Geophysical Investigations of Upward Migrating Saline Water from the Lower to Upper Floridan Aquifer, Central Indian River Region, Florida

James G. Flocks [1], Jack L. Kindinger [1], Jeffrey B. Davis [2] and Peter Swarzenski [1]

[1] U.S. Geological Survey, St. Petersburg, Florida USA, [2] St. Johns River Water Management District, Palatka, Florida USA

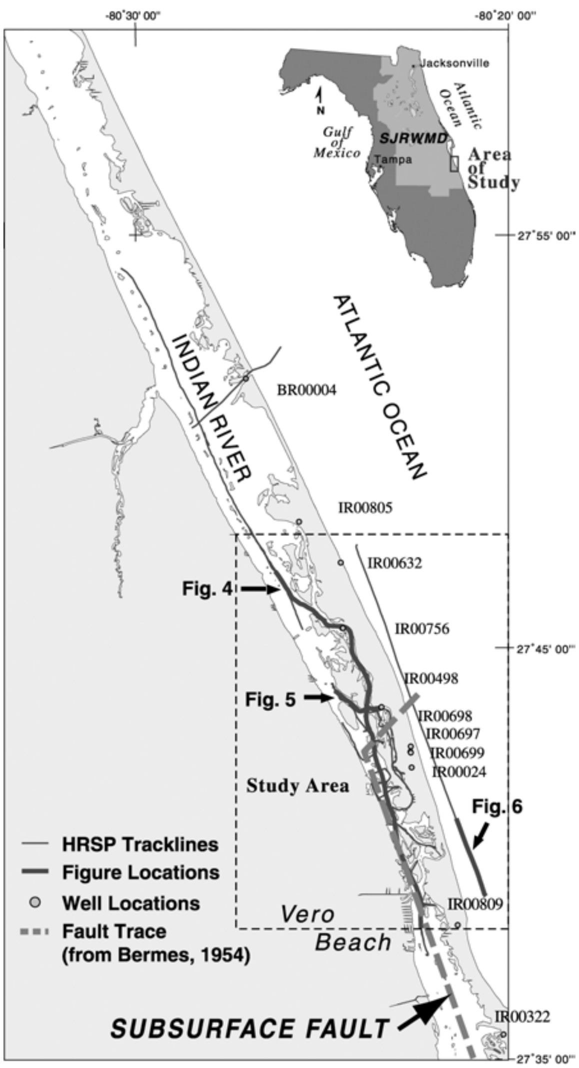

Fig. 1. Location of survey area.

Indian River Lagoon (IRL) extends approximately 250 km along the east central coast of Florida and consists of three interconnected basins: Mosquito, Banana River, and Indian River. The study area for this report is 75 square-km in the middle section of IRL (Fig. 1). The geology below the lagoon is of interest to researchers. Subsurface features are believed to control the hydrology, and the concern that prompted this investigation is that possible faulting at depth has provided a pathway for the upward migration of saline water from the Lower Floridan to the potable supply within the Upper Floridan Aquifer. Data collected for the study includes remote sensing of subsurface features using High-Resolution Single-Channel Seismic Profiles (HRSP). The HRSP was correlated to gamma-ray intensity profiles from well logs. The subsurface features identified in this study are believed to control the hydrology and have geomorphologic expression on the surface.

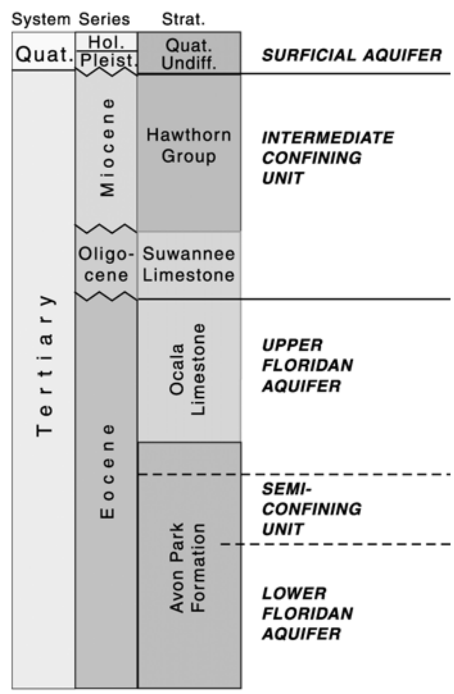

Fig. 2. Generalized stratigraphic column for the area.

The nearsurface geology can be divided into three main lithologic units: (1) Quaternary sands and clay of the surficial units; (2) variable clays, sands, and carbonates within the Hawthorn Group (Miocene), and; (3) Eocene limestones, which include the Ocala and Avon Park (Fig. 2). These units constrain the hydrology. The interbedded sands and clays of the

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Hawthorn Group provide the Intermediate-confining unit, separating the Upper Floridan Aquifer from the Surficial Aquifer (Fig. 2). At depth, the upper Avon Park Formation acts as a semi-confining unit, separating the fresh water Upper Floridan from the more saline Lower Floridan Aquifer. Discontinuities within these confining units may affect the regional hydrology by allowing leakance between the aquifers.

Profiles of gamma-logs provide a trend of the lithologic units roughly parallel to the barrier island system (Fig. 3). Gamma radiation is a product of naturally occurring radioactive material in the sediments, and is prevalent in the clays and silts of the Hawthorn Group. Peaks in the gamma intensity show a thickening of the Hawthorn Group southward, with a relatively consistent upper horizon and the lower horizon dropping away. This drop led to the postulation by Bermes [1958] that a displacement fault exists through the region. Subsequently, Schiner and others [1988], included water quality parameters to delineate the fault zone. The fault was reported to strike parallel with the lagoon in a NNW direction and turns NE towards the Atlantic Ocean in the center of the study area (Fig. 1). Water samples taken from Upper Floridan aquifer wells located east of the fault had chloride concentrations between 1,400 to 2,900 parts-per-million (ppm). Upper Floridan aquifer wells that were sampled to the north and west of the fault had chloride concentrations of < 700 ppm. The abrupt change in chloride concentration between wells suggest that the fault may provide a pathway for upward migration of saline water. The drop in elevation of the Ocala Limestone (Fig. 3) may delineate the location of the fault. The relatively consistent upper horizon of the Hawthorn Group indicates that any displacement that may have occurred had terminated during the late Tertiary.

Apart from well logs, subsurface data in the Indian River region is scarce due to the difficulty of sampling, both directly and remotely, in terrain that includes shallow water bodies, unconsolidated sediments and rock. HRSP was originally developed for offshore work, but is becoming increasingly more common in coastal and inland areas due to recent developments in the technology. Complete descriptions of the methods used in this study can be found in Kindinger and others [2000]. In 1997, approximately 82 km of seismic profiles were collected from the central IRL region and adjacent offshore areas (Fig. 1). Elsewhere on the Florida Platform, single-plate HRSP has proved adequate in imaging the subsurface, down to the uppermost Ocala Limestone [Kindinger and others, 2000, Wolansky and others, 1983]. Since the limestone lacks sufficient velocity contrasts such as bedding planes or lithologic variability, few internal reflectors

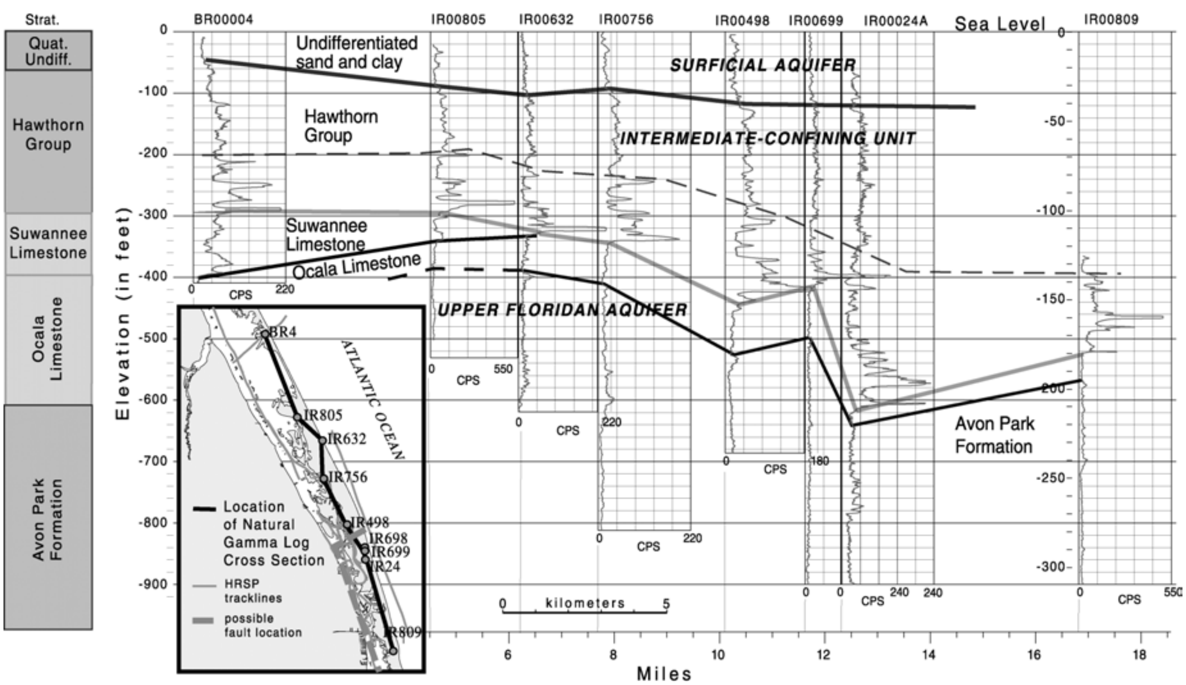

Fig. 3. Natural gamma log profiles from the study area (see inset map).

can be identified. At depth, increased acoustic noise obscures geologic structure. In the Indian River region, signal quality was generally good, even below depths interpreted by gamma logs to be within the Ocala and Avon Park limestones. Correlation between HRSP and gamma logs was accomplished

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by comparing time to depth of a distinctive horizon in both profiles, in this case the top of the Ocala Limestone (Figs. 3 & 4). The resulting velocity was calculated to be 1,955 meters per second between 100 and 200 meters depth. This velocity compares to similar velocities obtained elsewhere in Florida [Sacks and others, 1991, Weiner, 1982].

Once correlation of HRSP to the geology was accomplished, interpretation of the data could proceed. Figures 4, 5 and 6 are HRSP which show strong consistent reflectors across the profile. These reflectors are interpreted to be the bounding reflectors of the Hawthorn Group, Ocala Limestone and Avon Park Formation, with a few internal or intermediate reflectors. These reflectors are in close agreement with depth and attitude to the gamma log profiles, especially when considering figures 3 and 4, which run parallel to each other throughout the study area. Smaller, localized features are also present (Figs. 4 & 6) and are interpreted to be solution or collapse features. These features are important because they may represent localized breaches in the confining units, providing pathways for fluid migration between aquifers. Other features noted in the HRSP include intermediate reflectors within the Hawthorn Group separating to the south. Also, truncation of reflectors and small infilled channel-like features along the top of the Hawthorn suggest of a flooding surface (Figs. 4 & 5).

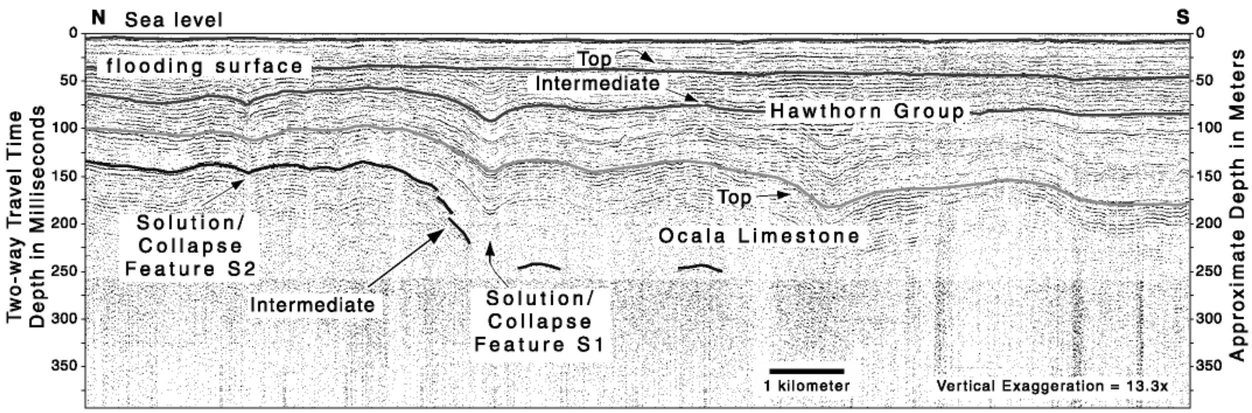

Fig. 4. HRSP with interpretations, see Figure 1 for location.

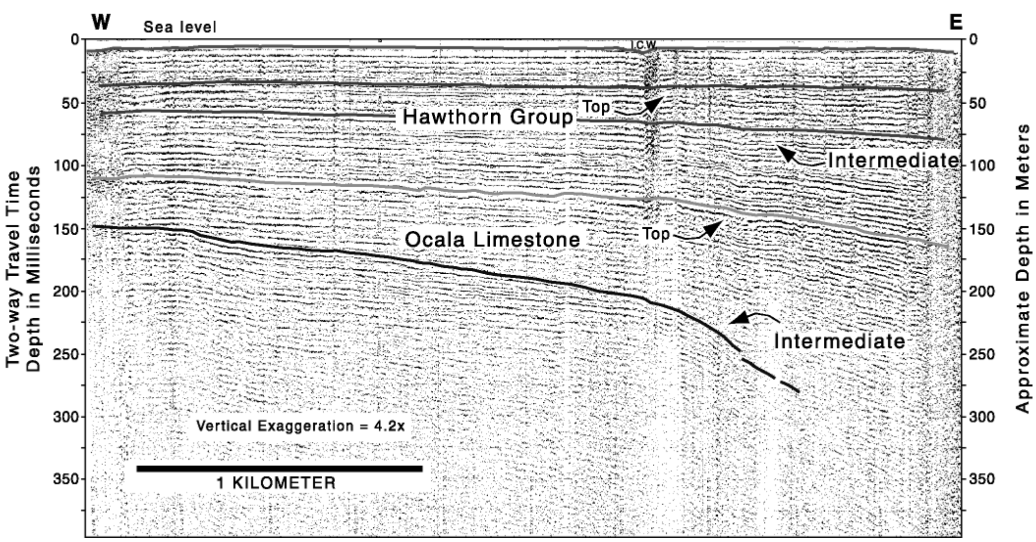

Fig. 5. HRSP with interpretation, see Figure 1 for location.

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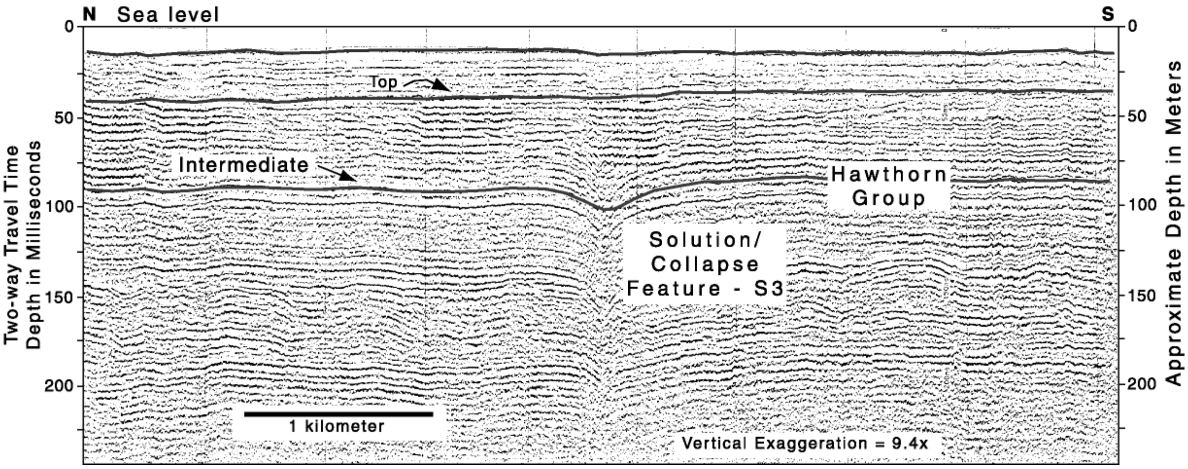

Fig. 6. HRSP with interpretation, see Figure 1 for location.

As with the gamma profiles, the most notable, large-scale feature noticed from the HRSP is the dramatic drop in the Ocala and Avon Park (?) reflectors, that eventually descend beyond resolution depth. Locating this drop across the HRSP tracklines (Fig. 7) indicates the feature strikes along the IRL, throughout the length of the study area.

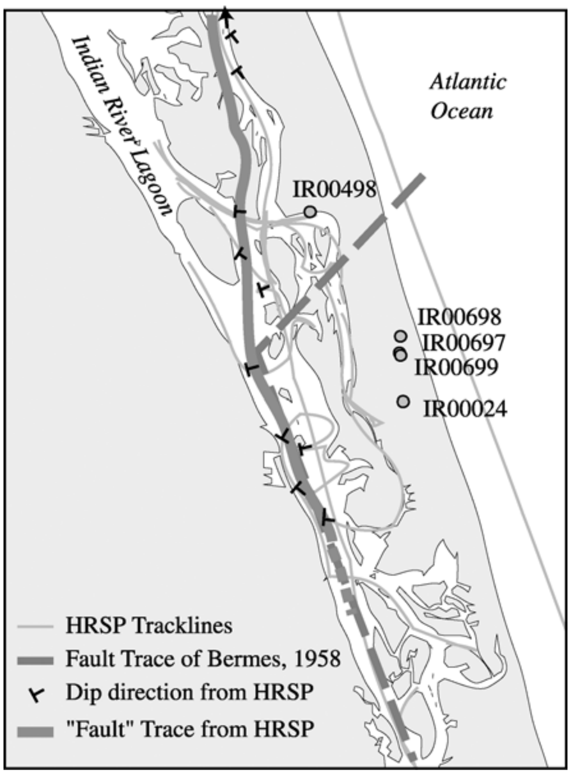

Fig. 7. Location of displacement features.

This strike is parallel to the fault trace postulated in the earlier studies, although the turn offshore is not apparent. The reflectors appear to downwarp (Figs. 4 & 5), and no obvious displacement along reflectors is visible. Unless the actual fault is too deep to resolve by the available HRSP, the acoustic pattern is more characteristic of common karst systems, such as dissolution and subsidence. Characterization of subsurface geology in karst systems elsewhere in Florida shows that these features are also capable of developing breaches in confining units and do not necessarily need to be related to large scale faulting [Kindinger and others, 2000].

Since the HRSP is capable of high-density regional coverage, reflectors can be digitized relative to geographic position, and contour structure maps can be produced (Fig. 8). The maps confirm that the most dramatic relief is in the deepest reflectors, which corresponds to the tops of the Ocala Limestone and Avon Park Formation. Although the Hawthorn Group thickens to accommodate this drop, the upper horizon remains relatively level. An isopach map of the Hawthorn Group shows that the unit widens from northwest to southeast (Fig 8).

A stratigraphic model to describe the data is suggested in the following four steps: 1.) pre-Miocene subsidence in the area; 2.) erosion of a headland to the northwest and deposition into the area occurred during Miocene times (Hawthorn Group) and possibly later; 3.) pre-Quaternary sea-level rise levels the upper Hawthorn Group and infills any channeling or small depressions, and; 4.) continued dissolution at depth from Tertiary to present has created localized subsidence features throughout the Hawthorn and possibly in more recent sediments. The large subsidence potentially controls the regional

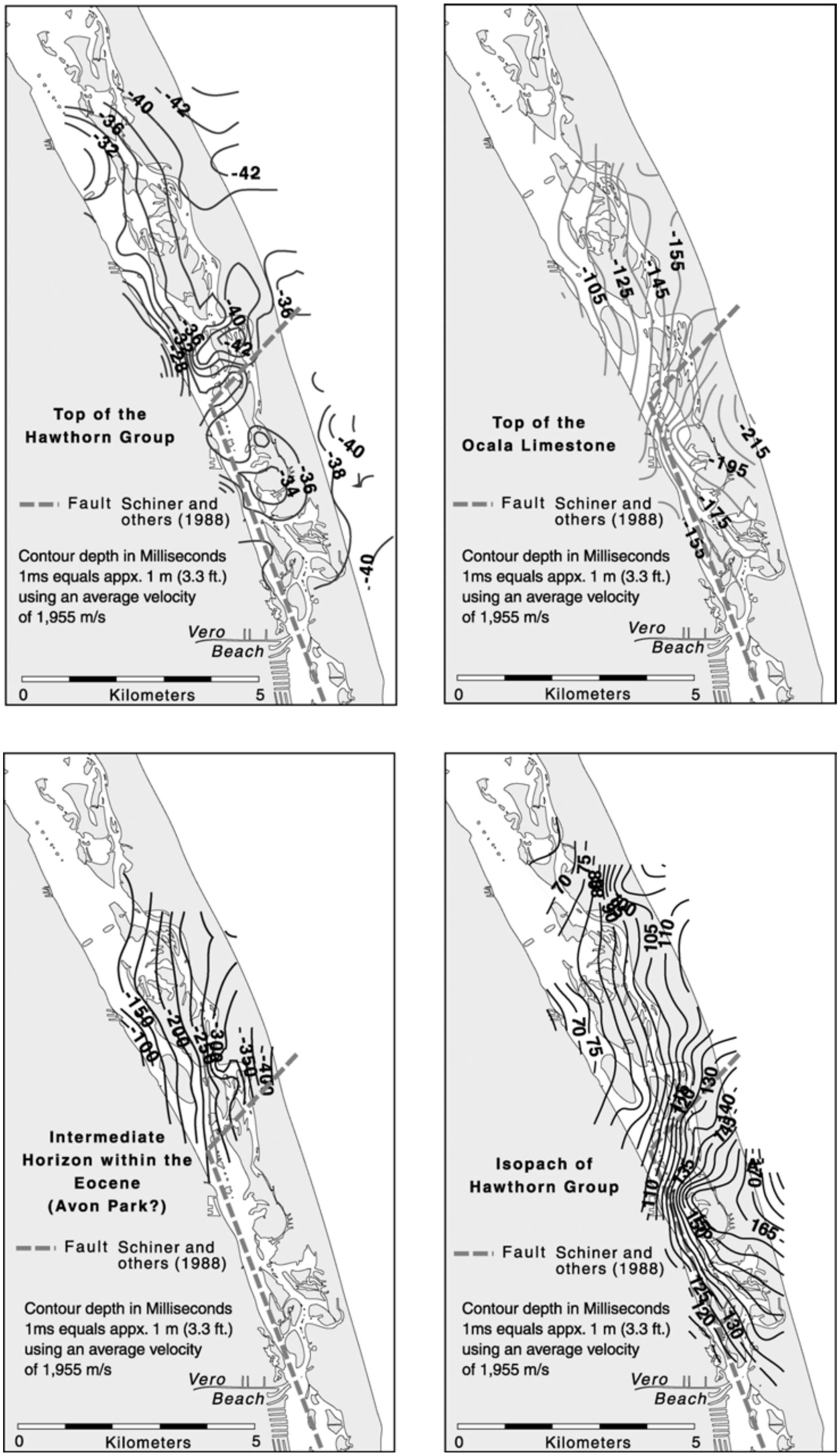

Figure 8. Structure contour and Isopach maps of horizons interpreted from HRSP.

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hydrology. Possible stress fractures or slumping along the periphery of the subsidence could produce breaches in confining layers and pathways for fluid migration. The smaller subsidence (piping) features associated with continued dissolution at depth could provide similar conduits.

Migration of saline waters from the Lower to Upper Floridan Aquifer can occur within the Avon Park Formation. Since the available HRSP is not resolvable into the Avon Park Formation, the presence of a fault at that depth cannot be ruled out. Since no displacement along reflectors is evident in the shallower reflectors, the influence of a deep fault on shallow stratigraphy would be through structural deformation of the geology as it accommodates the drop across the fault trace. However, the structural deformation reflected in the HRSP can also be created by karst-related dissolution and subsidence within the limestone units, without regional faulting. Subsequent dissolution can further compromise the confining units and continue to enhance migratory pathways.

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