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Delineation of macroporous zones in the unsaturated portion of the Miami Limestone using ground penetrating radar, Miami Dade County, Florida

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SUMMARY

The Atlantic Coastal Ridge in Dade County is an ooid shoal formed during the late Pleistocene. The ridge is composed of the eogenetic karst Miami Limestone, characterized by a heterogeneous distribution of porosity that can manifest as large touching-vug macroporous features with sizes in the meters and tens of meters. Direct evidence for the presence of such large dissolution features is only visible when exposed to the surface which may be problematic in urbanized areas. For that reason it is critical to detect any potential precursors for such dissolution features at the subsurface level. The purpose of this study was to investigate the ability of ground penetrating radar to detect areas of macroporosity by quantifying changes in electromagnetic wave velocity and relate them to changes in porosity after application of the complex refractive index model (CRIM). In order to constrain volumetric water content (VWC) in the CRIM, an experiment using Miami Limestone samples was designed to understand: (1) the range of typical VWCs; and (2) the effect of capillary fringe on water table elevation. The results show several areas where increases in EM wave travel time associated with contrasts in porosity exceeding 40% cannot be explained by changes in VWCs typically shown in the Miami Limestone. This study may help understand porosity variability in the unsaturated part of the Miami Limestone and if expanded to larger scales may aid groundwater flow models by better capturing distributions of macroporous areas that may contribute to direct recharge of the Biscayne aquifer.

1. Introduction

The majority of South Florida is underlain by the Miami Limestone (Fig. 1a and b), a shallow carbonate formation deposited during higher sea levels during the late Pleistocene. This lithostratigraphic unit composes the uppermost portion of the Biscayne Aquifer (Fig. 1b), a highly transmissive unconfined aquifer, which provides the bulk of potable water for nearly 6 million people in Miami-Dade, Broward, Monroe and Palm Beach Counties daily (McPherson et al., 2000). A series of sea level changes and subaerial exposures during the Late Pleistocene created the ideal environments for a very porous and karst ridden limestone depositional sequence. The currents responsible for the deposition of the carbonate sands also created an active ooid shoal system that consisted of a seaward oolitic barrier bar (approximately 3200 m long by 800 m wide), a back barrier channel (approximately 1600 m wide), and an extensive tidal ooid shoal complex to the west and southwest (Hoffmeister et al., 1967; Halley et al., 1977; Halley and Evans, 1983; Neal et al., 2008). The remaining extent of this shoaling system is now known as the Atlantic Coastal Ridge and, is approximately 8.0 m above sea level at its highest elevation and extends from southern Palm Beach County to Miami Dade County (Fig. 1b) (Hoffmeister et al., 1967; Neal et al., 2008).

The porosity of the Miami Limestone within the Atlantic Coastal Ridge has been investigated previously using traditional geologic techniques that generally involve invasive drillings. Robinson (1967) collected a series of 27, 0.025 m cores and provided a range of porosity values from 27.0% to 46.5%. Halley and Evans (1983) provides an average estimate of porosity at 45.0% (range of 20.0–60.0%), for 14 samples, and suggests that larger core samples account for touching-vugs, whereas smaller cores do not, and underestimate the values. Hester and Schmoker (1985) compiled 538 samples and porosity data from 249 additional samples which

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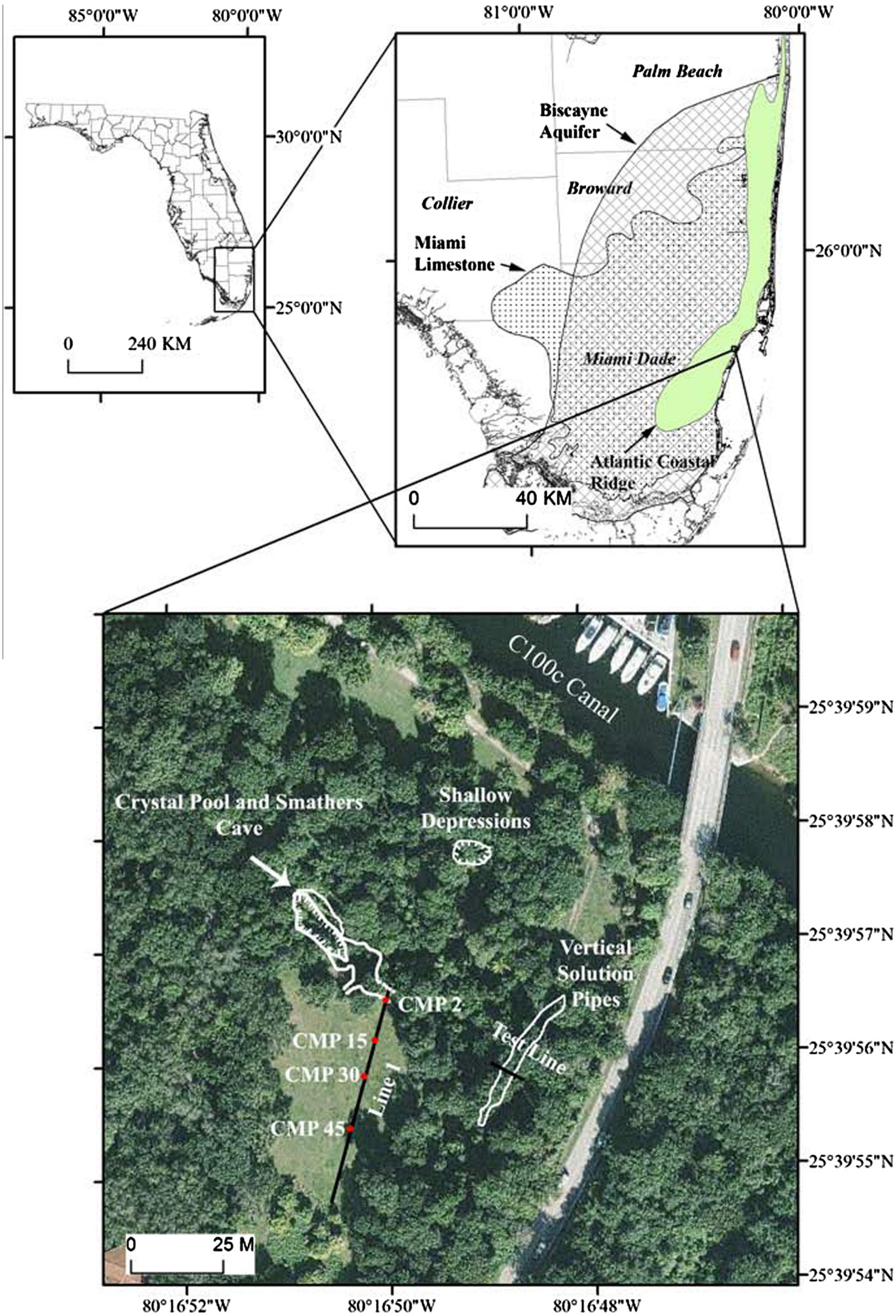

Fig. 1. (a) Map of Florida showing the regional area in relation to the state, (b) map of the south Florida regional area showing the areal extent of the Atlantic Coastal Ridge (green shaded area and label) (South Florida Water Management District, 2003), the Biscayne Aquifer (crosshatched area and label) (U.S. Geological Survey, 2003), Miami Limestone (solid black outline and label) modified from Dicken et al. (2005), and (c) aerial photograph of the Smathers Four Fillies Farm project area (http://www.labins.org) showing the location of the field site, including Smathers and Crystal Pool Caves (white polygon and label modified from Cressler (1993)), the approximate location of the shallow depressions (white polygon and label), the vertical solution pipe area (white polygon and label), Test Line and Line 1 common offset survey transects (white lines and labels), and common midpoints CMP 2, 15, 30 and 45 (symbolized by red circles). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)