

THE GEOMORPHOLOGY OF HOG ISLAND, VIRGINIA:
A MID-ATLANTIC COAST BARRIER

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ABSTRACT

Recent shoreline changes along the Virginia barrier islands indicate that these islands are the most dynamic along the mid-Atlantic coast. Hog Island, Virginia, has been rotating in a clockwise direction for the last 122 years; the shoreline has transgressed over 2.5 km along its southern shoreline and regressed over 1.5 km in the north. Prior to 1871, the island was rotating in a counter-clockwise direction. Between 1949 and 1989, high erosion rates (13 m/year) to the south and high accretion rates (13 m/year) to the north have led to reworking of approximately 50 percent of the island. There is, however, at least one feature on the island which is at least 300 years old.

The geomorphic history of Hog Island was deciphered by analyzing historical shoreline charts and aerial photography, juxtaposition of landforms, and the physical characteristics of the island along transects. On the modern landscape, five physiographic regions have been identified: 1) Overwash Flat and Dune Ridge; 2) Transitional; 3) Continuous Dune; 4) Overwash Fan and Terrace; and 5) Spit Complex. Sediment samples were collected from seven landform types (beach, berm, dune, overwash, relic overwash, runnel, and threshold) in each region and found to be homogeneous in mean grain size. By comparing the older landform morphologies and island configurations to the more recent island characteristics, it has been found that Hog Island has acted as a drumstick barrier throughout the history of visible landforms. It has also been found that at least three changes in the rotation of the island have occurred: 1) late 1600's; 2) middle 1700's; and 3) the most recent, around 1871.

Study of historical chart data reveals that the entire Virginia barrier chain has undergone major morphological change around 1871: Fishing Point was created as an extension of Assateague Island and Parramore and Cobb Islands switched from counter-clockwise to clockwise rotation. Comparison of these islands to Hog Island implies that there has been a change in a regional scale coastal agent.

The storm climate on the Eastern Shore of Virginia changed gradually from a few, continental track, storms in the late 1800's to frequent, offshore storms, in the the mid-1900's, peaking in the early 1960's. These climatological variations may be affecting the mid-Atlantic coast at intervals of 100 to 120 years (peak to peak). These climatological data coincide with a change along the Virginia barrier islands in the late 1800's, a decrease in the area of Hog Island from 1871 to the 1960's, and a shift in the ebb delta position and channel southward from the late 1800's to the 1970's. By projecting the 60 year climate variation to a 120 year cycle of peak to peak (a contemporaneous maximum clockwise rotation of Hog Island), the geomorphic data are independently fitted into a climate dominated system. Maximum clockwise rotation (with intervening maximum counter-clockwise rotation) occurred in the mid to late 1900's, early to mid 1800's, early 1700's, and around 1600.

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INTRODUCTION

The thirteen barrier islands located along the seaward margin of the Virginia coast are Holocene in age (Figure 1). Short- and long-term variations in marine processes have caused these islands to undergo rapid morphologic changes. Sea level change, tides, storms, waves, wind, and biota control the evolution of these islands and their morphology by creating, altering, and destroying barrier island landforms through the redistribution of sediments. These processes vary on daily, monthly, seasonal, and secular time scales. Although the Virginia barrier islands retain some evidence of their Holocene history, significant changes in shoreline position and island morphology have occurred in relatively recent times and obscure much of their older structure.

The goals of this study are to identify and map the different physiographic regions on Hog Island, reconstruct the island's geomorphic evolution, and determine those variations in short- and long-term changes which have influenced the island's development. Landform characteristics and landform juxtaposition are mapped and quantified using aerial photographs, shoreline charts, landform relationships, and field studies. Study of the juxtaposition of distinct landforms, the evolution of landforms, and the physical characteristics of the island, are the bases of a conceptual model of the Late Holocene history of Hog Island. More specifically, this study: 1) identifies the different landform patterns on Hog Island and describes the physical characteristics of each; 2) documents and describes the evolution of Hog Island; 3) relates differences in shoreline change along the island's

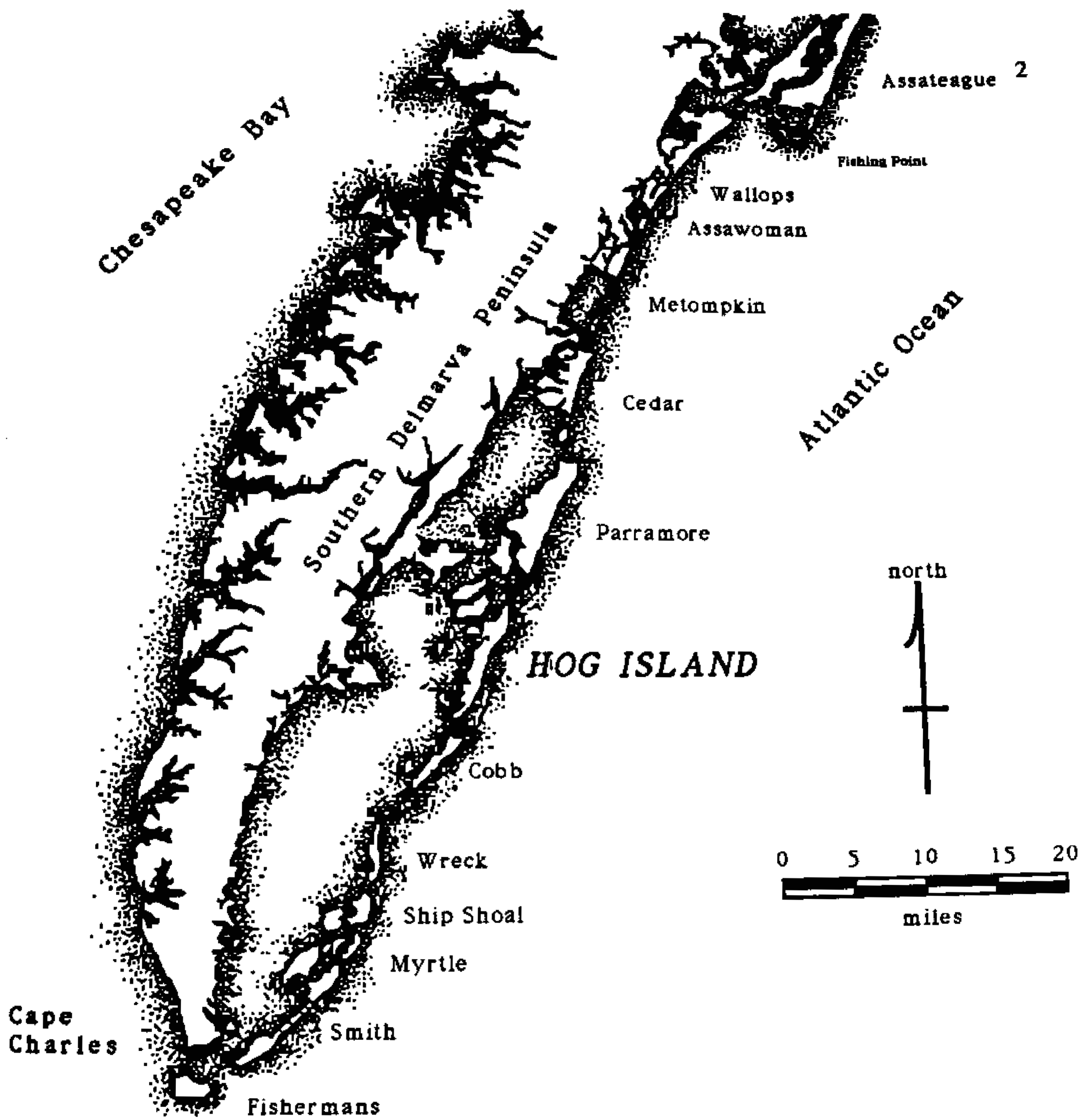


Figure 1. The Virginia barrier chain is located along the eastern margin of the southern Delmarva peninsula and is comprised of 13 major islands.

reach to the landforms and the evolution of the island; 4) develops a model of evolution for Hog Island; and 5) applies this model of development to other barrier islands along Virginia's coastal margin.

A detailed geomorphologic study of Hog Island has not been conducted in the past primarily because of its remote location. Recently, a National Science Foundation grant provided the support to establish a Long Term Ecological Research site along the Virginia coast. The University of Virginia Department of Environmental Sciences has been conducting meteorologic, ecologic, and geologic study of the central Virginia barriers as a part of this program.

Hog Island was chosen for my study because: 1) access and logistical and financial support were provided by the National Science Foundation; 2) it is similar to many drumstick barriers throughout the world which have been studied in detail; and 3) the island provides a study site in an area which has not been changed significantly by human activities.

Moreover, an aerial photographic record of the island is available from 1942 to the present. This, along with historic shoreline charts of the island from 1852, documents the island's rapidly changing shoreline (up to 13 m/year erosion and 13 m/year accretion along the island since 1949). In addition, Hog Island is similar to other Virginia barrier islands with regard to its orientation, general morphology, and overall configuration.

GEOMORPHOLOGY

Sediment deposition, erosion, and storage in the coastal zone by large scale processes contributes to regional-scale shoreline configurations (roughly 10-200 km). In contrast, local variations in island morphology (0.5-10 km) are governed by shorter-term variations in the waves, tides, storm surges and washovers, and vegetative colonization. These regional and local variations create island morphology and give rise to landform distributions.

Classification Systems: The dynamic agents involved in coastal change create a static morphology, albeit long- or short-lived. Researchers have analyzed coasts according to the dynamics of shorelines (Goldsmith, *et al.*, 1975; Rice and Leatherman, 1982), resultant static morphologies (Fisher, 1967), and a combination of dynamic and static variables (Kochel, *et al.*, 1985).

Fisher (1967) used large-scale morphologic patterns to divide the Delmarva Peninsula barrier islands into four groups (Figure 2), whereas Kochel *et al.* (1985) concluded from analysis of 15 variables (dynamic and static) that three groups of islands exist along this stretch of coast (Figure 2). Both investigations agree that the *Barrier Island Chain* (Fisher, 1967) is a region of *short, discontinuous* (Kochel *et al.*, 1985) barrier islands separated by many inlets; however, there is disagreement on the characteristics of regions to the north. The difference between group divisions in the north may be due to a lag in the expression of long-term, regional morphologic change as a response to more recent changes in the dynamic variables. Also, the superposition of similar variables onto varied stratigraphic and paleotopographic remnants in the geologic record may institute substantial

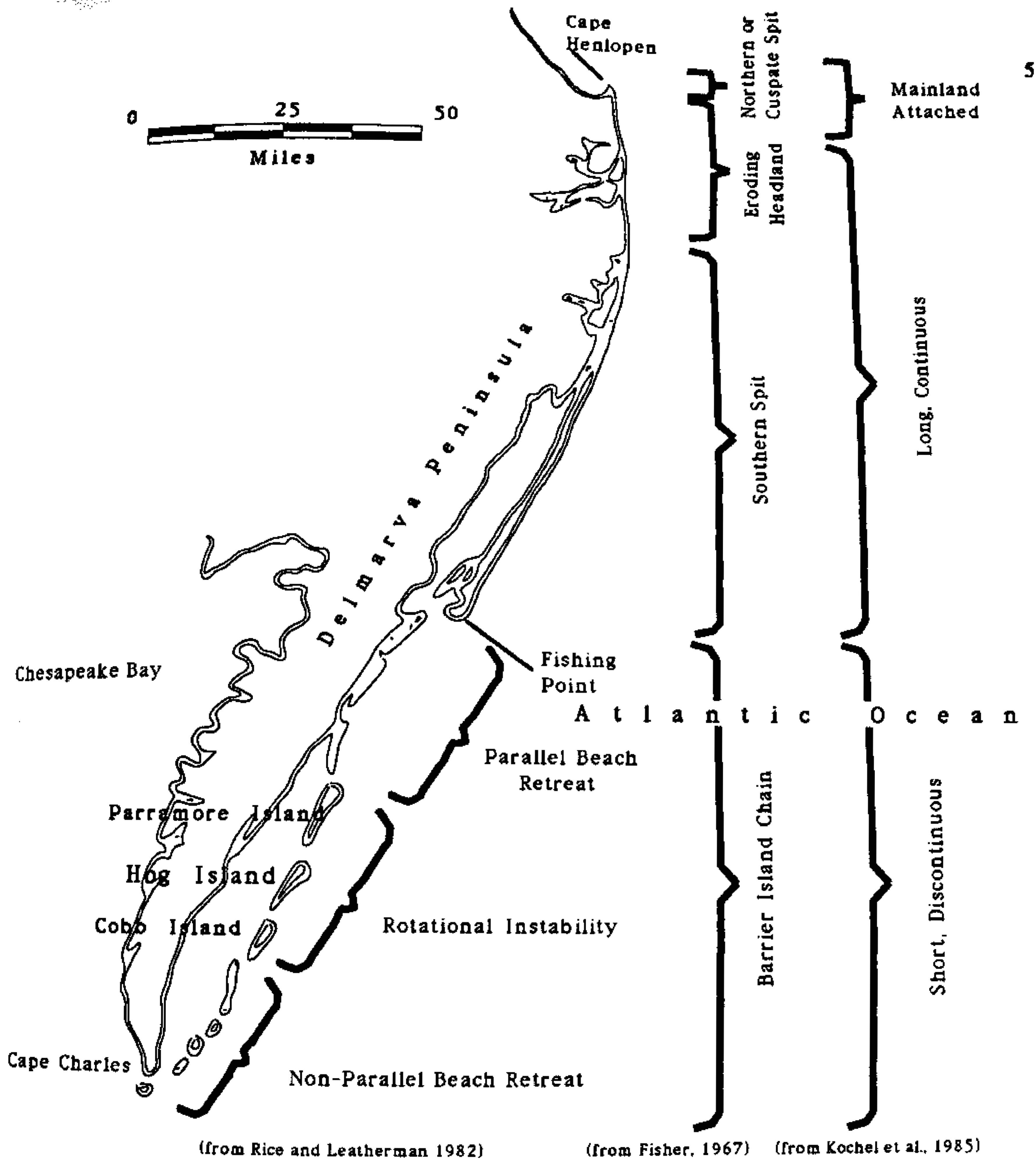


Figure 2. The mid-Atlantic coast has been divided into compartments based on coastal morphology (Fisher, 1967), on shoreline erosion rates and configuration (Dolan et al., 1979; Kochel et al., 1985; Rice and Leatherman, 1982), and on their physical environment (Hayes, 1979; Kochel et al., 1985).

differences in regional morphology. Halsey (1978, 1979) refers to paleotopographic influences as a cause for regional scale influences on the Virginia barriers (see section on Evolution of Hog Island).

Kochel, *et al.*, (1985) subdivided the Virginia portion of the Delmarva Peninsula barrier islands into a northern section and a southern section. The northern section extends from just south of Cape Henlopen, Delaware, to Fishing Point, Virginia, and is part of the *long, continuous* barrier (Kochel, *et al.*, 1985). The southern section of *short, discontinuous* barriers, extends from Fishing Point to Fishermans Island (Kochel *et al.*, 1985). Hog Island, Virginia, is located in the *Barrier Island Chain* as classified by Fisher (1967) and the *short, discontinuous* barrier of Kochel, *et al.* (1985). Rice and Leatherman (1982) divide the southern section of *short, discontinuous* barriers into a northern group characterized by *Parallel Beach Retreat*, a middle group characterized by *Rotational Instability*, and a southern group characterized by *Non-Parallel Beach Retreat* (Figure 2), reflecting regional-scale variations in the physical environment (e.g. wave climate, tides, sediment supply). The three barrier islands contained within the middle group (Cobb, Hog, and Parramore) have been "rotating" in a clockwise direction since the late 1800's, have exhibited reversal in offsets of the inlets (Rice and Leatherman, 1982), and display one of the most dynamic coastlines along the Atlantic seaboard (Dolan, *et al.*, 1979; Dolan, *et al.*, 1988).

Rotation of an island is the result of net shoreline erosion at one end (sediment translation landward or island transgression), and net shoreline accretion (regression) at the opposite end. During rotation, sediment

accreting to the regressive section of an island is stored in landforms, creating the geomorphic features which document a portion of the islands history.

Sediment Redistribution: Coastal processes alter shoreline positions by redistributing sediment from a source to either short- or long-term storage and finally to a sediment sink (Field and Duane, 1976). The sediment sink may either be temporary, to be later reworked into the same transgression as it was deposited (e.g. a back-barrier sequence overridden by the island transgression), or the sediment sink may be stranded during a eustatic regression and abandoned as a terrace deposit on the Coastal Plain.

Washover deposits, dune ridges, spits, and welded bars are landforms which store sediment and outline former shoreline positions (Halsey, 1978). Halsey (1979) has stated that the differences between the *long, continuous* barrier, extending from Cape Henlopen to Fishing Point and the *short, discontinuous* barriers south to Cape Charles (Figure 2) are due to sediment availability; as more sediment becomes available to the longshore currents due to the erosion of the Delaware headlands, inlets between the *short, discontinuous* barriers to the south will be filled and one *long, continuous* barrier with few inlets will be created. However, studies of drumstick, and *short, discontinuous* barrier island systems along the mid-Atlantic coast of North America, Alaska, the Netherlands, and the German Bight (Hayes, 1979), indicate that the difference between *long, continuous* and *short, discontinuous* barriers can be better explained by the ratio of tide dominance to wave dominance.

Tides: Low mesotidal (1-2 m) and microtidal (0-1 m) tidal range in areas of low to moderate wave energy are associated with the formation of drumstick

barriers (Hayes, 1979). This drumstick morphology is recognizable in the *rotational instability* section of Virginia's *short, discontinuous* barriers. According to Hayes (1979), the Virginia barriers consist of low mesotidal, short (3 to 20 km in length) drumstick barriers, with numerous tidal inlets. Tidal range and wave climate jointly results in the formation of large ebb dominated deltas with strong wave refraction effects.

Tidal Inlets: The tidal inlets of the Virginia barriers are ebb dominated with large ebb deltas that extend up to 6 km eastward from the barriers. The importance of ebb deltas and inlets in barrier island morphology and evolution is that the longshore currents, wave climate, and sediment flux in the littoral drift are greatly influenced by the ebb delta and ebb jet (Newman and Rusnak, 1965; Davis, *et al.*, 1972; Goldsmith, *et al.*, 1975; and Hayes, 1979). Reversal of longshore currents downdrift of the ebb deltas results in zones of deposition, offshore bar accretion, and a local surplus of sediment (Hayes, 1979; Davis *et al.*, 1972). In contrast, interruption of the littoral drift by discharge forces of the ebb jet and sediment storage in the large sediment sink of the deltas have been shown to create sediment deficiencies down-drift and create up-drift offset of barriers (Hayes, 1979). To compare these two seemingly contradictory ideas, reversal of the longshore currents and interference of the littoral drift by the ebb jet have both been cited as reasons for the existence of different offsets, or overlap, at inlets (Figure 3). Researchers often have discussed offsets at inlets; Boothroyd (in Davis, *ed.*, 1985) has listed five "documented" causes for barrier island offset at inlets:

1. large sediment supply from updrift creates updrift offset (earlier workers)

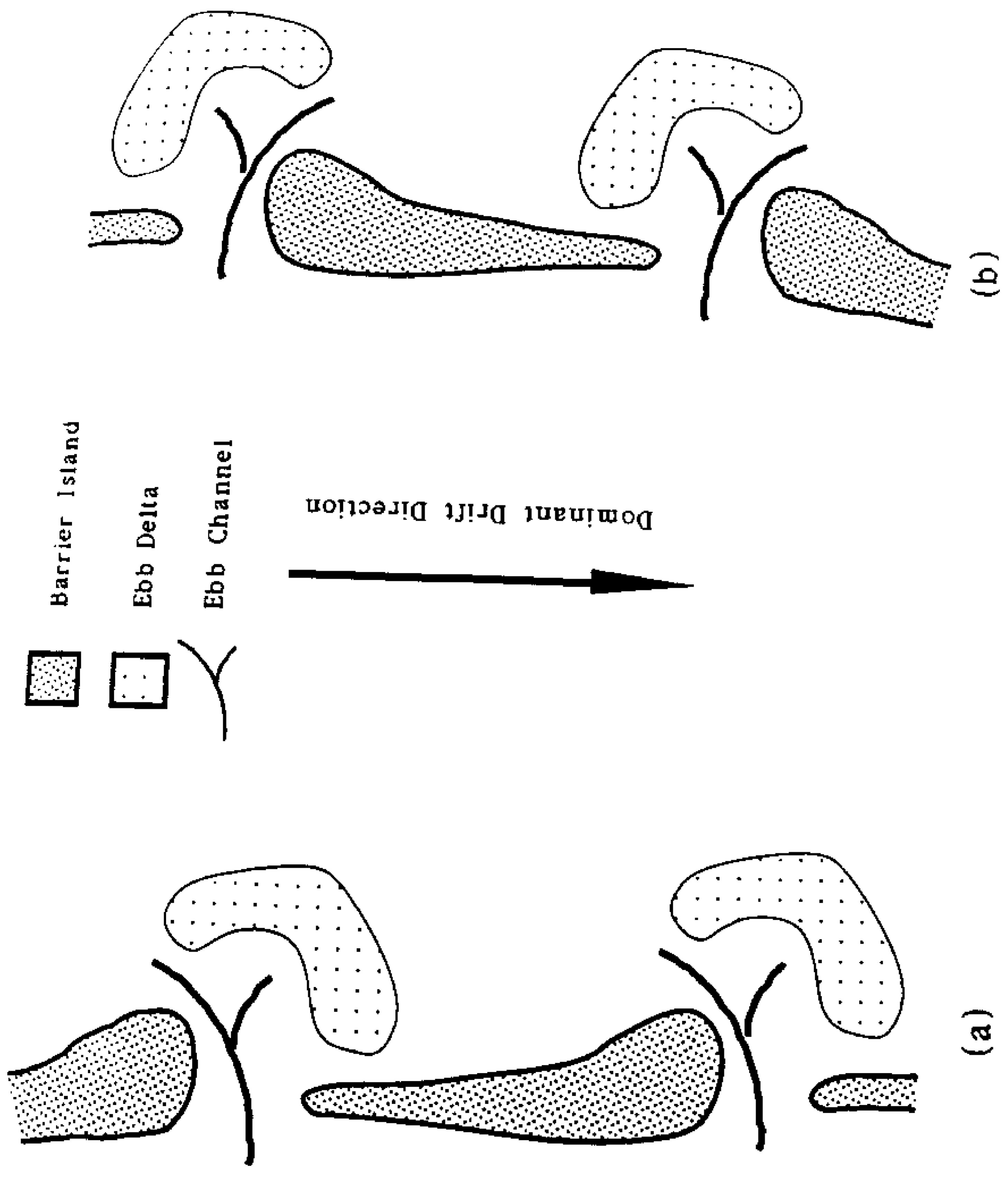


Figure 3. The origin of barrier island offsets at inlets has been disputed.

- a. Updrift offsets have been described as forming when 1) a large sediment supply from updrift collects at the downdrift end of the island, and 2) a strong ebb tidal flow along the downdrift side of an island inhibits sediment transport downdrift.
- b. Downdrift offsets have been described as forming when 1) wave refraction and bar welding on the downdrift island, and 2) the main ebb channel erodes into a cohesive mud.

2. wave refraction and subsequent drift reversal and deposition creates downdrift offset,
3. downcutting of the main ebb channel into a cohesive mud creates a downdrift offset,
4. asymmetry of tidal velocities (flood vs. ebb) and position of tidal flushing paths creates an updrift overlap, and
5. large availability of sediment creates updrift overlap.

Large sediment supply (1) and drift reversal around the ebb delta (2) have been documented to be the most frequent reason for barrier island offset. In relation to sediment distribution on barrier islands, Boothroyd (in Davis *ed.*, 1985) states that an updrift offset "is usually a supratidal part of the barrier itself," implying a strong relationship between the barrier and the attachment of the ebb delta sediment mass to an island.

Hog Island is presently offset downdrift, and may presently be described by wave refraction effects (2) and downcutting into a cohesive mud (3). Variations and changes in sediment supply may cause the system to be reversed. The position of the ebb delta in the *Rotational Instability Section* of the Virginia barrier islands has shifted slightly southward over the last 140 years (Goldsmith *et al.*, 1982). However, the position of the dominant ebb channel has changed from a northeast to a southeast orientation from the late 1800's to the middle 1900's, contemporaneous with the major morphologic changes in the island (Figure 4) and changes in island rotation.

Storms: Tropical and extratropical cyclones provide the energy in the form of waves and surges which drives barrier islands inland, changes island orientation, and maintains active sand regions on the island (Dolan, *et al.*, 1978; Hayden, 1975). Northeasters (extratropical cyclones) are more

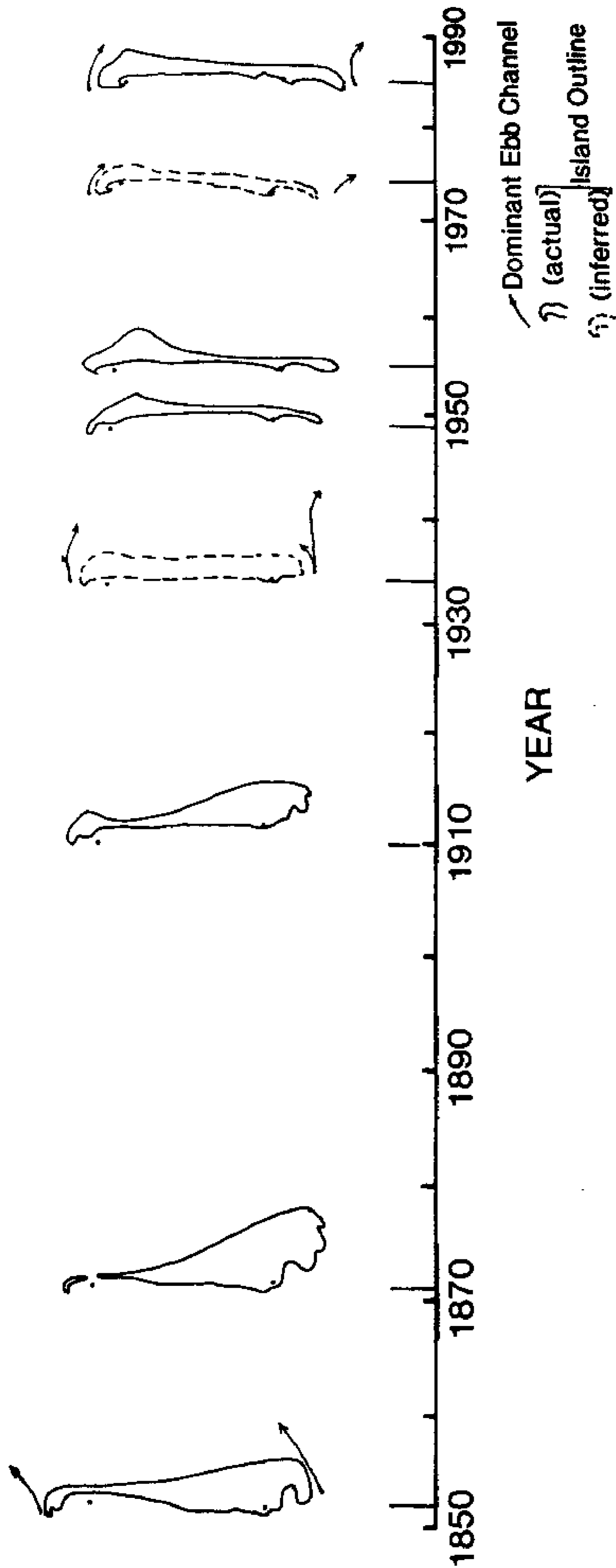


Figure 4. The position of the dominant ebb channel in the inlets to the north and south of Hog Island changed position from 1852 to 1986. In 1852, the inlet was situated to the north side of the inlet and trended in a more northerly direction. In 1934 the ebb channel has shifted southward, and in 1974, the channel shifted further south. Between 1974 and 1986, the dominant ebb channel shifted slightly northward. Each of these changes in ebb channel position corresponds with major changes in island morphology.

important than tropical cyclones because they occur more frequently along the mid-Atlantic coast than tropical cyclones (Dolan *et al.*, 1978). Over 1300 northeasters, producing waves of 1.6 meters or more, occurred along the mid-Atlantic coast during the 42 year period from 1942 to 1984 (Wayland and Hayden, 1975), with an average of 33 storms each year producing waves (>1.6 m) which are capable of eroding the beach (Hayden, 1975). Northeasters, with a wave climate dominant from the northeast, erode the beach and move sediments offshore (Davis, *et al.*, 1972); the otherwise southeast climate (in response to dominant high pressure near the coast) drives sediment onshore during calm periods (Davis, *et al.*, 1972).

Waves reaching the beach are directly related to the storm track, storm duration (Hayden, 1975), and offshore bathymmetry (Goldsmith, *et al.*, 1975). It has been suggested that if storm tracks or storm intensities change, that the result along the active coastline will be recognizable in shoreline configuration and orientation with time (Hayden, 1975; Wayland and Hayden, 1975; Dolan, *et al.*, 1988). Along the Atlantic coast of North America, Hayden (1981) analyzed spatial and temporal variations in storm frequencies occurring from 1885 to 1978. His first two eigenvectors represent the tracks of cyclones along the coast (E1, 28% of variance) and cyclogenesis (E2, 17.3% of variance; Figure 5). In the early 1900's, cyclones had a greater tendency to track to the west of the east coast (continental track: $E_1 < 0$); in the early 1960's, the dominant storm track was over the ocean (marine track: $E_1 > 0$). There tends to be a positive correlation with the number of storms and the marine track (Figure 5). The total increase of storms from the low to high over this 60 year variation was four-fold along Virginia's Eastern Shore (Figure 6).

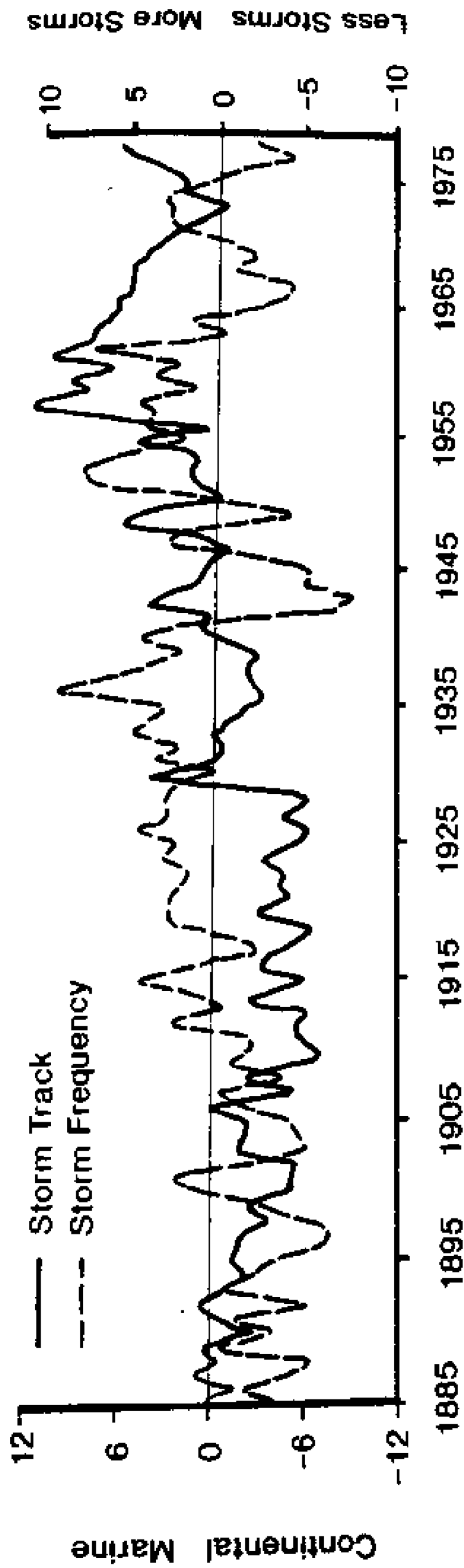


Figure 5. Storm track and storm frequency have varied along the mid-Atlantic coast. In the late 1800's and in the early 1900's, storms tracked mainly to the west of the eastern shore and storms were infrequent (value <0). In the middle 1900's, the storm tracks changed to a more easterly, maritime, position, and storms were more frequent. The dominant storm track was farthest east and the number of storms occurring along the coast was greatest around 1960 (modified from Hayden, 1980).

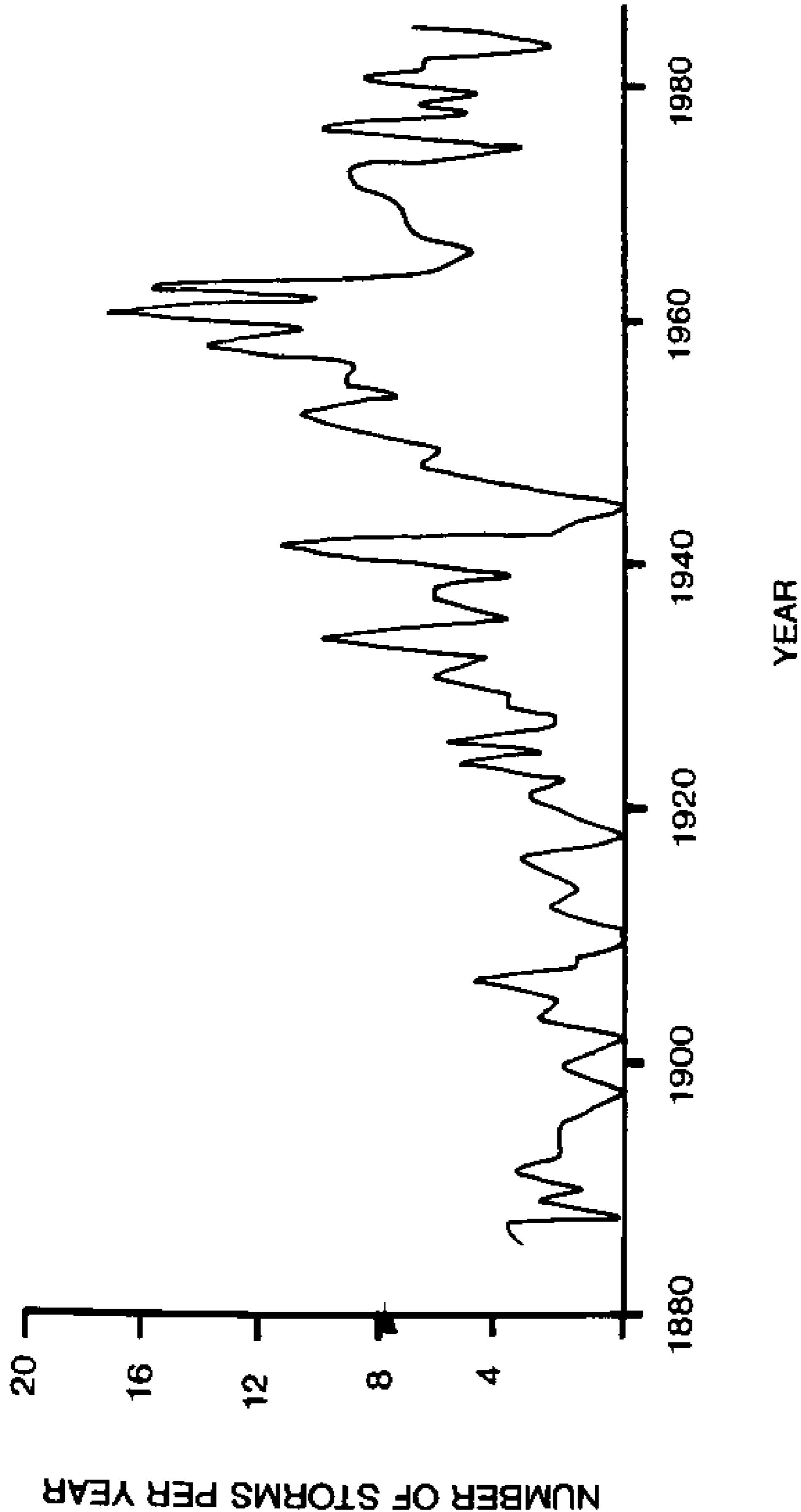


Figure 6. A detailed inspection of storm frequency along the southern Delmarva Peninsula clearly shows that few storms passed through the area around the turn of the century, and a peak in storm frequency occurred around 1960 (from Bruce P. Hayden).

Waves: Waves and storm surges commonly combine to overtop the threshold of the beach and spread across the island, depositing sediment and translating the island landward. As waves approach the coast, they are reflected and refracted by the bottom features offshore. Goldsmith *et al.* (1975) have studied the effect of offshore bathymetry on waves approaching the Virginia coast. Their study showed that the ebb deltas of the middle Virginia barrier islands generally cause the accretionary southeast waves, as well as the erosional northeast waves, to be concentrated at the southern ends of the islands. Most sediments would then tend to be either eroded from or deposited on the shoreface along the south ends of the islands, depending upon storm (high energy, erosional, northeast) or calm (low energy, accretional, southeast) conditions.

During a storm in March 1989, visual observations on Hog Island were made from the beach regarding the relative intensity of waves breaking in the surf zone, directly on the beach, and across the ebb delta. I began observations one day before the storm peak at the south end of the island at mid-tide and walked north as the tide rose, ending at the north end of the island just after high tide. It was apparent from the large number of breakers outlining the ebb delta northeast of Hog Island that a large amount of the wave energy coming from the north-northeast was released on the ebb delta. The ebb delta visibly reduced wave heights reaching the north end of the island. Wave energy reaching the shore increased south of the ebb delta where waves were breaking directly on the beach. There appeared to be a slight difference in wave energy at the extreme southern part of the island, and this may be due to the large ebb delta extending east of Machipongo Inlet or to the difference

