in mid-Namurian time. The presence and character of the mid-Namurian unconformity, which marks this geographically limited oblique-slip motion of Meguma Terrane relative to Avalon Terrane, and the attendant changes in paleogeography and sediment dispersal, are as yet poorly understood. Likewise, the regional stratigraphic architecture, sedimentology, biostratigraphy, paleoenvironments, and tectonic vs. climatic signatures of the Mabou Group (and correlatives) are poorly known. Further study will significantly advance understanding of units that are important in unravelling the tectonic evolution of the Maritimes Basin.

To reiterate, regional study of the Mabou Group provides several important kinds of information: 1) it fills the last, large gap in our basic geological knowledge of the upper Paleozoic of Nova Scotia; 2) it completes the picture of tectonic evolution of the Lower Carboniferous rift-wrench system, the presence and character of the Alleghanian unconformity, and petrographic (source and dispersal) changes through time; 3) it contributes to the elucidation of the poorly understood regional stratigraphic architecture and sedimentology, and the tectonic vs. climatic signatures; 4) it gives us the ability to compare lacustrine and fluvial phases of Carboniferous units through time; 5) it improves the poorly studied biostratigraphy, paleoenvironments, dating and poorly known paleogeography and distribution on a regional basis; 6) it investigates the significant, but virtually unknown, economic potential (including the correlation to the oil shales of the Rocky Brook Formation), the presence of lacustrine potential source rocks and fluvial-deltaic potential reservoir rocks, and the delineation of hydrocarbon plays and mineral host facies.

The sedimentology and resource potential of nonmarine sequences in fault-bounded basins have not received

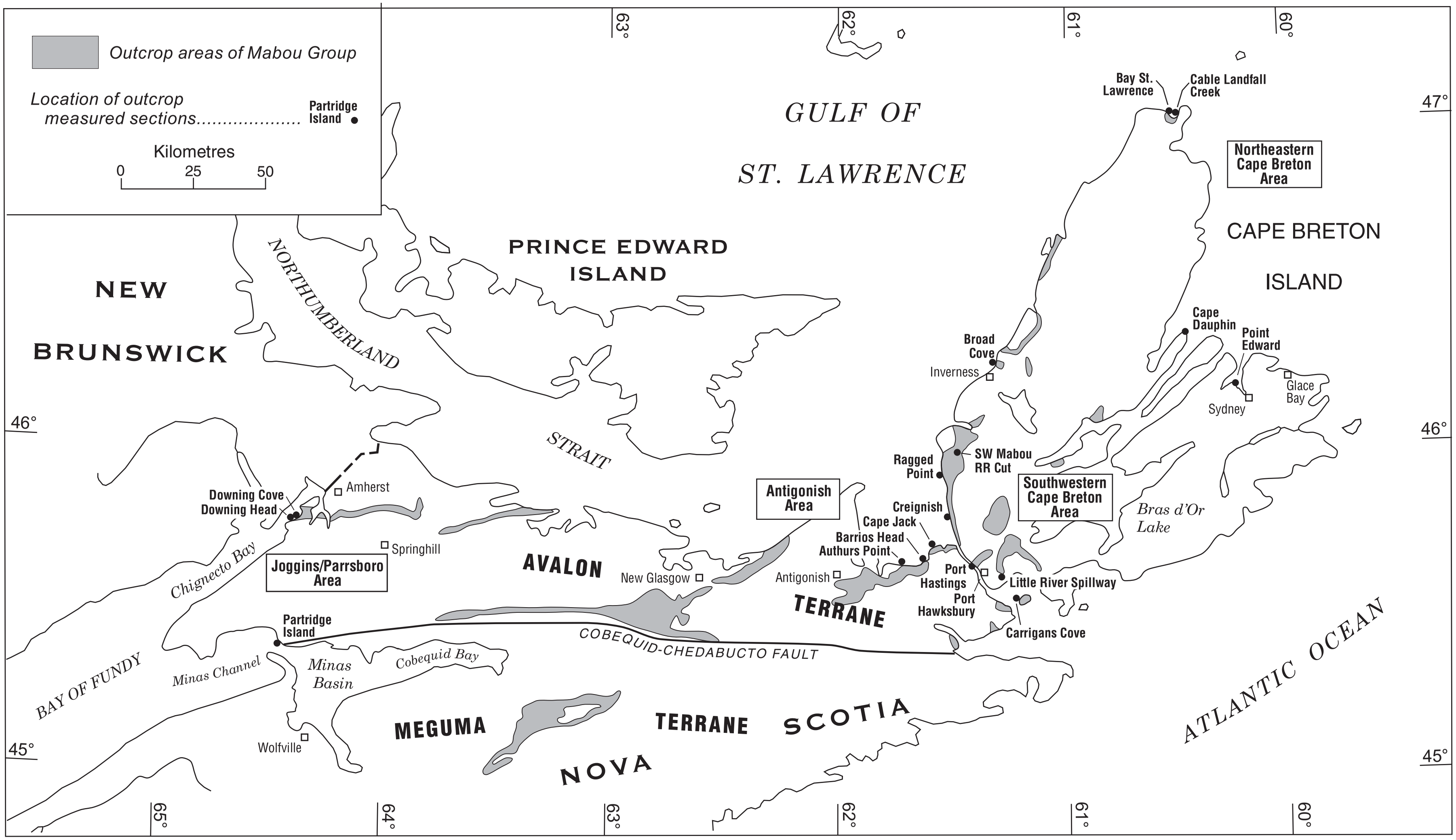

Figure 1. Areas of outcropping Mabou Group in Nova Scotia, showing measured sections.

adequate attention in Canada. Mabou Group strata have significant and long-recognized mineral and petroleum potential both onshore and offshore, but have not been investigated in detail using sedimentological data as a predictive tool. This study was undertaken to establish the complex interrelationships between tectonic setting, syn-depositional structural movement, types and characteristics of facies deposited, spatial distribution and geometry of facies assemblages, and resource potential of this sequence. It is an attempt to erect an integrated predictive framework for a little-studied unit, within which further studies can be organized.

Tectonosedimentary analysis of basin-fill sequences

The conclusions reached in this study are based on the treatment of the middle Carboniferous Mabou Group of Nova Scotia as a sedimentary sequence of diachronous deposits that filled tectonically active subbasins. The style and spatial arrangement of facies reflect the nature and distribution of sedimentary environments, which in turn result from local and regional tectonic activity before and during deposition. These facies can be used to interpret the sedimentary and structural evolution of the subbasins through time.

This study deals with a considerable, though variable, stratigraphic thickness present over a large area where extensive outcrops are uncommon. Therefore much of the basic information is derived from sedimentological observations on isolated exposures and is synthesized into a stratigraphic framework within which further studies can be organized. Stratigraphic and sedimentological analysis at two scales is involved: 1) the lithofacies observed in outcrops, which reflect local depositional environments, and 2) the depositional systems observed through a more regional correlation of facies assemblages, which reflect interaction of fault-related subsidence and sediment supply. The result is a four-dimensional tectonostratigraphic sedimentation model for the evolution of the basin.

Viewing the Mabou Group as a three-dimensional package of facies assemblages allows interpretations of paleogeography and depositional environments. The result is not a facies model in the conventional sense, but a tectono-sedimentary basin-fill analogue, the purpose of which is the understanding of the organization and significance of the depositional units. An analogue of this type forms the framework for future research because it involves a systematic approach to understanding the basic controls on the sedimentary characteristics of a unit.

A broad analysis of the depositional framework is useful in basins that are less well-known because it can indicate the kind and quality of economic deposits that may be present and it sets the stage for more systematic exploration approaches as knowledge increases. Important questions might include whether the basin is conducive to commercial deposits, what kind of deposits might be present, and what geological factors exert control on their distribution and predictability. By identifying the characteristics of the tectono-sedimentary basin-fill model it may be possible to construct local ore and hydrocarbon deposit models.

The Mabou Group in the Appalachian context

The Paleozoic history of the Appalachian Orogen involved the assembly of exotic terranes by orthogonal and oblique collisions. Deformational, intrusive and metamorphic effects, representing collisional episodes, peaked during the mid to Late Ordovician Taconian Orogeny, the mid to Late Devonian Acadian Orogeny, and the mid to Late Carboniferous Alleghanian Orogeny (Williams, 1979; Schenk, 1978; Williams and Hatcher, 1982; Kennedy et al., 1982). The interorogenic periods, which encompass the plate motions between, and leading to, these collisions can be deciphered from the sedimentary sequences. The Mabou Group was deposited during late Early Carboniferous time (late Viséan to early Namurian) immediately before the Alleghanian Orogeny. Understanding the tectonic controls on deposition of this interorogenic sequence can provide important information regarding plate interactions between collisional episodes that may be applicable elsewhere.

The subbasins that received Mabou Group sediments are here interpreted as tectonic in origin, characterized by fault-controlled extension (Belt, 1968a; Quinlan, 1988). The primary control on such a basin is an extensional stress field, and deformation is commonly manifested by a vertical component of subsidence on normal fault planes. However, overprinting by the pervasive compressional regime of the Late Carboniferous Alleghanian Orogeny hinders the structural interpretation of the Mabou basins. In this study, an attempt has been made to reconstruct the tectonic evolution of the subbasins from the results of these events in the sedimentary record (e.g., the presence of coarse-grained immature facies, grain size and thickness trends, lateral facies changes, and paleocurrent data all relate to the location and trend of original basin-margin faults). In addition to constraining the process of subbasin origin on a local scale, these fundamental relationships between tectonics and sedimentation also help define the regional tectonic framework.

Acknowledgments

This study could not have been completed without the cogent discussions and encouragement provided by J. Utting and P. Giles of the GSC over a span of some years. The

fieldwork was conducted, in part, in association with the GSC's Gulf of St. Lawrence NATMAP project. J. Utting provided palynological analysis and interpretation of samples. M. Fowler provided geochemical analysis and interpretation of samples. The figures were primarily drafted by B. Ortman and J. Reimer, with assistance from B. Chiang and P. Neelands. B. Rutley and G. Edwards provided photographic assistance. J. Utting and J. Dixon reviewed an earlier version of the manuscript, considerably improving the text. J. Monro Gray furnished careful scientific editing and C. Thompson handled final manuscript production duties.

TECTONIC SETTING

Regional Appalachian tectonic setting

The northern Appalachian Orogen is an elongate, northeast-southwest belt of deformed rocks on the eastern seaboard of North America. Deep seismic studies have identified three lower crustal blocks in the Nova Scotia-Newfoundland area (Stockmal, 1988; Marillier, 1988), although the upper crustal rocks of Atlantic Canada have been divided into five main tectonostratigraphic zones by Williams (1979) (Fig. 2, 3). These zones extend the length of the Orogen and are based primarily on stratigraphic and structural characteristics of late Precambrian to Ordovician rocks. Except for the Humber Zone (see below), these zones can be considered as "composite suspect terranes" (Williams and Hatcher, 1982; Keppie, 1985; after the definition of Coney et al., 1980), acquired by the North American craton during a long, complex tectonic history. Deformation, intrusion and metamorphism, though diachronous, were concentrated in the mid to Late Ordovician Taconian Orogeny, the mid to Late Devonian Acadian Orogeny, and the mid to Late Carboniferous Alleghanian Orogeny, which probably represent the main periods of terrane accretion.

Certain time-stratigraphic assemblages characterize the Appalachian Orogen (Schenk, 1978; Thomas, 1977): 1) Grenvillian crystalline basement present in the Humber Zone, 2) thick Late Precambrian to Ordovician sedimentary and volcanic rocks in all terranes (pre-Taconian Sauk sequence of Sloss, 1963), 3) Silurian to Middle Devonian sedimentary and volcanic rocks well preserved only in the Humber zone (pre-Acadian Tippecanoe sequence of Sloss, 1963), 4) numerous Devonian and Carboniferous granitic intrusions associated with the Acadian Orogeny, 5) thick, Middle Devonian to middle Carboniferous sedimentary and volcanic rocks that overlie all tectonostratigraphic zones and include the Mabou Group (post-Acadian Kaskaskia sequence of Sloss, 1963), 6) thick middle Carboniferous to Permian sediments that overlie all tectonostratigraphic zones (post-Alleghanian Absaroka sequence of Sloss, 1963).

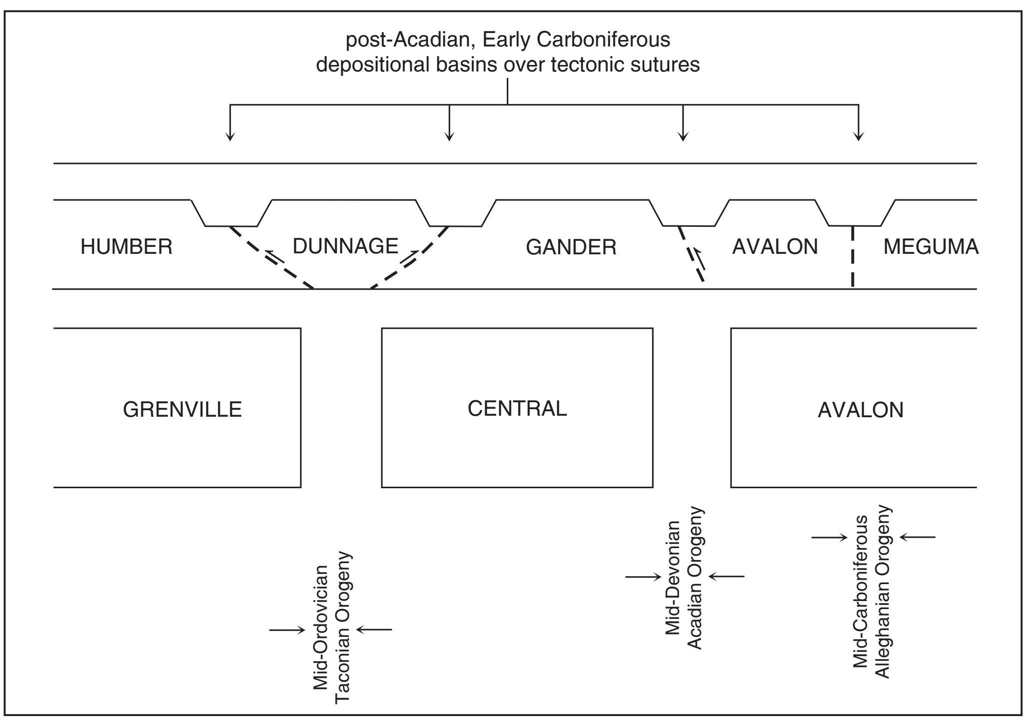

__Figure 2.__ Relationship between three lower crustal blocks, five tectonostratigraphic zones, and locations of post-Acadian, Early Carboniferous basins in the Canadian Appalachians.

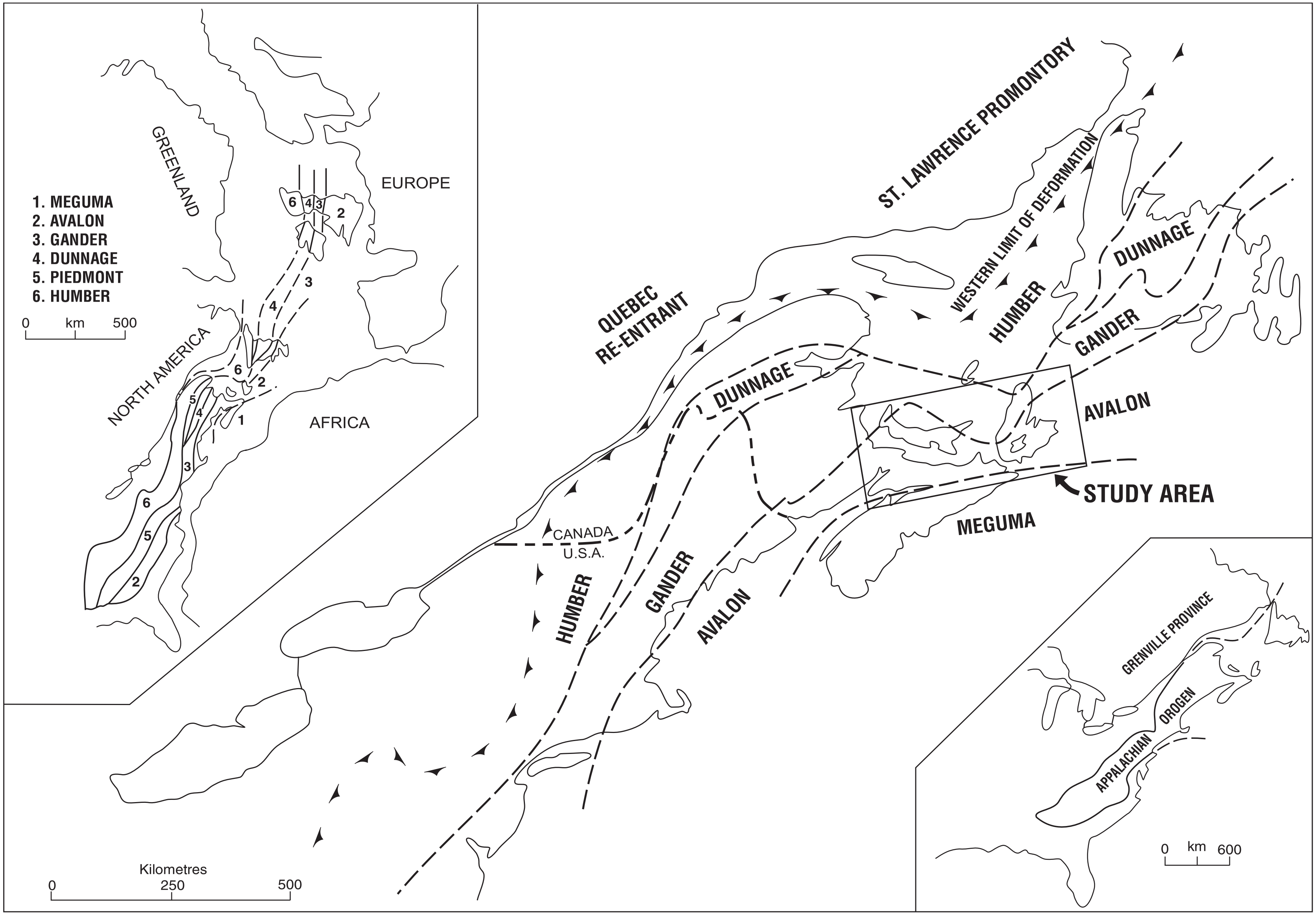

Figure 3. *Tectonostratigraphic zones of the Appalachian Orogen (compiled from Williams, 1984; Williams and Hatcher, 1982; Keppie, 1985; Stockmal et al., 1987; Barr and Raeside, 1986).*

Outboard terranes (Acadian and Alleghanian orogenies)

The Avalon and Meguma terranes both overlie the Avalon lower crustal block of Marillier (1988) (Fig. 2) in the southeastern part of the Orogen and constitute the bulk of the basement rock of Nova Scotia (Fig. 3). The Avalon Terrane is the most extensive of the composite tectonostratigraphic zones and consists of thick Proterozoic sedimentary and volcanic rocks overlain by Cambro-Ordovician shallow-water clastic deposits (Williams, 1984). There is no evidence of Taconian deformation, although the Acadian Orogeny affected the entire terrane. It has been interpreted by Williams (1979) as the margin of a thin, exotic, microcontinental mass that had stable platform conditions during the time when the Iapetus Ocean was generated and destroyed. This terrane was accreted to the North American craton along a high-angle suture that penetrated the entire crust, the "Minas Fault Zone", (Keppie, 1982; Marillier, 1988) during the Acadian Orogeny (Williams and Hatcher, 1982; Ziegler, 1984) and amalgamation of Pangea.

The Meguma Terrane is exposed only in southern Nova Scotia. It consists of a thick sequence of Cambrian to Lower Devonian marine clastic rocks transported from the southeast (Williams, 1984), which can be correlated with rocks in North Africa (Schenk, 1978). There is no evidence of Taconian deformation, but the Acadian and Alleghanian orogenies are recorded. The Meguma Terrane has variously been interpreted as the passive margin sequence of a continental mass, or a rift-fill sequence within the Avalon microcontinent (Williams, 1979). It is sutured to the Avalon Terrane along a high-angle fault zone. Keppie (1985) and Keppie and Dallmeyer (1987) suggested Late Silurian docking of the two terranes followed by accretion of the resulting "Acadia composite terrane", carried on the Avalon lower crustal block, onto North America during the Acadian Orogeny, possibly by transcurrent displacement (Kennedy et al., 1982; Williams and Hatcher, 1982).

The post-Acadian Horton, Windsor, and Mabou groups overlie both these tectonic zones in Nova Scotia, confirming that they were co-assembled by Late Devonian time. The Alleghanian Orogeny, although locally intense, apparently did little to alter this situation in Nova Scotia (Stockmal et al., 1987). The main phase of Alleghanian deformation is manifested in Nova Scotia as middle to Late Carboniferous dextral oblique transpression along various faults, including the Cobequid-Chedabucto Fault, which separates the Meguma and Avalon terranes (Fig. 1), and associated thrusting and folding (Keppie, 1982; Nance, 1986).

Paleomagnetic and structural evidence

A considerable body of paleomagnetic and structural data from both sides of the Atlantic suggests that sinistral oblique convergence of 1500–2000 km of northward displacement on major fault zones parallel to the inboard terranes was rapid in the Silurian–Devonian (Keppie, 1985, 1988; Webb, 1969). Morris (1976), Kent and Opdyke (1979), and Irving (1979) documented paleomagnetic evidence suggesting 1500–2000 km (10–15° latitude) of northward displacement of the Avalon Terrane relative to cratonic North America, probably in the Early Devonian or possibly Silurian. This would have brought these two areas together in the Middle Devonian, with Nova Scotia at about 10–15° S paleolatitude (Morel and Irving, 1978; Irving and Strong, 1984; Scotese et al., 1984; Kent, 1985; Woodrow, 1985) (Fig. 4). Based on various geological data Keppie (1988) suggested that progressive oblique sinistral convergence throughout the Ordovician, Silurian and Early Devonian led to closure of the Iapetus Ocean and culminated in transpressive emplacement of Avalonia along a deep vertical suture (as observed by Marillier, 1988) in the Acadian Orogeny.

There is ample paleomagnetic and structural evidence for oblique dextral offset of about 150 to 200 km and attendant folding and northwestward thrusting in the middle to Late Carboniferous Alleghanian Orogeny (Webb, 1969; Keppie, 1982; Bradley, 1982; Ziegler, 1984; Scotese et al., 1983; Piper and Waldron, 1988). However, this motion had ceased

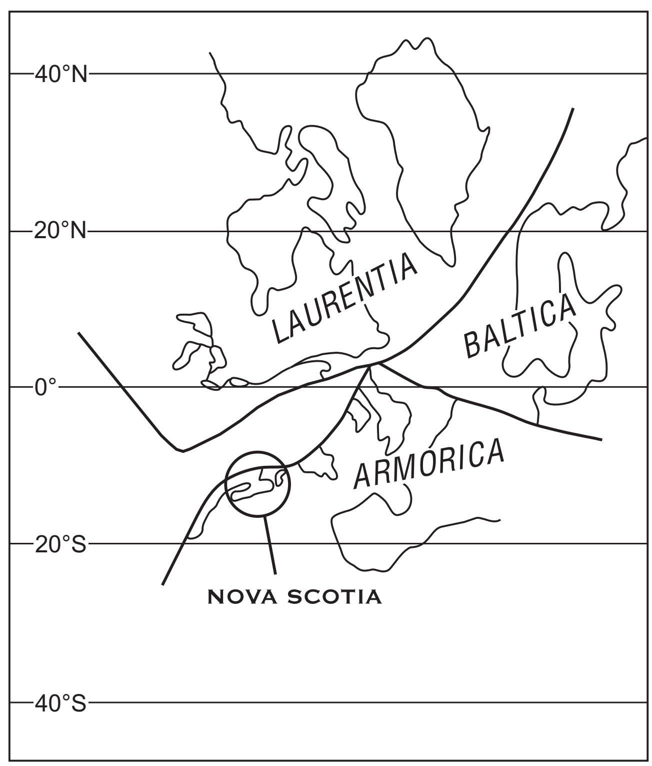

Figure 4. *Paleomagnetic reconstruction of Early Carboniferous northern Appalachian paleogeography. Nova Scotia was positioned at approximately 15° S paleolatitude (Morel and Irving, 1978; Kent, 1985; Woodrow, 1985).*

by the end of the Carboniferous (Scotese et al., 1984). If the above ideas are correct, there must have been a major reorientation of the tectonic stress field between the Acadian and Alleghanian orogenies, during which time the Horton, Windsor and Mabou groups (total of about 4000 m of strata, approximately equivalent to the Kaskaskia sequence of Sloss, 1963) were deposited in the area previously affected by the Acadian Orogeny (Fig. 5). This period of subsidence and basin formation in Late Devonian to Early Carboniferous time may represent a relaxation phase (Quinlan and Beaumont, 1984) or a period of adjustment of the regional stress field to new plate configurations (Ziegler, 1984). Hamblin (1989) and Hamblin and Rust (1989) marshalled considerable evidence from the Horton Group indicating a pervasive extensional stress field in the earliest Carboniferous.

The late Paleozoic Maritimes Basin

The Acadian Orogeny appears to have brought eastern and western tectonostratigraphic zones together into a single intracontinental area where postorogenic basins actively subsided. Bell (1929, 1944, 1958) visualized the "Fundy Basin", a wide series of partly interconnected downwarped subbasins separated by broad uplifts of pre-Carboniferous basement. Poole (1967) referred to the "Fundy Geosyncline" as a composite of uplifted source areas and miniature basins, each with its own local history. Kelley (1967a, b) had similar views; he emphasized that although similar lithofacies occur in all subbasins, they may not all correlate in age, and that deposition began in narrow basins that widened through time.

The depocentres have been collectively referred to as the "Maritimes Basin" (Williams, 1973) (Fig. 6). This term refers to a structurally complex, syn- and post-Acadian, intramontane or successor basin system, which includes platforms of thin, undeformed sediments, northeast-trending en-echelon subbasins with sedimentary successions up to 12 km thick, and linear northeast-trending ridges of exposed basement rocks of the Grenville, Avalon and Meguma terranes (Fig. 7). The Maritimes Basin overlies the structural suture zone between the North American craton and the African portion of the Gondwanan craton (van de Poll et al., 1995). Howie and Barss (1975) suggested the basin formed by a relaxation during the waning stages of the Acadian Orogeny, while Morel and Irving (1978), based on paleomagnetic data, related it to the separation of Gondwana from Laurasia after the Acadian Orogeny. Fyffe and Barr (1986) referred to the basin as a failed rift, based on the chemistry of enclosed volcanic rocks.

Enclosed strata, up to 12 km thick, are Middle Devonian to Early Permian in age, with few major gaps (Calder, 1998). The Maritimes Basin complex lay at the heart of paleoequatorial Euramerica (Calder, 1998). It is partly represented in the onshore geology of all the Maritime Provinces, but about two thirds of the 150 000 km^2 area of the basin is offshore in the Gulf of St. Lawrence (Williams, 1973). It appears to have undergone a two-phase history of a) localized Late Devonian–Early Carboniferous fault-bounded extensional subbasins with thick nonmarine and marine clastic sediments (Hamblin and Rust, 1989), and b) a Late Carboniferous broad thermal sag with a thinner blanket of nonmarine coal-bearing clastic sediments (van de Poll et al., 1995; Calder, 1998). These phases were separated by a period of deformation representing the Alleghanian Orogeny, or Maritimes Disturbance (Poole, 1967; St. Peter, 1987; van de Poll et al., 1995; Calder, 1998).

Belt (1968a, b) introduced the concept of the "Fundy Basin Rift" bounded by high-angle dip-slip faults or sharp flexures that controlled facies distributions through a long history (Fig. 8). This term essentially refers to the en-echelon

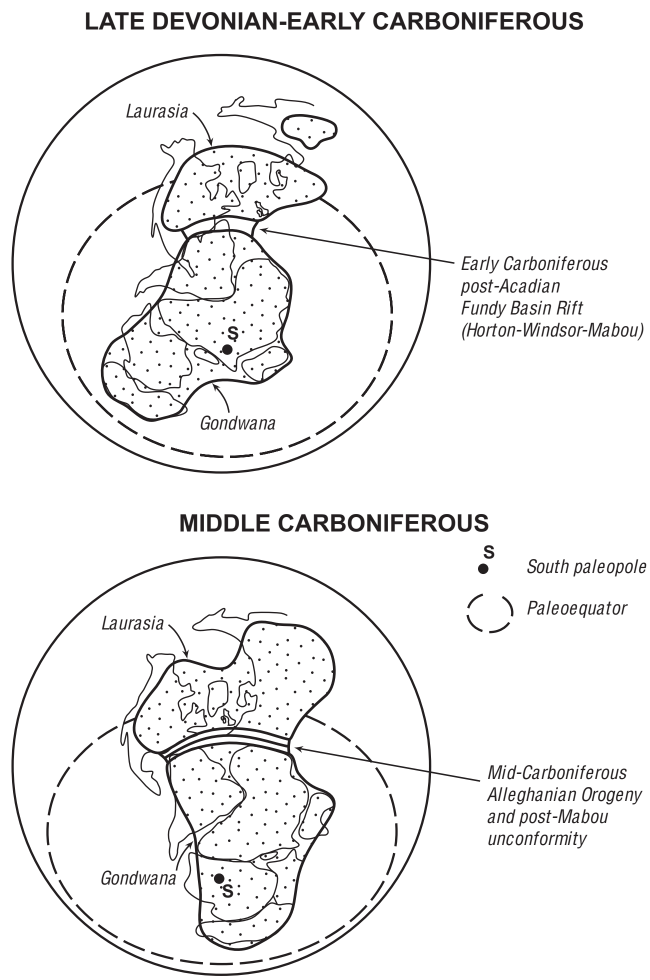

Figure 5. *Late Devonian to middle Carboniferous interaction of Gondwanan and Laurasian cratons, based on paleomagnetic data (from Morel and Irving, 1978).*

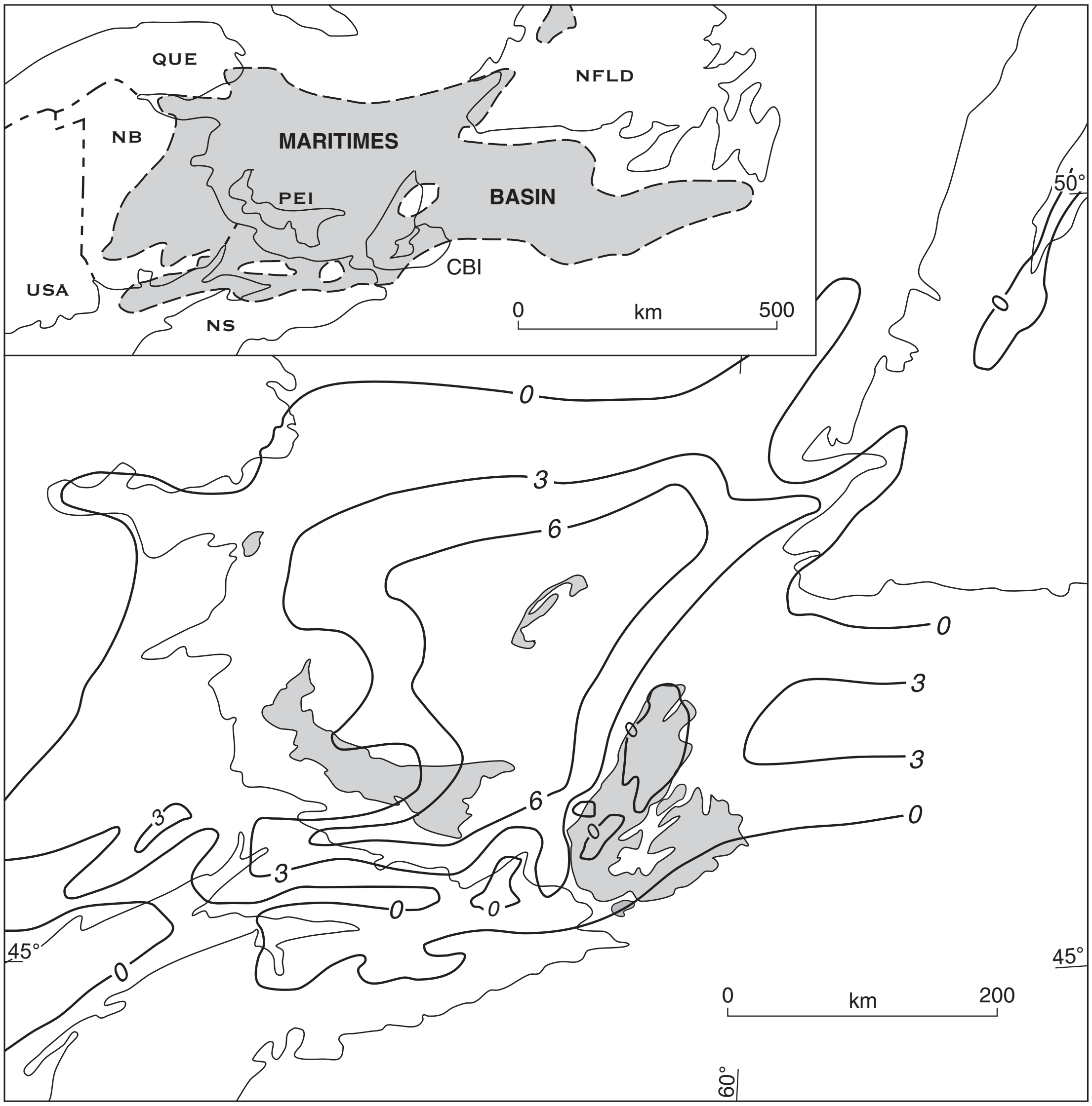

Figure 6. *Thickness of Carboniferous strata in the post-Acadian Maritimes Basin (from St. Peter, 1987; Howie and Cumming, 1963; Howie and Barss, 1975). Contours in kilometres.*

system of asymmetrical rift segments, which acted as loci for Late Devonian–Early Carboniferous deposition of nonmarine and marine strata (Hamblin and Rust, 1989; Hamblin, 1992). Belt (1968a, b) suggested that the timing, magnitude and sense of fault motion could vary along the rift, producing a different local stratigraphy in each local depocentre, although a fining of grain size toward the centre would be typical of all parts. However, despite the local variation, most major rock units (i.e. Groups) are present and are similar in most depocentres. These are therefore interpreted to have been partly linked (Hamblin, 1989; Hamblin and Rust, 1989; van de Poll et al., 1995).

Bradley (1982) suggested that most Carboniferous basins in Atlantic Canada are strike-slip pull-aparts that developed within the very large post-Acadian dextral Magdalen Basin (Mann et al., 1983). Webb (1969) earlier cited evidence for strike-slip motion on some faults throughout the northern Appalachians. While there is evidence for extension in the Magdalen area (Quinlan, 1988; Stockmal, 1988), the evidence for transtensive, as opposed to distensive, control is largely derived from post-Horton units. Hyde (1979) interpreted strike-slip basin formation in Viséan rocks of central Newfoundland, and Bradley and Bradley (1986) interpreted a small, dextral pull-apart of Viséan age in southeastern Cape Breton.

Although there have been conflicting interpretations, these have converged toward the idea that post-Acadian basins were intracontinental, fault-bounded, extensional successor basins with strong topographic relief, and that fault motions were likely episodic and multiple. Hamblin

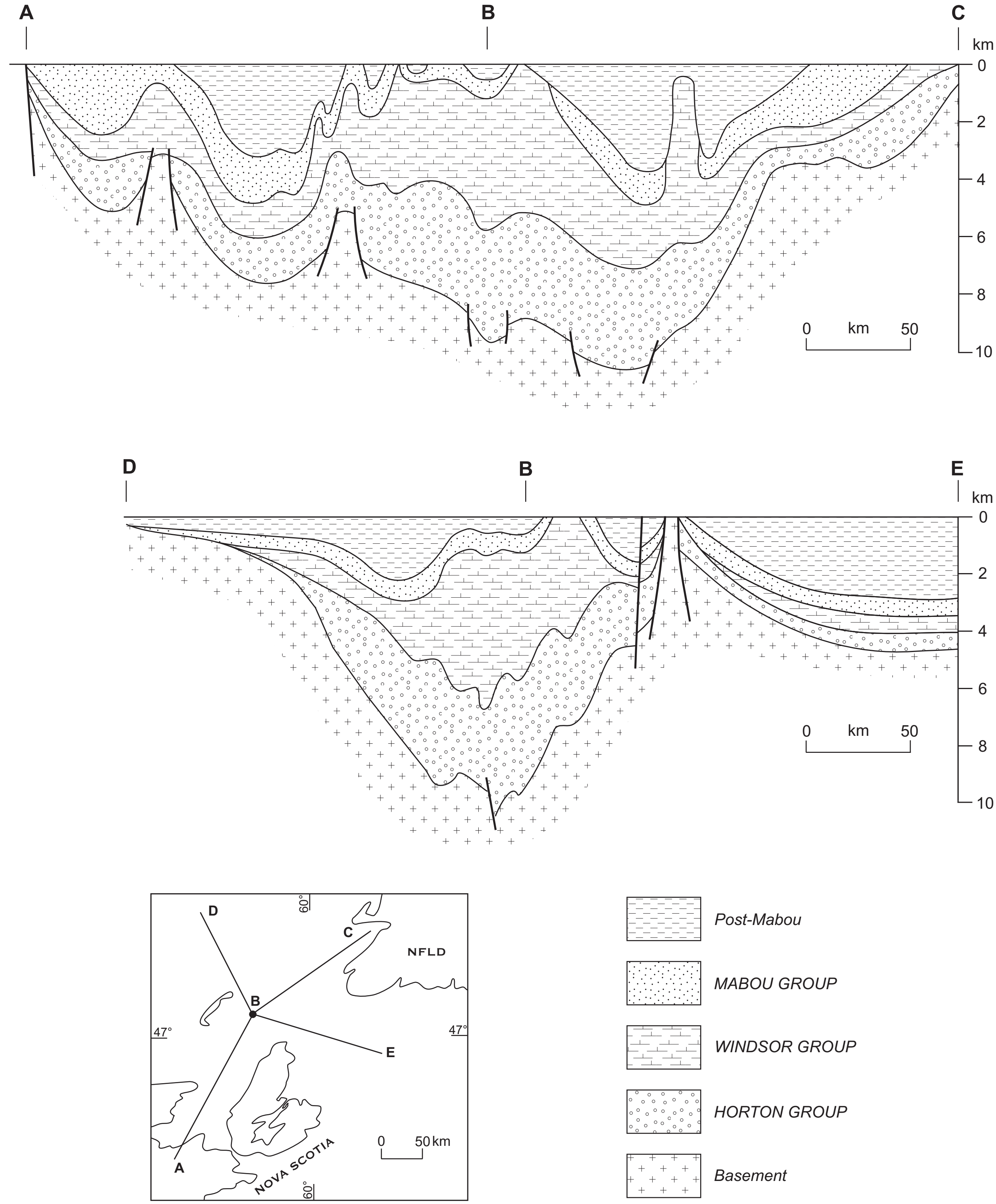

Figure 7. *Generalized cross-sections of the Maritimes Basin (from Howie and Barss, 1975).*

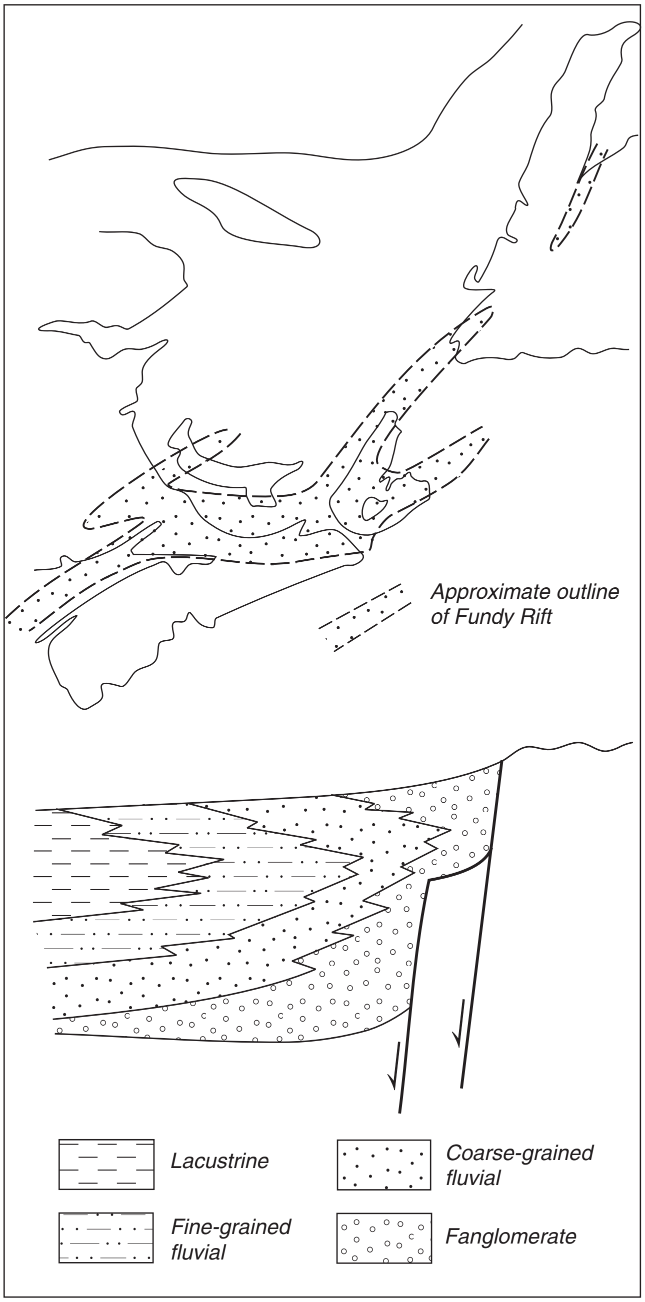

Figure 8. *The Fundy Basin Rift and control of depositional facies by bounding faults (from Belt, 1968a, b; Hamblin, 1989, 1992; Hamblin and Rust, 1989).*

(1989), Hamblin and Rust (1989), and Hamblin (1992) studied the initial rift deposits of the Horton Group and established that the subbasins of Cape Breton Island were longitudinally linked, asymmetrical, distensive, half-graben rift segments, parts of a linear Fundy Rift system in the Late Devonian–Tournaisian, where the polarity of asymmetry alternated between segments along the length of the rift. Within these segments, subsidence and coarse facies were concentrated at the master footwall fault margin of strong relief, whereas the bulk of fluvial, deltaic, and lacustrine input was from the hanging-wall margin ramp (Hamblin and Rust, 1989; Hamblin, 1992).

In summary, it appears that the Late Devonian to Early Permian evolution of the Maritimes rift involved: 1) the mid-Devonian orthogonal collision and suture of Avalon and Meguma terranes manifest as the Acadian Orogeny compression; 2) Late Devonian–Early Carboniferous post-orogenic extension of the Fundy Rift with locally thick Horton, Windsor, and Mabou deposition (Kaskaskia Sequence of Sloss, 1963) containing known and potential oil and gas, metallic and industrial mineral deposits and spanning 50 Ma; 3) a mid-Carboniferous Alleghanian compression event (oblique-slip) motion of Meguma relative to Avalon terranes with localized renewed extension and compression; and 4) Late Carboniferous to Permian regional thermal sag that created the wide Maritimes Basin with very thick successions dominated by redbeds and coal measures (Absaroka Sequence of Sloss, 1963) and which may have gas potential at depth.

Pre-Mabou basin configuration

Hamblin (1989) and Hamblin and Rust (1989) demonstrated that the initial post-Acadian sedimentation in the intracontinental Fundy Rift, the Horton Group, was deposited in a series of longitudinally linked, fault-bounded, asymmetrical half-graben subbasins. These subbasins had opposed polarity and were approximately 100 x 50 km in size. Rift extension likely continued through late Viséan and Namurian time, allowing the isolated rift system to subside below sea level (Geldsetzer, 1977). Rapid marine transgression of these continental subbasins and deposition of Windsor Group marine carbonate, evaporate and coarse red clastic rocks continued within a more extensive rift setting during renewed fault-bounded subsidence (Hamblin and Rust, 1989). It is likely that the structural asymmetry of fault-bounded subbasin segments of the Fundy Rift, so prevalent during the time of Horton deposition (Hamblin, 1989; Hamblin and Rust, 1989), persisted through the time of Windsor and Mabou deposition, because there is no evidence of a major structural or tectonic reorganization in the late Viséan. However, those subbasins apparently widened through time because the Windsor is known to unconformably overstep the Horton onto basement, and the Mabou is known to overlap the Windsor onto basement (Williams et al., 1985; Giles and Utting, 1999a). This bears striking similarity to the well-known "steer's head" configuration of many distensive rifts, a broadening through time of basins as a result of thermal subsidence (McKenzie, 1978).

Boehner and Giles (1993) and Crawford (1995) observed that the lower Mabou was conformable on the underlying Windsor Group in most locations (confirmed in this study), and suggested that it was deposited in basins that were gradually converted from hypersaline marine to shallow lacustrine environments through withdrawal, or progressive isolation from, the Windsor sea. The long period of continuous carbonate and evaporate deposition of the Windsor Group resulted in the near filling of the fault-bounded Horton subbasin floors, so that initial Mabou deposition occurred across rather featureless, arid, flat-floored basin plains (Crawford, 1995). The fault-bounded subbasin margins may still have been somewhat active however. Therefore, the lower Mabou was probably deposited in wide, flat-floored, loosely connected subbasin segments along the length of the Fundy Rift, in which the original asymmetry of structural polarity (and reversals of such along strike) may still have been expressed.

Post-Mabou (?Port Hood) Namurian event

Van de Poll et al. (1995) and Calder (1998) described in detail the evidence for the "pivotal" mid-Carboniferous event that instituted a major reorganization of the tectonic regime of Atlantic Canada, first suggested by Poole (1967) and Webb (1969). Deformation of earlier plutons near the Cobequid-Chedabucto Fault is dated as Namurian (K/Ar: 329 $\pm$ 11 Ma) and is interpreted to have been the result of transpression along the Avalon–Meguma contact (Keppie, 1982; van de Poll et al., 1995; Calder, 1998). This dextral transpression also inverted basement massifs and allowed cannibalization of Namurian strata, which were incorporated into early Wesphalian deposits (Keppie, 1982; van de Poll et al., 1995; Calder, 1998).

It also was a time of salt deformation, flowage and diapirism (van de Poll et al., 1995; Lynch and Giles, 1996). Identification of the Ainslie Detachment, a regional-scale salt-related gravity slide, by Lynch and Giles (1996) greatly altered the frame of reference for structural interpretation in the western Cape Breton-Gulf of St. Lawrence area. Development of this feature, which occurred in post-Mabou time, involved flowage of Windsor Group evaporites, which piled up salt pillows in the Gulf west of Cape Breton. The structures deform Mabou strata, which conformably overlie the salt pillows, and are onlapped by overlying Cumberland Group rocks.

Angular unconformities are present between the Mabou Group below and the Cumberland Group above in Minas and Sydney subbasins where later Namurian and early Westphalian strata are missing (Giles, 1983; van de Poll et al., 1995). Giles and Utting (1999a, b) documented evidence for a regional post-Namurian A–pre-Westphalian B unconformity throughout the central Maritimes Basin (Prince Edward Island and Gulf of St. Lawrence area). In Europe, a mid-Carboniferous floral extinction event is known from late early Namurian strata (Utting, pers. comm., 1999). This regional late Namurian event, originally termed the "Maritimes Disturbance" by Poole (1967) deformed the Horton-Windsor-Mabou (-?Port Hood/Boss Point) succession. It also marked a change in regime from the waning extensional tectonics and semiarid climate of the Early Carboniferous Fundy Rift, which had been dominated by grey, lacustrine, marine and redbed deposits of relatively immature character. Now oblique-slip tectonics became dominant, and in the seasonally humid climate of the Late Carboniferous, deposition consisted dominantly of grey, fluvial, mature sediments, and extensive coal seams in the broad, regional, thermal sag basin (van de Poll et al., 1995). St. Peter (1996) and Johnson (1996) cited miospore evidence for a break in southeastern New Brunswick between the Viséan–early Namurian Hopewell Group and the overlying late Namurian–early Westphalian Cumberland Group. In west-central Newfoundland, the Deer Lake Group (Mabou correlative) is unconformably overlain by strata of mid-Westphalian age (Langdon and Hall, 1994; Hamblin et al., 1997).

This major erosional event is approximately correlative to the Mississippian–Pennsylvanian boundary throughout North America, and is marked by a regional unconformity separating the Kaskaskia from the Absaroka sequences of Sloss (1963). This unconformity is actually of early Pennsylvanian age throughout the Appalachians, and represents the superposition of several erosional surfaces that resulted from the removal of Lower Pennsylvanian and Upper Mississippian strata (Ettensohn, 1994). Ettensohn and Chestnut (1989) attributed this hiatus to (peripheral bulge) flexure during convergence. Initiation of Alleghanian thrusting in the Appalachians of the U.S.A. led to deposition of Namurian-aged fluvial deposits (van de Poll et al., 1995). As quoted by Calder (1998), Bell (1944) suggested that "the top of the Canso [Mabou] Group marks the most pronounced paleontological break in the sequence of Canadian maritime Carboniferous floras".

The plate reconstructions of Morel and Irving (1978), Scotese et al. (1984) and Ziegler (1984) indicate that the United Kingdom, western Europe, and Northwest Africa were positioned closer to Atlantic Canada during the Early Carboniferous. The successions of these areas display similarities to those of Nova Scotia. In Morocco, Piqué (1981) observed that discrete but interconnected subbasins, which began to form in the Late Devonian, were filled with Lower Carboniferous deposits, and then were folded during the Namurian (or early Wesphalian) Maritimes Disturbance, a process that involved vertical uplift of some basement blocks and some thrusting. This is remarkably similar to the Horton-Windsor-Mabou succession of Nova Scotia, suggesting a regional consistency of tectonic effects. In the Appalachian Orogen the peak of deformation apparently occurred later southward, consisting of mid-Carboniferous folding and limited thrusting in the north (Hercynian), and Late Carboniferous thrusting in the south (Alleghanian) (Piqué, 1981). On the Irish continental shelf, Tate and Dobson (1989) observed a large-scale terrestrial-to-marine transition consisting of Tournaisian clastic rocks (Horton-equivalent) that are overlain by Viséan carbonates (Windsor-equivalent), which grade upward into a late Viséan–Namurian A coarsening-upward sandstone and shale succession (Mabou-equivalent), which terminates at a regional unconformity. In that area, the Viséan–Namurian A strata are conformable and continuous, but unconformity-bound, both onshore and offshore, and rocks of Namurian B and C ages are essentially absent (Tate and Dobson, 1989).

STRATIGRAPHIC SETTING OF THE MABOU GROUP

Regional stratigraphy

The Maritimes Basin is here considered to include an unconformity-bounded first-order basin-fill succession of Late Devonian–Permian (Kaskaskia–Absaroka) strata that resulted from the uplift and tectonic reorganization of the mid-Devonian Acadian Orogeny (Fig. 9). Nested within this succession are four, unconformity-bounded, second-order basin-fill successions of a) Late Devonian to Early Carboniferous (Horton Group), b) Early Carboniferous (including the Windsor and Mabou groups), c) Late Carboniferous (Cumberland Group), and d) Late Carboniferous to Permian (Pictou Group). Successions a and b above correlate to the Kaskaskia Sequence of Sloss (1963); successions c and d correlate to the Absaroka Sequence of Sloss (1963). The second of these four successions can be further divided into two conformable third-order sequences, the second of which is the Mabou Group coarsening-upward succession from the Hastings to the Pomquet formations (Fig. 9). Within this sequence are several fourth-order coarsening-upward sequences, detailed below.

The Upper Paleozoic succession of Nova Scotia rests unconformably on Acadian basement. Basement rocks are unconformably overlain by Horton Group grey and red sandstone, siltstone, and conglomerate, followed by Windsor Group limestone, anhydrite, salt, and red siltstone, both of Early Carboniferous age. Mabou Group red and grey siltstone, sandstone, and minor limestone, representing the upper portion of the Kaskaskia Sequence, conformably overlie the Windsor Group but are only sporadically preserved. Upper Carboniferous to Permian rocks (Absaroka Sequence) unconformably overlie the Lower Carboniferous sequence. These strata occupy most of the Sydney Basin of eastern Cape Breton Island and Cumberland Basin of Nova Scotia and Gulf of St. Lawrence region. The Cumberland Group was redefined by Ryan et al. (1991) to include grey coal-bearing strata and also includes rocks previously assigned to the Riversdale Group (Van de Poll et al., 1995). The Pictou Group, a thick, predominantly red unit of sandstone and shale, is well developed in the greater Prince Edward Island-Gulf of St. Lawrence area (Gibling et al., 1995).

History of stratigraphic nomenclature (Fig. 10)

Mather and Trask (1928) proposed the informal unit “Mabou formation” for a dark, shaly unit between the marine Windsor Group and the coal-bearing Port Hood Formation. Norman (1935) formally defined the term “Mabou Formation” for red and grey, fine- to medium-grained sandstone and shale exposed along Southwest Mabou River and at Broad Cove in the Lake Ainslie area of Cape Breton Island. He described 100 m of grey shale with limestone beds lying unconformably on the Windsor Group, gradationally overlain by 300 m of red shale and thin red sandstone beds, in turn gradationally overlain by 500 m of Port Hood Formation grey shale and sandstone with a few coals. The latter outcrop is included in this study.

Bell (1944) biostratigraphically defined the “Canso Group”, as up to 1000 m of nonmarine red and grey shale and sandstone, conformably overlying the Windsor Group, and disconformably underlying Riversdale strata. Bell (1944) emphasized the dominance of grey colours near the base, red colours toward the top, lack of conglomerate, abundance of ripples and mudcracks, and freshwater fauna. In addition, Bell (1944) emphatically stated that the “top of the Canso marks the most pronounced paleontological break in the sequence of Canadian Maritimes Carboniferous floras”, equal to the marked break at the top of the Lower Namurian of Europe.

Rostoker (1960) described the Canso Group and formally subdivided it into a lower, grey shaly unit and an upper, red, silty to sandy unit. The Hastings Formation was formally named by Rostoker (1960), comprising up to 1250 m of dark grey and red shale, siltstone, fine-grained sandstone and minor limestone in the lower part of the Canso Group. He designated the type section on the east shore of the Strait of Canso between Port Hastings and Port Hawkesbury (an outcrop included in this study), and a reference section along Pomquet River near Antigonish. Rostoker (1960) also formally named the Pomquet Formation, comprising up to several thousand metres of thinly interbedded red siltstone, shale, and sandstone in the upper part of the Canso Group, with a composite type section in the vicinity of the Pomquet and Afton rivers near Antigonish.

Belt (1964, 1965) studied the post-Windsor strata and recommended abandonment of the stratigraphic names “Canso” and “Riversdale” because they were too time-

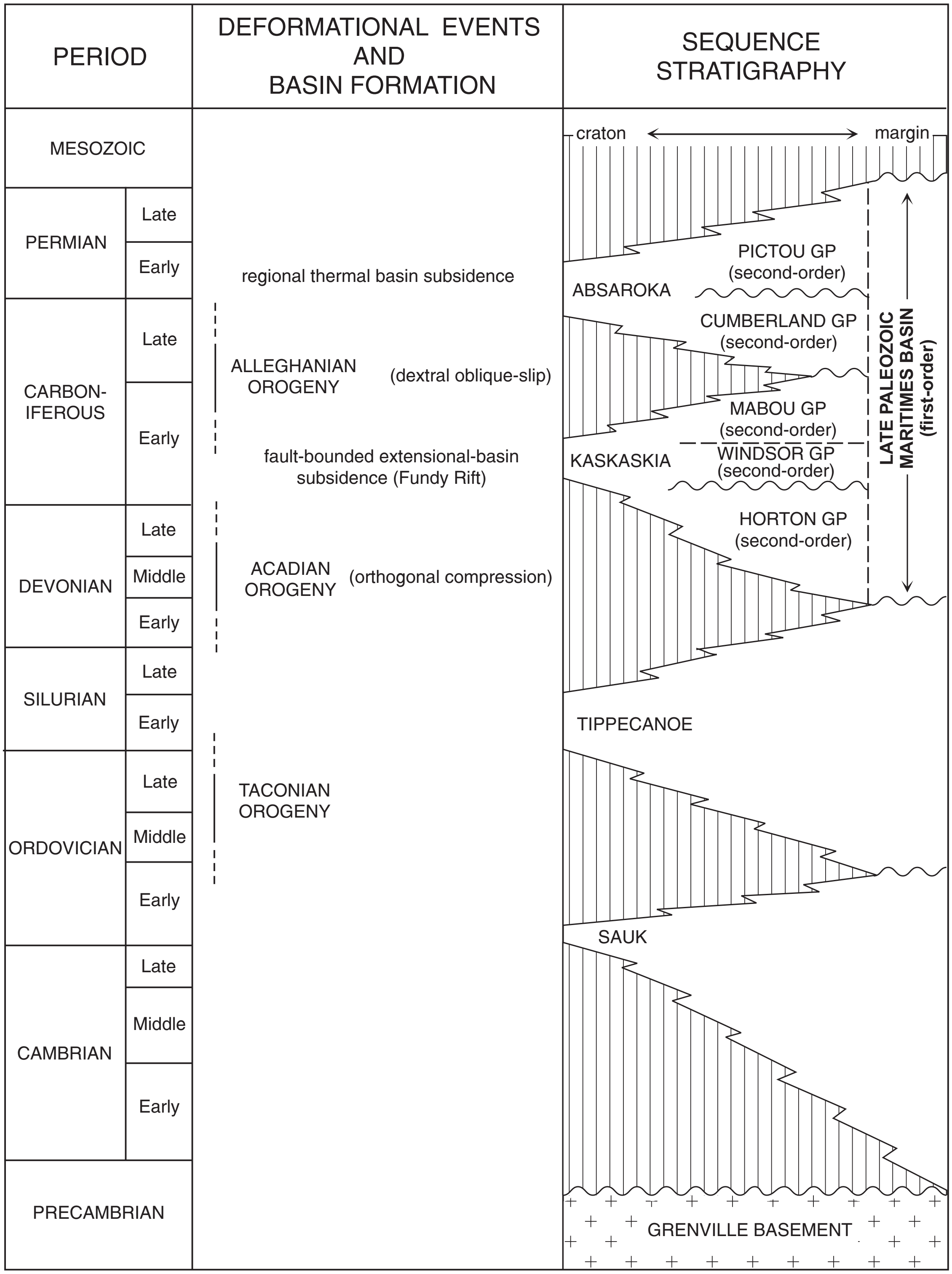

__Figure 9.__ Terrane accretion and time-stratigraphic sequences of the northern Appalachian Orogen, highlighting events of the late Paleozoic Maritimes Basin and the setting of the Mabou Group (compiled from Thomas, 1977; Schenk, 1978; Sloss, 1963; Hamblin, 1989).

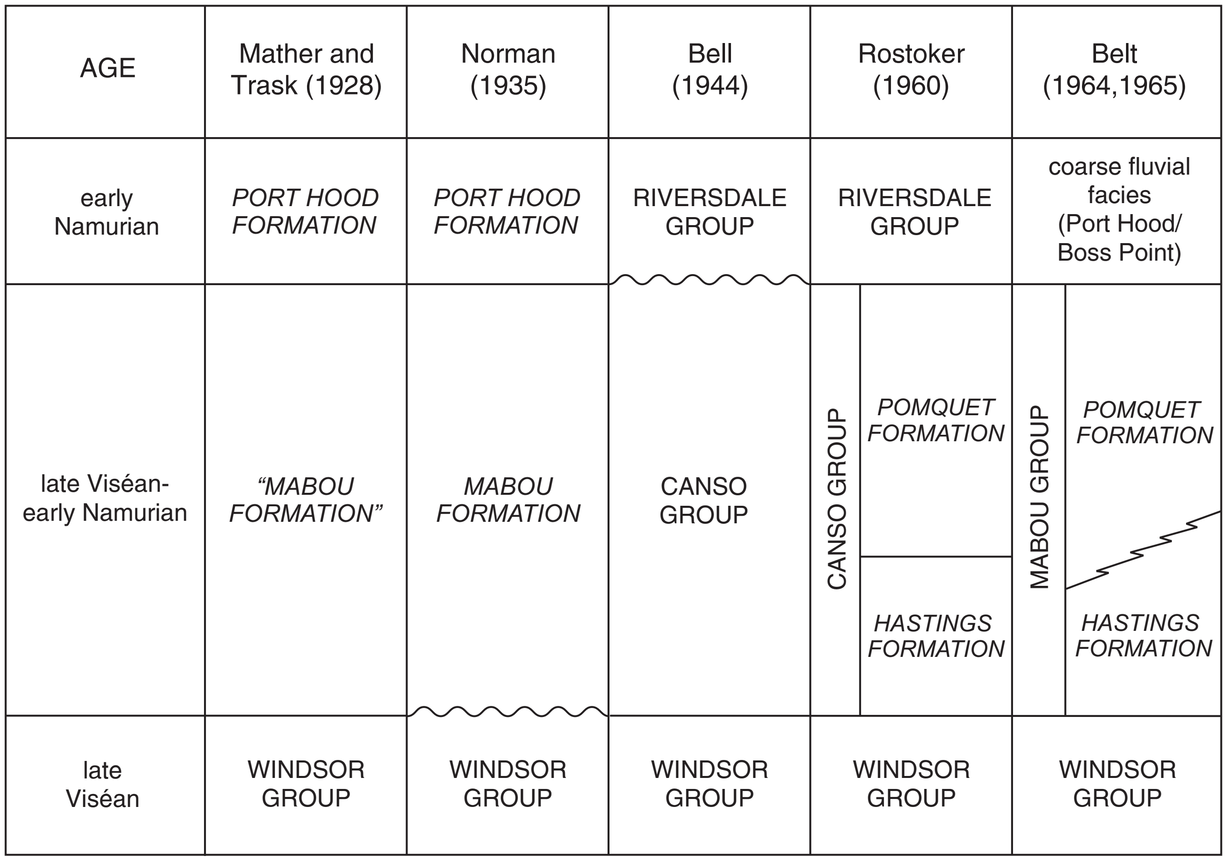

Figure 10. *History of stratigraphic nomenclature of the Mabou Group.*

restrictive to be useful lithostratigraphic terms. He suggested employing the purely lithostratigraphic terms "Mabou Group" for red and grey nonmarine mudstone and sandstone of the original Canso and part of the Riversdale, and an informal "Coarse Fluvial Facies" for the coarser fluvial sandstones with lesser mudstone of the overlying Port Hood and Boss Point formations. As summarized by Ryan et al. (1991), Belt suggested that unconformities in this region are too localized to be used as reliable group boundaries (present only near basin margins), and that age should not be used as a primary criterion for definition. Belt (1964) proposed the purely lithostratigraphic Mabou Group for all mid-Carboniferous strata above the marine Windsor, below the base of the Port Hood-Boss Point medium- to coarse-grained sandstone with coal, and distinguished by the absence of marine strata, coal and coarse extrabasinal detritus. He designated a type section on Southwest Mabou River, acknowledging that the base was faulted, the upper part was unexposed and there were many faults within, and so also designated a reference section at Plaster Cover near Port Hastings on the Strait of Canso. Belt (1965) accepted Rostoker's (1960) Hastings and Pomquet formations as valid interfingering lithofacies with conformable interrelationships. The Southwest Mabou River section was not included in this study for the reasons Belt mentioned, and because exposure is now rather poor.

Mabou Group and its relation to other units

The Mabou Group spans the latest Viséan to Namurian, is continental in nature and likely transitional with the underlying marine Windsor Group. It has been described as conformable to disconformable on the Windsor, but locally onlaps older rocks. The upper contact may be conformable or unconformable. The terms Canso and Riversdale groups have been abandoned. The maximum thickness of the Mabou is said to be about 2100 m (van de Poll et al., 1995), although no thickness greater than 500 m was measured in this study. The type section is at Southwest Mabou River, and a reference section at Port Hastings, both on Cape Breton Island. The Mabou Group is of late Early Carboniferous age (late Viséan–early Namurian) and is dominated by red and grey nonmarine strata, with coarse conglomerate and arkosic sandstone near basin margins, but mostly fine-grained sandstone and mudstone toward the centres of basins.

A number of other stratigraphic units in Nova Scotia are known, or thought, to be approximately equivalent to the Mabou Group, as follows.

In Sydney Basin, Giles (1983) described the Cape Dauphin Formation (originally described by Bell and Goranson, 1938) as 78 to 84 m of grey to dark grey shale with minor grey sandstone and intercalated freshwater limestone and algal stromatolites. The type locality is at a coastal section at Cape Dauphin at the northwestern tip of Kellys Mountain, but the unit outcrops at only a few places nearby. At the type section, it conformably overlies the Windsor, and is overlain with angular unconformity by the Westphalian to Permian Morien Group. It is of late Viséan age as dated by spores, approximately correlative to the Hastings Formation (Giles, 1983; Utting, 1996; Appendix 2). Giles (1983) also described the Point Edward Formation: 213 m of lacustrine red and greenish grey shale with minor sandstone and freshwater limestone and stromatolites. The type locality is at the coastal section at Point Edward where the lower 140 m is concealed (possibly representing unexposed Cape Dauphin Formation). It is assumed to conformably overlie the Windsor, and is overlain with angular unconformity by the Morien Group. Megaplant fossils give a Namurian A age (Bell, 1944), approximately correlative to the Pomquet Formation, although some miospores suggest a late Viséan age (Neves and Belt, 1970). Both these sections are included in this study.

The informal Hollow Conglomerate and Lismore Formation of the Merigomish subbasin is a fining-upward succession up to 2500 m thick adjacent to the Hollow Fault subbasin margin (Fralick and Schenk, 1981; McCabe and Schenk, 1982). It includes quartzitic conglomerate, reddish, fine- to medium-grained sandstone and red siltstone in fining-upward sequences, which unconformably overlie pre-Acadian units, and which may partly correlate with the Windsor and Mabou groups (Stevens et al., 1999). Paleocurrent flow was toward the southeast (Fralick and Schenk, 1981; Stevens et al., 1999). The type section is an extensive outcrop on Knoydart Brook and the adjacent shoreline near Knoydart Point (Fralick and Schenk, 1981; McCabe and Schenk, 1982; Stevens et al., 1999). This section was not included in this study, to avoid duplication of the work of Stevens et al. (1999).

In the Cumberland Basin area of western Nova Scotia several units appear to be correlative. The West Bay Formation was defined by Carroll et al. (1972) as about 550 m of reddish and greenish shale and thin bedded sandstone with minor dark grey shale, sharpstone conglomerate and limestone, with a type locality at East Bay near Partridge Island, south of Parrsboro (included in this study). There, it has a faulted base but is presumed to conformably overlie the Windsor and is unconformably overlain by the Parrsboro Formation. Spores indicate a late Viséan to Namurian A age (Carroll et al., 1972; Utting, 1996; Appendix 2), approx-imately equivalent to the Hastings Formation, and abundant amphibian trackways are spectacularly exposed.

Farther west, in the Cumberland Basin, Bell and Norman (1938) defined the Middleborough Formation as 900 m of brownish red mudstone, siltstone, and sandstone, and the Claremont Formation as up to 1000 m of red and green matrix- or clast-supported, polymictic boulder to pebble conglomerate with arkosic sandstone (Williams et al., 1985). The Claremont strata were assigned by Ryan et al. (1991) to the base of the Cumberland Group and are conformably overlain by the Boss Point Formation. However, recent palynological study (Utting, pers. comm., 1999) concluded that some Claremont rocks are of late Viséan–early Namurian age and may represent the erosional remnant of the Mabou Group in this area, adjacent to the basement highlands. The reference section at Downing Head, and another section, are included in this study.

In the offshore area of the Gulf of St. Lawrence, Rehill (1996) described an interpreted 550 to 700 m thick sequence of generally coarsening-upward and thickening-upward interbedded sandstone, siltstone, shale, and thin limestone. Designated reference wells are Soquip et al. Tyrone No. 1, 3259–3949 m and Hudson Bay-Fina Green Gables No. 1, 2418–2971 m. There is an abruptly conformable to disconformable lower contact with an abrupt increase in gamma-ray value and in acoustic velocity (i.e., abrupt increase in mudstone content), and it locally onlaps older units and basement. The upper contact is marked by a sharp decrease in gamma ray value (i.e., abrupt increase in sandstone content), and is locally unconformably overlain by Westphalian strata. The unit is present throughout the offshore (identified with internally concordant seismic sequence LEZ A of Rehill, 1996) and is thickest and sandiest near the centre of the Maritimes Basin, thinning toward the flanks. The sandstone facies includes light grey to buff, very fine- to fine-grained sandstone, which is medium to well sorted, subangular, with silica and calcareous cement, and has a porosity of 7–10%, and low permeability. The shale facies is red to grey to green, silty, micaceous, and reddens upward. Overall, the sandstone to shale ratio is 1:13, but there is an increase in sandstone upward. The thin limestones are light brown, silty and dolomitic. There are a few coaly stringers toward the top of the succession. This was interpreted as an extensive prograding alluvial floodplain sequence.

Areas outside Nova Scotia

The mid-Carboniferous of southeastern New Brunswick comprises the Hopewell Group, which is well exposed around the shores of the Bay of Fundy. McCabe and Schenk

(1982) described the Maringuoin Formation (named by Norman, 1941) as 180 to 810 m of alternating red mudstone and very fine-grained sandstone with ripple crosslamination and horizontal lamination (sheetflood deposits) passing up into channelized sandstone (meandering river deposits). Abundant desiccation cracks and gypsum casts suggest an arid paleoclimate. The unit conformably to disconformably overlies Windsor strata, is conformably overlain by the Shepody Formation, and is likely of late Viséan age (Williams et al., 1985). It is considered to be correlative to the Middleborough Formation of western Nova Scotia (Williams et al., 1985). The Shepody Formation (Norman, 1941) includes up to 700 m of greenish grey to red, fine- to coarse-grained sandstone, mudstone, and minor limestone-pebble conglomerate. The Shepody gradationally overlies the Maringuoin, is disconformably overlain by the Enragé Formation and is of Namurian A age (Williams et al., 1985). The Enragé Formation comprises up to 400 m of lower red conglomerate and sandstone overlain by red mudstone with calcrete limestones. It is conformably overlain by the Boss Point Formation and has similarities to the Claremont of Nova Scotia (Williams et al., 1985) (i.e., is Mabou-equivalent).

In the Restigouche Basin of northern New Brunswick and Gaspé around Baie des Chaleurs, the Lower Carboniferous Bonaventure and Cannes de Roche formations consist of up to 200 m of red, coarse-grained clastic rocks, which lie unconformably on Devonian strata (Rust, 1981; Zaitlan and Rust, 1983). Paleocurrent data suggests eastward transport of alluvial fan and fluvial detritus along the axis of the subbasin paleovalley, opposite to that of the underlying Devonian (Rust, 1981; Zaitlan and Rust, 1983). The two units may be correlative, or the Bonaventure may be slightly older (van de Poll et al., 1995). The relation of these two units to the Mabou Group is unclear.

In west-central Newfoundland, Baird (1959) described the Deer Lake Group as consisting of nonmarine conglomerate, sandstone, mudstone and oil shale. These strata were described by Hyde et al. (1988) and the sedimentology and hydrocarbon potential of the enclosed Rocky Brook Formation were detailed by Hamblin et al. (1997). The lacustrine grey shale and oil shale of the Rocky Brook Formation are dated as late Viséan (V_3) and are correlative with the Hastings Formation of the Mabou Group (Hamblin et al., 1997). The Rocky Brook is overlain by greenish and reddish pebbly sandstone, arkosic conglomerate, and red siltstone of the Humber Falls Formation, possibly a Pomquet equivalent (Hamblin et al., 1997). This deposition was followed by a regional Namurian–Westphalian erosional event, and the Humber Falls is unconformably overlain by strata of mid-Westphalian age (Langdon and Hall, 1994). The Searston Formation of southwestern Newfoundland may be partly equivalent to the Mabou Group (Knight, 1983; Utting, pers. comm., 1999).

Lithology

Norman (1935) described the Mabou Formation as including a lower grey shale with limestone beds and minor red shale and sandstone, and an upper red shale with thin, red sandstone beds. Bell (1944) described two lithofacies:1) finely laminated grey shale with local thin limestone beds, especially near the base, and a few thin, fine-grained sandstone beds, and common sideritic bands (which he referred to as the "Minas" facies); and 2) red shale and thick sandstone beds with ripples, and mudcracks (which he referred to as the "Cumberland" facies). He emphasized that it is common to observe dominantly grey colours and shaly lithologies near the base, mixed red and grey colours in the middle and dominantly red colours near the top, with an overall increase in sandstone upward. Bell (1944) also emphasized the ubiquitous thin bedding and lamination, abundant oscillation ripples, mudcracks, and meagre freshwater fauna.

Stevenson (1958) also noted the increase in sandstone upward, and suggested that the Canso Group [Mabou] deposits in the Truro area were probably derived from the Meguma Terrane to the south and were likely separated from the overlying Riversdale strata by a significant unconformity. Rostoker (1960) informally defined the Hastings Formation as dark grey to black shale and siltstone with interbeds of reddish siltstone and sandstone and minor limestone. In addition, Rostoker (1960) informally defined the Pomquet Formation as thinly interbedded red siltstone, sandstone, and shale.

Belt (1964, 1965, 1968a, b) did a large amount of important work on the strata of the middle part of the Carboniferous of Nova Scotia. Belt described two main lithofacies assemblages: 1) red and grey-green mudstone with lesser sandstone, interpreted as fluvial interchannel deposits with thin channel bodies; and 2) grey, laminated shale with lesser calcareous sandstone and some reddish mudstone beds, interpreted as lacustrine with red fluvial intercalations. One important contribution was the formal definition of the lithostratigraphic Mabou Group, and the enclosed Hastings and Pomquet formations. He defined the Mabou Group as about 2000 m of nonmarine lutite with up to 50 per cent sandstone, primarily composed of inter-tonguing, grey, laminated, lacustrine shale with thin beds of sandstone and freshwater limestone (Hastings Formation), and reddish to greenish lutite and fine- to medium-grained, mature, fluvial sandstone, with minor intraformational conglomerate (Pomquet Formation) (Belt, 1964, 1965). He emphasized the intertonguing of these two lithofacies-based formations, the absence of marine indicators, coal, and extrabasinal coarse detritus, and that the interbedded sandstones are 80 to 100 per cent quartz in contrast to the 45 to 75 per cent of the overlying medium- to coarse-grained sandstones (Belt, 1964, 1965).

Benson (1967) and Kelley (1967) mapped Canso and Mabou rocks in the Hopewell and Baddeck and Whycocomagh areas respectively, finding laminated grey shale and siltstone with red siltstone and fine-grained sandstone. Carroll et al. (1972) described similar mid-Carboniferous rocks from the Grand Étang and Point Edward areas, emphasizing the abundance of shallow-water indicators and including comprehensive lists of nonmarine fauna. Benson (1974) mapped the correlative Lismore Formation of the Arisaig-Merigomish area, describing a coarsening-upward sequence of reddish shale, siltstone, sandstone, and minor conglomerate, which conformably overlies the Windsor, unconformably overlies adjacent basement and is unconformably overlain by younger rocks. Fralick and Schenk (1981), McCabe and Schenk (1982) and Stevens et al. (1999) provided further sedimentological details on the Lismore Formation and its depositional relation to the nearby Hollow Fault.

McCabe and Schenk (1982) described four facies in the West Bay Formation: 1) wavy bedded, grey sandstone and mudstone with symmetrical ripples and desiccation cracks interpreted as deep lakes with occasional exposure; 2) red and green laminated mudstone with desiccation features, interpreted as fringing mudflats; 3) minor crossbedded sandstone up to 1 m thick, interpreted as sheet floods or ephemeral streams; and 4) pebbly sandstone up to 1 m thick, interpreted as transgressive lags with oolite clasts and shells.

Boehner and Giles (1993) remapped the Antigonish area and presented further lithological details of the Mabou Group there. The Hastings Formation comprises grey shale with distinctive interbeds of buff- to tan-weathering stromatolitic limestone and dolostone, and locally interbedded red siltstone and sandstone. The Pomquet Formation is thinly bedded red sandstone interstratified with red siltstone and shale. Grey colours are less common. In New Brunswick, Johnson (1996) and St. Peter (1996) described the equivalent strata of the Maringuoin, Shepody and Enragé formations, the distal equivalents of the Hopewell Conglomerate, which conformably overlie the Windsor. The Maringuoin includes red mudstone, siltstone, and fine-grained sandstone, the Shepody includes red and grey sandstone, mudstone and minor conglomerate, and the Enragé comprises red and buff arkosic sandstone, conglomerate and red mudstone (Johnson, 1996; St. Peter, 1996).

At Broad Cove, Browne and Plint (1994) identified two similar facies assemblages: 1) calcareous shale and dolostone with stromatolites and oolites in 8 to 30 m units, interpreted as ephemeral playa lakes; and 2) interbedded red mudstone and sandstone in 6 to 60 m units (sandstone beds up to 10 m) interpreted as lake margin flats subject to sheetfloods and channelization. These two facies assemblages were in some places interbedded.

In a very detailed study of the Hastings Formation on Cape Breton Island, Crawford (1995) described the two types of siltstone that form the dominant lithologies of the formation. Grey to dark grey, laminated siltstone with couplets of alternating light grey calcareous siltstone and organic-rich mudstone and minor, thicker lenses of laminated, dolomitic mudstone is very characteristic, whereas reddish blocky siltstone with slickensides and roots are less common. In addition, Crawford (1995) described three types of limestones in the Hastings: 1) common, laterally continuous to discontinuous laminated stromatolitic colonies with sharp bases and planar to domal tops; 2) laterally continuous grainstone beds composed of sand- to pebble-sized grains of micrite, ooids, stromatolite, and fossil fragments in a micritic or sparry cement; and 3) rare, laterally continuous beds of oolites cored by grains of quartz, micrite, and ostracod fragments, and set in a sparry cement. Crawford (1995) also mentioned that thin beds and veins of gypsum occur with red siltstone near the base of the Hastings in a few outcrops and cores.

Thickness and distribution

In general, Mabou Group rocks range from several hundred to, reportedly, several thousand metres in thickness, and occur as preservational remnants in widely scattered areas throughout Nova Scotia. Isopach maps compiled by Howie and Barss (1975) of a combined Mabou-Riversdale unit in the offshore areas, indicate thicknesses in the 1000 m range, with a maximum of about 1500 m (Fig. 11). In no section in this study were more than 500 m of strata exposed, and the maximum thickness in the nearby offshore area is now thought to be about 700 m (Rehill, 1996). Clearly, the Group is not as thick as earlier estimates implied, especially in onshore areas. The rocks are mildly deformed at most outcrops. They occur over a large depositional region in the Sydney, Mabou, Antigonish, Pictou, Parrsboro and Joggins areas of the province, as well as in the offshore area of the Gulf of St. Lawrence. In most areas, Mabou strata constitute a thick unit, and almost invariably include a vertical stacking of two laterally persistent stratigraphic units: lower, dark-coloured shaly rocks overlain by upper, red, silty to sandy deposits.

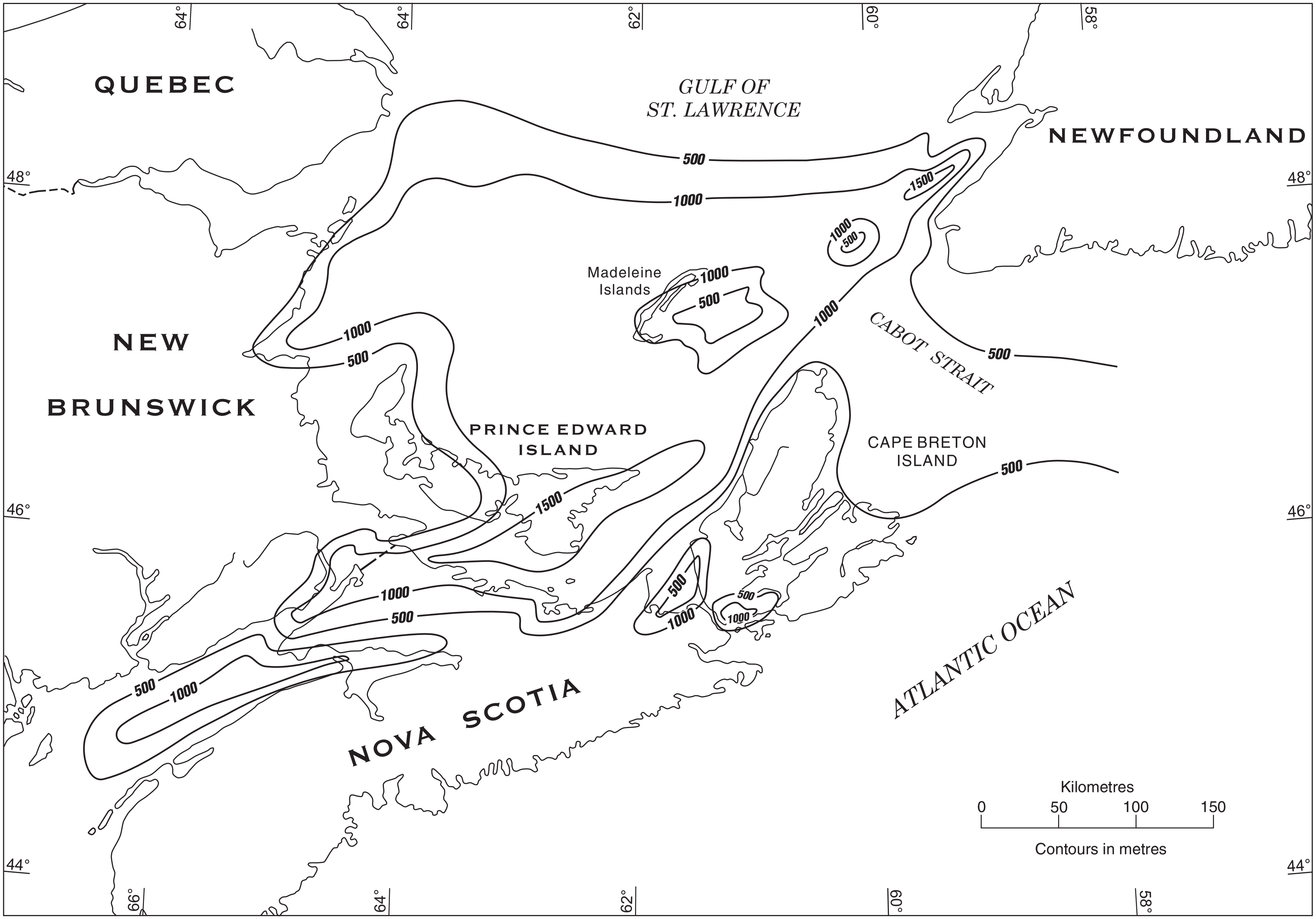

Figure 11. Isopach of Mabou Group in Gulf of St. Lawrence region (simplified from Howie and Barss, 1975).

Age and correlation

The age of the Mabou Group has long been a subject of contention. Bell's (1944) study of the megaflora suggested to him that the Canso Group was Namurian A in age, and this publication has had great influence on subsequent workers. The most comprehensive study of the age of the Mabou Group was palynological work published by Neves and Belt (1970), in which they concluded that the Mabou was of late Viséan to Namurian A/B age. They recovered late Viséan palynomorphs from the Hastings, Cape Dauphin, Point Edward, and West Bay formations, and Namurian palynomorphs from the Pomquet and West Bay formations. In a palynological study of the Windsor Group from a borehole in the Shubenacadie Basin, Utting (1980) found a late Viséan floral assemblage in the Watering Brook Formation, comparable to that of the Mabou Group, as noted by Neves and Belt (1970).

More recent work by Utting et al. (1999) and Giles and Utting (1999a), including some samples collected in this study, found that miospore zones in the nonmarine late Viséan, Namurian and Westphalian can be compared (with some difficulty) to the zones of Europe where there is some stratigraphic control from marine faunas, and that the Mabou Group is of late Viséan to early Namurian A age (Fig. 12). Samples from the Hastings Formation generally yielded well-preserved floras of the *Grandispora spinosa–Ibrahimispores magnificus* (SM) Concurrent Range Zone (Utting, 1987) of late Viséan age (Utting, 1996; Appendix 2). However, this age assignment is older than that indicated by the foraminifers (Mamet, 1970), which suggested that the uppermost beds of the Windsor Group were early Namurian. If that suggestion is correct, then the SM Zone may be of early Namurian age (Utting, pers. comm., 2000).

The few samples from the Pomquet Formation suitable for palynological analysis yielded poorly preserved floras, which included elements characteristic of an (?early) Namurian age, (Utting, 1996; Appendix 2). There is a major microfloral extinction of typical Viséan and early Namurian (Mississippian) taxa at the top of the Mabou Group (Fig. 12), indicating a hiatus of unknown duration between these rocks and the overlying Port Hood and Boss Point formations of later Namurian to Westphalian A (Pennsylvanian) age (Utting et al., 1999).

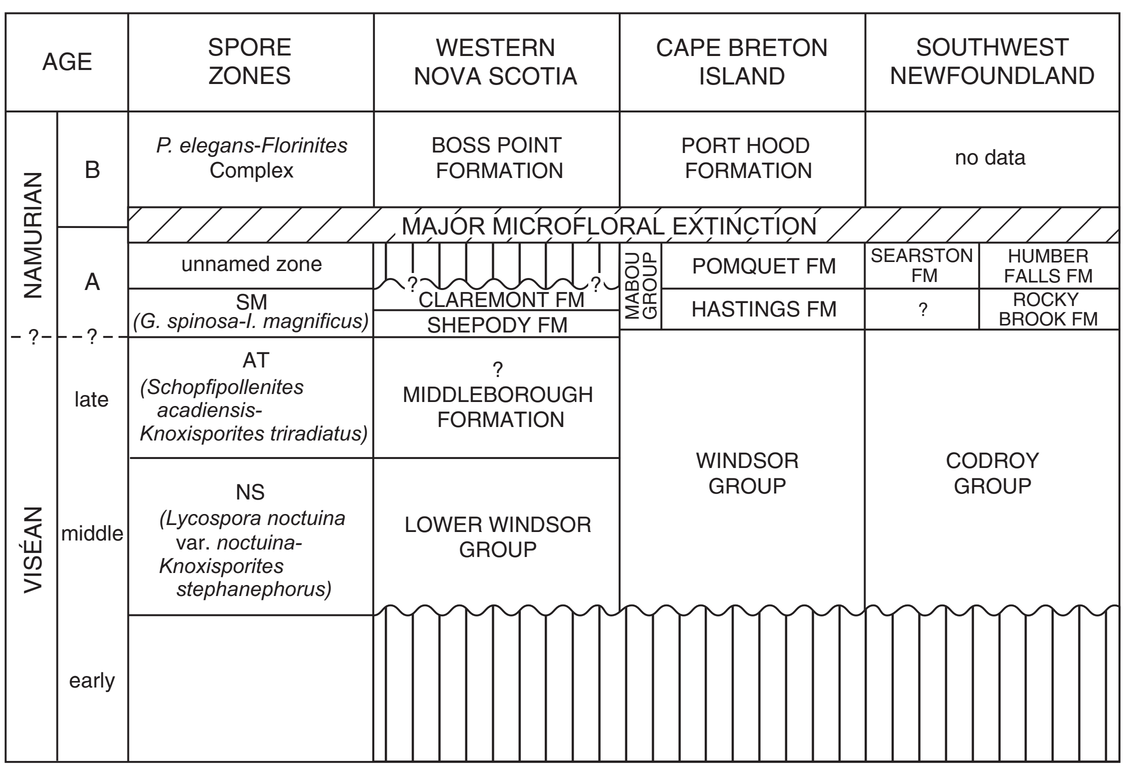

Figure 12. *Middle Carboniferous (Viséan–Namurian) palynological zones and stratigraphy. Results of this study and that of Rehill (1996) suggest that 700 m may be a realistic maximum thickness (compiled from Utting, pers. comm., 2000).*

Climate

During the Carboniferous, Nova Scotia (and Britain and western Europe) lay within an intermontane region in the interior of the recently assembled Euramerican continent, near the paleoequator. The area was positioned at approximately 12° S paleolatitude, and was drifting northward toward the paleoequator (Calder, 1998). Immediately to the west, the Appalachian mountain range created a climatic and drainage barrier (Calder, 1998). Climatic indicators from the Windsor marine carbonate and evaporite rocks and Mabou nonmarine strata suggest a warm, arid to semiarid, possibly seasonal, climate (Utting, 1987; Ryan and Boehner, 1995; Calder, 1998) where red and grey fluvial-lacustrine and evaporative marine deposits prevailed. However, various authors have speculated that the onset of major, although geographically distant, Gondwanan glaciation occurred during the Viséan and may have affected deposition of Windsor and Mabou strata, in part by causing glacio-eustatic cyclic sedimentation (see Giles, 1981 and Van de Poll et al., 1995). Crowell (1999) summarized evidence indicating that, during the late Viséan to early Namurian, the spread of glacial ice began, and generalized sea level drop was initiated.

McCabe and Schenk (1982) stated that the evaporites of the Viséan indicate arid climates, whereas the coal-bearing Westphalian strata suggest humid climates. This suggests that the late Viséan to early Namurian rocks of the Mabou Group mark the transition between these two states. They list a series of semiarid climatic indicators in the Namurian such as gypsum casts and beds, caliche soils, lack of preserved vegetation, and giant mudcracks (McCabe and Schenk, 1982), all of which were encountered in this study. Microfloral assemblages from the Mabou Group suggest a transition from very arid conditions of the Windsor Group, through increasing humidity of the Hastings and Pomquet formations to seasonably humid climates of the overlying Cumberland Group (Utting, 1996; pers. comm., 1999). Utting (1987) suggested that the Windsorian climate was hot and arid, with a uniform, low-diversity flora on land (due to the salinity?), and spore transportation was likely by wind, resulting in a consistent palynofloral assemblage dominated by a few species. He also indicated that most of these conditions applied to early Mabou time (Utting, 1987).

Paleontology

Calder (1998) reviewed the fauna and flora of the Mabou Group, enumerating a nonmarine to brackish-water assemblage of crustaceans, fishes, sharks, ostracods and amphibian trackways. Keighley and Pickerill (1997, 1998) detailed the varied nonmarine trace fossils of the Mabou and adjacent beds, describing a relatively diverse nonmarine ichnofauna including insects, reptiles, amphibians and crustaceans, correlative to the *Scoyenia* ichnofacies of Seilacher (1967) or the *Mermia* ichnofacies of Buatois and Manganeo (1993). Neves and Belt (1970), Giles and Utting (1999a) and Utting et al. (1999) recovered well-developed microfloral assemblages of terrestrial affinity from both the Hastings and Pomquet formations. No in situ marine fossils have ever been recovered from the Mabou Group.

SEDIMENTOLOGY OF THE MABOU GROUP

Previous interpretations

Norman (1935) noted the presence of ripple crosslaminae, desiccation cracks, pseudomorphs of salt crystals, and distinct channelization in the Mabou. He pointed out two conspicuous channel sandstones within grey shale near the top of his Mabou Formation, about 60 m wide x 10 m thick. Bell (1944) emphasized the nonmarine fauna and flora, abundance of low-energy ripples, and mudcracks, and raindrop impressions in advancing a fluviolacustrine interpretation, and every worker since that time has noted these features and confirmed this explanation. He also noticed the abundance of sandstone in the Cumberland area of western Nova Scotia and suggested a source area (New Brunswick) to the northwest of that. Stevenson (1958) likewise noted features suggesting a fluviolacustrine interpretation, and suggested sediment derivation from the south (Meguma Terrane) in the Truro area.

Belt (1964, 1965, 1968a, b) expounded upon the nonmarine character of the Mabou Group and deposition in fault-bounded basins separated by narrow upthrown blocks that acted as discrete sediment sources, away from which grain size decreases. He envisioned fanglomerates grading laterally away from high-angle fault margins into coarse-grained fluvial, then fine-grained fluvial facies and finally into lacustrine facies in the basin centre (Belt, 1968a, b), a basic model still applicable today. Marginal conglomerates are crudely stratified, subangular to subrounded, poorly to well sorted and reddish (Belt, 1968a, b). Belt identified very fine- to medium-grained fluvial quartzitic sandstones occurring in channel units 2 to 25 m thick alternating with red interchannel mudstones 5 to 100 m thick, with a relatively small channel to interchannel ratio (~ 1:5), suggesting high subsidence rates (Belt, 1968a, b). These facies intertongue with widely distributed central basin, lacustrine, grey mudstone with several types of freshwater limestones and thin rippled quartzitic sandstones (Belt, 1968a, b). Kelley (1967) suggested deposition on a fluvio-lacustrine floodplain, noting the varve-like nature of the laminated mudstone and that there is no evidence of basin margin facies in the Baddeck-Whycocomagh area of Cape Breton Island.

Carroll et al. (1972) noted a coarsening-upward trend from 90 per cent shale at the base to 65 per cent shale at the top, a channel to interchannel ratio of 1:3 at the top with channels averaging 14 m thick at Grand Étang. Benson (1974) described thin, calcareous beds in the red sandstone and siltstone of the fluvial Lismore Formation, which he interpreted as representing temporary lacustrine conditions on the floodplain. McCabe and Schenk (1982) noted that the Lismore fines upward and toward the east, in the direction of paleocurrent flow, whereas the intertonguing Hollow Conglomerate basin-margin facies coarsens upward and from east to west, suggesting different sediment dispersal systems. In New Brunswick, McCabe and Schenk (1982) detailed thickening- and coarsening-upward sequences in the Maringuoin-Shepody, with large channel sandstones up to 8 m deep, interpreted as representing increased rates of precipitation.

Boehner and Giles (1993) described evaporite beds up to 8 m thick and domal stromatolite beds in the lower Hastings Formation, representing the deposits of the waning phase of marine deposition grading into continental playa deposition, with a high residual salinity in the large lacustrine basins. They postulated variation in shoreline and fluvial input as the explanation for the intertonguing of grey lacustrine shale and exclusively continental red fluvial and mudflat sandstone and siltstone (Boehner and Giles, 1993). Crawford (1995) continued this theme, with a detailed study of the sedimentology of the Hastings Formation, suggesting the initial Mabou environment was a hypersaline marine to shallow sublacustrine setting on a flat-floored basin plain. Abundant evidence for intimate interbedding of shallow water and subaerial deposits includes low-amplitude ripples, oolites, stromatolites, desiccation cracks, roots, vertisols, limestone breccias, thin gypsum beds, halite hopper casts, solely brackish- and freshwater faunas, and paucity of trace fossils (Crawford, 1995). The lacustrine interpretation was judged to best account for the rapid variations in salinity and water depth implied by the sedimentological characteristics (Crawford, 1995).

Description and interpretation of Hastings Formation facies assemblages: basic motif

In the studied sections, the Hastings Formation has a maximum thickness of 325 m (Port Hastings), but is generally 100 to 150 m thick. It appears to abruptly but conformably overlie the Windsor Group and is gradationally overlain by the Pomquet Formation with an intertonguing relationship. Strata of the Hastings Formation, present in 12 studied outcrops, consist generally of grey mudstone with interbedded, grey, fine-grained sandstone and limestone, in marked contrast to the carbonate–evaporite succession of the Windsor below, and the redder and coarser rocks above. Many characteristics of the Hastings Formation, such as the lack of marine fossils, the presence of an exclusively nonmarine palynoflora and miscellaneous other fossils, suggest deposition in a shallow lacustrine setting. Therefore, basic comprehension of the lacustrine depositional environment is of paramount importance in understanding the Hastings.

In a lacustrine setting, lakes are relatively small, low-energy, standing bodies of water, fresh to saline, and enclosed in landlocked depressions. Although most modern lakes occur in small, glacially scoured basins, many preserved ancient examples represent large, long-lived bodies in tectonic depressions (e.g., Strathlorne Formation, Hamblin, 1992). In a closed lacustrine system, sediment supply, water chemistry and water level can vary independently and are very sensitive to subtle fluctuations of climatic and tectonic factors. This results in complex sedimentation patterns through time, producing intricate multiple basin-fill sequences (Picard and High, 1981). The regional tectonic setting controls basin size, shape, depth, gradient, and longevity, whereas the regional climatic regime controls precipitation, evaporation, runoff, vegetation, and weathering (Selley, 1985). A warm, semiarid climate, such as that of the late Viséan–Namurian of Nova Scotia, would promote stratification of density, temperature, oxygen, and salinity in the water column and consequent anoxia near the bottom by discouraging circulation and increasing surface evaporation. High saturation of calcium and magnesium are common in lake waters, and warm ambient temperatures consequently favour precipitation of abundant carbonates (Kelts and Hsü, 1978). A closed basin traps sediment, allowing thick accumulations, and low-energy conditions allow dominance and good preservation of fine-grained laminated deposits.

The moderate fetch and low-energy characteristics of most lakes create a shallow wave-mixing base. Infrequent storms may completely alter sediment patterns by redistributing nearshore deposits and circulation patterns for a relatively short time (Picard and High, 1972). Circulation below wave base is generally poor (especially in tropical climates) stratifying the water column into an upper, warm, oxygenated epilimnion (subject to refreshment and evaporation, and with high organic productivity), and a lower, cold, anoxic hypolimnion (stagnant, good preservation of organics) (Hakanson and Jansen, 1983). These are separated by a distinct thermo-, oxy-, halocline surface (Dean and Fouch, 1985). Sediment-laden inflow may form a suspended-load plume as an overflow at the surface or an interflow at the themocline, whereas bedload density underflows may travel downslope along the sediment surface (Sturm and Matter, 1978). The low-energy regime generally results in narrow nearshore and shoreline zones of coarser clastic sediment where fairweather waves are effective. Poorly developed beaches and abrupt facies transitions are typical (Picard and High, 1972). At main input points, the nearshore zones prograde rapidly into shallow low-energy water as river-dominated deltas (Van Houten, 1964). Finer sediment is deposited offshore below wave base, constituting the greatest volume of sediment. Density current deposits are common in the offshore areas where ripples (otherwise uncommon below wave base) have crestlines parallel to shoreline (Davis, 1983).

The strata of the Hastings Formation were deposited primarily in subaqueous and marginal-lacustrine environments, as has been suggested by previous authors, and include a large number of separate lithofacies (Fig. 13), typically arranged into coarsening-upward sequences of varying thickness. All deposits reflect fairly shallow deposition; there is no good evidence for profundal environments. In the following sections each facies assemblage and its component lithofacies are described in detail, illustrated in measured sections (see Fig. 14) and photographs, interpreted, and placed with others into the context of these sequences. These then can be interpreted in light of the overall depositional and paleogeographic setting.

FORMATION	FACIES ASSEMBLAGES		PALEOGEOGRAPHIC POSITION
POMQUET	P3	Thin-bedded quartz-pebble conglomerate (alluvial fan and braidplain)	↑ Basin margin
	P2	Thick-bedded, reddish sandstone (fluvial channel)	
	P1	Red, massive siltstone (subaerial pedogenic playa and floodplain)	
	P4	Thin-bedded grey mudstone (shallow-lacustrine)	↓ Basin centre
HASTINGS	H1	Dark grey mudstone (open, shallow-lacustrine)	↑ Basin centre
	H2	Thick-bedded, grey sandstone (lacustrine nearshore and shoreline)	
	H3	Red siltstone (subaerial pedogenic floodplain)	
	H4	Thick-bedded, reddish sandstone (fluvial channel)	↓ Basin margin

Figure 13. *Facies assemblages of the Mabou Group.*

LEGEND

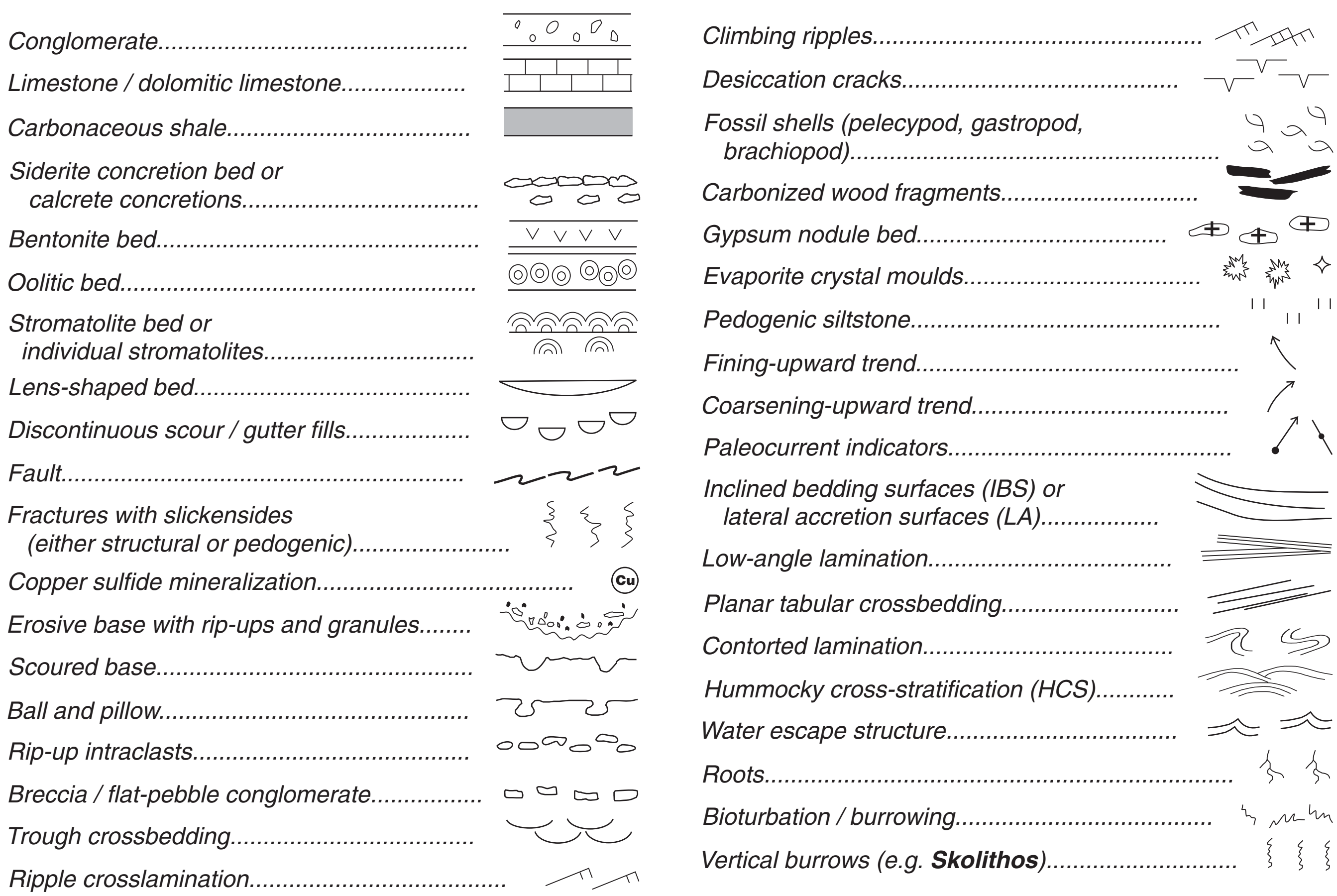

Figure 14. *Key to stratigraphic sections.*

Facies Assemblage H1: Dark grey mudstone (open, shallow-lacustrine)

Facies Assemblage H1 is the predominant rock type of the Hastings Formation in most outcrops except at fault-bounded margins. Typically, it conformably overlies the Windsor Group, but intertongues with Assemblages H2 and H3 upward through the formation. It is characterized by asymmetrical coarsening-upward fifth order sequences of seven thinly interbedded facies, as described below (Fig. 15). Stacked thickening- and coarsening-upward sequences up to 25 m thick (generally 2–10 m) thick are characteristic, with sandstone and limestone to mudstone ratios of 1:10 at the base and 2:1 at the top (Fig. 16, 17). At the base of each sequence, claystone is dark grey to black, uniform, with well-preserved, delicate laminae. Upward, grey, bioturbated mudstone to siltstone becomes predominant with increasing numbers and thickness of calcareous, coarse-grained siltstone to very fine- to fine-grained sandstone or limestone beds. There is a concurrent upward increase in burrowing and evidence of wave energy. The bulk of strata in these sequences is interpreted as representing the regressive systems tract of shoreline progradation, but rarely, a thin fining-upward basal unit is

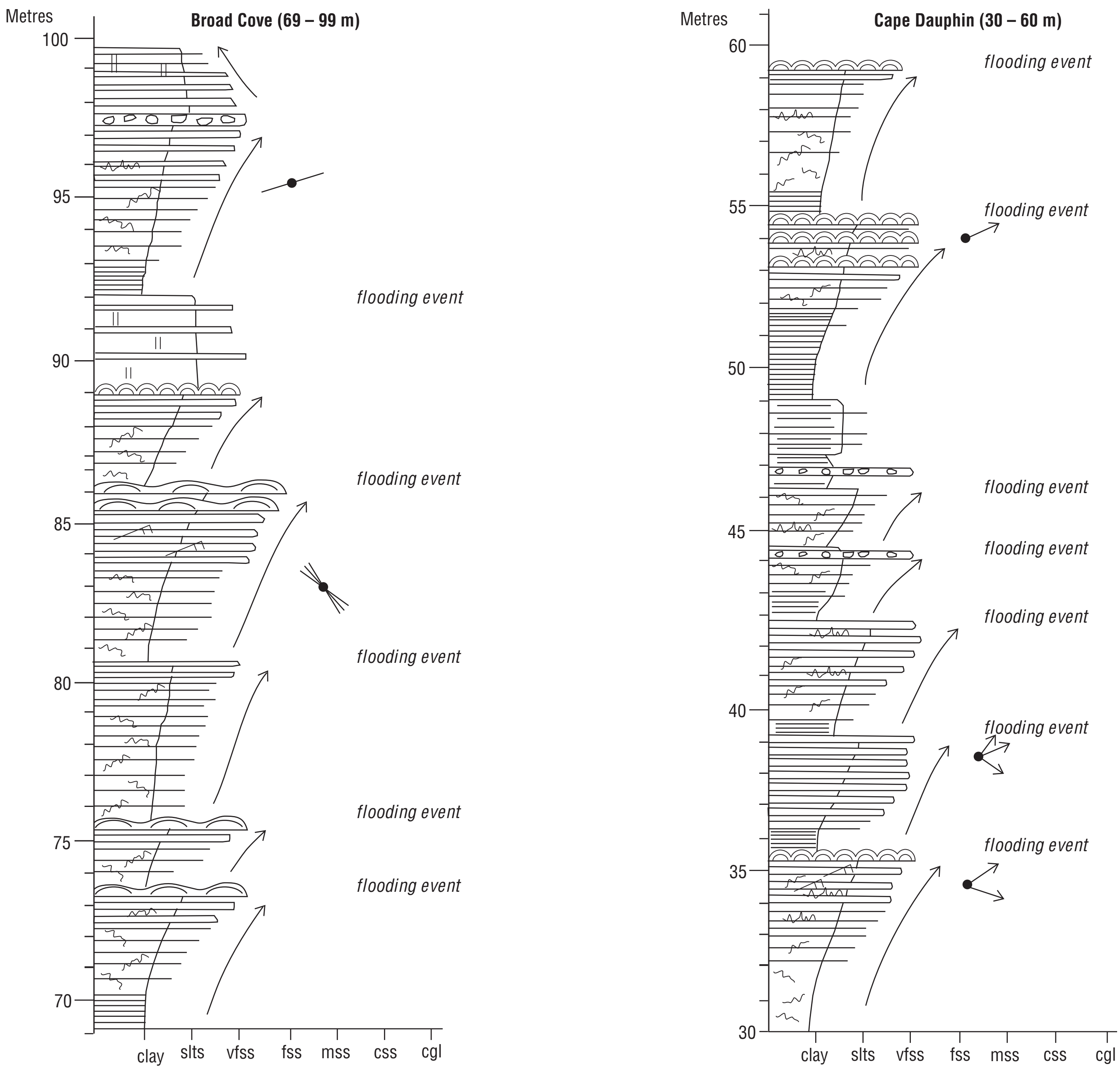

Figure 15. *Examples of the H1 Facies Assemblage. The section at Broad Cove records deposition in an area of greater clastic input, whereas that at Cape Dauphin is more dominated by carbonate and laminated mudstone facies.*

Figure 16. *Coarsening-upward sequence, Broad Cove. Top is to left. GSC Photo 4720-2.*

Figure 17. *Coarsening-upward sequence, Cape Dauphin. Top is to left. GSC Photo 4723-3.*

Figure 18. *Dark grey, laminated mudstone, Broad Cove. GSC Photo 4720-4.*

included (e.g., Broad Cove, 115–122 m) suggesting preservation of a minor transgressive systems tract. Coarsening-upward sequences may be capped by thin sandstone beds, a variety of limestone facies as described below, or occurrences of Facies Assemblage H2.

Dark grey laminated mudstone

Dark grey to greenish grey to black, thinly laminated mudstone to siltstone occurs in uniform units up to about 3 m thick, typically at the base of coarsening-upward sequences (Fig. 18). Laminae commonly consist of mm-scale couplets of dark grey, organic-rich shale and light grey calcareous siltstone. Bioturbation is uncommon and some occurrences have small sideritic concretions (e.g., Cable Landfall Creek). Rarely, 1 cm thick, sharp-based siltstone beds are present. Laminae surfaces are commonly covered by micaceous flakes. This facies is prominent at Cape Dauphin, Broad Cove, Cable Landfall Creek and Barrios Head.

This facies is interpreted as representing slow deposition of clays in a relatively deep, quiet sublacustrine environment, below storm and fair-weather wave base, in anoxic to dysoxic conditions where infaunal activity was limited. However, because this facies is intimately associated with others of more clearly shallow affinity, no great depth is implied. The light–dark couplets are reminiscent of varves, and although there is no evidence for postulating a true annual cyclicity, they may reflect seasonal variation in organic productivity and sediment supply (Tucker, 1978; Crawford, 1995). Most palynological and geochemical samples collected from the Hastings were obtained from this facies, yielding well-preserved terrestrial microfloras deposited in shallow, oxygenated, sublacustrine environments (Utting, 1996).

Grey, bioturbated mudstone to siltstone

Grey to greenish grey mudstone to siltstone to sandy siltstone, with varying intensities of bioturbation, occurs in units up to 5 m thick, and forms the bulk of Hastings rock types. Rocks are massive to partly laminated, with occurrences of wavy to low-amplitude ripple lamination (Fig. 19), and some units display desiccation cracks. Grain size and intensity of burrowing generally increases upward in any given unit. Burrows are horizontal to subvertical and of simple *Planolites* types. Small bivalve shells are present in abundance at Partridge Island (100–110 m above base of section). Thin units of other facies are commonly interbedded with this facies. This facies is common at all outcrops of the Hastings Formation but is especially well-developed at Port Hastings, Cape Dauphin, and Broad Cove.

This facies, reflecting the norm of deposition in the Hastings lakes, is interpreted as representing background, low-energy, shallow to very shallow, slow deposition of muds throughout much of the open lake area. Common to abundant infaunal activity confirms an oxygenated environment, and the lake floor was exposed at times. Energy levels were generally low, although there is some indication of minor currents.

Thin-bedded, grey, very fine- to fine-grained sandstone

Grey to greenish grey, calcareous coarse-grained siltstone to very fine- to fine-grained sandstone occurs in laterally extensive, thin to thick beds up to 1 m thick, and is intimately interbedded with the background bioturbated mudstone facies. The thickness and grain size of these beds, and evidence of current and wave energy, generally increases upward in a coarsening-upward sequence. The beds typically have sharp, commonly scoured, bases with some shale rip-up clasts and plant fragments, and sharp, flat to rippled tops. Tool marks, current lineation, scour and gutter fills, and simple burrow casts are present on the bases. The sandstones typically display fair to good sorting, and internal grain size grading is common. Internal sedimentary structures include horizontal lamination, ripple crosslamination, hummocky cross-stratification (HCS), and minor burrowing. Horizontal *Planolites* annelid burrows and *Lockeia* bivalve resting traces are the most common ichnofossils, typical of Early Carboniferous lacustrine units of eastern Canada (Hamblin, 1992). Bouma B (horizontally laminated), C (ripple crosslaminated) or BC beds are common. Beds with HCS invariably occur at the tops of coarsening-upward sequences (e.g., Port Hastings, 81 m; Broad Cove 52 m, 75 m, 85 m). Bed tops may be gradational and burrowed, but are commonly covered in one to several oblique sets of straight-crested symmetrical ripple forms oriented parallel to inferred shoreline (e.g., Broad Cove 122 m). Desiccation cracks are prominent at some outcrops (e.g., Ragged Point 62–70 m; Port Hastings 222–228 m) (Fig. 20). At SW Mabou RR Cut (9 m), straight-crested ripples display planed-off crestlines. At Partridge Island, several beds have well-preserved amphibian trackways on their bases, which are locally collected and sold as souvenirs (Fig. 21). This facies is prominent at Port Hastings, Cape Dauphin, and Broad Cove.

Figure 19. *Discontinuous rippled sandstone beds in dark grey siltstone, Little River Spillway. GSC Photo 4720-5.*

This facies is interpreted as representing rapidly emplaced, higher energy bedload, density current underflow deposits in the shallow-lacustrine setting, sourced from clastic input points at the lacustrine shoreline. This style of deposition likely occurred in a range of water depths, from moderate to very shallow to near-exposure. Mudcracks, planed-off ripples, and amphibian tracks attest to exposure in some cases. These underflows may have been related to fluvial flood events of sediment-laden water or to storm events.

Calcareous and dolomitic grainstone

Buff to grey, rusty weathering, very fine- to fine-grained crystalline calcisiltite to calcarenite grainstone is very common as thin interbeds up to 1 m thick in calcareous siltstone units. The grainstone is well indurated, and typically laterally continuous (Fig. 22) (although some is lensoid and discontinuous), has fair to good sorting, and is generally composed of micrite grains with minor fossil fragments and sparry cement. The interbeds have sharp bases, commonly with simple burrow casts and tool marks, and sharp, flat to rippled tops. The very sharp tops of some beds at the tops of coarsening-upward sequences are quite irregular and well-cemented (e.g., Cape Dauphin 18 m; Little River 44 m). Many calcarenites are thinly laminated

Figure 20. *Siltstone with preserved desiccation polygons, Barrios Head. GSC Photo 4720-6.*

Figure 21. *Amphibian tracks preserved on base of thin sandstone bed, Partridge Island. GSC Photo 4720-7.*

Figure 22. *Thin calcisiltite beds in grey, bioturbated mudstone, Broad Cove. GSC Photo 4720-8.*

with regular horizontal to wavy laminae (e.g., Little River), whereas others have ripple crosslaminae (e.g., Port Hastings) or both. Shallow desiccation cracks occur in some beds (e.g., Port Hastings 287 m). This facies is quite common throughout the Hastings and is prominent at Port Hastings, Cape Dauphin, Broad Cove and Little River, especially in the lower parts of the Hastings Formation.

This facies is interpreted as representing rapidly emplaced, higher energy bedload, density current underflow deposits in the shallow lacustrine setting, sourced from carbonate-rich areas where clastic accumulation was minimal. This style of deposition likely occurred in a range of water depths from moderate to negligible. Irregular cemented tops may represent sublacustrine hardgrounds, reflecting the high concentration of calcium and magnesium in lacustrine waters.

Thin-bedded stromatolitic limestone

Grey, thin-bedded, thinly laminated limestone units with sharp bases and bulbous to domal tops, up to 0.5 m thick, are common in the Hastings Formation (Fig. 23). They generally occur as laterally continuous beds (although some are lensoid), and are commonly associated with beds of calcarenite or oolite (Fig. 24). They are characterized by thin, generally convex-up laminae and irregular domal tops. Soft-sediment deformation and contorted lamination is common. Some beds have bases with foundered ball and pillow structures (e.g., Broad Cove 115 m), and some have desiccation cracks and small horizontal burrows on their upper surfaces (e.g., Ragged Point 55 m; Cape Dauphin 59 m; Port Hastings 13 m, 16 m, 32 m). At Cape Dauphin (72.5 m) and Broad Cove (52 m) the upper half of the stromatolitic beds are brecciated into a poorly sorted mass of large, flat, laminated clasts. These beds typically occur at the tops of coarsening-upward sequences and are commonly associated with units of Facies Assemblage H3 (e.g., Barrios Head 5 m, 37 m, 52 m).

Casanova (1986) found that stromatolites in the East African Rift lakes correspond to areas of clastic-poor shorelines, and that flattened bioherms and thin stomatolitic beds such as those of the Hastings formed in 2 to 7 m and 7 to 11 m of water depth, respectively. This facies, described in detail by Crawford (1995), is interpreted as representing low-energy, shoreline-related cyanobacterial and algal mat mudflats and nearshore zones in interdeltaic areas where clastic input was minimal, there was little water agitation and where exposure was common. This facies is prominent at Cape Dauphin, Port Hastings, Little River, SW Mabou RR Cut, and Barrios Head, especially in lower parts of the Hastings Formation.

Figure 23. Bulbous stromatolitic limestone, Cape Dauphin. GSC Photo 4720-9.

Figure 24. Stromatolitic calcisiltite, Little River Spillway. GSC Photo 4720-10.

Thin-bedded oolitic limestone

Grey, laterally continuous oolitic limestone beds with sharp, bases and sharp, flat to rippled tops, up to 1.0 m thick, are widely distributed, but not common. They generally occur at or near the tops of coarsening-upward sequences. Ooids are in the silt to very fine sand size range. The sediments are well sorted and ooids appear to be surrounded by micritic matrix or sparry cement. Many oolitic beds have erosive bases, rip-ups, ripple crosslamination, desiccation cracks, and convolute lamination (Fig. 25). Many beds have sharp tops covered by straight-crested ripples that strongly match the trends of other shoreline indicators. This facies is common at Cape Dauphin, Port Hastings, and SW Mabou RR Cut.

This facies is interpreted as representing shallow- to marginal-lacustrine deposition in warm, clear, agitated, carbonate-saturated water, in an area of interdeltaic, lacustrine shoreline where clastic input was low. This facies, and the previous, are thought to indicate shoreline "proxies" (comparable to Facies Assemblage H2) in low- and high-energy environments, respectively, where clastic input was low.

Limestone flat-pebble conglomerate and breccia

Grey, laterally continuous breccia and flat-pebble conglomerate beds of limestone clasts with sharp, erosive bases up to 1 m thick, are present in many outcrops. The beds have sharp bases and tops. They invariably occur at or near the tops of coarsening-upward sequences, suggesting a very shallow, shoreline-related derivation. Although some are overlain by reddish sediments, most are sharply overlain by the darkest, finest grained mudstones of the succeeding coarsening-upward sequence (e.g., Broad Cove 128 m; Partridge Island 4 m, 62 m). Clasts are generally dominated by angular, commonly distorted calcarenite (Fig. 26) and laminated stromatolitic fragments (Fig. 27), but may also include ooids, angular fragments of oolite, and fossil fragments. The tops of these beds commonly have desiccation cracks, burrows, ripples, and irregular, well-cemented surfaces that reflect large, plastically folded clasts (e.g., Cape Dauphin 68 m). This facies is prominent at Cape Dauphin, Broad Cove, and Partridge Island.

These beds can be interpreted as the result of transgression, erosion and redeposition in the shallow-lacustrine and mudflat settings as shallow lake water expanded over previously exposed and desiccated mudflats. In some outcrops many beds of breccia occur in the same coarsening-upward sequence, suggesting that fragments were swept offshore from desiccated mudflats into the shallow sublacustrine environment by storm-related underflows, during progradation as well as transgression.

Figure 25. Ripples in oolitic limestone, Ragged Point. GSC Photo 4720-11.

Figure 26. Mudcrack-brecciated calcarenite bed, Partridge Island. GSC Photo 4720-12.

Figure 27. Stromatolitic limestone clasts in brecciated bed, Cape Dauphin. GSC Photo 4720-13.

Facies Assemblage H2: Thick-bedded, grey sandstone (lacustrine nearshore and shoreline)

Facies Assemblage H2 is rare in the studied outcrops of the Hastings Formation and has a maximum single unit thickness of only 5.5 m (Fig. 28). It occurs at a few outcrops, especially at the tops of coarsening-upward sequences near the top of the Hastings where it intertongues with Facies Assemblages H1 and H3.

Thick-bedded, grey, fine-grained sandstone

Grey to greenish grey, calcareous, micaceous, well sorted, very fine- to medium-grained sandstone occurs in thick-bedded units up to 5.5 m thick, generally at the tops of fifth-order coarsening-upward sequences in the middle and upper parts of the Hastings (Fig. 29). These occurrences are commonly overlain by reddish facies (e.g., Partridge Island 144–146 m). The beds commonly have sharp, flat bases and tops, and are very uniform in aspect. Sets of horizontal and low-angle laminae and hummocky cross-stratification (HCS) are characteristic (Fig. 30), and trough-crossbedding is abundant in some outcrops. Desiccation cracks are present in some outcrops. At SW Mabou RR Cut, abraded caliche glaebules are present in hummocky cross-stratified sandstone (Fig. 31). Some units of this facies are composed of oolitic, fine-grained sandstone. One thick (2.5 m) oolitic sandstone at Port Hastings has ripples and HCS and is capped by an irregular, rusty, hardground bed (Fig. 32), while another 1.5 m thick unit has oolitic beds separated by thin, laminated stromatolitic beds. This facies is not common, but is prominent at Port Hastings, and Partridge Island, especially near the top of the Hastings. The best-developed example of this facies occurs at Port Hastings (112–120 m), where 4 m of thick-bedded, uniform, well-sorted, very fine- to fine-grained sandstone with abundant HCS overlies burrowed mudstone and algal laminated limestone in a thin coarsening-upward sequence. This is overlain by thinly interbedded, fining-upward sandstones and pedogenically altered siltstone.

This facies is interpreted as representing shoreline-related sandstone, probably an upper shoreface environment, although in the low-energy setting of these Mabou lakes, the sandy shorefaces were poorly developed in most localities. The presence of HCS confirms shoreface deposition above storm wave base. However, in at least some places (e.g., Port Hastings 114–124 m, and other proximal locations) well-developed shoreline sandstone units dominate up to 10 m of stratigraphy. These thicker occurrences of this sandy shoreface facies are considered to indicate areas near widely-spaced major clastic input points along the lacustrine shorelines.

Thin-bedded, rippled, very fine-grained sandstone

Greenish grey units, up to 1 m thick, of silty, very fine-grained sandstone separate thicker units of the previous facies in a few outcrops (e.g., Partridge Island 198–202 m, Port Hastings 284–287 m). These rocks are nearly always rippled, but contorted laminae and desiccation cracks also occur. The facies is not common, but occurs at Port Hastings and Partridge Island, especially near the top of the Hastings.

This facies is interpreted as representing more muddy shoreline-related sandstone, probably of lower to middle shoreface affinity.

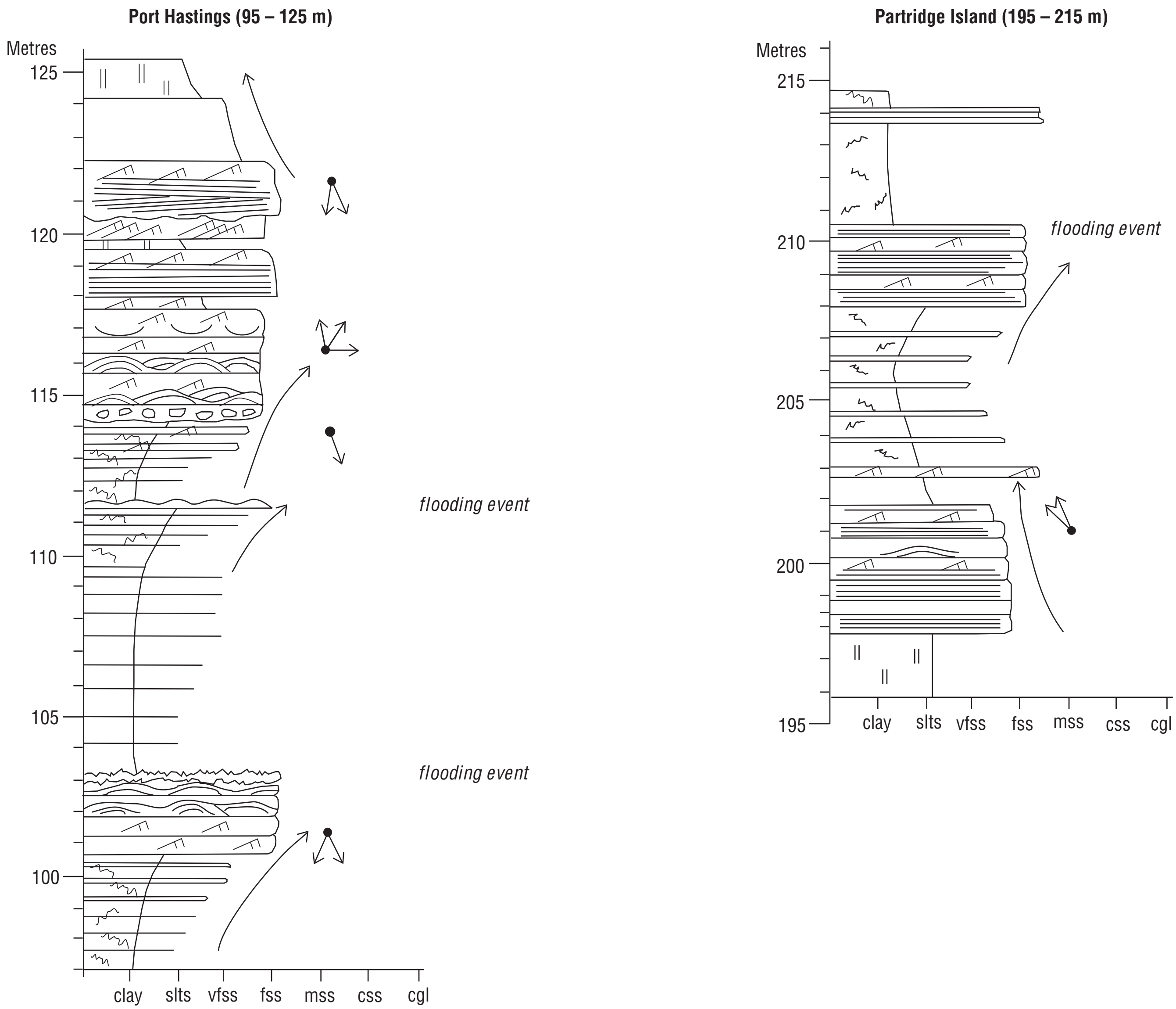

Figure 28. *Examples of the H2 Facies Assemblage. Many units contain subtle hummocky cross-stratification whereas others are dominated by horizontal or low-angle lamination.*

Facies Assemblage H3: Red siltstone (subaerial pedogenic floodplain)

Facies Assemblage H3 is a subordinate, but common, facies assemblage in most outcrops of the Hastings. The included facies are similar to those typical of the Pomquet Formation (Facies Assemblage P1) and occur as thick tongues within the predominantly grey, muddy Facies Assemblage H1, especially near the top of the Hastings (Fig. 33). These tongues are interpreted as wedges of Pomquet coastal subaerial facies, which periodically prograded into the Hastings lakes.

Red, massive siltstone

Brick red to greyish red siltstone to sandy siltstone occurs in units up to 15 m (generally 2–3 m) thick, as a subordinate facies in a number of outcrops. These rocks have a distinct massive, blocky, rubbly, and hackly texture with common vertical fractures, slickensides, and green reduction spots (Fig. 34). Desiccation cracks are common, in places with superimposed symmetrical ripples (Fig. 35) and ripples and evaporative crystal moulds are present in some places (e.g., Little River), but burrowing is rare. Very thin beds of very fine- to very coarse-grained sandstone, some with ripple

Figure 29. *Buff, fine- to medium-grained sandstone, 5.5 m thick, SW Mabou RR Cut. GSC 4720-14.*

Figure 30. *Reddish grey, fine-grained sandstone with hummocky cross-stratification, Port Hastings. GSC Photo 4720-15.*

Figure 31. *Caliche glaebules in hummocky cross-stratified, fine-grained sandstone, SW Mabou RR Cut. GSC Photo 4720-16.*

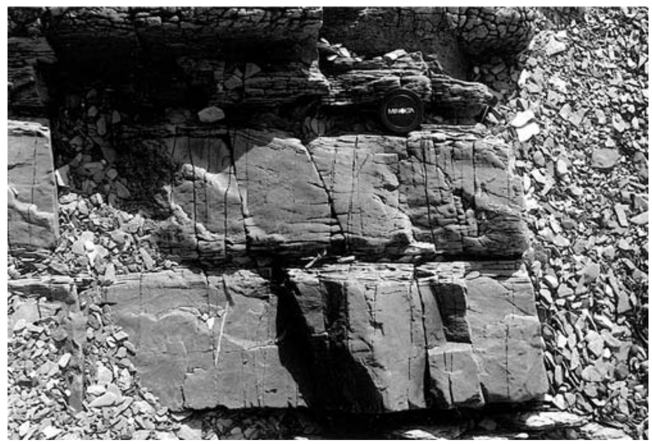

Figure 32. *Oolitic, fine-grained sandstone with ripples, Port Hastings. GSC Photo 4720-7.*

crosslaminae and rip-ups, are common within these units. At some outcrops, thin but prominent zones of caliche nodules and calcrete are present (e.g., Little River, Ragged Point) (Fig. 36). These units, which are similar to facies typical of the Pomquet Formation, occur in association with other reddish facies listed below and with stromatolite and breccia carbonate beds of Facies Assemblage H1 in thick successions within the dominantly grey, muddy, Hastings facies. In a few locations, this same facies has all the same characteristics, but is greenish grey rather than red. The facies is prominent at Port Hastings, Ragged Point, Little River, Cape Jack, Barrios Head, Partridge Island, Downing Cove, and Downing Head, but is rarely present at Broad Cove.

The red, massive siltstone facies is interpreted as representing pedogenically altered overbank sediments deposited on a fluvial floodplain at the lake margin, which periodically prograded over lacustrine deposits, and were periodically inundated again by lacustrine transgression.

Thickly interbedded red siltstone and very fine- to fine-grained sandstone

Thickly interbedded brick red to greyish red siltstone to sandy siltstone and very fine- to medium-grained sandstone occurs in units up to 10 m (generally 2–3 m) thick, as a subordinate facies in a number of outcrops. Siltstones typically have the massive, blocky texture of pedogenically altered deposits, whereas the sandstone beds have sharp, sometimes erosive bases with rip-ups, and sharp, flat to rippled tops. One occurrence at Partridge Island (63 m) occupies a wide, shallow, scour cut into underlying grey

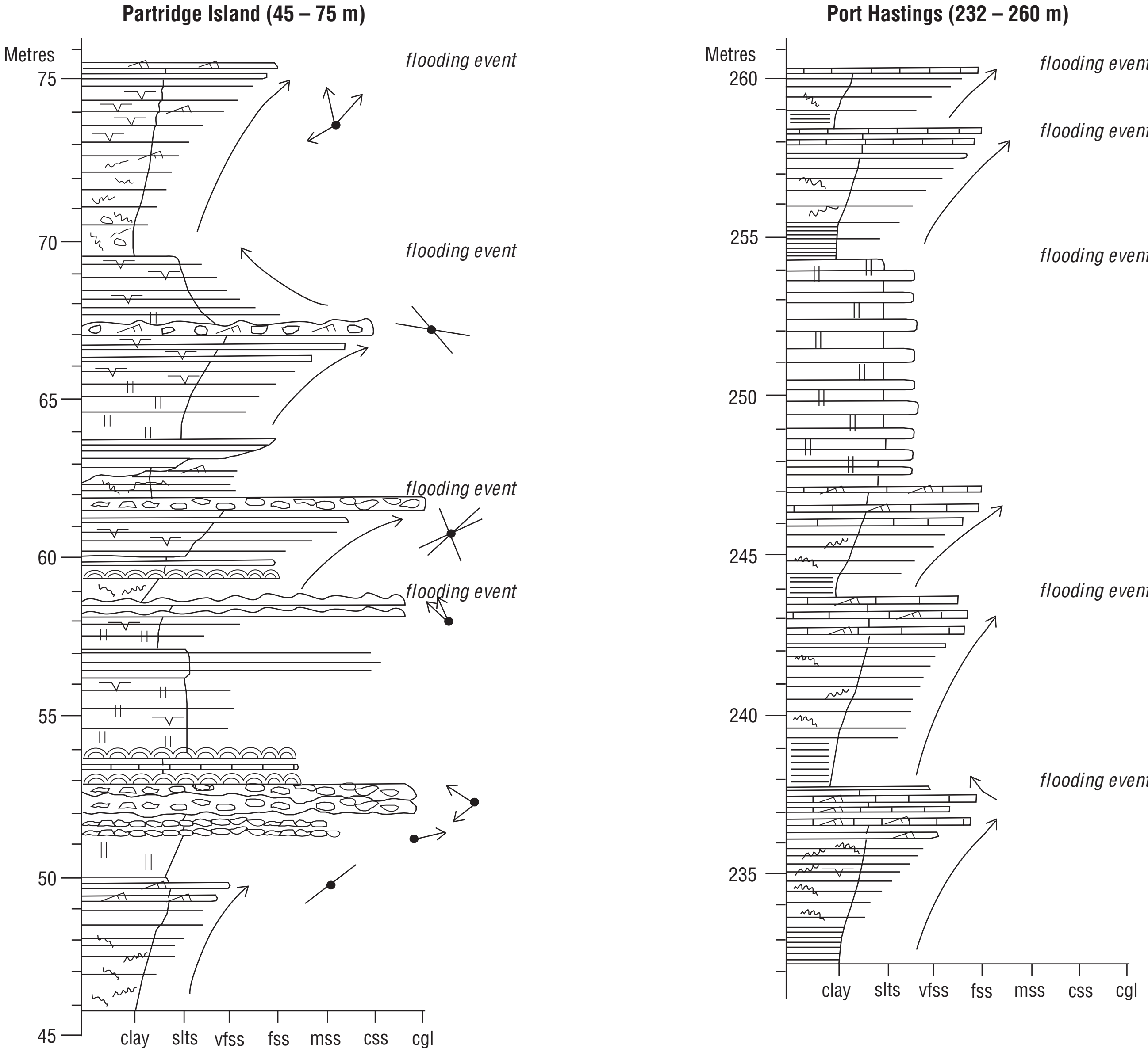

Figure 33. *Examples of the H3 Facies Assemblage. Units at Partridge Island are intimately interbedded with flat-pebble conglomerate and coarser sandstone beds, suggesting a more proximal setting, whereas the unit at Port Hastings occurs within a succession of lacustrine shallowing-upward sequences.*

mudstone and oolitic limestone of Facies Assemblage H1 (Fig. 37). Rarely, roots are present. Desiccation cracks are common and caliche glaebules occur in some outcrops. Sandstone to siltstone ratios range from 1:1 to 1:3, and sandstone bed thickness ranges from 5–50 cm. This facies is prominent at Port Hastings, Ragged Point, Barrios Head, Downing Cove, and Downing Head, and is rarely present at Broad Cove.

It is interpreted as representing overbank deposition in a floodplain setting medial to a fluvial channel, near the lake margin, where some fluvial input of coarser clastic rocks occurred through flood crevasse and suspension deposition.

Facies Assemblage H4: Thick-bedded, reddish sandstone (fluvial channel)

Facies Assemblage H4 is a minor component of the Hastings motif, but occurs as prominent beds in a few outcrops, especially associated with Facies Assemblage H3 near the top of the formation (Fig. 38). These occurrences are similar

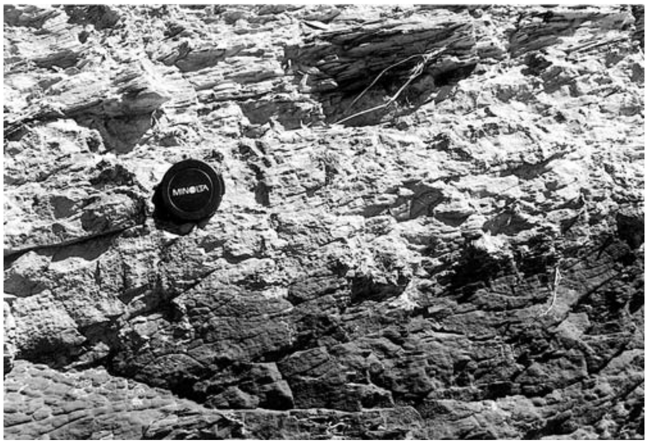

__Figure 34.__ Pedogenic red siltstone with mudcracks, overlain by very fine-grained sandstone, Port Hastings. GSC Photo 4720-18.

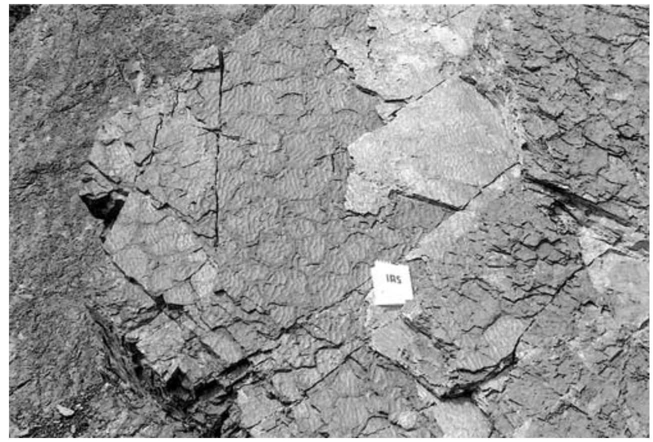

__Figure 35.__ Ripples and mudcracks in interbedded red and green mudstone, Partridge Island. GSC Photo 4720-19.

__Figure 36.__ Red pedogenic siltstone capped by green calcisol zone with sharp top and peds, Barrios Head. GSC Photo 4720-20.

__Figure 37.__ Interbedded red, fine-grained sandstone and siltstone filling broad, shallow scour, Partridge Island. Photo 4720-21.

to thick channel sandstone bodies of the Pomquet Formation (Facies Assemblage P2).

Thick-bedded, reddish grey, very fine- to medium-grained sandstone

Thick beds of red to reddish grey, very fine- to coarse-grained sandstone occur in units up to 8 m thick in only a few outcrops of the Hastings Formation. These have sharp, erosive bases with intraformational rip-ups (Fig. 39), horizontal lamination, trough crossbedding, ripple crosslamination and climbing ripples. One occurrence at Downing Head (53–57 m) includes trough crossbedding and preserved giant ripple bedforms (Fig. 40). The sandstones are well sorted, typically fine upward and are closely associated with the two reddish facies listed above. A few have deeply incised basal scour topography typical of high-sinuosity channels, but flat tops with roots (Fig. 41), where they intertongue with lacustrine deposits. They are similar to thick sandstone bodies in the Pomquet Formation, but less common in the Hastings. This facies is also well developed at Downing Cove and Downing Head, in a more basin marginal position, where very thick, fining-upward, multi-storied units of sandstone and thick, intraformational rip-up conglomerate are present interbedded with units of red pedogenic siltstone of Facies Assemblage H3. Extraformational pebbles are rare or absent (Fig. 42) and low-angle lamination and trough crossbedding are abundant. These characteristics suggest low-sinuosity fluvial deposition. This facies is present at Port Hastings, Ragged Point, Barrios Head, Downing Cove and Downing Head.

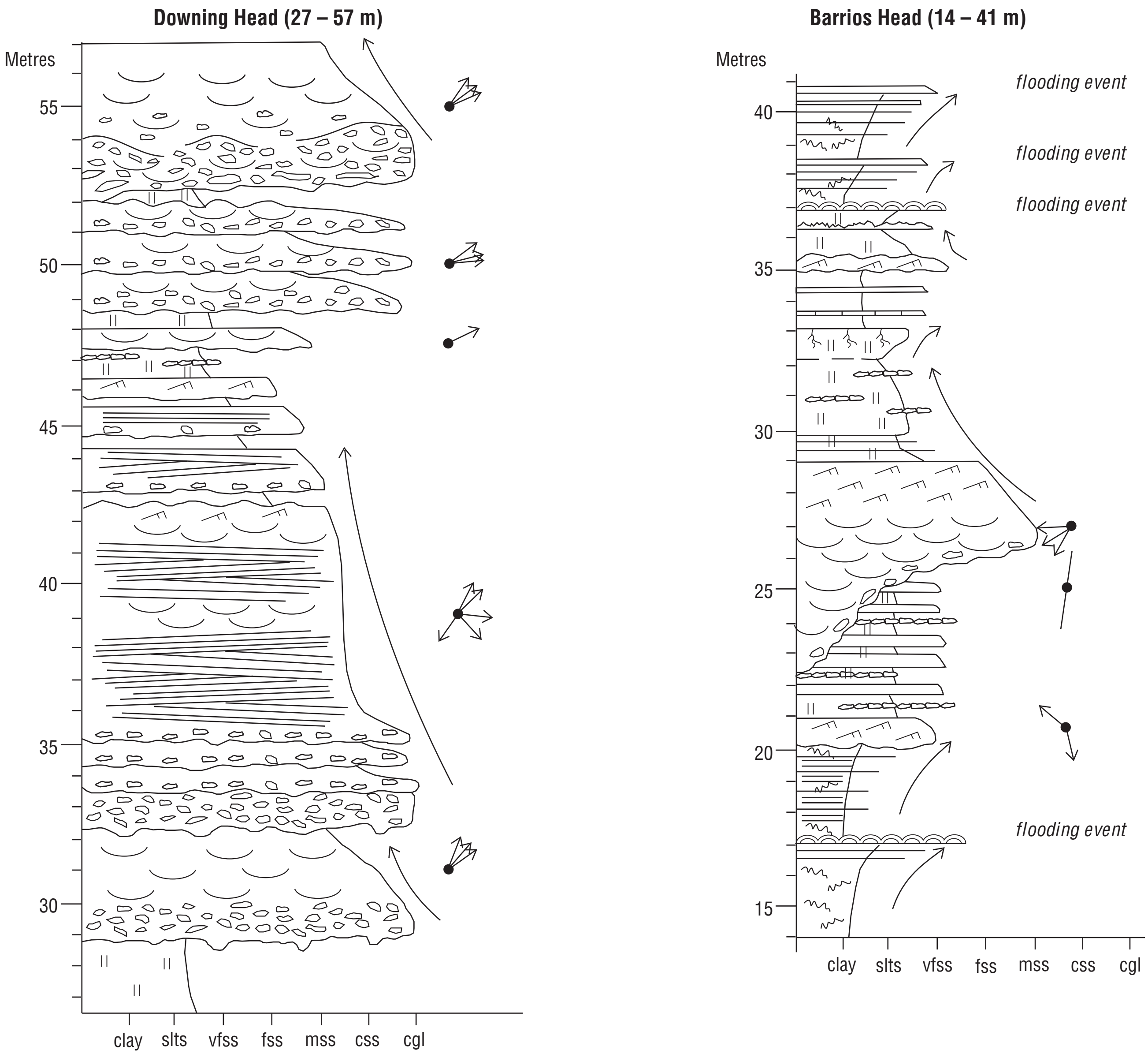

Figure 38. *Examples of the H4 Facies Assemblage. Thick units of sandstone at Downing Head are associated with pedogenic siltstone and calcretes in a relatively proximal setting, whereas those at Barrios Head represent a tongue of subarial deposits within dominantly lacustrine deposits.*

These sandstone units are interpreted as representing significant fluvial channels embedded in a floodplain adjacent to the lake margins, which periodically prograded over lacustrine deposits and supplied much of the clastic material to the Hastings lakes. Deltas in most lakes are river-dominated, allowing rapid progradation of high-sinuosity distributaries into the nearshore lacustrine environment. The intimate intertonguing of fluvial and lacustrine deposits indicates contemporaneity with the Hastings lakes. Near fault-bounded subbasin margins, low-sinuosity channels formed a network across the floodplain. They are not common, suggesting that for much of the time sandy fluvial sediment supply was limited to a small number of major input points that allowed prominent development of carbonate-rich deposits, including around large portions of the lacustrine shorelines.

Interpretation of the Hastings Formation depositional system

All lines of evidence, including biotic, sedimentological and facies association, point to deposition of the mud-dominated Hastings Formation in lacustrine and marginal lacustrine environments. In addition, deposition was into low-energy,

Figure 39. *Carbonized log at base of fine- to medium-grained sandstone, Downing Cove. GSC Photo 4720-22.*

Figure 40. *Preserved bedforms in red, intraformational rip-up conglomerate, Downing Head. GSC Photo 4720-23.*

Figure 41. *Deep, vertical root structures in red sandstone at top of coarsening-upward unit, Downing Cove. GSC Photo 4720-24.*

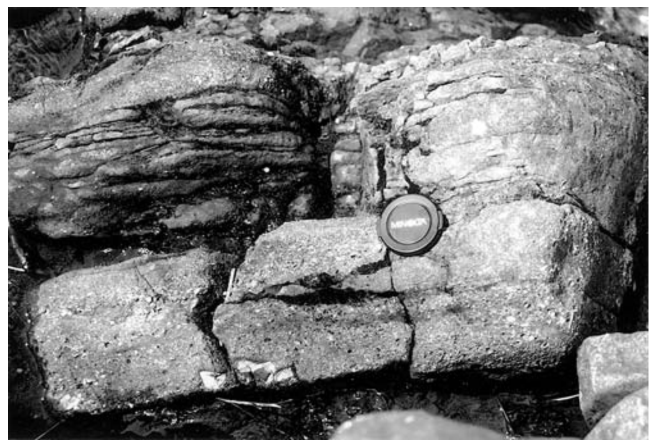

Figure 42. *Coarse-grained sandstone with intraformational rip-ups of laminated limestone, Bay St. Lawrence. GSC Photo 4720-25.*

very shallow basins where desiccation was common, clastic input was limited, and large areas of shoreline were characterized by carbonate sedimentation (Fig. 43).

The characteristic, asymmetrical coarsening-upward fifth-order sequences are interpreted as transgressive-regressive, shallowing-upward sequences that represent progradation, over a relatively broad front, of clastic and carbonate nearshore sediments over lower energy offshore sediments. Therefore the sequences delineate small shoreline progradational sequences, or the regressive systems tracts of relatively large, shallow lakes. Some, near major clastic input points, culminate in the sandy shoreface deposits of Facies Assemblage H2 and fluvial channel deposits of Facies Assemblage H4. Others, removed from the few clastic input points, culminate in the various carbonate facies of Facies Assemblage H1. Many sequences reached exposure conditions before circumstances reverted to offshore lacustrine deposition; others did not. In some outcrops the sequences are arranged into bundles, or fourth order asymmetrical megasequences, which themselves coarsen and thicken upward (e.g., Ragged Point 37–50 m; Broad Cove 107–155 m), and are interpreted as partial lake-filling sequences (Fig. 44).

Black laminated mudstones at sequence bases do not indicate great depth since the fill sequences are never more than about 25 m (generally 2–10 m) thick. Rather, they indicate relatively low-energy deposition beyond the range of sandy clastic input from shoreline-related processes (which need not be far offshore in the very low-energy setting of these lakes; Picard and High, 1972). The dark, organic-rich, thinly laminated, unburrowed mudstone of some areas suggests that anoxic stagnant conditions, typical

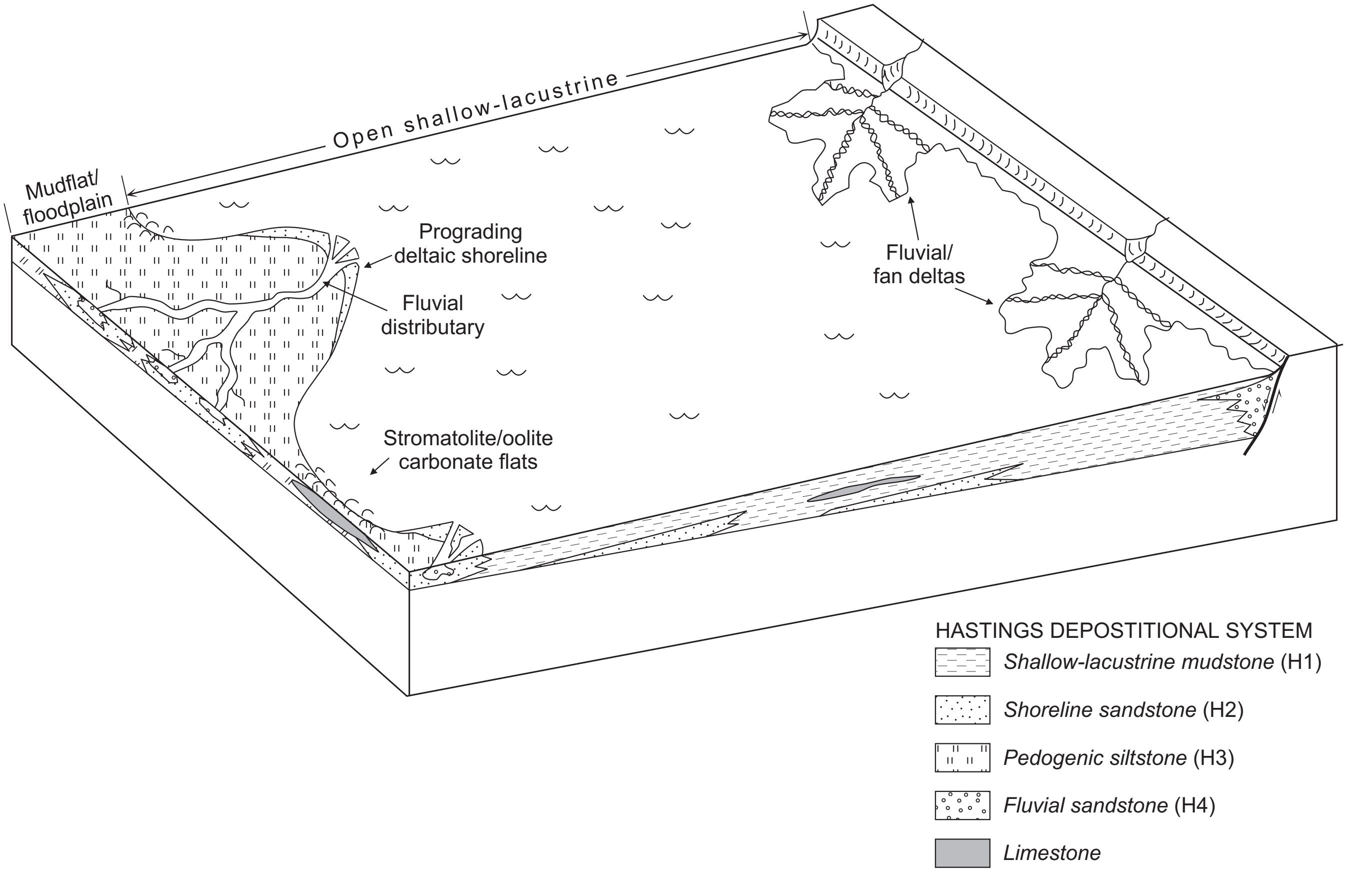

Figure 43. *Block diagram illustrating depositional environments and facies distribution of Hastings depositional system (large vertical exaggeration).*

of warm climates, developed below a thermocline in a stratified water column, in at least some parts of the subbasins (Hakanson and Jansson, 1983; Dean and Fouch, 1985).

Progradation of shoreline sediments was manifest as an upward increase in extensive thin sandstone beds rapidly deposited from sediment-laden, higher-energy currents. These sandstones are separated by grey, burrowed siltstone representing the slow deposition of low-energy background sediments. The pulses of more energetic deposition are interpreted as bedload density underflows that deposited turbidite-like beds similar to those described from Alpine Lakes by Lambert et al. (1976) and Sturm and Matter (1978), from Lake Mead by Grover and Howard (1938), and from an ancient lacustrine system by Hamblin (1992). These underflows may have been related to fluvial flood events of sediment-laden water, storm events, as is suggested by the presence of HCS, or seismic events, as is suggested by the presence of contorted laminae. Sequences are capped by either a) thick, reddish sandstone bodies of shoreline affinity at main clastic input points, b) thin sandstones with or without evidence of subaerial exposure interpreted as low-energy (interdeltaic) nearshore deposits removed from clastic input points, c) stromatolitic and oolitic limestones interpreted as very shallow-lacustrine and nearshore mudflat deposits, where chemical deposition prevailed, beyond the influence of clastic input points, or d) limestone flat-pebble conglomerate breccia beds indicating storm disruption and redeposition of mudflat rock types. Coarsening-upward sequences commonly have multiple recurrences in any vertical section of the Hastings Formation, suggesting numerous periods of shoreline progradation and lake filling. Each transgressive-regressive asymmetrical cycle includes a prolonged period of active progradation, manifested by the thick, shallowing-upward sequence capped by nearshore and shoreline facies, and a rapid abandonment period, manifested by the abrupt termination of that sequence, a flooding event, and initiation of another sequence beginning with offshore sediments.

Thick, shoreline-related sandstone facies are not common in the Mabou Group, even in apparently marginal positions in the subbasins during progradation. This facies intertongues with the coarsening-upward sequences and is interpreted as being of lacustrine nearshore and shoreline

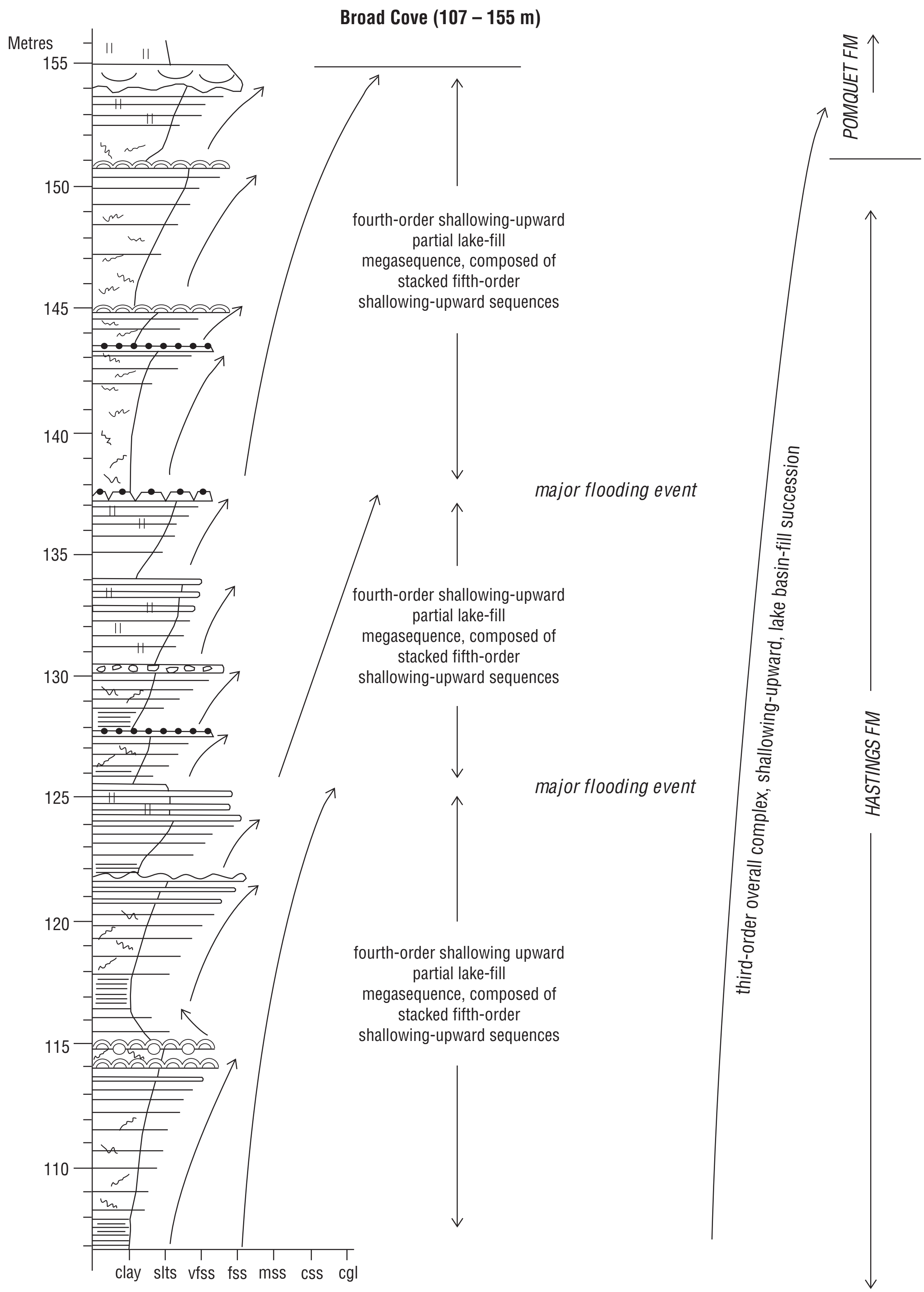

Figure 44. *Hierarchy of coarsening-upward sequences and megasequences, typical of Mabou Group H1 Facies Assemblage.*

origin. The typical association of sedimentary structures suggests moderate- to high-energy processes of wave and current activity at the shoreline near major clastic input points. Sandy shorelines that build into shallow, low-energy lakes are typically river-dominated, have abrupt lateral facies transitions and experience rapid outward progradation (Van Houten, 1964; Picard and High, 1972). Wave and current activity was sufficient to modify delta-front areas into shoreline-parallel bodies at least part of the time, although sharp-based fining-upward units are interpreted as the deposits of distributary that scoured into shallow sublacustrine deposits and prograded rapidly beyond the general shoreline. The presence of hummocky cross-stratification suggests shoreface deposition above storm wave base (which is very shallow in most lakes; Picard and High, 1972; Hamblin, 1992), where tempests could alter sediment distribution. Contorted lamination is attributed to sudden shock of subaqueous sediments, either by storm wave oscillatory loading or by tectonic seismic disturbance.

The general aspects of the reddish siltstone and sandstone tongues and their association with other basin-margin indicators, suggest deposition in an exposed floodplain-mudflat setting associated with clastic shoreline facies but in an interdeltaic area removed from significant coarse-grained deposition. Sedimentation of authigenically reddened silt was predominantly as suspension deposition from fluvial flood events. Pedogenic features, discussed more fully below, are ubiquitous, and calcareous nodules or calcrete beds developed during long periods of sediment surface stability and exposure in a warm, semiarid climate. Thicker sandstone beds are interpreted as the deposits of small fluvial channels that cut through the mudflat from marginal areas. The abundance of these deposits reflects the wide, extensive coastal plains in these fault-bounded subbasins of the Mabou Group. The range of facies described above is identical to those described from the coeval Rocky Brook Formation of the Deer Lake Subbasin of central Newfoundland (Hamblin et al., 1997), except that the Rocky Brook contains significant oil shales and oil source rocks not yet discovered in the Hastings Formation of Nova Scotia.

The coarse-grained lithofacies, while not abundant, have important interpretive value, and have characteristics that suggest erosive, high-energy deposition that carried large amounts of coarse-grained sediment into other settings. They are interpreted as sheetflood deposits and low-sinuosity fluvial deposits in front of the toes of alluvial fans near fault-controlled margins, or major high-sinuosity distributary channels of the lacustrine delta systems. In these settings, erosion dominates over deposition and these occurrences represent preservation of only a small fraction of time of Mabou deposition.

Description and interpretation of Pomquet Formation facies assemblages: basic motif

In the studied sections, the Pomquet Formation has a maximum thickness of 340 m (Broad Cove), but is generally exposed in outcrops 100 to 150 m thick. It conformably to gradationally overlies the Hastings Formation with an intertonguing relationship, and is conformably to unconformably overlain by the Port Hood or Boss Point formations. Strata of the Pomquet Formation, present in 10 studied outcrops, consist generally of red siltstone with interbedded reddish, fine-grained sandstone and calcrete limestone, with some thick, reddish, fine- to medium-grained channel sandstone bodies in marked contrast to the predominantly grey mudstone succession of the Hastings below, and the greyer and coarser rocks with coal above. Many characteristics of the Pomquet Formation suggest deposition in a subaerial setting, such as the lack of marine macrofossils, the presence of an exclusively nonmarine palynoflora, the red coloration, and the ubiquitous pedogenic features. These strata were deposited primarily in a fine-grained, subaerial, fluvial floodplain environment, and include a number of separate lithofacies. Pedogenic processes were of paramount importance, and therefore, basic comprehension of the processes of pedogenesis is of essential importance in understanding the Pomquet.

Retallack (1988) suggested that the most important preservable diagnostic features of paleosols are the presence of root traces, terrestrial fossils, soil horizons, and soil structures. In a seasonally dry to semiarid climate, such as that indicated for the Mabou Group, well-developed root systems are unlikely to be preserved. Deeply penetrating rhizocretions and reduction haloes around unpreserved former root traces are more likely (Retallack, 1988). Reddening of soils (“rubification”) and red and grey colour mottling are common in semiarid to arid climates (Retallack, 1981; Allen and Wright, 1989). The fossils of terrestrial gastropods, pelecypods, arthropods, and vertebrates are common in many pedogenic deposits (Retallack, 1988). In the early stages of soil development, pedoturbation processes begin to destroy the original layering of the sediment, through the action of bioturbation, argillation, and crystalturbation, which develop within a few hundreds to a few thousand years (Allen and Wright, 1989). The resulting hackly, massive to blocky jointed texture of the pedogenic sediment is quite distinctive (Retallack, 1981, 1988; Van Houten, 1982).

During early destratification (pedoturbation) of materials with abundant montmorillonitic or smectitic clays, repeated wetting and drying, even in semiarid climates, creates vertically oriented structures that crosscut original layering

(Allen and Wright, 1989). Elongate columnar and prismatic aggregates, called peds, result from repeated opening and closing of an array of desiccation cracks of various dimensions. The peds are defined by an irregular network of planes, called cutans, which are typically lined by thin skins of clay or minerals marked by randomly-oriented slickensides (Retallack, 1988). Definable peds, cutans and slickensides are typical of seasonally wetted soils (Retallack, 1988). Crusted, nodular or concretionary concentrations of carbonate, iron and silica are also common (Van Houten, 1982): irregularly shaped, hard glaebules of pebble-sized micrite are important in arid-climate soils (Esteban and Klappa, 1983; Retallack, 1988). If subaerial exposure is prolonged, vertically directed reorganization processes may become dominant and material in the weathering zone becomes differentiated into soil profiles of thin, laterally extensive distinct horizons (Van Houten, 1982; Allen and Wright, 1989; Retallack, 1988). Upper boundaries of paleosols may be quite sharp, but most horizon boundaries are diffuse and irregular, particularly at the base (Van Houten, 1982; Retallack, 1988).

Mack et al. (1993) proposed a classification system primarily for ancient soils that relies on the presence of morphological properties, textures and stable minerals likely to be preserved over time (Mack et al., 1993; Kraus, 1999). Of the nine orders of paleosol included, those which bear upon the Mabou Group are "vertisol" and "calcisol". Vertisols are characterized by greenish or reddish colours, homogenization and vertic features such as deep desiccation cracks and wedge-shaped peds, which form quite rapidly during initial destratification (Duchafour, 1982). They develop on parent materials with abundant expandable clays as a result of alternating seasonal wet and dry phases (e.g., savannah, desert, intramontane, playas or marginal lacustrine settings) (Duchafour, 1982; Buol et al., 1989; Allen and Wright, 1989). They are common in relatively low-slope areas characterized by calcium- and magnesium-rich alkaline substrates (Duchafour, 1982; Buol et al., 1989). During the dry season, deep desiccation cracks form and can partly fill with mixed surface debris, but upon wetting the clays expand, creating peds that slide against each other and develop cutans with slickensides (Buol et al., 1989).

Calcisols, or calcrete, develop just beneath the surface and are widespread in tropical to subtropical, arid to semiarid climates (Retallack, 1981; Van Houten, 1982; Esteban and Klappa, 1983), and therefore could be present in the Pomquet. They occur as accumulations of soluble minerals in thin, discontinuous veins (Stage I), scattered nodules (Stage II), or massive, nodular beds (Stage III) (Mack et al., 1993). Calcrete beds result from the eluvial and illuvial pedogenic concentration of minerals to form a duricrust, or as precipitates in the capillary fringe of groundwater zones as a result of methanogenic reactions (Allen and Wright, 1989). They form by interaction between CO_2 in meteoric water and Ca^{++} in the soil from weathering products (Esteban and Klappa, 1983). Because of early cementation, calcrete preservation may be excellent and these beds are often conspicuous. Mature calcretes require more than 10 000 years to form at a rate of 1 to 10 cm/1000 years (Van Houten, 1982; Leeder, 1976), and their presence suggests long periods of surface stability. Thin horizons of nodules in overbank deposits or as rip-ups in channel lags are more common (Leeder, 1976). Calcisols are typically chalky, micritic and densely crystalline carbonate, with massive and nodular–peloidal textures, common shrinkage cracks, and dissolution features (Allen and Wright, 1989). Because thick calcrete horizons take thousands of years to develop they are most likely to form and be preserved in areas distal from active braided fluvial sedimentation (Leeder, 1976). Van Houten (1982) suggested that most Paleozoic calcretes formed on intermittently aggraded redbeds on the Pangean supercontinent, the assembly of which had altered oceanic circulation and climatic patterns. Diagenetic red colours, so characteristic of Pomquet and other subaerial deposits, result from conversion of yellow ferric to red ferrous minerals and can be considered as an indicator of exposure in an arid climate during deposition (Retallack, 1981).

The strata of the Pomquet Formation were deposited primarily in subaerial floodplain and marginal lacustrine environments and include a large number of separate lithofacies. Tooth (1999) used the term "floodouts" in reference to the distal floodplains in arid climate settings where channelized flows gradually terminate and floodwaters spill across adjacent alluvial surfaces, resulting in slow vertical aggradation of continuously altered fine-grained subaerial sediments. Most deposits in the Pomquet reflect fairly low-energy, low-slope deposition; there is only minor evidence for extensive high energy, fault-bounded margin environments in Nova Scotia. In the following sections each facies assemblage and its component lithofacies are described in detail, interpreted, and placed with others into the context of the Pomquet Formation as a whole, which can be interpreted in light of the overall depositional and paleogeographic setting.

Facies Assemblage P1: Red, massive siltstone (subaerial pedogenic playa and floodplain)

Facies Assemblage P1 is the predominant rock type of the Pomquet Formation in most outcrops everywhere, except at fault-bounded margins. It occurs in units up to 17 m thick, generally 2 to 7 m thick (Fig. 45). It commonly intertongues with Assemblage P2, and with P3 near the base of the formation. It is characterized by two, commonly thinly interbedded, facies.

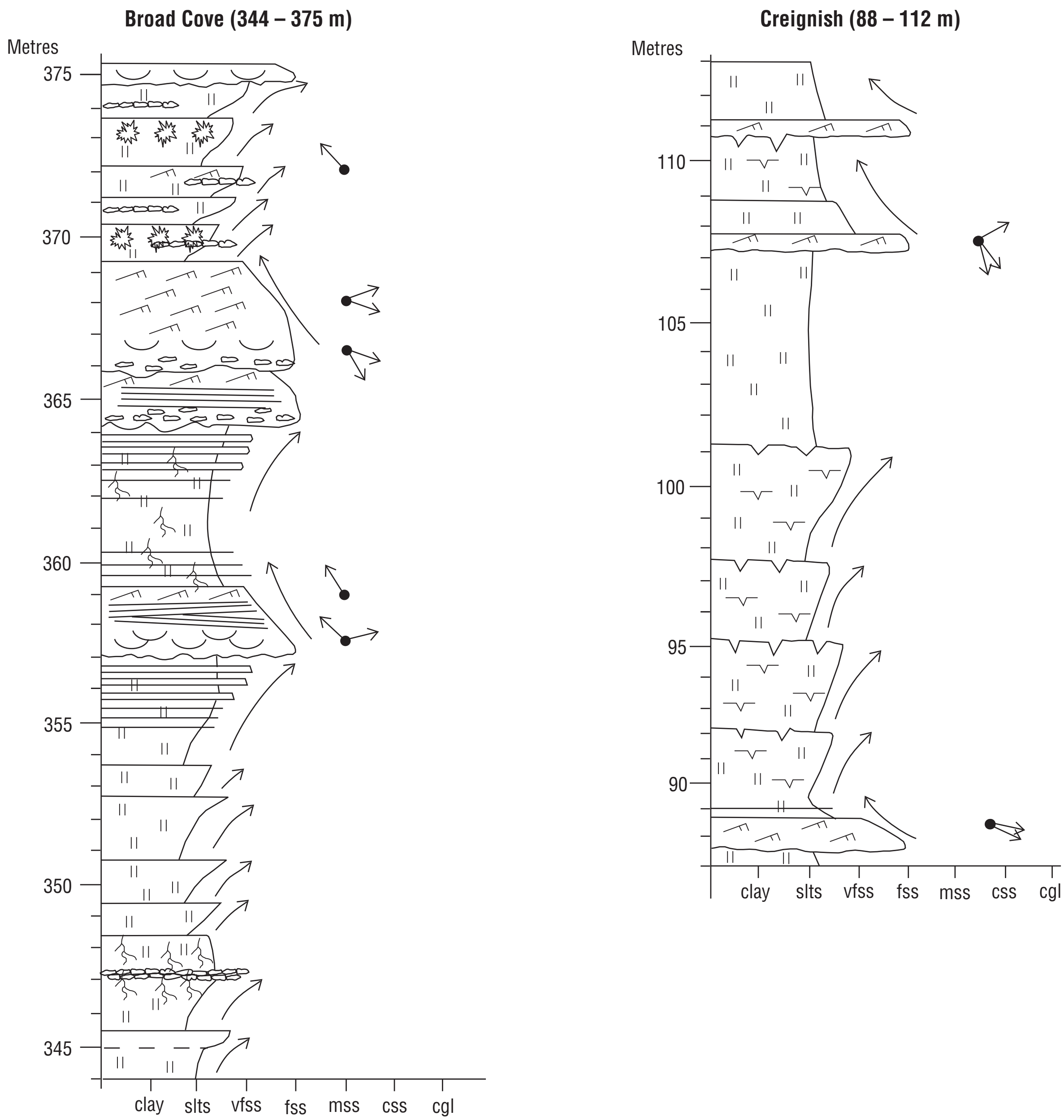

Figure 45. *Examples of the P1 Facies Assemblage.*

Red, massive, blocky siltstone

Brick red to maroon red to brownish siltstone to sandy siltstone occurs in units up to 17 m thick in most Pomquet outcrops and comprises the predominant lithofacies of the formation, although it is poorly exposed at some locations. These units, which are similar to facies locally present in the Hastings Formation (Facies Assemblage H3) but much more prevalent here, occur in association with other reddish facies listed below in thick successions. These rocks have a distinctly uniform, massive, blocky, rubbly, and hackly texture with common vertical fractures, slickensides and green reduction haloes (Fig. 46). Reddish and greenish colour mottling is common throughout. Elongate columnar aggregates, or peds, defined by an irregular network of randomly oriented planes, are present in many outcrops. Thin cutans of slickensided red mudstone are commonly discernible, defining the peds. Desiccation cracks are common (Fig. 47), and ripples and evaporative crystal moulds are present near the top in some occurrences (Broad Cove 369–374 m; Creignish 110 m). Burrowing is rare and roots, or green calcareous root casts, are well preserved at some outcrops. A number of occurrences have small, pale-coloured, calcareous caliche glaebules and concretions distributed either randomly or marking particular horizontal planes within the massive red siltstone (Fig. 48). At some

Figure 46. *Red pedogenic siltstone with vertical ped structures, Broad Cove. GSC Photo 4720-26.*

outcrops, thin, but prominent, greenish or rusty-weathering, nodular calcrete zones are present (Downing Head, Point Edward, Broad Cove), although these are not abundant anywhere. Calcretes generally have sharp to gradational bases, sharp "lumpy", irregular tops, vertical fractures, and commonly have well-preserved roots (Fig. 49, 50). Very thin, laterally discontinuous, very fine- to medium-grained sandstone beds, some with ripple crosslamination and rip-ups, are commonly interbedded with coarser sandy siltstone within many of these units. Many of these interbedded units have a coarsening-upward grain size trend, over 1 to 5 m (Fig. 51), capped by calcrete zones, and these asymmetrical sequences tend to stack up in thick successions (Broad Cove 164–168 m, 345–355 m; Creignish 12–15 m, 91–101 m; Carrigans Cove 12–20 m, 31–40 m, 56–73 m; Ragged Point 96–115 m). This facies is prominent at Broad Cove, Creignish, Carrigans Cove, Port Hastings, Point Edward, Ragged Point, and Downing Head.

This facies is interpreted as representing pedogenically altered playa, mudflat, and overbank sediments deposited

Figure 47. *Desiccation cracks in red pedogenic siltstone, filled with overlying sandstone, Creignish. GSC Photo 4720-27.*

Figure 48. *Caliche glaebules in red pedogenic siltstone, Broad Cove. GSC Photo 4720-28.*

through primarily vertical aggradation on a subaerial low-slope, low-energy playa-floodplain-floodout near the lake margin. The bulk of these sediments, dominated by silt size grades, may have originated as loess deposits blown from adjacent braidplains and alluvial fans. The ubiquitous presence of desiccation cracks, blocky structure, and vertic ped features (which develop quite quickly as a result of wetting and drying of expandable clays) is typical of paleosols developed in climates with seasonal wet and dry phases, and the presence of caliche and calcrete (which require thousands of years to develop because of evaporative precipitation of mineral salts) is typical of warm, semiarid climates. The majority of these units can be classified as vertisols, with minor calcisols. The asymmetrical, fifth-order, coarsening-upward units are interpreted as flood and splay sequences on the floodplain-floodout-playa. The ubiquitous development of vertisols and calcisols confirms that the climatic conditions under which the Pomquet was

Figure 49. *Green and red mottled calcisol at top of coarsening-upward sequence, Broad Cove. GSC Photo 4720-29.*

Figure 50. *Greenish calcisol with fractures, slickensides and roots, Point Edward. GSC Photo 4720-30.*

Figure 51. *Coarsening-upward sequence of red pedogenic siltstone grading up into interbedded sandstone and siltstone, Ragged Point. Top is to right. GSC Photo 4720-31.*

deposited were tropical, seasonally dry and generally semiarid. Mature calcrete develops during relatively long periods of sediment surface stability at a rate of a few centimetres per millennium. Because thick calcrete horizons take thousands of years to develop they are most likely to form and be preserved in areas distal from active braided fluvial sedimentation. The presence of calcisols implies numerous hiatuses of long, but unknown, duration, and the consequent repeated periods of erosion and dissection throughout aggradation of the Pomquet Formation.

Thickly interbedded, red siltstone and very fine- to fine-grained sandstone

Thickly interbedded brick red to greyish red siltstone to sandy siltstone and very fine- to medium-grained sandstone occurs in units up to 30 m thick, in a number of outcrops. The siltstone typically has the massive, blocky texture of vertisol pedogenic siltstones, whereas the sandstone beds have sharp, locally erosive bases with rip-ups (Fig. 52), and sharp, flat to rippled tops (Ragged Point 115–147; Broad Cove 403–449; Port Hastings 396–425). Roots are present at some localities, the sandstones are well sorted, and horizontal lamination and climbing ripples are common. Desiccation cracks are common (Fig. 53) and caliche glaebules occur in some outcrops. Sandstone to siltstone ratios range from 1:1 to 1:5 and sandstone thicknesses range from 5 to 50 cm. This facies is prominent at Broad Cove, Port Hastings, Ragged Point, Creignish, Carrigans Cove, and Downing Head.

This facies is interpreted as representing overbank and mudflat deposition in a floodplain-playa setting medial to a fluvial channel, where some fluvial flood input of coarser clastic rocks occurred. Aggradation of sediments was at a moderate rate, and some sandstones were deposited quite rapidly. Paleosol features suggest a warm, semiarid climate with a seasonal wetting phase.

Figure 52. *Erosional grooves on base of thin sandstone bed within pedogenic siltstone, Creignish. GSC Photo 4720-32.*

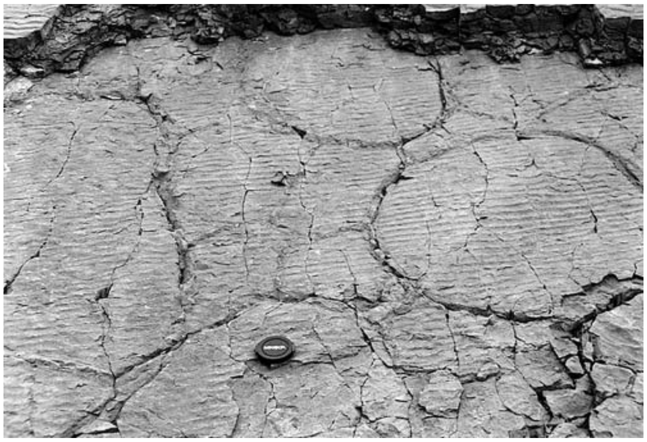

Figure 53. *Desiccation cracks on rippled surface of thin, fine-grained sandstone, Creignish. GSC Photo 4720-33.*

Facies Assemblage P2: Thick-bedded, reddish sandstone (fluvial channel)

Facies Assemblage P2 is less common, but still prevalent in the studied outcrops of the Pomquet Formation and has a maximum single unit thickness of 10 m (Fig. 54). It occurs at most outcrops, especially at the tops of coarsening-upward sequences near the top of the Pomquet, where it intertongues with Facies Assemblage P1, or at the very base where it erosionally overlies Hastings deposits.

Thick-bedded, reddish grey, very fine- to medium-grained sandstone

Red to reddish grey to greenish grey, very fine- to coarse-grained sandstone occurs in units up to 10 m thick in many outcrops of the Pomquet Formation. These have sharp erosive bases (Fig. 55) with thick lags of intraformational siltstone and caliche rip-up clasts (Fig. 56), horizontal lamination, trough crossbedding (Fig. 57), contorted lamination, ripple crosslamination and climbing ripples. They typically fine upward and are closely associated with the two reddish facies listed above. Most have deeply incised basal scour topography, but flat tops (Fig. 58) (Creignish 65–68 m, 111–116 m; Carrigans Cove 48–55 m; Broad Cove 279–284 m, 398–403 m; Port Hastings 322–331 m). Evaporative crystal moulds and desiccation cracks are present near the tops of some examples (Arthurs Point 1 m, Broad Cove 381–383 m). There are several examples of water-escape structures in thick, well-sorted sandstones at Arthurs Point and Broad Cove. Wood or plant fragments are very rare, although these are common in channel sandstones of the overlying Port Hood and Boss Point formations. These units are similar to thick sandstone bodies that rarely occur in the Hastings Formation (Facies Assemblage H4). One example at Broad Cove (398–403 m) contains numerous bright green nodules of metallic sulfides, an occurrence of “Red-Bed Cu” mineralization. This facies is prominent at Port Hastings, Broad Cove, Cape Jack, Arthurs Point, Point Edward, Creignish, Carrigans Cove, and Downing Head.

These units are interpreted as representing significant fluvial channels embedded in a floodplain adjacent to the lake margins. The floodplain prograded over lacustrine deposits and supplied much of the clastic material for the Hastings and Pomquet formations. These channel sandstones make up only about 10 to 20 per cent of Pomquet strata, and are separated by thick successions of finer grained floodplain deposits. They commonly have deeply erosive bases with steep sides, both features suggesting relatively high-sinuosity rivers. Where appropriate paleocurrent data is available, flow directions for fluvial channels are roughly obliquely offshore compared to the shoreline orientations derived from Hastings facies.

Facies Assemblage P3: Thin-bedded, quartz-pebble conglomerate (alluvial fan and braidplain)

Facies Assemblage P3 is a minor, but important, component of the Pomquet motif, and occurs as prominent beds in a few outcrops, especially associated with Facies Assemblage P2, near the top of the formation, and near basin margins (Fig 59).

Thin-bedded, quartz-pebble conglomerate to pebbly, coarse-grained sandstone

Thin units up to 1 m thick of pale grey to white to reddish-grey, clast-supported conglomerate and medium- to coarse-grained pebbly sandstone occur as minor facies in the upper portion of the Pomquet and equivalent upper Claremont at two outcrops. Some beds are laterally discontinuous over several metres, preserved only as scour-based lenses encased in red siltstone (Fig. 60). Extraformational pebbles appear abruptly in the sections and from there is a general upward increase in the pebble content up to a particular level at both locations: above this level they are not present. The pebbly interval includes 18 m exposed at Bay St. Lawrence, and 50 m at Downing Head. The pebbles are predominantly white quartzite and pink granite, up to 10 cm, moderately to well rounded and sorted (Fig. 61), and generally occur as thick lag concentrations or basal scour fills set in a coarse sandstone matrix. At Bay St. Lawrence, clasts of fossiliferous Windsor limestone are also present. The bases of beds are always erosional, scouring into underlying deposits (Fig. 62). Beds are massive, crudely stratified or trough crossbedded. At Downing Head, giant megaripple forms (52–54 m) and

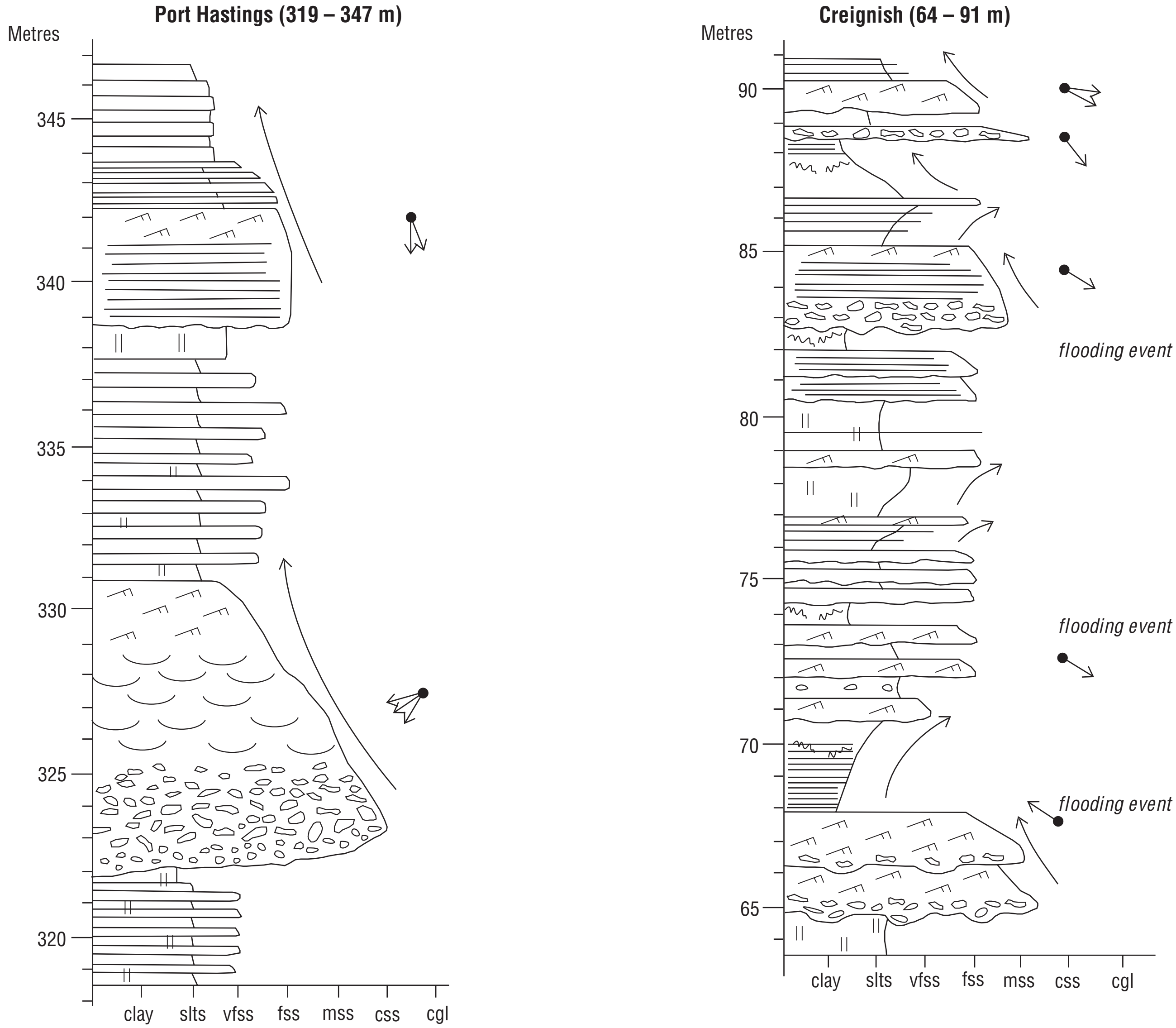

Figure 54. *Examples of the P2 Facies Assemblage. The section at Port Hastings records deposition in a more proximal floodplain setting, whereas that at Creignish suggests deposition close to the adjacent lake margin, with tongues of lacustrine mudstone.*

exhumed, pebbly antidunes (49–52 m) are preserved in conglomerate beds. This facies is rare in Nova Scotia, and was only observed at Downing Head and Bay St. Lawrence.

This facies is interpreted as representing low-sinuosity braided-stream flow deposits at the distal toes of prograding alluvial fans, with material shed from fault-bounded margins of the subbasins. Although uncommon, these beds are very important in regional interpretation of the tectono-sedimentary setting of the Mabou Group. In western Nova Scotia, these beds may represent the distal toes of the correlative Hopewell Conglomerate alluvial fans of eastern New Brunswick. This facies is probably more prevalent in subbasin margin areas beyond the bounds of the present study area (e.g., in the Gulf of St. Lawrence offshore area).

Facies Assemblage P4: Thin-bedded, grey mudstone (shallow lacustrine)

Facies Assemblage P4 is rare in outcrops of the Pomquet. It is similar to facies typical of the Hastings Formation (Facies Assemblage H1) and occurs as thin tongues within the predominantly red, silty to sandy Facies Assemblage P1, especially near the base of the Pomquet (Fig. 63). These tongues are interpreted as representing wedges of Hastings

Figure 55. Scour-based, fining-upward red sandstone unit, Downing Head. GSC Photo 4720-34.

Figure 56. Thick lag of rounded sandstone rip-ups at base of channel sandstone, Creignish. GSC Photo 4720-35.

Figure 57. Greyish red, medium-grained sandstone with trough crossbedding, Downing Head. GSC Photo 4720-36.

Figure 58. Lens-like sandstone channel-form, thinning from base, Broad Cove. GSC Photo 4720-37.

lacustrine facies, which record periodic, contemporaneous transgression of lacustrine environments onto the Pomquet coastal subaerial floodplain.

Dark greenish grey, burrowed or laminated mudstone

Thin units, up to 3 m thick, of dark greenish grey, laminated and burrowed, silty mudstone occur as minor facies within the lower portion of the predominantly red and coarser Pomquet Formation at four outcrops (Fig. 64). They typically have sharp bases overlying red, pedogenic siltstone, tend to coarsen upward, and display burrows of the simple, subhorizontal *Planolites* type, which increase upward. They include thin beds of stromatolitic limestone or very thin beds of siltstone. Occurrences of this facies either coarsen-upward up into interbedded red pedogenic siltstone and fine-grained sandstone or are sharply overlain by red, fine-grained sandstone (Port Hastings 379–394 m; Ragged Point 106–115 m). Where these coarsening-upward sequences occur, they tend to be stacked in sets of two or three. In several cases at Creignish (37 m, 48 m), where overlain by sandstone, the top of the unit is marked by deep, wide desiccation cracks filled with the overlying sandstone. The facies occurs at only one location in the lower part of the Pomquet at Broad Cove (217–220 m) where it coarsens up to a bed of very fine-grained sandstone with HCS, suggesting an association with lacustrine shorelines. The few palynological samples obtained from this facies that yielded results contain poorly preserved microfloras of terrestrial affinity (Utting, 1996). This facies is prominent at Creignish, and occurs at Broad Cove, Port Hastings, and Ragged Point.

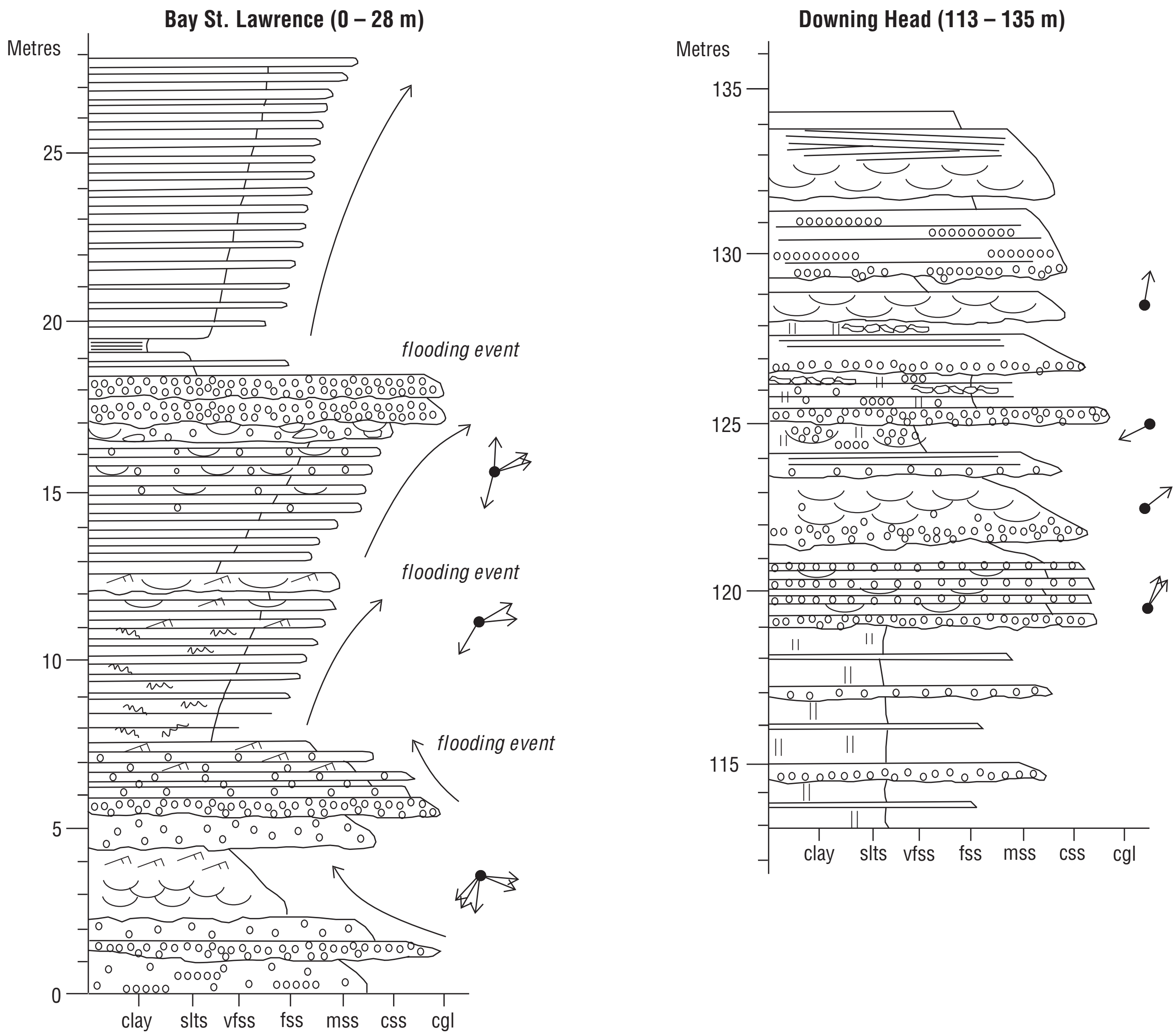

Figure 59. *Examples of the P3 Facies Assemblage. The section at Bay St. Lawrence records proximal, coarse-grained deposits interbedded with lacustrine mudstone, evocative of a fan-delta setting. The section at Downing Head represents proximal, coarse-grained deposits in a subaerial floodplain setting.*

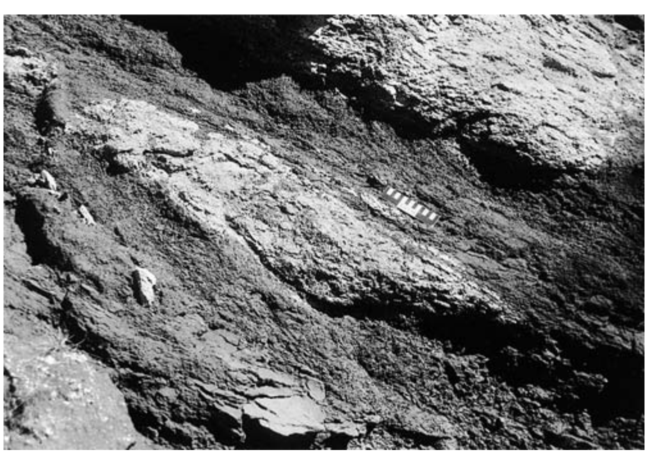

Figure 60. *Coarse-grained pebbly sandstone lenses encased in red pedogenic siltstone, Downing Head. GSC Photo 4720-38.*

Figure 61. *Exhumed sharp upper surface of conglomerate with granitic and Windsor limestone clasts, Bay St. Lawrence. GSC Photo 4720-39.*

Figure 62. *Scoured base of pebbly coarse-grained sandstone cutting into red siltstone, Downing Head. GSC Photo 4720-40.*

This facies is interpreted as representing thin tongues of quiet, lacustrine deposition resulting from short-lived transgressions into the marginal floodplain area within the predominantly subaerial Pomquet, another proof of the intertonguing relationship of the Hastings (lacustrine) and Pomquet (floodplain) facies.

Interpretation of Pomquet Formation depositional system

All lines of evidence, including biotic, sedimentological and facies associations, point to the deposition of the siltstone- and sandstone-dominated Pomquet Formation in subaerial and marginal-lacustrine environments (Fig. 65). The bulk of the deposits are represented by pedogenically altered playa-floodplain-floodout siltstone, deposited slowly over a great span of time. In addition, coarser clastic input was limited to

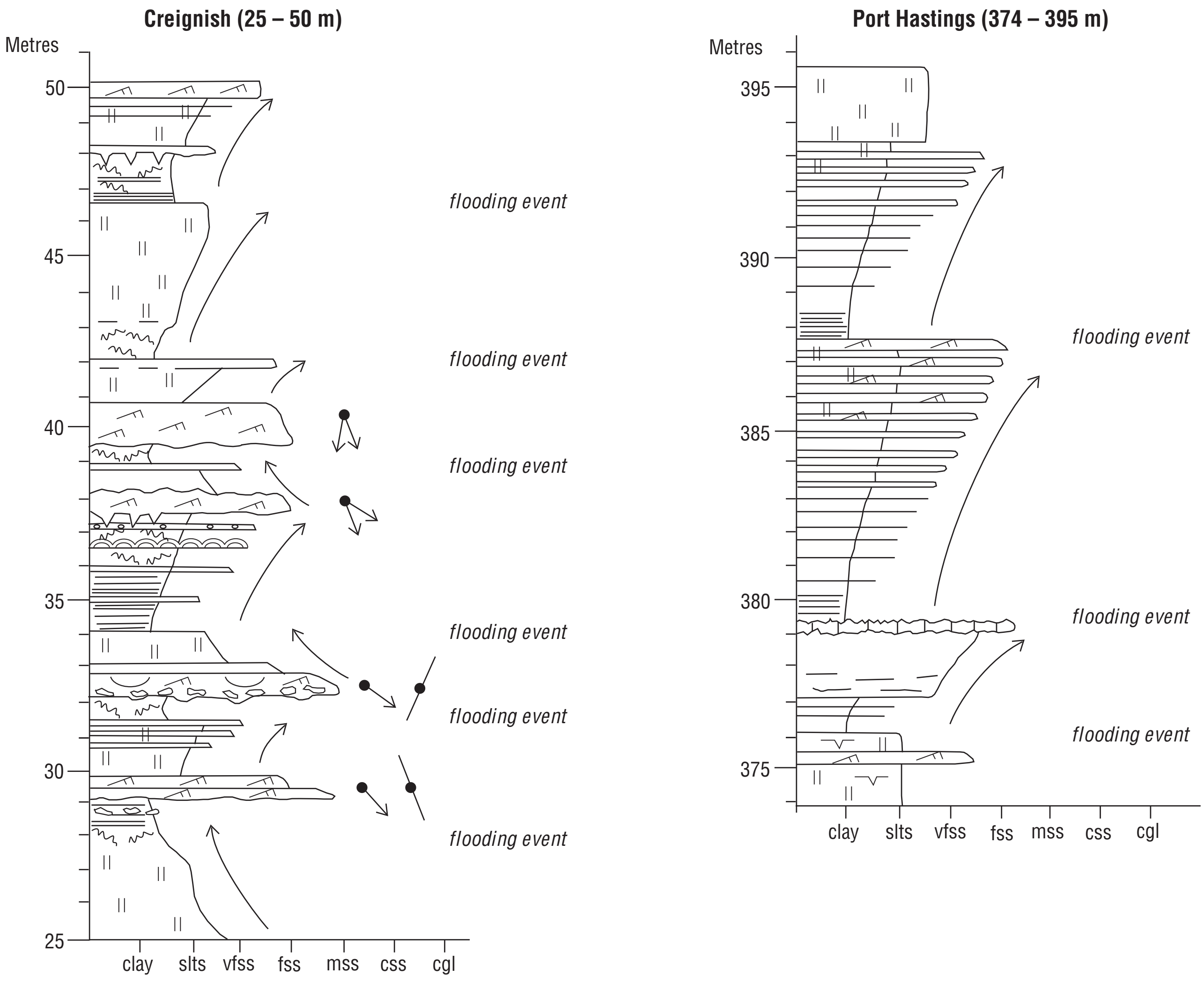

Figure 63. *Examples of the P4 Facies Assemblage. Thin units of laminated and bioturbated mudstone occur uncommonly within thick successions of reddish and greenish, pedogenically altered siltstone and sandstone, interpreted as lacustrine transgressions over the subaerial floodplain.*

Figure 64. Greenish grey siltstone with a few red sandstone beds, Carrigans Cove. Top is to right. GSC Photo 4720-41.

areas near the subbasin margins and a few main distributary networks.

The bulk of the Pomquet Formation comprises a distal-to-proximal arrangement of P1, P2 and P3 facies assemblages as components of a single depositional system extending from subbasin centre to fault-bounded subbasin margin. The three facies assemblages grade into each other laterally, based on observable intertonguing and position relative to original subbasin margins. The proximal subbasin margin areas (predominantly outside the study area) were dominated by high relief and vigorous coarse-grained sedimentation on alluvial fans and proximal braidplains (P3), medial zones included higher sinuosity fluvial channels (P2), and the basin centre area was dominated by low-relief extensive overbank-floodplain-floodout-playa-mudflat areas (P1). Within this floodplain-floodout-playa environment, numerous asymmetrical, coarsening-upward flood and splay sequences (fifth-order terrestrial "chronosequences"), up to 5 m thick, are present, in places combined into stacked fourth-order

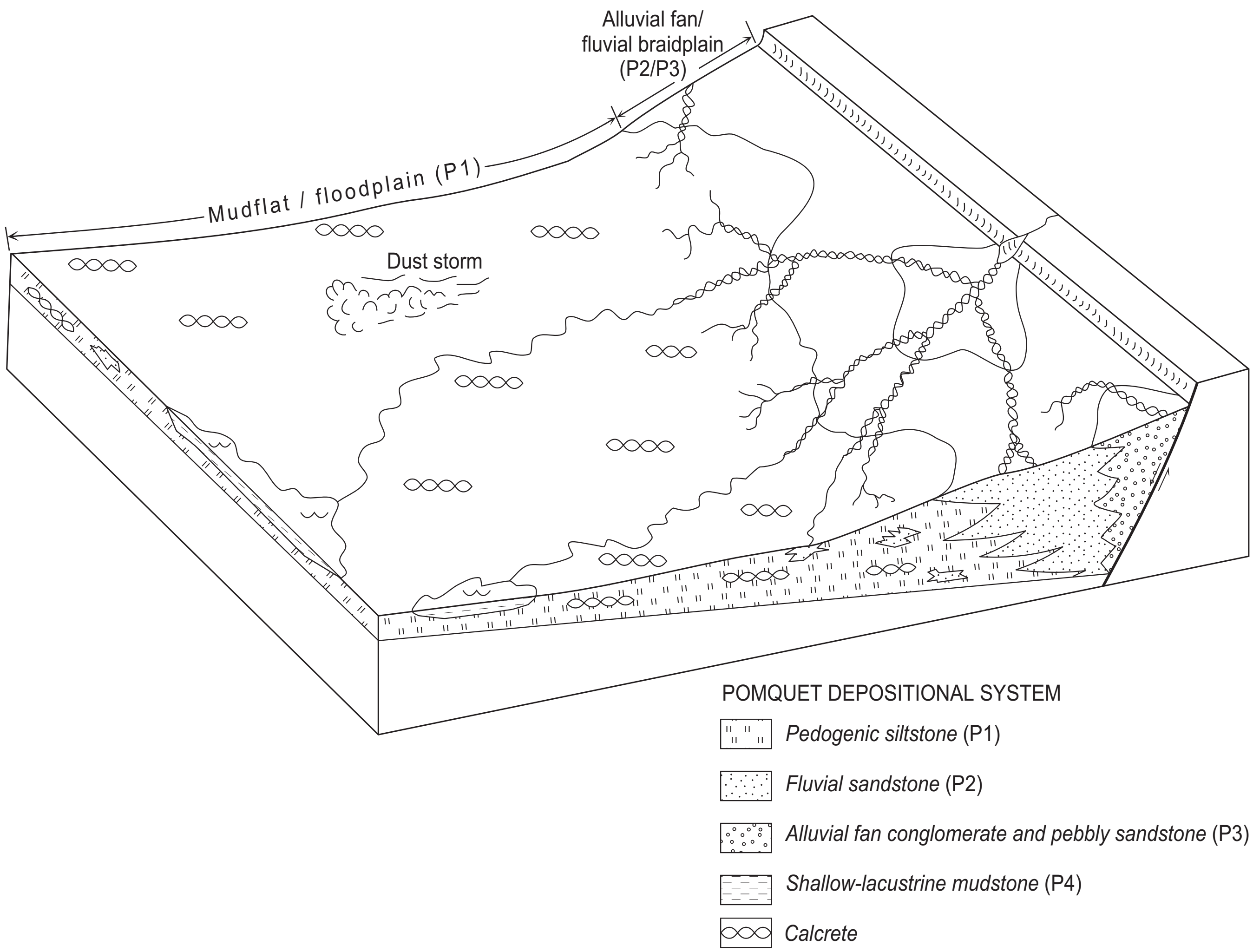

Figure 65. Block diagram illustrating depositional environments and facies distribution of the Pomquet depositional system (large vertical exaggeration).

bundles or megasequences (Fig. 66). Minor incursions of lacustrine mudstone facies are recorded in the lower part of the formation (P4). Vegetation was probably present but limited, due to a semiarid climate, and minor palynological data support a terrigenous setting. Red and green mottling and ubiquitous pedogenic features such as vertisols and calcisols indicate a warm, semiarid, seasonally dry climate.

The P3 alluvial fan and braidplain deposits represent predominance of very vigorous, steep-gradient depositional processes that transported coarse-grained, immature, intrabasinal sediment over rather short distances. Their presence, and content of extraformational pebbles in a few key outcrops, indicate that during the time of Pomquet deposition the subbasins were bounded by remotely located, high-relief fault scarps. This facies assemblage, although uncommon in Nova Scotia, is vital in delineating the fault-bounded margins because alluvial fan and braidplain sediments may be very thick adjacent to the fault scarp but extend only a few tens of kilometres basinward. The medial P2 fluvial channel deposits are not dominant anywhere but represent sandy bedload transport in fluvial channels of moderate sinuosity, a fluvial style somewhere between classical braided and meandering end members. They indicate a sedimentological gradation away from alluvial fan and braidplain environments at the fault-bounded subbasin margins into a more moderate-relief setting basinward of the fan toes. There is no clear evidence of basin-wide sequences related to specific fault subsidence episodes, but it is common for the dynamic processes of fluvial systems to "smooth out" tectonic effects (Rust and Koster, 1984). The distribution of this facies assemblage is more widespread than that of the P3 facies assemblage but has a similar asymmetry. The configuration implies a closed basin of deposition and a fundamental linkage of P3 and P2 deposits.

The distal P1 playa-mudflat-floodplain-floodout deposits are the main Pomquet facies assemblage present in the central subbasin area, where they overlie Hastings strata. The P1 assemblage represents a low-energy, low-relief setting, and was predominantly transported as abundant suspended sediment load, perhaps beyond the reach of most channelized flows, where long periods of exposure and pedogenesis occurred. The embedded, isolated channels of P2 migrated laterally through these extensive, pedogenically modified, fine-grained overbank areas in the low-lying central portion of the subbasin removed from the influence of coarse-grained sediment input from fault-bounded margins. Although vertical aggradation of fine-grained sediments on this floodplain-floodout zone was the hallmark of the Pomquet motif, the rate of accumulation must have been rather slow to allow near-continuous pedogenic alteration. In addition, that slow accumulation rate must have been continuously punctuated by periods of nondeposition of unknown durations, as witnessed by the ubiquitous presence of vertisols and calcisols.

Proximal-distal relationships and facies distribution

Because of the wide scattering of outcrops in several different subbasin areas and their general fragmentary nature, the paleogeographic details of the Mabou are not easily interpretable and, at some sections, the paleocurrent data set may not be statistically significant. Post-Mabou structural complications may have disrupted stratigraphic and paleogeographic relations. In addition, we should expect wide variability from deposits of shallow lakes, subject to repeated desiccation and refilling, and from low-slope, high-sinuosity fluvial systems. However, several general statements regarding the paleogeographic arrangement of depositional environments can be derived from facies distributions and paleocurrent measurements.

The transition from clearly marine Windsor deposition to clearly lacustrine Hastings deposition occurred over a short interval. This transition is exposed in unfaulted condition only at Cape Dauphin, where the upper surface of Windsor fossiliferous vuggy limestone is sharp, irregular, rust-stained, and covered by deep mudcracks (Fig. 67). This exposure surface is sharply overlain by a 20 m interval of thinly interbedded, burrowed, organic-rich mudstones, rippled limestones with mudcracks, stromatolites, and hardground beds (lacustrine transgressive systems tract). Above this are several thin units of dark grey laminated mudstone (maximum lacustrine flooding) and then successive coarsening-upward and shallowing-upward sequences typical of the Hastings. At Broad Cove, the uppermost thick anhydrite bed of the upper Windsor is faulted and deformed (Fig. 68). This tectonic surface is sharply overlain by a 5 m coarsening-upward sequence of interbedded, grey, bioturbated mudstone and very fine-grained sandstone with hummocky cross-stratification at the top. Above this are 2 m of dark grey, bioturbated mudstone (maximum lacustrine flooding) followed by a stack of three coarsening-upward sequences, which become progressively coarser and redder upward. At both outcrops the typical Hastings motif and the succeeding coarsening-upward character of the Pomquet floodplain and fluvial deposits depict the gradual filling of the subbasins (lacustrine-fluvial regressive systems tract).

In the vertical dimension, the Mabou Group is typified by a general third-order coarsening-upward, shallowing-upward trend from distal to proximal facies assemblages, although only the Broad Cove outcrop actually displays this in its entirety. This trend is characterized by an overall upward change in facies assemblages from: a) lacustrine-dominated facies in coarsening-upward sequences of the lower Hastings (H1, H2), through b) shallow-lacustrine and shoreline facies in the upper Hastings (H2), to c) intertonguing subaqueous Hastings and subaerial Pomquet facies (H3, P4), to d) thinly interbedded, subaerial,

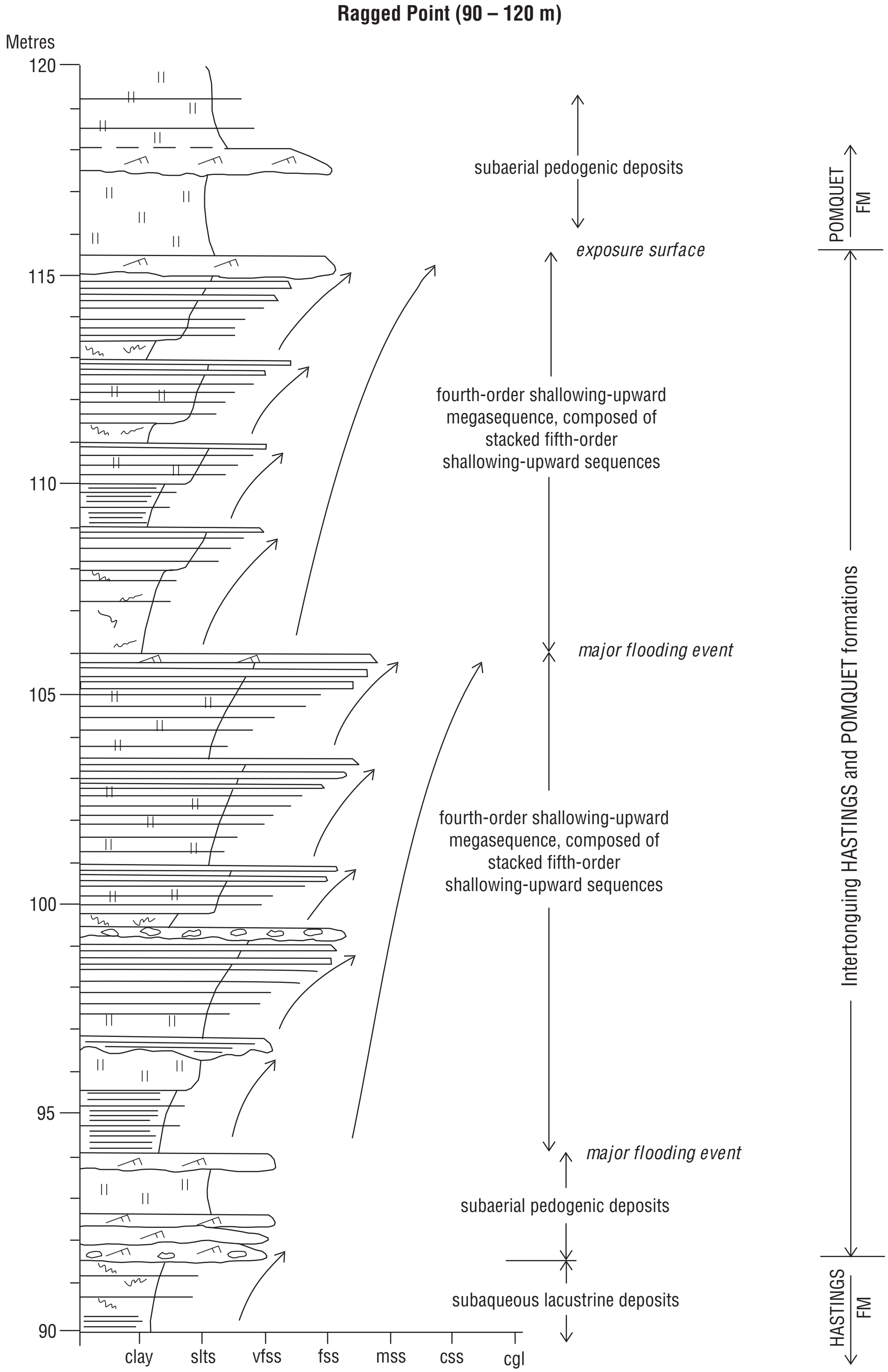

Figure 66. *Hierarchy of shallowing-upward sequences and megasequences, typical of Mabou Group H1 and P1 facies assemblages.*

***Figure 67.** Mudcracked upper surface of Windsor limestone, sharply overlain by Hastings mudstone, Cape Dauphin. GSC Photo 4720-42.*

***Figure 68.** Basal Hastings coarsening-upward sequence, in fault contact with uppermost Windsor anhydrite bed, Broad Cove. GSC Photo 4720-43.*

pedogenic siltstone with thin splay sandstones of the lower and middle Pomquet (P1, P2), to e) thick, subaerial sandstone channels and uniform pedogenic siltstone of the upper Pomquet (P2, P1). Near fault-bounded basin margins, coarser grained facies occur in the Hastings (H4) and especially the Pomquet (P3). Certainly, many outcrops display an intertonguing relationship between Hastings and Pomquet facies assemblages. However, although there are common tongues of Pomquet-like, red, pedogenic siltstone within the Hastings Formation (Facies Assemblage H3), tongues of Hastings-like grey mudstone are quite rare in the Pomquet (Facies Assemblage P4), demonstrating that once terrestrial deposition overwhelmed the lacustrine environment the subbasins remained essentially subaerial. This again, confirms the very shallow nature of Mabou lakes, the diminution of basin subsidence to near-cessation through Mabou time, and the overall upward basin-filling nature of the succession.

In the horizontal dimension, the Mabou Group is typified by a spectrum of facies assemblages that depict proximal to distal trends in both the Hastings subaqueous lacustrine depositional system and the Pomquet subaerial fluvial–alluvial depositional system (Fig. 69). Within the Hastings, a distal-to-medial-to-proximal continuum is indicated by the series of facies assemblages: a) H1 – open, shallow-lacustrine mudstone, siltstone, and limestone (e.g., Cape Dauphin, Broad Cove, Port Hastings, Cable Landfall, SW Mabou RR Cut), to b) H2 – nearshore-shoreline thick sandstone and siltstone (e.g., Partridge Island, Ragged Point, Little River, Cape Jack, Barrios Head), to c) H3 – floodplain siltstone (e.g., Port Hastings, Ragged Point, Barrios Head, Downing Head, Downing Cove), to d) H4 – fluvial sandstones (e.g., Downing Head, Downing Cove).

Within the Pomquet, a distal-to-medial-to-proximal continuum is indicated by the series of facies assemblages: a) P4 – shallow-lacustrine siltstone (e.g., Creignish, Broad Cove), to b) P1 – pedogenic playa-floodplain siltstone (e.g., Broad Cove, Port Hastings, Ragged Point, Creignish, Carrigans Cove, Downing Head), to c) P2 – fluvial channel sandstone (e.g., Port Hastings, Broad Cove, Point Edward, Creignish, Carrigans Cove, Arthurs Point, Downing Head), to d) P3 – coarse-grained, alluvial fan-braidplain sandstone and conglomerate (e.g., Downing Head, Bay St. Lawrence).

Paleocurrents

In the Hastings Formation lacustrine system, paleocurrent data consist primarily of straight, symmetrical ripple crests, ripple crosslamination and sole marks of various kinds associated with the sandstone and limestone beds within the mudstones, and with minor trough crossbeds, scours, and current lineations in coarser facies (see Appendix 1 and Fig. 70). It is interpreted that symmetrical ripple crest trends were approximately parallel to local shorelines and that other sedimentary structures indicate offshore-to-alongshore directions. In the Pomquet Formation fluvial-alluvial system, paleocurrent data consist primarily of trough crossbedding, ripple crosslamination and scours, with minor solemarks and current lineations (see Appendix 1 and Fig. 71). It is interpreted that these features essentially indicate flow directions of the predominantly fluvial deposits away from subdued subbasin margins toward lacustrine subbasin centres. With this in mind, the data can be used to suggest local subbasin margin, shoreline and offshore orientations in each of the areas where outcrops were studied.

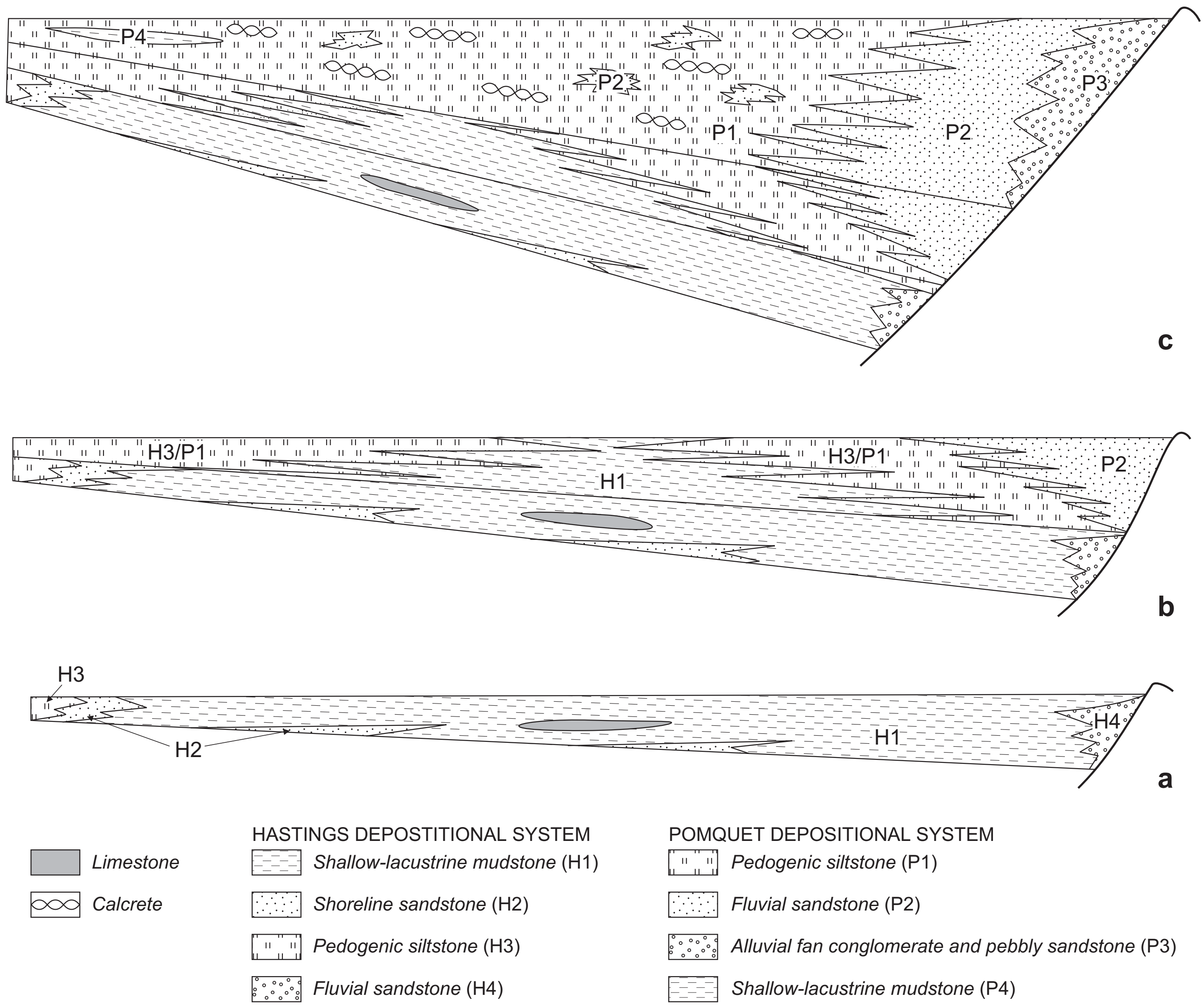

Figure 69. *Interpreted evolution of Mabou Group deposition within fault-bounded idealized subbasin during waning subsidence phase of Fundy Basin Rift.* ***a.*** *Hastings Formation depositional system, predominantly sublacustrine deposition;* ***b.*** *transitional phase, with intertonguing of predominantly sublacustrine and subaerial deposition; and* ***c.*** *Pomquet Formation depositional system, predominantly subaerial deposition.*

In western Nova Scotia, both proximal and distal lacustrine shorelines of the Hastings at Partridge Island, Downing Cove and Downing Head appear to have been oriented nearly north–south or north-northwest–south-southeast with east–northeast transport in proximal coarse-grained facies, and northward alongshore transport in the medial shallow lacustrine facies. Proximal Pomquet-equivalent coarse-grained deposits exposed at Downing Head indicate northeastward fluvial transport. These data suggest that the sediment source area was near by, to the west in New Brunswick.

In the Antigonish area, only three outcrops were studied. Exposure is modest to poor and data are sparse. Two of the outcrops are extensively faulted, including fault repetition of Windsor and Hastings over Pomquet at Cape Jack. The multiple fault blocks may have experienced unknown rotation about vertical axes. In addition, there are insufficient data from the Hastings exposures to yield any reliable conclusions. These factors render dubious the conclusions to be reached from the diverse paleocurrent data in this area. Good data from the Pomquet at Arthurs Point indicate fluvial flow to the northeast; more equivocal data at Cape Jack, flow to the northwest, and less data at Barrios Head, likely flow to the southwest. It is unknown whether these variable flow directions are structurally induced, but they certainly are not interpretable as they stand.

In the western Cape Breton area, outcrop sections and paleocurrent data appear to fit together well. Within the

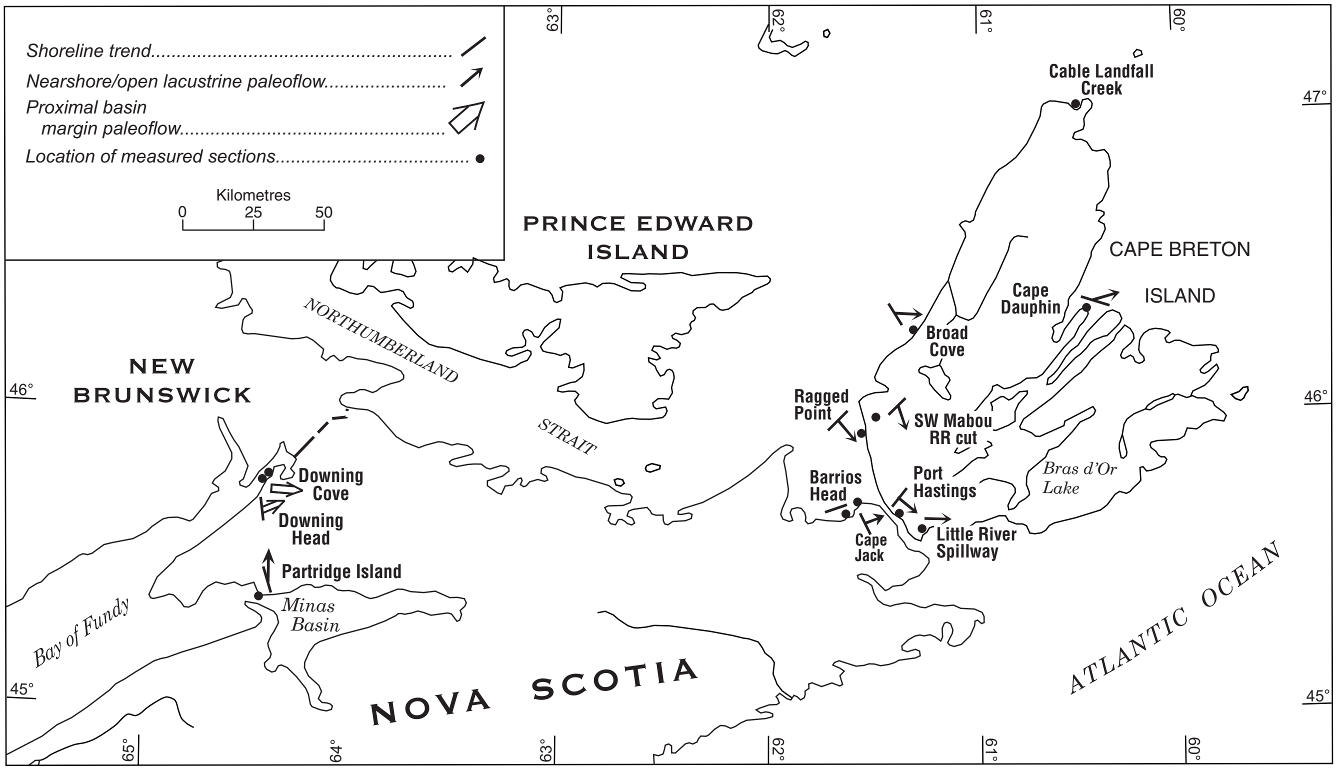

Figure 70. *Paleocurrent data for the Hastings Formation.*

Hastings lacustrine system abundant indicators at Port Hastings, Ragged Point, and SW Mabou RR Cut indicate a consistent shoreline trend of northeast–southwest, and offshore and alongshore transport to the southeast. Likewise, numerous fluvial flow indicators from the overlying Pomquet medial to distal fluvial and alluvial system at Port Hastings, Ragged Point, and Creignish point to consistent southeast flow directions. These data can be interpreted as suggesting a subbasin configuration similar to the fault-bounded asymmetrical half graben extant in the same area in Horton time. During earlier Horton deposition, lacustrine deposits were transported down the hanging wall ramp toward the southeast, to the axial area of this subbasin (Hamblin, 1989, 1992; Hamblin and Rust, 1989). The Hastings-Pomquet lacustrine-deltaic-floodplain system in western Cape Breton, with offshore transport to the southeast, may reflect a similar subbasinal configuration. Interestingly, the outcrop at Carrigans Cove, the most southeasterly section where only Pomquet is exposed, yields evidence of fluvial transport in the opposite direction, to the northwest. This, in fact, may reflect sediment input from the opposite subbasin margin, effectively illustrating how the Mabou depositional subbasins had evolved from the narrow (50 km wide) half graben of the Horton into broad, shallow lowlands (100+ km? wide). The relative width of Windsor marine subbasins, which represent the time period between late Tournaisian Horton deposition and late Viséan–early Namurian Mabou deposition, is currently unknown.

The Broad Cove outcrop is somewhat removed from the other southwestern Cape Breton outcrops and is located north of the Mabou Highland basement block, which experienced fault-bounded uplift in late Horton time (Hamblin, 1989; Hamblin and Rust, 1989). This may explain the internal consistency of paleocurrent data at this section, but lack of obvious relation to nearby sections. In the Hastings lacustrine system, the shoreline trend was oriented approximately northwest–southeast (although the data are sparse), and offshore and alongshore transport was to the northeast and southeast. Within the Pomquet fluvial and alluvial system, abundant indicators suggest fluvial flow to the northeast, approximately perpendicular to the proposed shoreline trend.

In the northeastern Cape Breton area, only Cape Dauphin provided significant data from the lacustrine facies of the Hastings, and it suggests a northwest–southeast shoreline trend with offshore and alongshore transport to the northeast. A single measurement at Cable Landfall Creek indicates offshore transport to the north. Within the Pomquet, coarse-grained proximal facies suggest fluvial flow to the east–northeast at Bay St. Lawrence, approximately perpendicular

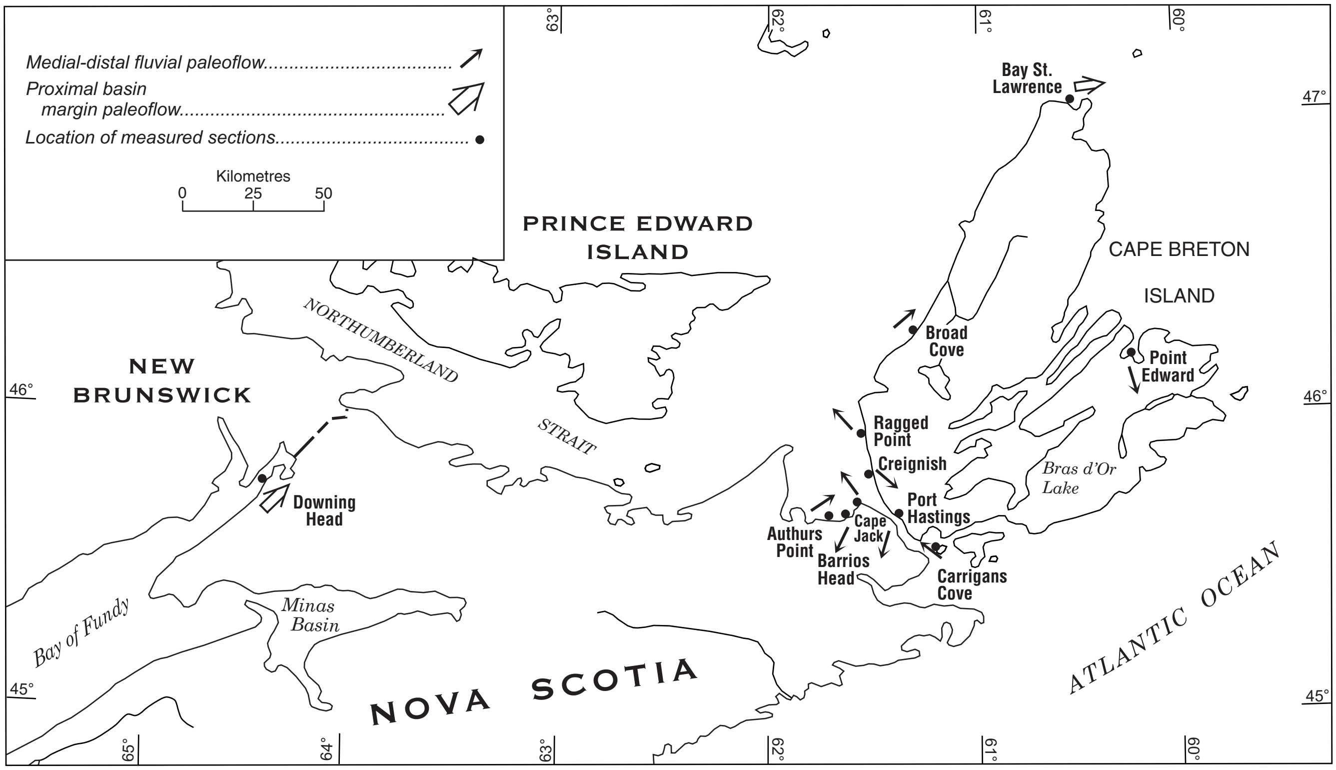

Figure 71. *Paleocurrent data for the Pomquet Formation.*

to that of the nearby lacustrine shoreline. Distal fluvial deposits at Point Edward yield evidence of south–southeast transport, perhaps longitudinal to the subbasin axis.

Summary

Combining the proximal-distal information, facies distributions, and paleocurrent data allows us to summarize the characteristics and sediment dispersal for both the Hastings and Pomquet depositional systems in each of the four outcrop areas (Fig. 72, 73). The stratigraphic and sedimentological data suggest remote fault-bounded subbasin margins that delineate a broadened rift system, with poorly defined subbasin segments. Synthesizing all the data and concepts from this study with indications from previous studies suggests a simplified picture for the broad Mabou depositional basin in Nova Scotia during the closing phase of the original Fundy Basin Rift, just before the tectonic reorganization of the middle Carboniferous Alleghanian Orogeny (Fig. 74). In most parts of the region, the basin margins are speculative only, and the identification of Mabou-age strata in the offshore Gulf of St. Lawrence (Rehill, 1996) indicates further refinement of this portrayal is necessary. The depositional basin appears to attain widths of 100 km in many areas, much wider than underlying Horton subbasins. A necking of the speculative margins in the Antigonish area may indicate the original separation area between the southwestern Cape Breton and the western Nova Scotia depositional subbasins. If so, then these subbasins, in similar locations to those defined for the underlying Horton Group (Hamblin, 1989; Hamblin and Rust, 1989), were about 150 to 200 km long by 100 km wide. This again, suggests the widening of the Fundy Basin Rift through time as fault-bounded subsidence waned.

Although there was initially a dominance of shallow lacustrine deposition (Hastings Formation) evolving from the former marine setting of the Windsor, the bulk of Mabou basin-fill deposits are nonmarine, low-slope floodplain-fluvial, and fine grained, in nature. The presence of some alluvial fan deposits, deficiency of preserved vegetation, evidence of significant lacustrine carbonate chemical sedimentation, abundant evidence of desiccation and ubiquitous pedogenesis throughout the Pomquet Formation attest to a generally warm, semiarid, but seasonally wet, climate.

Throughout deposition of the Mabou Group, the rate of subsidence likely decreased, reducing accommodation space and allowing increased erosion of, and sediment dispersal from, the subbasin margins. This was heralded by the upward transition from shallow-lacustrine facies of the Hastings to the subaerial floodplain deposition of the

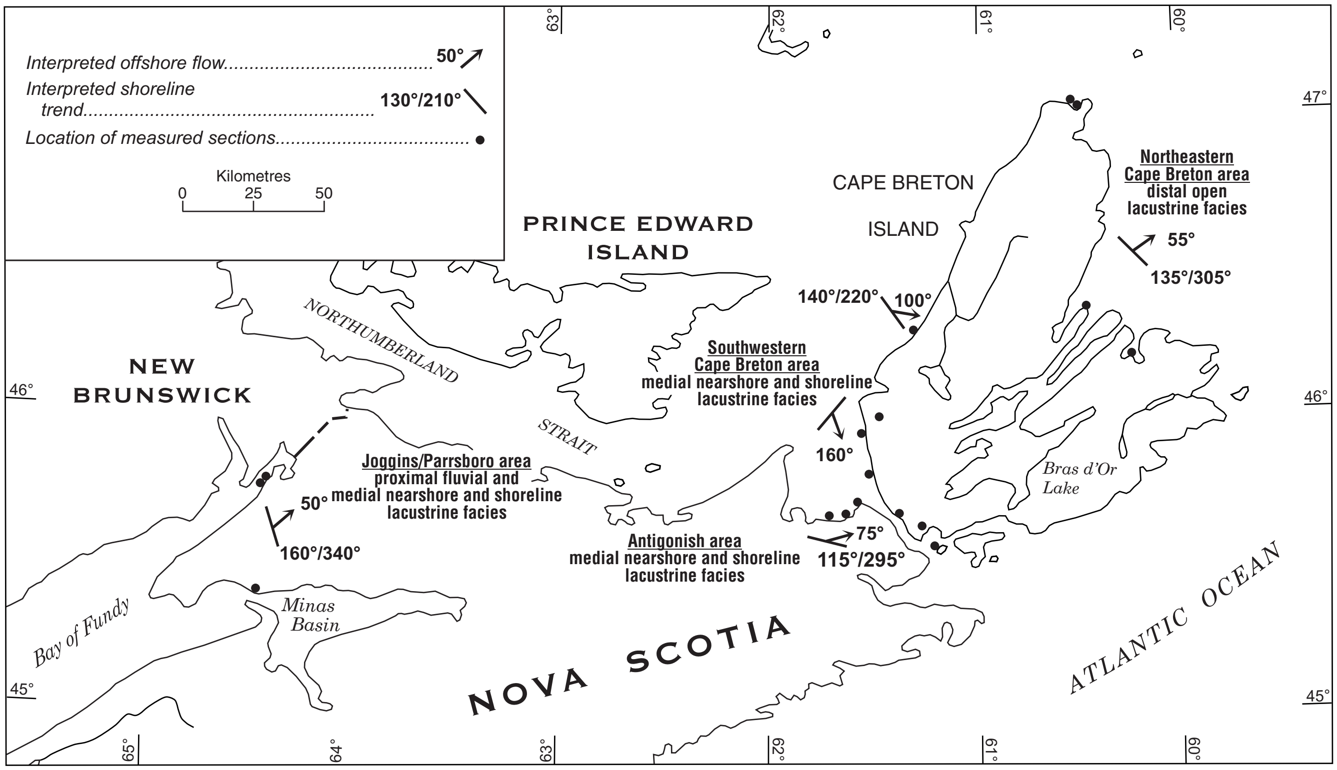

Figure 72. *Summary, by area, of paleocurrent trends and facies distribution of the Hastings Formation lacustrine depositional system.*

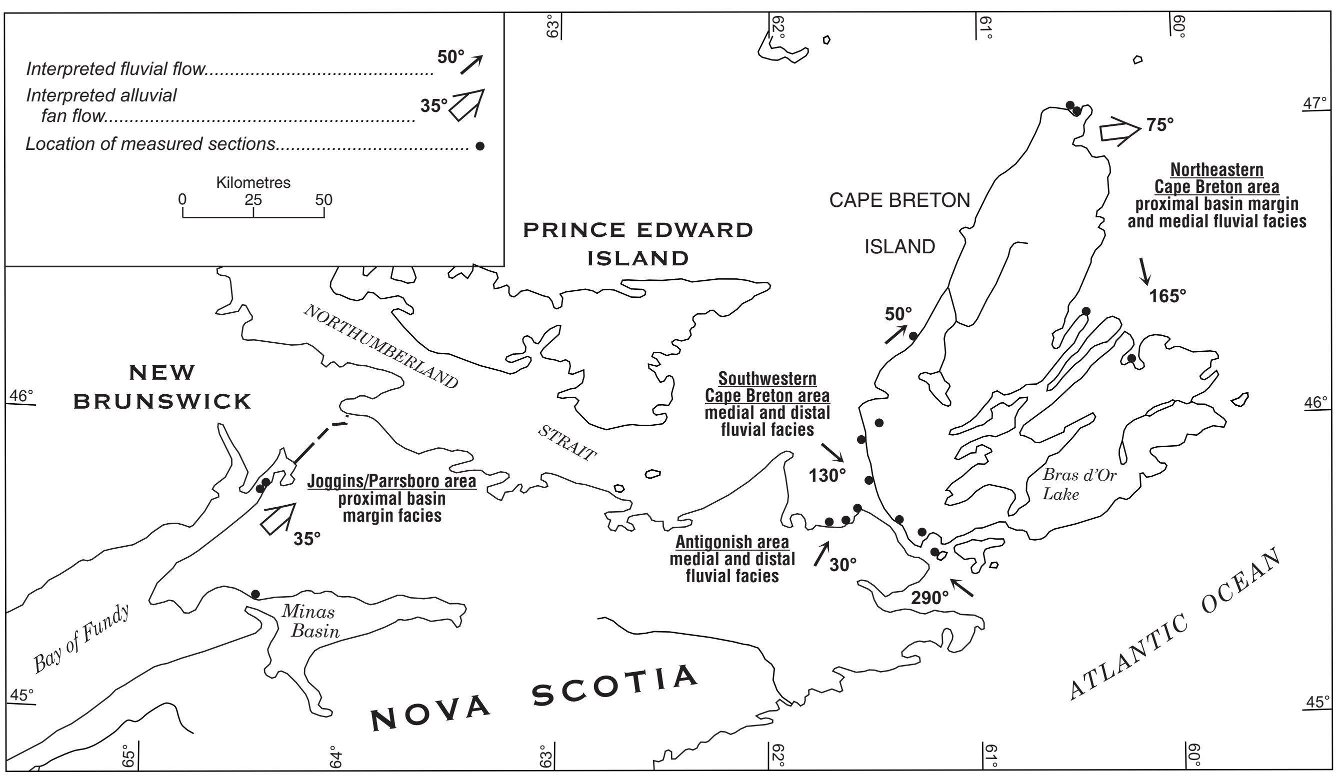

Figure 73. *Summary, by area, of paleocurrent trends and facies distribution of the Pomquet Formation fluvial depositional system.*

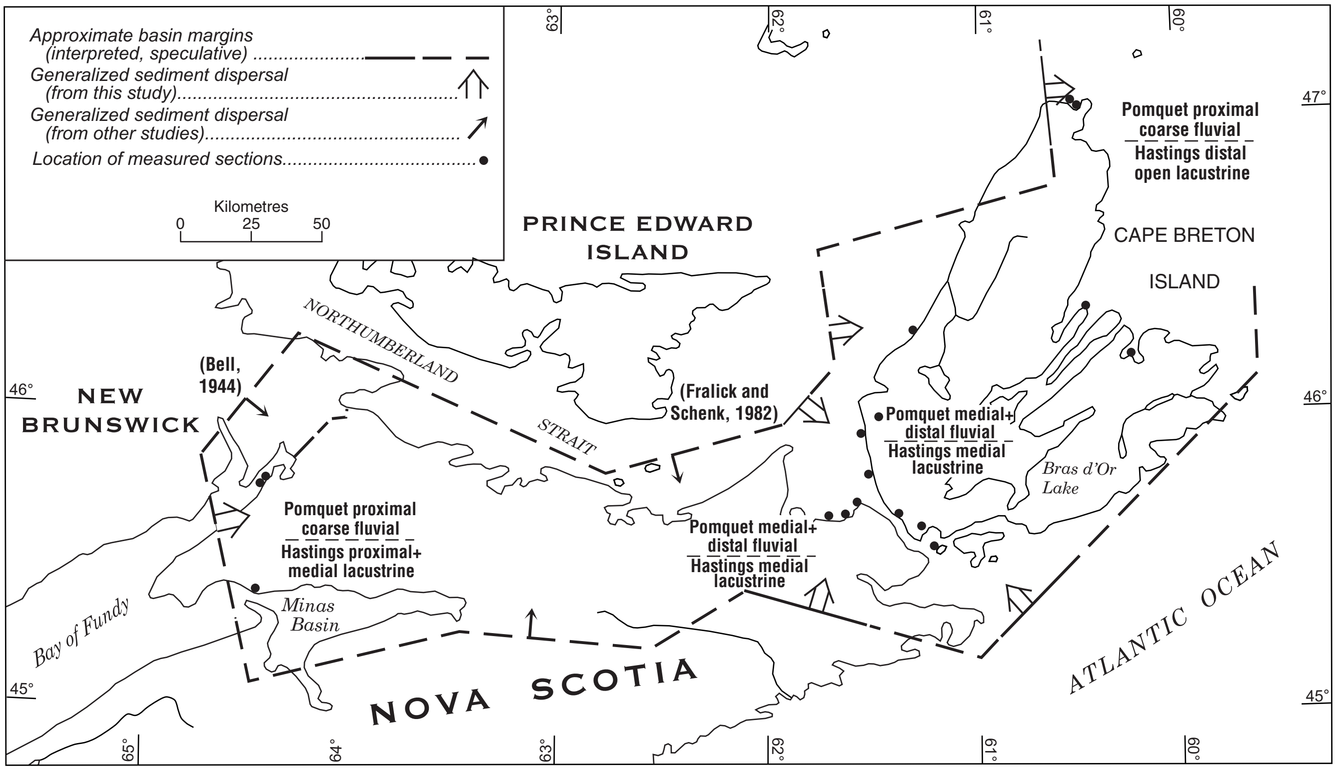

Figure 74. *Summary facies distribution, sediment dispersal, and interpreted depositional basin margins of the Mabou Group of Nova Scotia.*

overlying Pomquet in a coarsening-upward basin-fill succession. Within the third-order Mabou Group asymmetrical coarsening-upward basin-fill succession, much of the open, shallow-lacustrine deposition of the Hastings Formation (H1 and H2) is arranged into a few, fourth-order asymmetrical coarsening-upward mega-sequences representing major periods of fault-bounded subsidence followed by lacustrine shoreline-subaerial-floodplain progradation into subbasin central areas. These megasequences, in turn, actually comprise bundles of fifth-order asymmetrical, transgressive-regressive, coarsening-upward progradational fill sequences of a more local nature. This hierarchical arrangement of successive subsidence and fill phases is also typical of lacustrine deposits of the Horton Group (Hamblin, 1989, 1992; Hamblin and Rust, 1989).

As Mabou Group sediments gradually became increasingly dominated by subaerial deposition (Pomquet Formation), the influence of fault-bounded subsidence at subbasin margins, and this motif, became less obvious. In addition, the progressive widening of subbasins of the rift system through the Early Carboniferous is clear from the paucity of proximal facies and from the paleocurrent data in the Mabou. The decrease in the importance of fault-bounded subsidence signaled the gradual demise of the Lower Carboniferous Fundy Rift and prefaced the subsequent reorientation of the regional tectonic stress regime, from distensive to transpressive, which we know as the Alleghanian Orogeny.

TECTONIC STYLE DURING MABOU GROUP DEPOSITION

The Mabou Group tectonosedimentary basin-fill succession

The Mabou Group of Nova Scotia is part of the thick Lower Carboniferous post-Acadian, pre-Alleghanian Kaskaskia Sequence (Sloss, 1963) of the Appalachian Orogen. As documented by Hamblin (1989) and Hamblin and Rust (1989) the Horton-Windsor-Mabou succession represents deposition in asymmetrical, fault-bounded half-graben segments of a distensive rift system positioned at 10 to 15° paleolatitude in a warm, semiarid climate. This Fundy Basin Rift of Belt (1968) represented a postorogenic relaxation phase, a short-lived reorientation of stress regime and plate motions, between two compressional orogenic periods.

The Mabou Group occupies a position in the later part of the Lower Carboniferous interorogenic phase, just before orogenic activity (in the form of dextral oblique-slip motion) recommenced. Many of its large-scale characteristics were essentially predetermined by the tectonic basin configuration of the rift system of the Horton Group. Yet, there are significant differences from the Horton, which developed over the intervening 10 to 12 Ma of Viséan–Namurian time, and hundreds of metres of Windsor deposition, and these differences allow comparison and interpretation of the Mabou. Indeed, an important question is whether the Mabou Group was deposited during the waning stages of the distensive regime, or during the initial stages of the succeeding transpressional regime, which eventually led to the mid-Carboniferous unconformity.

The Mabou extensional regime

The Mabou Group of Nova Scotia displays many characteristics of distensive systems. These characteristics include: a) large depositional area; b) only moderate deformation over about 325 Ma of succeeding time; c) no identifiable strike-slip component of synsedimentary fault motion; d) several loosely defined subbasins about 150 to 200 km long by 100 km wide in size, with no definable uplifts between; e) vertical stacking of laterally persistent stratigraphic units and stationary sediment sources; f) relatively small total stratigraphic thickness, at least an order of magnitude less than subbasin dimensions; and g) long-term consistency of subbasin geometries and facies distribution.

There is little discernable evidence for initiation of a transpressive–transtensive regime during Mabou Group deposition. Hamblin (1989) and Hamblin and Rust (1989) summarized the characteristics expected in these kinds of basins, such as occurrence in series along contemporaneous en echelon fault segments, small size and short duration, rhombic shape separated by contemporaneous compressional uplifts, unique structural and depositional history for each subbasin, migration of depocentres through time parallel to the master faults, very rapid accumulation and extreme lateral diachroneity, and apparent stratigraphic thicknesses of the same order of magnitude as the size of the basin and two to five times the actual basin depth. Clearly, none of these characteristics are typical of the Mabou Group.

It is concluded that Mabou deposition occurred within the broadened, slowly subsiding remains of the previously developed Lower Carboniferous Fundy Rift, which had controlled sedimentation of the Horton Group, and probably of the Windsor Group. In addition, it is clear that the Mabou represents the waning phase of the distensive history of the Fundy Rift, and does not record the initiation of the Alleghanian transpressive regime. However, conversion to that transpressive–transtensive regime was soon to follow, and may have influenced deposition of the succeeding Port Hood and Boss Point formations. It certainly was instrumental in creating the mid-Namurian unconformity.

Major contrasts between the Mabou Group and the Horton Group

In many ways the deposits of the Mabou Group have much in common with those of the earlier, Tournaisian-age, Horton Group of Nova Scotia (see Hamblin, 1989; 1992; Hamblin and Rust, 1989). Both successions represent generally coarsening-upward, lacustrine to subaerial fill successions of subsiding fault-bounded basins, where laterally persistent depositional systems were vertically stacked. However, there are also many points of contrast, and a comparison between the two can be instructive in aiding interpretation of these rocks.

The Mabou subbasins did not begin with volcanic emplacement and a broad, shallow sag phase, as did the Horton rift. Thus they appear to represent a continuation or evolution of the existing setting, rather than a new regime. The Mabou Group conformably overlies the Windsor marine deposits and represents a gradual change to nonmarine deposition in the pre-existing subbasins, which had been partly filled by Windsor deposits. The Mabou subbasins were fault-bounded, but much wider than those of the Horton, and the margins are not obvious in most parts of Nova Scotia. Only minor proximal facies are present in a few locations in Nova Scotia, suggesting subdued margins with less topographic expression that were less dominated by fault-bounded subsidence. Subsidence did occur, but on a more modest scale and rate than that which characterized Horton Group deposition. The Mabou subbasins were not clearly asymmetrical structural segments of a larger rift system, but may show vestiges of this arrangement. It is likely that in this later stage of evolution of the rift, longitudinal, low-slope deposition was more dominant in the system. The coarsening-upward sequences are generally thinner and less clearly developed than in the Horton Group.

Mabou sedimentation occurred in a regional coarsening-upward sequence of two successive depositional systems, shallow-lacustrine (Hastings Formation) followed by low-slope subaerial floodplain-floodout-playa-mudflat (Pomquet Formation) in nearly all locations in Nova Scotia. These formations are considered to be tectonically controlled, three-dimensional depositional systems with diachronous boundaries, but their basinwide occurrences in an invariably consistent order indicates they represent general tectonic phases of basin evolution through time. Each depositional system includes several facies assemblages representative of specific depositional settings distributed in space throughout the depocentre during the phase of basin evolution represented by that system. Differences in distribution of proximal vs. distal assemblages and predominant sediment sources are apparent through the study area. However, these differences are insufficient to delineate definable structural segments of the rift, as is true of the Horton Group. Thick Windsor and Mabou deposits, and waning of the tectonic subsidence rate must have smoothed out the topographic features that controlled deposition in the subbasins.

The Mabou Group lacustrine facies (Hastings Formation) has much more limestone, dolostone, and algal and oolitic beds than the earlier Horton lacustrine phase (Strathlorne Formation), suggesting less clastic input and more calcareous chemical deposition in the Mabou lakes. The Mabou lacustrine facies always displays abundant evidence of deposition above wave base, periodic exposure and shoreline-floodplain impingement with only very thin anoxic units, denoting a generally shallower but still extensive lake system. In contrast, Horton lacustrine deposits represent more permanent and generally deeper lakes with thicker shaly and anoxic units, and abundant deposition below wave base. Mabou lacustrine facies also display abundant evidence of more saline and more fluctuating waters, reflecting their direct evolution from pre-existing Windsor marine evaporite subbasins and a generally shallower configuration, less dominated by fault-bounded subsidence.

Mabou subbasins existed during the waning phases of the Lower Carboniferous distensive tectonic regime and so were less dominated by fault-bounded subsidence and were primarily filled by fluvial deposits. Conversely, Horton subbasins were more directly dominated by fault subsidence during the period of maximum tectonic activity and had the primarily lacustrine infill expected for an underfilled basin. The Mabou nonaqueous fluvial-floodplain facies are much more dominated by red pedogenic siltstone (vertisol and calcisol) and small fluvial channels, and have much less fanglomerate than those of the Horton, where fluvial sandstones are extensive. Mabou sandstones are far more mature, suggesting dominance of multicyclic detritus derived primarily from erosion of prior Horton clastic rocks and Windsor carbonates (and therefore are very carbonate-rich) that were faulted and uplifted at the subbasin margins. In contrast, Horton clastic rocks were generally less mature, first-cycle sediments derived from newly exposed and uplifted granitic and metamorphosed basement at the fault-bounded margins.

ECONOMIC CONSIDERATIONS

Hydrocarbon potential

Hamblin et al. (1997) studied the lacustrine oil shales of the late Viséan–early Namurian Rocky Brook Formation (correlative to the Hastings Formation) of west-central Newfoundland (Fig. 75). They found dark grey, organic-rich, lacustrine mudstone with up to 15 per cent total organic carbon (T.O.C.) forming significant volumes of marginally mature hydrocarbon source rocks at surface. These can be directly correlated with oil and gas shows and solid bitumens recovered in Deer Lake Subbasin. They state that this data "suggests that the hydrocarbon source rock potential of the lower part of the Barachois, Mabou and Canso groups of Newfoundland, Nova Scotia and adjacent offshore areas, merits further study" (Hamblin et al.,1997).

A minor reconnaissance program of outcrop geochemical sampling of Hastings Formation mudstones in this study yielded very different results, which may discourage further inquiry (Appendix 3). Twenty-four samples taken from six different Hastings Formation outcrop sections showed the following ranges of Rock-Eval geocehmical parameters: Total Organic Carbon (TOC) 0.08–0.84 %, Hydrogen Index (HI) 0–161, Oxygen Index (OI) 0–408, and Maximum Temperature of Pyrolysis (Tmax) 344–450. Samples from Broad Cove (and to a lesser extent, Cape Dauphin and Cable Landfall Creek) were clearly more organic-rich than most. These data, from generally organic-lean rocks, are somewhat unreliable, but suggest oxidized, terrestrial, lipid-poor mudstones with relatively low thermal maturity (M. Fowler, M. Obermajer, pers. comm., 1999). Data regarding organic matter and thermal maturity were also derived from 27 palynological preparations from six outcrops of both the Hastings and Pomquet formations (Appendix 2) (Utting, 1996). Organic matter obtained was primarily dispersed, woody and coaly material deposited in oxygenated terrestrial environments with Thermal Alteration Index values (TAI) ranging from 2- to 4-, mostly 2-/2+ (Utting, 1996). The oil generation zone begins at TAI 2-, and ceases at TAI 3, whereas gas generation begins at TAI 3- and ceases at TAI 4 (Utting and Hamblin, 1991). Traces of *Botryococcus* algae were found in a few samples from the lower Hastings at Broad Cove. This, plus the more organic-rich nature of the strata there, suggest promising possibilities for the adjacent Gulf of St. Lawrence.

In total, these data suggest that the outcropping Mabou Group rocks that were sampled have modest quantities of gas-prone organic matter which is currently within the oil window or at the low end of the gas window. Even the underlying strata of the Horton Group generally lie within the oil and gas generating windows (Utting and Hamblin, 1991). However, it must be emphasized that sampling was not systematic, and many outcrops with dark coloured mudstone were not sampled at all, leaving doubt as to the presence of organic-rich hydrocarbon source rocks in the Mabou Group of Nova Scotia. Furthermore, the organic content and thermal state of deeper, unexposed Mabou rocks, or those present in the offshore areas, is still completely unknown. In a regional sense, Ryan et al. (1991) suggested that up to 4 km of younger strata were eroded from

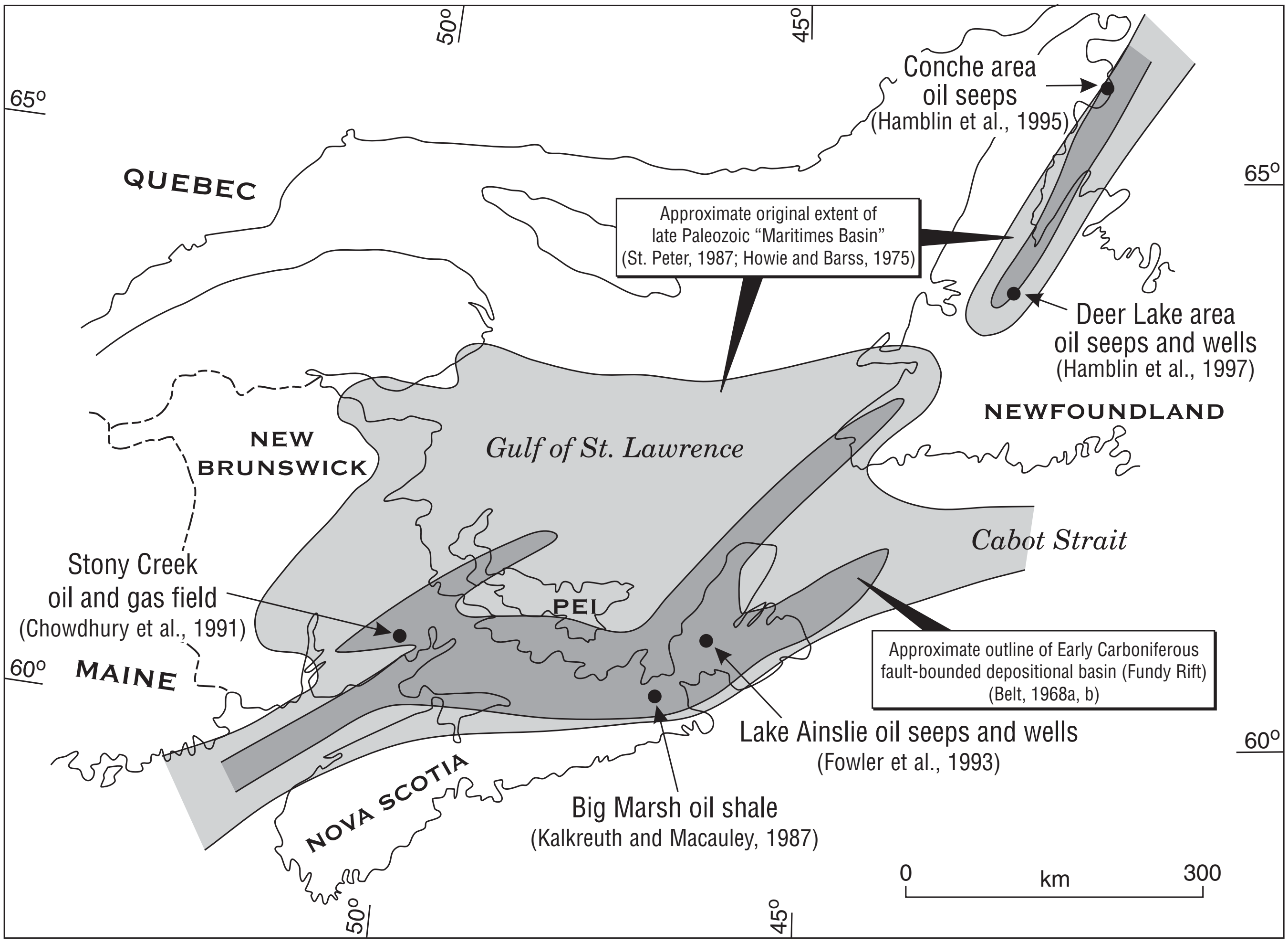

Figure 75. *Hydrocarbon shows of the Early Carboniferous Fundy Basin Rift within the late Paleozoic Maritimes Basin setting, including Mabou-age hydrocarbon shows at Deer Lake.*

much of Atlantic Canada, confirming that thermal maturity may be suitable for the generation and entrapment of hydrocarbons in most areas. The initial interpretive indication is that gas potential may be present in deeper parts of the Maritimes Basin.

Sandy shoreline deposits of the Hastings Formation (facies assemblage H2) and fluvial channel deposits of the Pomquet Formation (facies assemblage P2) provide potential reservoir traps. Lacustrine shoreline bodies of well-sorted sandstone, up to 4 m thick, were encountered in this study. They occur at the tops of fifth-order coarsening-upward sequences, and these sequences may be stacked into fourth-order megasequences. These potential reservoirs should have extensive mappable trends, parallel to the shoreline trend indicators (such as symmetrical ripple crests in associated shallow-lacustrine deposits) in each area or subbasin. These reservoirs are of moderate thickness, but the ability to trace them along depositional strike, their potential reservoir quality, and their intimate association with lacustrine mudstone source and seal rocks may make them attractive exploration targets.

Numerous previous authors have noted the presence and geometries of fluvial channel sandstone bodies in the upper Mabou Group. Norman (1935) noted two conspicuous channel sandstones (60 x 10 m) in western Cape Breton Island. Belt (1968b) identified channels 2 to 25 m thick with a low channel to interchannel ratio of 1:5. Carroll et al. (1972) observed channels averaging 14 m thick with a channel to interchannel ratio of 1:3 at the top of the Pomquet. McCabe and Schenk (1982) noted channels up to 8 m deep in New Brunswick. In this study, well-sorted, fluvial channel sandstone bodies up to 10 m thick were identified in the upper Hastings (H4) and the Pomquet (P2) formations. The lateral extent of these is unknown, as no outcrops in this study were exposed for more than about 15 m laterally. Belt (1964, 1965) stated that sandstones of the Mabou Group are 80 to 100 per cent mature quartz grains, as opposed to the 45 to 75 per cent quartz content of younger sandstone units. The lack of lithic fragments in these multicyclic sediments bodes well for reservoir quality. However, the only extant data on Mabou reservoir quality is that of Rehill (1996), in the offshore Gulf of St. Lawrence. There, very fine- to fine-grained sandstones have porosities of 7 to 10 per cent and low permeabilities.

The general stratigraphic arrangement of lacustrine potential source rocks overlain by shoreline and fluvial potential reservoir rocks, and the intimate interbedding of fluvial, shoreline and open lacustrine facies are positive features for potential hydrocarbon trapping. The absence of a thick regional seal unit, such as the Windsor Group evaporites, is a negative aspect. However, the Mabou Group was succeeded by a significant transpressive tectonic event (Alleghanian Orogeny) in mid-Carboniferous time, which may have provided new possibilities in the form of structural and unconformity-related traps. Clearly, more systematic and complete sampling and investigation of the hydrocarbon potential of the Mabou is required, and fully warranted, before final conclusions are possible.

Mineral potential

Redbed copper deposits, precipitated at low temperature from oxidizing, flowing, subsurface waters that encounter reducing conditions (Rose, 1976; Kirkham, 1989; Ryan et al., 1989), may be important in the Mabou Group. These solution-front ore deposits typically occur in thick, nonmarine, sandstone and mudstone redbed successions overlying evaporative successions, particularly in semiarid, fault-bounded, closed subbasins (Rose, 1976; Kirkham, 1989; Ryan et al., 1989). These basic conditions are clearly fulfilled by the redbeds of the Pomquet Formation. Silver, gold, and uranium are common accessories in these occurrences, which are usually found in lenses in channel sandstone lags where plant fragments are concentrated (Rose, 1976; Ryan et al., 1989). The Pomquet Formation is characterized by many of the factors present in these deposits elsewhere, and Ryan and Boehner (1995) emphasize that redbed copper deposits are commonly concentrated at the boundary between red clastic rocks below (Pomquet?) and grey clastic rocks above (Port Hood?). Hence the upper portion of the Mabou Group, and, more specifically, the trends of channel sandstone reservoir and aquifer bodies, are important in delineating potential areas for these deposits. During this study, a small showing of copper was recorded, occurring as numerous small greenish nodules in a thick, red, channel sandstone of the Pomquet Formation at Broad Cove. Again, it is obvious that further investigation of these possibilities is required in order to properly evaluate the economic potential of the Mabou Group.

CONCLUSIONS

This study utilized a systematic sedimentological approach to establish facies distributions of the Early Carboniferous (late Viséan to early Namurian) Mabou Group of Nova Scotia. Lithological and paleocurrent data establish the basin geometry and style, positions of controlling margins, the spatial arrangement and distribution of sedimentary environments, and the evolution of depositional style during the time of Mabou deposition. This information is organized into a four-dimensional tectonosedimentary analysis of the basin-fill sequence, which can serve as a framework for more detailed studies and comparisons, and ultimately for resource exploration.

1. The late Viséan to early Namurian portion of the Maritimes Basin represents the waning stages of the previously developed Late Devonian-Early Carboniferous Fundy Basin Rift, which postdated Acadian compression and predated Alleghanian transpression. The Mabou Group basin-fill succession of Nova Scotia is similar to that of known, distensive, fault-bounded basin-fills (such as the Horton Group) with no characteristics of transtensive systems. It is characterized by a large total depositional area (100 000’s km^2), and near-vertical stacking of laterally continuous formations of moderate total thickness (1–2 km) in several related subbasins.

2. The several subbasins can be loosely defined as about 150 to 200 km long x 100 km wide in size (broader than the underlying Horton subbasins), not distinctly separated by intervening uplifts, and laterally conjoined along the length of the rift, each containing essentially the same facies and overall sequence. There is a suggestion in the paleocurrent data of southwestern Cape Breton Island that the asymmetrical half-graben subbasin segments, typical of the Horton Group and developed about 15 Ma earlier, may have still exerted some influence. Post-Mabou deposition, mid-Carboniferous transpression altered the regional stress regime and separated some Mabou subbasins along the Cobequid-Chedabucto Fault.

3. Deposition in the subbasins of Nova Scotia was primarily influenced by mild subsidence and relatively slow sedimentation. Subdued fault-bounded margins were located primarily beyond the edges of the study area outcrops, reflecting broadening and homogenization of the original rift through Early Carboniferous time. Detritus was primarily derived from cannibalized Horton and Windsor sedimentary cover rocks, rather than metamorphosed basement. However, in a few locations, coarse-grained marginal facies, with extraformational pebbles, indicate the nearby presence of subbasin margins beyond the boundaries of the present study.

4. Two, stacked, three-dimensional depositional systems (Hastings Formation, Pomquet Formation) form a single, internally complex, third-order asymmetrical coarsening-upward succession (Mabou Group) that represents progressive waning of tectonic subsidence in the late evolution of the rift. The marine carbonate and evaporite environment, which characterized the underlying Windsor Group, gradually gave way to a nonmarine, shallow-lacustrine, muddy setting (Hastings Formation). This may have occurred as a result of cessation of tectonic subsidence, blockage of the marine connection, or glacially induced global eustatic sea-level fall. As subsidence decreased, it allowed renewed, widespread dispersal of subaerial fine-grained floodplain, floodout, and fluvial deposits (Pomquet Formation), which intermittently intertongued with, and finally overwhelmed the lakes and overfilled the subbasins.

5. The Hastings Formation, of late Viséan–early Namurian age, comprises thin bedded, grey mudstone with interbedded fine-grained sandstone, stromatolitic and oolitic limestone, and minor reddish siltstone and sandstone. It was deposited as the early phase of Mabou Group sedimentation in most areas of Nova Scotia. Four facies assemblages are identified and interpreted as components of a primarily lacustrine depositional system deposited within pre-existing, fault-bounded subbasins as the marine realm of the Windsor Group slowly converted to a nonmarine basin-fill during the waning stages of rift filling. The lakes were large, about 150 to 200 km long by 100 km wide in size, but very shallow, perhaps only a few tens of metres deep in most parts.

6. The components of the Hastings lacustrine depositional system include: a) Facies Assemblage H1 – dark grey mudstone with thin sandstone and limestone (open, shallow-lacustrine) comprising the bulk of the formation, b) Facies Assemblage H2 – thick, grey, fine-grained sandstone (lacustrine nearshore and shoreline), c) Facies Assemblage H3 – red siltstone with thin interbeds of very fine- to fine-grained sandstone (subaerial pedogenic floodplain), and d) Facies Assemblage H3 – thick, red, very fine- to medium-grained sandstone (fluvial channel), which is only a minor component. Paleocurrent data suggest that trends of symmetrical ripple crests approximate lacustrine shoreline trends, and that flow directions of ripple crosslamination indicate offshore and obliquely alongshore transport.

7. The open, shallow-lacustrine facies assemblage (H1) is characterized by multiple, stacked, fifth-order, asymmetrical, transgressive-regressive, shallowing-upward sequences attributed to tectonic control. Each coarsening-upward sequence is inferred to represent minor, but instantaneous, deepening followed by gradual filling into shallow water as sediment input from the lake margins replenished the lacustrine basin. Sequences are numerous, thin, muddy, and can be combined into similar, shallowing-upward fourth-order bundles or megasequences, interpreted as partial lake-fill sequences. The dominance of this style of deposition in the Hastings has not been emphasized previously. In the western Cape Breton area, the depositional subbasin may have been a broad, shallow, asymmetrical half-graben similar to, and evolved from, those that characterized earlier Horton deposition.

8. The Pomquet Formation, of early Namurian age, comprises thin-bedded red siltstone, fine- to medium-grained sandstone, minor, red, pebbly, coarse-grained sandstone, and minor, grey mudstone. It was deposited as the later phase of Mabou sedimentation in most areas of Nova Scotia. Four facies assemblages are identified and interpreted as components of a primarily subaerial floodplain-floodout-playa-mudflat depositional system with fluvial channels, deposited as the final fill of the fault-bounded subbasins in the waning stage of rift filling.

9. The components of the Pomquet floodplain depositional system include: a) Facies Assemblage P1 – red, massive, blocky siltstone (subaerial pedogenic floodplain-floodout-playa-mudflat) comprising the bulk of the formation, b) Facies Assemblage P2 – thick, red, fine- to medium-grained sandstone (fluvial channel), c) Facies Assemblage P3 – thin, quartz-pebble conglomerate (alluvial fan-braidplain), which is a minor (but very important) component, and d) Facies Assemblage P4 – thin, grey mudstone (shallow lacustrine), which is only a minor component. Paleocurrent data suggest that fluvial flow indicators are generally oriented approximately perpendicular to subbasin margins and lacustrine shorelines in most areas. The flow directions obtained at Carrigans Cove, opposite to those of nearby outcrops and interpreted as representing sediment input from the opposite margin, suggest subbasin widths of 100+ km, much wider than those of the earlier Horton deposits.

10. The subaerial pedogenic playa-mudflat-floodplain-floodout facies assemblage (P1) is characterized by ubiquitous pedogenic features and effects such as desiccation cracks, peds, slickensides, massive blocky to hackly texture, caliche glaebules and concretions, calcrete layers, evaporative crystal moulds, and rare rootlets. These all attest to the dominance of relatively slow, low-energy, subaerial deposition as the predominant setting for Pomquet deposition. The pervasive occurrence of vertisols suggests dry conditions with seasonal wet phases, and the presence of calcisols is typical of warm, semiarid climates, with repeated depositional hiatuses of relatively long duration. Significant portions of this facies occur in asymmetrical coarsening-upward fifth-order terrestrial “chronosequences”, interpreted as representing flood and splay sedimentation. In some areas, these are arranged into fourth-order coarsening-upward megasequences. The dominance of this style of

deposition in the Pomquet has not been previously emphasized and more detailed sedimentological and stratigraphic study is recommended.

11. The alluvial fan and braidplain deposits of Facies Assemblage P3 represent immature, low-sinuosity braided stream deposits at the distal toes of prograding alluvial fans, with intraformational and some extraformational detritus shed from the subdued, fault-bounded, subbasin margins. This facies is thus the key to delineating those margins and the subbasin size. As these margins are primarily located outside the confines of the onshore study area, the facies could be much more important in offshore areas, and in New Brunswick.

12. In comparison to similar Horton Group deposits, the Mabou Group displays no associated volcanics; broader, shallower and less well-defined subbasins; subdued subbasin margins less dominated by fault-bounded subsidence; deposition that occurred in the final waning phase of the Fundy Rift; more abundant lacustrine carbonate deposition indicating less clastic input; more abundant evidence of very shallow, saline, lacustrine deposition and exposure; less abundant and less organic-rich lacustrine mudstone; more abundant fine-grained floodplain deposits with pedogenic alteration indicating dominance of subaerial accumulation punctuated by numerous hiatuses; fluvial deposits dominated by multicyclic mature detritus cannibalized from prior sedimentary strata rather than basement sources; and significant, but less obvious, economic resources.

13. There are hints that the Mabou Group may contain significant, as yet undiscovered, economic resources of hydrocarbons. Shallow-lacustrine facies in central Newfoundland, coeval to the Hastings Formation, contain oil shales and oil source rocks, although comparably rich strata have not yet been identified in the Hastings of Nova Scotia. The strata lie within the oil and gas generating window of thermal maturity. There are potential reservoir rocks present in thick lacustrine shoreline and fluvial channel sandstone facies of both the Hastings and Pomquet formations (Facies Assemblages H2, H4, P2). Complex intertonguing of lacustrine and shoreline and fluvial facies, the presence of a major post-Mabou depositional hiatus and the regional orogenic event of the post-Mabou Alleghanian transpression may have created numerous stratigraphic, unconformity, and structural trap possibilities. Further investigation, onshore and offshore, may yield more positive results.

14. There are also hints that the Mabou Group may contain significant, as yet undiscovered, metal resources. Redbed copper showings are present in at least one fluvial channel sandstone of the Pomquet Formation (Facies Assemblage P2), and additional deposits may occur elsewhere. The basic indicator conditions for redbed copper deposits (i.e., solution-front ore deposits occurring in thick, nonmarine, sandstone and mudstone redbed strata overlying evaporite successions in fault-bounded closed subbasins during a semiarid climate period) are admirably met by the upper Mabou Group (Pomquet Formation). Further investigation is recommended.

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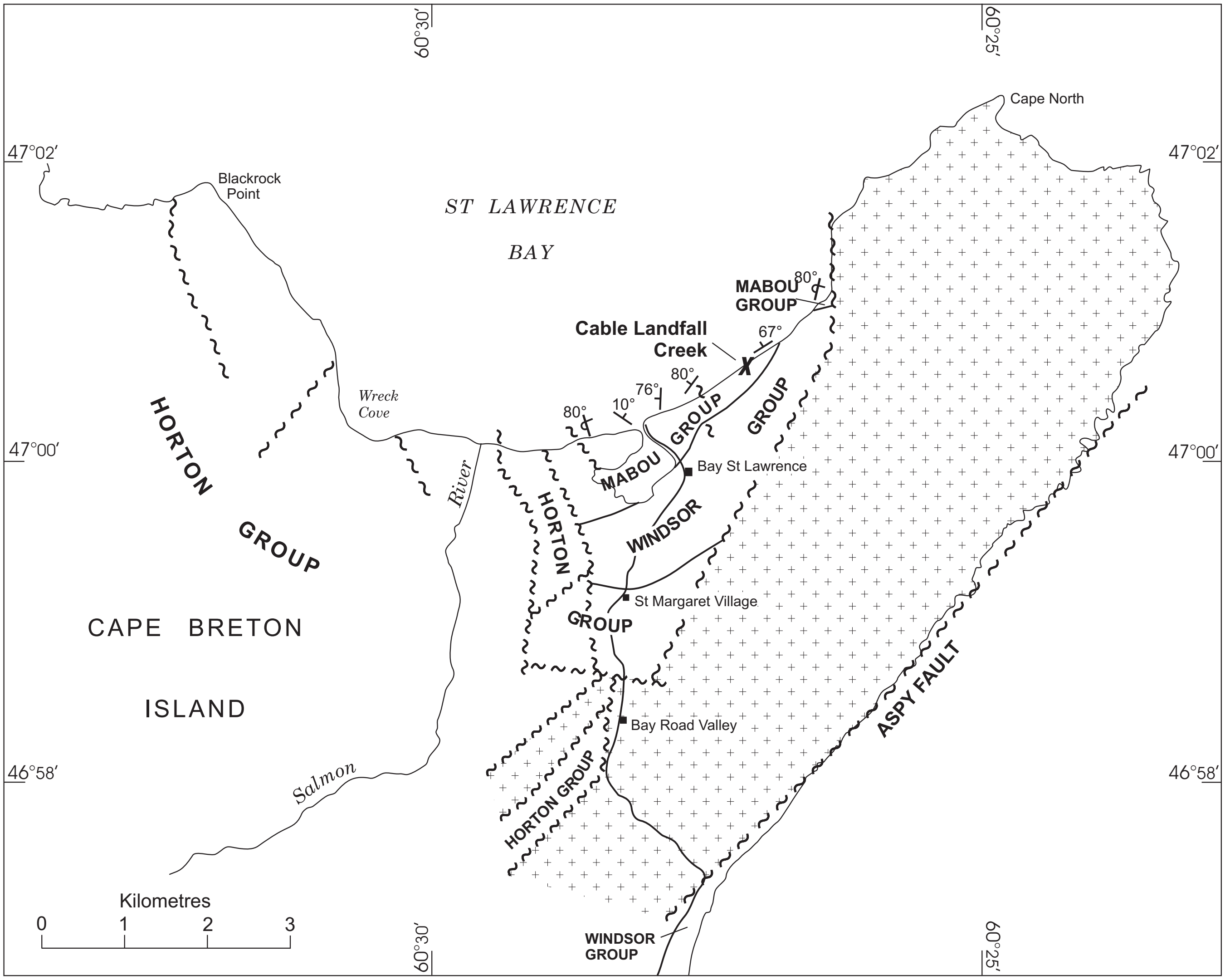
APPENDIX 1

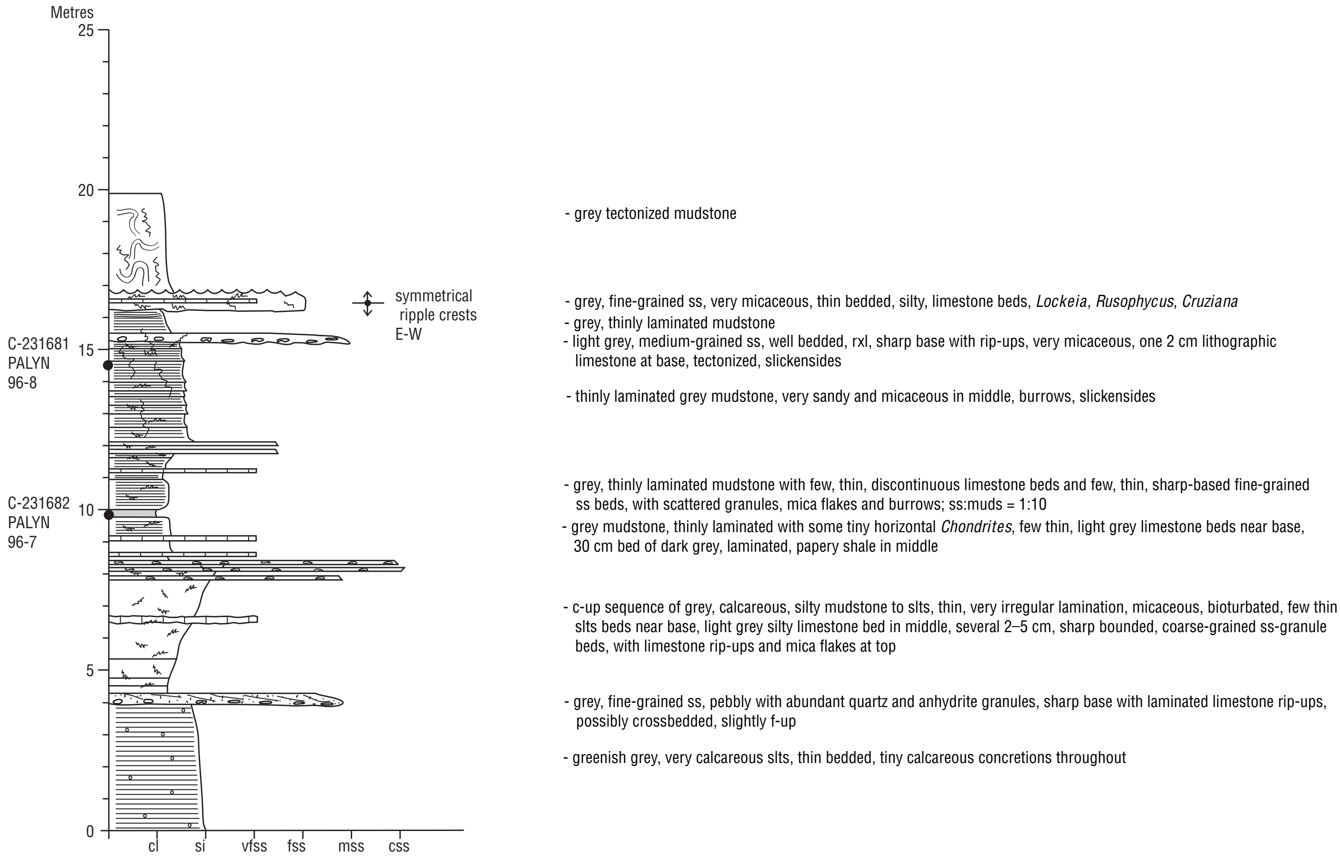
MEASURED SECTIONS, LOCATIONS, AND PALEOCURRENT DATA

Outcrop	Latitude/ longitude	1:50 000 NTS sheet	NTS grid location	Stratigraphic interval
		N. Cape Breton Island		
Cable Landfall Creek	47° 01' N, 60° 27' W	Cape North 11 N/1	937092	Hastings
Bay St. Lawrence	47° 00' N, 60° 27' W	Cape North 11 N/1	905084–909083	Pomquet
Cape Dauphin	46° 21' N, 60° 25' W	Bras d'Or 11 K/8	985353–989352	Windsor-Hastings-Cumberland
Point Edward	46°11' N, 60° 14' W	Sydney 11 K1	131182–138184	Hastings-Pomquet
		S.W. Cape Breton Island		
Broad Cove	46° 16' N, 61° 17' W	Margaree 11 K/6	327244–331254	Windsor-Hastings-Pomquet-Cumberland
SW Mabou RR Cut	46° 01' N, 61° 27' W	Lake Ainslie 11 K/3	196975	Hastings
Ragged Point	45° 58' N, 61° 32' W	Cape George 11 F/13	139911	Windsor-Hastings-Pomquet
Creignish	45° 44' N, 61° 28' W	Port Hawkesbury 11 F/11	195649–195658	Pomquet
Port Hastings	45° 38' N, 61° 24' W	Port Hawkesbury 11 F/11	252552–262545	Windsor-Hastings-Pomquet
Little River Spillway	45° 36' N, 61° 16' W	Port Hawkesbury 11 F/11	355514	Hastings
Carrigans Cove	45° 32' N, 61° 11' W	Port Hawkesbury 11 F/11	414439	Pomquet
		Antigonish area		
Cape Jack	45° 42' N, 61° 34' W	Antigonish 11 F/12	115605	Hastings
Barrios Head	45° 39' N, 61° 36' W	Antigonish 11 F/12	088561–081560	Hastings-Pomquet
Arthurs Point	45° 38' N, 61° 42' W	Antigonish 11 F/12	015544–005544	Pomquet-Cumberland
		Joggins-Parrsboro area		
Partridge Island	45° 23' N, 64° 21' W	Parrsboro 21 H/8	948254–950251	Windsor-Hastings
Downing Cove	45° 45' N, 64° 25' W	Amherst 21 H/16	897673	Hastings-Pomquet-Cumberland
Downing Head	45° 45' N, 64° 24' W	Springhill 21 H/9	885670–885665	Hastings

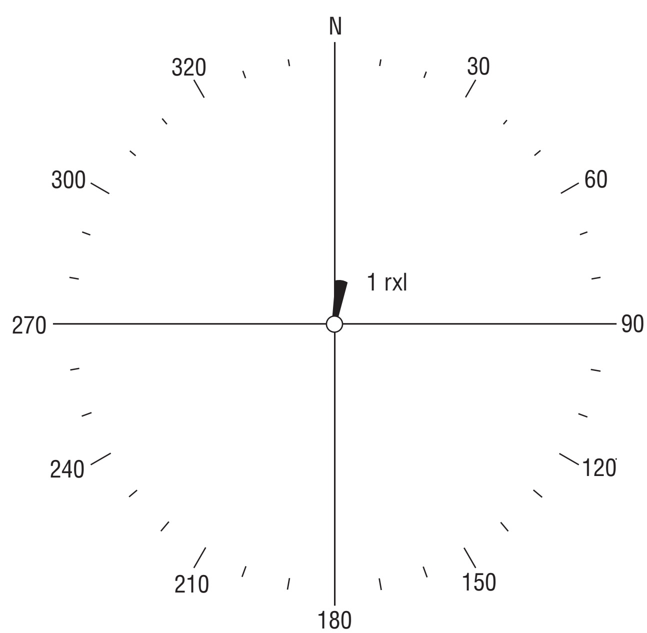


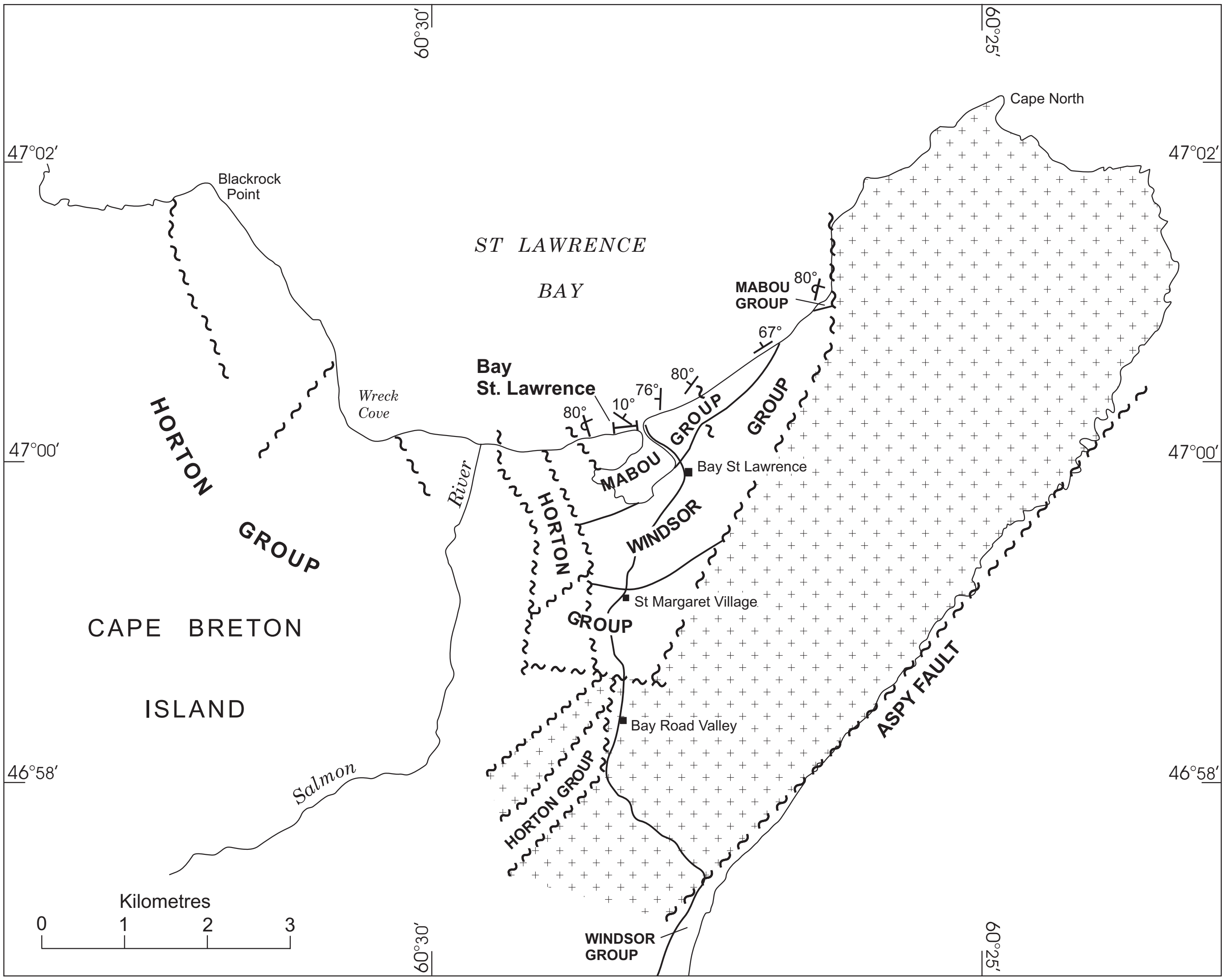
Cable Landfall Creek. Lower Hastings Formation; general strike 45°, dip 67° NW.

Cable Landfall Creek Section

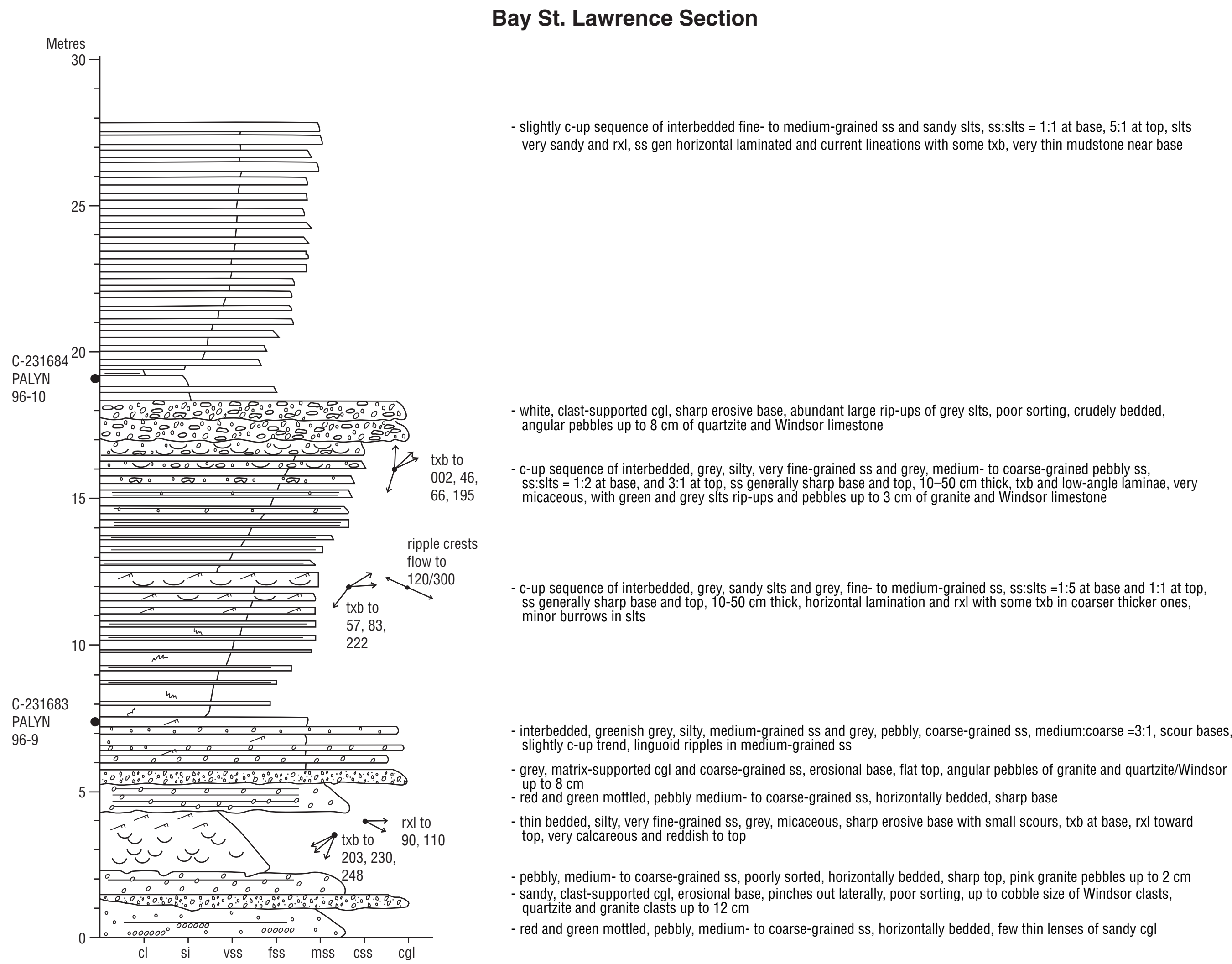


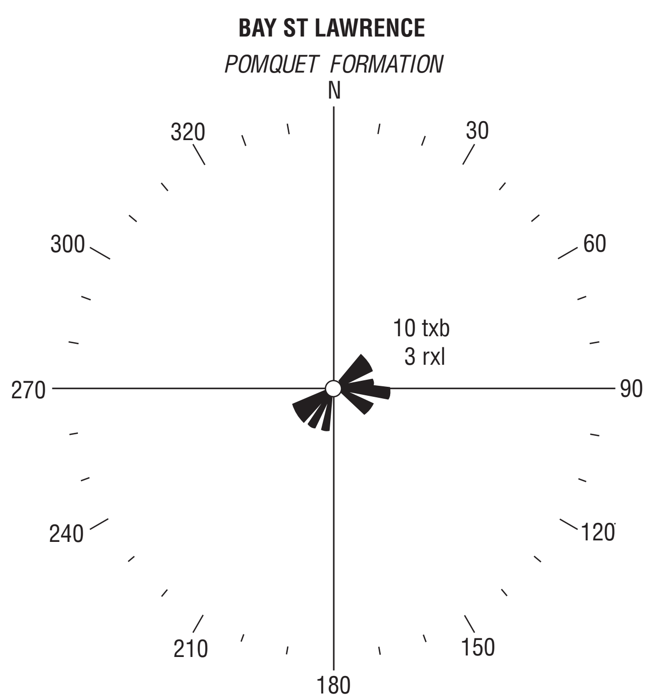
CABLE LANDFALL CREEK
HASTINGS FORMATION

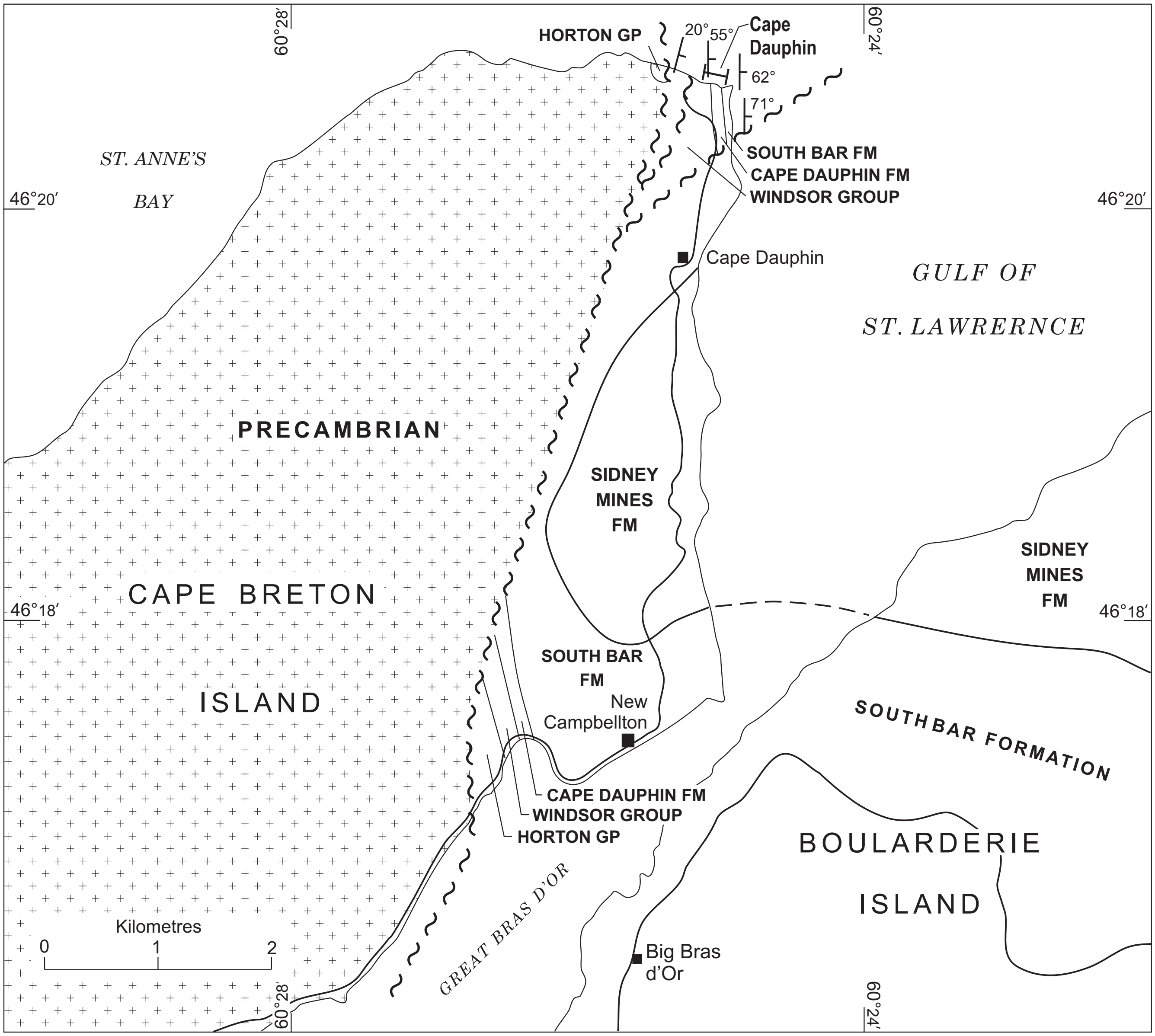




Bay St. Lawrence. Pomquet Formation; general strike 110°, dip 15° N.

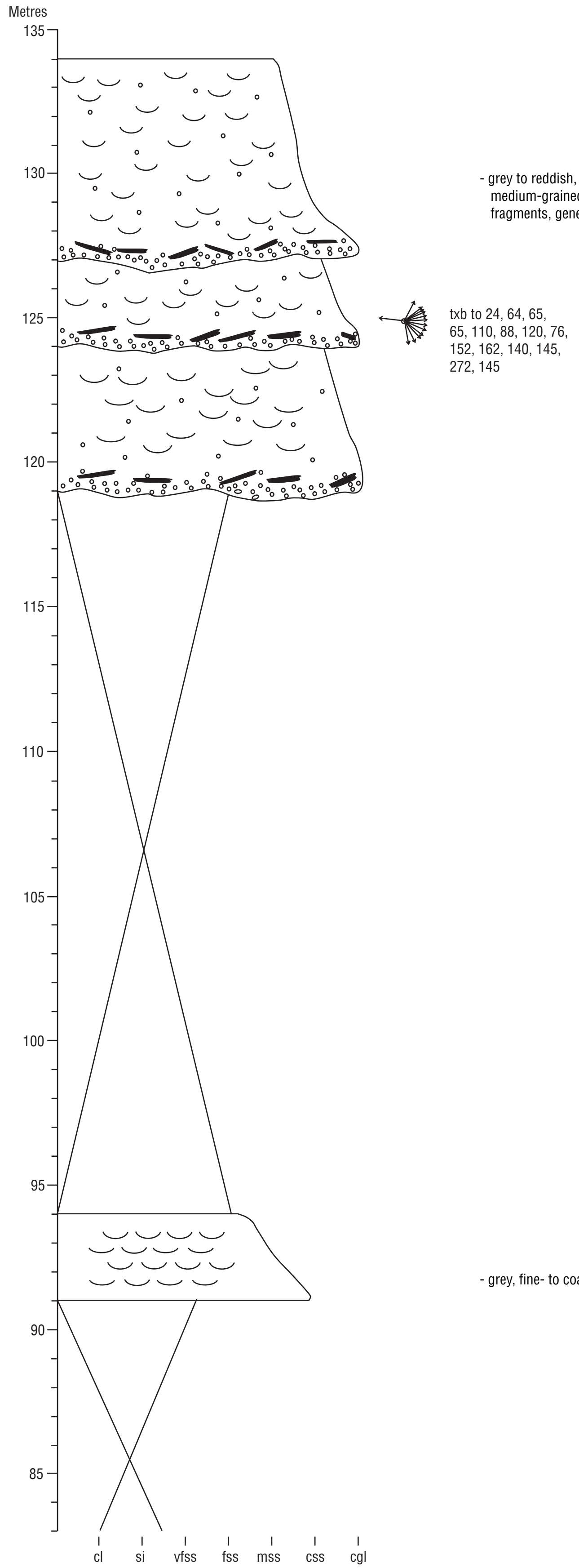

Bay St. Lawrence Section
Metres
30
25
20
15
10
5
0
C-231684
PALYN
96-10
C-231683
PALYN
96-9
cl
si
vss
fss
mss
css
cgl
txb to
002, 46,
66, 195
ripple crests
flow to
120/300
txb to
57, 83,
222
rxl to
90, 110
txb to
203, 230,
248
- slightly c-up sequence of interbedded fine- to medium-grained ss and sandy slts, ss:slts = 1:1 at base, 5:1 at top, slts very sandy and rxl, ss gen horizontal laminated and current lineations with some txb, very thin mudstone near base
- white, clast-supported cgl, sharp erosive base, abundant large rip-ups of grey slts, poor sorting, crudely bedded, angular pebbles up to 8 cm of quartzite and Windsor limestone
- c-up sequence of interbedded, grey, silty, very fine-grained ss and grey, medium- to coarse-grained pebbly ss, ss:slts = 1:2 at base, and 3:1 at top, ss generally sharp base and top, 10–50 cm thick, txb and low-angle laminae, very micaceous, with green and grey slts rip-ups and pebbles up to 3 cm of granite and Windsor limestone
- c-up sequence of interbedded, grey, sandy slts and grey, fine- to medium-grained ss, ss:slts =1:5 at base and 1:1 at top, ss generally sharp base and top, 10-50 cm thick, horizontal lamination and rxl with some txb in coarser thicker ones, minor burrows in slts
- interbedded, greenish grey, silty, medium-grained ss and grey, pebbly, coarse-grained ss, medium:coarse =3:1, scour bases, slightly c-up trend, linguoid ripples in medium-grained ss
- grey, matrix-supported cgl and coarse-grained ss, erosional base, flat top, angular pebbles of granite and quartzite/Windsor up to 8 cm
- red and green mottled, pebbly medium- to coarse-grained ss, horizontally bedded, sharp base
- thin bedded, silty, very fine-grained ss, grey, micaceous, sharp erosive base with small scours, txb at base, rxl toward top, very calcareous and reddish to top
- pebbly, medium- to coarse-grained ss, poorly sorted, horizontally bedded, sharp top, pink granite pebbles up to 2 cm
- sandy, clast-supported cgl, erosional base, pinches out laterally, poor sorting, up to cobble size of Windsor clasts, quartzite and granite clasts up to 12 cm
- red and green mottled, pebbly, medium- to coarse-grained ss, horizontally bedded, few thin lenses of sandy cgl


BAY ST LAWRENCE
POMQUET FORMATION
N
30
60
90
120
150
180
210
240
270
300
320
10 txb
3 rxl



Cape Dauphin. Hastings Formation; general strike 15°, dip 50° E.

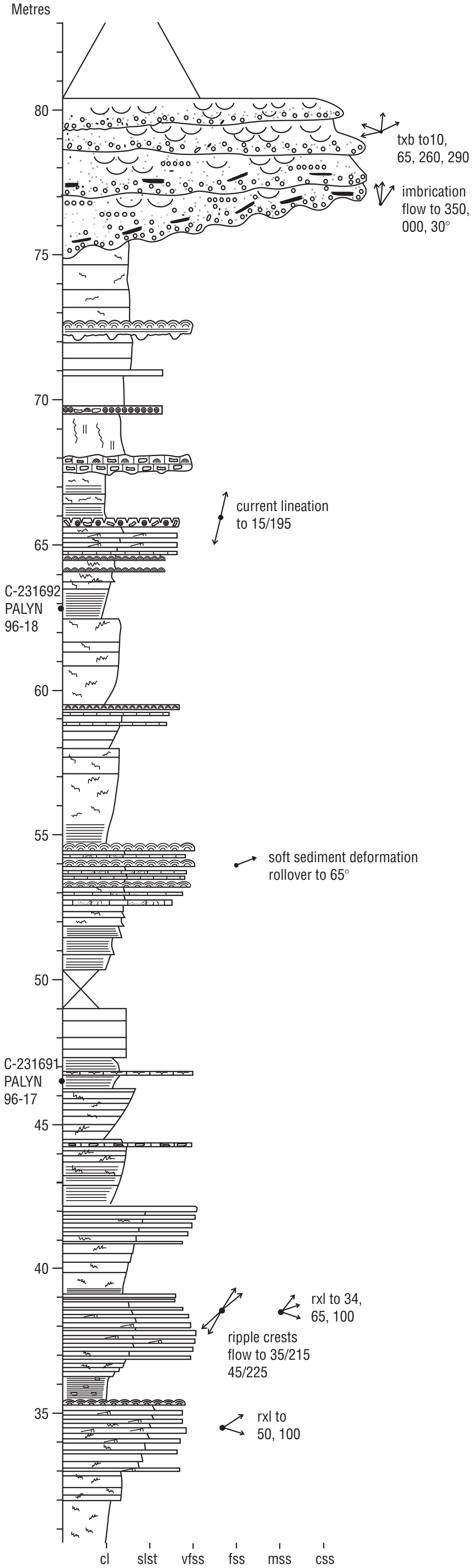
Cape Dauphin Section



- grey to reddish, medium-grained ss to pebbly coarse-grained ss, well sorted, thick bedded, multistoried, slightly f-up to medium-grained ss at top, mostly coarse-grained ss-granulestone, pebbles up to 3 cm, cgl lenses have large wood and log fragments, generally txb

- grey, fine- to coarse-grained ss, well sorted, f-up, txb, poorly exposed

Cape Dauphin Section cont.



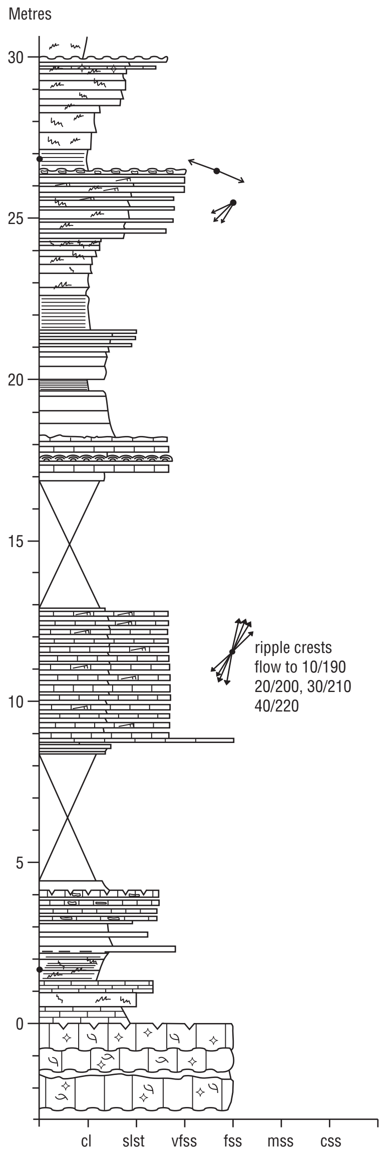
- grey, coarse-grained ss and cgl, multistoried, slightly f-up, poor to fair sorting, lenses of clast-supported cgl of 5–15 cm, pebbles of quartzite/granite, imbrication, faint crossbeds, large wood fragments, cgl separated by lenses of well sorted, pebbly, coarse-grained ss with txb

BASE OF SOUTH BAR FM

TOP OF HASTINGS FM

- dark greenish grey, silty mudstone to argillaceous slts, bioturbated, few, very thin, calcareous slts beds
- grey stromatolitic limestone, sharp scour base, muddy partings, minor brecciation
- greenish grey, very silty mudstone to slts, few, very thin slts beds with gradational boundaries
- grey, calcareous slts, bioturbated, brecciated
- greenish grey, silty mudstone
- dark grey, calcareous slts with oolites and few brecciated stromatolite fragments
- greenish grey, silty mudstone, fractures
- limestone breccia bed, erosional scoured base, lower 2/3 is dark grey, fine crystalline matrix with flat stromatolite breccia, upper 1/3 of large flat brecciated stromatolitic limestone in random deformed shapes, upper surface has bulbous and folded chunks
- dark greenish grey mudstone, some laminated, some blocky and bioturbated
- c-up sequence of dark greenish grey, laminated mudstone to grey, silty mudstone with few calcareous slts beds, to interbedded bioturbated silty mudstone and very fine-grained ss, to top bed of flat-pebble limestone breccia with mudcracks and pisolites/oolites
- greenish grey, silty claystone, blocky, bioturbated, few, thin calcareous slts beds with rxl in middle
- thin c-up sequence of interbedded, dark greenish grey mudstone and thin, argillaceous limestone beds, upper one has sharp erosive base and stromatolitic bulbous top with lamination and tiny mudcracks filled with dark mud from above
- dark greenish grey mudstone, laminated and organic rich near base, rest is bioturbated; very few, silty bands
- c-up sequence of interbedded, dark greenish grey laminated mudstone and grey stromatolitic or argillaceous limestone, some soft sediment deformation all rolled over consistently to NE
- very greenish grey, silty mudstone, laminated, few, very thin, calcareous siltstone beds
- dark grey, thinly laminated mudstone, no bioturbation, thin argillaceous limestone with mudcracks and breccia
- thin c-up sequence of interbedded grey to greenish grey mudstone and gradational-bounded, thin calcareous slts, bioturbated
- thin c-up sequence of laminated and bioturbated grey mudstone, with few thin silty beds, and one brecciated argillaceous limestone at top
- thick c-up sequence from mudstone at base, to interbedded calcareous slts and very fine-grained ss with sharp bases, to sharp upper surface on top, very fine-grained ss, bioturbated throughout
- thick c-up sequence from laminated grey mudstone with minor small concretions, to thinly interbedded mudstone and gradationally bounded slts with horizontal lamination and rxl, to interbedded laminated silty mudstone and calcareous slts to very fine-grained ss to argillaceous limestone with sharp boundaries and rxl, slight thinning in upper 1 m
- thick c-up sequence from greenish grey bioturbated mudstone at base, to mudstone with few thin calcareous slts beds, to interbedded greenish grey slts and grey, calcareous, silty, very fine-grained ss; ss have sharp bases and gradational tops with rxl, ss:slts = 1:2; top bed is sharp-bounded stromatolitic limestone with lumpy upper surface

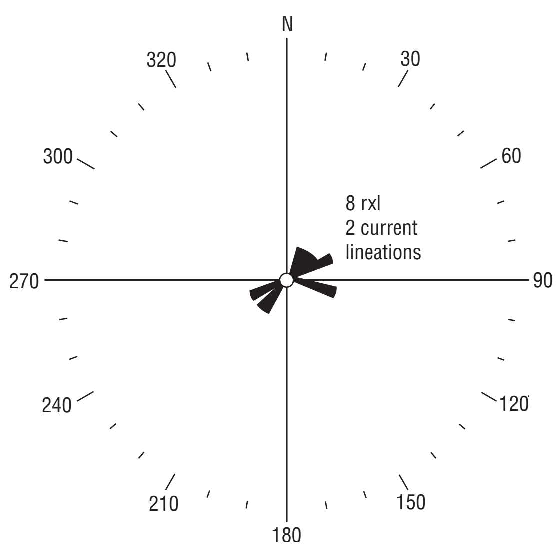
Cape Dauphin Section cont.



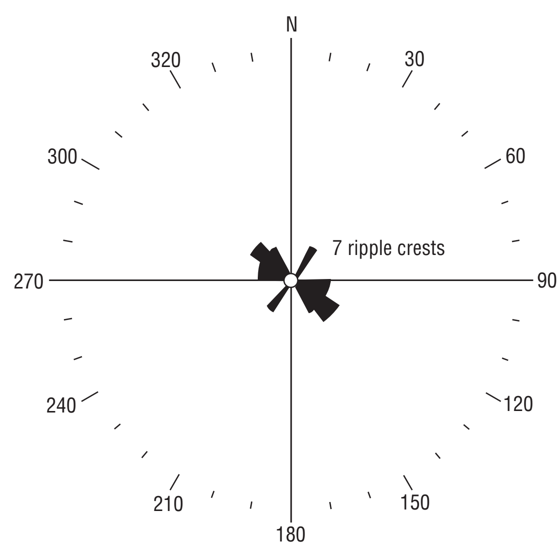
- interbedded, grey to greenish grey mudstone and argillaceous limestone in c-up sequence, ls:slts =1:5, bioturbated, ripple forms on top, calcite vugs
- dark greenish grey mudstone, laminated at base, bioturbated toward top, few discontinuous thin slts beds throughout
- c-up sequence of interbedded, grey, clay-rich siltstone and silty, very fine-grained ss, ss:slts =1:1 at base, 3:1 at top, ss general sharp-bounded and horizontal laminated and rxl, sharp erosive bases, organic debris on laminations, top surface has very calcareous cement and brecciated zone with linguoid ripples
- greenish grey, laminated mudstone, bioturbation increases upward, thin, gradationally bounded slts increase upward, thoroughly bioturbated at top
- grey laminated mudstone
- thin, c-up sequence of grey, silty mudstone and calcareous slts, slts have sharp scoured bases, lamination, sharp top
- dark grey, thinly laminated mudstone
- grey, silty mudstone, micaceous, few thin slts beds
- interbedded grey limestone and slts, one thin, stromatolitic limestone in middle, one at top with very irregular texture, sharp bases and tops, ls:slts = 1:2
- thinly interbedded, grey, clay-rich slts and pale grey, argillaceous limestone, sharp bases and tops, ls:slts = 2:1, limestones range up to 10 cm and are discontinuous, laminated, undulating concretion-like boundaries, few have rippled tops
- thin c-up sequence from silty mudstone, to thinly laminated slts, to thin, rusty-weathering very irregular calcareous fine-grained ss with fractures and sharp top
- dark greenish grey, silty mudstone, poorly exposed
- thinly interbedded, greenish grey, sandy slts and grey silty limestone with gradational boundaries, limestones have angular rip-ups and upper surfaces have mudcracks filled with green mud
- greenish grey, silty mudstone and sandy slts
- greenish grey, silty, very fine-grained ss, thin bedded, gradational base, sharp top
- dark grey, organic-rich silty mudstone, thinly laminated, minor burrowing
- pale grey silty limestone, thin bedded
- dark greenish grey slts, blocky, slickensides, bioturbated?
- greenish grey, calcareous clay slts, thin bedded, nonfossiliferous
- grey, fossiliferous limestone, thick bedded, vuggy, fine crystalline, more argillaceous bed in middle, top surface sharp and irregular with mudcracks, rusty staining

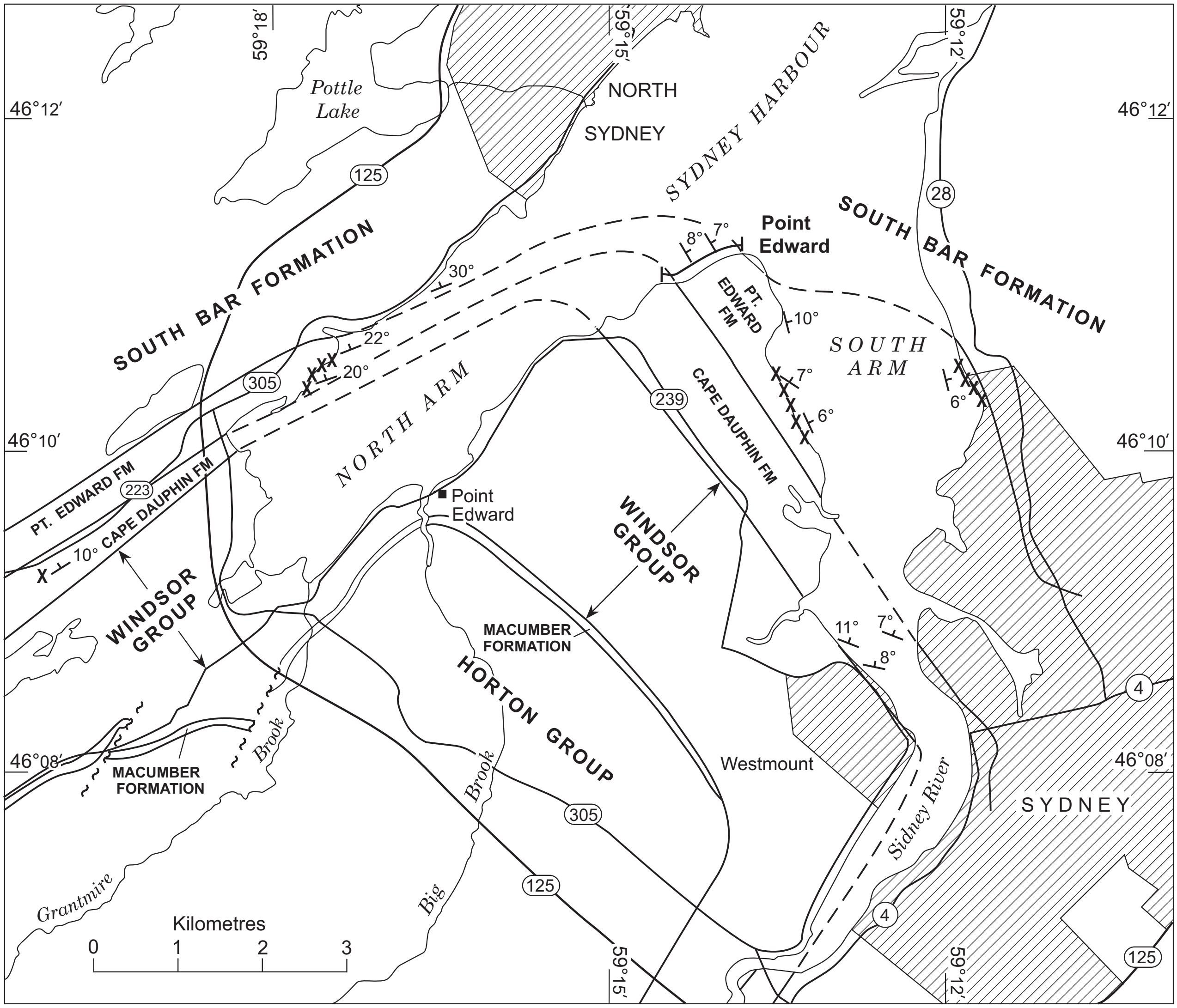
CAPE DAUPHIN

HASTINGS FORMATION



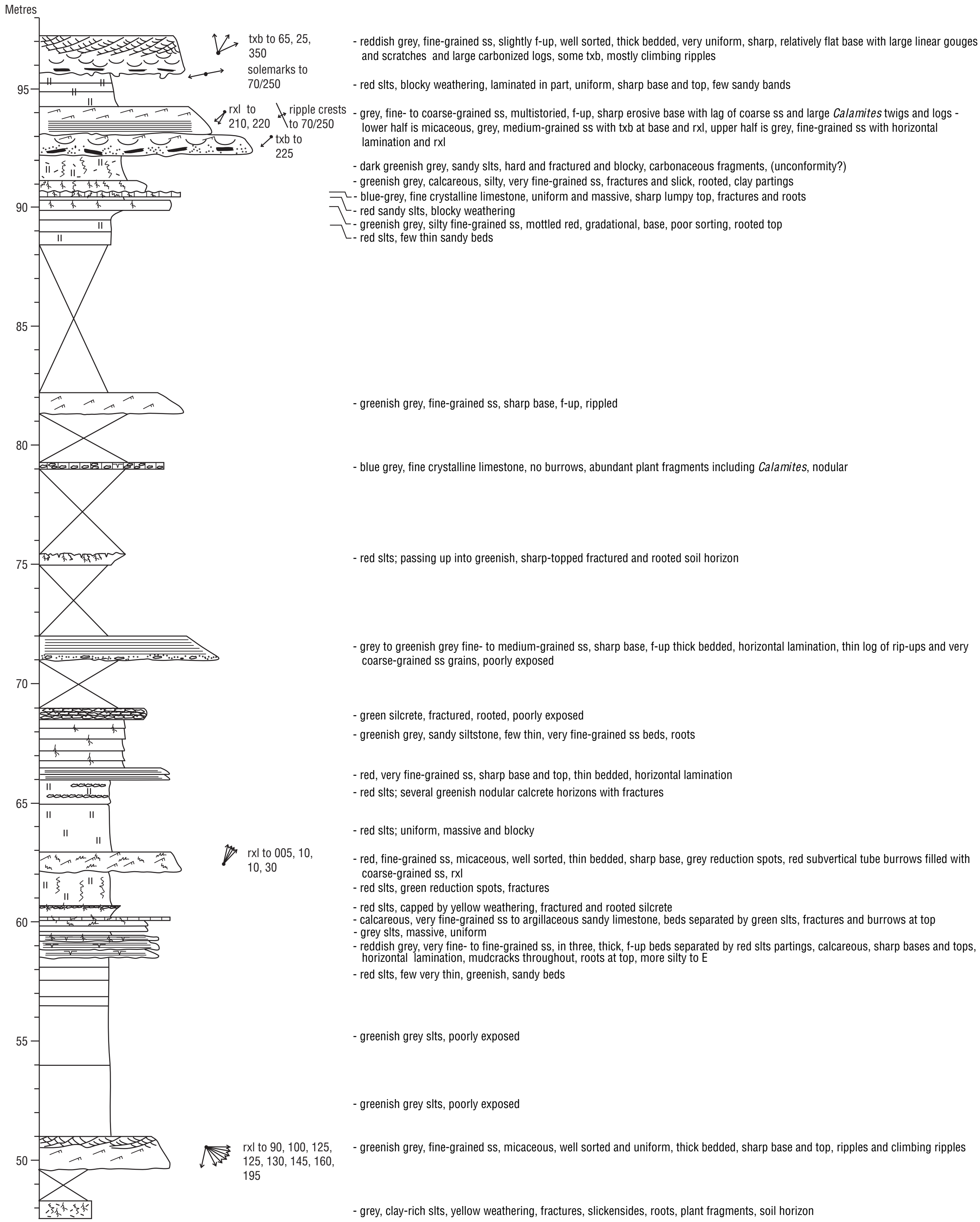
HASTINGS FORMATION



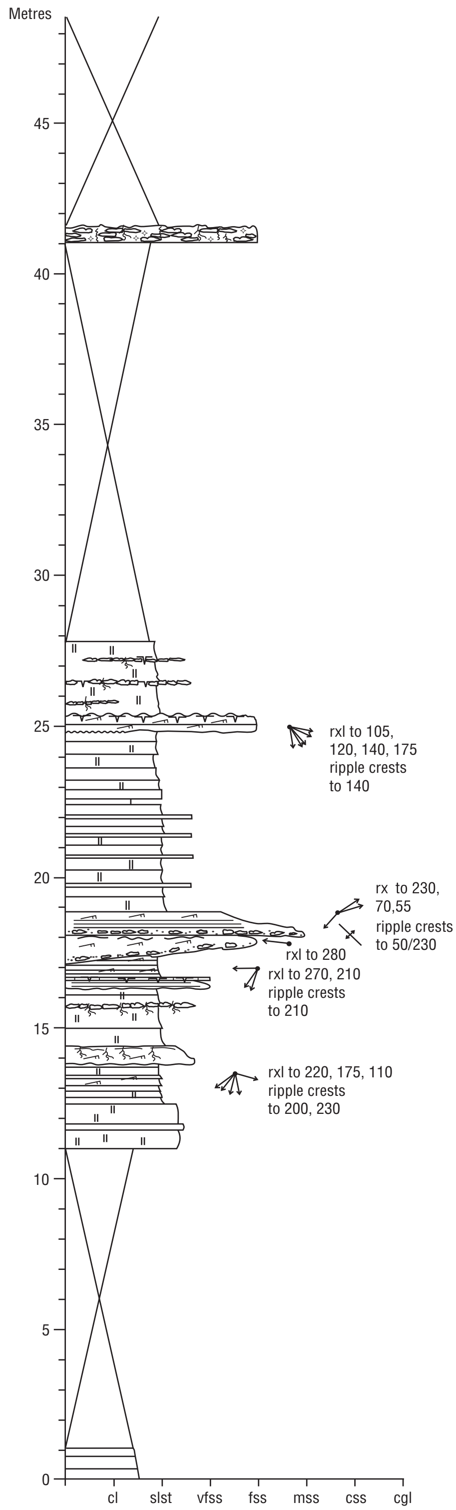


Point Edward. Pomquet Formation; general strike 75°, dip 8° N.

Point Edward Section



Point Edward Section cont.



- blue grey, very fine crystalline, massive, uniform limestone, nonpetroliferous irregular nodular texture and lumpy upper surface, abundant, long, vertical burrows and carbonized plant fragments, tiny vugs

- red slts, blocky weathering, several, thin, nodular calcrete horizons with rootlets and fractures filled with red mud, poorly exposed

- reddish grey, fine-grained ss, sharp, flat base, thin bedded, calcareous rxl, large ss-filled polygonal mudcracks on sharp degraded ripple surface
- red slts, thin sandy beds, poorly exposed

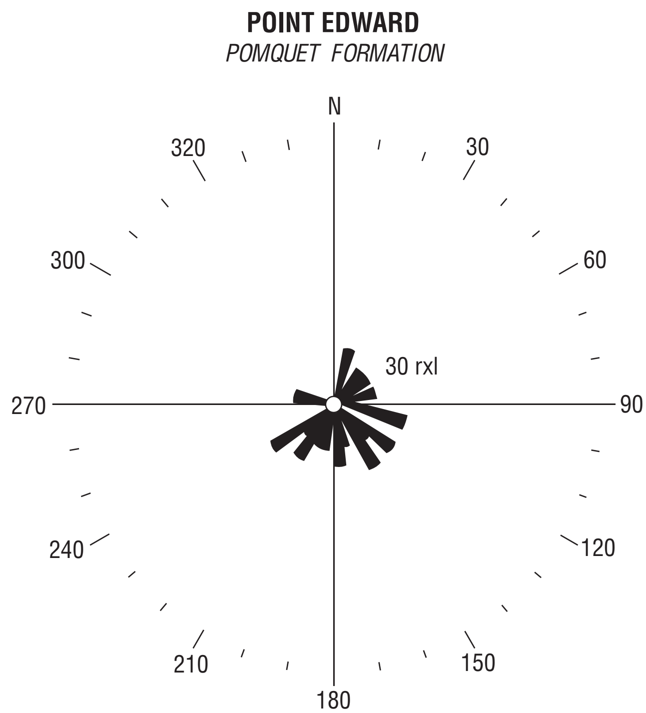
- red slts, blocky weathering, with interbedded red and green sandy slts beds, one greenish grey, silty mudstone at top, poorly exposed

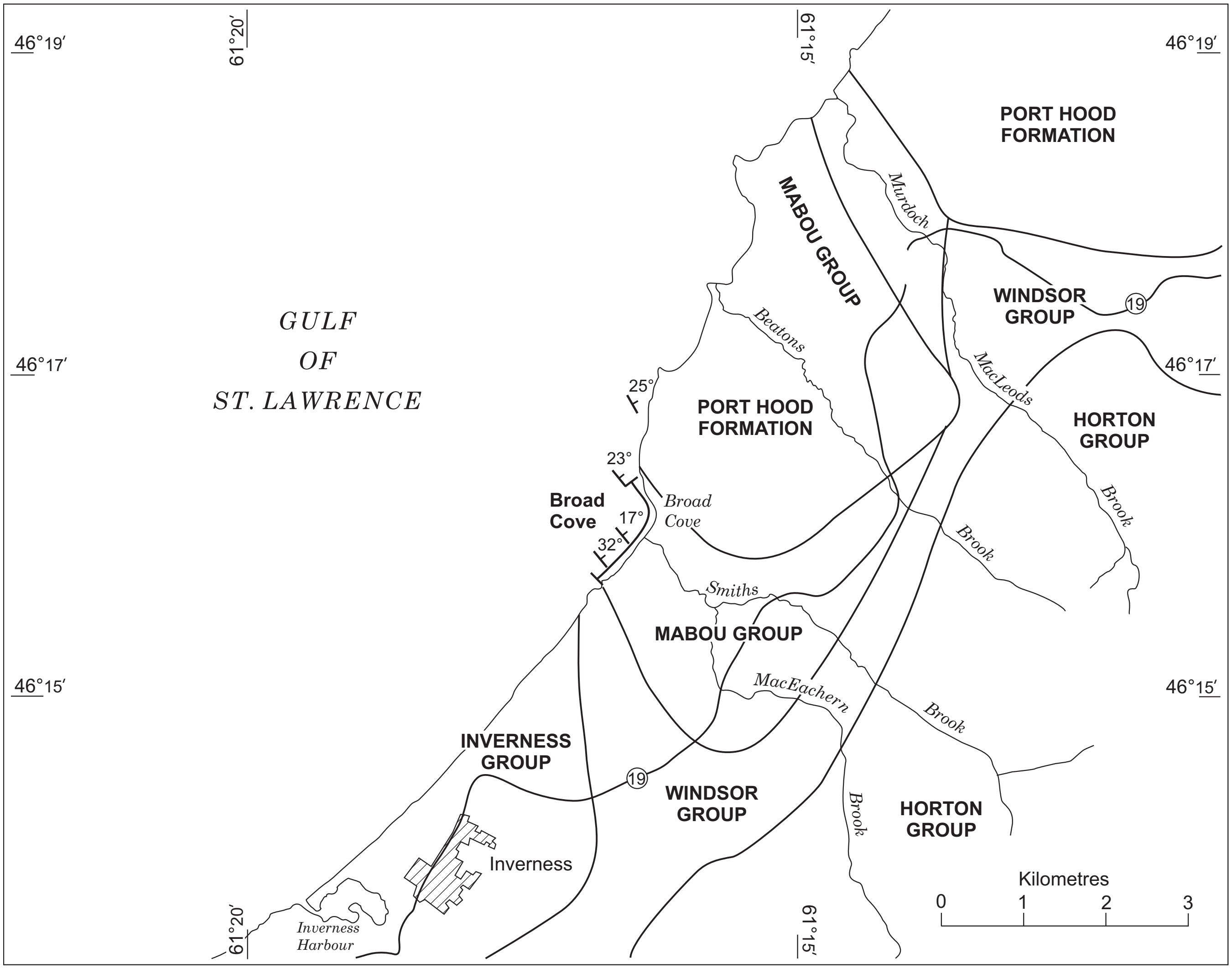
- reddish grey, fine- to medium-grained ss, sharp base with lag of red and green slts rip-ups and coaly fragments, calcareous, may be multistoried, horizontal lamination and rxl
- reddish grey, fine- to very fine-grained ss, sharp base with rip-ups and medium-grained ss, pinches out laterally, red slts at top
- red slts, many thin, discontinuous, very fine-grained ss with rxl
- greenish grey, f-up very fine-grained ss to slts, sharp base and top, laminated, capped by grey, sandy, brecciated limestone, mudcracks, sharp base and top
- red slts, blocky weathering, green reduction spots and fracture linings, slickensides, several red, sandier horizons, green calcrete zone with fractures and roots

- greenish grey, silty, very fine-grained ss, sharp erosional base, rooted, organics, rxl, thin red interbeds
- greenish grey slts, blocky, reddish at base, greenish sandy bed at top
- interbedded reddish slts and reddish grey, silty, very fine-grained ss with sharp bases and rxl
- reddish grey slts, uniform and blocky, thin, grey calcareous slts with erosional base and rxl
- greenish grey, sandy siltstone, blocky weathering, one thin, red, sandy siltstone in middle with gradational boundaries

POMQUET FM

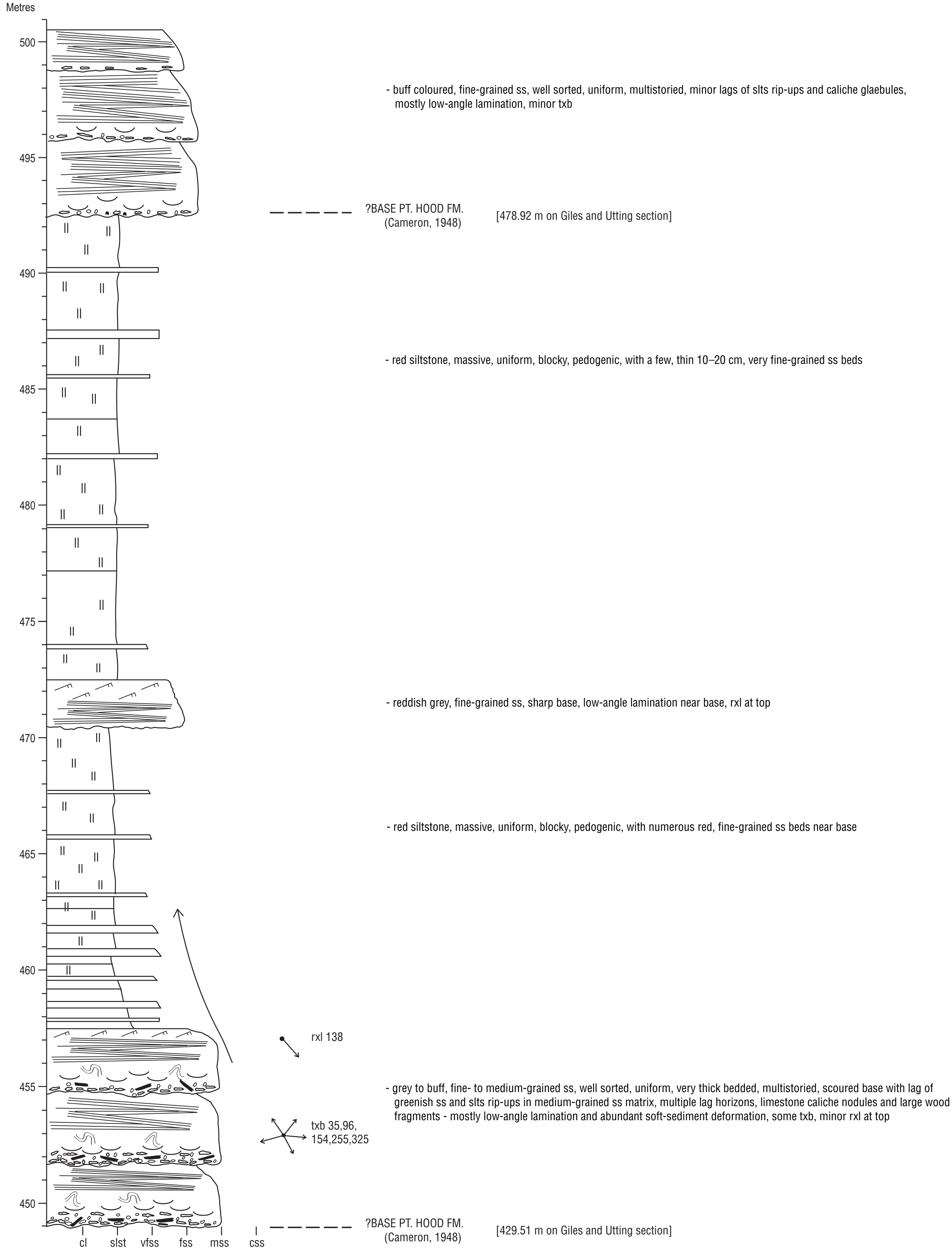
HASTINGS FM
- grey, silty mudstone, few thin calcareous slts beds, poorly exposed


POINT EDWARD
POMQUET FORMATION
N
30
60
90
120
150
180
210
240
270
300
320
30 rxl

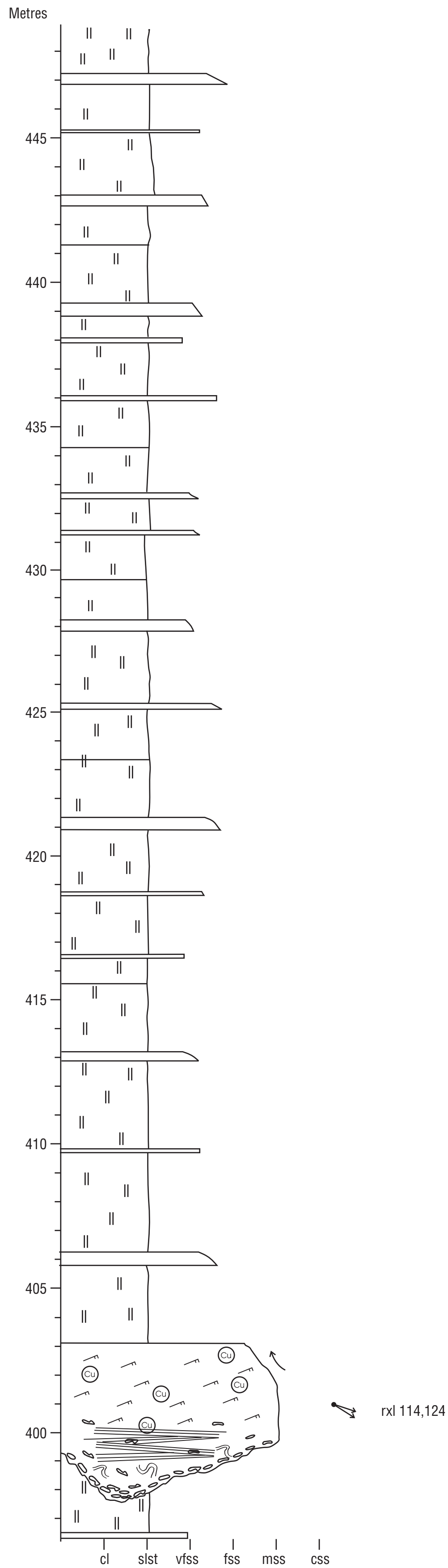


Broad Cove. Hastings and Pomquet formations; general strike 145°, dip 45° NE.

Broad Cove Section



Broad Cove Section cont.

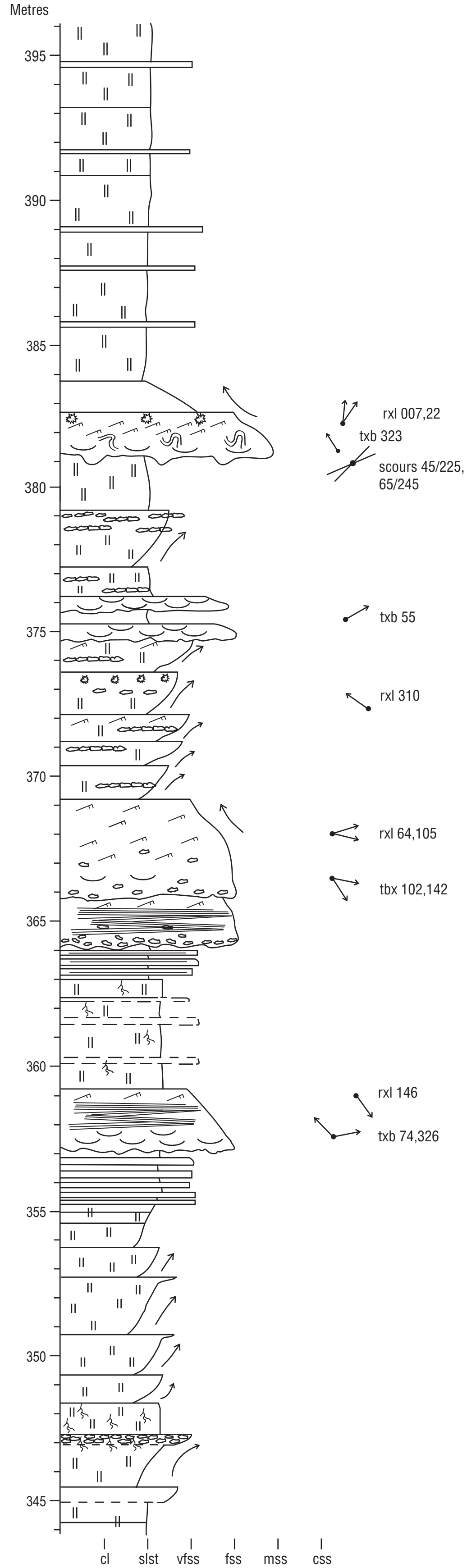


- red siltstone, massive, uniform, blocky, pedogenic, minor green siltstone, thin (5–50 cm), very fine ss beds scattered throughout

- red siltstone, massive, uniform, rubbly, pedogenic, minor green siltstone, thin (5–50 cm), very fine-grained ss beds scattered throughout

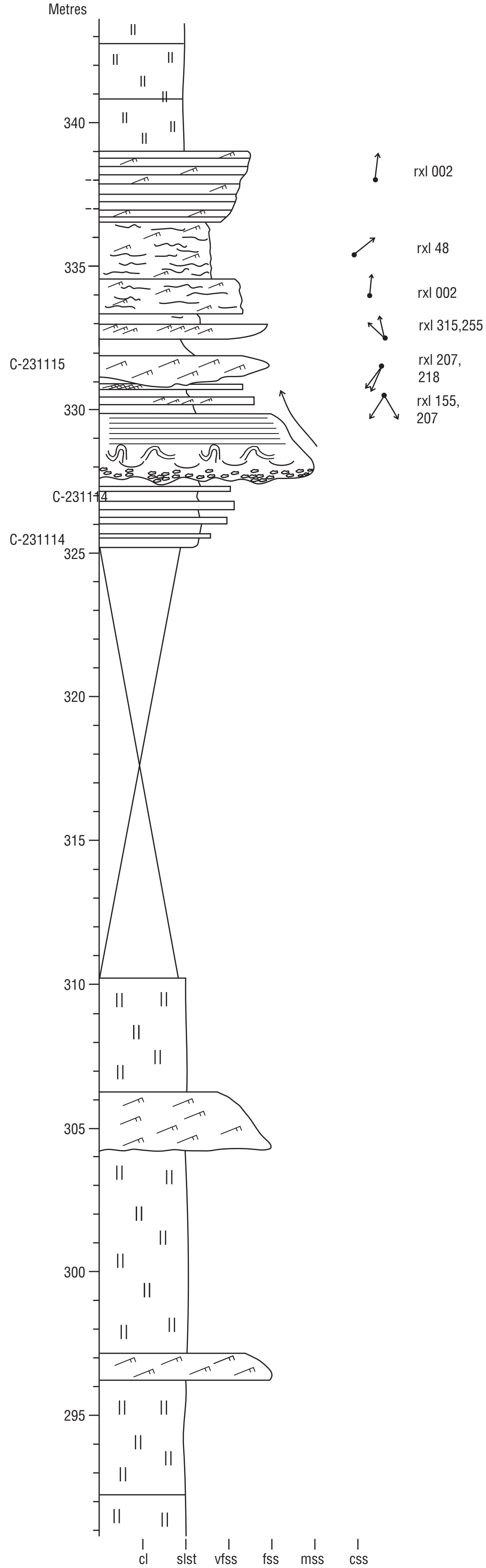
- reddish grey, fine- to medium-grained ss, well sorted, slightly f-up, scoured base downcuts into underlying slts, thins laterally over 30 m, mostly rippled except low-angle lamination and soft-sediment deformation at base, rip-ups, red bed Cu showings throughout

Broad Cove Section cont.



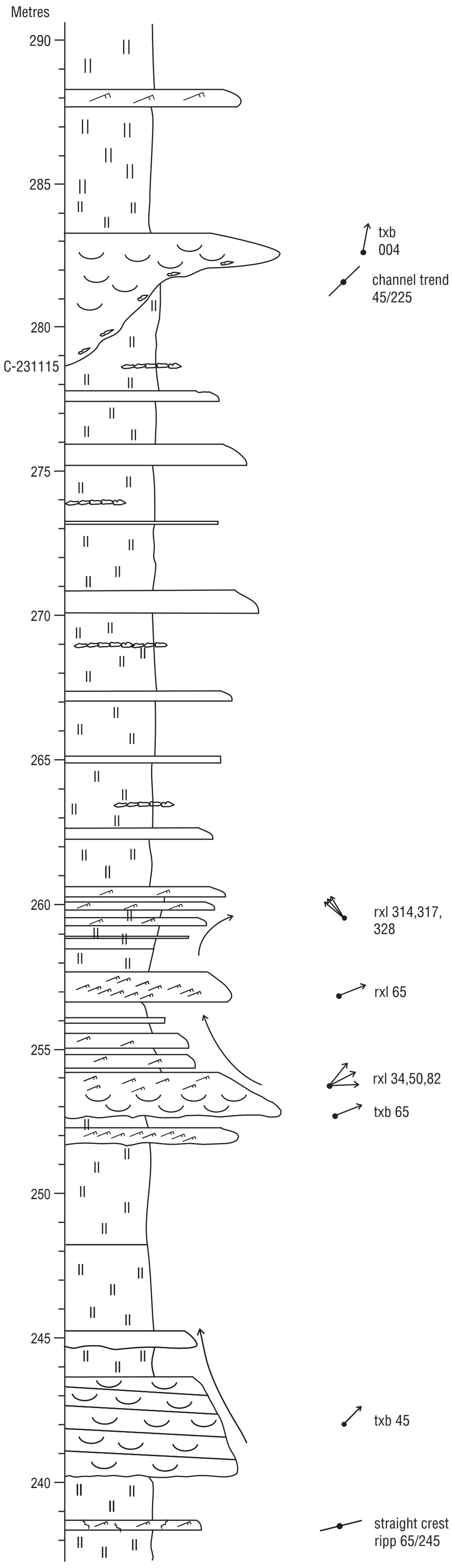
- red siltstone, massive, uniform, blocky, rubbly, pedogenic, with few, thin, very fine-grained ss beds scattered throughout
- f-up, red, silty, very fine-grained ss to siltstone
- reddish brown, fine- to medium-grained ss, well sorted, uniform, sharp, flat base with small scours, f-up at top with evaporite crystal moulds, minor txb, mostly rxl, soft-sediment deformation
- red siltstone, uniform, massive, blocky, pedogenic
- c-up sequence of red siltstone, abundant caliche glaebules near top
- red siltstone, massive, rubbly, pedogenic, caliche glaebules
- two very fine- to fine-grained ss beds with scoured bases, f-up, txb separated by red siltstone, txb
- stacked c-up sequences of red siltstone to silty, very fine-grained ss in 0.5–1.5 m units, many with horizons of caliche glaebules, some with evaporite crystals at tops
- red, fine-grained ss, well sorted, f-up at top, scoured base with rip-ups, few rip-ups throughout, low-angle lamination at base, mostly rxl, minor txb
- thinly interbedded, very fine-grained ss and siltstone, sharp bases and tops, horizontal and low-angle lamination, poorly exposed
- reddish grey, fine-grained ss, well sorted, scoured base, sharp top, txb at base, low-angle lamination, minor rxl at top
- red, sandy siltstone, massive, rubbly, blocky, pedogenic, thin very, fine-grained ss beds with gradational boundaries, rootlets
- thickly interbedded very fine-grained ss and red sandy slts
- c-up sequence of red siltstone to sandy siltstone, with 2 beds of very fine-grained ss, horizontal and low-angle lamination
- c-up sequence of red siltstone to red, sandy siltstone
- c-up sequence of red pedogenic siltstone to red, sandy siltstone and thin, silty very fine-grained ss
- c-up sequence red siltstone to thin, silty very fine-grained ss, massive, rubbly, pedogenic
- red c-up sequence of red siltstone to red, sandy siltstone, sharp base and top
- red and green mottled sandy siltstone, massive, rubbly, pedogenic, sharp base and top, abundant vertical root structures
- c-up sequence of red siltstone to red and green mottled sandy siltstone to 30 cm pale green, red mottled caliche zone with sharp top and vertical roots

Broad Cove Section cont.



- red siltstone, massive, blocky, poorly exposed, few, very thin, very fine-grained ss beds, capped by 50 cm greenish sandy slts with gradational base and sharp top
- red, silty, very fine- to fine-grained ss, c-up, thin bedded, rippled, poorly exposed
- red, very silty, very fine-grained ss, very rubbly, silty interbeds, rxl
- red, very fine- to fine-grained ss with silty interbeds, rxl
- red siltstone, sandy, poorly exposed
- red, very fine- to fine-grained ss, c-up, sharp top, climbing ripples
- red, sandy slts, f-up, then c-up
- buff, fine-grained ss, thins over 10 m laterally, scoured base
- thickly interbedded, greenish grey, sandy siltstone and buff, very fine-to fine-grained ss, slightly f-up, sharp bases, low-angle, climbing ripples
- grey to buff, fine- to medium-grained ss, well sorted, quartz-rich, sharp, scoured base, with abundant rip-ups of green slts and caliche glaebules, includes pockets up to 50 cm of glaebule cgl in medium-grained ss, horizontal lamination, txb at base, contorted lamination, water escape structures
- red, sandy siltstone to silty, very fine-grained ss, poorly exposed
- red siltstone, massive, rubbly, blocky, pedogenic
- red, fine-grained ss, sharp base, rippled, slightly f-up
- red siltstone, uniform, massive, blocky, pedogenic
- red, fine-grained ss, sharp base, slightly f-up, rippled
- red siltstone, uniform, blocky, rubbly, pedogenic
- red siltstone, uniform, massive, rubbly, pedogenic

Broad Cove Section cont.



- red, fine-grained ss, sharp base and top, rxl

- red siltstone, massive, uniform, blocky, pedogenic

- red, fine- to medium-grained ss, well sorted, uniform, minor lag, erosive base downcuts 3 m to south, and nearly pinches out over 15 m laterally except for 1 m thick wing which continues to north, txb

- thick, uniform succession of red, massive, blocky, pedogenic siltstone, rare horizons of caliche glaebules, common green horizons, some 10–100 cm very fine- to fine-grained ss beds with sharp bases, f-up, and rxl

- c-up sequence of red, pedogenic siltstone to red, very fine- to fine-grained ss, sharp bases and tops and each ss slightly f-up, all rippled, few, small, vertical *Skolithos*-type burrows at top

- red, fine-grained ss, sharp base and top, climbing ripples

- red siltstone, several 30 cm very fine-grained ss beds with rxl

- red, fine- to medium-grained ss, f-up, sharp flat base, txb and rxl

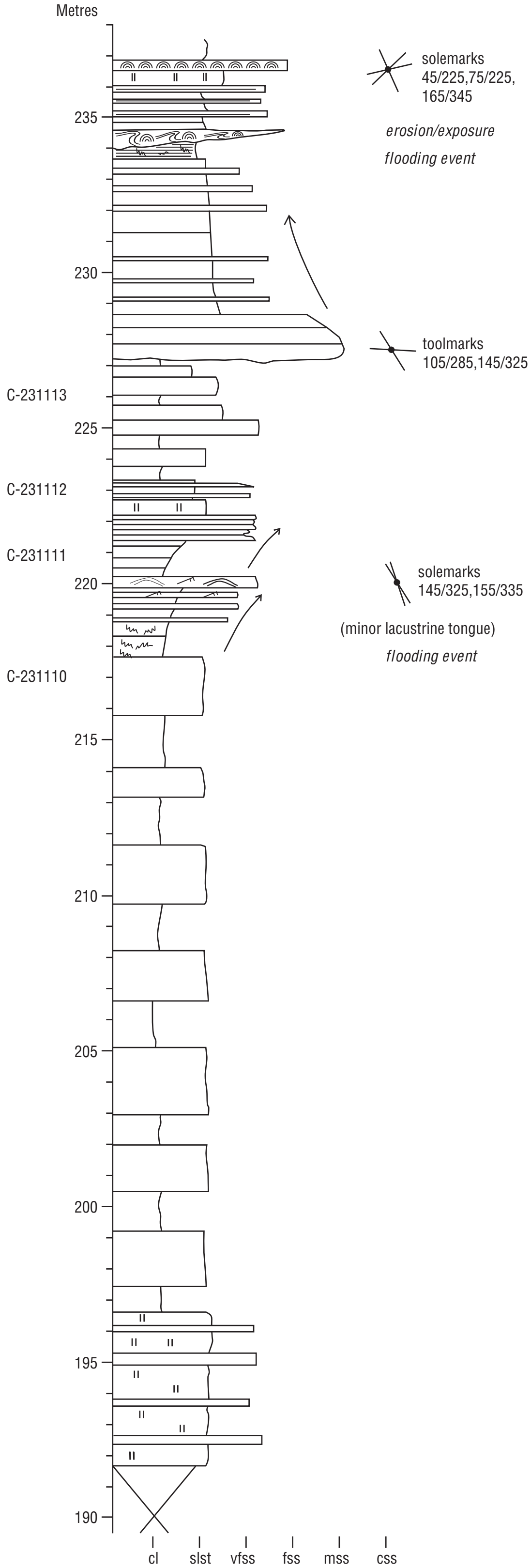
- red and green mottled siltstone, massive, uniform, pedogenic, one 50 cm fine- to medium-grained ss near top, with climbing ripples

- red siltstone, massive, blocky, rubbly, pedogenic, one 50 cm very fine-grained ss near base

- red, fine-grained ss, slightly f-up to very fine-grained ss at top, sharp, flat base, large, low-angle surfaces, txb

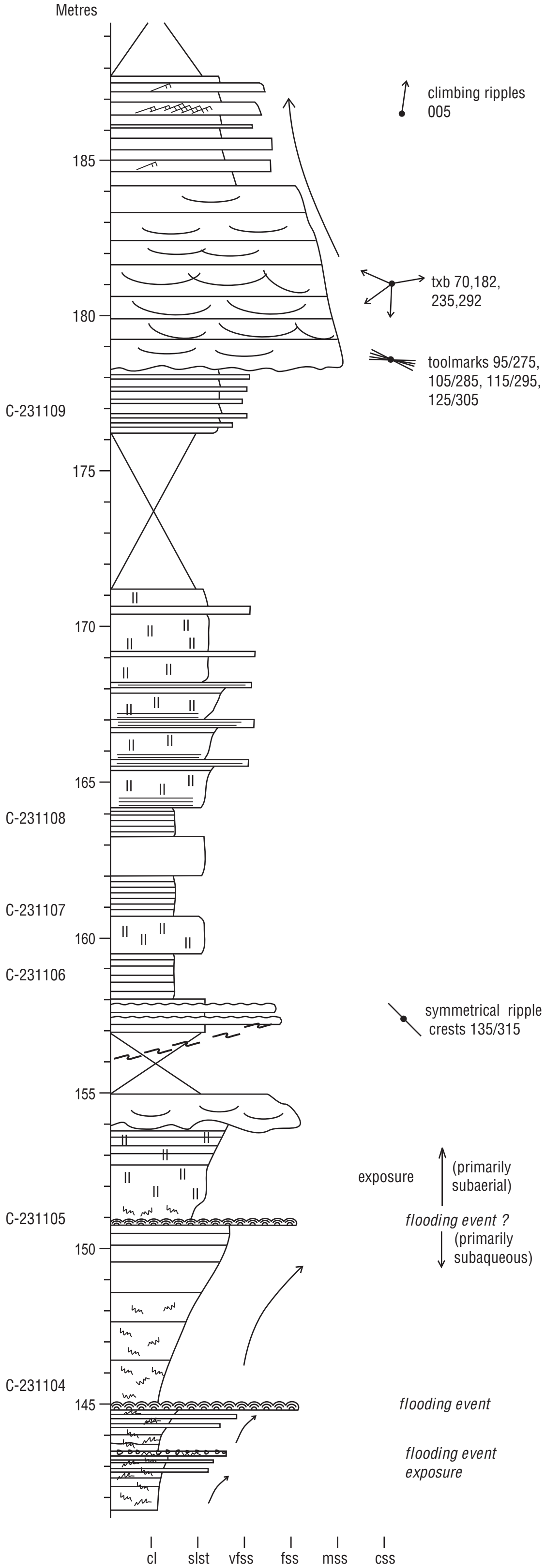
- red siltstone, uniform, massive, blocky, pedogenic, one 30 cm, very fine-grained ss in middle with vertical burrows and straight-crested ripples

Broad Cove Section cont.



- grey, algal-laminated limestone, sharp bases and top, solemarks
- interbedded greenish grey siltstone, laminated limestone, with red pedogenic slts at top
- greenish grey, thinly laminated and burrowed siltstone, capped by thick, scour-based stromatolitic laminated bed with deformation and convolution (erosional sequence boundary beneath algal limestone representing clastic nondeposition after scour and transgression?)
- f-up sequence of red siltstone, with thin, reddish or greenish fine- to very fine-grained ss beds, sharp base and top
- red, fine- to medium-grained ss, thick bedded, sharp, flat base with large solemarks
- thickly interbedded, greenish grey, muddy siltstone, silty, very fine-grained ss, and dark grey shale
- thinly interbedded very fine-grained ss and siltstone, grey
- c-up sequence of greenish interbedded siltstone and very fine-grained ss, to thin bedded, reddish grey, very fine-grained ss and thin, red siltstone, massive, blocky, pedogenic and sharp base
- c-up sequence from grey, bioturbated mudstone, to thinly interbedded siltstone and rippled, very fine-grained ss, to cap bed of 30 cm very fine-grained ss with small, vague, hummocky cross-stratification and convolute lamination
- very poorly exposed grey-green mudstone and red siltstone
- red sandy siltstone, massive, pedogenic, with few, thin, very fine-grained ss beds, poorly exposed

Broad Cove Section cont.



- thickly interbedded, red, sandy siltstone and red, very fine- to fine-grained ss, sharp bases, low-angle lamination, some climbing ripples

- thick bedded, red, fine- to medium-grained ss, sharp base with small scours and tool marks on base, and rip-ups, slightly f-up, sharp top, large, low-angle txb

- greenish sandy siltstone with silty, very fine-grained ss, poorly exposed

- red, massive siltstone, uniform, blocky, pedogenic, with several 20–30 cm very fine-grained ss beds

- stack of 3 c-up sequences from thin, laminated grey siltstone, to red, massive pedogenic siltstone, to thin horizontal-laminated very fine-grained ss

- greenish grey, silty shale, with grey, pinstripe, fine-grained ss beds

- red siltstone, massive, uniform, few thin, grey slts beds

- greenish grey, silty shale, with grey, pinstripe fine-grained ss beds

- red siltstone, massive, uniform, blocky, pedogenic

- thinly interbedded grey, silty shale and lighter grey, shaly siltstone

- thickly interbedded red, pedogenic siltstone and reddish grey, fine-grained ss, symmetrical ripples

- c-up sequence of greenish grey, burrowed siltstone to reddish grey, massive, pedogenic siltstone to reddish grey very fine-grained ss and slts, cap bed is 1 m scour-based, f-up, fine-grained ss cut down into slts

POMQUET FM

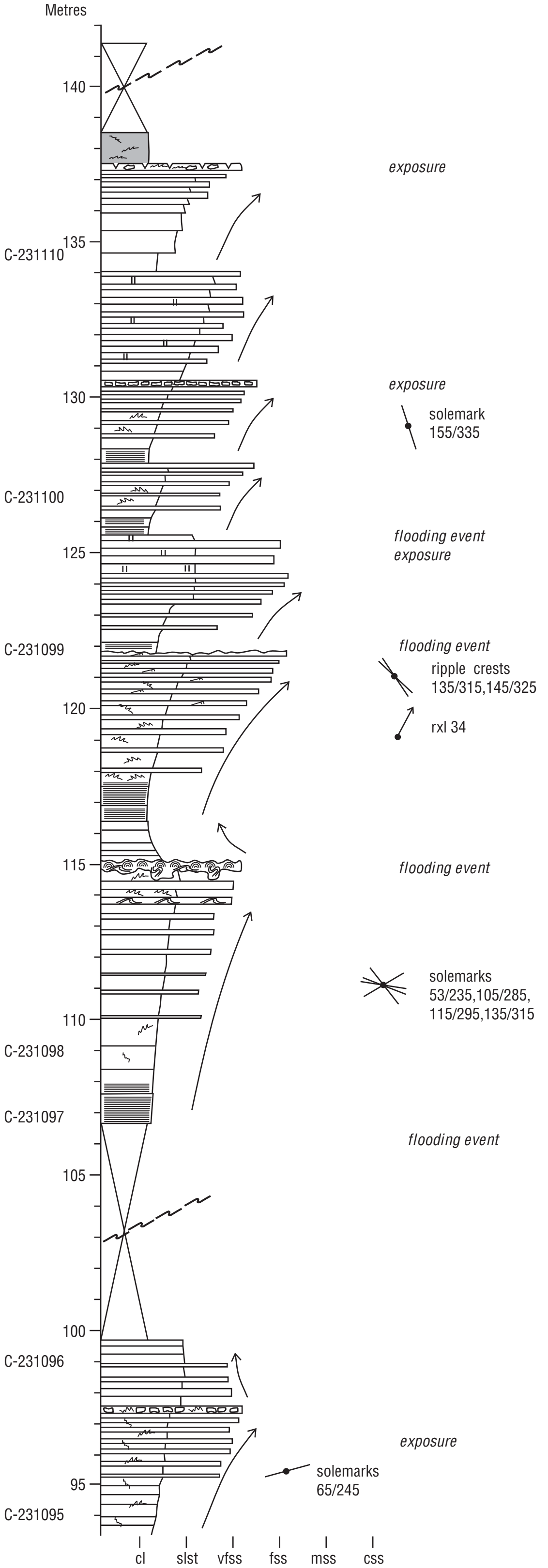
HASTINGS FM

- c-up sequence of burrowed, greenish grey mudstone, to burrowed, reddish sandy slts, to grey, sandy slts, to cap bed of 10 cm algal-laminated limestone with convolute lamination and irregular lumpy top

- c-up sequence of thinly interbedded grey mudstone and calcisiltite, well burrowed, cap bed of 20 cm algal-laminated limestone with irregular lumpy top and burrows

- c-up sequence of thinly interbedded grey mudstone and calcisiltite, thoroughly bioturbated, cap bed of 10 cm oolite with convolute lamination, phosphatic pellets, rip-ups

Broad Cove Section cont.



- dark grey mudstone, burrowed

- c-up sequence of interbedded grey shale, red slts and green slts, with cap bed of 20 cm grey limestone with desiccation cracks and lag of phosphatic pellets, coarse-grained ss, oolites, burrows, rip-ups

- c-up of reddish grey pedogenic siltstone and red slts to very fine-grained ss, thickly interbedded

- several thin, c-up sequences of dark grey laminated mudstone and laminated algal calcisiltite beds capped by brecciated algal bed, top bed has lag on upper surface of coarse-grained ss and pellets and burrows

- thickly interbedded, massive, red slts and red, fine-grained ss, pedogenic

- c-up sequence of dark grey, laminated shale, to greyish red, very fine-grained ss and slts, to red, fine-grained ss, thin bedded

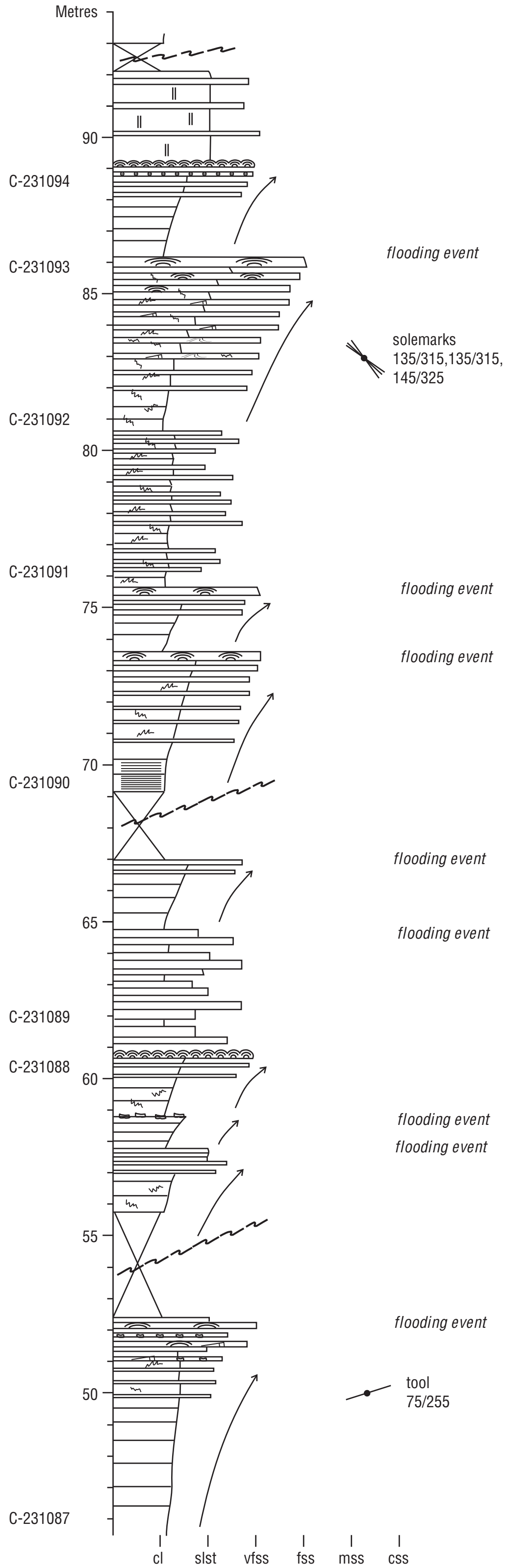
- c-up sequence of dark grey, laminated mudstone to bioturbated grey shale with minor, thin siltstone and very fine-grained ss beds, to interbedded grey siltstone, mostly rippled

- f-up sequence of grey mudstone with few, very thin siltstone beds

- c-up sequence of interbedded grey mudstone and slts to very fine-grained ss, dark grey and laminated at base with bioturbation increasing upward, several stromatolitic beds with convolute lamination in upper half, and top bed is 25 cm sharp-based deformed stromatolitic bed foundered into underlying mudstone

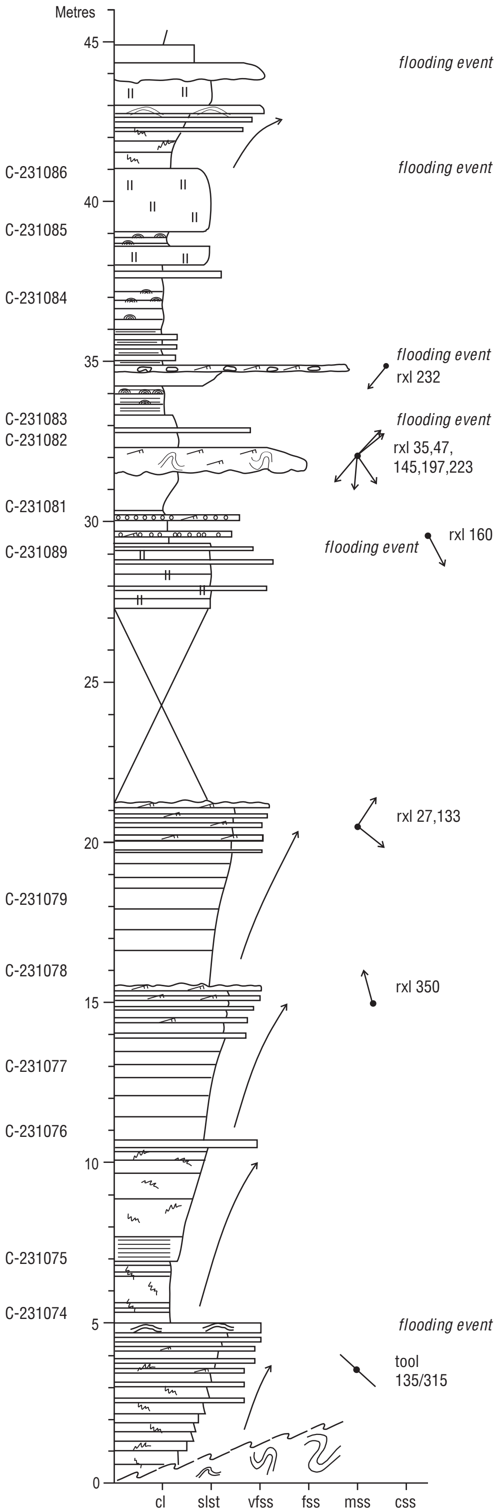
- c-up sequence of thinly interbedded grey mudstone and very fine-grained ss, generally bioturbated, near top is bed with large horizontal burrows and brecciated, upper 2 m tends to be f-up and reddish colour, solemarks on sharp bases

Broad Cove Section cont.



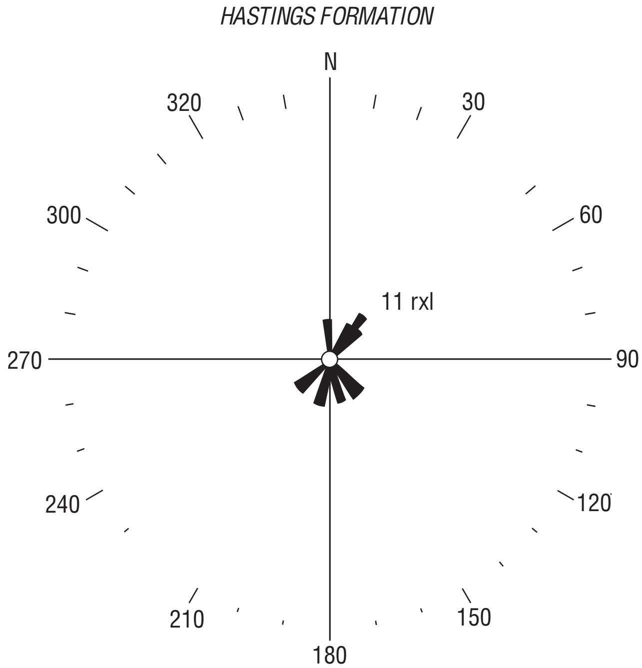
- red, massive siltstone with few, thin, grey very fine-grained ss, pedogenic?
- c-up sequence of dark grey shale to thinly interbedded calcisiltite and bioturbated shale, some oolitic and algal beds at top
- c-up sequence of grey mudstone and very fine- to fine-grained ss, generally bioturbated, sharp bases with toolmarks, several beds in middle with convolute lamination and lumpy tops with large horizontal burrows, mostly rxl, thick beds with hummocky cross-stratification at top, ss:slst = 1:5 at base, 1:1 at top
- thinly interbedded, grey, bioturbated mudstone and slts to very fine-grained ss, with burrows, beds have sharp bases and gradational tops
- c-up sequence of dark grey mudstone and calcareous siltstone to very fine-grained ss, 20 cm hummocky cross-stratification bed at top
- c-up sequence of dark grey mudstone and calcareous slts to very fine-grained ss, vague, low-amplitude hummocky cross-stratification at top
- c-up sequence of grey shale and pale grey calcisiltite
- interbedded grey shale, red, massive, siltstone and thinly laminated calcarenites
- c-up sequence of grey mudstone and pale grey calcisiltite, cap bed is 10 cm bulbous stromatolite bed, sharp top
- c-up sequence of grey mudstone and light grey calcisiltite, brecciated cap bed
- red siltstone, massive, few very fine-grained ss beds
- c-up sequence of grey mudstone and light grey calcisiltite
- c-up sequence of grey mudstone and light grey calcisiltite beds, hummocky cross-stratification and burrows near top, few, thin, red slts beds near top, brecciation at top

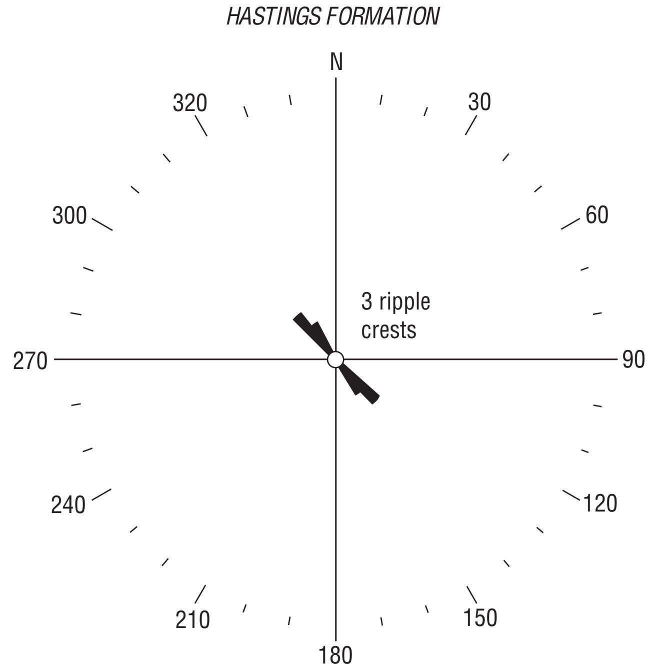
Broad Cove Section cont.

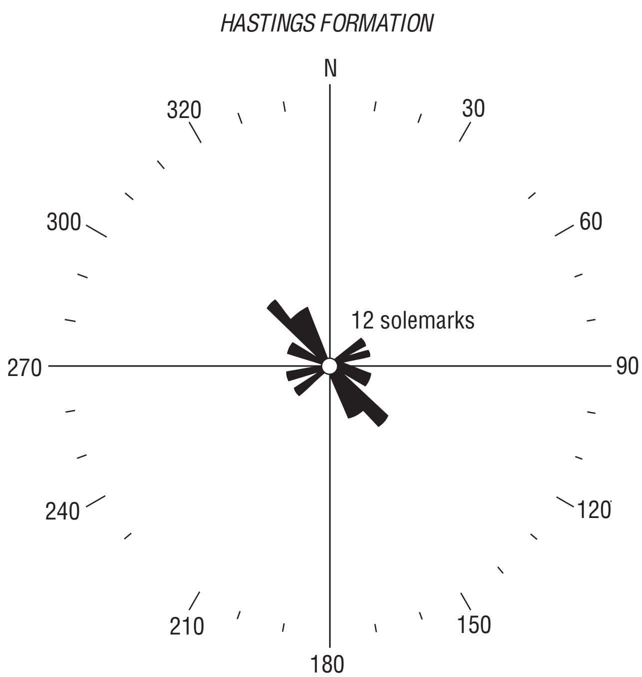


- grey calcisiltite, few shaly interbeds
- reddish grey, very fine-grained ss, massive
- red siltstone, massive, uniform, pedogenic
- c-up sequence of grey mudstone with thin, very fine calcarenite, well laminated, minor burrowing, sharp top with vague hummocky cross-stratification in capping 30 cm bed
- red siltstone, massive, uniform, blocky, pedogenic, one grey shale with stromatolitic beds
- grey, bioturbated mudstone with thin, stromatolitic calcisiltite beds, one red slts near top
- thinly interbedded, grey laminated shale and red, massive shale
- red, fine- to medium-grained ss, scour base with rip-ups, rxl
- red, sandy slts, c-up, partly laminated
- grey, calcareous mudstone, with very thin, pale grey calcisiltite bed with stromatolites
- red shale, single, thin, red, very fine-grained ss
- reddish grey, fine-grained ss, scoured base, sharp top, rxl, soft-sediment deformation
- grey shale grading up to red mudstone, poorly exposed
- grey shale with thin, oolitic calcarenites with gradational boundaries, scour bases, rxl, wrinkles
- interbedded red slts and very fine-grained ss, gradational boundaries, ss:slts = 1:2, massive, pedogenic?
- c-up sequence of red, massive, sandy slts, red, very fine-grained ss, rxl
- c-up sequence of red, massive, sandy slts and reddish grey, very fine-grained ss up to 20 cm thick with rxl
- c-up sequence of grey to dark grey shale, partly laminated, partly bioturbated, with few silty beds, cap bed of 20 cm gradational-based, very fine-grained ss, ss:slts = 1:10
- grey shale, bioturbated, several horizons of thin, silty beds
- c-up sequence of interbedded greenish grey to grey shale and slts to very fine-grained ss, shale bioturbated, ss sharp base and top, calcareous, toolmarks, vague hummocky cross-stratification at top
- faulted and folded anhydrite and gypsum of Upper Windsor Gp

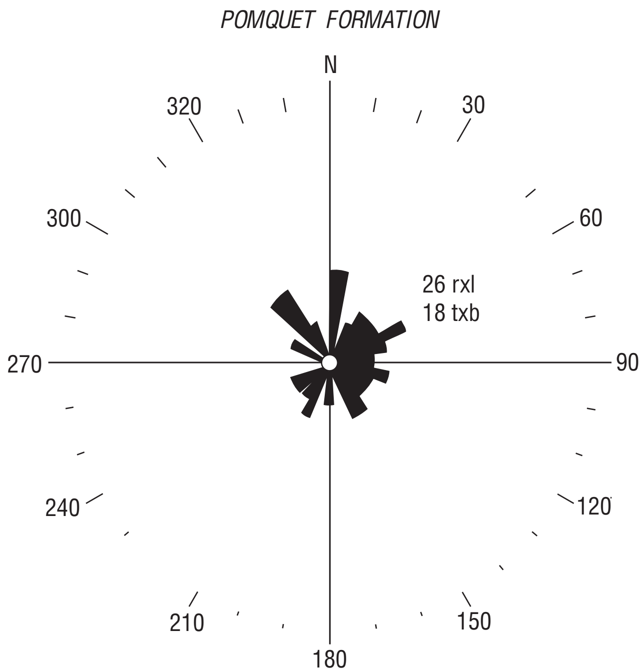
BROAD COVE


HASTINGS FORMATION
N
320
30
300
60
11 rxl
270
90
240
120
210
150
180

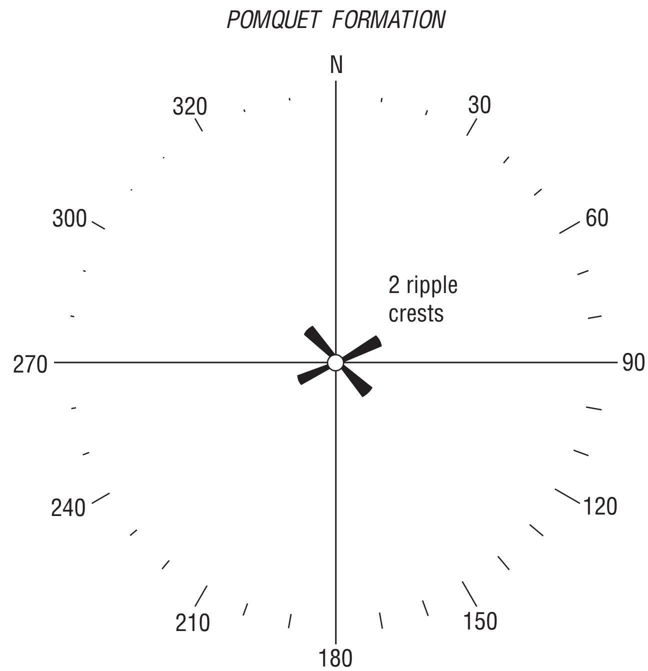

HASTINGS FORMATION
N
320
30
300
60
3 ripple crests
270
90
240
120
210
150
180


HASTINGS FORMATION
N
320
30
300
60
12 solemarks
270
90
240
120
210
150
180

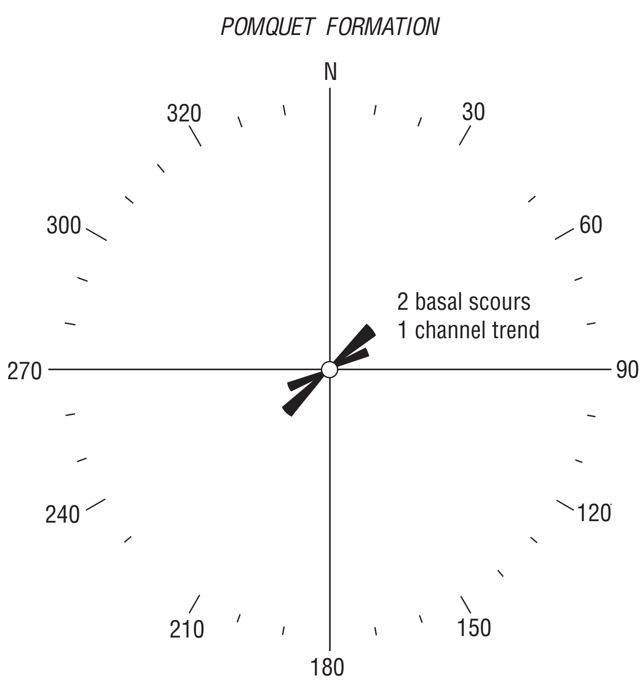
BROAD COVE



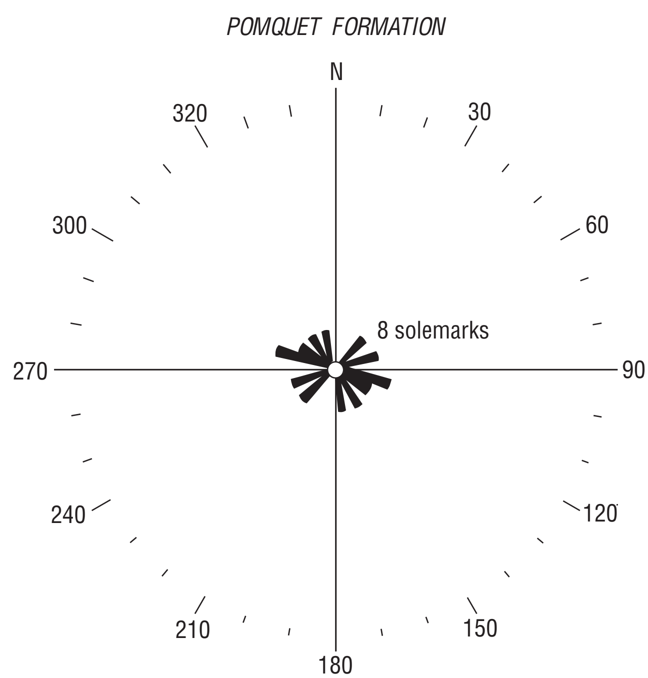
POMQUET FORMATION
N
30
60
90
120
150
180
210
240
270
300
320
26 rxl
18 txb



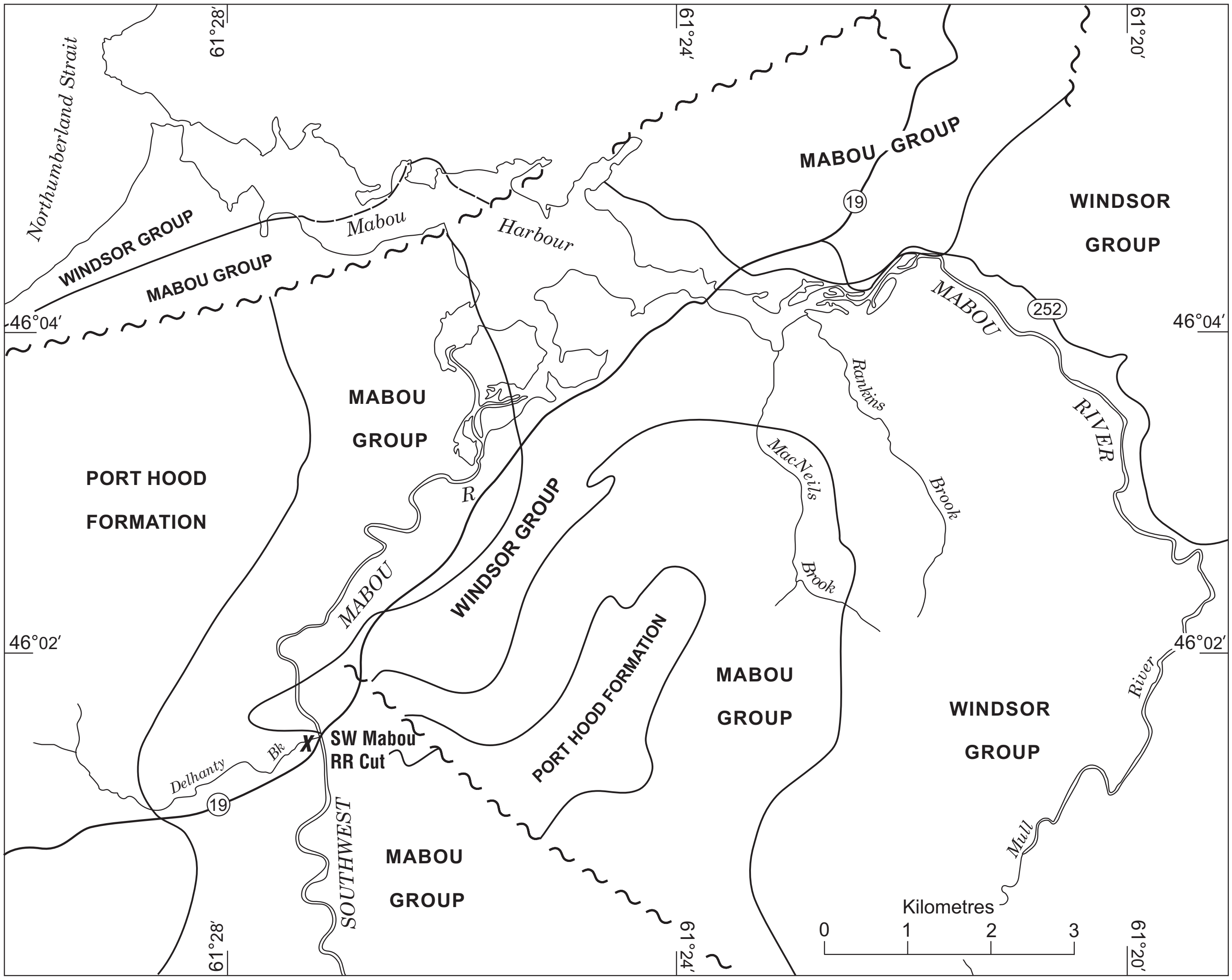
POMQUET FORMATION
N
30
60
90
120
150
180
210
240
270
300
320
2 ripple
crests



POMQUET FORMATION
N
30
60
90
120
150
180
210
240
270
300
320
2 basal scours
1 channel trend

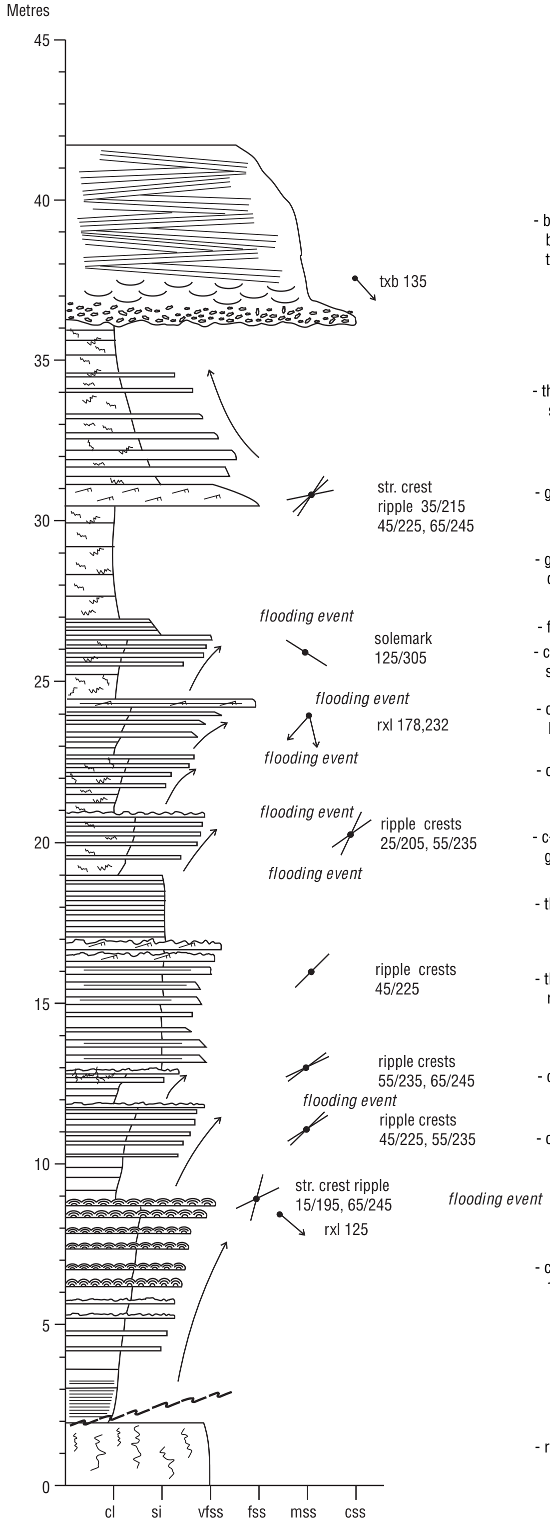


POMQUET FORMATION
N
30
60
90
120
150
180
210
240
270
300
320
8 solemarks



SW Mabou RR Cut. Hastings Formation; general strike 30°, dip 40° SE.

SW Mabou RR Cut Section



- buff to greenish grey, fine- to medium-grained ss, mostly fine-grained ss, well sorted, uniform, well laminated, scoured base with thick lag of caliche nodules in medium- to coarse-grained ss matrix, some caliche glaebules scattered throughout, slightly f-up, minor txb, mostly low-angle lamination

- thickly interbedded, grey, bioturbated, silty shale and grey, very fine- to fine-grained ss, generally f-up, beds 20–50 cm, ss:slts = 1:3 at base, 1:8 at top

- grey, very fine- to fine-grained ss, well sorted, slightly f-up, sharp base, rxl

- grey mudstone, abundant bioturbation, few, thin, very fine-grained ss beds with gradational boundaries, many disrupted by burrows

- f-up sequence of thinly interbedded, very fine-grained ss and slts

- c-up sequence of thinly interbedded, grey mudstone and slts to very fine-grained ss, mostly mudstone at base, mostly ss at top, all bioturbated, horizontal lamination and rxl

- c-up sequence of thinly interbedded grey mudstone and slts to very fine-grained ss, cap bed of 20 cm fine ss with horizontal lamination and rxl

- c-up sequence of thinly interbedded grey mudstone and slts, very bioturbated, gradational boundaries

- c-up sequence of thinly interbedded grey mudstone and slts to very fine-grained ss, bioturbated, sharp base and more gradational tops, horizontal lamination and straight-crested ripples

- thinly interbedded red slts and reddish, very fine-grained ss

- thinly interbedded reddish slts and reddish grey, silty, very fine-grained ss, ss:slts =1:1, horizontal lamination and ripples

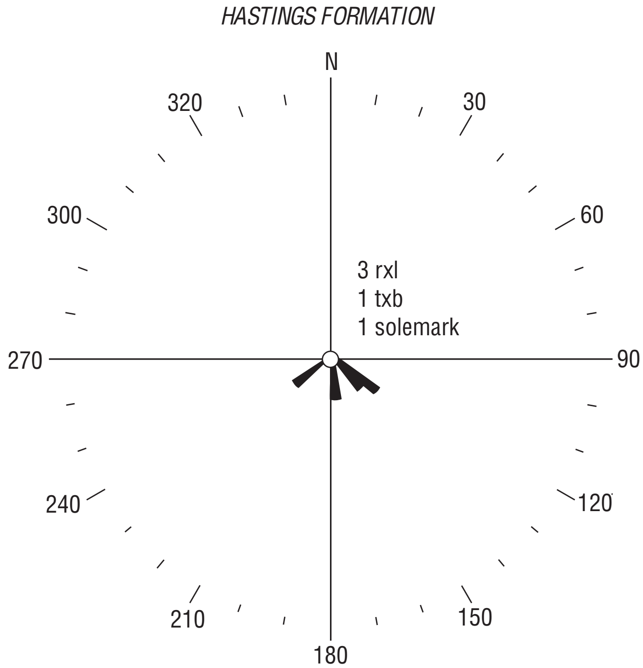
- c-up sequence of grey mudstone and slts, reddish, burrowed or rooted(?) at top

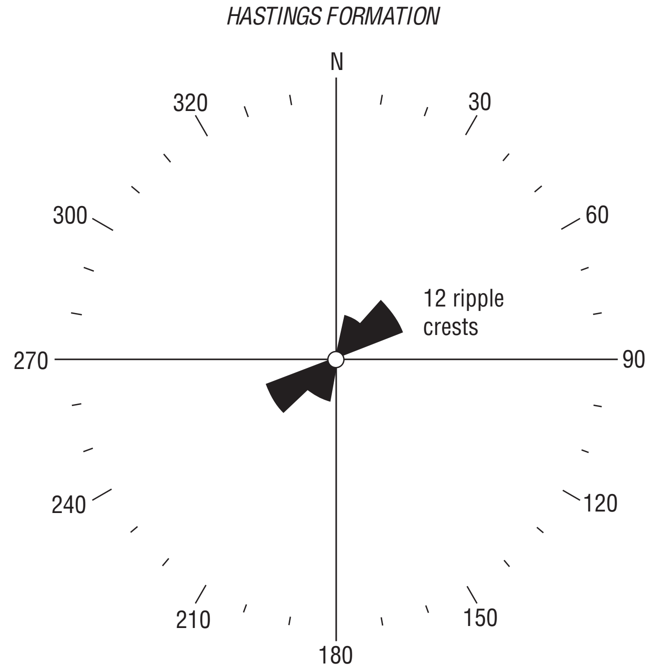
- c-up sequence of thinly interbedded grey mudstone and slts to very fine-grained ss

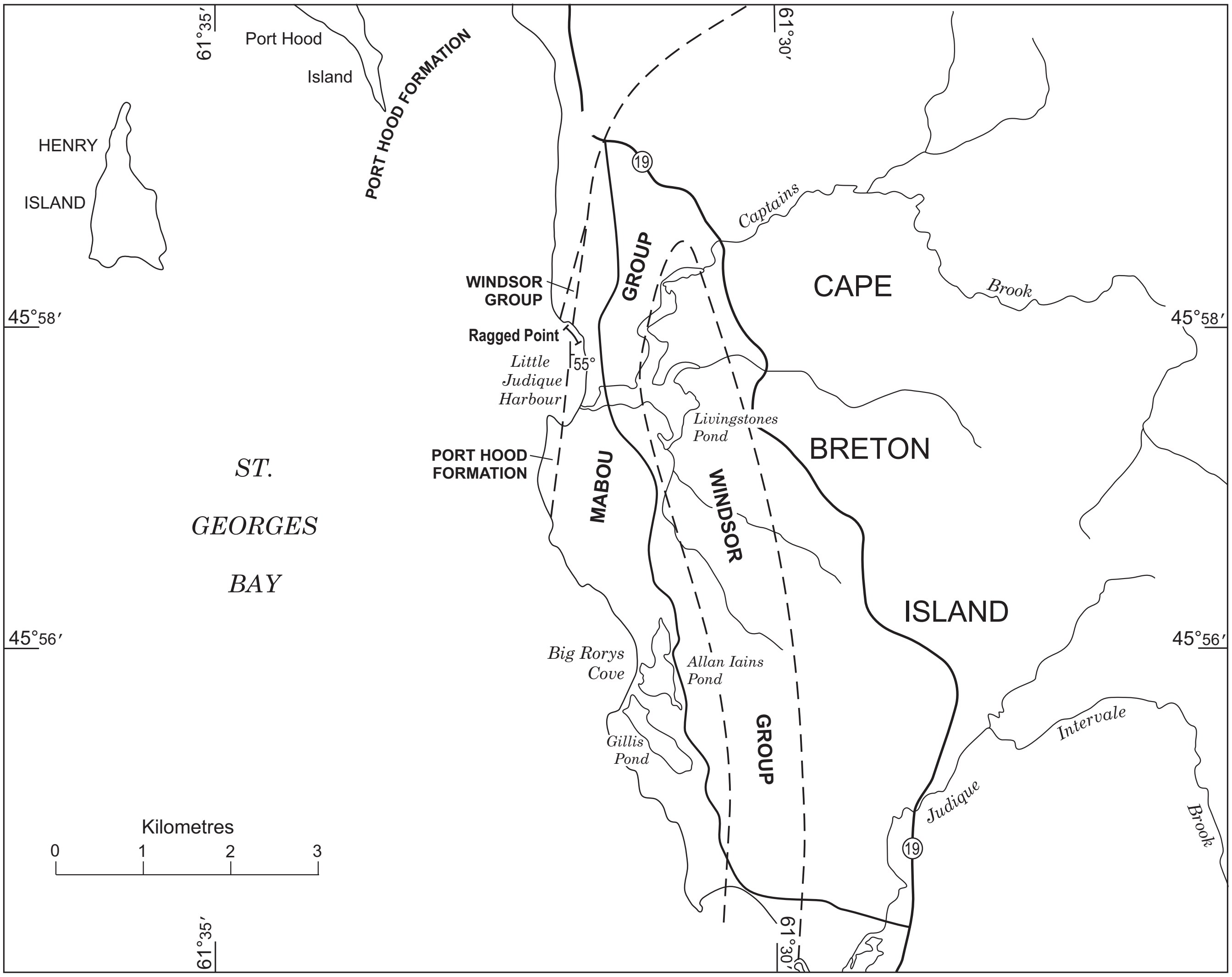
- c-up sequence of thinly interbedded greenish grey mudstone and stromatolitic limestone, ss:slts = 1:10 at base, 1:5 at top, upper beds very sandy or oolitic and up to 20 cm thick

- red, silty very fine-grained ss, very fractured

SW MABOU RR CUT

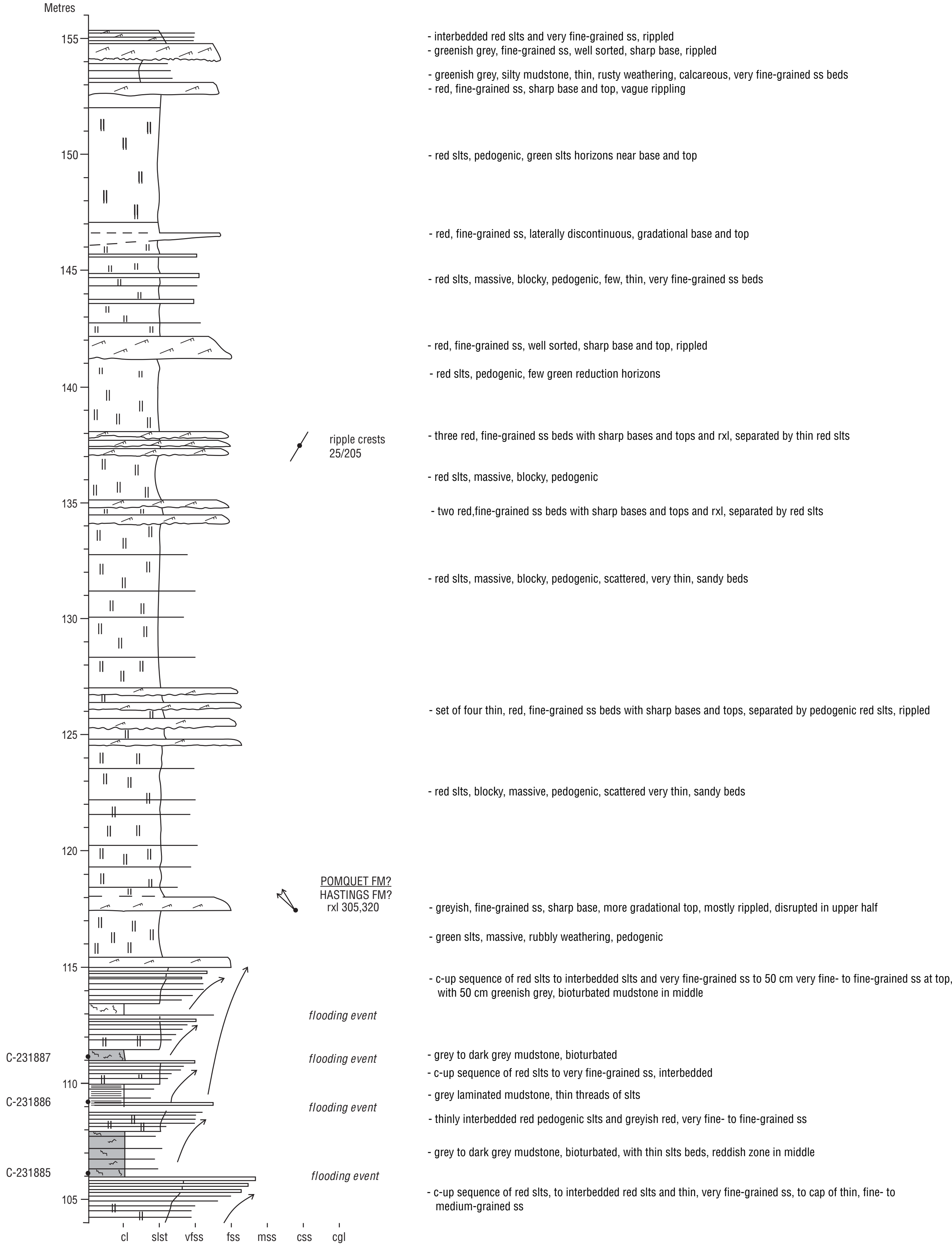




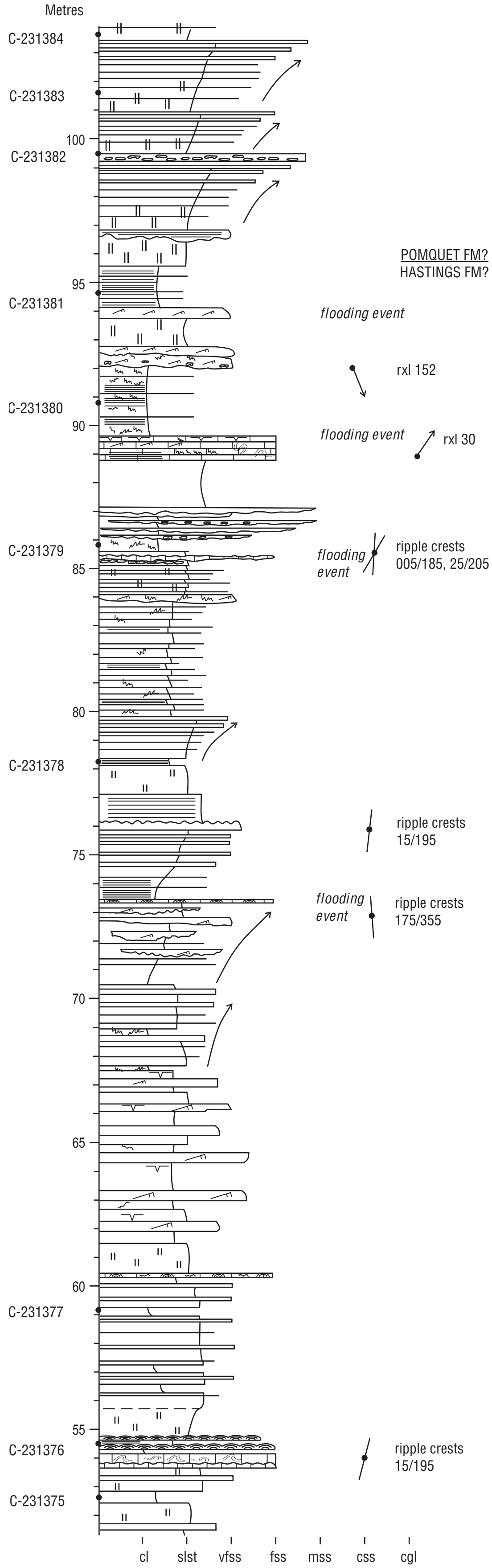


Ragged Point. Hastings and Pomquet formations; general strike 10°, dip 55° E.

Ragged Point Section

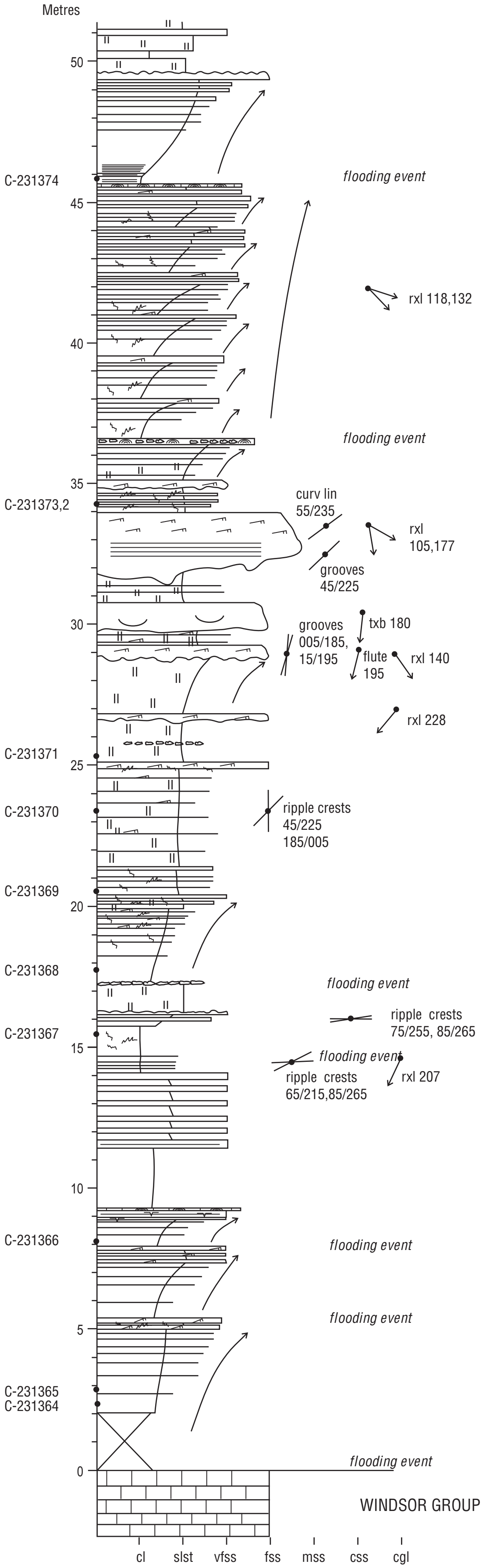


Ragged Point Section cont.



- c-up sequence of red slts, to interbedded red slts and thin, very fine-grained ss, to cap of thin, fine- to medium-grained ss
- c-up sequence of red slts, to interbedded red slts and thin, very fine-grained ss, to cap of thin, fine- to medium-grained ss
- c-up sequence of red slts, to interbedded red slts and thin, very fine-grained ss, to capping unit of 20 cm fine- to medium-grained ss full of rip-ups and lined with green mud on top
- grey, very fine-grained ss, sharp scoured base, horizontal lamination
- brick red slts, massive, rubbly, blocky, pedogenic
- greenish grey silty mudstone, laminated, few, very thin slts beds
- greenish grey, very fine-grained ss, sharp base, rippled
- red slts, blocky, rubbly, pedogenic, green reduction spots
- greenish grey, very fine-grained ss, well sorted, two storey, green and red shale rip-ups, rxl, few burrows
- dark greenish grey mudstone, bioturbated in places, laminated in places, few zones of reddish colour, few laterally discontinuous, thin sandy beds with burrows
- greenish grey calcarenite (oolite?), thick bedded, sharp base and irregular top with desiccation cracks, various horizons of ripples, horizontal lamination, contort lamination, and large, horizontal, simple burrows, some ripples have flasers of green mud
- greenish and reddish sandy slts
- reddish grey, very fine- to medium-grained ss, sharp base
- greenish grey bioturbated mudstone with red slts at base and three, thin, medium-grained ss beds at top with sharp, scoured bases and rip-ups
- greenish oolitic limestone, wavy lamination and sharp rippled top, sharp base with lag of red slts/white lst rip-ups
- thinly interbedded, red, pedogenic slts and red, very fine-grained ss, ss:slts = 1:1, gradational boundaries, very thin horizon of calcrete nodules at top
- reddish grey, very fine-grained ss, sharp base and top, originally rippled but mostly burrowed
- thinly interbedded, grey to greenish grey, silty mudstone and burrowed slts to very fine-grained ss, partly laminated, partly burrowed, gradational boundaries
- c-up sequence of greenish slts, to interbedded green slts and greenish grey very fine-grained ss
- dark grey, carbonaceous, silty mudstone
- red slts, massive, blocky, rubbly, rusty horizons near base, pedogenic
- greenish sandy slts, generally laminated
- c-up sequence of grey, laminated mudstone, to interbedded greenish grey slts and very fine-grained ss, to capping bed of calcareous, very fine-grained ss with straight, symmetrical ripples, sharp top
- c-up sequence of greenish grey mudstone, to interbedded greenish slts and laterally discontinuous, thick, very fine-grained ss, thin algal laminated limestone at top
- c-up sequence of interbedded, greenish, bioturbated mudstone and thinly laminated very fine-grained silty ss and red slts increase in ss thickness and red slts upward
- thickly interbedded, greenish grey, laminated clay-rich slts and very fine-grained ss, minor red slts, rippled, mudcracks, some burrowing
- red slts, rubbly, pedogenic, massive
- grey, laminated limestone, algal-laminated at base, burrowed at top
- greenish grey, bioturbated slts interbedded with dark grey mudstone and thin, calcareous very fine-grained ss, ss:slts = 1:5
- brick red slts, massive, rubbly, pedogenic, gradational top
- algal-laminated limestone, contorted lamination, desiccation cracks
- dark grey laminated mudstone
- grey, algal-laminated limestone with contorted lamination, sharp convex-upward knobs on top
- grey mudstone
- greenish grey calcarenite (oolite?), rusty weathering, thinly laminated and symmetrical ripples in lower half, contorted (water escape?) teepee structures at top
- randomly interbedded greenish pedogenic slts, reddish pedogenic slts, minor grey mudstone and greenish very fine-grained ss

Ragged Point Section cont.



- c-up sequence of dark grey laminated mudstone, to greenish grey slts, to reddish slts, to interbedded reddish slts and very fine-grained ss, to thick, fine-grained ss with sharp top and rxl

- series of six, thin c-up sequences of grey, bioturbated mudstone, to thinly interbedded grey mudstone and burrowed slts to very fine-grained ss with ripples, to thinly laminated and burrowed very fine-grained ss, overall succession c-up with thickest ss at top of upper sequence, uppermost bed is thin, stromatolitic algal-laminated limestone

- thinly interbedded, red, pedogenic slts and green, laminated, very fine-grained ss, slightly c-up trend, capping bed is green nodular horizon with algal lamination and bioturbation
- red, very fine-grained ss, sharp base and top, rxl
- greenish, thinly interbedded, very fine-grained ss and bioturbated slts, ss:slts =1:1
- red, fine- to medium-grained ss, well sorted, sharp erosive base with larger grooves, channel fill topography over 10 m laterally, some horizontal lamination, upper 1 m rippled, sharp top
- red slts, massive and rubbly, with few, thin, red, very fine-grained ss, few thin, green horizons
- red, fine-grained ss, well sorted, sharp base with minor topography, looks massive, but vague txb
- red slts, blocky, pedogenic, few thin, greenish, silty, very fine-grained ss with ripples
- greenish red, fine-grained ss, sharp, scoured base with burrow casts and sole marks, rxl
- red slts, massive, pedogenic, sandier upward
- reddish grey, fine-grained ss, slightly scoury base, rxl
- red slts, blocky, rubbly, pedogenic, thin horizon of round, calcareous nodules
-reddish grey, fine-grained ss, sharp base with vague burrow sole marks, rxl, well sorted, sharp top
- brick red slts, rubbly, pedogenic, some greenish, with minor, thin, very fine-grained ss with ripples

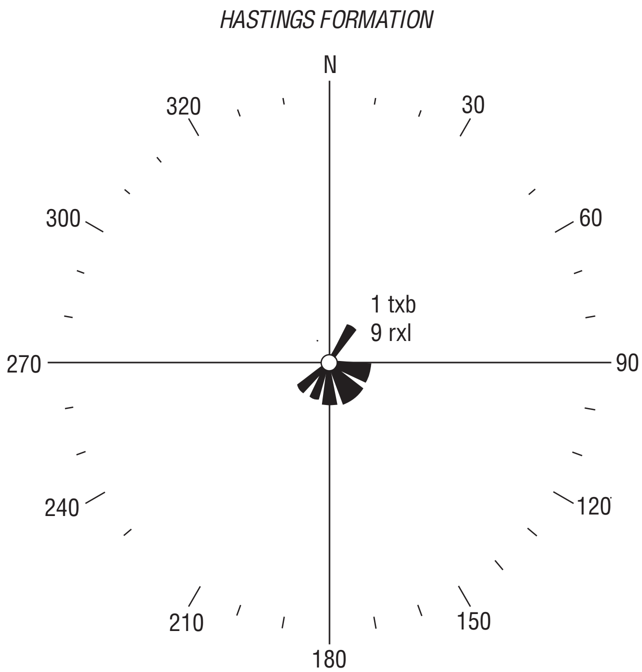
- thinly interbedded, greenish grey, burrowed slts and silty, very fine-grained ss with lamination ss:slts =1:2
- interbedded red, pedogenic slts and greenish grey, calcareous, very fine-grained ss, original lamination burrowed
- grey to greenish grey, c-up, silty mudstone, upward increase of very thin, sandy slts beds with ripples and bioturbation

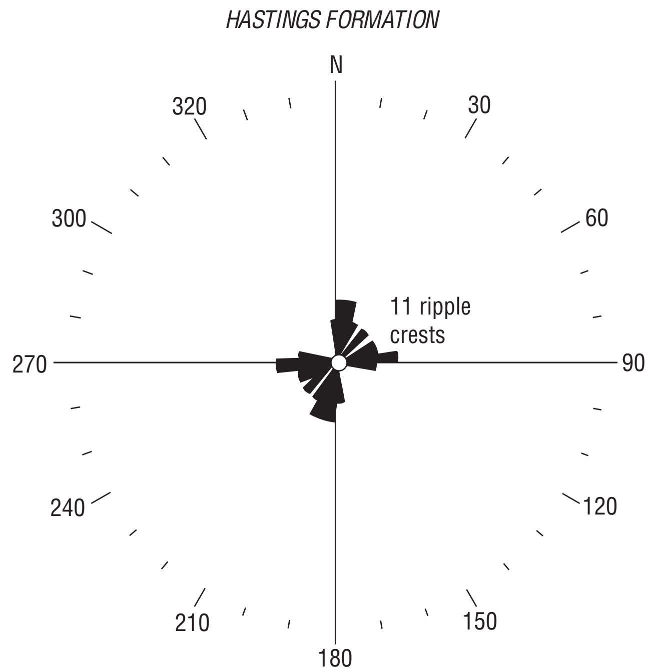
- brick red slts, massive, blocky, pedogenic, sharp top with thin, green, calcrete nodule horizon
- interbedded silty mudstone and very fine-grained ss, c-up, horizontal lamination, burrows, desiccation cracks, symmetrical ripples
- grey mudstone, bioturbated, no slts beds
- thinly interbedded, grey, laminated mudstone and buff weathering calcareous slts, rxl
- interbedded, reddish grey, very fine-grained ss and grey to greyish red silty mudstone

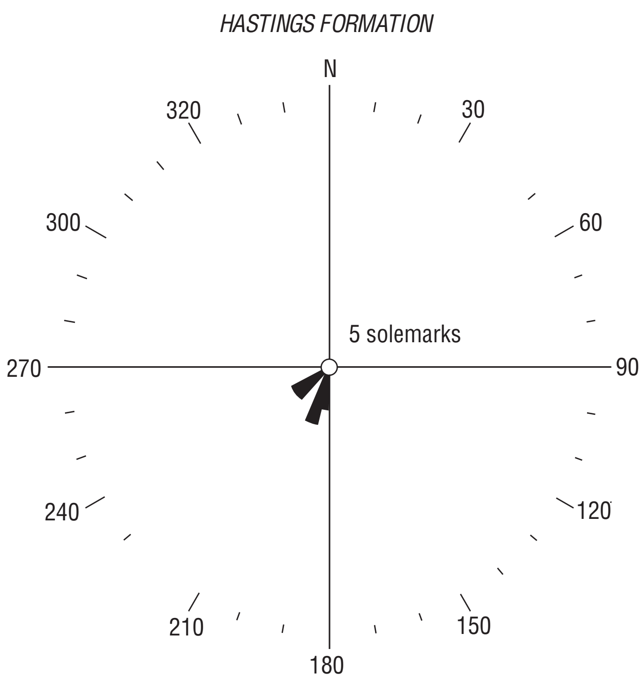
- thin bedded, very fine-grained ss
- grey mudstone, poorly exposed

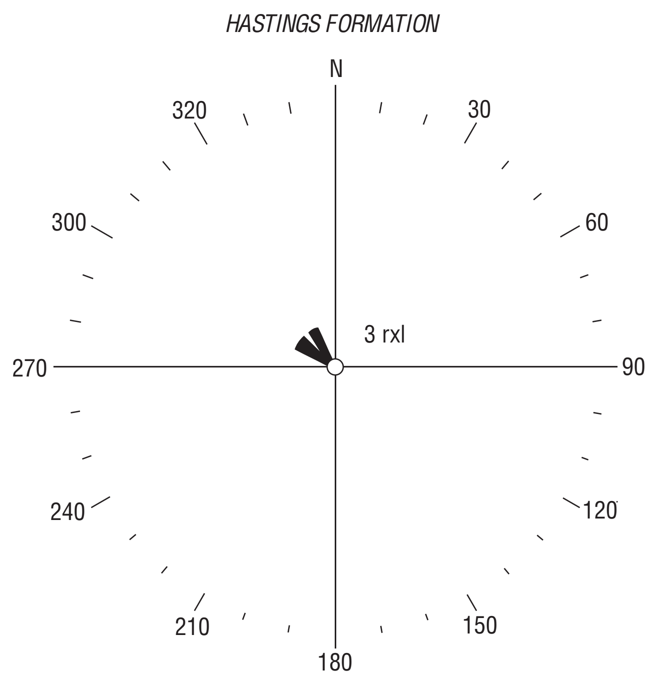
- several reddish grey, very fine-grained ss, one algal-laminated limestone horizon, desiccation cracks and breccia
- grey mudstone, few thin slts and sandy beds
- several thin, very fine-grained ss with rxl, separated by grey slts, calcareous
- c-up sequence of grey mudstone with thinly laminated, very fine-grained, silty ss
- several thin, very fine-grained ss with rxl, separated by grey, bioturbated slts
- c-up sequence of grey, calcareous mudstone with thinly laminated, very fine-grained silty ss

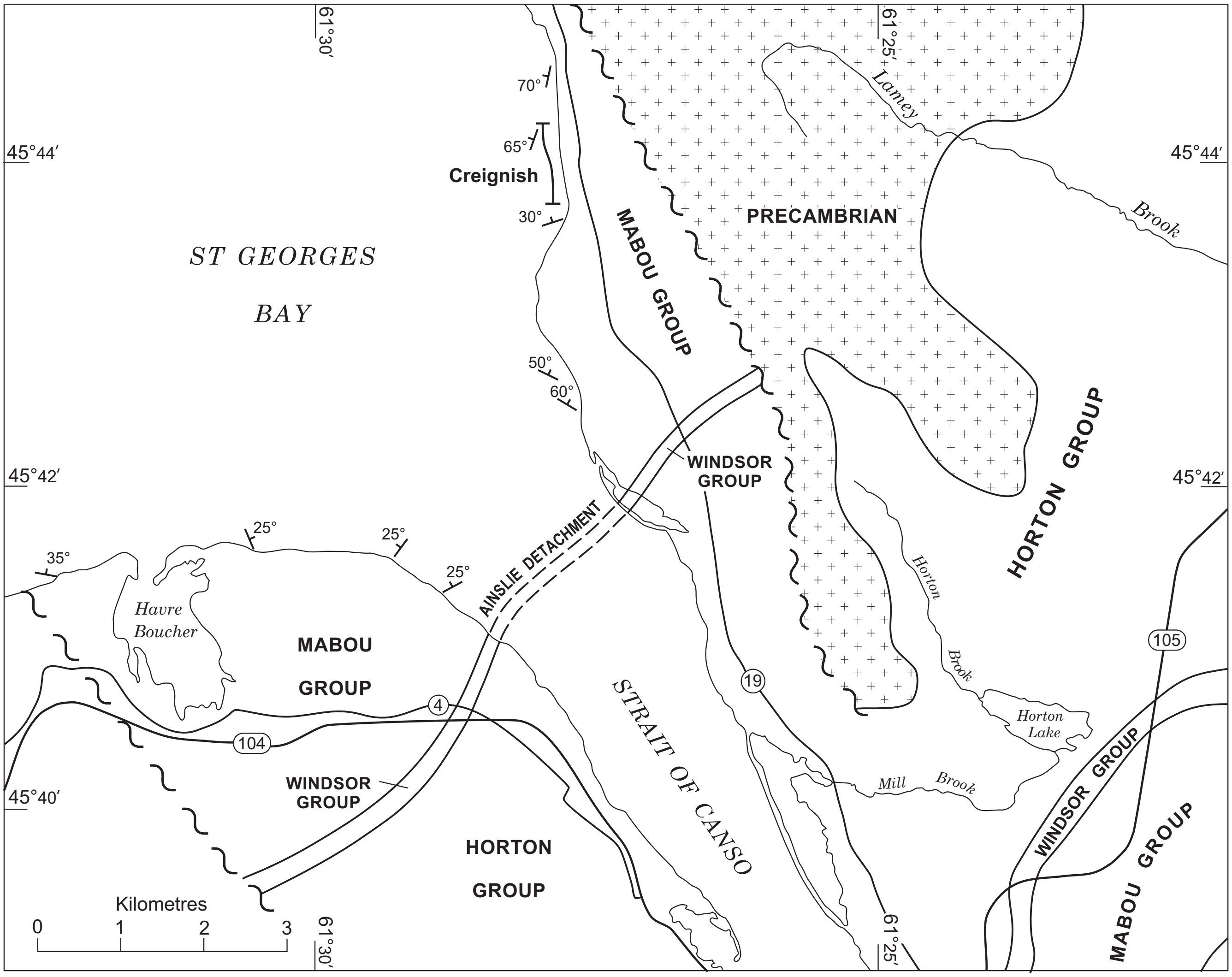
RAGGED POINT





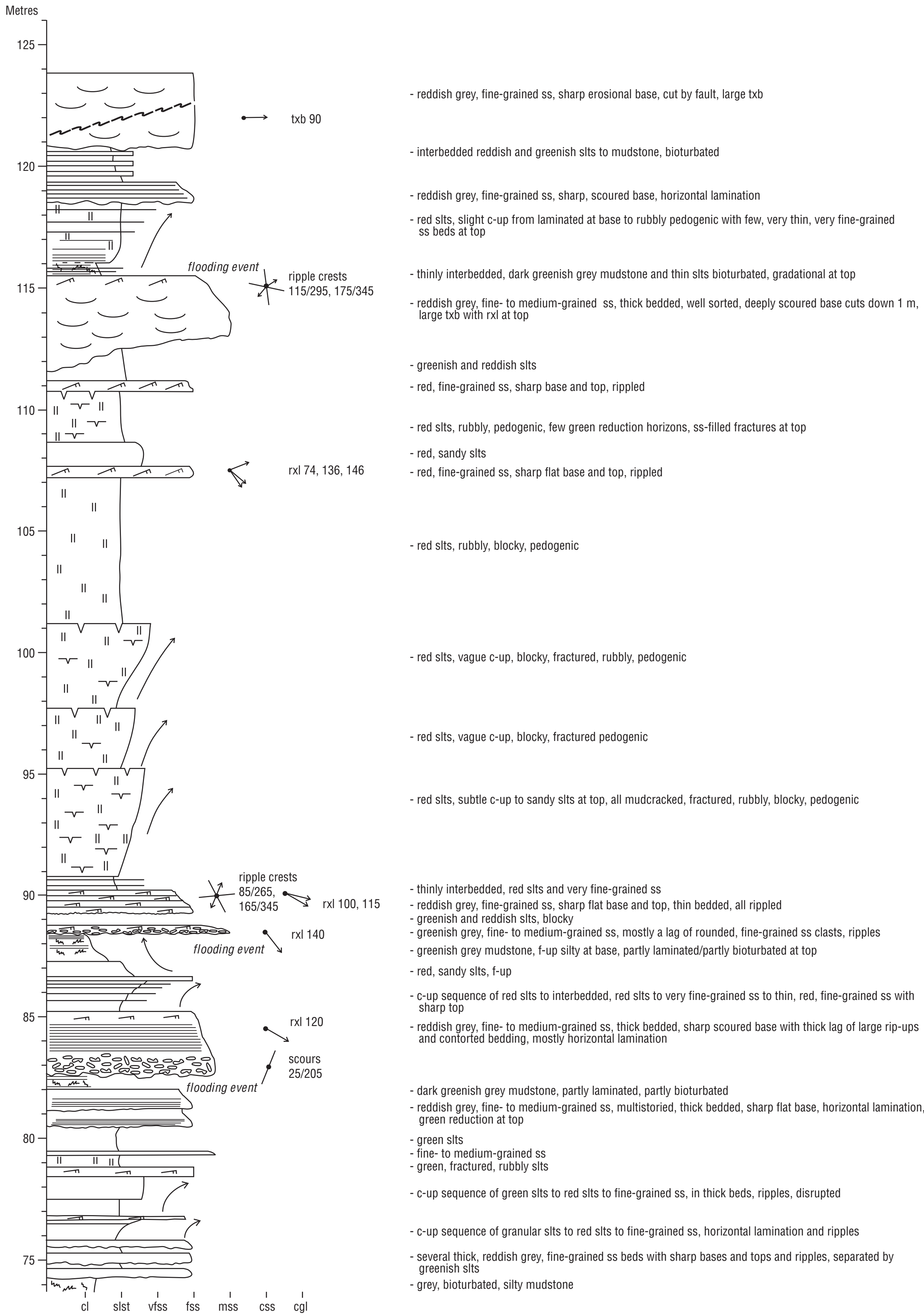




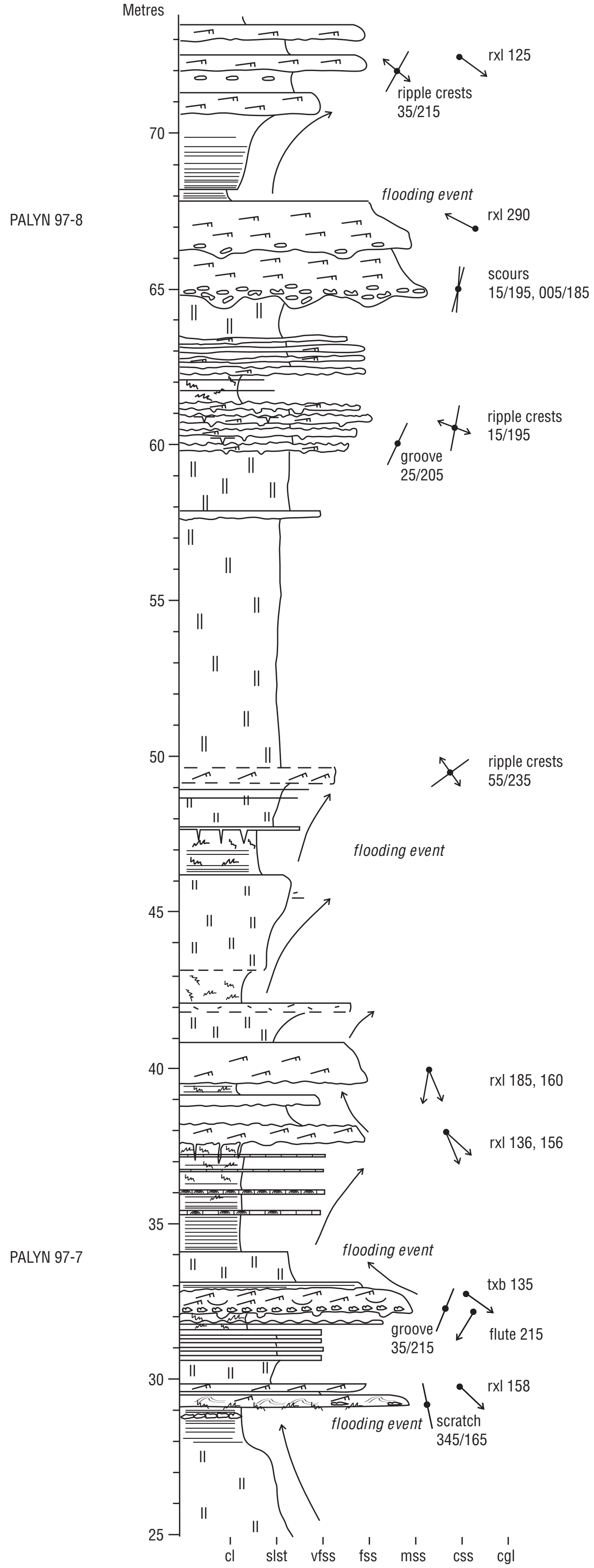


Creignish. Pomquet Formation; general strike 58°, dip 35° N.

Creignish Section

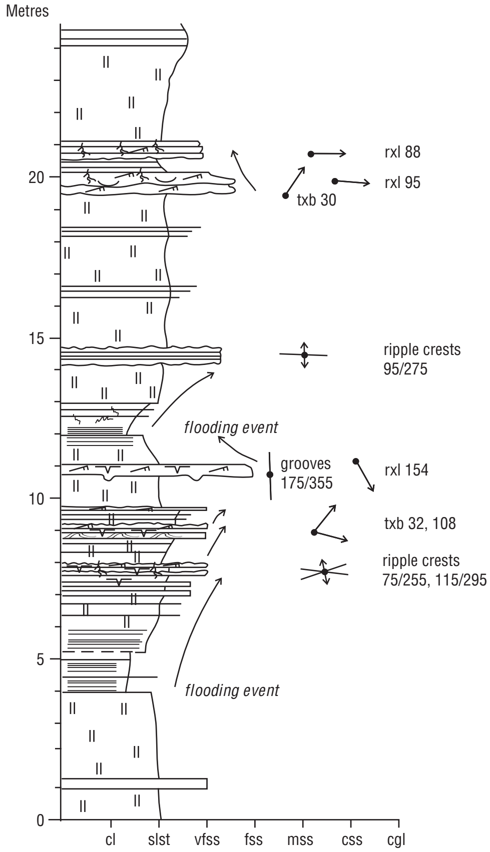


Creignish Section cont.



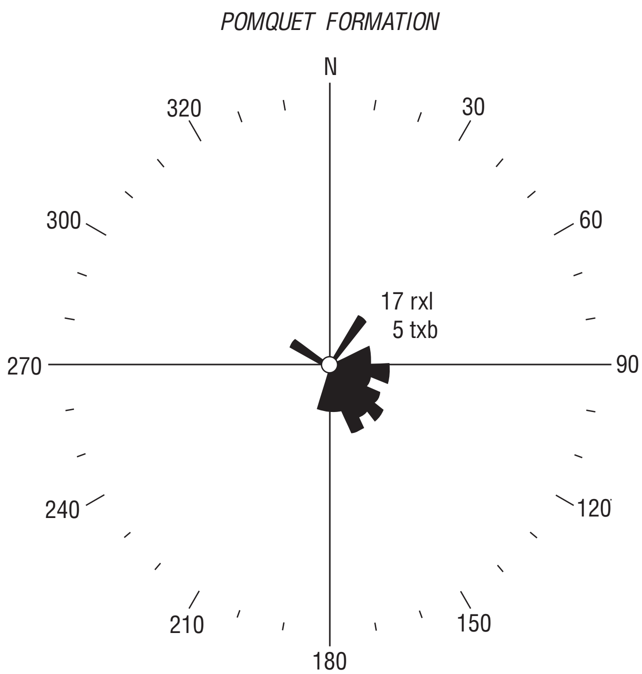
- greenish grey, fine-grained ss, sharp scoured base, rippled
- greensih sandy slts
- greenish grey, fine-grained ss, sharp flat base, rippled
- greenish, sandy slts, large concretions
- greenish, very fine-grained ss, rippled
- dark greenish grey, silty mudstone, laminated, sandier upward
- greenish grey mudstone
- multisorted fine- to medium-grained ss, thick bedded, well sorted, mostly rippled, thick 75 cm lag of large, rounded, red and green ss rip-ups at deeply scoured base
- green, sandy slts, rubbly, blocky
- interbedded, red slts and very fine-grained ss, some rippling
- greenish grey mudstone, partly bioturbated, few thin sandy beds
- bundle of thin, very fine- to fine-grained ss beds with sharp scour bases with grooves and ss-filled mudcracks and straight crested ripples, separated by sandy slts with concretion nodules
- green sandy slts, red at base, blocky, rubbly, pedogenic
- red very fine-grained ss, sharp base and top, horizontal lamination
- red slts, uniform, rubbly, fractured, few, thin, green reduction horizons, pedogenic
- very fine- to fine-grained ss, gradational at base and top, rippled
- red slts, rubbly, fractured, blocky, few, thin, very fine-grained ss beds
- greenish grey, silty mudstone, partly laminated, partly bioturbated, poorly exposed, sharp top with large ss-filled mudcracks
- red slts, c-up to sandy slts at top, rubbly, fractured
- dark greenish grey, silty mudstone, bioturbated, gradational top
- greenish grey, fine-grained ss, gradational base, sharp flat top, tiny wood fragments
- red slts, fractured, blocky, rubbly weathering
- reddish grey, fine-grained ss, sharp, flat base, rippled
- dark greenish grey mudstone, partly laminated, partly bioturbated
- reddish grey, very fine-grained ss
- greenish grey, sandy slts
- reddish grey, fine-grained ss, well sorted, sharp scoured base, sharp, irregular top, rippled
- dark greenish grey, silty mudstone, laminated, few, thin, algal laminated limestones, partly bioturbated toward top, long vertical ss-filled fractures at top
- green sandy slts, blocky, fractured, rubbly, pedogenic
- grey to buff, fine- to medium-grained ss, two storey, well sorted, lower story has sharp scour base with plates and grooves and rip-ups, minor txls and mostly rxl, rusty concretions near top, upper story laminations
- thinly interbedded, greenish grey, bioturbated mudstone and grey, fine- to medium-grained ss:slts= 1:2, ss have sharp bases and preserved ripple tops and burrows
- thinly interbedded, very fine-grained ss and sandy slts, ss:slts = 1:2, red, gradational bounds
- slts, blocky, rubbly, lower half green, upper half red
- grey, fine-grained ss, sharp base with ball and pillow, some rxl
- greenish grey, very fine-grained ss, laminated
- buff grey, fine- to medium-grained ss, sharp, flat base with abundant burrow casts and scratches, rxl, rip-ups and contorted lamination
- red and sandy slts, blocky and rubbly weathering upper 1m is dark greenish grey mudstone with laminae and bioturbated, near top is thin horizon of small, round, flat limestone concretions

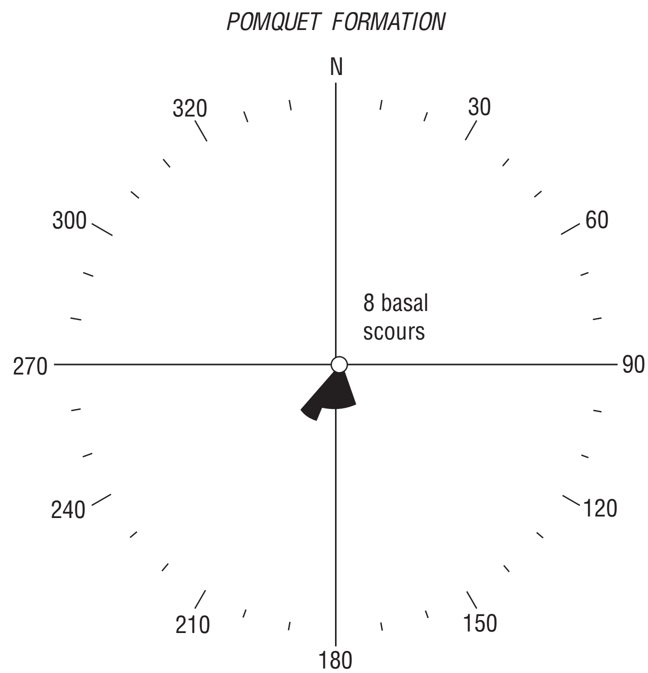
Creignish Section cont.

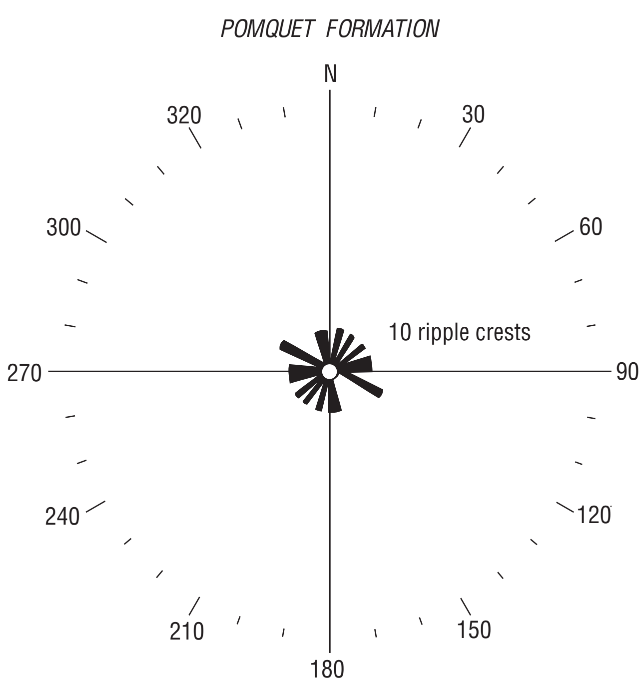


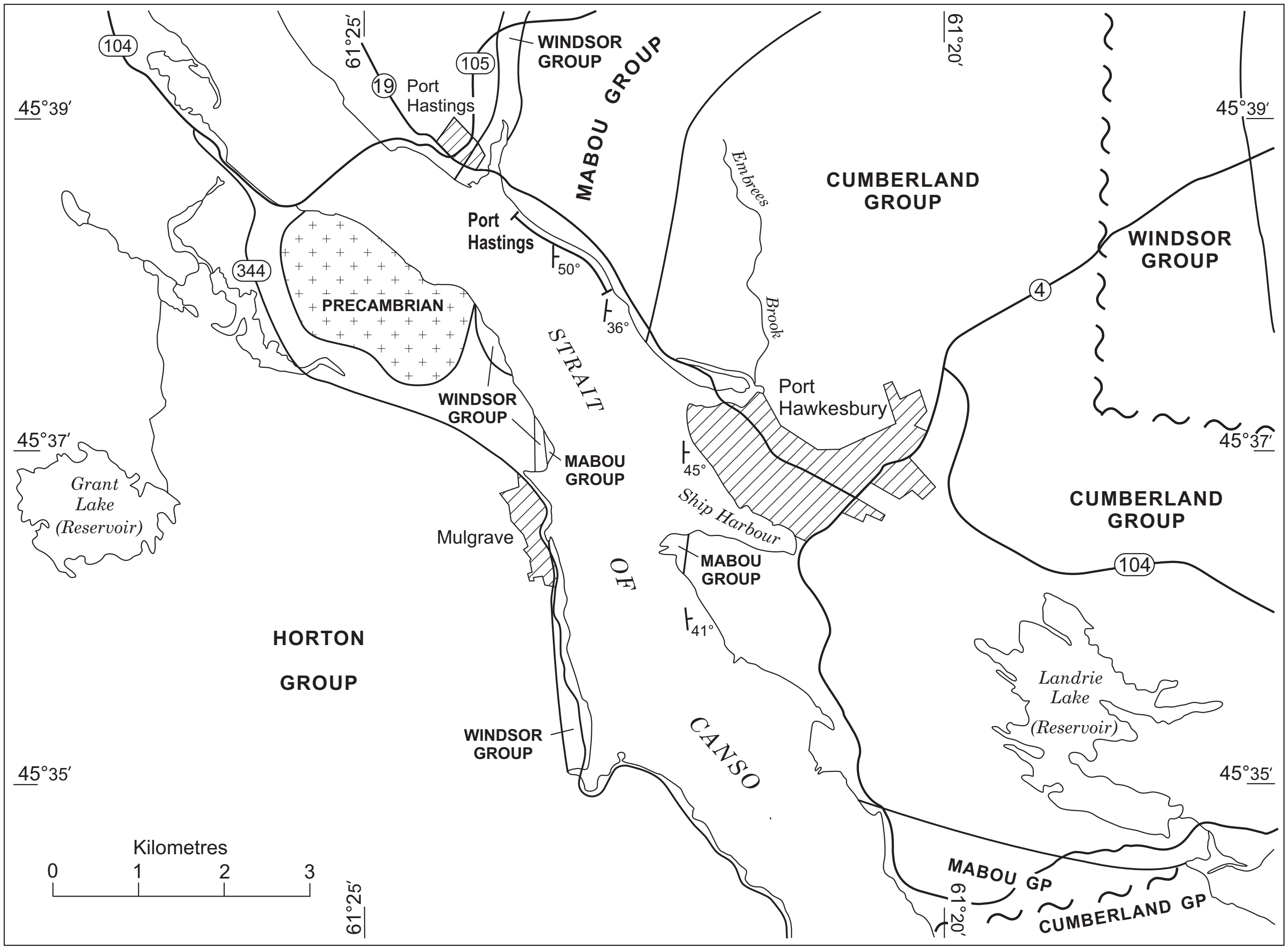
- greenish grey, very fine-grained ss, thin bedded silty, original rxl, rooted, sharp irregular top
- thinly interbedded, very fine-grained ss and slts, red, rippled
- reddish grey, very fine- to fine-grained ss, multistoried, sharp erosional base, mostly rippled, one set txb, one zone contorted, roots
- red, blocky slts, rubbly weathering, upper 1m mostly green, few, thin, very fine-grained ss beds in several bundles with sharp bases and gradational tops
- four, thin, very fine- to fine-grained ss separated by slts partings, sharp errosional bases, straight ripples on top, calcareous
- red slts, blocky, rubbly, pedogenic
- greenish grey silty mudstone, c-up, partly laminated, partly bioturbated, thin rusty slt at top
- red slts, rubbly near base and laminated at top, gradational top
- reddish grey, fine-grained ss, well sorted, sharp scour base with large grooves, rxl, mudcrack
- red, rubbly, blocky slts, pedogenic
- thin, c-up, red, rubbly slts to very fine-grained ss with rxl
- c-up sequence of red, rubbly slts with few, thin, very fine-grained ss beds to very fine-grained ss with contorted lamination and ss-filled vertical fractures to rippled, very fine-grained ss with minor contraction
- c-up sequence of red, laminated mudstone to red, rubbly slts with few, thin, very fine-grained ss beds, to red, rubbly slts with very fine-grained ss beds with straight, symmetrical ripples, sharp top, mudcracks and roots?
- greenish grey, silty mudstone, thinly laminated, sharp base, gradational top, few, thin, rusty calcareous slts
- red slts, rubbly, pedogenic, one thin, very fine-grained ss near base, poor exposures

CREIGNISH


POMQUET FORMATION
N
30
60
90
120
150
180
210
240
270
300
320
17 rxl
5 txb

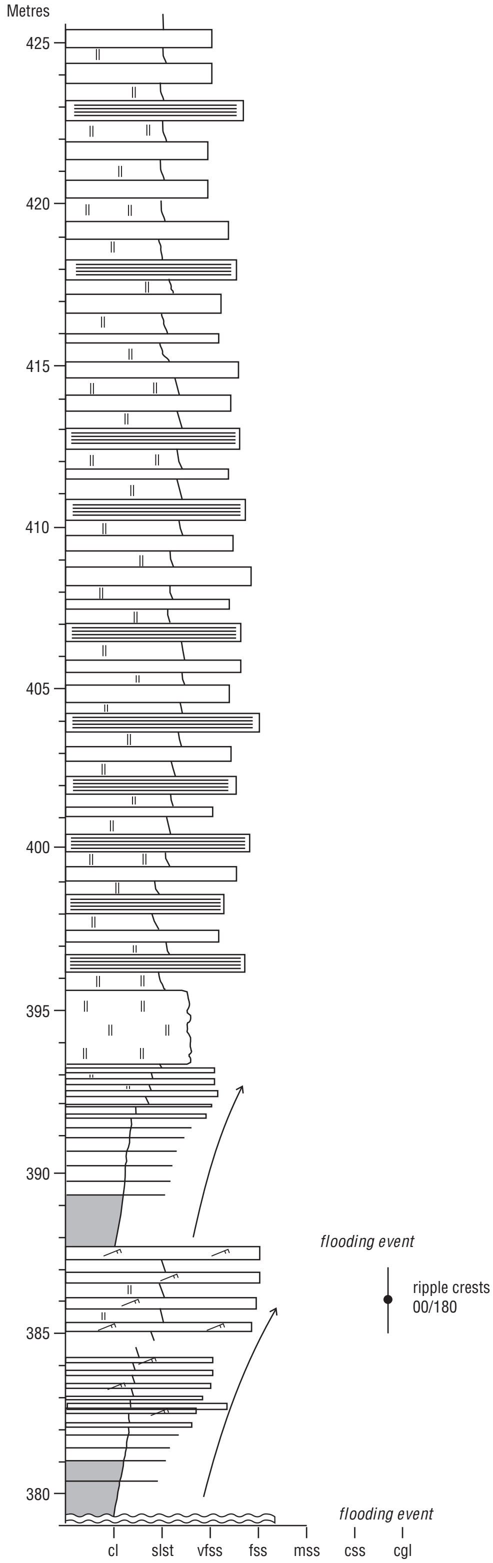

POMQUET FORMATION
N
30
60
90
120
150
180
210
240
270
300
320
8 basal
scours


POMQUET FORMATION
N
30
60
90
120
150
180
210
240
270
300
320
10 ripple crests



Port Hastings. Pomquet Formation type section; general strike 174°, dip 63° E.

Port Hastings Section



- thickly interbedded, red slts and red, very fine- to fine-grained ss, ss:slts = 1:5, few beds of rubbly green slts, and greenish grey, fine-grained ss, mostly massive, blocky and pedogenic, ss have sharp bases and gradational tops and horizontal lamination

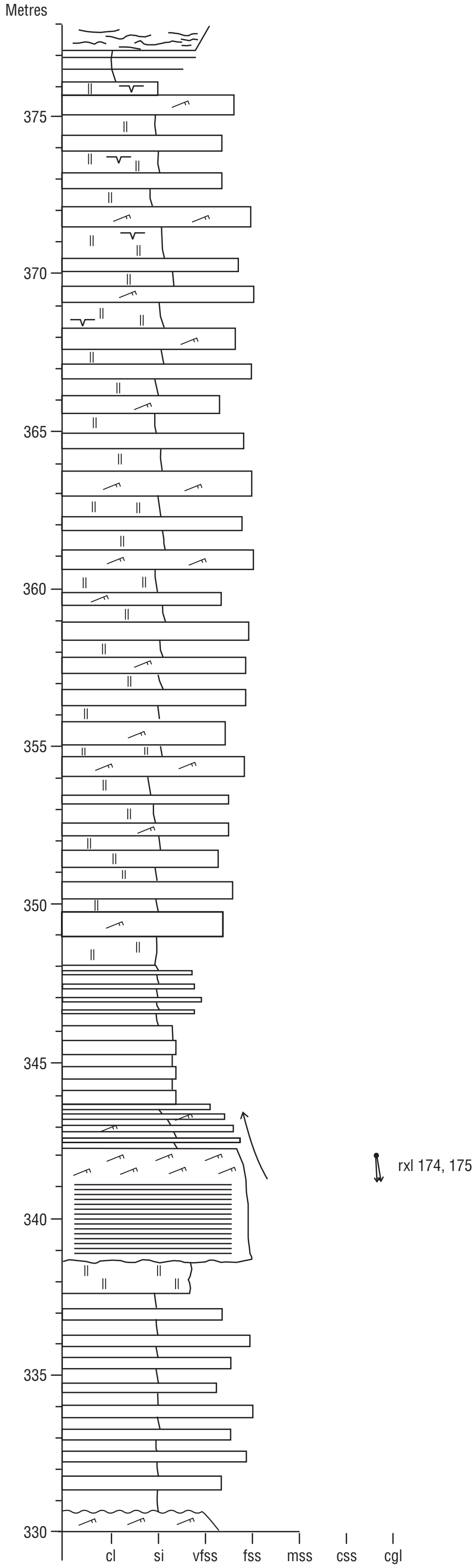
- greenish grey, silty, very fine-grained ss, massive, blocky, rubbly weathering, pedogenic, disrupted

- c-up sequence of grey to dark grey mudstone, to thinly interbedded mudstone and very fine-grained ss, to thinly interbedded red slts and very fine-grained ss, sharp top

- c-up sequence of grey to dark grey mudstone, to thinly interbedded mudstone and very fine-grained ss, to thickly interbedded red slts and grey fine-grained ss, sharp top, ripples

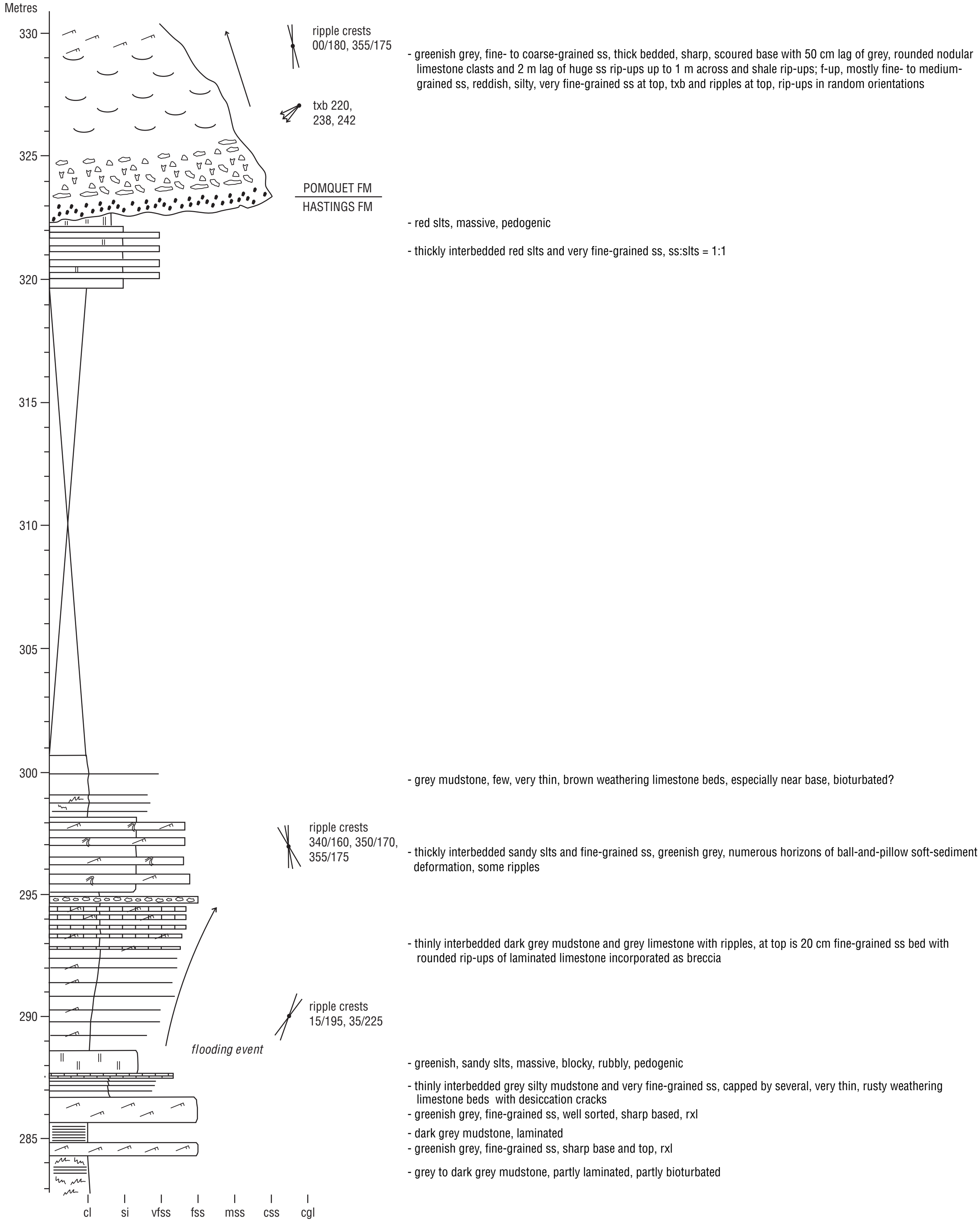
- brown weathering, irregular, nodular limestone, sharp base and top

Port Hastings Section cont.

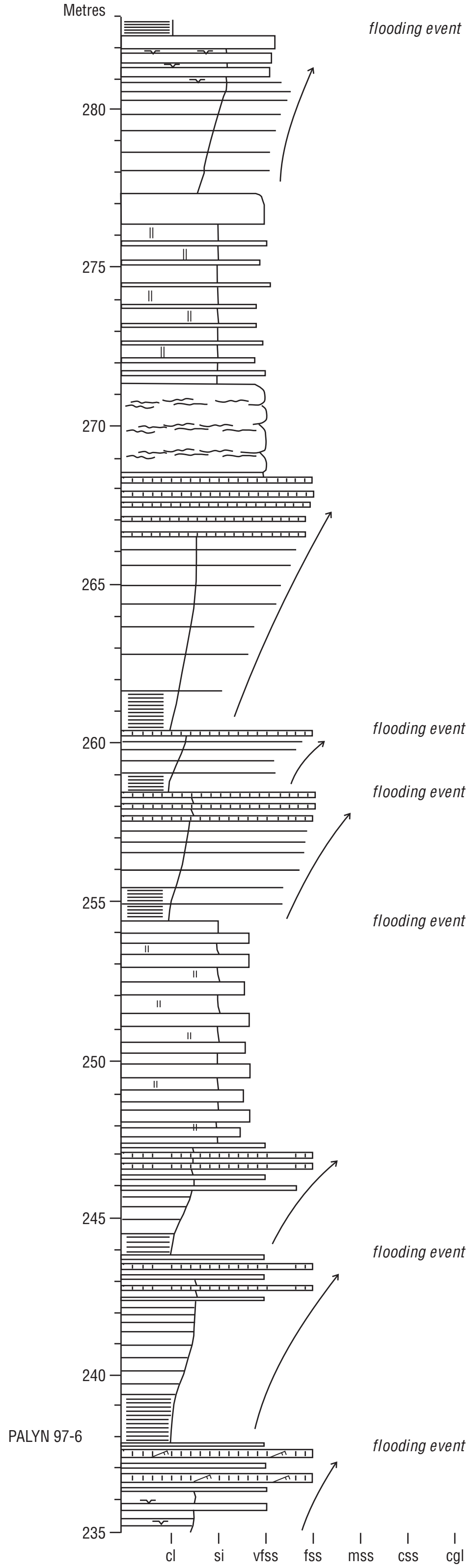


- greenish grey, very fine-grained ss, slightly c-up to reddish, fine-grained ss, slts partings near base
- grey mudstone, few, very thin, very fine-grained ss beds
- thickly interbedded brick red slts and red, very fine- to fine-grained ss, slts is massive, blocky, and pedogenic, ss:slts = 1:3 with mudcracks, ss have sharp bases and gradational tops with original ripples now mostly disrupted
- thinly interbedded, red slts and very fine-grained ss
- thickly interbedded, red and green sandy slts
- greenish grey, fine-grained ss, sharp based, slightly f-up, gradational top with thin, silty beds, horizontal lamination and rxl
- greenish grey, silty, very fine-grained ss, blocky, massive, pedogenic
- thickly interbedded red slts, and very fine- to fine-grained ss

Port Hastings Section cont.

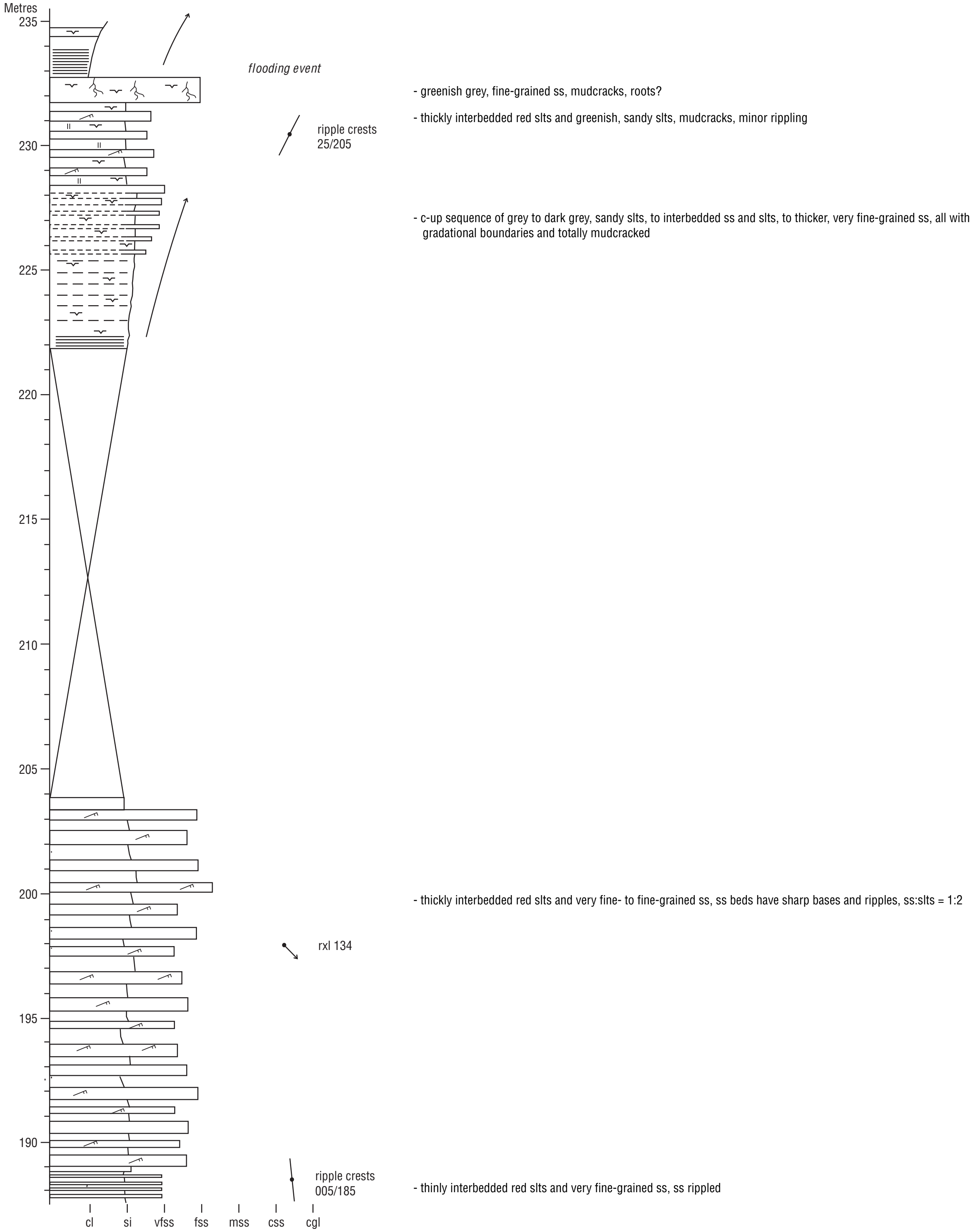


Port Hastings Section cont.

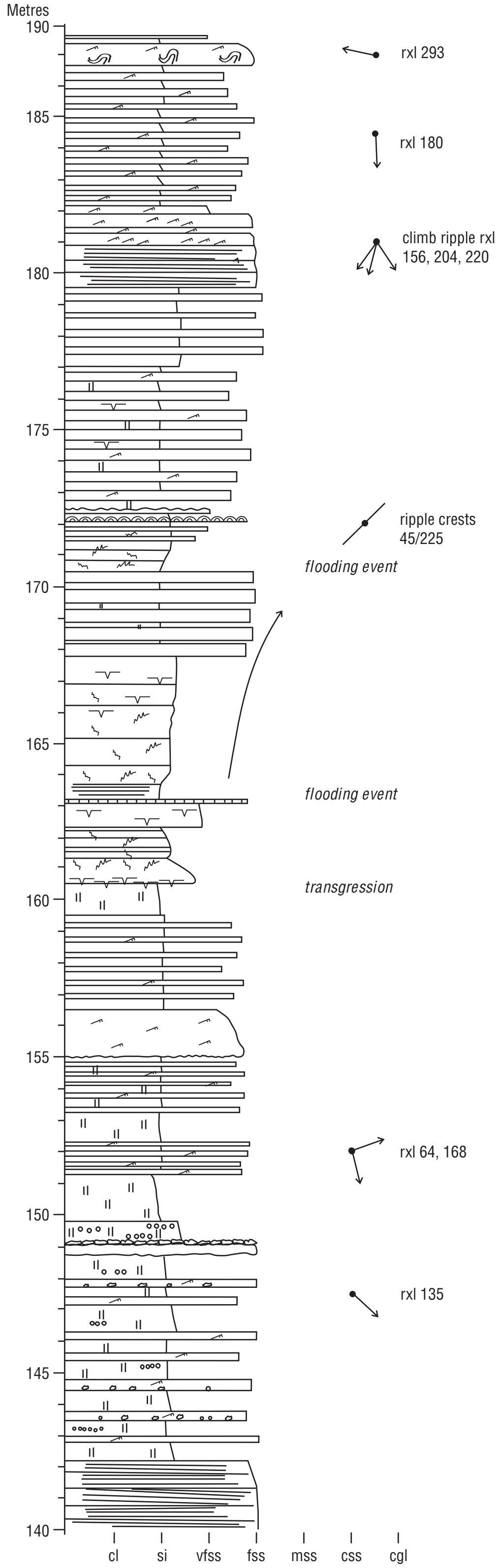


- c-up sequence of greenish grey mudstone with thin limestone beds, to thicker, greenish grey, very fine-grained ss with mudcracks
- greenish grey, very fine-grained ss
- brick red slts, numerous thin, very fine-grained ss beds
- greenish grey, very fine-grained ss, thick bedded, silty partings
- c-up sequence of grey to dark grey laminated mudstone, to silty mudstone with thin laminated limestone
- c-up sequence of grey to dark grey mudstone, to interbedded silty mudstone and thin limestone
- c-up sequence of grey to dark grey, laminated mudstone, to interbedded, silty mudstone and thin, laminated limestone
- thickly interbedded greenish slts and silty, very fine-grained ss, sharp base and top, massive and blocky, rubbly weathering, pedogenic
- c-up sequence of grey to dark grey, laminated mudstone, to silty mudstone with laminated limestone, to thinly interbedded, very fine-grained ss and rippled limestone
- c-up sequence of grey to dark grey, laminated mudstone, to silty mudstone with laminated limestone, to thinly interbedded very fine-grained ss and rippled limestone
- c-up sequence of grey to dark grey, laminated mudstone, to silty mudstone with brown algal laminated limestone and mudcracks, to interbedded, thin, very fine-grained ss and thicker rippled limestone

Port Hastings Section cont.

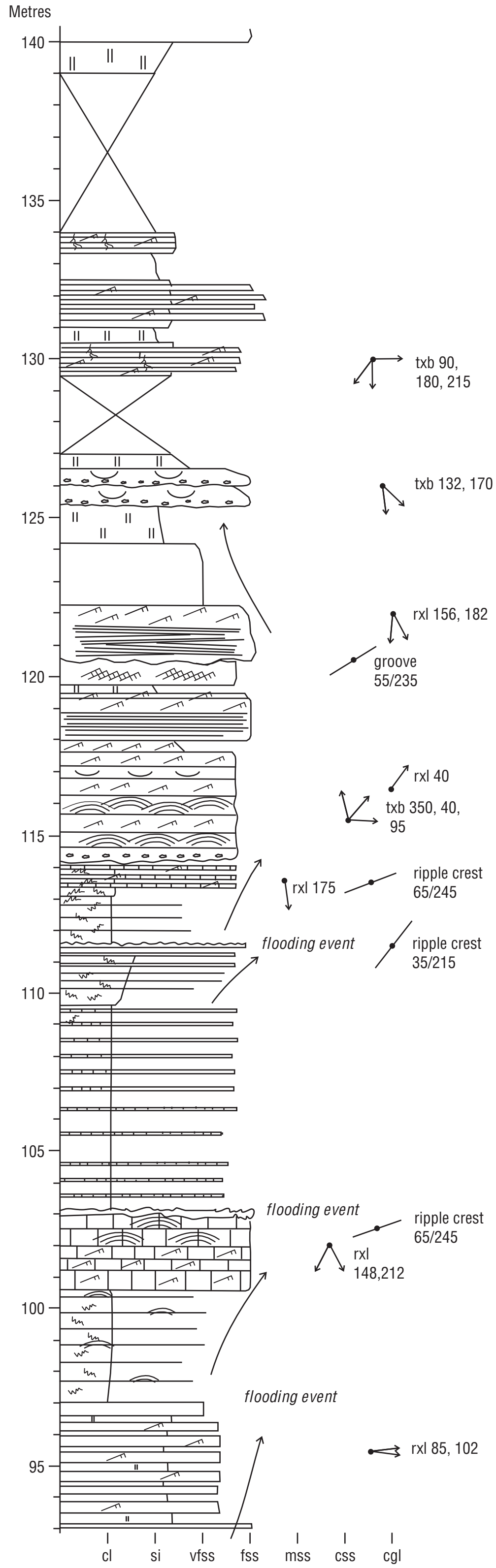


Port Hastings Section cont.



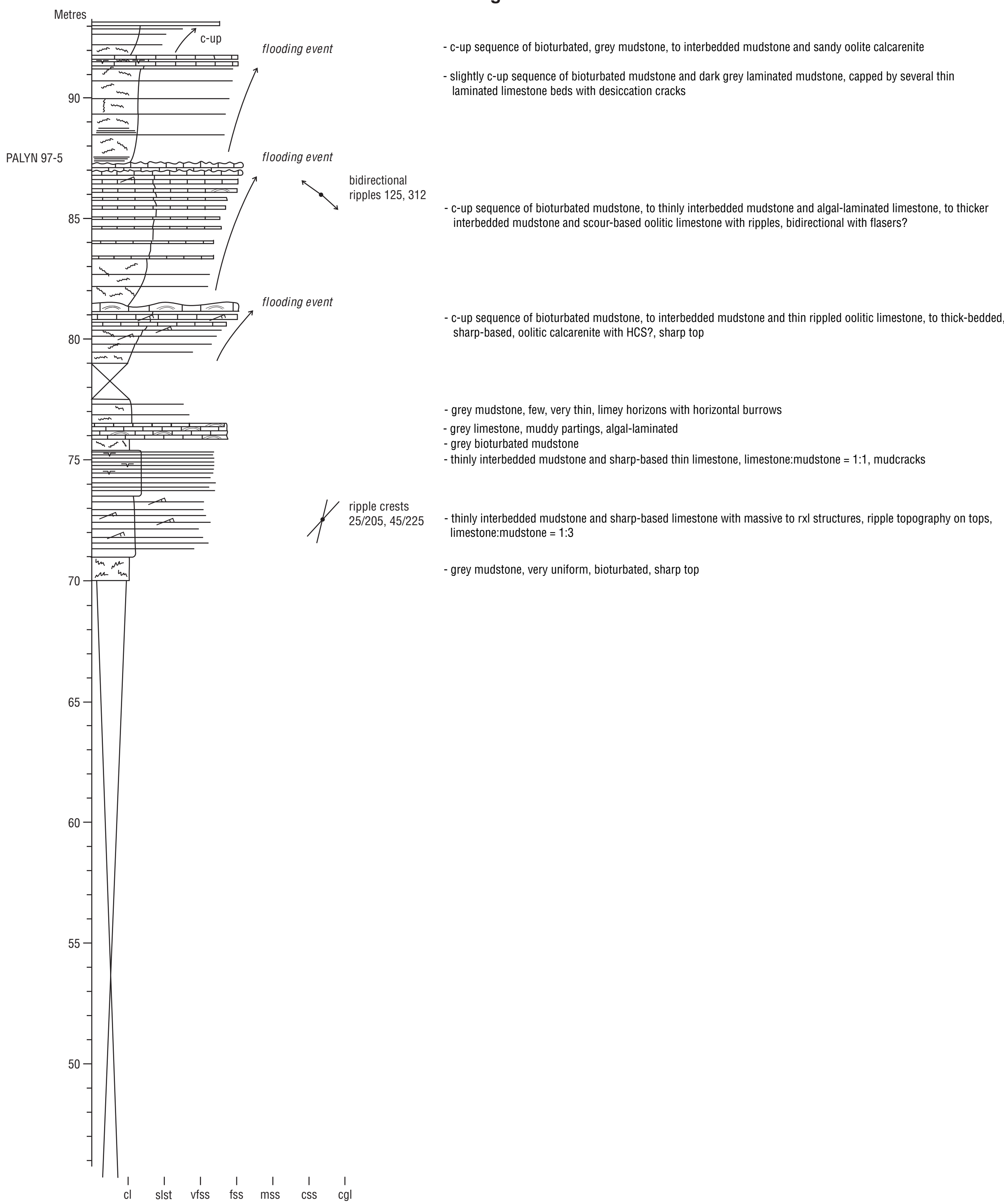
- greenish grey, fine-grained ss, well sorted, massive with minor rxl on top, contorted lamination
- interbedded red slts and fine-grained ss, ss:slts = 1:1, all rxl
- red, fine-grained ss, thick bedded, well sorted, sharp base and top, few, thin, very fine-grained ss partings, horizontal lamination at base, then climbing ripples
- thickly interbedded, greenish grey, fine-grained ss and sandy slts, ss:slts = 1:3
- thickly interbedded, brick red slts and red, very fine- to fine-grained ss, blocky and pedogenic, minor rxl, ss:slts = 1:1, desiccation cracks
- c-up sequence of bioturbated sandy slts, to interbedded thin limestone and slts, to thin bedded very fine-grained ss with subtle, straight-crested, symmetrical ripples, one thin, bulbous, stromatolitic limestone near top
- red, fine-grained ss, thick bedded, several thin, brick red pedogenic slts beds with gradational bounds
- grey to greenish grey to dark grey slts and sandy slts, mostly bioturbated, some horizons laminated, few thin, laminated, limestone beds, few mudcrack horizons
- greenish grey silty, very fine-grained ss, mudcrack disruption, capped by 20 cm limestone bed
- grey, sandy slts, bioturbated, many very thin limestone beds with sharp bases, lamination and desiccation cracks
- greenish grey, silty, very fine-grained ss, f-up, lower 20 cm disrupted by limestone-filled mudcracks, upper part bioturbated
- red slts, pedogenic
- interbedded red slts and red, fine-grained ss
- red, very fine- to fine-grained ss, thick bedded, well sorted, rxl
- thinly interbedded red slts and red fine-grained ss, rxl
- red slts, blocky, massive, rubbly, pedogenic
- thinly interbedded red slts and red, fine-grained ss, slts pedogenic, ss rxl
- brick red slts, massive, rubbly, pedogenic, vertical fractures, small green reduction spots
- red, sandy slts, rubbly massive, pedogenic; abundant, round, grey, calcareous caliche nodules
- thickly interbedded, brick red pedogenic slts and red, very fine- to fine-grained ss beds with sharp bases and gradational tops, green reduction horizons in slts, ss:slts = 1:5, ss have caliche nodule lags and rxl, upper 50 cm all red ss capped by green, irregular, lumpy horizon, some red slts have horizons of caliche nodules
- fine-grained ss, red at base, greenish grey at top, well sorted, sharp, flat base and top, horizontal and low-angle lamination

Port Hastings Section cont.

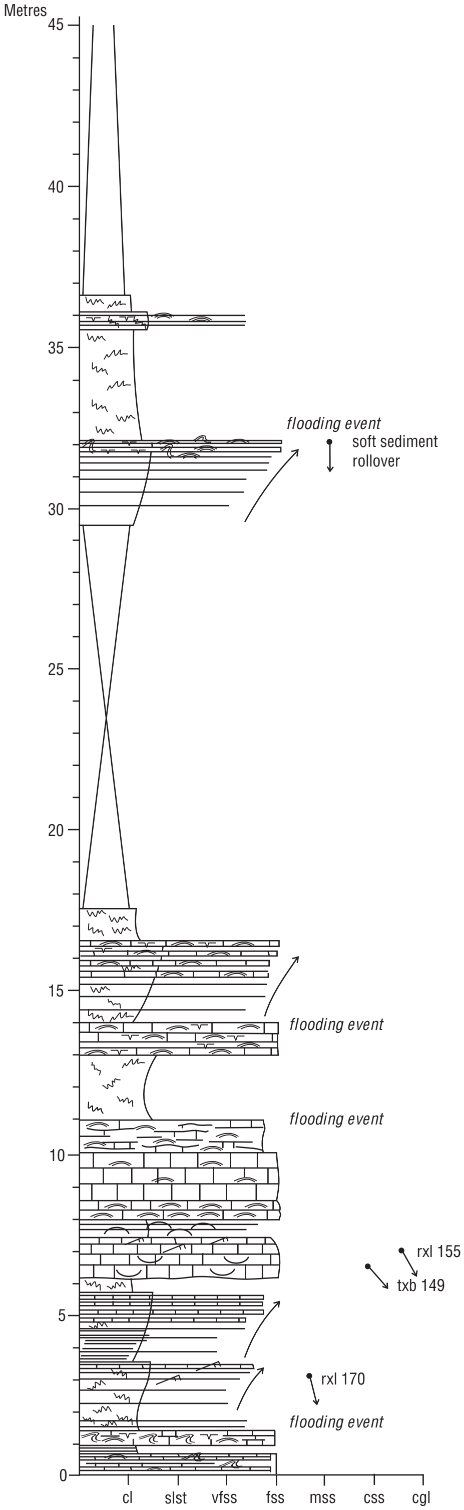


- red slts, sandier upward, massive, pedogenic
- green, sandy slts to silty, very fine-grained ss, thin bedded, rxl, rooted and disrupted
- red slts, abundant green reduction horizons
- red slts, blocky, pedogenic
- interbedded red, fine-grained ss and sandy slts, ss:slts = 1:1, ss have txb and rxl, possible roots
- red, sandy slts, gradational base, rubbly, disrupted
- red, fine-grained ss, well sorted, two-storey unit, sharp bases with lags of red slts rip-ups, gradational top
- brick red slts, fractures, blocky weathering, pedogenic
- greyish red, very fine-grained ss, reduction spots, poor exposure
- greenish grey, fine-grained ss, well sorted, uniformly sharp, scoured base with broad grooves, thinly laminated, wavy, low-angle lamination, minor rxl
- red, fine-grained ss, well sorted, all climbing ripples, green reduction spots
- brick red slts, blocky, massive, pedogenic
- reddish grey, fine-grained ss, well sorted, horizontal lamination, rxl
- greenish grey, sandy slts to silty, very fine-grained ss, rxl
- grey to greenish grey, very fine- to fine-grained ss, brown weathering, calcareous, well sorted, very uniform, thick bedded, sharp erosive base with lag of large rip-ups of distorted underlying limestone and shale, sets of low-angle? hummocky crosslamination, separated by thin, rippled units
- grey, bioturbated mudstone with thin, algal-laminated limestone beds with sharp bases and rippled tops, some soft-sediment deformation
- grey, bioturbated mudstone, uniform, many very thin limestone horizons <1 cm thick
- c-up sequence of bioturbated mudstone, to interbedded laminated limestone and mudstone, to 10 cm oolite bed with sharp base and rippled top
- thinly interbedded grey mudstone and laminated limestone, limestone to mudstone = 1:3
- grey calcarenite (oolite?), well sorted, sharp, flat base, clean, thick bedded, abundant rxl, some HCS near top, sharp top with irregular, rusty, hardground surface
- grey, bioturbated mudstone, many thin, algal-laminated limestone beds
- greenish grey, very fine-grained ss, calcareous, massive, sharp top
- greyish red, very fine-grained ss with 20–50 cm brick red, sandy slts beds, thin bedded, green reduction horizons, slts fractured, rxl in ss

Port Hastings Section cont.



Port Hastings Section cont.



- grey, bioturbated mudstone
- thinly interbedded, partly bioturbated mudstone and thin, brown weathering algal-laminated limestone, mudcracks

- grey, bioturbated mudstone

- c-up sequence of thinly interbedded, partly bioturbated grey mudstone and thin, algal-laminated limestone, increase in thickness and stromatolitic lamination and mudcracks toward top, soft-sediment contortion at top, rollover to south

- grey mudstone, bioturbated
- c-up sequence of interbedded, bioturbated mudstone and algal-laminated limestone, large mudcracks near sharp top

- brown weathering, algal-laminated limestone, mudstone partings, mudcracks, sharp top

- grey to greenish grey, silty mudstone, bioturbated

- grey, algal-laminated limestone with thin mudstone partings

- thick bedded, grey, sandy limestone, oolitic, minor, very thin, algal-laminated horizons, uniform

-grey, algal-laminated limestone

- thinly interbedded, grey to dark grey, papery shale and algal-laminated limestone
- greenish grey, calcarenite, sharp base and top, oolite, wavy lamination, ripples

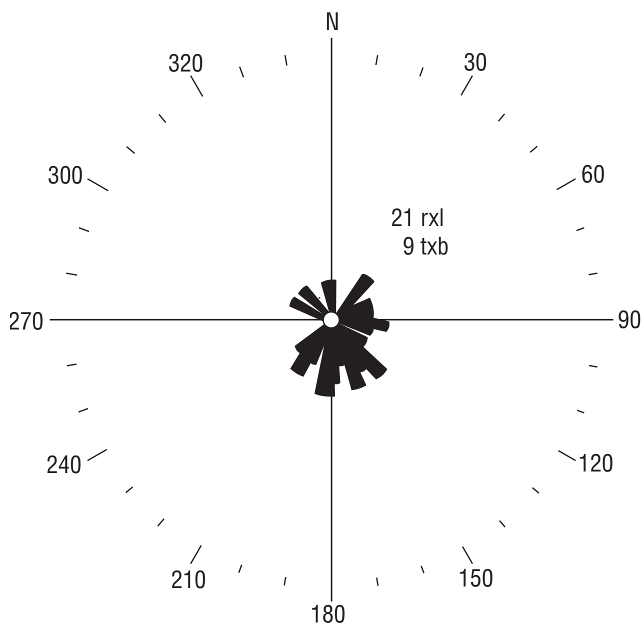
- grey mudstone, bioturbated

- slightly c-up sequence of interbedded laminated mudstone and laminated limestone, some bioturbated horizons with *Planolites*-like horizontal burrows

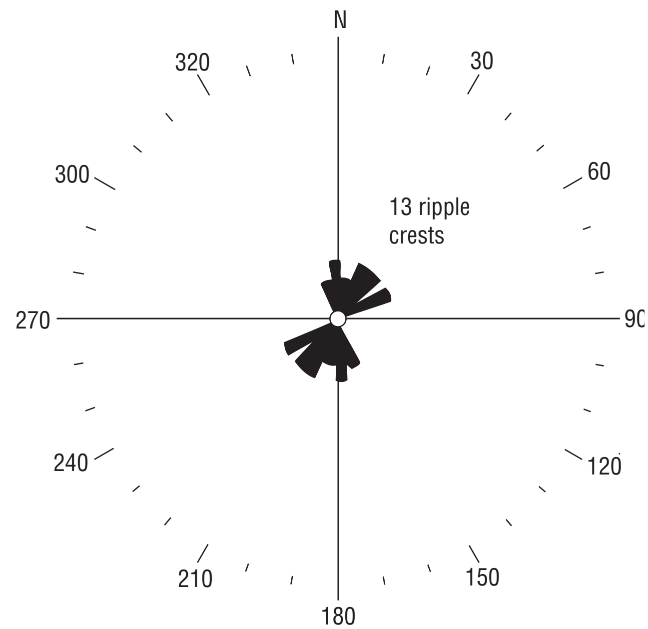
- thinly interbedded, grey, bioturbated mudstone and brown, laminated and rippled limestone, slightly c-up with increase of limestone toward sharp top, gradational base
- grey mudstone, bioturbated, few, very thin, algal-laminated limestone
- brown weathering limestone, minor algal-laminated, abundant contorted laminae, desiccation cracks
- grey mudstone, laminated, calcareous, uniform
- brown weathering limestone, thin bedded, muddy, some stromatolitic and crinkled lamination

PORT HASTINGS

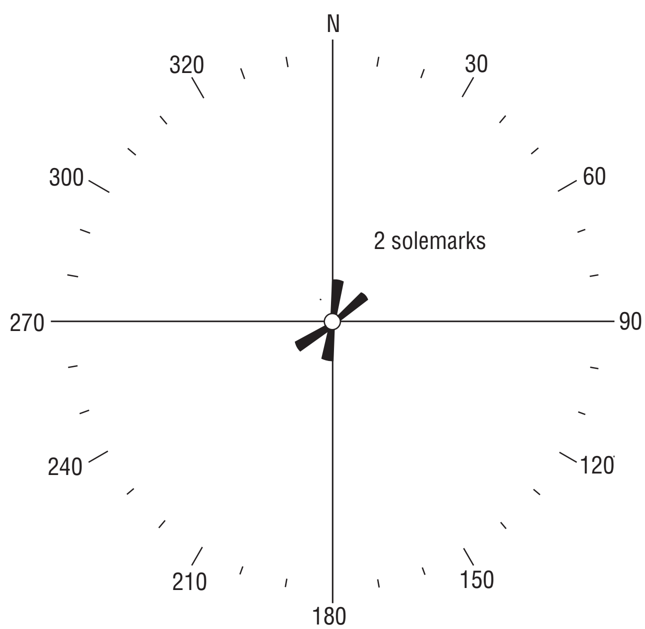
HASTINGS FORMATION



HASTINGS FORMATION

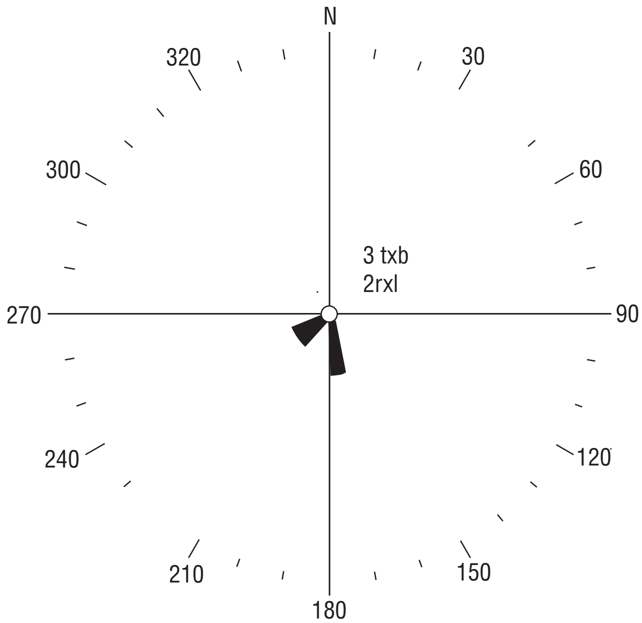


HASTINGS FORMATION

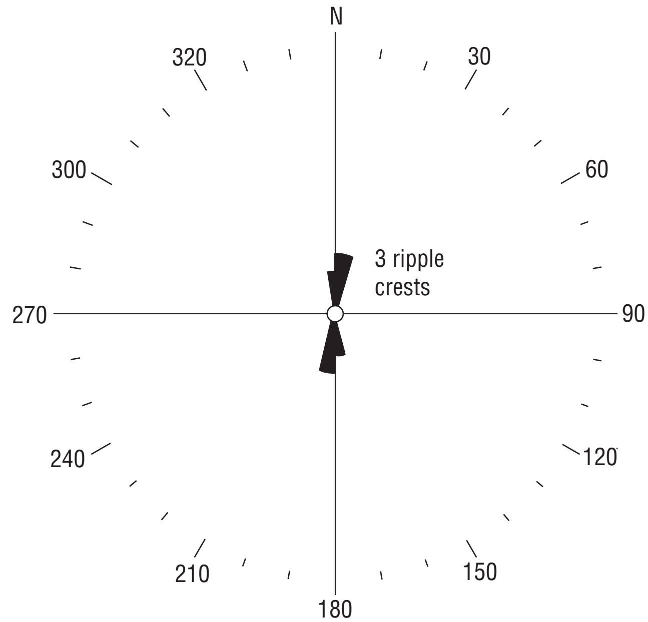


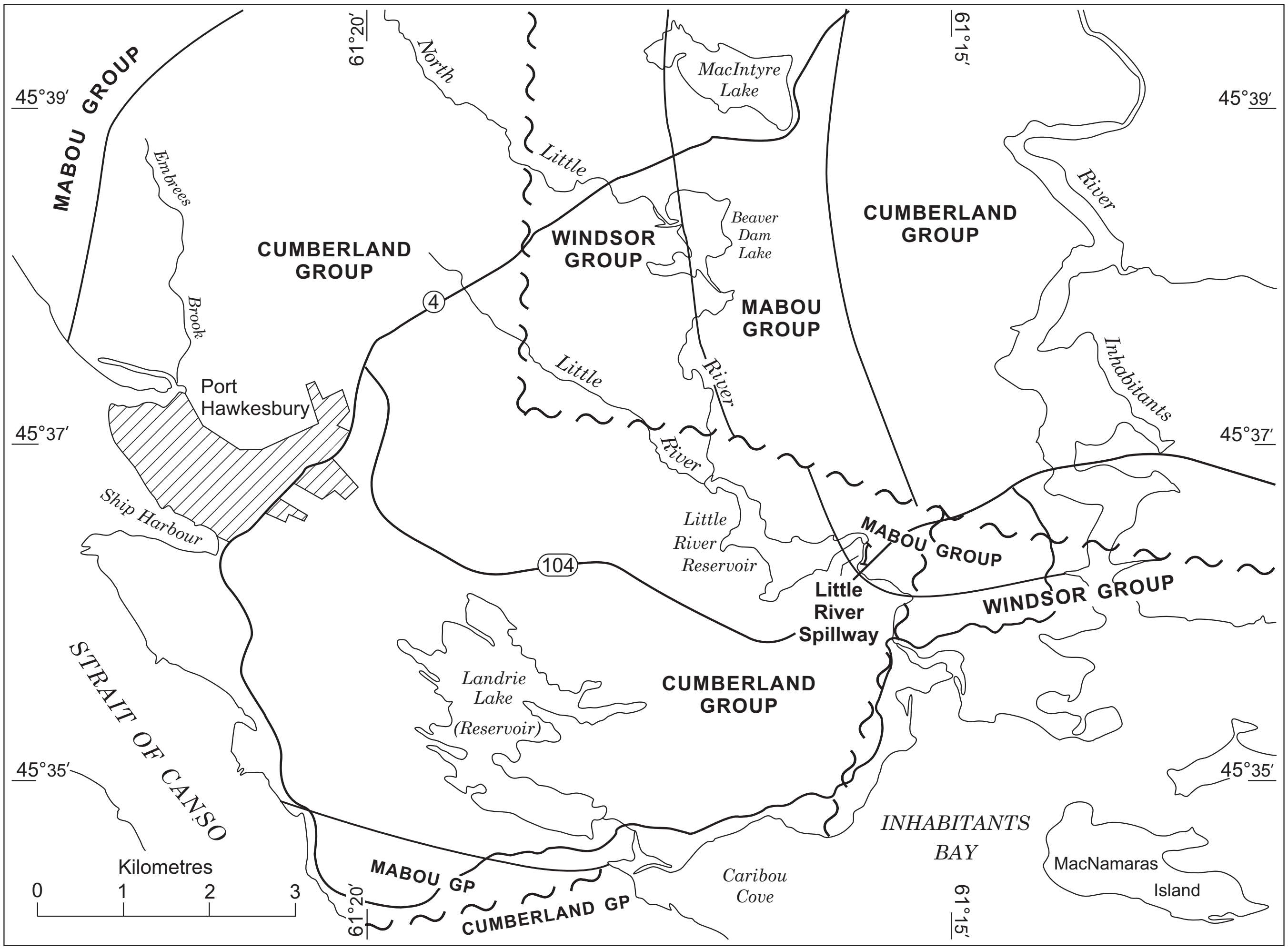
PORT HASTINGS

POMQUET FORMATION



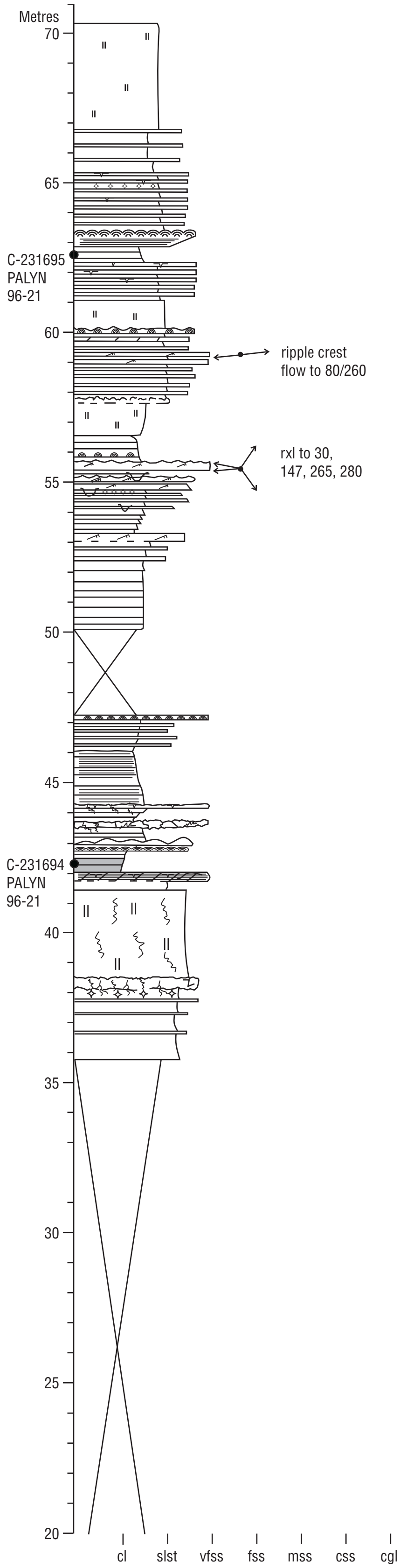
POMQUET FORMATION





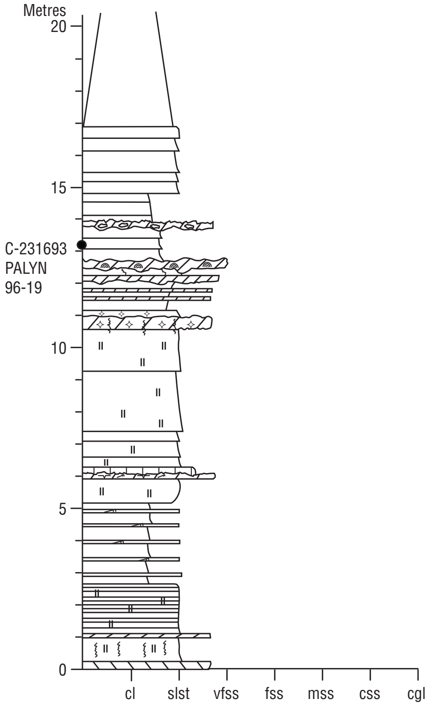
Little River Spillway. Hastings Formation; general strike 120°, dip 50° N.

Little River Spillway Section



- greenish grey slts, massive, blocky, poorly exposed
- thinly interbedded sandy slts and slts, ss:slts = 1:10, slts blocky weathering, ss has sharp boundaries
- thinly interbedded sandy slts and slts, ss:slts = 1:2, slts blocky weathering, ss has sharp bases and tops and is orange weathering, desiccation cracks, 5 cm horizon of calcite-lined vugs
- buff weathering, grey, dolomitic slst, slightly c-up, sharp top, algal?-laminated
- greenish grey clay-rich slts, few, very thin, dolomitic slts beds
- interbedded buff, sandy slts and grey slts, desiccation cracks
- greenish grey slts, massive, blocky
- thinly interbedded, buff weathering dolomitic slts and grey slts, dolostones are laminated with undulatory lamination
- thinly interbedded, grey, silty, very fine-grained ss and sandy slts, ss have erosional bases and rxl
- greenish grey, clay-rich slts, massive, blocky, upper 20 cm has lumpy texture and sharp top (paleosol?)
- grey, clay-rich slts with thin, sharp-based laminated dolomitic slts, at least one of which is algal-laminated
- c-up sequence of interbedded, grey to dark clay-rich slts and silty, very-grained fine ss, culminating in 40 cm of rippled, very fine-grained ss at top, distinct horizon of large, displacive calcite-lined vugs pseudomorphic after evaporites, several distinct mud-filled scours which cut through beds
- grey to dark clay-rich slts, laminated, with few, thin, buff weathering slts beds throughout and increasing to top, slts:mud = 1:10, top bed is 20 cm sandy slts with gradational base, sharp top and rxl
- bundle of interbedded, buff weathering slts and greenish grey, clay-rich slts, slts:mud = 1:2, buff slts have sharp bases and laminae and sharp tops, top one is algal?-laminated limestone
- greenish grey, clay-rich slts, many thin, buff weathering dolomitic slst beds, laminated
- thin, c-up sequence of grey, clay-rich slts and buff, dolomitic slts, desiccation cracks and burrows, laminated at top
- buff weathering, grey, calcareous slts, lumpy, irregular, gradational base and sharp top, fractured
- greenish grey, clay-rich slts, few, thin, buff slts
- thin, c-up sequence of interbedded, dark grey mudstone, laminated and discontinuous slts and algal-laminated argillaceous calcareous slts
- buff, dolomitic slts, laminated, gradational base over green slts, sharp top with organic-rich laminae and mudcracks
- red, sandy slts, very fractured, with sickensides, blocky and massive, green reduction colours
- red, very sandy slts, massive and blocky weathering, few green reduction spots and horizons, 20 cm buff weathering, calcareous bed with lumpy, sharp top/fractures/roots at top, thin zone of calcite- and gypsum-filled vugs in red slts just below

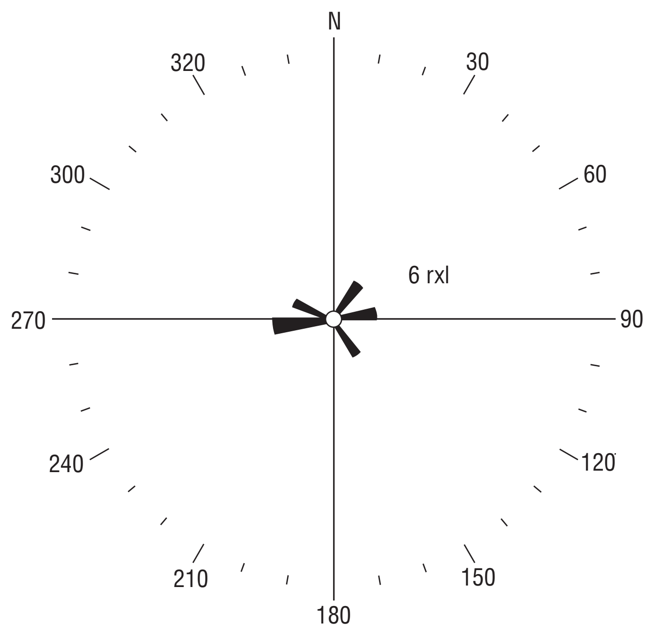
Little River Spillway Section cont.

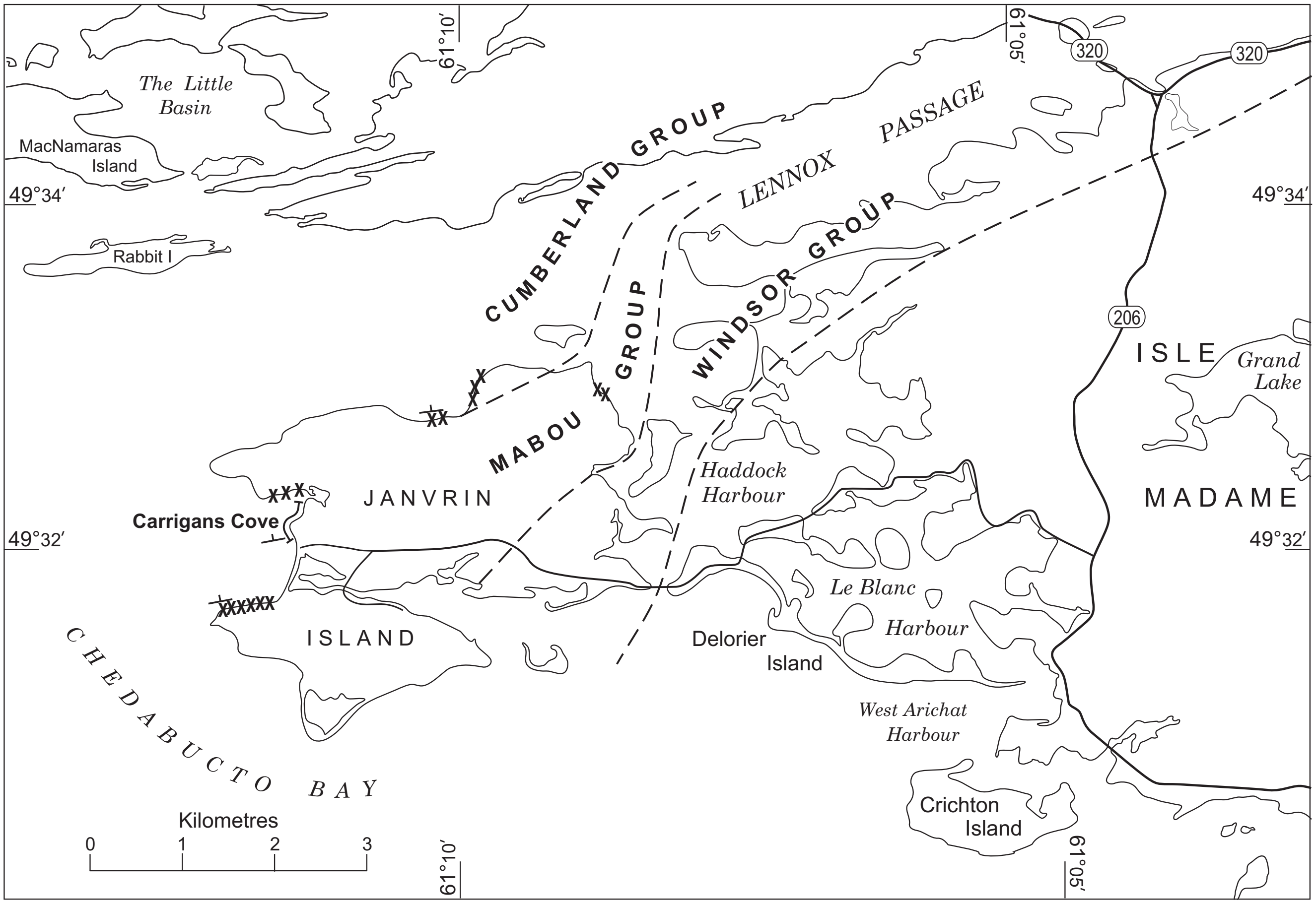


- red siltstone, thin, very fine-grained ss beds throughout
- greenish grey, clay-rich slts
- buff weathering, grey, calcareous slts, sharp erosive base with rip-ups, lumpy contorted sharp top (paleosol)
- greenish grey, clay-rich slts, thin laminae, few, very thin slts beds
- c-up sequence of buff, dolomitic slts and green, clay-rich slts, dolomitic beds have sharp, erosive bases, horizontal laminae, burrows, top one has undulating algal-laminae top
- red slts, calcite crystal nodules after evaporites
- buff weathering, dolomitic sandy slts, massive and fractured, very irregular texture, nodules filled with calcite crystals (after evaporites) near base
- red slts, massive, blocky, homogenous, few green reduction spots, fractures, few, very thin, buff, discontinuous dolomitic slts beds, especially near base
- green slts with cap of grey, silty limestone, laminated, sharp irregular top
- buff weathering, grey, calcareous slts, laminated and rxl, sharp, irregular top with mudcracks or burrow-fills of medium-grained ss
- red slts, green reduction spots and horizons, blocky weathering
- greenish grey, clay-rich slts with thin, buff-weathering, sharp-based slts beds with rxl, gradational base and top
- thinly interbedded red and green slts, irregular blocky weathering
- red, blocky weathering slts, green vertical fractures, capped by thin dolomitic slts
- buff weathering dolomitic slst

LITTLE RIVER SPILLWAY

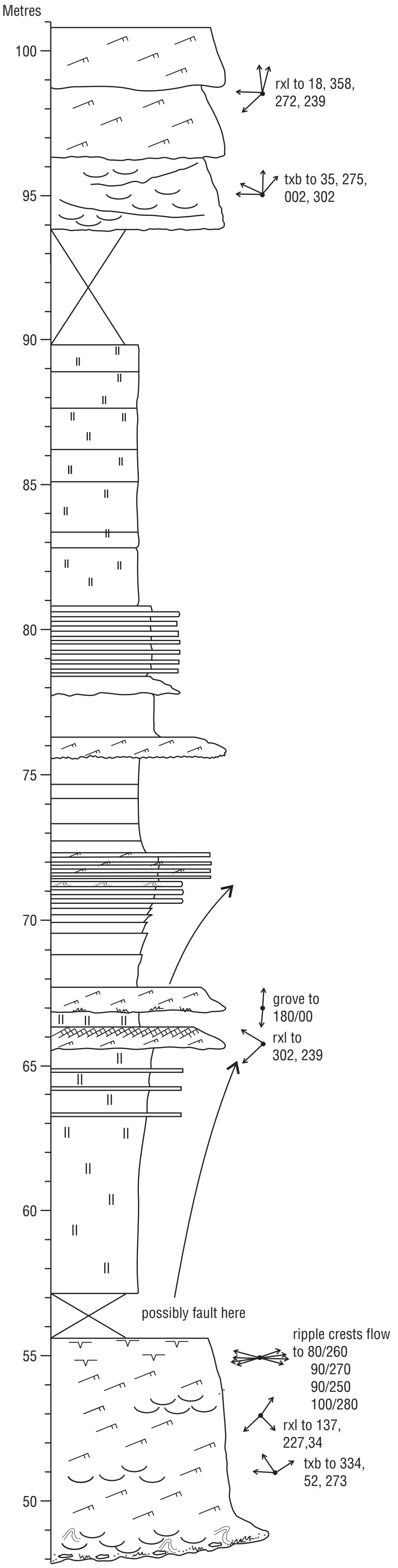
HASTINGS FORMATION





Carrigans Cove. Pomquet Formation; general strike 75°, dip 70° N.

Carrigans Cove Section



- greenish grey, fine-grained ss, well sorted, uniform, sharp base, multistoried, large troughy surfaces and txb in lower 2 m, rest is mostly rippled

- red slts, blocky weathering, massive, few with thin, sandy beds, poorly exposed on beach

- red slts, blocky weathering, massive

- interbedded, greenish, silty, very fine-grained ss and greenish, sandy siltstone

- greenish grey, silty, very fine-grained ss
- green, sandy slts

- reddish grey, fine-grained ss, well sorted, sharp base and top, rxl

- red and green mottled slts, minor sandy thin beds

- thinly interbedded, grey, fine-grained ss and sandy slts, ss with sharp bases and rxl

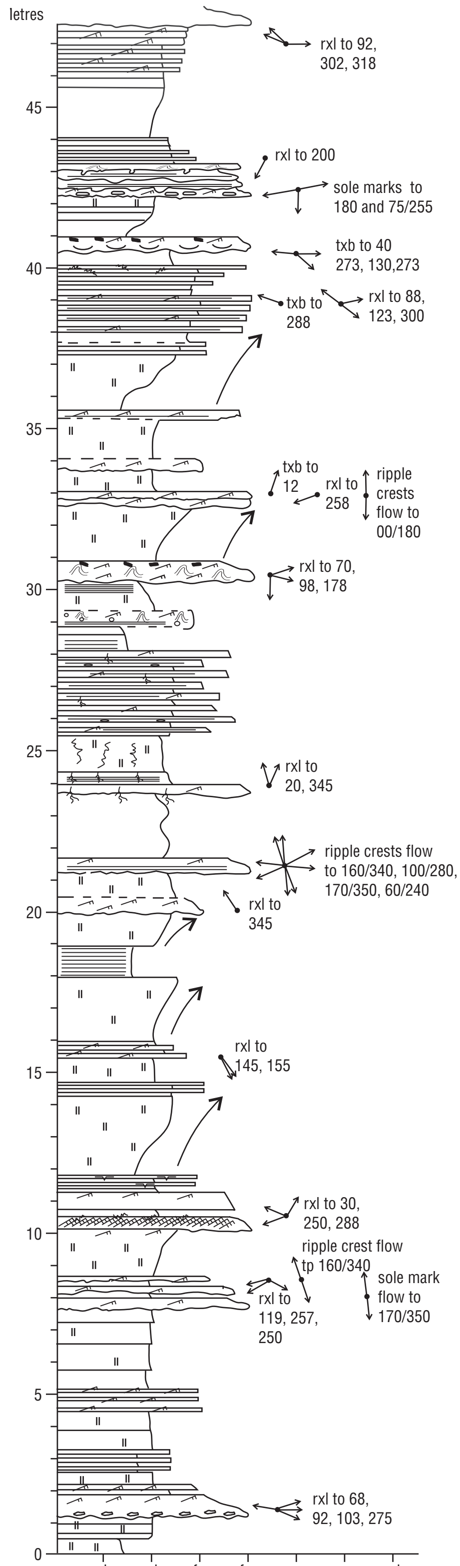
- c-up sequence of greenish grey slts, to reddish silts with few, very fine-grained ss beds, to few discontinuous beds of very fine-grained ss at top with soft-sediment deformation

- reddish grey, fine-grained ss, well sorted, uniform, sharp base and top, with large resting traces and subhorizontal burrows on base, all rxl
- red slts, massive, blocky weathering
- reddish grey, fine-grained ss, well sorted, sharp base and top, rxl and climbing ripples

- red slts, blocky weathering, with few, thin, very fine-grained ss beds toward top, poorly exposed

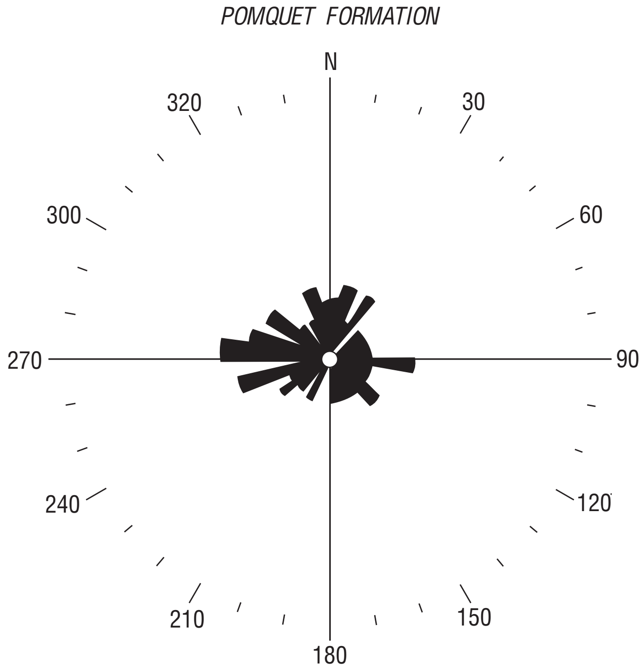
- greenish grey, fine-grained ss, well sorted, uniform slightly f-up, sharp erosive base with convolute lamination and large grooves and burrow casts, txb at base and in several horizons but mostly rxl, mudcracks near top and reddish, silty partings

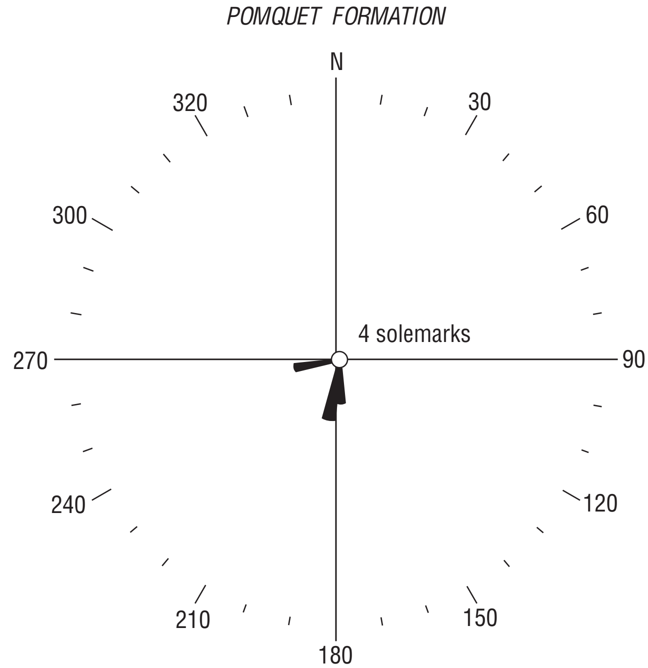
Carrigans Cove Section cont.

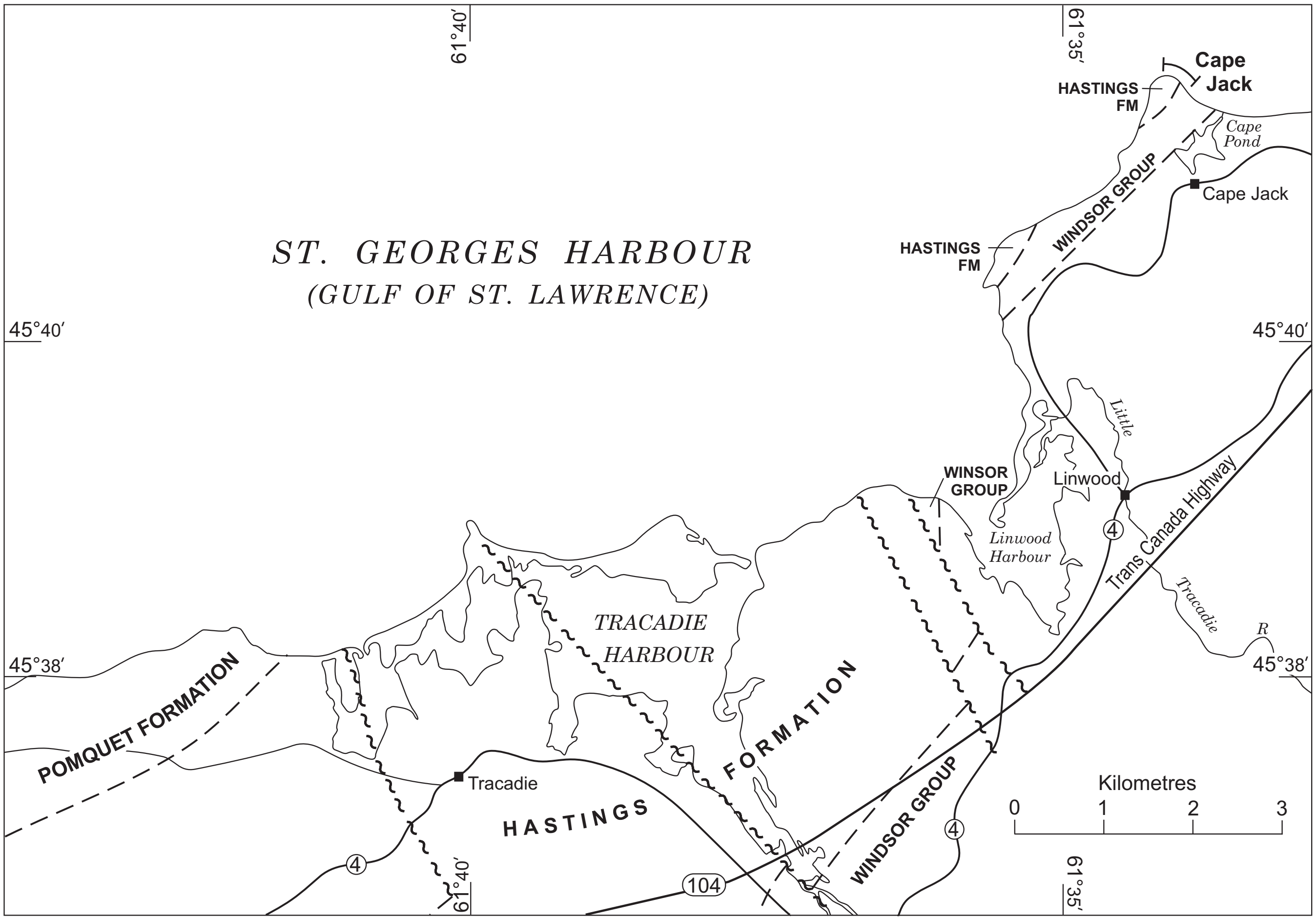


- greenish grey, fine-grained ss, f-up, sharp erosive base, more silty and greenish toward top, partly cut out by overlying ss
- c-up sequence of red slts to red, silty, very fine-grained ss with thin, red slts partings, rxl
- thinly interbedded, red, sandy, slts and red, very fine-grained ss, slightly f-up, gradational boundaries
- bundle of 4 greenish, fine-grained ss beds with sharp bases and gradational tops, large red slts rip-ups and rxl in lower one, ball-and-pillow and contorted lamination in upper one
- thin c-up sequence of green, clay-rich slts, to red and green mottled slts with thin, laminated, very fine-grained ss beds, to red massive slts
- reddish grey, fine-grained ss, sharp erosional base, txb and rxl, plant fragments on top
- red, laminated, sandy slts
- thin c-up sequence of thinly interbedded, greenish grey, fine-grained ss and green and red mottled, silty, very fine-grained ss, ss:slts = 2:1, plant fragments and *Planolites* at top
- thin c-up sequence of thinly interbedded, reddish, fine-grained ss and silty very fine-grained ss, sharp bases and tops, horizontal lamination and rxl, green reduction spots at top
- thin c-sup sequence of green, clay-rich slts, to red slts, to red sandy slts with few, thin, red, silty, very fine-grained ss beds, gradational top with green reduction spots
- greenish grey, fine-grained ss, slightly c-up, gradational base and sharp top, plant fragments and roots at top, horizontal lamination and r
- green slts, blocky reddish bound top, gradational bounds
- red, silty, very fine-grained ss gradational boundaries, rxl
- red slts, blocky weathering, green reduction spots
- red, fine-grained ss in several sharp-based beds, separated by red slts partings, rxl
- red slts, c-up to reddish grey, sandy slts, blocky weathering, green reduction spots and horizons
- reddish grey, fine-grained ss, well sorted, sharp base and tops, rxl and climbing ripples, convolute lamination in middle, plant fragments, medium ss at top
- red slts, f-up, blocky weathering, laminated near top, uniform
- greenish grey, silty, very fine-grained ss, gradational base and top, horizontal lamination and rxl and soft-sediment deformation, hard round concretions, organic fragments
- greenish grey, laminated, clay-rich slts, few, thin, sandy beds
- thinly interbedded, reddish grey, very fine- to fine-grained ss and red, sandy slts, ss:slts = 2:1, ss have sharp bases and gradational tops, horizontal lamination and rxl, minor roots and plant fragments
- red, sandy slts, massive, blocky, fractures, reduction spots
- green, sandy slts, laminated, roots
- grey, fine-grained ss, calcareous, sharp base and top, rxl, roots
- reddish and greenish slts and sandy slts
- reddish grey, fine-grained ss, f-up, horizontal lamination and rxl
- green, sandy slts, massive, blocky
- reddish grey, very fine-grained ss, sharp base, gradational top, rxl
- red slts, c-up, overlain by green, laminated, muddy slts overlain by red c-up slts
- reddish grey, silty, very fine-grained ss and sandy slts, f-up, sharp base, gradational top, rxl
- red slts, massive, blocky
- thinly interbedded, reddish grey, very fine-grained ss and sandy slts, c-up, horizontal lamination, sharp top
- red slts, uniform, blocky weathering, slightly c-up to more greenish, sandier slts
- thinly interbedded, red slts and red, very fine-grained silty ss, f-up, mudcracks, horizontal lamination
- reddish grey, fine-grained ss, sharp base, gradational top, horizontal lamination and rxl
- red slts, massive, blocky, green at base
- reddish grey, fine-grained ss, sharp base and top, climbing ripples, tiny trackways on upper surface
- red slts, c-up to sandy slts, uniform and massive, blocky weathering, green reduction spots and horizons, vague rxl at top
- reddish grey, very fine- to fine-grained ss in thin beds separated by laminated, red slts, mostly rxl
- red slts, uniform, upper 30 cm greenish, many, thin, greenish grey, very fine-grained ss beds throughout with sharp bases and gradational bases, with rxl
- interbedded, red slts and reddish grey, silty, very fine-grained ss, horizontal lamination
- red slts, blocky
- red, silty very fine-grained ss, sharp base and top, rxl
- red, sandy slts, blocky
- reddish grey, very fine- to fine-grained ss, sharp base with large, red slts rip-ups, horizontal lamination and rxl
- red slts, blocky weathering, few, very thin, sandy slts beds, green reduction spots at top
- greenish grey, silty mudstone, lamination to blocky weathering, gradational top, poorly exposed

CARRIGANS COVE

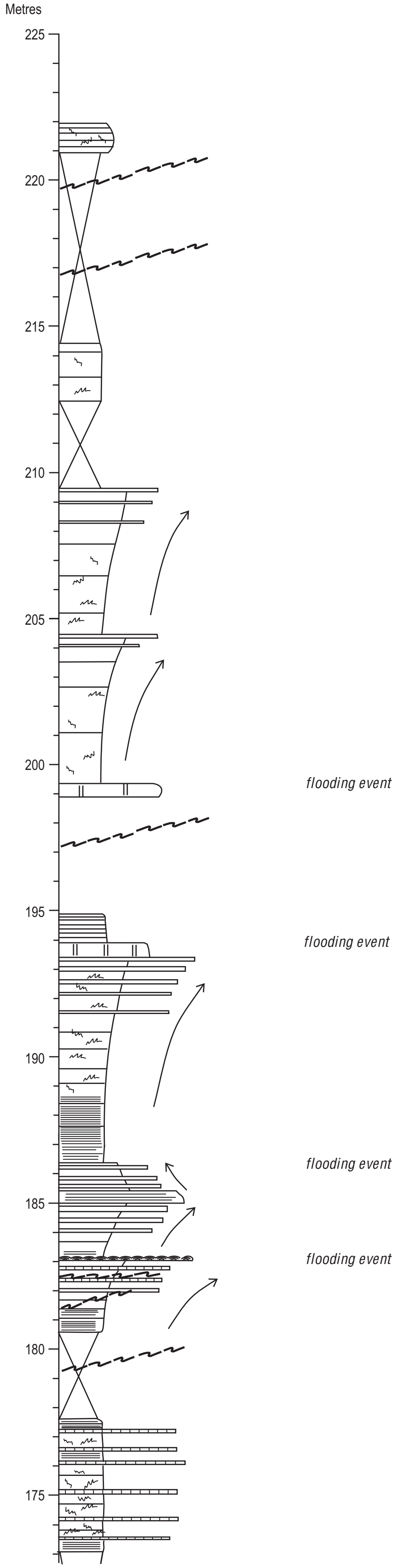






Cape Jack. Hastings and Pomquet formations; general strike 45°, dip 27° NW.

Cape Jack Section



- thinly interbedded, greenish grey, bioturbated silty mudstone and silty very fine-grained ss, ss:slts = 1:5

- grey mudstone, partly bioturbated with few, thin slts beds

- c-up sequence of grey mudstone and light grey slts, some burrowing

- c-up sequence of grey mudstone and light grey slts, ss:slts = 1:5–10

- red, sandy slts, massive, uniform, blocky, pedogenic

- greenish grey, interbedded mudstone and slts
- red, sandy slts, uniform, rubbly, pedogenic

- c-up sequence of interbedded, grey mudstone and light grey slts to calcisiltite, thin beds, lower 2 m laminated, rest bioturbated

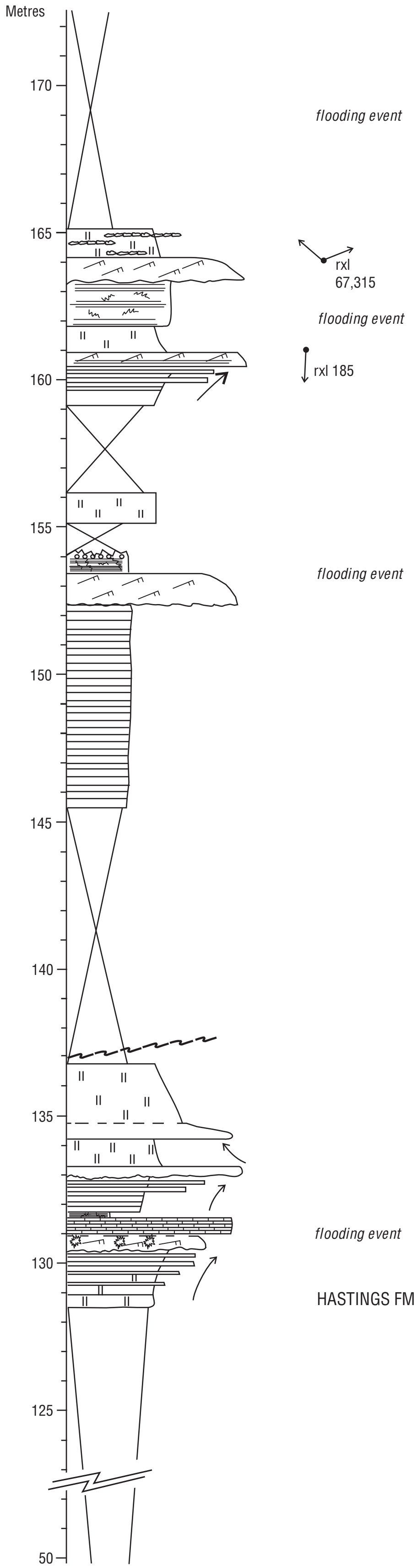
- thinly interbedded, grey mudstone and grey, very fine-grained ss, generally f-up

- c-up sequence of dark grey mudstone to interbedded mudstone and slts, with cap bed of greenish to reddish, very fine-grained silty ss

- c-up sequence of dark grey mudstone, laminated and organic-rich, with light grey slts to calcisiltite, cap bed of 5 cm algal-laminated limestone

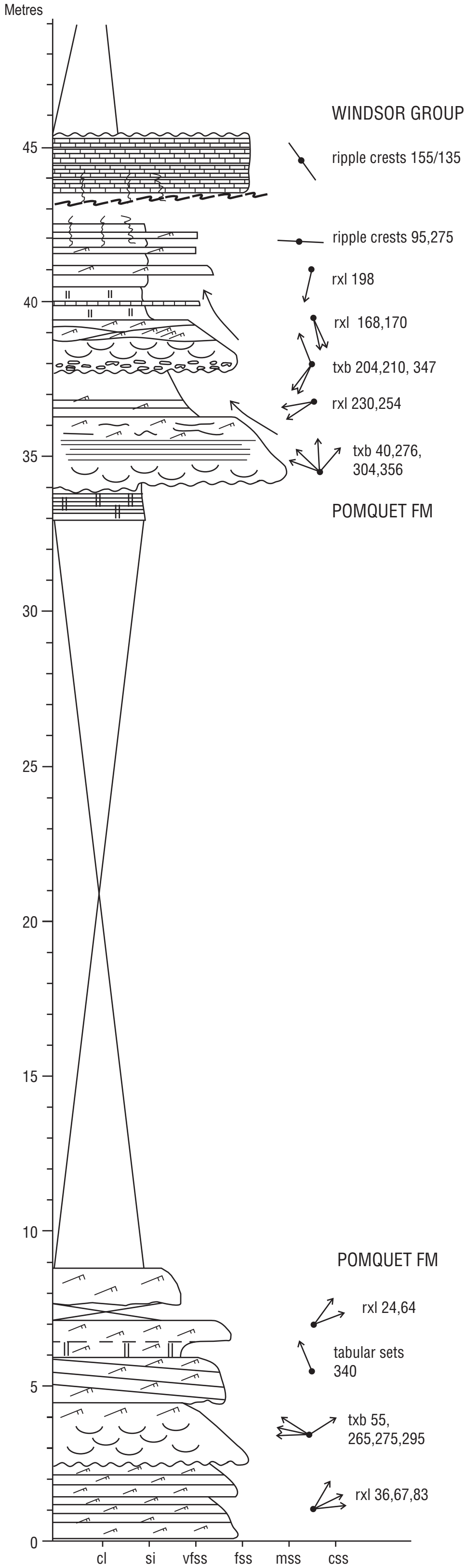
- thinly interbedded, grey, partly bioturbated mudstone and light grey slts to calcisiltite, sharp bases, horizontally laminated

Cape Jack Section cont.



- red slts, massive, rubbly, pedogenic with green calcrete horizons
- red, fine-grained ss, well sorted, rippled, sharp base and top
- greenish grey, sandy slts, partly laminated, partly bioturbated
- red slts, uniform, massive, blocky, pedogenic
- c-up sequence of greenish grey, sandy slts to red, laminated slts with thin, red, very fine-grained ss to red, fine-grained ss, very micaceous with horizontal lamination and rxl
- red siltstone, uniform, rubbly, pedogenic
- grey to dark grey, silty mudstone, sharp lumpy top with blocks of sandy material and phosphatic pellets
- greenish to reddish fine-grained ss, rippled
- thinly interbedded grey mudstone and greenish grey, very fine-grained ss, and some reddish, very fine-grained ss, poorly exposed
- red sandy slts, massive, uniform, blocky, pedogenic
- red, fine-grained ss, well sorted, f-up sharp base, gradational top, horizontal lamination
- red slts, massive, blocky, rubbly, pedogenic
- c-up sequence of thinly interbedded, greenish grey slts and very fine-grained ss, to cap bed of 30 cm red fine-grained ss with scoured base
- dark grey mudstone, horizontal lamination, minor burrowing
- greenish grey limestone, algal-laminated
- c-up sequence of red, rubbly, pedogenic slts to thinly interbedded red slts and very fine-grained ss, to thick cap bed of red very fine-grained ss with sharp base and gradational top with silty partings, evaporite-filled vugs at top

Cape Jack Section cont.

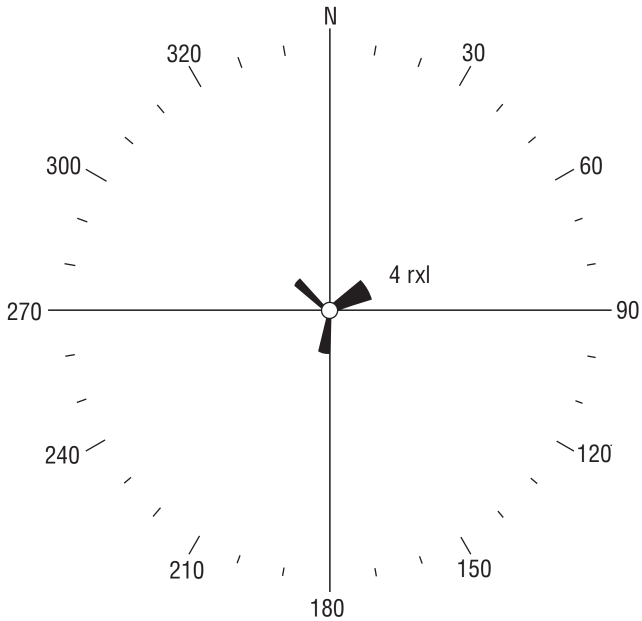


- grey, algal laminated limestone, thin bedded, calcarenite with pellets, vuggy porosity, calcite-filled fractures, upper surface has ripple crests and vuggy porosity
- thickly interbedded red slts and very fine- to fine-grained ss, rippled, calcite-filled fractures at top
- red slts, uniform, massive, blocky, pedogenic, thin green calcrete zone
- red very fine- to fine-grained ss, f-up, scoured base with abundant red slts rip-ups, curved reactivation surfaces, complex mix of txb/rxl/climbing ripples
- red, silty, very fine-grained ss, recessive, few harder beds, rxl
- red, fine- to medium-grained ss, well sorted, scoured base, f-up, txb near base, horizontal lamination and rxl, slts partings
- thinly interbedded, red, pedogenic slts and red, very fine-grained ss with sharp bases and gradational tops

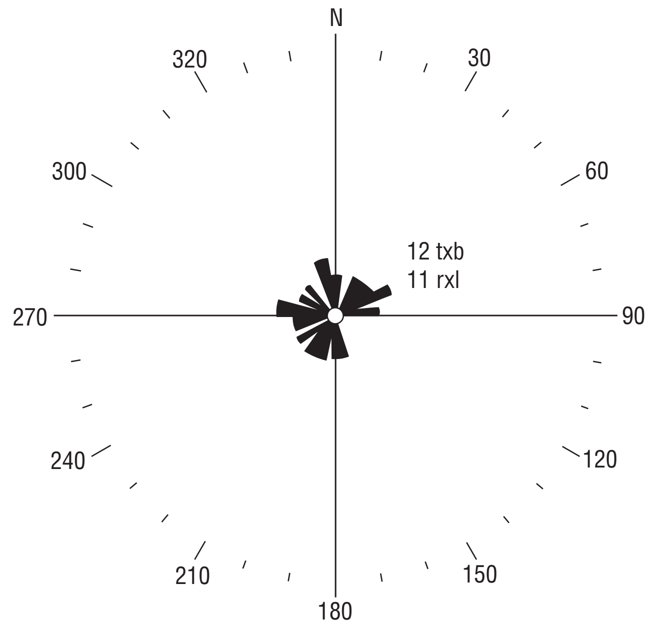
- red, silty, very fine-grained ss, rxl, rubbly
- red, fine-grained ss, rippled throughout
- red, silty, very fine-grained ss, generally massive, rubbly and pedogenic, with rippled horizons, gradational top
- red, fine-grained ss, sharp base and top, large dipping surfaces and planar tabular sets, ripples throughout
- red, fine-grained ss, well sorted, scoured base, mostly txb with rxl at top
- red, fine-grained ss, well sorted, thin bedded, sharp base and top, rippled
- grey, green, fine-grained ss, well sorted, thin bedded, sharp base top, all rippled

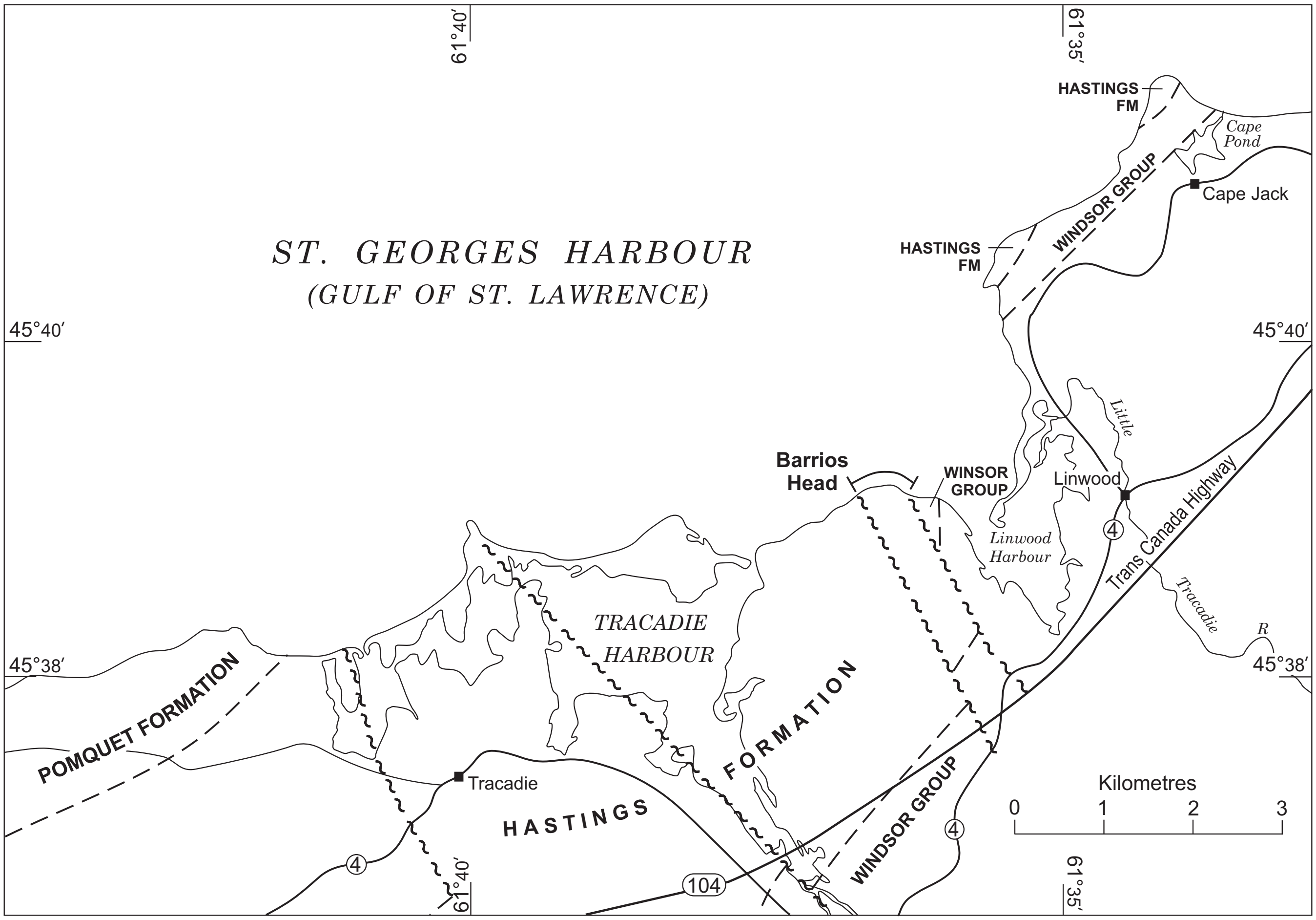
CAPE JACK

HASTINGS FORMATION



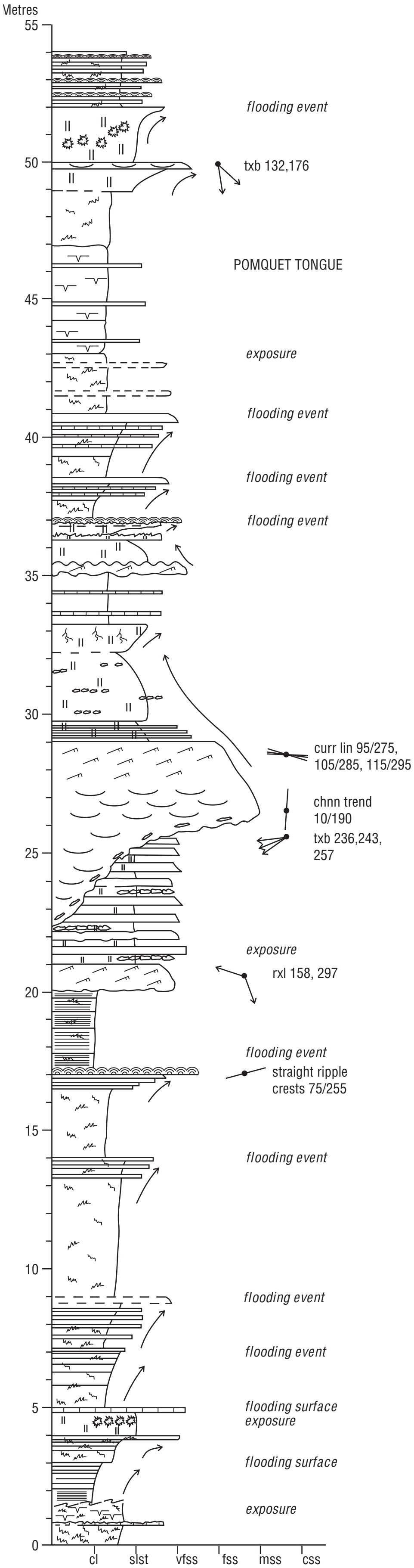
POMQUET FORMATION





Barrios Head. Hastings and Pomquet formations; general strike 355°, dip 12° E.

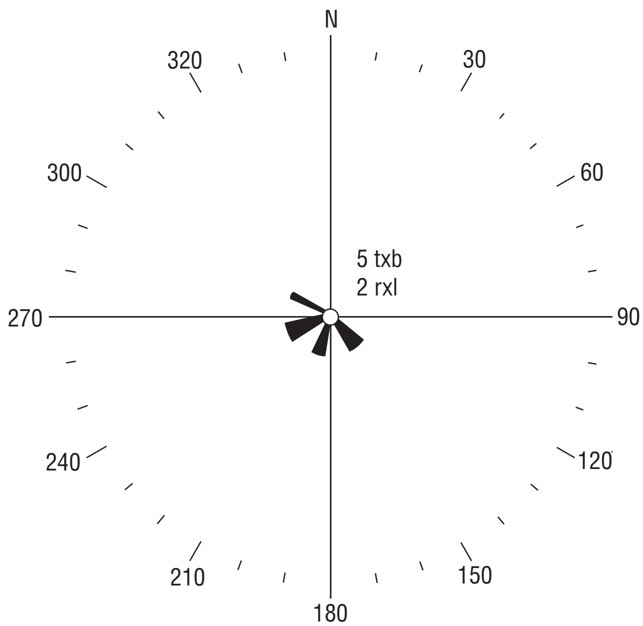
Barrios Head Section



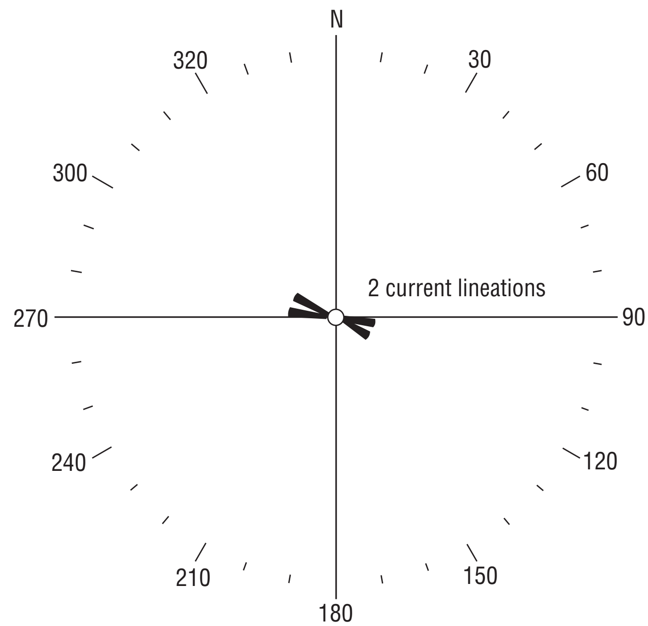
- greenish grey, muddy slts, bioturbated, with thin calcisiltite and algal-laminated beds, one in middle with bulbous top
- red, massive, rubbly slts with evaporite crystal moulds, capped by green, sandier zone
- c-up seq, red slts to sandy slts to very fine- to fine-grained ss, gradational boundaries, sharp top, txb
- greenish grey, sllty mudstone, very uniform, thinly laminated, gradational top, bioturbated
- thinly interbedded, grey, muddy slts, few, thin, laminated calcisiltite beds, few with algal lamination, abundant polygonal desiccation cracks throughout
- grey to greenish grey, bioturbated, silty mudstone, few thin, very fine-grained ss beds with gradational boundaries
- c-up sequence of grey, bioturbated, silty mudstone to mudstone with limestone beds, to reddish grey, very fine-grained ss
- c-up sequence of grey, bioturbated mudstone to mudstone with thin limestone beds, to greenish grey, very fine-grained ss
- grey algal-laminated limestone with bulbous top
- c-up red slts to green, sandy slts with sharp, irregular top
- f-up sequence of red, sandy slts to red slts to green, sandy caliche zone with sharp, irregular top and vertical ped structure
- reddish grey very fine-grained ss, scoured base, rippled top
- interbedded grey and red silty mudstone, few, thin limestone beds with wavy lamination
- reddish to greenish, sandy slts, gradational base, sharp top, abundant vertical rootlets
- f-up, sandy slts to slts, massive, rubbly, pedogenic, scattered caliche nodules
- red, thinly interbedded, very fine-grained ss and pedogenic slts
- grey to reddish grey, fine- to medium-grained ss, well sorted, f-up, scoured channelized base cuts down 3 m over distance of 10 m laterally, mostly txb, rxl at top
- thickly interbedded, red, rubbly pedogenic slts and red, very fine-grained ss with gradational boundaries, few, thin, calcareous caliche horizons
- red, very fine-grained ss, well sorted, sharp, flat base, thick bedded, rippled
- grey to greenish grey, laminated mudstone, very uniform, minor burrowing, few siltier bands
- limestone with large, bulbous stromatolitic heads up to 1 m across, straight-crested ripples
- several thin, sandy slts beds, with silty partings
- grey to greenish grey, bioturbated, silty mudstone
- greenish grey, muddy slts, very uniform, heavily bioturbated, capped by several slightly sandier beds
- c-up sequence of grey, bioturbated, silty mudstone to interbedded, greenish slts and reddish slts to cap bed of 20 cm very fine-grained silty ss with gradational boundaries
- grey, silty mudstone, bioturbated, uniform, slightly c-up, few, thin slts beds near top
- grey, algal laminated limestone, sharp top
- red, sandy slts, massive, rubbly, pedogenic, horizons of evaporite crystals
- c-up sequence of greenish grey, bioturbated, muddy slts with cap bed of thin, reddish grey, very fine-grained ss, rippled
- c-up sequence of thinly interbedded, dark grey mudstone to mudstone and slts, all horizontal laminated, sharp top
- grey, muddy slts, well bioturbated, abundant mudcracks throughout, scattered rip-ups
- grey to greenish grey, muddy slts, heavily bioturbated, cap bed of limestone with sharp lumpy top and gradational base

BARRIOS HEAD

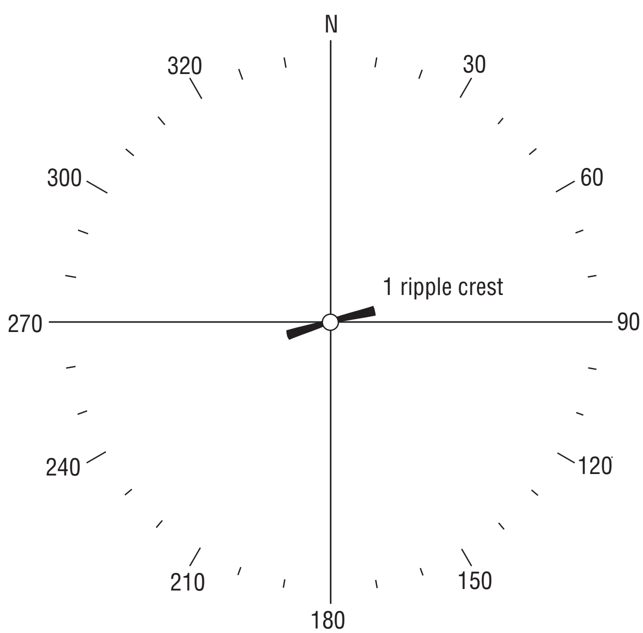
POMQUET FORMATION

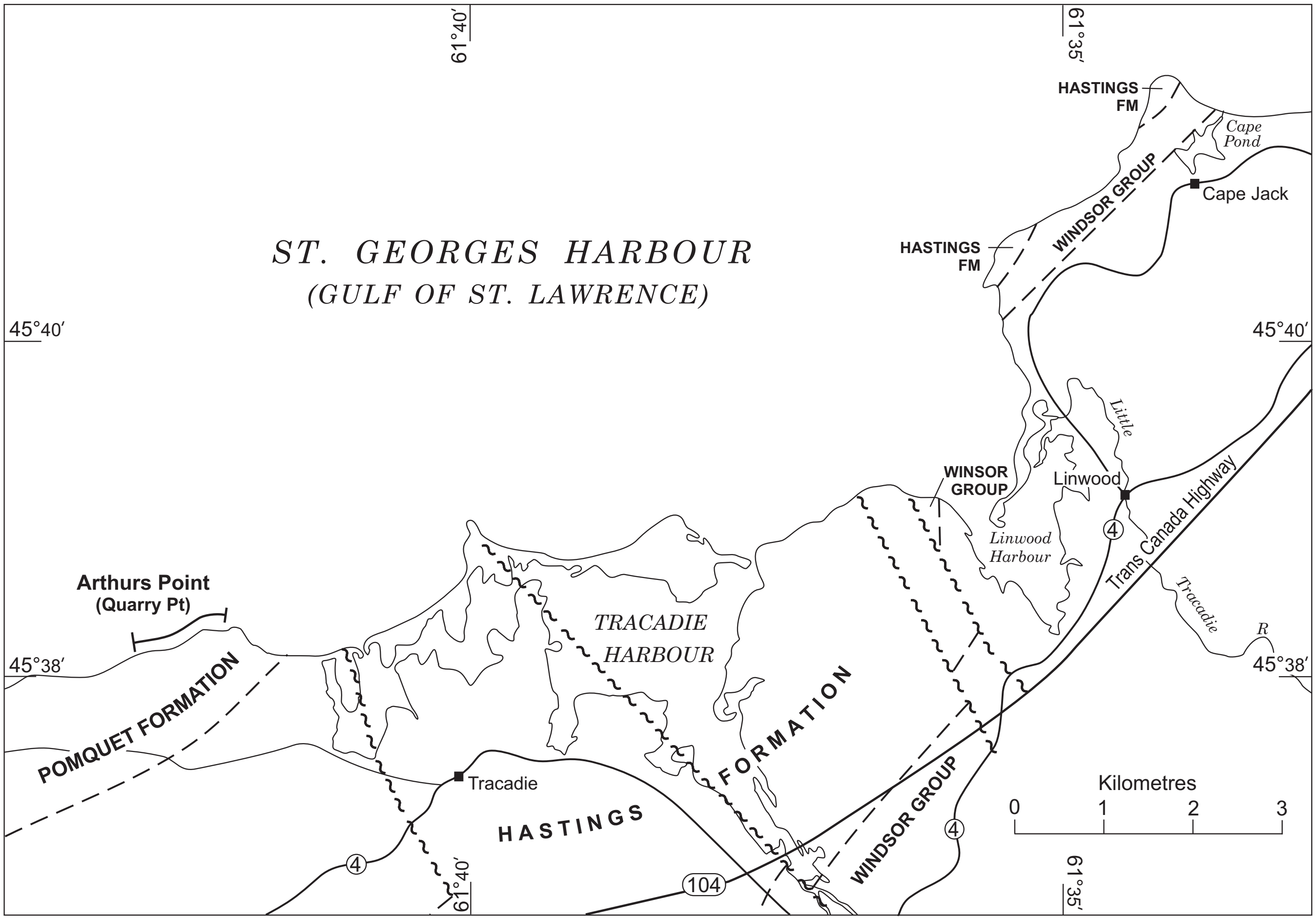


POMQUET FORMATION



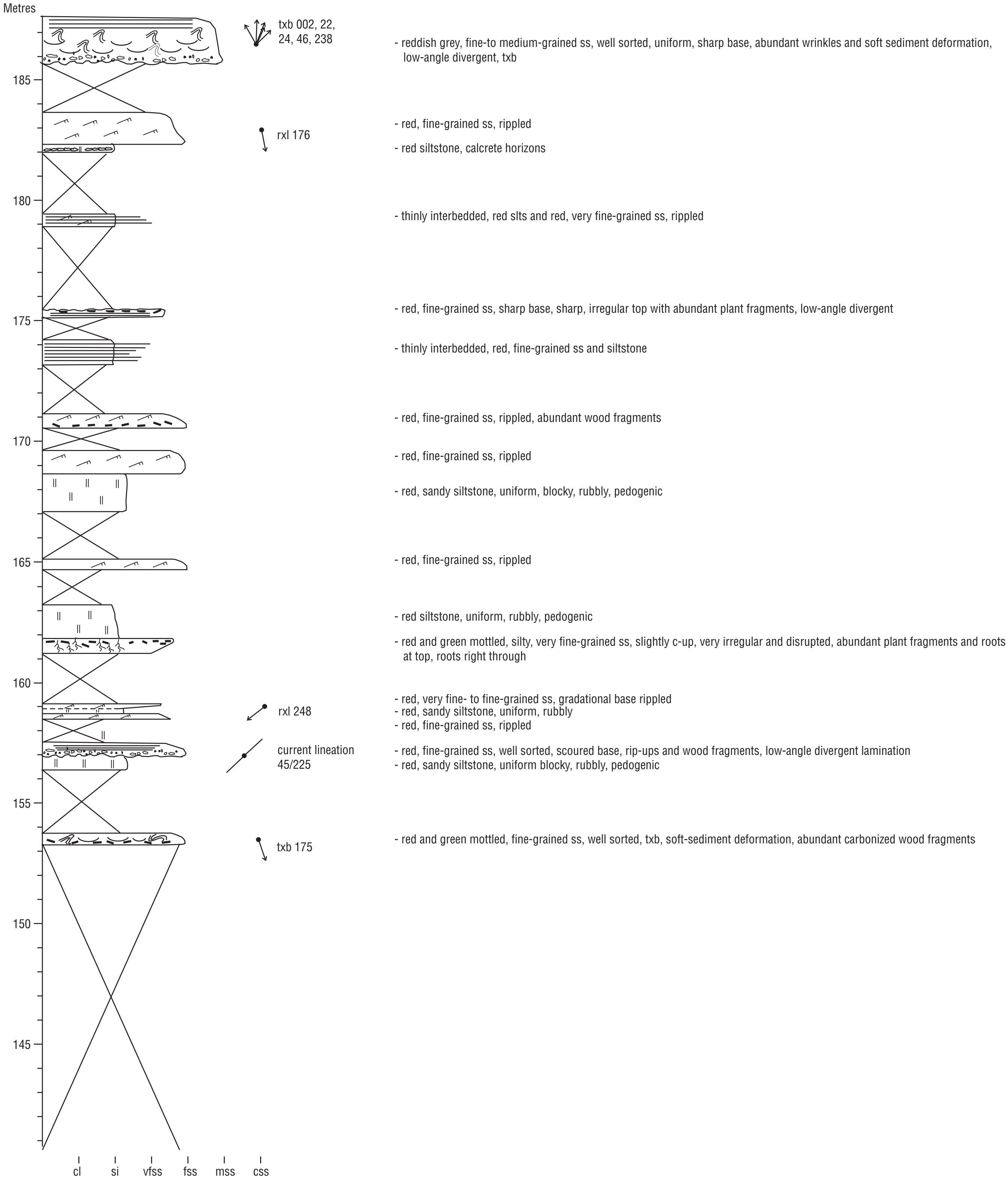
HASTINGS FORMATION



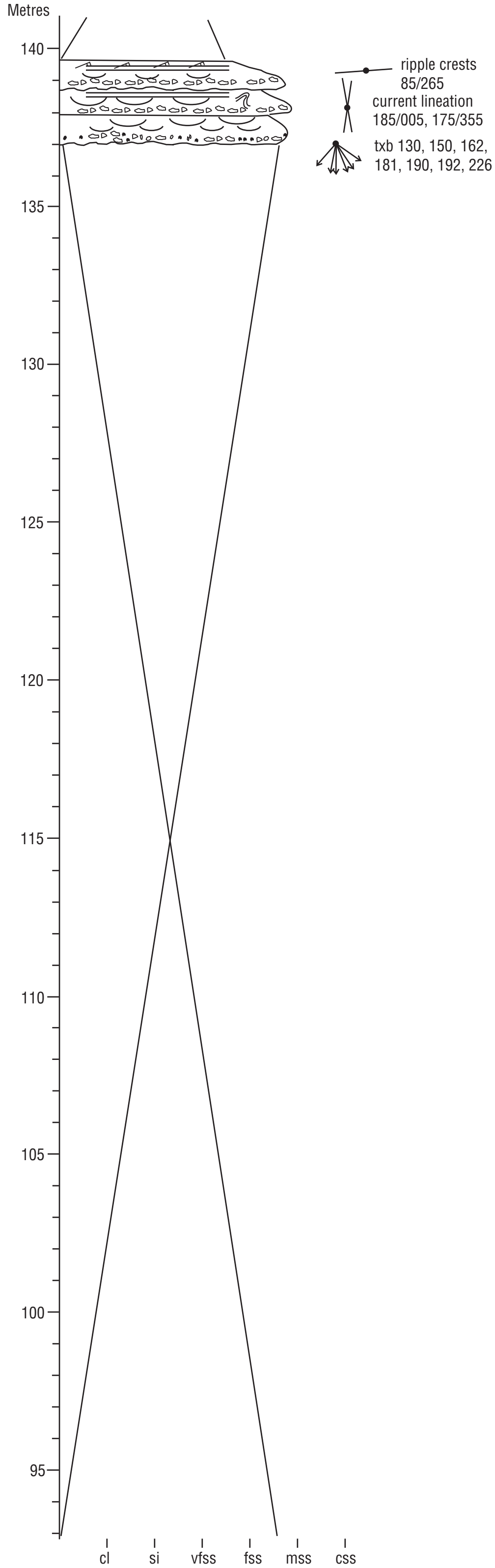


Arthurs Point. Pomquet and Port Hood formations; general strike 25°, dip 23° N.

Arthurs Point Section

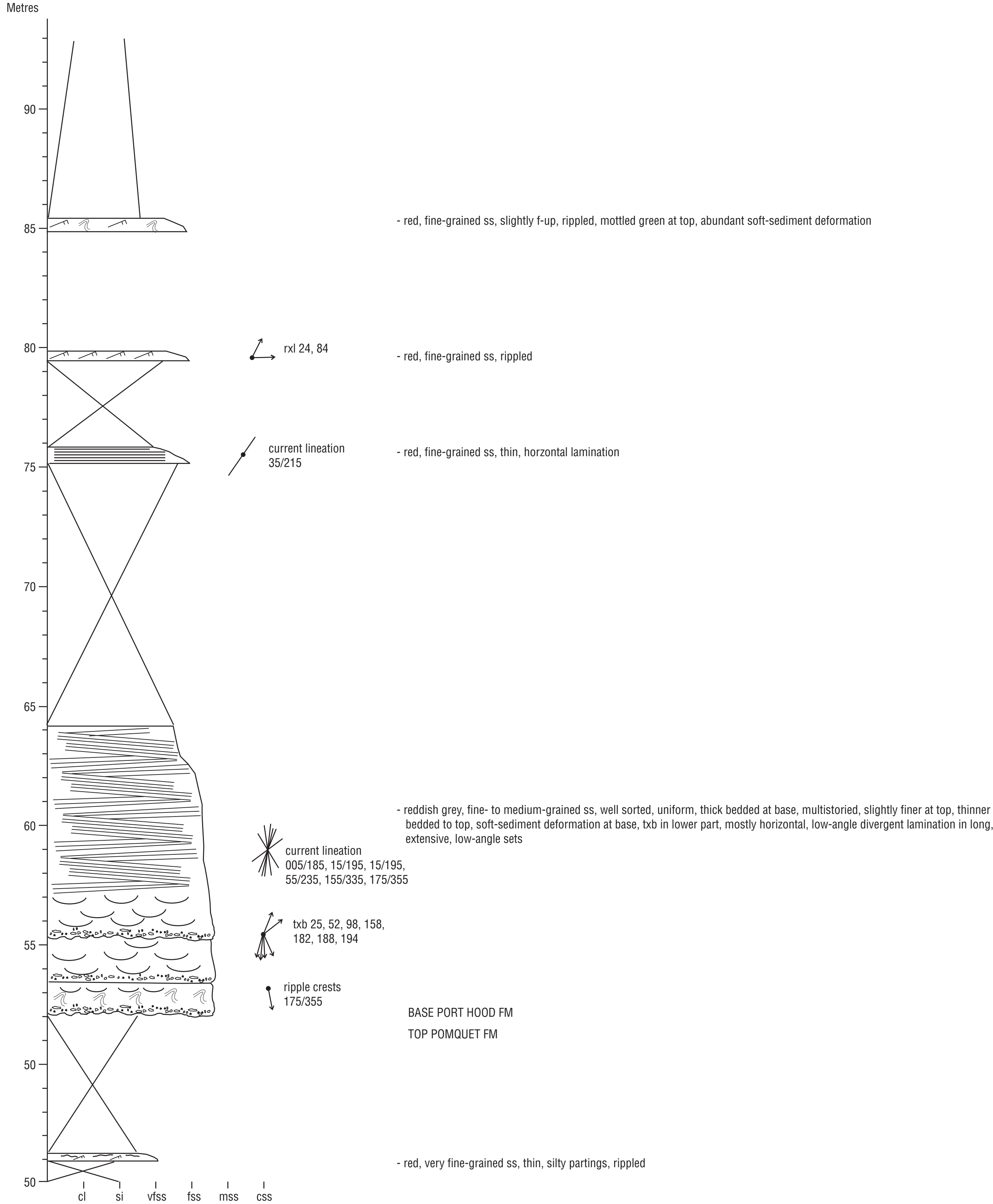


Arthurs Point Section cont.

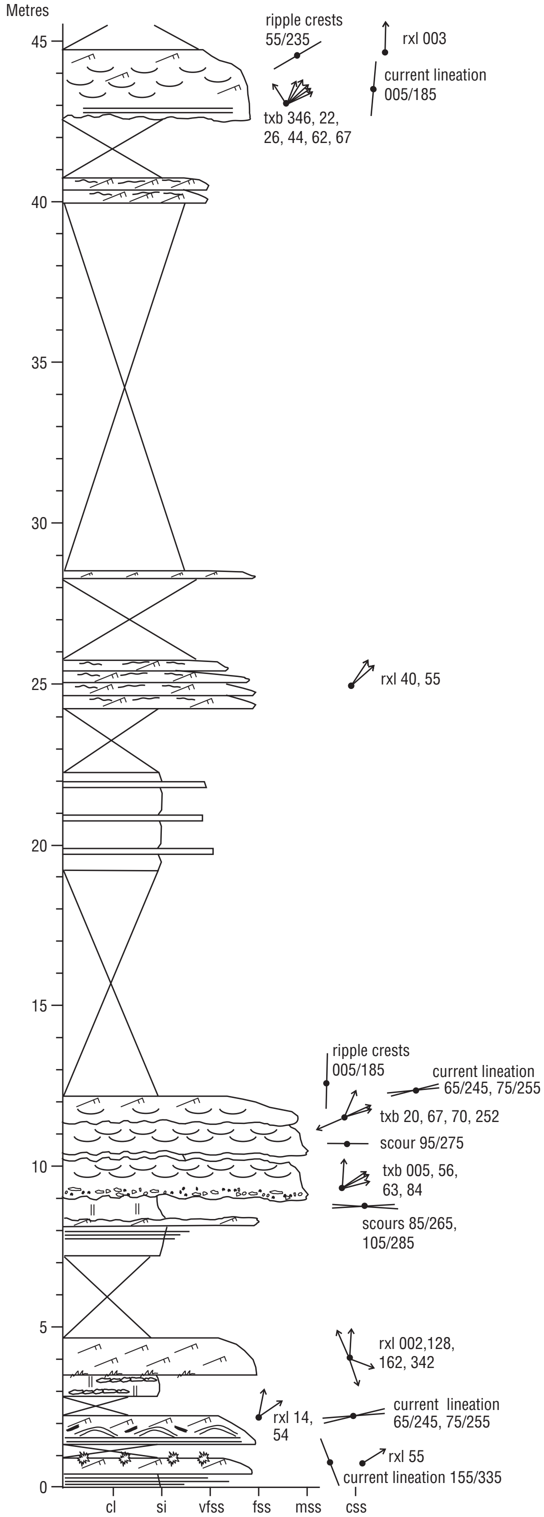


- red, fine- to medium-grained ss, well sorted, uniform, thick bedded, multistoried, sharp bases with rip-ups, mostly txb, low-angle divergent lamination, minor ripples at top, one horizon of soft-sediment deformation

Arthurs Point Section cont.

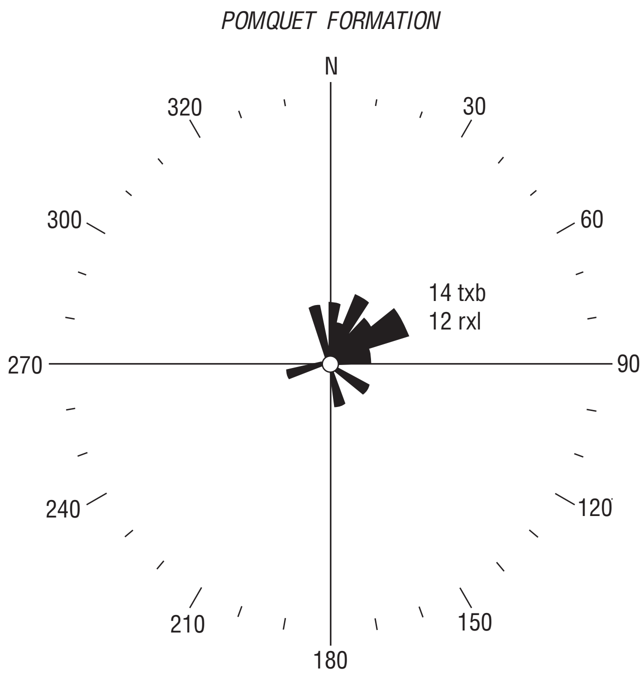


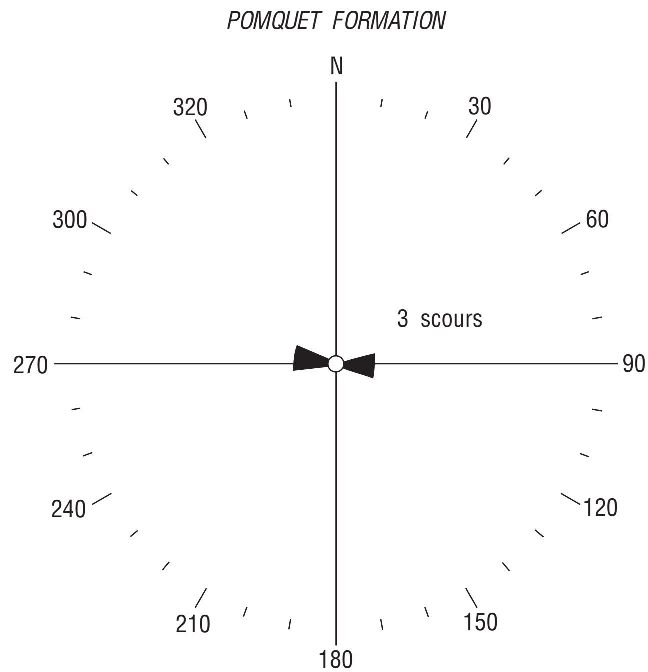
Arthurs Point Section cont.

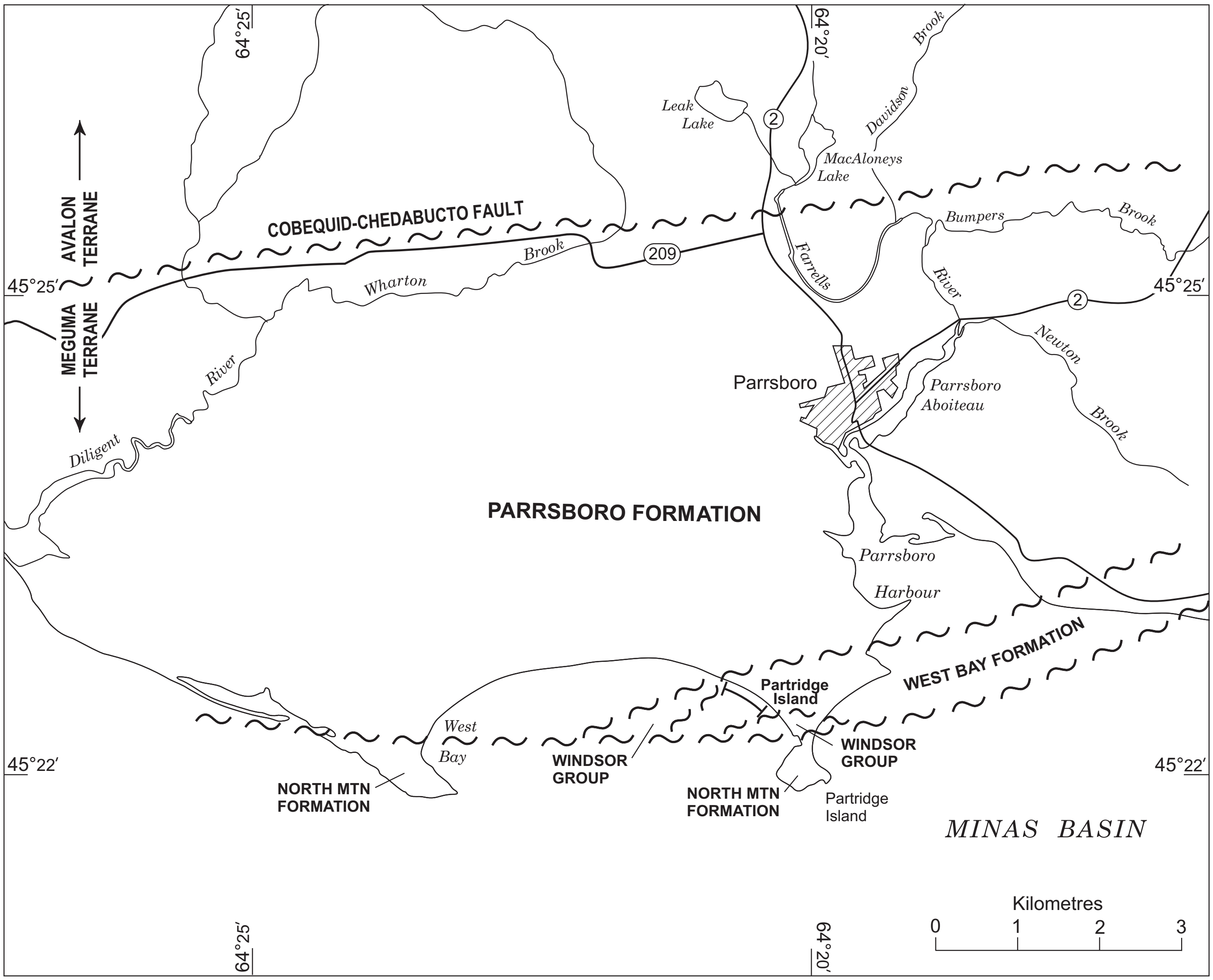


- red, fine-grained ss, well sorted, thin bedded, scour base, slightly f-up at top, horizontal lamination at base, mostly txb, minor rxl
- red, fine-grained ss, thin bedded, silty partings, sharp base, rippled
- red, fine-grained ss, well sorted, rippled, poor exposure
- red, very fine- to fine-grained ss, thin bedded, red slts partings, all rippled
- red slts, few very fine-grained ss beds, poorly exposed
- buff, fine- to medium-grained ss, well sorted, micaceous, thick bedded, multistoried, f-up, abundant fine wood fragments
- buff, fine- to medium-grained ss, well sorted, micaceous, thick bedded, scoured base with lag of rip-ups and granules, linear scours and burrow casts at base, rippled top, txb
- red, sandy siltstone, massive, uniform, rubbly, pedogenic
- c-up sequence of red slts to interbedded, red ss and silty, very fine-grained ss, to cap bed of 30 cm red, fine-grained ss, sharp base and top, rippled, irregular, green upper surface
- red, fine-grained ss, well sorted, micareous, thin bedded, slightly f-up, sharp base with burrow casts, rippled
- red slts, uniform blocky, pedogenic, green calcrete horizons
- reddish grey, fine-grained ss, slightly f-up, well sorted, thin bedded, horizontal lamination at base, thin HCS, thin rxl abundant carbonized wood fragments
- reddish grey, fine-grained ss, well sorted, thin bedded, rippled, evaporite crystals on upper surface, fine, delicate trace fossils
- red, interbedded slts and very fine-grained ss, rippled

ARTHURS POINT

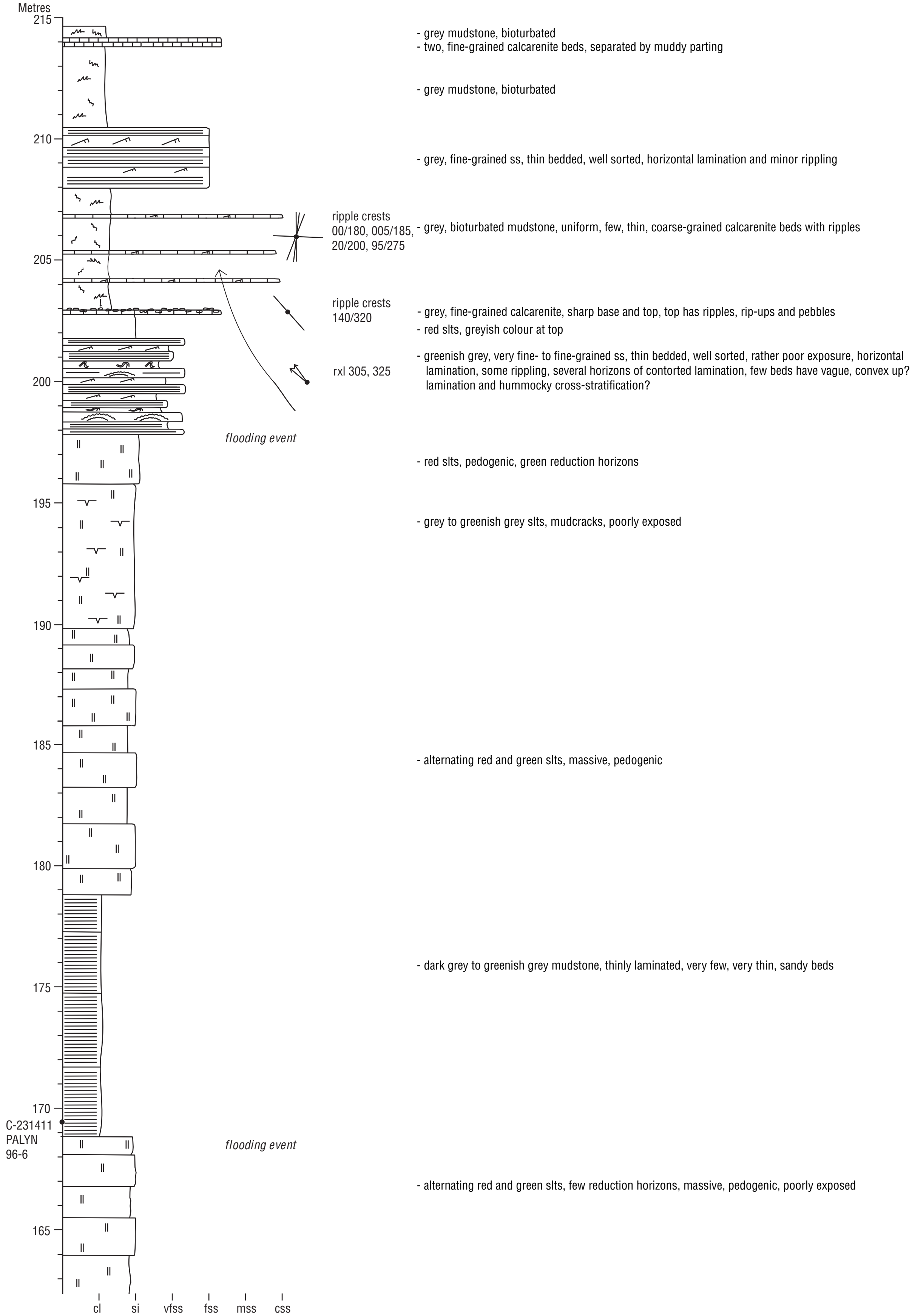




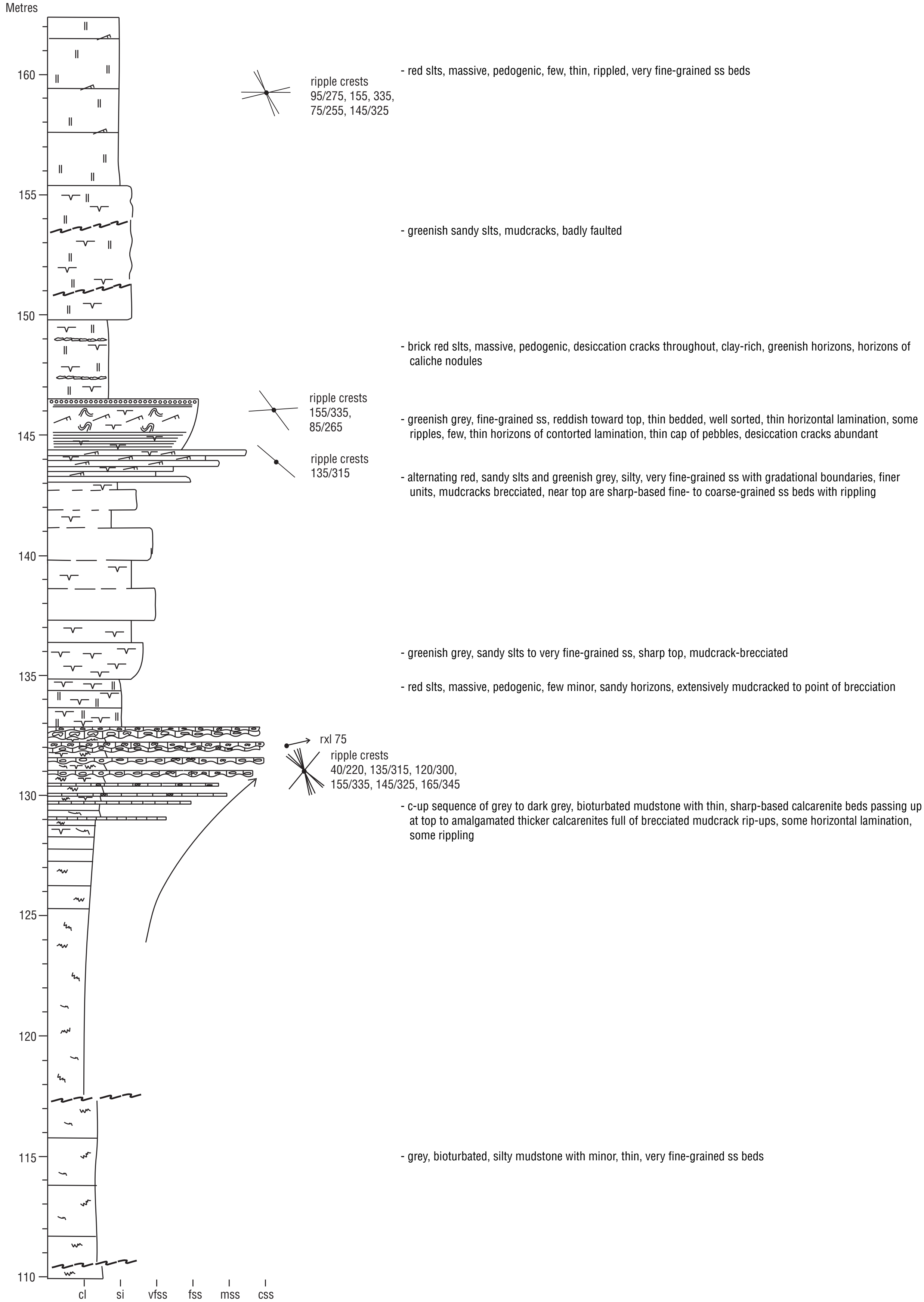


Partridge Island. West Bay (Hastings) Formation; general strike 62°, dip 70° S.

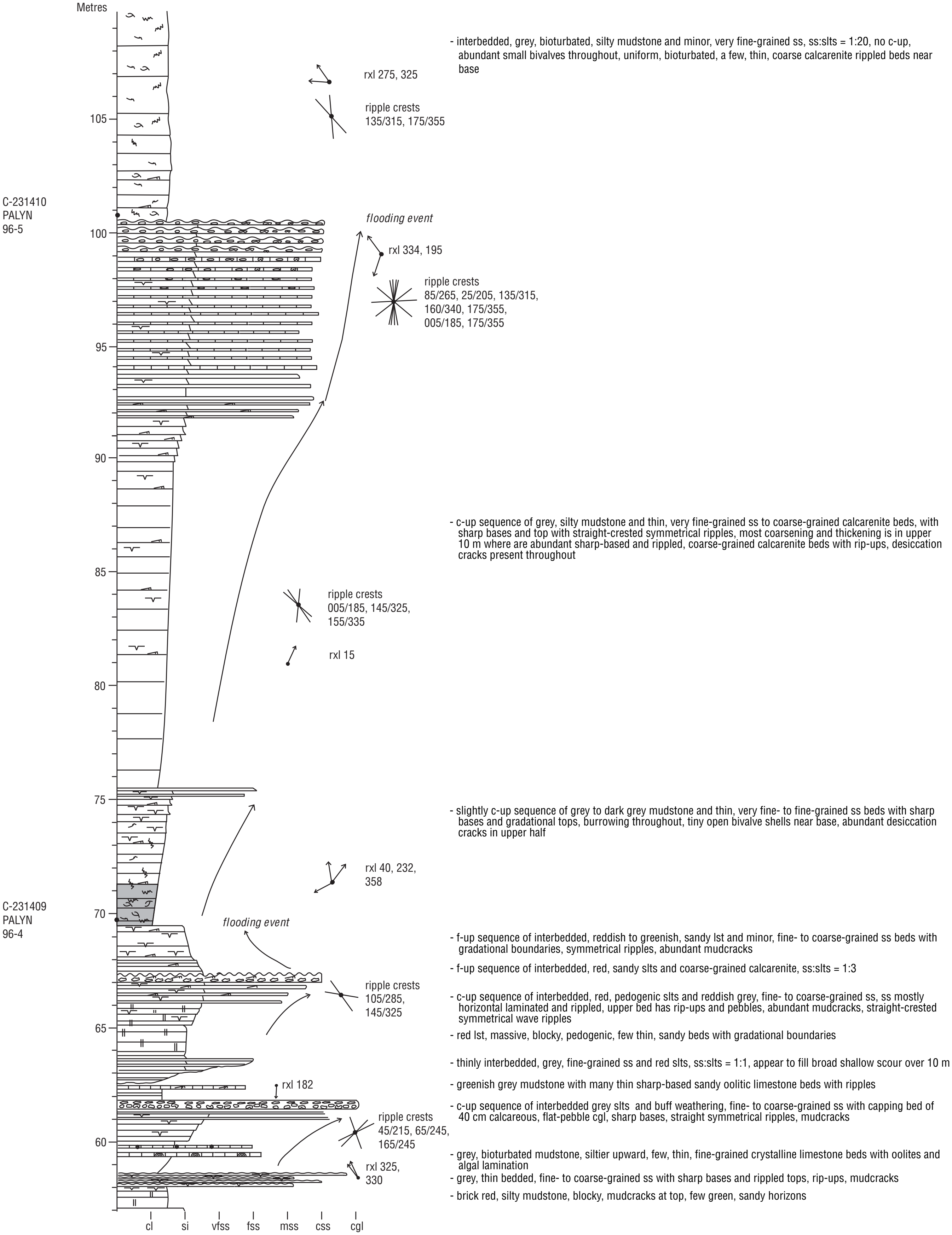
Partridge Island Section



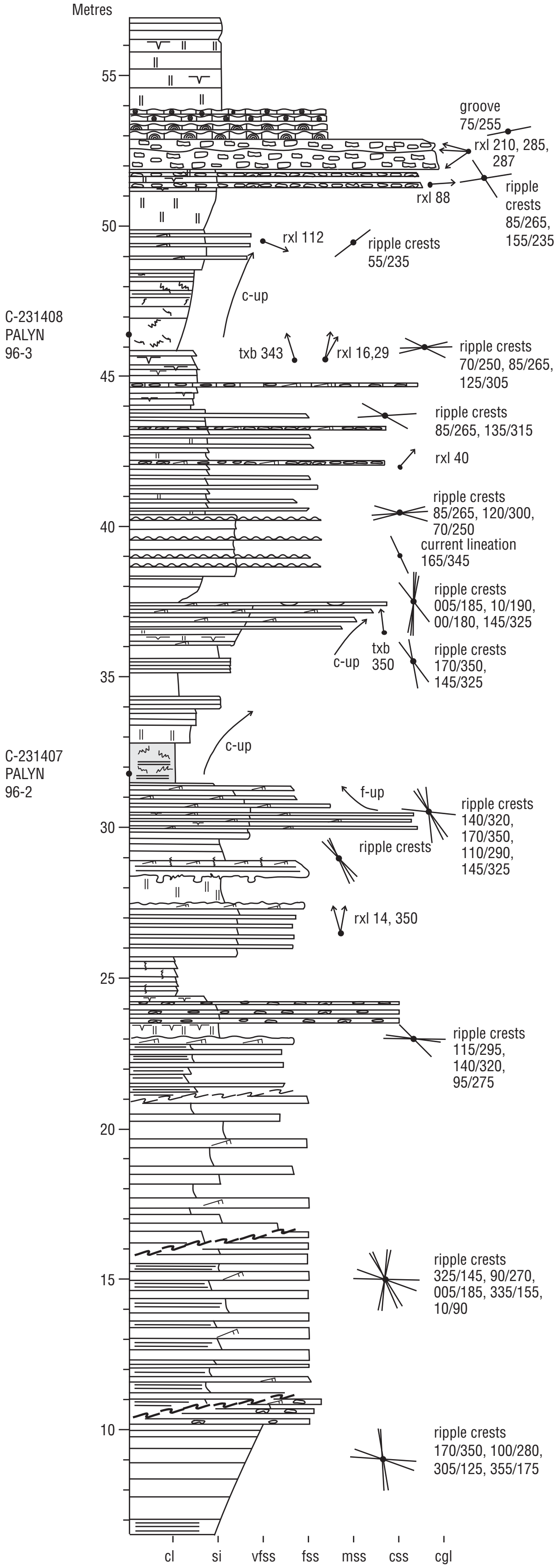
Partridge Island Section cont.



Partridge Island Section cont.

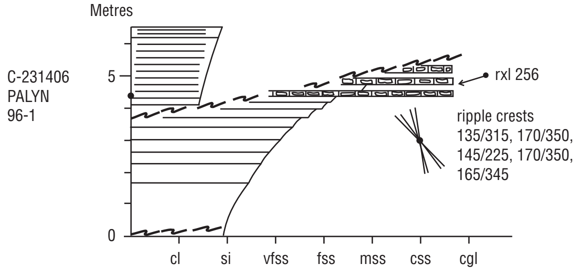


Partridge Island Section cont.



- interbedded, thin, calcareous, coarse-grained ss to cgl beds and discontinuous red slts
- red slts, massive, blocky, pedogenic, with few, thin, very fine-grained ss beds with straight-crested symmetrical wave ripples, desiccation cracks
- four grey, sandy, oolitic, algal laminated limestone beds with sharp bases, minor rippling, exposed by thin, discontinuous, grey mudstone partings
- several greenish, fine-grained ss-flat-pebble cgl silty beds with sharp bases and scours, completely full of rip-ups
- red, silty mudstone, pedogenic with several thin, sharp-based calcareous coarse-grained ss to cgl beds full of rip-ups, desiccation cracks
- red, silty, mudstone, massive, blocky, fractured, pedogenic, slightly c-up
- greenish, silty mudstone with few 20 cm, calcareous, sandy slts beds with ripples
- greenish grey mudstone with upward increase of thin silty beds with symmetrical ripples, bioturbated at base
- interbedded, red and green mudstone and very fine- to fine-grained ss with gradational bounds, desiccation cracks and burrows, single calcareous coarse-grained ss to cgl with sharp base and ripples
- interbedded, red, muddy slts and thin, silty, fine-grained ss, slts pedogenic, ss:slts = 1:1, slst gen horizontally laminated, few, thicker, calcareous, medium- to coarse-grained ss with abundant rip-ups and rxl (nearly flat-pebble cgl)
- thinly interbedded, greenish, sandy slts and grey to red fine-grained ss, with sharp bases and ripples and raindrop impressions, few, thin, porous coarse-grained ss beds
- greenish mudstone passing up into reddish, silty mudstone with few, very fine-grained ss beds
- c-up sequence green, sandy slts, to interbedded medium- to coarse-grained ss and red slts, to thin bedded fine- to coarse-grained ss, granulestone, all sharp based, desiccation cracks near base, tiny burrows, txb and ripples
- red and green slts
- thinly interbedded, greenish, sandy slts and medium- to coarse-grained ss to granulestone with sharp bases and rippled tops
- reddish and greenish mudstone
- interbedded, rusty weathering, porous, medium- to coarse-grained ss and greenish slts
- red, silty mudstone with minor, thin, laminated very fine-grained ss
- red, silty mudstone, blocky, massive pedogenic
- dark greenish grey mudstone, uniform, mostly bioturbated, minor lamination
- interbedded, greenish, sandy slts and rusty weathering, coarse-grained ss to granulestone, very porous, with desiccation cracks and straight ripples
- greenish grey slts, few, thin, very fine-grained ss
- greenish to reddish, fine-grained ss, thin bedded, sharp base with ball-and-pillow and burrow casts, top has symmetrical ripples, and vertical burrows and mudcracks, flasers of green mud
- brick red slts, massive, blocky, fractured, pedogenic
- interbedded, reddish, sandy slts and fine-grained ss, ss:slts =1:1, upper ss rippled
- thinly interbedded, greenish mudstone and grey, very fine- to fine-grained ss with scoured bases and rippled tops, f-up, vertical burrows?
- thinly interbedded, greenish grey, slts to very fine-grained ss and fine-grained ss to granulestone with limestone rip-ups, porous, sharp bases with scours, desiccation cracks at top
- brick red, silty mudstone, blocky, massive, fractured, desiccation cracks at top
- interbedded, grey to red, very fine- to fine-grained ss and laminated, green to reddish mudstone, ss with sharp, scoured bases and rippled tops, upper ss thickest
- thinly interbedded, grey, mudstone, reddish slts, and grey, very fine- to fine-grained ss
- interbedded, grey, fine-grained ss and red laminated, silty mudstone, possible rain imprints
- c-up sequence of grey, laminated mudstone and thin, very fine- to fine-grained ss with rippled tops, minor, small mud and limestone rip-up chips

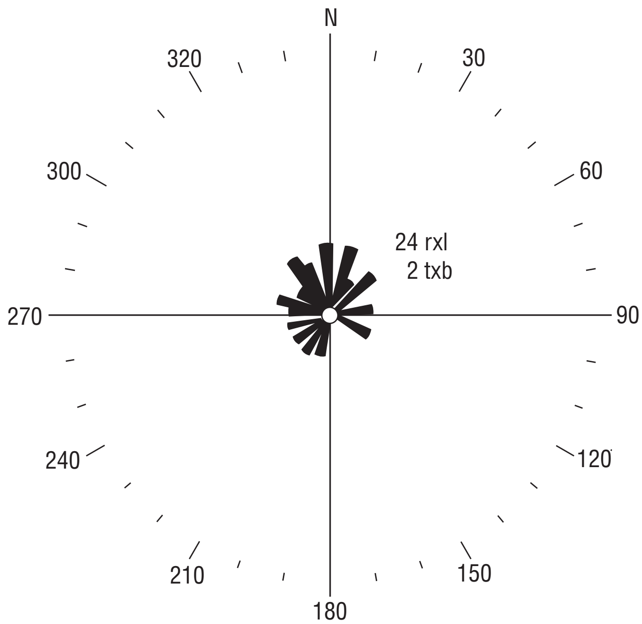
Partridge Island Section cont.



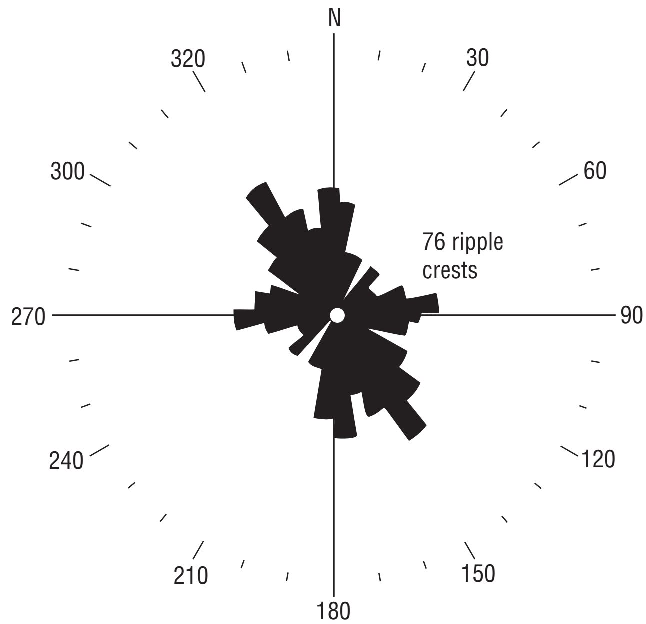
- c-up sequence of grey mudstone and thin, very fine-grained ss capped by several beds of porous, coarse-grained ss, flat-pebble cgl limestone, rippled tops

PARTRIDGE ISLAND

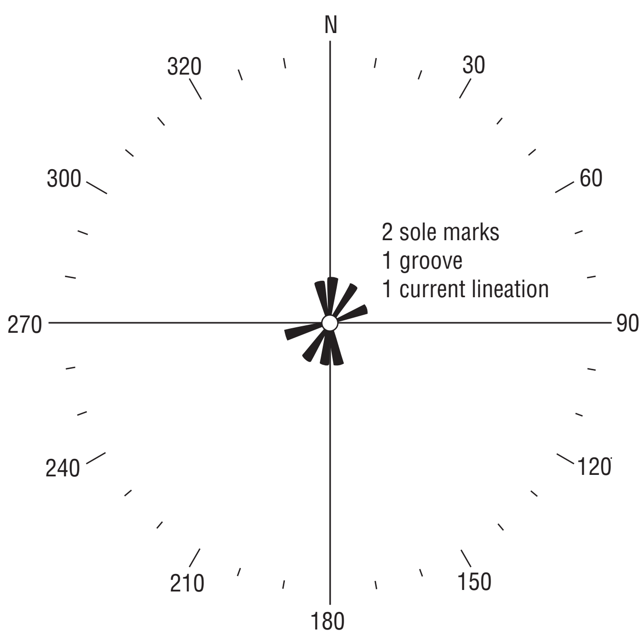
HASTINGS FORMATION

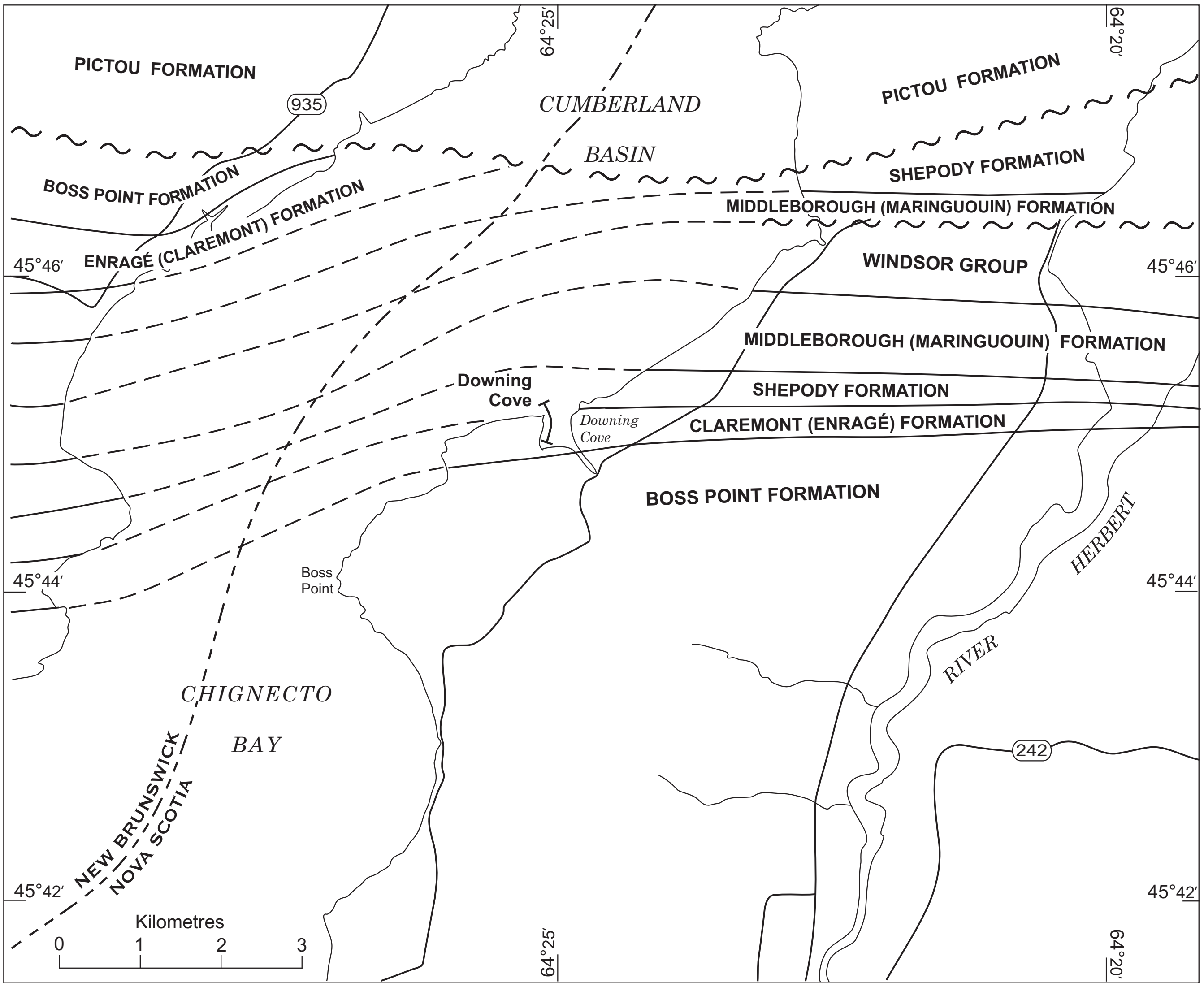


HASTINGS FORMATION



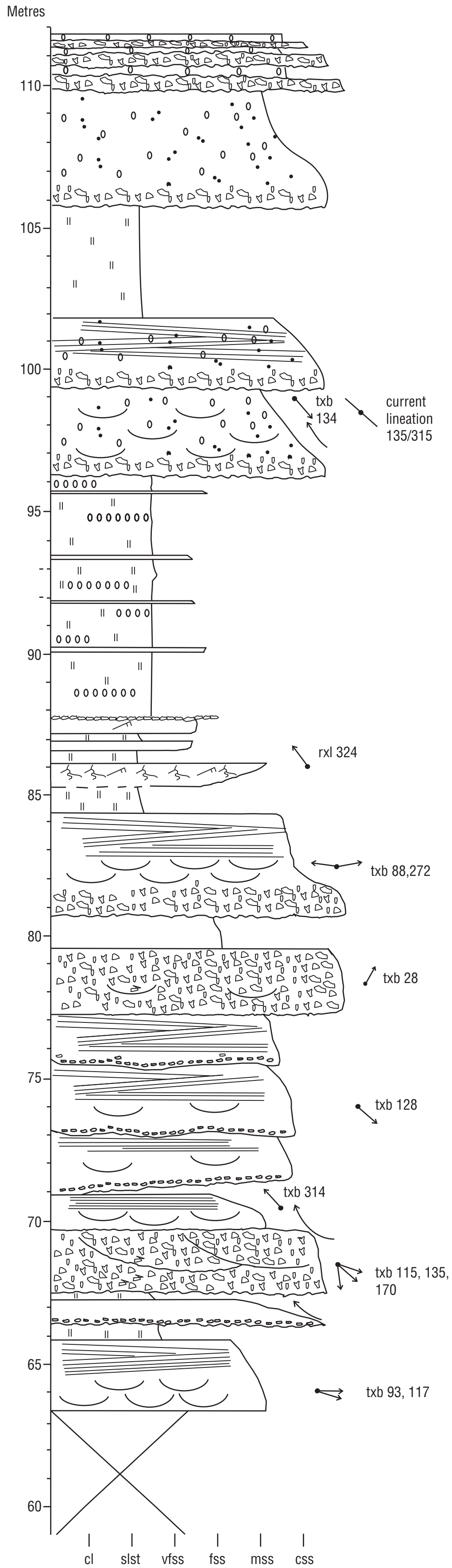
HASTINGS FORMATION





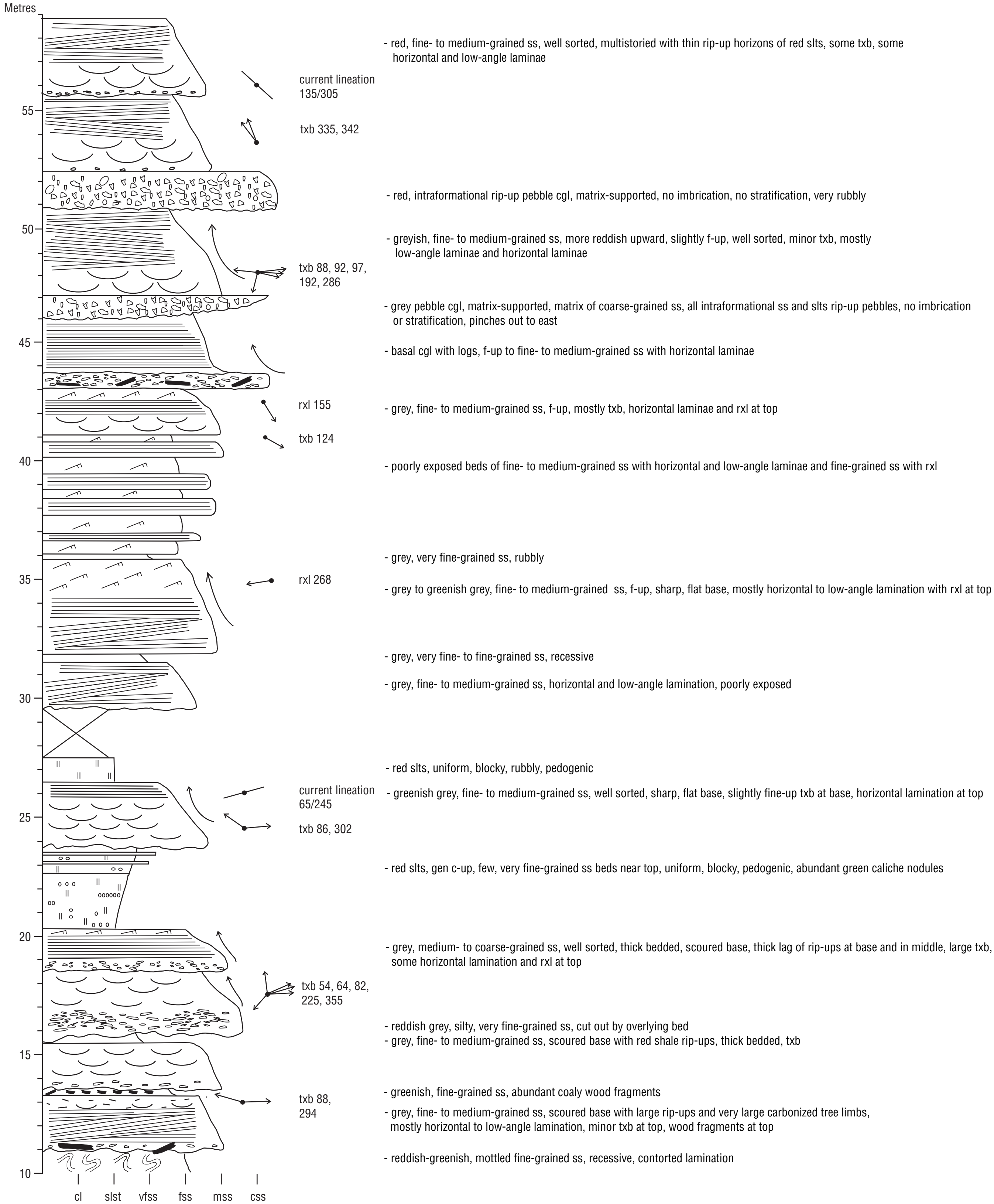
Downing Cove. Claremont Formation (Hastings equivalent); general strike 65°, dip 32° S.

Downing Cove Section

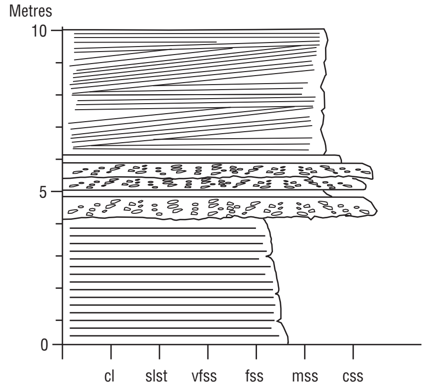


- red, intraformational cgl with interbeds of pebbly, coarse-grained ss
- red, f-up, intraformational cgl to medium-grained ss, mostly pebbly, coarse-grained ss
- red slts, uniform, massive, pedogenic, poorly exposed
- f-up, red, granule cgl to granular, coarse-grained ss, scoured base, sharp top, low-angle laminae
- f-up, red, granule cgl to granular, coarse-grained ss, scoured base, sharp top, large txb sets
- red, sandy slts, massive, uniform, rubbly, pedogenic, with few, thin, very fine-to fine-grained ss beds and horizons of caliche nodules, poorly exposed
- red, very fine- to fine-grained ss beds separated by thin, red slts, sharp bases and tops, mottled, cap bed of green caliche
- red slts, uniform, massive, pedogenic
- red, fine- to medium-grained ss, slightly c-up, gradational base, sharp top, larger vertic root structures right through, rxl
- red slts, uniform, massive, rubbly, pedogenic, sharp base, gradational top
- red, fine-grained cgl to medium-grained ss, basal 1 m of rip-up slts pebbles, mostly medium- to coarse-grained ss, txb and low-angle lamination
- red, fine-grained ss, massive
- red, intraformational rip-up cgl of ss and slts pebbles, sharp base, crude txb and low-angle laminae
- red, medium- to coarse-grained ss, uniform, well sorted, multistoried with several pebble lag beds, large txb sets and horizontal to low-angle laminae
- red slts
- red, fine- to medium-grained ss,
- f-up, txb near base, horizontal laminae at top
- red intraformational rip-up cgl of ss and slts pebbles with wood fragments, matrix-supported, giant txb
- red slts, massive, uniform, rubbly, pedogenic
- grey cgl to medium-grained ss, f-up
- red sandy slts, massive, blocky, rubbly, pedogenic
- red, fine- to medium-grained ss, well sorted, uniform, minor txb, low-angle laminae, sharp base and top

Downing Cove Section cont.



Downing Cove Section cont.

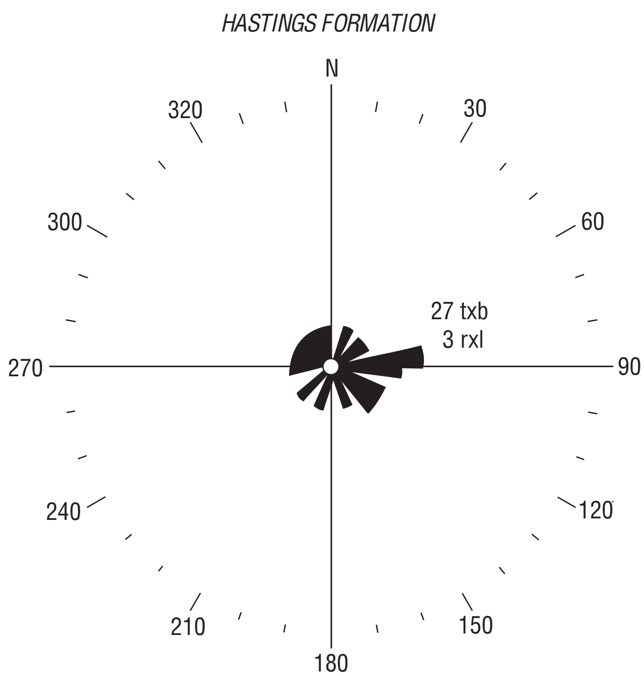


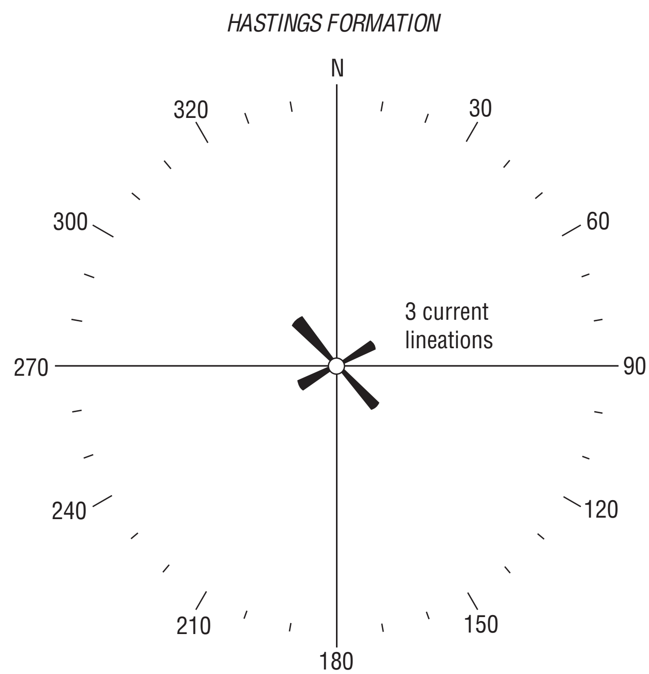
- grey, medium- to coarse-grained ss, thick bedded, uniform, well sorted, sharp base and top, horizontal to low-angle lamination

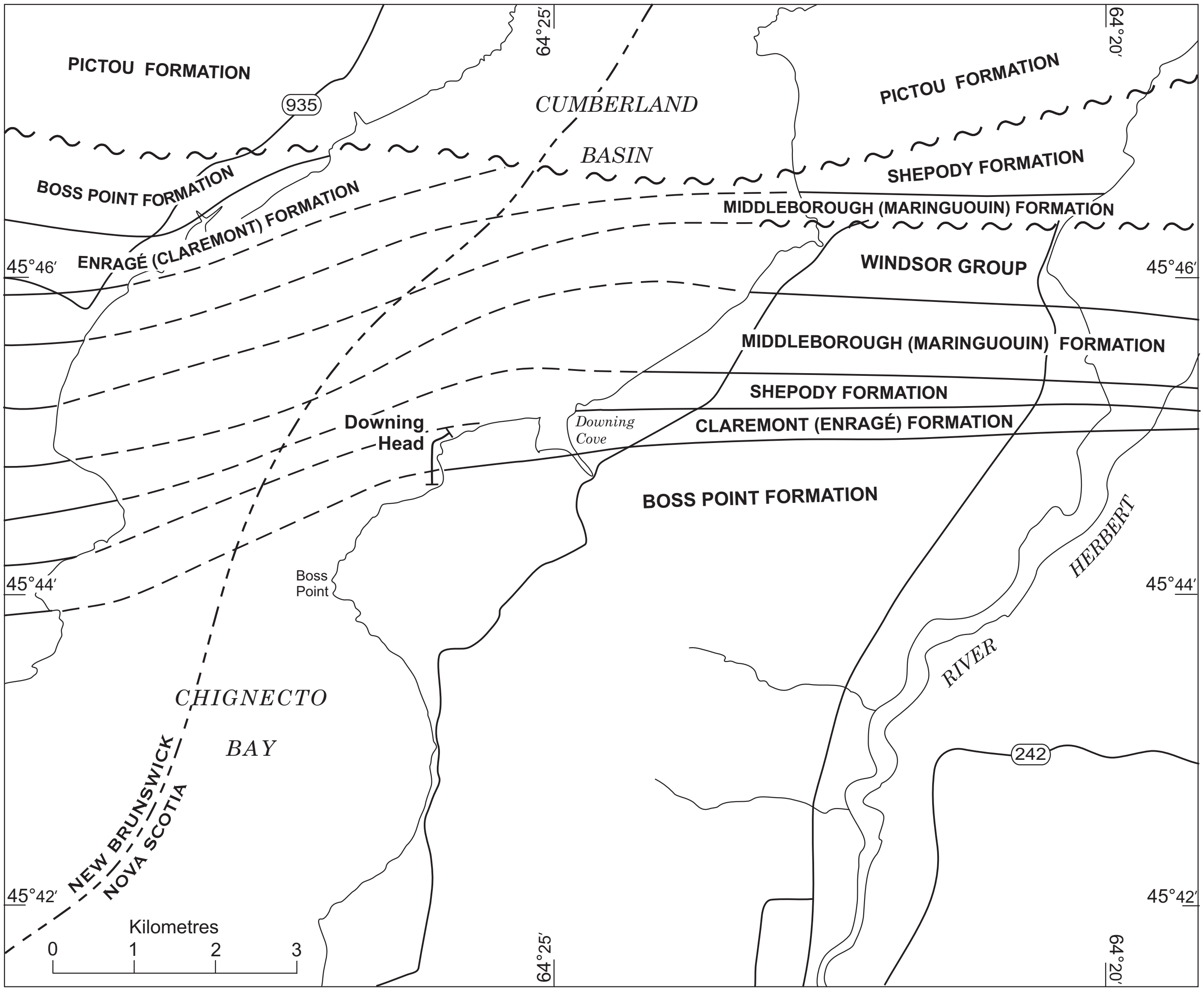
- grey, matrix-supported intraformational pebble cgl, thick bedded, fair sorting, sharp base, few, thin, medium- to coarse-grained ss beds, matrix of medium-grained ss, crude txb?, pebbles up to 5 cm of ss and slts rip-ups, angular to subangular

- buff, fine- to medium-grained ss, thick bedded, well sorted, horizontal lamination

DOWNING COVE

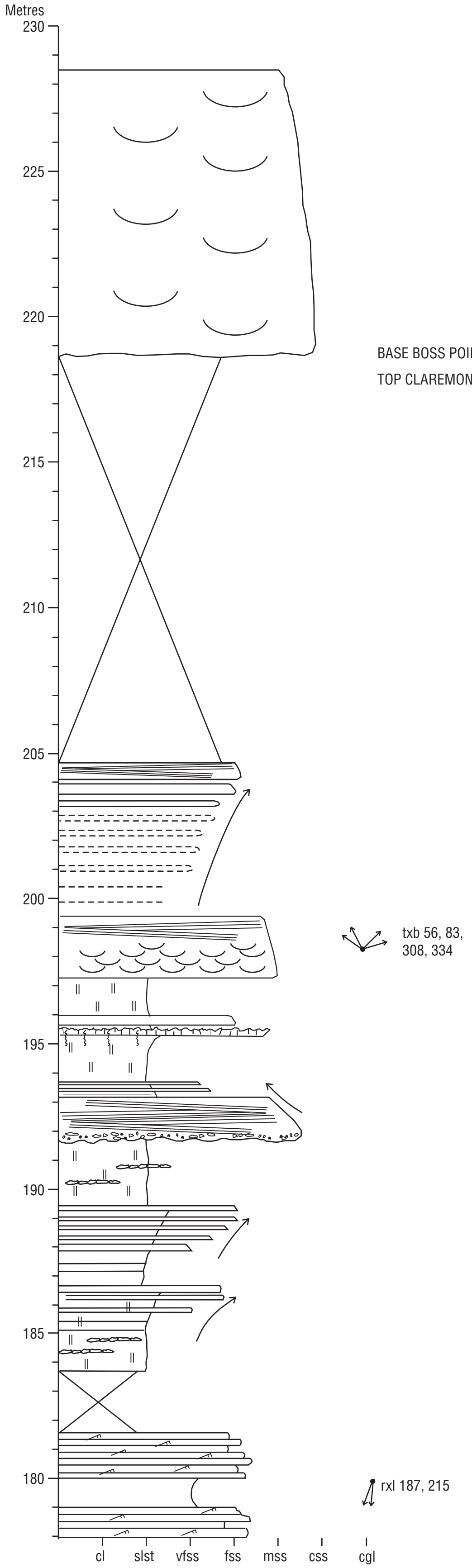






Downing Head. Claremont Formation (Hastings equivalent); general strike 75°, dip 30° S.

Downing Head Section



- greenish grey, medium- to coarse-grained ss, thick bedded, sharp base, txb

- c-up sequence of interbedded red, sandy, siltstone and very fine- to fine-grained ss, slts massive, pedogenic, as all gradational boundaries, cap bed 70 cm low-angle divergent fine-grained ss

- grey to greyish, red, medium-grained ss, well sorted, uniform, sharp, flat base and top, mostly txb, some low-angle divergent

- red siltstone, massive, uniform, pedogenic

- red, fine-grained ss, sharp base and top

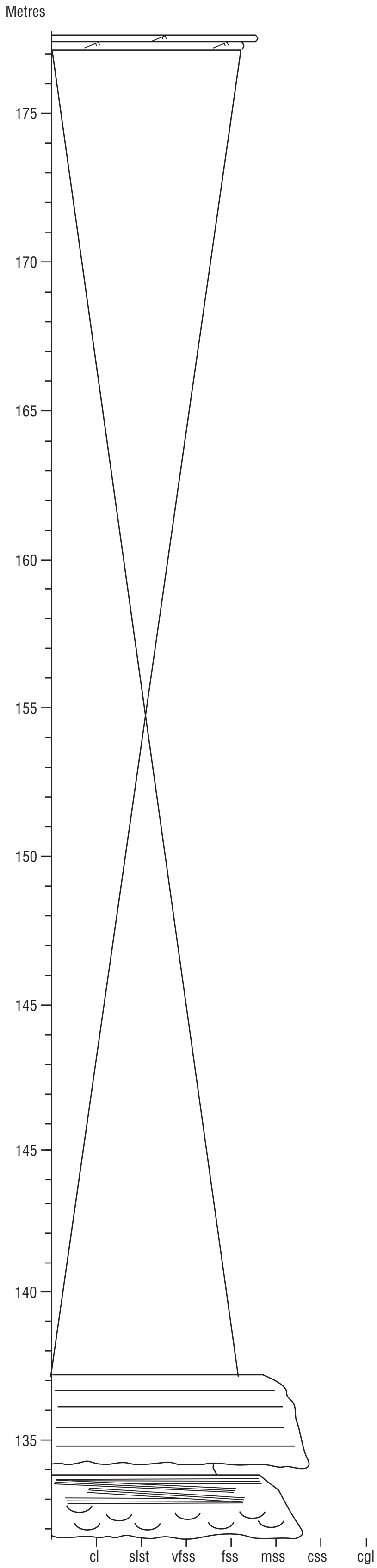
- red siltstone, massive, uniform, blocky, pedogenic, cap bed of 20 cm, greenish limestone with sharp irregular top and vertical fractures and geodat base

- thinly interbedded, red slts and very fine-grained ss

- reddish grey, fine- to medium-grained ss, well sorted, micaceous, scoured base, sharp flat top, low-angle divergent

- red siltstone, massive, uniform, pedogenic, horizons of caliche nodules, in middle are several thin, c-up segments of inter-bedded red slts and very fine- to fine-grained ss

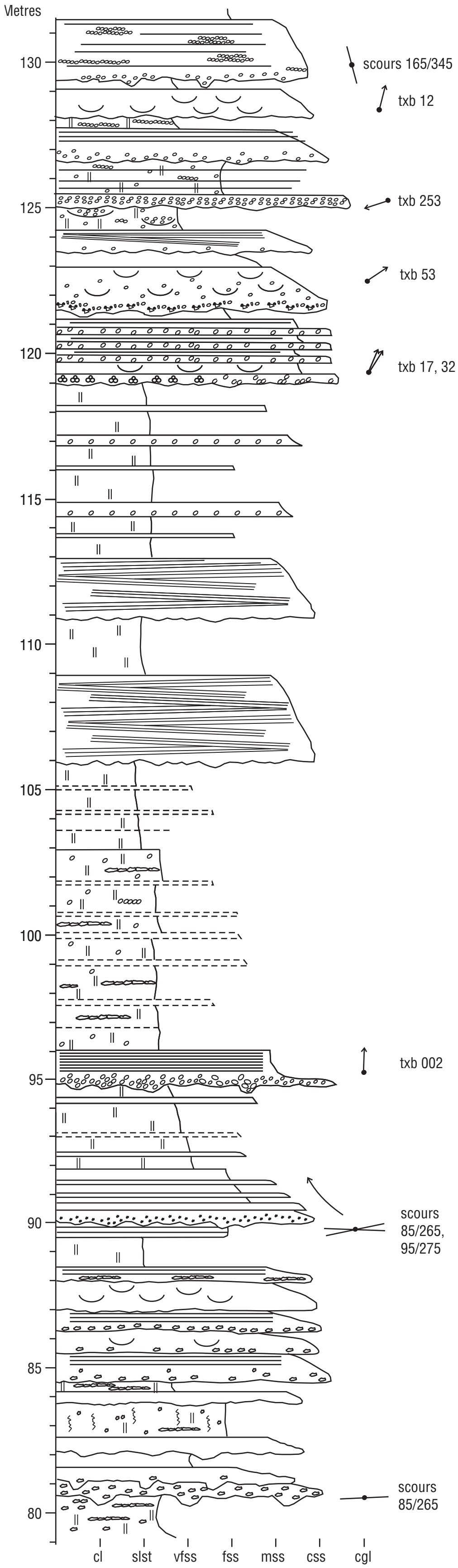
- grey to buff to slightly reddish, fine- to medium-grained ss, thin bedded, rippled, 1 m bed silty fine-grained ss in middle



- red, coarse-grained ss, thick bedded, sharp base, poorly exposed on tidal platform

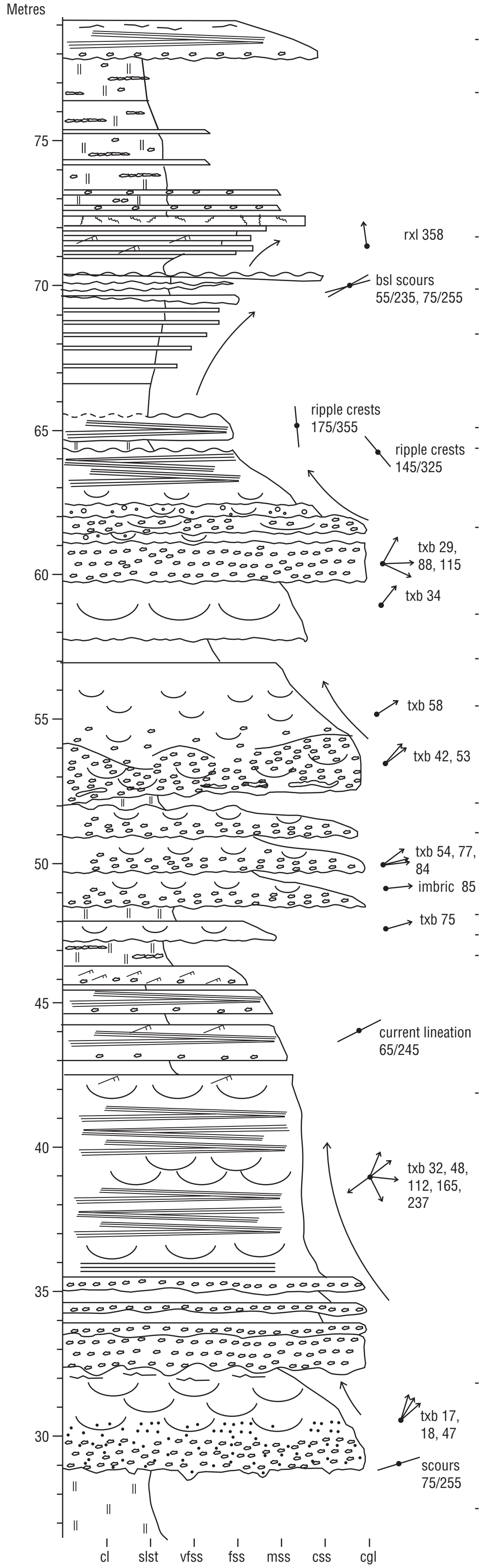
- red, fine-grained ss, poorly exposed on tidal platform
- red, coarse-grained ss, slightly f-up, sharp base, txb and low-angle divergent lamination

Downing Head Section cont.



- red, fine-grained ss, recessive
- reddish grey, coarse-grained ss, scoured base with linear scours, stringers of pebbles throughout
- red slts to very fine-grained ss, recessive
- reddish grey, coarse-grained ss, sharp base, txb
- red, silty, fine-grained ss, recessive, green caliche horizons
- reddish grey, coarse pebbly ss f-up to medium-grained ss with coarse stringers
- red, fine-grained ss, thin, coarse-grained ss stringers, caliche nodules
- reddish grey, pebbly, coarse-grained ss to conglomerate, quartz pebbles abundant, txb
- red siltstone to fine-grained ss, massive, blocky, pedogenic, few pebbly horizons caliche nodules
- red, coarse-grained ss, f-up, sharp base and top, few pebbles, low-angle divergent lamiantion
- red, fine- to medium-grained ss, silty, recessive, sharp base and top
- reddish grey, pebbly, coarse-grained ss, f-up, sharp, scoured base, txb
- red, fine-grained ss, recessive, partly cut out by succeeding unit
- red, pebbly, coarse-grained ss and coarse-grained ss, interbedded, slightly f-up, sharp, flat base and top, horizontal and low-angle divergent lamination, some txb
- red siltstone, blocky massive, uniform, rubbly pedogenic, with few, thin to thick medium- to coarse-grained ss beds, some with pebble lags
- greyish red, medium- to coarse-grained ss, scour base, low-angle divergent lamination
- red siltstone, uniform, massive, blocky, pedogenic
- greyish red, medium- to coarse-grained ss, slightly f-up, scour base, low-angle divergent lamination
- red siltstone, uniform, massive, blocky, pedogenic, with few, very fine- to fine-grained ss beds with gradational boundaries
- thinly to moderately interbedded, red, sandy, pedogenic siltstone and red, fine-grained ss and red, fine- to medium-grained ss, all boundaries gradational, caliche nodules throughout and in horizons
- reddish grey, f-up quartz pebble cgl to medium-grained ss, large, narrow scours at base, horizontal lamination, pebbles up to 10 cm
- red, silty, fine-grained ss, pedogenic, with fine- to medium-grained ss beds, medium- to coarse-grained bed near top with low-angle divergent lamination
- red, f-up sequence from scoured base with coarse-grained ss to thinly interbedded red, fine- to coarse-grained ss
- red, fine-grained ss, thin bedded
- red siltstone, sandy, pedogenic
- red, stacked, medium- to coarse-grained ss beds with pebbly lags, low-angle divergent lamination and txb, some quartzite Precambrian pebbles
- reddish grey, f-up, pebbly, coarse-grained ss to granule to red medium-grained ss, low-angle divergent lamination, few quartzite Precambrian pebbles
- red, silty, very fine-grained ss, green horizons
- grey, coarse-grained ss, sharp base and top
- red, fine-grained ss, vertical fractures, green reduction spots
- reddish grey, coarse-grained ss, scoured base
- red, silty, fine-grained ss, recessive
- reddish grey, pebbly, coarse-grained ss f-up to medium-to coarse-grained ss, large scours at base and within bed, few quartzite Precambrian pebbles
- red, sandy siltstone, uniform, massive, blocky, pedogenic, abundant caliche nodules near top

Downing Head Section cont.



- red, fine- to coarse-grained ss, f-up, sharp base with caliche lag, siltier at top and gradational top, low-angle divergent lamination

- red, sandy siltstone, few, thin, very fine- to fine-grained ss beds, few coarse-grained ss beds with lags of caliche nodules near base, massive, uniform, blocky, pedogenic, with abundant horizons and scattered nodules of grey, calcareous caliche

- c-up sequence, red, sandy siltstone to thinly interbedded, silty, fine-grained ss and medium- to coarse-grained ss to 50 cm cap bed of horizontally laminated, medium-grained ss with burrowed top surface

- reddish grey, coarse-grained ss, pinches out into silt over 5 cm, scoured base, sharp top with large ripple forms, well sorted, low-angle divergent lamination

- c-up sequence of red slts to thinly interbedded, red slts and very fine-grained ss, to thickly interbedded red, sandy silt and fine-grained ss, lens-like beds pinch out over 5–10 cm laterally, ss are sharp based and have gradational tops

- red, fine-grained ss, sharp base, gradational top, horizontal and low-angle divergent lamination with ripple at top
- red siltstone, massive, uniform, rubbly, pedogenic

- red, f-up from thick, matrix-supported cgl to thickly interbedded cgl and pebbly coarse- to medium-grained ss with horizontal and low-angle divergent lamination to fine-grained ss with rxl; cgl granular matrix-supported with clasts of varicoloured ss and slts, subround to subangular, 1–5 cm generally 2 cm, rare imbrication in matrix of coarse-grained ss to granular, crude txb or low-angle divergent lamination

- red, medium- to coarse-grained ss, sharp, flat base and top, comprises single, large txb set

- red, fine-grained ss, silty, recessive, green horizons

- red, f-up clastics-supported cgl to matrix-supported cgl to medium-grained ss, sharp, scoured base cuts out previous unit, thick basal cgl has large txb and large, red, slts rip-ups and preserved giant ripple forms

- red siltstone, massive, blocky, pedogenic

- three stacked, f-up beds of cgl to pebbly, coarse-grained ss to medium- to coarse-grained ss to fine- to medium-grained ss with txb, imbricated cgl with txb and exhumed antidures on top of ss, intraformal conglomerate pebbles are rip-ups

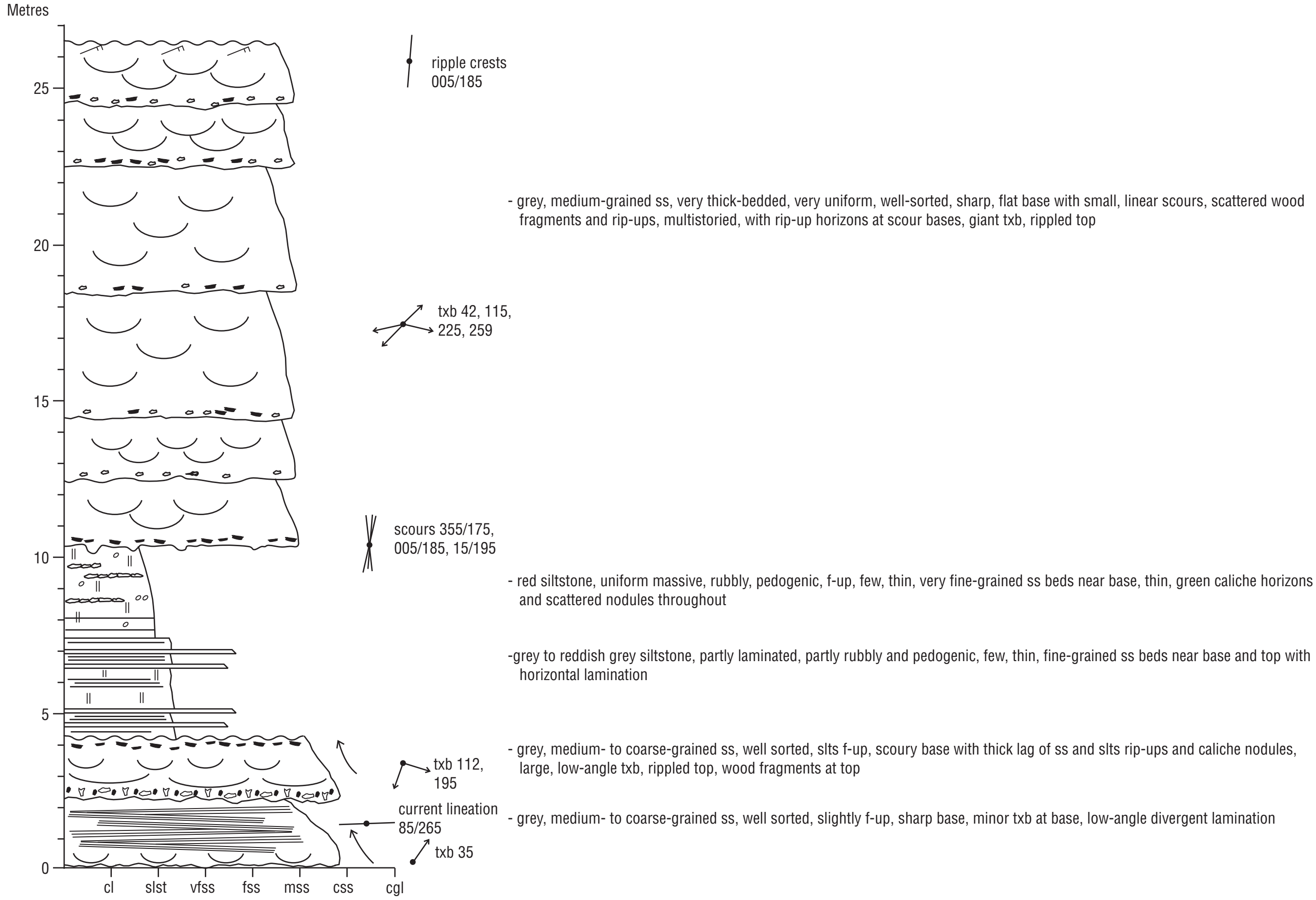
- red, sandy siltstone, uniform, massive, pedogenic
- red, fine- to medium-grained ss, sharp flat base, txb
- red, sandy siltstone, uniform, massive, rubbly, pedogenic, abundant caliche nodules

- red, medium- to coarse-grained ss, general f-up from basal cgl, to interbedded thick cgl and coarse-grained ss to thick bedded medium- to coarse-grained ss with low-angle divergent lamination and txb, to fine- to coarse-grained ss with siltstone beds with low-angle divergent lamination and rxl

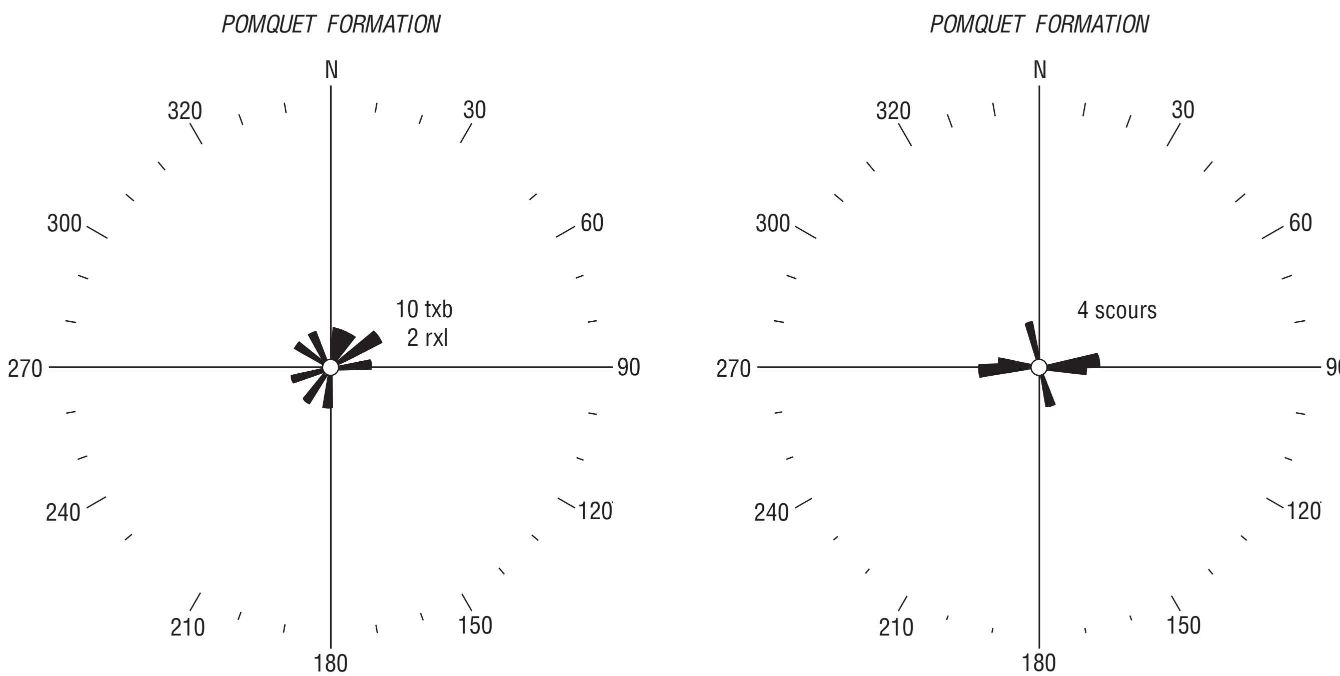
- grey, medium-grained ss-cgl, f-up, cgl at base is pebble of ss and slts rip-ups and wood fragments matrix-supported in coarse-grained ss granular matrix, no imbrication, crudely stratified, lends of ss within, medium- to coarse-grained ss toward top with silty streaks

- red siltstone, uniform, massive, rubbly, pedogenic

Downing Head Section cont.

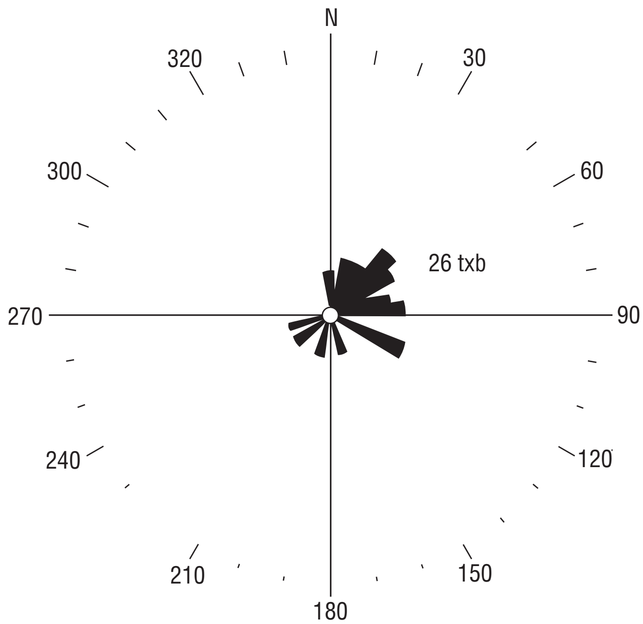


DOWNING HEAD

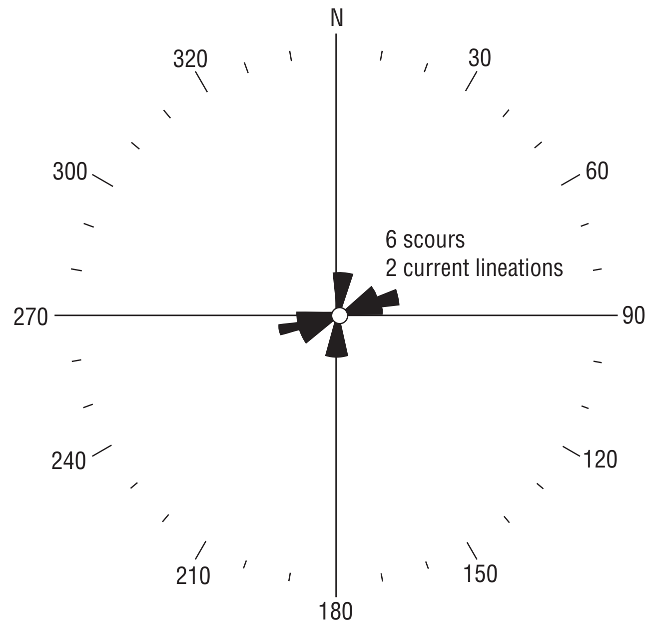


DOWNING HEAD

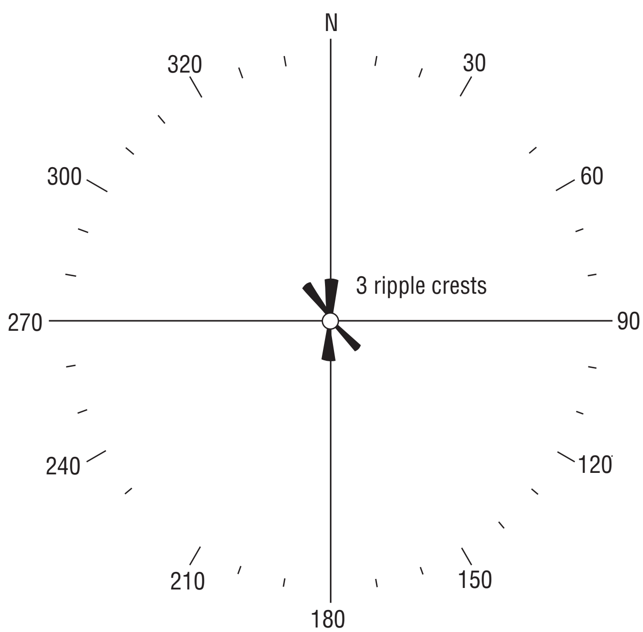
HASTINGS FORMATION



HASTINGS FORMATION



HASTINGS FORMATION



APPENDIX 2

PALYNOLOGICAL DATA (provided by J. Utting, GSC Calgary)
Sample locations and C-numbers

Outcrop	Latitude, longitude	1:50 000 NTS sheet	NTS grid location	Sample C-numbers
Cable Landfall Creek	47° 01' N, 60° 27' W	Cape North 11 N/1	937092	C-231682, C-231681
Bay St. Lawrence	47° 00' N, 60° 30' W	Cape North 11 N/1	905084–909083	C-231683, C-231684
Cape Dauphin	46° 21' N, 60° 25' W	Bras d'Or 11 K/8	985353–989352	C-231687, C-231688, C-231689, C-231690, C-231691, C-231692
Broad Cove	46° 16' N, 61° 17' W	Margaree 11 K/6	327244–331254	C-231077, C-231089, C-231090, C-231097, C-231102, C-231103, C-231108, C-231110
Little River Spillway	45° 36' N, 61° 16' W	Port Hawkesbury 11 F/11	355514	C-231693, C-231694, C-231695
Partridge Island	45° 23' N, 64° 21' W	Parrsboro 21 H/8	948254–950251	C-231406, C-231407, C-231408, C-231409, C-231410, C-231411

Sample results

Outcrop	Formation	Sample S	Age	Organics	Depositional environment	TAI
Cable Landfall Creek	Hastings	2	late Viséan–early Namurian	mostly dispersed	lacustrine, oxygenated	2+
Cape Dauphin	Hastings	6	late Viséan–early Namurian	mostly coaly	lacustrine, oxygenated	2-
Little River Spillway	Hastings	3	late Viséan–early Namurian	mostly coaly	lacustrine, oxygenated	3+
Broad Cove	Hastings	6	late Viséan–early Namurian	traces of *Botryococcus*	lacustrine, oxygenated	2- / 2+
Partridge Island	Hastings	6	late Viséan–early Namurian	no data	lacustrine, oxygenated	2- / 2+
Bay St. Lawrence	Pomquet	2	early Namurian	mostly dispersed and coaly	terrestrial	2 / 2+
Broad Cove	Pomquet	2	early Namurian	mostly coaly	terrestrial	2- / 2+

APPENDIX 3

ORGANIC GEOCHEMICAL DATA (provided by M. Fowler, GSC Calgary)

Outcrop	Formation	Samples	TOC	HI	OI	Tmax
Cable Landfall Creek	lower Hastings	2	0.40–0.49	51–76	24–33	450
Cape Dauphin	lower Hastings	6	0.11–0.51	3–81	2–86	354–436
Little River	lower Hastings	3	0.22–0.32	0–15	14–70	377–456
Broad Cove	lower Hastings	5	0.22–0.84	4–92	75–268	373–436
Partridge Island	lower Hastings	6	0.14–0.34	0	0–55	- - -
Bay St. Lawrence	Pomquet	2	0.08–0.42	19–20	70–408	413–440