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Growth and development of notch speleothems from Cayman Brac, British West Indies: Response to variable climatic conditions over the last 125,000 years

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ABSTRACT

The spectacular wave-cut notch on Cayman Brac, which is ~6 m above sea level, formed during Marine Isotope Stage 5e highstand, 128,000 to 116,000 years ago. On Cayman Brac, the notch is commonly decorated with speleothems (mostly stalactites) that are formed of calcite, aragonite and micrite. These notch speleothems are characterized by numerous growth zones that are delimited by minor and major hiatal surfaces. U/Th dating indicates that the major growth phases, which took place ~73,000 to 59,000 years ago, 46,000 to 49,000 years ago, and ~4000 to 1000 years ago, were separated by periods when erosion and minimal precipitation were the norm. The $\delta^{18}O_{VPDB}$ values range from −6.5‰ to +0.3‰ with a mode between −2 and −4‰ and an average of −3.1‰, whereas the $\delta^{13}C_{VPDB}$ values range from −10.5‰ to +1.9‰ with one mode between −2.0 and −3.0‰, a second mode between −7.0 and −8.0‰, and an overall average of −6.1‰. The $\delta^{18}O$ and $\delta^{13}C$ values co-vary. The $\delta^{18}O_{VPDB}$ and $\delta^{13}C_{VPDB}$ values are similar to those from the "young" (<125,000 years old) cave speleothems but heavier than those from the "old" (>125,000 years) cave speleothems. Today, with the little evidence of active speleothem growth in the notch or caves, Cayman Brac is characterized by dry sub-tropical forest and shrubland with xeric components on the elevated eastern end of the island. Available data indicate that most of the speleothem growth took place during the transitions from Marine Isotope Stage (MIS) 5a to 4, and MIS2 to 1. These transitional periods, which define the onset and termination of glaciation in the northern latitudes, were probably characterized by higher rainfall and development of tropical rainforests. It is evident that notch speleothems, like those from Cayman Brac, are valuable archives of the paleoclimate conditions that have existed since the highstand associated with MIS5e.

1. Introduction

Wave-cut notches, found at various localities throughout the world, are important because they offer evidence of past sea-level standstills (e.g., Neumann, 1966; Harmon et al., 1981; Mylroie and Carew, 1991; Gvirtzman, 1994; Rust and Kershaw, 2000; Kershaw and Guo, 2001; Furlani et al., 2011; Trenhaile, 2015). Many notches are adorned with precipitates that have been variously labeled as "non-vertical stalactites" and "stalactite tufa" (Bull and Laverty, 1982), "tufa-like speleothems" (Ford, 1989), "gigantic stromatolite stalactites" (Forti, 2001), "outside stalactites" (Sweeting, 1978; Taboroši and Hirakawa, 2004), "remora" (Pentecost, 1993), "littoral dripstones" and "littoral flowstones" (Taboroši and Stafford, 2003), or "exposed stalactites and stalactitic tufa" (Taboroši et al., 2006). These "notch speleothems" (Jones, 2010a) differ from cave speleothems because they grew in an environment that is open to the atmosphere and sunlight rather than in the confines of a dark cave. Although not present in every wave-cut notch, notch speleothems have been reported from many localities worldwide, including New Georgia, Solomon Islands (Stoddart, 1969), Guam (Taboroši et al., 2006), Tinian in the North Mariana Islands (Taboroši and Stafford, 2003), Cayman Brac (Woodroffe et al., 1983), and Israel (Arbel et al., 2009).

One of the most spectacular features on Cayman Brac (Figs. 1–3), first noted by Matley (1926, p. 357 and 359) during his geological exploration of the Cayman Islands, is the wave-cut notch, 6.4 m above current sea level (asl), that probably formed during the highstand associated with Marine Isotope Stage 5e (MIS 5e), ~125,000 years ago (Sauer, 1982; Woodroffe et al., 1983; Jones and Hunter, 1990; Tarhule-Lips, 1999; Vézina et al., 1999; Murray-Wallace and Woodroffe, 2017; Zheng, 2017). The cliff recession associated with that highstand also impacted the development of cave speleothems on Cayman Brac, because many of the isolated interior caves were opened to the atmosphere (Tarhule-Lips, 1999; Ford, 2002). Herein, analysis of the notch speleothems is based on (1) their mineralogical and petrographic characteristics, (2) the ages of the growth cycles and hiatal surfaces, and

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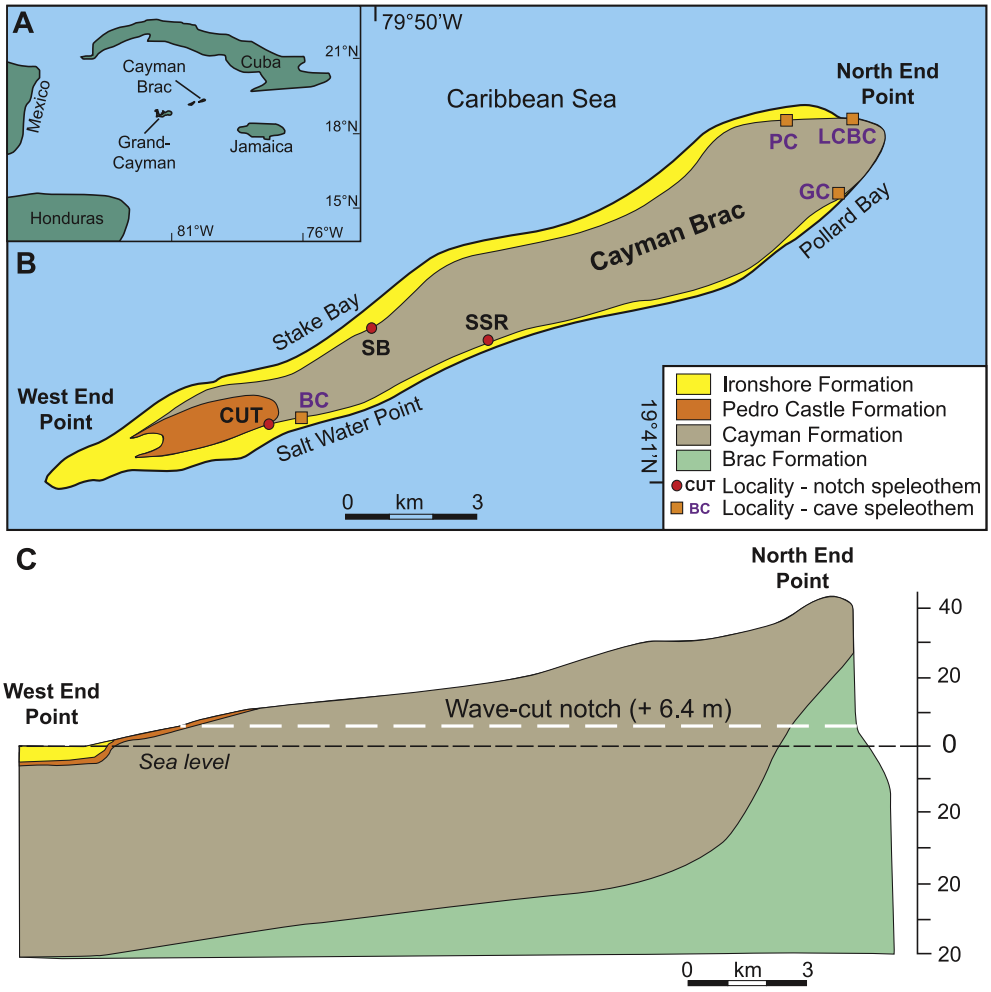

Fig. 1. Location map and geology of Cayman Brac. (A) Location of Grand Cayman and Cayman Brac. (B) Geology map of Cayman Brac (modified from Jones, 2010a, his Fig. 1) showing locations where notch-speleothems (SB, SSR, CUT) are found and cave locations (LCBC = Little Cayman Brac Cave; PC = Peter's Cave; GC = Great Cave; BC = Bat's Cave. (C) Cross-section from North End Point to West End Point showing location of wave-cut notch relative to the dipping strata that forms the core of the island.
Modified from Jones, 1994, his Fig. 2.7.

(3) their stable isotope values. This information provides the basis for comparing the notch speleothems with cave speleothems from Cayman Brac with the view of establishing similarities in the growth cycles and the stable isotope values of these two types of speleothems. These comparisons are then used to assess the factors that controlled growth of the notch speleothems and the impact that variable conditions had on their development since the MIS 5e highstand. This is important from a regional perspective because little is known about the climatic conditions that have affected this part of the Caribbean over the last 125,000 years.

2. Geology, hydrogeology, and vegetation of Cayman Brac

2.1. Geology

The Cayman Islands (Fig. 1) are situated on the Cayman Ridge that is bounded to the south by the Oriente Transform Fault that forms the boundary between the North American and Caribbean plates (MacDonald and Holcombe, 1978; Perfit and Heezen, 1978). Each island is probably located on different fault blocks that experienced independent tectonic movements (Horsfield, 1972; Jones and Hunter, 1990).

Cayman Brac has a rugged karst surface (Liang and Jones, 2015b) that slopes gently from ~ 43 m above sea level at its northeast end to sea level at its southwest end (Fig. 1C). The uplifted core of Cayman Brac is formed of the Bluff Group (Fig. 1C), which includes the Brac Formation (late Oligocene), Cayman Formation (middle Miocene), and Pedro Castle Formation (Pliocene) (Jones et al., 1994a, 1994b; MacNeil and Jones, 2003; Uzelman, 2009). The strata in these unconformity-bounded formations dip (<1°) gently to the west. The Ironshore Formation forms a narrow coastal platform around Cayman Brac (Fig. 1B), with surface exposures belonging to Unit D that was deposited ~ 125,000 years ago when sea level was ~6 m asl (Coyne et al., 2007; Zhao and Jones, 2013).

2.2. Hydrogeology

Today, the rainfall intensity and distribution on Cayman Brac is controlled by the prevailing easterly winds and the high land that forms the core of the island (Ng, 1990). Rainfall recorded at Stake Bay, located on the north side of the island, varied from 1472 mm in 1979 to 587 mm in 1986 (Ng, 1990). Today, fresh groundwater lens are restricted to (1) the Tibbetts Turn Lens, located on the north-central part of the island, (2) some small, unnamed lens on the north side of the western end of the island, and (3) some small perched water lenses in central part of the eastern end of the island (Ng and Beswick, 1994). On the uplifted core of the island there are no streams or ponds because rainwater quickly drains away through the karst landscape that characterizes the exposed Cayman Formation (Jones, 1994; Liang and Jones, 2015a).