

Characterization of the Karstic Biscayne Aquifer in Southeastern Florida Using Ground-Penetrating Radar, Digital Optical Borehole Images and Cores

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Abstract

Ground-penetrating radar is a useful tool in the characterization of shallow carbonate aquifers. This technique was applied to karstic carbonate rocks of the upper Biscayne aquifer in southeastern Florida. Resultant ground-penetrating radar profiles showed the following geologic features: (1) paleo-sinkholes, (2) paleo-outliers, (3) paleotopographic relief on subaerial exposure surfaces, (4) low-angle accretion bedding and (5) vertical stacking of upward-shallowing cycles. These features were then ground-truthed by comparing them to features recognized in digital optical borehole images, cores, and outcrops. Ground-penetrating radar was used to map a hydrologically important low-permeability layer which, at least in local areas, retards vertical movement of groundwater. This hydrologic layer spans the geologic contact between the Miami Limestone and the underlying Fort Thompson Formation, and includes multiple subaerial-exposure surfaces.

Digital optical borehole images were utilized to orient core samples, "reconstruct" missing core samples, and define vug geometry, bedding, depositional features and grain size in the carbonate rocks of the upper Biscayne aquifer. Features identified on log-derived images were correlated or calibrated to existing core samples; when core samples were absent, images served as a substitute. Other common applications for the digital optical borehole images include identification and characterization of fractures, depositional features, aquifer architecture, faults, and evaluation of borehole stress.

Using a pixel-counting technique, vuggy porosity was measured for 290 feet of digital optical borehole images. These images were recorded in the upper Biscayne aquifer from 17 coreholes in an approximately 110-square mile area contiguous to the eastern boundary of the Everglades. Quantification of vuggy porosity in another 24 borehole imaging logs is in progress. Analysis of the 17 borehole imaging logs suggests that geologic depositional cycles, rock fabric, and quantity and type of vuggy porosity are all interrelated and that karst-related conduit flow is the principal mechanism of ground-water movement in the upper Biscayne aquifer.

Findings indicate that conduit-flow paths within the Fort Thompson Formation are produced by well-connected, solution-enlarged pore space. Characteristics of the solution-enlarged pore space vary as a result of depositional textures, diagenesis in a meteoric-water system, and vertical position within stacked lithofacies that combine to form each upward-shallowing cycle. Thin, vertical solution pipes are usually associated with tidal-flat deposits that commonly cap cycles and contain a low permeability matrix. These pipes provide a network of passageways for vertical ground-water flow across the low-permeability cycle caps. Middle portions of cycles are relatively non-vuggy. Well-connected pelecypod molds and irregular vugs are mainly in the lower portion of cycles. Horizontal conduit flow appears to be largely within the vuggy porosity at the base of each cycle.

Dividing the Biscayne aquifer into small-scale, time-bounded cycles has facilitated accurate assessment of depositional and diagenetic facies and will form the basis of a high-resolution aquifer conceptual model. This conceptual model, which is suitable for numerical modeling, will show the distribution of porosity and hydraulic conductivity. Because of the direct hydraulic connection between surface-water features and the aquifer, a thorough understanding of the Biscayne aquifer and its characteristics is critical to properly managing water levels within existing and planned surface-water reservoirs in the Everglades.