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Central Atlantic Coastal Plain - A Summary of the Geological Evolution of Chesapeake Bay, Eastern United States

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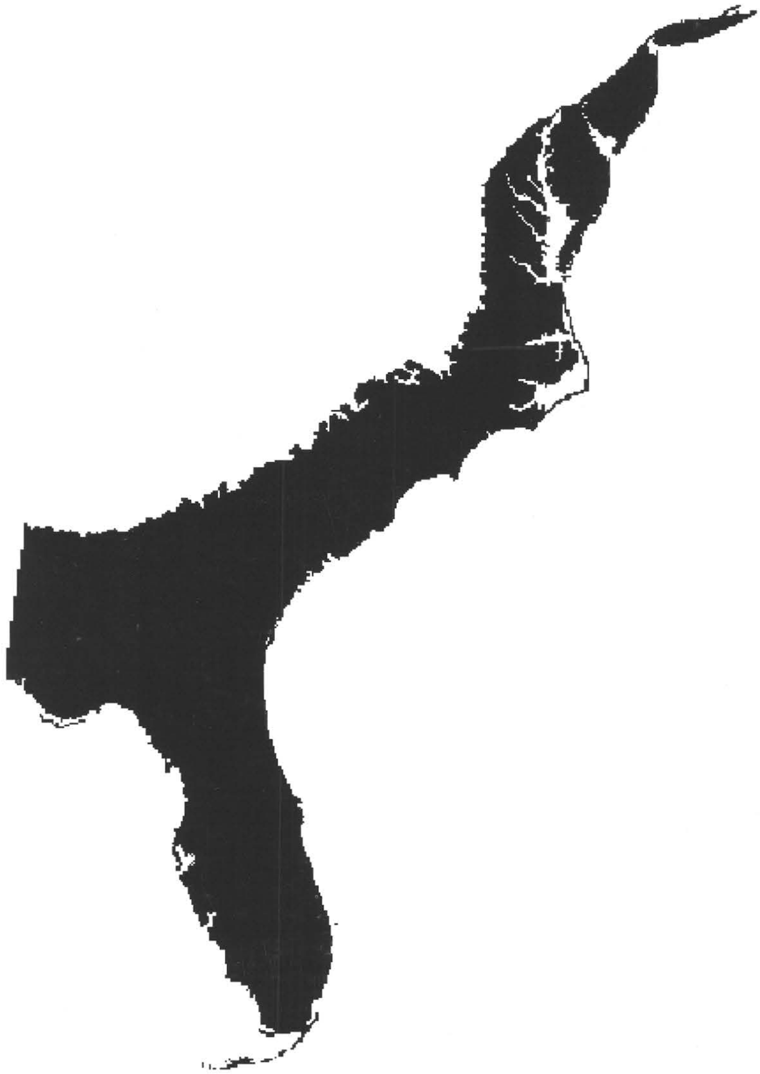

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Central Atlantic Coastal Plain

12. A Summary of the Geological Evolution of Chesapeake Bay, Eastern United States[1]

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INTRODUCTION

The seaward margin of the U.S. Atlantic Coastal Plain has fluctuated through time, from near the Fall Line to near the edge of the present Outer Continental Shelf, owing to changes in relative sea level. The strata that underlie the Coastal Plain were deposited in environments that ranged from fully terrestrial to fully marine. Estuarine environments are critical components of the Coastal Plain; they represent the interface, otherwise known as the shoreline, between the marine and terrestrial depositional systems. The Quaternary evolution of estuaries has important implications for both documenting the history of sea-level changes and interpreting ancient coastal-plain strata.

In this paper, we briefly summarize the Quaternary history of the Chesapeake Bay, the largest of the many Coastal Plain estuaries on the Atlantic coast. This summary is based on recent syntheses of a wide variety of data (Colman and others, 1988, 1990; Colman and Mixon, 1988) on the history and evolution of the bay.

DATA AND METHODS

The Quaternary stratigraphic record in the Chesapeake Bay and the Delmarva Peninsula area is interpreted primarily from three basic types of data: (1) almost 1,600 mi of shallow-penetration, high-resolution, seismic-reflection profiles collected in the main part of the Chesapeake Bay (fig. 12.1); (2) onshore geologic mapping; and (3) boreholes drilled both onshore and in the bay for engineering work, water wells, and stratigraphic studies.

The seismic-reflection data were collected by using both boomer-type systems and 3.5- to 5-kHz systems (Colman and Hobbs, 1987, 1988; Colman and Halka, 1989a, b). The seismic signals were filtered between 300 Hz and 5 kHz and were recorded at a 0.25-s sweep rate. Loran-C was used for navigation during the seismic-reflection surveys.

Results of recent detailed surficial geologic mapping and descriptions of boreholes for the southern Delmarva Peninsula have been published by Mixon (1985). Additional unpublished core data were used to refine ideas about the locations and depths of the ancient channels of the Susquehanna River beneath the Delmarva Peninsula (Colman and Mixon, 1988). Boreholes in the bay itself are concentrated along the bridge and tunnel crossings (Ryan, 1953; Hack, 1957; Harrison and others, 1965) and near the bay mouth (Meisburger, 1972; Colman and Hobbs, 1987).

PALEOCHANNELS OF THE SUSQUEHANNA RIVER

The Quaternary stratigraphy beneath the Chesapeake Bay is dominated by paleochannels cut into the underlying Tertiary marine deposits by the Susquehanna River and its tributaries and by the sediments that fill those channels. We have identified three distinct generations of these paleochannel systems, which we informally call the Cape Charles, the Eastville, and the Exmore paleochannels, in order of increasing age (fig. 12.1). All three channels cross beneath the southern Delmarva Peninsula, and each is named for a geographic feature on the peninsula.

Seismic-reflection and borehole stratigraphic data clearly show that the three paleochannel systems are of different ages and that the sediments that fill them are separated by significant unconformities. The courses of the paleochannels are rarely coincident, although they commonly intersect. Their relative ages can be determined by map patterns and by crosscutting relationships seen on seismic-reflection profiles. The three paleochannel systems have been mapped throughout the bay; their courses projected from the seismic-reflection data in the bay coincide exactly with their known positions onshore (fig. 12.1).

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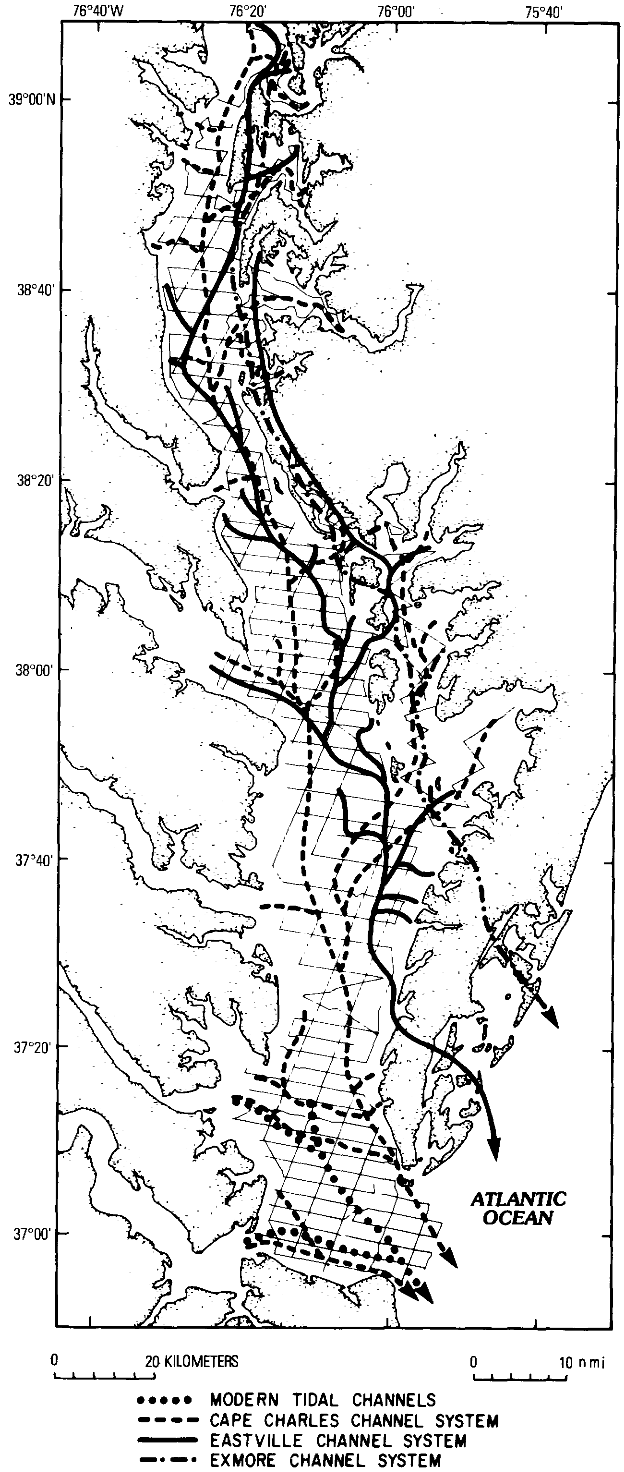

Figure 12.1. Modern tidal channels in the Chesapeake Bay and the three ancient channel systems of the Susquehanna River. The channel systems are listed in order of increasing age; see text. The Cape Charles paleochannel crosses beneath Fishermans Island at the southern tip of the Delmarva Peninsula. The light grid shows tracklines along which seismic-reflection profiles were collected. n mi, nautical miles.

The paleochannel-fill sequences have been divided into two units, whose seismic-reflection attributes are distinctly different. The lower unit of each fill is characterized by relatively strong, irregular, discontinuous reflections, whereas the upper unit of each fill is characterized by relatively weak, long, smooth, continuous, gently dipping reflections. These seismic characteristics, together with lithologic and paleontologic data from relatively deep boreholes (Harrison and others, 1965; Mixon, 1985), indicate that the lower channel-fill unit of each paleochannel is a fluvial deposit, typically consisting of coarse sand and fine gravel. The upper unit of each paleochannel fill, in contrast, was deposited either in restricted river-estuary to open-bay environments or in nearshore-marine environments at the bay mouth. The lithologies of the upper units of the paleochannels are commonly complex, consisting of interbedded muddy sand, silt, and peat. The upper, estuarine, units are finer grained than the lower, fluvial, units, and the estuarine units become finer grained both upsection and upbay.

Where the paleochannels underlie present land areas, their internal structure and fill lithology are known from well logs and stratigraphic boreholes. The Eastville paleochannel is especially well documented where it crosses beneath the Delmarva Peninsula. Mixon (1985) divided the channel fill into several units and showed that, on the Delmarva Peninsula, the paleochannel is overlain by a barrier-spit complex. Both the channel geometry and the fill stratigraphy derived from the borehole data are remarkably similar to those derived from the seismic-reflection profiles of channels beneath the bay.

The geometry and stratigraphy of the paleochannel systems indicate that the channels were formed during periods of low sea level, when the mouth of the Susquehanna River was far out on the present continental shelf. The geometries of the paleochannel systems are similar. The main trunk channel of each system is about 1 to 2.5 mi wide and about 100 to 160 ft deep. Longitudinal profiles of the paleochannels are irregular, and the overall gradients of the trunk channels within the bay are unexpectedly low. During the last major low sea-level stand, about 18,000 yr ago, sea level was perhaps 280 ft below present sea level on the mid-Atlantic Continental Shelf (Dillon and Oldale, 1978). Near the eastern margin of the bay, the bases of the channels are about 200±20 ft below present sea level, and they presumably grade to the deeper lowstand shorelines on the Outer Continental Shelf.

The channel systems show progressively less relation to the present configuration of the Chesapeake Bay with increasing age (fig. 12.1). The channels are relatively close together in the northern part of the Chesapeake Bay, but they diverge significantly toward the southeast; all three cross beneath the present Delmarva Peninsula. Where they cross the peninsula, the major paleochannels are progressively younger toward the south.

The primary reason for this systematic divergence and southward age progression is the southward progradation of the Delmarva Peninsula during major interglacial high sea-level stands (Colman and Mixon, 1988). The latest episode of this progradation process is evident in the late Holocene history of the bay mouth, where the axial channel of the bay has been displaced as much as 7.5 mi in the last few thousand years (Colman and others, 1988). This progradation of the peninsula and the southward migration of the mouth of the bay were episodic, occurring only during the highest of interglacial high sea-level stands (Colman and Mixon, 1988). As sea level fell following a major interglaciation, the displaced estuarine channel became the new fluvial channel, the previous generation of the fluvial channel and its fill were preserved, and the course of the Susquehanna River was altered.

AGES OF THE PALEOCHANNELS AND CHANNEL-FILL SEQUENCES

Evidence for the ages of the paleochannels comes from a variety of chronometric and stratigraphic data. The ages of the Cape Charles paleochannel and its fill are relatively well known because they represent the most recent sea-level cycle and because radiocarbon ages are available for the channel fill. The paleochannel is correlated with marine oxygen-isotope stage 2 (Colman and Mixon, 1988), the peak of which occurred about 18,000 yr ago (Imbrie and others, 1984). The Cape Charles paleochannel has been only partly filled by the Holocene transgression, and the channel itself is clearly related to the low sea-level stand associated with the last major glaciation, the late Wisconsinan. Radiocarbon ages from the channel fill range from about 8,000 to 15,000 yr before present (Harrison and others, 1965; Meisburger, 1972).

Each of the older paleochannels is assumed to correlate with an interval of low sea level of about the same magnitude as that of the late Wisconsinan glaciation and oxygen-isotope stage 2. Each of the older paleochannels is filled with estuarine sediments and overlain by barrier-spit deposits on the Delmarva Peninsula, and no major unconformities exist within these sequences (Colman and Mixon, 1988). Therefore, each of the paleochannels is inferred to correlate with a major glaciation immediately followed by a major interglaciation. These major glacial-interglacial transitions have been called terminations (Broecker and van Donk, 1970); the Cape Charles paleochannel and its Holocene fill represent termination I (Colman and Mixon, 1988). The barrier-spit deposits that overlie the paleochannels on the Delmarva Peninsula represent the last events of previous terminations and thus constrain the ages of the paleochannels.

Uranium-series, uranium-trend, and amino acid age estimates exist for the two ancient barrier systems on the Delmarva Peninsula; the ages of these and nearby deposits have been the subject of considerable discussion and argument, which have been reviewed in relation to the history of the bay by Colman and Mixon (1988). Uranium-series and amino acid age estimates are incompatible for some deposits; ages estimated by both methods conflict with stratigraphic interpretations of other deposits; and some of the uranium-series age estimates do not closely correspond to known times of high sea level. Nevertheless, the barrier spit that overlies the Eastville paleochannel appears to correlate with the last major (Sangamon) interglaciation and with oxygen-isotope stage 5. Accordingly, the Eastville paleochannel presumably dates from oxygen-isotope stage 6, about 150,000 yr ago (Colman and Mixon, 1988). The age of the barrier spit that overlies the Exmore paleochannel is more problematic, but Colman and Mixon (1988) have suggested that these deposits may correlate with oxygen-isotope stage 7 (about 200,000 yr ago) or with stage 11 (about 400,000 yr ago). The Exmore paleochannel likely correlates with the next older stage (stage 8, about 270,000 yr ago, or stage 12, about 430,000 yr ago).

EVOLUTION OF THE CHESAPEAKE BAY

The Quaternary evolution of Chesapeake Bay is intimately related to major eustatic sea-level changes. The record of these changes in the Chesapeake Bay area consists of three generations of paleochannels of the Susquehanna River system, representing low sea levels, and three generations of barrier-spit and channel-fill deposits, representing high sea levels. This unusual record contains features related to both maximum and minimum sea levels, along with nearly complete sedimentary records of three major transgressions. The record has a climax aspect, preserving mainly evidence of the highest and lowest sea levels. On the basis of available age information, the sea-level changes recorded in the Chesapeake Bay area appear to correlate well with the marine oxygen-isotope record and to represent the last few hundred thousand years of sea-level history.

The present Chesapeake Bay is only the latest in a series of at least three generations of the bay, each configured differently. During each period of the bay's existence, progradation of the Delmarva Peninsula caused southward migration of the bay mouth. As sea level fell following each estuarine episode, the bay drained and the fluvial channel of the Susquehanna River incised in a new location, south and west of its former position. As a result, the stratigraphy and morphology of the bay generally became younger toward the south and west. The evolution of Chesapeake Bay shows that coastal-plain estuarine environments can be geologically dynamic, on both short and long time scales.

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