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Quaternary Seismo-stratigraphy of the Lower St. Lawrence Estuary

(1:250,000 GSC/EMG Open File Map Series)

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INTRODUCTION

This map series shows the distribution and acoustic properties of unconsolidated Quaternary units flooring the Lower St. Lawrence Estuary. Dyke & Prest (1987) and LaSalle (1984) have noted that the Laurentian Trough was the confluence of ice domes to the north (Laurentian) and south (Appalachian). The Estuary was ice covered before 18 ka, and between 14 to 13 ka a calving margin had retreated up the estuary to a still stand position off the mouth of the Saguenay, thus separating the Laurentide ice by a glacial (Goldthwait) sea. Goldthwait Sea refers to the expanded body of water in the St. Lawrence Estuary during the time of deglaciation when sea levels were at their Late Wisconsinan marine limit. By 12 ka, the Appalachian ice dome had withdrawn from the Goldthwait Sea and was completely ablated by 11 ka. The Laurentian dome withdrew from most of the Goldthwait Sea by 10 ka. Sea levels reached a maximum of 125 m at Matane, and 75 m at Ste-Anne-des-Monts along the Gaspé (Dionne, 1988; Sheet 7). Between 13 and 9 ka the rate of land emergence was 3 cm a^{-1} (Dionne, 1988). A low sea level stand (≈ 5 m below present datum) occurred ca. 7 to ~~6 ka;~~ followed by a 10 m marine transgression ca. 5 ka, which persisted until sea level reached present levels at 3 ka (Dionne, 1988). Syvitski & Praeg (1989) recognized five Quaternary stratigraphic units in the Lower St. Lawrence Estuary related to the advance and retreat of the Late Wisconsinan Ice Sheet. This open file presents a series of 1:250,000 isopach and depth to reflector maps of the lower estuary, describing the distribution and character of these 5 seismo-stratigraphic units.

METHODS

The maps are based on a grid of 1330 km of multi-parameter survey lines (Sheet 1) collected during three Bedford Institute of Oceanography (BIO) cruises (Praeg et al., 1987a,b; Syvitski, 1988). The survey was conducted at speeds of 6-10 km/hr, and positioning was by Loran C (± 50 m), supplemented by radar and transit satellite fixes. Filtered air gun seismic reflection profiles (100 to 550 Hz and 300 to 1500 Hz) provide low resolution (3 to 10 m vertical, 4 to 10 m horizontal) penetration to the bedrock surface. Filtered Huntec® deep-tow seismic reflection profiles (internal hydrophone: 0.5 to 10 kHz, and external hydrophone array: 0.5 to 3 kHz) provide up to 100 m of high resolution (30 to 50 cm vertical, 1 to 2 m horizontal) subbottom information. Echosounder records were collected using a 12 kHz transducer mounted on the ships' hull. Sediment thicknesses are reported in metres, calculated using an assumed water velocity of 1.5 km s^{-1}; the thicknesses therefore represent minimum estimates.

Seismo-stratigraphic units are defined as successive intervals that can be traced on the basis of distinctive acoustic attributes, bedding styles, and/or unit geometry. Acoustic attributes are the presence and relative strength of both coherent reflections (stratification) and incoherent backscatter (tone), coherency being limited by the resolution of the system. Bedding styles refer to the internal acoustic stratification in relation to the bounding surfaces of the unit. Unit geometry is the nature of the upper bounding reflector and its relation to the basal bounding reflector, and the relation of the interval as a whole to basal topography. Units were established at one or more areas of well-defined or typical section and then traced laterally to establish a regional stratigraphy within which units often display facies variability in their acoustic attributes, bedding style, and geometry.

SEISMO-STRATIGRAPHIC UNITS

The Laurentian Trough is an overdeepened basin partly filled by a wedge-shaped Quaternary sediment sequence that thickens from less than 50 m north of the Gaspé Peninsula to > 400 m at the mouth of the Saguenay Fiord (Sheet 2). North of the Gaspé Peninsula the Trough is 400 m deep and underlain by Ordovician sediments. The Trough narrows and deepens to over 700 m between marginal shelves (< 100 m), where it straddles the contact between resistant bedrock of the Precambrian Shield to the north and the Appalachian Orogen to the south. Five Quaternary seismo-stratigraphic units are recognized that together record at least one glacial-deglacial cycle.

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BEDROCK: The bedrock surface at the base of the Quaternary sequence (Sheet 3) is recognized either as acoustic basement, characterized by variable relief and lack of acoustic penetration, or as an angular unconformity truncating deformed stratified sequences. Acoustic basement represents an offshore extension of the crystalline rocks of the Precambrian Shield in the north, and highly deformed sedimentary and volcanic rocks of the Appalachian Orogen in the south. Adjacent to Rimouski the contact between these two provinces, known as Logan's Line, is marked by a change in the basement morphology, from up to 100's of metres of shore-parallel relief beneath the southern shelf, to a lesser relief (< 50 m) beneath the trough and shelf to the north. Seaward from Rimouski/Manicouagan and from the north shore, acoustic basement gives way to an angular unconformity at the surface of gently folded (dips generally <10°) and locally faulted Ordovician strata (cf. Loring, 1975).

UNIT 1: Stratigraphically the lowermost unconsolidated layer, unit 1 is characterized by moderate to high tone, poor to absent stratification, and by upper and lower bounding surfaces that are highly variable. With its basin-fill geometry, unit 1 exists as a regionally continuous facies, but with an irregular surface reflector that is smooth on a large scale and independent of basement morphology. The contact with overlying units 2 or 3 is usually distinct. Syvitski & Praeg (1989) proposed that this facies is composed of pre-Late Wisconsinan sediment deposited during a prior glacial cycle. This basin-fill facies exceeds 200 m in thickness near the head of the Laurentian Trough, but thins to < 10 m by Pointe-des-Monts (Sheet 4). In the deeper parts of the Estuary and in depressions within the surrounding shelves, unit 1 can contain discontinuous reflections, or can be separated by continuous reflections or contrasting tone into two or more intervals, the upper of which can be locally stratified. Sub-units may relate to an early deglacial sequence, conceivably with a lower unit of ice contact deposits, overlain by ice proximal deposits, and finally ice distal deposits. The surface relief of unit 1 may reflect the sole markings of the glacier.

UNIT 2: Characterized by high intensity, closely spaced reflections, this unit contains: unit 2a a relatively thin facies that is conformable with unit 1, and unit 2b a wedge-shaped facies containing ponded sequences and slump deposits. The conformable facies is variably thick (< 20 m) and underlies the wedge-shaped facies that thins from ≈ 160 m near the head of the Trough to zero at its limit 40 km seaward (Sheet 5). Interpreted as an ice-proximal unit (Syvitski & Praeg, 1989), the conformable facies may record the deposition during the rapid retreat of an ice terminus, and the wedge-shaped facies may relate to the rapid deposition of sediment at an ice marginal still stand position. The distribution of unit 2 within the Laurentian Trough suggests that the major source of sediment is a 13 ka ice margin still stand, near the head of the Trough (Cf. Dyke & Prest, 1987).

UNIT 3: Characterized by distinctive very low intensity, weak reflections, and a conformable bedding style in which basal topography (Sheet 6) underlying the unit is mimicked through internal reflections to the surface of the unit. The unit can be traced up to, and correlated with, the extensive marine clays along the shores of the St. Lawrence Estuary. These sediments consist of distinctive blue-grey, stiff, massive to laminated clays deposited between 14 to 10 ka BP (Locat et al., 1984). Unit 3 represents ice-distal deposition of fine-grained sediment under highly turbid buoyant glacial plumes, during a period of elevated sea levels and a rapidly ablating ice sheet (Syvitski & Praeg, 1989). Unit 3 reaches 167 m thickness within the Laurentian Trough off Rimouski and is absent at the entrance to the Saguenay. Other marginal sources for unit 3 are observed along the shores of the Estuary, indicated by intervals of strong internal stratification that grade laterally into ponded lobes. Unit 3 has been locally affected by sediment failure and mass flow transport (Sheet 7). The largest is > 30 km^2 in areal extent and is located on the slope off Rimouski, where failure scarps up to 30 m high and associated with large listric faults are observed.

UNIT 4: Occurs as deltaic lobes that extend from the northern shores of the Estuary. The largest, a 100 m thick progradational wedge, extends into the trough, a consequence of the paraglacial expansion of the Manicouagan delta system (Sheet 8). Paraglacial sedimentation refers to the abnormally high transport of sediment from land to the sea via fluvial discharge from a terrestrial ice sheet that is experiencing rapid ablation during a period of rapidly falling sea level (Syvitski & Praeg, 1989). Unit 4 is characterized by high intensity continuous coherent reflections with a generally ponded bedding style, although the unit may distally be conformable over unit 3 and laterally grade into unit 5. The unit contains syn-depositional mass flows, buried channels and shear planes related to submarine slides. It is interpreted to represent coarse sediment transported offshore via slumps, slides and turbidity currents.

UNIT 5: As the uppermost Quaternary deposit, unit 5 marks the establishment of modern (post glacial) sedimentation patterns concomitant with a lowered sea level and established terrestrial vegetation. Unit 5 occurs in two main acoustic facies: deep-water basinal muds and shallow-water sand and/or gravel lags. The basinal mud facies is characterized by

low tone, weak reflections, some of which are interpreted as gas horizons, and a basinal fill geometry which smooths or masks basal relief. These acoustic attributes together with core information indicate a muddy, organic-rich facies that corresponds to pelites of Loring & Nota (1973). The deposition of mud is confined to deep or protected waters not subjected to erosion by tides or waves, and it thins from > 60 m, near the head of the Laurentian Channel, to < 15 m at the entrance to NW Gulf (Sheet 9). Maximum sedimentation rates are ≈ 1 cm/a (Syvitski & Praeg, 1989). At the head of the Channel, sediment slides from both the north and south walls are observed. At the head of the trough and along the southern shelf above 30 to 50 m depths, and locally on banks on the north shore, the muds grade into sand/gravel lags developed on older Quaternary units or bedrock. Generally these lags are thin (< 1 m) although thicker accumulations of sand can be found locally. These lags are thought to reflect increased post-glacial current erosion in shallower water since the time of the Goldthwait Sea maximum. Thick, shallow water sandy deposits are located along the northern shelf where modern deltas are being deposited.

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ENCLOSURES

Text - 3 p.
Sheet 1a,b: Data control.
Sheet 2a,b: Isopach of total sediment thickness.
Sheet 3a,b: Depth to bedrock (from present sea level).
Sheet 4a,b: Isopach of unit 1 thickness.
Sheet 5a,b: Isopach of unit 2 thickness.
Sheet 6a,b: Depth from present sea level to the surface of unit 2 &/or bottom of unit 3.
Sheet 7a,b: Isopach of unit 3 thickness.
Sheet 8a,b: Isopach of unit 4 thickness.
Sheet 9a,b: Isopach of unit 5 thickness.