Chapter 4

Results

Introduction

The recent geomorphic changes of Cove Point was reconstructed using shoreline change maps, bathymetric data, and wind climate data. The long-term evolution of Cove Point was derived through a study of stratigraphy, beach ridge mapping, and radiocarbon dating.

Shoreline change

Long-term shoreline change at Cove Point is characterized by several different types of shoreline behavior and can thus be divided into morphologically distinct units (Figure 14). The northern flank of Cove Point is erosional, like much of the Calvert County coastline. By contrast, the southern flank of the foreland is accretional over the long term period of record. Further south along the coast the shoreline is again eroding. The tip of Cove Point is ephemeral; its shape and orientation is observed to change between 1908 and 1996, but no definable trend can be discerned. This spit tip is influenced by the emplacement of a seawall and a series of small groins which protect the Cove Point lighthouse (Figure 6). The evidence also suggests that the influence of these shoreline protection structures may be increasing. A plot of all the shorelines for the Cove

Point study area can be seen in Figure 15. Frames 1 to 6 are mapped in Figures 16 to 21. These larger scale plots allow for a more detailed analysis of the shoreline behavior.

Cove Point, Zone #1: Northern flank of Cove Point (transects 1-117)

This stretch of the study area comprises 2320 meters of coastline, and is oriented northwest to southeast, perpendicular to the direction of storm wave attack (northeast). This beach is narrow and the foreshore is gently sloped; the backshore is almost nonexistent. Typically the poorly developed dunes exhibit an erosional scarp. This portion of Cove Point is erosional over the long term record (1908-1996), with an average annual erosion rate of 1.0 meter per year using linear regression (see Figure 22). There is considerable variability around this average as seen from a histogram plot of the shoreline change rates (Figure 23). The most northern part of the Cove Point coast is eroding at approximately 0.5 meters per year. Erosion rates increase to the south, peaking at 1.8 meters per year at the center of the northern flank. This area of rapid erosion is also the center of the curve which characterizes the northern flank. South of this zone the erosion rates gradually decreases as the orientation of the shoreline curves around to face almost due north.

The larger scale maps of Cove Point's historical shorelines also reveal this pattern. In Frame 1 (Figure 16) there is a continuous succession of the shoreline position from east to west between 1908 and 1996. In Frame 2 (Figure 17), the

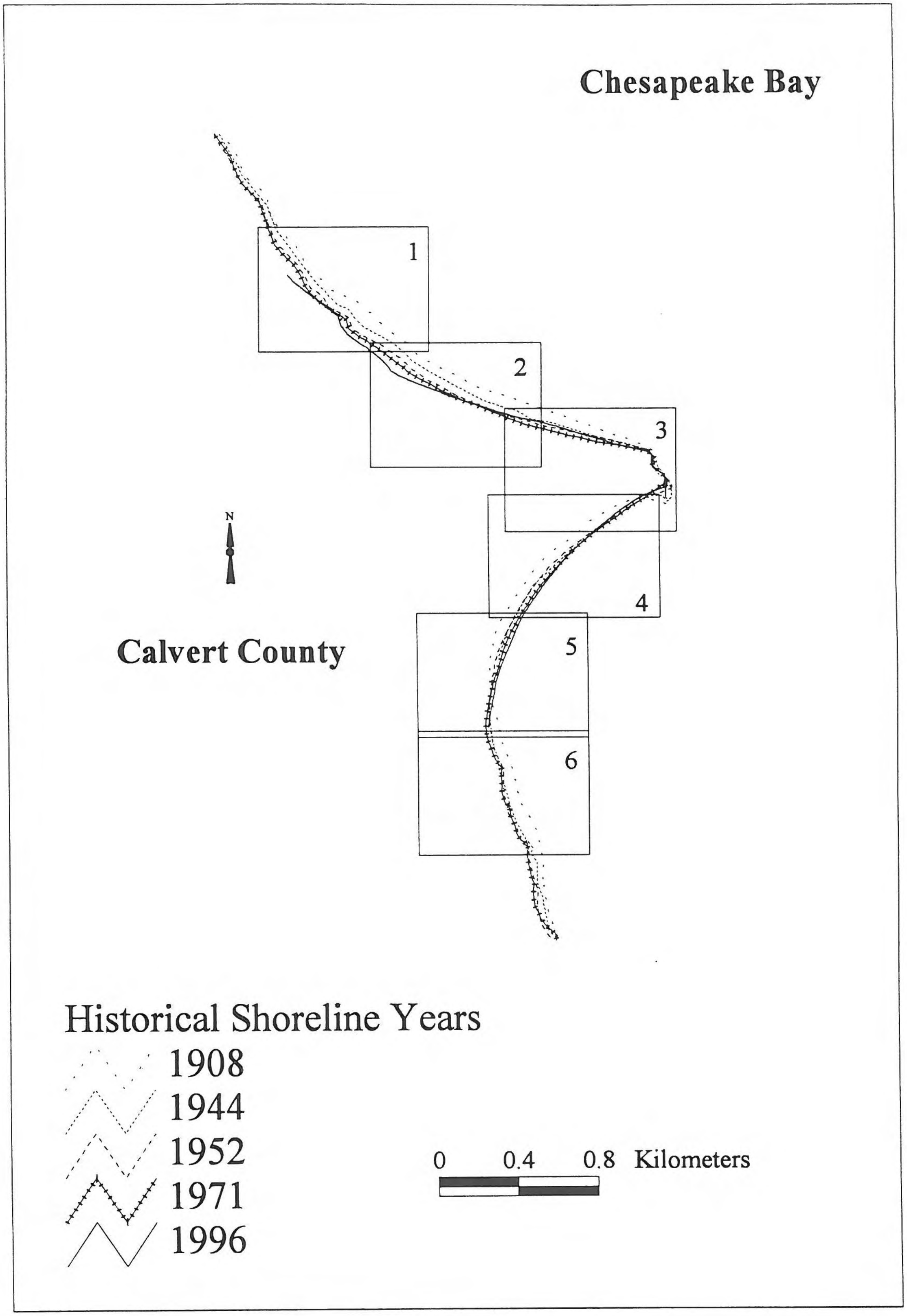


Figure 15. Cove Point historical shoreline index map.

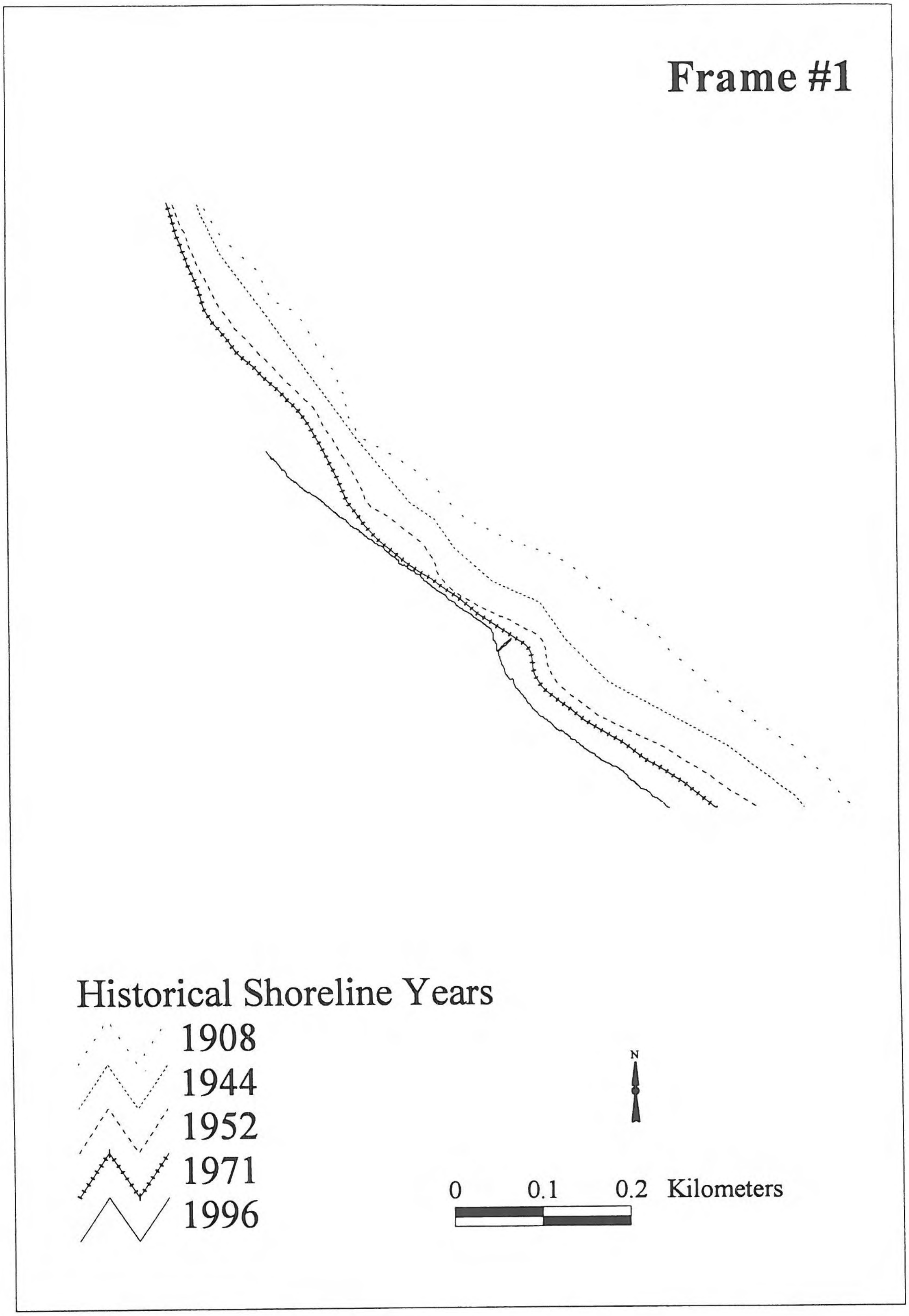


Figure 16. Cove Point historical shorelines, Frame #1.

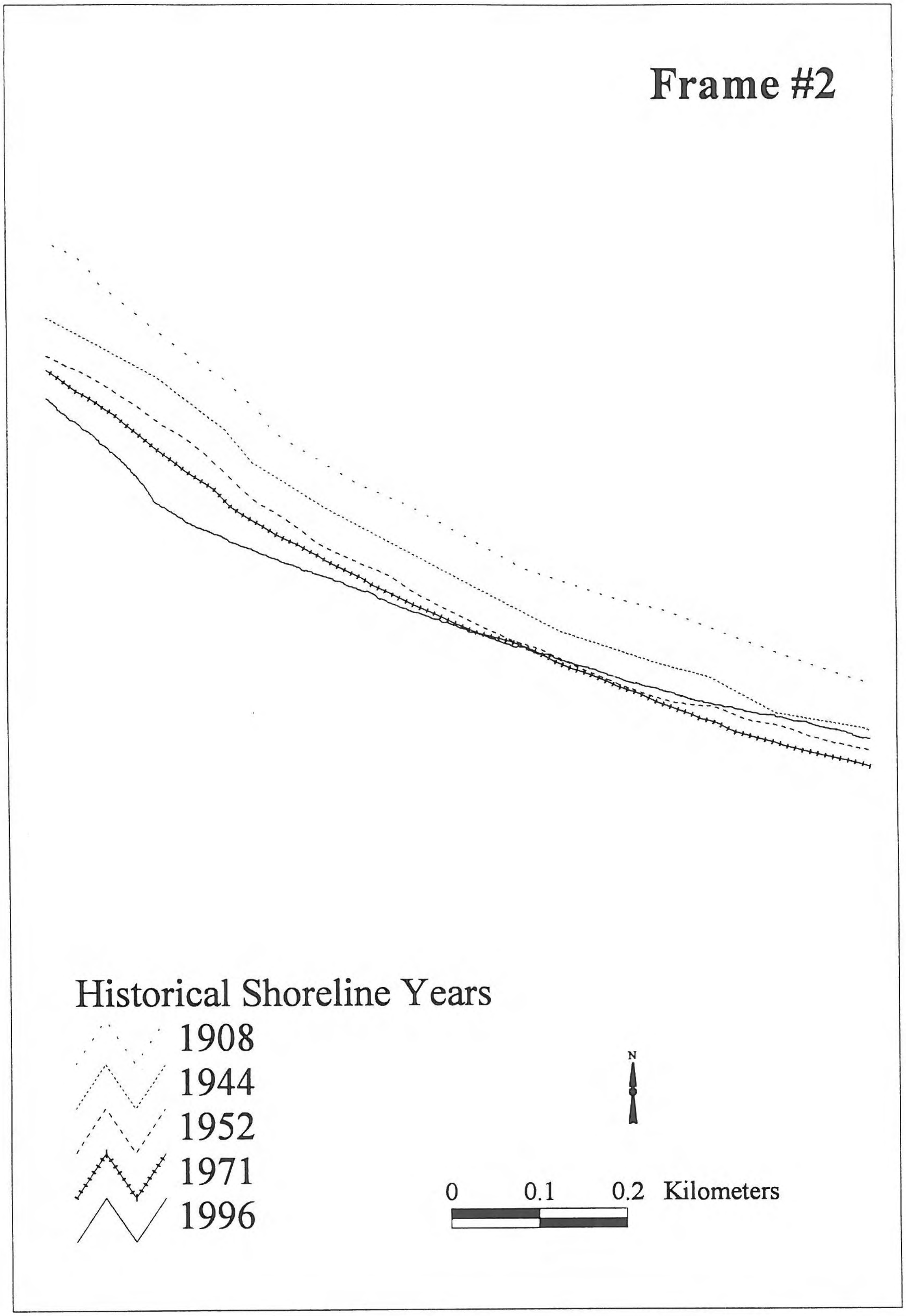


Figure 17. Cove Point historical shorelines, Frame #2.

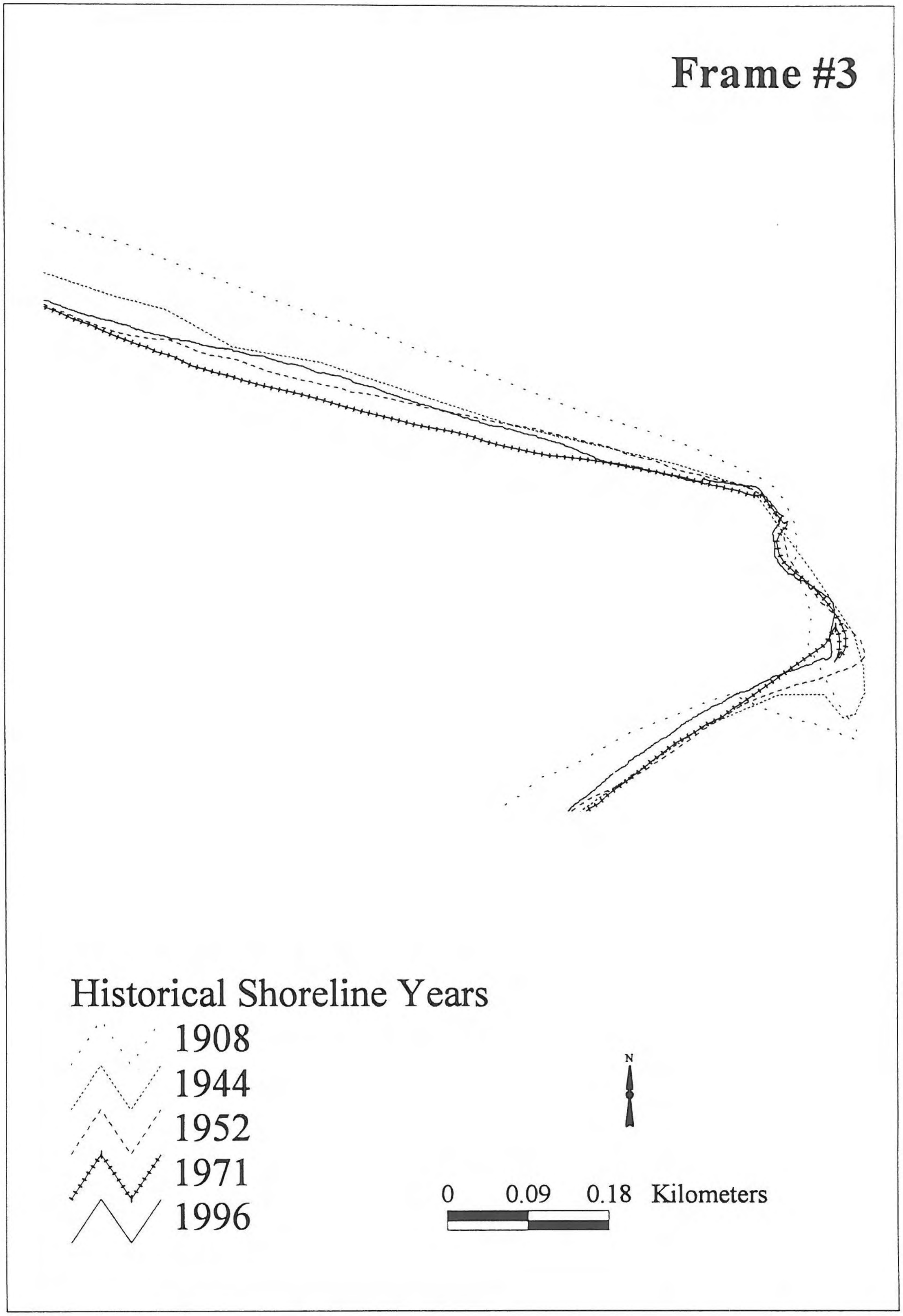


Figure 18. Cove Point historical shorelines, Frame #3.

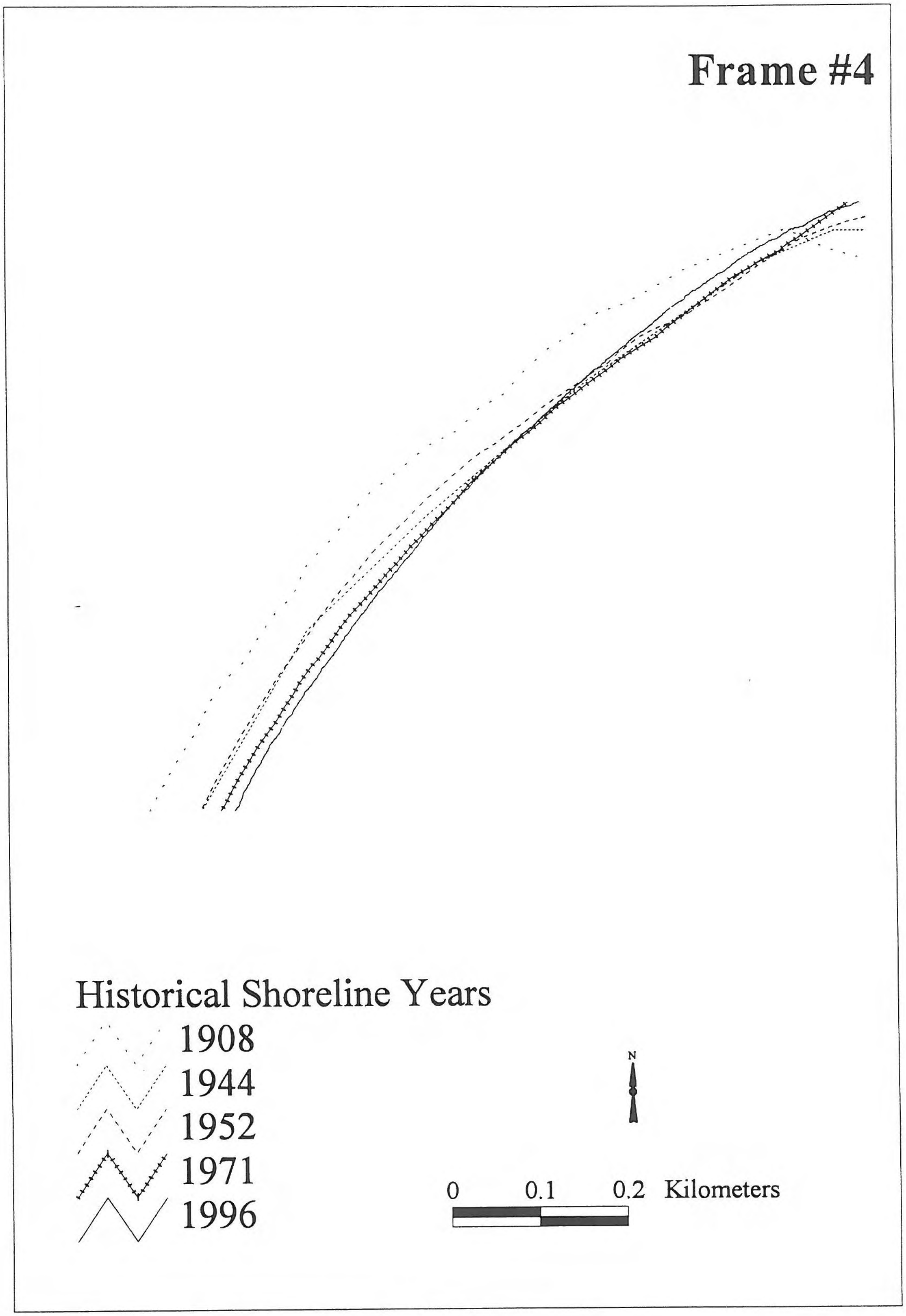


Figure 19. Cove Point historical shorelines, Frame #4.

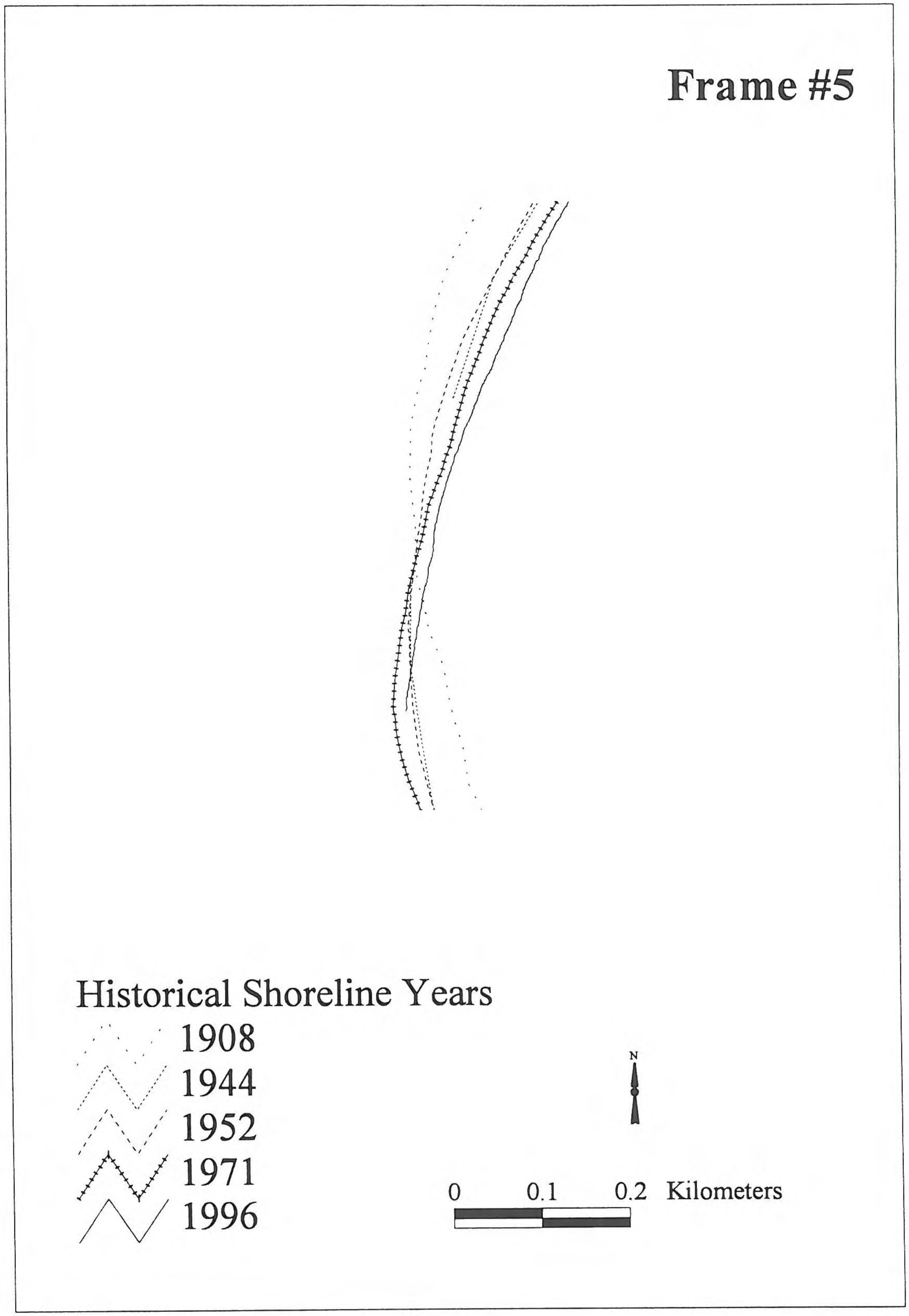


Figure 20. Cove Point historical shorelines, Frame #5.

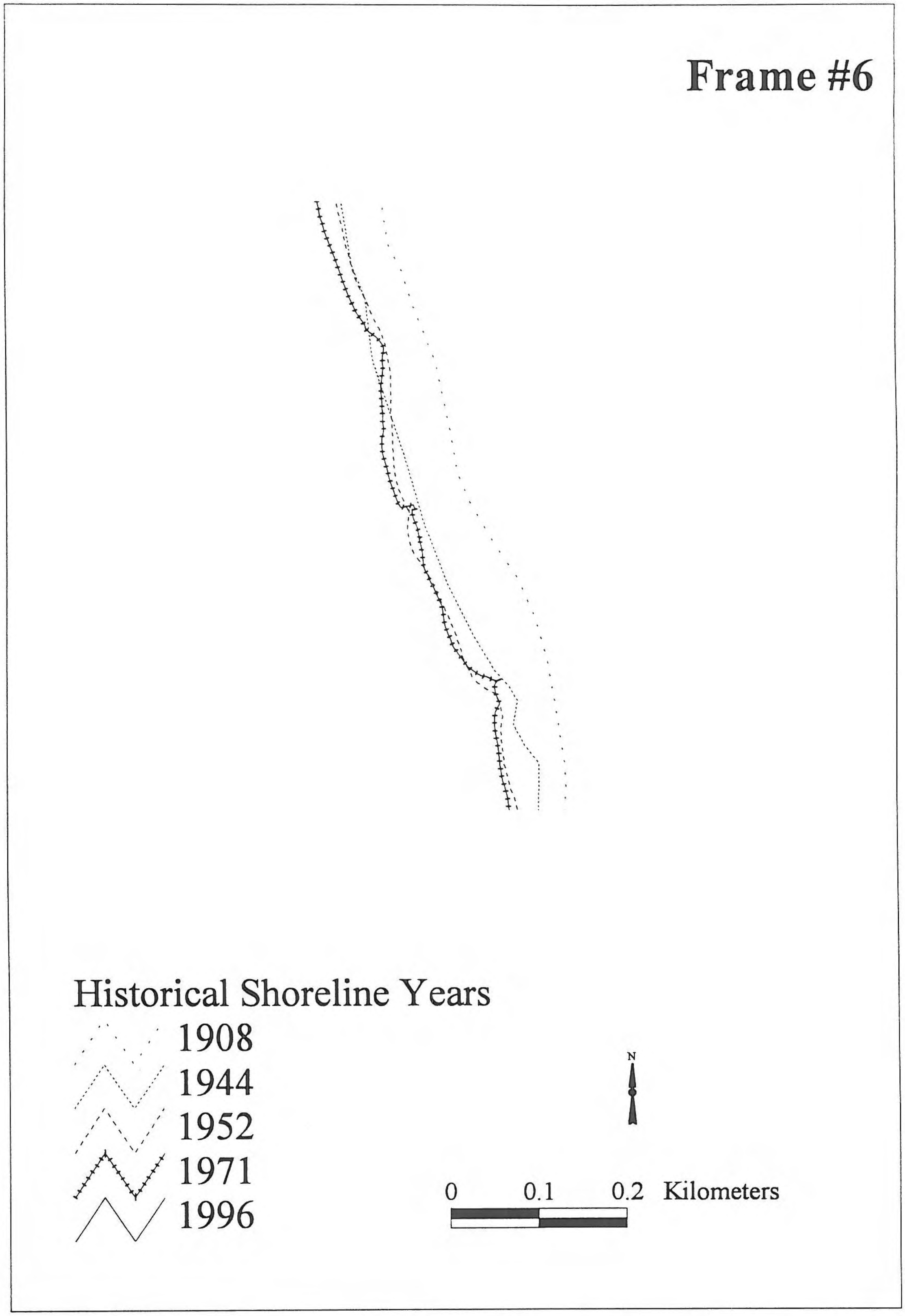


Figure 21. Cove Point historical shorelines, Frame #6.

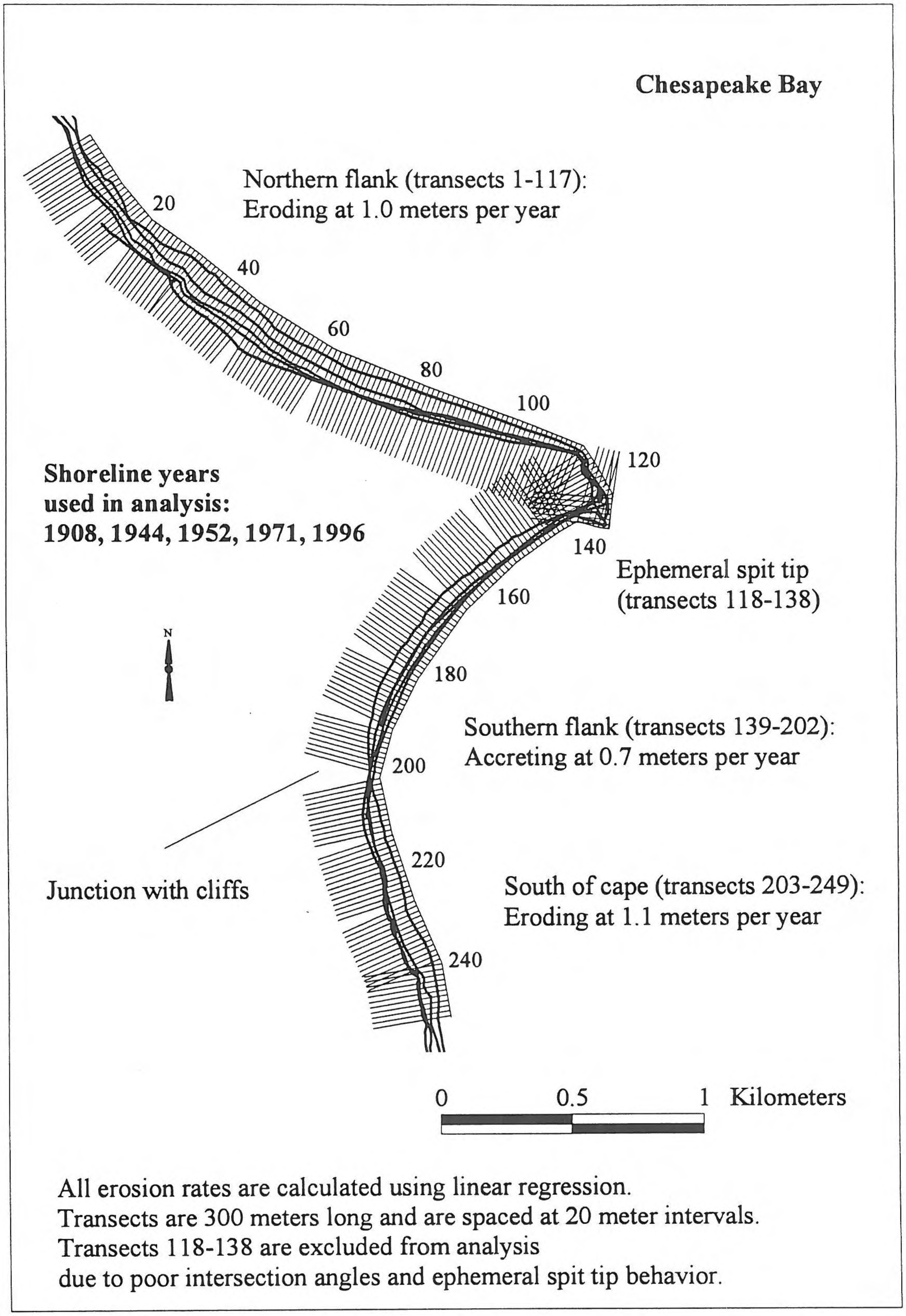


Figure 22. Cove Point, average erosion rates and transects map.

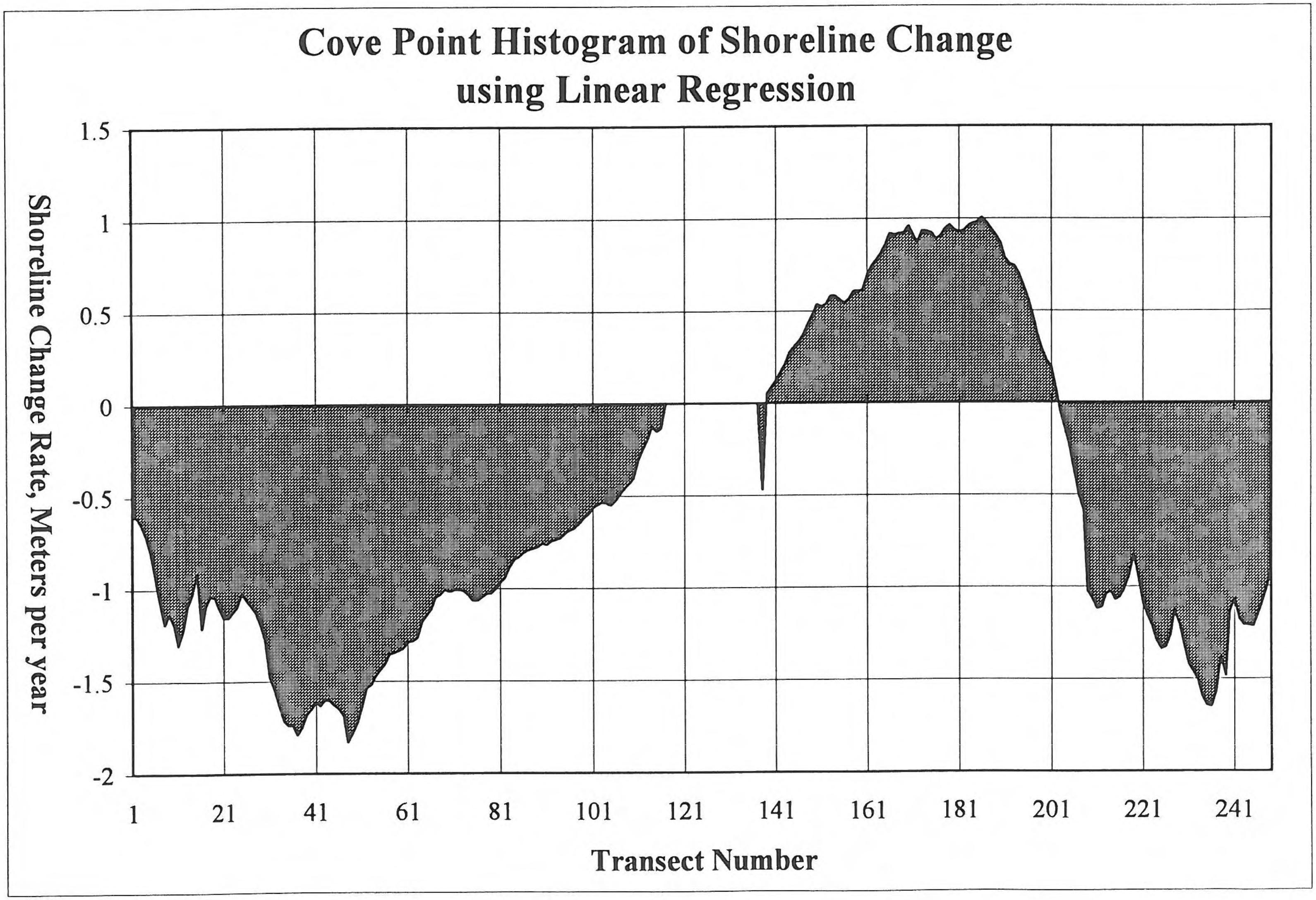


Figure 23. Histogram of Cove Point historical shoreline change rates.

same erosion is apparent; however, the spacing between individual shorelines is larger, reflecting the higher erosion rates. In Frame 3 (Figure 18) erosion is again evident, but the spacing between shorelines decreases further south. Frame 3 also reveals a localized erosion reversal between 1971 and 1996. Figure 24 shows that while this part of the coast was erosional between 1908 and 1971, it has experienced accretion between 1971 and 1996 along a 680 meter section of coastline, with a maximum seaward movement of 30 meters. A histogram of recent shoreline change at this zone of accretion (Figure 25) shows that the shoreline has prograded at up to 1.2 meters per year over this 25-year period. A histogram plot (Figure 26) reveals that the shoreline change rate for this zone was erosional prior to 1971, ranging from almost 1.2 meters of retreat per year (near the middle of the northern flank) to nearly zero meters of erosion at the tip of Cove Point (the location of the concrete seawall which protects the Cove Point Lighthouse). The northern end of this seawall marks the boundary between the zone #1 (the northern flank of Cove Point) and zone #2.

Cove Point, Zone #2: Tip of Cove Point (transects 118-138)

The most seaward projecting portion of Cove Point has been partially stabilized by the construction of a 2.0 meter high concrete seawall and nine small jetties along 130 meters of coastline (Figure 6). The southern tip of the spit has not been armored; this area exhibits erratic behavior with no discernible long-term trend of shoreline change (Frame 3, Figure 18). This ephemeral spit, which

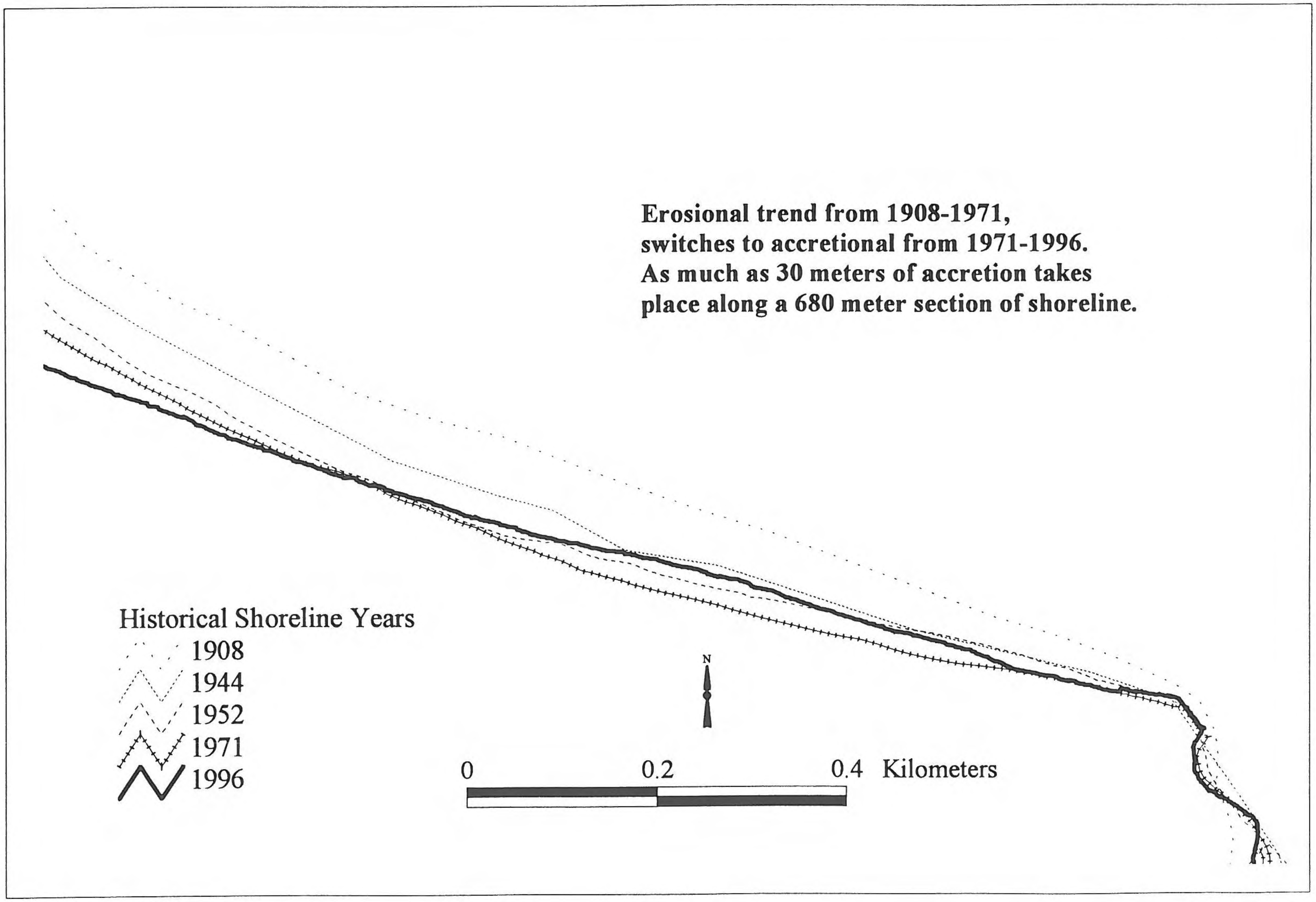


Figure 24. Area of recent accretion at Cove Point.

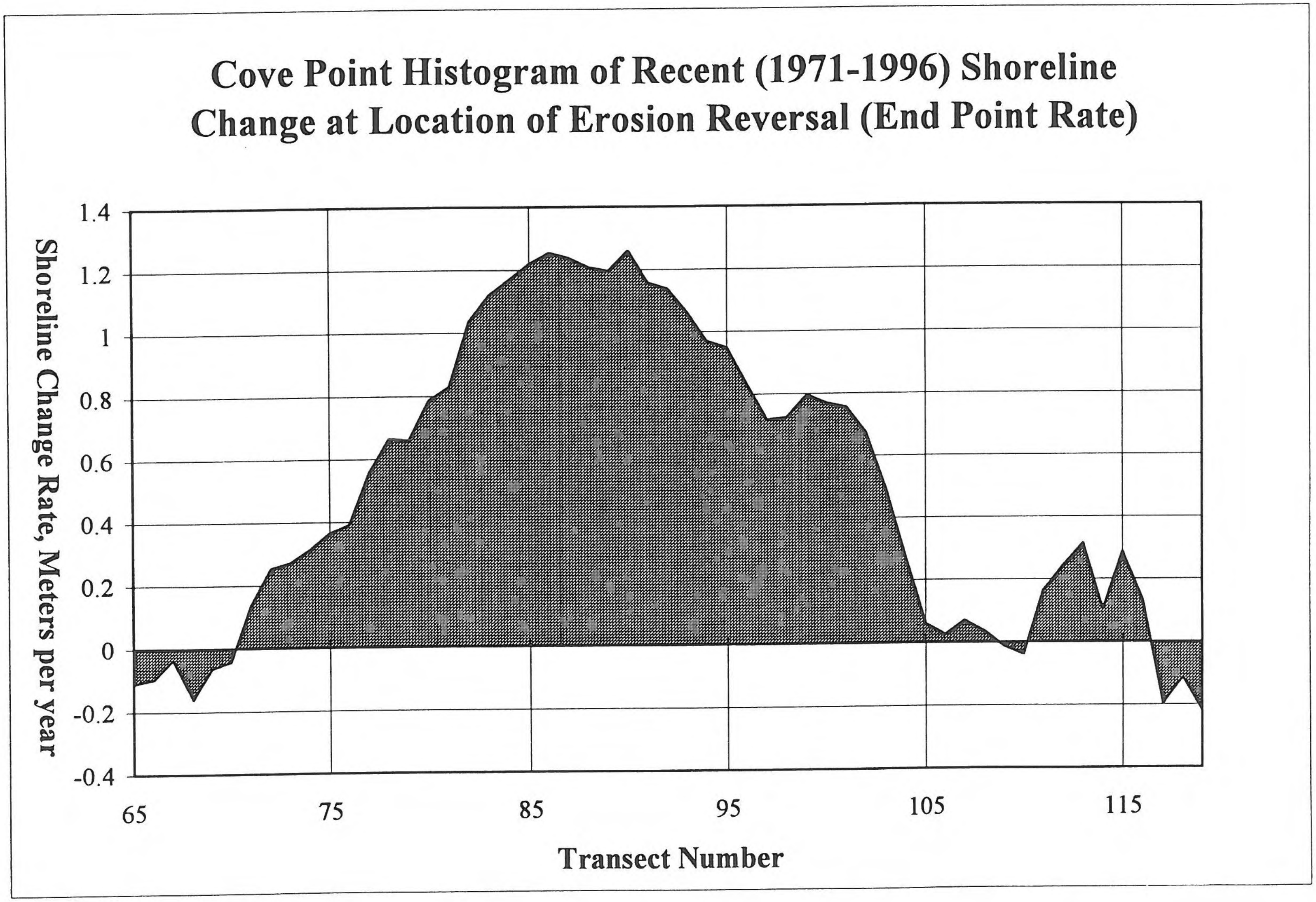


Figure 25. Cove Point shoreline change rates (1971-1996).

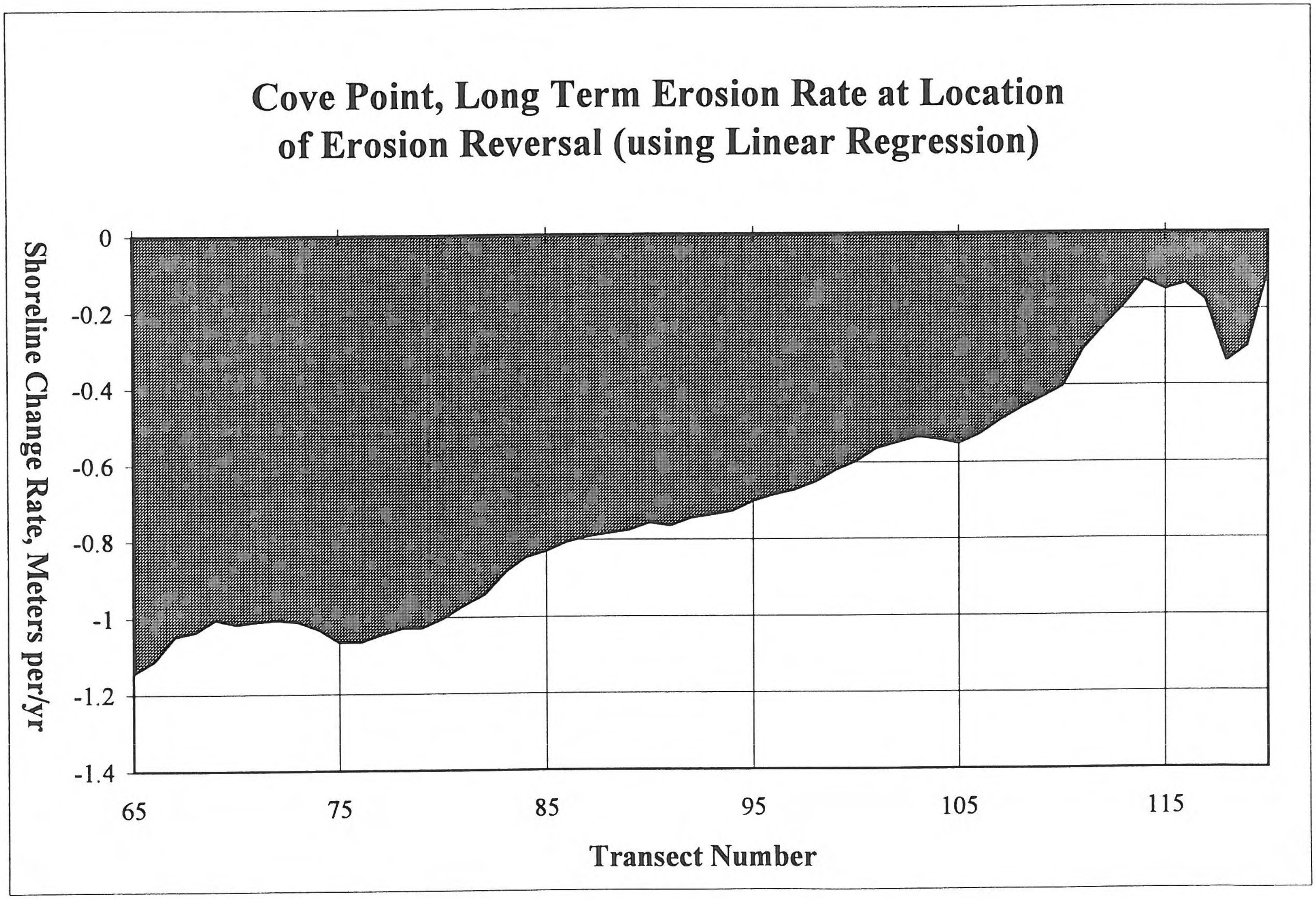


Figure 26. Cove Point shoreline change rates (1908-1971).

appears largest in 1908, is constantly reorienting and reforming and is closely related to the large shoal associated with the apex of the foreland. This spit feature is low-lying, and is usually covered at high tide.

The portion of this zone which is protected by shoreline structures has been stable for most of the historical record. The concrete seawall was built in 1929; the nine groins (each 10 meters in length) were constructed between 1963 and 1971. Because the earliest accurate shoreline available for this area is 1908, it is not possible to determine the historical trend prior to anthropogenic impact for zone #3.

Cove Point, Zone #3: Southern flank of Cove Point (transects 139-202)

The southern flank of Cove Point is characterized by a wide beach and a steeply sloping foreshore. The backshore is wide and well elevated above sea level. The ridge at the crest of the backshore represents the highest natural topographic feature of the foreland. There is some eolian deposition, but no real dunes have developed.

This zone is accreting at an average rate of 0.7 meters per year during the long-term historical shoreline record of Cove Point (1908-1996). Again, there is considerable variability within this average as seen from a histogram plot of the linear regression rates of shoreline change (Figure 23). Near the tip of spit, accretion is as slow as 0.1 to 0.2 meters per year. There is some recent localized erosion at this point, although the change is too small to be significant. It is possible that the seawall and groins at the tip of Cove Point are influencing this stretch of coastline. Shoreline progradation is more rapid to the southwest, peaking between transects 163 to 185 at nearly 1.0 meter of accretion per year. This is also the center of the curve which comprises the southern flank of the foreland. Further southwest the accretion slows, eventually reversing to erosion at transect number 203 (the junction of the cape and the cliffs).

These trends are illustrated in the large scale maps of the historical shorelines (Frame 4, Figure 19, and Frame 5, Figure 20). Frame 4 shows the steady southeast advance of shoreline position between 1908 and 1996. The distance between successive years increases alongshore to the southwest. Frame 5 reveals a narrowing of this distance between individual shorelines, indicating a slower rate of accretion. The shorelines converge on a point and cross over each other so that the most recent shoreline (1996) is landward of the oldest shoreline (1908) south of transect 202 (Figure 20). This boundary between erosion and accretion is moving south with the migration of the cape at a rate of 1.7 meters per year. The 1908 shoreline intersects the 1944 shoreline at a point 150 meters north of the 1944-1996 intersection, reflecting a southward movement of the accretional zone. This inflection point marks the end of the present-day foreland, and is also the boundary between zones 3 and 4.

Cove Point, Zone #4: South of the foreland (transects 203-249)

This section of the coast is characterized by a very narrow foreshore with no backshore. The Miocene-aged bluffs are wave cut and are part of the active beach system. This zone has been eroding at 1.1 meters per year for the duration of the historic record (1908-1996). An examination of the historical shorelines displays the continuous long-term erosion (Frame 6, Figure 21). This stretch of shoreline is morphologically similar to the Calvert Cliffs area just north of Cove Point. The coastline is retreating on both sides of Cove Point as well as on the northern flank of the cape itself. The southern flank continues to prograde, which is part of the long-term morphological process which has constructed this sandy cape.

Flag Ponds shoreline change

Flag Ponds is a sandy cape feature a few kilometers north of Cove Point. It is also migrating to the south, a reflection of the overall southerly littoral drift. Beach ridges are evident from aerial photographs, and cat-eye ponds can also be discerned. Flag Ponds is much smaller than Cove Point, and can be considered an incipient cuspate foreland. It is possible that the shoreline movement which can be observed from the historical record of Flag Ponds are similar to the early morphological behavior of Cove Point. Flag Ponds may be divided into three basic zones or units of behavior; the northern erosional flank (zone #1), the southern accretionary flank (zone #2), and a short stable area just south of the cape (zone #3) (Figure 27). Figure 28 shows the historical shorelines for Flag Ponds as well as frame numbers for larger scale maps (Frame 1, Figure 29; Frame 2, Figure 30; and Frame 3, Figure 31).

The northern unit of Flag Ponds is approximately 1060 meters long. This stretch of the Calvert sandy cape has been eroding at 0.9 meters per year for the duration of the historic record (1847-1971). This is similar to erosion rates associated with the northern flank of Cove Point. Frame 1-2 (Figure 29 and Figure 30) shows this pattern of continuous retreat. A histogram plot of the shoreline change shows the variability of the shoreline change rates (Figure 32). Part of Flag Ponds is eroding at over 1.0 meters per year. Further south, the erosion rate slows, eventually reversing to accretion at transect #55.

The southern flank of Flag Ponds is accreting at an average rate of 1.6 meters per year along a 900 meter stretch of the coast between 1847 and 1971. The oldest shoreline (1847) appears to be a large sand hump along the coast. The northern side of this feature is eroded while the hump migrates rapidly south. A noticeable spit developed at the distal end of the foreland in 1908. It is probable that such spit development is continuous at Flag Ponds; the other historical shorelines do not show spits because they were mapped after the spit welded onto the front of the foreland. The rapid and continual southward migration is apparent in Frames 2 and 3 (Figure 30 and Figure 31).

The histogram plot of shoreline change for Flag Ponds (Figure 32) shows that accretion averages around 1.8 meters with a large spike of 3.5 meters near the

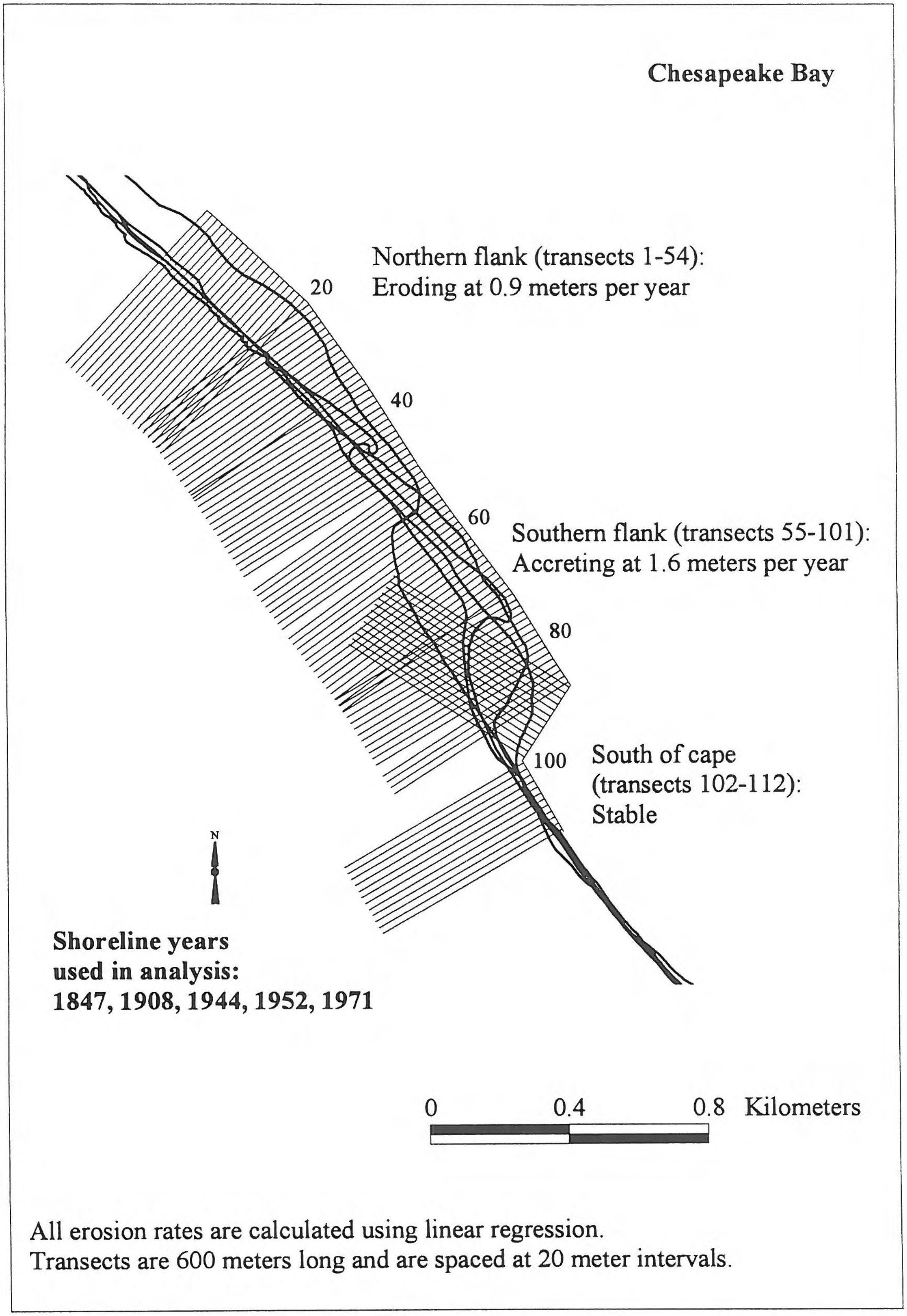


Figure 27. Flag Ponds, average erosion rates and transects map.

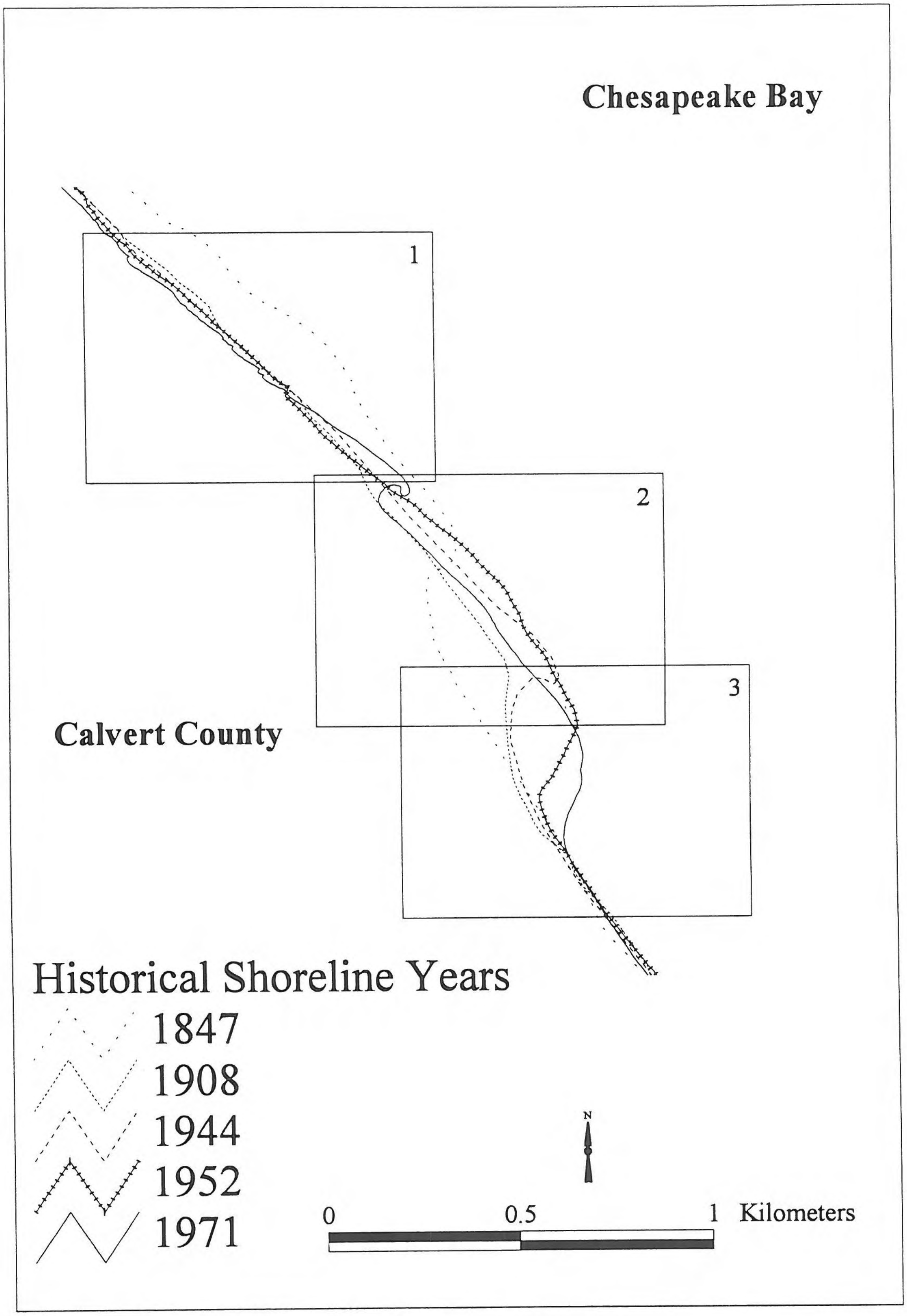


Figure 28. Map of Flag Ponds historical shorelines index map.

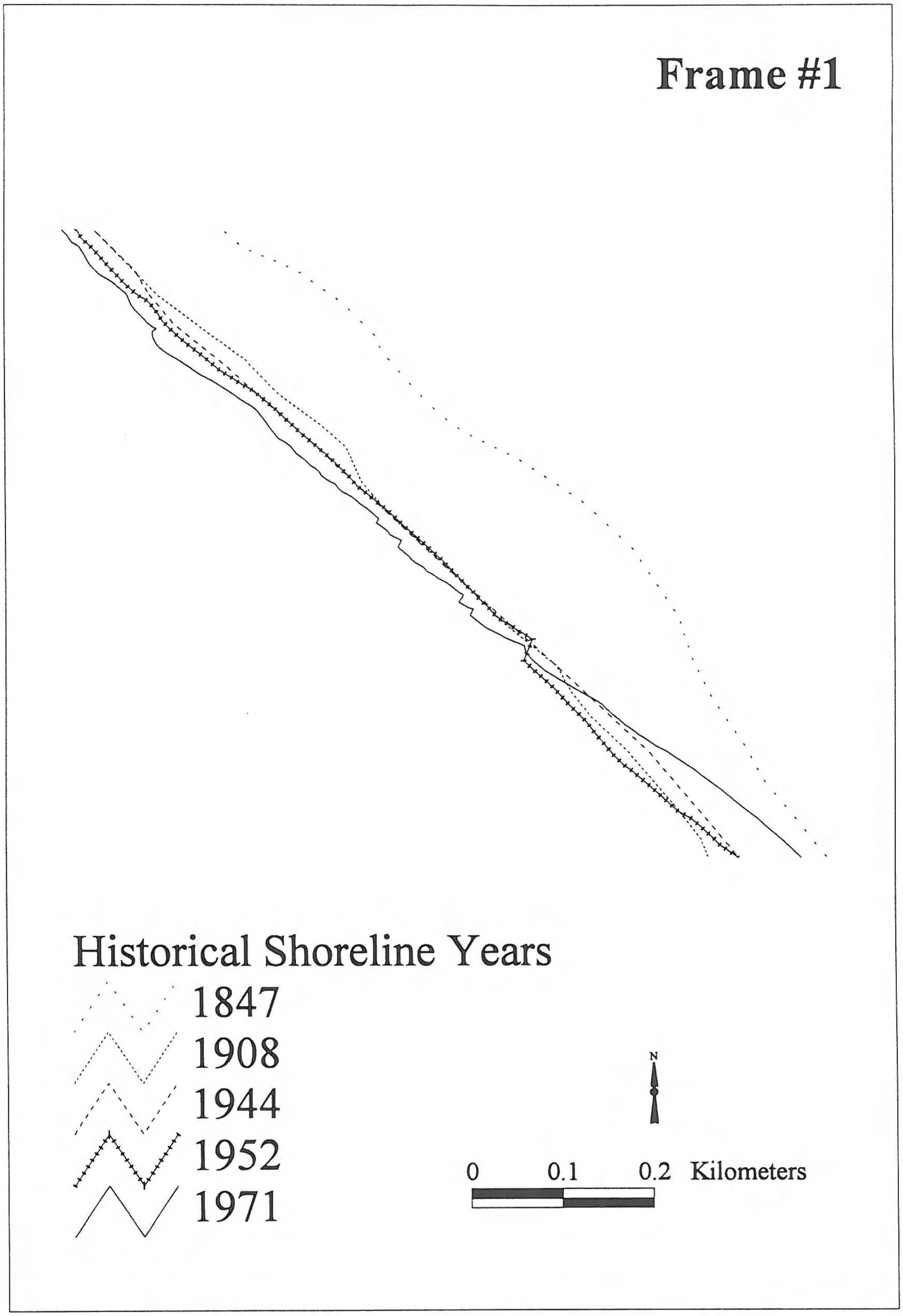


Figure 29. Map of Flag Ponds historical shorelines, Frame #1.

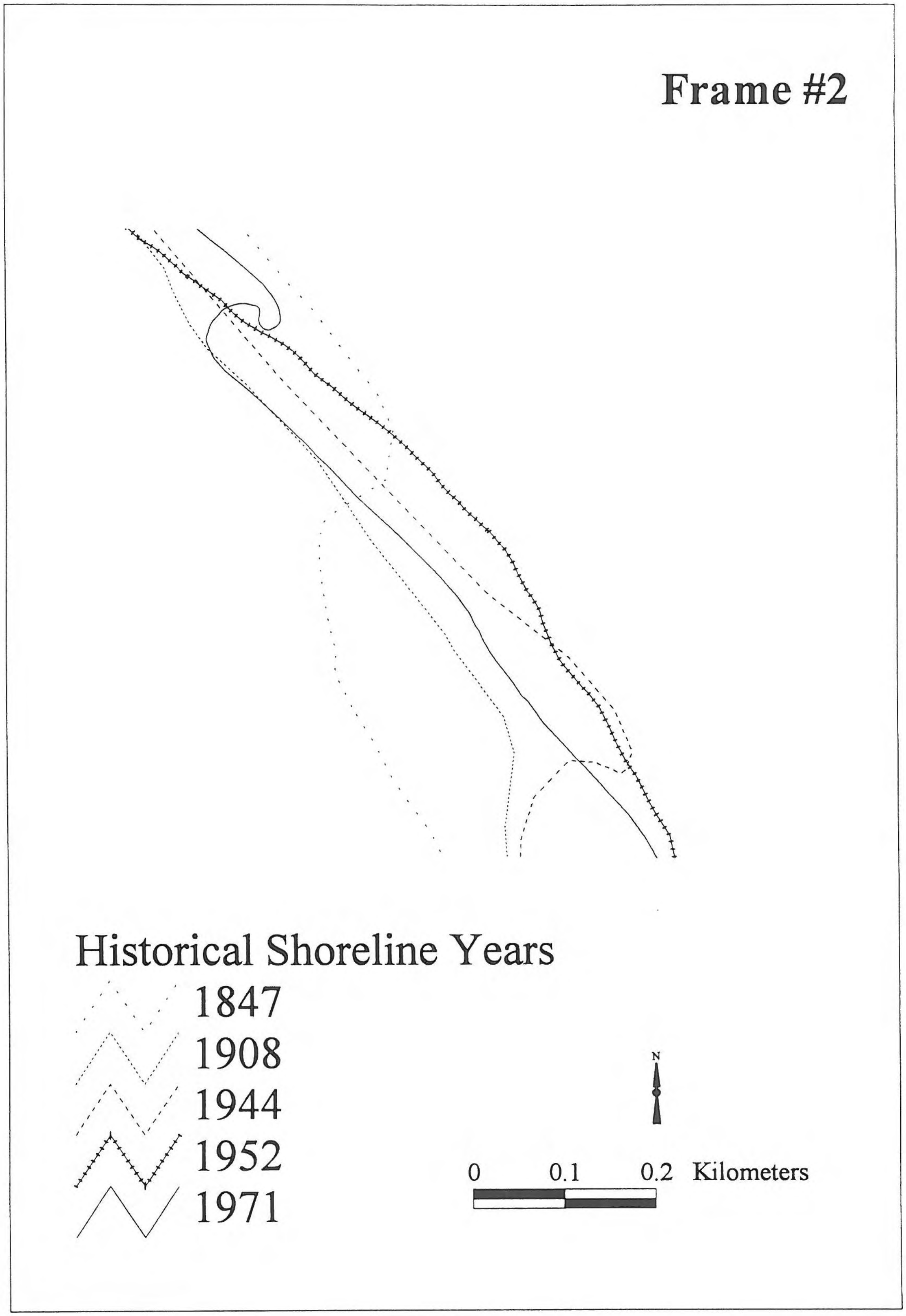


Figure 30. Map of Flag Ponds historical shorelines, Frame #2.

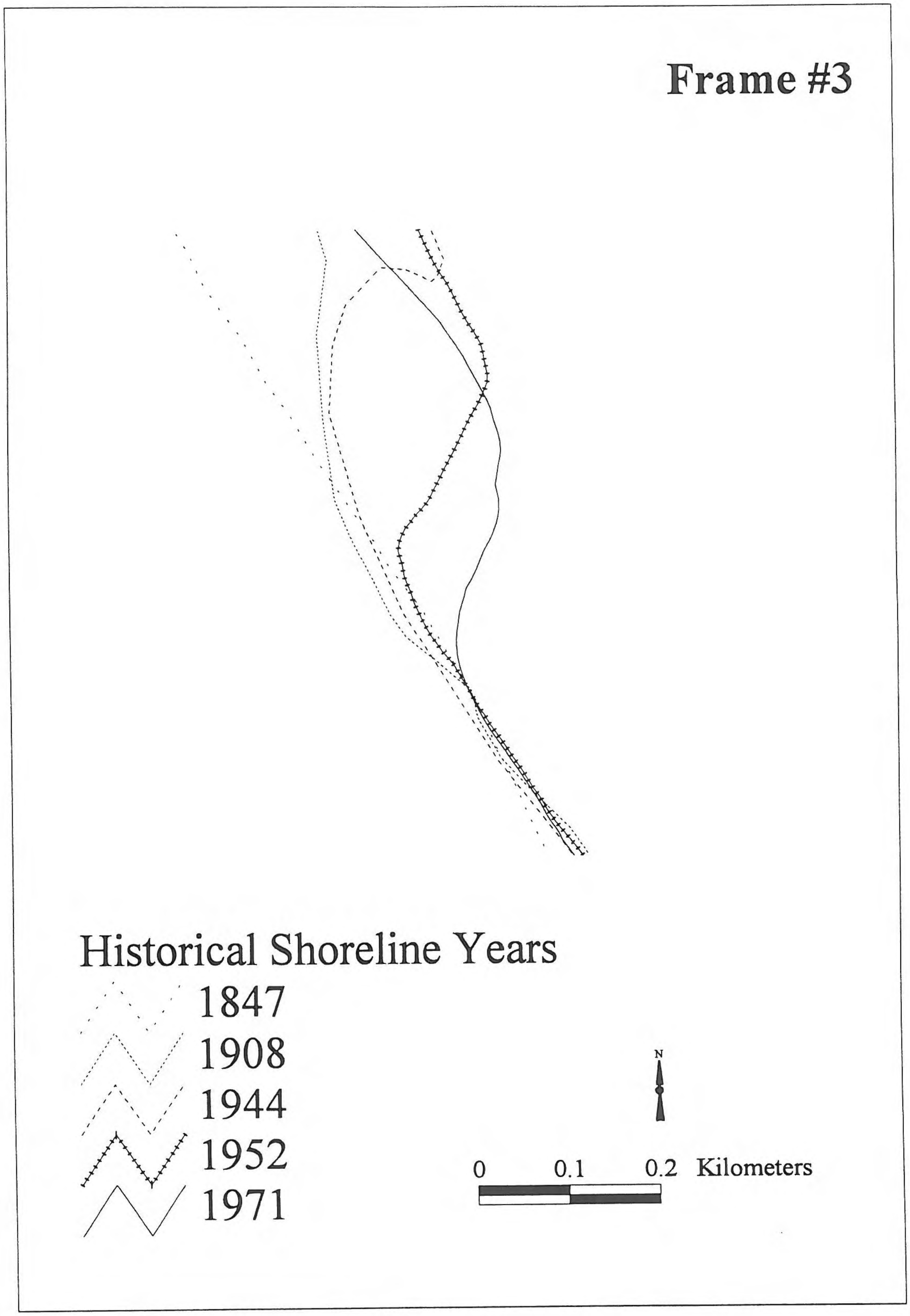


Figure 31. Map of Flag Ponds historical shorelines, Frame #3.

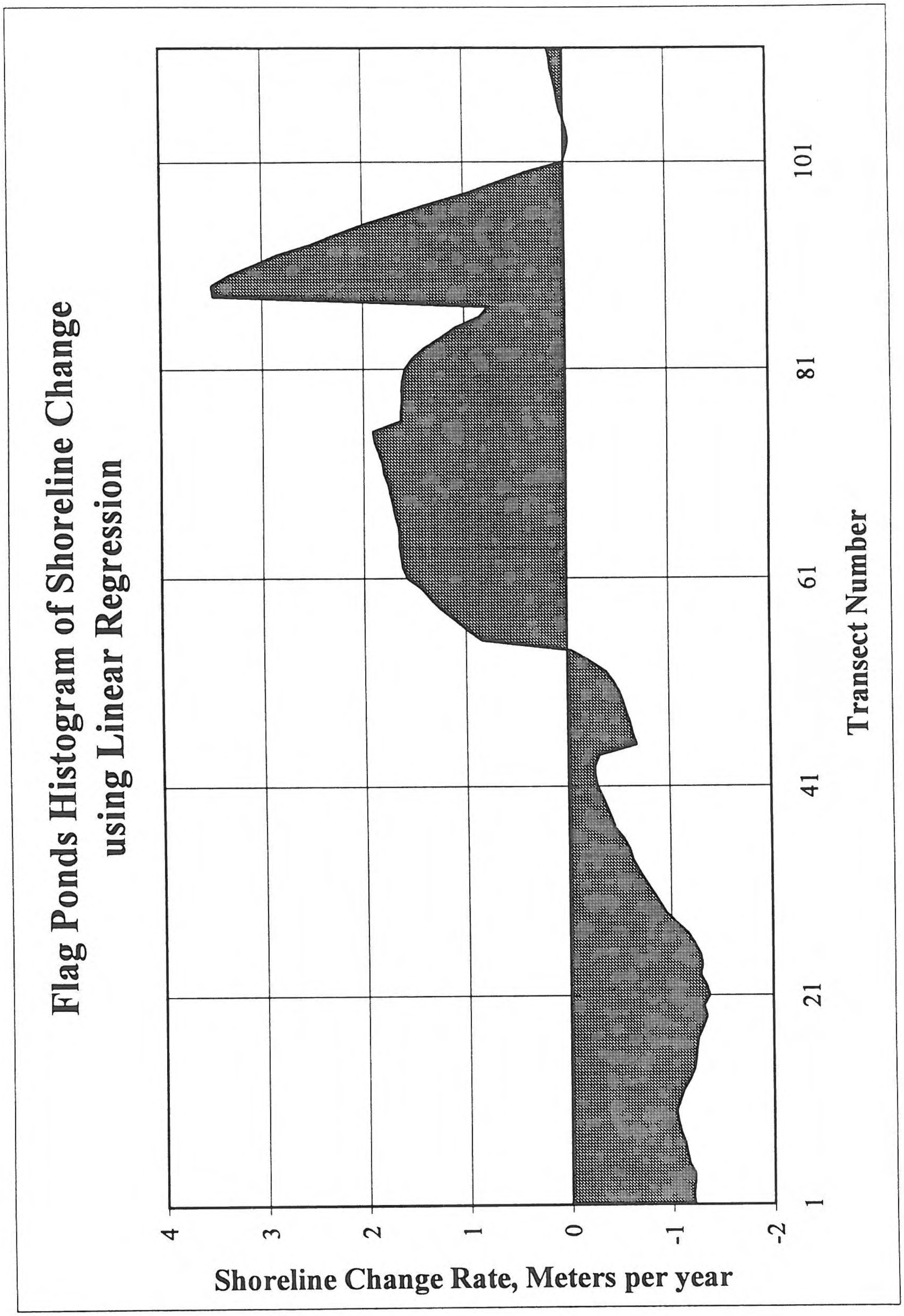


Figure 32. Histogram of Flag Ponds historical shoreline change rates.

south end of this zone. This spike is due to the odd intersection angles of some of the transects. These errors were unavoidable; the rapid lateral migration of the cape feature created difficulties when lining up transects perpendicular to all the shorelines.

The shoreline mapped in 1971 reveals a spit accreting laterally along the northern (erosional) flank of the foreland (Figure 30). This process is part of the normal development of the cuspate foreland, and provides evidence for explaining similar processes operating at Cove Point.

This section of the Calvert County coastline is 180 meters long, and is fairly stable over the period of record. The shorelines converge on a point in Frame 3 (Figure 31), indicating the end of the present day foreland. This area is relatively stable due to abundant sediment supply; further south, this trend becomes erosional (Downs, 1993).

Cove Point bathymetry

Local bathymetry for Cove Point is derived from an ADC Chesapeake Bay navigational chart book. Delineation of individual nearshore features is not possible due to the coarse resolution of the soundings. However, the bathymetry chart does provide a good overview of the nearshore conditions (Figure 33). The northern flank of Cove Point is generally much shallower than the southern flank. Offshore linear shoals are apparent from aerial photographs (Figure 3) along this flank. The northern flank is typically no deeper than 2 meters as much as a

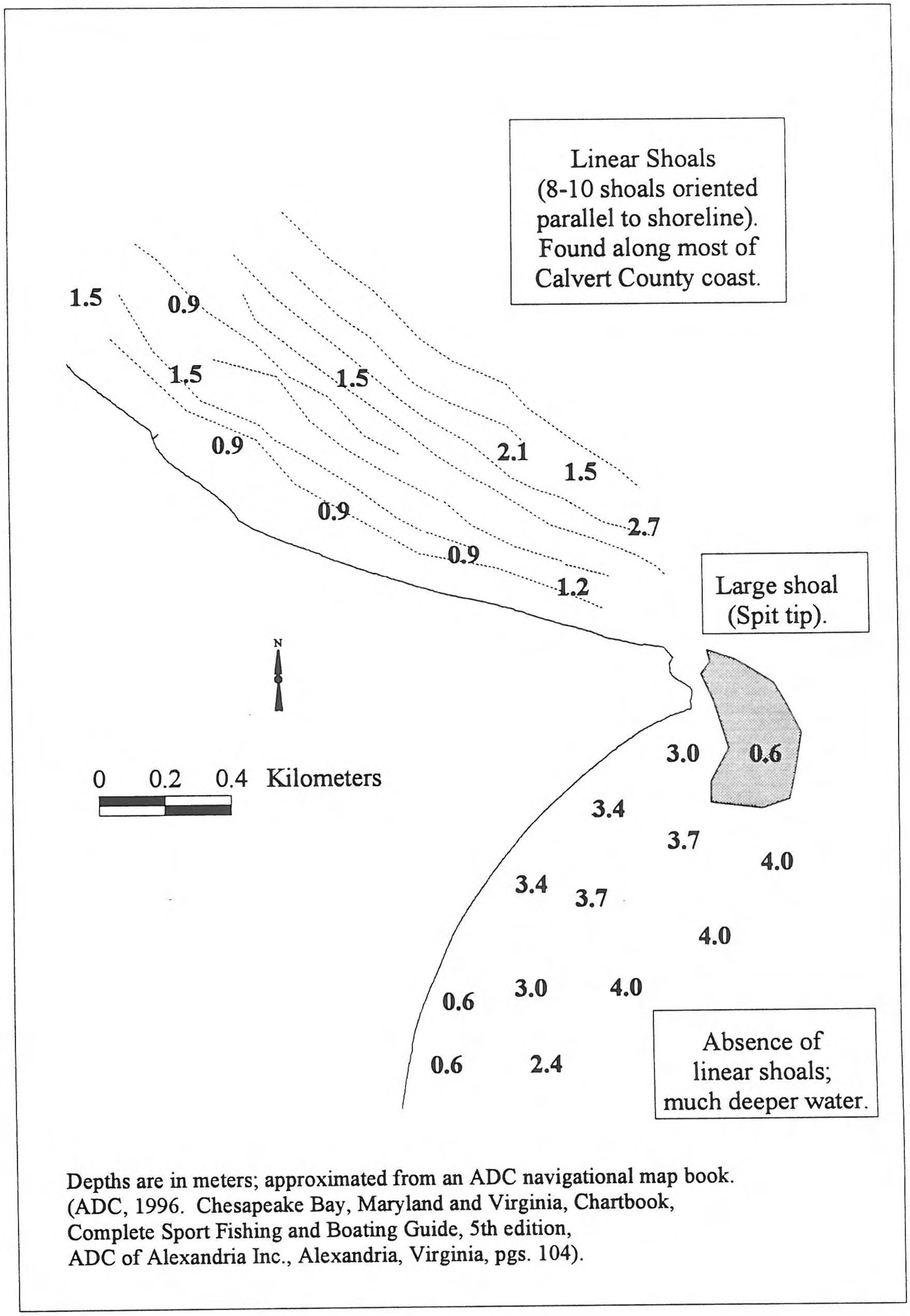


Figure 33. Map of Cove Point nearshore region showing bathymetry.

kilometer offshore. The southern flank of Cove Point is accreting into deeper water, and soundings indicate that the nearshore slope is much steeper. Much of this area, with the exception of the large shoal at the tip of Cove Point, is at or below the depth of closure (3 meters).

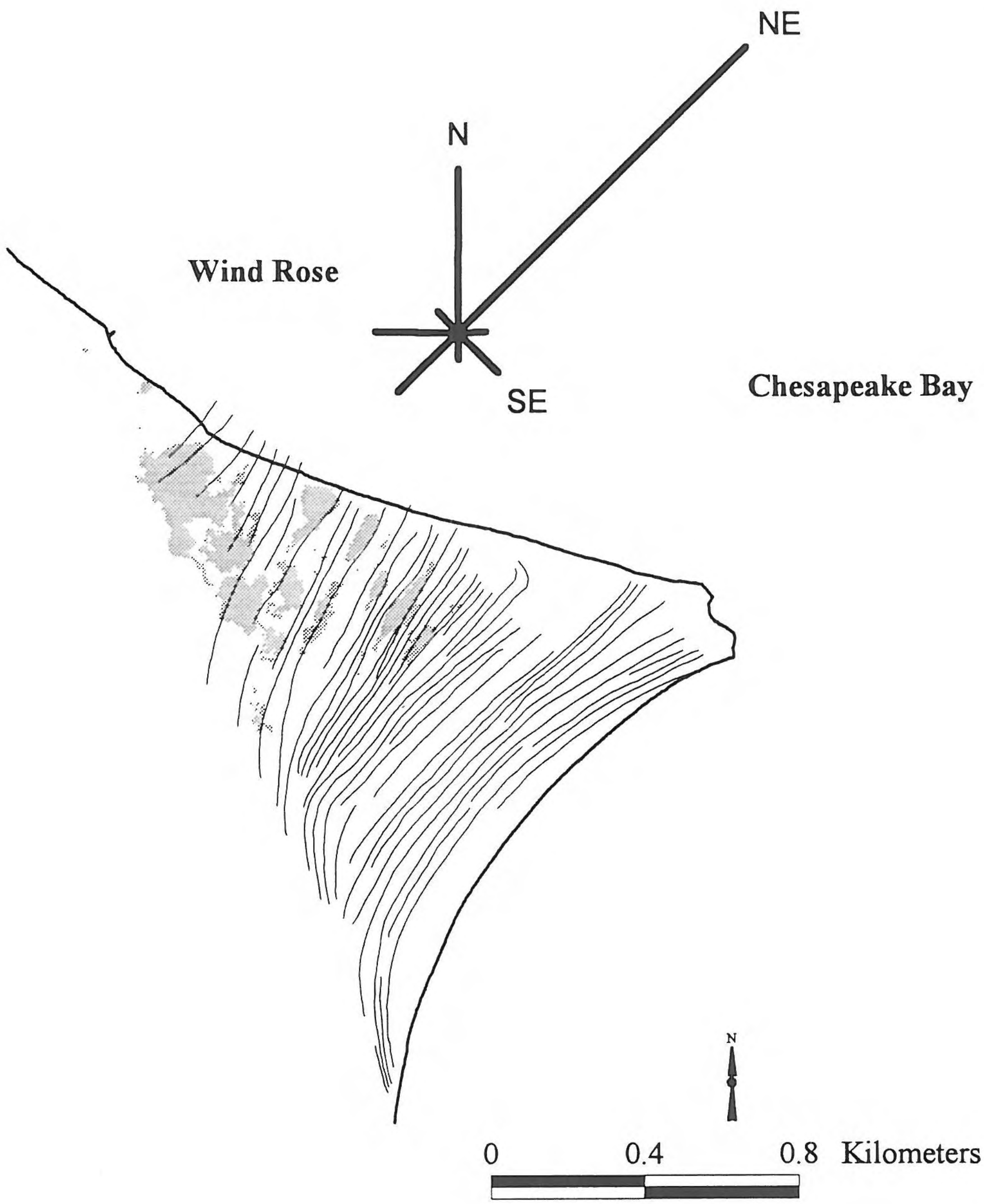
This bathymetry is consistent with the pattern of foreland migration. The nearshore conditions of the northern flank represent sediments eroded from this side of the foreland and deposited just offshore. The deep waters off the southern flank indicate that the present day cape has not yet migrated far enough south to begin deposition on top of the pre-Holocene marine sediments.

Cove Point wind climate

An analysis of the wind conditions between 1945-1980 at Patuxent Naval Air Station shows that Cove Point experiences winds from two primary directions; north/northeast and southeast, approximately normal to the flanks of the foreland (USACOE, 1985). Winds from the northeast tend to be stronger than the southeast as shown by the wind rose, a reflection of the dominant storm wind conditions which affect the Chesapeake bay (i.e. northeasters; Figure 34). These two directions also have the longest fetch for wave construction for Cove Point.

Pond mapping

The interior ponds of Cove Point have expanded significantly between 1938 and 1990, a process which is likely caused by an elevated water table



Wind rose is based on recurrence interval of high velocity winds (> 15 m.p.h.) at Patuxent Naval Air Station, between 1945 and 1980 (USACOE, 1985)

Figure 34. Map of Cove Point showing wind rose.

controlled by relative sea level rise. Analysis shows that the number of ponds has decreased from 48 in 1938 to 34 in 1990 (Figure 35). The total area of the interior ponds has increased from 7.43 to 11.72 hectares during the same time period. The reduction in the number of ponds coupled with the increase in total area indicates that individual ponds are enlarging and merging with other nearby ponds. This is resulting in a decrease in the total area of freshwater marsh.

Cove Point vibracores

A total of 21 vibracores were taken along a transect trending from northwest to southeast, perpendicular to the orientation of the beach ridges (Figure 36). These cores were used to reconstruct the depositional history of the cape. A log of each core taken is shown in Appendix A. Sediment size, sorting, color, and organic content were recorded for each stratigraphic unit. An interpretation of the depositional history is provided below with cross-sectional and plan-view illustrations. Cores are described in order from north to south along the transect. Each core is interpreted by depositional environment from bottom to top.

Samples from each core were tested for organic content. The irregular sampling design precludes a systematic analysis of carbon content by depth (the typical method of organic content analysis). The percentage carbon tests helped to differentiate between sediments which appeared to be high in organic content (darker clays, darker-mineral sands, etc.) from those sediments which are actually formed by the decay of organic material (e.g.., peat). The results of the organic

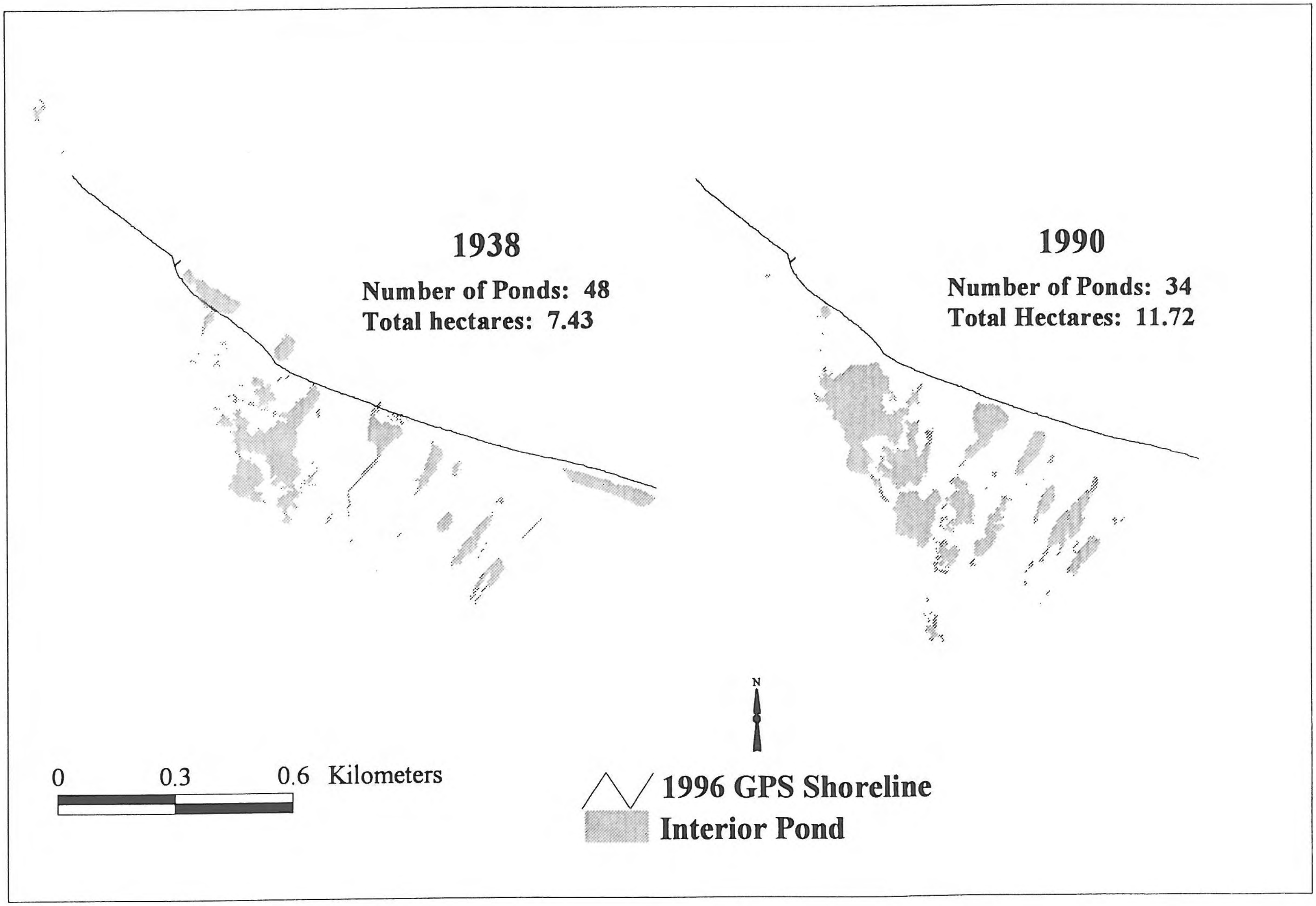


Figure 35. Maps of Cove Point interior ponds (1938 and 1990).

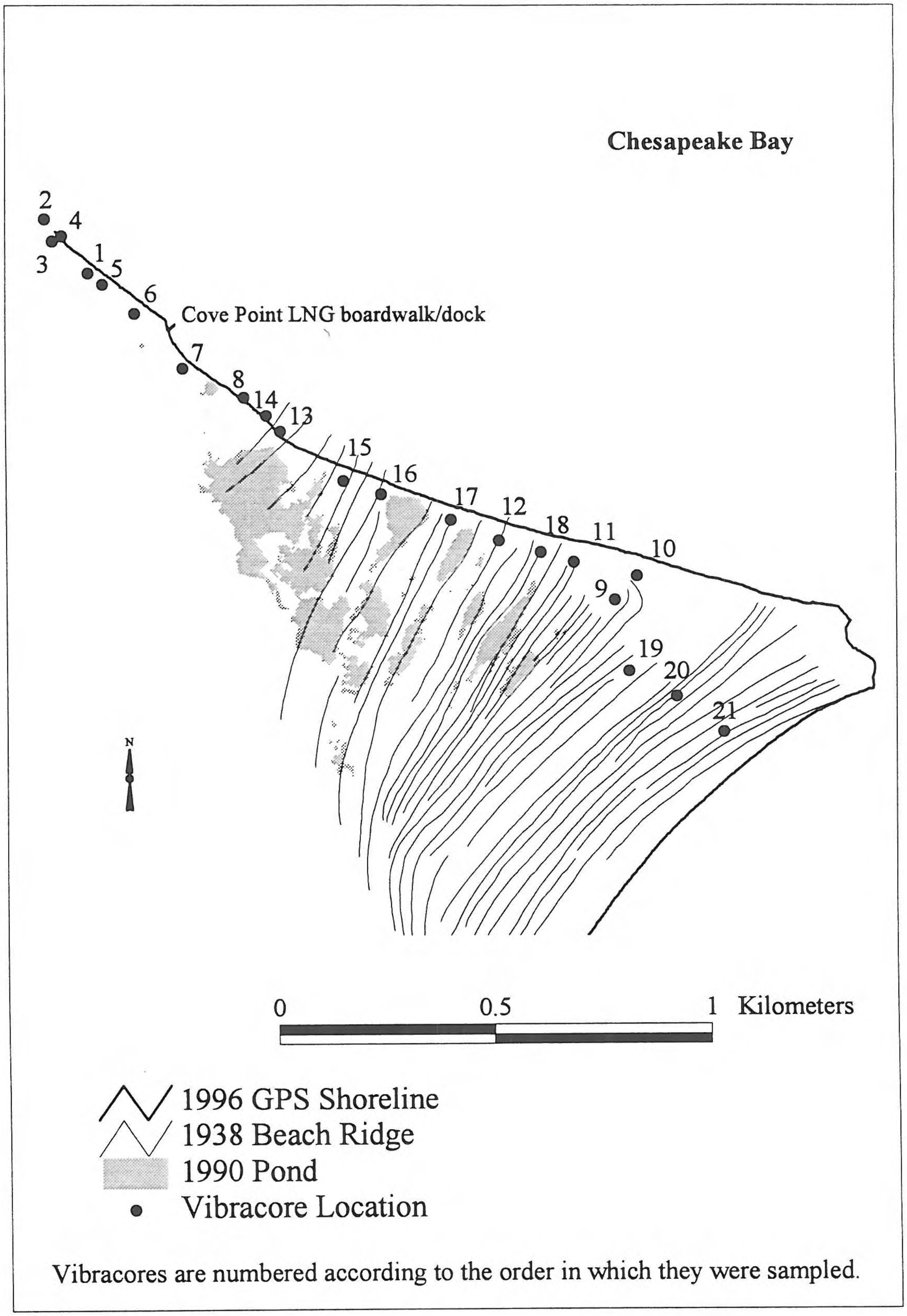


Figure 36. Map of Cove Point showing location of vibracores.

tests are plotted directly on each core log; these figures were useful when reconstructing the depositional history of each core.

Most of the vibracores reached through the Holocene littoral deposits to the underlying Miocene basement. This basement was typically a gray-green, silty clay or clayey silt and is part of the St. Mary's formation of the Chesapeake Group. The uppermost part of this unit often showed evidence of reworking and mixing with the coarser Holocene littoral sediments. Most of the cores contained coarse Holocene littoral sediments above the Miocene unconformity, usually shell lag deposits and larger-grained sands and gravels which were poorly sorted. Typically these coarse sediments were gray in color. This indicates that they were probably deposited in a high energy subaqueous environment such as a nearshore beach step or somewhere in the lower swash zone. Higher concentrations of shell lag were indicative of erosion (finer grained sediments are winnowed away, leaving the heavier shell deposits). The beach ridges usually are built over these units of coarser material, with a general fining upwards of sediments. The upper units of littoral deposition are usually orangish in color, indicating oxidation and hence subaerial deposition. This subaerial deposition took place as the berm (which comprises the future beach ridge) was built above the water level. As the ridge grew, the competence of the swash energy lessened, providing less energy for transporting large particles to the top of the ridge. Thus, the higher the ridge is built, the finer and more well-sorted the sediment. There were some shell lag deposits on this berm as well, probably because ridge construction is not continuous, but involves an overall process of accretion punctuated by shorter-term erosional events. The littoral sequences are generally thicker moving southeast along the transect. This is because more recent ridges were constructed during a higher sea level so their sand layers must be thicker to build above the water level. The sediment samples taken from the present day active beach were used to interpret these paleodepositional environments.

Some of these ridges were capped with short sequences of eolian sands as indicated by the excellent sorting and small grain size of the deposits. Above the littoral sediments nearly all the vibracore locations had peat deposits. This peat was typically black, indicating a freshwater marsh. Some of the peat deposits had sand particles in the matrix. This is eolian deposition, and means that the core location was near the active beach for some time so that sand could be blown into the marsh. Typically these fine-grained eolian deposits lessened near the top of the peat unit; probably because as the marsh accreted vertically, the active shoreline moved further from the core location. The top of each core was usually capped by active vegetation, either cattails or Phragmites. The following descriptions are specific to each core; also included are diagrams which are generic to several cores. Stratigraphic sequences of particular interest are diagrammed separately.

Core #1 (Figure 37)

This sedimentary column reached the underlying St. Mary's formation. The upper part of this clay/silt layer was reworked somewhat as beach ridge construction began. Above this is a high energy swash layer which is gray in color and is composed of coarse gravels and shell hash. This unit was probably deposited in the lower swash zone near the step. This unit fines upward to a contact with an orangish tan sand which has few shells. This is an indication of subaerial deposition, and suggests the construction of a berm. Phragmites rhizomes were found in these sands, possibly because these plants took root in the recently constructed berm before being topped by renewed berm construction. These berm deposits fine upward to the peat contact, which had some eolian sand (fine; well-sorted). The completeness of the littoral sequence suggests that this core was taken in the top of a ridge.

Core #2 (Figure 38)

This core is located furthest north along the transect in a shoreface peat outcrop. The base of the core may have contacted the top of the Choptank formation (a silty clay formation which is Miocene aged and is part of the Chesapeake Group). There is evidence that the upper part of this Miocene layer was reworked in the early stages of ridge construction. Above this reworked layer is a unit of charcoal which was dated at 1710 B. P. This material probably fell into the water from the nearby cliff and was trapped in the prograding ridge

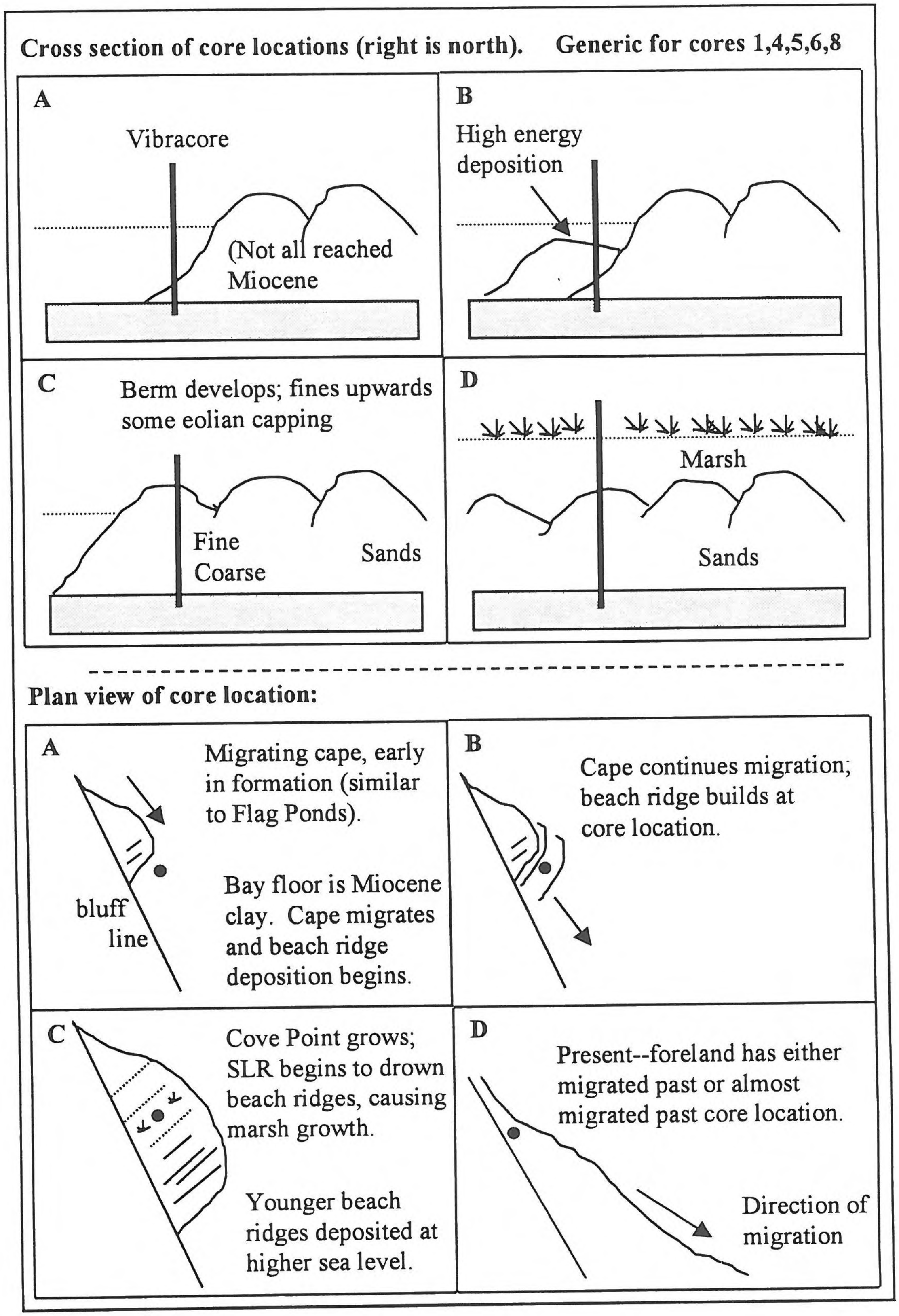


Figure 37. Diagram of stratigraphic development of cores #1, 4, 5, 6, 8.

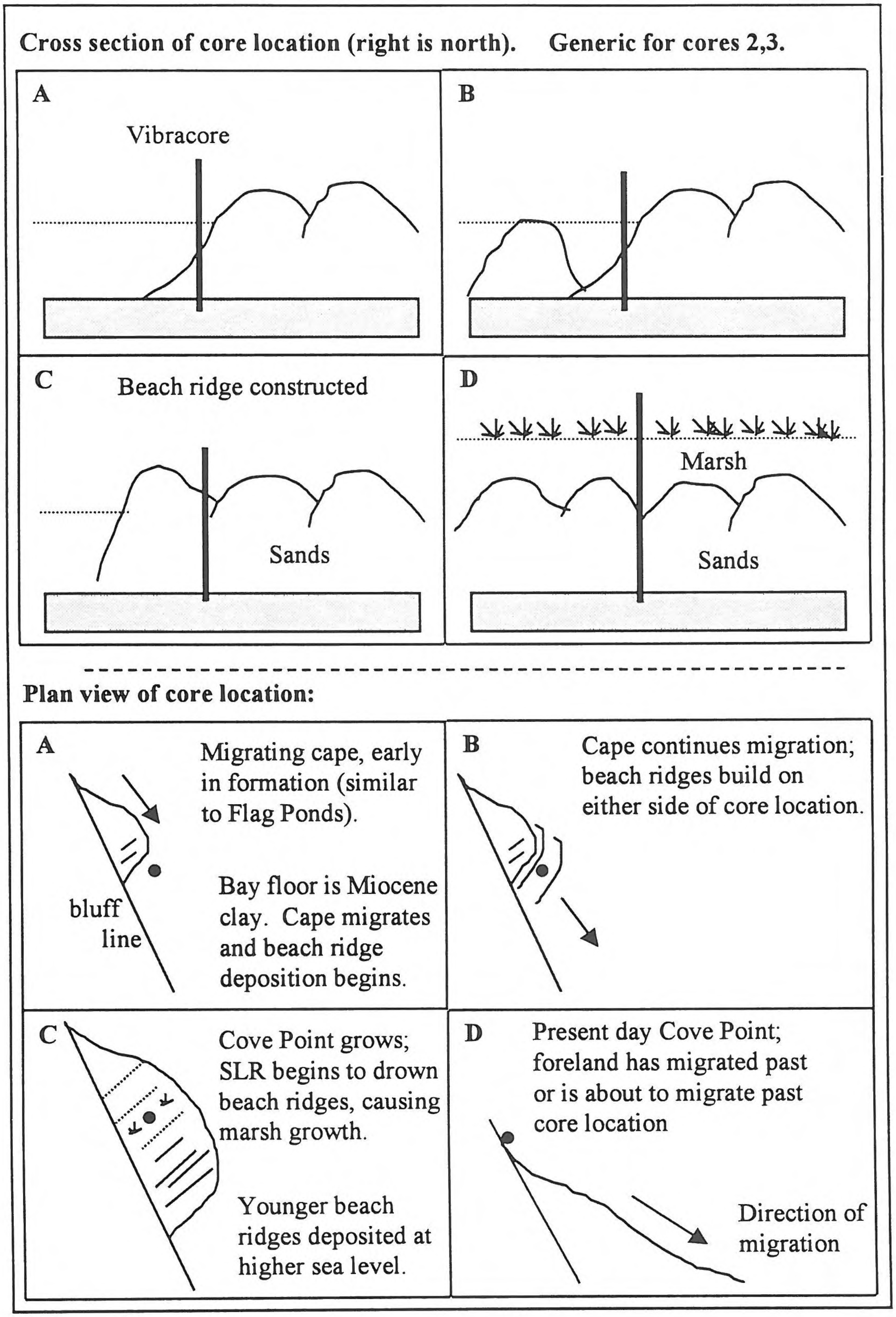


Figure 38. Diagram of stratigraphic development of core #2, 3.

sequence. It is likely that this charcoal was the product of either a lightning fire or a forest clearing fire set by local Indians. Above the charcoal is a high energy swash layer which is gray in color, indicating subaqueous deposition. This fines upwards until it contacts an orangish sand with very few shells. These sands appear to be berm deposits, and again they fine upwards to the peat contact. There is evidence of Phragmites within these berm sands, indicating that this plant may have taken root while the berm stopped growing, then was buried by renewed ridge building. The last few centimeters of the berm sands may be eolian. The peat unit has some eolian sands throughout the preserved sequence, an indication that this core location was never very far from the active shoreline at that time. Much of the peat unit was water, and poured out when the core was opened.

Core #3 (Figure 38)

This core reached the underlying Miocene layer, probably the St. Mary's formation of the Chesapeake Group. There is some reworking of the Miocene evident; above this is a very coarse unit, mostly gray in coloration. This is probably a high-energy zone of the foreshore such as the step. Above this is a variable unit of alternating clay and sand. The clay is probably aggregates which fell in from the nearby cliff, while the sand is part of the prograding ridge. Above this is a fairly well sorted sand layer which is tan colored, indicating that it was deposited in a subaerial environment and is probably part of the berm. This short ridge sequence is due to proximity of the antecedent shoreline, and the probable location of the core in a swale. The peat unit is very deep, indicating a long period of vertical marsh accretion. There is a thin band of sand within the peat unit which is from a fairly recent overwash event which probably occurred as the northern flank of the foreland approached this core location. The marsh resumed growth atop this overwash band.

Core #4 (Figure 37)

This core was probably taken in a swale, possibly the same swale as Core #3. It did not reach the Miocene basement material. The sands which comprise the littoral sequence appear to be entirely subaerial and is fairly well sorted with a general fining upwards. There are subtle changes within this until between coarser and finer grains of sand, indicating that the construction of this ridge was probably in stages with storms playing a role in these changes in composition. Above this sand unit the marsh has accreted vertically. There is some fine, well-sorted sand within this unit, an indication that this core location was probably close enough to the active beach for wind transport of finer grain sediments into the marsh.

Core #5 (Figure 37)

This core may have sampled a short layer of reworked Miocene sediments mixed with a higher energy unit of sand and shells. Above this reworked unit is a layer of coarse gray sediment which was deposited in the high energy foreshore.

This unit is topped by the orangish sand of the constructional berm; this layer has few shells and fines upward. It is probably capped by finer grained and well-sorted eolian sand. Above this is a fairly well developed peat unit, probably a result of the long period of marsh development (this core was taken in the oldest part of the cape). The depth of the littoral segment suggests that this core was in the top of a beach ridge. This core had one of the longest sandy units of any of the cores; it is possible the littoral sediments were deep here because they had to fill in a low in the Miocene surface. This local dip in the Miocene may have been from riverine dissection of the Miocene surface prior to the recent Holocene transgression.

Core #6 (Figure 37)

This core reached the Miocene unconformity. Above this is a zone of reworked Miocene sediments mixed with coarser littoral deposits. This is topped by the early construction of the beach ridge in the high energy foreshore zone. A piece of wood floated in and was trapped in this sequence; this wood was radiocarbon dated at 1270 B. P This sandy unit fines upwards to a unit which is probably constructed as a subaerial berm. Above this is the peat unit. This unit is relatively short; coupled with the depth of the littoral segment, this indicates that the core was taken in a ridge. It may also have been taken in a dip in the underlying Miocene, similar to Core #5.

Core #7 (Figure 39)

This core was taken in a cat-eye pond. The bottom of the core is in the Miocene; this Miocene clay grades into the recent clays and silts of the cat-eye pond. This pond formed when a spit wrapped around the front of the prograding foreland, cutting off an area of deeper water without depositing any littoral sediments within the pond itself. Sedimentation has partially filled in the pond (probably from the nearby cliffs), and an active marsh has grown above the older Miocene.

Core #8 (Figure 37)

The bottom of core #8 is highly variable and is probably a reworking of the upper Miocene as indicated by the presence of gray silt/clay. This silt may also be aggregates from the nearby cliffs. Wood floated in and was trapped during this reworking process; radiocarbon dating shows that the plant died at 1175 B. P.. There is a band of well-sorted sand above this of uncertain origin; above this layer is a coarse sandy layer with numerous shells. This unit is grayish in color, suggesting that it was deposited in a high energy subaqueous environment such as the foreshore. There are fewer shells in the unit above, indicating a lower energy deposition (higher in the swash zone). This is topped by a layer of shell hash which is probably the result of a storm or some high energy event. This event may have removed any berm sands which might have made up the top of ridge before depositing these higher energy sequences. Above this layer

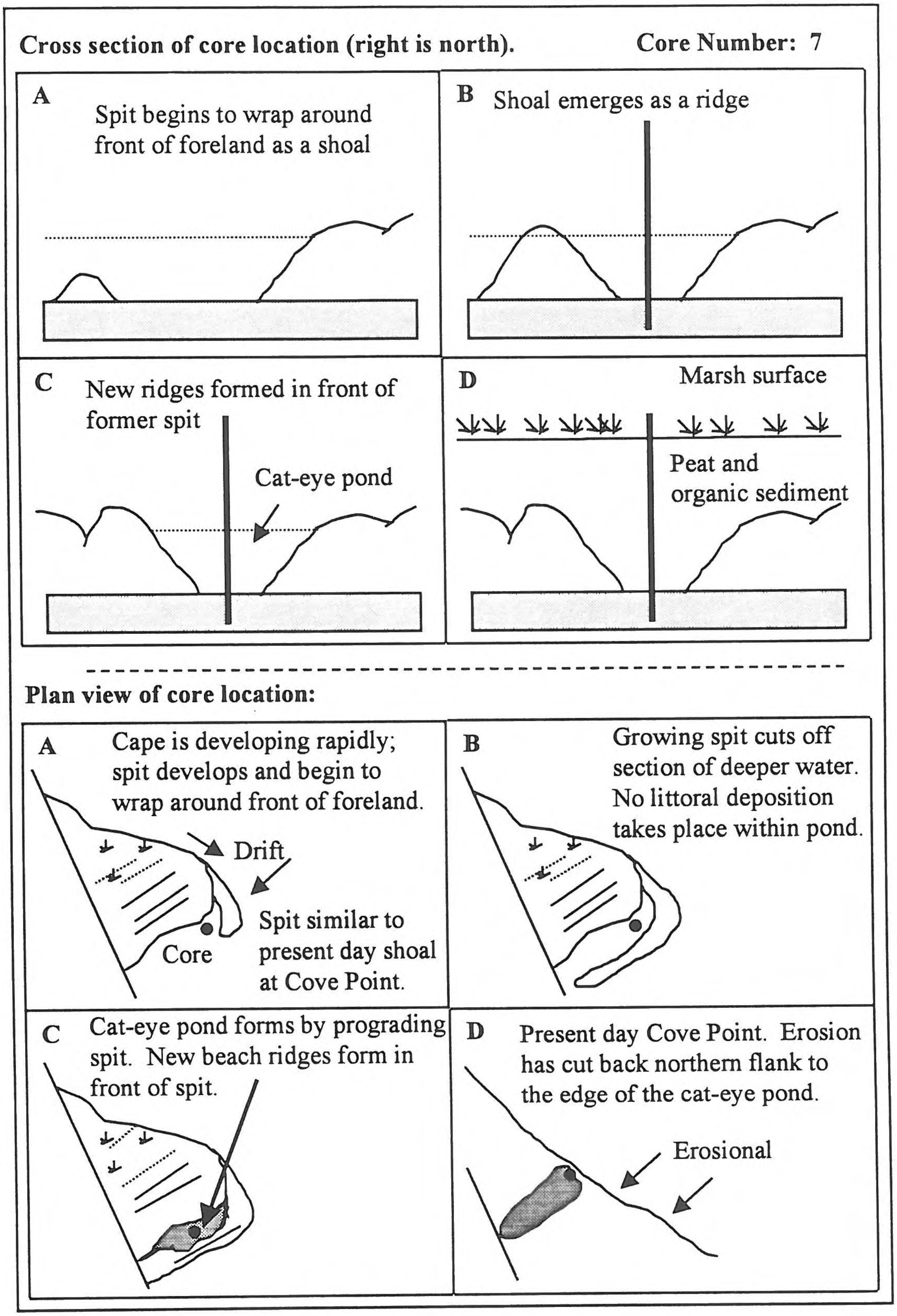


Figure 39. Diagram of stratigraphic development of core #7.

is the peat. Some of this peat may have eroded, as this core was taken in a shoreface peat outcrop.

Core #9 (Figure 40)

This core reached the Miocene basement material (the silt/clay of the St. Mary's formation). There is some reworking of the Miocene material as the ridge began to build; this unit is topped by a very high energy gray colored unit composed of gravel and shell hash. This indicates subaqueous deposition in the lower foreshore, possibly in the step. This fines upward to another unit of shell hash, also high energy but tan in coloration, an indication of erosion in the lower subaerial swash zone (fines are removed to leave the hydraulic lag deposits). A coarse sand without shells tops this layer, possible representing construction of a small berm. Above this is the relatively thin peat unit. The overall coarseness of the littoral sediments indicates that this area was in a very high energy environment. Beach ridge mapping shows that this core location is at this tip of the foreland where ridges curved around between the northern and southern flank. This is a focal point for wave energy, and explains the extreme coarseness of the sediments deposited here.

Core #10 (Figure 41)

This core has a complicated depositional history. It contacts the Miocene unconformity (the gray-green silt of the St. Mary's formation). Above this unit

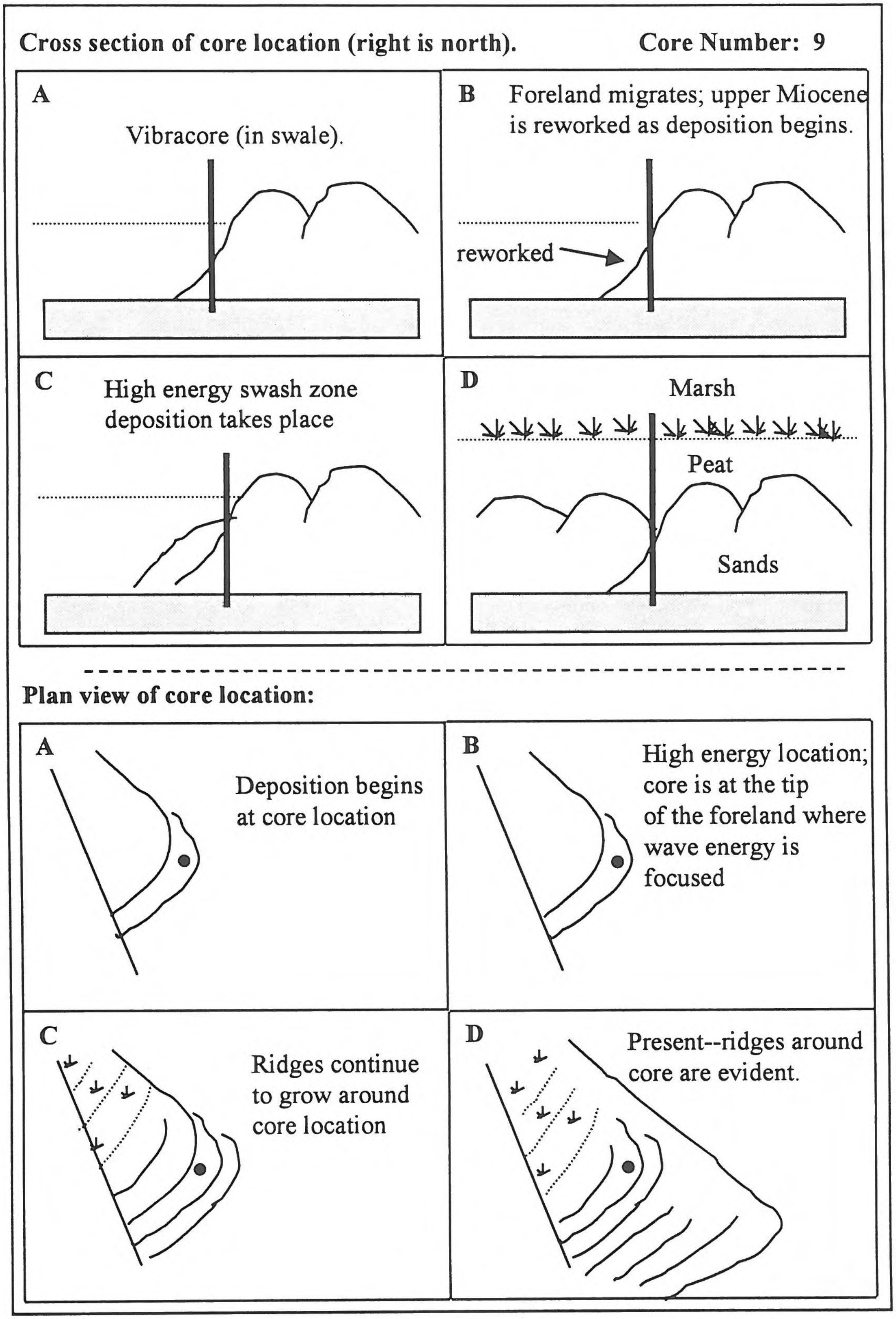


Figure 40. Diagram of stratigraphic development of core #9.

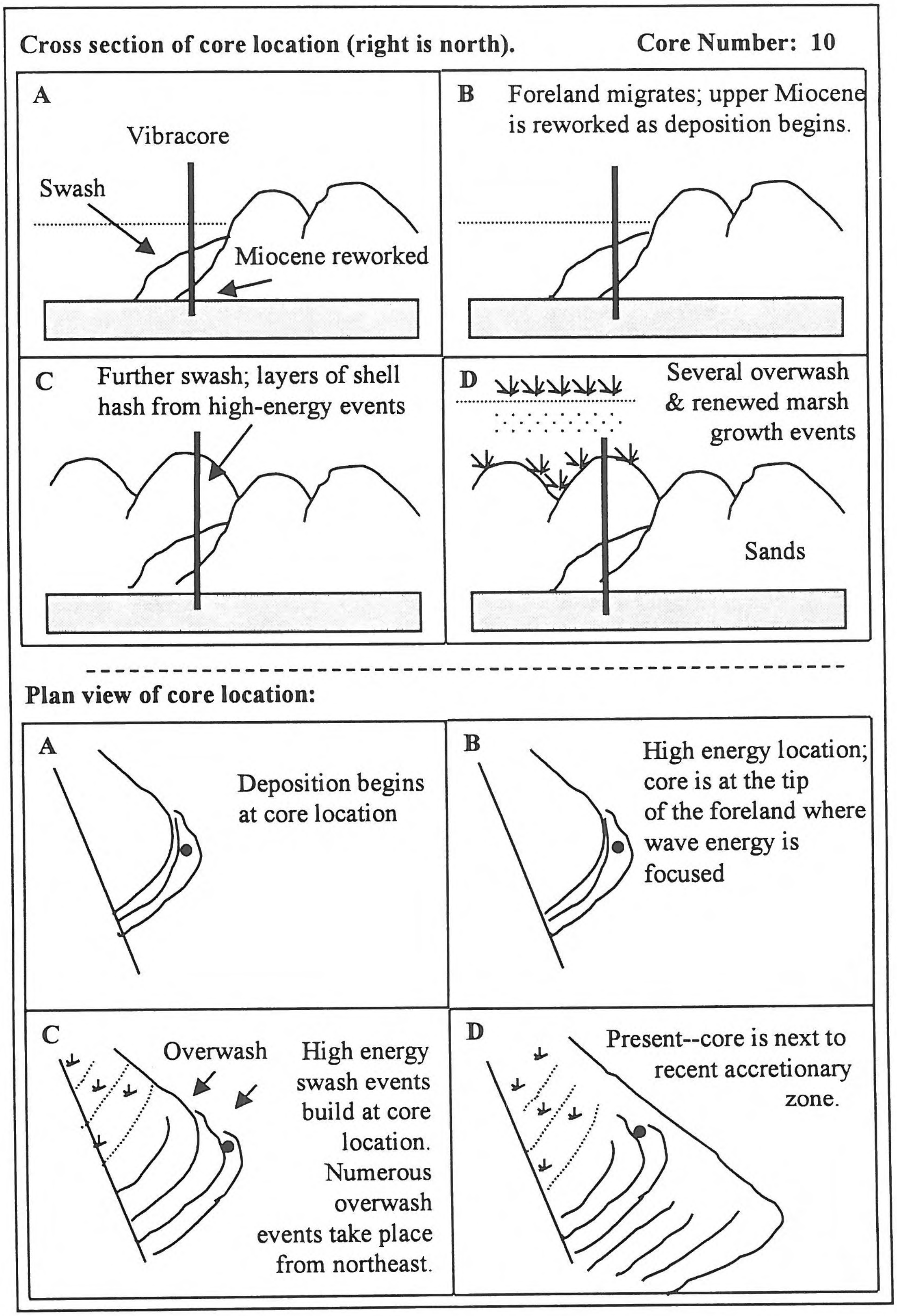


Figure 41. Diagram of stratigraphic development of core #10.

there is some reworking of the clay and silt layers. A high energy unit is above this layer which is gray in color and composed of coarse sand and gravel, topped by a thin layer of shell hash. These units are gray in color and were probably deposited in the subaqueous lower foreshore. Above this is a finer sand with fewer shells, probably deposited in the higher energy subaerial area of the swash zone. A storm event probably winnowed away some of the finer sediments of this unit, leaving a layer of shell hash on top of the sand unit. Above the shell hash are alternating units of peat and sand. The peat layers represent periods of marsh growth punctuated by intermittent overwash events. It is likely that this core location was at the tip of the foreland and may have experienced overwash from two directions. It was near the active shoreline for some time as evidenced by the number of storm depositional events apparent in the stratigraphic sequence.

Core #11 (Figure 42)

This core reached the underlying Miocene basement material. There is some mixing of the Miocene with the modern littoral deposits as beach ridge construction began. Above this are several units of coarse, gray sediments (shell hash and coarse sand with shells). These represent depositional periods for the ridge construction in the lower foreshore, with several storm events contributing to the varying composition of the high energy layers. Wood was trapped during this early constructional phase and radiocarbon dating indicates that this plant material died about 700 B. P.. This is topped by a short sequence of berm sand.

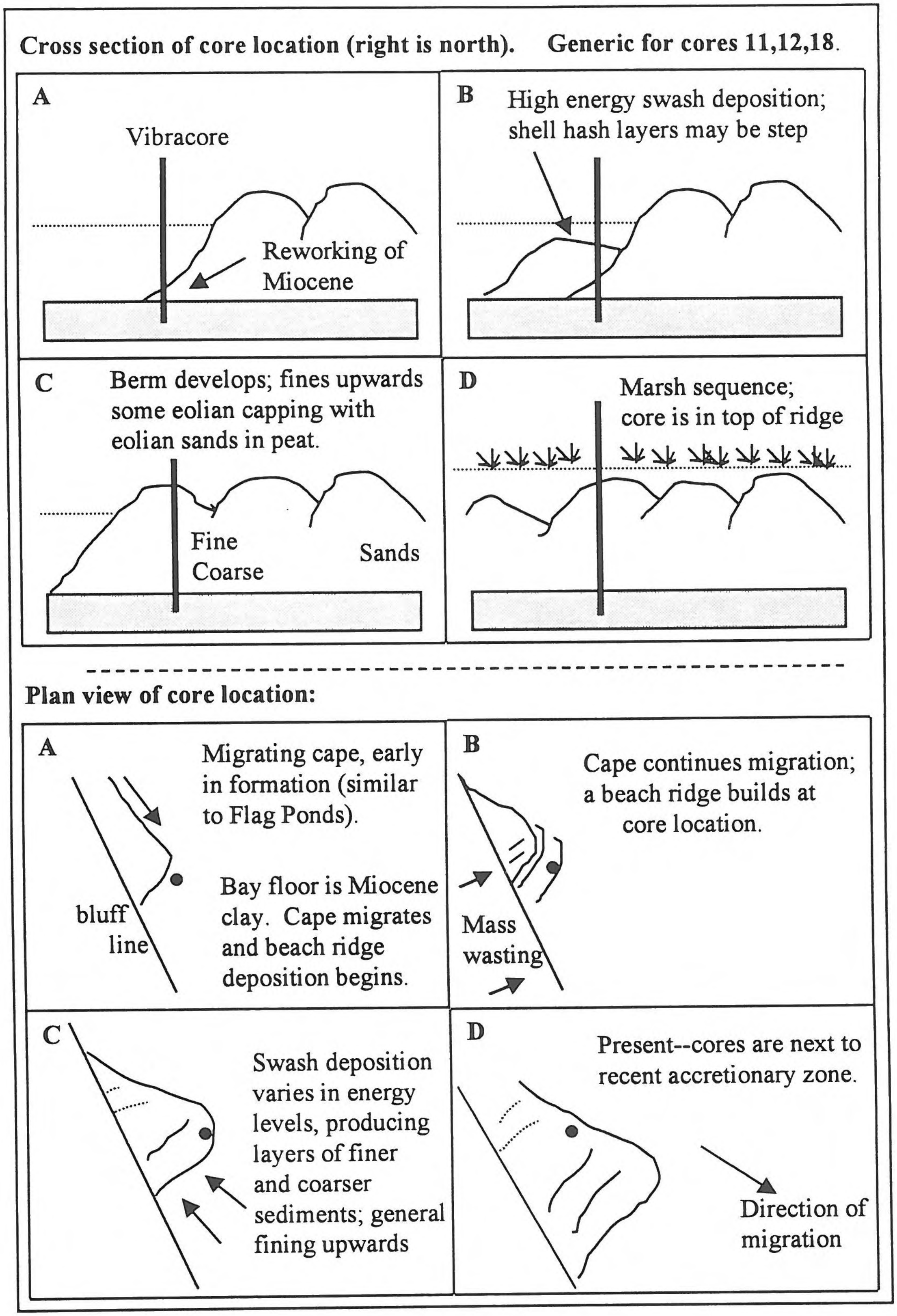


Figure 42. Diagram of stratigraphic development of cores #11, 12, 18.

Probably this is part of a larger berm which was eroded before a new sequence of ridge construction began. This new sequence is characterized by a fairly high energy layer, probably deposited in a subaqueous environment as indicated by the gray coloring, topped by a new berm composed of finer, better sorted sands. Above this is the peat sequence. The berm suggests that this is a beach ridge, but the depth of the peat contact indicates that this may not be in top of the ridge; instead it may be in the backslope of the ridge. This is supported by the presence of eolian sand in the peat; this marsh developed close enough to the active beach for wind transport to be effective.

Core #12 (Figure 42)

This core is probably in the top of a ridge. It just reaches the Miocene unconformity which is the gray-green silt of the St. Mary's formation. Above this is a high energy layer of coarse sand and shell hash, probably deposited in the lower foreshore subaqueous environment. This unit fines upward, eventually contacting the upper unit of finer sand which has few shells, is tan in coloration, and is somewhat better sorted. This is the berm of the beach ridge, and it fines upwards as well. The peat layer tops this littoral unit. There are fine-grained, well-sorted sands throughout the peat sequence, an indication that this part of the marsh was near the active shoreline during its period of vertical accretion (close enough for eolian transport to take place).

Core #13 (Figure 43)

This core reached well into Miocene basement material. There is some reworking of the Miocene clay/silt above the unconformity as evidenced by clay mixed with shell hash, topped by a relatively thin section of sand with shells. This unit was probably deposited in the higher energy lower foreshore, although its coloration is not as gray as most other subaqueous units. Above this is a thin unit of finer sand with fewer shells, indicating deposition higher in the swash zone. A marsh has accreted vertically above these littoral deposits; the upper part of these peat units may have been eroded as in Core #14 (this core was taken in a shoreface peat deposit). The peat has some eolian sands held in matrix; this marsh location was probably close enough to the active beach for eolian transport. The short littoral sequence and this peat layer indicates that this core was probably taken in a swale between two ridges.

Core #14 (Figure 44)

This deep core reached well into the Miocene basement. Just above the Miocene layer is a thin layer of peat at 214 cm. This peat was probably deposited similarly to Core #7. As beach ridges wrapped around the front of the foreland, they cut off the deeper water without depositing any sand on top of the Miocene clay. A marsh grew in this pond for some undetermined length of time before the spit was eroded away. This erosion was probably a short term reversal of the normal trend of accretion for the southern flank of the foreland. Most of the peat

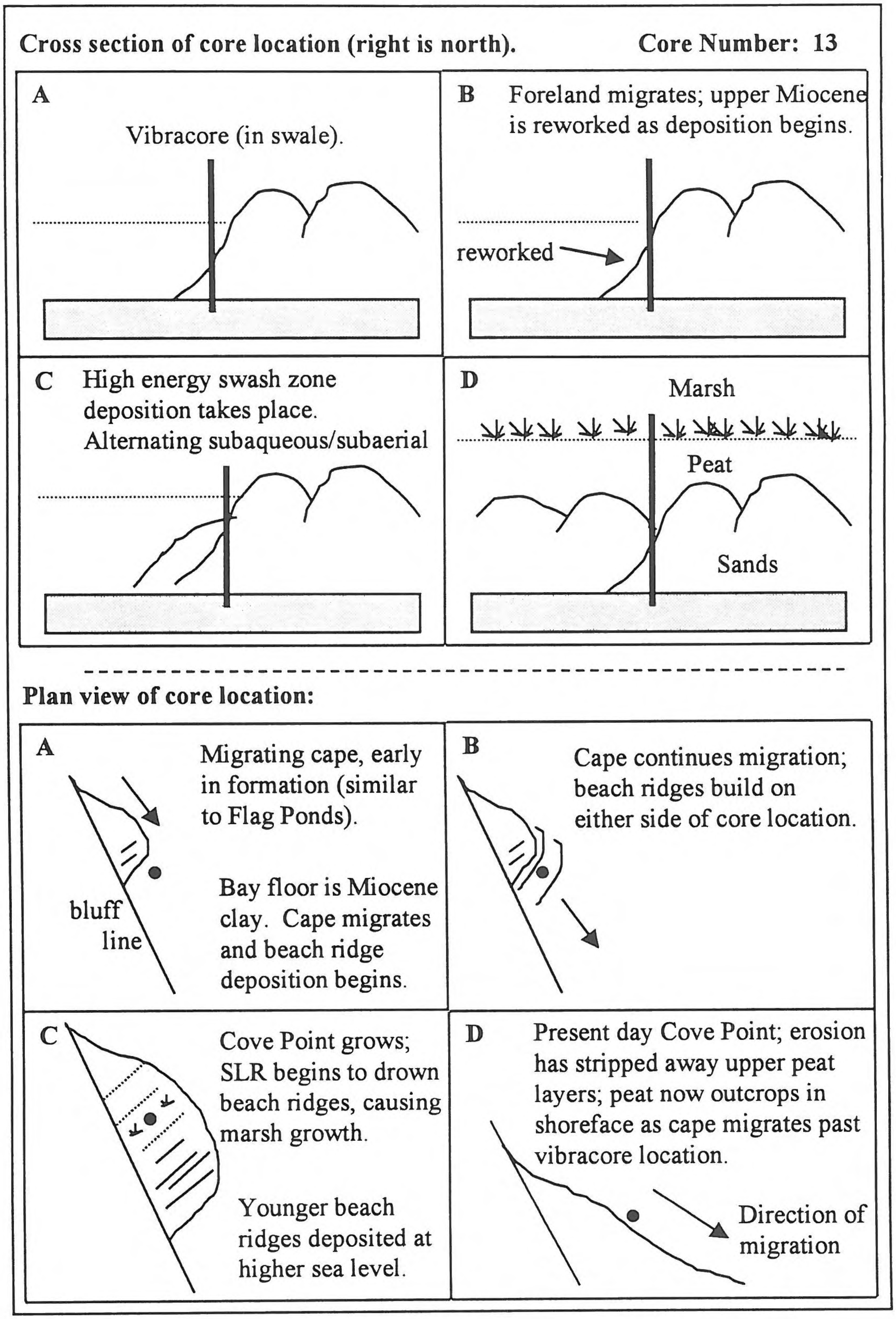


Figure 43. Diagram of stratigraphic development of core #13.

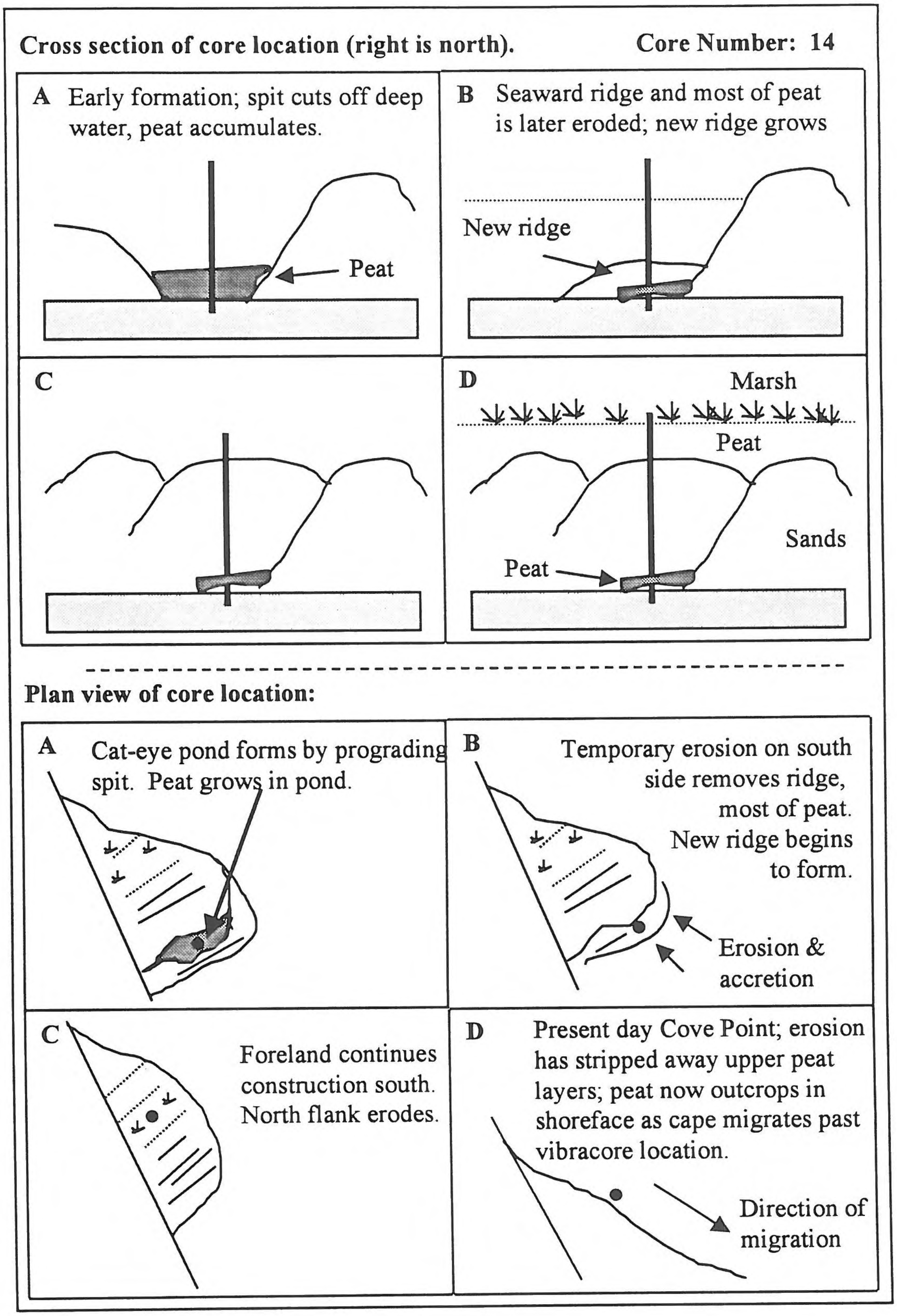


Figure 44. Diagram of stratigraphic development of core #14.

was removed during this erosion, leaving a sharp erosional contact and a thin layer of peat just above the Miocene. The erosion then reverted back to accretion, and a ridge began to build on top of the early marsh deposit. The unit above the peat is gray, has shells, and was probably deposited in a subaqueous high energy environment such as the lower foreshore. This is topped by orangish berm sands which tend to fine upwards. A marsh then grew above this ridge. Some finer, well-sorted eolian sands are in the peat unit, indicating this vertically accreting marsh was near the active beach for some time. The completeness of the littoral units and the relatively thin peat layer indicates that this core was probably taken in the top of a beach ridge. The upper peat unit may have been partially eroded, as this core was taken in a shoreface peat outcrop.

Core #15 (Figure 45)

Core #15 reached deep into the Miocene St. Mary's formation. Above this is a thick unit of high energy littoral deposition (coarse gray sands and shells). This indicates subaqueous deposition. A cluster of Phragmites rhizomes was trapped in this unit; radiocarbon dating indicates it is modern (less than 200 years old). This area of the Cove Point shoreline has probably been recently accretional, similar to the erosion reversal noted along the northern flank of the cape just north of the lighthouse. Shoreline records indicate that it probably eroded back past this core location after 1971, then accreted to cover this area with more recent littoral sediments (either ridge or swale). The temporally poor

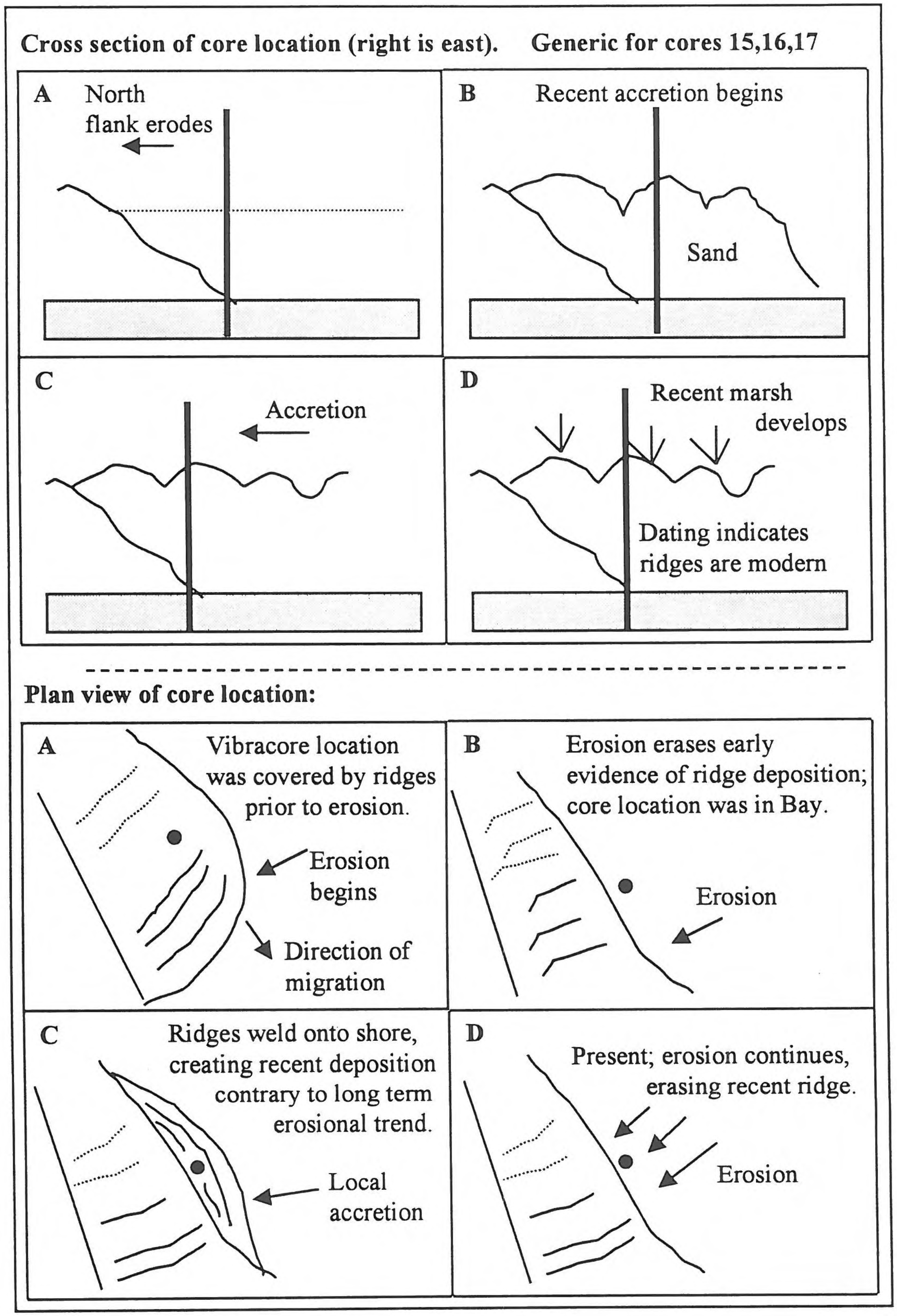


Figure 45. Diagram of stratigraphic development of core #15, 16, 17.

historical shoreline database did not capture this phenomenon. This recent accretion of sands is topped by marsh growth with an intervening unit of overwash. This peat unit is fairly thick, an indication that this recent marsh growth was not governed entirely by sea level rise (sea level has only risen approximately 54 cm over the last 150 years in the Chesapeake Bay; Douglas, 1991). Over the long-term the water table of the marsh is controlled by sea level; during the short-term, seasonal impacts, marsh drainage, and inputs from the nearby cliffs probably have more effect.

Core #16 (Figure 45)

This core probably contacted the Miocene unconformity, with some evidence of reworking of this clay/silt layer above the contact. This is topped by a coarse, poorly sorted sand with numerous shells, a unit indicative of deposition in the high energy lower foreshore. The unit above this is colored gray as though it was deposited in a subaerial environment, but it is very coarse suggesting a high-energy event for transport. A unit of finer sand above indicates the construction of a small berm. This core is probably modern; it is between Cores #15 and #17, both of which have modern radiocarbon dates. The overlying peat sequence has fine-grained, well-sorted sands deposited in matrix, indicating that it has been near the active shoreline during marsh development so that eolian transport could take place.

Core #17 (Figure 45)

This core was taken in the top of a beach ridge; there is little peat apparent in the stratigraphic cross-section. The bottom of the core is deep in the Miocene basement material. There is some slight reworking of this Miocene material, followed by a high energy lower foreshore depositional unit composed of gray sands and shells. A cluster of Phragmites was trapped in this unit, and radiocarbon dating indicates that it is a modern plant (less than 200 years old). Above this is a thin layer of peat. This vegetation probably grew on top of the ridge before the ridge began to build again. Overlying units mostly represent high energy conditions, indicating that this thin peat layer may have been topped by a high energy event or several high energy events. The littoral sequences are modern as indicated by the radiocarbon date; this is supported by the absence of a marsh. This core was probably taken in the top of ridge which has recently welded onto the northern flank of the foreland (a short term reversal of the long-term erosional trend). Shoreline records indicate this probably occurred between 1971 and 1996; the temporally poor database does not capture the short term movement. This process of erosion reversal is similar to the present day erosion reversal along the northern flank of the foreland just south of this location and just north of the lighthouse. This previous erosion reversal encompasses Cores #15, #16, and #17.

Core #18 (Figure 42)

This core reached the Miocene basement, and there is some evidence of reworked clay and silt above the unconformity contact. Above this is a highly variable unit composed of overall coarse sediments and shell hash that is gray in color. This unit was probably deposited in a high-energy subaqueous environment such as the lower foreshore. Topping this unit is a finer sand layer, followed by a somewhat coarser sand, and capped by a finer sand with better sorting. These units represent the construction of the berm with a slightly higher energy event contributing to the intervening unit. Above this is the peat unit which has some eolian sand near the bottom of the layer.

Core #19 (Figure 46)

This core did not reached the Miocene unconformity, although there is a thin layer at the end of the core which might be evidence of reworking of the clays and silts of the Miocene basement material. Above this is a very thin unit of gray sand with shells, followed by a thick unit of sand with shells which is orangish in tint. This indicates subaerial deposition, and it is possible that only the top of the subaqueous beach ridge was cored. Above this is a unit of peat which represents the vertically accreting marsh. The base of this peat layer yielded an organic sediment which radiocarbon dated at 500 B. P.. The depth of the peat deposits indicates that this core is probably between beach ridges. This core displays a thick littoral sequence despite the fact that it may not have reached

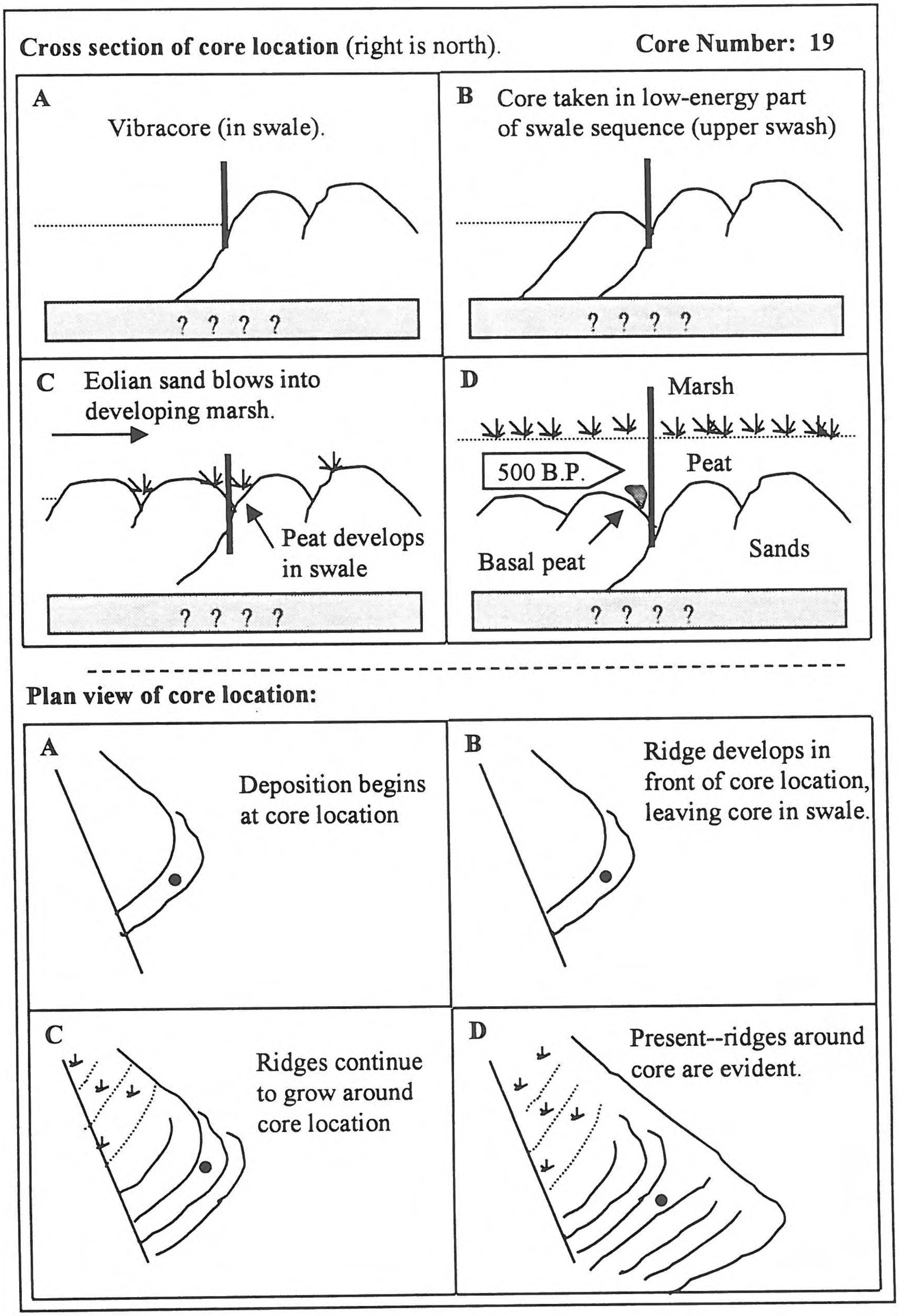


Figure 46. Diagram of stratigraphic development of core #19.

the subaqueous units of ridge construction. This is indicative of the thickening wedge of littoral deposits as the foreland advances into deeper water. Eolian sands were found throughout the peat unit, suggesting that this marsh grew near the active beach for some time.

Core #20

This core was excluded from the analysis due to poor sediment recovery during sampling.

Core #21 (Figure 47)

This core was taken within the Cove Point community in a resident's front yard. It did not contact the presumed Miocene basement; however, it did reach a coarse subaerial unit of berm construction, probably deposited in the lower swash zone. Above this is fairly well sorted sand which appeared to be fill (moved anthropogenically). This is capped by a thin layer of topsoil with ordinary grass growing in it. It is likely that part of a beach ridge was reached, but it is difficult to draw conclusions because the lower constructional phases of the ridge were not contacted.

Radiocarbon dating

Samples from the vibracores were radiocarbon dated so the evolution of the cuspate foreland could be determined. A table of the radiocarbon dates derived is given in Chapter 3 (Methodology). These dates were plotted at the location of the vibracore from which the organic material was taken (Figure 48). There appears to be a steady migration south of the foreland as interpreted from these dates. A plot of these dates in A.D. against the distance between the vibracores shows that the movement of the cape has occurred at an average rate of 1.3 meters per year (Figure 49). The high R-squared value (0.95) indicates that this migration has been fairly constant over the period of record.

It should be noted that two of the radiocarbon dates were modern. These materials may have been contaminated; however, it is likely that the area sampled was a zone of recent accretion, similar to the accretionary area seen on the northern flank of the foreland just north of the lighthouse.

Beach ridge mapping

The beach ridges of Cove Point were mapped and examined in the context of the radiocarbon dates derived through vibracoring. A reconstruction of the rates of ridge growth was performed by measuring the distance between radiocarbon dating sites and counting the number of intervening beach ridges. There appears to be two distinct geomorphic divisions (Figure 50). The northern part of the foreland is characterized by ridges which are more widely spaced and are interspersed with occasional cat-eye ponds. They have an average construction interval of 27 years and an average spacing of 38 meters. Further south, the spacing of the ridges is narrower (25 meters), the construction interval

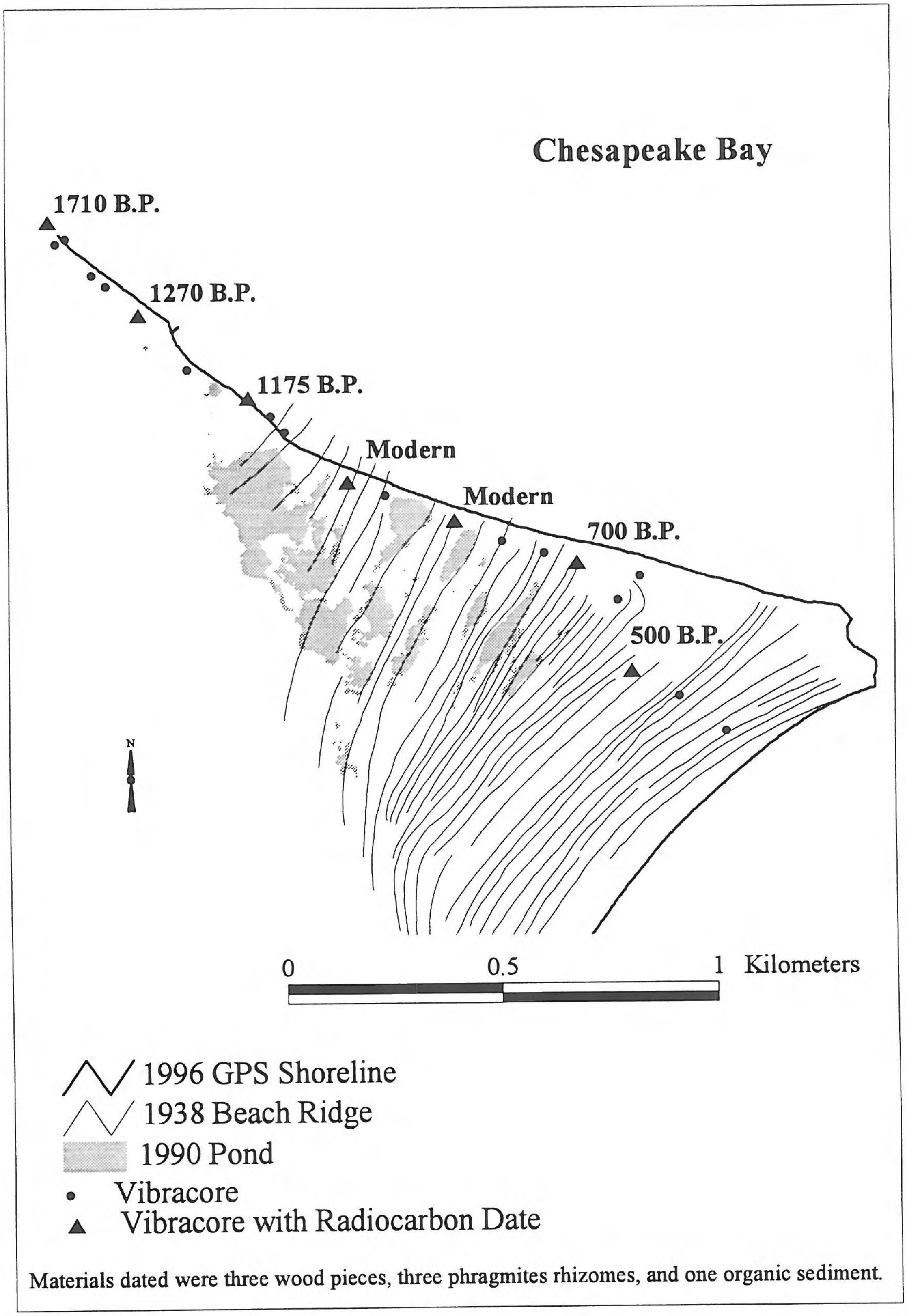


Figure 48. Map of Cove Point vibracores and radiocarbon dates.

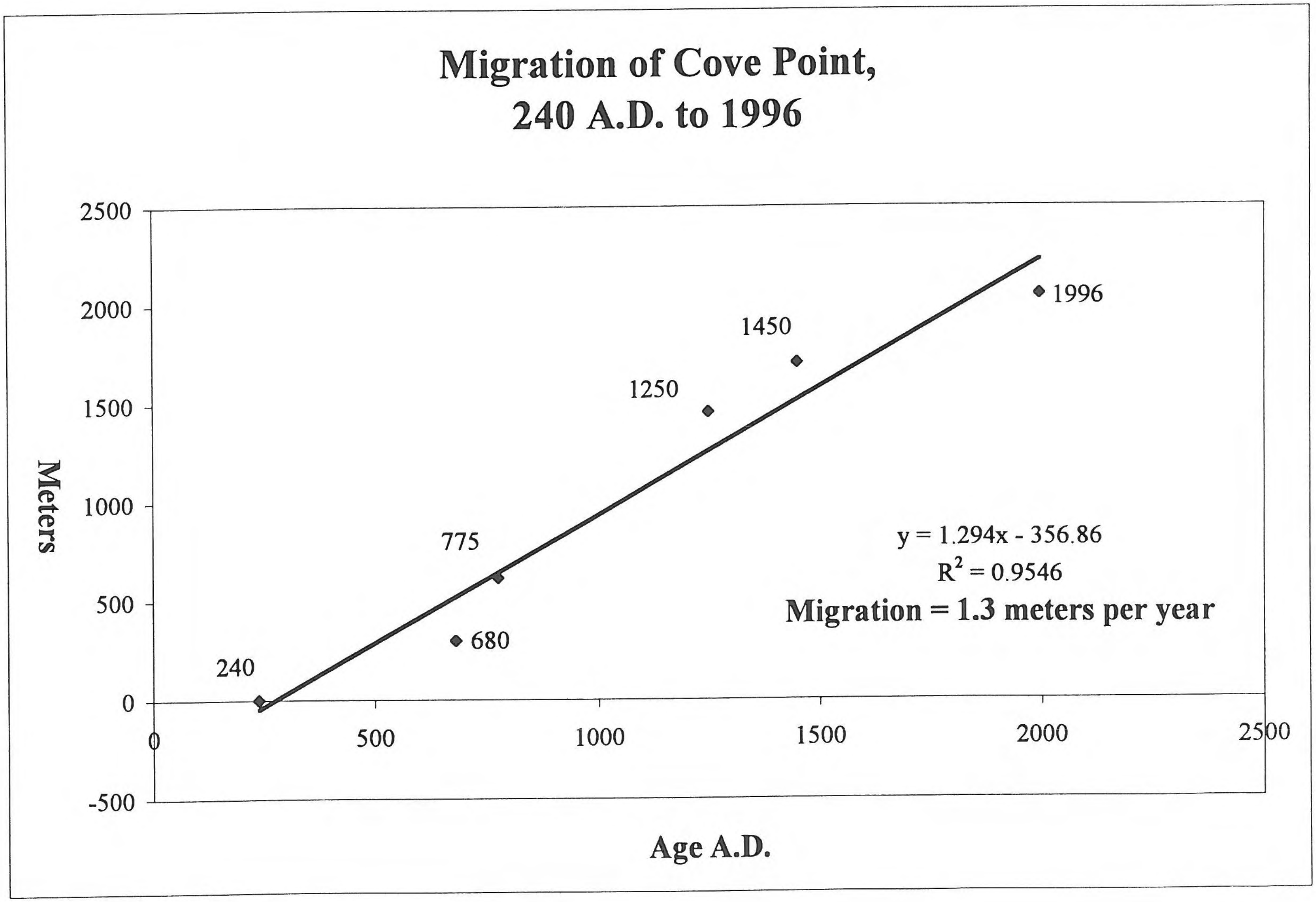


Figure 49. Plot of radiocarbon dates against distance.

is longer (35 years), and there are no cat-eye ponds apparent. Part of this discrepancy may be due to the drowning of the more northern ridges. This drowning made it difficult to discern older ridges from aerial photographs. However, if there are more ridges, this would mean that the construction interval is even shorter than 27 years, widening the discrepancy between the two sets of ridges. In addition, there is definite evidence of cat-eye ponds as revealed in vibracore #7 for the older part of the cape. Such features are unmistakable on aerial photographs, but no such ponds are evident within the southern set of beach ridges. This suggest that there is a morphological difference between the two sets of beach ridges, possibly driven by sediment supply, local bathymetry, or a fluctuation in the rate of sea level rise.