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Late Quaternary Geology of the Eastern Pedro Bank

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Abstract – A limestone consisting of cross-bedded oolitic grainstone with abundant root traces crops out over 400 km2 of the south-eastern portion of the Pedro Bank and is herein formally named the Portland Rock Formation. The large-scale cross-bedding is interpreted to be due to aeolian dune migration, while surfaces with root traces are interpreted as palaeosols and indicate that the dunes were periodically stabilized by vascular plants. A radiocarbon age of 32.04 kyr (+3.2/-2.28 kyr) on a single whole rock sample from this formation is interpreted to be a composite age reflecting the ages of the nuclei, oolitic laminae and vadose zone cement. Since the cement volume is relatively insignificant, this gives an approximate age for the formation of the sediment and a maximum age for the formation of the dunes. The Portland Rock Formation therefore represents the largest last-glacial palaeodune field in the northern Caribbean.

INTRODUCTION

THE PEDRO BANK is a largely submarine bank with an area (above the 40-m bathymetric contour) of approximately 7900 km2; it is separated from the island shelf of Jamaica by the Walton Basin (Fig. 1). Below the 40-m bathymetric contour, the bank falls off steeply. Along its south-eastern margin (Fig. 2), which is notably shallower than its north-western margin, there are a number of rocky islands (Portland Rock, Blower Rock and Southwest Rock), shoals (Shannon Shoal), and sandy islands (Pedro Cays). The Pedro Cays are sparsely vegetated, low-lying islands composed of coralgal sands and coral boulders.

Two trips were made to the Pedro Bank in 1995 and 1996 to study the geology. Descriptions of the rocks were made and data on the sedimentary structures collected. Samples were collected for thin section preparation and radiocarbon dating.

PREVIOUS WORK

Zans (1958, p. 6) stated that the "*formations immediately below the Recent and Pleistocene coral rock [of the Pedro Bank] may be Tertiary White Limestone and Yellow Limestone similar to those formations in Jamaica where they overlie Cretaceous basement with marked unconformity*." Zans (1958) described the rocky exposure found at the Portland Rock on the eastern margin of the Pedro Bank as a hard oolitic limestone with pronounced cross-bedding, which he believed was deposited by marine currents. He found that other similar rocks (Blower Rock and South West Rock) and shoals (Shannon Shoal) along the eastern margin of the Pedro Bank were composed of the same lithology. Zans' (1958) petrographic analyses of this rock confirmed the presence of abundant well-sorted ooids (with diameters ranging from 0.15 to 0.33 mm and mean diameter of 0.2 mm) and rare bioclasts (dominantly globigerinid and miliolid foraminifera). No definite central nuclei were detected in the ooids, although in some cases the centres were "hollow".

Dolan (1972) undertook a more extensive study on modern carbonate sediment production on the Pedro Bank. He reported that ooids were rare in the modern carbonate sediments, and restricted to a narrow belt along its northern limit. After examining 153 thin sections, Dolan (1972, p. 69) was able to identify ooids from only 25 samples. Of these 25 samples, seventeen had trace quantities, seven had 1% ooids, and one contained 3% ooids. Therefore, only 16% of his samples contained any ooids, and even these constituted only a minor fraction of the total sediment. The ooids were found in samples taken at water depths between 10 and 15 m on the northern margin of the bank, and appear to be unrelated to the occurrence of oolitic limestones found on the eastern margin. Dolan, (1972, p. 177) did not find ooids forming at the present time in the vicinity of the oolitic limestone exposures on the eastern margin of the Pedro Bank "No evidence of the oolitic nature (Zans, 1958, p. 5) of the Portland and Blower Rocks was reflected in the surrounding sediments, possibly due to severe sub-aerial attack and destruction of characteristic grain structures". He

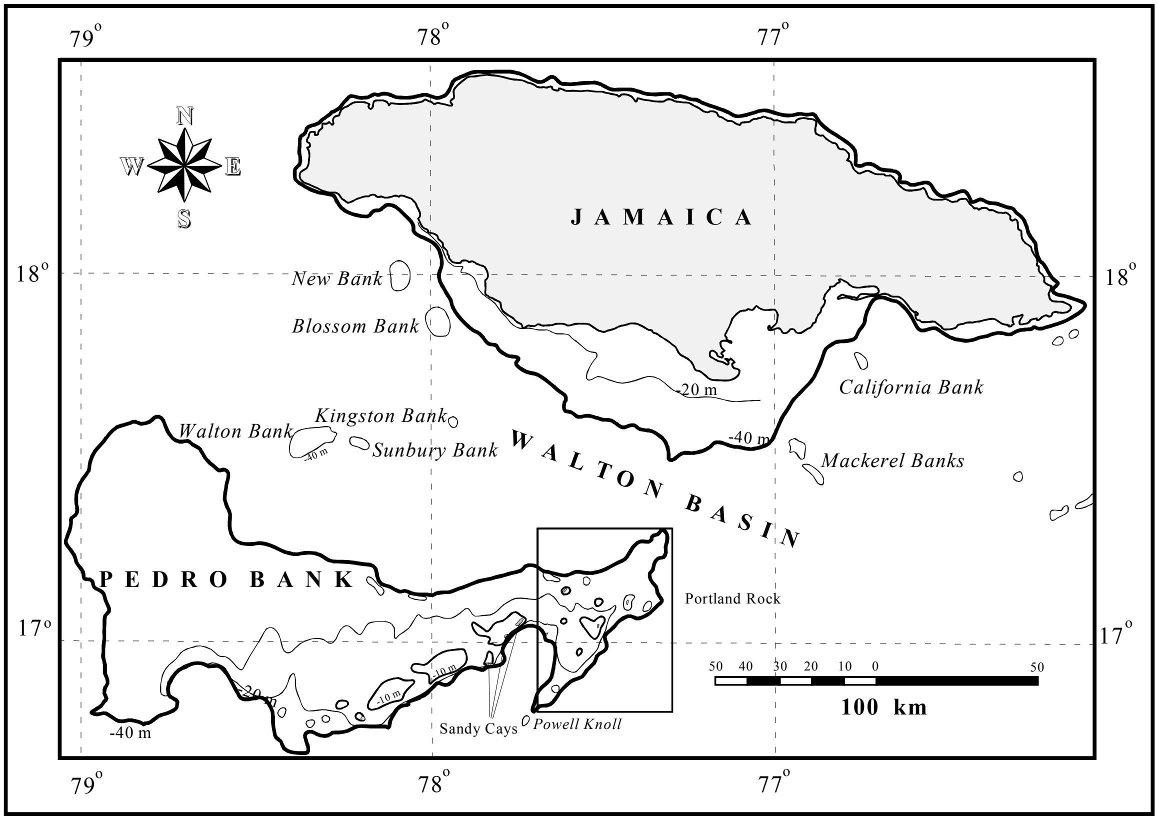

Figure 1. Jamaica and the Pedro Bank (based on Admiralty Charts, 1995, Haslam, 1976, and Zans, 1958).

concluded that the ooids that comprised the oolitic limestone were likely to be relics of a past environment.

PORTLAND ROCK FORMATION (NEW NAME)

Introduction. The name Portland Rock Formation is introduced here for the oolitic limestone recognised by Zans (1958) on the small island of Portland Rock.

Type Locality. The type locality, Portland Rock (Fig. 2), is an elongate ridge 232 m long, 52 m wide and 15 m high (Zans, 1958), with its main axis trending 030° (NNE-SSW). No soil is developed on Portland Rock, and the vegetation comprises solely halophytic lichens and algae. The surface of the rock is case hardened and strongly karstified, creating a honeycomb appearance. Karstification is more intense along joints and bedding planes creating deep fissures. The rock appears dark grey on weathered surfaces, but is white when freshly broken.

Description. The Portland Rock Formation is composed of oolitic grainstones with large-scale cross-bedding and fossil root traces. Ooids are clearly visible in fresh hand specimens. Petrographic analysis of thin sections indicates that the Portland Rock Formation is largely composed of fine-grained, well-sorted ooids with grain sizes averaging 0.2 mm. Some mouldic porosity is also present suggesting the dissolution of bioclasts. The nuclei of the ooids comprise micritised pelloids. The limestone is cemented by meniscus cements indicating cementation in the vadose zone. No pressure solution features are present.

The cross-bedding consists of large-scale (1-m or more) sets: low angle wedge-planar foresets predominate, while steeper-angle foresets are rare. Festoon cross-bedding associated with parabolic trough structures (possibly blowouts) is common towards the top of the sequence. Low-angle bounding surfaces truncate underlying sets. These surfaces are often the site of development of laminar caliche up to several centimetres thick.

Root fossils such as rhizocretions, root casts and lithified roots are common in the Portland Rock Formation. Rhizocretions are the most

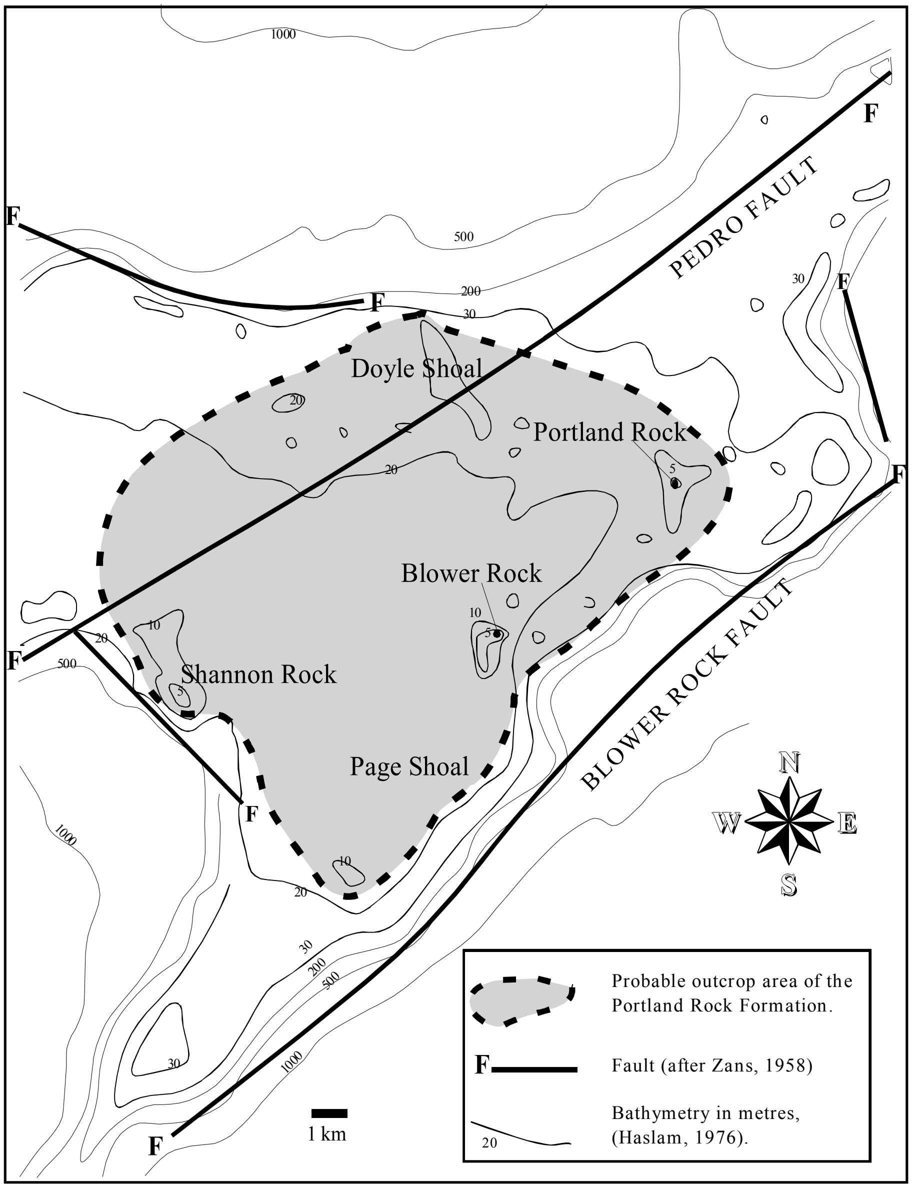

Figure 2. The Physiography and Geology of the Eastern Margin of the Pedro Bank (contours in metres).

abundant of these. Of the 20 rhizocretion specimens examined, all comprised a sub-vertical to vertical cylindrical structure of cemented ooilitic limestone, up to 5 cm in diameter and 20 cm long. Usually there was a smaller brown micritic core of less than 1 cm in diameter; although in some cases, the micritic core was absent and a thin cylindrical cavity (less than 1 mm in diameter) was present. Rhizocretions are surrounded by a zone of poorly-cemented oolitic limestone, which weathers back preferentially, so that the rhizocretions stand out in positive relief. Rhizocretions are concentrated in sub-horizontal zones in the sequence, which are interpreted as fossil rhizospheres (zones of maximum root penetration). These rhizospheres are frequently truncated by large scale bounding surfaces. Root casts and lithified roots are preserved towards the base of the type section, close to sea level along the south-western side of the island. Root casts are sub-horizontal and are up to ~40 cm long and 3-6 cm in diameter. The root traces penetrate the aeolian cross-bedding and are therefore in life position. Well-preserved lithified roots are stained brownish-red by iron compounds. The outer woody layer of the root is better preserved than the less well-lithified interior, which weathers out preferentially producing moulds.

The moulds are sometimes filled with brown micrite. The largest root observed was 10 cm in diameter and could be traced for at least a metre before it disappeared into the sediment. Although there is abundant evidence of previous plant growth on the Portland Rock, at present environmental conditions at this locality do not support vascular plants. Neither marine body fossils nor fossil terrestrial gastropods were found.

Geographical distribution. The extent of the formation, estimated from known exposures (Fig. 2) is approximately 400 km2. The formation is evidently limited to the eastern margin of the Pedro Bank, forming extensive submerged shoals (Shannon Shoal) or intermittently projecting above sea level to produce tiny rocky islands (Portland Rock, Blower Rock, South West Rock). The distribution of the formation may be structurally controlled by NE-SW trending faults (the Pedro and Blower Rock faults, Fig. 2) that were recognised by Zans (1958).

Age. A whole rock sample of fresh carbonate from the Portland Rock Formation was dated radiometrically by Geochron Laboratories (Massachusetts). Dating of the total carbonate in the sample was based on the Libby half-life (5570 years for 14C). The age was referenced to the year AD 1950 (pre-nuclear testing) and was corrected for d13C. The error quoted is ± 1 standard deviation. The material that was submitted for dating was selected from a fresh section of rock, that was unaffected by root traces or surface karstification. The sample yielded a radiocarbon age of 32.04 +3.2/-2.28 kyr. This age is a combination of the ages of the nuclei, the oolitic laminae and the meniscus cements. Since the volume of meniscus cements is generally small, this probably represents a reasonable age for the carbonate sediment forming the dunes, and a maximum age for dune formation.

DISCUSSION

The Portland Rock Formation is classified as a fine-grained oolitic grainstone, based on its petrography. Vadose zone cements, large-scale cross-bedding and root fossil indicate an aeolian depositional environment. The ooids formed in shallow water, were transported to the shoreline, and entrained by the wind into an extensive aeolian dune complex. The radiometric date suggests that the dunes formed less than 32 kyr ago, and date from the last glacial. Similar aeolianites, attributed to the last glacial, are widespread in the Caribbean (e.g., Jamaica: Hendry and Head, 1985; Maharaj, 2000; Cuba: Schubert, 1988; and Puerto Rico: Kaye, 1959). The extensive exposure of the Portland Rock Formation indicates that the palaeodune field on the Pedro Bank was probably the most significant Wisconsin dune field in the northern Caribbean. Ice age aridity (Bonatti and Gartner, 1973), an abundant supply of ooid sand, sub-aerial space for large-scale aeolian bed forms to accumulate and migrate, and strong driving winds are amongst the environmental conditions that may have been prevalent at the eastern margin of the Pedro Bank. Abundant root traces indicate that aeolian activity in this area was periodically interrupted by humid phases when vascular plants colonised the dunes.

This glacial age (32.04 +3.2/-2.28 kyr) of the sediment indicates a shallow-water ooid-producing environment on the eastern margin of the Pedro Bank. As ooids typically form in water depths of less than 2 m (Bathurst, 1975), they are potentially useful palaeodepth indicators. Early to middle last glacial sea levels (~80 kyr to 18 kyr) are generally poorly known. Evidence from the Bahamas suggests the possibility of a glacial highstand around 35 to 40 kyr (Titus 1984; Richards et al., 1994). Richards et al. (1994) estimated a highstand of □18 m at 37.6 kyr, but had no other estimates for sea levels until 19.6 kyr, when sea level had already retreated to -53.6 m. Data from the Huon Peninsula (Chappell et al., 1996) does not support a glacial highstand between 37.6 and 32 kyr, but indicate significantly lower sea levels (-84 m) by 33.4 kyr. Assuming the Pedro Bank is tectonically stable (depths on the bank do not exceed 40 m), and that the -84 m sea level (Chappell et al., 1996) is a reasonable estimate for the ~32 kyr sea level, the bank would have been entirely sub-aerially exposed once sea level fell below -38 m. The emergent platform would have been a large island delineated by fault scarps at the shorelines, which plummeted to water depths greater than -540 m (Fig. 3). Under these circumstances, there is no feasible ooid production area in the eastern section of the Pedro Bank. This suggests that there either has been significant subsequent tectonic uplift on the eastern margin of the Pedro Bank, or that there was a last glacial highstand which allowed ooid production areas on the Pedro Bank around 32 kyr BP.

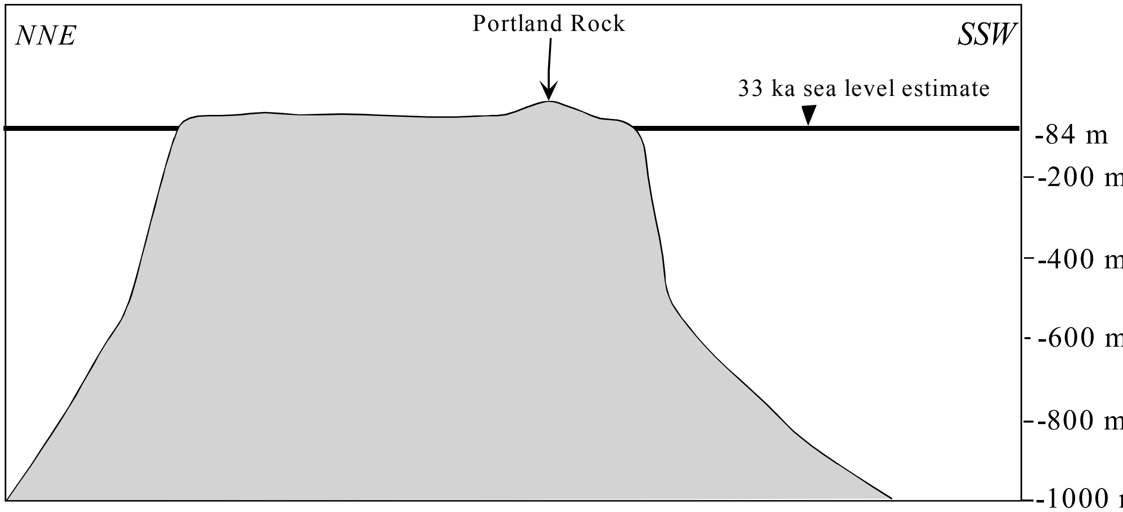

Figure 3. Reconstruction of Pedro Bank 32 kyr ago showing that the platform is completely exposed and available for aeolian sediment deposition. The problem is with the whole platform exposed there is nowhere for ooids to be produced. Sea level based on Chappell *et al.* (1996).

CONCLUSION

The Portland Rock Formation represents an extensive deposit of oolitic grainstones that were formed in an aeolian environment and represent the largest known last-glacial aeolian dune field in the northern Caribbean. The ooids formed in a shallow sea on the north-eastern margin of the Pedro Bank, and were subsequently incorporated into the aeolian system. It is likely that this area of the bank was partially submerged around ~32 kyr, and not completely emergent as sea level estimates for this time would suggest.

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