DOCUMENT RESUME

ED 086 556 SE 017 228

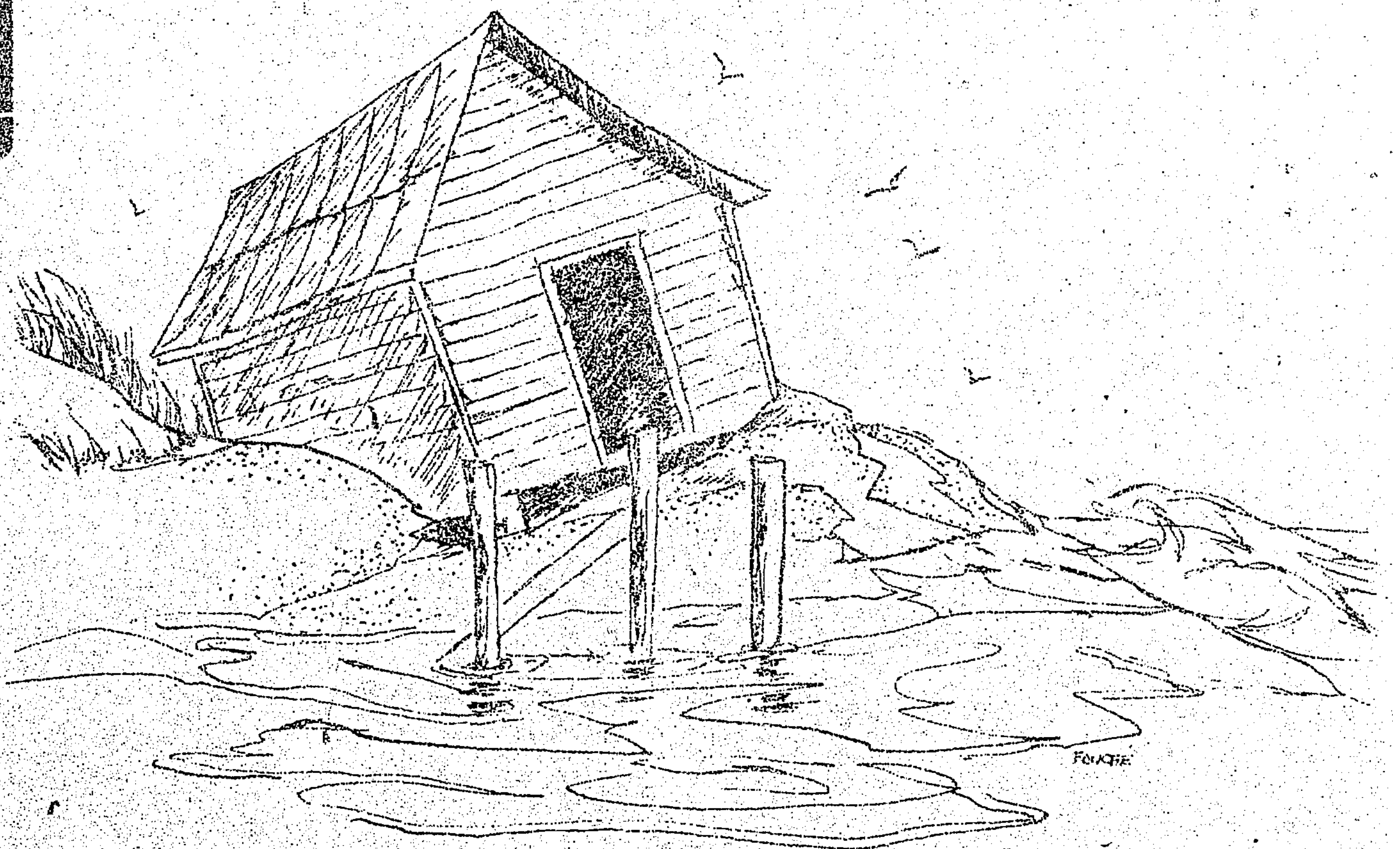
AUTHOR	Awkerman, Gary L.
TITLE	Sea Changes. Topics in Marine Earth Science.
INSTITUTION	Charleston County School District, North Charleston, S.C.
SPONS AGENCY	Bureau of Elementary and Secondary Education (DHEW/OE), Washington, D.C.
PUB DATE	[73]
NOTE	27p.
EDRS PRICE	MF-$0.65 HC-$3.29
DESCRIPTORS	Biology; Earth Science; *Environmental Education; *Instructional Materials; *Marine Biology; Natural Sciences; *Oceanology; *Secondary School Science; Study Guides
IDENTIFIERS	Elementary Secondary Education Act Title III; ESEA Title III

ABSTRACT

This publication is designed for use in standard science curricula to develop oceanologic manifestations of certain science topics. Included are teacher guides, student activities, and demonstrations designed to impart ocean science understanding to high school students. The principal theme of Changes in the Sea is presented in this particular publication. Topics discussed include: (1) Continental Drift; (2) Shoreline Changes; (3) Sea Level Changes; (4) Beaches; (5) Nearshore Currents and Man-Made Structures; and (6) Estuaries. This particular publication is content-oriented rather than activity-oriented. This work was prepared under an ESEA Title III contract. (Author/EB)

SEA CHANGES

TOPICS IN MARINE EARTH SCIENCE



CHARLESTON COUNTY OCEAN SCIENCE PROJECT
ESEA TITLE III, P.L. 89-10

Dr. Alton C. Crews
Superintendent

r. Michael V. Woodall
sistant Superintendent

Dr. Gary L. Awkerman
Director of Natural Sciences

Mr. Paul F. Teller
Ocean Science Specialist

FOREWORD

Prior to 1970, Charleston County possessed no formal program to develop an organized study of ocean science. A few teachers would cover selected topics on occasion, but there was no formal, district-wide effort to make ocean science curricula available to all students in the secondary schools of the district.

The increasing emphasis on the study of the oceans by federal, state, and local governments and the resultant increase in the importance of the ocean to all citizens has created a need for coherent ocean science programs for all students. Nowhere is the need for coherent study of the sea more immediately relevant than in Charleston County. The county is permeated with food and sport-filled waterways and heavily dependent on naval and commercial shipping. Present and future problems in harbor maintenance and problems of estuarine multiple use indicate a need for a local citizenry literate in ocean science. The most effective means of developing large-scale literacy is the public school.

This publication is one of a series made possible through a Title III, ESEA grant entitled Oceanographic Science Conceptual Schemes Project. These publications are designed for use in standard science curricula to develop oceanologic manifestations of certain science topics. The publications include teacher guides, student activities, and demonstrations designed to impart ocean science understanding to Charleston County high school students.

The members of the ocean science staff include Dr. Gary Awkerman, Director of Natural Sciences, Mr. Michael Graves, Assistant Director of Natural Sciences, and Mr. Paul F. Teller, curriculum specialist in ocean science. They were assisted by the following writing staff: Sister Bernadette Kostbar, Ms. Beverly Lauderdale, Ms. Dorothy Bonnett, Ms. Caroline Pearson, Ms. Pat Hayes, Mr. Tommy Yon, Mr. Nat Bell, Mr. Steve Proctor, and Mr. Leonard Higgins. Principal typists were Ms. Anita Skinner, Ms. Roberta Brown, and Ms. Lynda Wallace. Without their cheerful, dedicated efforts and excellent typing, this project could not have been completed.

Special thanks are due to consultants Dr. Norman A. Chamberlain and Dr. F. J. Vernberg, who contributed much valuable information on tides and estuaries, respectively. Ms. Virginia Bolton prepared the cover drawings. Mr. Paul F. Teller completed the internal figures.

Gary L. Awkerman
Director of Natural Sciences

<u>Introduction</u>

One of the principal themes of Earth Science is change. Changes in the Earth may vary from momentary changes to those taking place over billions of years. When we examine the sea, we find changes taking place on all these time scales.

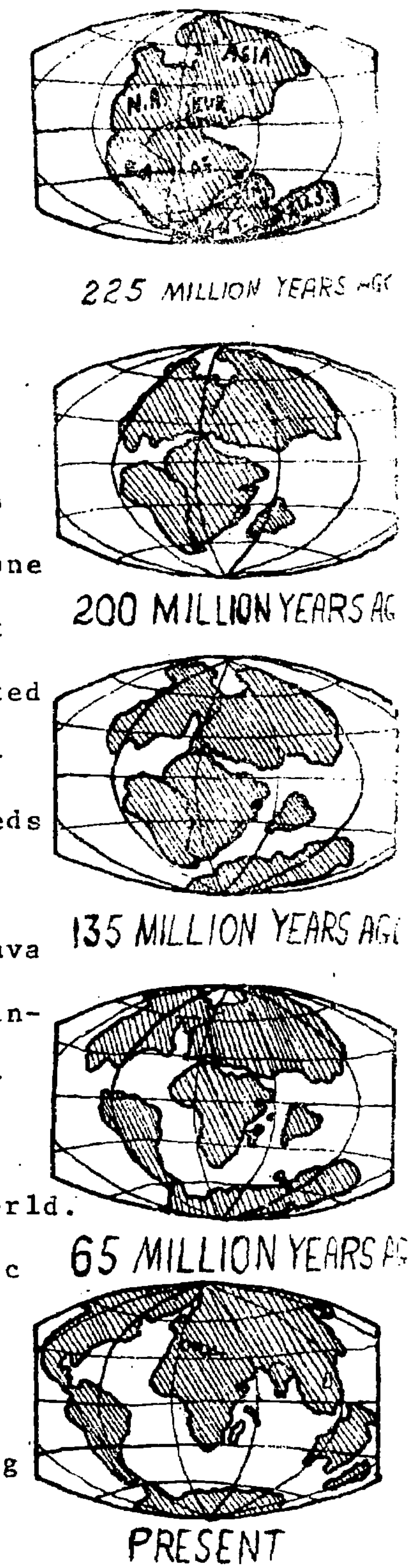
Continental Drift

One long term change that is currently of interest is continental drift. According to this theory, all the continents were once joined in one great land mass called Gondwanaland. As a result of seismic activity, the original land mass parted and the present continents were formed. The continents are still moving apart at different speeds and in different directions.

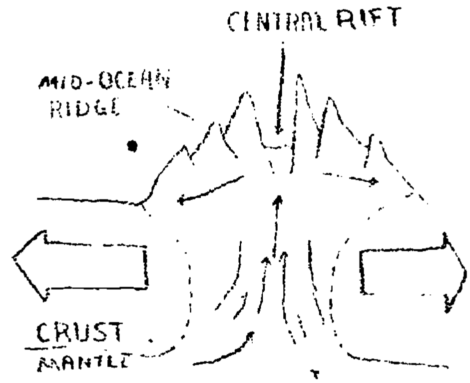
The continents are being pushed apart by lava flows from the bottom of the sea. One of the principal sites of the separating forces is the Mid-Ocean Ridge. The Mid-Ocean Ridge is a mountain range extending through all the oceans of the world. The Mid-Ocean Ridge is a site of intense volcanic activity. As new lava flows occur, they push the continents apart on well-defined crustal plates.

North America and Europe are presently being

DRIFTING OF CONTINENTS THROUGH THE AGES

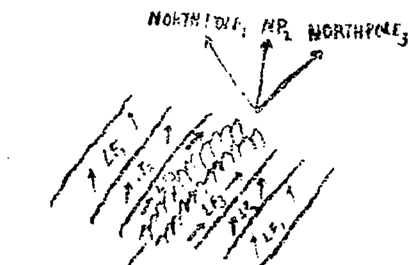


pushed apart by the deposition of new flows from the Mid-Atlantic portion of the Mid-Ocean Ridge. A series of bands of solidified lava has been found in the Atlantic. On either side of the Mid-Atlantic Ridge can be found lava bands of equal age. The paired lava bands are more recent near the ridge and older near the continents.

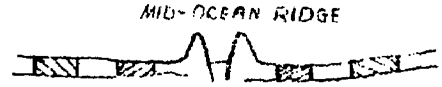


LAVA FLOWS AT THE MID-OCEAN RIDGE EXERT FORCES WHICH SPREAD THE SEA FLOOR (AFTER WEYL, OCEANOGRAPHY, JOHN WILEY & SONS)

The lava bands are shown to be of equal age because each member of a pair will deflect a compass in a different direction. This came about because the flowing lava was magnetized in the direction of the Earth's magnetic pole at that time. As the lava cooled, its polarity was frozen in place. As the magnetic pole wandered, it magnetized the next lava flow in a different direction. The polarity of those rocks was frozen in place when they cooled, forming a series of bands of rocks magnetized in different directions. These bands enable us to trace the gradual moving apart of the portions of sea floor on either side of the Mid-Ocean Ridge.

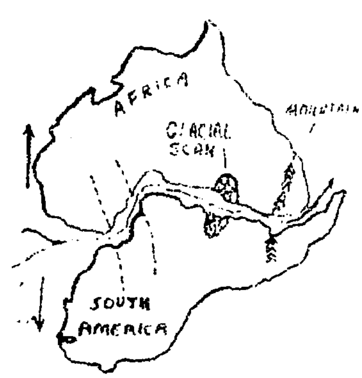


EACH SUCCESSIVE LAVA FLOW IS MAGNETIZED IN THE DIRECTION OF THE NORTH MAGNETIC POLE AT THE TIME OF FLOW.

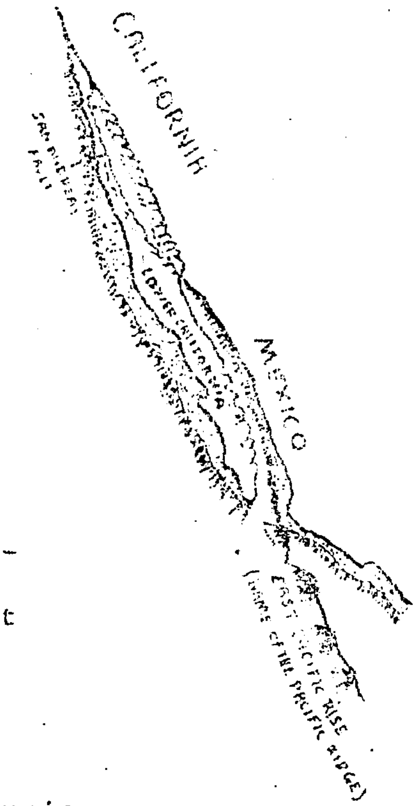


BANDS OF ROCKS OF EQUAL MAGNETIC POLARITY AND AGE ARE FOUND ON EITHER SIDE OF THE MID-OCEAN RIDGE.

As the width of solidified lava grew, the American and Afro-Eurasian land masses were pushed apart. This would create problems if the earth were to remain the same diameter at the



time the continents were being pushed apart. The continents would have to have some place to go.



If we now look at the American side of the Pacific, we can see what has happened. As the North American continent was pushed westward, it rode up over the Pacific Ridge. If we look closely at a topographic map of the floor of the eastern Pacific, we can see that a mountain range runs northward off the western coast of South America. It disappears in the Baja pennisula south of California.

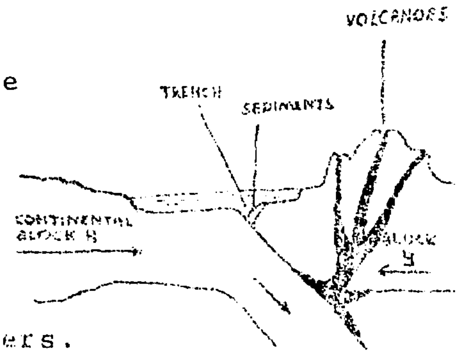
If we examine the western coast of California, we can see a chain of mountains running northward in line with the East Pacific mountain range. Associated with these mountains is the famous San Andreas fault, a site of damaging earthquakes in California. This fault traces the line of the Pacific Ridge which has been buried by the western edge of California.

The east Pacific mountain range, called the Antarctic Pacific Ridge, is a site of volcanic activity just as is the Mid-Atlantic Ridge. It is also exerting forces tending to widen the Pacific Ocean between Eurasia and America.

The Antarctic Pacific Ridge is also slashed great perpendicular gashes called <u>fracture</u>

zones. These fracture zones result from shearing stresses caused by the movement of the great crustal plates past each other.

In the western Pacific, there is another site of crustal plate overlap. It is reversed in respect to the California system. In California, the great land mass was riding up over the lower sea floor. In the western Pacific, the seafloor is sliding under the edge of the eastward-moving Eurasian land masses. The points of submergence of the seafloor beneath Eurasia are visible as great trenches, as deep as 10,00 meters.



Once an area of the sea floor sinks beneath the Eurasian continent, it enters the mantle, where it melts and enters the general semi-molten rock pool of the mantle. It will eventually take part in great mantle convection currents to emerge once again as new seafloor hurled from volcanoes of the Mid-Ocean Ridge. Submergence and eventual recycling make room for the moving continents. They are reasons why continents can move about without a general expansion of the earth. The lava pouring from undersea volcanoes eventually recycles into the mantle to emerge in some other lava flow eons hence.

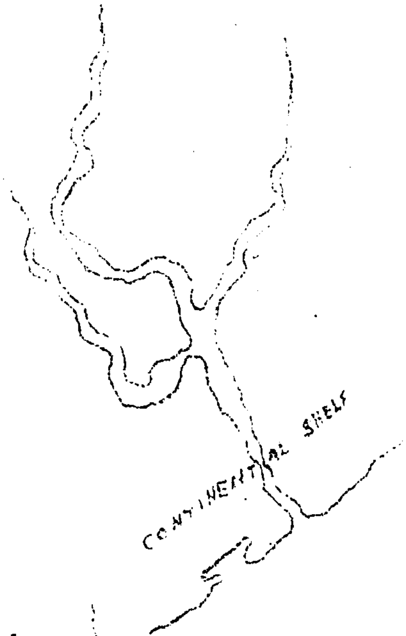
As the seafloor passes under the Eurasian continent, the eastern Eurasian land edge buckles, throwing up great mountain ranges that form the islands of Japan and Korea and other western Pacific groups. Some northward movement also occurs in the Pacific crustal plate, forming the Aleutian trenches and the mountainous Aleutian Islands. The Pacific ocean is ringed with a series of actively forming mountains which are often distorted in such a way as to let their underlying lava escape to the surface in violent volcanic eruption. This is the origin of the famous Pacific "Ring of Fire". The coasts of nations bordering the Pacific are wracked by volcanic eruptions and earthquakes. These upheavals result from the dynamic nature of the earth in the whole Pacific region.

VOLCANIC ACTIVITY IN THE PACIFIC-THE "RING OF FIRE"

Sea level changes

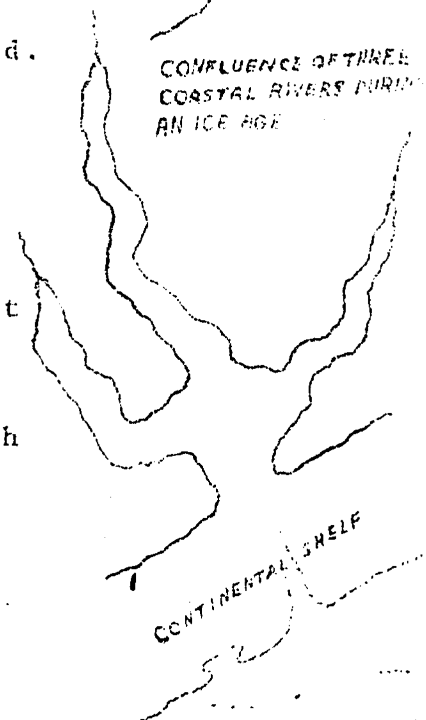
A shorter-period change, in the scale of tens of thousands of years, is a rhythmic change in world sea level. These changes result from periodic fluctuations in global temperatures which bring about ice ages. The waters of the world ocean become locked up in great ice sheets which cover the land masses of the earth. Sufficient water becomes frozen to lower sea level by as much as 150 meters. The land sags under the weight of the ice, decreasing the rate of coastline exposure, but eventually the shoreline becomes lower by 100-150 meters. In horizontal distance, the sea recedes from the coast by many miles.

In ice ages, many rivers cut their beds to the edge of the continental shelf, carving great canyons in the shelf. Glaciers move out on the exposed shelf, gouging great holes in it and leaving large piles of debris.



CONFLUENCE OF THREE COASTAL RIVERS DURING AN ICE AGE

As the ice age ends, the river mouths are drowned and the great river canyons are submerged. The drowned river mouths are called estuaries. Examples of estuaries are the Chesapeake Bay and Charleston Harbor. The river canyons remain as indentations in the undersea landscape. Two great canyons of note are Norfolk canyon at the mouth of the Chesapeake and Hudson Canyon off the mouth of the Hudson River in New York.

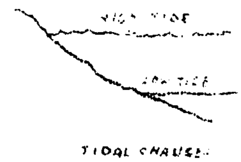


WHEN ICE-AGE GLACIERS MELT WORLD SEA LEVEL RISES. OLD RIVER VALLEYS ARE FLOODED, FORMING ESTUARIES.

The glacial debris left on the shelf forms great "banks" which attract many fish. This is the origin of the famous Grand Banks off Newfoundland. The Grand Banks are the site of one of the greatest fisheries in the Atlantic.

In places where mountains came down to the shelf, long narrow fjords are found, such as in Norway and Newfoundland. Fjords were carved by glaciers which left debris near the present mouth of the fjord. The resulting sill inhibits deep circulation in the fjord, leading to anaerobic bottom conditions. The scenery of fjords is genneraily spectacular.

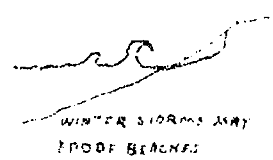
We are currently between ice ages. Water levels have generally remained stable during historic times.



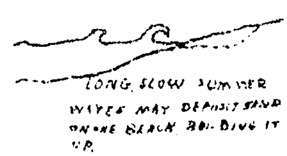
DAILY CHANGES

Shoreline Changes

Changes in the shoreline can range in time from the scale of ice age changes to changes taking place in a few decades or a few hours.

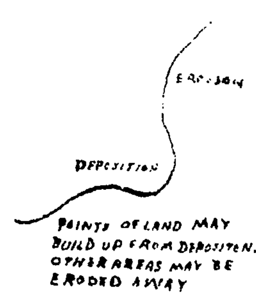


The changes in the shoreline which take place in periods of decades, seasons, weeks, days, or hours, result from the day to day interactions of the sea with the land at its edge.



SEASONAL CHANGES

The two basic processes affecting shoreline changes are erosion and deposition. At time, the sea carries the land away. At other times, the sea builds it up. Both processes occur constantly. The stability, buildup, or breakdown of the shore depend on the balance between erosion and deposition.



CHANGES OVER YEARS TO DECADES

Wind and waves are the basic agents of both processes. When the wind and sea are clam, particles tend to settle out on the beach and build the shoreline outward. When the high winds of winter gales send towering waves crashing against cliffs, beaches, walls, and other shore-based objects, the shoreline can be eroded away.

The force of storm waves is almost unbelievable. They can move whole breakwaters weighing as much as two and a half thousand tons and throw boulders like connonballs. At Tillamook light on our east coast, a storm wave threw a 135-pound rock 91 feet high to pierce the roof of the lighthouse. Such incidents are fairly common on stormy coasts.

A single storm can change the face of whole harbors overnight. In 1970, a major channel in North Carolina was closed by heavy December storms. On December 23, 1971, the U.S. Army Corps of Engineers needed to use 26 tons of explosives to reopen the channel.

In quieter times, waves lapping at an angle up a coast may remove sediments from points and distribute them along the coast, gradually eroding the points and building up the rest of the coast. In our area, we are concerned principally with two types of shoreline features: estuaries and beaches.

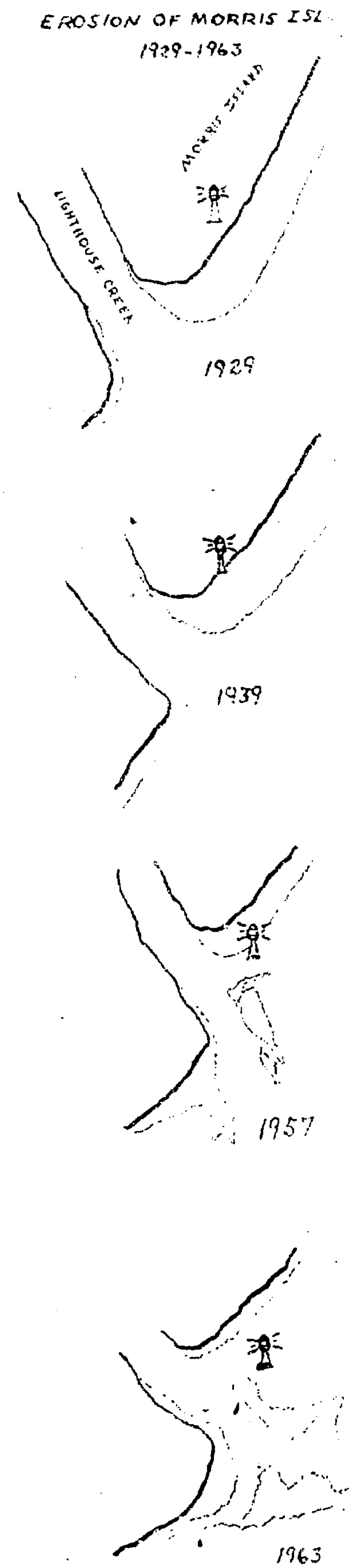
<u>Beaches-general</u>

Beaches are expanses of sand and rocks found at the edge of the sea. They are often associated with sand dunes and special forests called maritime forests. The periods of change associated with beaches may vary from years to hours.

Over a period of years, beaches and whole land areas behind them may be worn away. Morris Island lighthouse off Charleston Harbor is an example of such a change.

Before 1939, Morris Island light was located on the beach of Morris Island (figure 1a). Successive erosion over the years has left the light about ¼ mile offshore (figure 1c). Erosion continues on the tip of Folly Island and Morris Island. The U.S. Coast Guard Station on Folly Beach has placed great plastic pillows of sand on their beach to prevent further erosion.

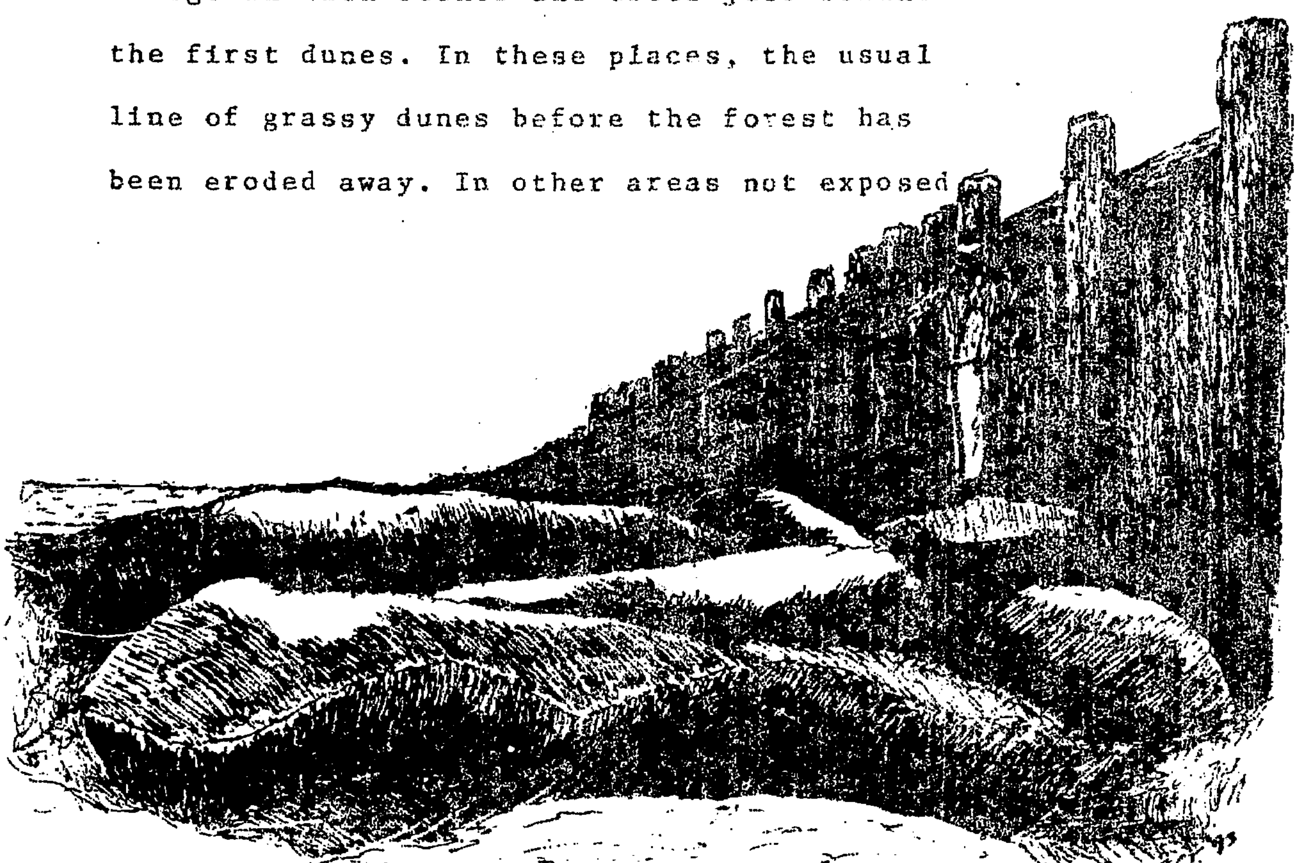
The erosion on the east end of Folly Beach has been sufficiently recent that signs of sold marshes still persist. Just north of the northermost groin at the Coast Guard Station a flat of hard mud is exposed at low tide. The flat is full of old mussel and clam shells. When the flat was part of marsh, the mussels lived in a pile of their



own wastes which became hardened to form the present flat.

The extent of erosion of Folly and Morris Islands is evident from figure 1. The lighthouse was on the front beach in 1939 and is now about ¼ mile offshore.

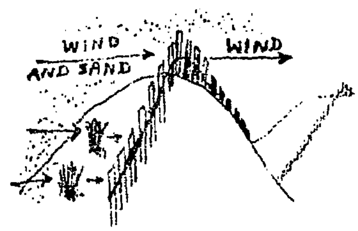
Another indication of the erosion of Folly Beach is in the sand dunes. Dunes on the front beach are often heavily overgrown with bushes and trees just behind the first dunes. In these places, the usual line of grassy dunes before the forest has been eroded away. In other areas not exposed



Sandbags to prevent erosion at USCG Loran Station, Folly Beach, S.C.

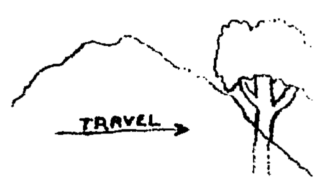
to the full force of the waves, dunes are being built. Further up the beach, a whole line of beach houses has been washed away in the last few decades.

One agent building dunes are the sea oats and other grasses growing on the dunes. Their roots hold the sand as it comes in, helping to build the dunes higher and higher. In some parts of the country, slat fences are built on top of the dunes for the same reason. The slats cause eddy currents in the wind passing through them. Sand falls to the ground on the lee side of the fence.



The wind which drops the particles is the principal force building the dunes. It picks up sand and blows it up the beach, piling it into dunes which can be anchored by grass roots and fences.

Traveling dunes result where the sand has not been sufficiently anchored. The sands are blown further and further back along the beach. Sometimes it is possible to see trees which are being buried beneath the leeward edge of moving dunes. The moving dunes are made up of sand grains blown from the beach. This aids the water in its work of eroding the beach.



If one helps build front dunes, he helps to preserve and even extend the beach. A favorite environmental project of coastal schools has been dune stablization. In these projects, the classes involved have planted grasses on the dunes or used various windbreak materials. One of the most resourceful projects gathered old Christmas trees from their town. They anchored the trees in rows on the beach with heartening results the following spring. The old trees were covered with new dunes.

Beach terminology

The beach itself has a characteristic shape. Just at the water's edge, there is a raised plateau of deposited sand called a berm. The waves swash against the berm as they come in, giving the region in front of the berm the name swash zone. Usually, the endpoint of the waves digs a shallow trough called a runnel, which has a ridge in front of it. Seaward of the ridge, we can see a line of small breakers, the secondary breaker line. There is usually a trough in this area which is dug by wave action. Seaward of the secondary breaker line is a line of larger breakers called the primary breaker line. Usually, the confused currents in this area have deposited a bar of sand, commonly called a "sandbar". The terminology of the various zones is shown in figure 2. In between the swash zone and the breaker zone is the surf zone.

The surf zone and swash zone comprise the foreshore zone. The breaker zone and just seaward of it are called the inshore zone. Seaward of this is the offshore zone. The flat beach and dunes would be the backshore zone.

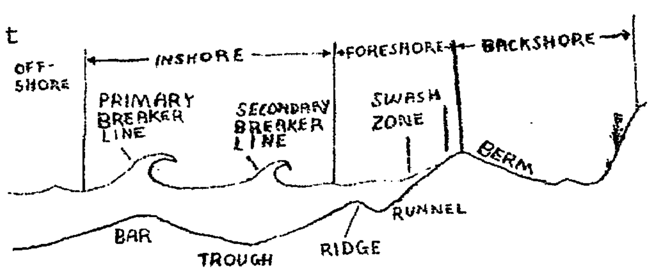
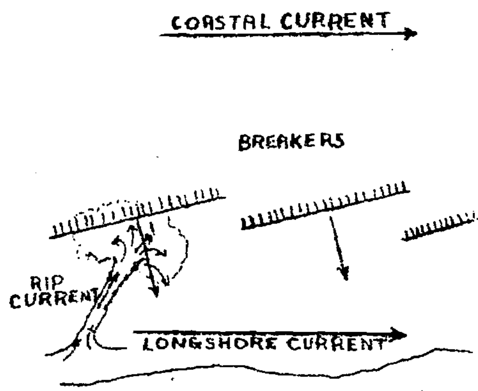


FIGURE 2. BEACH TERMINOLOGY [REDRAWN FROM INGLE(1966) THE MOVEMENT OF BEACH SAND: DEVELO DEVELOPMENTS IN SEDIMENTOLOGY 5:12: AMERICAN ELSEVIER]

Beaches with gentle slopes usually have a wide surf zone. Steep beaches have no surf zone.

The currents of the waves carry sand back and forth through the water. These currents can cause seasonal changes in the character of the beach. In parts of California, there are sandy beaches in summer. Winter storms build up strong enough currents to carry away the sand, but not the heavier gravel beneath. In winter, the sandy beaches become rocky for this reason.

The currents produced by wave action can all be classed as near-shore currents. One of the most obvious nearshore current systems is composed of the currents produced by the washing of the waves. On the surface, as the wave is coming in, there is a shoreward current. Under this, there is a seaward current. The resulting turbulence keeps the sand in the surf zone stirred up.



FROM INGLE (1966

If the waves are coming in at an angle to the shore, the suspended sand may be transported along the shore in a longshore current. Longshore currents may keep building up in front of the bar until they reach a channel through which they can escape. They then spill through the channel in the bar as a rip current.

Rip currents drown many people each year, principally because the victims attempt to fight the currents. The wise bather will swim parallel to the shore to pass out of the narrow current.

Nearshore Currents and man-made structures

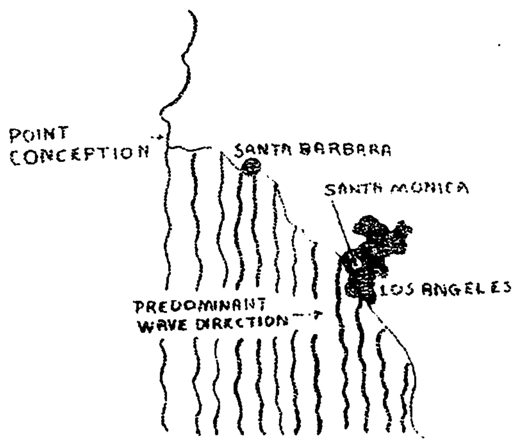
FIGURE 3. EFFECTS OF BREAKWATERS IN SOUTHERN CALIFORNIA. After W[illegible] 1970.

Nearshore currents can have several effects on the shoreline and man's attempts to maintain it. Groins and breakwaters are two frequently used devices for coastal maintenance. Both of these require considerable study before they can be constructed properly.

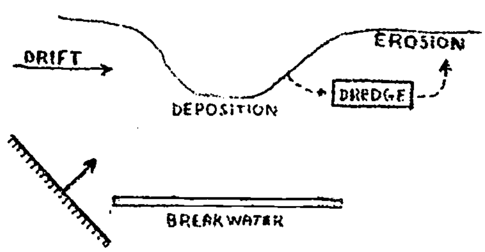
Breakwaters are often built to shelter small craft from the force of the open sea. They are very expensive undertakings. Their purpose of building harbors can be defeated by filling in, as in the following two cases.

In Santa Barbara, California, a breakwater was built to form a small boat harbor, as in figure 3c. However, Santa Barbara is located South of Point Conception, a bend in the coast. Along the bend, the waves move parallel to the shore, causing much longshore drift of sand along the coast (figure 3a).

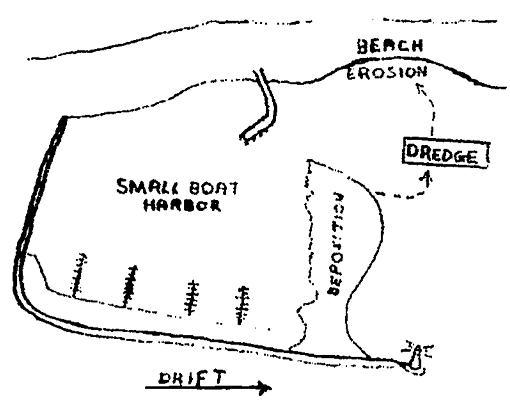
The Santa Barbara breakwater interrupted this flow. The sand coming from beaches to the west settled just



3a. THE COAST OF SOUTHERN CALIFORNIA



3b. SANTA MONICA HARBOR



3c. SANTA BARBARA HARBOR

inside the harbor (figure 3c).

Beaches to the east of the breakwater were usually maintained by sediment recruitment from the west. As a result of the trapping of western sediment by the breakwater, the eastern beaches eroded away. Now a very expensive dredge must constantly take sand from the harbor and deposit it on the eastern beach.

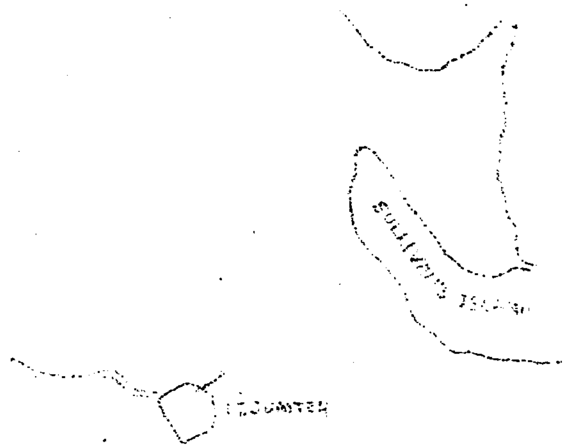
The town of Santa Monica thought they would avoid the problems of Santa Barbara by putting their seawall several hundred meters offshore, parallel to the shoreline but with no direct connection to it. It was believed that this would allow the longshore sediment drift to operate but still shield their harbor from the open sea (figure 3b).

In Santa Monica, the lack of the direct force of ocean waves allowed the beach behind the breakwater to build out from lack of erosion. The built-up point interfered with the longshore currents, trapping sand. As a result, the harbor still filled in, and the eastern beaches were still eroded (figure 3b).

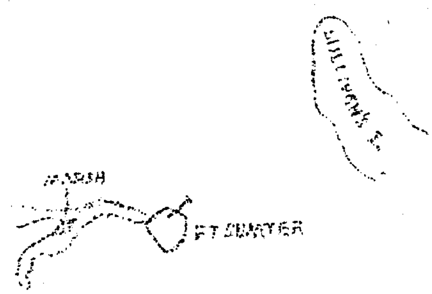
Santa Monica has also had to employ a dredge to move the sand.

Both breakwaters altered the natural equilibrium between erosion and deposition which had previously maintained the shoreline. The result in both cases was a change that was expensive to man. A perfect breakwater has probably still not been found. Any object of this type will interrupt the sea-air-substrate equilibrium in its area causing undesirable changes.

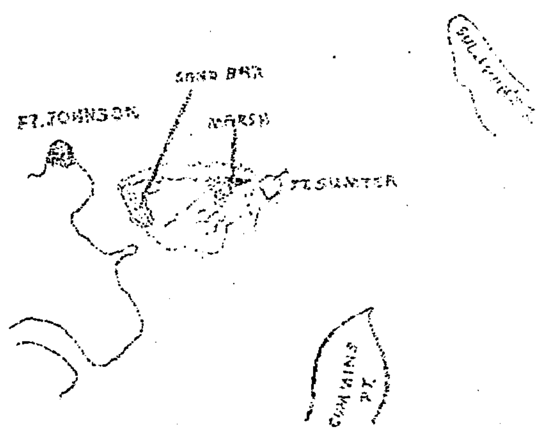
In Charleston Harbor, we have an excellent example of the effect of an artificial obstruction. Over the last thirty years or so, the area of land occupied by Fort Sumter has been increasing. In 1939, Fort Sumter had very little land around it. Beginning in the 1940's, the land began to ex-extend shoreward. Now one can almost walk from the mainland to the Fort from the James Island side. The progression of building is shown in figures 4a - 4e.



4a. FORT SUMTER - 1939

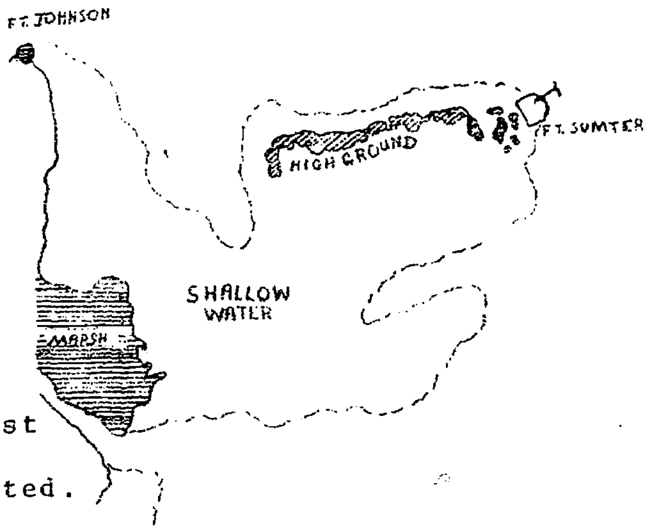


4b. 1957



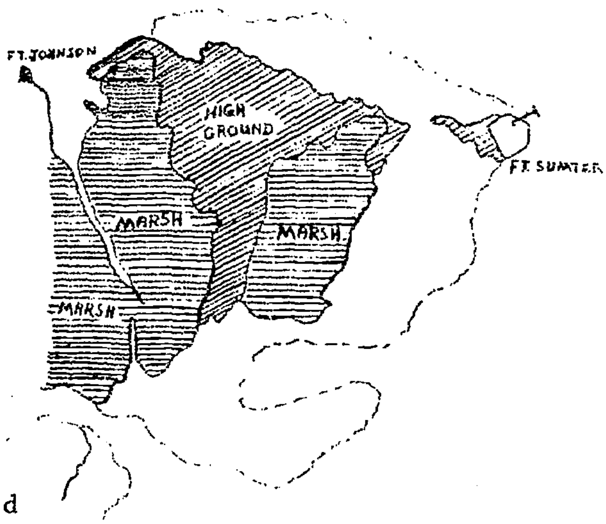
4c. 1963
(4a-4c drawn from aerial photographs, courtesy USDA)

Maps of Charleston harbor as early as 1780 show that the area between James Island and where Fort Sumter was built has always been shallow. Some parts of it have almost always been dry at low tide. The growth of the last three decades has been unprecedented. Considerable vegetation now grows around the fort on the new land. An entire island seems to be building behind the fort, as shown in figure 4e. The relation of the fort to surrounding areas in 1939 is shown in figure 4b. Growth has been very fast since 1963.



4d. 1970

The island is probably growing because the fort is helping to shield it from heavy storm waves. The sediments are collecting behind the fort and are not blown away in bad weather.



4e. 1972
(4d-4e. REDRAWN FROM U.S.C.G.S. CHART 470.)

One contributing factor in island growth may be an increased sediment load in this century. A few decades ago, the Santee River was diverted into the Cooper River with damaging effects to Charleston

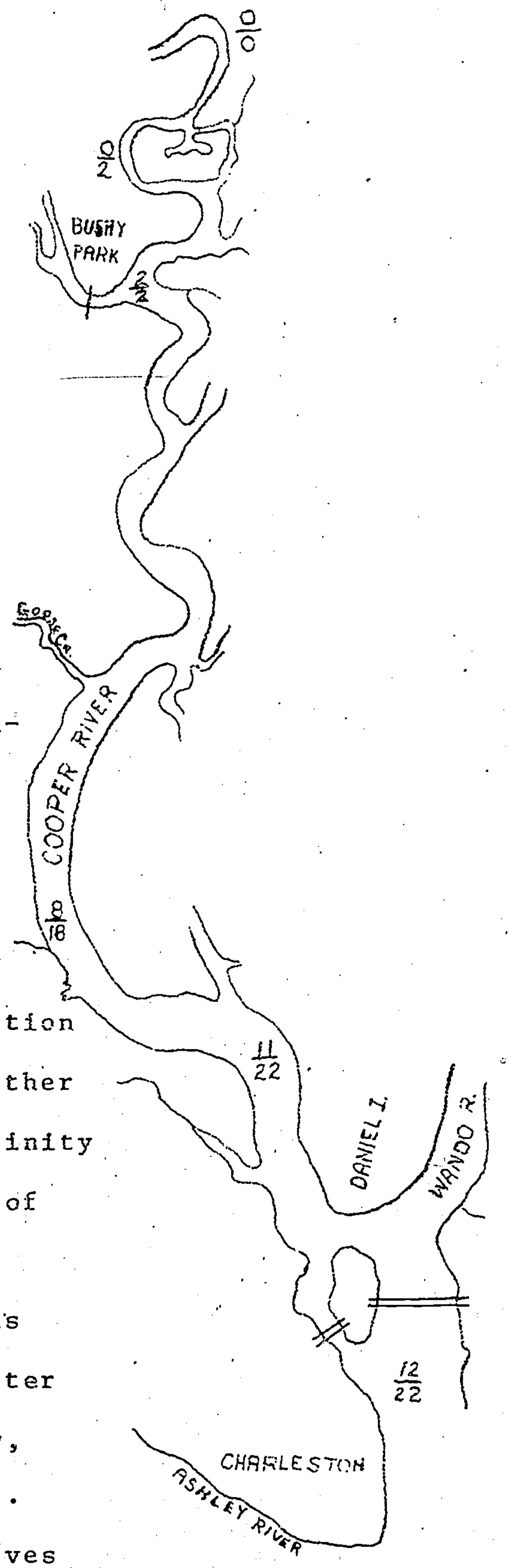
Harbor in general. The silting of the harbor resulting from the diversion may be reflected in the buildup of the island behind Fort Sumter.

Estuaries

Most estuaries are drowned river mouths. The rivers submerged as sea level rose at the end of the last ice age.

Estuaries by definition are bodies of water with a free connection to the open sea but with a measurable dilution by freshwater. Seawater is salty. Its salt content usually is in the neighborhood of 3.5 o/o or 35 o/oo (parts per thousand). The seawater is saltier than freshwater, so we say that it is water of high <u>salinity</u>. The addition of fresh water lowers the salinity. The further one moves up the estuary, the lower the salinity becomes. One of the most striking features of the estuary is its <u>salinity gradient</u>.

The salinity gradient of the estuary is vertical as well as horizontal. The freshwater outflow is lighter than the seawater inflow, so it floats on top of the heavier seawater. As the tide moves in, the seawater often moves up the estuary, displacing freshwater from the bottom layers in the area it traverses. When the



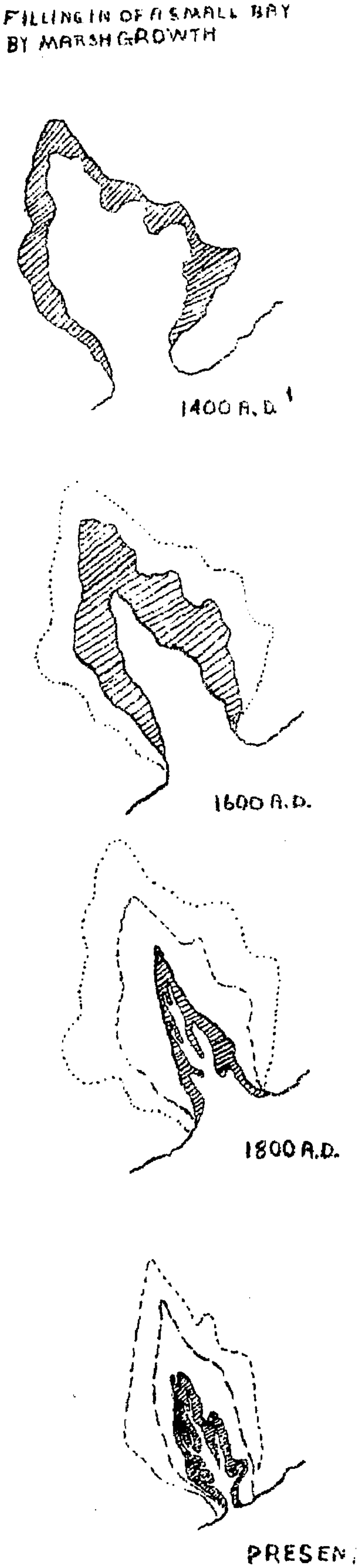
SALINITY GRADIENT (‰) IN THE COOPER RIVER IN SOUTH CAROLINA - NOVEMBER, 1972 (SURFACE/BOTTOM) tide ebbs, freshwater will replace it. Another prominent feature of the estuary is this salinity fluctuation.

The salinity fluctuation makes the estuary a difficult place for organisms to live. Organisms which can withstand the fluctuating salinities can move into the estuary and be free of much of the competition from other species which they would find in milder environments. The estuary has become an ideal home for organisms which can withstand the wildly fluctuating conditions. A typically estuarine set of communities has arisen which are composed of relatively few species. Those few species can reach enormous numbers.

The enormous numbers of organisms of one species which can occur in estuaries has profound effects on the morphology of the estuary. Among the prominent estuarine changers are marsh cordgrass, mussels, oysters, and polychaete worms.

Marsh cordgrass (*Spartina*) is one of the most important geologic agents in the estuary. This is the tall green grass which constitutes the principal vegetation of the marsh. It grows in sheltered estuarine waters, particularly along the shores of creeks and quiet bays and coves within the estuary. Once Spartina gains a foothold in the marsh, it grows into enormous meadows.

As the Spartina grows, it helps to build new marsh. Sediments are constantly moving through the estuary in suspension in the currents. When the water rushes through stands of Spartina, the eddies and dead spaces resulting from the turb-ulance set up in the grass allow particles of silt, sand, mud, and organic matter to settle out. As the mud settles out, it will spill over the edge of the Spartina stand. New Spartina growth will occur at the newly built edge of the marsh. In this fashion, the marsh slowly creeps across the estuary. Over a period of many years, it may fill the estuary in and turn it into dry land. The marshes act as natural reclaimers of land from the sea.



The marsh not only builds new land, but protects the old. The marsh roots held to hold the soil in place at the edge of the land, preventing its erosion by daily wind and wave action. During heavy storms, the roots hold the soil and the stems diminish the force of storm-driven waves. If the waves strike the land behind the marsh, the marsh grass traps the soil particles that become eroded from the land.

When marsh is filled in, the coastal area not only loses the enormous fishery potential of the marsh, but also its protective features. The marsh acts as a natural retaining wall to keep one's property from washing away. If the marsh is filled in as "sanitary landfill" or covered with dredging spoil, the land it protected is in more danger of eroding away. Structures built on the landfill or spoil are particularly liable to storm damage.

Mussels can give the marsh a hummocked appearance. As they feed, the food they sort out and do not eat is passed from the body as mucus-covered pseudofeces. The pseudofeces tend to compact themselves into very stiff, rigid mud. We have already mentioned the patch of old mussel mud at the Folly Beach Coast Guard station. As the mussels feed, they are under a threat of burial by their own pseudofeces and must keep moving upward to remain on top. This results in little hills and hummocks of cemented pseudofecal mud being raised throughout the marsh when a large mussel population is present.

Oyster reefs are one of the most prominent features of the estuary. They cover almost every exposed part of the low tide estuary and range into deeper waters. Oyster shells are one of the most characteristic mineral deposits in an estuary. The oyster reefs trap sediments and form mud, just as in the case of Spartina. They are also filter feeders, filtering particles of silt from the water along with their food. They excrete both feces and pseudofeces as fecal pellets. The fecal pellets of oysters and other animals are one of the principal constituents of estuarine muds and other sediments.

Out in the estuarinemud flats in some areas, the bottom is constantly worked over by hordes of bottom feeders, including legions of polychaete worms. These relatives of the earthworm constantly work over the sediments, sinking the surface ones and bringing deeper sediments to the top. This constant biological turnover of sediments releases nutrients from deeper sediments and takes surface sediments to the bottom for mineralization.

The process of particle entrapment by oysters and other filter feeders in the estuary and their incorporation into sediments by polychaetes and other bottom dwellers is part of bio-deposition. Bio-deposition is a very important process in the buildup of sediments in the bottom of the estuary.

References

1. Ingle, J. C., Jr. *The Movement of Beach Sand*. New York: American Elsevier, 1966

2. Weyl, P. K., *Oceanography: An Introduction to the Marine Environment*. New York: John Wiley and Sons, 1970