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Ongoing, long-term evolution of an unconformity that originated as a karstic surface in the Late Miocene: A case study from the Cayman Islands, British West Indies

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ABSTRACT

On Grand Cayman and Cayman Brac, karst development on the upper surface of the Cayman Formation during the late Miocene lowstand produced the Cayman Unconformity. On Grand Cayman, this led to the development of a deep, atoll-shaped depression on the western part of the island. The ensuing Lower Pliocene transgression buried that unconformity and led to deposition of sediments that now form the Pedro Castle Formation. Today, on Grand Cayman, the dolostones of the Cayman Formation remain largely buried on the western half of Grand Cayman but are widely exposed on the central and eastern parts of the island where they have been subjected to extensive weathering over the last 4.3 Ma. Although the situation is similar on Cayman Brac, uplift of the central core led to removal of the Pedro Castle Formation and much of the Cayman Formation. Karst development on both islands reflects the interplay between Neogene sea-level changes, climate, and tectonic uplift. Today, weathering is further modifying the Cayman Unconformity on the eastern parts of both islands.

The Cayman Unconformity on the central and eastern parts of Grand Cayman is characterized by karst landforms, including a peripheral rim, sinkholes, solution-widened joints, and photolineaments (surface traces of joints and/or faults). The westward tilting of Cayman Brac (4.3 Ma to 400 ka) led to more severe weathering of the exposed Cayman Formation that included (1) enhancement of the peripheral rim and karst features on the upslope margin, and (2) higher denudation rates than on Grand Cayman. During the Messinian, the denudation rate on the west end of Grand Cayman was 0.03–0.10 mm yr^{-1}. In contrast, the denudation rate over the an estimated period of 4.9 to 6.2 Ma for the eastern half of Grand Cayman has been about 0.01 mm yr^{-1}, whereas on the east end of Cayman Brac it has been 0.03–0.04 mm yr^{-1}. On both islands, substantial thicknesses of strata have been lost to erosion and the Cayman Unconformity has been subject to ongoing modification over a period of 4.9 to 6.2 Ma.

1. Introduction

The evolution of carbonate successions on isolated oceanic islands is fundamentally controlled by changes in sea level and tectonic activity (e.g., Schlanger and Premoli Silva, 1986; Lincoln and Schlanger, 1987; Jones and Hunter, 1994b). Weathering that takes place while the islands are subaerially exposed commonly leads to loss of strata and significant surface and subsurface modifications of the exposed carbonates (Bathurst, 1975; Esteban and Klappa, 1983; James and Choquette, 1990; Flügel, 2004; Frisia and Borsato, 2010). Karst surfaces, which commonly develop under the influence of hot, humid climates, are particularly important because they (1) form the antecedent topography that may influence the early stages of sedimentation during the ensuing highstand (e.g., Purdy, 1974; Purdy and Winterer, 2001; Purkis et al., 2010; Liang and Jones, 2014), (2) will become the unconformities (i.e., sequence boundaries) that separate successive depositional packages (Tucker, 1990; Wright, 1994; Clari et al., 1995; Hillgärtner, 1998; Sattler et al., 2005), and (3) will delineate horizons with which meteoric diagenesis and/or dolomitization may be genetically related (Esteban and Klappa, 1983; James and Choquette, 1988; Tucker, 1990; Saller et al., 1994, 1999; Wright and Smart, 1994; Whitaker et al., 1999; Frisia and Borsato, 2010; Miller et al., 2012; Zhao and Jones, 2012). The karst topography that develops on erosional surfaces such as these is controlled by the complex interplay between numerous variables, including eustatic changes in sea level, tectonics, climate, hydrogeology, lithology, vegetation, porosity and permeability of the bedrock (White, 1988; Ford and Williams, 2007). The impact of factors such as sea-level change and tectonic movement is commonly difficult to decipher because they may produce the same end-result.

This study focuses on the unconformity that defines the upper boundary of the Cayman Formation (Miocene) that is found on Grand Cayman and Cayman Brac (Figs. 1, 2). This unconformity, named the

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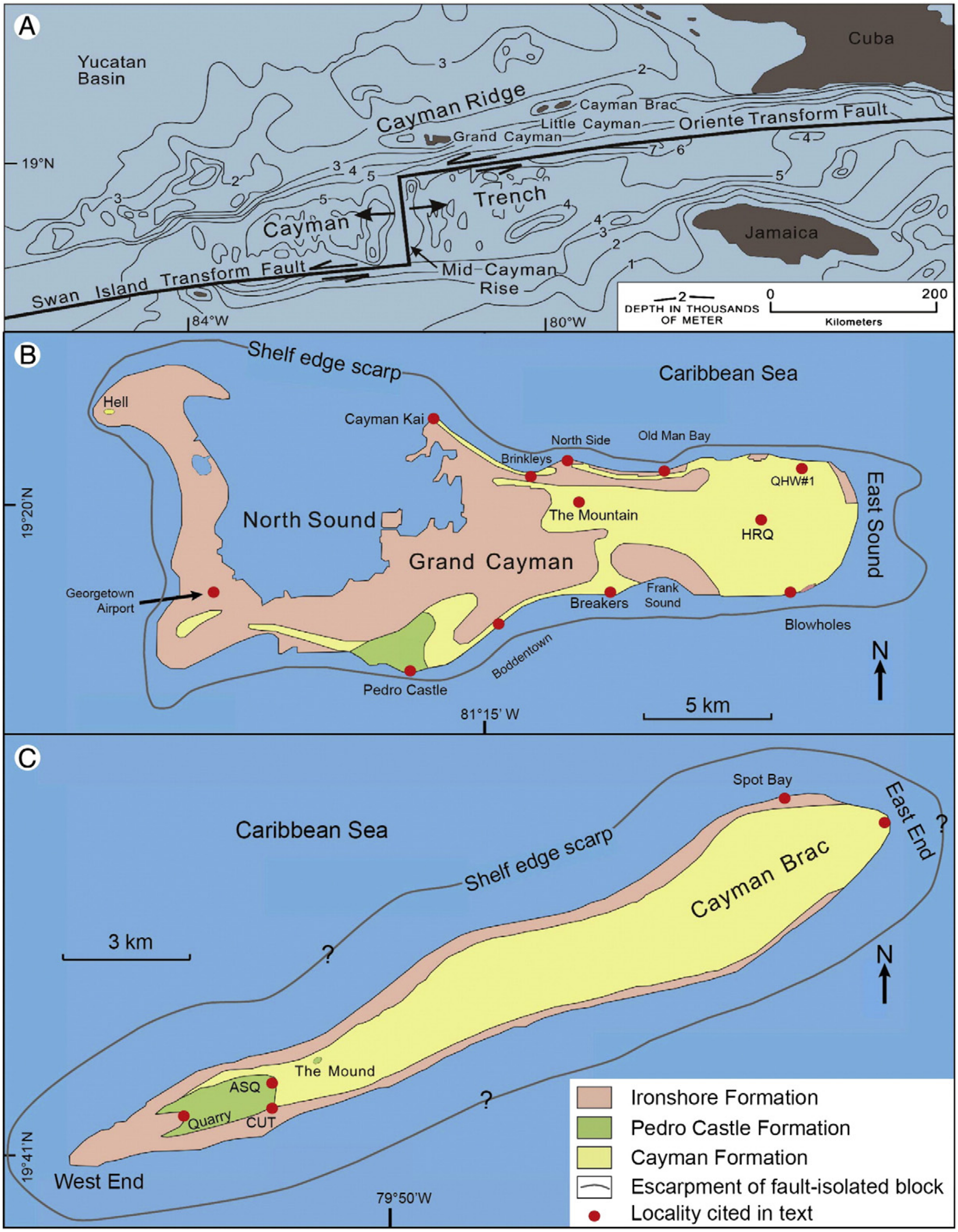

Fig. 1. (A) Location of Cayman Islands relative to the Mid-Cayman Rise, Cayman Trench, and Oriente Transform Fault (modified from Jones, 1994, and based on maps from Perfit and Heezen, 1978; MacDonald and Holcombe, 1978). (B) Surface geology on Grand Cayman (modified from Jones, 1994) and position of the shelf-edge scarp of Grand Cayman (modified from Blanchon and Jones, 1995). (C) Surface geology on Cayman Brac (modified from Jones, 1994) and position of the shelf-edge scarp (derived from Google Earth images).

Cayman Unconformity by Jones and Hunter (1994b), first developed during the Messinian lowstand. Estimates of eustatic fall at that time range from 30 m (Aharon et al., 1993) to 180 m (Pigram et al., 1992) below present-day sea level. Since then, this unconformity has experienced a complex developmental history. Today, parts of the original unconformity are still covered by younger sediments whereas other parts are exposed to the atmosphere and being actively weathered. Where exposed on the eastern part of Grand Cayman and the uplifted core of Cayman Brac, the surface of the Cayman Formation is characterized by phytokarst, pinnacles, sinkholes, and solution-widened joints (Doran, 1954; Folk et al., 1973; Jones and Smith, 1988; Squair, 1988; Jones, 1989, 1992). Although these islands have undergone different tectonic