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REPORT

to

CANADA CENTRE FOR INLAND WATERS
BURLINGTON, ONTARIO

on

BLUFF PROFILES
SHEAR TESTING
AND
PRELIMINARY CLAY MINERALOGY
PORT STANLEY, ONTARIO

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PORT STANLEY EAST, BLUFF PROFILES, SHEAR TESTING AND PRELIMINARY CLAY MINERALOGY

INTRODUCTION

In accordance with the requirements of DSS Contract No.OSS76-00210, direct shear testing has been carried out on four block samples obtained from the Lake Erie bluffs at the rapidly eroding section just east of Port Stanley. Approval to proceed with this specific work was given orally by Mr. A. Zeman following the writer's specific recommendations dated October 4, 1976.

The purpose of the testing has been to characterize the engineering properties of the exposed strata at this Port Stanley site with a view to extending the geotechnical classification of the glacial strata along the shoreline to the east and west.

A distinct pattern of engineering behaviour is beginning to emerge and preliminary x-ray diffraction analyses were carried out to explain the distinctly different residual strength parameters of the till layers compared to the lacustrine silty clay layer within the stratigraphic section.

SITE DESCRIPTION

The site is located just east of Port Stanley within the rapidly

eroding section just beyond Orchard Beach as shown in Figure 1. Since the Pumping Station (located at the east edge of the figure) is now acting as a short jetty, this stretch of shoreline represents a growing erosion embayment between a major headland (Port Stanley jetty) and a minor growing headland at the Pumping Station.

The photographs shown in Figure 2 illustrate the nature of the bluffs (looking easterly from the end of the road servicing Orchard Beach).

The profiles measured by chain and inclinometer survey on November 22, 1976 are shown in Figure 3. Profile #1 represents a scallop in the bluffs caused by seepage outwash of surface sands overlying the lacustrine clays. Profile #2 represents the adjacent bluff face with slide debris at the toe. Profile #3 represents a steeper section of the bluffs about 100 m east where Port Stanley till rises much higher in the section forming a vertical cliff some 20 m high. The overall bluff height is about 28 m and is cut by a major gully between profiles #2 and #3 as shown in Figures 1 and 2a.

Five block samples were taken at this site, four from profiles 1 and 2 and one from profile 3. Block #4 is believed to be slumped material from higher in the section and was not tested.

DESCRIPTION OF SOILS TESTED

The soils tested are identified and described in Table I. Brief visual descriptions are as follows:

Block 1. Compact yellowish surface sands having a thickness of about 10 m.

Block 2. Stiff, grey, laminated silty clays grading downwards into pebbly grey silty clay.

Block 3. Stiff grey pebbly silty clay believed to be waterlain till.

Block 5. Hard gritty to pebbly clayey silt till believed to be Port Stanley till.

The surface of the Port Stanley till could not be observed at the location of profiles 1 and 2 but is believed to be below lake level. To the east it rises above lake level forming a vertical cliff front as shown by profile 3 in Figure 3. Near profiles 1 and 2, the lowermost bluff sections are composed of highly contorted lacustrine beds believed to represent penecontemporaneous slumping.

The waterlain till is thus of highly variable thickness and seems to grade upwards into poorly laminated lacustrine clays.

TESTING PROCEDURES

The sand samples were trimmed as carefully as possible from the intact blocks and tested in the direct shear box, hopefully with only slight disturbance. Normal loads of 100, 300 and 500 kN/m^2 were applied to the samples during shear testing.

All clayey samples were consolidated in stages to normal loads of

100, 300 and 500 kN/m^2 and run drained at a rate of 0.0162 mm/min. Multiple traverses were made until the samples reached residual drained strength. The samples were allowed to reconsolidate overnight between each traverse. All samples were oriented with the failure plane in the horizontal plane of the block sample.

TEST RESULTS

Surface Sand (Block #1)

Stress-displacement curves for the sand samples from Block #1 are presented in Figure 4. The vertical displacement was positive at peak strength in all plots indicating a compact sand. The absence of a strong peak strength for the lightest loaded sample ($\bar{\sigma}_N$ = 100 kN/m^2) suggests, however, that the sand is likely of loose to compact relative density. Calculated porosities of about 39% are fairly high confirming the loose to compact state of the sands.

Strength envelopes for the sand, representing peak and ultimate conditions, are given in Figure 5. Since the sands are only loose to compact, there is little difference between the peak and ultimate values of friction angle (~ 37° and 34° respectively).

Stiff Grey Laminated Silty Clay (Block #2)

Stress-displacement curves for the laminated silty clays are given in Figure 6 and strength envelopes in Figure 7. Four passes appeared to bring the clay down to residual strength from a fairly significant

peak strength as shown in Figure 6. Although the peak and residual values of friction angle were the same at 23 to 24°, a marked reduction in cohesion intercept is apparent from Figure 7. From the data, C_d(peak) is inferred to be about 35 kN/m^2 compared to 0 kN/m^2 at residual.

Stiff, Grey Pebbly Silty Clay (Block #3)

Stress-displacement curves and strength envelopes for this material are given in Figures 8 and 9. The strength envelopes yield a friction angle of 28° at both peak and residual conditions. The cohesion intercept drops from a peak value of about 25 kN/m^2 to 5 kN/m^2 at residual.

Hard, Grey, Gritty, Pebbly Clayey Silt Till (Block #5)

Stress-displacement curves and strength envelopes for the Port Stanley till stratum are given in Figures 10 and 11. The peak and residual friction angles are the same at 29° as shown in Figure 11. The cohesion intercept drops from about 20 kN/m^2 at peak strength to 0 - 5 kN/m^2 at residual.

The most significant observation to be derived from the testing seems to be the difference between the waterlain clayey till and the lacustrine clays. Both the peak and residual friction angles of the faintly laminated clays are about 23° at Port Stanley. The underlying slightly pebbly clays look very similar yet have a friction angle of 28°.

This latter value is similar to the 29° obtained on the much grittier Port Stanley till.

Since low friction angles generally indicate the presence of some swelling clay in soils along the Lake Erie bluffs, a series of preliminary x-ray diffraction analyses were carried out on the fine fractions from Blocks 2, 3 and 5.

PRELIMINARY X-RAY DIFFRACTION

The < 2 μm fraction was suspended in distilled water and centrifuge oriented onto ceramic plates for x-ray. The x-ray traces obtained in water wet (Wet PO), air dried (ADPO) and glycolated (GPO) states are shown in Figures 12, 13 and 14. Although the swelling clay peaks are broad and rather low, it is clear from Figure 12 that the lacustrine clay sample (Block #2) contains more swelling clay than the lower two till samples (Blocks #3 and #5 illustrated in Figures 13 and 14). The other clay minerals present in all samples are abundant illite and iron chlorite.

At both Port Burwell (CCIW Project HY-34) and Port Stanley, preliminary x-ray diffraction analyses have shown that the lacustrine clays contain more swelling clay minerals than associated till deposits. These minerals play a significant role in producing lower friction angles in these lacustrine deposits. Such information seems significant in any attempt to classify the shorelines on a geotechnical basis.

SUMMARY AND CONCLUSIONS

Four distinct soil types form the stratigraphic section exposed in the bluffs just east of Port Stanley. They are; 1) surface sands, 2) lacustrine silty clay, 3) waterlain clayey silt till, and 4) Port Stanley clayey silt lodgement till. The shear strength parameters of these four strata have been determined by multiple traverse drained direct shear testing. The following conclusions are drawn.

1. The surface sands are loose to compact and yield peak and residual friction angles of 37 and 34° respectively.

2. The lacustrine silty clays contain enough more fines and swelling clay (smectite) to reduce the residual friction angle from the 28° characteristic of the clayey tills to 21° to 23° which seems characteristic of the lacustrine clays.

3. X-ray diffraction traces of oriented <2 μm soil fractions give a rapid, cheap indication of the clay minerals present.

4. Index tests performed on the samples yielded distinctly higher Atterberg limits for the lacustrine clays than for the tills. Once a meaningful correlation between the Atterberg limits, grain size and strength properties is established, the index tests themselves may become a useful method of lateral correlation along the shoreline bluffs.

ACKNOWLEDGEMENTS

The research testing carried out for this report was performed in the Soil Mechanics Laboratory of The University of Western Ontario by Messrs. G. Lusk and L. DiNardo within the terms of reference of account 1319-S17 under the supervision of Professor R.M. Quigley.

TABLE I. DESCRIPTION OF SOILS TESTED

Block No.	Brief Description (visual and tactile)	Water Content %	Liquid Limit %	Plastic Limit %	Specific Gravity	Wet Density kg/m^3
1	Loose to compact, yellowish, lacustrine, fine to medium, stratified sands	-	-	-	-	1993
2	Stiff to very stiff grey silty clay with thin lenses and laminae of silt and fine sand	~ 19	34	18	2.74	2127
3	Very stiff brownish grey clayey silt with scattered pockets of silt and sand and occasional pebbles (till)	13.8	24	14	2.74	2231
5	Hard brownish grey, gritty clayey silt till with scattered sand and gravel (Port Stanley Till)	12.5	22	14	-	2241

TABLE II. WATER CONTENTS OF DIRECT SHEAR SPECIMENS

Block No.	Soil Description	Normal Stress kN/m^2	Water Content, %	
			Initial	Final
1	Compact yellow sand	100	23.8	25.4
		300	22.4	25.2
		500	23.0	25.8
2	Laminated grey silty clay	100	15.9 ?	18.8 ?
		100	18.2	22.8
		300	20.3	22.3
		500	18.7	19.2
3	Stiff grey silty clay (till?)	100	13.5	15.3
		300	13.8	14.4
		500	14.0	13.5
5	Hard grey gritty clayey silt till	100	12.4	15.4
		300	12.6	13.4
		500	12.5	13.3

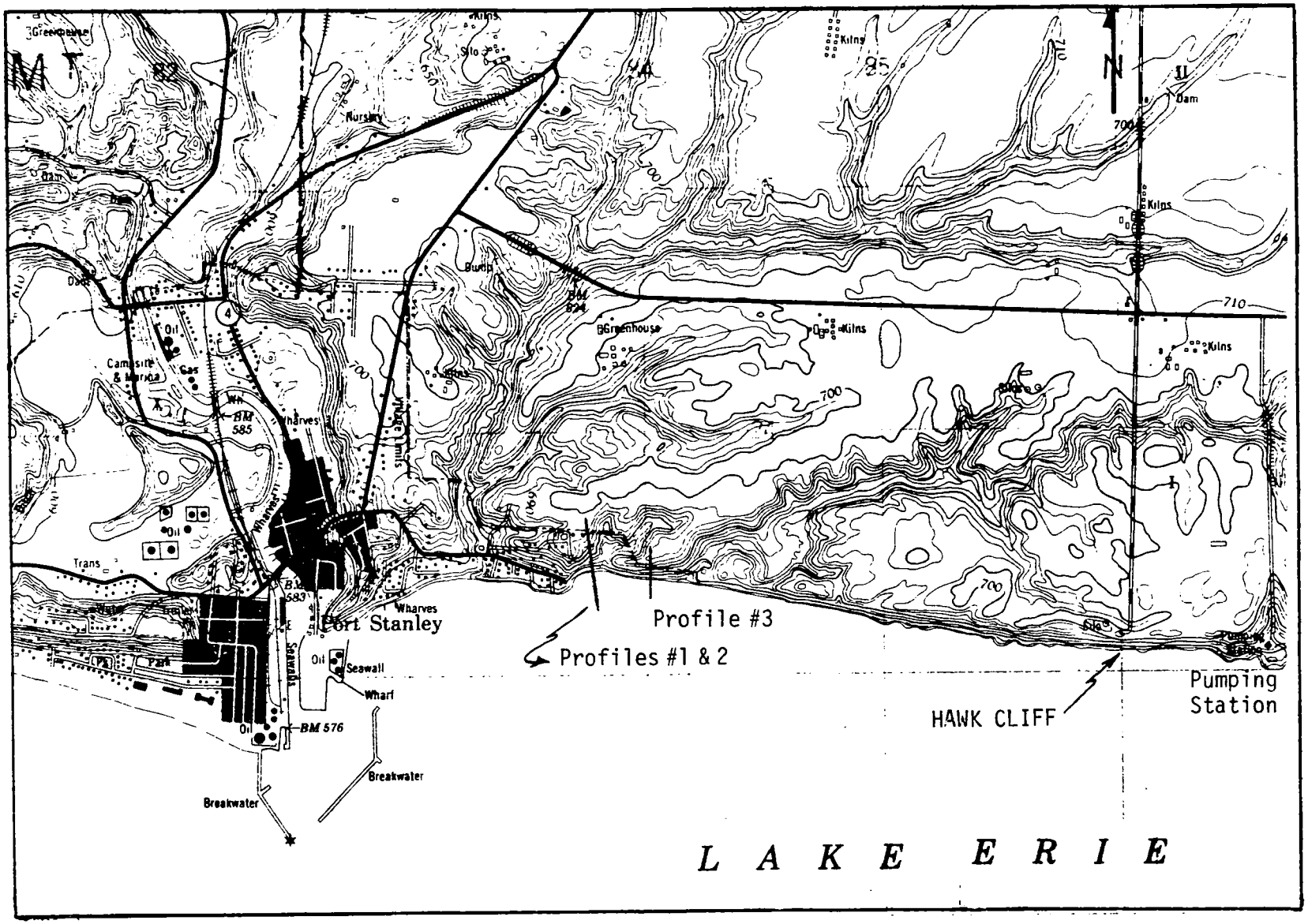

FIG. 1. LOCATION PLAN OF PORT STANLEY BLUFF PROFILES

FIG. 2a. BLUFF PROFILE #3 EAST OF PORT STANLEY

FIG. 2b. BLUFF PROFILES #1 AND 2 LOOKING EAST FROM PORT STANLEY

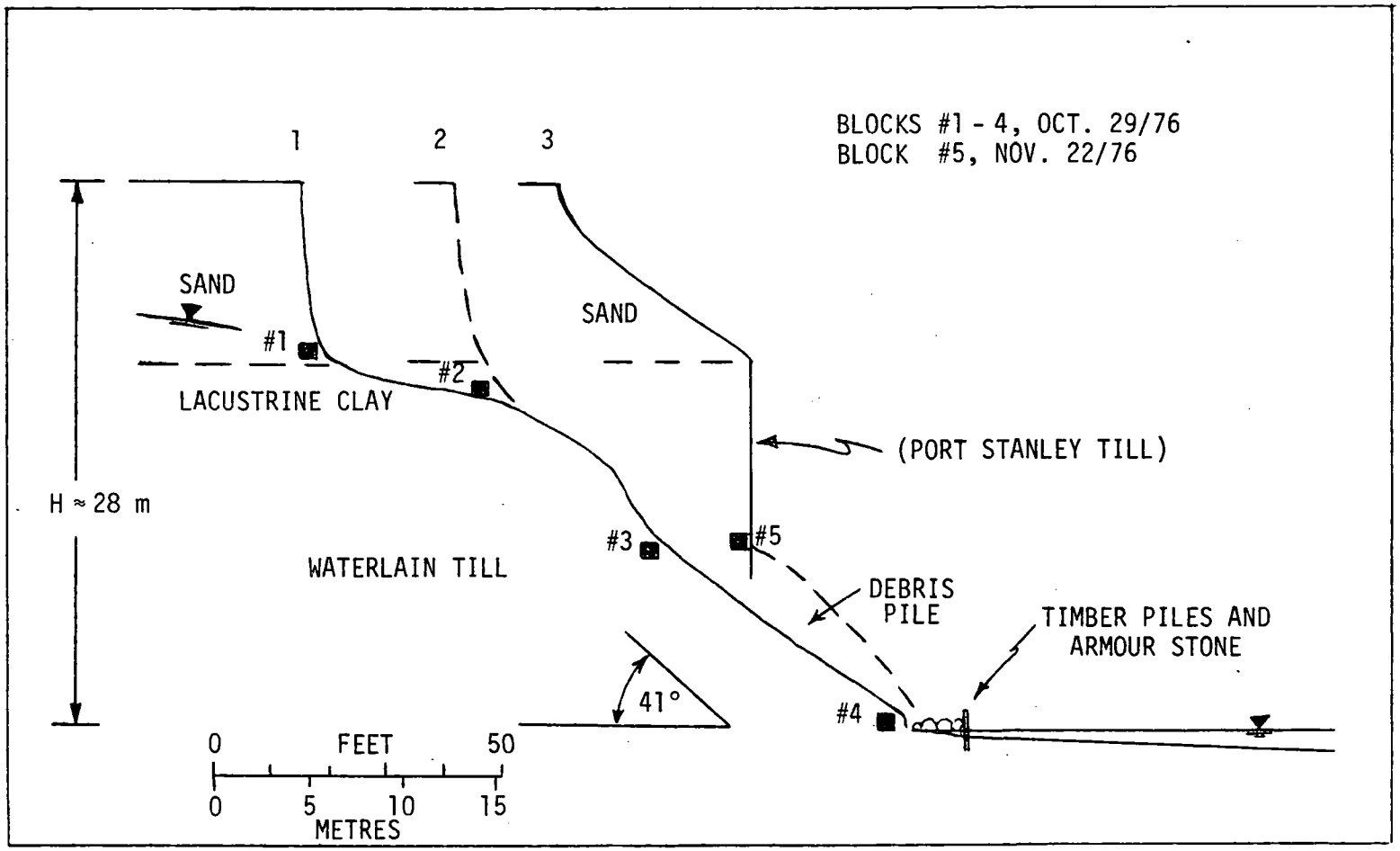

FIG. 3. BLUFF PROFILES AT PORT STANLEY, NOV. 22, 1976, SHOWING BLOCK SAMPLE LOCATIONS

[Profile 1 - Slide Scallop; Profile 2 - Adjacent Rib; Profile 3 - Till Cliff 100 m East]

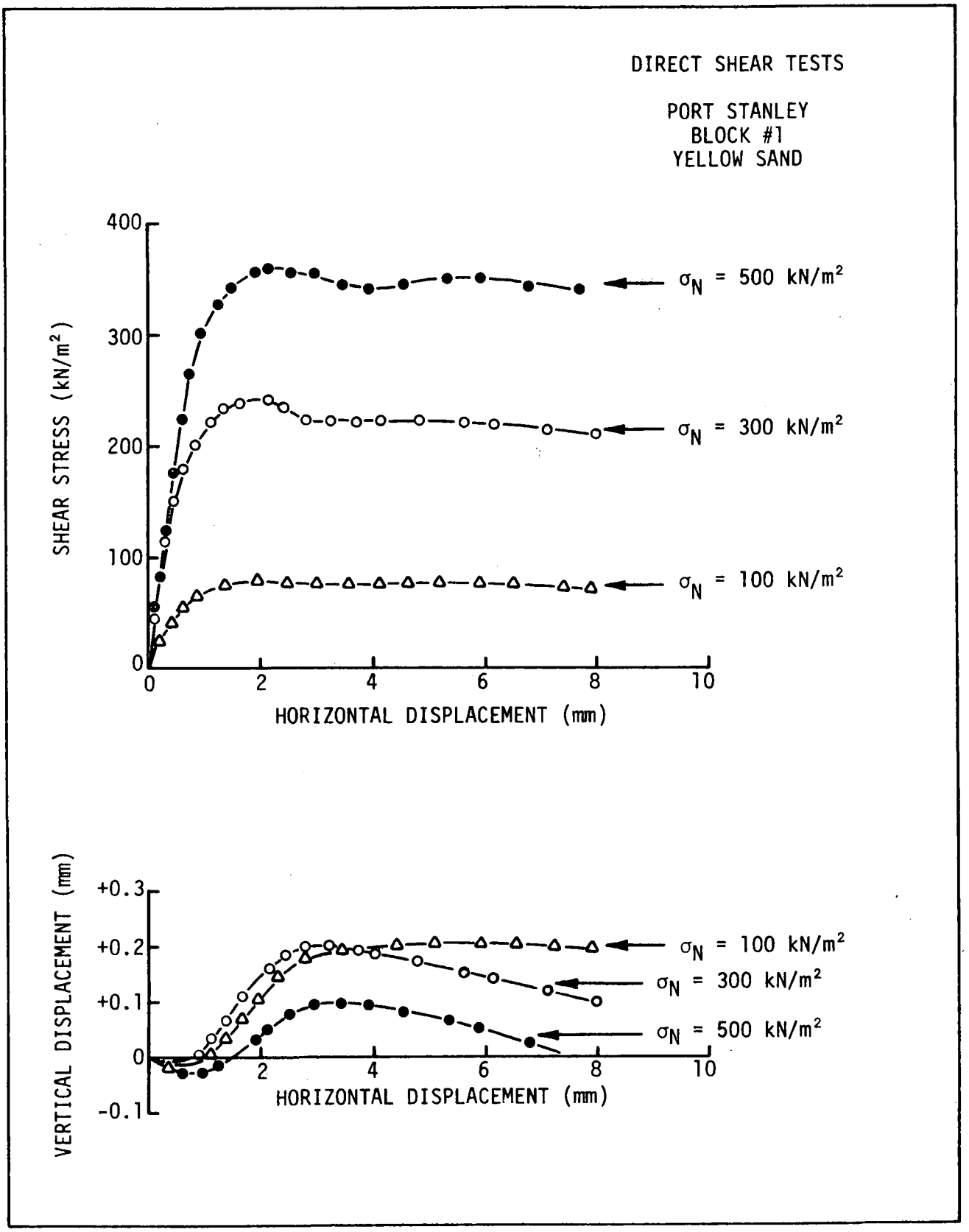

FIG. 4. STRESS-DISPLACEMENT CURVES FOR SAND FROM BLOCK #1, ~ 9 m DEPTH, PORT STANLEY, ONT.

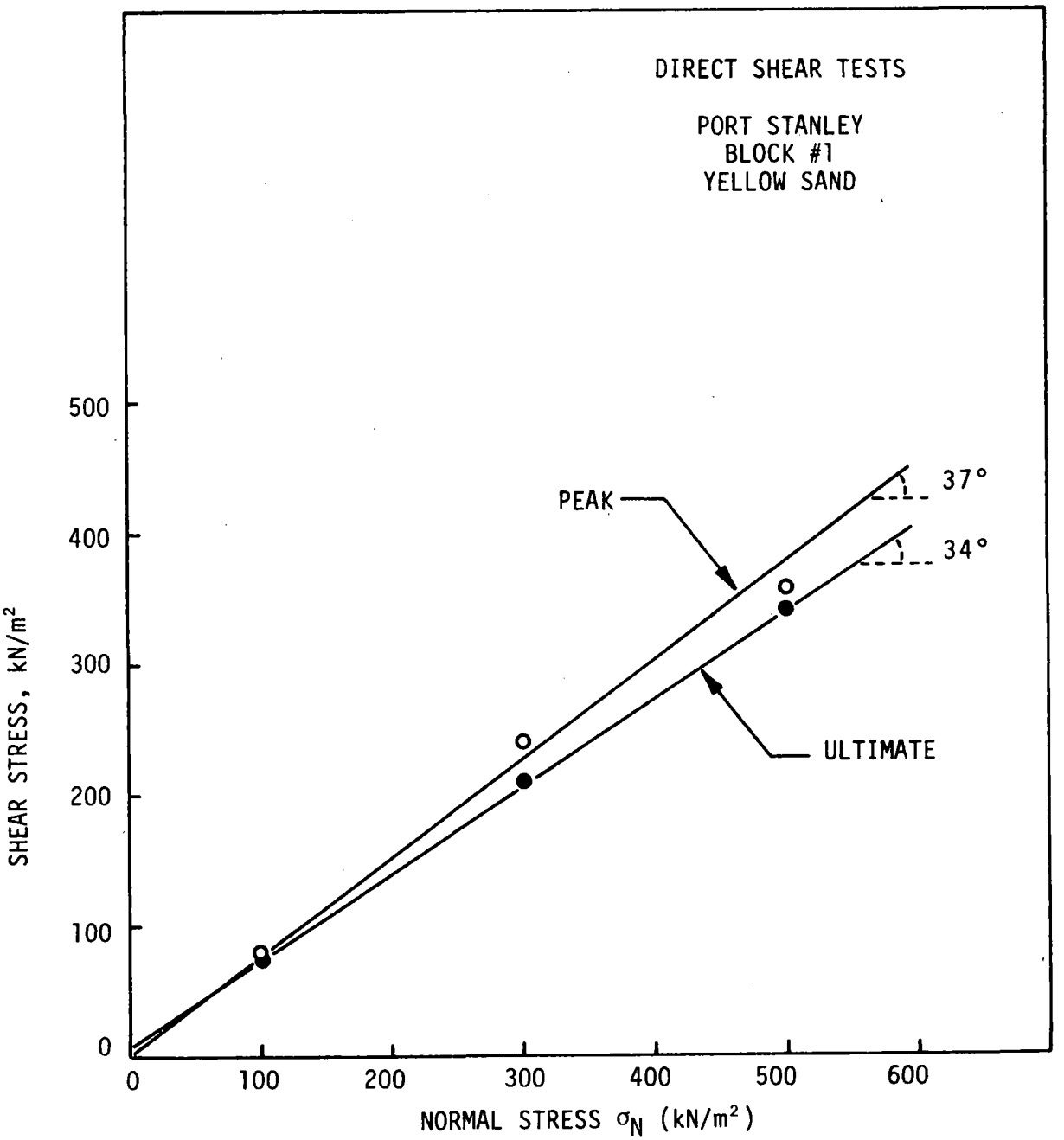

FIG. 5. PEAK AND ULTIMATE STRENGTH ENVELOPES, PORT STANLEY SURFACE SANDS (~ 9 m DEPTH)

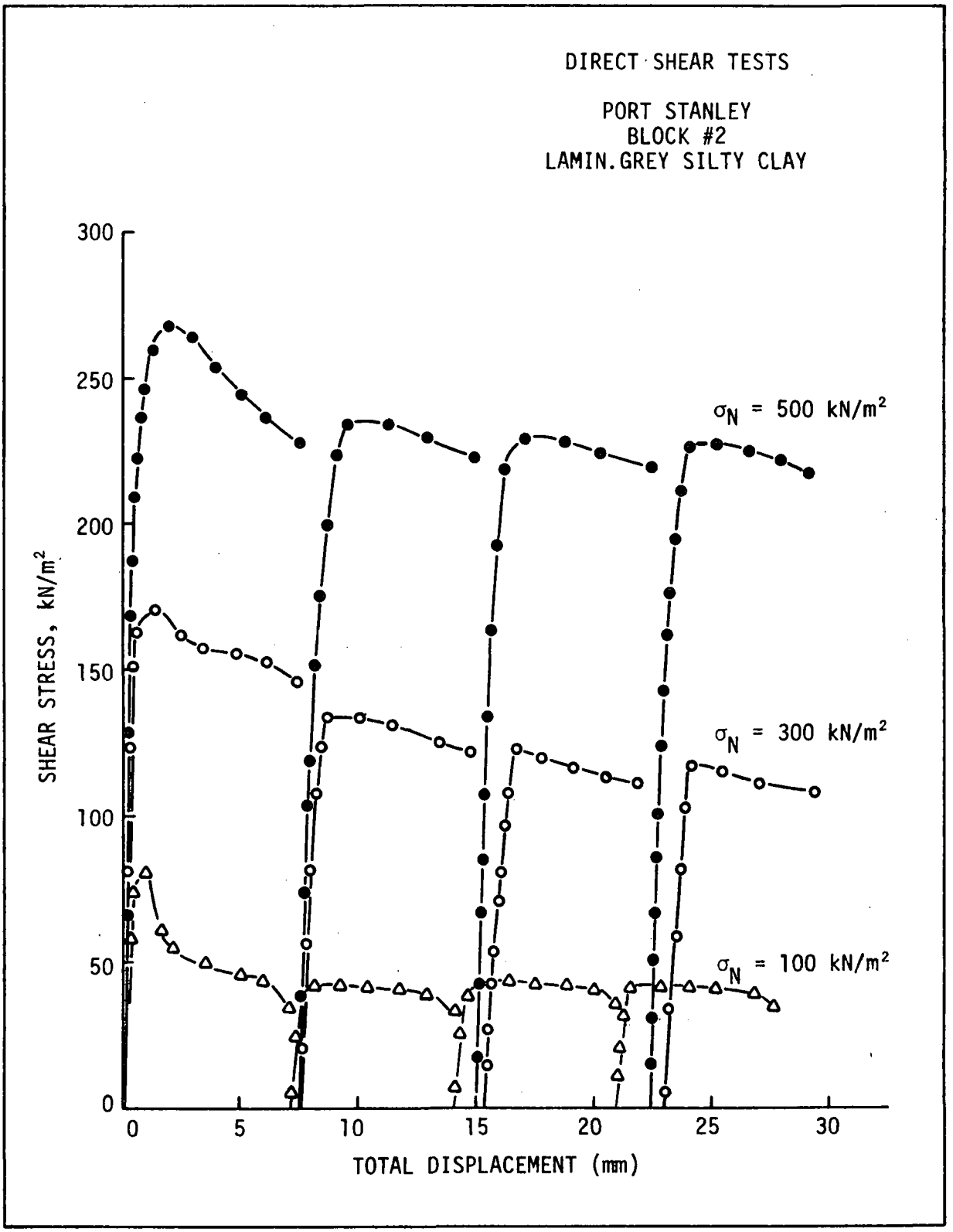

FIG. 6. STRESS-DISPLACEMENT CURVES FOR LAMINATED GREY SILTY CLAY, BLOCK #2, PORT STANLEY

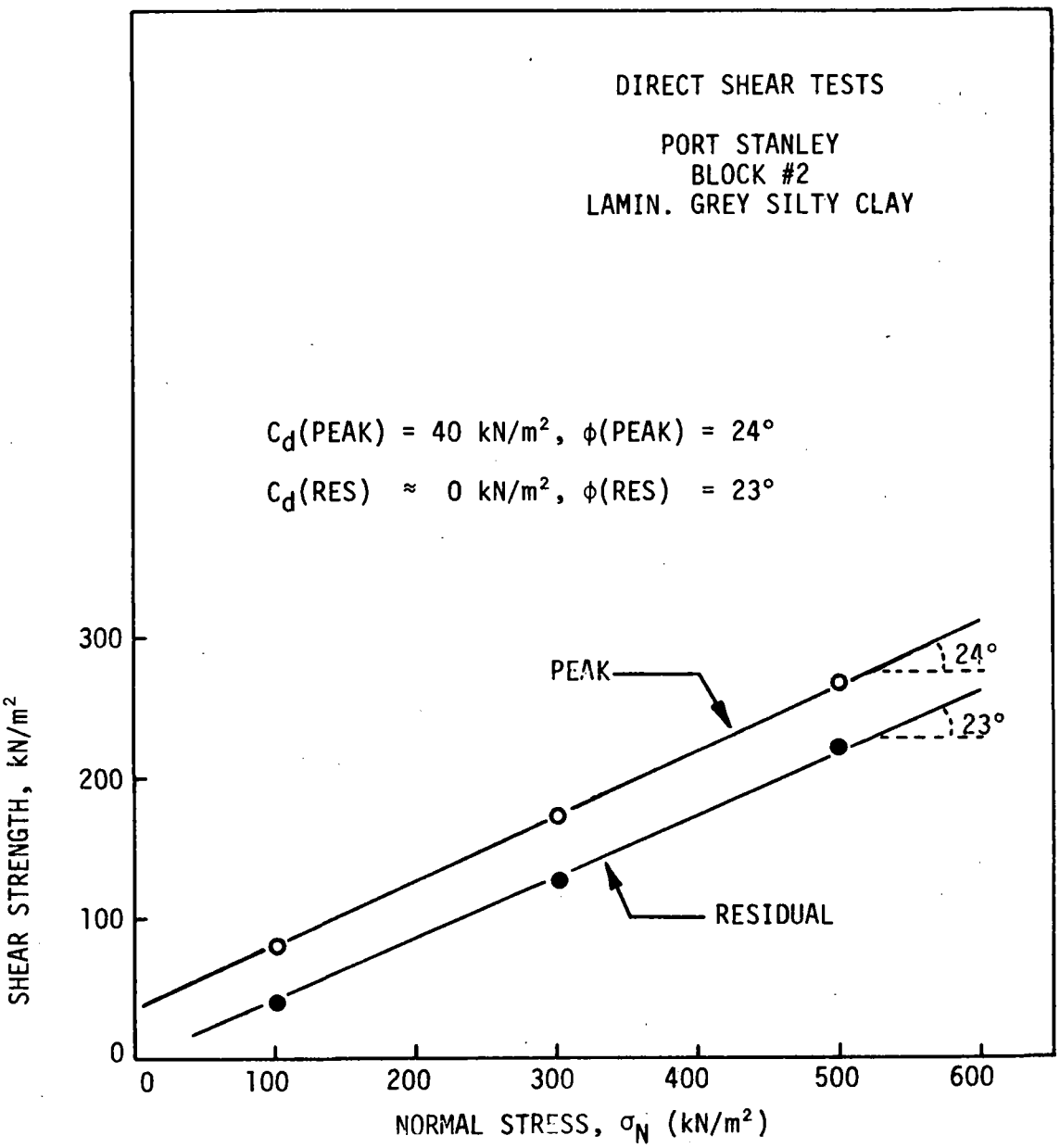

FIG. 7. PEAK AND RESIDUAL DRAINED STRENGTH ENVELOPES FOR LAMINATED SILTY CLAY FROM BLOCK #2, PORT STANLEY

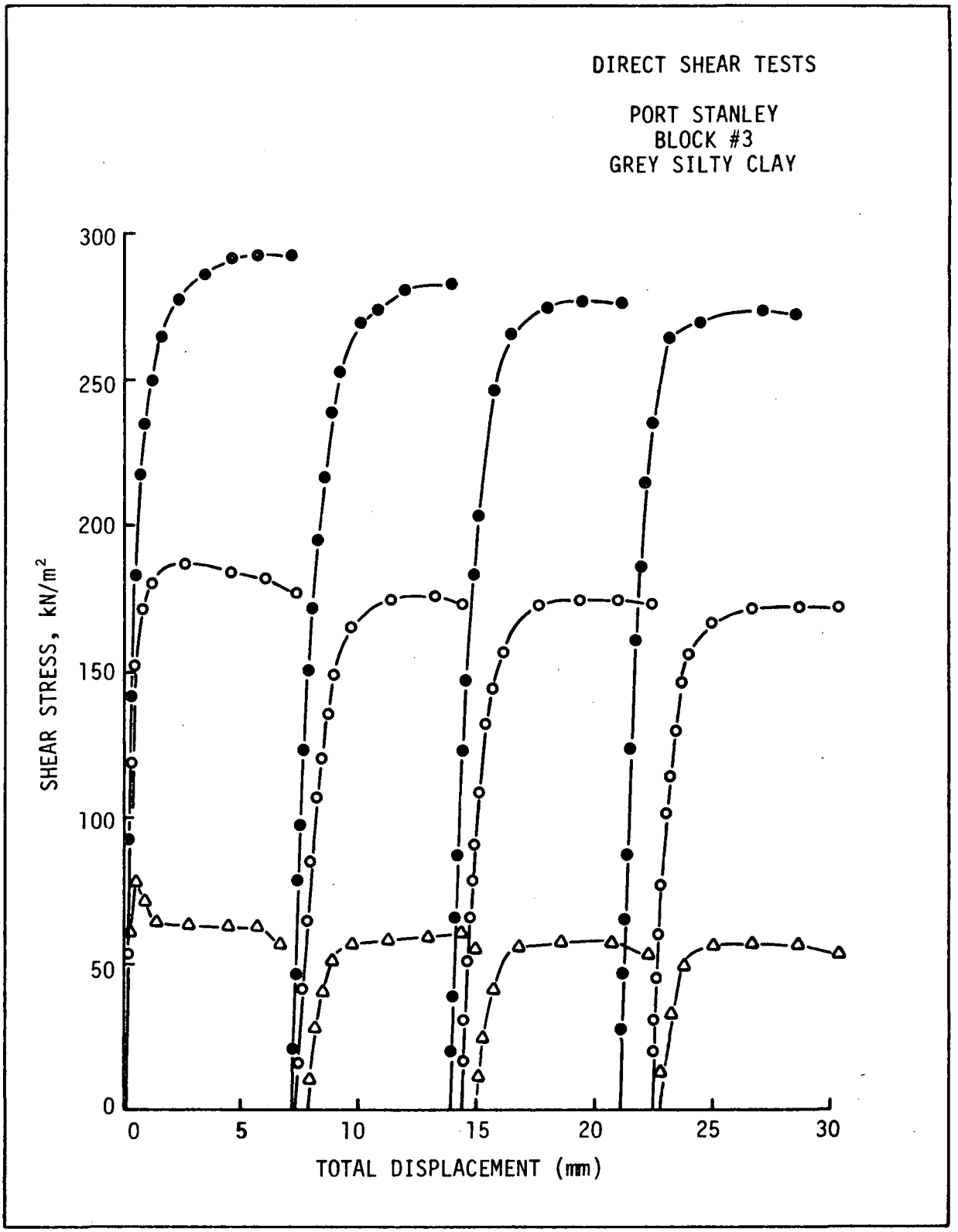

FIG. 8. STRESS-DISPLACEMENT CURVES FOR GREY SILTY CLAY STRATUM (WATERLAIN TILL)

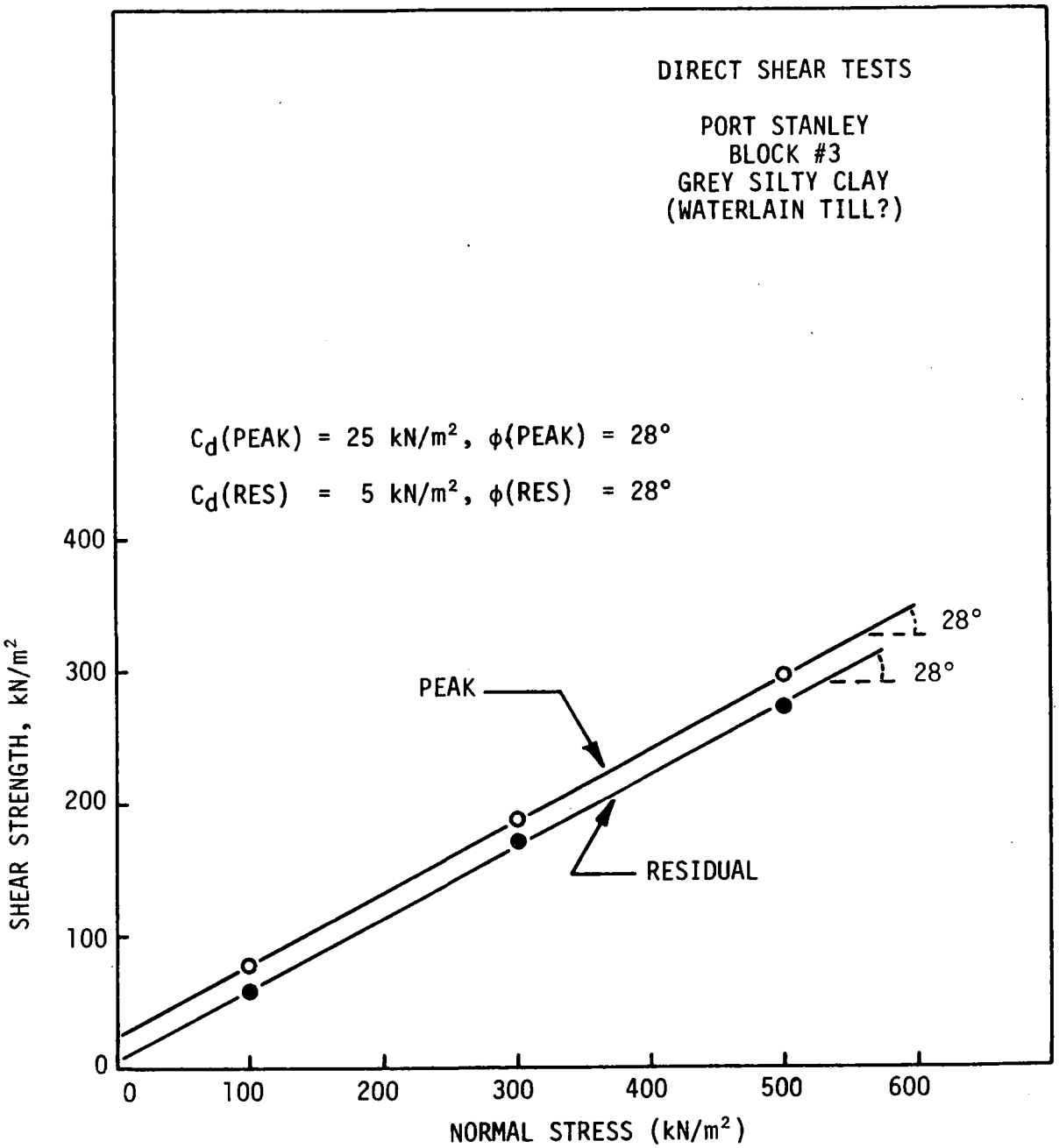

FIG. 9. DRAINED DIRECT SHEAR STRENGTH ENVELOPES OF GREY SILTY CLAY STRATUM

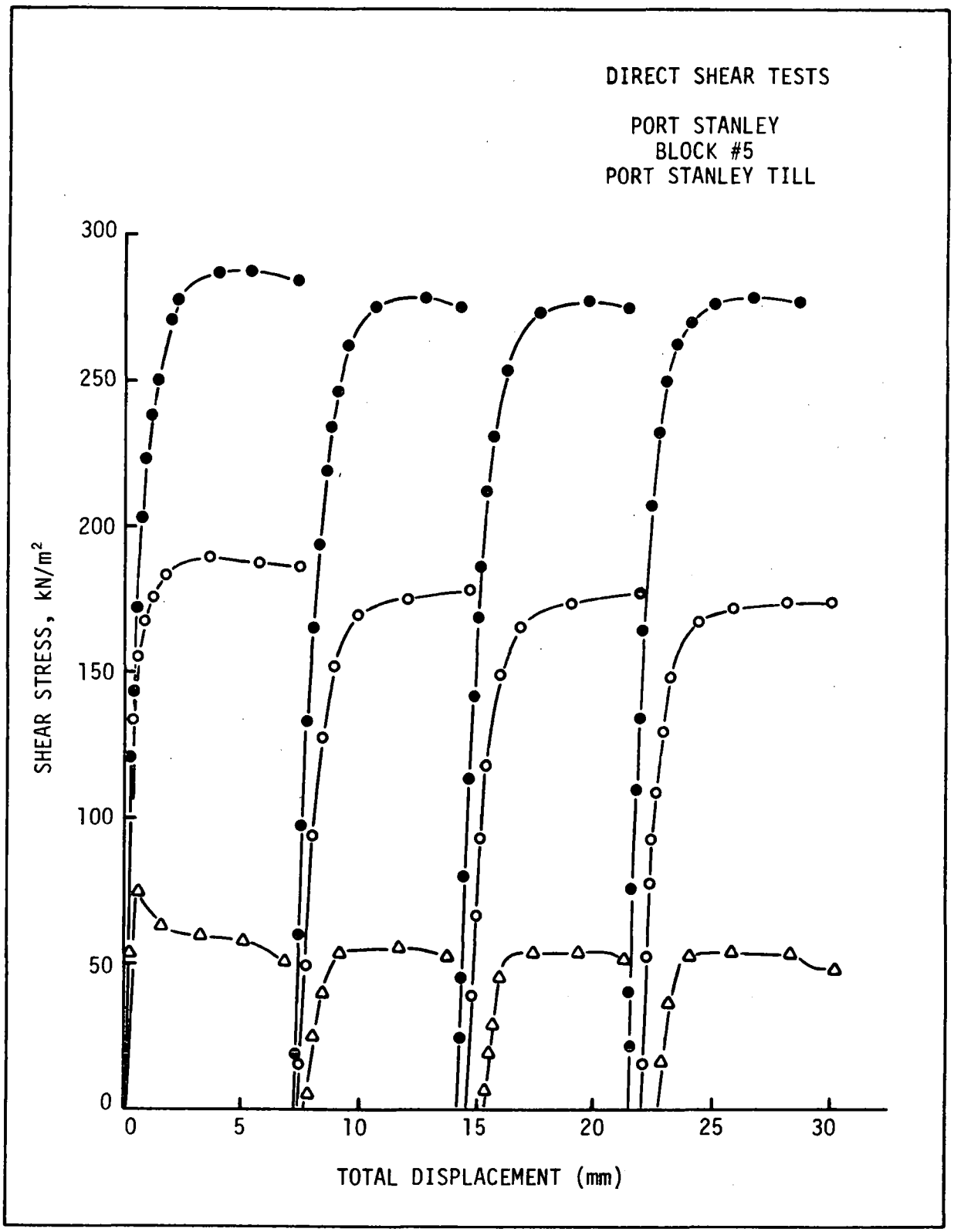

FIG. 10. STRESS-DISPLACEMENT CURVES OF PORT STANLEY SILT TILL AT PORT STANLEY

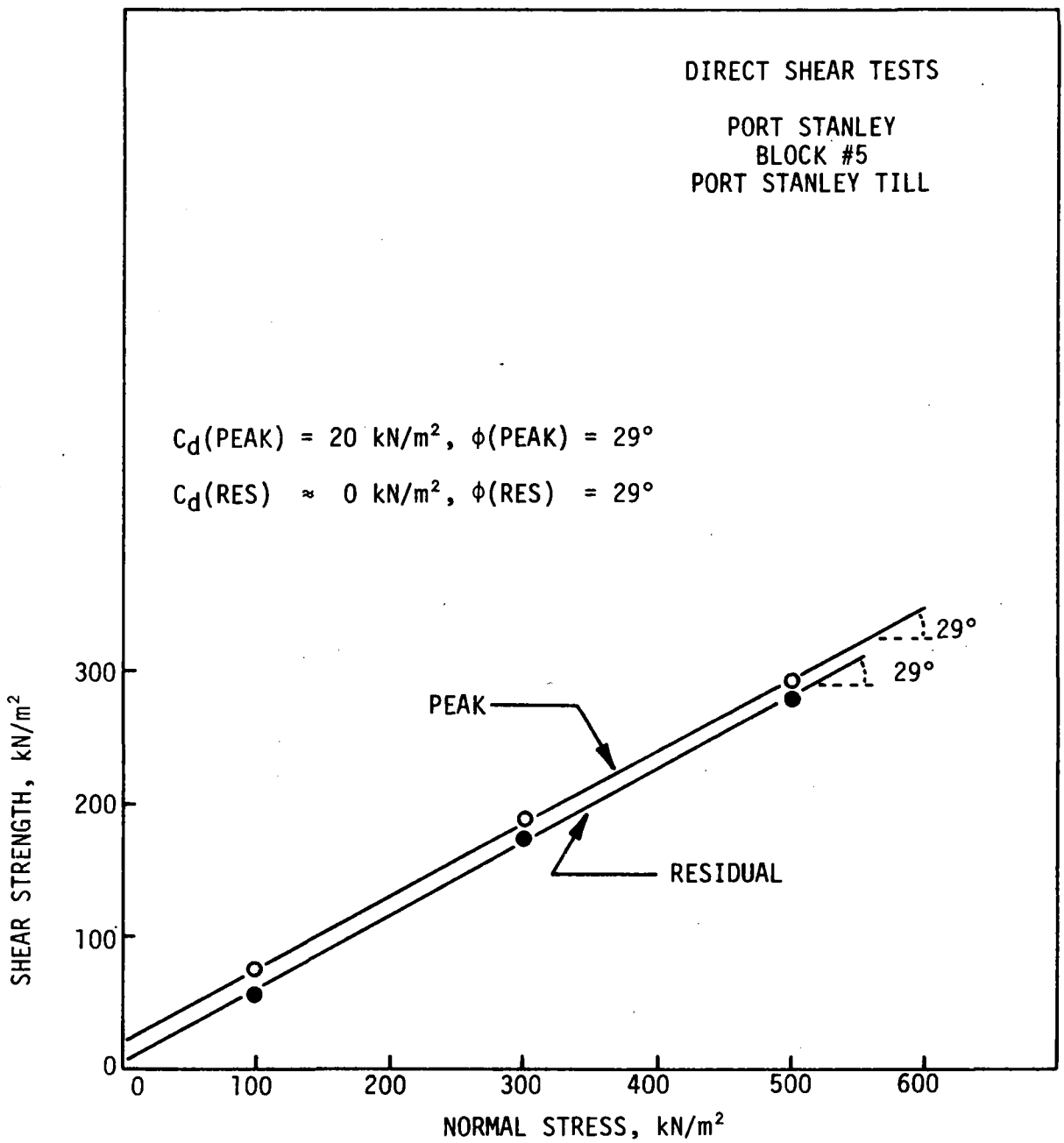

FIG. 11. DRAINED DIRECT SHEAR STRENGTH ENVELOPES FOR PORT STANLEY SILT TILL

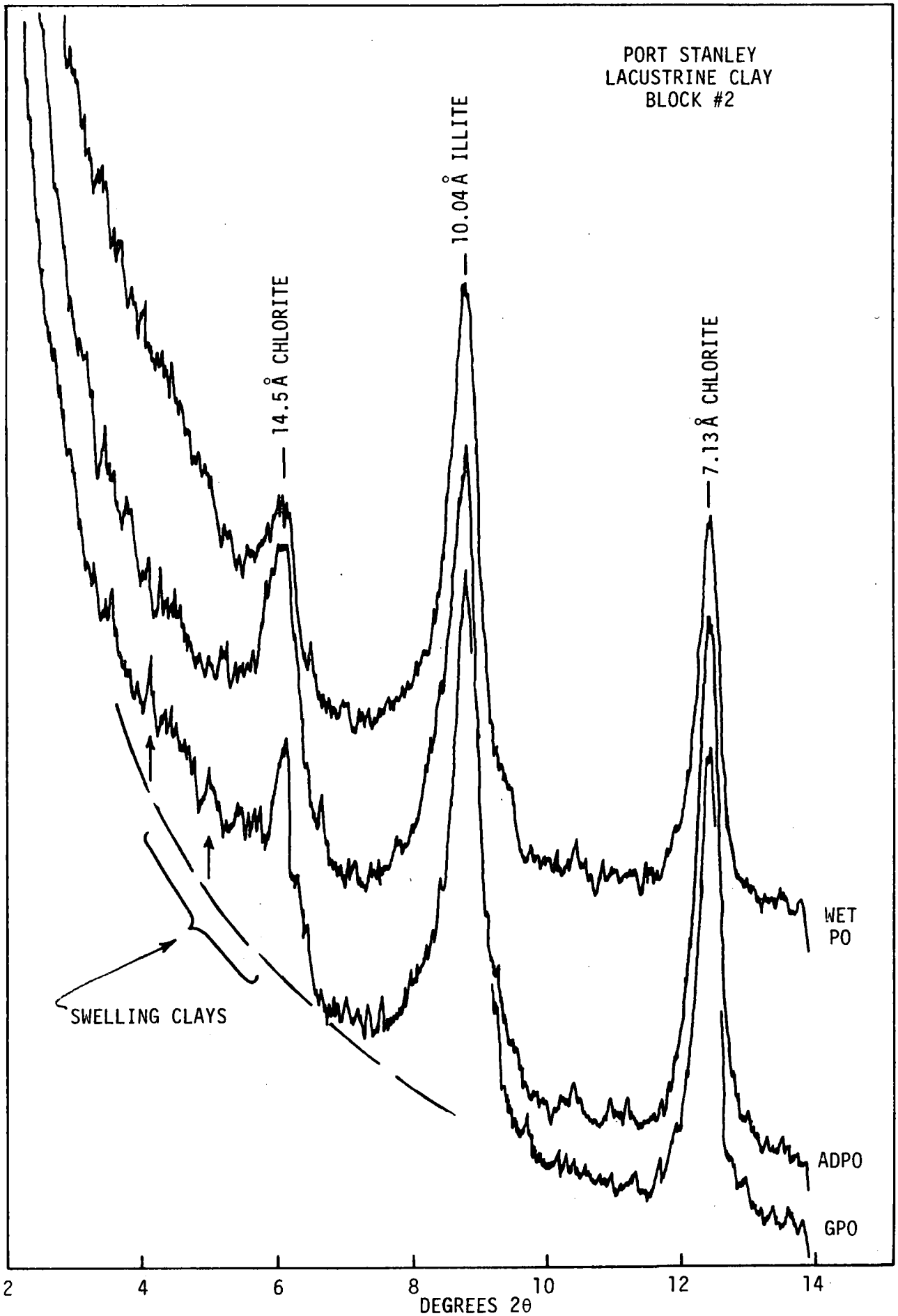

FIG. 12. X-RAY DIFFRACTION TRACES OF < 2 μm FRACTION OF LACUSTRINE CLAYS, BLOCK #2, PORT STANLEY

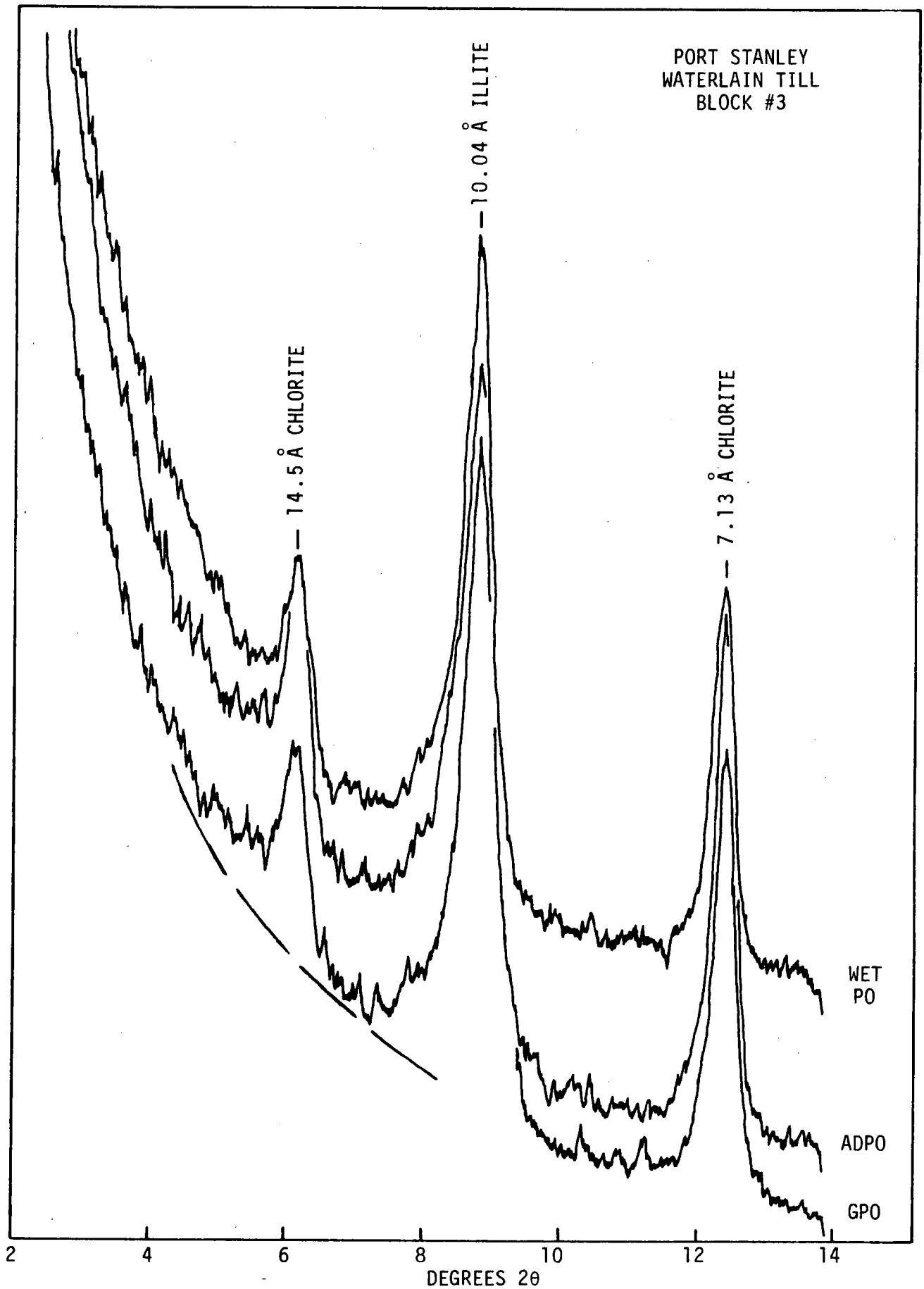

FIG. 13. X-RAY DIFFRACTION TRACES OF < 2 μm FRACTION OF PEBBLY SILTY CLAY STRATUM, BLOCK #3, PORT STANLEY

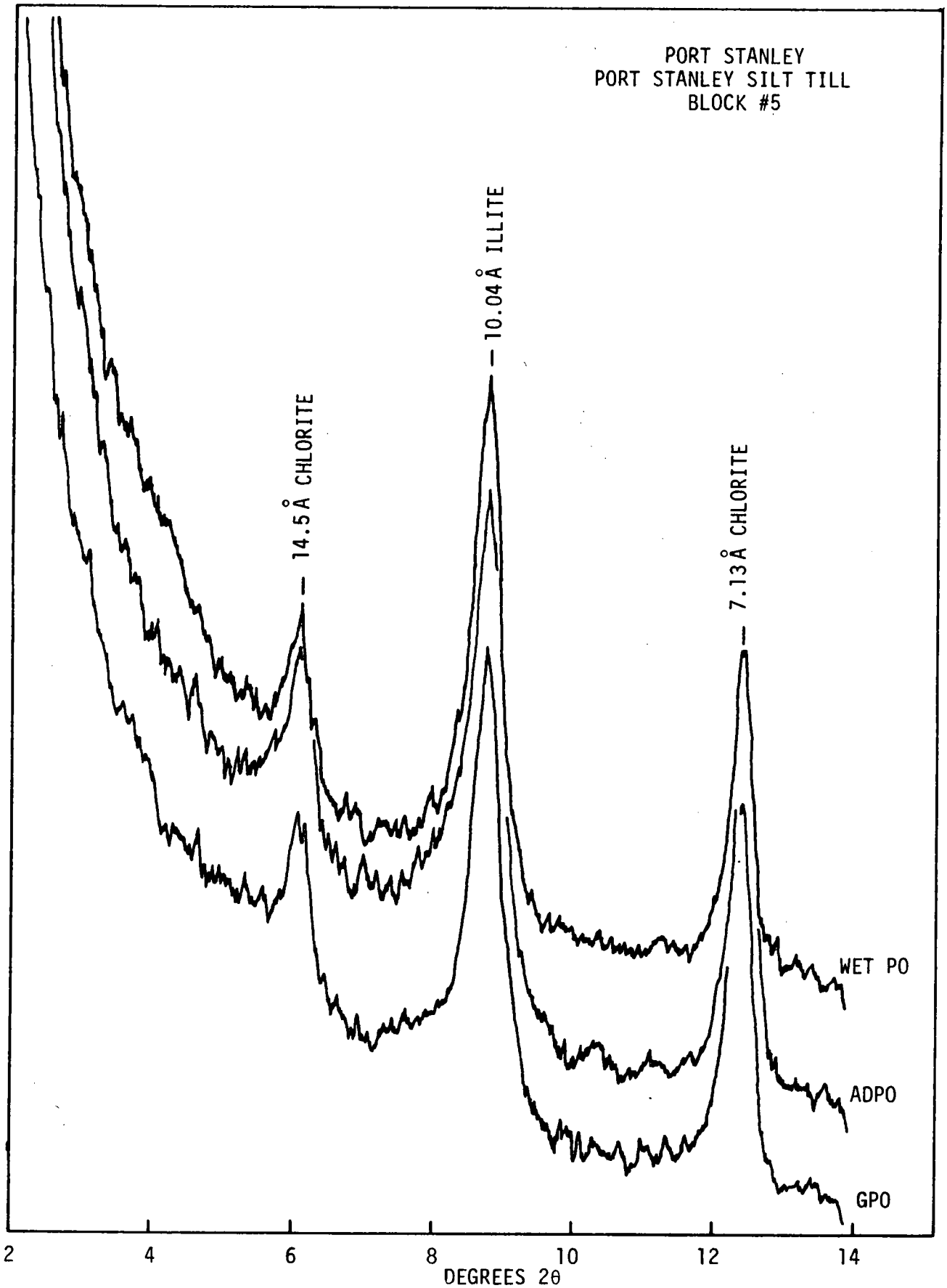

FIG. 14. X-RAY DIFFRACTION TRACES OF < 2 μm FRACTION OF PORT STANLEY TILL, BLOCK #5, PORT STANLEY