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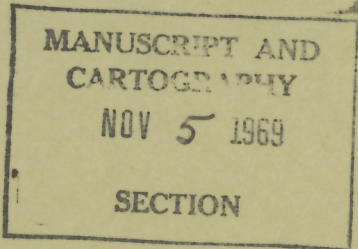
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PAPER 69-31

STRATIGRAPHY AND ENGINEERING DESCRIPTION
OF THE SOILS EXPOSED ON A SECTION OF THE
WELLAND CANAL BY-PASS PROJECT (Contract 743)
ONTARIO, CANADA

(Report and 17 figures)

E. B. Owen





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CONTENTS

	Page
Abstract	v
Introduction	1
General description	1
Description of materials	2
Surficial glaciolacustrine sediments (units 9 and 11)	2
Upper till (unit 8)	3
Intertill deposits	5
Lower till (unit 8A)	5
Excavation problems arising from the geology	7
Comparison of inferred and observed geology	7
Hammer seismic profile	8
Geotechnical profiles	8
Reference	22

Illustrations

Figure 1. Location of Contract 743, Welland Canal By-pass Project	vi
2. Seaway Authority plan of Contract 743, and inferred and observed geological profiles	in pocket
3. Fine-grained, buff-coloured, sandy silt at base of upper lacustrine deposit. (Photo)	3
4. Large limestone boulder from lower part of upper till. (Photo)	4
5. Hammer seismic profile along Carl Road	6
6 to 17. Geotechnical profiles for 12 test borings put down in Contract 743	9-21

ABSTRACT

The methods and procedures used to forecast excavation requirements in the Welland Canal By-pass Project (Contract 743) are outlined. Comparison is made between geological conditions inferred before excavation and the conditions actually encountered by the contractor.

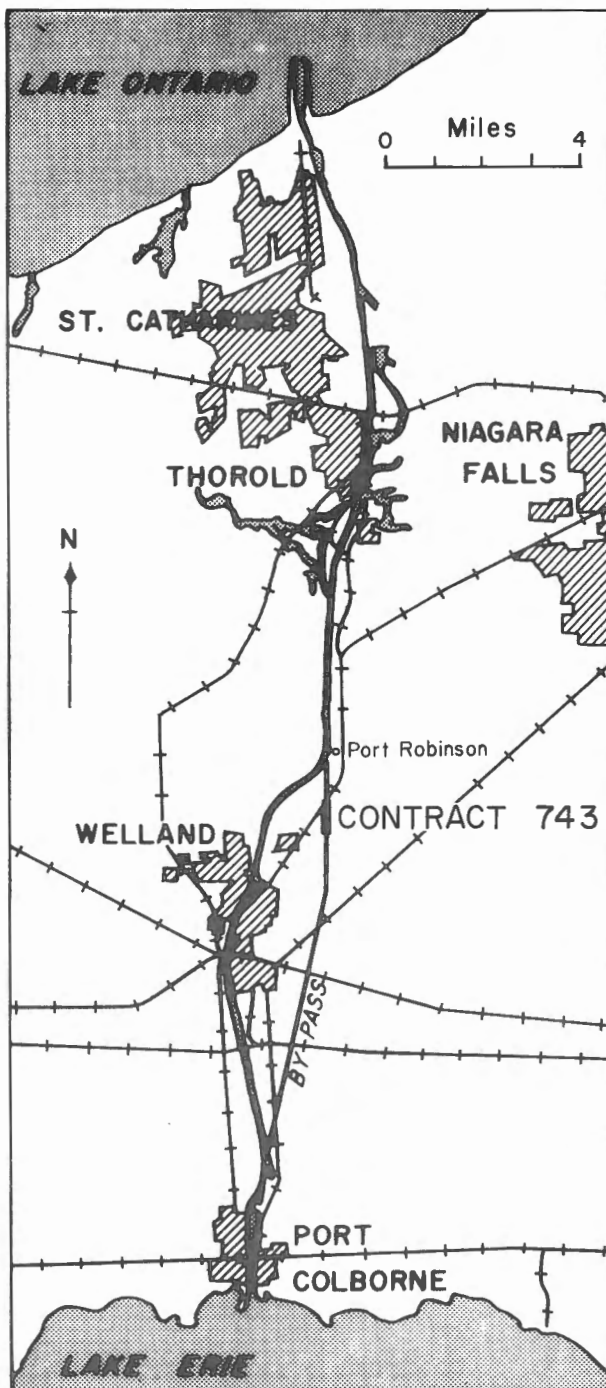


Figure 1. Location of Contract 743 Welland Canal By-pass Project.

STRATIGRAPHY AND ENGINEERING DESCRIPTION OF THE SOILS EXPOSED ON A SECTION OF THE WELLAND CANAL BY-PASS PROJECT ONTARIO, CANADA

INTRODUCTION

This paper, compiled from the results of detailed examination of the soils exposed during the excavation and removal of materials by the contractor under the terms of Contract 743, is based on a report on the Welland Canal By-pass project, submitted to the St. Lawrence Seaway Authority upon completion of the contract. The purpose of the study was to provide the Authority with information regarding the actual soil conditions encountered by the contractor during excavation should he, at some future time, file claims based on discrepancies between the pre-excavation and post-excavation information.

GENERAL DESCRIPTION

The objective of the Welland Canal By-pass project is the construction of an entirely new Welland Canal between Port Robinson, Ontario and Port Colborne at the Lake Erie end of the Canal, a distance of about eight miles (Fig. 1). The area of Contract 743, one of several contracts let by the St. Lawrence Seaway Authority in the excavation for the By-pass, is located between chainages 53+26.5 and 96+20 (a distance of 4,293.5 feet) measured south along the centre line of the project from bridge No. 12 which crosses the existing Canal at Port Robinson.

Contract 743 called for removal of some 6,000,000 cubic yards of overburden and the placing of much of this material along the sides of the excavation as dykes. The data observed along the centre line during this excavation was plotted as a geological profile on St. Lawrence Seaway Authority sheet No. F-2074 (4) (Fig. 2), and includes:

- the locations of test borings put down by the Authority in the contract area;
- the location of the various materials the contractor might expect to encounter during the excavation and of the contacts between them - plotted on a geological profile based on data provided by the Engineering staff of the Authority from the results of the test borings and other sources;
- the geological profile as actually observed during the excavation.

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Author's address: Geological Survey of Canada,
601 Booth Street,
Ottawa, Canada.

DESCRIPTION OF MATERIALS

Test borings indicated that the thickness of the Quaternary deposits in this contract area ranges from 64 to 113 feet. As the original ground surface was relatively level, with relief of about 10 feet, variations in drift thickness are due in large part to irregularities in the bedrock surface. The maximum depth of overburden excavated was about 65 feet. Bedrock was not encountered in the excavation - although test borings had indicated that it lies about 3 feet below grade (elevation 538.3) at station 71+31 on the centre line. Therefore, no complete vertical section of the unconsolidated materials was exposed.

Commencing at ground surface the materials consisted of soft, glaciolacustrine, clayey silt (unit 11) and sandy silt (unit 9) overlying soft, clayey, silty till (unit 8). This in turn overlay a dense, stony, basal till (unit 8A). A deposit of soft, clayey silt with sandy beds occurred intermittently between the two tills. This was described as a transitional zone on the inferred geological profile.

Surficial glaciolacustrine sediments (units 9 and 11)

The material exposed at ground surface throughout the entire contract area consists of soft, brownish grey, glaciolacustrine, clayey silt. The deposit is frequently stratified and contains scattered varved clay zones. The material was constantly being disturbed by construction equipment, and consequently, it was difficult to trace any varved clay zone accurately for more than a few feet. The largest one observed was about 15 feet long and 3 feet thick. In general, the varves are horizontal and are about one inch in thickness, grading downward from a reddish brown, clayey member to a dark brown, more silty member.

In the north half of the contract area, the lower part of the lacustrine, clayey silt becomes progressively coarser as one goes down, grading within a vertical distance of about 10 feet first to a buff-coloured, sandy silt and then to a light brown, fine-grained, silty sand directly overlying till (Fig. 3). There is also a lateral change in gradation in this lower zone. At its south end, near the centre of the contract area where it terminates against a rise in the underlying till, the material consists almost entirely of fine-grained sand whereas at the north end of the area, it is essentially a sandy silt. The southward gradation into coarser grained material may indicate the shore zone of a glacial lake in which these materials were deposited. The shoreline would have been to the south with the deeper water to the north. Consequently, more clayey, lacustrine deposits can be expected in the area north of Contract 743. The sharp rise in the underlying till at station 76+00, against which the material terminates, may be a wave-cut bluff along a temporary shoreline representing an early stage in the formation of the lake. Its present elevation is approximately 575 feet above sea level.

The interpretation of this area as a lacustrine shore zone has far-reaching implications and further corroborative observations would be necessary before it could be accepted. To account for the overlying glaciolacustrine clay, this interpretation would require a general ice retreat and drainage of the Erie Basin, followed by a glacial advance and rising water levels.

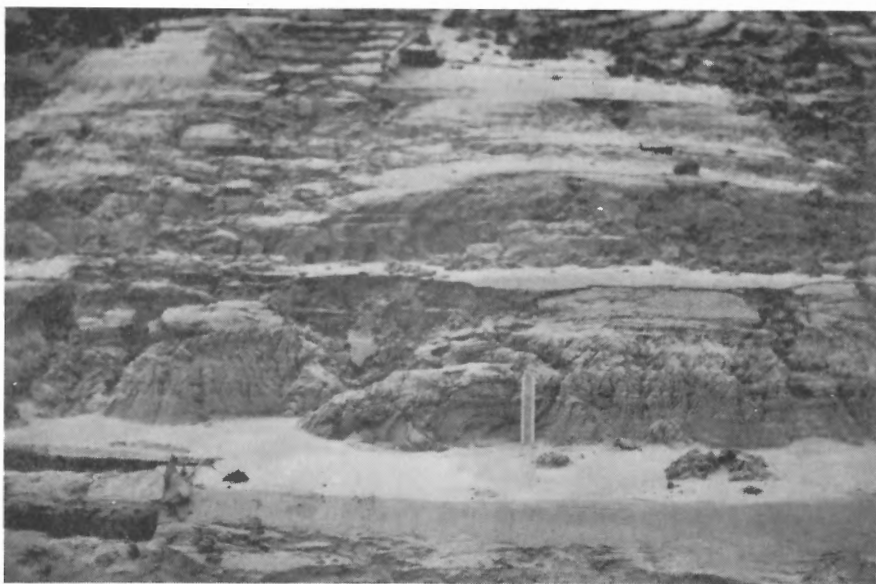


Figure 3. Fine-grained, buff-coloured, sandy silt (unit 9) at base of upper lacustrine deposit, directly overlies upper till (unit 8); station 60+00, elevation 568 feet, 100 feet east of centre line. Six-inch ruler gives scale. (GSC photo No. 2-1-68)

The sandy deposits and bluff-like till surface might also be interpreted as resulting from ice-contact processes during the retreat of the glacier terminus across the area.

According to Chapman and Putman (1966) these deposits were laid down by glacial Lake Warren which at one time covered a large part of south-western Ontario. The east side of the lake was confined by an ice barrier near the top of the Niagara Escarpment and it is, therefore, possible that the lacustrine materials, observed in the area of Contract 743, were deposited within two miles of the ice.

At the surface, soil has developed to a depth of about twenty-four inches. Below this, weathering is evident in the clayey silt, along vertical fractures which extend downward to ten or more feet. In places, the fractures have extended to the underlying till but in no place were they observed to have penetrated into it. They serve as intake conduits through which surface water can drain downwards under the influence of gravity. As a result of this increase in water content, the lacustrine, clayey silt directly above the till was frequently very soft, especially in areas of numerous vertical fractures.

Upper till (unit 8)

A soft, brown to dark grey, clayey, silty till underlies the lacustrine clayey silt. The contact between the two materials is distinct and easily recognizable. In the contract area, the surface relief of this till is about twenty-three feet, ranging in elevation from 567 feet above sea level at

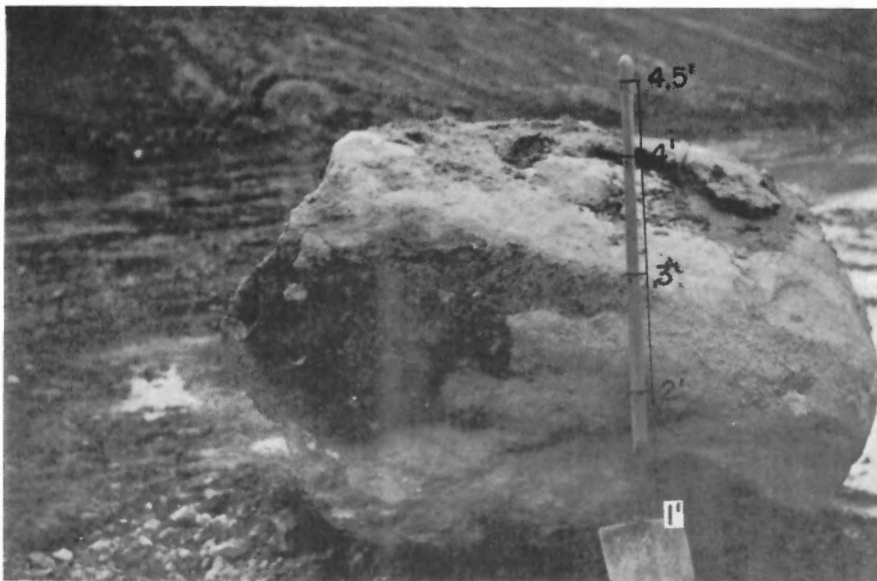


Figure 4. Large limestone boulder that was imbedded in the lower part of the upper till; station 67 + 50, elevation 550 feet, 150 feet east of the centre line. (GSC photo No. 2-4-68)

station 57 + 00 to 590 feet at station 82 + 00. Its thickness varies from 27 to 37 feet, with an average of about 30 feet. The till consists of silt and clay and, in general, contains few stones. In some places, however, numerous angular stones are present, most of them being less than 3 inches in diameter. Many were derived from local Paleozoic sedimentary bedrock formations, but a few Precambrian granitic erratics are also found. The disturbed condition of the till, due to the constant movement of construction equipment, prevented any accurate till fabric data being obtained. Some of the coarser grained, granitic stones were weathered to a soft, friable rock which disintegrated readily when struck with a hammer. A few large boulders up to four feet in diameter were imbedded in the lower 4 to 6 feet of the till (Fig. 4). Of these, the larger usually occurred singly whereas the smaller, in the eighteen-inch to twenty-four-inch range, were in nests containing several boulders, usually all of the same rock type.

The location of the large boulders in the till was so consistent that, during the excavation, their presence could be used as an indication of nearness, to the base of the till. Many of the larger boulders consisted of fine-grained, dense, dark grey to black limestone of local origin. Most were flat-sided and were bound by joint and bedding surfaces. Striations were common on the surfaces of these stones. In general, the striae had no consistent orientation but on some, one or more sets of well-developed, parallel grooves were observed. Probably the latter were part of the ground surface over which the ice had moved. Granitic boulders were more rounded and exhibited fewer striae than boulders derived from sedimentary rocks.

Another criteria used during the excavation as an indication of the proximity of the base of the upper till, was the presence of well-defined

inclusions of an underlying dense, red-brown, stony, basal till. These inclusions could easily be distinguished because of their contrasting colour and difference of stone content. In the lower ten feet of the upper till they occur as sharp-edged, irregularly shaped fragments up to 24 inches in their longest dimension. Above this, they are less numerous, larger and have usually been partly assimilated by the surrounding till. The largest fragment seen was about 5 feet above the base of the till. The ability of the ice to pluck large fragments from its surface is an indication of the high density of the basal till.

Intertill deposits

A deposit of soft, horizontally stratified, dark brown, clayey silt with thin beds of buff-coloured, sandy silt occurs between the upper and lower tills in the southern part of the contract area. Its maximum thickness is about ten feet. Varves ranging from 1 to 6 inches in thickness, are common. Except for the sandy, silt layers and the greater thickness of the varves, this material is similar to the lacustrine, clayey silt overlying the upper till. Traces of this material occurred between the two tills in other parts of the excavation but were usually too small to be included on the accompanying geological profile (Fig. 2). The contact with the underlying basal till (unit 8A) is distinct. On the other hand, a transitional zone, about twenty-four inches thick, consisting of a mixture of till and stratified material separates these stratified sediments from the upper till (unit 8). The strata are folded and crumpled for about three feet below this zone, probably as a result of overriding by ice. A large part of the overlying upper till probably consists of material from these lacustrine beds, reworked under water.

Geological and engineering evidence in the contract area indicates that ice advanced in a general southerly direction across a large lake covering the area. The ice eroded the sedimentary materials deposited on its floor and incorporated them into the upper till. Subsequently, the ice withdrew and the area was again covered by lake water from which the upper clayey silt was deposited upon the till. This lake is thought to have been glacial Lake Warren.

Lower till (unit 8A)

At the completion of the work, a dense, reddish brown, silty, clayey, stony basal till was exposed on the floor of the excavation throughout the entire length of the contract area. In general, the surface of this till follows the contours of the upper till. At station 60+00, at the north end of the excavation, its surface elevation is about 538 feet above sea level. From this point it slopes gently upward to the south to a maximum elevation of about 560 feet at station 80+60. As the elevation of the floor of the excavation is at 538.3 feet, the amount of basal till excavated varied from a very small quantity at the north end of the contract area to a maximum of 21 feet at station 80+60. The red colour of the basal till is probably due to incorporation of shale from the Queenston Formation. The nearest occurrence of these rocks is about 10 miles to the north. Actual fragments of Queenston shale did not occur in that part of the basal till exposed in the excavation although a few, small, angular fragments of white, quartzose sandstone from the Whirlpool Formation which overlies the Queenston, were present. Most of the stones

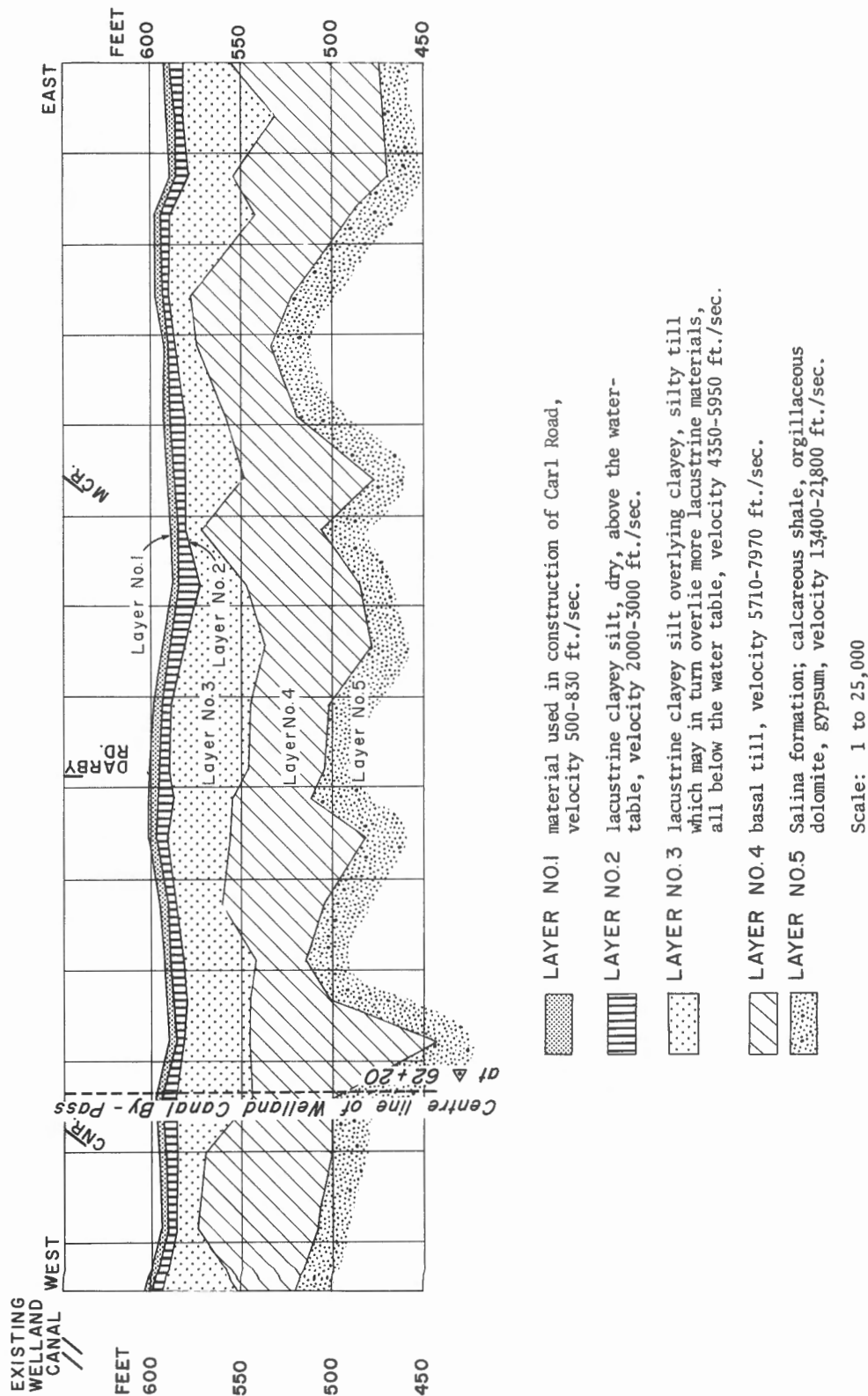


Figure 5. Hammer Seismic Profile along Carl Road.

observed in the till consisted of hard limestone and dolomite from nearby bedrock formations. Granitic erratics were rare. Usually, the contact between the upper and lower tills is distinct, but, as mentioned earlier, a transitional zone one to three feet thick occurs in places.

EXCAVATION PROBLEMS ARISING FROM THE GEOLOGY

Scrapers and draglines were used by the contractor in excavating the various types of overburden encountered on Contract 743. The upper, lacustrine, clayey silt, which was relatively hard from ground surface down to the water table or to a point close to the underlying till, was removed by scrapers. As the lacustrine material became softer with depth, the contractor apparently attempted to remove it by skimming off a few inches at a time with scrapers and then allowing the material to dry for a short time before making another pass with the scrapers. This method was only partially successful and, subsequently, the contractor changed to draglines with which the remaining material was removed to grade. It is believed that, instead of removing it by dragline, scrapers could have been used to excavate the dense, stony, basal till as this material provided good traction for construction equipment.

During construction of the ramp down the east side of the excavation, between stations 63+00 and 67+00, about ten feet of the fine-grained, sandy silt in the lower part of the lacustrine material had to be removed and replaced in order to provide a more satisfactory foundation for the road. This low-strength material directly overlay the upper till throughout much of the northern half of the contract area. Most of the large boulders and nests of smaller boulders in the lower part of the upper till were encountered in the southern part of the excavation. Many of these boulders were so large the contractor had to remove them individually.

COMPARISON OF INFERRED AND OBSERVED GEOLOGY

The materials which the contractor might expect to encounter in the excavation were plotted on a geological profile prepared for the centre line of the contract area (see Fig. 2). This information, inferred from test borings, was included in the contract specifications. In general, the geological data provided for the contractor were correct.

The two tills indicated on the inferred profile were identified in the excavation. Sufficient evidence was obtained to suggest they were deposited by different glaciers and are not facies of the same till sheet. The properties of these materials as observed in the excavation agreed with those obtained from laboratory studies, made by the Authority, of samples taken by test borings. One difference between the inferred and observed profiles resulted from the undulations in the surfaces of the tills. Because of this, the volumes of the materials excavated differed from the amounts that would have been calculated from the inferred profile. A very large number of borings would have been necessary to contour the surfaces of the tills accurately. Another difference was the presence of large boulders in the upper till. Considering the extent of the contract area, it is doubtful if the presence of these boulders would have been indicated even by an extremely large number of borings. The observed thickness of the upper, lacustrine, clayey silt was greater than

inferred from the test borings. As a result there was less till and more soft, lacustrine material to excavate. The narrow transition zone between the tills was found to consist of soft, lacustrine, clayey silt, which is much more extensive than indicated on the inferred profile.

HAMMER SEISMIC PROFILE

The Hammer Seismic Profile along Carl Road (Fig. 5) which accompanies this report was prepared by the Exploration Geophysics Division of the Geological Survey of Canada. Carl Road crosses Crowland Township, Welland County in an east-west direction, intersecting the centre line of the Welland Canal By-pass on Contract 743 at station 62 + 20. The seismic investigations were made at approximately 1,000-foot intervals along the road, commencing at the existing Welland Canal and extending west for a distance of about six miles.

A comparison with subsurface data obtained from the test borings put down by the Seaway Authority suggests that the boundary between layers Nos. 2 and 3 on the seismic profile represents the groundwater table, that layer No. 3 consists of lacustrine materials overlying silty, clayey till, and that layer No. 4 is a dense, basal till. The results of two seismic investigations along Carl Road within the area of Contract 743 are compared below with the information obtained from test borings put down previously at the same locations:

	Test Boring No. P-6 (depth in feet)		Test Boring No. P-36 (depth in feet)	
	Boring	Seismic	Boring	Seismic
Top Basal Till	23	24	30	26
Bedrock	42.5	70	45	41

GEOTECHNICAL PROFILES

The accompanying geotechnical profiles (Figs. 6 to 17 inclusive) on which pertinent properties of the soils encountered in the excavation for Contract 743 are described, were prepared by the St. Lawrence Seaway Authority from soil samples obtained from test borings put down in the contract area. The locations of the borings are indicated on the geological profile (Fig. 2).

In general the various soil types can be identified on the geotechnical profiles by comparing their properties. The approximate boundaries of the soils have been indicated on the profiles. The similarity in the properties of the lacustrine materials and the upper till suggests that a large part of the material comprising the till was derived from lacustrine deposits. This similarity in properties is further indicated on the Hammer Seismic Profile along Carl Road. Here, in layer No. 3, it was not possible to differentiate between the lacustrine deposits and the till, both of which, from test borings, are known to occur in the layer.

12 GEOTECHNICAL PROFILES

THE ST. LAWRENCE SEAWAY AUTHORITY
(WELLAND CHANNEL RELOCATION)

Figures 6 to 17

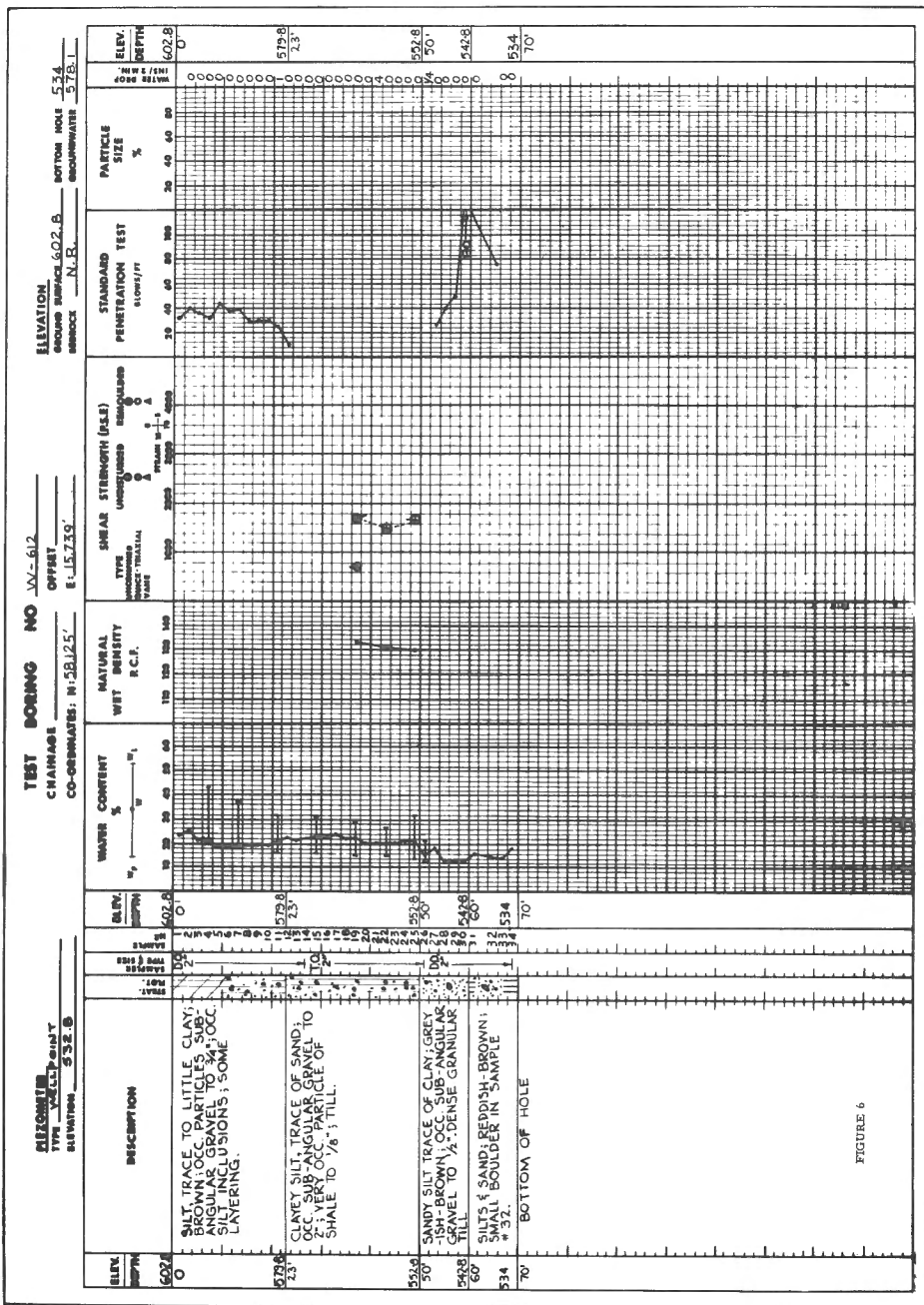
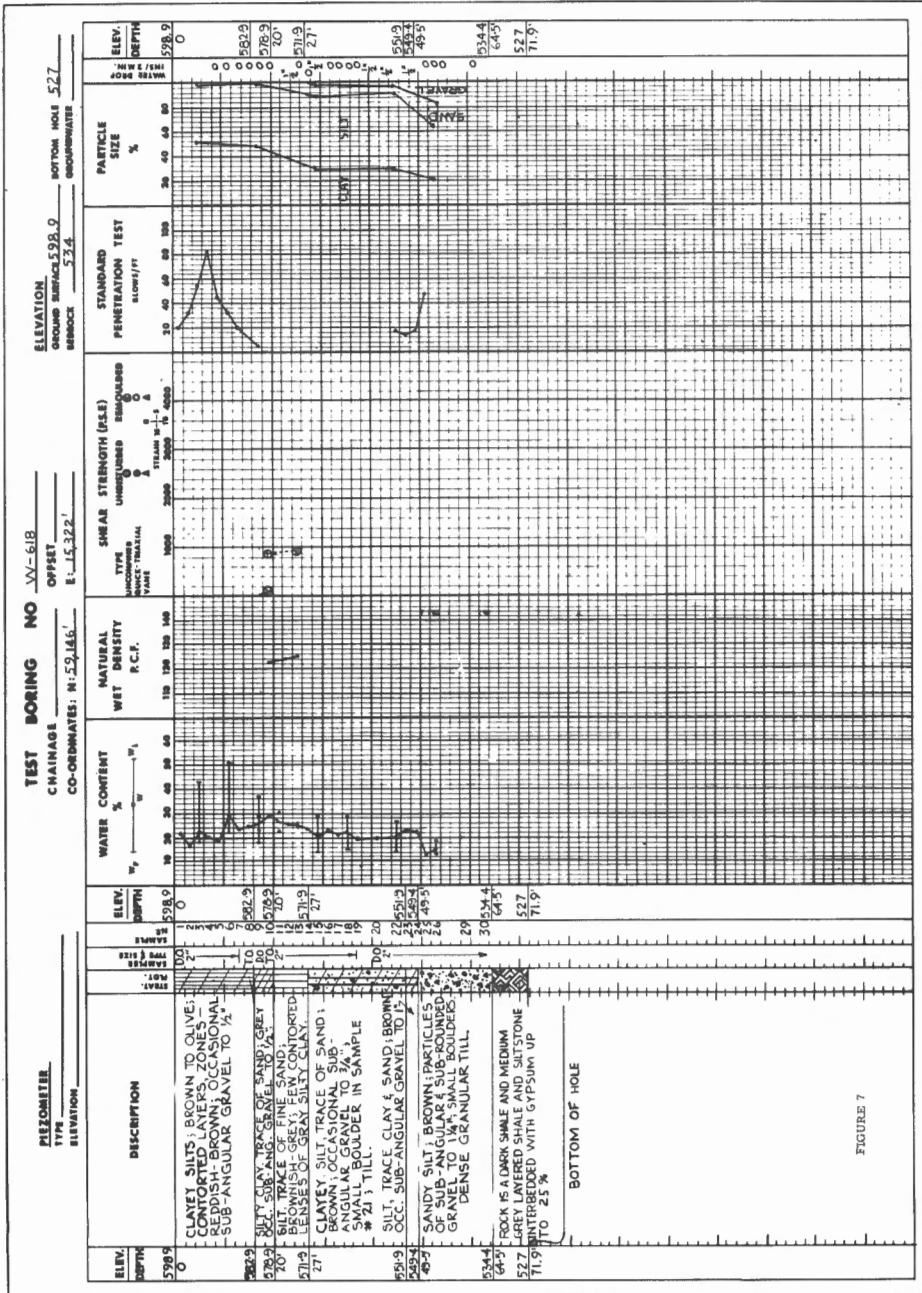
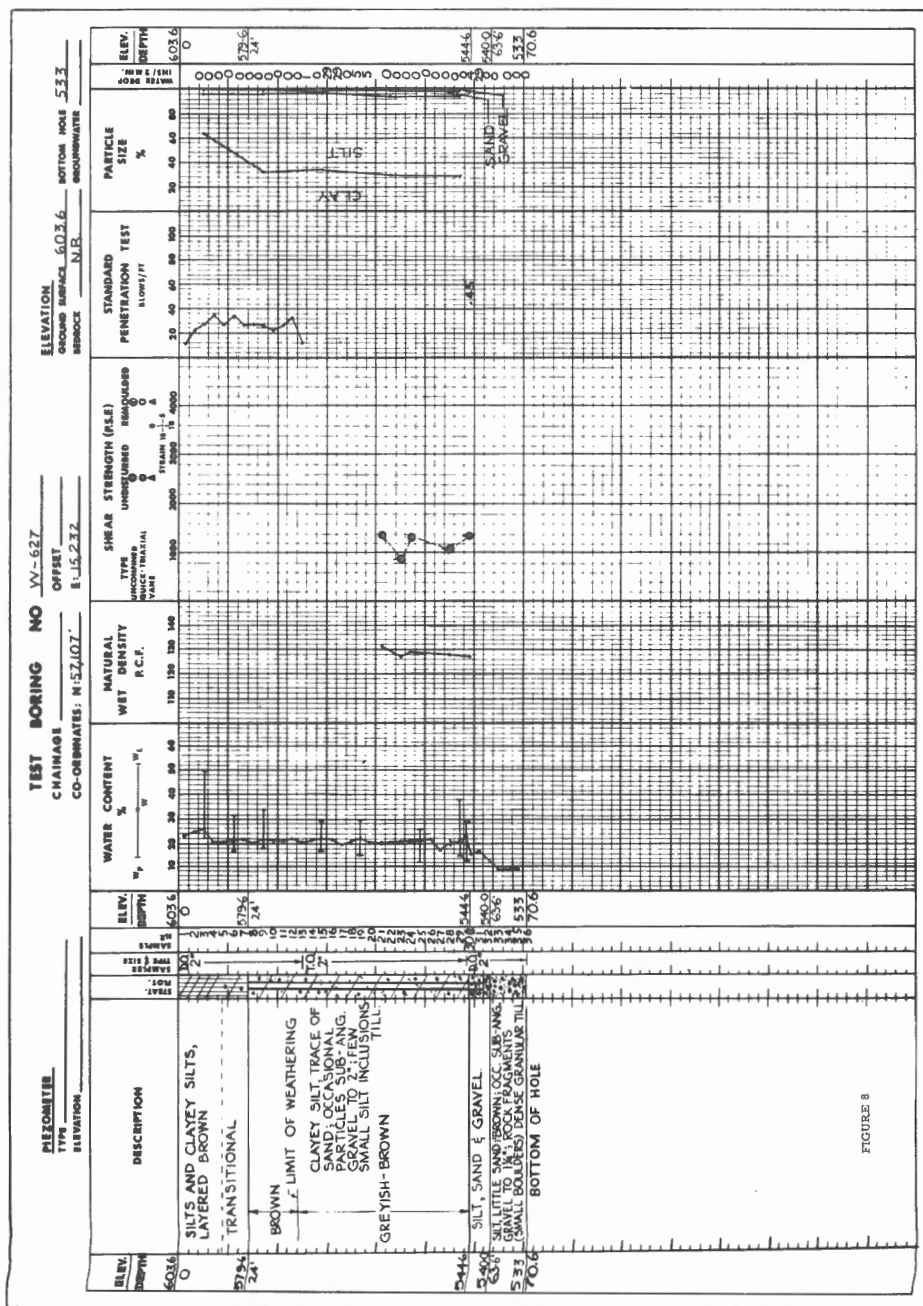
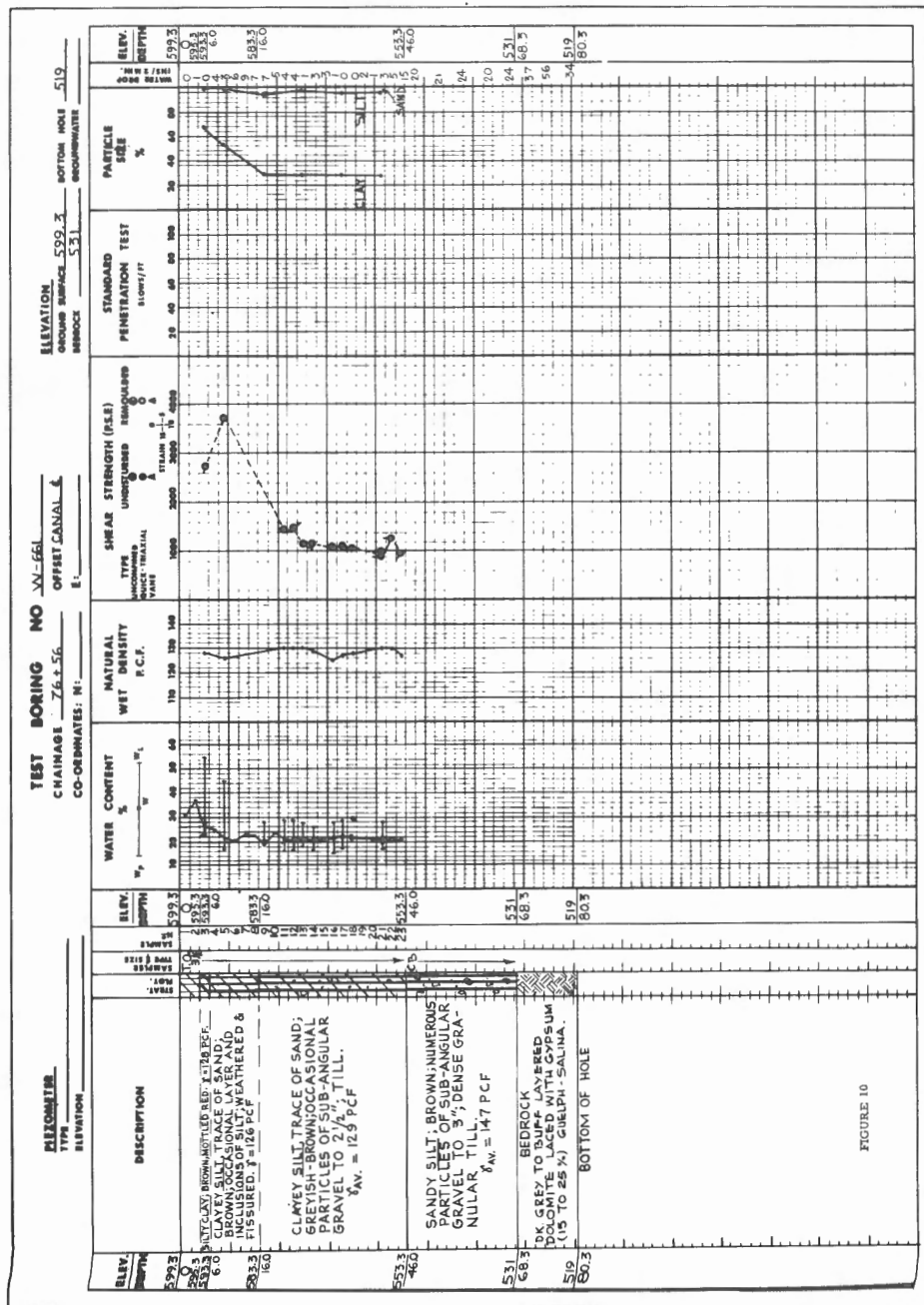
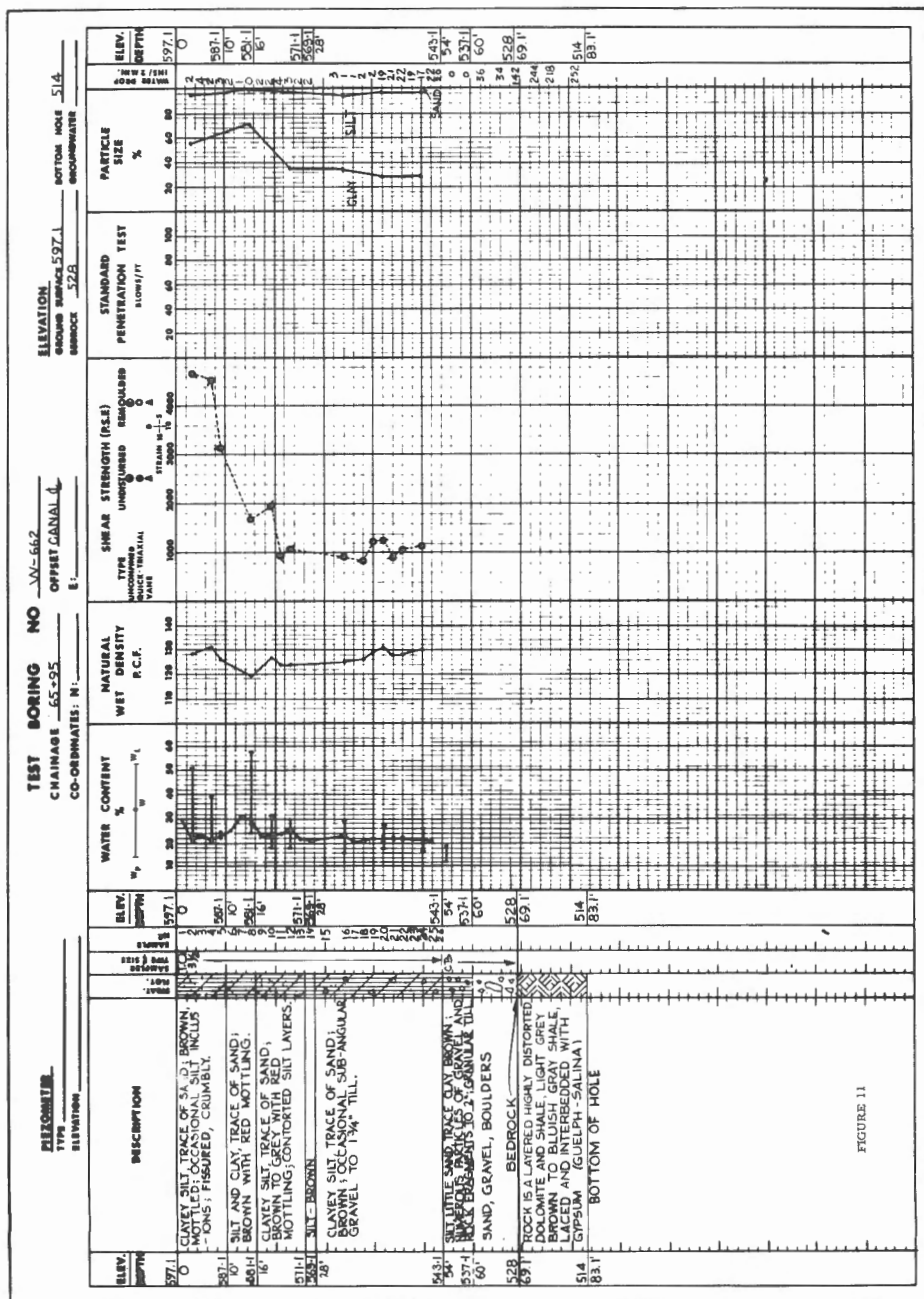


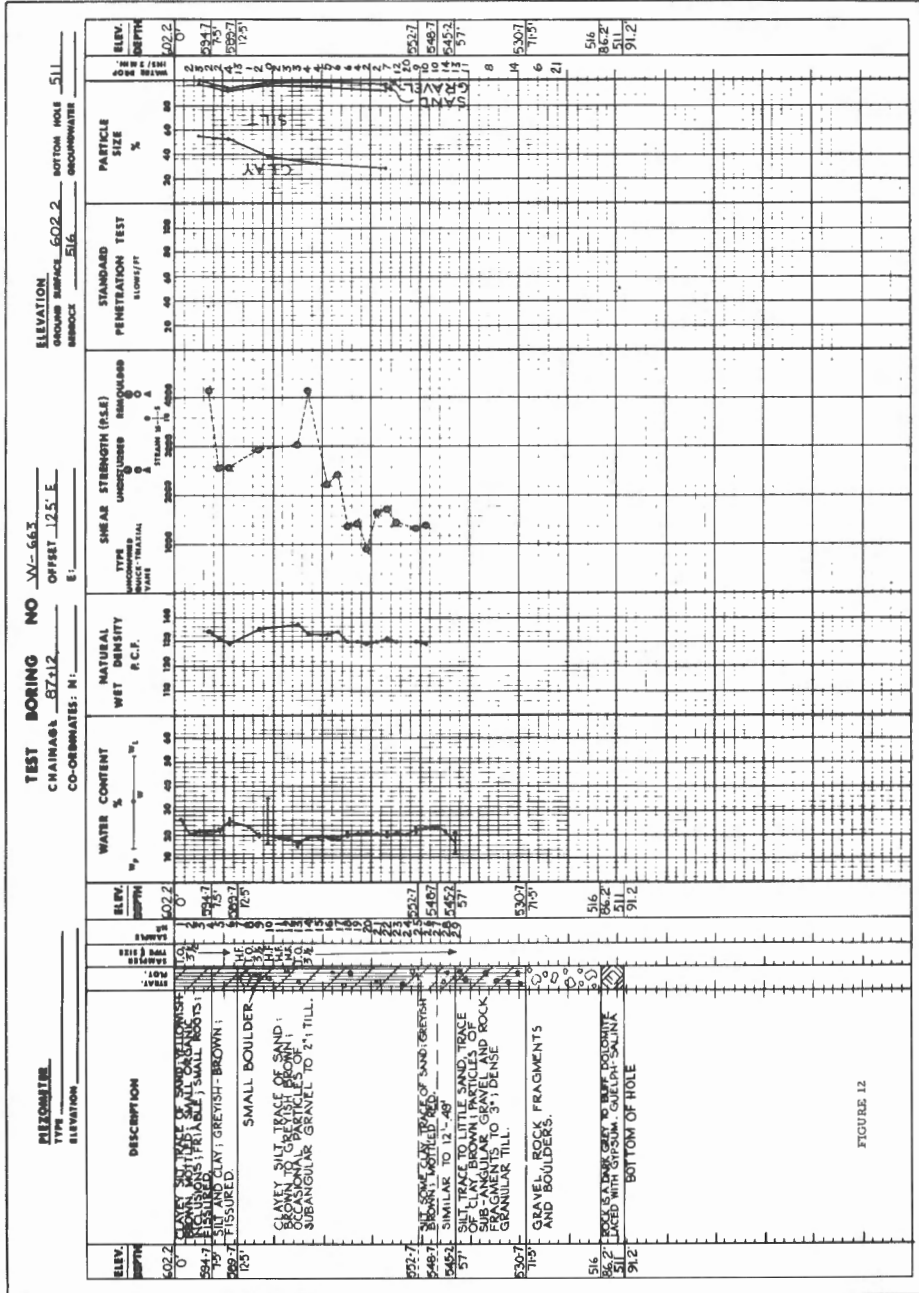
FIGURE 6

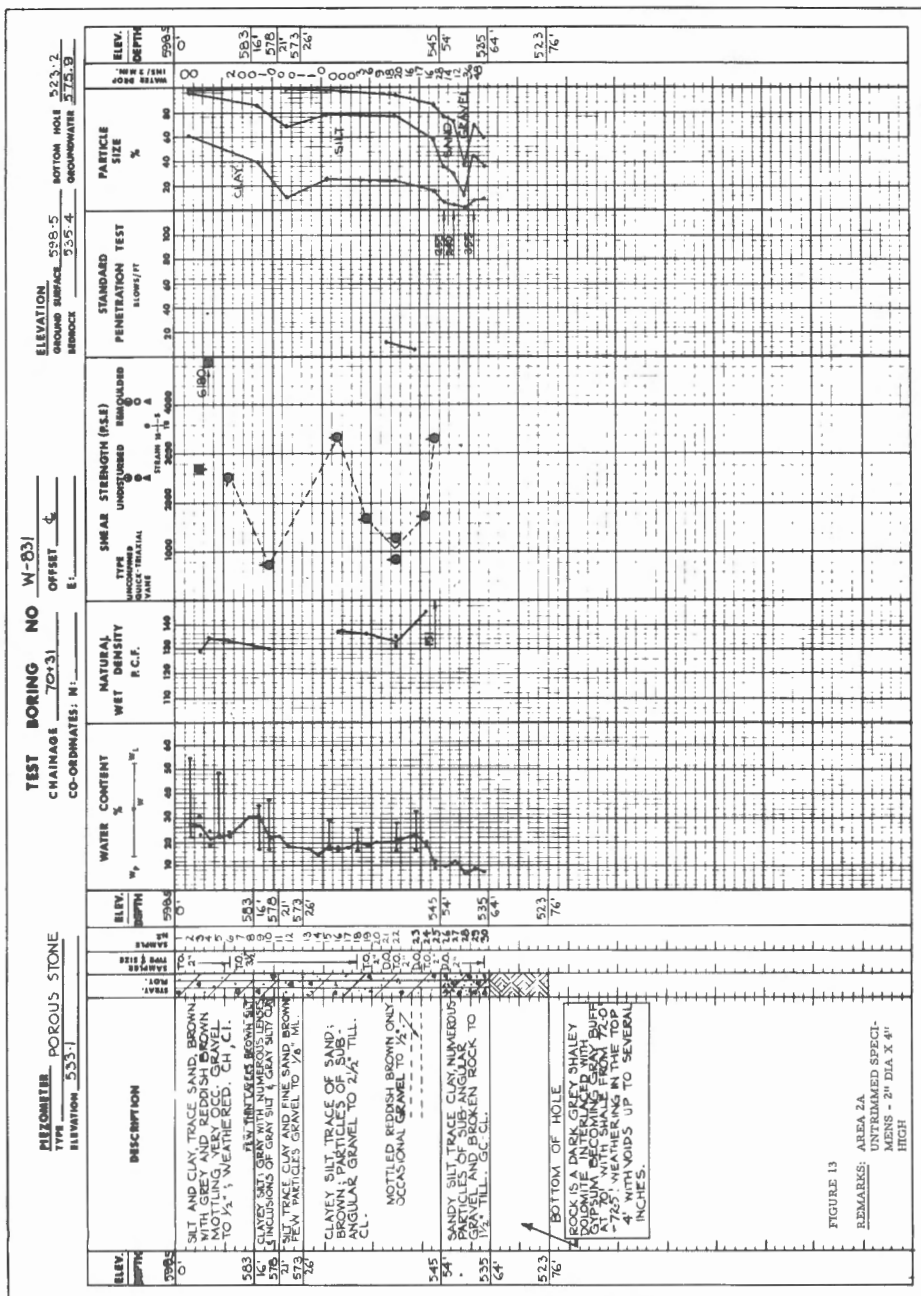


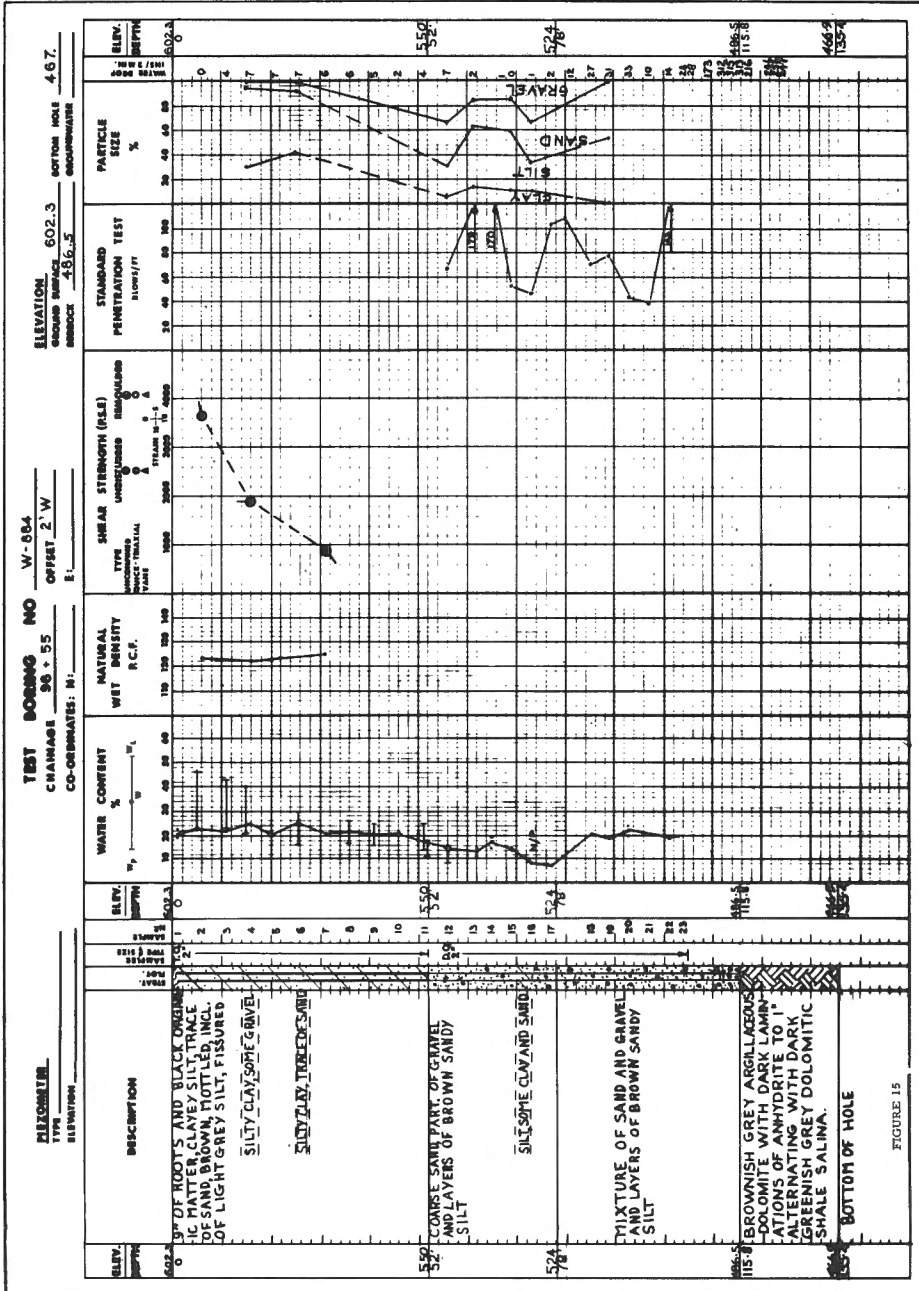


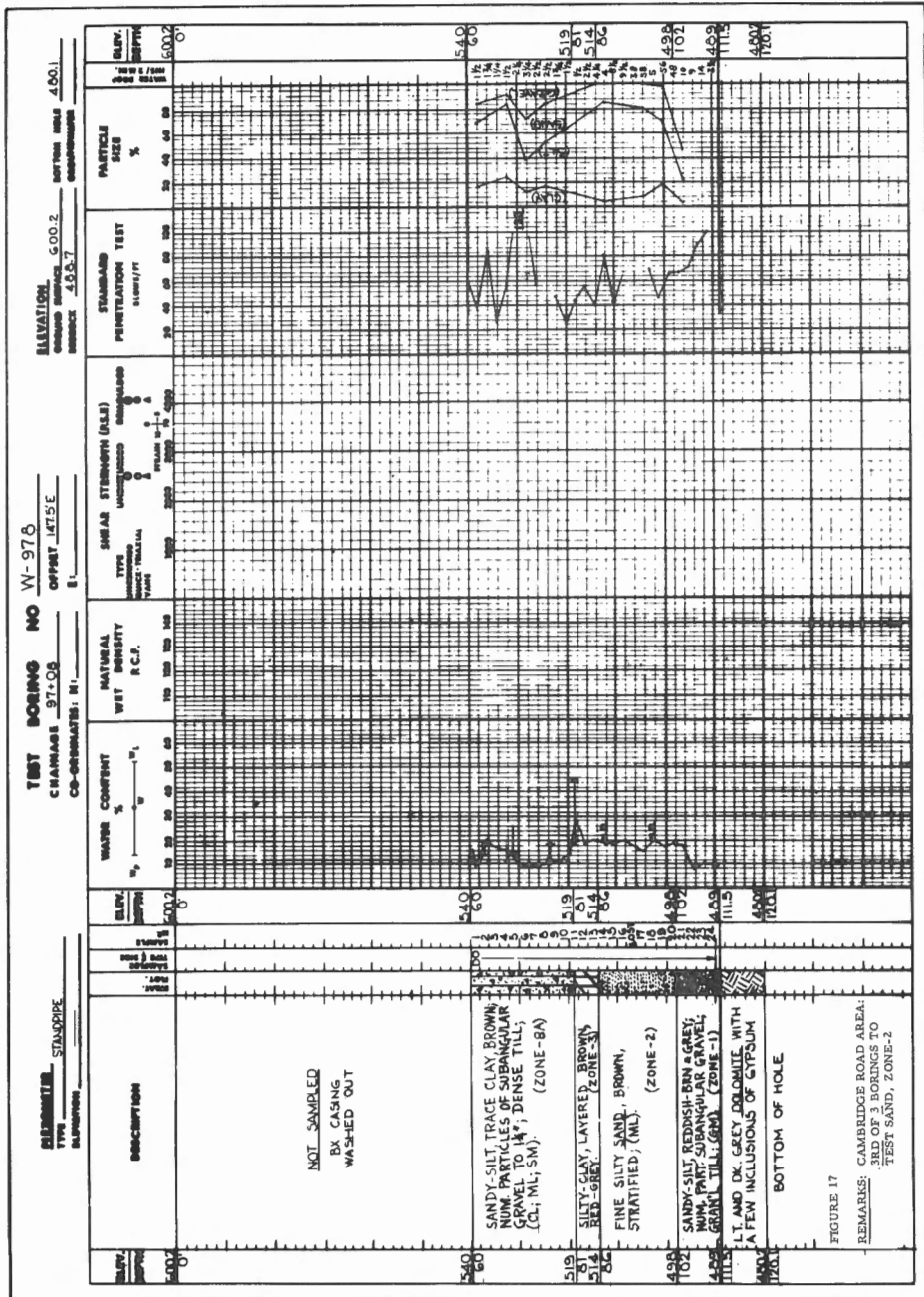












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