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We focus on two major problems in the study of paleokarst of the Biscayne aquifer in southeastern Florida: (1) current conceptual models of karst aquifers do not adequately characterize much of the eogenetic macropore system within the carbonate rocks of the Biscayne aquifer, and (2) standard laboratory core-analysis methods cannot be used to accurately measure the permeability of highly macroporous carbonate core samples.

Cyclostratigraphic and borehole geophysical analyses of continuous coreholes (Cunningham et al., 2004; 2006a,b), tracer-test analyses (Renken et al., 2005), high-resolution X-ray computed tomography (HRXCT), and flow simulations using lattice Boltzmann methods (Sukop and Thorne, 2006) were used in combination to characterize the macroporosity and permeability of the eogenetic karst limestone of the Biscayne aquifer, principally within the 246-km^2 study area (Figure 1) of Cunningham, et al. (2004; 2006a,b). Results show that tabular-shaped, touching-vug hydrogeologic units are commonly stratiform within high-frequency cycles. Much of this macroporosity is biogenic in origin and concentrates groundwater flow to form the dominant type of flow passageway (Figure 2). Biogenic

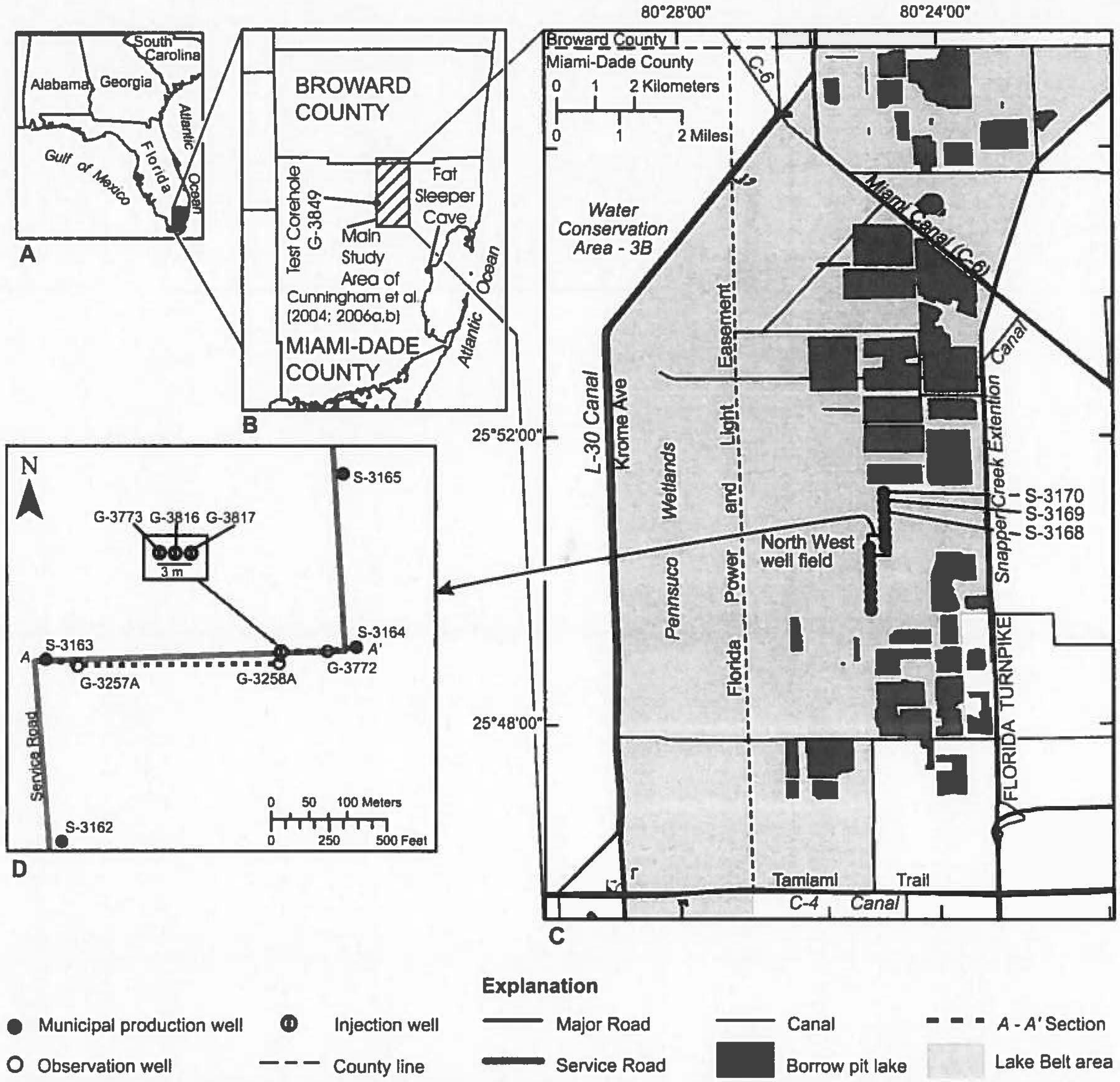

Figure 1. Maps of study area. A. General location within the United States. B. Main study area of Cunningham et al. (2004; 2006a,b) in southeastern Florida and focus of this paper. C. Location of Northwest Wellfield within main study area. D. Location of cross-section A-A' (Figure 2.) within the Northwest Wellfield.

macroporosity largely manifests as two forms of touching-vug macroporosity: (1) ichnogenic macroporosity primarily related to post-depositional burrowing activity by callianassid shrimp (Figure 3); and (2) biomoldic macroporosity originating from the dissolution of fossil hard parts, principally mollusk shells. Ichnogenic macroporosity constrains the spatial distribution of at least some of the near-surface small caves (Figure 4) known to exist within the upper Pleistocene limestone of the Biscayne aquifer (Cressler, 1993). Biogenic macroporosity represents an alternative pathway for concentrated groundwater flow that differs considerably from the modern paradigm of karst aquifers that describe groundwater movement through cross-stratal dissolution features, bedding-plane vugs, and fractures (White, 1988; Ford and Williams, 1989; Worthington et al., 2000). Although some of these more typical karst features occur in the study area, they less important then the biogenic flow zones.

The permeability of macroporous karstic rocks is extremely difficult to measure in a laboratory setting due to flow-rate limitations of the measuring apparatus, and issues related to maintaining and measuring the extremely small gradients needed to sustain Darcian flow regimes. HRXCT methods can produce digital reconstructions of porous media that are essential for detailed pore-scale flow modeling. The HRXCT provided rendering data for lattice Boltzmann calculation of permeability in samples with well-connected macropores.

Seven samples representative of biomoldic and trace-fossil

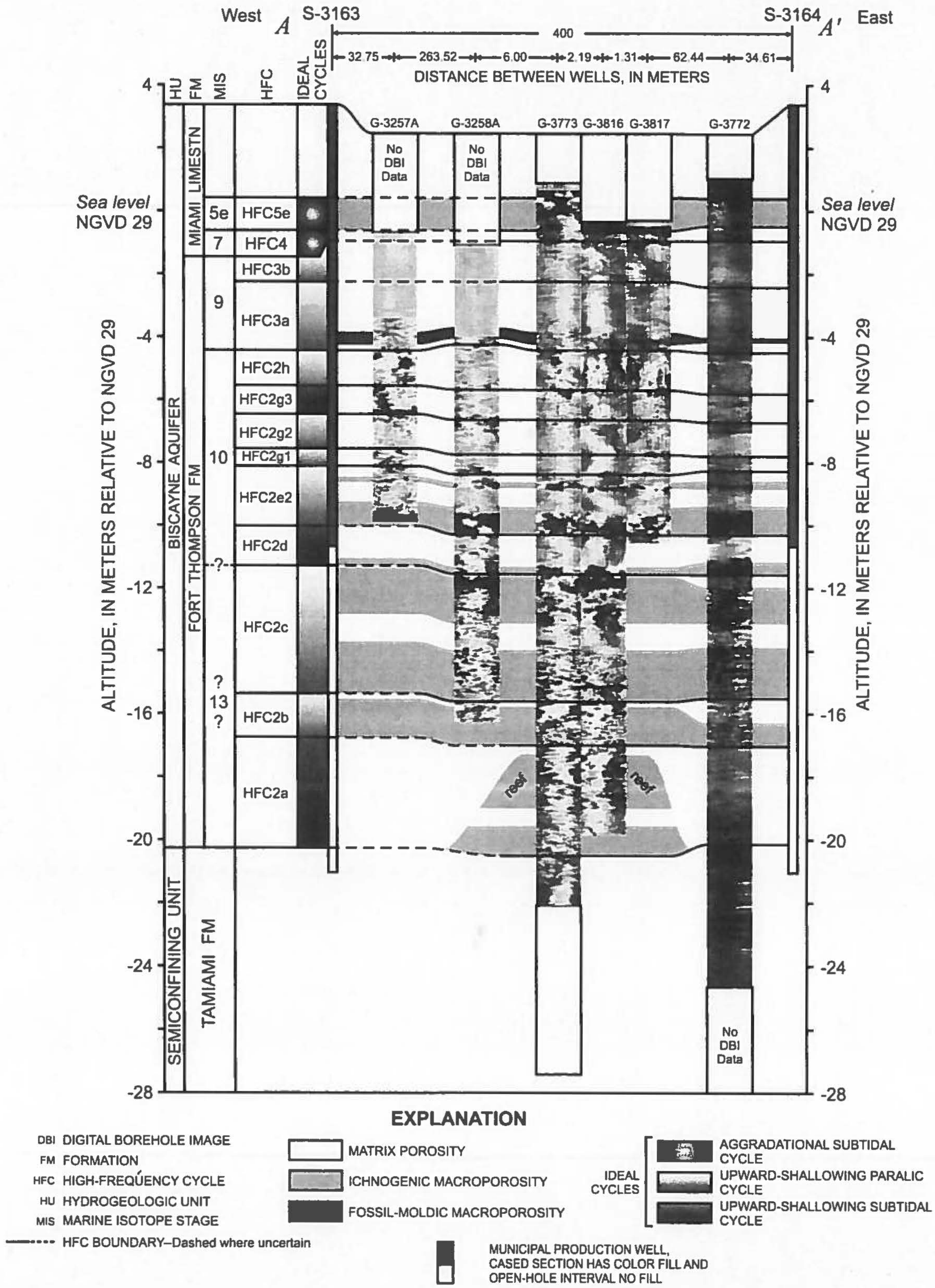

Figure 2. Cross-section A-A' showing vertical and lateral arrangement of biogenic macroporosity (fossil-moldic and ichnogenic macroporosity) and matrix porosity in the context of a high-frequency cyclostratigraphy for the Fort Thompson Formation and Miami Limestone of the Biscayne aquifer, Northwest Well Field (Figure 1.). Stratiform zones of substantial ichnogenic macroporosity interpreted to be related principally to callianassid burrowing are shown in light gray. Modified from Cunningham et al. (2006b).

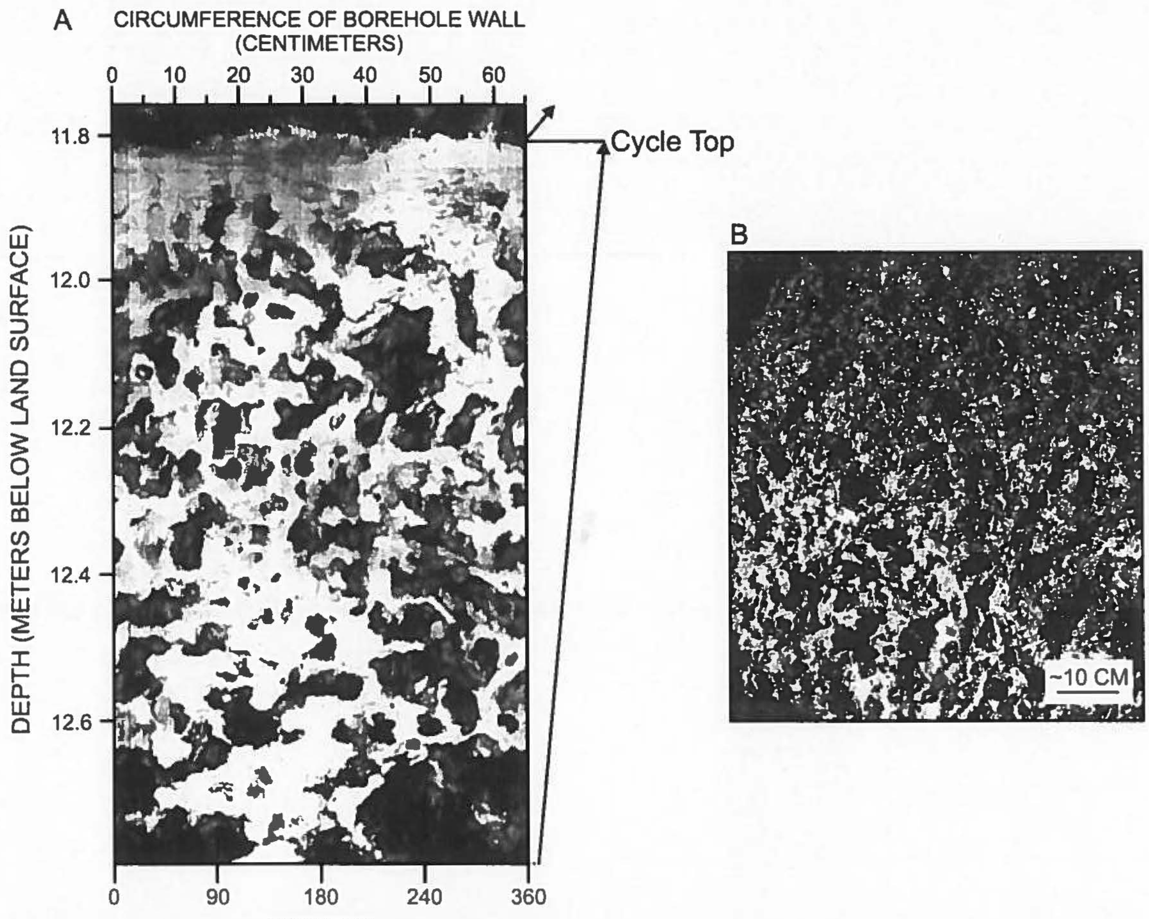

Figure 3. Examples of ichnogenic macroporosity (intra- and inter-burrow) formed by the dense occurrence of *Ophiomorpha* shafts and tunnels within limestone of the Biscayne aquifer, Miami, Florida (Figure 1.). A. Photograph was acquired by a digital-optical borehole-image tool scanning the borehole wall of monitoring well G-3849 (Figure 1B.) in the Fort Thompson Formation (Middle Pleistocene, Marine Isotope Stage 11). The borehole wall image has been unwrapped to display an entire 360° view. Throughout the vertical interval, the borehole has a diameter of about 20.3 cm and an approximate circumference of 65 cm. Modified from Cunningham and Curran (2007). B. Ichnogenic macroporosity along cave wall inside Fat Sleeper Cave located about 26 km to the southeast of test corehole G-3849. The cave is developed in peloid-ooid grainstone of the Late Pleistocene, Marine Isotope Stage 5e part of the Miami Limestone. The grainstone is overprinted with a maximum-intensity Ophiomorpha ichnofabric. The scale and distribution of cm-scale ichnogenic macroporosity on the walls of the cave are comparable to that shown on the borehole walls of test corehole G-3849. Photo by Allan M. Cressler.

related macroporosity were collected from the Fort Thompson Formation and Miami Limestone of the Biscayne aquifer in southeastern Florida. These samples were scanned using HRXCT methods that provided resolution on the order of 0.3 mm per pixel. Permeability calculations were conducted using lattice Boltzmann techniques applied to seven renderings of samples created from the HRXCT scans. Permeability was only calculated for the macroporous part of the seven samples and not the matrix porosity, because the rock matrix was simulated as a solid material in the computer renderings. Non-Darcian inertial flows were avoided by applying extremely small gradients while making the permeability calculations. The lattice Boltzmann method was verified against analytical solutions for pipe and conduit flow. Measured horizontal permeabilities derived from lattice Boltzmann methods correspond to hydraulic conductivity values ranging from 0 m/s (for a sample lacking well-connected macroporosity) to 136 m/s, and are as much as five orders of magnitude greater than the largest values documented in laboratory tests.

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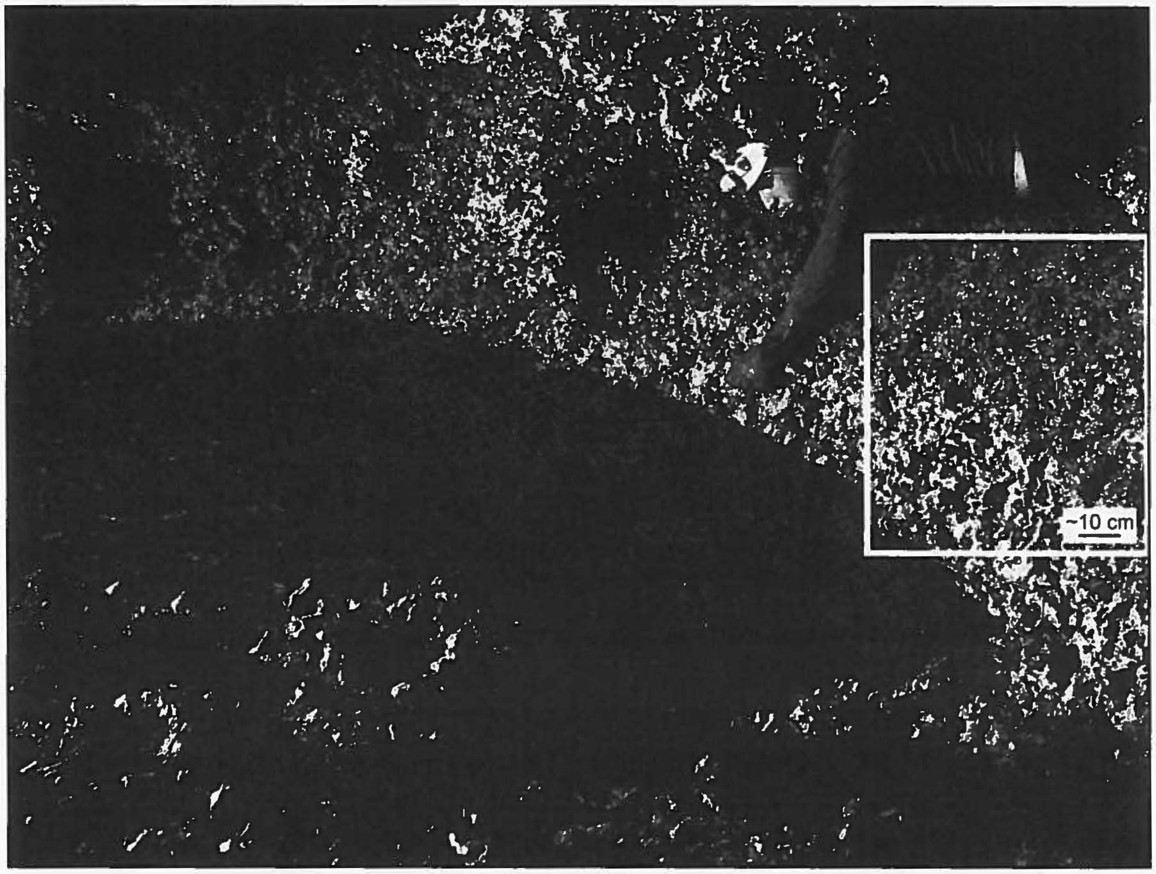

Figure 4. Inside Fat Sleeper Cave located near the shore of Biscayne Bay and about 17 km to the southeast of the main study area (Figure 1.) of Cunningham et al. (2004; 2006a,b). The cave is developed in peloid-ooid grainstone overprinted with a maximum-intensity callianassid ichnofabric dominated by *Ophiomorpha.* White box inset is displayed in Figure 3B. The callianassid ichnofabric dominates a widely occurring stratiform layer within the Miami Limestone. Photo by Allan M. Cressler

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