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INDIAN RIVER REGION
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SEISMIC STRATIGRAPHY OF THE CENTRAL INDIAN RIVER REGION

Indian River County, Florida

By
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Introduction

The geology and and hydrology of the central Indian River region along the central east coast of Florida (Fig. 1) is of critical concern to the St. Johns River Water Management District (SJRWMD). In this area the upward migration of deeper, more saline ground water in the lower Floridan aquifer to the shallower, fresher ground water of the upper Floridan aquifer and above, may impact the water quality of this resource. Higher than normal chloride concentrations occur in wells east of a reported fault within the Indian River south of Johns Island (Bermes, 1958). The nature and extent of the fault is not well defined. High-resolution seismic tools using digital technology were utilized in collecting geophysical data in an attempt to identify the fault. Additionally, the data collected exhibits the benefits of these techniques in understanding the formation of the upper Florida platform. The application of these techniques aid in the management of water resources by identifying the stratigraphy that contain the surface water bodies and the various aquifer systems.

Physiography and Lithology

Beneath Indian River, the horizons of acoustic impedance are generally related to lithologic changes between clays and carbonates within the Hawthorn Group and with the underlying carbonates of the Ocala Limestone. The Hawthorn Group sediments are highly variable, layered sediments that range from poorly indurated sands and shells to clays, and well indurated carbonates (Scott, 1991). The variable bedding in the sediments provide multiple reflections. The upper Ocala Limestone contact is an irregular horizon identified as an erosional karst surface. The limestone has few bedding planes that have sufficient velocity contrasts to produce coherent reflections.

Strata above the Hawthorn are comprised of variable, undifferentiated sediments associated with ridges formed by Plio-Pleistocene barrier island and dune development. The ridges form the Cocoa-Sebastian Ridge, the Sebastian-Juniper Ridge and Upper St. Johns Karst Regions of the Eastern Flatwoods District physiographic provinces described by Brooks and Merrit (1981) (Fig. 1). The ridges have elevations of less than 28 m (90 ft). The Indian River occupies the interstices of these paleo-ridges and the modern offshore barrier development.

Discussion and Results

Approximately 82 line-km of seismic profiles were collected from the central Indian River region and adjacent offshore areas (Fig. 1) in an attempt to identify the fault postulated by Bermes (1958) and Schiner and others (1988). Bermes' (1958) identification of the fault was based on well logs. Schiner and others (1988) included water quality differences to delineate the fault. The fault is reported to strike parallel with the lagoon in a NNW direction and turns NE towards the Atlantic Ocean north of Johns Island (Fig. 1). Water samples taken from Floridan Aquifer wells located east of the fault had chloride concentrations between 1,400 to 2,900 parts per million (ppm). The Floridan Aquifer wells that were sampled to the north and west of the fault had chloride concentrations of less than 700 ppm. The chloride gradient suggests that the fault may provide a pathway for upward migration of saline water. The location of the fault as suggested by well logs (Bermes, 1958) indicate a ~60 to ~90 m offset (~200 to ~300 ft) of the top of the Ocala Limestone. The Hawthorn Group thickens from ~73 m (240 ft) north of Johns Island to ~153 m (500 ft) south of the proposed fault. The cross section of natural gamma logs (Fig. 4) shows the dramatic change in elevation of the top of the Ocala Limestone and the relatively constant elevation of the top of the Hawthorn Group.

Where possible, survey tracklines were run parallel and perpendicular to the proposed fault trace. The tracklines acquired within the lagoon were constrained by navigable waters. Data quality varied from good to poor depending on the geologic and environmental conditions. Examination of gamma logs indicate a major lithologic change from sediments with high percentage clay to carbonates (Fig. 4, orange line). This change, interpreted to be near the top of the Ocala Limestone, could provide sufficient amplitude and velocity contrast to produce reflectors. In the seismic profiles, a series of strong reflections are laterally continuous at approximately 100-120 ms (Fig. 9, 10, 11; shown as orange line).

Plotting the depths to the Ocala Limestone from the gamma logs versus TWTT from the orange horizon on the seismic data throughout the study area yields a best fit curve that can be used to calculate an average velocity of 1,955 m/s for the Hawthorn Group sediments (Fig. 3). The peaks in the gamma logs are interpreted to lie just above the top of the Ocala Limestone . Though the orange reflection cannot be positively identified as the top of the Ocala Limestone, it is sufficiently close and can be used to identify morphology and/or structural trends. Due to the massive nature and the irregular surface of the Ocala, the high-frequency acoustic signal used in the HRSS generally provide poorly resolved reflectors in the carbonates below the Hawthorn Group (Kindinger and others, 1994), but resolution was better than expected in these data. In some areas a horizon was identified that may correlate with the Avon Park formation, as interpreted from the gamma logs. This is represented by the blue horizon on the profiles. The blue horizon can be seen in the northern section of the profiled area and is lost where it dips steeply to the south and east near Johns Island (Fig. 8, 9, 10, 11, 12). Above the orange horizon another reflector can be traced throughout the study area (purple line). This horizon is laterally continuous and remains level to gently dipping to the south and east (Fig. 6). The horizon can be correlated with the gamma logs to represent a laterally continuous unit within the Hawthorn Group. The shallowest reflector (red) traced throughout the study area represents a surface that truncates deeper, low-angle bedding and levels off subsidence or channel fill (Fig. 11). This stratigraphic and seismic character is indicative of a flooding surface. An average velocity of 1,955 m/s places the reflector at approximately 120 meters depth adjacent to wells IR00498, IR00699 and IR00024. This correlates very well with the interpretations of the gamma logs from those wells (Fig. 4), which indicate the top of the Hawthorn Group at that depth.

The Schematic Cross-section A-A' (Fig. 13) and corresponding seismic profiles of Figures 9 and 11 show how the sediments between the orange and the red reflectors thicken dramatically from the north-northwest to the south-southeast. The red reflector dips somewhat, but not nearly as much as the orange and blue reflectors. The thickening of the units below the red reflector suggest deposition into a basin or subsidence or faulting occurring during deposition (Fig. 14). There are smaller subsidence and solution/collapse features found beneath the red horizon throughout the study area (Fig. 10, 11-S1 & S2, 12 - S3). The deeper area of the thickened sequence is much too large to simply be subsidence into a single collapse sinkhole. This trend is of a magnitude that could effect water quality such as identified by Schiner and others (1988).

Summary

Analysis of seismic data and natural gamma logs from wells within the study area indicate the Hawthorn Group to be dipping to the southeast in response to subsidence or dissolution in the underlying carbonate rock. Fluid migration and rock movement and dissolution along a deeper fault zone is a possible mechanism for the subsidence. Bermes (1958) and Schiner and others (1988) used well logs and water quality data to infer the presence of a fault system within the area. The fault system would predate the Miocene since the seismic profiles show no evidence of faulting within the Hawthorn Group.

Comparison of trends in contours generated from the seismic data with the cross section from the natural gamma logs show good correlation. Correlating measured depths on the gamma logs with depth-to-horizon on the seismic profiles indicate an average sound velocity of 1,955 m/s through the Hawthorn Group. This estimate is within the range of velocities suggested from other studies of the Miocene sediments in Florida. Absolute correlation between gamma log depth and two way travel time could not be established since the gamma log cross section did not intersect the seismic profiles.

Other features identified in the seismic profiles include three collapse sinkholes within the Hawthorn Group sediments. Two are located north of Johns Island in the Intracoastal Waterway on profile SB_2 (Fig. 11, S1 & S2). The other is located about one mile offshore east of the city of Vero Beach on profile SB_1 (Fig. 12).

Methods

Figure 2: Equipment used to acquire high-resolution single-channel subbottom seismic reflection profiles. Figure includes sound source (A), receiver (B), power supply (C), hard copy output (D) and computer (E) to process, display and store digital signal.

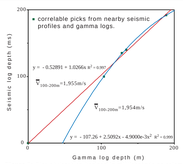


Figure 3: Plot of depth-to-horizon in milliseconds on seismic profiles, versus depth-to-peak in meters on natural gamma logs. The resulting equations from the best fit curve (blue) or the best fit curve with zero origin (red) can be used to determine sound velocity for a given depth. Averaged velocity for 100 to 200 meters depth is 1,955 meters per second.

This study is part of a series of cooperative investigations conducted from 1993 to 1997 by the SJRWMD and U.S. Geological Survey Center for Coastal Geology (USGS). Areas of study include inland and offshore waters and adjacent terrain throughout much of the SJRWMD. In cooperation with SJRWMD, the USGS has acquired and upgraded a digital seismic acquisition system. The Elics Delph2 High-Resolution Seismic System (HRSS, Fig. 2) was acquired with proprietary hardware and software running in real time on a Kontron Electronics IP Lite laptop computer. Hard-copy data was displayed using a gray scale thermal plotter with digital data backed up on removable 1 Gigabyte hard disks. Navigation data was collected using a PLGR (Rockwell) GPS with Fugawi mapping software.

The acoustic source was a Huntec Model 4425 Seismic Source Module and a catamaran sled equipped with an electromechanical device (Fig. 2). An ORE Geopulse power supply was substituted for the Huntec Model 4425 for small boat operations . Power settings ranged from 60 to 265 joules depending upon conditions. An Innovative Transducers Inc. ST-5 multi-element hydrophone was used to detect the return acoustical pulse. This pulse was fed directly into the Elics Delph2 system for storage and processing.

The Elics Delph2 system measures and displays two-way travel time (TWTT) of the acoustical pulse in milliseconds (ms). Amplitude and velocity of the signal are affected by variations in lithology of the underlying strata. Laterally consistent amplitude changes (lithologic contacts) are displayed as continuous horizons on the seismic profiles. Depth to horizon is determined from the TWTT, adjusted to the subsurface velocity of the signal. Suggested compressional velocities for Hawthorn Group sediments for the Florida Platform range from 1,500 to 1,800 meters per second (m/s) (Tihansky, pers. comm.; Sacks and other, 1991). Refraction studies conducted in areas within Alachua County Florida (Weiner, 1982) yielded velocities of 1,707 to 4,939 m/s for the Hawthorn Group sediments. Weiner, (1982) reported lower velocities for the sand and clay sediments and higher velocities for the carbonate sediments. To correlate horizons from gamma logs to seismic profiles, best-fit-curve plots were used to determine local velocities (Fig. 3). Contour structure maps were constructed for horizons interpreted from seismic profiles (Fig. 5, 6, 7, 8). The digitized surfaces were gridded using CPS3 (commercial contouring package).

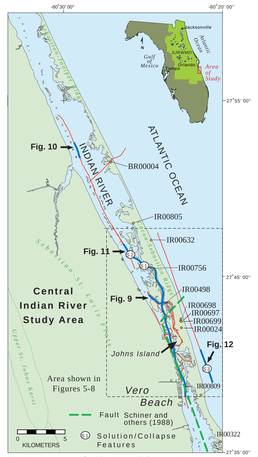


Figure 1: Location of study area including seismic survey, well logs, locations of Figures (9, 10, 11,12), and the subsurface fault identified by Bermes (1958) and Schiner and others (1988).

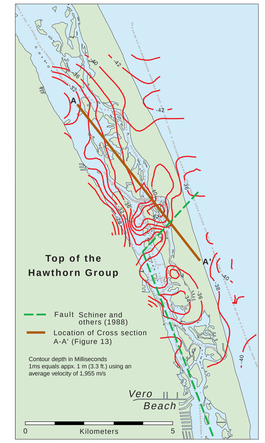


Figure 5: Top of the Hawthorn Group structure contour map. See Figure 1 for location. Line colors correspond to line colors on seismic profile.

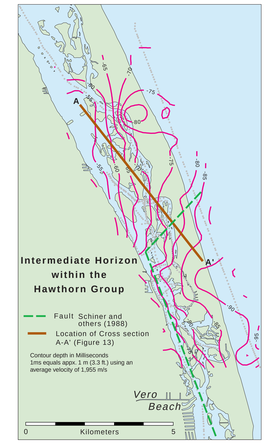


Figure 6: Intermediate horizon within the Hawthorn Group structure contour map. See Figure 1 for location. Line colors correspond to line colors on seismic profile.

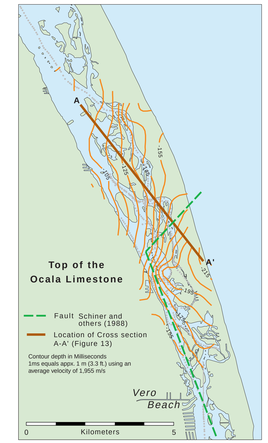


Figure 7: Top of the Ocala Limestone structure contour map. See Figure 1 for location. Line colors correspond to line colors on seismic profile.

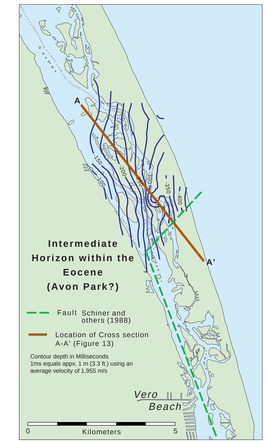


Figure 8: Intermediate horizon within the Eocene (Avon Park?) structure contour map. See Figure 1 for location. Line colors correspond to line colors on seismic profile.

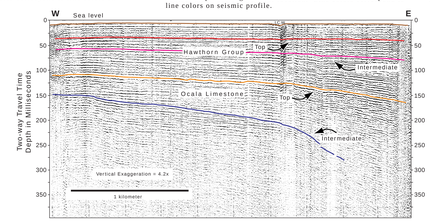


Figure 9: Seismic profile line stj/SB_5. See Figure 1 for location. Intercoastal Waterway (I.C.W.). Depths are below sea level.

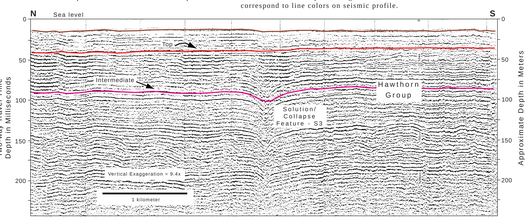


Figure 12: Seismic profile line stj/SB_1. See Figure 1 for location. Depths are below sea level.

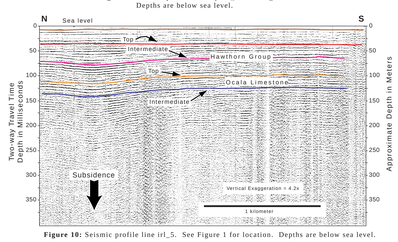


Figure 10: Seismic profile line irl_5. See Figure 1 for location. Depths are below sea level.

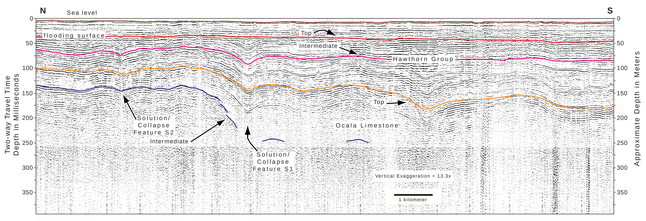
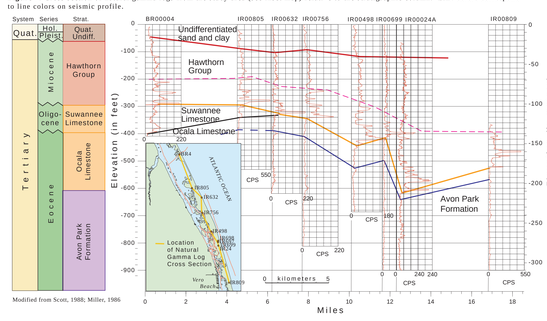


Figure 11: Seismic line stj/SB_2. See Figure 1 for location. Depths are below sea level.

Figure 4: Cross section of natural gamma logs from the study area (see inset map) relative to the stratigraphic column. Line colors correspond to line colors on seismic profile.



Modified from Scott, 1988; Miller, 1986

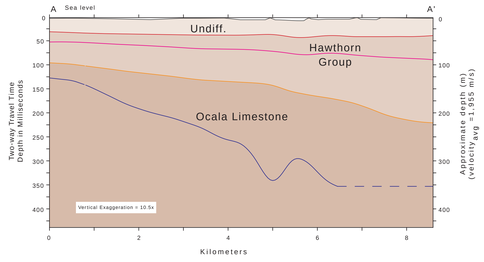


Figure 13: Schematic structural cross section. See Figures 5 to 8 for location. Depths are below sea level.

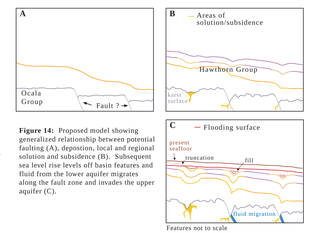


Figure 14: Proposed model showing generalized relationship between potential faulting (A), deposition, local and regional solution and subsidence (B). Subsequent sea level rise levels off basin features and fluid from the lower aquifer migrates along the fault zone and invades the upper aquifer (C).

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References

Bermes, B.J. , 1958, Interim report on geology and ground-water resources of Indian River County, Florida: Florida Geological Survey Information Circular 14, 74 p.

Brooks, H.K., and Merrit, J.M., 1981, Guide to the physiographic divisions of Florida: Florida Cooperative Extension Service Institute of Food and Agricultural Sciences, University of Florida, Gainesville. 1 map 150x105 cm and text 16 p.

Kindinger, J.L., Davis, J.B., Flocks, J.G., 1994, High-Resolution Single-Channel Seismic Reflection Surveys of Orange Lake and other selected sites of North Central Florida: U. S. Geological Survey Open File Report 94-616, 48 p.

Miller, J.A., 1986, Hydrogeologic framework of the Floridan Aquifer system in Florida and parts of Georgia, Alabama, and South Carolina: U. S. Geological Survey Professional Paper 1403-B, B91 p.

Sacks, L.A., Lee, T.M., and Tihansky, A.B., 1991, Hydrogeologic setting and preliminary data analysis for the hydrologic budget assessment of Lake Barco, an acidic seepage lake in Putnam County, Florida: U. S. Geological Survy Water-Resources Investigations Report 91-4180.

Schiner, G.R., Laughlin, C.P. , and Toth, D.J. , 1988, Geohydrology of Indian River County, Florida: U. S. Geological Survy Water-Resources Investigations Report 88-4073, 110 p.

Scott, T.M., 1988, The lithostratigraphy of the Hawthorn Group (Miocene) of Florida: Florida Geological Survey Bulletin 59, 148 p.

Wiener, J.M., 1982, Geologic modeling in the Lake Wauberg-Chacala Pond vicinity utilizing seismic refraction techniques. University of Florida M.S. thesis. 94 p.

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