CHAMPLAIN SEA SEDIMENTS AND LANDFORMS IN THE ALEXANDRIA MAP AREA

by

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ABSTRACT

Characteristics of the depositional environments were reached from the study of the textural features of the Champlain Sea sediments in Alexandria Map Area. Sediment mixing was correlated to the presence of ice sea cover. This fact impedes the effective use of the bivariate plots og grain size parameters for environment descrimination, which tell us about the limitacio of this method.

Depositional marine landforms indicate the importance of the coastal processes operating during Champlain Sea Episode, which were function of the position of the emerging land in relation to the prevailing winds and wave direction; submarine topography and the resistence of the material to the erosional processes.

The absence of glaciomarine or fluvioglacial outwash deposits in the area indicate that the glacier had retreated from the area at the time of Champlain Sea Episode.

RESUME

L' étude sédementologique des dépôts marins de la région d'Alexandria a permis la reconstitution des paléo-environnements. L'allure bimodale des courbes granulométriques souligne les mélanges dûs à la présence de glace de mer pendant une partie de l'année. Il est apparu que les méthodes graphiques traditionnelles utilisées en granulométrie sont inopérantes pour ce type de situation.

L'importance et les caractéristiques des formes de gradation littorales sur une côte en voie d'émersion doivent être reliées à la topographie pré-littorale et à la nature du matériel disponible. Elles permettent de plus de reconstituer les modalités de l'action des vagues et des courants littoraux ainsi que la direction des vents dominants.

L'absence de sédiments fluvioglaciaires ou glaciomarins dans la région montre que l'inlandsis devait avoir reculé substantiellement au moment de l' épisode champlainien.

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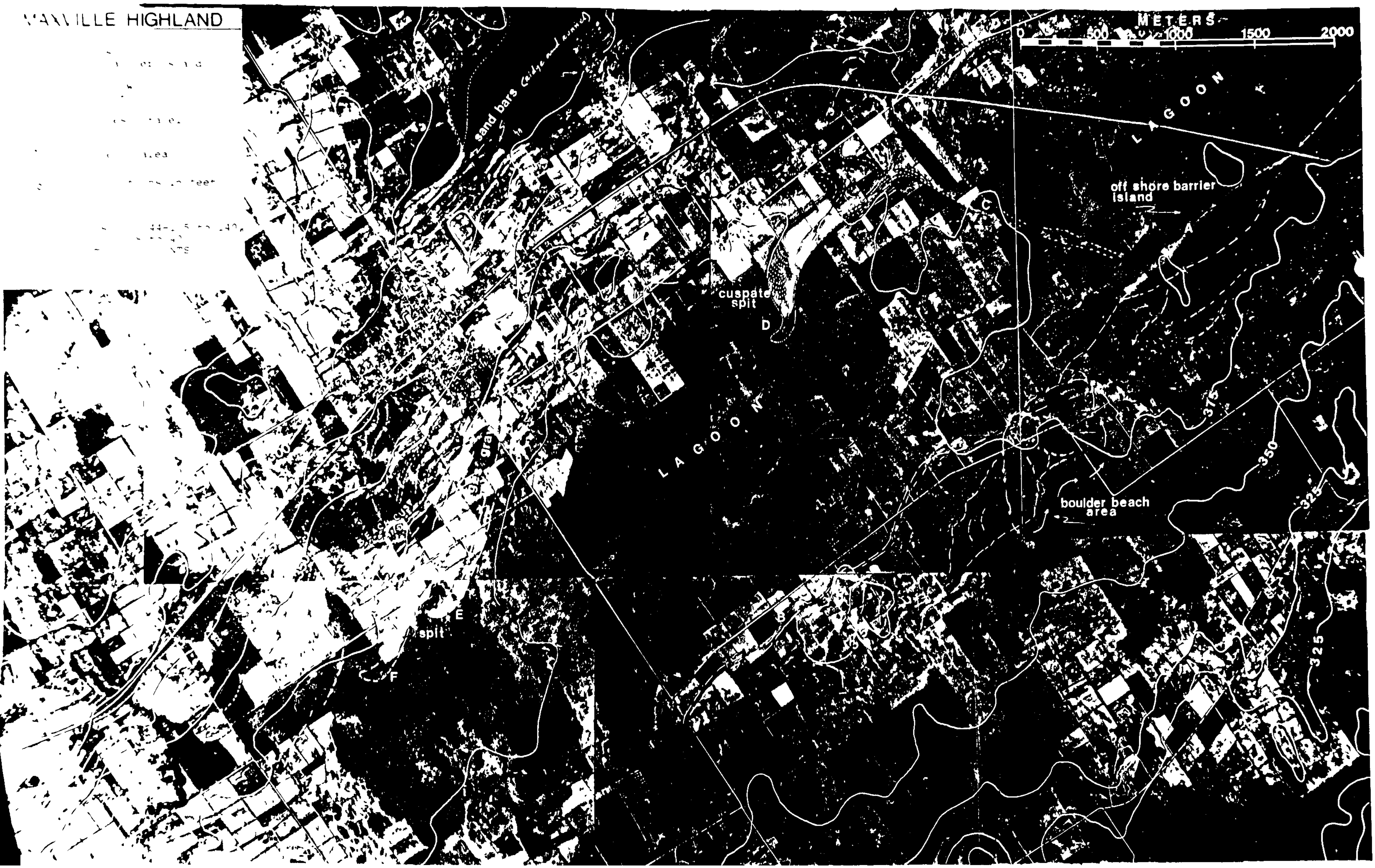

VILLE HIGHLAND
METERS
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CHAPTER I

INTRODUCTION

The purpose of this study is to do a paleo-geographical reconstruction of the environments during the Champlain Sea Episode in the Alexandria Map Area, and to show through the study of the marine landforms present, the importance of the coastal processes in this area.

The Champlain Sea is the name given for the marine invasion of one arm of the Atlantic Ocean West of Quebec City into the St. Lawrence-Ottawa River lowlands. The Champlain Sea was formed after the Laurentide glacier retreated from the Highland Front Moraine System in southern Quebec (Elson 1968a). Radiocarbon dating on fossil shells of this sea covered the period of extension of the Champlain Sea between 12,000 and 10,000 B.P. (Elson 1969). It covered roughly 50,000 km^2 in Ontario and Quebec in the St. Lawrence-Ottawa River lowlands (Elson 1968), see figure 1.

Despite the short duration of the submergence (less than 3,000 years) the marine deposits associated with it are an important element of the surficial geology of the St. Lawrence-Ottawa River lowlands, in which the Quaternary deposits are well recognized and mapped.

Towards the east of this former sea, in the central St. Lawrence lowland, gradational strong influences

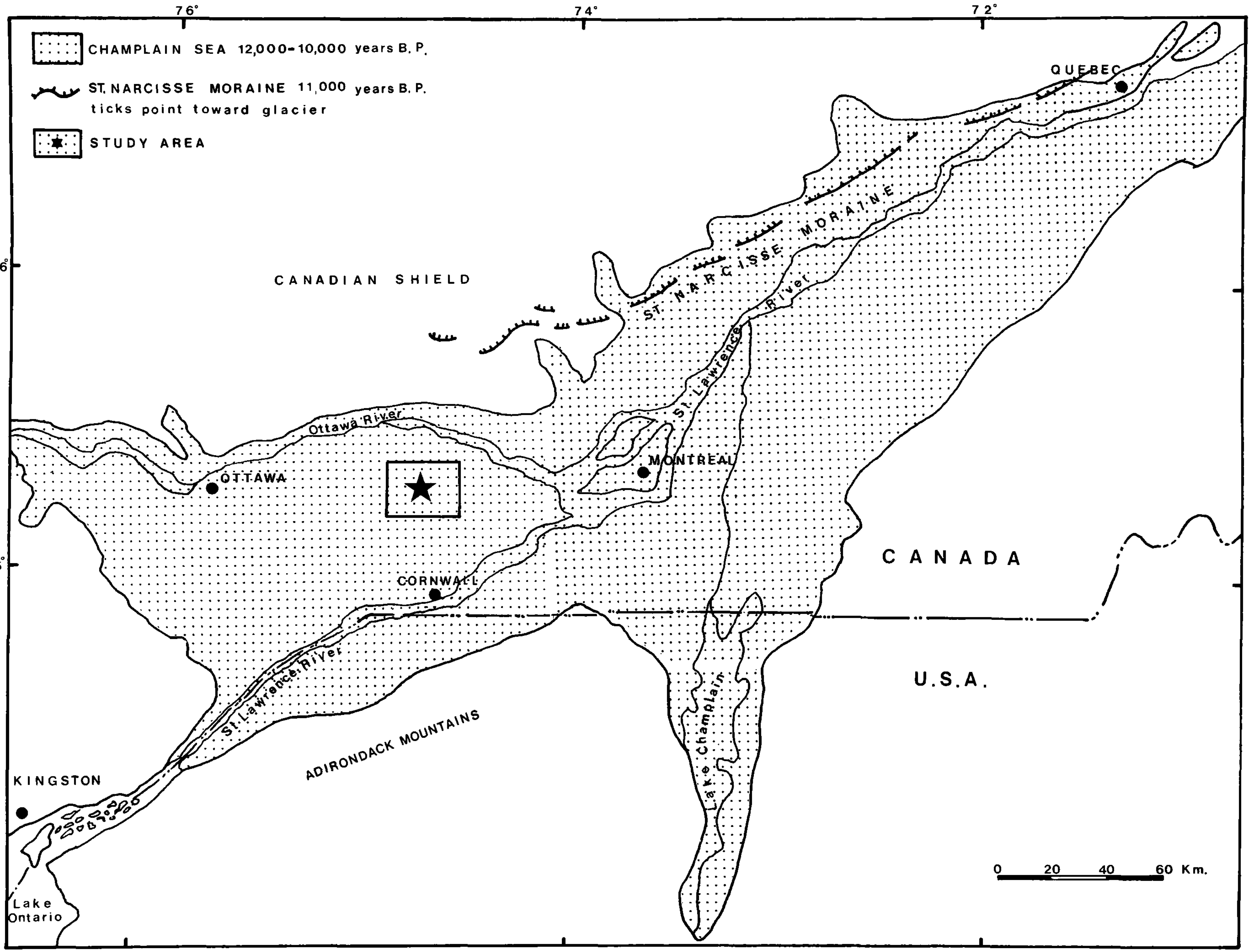


Figure 1 . Map showing the approximate maximun extent of the Champlain Sea. (After Elson (1968),and Denny (1974)

of the glacial in the sedimentary environments of the Champlain Sea has been established from the intertonguing relationship between glacial and marine sediments in the St. Narcisse Moraine (Gadd 1971). Towards the west in the St. Lawrence-Ottawa River lowlands the glacial deposits equivalent to the St. Narcisse Moraine will be found further north of the Ottawa River. However, recently, subaqueous outwash sediments due to the retreat of the glacier in water has been pointed out by Rust and Romanelli (1975); Rust 1977; Cheel 1979, in the Ottawa area. In the same area Hayward (1979) and Hayward and French (1980) have recognized a marine facies associated with the melting of ice buried by the subaqueous outwash sediments mentioned before, which they called "hollow-fill facies".

In the Alexandria Map Area no evidence of ice contact or outwash characteristics was observed in the deposit studied in this present work nor in the work of Gwyn and Lohse (1973a,b), which discount the influence of the glacial in the depositional marine environments as established in the Ottawa area. This fact is supported by the only C^{14} dating in the Alexandria Area (at Dornie) which gives an age of 9,910 ± 150 years B.P. for marine fossils sampled at 350 feet above sea level (Sharpe 1979); this means that at the time of deposition, the glacier had withdrawn from the area. For this reason, besides the study of the depositional environments made through the study of sediments we looked for the geomorphology related to the marine deposits. As Harrison (1977) stated, referring to studies of the coastal geomorphology associated with the Champlain Sea, there is no doubt that "during the time that elapsed between the first incursion of salt water and its disappearance, the emerging land was subjected to all those active processes generally studied under coastal geomorphology."

Location of the Study Area

The Alexandria Map Area (Nts 31G/7) is located in the southeastern part of Ontario. The coordinates of references are 74^{o} 30' and 75^{o} 00' of longitude west and 45^{o} 30' of latitude north. The area covers about 1,000 Km^2. The localities of Alexandria, Maxville, Moose Creek, St. Isidore de Prescott and the Alfred Bog are major points of references for the area (figure 2).

Physiography

The whole area is located to the east of the Frontenac axis (crystalline Precambrian rocks), in the area known as the Paleozoic-St. Lawrence Basin. The limit north of the basin is the Laurentian Highlands of the Canadian Shield, and the Adirondack Mountains to the south. The eastern border is defined by a lesser axis named the Beauharnois Anticline, which is covered with basal Paleozoic sandstone (Napean Formation) with the exception of the Rigaud area where Precambrian rocks outcrop.

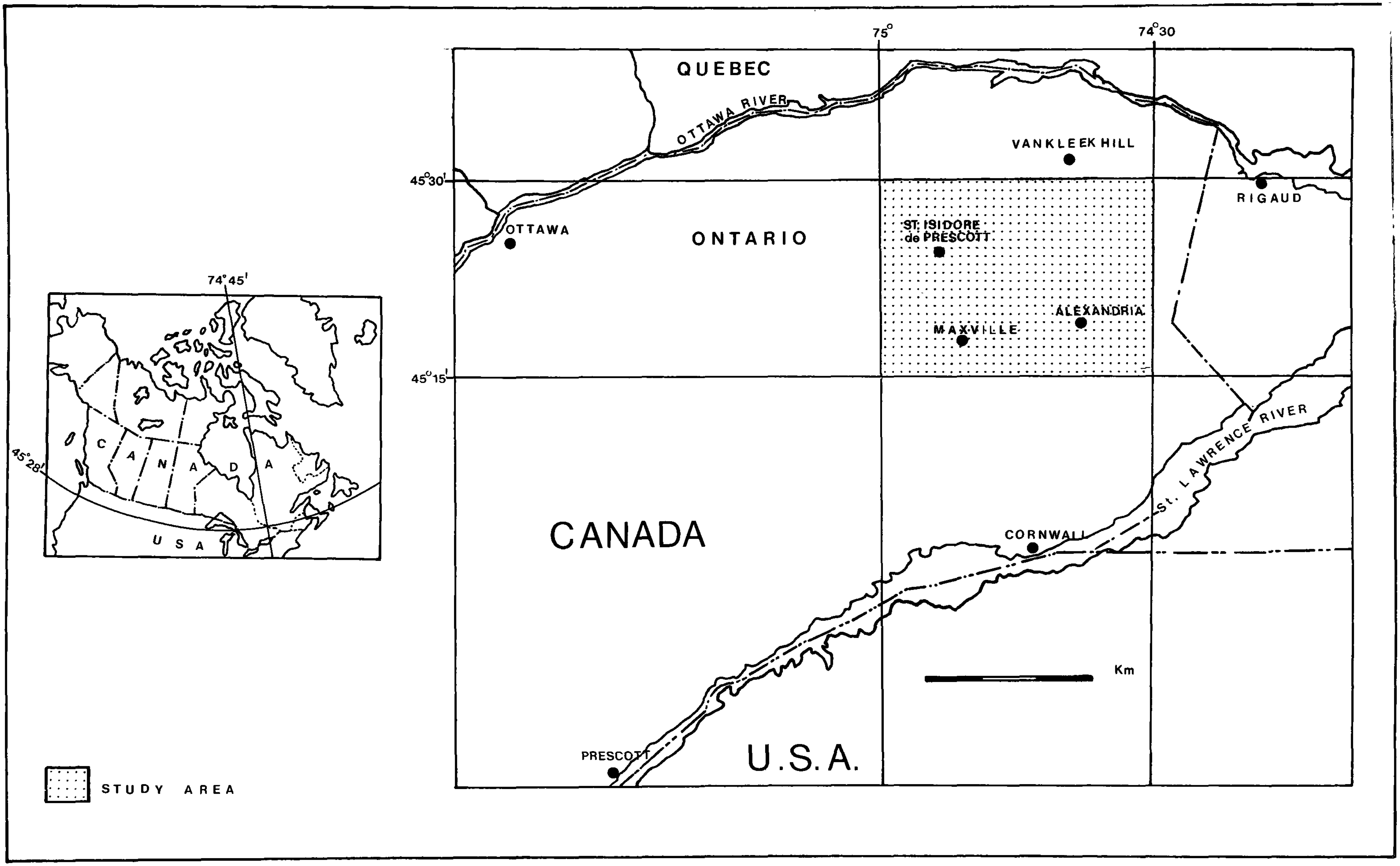


Figure 2 . Map showing the location of the study area.

The map area covers the drainage divided between St. Lawrence and Ottawa Rivers. More than 50% of the area is drained towards the basin of the Ottawa river especially through the sub-basin of the South Nation and Rigaud rivers. The topographic elevations in the area range from 175 feet (53 m) to 375 feet (114 m) above sea level. The whole area can be divided according to the topography, into two well-defined zones, the first includes elevations between 250 and 375 feet above sea level, where the topographic features are dominated by widespread hillock and low ridges (figure 3a). The second zone corresponds to the land below 250 feet (northwestern area of the map sheet) where the topographic features include flat land with localized bluffs, due to modern fluvial erosion on the deltaic and marine clay sediments (figure 3b).

Rock Outcrops

The bedrock in the area is predominantly limestone, with some small areas of shale and sandstone outcrops. The age of these rocks range from Cambrian to Middle Ordovician, Wilson (1946) see figure 4.

The map area is mainly covered by unconsolidated Quaternary deposits, as Pleistocene glacial till and marine sediments and recent alluvial and deltaic deposit. However, rock outcrops are found in the faulted blocks of the Ottawa and Oxford Formations, and where the streams have excavated the surficial deposits. Several of these outcrops are

A

B

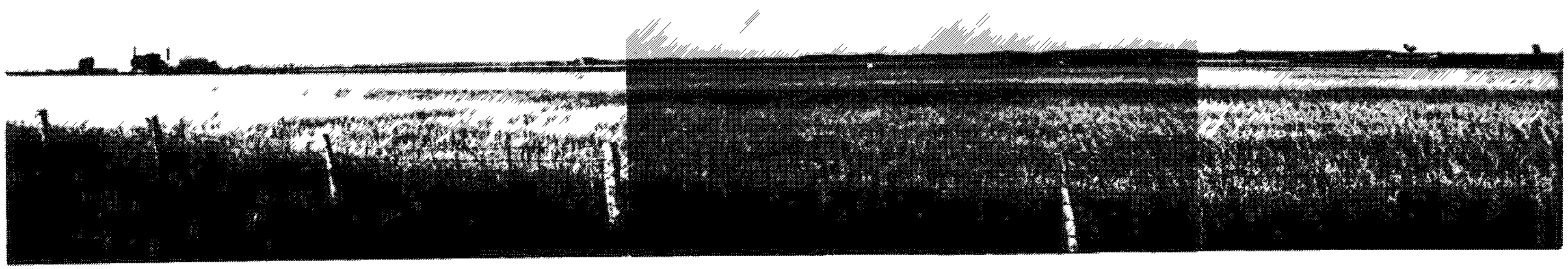


Figure 3. Topography features of the study area. A.= glacial deposit moulded by wave action
B.= flat topography characteristic of the land below 250 feet

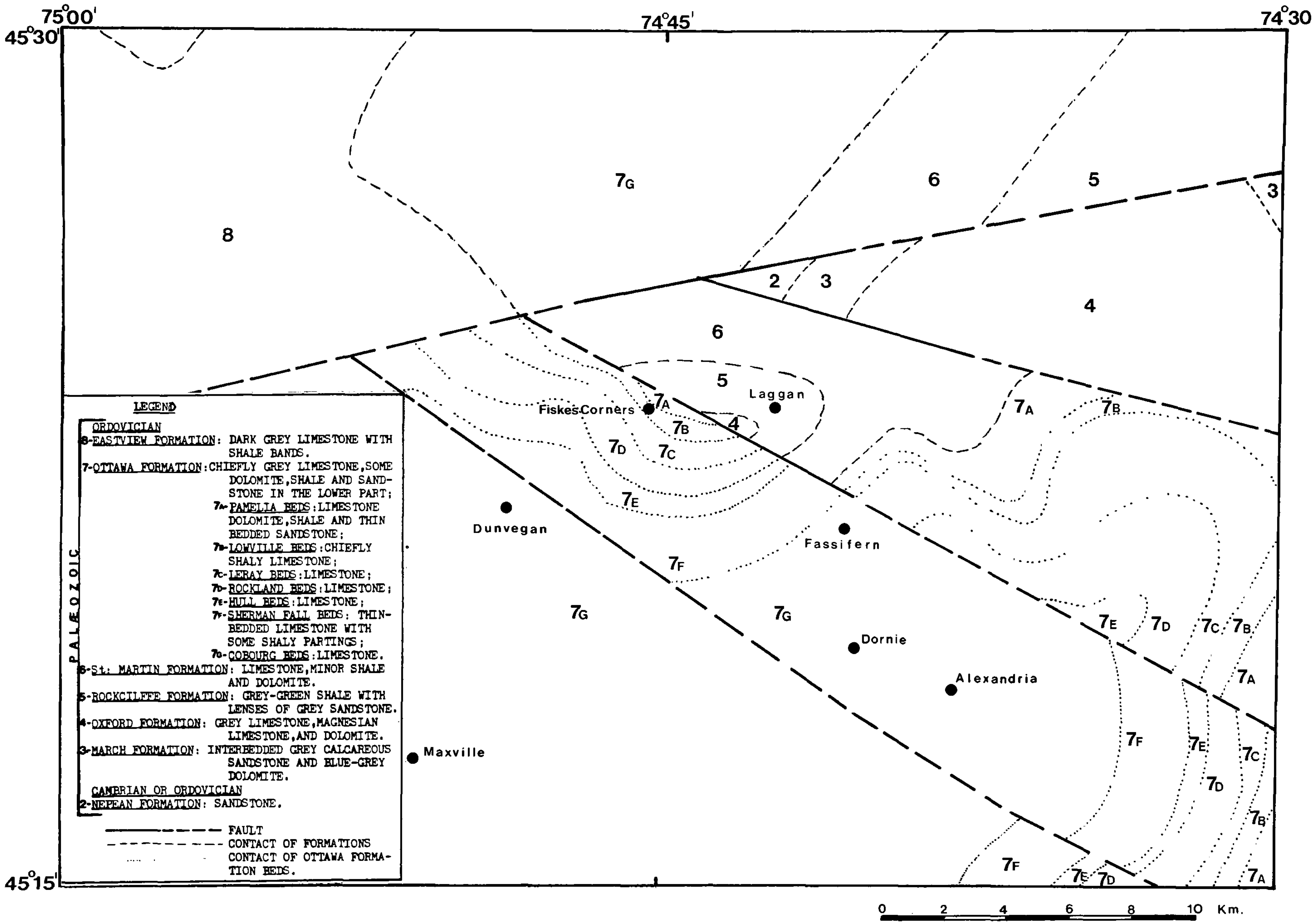


Figure 4. Geology of Alexandria Map Area. (after Wilson 1946, and Geological Survey Canada Map 1334A, 1977.)

exploited as quarry material.

The distribution of rock outcrops and their topographic position are shown in map 1 (in pocket). The land below 225 feet, the outcrops are scarce and are covered mainly by marine clay of the deep off-shore facies of the Champlain Sea and deltaic and fluvial sand, with the exception of the central east part of the map area where the outcrops correspond to the upward faulting block of the Ottawa formation. Here it has only a thin layer of silty-clay marine deposition and is exploited as a quarry. In this area towards the South National River, the bed rock topography is deeper than in the north as a function of the faulting blocks, and the excavation of pre-Pleistocene channel cut in the bed-rock as observed from the water well record information (see figure 16).

From map 1 it can be seen that the area between 225 and 300 feet of elevation is the area with the most prominent outcrop, which corresponds mainly to the Ottawa formation, and which as in the whole Ottawa-St. Lawrence basin is the most extensive and best exposed unit (Wilson 1946). It is important to say that most of the seven biostratigraphic zones identified by Wilson (1946) (the former seven members of the Black River, Trenton Formation) are present as bedrock or outcrops in the area (see figure 4). This is very important when we take into consideration the size of the limestone fragments found in the Quaternary deposits, which in most cases is a strong indicator of the local character of the glacial till, the principal source of sediment for the Champlain Sea coastal processes that followed the retreat of the Wisconsinian ice.

In the central-east part of the map area, in the periphery of Dunvegan, between 225 and 275 feet above sea level, there are large areas of bare rocks, (see map 1 and figure 5). These outcrops are almost horizontal stratas forming a flat floor with open joints, a product of dissolution process. This outcrop corresponds to the Cobourg bed of the Ottawa formation, see figures 4 and 5.

Another important outcrop is located between Fiskes Corner and Laggan at an elevation between 325 and 350 feet above sea level. Here the limestone is weathered in many small pieces. In this case, the outcrop corresponds to the Lowville beds of the Ottawa formation which are mainly shaly limestone, see figures 4 and 6.

With the exception of the area mentioned above at above 300 feet of elevation the rock outcrops are less important as most of them are exposed by the erosion of the surficial deposits by the local streams.

Glacial Drift and Landscape

A study of the glacial drift and the landforms associated with it is very important because it formed the pre-marine topography on which the coastal processes operated.

Figure 5. Area of bare rock, near Dunvegan. The outcrop corresponds to the Cobourg bed of the Ottawa Formation.

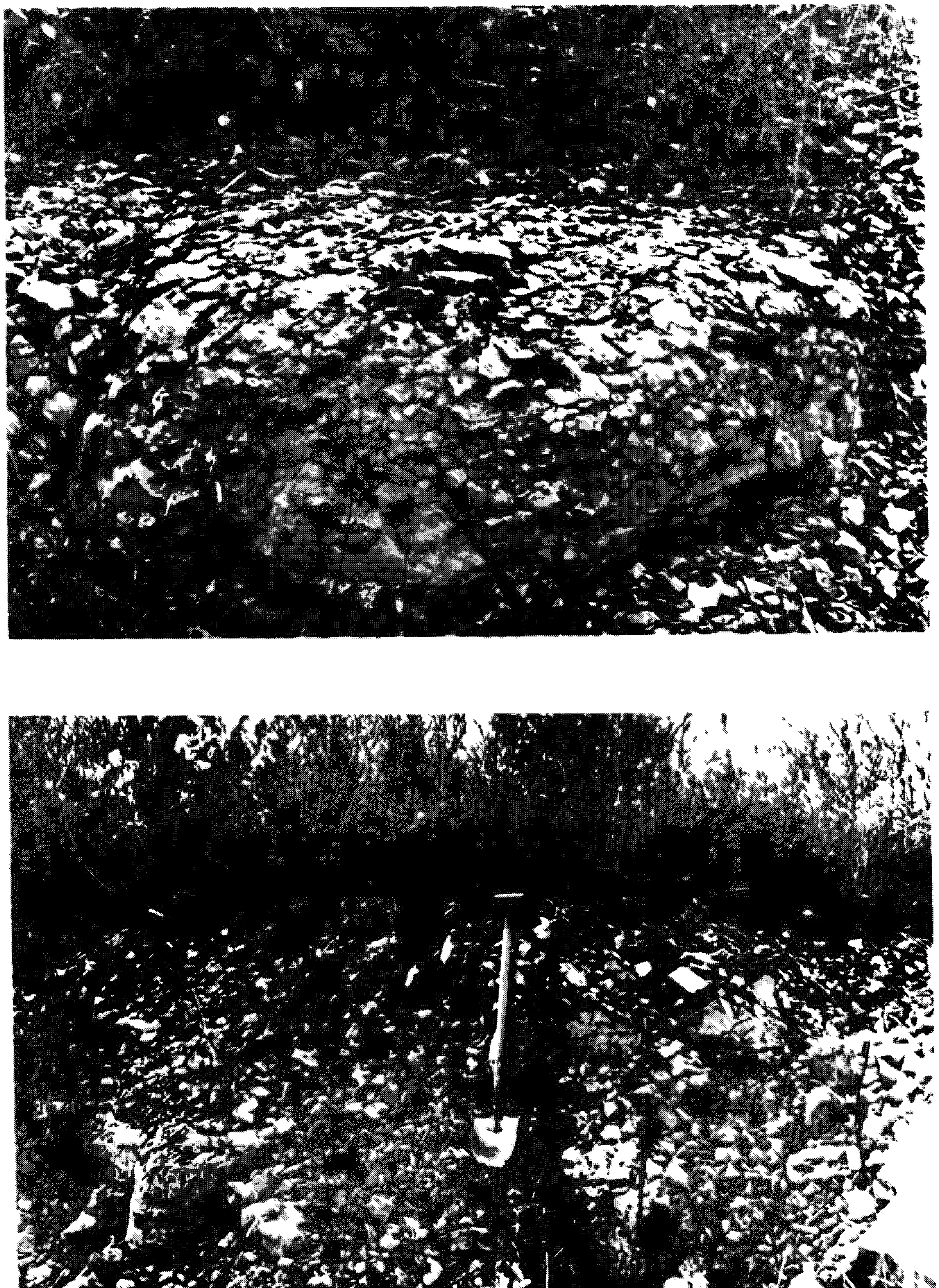


Figure 6. Outcrop of the Lowville Bed (shaly limestone) of the Ottawa Formation.

For the Alexandria Map Area only two specific references about the glacial landscape have been found in the literature review. Johnston (1916) observed that "..... between Ottawa and Montreal, a strongly marked kettle moraine or series of moraines, showing characteristic knob and basin topography, extend south westward from a point of the Ottawa River a few miles below Hawkesbury through Alexandria and beyond, towards the St. Lawrence River. This moraine or series of moraines appear to mark the culmination of slight readvance of the ice during the latest stage of Pleistocene glaciation." On the other hand, Chapman and Putman (1966) said that the stony ridges of Glengarry and Stormont counties (most of the 95% of the land above 225 feet elevation in the map area belong to these two counties) are planed and moulded into ridges and for this reason they are mapped as till plains rather than moraines because of the smoothing of their surfaces owing to wave action.

The last of the above descriptions appears to be more true of the topographic features observed during the detailed field work.

Above 300 feet of elevation the till has mainly been reworked by the combined action of wave and current and for this reason the glacial landforms if they existed before the Champlain Sea Episode, have not been preserved.

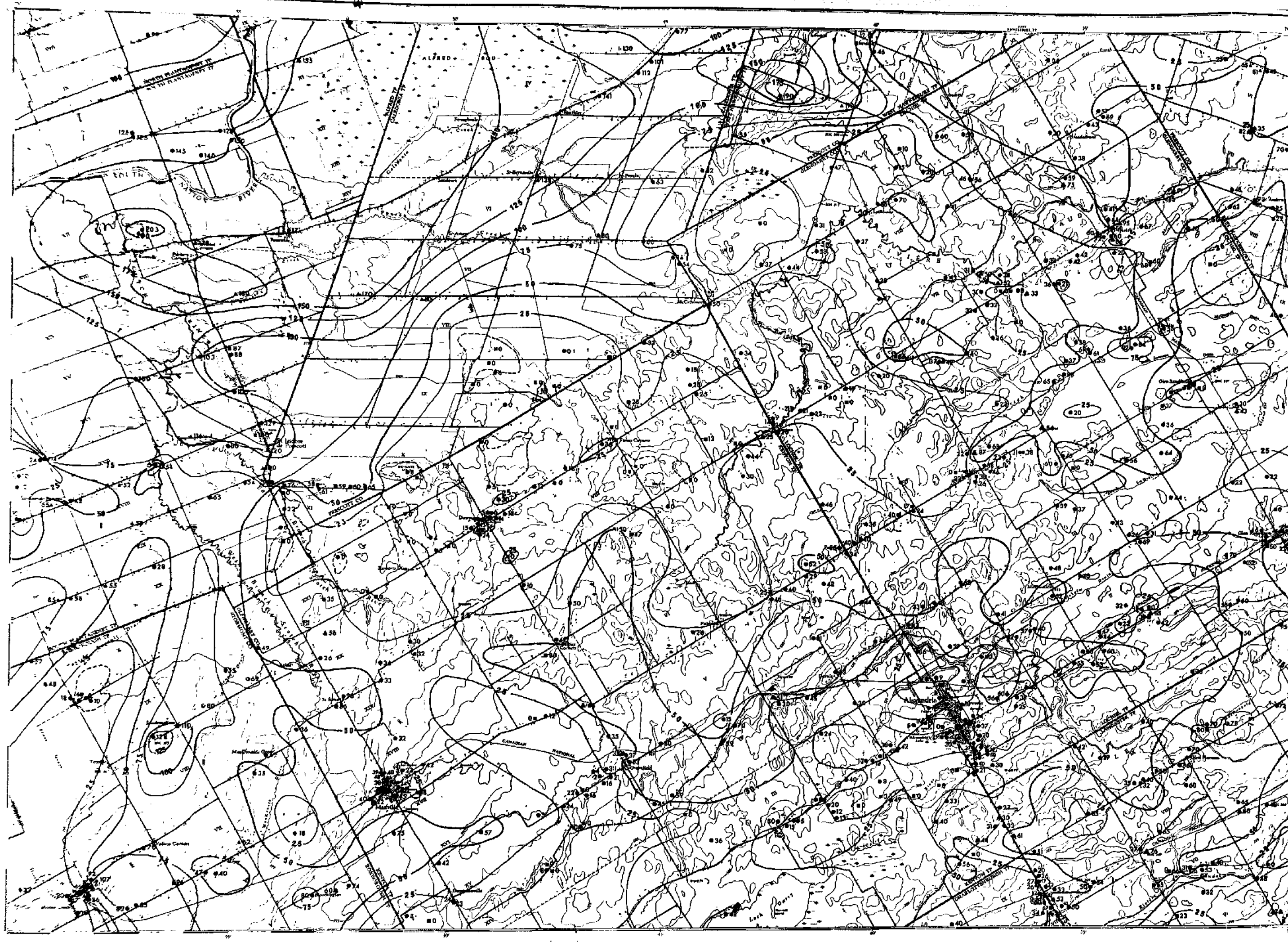
Below 250 feet elevation the till is buried by fine sediment (silt-clay) off the deep offshore facies of the

Champlain Sea. In many places of the northwest corner of the map area, the till does not exist in the stratigraphic sequence as revealed by the water well record (Water Resource Report , 1978) or in several outcrops (see figures 16 and 7).

The till thickness in the area is a function of the bedrock topography which controlled the original glacial deposition. Comparing the map of total drift thickness to the map of bedrock topography (figures 8 and 9), it can be observed that the drift thickness is very thin or does not exist in the central part of the map area, which corresponds to the faulted block of the Ottawa Formation. Drift thickness becomes thicker where the pre-Pleistocene streams or glacial erosion built depressions are suitable for thicker drift accumulation. Here it can be more than 50 feet thick (16 m) and in several places up to 80 feet (25 m) as revealed by water well records.

Fluvioglacial deposits and related landforms were not observed on the surface during the field work. However, water well records reveal the presence of fluvioglacial gravel below the Wisconsinian till for many places in the area. These deposits can be attributed to the front of the glacier prior to the advance of the ice. The presence of this oldest deposit has been mentioned by Owens (1951) for the Cornwall-Cardinal Area, but the stratigraphic position of these deposits are not the same; because in most cases, the deposits reported by Owens (1951) were overlaid by marine clay.

Figure 6. Marine clay resting over the Ottawa limestone Formation, near St Isidore de Prescott (elevation 225 feet).



DRIFT THICKNESS

ALEXANDRIA MAP AREA

SYMBOLS

● 67 — Water well which reaches bedrock with drift thickness in feet.

▲ 78 — Water well which does not reach bedrock with minimun drift thickness in feet.

■ 0 — Small bedrock outcrop

Area of bedrock outcrop

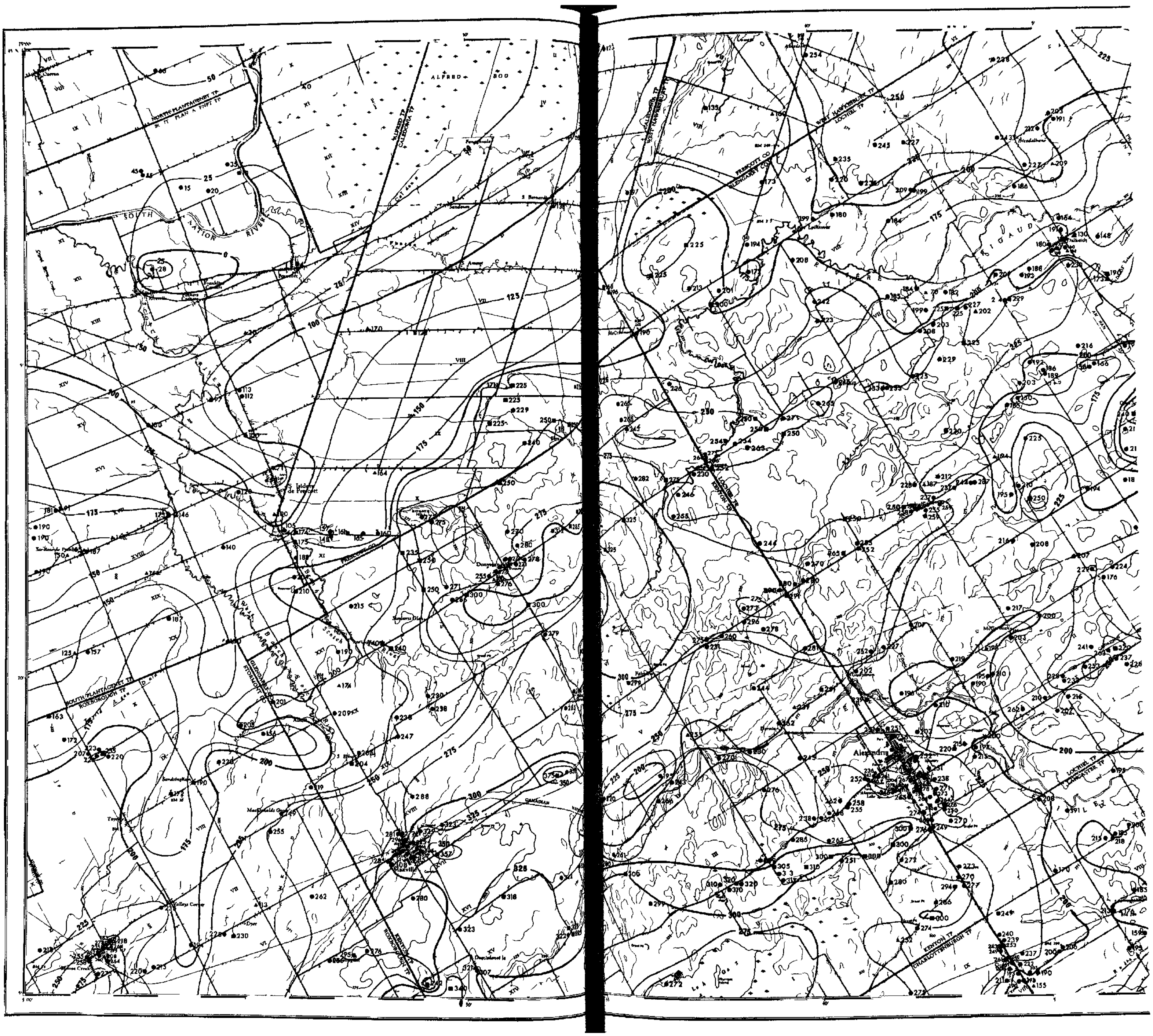
—25— Contour line of drift thickness (interval 25 ft.)

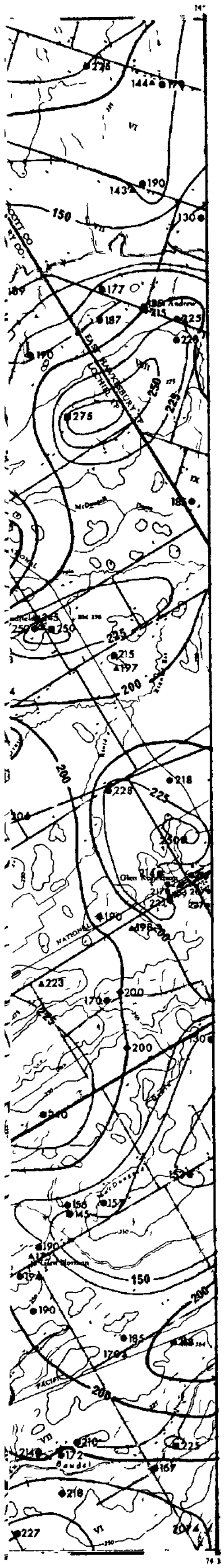
Map by Gwyn and Thibault, 1973. Ontario Div. Mines, Prelim. Map P.910.

Miles 1 0 1 2 3

Km. 0 1 2 3 4 5

Fig. 8 Drift Thickness. ALEXANDRIA MAP AREA.


NORTH PLANTAGENET TP
ALFRED
SOUTH NATION RIVER
ALFRED TP
CALEDONIA TP
PRESCOTT CO
GLENGARRY CO
WEST HAWKESBURY TP
LOCHIEL TP
SOUTH PLANTAGENET TP
ROXBOROUGH TP
KENYON TP
Alexandria
CHARLOTTENBURGH TP
LANCASTER TP



BEDROCK TOPOGRAPHHY

ALEXANDRIA MAP AREA

SYMBOLS

● 135 — Water well which reaches bedrock with elevation of bedrock in feet.

▲ 85 — Water well which does not reach bedrock with elevation of bottom of well in feet.

■ 325 — Bedrock outcrop with elevation in feet.

—175— Contour line of bedrock topography (interval 25 ft.)

Map by Gwyn and Girard, 1973. Ontario Div. Mines, Prelim. Map P.908.

Miles 1 0 1 2 3

Km. 0 1 2 3 4 5

Fig. 9. Bedrock Topography of The Alexandria Map Area.

The absence of ice frontal and ice contact deposits in the Alexandria Map Area is an important phenomena if we want to make a geographical correlation of continuity with the adjacent areas. This kind of deposit was not reported to the East outside of the map area (Gwyn and Girard, 1975). For the north outside of the map area only one deposit of ice-contact stratified drift has been found, to the east of Hawkesbury, where no till was associated with the material, yielding the hypothesis that these sediments were deposited during the retreat of the glacier (Gwyn and Thibault, 1975). To the East outside the map area, only three small ice contact deposits have been found (Gadd 1963). Towards the south (Cornwall area) the surficial deposits of glacio-fluvial origin of insignificant volume and extent have been reported by Terrasmae (1965).

This is very important if we are to take into account that in the eastern area of the whole Ottawa-St. Lawrence lowlands, the fluvioglacial, ice contact and ice frontal deposits have been reported as an important unit in the surficial deposit maps (Gadd 1963, 1976; Richard 1970, 1971, 1972, 1976a, 1976b; Richard and Gadd 1976; Vincent 1976).

Gwyn and Thibault (1975) suggest that the absence of these kinds of deposits on a regional level indicate that the ice retreated rapidly without a prolonged period of stagnation from further east of southern Ontario.

We agree with this view and will add that if fluvioglacial deposits existed on surface prior to the invasion of the marine water in the Alexandria Map Area, they were reworked completely by the wave action and coastal processes which operated especially above 300 feet of elevation. Below this elevation the possible deposits were buried by the fine material coming from the reworked glacial deposits. A similar situation has been reported in the Merrickville Map Area (Sharpe 1979), where the beach deposits are an important unit in the surficial deposits above 300 feet of elevation. No unaltered fluvioglacial deposits have been observed.

Till Features and glacial movement

Considerations about the till features in the area are important because it was the most important source of material from which marine deposits derive.

The St. Lawrence-Ottawa River lowlands were not affected by the lobal activity of the ice front during the middle Wisconsin Interstade, as were other parts of Southern Ontario (e.g. Lake Ontario basin), for this reason, the glacial deposits are of late Wisconsin Age, which means that the area was not deglaciated until the end of the Wisconsin glaciation (Dreimanis and Karrow, 1972).

Gwyn and Lohse (1973) in base to geographical continuity, the same textural features and stratigraphy position

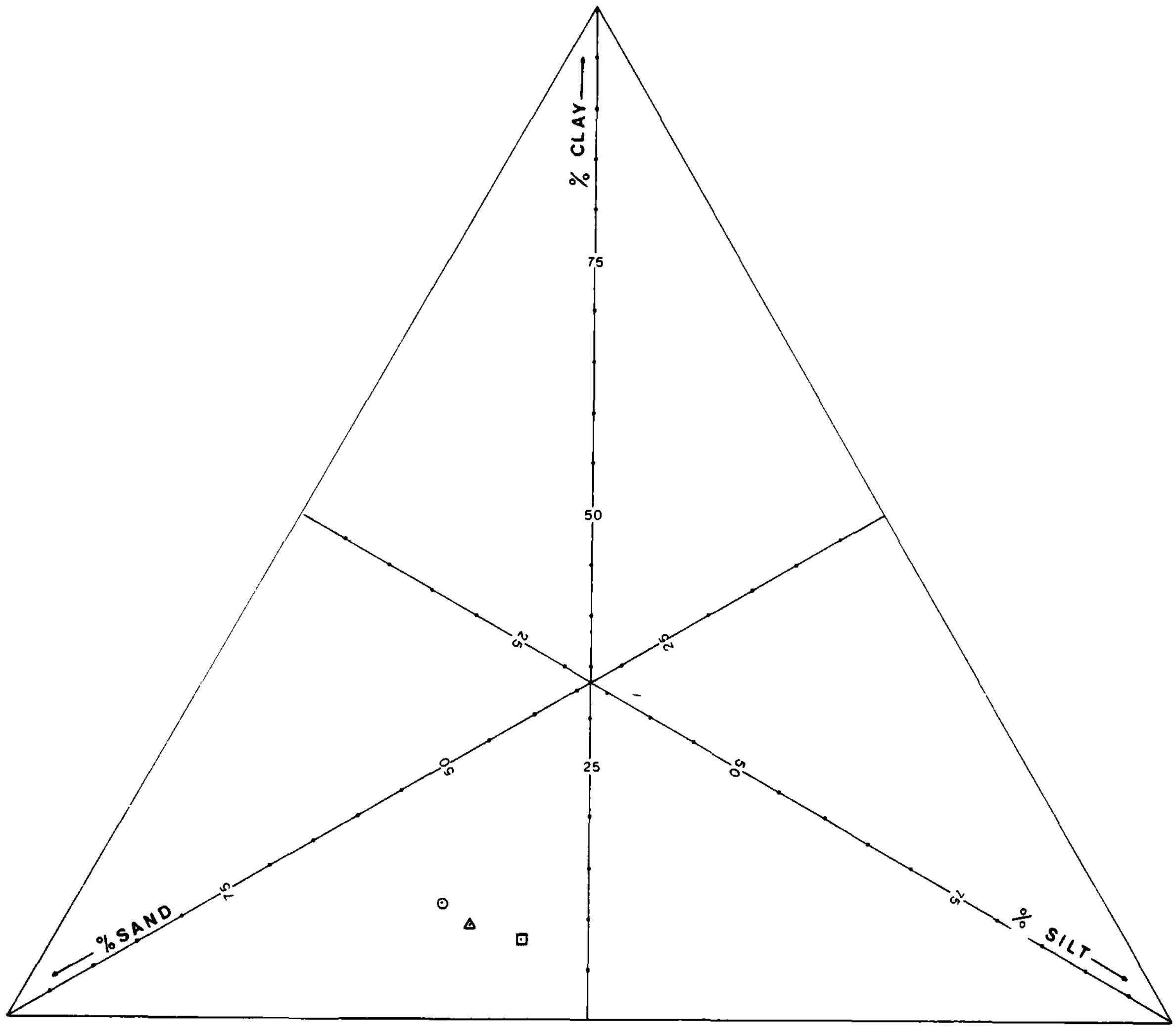
Location	Elevation	Rock type % Limestone	% Crystalline	% Sandstone
North of Sandringham	300 feet	95	5	0
Dunvegan	300 feet	100	0	0
Northwest of Lochinvar	325 feet	96	4	0
Southeast of Glen Norman	275 feet	100	0	0

Table 1 . Petrographic analisys of till, size class of the pebble fraction 6-12 cm.

have correlated the till of the Alexandria Map Area with the till of the Cornwall area, which according to Terasmae (1965) is equivalent to the Fort Covington till in New York State (McClintock, 1958).

The lithology of this till reflects the local bedrock before described, especially in the pebble fraction which we studied in five localities. It gives high values for the pebble limestone fraction. The low percentage of crystalline pebbles is explained by the fact that Precambrian crystalling rocks weathered to boulders and then to sand without the formation of abundant pebble size clast (Denny 1974), see table 1. The influence of the crystalline Precambrian rocks are more evident in the sand fraction, as shown by the percentage of the quartz-feldspar fraction.

Textural analysis of some till samples in the Alexandria Map Area shows that the matrix is sandy silt (see figure 10) which is in accordance with the same till as reported in Cornwall (Terasmae 1965) and Merrickville (Sharpe 1979) areas. According to Terasmae (1965) "the higher sand content in the Fort Convington till is consistent with the established ice-flow direction from the northwest where sandy till are predominant." We will see later that the sorting values of the sand beaches coming from this till will be a function of the effectiveness of wave and current in separated different sand size class present and silt-clay fraction.



△ Fort Covington Till Alexandria Map Area, mean value for 5 samples.

□ Fort Covington Till in Merrickville area, mean value for 22 samples. (Source Sharpe 1979.).

○ Fort Covington Till in Cornwall area (Source Terasmae. 1965.)

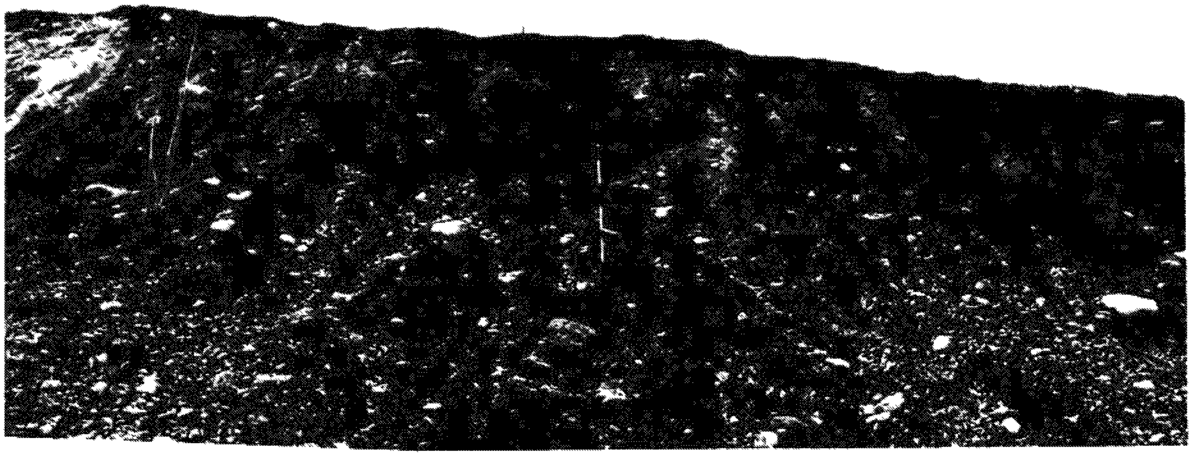
Figure 10. Textural diagram for Fort Covington Till.

In relation to the boulder fraction direct observation of till outcrop (see figure 11) up to 5 m. thick, did not show big boulders of crystalline rocks. On the other hand, big crystalline boulders could be observed everywhere in the coarse gravel beach deposits, and the presence of these boulders have been considered to be the residual produce as a result of the wave wash action on the till (Karrow 1961; Gadd 1971; Terasmae 1965), this is not, however, consistent with the observed feature. Ice floating transported boulder material should be taken into consideration when evaluating big boulder presence. The big boulders of local limestone which were observed especially in the central north part of the map area were angular indicating their local derivation.

No measurement of stria directions or till analysis were made (during the field work) as the data has already been provided by Gwyn and Lohse (1973), who give three directions of ice movement: from the north, from the northwest and east-northeast. These movement directions corroborate the movement observed by Owens (1951), Terasmae (1965), Gwyn and Thibault (1974) and Richard (1975) for the surrounding Alexandria Map Area. According to Terasmae (1960) the east-northeasterly striaes are the oldest and the north are the youngest.

Stone distribution by size class and origin in 29 gravel pits of gravel beach, which are reworked till in place or transported by longshore currents suggest a trend

A



B

Figure 11. Open pits in till deposit.

roughly in concordance with the general direction of the ice movement shown by the glacial striae and till fabric analysis, especially the sandstone fraction. The crystalline boulders present in the surface, appear to represent a direct relationship between the crystalline percentage of rock and drift thickness (see figures 8, 12 and 13). That is, we can usually see that with a decrease of drift thickness there is also a decrease of the percentage of crystalline boulders. Where the drift thickness is very thin, boulders are almost exclusively of local limestone. It can also be observed that crystalline rocks do not have a definite trend and its percentage always (regardless of the size) increases with increased elevation. This supports somewhat the hypothesis that much of this material is ice-floating transported material.

The direction of transport seems to be more clearly indicated by the distribution of the sandstone fraction of the Nepean Formation (size class 32-64, figure 12). In general, we can observe a N-S and northeast-southwest direction which reflects to some degree the direction of the original glacial movement and deposition. The source of this sandstone could be the outcrops east of Ste. Anne de Prescott or the outcrops further east in the Rigaud Mountain.

However, the boulder distribution of the limestone fraction is a direct function of the outcrops present in the Alexandria Map Area as can be seen when figures 12 and 13

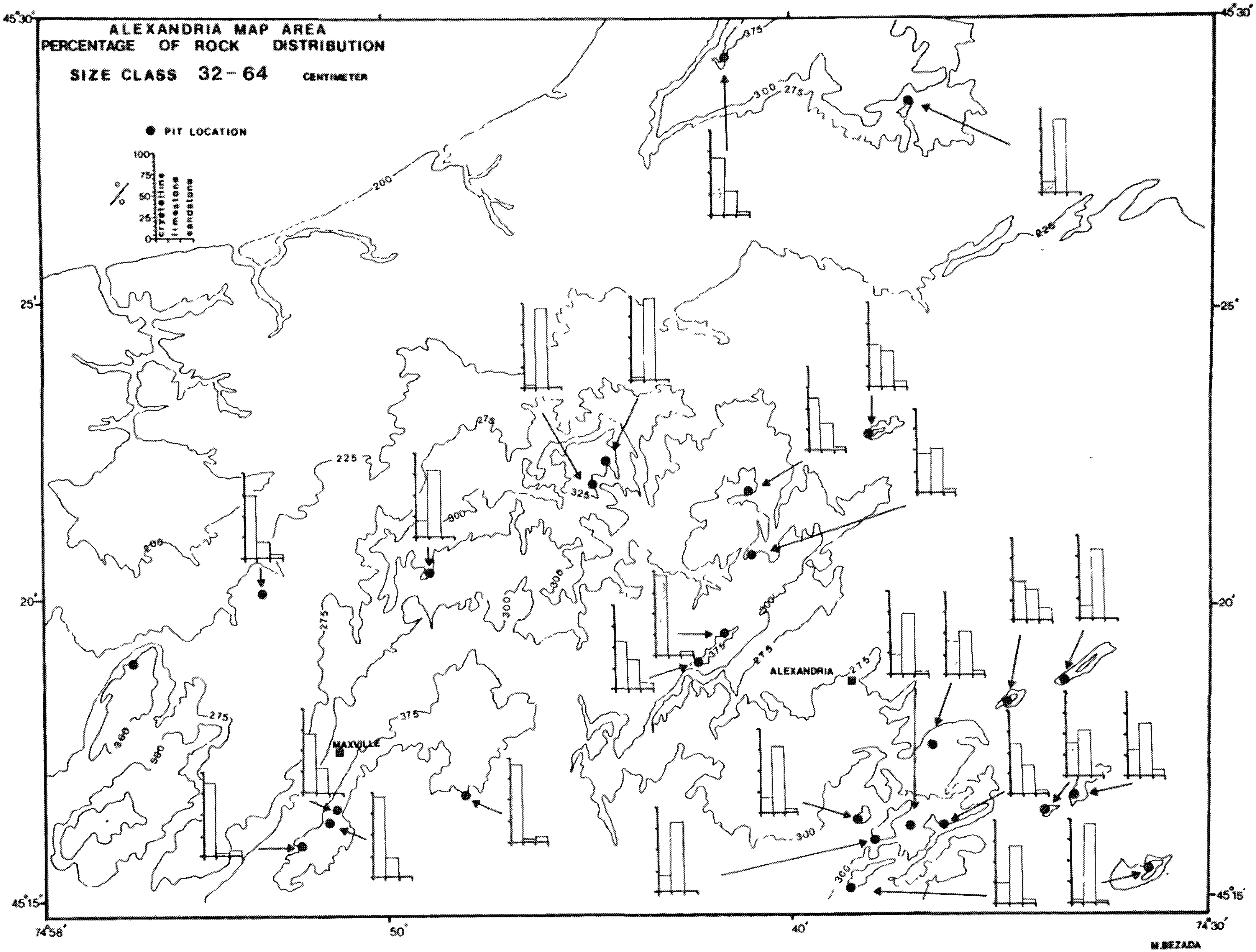


Figure 12 . Percentage of rock distribution in the boulder-gravel pits of Alexandria Map Area. (size class 32-64 cm.)

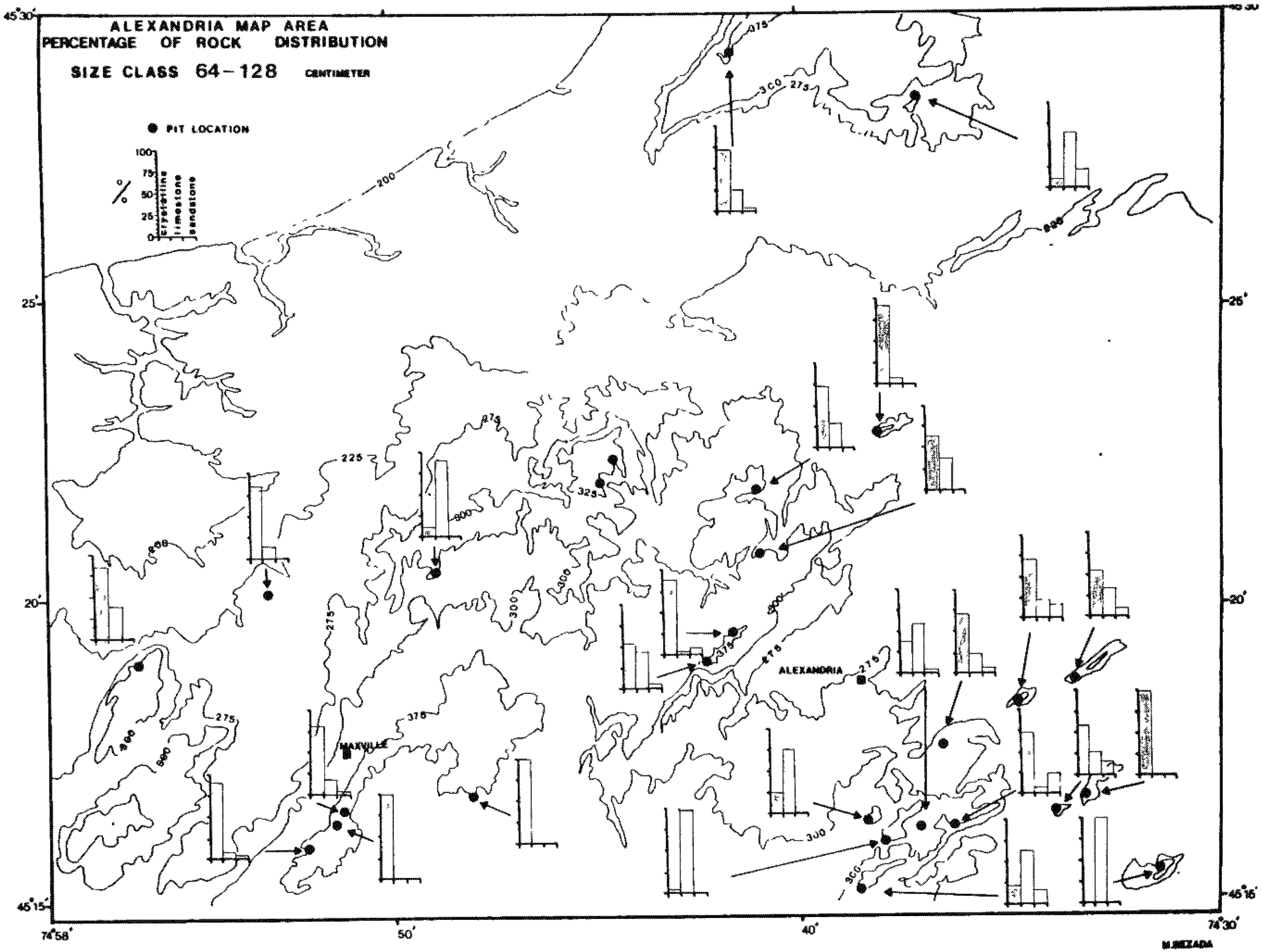


Figure. 13. Percentage of rock distribution in the boulder-gravel pits of Alexandria Map Area. (size class 64-128 cm.)

are compared to the map of rock outcrop (see map 1). Thus, no definite trend can be established.

Finally, if the trend of topography of the reworked glacial deposits is a reflection of the direction of ice movement, we can observe in map 2, that the general trend is approximately NE-SW in the east section of the map and NS in the western area. This would also support the indicated directions of different glacial movement or represent shift direction of ice movement as a result of the bedrock topographic control at the time of glacial deposition.

CHAPTER 2

METHODS AND TECHNIQUES

To assess the paleo-environments of the Alexandria Map Area, during the Champlain Sea Episode, and to study the marine land forms built in it, a study of the pre-marine topography and their sediments source will be very important, as they were factors determinant in the spatial distribution and sediment features of these marine deposits.

The paleo-environment features at different elevations were established from the textural feature of the sediments; the various depositional landforms were recognized, classified and their spatial distribution and morphological features determined.

Besides an extensive field study, several field and laboratory techniques, common to geomorphological research were used, as well summarized by King (1966):

> "Geomorphology is essentially a field study; the emphasis has, therefore, been placed on field work. However, not all the problems can be solved in the field, partly because of the great complexity of geomorphological processes in nature; other methods of attacking the problems must be considered. .... Statistical techniques play their part in many stages of study; they provide a sound basic for field sampling, for assessing the significance of the results and for establishing correlations. The laboratory analysis of

> sediment samples can often provide data that are of considerable geomorphological significance. Empirical relationship can often form a useful preliminary analytical study and can be set up both from field observation and cartographic analysis; but to be of value they must depend on quantitative measurement."

The techniques used in the data collection to make the interpretations and develop the conclusions about the environments, landforms and processes in the study area are summarized below.

Grain Size Analysis, Method

The analysis of the sample was performed in the fine fraction (below 2 mm) and sieve and pipette were the methods used. A sieve gradient of the 1/2 phi (Ø) intervals was employed, and the samples were sieved on soiltest sieve shakes machine model (Cl-390-K) for 20 minutes, using the Canadian Standard Sieve Series.

If material below than 4 Ø (62.5 microns) were estimated to be 5% or less the percentage by weight they were dried at room temperature, disaggregated and approximately 100 grams sieved. On the other hand, if the fraction below 4 Ø was estimated to be more than 5% by weight and with substantial clay size material, wet sieving was performed through a 4 Ø sieve; the coarse material (over 4 Ø) was then oven-dried, disaggregated and sieved, and the silt-clay fraction analyzed by the pipette method, following the Galehouse (1971) procedure. According to Folk (1968) the wet sieving method, although it is slow and messy, is probably the most accurate way to separate the sand from the silt-clay fraction.

Using a chemical balance each sieved sand fraction, by size interval, was weighed to the 0.01 grams and the weight of each of the silt or clay fraction coming from the pipette analysis, weighed to the 0.001 grams.

To obtain the grain size parameters, the graphical method was used, which according to Folk (1966) is faster than the mathematically method (moment method) and equally valid for comparing a series of samples for environmental depositional interpretation. The weight in grains by sieve intervals and pipette analysis was transformed to percentage to draw the cumulative curve on a paper with gaussian probability ordinate, and this allows one to read the statistical parameters, the interpretations and the extrapolation with greater accuracy and ease than paper with arithmetic ordinate (Folk 1968).

Phi (Ø) unit measurements were taken from each of the cumulative curves at the Ø 5; Ø 16; Ø 25; Ø 50; Ø 75; Ø 84 and Ø 95 percentiles and punched in cards for the computer calculations of the grain size parameter discussed below (RESULT Appendix A).

Statistical Parameters used in this Work

For environmental interpretation from the grain size analysis, the graphic measure proposed by Folk and Ward

(1957) were used. These parameters are in a sense the same proposed by Imman (1952), but include more points in the curve. The following are the Folk and Ward parameters:

<u>Measure of Average Size</u>: Graphic Mean (Mz)

$$Mz = \frac{(\phi\ 16 + \phi\ 50 + \phi\ 84)}{3}$$

The graphic mean is a measure of average grain diameter. The ϕ 16 is considered as the approximate average size of the coarse third of the sample, and the ϕ 84 as the average size of finest third, and ϕ 50 the average of the middle third. In this way, an overall representation of the true phi mean is obtained, which corresponds closely to the mean found by the method of the moment, but it is much easier to find.

<u>Measure of Uniformity</u>: Inclusive Graphic Standard Deviation (σ_I)

$$\sigma_I = \frac{\phi\ 84 - \phi\ 16}{4} + \frac{\phi\ 95 - \phi\ 5}{6.6}$$

Inclusive Graphic Standard Deviation is an overall measure of sorting which includes the 90% of the distribution of the accumulative curve.

On the base of hundreds of analysis in different environments, Folk (1968) has suggested the following verbal scale for σ_I:

σ_I under 0.35 Ø, very well sorted

0.35 to 0.50 Ø, well sorted

0.50 to 0.71 Ø, moderately well sorted

0.71 to 1.0 Ø, moderately sorted

1.0 to 2.0 Ø, poorly sorted

2.0 to 4.0 Ø, very poorly sorted

σ_I over 4.0 Ø, extremely poorly sorted.

Measure of Skewness or Asymmetry: Inclusive Graphic Skewness (SK_I)

$$SK_I = \frac{\phi 16 + \phi 84 - 2\phi 50}{2(\phi 84 - \phi 16)} + \frac{\phi 5 + \phi 95 - 2\phi 50}{2(\phi 95 - \phi 5)}$$

As a measure of asymmetry this parameter is very useful for differentiated curves with similar average size, sorting and with different asymmetry. Skewness measures the degree of asymmetry. The sign of Skewness, positive or negative, tells us whether a curve has an asymmetrical tail on the left or right.

Asymmetrical curves have Skewness values of 0.00; sediments with excess fine material have a tail to the right and positive Skewness; and sediments with excess coarse material have a tail to the left and negative Skewness value. Thus, the greater value of asymmetry (- or +) will be a function of Skewness values departing from 0.00 value.

Folk (1968) and Folk and Ward (1957) have suggested the following verbal limits for Skewness value:

SK_I values between: - 1.00 to -0.30, very negative-Skewed or strongly coarse-Skewed.

- 0.30 to -0.10, negative-Skewed or coarse-Skewed.
- 0.10 to +0.10, near asymmetrical.

+ 0.10 to +0.30, positive-Skewed or fine-Skewed.
+ 0.30 to +1.00, very positive-Skewed or strongly fine-Skewed.

<u>Measure of Kurtosis or Peakedness</u>: Graphic Kurtosis (K_G)

$$K_G = \frac{\emptyset\ 95 - \emptyset\ 5}{2.44\ (\emptyset\ 75 - \emptyset\ 25)}$$

Kurtosis is the quantitative measure that describes the departure of the accumulative curve from the normal distribution. In other words, it measures the ratio of the sorting in the extremes of the cumulative curve compared with the sorting in the central part and as such is a sensitive and valuable test of the normality of a distribution (Folk and Ward 1957). If the central portion is better sorted than the tails, the curve is excessively peaked or leptokurtic, if the tails are better sorted than the central portion, the curve is flatpeaked and platykurtic. Platykurtic curves are often bimodal with subsequel amounts of the two modes (Folk 1968).

Folk and Ward (1957) have suggested the following verbal limits for Kurtosis value:

K_G values under 0.67, very platykurtic
K_G values between 0.67 to 0.90, platykurtic
0.90 to 1.11, mesokurtic
1.11 to 1.50, leptokurtic
1.50 to 3.00, very leptokurtic
K_G over 3.00 extremely leptokurtic

Other parameters calculated for the grain size analysis were, the first percile (C), and the 50 percentile (M), they were calculated in phi (Ø) values directly from the accumulative curve and transformed to microns using the phi-millimeter conversion table (Pages 1955). These parameters were used to build the C-M diagram developed by Passega (1957, 1964) in an attempt to deduce the mode of transportation rather than to discriminate depositional environments.

Shape Analysis of the Pebble and Sand fraction

Historic Consideration: morphometric studies on pebble and sand fraction have been carried out for a long time in order to indicate the direction of transport of sediment and the possible agent.

The Roundness Index: The first estimation of roundness on sand and pebble fraction was based on visual charts (Mackie 1897; Dum 1911. Cited by Dodkins and

Folk 1970).

Wentworth (1919) created the first quantitative measurement technique, which consists of measuring the diameter of curvature of the sharpest developed corner (D_K) divided by the long axis. In 1922, Wentworth changed the long axis for the mean pebble radius (see figure 14). Cailleux (1947) using in principle the former measurement of Wentworth (1919) developed the widely used "Cailleux Index", which is calculated by the formula:

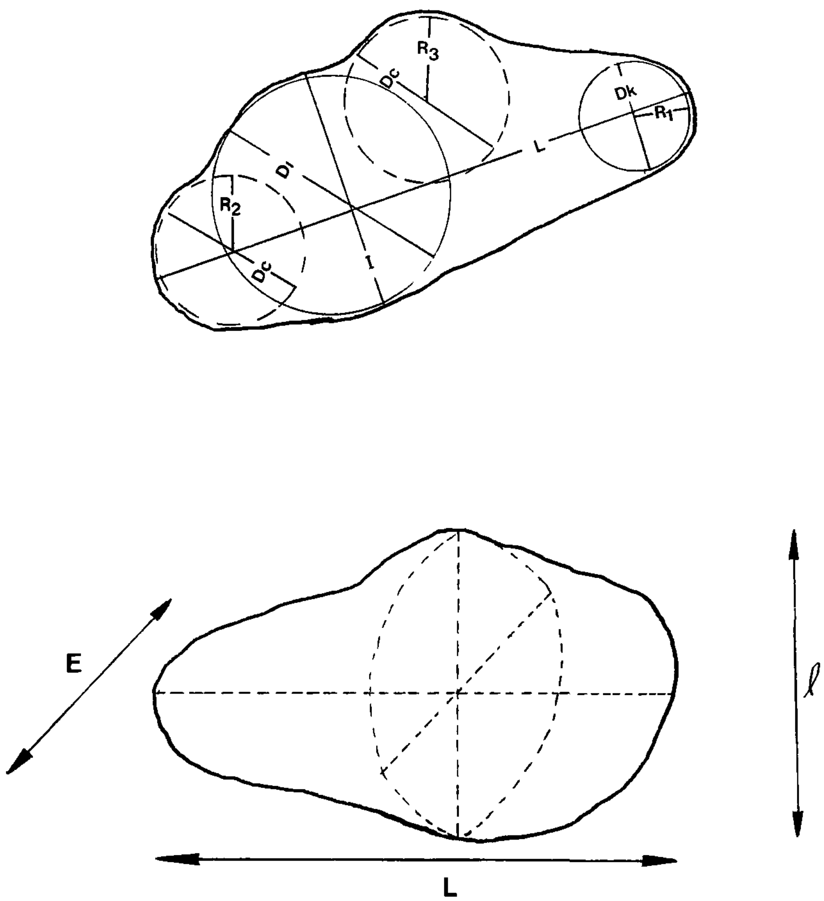
$$R = \frac{2\ R}{L} \times 1{,}000$$

where R is the radius of the sharpest corner in the maximum projection plane and L is the greatest pebble axis, the resultant value is multiplied by 1,000 to avoid fractionary numbers. The roundness values coming from this formula have a range between 0 (no rounding at all) to 1,000 (best possible sphere). Dobkins and Folk (1970) said the use of this formula introduces lower roundness index for elongated pebbles (hot dog shape) than for equal ones, and proposed a "new" measure of roundness.

$$R = \frac{Dk}{Di}$$

where Dk is the radius of the sharpest developed corner and Di is the radius of the largest inscribed circule (see figure 14).

Kuenen (1956) felt that the "Cailleux's roundness index" had elements of spherecity confused with it, consequently, he proposed that the longest axis, L, be replaced by the intermediate diameter (I), which is the largest axis



Dk : Diameter of curvature of the sharpest developed corner (Wentworth. 1919).

R_1 : Radius of the sharpest corner (Cailleux. 1945).

I : Intermediate diameter (Kuenen. 1956).

Di : Radius of the largest inscribed circule (Dobkins and Folk. 1970).

L : Greater peabble axis.

Dc : Diameter of curvature of corners.

R_2,R_3 : Radius of corners.

ℓ : Width of pebble.

E : Thickness of pebble.

Figure 14 . Measurements for shape analysis of pebbles.

at right angle to L (see figure 14).

Despite the above critics "Cailleux's Index" was used in this thesis. According to King and Buckley (1968) who tested different methods, the roundness of Cailleux Index was found to be the most efficient for diagnostic purposes. As this index has been widely used, results obtained from different areas can be easily and rapidly compared.

The flatness index: developed by Wentworth (1922) and very popular in Europe after Cailleux (1945) work had been used for many workers to try to differentiate between the shapes of fluvial and beach pebbles. However, there are divergences of opinion about whether the flatter pebble in a beach deposit is a result of selective shape sorting or abrasion due to wave action. Keymine (1960) had interesting citations of Democritus (420 B.C.) and Aristosteles (350 B.C.) to show how old this controversy is.

Because the purpose of this thesis is not to look for significant quantitative differences in morphology between beach and fluvial stream pebbles, the values obtained are presented in this thesis as a reference for further studies. Otherwise fluvioglacial deposits, at least, as original deposits are not present in the surficial deposits in the Alexandria Map Area. On the other hand, as King and Buckley (1968) said "..... it seems that flatness and spherecity depend more on rock type whereas roundness is a product of the processes operating." For this reason, the roundness index is the more valuable in this study where we are looking for the degree and direction of transport of the marine material.

The flatness index was calculated using the formula $\frac{D' - D''}{2D'''}$ (Wentworth 1922) = $\frac{L - l}{2E}$ (Cailleux 1945).

where D' = length L = the longest axis

D" = breadth l = width

D''' = thickness E = thickness

and the results are shown in Appendix B.

The sand fraction: For the roundness values the visual comparison chart of Tricart and Cailleux (1963) was used in this thesis. For the morphoscopic analysis, Cailleux and Tricart's Index (1963) were used. The sand size class for the morphometric and morphoscopic analysis was performed in the size classes 0.5 Ø to 1 Ø and 1.5 Ø to 2 Ø (Cailleux and Tricart, 1963).

Sampling Techniques

In sampling pebbles for morphometric analysis some safeguards must be taken in order to eliminate operator bias entering into the sample procedure. These safeguards are discussed below.

Between 50 and 75 pebbles (75 in most cases) at the 45-60 mm class size (Cailleux and Tricart, 1963) were measured at each of the selected sites. A square meter was randomly chosen in each of the pits at approximately 2 meters from the surface of the exposed pit. As Steinmetz (1962) cautions one must be careful in obtaining a random sample: "A random sample is one in which every individual composing the sample population has an equal chance of being included in the sample".

Wentworth (1919) showed that rock type is one important factor on which pebble shape depends, for this reason the local limestone of the Ottawa formation was taken as the only rock type for the shape measurement. The pebble fraction of the beach deposits in the area is composed in many cases by - 90% of this rock. Although shape of pebble represents the summatory of all the processes suffered by the rock fragment before the last deposition, we can state that roundness values in these gravel beaches derived from the reworked local till present in the area, is to a great extent a result of the wave action process.

Changes in roundness values across the strand zone have been reported in Arctic beaches (McCann and Owens 1969). However, it was not possible to establish beach zonation in the sampled deposits because the commercial extraction of gravel had disturbed the deposits. For this reason, in this work, the obtained values will be considered as a representative of each of the places measured. Thus, the degree of roundness would provide an indirect measure of the amount and intensity of wave action and changes of this value along the beach deposits will provide some indication of the extent of the longshore movement of material due to wave action.

The axis of the pebbles was measured with a transparent rule and the radius of the two sharpest corners with the roundness target device introduced by Cailleux (1945). Pebbles showing bedding or joint lineation and those fractured or with dissolution features were discarded. In this way more than 10,000 measurements were made in the field. These measurements were punched onto cards for computer calculation. The statistical mean and the standard deviation of these values were also computed to permit statistical test comparisons of sample sets.

Petrographical analysis of sand.

For the purpose of this thesis a detailed study of the minerology of the sand fraction was considered only in a general way in interpreting the environmental conditions of deposition during the Champlain Sea Episode in the Alexandria Map Area. With this in mind, a scanning of sample from different deposits was done making use of the binocular microscope, to identify the main petrographic compound and estimate their relative abundance and possible variations with changing conditions.

Stratigraphical Analysis

General stratigraphical analysis was performed wherever it was possible. Thus, many sand and gravel pits in the area were examined and description of stratigraphical units recorded. This analysis was a valuable aid in supporting the morphological evidence of marine coastal processes derived from the study of many Quaternary deposits in the map area.

CHAPTER 3

DISTRIBUTION OF THE MARINE SEDIMENTS AND ELEVATIONS

Using the Quaternary geological map of Alexandria as a base (Gwyn and Lohse, 1973), the distribution of surficial marine sediments, in terms of areas at different elevation was calculated, see figure 15. This distribution will be explained in function of the environmental conditions and processes operating at the different elevations at time of deposition, as interpreted from the study of the textural features of the sediments.

Till was the first source of material for marine sediments, the distribution of gravel, sand and silt-clay sediments would be a function of the processes acting over it.

The Marine Sediments

Gravel Beach

The presence of beach deposits is the most distinctive feature which indicates the former wave action against the till deposits. Cobbly and bouldery deposits are found on the slope and on the ridge crests at elevations between 400 and 250 feet. From figure 15 it can be seen that percentage distribution of gravel material decreases

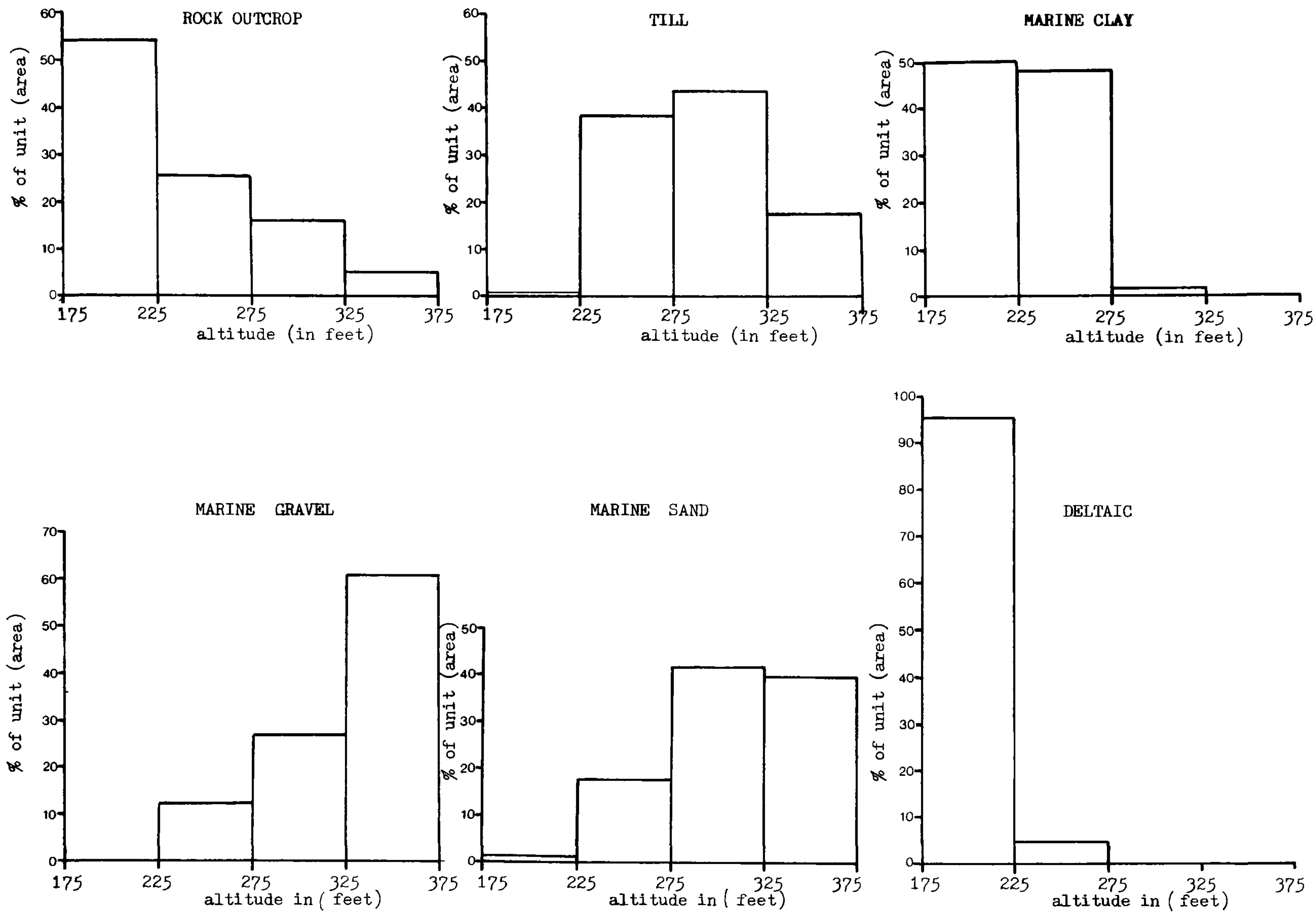


Figure 15. The distribution of sediments and rock outcrop (in terms of area) at different elevations, in Alexandria Map Area.

with decreasing elevation which implies that conditions suitable for its accumulation would disappear.

The macrofossils present in these deposits indicate their marine origin. The species more frequently observed in the gravel material were _Hiatella arctic_ (Linné), which was observed mainly in the coarse stratified sand _Mytilus edulis_ (Linné) observed as a broken shell in the very coarse sand and fine gravel, and in place of growing in more coarse and mixture material, _Balanus hameri_ (Bruguière) were observed attached to the coarsest fraction (big boulders and pebbles). _Macoma balthica_ (Linné) was not observed in the gravel material, when observed it was in the thin marine silt-clay that overlay the less reworked till.

The most prominent beach deposits were observed at an elevation of between 300 and 375 feet, and it is at these elevations where the best developed marine landforms are. The distribution of these beach deposits are the results of the combination of several factors such as: direction of prevailing wind, submarine topography and the disponibility of easy erodable material.

As a result of these factors, the features of the beach deposit are different. For instance, well stratified and moderately well to moderately sorted marine beach sediments were found where the wave attacks and the distribution of longshore currents were effective. On the other hand, many deposits presented poorly developed internal structure; in other words, the material was coarse, not stratified and the values of sorting and roundness were indicative of the lower stress of the processes.

The high percentage of limestone fraction in all these beach deposits (especially gravel and cobble fraction) reflects their origin from the till material. However, in several beach deposits, big crystalline boulders were observed which did not have a relation with the till outcrops (up to 5 m) studied where big boulders were not observed, and this suggests another mechanism of transport due to coastal processes or ice floating transported material from the front of the glacier further north of the area.

The Marine Sand

Extensive sand deposits were found between 275 and 375 feet of elevation. They are the product of the sorting processes of the wave and currents and they accumulated in the shallow environments near coasts. Their extension indicate the amount of reworked till from which this sand comes. They were always observed as a deposit of uniform, planned-bedded with a mean size mainly between 2 and 3.5 ϕ. This sand occurs mainly near the beach zone but were specially extended in the northwest area down slope from the Maxville Highland where they form very well defined ridge sand bars. This sand is different from the sand in the gravel deposits in terms of mean size, petrographic and sorting values.

Marine fine sediment silt-clay: Fine sediments composed of silt-clay were washed from the original till source by the wave wash process at the time that land was emerging. These sediments were transported mainly in suspension processes further from their original sources. In the Alexandria Map Area these deposits are mainly present at elevations below 275 feet where they form the deep offshore facies of the Champlain Sea sediments. Above this elevation, its presence is covered by the sand or sparsely located in the small closed depression suitable for its former deposition.

It is necessary to point out that below 200 feet of elevation these fine sediments were covered by the younger sediments of the proto-Ottawa River delta and the lagoonal and estuarine deposition prevailing during the last stage of the Champlain Sea Episode in the area. However, posterior stream erosion on the deltaic and lagoonal sediments have exposed these marine fine sediments again.

Deltaic Sediments

Deltaic deposits are located exclusively below 225 feet of elevation. They cover an important area in the extreme northwest corner of the map area. This deposit belongs to the delta formed by the proto-Ottawa River (Chapman and Putman 1966). With the recession of the Champlain Sea towards the east, the Ottawa River built channels into the deltaic deposits and exposed the underlaying marine silt-clay which actually shows the linear erosional features due to this stream erosion (see map 2 and figure 16). In the remnant deltaic deposits a series of terrace scarps were built, which are very well displayed along the road coming from Franklins Corners to Vankleek Hill (see map 2 and figure 16). Actually, the south National River drained one section of the former channel of the Ottawa River and the Alfred Bog represents one undrained segment of this former southern channel of the Ottawa River.

The main stratigraphic unit present in the Alexandria Map Area shown in figures 16, and figure 17 is an idealized sequence of the geomorphological evolution of the area drawn from the stratigraphic sequence of figure 16.

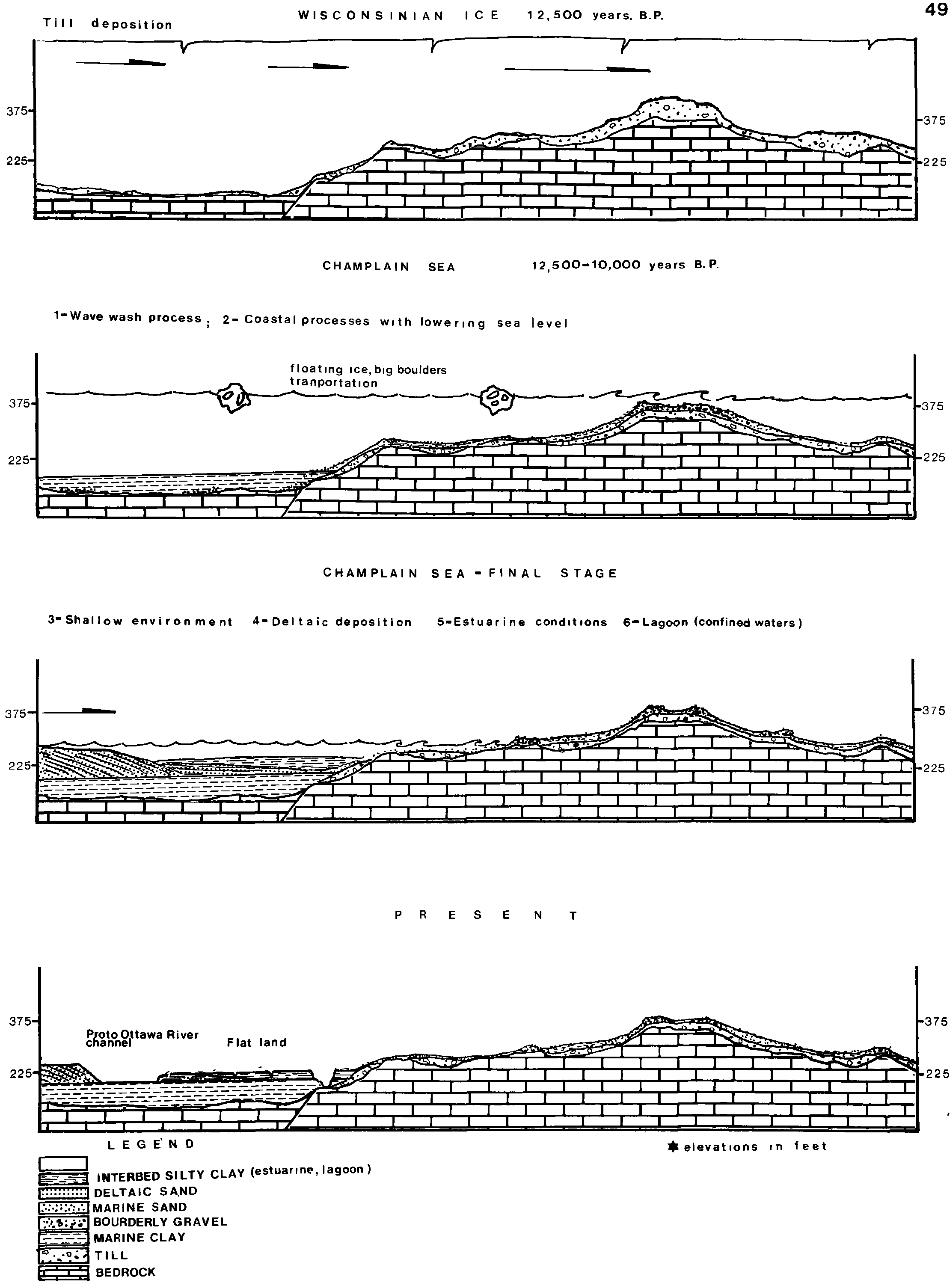


Figure 17. Idealized sequence of the geomorphological evolution of the study area.

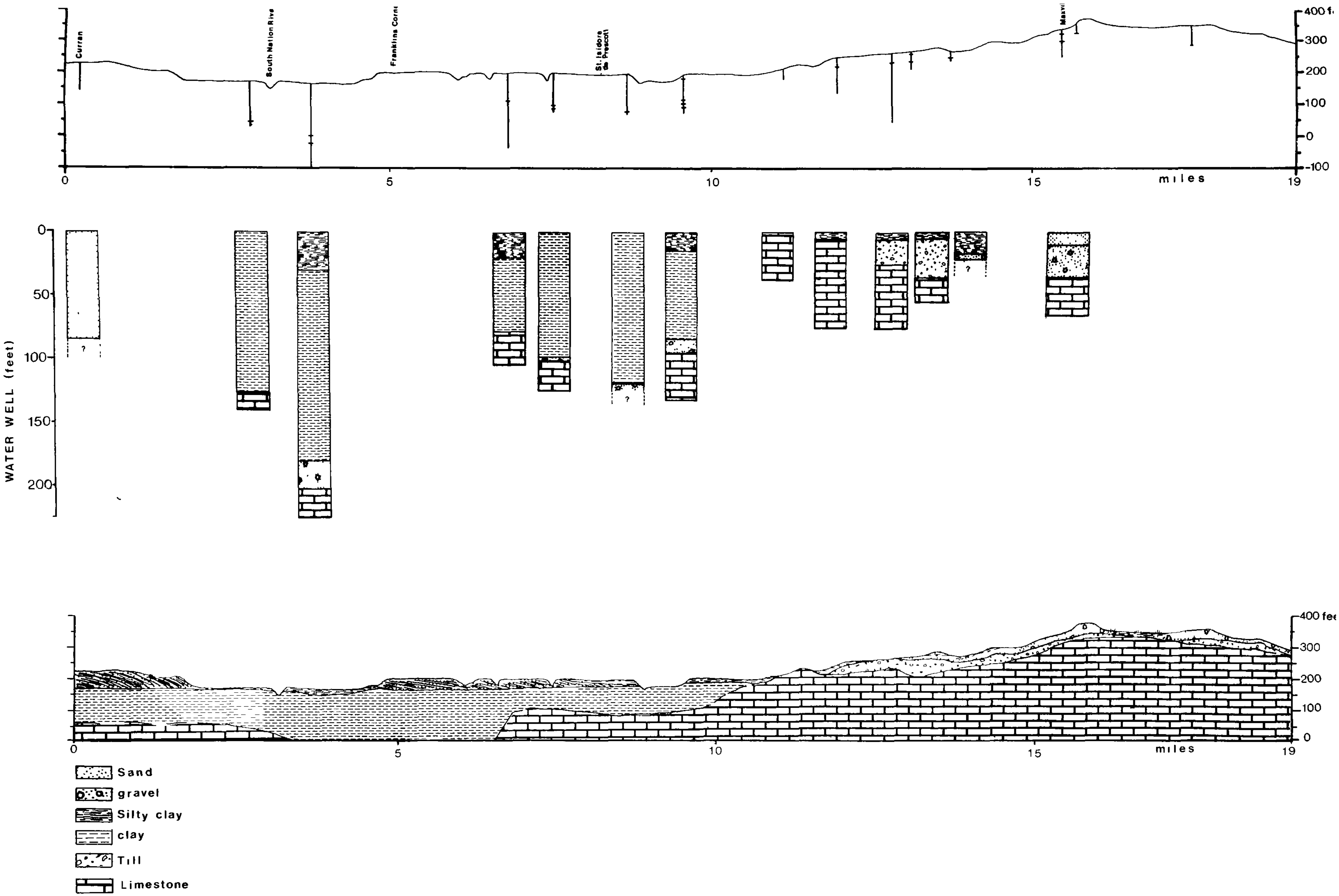


Figure 16. Topographic and geologic section through NW-SE of the map area.
Source: topographic map 31 G/7 NTS. Subsurface information from Water Resource Report Nº 13.

CHAPTER 4

GRAIN SIZE ANALYSIS

Using the Alexandria Quaternary Geologic Map as the original reference (Gwyn and Lohse, 1973), sediments were sampled and analyzed. The method of environmental interpretation of Folk and Ward (1957) was primarily followed, this consists in comparing pairs of grain size parameters in scattered diagrams to see how they could be correlated one to another and to determine a possible correlation. The usefulness of this method and the different grain size parameters in identifying the complex marine environments associated with the Champlain Sea Episode will be evaluated.

In the Ottawa-St. Lawrence Lowlands this method of environmental interpretation from the textural features of sediments had been used previously by Romanelli (1976) in the Gatineau River Valley.

Besides the above environmental interpretation, the processes of transportation of these marine sediments were investigated using a C-M diagram (Passega 1957, 1964).

Results

As it will be seen, the mean size and the standard deviation appear to be the most useful parameters in this case. By plotting the pairs of grain size parameters, clusters of sediment samples were observed (especially in fig. 18 , 19 and 21) which, although not clearly, allowed an environmental interpretation to be made from different textural features.

Sorting vs Mean Size

In a general way the plotted samples form a trend in a wide V shape (see figure 18), where the best sorting samples correspond to the dominant size mode for the analyzed samples (medium to very fine sand). On the other hand, poor sorting values occur in samples with size modes above or below the above-mentioned.

As observed by Imman (1949) and Griffiths (1951) sorting is a sinuosidal function of mean size, and the best sorted material has been observed to fall in the class size of the medium sand (1 Ø to 2 Ø) and fine sand (2 Ø to 4 Ø). On the other hand, clay, silt and gravel in general are poorly sorted.

Although the mean size of a sediment changes with transport, the improvement in sorting value depends only on the decreased mean size not the distance. In other words, when sediments reach a minimum of best sorting they continue to get finer, the sorting process starts again and the sorting values worsen anew as a response to the energy incapacity to separate the sediment modes present.

LEGEND UTILIZED FOR FIGURES 18 to 24

▲ Sediments sampled at elevations above 325 feet, they correspond to beach deposits. (coarse to medium sand),

■ Sediments sampled at elevations between 300 and 325 feet (near shore sediments)

□ Sediments sampled at elevations between 275 and 300 feet (very fine sand).

● Sediments sampled at elevations below 200 feet(medium to fine sand).

○ Sediments sampled at elevations below 200 feet (very fine sand to coarse silt).

Table 2. Legend utilized for figures 18 to 24.

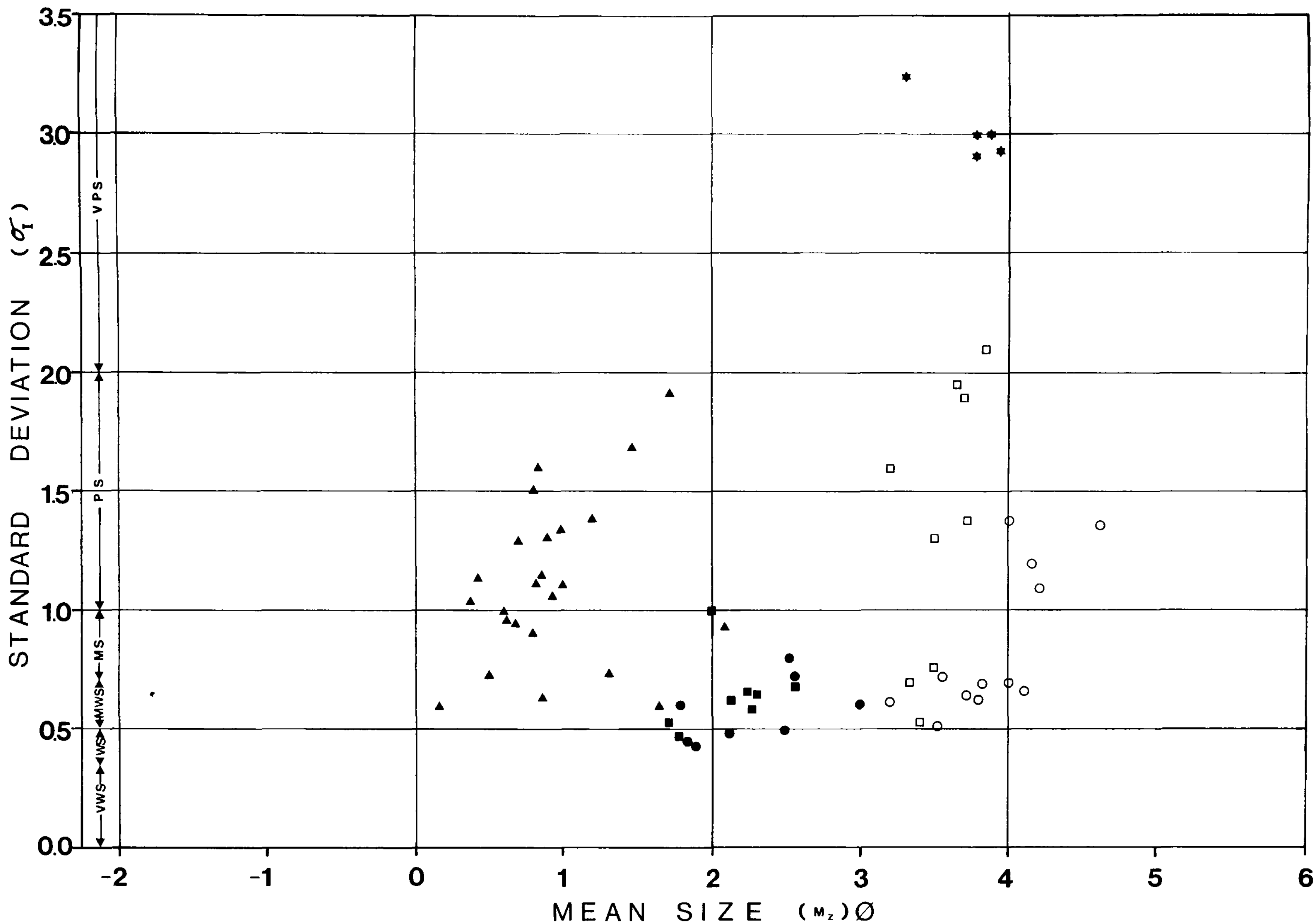


Figure 18. Scatter diagram of Mean Size (M_z) versus Inclusive Standard Deviation (σ_I).

MBD

This means that the mean size (M_z) or average grain size diameter is a representation of the average energy of the depositional environment. This accounts for the fact that the sinuosidal relationship observed in figure 18, is the result of the changing competency is the different environments at the time of the Champlain Sea Episode.

Sediment samples plotted in figure 18 show that samples coming from the pits located over the 325 feet above sea level, have the larger mean size among the sampled sediments (M_z between 0 to 1.5 $\emptyset$). However, the sorting values range between moderately well sorted to poorly sorted (see figure 18) which indicated that changing conditions existed in the depositional environments in this area.

Because of the presence of abundant marine shell fossils here these deposits are designated as a marine beach. The difference in sorting values in the samples coming from this environment indicates different sub-environments, probably as follows:

A. Beaches where the longshore current played an important role in the depositional processes, located in front of the dominant wind direction;

B. Beaches formed by the reworked till in place, where no substantial transport of material was performed;

C. Beaches located in sheltered areas or with their back to the predominant wind direction.

The mixing of two model class size could explain the changing of sorting values; the causes of this mixing will be related to the energy conditions later.

With a decrease in its mean size, the sorting sediments improve from moderately sorted to moderately well-sorted and well-sorted at the mean size class between 1.5 and 2.5 ø (see figure A). These sediment samples were collected generally at elevations above 325 feet and below 200 feet (see figure 18).

For the samples mentioned above, the environments were different, samples collected above 325 feet are designated as marine in origin due to the presence of marine shell; samples below 200 feet above sea level are of fluvial origin and correspond to the deltaic unit (Gwyn and Lohse, map 1973) of the proto-Ottawa River delta (Chapman and Putnam, 1966).

For the samples located above 300 feet above sea level, the accumulation of these moderately well-sorted marine fine sand was due to coastal processes related to the longshore currents in forming offshore sand bars accumulated in a shallow marine environment.

With a further decrease in mean size (M_z between 3.5 to 4.5 Ø) it can be observed in figure 18 that there is a wide range in the sorting material, with a tendency towards clustering in the moderately well-sorted to moderately sorted sediment and in the poorly sorted sediment. Samples in this mean size class (3.5 to 4.5 Ø) come from two different areas:

A. sampled between 275 and 325 feet above sea level;

B. sampled below 200 feet above sea level.

By using the elevation as a base in the sediment samples above, we find that those samples below 200 feet of elevation are deltaic while those samples between 275 and 325 feet above sea level are marine.

From the sorting of these sediments it can be shown that the energy of the environment was in great flux. In the case of the marine samples, samples with the poorest sorting value corresponds to sediments sampled furtherest from the beach environment and where the deepest water was. Here the mixing of fine sand and silt-clay sediments are the cause of the bad sorting value observed. In the case of the deltaic deposit, samples with the poorest sorting value probably correspond to the more distal deposits where energy combined with wave and current were ineffective in separating sediment size class (fine sand and silt-clay).

<u>General Discussion</u>

The sediments of the upper area, above 325 feet have the greater mean size value, with range values between 0 Ø and 1.5 Ø (coarse to medium sand). The sorting values are very wide ranging between moderately well-sorted to poorly sorted (0.50 Ø to 2.0 Ø).

The Skewness values (figure 20) vary from nearly symmetrical (Sk_I value between -0.10 and -0.10) to very positive skewed or strongly fine skewed (Sk_I - 0.30).

The Kurtosis values departing (see figure 19) from Mesokurtic values (0.90 to 1.11) tend to be leptokurtic which means that the sediment samples of this area are very well sorted in the central portion of their cumulative curve and badly sorted in the tails. A trend observed in these sediments is that with a decrease in mean size the bad sorting values increase as well as the Kurtosis values (figures 18 and 19). This fact is explained by the presence of fine material. The increase in bad sorting values explains the increase of Skewness values (see figure 20) in these samples.

The trend shown by these beach sediments is contrary to the "established" trend for actives beaches in more temperate latitudes. The explanation for these inverted trends could be the presence of fine material in beach sediments which give these samples a mixture character

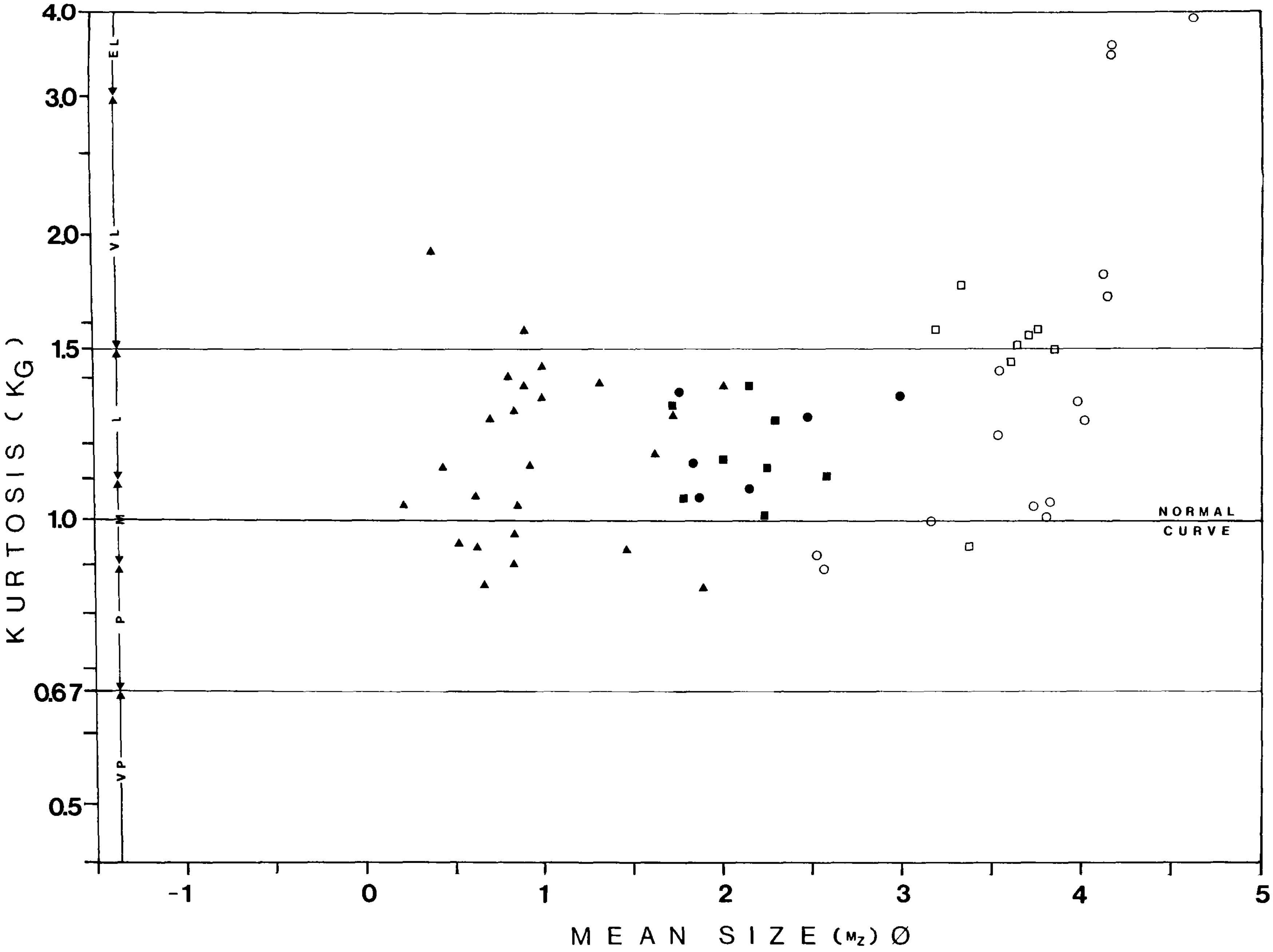


Figure 19. Scatter diagram of Mean Size (M_z) versus Graphic Kurtosis (K_G).

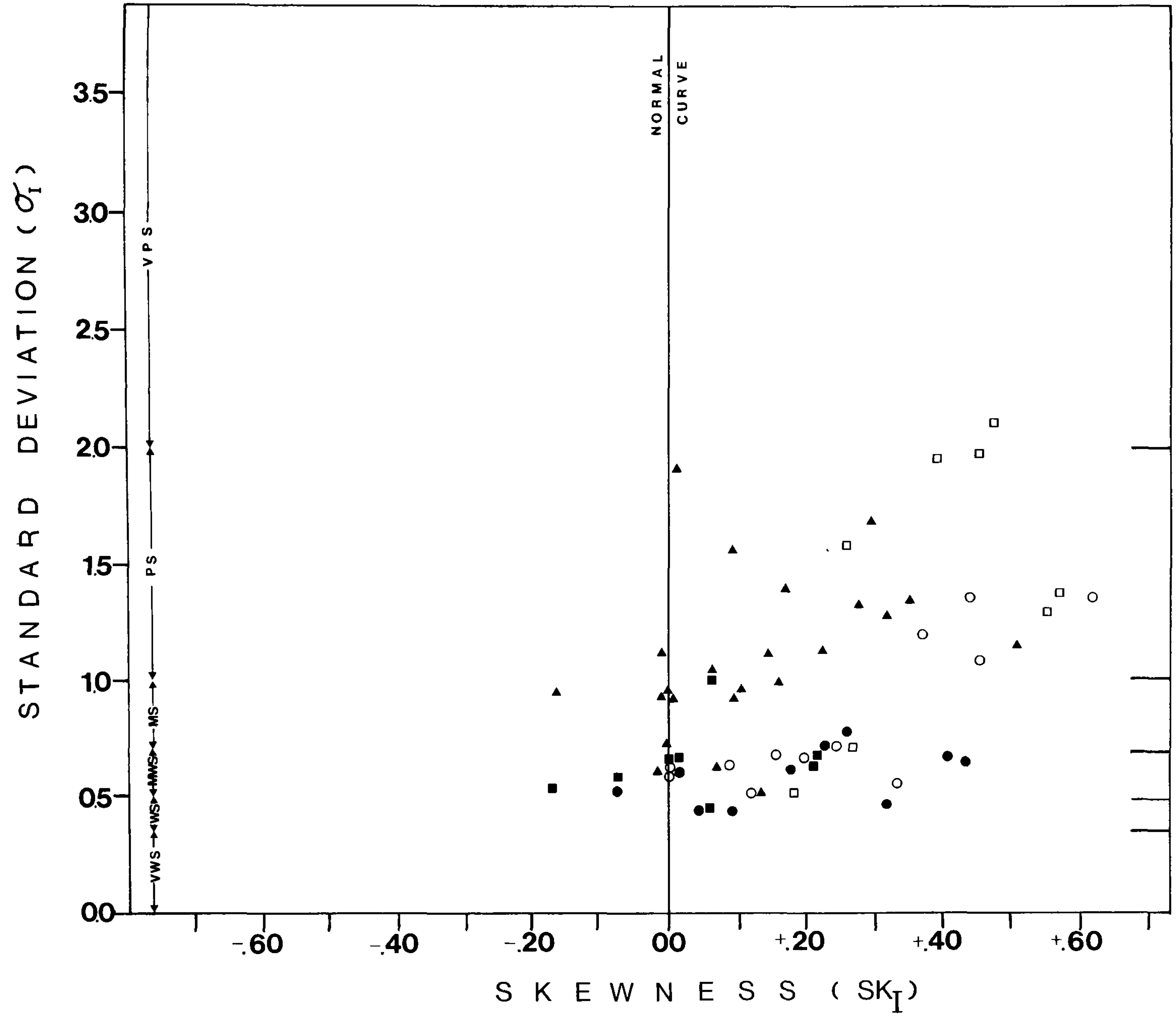


Figure 20. Scatter diagram of Inclusive Standard Deviation versus Inclusive Graphic Skewness (SK_I)

samples a mixture of character. The mixture character of the beach material, impedes the effective use of very sensitive parameters as Skewness and Kurtosis in this kind of environment. Thus, in the conditions studied, the theoretical trends as shown by Folk and Ward (1957) are not really achieved (see figures 21, 22 and 23).

Thus Skewness which has been reported as discriminatory depositional parameters (Duane 1964; Friedman 1961; Manson and Folk 1968; Mothersill 1969) appears to be useless, especially when dealing with coarse-grained beach deposits, as it is the case of the beach sediments of the Alexandria Map Area (over 325 feet). According to Friedman (1961), coarse-grained beach sediments may be either negatively or positively skewed. In our case, the beach deposits are mainly positive skewed.

Sediments with mean size between 1.5 Ø and 2.5 Ø (medium to fine sand), were sampled in two different areas, one above 325 feet (but distal from the coarse sediment) and the other, below 200 feet. They show better values of sorting with ranges between well-sorted and moderately sorted (between 0.40 Ø and 0.80 Ø) see figure 18. The Skewness values of these sediment samples are clustered in the near symmetrical values (Sk_I -0.10 to -0.10). However, there is a tendency towards the positive or fine skewed with decrease mean size (see figure). This can be explained by the mixing of the fine sand (2 Ø to 3 Ø)

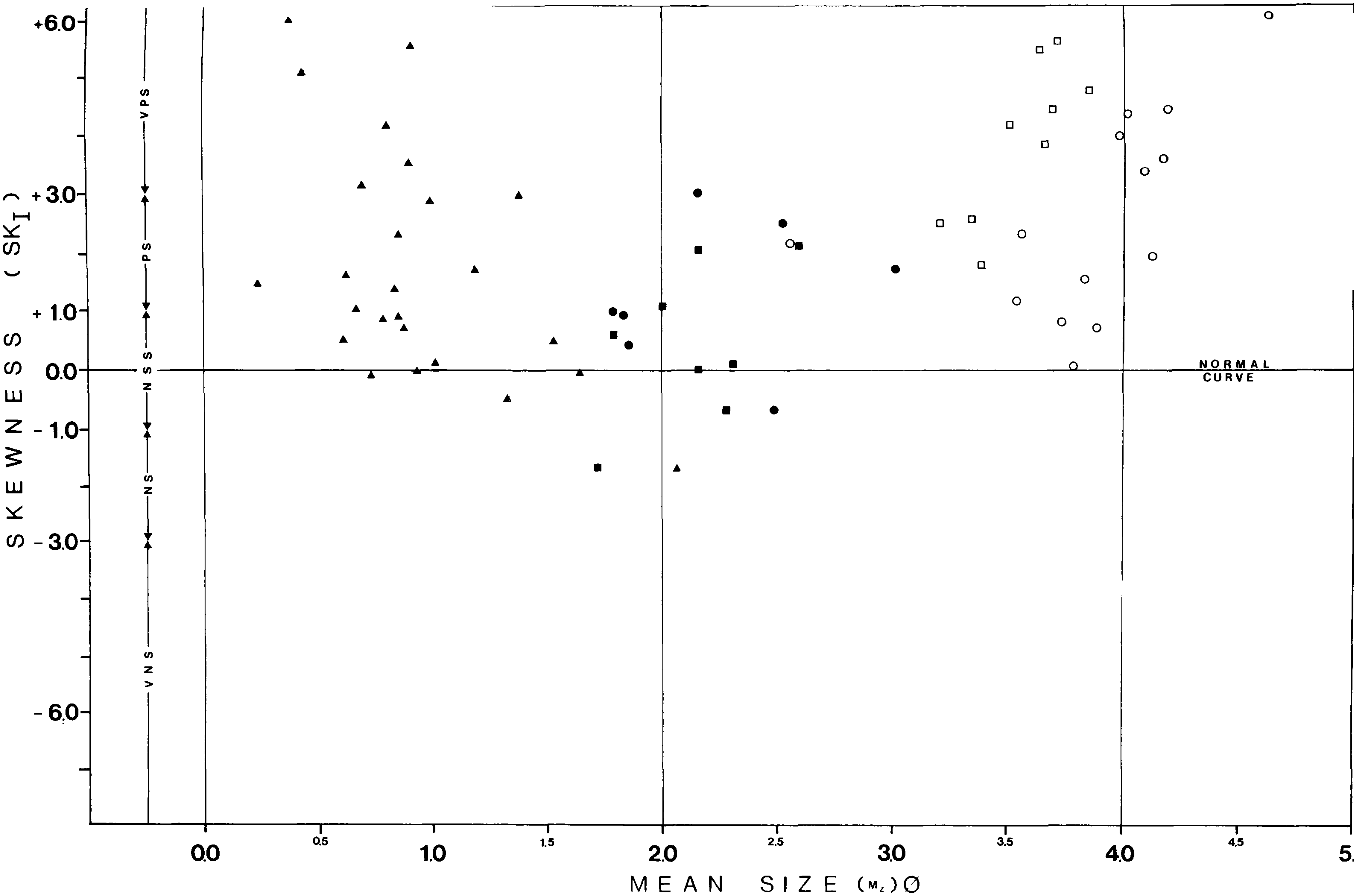


Figure 21. Scatter diagram of Mean Size (M_z) versus Inclusive Graphic Skewness (SK_I

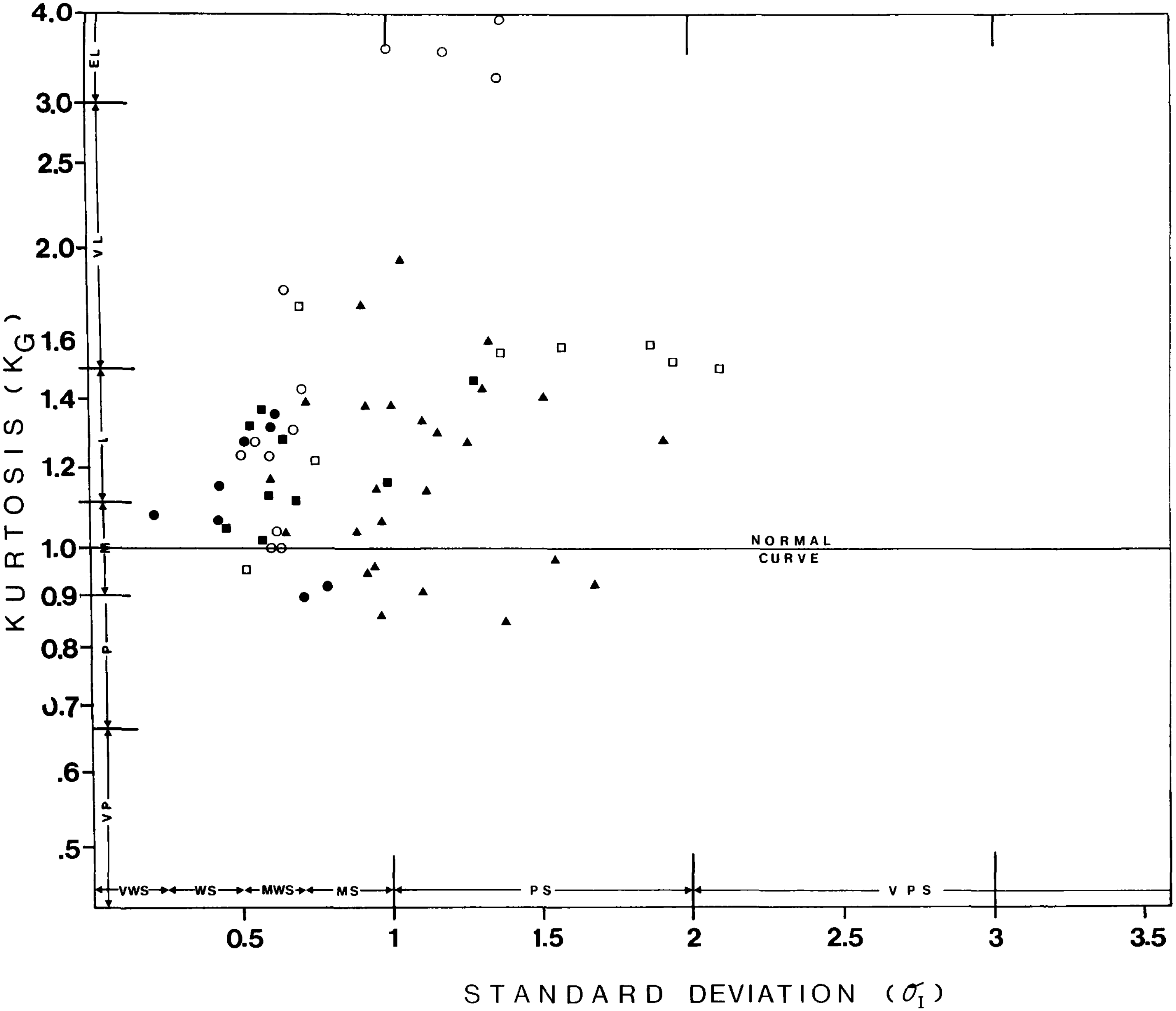


Figure 22. Scatter diagram of Inclusive Standard Deviation (σ_I) versus Graphic Kurtosis (K_G).

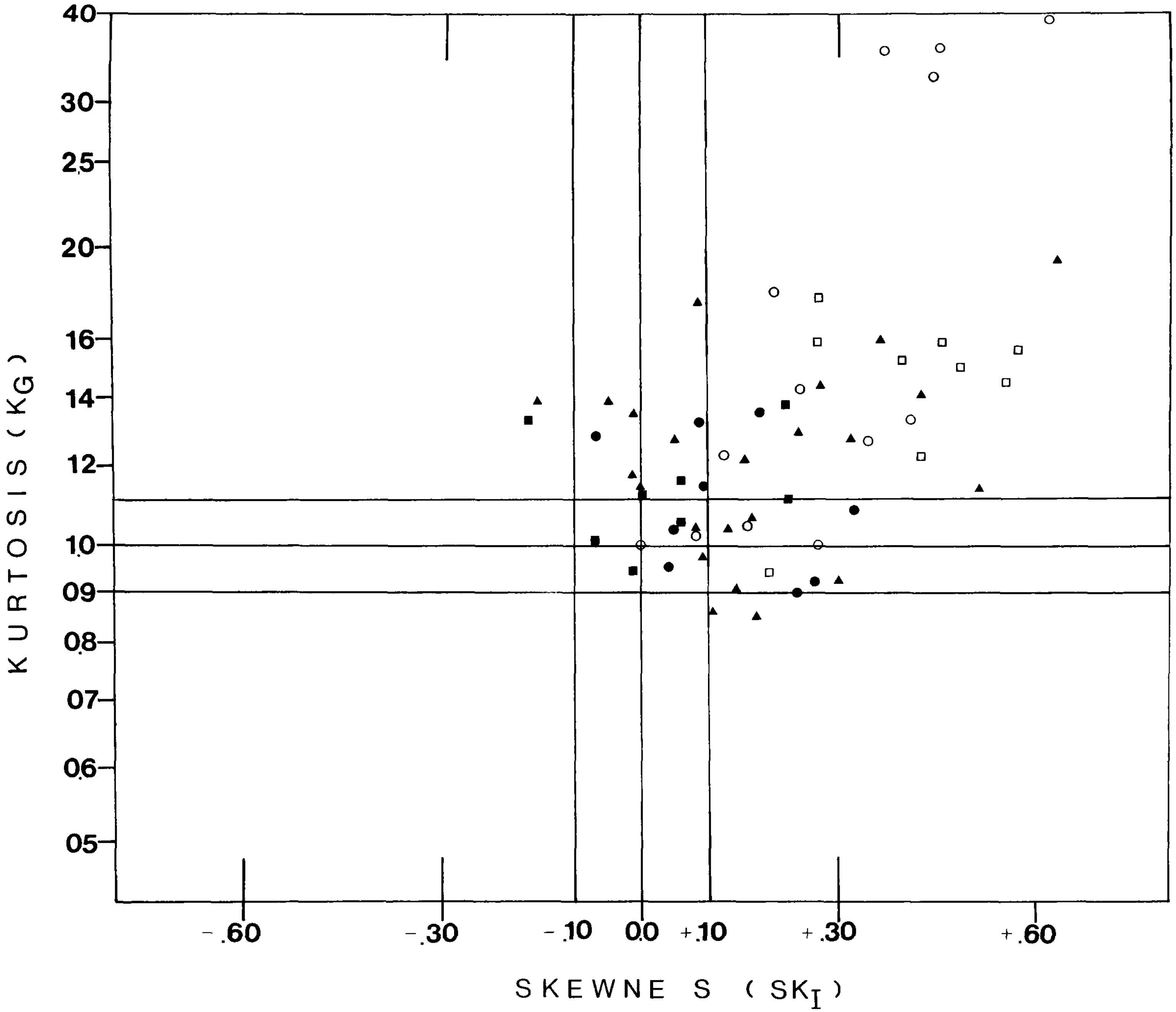


Figure 23. Scatter diagram of Inclusive Graphic Skewness (SK_I) versus Graphic Kurtosis (K_G)

with very fine sand (3 Ø to 4 Ø).

Sediment samples of this area have Kurtosis values from 1 to 1.4 (sediment curves are mesokurtic to leptokurtic), which means that there is a tendency for these sediments to be better sorted in the central portion of the curve than in the tails (see figure 19). However, there was no significant relationship between Kurtosis and mean size, for this size class, and the samples formed a clustered pattern (see figure 19).

Sediment samples with mean size between 3.5 Ø and 4.5 Ø are classified in two groups:

a) sediments coming from elevations between 275 and 325 feet above sea level, which has the M_z in the range of the very fine sand (3.5 Ø to 4.0 Ø); and

b) sediments coming from elevations below 200 feet above sea level which have a M_z range between very fine sand and coarse silt (3.5 Ø to 4.5 Ø).

For this mean size class (3.5 Ø to 4.5 Ø) the same trend of the samples coming from the upper area (beaches) can be observed (see figure 18). This means that the sorting values are very wide, ranging from moderately well-sorted to very poorly sorted (0.5 Ø to 2.1 Ø).

The Skewness values for most of these samples are positively skewed or fine skewed to very positively skewed or strongly fine skewed (Sk_I values between -0.10 to -0.60) see figure 21.

High Kurtosis values are observed for these samples with values between 0.90 to 3.0 (see figure 18). Another trend observed in this sample is an increase of Kurtosis and Skewness values with decrease of mean size (M_z) (see figures 19 and 21). Both trends are the result of mixing sediments with different modal classes. In this case, it is produced by an increment in the content of silt clay fraction.

As we have discussed the relationship between grain size parameters is a function of the mixing of the size modes present in the sediments, which in turn is a function of the original source of the marine sediment (fundamentally the fine till matrix, see page 21) and the processes responsible for the sorting of these sediments (wave and currents) as well as the specific conditions prevailing at the time of the Champlain Sea Episode, which of course, were climatically controlled.

In the Alexandria Map Area the beach deposits related to the Champlain Sea are located above 250 feet above sea level (sampled over 300 feet). These deposits do not have geographical continuity due to the irregular glacial landscape existing prior to the complete sea innundation. This created many isolated islands with a decrease in sea level.

The origin of the marine sediments associated with the Champlain Sea, as elsewhere in the Ottawa-St. Lawrence Lowlands are related to the reworking of the till material, due to the wave action and its distribution was the product of the longshore currents (Gadd 1962, 1971; Terasmae 1965; Karrow 1961, among others).

At the height of the Champlain Sea Episode, the sea was extensive enough to permit high wave energy to attack the till material, a very erodable material, as observed in the wave attack on till material in actual active beach (e.g. Johnson and Reed, 1910; Shou 1959; Guilcher 1962, 1965; Guilcher and King, 1965; Moign and Guilcher, 1967; Owens and Bowen 1977). It is very important to point out that at the time of the Champlain Sea Episode, the presence of ice sea cover during several months of the year was also an important factor in limiting the sorting processes of wave and current on the reworked till material.

In relation to the above statement it is important to say that many researchers have investigated the presence of glacial ice at the time of the Champlain Sea (Gadd 1971; Rust and Romanelli 1975; Rust 1977; Cheel 1979) and much has been said about subaqueous outwash marine deposits. However, not much has been written about the marine sedimentological conditions associated with the presence of ice cover in the Champlain Sea environments. We think that temporal climatic effects on the sedimentological processes played a significant role at the time of deposition.

The positive Skewness values observed in most of the sediments sampled should be discussed by taking into account the above conditions. The presence of fine material is responsible for the positive skewness and for the poor sorting of many sampled beach sediments, in contrast with the well-sorted beach sediments of marine environments in more temperate latitudes. This can be attributed in part to the presence of ice cover on the sea during several months of the year or an excessive rate of supply of sediment due to the easily erodable nature of the till material. Thus the beach material received continually fine material into the coarse one.

In the case of ice cover the situation can in some ways be related to the present Arctic beach, where a seasonal "steady state" sedimentological regimen exists because of the presence of winter ice (Burrel _et al._, 1974).

Thus, the variability in sorting values observed in the beach sediments from moderately well-sorted to poorly sorted (0.5 ∅ to 2.0 ∅) can be related to differences in wave energy at the time of open water (ice free), which was a function of beach position in respect to the prevailing wind direction.

The well-sorted to moderately sorted (0.5 Ø to 1.0 Ø) sand sampled at elevations above 325 feet correspond to sand bars formed by long shore currents in a near shore environment. These deposits reflect a greater capacity of the energy environment in sorting sediment and they probably occupied the position immediately beside the breaking wave.

Samples with the same mean size as the above but sampled at a lower elevation (below 200 feet above sea level) is thought to be deltaic in origin (Chapman and Putnam 1966; Gwyn and Lohse 1973). They are believed to correspond to channel filling in the deltaic environment, where conditions were probably directly related to the fluvial currents alone, and this can explain the differences with the other deltaic sediments to some degree. It is necessary to point out that the source of sediment of these well-sorted to moderately sorted deltaic sand was not the same as the distal deltaic deposit where at least the mixing of the two sources occurred.

Sediment samples with mean size between 3.5 Ø and 4.5 Ø sampled at elevations between 275 and 300 feet and below 200 feet as mentioned before, correspond to different environments, marine and deltaic. However, in their textural features they show conditions of deposition which are very similar. From the mean size of these sediments it can be said that these sediments had been deposited in a quiet environment or that the sediment came from a source of sediment dominated by a sand-silt size mode. According to our observations, the combination of both possibilities are responsible for the textural features of both environments. As discussed before, the textural feature of the Fort Convington (see page 21) lies in the sandy-silt mode and on the other hand a quiet environment is also expected as a result of ice protection during the winter time which allows the fine sediment deposition and which became resistant to the move by wave and current at the time of open water. In this way, the mixture of fine sand and silt and clay material was preserved in these deposits. In the case of the deltaic deposits (below 200 feet) it corresponds to the most distal deposits where transition of river and sea environments occurred.

In conclusion, it can be said that the use of diagrams of scarterplot pairs of grain size parameters can only be used in paleogeographical analysis of depositional environments if we take consideration of all the specific conditions prevailing at the time of deposition. As is the case with the Champlain Sea environment where the presence of ice cover and near freezing temperature of the water during several months of the year caused overlapping among depositional environments thus no clear separation of environments is possible as found by Folk and Ward (1957); Friedman (1961); Mason and Folk (1958); Duane (1964); Mothersill (1969). It is important to note that these researchers obtained their conclusions from a very differentiated environment on recent sediments, and this method of environmental interpretation has not been tested sufficiently in former sediments. The most important point to be noted is that when they found a mixture of sediments this method did not work very well, in these cases these authors spoke about a typical environment, as is the case of the beaches sand, positively skewed on Padre Island, Texas, near the delta of the Rio Grande River, and on Horn Island, Mississippi, or in the Louisiana sand beach (Atchafalaya River area) where the cause of the "problem" is the mixture of two fine sediment modes sand and silt-clay (Friedman 1961, 1967). Shepard and Young (1961) had pointed out the uselessness of the method in differentiating between beaches and dunes, where there are longshore currents, extremely variable, or offshore-onshore winds. In such localities the dunes sand are blown back onto the beaches causing intermixture of material.

For this reason, the theoretical trends as postulated by Folk and Ward (1957) <u>had not been clearly observed</u> when the method was applied to recent sediments in the Arctic beach (Burrel *et al*., 1974; Naiden and Mowall, 1974) or Pleistocene marine sediments influenced by ice cover as was the case with the Champlain Sea (this present thesis 1981). On the other hand, it is necessary to note that not all modern sand environments have been exhaustively examined and more information is necessary about the features of sand deposits on the continental shelf and tidal sand bar or offshore bar environments (Blatt, Middleton and Murray, 1972).

Processes of Deposition (C-M Diagram)

The C-M diagram is an alternating approach of studying recent sediment and reconstructing the conditions of deposition of ancient sediments. The method was developed by Passega (1957, 1964) and an alternate method was proposed by Rizzini (1968).

The C-M diagram attempts to establish relationships between texture of sediment and processes of deposition, rather than between texture and environment as a whole (Passega 1957).

Passega (1957) defends the choice of the first percentile (C) as the coarsest fraction, because strong variations of C correspond with variations of the texture as a whole, which are depositional features, and the choice of the 5th percentile as a parameter may reduce the sampling error but would be less representative than C as the maximum grain size.

Passega (1957, 1964) and Passega _et_ _al_. (1967) had given examples of the utility of this kind of diagrams in investigating processes of deposition in different environmental conditions. However, it is necessary to say that Passega's diagram is not an infallible tool, as demonstrated by published C-M diagrams (e.g. Burrel _et_ _al_., 1974; Eynon and Walker, 1974), which does not show the same general patterns as established by Passega (1957, 1964). We will discuss the advantages and disadvantages of this diagram later.

Figure 24 is a C-M diagram for the Alexandria Map Area samples and figure 25 shows the complete C-M patterns for tractive currents as presented by Passega (1957, 1964).

Figure 24 shows that for the series of samples of the Alexandria Map Area the C-M patterns as presented in figure is almost complete with the exception of the segment S-R, which corresponds to the finest material transported as uniform suspension and deposited in still water (Pelagic suspension). They would probably correspond to the deep offshore facies of the Champlain Sea (marine silt-clay) but this kind of sediment was not sampled for this work.

From the textural features (C-M) of the coarse to medium sand sampled at elevation above 325 feet (segment N-O-P in figure 25) it was deduced that processes

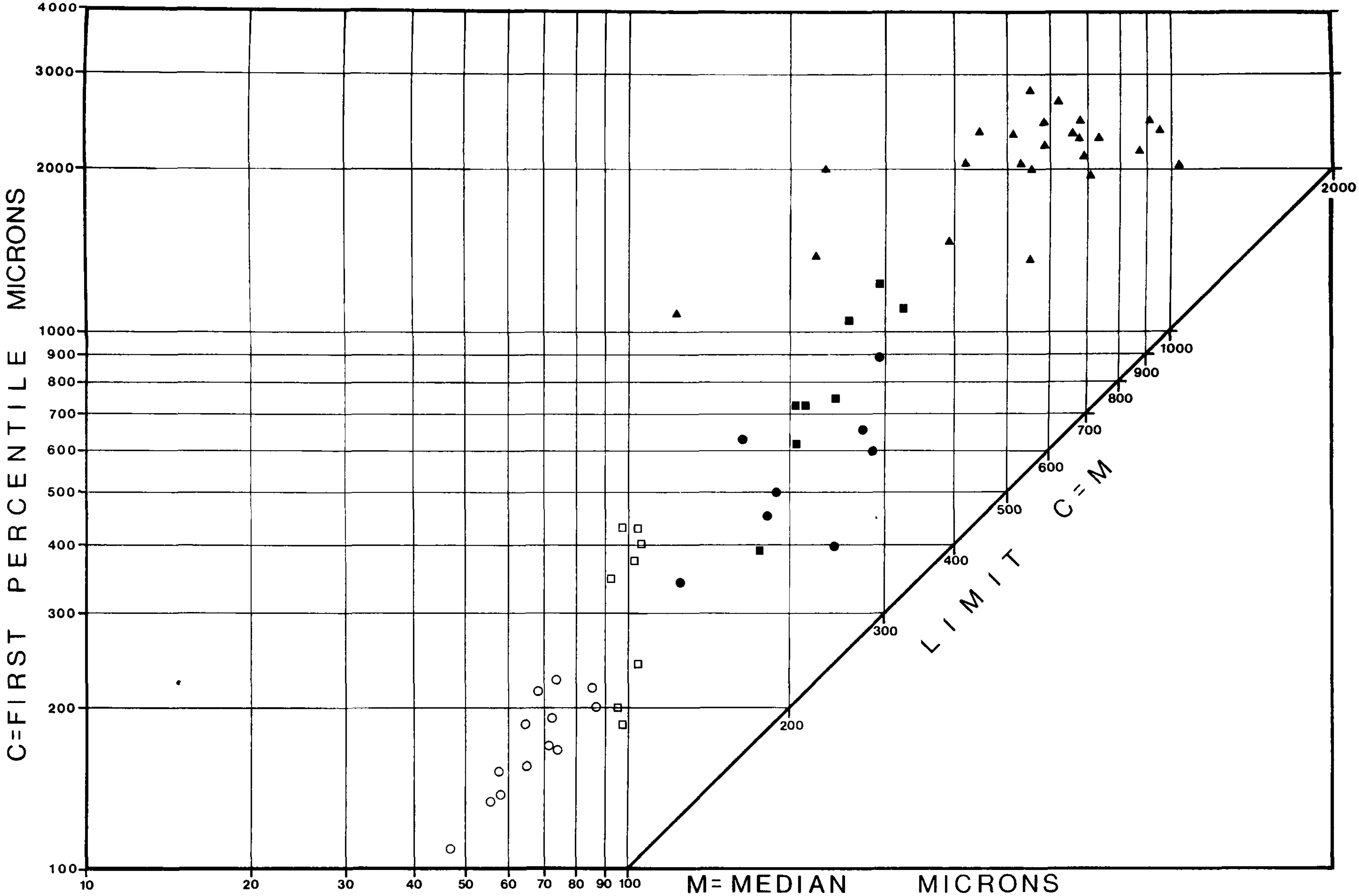


Figure 24. CM diagram of tractive current deposit, for sediments sampled in Alexandria Map Area.

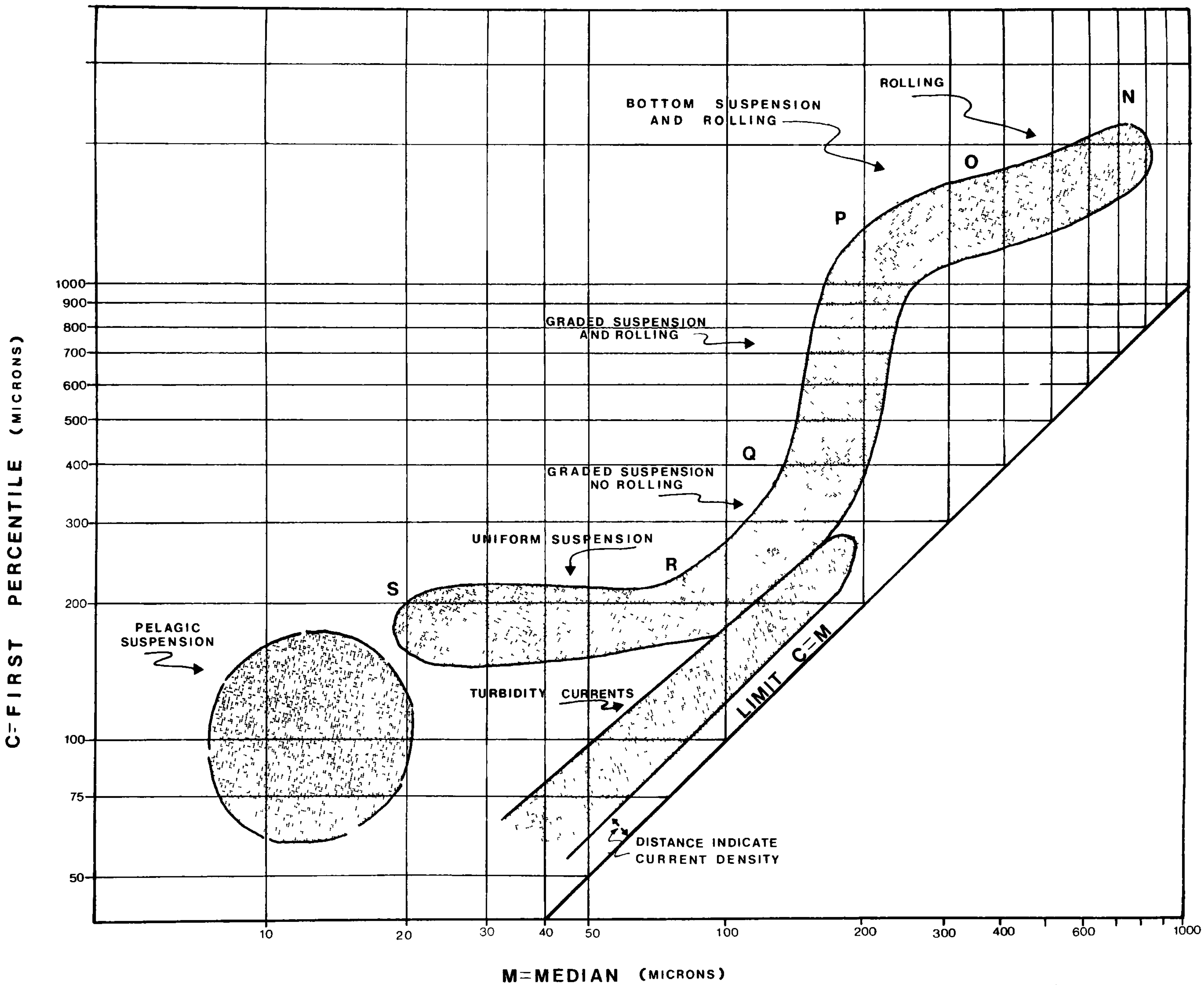


Figure 25. Complete CM pattern of tractive current deposit (After Passega 1957, 1964.)

of transportation responsible for these deposits were fundamentally rolling although bottom suspensions were also present. The combination of both processes is understood to be a function of the ice-cover during the winter months. However, it can be stated that samples were the rolling transportation which was predominant and correspond to beaches having higher energy, while processes of rolling and suspension combined appear to be a characteristic associated with beaches where lower energy was present.

Medium to fine sand sampled above 325 feet and below 200 feel of elevation displayed in figure 25 a positive similar to the segment P-Q of figure 25, which corresponds to samples transported essentially by graded suspension and rolling processes. However, in Passega's diagram the range of sediment median is more limited (125 to 250 μ) than samples of figure 24, which are in a range of 125 to 250 μ. Samples in this segment (P-Q) correspond to the near coastal sand bar (for the upper samples) and to probably deltaic channel filling (samples below 200 feet elevation).

The sediment sampled at elevations between 275 and 300 feet (figure 24) and as determined before, corresponds to the intermediate marine water and are located in the position of segment Q-R in figure 25, which means that they were transported by graded suspension and no rolling process was present.

The very fine sand and coarse silt sampled below 200 feet and corresponding to distal deltaic deposits showed a distribution parallel to the limit C=M (figure 24) which means that C is proportional to M and accordingly the general C-M pattern (figure 25) this distribution indicates a process of deposition associated with turbidity current, probably caused by the differences in densities of the approaching waters.

From a review of the literature it was found that the most severe critics of Passega's C-M diagrams have been by Eynon and Walker (1974). These critics are summarized below:

1. The P-Q segment, which is assignated to suspension deposition is very sensitive to the competency of the current to maintain various sizes in suspension and for this reason the median (M) is not a good measure of the suspended size.

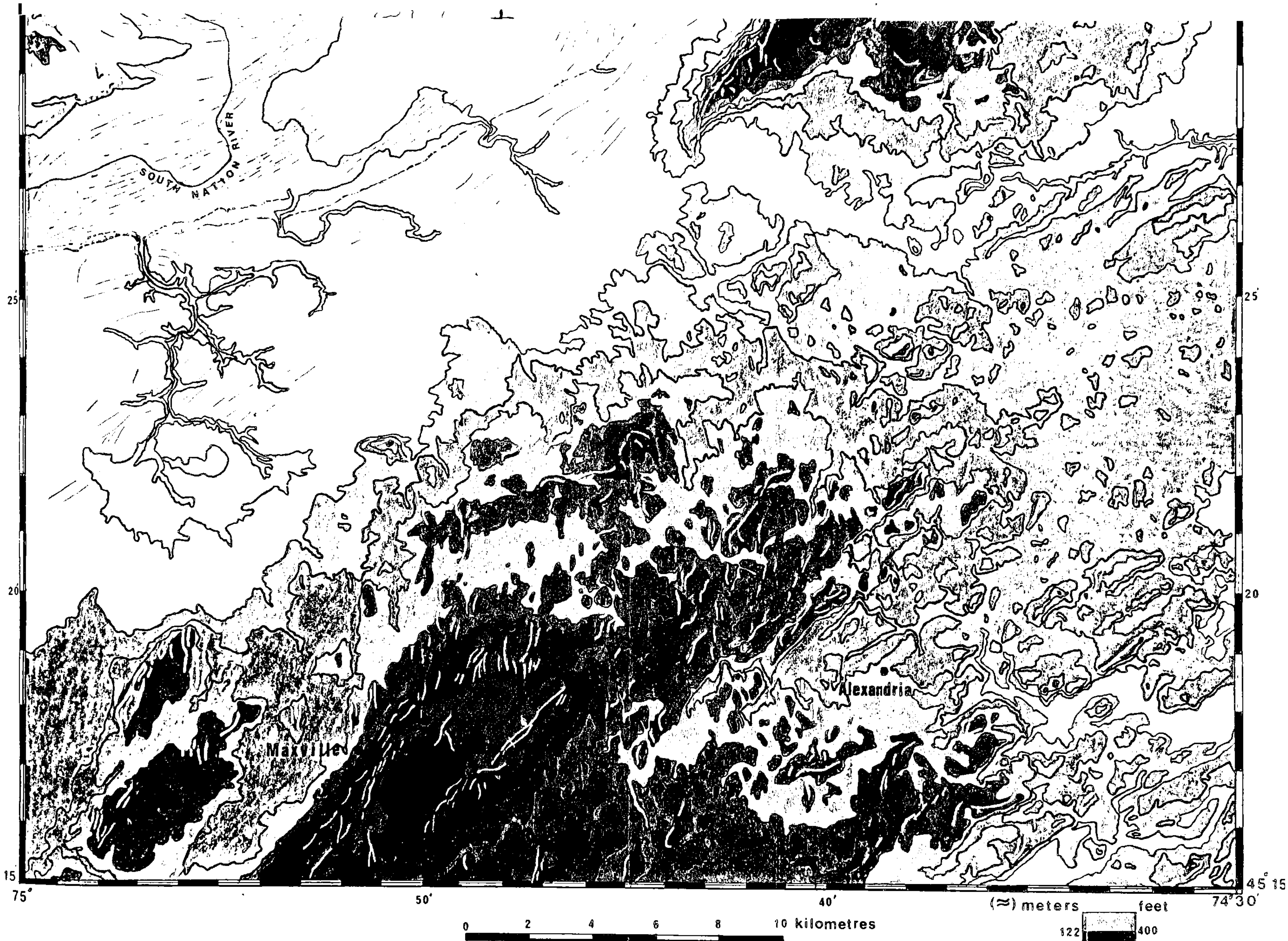
2. The clear distinction between rolling and suspension transportation (inflection in point P) processes will be blurred in systems capable of transporting the same size of sand either in suspension or by rolling, depending on the flow stage.

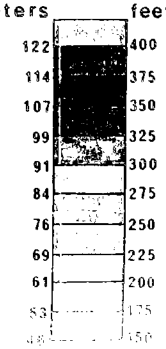
3. The median is not a good parameter to characterize bimodal or polymodal distributions and for this reason, the cumulative curve should be plotted to check the bimodal distribution; sedimentary structures associated with the sediments should be recorded in order to assess whether

suspension or rolling is a reasonable mechanism in explaining this process.

One of the advantages of Passega's diagram is that it uses the coarsest (C parameter) size, capable of being accurately measured, and less subject to errors caused by imperfect disaggregation, as is the case of the fine fraction.

In conclusion, as Eynon and Walker (1974) have stated, Passega's general pattern distribution (see figure 25) can be used to investigate processes of transportation, but it cannot be used to interpret these processes as easily as Passega implies, without plotting the cumulative curve and checking for bimodality; that is, without taking into account the specific sediment features.



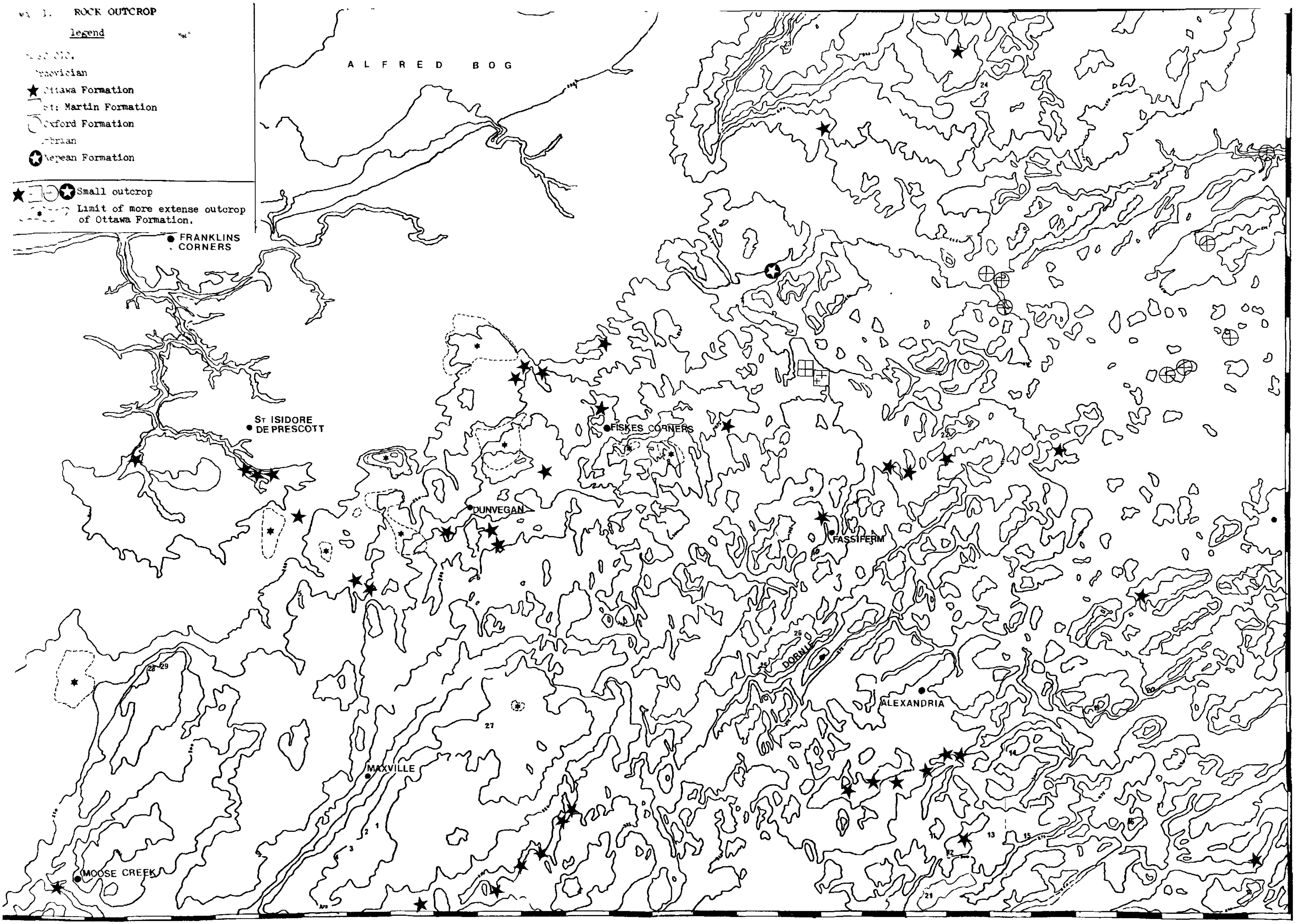


MAP. 2 . HYPSOMETRIC MAP OF THE STUDY AREA.

Legend

Erosional marks of the Proto-Ottawa River.
Edges of river terrace.
Littoral deposits formed during Champlain Sea Episode.

Source: Topographic map 31 G/7 NTS. scale 1/50,000.
Air photos: A18360 137 to 147, 187 to 196, 201 to 211.
A18649 34 to 46. Scale 1/36.000.



ROCK OUTCROP
legend
raovician
Ottawa Formation
St: Martin Formation
Oxford Formation
brian
Nepean Formation
Small outcrop
Limit of more extense outcrop of Ottawa Formation.
A L F R E D B O G
FRANKLINS CORNERS
ST ISIDORE DE PRESCOTT
FISKES CORNERS
DUNVEGAN
FASSIFERN
DORNIE
ALEXANDRIA
MAXVILLE
MOOSE CREEK

CHAPTER 5

MARINE LANDFORMS IN ALEXANDRIA - MAXVILLE AREA

As mentioned before, photo interpretation (scale 1/25.000) of the map area shows the presence of linear features in the coastal marine deposits, which are displayed in map 2

The distribution of these marine accumulation appears to be related to the area where the wave-wash process was stronger and more easily erodable material was available for wave and current distribution at the time of land emersion, rather than any lengthy period of sea level at determined elevations, as suggested by Sharpe (1979) for the Merrickville Area. From this point of view, we can say that the principal factors which explain the distribution of littoral depositional forms are: position of the emerging land in relation to the prevailing wind and wave direction; submarine topography and resistence of the material to the erosional processes.

In relation to the sea level position maintained at any determined elevation, most researches appear to be in agreement that the retreat of the Champlain Sea level was a slow continuous process (Johnston 1916; Goldthwait 1933; Owens 1951; Gadd 1971; Hillaire Marcel *et al.*, 1974; Karrow 1961). This would explain why beaches developed at any elevation where the conditions for their development existed.

In the map area (see map 2) it can be seen that these linear features (coastal deposits) occur everywhere above 250 feet. However, they are mainly concentrated in the elevations above 325 feet; in most cases, they are found in the contour of the slope or are in the crest of the hills. Similar marine coastal features have been observed everywhere in the St. Lawrence-Ottawa River basin (Goldthwait 1913; Johnston 1916; Owens 1951; Karrow 1961; Terasmae 1965; Sharpe 1979), they are mainly present in the west and northwest slopes of the modified pre-marine topography. This would suggest that the prevailing wind direction was west, and northwest as indicated by Owens (1951); Terasmae (1965); Sharpe (1979).

Another significant feature of these littoral accumulations is that they are very discontinuous and its length depends on the coastal exposure of the individual till island where favourable conditions to beach formation existed. This feature is a direct function of the pre-marine topography mentioned on page 13, and has been previously described by Owens (1951); Karrow (1961); and Terasmae (1965) for adjacent areas.

From detailed photo interpretation (scale 1/15.840) it can be observed that many of these linear features display well defined forms morphologically similar to those produced by coastal processes. Thus, from a morphological point of view, beach, wave built terraces, spits, tombolos, barrier island and offshore bars are easily distinguishable, which favour the hypothesis that the coastal processes in the area were important during the Champlain Sea Episode.

In order to test the hypothesis which arises from the morphological criteria, stratigraphic investigation was done where open pits permitted the distinction of upper and lower contact. In areas where stratigraphic studies were not possible certain extrapolations were made using the results from the open pits. This can be seen as a morphostratigraphic unit proposed by Frye and Willman (1960, 1962) which, according to them "...... serve a need long, apparent to those working in the bordering field of geomorphology and stratigraphy." The use of forms as stratigraphic units has been criticized by the pure stratigraphers (Richmond 1962), nevertheless, as stated by Fairbridge (1968), morphostratigraphic units can be very helpful for field mapping.

Once the marine accumulation was delimited much of the analysis and description of the forms were made following Gilbert's classic approach (1890). Because, as in the case of Lake Bonneville, landforms belonging to Champlain Sea coastal processes are now exposed which permit his study in three dimensions.

Mobile forms as spits were studied and inferences about the processes operating in his construction were derived from the morphological features of the deposits. Thus, we will see that prograding deposition is located in areas where an excessive sediment supply existed and the variable mobile forms occurred in places where the longshore currents lost their capacity of transport as a result of change in former coastal configuration, which as the former submarine topography can be elucidated from the actual topography features.

Shape analysis of the coarse fraction was a valuable tool in investigating the degree of transportation of the beach material and its direction followed where it existed.

In several cases landforms were identical, however, their mode of formation and origin of material were found to be completely different as is the case of marine terraces (wave or current built) and barriers which can be formed by wave or current and their material derived from the sea bed or transported by longshore current along the coast (Zenkovich 1967, 1971), or landforms of mixed origin can be caused by the interruption of such "normal" processes by storm wave or ice pushing action.

Thus, map and photo analysis, a necessary first step, was followed by a long and intensive field examination from which stratigraphic conclusions were drawn and samples for laboratory analysis were obtained. This gives the data for the environmental interpretation of the whole area. All the information was combined to explain how these landforms were created, why they are located where they are and finally to help elucidate some of the unresolved problems relating to the Quaternary stratigraphy in the Champlain Sea Area.

Maxville Highland

With isostatic rebound the first land subjected to wave action in the map area was the Maxville Highland (see figure 26 in pocket). It has a flat topography which could be the product of wave wash action. Observation of the bedrock topography and drift thickness maps (figures 8 and 9) indicates that a bedrock structural control also exists (Ottawa formation).

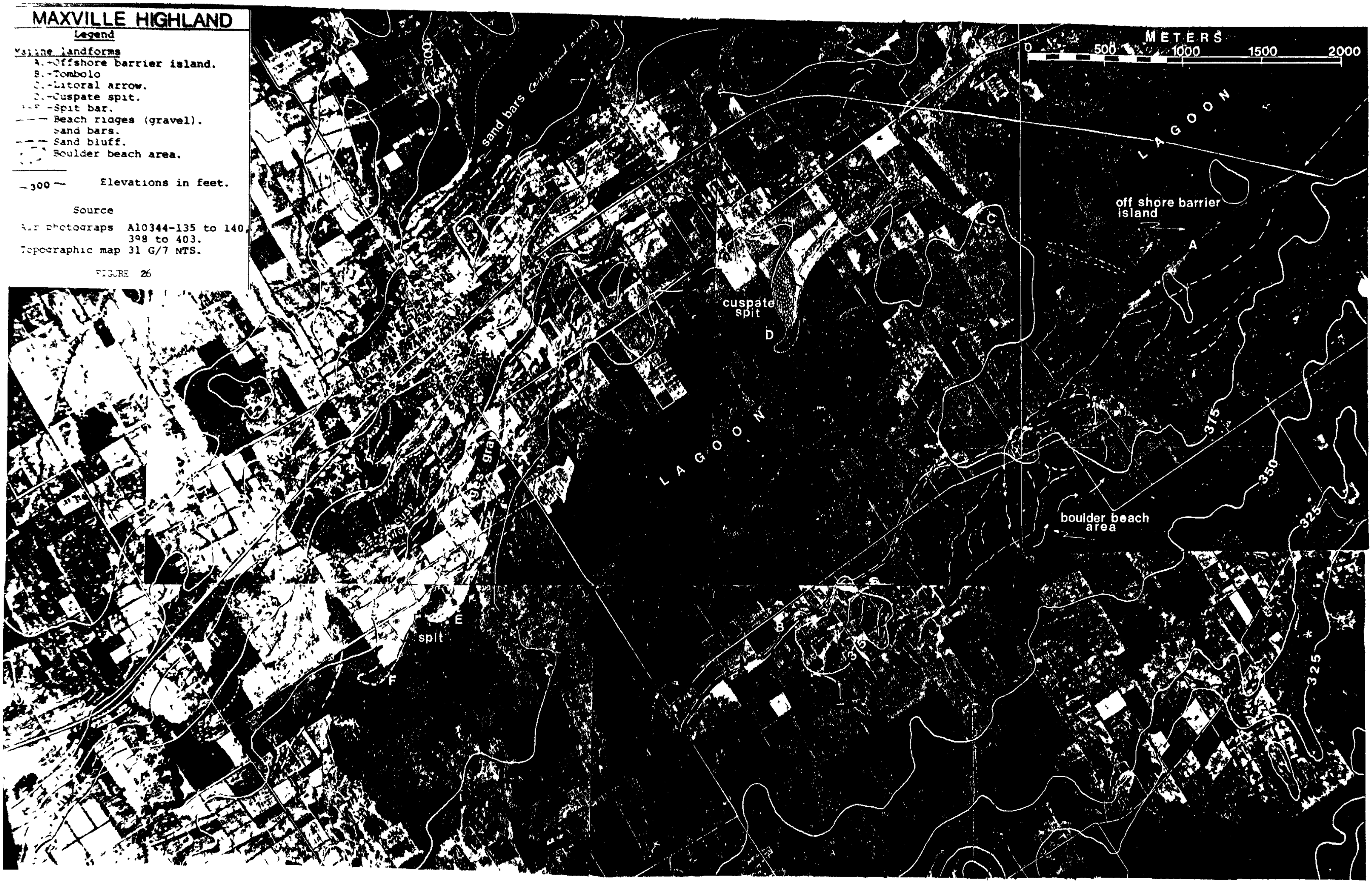
The land above 350 feet of actual sea level was the biggest "Till Island" in the area with an opened deep water section towards the NW side. In this former island the presence of numerous fossil marine landforms underline the significance of the Champlain Sea coastal processes.

Field observation showed that these marine landforms are constructed in a wide range size of sediment; some consist of coarse sediment (pebbles, cobbles and small boulders) and others only of coarse or fine sand. The size of material appears to be a function of the beach position in relation to the prevailing winds, and deep water sea, which determined the magnitude of the wave action.

Without regards to the size of material, marine landforms were well preserved naturally in the area. However, plowing has disturbed the sand deposits, and the commercial extraction of gravel has resulted in the disappearance of some of the best gravel marine landforms of the Champlain Sea. For this reason, the use of the former aerial photo coverage (1936) is a valuable instrument in identifying these former marine landforms.

Field observation and air photo analysis show the existence of an extensive area of organic deposits laying in the central area of the former island (see figures 26 and 27). This, besides the almost flat feature of the emerging land, indicates that the depth of the sea in the above mentioned area was very shallow and that lagoonal conditions prevailed. According to those features already described, Maxville Highland can be classified as a flat coast (Johnston's classification, 1919).

Towards the northwest side of the emerging till island the shore was in front of the prevailing winds (NW-W) and deeper water; therefore, the stronger wave action performed in this area created a complicated series of ridges in the NW extreme of the island. The shore opposite to the south east side, where the water was shallow and the



MAXVILLE HIGHLAND
Legend
Marine landforms
A.-Offshore barrier island.
B.-Tombolo
C.-Litoral arrow.
D.-Cuspate spit.
E-F -Spit bar.
Beach ridges (gravel).
Sand bars.
Sand bluff.
Boulder beach area.
300 Elevations in feet.
Source
Air photograps A10344-135 to 140, 398 to 403.
Topographic map 31 G/7 NTS.
METERS
0 500 1000 1500 2000
LAGOON
off shore barrier island
A
C
cuspate spit
D
LAGOON
sand bars
boulder beach area
375
350
325
325
B
E
spit
F
300

FIGURE 26

Figure 27. Organic deposit in the former lagoon of the Maxville Highland area.

wide open bay was almost closed by the growth of gravel bars creating conditions similar to the lagoon environments and marine landforms associated with it.

From aerial photos this lagoon area can easily be delimited in two areas established in relation to the elevation. The first area is located at 375 feet of elevation and the second one between 350 and 375 feet. Both areas have their long axis oriented in NE-SW direction. The total area covered by this lagoon was 9 km^2. It was a narrow body of water with a length of 6 km and a width of 2 km (see figure 26). Beneath the organic deposit the sediment size ranges from gravel (peripheric) to fine sand-silt (towards the centre).

The first marine landforms formed in the area were the gravel ridges located over 375 feet in the north-west area of the emerging till island. These ridges are extremely complex and they present a wide range of direction (see figures 26 and 32). These forms were the products of the strong wave action on the easily erodable till material. According to MacClintock (1958) wave wash action lowered till ridges up to 50 feet, which demonstrates its tremendous effects to the pre-existent topography and the enormous quantity of sediments to the disposition of coastal processes.

Boulders Beach

The best developed boulders beach in the map area were observed at the southwest end of the "Maxville Island" at an elevation between 350 and 375 feet above sea level (see figure 27). This deposit does not have the same position as observed by Terasmae (1965) in the Cornwall area (see figure 28). Here they were not concentrated on the slope of the till ridges, but were found on an almost flat surface. Rock count gives a percentage of 90% crystalline rock. Whether they are the result of wave wash action on till or representing transported ice floating material will be discussed later. On the other hand, their transportation due to wave action is doubtful and according to Zenkovich (1967) rocks of the observed size are too large for the waves to move them.

Offshore Barrier Island

The Maxville Highland flat coast was limited towards the SE shore by an offshore barrier, which are marine depositional landforms associated with a flat coast. Its essential character is that it can be an entirely free form or unattached to the coast at either end. It is this condition that is not always trus as barrier islands are sometimes attached to one or both extremes of the coast (King 1972). In this case, a combination of both forms can be observed (see figure 32).

Shape analysis of the gravel forming this deposit was performed in order to investigate the direction of material transportation. Due to the presence of only two

Figure 27. Boulder Beach near Maxville.

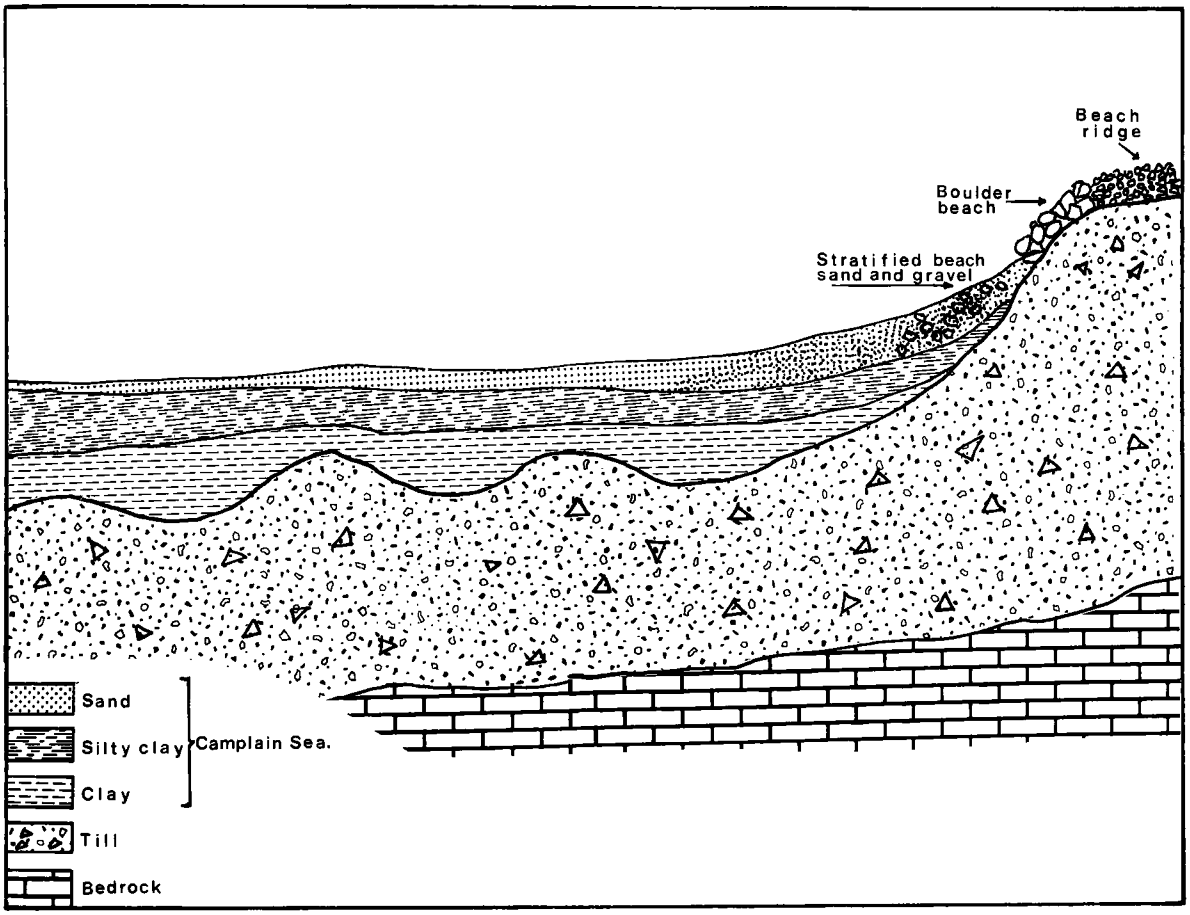


Figure 28. Champlain Sea sediments in the Cornwall area. (After Terasmae. 1965.).

open exposures along the deposit (train track cut and small pit) samples were taken from a shovel cut hole, 3 feet deep. Location of the site samples are shown in figure 29 and results of the gravel shape analysis are presented in table 3.

From values of table 3, it is clearly shown that the gravel material apparently did not follow only one direction during its deposition. These values can perhaps be explained by the fact that some of the supplied material came directly from the sea bottom (storm waves); sediment current can also migrate in two directions, depending on the alternating action of a spectrum of wave which can vary in power or direction, which can be normal to the coast, longitudinal or act in both directions (Zenkovitch 1967, 1971). Another explanation could be that the barrier received in part is the material from different sources during its development, joining small till hills (see figures 26 and 29).

The coarse feature of the material forming the barrier is expressed on the steeper slope of the transversal profile (see figure 30), from it a steep depositional slope lies in front of the former foreshore side can be distinguished. Thus, stronger wave energy coming from the lagoon side can be established. This was due to the fact that offshore area of the southeast side of the emerging island was in back position to the prevailing wind direction.

Location (*)	Mean roundness ($\bar{X}$)	Standard deviation	Statistical test (Z) test : 0.02: 2.05
1	231	63	Location 1 and 2 : 2.81 significant difference.
2	266	61	Location 2 and 3 : 3.99 significant difference.
3	217	62	Location 3 and 4 : 1.07 no difference.
4	203	69	

(*) location in figure 29.
sample number: 50 pebbles.
size class 45-60 mm.

Table 3. Roundness values for pebbles along the offshore barrier, Maxville Highland area (landform A in figure 26).

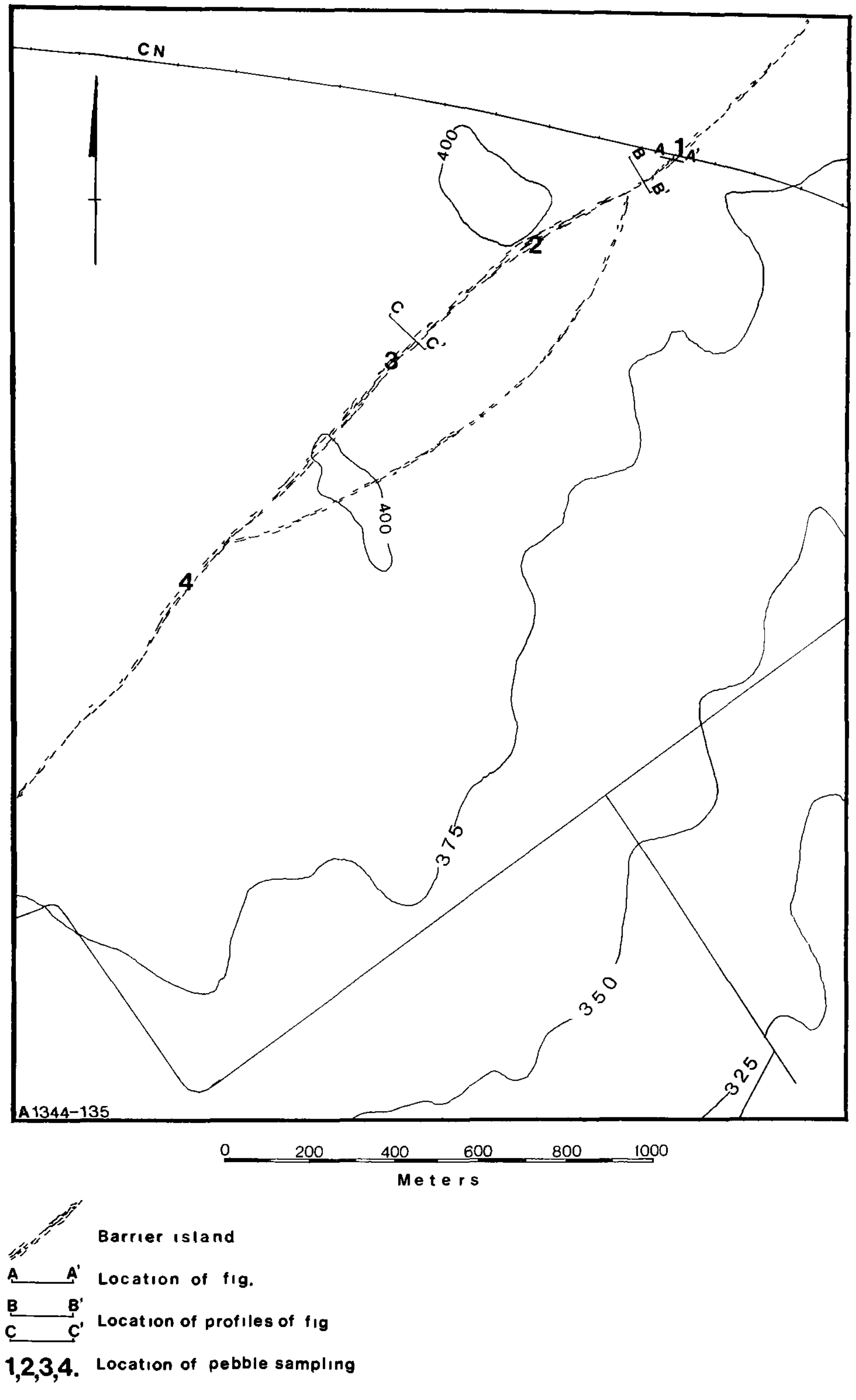


Figure 29. Map showing the offshore barrier island, and the location of sites of pebbles sampling, and transect of topographic profiles of figures and .
Source: topographic map 31 G/7 NTS.
air photographs A10344-136 and 135.

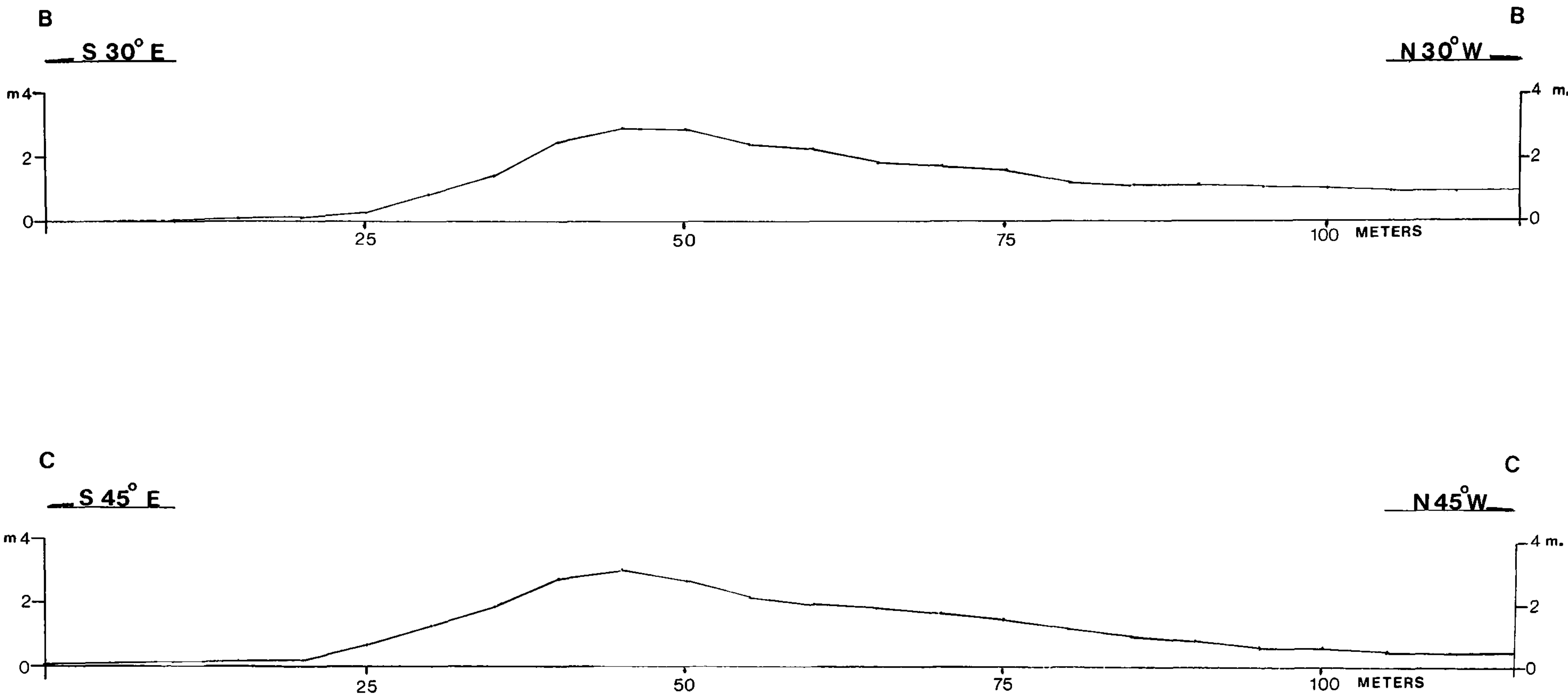


Figure 30. Topographic profile on the offshore barrier island. For transect location see figure 29.

Figure 31. Cross section of the offshore barrier island. Correspond to transect B-B´in figure 29.

Landform B (figure 32) appears to be a tombolo which joins the boulder beach area to a small till island located at the central zone of a wide open shallow bay (see figure 26).

<u>Free and Fringing Landforms</u>

Inside the shallow water of the lagoon, environment free (spit, arrow) and fringing (cuspate spit, spit bar, cuspate foreland) depositional landforms were formed. These forms are specially observed in the northwest shore of the lagoon.

Depositional form C in figures 26 and 32, is a littoral arrow growing towards the southeast of the lagoon. The process of formation of this deposit displayed a bilateral supply of sediment which is explained by the different wave system approaching the coast of the lagoon. The curvature of the beach zone at both sides of the form indicates that wave refraction was effective during the accumulation.

Deposit D in figure 26 is a complex accumulation form. It started to grow as an arrow in direction southwest with a bilateral supply of material coming from the NE and SW (see figure 32); at this time probably the environment was a bay. Later, because the sea level "fell" the growth of the distal landform turned towards the "deeper" zone of the "new" lagoon acquiring the spit form. The spit development created a "wave shadow" protecting the adjacent portion of the shore from predominant waves and permitted "subordinate waves" in the opposite direction to penetrate and fill the linear angle between spit and shore (see figure 32). When this process takes place, the whole accumulation is called a cuspate spit (Shepard 1952), that is, a compound spit developing by progradation from a barrier or land ward shore of a lagoon into a lagoon or sound area. The term "cuspate" was taken from Gulliver (1896) who appears to be the first person to use the word "cuspate" to design prograding marine material by coastal processes (cuspate foreland).

Cuspate spit has been found everywhere from tropical to Arctic environments (e.g. Fischer 1955; Zenkovich 1959; Shepard and Wanless 1971). The material forming cuspate spit, ranges from pure sand (Shepard and Wales 1971) to sand and gravel (Fischer 1955). Cuspate spit developed in coarse material (pebble, cobble or even small boulders and without sand) has been reported in many places in the seas of USSR (Zenkovich 1959).

Zenkovich's theory (1959) on cuspate spit formation is the most currently accepted. This form is considered to be the product of shore-drifting processes caused by wind induced current in a lagoon area. According to this investigator, cuspate spit formations "..... are formed only in narrow bodies of water, the widths of which are about half or less than half of their length .....". Such conditions existed in the shallow water bodies of the former Maxville Island flat coast.

Figure 32 is an idealized sequence of the current transportation and wave system drawn from the form of the deposits and in base of Zenkovich (1959, 1971) idealized patterns.

Actually, marine landforms C and D have been almost completely excavated. Field examination of the place where these deposits were formed (see figure 33) and photo analysis of the former coverage (see figure 26) show us that there was a well defined deposit resting on the finer material of the lagoon.

Despite the above, gravel samples from the remnant of the original deposit (towards the lagoon side) were taken for shape analysis. Results are shown in table 4 and sample location in figure 33.

From table 4, no clear trend of transportation of debris is observed. However, the roundness values increase towards the distal ends of forms C and D, which represent directions of transportation from the principal currents in figure 32.

Gravel Beach Ridges

A series of well-developed linear gravel beach ridges up to 2 km long are found to the west of the top of

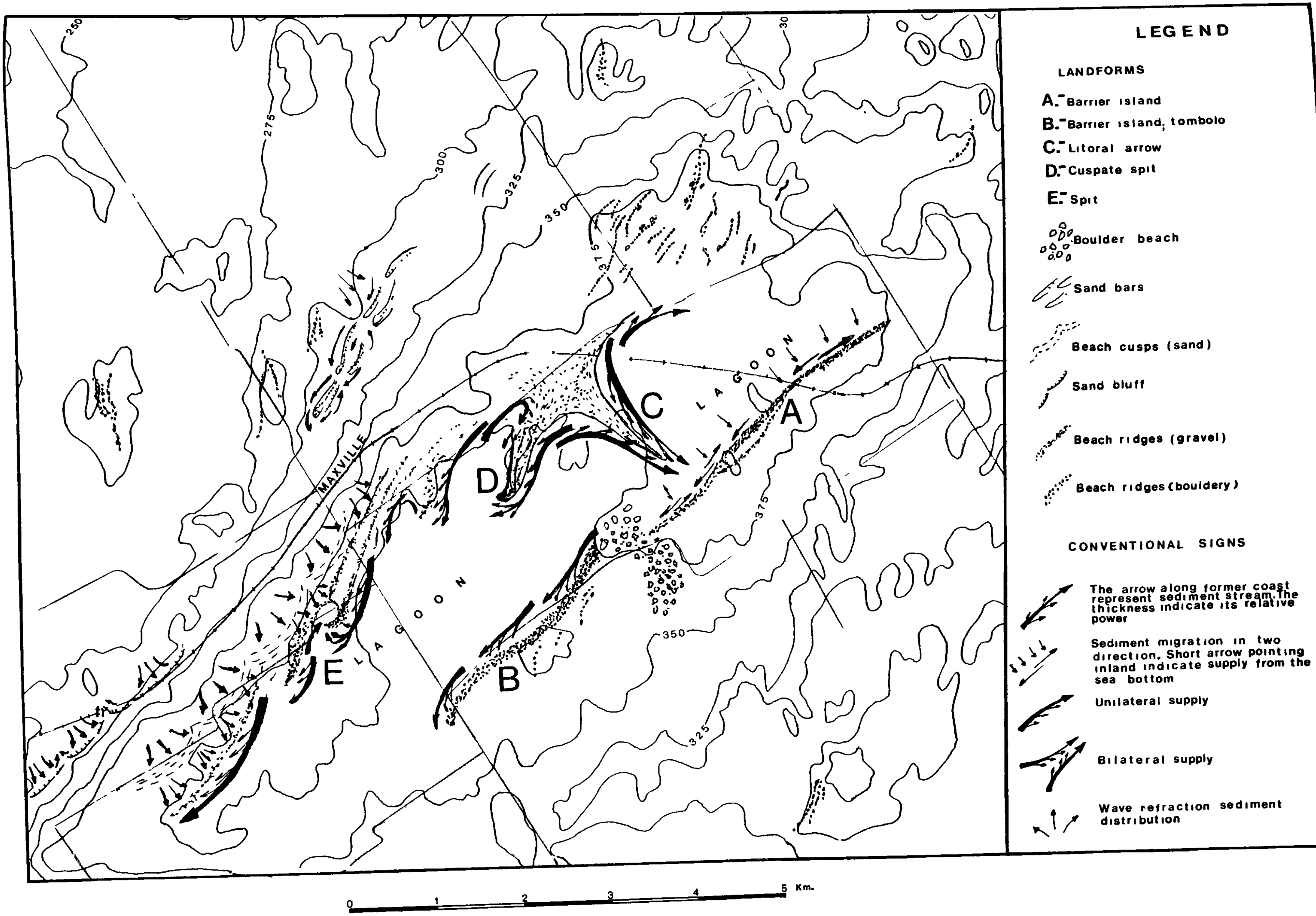


Figure 32. Marine landforms in Maxville highland area, and idealized sequence of sediment streams.

Location (*)	Mean roundness ($\overline{X}$)	Standard deviation	Statistical test (Z) test α : 0.02: 2.05
1	233	84	Locations 1 and 2 : 3.53 significant difference
2	182	58	locations 2 and 3 : 0.40 no difference
3	191	39	locations 3 and 4 : 0.62 no difference
4	184	70	locations 4 and 5 : 3.65 significant difference
5	235	73	locations 5 and 1 : 1.13 no difference

(*) location in figure 33.
sample number: 50 pebbles.
size class: 45 - 60 mm.

Table 4 Roundness values for pebbles along cuspate spit and littoral arrow, Maxville Highland area.

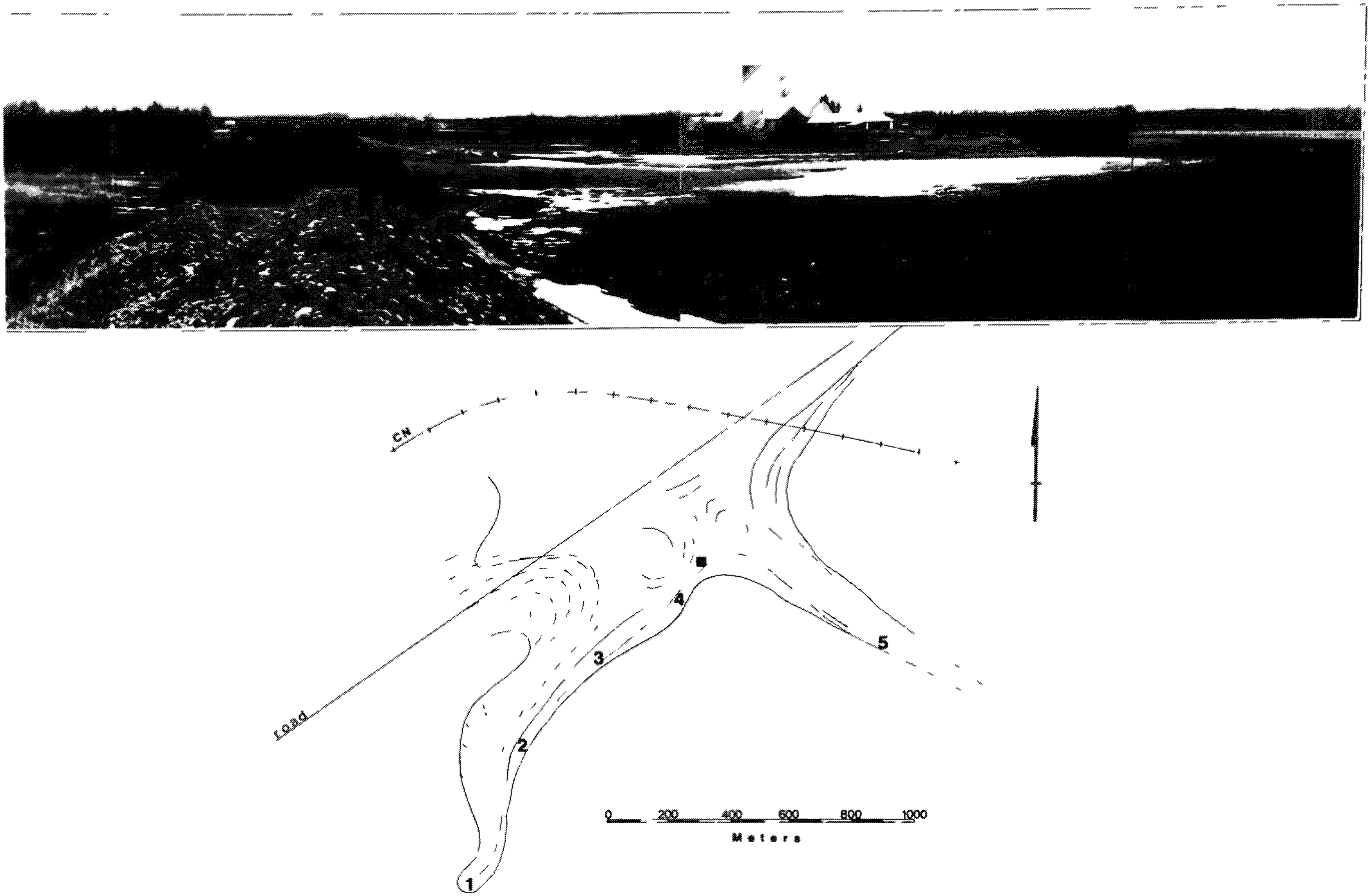


Figure 33. Sketch of the cuspate spit and littoral arrow before gravel excavation.
Source air photographs A10344-137 to 139.
Photo shows that this former marine acculation is almost complete excavated.

the Maxville Highland (see figure 26) above 375 feet elevation. In this area, no boulder beach deposits were observed.

The good preservation of these ridges are an indication that they are made of coarse gravel.

From figures 26 and 32 it can be seen that this section of the Maxville Highland coast was in front of the prevailing wind and wave action, in front of open and relatively deep sea water. The general orientation of this section of the Maxville Highland was NE-SW. The waves produced by wind direction W-NW approached the coast at an approximate angle of 45°, which including the coarseness of material and bottom inclination are the necessary conditions for shore drifting transportation. Therefore, as the upper ridges are not attached forms here, storm wave accumulations were an important force in the formation of these ridges.

It was not possible to obtain samples of pebbles as many open pits were unavailable along these ridges. The few pits are found in the terminal section of these ridges which have the good gravel quality due to greater transportation. Roundness values for these open pits are shown in table 5. From it, conclusions about the transportation of material cannot be made because these pits correspond to different ridges.

Location	Mean roundness ($\bar{X}$)	Standard deviation	Statistical test (Z) test : 0.02: 2.05
1	252	71	location 1 and 2 :1.03 no significant difference
2	240	73	

1. open pit in terminal section of landform E in figure 26.
2. open pit in terminal section of landform F in figure 26.

Sample number: 75 pebbles.
size class: 45-60 mm.

Table 5 . Roundness values for pebbles in two differents gravl beach ridges in Maxville Highland.

Figure 34 shows a profile across several of these gravel ridges. The dimensions of this profile are concordant with those of a series of gravel ridges as a result of storm waves observed by Zenkovich (1967) in Kobuleti, (USSR). A series of beach ridges on gravel material have been reported by King (1969) in raised beaches in Foley Island (Arctic Canada). These were attributed to single storms.

It appears that at least the main section of these top beach ridges are the combined product of wave storm accumulation and long shore redistribution. While only the terminal section of these gravel ridges, especially towards the former south shore are definite transported material, as observed, from the stratigraphical features in the open pits (see figure 35). Here it was found that the gravel coarse material rests over a fossiliferous sand, and records deposition from relative deeper water to shallowing of sea level. Otherwise, the morphological feature of the terminal section of deposits E-F corresponds to a "spit bar" (Yasso 1964). These are depositional marine landforms, defined as an accumulation attached to the land at its proximal end, and in deeper water at its distal end. It decreases in elevation towards the distal end and has a curvature convex to the sea (see forms E and F in figure 26). Figure 36 shows the place where the distal section of form E was, which has been completely excavated.

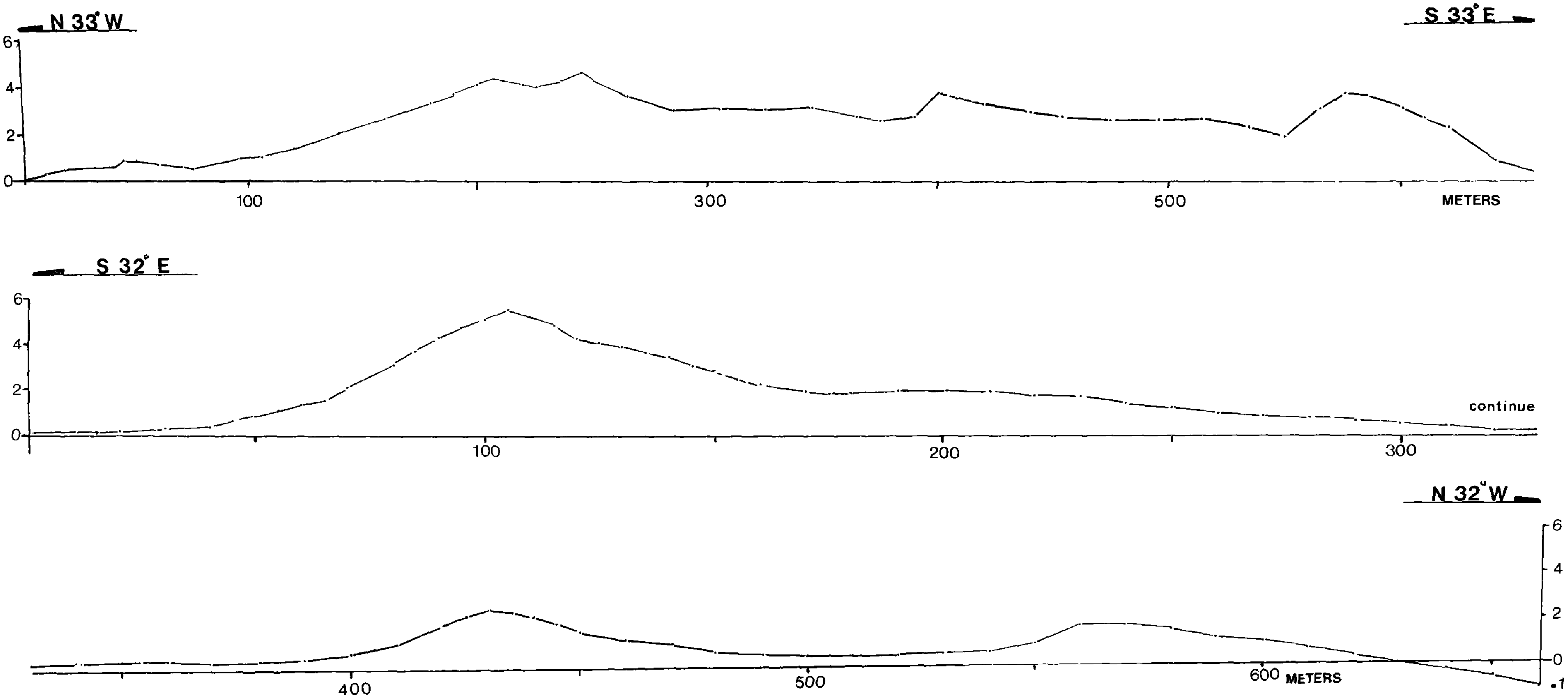


Figure 34. Topography profiles on a serie of beach gravel ridges in Maxville highland area. For location see figure 27.

Figure 35. Open pit in the terminal section of the spit bar.
Landform F in figure 26

Figure 36. Excavated area of spit bar E in figure 26.

Offshore Sand Bars

Large areas of marine sand deposits occur around Maxville Highland (especially towards the north side) since this was the area with the most extensive shoreline development. These sand deposits are directly related to the nearshore areas where the strong wave attack occurred and the sorting process of wave and current was most effective.

The depth of these sand accumulations is related to the submarine topography at the time of deposition. Where depressions created suitable conditions for deposition we found the thickest deposits as observed in the northeast section of the "Maxville Highland Island" (see figure 26). On the other hand, with decreased elevation, below 275 feet, sand deposit gradually changed to silty-sand and silty-clay.

In most cases, the stratigraphical position of the sand overlies the marine silty-clay or marine clay. This indicates that this sand was deposited in the near shore environment when sea level fell, while the silty-clay and clay sediments were deposited when water from the sea was deeper.

The morphometric analysis of the Champlain Sea sand, showed that rounding process did not affect the quartz fraction, due fundamentally to the short time elapsed

by this marine episode. For this reason was observed that more than 95 % of the quartz sand grain are angular fundamentally derived from weathered crystalline rocks.
The small rounded fraction corresponds to the Nepean and March formation, in other words the roundness of these quartz grains is an inherited feature of the Cambrian-Ordovician rocks . This lack of rounding was also observed by Hillaire Marcel et al., 1974 in the morphoscopic analysis of the Champlain Sea sand in Oka Hills area (Montreal).

The general petrographical analysis of this sand (table 6) confirmed that the till was the source of the marine sand. The main size and sorting values are discussed in detail on page

In figure 26, we can observe that between 375 feet and 325 feet, towards the north side of the former Maxville Highland Island, that the sand material have a "crescent beach" pattern, which tells us that wave refraction was an important process in the transportation and redistribution of the marine sand at these elevations. The development of these crescent sand forms was probably preceded by the formation of long beach sand ridges built up in the sand and parallel to the upper gravel beach ridges (above 375 feet).

Sand accumulations were thickest where the slope of the submarine topography was less accentuated,

SOURCE	MEAN SIZE (ϕ)	SORTING (σ_I ϕ)	size class 0.5 ϕ to 1.0 ϕ			size class 1.5 to 2.0 ϕ		
			% L	% Q-F	% Rf	% L	% Q-F	% Rf
TILL	3.75	3.00	57	10	33	22	44	34
SAND FROM GRAVEL BEACH	o.92	1.17	44	25	31	20	52	28
SAND FROM OFFSHORE SAND BARS.	3.11	0.745	10	70	20	00	85	15
SAND FROM INTERMEDIATE DEEP WATER. (*)	3.38	1.60	0	90	10	0	90	10

(*) sampled at elevation between 250 and 300 feet.

L: Limestone grains .

Q-F: Quartz-Feldspar grains

Rf: Rock fragment grains.

Table 6. Features of sand from different sources.

towards the northeast between 300 and 325 feet (see figure 26). Here the sand deposit was built up into well-defined sand bars, parallel to the former coast. According to King and William's classification of sand bars (1949), these types correspond to the "ridge and runnel" type. One distinctive feature of this type of sand bar is that they are interconnected by drainage channels at a right angle to the water line. They are usually formed in beaches with considerable tidal range (King and Williams 1949).

Very well preserved sand bluff (figure 37B) was observed below an elevation of 300 feet. In front of these sand bluffs, straight or crescentic sand bars were formed parallel to the sand bluff (see figure 37C). Below 275 feet of elevation the sand deposit becomes very thin and changes gradually to silty clay and clay, sediments characteristics of the deeper facies of the Champlain Sea deposition.

Dornie Area

This area is located to the NW of Alexandria Town (see figure 38 in pocket). It shows a very well-developed marine landform at an elevation of between 325 and 350 feet above sea level.

The Dornie Area at the time of active marine processes was an example of a dissected coast caused by the irregular pre-marine topography. According to Zenkovich

A

B

C

Figure 37. Sand bluff and parallel sand bar near Maxville highland. fig., 37A is a panoramic view of the area.

(1971), this kind of environment is characterized by waves varying in length and direction of approach which created converging and diverging currents that gives for each part of the coast its "own local currents".

The bigger and best developed free landforms (e.g. spits) in the whole Alexandria Map Area are found there. According to King (1972) spit forms "..... are most likely to form where the coastline is irregular and their form will also be more complex as a result. Where the coastline is irregular, longshore movement of material will be unlikely to be uniform and spits will form in those areas where more material is reaching a stretch of coast than leaving it. Such areas will be determined by the wave pattern in association with the coastal outline."

In the paleogeographical interpretation of the coastal processes from the landforms present, this area will be considered as a whole and the interpretation will be made in chronological sequence following the raising of the land in the area.

Land Above 350 Feet

The first land to emerge in the area was the Dornie till ridge, which is 350 feet above the present sea level. It formed a long and narrow island located to the east of the biggest till island of Maxville Highland, already studied. The general orientation of the new island was NE-SW. It was located in front of open sea and inferred prevailing wind direction, thus the north side of the emerging land was subjected to strong wave-wash action.

The wave-wash processes produced a "plane" surface on the top of the ridge till and a large amount of cobble, gravel and fine material was deposited subaquatically on both sides of the ridge forming aggradation deposits. These are divided by Hesseland (1946) in progradational, deposited in the main direction of movement of the transporting medium and regradational, those aggraded in the opposite direction, see figure 39.

On the flat surface of the emerging island beach ridges of bouldery material were built, probably by storm waves.

Because of the disponibility of easily erodable till material (in situ and reworked aggradational deposits) and the irregularity shown by the coast of the emerging till ridge, the mobility of the material due to longshore current wave induce was contemporaneous with the emerging of the land.

Coast orientation NE-SW and inferred wind direction W-NW created a wave ray making contact with the shoreline at about 45°, which is a requisite for shore drafting (this value changes depending on the coarseness of

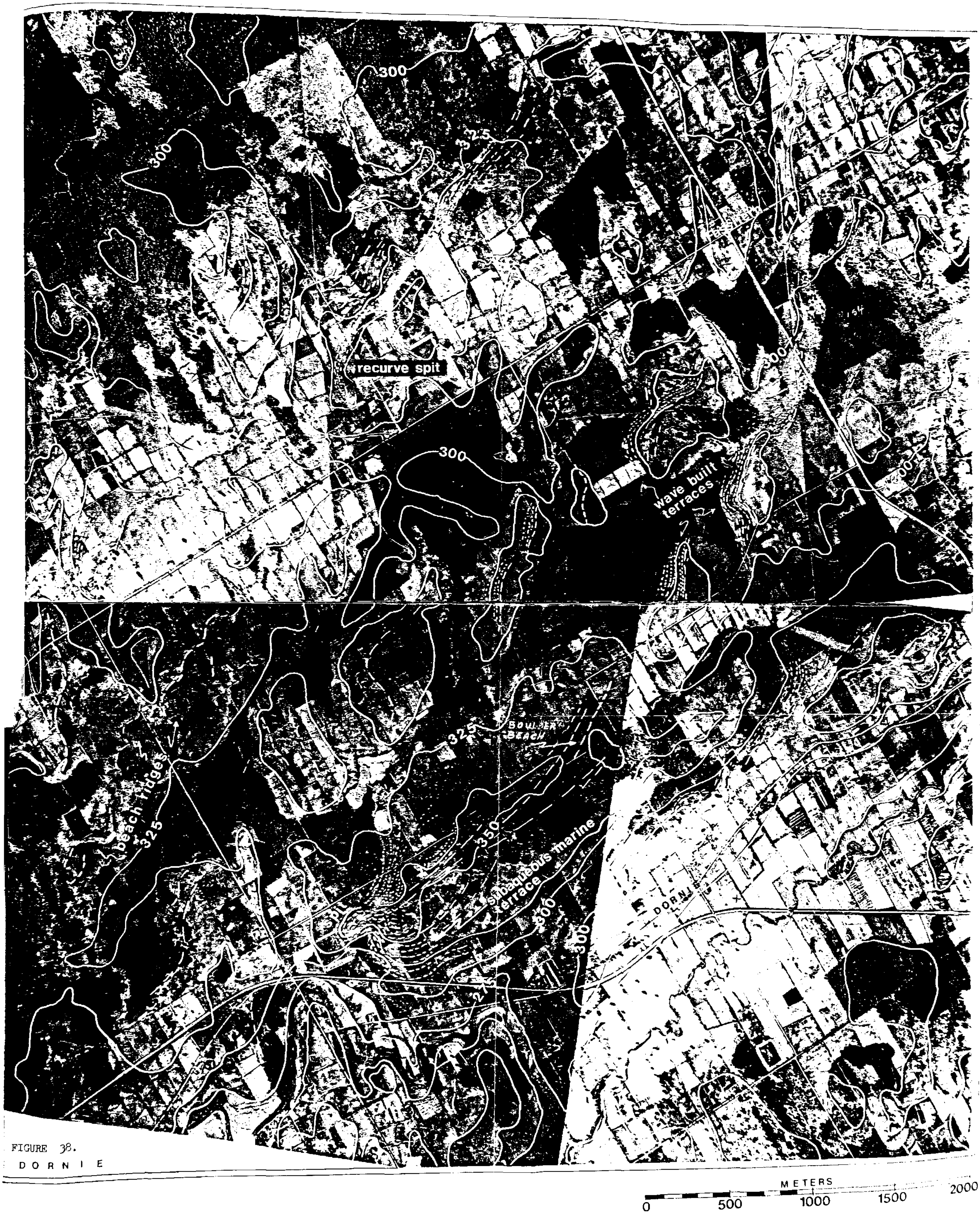


FIGURE 38.
D O R N I E

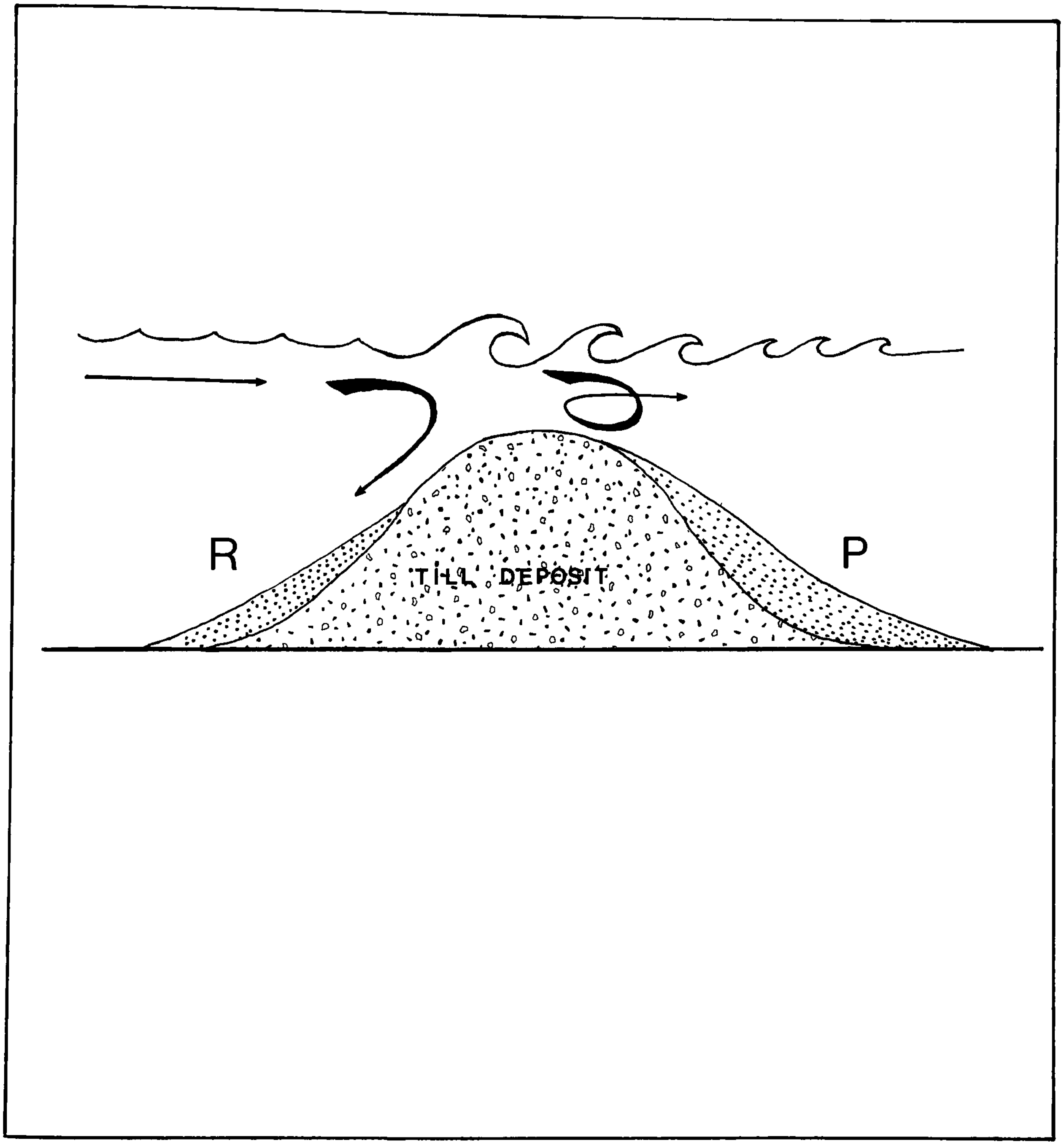


Figure 39. Wave-washed deposits. P: progradational sediments, deposited in main direction of wave. R: regradational sediments, deposited in the opposite direction of main wave direction. (After Hessland. 1946.).

material and the slope of the bottom) Zenkovich (1967, 1971), with the net resultant stream sediment towards the distal SW extreme of the emerging till island, where the direction of the shoreline changed to the southeast. Here the current went from shallow to deeper water and the waves reaching the coast are refracted. Because the drift cannot follow the deflected coast the supply of sediment by long shore current results in a forward accumulation to where the water is deeper. This builds an embankment and then facilitates the transportation of more drift and the construction of a spit form, with the same direction of the littoral current (Gilbert 1890). This process explains the coarseness of its upward feature showed by this kind of deposit. The construction of a submarine embankment (Gilbert 1890), as a prerequisite for developing spit has been further demonstrated in the wave tank experiment by Meistrell (1966), who proposed the spit platform concept.

Towards the south shore of this till island the same processes operated but here the wave action was less strong (back to prevailing wind) but not less effective in redistributing the progradational deposits resulting in the wave washing processes, which were stronger in the south side of the island.

To the extreme southwest towards the south shore, there is an extensive subaqueous marine terrace prograding from the reworked till (see figure 38), towards the northwest the terrace is attached to the spit. There appears to be a mixture of regradational progradational and shore-transported material.

The terrace formation seems to be a combination of progradational and shore process. The roundness value of this deposit is lower than in the spit from which we can deduce less transportation in the redistribution of the material. In general, the "body" of the gravel deposit tends to be homometric and scarcely boulders can be observed in it. Over these foreset gravel beds, a discordant coarse layer of cobbles and boulders is present. Similar discordant coarse layers in prograded sand layers from reworked till material have been observed by Glomquist (1969) who attributed this presence to the strong wave turbulence in shallow water.

Morphological Considerations

Figures 38 and 40 show the total deposit before gravel excavation. This spit is a distinguishable form with a length of approximately 400 m and a width of 75 m. The height of the accumulation is approximately 3 m and the general orientation of the spit is NE-SW.

Towards the distal SW portion in the direction of spit grows the slope that is steep as a result of the coarseness of the material that forms the deposit. Thus following Gilbert's deductions (1890), it can be stated

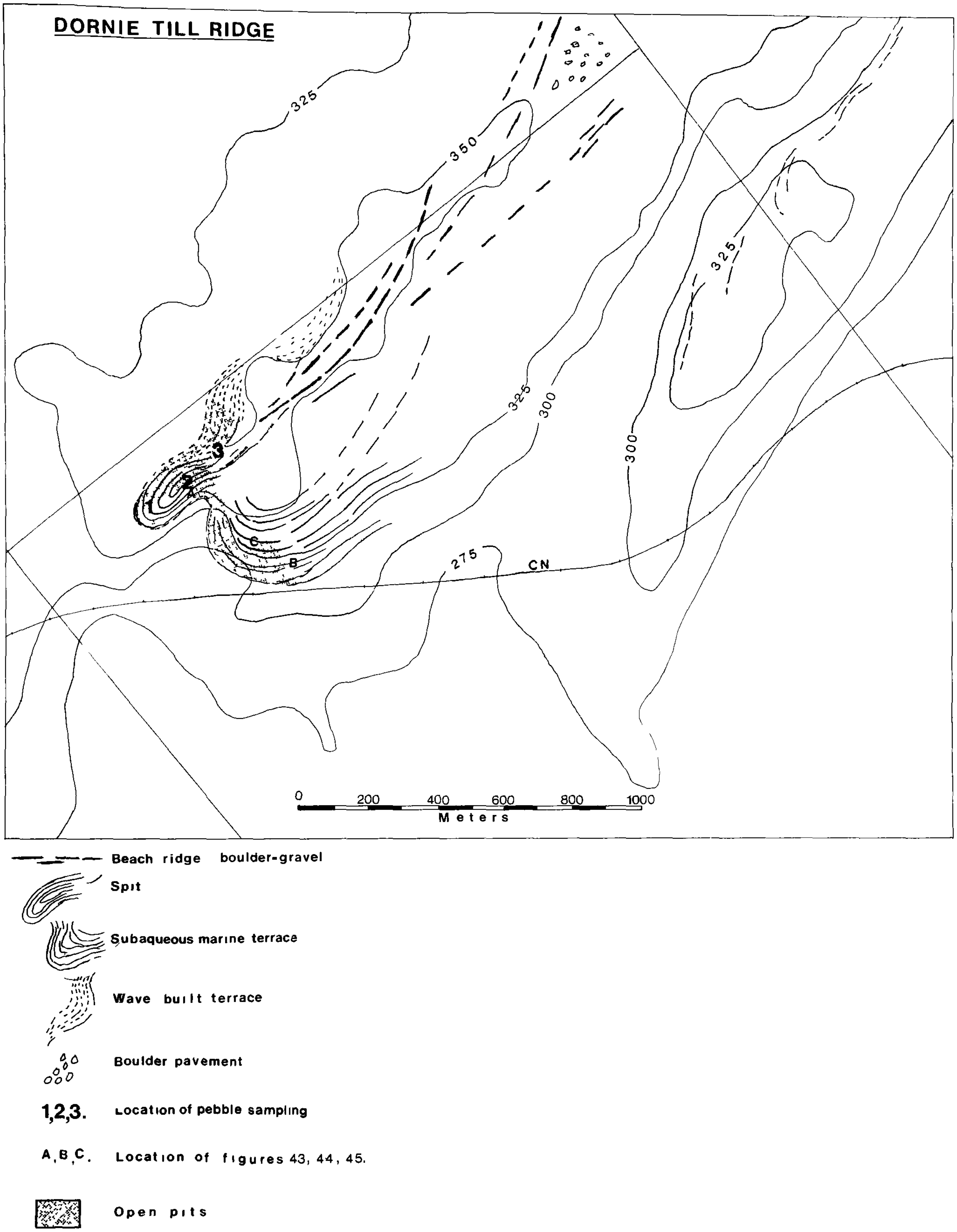


Figure 40. Map showing the marine landforms of the Dornie till ridge area.
Source: topographic map 31 G/7 NTS.
air photographs A10344-101 to 104.

that at the time of spit formation the distal portion of this form was very slightly submerged.

On the top of the spit gravel beaches ridges were well preserved due to the coarseness of the material. Towards the NE of the till island , bouldery beach ridges are present (see figure 40). In this area boulder beaches were found in several places (see figure 41), but without continuity; the stone count in these deposits gave more than 90% of crystalline rocks. The origin of these boulder deposits will be discussed later.

Stratigraphy and Structural Features of the Deposits

The commercial excavation of the gravel deposits allowed us to make a general stratigraphy analysis to determine the validity of the morphological view point (interpretation) made following Gilbert's analysis of emerged lake landforms.

The elevation of these deposits coming from above 350 feet towards 300 feet, tells us that if these accumulations are of marine origin they should record the main events of the depositional processes occurred from deep to shallow water sedimentation as a result of the retreat of the Champlain Sea level.

In effect, in all the exposed wall pit the stratigraphy of the deposits is coarse upward which gives greater weight to the idea of prograding forms into the

Figure 41. Boulder beach in the Dornie area (elevation 350 feet)

water sea which correspond with the general character of a "regressional" sea.

"The Spit"

Observations of the development of the excavation in the spit form, from September 1979 to February 1981 permit us to observe the structural features of the distal section of this marine landform.

Observations showed that this deposition has a large stratigraphic unit which conforms with its external form. Strata dipping to both sides, are steeper towards the side opposed to the former wave direction. The longitudinal axis of this accumulation dips slightly towards the distal end of the prograding forms, with steep slopes in the terminal area.

The observed structural feature of the spit form is concordant with the ideal cross section defined by Gilbert for bar structure (see figure 42), which confirms the conclusion derived from the morphological point of view about the importance of coastal processes in building this form.

Figure 43 is a cross section of the spit form, the gravel is coarse upwards. A distinctive feature of this section is the presence of definite layers of broken shells of *Mytilus edulis* mixture with fine gravel (2 to 4 mm). As a fossil, *Mytilus edulis* shells are indicators of the

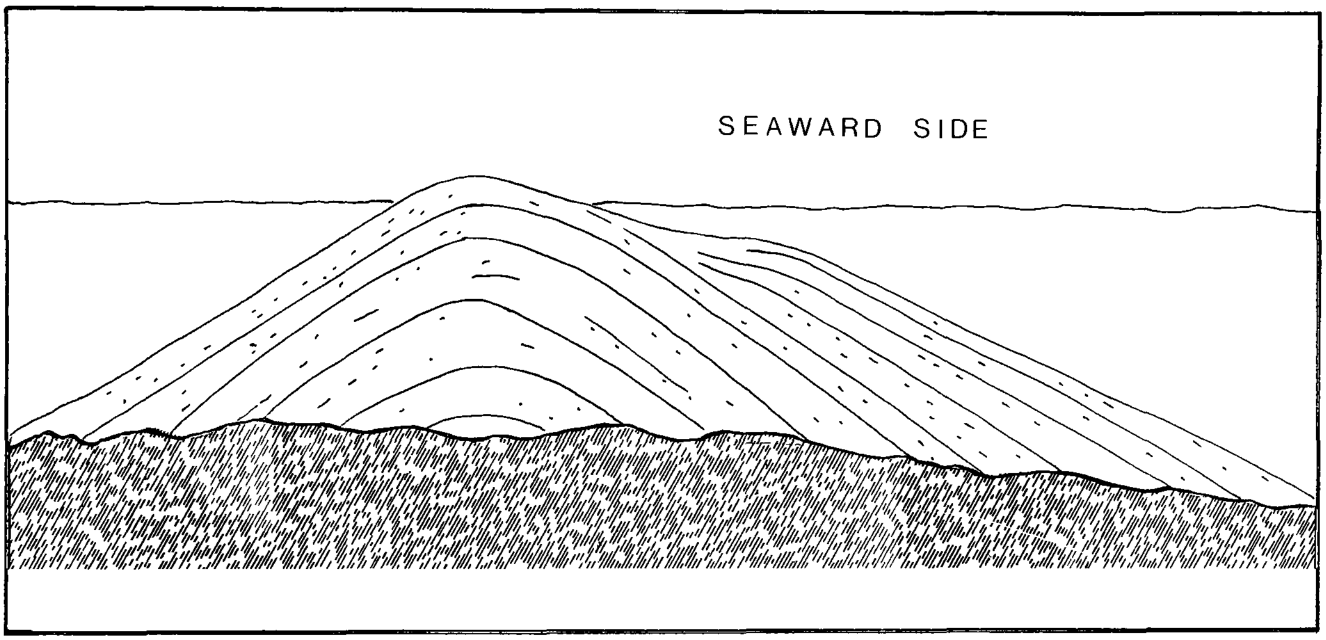


Figure 42 . Ideal cross section for spit and bar (After Gilbert. 1890).

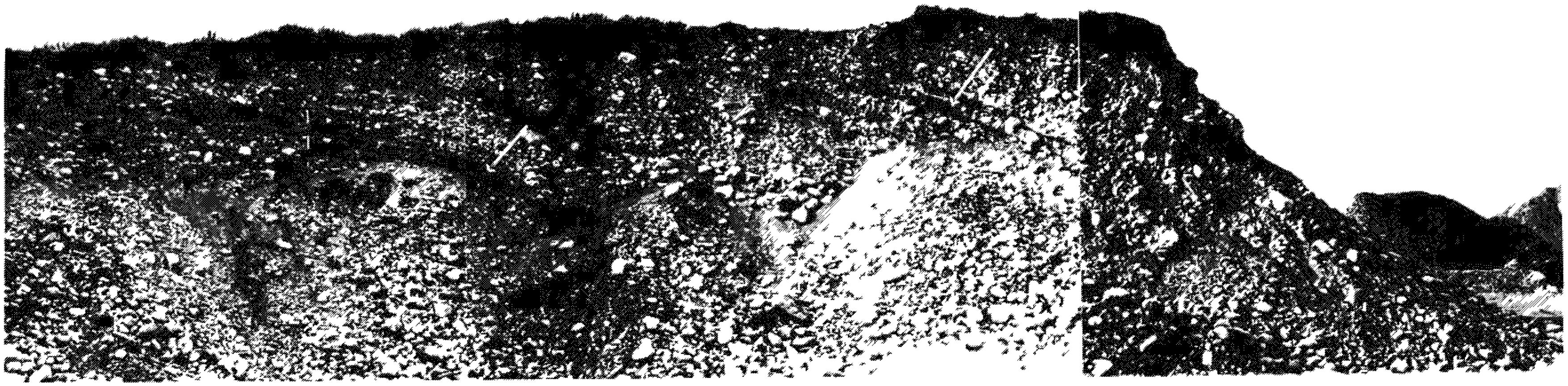


Figure 43. Cross section of the spit landform.
Arrow point out the layers of broken shell of *Mytilus edulis*.

shallowness of the water, as observed in modern environments in Atlantic Canada (Bousfield 1960). On the other hand, if fossil shells of pelycipods species in living position or with valves inseparated are indicators of little or no transport after death (Wagner 1969), the presence of these completed broken Mytilus edulis layers is another significant indicator that would support the view of the transportation process by longshore currents in the construction of this marine landform.

Marine Terrace

Figures 44 and 45 represent cross and longitudinal sections of the wide marine terrace developed from the initial progradational deposit (wave wash) and the posterior redistribution by wave action. The wall pit in figure 44 is deeper and a lower elevation than the wall pit in figure 45, and for this reason it showed the complete record from "deep" to shallow water sedimentation to a greater degree.

In figure 44, towards the base of the exposed pit, the oldest sedimentation corresponds to a grey blue silt-clay layer. A detailed observation of this unit was not possible because it represents the base limit of the gravel operations and most of the time it is covered by taluds. This silt-clay unit is sharply overlaid by a sand-clay layer and in which Hiatella arctic shells are present. A very well defined sand layer follows in the

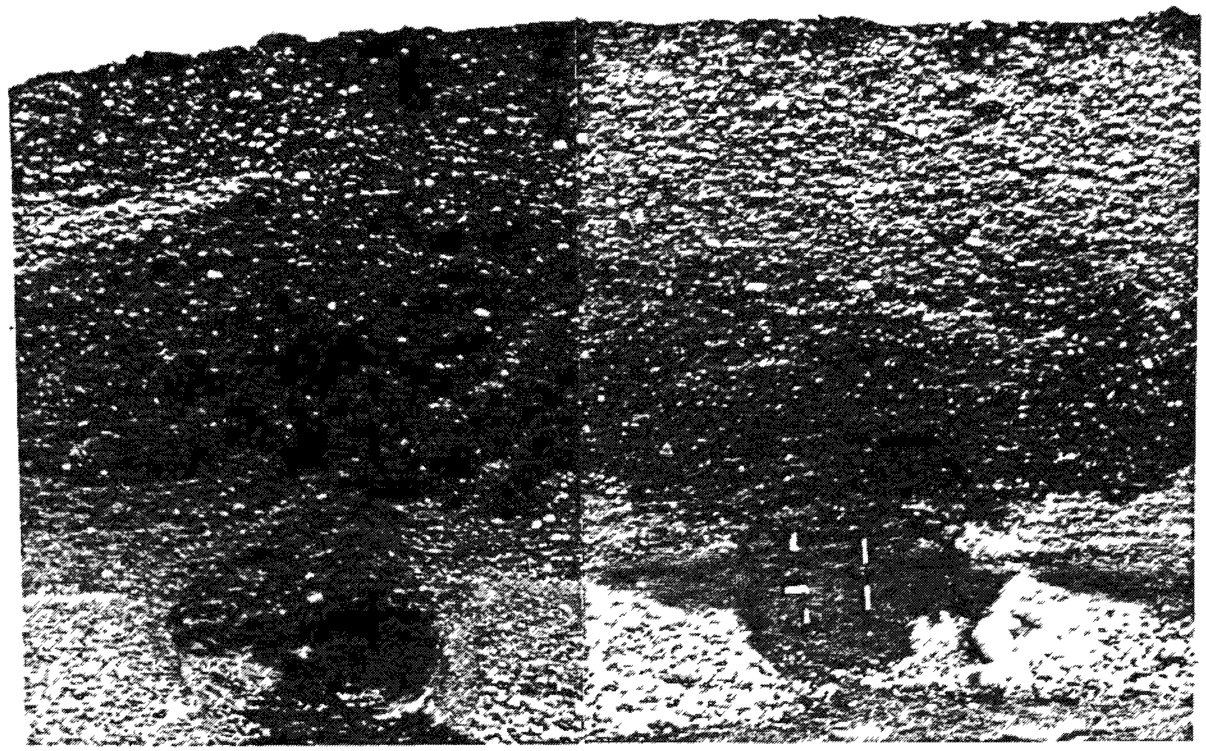


Figure 44. Cross section of the subaqueous marine terrace.
For location see figure 40.

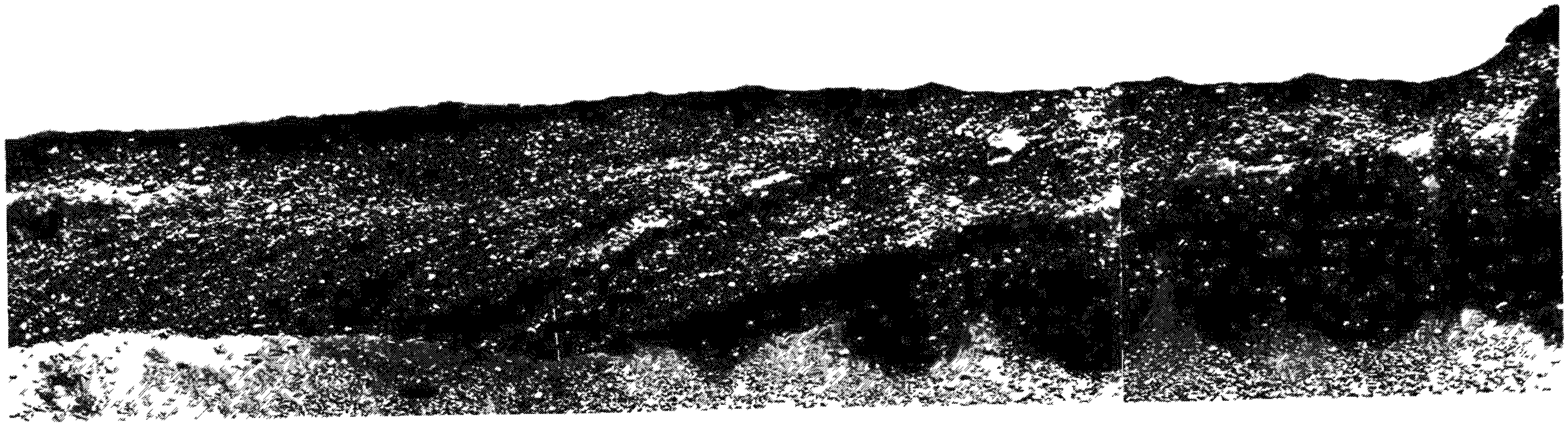


Figure 45. Foreset beach gravel in the subaqueous marine terrace at Dornie area. For location see figure 40.

deposition which showed a large population of Hiatella Arctic in growing position. Intercalate thin layer (5 cm) of coarse sand and gravel continue in the stratigraphic column for 1.5 m. The accumulation ends with a wide accumulation (6 m) of coarse sandy gravel, and is coarsest towards the top. Through all the units pieces of Hiatella artic were scarcely observed in the sand fraction; Balanus hameri were observed attached to the coarsest fraction (see figure 46).

The foreset beds observed in the longitudinal section of this gravel (figure 45) suggest a subaquatically accumulation of the main body of this deposit, the stratigraphy is the same as in figure 44 but its relative higher altitude did not permit the observation of the three first units pointed out for figure 44. This section corresponds to the distal portion of a progradational terrace. The low roundness values found for the analyzed samples of this deposit would indicate that not much littoral transport caused by coastal processes were performed.

A decrease in sea level wave action was important to the top of the subaqueous marine terrace and it created a discordant top layer, a distinguishable unit in the uppermost part of this accumulation.

According to Hesseland (1946) subaquatic marine terraces are often quite minerogenous due to the faster process of sediment mobilization on the till ridge top. However,

Figure 46. Balanus hameri (Bruguière) in living position.

the construction of the studied deposit (at least the distal portion) would indicate that it was a steady process since fossil shells are present in living position in the bulk of this deposit.

Pebble Shape Analysis

The morphometric analysis of pebble fraction in the spit showed a definite trend of transportation towards the distal section of this deposit. This supports the conclusion that this landform was built with material carried by longshore currents. Results are shown in table 7 and sample location in figure 40.

Accumulation forms in the land between 325 and 350 feet

With the further lowering of the sea level, many small islands started to emerge in this area. According to whether they were in a sheltered or open sea area, they suffered the strongest or weakest wave attack, the wave wash process would have the same effect on them as in the Dornie Till Ridge.

The whole area acquired the feature of a dissected coast when the sea level was near to the actual 325 feet of elevation. Wave built terraces by the infilling of coastal concavity were produced in the area. The material of these deposits could be supplied laterally or from the sea bottom by the action of waves and current.

Location (*)	Mean roundness ($\bar{X}$)	Standard deviation	Statistical test (Z) test α : 0.02 : 2.05
1	338	76	locations 1 and 2 : 6.45 significant difference
2	256	80	
3	166	74	locations 2 and 3 : 7.18 significant difference

(*) location in figure 40 .
sample number: 75 pebbles
size class: 45-60 mm.

Table 7 . Roundness values for pebbles along the spit locate in Dornie till ridge.

The Recurve Spit (West of Fassifern)

The east of Fassifern town, above 325 feet of elevation was an area conducive to wave attacks because of its location in front of the prevailing wind and an open sea (map 2).

Wave wash processes were as strong as in the Dornie Till Ridge, and this explains the presence of a well-defined vigorous accumulation form with all the morphological features of a recurve spit, see figures 38 and 47.

Morphological Considerations

The accumulation has a general direction of NE 30 SW for the main body and NE 13 SW and NE 18 SE for its two branches (see figure 47).

Field observation and photo-analysis showed that the initial growth of the spit form was mainly controlled by the orientation of the original till deposit (pre-Champlain Sea topography). Two phases can be established in the development of this spit. The branch A of figure 47 appears to be the first "barb" developed from the main body. This conclusion is essentially based on its topographic position and the coarseness of the deposit (gravel bouldery). A second and more important "barb" developed with the growth of the spit main body towards the southern branch (B).

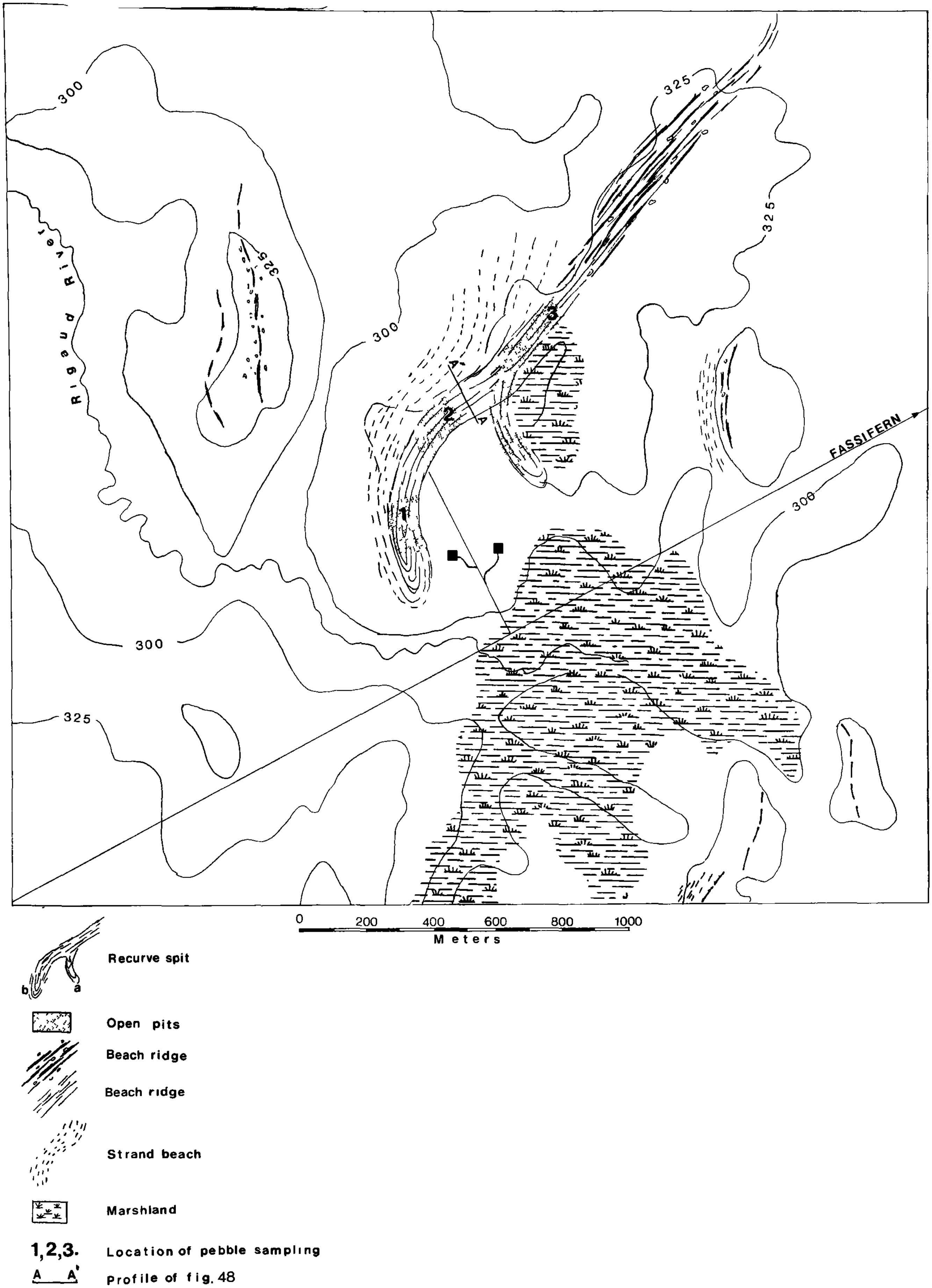


Figure 47. Map showing the recurve spit located to the west of Fassifern.
Source: topographic map 31 G/7 NTS.
air photographs A10370-155 to 157.

In this latest accumulation the material is less heterometric and located in the more distal section. Here the material forming the deposit is finer as established from the morphological feature of the slope (gradual dipping). As established by Gilbert (1890) in another emerged landform, the area above water in this kind of material is usually narrow throughout and a "submerged" plateau can be observed flanking the terminal portion. The profile of the plateau is that normal to the beach, the emerged area diminishes its width towards the end and the crest line of the spit is joined to its outer and limiting contour.

Figure 48 shows a cross profile of the spit. It corresponds to the description of the cross profile made by Gilbert (1890) for this kind of landform: "..... shows a plateau bounded on either hand by steep slope. The surface of the plateau is not level but has the beach profile; it is slightly submerged on the windward side and rises somewhat above the ordinary water level at the sea ward margin."

The extreme NE of this deposit, which corresponds to the unplowed forest section is bouldery at the top. Here the deposit is attached to the northwest slope of the till accumulation forming bouldery beach ridges. In this section, the deposit is very shallow over the glacial material (see figure 49).

From the topographic map, we can observe that

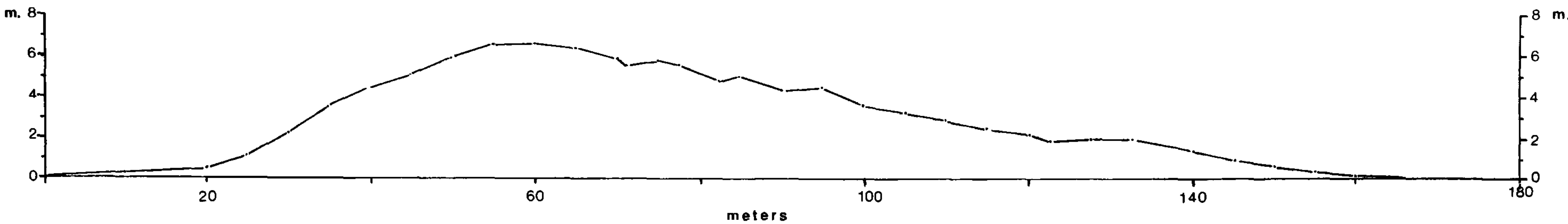


Figure 48. Cross profile of the recurve spit (west of Fassifern).
For transect location see figure 47.

Figure 49. Excavated area in the recurve spit (west of Fassifern). Arrow point out the pebble sampling location N [illegible] , here the beach material is very shallow.

this deposit decreased in elevation from over 325 to nearly 300 feet above actual sea level.

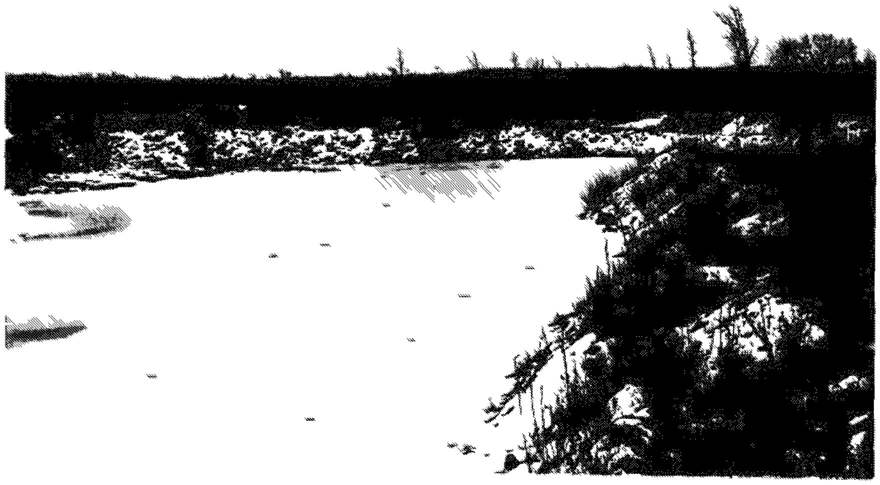
Stratigraphical Analysis

The recurved spit is actually excavated in many places (see figure 50) for commercial purposes. Thus, a general stratigraphical observation was realized in order to support the morphological evidences.

Stratigraphic studies show that the deposit coarsens upwards, the core is gravel cobble with a coarse sandy matrix, the cobble fraction showed marks of fossil shells previously attached and Macoma balthica was present in sand pocket. Across the profile, boulders and cobble fraction dipped to both sides of the slope. A ditch cut at the base of a cross section of the spit reveals a gravel fraction as the lower unit of the deposit, at this point.

The area occupied between both "barb" of this recurved spit is mainly silty-clay. The owner of the house, located just to the east of the distal section of barb B of the spit stated that the house and the road which connected it to the principal road is over gravel material taken from the near pit. This was done because of the swampy conditions of this section of the land. Another significant piece of information was that in the basement excavation, a grey clay with abundant shell was observed. This would support the view that this deposit prograded into "deeper" Champlain Sea water.

A



B

Figure 50. Cross section of the two branches of the recurve spit

This view can be further corroborated with the observation of the present erosional processes of the southern branch of the Rigaud River, which dissects easily erodable fine sediments (silt-clay) from the Champlain Sea. This is also concordant with the measured isostatic re-bounding of the land persisting even in the former glaciated regions (e.g. Gale 1970).

Pebble Shape Analysis

Pebble shape analysis of the gravel material along the main body of the recurve spit, indicates a movement of the material in a direction NE to SW because of longshore current transportation. Results of this analysis are shown in table 5. From it we can observe that roundness values increase from site 3 to 1 (see figure 47 for location). The standard deviation values for each set of samples is lower and this supports the significance of the mean roundness values.

Nevertheless, the clear trend indicated by the roundness values, analysis of variance test was performed to see if the samples belong to the same population and, from the results (see table 8) samples should be considered significantly different.

Taking into account the distance travelled by the material along the beach from the source of the material (till ridge, reworked till), roundness values for the location

Location (*)	Mean roundness ($\bar{X}$)	Standard deviation	Statistical test (Z) test α : 0.02 : 2.05
1	346	68	locations 1 and 2 : 5.55 significant difference
2	281	74	locations 2 and 3 : 11.00 significant difference.
3	160	58	

* location in figure 47 .
sample number: 75 pebbles
size class: 45-60 mm.

Table 8 . Roundness values for pebbles along the recurve spit locate to the west of Fassifern.

there appears to be a very low comparison with the other values. However, when we deal with limestone fragments this difference in values in a short distance of transportation is not surprising, as demonstrated by Krumbein and Scott (1938) in Little Sister Bay of Lake Michigan, where roundness values of pebble limestone changes abruptly in only 100 yards of transportation.

Another consideration could explain the reason for the low value recorded for sample three. First, is the variability observed in roundness values across beach deposits (King and Buckley 1968; Donkins and Folk 1968; McCann and Owens 1969). However, as indicated on page beach zonation was not established for any of the studied deposits. Second, samples of site three come from a higher elevation in a shallow cut on the spit deposit. This could mean that the dissolution process (due to time of exposition, organic acid) could affect the roundness values, as demonstrated by King and Buckley (1968) in rise Arctic Beaches.

Nevertheless, despite the above considerations, the trend of the values is significant enough to be considered as the result of the distance travelled by the beach material and would show the effectiveness combined of waves and currents to transport material and build marine landforms.

Wave-built Terraces

With the continuous emergence of the land and the withdrawal of the sea, wave-built terraces were formed with the accretion of the beach zone. These wave-built terraces do not have a topographic feature as individualized landform units. However, their wide deposits have a topographic position and a well defined stratigraphy in the area of the coastal zone.

In the Dornie Area, these terraces are located below the emerged bluffs formed in the pre-existant till topography. Its internal structure is characterized by a gentle dip towards the former sea ward. The best developed wave-built terraces in this area are located towards the NE section of this former "dissected coast" see figure 38.

The material in these terraces range from sand gravel to coarse boulder cobble gravel, depending on their distance from the bluffs. The depth of these deposits are shallow, in the observed pit they were excavated up to 6 feet.

The surficial expression of these deposits are extensive cusps beach forms, which according to Zenkovich (1967) can also be formed during the accretion of a beach. At the top of these cusp forms, the coarsest sediment is predominant and this can be correlated to the storm waves or probably to tidal deposition conditions.

An important feature of these deposits is the presence of abundant shells of *Mytilus edulis* in growing positions (see figure 51) which is not usually observed as

Figure 51. Mytilus edulis (Linné) fossil shell, in the wave built terraces at Dornie area.

a well preserved fossil shell in the Champlain Sea deposits. This feature indicates that at the time of decreasing sea level the environment was quiet. This would support the initial view of a dissected coast.

The angular character of the coarsest fraction should mean that some material could be supplied from the sea bed by wave or tidal currents, as observed in similar deposits in the Chuckki, Bearing and Black Seas (Zenkovich 1967). It has already been established that the coarsest fraction of cusp forms are derived mainly from the step beach zone (Russel and McIntyre, 1965) and which would support to some degree the above assumption.

The abundance of *Mytilus edulis* shells supports the view that the environment of deposition was shallow (Bousfield 1960). Furthermore, Mytilus species have also been reported as being very common in the tidal zone (Shrock and Twenhofel, 1953).

CHAPTER 6

ICE RAFTING AND ICE PUSH DEPOSITS

The presence of big crystalline boulders in the gravel beach, or in the boulder beach of the Champlain Sea sediments has been related since long to floating ice transportation (Goldthwait *et al.*, 1913; Reinecke, 1917). However, concentration of big boulders has been reported to be a fundamentally residual deposit because of the strong wave wash action of the fine till matrix (Karrow 1961; Terasmae 1965; Gadd 1971).

Study of the unreworked till at a relatively short distance from the beach deposits showed only crystalline boulders up to 40 cm. This was also observed in the same till in the surrounding area by Owens (1951). This observation does not support the idea of a boulder beach as a residual till deposit due to the wave wash process.

Recent investigation in Arctic Canada has shown the importance of ice in transporting or concentrating erratic material in actual coastal processes (Dionne 1972, 1974, 1978). According to Dionne's study in James Bay, drift ice processes are more active in Periglacial regions.

For the above reason, in the study of the Champlain Sea sediments, considerations about processes associated with lower temperature, movement of sediment by ice push and ice rafting material are very important. The Champlain Sea was in a periglacial environment with glacial presence towards the furthest north side and this acted as the supplier of ice rafted sediment transported towards the south side of the Champlain Sea.

In the Alexandria Map Area, the observed distribution of crystalline boulders by size in the beach deposits (see figures 12 and 13) showed that big boulders are found at a higher elevation. This is concordant with the area where the wave wash process was strong, and could account for the deposit being residual. But concentration of big boulders at a higher elevation is also concordant with the time at which the Champlain Sea was deeper and ice floating was a mechanism of boulder transportation.

One of the principal features of the big crystalling boulder observed is that they are rounded material and this can be correlated with the existence of glacial stream and ice of the further north. As Hume and Schalk (1967) stated that glacial ice, is probably the most important carrier of rafted sediment.

The presence of rounded big boulders concentration at a high elevation where no bluff was observed cannot be satisfactorily explained as a residual deposit from the original till due to wave wash processes.

In the Alexandria Map Area there is evidence of ice drafting material and ice push boulder concentration. A very good example of ice push material was found in the Dornie area as a very well defined ice push ridge forming a "nests" of boulders (the term used by Krumbein and Griffith, 1938) see figure 52A. Ice drafting material and ice push concentration always rest over a small size material (Krumblin and Griffith, 1938). The stratigraphic feature of this deposit shows that boulders are resting over a cobble gravel material (see figure 52C) with abundant Hiatella arctic fossil shell in growing position (see figure 52B). Another important feature of this boulder material is that the open spaces in them are filled with sand (see figure 52D). Here abundant Hiatella arctic shells were found with marks of attachment of Balanus species in the boulder. This indicates that at the time of the ice push action the material was completely submerged on the coast. In relation to this kind of deposit and its position in the coastal zone, it appears to be an optimal water depth for ice push action related to the thickness of ice and the size of the boulders (Norman 1964).

In the map area, at different elevations, isolated big crystalline boulders were observed resting over gravel beach; sand or clay material (see figure 53 A-E) and this can be explained to be a result of ice floating material

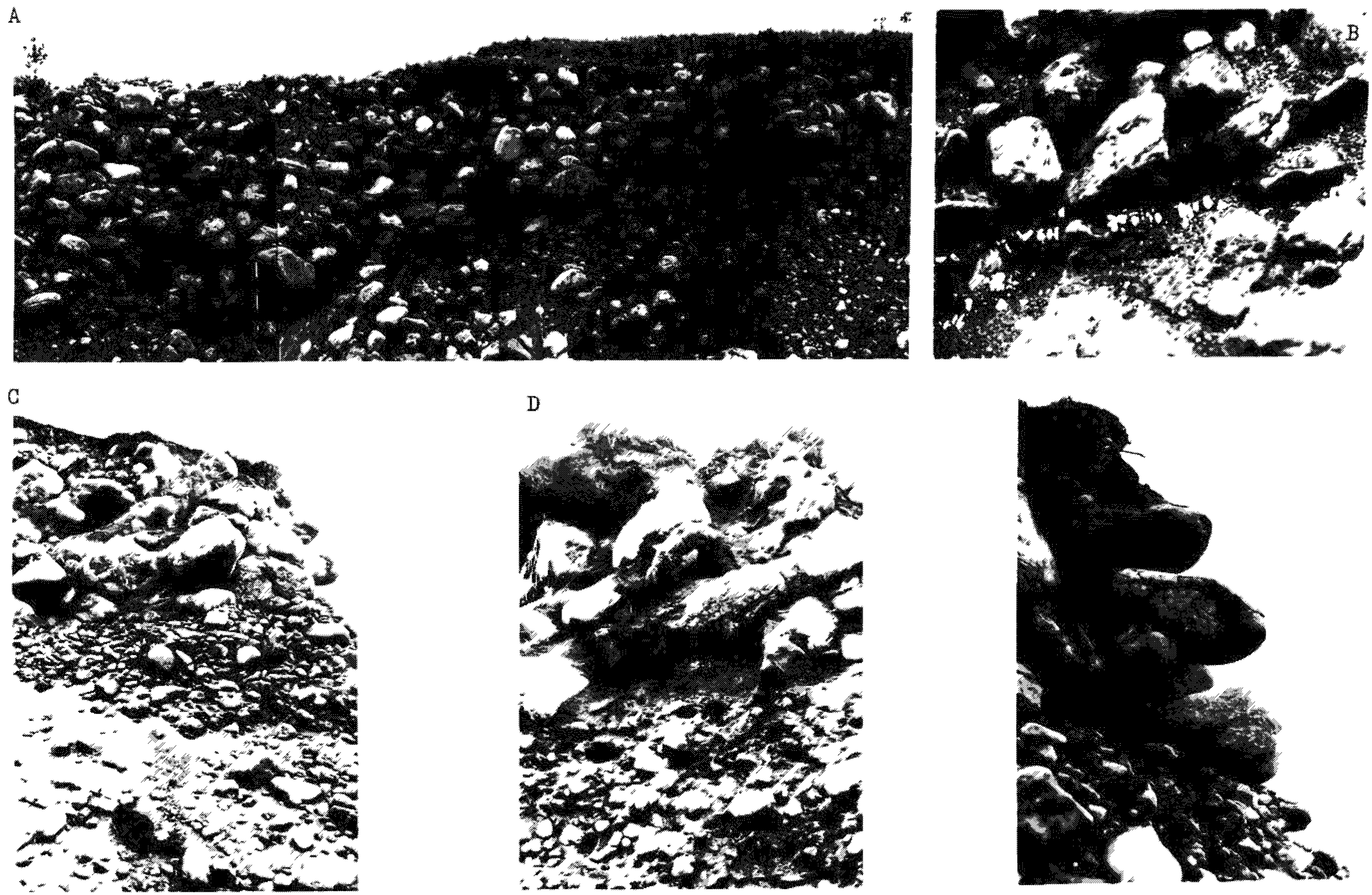
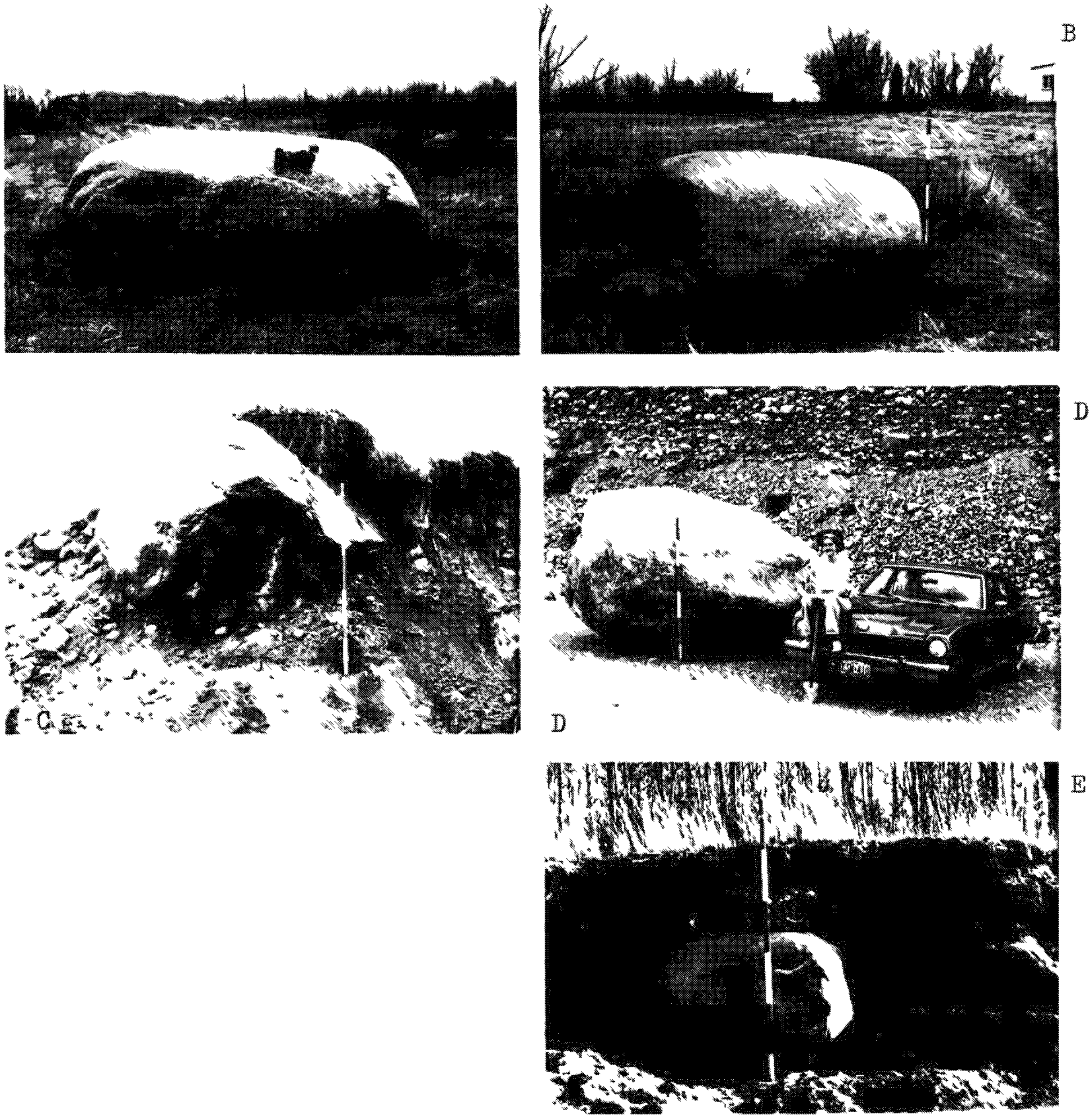


Figure 52. Ice push deposit.



'igure 53. Crystalline Boulders: (A)resting on gravel beach, at 350 feet a.s.l (B)resting over marine clay at 250 feet a.s.l. (C)in gravel beach, at 300 feet a.s.l. (D)was resting on gravel beach, at 350 a.s.l. (E)resting over marine sand and overlied by gravel beach, at 375 feet a.s.l.

or perhaps by the tidal transport in the case of the near shore zone (see figure 53D). Big boulders, as shown in figure 53 C-D, have been observed by Professor Guilcher (personal communication) in similar bouldery gravel marine deposits in the Caspian Sea and their location related to ice floating transportation.

Comparing the field observation with the literature review it was found that Owens' (1951) explanation for the big boulder concentration is the most realistic, because he said that "..... accumulations of large boulders were probably formed in part by wave or current action carrying away the firmer material from the till composing of the bluff, and leaving the larger stone behind. However, it is considered that most of the boulders were carried and deposited by ice floating in the Champlain Sea."

In conclusion, it can be said that ice floating transportation and ice pushing concentration played an active role in the coastal process during the Champlain Sea Episode. In this view, big boulder concentration appears to be more the result of these combined processes rather than a residual produce owed to the wave wash action on the former ice sheet till deposit.

CONCLUSIONS

The importance of the coastal process in the Alexandria Map Area, during the Champlain Sea Episode was demonstrated by the presence of well-developed depositional marine landforms.

The attempt to characterize the environments of the Champlain Sea from the textural features of their sediments, following Folk and Ward's (1957) method of bivariate plots of grain size parameters showed that the use of sensitive parameters like Kurtosis and Skewness are not very effective on environment discrimination in areas where there is a mixture of sediment modes as the principal feature of the material. Thus, grain-size distribution reflects depositional processes rather than environments (Solohub and Klovan, 1969), which were better established on the basis of topographic sedimentogic and stratigraphic criteria.

The principal cause of the mixture of these sediments was a function of the presence of ice covered during several months of the year on the former Champlain Sea waters, and the fast rate of sediment supply coming from the easy erodable till, where the conditions of slope and orientation of the pre-marine topography permitted strong wave attack.

The absence of glacial ice deposit as described towards the west side of the Ottawa-St. Lawrence Basin indicates that glacial ice had effectively retreated from the area at the time of the Champlain Sea Episode. Otherwise, none of the many pits in the map area showed features of subaqueous outwash deposits as diagnosed by Rust (1977), which is another support of this idea.

Thus, the presence of very well-developed accumulative marine landforms indicates that the coastal processes due to the wave and current of the Champlain Sea water played an important role in building the landscape of the area.

Strong marine accumulations as observed in the Maxville Highland and Dornie Area mean there were large quantities of material affected by the coastal processes and effectiveness of the wave and currents.

The presence of big crystalline boulders everywhere and piled-up boulder forming ridges, are indicative of processes associated with ice floating rafting transportation and ice push concentration. This means that this kind of process was important in the area at the time of the Champlain Sea Episode. This is an important fact, which helps us to understand and explain the presence of till-like material reported in the Ottawa-St. Lawrence Basin, moreover, this has led to the controversy about a late glacial readvance (e.g. Gadd 1977; Richard 1975; Rust 1977).

The observed ice push deposits confirm that Harrison (1976) said: "There is reason to believe that sea ice formed in the Champlain Sea, and large ice flows driven onshore by wind can certainly rearrange the stratigraphy nearshore."

In relation to the above point, Gadd (1977) said that the deformation of the fossiliferous strata of the Champlain Sea sediments must be related to the marine environment itself and may not, in any way, result in active glacier ice.

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A P P E N D I X   I

Computer ĉalculation of grain size parameters

GRAIN SIZE DISTRIBUTION PARAMETERS OBTAINED FROM
MECHANICAL ANALYSIS SAMPLES FROM THE
ALEJANDRITA MAP AREA (REZADA 1960)

SAMPLE#	5%	16%	25%	50%	75%	84%	95%	MEAN	SORTING	SKEWNESS	KURTOSIS	[illegible]
1	-0.45	0.05	0.35	0.85	1.23	1.45	3.30	0.78	[illegible]	0.08	1.75	[illegible]
2	-0.68	-0.15	0.05	0.75	1.40	1.90	3.00	0.83	1.16	0.23	1.30	0.5[illegible]
3	-0.62	-0.05	0.38	0.93	1.50	1.88	2.50	0.92	0.96	-0.00	1.14	[illegible]
4	-0.70	-0.45	-0.35	-0.05	0.40	1.60	2.78	0.37	1.04	0.62	1.90	[illegible]
T3	-0.15	1.20	1.95	3.60	5.60	6.95	9.70	3.92	2.93	0.20	1.11	[illegible]
6	-0.50	0.15	0.05	0.50	1.18	2.05	3.43	0.90	1.07	0.56	1.43	0.5[illegible]
9	-0.75	-0.35	-0.10	0.55	1.60	2.20	5.10	0.80	1.52	0.42	1.41	0.5[illegible]
10M	-0.80	-0.25	-0.05	0.65	1.62	1.95	3.20	0.85	1.16	0.09	0.98	0.5[illegible]
10T	-0.72	-0.30	-0.07	0.57	1.23	1.60	2.65	0.62	0.98	0.16	1.06	0.5[illegible]
11	-0.58	-0.01	0.15	0.00	1.65	2.08	4.05	0.99	1.31	0.28	1.43	0.5[illegible]
12	-0.50	-0.02	0.40	1.20	2.90	2.40	4.69	1.19	1.39	0.17	0.65	[illegible]
13	-0.70	-0.25	-0.02	0.59	1.59	1.75	4.35	0.70	1.27	0.32	1.29	0.5[illegible]
14	-0.55	-0.20	0.75	1.15	3.00	3.45	4.00	1.47	1.69	0.30	0.94	[illegible]
15	-0.62	-0.38	-0.10	0.55	1.20	1.50	2.20	0.56	0.93	0.05	0.95	[illegible]
16	-0.55	-0.10	0.15	0.75	1.50	2.05	4.70	0.90	1.33	0.36	1.59	[illegible]
17	0.0	0.65	0.95	1.35	1.73	1.95	2.05	1.32	0.73	-0.05	1.39	0.5[illegible]
T1	-0.50	0.0	1.20	3.20	5.35	6.70	9.60	3.30	3.21	0.16	1.00	0.5[illegible]
19	-0.35	-0.40	0.45	1.90	2.40	3.65	5.60	1.72	1.91	0.05	1.25	0.5[illegible]
20	-0.05	-0.02	0.43	1.12	1.68	1.95	3.45	1.02	1.11	-0.01	1.34	0.57
21	-0.85	-0.50	-0.35	0.06	1.04	1.72	3.00	0.43	1.14	0.51	1.14	0.53
23A	0.15	1.20	1.60	2.15	2.60	2.85	3.55	2.07	0.93	-0.16	1.39	0.5[illegible]
23B	-0.82	-0.33	-0.05	0.66	1.31	1.55	2.32	0.63	0.95	-0.01	0.95	0.4[illegible]
T2	-0.35	1.10	1.45	3.45	5.80	6.75	9.45	3.77	2.90	0.20	0.92	0.48
DA	-0.10	0.25	0.45	0.85	1.30	1.50	2.05	0.87	0.64	0.08	1.04	0.51
DM	-0.50	-0.30	-0.15	0.20	0.55	0.75	1.30	0.22	0.54	0.13	1.05	0.51
30	2.70	2.88	3.00	3.35	3.75	3.95	4.43	3.39	0.53	0.19	0.95	0.40
31	1.10	1.35	1.50	1.70	2.08	2.25	2.58	1.79	0.45	0.06	1.05	0.5[illegible]
32	-0.73	-0.30	-0.10	0.62	1.38	1.66	2.40	0.67	0.97	0.10	0.67	[illegible]
T4	-0.25	1.20	2.00	3.75	5.75	7.00	9.60	3.97	2.97	0.18	1.10	0.52
34	0.50	1.08	1.25	1.63	2.00	2.20	2.65	1.64	0.61	-0.02	1.17	0.5[illegible]
T3	-0.55	0.76	1.40	3.80	5.90	6.82	9.15	3.79	2.98	0.05	0.90	0.47
35	1.75	2.32	2.60	3.42	5.00	5.80	9.68	3.85	2.10	0.46	1.51	[illegible]

Grain size distribution parameters (continuation)

36	1.55	2.15	2.50	3.35	4.50	5.45	9.00	3.65	1.95	0.39	1.53	0.60
37	0.90	1.95	2.35	3.00	3.90	4.65	[illegible]	3.20	1.58	0.26	1.59	0.61
38	1.60	2.25	2.55	3.25	4.35	5.50	8.55	3.67	1.87	0.45	1.58	0.61
39	2.45	2.70	2.85	3.30	4.25	4.85	7.45	3.62	1.50	0.55	1.46	0.59
40	2.52	2.78	2.90	3.30	4.32	5.00	7.95	3.72	1.38	0.57	1.57	0.61
41	0.58	1.20	1.46	1.75	2.05	2.20	2.48	1.72	0.54	-0.17	1.32	0.57
42	0.42	1.08	1.40	2.00	2.65	2.95	3.95	2.01	1.00	0.06	1.16	0.59
44	1.15	1.60	1.75	2.05	2.40	2.80	3.30	2.15	0.63	0.21	1.36	0.59
45	1.15	1.65	1.85	2.25	2.64	2.84	3.38	2.25	0.64	0.00	1.11	0.53
46	1.15	1.70	1.95	2.30	2.70	2.90	3.50	2.30	0.66	0.01	1.28	0.56
47	-0.75	-0.25	-0.05	0.75	1.60	2.00	2.90	0.83	1.12	0.14	0.91	0.49
48	1.25	1.70	1.90	2.30	2.65	2.80	3.25	2.27	0.58	-0.07	1.09	0.52
49	1.65	1.95	2.15	2.50	3.00	3.30	3.95	2.58	0.69	0.22	1.11	0.53
51	3.05	3.45	3.65	3.80	4.40	4.70	5.45	3.98	0.68	0.41	1.31	0.57
52	3.25	3.65	3.80	3.95	4.45	4.60	5.30	4.07	0.55	0.34	1.29	0.56
53	2.80	3.15	3.40	3.80	4.25	4.40	4.90	3.78	0.63	0.00	1.01	0.51
54	3.30	3.65	3.80	4.10	4.40	4.80	6.50	4.18	1.08	0.45	3.55	0.79
55A	2.40	2.75	2.95	3.25	3.55	4.00	5.00	3.33	0.71	0.27	1.78	0.61
55B	2.62	2.85	3.00	3.30	3.65	4.35	5.15	3.50	0.76	0.43	1.22	0.55
56	3.10	3.35	3.50	3.95	4.35	4.75	9.60	4.02	1.37	0.44	3.23	0.76
57	3.25	3.60	3.80	4.15	4.50	4.75	9.25	4.17	1.20	0.37	3.51	0.78
58	3.25	3.60	3.80	4.10	4.40	4.65	5.90	4.12	0.66	0.20	1.81	0.69
60	2.90	3.10	3.35	3.75	4.20	4.35	5.05	3.73	0.64	0.08	1.04	0.51
61	1.48	2.00	2.20	2.50	2.80	2.95	3.35	2.48	0.52	-0.07	1.28	0.56
62	2.15	2.50	2.65	3.00	3.35	3.60	4.45	3.03	0.62	0.18	1.35	0.57
63	2.65	3.10	3.20	3.50	3.85	4.00	4.60	3.53	0.52	0.12	1.23	0.55
64	1.55	1.90	2.05	2.45	3.10	3.35	3.85	2.57	0.71	0.23	0.90	0.47
65	1.45	1.80	1.95	2.40	3.10	3.40	4.05	2.53	0.79	0.26	0.93	0.49
66A	1.10	1.45	1.55	1.80	2.15	2.30	2.65	1.67	0.45	0.05	1.06	0.51
66B	1.15	1.40	1.55	1.80	2.05	2.30	2.55	1.83	0.44	0.09	1.15	0.53
66C	1.50	1.75	1.85	2.05	2.45	2.65	3.10	2.15	0.47	0.32	1.09	0.52
66D	0.85	1.20	1.45	1.75	2.10	2.35	2.95	1.77	0.61	0.09	1.32	0.57
67	2.60	3.00	3.15	3.50	3.95	4.15	5.40	3.55	0.71	0.24	1.43	0.57
68	2.85	3.25	3.40	1.85	4.25	4.40	4.95	3.17	0.61	2.08	1.01	0.59
68B	2.75	3.20	3.35	3.73	4.25	4.55	5.05	3.63	0.69	0.16	1.05	0.51
69	3.00	4.05	4.20	4.40	4.90	5.40	10.40	4.62	1.37	0.62	3.98	0.60

A P P E N D I X II

Computer calculations of pebble shape analysis

LITTORAL ARROW-CUSPATE SPIT (1)

L	l	E	R_1	R_2	ROUNDNESS INDEX		FLATNESS INDEX
49.0	48.0	21.0	6	8	244	326	2.31
60.0	40.0	30.0	10	12	333	400	1.67
52.0	37.0	24.0	4	6	153	230	1.85
53.0	40.0	28.0	4	10	151	377	1.66
51.0	37.0	27.0	4	6	156	235	1.63
45.0	34.0	21.0	8	10	355	444	1.88
60.0	39.0	31.0	10	12	333	400	1.60
60.0	45.0	32.0	10	12	333	400	1.64
45.0	32.0	22.0	8	10	355	444	1.75
46.0	42.0	28.0	6	8	261	347	1.57
45.0	45.0	20.0	8	8	355	355	2.25
50.0	40.0	25.0	8	12	320	480	1.80
47.0	38.0	25.0	8	12	340	510	1.70
57.0	40.0	20.0	8	10	280	351	2.42
59.0	30.0	20.0	4	6	135	203	2.22
49.0	40.0	17.0	4	6	163	244	2.62
50.0	40.0	27.0	4	6	160	240	1.67
60.0	48.0	28.0	4	6	133	200	1.93
51.0	48.0	20.0	6	10	235	392	2.47
49.0	33.0	26.0	6	6	244	244	1.58
50.0	46.0	20.0	4	8	160	320	2.40
45.0	34.0	18.0	6	8	266	355	2.19
52.0	38.0	21.0	8	10	307	384	2.14
45.0	36.0	20.0	6	8	266	355	2.02
60.0	42.0	30.0	4	10	133	333	1.70
48.0	38.0	17.0	8	12	333	500	2.53
49.0	40.0	15.0	6	10	244	408	2.97
48.0	30.0	20.0	6	6	250	250	1.95
50.0	34.0	25.0	6	8	240	320	1.68
45.0	31.0	31.0	4	6	177	266	1.23
46.0	36.0	20.0	6	8	260	347	2.05
59.0	42.0	29.0	4	10	135	338	1.74
48.0	48.0	20.0	6	8	250	333	2.40
54.0	39.0	26.0	4	6	148	222	1.79
63.0	41.0	27.0	4	10	126	317	1.93
50.0	37.0	28.0	4	6	160	240	1.55
60.0	44.0	33.0	10	14	333	466	1.58
46.0	30.0	23.0	6	10	307	434	1.65
56.0	39.0	21.0	8	10	285	357	2.26
60.0	39.0	17.0	8	10	266	333	2.91
60.0	29.0	21.0	4	6	133	200	2.12
49.0	45.0	22.0	6	8	244	326	2.14
45.0	39.0	25.0	8	12	355	533	1.68
50.0	36.0	19.0	8	10	320	400	2.26
57.0	39.0	27.0	4	10	140	350	1.78
49.0	47.0	20.0	4	8	163	326	2.40
53.0	38.0	24.0	4	6	150	226	1.90
45.0	33.0	16.0	6	8	266	355	2.44
57.0	28.0	20.0	4	6	140	210	2.13
48.0	40.0	27.0	6	8	250	333	1.63

LITTORAL ARROW-CUSPATE SPIT (2)

L	l	E	R_1	R_2	ROUNDNESS INDEX		FLATNESS INDEX
46.0	30.0	28.0	4	8	173	347	1.36
45.0	27.0	26.0	2	8	88	355	1.38
45.0	30.0	16.0	4	4	177	177	2.34
45.0	33.0	31.0	2	4	88	177	1.26
55.0	35.0	18.0	2	4	72	145	2.50
48.0	28.0	15.0	4	8	166	333	2.53
52.0	35.0	25.0	4	6	153	230	1.74
51.0	35.0	22.0	4	6	156	235	1.95
53.0	34.0	26.0	6	8	226	301	1.67
51.0	32.0	25.0	6	8	235	313	1.66
54.0	38.0	18.0	8	10	296	370	2.56
52.0	45.0	22.0	4	8	153	307	2.20
46.0	32.0	17.0	4	6	173	260	2.29
55.0	45.0	25.0	6	8	218	290	2.00
52.0	37.0	32.0	4	8	153	307	1.39
53.0	35.0	15.0	4	6	150	226	2.93
54.0	31.0	21.0	8	12	296	444	2.02
54.0	50.0	28.0	8	12	296	444	1.86
52.0	50.0	31.0	6	8	230	307	1.65
51.0	37.0	26.0	4	6	156	235	1.69
49.0	45.0	20.0	4	6	163	244	2.35
55.0	45.0	40.0	6	8	218	290	1.25
60.0	44.0	24.0	4	6	133	200	2.17
59.0	41.0	25.0	6	8	203	271	2.00
60.0	34.0	24.0	4	8	133	266	1.96
50.0	39.0	28.0	6	8	240	320	1.59
57.0	37.0	30.0	6	10	210	350	1.57
47.0	38.0	27.0	4	8	170	340	1.57
46.0	29.0	15.0	4	4	173	173	2.50
54.0	36.0	19.0	2	4	74	148	2.37
49.0	29.0	16.0	4	8	163	326	2.44
46.0	28.0	26.0	2	8	86	347	1.42
51.0	37.0	24.0	4	6	156	235	1.83
53.0	37.0	17.0	8	10	301	377	2.65
51.0	45.0	23.0	4	8	156	313	2.08
47.0	45.0	26.0	6	8	255	340	1.77
50.0	35.0	30.0	4	8	160	320	1.42
52.0	34.0	17.0	4	6	153	230	2.53
54.0	30.0	22.0	8	10	296	370	1.91
45.0	36.0	25.0	4	8	177	355	1.62
55.0	56.0	28.0	6	10	218	363	1.98
46.0	30.0	15.0	4	6	173	260	2.53
47.0	36.0	28.0	4	8	170	340	1.48
46.0	34.0	32.0	2	4	86	173	1.25
50.0	39.0	27.0	6	10	240	400	1.65
50.0	35.0	24.0	4	6	160	240	1.77
58.0	34.0	26.0	4	8	137	275	1.77
56.0	35.0	19.0	4	6	142	214	2.39
47.0	29.0	16.0	4	8	170	340	2.38
59.0	40.0	23.0	4	6	135	203	2.24

LITTORAL ARROW-CUSPATE SPIT (3)

L	l	E	R_1	R_2	ROUNDNESS INDEX		FLATNESS INDEX
50.0	32.0	28.0	6	8	240	320	1.46
45.0	42.0	26.0	6	10	266	444	1.55
48.0	38.0	30.0	4	6	166	250	1.43
47.0	28.0	24.0	4	6	170	255	1.56
50.0	41.0	22.0	4	8	160	320	2.07
53.0	36.0	27.0	8	14	301	528	1.65
46.0	41.0	22.0	6	8	260	347	1.98
46.0	36.0	21.0	2	6	86	260	1.95
54.0	36.0	29.0	2	8	74	296	1.55
48.0	36.0	25.0	4	8	166	333	1.68
46.0	28.0	23.0	4	6	173	260	1.61
48.0	38.0	28.0	6	8	250	333	1.54
52.0	24.0	20.0	8	12	307	461	1.90
58.0	39.0	25.0	6	8	206	275	1.94
53.0	38.0	22.0	4	6	150	226	2.07
54.0	38.0	20.0	4	6	148	222	2.30
45.0	38.0	17.0	6	8	266	355	2.44
50.0	40.0	20.0	2	8	80	320	2.25
45.0	35.0	16.0	4	6	177	266	2.50
45.0	28.0	23.0	4	8	177	355	1.59
46.0	27.0	21.0	4	8	173	347	1.74
46.0	35.0	30.0	4	6	173	260	1.35
48.0	39.0	23.0	4	8	166	333	1.89
47.0	37.0	27.0	4	8	170	340	1.56
56.0	34.0	26.0	8	12	285	428	1.73
50.0	25.0	22.0	8	12	320	480	1.70
47.0	39.0	29.0	6	8	255	340	1.48
53.0	35.0	28.0	4	8	150	301	1.57
56.0	38.0	27.0	6	8	214	285	1.74
45.0	39.0	23.0	6	8	266	355	1.83
46.0	37.0	31.0	4	6	173	260	1.34
47.0	38.0	24.0	4	8	170	340	1.77
47.0	36.0	17.0	4	6	170	255	2.44
53.0	37.0	21.0	4	6	150	226	2.14
46.0	38.0	26.0	4	10	173	434	1.62
52.0	37.0	21.0	4	6	153	230	2.12
50.0	23.0	21.0	8	12	320	480	1.74
47.0	29.0	19.0	4	8	170	340	2.00
45.0	37.0	22.0	2	6	88	266	1.86
47.0	37.0	29.0	6	8	255	340	1.45
46.0	37.0	19.0	6	8	260	347	2.18
45.0	36.0	25.0	2	6	88	266	1.62
50.0	34.0	26.0	2	8	80	320	1.62
45.0	42.0	23.0	6	8	266	355	1.89
48.0	39.0	20.0	2	8	83	333	2.17
47.0	37.0	18.0	4	6	170	255	2.33
47.0	26.0	24.0	4	6	170	255	1.52
46.0	39.0	16.0	6	8	260	347	2.66
52.0	37.0	23.0	4	6	153	230	1.93
48.0	34.0	22.0	2	6	83	250	1.86

LITTORAL ARROW-CUSPATE SPIT (4)

L	l	E	R_1	R_2	ROUNDNESS INDEX		FLATNESS INDEX
49.0	35.0	31.0	4	10	163	408	1.35
45.0	40.0	25.0	6	10	266	444	1.70
59.0	38.0	31.0	6	6	203	203	1.56
51.0	33.0	22.0	4	6	156	235	1.91
54.0	44.0	30.0	4	6	148	222	1.63
55.0	40.0	23.0	6	6	218	218	2.07
54.0	35.0	30.0	4	6	148	222	1.48
52.0	31.0	21.0	4	4	153	153	1.98
46.0	42.0	23.0	6	8	260	347	1.91
50.0	48.0	25.0	4	8	160	320	1.96
51.0	34.0	23.0	4	6	156	235	1.85
56.0	42.0	22.0	4	6	142	214	2.23
56.0	45.0	28.0	4	6	142	214	1.80
52.0	45.0	21.0	8	10	307	384	2.31
60.0	37.0	31.0	10	12	333	400	1.56
52.0	35.0	23.0	4	6	153	230	1.89
56.0	38.0	21.0	2	8	71	285	2.24
56.0	43.0	30.0	6	10	214	357	1.65
54.0	43.0	32.0	8	12	296	444	1.52
57.0	45.0	28.0	2	6	70	210	1.82
45.0	40.0	28.0	4	8	177	355	1.52
50.0	37.0	34.0	4	10	160	400	1.28
47.0	31.0	24.0	4	4	170	170	1.63
51.0	39.0	39.0	6	10	235	392	1.15
53.0	36.0	34.0	4	6	151	226	1.31
49.0	47.0	24.0	4	8	163	326	2.00
55.0	37.0	22.0	2	6	72	240	2.09
49.0	30.0	24.0	6	10	244	408	1.65
45.0	33.0	25.0	4	6	177	266	1.56
56.0	35.0	34.0	4	6	142	214	1.34
52.0	36.0	24.0	4	6	153	230	1.83
55.0	41.0	23.0	4	6	145	218	2.09
50.0	40.0	38.0	6	10	240	400	1.18
55.0	45.0	32.0	6	8	218	290	1.56
50.0	36.0	35.0	4	10	160	400	1.23
47.0	32.0	28.0	6	8	255	340	1.41
50.0	43.0	22.0	8	10	320	400	2.11
49.0	43.0	27.0	2	6	81	244	1.70
46.0	40.0	27.0	4	8	173	347	1.59
45.0	32.0	23.0	4	6	177	266	1.67
47.0	44.0	25.0	6	8	255	340	1.82
49.0	47.0	24.0	4	8	163	326	2.00
58.0	35.0	31.0	10	12	344	413	1.50
50.0	33.0	22.0	4	6	160	240	1.89
55.0	34.0	33.0	4	6	145	218	1.35
56.0	43.0	27.0	2	6	71	214	1.83
48.0	45.0	23.0	4	8	166	333	2.02
54.0	37.0	21.0	2	8	74	296	2.17
51.0	46.0	20.0	6	10	235	392	2.42
55.0	44.0	27.0	4	6	145	218	1.83

LITTORAL ARROW-CUSPATE SPIT (5)

L	l	E	R_1	R_2	ROUNDNESS INDEX		FLATNESS INDEX
50.0	44.0	22.0	10	12	400	480	2.14
48.0	40.0	36.0	8	10	333	416	1.22
45.0	36.0	28.0	4	6	177	266	1.45
48.0	36.0	20.0	6	12	250	500	2.10
47.0	40.0	25.0	6	10	255	425	1.74
51.0	48.0	35.0	10	12	392	470	1.41
53.0	37.0	35.0	8	10	301	377	1.28
52.0	36.0	30.0	4	8	153	307	1.47
50.0	50.0	29.0	4	6	160	240	1.72
45.0	29.0	29.0	4	8	177	355	1.28
46.0	30.0	30.0	4	8	173	347	1.27
48.0	33.0	20.0	4	8	166	333	2.02
48.0	36.0	18.0	6	14	250	583	2.33
54.0	38.0	29.0	6	8	222	296	1.59
45.0	30.0	24.0	4	6	177	266	1.56
50.0	47.0	36.0	10	10	400	400	1.35
50.0	49.0	30.0	4	6	160	240	1.65
56.0	37.0	25.0	8	10	285	357	1.86
48.0	43.0	21.0	4	10	166	416	2.17
48.0	42.0	26.0	6	10	250	416	1.73
45.0	43.0	33.0	8	10	355	444	1.33
53.0	38.0	34.0	8	10	301	377	1.34
50.0	37.0	16.0	8	12	320	480	2.72
52.0	39.0	17.0	8	12	307	461	2.68
57.0	35.0	24.0	6	8	210	280	1.92
45.0	34.0	25.0	4	8	177	355	1.58
45.0	44.0	23.0	4	8	177	355	1.93
55.0	42.0	25.0	4	8	145	290	1.94
47.0	39.0	32.0	4	6	170	255	1.34
48.0	35.0	23.0	4	6	166	250	1.80
50.0	35.0	21.0	4	6	160	240	2.02
45.0	36.0	33.0	4	8	177	355	1.23
50.0	26.0	20.0	8	10	320	400	1.90
50.0	47.0	33.0	10	12	400	480	1.47
57.0	35.0	26.0	8	12	280	421	1.77
54.0	37.0	28.0	6	6	222	222	1.63
49.0	43.0	22.0	8	10	326	408	2.09
50.0	27.0	21.0	8	10	320	400	1.83
47.0	33.0	19.0	4	8	170	340	2.11
45.0	36.0	28.0	4	6	177	266	1.45
54.0	40.0	26.0	8	12	296	444	1.81
47.0	45.0	24.0	4	8	170	340	1.92
46.0	41.0	19.0	4	10	173	434	2.29
46.0	33.0	27.0	4	8	173	347	1.46
45.0	30.0	23.0	4	6	177	266	1.63
48.0	37.0	30.0	6	8	250	333	1.42
47.0	37.0	24.0	4	6	170	255	1.75
51.0	35.0	2.0	4	8	156	313	14.83
49.0	38.0	21.0	6	12	244	489	2.07
50.0	48.0	32.0	4	6	160	240	1.53

OFF SHORE BARRIER ISLAND (1)

L	l	E	R_1	R_2	ROUNDNESS INDEX		FLATNESS INDEX
30.0	24.0	16.0	4	6	266	400	1.69
33.0	31.0	13.0	4	8	242	484	2.46
32.0	27.0	19.0	4	6	250	375	1.55
34.0	20.0	19.0	4	6	235	352	1.42
30.0	20.0	12.0	4	6	266	400	2.08
35.0	20.0	10.0	4	4	228	228	2.75
40.0	27.0	22.0	6	6	300	400	1.52
40.0	31.0	21.0	6	6	300	500	1.69
40.0	23.0	16.0	6	6	300	400	1.97
39.0	28.0	20.0	6	6	307	307	1.67
38.0	25.0	15.0	6	8	315	421	2.10
32.0	25.0	17.0	4	6	250	375	1.68
34.0	30.0	14.0	4	6	235	352	2.29
33.0	28.0	20.0	4	6	242	363	1.52
34.0	18.0	18.0	4	8	235	470	1.44
33.0	22.0	14.0	4	10	242	606	1.96
36.0	20.0	12.0	4	6	222	333	2.33
40.0	27.0	24.0	4	8	200	400	1.40
40.0	32.0	22.0	4	6	200	400	1.64
40.0	25.0	17.0	4	6	200	400	1.91
39.0	27.0	22.0	4	6	205	307	1.50
38.0	26.0	17.0	4	10	211	526	1.88
32.0	26.0	16.0	4	8	250	500	1.81
34.0	28.0	15.0	2	6	117	352	2.07
32.0	27.0	20.0	4	8	250	500	1.47
33.0	17.0	17.0	2	6	121	484	1.47
39.0	22.0	13.0	6	6	307	307	2.35
35.0	20.0	11.0	2	6	114	342	2.50
40.0	33.0	21.0	4	6	200	300	1.74
39.0	24.0	16.0	2	4	102	205	1.97
34.0	24.0	22.0	2	6	117	352	1.32
38.0	26.0	23.0	4	6	210	315	1.39
36.0	25.0	14.0	2	6	111	333	2.18
38.0	28.0	18.0	4	8	210	421	1.83
37.0	27.0	19.0	6	6	324	324	1.68
30.0	26.0	17.0	2	4	133	266	1.65
33.0	26.0	18.0	4	4	242	242	1.64
38.0	19.0	16.0	6	8	315	421	1.78
35.0	22.0	19.0	6	8	342	457	1.50
39.0	22.0	19.0	4	6	205	307	1.61
37.0	23.0	20.0	2	6	108	324	1.50
31.0	28.0	13.0	4	6	258	387	2.27
31.0	24.0	16.0	4	8	258	516	1.72
35.0	27.0	14.0	4	6	228	342	2.21
39.0	29.0	12.0	6	8	307	410	2.63
36.0	27.0	17.0	4	8	222	444	1.85
37.0	26.0	18.0	6	8	324	432	1.75
38.0	27.0	19.0	4	6	210	315	1.71
39.0	24.0	17.0	6	8	307	410	1.85
30.0	25.0	19.0	4	6	266	400	1.45

OFF SHORE BARRIER ISLAND (2)

L	l	E	R_1	R_2	ROUNDNESS INDEX		FLATNESS INDEX
40.0	36.0	23.0	4	4	200	200	1,65
39.0	27.0	25.0	4	6	205	307	1,32
38.0	24.0	15.0	4	8	210	421	2,07
40.0	26.0	14.0	4	6	200	300	2,36
39.0	37.0	14.0	4	6	205	307	2,71
35.0	24.0	20.0	4	6	228	342	1,47
34.0	22.0	13.0	4	6	235	352	2,15
32.0	23.0	14.0	4	4	250	250	1,96
37.0	30.0	26.0	4	8	216	432	1,29
34.0	26.0	18.0	4	6	235	352	1,67
37.0	24.0	21.0	4	6	216	324	1,45
30.0	22.0	17.0	6	8	400	533	1,53
37.0	34.0	14.0	6	8	324	432	2,54
35.0	29.0	15.0	4	4	228	228	2,13
38.0	29.0	19.0	4	8	210	421	1,76
34.0	24.0	20.0	6	6	352	352	1,45
31.0	25.0	13.0	6	6	387	387	2,15
34.0	28.0	27.0	4	6	235	352	1,15
35.0	24.0	17.0	4	8	228	457	1,74
38.0	26.0	21.0	6	8	315	421	1,52
32.0	24.0	18.0	4	6	250	375	1,56
39.0	28.0	14.0	4	6	205	307	2,39
38.0	30.0	19.0	6	8	315	421	1,79
40.0	21.0	18.0	6	6	300	300	1,69
32.0	27.0	14.0	6	6	375	375	2,11
38.0	29.0	27.0	6	8	315	421	1,24
34.0	21.0	16.0	4	8	235	470	1,72
40.0	31.0	20.0	4	6	200	300	1,77
36.0	25.0	16.0	4	6	222	333	1,91
34.0	24.0	19.0	4	6	235	352	1,53
38.0	27.0	13.0	4	6	210	315	2,50
40.0	28.0	24.0	6	6	300	300	1,42
34.0	22.0	18.0	6	8	352	470	1,56
36.0	20.0	15.0	6	6	333	333	1,87
32.0	24.0	16.0	4	6	250	375	1,75
36.0	24.0	16.0	4	8	222	444	1,88
35.0	22.0	14.0	6	8	342	457	2,04
36.0	30.0	17.0	6	8	333	444	1,94
32.0	31.0	17.0	4	6	250	375	1,85
35.0	26.0	18.0	4	6	228	342	1,69
33.0	22.0	19.0	4	6	242	363	1,45
34.0	24.0	18.0	6	6	352	352	1,61
33.0	26.0	18.0	4	6	242	363	1,64
32.0	26.0	19.0	4	6	250	375	1,53
31.0	27.0	18.0	4	8	258	516	1,61
38.0	28.0	15.0	6	8	315	421	2,20
39.0	27.0	14.0	6	6	307	307	2,36
33.0	25.0	13.0	4	6	242	363	2,23
31.0	24.0	16.0	6	8	387	516	1,72
30.0	23.0	18.0	4	8	266	533	1,47

OFF SHORE BARRIER ISLAND (3)

L	l	E	R_1	R_2	ROUNDNESS INDEX		FLATNESS INDEX
40.0	33.0	120.0	4	6	200	300	0.30
36.0	25.0	21.0	4	6	222	333	1.45
30.0	25.0	12.0	3	4	200	266	2.29
30.0	23.0	15.0	4	4	266	266	1.77
40.0	31.0	21.0	4	6	200	300	1.69
30.0	21.0	17.0	4	4	266	266	1.50
34.0	24.0	17.0	4	6	235	352	1.71
35.0	29.0	17.0	4	6	228	342	1.88
34.0	26.0	19.0	2	4	117	235	1.56
39.0	33.0	16.0	2	4	102	205	2.25
37.0	24.0	20.0	4	6	216	324	1.52
32.0	27.0	14.0	2	4	125	250	2.11
33.0	25.0	18.0	4	6	242	363	1.64
40.0	32.0	22.0	4	4	200	200	1.64
35.0	22.0	18.0	6	6	342	342	1.58
34.0	26.0	19.0	2	4	117	235	1.58
31.0	30.0	19.0	4	4	258	258	1.61
35.0	19.0	15.0	6	6	342	342	1.60
36.0	27.0	17.0	4	6	222	333	1.85
38.0	36.0	18.0	4	6	210	315	2.00
39.0	26.0	22.0	4	6	205	307	1.45
31.0	29.0	17.0	2	6	129	387	1.76
35.0	27.0	19.0	4	6	228	342	1.63
32.0	33.0	22.0	2	4	125	250	1.46
32.0	23.0	17.0	4	6	250	375	1.62
39.0	32.0	20.0	6	6	307	307	1.77
33.0	20.0	17.0	4	4	242	242	1.56
35.0	28.0	16.0	2	6	114	342	1.75
34.0	37.0	19.0	2	4	117	235	1.67
37.0	27.0	22.0	4	6	216	324	1.45
40.0	32.0	24.0	6	6	300	300	1.50
31.0	22.0	17.0	4	6	258	387	1.56
33.0	23.0	18.0	4	6	242	363	1.56
31.0	21.0	17.0	2	4	129	258	1.53
31.0	27.0	19.0	2	6	129	387	1.53
36.0	26.0	20.0	6	6	333	333	1.55
35.0	28.0	18.0	4	4	228	228	1.75
36.0	21.0	17.0	4	6	222	333	1.66
34.0	27.0	22.0	4	6	235	352	1.39
37.0	18.0	18.0	4	6	216	324	1.53
34.0	18.0	11.0	4	6	235	352	2.36
38.0	21.0	12.0	6	6	315	421	2.45
32.0	19.0	14.0	2	6	125	375	1.82
40.0	19.0	17.0	4	6	200	300	1.74
36.0	28.0	12.0	4	6	222	333	2.67
40.0	29.0	20.0	4	8	200	400	1.72
32.0	27.0	17.0	4	6	250	375	1.74
30.0	19.0	14.0	4	4	266	266	1.75
35.0	21.0	18.0	6	6	342	457	1.56
33.0	24.0	20.0	4	6	242	363	1.42

OFF SHORE BARRIER ISLAND (4)

L	l	E	R_1	R_2	ROUNDNESS INDEX		FLATNESS INDEX
31.0	19.0	14.0	4	6	258	387	1.79
40.0	28.0	11.0	4	4	200	200	3.09
34.0	27.0	13.0	2	6	117	352	2.35
30.0	25.0	14.0	4	8	266	533	1.96
32.0	24.0	14.0	2	4	125	250	2.00
32.0	23.0	13.0	4	6	250	375	2.12
33.0	23.0	20.0	2	4	121	242	1.40
35.0	25.0	18.0	4	6	228	342	1.67
35.0	26.0	19.0	2	6	114	342	1.61
40.0	27.0	17.0	6	8	300	400	1.97
33.0	21.0	16.0	2	4	121	242	1.69
35.0	24.0	18.0	6	8	342	457	1.64
39.0	30.0	14.0	2	4	102	205	2.46
37.0	19.0	15.0	6	8	324	432	1.87
38.0	25.0	16.0	4	6	210	315	1.97
36.0	24.0	14.0	4	6	222	333	2.14
36.0	22.0	15.0	6	8	333	444	1.93
34.0	21.0	17.0	4	6	235	352	1.62
31.0	18.0	16.0	4	6	258	387	1.53
32.0	19.0	17.0	4	6	250	375	1.50
37.0	17.0	15.0	4	8	216	432	1.80
37.0	17.0	18.0	2	4	108	216	1.50
40.0	18.0	15.0	6	6	300	300	1.93
39.0	20.0	18.0	6	8	307	410	1.64
32.0	24.0	20.0	4	6	250	375	1.40
40.0	26.0	16.0	6	8	300	400	2.06
33.0	23.0	18.0	4	6	242	363	1.56
35.0	21.0	19.0	4	6	228	342	1.47
37.0	27.0	15.0	2	4	108	216	2.13
38.0	26.0	17.0	4	6	210	315	1.88
36.0	20.0	19.0	2	4	111	222	1.47
38.0	18.0	17.0	4	6	210	315	1.65
30.0	21.0	15.0	2	4	133	266	1.70
33.0	19.0	17.0	2	6	121	363	1.53
38.0	26.0	20.0	4	6	210	315	1.60
39.0	209.0	18.0	6	8	307	410	6.89
37.0	24.0	14.0	2	4	108	216	2.18
35.0	23.0	13.0	4	6	228	342	2.23
38.0	21.0	12.0	2	6	105	315	2.46
30.0	23.0	10.0	2	4	133	266	2.65
34.0	31.0	22.0	2	4	117	235	1.48
39.0	23.0	16.0	4	6	205	307	1.94
34.0	27.0	11.0	4	6	235	352	2.77
40.0	27.0	21.0	2	4	100	200	1.60
30.0	27.0	14.0	2	4	133	266	2.04
34.0	22.0	13.0	2	4	117	235	2.15
30.0	23.0	17.0	4	4	266	266	1.56
31.0	20.0	18.0	2	4	129	258	1.02
34.0	27.0	11.0	4	6	235	352	2.77
39.0	26.0	16.0	4	4	205	205	2.03

SPIT BAR , MAXVILLE (E)

L	l	E	R_1	R_2	ROUNDNESS INDEX		FLATNESS INDEX
59.0	46.0	30.0	2	4	67	135	1.75
45.0	33.0	20.0	4	8	177	355	1.95
58.0	40.0	37.0	10	12	344	413	1.32
60.0	41.0	22.0	6	10	200	333	2.30
60.0	52.0	30.0	10	16	333	533	1.87
54.0	50.0	25.0	4	10	148	370	2.08
58.0	48.0	16.0	8	12	275	413	3.31
60.0	43.0	26.0	12	14	400	466	1.98
50.0	32.0	28.0	8	8	320	320	1.46
60.0	46.0	23.0	10	16	333	533	2.30
58.0	50.0	30.0	8	10	275	344	1.80
50.0	45.0	30.0	6	10	240	400	1.58
46.0	43.0	24.0	4	8	173	347	1.85
58.0	52.0	28.0	10	14	344	482	1.96
57.0	45.0	20.0	6	8	210	280	2.55
51.0	46.0	35.0	6	10	235	392	1.39
59.0	53.0	25.0	6	8	203	271	2.24
58.0	47.0	36.0	8	14	275	482	1.46
57.0	54.0	27.0	10	14	351	491	2.06
55.0	35.0	31.0	8	10	290	363	1.45
48.0	34.0	30.0	6	8	250	333	1.37
45.0	39.0	31.0	4	6	177	200	1.35
59.0	44.0	28.0	4	6	135	203	1.84
60.0	43.0	27.0	6	8	200	266	1.91
60.0	40.0	39.0	10	14	333	466	1.28
45.0	43.0	27.0	6	10	266	444	1.63
48.0	37.0	40.0	4	6	166	250	1.06
53.0	43.0	35.0	8	8	301	301	1.37
54.0	50.0	25.0	4	10	148	370	2.08
60.0	47.0	26.0	6	8	200	266	2.06
47.0	36.0	27.0	6	10	255	425	1.54
55.0	47.0	35.0	6	8	218	290	1.46
60.0	45.0	28.0	12	12	400	400	1.88
49.0	43.0	21.0	6	8	244	326	2.19
58.0	40.0	30.0	10	12	344	413	1.63
45.0	32.0	20.0	6	6	266	266	1.92
47.0	35.0	26.0	4	6	170	255	1.58
58.0	44.0	36.0	6	10	206	344	1.42

L	l	E	R_1	R_2	ROUNDNESS INDEX		FLATNESS INDEX
45.0	42.0	24.0	6	10	266	444	1.81
60.0	45.0	28.0	8	1	266	33	1.88
60.0	41.0	22.0	6	10	200	333	2.30
58.0	44.0	32.0	4	8	137	275	1.59
52.0	43.0	34.0	6	10	230	384	1.40
53.0	45.0	30.0	8	10	301	377	1.63
50.0	41.0	35.0	8	10	320	400	1.30
52.0	43.0	35.0	8	10	307	384	1.36
53.0	35.0	20.0	8	10	301	377	2.20
59.0	36.0	31.0	8	12	271	406	1.53
57.0	46.0	35.0	8	14	280	491	1.47
58.0	46.0	30.0	10	12	344	413	1.73
45.0	37.0	18.0	8	10	355	444	2.28
53.0	37.0	18.0	8	10	301	377	2.50
55.0	51.0	32.0	6	8	218	290	1.66
59.0	37.0	30.0	8	12	271	406	1.60
58.0	39.0	38.0	10	12	344	413	1.28
56.0	36.0	32.0	8	8	285	285	1.44
60.0	46.0	42.0	6	12	200	400	1.26
60.0	47.0	32.0	6	12	200	400	1.67
52.0	35.0	25.0	4	6	153	230	1.74
59.0	47.0	21.0	6	8	203	271	2.52
50.0	32.0	28.0	8	8	320	320	1.46
45.0	37.0	32.0	4	6	177	266	1.28
49.0	38.0	40.0	4	6	163	244	1.09
53.0	41.0	25.0	4	12	150	452	1.88
56.0	50.0	32.0	6	8	214	285	1.66
45.0	45.0	30.0	8	10	355	444	1.50
51.0	43.0	33.0	6	10	235	392	1.42
60.0	40.0	40.0	10	14	333	466	1.25
60.0	48.0	34.0	8	12	266	400	1.59
50.0	33.0	24.0	4	6	160	240	1.73
60.0	43.0	39.0	8	10	266	333	1.32
59.0	51.0	28.0	10	16	338	542	1.96
60.0	46.0	23.0	10	16	333	533	2.30
51.0	46.0	35.0	6	10	235	392	1.39
53.0	50.0	28.0	8	10	301	377	1.84

SPIT BAR, MAXVILLE (F)

L	l	E	R_1	R_2	ROUNDNESS INDEX		FLATNESS INDEX
45.0	40.0	19.0	6	10	266	444	2.24
52.0	41.0	18.0	8	10	307	384	2.58
51.0	46.0	35.0	6	8	235	313	1.39
45.0	34.0	21.0	4	8	177	355	1.88
50.0	40.0	28.0	6	8	240	320	1.61
48.0	35.0	23.0	4	6	166	250	1.80
58.0	38.0	37.0	6	10	206	344	1.30
60.0	45.0	40.0	10	12	333	400	1.31
53.0	44.0	35.0	8	10	301	377	1.39
55.0	40.0	19.0	6	8	218	290	2.50
52.0	45.0	33.0	6	8	230	307	1.47
60.0	47.0	30.0	6	8	200	266	1.78
49.0	36.0	26.0	4	8	163	326	1.63
47.0	36.0	27.0	6	10	255	425	1.54
52.0	44.0	41.0	6	10	230	384	1.17
55.0	39.0	27.0	6	8	218	290	1.74
52.0	41.0	20.0	8	10	307	384	2.32
45.0	43.0	37.0	8	12	355	533	1.19
58.0	47.0	37.0	8	14	275	482	1.42
55.0	40.0	34.0	4	8	145	290	1.40
48.0	35.0	22.0	4	8	166	333	1.89
47.0	34.0	25.0	6	10	255	425	1.62
57.0	46.0	34.0	10	12	350	421	1.51
45.0	43.0	26.0	6	10	266	444	1.69
45.0	29.0	25.0	6	10	266	444	1.48
46.0	36.0	18.0	6	10	261	434	2.21
56.0	40.0	36.0	4	6	142	214	1.33
58.0	45.0	30.0	2	4	68	137	1.72
58.0	50.0	31.0	8	10	275	344	1.74
55.0	40.0	26.0	8	12	290	436	1.83
60.0	45.0	21.0	6	8	200	266	2.50
59.0	46.0	28.0	6	8	203	271	1.88
60.0	45.0	29.0	8	12	266	400	1.81
45.0	40.0	24.0	6	8	266	355	1.77
49.0	35.0	28.0	6	6	244	244	1.50
49.0	47.0	29.0	10	14	408	571	1.66
48.0	35.0	24.0	4	8	166	333	1.73
46.0	42.0	26.0	6	10	261	434	1.69
51.0	46.0	38.0	6	10	235	392	1.28
50.0	36.0	29.0	6	8	240	320	1.48
46.0	39.0	22.0	6	6	260	260	1.93
49.0	47.0	27.0	12	14	489	571	1.78
59.0	38.0	36.0	6	10	203	338	1.35
53.0	41.0	25.0	4	10	151	377	1.88
53.0	42.0	24.0	2	6	75	226	1.98
55.0	39.0	27.0	8	12	290	436	1.74
45.0	37.0	21.0	6	6	266	266	1.95
45.0	44.0	38.0	8	12	355	533	1.17
52.0	44.0	34.0	6	8	230	307	1.41
50.0	38.0	25.0	8	14	320	560	1.76
51.0	40.0	29.0	6	8	235	313	1.57
49.0	36.0	22.0	4	4	163	163	1.93
49.0	26.0	29.0	4	8	163	326	1.29
45.0	33.0	23.0	6	10	266	444	1.70
60.0	40.0	30.0	6	10	200	333	1.67
60.0	46.0	21.0	6	8	200	266	2.52
45.0	34.0	26.0	4	8	177	355	1.52
49.0	27.0	28.0	4	8	163	326	1.36
48.0	48.0	28.0	12	14	500	583	1.71
45.0	39.0	18.0	6	10	266	444	2.33
54.0	50.0	30.0	8	14	296	518	1.73
51.0	39.0	26.0	8	14	313	549	1.73
59.0	47.0	29.0	6	8	203	271	1.83
55.0	40.0	35.0	4	8	145	290	1.36
55.0	40.0	35.0	4	8	145	290	1.36
57.0	41.0	37.0	4	6	140	210	1.32
50.0	42.0	30.0	6	8	240	320	1.53
60.0	46.0	20.0	6	8	200	266	2.65
52.0	41.0	19.0	8	10	307	384	2.45
55.0	39.0	19.0	6	8	218	290	2.47
47.0	35.0	28.0	4	6	170	255	1.46
49.0	40.0	37.0	6	8	244	326	1.20
45.0	38.0	35.0	4	6	177	266	1.19
52.0	37.0	28.0	4	6	153	230	1.59
46.0	35.0	22.0	6	8	260	347	1.84

SPIT,DORNIE TILL RIDGE (1)

L	l	E	R_1	R_2	ROUNDNESS INDEX		FLATNESS INDEX
55.0	42.0	22.0	8	10	240	363	2.20
50.0	34.0	24.0	6	12	520	480	1.75
60.0	50.0	35.0	8	10	266	333	1.57
56.0	43.0	23.0	6	10	265	357	2.15
57.0	46.0	39.0	12	14	421	491	1.32
47.0	40.0	30.0	6	8	255	340	1.45
45.0	47.0	33.0	6	10	355	444	1.39
50.0	45.0	38.0	10	14	400	560	1.25
55.0	48.0	22.0	6	12	290	436	2.34
53.0	47.0	20.0	6	12	311	452	2.50
47.0	41.0	26.0	6	10	300	425	1.69
45.0	44.0	33.0	8	12	355	533	1.35
60.0	43.0	31.0	10	10	333	533	1.66
60.0	45.0	32.0	8	16	266	533	1.64
52.0	35.0	28.0	8	12	307	461	1.55
48.0	40.0	15.0	6	12	250	500	2.93
60.0	47.0	42.0	10	12	333	400	1.27
54.0	33.0	23.0	6	10	296	370	1.89
53.0	48.0	25.0	14	16	528	603	2.02
54.0	49.0	26.0	12	16	444	592	1.98
58.0	51.0	22.0	10	12	344	413	2.48
50.0	48.0	18.0	6	12	24	480	2.72
59.0	45.0	40.0	10	12	336	406	1.30
50.0	46.0	27.0	8	10	320	400	1.78
54.0	44.0	30.0	10	12	370	444	1.63
57.0	53.0	28.0	12	16	421	631	1.96
60.0	47.0	38.0	14	18	466	600	1.41
54.0	40.0	28.0	8	10	296	370	1.68
55.0	40.0	26.0	6	8	216	293	1.83
46.0	40.0	25.0	6	[illegible]	347	434	1.72
53.0	35.0	27.0	8	12	311	452	1.63
46.0	45.0	34.0	8	12	347	521	1.34
53.0	32.0	22.0	6	8	226	301	1.93
53.0	45.0	22.0	8	12	311	452	2.23
50.0	48.0	20.0	6	12	32	480	2.45
47.0	44.0	29.0	6	8	255	340	1.57
49.0	42.0	30.0	6	8	244	326	1.52
55.0	43.0	39.0	12	14	436	509	1.26
47.0	36.0	24.0	8	10	311	425	1.73
48.0	42.0	20.0	11	14	416	583	2.25
48.0	40.0	15.0	6	12	250	500	2.93
57.0	54.0	27.0	12	14	421	631	2.06
50.0	35.0	23.0	8	12	320	480	1.85
48.0	44.0	26.0	8	10	333	416	1.77
60.0	45.0	40.0	10	12	333	400	1.31
46.0	45.0	34.0	6	12	347	521	1.34
45.0	45.0	32.0	6	10	355	444	1.41
53.0	36.0	28.0	8	12	301	452	1.59
55.0	44.0	29.0	10	12	363	436	1.71
53.0	47.0	26.0	14	16	528	603	1.92
58.0	50.0	20.0	10	14	344	482	2.70
50.0	43.0	28.0	10	12	400	480	1.66
60.0	47.0	36.0	10	18	533	600	1.49
46.0	42.0	27.0	6	8	260	347	1.63
47.0	44.0	27.0	8	10	340	425	1.69
47.0	42.0	21.0	10	14	425	595	2.12
45.0	39.0	24.0	8	10	355	444	1.75
60.0	44.0	39.0	10	12	333	400	1.33
49.0	35.0	23.0	8	10	326	408	1.83
50.0	40.0	25.0	6	8	222	296	1.88
58.0	50.0	20.0	10	12	344	413	2.70
48.0	34.0	22.0	8	10	333	416	1.86
50.0	42.0	29.0	10	12	400	480	1.59
56.0	45.0	30.0	10	12	357	428	1.68
45.0	39.0	29.0	6	8	266	355	1.45
46.0	43.0	28.0	6	8	260	347	1.59
56.0	49.0	21.0	10	12	357	428	2.50
53.0	30.0	21.0	6	8	226	301	1.98
50.0	46.0	27.0	8	10	320	400	1.78
48.0	45.0	28.0	8	10	333	416	1.66
53.0	43.0	23.0	6	10	301	377	2.09
60.0	46.0	37.0	10	16	533	600	1.43
57.0	45.0	40.0	12	14	421	491	1.27
50.0	46.0	39.0	10	14	338	474	1.35

SPIT, DORNIE TILL RIDGE (2)

L	I	E	R_1	R_2	ROUNDNESS INDEX		FLATNESS INDEX
0.0	0.0	0.0	0	0		0	0.0
56.0	48.0	26.0	6	12	285	428	2.00
47.0	41.0	33.0	6	8	255	340	1.33
46.0	35.0	31.0	4	6	173	260	1.31
60.0	45.0	36.0	6	10	266	333	1.38
48.0	45.0	23.0	8	10	333	416	2.02
54.0	41.0	32.0	12	14	444	518	1.48
54.0	45.0	28.0	6	8	222	296	1.77
60.0	45.0	36.0	10	14	333	466	1.38
60.0	41.0	30.0	6	8	200	266	1.09
56.0	47.0	30.0	4	6	142	214	1.72
55.0	38.0	30.0	6	8	218	290	1.55
54.0	37.0	29.0	6	8	222	296	1.57
59.0	37.0	34.0	12	14	400	474	1.41
53.0	32.0	29.0	4	6	151	301	1.47
57.0	48.0	32.0	6	10	210	350	1.64
52.0	40.0	34.0	6	8	230	307	1.35
50.0	43.0	40.0	6	10	240	400	1.16
45.0	42.0	28.0	6	8	260	355	1.55
50.0	45.0	42.0	6	12	240	480	1.13
59.0	44.0	37.0	10	14	338	470	1.39
58.0	45.0	32.0	6	8	206	275	1.01
61.0	38.0	35.0	12	16	393	520	1.41
56.0	47.0	26.0	10	14	357	500	1.98
55.0	50.0	30.0	6	10	216	303	1.75
60.0	52.0	27.0	8	10	266	333	2.07
60.0	40.0	29.0	6	8	200	266	1.72
58.0	40.0	22.0	6	8	206	275	2.23
56.0	40.0	39.0	6	10	214	357	1.23
60.0	50.0	25.0	6	8	200	266	2.20
53.0	41.0	35.0	6	8	220	301	1.34
56.0	45.0	31.0	6	14	285	500	1.63
55.0	46.0	27.0	10	16	303	509	1.87
57.0	52.0	32.0	6	10	266	350	1.70
53.0	38.0	39.0	8	10	301	377	1.17
52.0	40.0	29.0	6	10	230	384	1.59
54.0	32.0	30.0	4	8	140	290	1.43
55.0	45.0	30.0	6	14	291	509	1.67
54.0	44.0	24.0	6	8	222	296	2.00
53.0	38.0	37.0	8	10	301	377	1.23
55.0	47.0	25.0	10	12	363	436	2.06
59.0	47.0	33.0	6	8	203	271	1.61
59.0	43.0	36.0	8	12	271	406	1.42
55.0	45.0	25.0	6	8	218	290	2.00
56.0	46.0	31.0	8	12	245	428	1.65
58.0	45.0	35.0	10	14	344	482	1.47
60.0	37.0	34.0	12	16	400	533	1.43
60.0	46.0	32.0	6	8	200	266	1.06
55.0	42.0	26.0	4	6	145	290	1.67
56.0	39.0	31.0	6	8	214	285	1.53
58.0	44.0	30.0	6	8	206	275	1.76
53.0	41.0	35.0	6	8	220	301	1.34
60.0	38.0	28.0	6	8	201	266	1.75
54.0	39.0	40.0	8	10	296	370	1.16
55.0	46.0	25.0	10	12	363	436	2.02
54.0	48.0	30.0	6	10	222	370	1.70
45.0	37.0	32.0	4	6	177	266	1.28
45.0	40.0	32.0	8	10	355	444	1.38
52.0	30.0	30.0	10	14	384	538	1.52
55.0	37.0	25.0	8	10	29	363	1.64
58.0	53.0	33.0	8	10	275	344	1.68
54.0	45.0	27.0	6	6	222	296	1.83
60.0	52.0	24.0	10	14	333	466	2.33
59.0	44.0	37.0	8	10	271	338	1.39
54.0	44.0	24.0	6	8	222	296	2.08
53.0	40.0	30.0	12	14	452	528	1.55
54.0	49.0	29.0	6	10	222	370	1.78
56.0	36.0	25.0	4	6	142	214	1.84
56.0	43.0	27.0	4	6	142	265	1.83
53.0	32.0	29.0	4	8	151	301	1.47
45.0	39.0	25.0	6	8	266	355	1.58
60.0	50.0	23.0	10	14	333	400	2.30
54.0	48.0	24.0	6	10	296	370	2.13
60.0	41.0	23.0	6	8	200	266	2.20
49.0	42.0	40.0	6	10	244	408	1.14
56.0	36.0	26.0	4	6	142	214	1.77

SPIT,DORNIE TILL RIDGE (3)

L	l	E	R_1	R_2	ROUNDNESS INDEX		FLATNESS INDEX
0.0	0.0	0.0	0	0		0	0.0
57.0	47.0	33.0	4	6	140	210	1.58
57.0	37.0	32.0	2	6	70	210	1.47
59.0	40.0	40.0	4	8	135	271	1.24
56.0	40.0	36.0	6	8	214	285	1.33
58.0	48.0	34.0	4	4	137	137	1.54
55.0	35.0	31.0	6	8	218	290	1.45
60.0	42.0	21.0	4	6	133	200	2.43
56.0	36.0	32.0	6	8	214	285	1.44
50.0	38.0	23.0	6	8	240	320	1.91
60.0	45.0	34.0	6	8	200	266	1.54
51.0	39.0	26.0	4	6	156	235	1.73
58.0	45.0	33.0	6	8	206	275	1.56
51.0	51.0	25.0	8	12	313	470	2.04
58.0	46.0	38.0	2	4	68	137	1.53
59.0	46.0	34.0	6	8	203	271	1.54
57.0	42.0	22.0	6	12	210	421	2.25
56.0	50.0	25.0	6	10	214	357	2.12
50.0	43.0	40.0	8	10	320	400	1.16
50.0	38.0	25.0	4	6	160	240	1.76
58.0	43.0	23.0	6	12	206	413	2.20
57.0	35.0	31.0	6	8	210	280	1.48
51.0	34.0	31.0	2	6	78	235	1.37
52.0	41.0	35.0	4	10	153	384	1.33
56.0	34.0	30.0	6	8	214	285	1.50
55.0	51.0	26.0	6	10	218	363	2.04
56.0	41.0	22.0		8	142	285	2.20
50.0	48.0	27.0	2	2	80	80	1.81
59.0	45.0	30.0	4	8	135	271	1.73
58.0	44.0	29.0	4	8	137	275	1.76
53.0	41.0	29.0	4	6	150	226	1.62
57.0	40.0	34.0	4	8	140	280	1.43
50.0	39.0	33.0	4	10	160	400	1.35
57.0	44.0	32.0	2	4	70	140	1.58
57.0	42.0	23.0	6	12	210	421	2.15
60.0	43.0	20.0	4	4	133	133	2.57
50.0	50.0	26.0	8	12	320	480	1.92
55.0	47.0	30.0	4	6	145	218	1.70
56.0	39.0	34.0	4	8	142	285	1.40
56.0	33.0	35.0	4	6	142	214	1.27
58.0	46.0	31.0	4	8	137	275	1.68
60.0	50.0	36.0	4	4	133	133	1.53
46.0	41.0	27.0	6	10	260	434	1.61
50.0	39.0	26.0	4	6	160	240	1.71
58.0	50.0	34.0	6	8	206	275	1.59
57.0	38.0	38.0	4	8	140	280	1.25
52.0	45.0	31.0	2	6	76	230	1.56
54.0	43.0	35.0	8	10	296	370	1.39
58.0	43.0	24.0	4	8	137	275	2.10
49.0	48.0	26.0	8	12	326	489	1.87
58.0	40.0	39.0	4	8	137	275	1.26
46.0	40.0	26.0	6	10	260	434	1.65
55.0	35.0	30.0	2	6	72	218	1.50
56.0	47.0	32.0	4	6	142	214	1.61
60.0	52.0	35.0	6	8	200	266	1.60
57.0	51.0	34.0	6	8	210	280	1.59
53.0	44.0	30.0	2	6	75	226	1.62
57.0	34.0	36.0	4	6	140	210	1.26
54.0	40.0	29.0	4	4	148	148	1.68
58.0	38.0	34.0	4	6	137	206	1.41
52.0	43.0	31.0	2	6	76	230	1.53
58.0	35.0	35.0	4	6	137	206	1.33
55.0	46.0	31.0	4	6	145	218	1.63
55.0	39.0	35.0	6	8	218	290	1.34
60.0	40.0	37.0	2	4	66	133	1.35
59.0	39.0	36.0	2	4	67	135	1.36
50.0	37.0	22.0	6	8	240	320	1.98
60.0	40.0	35.0	4	6	133	200	1.43
49.0	42.0	40.0	8	10	326	408	1.14
58.0	39.0	36.0	6	8	206	275	1.35
50.0	33.0	30.0	2	6	80	240	1.38
50.0	47.0	26.0	2	4	80	160	1.87
58.0	30.0	34.0	2	4	68	137	1.29
60.0	32.0	35.0	2	4	66	133	1.31
60.0	45.0	25.0	6	12	200	400	2.10
54.0	42.0	34.0	8	10	296	370	1.41

RECURVE SPIT, WEST OF FASSIFERN (1)

L	l	E	R_1	R_2	ROUNDNESS INDEX		FLATNESS INDEX
60.0	50.0	48.0	14	16	466	533	1.15
50.0	42.0	20.0	8	10	320	400	2.30
45.0	35.0	24.0	8	10	355	444	1.67
51.0	43.0	22.0	8	10	313	392	2.14
58.0	49.0	47.0	14	16	482	551	1.14
57.0	50.0	23.0	6	12	210	421	2.33
51.0	40.0	33.0	8	10	313	392	1.38
45.0	40.0	23.0	8	10	355	444	1.85
65.0	48.0	35.0	10	12	307	369	1.61
61.0	50.0	49.0	14	16	459	524	1.13
55.0	40.0	29.0	8	10	290	363	1.64
55.0	43.0	22.0	12	14	436	509	2.23
58.0	51.0	24.0	6	12	206	413	2.27
46.0	36.0	23.0	8	10	347	434	1.78
45.0	40.0	30.0	8	10	355	444	1.42
54.0	39.0	30.0	8	10	296	370	1.55
60.0	39.0	23.0	8	10	266	333	2.15
56.0	47.0	25.0	12	16	428	571	2.06
46.0	42.0	29.0	8	10	347	434	1.52
45.0	33.0	22.0	8	10	355	444	1.77
50.0	399.0	30.0	8	10	320	400	7.48
60.0	52.0	33.0	12	14	400	466	1.70
50.0	42.0	28.0	8	12	320	480	1.64
47.0	41.0	28.0	8	10	340	425	1.57
45.0	42.0	30.0	8	14	355	622	1.45
45.0	37.0	18.0	8	10	355	444	2.28
48.0	44.0	24.0	12	14	500	583	1.92
51.0	34.0	24.0	6	10	235	392	1.77
45.0	25.0	16.0	8	10	355	444	2.19
45.0	37.0	23.0	6	8	266	355	1.78
60.0	52.0	33.0	12	14	400	466	1.70
45.0	40.0	30.0	8	10	355	444	1.42
59.0	40.0	24.0	8	10	271	338	2.06
60.0	49.0	36.0	10	12	333	400	1.51
60.0	39.0	24.0	8	10	266	333	2.06
56.0	48.0	26.0	12	16	428	571	2.00
50.0	40.0	31.0	8	10	320	400	1.45
46.0	34.0	23.0	8	10	347	434	1.74
45.0	41.0	24.0	8	10	355	444	1.79
45.0	35.0	18.0	10	12	444	533	2.22
45.0	40.0	21.0	8	10	355	444	2.02
50.0	40.0	31.0	8	10	320	400	1.45
45.0	32.0	21.0	8	10	355	444	1.83
60.0	53.0	34.0	12	14	400	466	1.66
52.0	41.0	34.0	8	10	307	384	1.37
45.0	33.0	22.0	8	10	355	444	1.77
45.0	36.0	17.0	10	12	444	533	2.38
51.0	409.0	34.0	8	10	313	392	6.76
59.0	51.0	33.0	12	14	406	474	1.67
52.0	35.0	24.0	6	10	230	384	1.81
46.0	43.0	31.0	8	14	347	608	1.44
47.0	43.0	25.0	12	14	510	595	1.80
45.0	26.0	15.0	8	10	355	444	2.37
47.0	41.0	30.0	8	10	340	425	1.47
60.0	53.0	32.0	12	14	400	466	1.77
59.0	52.0	33.0	12	14	406	474	1.68
45.0	36.0	24.0	6	8	266	355	1.60
52.0	35.0	24.0	6	10	230	384	1.81
51.0	40.0	31.0	8	10	313	392	1.47
45.0	36.0	22.0	6	8	266	355	1.84
60.0	50.0	48.0	14	16	466	533	1.15
49.0	41.0	27.0	8	12	326	489	1.67
45.0	24.0	15.0	8	10	355	444	2.30
45.0	40.0	29.0	8	10	355	444	1.47
60.0	40.0	259.0	8	10	266	333	0.19
59.0	49.0	47.0	14	16	474	542	1.15
60.0	45.0	34.0	8	12	266	400	1.54
60.0	53.0	34.0	12	14	400	466	1.66
48.0	42.0	29.0	8	10	333	416	1.55
49.0	40.0	31.0	8	10	326	408	1.44
57.0	49.0	23.0	6	12	210	421	2.30
52.0	39.0	33.0	8	10	307	384	1.38
51.0	33.0	25.0	6	10	235	392	1.68
56.0	41.0	28.0	8	10	285	357	1.73
56.0	43.0	34.0	8	8	285	285	1.46

RECURVE SPIT, WEST OF FASSIFERN (2)

L	1	E E	R_1	R_2	ROUNDNESS INDEX		FLATNESS INDEX
55.0	44.0	34.0	8	8	290	290	1.46
48.0	39.0	32.0	8	16	333	666	1.36
52.0	33.0	23.0	6	8	230	307	1.85
53.0	35.0	27.0	4	8	150	301	1.63
60.0	36.0	27.0	8	10	266	333	1.78
60.0	49.0	28.0	6	6	200	200	1.95
48.0	44.0	21.0	8	10	333	416	2.19
55.0	52.0	31.0	14	16	509	581	1.73
49.0	30.0	30.0	8	16	376	653	1.32
59.0	49.0	28.0	6	6	203	203	1.93
54.0	48.0	34.0	6	8	222	296	1.50
55.0	42.0	33.0	8	8	290	290	1.47
50.0	32.0	30.0	8	16	320	640	1.37
59.0	28.0	37.0	8	10	271	338	1.18
50.0	48.0	34.0	6	14	240	560	1.44
45.0	40.0	32.0	6	8	266	355	1.33
52.0	34.0	27.0	4	8	153	307	1.59
49.0	47.0	35.0	8	12	326	489	1.37
45.0	36.0	32.0	6	6	266	266	1.27
52.0	32.0	26.0	8	12	307	461	1.62
51.0	31.0	22.0	6	8	235	313	1.86
45.0	38.0	30.0	6	8	266	355	1.38
55.0	32.0	27.0	4	10	145	363	1.61
47.0	44.0	21.0	8	10	340	425	2.17
60.0	50.0	29.0	6	6	200	200	1.90
45.0	39.0	32.0	6	8	266	355	1.31
45.0	35.0	30.0	6	6	266	266	1.33
51.0	31.0	24.0	8	12	313	470	1.71
54.0	41.0	32.0	8	8	296	296	1.48
45.0	35.0	25.0	6	6	266	266	1.60
50.0	49.0	35.0	8	12	320	480	1.41
54.0	35.0	26.0	4	8	148	296	1.71
47.0	30.0	30.0	8	16	340	680	1.28
53.0	47.0	33.0	6	8	226	301	1.52
60.0	50.0	29.0	4	6	133	200	1.90
55.0	44.0	34.0	10	12	363	436	1.46
45.0	33.0	30.0	6	6	266	266	1.30
40.0	38.0	30.0	6	8	300	400	1.30
54.0	31.0	27.0	4	10	148	370	1.57
45.0	35.0	25.0	6	8	266	355	1.60
56.0	44.0	35.0	16	18	571	642	1.43
50.0	31.0	21.0	6	8	240	320	1.93
56.0	40.0	31.0	8	10	285	357	1.55
45.0	40.0	36.0	6	8	266	355	1.18
55.0	36.0	27.0	4	8	145	290	1.69
56.0	45.0	35.0	16	18	571	642	1.44
51.0	40.0	27.0	8	12	313	470	1.69
55.0	39.0	30.0	8	10	290	363	1.57
50.0	40.0	27.0	8	10	320	400	1.67
53.0	30.0	25.0	4	10	150	377	1.66
55.0	49.0	34.0	6	8	218	290	1.53
52.0	31.0	27.0	8	12	307	461	1.54
45.0	32.0	27.0	6	8	266	355	1.43
54.0	38.0	29.0	8	10	296	370	1.59
45.0	30.0	24.0	6	8	266	355	1.56
53.0	43.0	34.0	16	18	603	679	1.41
46.0	37.0	34.0	6	6	260	260	1.22
57.0	41.0	33.0	8	10	280	350	1.48
50.0	41.0	27.0	8	12	320	480	1.69
55.0	31.0	26.0	4	10	145	363	1.65
45.0	37.0	26.0	6	8	266	355	1.58
60.0	37.0	28.0	8	10	266	333	1.73
54.0	47.0	34.0	6	8	222	296	1.49
59.0	38.0	28.0	10	12	338	406	1.73
47.0	39.0	27.0	8	8	340	340	1.50
56.0	45.0	35.0	16	18	571	642	1.44
45.0	36.0	27.0	6	8	266	355	1.50
54.0	48.0	34.0	6	8	222	296	1.50
48.0	44.0	21.0	8	10	333	416	2.19
51.0	32.0	22.0	6	8	235	313	1.89
53.0	39.0	30.0	8	8	301	301	1.53
48.0	45.0	22.0	8	10	333	416	2.11
52.0	35.0	28.0	8	8	307	307	1.55
45.0	34.0	28.0	4	6	177	266	1.41

RECURVE SPIT, WEST OF FASSIFERN (3)

L	l	E	R_1	R_1	ROUNDNESS INDEX		FLATNESS INDEX
58.0	36.0	29.0	4	6	137	206	1.62
51.0	39.0	21.0	6	8	235	313	2.14
45.0	34.0	28.0	4	6	177	266	1.41
59.0	48.0	25.0	2	6	67	203	2.14
59.0	32.0	32.0	8	10	271	338	1.42
56.0	41.0	29.0	4	6	142	214	1.67
52.0	40.0	22.0	6	8	230	307	2.09
60.0	33.0	32.0	8	10	266	333	1.45
47.0	34.0	21.0	6	6	255	255	1.93
52.0	37.0	27.0	4	6	153	230	1.65
54.0	34.0	29.0	6	8	222	296	1.52
46.0	36.0	30.0	4	6	173	260	1.37
50.0	35.0	25.0	4	6	160	240	1.70
56.0	30.0	29.0	4	8	142	285	1.48
50.0	37.0	27.0	4	6	160	240	1.61
49.0	37.0	21.0	4	6	163	244	2.05
53.0	41.0	23.0	6	8	226	301	2.04
53.0	38.0	28.0	4	6	150	226	1.63
48.0	35.0	22.0	6	6	250	250	1.69
50.0	42.0	27.0	4	6	160	240	1.70
58.0	47.0	25.0	2	6	68	206	2.10
48.0	37.0	29.0	4	4	166	166	1.47
52.0	42.0	28.0	4	6	153	230	1.68
55.0	40.0	28.0	4	6	145	218	1.70
49.0	36.0	23.0	6	6	244	244	1.85
49.0	37.0	28.0	4	4	163	163	1.54
52.0	32.0	28.0	6	8	230	307	1.50
57.0	31.0	30.0	4	8	140	280	1.47
52.0	45.0	27.0	6	6	230	230	1.80
50.0	34.0	24.0	4	6	160	240	1.75
50.0	38.0	29.0	4	4	160	160	1.52
50.0	38.0	22.0	2	6	80	240	2.00
54.0	42.0	25.0	6	8	222	296	1.92
53.0	46.0	28.0	6	6	226	226	1.77
48.0	47.0	25.0	4	6	166	250	1.90
55.0	43.0	26.0	6	8	218	290	1.88
59.0	31.0	32.0	8	10	271	338	1.41
55.0	42.0	28.0	4	6	145	218	1.73
52.0	42.0	30.0	2	6	76	230	1.57
53.0	33.0	28.0	6	8	226	301	1.54
49.0	38.0	23.0	2	4	81	163	1.89
56.0	52.0	21.0	6	8	214	285	2.57
50.0	38.0	25.0	2	4	80	160	1.76
47.0	46.0	24.0	4	6	170	255	1.94
57.0	42.0	36.0	4	6	140	210	1.38
45.0	35.0	28.0	4	6	177	266	1.43
47.0	32.0	23.0	2	4	85	170	1.72
55.0	30.0	30.0	4	8	145	290	1.42
48.0	46.0	26.0	4	6	166	250	1.81
58.0	47.0	27.0	2	6	68	206	1.94
51.0	39.0	27.0	2	4	78	156	1.67
55.0	53.0	23.0	6	8	218	290	2.35
48.0	34.0	20.0	2	8	83	333	2.05
51.0	41.0	28.0	2	6	78	235	1.64
57.0	35.0	28.0	4	6	140	210	1.64
52.0	45.0	26.0	6	6	230	230	1.67
55.0	40.0	34.0	4	6	145	218	1.40
50.0	40.0	23.0	2	4	80	160	1.96
45.0	37.0	25.0	4	6	177	266	1.64
49.0	48.0	27.0	4	6	163	244	1.80
45.0	34.0	28.0	4	6	177	266	1.41
55.0	33.0	26.0	4	6	145	218	1.69
45.0	37.0	28.0	4	6	177	266	1.46
56.0	42.0	30.0	4	6	142	214	1.63
56.0	44.0	27.0	6	8	214	285	1.85
50.0	43.0	28.0	4	6	160	240	1.66
56.0	34.0	27.0	4	6	142	214	1.67
56.0	30.0	30.0	4	8	142	285	1.43
56.0	39.0	33.0	4	6	142	214	1.40
55.0	42.0	34.0	4	6	145	218	1.43
48.0	33.0	24.0	2	4	83	166	1.69
52.0	40.0	28.0	2	4	76	153	1.64
47.0	38.0	30.0	4	6	170	255	1.42