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Publisher's version / Version de l'éditeur:

<https://doi.org/10.4224/20337921>

Internal Report (National Research Council of Canada. Division of Building Research), 1965-09-01

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NATIONAL RESEARCH COUNCIL
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DIVISION OF BUILDING RESEARCH

A STUDY OF CLAY SEDIMENTS
IN THE OTTAWA-HULL AREA

by

Edward Penner

Internal Report No. 321
of the
Division of Building Research

OTTAWA
September 1965

PREFACE

In the last 15 years, considerable advance has been made in understanding the unique engineering properties of Leda clay - a deposit found extensively in the St. Lawrence Lowlands. Its origin, however, still is not properly known.

The present study of sensitivity and carbonate content of Leda clay in the Ottawa-Hull area is a further attempt to characterize these soils as an aid to the determination of their true origin.

The author is a graduate in agriculture with special training in soil science and is a research officer with the Soil Mechanics Section.

Ottawa

R. F. Legget,

September 1965

Director

A STUDY OF CLAY SEDIMENTS IN THE OTTAWA-HULL AREA

by

Edward Penner

The fine-grained surficial deposits that are found extensively along the Ottawa - St. Lawrence Rivers and their tributaries are frequently referred to as marine sediments. At Ottawa, there appear to be two main deposits; the lower clay is known to have had its depositional origin in the Champlain Sea, but the question arises frequently whether the so-called "upper clay" had a somewhat different depositional origin, perhaps even a fresh water environment.

The engineering properties of the upper and lower clays are very similar, which makes the question of origin somewhat academic to the soils engineer but the problem has remained of sufficient interest to explore new methods of determining their identity.

The existence of two distinctly different deposits, one marine and a later one of fresh water origin is supported strongly by recent studies (1). Gadd (1) concludes from his work that "the physical differences in these two clays are best explained by assigning the older of the two to a marine or brackish water environment - the Champlain Sea - and the younger to a fresh-water lacustrine or fluvial environment of deposition - the ancestral Ottawa".

Many of the engineering problems with the fine-grained sediments in this area can be attributed to soil sensitivity. This introduces difficulties of special significance in sampling and in the evaluation of laboratory tests for application in the field. It was, in fact, the highly sensitive nature of both the upper and lower clays that led engineers to assume a similar geological origin for both. Some of the early geological studies claimed that the whole deposit was of marine origin and when sensitivity of marine deposits was shown elsewhere to arise from fresh water leaching (2), this claim was given a much stronger basis.

In describing the deposits Gadd states "thus oxidized non-calcareous and non-fossiliferous lies unconformably upon soft unoxidized calcareous fossiliferous marine clay". The present study was carried out to explore the suggestion that a separation between fresh water and marine deposits in this area (Ottawa-Hull) could be made on the basis of their carbonate content. Gadd also describes the younger sediment as "stiff" and the older and marine deposits as "soft". Sensitivity determinations were included in this study to check this comparison on a quantitative basis.

METHODS

Calcite and Dolomite Determination

The analysis used is based on the relative rates of CO₂ evolution from the two minerals after treatment with an excess of HCl solution and follows the method described by Skinner and Halstead (3) and Skinner et al. (4). Pressure changes were measured with a 10 psi pressure transducer (instead of using a mercury manometer) and recorded with a millivolt recorder. A diagram of the apparatus is shown in Figure 1.

The analysis procedure is as follows. A small waxed-paper cup containing the soil is floated on 30 ml of 4 N HCl in a 500-ml wide-mouth flask. The flask is then closed and submerged in a constant temperature water bath maintained at 25°C. The automatic wrist-shaker is set in motion and the pressure is recorded continuously until a maximum is reached.

The recorded data are reduced for plotting by subtracting the interval millivolt readings from the final value. Using semi-log paper, these values are plotted on the log scale against time in seconds on the arithmetic scale.

Separation of dolomite and calcite depends on the straight-line portion which occurs after all the calcite has reacted with the HCl. This takes about 60 sec if the soil is crushed to pass a 0.5-mm sieve; i. e. no calcite particle is larger in diameter

than 0.5 mm. The dolomite straight-line portion is projected to zero time which gives the relative amount of CO_2 derived from dolomite. The remainder of the CO_2 is attributed to the calcite-HCl reaction. The apparatus is calibrated using various amounts of pure calcium carbonate so that the millivolt readings can be converted to weights of CO_2 . Most soil samples were analysed twice and both the individual results and averages are given in the tables. The soils were air dried and ground to pass a 0.5-mm sieve. As suggested in the literature, excessive grinding to a fine powder was avoided.

The sensitivity values were calculated from laboratory cone-penetration measurements in disturbed and remoulded samples. Salt content of the pore water was determined by pressure extraction of the soil water. The water was evaporated at 105°C and the salt content determined by weighing.

SAMPLING LOCATIONS

The soil samples analysed were selected from samples available from recent engineering studies in the Ottawa-Hull area. The locations are marked on a map of the area shown in Figure 2. Samples were secured either with the thin-wall Norwegian Sampler, or the Swedish Foil Sampler. A few results are from block samples, which were procured at the time of the excavation for the Green Creek Sewage Plant.

RESULTS AND DISCUSSION

At the Sewage Plant location (Table I), the combined calcite and dolomite contents are low to a depth of 45 or 50 ft. At this depth the combined and individual values both increase from a combined total of 1.73 to 4.40 per cent. The surface material is mapped (1) as "probably of fresh water origin", "non-calcareous" and "stiff". Some underlying material exposed in nearby Green Creek is mapped as Champlain Sea clay and is described as "soft" and "calcareous".

According to other measurements carried out at this laboratory, the material below the surface oxidized layer down to

a depth of 47 ft is reasonably uniform in sensitivity. A sensitivity of 30 - given for the 20-ft level - is considered to be characteristic of the upper zone. There is, however, a radical change in sensitivity at 47 ft and the natural soil below this depth is a fluid in the remoulded state.

Regarding salt content, a value of 0.6 gm/l is characteristic of the upper clay and 1.0 to 1.5 is about the range between extremes for the lower clay. From clay fabric studies (5), both the upper and lower clays are known to have a flocculated structure, although the upper clay shows somewhat greater particle alignment and the moisture content is about 10 per cent less in the lower clay. In part, the high sensitivity of the lower clay can be attributed to its slightly coarser texture but more important is the much higher sodium ion content of the pore water. For example, at 22 ft, where the sensitivity was 30, the calcium and sodium ion contents were 1.8 and 9.7 mgts/l respectively; at 47 ft, where the sensitivity was 1500, the calcium and sodium ion contents were 0.7 and 37 mgts/l respectively. The higher sodium content causes the remoulded soil to disperse more readily and at these water contents it has a tendency to liquefy.

The lower clay has a low pore-water salt content at present and consequently, if its origin is assigned to a marine environment (≈ 32 gm/l) it must have been leached subsequently. The lower clay is fairly calcareous and soft and this agrees with Gadd's description of a marine deposit (1). It is difficult to accept the upper clay as a fresh water deposit as its structure is typical also of a salt flocculated clay. It is, however, essentially non-calcareous and much less sensitive than the lower clay, but the sensitivity is much higher than is normally associated with typical lacustrine deposits.

The location of hole No. 3, Queensway overpass area, is some 1700 ft S. E. of the Sewage Plant location, and its present elevation is approximately 3 ft higher. The salt content of the pore water increases at this location from 2 to 8 gm/l between 21 and 71 ft (Table II). In general, the sensitivity near the surface is much the same as the upper clay at the Sewage Plant and it

decreases with depth as the salt content increases. The salty nature of the pore water suggests that the soil had a marine origin but at the same time the dolomite and calcite contents are low.

Hole No. 7 is some 1700 ft due south of hole No. 3 and is also essentially non-calcareous (Table III). The pore-water salt contents range between 1 and 1.8 gm/l down to a depth of 60 ft and they are slightly higher at 71 ft. At this location, the pore-water salt content does not increase appreciably with depth and the sensitivities are about twice that measured at hole No. 3. The surficial deposits for the area containing the above three locations are mapped as clays which are "probably of fresh water origin" (1).

The distribution of the dolomite and calcite content at the Gloucester location (Table IV) corresponds roughly with published results of Brydon and Patry (6). Table IV shows that the combined carbonates reduce from 5.5 per cent at 8 ft to a low of 0.5 per cent at 35 ft. This is followed by an increase to 9.29 per cent at 50 ft and reduces to 4.40 per cent at 60 ft. The pore-water salt content is low (1 gm/l) and the sensitivity is high. If the material is considered sufficiently calcareous to be classed as "lower clay", and if this is taken as a reliable criterion, the present status of the pore-water salt content suggests that leaching has taken place following deposition. A further complication is the observed low carbonate values in the centre part of the profile.

At the Breckenridge location (Table V), the soils are somewhat less sensitive than at the Gloucester location; the combined carbonates are low and salt contents are low (0.4 to 2 gm/l). Since the present work was completed, borings below 90 ft have revealed extremely high pore-water salt concentrations (up to 23 gm/l). Based on qualitative tests, however, the soil at this depth is also non-calcareous.

SUMMARY

Sewage Plant Location, Surface elevation 172 ft, Map-unit 7 (1).

There appear to be two different deposits in the profile. The upper 47 ft is low in carbonates and low in sensitivity as compared to the lower clay. Below 47 ft the clay is extremely sensitive and has a three-fold increase in carbonates. The salt content is low throughout the profile. The upper clay appears to be too sensitive for a lacustrine deposit.

Hole No. 7, Surface elevation 175 ft, 1700 ft S. E. of Sewage Plant, Map-unit 7 (1).

The salt content increases with depth from the surface downward from 2.2 to 8.2 gm/l. Carbonates are low, sensitivities range from 21 to 39. Other studies show that the salt content at 107 ft is 14 gm/l.

Hole No. 3, Surface elevation 185.5 ft, 1700 ft S. of Hole No. 3, Map-unit 7 (1).

The salt content is less than 2 gm/l down to 61 ft and increases to 2.6 at 71 ft. Carbonates are low, sensitivity 34 to 74.

Gloucester Naval Station, Surface elevation 260 ft, Map-unit 6 (1).

The profile is highly sensitive and the salt content is less than 1 gm/l. The carbonate content is high at the surface, decreasing with depth to about 40 ft and then increasing again.

Breckenridge, P. Q., Surface elevation 330 ft, Map-unit 7 (1).

The carbonate contents are low, the salt contents are low and sensitivities are moderately high, but lower than at Gloucester.

CONCLUSIONS

It is difficult to draw any definite conclusions on the origin of the clays on the basis of carbonate content. The most striking anomaly is at hole No. 3 where the present pore-water salt contents increase from the surface downward, which strongly suggests a marine depositional environment. The present study shows an increase in the salt content from 2 gm/l at the surface to 8.2 gm at 71 ft. In other studies, the salt content at this location has been shown to increase to 14 gm/l at 107 ft. The carbonate contents are low at this location, which is contrary to what might be expected on the basis of Gadd's report (1). On the other hand, the lower clay at the Sewage Plant and the profile at Gloucester are fairly calcareous and highly sensitive. On the basis of the latter they are assumed to be Champlain Sea deposits which fits Gadd's criteria. At present, the pore-water is low in salt content.

Based on criteria such as sensitivity, the structure of the clay and its engineering and physico-chemical properties, the differences between the two clays are much less than would be anticipated if one was lacustrine and the other marine. If the assumption is correct about the upper clay being derived from the reworking and resuspension and redeposition of Champlain Sea deposits, some of the similarities may be due to inherited properties, and as a result of this, the effect of the new depositional environment would be partially obscured. As a generalization, it may be said that the properties of the clays that are mapped as fresh water deposits (upper clays) in this area are more similar to known leached marine sediments (but not the same) than to fresh water sediments.

ACKNOWLEDGEMENTS

The author expresses his appreciation to Mr. D. Eldred for his assistance with the construction of the carbonate apparatus and for supervising the carbonate analyses.

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TABLE I

LOCATION - SEWAGE PLANT

(Swedish Foil Samples, Surface Elevation 172 ft)

Sample No.	Depth, ft	Calcite, %	Dolomite, %	Cal + Dol, %	Inorganic C, %	Sensitivity	Salt, gm/l	Clay, %
94-36	9	0.24	0.08	0.32	0.04			
		0.23	0.09	0.32	0.04			
AVE.		0.23	0.08	0.32	0.04			
94-49	18	1.65	0.10	1.75	0.21	30	0.60	83
		1.62	0.11	1.74	0.21	(22 ft)		
AVE.		1.63	0.10	1.75	0.21			
94-65	29	0.88	0.12	1.00	0.12			
		0.88	0.12	1.00	0.12			
AVE.		0.88	0.12	1.00	0.12			
94-82	37.5	1.25	0.30	1.55	0.19			
		1.25	0.33	1.58	0.19			
AVE.		1.25	0.31	1.56	0.19			
94-93	45	1.25	0.47	1.72	0.21			
		1.24	0.50	1.74	0.21			
AVE.		1.24	0.48	1.73	0.21			
94-101	51	2.96	2.55	5.51	0.69	1500	1.10	71
		3.03	2.49	5.52	0.69	(47 ft)		
AVE.		2.99	2.52	5.51	0.69			
94-113	60	3.11	2.47	5.58	0.69			
		3.02	2.57	5.59	0.70			
AVE.		3.06	2.52	5.58	0.69			
94-127	72	2.76	0.73	3.49	0.43	900	1.34	61
		2.76	0.70	3.46	0.42			
AVE.		2.76	0.71	3.47	0.42			

TABLE II

LOCATION - QUEENSWAY OVERPASS

(Sounding Hole No. 3; Surface Elevation 175 ft)

Sample No.	Depth, ft	Calcite, %	Dolomite, %	Cal + Dol, %	Inorganic C, %	Sensitivity	Salt gm/l	Clay, %
132-1-3	21	1.30	0.36	1.66	0.20	39	2.2	
		1.18	0.34	1.52	0.18			
		1.33	0.32	1.65	0.20			
AVE.		1.27	0.34	1.61	0.19			
132-2-2	31	0.36	0.12	0.48	0.06	27	4.0	
		0.37	0.09	0.46	0.06			
AVE.		0.36	0.10	0.47	0.06			
132-3-2	41	0.97	0.14	1.11	0.13	17	6.6	
		0.92	0.13	1.05	0.13			
		0.86	0.12	0.98	0.12			
AVE.		0.92	0.13	1.05	0.13			
132-4-2	51	0.93	0.27	1.20	0.15	24	7.6	
		0.87	0.28	1.15	0.14			
AVE.		0.90	0.27	1.17	0.14			
132-5-2	61	1.13	0.32	1.45	0.18	25	7.2	
132-6-2	71	0.94	0.18	1.12	0.14			
		0.93	0.19	1.12	0.14	21	8.2	
AVE.		0.93	0.18	1.12	0.14			
<u>SEWER INTERCEPTOR SHAFT</u>								
136-2	32	0.84	0.27	1.11	0.14	11	≈0.5	
		0.85	0.28	1.13	0.14			
AVE.		0.84	0.27	1.12	0.14			

TABLE III

LOCATION - QUEENSWAY OVERPASS

(Sounding Hole No. 7; Surface Elevation 185.5 ft)

Sample No.	Depth, ft	Calcite, %	Dolomite, %	Cal + Dol, %	Inorganic C, %	Sensitivity	Salt gm/l	Clay, %
132-7-2	21	0.67	0.17	0.84	0.10		0.80	
		0.68	0.18	0.86	0.10			
AVE.		0.67	0.17	0.85	0.10			
132-8-2	31	0.49	0.13	0.62	0.08	53	1.20	
		0.52	0.12	0.64	0.08			
AVE.		0.50	0.12	0.63	0.08			
132-9-2	41	1.10	0.24	1.34	0.16	74	1.00	
		1.08	0.24	1.32	0.16			
AVE.		1.09	0.24	1.33	0.16			
132-10-2	51	1.03	0.17	1.20	0.15	60	1.80	79
		0.99	0.20	1.19	0.14			
AVE.		1.01	0.18	1.19	0.14			
132-11-2	61	0.49	0.12	0.61	0.07	45	1.60	89
		0.46	0.13	0.59	0.07			
AVE.		0.47	0.12	0.60	0.07			
132-12-2	71	0.81	0.14	0.95	0.12	34	2.60	85
		0.84	0.15	0.99	0.12			
		0.86	0.16	1.02	0.12			
AVE.		0.84	0.15	0.98	0.12			

TABLE V
LOCATION - BRECKENRIDGE
(Surface Elevation 330 ft)

Sample No.	Depth, ft	Calcite, %	Dolomite, %	Cal + Dol, %	Inorganic C, %	Sensitivity	Salt gm/l	Clay %
129-2-6	17	0.10	0.28	0.38	0.05	21	0.4	82
129-6-6	29	0.53	0.18	0.71	0.09	54	0.8	82
129-7	30					183		
129-11	44					74		
129-12-1	45	0.42 0.40	0.11 0.11	0.53 0.51	0.06 0.06			88
AVE.		0.41	0.11	0.52	0.06			
129-12-4	46	1.06 1.03 1.03	0.19 0.20 0.20	1.25 1.23 1.23	0.15 0.15 0.15			
AVE.		1.04	0.20	1.24	0.15			
129-13-4	49					72	1.2	85
129-14-6	53	0.72	0.06	0.78	0.09			
129-15-4	55					75	1.5	
129-16-10	60	1.13 1.16 1.16	0.31 0.34 0.35	1.44 1.50 1.51	0.18 0.18 0.18	118		85
AVE.		1.15	0.33	1.48	0.18			
129-17-6	62					53	1.9	80
129-18-3	66	1.12 1.11	0.18 0.19	1.30 1.30	0.16 0.16	53		
AVE.		1.11	0.18	1.30	0.16			
129-20-1	75	0.86 0.84	0.14 0.15	1.00 0.99	0.12 0.12	37	2.0	83
AVE.		0.85	0.14	0.99	0.12			
129-20-5	87					31		
129-23-1	90	1.68	0.81	2.49	0.31			

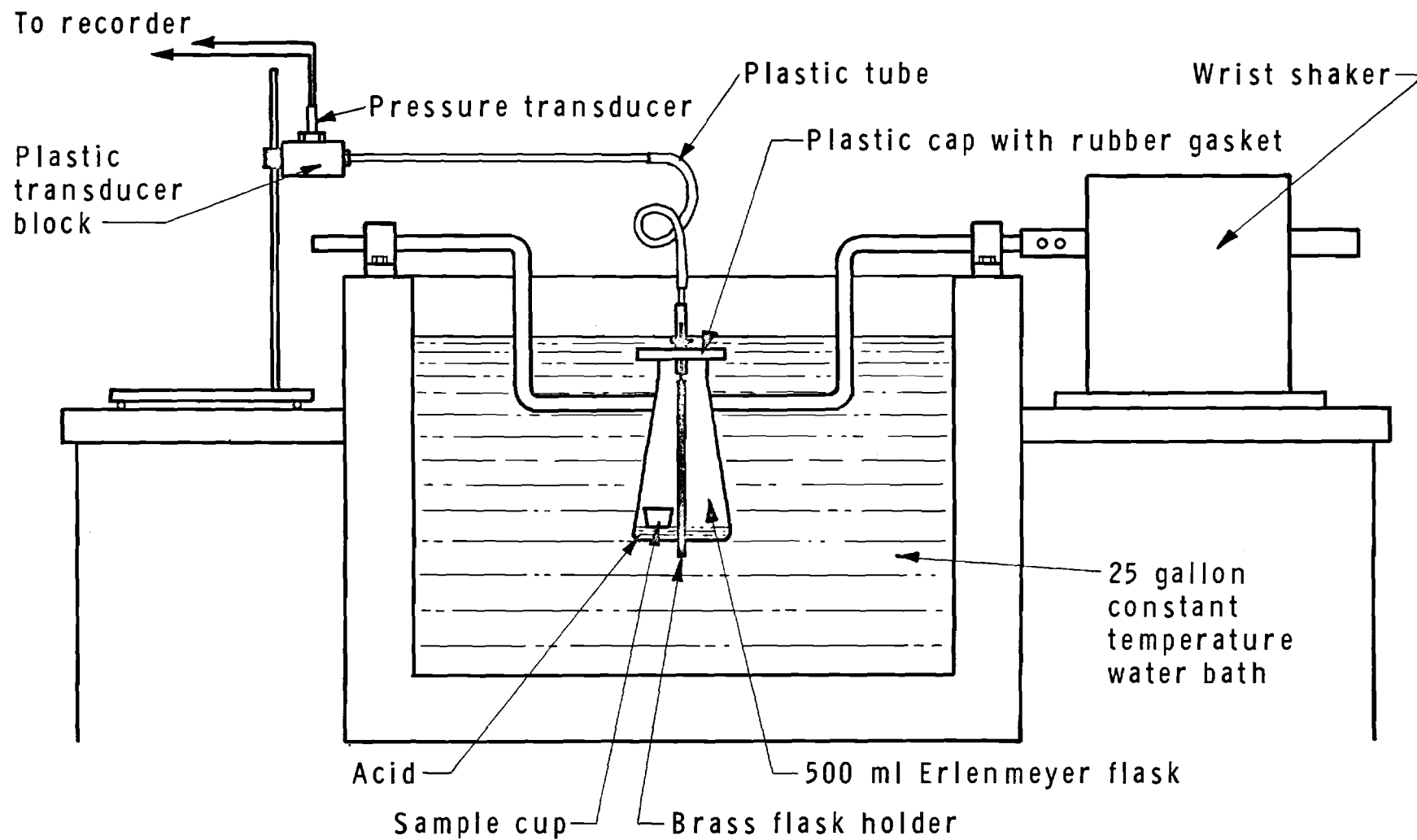


FIGURE 1 CARBONATE APPARATUS

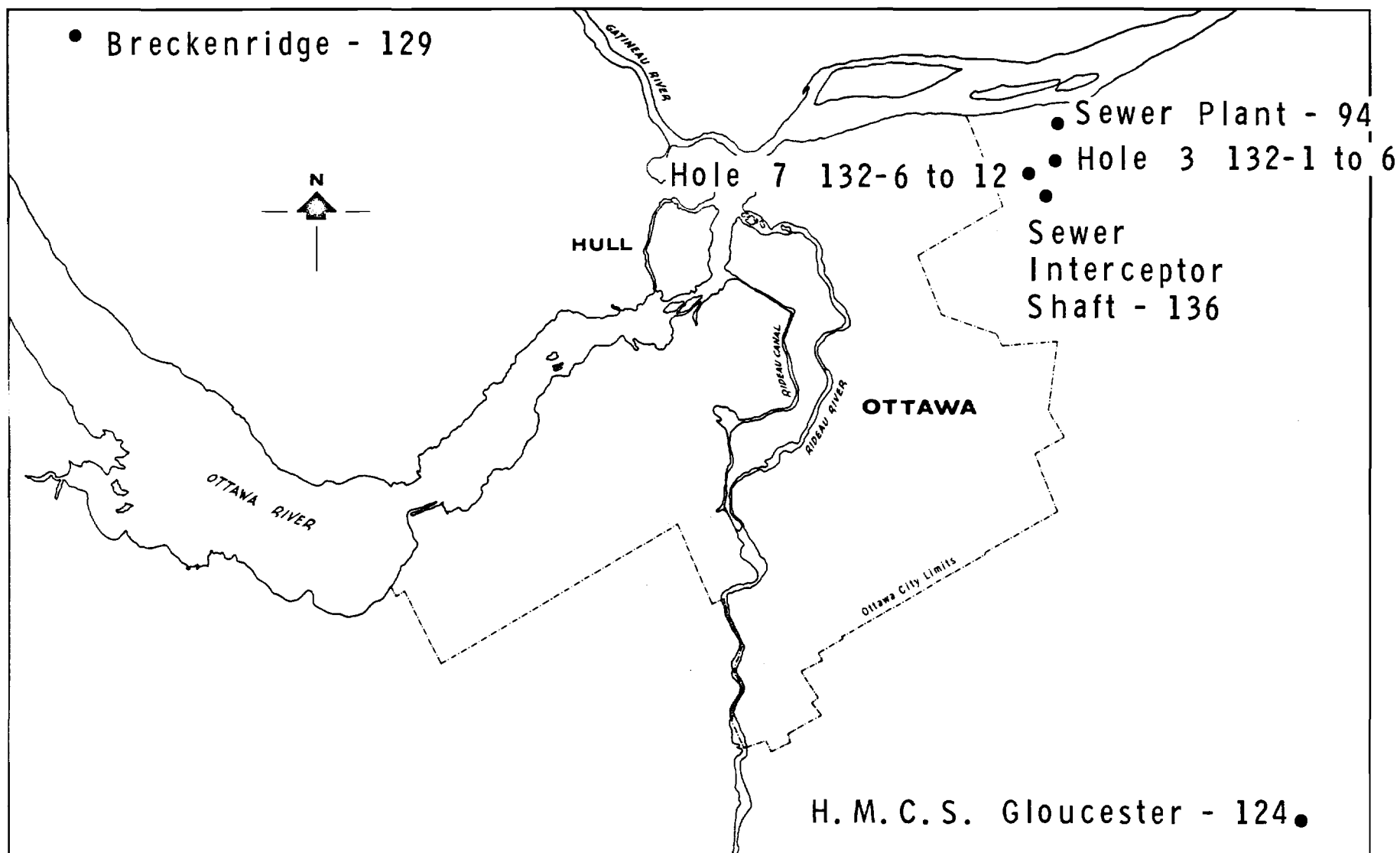


FIGURE 2

SAMPLING LOCATIONS IN THE OTTAWA-HULL AREA