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The mystique of beachrock

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ABSTRACT

Parallel rows of intertidal beachrock composed of large (up to 4 m), oblong, pillow-shape blocks submerged by rising Holocene sea level occur throughout the Caribbean. Such blocks have recently been discovered in 90 m of water off southwest Florida. The best known example is in 5–7 m of water off the northwest side of Bimini, Bahamas, where the feature is known as the Bimini Road. 'New-Age' alternative thinkers assert that the arrangement of the Bimini stones, and similar stones off Andros Island in the Bahamas, is actually man-made. The theory holds that ancient humans, principally citizens of the mythical city of Atlantis rearranged blocks of beachrock to form a harbour. This paper demonstrates that the stones and their arrangement are natural and suggests that some villages protected by ancient harbours in the Mediterranean may in fact have been developed on naturally occurring beachrock.

Keywords Atlantis, Bimini Road, Bahamas, Beachrock, Cayce Foundation, Keystone Vug.

INTRODUCTION

The purpose of this paper is to highlight opposing interpretations that currently exist between geologists and a growing number of 'New-Age' alternative thinkers/archaeologists. A general account of beachrock formation, especially beachrock submerged by rising Holocene sea level, is provided; however, the main intent is to discuss the various alternative origins for submerged beachrock. That beachrock forms in the intertidal zone has been known for almost two centuries, although the precise mechanism of origin has been debated for more than 50 years. For the most recent and detailed history of beachrock distribution and theories of origin, the reader is directed to Gischler (2007). A pivotal paper on beachrock at Loggerhead Key, Dry Tortugas in the Gulf of Mexico, was Robert N. Ginsburg's first paper in 1953.

ANTHROPOGENIC VERSUS NATURAL ORIGIN

Rows of large oblong and polygonal limestone blocks popularly called the 'Bimini Road', lie off the northwest coast of the Bahamian island of Bimini (Fig. 1). The underwater feature first attracted the attention of adventurers/divers in the mid-1960s. The mystique of these huge rocks, aligned in several rows in approximately 7 m of water (Fig. 2), has continued to resonate among alternative thinkers. Since their discovery, made possible after erosion of overlying sediment, the proposition that the stones are man-made and/or 'intelligently' placed by ancient cultures has proliferated and gained credibility. The anthropogenic-origin hypothesis initiated with Valentine (1969, 1976), Rebikoff (1972, 1979) and followed the suggestion of Cayce (1968). Berlitz (1969, 1984) and Zink (1978) related the origin of the Bimini Road to the legend of the lost continent of Atlantis. Zink's study was funded by the Cayce Foundation, a spirit-based group located in Virginia Beach, Virginia.

Little was published about the Bimini Road during the 1980s. However, after a decade-long hiatus of interest and activity, the anthropogenic-origin hypothesis was revived in a two-part pro/con article (Hearty & Donato, 1998) in which Donato argues for a human origin and Hearty argues for a natural origin. More recently, Menzies (2002) proposed that the stones were placed on the sea floor by ancient Chinese merchantmen who he maintains travelled to the Bahamas before Columbus. The stones were thought to be part of a system for hauling and repairing damaged ships (Menzies, 2002).

Although many scientists have examined the Bimini rocks and their peculiar alignment John

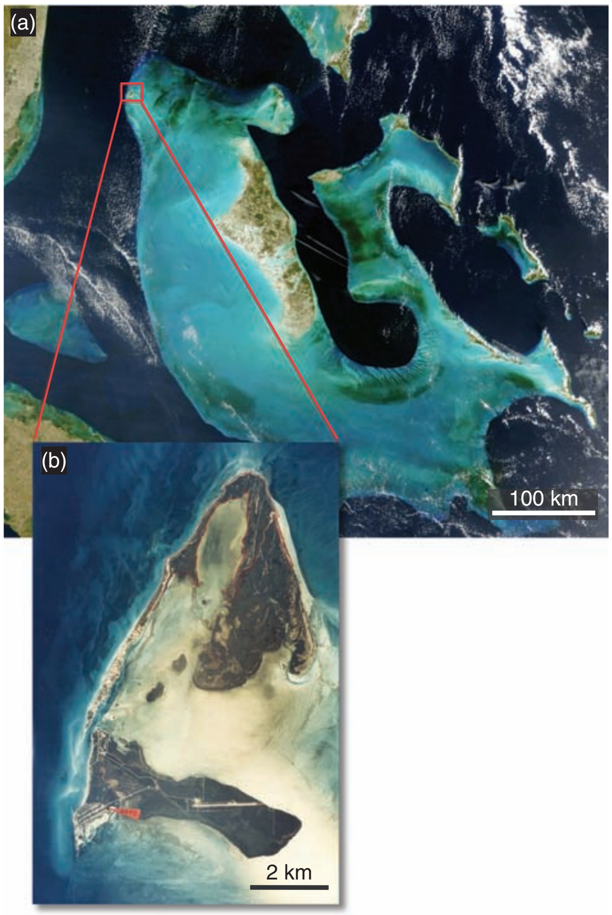

Fig. 1. (a) Satellite image of Great Bahama Bank and Andros Island in the Bahamas. North is at top. Florida is upper left corner. Inset (b) shows North and South Bimini. The underwater Bimini Road parallels the northwest coast of North Bimini. North Bimini and South Bimini are separated by a navigation channel that leads to Bimini Harbour. The harbour is partially protected by shallow water and a series of mangrove-populated sand spits to the east. The arrow indicates Port Royal.

Fig. 2. Underwater view of the submerged 'Bimini Road' beachrock stones.

Gifford conducted the first serious geological study in the 1970s. Relying on keen observation, hand specimens and some core samples, Gifford & Ball (1980) determined that the stones were naturally emplaced. In a study of supposedly anthropogenic objects from the vicinity Harrison (1971), also concluded the stones and their alignment were natural. Adventurer and book writer Peter Thompkins later initiated and financed a study during which the stones were extensively sampled with a newly developed coring device. A summary of the expedition is provided by Shinn (2004). The cores proved that the stones are composed of *in situ* natural beachrock that has been submerged by a combination of rising Holocene sea level and erosion of underlying sand (Shinn, 1978). Coring and examination showed that they rest directly on weathered Pleistocene limestone. The Pleistocene limestone is coated by a reddish-brown calcrete, indicating subaerial exposure preceding Holocene sedimentation and beachrock formation.

Later, McKusick & Shinn (1980) presented bulk 14C age data from the cores. The dates ranging from 3510 to 2745 years BP indicate the stones are much too young to be part of the mythological city/state of Atlantis, which was said to be a legend 7 ka when told to Plato 2 ka.[1] Randi (1981) also concluded that the stones are natural, as did geologist Paul Hearty (Hearty & Denato, 1998). Richards (1988), Cayce *et al.* (1988) and Denato (Hearty & Denato, 1998) had already challenged the earlier studies and at the time of writing, internet bloggers, including a sizeable group with a website and a journal called *Atlantis Rising* have challenged all science-based investigations. A psychologist (see Little (2006), recently joined the ranks of alternative believers. He claims in his website that the author (Shinn) is part of a government conspiracy to prevent people from learning the true origin of the stones.

Whereas the 1978 study by Shinn was based on more than a dozen *in situ* core borings and ^{14}C dates (McKusick & Shinn, 1980), human-origin theories of formation were, and still are, based almost entirely on the seemingly man-made pattern of the stones. These hypotheses state that beaches, and hence beachrock, cannot form such straight lines. However, proponents of the hypotheses, often point to the area of curved stones at their southern end, called the 'inverted J', as proof of their anthropogenic origin (Little, 2006). If ancient man did construct the so-called Bimini Road or harbour using beachrock or a man-made material, there should be abundant human artefacts at the site. Scoffin (1970) noted glass bottles being incorporated into contemporary beachrock at Bimini, as did Shinn (1978). However, to date no obvious human artefacts, such as tools, pottery, etc., have been found incorporated within the Bimini Road beachrock or otherwise conclusively linked with formation of the stones.

The lack of certifiable artefacts presents a problem for those who believe the stones are anthropogenic. The proponents generally describe the fabled city/state of Atlantis, following descriptions of Spence (1968), to be a highly technical society. An advanced technical society, similar to ours, should have produced many artefacts much as those of other ancient cultures. Certifiable artefacts that have been found in and near the site post-date the stones by as much as 3 kyr and consist mainly of shipwreck remnants such as ballast stones, cement barrels or other material discarded from ships. For example, Portland Cement was originally transported aboard ships in wooden barrels. When jettisoned overboard, the wood decays, leaving cement cylinders that can be confused with columns (Harrison, 1971). Finally, the alternative thinkers may be influenced by myths of the so-called Bermuda Triangle and the often repeated stories of buried pyramids and temples. The cement barrels misidentified as columns (Harrison, 1971) probably initiated the stories of submerged temples. These legends abound and appear to be proliferating with time.

How underwater 'roads' are created

To evaluate the Bimini Road more accurately, it is appropriate here to review the fundamentals of beachrock formation and configuration. For a thorough review of beachrock origins and theories, see Gischler (2007). His scholarly review includes observations by nineteenth-century scientists Chamisso (1821), Lyell (1832), Darwin (1842), Dana (1875) and Gardiner (1898). These were the earliest scientists to recognize beachrock formation. Later in the twentieth century, Vaughan (1914), Field (1919, 1920), Daly (1924) and Keunen (1933) described or noted the presence, and rapidity, of beachrock formation in various parts of the world. These twentieth-century researchers noted that beachrock is restricted to warm tropical seas, in essence the same latitudes to which coral reefs are restricted, the so-called Coral Seas.

Modern studies using petrography and carbonate chemistry began with Ginsburg (1953), Stoddart & Cann (1965), Dunham (1970, 1971) and Multer (1971). These workers, like those before, recognized that beachrock formation is restricted to the intertidal zone, but unlike previous studies, they elucidated diagnostic attributes such as the presence of internal laminations caused by grain-size variations, seaward-dipping layers and bubble-shape voids, i.e. keystone vugs (Dunham, 1970). Keystone vugs are features identical to those found in adjacent uncemented beach sands. As rising tides and waves cover the part of a sandy beach that dries during low tide, air trapped within the sand is confined and coalesces to form bubbles. Most such bubbles reach the surface, producing the circular pits so common to beachcombers. However, some air bubbles, however, remain over many tidal cycles. The bubbles tend to push grains upward, forming an arch. These arches function much like the keystone arches used in stone buildings for millennia. Some of these millimetre-size arches can remain locked in position long enough to be 'frozen' in place by precipitation of calcium-carbonate cement between the grains. This process results in the formation of near-spherical to elongate voids within the forming beachrock (Dunham, 1970).

Beachrock voids are similar to the more linear fenestral birds-eye structures that are usually restricted to fine-grained tidal-flat accumulations (Shinn, 1983). For a number of reasons, such voids rarely form in beaches composed of quartz sand. The lack of preserved voids in quartz-sand beach accumulations is probably due to a combination of mineralogy, shape of the grains, the apparent inability of carbonate cement to initiate precipitation on quartz grains and the colder water temperature often associated with quartz sand beaches. However, voids are very common in carbonate-sand beaches, even those composed of spherical ooid sands.

Many questions remain concerning beachrock genesis including (1) cement mineralogy (not all cements are aragonite; some are high-magnesium calcite), (2) proper identification of beachrock (sediment cemented in a freshwater lens beneath an island and later exposed in the intertidal or subtidal zone by rising sea level and erosion can be misidentified as beachrock), (3) rate of cementation, (4) influence of fresh water and temperature and (5) the role of microbes in the cementation process. These considerations and others are beyond the scope and purpose of this paper.

DISCUSSION

Arid versus humid climate

During the mid-1960s, the author examined many beaches and offshore sediments in the Persian and Arabian Gulf. The Persian Gulf climate is arid, and salinity is elevated (Purser & Seibold, 1973). Aridity and high salinity favour rapid calcium-carbonate precipitation, and with little rainfall the rate of freshwater cementation is retarded. Observations in the Arabian Gulf were biased toward areas of the southern windward shore (Trucial Coast), where sedimentation and shoreline accretion are most rapid. The author's observations in the more humid Florida and Bahamas platform environments were generally biased toward areas of erosion and locally to areas of complicated onlap sedimentation (Strasser & Davaud, 1986).

These contrasts in sedimentation style and diagenesis provided unique insights to the processes of beach formation as well as to both intertidal and submarine sediment diagenesis. For example, cementation in the Persian Gulf is so rapid that even sandy sediment a few centimetres below the intertidal surface can be rapidly lithified. The resulting rock often includes glass, pottery, nuts and bolts, and other human artfacts. Subtidal cementation of sandy sediment is rapid and has been shown to transform sediment into hard limestone in less than 30 years (Shinn, 1969). This rapidly forming submarine rock does not contain keystone vugs. In the intertidal beach sands that do contain keystone vugs, cementation proceeds even more rapidly. Tidal pumping in the intertidal beach provides a continual supply of supersaturated seawater, and during low tide, high evaporation and rapid degassing probably accelerate cementation (Fig. 3).

Ginsburg (1953), Evamy (1973) and many others have shown that the most common cementing agent is fibrous aragonite. In areas of rapid lateral beach accretion, cemented zones are continually buried beneath sand as fast as the biogenic and oolitic grains are created and deposited. In such areas, hidden from view, the continual formation of beachrock proceeds unnoticed. If the beach accretes rapidly beyond some unknown threshold, the sediment is taken out of contact with seawater and cementation is slowed or does not take place. When the accretion rate is retarded or periodically stopped, cementation is enhanced. The result of this fluctuating process was repeatedly observed by the author in excavations around the Qatar Peninsula in the mid-1960s, where construction workers mined sand with shovels. The mined areas revealed beachrock zones that were sufficiently lithified as to resist removal with picks and shovels. Such areas were generally left and because of the removal of soft sand around them, they could be observed in three dimensions. The rock areas formed distinct ridges parallel to the accreting beach.

Significantly, sandy sediment in the back-beach areas away from the active intertidal beaches was not being cemented either by aragonite or calcite. Lack of calcite cementation in back-beach areas is probably due to aridity and lack of a rainfall-source of fresh water. In contrast, back-beach areas in the humid Bahamas are quickly lithified (probably <1000 years) by freshwater diagenesis, namely by the precipitation of low-magnesium calcite (Halley & Harris, 1979). Thus, varying rates of sedimentation and absence of fresh water often control formation and distribution of beachrock. Numerous examples of the overriding effect of sedimentation rate, such as rapidly forming submarine sand spits, are provided in Shinn (1969, 1971).

Fishhook spits and 'J' shaped structures

Intertidal cementation in the Persian Gulf is especially rapid on the protected inner margins of curved, fishhook-shaped accreting sand spits. The rock forming on the sand spits is exposed to more than a metre of tidal fluctuation but is protected from waves that would disrupt cementation before it could occur. The formation of new spits is clearly documented in repeated photographs of an area on the northeast coast of Qatar (Shinn, 1973). Newly cemented sediment and increasingly more cementation occur in progressively older and older spits (Fig. 4). Microbial inducement cannot be ruled out, but low rainfall precludes freshwater involvement in the cementation process at this site. The large thick blocks such as those at Bimini and elsewhere in the Caribbean were not observed. Possibly the rapid rate of sedimentation does not allow sufficient subaerial exposure for thermal fracturing and creation of thick blocks. Beachrock that forms beneath accreting sand is not exposed to as much sun and weathering as rock that forms

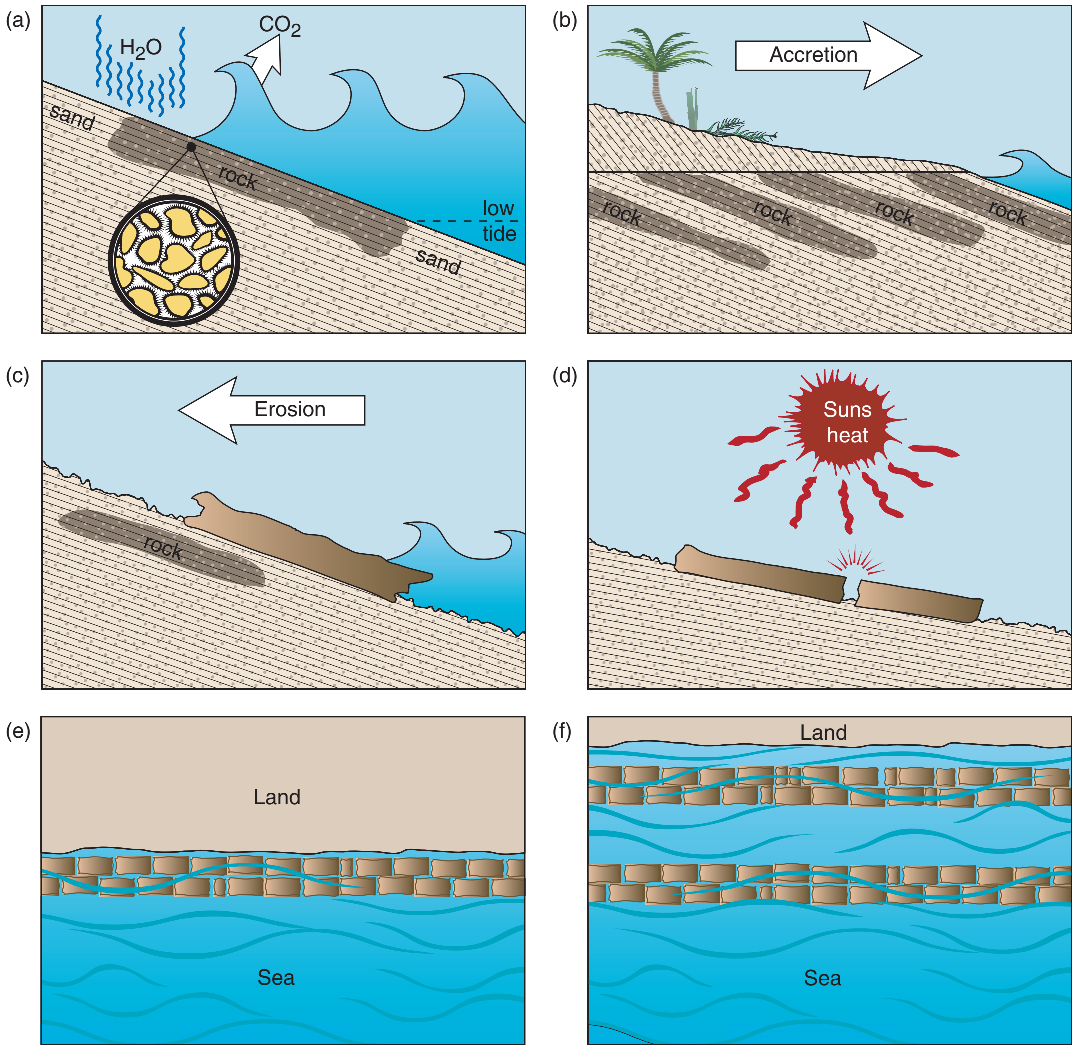

Fig. 3. Schematic drawings of beachrock formation that can lead to formation of a road-like feature. (a) Cross-section through a beach shows formation of beachrock beneath intertidal beach sands. Waves and tides serve to pump huge volumes of seawater through intertidal sands. Evaporation of seawater, which may aid in the cementation process, is enhanced by tidal fluctuation and waves. Circular inset shows microscope view of acicular aragonite growing on and fusing beach-sand grains together to form rock. (b) Beachrock forms beneath a seaward-prograding beach during intermittent beach accretion. Pulses of sedimentation cause progradation of beach sand beyond area of most active cementation. During this process, the forming beachrock lies hidden beneath soft sand. (c) Transgression of the sea over the beach occurs when supply of sand is halted or when sea level rises. Erosion of overlying sand exposes the previously formed beachrock while the intertidal (and submarine) process of aragonite cementation continues. Good examples of this process can be seen along a swimming beach at Bimini. Such quickly formed rock often contains broken bottles, pottery and other human artefacts. (d) Exposure to the sun and to constant wetting and drying causes the rock to crack into separate slabs in much the same way as a concrete road. The size of individual slabs is controlled by rock thickness. Uncemented sand underlying the rock also promotes cracking as the rock settles in much the same manner as ice on a frozen pond. Constant abrasion by moving beach sand rounds off corners to form pillow shapes. (e) Viewed from above, the straight row of broken rock slabs can resemble a road. (f) When sea level rises and erosion of underlying sand takes place, the stones are submerged to various depths (see Figs 5 and 6). Multiple parallel ‘roads’ may be produced in this manner. The ‘road’ may curve when beachrock forms on a hook-shape sand spit.

on a transgressive beach. In the Persian Gulf, both in the intertidal and subtidal zone, the rapidly forming rock is horizontal and thin. Although this rock cracks and buckles extensively, it tends to form polygonal shapes separated by expansion ridges (Shinn, 1969; Evamy, 1973; Assereto & Kendall, 1977).

The process of intertidal cementation on fish-hook sedimentary spits is relevant to the Bimini Road beachrock. Off Bimini, the area of curved

Fig. 4. (a) A recent Google Earth image (rotated to produce an oblique view) of accreting hook-shape sand spits on the northeast coast of Qatar in the Persian Gulf (Shinn, 1973). Arrow shows approximate location of forming beachrock shown in photograph (b) taken in 2005. Soft drink can (circled) provides scale. The spit indicated by arrow is the second spit to form since the original study by Shinn (1973) that was conducted in 1967. Beachrock occurs on all the spits and increases in hardness in the older spits.

stones, the so-called ‘inverted J’, is often cited as evidence of human construction. Observations of beachrock formation on curved spits in the Persian Gulf indicate that similar processes probably have produced the ‘inverted J’ off Bimini. Even at Bimini, a similar present-day ‘J’ probably would be evident at the entrance into Bimini Harbour were it not for human intervention. That area has been extensively modified by a seawall and a small boat channel.

Other areas of submerged beachrock

The ‘road’ of beachrock stones is not restricted to the Bimini area. Similar road-like alignments of oblong beachrock can be found throughout the Bahamas. A large area of identical pillow-shape rocks can be seen in 3–5 m of water off the east side of Andros Island near Nichols Town. Many of the rocks there have provided a foundation for reef initiation, but for the most part, the rocks are visible and easy to access by swimming off the beach. Little (2006) believes these stones, like those at Bimini, are anthropogenic. Other personal observations have been made in Abaco and the Exuma Islands in the Bahamas and off the northwest coast of Vieques Island, Puerto Rico.

Hurricanes Charley in 2004 and Katrina in 2005 exposed and undermined beachrock with identical shapes as those at Bimini on the east side of Loggerhead Key at Dry Tortugas (Fig. 5). These stones were in the intertidal zone when first observed by the author in the early 1970s. Because of undermining by storm waves, they are now in water approximately 1 m deep. Similar large beachrock slabs are present at nearby Hospital Key in water depths up to 3 m. These observations provide support for the conclusion of Shinn (1978) that the Bimini stones were submerged by both erosion of underlying sand and rising sea level. Based on the bulk ^{14}C ages of around 3 ka, they are too deep to be explained by sea-level rise alone.

Ginsburg (1953) conducted his research on beachrock that was mostly buried on the west side of Loggerhead Key. Recent erosion of overlying sand has exposed the rock and revealed a 10- to 15-cm diameter iron pipe extending several metres perpendicular to the beach. The pipe, now a part of the rock, is believed to have been a sewage pipe laid in sand for the Carnegie Institution Marine Laboratory that first opened in 1905 (Shinn & Jaap, 2005). Alfred G. Mayor, the first director of the laboratory, reported to R.A. Daly that sand deposited at Loggerhead Key by a hurricane in 1919 became beachrock in one year (Daly, 1924).

One of the more interesting recently discovered beachrock sites is at Pulley Ridge in 90 m of water on the west Florida shelf. Pulley Ridge is a drowned barrier island as detailed by recent multibeam surveys (Jarrett *et al.* 2005). Pulley Ridge is for the most part capped by a veneer of live coral but in places the underlying rock is exposed, revealing pillow-shape limestone blocks with dimensions identical to the stones off Bimini (Fig. 6). Pulley Ridge has a well-defined fishhook or J shape at its northern end (Fig. 7). Such J shapes are typical features of barrier

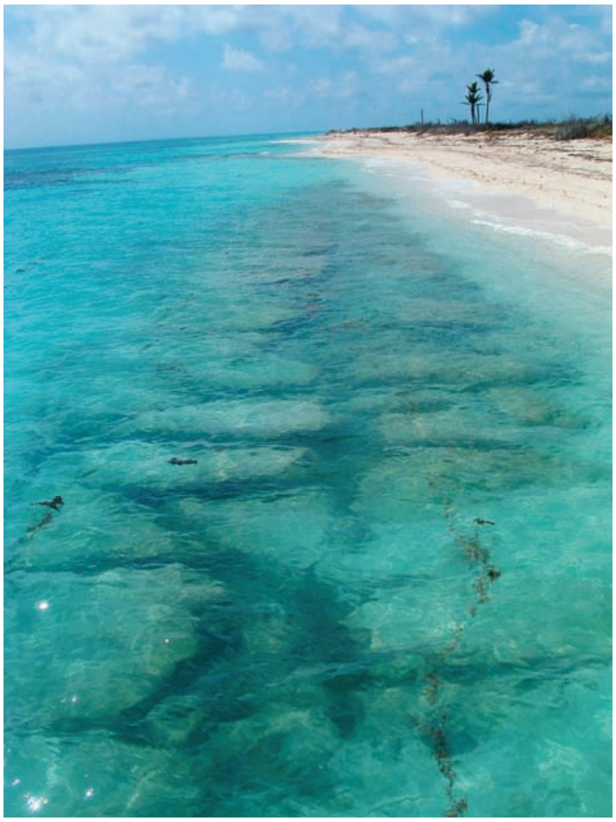

Fig. 5. Newly exposed submerged beachrock 'road' on east side of Loggerhead Key at Dry Tortugas. The 'Loggerhead Road' was exposed by Hurricane Katrina in 2005. Undermining of sand beneath the stones caused the rock to subside approximately 1 m. The blocks are 1–2 m long.

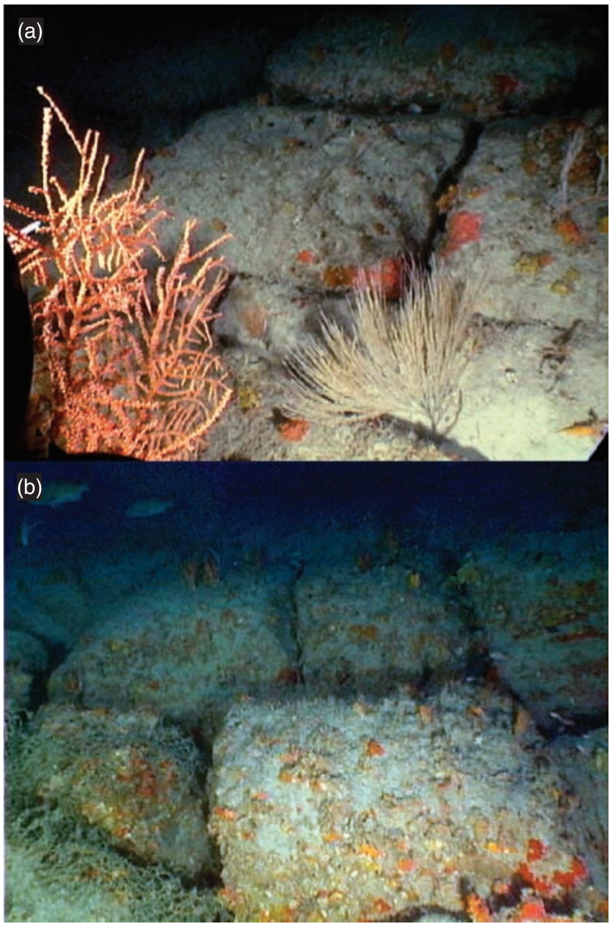

Fig. 6. A new beachrock road was recently discovered in 90 m of water at Pulley Ridge off the southwest coast of Florida (Jarrett *et al*., 2005). The blocks are 1–2 m long. The discovery was made in a joint investigation by University of South Florida, US Geological Survey, and the National Oceanic and Atmospheric Administration.

islands near tidal inlets and occur on barrier islands all along the eastern USA, the west coast of Florida and the northern Gulf of Mexico.

Similar rows of carbonate beachrock to those at Pulley Ridge have been reported from the same water depth (90 m) in the northern Gulf of Mexico (unpublished Minerals Management Report). It is well documented that sea level has risen at least 100 m worldwide in the past 13–10 kyr world-wide (Fairbanks, 1989).

Speculation and future research possibilities

Alternative thinkers who believe the Bimini stones are anthropogenic features often cite historic harbours in the Mediterranean Sea as models for what they believe occurred at Bimini during prehistoric or 'Atlantian' times. The sand spits and offshore barrier islands that migrate and form harbours in the Persian Gulf may well indicate that some ancient harbours in the Mediterranean Sea developed geologically in a similar fashion. In the Persian Gulf or Arabian Gulf, one can observe that curved spits have provided natural sheltered harbours allowing villages to be established because of the shelter they provide. As the spits migrate laterally along the coast and the harbours fill in, villages adjacent to the shallowing end of the harbour are abandoned and rebuilt around the deepening newly forming harbour entrance.

Similar processes are likely to have occurred along the southern Mediterranean shore, where the climate is arid and seawater salinity is generally elevated. In areas where the harbours were especially important for commerce, it would be reasonable to build structures around previously formed natural beachrock-protected

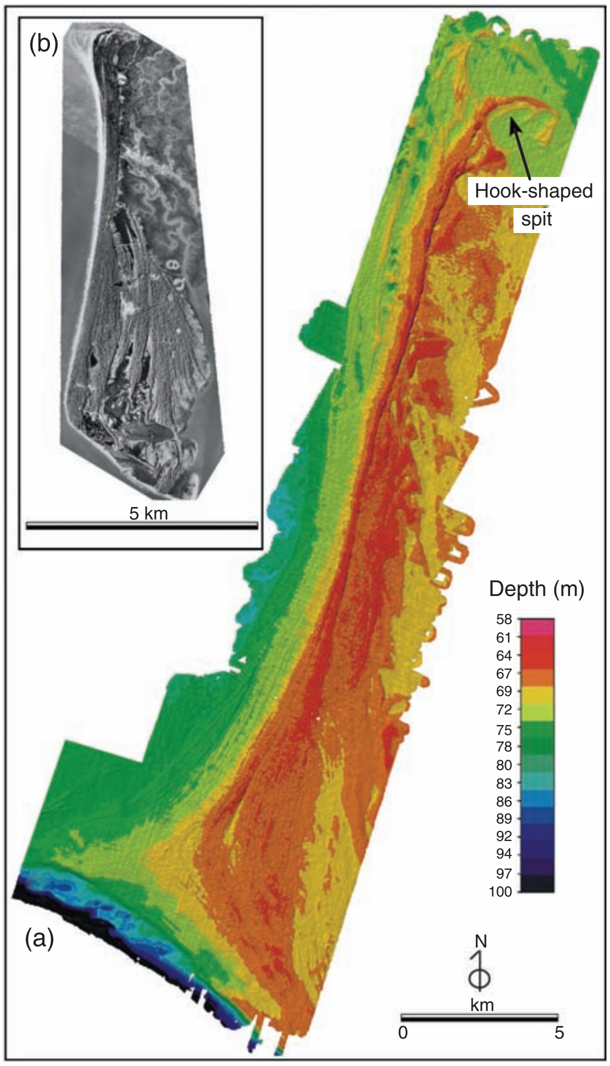

Fig. 7. (a) A multibeam map image of Pulley Ridge, compared with (b) an aerial image of Bull Island, South Carolina (image rotated for easy comparison). Hook-shape spit features typical of most barrier islands (Jarrett *et al.*, 2005).

harbours. 'J' shapes would be expected in such areas. Because of the abundant ancient cultures in the Mediterranean region, it would also be reasonable to expect an abundance of artefacts that might lead archaeologists, both conventional and alternative, to conclude that the harbours were entirely man-made. Ancient Mediterranean cultures may have simply taken advantage of and added to what nature had already provided. Therefore, the argument that the Bimini Road is anthropogenic because of similarities with stones around ancient Mediterranean harbours may not be valid.

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ENDNOTE

1 The legend is told in two of Plato's works, *Timaeus* and *Critias*, written around 500 BC. For a more complete history of the legend, see Spence (1968). Lewis Spence was the author of five books on Atlantis of which the most complete, *The History of Atlantis,* was published in London in 1926. The cited book (Spence, 1968) is a republication of the original 1926 book. In 1932, Lewis Spence edited a journal, the *Atlantis Quarterly*. Clearly, Lewis Spence, a renowned writer and historian of legends and the occult, can be credited with stimulating popular interest in the legend as well as belief in the existence of Atlantis.

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