HOLOCENE HISTORY OF
KINGS AND HARTLING BAYS,
ATLANTIC COAST OF NOVA SCOTIA

by

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ABSTRACT

Kings and Hartling Bays are typical of many exposed inlets with bayhead beaches which are prevalent along the Atlantic Coast of Nova Scotia. The present morphology of these two bays is a result of Pleistocene glaciation and subsequent Holocene transgression. Kings Bay differs from Hartling Bay in that it has a negligible sediment input while Hartling Bay has actively eroding drumlins. This greatly influences the sediment budgets for these bays. As the sea level continues to rise, (20 cm/century) the amount of sediment input will become increasingly important to predict the rate at which the beaches will retreat.

A scanning electron microscopy study of quartz surface textures appears to indicate that over one third of the grains examined had undergone diagenesis. Similar criteria were used with some success to identify eolian grains associated with relict beach systems in Hartling Bay.

It has been concluded that at about 7000 B.P., the present day Hartling Bay was a semi-restricted lagoon which backed a seaward barrier beach system. Evidence supporting such a theory involves extrapolation of the rise in sea level over the past 14000 years. Other evidence includes the presence of *in situ* brackish-water peat indicating a paleo-high water mark and a sample of muddy reducing sediment which was inferred to be a relict of the former lagoon.

INTRODUCTION

Purpose of Study

Kings and Hartling Bays are two of many inlets which form the coastal features of Nova Scotia's Atlantic Coast. The present morphology of these bays is a direct result of Pleistocene glaciation and attendant Holocene transgression.

This work differs from previous detailed studies of large, sheltered bays (St. Margaret's Bay: Piper and Keen, 1974; Mahone Bay: Piper and Keen, 1975 and Barnes, 1976) in that Kings and Hartling Bays are smaller, exposed to open ocean waves and are sand-rich. Exposed beaches have been studied before by Keeley, (1975) and Bowen, (1975) but no beach system inspection has, to date, incorporated offshore sediment data. Kings and Hartling Bays were thus chosen to represent exposed coastal bays. Kings Bay offers contrast to Hartling Bay because the former has essentially no sediment input while eroding drumlins in Hartling Bay provide a great deal of sediment influx to both the nearshore and the beach. This thesis was carried out with the intention of developing a sediment budget and tracing the history of these bays over the last 20000 years.

Location of Study Area

Kings Bay and Hartling Bay are located in Lunenburg County, 70 kilometres southwest of Halifax, Nova Scotia (Figure 1).

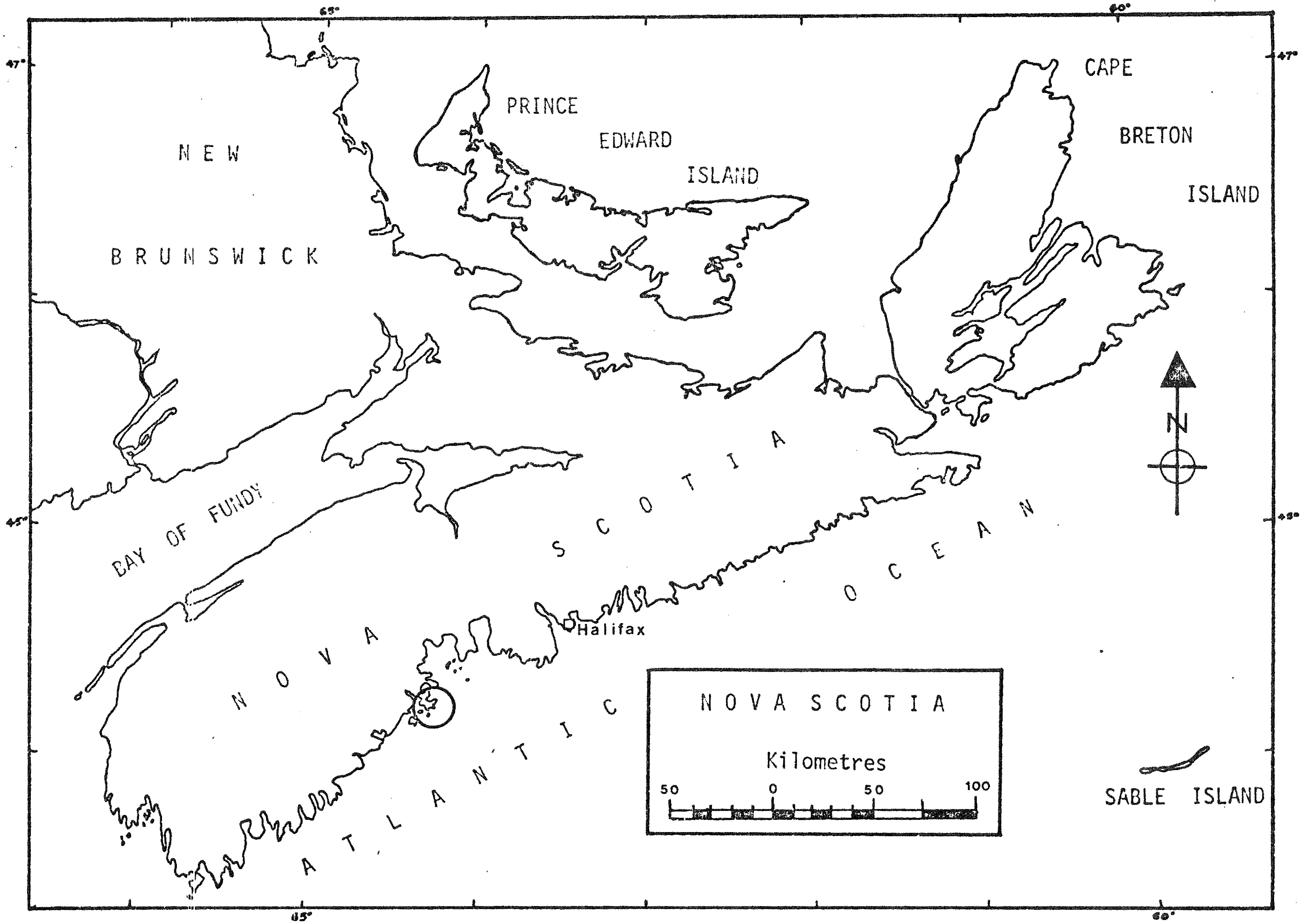


Figure 1: Location os Study Area.

These bays are separated by Point Enrage - a tombolo and headland of Halifax slate. Both bays have bayhead beaches, known locally as Kingsburg and Hirtles Beaches. Kings Bay (44° 16.5'N, 64° 15'W) is 650 metres wide, 1400 metres in length and covers an area of 0.6 km^2. Hartling Bay (44° 15.5'N, 64° 16'W) is 1750 m in length by 900 m wide and encompasses 1.1 km^2. Kings Bay reaches a maximum depth of 13 metres. Hartling Bay is much deeper (22 m).

Previous Work

Cursory examinations of the study area were undertaken by Goldthwait (1924) and Taylor (1969). Extensive related research has been compiled further north along the coast: Piper and Keen: Lunenburg Bay (1977), Mahone Bay (1975-76), St. Margaret's Bay (1974); Barnes: Eastern Mahone Bay (Unpublished M.Sc. thesis, 1976); Letson: Western Mahone Bay (M.Sc. thesis in progress). No detailed beach or sediment budget analysis has, however, been attempted for Kings and Hartling Bays.

Other beach work in the province of Nova Scotia has been compiled by Bowen, (1975) and Keeley, (1975) but these studies have been concentrated on land and nearshore areas. Offshore areas seaward of the beaches were not incorporated into these studies.

Field Work

Approach

Field work was begun in the spring of 1976 and was completed in January, 1977. The general approach to this study involved obtaining samples of till, beach, nearshore and offshore sediments in both bays to compare respective grain size distributions. Till samples were collected to determine the relative amounts of gravel, sand and mud which are being introduced to the area during erosion. Beach samples were gathered to reveal typical grain size and degree of sorting - direct parameters of energy conditions. Nearshore and offshore sediments were procured to determine the extent of seaward sediment transport. Echo sounding and diving traverses were undertaken to learn general sediment types, distribution and depth to bedrock. Beach profiles in both bays were measured to discover the effect of wind and waves on sediment transport. It was decided that the extent of drumlin erosion could be obtained by aerial photographs, visual observations and by interviews with knowledgeable townsfolk.

Procedure

Bench marks were strategically located above the storm berm crests on Kingsburg and Hirtles beaches. These points consisted of stakes which were driven to a depth of 1 metre. Ten beach profiles (4 in Kingsburg, 6 in Hirtles) were run from these bench marks normal to the shoreline up to a water depth of about 1.5

metres. The profiles of these beaches and their relation to a common datum level were monitored over a nine month period and recorded at four month intervals (May 1976, September 1976 and January 1977). The surveying technique involved back-sighting on measuring poles using a Geotec 359-1040 survey level (Plate 1).

Till sampling included preliminary scraping and cleaning of a random area to a depth of 0.5 metres (to prevent contamination) before extracting a 2-3 kg sample. Representative beach samples were obtained at a depth of 20 cm at the mid water mark (Plate 2). This depth was chosen in order to eliminate direct sample sorting by recent swash-backwash and to prevent contamination by a non representative eolian content. Near and offshore sampling was accomplished by skin- and scuba-diving using an Avon rubber boat and "Saltfinger" - a 5.8 metre Cape Islander belonging to the Department of Oceanography at Dalhousie University. A limited amount of sampling also included the use of "Trying-To", a 10.7 metre Cape Island fishing boat rented for summer work in the Lunenburg area. The grab sampler used was a Diez-Lafond snapper and positioning of sites was determined using a sextant or prismatic compass. The accuracy of using the first method is estimated to be 100 metres; the second is roughly 200 m. The water depth of each location is known by MS26-B echo soundings, the boat's own depth sounder or by diving. The position of the sample can therefore be determined with greater precision when the

Plate 1: Beach Profile Surveying Technique.

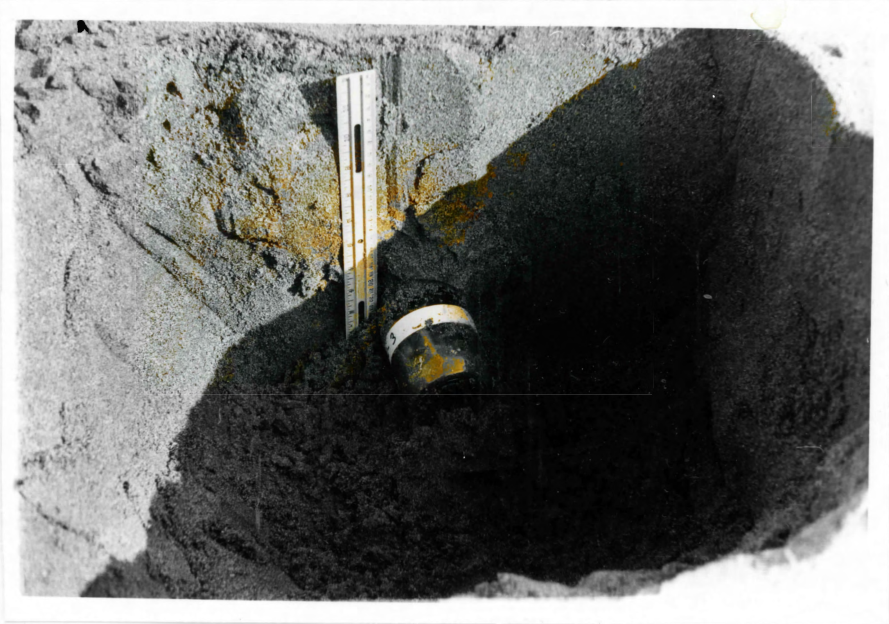


Plate 2: Beach Sample Collection Technique.

bathymetry and the inferred site are incorporated.

A limited number of MS26-B echo sounding traverses were run in Kings and Hartling Bays. During the summer, an intense search was undertaken for underwater *in situ* peat suitable for dating. The intention of dating it was to provide data on the rise in sea level in the area. An outcrop of peat was finally discovered in January, 1977 while diving in Hartling Bay.

REGIONAL GEOLOGY

Bedrock

The general geology of Lunenburg County has been well documented by Faribault, (1908), Goldthwait, (1924) and Taylor, (1969). The oldest rocks are the Meguma Group (Goldenville quartzites overlain by Halifax slates) of probable Cambro-Ordovician age. Lunenburg County also has outcrops of the Devonian South Mountain batholith; a quartz diabase of Tertiary or possibly Devonian age (Taylor, 1969) and carbonates of the Windsor Group. The actual study area is underlain entirely by Halifax slates with the exception of a quartz diabase dyke which outcrops on West Ironbound Island and strikes northeasterly (Figure 2). Tectonism in the area has resulted in gentle anticlines and synclines which trend in a northeast-southwest direction. A syncline trends southwest from Rose Bay toward the mouth of the La Have River and an anticlinal axis extends across Point Enrage and Gaff Point (Figure 2).

Pleistocene

During the late Pleistocene, Nova Scotia was completely covered by glacial ice. Glacial striae and drumlins in Lunenburg County trend in a northwest-southeast direction indicating the direction of this glacial advance (Figure 3). The

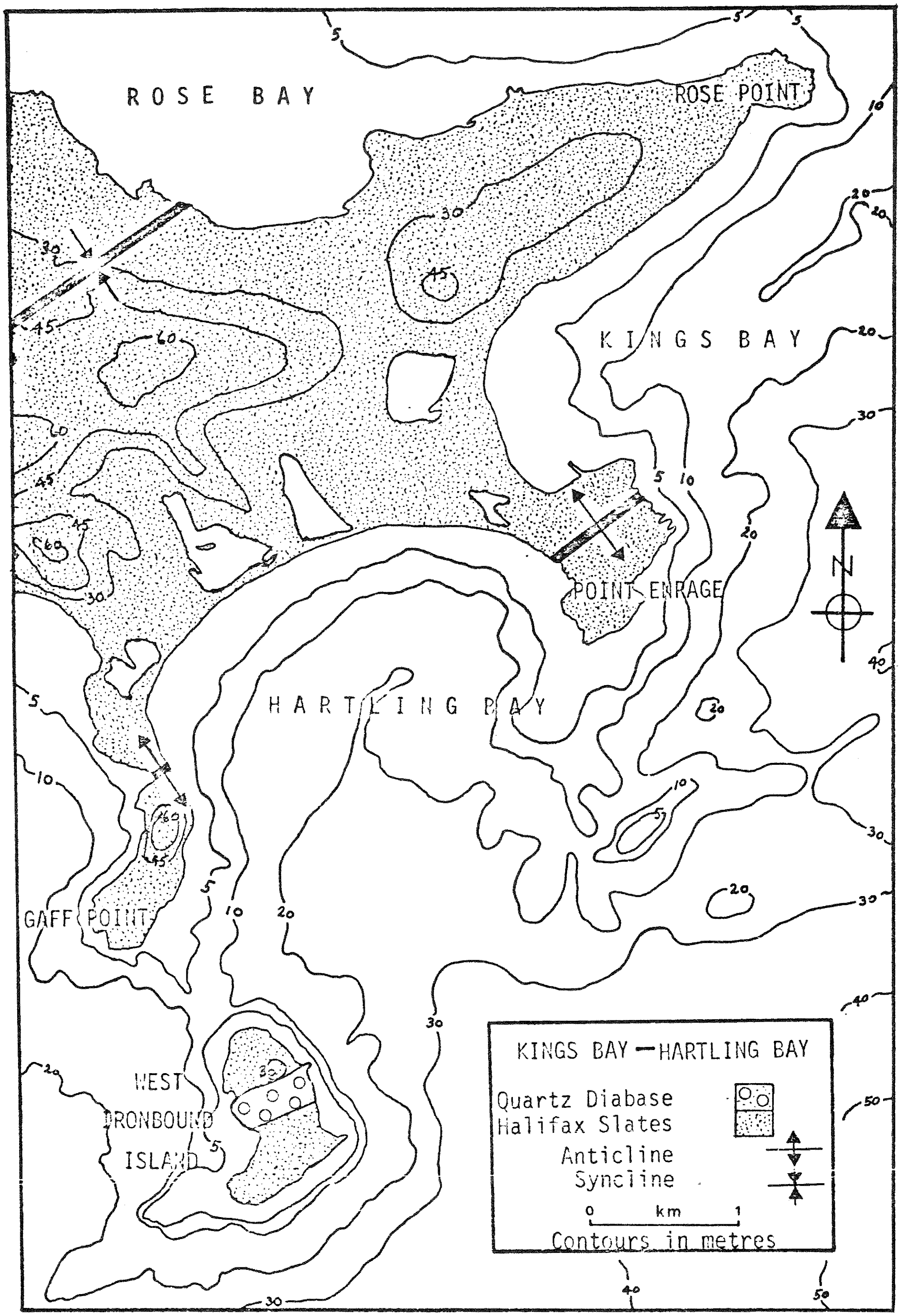


Figure 2: Bedrock Geology of Study Area.

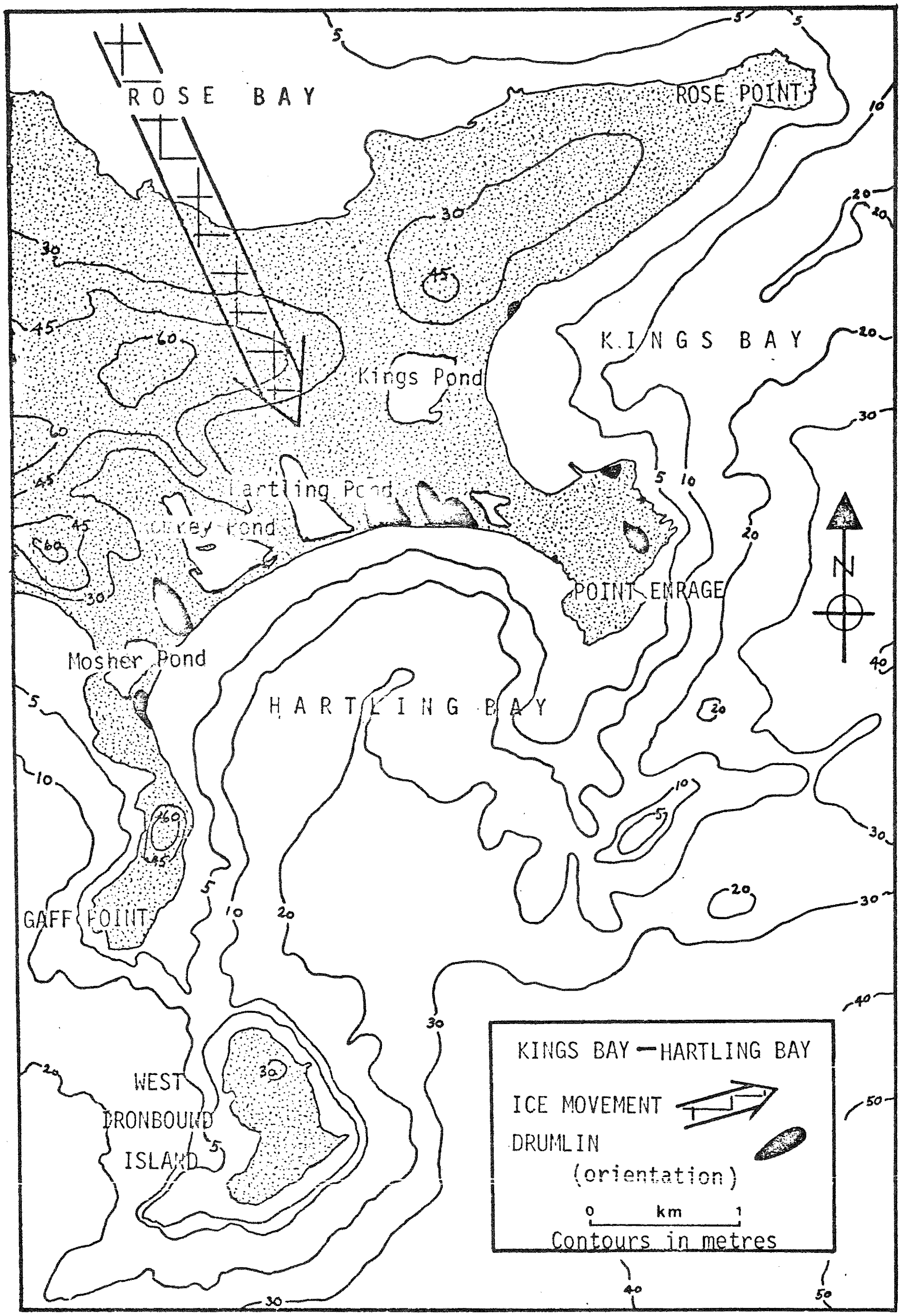


Figure 3: Direction of Ice Movement and Drumlin Orientation, Kings and Hartling Bays.

Wisconsinan glaciation reached its peak at 18000-19000 B.P. (Douglas, 1972; Grant, 1970) and subsequently began to wane, leaving terminal moraines on the Scotian Shelf as far as 40 km from the present day coastline (Nielsen, 1976; Grant, 1970). Minimum ice thickness on the shelf is estimated at 40-120 m (King, 1969) during this peak. Water depth during the Wisconsinan was at least 121 m below present day sea level (Stanley *et al.*, 1968).

An outcrop of Bridgewater conglomerate was found underlying the southern drumlin in Kings Bay. This is the only possible evidence of a pre-Wisconsinan glacial deposit in Kings Bay. Sage, (1953) claimed that the Bridgewater conglomerate was a Tertiary deposit but recently MacNeil, (1972) proposed an early to mid Pleistocene age for it. The majority of highly consolidated glacial deposits, however, are inferred to be early to mid-Wisconsin in age (Nielsen, 1976). No outcrop of Bridgewater conglomerate was discovered in Hartling Bay but a consolidated grey till of concrete-like consistency was found underlying the most northeasterly drumlin within the bay. This till also was reportedly deposited prior to the late Wisconsinan (Nielsen, 1976).

Following the deglaciation of Nova Scotia there was probably a continuous transgression on the Atlantic Coast. Total deglaciation of the Scotian Shelf ensued about 14000 B.P. (Prest and Grant, 1969). Since Mahone Bay was completely free of ice by

11700 ± 160 B.P. (Railton, 1973) it is not unreasonable to assume that Kings and Hartling Bays were similarly liberated at the very latest by this time.

Geomorphology

Kings Bay

Kings and Hartling Bays are backed by coastal dunes and lagoons. Kings Bay has two lagoons and Hartling has four with each bay sharing one (Figure 2). The northern shore of Kings Bay (from the town of Kingsburg to Rose Point) is made up of an eroded drumlin, associated boulder armour and grades northeastward into bedrock cliffs. There is a topographic high north of Kingsburg which exceeds 45 m in height. East of the town a bathymetric high extends seaward perpendicular to the strand. This feature consists of cobbles 10-15 cm in diameter and is likely the remains of the eroded drumlin mentioned above. The reason for the apparent east-west trend (contrary to the regional northwest-southeast drumlin orientation) is attributed to the construction of a sluice which was built to drain Kings Pond. Bathymetry within the bay conforms roughly to regional strike of the slates (ENE). The south shore of Kings Bay consists of granite boulders and outcrops of Halifax slate. The construction of the breakwater there involved the redistribution of this boulder armour. The sand which is found on the beach is also found in the centre of the inlet. Sandy pockets are prevalent along the perimeter. On the south shore, the glacial feature does not appear to be a drumlin as very clean, well sorted coarse sand and gravel exhibits cross-bedding and cross-stratification (Plate 3). It is a channel fill deposit, perhaps supra glacial in origin.

Kingsburg Beach

Kingsburg Beach extends for over 650 metres, averaging 50 m in width. The storm berm crest rises about 2 metres from the normal high water mark (HWM). This ridge is able to maintain a steep angle (~ 80°) due to the stabilizing effect of the dune grasses. Blowouts are sporadic but important: all are associated with human activity. The beach material consists mostly of a fine grained sand which is darker than the sands at Hirtles Beach. This color change is attributed to the high erosional ratio of bedrock (Halifax slates) to till - a condition which is reversed in Hartling Bay.

Hartling Bay

As in Kings Bay, the bathymetry of Hartling Bay appears to be governed by the regional strike of the bedrock. Shoals are located southwest of Point Enrage, northeast of West Ironbound Island and, further offshore, on Ironbound Bank. These shoals are sediment free, bedrock outcrops. The eastern and western edges of the bay, Point Enrage and Gaff Point, are exposed bedrock. Also unprotected along the coast of Hartling Bay are four drumlins of considerable height (10-20 m).

Plate 3: Channel Fill Deposit, South Shore of Kings Bay.

Hirtles Beach

Hirtles Beach, 1.6 km in length, averages 60 metres in width and consists of light coloured medium grained sand. The sandy portions of Hirtles Beach are restricted to the central region of the bay (with the exception of a small pocket beach on the western extremity). They are not backed by any definite dune system as dune grasses have been destroyed by human activity which is much more extensive on this beach than on Kingsburg. This causes the migration of sands which are blown into the lagoon by onshore summer winds. The east shoreline is mostly bedrock and boulder armour. The west part of the beach consists of cobbles, 15-20 cm in diameter, and thus is able to maintain a steeper profile than the other sandier portions of the bay. This cobble section sustains two crests: one is a result of daily surf action while the higher ridge delimits the extent of storm surges. Occasional large storms do breach the beach ridge, burying spruce trees, but these occurrences are rare.

SURFICIAL SEDIMENT DISTRIBUTION

Methodology

Till, beach, nearshore and offshore samples were positioned on base maps of Kings and Hartling Bays. Following the compilation of these maps, a detailed grain size analysis of each sample was undertaken. Analytical procedures for determining percentages of grain size were those described by Galehouse, (1971) and Piper, (1974).

Kings Bay

Results of 28 grain size analyses in Kings Bay (Appendix A) are summarized in Table 1. Tills on the northern section of the bay consisted of a homogeneous array of gravelly muddy sand. Tills on the southern shore are moderately sorted gravelly sands generally with less than 5% mud content. Kingsburg Beach consists of over 99% fine grained, moderately sorted sand. Nearshore samples contain > 99% well- to very well-sorted fine grained sand. Offshore samples were sparse but did indicate moderately sorted gravelly sand to well sorted sandy gravel. Representative samples are shown in Figure 4. From these textural analyses, MS26-B profiles and bathymetric data a detailed map of surficial sediment distribution has been compiled (Figure 5).

TABLE 1

Grain Size Distribution
Kings Bay

Sample Type	Sample No.	Field Sample No.	% Gravel	% Sand	% Mud
Till	T1	TK1-1	19.9	42.6	37.5
	T2	TK2-2	13.0	81.4	5.6
	T3	TK2-3	5.3	90.5	4.2
	T4	TK2-4	18.5	77.5	4.0
Beach	B5	BP1-20C-1	0.3	99.7	-
	B6	BP1-20C-2	0.5	99.5	-
	B7	BP2-20C-3	3.7	96.2	0.1
	B8	BP3-20C-4	-	100.0	-
	B9	BP3-20C-5	0.5	99.5	-
	B10	BP4-20C-6	0.6	99.4	-
Nearshore	N11	ESF1-76-1	-	99.7	0.3
	N12	ESF1-76-2	-	99.3	0.7
	N13	ESF1-76-3	-	99.8	0.2
	N14	ESF1-76-4	-	99.8	0.2
	N15	ESF1-76-5	0.1	99.8	0.1
	N16	ESF1-76-6	-	99.9	0.1
	N17	ESF1-76-8	13.7	85.3	1.0
	N18	ESF1-76-9	-	99.8	0.2
	N19	ESF1-76-10	-	99.6	0.4
	N20	ESF1-76-11	0.1	99.7	0.2
	N21	ESF1-76-12	0.1	99.3	0.6
	N22	ESF1-76-13	100.0	-	-
	N23	ESF3-76-17	-	99.4	0.6
	N24	ESF3-76-18	0.3	99.6	0.1
Offshore	O25	506-76-080	sandy gravel		-
	O26	506-76-129	38.0	61.5	0.5
	O27	506-76-130	60.4	40.6	-
	O28	506-76-132	sandy gravel		-

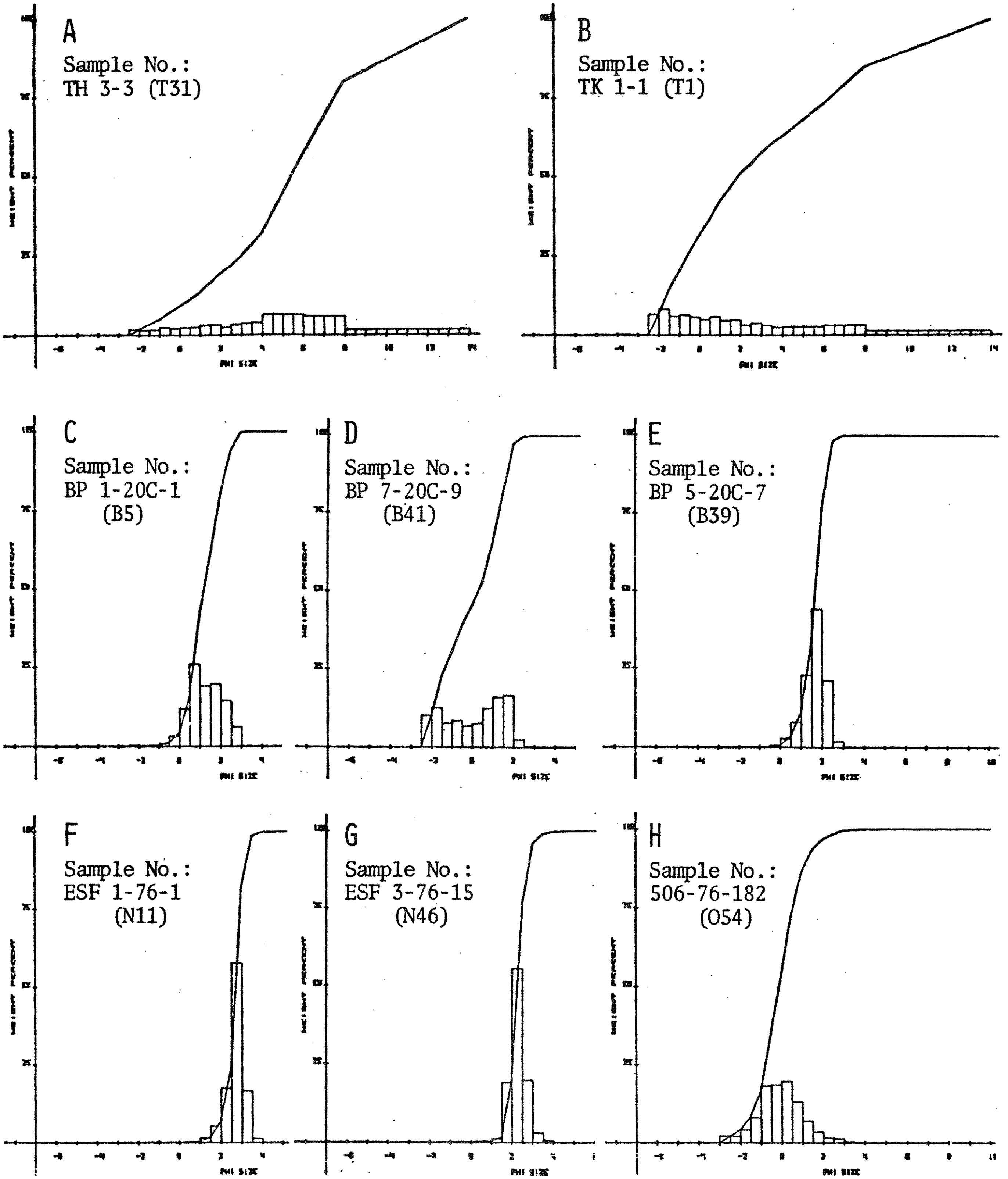


Figure 4: Representative grain size distribution, Kings and Hartling Bays A: Till, Hartling Bay. B: Till, Kings Bay. C: Beach sand, Kings Bay. D: Beach sandy gravel, Hartling Bay. E: Beach sand, Hartling Bay. F: Fine sand, Kings Bay nearshore. G and H: Sands, Hartling Bay offshore.

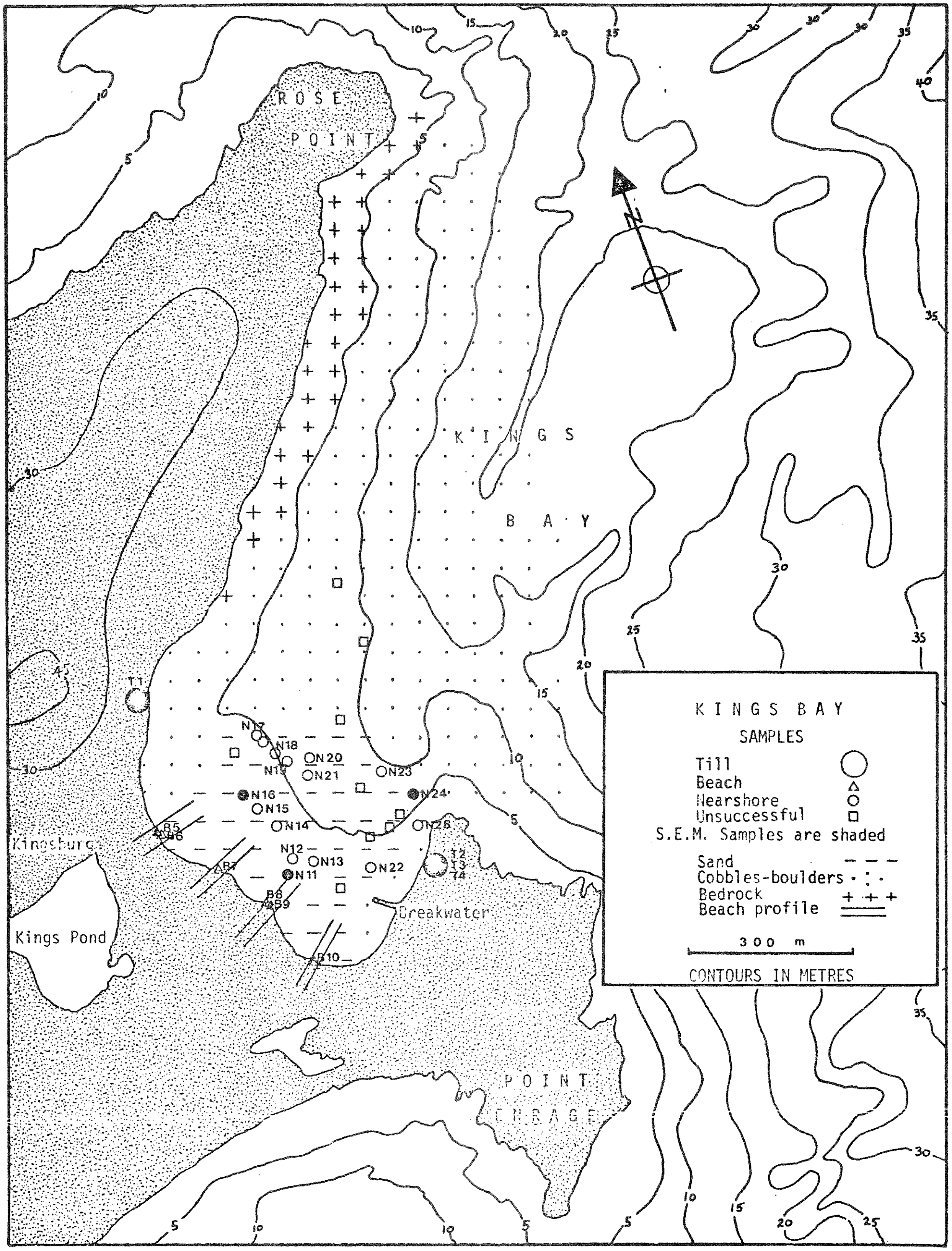


Figure 5: Surficial Sediment Distribution, Kings Bay.

Hartling Bay

Results of 28 grain size analyses in Hartling Bay (Appendix A) are outlined in Table 2. The till samples are generally poorly sorted and contain an average of 50% mud with one till location (T31) having almost 70% silt and clay content. Beach sediment consists of medium grained sand with some gravel. The degree of sorting increase and clast size decrease appears to be directly proportional to the distance from the sediment source (the eroding drumlin cliffs). Nearshore samples comprise well sorted medium grained sand with low gravel and mud content. The one exception, however, is sample number N52 which is a sandy mud containing 73% silt and clay. When collected, it was black and odoriferous, suggesting a reducing environment. Besides the usual grain size analysis this sample was analyzed for foraminifer content to attempt to determine depositional environment. Foram content proved to be inconclusive (D. Scott, pers. comm., 1977). Offshore sediments in Hartling Bay are generally sandy gravel. Representative samples are shown in Figure 4. Textural analyses combined with bathymetric data permit a map of surficial sediment distribution to be constructed for this bay (Figure 6).

TABLE 2

Grain Size Distribution
Hartling Bay

Sample Type	Sample No.	Field Sample No.	% Gravel	% Sand	% Mud
Till	T29	TH3-1	12.6	37.6	49.8
	T30	TH3-2	7.1	44.9	48.0
	T31	TH3-3	4.8	27.0	68.2
	T32	TH3-4	6.9	41.2	51.9
	T33	TH3-5	12.5	47.5	40.0
	T34	TH4-6	8.2	34.7	57.1
	T35	TH4-7	9.3	61.7	29.0
	T36	TH5-8	11.5	33.8	54.7
	T37	TH5-9	6.1	44.8	49.1
	T38	TH5-10	9.6	41.3	49.1
Beach	B39	BP5-20C-7	-	100.0	-
	B40	BP6-20C-8	35.7	64.3	-
	B41	BP7-20C-9	30.2	69.8	-
	B42	BP8-20C-10	35.9	64.1	-
	B43	BP9-20C-11	1.4	98.6	-
	B44	BP10-20C-12	21.7	78.3	-
Nearshore	N45	ESF3-76-14	0.2	99.7	0.1
	N46	ESF3-76-15	-	99.7	0.3
	N47	ESF3-76-16	-	99.9	0.1
	N48	506-76-184	-	98.7	1.3
	N49	506-76-186	0.6	98.4	1.0
	N50	506-76-187	-	99.2	0.8
	N51	506-76-188	0.1	99.4	0.5
	N52	506-76-191	0.1	27.0	72.9
Offshore	O53	506-76-181	98.3	1.7	-
	O54	506-76-182	16.3	83.6	0.1
	O55	506-76-200	91.0	9.0	-
	O56	506-76-202	61.8	35.1	3.1

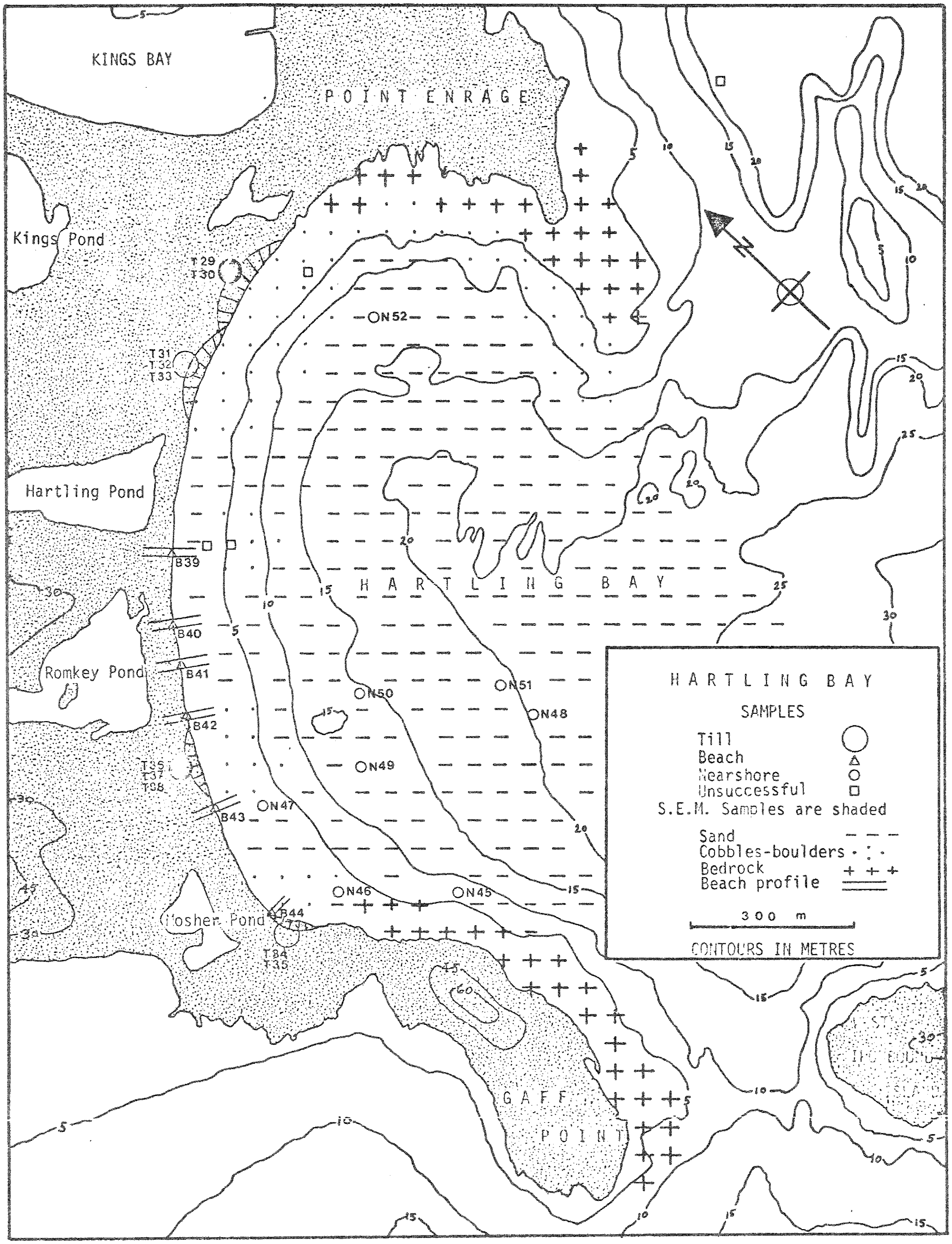


Figure 6: Surficial Sediment Distribution, Hartling Bay.

SOURCES OF SEDIMENT

On a world-wide scale, fluvial networks introduce by far the most sediment to coastal regions. However, in the case of the southern coast of Nova Scotia, including the study area, the sediment has not been affected to any extent by fluvial input (despite the proximity of the La Have River). What sediments there are in these slow flowing streams (steepest gradient 3 metres/km, Goldthwait, 1924) tend to settle out due to man-made obstructions and numerous lakes. Fluvial input is therefore determined to be minimal. The majority of beach and bay material in Kings and Hartling Bays is palimpsest (reworked glacial) sediments. To aid in determining the origin of such sediment, a detailed scanning electron microscopy (S.E.M.) study was made of quartz grain surface textures.

Sampling for S.E.M. Study

Twenty sample locations (9 from Kings Bay and 11 from Hartling Bay) were selected to give a representative overview of the two bays. Two samples were taken from till outcrops in Kings Bay (T1, T4); two from beach locations (B6, B8); three from nearshore (N11, N16, N24) and two offshore samples were selected (O25, O28). Strategic samples in Hartling Bay included tills (T30, T38); beach (B39, B43); nearshore locations (N45, N46, N47, N48, N51, N52) and one offshore sample (056). Sample locations for Kings and Hartling Bays are illustrated in Figures 5 and 6 respectively and have been assigned different symbols as denoted on the maps.

S.E.M. Sample Stub Preparation

The samples chosen were first repeatedly washed with distilled water to remove any detrital organics, muds or salts and subsequently dried under heat lamps. Krinsley and Margolis, (1971) suggest a sample preparation procedure involving boiling the quartz grains in concentrated nitric acid and stannous chloride solutions. They also recommend removing organic debris by immersing the grains in a solution of potassium dichromate, potassium permanganate and concentrated sulphuric acid. These treatments were purported to have no effect on the quartz grain surface textures (Krinsley and Margolis, 1971; McIntyre and Be, 1967). These cleansing methods were, however, rejected on the grounds that some micro-chemical etching could occur.

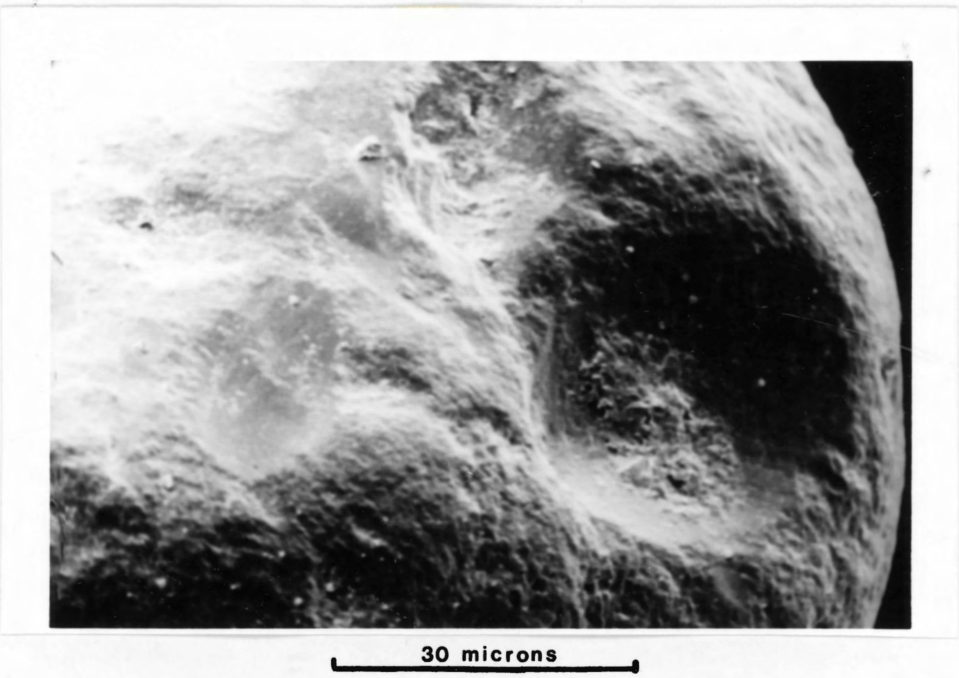
The quartz grains were not size sorted by conventional methods (Galehouse, 1971) as minute alterations to the grain surface might have occurred during contact with the sieve meshes. This sieving could effectively imitate eolian abrasion. Quartz grains in the 0.5-1 mm size range (1Ø - 0Ø) were chosen at random under the binocular microscope (Krinsley and Margolis, 1971). Twenty of these grains from each sample were handled with a moist camel hair brush and placed in rows of four (5 per row) on doubly adhesive cellulose tape which was already stuck to the top of the specimen holder (stub). This adhesive tape was "grounded" to the stub using silver paint. The twenty stubs containing 398 grains were then coated with a very thin film of gold to ensure maximum electron conductivity.

Surface Texture Criteria

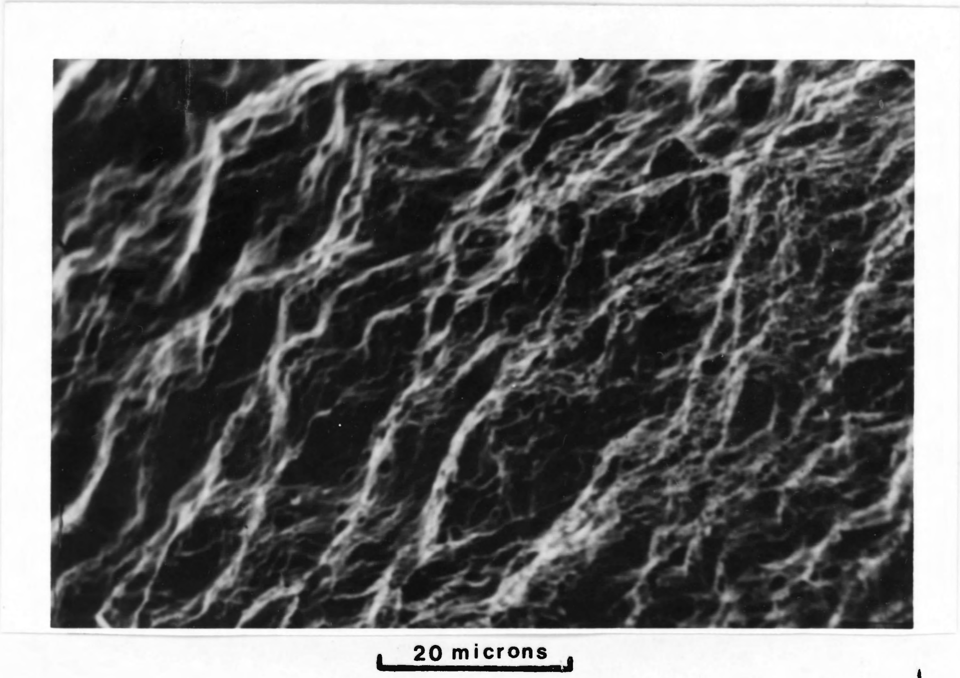
No single feature is indicative of any particular milieu. A series of related features was used to define a specific environment.

Primary eolian features invariably include dish-shaped depressions and upturned plates on a rounded- to well-rounded grain (Plate 4). Krinsley, (1973) claims that few dish-shaped concavities have been observed in coastal eolian sands and as such the presence of upturned plates is more crucial.

Subaqueous environmental indicators include the presence of "V" shaped and curved gouges which are caused by abrasion within a medium more viscous than air (Plate 5). The abundance and orientation of these features is indicative of the degree of energy involved. Above wave base these notches are more regular and less abundant (Krinsley and Doornkamp, 1973). Subaqueous grains range in shape from subangular to subrounded, depending upon the length of time spent within the aqueous medium.

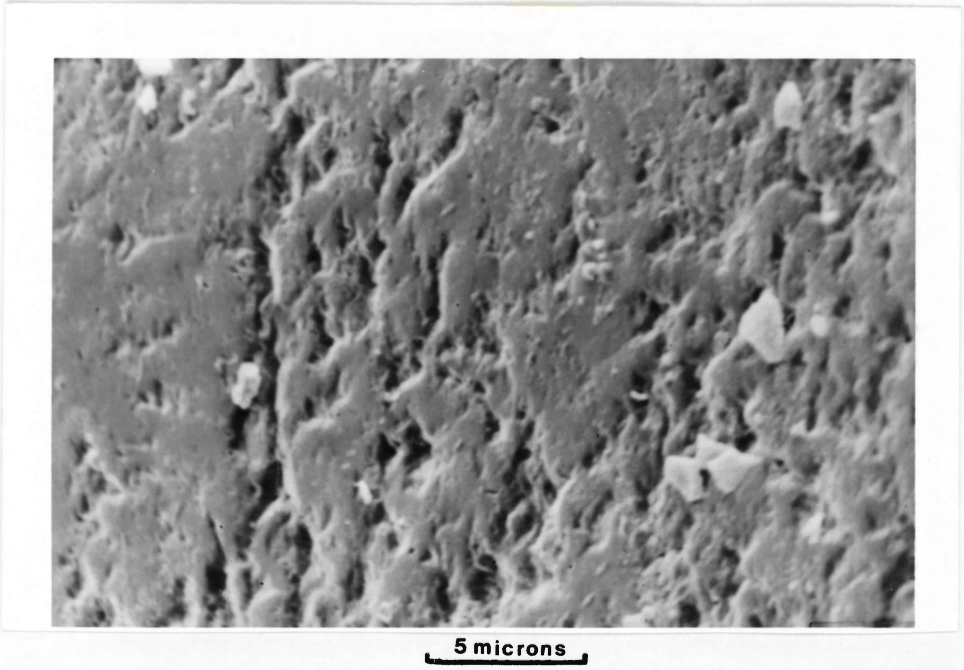


Dish-shaped concavity.



Upturned plates.

Plate 4: Photomicrographs of Eolian Features.

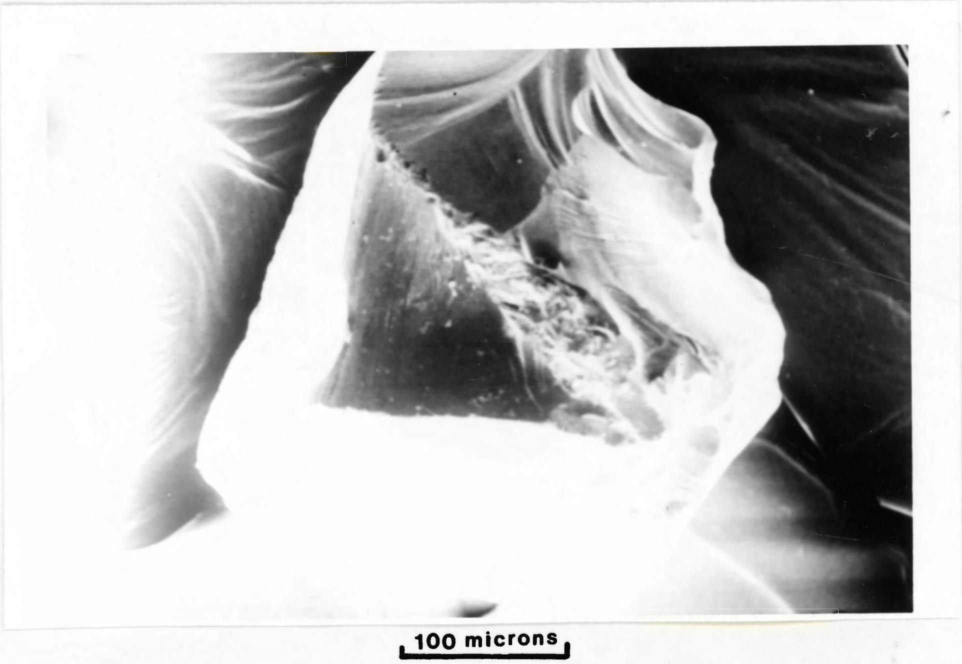


Curved grooves and "V" forms.

Plate 5: Photomicrograph of Subaqueous Features.

Glacial grains are angular to subangular and primary features include high relief, parallel striae and conchoidal fractures of diverse dimensions (Plate 6). The striae are very similar to those observed on a macro-scale in the field and are reputedly caused by the same scraping process (Krinsley and Doornkamp, 1973). Grains altered by diagenesis are indicated by distinct solution/precipitation features and silica plastering (Plate 7). Diagenetic surface features indicate glacial reworking of pre - Late Wisconsinan till and thus the percentage of grains affected by diagenesis is a direct measure of glacial input to Kings and Hartling Bays. Since mode of transport and type of environment involved was of the prime motive for the S.E.M. study, diagenetic grains were included in the "glacial" class.

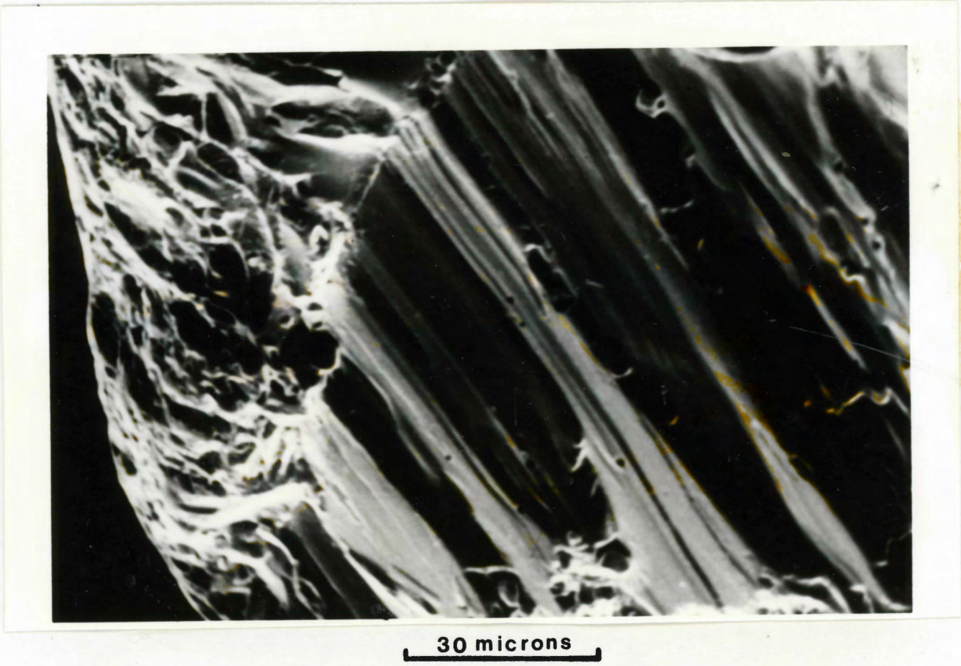
When the origin of a grain was deduced to be a combination of environments then each background was given equal status. If twenty grains on the stub, for instance, indicated 10 glacial, 5 subaqueous, 1 eolian and 4 subaqueous/glacial environments then the environment for that sample would be inferred to be 60% glacial, 35% subaqueous and 5% eolian. A typical glacial grain exhibiting subsequent modification within a subaqueous environment is shown in Plate 8.



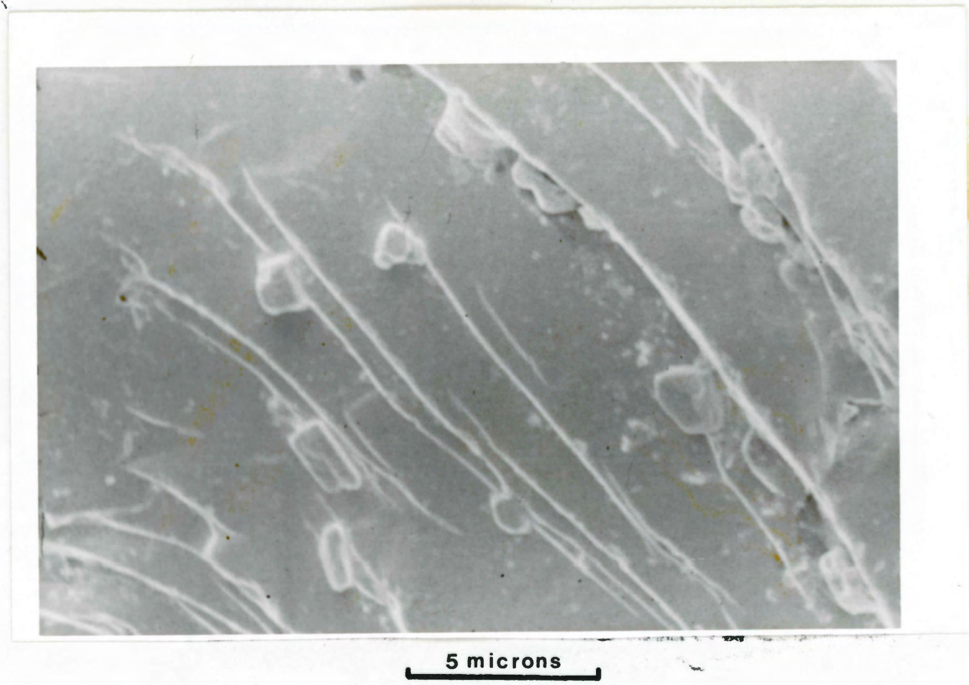
Angular quartz grain showing high relief and conchoidal fracturing.

Parallel striae and silica plastering.

Plate 6: Photomicrographs of Glacial Features.



Solution/Precipitation (left) on glacial grain.



Silica plastering on cleavage faces.

Plate 7: Photomicrographs of Diagenetic Features.

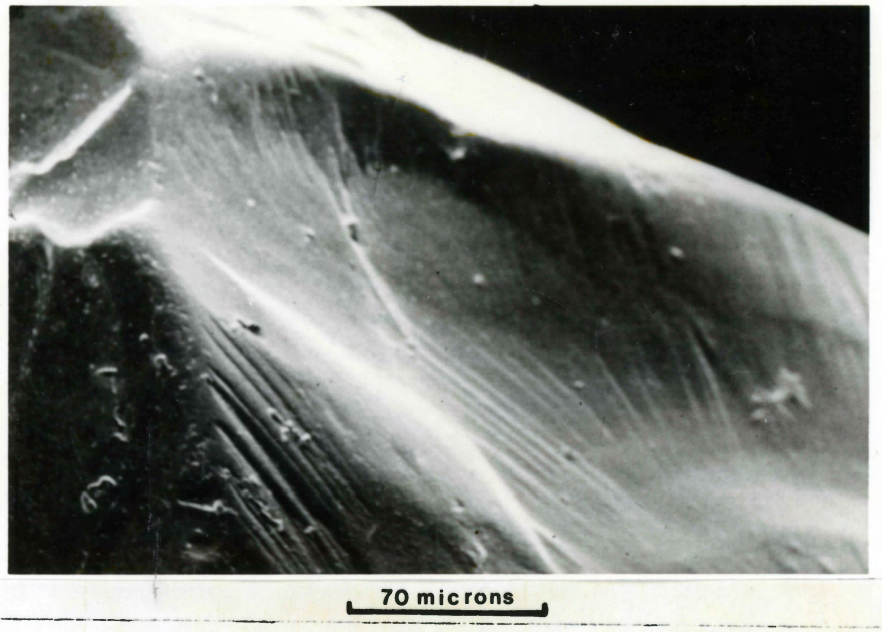


Plate 8: Photomicrograph showing Subaqueous Modification of Glacial Features.

Results

Results of data obtained from the S.E.M. quartz surface texture study of Kings and Hartling Bays (Appendix B) are summarized in Tables 3 and 4. When averaged, the inferred subaqueous, eolian and glacial origins for the quartz grains in both bays are very similar. Kings Bay samples contained 41.4% subaqueous, 11.8% eolian and 46.8% glacial grains. Hartling Bay averaged 42.3% subaqueous, 7.2% eolian and 50.5% glacial origin grains.

Of the quartz grains studied, 36.3% showed diagenetic features. It can then be estimated that of the study area, over one third were derived from previous unconsolidated sediments which may to a large extent be earlier glacial deposits (Table 5). It should be noted that of the grains associated with diagenesis, the majority were found in the offshore samples, not in the drumlins as might be expected.

Discussion

The glacial grains are assumed to be derived from drumlins associated with the late Wisconsinan glaciation. The fact that these grains are sometimes found in an aqueous medium indicates either that energy conditions are stable or that they have only recently been introduced to the water by erosion. Diagenetic grains were included in this class despite the fact that some of these grains were now recognizable only as

TABLE 3

Origin of Kings Bay Sediments Using S.E.M. Textural Criteria

Sample Location	Subaqueous Range %	Mean %	Eolian Range %	Mean %	Glacial Range %	Mean %
Tills	15-30	22.5	15-20	17.5	50-70	60
Beach	50-60	55	7.5-23.7	15.6	26.3-32.5	29.4
Nearshore	25-45	37.3	2.5-10	5.8	45-70	56.7
Offshore	40-65	52.5	10-12.5	11.3	22.5-50	36.3
Overall	15-65	41.4	2.5-23.7	11.8	22.5-70.0	46.8

TABLE 4

Origin of Hartling Bay Sediments Using S.E.M. Textural Criteria

Sample Location	Subaqueous		Eolian		Glacial	
	Range %	Mean %	Range %	Mean %	Range %	Mean %
Tills	19-20	19.5	6.5-15	10.8	65-74	69.5
Beach	47.5-68.4	58	2.6-5.3	3.9	29-47.5	38.3
Nearshore	20-67.5	43.3	0-15	6.7	22.5-75	50
Offshore	50	50	10	10	40	40
Overall	19.2-68.4	42.3	0-15	7.2	22.5-75	50.5

TABLE 5

Distribution of Diagenetic Quartz Grains
Kings and Hartling Bays

Sample Location	Kings Bay	Hartling Bay
Drumlin Tills	30.0%	27.5%
Beach	43.6%	31.6%
Nearshore	10.0%	13.8%
Offshore	65.0%	68.3%

Average Kings Bay = 37.2%

Average Hartling Bay = 35.3%

Overall Average = 36.3%

subaqueously modified quartz. Subaqueous grains are usually reworked glacial, former subaqueous or eolian grains.

The eolian depositional environment statistics would appear to support the existence of former dune complexes seaward of the present shoreline. Eolian grains could also have been blown by offshore winds from the present dunes. The fact that an anomalous number of eolian grains is found in the tills can be attributed in part at least, to former beach or dune sands which have been transported south by glacial ice. This explanation is admittedly weak and constitutes a major problem for interpretation of the data. An intensive study of these tills and other drumlins in the area is necessary to provide supportive data or to reveal flaws in textural criteria used for identification.

SEDIMENT RESPONSE TO ENERGY CONDITIONS

Wind direction varies in Kings and Hartling Bays but generally during the late fall and winter (November-March) it blows from the west-northwest. During the spring, summer and early fall (May-October) winds are predominantly south-southwesterly (Figure 7). The effect of these surface winds, however, is minor in comparison to the effect on sediment transport by wave action. Storm waves during the fall and winter months are extremely important and it is these waves which were responsible for the drastic changes in the beach profiles. Both Kingsburg and Hirtles Beaches show a classic flat summer and steep winter profile (Appendix C). The steep angle of repose is a function of the wave energy expended on the shore during the winter months.

Kings Bay

Offshore topography is mostly bedrock in the channel between Kings Bay and Cross Island (D. Piper, pers. comm., 1976). This could indicate a high current velocity but probably is the result of exposure to big waves. No mud was found in Kings Bay, indicating winnowing by these waves.

Profiles of Kingsburg Beach show that the flattest angle was measured in May when local (as opposed to predominant monthly) winds were important as they were northeasterly, causing onshore

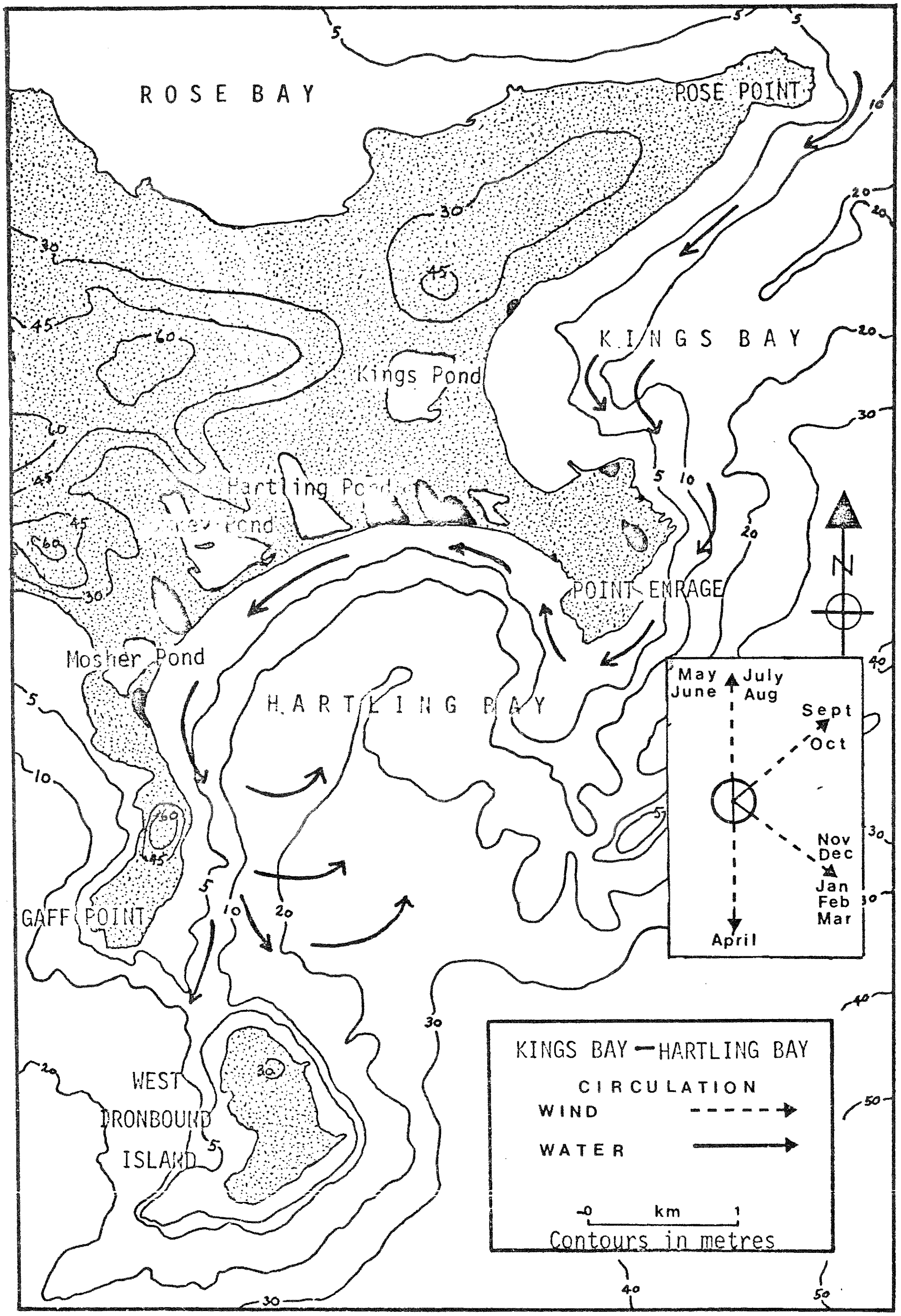
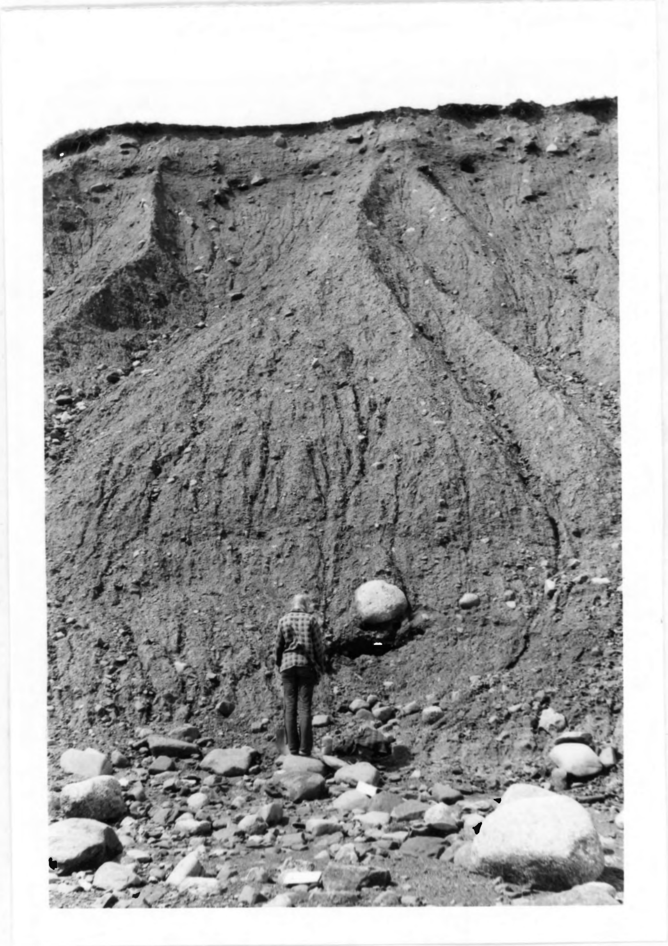


Figure 7: Predominant Surface Wind Direction and Circulation Patterns, Kings and Hartling Bays.

sediment transport. Increased wave energy during the fall and winter result in seaward movement of beach material. The profiles measured in January thus have the steepest angle with an average decrease in beach elevation of about one metre. This winter profile can be attained in a matter of a few days of stormy weather (A. Bowen, pers. comm., 1977). The flatter summer profile is the result of a much slower process involving several months.

Hartling Bay

Rates of cliff erosion in Hartling Bay increase in an easterly direction. This would appear to be indicative of the importance of winter west-northwesterly winds and storms. The boulder armour at the base of each drumlin is essential for protection from the surf. Sediment is not extensively lost by surf action however; rather the unconsolidated tills tend to steepen in the winter and slump during the spring thaw (Plate 9). As at Kingsburg Beach the profiles of Hirtles Beach show a general summer low angle trend while the winter profiles are considerably steeper (indicating a net offshore transport). Drops in profile attitude of over two metres were recorded (1.5 m average). By comparing profile attitudes along the beach (Figure 8) it can also be noted that there is a general trend for decreased removal rate and consequent flatter beach profile from west to east. This would indicate a net longshore transport from east to west (Figure 7).



Extensive gullying and boulder armour.

Plate 9: Most Easterly Drumlin, Hartling Bay.

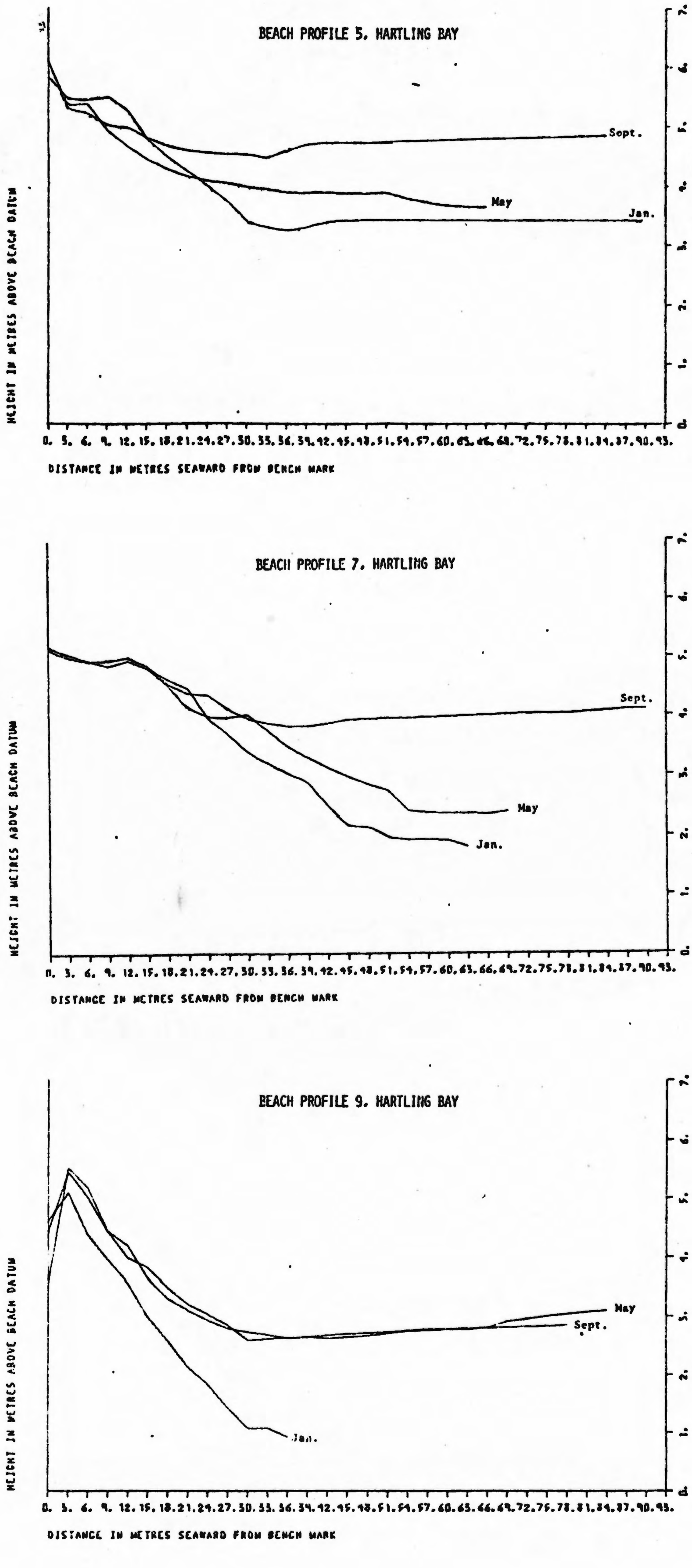


Figure 8: Typical Beach Profile Attitude Changes along Hirtles Beach from East (top) to West.

This anticlockwise longshore current results in sediment loss in a southeast direction along Gaff Point and West Ironbound Island. Most of this sediment results in a thick sandy deposit (Piper and Keen, 1976) east of these two regions. This sand is then available for recirculation to the beach during the summer months.

Both Kings and Hartling Bays have steepest beach angles in January but differ in their September to May profile. Kingsburg Beach is flattest by May while Hirtles Beach does not attain its most level profile until September. This difference is in direct response to local onshore winds and flatter angled waves early in the spring. These conditions are more advantageous to Kings Bay than Hartling Bay. This causes Kingsburg Beach to reach its summer profile faster than Hirtles Beach.

SEDIMENT BUDGET

Kings Bay

Rates of drumlin cliff retreat were estimated using aerial photographs which spanned 20 years (August 1945 to July 1965). Visual field observations and interviews with local townsfolk were also employed. The north drumlin in Kings Bay is retreating at a rate of 0.1 m/yr and thus supplies 4 m^3/yr to the bay. Of this, 0.8 m^3 is gravel, 1.7 m^3 is sand and 1.5 m^3 is mud (calculated from Table 1). The glacial deposit on the south shore of the bay appears to be losing 0.4 m/yr. This would yield 22 m^3/yr of sediment of which gravel comprises 2.7 m^3, sand accounts for 18.3 m^3 and silt and clay input is 1.0 m^3 (calculated from Table 1).

Total sediment input through drumlin erosion is thus estimated at 26 m^3/yr. Extrapolated sediment loss to mid bay during the winter (using beach profile data) can be estimated at 23,000 m^3. This is almost exclusively in the form of sand.

Hartling Bay

Similar techniques to determine cliff erosional rates were employed in Hartling Bay. The fine fraction from the tills is being supplied to the nearshore and beach while the boulders remain at the foot of the drumlin. The most easterly drumlin (T29) is retreating at about 1.5 m/yr. This involves a sediment input exceeding 4500 m^3/yr. The drumlin west of this (T30) is receeding at 1.2 m/yr and total erosion is about 1100 m^3/yr. Further west down the beach, the erosion of the highest drumlin (T37) appears to be greatly arrested by stabilizing plant growth. Rates of retreat at this location do not exceed 0.3 m/yr and thus sediment input is only 440 m^3/yr. The final and most westerly drumlin (T34) is supplying about 40 m^3/yr. This is due to its sheltered location and low cliff retreat (0.1 m/yr).

Total sediment input to Hartling Bay from drumlin erosion thus exceeds 6000 m^3/yr. Of this, 534 m^3 is estimated to be gravel, 2490 m^3 is sand and mud content is 2976 m^3 (calculated from Table 2). A rough estimate of sediment volume loss seaward during the winter (according to beach profile data) is over 70000 m^3. This consists chiefly of sand.

Hartling Bay has much more sediment supply than does Kings Bay but it also has more wave energy expended on its shore. Except for the mid-bay, beach and isolated pockets along its perimeter, there is little sand cover in Kings Bay. Hartling Bay appears to have a uniformly thick veneer of medium grained sand blanketing most of its nearshore and offshore regions. In the northeast sector of the bay a muddy sample was found but this area could not be resampled due to weather and lack of availability of "Saltfinger". This sample could represent a relict of the previous lagoonal sediments which were deposited prior to the rise in sea level. This explanation seems plausible since the mud shows that it has been reduced - a parameter indicative of a stable environment.

Hirtles Beach was designated a "Protected Beach" in August 1975 (M. E. Wortman, pers. comm., 1977). Kingsburg Beach on the other hand, is not protected by the Nova Scotia Department of Lands and Forests. On practically every occasion in which an entire day was spent at Kings Bay, local townsfolk removed sand from the beach. In most cases this amounted to little loss of consequence. In some cases, however, trucks were loaded with sand. Should this removal persist, Kingsburg Beach will gradually become a pebble beach as there is no active sediment source for replenishment. Twenty six cubic metres per annum cannot be considered an important contribution to the sediment budget of the bay.

Kingsburg and Hirtles Beaches are retreating landward due to rising sea level. Sand and gravel removal from these beaches has speeded up this natural process. Human activity has destroyed a great deal of the dune grass in Hartling Bay permitting blow-outs which introduce sand to the lagoons. Kings Bay dune grass is generally abundant but despite this, blow-outs along pathways also occur.

HISTORY OF KINGS AND HARTLING BAYS

About 14000 B.P. the glacial ice cover over Nova Scotia was cut off from its source to the north by the incursion of the sea over Georges Bank and into the Bay of Fundy. This caused stagnation of the ice sheet or glacial lobes resulting in the deposition of extensive till sheets which covered the shelf as well as the mainland. In southern Nova Scotia ice retreat was radial with the ice centre situated over present day Kejimkujik National Park. The sea followed the retreating ice as more melt water drained to the ocean. Rebound is believed to have begun during the deglaciation process and thought to have reached its maximum very shortly thereafter. Isostatic rebound made sea level fall for thousands of years. Sea level began to rise only within the last 6000-8000 B.P. (Grant, 1975). This transgression might have been more extensive on the Atlantic Coast had it not been for a possible negating effect attributed to the marine incursion of the Fundy Coast. Since Nova Scotia tilts about its long axis in response to the Fundy tides, it is not unreasonable to assume that complete inundation of the Bay of Fundy arrested, to some extent, the sea level rise along the southern coast of Nova Scotia.

The beach systems that existed about 18000 B.P. (Sable Island being a modern relict of an outwash plain (Bowen, 1975)) were unable to maintain their respective positions against the onslaught of rising sea level. These beach systems retreated landward during this Holocene transgression. As these systems withdrew, the old beaches would provide reworked material for the new beach or, if the transgression was swift (as it was at first), the sediment would be left behind as a veneer of sand and gravel. Rise in sea level was generally consistent until from about 3000-2500 B.P. when the rate was 44 cm/century. A decrease thereafter to 20 cm/century has been postulated by Scott, (1977). Grant, (1970) proposes a 15 cm/century rate for this area.

Beaches tend to join bedrock headlands. Bathymetry was used to recognize possible sites of former barrier beach systems. Ironbound Bank (delineated by a 20 m contour) could have supported such a system which was subsequently destroyed by sea level rise (Figure 9). Using a sea level curve compiled from Grant, (1970) and Scott, (1977) (Figure 10) this system can be dated at 8000-9000 B.P. and chronologically correlated with Mahone Bay's outer sill (Barnes, 1976).

The next relict and more definite system was a barrier beach backed by a restricted, brackish lagoon. This beach tied the present day island of West Ironbound and Shag Rock to Pollock Shoal and Hell Reef (Figure 9). The quartz diabase dyke cutting

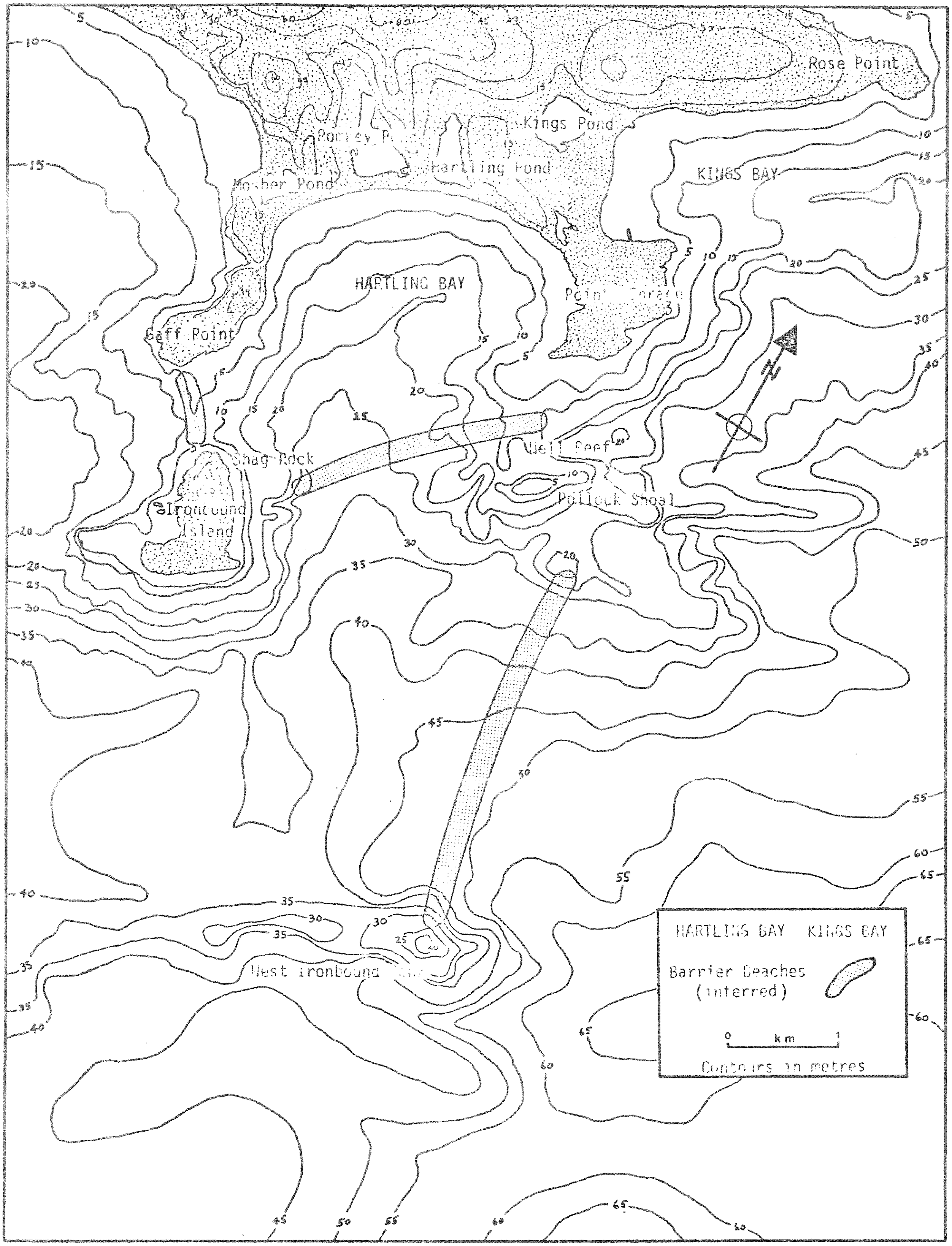
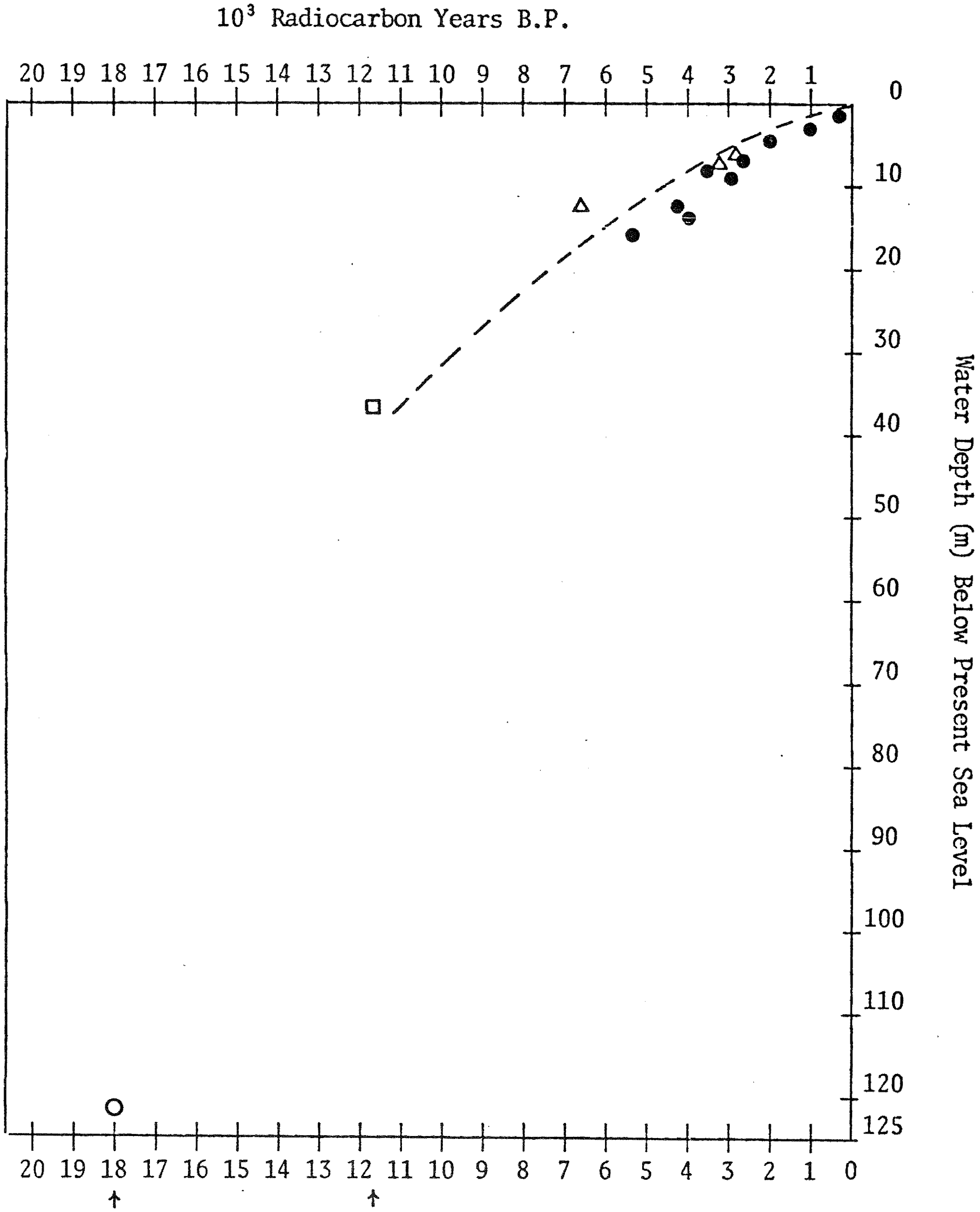


Figure 9: The Development of Barrier Beach Systems, Kings and Hartling Bays.



Presumed maximum lowered sea level.

Latest date deglaciation of Mahone Bay.

Figure 10: Theoretical Sea Level Curve.

● Grant, (1970b)

△ Scott, (1977)

□ Railton, (1973)

○ Stanley *et al.*, (1968)

(modified from Barnes, 1976)

West Ironbound Island would have provided an excellent foundation for the barrier beach. The depth, 14 metres, dates this system at about 7000 B.P. Besides S.E.M. eolian textures, supportive evidence for such a theory was the presence of *in situ* peat at 3.1 metres below high water mark. This peat, which is in the process of being dated, was discovered in late January 1977 but due to time limitations, the C^{14} date will not be available for this thesis. The peat consists of a variety of sedge and bullrush which grow at the high water mark in a brackish milieu. It is quite compact, having been compressed to 20% of its former volume (Scott, pers. comm., 1977). It has been tentatively dated using Scott's, (1977) data at about 1800 B.P. Failure of the barrier beach system about 2500 B.P. and influx of more saline waters killed the peat. The continued sea level trend has outlined the present coastline.

Kings Bay offered no "resistance" to the Holocene transgression in the form of barrier beaches. The bedrock outcrops were unsuitable for foundation for these beaches because the distance between such points was too great for beaches to form. The volume of sediment required for such a system to exist was not available. The history of Kings Bay thus merely involves the slow incursion of the sea.

Read this

DISCUSSIONS AND CONCLUSIONS

Kings Bay and Hartling Bay are being subjected to continued submergence due to the relative rise in sea level. Since the sediment influx is unable to restrain this rise by building up beach ridges the coastline is slowly receeding at a rate of 0.2-0.4 m/mm rise in sea level or 30-60 metres per century (Brunn, 1973).

From the beach profile survey it can be concluded that within the limited chronologic framework involved (9 months), Hirtles Beach and Kingsburg Beach each responded differently to local winds and wave energy. The flattest profile was achieved during May in Kings Bay (due to local onshore winds and flatter waves) while Hartling Bay's lowest angle was in September (as a result of steeper waves (both daily and storm) experienced then). It would thus appear that wave energy, particularly during the winter, is the major factor controlling the beach profile. While surface wind direction is of minor consequence in Kings Bay, it has a negligible profile effect in Hartling Bay.

Origins of sediment within Kings Bay was determined, primarily by scanning electron microscopy to indicate 41.4% subaqueous, 11.8% eolian and 46.8% glacial environments. Of these grains 37.2% exhibited diagenetic features linking them to previous glacial deposits. Hartling Bay sediments were likewise calculated to be 42.3% subaqueous, 7.2% eolian and 50.5% glacial. Grains which had undergone diagenesis amounted to 35.3%.

Eolian content offshore might indicate a former stable beach-dune system which has been proposed for the area.

The muddy nearshore sample in Hartling Bay is deduced to be a relict of the former lagoonal muds which were deposited when the present bay was a lagoon backing a beach system extending from Point Enrage to West Ironbound Island.

The peat found in Hartling Bay acts as a distinct marker zone for paleo-high water mark (HWM). Vertical ranges of such brackish water peat are restricted to ± 15 cm of HWM (Scott, 1977) and can thus be employed accurately as time horizons.

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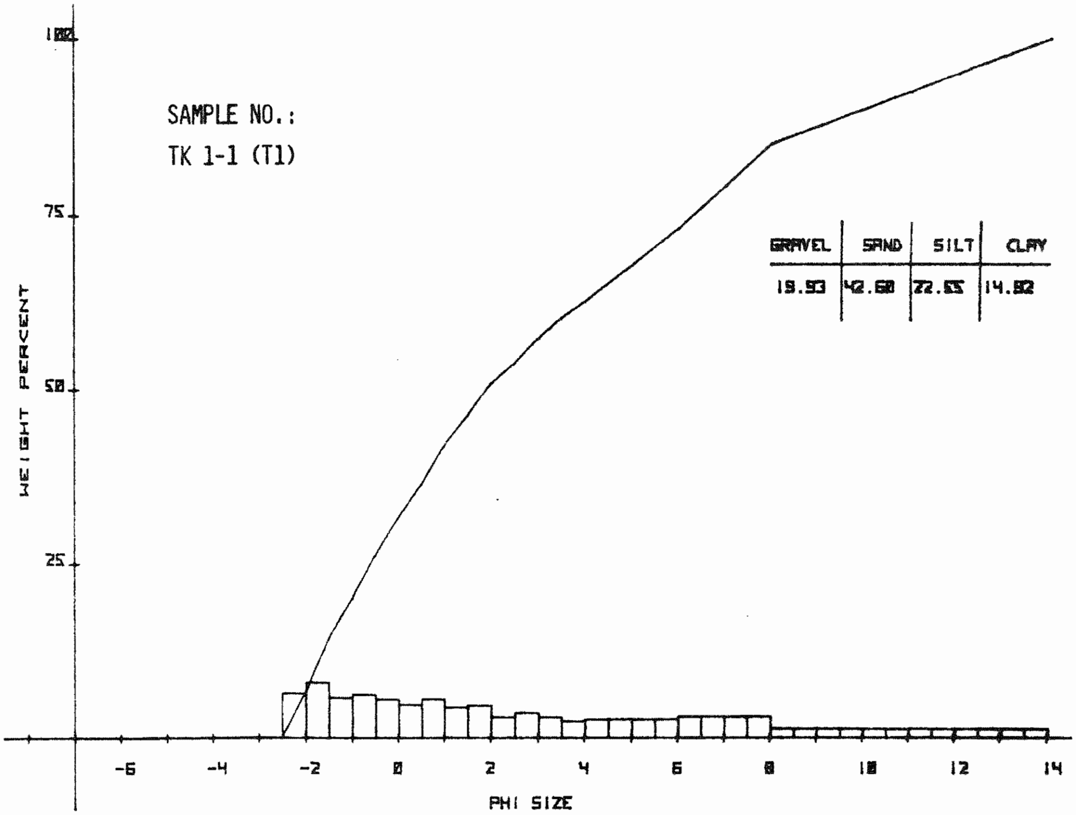
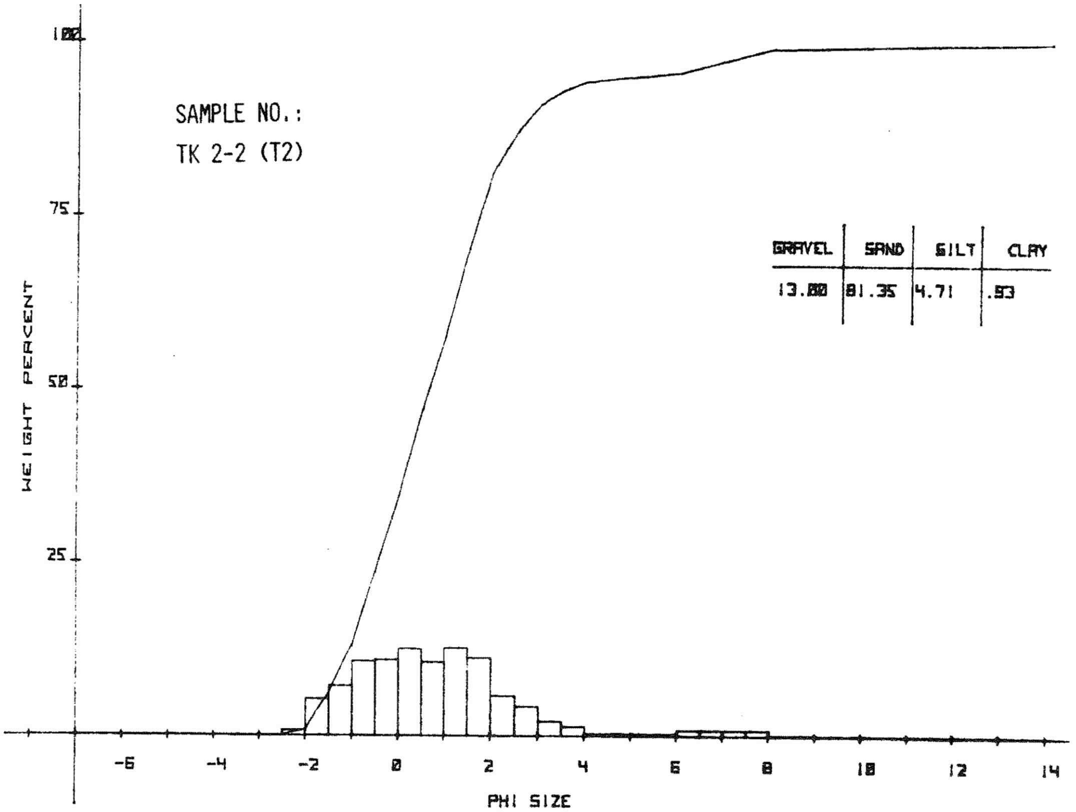
APPENDIX

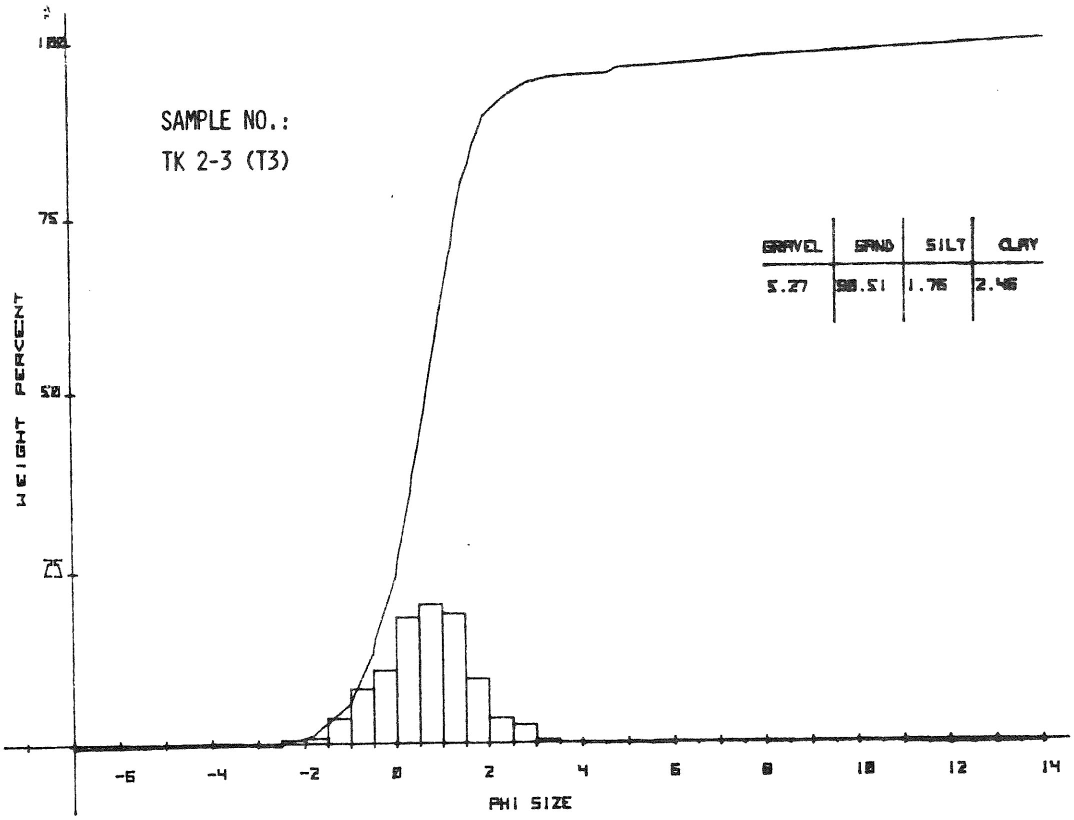
A



GRAVEL	SAND	SILT	CLAY
19.93	42.60	22.55	14.82

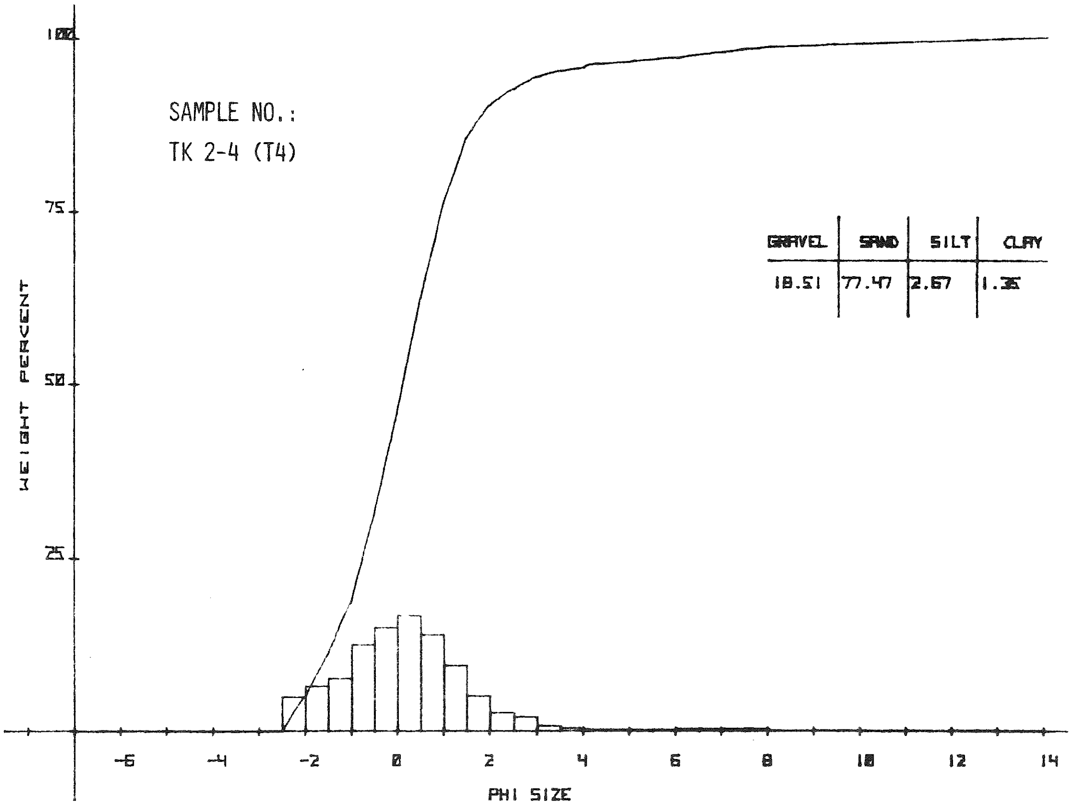


GRAVEL	SAND	SILT	CLAY
13.00	81.35	4.71	.93



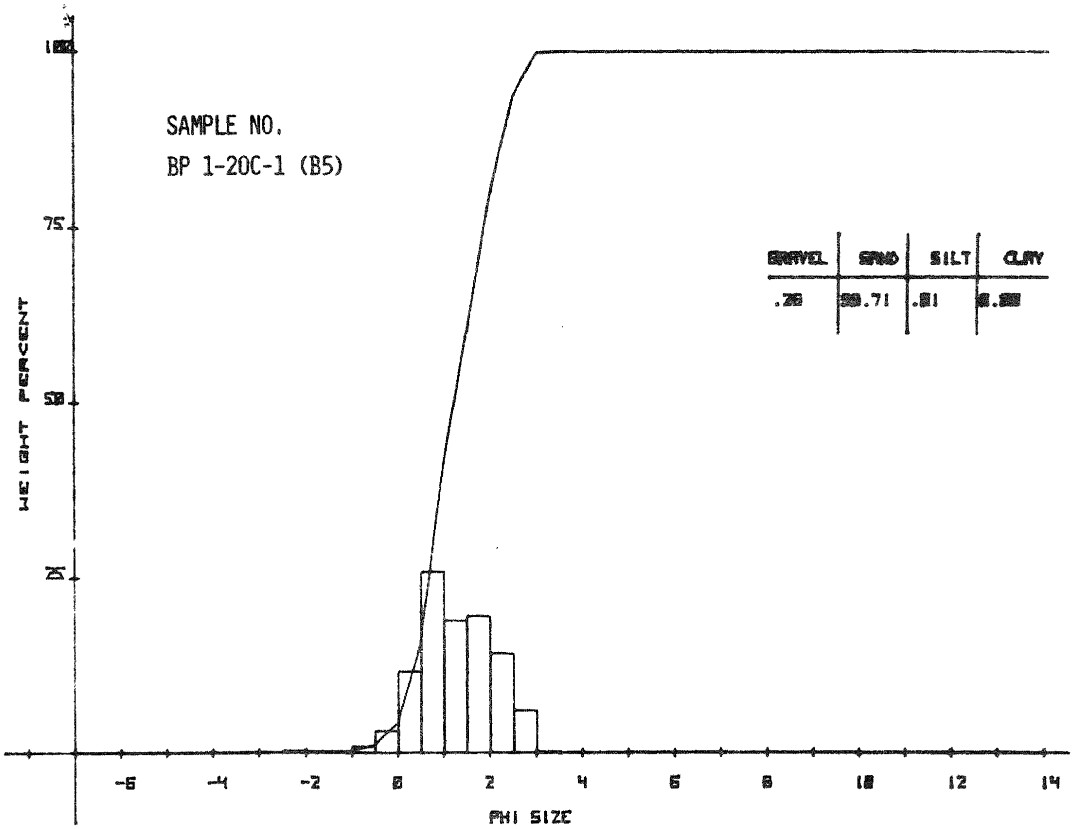
SAMPLE NO.:
TK 2-3 (T3)

GRAVEL	SAND	SILT	CLAY
5.27	90.51	1.76	2.46

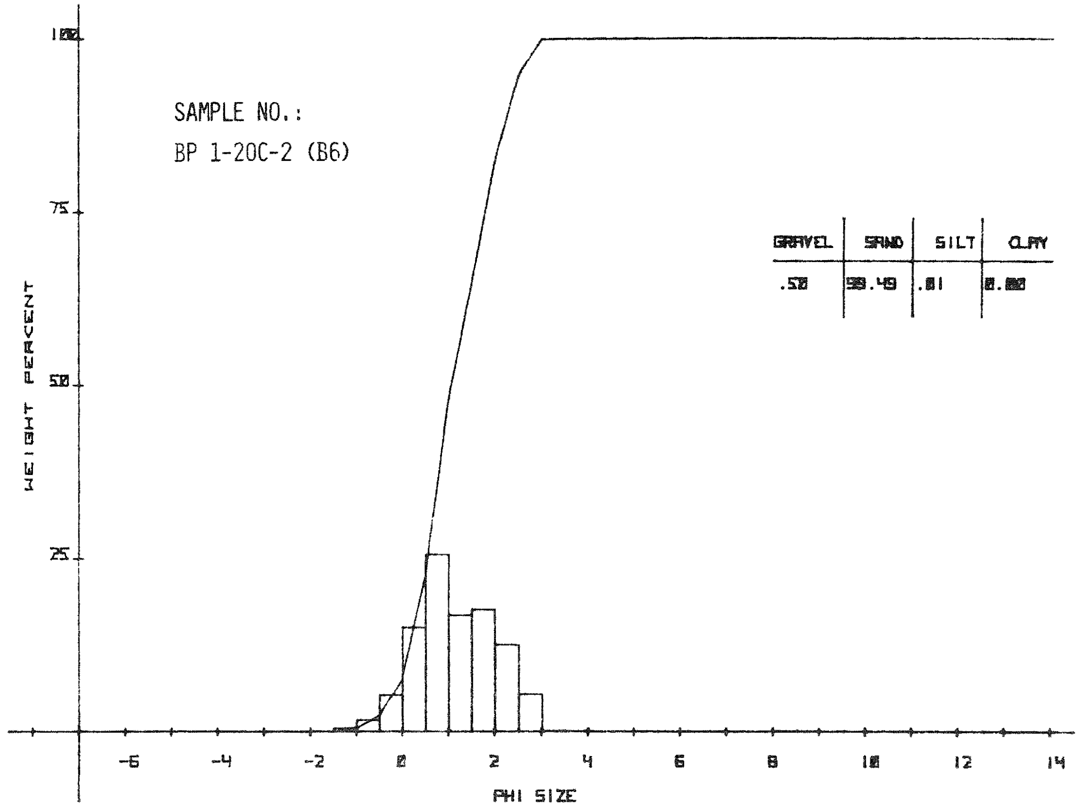


SAMPLE NO.:
TK 2-4 (T4)

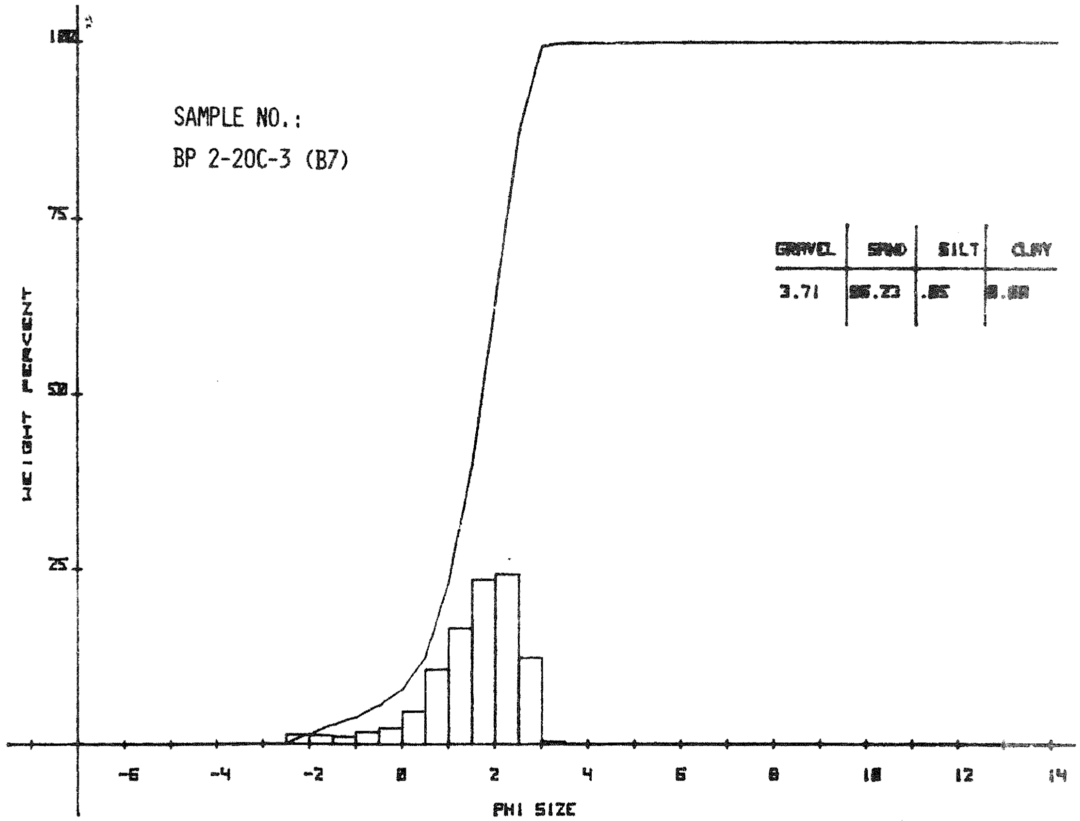
GRAVEL	SAND	SILT	CLAY
18.51	77.47	2.67	1.35



GRAVEL	SAND	SILT	CLAY
.28	99.71	.01	0.00



GRAVEL	SAND	SILT	CLAY
.50	99.49	.01	0.00


SAMPLE NO.:
BP 2-20C-3 (B7)
GRAVEL
SAND
SILT
CLAY
3.71
96.23
.06
0.00
WEIGHT PERCENT
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50
25
-6
-4
-2
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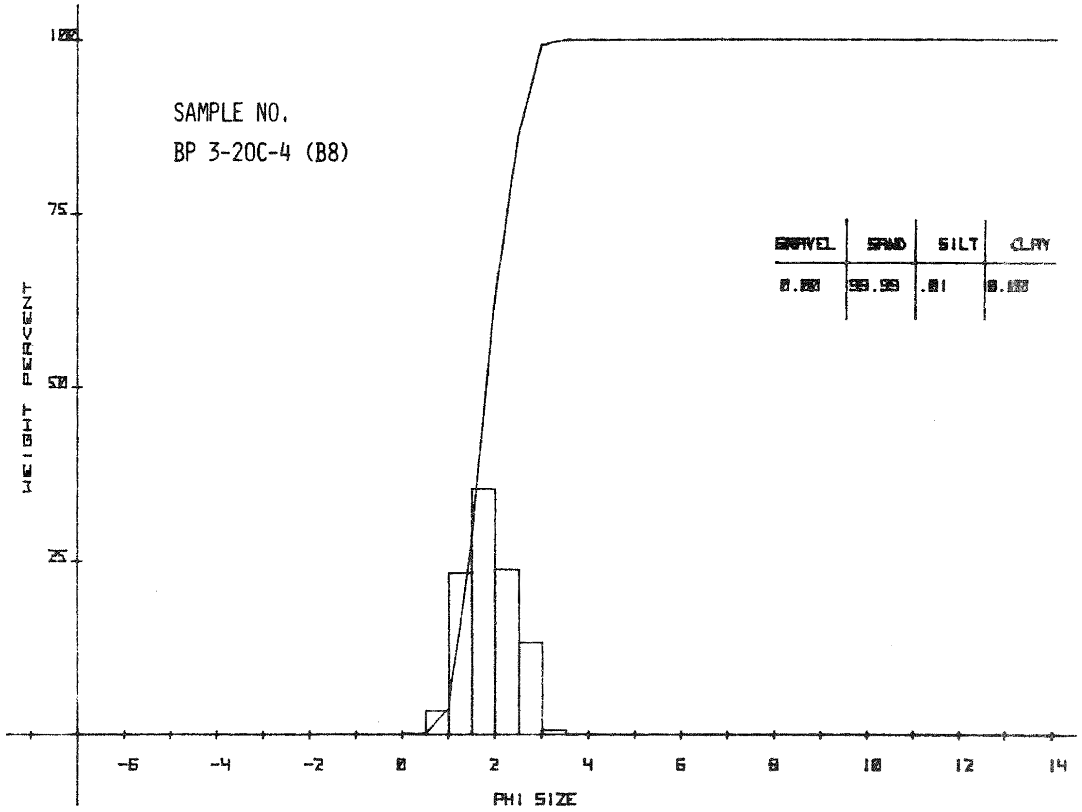
2
4
6
8
10
12
14
PHI SIZE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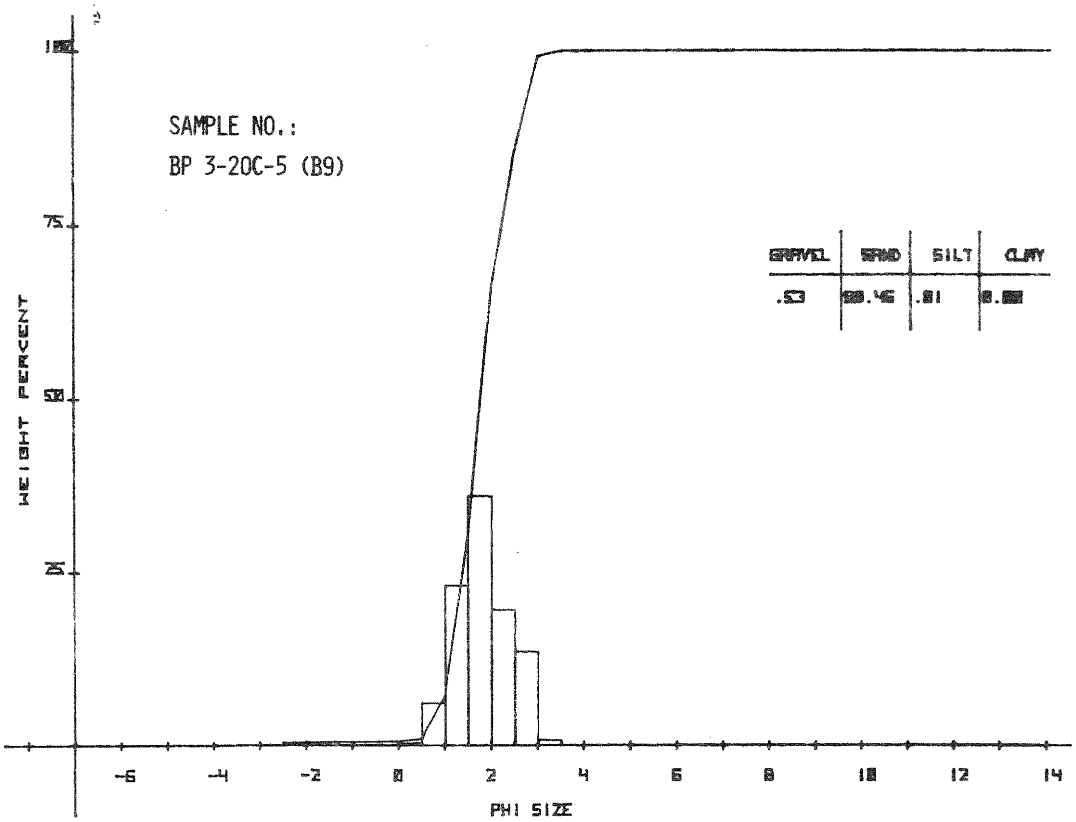
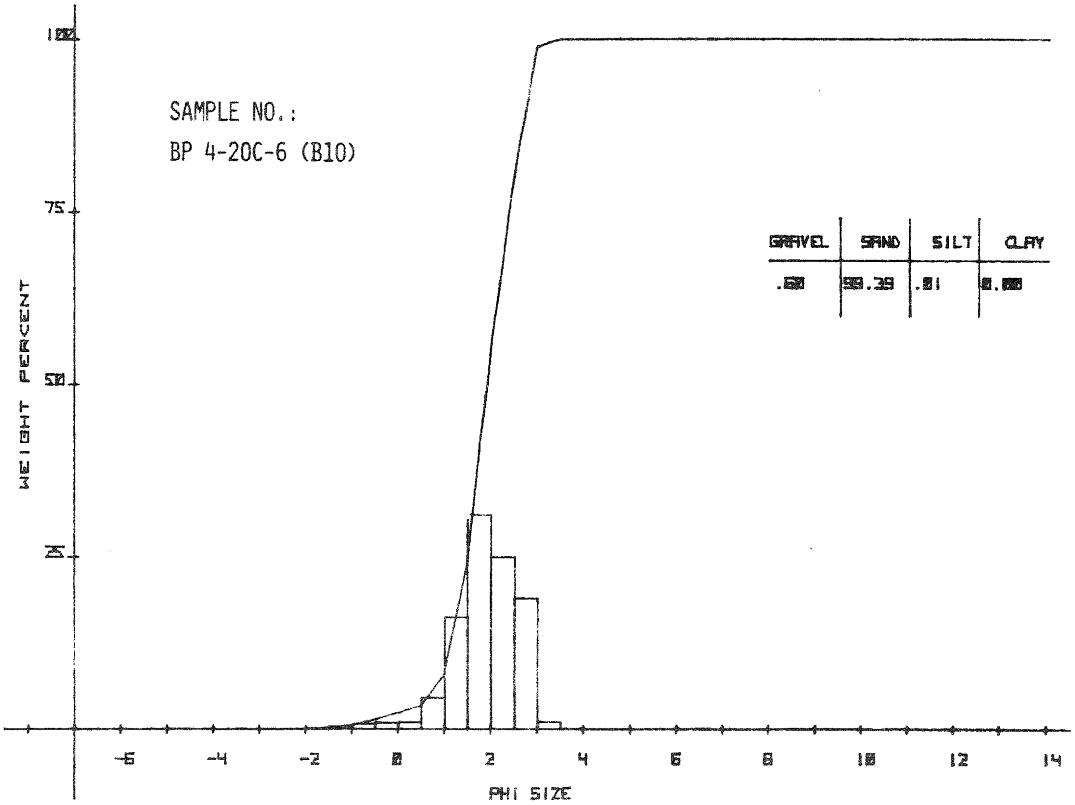
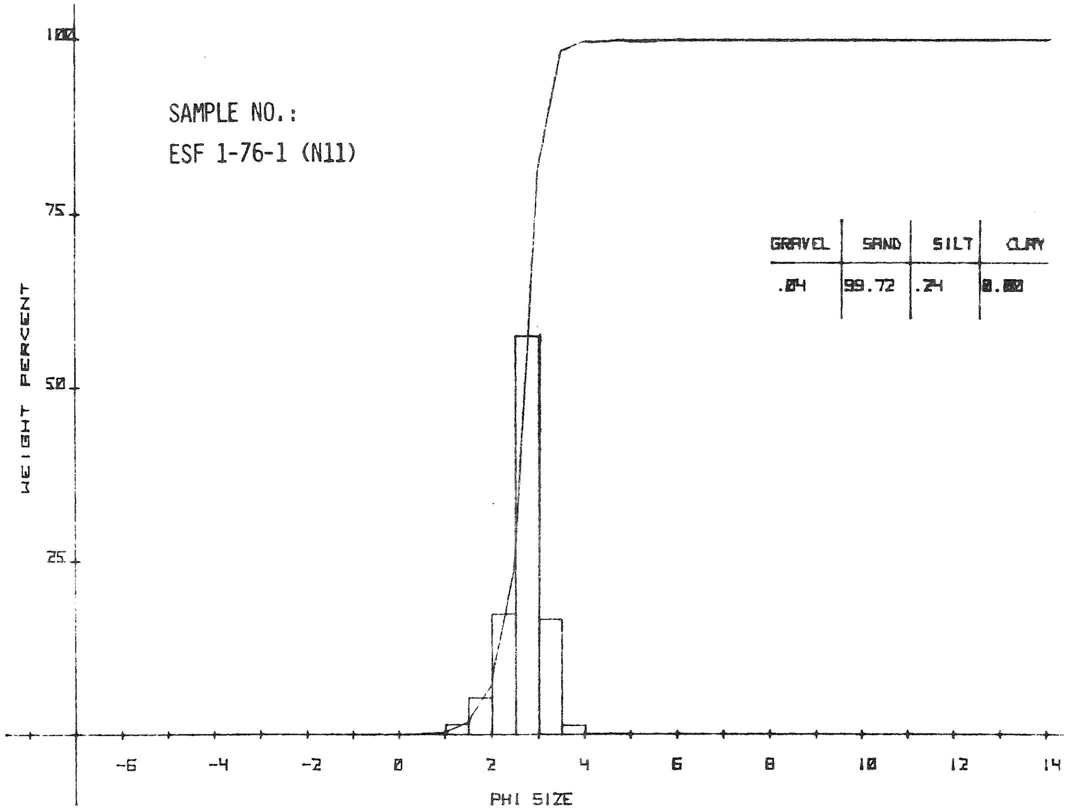
BP 3-20C-4 (B8)
GRAVEL
SAND
SILT
CLAY
0.00
99.99
.01
0.00
WEIGHT PERCENT
100
75
50
25
-6
-4
-2
0
2
4
6
8
10
12
14
PHI SIZE



GRAVEL	SAND	SILT	CLAY
.53	99.46	.01	0.00

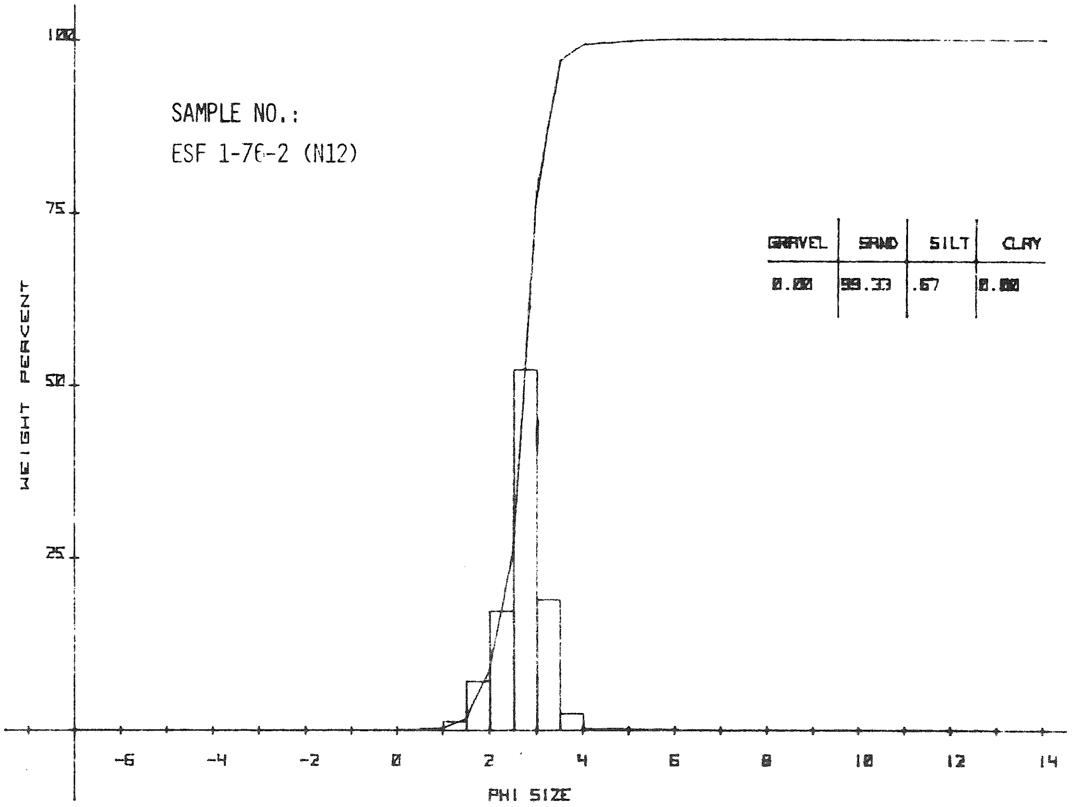


GRAVEL	SAND	SILT	CLAY
.60	99.39	.01	0.00



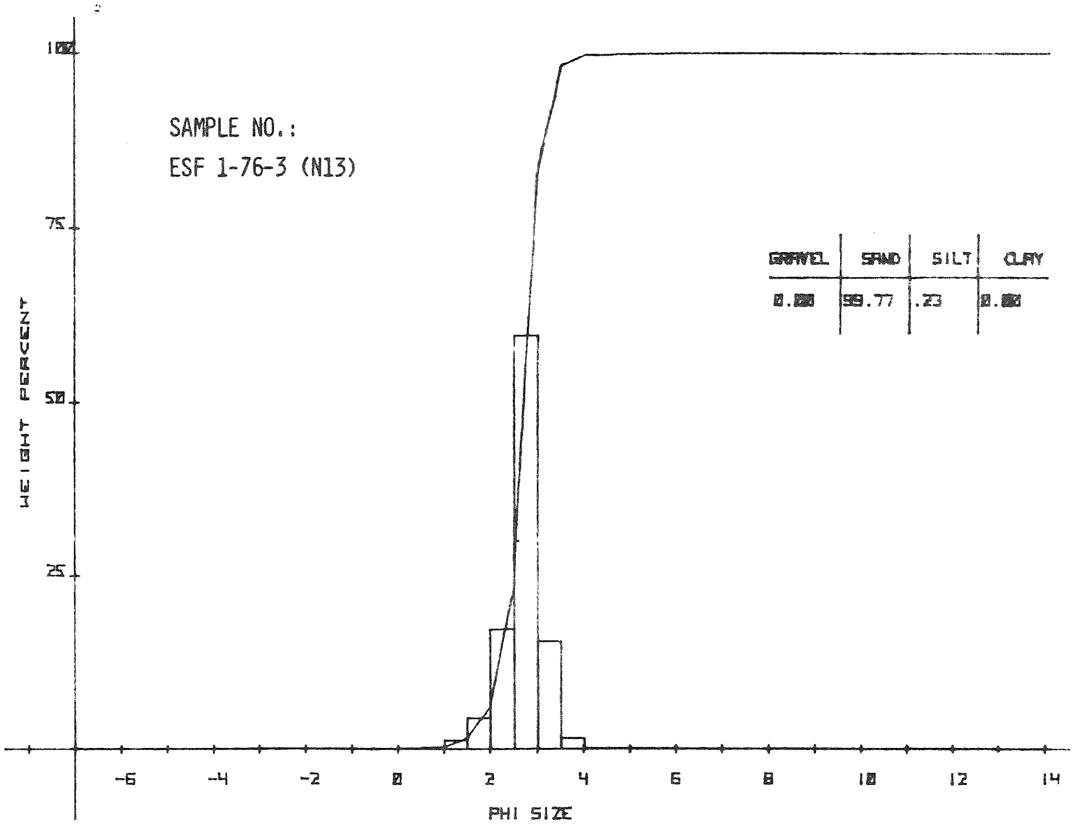
SAMPLE NO.:
ESF 1-76-1 (N11)

GRAVEL	SAND	SILT	CLAY
.04	99.72	.24	0.00



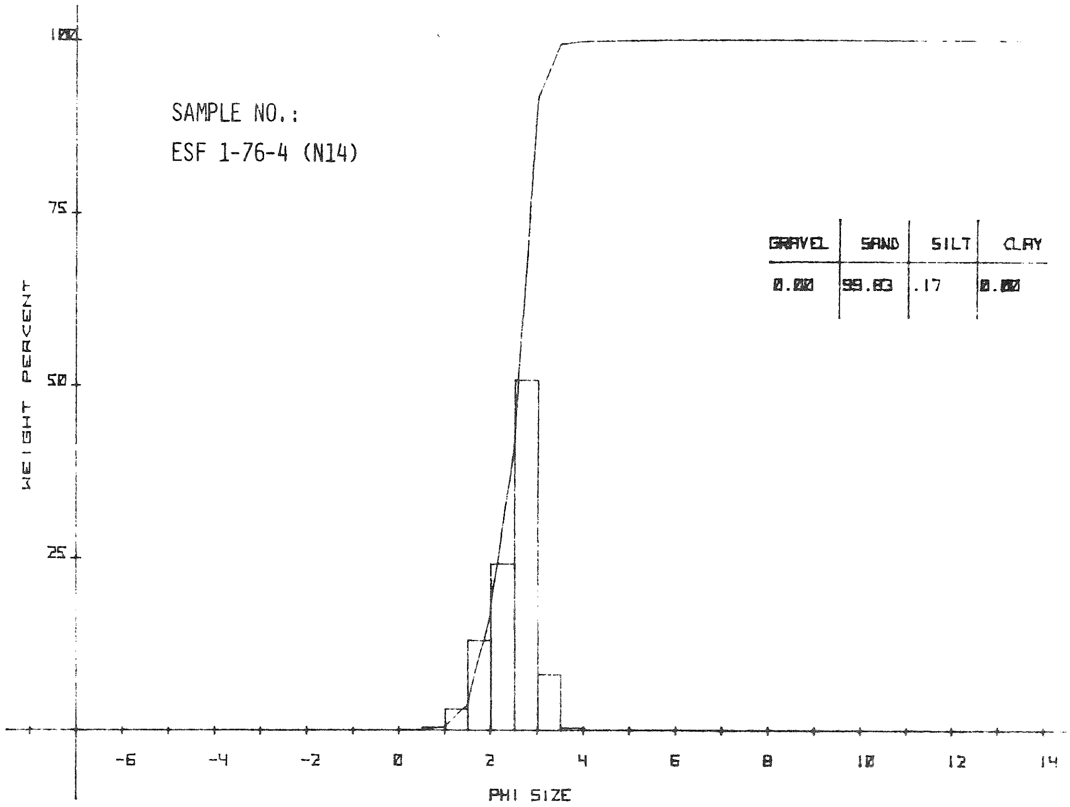
SAMPLE NO.:
ESF 1-76-2 (N12)

GRAVEL	SAND	SILT	CLAY
0.00	99.33	.67	0.00



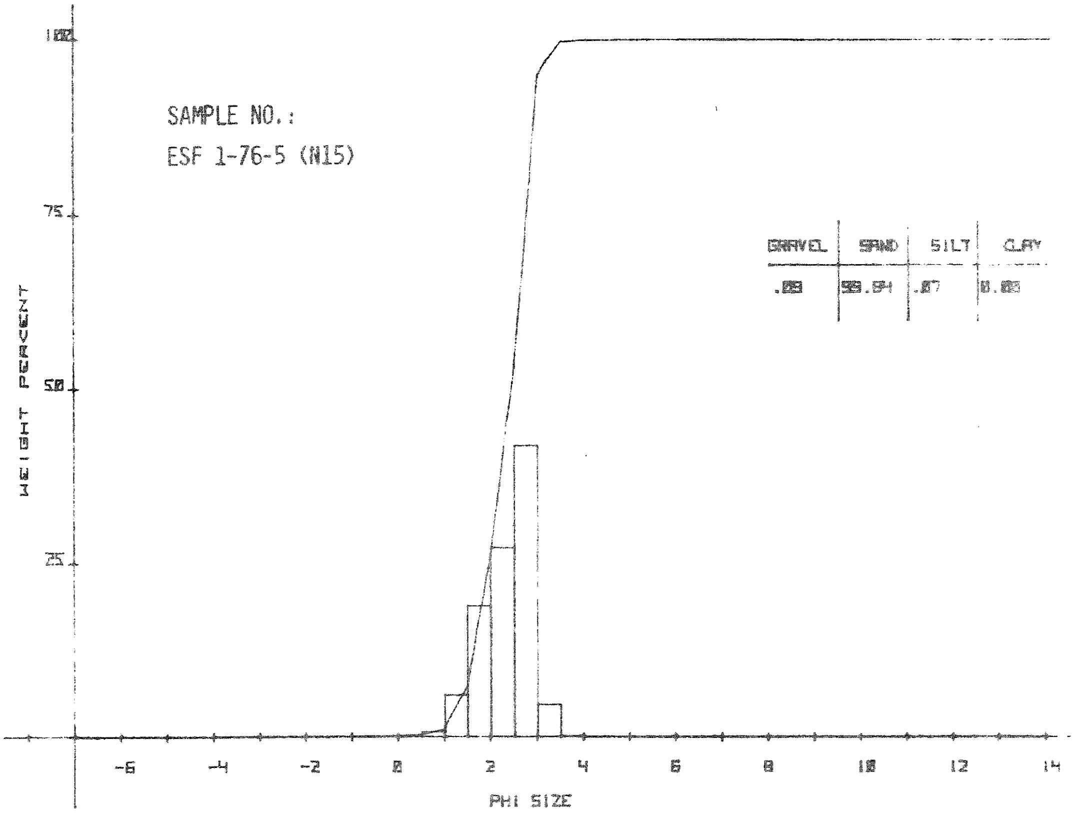
SAMPLE NO.:
ESF 1-76-3 (N13)

GRAVEL	SAND	SILT	CLAY
0.00	99.77	.23	0.00

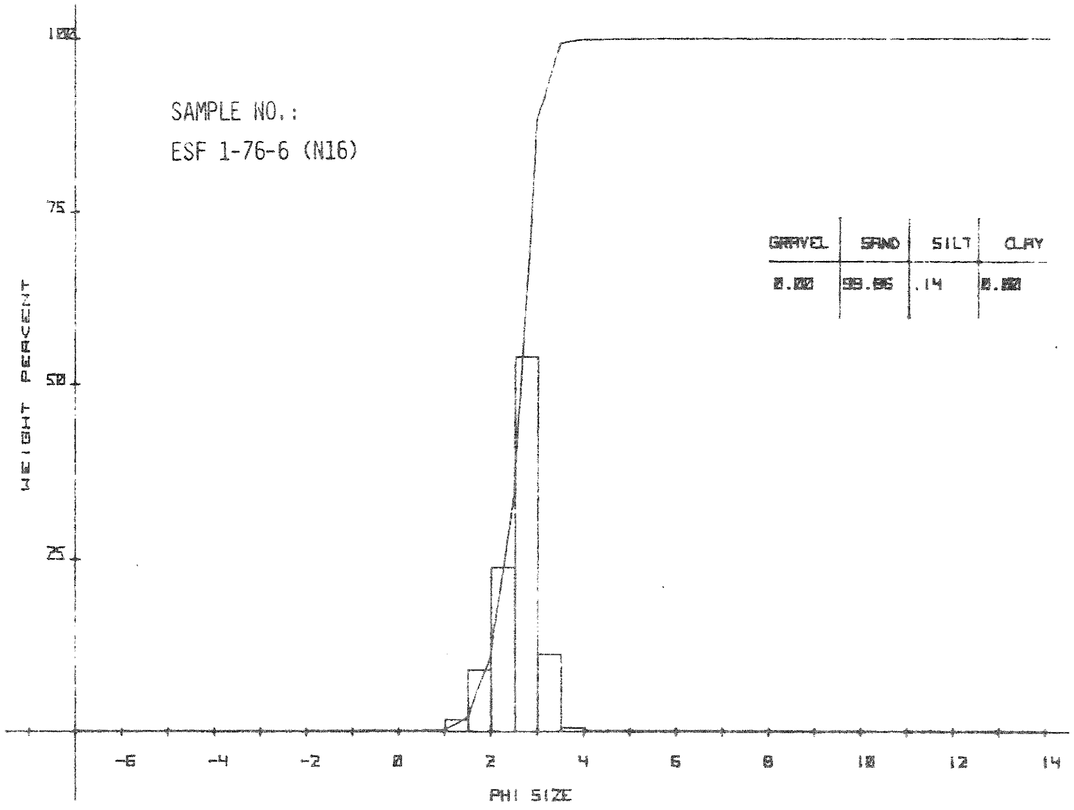


SAMPLE NO.:
ESF 1-76-4 (N14)

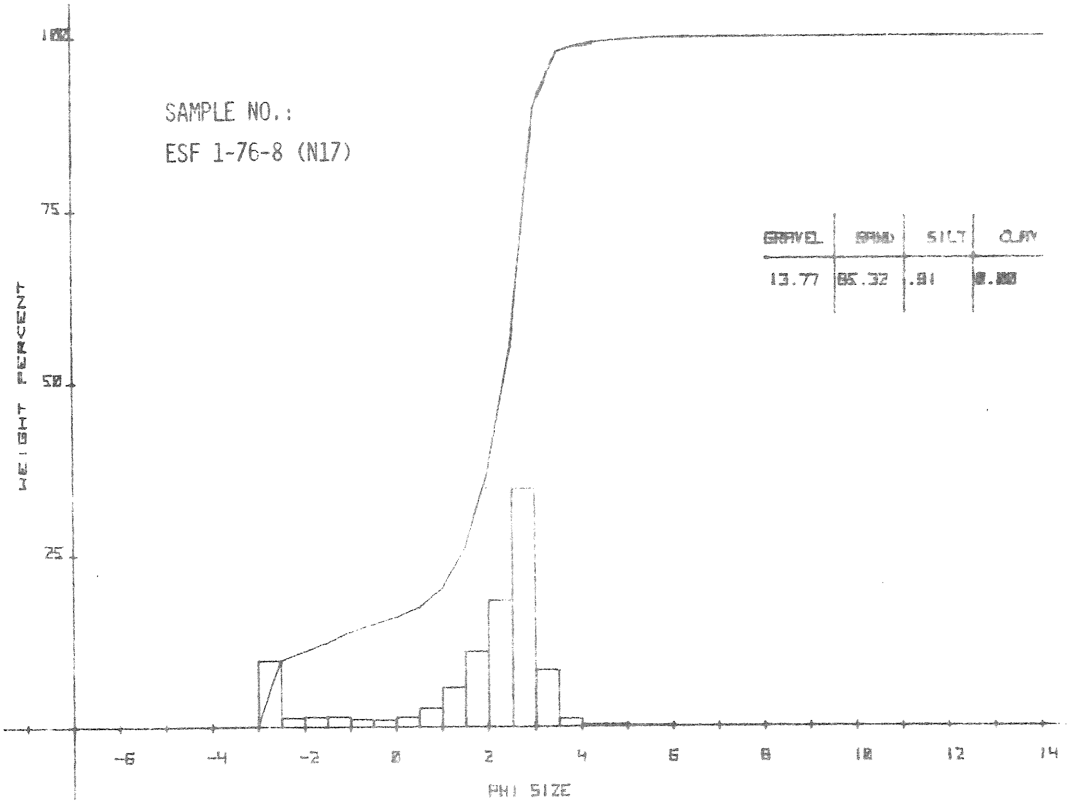
GRAVEL	SAND	SILT	CLAY
0.00	99.83	.17	0.00



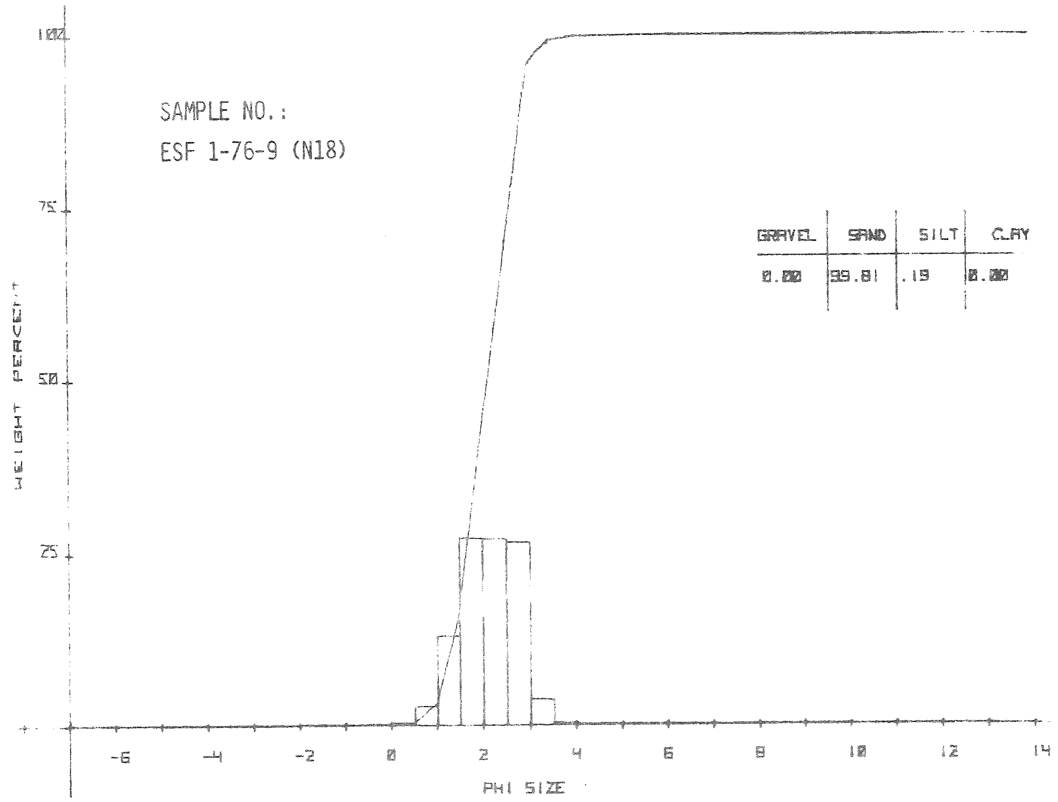
GRAVEL	SAND	SILT	CLAY
.09	99.84	.07	0.00



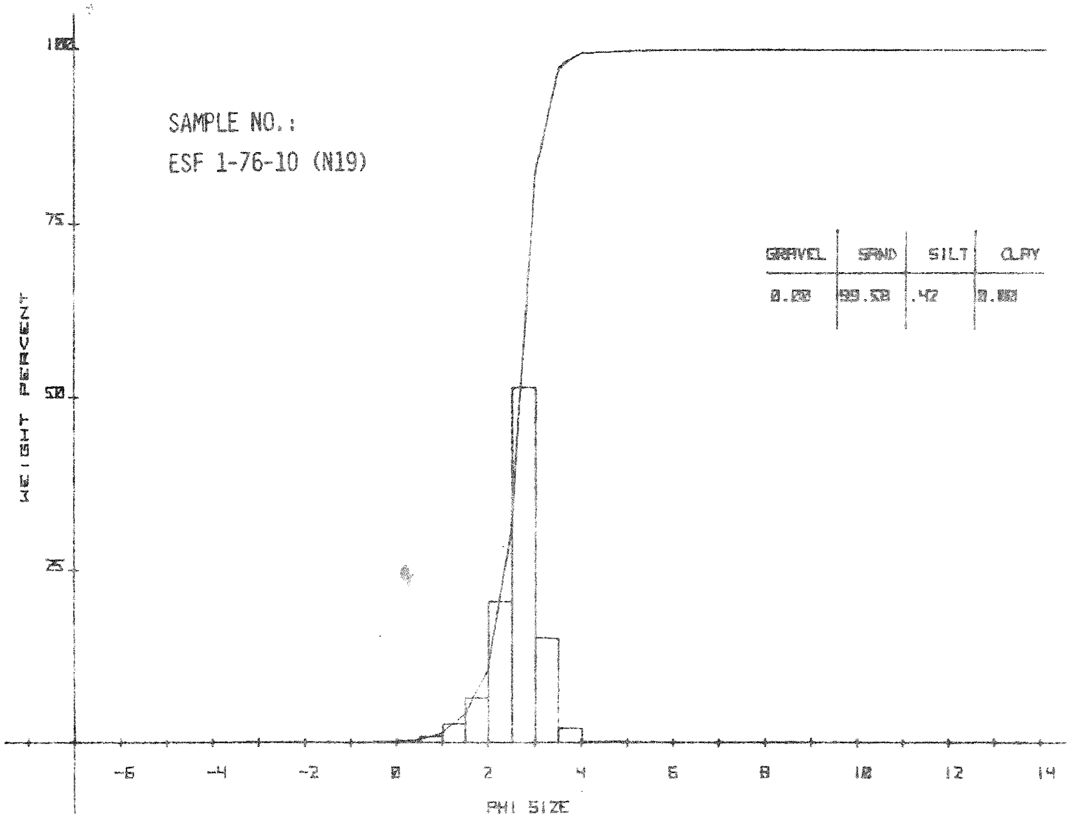
GRAVEL	SAND	SILT	CLAY
0.00	99.86	.14	0.00

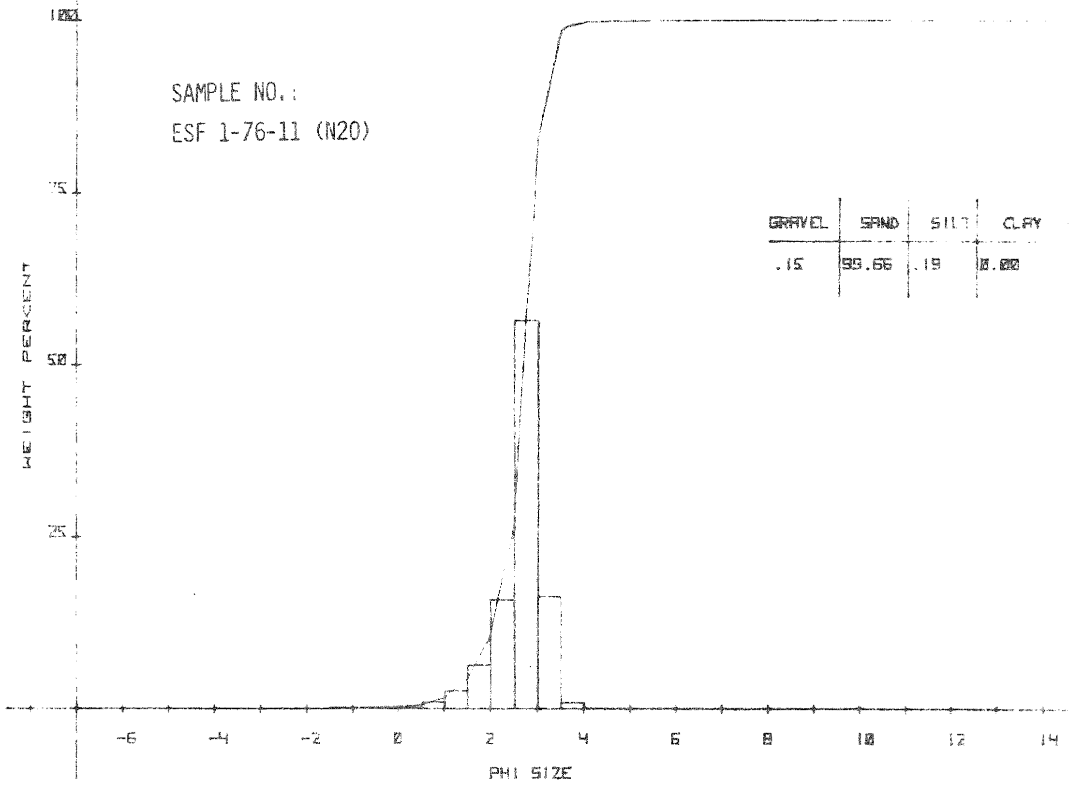


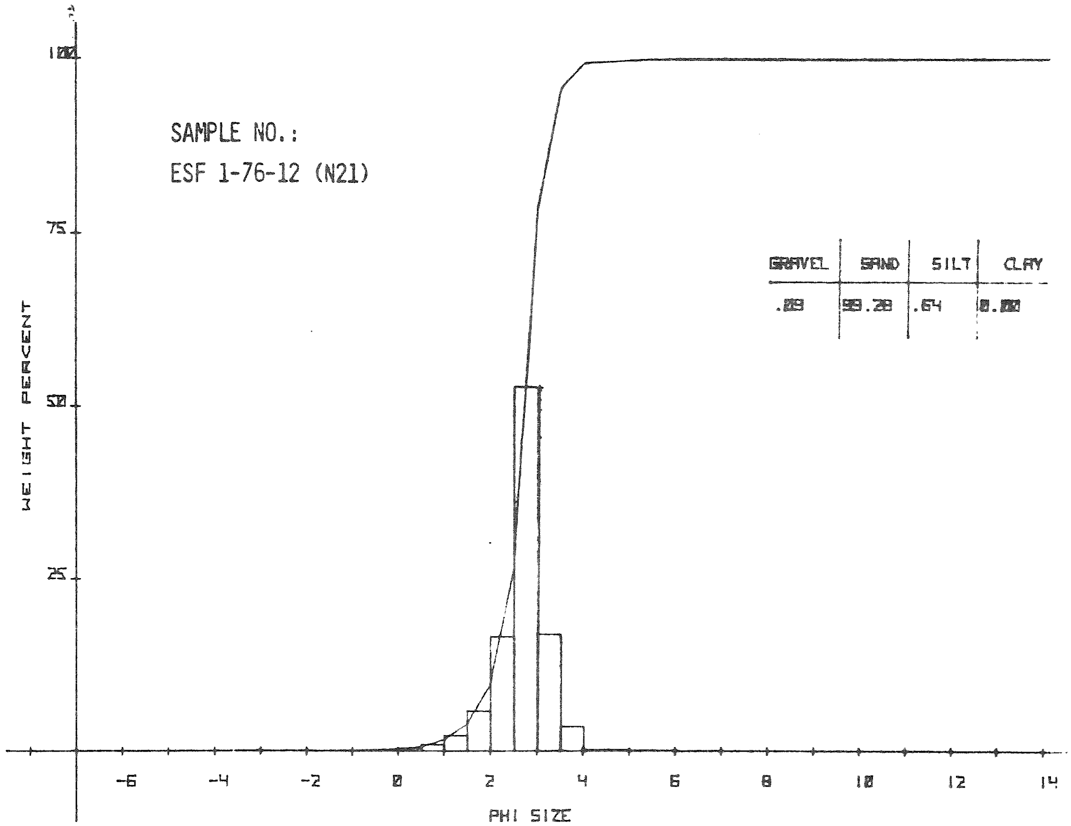
GRAVEL	SAND	SILT	CLAY
13.77	85.32	.91	0.00



GRAVEL	SAND	SILT	CLAY
0.00	99.81	.19	0.00


SAMPLE NO.:
ESF 1-76-10 (N19)
GRAVEL | SAND | SILT | CLAY
0.00 | 99.58 | .42 | 0.00
WEIGHT PERCENT
100
75
50
25
-6
-4
-2
0
2
4
6
8
10
12
14
PHI SIZE

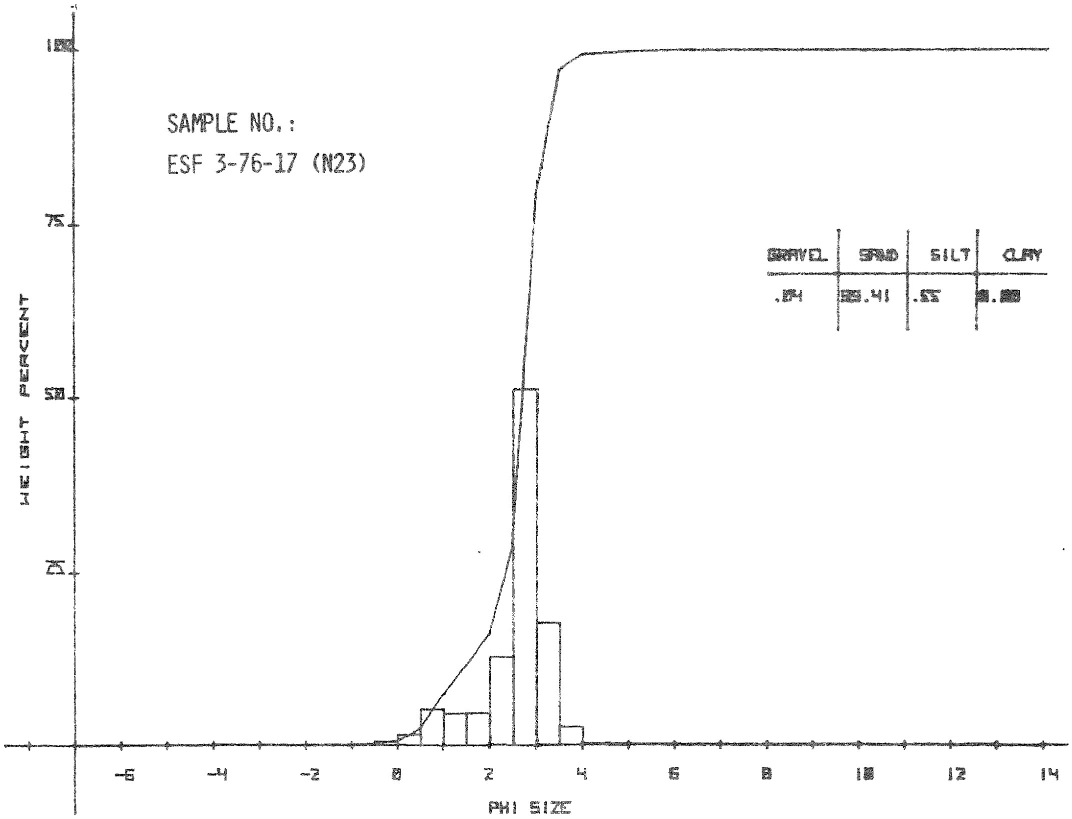

SAMPLE NO.:
ESF 1-76-11 (N20)
GRAVEL | SAND | SILT | CLAY
.15 | 99.66 | .19 | 0.00
WEIGHT PERCENT
100
75
50
25
-6
-4
-2
0
2
4
6
8
10
12
14
PHI SIZE

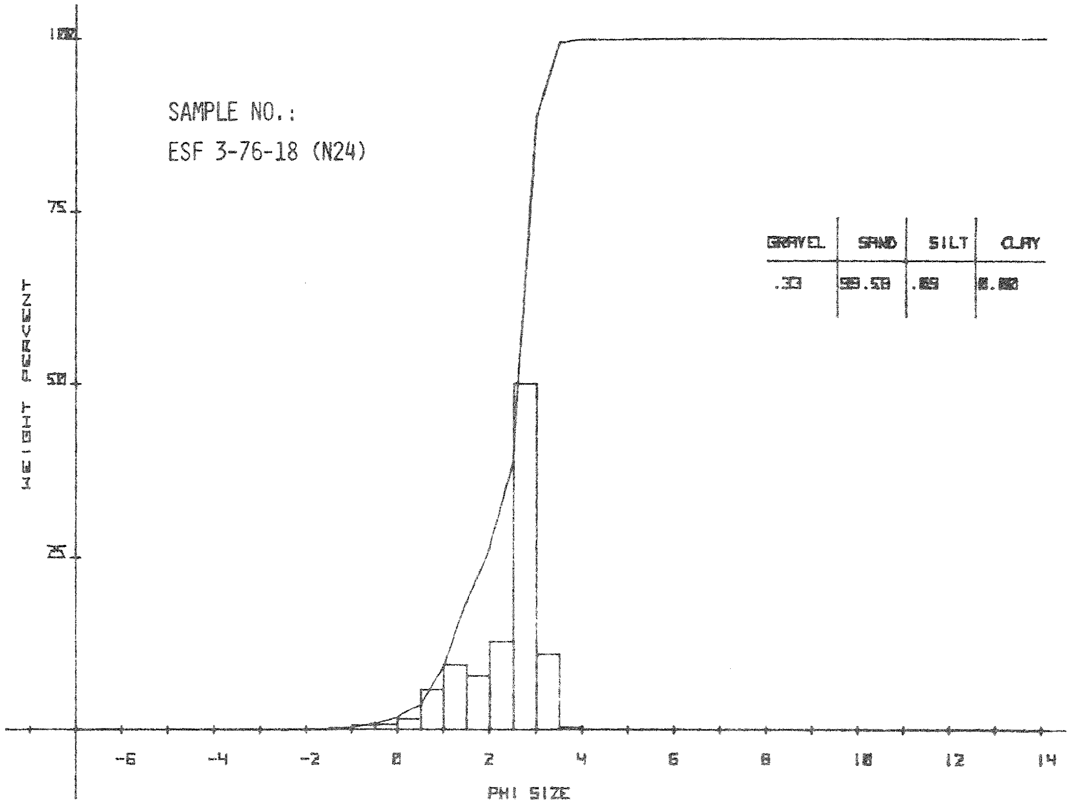


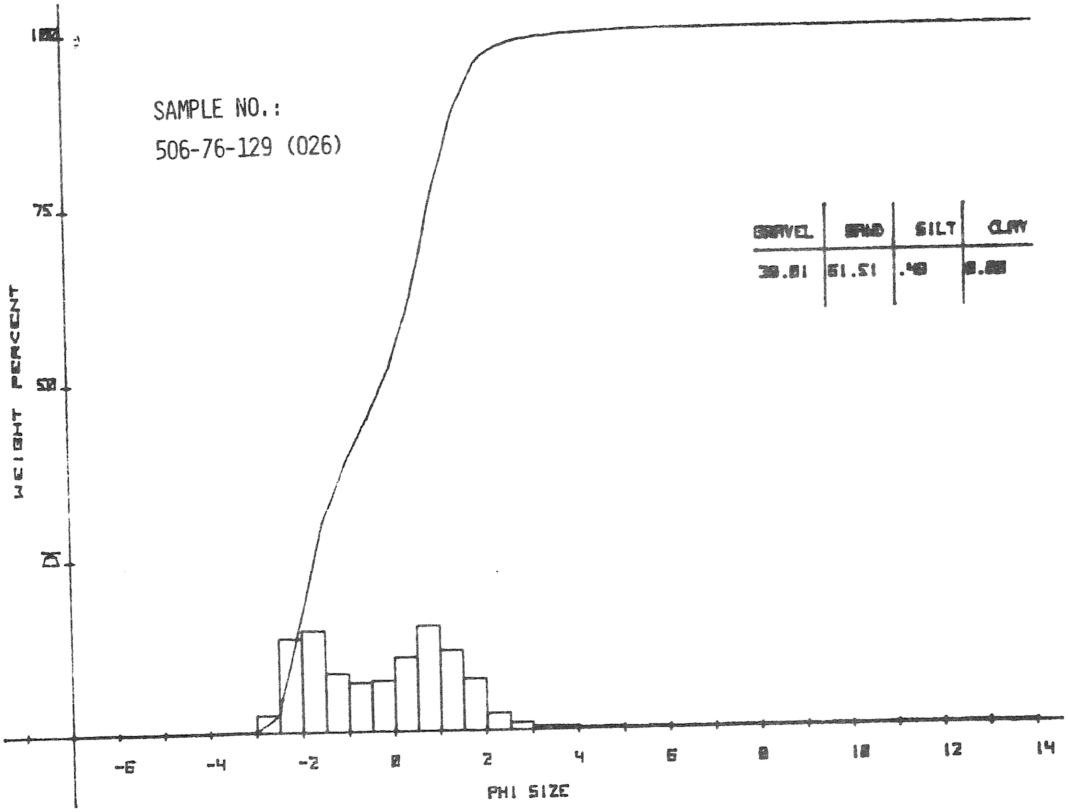
SAMPLE NO.:

ESF 1-76-13 (N22)

6 cm × 8 cm Rounded Granite Cobble

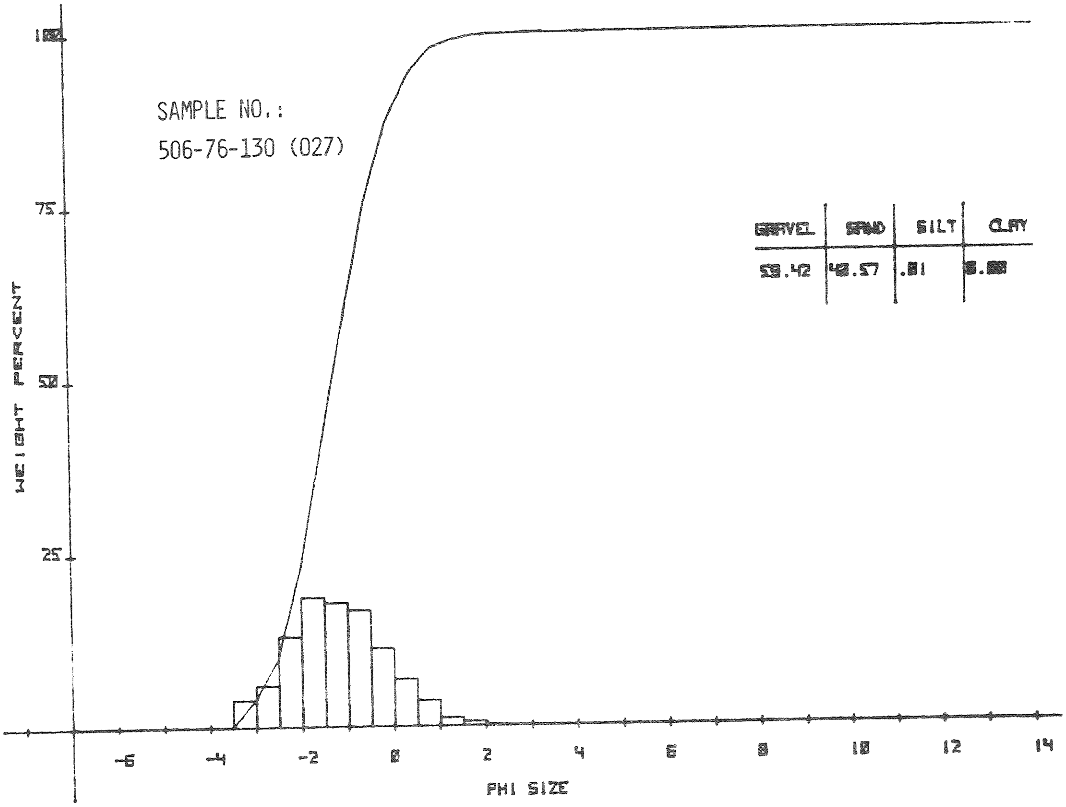

SAMPLE NO.:
ESF 3-76-17 (N23)
GRAVEL | SAND | SILT | CLAY
.04 | 99.41 | .55 | 0.00
WEIGHT PERCENT
100
75
50
25
-6
-4
-2
0
2
4
6
8
10
12
14
PHI SIZE


SAMPLE NO.:
ESF 3-76-18 (N24)
GRAVEL | SAND | SILT | CLAY
.33 | 99.58 | .09 | 0.00
WEIGHT PERCENT
100
75
50
25
-6
-4
-2
0
2
4
6
8
10
12
14
PHI SIZE



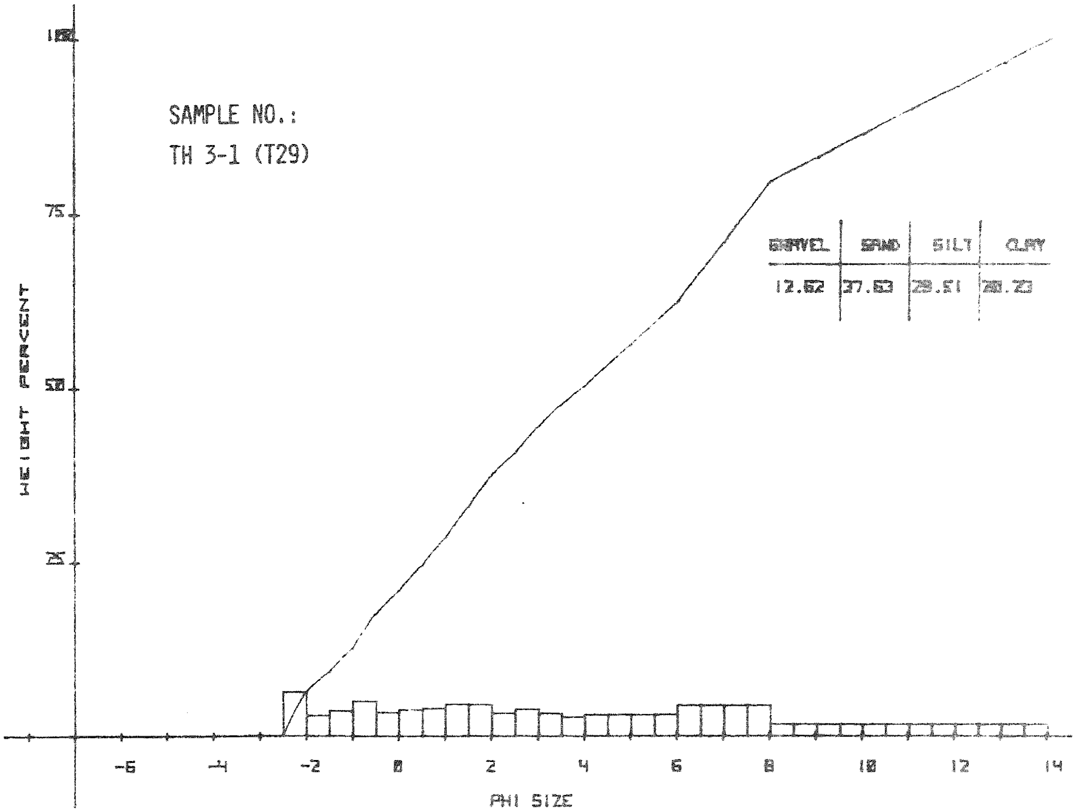
SAMPLE NO.:
506-76-129 (026)

GRAVEL	SAND	SILT	CLAY
38.01	61.51	.48	0.00

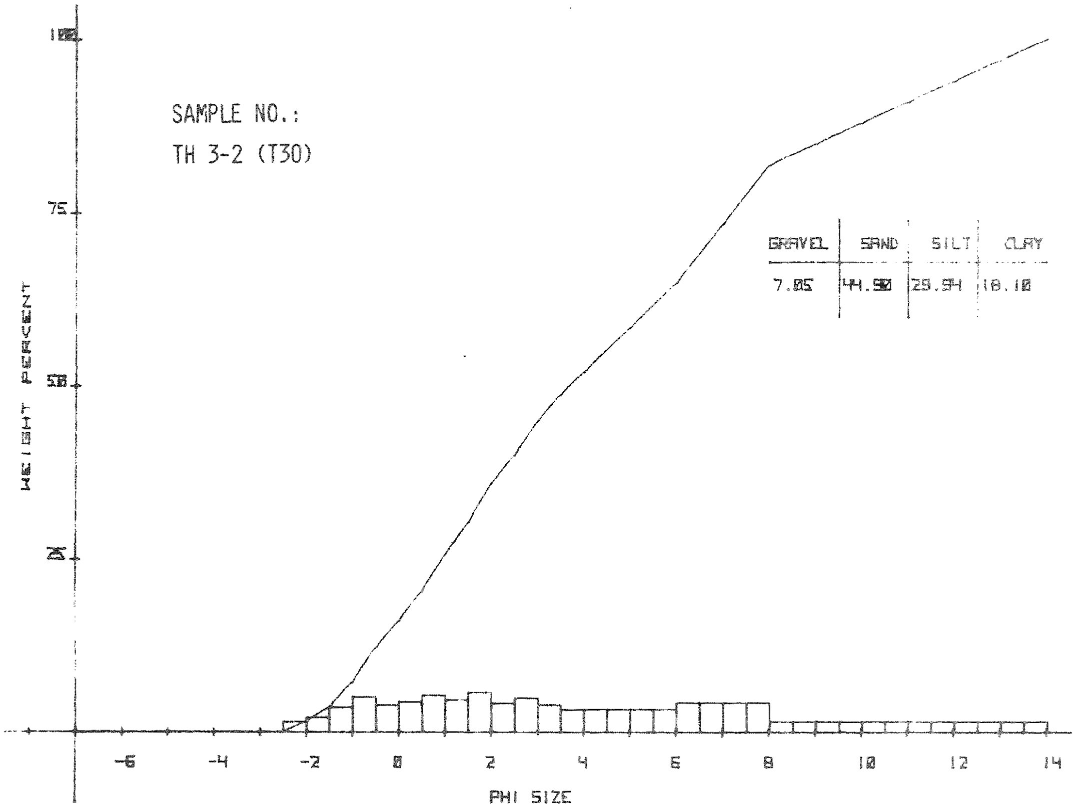


SAMPLE NO.:
506-76-130 (027)

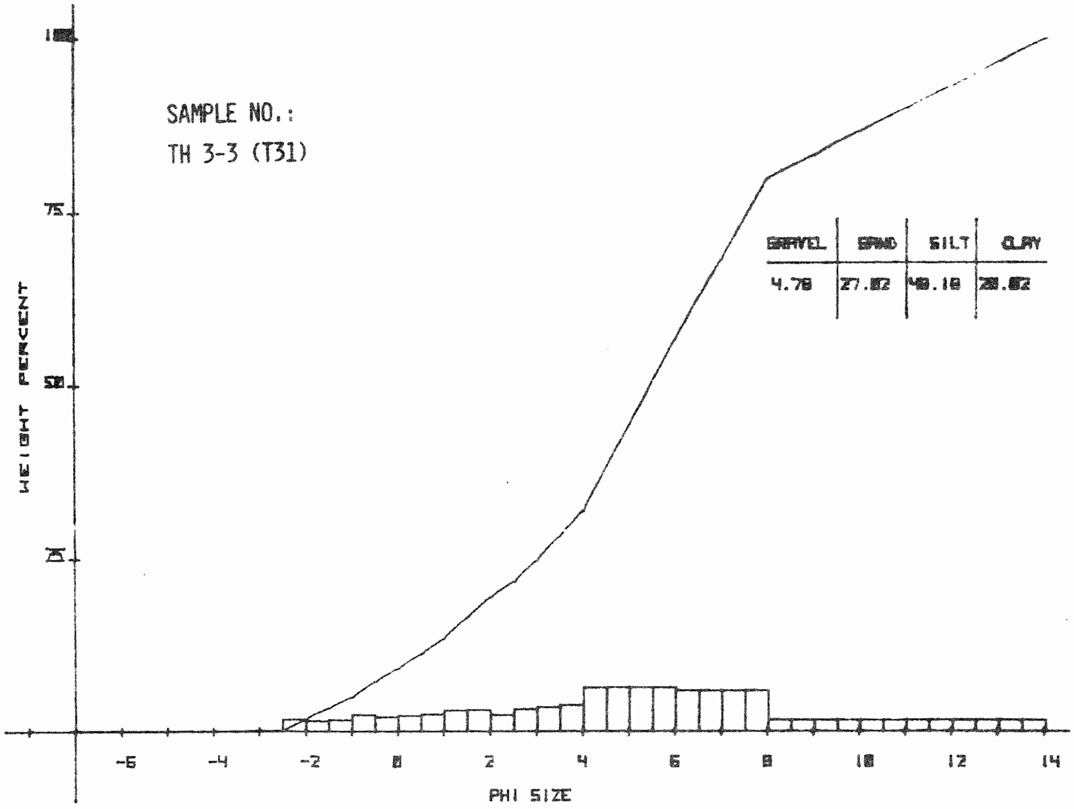
GRAVEL	SAND	SILT	CLAY
59.42	40.57	.01	0.00



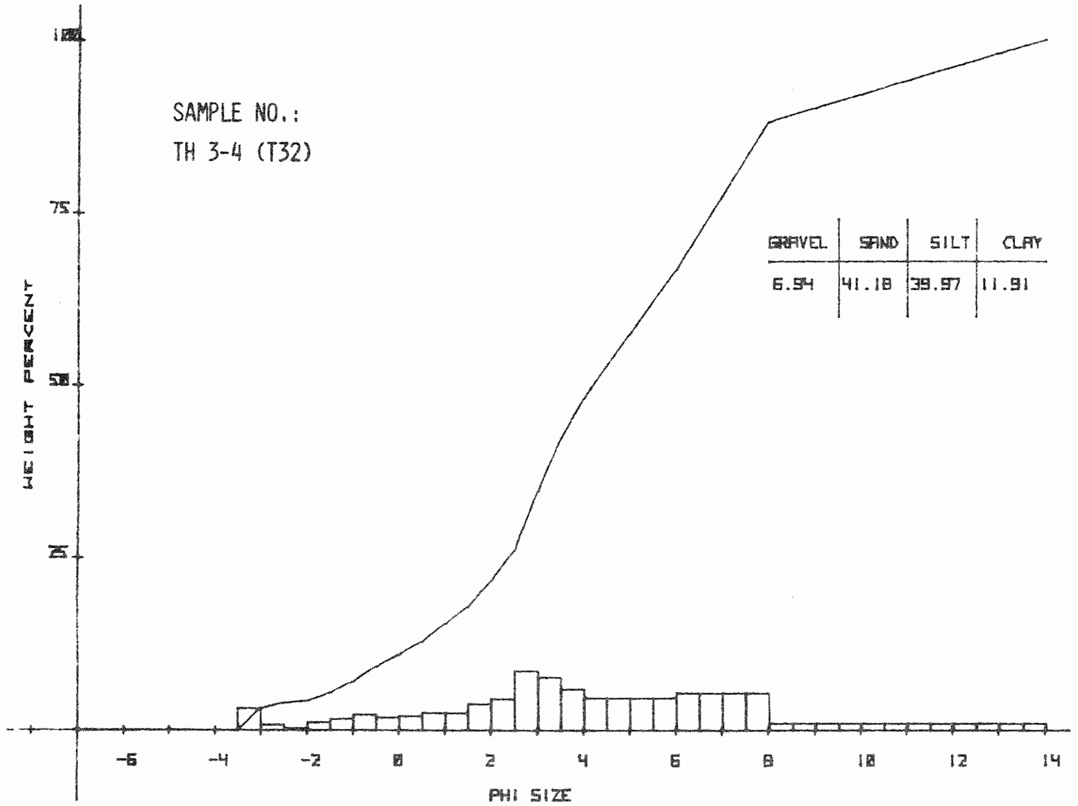
GRAVEL	SAND	SILT	CLAY
12.62	37.63	29.51	20.23



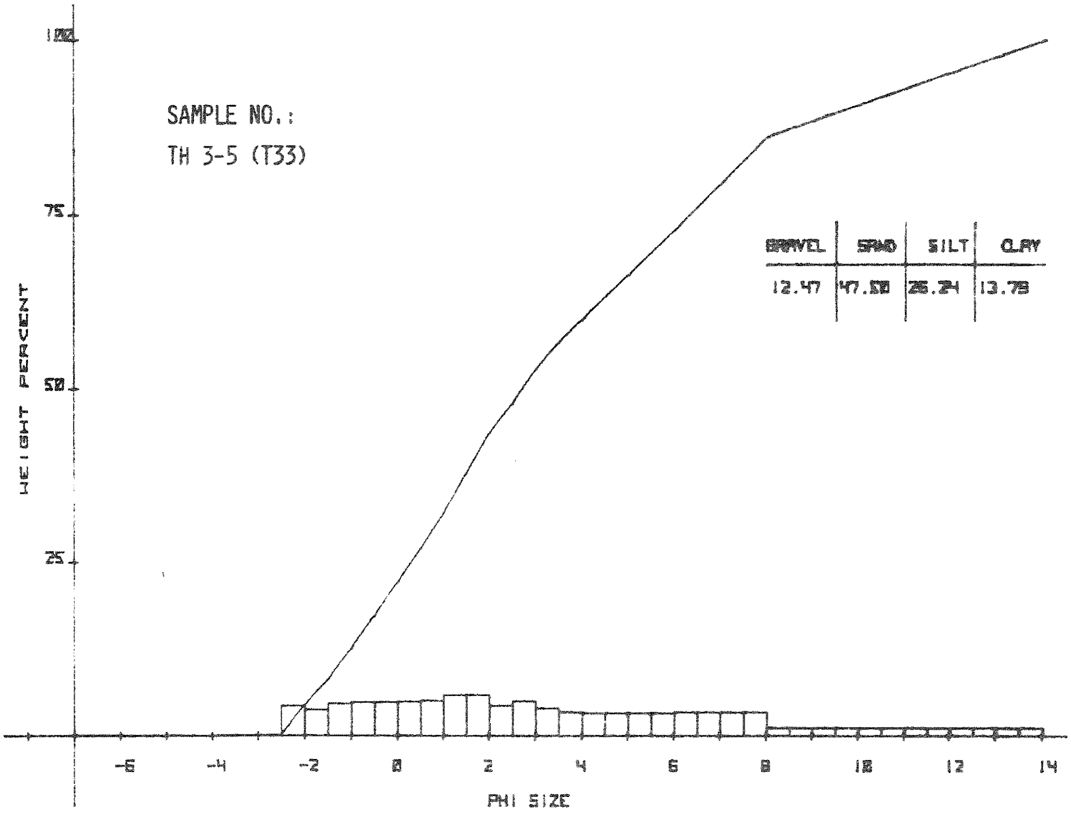
GRAVEL	SAND	SILT	CLAY
7.05	44.90	29.94	18.10

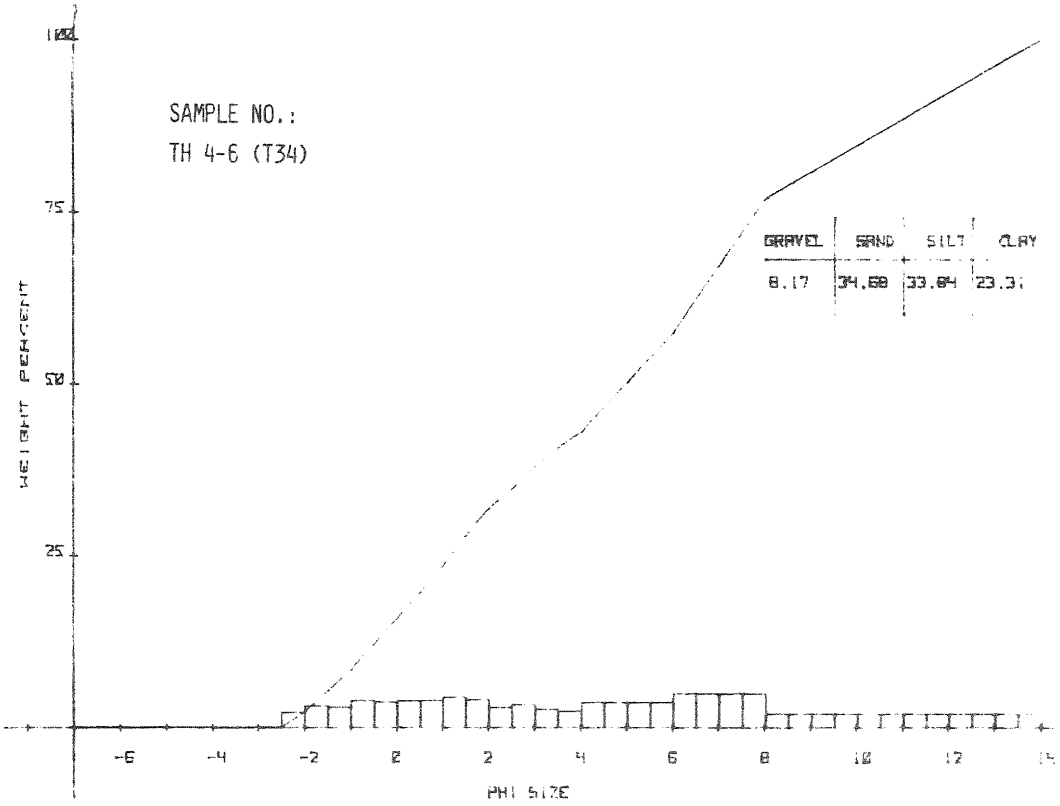


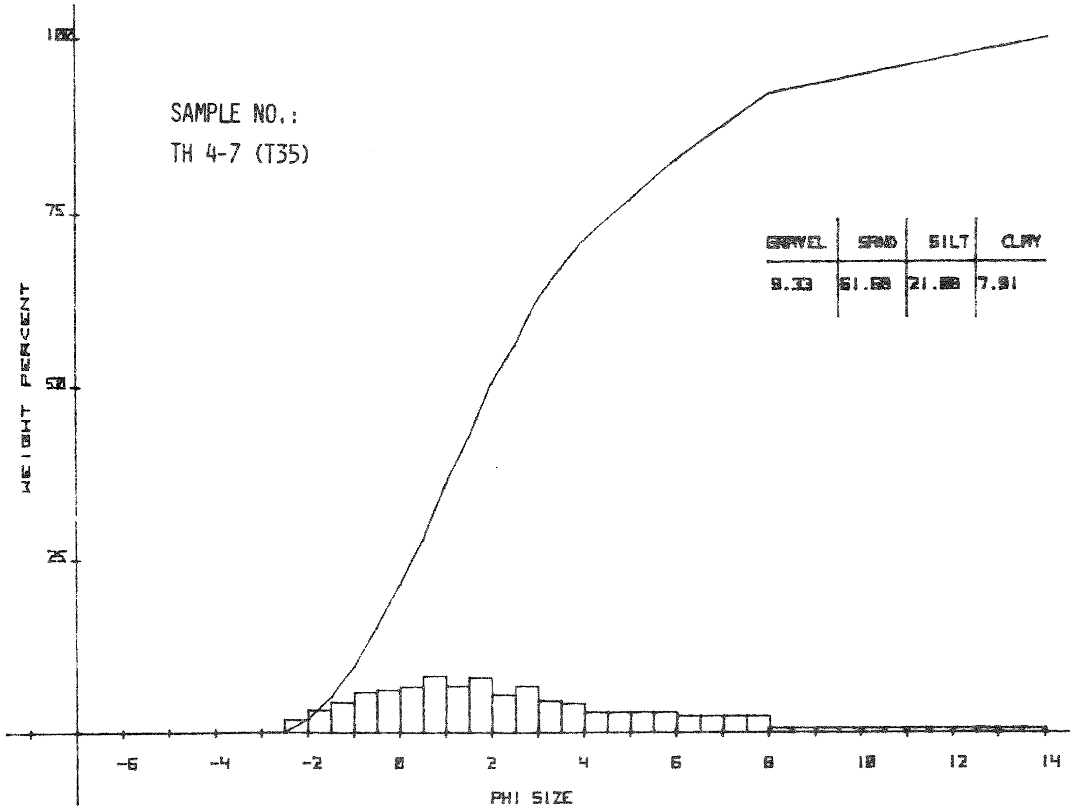
GRAVEL	SAND	SILT	CLAY
4.78	27.02	40.18	28.02

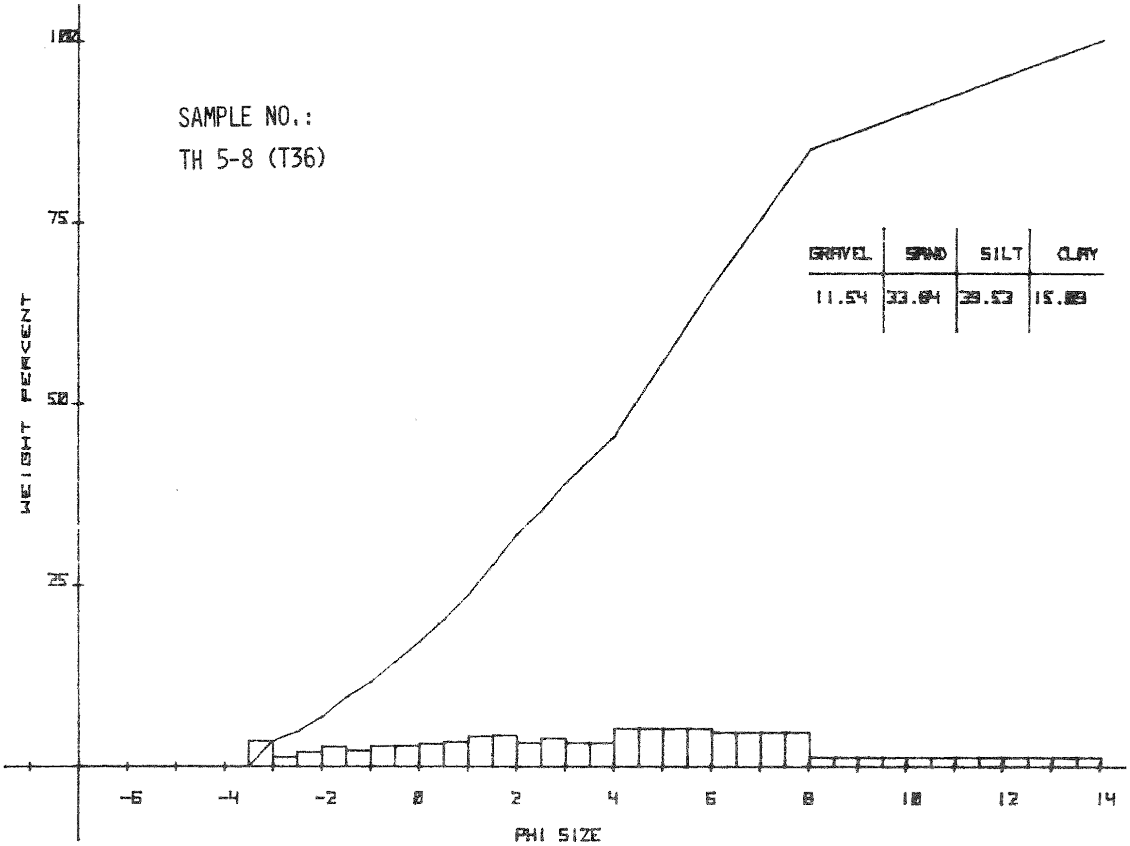


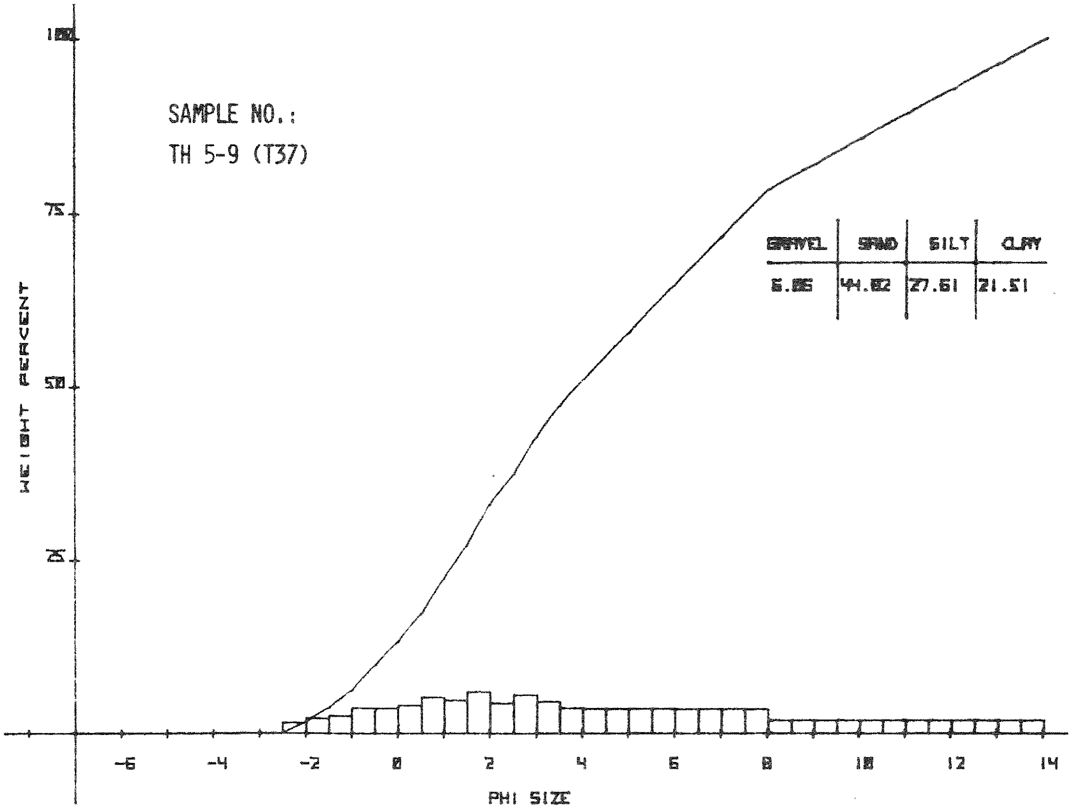
GRAVEL	SAND	SILT	CLAY
6.94	41.18	39.97	11.91


SAMPLE NO.:
TH 3-5 (T33)
GRAVEL
SAND
SILT
CLAY
12.47
47.50
26.24
13.79
WEIGHT PERCENT
100
75
50
25
PHI SIZE
-6
-4
-2
0
2
4
6
8
10
12
14


SAMPLE NO.:
TH 4-6 (T34)
GRAVEL
SAND
SILT
CLAY
8.17
34.68
33.84
23.31
WEIGHT PERCENT
100
75
50
25
PHI SIZE
-6
-4
-2
0
2
4
6
8
10
12
14

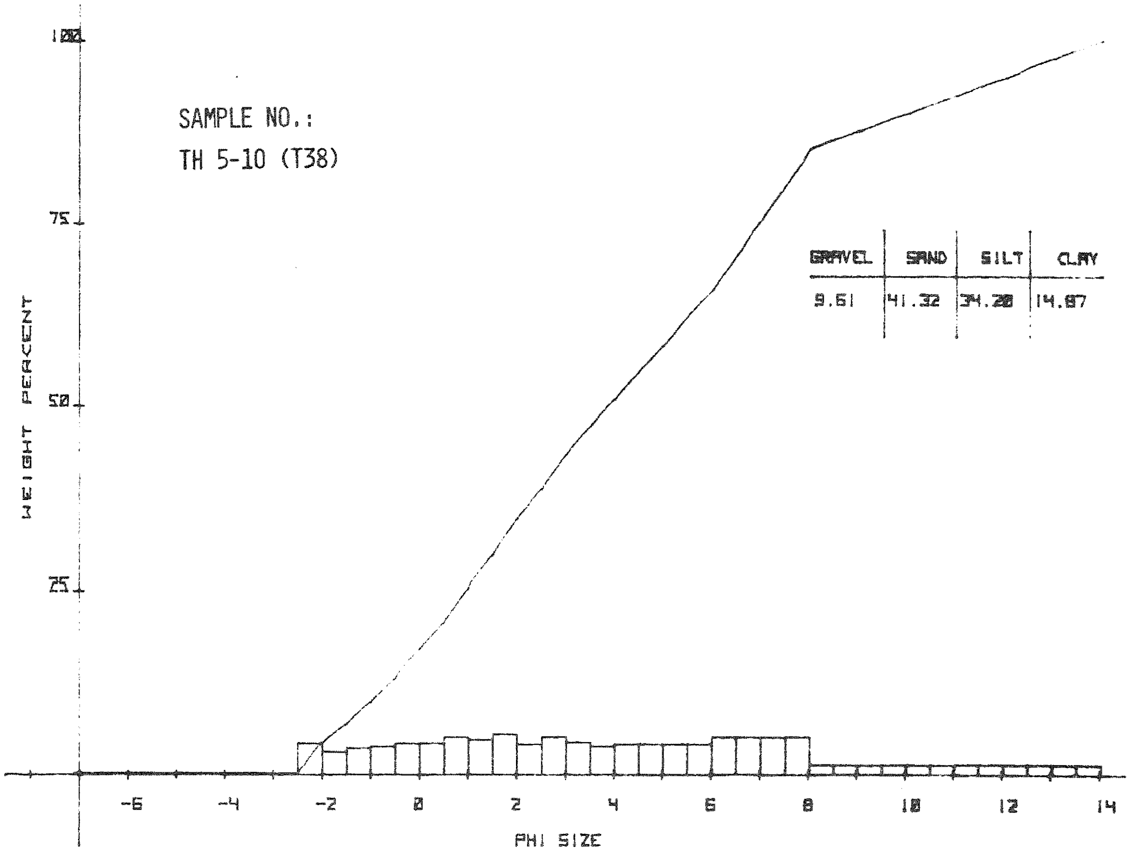

SAMPLE NO.:
TH 4-7 (T35)
100
75
50
25
WEIGHT PERCENT
GRAVEL
SAND
SILT
CLAY
9.33
61.68
21.08
7.91
-6
-4
-2
0
2
4
6
8
10
12
14
PHI SIZE


SAMPLE NO.:
TH 5-8 (T36)
100
75
50
25
WEIGHT PERCENT
GRAVEL
SAND
SILT
CLAY
11.54
33.84
39.53
15.09
-6
-4
-2
0
2
4
6
8
10
12
14
PHI SIZE



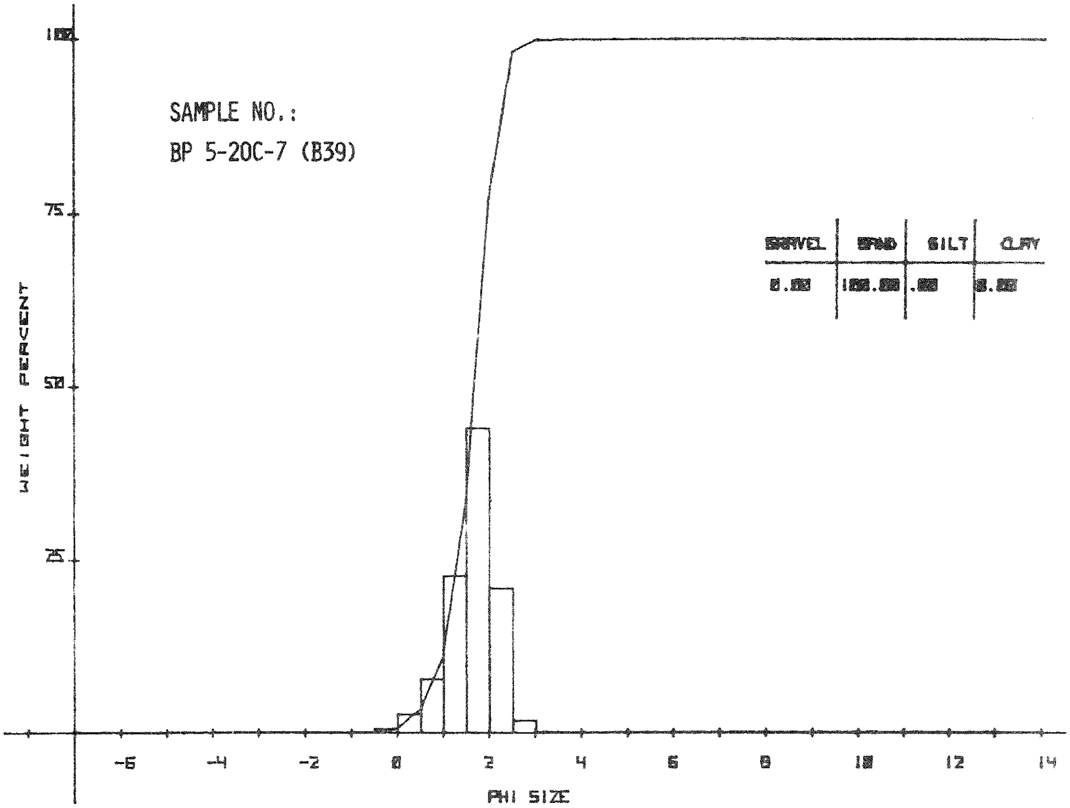
SAMPLE NO.:
TH 5-9 (T37)

GRAVEL	SAND	SILT	CLAY
6.06	44.82	27.61	21.51



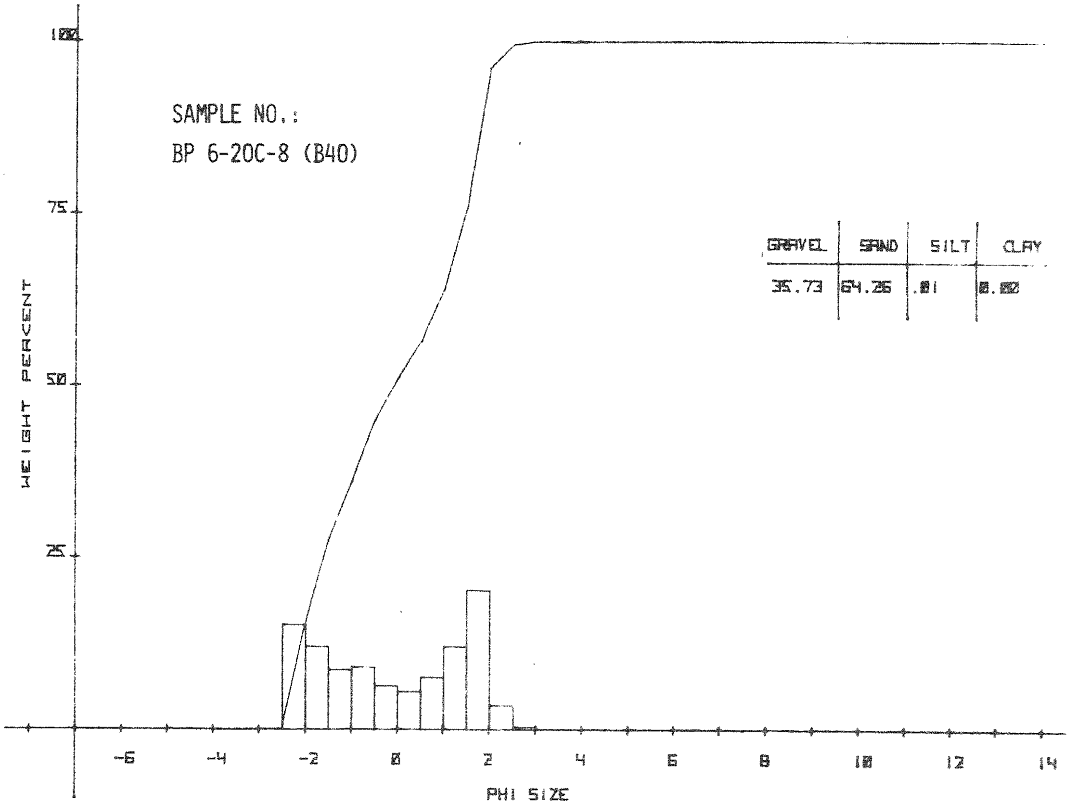
SAMPLE NO.:
TH 5-10 (T38)

GRAVEL	SAND	SILT	CLAY
9.61	41.32	34.20	14.87



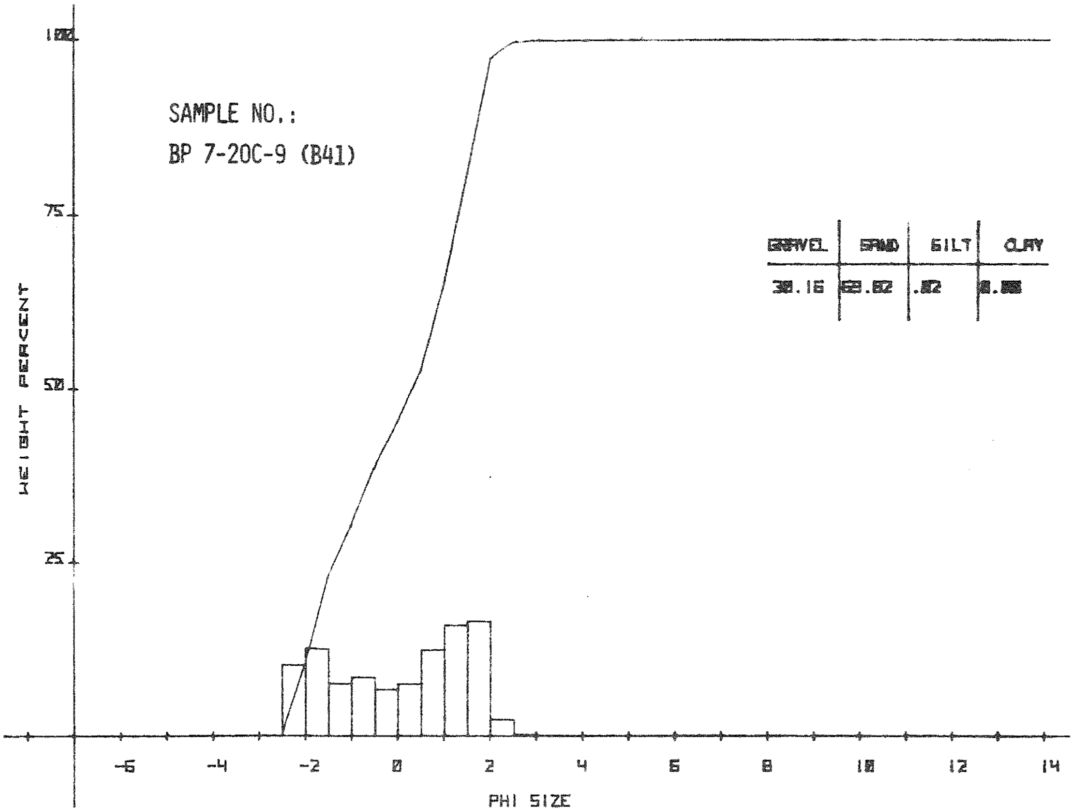
SAMPLE NO.:
BP 5-20C-7 (B39)

GRAVEL	SAND	SILT	CLAY
0.00	100.00	.00	0.00

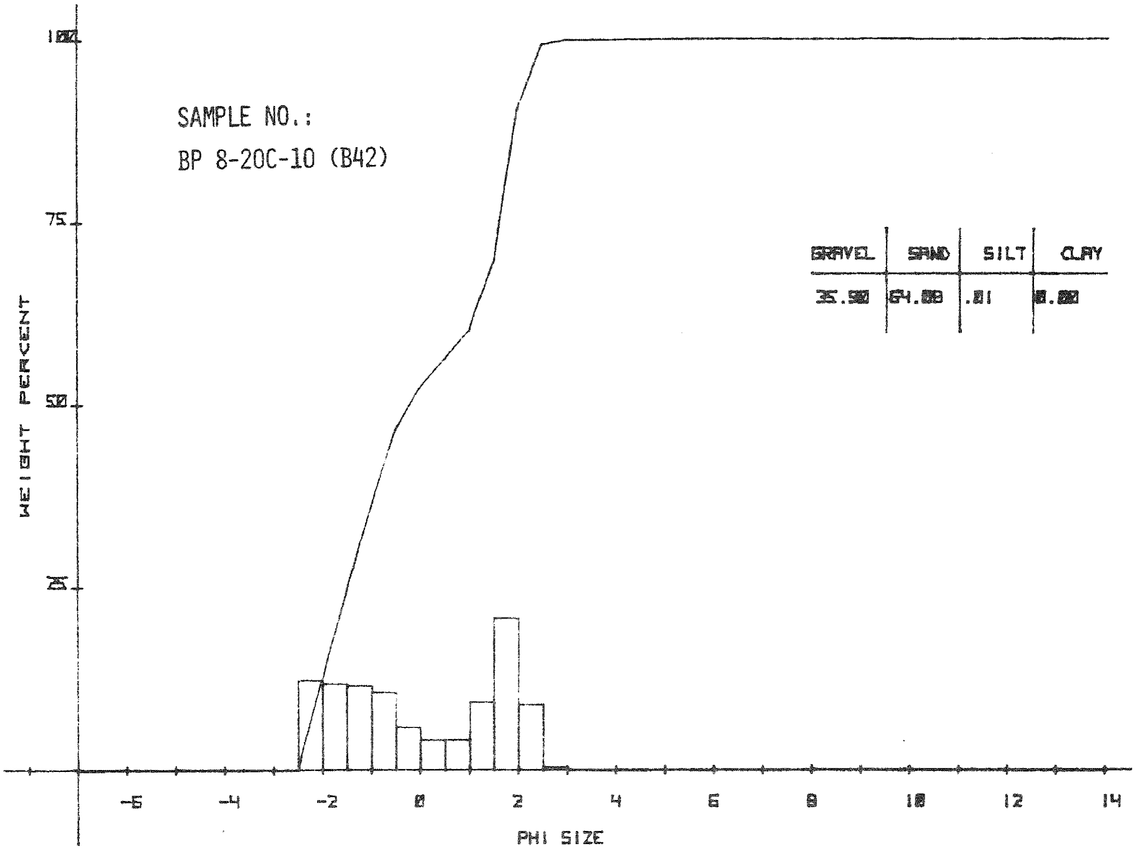


SAMPLE NO.:
BP 6-20C-8 (B40)

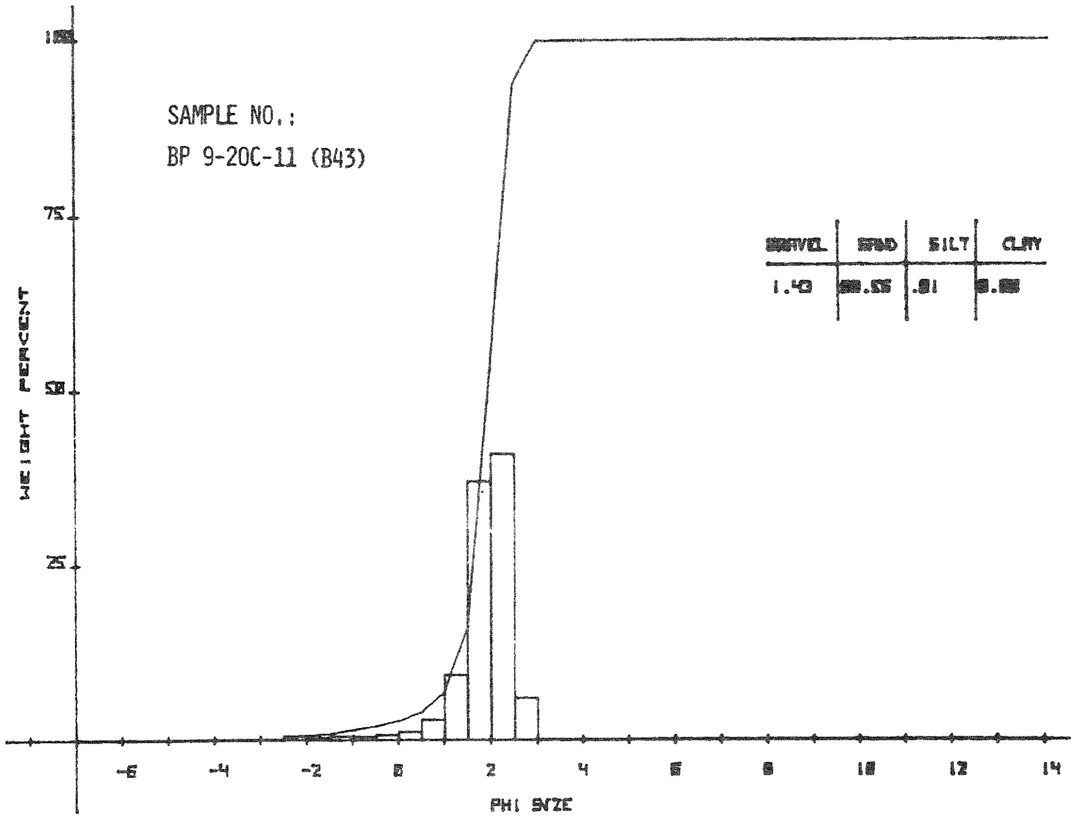
GRAVEL	SAND	SILT	CLAY
35.73	64.26	.01	0.00



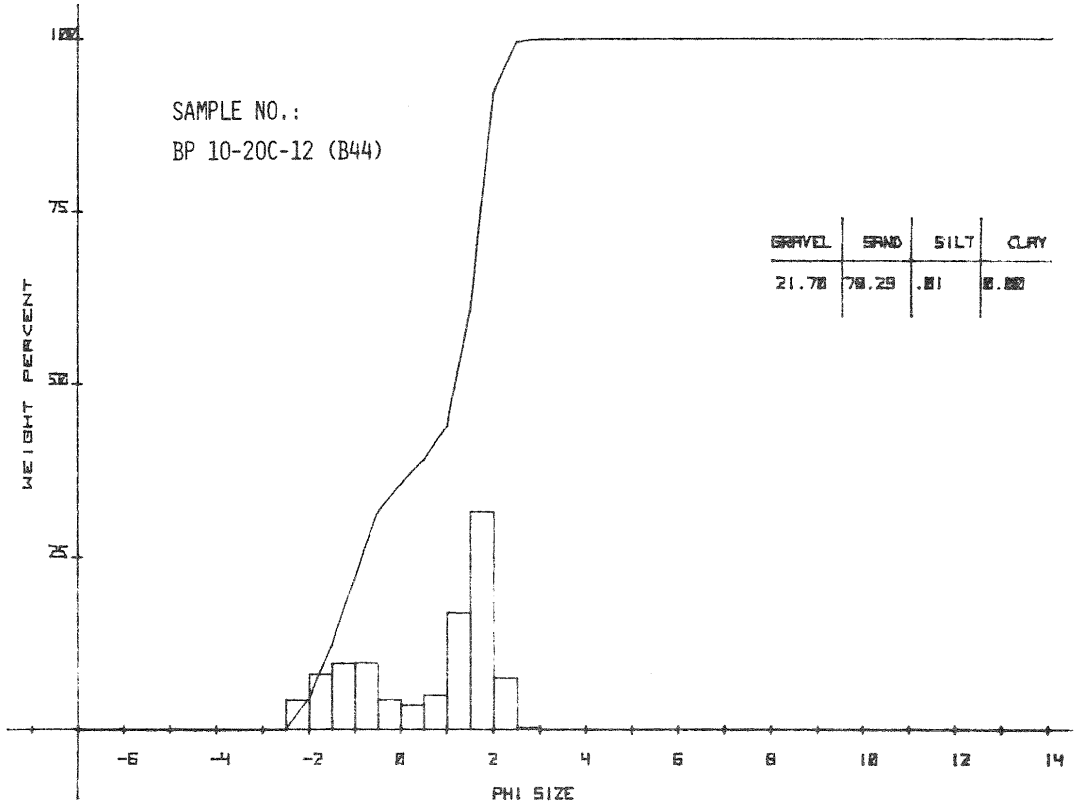
GRAVEL	SAND	SILT	CLAY
30.16	69.82	.02	0.00



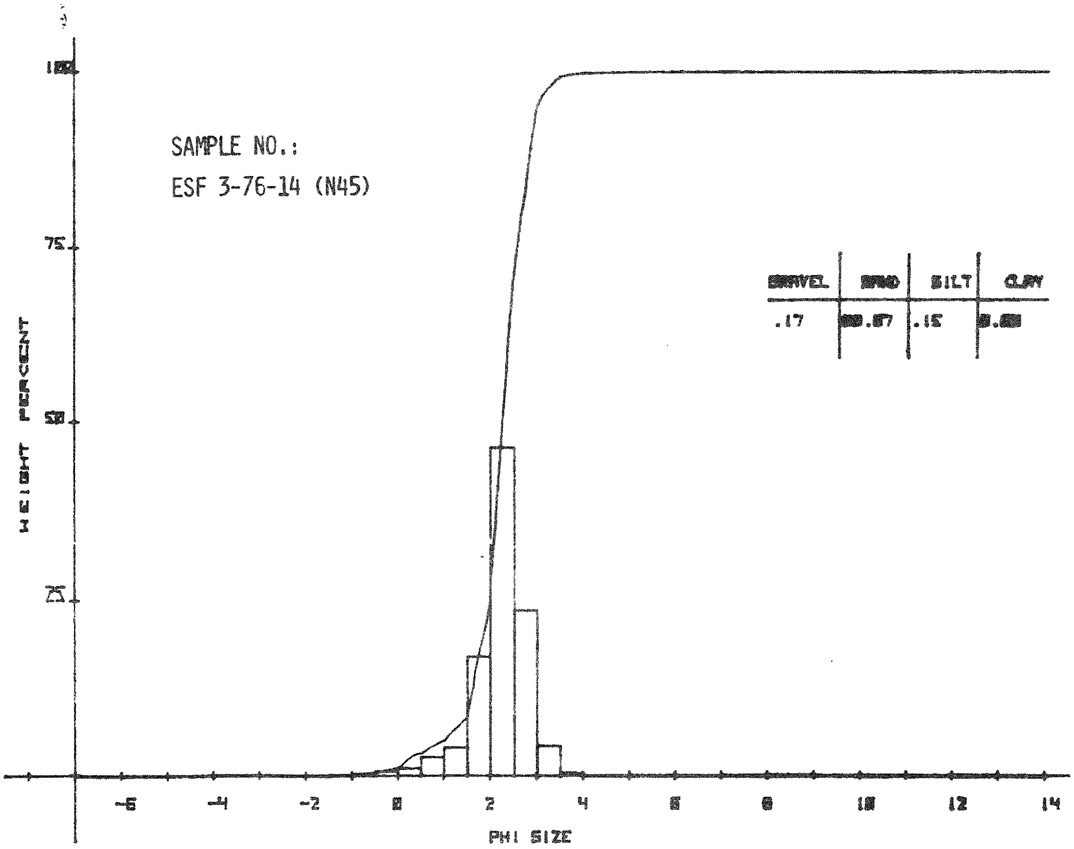
GRAVEL	SAND	SILT	CLAY
35.90	64.08	.01	0.00

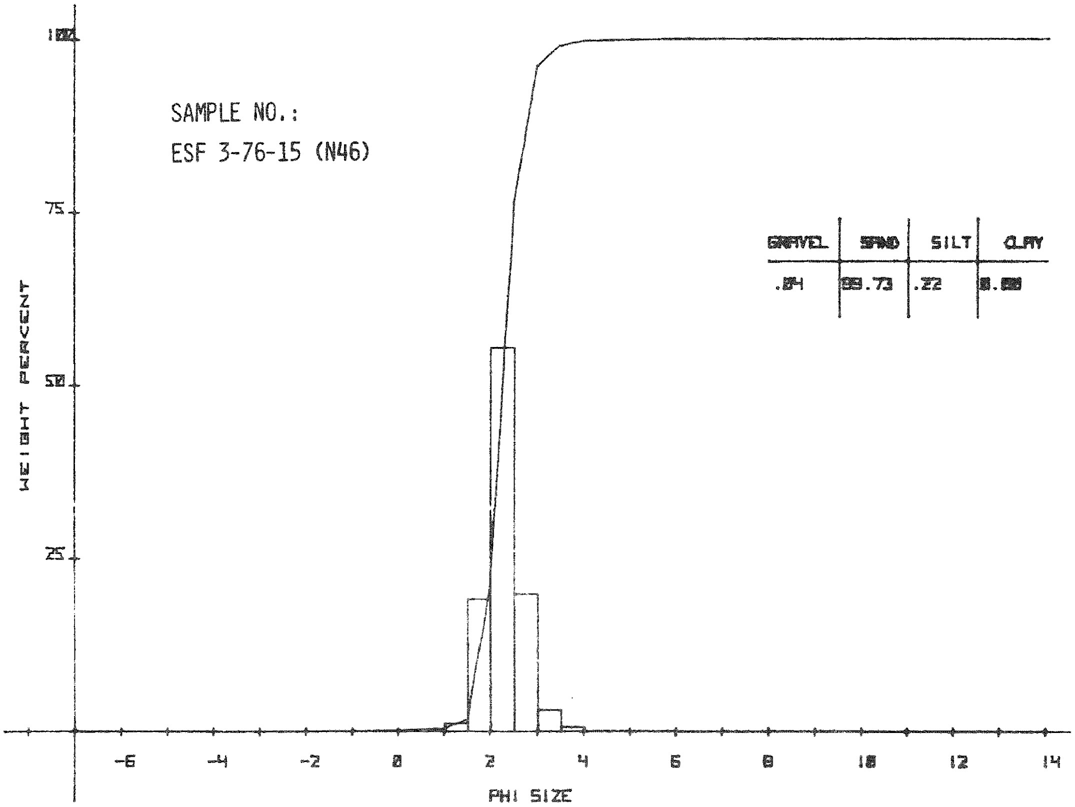


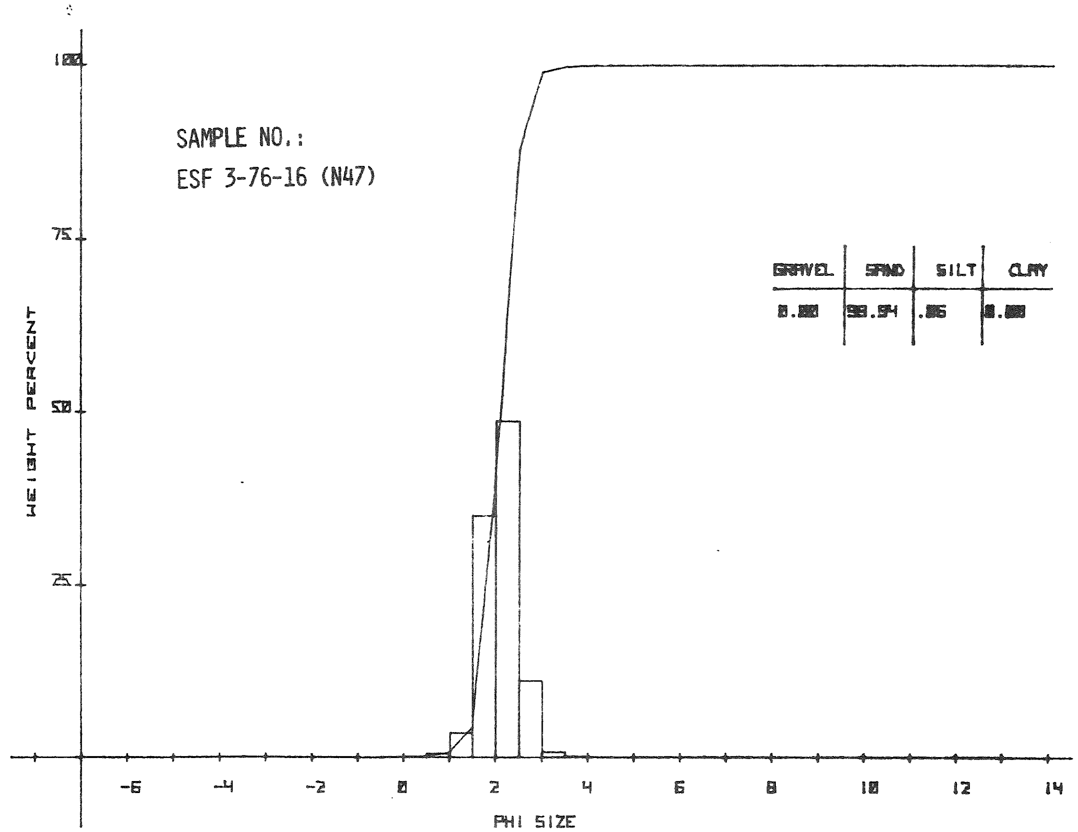
GRAVEL	SAND	SILT	CLAY
1.43	98.55	.01	0.00



GRAVEL	SAND	SILT	CLAY
21.70	78.29	.01	0.00

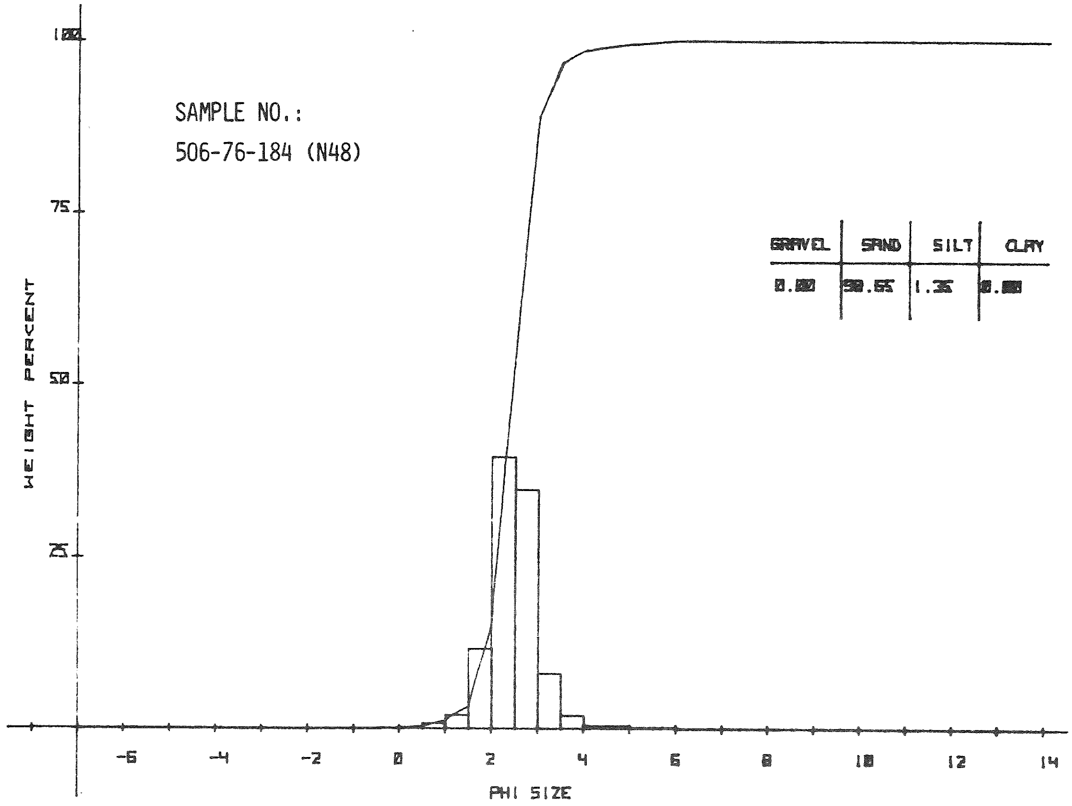

SAMPLE NO.:
ESF 3-76-14 (N45)
GRAVEL
SAND
SILT
CLAY
.17
99.67
.15
0.00
100
75
50
25
WEIGHT PERCENT
-6
-4
-2
0
2
4
6
8
10
12
14
PHI SIZE


SAMPLE NO.:
ESF 3-76-15 (N46)
GRAVEL
SAND
SILT
CLAY
.04
99.73
.22
0.00
100
75
50
25
WEIGHT PERCENT
-6
-4
-2
0
2
4
6
8
10
12
14
PHI SIZE



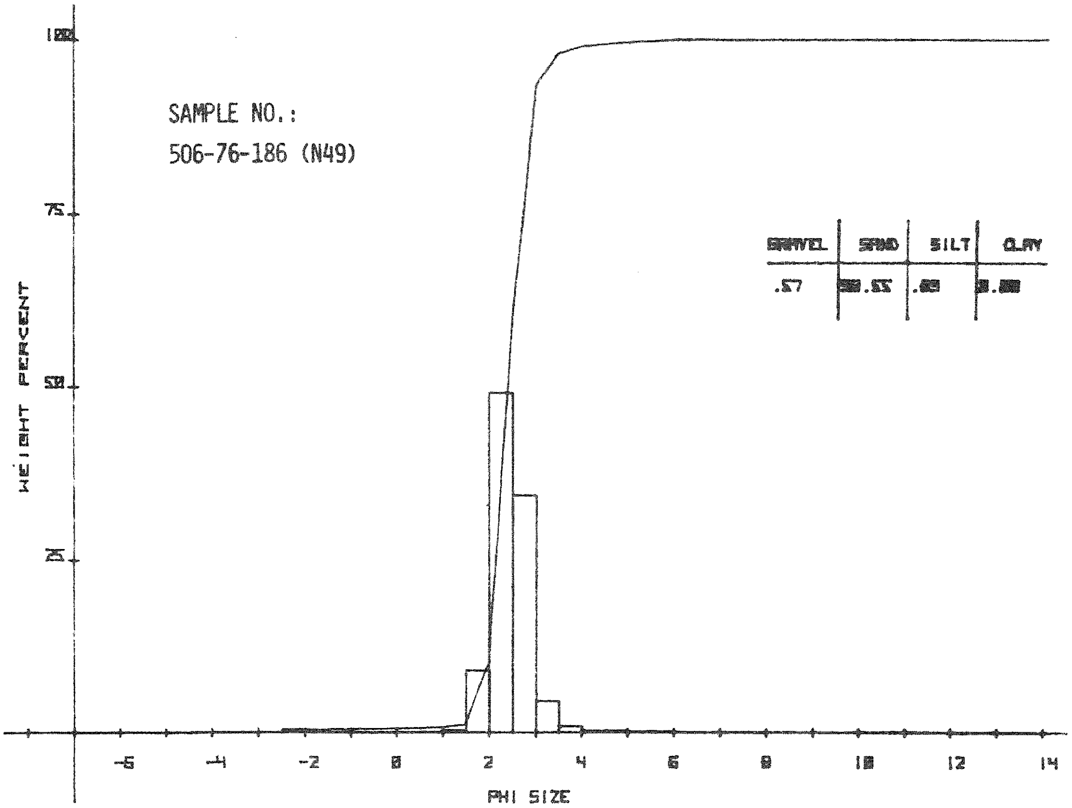
SAMPLE NO.:
ESF 3-76-16 (N47)

GRAVEL	SAND	SILT	CLAY
0.00	99.94	.06	0.00

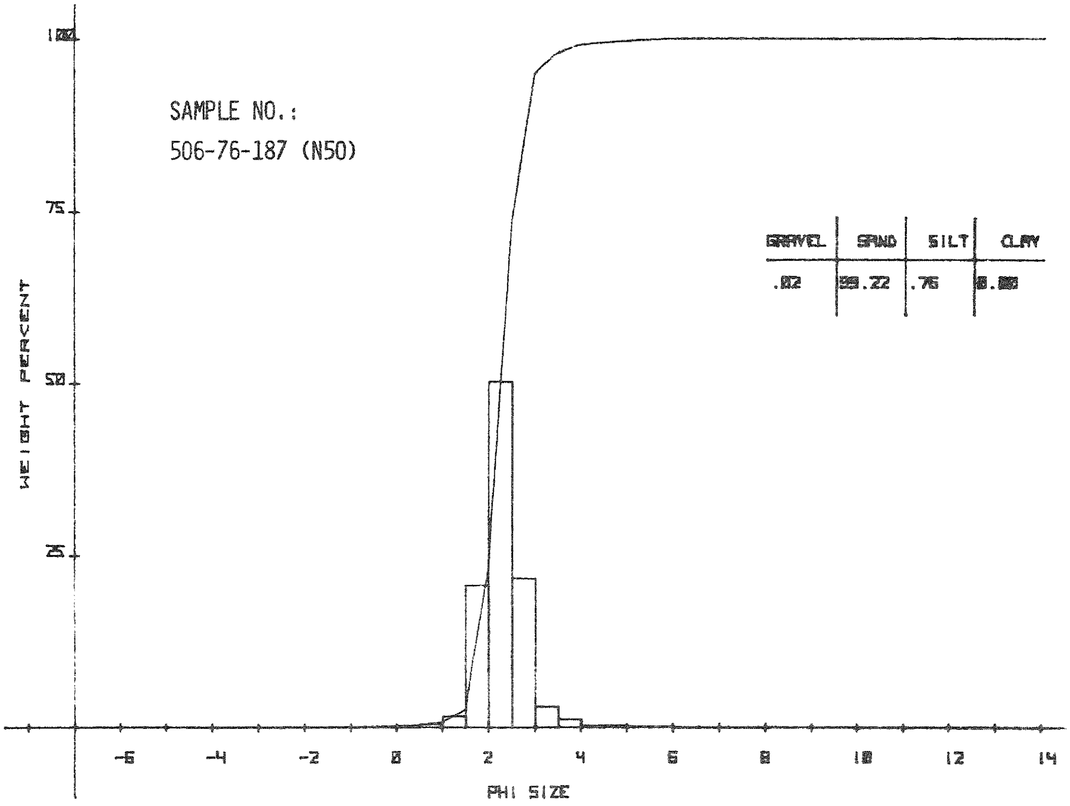


SAMPLE NO.:
506-76-184 (N48)

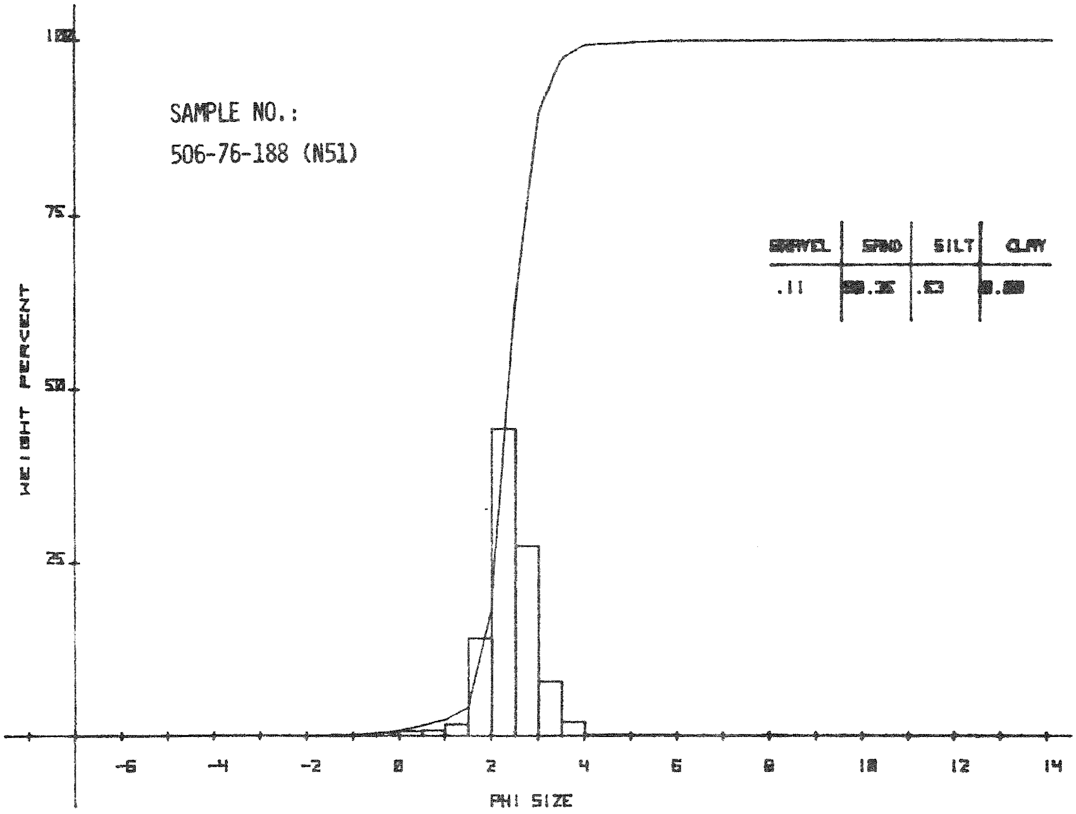
GRAVEL	SAND	SILT	CLAY
0.00	98.65	1.35	0.00

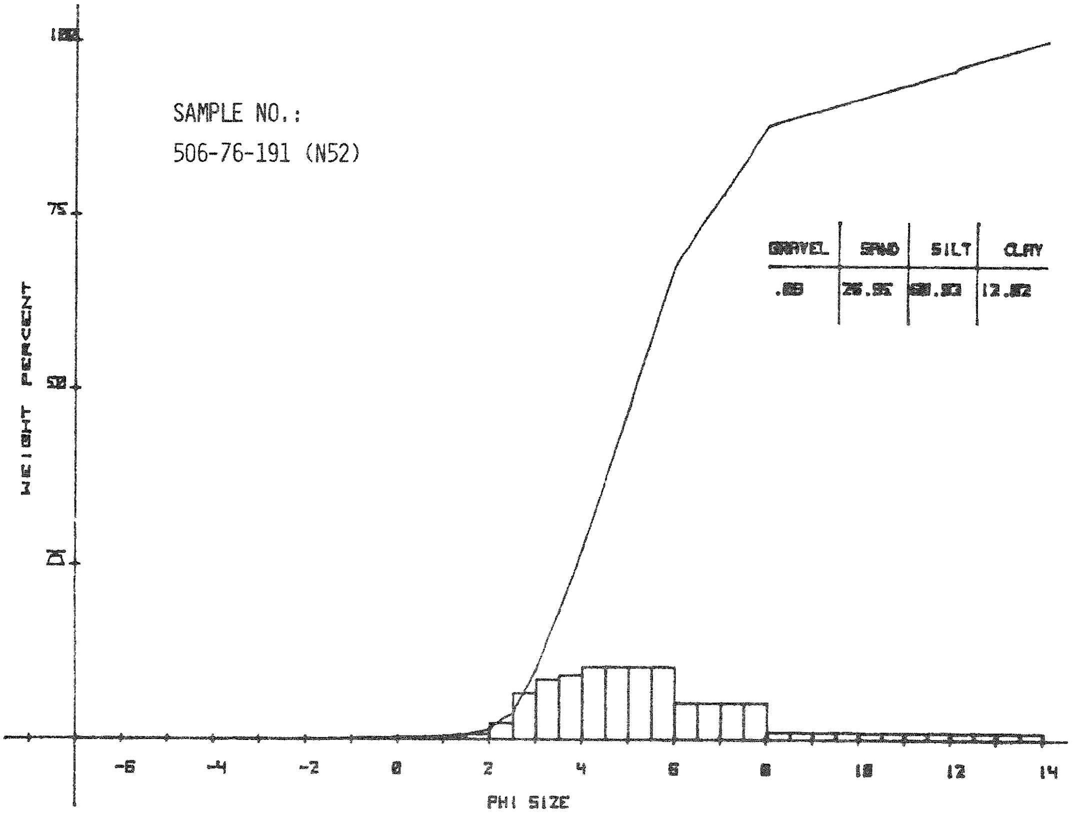


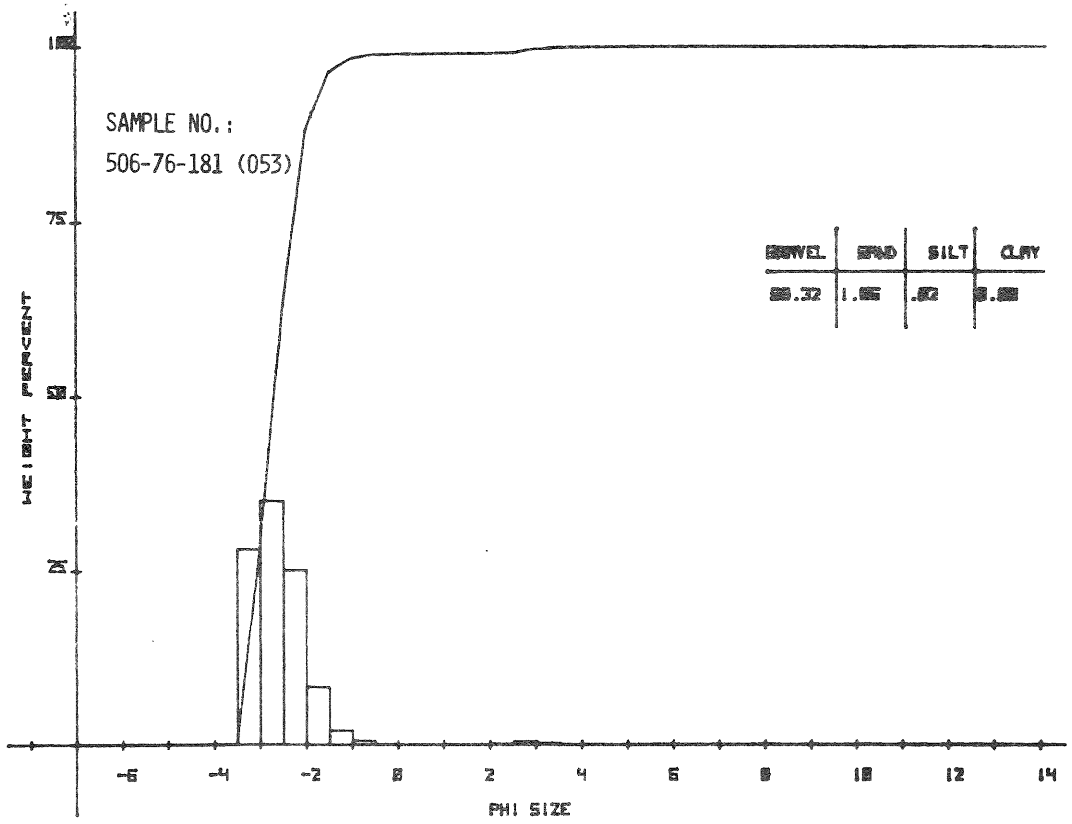
GRAVEL	SAND	SILT	CLAY
.57	98.55	.88	0.00

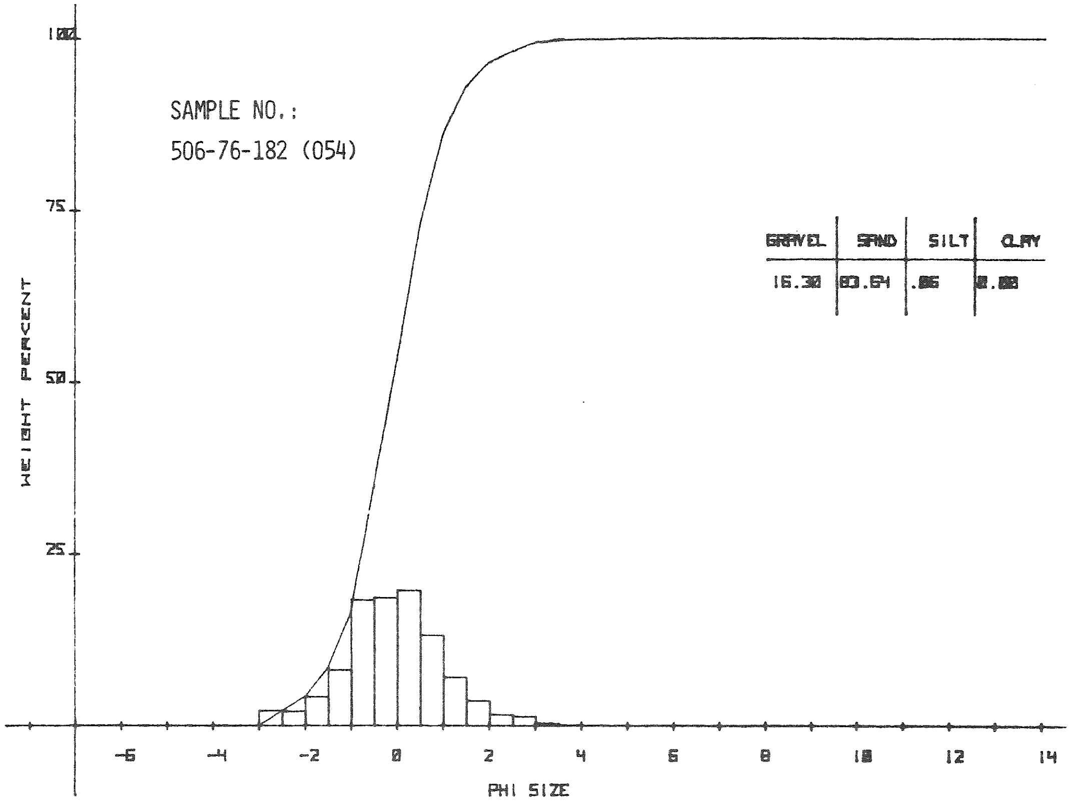


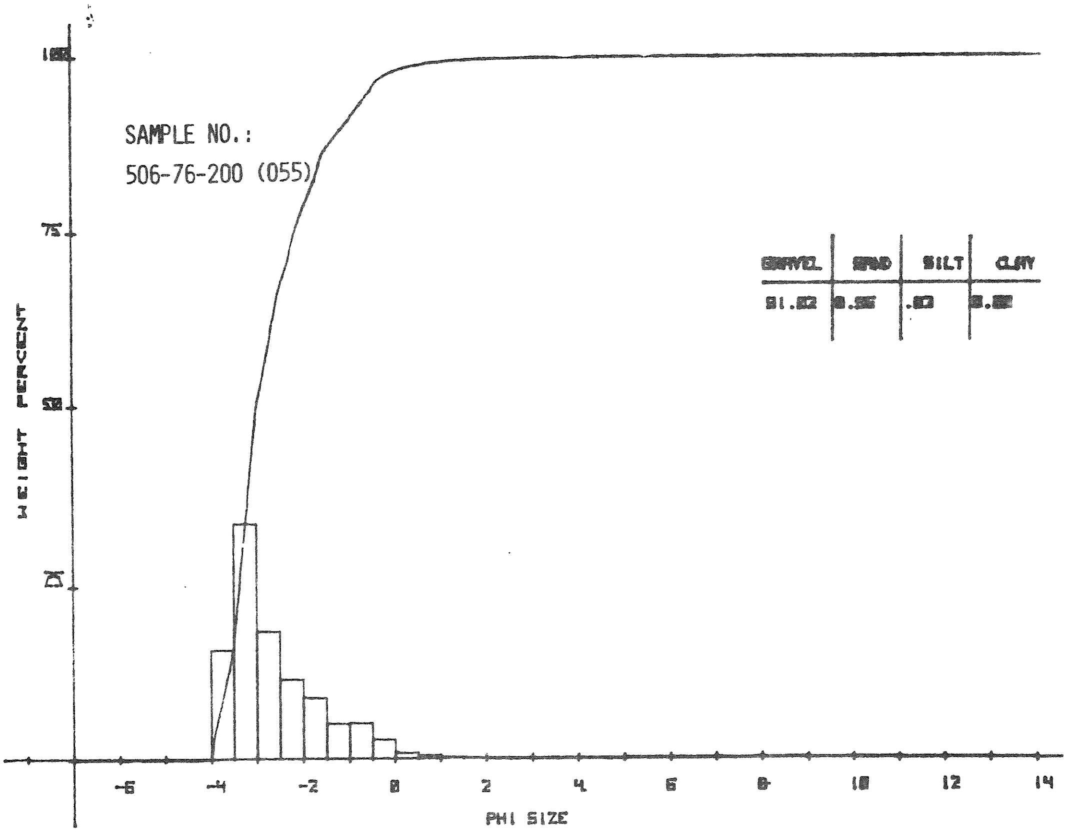
GRAVEL	SAND	SILT	CLAY
.02	99.22	.76	0.00

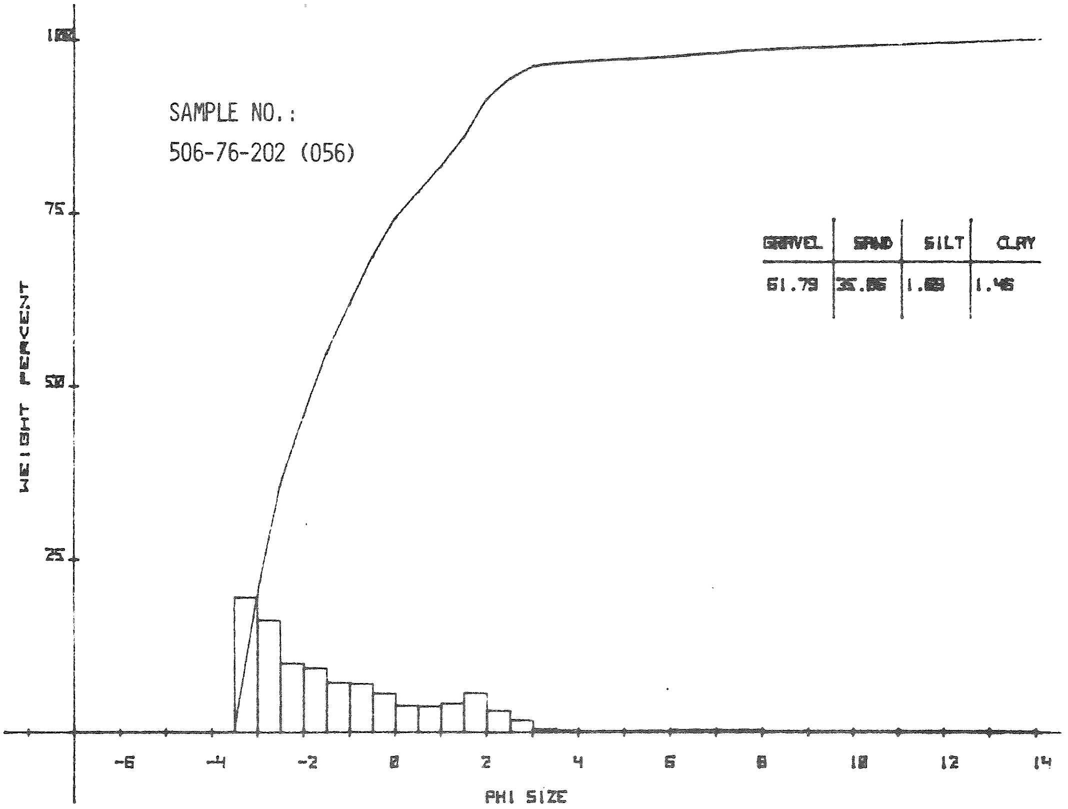

SAMPLE NO.:
506-76-188 (N51)
GRAVEL
SAND
SILT
CLAY
.11
.53
WEIGHT PERCENT
100
75
50
25
-6
-4
-2
0
2
4
6
8
10
12
14
PHI SIZE


SAMPLE NO.:
506-76-191 (N52)
GRAVEL
SAND
SILT
CLAY
26.95
12.02
WEIGHT PERCENT
100
75
50
25
-6
-4
-2
0
2
4
6
8
10
12
14
PHI SIZE


SAMPLE NO.:
506-76-181 (053)
GRAVEL | SAND | SILT | CLAY
98.32 | 1.66 | .02 | 0.00
WEIGHT PERCENT
100
75
50
25
-6
-4
-2
0
2
4
6
8
10
12
14
PHI SIZE


SAMPLE NO.:
506-76-182 (054)
GRAVEL | SAND | SILT | CLAY
16.30 | 83.64 | .06 | 0.00
WEIGHT PERCENT
100
75
50
25
-6
-4
-2
0
2
4
6
8
10
12
14
PHI SIZE


SAMPLE NO.:
506-76-200 (055)
GRAVEL
SAND
SILT
CLAY
91.02
8.56
.03
0.[illegible]
100
75
50
25
WEIGHT PERCENT
-6
-4
-2
0
2
4
6
8
10
12
14
PHI SIZE


SAMPLE NO.:
506-76-202 (056)
GRAVEL
SAND
SILT
CLAY
61.79
35.86
1.09
1.46
100
75
50
25
WEIGHT PERCENT
-6
-4
-2
0
2
4
6
8
10
12
14
PHI SIZE

APPENDIX

B

S.E.M. QUARTZ GRAIN SURFACE TEXTURE DATA

Sample # TK 1-1 (T1)
Stub # A15

Grain No.	Shape	Parallel Ridges	"V" Gouges	Precipitation/ Solution	Dish Shaped Concavities	Curved Grooves	Meandering Ridge Pattern	Silica Plastering	Cleavage Planes	Oriented Fracture Pattern	Rounded Glacial Features	Origin†
1	Subrounded	?		*					*		*	G/S
2	Subrounded							*			*	G/S
3	Subangular		*	*					*		*	G/S
4	Subrounded	*	*					*			*	G/S
5	Subrounded		*						*	*		E
6	Rounded				*			*				E
7	Subangular	*						*				G
8	Subangular	*						*				G
9	Subangular	*						*				G
10	Subangular	*						*				G
11	Rounded			*	*							E
12	Rounded			*	*							E
13	Subrounded							*			*	G/S
14	Subangular	*						*	*		*	G/S
15	Subrounded							*			*	G/S
16	Subangular - Subrounded							*			*	G/S
17	Subrounded							*			*	G/S
18	Subangular - Subrounded							*			*	G/S
19	Subangular - Subrounded									*	*	G/S
20	Subrounded									*	*	G/S

† E = Eolian G = Glacial S = Subaqueous

S.E.M. QUARTZ GRAIN SURFACE TEXTURE DATA

Sample # TK 2-4 (T4)
Stub # A4

Grain No.	Shape	Parallel Ridges	"V" Gouges	Precipitation/ Solution	Dish Shaped Concavities	Curved Grooves	Meandering Ridge Pattern	Silica Plastering	Cleavage Planes	Oriented Fracture Pattern	Rounded Glacial Features	Origin†
1	Subangular			*							*	G/S
2	Angular	*		*								G
3	Subangular - Angular		*								*	G/S
4	Subangular			*				*				G
5	Well Rounded				*							E
6	Subangular	*		*								G
7	Subangular	*									*	G/S
8	Subangular	*		*								G
9	Subangular	*		*								G
10	Subrounded - Rounded			*				*				E/G
11	Angular	*										G
12	Angular	*										G
13	Angular	*										G
14	Angular	*										G
15	Angular	*										G
16	Subangular			*								G
17	Well Rounded				*							E
18	Subangular		*								*	G/S
19	Well Rounded		*		*							E/S
20	Angular	*										G

† E = Eolian G = Glacial S = Subaqueous

S.E.M. QUARTZ GRAIN SURFACE TEXTURE DATA

Sample # BP 1-20C-2 (B6)
Stub # A13

Grain No.	Shape	Parallel Ridges	"V" Gouges	Precipitation/ Solution	Dish Shaped Concavities	Curved Grooves	Meandering Ridge Pattern	Silica Plastering	Cleavage Planes	Oriented Fracture Pattern	Rounded Glacial Features	Origin†
1	Subrounded		*	*				*			*	G/S
2	Subangular	*		*				*			*	G/S
3	Subrounded	*									*	G/S
4	Angular		*								*	G/S
5	Subangular			*				*			*	G/S
6	Subangular		*						*		*	G/S
7	Angular - Subangular	*	*						*		*	G/S
8	Subangular - Subrounded	*	*						*		*	G/S
9	Well Rounded				*							E
10	Well Rounded		*		*							E/S
11	Subrounded	*									*	G/S
12	Subangular	*	*	*				*			*	G/S
13	Subrounded		*	*								S
14	Subangular - Subrounded	*	*	*							*	G/S
15	Subrounded		*					*				S
16	Subrounded	*	*					*			*	G/S
17	Subangular Subrounded			*								S
18	Subangular	*		*							*	G/S
19	Subangular - Subrounded		*									S
20	Subrounded		*	*								S

† E = Eolian G = Glacial S = Subaqueous

S.E.M. QUARTZ GRAIN SURFACE TEXTURE DATA

Sample # BP 3-20C-4 (B8)
Stub # A18

Grain No.	Shape	Parallel Ridges	"V" Gouges	Precipitation/ Solution	Dish Shaped Concavities	Curved Grooves	Meandering Ridge Pattern	Silica Plastering	Cleavage Planes	Oriented Fracture Pattern	Rounded Glacial Features	Origin†
1	Subrounded	*	*								*	G/S
2	Subangular - Subrounded	*	*	*							*	G/S
3	Subangular	*	*						*		*	G/S
4	Subangular - Subrounded		*	*	*							E/S
5	Subangular		*	*	*				*			E/S
6	Subrounded - Rounded		?		*							E
7	Subrounded - Rounded				*							E
8	Subangular	*	*								*	G/S
9	Subrounded - Rounded				*							E
10	Subangular		*						*	*	*	G/S
11	Subangular		*	*					*			S
12	Subrounded	*	*	*							*	G/S
13	Subangular - Subrounded		*						*		*	G/S
14	Subrounded		*	*								S
15	Subangular	*	*						*		*	G/S
16	Subangular	*	*								*	G/S
17	Subangular	*	*	*							*	G/S
18	Subangular - Subrounded		*		*				*			E/S
19	Subrounded		*	*								S
20	Missing											

† E = Eolian G = Glacial S = Subaqueous

S.E.M. QUARTZ GRAIN SURFACE TEXTURE DATA

Sample # ESF 1-76-1 (N11)
Stub # A6

Grain No.	Shape	Parallel Ridges	"V" Gouges	Precipitation/ Solution	Dish Shaped Concavities	Curved Grooves	Meandering Ridge Pattern	Silica Plastering	Cleavage Planes	Oriented Fracture Pattern	Rounded Glacial Features	Origin†
1	Angular	*										G
2	Angular	*							*			G
3	Angular - Subrounded	*	*								*	G/S
4	Angular	*							*			G
5	Subrounded		*			*			*			S
6	Angular	*							*			G
7	Subangular	*										G
8	Angular	*							*			G
9	Angular	*							*			G
10	Angular	*							*			G
11	Subangular			*							*	G/S
12	Subangular	*	*	*					*		*	G/S
13	Subangular	*	*	*					*		*	G/S
14	Subangular	*				*			*			G
15	Subangular - Angular	*							*			G
16	Subrounded				*					*		E/S
17	Angular	*										G
18	Subangular	*						*			*	G/S
19	Subangular										*	G/S
20	Subrounded		*				*	*				E/S

† E = Eolian G = Glacial S = Subaqueous

S.E.M. QUARTZ GRAIN SURFACE TEXTURE DATA

Sample # ESF 1-76-6 (N16)
Stub # A8

Grain No.	Shape	Parallel Ridges	"V" Gouges	Precipitation/ Solution	Dish Shaped Concavities	Curved Grooves	Meandering Ridge Pattern	Silica Plastering	Cleavage Planes	Oriented Fracture Pattern	Rounded Glacial Features	Origin†
1	Subangular	*	*	*							*	G/S
2	Subangular	*	*								*	G/S
3	Subangular	*	*								*	G/S
4	Subangular - Subrounded		*									S
5	Subrounded	*	*				*				*	G/S
6	Angular - Subangular	*	*								*	G/S
7	Subangular - Subrounded		*	*								S
8	Subrounded		*	*								S
9	Subangular	*							*			G
10	Subangular - Angular	*		*					*			G
11	Angular - Subangular	*							*			G
12	Angular - Subangular	*							*			G
13	Angular - Subangular	*							*			G
14	Angular - Subangular	*							*			G
15	Subangular - Subrounded		*	*								S
16	Angular - Subrounded	*							*		?	G
17	Subrounded	*	*	*					*		*	G/S
18	Subrounded		*		*							E/S
19	Subangular - Subrounded	*	*								*	G/S
20	Subangular - Subrounded	*	*						*		*	G/S

† E = Eolian G = Glacial S = Subaqueous

S.E.M. QUARTZ GRAIN SURFACE TEXTURE DATA

Sample # ESF 3-76-18 (N24)
Stub # A1

Grain No.	Shape	Parallel Ridges	"V" Gouges	Precipitation/ Solution	Dish Shaped Concavities	Curved Grooves	Meandering Ridge Pattern	Silica Plastering	Cleavage Planes	Oriented Fracture Pattern	Rounded Glacial Features	Origin[†]
1	Subangular	*									?	G
2	Subangular	*					*		*	*	?	G
3	Rounded		*	*						*		E/S
4	Angular		*			*					*	G/S
5	Subrounded	*	*								*	G/S
6	Subrounded		*		?							E/S
7	Subangular	*						*			*	G/S
8	Subangular - Subrounded		*								*	G/S
9	Subangular - Subrounded		*								*	G/S
10	Subangular		*					*	*			G/S
11	Subangular - Subrounded		*								*	G/S
12	Subangular	*		*							*	G/S
13	Subrounded		*						*		*	G/S
14	Subrounded		*								?	S
15	Subangular	*	*						*			G/S
16	Rounded				*	*						E/S
17	Subangular	*										G
18	Rounded							*				E/S
19	Subangular	*					*					G
20	Subangular - Subrounded		*	*								S

[†] E = Eolian G = Glacial S = Subaqueous

S.E.M. QUARTZ GRAIN SURFACE TEXTURE DATA

Sample # 506-76-080 (025)
Stub # C14

Grain No.	Shape	Parallel Ridges	"V" Gouges	Precipitation/ Solution	Dish Shaped Concavities	Curved Grooves	Meandering Ridge Pattern	Silica Plastering	Cleavage Planes	Oriented Fracture Pattern	Rounded Glacial Features	Origin†
1	Subangular - Subrounded	*	*	*					*		*	G/S
2	Subrounded	*	*				*				*	G/S
3	Subangular - Subrounded			*		*	*					S
4	Subangular	*	*	*				*			*	G/S
5	Rounded		*	*	*							E/S
6	Subangular - Subrounded	*	*					*	*		*	G/S
7	Subrounded		*	*	?*			*				S
8	Subrounded		*	*				*	*	*		S
9	Subrounded	*	*	*					*		*	G/S
10	Subangular - Subrounded		*	*								S
11	Subrounded	*	*	*			*	*	*		*	G/S
12	Subangular - Subrounded	*	*	*					*			G/S
13	Subrounded		*	*		*		*				S
14	Subrounded - Rounded		*	*	*	*						E/S
15	Subangular - Subrounded		*			*		*	*		*	G/S
16	Subrounded		*	*				*				S
17	Subrounded		*		*	*		*				E/S
18	Subrounded		*		*			*				E/S
19	Subrounded		*		*		*		*			E/S
20	Subangular - Subrounded	*	*	*		*		*	*		*	G/S

† E = Eolian G = Glacial S = Subaqueous

S.E.M. QUARTZ GRAIN SURFACE TEXTURE DATA

Sample # 506-76-132 (028)
Stub # C16

Grain No.	Shape	Parallel Ridges	"V" Gouges	Precipitation/ Solution	Dish Shaped Concavities	Curved Grooves	Meandering Ridge Pattern	Silica Plastering	Cleavage Planes	Oriented Fracture Pattern	Rounded Glacial Features	Origin†
1	Rounded		*	*	*			*				E/S
2	Subrounded - Rounded		*	*	*	*						E/S
3	Subangular	*		*			*		*		*	G/S
4	Subangular - Subrounded	*	*	*				*	*		*	G/S
5	Subangular	*	*	*			*				*	G/S
6	Subangular - Subrounded	*		*			*		*	*	*	G/S
7	Subangular	*		*					*	*		G
8	Subangular					*	*		*			G
9	Subangular - Angular	*	*	*			*		*			G
10	Subrounded		*	*							?	S
11	Subangular - Subrounded	*	*			*			*		*	G/S
12	Angular	*				*			*			G
13	Subangular	*				*	*		*			S
14	Subangular - Subrounded		*			*			*		*	G/S
15	Rounded		*		*	*						E/S
16	Subrounded		*			*				*	*	G/S
17	Subangular - Subrounded	*		*			*		*			G
18	Rounded			*	*				*			E/S
19	Subangular	*	*				*				*	G/S
20	Subangular - Angular	*	*	*			*			*		G

† E = Eolian G = Glacial S = Subaqueous

S.E.M. QUARTZ GRAIN SURFACE TEXTURE DATA

Sample # TH 3-2 (T30)
Stub # A10

Grain No.	Shape	Parallel Ridges	"V" Gouges	Precipitation/ Solution	Dish Shaped Concavities	Curved Grooves	Meandering Ridge Pattern	Silica Plastering	Cleavage Planes	Oriented Fracture Pattern	Rounded Glacial Features	Origin†
1	Angular	*		*					*			G
2	Angular	*					*			*		G
3	Angular			*								G
4	Angular			*					*			G
5	Well Rounded		*		*	*						E
6	Angular - Rounded	*	*		*	*						E/S
7	Angular	*		*								G
8	Subangular			*							*	G/S
9	Angular	*						*	*			G
10	Angular	*						*				G
11	Angular	*			?			*				G
12	Subangular	*		*	?							G
13	Well Rounded		*		*							E/S
14	Well Rounded		*	*								E/S
15	Well Rounded		*		*							E/S
16	Subangular	*	*								*	G/S
17	Subangular	*	*								*	G/S
18	Subangular	*	*					*			*	G/S
19	Angular	*						*		*		G
20	Angular	*								*		G

† E = Eolian G = Glacial S = Subaqueous

S.E.M. QUARTZ GRAIN SURFACE TEXTURE DATA

Sample # TH 5-10 (T38)
Stub # B3

Grain No.	Shape	Parallel Ridges	"V" Gouges	Precipitation/ Solution	Dish Shaped Concavities	Curved Grooves	Meandering Ridge Pattern	Silica Plastering	Cleavage Planes	Oriented Fracture Pattern	Rounded Glacial Features	Origin†
1	Angular - Subangular	*										G
2	Rounded				*							E
3	Subangular	*						*			*	G/S
4	Subangular	*						*			*	G/S
5	Subangular	*										G
6	Angular	*		*								G
7	Angular							*				G
8	Subangular			*				*				G
9	Subangular	*	*								*	G/S
10	Subrounded	*									*	E/S/G
11	Subrounded	*	*								*	G/S
12	Subangular	*							*			G
13	Subangular	*							*			G
14	Subangular	*							*			G
15	Subangular	*							*			G
16	Subrounded		*			*		*			*	G/S
17	Subrounded	*		*							*	G/S
18	Subangular - Subrounded	*							*			G
19	Angular	*						*	*			G
20	Subangular - Subrounded	*	*	*				*	*		*	G/S

† E = Eolian G = Glacial S = Subaqueous

S.E.M. QUARTZ GRAIN SURFACE TEXTURE DATA

Sample # BP 5-20C-7 (B39)
Stub # A7

Grain No.	Shape	Parallel Ridges	"V" Gouges	Precipitation/ Solution	Dish Shaped Concavities	Curved Grooves	Meandering Ridge Pattern	Silica Plastering	Cleavage Planes	Oriented Fracture Pattern	Rounded Glacial Features	Origin[†]
1	Subrounded		*						*			E/S
2	Subangular - Subrounded	*	*								*	G/S
3	Subangular - Subrounded		*								*	G/S
4	Subrounded		*						*		*	G/S
5	Subrounded	*	*						*		*	G/S
6	Subangular	*	*						*		*	G/S
7	Subrounded		*								*	G/S
8	Subrounded		*								*	G/S
9	Subangular - Subrounded	*	*						*			G/S
10	Subangular		*			*		*			*	G/S
11	Subrounded	*	*								*	G/S
12	Subrounded	*	*								*	G/S
13	Subangular	*						*			*	G/S
14	Subrounded		*								*	G/S
15	Subangular	*							*			G
16	Subangular - Subrounded	*	*								*	G/S
17	Subangular - Subrounded	*	*								*	G/S
18	Subangular - Subrounded	*	*								*	G/S
19	Subangular - Subrounded		*						*		*	G/S
20	Subrounded		*		*			*				E/S

[†] E = Eolian G = Glacial S = Subaqueous

S.E.M. QUARTZ GRAIN SURFACE TEXTURE DATA

Sample # BP 9-20C-11 (B43)
Stub # A11

Grain No.	Shape	Parallel Ridges	"V" Gouges	Precipitation/ Solution	Dish Shaped Concavities	Curved Grooves	Meandering Ridge Pattern	Silica Plastering	Cleavage Planes	Oriented Fracture Pattern	Rounded Glacial Features	Origin†
1	Subangular - Subrounded	*	*	*					*		*	G/S
2	Subrounded	*	*						*		*	G/S
3	Subangular - Subrounded		*								*	G/S
4	Subrounded		*	*					*		*	G/S
5	Subrounded		*	*					*		?	S
6	Subangular	*	*						*		*	G/S
7	Angular	*							*			G
8	Subangular - Subrounded		*	*						*		S
9	Subangular			*					*			S
10	Subangular - Subrounded			*					*			S
11	Subangular	*	*						*		*	G/S
12	Subangular	*	*						*		*	G/S
13	Subangular - Subrounded	*	*	*					*		*	G/S
14	Subrounded		*	*								S
15	Subrounded		*	*							?	S
16	Subrounded - Rounded	*	*	*	*							E/S
17	Subangular		*	*					*			S
18	Subangular - Subrounded		*	*								S
19	Subangular	*	*					*			*	G/S
20	Missing											

† E = Eolian G = Glacial S = Subaqueous

S.E.M. QUARTZ GRAIN SURFACE TEXTURE DATA

Sample # ESF 3-76-14 (N45)
Stub # B5

Grain No.	Shape	Parallel Ridges	"V" Gouges	Precipitation/ Solution	Dish Shaped Concavities	Curved Grooves	Meandering Ridge Pattern	Silica Plastering	Cleavage Planes	Oriented Fracture Pattern	Rounded Glacial Features	Origin†
1	Angular	*										G
2	Angular	*					*			*		G
3	Angular	*								*		G
4	Subangular		*								*	G/S
5	Subangular		*							*	*	G/S
6	Subangular	*										G
7	Angular	*							*			G
8	Angular	*										G
9	Angular	*							*			G
10	Angular	*										G
11	Subangular	*	*								*	G/S
12	Subangular	*				*			*		*	G/S
13	Subangular		*					*			*	G/S
14	Subangular - Angular		*	*		*					*	G/S
15	Angular	*										G
16	Angular	*		*								G
17	Subangular	*					*			*	*	G/S
18	Well Rounded		*									E/G
19	Subangular		*								*	G/S
20	Angular	*		*								G

† E = Eolian G = Glacial S = Subaqueous

S.E.M. QUARTZ GRAIN SURFACE TEXTURE DATA

Sample # ESF 3-76-15 (N46)
Stub # A2

Grain No.	Shape	Parallel Ridges	"V" Gouges	Precipitation/ Solution	Dish Shaped Concavities	Curved Grooves	Meandering Ridge Pattern	Silica Plastering	Cleavage Planes	Oriented Fracture Pattern	Rounded Glacial Features	Origin†
1	Angular	*							*			G
2	Subangular	*							*			G
3	Subangular	*					*		*			G
4	Subangular	*							*			G
5	Subangular	*						*			*	G/S
6	Subangular	*						*			*	G/S
7	Subangular	*						*			*	G/S
8	Angular							*	*			G
9	Subangular	*										G
10	Subrounded	*	*								*	G/S
11	Subangular - Subrounded	*	*								*	G/S
12	Subangular - Subrounded	*	*								*	G/S
13	Subangular	*	*								*	G/S
14	Subrounded		*								?	S
15	Subangular - Subrounded	*						*	*		*	G/S
16	Subangular	*										G
17	Subangular	*		*								G
18	Subangular	*	*								*	G/S
19	Subangular	*						*	*		*	G/S
20	Subrounded		*								?	S

† E = Eolian G = Glacial S = Subaqueous

S.E.M. QUARTZ GRAIN SURFACE TEXTURE DATA

Sample # ESF 3-76-16 (N47)
Stub # A17

Grain No.	Shape	Parallel Ridges	"V" Gouges	Precipitation/ Solution	Dish Shaped Concavities	Curved Grooves	Meandering Ridge Pattern	Silica Plastering	Cleavage Planes	Oriented Fracture Pattern	Rounded Glacial Features	Origin[†]
1	Subrounded		*								?	S
2	Subangular	*							*		*	G/S
3	Subangular - Subrounded	*									*	G/S
4	Subangular - Subrounded	*		*							*	G/S
5	Subangular	*										G
6	Subrounded		*			*						S
7	Subrounded	*	*			*					*	G/S
8	Subangular	*	*						*		*	G/S
9	Subangular		*	*							*	G/S
10	Angular	*							*			G
11	Angular	*							*			G
12	Subangular - Subrounded	*	*								*	G/S
13	Subrounded	*	*								*	G/S
14	Subrounded		*		*							E
15	Subangular - Subrounded	*	*								*	G/S
16	Subangular - Angular	*										G
17	Angular	*	*					*			*	G/S
18	Subangular		*						*		*	G/S
19	Angular	*						*			*	G/S
20	Subrounded		*						*			S

[†] E = Eolian G = Glacial S = Subaqueous

S.E.M. QUARTZ GRAIN SURFACE TEXTURE DATA

Sample # 506-76-184 (N48)
Stub # B1

Grain No.	Shape	Parallel Ridges	"V" Gouges	Precipitation/ Solution	Dish Shaped Concavities	Curved Grooves	Meandering Ridge Pattern	Silica Plastering	Cleavage Planes	Oriented Fracture Pattern	Rounded Glacial Features	Origin†
1	Subrounded		*	*					*			S
2	Subangular - Subrounded		*	*								S
3	Subangular Subrounded	*	*	*					*		*	G/S
4	Subrounded	*		*	*							E/S
5	Subangular Subrounded	*	*						*		*	G/S
6	Subangular Subrounded	*	*			*					*	G/S
7	Subangular - Subrounded	*	*						*		*	G/S
8	Subangular - Subrounded		*	*					*			S
9	Subangular	*		*					*			G
10	Subangular - Angular	*		*					*			G
11	Subangular Subrounded			*		*	*					S
12	Subangular - Angular	*							*			G
13	Subangular - Subrounded	*	*	*					*		*	G/S
14	Subangular		*	*					*			S
15	Subangular - Subrounded	*	*	*						*	*	G/S
16	Subrounded		*	*					*			S
17	Subrounded	*		*					*		*	G/S
18	Subangular - Subrounded	*	*	*		*					*	G/S
19	Rounded		*		*							E/S
20	Subangular		*	*					*			S

† E = Eolian G = Glacial S = Subaqueous

S.E.M. QUARTZ GRAIN SURFACE TEXTURE DATA

Sample # 506-76-188 (N51)
Stub # C9

Grain No.	Shape	Parallel Ridges	"V" Gouges	Precipitation/ Solution	Dish Shaped Concavities	Curved Grooves	Meandering Ridge Pattern	Silica Plastering	Cleavage Planes	Oriented Fracture Pattern	Rounded Glacial Features	Origin†
1	Subangular - Subrounded	*	*				*		*		*	G/S
2	Subrounded	*	*		*		*				*	G/S
3	Subangular	*	*			*	*				*	G/S
4	Subangular - Angular	*							*			G
5	Angular	*		*			*		*			G
6	Subangular	*				*			*			G
7	Subangular	*				*			*			G
8	Subangular - Subrounded		*	*	*		*		*			E/S
9	Subrounded	*	*	*								S
10	Subrounded		*			*		*				S
11	Subangular	*							*			G
12	Subangular - Subrounded	*	*	*					*		*	G/S
13	Subangular	*		*			*		*		*	G/S
14	Subangular - Subrounded		*			*			*		*	G/S
15	Subrounded		*		*	*						E/S
16	Angular	*					*		*			G
17	Subrounded	*	*			*	*				*	G/S
18	Subangular	*							*		*	G/S
19	Subangular	*	*			*			*			G/S
20	Subrounded		*		*	*			*			E/S

† E = Eolian G = Glacial S = Subaqueous

S.E.M. QUARTZ GRAIN SURFACE TEXTURE DATA

Sample # 506-76-191 (N52)
Stub # C27

Grain No.	Shape	Parallel Ridges	"V" Gouges	Precipitation/ Solution	Dish Shaped Concavities	Curved Grooves	Meandering Ridge Pattern	Silica Plastering	Cleavage Planes	Oriented Fracture Pattern	Rounded Glacial Features	Origin†
1	Subangular - Subrounded	*				*		*	*		*	G/S
2	Subrounded		*	*	*							E/S
3	Rounded		*		*			*				E/S
4	Subangular - Subrounded		*	*		*	*		*			S
5	Subangular Subrounded	*	*	*		*			*		*	G/S
6	Subangular - Subrounded	*	*					*	*		*	G/S
7	Subangular - Subrounded		*	*			*		*			S
8	Subrounded - Rounded		*		*		*	*				E/S
9	Subangular	*	*					?	*		*	G/S
10	Subangular - Subrounded	*	*			*		*	*		*	G/S
11	Subangular	*	*	*			*		*			S
12	Subrounded	*	*	*		*			*		*	G/S
13	Subangular - Subrounded		*			*	*	*				S
14	Subrounded		*	*			*	?				S
15	Subangular - Subrounded	*	*						*		*	G/S
16	Subrounded		*	*	*	*						S
17	Subangular - Subrounded	*	*	*		*			*		*	G/S
18	Subrounded		*	*	*	*						A/S
19	Subangular - Subrounded		*	*		*			*	*?		S
20	Subangular - Subrounded	*	*	*					*		*	G/S

† E = Eolian G = Glacial S = Subaqueous

S.E.M. QUARTZ GRAIN SURFACE TEXTURE DATA

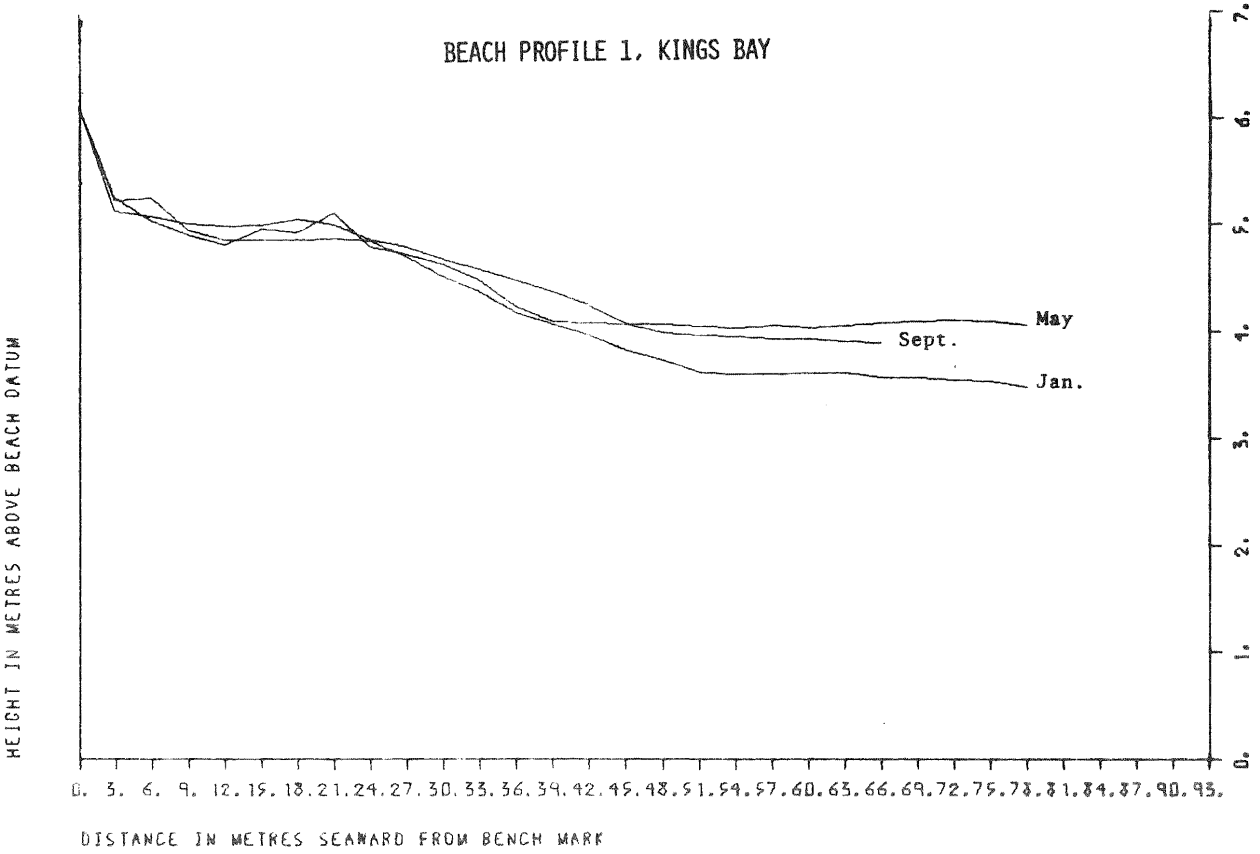
Sample # 506-76-202 (056)
Stub # C21

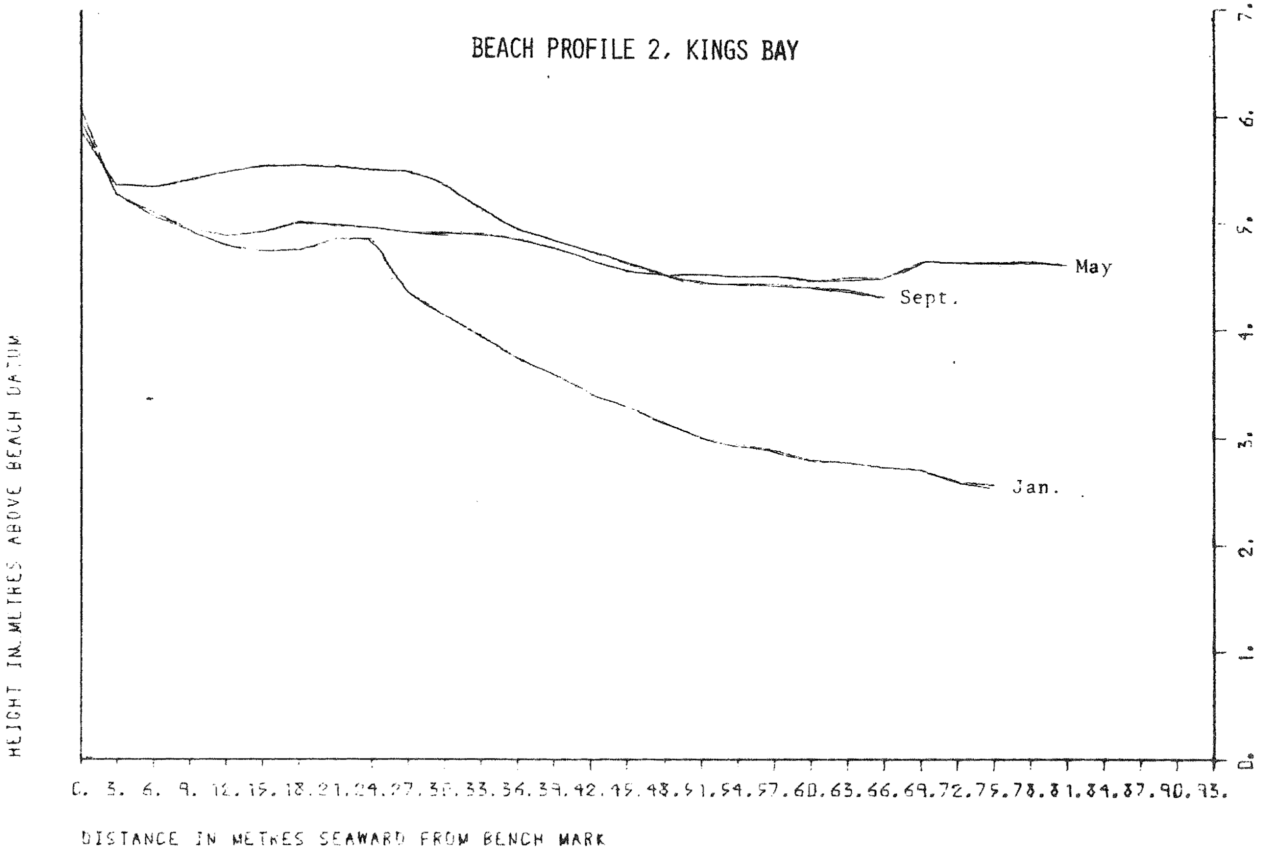
Grain No.	Shape	Parallel Ridges	"V" Gouges	Precipitation/ Solution	Dish Shaped Concavities	Curved Grooves	Meandering Ridge Pattern	Silica Plastering	Cleavage Planes	Oriented Fracture Pattern	Rounded Glacial Features	Origin†
1	Angular	*		*		*			*			G
2	Subangular	*				*			*			G
3	Subangular - Subrounded		*	*							*	G/S
4	Subangular - Subrounded	*				*			*		*	G/S
5	Subangular - Subrounded		*	*					*		*	G/S
6	Subrounded	*	*	*					*		*	G/S
7	Subrounded - Rounded		*	*	*							E/S
8	Subangular - Subrounded	*		*			*		*		?	G/S
9	Subangular - Subrounded	*	*						*		*	G/S
10	Subangular - Subrounded	*	*	*		*						S
11	Subrounded		*		*					*		E/S
12	Subangular - Subrounded		*	*			*		*		*	G/S
13	Subangular - Subrounded	*	*	*					*		*	G/S
14	Subrounded		*	*	*							E/S
15	Subrounded - Rounded		*	*	*							E/S
16	Subangular	*		*					*		*	G/S
17	Subangular	*		*			*		*		*	G/S
18	Subangular - Subrounded	*	*						*		*	G/S
19	Subangular	*		*			*				*	G/S
20	Subangular - Subrounded		*			*	*					S

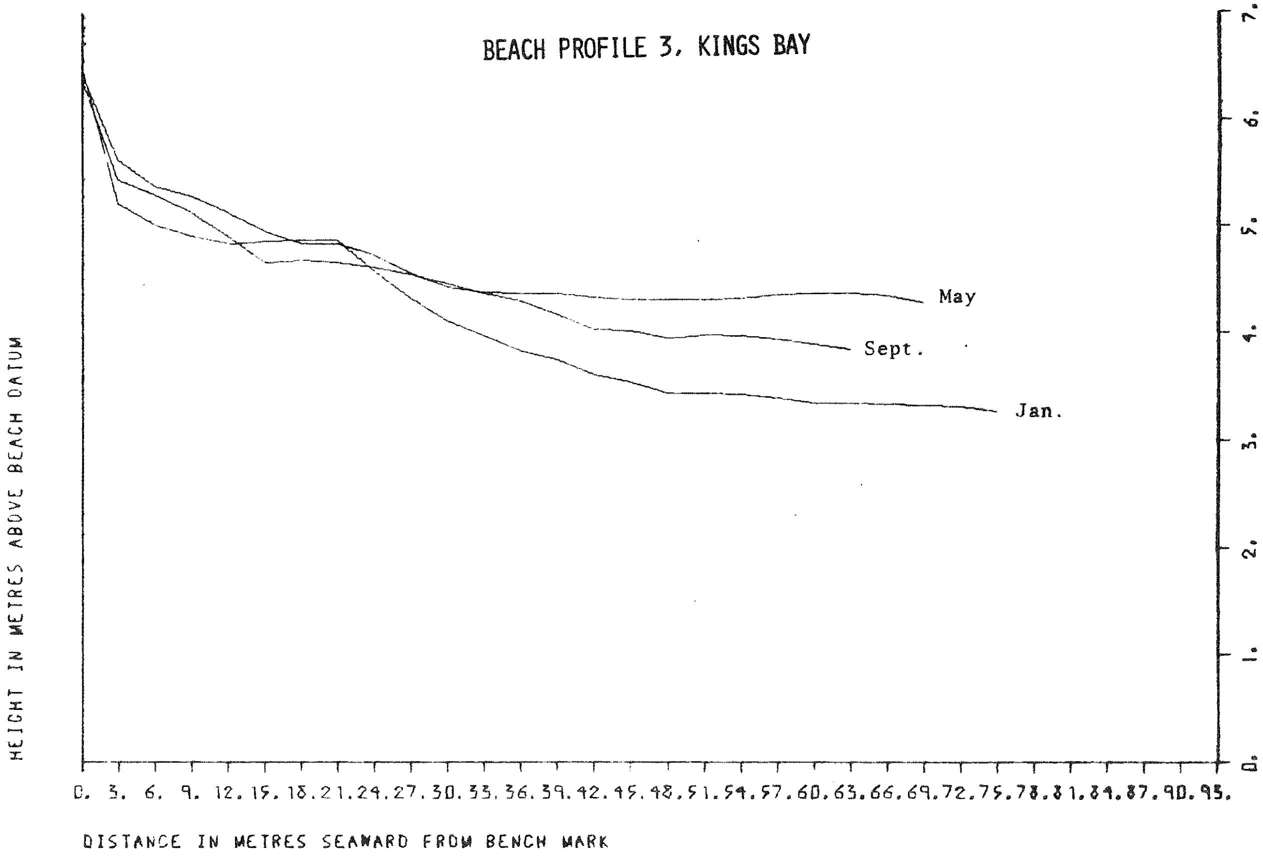
† E = Eolian G = Glacial S = Subaqueous

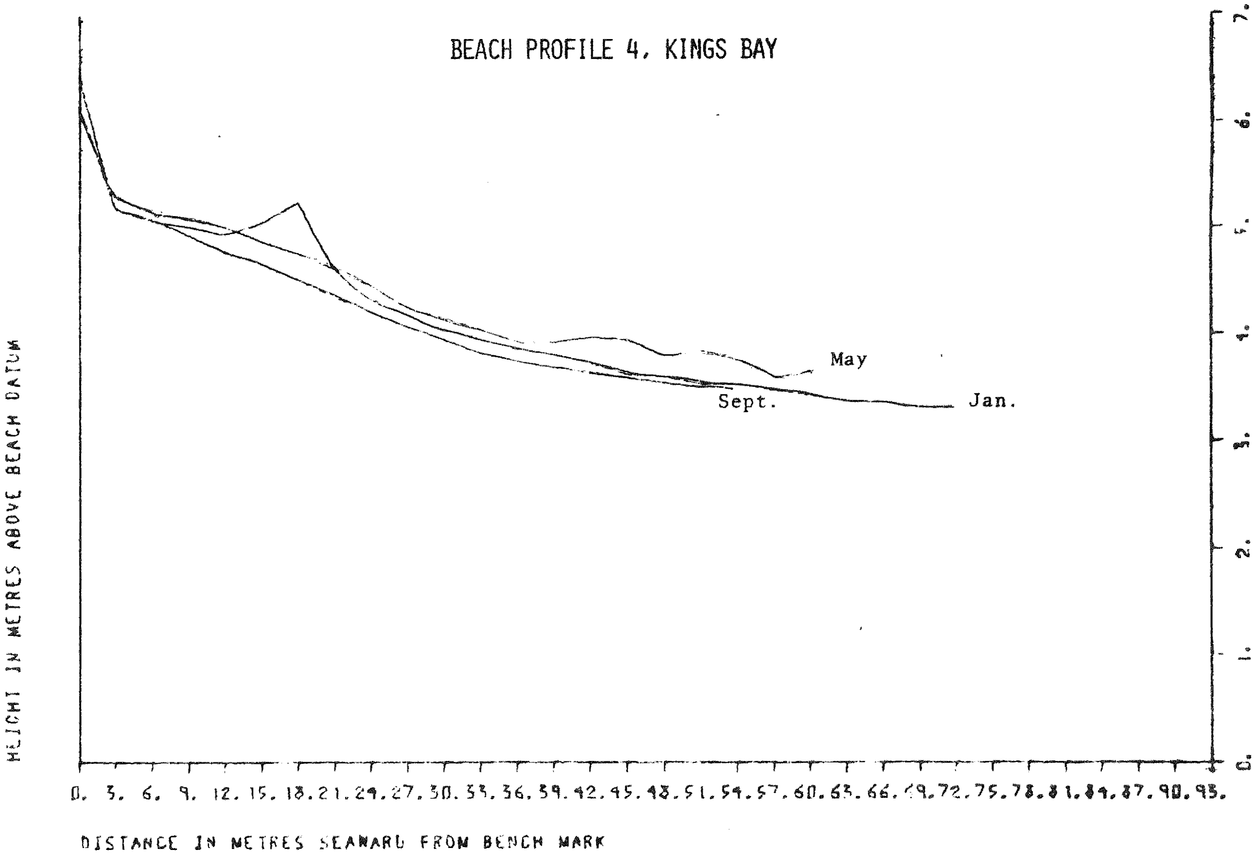
APPENDIX

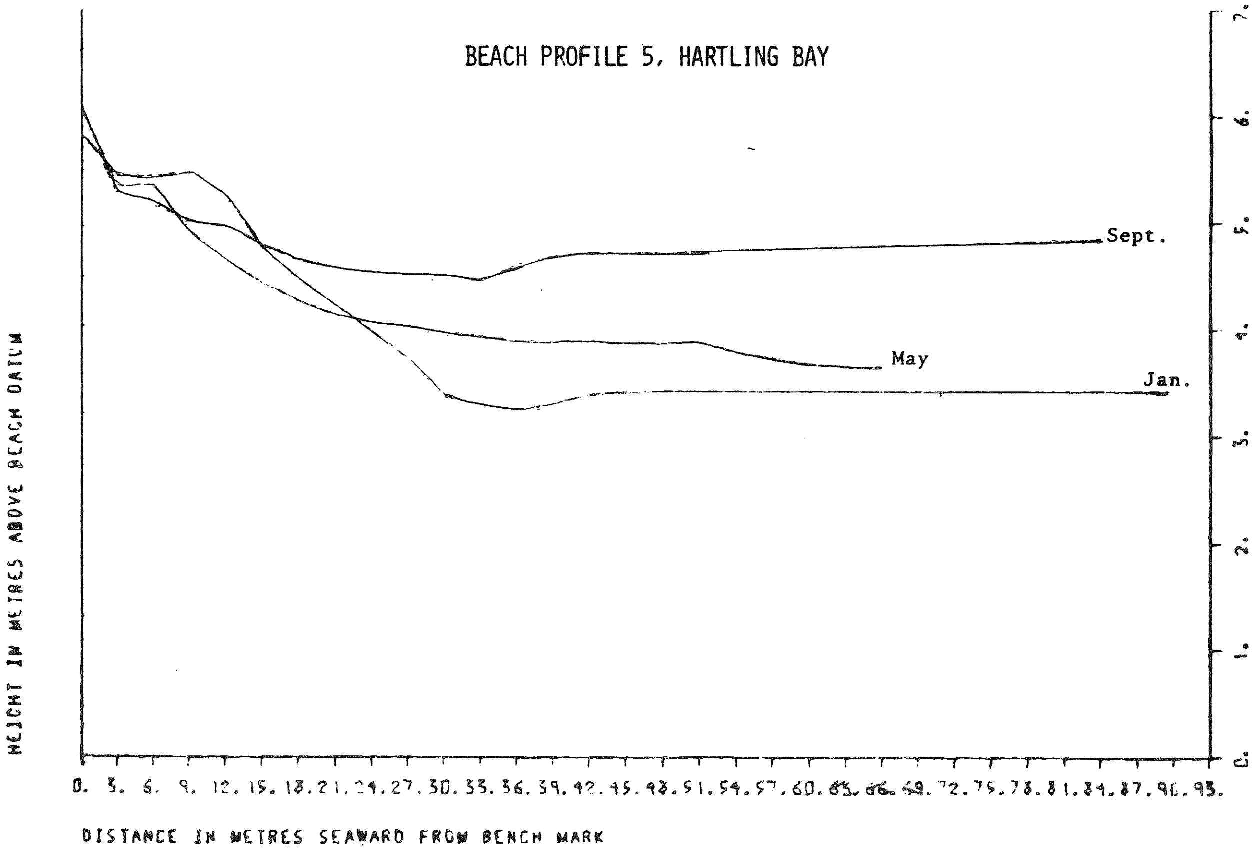
C

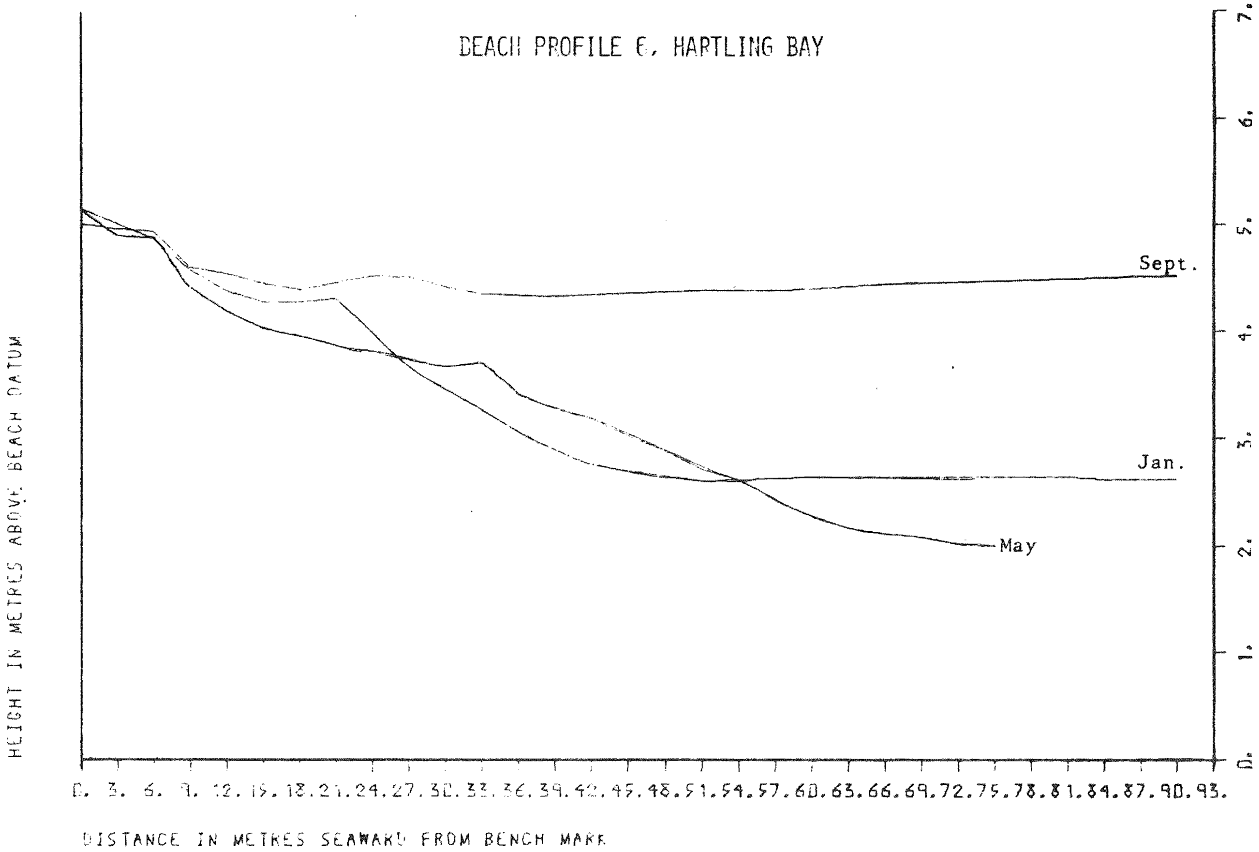

BEACH PROFILE 1, KINGS BAY
HEIGHT IN METRES ABOVE BEACH DATUM
0.
1.
2.
3.
4.
5.
6.
7.
0. 3. 6. 9. 12. 15. 18. 21. 24. 27. 30. 33. 36. 39. 42. 45. 48. 51. 54. 57. 60. 63. 66. 69. 72. 75. 78. 81. 84. 87. 90. 93.
DISTANCE IN METRES SEAWARD FROM BENCH MARK
May
Sept.
Jan.

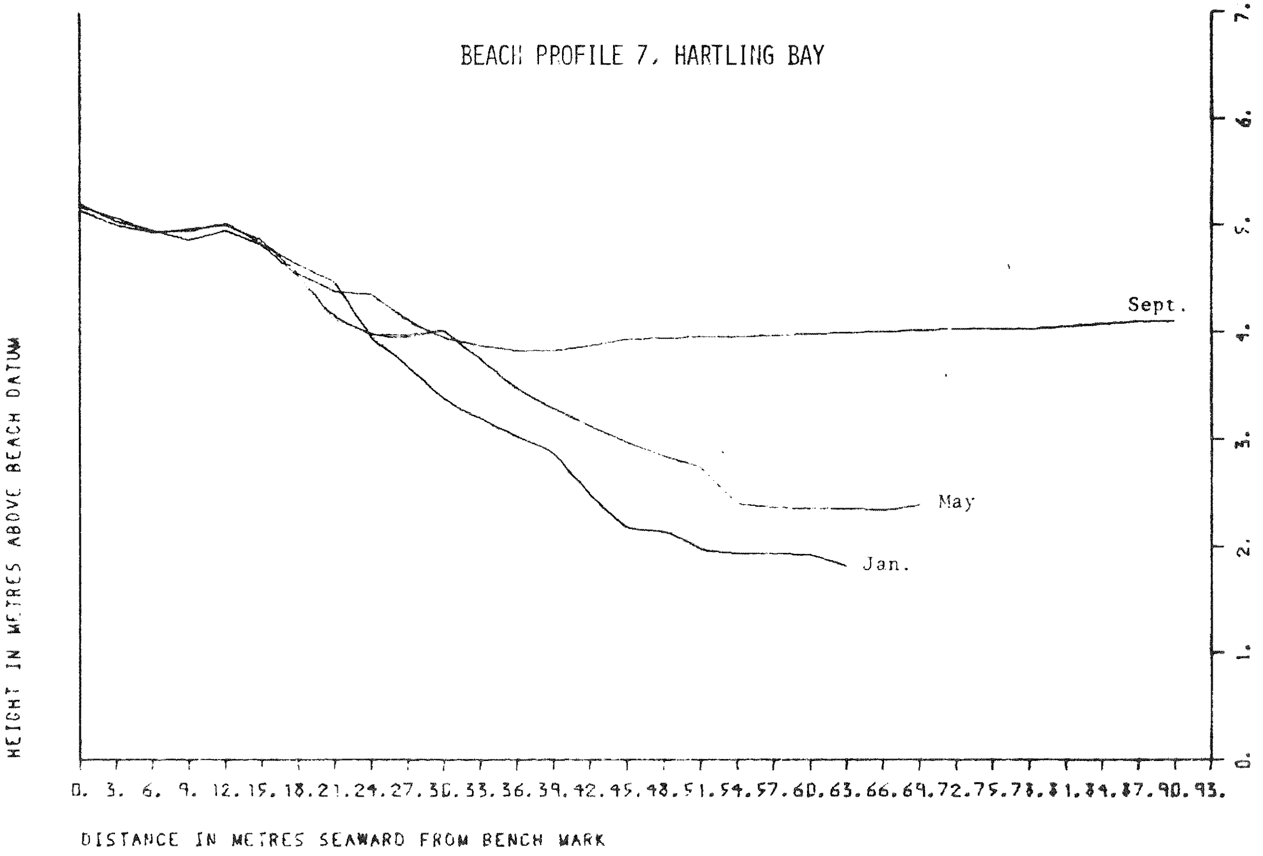

BEACH PROFILE 2, KINGS BAY
HEIGHT IN METRES ABOVE BEACH DATUM
0.
1.
2.
3.
4.
5.
6.
7.
May
Sept.
Jan.
0. 3. 6. 9. 12. 15. 18. 21. 24. 27. 30. 33. 36. 39. 42. 45. 48. 51. 54. 57. 60. 63. 66. 69. 72. 75. 78. 81. 84. 87. 90. 93.
DISTANCE IN METRES SEAWARD FROM BENCH MARK

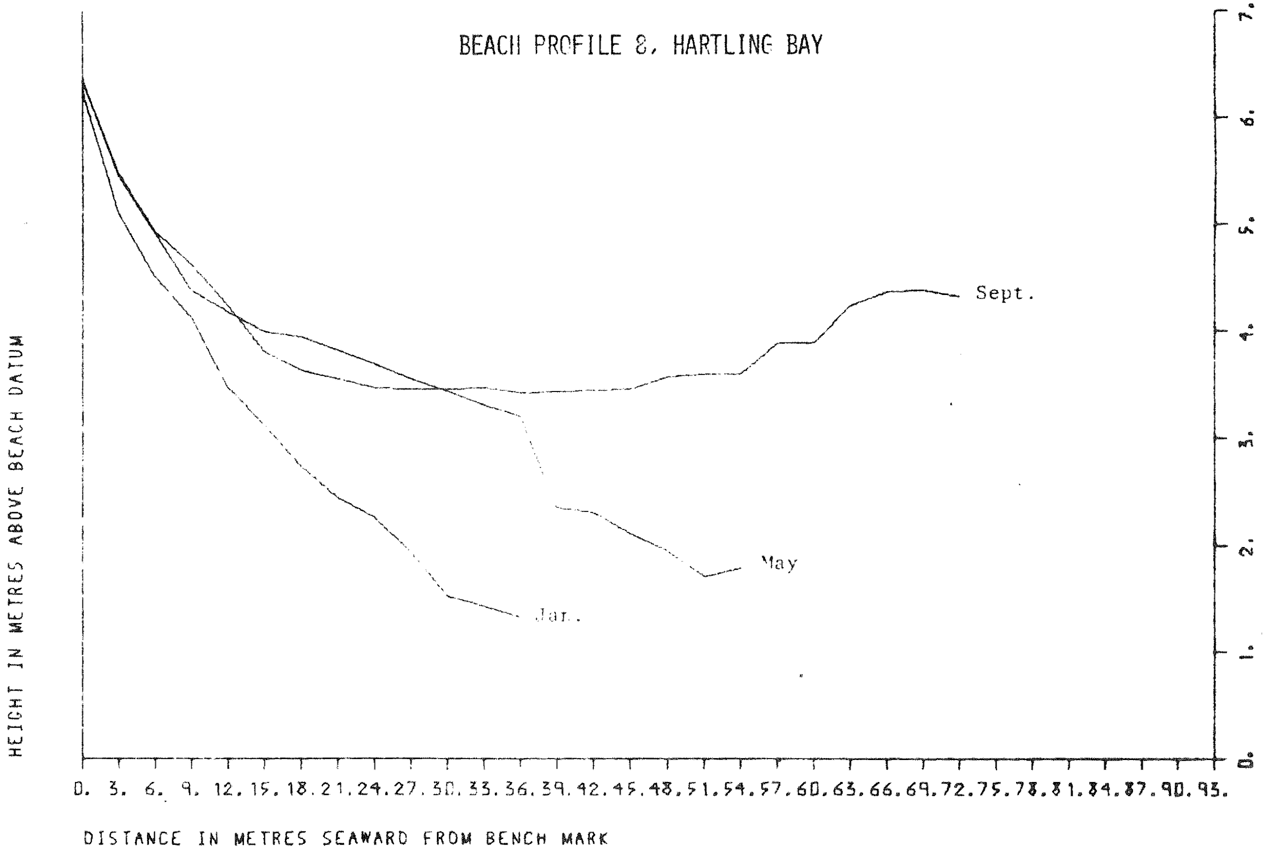

BEACH PROFILE 3, KINGS BAY
May
Sept.
Jan.
HEIGHT IN METRES ABOVE BEACH DATUM
0.
1.
2.
3.
4.
5.
6.
7.
0. 3. 6. 9. 12. 15. 18. 21. 24. 27. 30. 33. 36. 39. 42. 45. 48. 51. 54. 57. 60. 63. 66. 69. 72. 75. 78. 81. 84. 87. 90. 93.
DISTANCE IN METRES SEAWARD FROM BENCH MARK

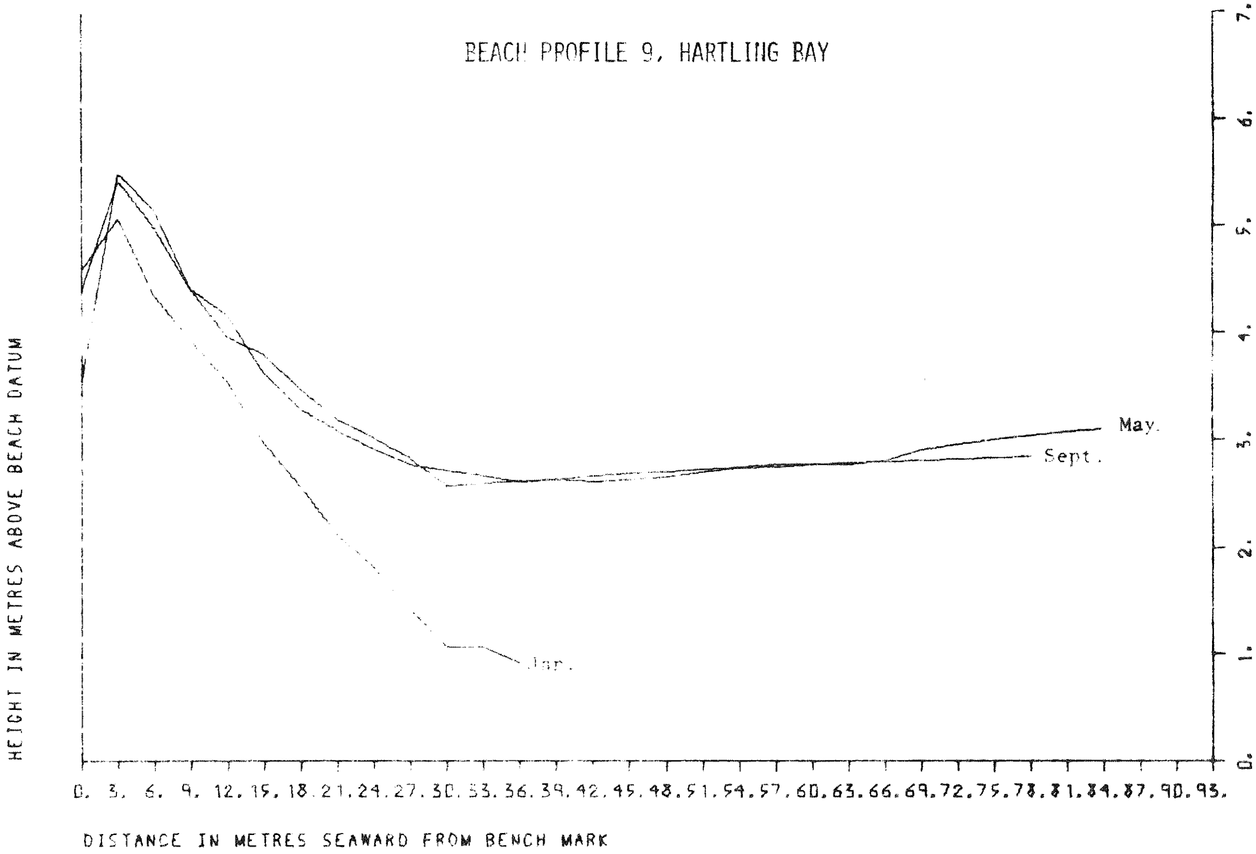

BEACH PROFILE 4, KINGS BAY
May
Sept.
Jan.
HEIGHT IN METRES ABOVE BEACH DATUM
0. 1. 2. 3. 4. 5. 6. 7.
0. 3. 6. 9. 12. 15. 18. 21. 24. 27. 30. 33. 36. 39. 42. 45. 48. 51. 54. 57. 60. 63. 66. 69. 72. 75. 78. 81. 84. 87. 90. 93.
DISTANCE IN METRES SEAWARD FROM BENCH MARK


BEACH PROFILE 5, HARTLING BAY

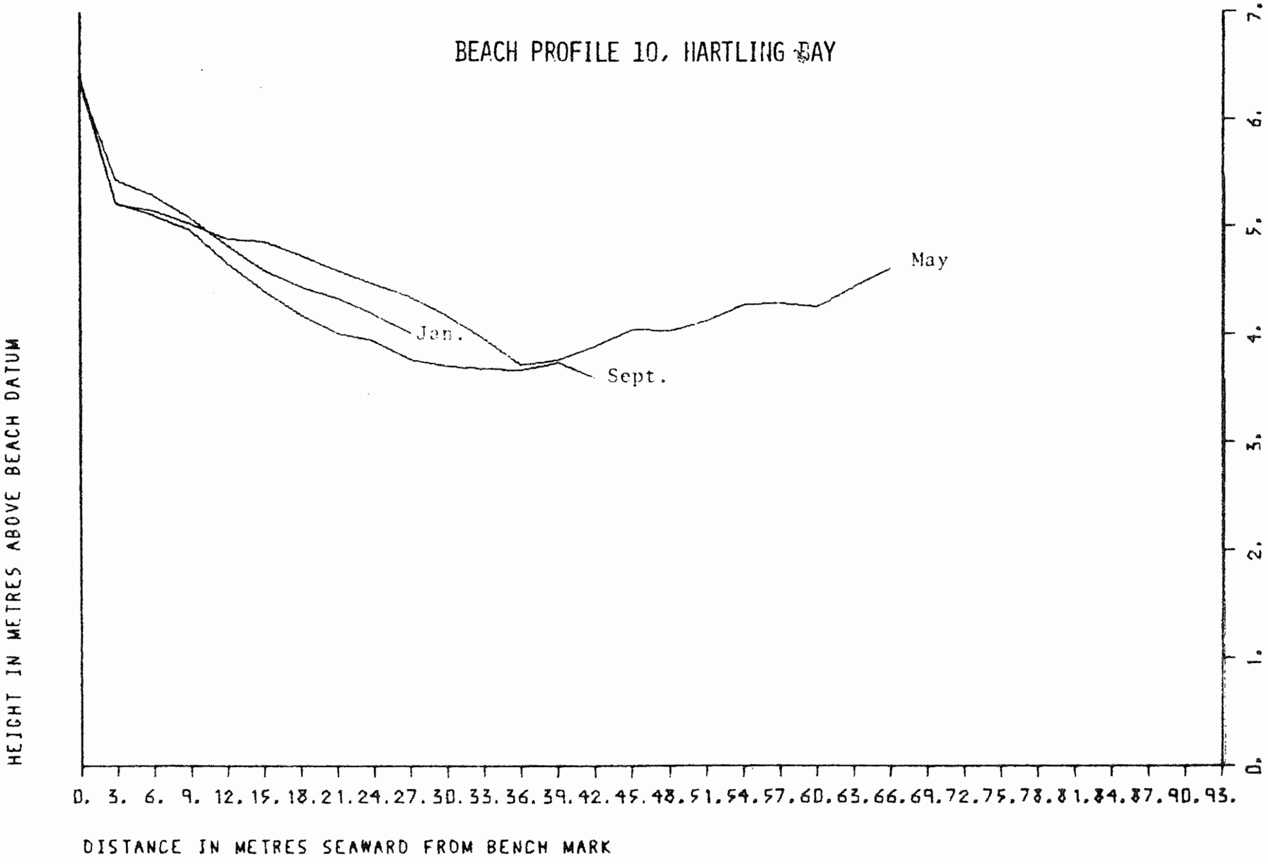

BEACH PROFILE 6, HARTLING BAY


BEACH PROFILE 7, HARTLING BAY
Sept.
May
Jan.
HEIGHT IN METRES ABOVE BEACH DATUM
0.
1.
2.
3.
4.
5.
6.
7.
0. 3. 6. 9. 12. 15. 18. 21. 24. 27. 30. 33. 36. 39. 42. 45. 48. 51. 54. 57. 60. 63. 66. 69. 72. 75. 78. 81. 84. 87. 90. 93.
DISTANCE IN METRES SEAWARD FROM BENCH MARK


BEACH PROFILE 8, HARTLING BAY
Sept.
May
Jan.
HEIGHT IN METRES ABOVE BEACH DATUM
0.
1.
2.
3.
4.
5.
6.
7.
0. 3. 6. 9. 12. 15. 18. 21. 24. 27. 30. 33. 36. 39. 42. 45. 48. 51. 54. 57. 60. 63. 66. 69. 72. 75. 78. 81. 84. 87. 90. 93.
DISTANCE IN METRES SEAWARD FROM BENCH MARK



BEACH PROFILE 9, HARTLING BAY


BEACH PROFILE 10, HARTLING BAY