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# THE BAHAMA BANKS: A "LIVING" FOSSIL-ENVIRONMENT

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ABSTRACT. The Bahama Banks represent an environment of carbonate sedimentation widespread in the past but extremely rare today. Its occurrence presents the geologist with the opportunity of learning firsthand about geologic processes once prevalent on the earth's surface, but he has been slow to take advantage of the opportunity and slower to use the Bahama story in the classroom. Some literature on the Babamas is reviewed, and pertinent information on geologic history, sediments, and ecology is summarized for classroom use.

## INTRODUCTION

In 1938, a modern coelacanth, *Latimeria,* thought to have been extinct some 50 million years, was caught by fishermen off the east coast of South Africa. This event caused considerable excitement among zoologists and paleontologists. Further excitement was caused when a limpet-like gastropod, *Neopolina,* a representative of a group believed extinct some 350 million years, was captured in a trawl by the Danish research vessel "Galathea." The discovery of these animals meant that creatures previously known only by partial remains, such as bones and shells, could now be studied as complete organisms. The excitement of the zoologist and paleontologist is indeed justifiable. But why has the Bahama Banks not awakened this kind of excitement among sedimentologists, petrologists, and paleontologists? As the study of areas in the world where carbonate sediments are being deposited progresses, it becomes increasingly evident that the Bahama Banks are in many ways unique and represent an environment widely distributed in the past but of rare occurrence in today's seas. Geological exploration in the Bahamas goes back about 68 years to the time when Alexander Agassiz studied coral reefs along the eastern margin of the Great Bahama Bank; but only in the last 15 years, with the discovery of the rich potential of carbonate areas as petroleum reserves, has the Bahamas attracted more than a handful of geologists. And how much (or how little) time is spent in the geology class with this relict environment from which we might learn so much about the operation of geologic processes so prevalent in ages past? As the literature concerning the Bahamas is widely scattered, pertinent information concerning the geologic history, sediments, and ecology of the region is summarized here for classroom use.

## GEOGRAPHY

The Bahamas consist of several shallow, flat-topped banks; the largest, the Great Bahama Bank, has received the greatest amount of scientific study. The Little Bahama Bank lies north of the Great Bahama Bank and is separated from it by a deep channel (Figure 1). Smaller banks completely surrounded by ocean lie to the southeast. Cay Sal Bank, which is separated from the Great Bahama Bank

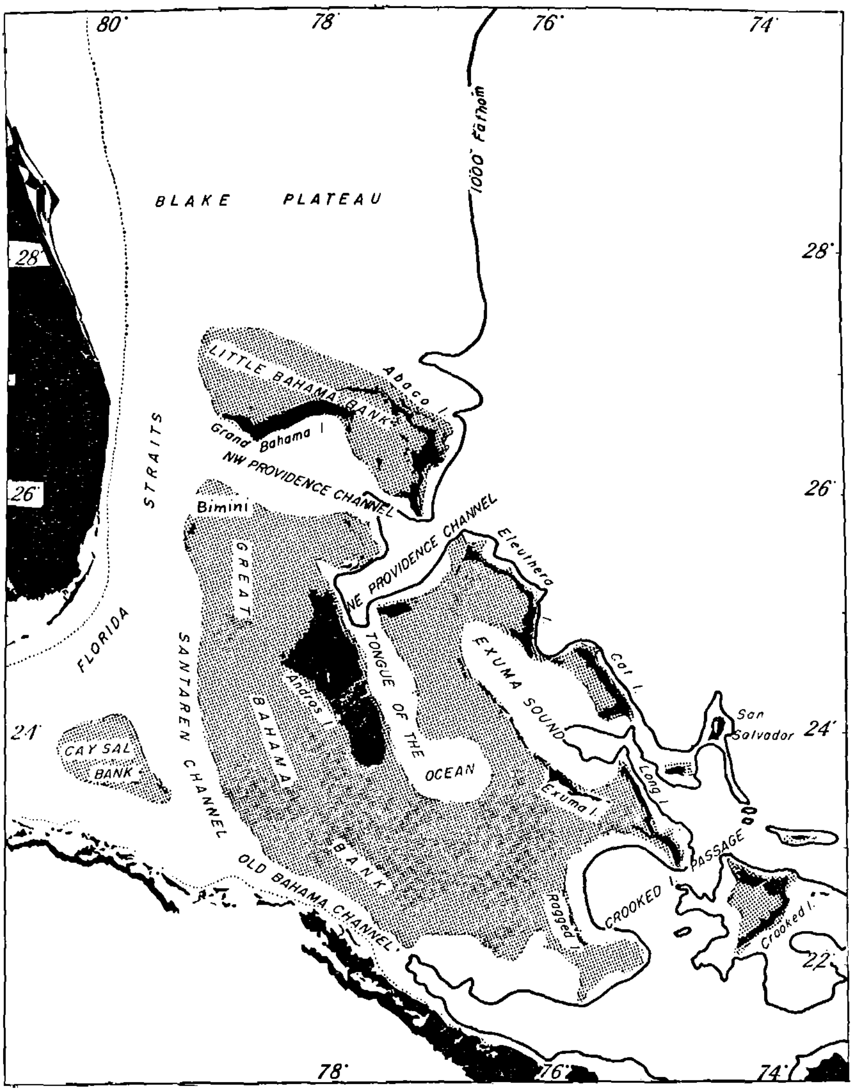

Figure 1. Bahama Islands.

by the deep Santaren Channel, is not considered as part of the Bahamas geographically, although it is part of the same geologic province. The Bahamas cover about 40,000 square miles, which is roughly the size of the state of Tennessee.

The Tongue of the Ocean and Exuma Sound, with depths of 1,000 fathoms, penetrate the eastern part of the Great Bahama Bank. Depth in these bodies of water exceeds that in the Florida Straits, where depths of about 500 fathoms are encountered. Exuma Sound, the Tongue of the Ocean, the Providence N. E. Channel, and the Old Bahama Channel seem to be oceanic tongues, whereas the Florida Strait, Santaren Channel, and Providence N. W. Channel are more closely related to the shallower continental shelf.

Water depth on the Great Bahama Bank platform is generally less than 4 fathoms, and the platform is basin-like in form. Broad shoals extending across the Bank in a west–northwest direction from Northern Andros Island to Bimini and from the middle of Andros Island to Billy Island have been interpreted as relatively recent tectonic flexures (Newell et al., 1959, p. 187).

A narrow shelf with beach ridges and erosional terraces borders the Bank rim outside the chain of islands (Newell and Imbrie, 1955). A precipitous marginal escarpment at about 20 fathoms has been interpreted as a drowned coral reef of Tertiary age (Newell, 1955).

### *Climate*

The average winter temperature is about 22°C., and the summer averages about 28°C. The climate may be considered subtropical. The average rainfall is about 47.5 inches and most rain occurs during September and October. Freezes do not occur in the Bahamas and minimum temperature is about 7°C.

The region lies within the Tradewind Belt, and in the winter is exposed to easterly winds which blow at an average velocity of 10–15 mph. "Northers," with wind velocities of 30–40 mph, occasionally blow in from the northwest and northeast from November through April. Between May and October breezes from the south predominate, but occasional squalls appear from the northeast and east.

The Bahamas are in the West Indian hurricane belt, but most storms pass to the south. The high winds on the outer edge of passing hurricanes create stormy waters over the Bahama area. The subtropical climate is maintained by warm West Indian waters which bathe the area as they move north. The major component of the current moves through the Florida Straits west of the Bahamas, where it is called the Florida Current.

### *Water Temperature and Salinity*

The mean water surface temperatures in the Bahama area range between 24°C. in the winter and 28.5°C. in the summer (Fuglister, 1947). However, when air temperatures drop during winter "northers," the shallow water in semi-stagnant lagoonal areas is chilled sufficiently to kill fish and probably some invertebrates (Kornicker, 1958).

Because of incomplete tidal drainage of water off the Banks, and high evaporation rates, salinity of Banks water is generally higher than that of surrounding waters, which have a salinity of about 35.7 parts per thousand. Although data concerning salinity are not abundant, Black (1933) and Smith (1940, 1941) found salinities of 40 parts per thousand fairly common in the north-central part of the Great Bahama Bank. Newell and Rigby (1957) reported water in this region to have salinities of 38 and 39 parts per thousand. High salinities have also been reported from shallow flats and lagoons in the islands around the edge of the Bank (Turekian, 1957; Smith, 1940, 1941). After extensive rains during the wet season the salinity of water in lagoons and shallow flats falls as low as 30 parts per thousand, but the rains seem to have little effect on the salinity in the central part of the Bank where the water is somewhat deeper.

### *Islands of the Bahamas*

The periphery of the Bank is dotted by islands of various sizes, the largest being Andros Island, which is about 90 miles long and 40 miles wide. In general, the islands tend to be long and thin with the long axis parallel to the Bank edge.

Islands are composed of Pleistocene and Recent limestones. Limestones may be predominantly oolitic or skeletal; only rarely do the oolitic limestones contain a large component of skeletal matter. The oolitic limestones are usually steeply cross-bedded and have been interpreted as sand dunes of Pleistocene age. Recent limestones are generally wind or storm deposits of skeletal sands. Cement is calcite, except for intertidal beachrock which has interstitial cement of aragonite with some calcite.

Wave action and organic activity create notches with overhangs in the intertidal zone. Tidal pools are formed on limestone coasts exposed to sea spray. Considerable destruction within the spray zone is accomplished by algae, which penetrate interstices in the rock and loosen particles.

### *Age of the Bahamas*

Sea-level recession at the beginning of Wisconsin glaciation is generally estimated to have started about 100,000 years ago. Unconsolidated sediments on the Bank rapidly became lithified as they were subaerially exposed. Coral reefs and erosional platforms about 2 or 3 meters above sea level are interpreted as having formed during the Sangamon interglacial stage prior to Wisconsin glaciation. Three C-14 dates of shells and calcarenite indicate an age of more than 25,000 years for Bahamian lithified sediments. Younger dates have also been obtained, but these may have been caused by recrystallization, or pore filling by recent carbonate (Newell et al., 1959, p. 194).

Lithified sediments of recent origin are beach-rock formed by cementation in the intertidal zone, and windblown sand which becomes loosely cemented where exposed to salt spray. Sand dunes are not common on the present-day islands.

Because of the rapidity with which subaerially exposed carbonates become lithified, presently unlithified Bahamian sediments are considered to have begun forming when sea level started to rise about 18,000 years ago, but sediments on the Bank are not more than 5,000 years old, having formed when rising water first flooded the Bank (Newell et al., 1959).

A deep boring in Andros Island showed that more than 2¾ miles of limestone and dolomite are present beneath the Bahamas. Deposition has proceeded at least since the Cretaceous period (Spencer, *in* Eardley, 1951, p. 573). Quaternary limestones have been reported to be 400 feet thick under Andros Island (Illing, 1954, p. 91). Tertiary sediments (unconsolidated) underlie thin Quaternary deposits in the Tongue of the Ocean (Ericson et al., 1952). The steep slope surrounding the Bank is considered to have been constructed by reefs during the Tertiary age (Newell and Rigby, 1957, p. 24).

## SEDIMENTS

Bahamian sediments have been studied in considerable detail by Illing (1954), who divided them as follows:

- I. Skeletal Material
- II. Non-Skeletal Calcareous Sand Grains
    1. Fecal pellets
    2. Friable aggregates
    3. Grains of aragonite matrix
    4. Lumps
        - a. grapestone
        - b. botryoidal lumps
        - c. encrusted lumps
        - d. irregular well-cemented forms
    5. Oolitic sand grains

*Skeletal material* is the dominant component of sediment in a narrow area along the margins of the Great Bahama Bank. Components of skeletal material in general order of abundance are calcareous algae, Foraminifera, mollusks, echinoid spines, and ostracods. Skeletal sands are especially abundant around islands and reefs, and are least abundant in bores (shallow-water submarine sand ridges) of oolite. The skeletal component decreases inward from the Bank margins.

*Elliptical pellets,* which have been interpreted as lithified fecal pellets, occur in varying amounts but are generally found in abundance only in protected areas, such as in the lee of islands and in lagoons. The animal from which the fecal pellets are derived is not known, but many animals including clams, snails, worms, and enchinoderms have been suggested. Pellets are usually found in the firmly cemented form or as soft mucoid masses, but Illing (1954, p. 25) observed transitional stages. Cementation is evidently rapid, with aragonite precipitated as cement binding silt-sized carbonate grains which are in the feces of many invertebrates.

*Friable aggregates* are composed of silt-sized particles that are held together by slight cementation and are fairly easily separated with a pin. The origin of the silt-size particles is not known with certainty. Although not abundant, they are generally found inward from the Bank margins. After the aggregates become firmly cemented, they may lose their irregular shape by abrasion, and become well-rounded grains of cryptocrystalline aragonite, leaving no evidence of their original aggregate nature (Illing, 1954, p. 26).

*Grains of aragonite matrix* are particles resulting from the cementation of friable aggregates. They are composed of cryptocrystalline aragonite and have a rounded to irregular shape. When oval they cannot be distinguished from fecal pellets composed of cryptocrystalline aragonite (Illing, 1954, p. 27).

*Lumps* consist of grains that become cemented together. If the grains are cemented primarily in the interstices they are termed *grapestone,* but if coated by sufficient cement to obscure individual grains, they are termed *encrusted lumps*. The cement seems to be composed of finely divided particles of aragonite without recognizable crystalline shape (Illing, 1954, p. 30). Cavities in the lumps may contain prismatic crystals of aragonite projecting into the cavity. When grapestone is coated with laminated aragonite, as in oolite, it is termed *botryoidal lumps* (Illing, 1954, p. 31).

*Oolitic sand grains* are grains having concentric laminations of aragonite. Laminations may be few or many and are generally restricted to the outer part of the grain. The central unlaminated part, termed the nucleus, may be a fecal pellet, skeletal grain, or aragonite matrix. Concentric rings in Bahamian oolite generally consist of tangentially oriented aragonite separated by discontinuous layers of organically rich unoriented cryptocrystalline aragonite.

Oolitic sand is abundant along the margins of the Great Bahama Bank, forming dune-like bores between islands. It is seldom abundant towards the Bank interior; extensive deposits occur at the heads of Exuma Sound and Tongue of the Ocean. The origin of oolite is in question, but on the Bahama Banks it is located in shoal waters and seems related to turbulence (Newell et al., 1960, p. 493).

In addition to the above sediment types, *aragonite mud* forms extensive deposits to the lee of Andros Island. The origin of the muds is not agreed upon; bacteriological theories of origin (Drew, 1914) are arrayed against algal origin (Lowenstam and Epstein, 1957) and physico-chemical precipitation (Smith, 1940). The distribution behind Andros Island seems to be the result of protection from currents (Newell et al., 1959, p. 223). Thickness of the mud is less than 10 feet (Cloud, 1955).

### *Age of Sediments*

Unlithified sediments are considered to have formed when the sea rose to almost its present level after Wisconsin glaciation. A peat layer lying on bedrock 9 feet below low-tide level on Bimini was dated as 4370 ± 110 years, indicating that the unlithified sediment began accumulating roughly 5000 years ago (Newell et al., 1959, p. 193).

Four samples of drewite mud from Andros Island were found to range from 1025 ± 100 years by the C-14 method of dating (Rubin and Alexander, 1958; Newell et al., 1959). Dates of unlithified oolite from several areas in the Bahamas have ranged from 480 ± 180 years to 1970 ± 230 years. The outer 10 percent of oolite from Brown's Cay was dated as 225 ± 100 years and the inner 20 percent as 2530 ± 100 years; the unleached grains dated 740 ± years B.P. (Newell et al., 1960, p. 489).

### *Extent of Bahama-Like Sediments in the Past*

Beales (1956) found Paleozoic limestones of southwestern Alberta to be very similar to Bahamian deposits in composition, texture, and structure, and in 1958 (Beales, 1958, p. 1846) he proposed the name *Bahamite* for limestones composed of aggregates described by Illing (1954) from the Great Bahama Bank interior region.

Prior to the work of Illing and Beales, extensive ancient limestones were usually interpreted as being of clastic origin, i.e., eroded from older limestones. The agglutination and aggregation of cryptocrystalline aragonite grains to form sand-size grains offers a more reasonable explanation for the process of formation of extensive limestones (Beales, 1958). Ancient limestone erosion is generally accomplished by solution, and clastic grains formed by mechanical decomposition are rapidly broken down during transport by either solution or attrition.

Oolitic and skeletal sediments similar to those in the Bahamas formed extensive limestone deposits in Paleozoic and later eras.

## ECOLOGY

Organism habitats on the Great Bahama Bank have been divided according to substrate and environment by Newell et al. (1959) as follows:

I. Rock-Bottom Habitats
   1. Rocky shores
   2. Infratidal prominences
   3. Coral reefs
   4. Rock pavements of submerged marine terraces

II. Sediment-Bottom Habitats
   1. Mixed skeletal sand
   2. Unstable oolite
   3. Stable oolite
   4. Grapestone sand
   5. Pellet sand
   6. Muddy sand and mud

*Rocky shores* usually have tidal pools and rough surfaces in the splash zone and an intertidal notch if cliffing has previously occurred. These shores, almost on a worldwide basis, may be divided on the basis of coloration of the rock (caused by algae) into upper white and gray zones, which are above the spray area, a black zone in the spray area, and a yellow zone that extends into the intertidal area. These zones are characterized by an abundance of gastropods, some of which are active in eroding the limestone in search of algae on which they feed.

*Infratidal prominences* seem to be erosional remnants that occur seaward of many rocky shores in the Bahamas. They are colonized by alcyonarians, algae, and sea urchins.

*Coral reefs* in the Bahamas are located along the windward or eastern Bank margins and are usually best developed offshore from islands. Reef corals are present along the western margin of the Great Bahama Bank where they colonize rock substrate seaward of islands, but they have not developed into reefs like those along the eastern margins. The location of better-developed reefs on the eastern margin is related to the prevailing easterly wind. Coral growth is more vigorous when exposed to windward conditions; the precise reason for this is not known with certainty, but it has been attributed to coral requirements for food, oxygen, water turbulence, and transparency. Low temperature and turbidity has been suggested as restricting reef growth on the leeward margins by Newell et al. (1959, p. 212).

*Rock pavements* occur where the submerged country rock has not been covered by sediment. These are colonized by corals, alcyonarians, sponges, and algae.

*Mixed skeletal sand,* which is composed of primarily skeletal debris, but in some areas contains high proportions of grapestone and oolite, is abundant along the seaward margin of the Bank and around reefs. It often is unstable and rippled where above wave base or exposed to high-velocity currents, but tends to become stabilized by *Thalassia* (turtle grass). It is colonized by burrowing clams and snails.

*Unstable oolite* ridges and bores around the Bank margin are quite barren of organisms.

*Stable oolite, grapestone sand, and pellet sand* lie back from the Bank margins and are protected by islands and colonized by *Thalassia.* They are characterized by many enchinoderms and mollusks.

*Muddy sand and mud* in the lee of Andros Island is characterized by the tunicate *Didemnum* where the water is hypersaline, and by the snail *Cerithidea* near shore where variable salinities occur. On intertidal flats mangroves are abundant (Newell et al., 1959, p. 223).

## IMPORTANCE OF BAHAMIAN STUDIES TO OIL EXPLORATION

The normal marine salinity and the shallow well-aerated water around Bank margins promote the growth of coral reefs and oolite, and the accumulation of skeletal material. These characteristically have high porosity and good potential as petroleum reservoir rocks, especially when edges of the Bank face potential source rocks and permit updip migration to the high-porosity marginal rocks. The method of formation of interior Bank deposits (precipitation) results in nonporous rocks, which present a barrier to further migration (Beales, 1958, p. 1859).

Because the deposits on the Bank interior are more extensive than marginal deposits, they should be more extensive in ancient rocks and will be encountered more often during drilling. The simple sedimentation and ecological pattern in the Bahamas indicates to the geologist that when exploring for petroleum, if bahamite deposits are encountered in the subsurface, a search should be made for marginal deposits that may be good reservoirs (Beales, 1958).

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