EXCURSION G

GLACIOMARINE FANS BUILT WITHIN AND MARGINAL TO THE CHAMPLAIN SEA

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This excursion includes a stop 5 km southwest of Ottawa to examine glaciomarine outwash deposited within the Champlain Sea basin and stops 15 km north of Ottawa in a valley of the Laurentian Highlands to examine outwash and other features formed near the margin of the Champlain Sea. The trip objectives are to examine sediments deposited by glacial meltwater discharging into a marine water body (Champlain Sea) and also to assess the local effect of meltwater erosion on rock surfaces. A general description of subaqueous outwash, as it occurs in this area, is provided in the introduction to this volume; Day Excursions A and L. The present subject and scour marks on bedrock are also described in Day Excursion L.

There is considerable controversy concerning the Quaternary history of the Western Basin of the Champlain Sea and this trip may offer alternate views to those discussed in the summary at the beginning of this volume. This trip will look mainly at one aspect of Champlain Sea history, namely deposition of coarse sediment, considered to have been deposited proximal to the ice margin.

Ridges of coarse-grained outwash sediment are common within the Champlain Sea deposits near Ottawa (Richard, 1982a). Some of these ridges have been studied (Rust and Romanelli, 1975; Rust, 1977; Hayward and French, 1980; Cheek, 1982; and Rust, in press) and they are considered to represent overlapping sediments of subaqueous fans deposited within or close to the mouth of meltwater conduits that entered the Champlain Sea.

An understanding of these ridges is critical to assessing the style of sedimentation and to understanding the Quaternary history of the Champlain Sea deposits within the Ottawa area. The Brazeau Pit is particularly important because it shows the relationship between coarse glaciomarine sediments and fine-grained glaciomarine sediments.

The Cantley Pit offers an opportunity to examine ice-marginal sediment deposited into the Champlain Sea within a constricted environment. The site occurs within what was an embayment of the sea which trended northerly from the valley of the Gatineau River. It permits a comparison with the ice-marginal, glaciomarine sediment of the open basin at Ottawa (the Brazeau Pit).

Erosional marks on bedrock are present at the Cantley Pit and will be examined in more detail at a separate site. Traditionally groove-like erosion marks in glacial areas have been attributed to glacial scour. Erosional marks with similar form have been observed in other environments including: eolian, fluvial, marine and littoral. On this trip we will examine the significance of subglacial meltwater and glacial scouring in producing these widespread erosional forms.

Stop G-1: Brazeau Glaciomarine Fan
Active gravel pit located on the east side of Cedarville Road 2 km south of the Rock River; elevation ca. 100 m; Figures C.1 to C.4 (see also Stop A-2 of this volume); map 31G/4, G.R. 430 302.

The Brazeau Pit is one of the few sites that shows a more or less complete sequence of the glaciomarine and marine facies which may be seen in the area. These facies are illustrated in Figures C.2 and C.3 and Figure C.4 is a diagrammatic model of glaciomarine deposition of this site.

The gravelly facies (A) forms part of a 40-50 m wide zone of coarse sediment that occurs as a ridge of stratified cobble to massive bouldery gravel that coarsens upwards (Fig. G.3a). As shown in Fig. G.2a, its upper part is interbedded and gradational with massive, stony, sandy, silty diamicton which locally contains massive pebbly sand (B). These diamictons are overlain by fine sandy silt and graded pebbly sand (C) which include blocks of fine sandy silt. A 2.0-3.0 m thick sequence of rhythmic...
beds (with dropstones) consisting of several 75 to 100 cm thick fining-upward sequences of fine sandy silt with clayey caps and interbedded diamictons (both sandy and silty), with minor gravel and sand silt on top (D). This completes a spectacular fining upward sequence that started with the coarsest gravel.

In an adjacent section (section b of plan view in Fig. G.2), the coarse gravel is overlain by a thin coarse, sandy diamicton and a thin rhythmic, that is directly overlain by massive silty clay (about 1 m thick) containing marine bivalves (*Portlandia arctica*). The massive clay occurs as a thick plug within a depression between apparent ridges or lobe-like accumulations of sand and gravel. The glaciomarine silty clay shown in Figure G.2b is undeformed but commonly occurs as a disturbed, deformed unit. An apparently similar silty clay unit containing *Portlandia arctica* has been dated at 11 200 ± 200 in an adjacent pit by Rich (GSC-3641; Blake, 1983).

In another adjacent section (section c of plan view on Fig. G.2), the sandy ridges or lobe-like deposits are overlain by an interbedded sequence of thick, stony, sandy diamictons and pebbly sand and gravel that contains abundant marine bivalves (*Hastrellaria arctica* and *Macoma balthica*, Fig. G.3b). This sequence contains many deformation features including vertical beds, flame-like diapir structures, other flow structures (lobe-like) and load structures. The diamicton units are 1-2 m thick and form massive interbeds. The deformation is apparently
Figure G.2: Successions of units exposed in the Brazeau Pit (Stop G-1). The plan view shows the location of different sections illustrated in the figure. (a) A relatively complete succession of lithofacies; (b) exposure of largely fine grained sediments; and (c) exposure consisting mainly of diamictons. The facies A, B, C, and D are described in the text.
Figure G.3. Exposures of sediments at the Brazeau Pit (Stop G-1) as of November, 1985. (a) Main facies exposed in the core of the glacimarine fan (see section a of Figure G.2) Note faulted sand and gravel at right; (b) shell rich, gravelly sand interbedded with sandy diamictons (near section b of Figure G.2).
limited to a 10-20 m wide portion of the outcrop outside of which bedded strata are undeformed.

Major sandy facies are also an important part of the sequence exposed in the pit. These apparently are downstream facies and laterally equivalent to the coarse gravelly facies (Fig. G.3b). Where overlain by gravel (i.e. proximal) they are commonly faulted (Fig. G.3a). In most places they consist of graded units (commonly displaying complete Bouma sequences) ranging from massive sand to rippled sand with silty clay drapes. In places dropstones and thick massive wedges of sand occur in these sequences. Thick diamictons (2-3 m) and broad channels (ten’s of metres) are also present. These are filled with clay and silt plugs, and massive and bedded sand with rip-ups, and flow and load structures. Graded gravel/silt sequences cap or cover the channel deposits. Through cross-bedded sands also occur within the sequence.

The Brazeau sequence in places is capped unconformably by a well-stratified pebbly sand that contains Macoma balthica bivalves and Belonia ctenites plates. In other places there is an interbedded relationship between thick, sand accumulations (Hiatella arctica and Macoma balthica) in silty sandy beds, angular gravel and massive stoney sand diamictons that lie under a thin sand blanket.

Interpretation

A tentative model depicting glaciomarine fan sedimentation into the Champlain Sea is portrayed in Fig. G.4. Deposition is considered to have occurred in and at the mouths of subglacial conduits which debouched on the floor of the Champlain Sea in more than 65 m of water. (Local marine limit is 108 m in the west near Clayton and 200 m in the north near Cantley whereas the Brazeau Pit is about 100 m a.s.l.). Deposition occurred from a variety of processes such as: underflows, overflows, direct suspension, settling, and slumping. These processes produced fan-shaped accumulations of gravelly, sandy and mud facies. Disturbance from glacial ice, iceberg scour or sea ice may have occurred and littoral processes reworked the top of the sediment package during emergence.

Despite the striking, abrupt changes in grain size, it is the gradational nature of the sequence that is most significant in interpreting genesis of the sediments in the Brazeau Pit. The coarse boulder gravel is class-supported and relates to high-energy water flow probably in a subglacial conduit. Massive beds may be due to pipefull flow with high-density suspensions or sliding bed deposition. Adjacent, transitional to conformably bedded, stratified, gravelly sand could be lower flow equivalents within the conduit, or a slumped unit that avalanched over existing coarse gravel. Fluctuating water flow in the subglacial drainage network resulted in several pulses of graded pebbly sand that downstream gave way to graded sand units. These were probably deposited as continuous density underflows. Whereas most gravels represent an ice confined facies, their rapid lateral transitions to sand and clay indicate deposition as distal equivalents of the density underflows at the juncture of the glacier and the Champlain Sea.

The transition from gravel and sand to diamicton units (with coarse sandy texture) suggests sediment flowing directly from an ice margin. These flows could come from the glacier surface or more likely from the debris-rich basal ice. The debris flows of till could also
Figure G.4: Diagramatic depositional model for glaciomarine fan sediments in the Champlain Sea near Ottawa. Major processes of deposition are underflows, interflows, overflows, suspension, rafting and sediment slumping. Letters on the cross section are A, gravel facies; B, sandy diamictont facies; C, sandy facies; and D, clay rhythmites.
have been deposited in enlarged subglacial tunnels because there are interbeds of gravel and sand. The enlarged tunnels would have eroded actively back into the debris-rich grounded basal ice.

The sandy sediments (graded, ripple-drift and massive) are probably down-current or lateral equivalents of the underflows that deposited the stratified sandy gravel facies on the surface of a subaqueous fan (Rust, 1977; in press). Massive sand, particularly where channelized, may have been deposited as a slump-generated surge when the fan was saturated and unstable. In addition to a rapid lateral transition from gravel to sand, there is an equally rapid transition upwards from sand and gravel to rhythms and massive fine sediments (Sharp, in press). The rhythms relate to episodic sedimentation events (turbidites) on a distal part of the fan, or where they are proximal, relate to constricted (low-flow) flow from the conduit. Each fining-upward unit (ca. 1 m thick) of the rhythmic sequence may be annual. If this is the case, then sediment accumulation rates during the ten or so years represented by the sequence were high. Rates of sedimentation of 30-50 cm a year in sandy facies on a glaciomarine fan, in another part of the Champlain Sea basin are reported by Burbidge (1985).

Dropstones, which are common within the rhythms, suggest ice was still near or over the site during deposition of the rhythmic unit. The massive glaciomarine clay, which conformably overlies the rhythms in place, is an additional factor that must be worked into the depositional model. It is probably a suspension deposit that was derived from plumes of fine sediment that were carried into the marine basin by overflows of meltwater (Fig. G.4).

Marine bivalves (Portlandia arctica) present in the massive clay are compatible with ice marginal sedimentation (R. Gilbert, personal communication, 1985). Other fossiliferous beds containing Macoma ballica and Hastelia arctica in a coarse, sandy silt are interbedded with a glacially-derived sediment flow that suggests proximity of the ice margin.

Deformation in the proximal sediments could be due to several mechanisms: (1) iceberg scouring; this may have triggered debris-flows in unstable sediment masses, and slumping; (2) ice shove deformation of fan sediments, accompanied by debris flows from the glacier or from saturated fan sediments; and (3) slumping and faulting related to loss of lateral or underlying support (e.g. ice-melt) and (4) penecontemporaneous deformation due to sediment loading and dewatering of rapidly deposited fine sediment. In addition, later reworking by the regressing Champlain Sea (and probably by sea ice) has distorted some of the upper ridge sediments. The major apparent impact of this reworking at this site was deposition of a sequence of well-stratified fossiliferous sandy gravels and sands. In other localities in the Ottawa area, more extensive erosion and deposition by littoral processes seems evident. In fact, Hayward and French (1982) have proposed a major phase of marine reworking during regression which filled kettles left by melting of buried ice.

Questions which should be discussed at this site are:
1. Is there a transitional relationship between the gravelly and sandy sediments?
2. Is there evidence that deposition of fine grained sediments is separated from coarse grained sediments by a major hiatus?
3. If a hiatus separated deposition of the two units, what was the source and transport history of the fine sediments?
4. Is there an alternate depositional model to that of an ice marginal glaciomarine fan?
5. Where do marine fossils occur within the sequence and is the marine fauna contemporaneous with fan deposition?
6. How extensively have marine shallow-water processes affected the sediments?
7. How may ice blocks become buried in sediments beneath 70 m of water?

Stop G-2: Cantley Ice Marginal Sediments

Gravel pit located on the east side of Highway 307; 2 km north of Cantley, Quebec; elevation ca. 200 m; Figure G.1, G.5-G.7; map 3 G/12, G.R. 394 460.

The Cantley site was studied by Romanelli (1975) who described the sediments and the marine fauna. He concluded that the coarse sediments were deposited subaqueously into the sea at the ice margin. Deposition of sediment apparently occurred during colonization of the site by marine bivalves, Portlandia arctica, Macoma ballica, Hastelia arctica and barnacles.

A brief study in the fall of 1985 provided some additional findings to those of Romanelli. The pit is located south of an esker ridge that connects a string of similar deposits to the north with the study site (Fig. G.5). The pit exposes a thick sand sequence with some gravel, that forms several large lobe-shaped accumulations resting on Precambrian gneiss. An interesting feature of the bedrock surface at this stop is the presence of scallop-shaped erosion marks. These are attributed to erosion by turbulent eddies in high energy, subglacial, meltwater discharge. Better examples will be seen at stop G-3.

The main face to be examined consists of an upward-fining sequence of sand and gravel. A cobble gravel facies, consisting of several cross-cut units, forms a steeply dipping core (A of Fig. G.6a). This is overlain by a sequence of increasingly more gently-dipping beds comprising steeply dipping pebbly sand (B), steeply dipping sand, with faulting (C), pebbly, cobbly gravel and sand (D); massive, silty sand deformed at base (E); ripple-drift, fine sand (E), and, rhythmically bedded silty fine sand (F). This arrangement of strata forms a transition from coarse to fine sediments that is similar to, but more gradual than, the sequence at the Brazeau Pit (Stop G-1).