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Heightened hurricane activity on the Little Bahama Bank from 1350 to 1650 AD

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A B S T R A C T

Deciphering how the climate system has controlled North Atlantic tropical cyclone activity through the Holocene will require a larger observational network of prehistoric hurricane activity. Problematically, the tropical North Atlantic is dominated by carbonate landscapes that typically preserve poorer quality coastal sediment records in comparison to their temperate-region counterparts (e.g., sedimentation continuity and rate). Coastal karst basins (CKBs), such as sinkholes, blueholes, and underwater caves, are widely distributed on carbonate platforms and contain overlooked sedimentary records. Here we present a millennium of hurricane deposits on the Little Bahama Bank archived in a 165 cm core that was extracted from 69 m below sea level in a bluehole on Great Abaco Island, The Bahamas. The coarse-grained overwash deposits associated with both hurricanes Jeanne (2004) and Floyd (1999) were identified using radioisotopes (^{137}Cs, ^{14}C, ^{210}Pb), and indicate that the bluehole is sensitive to hurricane-induced sedimentation. Over the last millennium, the Little Bahama Bank experienced heightened hurricane activity from 1350 to 1650 AD. The simplest explanation for this active interval is that favorable climate conditions (El Niño, West African Monsoon, and sea surface temperatures) encouraged North Atlantic hurricane activity at that time. However, asynchronous hurricane activity at similar latitudes in the North Atlantic and Gulf of Mexico suggest that regional oceanography has modulated or amplified regional hurricane activity over the last millennium.

1. Introduction

Any possible increase in North Atlantic hurricane frequency or intensity is quite ominous because tropical cyclones are a frequent source of coastal destruction and loss of human life (Goldberg et al., 2001; Elsner et al., 2008). According to recent predictions, average global tropical cyclone intensity may increase from 2% to 11% by 2100 (Knutson et al., 2010). However, regional ocean-atmospheric effects in specific oceanic basins will likely further influence tropical cyclone variability in response to future changes in climate (Maloney and Hartmann, 2002; Webster et al., 2005; Emanuel et al., 2008). Perhaps the best way to contextualize these forecasts in our currently warming climate is to understand how tropical cyclone climatology evolved by extending the short instrumental record with proxy-based tropical cyclone reconstructions.

Overwash deposits have emerged as the main technique for reconstructing prehistoric tropical cyclone events. Mckee and Blumenstock were likely the first to recognize the potential for reconstructing tropical cyclone events using their overwash deposits (Blumenstock, 1958; McKee, 1959; Blumenstock et al., 1961). Typoon Opelia struck Jaluit Atoll of the Marshall Islands on 7 January 1958 and deposited laterally-extensive gravel sheets (McKee, 1959; Blumenstock et al., 1961), leading Mckee (1959) to hypothesize that prehistoric overwash deposits would provide proxy evidence for tropical cyclones. Later, Emery (1969) documented and dated sand layers in the sediments from Oyster Pond, a coastal kettle basin on Cape Cod (Massachusetts), and inferred that they were overwash deposits from prehistoric hurricane strikes. Hurricane overwash deposits are now documented in lakes (Liu and Fearn, 1993, 2000), coastal wetlands (Donnelly et al., 2001b; McCloskey and Keller, 2009; Boldt et al., 2010), and back-barrier lagoons (Davis et al., 1989; Donnelly and Woodruff, 2007; Malaize et al., 2011; Park, 2012).

To explain the pattern of hurricane-related overwash deposits in a back-barrier lagoon, Donnelly and Woodruff (2007) posited

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that intense hurricane events were inhibited by El Niño-like conditions and encouraged by the African Easterly Jet over the last 5.0 ka, similar to the modern climate system (Landsea, 1993; Goldenberg and Shapiro, 1996). However, modeled tropical cyclone climatologies forced to a constant El Niño state were unable to produce the reductions in activity observed in the paleo record (Woodruff et al., 2008). In contrast, others hypothesize that the North Atlantic Oscillation (NAO) or Intertropical Convergence Zone (ITCZ) may have forced latitudinal migration of an Atlantic hurricane belt through the Holocene (Liu and Fearn, 2000; Scott et al., 2003; McCloskey and Keller, 2009); interpretations which are also based on the instrumental record (Elsner et al., 2001; Elsner, 2003). Only by increasing our spatial network of prehistoric hurricane observations in the tropical Atlantic region will we understand how the climate system controlled prehistoric hurricane activity in the North Atlantic Ocean.

Problematically, the tropical Atlantic region is dominated by carbonate terrain, which has fewer coastal wetlands and lagoons suitable for paleo hurricane research. Hurricane overwash deposits have been recovered from tropical wetlands that developed on antecedent carbonate platforms (McCloskey and Keller, 2009). However, the sedimentation rate and continuity, and thus the resolution of these archives are limited by the accommodation space provided by sea-level rise, which has been relatively modest (≤0.5 mm yr^{-1}) over the last several millennia in the Atlantic Ocean (Fairbanks, 1989). Therefore, we need to develop more sedimentary environments with higher deposition rates to increase the spatial network of tropical paleo hurricane observations. Coastal karst basins (CKBs), which are features such as sinkholes, blueholes, and underwater caves, provide an alternative on carbonate landscapes (van Hengstum et al., 2011). Continual dissolution and modification of carbonate terrain over Quaternary time-scales creates a variety of basin-like features in limestone bedrock (Smart et al., 1988, 2006; Mylroie et al., 1995a, 1995b). In a recent study by Lane et al. (2011), a decadally-resolved and 4.5 ka record of hurricane activity in the Gulf of Mexico was preserved in a subaerial sinkhole (Apalachee Bay, Florida). In a submerged example, annually-laminated sediments containing hurricane-induced overwash deposits were described by Gischler et al. (2008) from a bluehole in Belize. These results indicate that sinkholes and blueholes may be an important, and largely overlooked, resource of paleo tropical cyclone deposits.

The purpose of this study is to examine sedimentation in a submerged Bahamian bluehole to (i) evaluate the suitability of submerged blueholes to paleo hurricane research, and (ii) provide evidence for prehistoric hurricane activity in the northwestern Caribbean region.

2. Regional setting

The archipelago of The Bahamas comprises multiple carbonate islands and shallow banks in the western North Atlantic Ocean, whose upper lithology is characterized by at least 10 km of highly-karstified shallow water carbonates (Mylroie et al., 1995b; Carew and Mylroie, 1997). The Little Bahama Bank is located in the northwestern region of the Bahamas and bordered by the North Atlantic Ocean and the Florida Straits (Fig. 1A). Two primary island groups are located on the Little Bahama Bank: The Abacos and Grand Bahama Islands (Fig. 1B). Thatchpoint Bluehole (TPBH) is a submerged bluehole on the western shallow shelf of Great Abaco Island (Fig. 1C), likely originating from both limestone dissolution and collapse events over the late Pleistocene (Mylroie et al., 1995a). Local SCUBA divers provide eyewitness evidence that a layer of hydrogen sulfide exists above the sediment–water interface in Thatchpoint Bluehole. This indicates that the sediment water interface is severely oxygen-depleted, caused by either flooding in by anoxic saline groundwater circulating through the carbonate platform, or localized oxygen depletion from the lack of circulation with the coastal ocean (Schwabe and Herbert, 2004; Steadman et al., 2007).

Hurricanes regularly strike The Bahamas because they are positioned along a major hurricane trackway of storms originating in both the Caribbean and Atlantic basins that then often translate northwestwards (Reading, 1990). Since 1850 AD, 10 tropical storms, 12 total hurricanes (category 1–5 on the Saffir–Simpson Hurricane Scale, this scale used hereafter) and 9 intense hurricanes (category 3–5) have passed within a 50 km radius of Thatchpoint Bluehole (http://csc.noaa.gov/hurricanes/#). The three most recent intense hurricane strikes on Abaco Island were Hurricanes Irene in 2011, Jeanne in 2004 and Floyd in 1999, each striking Great Abaco Island with category 3 intensity. Throughout the last century, the 1930s and 1940s saw a rapid increase in hurricane strikes to the Little Bahama Bank, but the number of hurricanes peaked in the 1940s and 1950s (Reading, 1990), similarly to the rest of the North Atlantic region (Goldenberg et al., 2001). On 17 September 1947 a category 5 hurricane passed about 50 km north of TPBH. A category 5 hurricane and category 4 hurricane passed directly over TPBH on 6 September 1932 and 6 October 1933, respectively. Three intense hurricanes passed near TPBH in the late 19th century. On September 6, 1896 a category 3 hurricane passed about 50 km east of the study site. A weak category 3 hurricane passed about 25 km north of TPBH on 22 August 1887 and a minimal category 4 storm passed about 45 km west of the site on 2 October 1866. According to newspaper records from the Bahamian capitol in Nassau, the 1830s was an especially active interval for increased gale force winds

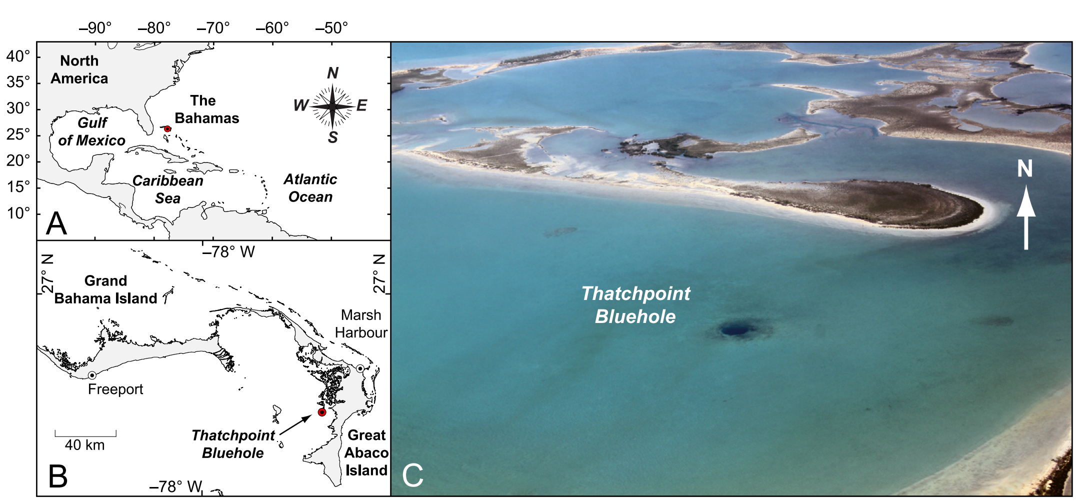

Fig. 1. Thatchpoint Bluehole (TPBH) is positioned in the northwestern Caribbean region (A) on the Little Bahama Bank between Grand Bahama and Abaco Islands (B). An oblique aerial photograph of TPBH (45 m diameter) identifying its position on the shallow shelf surrounded by sediment banks that are colonized by mangroves (C).