Geological Survey of Canada
Commission géologique du Canada

PAPER 85-21

LITHOFACIES OF LEDA CLAY IN THE OTTAWA BASIN OF THE CHAMPLAIN SEA

N.R. Gadd

1986

Canada

Geological Survey of Canada
Paper 85-21

LITHOFACIES OF LEDA CLAY IN THE OTTAWA BASIN OF THE CHAMPLAIN SEA

N.R. Gadd

1986

Available in Canada through

authorized bookstore agents and other bookstores

or by mail from

Canadian Government Publishing Centre
Supply and Services Canada
Ottawa, Canada K1A 0S9

and from

Geological Survey of Canada offices:

601 Booth Street
Ottawa, Canada K1A 0E8

3303-33rd Street N.W.,
Calgary, Alberta T2L 2A7

100 West Pender Street
Vancouver, British Columbia V6B 1R8
(mainly B.C. and Yukon)

A deposit copy of this publication is also available
for reference in public libraries across Canada

Cat. No. M44-85/21E	Canada: $4.00
ISBN 0-660-12089-5	Other countries: $4.80

Price subject to change without notice

Critical Readers

B.R. Pelletier
J.S. Scott
R.J. Fulton

Original manuscript submitted for publication – 1983-01
Final version approved for publication – 1985-03

CONTENTS

Figures

LITHOFACIES OF LEDA CLAY IN THE OTTAWA BASIN OF THE CHAMPLAIN SEA

Abstract

In an attempt to establish the lithological variation of sediments in a selected part of the Champlain Sea, closely spaced core samples have been used in a number of stratigraphic borings that penetrate the entire suite of fine sediments. Texture, structure, and colour banding in the sediments reveal a suite of lithologies that reflect the environmental changes from immediately post-last-glacial (late Wisconsinan) to late Holocene, excluding active sedimentation of modern alluvium, but including some sediments of relatively young abandoned terraces.

Two trends in grain-size gradation occur: 1) a vertical coarsening upwards within the sediment body as a whole and within each lithic unit and 2) a radial fining from the margin towards the centre of the basin.

Offlap of the sea produced the following suite of sedimentary environments, from oldest to youngest:

Prodelta deposits – an early varve-like rhythmite unit that rapidly grades upwards into a massive blue-grey marine clay; this in turn grades upwards into thick bedded, rhythmically or cyclically stratified fine sediments;

Delta front deposits – rhythmically or cyclically stratified fine sediments (clay-silt) in which frequency and quantity of coarse sediment (silt-sand) increase upwards in the suite; they exhibit features of channel erosion and deposition, including mass wasting phenomena;

Delta top deposits – mainly coarse sediment in the silt-sand range, exhibiting structures of open channel and interfluve environments of the emergent delta; associated beds of stratified silt probably represent slackwater conditions or pondings; bodies of these sediments are tabular and extensive;

Fluvial deposits – sand and silt derived mainly from erosion and redeposition of older basin sediments have typical fluvial features and occur in abandoned channels and terraces of the Holocene proto-Ottawa drainage system.

Comparisons of sedimentary suites show that Ottawa valley sediments have many similarities to the Mississippi Delta and Black Sea sediments, while revealing significant differences that relate to the particular glacio-isostatic conditions of the study region.

Résumé

Dans une première tentative pour définir la variation lithologique des sédiments dans une partie choisie de la mer de Champlain, on a examiné des échantillons très rapprochés les uns des autres provenant de sondages stratigraphiques qui traversaient toute la série de sédiments fins. La texture, la structure et la zonation des couleurs de ces sédiments, y compris certains sédiments de terrasses abandonnées relativement récentes, mais non les alluvions en voie d'accumulation, révèlent l'existence d'une série de lithologies qui traduisent les changements environnementaux survenus immédiatement après la dernière glaciation (Wisconsinien supérieur) et qui se sont poursuivis jusqu'à l'Holocène supérieur.

Deux tendances granulométriques ont été identifiées: 1) un granoclassement vertical inverse dans l'ensemble des sédiments et dans chaque unité lithologique et 2) une décroissance radiale de la grosseur des grains de la marge du bassin vers le centre.

La régression marine est responsable de la mise en place de la série de milieux sédimentaires suivants, soit du plus ancien au plus récent.

Dépôts de prodelta – une ancienne séquence sédimentaire similaire à des varves, qui se transforme rapidement vers le haut en une argile marine massive de couleur gris bleu, laquelle se transforme à son tour en couches épaisses de sédiments fins à stratification rythmique ou cyclique.

Dépôts de front de delta – des sédiments fins (argile-limon) à stratification rythmique ou cyclique, dans lesquels la fréquence et la quantité de sédiments grossiers (limon-sable) augmentent vers le haut de la série; ces sédiments contiennent des éléments formés par érosion et sédimentation fluviales, et par des mouvements de masse.

Dépôts de delta sommitaux – il s'agit surtout de sédiments grossiers de la taille du limon et du sable, qui contiennent des structures de chenaux libres et d'interfluves du delta émergent; les couches associées de limon stratifié se sont vraisemblablement accumulées en eaux étales ou retenues; ces sédiments se présentent sous forme de masses tabulaires et étendues.

Dépôts fluviatiles – les sables et limons dérivés surtout des sédiments érodés et redéposés d'anciens bassins contiennent des structures fluviatiles typiques et se manifestent dans les terrasses et chenaux abandonnés du réseau hydrographique holocène de l'ancienne rivière des Outaouais.

En comparant les séries sédimentaires, on peut voir que les sédiments de la vallée de l'Outaouais et ceux du delta du Mississippi et de la mer Noire présentent de nombreuses similarités, bien que les premiers laissent voir des différences marquées qui sont dues aux conditions glacioisostatiques particulières de la région étudiée.

INTRODUCTION

This study of Leda Clay, though inspired by investigations related to landslides, gives little new information directly applicable to the landslide problem, but does help place a new perspective on some previous observations by earlier workers. It is a first analysis of the variation in lithology of continuous sedimentary records within the basin of the Champlain Sea.

Earlier descriptions of Leda Clay, based mainly on natural exposures and only a few widely spaced excavations and borings, noted some textural and structural differences in the various sediments represented by that name. Correlative interpretations were highly speculative. The present study, limited to only a part of the Champlain Sea basin, examines the full suite of Leda Clay sediments. Some of the older units described here presently are not known to be exposed anywhere in the study area or have been exposed only rarely and therefore are described mainly from widely spaced core sections only a few centimetres in diameter. Thus, it is impossible to show clearly lateral continuity and gradation of sedimentary facies. Bates and Jackson (1980, p. 363) defined lithofacies as: "a lateral, mappable subdivision of a designated stratigraphic unit", but Walker (1981) argued "that in a vertical sequence, a gradational transition from one facies to another implies that the two facies represent environments that once were adjacent laterally". Such vertical gradational transitions are characteristic of all lithological units considered here to be in sequence (for it is recognized that there are numerous erosional breaks). The broad coverage of the Ottawa valley sector of the Champlain Sea basin in this study permits observation of trends that suggest lateral continuity of subunits within the formation and within the sedimentary basin as a whole. The effect of offlap of the Champlain Sea over a great distance and over a long period of time has been that each lithological unit has prograded through and beyond this model basin, with the result that units are "stacked" in the study area and, hence, observable transitions in structure and texture are seen mainly in their vertical aspect. Therefore, in the Walker interpretation of the term, lithologies interpreted as representing sedimentation under common environmental conditions and showing vertical and some lateral gradations may properly be considered as lithofacies.

The term *Leda Clay* (Dawson, 1857, p. 405) is the oldest term applied to fine, nonglacial sediments of Pleistocene and Holocene age that are widespread in Eastern Canada and that are notorious for liquefaction and related landslide phenomena under particular conditions. As the name is used in soil mechanics studies, it encompasses not only the glaciomarine sediment flocculated into the Champlain Sea as a relatively massive, blue-grey silt or silty clay, but also a number of clearly laminated sedimentary units; in short, the term applies to all silty clay sediments involved in liquefaction and related landsliding within the Champlain Sea basin. The previously recognized forms of Leda Clay have been variously interpreted as representing, for example: two separate marine invasions of Ottawa valley (Antevs, 1925); an early glacial lake predating the Champlain Sea (Johnston, 1917); a weathering phenomenon (Eden, 1976 and references therein); and a simple sequence of glaciomarine, marine, lacustrine, and fluvial sedimentation representing progressive development of the modern drainage system (Gadd, 1963a, 1976). It would appear, in the light of the present report, that much of the discordance of earlier interpretations lies in the lack of stratigraphic control and in the equating of similar lithologies outside their stratigraphic context.

Investigations carried out by the writer during the past several years have dealt with various aspects of geological and geomorphic settings of landslides in Leda Clay of St. Lawrence Lowland, and in particular of Ottawa valley. The first of these (ca. 1971) resulted in a series of unpublished maps (produced for and filed by the Quebec Ministry of Natural Resources) showing the probable limits of late glacial submergence and the limits of distribution of Leda Clay in Eastern Canada. Having delimited in this way the area of potential flowslides, ancient and modern landslides in the Thurso-Russell area of Ottawa valley were then compared (Gadd, 1976b). This identified a progressive change, through time, in the size-shape parameters of landslides that apparently was dependent on progressive lowering of the water table over the past 10 000 years. Gadd (1976a), in summary report on the geology of Leda Clay, evaluated the function of other geological factors as trigger mechanisms for landslides.

At this stage it still was not known whether variation in texture and structure of Leda Clay, and the stratigraphy of such variation, could have a bearing on landslide distribution. The first step towards an investigation of these latter factors was to select a part of the Champlain Sea, which occupied Ottawa valley between Hawkesbury and Pembroke, Ontario, as a model basin. The study basin was mapped at 1:50 000 scale to show the distribution of bedrock, glacial deposits, marine clay, sand, and all landslides, both ancient and modern (Fransham et al., 1976). The follow-up program of stratigraphic borings made in various geomorphic settings within this Ottawa valley 'model' basin is the source of data for this report. Lithofacies and their geological setting are the main themes of this report; geotechnical aspects have been treated separately (Fransham and Gadd, 1977; Fransham, 1980); the relationship between depositional environment and sensitivity of Leda Clay has been detailed by Fransham (1980).

As can be seen in this report and in other similar studies, interpretation of depositional environment depends on recognition of subtle differences or gradational changes in structure and lithology. These may be used to subdivide units that may have been correlated previously because of their macroscopic similarities. Coleman and Gagliano (1965) studied deltaic and marginal deltaic plains of Mississippi River in the United States in order to "define minor structure types found in modern sediments .... by sampling selected active environments and recording the processes and resulting sedimentary structures typical of each".

The tabulated results (Coleman and Gagliano, 1965, Table 1, p. 147) were summarized as follows (p. 148):

> "environments of the delta front and subaerial levee show the greatest variety and number of sedimentary structures. These are the dynamic environments; areas where variable currents are active, where sedimentation rates are high, and where abrupt facies changes are the norm. In contrast, other environments (shelf, prodelta, paludal and lacustrine) which are marginal to the locus of the active deltaic deposition lack this variety and are characterized by monotonous repetition of a few types. Here rates of accumulation are comparatively low and effects of aquatic organisms often dominate the structural configuration. These deposits constitute the laterally continuous units of a section. Hence the number and variety of sedimentary structures reflect intensity of processes and deposition rates .... Individual structures tell of one or several events, while the total assemblage of structures approximates many of the conditions active during deposition. In the environments studied this is clearly the case; the assemblage is the key to the interpretation of depositional conditions."

There are strong similarities between the criteria presented by Coleman and Gagliano (1965) and the observations made on a number of cores from Pleistocene-Holocene sediments in Ottawa valley studied for this report. Although not all twelve depositional environments described by those authors were recognized in the present study, the main categories of the deltaic environmental suite were observed in the Champlain Sea sediments and younger sediments of Ottawa valley and are adopted here for descriptive purposes.

Field Methods

The area of the 'model' basin investigated extends 200 km east-west from Sheenboro to Fassett, and 100 km north-south from Venosta to Casselman; location of stratigraphic borings within this part of Ottawa valley is shown in Figure 1. Drilling carried out during 1974 and 1975 summer field seasons was done mainly with geotechnical studies in mind and most samples were preserved intact for physical testing; drilling carried out during the 1976 field season by Gadd and P.B. Fransham more specifically was oriented towards stratigraphy. Detailed description of samples based on visual inspection in field and laboratory are found in Appendix 1.

Cores were taken by conventional 2-inch Shelby tubes, using both open tubes and piston apparatus, by 3-inch Shelby and by 4-inch Osterberg piston devices operated from a Failing 2000 rotary rig. The drill rig was owned and operated by the Department of Public Works. Vane shear tests were done in situ in most holes. Sampling was done at 5, 10, and 20 foot intervals. One complete drillhole (CRF-21A, Mer Bleue) was cored continuously for another study under the supervision of M.J.J. Bik. That core, stored for about seven years, was extruded and examined for this report and constitutes a valuable reference section. Some short sections of borings made specifically for the present project were also cored continuously, mainly for the purposes of placing lithofacies boundaries and sampling across transitional boundaries. It was possible on occasion, when uncased holes were standing open, to take more than one Shelby tube consecutively without cleaning the hole and driving casing by careful use of Shelby tubes with successively smaller diameter (first 4", then 2"). This was possible only where open-tube sampling was effective and not in highly unstable, sensitive clay where piston coring was necessary.

Most stratigraphic drilling for this project was to bedrock or to a very shallow depth within bedrock, but no rock samples were taken. The rock unit has not been subdivided in this report.

Cores taken in 1976 were extruded at the drill site, sectioned, described, and photographed on Kodacolor film.[1] In order to avoid as much as possible desiccation or oxidation of the sediment, these procedures were carried out, whenever possible, immediately after recovery. When delays (never more than 48 hours) occurred, the Shelby tubes were sealed with paraffin. In this manner observations were made on material as close as possible to the natural state.

Geological Setting

Distribution and physical properties of Leda Clay depend in large part on the origin and history of the Champlain Sea and on its relationship to continental glaciation and deglaciation of Eastern Canada. Therefore, a brief summary of the pertinent sequence of events and related control factors is made here.

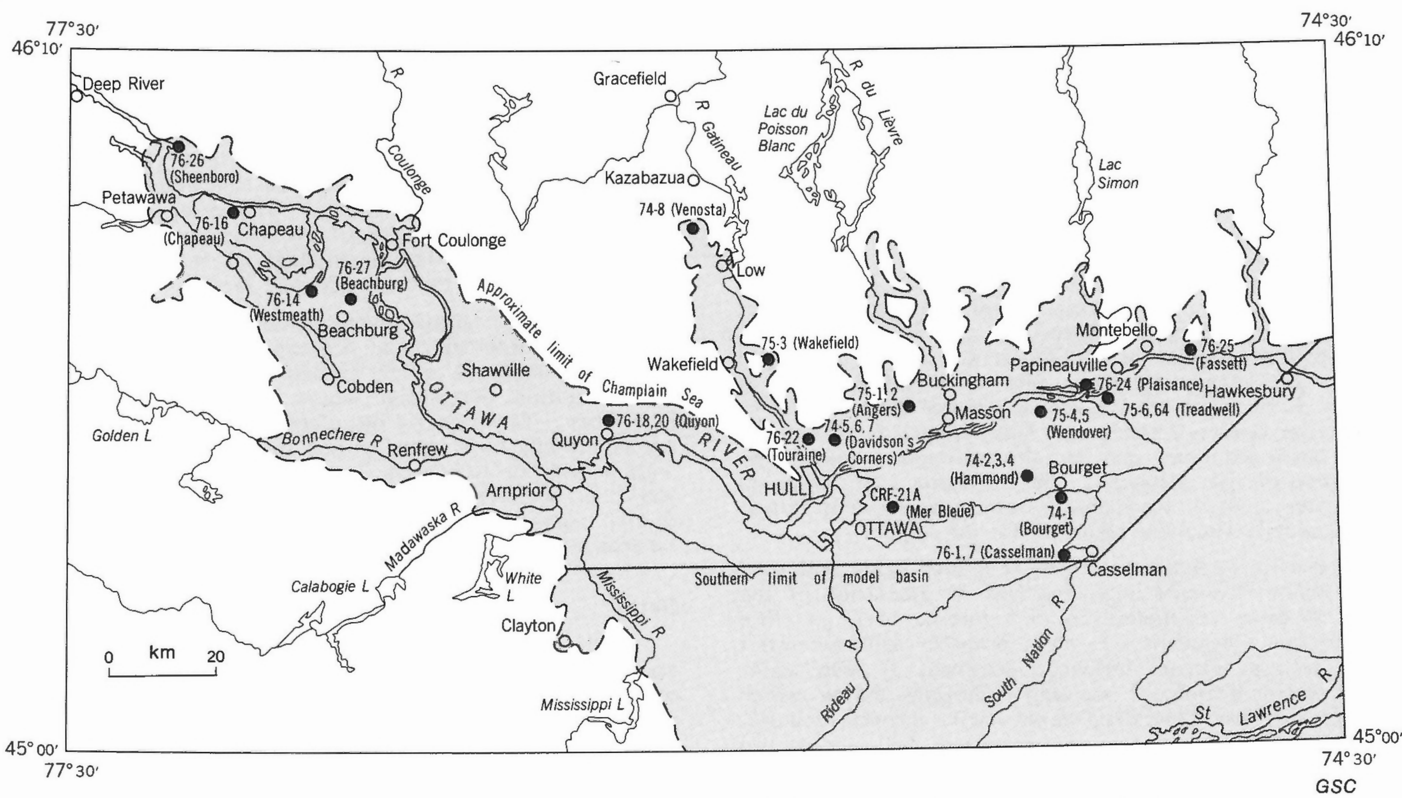


Figure 1. Location map showing the study area and sites of stratigraphic borings in the Ottawa basin of the Champlain Sea. Dashed line is the approximate limit of the Champlain Sea; solid line marks the southern limit of the study area. The reader is referred to Figures 28 and 29 showing correlation charts for the stratigraphic borings shown here.

1 Black-and-white reproduction of text figures produced for this report lack some of the definition of the original Kodacolor prints.

The geological data indicate that the St. Lawrence Lowland region was occupied by a continental ice sheet during the maximum of the Wisconsinan glaciation (ca. 20 000 BP). At that time the earth's crust was depressed perhaps as much as 300 m below its present level by the mass of ice. As that glacier melted and as sea levels rose on a world-wide scale, the earth's crust began to rebound rapidly, but at a rate that lagged behind sea level rise, so that much of the St. Lawrence Lowland region, when free of glacial ice, remained below the sea level of that time. The resultant submergence has been named the Champlain Sea. During the entire history of the Champlain Sea, and probably to the present, isostatic rebound has continued; the depressed land surface and shoreline imprints on it as well as much of the main basin sediment have been raised above sea level; and the sea, in a sense, has retreated down the valleys to its present position in the Gulf of St. Lawrence. Freshwater regimes have extended seaward across the uplifted seabottom, their deltas migrating seaward during offlap, and their streams eroding and redepositing marine sediments and other available materials as elements of early and modern fluvial systems. The sediments themselves record the changes in depositional environment from deep water marine to modern fluvial conditions, and the rather sparse fossil record gives us a rough time frame for their occurrence.

Radiocarbon dates from fossiliferous beach deposits at the highest elevations give the best approximation of the time at which the area was clear of ice and when the Champlain Sea inundated the area. For Ottawa valley the oldest date is 12 800 ± 220 BP (GSC-1859; Richard, 1975), obtained on shells in a beach at 170 m a.s.l. near Clayton, Ontario. Beaches are known at greater elevations (up to about 210 m) in Gatineau valley, but the ages there range between 11 600 and 12 200 BP. This may indicate both a time lag in the opening of the northernmost reaches of the sea in that valley as well as differential tilting of shorelines upwards towards the north. This kind of factor, plus clear evidence that the sea and the Laurentide ice mass were in contact at the St. Narcisse moraine at 11 500 ± 630 BP (GSC-1526; Gadd et al., 1972), indicates that ice was present on the land near the shores of the Champlain Sea during most of its history and that, therefore, glacial meltwater and transported glacial sediments must have greatly influenced the rate of accumulation of sediment and the rhythmicity of sedimentation in Champlain Sea basin.

Termination of the Champlain Sea as a body of salt water in Ottawa valley is indicated by the development of fluvial systems there. Freshwater clams, **Lampsilis** sp., collected from fluvial or lacustrine silt in an abandoned channel at Bourget, Ontario, give a minimum age of 10 200 ± 90 BP (GSC-1968; Gadd, 1976b) for the existence of a freshwater system in this area. This sytem is incised in the marine basin sediments and contains sediments produced by the erosion of the channels. The transition from saline to fresh water, and its approximate date, may serve to define the Pleistocene-Holocene boundary for the region.

The suite of sediments to be described below follows a logical chain of events beginning with 1) glaciation of the valley, 2) early sedimentation in a marine basin in close proximity to a remnant ice mass, probably still somewhat active, and, as glacial influence declined, 3) deep water marine sedimentation, 4) shoaling conditions during which transition occurred from deep water marine through prodelta, delta foreset, and delta topset environments, followed in turn by 5) freshwater channel and terrace sedimentation of clay, silt, and sand. The marine events occurred during a time span of 2000 to 2500 years bracketed between 12 800 and 10 200 BP (see above); the fluvial events, including the development of modern drainage, dominated the remaining 10 000 years to present.

Acknowledgments

On behalf of the Geological Survey of Canada, I acknowledge the co-operation of the Testing Laboratories of the Department of Public Works, and in particular Dr. N.E. Laycraft, and Mr. Ronald Vogan, in providing expertise, the use of various laboratory and storage facilities and services, as well as for the extended loan of drill equipment and crew. Special recognition is due Harold Robinson and Brian "Buck" Leafloor for their expertise and versatility in operation of the sometimes cantankerous drill rig and in the recovery and preservation of cores, often under difficult conditions. Without their craft this report could not have been written; without their good humour and wit under stress, the fieldwork could not have been accomplished with such great personal pleasure.

To my colleague and collaborator, Peter Fransham, I owe a debt of gratitude for his patience and understanding as well as for supervision of much of the field drilling program, for written and photographic records of cores both at the drill site and in the laboratory, and for valued discussion concerning the geology and related geotechnical studies. The latter studies have formed the basis for separate publications, including a thesis at McGill University.

Identification of **Lampsilis** sp. from the Bourget (74-1) site was made by A.H. Clarke, Jr., National Museum of Natural Sciences, Ottawa.

I very much appreciate the efforts as critical readers of my colleagues Bernard Pelletier and Robert Fulton. Their meticulous and highly constructive criticism has been of very great assistance. The writer remains, of course, fully responsible for the present format of the paper.

DESCRIPTIVE GEOLOGY – LITHOFACIES

Sediments encountered at 18 boring sites (Fig. 1) within the model basin of Ottawa valley are described in this section in their order of deposition and superposition. Some elements of the suite are missing from a number of borings and, therefore, identification of lithological units has been subjective in some degree. The criteria of gross physical character and colour described as characteristic of the various lithofacies are necessarily composite, and one should not expect to recognize all of the diagnostic phenomena in each core section. The assemblage of features falls into groupings or classes that characterize facies or subfacies.

Classes or groups were established for descriptive purposes, in order to avoid presentation of detailed logs of 18 borings, most of which exceed 30 m depth; Appendix I gives detailed descriptive notes taken at drill sites or laboratory. Thus criteria discussed in a later section of the report already have been applied to establish six lithofacies units in addition to bedrock and till; till is designated Unit I, and finer sediments are identified by II to V and B and A; Roman numerals refer to basin facies and the letters to superposed channel facies.

Unit I

Till, together with some gravel of probably glacial origin, constitutes this glacial unit. Regionally, till units observed in outcrop reach 10 m thick, but in borings carried out in Ottawa and Gatineau valleys the range is from 0 to 5 m. All samples recovered from borings (chiefly by means of the split spoon sampler) were light to medium grey and were compact basal (or lodgment) till of a sandy to gravelly texture. Free carbonate content (field test) is high and in most samples both magnetite and pyrite are common accessory minerals. Associated gravel in upper Gatineau valley borings (Venosta, 74-8[1]; Wakefield, 75-3[1]) (Fig. 1)

[1] Numbers are year-site designations for borings identified and located by numbers in Figures 1, 28, 29.

is poorly sorted, containing numerous cobbles, boulders, and much angular material. Stratification was not apparent in the few gravel samples recovered.

The material of this lithological unit commonly is permeable, thus providing little impedence to downward flow of groundwater to bedrock aquifers.

Unit II

This unit, nearly ubiquitous in borings and exposures in the Ottawa basin of the Champlain Sea, is at the base of the fine sediment sequence superposed on till or bedrock. In most sections it constitutes regularly laminated sediments with the appearance of typical varves (diatactic) comprising coarse to fine silt and silty clay (Fig. 2). The colours are commonly shades of grey that are dependent on grain size, i.e., light grey "summer" layers of coarse sediment and dark grey "winter" layers of fine sediment. In a few localities some of the winter layers are dark red (e.g., 2.5YR 3/6)[2], dark reddish brown (e.g., 2.5YR 3/4) to red (e.g., 25YR 5/6) (Sheenboro, 76-26; Beachburg, 76-27; Mer Bleue, CRF-21A; Fassett, 76-25)[1]. It would seem that the reddish coloration is more common to Ottawa valley than to Gatineau valley, where grey is dominant.

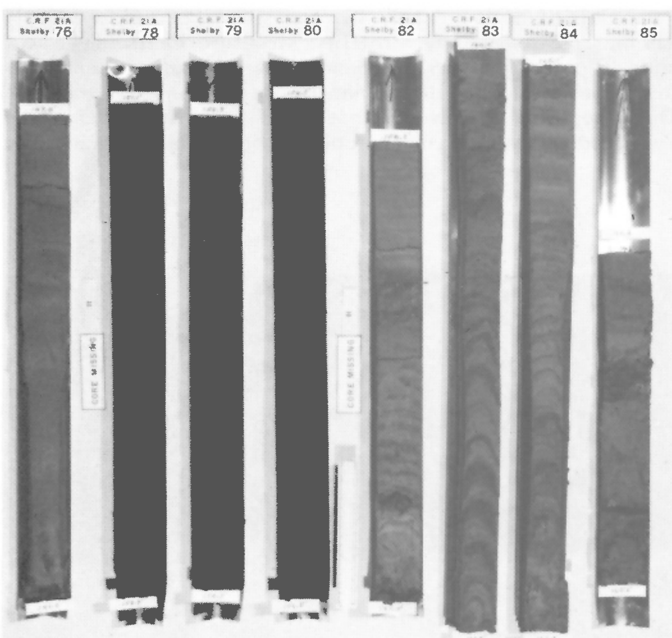


Figure 2. Lower portion (147.8' to 165.6' below surface) of boring CRF-21A, Mer Bleue. Shelby No. 85 contains sandy till (Unit I) overlain by stratified silt. Shelby No. 84, 83, and the lower half of 82 contain typical varves (Unit II), (diatactic?), that grade upwards into less distinctly banded silty clay (Unit III), (symminct?). Shelby No. 80 and 79 contain massive grey marine clay (Unit III) that grades upwards into relatively thick bedded, colour-banded silty clay (facies of Unit III). Some dark bands shown in Shelby No. 78, 79, 80, and 82 are rust bands that probably mark positions of black bands in the original unoxidized sediment.

NOTE: All Shelby tubes from CRF-21A were collected for another project and were stored in a cool, moist atmosphere for about seven years before extrusion for this study. Some of the tubes were coated internally with teflon, others were untreated. Material in treated tubes extruded relatively easily and was remarkably well preserved; some material from untreated tubes was heavily rusted and therefore was distorted and extended due to heavy skin friction during extrusion, e.g., Shelby No. 76, 83, 84.

Free carbonate content of this sediment is variable, being absent to barely detectable by field methods in some samples, to very abundant in others. In all cases when an acid (dilute HCl) test was positive, the summer layer had a stronger effervescence than the winter layer.

Several attempts (by S. Lichti-Federovich) to separate microfauna, particularly diatoms, from this unit have been unsuccessful. A few isolated entire fossils and some shell fragments, most of which were recognizable as **Portlandia** sp., occur near the top of the zone classified here as varved sediment (Unit II).

Sedimentary couples in which grain size grades upwards from coarse to fine silt, or from silt to clay, are most common in Unit II. Thicknesses of varve couples range from a few millimetres to 5 cm and rarely to 10 cm. The thicker varves commonly have partings, consisting of crossbedded, very light grey to white, very fine grained sand or very coarse silt, that break the continuity of grading in the cycles.

Borings in sediments near the limits of marine submergence in both Ottawa and Gatineau valleys (e.g., Sheenboro, 76-26; Chapeau, 76-16; Venosta, 74-8; Wakefield, 75-3) (Fig. 1) have sediments that show varve-like graded cycles but with a variety of textures and structures that apparently reflect their position proximal to the source.

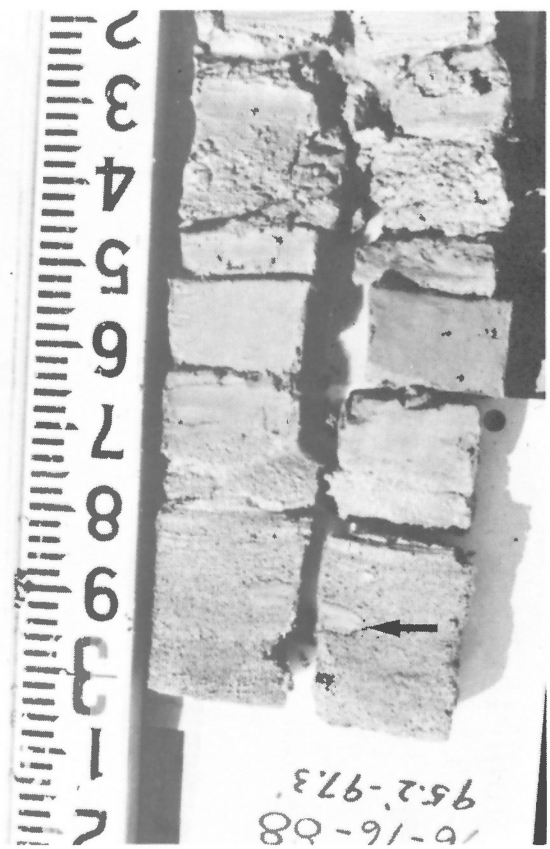


Figure 3. Sandy varves (Unit II) with unusually thick clay-silt bands. Note clay-ball (arrow) in unsorted sand layer. The scale used in this figure and most illustrations in this report is a stadia rod numbered in feet and tenths of a foot. GSC 203621-P

[1] Numbers are year-site designations for borings identified and located by numbers in Figures 1, 28, 29.

[2] Colour names and coded designations are from Munsell colour charts, by direct comparison of freshly exposed moist sediment.

Regularly cyclic, graded suites of gravel – coarse sand – fine sand or of sand – silt (e.g., Fig. 3) are either interstratified with fine sediment couples or replace them entirely.

Particularly where finer (silt-clay) varves are associated with sand and coarser graded beds, the varve repetition may be interrupted by the presence of unsorted beds. Such beds rest on eroded surfaces, are generally thicker than one varve cycle, and may be equal in thickness to four or five cycles. They may contain clay balls of irregular size and shape (Fig. 3, 4; 76-16-88, 76-16-87, Appendix 1), along with granules and sand grains. However, such unsorted beds have a general grain-size composition that is similar to that of the varve sequence with which they are found. They are also found in the graded rhythmites of coarse grained sediments, and the grain size of the unsorted material is compatible in this case also.

Within this unit a regional grain-size gradation from coarse to fine occurs laterally, from the margins towards the centre of the basin. Overall thickness of the units appears to decrease in the same direction. For example, at Venosta (74-8) and Sheenboro (76-26; Fig. 1) the coarse or proximal varve sequences are between 9 and 15 m thick, and at Bourget (74-1) and Mer Bleue (CRF-21A) the varved silt sequence is apparently less than 1.5 m thick. It is assumed that individual varves may thin towards the centre of the basin, but because of the lack of exposures, no attempt has been made in this study to trace single strata.

The upper boundary of the varve unit is gradational (Fig. 2, 5) and the varves becomes less regular and less distinct upward, giving way to relatively massive marine clay of the overlying unit (III). In the borings from near the basin margins the transition zone is broad, up to 6 m, and may include several fluctuations from varved to massive sediment, and reverse; near the centre of the basin the transition commonly is rapid and distinct, occurring in most places over a sediment thickness of about 10 cm to 1 m.

Field observations related to previous work in the Ottawa map area (Johnston, 1917; Gadd, 1963a) reveal that the lower contact of the varve sequence may be gradational as well. Sections in a railway cut in Ottawa have a complex of thin layers of flowtill interstratified with stony silt, which grades within 25 cm into normal silty clay varves (Fig. 5). The same phenomenon has been observed at another site by Johnston (1917, Plate III, p. 53). This relationship has not been observed in cores from borings carried out for this project.

Unit III

Unit III is dominantly silt and silty clay and commonly has massive to vaguely stratified structure in its lowermost units (Fig. 6; 76-22-161, Appendix 1). Most of the relatively thin deposits of Unit III are nearly isotropic or structureless. Thick deposits of this unit grade upward into, and may be interbedded with, regularly colour-banded and horizontally

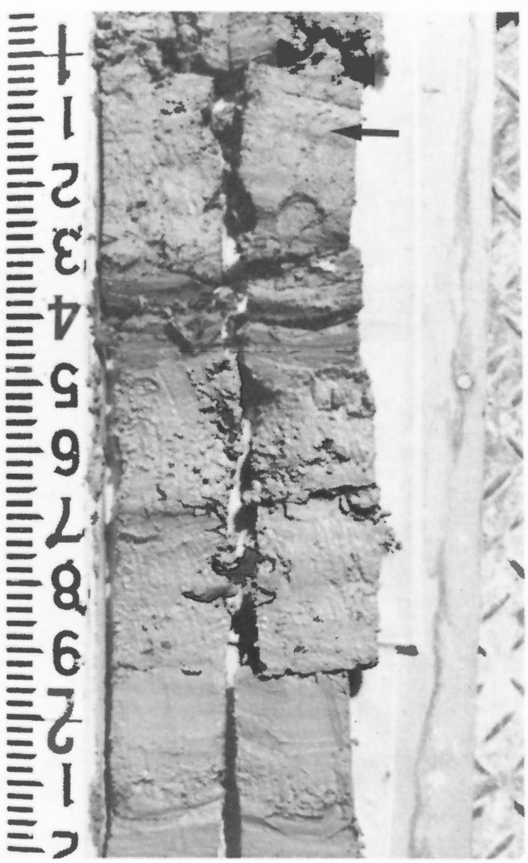


Figure 4. Sandy varves (Unit II) with thin silt bands (dark, fine grained). Note the cluster of clay balls (arrow) in the unsorted sand layer near the top of the core. Scale in tenths of a foot. GSC 203621-Q

Figure 5. Transition zone sediments showing laminated till (flowtill or waterlain till ?) at base, interstratified laminae of till and stony varves, and typical varves (upper contact of these units indicated by white arrows, left), grading upwards into laminated marine sediments. The lowermost occurrence of marine fossils **(Portlandia arctica)** in the section is at the level shown by the white arrow, right centre; below this, the material is barren of fossils. This section was exposed in a railroad cut about 275 m northwest of the intersection of Gladstone and Preston Streets in Ottawa, Ontario. (GSC 1-12-66)

Figure 6. Massive subfacies of Unit III with general dissemination of black coloration in dark grey groundmass. GSC 203621-B

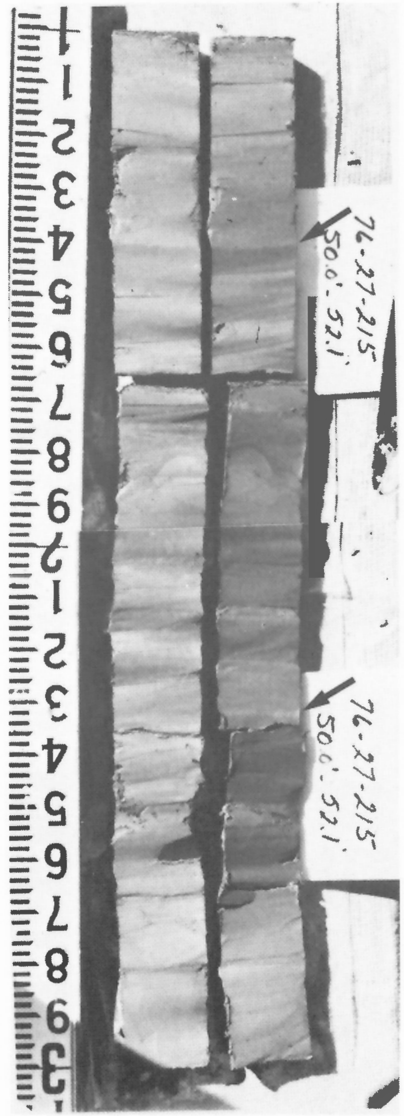


Figure 7. Colour- and texture-banded strata of Unit III. Sharp textural boundaries, also marked by colour change upwards from grey to brownish grey, at 1.4 and 2.35 on the scale (arrows). GSC 203621-R

Figure 8. Massive subfacies of Unit III showing abundant black mottling. Note localized black material compared to dissementation in Figure 6. GSC 203621-O

stratified silt-clay cycles (Fig. 7; 76-27-215, Appendix 1). Graded bedding is present in the cycles but is irregular (symminct varves?) compared with the consistency of grading in Unit IV (diatactic?). Clay layers of the cycles range from dark grey through increasingly reddish shades of reddish grey (e.g., 5YR 4/2) to red (e.g., 2.5YR 4/6; some bands are as bright as 2.5YR 5/8). Sedimentary layers having reddish shades increase in abundance and intensity of colour upward in the section; they dominate in strata with the highest clay content in clearly stratified or cyclically banded material. The indistinctly banded to massive clay strata are commonly dark grey.

Massive and banded forms of this sedimentary unit are shown by Fransham and Gadd (1977) to have somewhat different average content of clay-sized sediment: the more massive form has less clay-sized material than the stratified one, or, conversely, the massive one has relatively higher silt content. These were described for geotechnical purposes (Fransham and Gadd, 1977) as "deep-water" and "prodelta" facies, respectively. In this report, however, these are considered as subfacies, or as depositional varieties of a "shelf" or "prodelta" sediment, and to have been deposited in essentially identical basin environments. Sedimentation rate and volume of supply of sediment may be the only essential factors controlling the variation in stratification (see *Discussion*).

This unit is the most uniform and regular of the clay-silt facies of Leda Clay. Minor sedimentary structures and textural variations are rare and stratification, where obvious, is generally horizontal and cyclic and most clearly discernible where size-related colour bands are present (e.g., Fig. 7).

Figure 9. Close-up view of Figure 8 showing tubular and branching nature of some black streaks in the massive subfacies of Unit III. GSC 203621-N

Unit III is the most abundantly fossiliferous of the facies described here. **Portlandia** sp. is the most commonly identified macrofossil and there are several species of microfauna, mainly foraminifera and ostracoda.[1]

Attempts by S. Lichti-Federovich to separate diatoms from this fauna have been unsuccessful. The presence of fossils with carbonate tests in the sediments suggests a general content of free carbonate in the sediment which is confirmed in field testing by the presence of weak to vigorous effervescence of the sediment when dilute HCl is applied. Where the sediment is heavily charged with black unctuous material (e.g., Fig. 8, 9; 76-22-153, Appendix 1) effervescence with acid is generally strong and an abundant, pungent odour of H_2S and SO_2 is produced. In such cases one cannot be certain that any free carbonate reaction is being observed.

Figure 10. Black mottling and banding in Unit III, showing cyclic pattern of occurrence. (The material changes colour from grey to reddish brown in the several inches of sediment above the black bands). GSC 203621

[1] No identifications of microfauna have been made for this report because appropriate expertise was not available at the time of writing.

Black colouring occurs in this sediment as a general dissemination (Fig. 6), as concentrations in irregular tubular patterns (Fig. 9; 76-22-153, Appendix 1), as mottling (Fig. 10; 76-25-184, Appendix 1), or as discrete bands (Fig. 11; 76-24-166, Appendix 1) in otherwise normally coloured grey or 'red' sediment. In all cases where black is present the samples have a fetid sulphurous odour on fresh exposure and produce H_2S (and SO_2) when tested with acid. During treatment with acid, the black disappears from the spot tested. It is also a consistent observation of this study, and of studies in other areas, that the black will disappear over a period of several hours, certainly within a day, if the core, or a fresh section, is simply exposed to the air. This reaction is invariably accompanied by production of pungent sulphurous odour. In the presence of sufficient moisture, black spots and bands will be replaced by reddish orange to ochrous yellow ones during this process of rapid oxidation.

During the washing of sediment for fossil separation, pyrite was found as minute grains and crystals, as encrustations on and fillings in microfossils, and as irregular tubules and rods, some of which were branching. When samples were cut from cores, gritty nodules or concretions of pyrite of relatively small size were sometimes struck by the

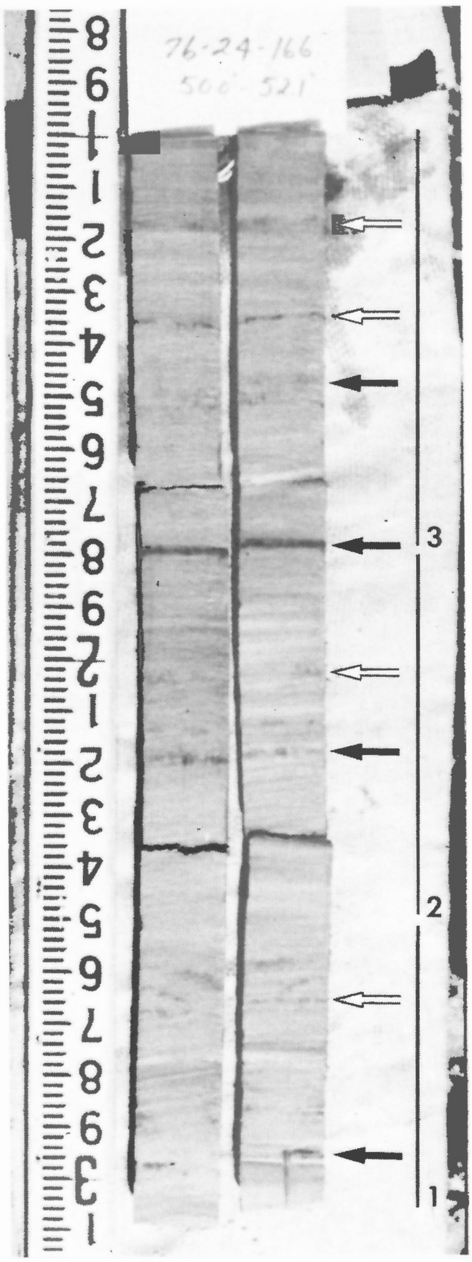
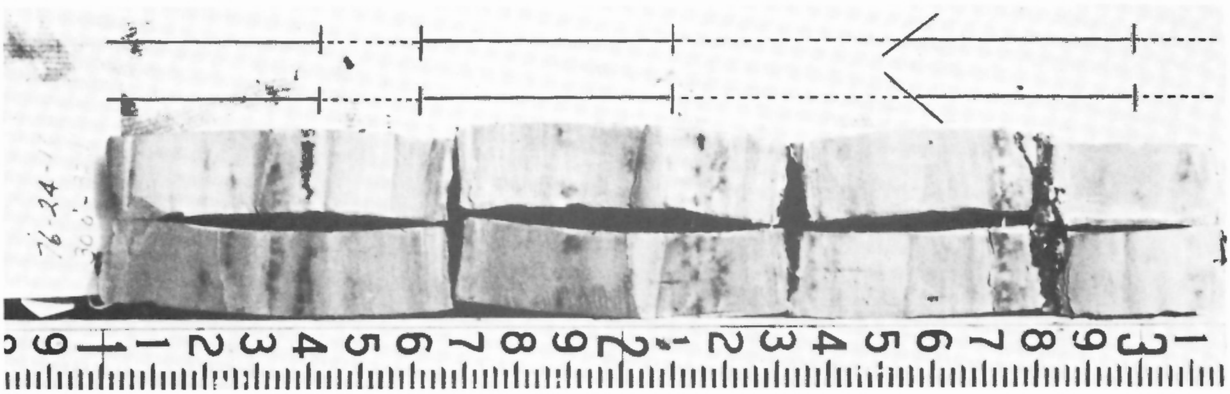


Figure 11. The distinct black band, at 1.8 on the scale, occurs in the lowermost part of a grey silty clay band near its contact with underlying pinkish grey clay. There is a gradational change of colour from grey to pink upwards in section; this core exhibits three cycles of colour-texture variation, identified by the broken vertical black line and numbered 1, 2, 3, in order of deposition. Note that black bands and mottling occur in both grey (black arrows) and pink (white arrows) sediment. This is an example of thick cyclic colour-texture banding in Unit III. GSC 203621-T

Figure 12. Regularly alternating thick grey silty sand and thin reddish brown silty clay layers (arrows). Basin-margin sediments like these may be classified as shallow-water phase of Unit III or, alternatively, as proximal varves of Unit II; in the absence of fossils, distinction is impossible. GSC 203621-J



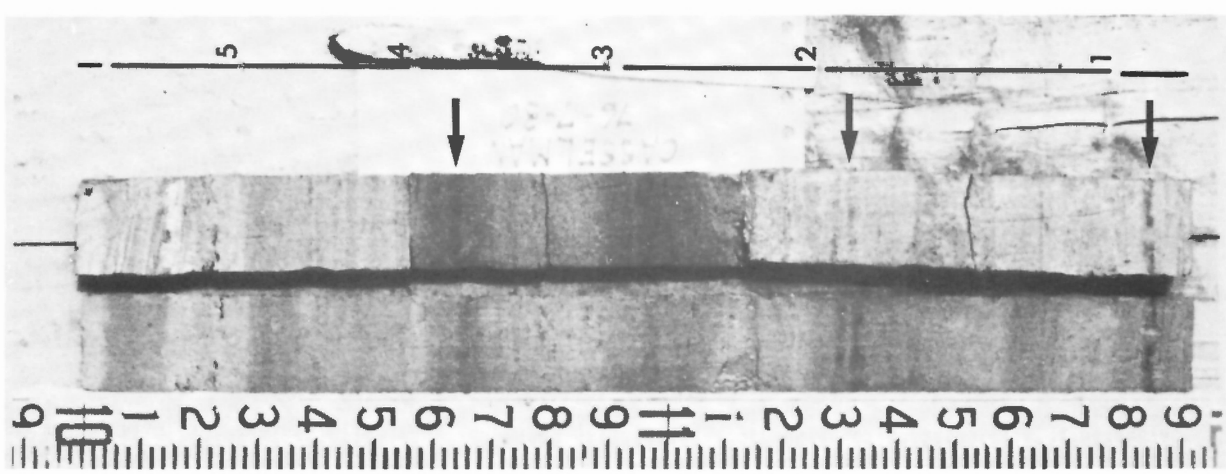


Figure 13. Relatively thin bedded, colour- and texture-banded silty clay of Unit IV. Five complete and two incomplete colour cycles (broken vertical line numbered in order of deposition) show gradation upwards from grey (light tone) to reddish grey (dark tone). Note black bands (arrows), commonly in the finer grained (dark) material. Note also silty sand partings at 10.15 to 10.25 and 11.1 to 11.2 on scale. GSC 203621-A

Figure 14. Rhythmically colour- and texture-banded strata of Unit IV showing tilted strata (1.7 to. 2.2 on scale) between horizontal strata above and below. The tilted beds are accented by black banding. GSC 203621-C

Figure 15. Bar diagram to the right of the sectioned core of Unit IV illustrates alternation of subtle colour change from bluish grey (dashed line) to pinkish grey (solid line) that represents cyclic variation from relatively coarse (dashed) to relatively fine (solid) silty clay sediments. Diagonal lines on the diagram at 2.55 to 2.65 on the stadia scale represent a diagonal erosional contact between fine grained facies (below diagonal) and coarse grained facies (above diagonal). (See also Figure 16). GSC 203621-E

(Note: Colour changes indicated, being of equal tone, do not reproduce well in black and white prints.)

knife or wire saw. Many of these are about the size of the microfossils (± 1 mm) and smaller, but rods and tubules may attain lengths of 5 or 6 mm and diameters of 2 to 3 mm.

The dominant colour of this unit is light grey, but is commonly dark grey and grading to black where iron-sulphur compounds are abundant. In the relatively massive units of this facies, there are rare diffuse zones of dark reddish grey (e.g., 10R 4/1) to dark reddish brown (e.g., 2.5YR 2/4). Upper parts of the sequence, particularly where cyclically stratified, have distinct dusky red (e.g., 10R 3/3) to reddish brown (e.g., 2.5YR 4/4) clay-rich bands or zones. The amount of red coloration appears to increase upward in the section.

The massive to thick bedded, relatively irregularly colour- and texture-banded clay-silt facies is absent in at least parts of the section encountered in borings at the western and northern limits of the Ottawa basin of the Champlain Sea. In the Venosta (74-8) and Wakefield (75-3) borings, no massive or thick bedded units are known and facies of all nonglacial units are stratified and relatively thinly bedded. Sediments in borings at Sheenboro (76-26), Chapeau (76-16), and Westmeath (76-14) have relatively massive to poorly stratified, medium grained to fine grained sands near the base of the section that grade upwards into sand-silt cycles with reddish coloration in the silt bands (Fig. 12). Cycles are thick, commonly greater than 20 cm, but fairly regular. These sandy units, because of their regularity, horizontal attitude, and apparent lack of clearly defined current phenomena are correlated with relatively structureless to regularly stratified sediments of finer grain size that dominate Unit III. It is possible that they might be classified, alternatively, as proximal varves.

Unit IV

Rhythmically or cyclically texture- and colour-banded sediment in the silt-clay range (silt dominant) comprises the bulk of Unit IV. Very fine grained sand occurs as partings that are lenticular and infrequent in lower parts of section; the frequency, regularity, and thickness of sand layers increase upwards in section. Otherwise, texturally and physically this sediment closely resembles the banded portion of the underlying Unit III.

In these similar units, commonly there is a sharp depositional break between fine grained (dark grey to red shades) clayey sediment and the overlying coarse (light grey) silty clay and silt (with some very fine grained sand partings). Quantity and intensity of red colouring of clayey layers increases upwards throughout this facies, and red becomes the dominant colour in the uppermost strata of this unit. Fossils are present, but not abundant.

The most significant difference between Units IV and III is their structural variety. Unit III is massive to poorly stratified and, where stratified, is thick bedded. In contrast, Unit IV is relatively thin bedded, clearly stratified (Fig. 13; 76-7-30, Appendix 1) and has a number of characteristic minor structures that break the continuity of sedimentary sequences, as follows:

1. tilting of beds (Fig. 14; 76-24-170, Appendix 1) – series of beds tilted at angles commonly as much as 30° (apparent) lie unconformably within horizontally bedded strata;
2. erosional truncation (Fig. 15, 16; 76-24-164, 76-7-28, Appendix 1) – relatively coarse sediment occurs in an erosional relationship, commonly as channel cut-and-fill structures, within compatible stratified sediment above and below the erosional surface and fill units;

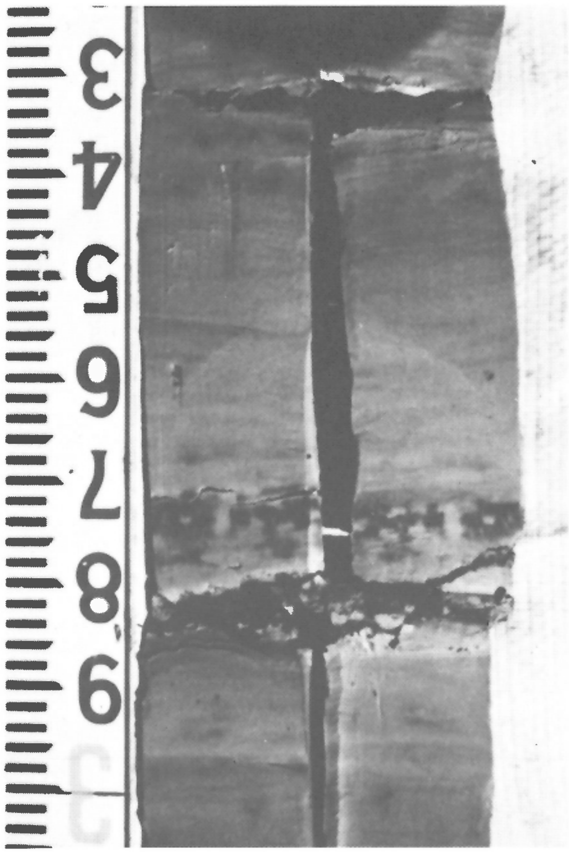


Figure 16. Close-up of a part of Figure 15 to show diagonal erosional contact between fine sediment (below) and coarse sediment (above).

(Note: Use of filters and high contrast paper for this black and white print have given the fine grained sediment a lighter tone, whereas in nature the fine grained sediment is darker than the coarse.)

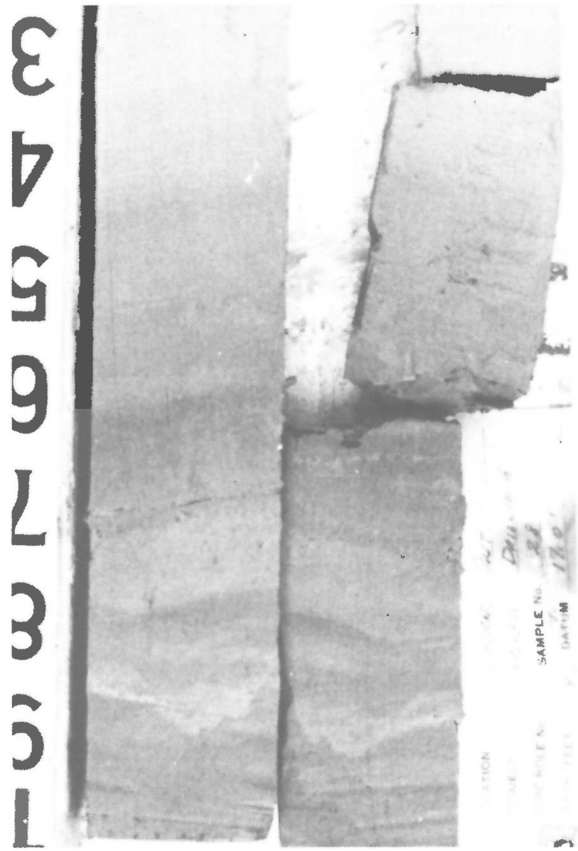


Figure 17. Unit IV showing distorted lamination with both lenticular and erosional truncations. GSC 203621-V

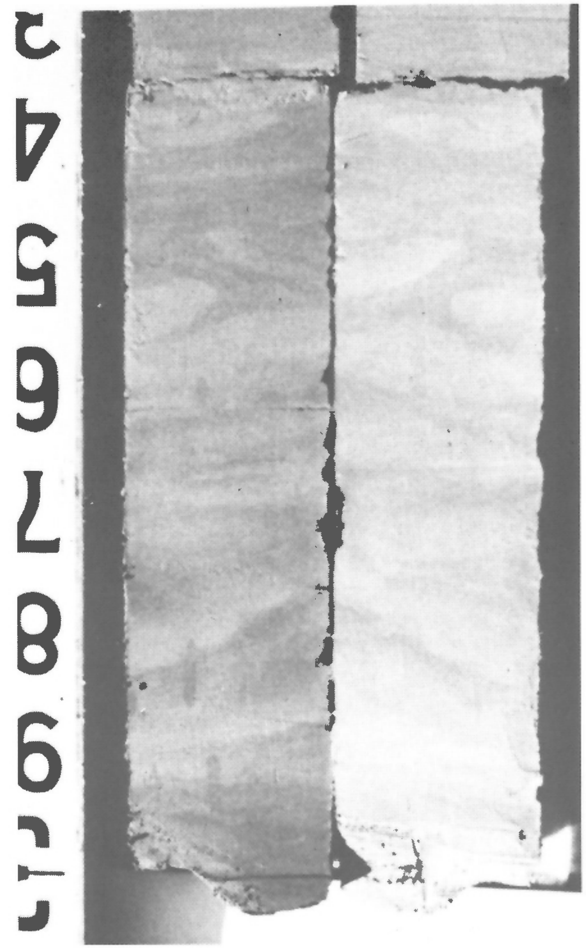


Figure 18. Distorted lamination in Unit IV showing lenticular and rounded or "mud-ball" structure in light-coloured material. GSC 203621-U

3. unsorted strata and distorted laminations (Fig. 17, 18, 19) – beds including unsorted material, detached and distorted laminations, as well as mud balls and clay lenses occur on erosional surfaces within regularly bedded strata;

4. black banding and mottling (e.g. Fig. 20; 76-24-165, Appendix 1) – bands and mottling of black are characteristic and most abundant in this lithofacies; they are also present to limited extent in Unit III but are not known in Unit V. Commonly, but not exclusively, the black bands and mottlings are found associated with the light-coloured coarse facies of a sedimentary couple (or cycle); diffuse bands of black mottling may have a thickness of several centimetres, or there may be several thin (to 1 mm) black bands in a similar thickness of sediment (e.g., Fig. 21; 76-24-167, Appendix 1).

Unit V

This unit has structures similar to those of the underlying Unit IV but its texture is dominantly sandy. Unit IV commonly grades upwards into Unit V through a gradual increase in sand content. In such cases a boundary between units is a matter of arbitrary choice, but in some sections the contact appears to be erosional and the transition from Unit IV to Unit V is distinct.

Structural features of Unit IV continue upwards into Unit V. Although they are commonly masked by weathering and by coarseness of grain, one may recognize erosional truncations, scour-and-fill structures, distortion due to slump (Fig. 22, 23; 76-16-94, Appendix 1), intraformational folding and slumping, convolutions (perhaps due to compaction), inclusions of various kinds (e.g., mud balls), and possible turbidite layers. Inclusions of some pebble-sized fragments of laminated sand indicate that some eroded materials may have been transported in a frozen state, or otherwise preserved in a conglomerate or breccia. In addition, the unit exhibits various cross-laminations and ripple marks that suggest either current or wave action, or both. All the above structures are exceptional, however, because the bulk of the sediment consists of horizontal beds or laminae of sand to silty clay that have two common forms: regular, fining upward cycles (Fig. 24) and regularly alternating sand and silty clay bands (Fig. 25, 26; 76-14-65, Appendix 1). Silty clay layers, where present, may be pink, red, or reddish brown. From the present study, black banding is unknown in this unit, but concentrations of dark minerals including magnetite, pyrite, and possibly hornblende give a colour accent to bedding structures. Fossils are commonly fragmentary and are generally rare or absent.

More obvious in this sandy facies, but true of all facies of basin sediments described above, is the fact that although the texture of the individual bands, layers, and cycles fines upwards, the texture of the unit as a whole coarsens upwards. For example, first layers of this unit encountered in several borings consist of fining upwards, graded beds of coarse to fine sand, and strata encountered at greater depth in the same unit consist of fining upwards, graded beds of fine sand and silt.

Units IV and V occur in extensive planar bodies of regional extent. Younger fluvial deposits described below are found in channels and terraces incised within these tabular bodies of sediment.

Units A, B, A-B

Sediments in abandoned channels and terraces of the Ottawa basin are similar to other units described above and particularly to units IV and V in that apparently they have identical lithologies and physical characteristics, but subtle differences have been recognized here and in earlier studies (Johnston, 1917; Antevs, 1925; Gadd, 1963a). Within this specific geomorphic setting there are two units: one comprises silt-clay strata (Unit B) and the other comprises a sand facies (Unit A). Interstratification of units A and B are designated A-B. These are in part derived by erosion from the suite of sediments (units II to V) described above, on which they commonly are superposed.

Unit B is relatively thin bedded, comprises a cyclically or rhythmically laminated silt and clayey silt, and is light and dark grey to dark reddish brown; the darker colours are those of the finer grained material. The cycles comprise light and dark layers, commonly with graded bedding but with many erosional breaks. Erosional truncations of strata, scour-and-fill structures, slumps and convolutions, though present, are seemingly less common than in the underlying units (V and IV). More common in Unit B are relatively thick (3 to 10 times the thickness of enclosing paired laminations) beds of completely disoriented and distorted material apparently derived by mass wastage from former horizontally bedded and colour-banded strata. Such layers may also include a few rock pebbles and granules as well as disseminated sand grains and pockets of sand (Fig. 27; 76-14-69, Appendix 1).

The lower contact of Unit B commonly is erosional and it may rest unconformably upon any of units I to V or on bedrock; but also Unit B may be interstratified with Unit A. In a number of places, particularly on the terraces in the vicinity of the Treadwell (75-6) and Fassett (76-25) borings, Unit B is underlain by thick deposits of Unit A. Previous work by Gadd (1961, 1963a) has shown that Unit B has rusty coloured or ochrous patches or mottlings at depths well below the regional water table. Similar mottling is observed in material retrieved from borings carried out for the present project. Small concretions, commonly comprising silt cemented by $CaCO_3$, have been found in a few borings. These concretions are well known and abundant in some natural exposures and seem to be characteristic of this unit.

Unit A is the sandier facies of the two channel sediments. Cyclic stratification of coarse and fine sediment in the sand-silt range is characteristic of the sandy unit (A). Individual strata commonly range from coarse sand to coarse silt, with some clay-silt bands occurring particularly in the lower part of the sequence. The lower contact of this unit commonly is erosional, but has a gradational contact or interfingering relationship with the clay-silt Unit B facies that most commonly underlies the sand Unit A.

Unit A exhibits seemingly unique characteristics. Coarsening upwards cycles are common. In these a sharp contact occurs between the coarser element of the cycle and overlying finer sediment. Grain size then grades upwards from fine to coarse to the next sharp contact with fine sediment. This is the reverse of the gradation observed in all other strata described above. Increasing current energy during deposition of individual sedimentary cycles is clearly indicated. Because the phenomenon is cyclic and gradational, it would seem to relate more to seasonal or episodic conditions such as may occur in levees during overbank flooding, than to the more uniform conditions of erosion and deposition in migrating channels.

These units (A and B) are restricted to abandoned channels and to broad erosional terraces set within regional bodies of older unconsolidated sediment. At the Bourget site (74-1) in an abandoned channel, a transitional (A-B) zone between Units A and B has alternate bands of coarse to medium sand and silty clay of 5-10 cm thickness each that are fossiliferous. In contrast to the marine fauna of other basin sediments described above, the fossils of this

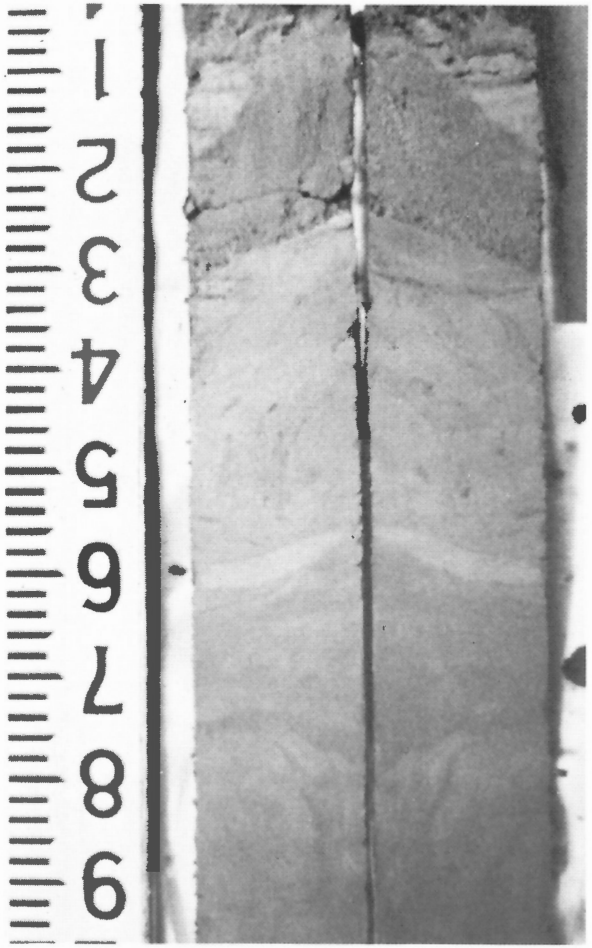


Figure 19. Distorted lamination in Unit IV. Some strata above and below the silty clay lens (light band at 1.6 on scale) are completely distorted to near-vertical. The sand layer at 1.2 to 1.3 on scale is probably in place and not due to drilling disturbance. GSC 203621-X

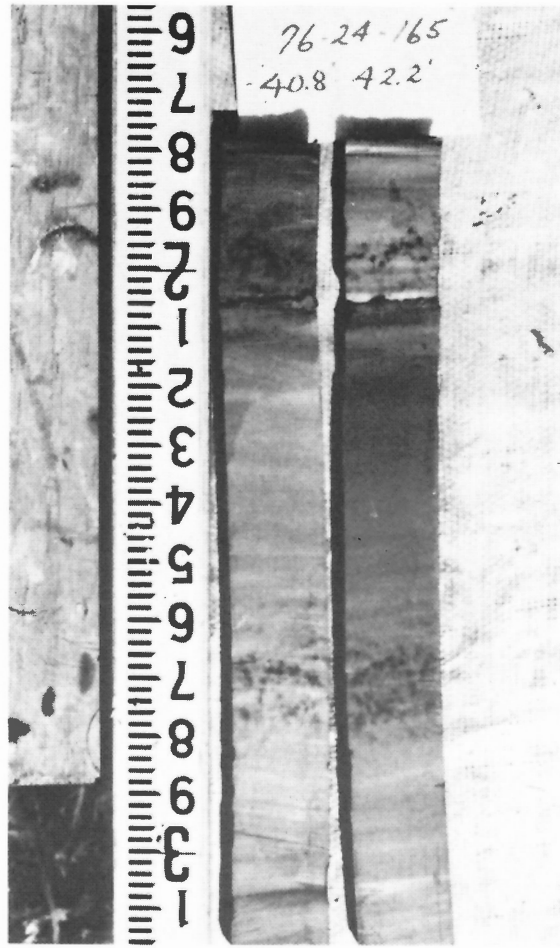


Figure 20. Black mottling by sulphurous material in coarse grained (lighter coloured) subfacies of Unit IV. GSC 203621-G

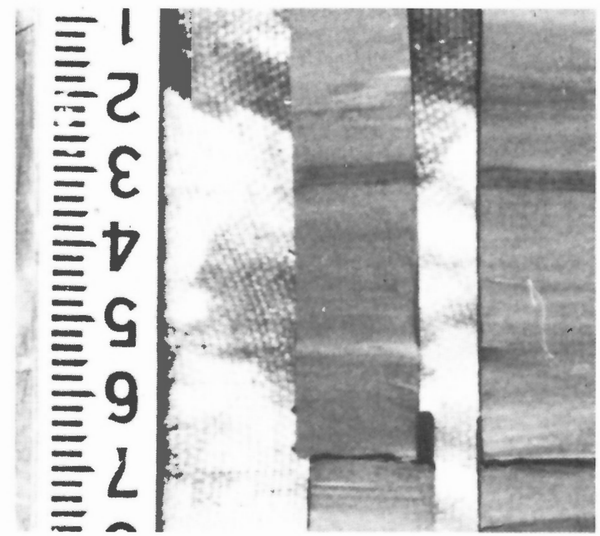


Figure 21. Black bands in Unit IV. The black zone at 1.3 on the scale comprises three distinct thin and very closely spaced black bands. GSC 203621-F

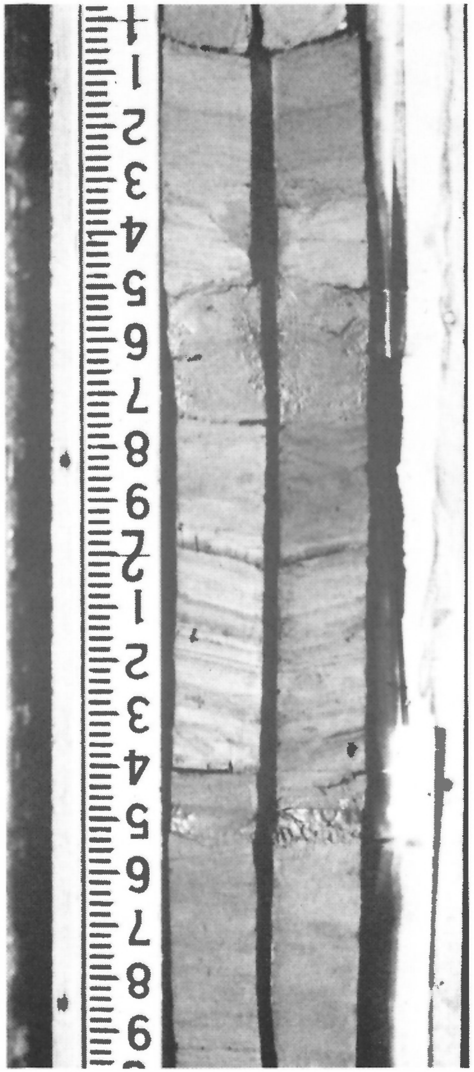


Figure 22. Interbedded sand and silt strata of Unit V showing unsorted sand layer at 2.5 on scale; distorted silty sand at 1.8 to 1.95; cut-and-fill erosional truncation at 1.3 to 1.4. GSC 203621-I

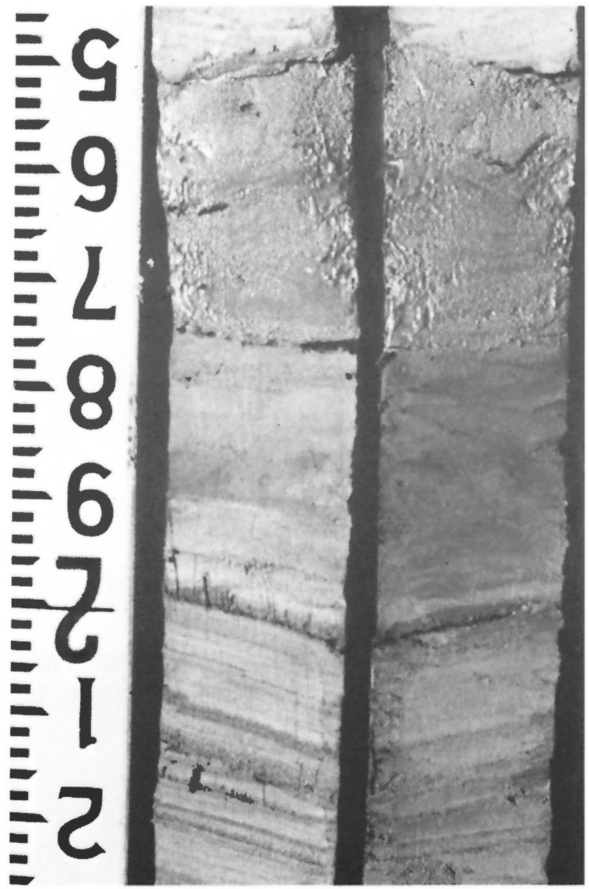


Figure 23. Close-up detail of part of Figure 22 showing rhythmically thin bedded sand and silt strata overlain in turn by a zone of distorted lamination of the same materials (1.74 to 1.94) and an unsorted layer of mainly sand (1.5 to 1.74). Note the irregular contacts above and below these layers of disturbed sediment. GSC 203621-H

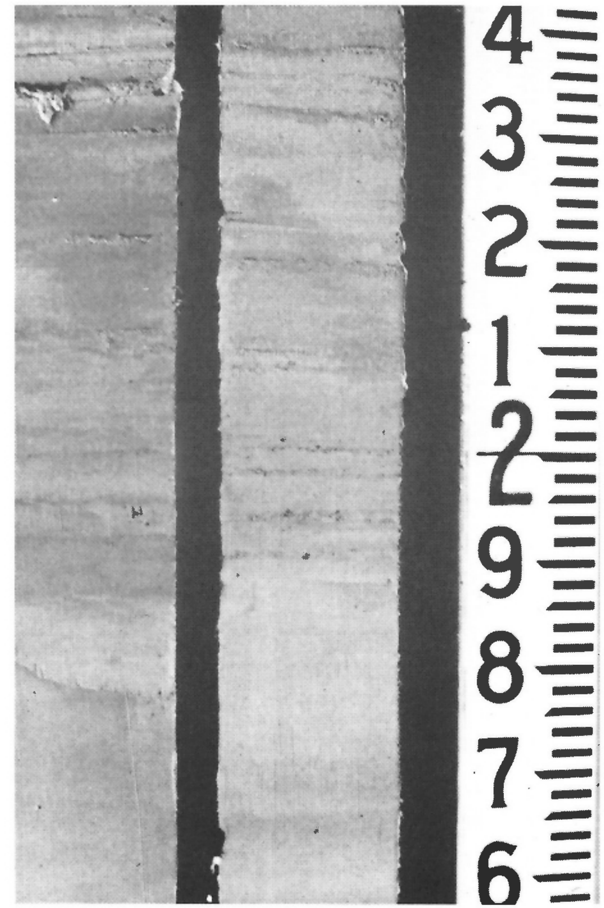


Figure 24. Regular, horizontally bedded sandy silt with thin sandy partings, typical of Unit V. GSC 203621-K

interstratified Unit A-B at Bourget, Ontario, are freshwater clams, **Lampsilis** sp. (identified by A.H. Clarke, Jr.). Examination of samples for other fossil remains such as ostracods and diatoms has been unsuccessful. Radiocarbon dating of the **Lampsilis** sp. shells gives a probable maximum age of 10 200 ± 90 BP (GSC-1968; Lowdon and Blake, 1976, p. 6) for the time of deposition of the sediment in which they occur.

PROBABLE CORRELATIONS OF LITHOFACIES OF THE OTTAWA BASIN

It is clear from the limited study reported here that basin sediments of Ottawa valley have consistent and significant grain-size variation on both horizontal and vertical axes. On the horizontal axis, there is a general decrease in grain size from the margins towards the centre of the basin. On the vertical axis a pattern of increase upwards in grain size of relatively fine grained facies of sediment has superposed on it a suite of sedimentary structures that reflect an increase upwards in strength of current activity. These are the basic elements of criteria used to subdivide the sediments into lithofacies. Where these elements are found in continuous sequence in a single boring, subdivision into specific lithofacies is relatively simple, even though the choice of boundaries between facies is somewhat arbitrary because of broadly gradational contacts and interfingering relationships. Some borings apparently lack parts of the suite and these breaks have been explained either by the erosional history at a particular site, by the position of the site within the basin relative to source of sediment, or by an assumed relationship to the position of the ice margin during the deposition of basin sediments. In addition, the spacing of samples (as much as 6 m in deeper borings) may have resulted in critical sections being missed from the core records. The one boring that was cored continuously (CRF-21A), however, gives good reference control for the basin, and is therefore placed in both correlation diagrams (Fig. 28, 29).

The classification used in this paper for some of the sedimentary units and/or facies may be rather arbitrary. Although the following interpretation and correlation diagrams are subject to change as a result of further detailed study of the region, nonetheless, the scheme of correlations presented in Figures 28 and 29 and is thought to be consistent with observations. Some alternative interpretations are indicated in a few of the diagrams.

Figure 28 shows the interpretation of the stratigraphic section in 11 borings made along the east-west axis between the localities of Sheenboro and Fassett (Fig. 1), a distance of 200 km; Figure 29 depicts stratigraphy of 8 borings in a north-south direction between Venosta and Casselman (Fig. 1), a distance of approximately 95 km, one of the borings (CRF-21A) being common.

In Figure 28 it is noted that units V, IV, II have sandy facies in the four more westerly borings. Unit III has been identified as a thin unit in only one of these borings (Westmeath).

Borings at Wendover, Ontario (75-4 and 75-5; Fig. 28), show identical sections, i.e., Unit IV over Unit I at the top and base of a bedrock escarpment (presumably exhumed). Intervening units known in adjacent sections are absent here; this is assumed to be the result of erosion before and during deposition of Unit IV (see *Discussion*).

Units A (sand facies), B (clay-silt facies), and A-B (interstratifications of A and B), which as a group are thought to be fluvial units, in many sections show a normal

Figure 25. Sandy subfacies of Unit V from the western limit of the basin, showing cyclic alternation of thick sand strata grading upwards into thin red (dark bands) silty clay layers. GSC 203621-L

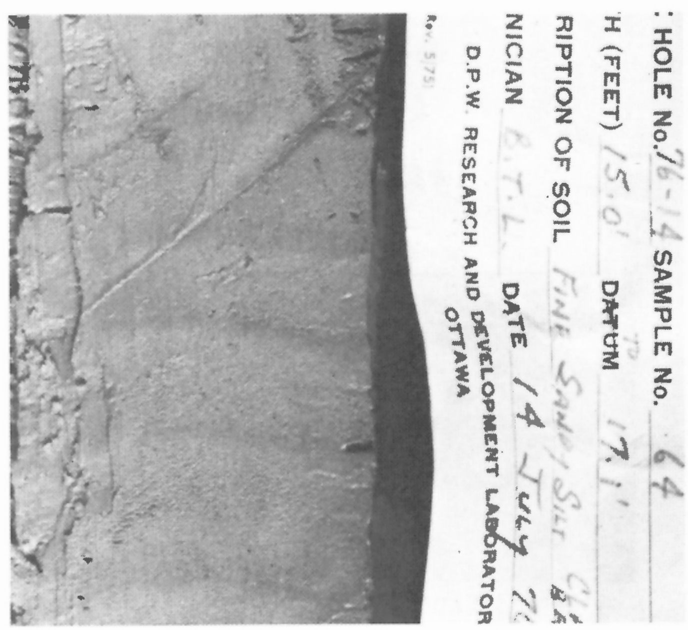


Figure 26. Close-up detail of Figure 25 showing cyclic sand-silt laminations of Unit V; darker bands are silt. GSC 203621-M

gradational contact relationship with Unit V, uppermost of the marine deltaic units. In a number of sections (e.g., Fig. 28, Plaisance and Fassett), the contact with the underlying sediments is clearly erosional.

Unit II is observed in all borings with the exception of those occurring in areas where local highs in the bedrock surface apparently have caused nondepositional sites (e.g., Hammond, Davidson's Corners, Fig. 29) or where erosion of older sediments may have taken place during the deposition of younger ones (e.g., Wendover, Fig. 28).

DISCUSSION

Unit I

The apparent absence of till in many measured sections may relate to the fact that the borings were made along the axes of two major valleys, both of which may have carried large volumes of meltwater during downwasting of the ice sheet. In these valleys, therefore, a high probability exists that till may have been eroded from bedrock surfaces by meltwater streams before deposition of fine sediment in the same area, i.e., at a later time when low current velocities and quieter conditions prevailed in that part of the basin.

Unit II

Unit II (varves) was identified by Antevs (1925) as a deposit of glacial Lake Frontenac; this was described as a pre-Champlain Sea freshwater body of unknown dimensions that was said to predate an early eustatic change of

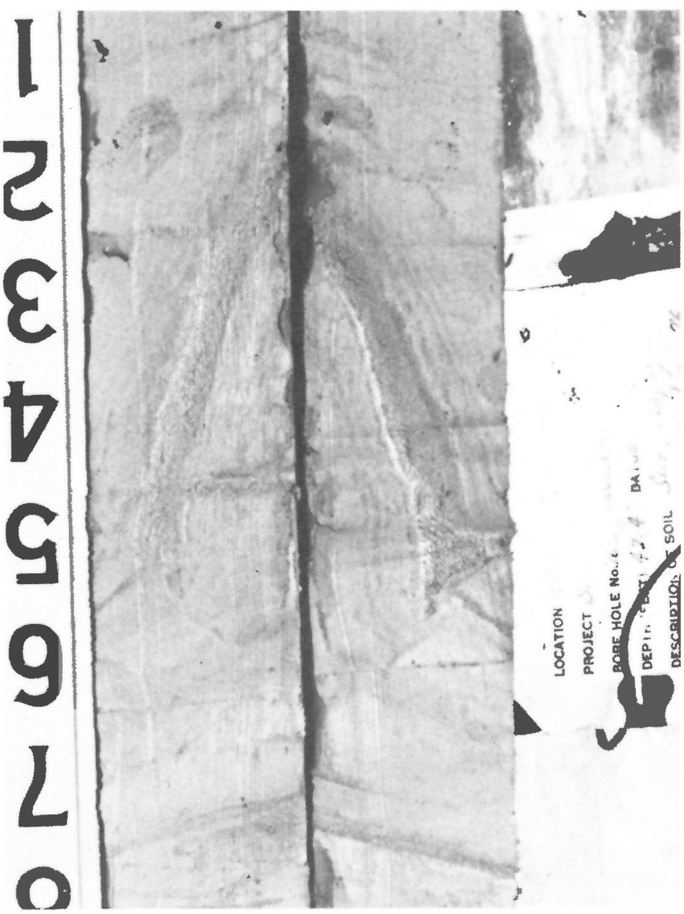


Figure 27. Distorted sediments of units A and B with large sand lens (dark area in centre) in near-vertical position, probably due to slump. GSC 203621-W

sea level. In Antevs' interpretation, the Champlain Sea postdates the opening of Ottawa valley and the existence of a free drainage system between glacial Great Lakes and Ottawa-St. Lawrence valleys. This system would have had to exist prior to the Champlain Sea in a position above the then sea level, or separated from the sea by an ice barier.

Records from exposures in the Ottawa area clearly show a gradational relationship between till (Unit I) and varves (Unit II) (Fig. 5). Equally clear in Figure 5 is the gradational relationship between the varves (Unit II) and the relatively massive and fossiliferous marine clay (Unit III, massive subfacies). The transition occurs over a relatively small vertical distance and therefore the time interval is assumed to have been short. Although Antevs' descriptions and interpretations favoured separate glacial and glaciolacustrine (Lake Frontenac) events followed by marine invasion (Champlain Sea), I would not think of the events as separate. On the contrary, the gradational relationships indicate a continuity of sedimentation, presumably in one basin, and a rapid and gradational transition from glaciolacustrine or glaciomarine to marine conditions.

The glaciomarine transition observed at the centre of the study basin constitutes an interstratified till – flow till – varved clay suite, whereas borings made for this study reveal that proximal varves of gravel and sand occupy the western and northern margins of the basin. This might suggest that the ice retreated rapidly from the central part of the basin but remained for some time in contact with the western and northern limits of the basin. Such a relationship might suggest that ice calved from the centre of the basin and from its tributary valleys. In such an interpretation, a glacial lake, as such, may never have existed; instead there may have been a (estuarine?) part of a larger marine basin that had relatively short-term glaciolacustrine and glaciomarine conditions imposed upon it during persistence of glacier ice in nearby highlands.

The presence in a few places of shells and shell fragments in apparently varved material may indicate that conditions under which the varves formed were not strictly freshwater conditions. Antevs (1925), for example, wrote of 'marine varves'. Rather than a separate freshwater lake, the barren to sparsely fossiliferous varves may represent essentially glacial conditions near the ice margin in the marine basin before depth and salinity reached their maxima. No faunal evidence is yet available to allow a decision as to whether these glacially controlled conditions were in fresh water or salt water[1].

Unsorted beds in coarse sediment suites – e.g. gravel and sand facies of proximal varves – were observed only rarely because of the relative infrequency with which coarse material is recovered by Shelby tube sampling and because of the wide spacing of cores in coarse materials. It is reasonable to assume that the unsorted beds may be observed more commonly in exposed sections than they have been observed from borings.

The seemingly normal varves at the centre of the basin are the earliest post-last-glacial sediment. These would seem to indicate relatively uniform and slow melting of the ice. However, coarse proximal sediments at the western and northern margins of the basin, containing as they do unsorted beds related to slumping or to turbid flow, suggest a rapid, high volume discharge of meltwater. A rapid change from thinly varved to massive marine beds probably indicates a rapid change in sedimentation rate at the centre of the basin. These events, therefore, possibly may correlate in time. However, the thin varves found in section at the centre of the basin may represent a time during breakup and removal of ice from the central part of the basin, say by calving, or under ice-shelf conditions, before the ice sheet meltwater

[1] C.G. Rodrigues, University of Windsor (personal communication, 1984) indicates the existence of a freshwater fauna in these rhythmites.

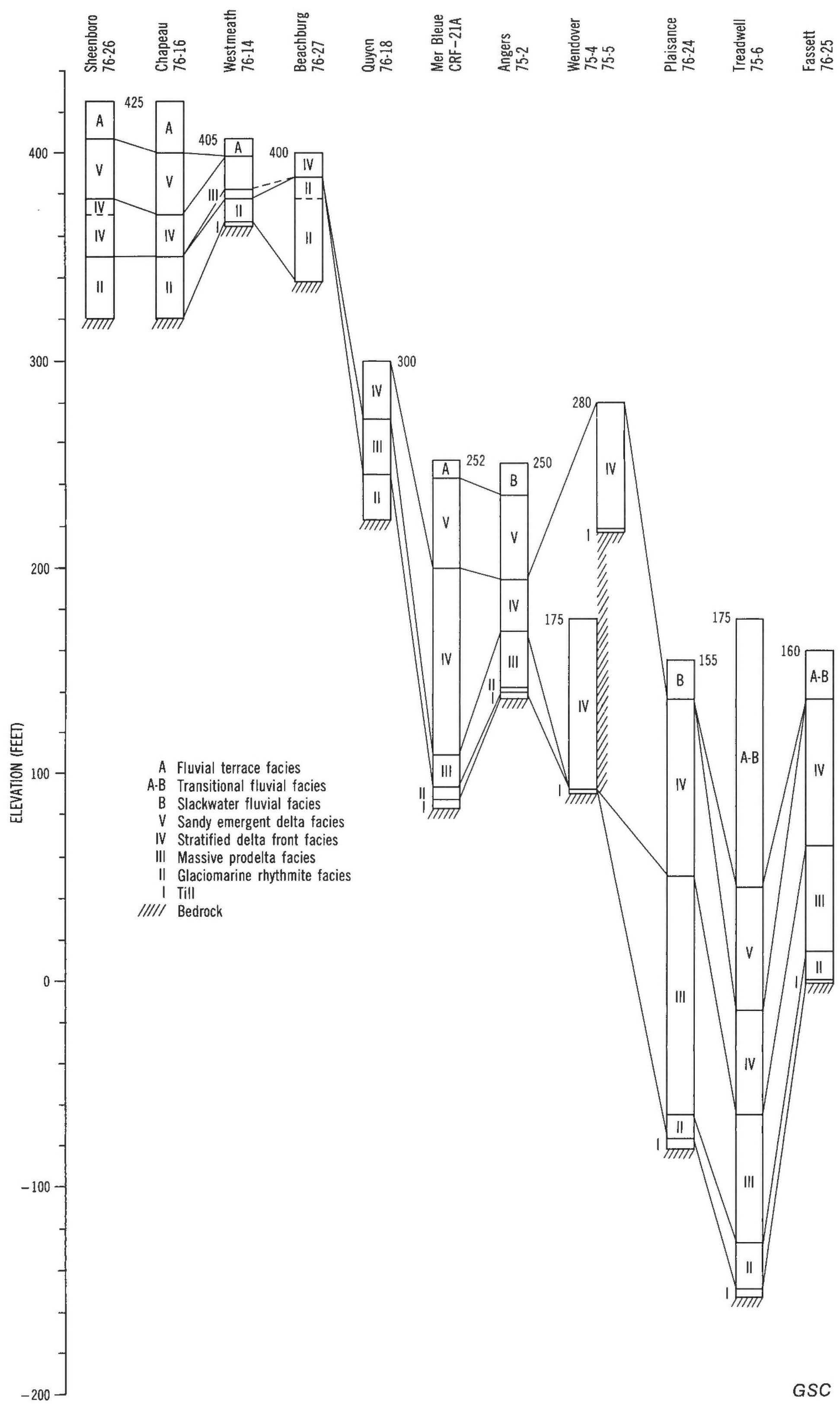


Figure 28. Correlation chart for stratigraphic borings on an east-west axis of the Ottawa basin of the Champlain Sea; horizontal distances are not to scale. Borings are identified by locality and driller's record number (year-boring number). See Figure 1 for location of boreholes.

system became re-organized and concentrated in the margins of the newly opened basin, or before the maximum of melting rate came into effect locally. In a relatively short time (30 to 50 varve years) both salinity and sedimentation rate had increased to the extent that the typical deep-basin sediment became massive silty clay with indistinct to thick bedded stratification of a rapidly accumulated high silt sediment at a time when glacier ice possibly still was at the northern and western limits of the basin.

Unit III

An association, such as that suggested above, between high volume flow indicated by coarse proximal varves and the massive silty clay explains the apparent correspondence in the type of sediment, but does not necessarily accord with the fact that the more massive facies of Unit III is the most abundantly fossiliferous of the marine sediments. Therefore some attention must be paid in future paleontological studies to the question of whether the species present are those that would tolerate a high rate of deposition of silt-sized sediment.

Similar reasoning can be applied to the second subfacies of Unit III. Regularly stratified, cyclically laminated, horizontally bedded, fossiliferous sediment has been classified by Fransham and Gadd (1977) as "prodelta clay" in contrast to the massive facies they called "deep-water marine clay". They treated the facies as separate units. In the present report the massive and the regularly stratified sediments are identified as subfacies of a single deep-water environment, equivalent of the low energy "shelf" and/or "prodelta" environments of Coleman and Gagliano (1965). Although the bedded strata have higher clay content than the massive strata (Fransham and Gadd, 1977), and although this has considerable influence on the geotechnical properties of the sediments (Fransham, 1980), the two may be considered as facies that are a function of supply rather than of a change of depositional environment. Consider that when a higher content of clay-sized material is recorded in a given volume of sediment than in another, it is in fact a clay content percentage relative to (basically) the other dominant grain size – the silt – that is recorded. Thus these two subfacies may be considered as high silt (massive) and low silt (laminated) facies rather than low clay content (massive) and high clay content (laminated) facies. The difference in sedimentary texture and structure may be simply a function of the supply of silt reaching the basin. We may also consider that the relatively thinner strata of the regularly bedded subfacies represent an overall lower sedimentation rate.

Both a lower sedimentation rate and a lower relative amount of coarse sediment may reflect retreat of the ice margin from the immediate margins of the basin; also it may reflect a diversion of a large amount of sediment, mainly silt, into other lake basins above the marine limit. For example, such areas as upper Ottawa valley near Sheenboro and Deep River (Gadd, 1963b) and Gatineau valley near Gracefield, Quebec (Gadd, 1971, unpublished field data) contain lacustrine silt and were, therefore, available as silt reservoirs. Both these areas had temporary morainic barriers between them and the Ottawa basin of the Champlain Sea. Also available as silt traps, farther up-glacier, were the major glacial lake systems like glacial Lake Barlow-Ojibway (Antevs, 1925).

Neither relatively massive nor clearly stratified subfacies of Unit III show sedimentary structures other than cyclic lamination and textural grading of sediments. Therefore they are here assigned to the "shelf" and "prodelta" environments, identified for the Mississippi Delta where they are "characterized by monotonous repetition of a few types" of structure (Coleman and Gagliano, 1965, p. 148). Fairly

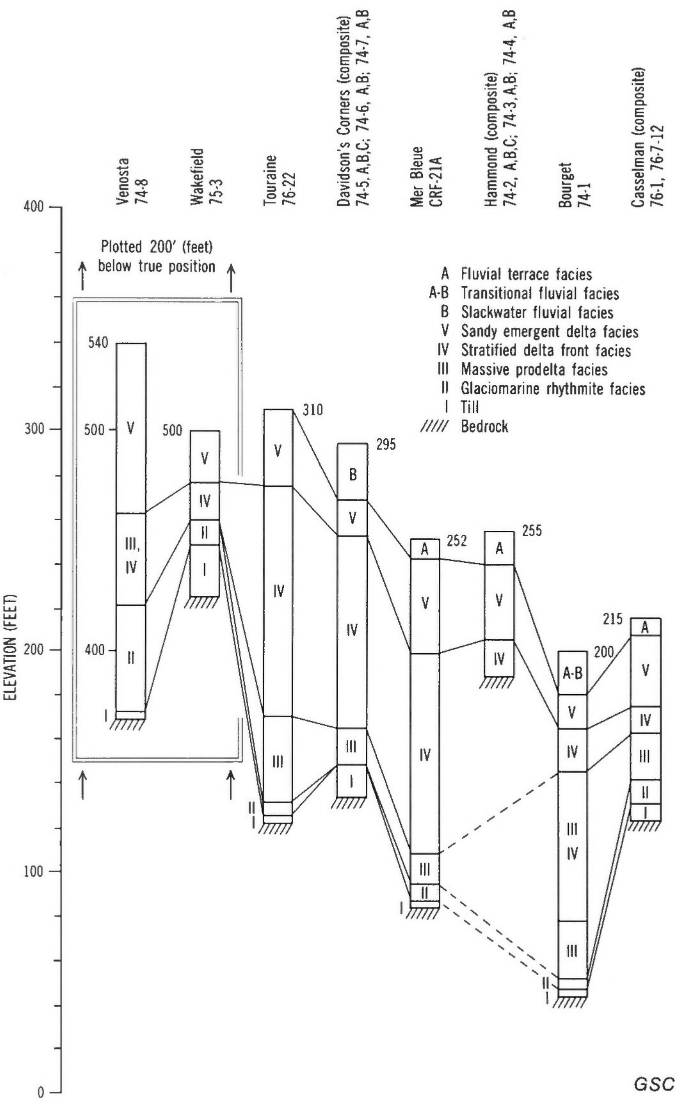


Figure 29. Correlation chart for stratigraphic borings on a north-south axis of the Ottawa basin of the Champlain Sea; horizontal distances not to scale. Borings are identified by location and driller's record number (year-boring number). See Figure 1 for location of boreholes.

regular cyclic repetition of strata and fining-upwards gradation of texture in individual couplets suggests a seasonal influence on sedimentation. It is considered most probable that cyclicity was enhanced by seasonal melting of nearby glaciers. Much of what is recorded in this report as stratified marine sediment may have been observed, in part, by Antevs (1925) and probably would have been classified by him as marine varves or as symminct varves. Whereas the Antevs classification of marine varves suggests the near presence of ice, if not retreats and readvances of the ice margins during much of Champlain Sea time, the stratigraphic sequence of apparently true varves (Unit II), followed in turn by the two facies of Unit III, is interpreted here to represent progressive retreat of ice from Ottawa valley during early deep-water stages of marine submergence.

Units IV and V

These units, on the basis of their different lithologies, represent different energy levels of currents in a single environment. Unit IV, the lower and older unit, is basically clayey silt with minor sand, and Unit V, the upper unit, is basically silty sand with minor clay. Commonly they are found in conformable contact with underlying Unit III which grades upward, in turn, into units IV and V. In places this appears as a suite representing continuous deposition, with the sediment coarsening upwards. This is considered to be a typical offlap suite (Gadd, 1977). One of the special characteristics of these younger units, however, is the occurrence of erosional contacts between these units at some places, as well as between them and other older units. This erosional relationship indicates deposition of these units following fairly extensive channel erosion.

Units IV and V occur as broad, flat, tabular bodies of regional extent within the marine basin. This feature has been demonstrated in previous mapping projects; in these reports the sand facies (more common at the surface than clay facies) is referred to variously as a littoral facies of Champlain Sea deposits and estuarine deposits (Richard et al., 1977) or as high terrace sand (Gadd, 1971). These deposits, though in places several kilometres wide in both Ottawa and St. Lawrence valleys, are laminated and crossbedded by current action, but lack the defined channels, levees, bars, spits, and other features of the younger but similar units A and B. The sediments, therefore, appear to have been deposited and reworked in a large, flat-lying water body with significant currents, probably in an estuary rather than in a graded fluvial system. Deposition apparently was essentially subaqueous rather than partially or intermittently emergent.

Increases upwards in section of the frequency of minor erosional features and in the grain size of materials indicate that currents active during deposition of the units were increasing in capacity through time. Increasing frequency of occurrence of mass flow and turbidity features shows that mass wastage in the vicinity of streams was increasing through time. These are characteristics similar to those described by Coleman and Gagliano (1965) for the environments of the subaqueous delta and delta front of the Mississippi Delta in the United States. As in the Mississippi example, these deposits exhibit the greatest variety and number of sedimentary structures, and reflect environments where relatively strong currents, rapid deposition, and abrupt facies changes are the norm.

Extension of these units typical of a subaqueous delta over extremely large regions, however, distinguishes them in size from the relatively limited areal extent of such sediments in the Mississippi Delta. Because the entire suite of Champlain Sea sediments was deposited over a relatively shorter period of time than was that of the Mississippi Delta, the extent of these units must depend on local factors. Principal of these must be rapid isostatic uplift of Ottawa valley which would have cause the environments to prograde seaward at a very rapid rate. Another factor is the existence of a major source of supply of coarse sediment, that is, the Laurentide ice mass lying near Ottawa valley. Finally, the Champlain Sea basin itself is a source in which great tracts of sediment were progressively exposed to erosion during uplift.

Where fossils are present, units IV and V may be clearly identified as Champlain Sea marine sediments.

Units A and B

The linear form of these deposits is known from earlier work (Gadd, 1963a, 1976a). Typically the deposits occur in channels limited by erosional scarps and have linear bars, streamlined "islands", and point bars. Occurrences of terrace-margin minor sand levees, also known to occur in Unit A both in Ottawa valley and in the central St. Lawrence Lowland region (Gadd, 1971), suggest overbank flooding of proto-Ottawa River floodplains and terraces. It is in this context that coarsening-upward cycles, particularly in the sandy facies (A), have been interpreted above. Interstratification of sand (main channel) and silt-clay (slackwater) facies probably represents migration of principal channels within a floodplain complex.

The freshwater nature of these sediments is confirmed by the occurrence at Bourget, Ontario, of well preserved articulated specimens of **Lampsilis** sp. in a transition zone of interstratified silty (B) and sandy (A) facies of these fluvial sediments.

Comparison with Mississippi River Deltaic Sediments

The foregoing description and discussion, though speculative in large degree, strongly suggests that Ottawa valley Leda Clay strata are similar structurally and sedimentologically to sediments of the modern Mississippi Delta in the United States. The summary table of sedimentary structures in depositional environments of the Mississippi Delta (Coleman and Gagliano, 1965, Table 1, p. 147) lists as dominant (D), abundant (A), common (C), and rare (R) the distribution of 28 categories of structures as they occur in 13 depositional environments and 8 subdivisions. Using only the structures listed as D, A, or C in their table, the following comparison is made:

Ottawa valley (OV) Unit III has four features (of four listed) in common with the combined categories of "shelf" and "prodelta" in their table: thick bedding, parallel lamination (both textural and colour), presence of burrows, shell fragments; scour-and-fill structures and erosional truncations are absent in both.

OV Unit IV has nine features (of nine) in common with "distal bar" and "distributary mouth bar" subdivisions of "delta front": thin to medium bedding, parallel lamination (texture and colour), cross-lamination, current and wave ripple lamination, scour-and-fill structures, erosional truncations, clay inclusions, load casts, distorted laminations (including slump).

OV Unit V has the same nine features listed above in common with the "subaerial levee" category of "delta front" with similar stronger emphasis on current-related phenomena than in the previous grouping.

OV Unit B, has features in common with "mudflat": relatively thin beds, parallel laminations, scour-and-fill structures, and erosional truncations.

The Ottawa valley units, because of the features mentioned above, are identified as the lithofacies of an uplifted delta. The lack of physical form of the delta in Ottawa valley, together with the fact that Ottawa valley units are more extensively superposed, emphasizes fundamental differences between these major depositional environments; the Mississippi, being an active delta with recognizable form and zonal distribution of sediments, represents relatively slow accumulation in a slowly subsiding basin; the extensively superposed strata of Ottawa valley represent a migrant prograding delta formed in a basin undergoing extremely rapid sedimentation and isostatic uplift.

Red Bands

Red clay bands may seem anomalous in materials derived from glacial erosion of mainly Precambrian crystalline rocks, and in an area that during Pleistocene time showed no evidence of a climate significantly warmer than the present north temperate one. Whereas commonly red clays are the product of soil formation under tropical or subtropical conditions, the red clay bands in the Leda Clay must have their origin either in the primary materials available or in their oxidation products. Primary bedrock sources of red colour in the Ottawa-Gatineau valley region are hematite-rich feldspars in some Precambrian granites and red coloration of mineral rock grains and of the matrix of some facies of the Cambro-Ordovician Potsdam (Nepean) sandstone. However, when these are combined with most glacial and nonglacial sediments, along with commonly abundant primary iron minerals such as magnetite, ilmenite and pyrite, they produce sediments of various shades of grey. When grey glacial and nonglacial sediments are separated in the sedimentation laboratory during grain-size analysis, the clay-colloid fraction is most commonly red. Because the clay fraction is the preferred size mode for red iron oxide in glacial sediments of Canadian Shield areas (Shilts, 1978a, b, 1979, and personal communication, 1980), the principal source of the red colour may be red iron oxide, and size sorting may be the principal factor in producing red-coloured clay bands in these sediments. But not all clay-rich strata in Leda Clay are red, and therefore size sorting alone does not seem to explain fully the occurrence of red bands in sediments of the Ottawa basin of the Champlain Sea.

In the sedimentary sequences described in this report, the amount and intensity of red coloration appears to increase progressively towards the centre of the basin and progressively upwards in the suite of sediments; the former is probably a function of size gradation over distance, and the latter is probably primarily a function of grain size gradation with time. Continued oxidation of sediment and (because of uplift) the increasing areas of sediment exposed to oxidation through time are additional factors that may explain some aspects of distribution of the red clay bands. Hence, red is a common to dominant colour in fluvial terrace sediments (Unit B) and less common in older units.

Cyclic alternation of red clay bands with grey silt or silty clay bands is a common characteristic of the sediments described; whether or not directly or indirectly related to glacial melt cycles, it appears to be seasonal or episodic. It is assumed that much coarse sediment is mobilized during seasons of maximum melt and rainfall (frost-free spring-summer season), producing a grey sedimentary layer, and little coarse sediment is produced during seasons of minimum melt and rainfall (freeze-up or fall-winter season), resulting in a red clay layer. I believe that the red colour is associated with clay-sized particles in all of the sediments, but that the colour is masked by the grey colour of larger sized grains if these are present. Oxidation in situ in the marine basin is unlikely under "winter" conditions, and postmarine oxidation due to groundwater flow should occur preferentially in the coarser sediments; therefore, these alternatives to sedimentological separation of the red fine material are not considered further here.

In addition to the above mentioned observations by Shilts (1978a, b, 1979, personal communication, 1980), other studies of the mineralogy of Leda Clay based on borings made near Hawkesbury, Ontario, in Ottawa valley (Haynes and Quigley, 1976) indicate that "differences in mineralogical composition were observed between gray and brown bands of soil". (It is assumed here that their "brown" bands are identical with "red" and "reddish brown" clays of this report.) Haynes and Quigley (1976, their Fig. 25) found further that the amorphous material fraction of Leda Clay samples contained SiO_2, Al_2O_3, and Fe_2O_3 in nearly equal amounts, each being 25 to 33% of the total amorphous material. Their report does not make it clear whether iron present in the sediments actually existed in the form of red iron oxide (Fe_2O_3) in red (brown) soils, but the figures apply to both red and grey clay sediments. The colour alone indicates that red iron oxide may be present in the sediment.

Clay strata in the younger sediments are dominantly red. But, recalling that the sedimentary suite is known to coarsen upwards, one would expect the red colour to be masked, as suggested above. Therefore, the distribution of red colour in the sedimentary suite, that is, the appearance early (during near-ice conditions) and late (during emergent delta and offlap conditions) in the sedimentary sequence and rapid increase in red coloration near the end of the sequence, must depend on supply of the red oxide form of iron to the basin, and not simply on concentration by grain size sorting.

Recent work on sediments of the Mediterranean basin (e.g., Butzger, 1963, 1964; Ryan, 1972) indicates that the source of red clay during interglacial intervals is mainly due to erosion of soil profiles on land surfaces and of nearshore sediments. Although no direct parallel may be drawn for the Ottawa valley region, it may be suggested that the soils of the interval that preceded the last glaciation produced iron oxides that were picked up during the last glaciation and released early in the first sediments of the near-ice and prodelta basin. In the same sequence, weathering products would later be much diluted by fresh rock flour from unweathered rock and soil, hence a lower incidence or absence of red colour would occur in the clay strata. Offlap conditions, however, would involve two factors: 1) reworking of glacial sediments on land and nearshore sediments in the basin and 2) oxidation of increasingly large areas of fine grained sediment with a relatively high hematite and iron content (in various forms) as more extensive areas of seabottom were exposed to soil formation. Thus the occurrence of red clay bands in varves and earliest deposited stratified marine sediments of the prodelta environment, a lessening or absence of red colour in more massive prodelta and delta foreset sediments, and a reappearance of red in the clays of the upper delta and the particular abundance in the fluvial units occupying channels in the uplifted marine strata may all primarily reflect the availability of oxides generated by soil formation. Reworking and refinement of sorting of older sediments, which would concentrate clay-sized materials, appear to be secondary factors controlling distribution of the red colour in the Leda Clay sediments of the Ottawa basin of the Champlain Sea.

Black Sediment Phenomena

Black bands, mottling, and general dissemination of black colour in several facies of sediment of the Ottawa basin are described from field observations only. On this basis I disagree with numerous earlier descriptions that refer to 'organic' sediments, or to sediments having 'disseminated organic matter', because no organic matter is clearly identifiable visually. In addition, the observed black material is commonly accompanied by a predominantly sulphurous odour and the black colour rapidly disappears on exposure to dry air or is transformed to yellow-orange ochrous substances in the presence of abundant moisture. On application of field strength HCl (10%), the black sediment commonly effervesces and emits the pungent odour of H_2S (and possibly also SO_2) and the reaction is accompanied by some loss of black colour. In short, the field observations would indicate that the black coloration of Leda Clay is due primarily to the presence of unstable sulphurous compounds of iron; this is in addition to pyrite which is commonly present as crystals, nodules, tubules, and as encrustations and fillings or replacements in fossils, but which does not react vigorously with dilute acid.

Thus, although the lithofacies suite observed and described above is similar to that of the modern Mississippi Delta described by Coleman and Gagliano (1965), the organic sediment or sapropel element common to the Mississippi

(Coleman and Gagliano, 1965) and African Nile (Maldonado and Stanley, 1975, 1976) deltas is lacking in the Ottawa basin. This is likely because little organic matter was available to the late glacial Champlain Sea basin.

Research into the chemistry of sulphide-bearing sediments from cores of unconsolidated sediment in the Black Sea (Berner, 1974, p. 527) indicates that monosulphides of iron "normally disappear during early diagenesis as a result of being transformed to pyrite" in the presence of elemental sulphur derived by microbial action on the sulphates of normally saline sea water. Berner (1974, p. 527) added "Thus, the basic problem is why these unstable black minerals persist to depths of several meters in Black Sea sediments representing time spans of more than 10,000 years. The most probable reason is that insufficient elemental sulfur was present during early diagenesis to accomplish complete transformation to pyrite." Where the pyritization takes place "the sediments are gray, high in pyrite, and low in monosulfides." In further discussion Berner (1974, p. 529) recognized that in glacial times "organic matter was sufficiently scarce to limit sulfate reduction severely" and also that it is reasonable to assume that sulphate concentrations were low during the last late Pleistocene glaciation because of the flushing action of incoming freshwater from glacial meltwater sources. Under the conditions of low salinity, low sulphate concentrations, and low organic content of the sediments, unstable monosulphides were preserved as black sediment. These black layers were buried and further protected from transformation to pyrite by rapid deposition of coarser materials, especially so, it seems, in a system where rhythmic variation of rates of deposition occurs. These conditions in the Black Sea at the time of deposition of the black sediments (15 000 BP with sedimentation rate $\geq$ 10 cm/1000 years) were ideal for the preservation of the black unstable sulphides.

Berner (1981, p. 262) later extended these concepts and stated that in normal marine conditions, in which both dissolved sulphate and organic matter are abundant, "sulfidic conditions" prevail under which the "first formed minerals produced by the reaction of hydrogen sulfide with detrital iron minerals are not pyrite and marcasite but instead a number of monosulfide phases .... in the presence of excess H_2S (sulfidic environment) these minerals are unstable and, ultimately, are transformed to pyrite with depth and addition of sulfur .... However, if nonsulfidic conditions are attained via the exhaustion of all sulfate and sulfide,.... the monosulfides, due to lack of additional sulfur, can persist metastably for long periods of time."

It appears that unstable iron-suphur compounds have been preserved in Leda Clay and that conditions (sulphidic) for formation of pyrite have not occurred on a broad scale; therefore it is suggested here that deeper parts of the model basin had low salinity and low organic matter content under glaciomarine conditions. Such factors are believed to have produced 'anoxic-nonsulphidic' environments in which unstable minerals, here assumed to be iron monosulphides, have been preserved until exposure to air by either natural or artificial means.

No chemical analyses have been made to compare the sulphide content of the black facies of Leda Clay with that of the Black Sea and, of course, this needs to be done. I am convinced on the basis of more or less circumstantial evidence, however, that the two must have similar sulphide mineralogy. Several of the parameters that Berner (1974) used to explain the preservation of monosulphides in Pleistocene sediments of the Black Sea are discussed below as they apply to the Ottawa valley basin of the Champlain Sea under subheadings: *Salinity*, *Organic sediment*, *Sedimentation rate*, *Sulphides*:

Salinity. Based on detailed analysis of paleontologic evidence from her own work and that of others, Wagner (1970, p. 13) stated that: "Waters of Champlain Sea were probably not truly marine anywhere, and the salinity was certainly variable, being lower on the restricted extremities of the sea where influx of fresh water had a marked effect".

The Ottawa basin of the Champlain Sea is a specific example of one of the "restricted extremities", being narrow, possibly a reentrant in the Laurentide Ice Sheet, and always recipient of a major part of the meltwater from the Laurentide Ice Sheet during at least the first half of the existence of Champlain Sea there. Thus salinity and presumably sulphate content of the Ottawa basin of the Champlain Sea were lowered by the diluting influx of glacial meltwater.

Organic sediment. According to Mott and Farley-Gill (1980), forestation of highland areas of Gatineau Park, on the interfluve between Ottawa and Gatineau rivers, had barely begun 10 700 years ago, prior to which vegetation was dominated by grasses and sedges; lowland areas were submerged at this time. Thus during almost the entire time span of the Champlain Sea in the Ottawa basin, terrestrial vegetation was minimal and could, therefore, contribute limited amounts of organic matter to the marine basin. Accumulation of organic matter in even today's soils in the region is limited and probably was sparse during Champlain Sea time; the product of soil erosion would have been correspondingly low in organic matter. The fact that none of the borings and sections recorded here or otherwise known to the author has revealed an organic stratum, or sapropel, within the Leda Clay suite, supports this assumption.

Sedimentation rate. Ottawa basin was the site of rapid sedimentation during the 2000-2500-year span of Champlain Sea time. The greatest measured thickness of sediment in the basin is at the Treadwell site where in excess of 100 m has been measured. The rate of sedimentation represented is approximately 35-50 m/1000 years and this must be considered a minimum because there may be an erosional hiatus in the Treadwell section. The rate is far in excess of that for the Black Sea (>10 cm/1000 years) calculated by Berner (1974).

Sulphides. In addition, because the Ottawa basin lies at the southern margin of the Laurentian Shield of Precambrian rocks, iron and sulphide minerals are abundant in the basin sediments. Pyrite, magnetite, ilmenite, hematite, among other iron and sulphide minerals, are common accessories of the source rocks of regional glacial sediments. Through mechanical sorting, these minerals were concentrated in the finer fractions of sediments deposited in the Champlain Sea.

The origin of unstable sulphides or monosulphides in Leda Clay is an open question that perhaps permits one further line of speculation; it is not clear from the Berner (1974, p. 529-30) report whether the black monosulphides are considered to be primary sedimentary elements, or whether they have formed in situ under anaerobic conditions; perhaps both are valid. On the one hand, in low concentrations of elemental sulphur "the depositional rate could have dictated whether black sediment was preserved", the preservation being enhanced by rapid sedimentation. On the other hand, diagenetic exchange between black and grey layers of sediment may have led "to the migration of Fe^{+2} and H_2S, and to the formation of iron sulfide Liesegang banding (Berner, 1969). Some of the thin, sharply defined black layers .... may have formed, at least partly, in this manner." There seems to be a parallel between black banding in Leda Clay and that in Black Sea sediments. Where rhythmic alternation of fine grained black bands and coarser grained grey bands appears to be in a varve-like sedimentary relationship, the black bands may represent primary deposition of unstable sulphides in times of low inflow into the basin; these were protected from complete pyritization by later rapid sedimentation of the coarser grey sediment, during heavier inflow. Berner (1981) indicated that preservation of black monosulphides is enhanced in the low sulphur conditions of the glaciomarine environment; cyclic stratification of black and grey bands of fine and coarse sediment also appears to be a product of glacial melt cycles. However, very short-term repetition of black bands without apparent change in granulometry, such as that illustrated in Figure 21 where three millimetric black bands occur in less than 1 cm of uniform sediment, may possibly represent the diagenetic chemical migration phenomenon.

Black Banding in Red Clay

Red clay strata in Leda Clay, whose colour apparently depends on the preservation of iron oxides (mainly hematite), in places contain black bands, whose colour depends on the preservation of unstable monosulphides of iron; such relationships are represented in Figures 13 and 16. Their interstratification might suggest rapid changes in the environment of the marine basin from oxidizing to reducing conditions and reverse, but mechanisms for such rapid change are not obvious. No granulometric or structural clues seem to be available. It has been suggested above that red banding occurs in the basin sediments mainly as a result of availability to distributary systems of oxidized materials from land surfaces and exposed basin sediments. Preservation of oxidized sedimentary granules in a marine basin suggests that the seabottom at the time was an aerated and oxidizing environment. The presence of black bands in similar sediment and in apparently continuous strata, however, suggests rapid, short-term change to anaerobic and reducing conditions.

The explanation of this seeming enigma may possibly be in the fact that the sediments involved were not deposited in a quiescent basin remote from fluvial current action, but rather were deposited in a prodelta and delta-front environment, where currents were constantly changing in response to the melting of adjacent glacial ice masses and where sedimentation rates were very high. Thus it is conceivable that variations in direction and volume of flow of distributaries of the deltaic system might rapidly vary the state of chemical equilibrium of the basin floor between the extreme of freshwater oxidizing and brackish-water reducing conditions, without any significant change in the granulometry or structure of the sediment. Rates of sedimentation might be expected to vary locally depending directly on localized supply. Because of the extremely high sedimentation rate estimated for Leda Clay (35-50 m/1000 years), preservation of material in any initial state might be expected to occur readily; thus both oxidized (red) and reduced (black) sediments may be expected to be preserved in the Ottawa basin of the Champlain Sea regardless of the oxidation/reduction state of the basin as a whole.

Diagenetic migration of iron and hydrogen sulphide in the manner discussed by Berner (1974, 1969) and suggested for some thin black bands in the preceding section of this report is a further possible explanation.

Black banding does not appear to be present in red clay strata of Unit B. If, as postulated above, Unit B is an essentially freshwater, slackwater channel sediment, it should have been deposited in the most highly aerated, oxidizing environment of the entire suite. In such an environment, of course, sulphidic black bands could not persist. Older sediments of units II and III, which do have sulphidic black bands, even interbedded with red clay bands, probably were sedimented in a reducing environment of brackish water whose influence was at times overwhelmed by voluminous influx of iron-oxide-bearing sediment accompanied by aerated fresh water.

Comment on Glacial History

Although the interpretation of glacial history has not been a prime objective of this report, at least two points emerge that should be mentioned: First, the inclusion of the lower varved sequence (Unit II) in the early Champlain Sea suite of sediments does away with the necessity of a pre-Champlain Sea glacial lake (Lake Frontenac of Antevs, 1925). Second, the apparent continuity of sedimentation, the presence of gradational boundaries between lithofacies, and the existence of a complete, unbroken suite of deltaic sediments are proof that a readvance of glacial ice across the Champlain Sea into St. Lawrence valley did not occur as was proposed by Richard (1975, 1976) and as refuted by Gadd (1977).

In arriving at these conclusions, it is assumed that radiocarbon dates on shell material (marine and freshwater) in the Ottawa-St. Lawrence system are at least internally consistent, even though the dates themselves may be subject to correction. Dates on high-level marine beach deposits at Clayton, Ontario, establish the probable maximum of Champlain Sea in Ottawa basin at ca. 12 800 ± 220 BP (GSC-1859; Richard, 1974, p. 218). This means that an earlier Lake Frontenac, defined as occupying parts of Ottawa, St. Lawrence, and Lake Ontario basins, would have to have been in existence ca. 13 000 BP and earlier and that ice-free conditions existed in all those areas of eastern Ontario at such a time. However, the history of Lake Ontario basin and the drainage of Lake Iroquois in particular, as determined by Karrow et al. (1975) and by Dreimanis (1977), requires an ice barrier at the outlet of the modern Lake Ontario basin until about 12 000 BP; this fact would cause one to seriously question the existence of Lake Frontenac.

In passing, the writer would also indicate that the Karrow et al. (1975) suggested correction of "too old" radiocarbon dates in Ottawa valley to a figure of about 11 000 BP is opposed by the thick accumulation of sediments seen in cores described in this report. We know that more than 100 m of sediment was deposited under marine conditions in the Ottawa basin of the Champlain Sea (Treadwell core). From this, and using 12 800 BP (marine maximum) and 10 200 BP (freshwater minimum) as time limits for those marine conditions, we arrive at a phenomenal sedimentation rate of 35-50 m/1000 years. Arbitrarily reducing the time span to a mere 800 years by assuming an 11 000 year maximum for the Champlain Sea in the Ottawa basin (as suggested by Karrow et al., 1975) would allow an incredibly short time for sedimentation of 100 m of fine grained material. The apparent discrepancy in age relationship between the Champlain Sea in Ottawa valley and drainage of glacial Lake Iroquois in Lake Ontario basin has been the subject of further study that identifies location of late ice in that region, presents a new hypothesis for ice margin retreat, and allows for possible reconciliation of dates previously considered incompatible (Gadd, 1980).

CONCLUSIONS

1. Borings in the Ottawa basin of the Champlain Sea show that there are four basic lithofacies of Leda Clay.
2. The facies compare favourably with those of the Mississippi Delta in both texture and sedimentary

structure. Three of the facies, therefore, are said to represent "upper delta" (Unit V), "delta front" (Unit IV), and Prodelta and Shelf (Unit III) environments. Unit II of the Ottawa basin, being of glaciolacustrine or glaciomarine origin, has no direct counterpart in the Mississippi Delta, but has general characteristics in common with "prodelta" and "shelf" environments of deposition.

3. Two lithofacies (units A and B), occupying erosional channels in the marine deltaic deposits, contain freshwater clams of approximately Holocene age. These sediments are derived in large part as erosional products of older Champlain Sea sediments on which they lie.

4. Freshwater clam shell remains collected in the zone of transition from a marine upper deltaic environment to a subaerial freshwater fluvial system have radiocarbon dates (e.g., 10 200 ± 90 BP; GSC-1968) indicating that the Pleistocene-Holocene boundary (if standardized at 10 000 BP) in Ottawa valley may be within the time of that transition.

5. Offlap due to regional isostatic uplift and the migration from west to east through the region of a major deltaic system is indicated by the lack of simple delta morphology, by direct superposition of all lithofacies, and by extensive regional development of the "upper delta" facies.

6. Minor sedimentary structures in the sediments clearly show progressive development through time of increasing capacity of currents, of channel erosion, and mass wastage – a typical offlap phenomenon.

7. The age of marine shells (maximum ca. 12 800 BP) in the basin and of freshwater shells in units A and B (ca. 10 200 BP) provide time limits within which deposition of all sediments, totalling in excess of 100 m thick, must have occurred. The sedimentation rate is extremely high.

   Although Leda Clay has many sedimentary, structural, and mineralogical features in common with bodies of similar sediments in the Mississippi Delta, the Mediterranean and Black seas, it appears to have been accumulated at a phenomenally high rate of sedimentation, unknown elsewhere. This sedimentation rate (35-50 m/1000 years) is probably a significant factor controlling features preserved in Leda Clay that are anomalous to the environments in those other basins.

8. This study is based on the macroscopic characteristics of a limited number of samples of Leda Clay. It must therefore be considered rudimentary and preliminary; it is hoped that further study of other aspects may follow. This uplifted basin is a model that is ideally suited as a laboratory for studies of the glaciomarine environments of eastern North America. Its use is highly recommended because it contains the most extensive and most readily accessible suite of glaciomarine and marine sediments of that region.

REFERENCES

Antevs, E.
1925: Retreat of the last ice-sheet in Eastern Canada; Geological Survey of Canada, Memoir 146.

Bates, R.L. and Jackson, J.A. (Editors)
1980: Glossary of Geology, Second Edition; American Geological Institute, Falls Church, Virginia, p. 363.

Berner, R.A.
1969: Migration of iron and sulfur within anaerobic sediments during early diagenesis; American Journal of Science, v. 267, p. 19-42.

1974: Iron sulfides in Pleistocene deep Black Sea sediments and their paleo-oceanographic significance; in The Black Sea – Geology, Chemistry, and Biology, ed. E.T. Degens and D.A. Ross; American Association of Petroleum Geologists, Memoir 20, p. 524-531.

1981: A new geochemical classification of sedimentary environments; Journal of Sedimentary Petrology, v. 51, no. 2, p. 0359-0365.

Butzger, K.W.
1963: Climate-geomorphic interpretation of Pleistocene sediments in the Eur-african subtropics; Anthropology, v. 36, p. 1-27.

1964: Environment and Archaeology: An Introduction to Pleistocene Geography; Aldine, Chicago, 528 p.

Coleman, J.M. and Gagliano, S.M.
1965: Sedimentary structures: Mississippi River deltaic plain; in Primary Sedimentary Structures and Their Hydrodynamic Interpretation, ed. G.V. Middleton; Society of Economic Paleontology and Mineralogy, Special Publication, no. 12, p. 133-148.

Dawson, J.W.
1857: On the newer Pliocene and post Pliocene deposits of the vicinity of Montreal, with notices of fossils recently discovered in them; The Canadian Naturalist and Geologist, v. 11, no. 6, p. 401-426.

Dreimanis, A.
1977: Correlations of Wisconsin glacial events between the eastern Great Lakes and the St. Lawrence Lowlands; Géographie physique et Quaternaire, v. 31, no. 1-2, p. 37-51.

Eden, W.J.
1976: Mechanism of landslides in Leda Clay with special reference to the Ottawa area; in Mass Wasting, ed. E. Yatsu, A.J. Ward, F. Adams; 4th Guelph Symposium on Geomorphology; Geo Abstracts Limited, University of East Anglia, Norwich, England; p. 159-171.

Fransham, P.B.
1980: Geological and groundwater controls of natural slope stability; unpublished Ph.D. dissertation, McGill University, Montreal.

Fransham, P.B., Gadd, N.R., and Carr, P.B.
1976: Distribution of sensitive clay deposits and associated landslides in Ottawa valley; Geological Survey of Canada, Open File 352.

Fransham, P.B. and Gadd, N.R.
1977: Geological and geomorphological controls of landslides in Ottawa valley, Ontario; Canadian Geotechnical Journal, v. 14, no. 4, p. 531-539.

Gadd, N.R.
1961: Surficial geology of the Ottawa area, report of progress; Geological Survey of Canada, Paper 61-19.

1963a: Surficial geology of Ottawa map-area, Ontario and Quebec; Geological Survey of Canada, Paper 62-16.

1963b: Surficial geology of Chalk River area, Ontario and Quebec; Geological Survey of Canada, Map 1132A.

Gadd, N.R. (cont.)
1971: Pleistocene geology of the central St. Lawrence Lowland; Geological Survey of Canada, Memoir 359.

1976a: Geology of Leda Clay; in Mass Wasting, ed. E. Yatsu, A.J. Ward, F. Adams; 4th Guelph Symposium on Geomorphology; Geo Abstracts Limited, University of East Anglia, Norwich, England, p. 137-151.

1976b: Surficial geology and landslides of Thurso-Russell map-area; Geological Survey of Canada, Paper 75-35.

1977: Offlap sedimentary sequence in Champlain Sea, Ontario and Quebec; in Report of Activities, Part A, Geological Survey of Canada, Paper 77-1A, p. 379-380.

1980: Late-glacial regional ice-flow patterns in eastern Ontario; Canadian Journal of Earth Sciences, v. 17, no. 11, p. 1439-1453.

Gadd, N.R., LaSalle, P., Dionne, J-C., Shilts, W.W., and McDonald, B.C.
1972: Quaternary geology and geomorphology, southern Quebec; 24th International Geological Congress (Montreal), Guidebook to Field Excursion A44-C44, 70 p.

Haynes, J.E., and Quigley, R.M.
1976: Mineralogy and physico-chemistry, Leda Clay from deep boreholes, Hawkesbury, Ontario; Ontario Division of Mines, Geological Branch, Open File Report 5214.

Johnston, W.A.
1917: Pleistocene and recent deposits in the vicinity of Ottawa, with description of the soils; Geological Survey of Canada, Memoir 101.

Karrow, P.F., Anderson, T.W., Clarke, A.H., Delorme, L.D., and Skreenivasa, M.R.
1975: Stratigraphy, paleontology, and age of Lake Algonquin sediments in southwestern Ontario, Canada; Quaternary Research, v. 5, p. 49-87.

Lowdon, J.A. and Blake, W., Jr.
1976: Geological Survey of Canada radiocarbon dates XVI; Geological Survey of Canada, Paper 76-7.

Maldonado, A. and Stanley, D.J.
1975: Nile cone lithofacies and definition of sediment sequences; IXième congrès internationale de sédimentologie, Nice, 1975, v. 6, p. 185-191.

1976: The Nile cone: submarine fan development by cyclic sedimentation; Marine Geology, v. 20, p. 27-40.

Mott, R.J. and Farley-Gill, L.D.
1980: Two late-Quaternary pollen profiles from Gatineau Park, Quebec; Geological Survey of Canada, Paper 80-31.

Richard, S.H.
1974: Surficial geology mapping: Ottawa-Hull area (parts of 31 F, G); in Report of Activities, Part B, Geological Survey of Canada, Paper 74-1B, p. 218-219.

1975: Surficial geology mapping: Ottawa valley lowlands (parts of 31 B, F, G); in Report of Activities, Part B, Geological Survey of Canada, Paper 75-1B, p. 113-117.

1976: Surficial geology mapping: Valleyfield-Rigaud area, Quebec (31 G/1, 8, 9); in Report of Activities, Part A, Geological Survey of Canada, Paper 76-1A, p. 205-208.

Richard, S.H., Gadd, N.R., and Vincent, J-S.
1977: Surficial materials and terrain features, Ottawa-Hull, Ontario and Quebec; Geological Survey of Canada, Map 1425A.

Ross, D.A., and Degens, E.T.
1974: Recent sediments of Black Sea; in The Black Sea – Geology, Chemistry, and Biology, ed. E.T. Degens and D.A. Ross; American Association of Petroleum Geologists, Memoir 20, p. 183-199.

Ryan, W.B.F.
1972: Stratigraphy of Late Quaternary sediments in the eastern Mediterranean; in The Mediterranean Sea: A Natural Sedimentation Laboratory; ed. D.J. Stanley; Dawden, Hutchinson and Ross, Inc., Stroudsburg, Pa. p. 149-169; Lamont-Doherty Geological Observatory Contribution no. 1894.

Shilts, W.W.
1978a: Nature and genesis of mudboils, central Keewatin, Canada; Canadian Journal of Earth Sciences, v. 15, p. 1053-1068.

1978b: Detailed sedimentological study of till sheets in a stratigraphic section, Samson River, Quebec; Geological Survey of Canada, Bulletin 285, 30 p.

1979: Keewatin Ice Sheet – re-evaluation of the traditional aspect of the Laurentide Ice Sheet; Geology, v. 7, no. 11, p. 537-541.

Walker, R.G. (editor)
1981: Facies models; Geoscience Canada, Reprint Series 1, Fourth Printing.

Wagner, F.J.E.
1970: Faunas of the Pleistocene Champlain Sea; Geological Survey of Canada, Bulletin 181.

APPENDIX 1

Drill Site Logs and Notations

In this Appendix of drilling logs, boring intervals and sample depths are given as originally measured in feet from zero (0') at the surface. Text Figure 1 shows the locations of the drillsites.

Both borings and core samples are numbered consecutively in each year. In 1976, for example, the 14th boring was made near Westmeath, Ontario; it is designated either Westmeath Site or Boring no. 76-14. The first sample taken in that boring was the 63rd for that year, hence sample 76-14-63; 62 previous samples were taken in the 13 previous borings made in 1976 (they number 76-1-1 to 76-13-62). This numbering system was the standard procedure for the crews (Department of Public Works) who carried out the drilling for this study.

The samples were taken and numbered from the surface to the bottom of the hole. However, in order to conform with common stratigraphic practice, where cores are described in detail, the cumulative thickness of subunits is numbered from the bottom to the top of the respective sample, i.e. in their order of sedimentation, and within the footage limits given for each sample. These irregular measurements are given in feet to one or two decimal places.

Descriptive symbols placed before sample numbers are as follows:

WS – Wash sample	OS – Osterberg (piston) sample
SS – Shelby tube sample	HW – Hard wall sample
PS – Piston sample	DD – Diamond drill core

These indicate in a general way the nature and physical state of materials encountered at the sampling level.

Boring CRF-21A is the exception to the above notes. It was part of a special project in the Central Research Forest that was conducted by M.J.J. Bik. The boring was sampled continuously from the surface, using a piston corer, and the record shows very few breaks. To simplify calculation and to avoid confusion, the details of this one core are given in terms of measurements (in feet to one or two decimals) below the surface (0'). For all other individual cores in this Appendix, measurements are given in order of deposition within individual samples.

BORING #76-14
(Westmeath Site)

0'-10'	Mainly fluvial sand over reworked clay.
10'-12.1'	SS 74-14-63 – sand, silt, and clay in layers of varying thickness, some beds are tilted; medium grey with some light grey banding; three distinct red clay bands near top about 0.5 cm thick, upper 5 cm of core is rust-coloured (oxidized).
15.0'-17.1'	SS 74-14-64 – sand, silt, clay; central 1' bed in core is uniform fine grained grey sand; upper and lower parts are interbedded silt and clay resembling varves; red clay bands 0.5 cm, grey silt bands 1 cm; lower contact of sand is gradational, upper is sharp; also lower contact of silt bands with clay is gradational, upper is sharp; all beds horizontal; varved clay.
20.1'-22.2'	SS 74-14-65 – red-grey banded sand, grey silt, red clay.
25.0'-27.1'	SS 74-14-66 – massive grey silt, occasional pebble; banding indistinct or absent.
30.0'-32.1'	SS 74-14-67 – red-grey banded clay with some silt partings; grey predominates; some of lower contacts are sharp.
35.0'-37.1'	SS 74-14-68 – red-grey banded clay; some distortion in upper 6" of core – occasional pebble; clay is stiff, but sensitive.
42.4'-44.2'	SS 74-14-69 – red-grey silt and clay, contorted and distorted; large pebble at top of core.
45.1'-46.9'	SS 74-14-70 – very distorted; red clay balls in matrix of grey silty clay; very soft and sensitive.
49.3'-51.6'	HW 74-14-71 – Till.

BORING #76-27
(Beachburg Site)

5.0'-7.1'	SS 76-27-206 – weathered, banded silt and clay; upper half of core brownish grey silt with medium and coarse grained sand (some pebbles) in layers up to 2" thick; lower half is regularly banded grey silt with red clay bands (5) up to 1/2" thick.
10.0'-12.1'	SS 76-27-207 – red and grey banded silty clay; sensitive; upper half of sample mottled with iron oxide; concretions at 1.25' and 1.45' (from base); six red bands in core, rest of sediment is bluish grey; three silt bands.
15.0'-17.1'	SS 76-27-208 – massive to regularly stratified dark grey mottled coarse silt, some sand grains; black mottling 0.3'-0.5' and 0.9'-1.4' (above base).
20.0'-21.3'	SS 76-27-209 – massive blue-grey clayey silt; one blue-grey clay ball at 0.3' above base; material very sensitive (half of core slid out of tube).
25.0'-27.1'	SS 76-27-210 – regular cyclic banding of pink clay and grey silty clay; probable varves; ±20 colour-band cycles in this core.
30.0'-31.5'	SS 76-27-211 – very sensitive, soft, regularly banded pink and grey clay and silty clay; a few sand partings.
35.0'-37.1'	SS 76-27-212 – cyclic stratification of red clay and grey silty clay; four cycles in core based on red clay bands at 0.3', 0.6', 1.1' and 1.9' (measured from base of core); some contacts appear to be erosional; bedding horizontal.
40.0'-42.1'	SS 76-27-213 – beds of variable thickness of pink and grey silty clay with thin sand partings (1/2" max).
45.0'-47.1'	SS 76-27-214 – beds of variable thickness of red clay and grey silt; reddish grey to red bands thicker and more common than in cores higher in section.
50.0'-52.1'	SS 76-27-215 – cyclic bedding; 4 cycles, base of each cycle is pink clay grading upwards to grey; wavy contact (erosional?) between pink band and underlying dark grey.
55.0'-57.1'	SS 76-27-216 – large pebble in sand at top of sample; lower half of core: pink and grey colour-banded clay and silt with sand partings; bedding contorted by slumping; upper half core is stratified medium to fine grained sand.
60.0'-61.1'	SS 76-27-217 – from base of core: 0'-0.3' – grey silt; 0.3'-0.45' – reddish grey band, irregular lower contact; 0.45'-0.6' – fine grained grey silty sand; 0.6'-0.85' – massive grey silt; 0.85'-1.1' – contorted stratified sand and silt; thin bedded.
65.3'	refusal; apparently hole ends on bedrock.

BORING #76-18
(Quyon Site – Top of Scarp)

0'-10'	Fine grey sand; oxidized at surface.
11.6'-13.7'	SS 76-18-93 – grey clay with some red bands; light and dark grey, poorly to well colour-banded; very silty clay.
15.0'-17.1'	SS 76-18-94 – light and dark grey colour-banded clay; some red bands; some mottling; red-grey contacts are sharp.
20.0'-22.1'	SS 76-18-95 – red and grey clay; large red band 3" thick with thin silt parting in middle; grey silty clay is massive.
25.0'-27.1'	SS 76-18-96 – massive, very silty grey clay with some faint red banding.
30.0'-32.1'	SS 76-18-97 – massive, light grey silty clay with very faint red bands.
35.0'-37.1'	SS 76-18-98 – light and dark grey clay with some silt partings; minor black mottling; contacts sharp between colour bands; parts of three cycles.
40.0'-42.1'	SS 76-18-99 – indistinct banding of light and dark grey clay; minor black mottling.
45.0'-47.1'	SS 76-18-100 – very sensitive, vaguely banded light and dark grey clay; slight reddish colour in some bands; liquified completely when trimmed.
51.0'-52.0'	SS 76-18-101 sample short (drilling error); shell fragments in drill water; very sensitive clay, completely liquified on remolding; stiff, undisturbed; light and dark grey colour banding; some black mottling.
56.0'-58.1'	SS 76-18-102 – light and dark grey banded clay, a few silt partings; subgranular texture indicates high silt content; very sensitive.
60.0'-62.1'	SS 76-18-103 – light and dark grey banded clay or silty clay with fine sand or silty sand seams; not as regular as varves; vane shear test aborted because vane spear lodged in sand or gravel even under heavy pressure; i.e. sand layer below 62.1'.
63.1'-65.2'	SS 76-18-104 – sample lost; apparently fine silty sand that ran out of tube; hole was cased to 70'; drove hard at first then slipped down easily; cuttings from cleaning hole to 70' were fine sand and clay, probably interbedded sand and clay layers each up to several feet thick.
70.0'-72.1'	SS 76-18-105 – light and dark grey banded silty clay with several sand or silt layers to 1/2" thick; some strata have varve-like appearance.
75.0'-76.5'	SS 76-18-106 – half of sample lost; tube flattened on boulder or bedrock; very stiff sand and silty clay layers in varve-like alternation.
76.5'-77.5'	silty sand and gravel over bedrock; probable till layer; hole ends 77.5'.

BORING #76-20
(Quyon Site – Base of Scarp)

0'-5' silty sandy topsoil.

5.0'-6.8' SS 76-20-109 – olive brown to grey clay; upper half of tube highly fractured, crumbly; one red band.

10.0'-12.1' SS 76-20-110 – grey clay with some red bands, very distorted; clay soft and sensitive.

15.0'-17.1' SS 76-20-111 – red and grey banded clay; red clay in thinner beds, slightly tilted; grey clay has alternate bands of two tones of grey, some distortion; fissured.

20.0'-22.1' SS 76-20-112 – red and grey banded clay; most contacts in both red and grey clay are sharp, although parts of the sample have diffuse reddish colour; beds are tilted ~10°; fissures along bedding.

25.0'-27.1' SS 76-20-113 – clay at top and bottom of tube is of strong red colour, with relatively massive dark grey clay between; lower contact of grey clay is sharp, upper is gradational; for 2" below sharp contact there are thin red and grey alternating clay beds.

30.0'-32.1' SS 76-20-114 – mainly massive dark grey clay with one 2" red band containing two silt partings; bedding dips 10°.

35.0'-37.1' SS 76-20-115 – lower half of core is very distorted red and grey banded clay, below sharp break; top of core is massive, undisturbed grey clay.

40.0'-42.1' SS 76-20-116 – banded light and dark grey clay, some traces of red; silt partings (to 2") common; clay silty.

45.0'-47.1' SS 76-20-117 – banded sand, silt, clay in light and dark grey tones; contacts slightly tilted.

50.0'-52.1' SS 76-20-118 – interbedded sand and clay; clay and silty clay are light and dark grey; core is 50% sand.

55.0'-57.1' SS 76-20-119 – grey sand, silt, clay; traces of red; some small pebbles.

60.0'-61.9' Shelby tube driven, but no recovery because end of tube flattened.

62.5' gravel backwash to this level probably represents till; over bedrock.

BORING #CRF-21A (M.J.J. Bik)
(Mer Bleue Site)

0'-9.5' silty sand and sand.

9.5'-11.3' PS 69-21A-1 – Shelby tubes were cored in 1969, but extruded in 1976; some untreated tubes were heavily rusted inside and therefore extruded badly or not at all; most other tubes that were coated internally with teflon extruded easily and samples were in good condition; piston sampling throughout. 9.5'-9.85'[1] – massive light grey clay with slump structures; 9.85'-10.4' – light grey clay with slump structures; 10.4'-11.3' – massive light grey clay.

11.3'-13.1' PS 69-21A-2 – light and dark grey, vaguely texture- and colour-laminated silty clay; thin silt partings at 11.7' and 12.6'.

13.2'-15.1' PS 69-21A-3 – massive to vaguely colour-banded light and dark grey clay; reddish tint 13.6'-13.8' and 14.4'-14.6'.

15.1'-16.9' no recovery.

17.2'-19.1' PS 69-21A-4 – massive to indistinctly colour-banded grey clay; reddish tint at 17.85'-17.9' and 19.0'-19.1'.

19.1'-21.0' PS 69-21A-5 – colour- and texture-banded grey clay; some bands distinct.

21.0'-22.8' PS 69-21A-6 – sample poorly preserved, dessicated; core shows three colour-band cycles, as follows (colour banding is diffuse, gradational): cycle 3: 21.0'-21.35' – banded light and dark grey clay; 21.35'-21.7' – reddish brown clay; cycle 2: 21.7'-22.2' – banded light and dark grey silty clay; 22.2'-22.3' – reddish brown clay; cycle 1: 22.3'-22.78' – banded light and dark grey clay; 22.78'-22.8' – reddish brown clay.

23.0'-24.8' PS 69-21A-7 – five colour bands in 2 1/2 cycles.

1/2 cycle: 23.0'-23.55' – banded light and dark grey silty clay and clay; cycle: 23.55'-23.7' – dark reddish grey silty clay and clay; 23.7'-24.3' – banded light and dark grey silty clay and clay; cycle: 24.3'-24.5' – dark reddish grey silty clay and clay; 24.5'-24.8' – banded light and dark grey silty clay and clay.

24.8'-26.5' PS 69-21A-8 – very sensitive, soft clay. 24.8'-25.2' – light grey clay, vaguely stratified; 25.2'-25.5' – dark grey clay; 25.5'-25.8' – light grey clay; 25.8'-26.5' – dark grey clay; banded; upper 1" brownish-grey.
Note – thickness of dark grey clay bands has increased in last three samples (8, 7, 6).

26.6'-28.4' PS 69-21A-9 – silty clay and clay in fairly distinct colour bands, each with minor thin colour-band variations; soft, sensitive material. 26.6'-26.8' – light grey; 26.8'-27.2' – dark grey; 27.2'-27.7' – light grey; 27.7'-28.0' – dark grey; 28.0'-28.35' – light grey; 28.35'-28.4' – dark grey.

28.4'-30.3' PS 69-21A-10 – banded grey clay with some distinct reddish bands. 28.4'-29.0' – banded light and dark grey clay; 29.0'-29.1' – brownish grey clay; 29.1'-29.5' – light and dark grey horizontally stratified clay; 29.5'-30.1' – tilted, disturbed beds, mainly light and dark grey, one red band; 30.1'-30.3' – light grey silty clay; lower boundary of disturbed zone.

30.3'-32.1' PS 69-21A-11 – soft, sensitive clay; sample cut very easily by wire saw and separated easily without breaking; banded light and dark grey. 30.3'-30.5' – light; 30.5'-30.9' – dark; 30.9'-31.0' – light grey; 31.0'-31.4' – dark, banded clay; 31.4' -31.7' – light, banded; 31.7'-32.0' – dark grey; 32.0'-32.1' – oxidized material (due to poor wax seal in tube).

32.1'-33.9' PS 69-21A-12 – colour-banded light and dark grey silty clay; upper part of each dark layer has reddish brown tone. 32.1'-32.3' – light; 32.3'-32.6' – dark; 32.6'-33.0' – light; 33.0'-33.2' – dark; 33.2'-33.6' – light; 33.6'-33.7' – dark; 33.7'-33.8' – light.

33.9'-35.7' no recovery.

35.8'-37.6' PS 69-21A-13 – soft, sensitive colour-banded clay and silty clay. 35.8'-36.0' – light grey; 36.0'-36.5' – disturbed zone, light, dark and reddish grey with slump structures; 36.5'-36.9' – massive light grey; 36.9'-37.0' – dark grey; 37.0'-37.1' – dark grey with black mottling; 37.1'-37.4' – light, banded; 37.4'-37.6' – dark, stratified clay, upper 1" brownish grey.

37.6'-39.4' PS 69-21A-14 – cyclically banded light, dark, reddish grey clays. 37.6'-37.9' – light grey, banded; 37.9'-38.0' – brownish to reddish-grey clay; 38.0'-38.45' – light and dark grey banded clay with black mottling at 38.15'-38.3'; 38.45'-38.55' – brownish to reddish grey clay; 38.55'-38.85' – light and dark grey banded clay; 38.85'-38.9' – brownish to reddish-grey clay; 38.9'-39.2' – light and dark grey, banded clay; 39.2'-39.3' – brownish to reddish grey clay; 39.3'-39.4' – light grey.

39.4'-41.2' PS 69-21A-15 – vaguely stratified grey to brownish grey clay and silty clay; no clear cycles. 39.4'-40.1' – vaguely stratified dark brownish grey clay; 40.1'-40.45' – light grey silty clay with distinct dark grey band 1-3 mm thick at 40.37'; 40.45'-40.54' – dark grey silty clay;

[1] Because this hole was cored more or less continuously, all measurements are given in tenths of a foot below the surface; samples are described from top down, the reverse of the order for other cases in the Appendix.

40.54'-40.8' – light grey silty clay; thin (1-3 mm) dark grey layer at lower contact; 40.8'-40.9' – light grey silty clay; thin (1-3 mm) dark grey band at lower contact; 40.9'-41.07' – light grey silty clay; 41.07'-41.2' – dark grey silty clay with black band at 41.17'.

41.2'-43.0' PS 69-21A-16 – except for thin reddish grey zone near base of sample (42.75'-42.8'), this core is dominantly dark grey clay with two indistinct light grey bands at 41.9'-42.0' and 42.6'-42.75'.

43.0'-44.8' PS 69-21A-17 – indistinctly banded light and dark grey clay; some traces of red coloration.

44.8.-44.5' PS 69-21A-18 – erosional (?) break in sequence. 44.8'-ca.45.4' – vaguely banded light and dark grey clay (horizontal); at ca.45.4' – diagonal disconformity over approx 0.25' vertical distance; ca.45.4'-46.1' – inclined beds of light and dark grey clay and silty clay; minor crenulations along bedding planes; 46.1'-46.5' – banded light and dark grey clay.

46.6'-48.4' PS 69-21A-19 – Note: part of this tube was badly rusted in storage; sediment is dominantly irregularly bedded light and dark grey clay with reddish coloration in upper part of each dark grey layer, then rapid transition upward to light grey. 46.6'-46.7' – dark grey; 46.7'-46.8' – light; 46.8'-47.0' – dark; 47.0'-47.6' – light; 47.6'-47.8' – dark; 47.8'-48.2' – banded layer; 48.2'-48.4' – dark.

48.4'-50.2' PS 69-21A-20 – mainly dark grey clay with indistinct thin bedding; gives off H_2S when dilute HCl applied; 1" red bands at 48.6'-48.7' and 49.8'-49.9'; black mottled bands at 49.0'-49.15' and 49.8'-49.9'.

50.2'-52.0' PS 69-21A-21 – irregularly banded light and dark grey silty clay and clay with several bands of dark reddish to brownish grey. 50.2'-50.28' – light grey; 50.28'-50.29' – reddish-grey; 50.29'-50.45' – dark grey; 50.45'-50.78' – light grey; 50.78'-50.86' – dark reddish grey; 50.86'-51.1' – light grey; 51.1'-51.2' – reddish grey; 51.2'-51.4' – dark grey; 51.4'-51.6' – banded light grey; 51.6'-51.7' – brownish grey; 51.7'-52.0' – dark grey.

52.0'-53.8' PS 69-21A-22 – mainly light and dark grey; some reddish tones; some disturbed beds. 52.1'-52.2' – dark reddish grey; 52.2'-52.9' – massive dark grey; 52.9'-53.0' – thin-bedded light and dark grey; disturbed; minor faults; 53.0'-53.1' – dark brownish grey; 53.1'-53.3' – light grey; small fault in light banding near top (53.14'); 53.3'-53.4' – dark; 53.4'-53.6' – light; 53.6'-53.8' – dark.

53.8'-55.6' PS 69-21A-23 – massive grey silty clay to clayey silt; no apparent banding.

55.6'-57.4' PS 69-21A-24 – 55.6'-56.1' – massive dark grey silty clay; 56.1'-56.2' – dark grey; vague banding; fossil fragment at 56.4' and 57.2'; 56.2'-57.4' – banded brownish grey and grey clay.

57.5'-59.3' PS 69-21A-25 – upper 8" of core oxidized, poorly preserved. 57.5'-57.9' – light and dark grey silty clay (oxidized in storage). 57.9'-59.2' – dark grey and brownish grey silty clay; irregularly stratified (i.e. strata of varied thickness); 59.2'-59.3' – soft blue-grey silty clay (partly liquified by extrusion).

59.3'-61.1' PS 69-21A-26 – untreated Shelby tube; sample in poor state of preservation. 59.3'-60.3' – dark clay; 60.3'-60.6' – silt, liquified by extrusion; 60.6'-60.95' – dark clay; 60.95'-61.1' – silt.

61.1'-62.9' PS 69-21A-27 – poorly preserved core; some distortion by extrusion. 61.1'-61.3' – stratified light and dark grey silty clay; 61.3'-61.4' – dark grey clay (hard and dessicated); 61.4'-62.6' – thin-bedded dark grey, light grey, brownish to bluish grey silty clay; 62.6'-62.9' – section disturbed by extrusion.

62.9'-64.7' PS 69-21A-28 – untreated tube; core heavily rusted, stuck in tube and badly distorted by extrusion; appeared to be mainly blue-grey silty clay with silt partings.

64.7'-66.5' PS 69-21A-29 – untreated tube; sample badly distorted by extrusion; apparently mainly grey silty clay and clay.

66.5'-68.3' PS 69-21A-30 – untreated tube, sample badly distorted by extrusion; grey silt and clay, discrete silt layers.

68.3'-70.1' PS 69-21A-31 – untreated tube; very disturbed by extrusion; light and dark grey silty clay; silt bands may be 1"-2" thick.

70.1'-71.9' PS 69-21A-32 – untreated tube, top 5" rusted. 70.1'-70.4' – oxidized, disturbed clay; 70.4'-71.5' – dark blue-grey to brownish grey silty clay; thin-bedded; 71.5'-71.9' – disturbed material.

71.9'-73.7' PS 69-21A-33 – untreated tube, sample very distorted; appears to be mainly blue-grey clay and silty clay.

73.7'-75.4' PS 69-21A-34 – untreated tube, rust problem. 73.7'-74.3' – thin-bedded grey and brownish grey clay; some "near-red" bands; 74.3'-75.4' – apparently laminated blue-grey silty clay with some black-mottled layers.

75.4'-77.2' PS 69-21A-35 – rusty tube; top and bottom of sample rusted and distorted beyond recognition; middle section 75.9'-76.7' – stratified blue-grey and brownish to reddish grey, thin bedded clay; some black mottling.

77.2'-79.0' PS 69-21A-36 – normal extrusion except distortion in lower 4"; mainly irregularly thin-bedded dark grey clay and silty clay with approximately 1" reddish brown to brownish grey bands at 77.4'-77.45', 77.8'-77.85', 78.13'-78.15', and 78.6'-78.61'.

79.0'-80.8' PS 69-21A-37 – uncoated tube. 79.0'-79.7' – top of tube oxidized; thin-bedded clay, possible red band at 79.35'-79.4'; 79.7'-80.3' – dark grey silty clay, irregular; indistinct bedding; red band at 80.0'-80.05'; 80.3'-80.35' – black mottled band; 80.35'-80.08' – disturbed material (extrusion?).

80.8'-82.6' PS 69-21A-38 – uncoated tube, sample stretched by extrusion; lower half of sample discoloured by rust; remainder is indistinctly stratified light and dark (blue-grey) grey silt and silty clay.

82.6'-84.4' PS 69-21A-39 – uncoated tube, sample very disturbed; reddish brown and bluish grey silty clay and clayey silt with several bands of black mottling (some transformed to rust by oxidation within tube?).

84.4'-86.2' PS 69-21A-40 – uncoated tube; sample well preserved, extruded without distortion; indistinctly stratified dark silty clay; bedding irregular and slump distorted in lower half of tube; faulted and bedding inclined in upper half of core.

86.2'-87.4' PS 69-21A-41 – uncoated tube, sample distorted; appears to be light and dark grey silty clay with indistinct bedding; possibly with faults and dipping beds.

87.4'-89.2' PS 69-21A-42 – uncoated tube, sample extruded well. 87.4'-88.8' – thin-bedded dark grey silty clay with 1" thick (approx.) red bands at 87.6' and 87.95'.

89.2'-91.0' PS 69-21A-43 – 89.2'-89.6' – laminated brownish grey to grey clay with red band at 89.45'-89.55'; 89.6'-91.0' – indistinctly stratified dark grey silty clay with several black bands and black mottled zones; intraformational slumping.

91.0'-92.8' PS 69-21A-44 – core heavily rusted; appears to be dark grey to brownish grey silty clay, much distorted by extrusion.

92.8'-94.6' PS 69-21A-45 – cyclic sedimentation in indistinctly stratified silty clay. 92.8'-93.4' – dark grey silty clay; 93.4'-93.5' – light grey; 93.5'-93.6' – dark grey; 93.6'-93.65' – light grey; 93.65'-93.8' – dark grey (black band at 93.7'); 93.8'-93.9' – light grey; 93.9'-94.0' – dark grey grading upwards to brownish grey; 94.0'-94.1' – light grey; 94.1'-94.25' – dark grey grading upwards to brownish grey; 94.25'-94.3' – light grey; 94.3'-94.6' – dark grey grading upwards to brownish grey.

94.6'-96.4' PS 69-21A-46 – cyclic colour banding light grey → dark grey → reddish grey in ascending order; three fairly distinct red bands at 94.7'-94.8' (thin diagonal band), 95.6'-95.63', and 95.9'-95.95' (half-inch bands); a nearly vertical black streak between 95.95' and 96.1' is offset along bedding planes.

96.4'-98.2' PS 69-21A-47 – repeated (or cyclic) colour sequence dark grey → reddish grey → light grey, in ascending order; two clearly reddish grey bands at 96.95' and 97.2'. Note: Tubes seem more rusted where material is more silty. Silt bands are more disturbed and compacted during extrusion.

98.2'-100.0' PS 69-21A-48 – sample extruded poorly; material appears to be massive to indistinctly stratified dark grey silty clay.

100.0'-101.4' PS 69-21A-49 – sample very distorted by extrusion; colour-banded, indistinctly stratified grey and reddish grey silty clays.

101.4'-103.2' PS 69-21A-50 – sample extruded well, upper half rusted. 101.4'-102.2' – distorted material, silty (distortion may be due to extrusion). 102.2'-102.8' – massive dark grey clay; 102.8'-103.2' – thin-bedded grey and reddish grey silty clay, bedding dips at 45° (lower 5" of core).

103.2'-105.0' PS 69-21A-51 – sample extruded well, drag phenomena around circumference. 103.2'-103.8' – light-coloured stratified silt, completely distorted, some beds near vertical, some at 60°-70° to long axis of tube; distortion seems intrinsic and not related to extrusion; 103.8'-104.7' – grey and red bands of silty clay, horizontal, edges disturbed by extrusion drag; 104.7'-105.0' – material very disturbed, apparently by sampling. Black bands occur at 103.75'-103.78', 104.0'-104.1'; some other irregular bands and streaks of black.

105.0'-106.8' PS 69-21A-52 – cyclically colour-banded (e.g. 1/2" light grey, 2" dark grey, 1/2" red, ascending order). 105.0'-105.55' – oxidized, stratified clays, bedding and colours indistinct; rest of core cyclically colour-banded as above with top of red beds at 105.55', 105.7', 105.9', 106.2', 106.5', 106.7' (i.e. cycles 1.5" to 4" thick).

106.9'-108.7' PS 69-21A-53 – cyclic colour banding as in #52 (above); tops of red bands at 107.1', 107.4', 107.7', 108.0', 108.35', 108.6'; shell fragments at 107.5' and 108.35'.

108.7'-110.5' PS 69-21A-54 – cyclic colour-banding: 108.7'-108.75' – light to dark grey silty clay; 108.75'-108.8' – red clay band; 108.8'-109.2' – light grading to dark grey upwards; 109.2'-109.25' – red clay band; 109.25'-109.45' – light to dark grey; 109.45'-109.5' – red clay band; 109.5'-109.7' – light to dark grey gradation; 109.7'-109.75' – red clay band; 109.75'-110.0' – light to dark grey; 110.0'-110.05' – red clay band; 110.05'-110.1' – dark grey; 110.0'-110.5' – sediments disturbed by extrusion.

110.5'-112.3' PS 69-21A-55 – badly rusted tube; "toothpaste" extrusion; apparently most of sample was relatively massive medium grey silty clay with two red bands at about 6" (15 cm) spacing near top of core.

112.3'-113.8' PS 69-21A-56 – sample badly distorted and extruded around ram piston; soft, sensitive grey silty clay.

113.8'-115.6' PS 69-21A-57 – sample extruded poorly, but some distortion appears to be primary; irregular thin beds of very dark grey and red silty clay, with possible slump structures in upper 6".

115.6'-117.4' PS 69-21A-58 – poor extrusion, only upper third of sample well enough preserved for valid observations. 115.6'-116.5' – cyclically colour-banded light grey → dark grey → reddish grey; parts of two cycles preserved: 115.6'-116.1' – light grey grading upwards to dark grey; 116.1'-116.2' – reddish grey; 116.2'-116.7' – light grey grading upward to dark grey.

117.4'-119.2' PS 69-21A-59 – poorly extruded; oxidized. 117.4'-117.5' – indistinctly stratified light and dark grey silty clay. 117.5'-118.5' – massive very dark grey clay with a number of black mottled bands; 118.5'-119.2' – distorted and oxidized sediment.

119.2'-121.0' PS 69-21A-60 – upper half of core is oxidized, lower half is indistinctly stratified dark to medium grey silty clay with several zones of black mottling; fossil at 119.5'.

121.0'-122.8' PS 69-21A-61 – mainly stiff dark grey clay with indistinct bedding that is horizontal in lower half of core, but tilted and shows evidence of intra-formational slump in upper half of core.

122.8'-124.6' PS 69-21A-62 – sample extruded poorly; dark grey indistinctly stratified silty clay; some material very sensitive.

124.6'-126.3' PS 69-21A-63 – massive to indistinctly stratified dark silty clay; consolidated very dark grey to black shaly layers at 125.2'-125.3' and 125.47'-125.5' (these are interpreted as having formed in the tube during storage by consolidation of what were originally black sulphidic strata interacting with the metal of the Shelby tube).

126.3'-128.1' PS 69-21A-64 – upper part 126.3'-126.9' heavily oxidized; 126.9'-128.1' – dark grey clay, indistinctly stratified; black shaly layers at 126.9'-127.0' and 127.3'-127.35'.

128.1'-129.9' PS 69-21A-65 – indistinctly stratified dark grey clay with reddish-grey bands at ~ 3" intervals; two bands of black mottling.

129.9'-131.6' PS 69-21A-66 – core is regularly colour-banded, approximately as follows: 1/2" light grey → 1" dark grey → 1/2" reddish grey, in ascending order; six black mottling bands of 0.25"-0.5" observed.

131.6'-133.4' PS 69-21A-67 – sample stretched on extrusion; consists of regularly colour-banded silty clay and clay (light-dark-red) in approximately 3" cycles.

133.4'-135.2' PS 69-21A-68 – mainly dark grey clay with some indistinct reddish grey bands; one shaly band at 134.2'.

135.2'-137.0' PS 69-21A-69 – 2"-3" cycles of light → dark → reddish grey silty clay; regular; several zones of black mottling; shaly layer at 136.0'.

137.0'-138.8' PS 69-21A-70 – 2" cycles with irregular stratification (i.e. varied colour sequence, apparently missing strata).

138.8'-140.6' PS 69-21A-71 – 2"-3" cycles, irregularly colour-banded, but mainly light – dark – red, distinct colour bands; reddish colour dominant.

140.6'-142.4' PS 69-21A-72 – dominantly dark reddish grey clay with some light grey grading upwards to dark shades of red or reddish grey; shell fragment on outside of tube.

142.4'-144.2' PS 69-21A-73 – cyclic stratification of light and dark grey and reddish grey; cycles of variable thickness 2", 2 1/2", 3".

144.2'-146.0' PS 69-21A-74 – lower half of core oxidized because of poor lower seal; indistinct colour banding; shell fragment at 144.6'.

146.0'-147.8' PS 69-21A-75 – sample badly distorted; regularly colour-banded silty clay; red colour bands are brighter shade of red than seen previously; shell fragments at two levels; four distinct red bands spaced 4"-6" apart, thickness up to 1".

147.8'-149.5' PS 69-21A-76 – lower 10" of core distorted by extrusion; most of material is indistinctly stratified, dark grey and reddish grey silty clay, with 1/2" bright red band at 148.6'; fossil fragment at 148.6'.

149.5'-151.0' PS 69-21A-77 – heavily rusted material; apparently banded dark grey clay with some light grey, some reddish tints.

151.1'-152.9' PS 69-21A-78 – indistinctly stratified light and dark grey silty clay with some reddish coloration; upper half of tube oxidized to browns and reds; shell fragment at 151.6'.

152.9'-154.7' PS 69-21A-79 – some material liquified and squirted out of tube during extraction; apparently indistinctly colour-banded to massive dark grey silty clay; possible clay balls at 153.4'-153.5'.

154.7'-156.5' PS 69-21A-80 – very dark grey, stiff silty clay, black mottling in lower 9", rest of tube oxidized during storage; shell fragments.

156.5'-158.3' PS 69-21A-81 – core extremely extended during extrusion; apparently massive dark grey clay, some mottling (?).

158.3'-160.0' PS 69-21A-82 – entire tube consists of varves or pseudo-varves; pairs approximately 1/2" thick; light and dark grey in alternate layers.

160.0'-161.8' PS 69-21A-83 – sample stretched during extrusion; apparently all varves or varve-like sediment in shades of grey.

162.0'-163.8' PS 69-21A-84 – sample stretched; varves or varve-like strata in pairs up to 1.5" thick.

163.8'-165.6' PS 69-21A-85 – coarse varved silt, coarsening with depth; pebbly, and stony pebbly silt (= till) at base.

165.6'-167.0' PS – end of tube flattened – no recovery.

167.0'-168.5' HW 69-21A-86 – silty sandy gravel

166.8'-167.3' auger 69-21A-87 – till

167.3'-168.9' auger 69-21A-88 – till

172.0'-174.8' auger 69-21A-89 – till

174.8'-175.1' HW 69-21A-90 – silty sandy gravel (= till).

175.1'-186.0' DD – shaly limestone bedrock.

BORING #75-1
(Angers Site – Base of Slope)

0'-5' brownish-grey hard clay; medium to high plasticity; some angular to subangular pebbles (1 mm).

5'-7' hard grey clay, some silt, highly plastic; some brown mottling.

7'-9.8' stiff grey silty clay; rusty brown mottling.

10.0'-12.1' SS 75-1-1 – dark grey clay, some silt.

10.0'-15' wash samples show 2 components: a) highly plastic, grey, soft to firm clay (~75%) and b) brownish red silty clay to silt layers, less plastic than a); a) and b) are laminated in varve-like alternation.

15'-18' wash samples – dark grey soft clay with amounts of coarse, brownish to reddish silty clay decreasing with depth.

18'-20' dark grey soft, massive clay; shell fragments present.

20.0'-22.1' SS 75-1-2 – dark, soft grey clay; some black mottling.

20.0'-25' wash samples – dark grey, very soft, highly plastic clay; some shell fragments, black mottling; high sulphide, low carbonate.

25'-29' similar to 20'-25' section; no shell fragments seen.

29.9'-31.5' SS 75-1-3 – from base of tube; 0'-0.5' – sandy silty till; 1" granite pebble; refusal of shelby tube at 31.5'; 0.5'1.6' – dark grey very soft clay.

32.7'-37.6' NX-diameter diamond drill core; shaly limestone bedrock.

BORING #75-2
(Angers Site – Top of Slope)

0'-5' WS – stiff to hard brownish-grey silty clay; some sand.

5'-10' WS – brownish-grey and reddish brown layers of medium plastic to firm silty clay.

9.9'-12.0' SS 75-2-4 – brownish grey clay, some silt; firm, medium plasticity; mottled; three diffuse pink bands 0.5"-0.75" thick; no HCl reaction.

10'-15' WS – olive or brownish grey, soft highly plastic clay, some silt, some reddish bands.

14.8'-18.5' WS – olive-brown to grey soft silty clay, highly plastic; some red bands.

18.5'-19.8' WS – massive grey, soft to very soft clay; little or no silt. Note transition at 18.5'.

19.8'-21.9' SS 75-2-5 – mainly dark grey, homogeneous, very soft, highly plastic clay; three cycles, each with 1/2" thick red clay band; indistinctly stratified grey silty clay between red bands.

19.8'-24.9' WS – very soft, uniform, highly plastic, dark grey clay.

25.0'-30.0' WS – highly plastic homogeneous, very soft grey clay; some shell fragments.

30.0'-32.1' SS 75-2-6 – relatively massive dark grey clay; low HCl reaction; H_2S odour; shell fragments; two small concretions in top of core.

30.0'-35.0' WS – plastic, homogeneous, very soft grey clay.

35.0'-40.0' WS – massive dark grey clay; small bivalve in wash water (drawing resembles **Hiatella** sp.).

39.9'-42.0' SS 75-2-7 – five pink bands approximately 1/2" thick interbedded with grey clay; stiff, noncalcareous; H_2S odour; concretion in top of core.

40.0'-45.' WS – very soft, highly plastic grey clay; some sand grains.

45.0'-50.0' WS – very soft grey clay; some sand grains.

50.0'-52.1' SS 75-2-8 – 1"-3" spacing of pink to reddish grey clay bands interstratified with grey clay; noncalcareous.

50.0'-55.0' WS – very soft grey clay; some sand; H_2S odour.

55.0'-60.0' WS – very soft grey clay.

59.9'-62.0' SS 75-2-9 – alternate bands of pink and grey clay, cycles 1"-3" thick; black mottling; **Hiatella** sp. shell 2 mm long, single valve, no periostracum.

60.0'-65.0' WS – very soft, highly plastic dark grey clay; high sulphide odour, black mottling; no sand.

65.0'-70.0' WS – very dark grey and reddish brown, very soft clay; sulphurous odour; very sensitive.

69.9'-72.0' SS 75-2-10 – stiff, very sensitive clays; alternate red and grey bands; black bands exclusively in grey strata; low carbonate content.

70.0'-75.0' WS – very soft dark grey clay; black mottling; sulphurous odour.

75'-80' WS – very soft dark grey clay; black mottling; sulphurous odour.

81.3'-82.9' SS 75-2-11 – very soft dark grey clay; shell fragments; faint reddish banding; noncalcareous.

80'-85' WS – very soft dark grey clay; black mottling; some faint red banding; noncalcareous.

85'-90'	WS – very soft dark grey clay, some reddish brown layers, no black mottling.
89.8'-91.9'	SS 75-2-12 – dark grey highly sensitive clay; very weak colour banding; black mottling throughout core; strong H_2S odour.
90'-95'	WS – very soft dark grey clay; black mottling; shell fragments.
95'-100'	WS – very soft dark grey clay; shelly; black mottling; sulphurous; highly thixotropic mud in wash.
99.9'-102.0'	SS 75-2-13 – tube struck something solid at 101.8'; dark grey very soft, sensitive, shelly clay; one undetermined foram observed; strongly calcareous.
100.0'-105'	WS – very soft dark grey clay; black mottling; shelly.
105'-110'	WS – very soft grey clay with subangular fragments of rock 3-4 mm diameter – stony zone begins at 107'.
110.1'-111.0'	SS 75-2-14 – pushed first 0.4' by hand, final 0.5' by hydraulic system; lifted rig, recovery 0.3; stony silty till overlain by a few silty varves; strongly calcareous.
110.5'-111.5'	HW – medium plastic, firm, silty clay till, some stones 2-4 mm diameter.
112.1'	bedrock fragments.

BORING #75-2A
(Angers Site – for Osterberg samples)

18.0'-20.5'	OS 75-2A-15 – soft grey clay.
47.0'-49.5'	OS 75-2A-16 – soft grey clay; shells.
75.0'-77.5'	OS 75-2A-17 – very soft dark grey clay; shells.

BORING #75-4
(Wendover Site – terrace)

0'-1.3'	silty sand topsoil.
1.3'-5.0'	stiff brownish grey sandy silty clay with reddish brown layers; some small stones 3-5 mm diameter.
5'-10'	WS – firm silty brownish-grey clay with regularly spaced red bands; rhythmite.
9.9'-12.0'	SS 75-4-28 – alternately red and grey banded clay; sharp contact at top of red bands; bands 3"-5" thick; five cycles in core; grey reacts slowly to acid, red more vigorously.
10'-15'	WS – dark grey very soft clay, some silt with reddish grey bands; minor sand.
15'-20'	WS – very soft grey clay, some silt; reddish brown layers and black mottling.
20.1'-22.2'	SS 75-4-29 – red and grey banded clay; black mottling at base of red bands; grey reacts slowly to HCl; five cycles; grey bands up to 6", red to 2" thick.
20.0'-25'	WS – very soft dark grey clay, some reddish brown layers; black mottling.
25'-30'	WS – very dark grey clay with some reddish grey bands; black bands.
30.1'-32.2'	SS 75-4-30 – silty clay, lower half of core has slump structures. Comment: slide debris occurring beneath well stratified, shows slumping was followed by regular deposition in the same basin.
30'-35'	WS – very soft silty clay in grey and brown layers; sulphurous odour.
35'-40'	WS – layers of very soft grey silty clay and brownish grey fine silt or clayey silt; brownish strata have higher % silt and fine sand; black mottling; shell fragments; sulphurous odour.
40.3'-42.4'	SS 75-4-31 – dark grey silt and fine sand, some clay; lower half of core has two red-grey cycles, upper half uniform sandy silt.
40'-45'	WS – soft grey silty clay interstratified with brownish grey silt or clayey silt.
45'-50'	WS – very soft grey and brownish grey clay; black mottling; sulphurous odour.
50.1'-52.2'	SS 75-4-32 – lower half of core is red silty clay with distorted thin grey band at 52.0'; upper half of core is grey silty clay grading upwards to pink or red.
50'-55'	WS – very soft grey (85%) and brownish grey (15%) clay, some silt; light sulphurous odour; black mottling in brownish layers.
55'-60'	WS – very soft grey clay, some silt; black and brown mottling; sulphurous odour.
60.1'-62.2'	SS 75-4-33 – red and grey clay with black mottling bands in red; three grey-red cycles.
60'-65'	WS – very soft grey clay with some silt (60%) with black and brownish grey banding (40%); sulphurous odour.
65'-70'	WS – similar to material at 60'-65', less black mottling.
70.2'-72.3'	SS 75-4-34 – distorted red and grey bands; axis of distortion in horizontal plane; marble-like appearance; very little mottling.
70'-75'	WS – very soft grey clay, some silt; black bands and mottling, some reddish brown colour; light sulphurous odour.
75'-80'	WS – very soft grey and brownish grey clay, some silt, minor black mottling.
80.0'-82.1'	SS 75-4-35 – banded grey and red clay; slumping between 81.4' and 81.8'; no reaction to HCl.
80.0'-85.2'	WS – very soft grey clay and silt (no brown or red), some sand, some angular to sub-angular pebbles (to 10 mm); very shelly.
85.2'	refusal on bedrock.
85.2'-85.8'	WS – angular fragments of shale and limestone.

BORING #75-5
(Wendover Site – Top of Scarp)

0'-3.5'	WS – medium to fine grained, buff sand.
2'-5'	WS – brown clayey silt and medium sand; silt is firm.
5'-10'	WS – brown and grey silty clay with layers of sand, silt; variations in rate of drill advance identified with sand, silt, and clay.
10.1'-12.2'	SS 75-5-38 – alternating 2" red bands and grey silty clay mark 4 1/2 sedimentary cycles within core; grey layers have silt and sand partings.
10'-15'	WS – very soft grey silty clay with some brown silt, some sand.
15'-20'	WS – very soft grey silt and clay; some sand.
20.3'-22.4'	SS 75-5-39 – mainly very soft grey silty clay with some indistinct reddish grey zones, no clear banding.
20'-25'	WS – very soft grey clay, some silt.
25'-30'	WS – very soft grey clay, some silt.
29.9'-32.0'	SS 75-5-40 – banded red and grey silty clay with some silt bands; 4 1/2 grey-red sedimentary cycles in core.
30'-35'	WS – very soft grey clay, some silt, red bands.
35'-40'	WS – very soft grey and reddish brown layers of silty clay.
40.1'-42.2'	SS 75-5-41 – soft silty clays; nine grey-red sedimentary cycles; some with minor silt bands.
40'-45'	WS – very soft reddish brown (20%) and grey (80%) layers of silty clay; some sand partings.
45'-50'	WS – very soft grey silty clay; some reddish bands.

50.0'-52.1'	SS 75-5-42 – thin-bedded grey and red silty clay bands; bedding indistinct; some tilting of beds.
50'-55'	WS – very soft grey silty clay; some reddish grey bands.
55'-60'	WS – very soft grey silty clay, some reddish grey bands.
60.1'-62.2'	SS 75-5-43 – thin bedded red and grey silty clay with sand, some stones; distorted or slumped zone in upper middle part of core (60.6'-60.9').
60'-63.2'	WS – very soft grey silty sandy clay with angular and subangular stone fragments.
63.2'-64.2'	WS – fossiliferous limestone (grey to dark grey), some calcareous claystone.

BORING #76-24
(Plaisance Site)

10.0'-12.1'	SS 76-24-162 – all rusty reddish brown silty clay, some mottling of reddish colour, some distortion in upper 6" and lower 6" of core; otherwise massive.
20.0'-22.1'	SS 76-24-163 – cyclic banding in red grey clay and silty clay; erosion breaks; clay relatively soft. (From base) 0'-0.35' – reddish brown silty clay; 0.35'-0.45' – truncated grey band; 0.45'-0.6' – red silty clay; base in diagonal erosional contact with underlying grey clay; 0.6'-0.85' – grey band with 1" black mottled zone in middle; 0.85'-1.05' – red band; 1.05'-1.25' – grey band with 1" black mottled band in middle; 1.25'-1.58' – red clay band; strata tilted; 1.58'-1.8' – grey silty clay; 1.8'-2.1' – red band with sand partings, grades downwards to light grey.
30.0'-32.1'	SS 76-24-164 – 0'-0.1' – grey band; 0.1'-0.5'/0.6' – red band with black mottling at 0.4'; 0.5'/0.6'-0.9' – grey band with diagonal erosional contact; 0.9'-1.5' – red band, black mottling between 0.9' and 1.2'; 1.5'-1.65' – grey band, sharp upper contact, gradational lower contact; 1.65'-2.1' – red clay band; three black bands between 1.7' and 1.9'.
40.8'-42.2'	SS 76-24-165 – 1.4' recovery; 0'-0.2' – red clay band; 0.2'-0.6' – grey silty band, black mottling in middle of band; 0.6'-1.0' – indistinctly stratified red silty clay; 1.0'-1.35' – grey band; speckled with black in middle layer; diagonal erosional contact at base; 1.35'-1.4' – red band. Cyclic stratification with erosional contacts = upper delta.
50.0'-52.1'	SS 76-24-166 – 0'-0.05' – grey band; 0.05'-0.12' – red band, possible erosional break at top of red (diagonal contact observed in core before splitting); 0.12'-0.35' – grey band with some black mottling; 0.35'-0.6' – red band with grey partings, black mottling at 0.4'-0.55'; 0.6'-0.9' – grey band; 0.9'-1.3' – pink to red clay band, black mottling at 1.1'-1.3'; 1.3'-1.7' – grey silty clay, very distinct black band 1/4" thick at 1.7'; 1.7'-2.1' – banded red and grey silty clay with black bands at 1.9' and 1.75'.
60.0'-62.1'	SS 76-24-167 – 0'-0.3' – grey band, mottling at 0.2'; 0.3'-0.7' – red grading downward to grey; gradational contact; upper contact sharp; 0.7'-1.36' – grey band; 1.36'-1.78' – red band; grades upwards to grey; 1.78'-2.1' – grey band with discrete black bands near lower contact.
70.0'-72.1'	SS 76-24-168 – 0'-0.15' – red clay band; 0.15'-0.75' – grey band with black mottling between 0.35' and 0.55'; 0.75'-1.15' – pink band, black mottling in lower half; 1.15'-1.95' – grey band, black mottling between 1.25' and 1.65'; 1.95'-2.1' – pinkish grey band with black mottling.
80.0'-82.1'	SS 76-24-169 – 2.0' recovery; 0'-0.45' – thin-bedded red and grey silty clay, alternate distinct layers; 0.45'-0.7' – grey silty sand; 0.7'-1.3' – coarse red silt and silty clay; 1.3'-2.0' – massive reddish brown silty clay with sand "balls"; possibly sections of worm tubes?
90.0'-92.1'	SS 76-24-170 – 0'-0.45' – indistinctly bedded red silt and coarse red silt, sand parting at 0.2'; thin light grey band at 0.05'-0.1'; 0.45'-0.95' – grey silt with some reddish bands; 0.95'-1.4' – strata dip at ~30° across sample as shown by black mottling bands; material is relatively massive reddish grey clay and silty clay; 1.4'-1.65' – relatively massive red clay; 1.65'-2.1' – coarse grey silt and clayey silt.
100.0'-102.1'	SS 76-24-171 – 2.0' recovery; 0'-0.6' – red silty clay with irregular black mottling and bands; 0.6'-1.0' – grey silty clay with black mottling at 0.75'; 1.0'-1.6' – red band grading downwards to grey, black mottling bands between 1.05' and 1.2'; 1.6'-1.85' – black mottled grey silty clay; 1.85'-2.0' – red silty clay.
110.0'-112.1'	SS 76-24-172 – 0'-0.25' – light grey coarse silt; 0.25'-0.55' – reddish grey silty clay with black mottling in lower half; 0.55'-0.75' – grey silty clay, black mottling at 0.55' and 0.85'; 0.75'-1.2' – red silty clay with some indistinct grey zones; 1.2'-1.35' – indistinct grey band, some reddish coloration; 1.35'-1.9' – indistinctly stratified red silty clay with black mottled bands 1/2"-1" thick at 1.4' and 1.5'; 1.9'-2.1' – grey silty clay.
120.0'-122.1'	*SS 76-24-173 – sample too brittle or stiff to cut with wire saw. 0'-1.5' – stratified light and dark grey silty clay with numerous black sulphurous bands; 1.5'-1.65' – red silty clay; 1.65'-2.1' – dark grey silty clay, black mottled and banded.
130.0'-132.1'	*SS 76-24-174 – banded light and dark grey clay with numerous black bands; shell fragments at 1.1', 1.3', and 1.4'.
140.0'-142.1'	*SS 76-24-175 – all dark and light grey, indistinctly banded clay; numerous black layers at 1"-2" intervals.
150.0'-152.1	*SS 76-24-176 – all indistinctly stratified dark and light grey silty clay, very stiff; numerous black bandings and mottlings.
170.0'-172.1'	SS 76-24-177 – relatively massive blue-grey to dark grey silty clay, some black mottling; shell fragment at 0.75' above base.
190.0'-192.1'	SS 76-24-178 – all dark grey silt and silty clay; black mottling, indistinct banding throughout; shell fragments (**Portlandia**?) at 1.6' and 1.7' above base.
210.0'-212.1'	SS 76-24-179 – all dark grey to black, mottled, indistinctly stratified to massive silt; shell fragments at 1.75' and 1.9'; sulphurous odour; very stiff, not sensitive.
230'	sample tube pushed only 1.5' to refusal; no recovery.
235'	no sample
231.5'-237.3'	WS 76-24-180 – probable till.
	Hole ends at refusal at 237.3'.

BORING #75-6
(Treadwell Site)

0'-5'	WS1 – hard to very stiff sandy brown clay with reddish strata.
5'-10'	WS2 – very stiff silty brown clay, some sand.
10'-15'	WS3 – firm silty brown clay with reddish layers, some sand.
15'-20'	WS4 – red, brown, and grey, firm to soft silty clay.
20'-25'	WS5 – grey silty clay with fine sand lenses.
25'-30'	WS6 – 25'-26' – fine grey sand; 26'-30' – soft silty grey clay with sand partings.
30'-35'	WS7 – 30'-32.5' – soft silty grey clay and sand; 32.5'-35.0' – silty fine grey sand.
35'-40'	WS8 – silty fine grey sand.
40'-45'	WS9 – 40'-43' – fine silty grey sand; 43'-45' – very soft, grey silt and clay.

* Cores 76-24-173 through -176: materials were very stiff, cutting with great difficulty with wire saw or spatula; samples were much broken up by attempts to cut.

45'-50'	WS10 – very soft grey and reddish brown silty clay; some sand lenses.
50'-55'	WS11 similar to WS10, grey 80%, red 20%.
55'-60'	WS12 – 55'-59' – grey and red silty clay, some sand; 59'-60' – fine grey sand.
60'-65'	WS13 – very soft clayey silt, some sand; reddish clay 30%, grey 70%.
65'-70'	WS14 – similar to WS13.
70'-75'	WS15 – reddish grey silt and clay, some sand.
75'-80'	WS16 – similar to WS15.
80'-85'	WS17 – grey (70%) and red (30%) very soft silty clay, some sand.
85'-90'	WS18 – similar to WS17.
90'-95'	WS19 – similar to WS17.
95'-100'	WS20 – similar to WS17.
100'-150'	WS21 – grey (70%) and reddish brown (30%) very soft silty clay; some sand lenses mainly between 148' and 150'.
150'-213'	no wash samples; materials similar to WS21, some black mottling; hole washed to 228', casing pushed to 238'.
238'-318'	WS22 similar to WS21; 300'-318' – firm, very dark grey silty clay, black mottling, sulphurous odour.
318'-321'	WS23 – stiff dark grey silty clay; shell fragments, black mottling.
338'-340'	gravel; rounded pebbles 3-7 mm diameter and silty clay.
	Bedrock at 340' – cored NX 340.3'-345.3'.

BORING #75-6A
(Treadwell Site)

19.8'-21.9'	SS 75-6A-46 – stratified red and grey silty clay; very distorted, marble texture; some black mottling.
39.9'-42.0'	SS 75-6A-47 – measuring from base of core; 0'-0.5' – reddish brown clay; 0.5'-2.1' – fine grained grey sand.
60.0'-62.1'	SS 75-6A-48 – stratified red and grey silty clay; beds irregular and distorted; some sand partings; irregular boundaries between colour and textural units.
80.1'-82.2'	SS 75-6A-49 – 0'-0.4' – interstratified sand, silt, clay; 0.4'-2.1' – fine grained grey sand, contorted, disturbed.
99.7'-101.8'	SS 75-6A-50 – bed of sand with clay layers, distortions, overlies banded grey clay in irregular strata; dipping beds, distortions; one pebble.
120.0'-122.1'	SS 75-6A-51 – highly distorted, colour-banded red and colour-banded grey clays, some sand; some beds in near-vertical attitudes; dipping beds.
140.1'-142.2'	SS 75-6A-52 – cyclic stratification of thick beds (8"-10") of red and grey clay; horizontal stratification; black mottling.
160.1'-162.2'	SS 75-6A-53 – red and grey banded silty clay and clay; some beds tilted and interstratified with horizontal beds.
180.0'-182.1'	SS 75-6A-54 – cyclically alternating thick-bedded red and grey clays; black bands; some disturbance in upper red layer.
200.2'-202.3'	SS 75-6A-55 – colour-banded light and dark grey clay; six black bands in core.
225.1'-227.2'	SS 75-6A-56 – colour-banded light and dark grey clay; black mottled; H_2S odour.
250.1'-252.2'	SS 75-6A-57 – massive dark grey clay and silty clay with black-mottled bands; very stiff; shell fragments throughout.
275.1'-277.2'	SS 75-6A-58 – massive to indistinctly colour-banded grey clay; black mottling; some shell fragments.
300.2'-302.3'	SS 75-6A-59 – massive mottled grey clay, lower 2" is interbedded silt and clay (varves?).
324.0'	sandy grey till.
327.5'	bedrock.

BORING #76-25
(Fassett Site)

0'-1.3'	sandy loam topsoil.
1.3'-10.3'	fine-grained grey silty to sandy clay.
10.3'-12.4'	SS 76-25-181 – fine grained to medium grained sand (overlain by 10' clay).
19.6'-21.6'	SS 76-25-182 – grey, stratified, fine grained to medium grained sand.
30.0'-32.1'	SS 76-25-183 – measuring from base of core; 0'-0.2' – red silt; 0.2'-0.8' – stratified grey clay, with black mottling at 0.5'-0.6'; 0.8'-1.35' – pink to pinkish grey indistinctly stratified silty clay; 1.35'-1.9' – grey and dark grey stratified silty clay; black mottling at base; 1.9'-2.04' – pinkish grey silty clay; dipping basal contact; 2.04'-2.1' – sand layer with diagonal basal contact. (possible drill debris).
40.0'-42.1'	SS 76-25-184 – 0'-0.5' – grey band, black mottled in middle of band; 0.5'-0.9' – red band with black mottling; 0.9'-1.1' – grey band grading to red; 1.1'-2.1' – red clay grading downwards to grey; black mottling between 1.25' and 1.4', 1.7' and 2.1'. Some sand injected into upper end of core during sampling.
50.0'-52.1'	SS 76-25-185 – 0'-0.45' – grey, vaguely stratified clay and silty clay, black mottling; 0.45'-0.7' – pinkish grey band, indistinct, black band at top; 0.7'-1.5' – grey, much black mottling; 1.5'-1.8' – pink band, pocket of black material (about a fossil?) at 1.55'; 1.8'-2.1' – grey silty clay with mottling between 1.85' and 1.95'. Small artesian flow while sampler at 52.1'.
60.0'-62.1'	SS 76-25-186 – 0'-0.25' – grey band; 0.25'-0.45' – red band; 0.45'-0.85' – grey band, black mottling at 0.65'-0.75'; 0.85'-1.15' – red band; 1.15'-1.55' – grey band; 1.55'-1.75' – red band; 1.75'-2.1' – grey band with black mottling at 1.85'-2.0'.
70.0'-72.1'	SS 76-25-187 – 2.1' of essentially massive very stiff red clay and silty clay.
80.0'-82.1'	SS 76-25-188 – irregularly and indistinctly banded red and grey silty clay. 0'-0.1' – pink to reddish brown; 0.1'-0.25' – grey; 0.25'-0.8' – pinkish grey; flat stony disc across tube in horizontal position, shale fragment or concretion (?) at 0.35'; 0.8'-1.15' – grey, dark nodule, possibly pebble with pyrite at 0.8'; 1.15'-1.45' – pink; 1.45'-1.9' – light and dark grey; 1.9'-2.1' – pink and grey.
90.0'-92.1'	SS 76-25-189 – 0'-0.1' – dark grey fairly coarse silt with black mottling bands; 0.1'-0.6' – indistinctly banded red clay grading downwards to grey; 0.6'-0.85' – grey with thin bands of black mottling, sharp lower contact; 0.85'-1.2' – pink grading downwards to grey, black mottling bands thickest of which is 1.0'-1.05'; 1.2'-1.3' – mainly grey; 1.3'-1.4' – alternating red and grey bands; 1.4'-1.7' – grey silty clay with black mottling at 1.6'-1.75'; 1.7'-2.1' – mainly pink, some grey clay; indistinctly banded, black mottling at 1.9'-1.95'.
100.0'-102.1'	SS 76-25-190 – regularly banded red and grey silty clay and clay; red is dominantly clay, grey is dominantly silt. 0'-0.06' – grey with black band at base; 0.06'-0.3' pink band grading downwards to grey; 0.3'-0.5' – grey band, sharp lower contact, very black band at 0.48'-0.5'; 0.5'-0.7' – pink band grading downwards to grey; 0.7'-0.72' – dark grey mottled band with sharp lower contact; 0.72'-0.9' – indistinctly banded grey silty clay;

0.9'-1.3' – red grading downwards to grey, sharp upper contact; black line at top of red; blue-grey clay ball 5 mm diameter at 1.26'; black banding and mottling from 0.9'-1.05'; 1.3'-1.5' – relatively massive grey clayey silt; 1.5'-2.0' – stratified pink and red (some grey) silty clay; 2.0'-2.1' – grey silty clay.

110.0'-112.1' SS 76-25-191 – cyclic stratification of red and grey silty clays; red not distinct. 0'-0.1' – red band; 0.1'-0.4' – grey with some black mottling, sharp lower boundary; 0.4'-0.65' – pinkish to brownish grey clays grading downwards to grey; 0.65'-1.0' – grey band with black mottling, all boundaries gradational or diffuse; 1.0'-1.35' – pink grading downwards to grey; 1.35'-2.1' – grey-brown grading to grey, speckled black mottling in upper part. Sand blebs or partings at 0.55' and 1.2'.

120.0'-122.1' SS 76-25-192 – 0'-0.4' – red clay with thin sand partings; 0.4'-0.5' – grey band; 0.5'-1.9' – relatively massive red clay with some thin sand partings; 1.9'-2.1' – grey silty clay, erosional lower contact with red clay.

130.0'-132.1' SS 76-25-193 – recovery 1.8'; all relatively massive dark reddish brown to brick-red clay; a few lenses or discontinuous partings of sand; no mottling.

140.0'-142.1' SS 76-25-194 – red clay throughout with numerous small sand "blebs" – possible worm-tube casts; discontinuous layers.

150.0'-152.1' SS 76-25-195 – regularly banded silt, clay, minor sand; clay is pinkish grey to red, remainder is dark grey. Fossil (**Portlandia**?) at lower end of tube; some other fragments.

160.0'-161.1' WS 76-25-196 – mainly gravel and thin layers of till.

161.1' bedrock.

BORING #74-8
(Venosta Site)

0'-2' gravel fill.

2'-20.4' sand, silty sand, some clay.

20.4'-22.5' SS 74-8-70 – alternate strata of uniform fine grained silty sand and dark grey silt clay; sand units to 0.75', clay units to 0.3'; some very thin sand partings in clay layers.

22.5'-24.6' SS 74-8-71 – lower part of sample lost; upper half is stratified silty clay (0.5') overlain by fossiliferous (frags.) silty grey sand; pebble in upper 2".

25.0'-26.8' PS 74-8-72 – alternate strata (0.4'-0.5') of sand and stratified clay; lower part of clay is dark grey, grading upwards to light grey.

26.8'-28.6' PS 74-8-73 – alternate strata (0.5'-0.66') of sand and stratified clay; clay grades upwards into sand.

28.7'-30.5' PS 74-8-74 – cyclically stratified; grey clay grading upwards into sand; three cycles in core; basal contact of dark grey clay with underlying light grey sand is sharp and distinct; some interstratification of clay and sand in transition zones.

30.5'-32.6' SS 74-8-75 – thick clay-sand cycles; three cycles in core; couples consist of stratified grey silty clay with some sand partings grading upwards into fine grey sand.

32.6'-34.7' SS 74-8-76 – lower 0.5' of core lost; 2 1/2 cycles of stratified silty clay and fine silty grey sand.

34.7'-36.5' PS 74-8-77 – highly saturated material slipping from tube as removed from boring; 1.3' recovery; laminated grey silty clay grading upwards into fine grey silty sand; units ca 0.5'.

36.8'-38.6' PS 74-8-78 – strata of variable thickness. 0'-0.9' – grey sand; 0.9'-1.0' – dark grey clay; 1.0'-1.45' – light grey clay; 1.45'-1.6' – interstratified clay and sand; 1.6'-1.7' – grey sand; 1.7'-1.85' – dark grey clay; 1.85'-2.1' – light grey clay. Grading is fine to coarse upwards in cycle; gradational contacts, except at top of sand unit where overlying clay has sharp basal contact.

39.4'-42.1' – PS 74-8-79 – two cycles of laminated grey clay grading upwards through interstratified silt and sand to sand.

45.4'-47.5' SS 74-8-80 – recovery 0.9'; parts of two cycles of dark grey clay overlain by light grey banded clay and sand.

50.1'-51.9' PS 74-8-81 – 1 1/2 cycles of grey stratified clay grading upwards to clay with some sand partings, overlain by sand; units 0.5'-0.6' thick; black band (1") at base of core in grey clay unit (first encountered in this boring); calcareous clays.

55.4'-57.2' PS 74-8-82 – three cycles of dark grey clay grading upwards to light grey clay, light grey clay with sand partings and sand; sand of uppermost cycle rests on an erosional surface.

59.6'-61.4' PS 74-8-83 – cyclic deposition of dark and light grey clay and grey sand; one 5" sand layer, but clay dominant; low free carbonate content.

64.6'-66.4' PS 74-8-84 – cyclic stratification of dark and light grey clay, no sand; three cycles.

69.5'-71.6' SS 74-8-85 – most of sample lost; portion recovered was fine sand and silty clay (may not be representative).

72.4'-74.2' PS 74-8-86 – dark and light grey clays in cyclic sequence (two cycles); 2" sand layer in middle of core, sharp contacts; some H_2S odour in sand; all strongly calcareous.

75.4'-77.2' PS 74-8-87 – 2" sand layer with sharp upper and lower contacts separates two cycles of banded grey clays; dark grey at base grading upwards to light grey; strongly calcareous.

79.6'-81.4' PS 74-8-88 – relatively massive grey clays; indistinct colour banding; calcareous.

84.7'-86.5' PS 74-8-89 – sensitive, relatively massive grey clay with indistinct dark-light colour banding; some thin silt bands; low free carbonate content.

89.8'-91.6' PS 74-8-90 – clays very sensitive, near liquefaction on remolding; core consists of four cycles of grey clay overlain by grey silt; clay units up to 0.5', silt 0.08'-0.25'; thicker clay strata colour banded dark grey at base grading to light grey upwards; low free carbonate content.

94.7'-96.5' PS 74-8-91 – massive to indistinctly colour-banded grey clay; one 2" silt band.

100.0'-101.8' PS 74-8-92 – 1" of sand at base of core; massive to indistinctly colour-banded grey clay; one 2" silt band; low carbonate content.

104.8'-106.6' PS 74-8-93 – massive grey clay with low free carbonate content has sand layer (0.5'-0.9' above base) with erosional lower contact.

109.8'-111.6' PS 74-8-94 – at top and bottom of sample are 5" layers of massive dark grey clay; lower bed grades upwards into alternating silt and clay bands, with silt content increasing upwards; upper clay unit has sharp contact with underlying silt; all calcareous.

114.5'-116.6' SS 74-8-95 – lower 6" of core is massive light and dark grey clay with a few silt partings; upper 2/3 of sample is disturbed banded silt and clay; possible flame structures (load-cast) and/or intraformational slumping.

119.7'-121.8' SS – no recovery.

121.9'-123.7' PS 74-8-96 – colour-banded, light and dark grey clay and silt couples – "pseudo-varves?"; intraformational slumping in lower 4"; calcareous.

125.3'-127.1' PS 74-8-97 – varve-like stratification of dark and light grey clay and silty clay in 1/2" couples; one shell fragment; calcareous; light H_2S odour.

130.0'-131.8' PS 74-8-98 – dark and light grey colour-banded clay and silty clay; a few sand partings; very sensitive; strongly calcareous.

135.4'-137.2' PS 74-8-99 – pseudo-varve laminations of dark and light grey clay and silty clay; strongly calcareous.

140.0'-141.8' PS 74-8-100 – clay is very sensitive, strongly calcareous; indistinct colour banding in lower portion, upper 5" is varve-like; two distinct whitish grey silt bands (1/2").

145.1'-146.9' PS 74-8-101 – massive to indistinctly banded grey clay; soft, sensitive, calcareous; three thin white silt bands.

149.7'-151.5' PS 74-8-102 – lower 6" of core is interstratified silt and clay; upper 12" of core is distorted banded clays (intraformational slumping?).

159.8'-161.6' PS 74-8-103 – interbedded sand, silt, clay; tilted beds, some discontinuous; clay very sensitive; very calcareous.

167.9' casing harder to drive – stratal change.

170.0'-171.5' attempted hard wall sample – no recovery; but hole made sand and gravel 6' up casing, therefore from 167.9', possible gravelly till.

171.5' refusal on bedrock or boulder.

BORING #75-3
(Wakefield Site)

0'-5' WS1 – very stiff silty grey clay, medium plasticity; some oxidation; small stones 2-5 mm.

5.0'-7.2' SS 75-3-18 – brownish grey silty clay; fissured, oxidized.

5.0'-10.0' WS2 – stiff to firm brownish grey silty clay; some sand.

10.1'-12.2' SS 75-3-19 – stiff to firm grey silt clay with some sand; fissured, oxidized; shell fragments; strong reaction to HCl.

10'-15' WS3 – brownish grey stiff to firm silty clay, some sand, change from stiff to firm at 14'.

15.1'-17.2' SS 75-3-20 – firm to soft brownish grey silty clay; no sand; shell fragments; strongly calcareous.

15'-20' WS4 – soft brownish to olive grey silty clay; some sand; shell fragments.

19.8'-21.9' SS 75-3-21 – soft, sensitive silty grey clay; strongly calcareous; a few indistinct brownish grey bands (granite pebble on top of core).

20'-25' WS5 – two components: upper 3' is brownish grey very soft silty clay, some sand, shells; lower 2' is dark grey, very soft silty clay, finer than upper part; shells.

24.8'-26.9' SS 75-3-22 – dark grey silty clay grading upwards to light grey silt, overlain by tilted sand layer (1.5"), overlain in turn by cyclically banded silt-clay strata with sand partings, sandy silt and grey clay.

25'-30' WS6 – very soft grey clayey silt; a few granules (2-5 mm).

30.0'-32.1' SS 75-3-23 – grey clayey silt; distorted light grey silt and dark grey clay strata; strongly calcareous.

30'-35' WS7 very soft clayey silt – some sand grains.

35.0'-37.1' SS 75-3-24 – recovery 1.2'; probably pebble or cobble in hole at 35'; very soft, grey clayey silt; distorted (possibly due to obstruction in boring).

35.0'-40' WS8 – very soft, steel-grey clayey silt, some sand. Note – after casing washed to 40.1' and Shelby tube lowered, driller could 'feel' hard material in bottom of hole, therefore put 3" hard wall sampler down, pushed from 40.1'-41.0' and recovered 0.7' silt, fine sand, and a pebble 2.5", which may have been the cause of poor recovery in SS 75-3-23 and -24.

41.3'-43.4' SS 75-3-25 – irregularly banded dark and light grey clays in layers 1"-3" thick; strongly calcareous.

40'-45' WS10 – very soft steel-grey clayey silt; shell fragments.

45.0'-47.1' SS 75-3-26 – recovery 2.1'; colour-banded dark and light grey silty clay; six cycles in core; shell fragments.

45'-50' WS11 – very soft clayey silt to silty clay, some fine grey sand; small granules and shell fragments.

50.0'-52.1' SS 75-3-27 – very soft grey clayey silt interstratified with lenses of fine grey sand; strongly calcareous.

50'-55' WS12 – very soft clayey silt with fine sand layers; some gravel.

55'-60' WS13 – clean gravel, some coarse sand, rounded pebbles to 1.75".

60'-65' WS14 – clean gravel, large pebble fragments.

65'-70' WS15 – two components: 65'-68' – clean gravel; 68'-70' – medium to coarse sand.

70'-73.7' WS16 – clean gravel.

73.7'-75.7' WS17 – clean gravel.

75.7' refusal on bedrock.

BORING #76-22
(Touraine Site)

0'-0.6' fill.

0.6'-4.5' brownish grey clay.

4.5'-5.8' buff sand.

5.8'-7.9' SS 76-22-122 – 0'-1.5' – very stiff clay; 1.5'-2.1' – sand. Clay is olive-brown, too dessicated and friable to cut for photo; sand is uniform and contact sharp.

10.0'-12.1' SS 76-22-123 – stiff, dessicated, olive-brown to grey clay; two 0.5 cm red bands; bedding horizontal.

15.0'-17.1' SS 76-22-124 – massive, fossiliferous grey clay; a few shiny (copper and black) grains.

20.0'-22.1' SS 76-22-125 – massive to indistinctly banded grey clay; fossiliferous. Shiny metallic specks; shell fragments seem to be weathered.

25.0'-27.1' SS 76-22-126 – upper foot is massive grey clay grading downwards into 3"-4" sandy silt layers, grading downwards, in turn, into banded red and grey clay.

30.0'-32.1' SS 76-22-127 – vaguely banded grey clay with red bands; one silt layer approximately 1".

35.0'-37.1' SS 76-22-128 – indistinctly banded clays; three colour-band cycles; (from base of core) 0'-0.5' – dark grey clay; 0.5'-0.525' pink clay; 0.525'-1.3' – light grey grading upwards to dark grey clay; 1.3'-1.325' – pink clay; 1.325'-2.1' – light grey silty clay grading upwards to dark grey clay and silty clay.

40.0'-42.1' SS 76-22-129 – cyclically banded silty clay and silt. 0'-1.25' – irregular banded dark grey and light grey silty clay; distortion in band at 1.1'; 1.25'-1.30' – pink band, 1.30'-1.4' – light grey silty clay, 1.4'-2.1' – dark grey silty clay (broken sand layer at 1.55').

45.0'-47.1' SS 76-22-130 – recovery 1.95'; 0'-0.6' – relatively massive dark grey silt to silty clay; 0.6'-0.63' – pink band; 0.63'-0.85' – light grey silty clay; 0.85'-1.95' – dark grey silt and silty clay with minor sand partings.

50.0'-52.1' SS 76-22-131 – 0'-0.66' – irregularly and indistinctly bedded dark grey silt and silty clay; 0.66'-0.68' – pinkish grey band; 0.68'-0.8' – light grey silty clay; 0.8'-2.1' – relatively massive, indistinctly banded dark grey silty clay and silt (narrow pinkish band at 0.825').

55.0'-57.1' SS 76-22-132 – 2' recovery; 0'-0.14' – dark grey silty clay; 0.14'-0.15' pink clay; 0.15'-0.3' – light grey silty clay; 0.3'-2.0' – irregularly bedded, relatively uniform dark grey silt with numerous sandy zones (not discrete sand layers); sensitive.

60.0'-62.1' SS 76-22-133 – 2.05' recovery; cycle 1: 0'-0.65' – dark grey massive to vaguely banded silt and silty clay; some sand grains; 0.65'-0.67' – pink clay; cycle 2: 0.67'-0.87' – light grey silty clay; 0.87'-1.87' – vaguely banded to massive dark grey silty clay; some sand grains; 1.87'-1.88' – pink band; cycle 3: 1.88'-2.05' – light grey silty clay; cycles fining upwards.

65.0'-67.1' SS 76-22-134 – 2.0' recovery; 2^+ cycles. 0'-0.05' – pink band grading downward to dark grey; cycle 1: 0.05'-0.2' – light grey silt; 0.2'-0.96' – vaguely stratified to texture-mottled dark grey silt; 0.96'-1.0' – pink clay; cycle 2: 1.0'-1.15' – light grey silty clay; 1.15'-2.0' – dark grey silty clay with irregular mottled texture, coarse and fine silt, silty clay.

70.0'-72.1' SS 76-22-135 – 2.1' recovery; mainly dark grey coarse silt; red band at 0.2'; very coarse silt at 0.2'-1.3'.

75.0'-77.1' SS 76-22-136 – 2.1' recovery; three cycles. cycle 1: 0'-0.44' – dark grey coarse silt, some sand grains; 0.44'-0.45' – pink clay; cycle 2: 0.45'-0.6' – light grey silty clay; 0.6'-1.44' – dark grey coarse silt, some sand grains; 1.44'-1.48' – pink clay; cycle 3: 1.48'-1.6' – light grey silty clay; 1.6'-2.1' – coarse dark grey silt, some sand grains.

80.0'-82.1' SS 76-22-137 – parts of four cycles. cycle 1: 0'-0.38' – dark grey silty clay; 0.38'-0.42' – pink clay; cycle 2: 0.42'-0.5' – light grey silty clay; 0.5'-1.12' – dark grey silty clay and silt; 1.12'-1.14' – pink silty clay; cycle 3: 1.14'-1.20' – light grey silty clay; 1.20'-1.83' – dark grey silty clay – shell fragment; 1.83'-1.86' – pink silty clay; cycle 4: 1.86'-1.9' – light grey silty clay; 1.9'-2.0' – dark grey silty clay.

85.0'-87.1' SS 76-22-138 – thin-bedded coarse to fine silt and silty clay; rhythmicity suggested by presence of three pink bands; beds dipping 5°-10°; some minor slump phenomena. 0'-1.77' – fairly massive to irregularly thin-bedded grey silt and silty clay with gently dipping pink bands (0.18' and 0.88'-0.9'), sand partings (1.0'-1.1'); 1.77'-1.8' – pink band; 1.8'-1.84' – light grey; 1.84'-2.1' – dark grey silty clay. (Upper three strata represent clearest sedimentary cycle in core).

90.0'-92.1' SS 76-22-139 – 0'-1.1' – relatively fine grained grey silt and silty clay with dips of ~30° shown by pinkish grey band at 0.8'-0.9', sand partings 1-2 mm thick at 0.2'-0.3'; 1.1'-2.1' – vaguely stratified to massive dark grey very coarse silt with some sand grains; very sandy silt (or silty sand) layer (0.8'-1.1') dips ~30°.

94.9'-97.0' SS 76-22-140 – indistinct bedding, but slump structures and erosional contacts noted, mainly in dark grey silt. 0'-0.04' – pinkish grey silty clay; 0.04'-0.5' – massive grey coarse silt; 0.5'-0.6' – relatively massive dark grey coarse silt, erosional lower contact; 0.6'-0.8' – dark grey fine silt and pinkish grey band with some black mottling; 0.8'-1.7' vaguely stratified dark grey silt grading downwards to light grey; 1.7'-2.1' – sediment lost from top of sample due to liquefaction during extrusion.

100.0'-102.1' SS 76-22-141 – sedimentary cycles mainly light grey grading upwards to dark grey: 0'-0.3', 0.3'-09', 0.9'-1.5', 1.5'-1.75'; pinkish grey bands at 0.9', 1.4', 1.5'; 1.75'-2.1' loss during extrusion.

105.0'-107.1' SS 76-22-142 – six cycles of light grey, dark grey, pink silty clays in core, lower three thin, not distinct. 0'-0.28' – cycle 1; 0.28'-0.62' – cycle 2; 0.62'-0.9' – cycle 3; 0.9'-0.95' – cycle 4; 0.95'-1.48' – cycle 5 (0.95'-1.0' – light grey silt, 1.0'-1.45' – dark grey silt, 1.45'-1.48' – pinkish grey clayey silt); 1.48'-1.94' – cycle 6 (1.48'-1.6' – light grey silty clay, 1.6'-1.92' – dark grey silt and silty clay, 1.92'-1.94' – pinkish grey clay); 1.94'-2.1' – light grey silty clay.

110.0'-112.1' SS 76-22-143 – cyclic stratification of light grey, dark grey, pink strata in repeated triplets. 0'-0.1' – dark grey grading upwards to pink; 0.1'-0.14' – pink band; 0.14'-0.2' – light grey; 0.2'-0.7' – dark grey; 0.7'-0.9' – thin pink band at base overlain by light grey; 0.9'-1.05' – black mottled zone; 1.05'-2.1' – poorly sorted coarse silt with some sand grains; stratification indistinct; fossil fragment.

115.0'-117.1' SS 76-22-144 – mainly dark grey silt, bedding indistinct throughout core; some light grey and pink zones, but no clear cycles; H_2S odour and mottling (0.3'-0.6' mainly). Note – freshly broken surface has oolitic texture (deep basin facies?).

120.0'-122.1' SS 76-22-145 – interstratified red and grey clays. 0'-1.1' – banded red and grey clay and silty clay; red not distinct but cycles are regular, with a) sharp red-grey contact, b) red grading to dark grey (downward), c) dark grey grading to light (downward); 1.1'-2.1' – slump distorted red bands 1-7 mm thick; dipping beds; recumbent folds.

125.0'-127.1' SS 76-22-146 – clearly banded red and grey clay; more red than previous samples. 0'-1.0' – cyclic stratification, alternate light grey – dark grey – red (upward gradation) cycles; four cycles in lower 1'; 1.0'-1.2' – red band; 1.2'-1.6' – vaguely banded grey clay; sharp contact with red below, gradational change upwards to dark grey; 1.6'-1.8' – grey grading upwards to red; 1.8'-2.1' – sharp lower contact, light grey grading upwards to dark grey.

130.0'-132.1' SS 76-22-147 – fossil fragment in top of tube; red-grey banded clay; parts of three cycles featuring sharp contact at top of red band, then light grey grading upwards to dark grey and red.

135.0'-137.1' SS 76-22-148 – 0'-0.4' – light and dark grey banded clay with diffuse black mottled bands; 0.4'-2.1' – red-grey banded clay; red beds not distinct, but upper contact sharp; parts of three cycles.

140.0'-142.1 SS 76-22-149 – massive dark grey clay with numerous black mottled bands; pebble or concretion at top of tube; clay too stiff to cut with wire saw, used spatula and clay broke into pieces like a dessicated clay; yet, clay very sensitive.

145.0'-147.1' SS 76-22-150 – massive to vaguely banded dark to light grey clay, black mottled throughout; clay very stiff, but liquifies on remolding; a few small pebbles (1-2 mm).

150.0'-152.1' SS 76-22-151 – massive grey clay with irregular black bands; fossil fragment in mid-core has nacreous lustre; pebbles.

155.0'-157.1' SS 76-22-152 – massive dark grey clay with irregular black mottling; some fine white specks (fossil fragments?).

160.0'-162.1' SS 76-22-153 – massive dark grey to black clay, irregular black mottling; fossil fragments appear weathered.

164.0'-166.1' SS 76-22-154 – very sensitive, dark grey, black mottled clay; fossil with irregular hinge, likely **Portlandia** sp.; shell soft.

170'	drilling water lost – probable sand layer.
171.1'-173.2'	SS 76-22-155 – very compact dark grey, black-mottled clay.
175.0'-177.1'	SS 76-22-156 – very stiff, black banded dark grey silt and silty clay.
180.0'-182.1'	SS 76-22-157 – variegated varves, mostly tones of grey but upper foot thin-bedded with red winter layers; sandy partings; pebble.
184'-189'	WS 76-22-158 – gravel or gravelly till.
189'	refusal on presumed bedrock.

BORING #74-5
(Davidson's Corners Site).

0'-5'	WS 74-5-33 – grey-brown clay with lenses of silt.
5'-10'	WS 74-5-34 – grey-brown clay; some red bands.
10'-15'	WS 74-5-35 – grey-brown clay.
15'-20'	WS 74-5-36 – clay, grey to light grey, some red bands; some silt.
20'-25'	WS 74-5-37 – clay, steel grey.
25'-30'	WS 74-5-38 – clay, steel grey; some silt.
30'-35'	WS 74-5-39 – clay, steel grey; some silt.
35'-40'	WS 74-5-40 – clay, steel grey.
40'-46.6'	WS 74-5-41 – clay, steel grey; sulphurous odour.
46.6'-48.7'	SS 74-5-48 – clay, dark grey; sulphurous odour; 1" concretion in tube.
50'	hole ends in clay; piezometer tip installed at 50.0' B.G.L.

BORING #74-5A (4.7' west of 74-5)
(Davidson's Corners Site)

0'-30'	hole washed – no samples.
30.0'-32.5'	OS 74-5A-49 – grey clay, some silt.
32.5'-50'	hole washed – no samples.
50'-55'	WS 74-5A-42 – clay, dark grey; some silt.
55'-60'	WS 74-5A-43 – dark grey clay; some silt.
60'-65'	WS 74-5A-44 – clay, dark grey, some silt.
65'-70'	WS 74-5A-45 – clay, dark grey.
70'-72.5'	OS 74-5A-50 – clay, dark grey, black mottling.
70'-75'	WS 74-5A-46 – clay, dark grey.
75'-80'	WS 74-5A-47 – clay, dark grey.
80'-85'	WS 74-5A-48 – clay, dark grey, some silt.
85'-90'	WS 74-5A-49 – clay, dark grey, some red bands; sulphurous odour.
90'-95'	WS 74-5A-50 – clay, dark grey, some silt.
95'-100'	WS 74-5A-51 – clay, dark grey.
100'-105'	WS 74-5A-52 – clay, dark grey.
105'-110'	WS 74-5A-53 – clay, dark grey.
110'-115'	WS 74-5A-54 – clay, dark grey; some red bands.
115'-120'	WS 74-5A-55 – clay, dark grey; stiff.
120'-125'	WS 74-5A-56 – clay, dark grey; black mottling; sulphurous odour.
125'-130'	WS 74-5A-57 – clay, dark grey; red bands; sulphurous odour.
130'-135'	WS 74-5A-58 – clay, dark grey; sulphurous odour; pebble 1/4" diameter.
135'-140'	WS 74-5A-59 – clay, dark grey; fossil fragments.
140'-144.7'	WS 74-5A-60 – clay, dark grey; some silt.
144.7'-147.2'	OS 74-5A-51 – clay, dark grey; some silt.
147.2'-149.3'	SS 74-5A-52 – clay, dark grey; some silt; several rock fragments; shell fragments at top of tube.
149.3'-150.6'	no samples – piezometer tip installed at 150.6'.

BORING #74-5B (5' west of 5A)
(Davidson's Corners Site)

2.0'-4.5'	OS 74-5B-53 – fissured reddish brown clay; some silt and sand.
7.0'-9.5'	OS 74-5B-54 – mottled grey-brown silty clay, some red clay bands; sand at top.
18.0'-20.5'	OS 74-5B-55 – grey clay, some silt; stiff.
35.0'-37.5'	OS 74-5B-56 – grey clay with trace of silt.
37.5'-39.9'	OS 74-5B-57 – clay, dark grey, some silt.
70'-72.5'	OS 74-5B-58 – soft, plastic grey clay; some silt.
86.6'-88.7'	SS 74-5B-59 – smooth, plastic grey clay, some red bands.
90.3'	well-point piezometer tip set at 90.3'.

BORING #74-5C*

35.0'-37.5'	OS 74-5C-X – dark grey clay, some silt; drill cuttings in top of tube, sample discarded.
37.5'-40.0'	OS 74-5C-60 – dark grey clay with some silt, some red bands.

BORING #74-5D*

35.0'-37.5'	OS 74-5D-61 – grey clay, some silt.
37.5'-40.0'	OS 74-5D-62 – grey clay, some silt.

BORING #74-5E*

35.0'-37.5'	OS 74-5E-63 – grey clay; 1" diameter concretion at top of tube.
37.5'-40.0'	OS 74-5E-64 – grey clay.

BORING #74-6
(Davidson's Corners Site)

0'-9'	sand.
9'-65'	clays; at 65' silty sand with pebbles (till?); hole making water at 62'.
65'-67'	HW 74-6-61 – medium to coarse sand with gravel, large granite gneiss pebbles.
65'-70'	WS 74-6-62 – sand and gravel, some silt; subangular pebbles to 0.75".
70'-72'	HW 74-6-63 – compact silt, sand and gravel – probable till; cable stuck in bottom of samples, recovery 0.6'. hole made water at faster rate than 10' higher in section; SO_2 odour.
70'-72.9'	WS 74-6-64 – fine to coarse gravel, subangular pebbles of Precambrian rock types.
72.9'-74.0'	WS 74-6-65 – fine to coarse gravel.
74.0'-74.9'	WS 74-6-66 – gravel.
78.4'	bedrock or large boulder (hole still making water).
74.9'-79.9'	DD 74-6-67 – 4.9' recovery
	piezometer tip set at 69.85'.

BORING #74-6A
(Davidson's Corners Site)

46.6'-48.7'	SS 74-6A-65 – grey silty clay.
	piezometer tip set at 49.9'.

BORING #74-6B
(Davidson's Corners Site)

16.6'-18.7'	SS 74-6B-66 – grey silty clay.
	piezometer tip set at 20.0'.

* Three borings 74-5C, -5D, -5E, closely spaced beside -5B, were drilled to obtain multiple samples for studies of engineering properties.

BORING #74-7
(Davidson's Corners Site)

31.6'-33.7' SS – sample lost; grey silty clay

piezometer tip set at 35.0'.

BORING #74-7A
(Davidson's Corners Site)

31.6'-33.7' SS 74-7A-67 – grey silty clay.

69.6'-71.7' SS 74-7A-68 – grey silty clay.

piezometer tip set at 73.0'.

BORING #74-7B
(Davidson's Corners Site)

109.6'-111.7' SS 74-7B-69 – stiff grey silty clay.

piezometer tip set at 113.0'.

BORING #76-26
(Sheenboro Site)

0'-10' WS – river gravel; capping of silt at surface.

10'-18' WS – sand.

20.4'-22.0' SS 76-26-197 – 1.7' extruded; irregular cycles of red clay, silty sand, and sand, repeating (ascending order); (from base of core) 0'-0.2' – fine grained silty sand; 0.2'-0.35' – red clay grading upwards to silty grey sand; 0.35'-0.75' – red clay – silty sand – sand cycle; 0.75'-1.30' – red clay – silty sand – sand cycle; 1.3'-1.7' – red clay (0.025' thick) – silty sand – fine grained sand cycle.

30.0'-32.1' SS 76-26-198 – very fine grained sand; one clay band at 0.75' above base of core.

40.0'-42.1' no sample; wash return suggests material is fine sand.

45.0'-47.1' SS 76-26-199 – 1.4' recovery; 0'-0.7' – no sample; 0.7'-0.9' – bright red clay bands; 0.9'-1.8' – grey silty clay – bright red clay – stratified sand; 1.8'-2.1' – disturbed, stratified sand with dark reddish brown clay balls.

50.0'-51.6' SS 76-26-200 – extruded 1.65'; stratified buff weathered sand and silty sand with red clay bands; sand becoming grey at 0.55' above base; sediment in cycles consisting of red clay – silty sand – sand (ascending order) 0'-0.25' – cycle 1 (grey); 0.25'-0.5' – cycle 2 (grey); 0.5'-0.65' – cycle 3 (buff); 0.65'-0.9' – cycle 4 (buff); 0.9'-1.1' – cycle 5 (buff); 1.1'-1.4' – cycle 6 (buff); 1.4'-1.65' – cycle 7 (buff).

60.0'-61.0' SS 76-26-201 – tube penetrated only 1' with difficulty; all medium grained sand (grey) with an oxidized band at mid-core.

70.0'-71.0' SS 76-26-202 – tough material; drill raised off jacks while pushing sample tube; mainly stratified buff sand.

74.0' drill record shows textural break from sand to silt.

80.0'-82.1' SS 76-26-203 – proximal varves of varying thickness consisting of grey 'summer' layer and deep reddish brown 'winter' layer. 0'-0.8' – laminated grey silty clay; thin red band at 0.8'; 0.8'-1.2' – grey to reddish grey silty clay; 1.2'-1.6' – dark grey silt and silty clay; 1.6'-2.1' – six red and grey varves.

90.0'-92.1' SS 76-26-204 – dominantly dark grey silt with numerous indistinct grey and/or pink clay bands; most pink is in lower half of core; interpreted as indistinct varves, with possibly ten varve couplets.

100.0'-101.9' SS 76-26-205 – 0'-0.3' – stratified grey and red silt and silty clay; 0.3'-1.0' – silty sand with contorted pinkish grey silt bands; 1.0'-1.9' –medium sand, stratified; silty band at 1.3'.

106.1' end of hole, apparently on bedrock; last recovery in wash water was sand and fine gravel, probably indicating thin till over bedrock.

BORING #76-16
(Chapeau Site)

0'-18.5' stratified, fine grained, well sorted sand; in abandoned terrace.

18.5'-25.0' clay, fine sand in layers and lenses; silt bands; grey and red.

25.0'-27.1' SS 76-16-75 – grey and red banded clayey silt and clay; beds distorted by slumping (upper delta facies?).

30.0'-31.5' SS 76-16-76 – material packed too hard to penetrate; lifted rig. 0'-1.4' – stratified fine to medium grained grey-brown sand; 1.4'-1.5' – banded grey silty clay; dips 10°-15°.

35.0'-37.1' SS 76-16-77 – 2.0' recovery; 0'-0.3' – fine to medium grained brownish grey sand with irregular slump masses of clay similar to that in upper part of core; 0.3'-2.0' – stratified pink and grey clay and silty clay; distorted by slumping.

40.0'-42.1' SS 76-16-78 – 2.0' recovery; entire core vaguely stratified, slump-distorted and faulted, dark and light grey silt, silty clay, red silty clay.

45.1'-47.1' SS 76-16-79 – all irregularly laminated, dark to light grey and pinkish grey silty clay; some distortion in beds in upper half of core; lower half more regularly banded and undisturbed.

50.0'-52.1' SS 76-16-80 – mainly grey and dark grey silt bands; thin pink silty clay partings; all distorted; several 1-2 mm sand partings near base of core.

55.0'-57.1' SS 76-16-81 – stratified coarse silt, silt, and silty clay with some discrete sand layers; grey with red bands at 0.2' and 0.7' above base; bedding regular; light grey silt layers 2"-3" thick were stiff, giving more resistance to pushing of sample tube and to cutting by wire saw than other sediment.

60.0'-62.1' SS 76-16-82 – imperfect cyclic banding pink – dark grey – light grey (ascending order); cyles up to 2" thick; several thin sand partings in core.

65.0'-67.1' SS 76-16-83 – irregularly stratified light and dark grey silt and fine grey sand.

0'-0.6' – dark grey silt and fine sand; some pinkish to reddish brown bands; bedding disrupted, like a breccia.

70.0'-72.1' SS 76-16-84 – 0'-0.6' – dark grey silt, grey-brown silty clay grading upwards into light grey silt; 1/4" mottled layer in grey-brown zone; 0.6'-0.9' – fine grained grey sand, some silt; 0.9'-1.6' – banded red and grey silt (varves?) with minor sand partings; black-mottled band (0.95'-1.0'); 1.6'-1.65' – fine grained grey sand; 1.65'-2.1' – variegated light and dark grey silt.

75.0'-77.1' no sample; probable sand layer; casing dropped to 75.9' to more resistant material; wash returns 75'-80' produced chips of clay, some small pebbles to 0.5" diameter.

80.0'-82.1' SS 76-16-85 – 1.5' recovery; proximal varves?; banded grey sand and grey silt in regular alternation; beds range from 1/4" to 2" approx.

85.0'-87.1' SS 76-16-86 – 2.0' recovery; 0'-0.6' – regularly banded light and dark grey silt (3 dark bands), possible proximal varves; 0.6'-2.0' – mainly fine grained grey sand with stiff grey silt bands 1/2"-3/4" thick at 0.7', 0.9', 1.1', 1.6'.

90.0'-92.1' SS 76-16-87 – 0'-0.4' – discrete clay balls in sand matrix; 0.4'-2.1' – grey sand with stiff silty clay bands 1/4"-1/2" thick at 0.4', 0.6', 0.8', 1.25', 1.9'; proximal varves?.

95.0'-97.1'	no sample.
100.0'-102.1'	SS 76-16-88 – all grey varves consisting of silty clay in 'winter' layer, very coarse silt and fine sand in 'summer' layer; some strata slightly brownish grey; thick sand layers (between 0.2' and 0.5' above base) are nearly fluid; varves from 1/4" to 2" thick; core sawed with difficulty because silt stata very stiff.
105.0'	Shelby tube refusal.
105.0'-105.4'	HW 76-16-90 – very stiff sandy silt, no pebbles; possible till.
	Hole ends at 105.4'.

BORING #74-2
(Hammond Site – Top of slope)

0'-10'	sand and fine gravel at surface grading downward to sand and silt.
10'-15'	WS 74-2-1 – grey clayey silt, some sand.
15'-20'	WS 74-2-2 – silty clay, grey to reddish grey; shell fragments.
20'-25'	WS 74-2-3 – grey coarse silt, and reddish grey clay.
25'-30'	WS 74-2-4 – coarse silt and clay; grey.
30'-35'	WS 74-2-5 – silty clay, grey to reddish grey.
35'-40'	WS 74-2-6 – coarse silt and clay; grey to reddish grey.
40'-45'	WS 74-2-7 – coarse silt and clay; grey to reddish grey.
45'-50'	WS 74-2-8 – clayey silt; grey to reddish grey.
50'-55'	WS 74-2-9 – silty clay; grey to reddish grey; drill casing penetrates easily.
55'-59'	WS 74-2-10 – silty clay; grey to reddish grey.
59'-60'	WS 74-2-11 – shale and limestone fragments; blue-grey.
60'-67.3'	WS 74-2-12 – shale and limestone chips.
67.3'-70.7'	WS 74-2-13 – shale and limestone chips.
70.7'-74.2'	DD 74-2-14 – core sample of shaly limestone; 1.3' recovery.
	Piezometer tip set at 73.6'.

BORING #74-2A
(Hammond Site)

0'-4'	sand.
4'-10'	fine sand with silt.
8.0'-10.1'	Shelby tube, no recovery.
10.1'-12.2'	Shelby tube, no recovery.
34.0'-36.1'	SS 74-2A-32 – clay with some silt; red and grey bands; soft, plastic.
44.5'-46.6'	SS 74-2A-33 – silty clay, grey, some pink; soft, plastic.
46.6'-48.4'	SS 74-2A-34 – clay with some silt; red and grey bands; fine sand at bottom of tube.
	Piezometer tip set at 50.0'.

BORING #74-2B
(Hammond Site)

0'-4'	fine, oxidized sand.
4'-15'	fine sand with silt and clayey silt bands; mainly grey.
8.0'-9.8'	PS 74-2B-35 – fine sand with silt and clay bands.
9.8'-11.5'	PS 74-2B-36 – grey silt with a few thin layers of reddish grey clay; some red bands.
11.5'-13.3'	PS 74-2B-37 – grey silt with some reddish grey clay bands and minor fine sand lenses.
13.5'-15.3'	PS 74-2B-38 – grey silty clay with layers of silt.
15.3'-17.1'	PS 74-2B-39 – grey silt to silty clay.
17.1'-18.9'	PS 74-2B-40 – grey silt to silty clay; sand seam 0.2' above base.
24.5'-26.6'	PS 74-2B-41 – grey clay with some light reddish grey bands.
26.6'-28.7'	PS 74-2B-42 – grey silty clay with indistinct reddish grey bands.
	Piezometer tip set at 30.0'.

BORING #74-2C
(Hammond Site)

0'-4'	fine sand, oxidized.
4'-15'	fine sand with silt and clay bands.
15'-19.3'	clay, silty clay, some sand lenses.
49.8'-51.9'	SS 74-2C-43 – clay, some silt; grey with red bands.
55.2'-57.3'	SS 74-2C-44 – top of core grey silty with dark grey, light grey and pink bands throughout; some gravel or bedrock fragments in bottom of core.
	Piezometer tip set at 61.7', in bedrock.

BORING #74-3 (mid-slope)
(Hammond Site)

0'-5'	WS 74-3-17 – sand and clayey silt.
5'-10'	WS 74-3-18 – clayey silt, grey with some reddish grey zones; minor sand.
10'-15'	WS 74-3-19 – clayey silt, grey; some sand.
15'-20.3'	WS 74-3-20 – silty clay, grey.
20.3'-25.3'	WS 74-3-21 – clay, grey with reddish grey zones; trace of silt.
25.3'-30.3'	WS 74-3-22 – clay; grey with some reddish grey.
30.3'-35.0'	WS 74-3-23 – clay; grey with some reddish grey.
35.0'-39.9'	WS 74-3-24 – clay; grey, some silt.
39.9'-45.0'	WS 74-3-25 – clay, grey with some reddish grey bands; minor silt content.
45.0'-47.7'	WS 74-3-26 – clay, grey; some silt; rock fragments of shaly limestone.
47.7'-50.5'	rock fragments; blue-grey shaly limestone; angular fragments, probably shattered bedrock.
	Piezometer tip placed at 50.6'.

BORING #74-3A
(Hammond Site)

31.6'-33.7'	SS 74-3A-45 – clayey silt; grey with some diffuse reddish grey bands.
	Piezometer tip placed at 35.0'.

BORING #74-3B
(Hammond Site)

16.6'-18.7'	SS 74-3B-46 – grey clay with reddish bands.
	Piezometer tip set at 20'.

BORING #74-4
(Hammond Site – Terrace at base of slope)

0'-5'	sand and silt.
5'-31.5'	clay, grey with some red bands.
31.5'-36.5'	fractured bedrock.
33.5'-35.4'	WS 74-4-28 – fractured bedrock and gravel.
35.4'-38.5'	DD 74-4-29 – quartzite boulder. DD 74-4-29A – shaly limestone.

40.2'-42.1' DD 74-4-30 – shaly limestone bedrock
DD 74-4-30A – shaly limestone bedrock.

Piezometer tip set at 43.0'.

BORING #74-4A
(Hammond Site)

16.6'-18.7' SS 74-4A-47 – grey silty clay with some red bands and sand partings.

BORING #74-4B
(Hammond Site)

30.5'-32.5' HW 74-4B-31 – silty clay, some fine gravel.

32.5'-34.5' HW 74-4B-32 – pebbles, shaly limestone, clay, silt, sand (= till?).

Piezometer tip set at 34.5'.

BORING #74-1
(Bourget Site)

0'-10' dessicated oxidized fine sand, silt, clay; some brownish red bands.

10.3'-12.4' SS 74-1-1 – extruded 2.4'; some extension; measuring from base upward: 0'-0.1' – fine grained grey sand; 0.1'-0.4' – grey silt grading finer upwards; 0.4'-0.95' – grey and red clay, grey silty clay layers, a few thin (2 mm) lenses of very fine grey sand; 0.95'-1.05' – fine grained grey sand; abundant mica; 1.05'-1.25' – reddish grey clay band; thin sand partings; 1.25'-1.4' – grey clay with irregular lenses of silt; 1.4'-2.0' – stratified grey sand and silt, dark heavy mineral concentrations; red clay ball 1x1x3 cm in centre of this band; 2.0'-2.3' – interstratified red clay and sand; lower half of layer very contorted, probably intraformational slumping; 2.3'-2.4' – massive clay band, reddish grey.

12.4'-14.2' SS 74-1-2 – 1.8' extruded to 2.0'; entire core is contorted sand with silty clay; some structures near vertical through most of tube; thin bands 2-5 mm thick of grey and reddish brown clay.

14.4'-16.3' SS 74-1-3 – 2.2' extruded; 0'-0.1' – alternately banded grey sand and reddish brown clay; 0.1'-0.3' – reddish grey clay; one grey clay ball; 0.3'-0.75' – grey silt with fine sand lenses and pockets; irregular; possible load-cast structures; becomes regularly and horizontally stratified upwards in section; 0.75'-1.75' – sand with thin grey clay bands; very contorted; 1.75'-1.85' – stiff reddish grey clay with sand partings; 1.85'-2.0' – uniform fine silty sand with sand partings; 2.0'-2.2' – very silty clay and sand in alternate discrete layers.

16.5'-18.5' SS 74-1-4 – extrudes to 2.25'; cyclic banding with transitional boundaries from base up as follows: red clay → grey clay → silt → sand; two complete cycles, plus other materials, present in this core. From base upward: 0'-0.6' – silty sand with distorted red clay band at 0.1'-0.175' – clay soft, high water content; 0.6'-0.85' – distorted red clay bands in silty sand; 0.85'-1.0' – horizontal strata of sand and red and grey silt; 1.0'-1.7' – sedimentary cycle as follows: 1.0'-1.17' – red clay with grey clay balls, transition to grey; 1.17'-1.3' – grey silty clay; 1.3'-1.4' – interbedded grey silt and sand; 1.4'-1.7' – grey sand; at 1.7' – sharp contact between sand and reddish grey silt; 2nd cycle: 1.7'-1.75' – reddish grey silt with thin sand partings; 1.75'-2.02' – massive reddish grey clay; 2.02'-2.15' – transition to grey silt with increasing sand content; 2.15'-2.25' – uniform grey silty sand.

18.5'-20.5' SS 74-1-5 – extruded 2.3'; parts of three sedimentary cycles: cycle 1: 0'-0.1' – grey clay, relatively stiff, calcareous; 0.1'-0.3' – stratified grey sand with grey silt partings; 0.3'-0.55' – fine grained silty grey sand; 0.55'-0.9' – 'disturbed' zone; grey silt, sand lenses and partings, irregular patches of 'red' clay; cycle 2: 0.9'-1.25' – red clay, lower contact with 'disturbed' material is gradational, indistinct; 1.25'-1.35' – grey clay, transitional from red below; 1.35'-1.42' – banded grey sand and silt; 1.42'-1.78' – horizontally stratified fine grained grey silty sand and fine-grained sand, top layer (0.1' approx.) is slightly oxidized. cycle 3: sharp contact between red clay and oxidized sand; 1.78'-1.95' – 'red' clay; 1.95'-2.1' – grey clay, lower contact gradational; 2.1'-2.3' – silty sand grading upwards to very fine grained grey-buff sand.

20.5'-22.5' SS 74-1-6 – extruded 2.35'; core has 3 1/2 sedimentary cycles: cycle 1: 0'-0.2' – red clay, a few sand lenses to 1 mm; calcareous; 0.2'-0.45' – grey silty clay, many sand blebs and lenses; 0.45'-0.5' – grey sand; cycle 2: 0.5'-0.7' – 'red' clay; 0.7'-0.85' – grey silty clay, lower contact gradational; 0.85'-1.05' – stratified silt and sand; 1.05'-1.3' – strongly calcareous grey sand; cycle 3: 1.3'-1.55' – 'red' clay; 1.55'-1.65' – grey clay, lower contact gradational; 1.65'-2.05' – silt and sand grading upwards to uniform grey sand; cycle 4: 2.05'-2.35' – red clay grading upwards to reddish grey, thin, crossbedded, channelled sand lens at 2.325'.

22.5'-24.5' SS 74-1-7 extruded 2.25'; only the uppermost 0.25' of this core appears to belong to the cyclic sequence of cores higher in sequence; most of the tube is contorted clay, mainly red. Measured from base: 0'-0.35' – grey silty clay with disseminated sand grains, strongly calcareous; 0.35'-2.0' – mainly stiff red clay mottled and streaked with clay 'plumes' up to 0.1' thick, but mainly less than 0.05', dark mottling at 0.65'-0.75', heavy H_2S odour; 2.0'-2.25' – horizontally laminated grey and red clays.

24.6'-26.6' SS 74-1-8 – extruded 2.2'; three essentially complete sedimentary cycles in this core: cycle 1: 0'-0.1' – banded sand and red silt; 0.1'-0.35' – red clay (slow reaction to HCl); 0.35'-0.4' – grey clay, gradational lower contact, strongly calcareous, H_2S; 0.4'-0.6' – grey silty sand, strongly calcareous, H_2S; cycle 2: 0.6'-1.0' – red clay; 1.0'-1.1' – grey clay, gradational lower contact; 1.1'-1.6' – grey silty sand; cycle 3: 1.6'-1.98' – red clay, sharp lower contact; 1.98'-2.0' – grey clay, gradational lower contact; 2.0'-2.2' – grey silty sand.

26.6'-28.5' SS 74-1-9 – extruded 2.2'; irregular, broken cycles: 0'-0.3' – grey clay, stiff, silty, strongly calcareous, gradational upper contact; 0.3'-0.6' – dark red clay, stiff, slow reaction with HCl; 0.6'-0.75' – grey clay, gradational contact with underlying red clay; 0.75'-0.8' – sand parting; 0.8'-0.825' – grey clay; 0.825'-1.05' – red clay; 1.05'-1.1' – sand interbedded with red clay; 1.1'-1.2' – dark red to brownish grey clay; 1.2'-1.25' – irregular black band; 1.25'-1.5' – brownish red clay grading upwards to red; 1.5'-1.7' – rapid transition upward to grey clay and grey sand with grey clay partings; 1.7'-2.2' – grey silty sand.

28.7'-30.7' SS 74-1-10 – extruded 2.3'; banded sediments, 2"-3" red bands in grey sandy silt strata, black mottling in several layers, mainly in lower half of tube. 0'-0.1' – missing; 0.1'-1.0' – irregularly banded red and grey clay with black mottling at 0.1'-0.2', 0.3', 1.0'; 1.0'-1.4' – grey silt with a few thin sand partings, black mottling at 1.4'; 1.4'-1.75' – red clay grading upwards to grey; 1.75'-1.85' – grey clay; 1.85'-2.15' – grey clay with irregular sand layers up to 1/2"; 2.15'-2.2' – dark reddish brown clay; 2.2'-2.3' – buff weathering very fine grained sand.

34.6'-36.7' SS 74-1-11 – extruded 2.3'; colour banding is less obvious than in previous 10 cores; more massive towards base; three cycles. cycle 1: 0'-1.05' – dark reddish brown clay, black mottled at top; cycle 2: 1.05'-1.15' – thin-bedded silt and sand; 1.15'-1.7' – red clay, horizontal black streaks, narrow grey band at 1.5'-1.55'; 1.7'-1.85 – thin-bedded grey clay with very thin fine sand (or coarse silt) layers (0.5-2 mm); cycle 3: 1.85'-2.15' – reddish-grey clay, horizontal black streaks in upper 0.2'; 2.15'-2.3' – grey silty clay grading upwards into sandy silt. Note: HCl reaction on black streaks produced strong H_2S odour.

39.5'-41.5' SS 74-1-12 – extruded 2.1'; colour-banded clay and silty clay with some thin sand layers; breaks between red-grey cycles are less distinct than samples higher in sequence; roughly six colour bands. 0'-0.1' – red clay; 0.1'-0.25' – grey clay; 0.25'-0.4' – red clay, black band at base; 0.4'-0.45' – interstratified red and grey clay; 0.45'-0.6' – red clay; 0.6'-0.85' – grey clay and silty clay with thin sand partings; 0.85'-1.25' – red clay with black sandy layer at 0.925; 1.25'-1.4' – grey clay; 1.4'-1.52' – red clay; 1.52'-1.85' – grey silt grading upwards into grey silty sand with black-mottled sand layers; 1.85'-2.0' – red clay; 2.0'-2.1' – grey silty clay. Note: boundaries gradational between red and grey clay or silt, but sharp between red clay and overlying sandy strata.

44.8'-46.8' SS 74-1-13 – colour-banded sediment, alternately red and grey; red colour, (e.g. 2.5 YR 5/2, weak red) is more distinct than reddish brown and reddish grey of previous cores; core contains seven red bands, all with black mottling ($\leq$ 0.2') and six grey bands ($<$ 0.15'); grey layers have fine sand partings. Note: black mottling is in red bands in this core, whereas in cores higher in section black mottling is more common in grey strata.

51.1'-52.3' SS 74-1-14 – red and grey banded clay with some thin sand partings; black band 0.3'-0.4' and at 0.8'; red colour (10R 5/2-4/2,weak red), is brighter than that in some cores closer to surface.

54.6'-56.7' SS 74-1-15 – 2.25' extruded; red-grey banded silty clay, some black mottling in red bands; low sand content in grey bands. 0'-0.3' – grey silty clay with sand lenses; 0.3'-0.6' – red-brown clay, middle of colour band is black mottled; 0.6'-0.8' – grey silty clay with sand layer (1-2 mm) at top; 0.8'-1.3' – pink-red-grey clay, 5 mm black band at 1.12'; 1.3'-1.6' – grey silty clay with minor sand lenses; 1.6'-1.85' – reddish-grey clay, two bands of black 1 cm apart at 1.7'; 1.85'-2.2' – grey clay, minor sand; 2.2'-2.25' – pink clay with black band at base; HCl reaction stronger in grey silty clay than in red clay.

59.5'-61.5' SS 74-1-16 – 2.2' extruded; alternate grey and red bands (five of each), distinct colour banding; sand lens at 2.0' has discernible crossbedding marked by heavy mineral concentrations; grey bands range 0.1'-0.25' thick, red bands range 0.2'-0.4' thick, red dominant; fossil, **Portlandia** sp.; black bands in red clay at 0.12', 0.5', 1.0', and 1.6'.

64.4'-66.5' SS 74-1-17 – 2.3' extruded; parts of three colour cycles, grey bands range 0.1'-0.3' thick, two red bands approx. 0.8' thick; nine black bands in core, seven of these in red clay, two (diffuse) in grey at 0.1'-0.25', 0.45', 0.6', 0.75'-0.8', 1.1', 1.5', 1.8'-1.9' (several bands), 2.0'-2.25' (diffuse), 2.22'-2.25' (diffuse); small sand lens in red clay at 1.9'.

69.3'-71.4' SS 74-1-18 – 2.3' extruded; thick red clay layers with alternating relatively thin grey silt and sand layers, all calcareous. 0'-0.05' – grey clay; 0.05'-0.275' – red clay with two black bands at 0.175'-0.2' and 0.225'-0.25'; 0.275'-0.4' – grey clay; 0.4'-0.55' – red clay, black band at 0.5'; 0.55'-0.75' – grey silty clay, no sand; 0.75'-1.125' – red clay, black bands at 0.9' (sharp) and 0.95' (diffuse); 1.125'-1.25' – grey stratified clay; colour laminated in light and dark shades of grey; 1.25'-2.0' – red clay with very fine sand partings increasing in frequency and thickness upwards; upper 0.02' is slightly oxidized; 2.0'-2.3' – uniform fine grained sand, buff to slightly oxidized (rusty); crossbeds delineated by heavy minerals.

74.4'-76.5' SS 74-1-19 – 2.35' extruded; alternate red and grey bands; red bands ~0.3', grey bands ±0.1' thick, red dominant. 0'-0.2' – grey silty clay; 0.2'-0.6' – red clay, black bands at 0.225'-0.25', 0.45'-0.5' (diffuse); 0.6'-0.75' – grey silty clay; 0.75'-1.1' – red clay, diffuse black bands at 0.8'-0.825', 0.975'-1.0', sharply defined black band at 1.075'-1.1'; 1.1'-1.2' – grey silty clay; 1.2'-1.6' – red clay; between 1.375' and 1.5' five black bands occur; 1.6'-1.7' – grey silty clay; 1.7'-1.95' – red clay; 1.7'-1.725' – two narrow black bands; 1.9'-1.925' – two narrow black bands; 1.95'-2.05' – grey silty clay; 2.05'-2.35' – red clay, two black bands at 2.2'-2.25'. Note: there are finer-scale laminations approx. 1 mm thick throughout this core, regardless of colour of sediment.

79.5'-81.6' SS 74-1-20 – 2.3' extruded; red-grey banded clay and silty clay with some black streaks or bands, most contacts gradational; red clay strata range 0.2'-0.3' thick, grey average 0.1' thick; about eight colour cycles in core.

84.4'-86.5' SS 74-1-21 – 2.3' extruded; alternating red and grey bands of clay and silty clay, some black bands; red bands generally thicker than grey, some exceptions; 9-10 colour-band cycles in core; thickness of layers ranges 0.05'-0.3'.

89.2'-91.3' SS 74-1-22 – 2.2' extruded; alternating red and grey layers. 0'-0.4' – massive red silt or silty clay, stiff; 0.4'-0.75' – interstratified grey sand and red clay; 0.75'-0.925' – massive red clay grading upwards into grey; 0.925'-1.025' – grey silty clay; 1.025'-1.15' – massive red clay, rapid gradation upward to grey; 1.15'-1.325' – banded light and dark grey silty clay; 1.325'-1.45' – massive red clay; 1.45'-1.6' – grey clay; 1.6'-1.9' – red clay, textural variations produce indistinct colour-tone banding; black band at 1.725'-1.75'; 1.9'-2.025' – grey clay; 2.025'-2.2' – red clay, black band at 2.05'-2.075'.

94.2'-96.3' SS 74-1-23 – 2.4' extruded; mainly massive red clay with a few black bands. 0'-0.15' – red clay, black band at 0.05'-0.075'; 0.15'-0.25' – grey clay with reddish tone (5YR 5/2, reddish grey); 0.25'-1.1' – massive red clay; 1.1'-1.25' – interstratified red clay and fine sand (or coarse silt); 1.25'-2.4' – massive red clay, some thin silt partings.

99.8'-101.9' SS 74-1-24 – 2.3' extruded; banded red and grey clay and silty clay; approx. eight colour-band cycles in core; colour-tone banding within colour bands; grey bands range 0.055'-0.1', red bands range 0.15'-0.4' thick.

104.2'-106.3' SS 74-1-25 – red and grey banded clay and silty clay, no black bands; some load-cast ("flame") structures involving convolution of grey clay penetrating overlying red clay; a few grey clay balls in red clay strata; one pebble of fossiliferous limestone at 1.625' above base of core; **?Portlandia** sp.? fragments at 0.275', nearly complete shell 5 mm long at 1.6'.

109.3'-111.4' SS 74-1-26 – mainly grey silty clay with a few thin indistinct reddish-grey bands near the top of the core; several black mottling bands; main colour 2.5 Y 5/0 (grey).

114.2'-116.3'	SS 74-1-27 – 2.4' extruded; two colour zones: 0.1'-1.8' – massive grey silty clay with black mottling throughout; 1.8'-1.4' – banded red and grey clay and silty clay; slow HCl reaction; strong H_2S odour; shell fragments at 0.1', 0.2', 0.5', 0.8'.
119.1'-121.2'	SS 74-1-28 – all massive grey clay with irregular black patches, blebs, tubules, etc; some shell fragments throughout core; strong H_2S odour.
124.3'-126.4'	SS 74-1-29 – massive grey clay with irregular black mottling throughout; some concretionary nodules (pyrite?).
129.0'-131.1'	SS 74-1-30 – varve-like regularly colour-banded light and dark grey clay and silty clay, a few red clay bands; several pebbles and seams of medium-grained sand; strongly calcareous.
134.2'-135.7'	HW 74-1-31 – silty sandy till, poorly sorted, compact; includes pebbles of limestone, granite, granite gneiss; strongly calcareous.
	Hole terminated in till at 135.7'.

BORING #76-1
(Casselman Site)

4.7'-6.7'	HW 76-1-1 – horizontally stratified fine grained to medium grained sand with silty sand layers.
10.0'-12.1'	SS 76-1-2 – silty clay and silt, colour-banded in alternate thin beds of dark grey and reddish grey; some silt bands.
15.0'-17.1'	SS 76-1-3 – red and grey banded clay with silt partings; some black mottling.
19.6'-21.7'	SS 76-1-4 – red and grey banded clay with silt partings, one silt layer 0.5" thick; intraformational slumping features; black mottling. Red-grey cycles average 0.2' thick.
23'-25'	Return water became red; mainly red clay.
24.9'-27.0'	SS 76-1-5 – red and grey banded clay with silt partings; clay balls; five cycles.
29.6'-30.7'	SS 76-1-6 – colour-banded clay with silt bands; black mottling in both red and grey sediments.
34.4'-36.5'	SS 76-1-7 red and grey colour-banded clay with black bands; silt layers up to 2" thick; red clay dominant.
39.2'-41.3'	SS 76-1-8 –colour-banded clay with black bands; dark grey is dominant colour; 2" silt layer.
44.3'-46.4'	SS 76-1-9 – red and grey colour-banded clay; 5" silt layer at base; 1/4"-1/2" black bands commonly in middle of red clay layers.
49.1'-51.2'	SS 76-1-10 – colour banding in upper foot of core; more massive and dark grey at base, 6" silt layer; transitional boundary.
54.2'-56.3'	SS 76-1-11 – dark grey clay with black bands; thick silt unit.
59.0'-61.1'	SS 76-1-12 – massive dark grey clay; black mottled; H_2S odour.
65.0'-67.1'	SS 76-1-13 – massive dark grey clay; irregular black mottling; fossils, probably foraminifera or ostracods.
68.9'-71.0'	SS 76-1-14 – most of sample lost; massive grey clay, black mottled, fossiliferous.
73.9'-76.0'	SS 76-1-15 – thin-bedded light and dark grey, varve-like couples; pebble approximately 2.5 cm; some black mottling.
79.0'-81.1'	SS 76-1-16 – sample lost.
84.0'	approximate level at which drill encountered numerous pebbles.
85.0'-87.1'	HW 76-1-17 split spoon sample; silty sandy grey till.
91.4'	drilling refusal at bedrock surface.
91.4'-95.9'	DD 76-1-18 NX CORE – fractured limestone bedrock.

BORING #76-7
(Casselman Site)

5.0'-7.1'	SS 76-7-26 – fine to medium sand with silty clay layers.
9.6'-11.7'	SS 76-7-27 – interbedded silt and clay; 0'-0.3' red and grey layers with grey clay ball in red band; 0.3'-0.8' – grey silt; 0.8'-2.1' – banded red and grey silty clay; at 1.7' sloping contact between silt and clay.
14.9'-17.0'	SS 76-7-28 – grey clay with reddish grey layers; contacts gradational; some black mottling, shell fragments.
19.4'-21.5'	SS 76-7-29 – grey clay with reddish grey layers; red colour distinct; one red band offset by fault; some black mottling in red bands.
25.0'-27.1'	SS 76-7-30 – grey clay with reddish grey layers, some silt partings; black bands in red clay layers up to 2" thick.
30.0'-32.1'	SS 76-7-31 – grey clay with reddish grey layers, silt parting; upper contact of red clay bands is sharp, lower contact gradational.
35.1'-37.2'	SS 76-7-32 dark red and blue-grey clay bands, slumped and tilted beds; black mottling; red dominant.
40.0'-42.1'	SS 76-7-33 – grey clay with reddish grey layers; black mottling in red; some beds tilted; red bands have sharp upper contact, gradational lower contact.
45.0'-47.1'	SS 76-7-34 – grey clay with reddish grey layers; black mottling in red; mainly clay, low silt content; bedding horizontal.
50.0'-52.1'	SS 76-7-35 – grey clay with reddish grey layers; H_2S odour; grey strata dominant; upper contact of red bands sharp, lower is gradational.
55.0'-57.1'	SS 76-7-36 – thin-bedded red and grey clay; black mottling; H_2S odour.
60.0'-62.1'	SS 76-7-37 – massive to indistinctly banded grey clay with shades of red; black mottling; H_2S odour.
65.0'-67.1'	SS 76-7-38 – massive dark grey clay; black mottling in "worm tracks" or tubules; one pebble 1 cm diameter; fossils, **Portlandia** sp. and unidentified specimen.
69.9'-72.0'	SS 76-7-39 – massive dark grey clay; H_2S odour; fossiliferous; black mottling general, but less than in 76-7-38.
74.9'-77.0'	SS 76-7-40 – alternate bands of silt and clay, light and dark grey, as varved; sedimentary couples thicken downwards in core; upper couples distorted.
77.1'-84.4'	sandy grey till; hard-wall sampler shoe broken by impact.
84.4'-85.3'	HW 76-7-41 – grey till, boulders.
85.3'	hole ends in refusal on boulder or bedrock surface.
85.3'-87.2'	NX diamond drill core in fractured limestone bedrock.