COBBLE BEACHES ALONG THE COASTLINES OF THE GEORGIAN BAY ISLANDS

BY

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ABSTRACT

This report is the only detailed study concerning the fresh water cobble beaches of the Georgian Bay Islands. It includes extensive studies on the morphological characteristics, especially the platform development and profile configuration, and the sedimentary provenance of the cobbles.

It was found that the platform configuration (step topography) acts as a substrate control for the cobble beaches. The presence of two cobble generations, angular and well-rounded, indicate that the shore platform is the source for these cobble beaches.

The roundness values of these cobble generations depends on their mode of transport. Evidence indicates that longshore movement of cobbles increases their roundness values, but their angular shape is indicative of their lack of transport.

Very little proof was found within this study to correlate relict cobble beaches with any specific stage of the Lake Huron Basin, although it was possible to generalize and state that the relict cobble beaches were generated by high-energy wave events during the transition from the Algoma stage to Lake Huron.

Clast analysis determines the relationship between the length of the wave fetch and its related energy environment. It was found that high-energy coastal environments have oblate cobbles with a high roundness and low sphericity. In each case, the samples were associated with a large fetch. Those cobbles of a low-energy coastal environment have a high sphericity, low roundness, and are associated with smaller fetches.

The steepness of the beach profile results from the increase in wave height, generated by an increase in shallowness. It also depends upon the volume of backwash. The backwash is reduced by the increased percolation rates through the cobbles, thus reducing the combing down effect of the backwash.

This study also provides a discussion on the minor morphological features such as sinkholes and imbrication.

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CHAPTER I

INTRODUCTION

1.1 GENERAL DESCRIPTION

This research paper examines the magnificent white cobble-pebble beaches of the Bruce Peninsula and the Georgian Bay Islands. This is a non-tidal coastal environment. The study offers an interpretation of the beaches' morphological characteristics, which include platform development and profile configuration, and attempts to determine sedimentary provenance for the cobbles.

At this point, the terms cobble, pebble and provenance should be defined. A cobble is a rock fragment with a diameter of between 64 and 256 mm, whereas a pebble is a rock fragment with a diameter between 4 and 64 mm (Whitten, 1972). Provenance may be defined as the source area from which the cobbles have been derived.

The cobble beaches under study are, in essence, shores, i.e. coastlines, which may be subdivided into three zones. These zones are:

1) the offshore zone extending from the waterline seawards;

2) the foreshore zone which includes the storm beach and extends from water level to the high storm swash limit (berm crest); and

3) the backshore zone which extends from the berm crest to the first vegetated beach ridge.

See Figure 1, a schematic diagram of these features.

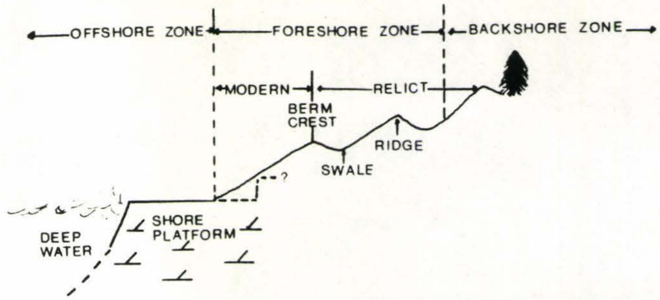


Figure 1. Schematic Morphology of a Beach.

Both the foreshore and the backshore zones contain an undulating pattern of ridges and swales. A ridge is a feature built above the limit of storm waves, while the term swale refers to the shallow depressions which separate the ridges (King, 1959) (see Figure 1).

The berm crest is determined by the presence of lichen growth. Lichen helps to distinguish an active coast from an inactive coast. An active (modern) coast is an area with rounded white cobbles that are constantly modified by coastal processes, whereas an inactive (relict) coast has a substantial amount of lichen cover, which indicates very slight movement with no modification by wave action.

Many beaches display two sets of cobbles at one profile position. One set is characterized by well-rounded tabular pebbles, while the other set has a very high sphericity. Roundness is defined as the sharpness of the corners and edges at a grain, and sphericity measures the degree to which the grain approaches a sperhical shape (BMM, 1980). Therefore, we can conclude that two cobble generations, exposed to various transport rates (immediate deposition versus longshore drift) do exist.

The major concern in the offshore zone is the shore platform. In recent years, all literature has referred to the platforms, as the wave-cut platforms. However, this term has genetic implications which do not apply here; hence, the term shore platform will be used.

This report will address the following questions:

1. Does the shore platform act as a substrate control and as the provenance for the cobble beaches?

2. Considering the forces that are required to move sediments, are the cobbles affected by varying rates of transport? Is it realistic to correlate abrasion rates and longshore drift with an increase in roundness values?

3. Wave height is affected by water depth. Does the wave height and volume of backwash modify the steepness of the beach face (a section of the beach between the waterline and the ridge)?

4. Does the wave fetch determine the type of coastal energy environment?

5. Can we correlate historical water levels with relict storm beaches?

1.2 STUDY AREA

The study area includes the northern tip of the Bruce Peninsula and the Georgian Bay Island unit. Coastal studies were undertaken along those shorelines, specifically, Gig Point-Cove Island, the east coast of Bears Rump Island, Little Cove and Marr Lake on the mainland.

Figure 2 shows the relative positions of the islands and the studied shorelines. The most northerly tip of Cove Island is 10 km from Tobermory, whereas the isolated Bears Rump Island lies 13 km east of Gig Point. Both of these islands vary with respect to physical form (cobble beaches) and geologic structure. The mainland beaches are near Tobermory, Ontario. They have similar physical features and geological structures as Cove Island.

The climate is cool temperate and is modified by Georgian Bay and Lake Huron. The mean annual temperature at Tobermory is 6.5°C,

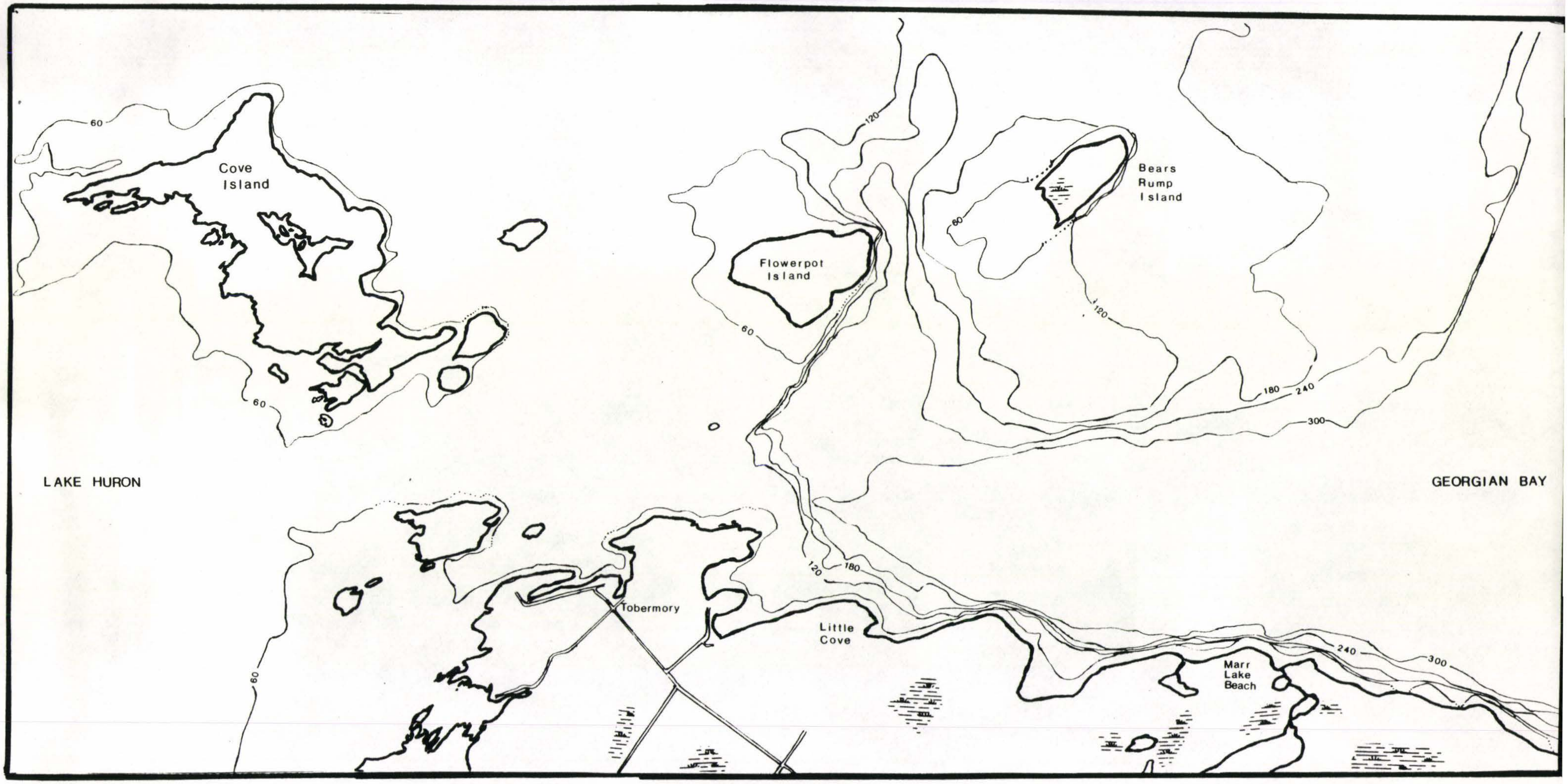


Figure 2. The Georgian Bay Island Unit.

with annual precipitation of 85 cms. Snow cover is essentially continuous from mid-November until April. Lake Huron and Georgian Bay freeze extensively, especially along the shorelines.

The beaches maintain morphological features, characteristic of ice abandonment during spring thaw. These features are sinkholes, which occur when abandoned ice is buried on the beach by cobbles. With time the ice melts, causing the cobble cover to collapse, leaving a small depression (sinkhole) in the landscape.

1.2.1 PHYSIOGRAPHY

The physiography of the region is a direct result of the advance, retreat and post-glacial drainage of the Wisconsin glacier, 15 to 20,000 years ago. Direct evidence for glacial action is glacial erratics on the cobble beaches.

The Bruce Peninsula is bound on the east and north by the Niagara Escarpment, which rises 122 m above the Georgian Bay waterline. Extensive talus deposits are found extending to great depths along these shorelines.

The Peninsula dips (5.6 m/km) to the southwest, controlling the major drainage system. Cowell (1976) indicates a small bedrock trough in the vicinity of Marr and Horse Lakes. This trough reverts the drainage to the northeast, as both surficial and underground flow.

The surface relief varies from flat limestone pavements to rugged bedrock topography. Much of this is covered with unconsolidated materials laid down during the Wisconsin glaciation (Soil Survey #16). Today, the physiography is controlled by coastal, fluvial and karst processes.

1.2.2 GEOLOGY

The study unit represents a partially submerged continuation of the Niagara Escarpment, which traces the northern rim of the sedimentary Michigan Basin.

In the early Cambrian, the Michigan Basin was flooded and received eroded sediments from the Precambrian Shield. During the Silurian, the Basin subsided and the climate became warmer providing perfect conditions for reefal development. Late in the Silurian Era the Basin was cut off, evaporation occurred and evaporites were laid down. Cowell (1976) believed these conditions allowed dolomitization of the reefs to a constant chemical composition - $Ca_6Mg_4\ (CO_3)_{10}$, calcium-rich dolomites.

The area stratigraphy is shown in Figure 3. The two major stratigraphic units of concern here are the Guelph Formation Formation Dolomite and the Amabel Dolomite (the main caprock). The Amabel Formation (equivalent to Lockport Formation) stretches from Cabot Head west to Cyprus Park, but is only exposed on Bears Rump Island. The Guelph Formation is exposed on Cove Island and the mainland.

Together, the Amabel and Guelph Formations are pure dolomite, comprising a thickness of 100 m. The dolomite is primarily a reefal complex of greyish, tan or dark brown, fine to medium granular or fine coarse crystalline dolomite (Cowell, 1976). These units contain bioherms and interreefal material. The Amabel Formation represents a facies change to the biohermal strata (Cowell, 1976). The bioherms are massive, with high porosity and little jointing or bedding. They are oriented in a northeast to southwest direction (see Appendix A, Plate 2). Surrounding the bioherm is highly jointed, structurally weak interreefal material - extensively eroded by coastal processes.

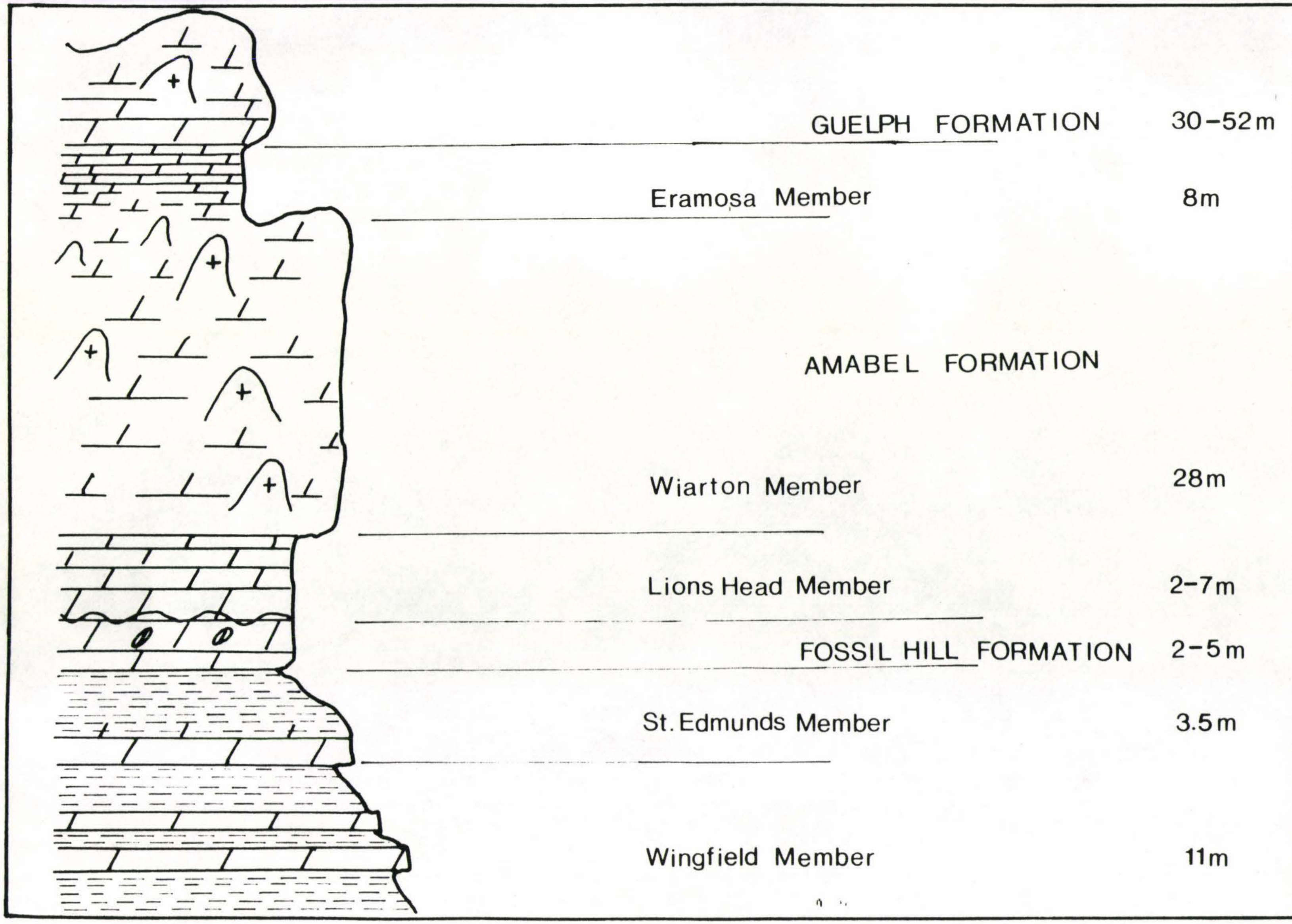


Figure 3 . Stratigraphy of the Bruce Peninsula, after Liberty and Bolton (1971). Source: Goodchild (1984).

1.2.3. LAKE HISTORY - WATER LEVELS

The existence of the Great Lakes and the associated water levels began after the Wisconsin glaciation.

Historical water levels of the Huron Basin were determined through correlations with inland gravel beach deposits. Figure 4 indicates the lake stages of the Huron Basin. The important lake levels are those of the early Algonquin stage to the present. Hough (1958) feels there is an absence of shoreline features in the Huron Basin, that can be linked to the early stage of Lake Algonquin.

The high Algonquin stage (185 masl) is positioned within the unwarped portion of the Huron Basin, and drains through the Chicago and Port Huron outlets. The Algonquin stage was eventually closed due to the opening of another outlet east of Georgian Bay. Hough (1958) states that inland relict beaches can be correlated to the high Algonquin stages right through to the low levels of Lake Stanley (61 masl). Lake Stanley has the lowest lake level in this Basin's history, and it is thought to have drained through the North Bay outlet.

The rapid rise to Lake Nipissing (185 masl) occurred when the North Bay outlet was uplifted and returned to the level of the southern outlets (Hough 1958). Due to the rapid rise, well-developed beach features are absent (Hough 1958). The Nipissing Beach has a strongly developed shoreline above the Great Lakes. This stage closed when the Port Huron outlet was downcut, thus generating the Algoma stage. This stage has highly correlated beaches at higher elevations than the present day beaches. Further downcutting of the Port Huron outlet terminated the Algoma stage.

Hough (1958) states "in the transition from the Algoma beach and the present shores of the Upper Great Lakes there are several

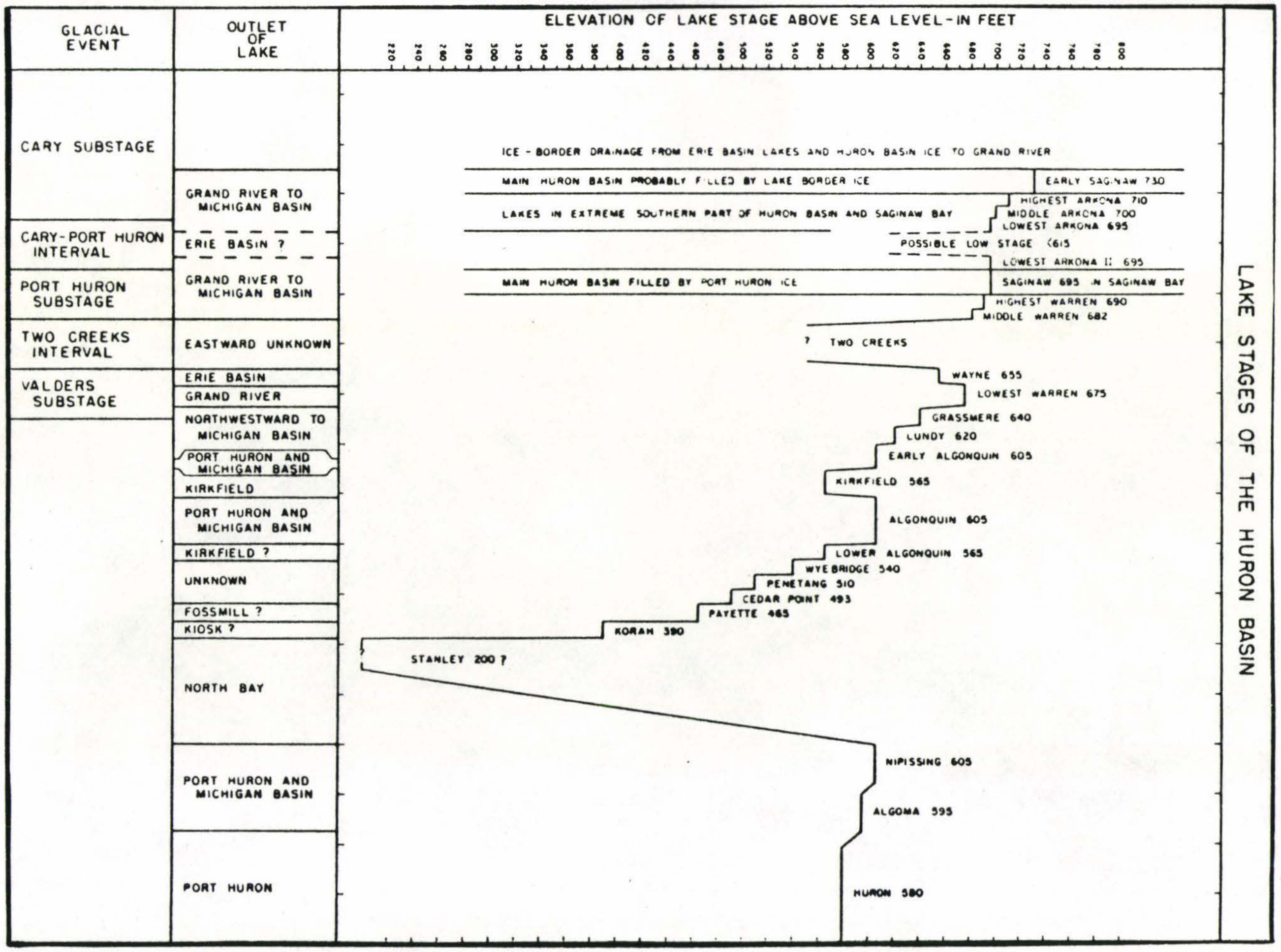


Figure 4. Lake Stages of the Huron Basin.
Lake Levels are Plotted Against an Unspecified Time Scale.

Source: Hough (1958)

ridges of sand or gravel. None of these are of sufficient magnitude to be singled out as a representative of a distinct lake stage".

The transitional period is due to the continuous uplift and downcutting of the Port Huron outlet. A series of beach ridges formed by wave action were preserved by isostatic uplift and the lowering of the lake levels (Hough 1958). During this time, beaches were developed and later modified by the seasonal pattern of high lake levels in the summer and low levels in winter. Therefore, it is plausible to correlate the beach ridges of this study to the transition period between Lake Algoma and the present day Lake Huron.

1.2.4 WAVE ACTION

Waves are the fundamental force acting on a beach. Their dimensions depend on the wind, fetch, and period (wind duration). The fetch is the length of uninterrupted deep water over which the wind blows. Wind directions, storm duration, and tidal effects may explain the changes occurring across a beach. The study area is non-tidal; therefore, tidal effects will not be considered.

The main factors which affect beach development are waves, wind and the type of beach material. The major concern here is the resultant profile and cobble shapes generated when a wave breaks in shallow water. A wave breaks when the increasing water velocity at the wave crest exceeds the decreasing velocity of the wave form. The forward movement of the water eventually overtakes the wave form and breaks.

There are two types of breaking waves which can be defined, based on beach gradient and wave steepness. (1) Plunging breakers, which are low waves commonly found on steep shingle beaches. They occur when the crest of the wave falls into a trough, enclosing a pocket of air (King 1959). (2) A spilling breaker that advances with a foaming crest. This wave gradually decreases in height until it becomes swash on the beach (see Figure 5). During the data collection, it was observed that plunging breakers dominate the shoreline (Appendix B, Plate 4).

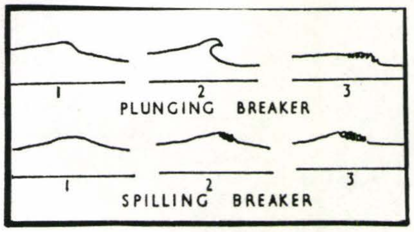


Figure 5. Spilling and Plunging Breakers.

After the initial wave break, the wave travels toward the beach, causing sea level to be tilted in that direction (King 1959, Lewis 1931). At the foot of the beach the wave breaks for a second time, generating turbulence at its base (Fairbridge, 1968). At this point the material is vigorously mixed, some is carried laterally by longshore drift, and the rest deposited immediately on the beach.

Lewis (1931) proposes two types of waves: constructive and destructive waves. Constructive waves move beach material towards the land, causing outward building of the coast. A small foreshore ridge is created at the limit of the swash zone, in direct response to the constructive waves. He determined that low frequency, flat waves (spilling breakers) were constructive, while higher frequency waves were destructive on the beach. Therefore, the low frequency waves broke in such a way that the swash (forward movement of water up beachface) was more important than the backwash (return water flow from the swash). The transition from flat waves to steep waves indicates a change from constructive to destructive wave energy. Destructive wave action is indicated by profile steepness, which tends to increase as the beach material becomes coarser (King 1959). Lewis (1931) determined that destructive waves remove material from the waterline to the beach, due to the greater energy of the swash as compared to the backwash. A high-velocity wind will allow a destructive wave to attack beach zones beyond its normal reach.

King (1959), states that storm waves do not actually comb down the beach, but rather, they steepen its profile. During the destructive wave action, some cobbles are thrown onto the beach crest, above normal wave action by swash waves. Bluck (1967) suggested that storm conditions may transport cobbles of various sizes above the swash zone. Since percolation increases through the cobble interstices, backwash cannot remove the pebbles deposited at the upper limit of the swash (King 1959, Philips 1980). Figure 6 is a schematic diagram depicting the before and after beach profile shapes. These results were also observed on Chesil Beach in Dorset, by King (1959). Bluck determined that backwash is the major factor in the development of imbrication. As long as the backwash is minimal, the tabular blocks are tilted seawards, but if a strong backwash occurs, the imbrication may dip landwards or be destroyed. Very large tabular cobbles displaying imbrication will not be affected by the backwash.

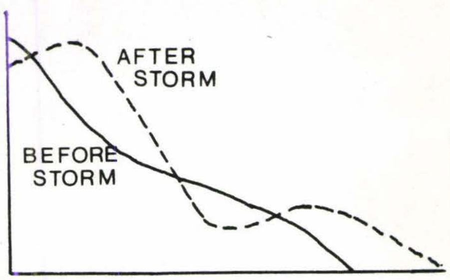


Figure 6. Schematic diagram depicting the before and after beach profile shapes.

Longshore movement of beach material is a response to the oblique movement of incoming waves. As a result, one major longshore movement zone is found. It is beach drifting which is related to swash and backwash movements. This moves sand up and down the beach in a zigzag fashion (King, 1959). Beach material is also transported by the direct impact of the waves of the shoreline. These cobbles are rafted onto the shore. These motions help to increase the grade of sorting found on a beach.

1.2.5. PLATFORM DEVELOPMENT

One of the major erosional forms of coastal geomorphology is the shore platform. In simplistic terms, the shore platform erodes as a result of alternating periods of cliff undercutting and debris removal. This is accomplished by wave erosion combined with a change in historical lake levels. Wave quarrying and erosion produce rounded caves under the cliff, which is enhanced by the limestone lithology. With water level changes, the platform becomes covered with beach sediments. See schematic diagram (Figure 1) of the platform and associated beach ridges.

Bartram (1938) indicates that shore platforms occur at the level of greatest wear. In a non-tidal environment, wave action and the existing water levels help to generate the step topography.

Byrne (1984) says the process begins with the formation of a notch in the land at the lake level. If the wave energy reaching the shore is sufficient to erode the local rock, then a shore platform will develop. Secondary erosion and weakening of the rock occurs through frost shattering and ice action (Byrne 1984). Figure 7 is a schematic diagram illustrating the progression for the development of a shore platform.

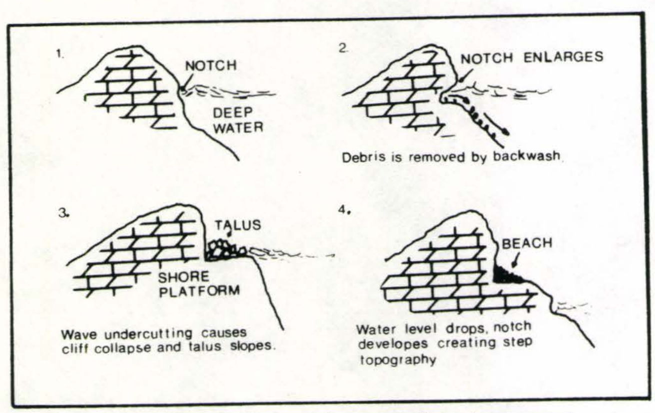


Figure 7. Schematic diagram of shore platform development

Trenhaile (1983) says that rock structure and lithology determine the shape of the platform profile. He suggested that wider platforms are cut when the lake level is stable. Bartram (1926) indicates that, as a platform becomes wider, rates of erosion decrease because the waves must travel farther to reach the cliff base and are less capable of erosion. Eventually a state of equilibrium will be reached.

In the Bruce Peninsula, the solution process may help erode and planate a platform surface. This occurs when small pools of water (replenished by wave splash) remain on the cliffs and eventually develop benches. The bench flattens through the process of successive wetting and drying of the rock.

1.3 METHODS - DATA COLLECTION AND ANALYSIS

Time played a major role in the collection of data for this thesis. A more thorough study could be performed at a later date. Data was collected in order to perform an analysis of grain and profile morphology. The three grain-form parameters used in this study are shape, roundness (RND) and sphericity (SPH). Before cobble samples were collected, the sample beach profiles were chosen at random and surveyed. A Brunton compass was used to survey the positions of the ridges and swales at a determined bearing. From a reference point, distances were measured with a meter tape, and beach undulations were angle measurements determined with the Brunton compass.

Trigonometric applications were applied to the data in order to construct the relevant profiles (Appendix D). Grain shape may be described by the observer or expressed as a linear dimension. Three dimensions were measured for each cobble: the longest axis, X; the intermediate axis, Y; and the shortest axis, Z. The standards used were described by Griffiths (1967) and have been incorporated into the measuring procedure. They are:

a) establish the plane of the maximum projection area,

b) the longest intercept across this particle normal to the plane is the shortest axis,

c) once the tangent rectangle of a particle is determined, the short side determines the intermediate axis, and the long side gives the long axis (see Figure 8).

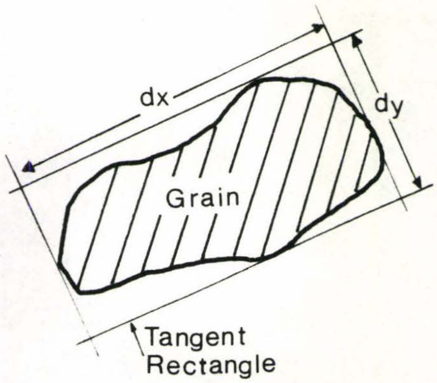


Figure 8. Linear dimensions of grain shape. SOURCE: BMM (1980).

The samples consisted of 20 cobbles, chosen at random from each ridge and swale, at every beach profile. A metric tape was used to measure the three principal axes.

The least radius of curvature (LRC) was also measured in the field. A circular scale, developed by Koster (1964), measures the radius of the smallest inscribed circle (LRC). Cailleux (1947) utilized this information and constructed 5 roundness shapes which are compared to the cobbles of this study (Figure 9).

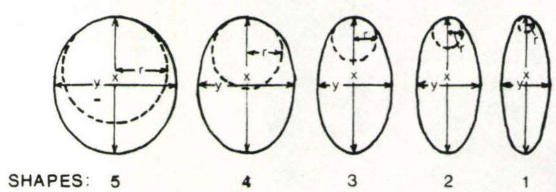


Figure 9. Cailleux's Index of Wear. Source: Pitty (1971).

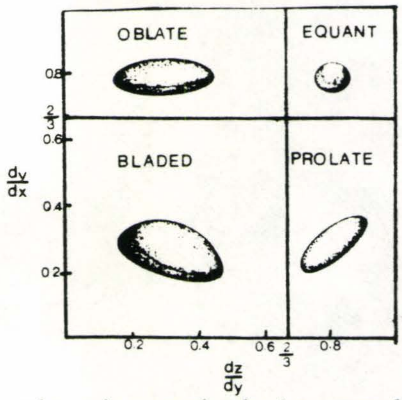
The above data was utilized in the determination of roundness and sphericity values. The roundness index by Cailleux (1947) is:

$$Pi = \frac{2\ LRC}{X}$$, where Pi = roundness index
LRC = least radius of curvature in cm
X = long axis in cm

Wadell's equation for sphericity (Y) is:

$$Y = \sqrt[3]{\frac{YxZ}{X^2}}$$, where X = long axis in cm
Y = intermediate axis in cm
Z = short axis in cm

The pebble shapes were further classified in a Zingg plot. Zingg (1935) developed two shape indices, which are $\frac{Y}{Z}$ and $\frac{Z}{Y}$. They create four main shape classes: oblate (disc shaped), equant, bladed, and prolate.



ZINGG PLOT-SHAPE CLASSES

The mean grain size and their standard deviations were also calculated.

Statistical t-tests were used to determine whether a significant difference in cobble sizes, at the ridges and swales, occurs within or between profiles. A two-tailed t-test was used, and the following assumptions were applied:

1. The sample size is greater than 25 (all ridges and swales within profiles, were grouped).

2. There are two independent samples with unequal variances.

Appendix 3 shows the procedure and results of this test.

Calculations of slope, horizontal distance, and height above the horizon were determined directly from the reconstructed profiles. Appendices I, J, and K provide a summary for all substantial statistics used to analyze the beaches.

Contouring of grain shape, roundness and sphericity was performed only for Cove Island. The reason being, Cove Island had more cobble samples than any of the other sites. The contouring, developed by

Krumbein and Jones (1970), is used to show a relationship between areal patterns and statistical correlations between sedimentary properties.

CHAPTER 2

BEARS RUMP ISLAND

2.1 INTRODUCTION

This chapter is concerned with the morphological characteristics of the east coast beaches on Bears Rump Island. It covers the effect of the shore platform on the morphological characteristics of these beaches. The surveyed beach profiles have been subdivided in order to discuss the cobble statistics and profile characteristics. Time limited the field study; therefore, only a small percentage of the east coast was studied.

The Georgian Bay Island Unit lies in Lake Huron, near Tobermory, at the tip of the Bruce Peninsula. Bears Rump is a small isolated island, 1300 m long and 800 m wide, approximately 10 km from Tobermory, at 45°18'N latitude and 81°34'W longitude.

The geology is different from that of the other islands. Three members of the Bruce Peninsula stratigraphy are found here. (See Figure 10). The Guelph Formation dolomite forms the plateau in the northeast, the Amabel Formation dolomite forms the flat pavement in the southwest, and between these two formations is the thin Eramosa dolomite.

Glacial scour from the northeast has streamlined the island. The surrounding deep water has allowed the island's outer boundaries to be well defined. The island itself contains a flat plateau in the northeast, which is 40 m above lake level (176.54 masl). Surrounding this plateau are steep cliffs protected from wave action by steep talus slopes. These cliffs and talus slopes are the result of mechanical erosion by ice and wave action.

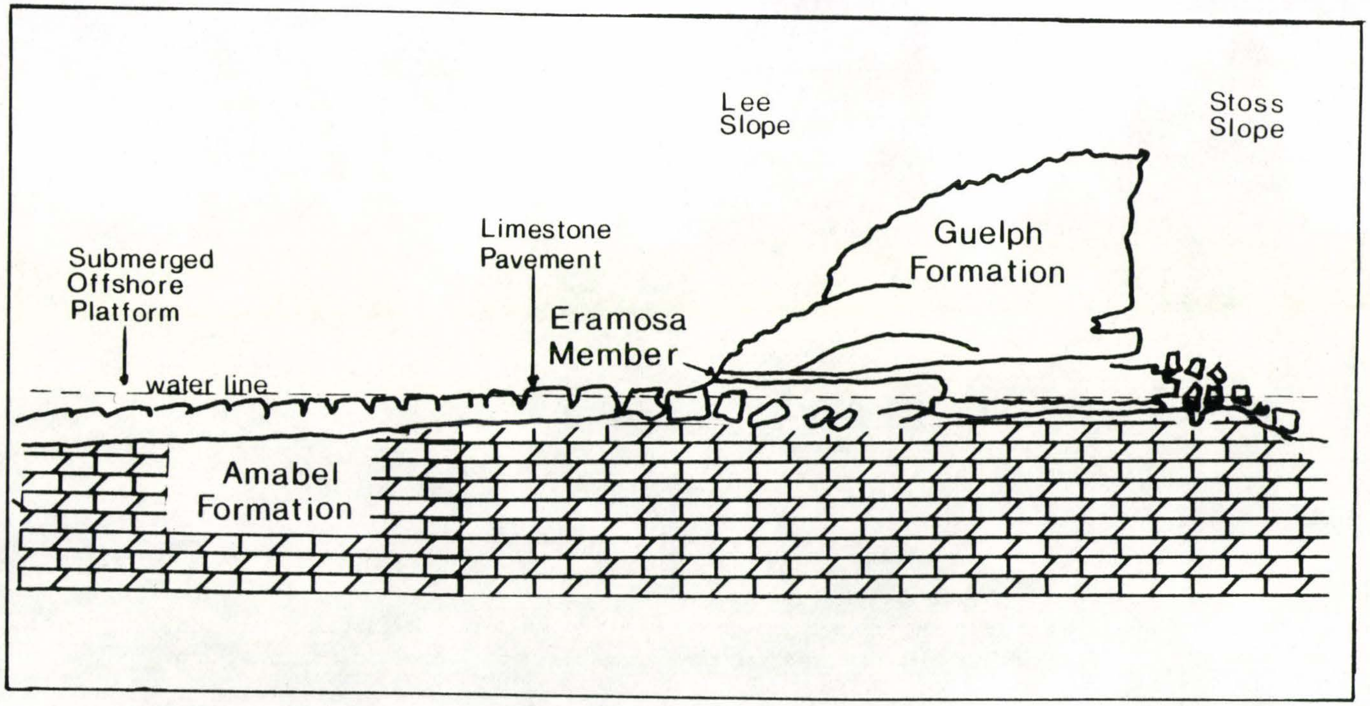


Figure 10. Lithomorphologic Section of Bears Rump Island.
Source: Goodchild (1984).

The flat limestone pavement slopes gradually to south-southwest and shows evidence of karstification. Extending from this pavement is a broad offshore platform, protected from extensive wave action and ice erosion by the Bruce Peninsula and Georgian Bay Islands. This obstruction limits the fetch to less than 7 km.

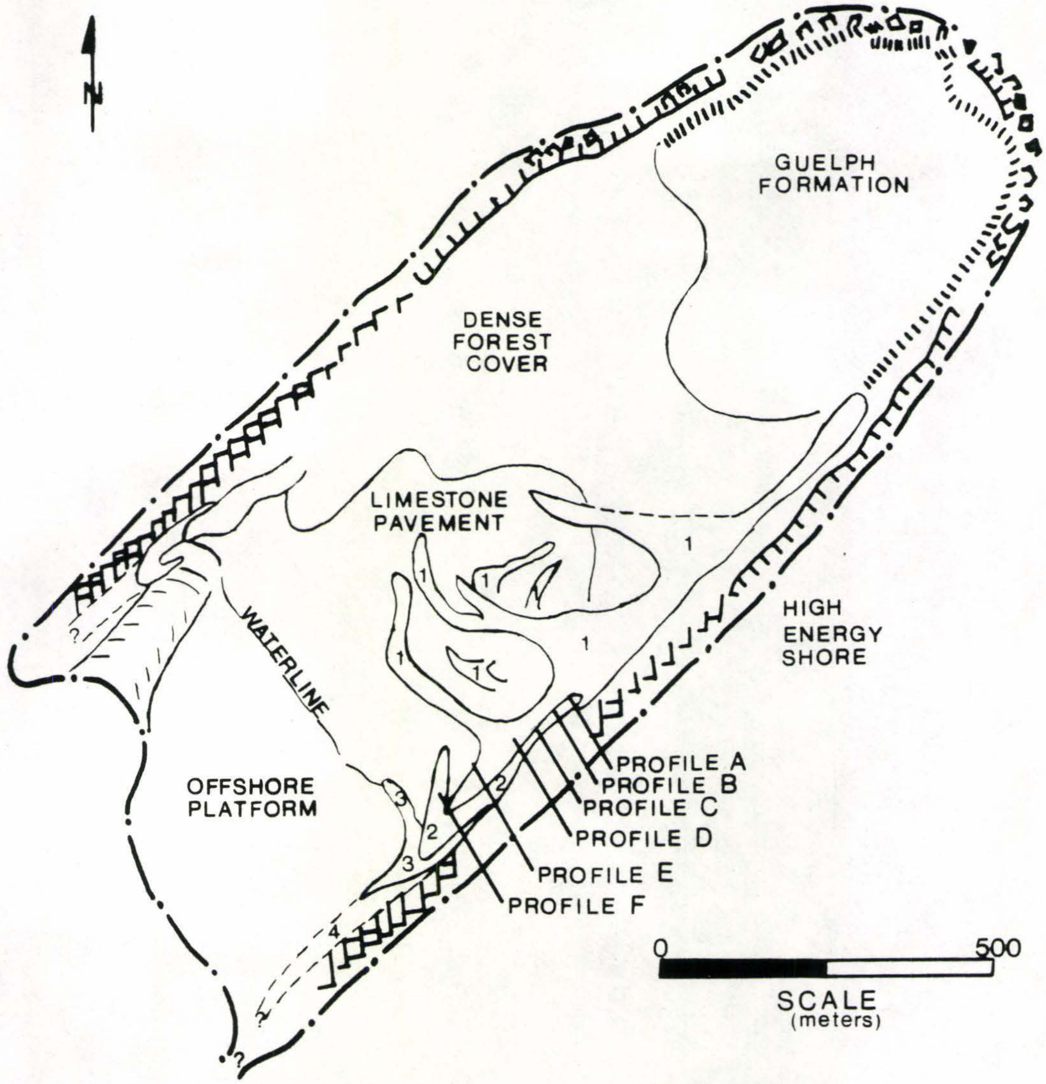
The strongest winds in this area are from the northwest, but in order for wave action to be efficient in mechanical erosion, a large fetch is required. The NNW-ESW coast of Bears Rump is a high-energy coastline, with the largest fetch of 75-100 km. The best developed active and inactive cobble beaches begin 500 m from the northeast end of the island. Besides the presence of active and inactive beaches, other morphological features include spit bars (are extensions of the mainland generated by longshore drift - King 1959), recurving spits (result from the deflection of the waves by refraction around the end of the spit - King 1959), imbrication and sinkholes.

2.2 BEACH MORPHOLOGY

This Section includes a description of the six surveyed profiles with regard to their beach morphology and clast shape. All profiles were surveyed at a bearing of 149° from north (see Figure 11). Appendix F contains a summary of the profile statistics discussed below.

2.2.1 PLATFORM DEVELOPMENT

The shore platform is composed of the Amabel Formation dolomite. It exhibits karstification and flaking. Statistics indicate that platform lengths decrease from profile A in the north to profile F in the south. Profiles A and B have minimum platform lengths of 13 m and 21 m, respectively, whereas profile C has the largest measured platform (27 m). The remaining profiles, D, E and F have varying



LEGEND

1. Relict Storm Beaches and Spits of Dolomite Cobbles.
2. Ancient to Modern Beaches, Greatest Storms.
3 Modern Cobble Spit at the Waterline.
4. Spit Extension Below Water.

Deep Water Line

Figure 11 . Schematic Morphology of Bears Rump Island.
Source: Goodchild (1984).

platform lengths, which help develop the beginning of the active and inactive beaches. Profile D has a platform length of 21 m to the active beach and 23 m to the beginning of the inactive beach. Profile E has a platform length of 10 m to the active beach and 15 m to the inactive beach, whereas profile F displays two submerged step platforms before the active beach.

A field traverse from profile A to profile F shows a decrease in platform height above the present water level. This change in platform height is due to the regional dip of the island and the associated water levels. This shore platform configuration acts as a substrate control on the beach development. It is evident that the platform height, at profile B, is sufficient to allow direct wave attack and longshore drift. These modes of transport generate two sets of cobbles. One set that has undergone longshore drift is composed of well-rounded cobbles, but the second set is a result of direct wave attack which creates large, angular, flat flakes. Both cobble sets have a local Amabel Formation provenance. Plate 3 (Appendix A) shows a fresh dolomite scar exposed after flaking has occurred. Plate 4 (Appendix A) shows the results of the powerful wave energy required to uplift these tabular blocks.

In conclusion, there is a relationship between platform length and the occurrence of the two-pebble sets. The pebble sets display a direct relationship between their degree of abrasion and their mode of transportation.

2.2.2 PROFILE DESCRIPTION

This Section deals with the physical characteristics across the beach. Appendix E illustrates the surveyed profiles used in this discussion.

Noticeable profile changes occur across the beach from profile A to F. Profile A has no substantial beach development before the treeline, and thus, may be termed a discontinuous beach, whereas profile F is a very continuous beach, consisting of six ridges and swales. The remaining profiles are found between these two extremes. The slopes of the six profiles range from steep, at profile A, to moderate at profile B, although profile C has the steepest slope of all the profiles. The maximum profile height is 5.2 m at profile D. Profile E has the smallest height (2 m), but it has one of the longest horizontal distances; profile F is the longest. The active beach begins at profile D and continues in width and complexity to profile F (see Sediment Analysis).

Profile F disects the beginning of the recurving spit. Plate 5 (Appendix A) indicates the symmetry of this spit.

As the exposed portion of this beach widened, the number of sinkholes increased. Unfortunately, time did not allow the determination of their dimensions. One final morphological feature present is imbrication of the tabular flakes. The flakes have an orientation of 14°SE, with their long axis parallel to the direction of wave propagation (Appendix A, Plate 6).

2.3 SEDIMENT ANALYSIS

This discussion includes a visual description of the clasts between sites and a statistical analysis of the pebble-cobble data. Random samples were chosen at the ridges and swales along the profiles. Sampling at profile F could not be completed, due to the limited timeframe. Appendix I indicates all the pebble statistics used in this analysis.

Profiles B to F, inclusive, display two sets of pebble-cobble clasts. They are:

1. well-rounded pebble-cobbles
2. angular tabular-flaky pebble-cobbles

Both of these pebble-cobble sets are found within the active and non-active zones of a profile (Appendix A, Plate 1). Within the cobble beach, two trends emerge. First, the well-rounded cobbles act as a support for the large tabular flakes; but beyond profile F, the tabular flakes are absent because longshore drift and wave refraction generate increased abrasion and better cobble sorting. Secondly, observations indicate an increase in lichen growth with increased distance from the waterline.

The mean length of the cobbles for the beach, as a whole, are X=16 cm, Y=9.7 cm, Z=2.6 cm. The Zingg plots (Appendix L) for all three profiles indicate that the sediments are distributed in the bladed and oblate quadrants.

Sphericity data shows higher sphericity values within the swales and an increase in average sphericity seaward. The statistics also indicate a wide variation in the mean sphericity values. This is in agreement with work done by Dobkins and Folk (1970). They state that two sphericity values indicates a high-energy coastline. They also state that a wide variation in sphericity is due to the range in wave energies, created by varying platform depths. Further evidence from Dobkins and Folk (1970) concerns the decrease in sphericity with an increase in pebble size. An example from profile D is X=26.04 cm, and SPH=.322. Dobkins and Folk concluded by stating that high-energy beaches have a high roundness, low sphericity and are oblate. The pebble-cobble roundness values, found on Bears Rump, do correlate with this statement.

Further developing trends are, first, pebbles found on the ridges are rounded to well rounded, and are found in the pebble-cobble size range. Secondly, the swales contain much larger cobbles with a larger sphericity, but smaller roundness. This is created by the abrasion occurring between these semi-static clasts. Thirdly, the beach faces and ridges are overlaid by flat tabular-shaped cobbles that have been easily rafted by waves to that place of deposition.

Direct evidence for glacial entrainment is found in the fine-grained diabase erratics, intermixed within the cobble beach.

The recurving spit was divided into two symmetrical halves and then studied. The reason being that both halves of the spit are affected by varying wave directions and energies. The cobble results obtained do correlate well with the other profiles.

2.4 SUMMARY

The eastern shore of Bears Rump Island has the following morphologic characteristics:

1. There is a relationship between platform height above present water level and the continuity of the cobble beach. As the platform height falls below 2 m, the number of exposed ridges and swales increases. Above this height, the beach lacks any extensive beach development.

2. Also associated with the decrease in platform height is the increased width of the active beach. As the active beach matures, two generations of cobbles can be seen. The first generation consists of well-rounded cobbles that have been transported by longshore drift, whereas the second generation is comprised of tabular, angular pebbles that appear to be lifted from the Amabel shore platform. Above the 2 m platform height, the active beach is absent.

3. The cobbles tend to be larger in the swales and smaller at the ridges. Statistical data indicates that high sphericity and low roundness values are found within the swales, whereas the opposite occurs for the ridges. According to Zingg plots, the cobbles fall into the oblate and bladed quadrants.

4. The steepness of the beach slope is directly associated with the increasing cobble size.

5. The following summarizes minor morphological features found here. The beachface has well-developed imbrication, preserved by large tabular flakes. These tabular flakes are supported by the more well-rounded cobbles. The lichen cover on the cobble surface increases from the berm crest to the forest edge.

Statistical t-tests reveals that ridges and swales within a profile have significantly different cobble sizes and, therefore, they have undergone varying transportation rates. The t-tests were also performed between profiles E and F; profile D did not meet the statistical assumptions. These tests also reveal a significant difference in cobble size between the profiles.

CHAPTER 3

COVE ISLAND

3.1 INTRODUCTION

This chapter discusses the morphological changes within and between the seven beach profiles at Gig Point, Cove Island. This island is the largest, most northerly island of the Georgian Bay unit, located 9.5 km from Tobermory, at 45°18' latitude and 82°45' longitude. The island is 5000 m by 5040 m at its widest point, with a relief of less than 15 m above the waterline.

The geology of Cove Island is of the Upper Guelph Formation, which is a reefal complex of fine to coarse crystalline dolomite. The shoreline is a complex mixture of raised cobble beaches, dolomite pavements (with extensive karren development), and biohermal cliffs. The cobble beaches tend to be restricted to small embayments along the coastline. The island is littered extensively with various stages of cave development, which are controlled by local stratigraphy and wave energy. Within these cave systems are extensive cobble beach deposits, transported by wave action.

Cove Island is holokarstic, i.e., it has no surface drainage and is relatively flat lying. The centre of the island contains a large lake which represents the inundation of ice scoured depressions (Ford, 1984). The drainage of the lake is through the dolomite to submerged springs (Ford, 1984).

The strongest wind directions are from the northwest, which correlate with the maximum fetch of 200 km on the northwest shore. The north shore has the smallest fetch equivalent to 10 km and the east coast has a fetch of 62 km.

3.2 BEACH MORPHOLOGY

Seven profiles with various platform lengths and associated water depths were surveyed at random positions along the coast (Figure 12). For easy comparison, the beach profiles have been divided into three groups:

1. Profile B is on the northwest coast, surveyed at 159° from north. This is a high-energy shoreline. The Guelph Dolomite, in the immediate area, is extensively fractured and may act as a cobble source for this beach (Appendix B, Plate 1).

2. Profile C was surveyed on the north beach at 248° from north. This is a low-energy shoreline.

3. Profiles A, D, E, and F are surveyed along the east coast at 108°, 90°, 102°, and 78° from north, respectively. This is a moderate to low-energy shoreline.

3.2.1 PLATFORM DEVELOPMENT

The shore platforms found here seem to control the morphological characteristics of these beaches.

Present at profile B is a prominent shore platform, 180 m long, with step topography exposed by wave action (Appendix B, Plate 12). At this profile position, the platform appears to control the overall beach shape (Appendix B, Plate 3).

Group two has the largest shore platform, but the smallest fetch. The steep beachface found at the waterline is direct evidence for substrate control by the platform. Further evidence is found within the profile when a platform step is exposed at swale 2.

The remaining profiles have small submerged platform lengths. This helps to generate a very continuous wave modified beach. The

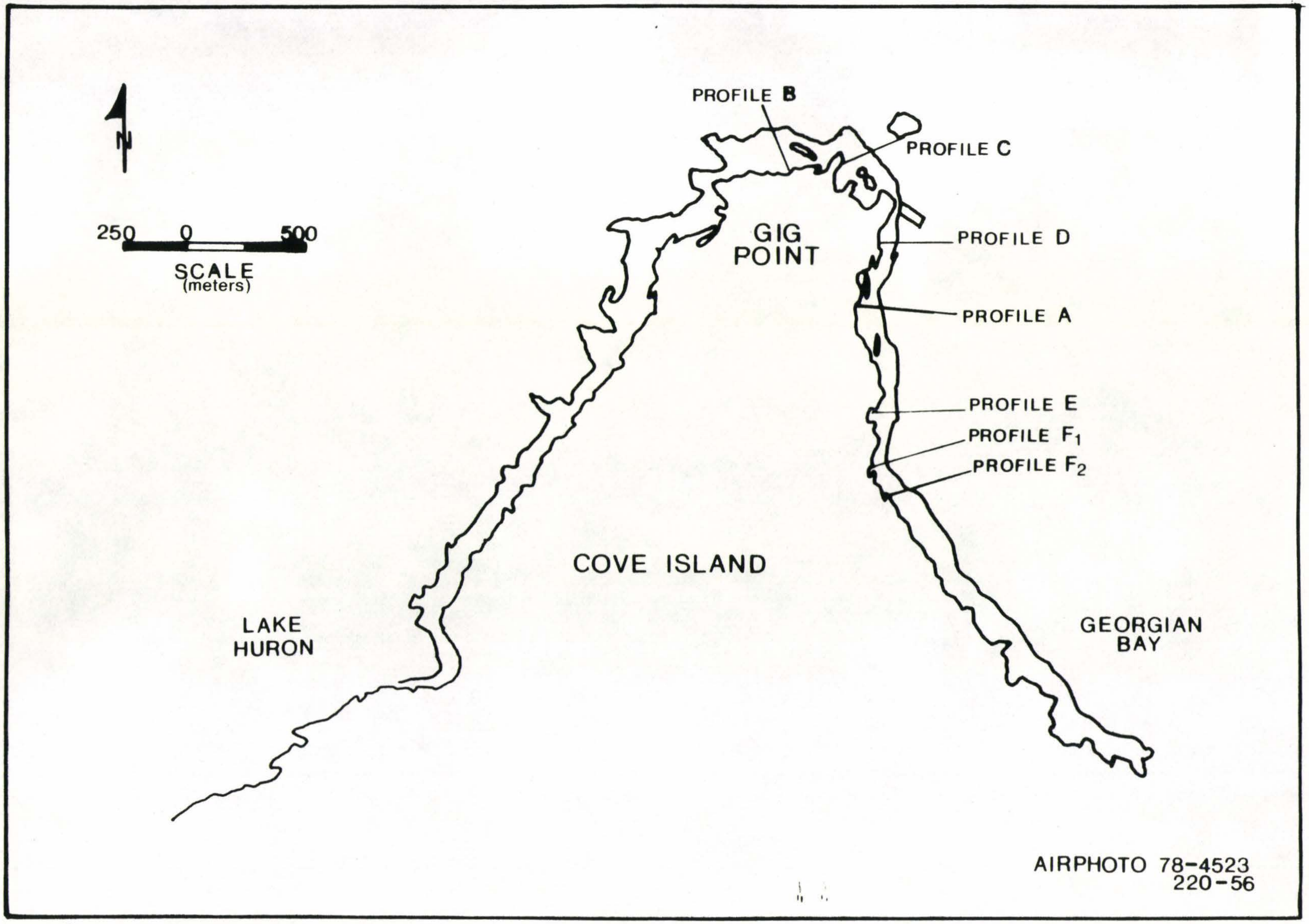


Figure 12. Profile Positions Along the Cove Island Shoreline

platforms of group 3 also appear to control the steepness of the beachface. Profile D closely resembles profile F on Bears Rump Island. With large imbricated tabular blocks found at the waterline. Due to their size, it is safe to assume that these flakes were removed from the weakened submerged platform, thus their provenance is of the Guelph Formation.

Profile E exhibits excellent step topography. The platform is submerged in the offshore zone, but resurfaces in the backshore zone, as a sea cave (Appendix F, Profile E). The existing beach appears to terminate at this cave, suggesting a drop in water levels.

Beach F has two platforms with similar platform lengths that vary due to the present shoreline curvature. This configuration enhances the longshore movement, which generates variations in the cobble sizes, thus affecting the steepness of the beachface.

Therefore, shore platforms act as a control and cobble source for these beaches, although the actual profile shape is modified by wave action.

3.2.2 PROFILE DESCRIPTIONS

The following describes the overall shape of the profiles. The ridges and swales of each profile cannot be correlated to historical water levels prior to the Algoma stage. This is because the Algoma water level was 182 masl, indicating that all relict beaches would be submerged. Philips (1980) states that wave action is the main modifier for the coastal cobble beaches, and not a static water level, although static water levels play a major role in shore platform development. Therefore, the Cove Island beaches formed in the post-Algoma stage to the present.

The profiles of Cove Island all have active beaches, ranging from 4 to 15 m wide (Appendix F). These active beaches tend to terminate after the berm crest, except for beach F. The active shoreline at beach F terminates at ridge two. Plate 4 (Appendix B) indicates the distance that cobbles and debris are shown during a severe storm. There is a high correlation between the profiles at beach F. The profiles have a similar overall slope, with a very steep active beach face (Figure 13).

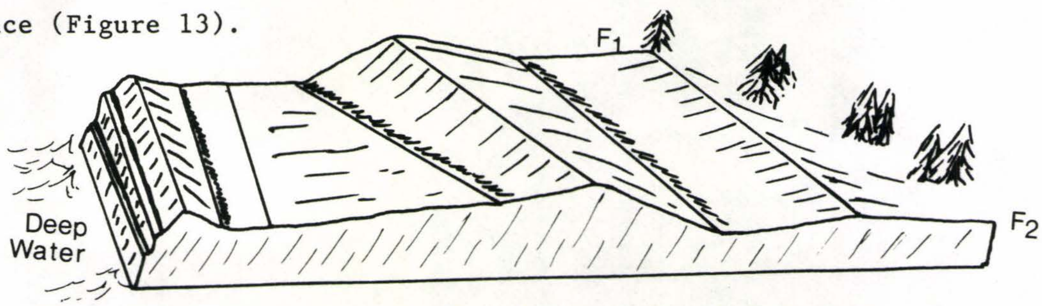


Figure 13. Correlation of Beach F Profiles.

The other surveyed profiles have steep active beachfaces ranging from .04 - .30. The sediment analysis indicates that the major differences in these steep profile shapes is due to cobble sizes.

The profiles are all very continuous, with a range in horizontal distance from 40-150 m. The number of ridges and swales varies from 3 at beach D to 8 at beach A and F. The maximum profile height of 4 m (180.54 masl) found at profile B is much less than the Algoma stage height (Appendix F).

Observations indicate an increase in lichen growth away from the waterline, with the maximum amount found within the backshore zone, at the forest edge. Beaches A and F are both littered with sinkholes of very large dimensions.

3.3 SEDIMENT ANALYSIS

The following discussion concerns the physical characteristics of the beach cobbles and how they change, both within and between the profile samples. Appendix J indicates the average statistics for sphericity, roundness, and cobble size.

Comparing the roundness values for each profile with Cailleux's index, the dominant shape appears to be shape 1. This is because the principle axis X is very long with respect to the small radius of the smallest inscribed circle. Zingg plots (Appendix L) help support these results and are discussed below. All profiles, except for profile A, have dominant pebble shapes in the oblate and bladed quadrants. Profile A has dominant pebble shapes in the oblate and prolate (roller) quadrants. Since beach B has flat, angular cobbles, their resultant shape is concentrated in the bladed quadrant. Therefore, the transportation modes are similar across the beach. The process, in simple terms, concerns the oblique movement of the cobbles, down the beachface. This movement is in response to backwash and longshore currents, which aid in cobble sorting.

With respect to cobble size, the mean X length ranges from 10-20 cm. In most cases, the cobbles at the waterline are two to three times this size. Philips (1980) states that larger boulders found along the waterline tend to rotate or shift only slightly. Their mass is too great to be moved by the storm waves. Referring to the active beach only, statistics reveal that smaller cobbles are found on the beach ridges. In a recent study by Philips (1980), he states that smaller cobbles - found along Lake Superior's shoreline - appear to be thrown upwards, with some falling back to the beachface. Therefore, a general trend that develops within the active beach is that cobble-pebble sizes decrease towards the ridge.

Statistical t-tests, performed on the ridges and swales within a profile, reveal no significant difference in cobble sizes at beaches A, B and C, but there is a significant difference in cobble sizes within profiles D, E and F. They also indicate a significant difference in cobble sizes, at the ridges and swales, between all seven profiles (Appendix H).

Variations in cobble sizes, due to abrasion, generate a change in sphericity values (Dobkins and Folk, 1970). Therefore, the cobble statistics indicate that profile B and D are high-energy beaches, and the remaining profiles are moderate to low-energy beaches. In the case of profile C, the active beach displays a moderate-energy beach, but the relict beach has high sphericity values which suggest a previous high-energy shoreline. The majority of the profiles have lower sphericity values at the waterline, compared to the rest of the profile. Associated with these low sphericity values are high roundness values.

Contouring of sphericity, roundness and cobble sizes, at each ridge and swale, was performed with only moderate success. The contouring results indicate a slight correlation of cobble sizes between profiles E and F. Within beach F, they show a decrease in cobble sizes towards F_1 which is from an increase in abrasion due to longshore drift. The sphericity contouring shows a high correlation at beach F between the active beaches and a slight correlation between the inactive beaches. Profiles A and D have a slight correlation in sphericity. No correlations exist in the roundness contour. Therefore, there is a slight relationship between areal patterns and statistical correlations.

Imbrication is found at beaches B and D because flat cobbles dominate the beach. The imbrication is 12°SW for profile B and 16°SE for profile D.

3.4 SUMMARY

The following is a summary of the morphological characteristics found on Cove Island.

1. The shore platform and its associated step topography act as a substrate control for the cobble beaches. This is displayed by the exposed platform in the offshore and backshore zones. Large tabular blocks, displaying similar characteristics to the platform, indicate that the Guelph Formation is the provenance for these cobble beaches. The shore platform also controls the steepness of the beachface. This slope decreases with an increase in wave energy and backwash, generated by the short platform length.

2. The beaches contain more than three ridges, indicating a very continuous beach development.

3. It is evident from the reconstructed profiles that the active beach terminates, either at the berm crest or one ridge behind the berm crest. The slopes of these active beaches are much steeper than the profile as a whole.

4. Contour diagrams show a slight correlation of cobbles statistics, between profiles on beach F, but there is no correlation between other Cove Island beaches.

5. In general, the sphericity and roundness values indicate a change in the wave energy environment. The high-energy beaches have low sphericity and high roundness values associated with it. The roundness values, based on Cailleux's classification, fall into shape one. According to Zingg plots the dominant pebble shapes are oblate and bladed. These results are comparable to those found on Bears Rump beaches.

6. Beach ridges and swales cannot be correlated before the Algoma Stage. Philips (1980) believes beach ridges are modified by wave action and not generated from static water levels.

Statistical t-tests reveal that no significant difference in cobble sizes occurs within the profiles, but there is a significant difference between the ridges and swales, across the whole beach.

CHAPTER 4

MARR LAKE AND LITTLE COVE, MAINLAND BEACHES

4.1 INTRODUCTION

This Chapter will include a discussion on two of the mainland beaches. Marr Lake and Little Cove will be considered separately, but a complete summary can be found at the end of this Chapter. At each site, there is an individual description of beach morphology and sediment analysis. Comparison of these two beaches occurs throughout the text.

4.2 MARR LAKE CYPRUS PARK

4.2.1 INTRODUCTION

This Section discusses a unique type of cobble beach, a cobble beach plug. Possible explanations for the growth and morphology of this cobble beach will be presented. Due to the limited study time, only one profile was surveyed and associated samples taken. Therefore, a comparison between profiles cannot be performed.

Marr Lake is contained within the boundaries of Cyprus Lake Provincial Park at 81°35' latitude north and 45°14.5' longitude north, 10 km from Tobermory.

The geology of this area is the Guelph Formation Dolomite. The dolomite is massive, with well developed karren features.

Marr Lake lies in a bedrock trough, which crosses the peninsula between Lake Huron and Georgian Bay (Cowell, 1976). It receives subsurface flow from Horse Lake and drains to Georgian Bay through the beach cobbles.

Found between Georgian Bay and Marr Lake is this cobble beach plug composed of seven distinct ridges. The beach plug is contained within a small inlet protected by steep dolomite cliffs.

The shore platform dips gently towards Georgian Bay, acting as a substrate and water depth control. The platform itself is extensively littered with large cobbles and boulders.

4.2.2 BEACH MORPHOLOGY

This section describes the seven ridges and swales, surveyed at 27° from north. There is also a short comparison between the Marr Lake cobble beach and those found on Bears Rump and Cove Island.

4.2.2a PLATFORM DEVELOPMENT

The actual submerged platform length could not be measured in the field. Evidence for the extension of the platform towards Georgian Bay can be seen by the abundance of large angular blocks, supported by the submerged platform (Appendix C, Plate 1). The platform dips 2° towards Georgian Bay, but appears to terminate at the trough containing Marr Lake. Therefore, we can assume the provenance for the cobble beach is the Guelph Formation Dolomite.

Historical water levels and isostatic rebound have aided in the planation and modification of this platform. As the water level dropped from the Algoma stage to the present, the water level was low enough to create conditions that are ideal for a sediment trap. Incoming waves eroded the surrounding dolomite cliffs and platform, then transported the material to a low wave energy position where the material is deposited. This process continued until Marr Lake was blocked from Georgian Bay. Time and wave action continue to build and modify the beach.

4.2.2b PROFILE DESCRIPTION

The Marr Lake cobble beach acts as a plug, controlled mainly by wave action rather than the shore platform.

The Marr Lake beach is 118 m long, which is comparable in length to the island sites. It should be noted that the actual profile length may be more extensive on Cove and Bears Rump Islands, since vegetation cover masks a portion of the inactive beach. The Marr Lake beach has no vegetable cover, thus its true length is visible.

The active beach is 10 m long, characterized by large angular boulders, maintaining a steep slope of .14. The whole beach reaches a maximum height of 183 masl (Appendix G, Profile Marr Lake), which is much higher than the present day level of 176.54 masl. Once again the beach ridges cannot be correlated prior to the Algoma stage, since the beach was submerged. Even the low levels of Lake Stanley (61 masl) are not appropriate for this beach development. Therefore, the beach has been developed from the Algoma stage to the present water level.

Ridge 3 has an extremely steep slope of .26. The major control on this slope is the severe wave height generated by the shallowness of the shore platform. Therefore, a slight rise in water level, combined with intense wave action over time, has built up this beach plug.

Located along the steep beachface to ridge 3 is a very large sinkhole, with dimensions of 3.7 m x 3.6 m x 2 m deep.

4.2.3 SEDIMENT ANALYSIS

A visual description and comparison of the clasts between the ridges and swales is presented. The samples were chosen at random along the profile. Appendix K indicates the average statistics for sphericity, roundness, and clast size.

The clasts of this profile exhibit the same general trend; the ridge has smaller clasts than the related swales. This is supported by a statistical t-test, which indicates a significant difference in the clast size within the profile. Traversing from swale 6 to Marr Lake, the clast size changes from cobbles to well sorted pebbles. Contrasting this are the large static (shift slightly in response to wave action) tabular cobbles along the Georgian Bay shoreline. The roundness values are larger here due to the increased abrasion between cobbles.

The sphericity values range from .55 to .56. According to the sphericity classification by Dobkins and Folk, this is a low-energy beach.

The Zingg plot (Appendix L) shows a concentration of cobble shapes in the bladed and oblate quadrants. This is comparable to the results formed at the other study sites.

A prominent feature found here is frost shattering (Appendix A, Plate 8). This increases the number of angular tabular cobbles, which changes the sphericity values.

4.3 LITTLE COVE

4.3.1 INTRODUCTION

Included within is a detailed discussion on the morphological characteristics of the Little Cove beach. These characteristics will be compared to the Marr Lake beach.

The Little Cove beach is also located in a small inlet along the Bruce Peninsula shoreline. It is located just off Highway #6, 4 km from Tobermory, at 81°36.5' north latitude and 45°15' longitude. Steep dolomite cliffs, of the Guelph Formation, protect this beach from Georgian Bay. These cliffs also act as the provenence for the cobble beach.

4.3.2 BEACH MORPHOLOGIES

The exposed beach at Little Cove is quite small, therefore, only one profile was surveyed at a bearing of 88° from north. The beach appears to be confined to the extreme southern end of the inlet (Appendix 3, Plate 13).

4.3.2a PLATFORM DEVELOPMENT

Observation suggests an extensive platform development towards Georgian Bay. A detailed study of the pavement requires underwater observation, therefore, a discussion on this platform is quite limited.

The shore platform can be traced from the offshore zone to the exterior limits of the backshore zone. Found between these two limits is a continuous beach. Therefore, it is safe to assume that the shore platform acts as a substrate control for this profile. This is not the case with Marr Lake, where the platform appears to have initiated the beach growth, but the profile shape was generated totally by coastal processes.

4.3.2b PROFILE DESCRIPTION

The surveyed portion of this profile terminates at the treeline, but the ridges and swales continue within the backshore zone to the dolomite outcrop. The surveyed profile has two ridges and two swales, over a horizontal distance of 17 m, and a maximum height of 2 m (Appendix G).

The active beach is 5 m wide, with a steep slope of .2. This steep slope results from the strong swash motion at the beachface. The beachface slope at ridge two is very similar to that at ridge one, except it has extensive soil cover. We may also assume that wave action and step topography help to maintain a consistent slope throughout the beach.

The overall profile shape only correlates to ridge three of the Marr Lake beach. The Little Cove beach does not possess the extensive cobble mound that is found at Marr Lake.

4.3.3 SEDIMENT ANALYSIS

The active beach contains clasts which can be classified as pebbles, but the inactive beach contains cobble-sized clasts. The average clast size, using the principle X axis, is 7 cm. Once again, the clasts found in the swales are larger than their related ridges.

Statistical t-tests reveal that there is a significant difference in pebble sizes within the profile.

Plate 5 (Appendix C) indicates how well sorted the active beach is. The sorting is dependent upon the competence rates within the moving water body. As the waves roll into shore, the competence decreases. This allows larger cobbles to be deposited while the finer pebbles are transported closer to the beachface. Shallowness will increase the wave steepness, so when the wave breaks, the very fine cobbles are thrown up to the ridge, while the coarse clasts remain at the swale and on the beachface.

During pebble transport, there is an increase in abrasion between the clasts, and the clasts and the platform. This tends to increase the roundness values.

The sphericity values are high, thus indicating a low-energy shoreline (using the classification by Dobkins and Folk).

There are no other significant morphological features found along this beach.

4.4 SUMMARY

The following summarizes the morphological features found at each beach on the mainland and compares them to the island sites.

1. The Marr Lake beach contains seven ridges and maintains a very continuous shape. The beach itself represents a plug separating Marr Lake from Georgian Bay, thus it is different from the other sites.

Little Cove is also a continuous beach, in which vegetation covers half of the relict beach.

2. The shore platform initiates the beach development at Marr Lake, but beach modification occurs mainly by wave action, whereas the shore platform at Little Cove acts as a substrate control.

3. The active beaches found at both Marr Lake and Little Cove have steep beachfaces and well-sorted cobbles. The active cobbles terminate at the berm crest.

At Marr Lake beach plug, the amount of lichen cover increases towards the Marr Lake waterline, but Little Cove exchanges lichen cover for a thin veneer of soil in the backshore zone. This trend is also found at the other island sites.

4. The height of Marr Lake beach, is much more extensive than any other profile sites studied.

5. The ridges and swales at both mainland beaches can be correlated to the transition from the Algoma stage to the present lake level.

6. Smaller cobbles are found on the ridges, rather than in the swales. Sphericity values vary from .5 to .6 and are indicative

of low-energy beaches at both mainland sites. The Zingg plots show a concentration of clasts in the oblate and bladed quadrants, which are comparable to other island sites.

7. With respect to Marr Lake, observations show a change in clast size from the boulders at Georgian Bay to the smaller cobbles at Marr Lake (Appendix C, Plates 1 and 2).

8. The presence of well-sorted pebbles at the active beach shows are dependent upon the long platform and the small protected inlet.

Statistical t-tests indicate that there is a significant difference between clast sizes, within the profiles.

CHAPTER 5

INTERPRETATION AND CONCLUSION

The shorelines of the Bruce Peninsula are unique in comparison to their marine counterparts. Very few studies pertaining to non-tidal fresh-water beaches are available. Therefore, this research paper has concentrated upon the beaches' morphological characteristics and sedimentary provenance. The following discussion points out the importance of cobble measurements in the interpretation of a coastal environment.

Throughout this proposal, evidence has been presented to show that the shore platform acts as a substrate control and provenance for the cobble beaches. The east coast of Bears Rump Island indicates a gradual change from a single cobble generation to a double cobble generation. The two generations are: (1) well-rounded active cobbles transported by longshore drift, and (2) large angular tabular flakes that have undergone limited amounts of transportation. The progression is related to the height of the shore platform above the existing water level. As the platform height decreases from 2 m to the present water level, the number of cobble generations increases. The second generation of angular cobbles are terminated when the shore platform becomes submerged. This indicates that the shore platform acts as a substrate control for the cobble beaches. The puzzle-like fit of the angular flakes with the shore platform indicates the provenance of the cobble beaches. Cove Island and the mainland beaches exhibit shore platforms in all three beach zones. The actual beach begins at the waterline and is often terminated by a shore platform step. All profiles on Cove Island illustrate a substrate control by these shore platforms. Philips (1980) also observed that the shore platforms of Lake Superior supported the modern and relict beaches.

It was stated previously that two cobble generations, affected by varying transport rates, exist within each beach. The type of transportation can be determined from the cobbles statistics, i.e., sphericity and roundness. Dobkins and Folk (1970) determined that cobbles with high sphericity values have undergone very little transportation, but the reverse is true for the roundness values. Large roundness values found at Marr Lake, Cove Island profile D and Bears Rump Island profile F are associated with large tabular blocks. Further study indicates that these blocks were uplifted from the submerged shore platforms. Due to the dissipation of wave energy generated by friction, these large boulders are deposited at the waterline. Philips (1980) observed that large tabular boulders rotate or shift slightly. Therefore, the removal of sharp protrusions from these boulders is easily accomplished by abrasion. Longshore transport also aids in the abrasion proces, as well as sorting of the cobbles. This process is best illustrated along the east coast of Bears Rump Island. At this position, the cobbles are transported in a southerly direction, towards the spit bar. This is a characteristic coastal feature, resulting from longshore transport. Dobkins and Folk (1970) determined that high abrasion rates, generated through longshore movements, are related to an increase in roundness, but a decrease in sphericity, resulting in oblate cobbles. Therefore, the compiled data correlates abrasion rates and longshore movement with an increase in roundness values.

The sediment analysis results correlate well with those of Dobkins and Folk (1970), who state that high-energy beaches have a decrease in sphericity, with an increase in roundness and cobble size, whereas low-energy beaches seldom move and have high sphericity values. The results of this study were then compared with fetch lengths. It was found that the high roundness values of Bears Rump and the majority of Cove Island correlate with high-energy beaches, and that the high sphericity values at Little Cove correlate with low-energy environments.

The beach gradient is affected by cobble sizes, length of waves and the steepness ratio of the waves. Of these three factors, only cobble sizes were available for analysis. King (1959) indicates that large cobbles have a steeper gradient than sand-sized particles. The following process summarizes the effect that the wave height, swash and backwash have on the beachface. As the water depth decreases, the velocity of an incoming wave decreases, allowing the wave to refract becoming parallel to the shore. This creates a steeper wave form. Eventually, the orbital velocities of the water particles overtake and collapse the wave form. This swash has large amounts of energy that are quickly dissipated on the steep beach by percolation, friction, and gravitational forces (Small, 1970). This swash has enough energy to throw debris to the berm crest.

Both Philips (1980) and Lewis (1931) state that, during severe storm conditions, waves breaking on a steep beachface will direct most of their energy upwards. This is the basis for the presence of smaller cobbles at the ridges with larger cobbles in the swales.

The resultant steep beachface is also dependent upon the percolation rates. Cobble beaches are very permeable, thus permitting large amounts of the advancing swash to percolate into the beach. This reduces the combing down effect of the backwash, which results in a steep beachface. These results are portrayed at all of the profile sites, except for a few on Bears Rump, which receive very little direct wave contact. An excellent example of a steep beachface is found at profile D on Cove Island and Marr Lake on the mainland. Therefore, the wave height and volume of backwash modify the steepness of the beachface.

Bluck (1967) proposed that backwash plays a major role in the preservation of imbrication. The percolation of the backwash downward through the porous gravels produces seaward dipping imbrication, but with strong backwash, the imbricate cobbles may be destroyed. He also states that large imbricated cobbles are not affected by the backwash.

Water levels of the Huron Basin have fluctuated drastically since the Wisconsin glaciation. There are a few extensive inland beaches, outside of this study area, that can be correlated to these changing water levels, although the preserved relict beaches of this study cannot be specifically correlated to any lake stages. Water levels indicate that these preserved beach ridges have been generated during the transition period from the Algoma stage to the present day Lake Huron level. Philips (1980) feels strongly that beach development occurs from short-term high-energy events, not lengthy water level phases. The major emphasis on this lack of correlation is that the area has been submerged until the low Lake Stanley stage, but this stage was terminated by a rapid rise in sea levels, which destroyed any existing coastal features (Hough, 1958). Pitty (1971) concludes that sea level changes may not be correlated to beach profiles, but they may be directly related to the step topography of the shore platforms. Upon these platforms are constructed beaches which are later modified by wave action.

Presently, the foreshore zone is modified by wave action, creating an active beach which terminates at the berm crest. This is found at each profile site. The active beach is distinguished from the inactive beach by the amount of lichen cover. It was observed at each study site that the amount of lichen cover increased towards the backshore zone, eventually grading into soil cover. This is due to the stagnant nature of the cobbles.

Many of the Cove Island beaches contained small multiple ridges which were not surveyed. These result from day-to-day variations in wave energy. This decreases the correlations between the Cove Island beaches. Statistical t-tests indicate further that there is a significant difference in cobble sizes at the ridges and swales between the profiles, but within a profile there is no significant difference in cobble sizes.

APPENDIX A

Plate 1: An eroded bioherm with interreefal material. The regional dip to the southwest, is well defined.

A

B

Plate 2: A high roundness is displayed by the cobble on the left, and the cobble on the right has a high sphericity. (a) is active beach and (b) is inactive beach.

Plate 3: A dolomite scar exposed on the Amabel shore platform. The darker material is lichen growth. Found on Bears Rump Island.

Plate 4: Large tabular blocks have been uplifted from the platform and deposited at the waterline. Notice the step topography to the right of the photograph. Found on Bears Rump Island.

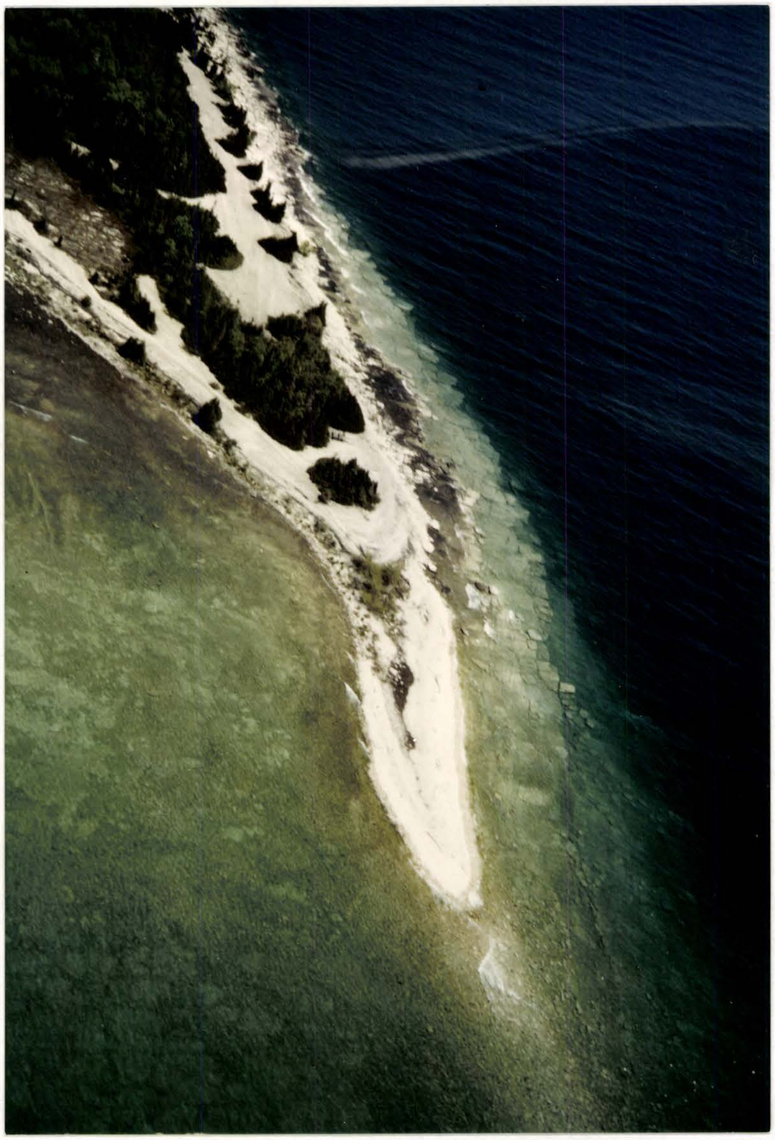


Plate 5: Shows the symmetry of the white cobble beaches along Bears Rump recurving spit. The study area was to the top right.

Plate 6: This displays imbrication on the inactive beachface of profile F, Bears Rump Island. The tape measure in the centre of the photo displays the imbrication at 14°SE.

A

B

Plate 7: Displays the two cobble generations found along the shoreline at Bears Rump Island. These are also present in the inactive zone. (a) The small black spots on the cobbles is lichen cover from the platform. This is indicative of limited transportation. (b) Two cobble generations with no lichen cover.

Plate 8: Evidence of frost shattering. This decreases the roundness values by increasing the number of sharp corners. This is found throughout the study area.

APPENDIX B

Plate 1: Presence of step topography with extensively fractured bedrock, acts as a source for the cobble beaches on Cove Island. Notice the six-inch notebook for scale.

Plate 2: A submerged shore platform along Cove Island's high-energy coastline. It indicates the possible undercutting done by waves.

Plate 3: Beachface at profile B, Cove Island. The shore platform in the front of the photo supports the overlying cobble beach, acts as a substrate control.

Plate 4: Photo indicates the energy of a storm wave. The debris is thrown beyond the berm crest and ridge 1. Plunging storm waves generate steep beachfaces (centre of photo).

APPENDIX C

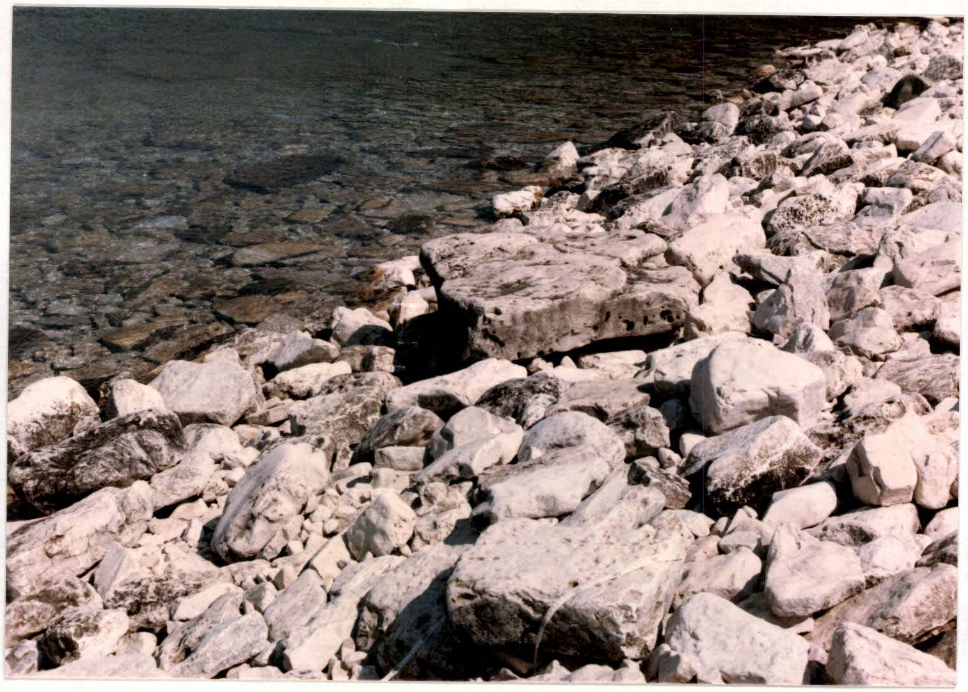


Plate 1: The waterline and shallow water platform of Marr Lake Beach, Georgian Bay. Notice the large cobble debris on the shoreline and submerged platform.

Plate 2: Contrast these Marr Lake cobbles to those on the Georgian Bay side of the plug (Plate 1). Cobbles are small and subrounded. Lens cap for scale to the right.

Plate 3: The Little Cove cobble beach surrounded by exposed Guelph Dolomite. Confined to southern end of the inlet.

Plate 4: Soil covered beach ridge at Little Cove.

Plate 5: Well-sorted cobbles on the beachface at Little Cove.

APPENDIX D

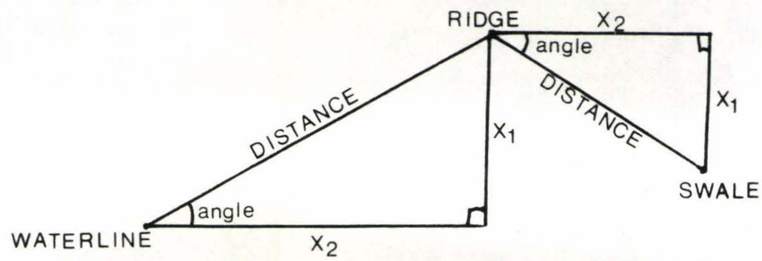
APPENDIX D

PROFILE CONSTRUCTION PROCEDURE

1. Convert distance and angle measurements to trigonometric functions.

lef $X_1 = SIN = \frac{\text{opposite}}{\text{hypotenuse}}$, where X_1 - vertical component of the profile

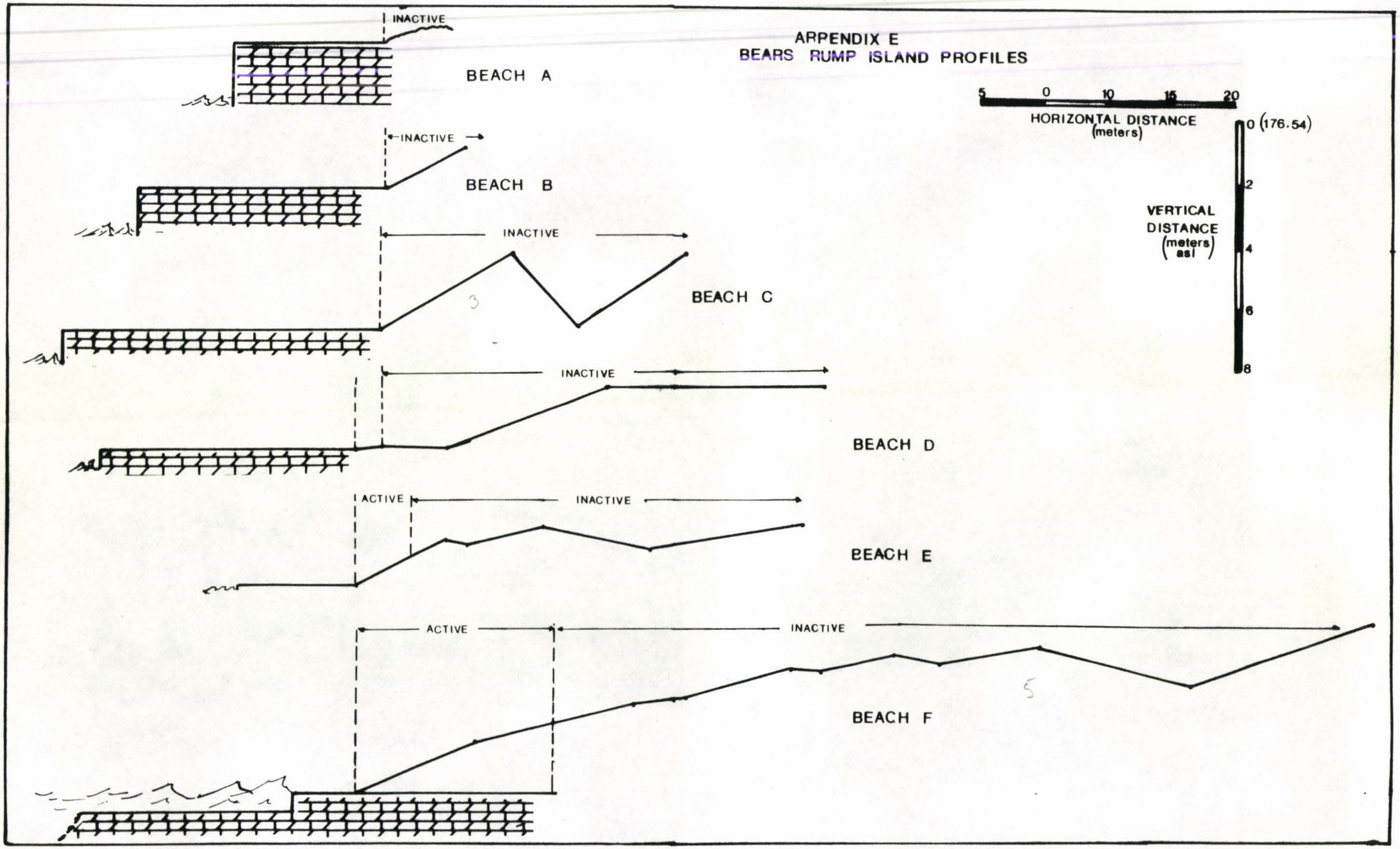
$X_2 = COS = \frac{\text{adjacent}}{\text{hypotenuse}}$, where X_2 - horizontal component of the profile



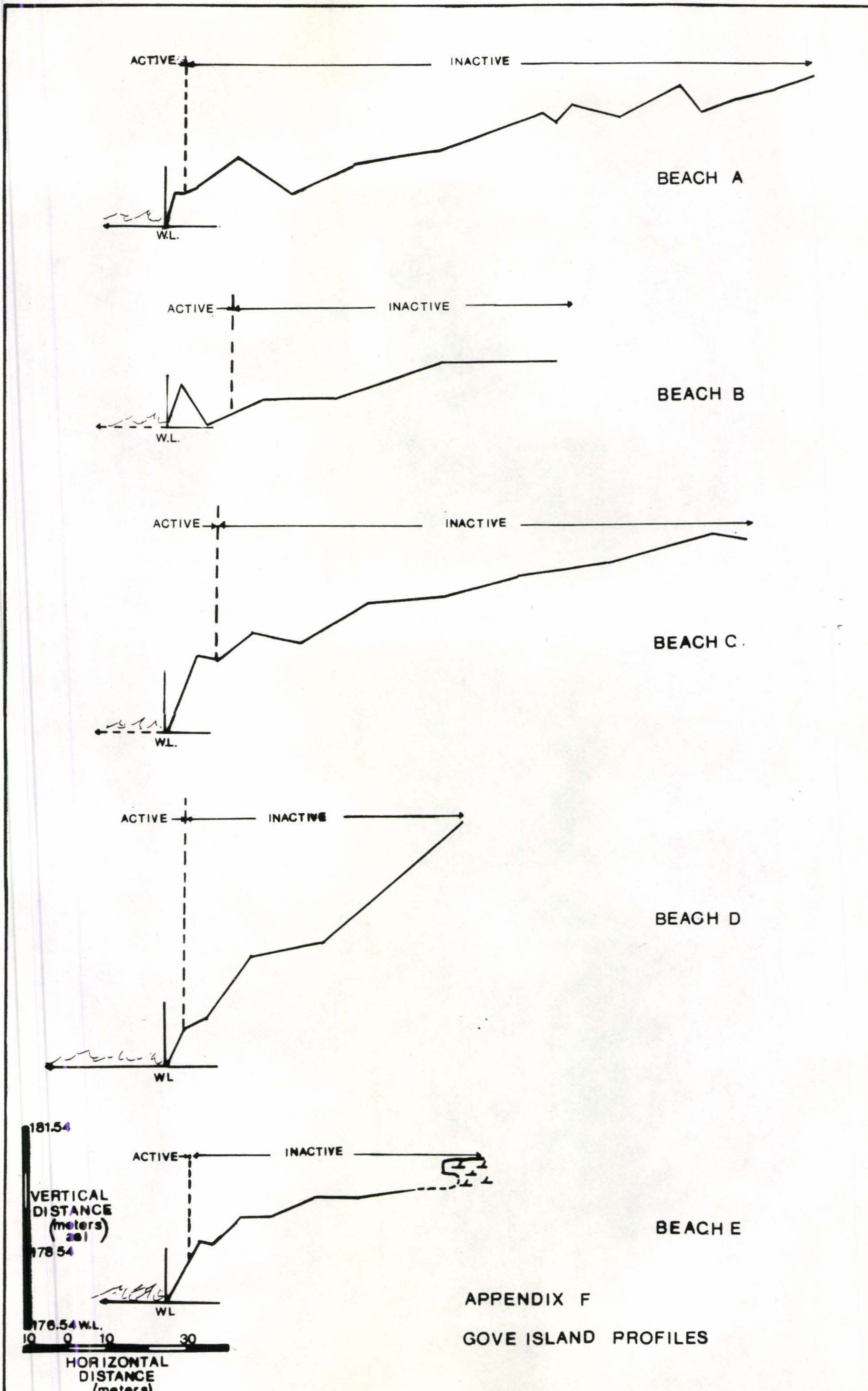
2. Construct profile from calculated results.

APPENDIX E

APPENDIX E
BEARS RUMP ISLAND PROFILES

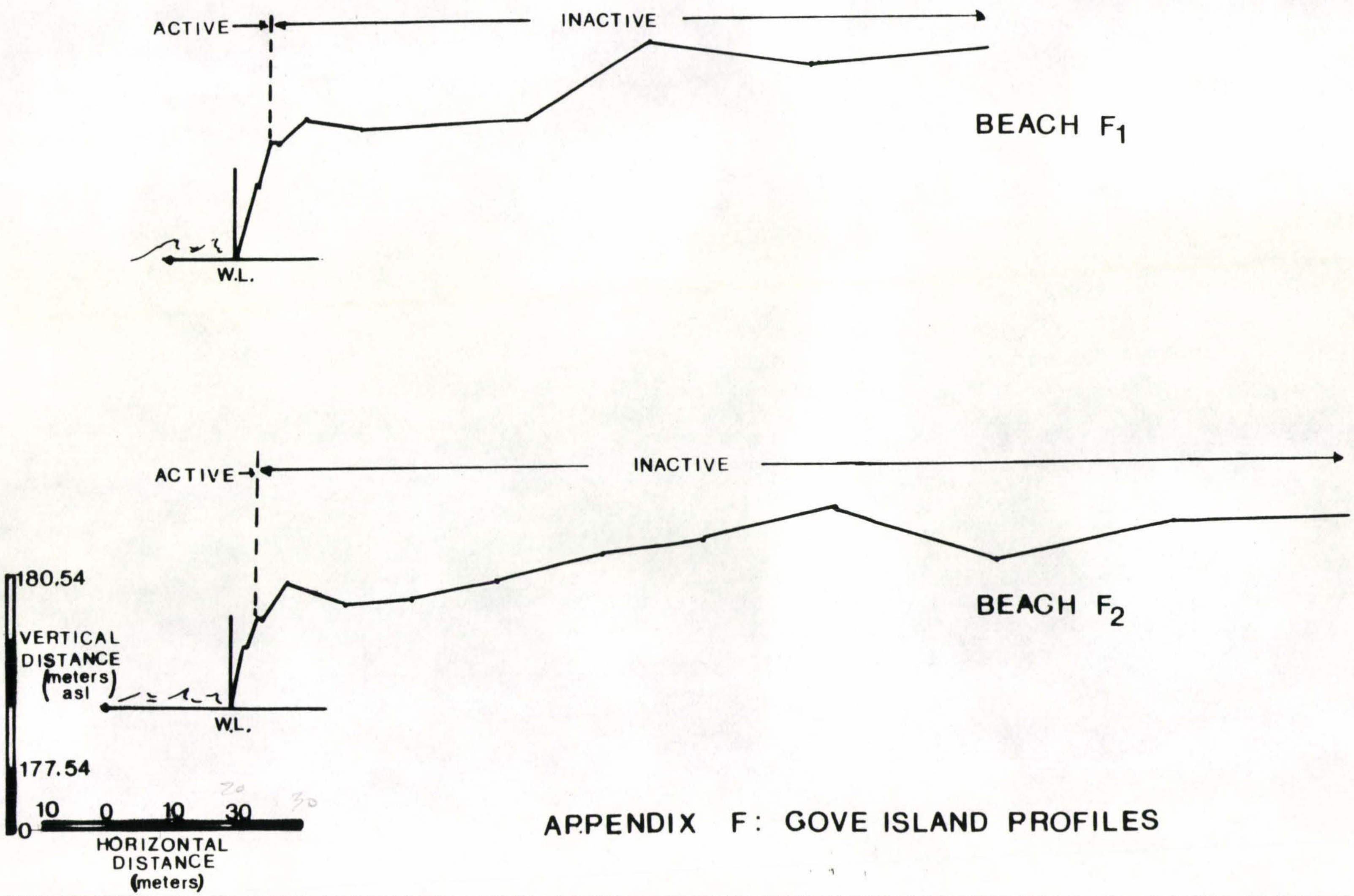


APPENDIX F



APPENDIX F

GOVE ISLAND PROFILES

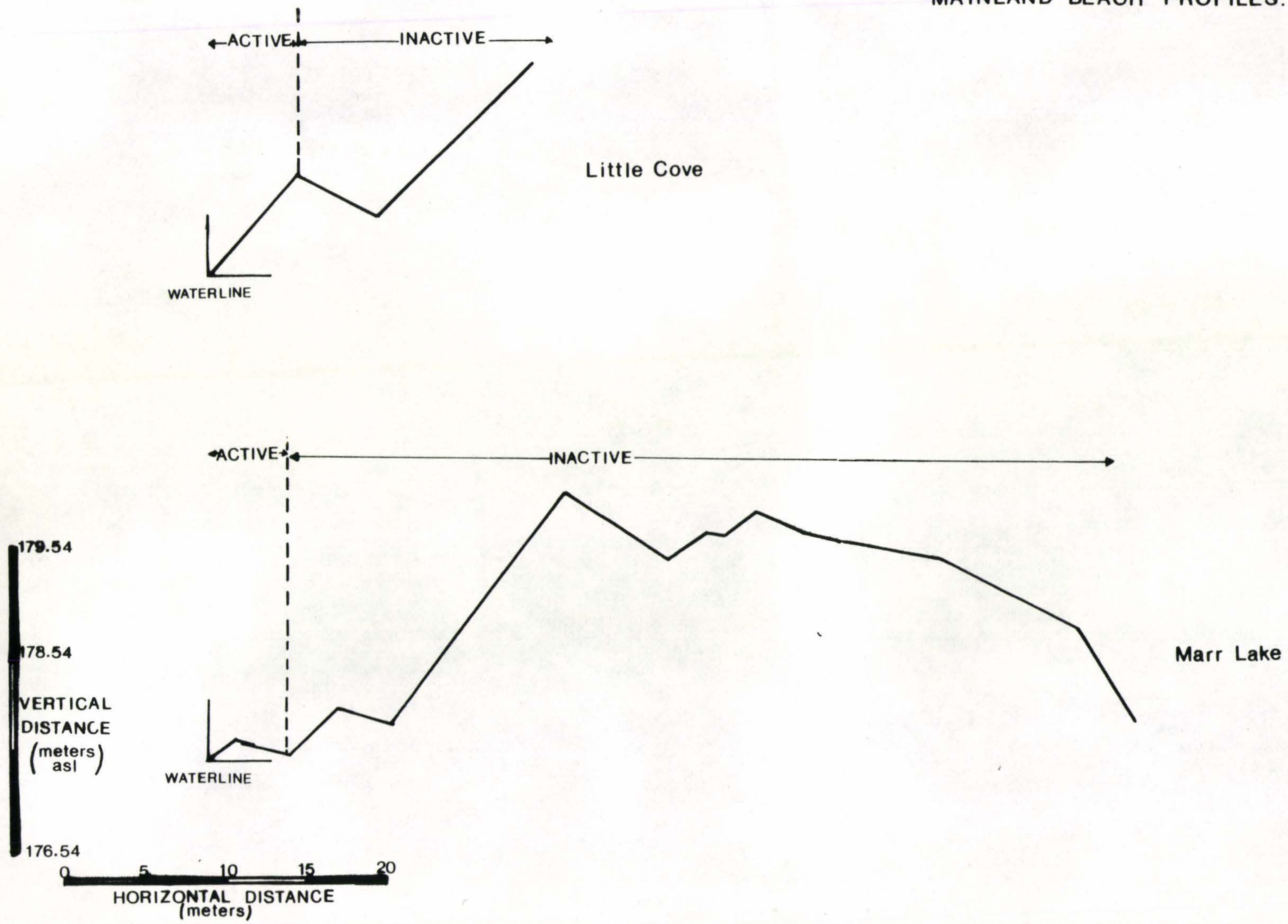


APPENDIX F: GOVE ISLAND PROFILES

APPENDIX G

APPENDIX G

MAINLAND BEACH PROFILES.



APPENDIX H

APPENDIX H

STATISTICAL T-TEST PROCEDURES AND RESULTS

Procedures

1. A two-tailed t-test in which a comparison occurs between the means of the two independent samples with unequal variances ($\sigma_1^2 \neq \sigma_2^2$).

2. Hypotheses are: $H_0\ \mu_1 = \mu_2$, there is no significant difference in cobble sizes between the ridges and swales.

   $H_1\ \mu_1 = \mu_2$, there is a significant difference in cobble sizes between the ridges and swales.

3. Assumptions: a) N_1 and $N_2 \geq 25$ where N_1 are the cobble samples from the ridges and N_2 are cobble samples from the swales.

   b) there are two independent random samples.

4. Test Statistic:

$$\hat{S}_{\bar{X}1 - \bar{X}2} = \sqrt{\frac{\hat{S}_1^2}{N_1} + \frac{\hat{S}_2^2}{N_2}}$$

$$|t| = \left| \frac{X_1 - X_2}{S_{X1 - X2}} \right|$$

t_{α},df where $\alpha = .05$

$df = N_1 + N_2 - 2$ (from Norcliffe, 1977)

if $|t| \geq t$ Ho is rejected, H_1 is accepted.

Results

Comparison within individual profiles:

POSITION \ PROFILE	A	B	C	D	E	F
BEARS RUMP ISLAND	DOES NOT FULFILL ASSUMPTION #1				Reject H_0 and Accept H_1	Reject H_0 and Accept H_1
COVE ISLAND	Do not reject H_0	Do not reject H_0	Do not reject H_0	Reject H_0 and Accept H_1	Reject H_0 and Accept H_1	Reject H_0 and Accept H_1

Comparison between profiles:

BEARS RUMP ISLAND

Profiles	F
F	Reject H_0 and Accept H_1

SWALES

Profiles	F
F	Reject H_0 and Accept H_1

COVE ISLAND

Ridges:

Profiles	A	B	C	D	E	F_1	F_2
A		R	R	R	R	R	R
B	R		A	A	R	R	R
C	R	A		A	R	R	R
D	R	A	A		A	R	R
E	R	R	R	A		R	A
F_1	A	R	R	R	R		R
F_2	A	R	R	R	R	R	

Let R indicate reject H_0 and accept H_1

Let A indicate accept H_0

Swales:

Profiles	A	B	C	D	E	F_1	F_2
A		R	R	A	R	R	R
B	R		A	R	R	R	R
C	R	A		R	R	R	R
D	A	R	R		R	R	R
E	R	R	R	R		R	R
F_1	R	R	R	R	R		R
F_2	R	A	R	R	R	R	

APPENDIX I

APPENDIX I

SUMMARY STATISTICS FOR BEARS RUMP ISLAND PROFILES

PROFILE	POSITION	PEAK SLOPE	HEIGHT (m)	HORIZONTAL DISTANCE	AVERAGE SPHERICITY	AVERAGE ROUNDNESS	LEAST RADIUS CURVATURE (m)	X (cm)	Y (cm)	Z (cm)	STANDARD DEVIATIONS X	Y	Z	DESCRIPTION
Profile A	1050 m													- ancient angular beach with 1
(P_A)	from NE end		NO EXPOSED BEACH PROFILE											generation of pebbles -
Profile B	35 m to SSE	.20	3.3 m	6.7 m			NO PEBBLE SAMPLES MEASURED							inactive beach; two pebble
(P_B)	from P_A													generations small rounded an
Profile C	40 m to SSE													and large angular inactive
(P_C)	from (P_B)													pebbles
	Ridge 1	.22	6.3	10.77										- platform pebbles are larger
	Swale 1	.45	.4	9.14										angular flakes, ridge 1 are
	Ridge 2	.27	6.3	5.40			NO PEBBLE SAMPLES MEASURED							rounded pebbles with lichen
				25.31 Total										cover
														- sinkhole present
Profile D	43 m to SSE													- has an active zone, with 2
(P_D)	from (P_C)													pebble generations
	Ridge 1	.03	.3	2.2	.55	21.7	2.27	11.43	7.94	2.76	3.62	2.06	1.29	- inactive beach begins at 1
	Swale 1	.01	.2	5.3	.32	1.75	1.15	26.04	14.89	1.65	8.28	5.67	1.07	ridge to the treeline
	Ridge 2	.14	5.2	13.7	.40	4.00	.51	19.14	12.44	1.81	9.13	5.14	1.05	- in lichen cover 90-100%
				21.2 Total	.42 Ave.	9.15 Ave.								

APPENDIX I

SUMMARY STATISTICS FOR BEARS RUMP ISLAND PROFILES

(Continued)

PROFILE	POSITION	PEAK SLOPE	HEIGHT (m)	HORIZONTAL DISTANCE	AVERAGE SPHERICITY	AVERAGE ROUNDNESS	LEAST RADIUS CURVATURE (m)	X (cm)	Y (cm)	Z (cm)	STANDARD DEVIATIONS X	Y	Z	DESCRIPTION
Profile E (P_E)	80 m to SSE from (P_D)													- wide active beach with two pebble generations
	waterline round)	.22		7.3	.54	26.5	2.23	7.93	5.58	2.09	1.88	2.05	.63	- lichen cover to treeline
	flat)				.36	3.15	.76	26.18	15.38	1.98	11.62	7.38	1.36	- pebbles are rounded and
	Ridge 1	.05	4.0	2.0	.39	2.55	.59	23.00	13.52	2.32	8.90	7.13	.90	tabular amabel flakes
	Swale 1	.10	3.6	5.9	.39	5.85	1.12	27.93	17.37	2.28	15.54	11.39	.98	
	Ridge 2	.09	5.0	8.6	.53	13.70	1.26	10.76	7.40	2.21	4.16	2.87	1.24	
	Swale 2	.08	3.2	12.3	.46	8.05	1.14	16.71	9.10	2.80	6.67	2.66	1.52	
				36.1 Total	.45 Ave.	9.97 Ave.								

APPENDIX I

SUMMARY STATISTICS FOR BEARS RUMP ISLAND PROFILES

(Continued)

PROFILE	POSITION	PEAK SLOPE	HEIGHT (m)	HORIZONTAL DISTANCE	AVERAGE SPHERICITY	AVERAGE ROUNDNESS	LEAST RADIUS CURVATURE (m)	X (cm)	Y (cm)	Z (cm)	STANDARD DEVIATIONS X	STANDARD DEVIATIONS Y	STANDARD DEVIATIONS Z	DESCRIPTION
Profile F	65 m to SSE													- small platform
(P_F)	from (P_E)													- largest active beach
	Ridge 1	.17	1.3	3.3)										- 5P marks centre of recurving
	Swale 1	.17	4.4	7.0)										spit
	Ridge 2	.09	7.6	12.3)	UNABLE TO PERFORM PEBBLE MEASUREMENTS DUE TO TIME RESTRICTIONS									- imbrication at 14°SE
	Swale 2	.06	8.3	5.0)										- 2 generations of pebbles -
	Ridge 3	.11	10.8	8.5)										active has round and flat
	Swale 3	.02	10.5	2.6	.54	12.70	1.41	12.15	7.06	3.10	4.42	2.27	1.45	pebbles so does inactive
	Ridge 4	.10	11.2	3.8	.57	13.95	1.37	9.80	6.13	2.89	2.15	1.72	1.07	beach
	Swale 4	.10	12.0	5.6	.54	16.75	2.37	16.73	10.63	4.19	5.63	4.84	2.01	- increase in lichen cover to
	Ridge 5	.07	12.8	8.5	.50	13.55	1.59	11.89	6.47	3.20	2.45	2.38	.99	treeline
	Swale 5	.10	9.8	12.7	.55	10.20	1.07	11.20	6.60	3.17	3.92	2.51	1.55	
	Ridge 6	.14	14.3	14.3	.53	10.80	.93	9.02	4.97	2.29	2.58	1.25	.79	
				83.6 Total	.53 Ave.	13.00 Ave.								

APPENDIX J

APPENDIX J

SUMMARY STATISTICS FOR COVE ISLAND

PROFILE	POSITION	BEACH-FACE SLOPE	HEIGHT (m)	HORIZONTAL DISTANCE	AVERAGE SPHERICITY	AVERAGE ROUNDNESS	LEAST RADIUS CURVATURE (m)	X (cm)	Y (cm)	Z (cm)	STANDARD DEVIATIONS X	STANDARD DEVIATIONS Y	STANDARD DEVIATIONS Z	DESCRIPTION
Profile A	waterline	-	-	-	.66	.86	1.40	10.13	6.61	4.20	4.42	2.42	2.11	- very small active zone
(P_A)	Ridge 1	.04	.80	2.2	.63	1.26	1.10	9.66	6.57	3.50	3.86	3.10	1.01	- extensive platform development
	Swale 1	0	.90	5.4	.64	.74	1.60	9.12	5.91	3.47	3.46	2.03	1.42	- active pebbles are well round-
	Ridge 2	.08	1.80	9.4	.61	1.14	1.60	15.12	9.53	4.72	9.27	3.40	2.78	ed (1 generation)
	Swale 2	.06	.80	12.5	.62	.88	2.30	14.54	9.83	5.27	4.64	3.22	2.19	- there is increase in lichen
	Ridge 3	.04	1.60	15.0	.66	43.00	1.50	8.26	5.41	3.48	5.15	3.07	1.92	growth from waterline to tree-
	Swale 3	.01	1.80	19.2	.67	.97	2.20	14.14	9.83	6.04	5.24	4.48	2.31	line
	Ridge 4	.04	2.70	24.0	.59	1.11	2.30	11.04	7.78	3.15	4.09	3.00	1.34	- inactive beach has two gener-
	Swale 4	.08	2.50	3.2	.57	1.31	1.00	9.51	5.74	2.74	3.92	2.67	0.83	ations at pebbles 1) well-
	Ridge 5	.11	2.90	4.4	.57	3.22	.50	14.08	8.89	.42	3.82	2.40	4.34	rounded; 2) angular
	Swale 5	.02	2.80	9.0	.60	4.35	.70	15.72	9.75	5.52	3.74	2.73	1.47	
	Ridge 6	.05	3.30	14.4	.60	9.55	.60	13.81	8.77	4.60	4.21	2.99	1.54	
	Swale 6	.13	2.70	5.0	.62	5.90	.40	13.86	8.77	5.36	3.31	2.55	1.63	
	Ridge 7	.04	3.00	8.5	.58	8.60	.70	17.85	10.38	5.48	6.86	3.08	1.54	
	Swale 7	.02	3.30	9.5	.58	9.55	.80	15.88	16.52	5.01	3.15	3.98	1.93	
	Ridge 8	.03	3.60	10.0	.58	15.60	.60	17.17	9.84	5.80	5.93	3.08	2.70	
				151.7 Total	.61 Ave.	6.75 Ave.								

APPENDIX J

SUMMARY STATISTICS FOR COVE ISLAND

(Continued)

PROFILE	POSITION	BEACH-FACE SLOPE	HEIGHT (m)	HORIZONTAL DISTANCE	AVERAGE SPHERICITY	AVERAGE ROUNDNESS	LEAST RADIUS CURVATURE (m)	X (cm)	Y (cm)	Z (cm)	STANDARD DEVIATIONS X	Y	Z	DESCRIPTION
Profile B	waterline	-	0	-	.54	12.65	.80	16.09	9.15	3.94	7.68	3.11	1.70	- much wider active beach than P_A
(P_B)	Ridge 1	.25	1.8	6.6	.56	9.40	.90	21.65	13.68	5.08	13.20	6.06	1.96	- active and inactive cobbles are
	Swale 1	.02	1.7	4.7	.49	6.50	.60	21.79	12.16	4.10	8.20	3.72	1.75	angular with high degree of
	Ridge 2	.07	2.3	8.4	.53	15.15	1.10	17.83	10.54	4.16	7.24	4.21	1.49	roundness and low sphericity
	Swale 2	.02	2.1	9.8	.53	16.00	1.20	16.21	9.73	3.75	6.30	4.52	1.29	- individual ridges and swale
	Ridge 3	.06	3.0	14.9	.52	12.45	1.10	14.97	9.33	3.42	5.62	4.47	1.57	have numerous randomly-oriented
	Swale 3	.01	3.2	16.0	.53	9.90	.90	19.24	10.78	4.76	8.19	3.42	2.33	ridges resulting from various
	Ridge 4	.03	3.6	17.7	.52	4.40	.40	17.40	9.90	4.15	6.06	2.55	1.38	wave energies
	Swale 4	.01	3.9	21.4	.55	4.25	.40	18.52	11.83	4.96	4.78	4.39	1.55	
	Ridge 5	.02	4.6	24.5	.53	3.65	.40	23.91	13.20	6.25	9.00	5.78	2.50	
	Swale 5	.03	4.4	8.0	.52	3.00	.30	21.84	11.28	5.73	6.67	3.24	2.20	
				132.0 Total	.52 Ave.	8.85 Ave.								

APPENDIX J

SUMMARY STATISTICS FOR COVE ISLAND

(Continued)

PROFILE	POSITION	BEACH-FACE SLOPE	HEIGHT (m)	HORIZONTAL DISTANCE	AVERAGE SPHERICITY	AVERAGE ROUNDNESS	LEAST RADIUS CURVATURE (m)	$\underline{X}$ (cm)	$\underline{Y}$ (cm)	$\underline{Z}$ (cm)	STANDARD DEVIATIONS X	Y	Z	DESCRIPTION
Profile C	waterline	-	-		.66	17.20	.17	25.56	17.80	8.63	15.52	9.95		- very large active beach with
(P_C)	Ridge 1	.30	1.5	3.4	.56	14.45	.11	17.15	9.08	5.00	6.59	2.51		extensive development and a
	Swale 1	.14	.1	6.3	.65	19.85	.16	15.76	10.67	6.23	5.91	4.93	2.39	steep peak
	Ridge 2	.05	.7	12.5	.65	12.75	.12	17.96	12.43	6.86	5.19	4.56	2.06	- bedrock platform exposed, it
	Swale 2	0	.7	16.4	.55	7.35	.66	17.27	10.41	4.92	3.73	3.24	1.44	appears to control beach shape
	Ridge 3	.03	1.5	25.7	.54	8.8	.97	21.60	14.50	4.95	6.04	4.70	1.74	- inactive cobbles have low
	Swale 3	0	1.6	27.7	.55	7.7	.73	18.18	12.27	4.57	4.26	3.15	2.31	roundness, active have high
				92.0 Total	.59 Ave.	12.58 Ave.								roundness and sphericity

APPENDIX J

SUMMARY STATISTICS FOR COVE ISLAND

(Continued)

PROFILE	POSITION	BEACH-FACE SLOPE	HEIGHT (m)	HORI-ZONTAL DIS-TANCE	AVER-AGE SPHERI-CITY	AVER-AGE ROUND-NESS	LEAST RADIUS CURVA-TURE (m)	X (cm)	Y (cm)	Z (cm)	STANDARD DEVIATIONS X	Y	Z	DESCRIPTION
Profile D	waterline	-	-	-	.57	11.60	2.74	73.25	47.80	17.75	48.37	31.11	10.65	- has two generations of cobbles
(P_D)	Ridge 1	.22	.6	2.6	.64	16.25	1.64	26.44	17.10	9.00	15.91	8.40	2.88	- waterline shows flaking of
	Swale 1	.04	.7	3.0	.70	17.50	1.58	17.88	13.00	8.24	6.96	5.51	3.37	tabular blocks with high
	Ridge 2	.13	1.6	6.8	.66	15.90	1.05	13.58	9.12	5.56	4.55	2.76	2.04	roundness
	Swale 2	.02	1.9	11.0	.53	10.50	.79	16.62	10.85	5.65	7.65	4.99	3.03	
	Ridge 3	.08	3.7	21.0	.57	6.20	.50	16.45	9.52	5.29	4.20	1.77	1.85	
				44.4 Total	.61 Ave.	13.00 Ave.								

APPENDIX J

SUMMARY STATISTICS FOR COVE ISLAND

(Continued)

PROFILE	POSITION	BEACH-FACE SLOPE	HEIGHT (m)	HORIZONTAL DISTANCE	AVERAGE SPHERICITY	AVERAGE ROUNDNESS	LEAST RADIUS CURVATURE (m)	X (cm)	Y (cm)	Z (cm)	STANDARD DEVIATIONS X	Y	Z	DESCRIPTION
Profile E	waterline	-	-	-	.56	11.15	2.05	53.32	34.43	12.44	39.19	21.03	10.76	- extensive platform development
(P_E)	waterline swale	-	-	-	.57	20.10	2.30	38.95	25.30	8.07	29.86	21.01	2.86	and presence of cave, thus
	Ridge 1	.20	1.5	7.4	.63	14.35	1.19	14.28	9.00	5.22	4.83	2.10	1.75	platform acts as a substrate
	Swale 1	.02	1.4	3.6	.54	15.00	1.89	38.03	23.42	7.03	26.31	16.08	3.79	control
	Ridge 2	.09	2.0	6.3	.57	18.65	1.64	17.49	10.50	4.88	6.34	3.54	1.47	- well-sorted and rounded
	Swale 2	0	2.0	7.3	.59	13.80	0.94	14.12	8.40	4.62	3.47	2.70	1.26	cobbles, with low sphericity
	Ridge 3	.06	2.5	10.0	.57	14.20	1.30	18.05	10.84	5.35	5.18	3.38	1.92	- very little active beach
	Swale 3	0	2.5	11.5	.59	13.40	1.03	15.35	9.34	5.24	3.83	2.97	1.69	present
	Ridge 4	.02	2.7	12.7	.63	17.70	1.13	14.39	9.57	4.98	4.57	2.31	1.44	
				58.8 Total	.58 Ave.	15.37 Ave.								

APPENDIX J

SUMMARY STATISTICS FOR COVE ISLAND

(Continued)

PROFILE	POSITION	BEACH-FACE SLOPE	HEIGHT (m)	HORIZONTAL DISTANCE	AVERAGE SPHERICITY	AVERAGE ROUNDNESS	LEAST RADIUS CURVATURE (m)	X (cm)	Y (cm)	Z (cm)	STANDARD DEVIATIONS X	Y	Z	DESCRIPTION
Profile F_1	waterline				.66	37.25	1.74	9.16	6.63	3.65	1.57	1.22	.67	- small active beach, with
(P_{F1})	Ridge 1	.68	1.09	2.3	.63	28.90	1.48	10.48	6.67	4.06	2.41	1.13	1.18	steep slope and rounded cobbles
	Swale 1	0	1.07	0.7	.63	28.95	1.52	10.48	6.97	3.87	2.25	2.18	.96	- inactive cobbles are angular
	Ridge 2	.40	1.72	1.4	.61	22.70	1.06	10.16	7.13	3.02	6.06	4.69	.86	with lichen cover
	Swale 2	0	1.70	1.2	.62	21.05	1.33	12.89	8.24	4.64	5.51	3.06	2.03	- platform lengths small
	Ridge 3	.10	2.08	3.7	.62	21.45	1.38	12.91	8.95	4.55	2.99	2.58	1.43	- highly correlated with P_{F2}
	Swale 3	.02	1.91	8.0	.58	18.00	1.60	19.62	13.98	5.16	6.69	3.92	2.05	- transition zone from active
	Ridge 4	.01	1.97	10.0	.61	16.35	1.19	14.81	9.68	4.90	5.74	2.91	1.49	to inactive is at swale 2
	Swale 4	.01	2.06	14.0	.59	16.45	1.45	20.60	12.57	6.27	9.20	6.03	2.42	
	Ridge 5	.06	3.20	18.4	.61	18.45	1.58	16.72	10.09	5.84	4.63	2.62	1.39	
	Swale 5	.01	2.89	24.8	.62	19.95	1.74	18.52	11.42	6.24	7.48	4.38	1.46	
	Ridge 6	.01	3.13	26.5	.60	21.85	1.10	10.41	6.21	3.49	3.38	2.31	.85	
				111.0 Total	.62 Ave.	22.62 Ave.								

APPENDIX J

SUMMARY STATISTICS FOR COVE ISLAND

(Continued)

PROFILE	POSITION	BEACH-FACE SLOPE	HEIGHT (m)	HORIZONTAL DISTANCE	AVERAGE SPHERICITY	AVERAGE ROUNDNESS	LEAST RADIUS CURVATURE (m)	X (cm)	Y (cm)	Z (cm)	STANDARD DEVIATONS X	Y	Z	DESCRIPTION
Profile F_2	waterline				.71	45.05	2.88	14.36	10.25	6.34	5.31	2.57	.78	- very small cobble beach same
(P_{F2})	Ridge 1	.60	0.90	1.5	.68	39.40	2.47	13.03	9.53	5.63	2.38	1.79	1.25	width as P_{F1}
	Swale 1	0	0.89	0.6	.64	38.35	2.54	15.59	10.06	6.08	3.46	2.18	1.03	- transition zone from active
	Ridge 2	0	1.29	0.7	.59	24.55	1.94	18.43	12.35	5.95	4.46	3.56	2.51	to inactive is same as P_{F1}
	Ridge 3	.14	1.80	3.4	.62	21.55	1.55	14.84	10.00	5.32	2.94	2.53	2.03	- highly correlated with P_{F1}
	Swale 3	.02	1.54	8.5	.61	18.75	1.53	16.84	10.80	6.24	3.42	2.58	1.80	
	Ridge 4	.01	1.60	10.0	.64	27.4	1.94	18.59	11.60	7.28	5.62	3.42	2.35	
	Swale 4	.02	1.89	13.1	.66	29.65	2.22	19.91	12.51	7.87	10.76	6.96	2.37	
	Ridge 5	.03	2.27	15.0	.61	18.35	.74	7.67	4.83	2.82	2.83	1.92	1.23	
	Swale 5	.01	2.50	15.9	.67	31.20	1.82	14.89	9.11	6.14	10.35	5.21	3.26	
	Ridge 6	.02	2.97	18.8	.67	22.10	2.06	20.21	15.74	7.80	5.96	6.08	2.07	
	Swale 6	.03	2.16	24.0	.68	18.95	1.64	17.38	11.91	7.17	6.04	4.01	2.04	
	Ridge 7	.03	2.67	26.0	.66	25.00	1.50	15.27	10.13	6.12	5.78	4.43	2.14	
				139.3 Total	.64 Ave.	27.93 Ave.								

$$SPH = 3 \frac{ZxY}{X^2} \qquad RND = \frac{2LRC}{X} \qquad STAN\ DEV = \frac{(X_i - X)}{N-1}$$

APPENDIX K

APPENDIX K

SUMMARY STATISTICS FOR THE MAINLAND

PROFILE	POSITION	PEAK SLOPE	HEIGHT (m)	HORIZONTAL DISTANCE	AVERAGE SPHERICITY	AVERAGE ROUNDNESS	LEAST RADIUS CURVATURE (m)	X (cm)	Y (cm)	Z (cm)	STANDARD DEVIATIONS X	STANDARD DEVIATIONS Y	STANDARD DEVIATIONS Z	DESCRIPTION
Little Cove														
Profile 1	water level	-	-	-	.60	29.30	0.94	6.35	4.02	2.18	1.14	.77	.51	- well sorted and well
	Ridge 1	0.2	1.00	4.80	.59	20.70	.66	6.53	4.04	2.29	2.61	1.74	1.08	rounded active cobbles
	Swale 1	0.1	.55	4.20	.59	22.60	1.35	12.48	7.99	4.01	2.78	2.07	1.17	- vegetation growth covers
	Ridge 2	0.2	2.10	8.00	.63	18.40	1.08	13.41	9.52	4.59	5.04	3.59	1.90	relict beach
				5.67 Total	.60 Ave.	22.75 Ave.								

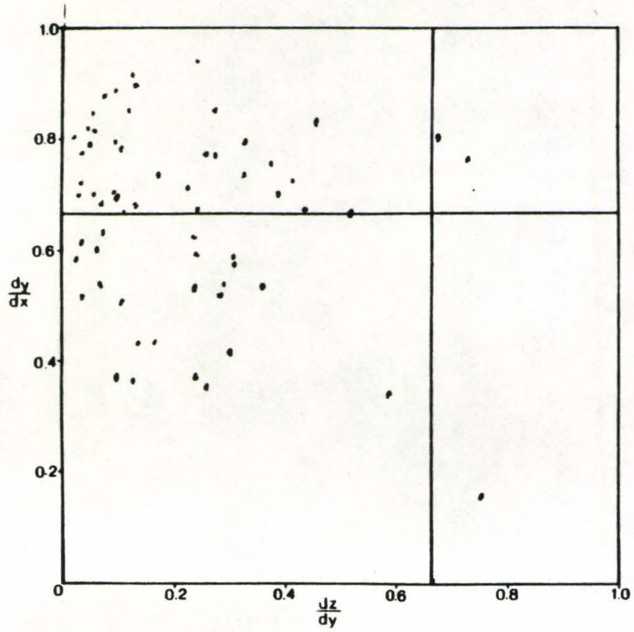
APPENDIX K

SUMMARY STATISTICS FOR THE MAINLAND

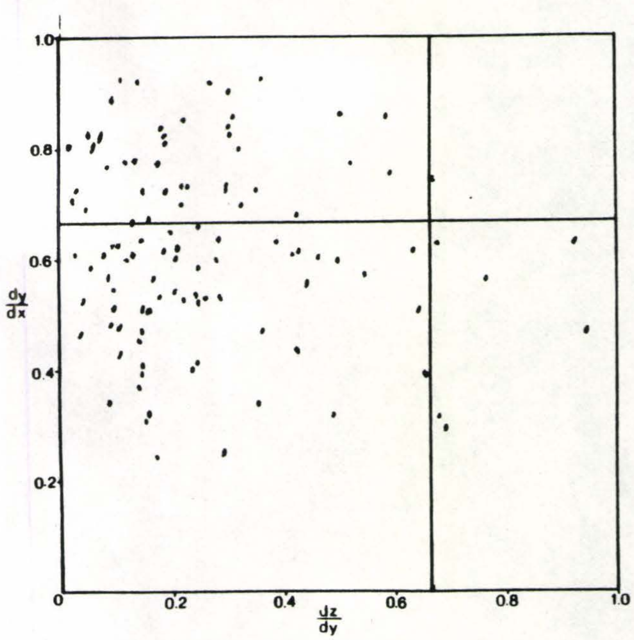
(Continued)

PROFILE	POSITION	PEAK SLOPE	HEIGHT (m)	HORIZONTAL DISTANCE	AVERAGE SPHERICITY	AVERAGE ROUNDNESS	LEAST RADIUS CURVATURE (m)	X (cm)	Y (cm)	Z (cm)	STANDARD DEVIATIONS X	Y	Z	DESCRIPTION
Cyprus Park Marr Lake Profile 1	Georgian Bay water level				.52	12.65	2.77	47.22	26.75	10.61	26.49	16.20	6.87	- acts as a plug between Marr and Georgian Bay (GB)
	Ridge 1	.14	.25	3.5	.54	14.45	2.04	31.18	19.50	7.56	20.76	14.38	4.90	
	Swale 1	.06	.10	7.0										- cobbles much larger at GB than Marr Lake
	Ridge 2	.20	1.30	13.0	.56	15.00	1.53	20.49	14.54	4.84	15.84	12.29	3.69	
	Swale 2	.05	.90	22.0	.64	19.80	1.32	13.15	9.32	4.52	6.63	4.10	1.75	- profile is very high
	Ridge 3	.26	6.70	13.0	.47	11.40	1.01	18.51	11.44	3.40	6.80	6.41	1.66	- lichen cover increases from GB to Marr Lake
	Swale 3	.13	5.10	5.0				DATA UNAVAILABLE						
	Ridge 4	.12	5.70	2.0	.54	15.25	1.11	13.49	8.39	3.43	3.78	2.80	1.29	- small cobbles found at Marr Lake
	Swale 4	.50	5.60	4.0				DATA UNAVAILABLE						
	Ridge 5	.15	6.30	5.5	.54	12.60	.71	11.06	6.59	2.81	4.00	3.05	.95	
	Swale 5	.08	5.80	5.5	.48	6.05	.91	24.31	14.36	4.62	14.74	9.81	2.44	
	Ridge 6	.03	5.50	12.5	.55	11.65	.62	10.96	7.25	2.95	3.17	3.15	1.47	
	Swale 6	.03	5.10	17.5	.53	6.55	.79	21.25	14.45	5.15	8.24	7.17	3.08	
	Ridge 7	.10	3.30	7.5	.57	17.90	.92	10.53	6.39	2.82	4.33	2.27	1.27	
	Marr Lake water level	.31	1.00		.64	14.05	.53	7.68	5.28	2.81	2.57	1.17	.97	
				118.0 Total	.54 Ave.	13.11 Ave.								

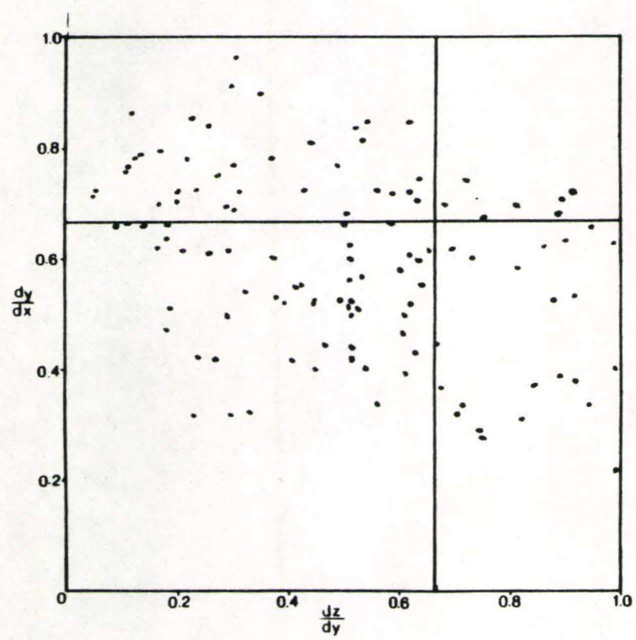
APPENDIX L



Beach E

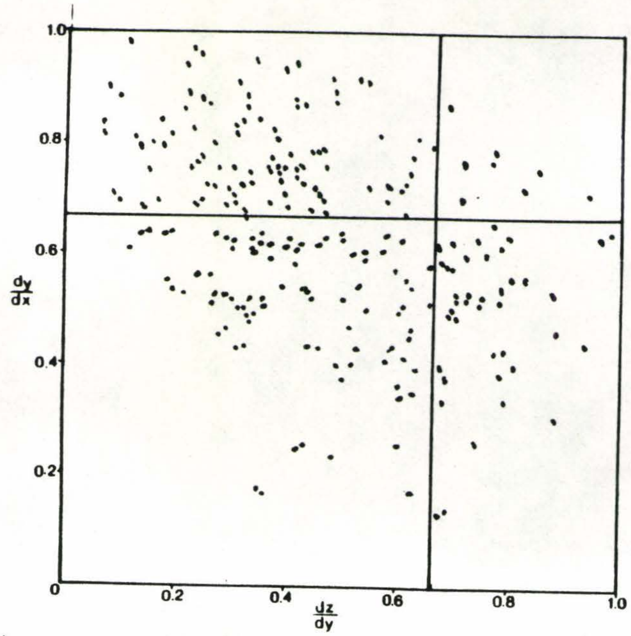


Beach D

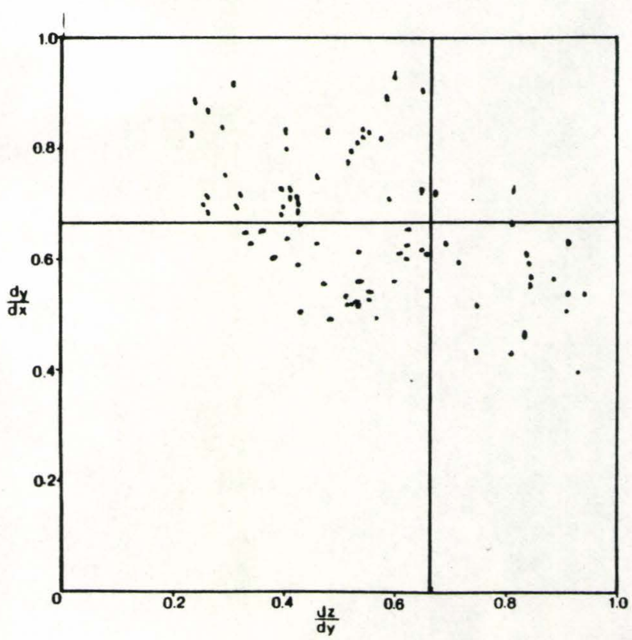


Beach F

Appendix L: Zingg Diagram Plots for Bears Rump Island

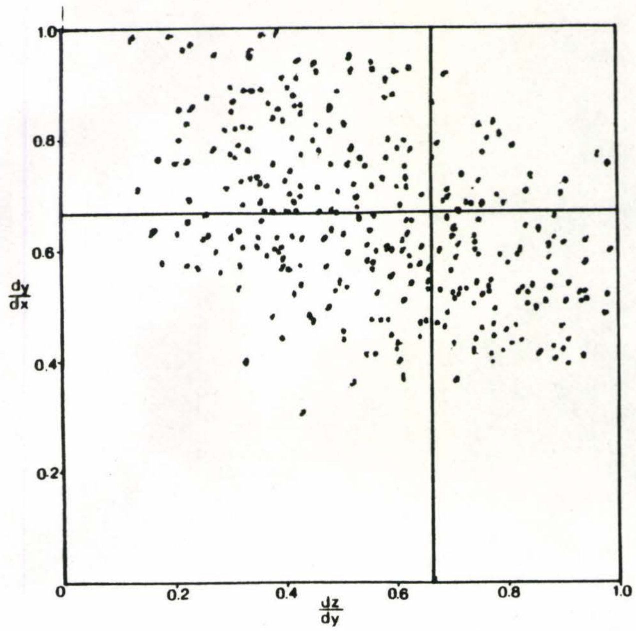


Marr Lake Beach

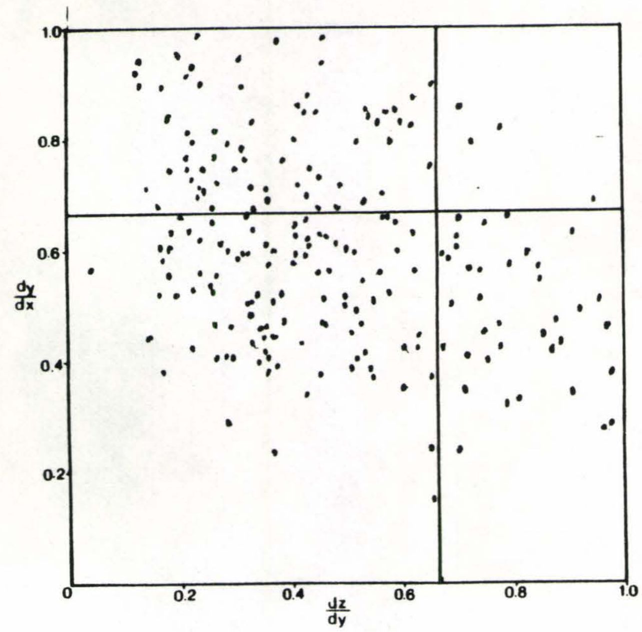


Little Cove Beach

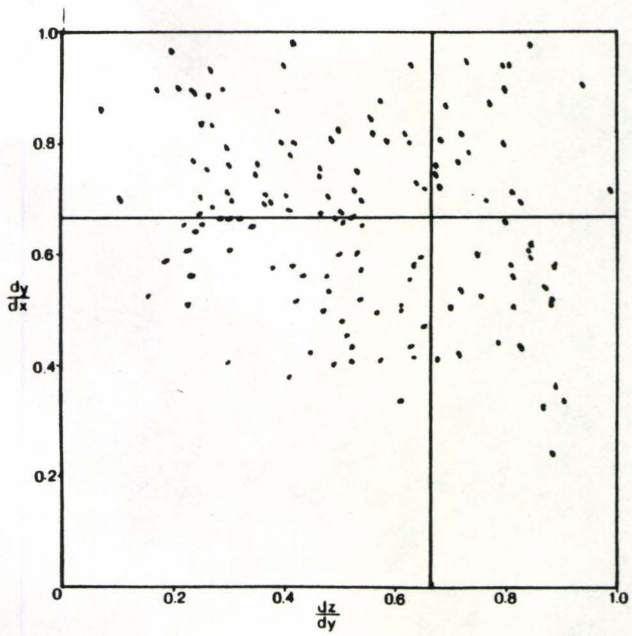
Appendix L: Zingg Diagram Plots for Mainland Beaches



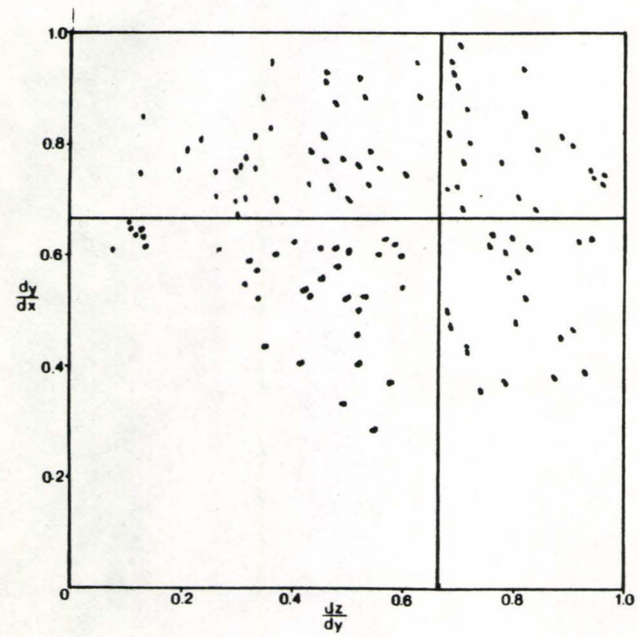
Beach A



Beach B

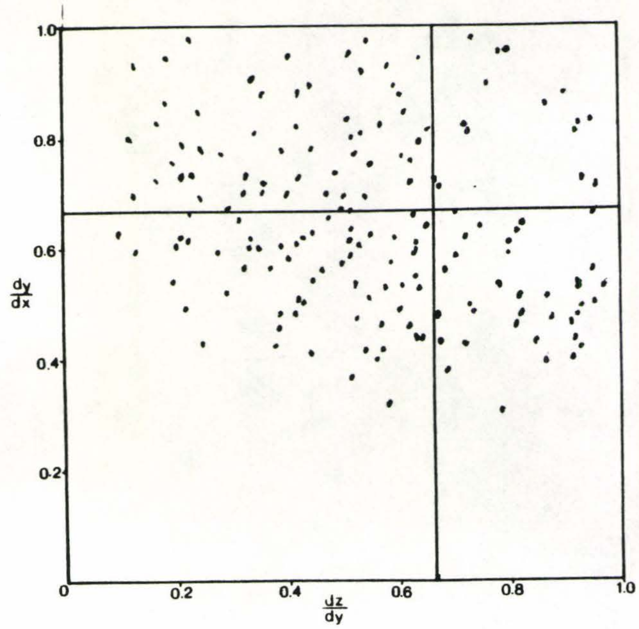


Beach C

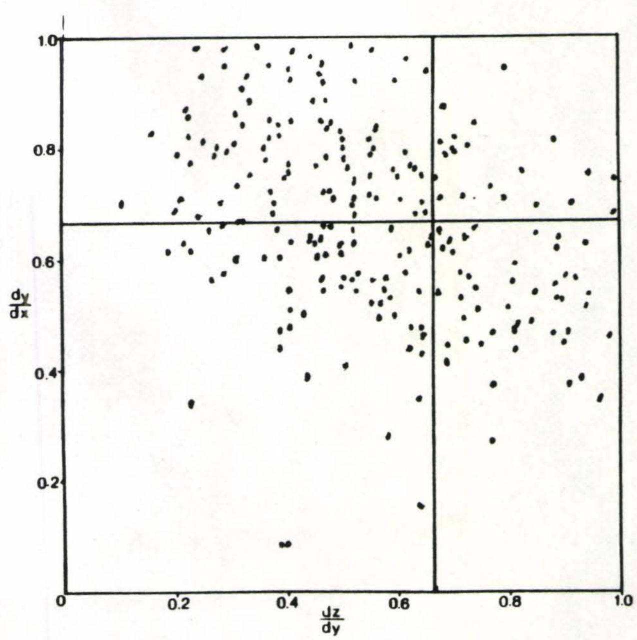


Beach D

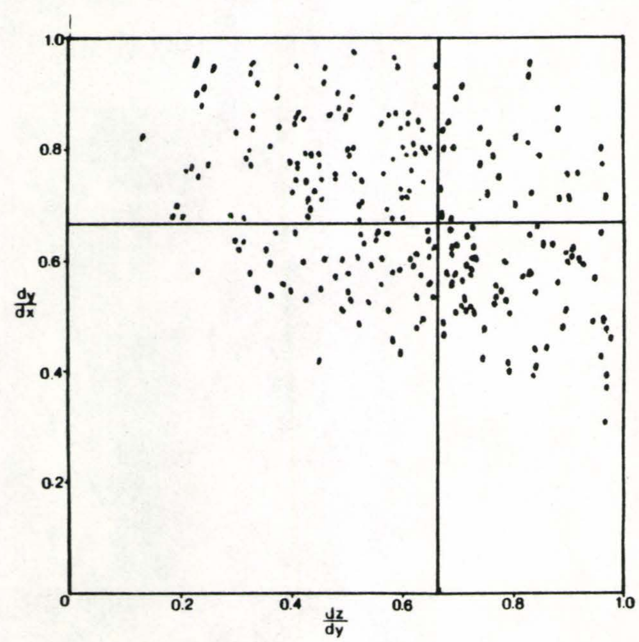
Appendix L: Zingg Diagram Plots for Cove Island cont'd



Beach E



F_1



F_2

Beach F

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