Preliminary stratigraphic results in late Cenozoic carbonate deposits from borehole cuttings in New Providence Island (Great Bahama Bank)

Resultados preliminares del estudio de cuttings en los depósitos carbonatados del Cenozoico superior de la isla de New Providence (Gran Banco de las Bahamas)

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ABSTRACT

On the basis of borehole cuttings from 2 cores located near the NE edge of the Great Bahama Bank (New Providence Island), we studied facies evolution of the Lucayan Fm. and the pre-Lucayan carbonates. Three depositional sequences were identified, perhaps correlative to prograding secuences a, b, and c (megasequence A; Pliocene-Holocene, in Eberli and Ginsburg, 1989) and perhaps also to 3rd Order depositional cycles 3.10, 3.9, and 3.8 in the 2nd Order cycle TB3 (Haq et al., 1988). The upper limit of dolomitization in this sector of the Bahamas platform was found in cores around 50m depth.

Key words: *Great Bahama Bank, Lucayan Fm. and pre-Lucayan carbonates, late Cenozoic, sequence stratigraphy.*

RESUMEN

El estudio de cuttings en dos sondeos realizados cerca del borde NE del Gran Banco Carbonatado de las Bahamas (Isla New Providence) permitió el análisis de la evolución de las facies en las Fms. Lucayan y pre-Lucayan. Han sido reconocidas tres secuencias deposicionales que se correlacionan con las secuencias progradantes a, b, y c (megasecuencia A; Pliocene-Holoceno, en Eberli and Ginsburg, 1989), y con las secuencias deposicionales de 3er orden 3.10, 3.9, y 3.8 del Superciclo TB3 (Haq et al., 1988). El límite superior de la dolomitización para este sector de la Plataforma de Bahamas se sitúa en torno a 50m de profundidad en los sondeos.

Palabras clave: *Gran Banco de las Bahamas, Fm. Lucayan y carbonatos pre-Lucayan, Cenozoico Superior, estratigrafía secuencial.*

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Introduction and geological setting

During the late Cenozoic the Great Bahama Bank was a tropical carbonate platform that evolved by shedding excess sediment off-bank in the form of prograding clinoforms as a result of the high calcareous productivity during sea level highstands (Mullins, 1983; Eberli and Ginsburg, 1989). On the contrary, during sea level drops portions of the platform are usually subaerially exposed, leading to nondeposition, meteoric cementation and erosion. Neumann and Land (1975) considered the calcareous productivity during sea level highstand are up to three times that of the available top-platform accomodation. Thus, it is expected sedimentation in the slope of Great Bahama Bank to correspond mainly with highstand deposits; Lynts *et al.* (1973) considered the highstand deposition in the Bahama slopes to be from 4 to 6 times greater than those of lowstand. Moreover, Eberli and Ginsburg (1989) recognized 1,500m vertical aggradation of the Great Bahamas Bank and 25Km lateral migration in the leeward margin, meanwhile the windward margin has remained either erosional, bypass or aggradational, since the Late Cretaceous. For further information, a recent and complete revision of the sequence evolution under humid and arid climate in detached rimmed shelves is given by Handford and Loucks (1993; their Figures 11 & 14); Eberli and Ginsburg (1989); Eberli *et al.* (1994).

Late Cenozoic deposits beneath Great Bahama Bank are composed of the upper limestones, and the lower dolomites. Traditionally, the limit between limestones and dolomites has been considered to be around the Plio-Pleistocene boundary as first proposed by Field and Hess (1933) and more recently by Dawans (1988), even though the depth of occurrence, and probably the age, vary within the Great Bahama Bank and other Bahamian platforms such as Little Bahamas Bank, Great Abaco, San Salvador, Crooked Island, and Mayaguana (for an extended discussion of the dolomitization see Williams, 1985; Dawans, 1988).

Beach and Ginsburg (1980) defined the Lucayan Formation in the NW Great Bahama Bank as the upper part of the non-dolomitized limestones (43m average thickness). This formation is mainly packstone (occasionally mudstone to grainstone) where peloids are the overall most abundant grain type. Ooids, however, predominate in the topmost 10m, while corals and coralline algae may be present through the entire formation near the platform margin. Beneath the Lucayan Formation, there are at least 25m of poorly stratified white skeletal limestones with abundant corals and bivalves (pre–Lucayan carbonates). The Lucayan Formation and the pre–Lucayan carbonates are well recorded in the subsurface of the Great Bahama Bank, although they turn in to undifferentiated reefal limestones and skeletalgrainstones near the platform margin.

Stratigraphy

Borehole cuttings have been studied in two cores (MP; Malcolm Park, and YEW; Yellow Elder) from New Providence Island in NE Great Bahama Bank (Figure 1). The cores are 212m (MP) and 182m (YEW) depth. Cuttings were recovered every 300cm and two thin sections were analyzed from each cutting sample (fragments>10mm [coarse], and fragment<10mm [fine]). All thin sections were stained by alizarine red S. to assess the degree of dolomitization. Complementary log data including, gamma ray, caliper, electric logs, and dual induction were also taken into account to help identify boundaries of major depositional sequences.

This study is centered on the upper 60–70m (mainly non–dolomitic limestones) from MP and YEW cores (Figures 2, 3). Although cores extend far into the dolomite member (212m MP and 182m YEW), only the upper parts that correspond to the Lucayan Fm. and the underlying pre–Lucayan limestones still remain undolomitized. Similarly to the MP core, the YEW core has about 50m of limestone over the dolomite member. Moreover, the former contains an interval of incipient dolomite around 40–45m depth (Figure 3).

Analysis of microfacies allows us to recognize similar lithostratigraphic evolution in both cores. Thus, three sequences, two of which appear bounded by exposure surfaces, were recognized within the Lucayan Fm., the pre–Lucayan carbonates and the uppermost part the dolomitic member. Platform subaerial exposure was suggested in the cuttings by abundance of fine, laminated brownish–black clasts (caliche–like crusts) which also correspond to intervals of abundant clasts stained and coated by Fe and Mn oxides.

These three sequences are perhaps equivalent to the prograding sequences a, b, and c belonging to the mega-sequence A (Pliocene–Holocene) in Eberli and

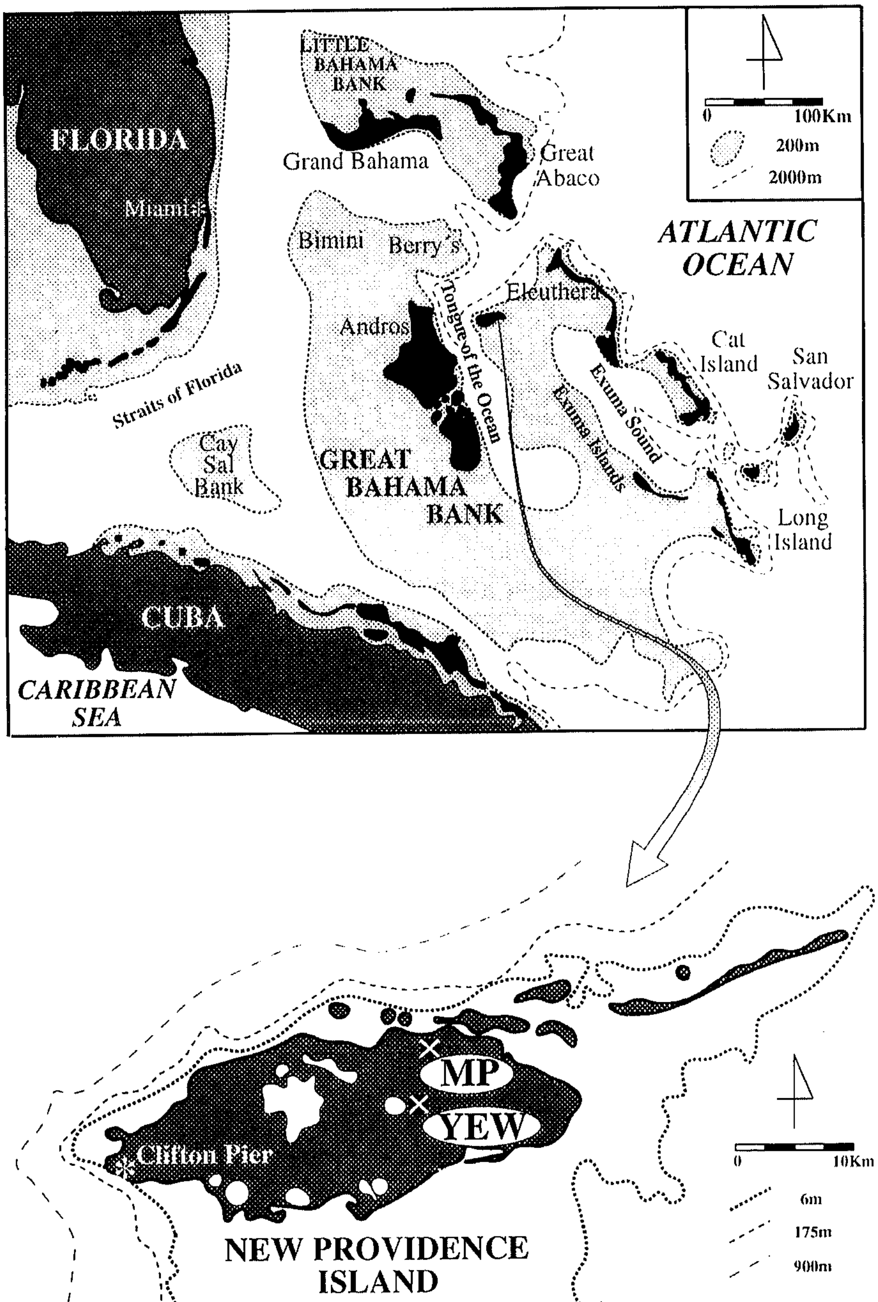

Fig. 1.–General location of the studied area within the Great Bahama Bank platform. Location of the studied cores on New Providence Island, at bottom.

Fig. 1.- Localización del área de estudio en el Gran Banco de las Bahamas, y situación de los sondeos en la Isla New Providence (abajo).

Ginsburg (1989). Furthermore, they would be equivalent with those of global character proposed in the eustatic curve (Haq *et al.*, 1988); third–order depositional sequence 3.10, 3.9, and 3.8 of the second–order cycle TB3. We realize, however, that no age information is available at this time from either hole. Recent work on western New Providence by Aurell *et al.*, (1995) has placed the Brunhes/Matuyama boundary (0.78Ma) at about –12m below mean sea level. This upper unit is likely correlative to mega-sequence A–a of Eberli and Ginsburg (1989) and cycle 3.10 of Haq *et al.*, (1988). Correlation to cycles 3.9 and 3.8 remains highly speculative at this time.

The first depositional sequence encompasses the topmost part in the cores; 6m of oolitic grainstones/oolitic and peloids packstone facies which are

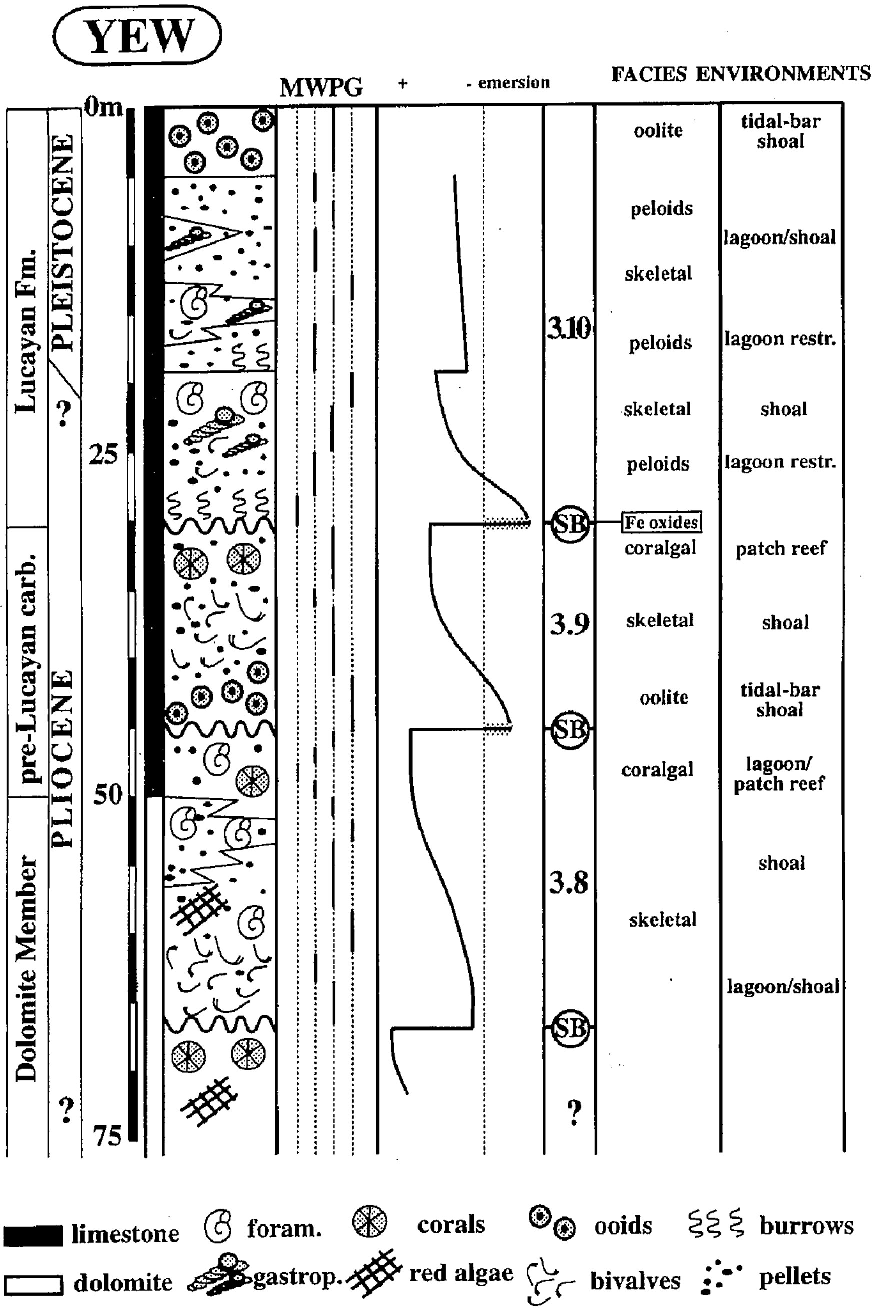

Fig. 2.–Synthesis of the more relevant characters in core YEW (Yellow Elder). From left to right: Formations, estimated age, depth below land surface, stratigraphic profile, Dunham textural classification (M=Mudstone, W=Wackestone, P=Packstone, G=Grainstone), 3rd order depositional sequences (Haq et *al.*, 1988) or prograding sequences (Eberli and Ginsburg, 1989), facies, and depositional environments. Core top equals +3m elevation.

Fig. 2.- Síntesis de los aspectos más relevantes del sondeo YEW (Yelow Elder). De izquierda a derecha: Formaciones, edad estimada, profundidad, columna estratigráfica, clasificación textural de Dunham (M = Mudstone, W = Wackestone, P = Packstone, G = Grainstone) secuencia deposicional de 3er orden (Haq et al., *1988) o secuencia progradante (Eberli and Ginsburg, 1989), facies y ambiente deposicional. Techo del sondeo situado a 3m sobre el nivel del mar.*

interpreted as Pleistocene tidal–bar shoal environments, and from 14m (MP) to 24m (YEW) of peloid–rich facies developed in a lagoon/shoal to lagoon restricted environment underlie the oolitic interval. According to Beach and Ginsburg (1980), this oolitic and peloid–rich interval, represent the upper and lower members of the Lucayan Fm., respectively. Consequently, we could assume a Pleistocene age for this depositional sequence (3.10 3rd order cycle, supercycle TB3 in Haq *et al.*, 1988).

The sequence (?) boundary that separates the first and second depositional cycles (3.10 and 3.9 3rd Order depositional sequence in Haq *et al.*, 1988) is better recognized in the MP core through clasts stained and coated by Fe and Mn oxides. Whichever, it is worth noting in both cores the abrupt facies change from coralgal and skeletal–rich facies at the top of sequence 3.9, to peloid–rich facies at the base of the cycle 3.10. The middle part of the cycle 3.9 is dominated by skeletal facies from a shoal area partly influenced by patch reef deposits, whereas oolitic grainstones are recorded at the base. This facies is interpreted as having been deposited in an oolitic shoal (MP core) and a tidal–bar enviroment (YEW core).This depositional sequence together with the upper part of the 3.8 represent the pre–Lucayan carbonates.

The 3.8–3.9 sequence (?) boundary is situated in a horizon also enriched in fine, laminated brownish–black clasts, and skeletal fragments heavily stained and coated by Fe and Mn oxides. Once more, similar to the 3.10–3.9 boundary, the abrupt change in facies occurs from skeletal/ coralgal (top of 3.8 cycle) to oolitic grainstones (base of 3.9) assists in the recognition of depositional sequences. Although cycle 3.8 is partly dolomitized, it is possible to recognize an equivalent evolution with respect to the 3.9 and 3.10 depositional sequences. Actually, the subtle dolomitization in this upper part of the dolomitic member still allows textural recognition and the identification of bioclasts, especially those more resistant to dolomitization (e.g. echinoderm, red algae and corals; Dawans, 1988). Dolomite textures are in general crystalline mimetic, sometimes crystalline non–mimetic.

Conclusions

The study of borehole cuttings from two cores located at the edge of Great Bahama Bank (New Providence Island) leads us to recognize three, general depositional sequences within the non–dolomite unit of the Lucayan Fm. and the pre–Lucayan carbonates. Facies evolution is comparable to other examples from the Great Bahama Bank and others Bahamian platforms. The main conclusions are summarized as follows:

– Borehole cuttings permit recognition of four basic facies: Oolitic grainstones; peloid–rich wackestones/packstones with variable amount of ooids, foraminifera, gastropods, bivalves, echinoids, red algae and corals; skeletal wackestones to grainstones; and coralgal (corals and red algae–rich packestones). These Type–facies lead us to tentatively interprete 5 depositional environments involved, which range from tidal–bar shoal, shoal,

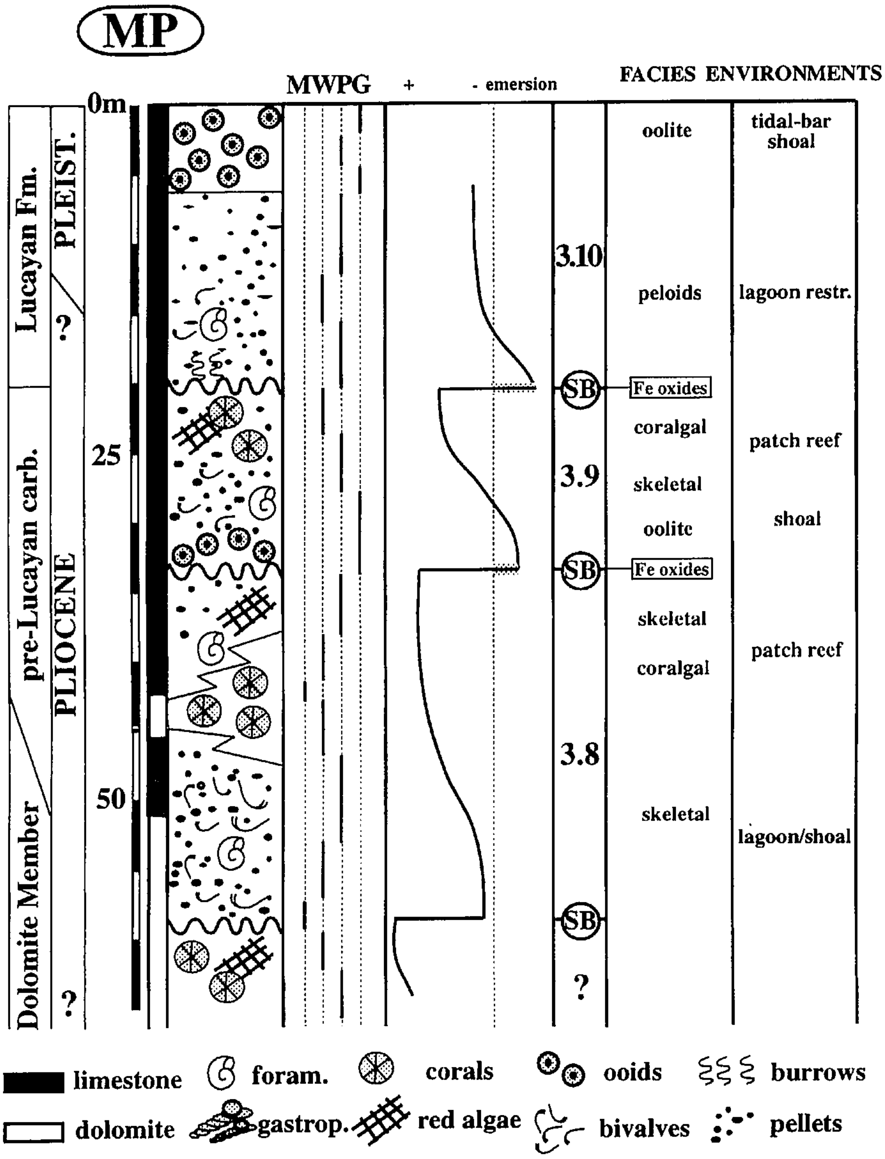

Fig. 3.–Synthesis of the more relevant characters in core MP (Malcolm Park). From left to right: Formations, estimated age, depth below land surface, stratigraphic profile, Dunham textural classification (M=Mudstone, W=Wackestone, P=Packstone, G=Grainstone), 3rd order depositional sequences (Haq *et al.*, 1988) or prograding sequences (Eberli and Ginsburg, 1989), facies, and depositional environments. Core top equals +3m elevation.

Fig. 3.- Síntesis de los aspectos más relevantes del sondeo MP (Malcolm Park). De izquierda a derecha: Formaciones, edad estimada, profundidad, columna estratigráfica, clasificación textural de Dunham (M = Mudstone, W = Wackestone, P = Packstone, G = Grainstone), secuencia deposicional de 3er orden (Haq* et al., *1988) o secuencia progradante (Eberli and Ginsburg, 1989), facies y ambiente deposicional. Techo del sondeo situado a 3m sobre el nivel del mar.

restrictedlagoon, lagoon to patch reef environments, according to type–facies abundance.

– We interprete subaerial exposure by the recognition of abundant, fine laminated brownish–black clasts (caliche–like crusts) which are related to intervals rich in clasts stained by Fe and Mn oxides. As previously stated (Neumann and Land, 1975; Mullins, 1983; and Eberli and Ginsburg, 1989) higher productivity during sea level highs, and submarine and/or subaerial erosion during sea level lows provides for a better representation of upper Transgressive System Tract and Highstand System Tract deposits within the depositional sequence. These depositional dynamics seem to work in this case–study where those facies representing tidal–bar shoal are greatly reduced.

– The upper limit of dolomitization along the northern edge of the Great Bahama Bank (New Providence Island) is around 50m in both cores (50m in core YEW [+3m core top elevation], and 52m in core MP [+3 core top elevation]). Moreover, meters 40–45 in core MP show incipient dolomitization as a result of the assumed irregularity of this surface. Red algae, echinoderms, and corals were confirmed to be the bioclasts most resistant to dolomitization.

– We recognized a general shallowing upward trend, emcompassing the whole studied interval, which starts with coralgal, skeletal and reefal–rich facies evolving upward to ooids and peloid–rich facies. This trend is in accordance with the general regressive trend 2nd order cycle TB3, long term curve in Haq *et al.* (1988).

– Three 3rd order depositional sequences are perhaps recorded and correlated to prograding sequences a, b, and c (megasequence A; Pliocene–Holocene, in Eberli and Ginsburg 1989). They may also match with 3rd Order depositional cycles 3.10, 3.9, and 3.8 in the 2nd Order cycle TB3 (Haq *et al.* 1988).

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