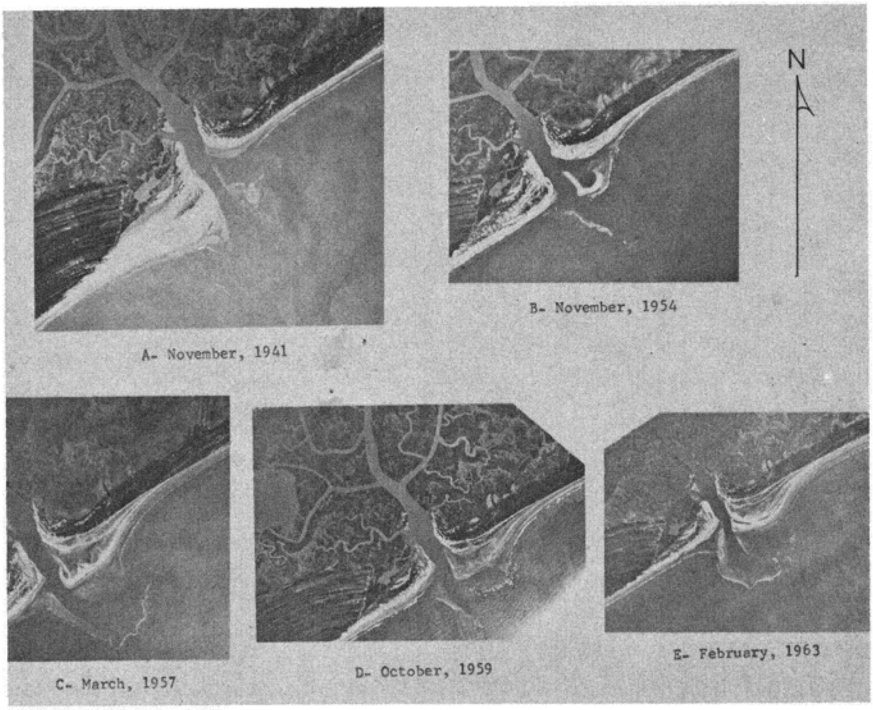

FRONTISPIECE. Shoreline development at Price Inlet, Charleston County, South Carolina. (See text page 187).

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Shoreline Features and Their Changes

Sequence photos show long-term trends as well as alterations by storms.

INTRODUCTION

SINCE WORLD WAR II aerial photographs have been used in the study of coastlines and in coastal engineering to an increasingly large extent. An aerial photograph provides an excellent record of the pattern of features on a coastline that existed at the time of photography. The size of waves, direction of wave fronts, distribution of shallow water sediment accumulations, and the direction of littoral drift may easily be determined. More detail of configuration of coastal and near-shore features is observable than is usually recorded in careful field surveys of a coastline.

From sequential aerial photography it is possible to observe and measure changes resulting from sediment shift during the inter-

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val between dates of photography. The greatest difficulty encountered in interpreting the changes results from the lack of a continuous day-by-day photographic coverage of the coastline. If the photographs indicate that a new inlet has been opened, an old one closed, a new beach ridge formed, or a spit lengthened or cut away, all that can be said is that these changes have occurred between the two dates of photography. The greatest advantage of sequential aerial photography, especially when supplemented by older surveys and charts, is in recording long-term trends in shoreline changes that help in planning shore protection programs.

ABSTRACT: *Sequential aerial photography is an excellent tool for recording long-term trends in shore line changes and for studying shoreline features. Such minor features as wave-cut scarps, sluiceways, washover fans, and underwater sediment patterns are better represented than on charts or maps. The photographs provide an exact basis for measuring net changes in dimension or shape between photographic dates. Changes in the width and position of inlets can be measured directly from the photographs and the amount of sediment eroded or added to the beach can be estimated. At the same time, an estimate of the amount of sediment carried by longshore currents or deposited in the form of shoals or tidal deltas can be determined.*

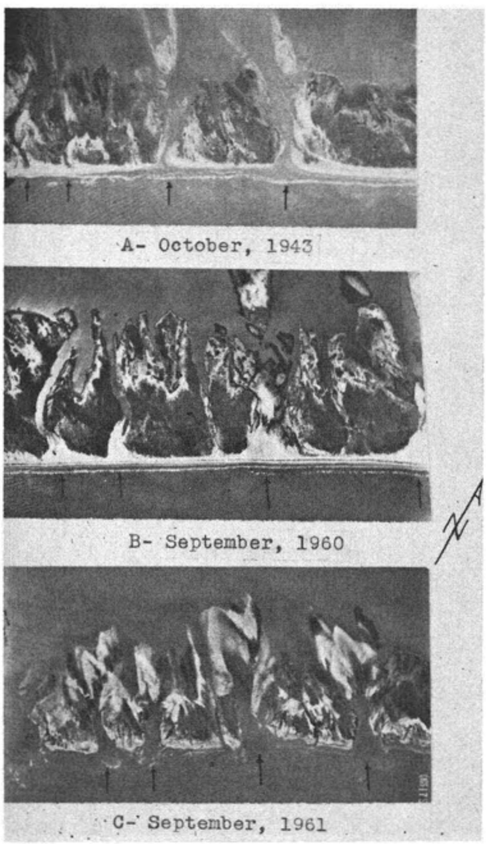

FIG. 1. Portion of Matagorda Peninsula, west of the Colorado River in Texas, showing some of the effects of hurricanes on narrow barrier islands.

Studies of hurricane effects and shoreline changes in selected areas along the Atlantic and Gulf Coasts of the United States by the authors in the past four years have demonstrated that sequential aerial photography is an indispensable tool, and those studies have suggested various other geologic and engineering applications of this tool. Examples of these applications include: river flood effects; changing outlines of deltas and their distributaries; shifting sand dunes; glacial fluctuations; landslides; earthquake effects; volcanic eruptions; and man-made changes.

The principal sources of aerial photography used by the authors are the U. S. Coast and Geodetic Survey and the U. S. Department of Agriculture. The number of dates of photography for the different coastal areas ranges from 3 to 10. Six examples are used in this paper to illustrate some of the phenomena and features discussed.

It should be mentioned that the two parts of the paper—the first dealing with shoreline changes, and the second with shoreline features—are interrelated and are only separated for the sake of the discussion.

SHORELINE CHANGES

A preliminary study of sequential aerial photographs of the United States coast between Massachusetts and Texas shows that many parts have experienced notable changes in outline since the early 1930's when systematic aerial photography of the United States began. Detailed studies were carried out in North Carolina, South Carolina, the west coast of Florida, and Texas. Other

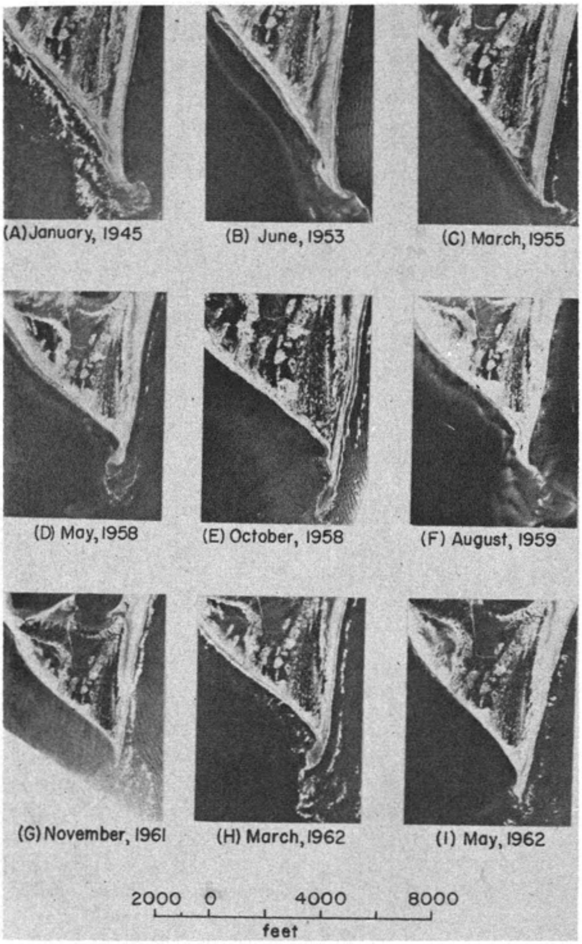

FIG. 2. Aerial photographs of Cape Lookout, North Carolina, 1945 to 1962.

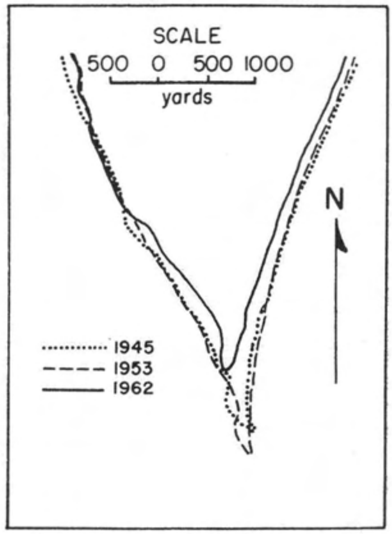

FIG. 3. Sketch diagram, traced from aerial photographs showing the outline of Cape Lookout, North Carolina, in 1945, 1953, and 1962.

studies are underway by colleagues at the University of Illinois in Massachusetts, New Jersey, Maryland, and Virginia.

Careful examination of the photographs shows that the width of the beaches increases and decreases with the seasons and that a single storm may alter the configuration of a shoreline to such a great extent that a long period of time may be required for a shoreline to regain its normal outline and width.

The U. S. Coast and Geodetic Survey commonly photographs a coast just at the end of a violent storm (or in its later phases) to assess storm damage and to revise nautical charts. The photographs show that the greatest changes in coastal form are catastrophic, accomplished by high winds, waves and tides. Photographs taken during an interval of calm weather after a past major storm show that storm-induced changes are gradually smoothed and obliterated; thus, the coast may appear to have reassumed the form it had before the storm. Measurements on photographs show whether the beaches are at the same or different locations.

Figure 1 illustrates the effects of two hurricanes on a portion of Matagorda Peninsula, west of the Colorado River in Texas, and the changes that took place during a period of non-hurricane weather. Two inlets were opened by storm waves of the hurricane of August, 1942 (Figure 1A), washing across low and narrow parts of the barrier island. Spits growing in a southwesterly direction, across the mouths of the inlets, were formed during the year following the hurricane by littoral drift. Figure 1B shows the inlets completely closed, but they were reopened by hurricane Carla of September, 1961 (Figure 1C). Hurricane waves and surges associated with Carla eroded the beaches to a great extent and cut a number of sluiceways through the foreshore dunes. Material eroded from the outer beaches was deposited as washover deltas in the lagoon behind the barrier.

Price Inlet is the outlet of Price Creek in Charleston County, South Carolina (Frontispiece). Erosion of the southwest side and progradation on the northeast side of the inlet took place during the period of 1941 to 1963. A headland on the southwest side of the inlet (*A* in the Frontispiece) was eroded by concentrated wave action due to wave refraction by the headland. At the same time, the northeast side was prograding by the addition of a series of recurved spits built by the southwesterly littoral drift. The position of older spits on this side of the inlet is now marked by beach ridges that help in restoring the original outline of the shore *E* in the Frontispiece.

The Capes of North Carolina provide the largest number of photographic dates of any of the coastal areas studied. Nine dates of photography are available for Cape Lookout (Figure 2). The presence of old beach ridges help in restoring older outlines of the cape. From 1945 to 1962 approximately 100 yards of beach were eroded along the entire stretch of the east shore of the cape (Figure 3), and the spit extending southward from the cape point was cut back by about 650 yards, averaging about 40 yards per year (Figure 3). The orientation of the spit provides information as to the wind direction during the month preceding photography. From 1945 to 1955 the spit was oriented eastward from the cape point (Figure 2A, 2B, 2C); whereas, in most of the other photographs it curves slightly westward from the cape point.

Shoreline Features

Depositional features (such as bars, spits, sandkeys, washovers, barriers and beach ridges) and *erosional* features (such as wave-cut terraces, sea cliffs, and stacks) show more clearly and are easier to study from aerial photographs than from the ground. From sequential aerial photography it is possible sometimes to date individual beach ridges or to record the period of their formation within a decade or so. Changes in width and position of inlets can be measured directly from the photographs, and an estimate of the amount of sediment deposited in the form of shoals or tidal deltas, on either the lagoon-side or the ocean-side of the inlets, can easily be de-

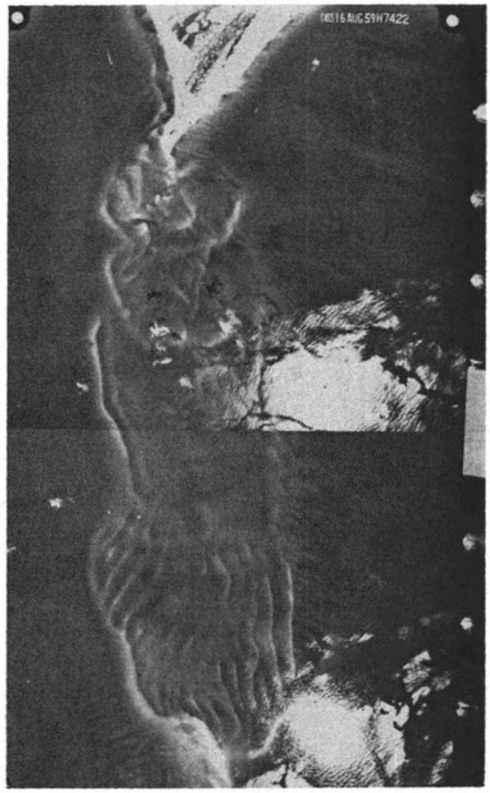

FIG. 4. Aerial photo mosaic of Cape Lookout Shoals, North Carolina.

termined. Studies of the amount of sediment carried by littoral currents into shoaling areas, as, for example, off the southern tips of the North Carolina Capes, can be made by contouring the shoals at different dates, using a stereo plotter and estimating the amount added or removed during a given period of time. Figure 4 gives an excellent picture of the form of sand deposits composing Cape Lookout Shoals in North Carolina. The shoals extend about 9 miles south-southwestward from the cape point, reaching 2 miles in width and 2 to 18 feet in depth. These shoals were formed by sediment eroded from beaches north of the cape and carried southward into the ocean by littoral currents, particularly during times of severe storms.

The formation of new *barrier islands* and *sandkeys* from submerged sand deposits by storm waves and their subsequent changes can also be studied from sequential aerial photographs. Figure 5 shows LaCosta Island, which is located in Lee County, on the west coast of Florida. A strong outflow from Charlotte Harbor (on the north side of the island) drifts sediment in a southerly direction to

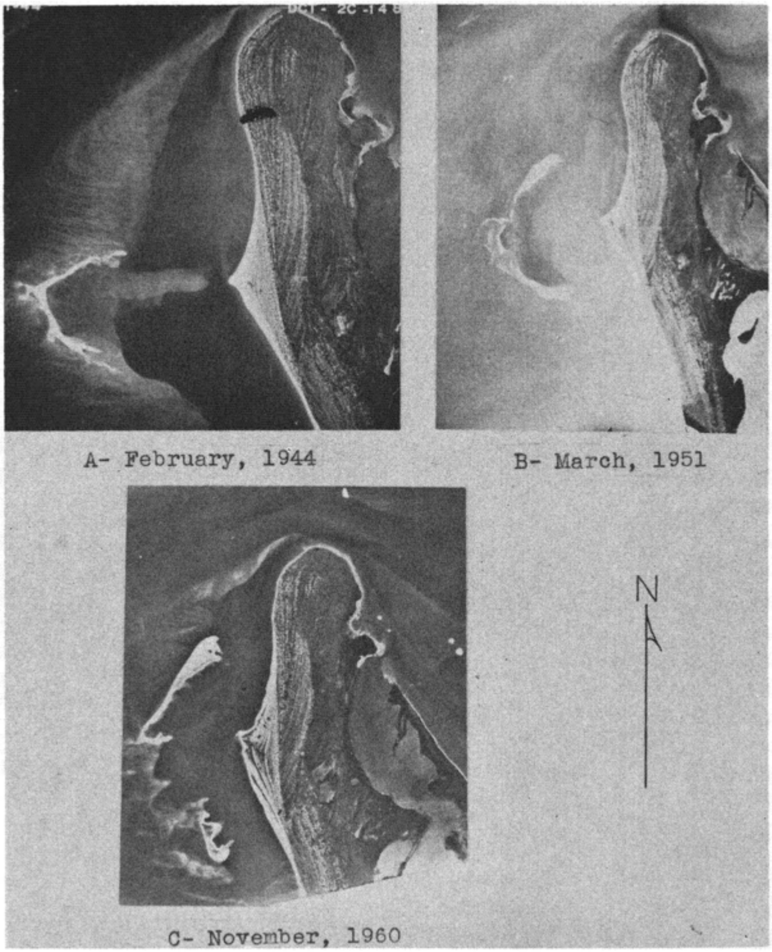

FIG. 5. Aerial photographs of LaCosta Island, Lee County, Florida, 1944 to 1960.

form a big shoal that resembles an arc surrounding the island (Figure 5A). A cuspate sandkey was formed by storm waves scouring the sediments of the shoaling area and a tombolo grew eastward towards the island. The presence of the shoal resulted in a wave refraction pattern that constantly brought material towards the island, and a cuspate foreland was formed at a point facing the sandkey. By 1951 (Figure 5B) the sandkey was split into two. By 1960 (Figure 5C) it migrated eastward, and its northern portion grew in length and developed a form close to that of 1944.

The building of a cone-shaped *delta* at the new outlet of the Brazos River in Texas and the alternate formation of barrier islands around the delta are illustrated in Figure 6. A diversion channel, cut by the U. S. Corps of Engineers in the late 1920's, allowed the river to enter directly into the Gulf after an older bay approximately 6 miles northeast of the present outlet had become filled. Sediments carried by the river were deposited to form an arcuate delta, and its seaward limit was marked by two barrier islands, one on each side of the river channel (Figure 6A).

From 1938 to 1952 the delta had extended a distance of about one mile into the Gulf, and the marshy areas had appeared above water due to accumulation of fine sediment from the river (Figure 6B). In 1952 the east side of the delta was marked by a barrier island, and the southwest side had two lines of emergent barrier islands. These islands were formed by hurricane surges from submerged longshore bars just below the intertidal zone off the river outlet. By 1960 a third line of barriers was built on the southwest side of the outlet (Figure 6C). After hurricane Carla of September 1961, the southwest side of the delta was cut back by a distance of about one-

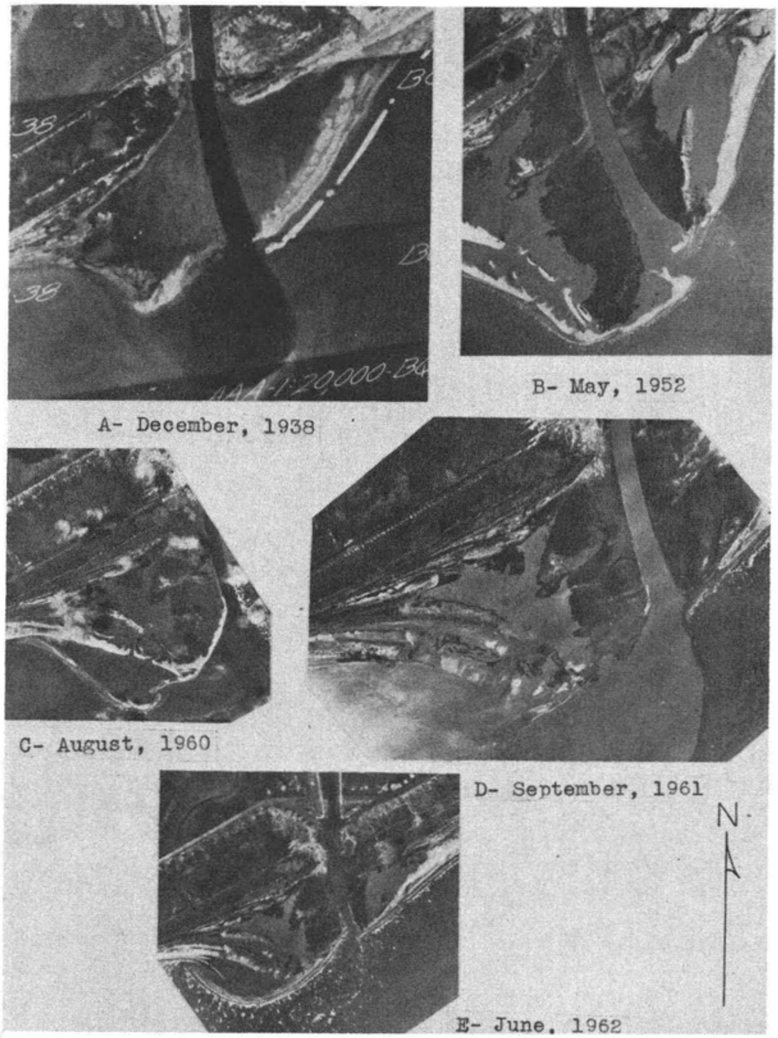

FIG. 6. Aerial photographs showing changes in the size and form of the Brazos River delta, Texas.

third of a mile; the barriers were almost entirely eroded and a large shoal was formed in their place (Figure 6D). About nine months after the hurricane, the sediments of the shoal were reworked and a large lunate bar was built enclosing remnants of the destroyed barriers (Figure 6E).

CONCLUSION

Sequential aerial photography is an excellent tool for the study of shoreline features and shoreline changes. Such minor features as wave-cut scarps; sluiceways; washover fans; and underwater sediment patterns in lagoons, inlets, or the seas are better represented than on any charts or maps. The photographs provide an exact basis for measuring net changes in dimension or shape between photographic dates. However, they do not provide information as to the exact time of origin of a new coastal feature, nor its impelling cause.