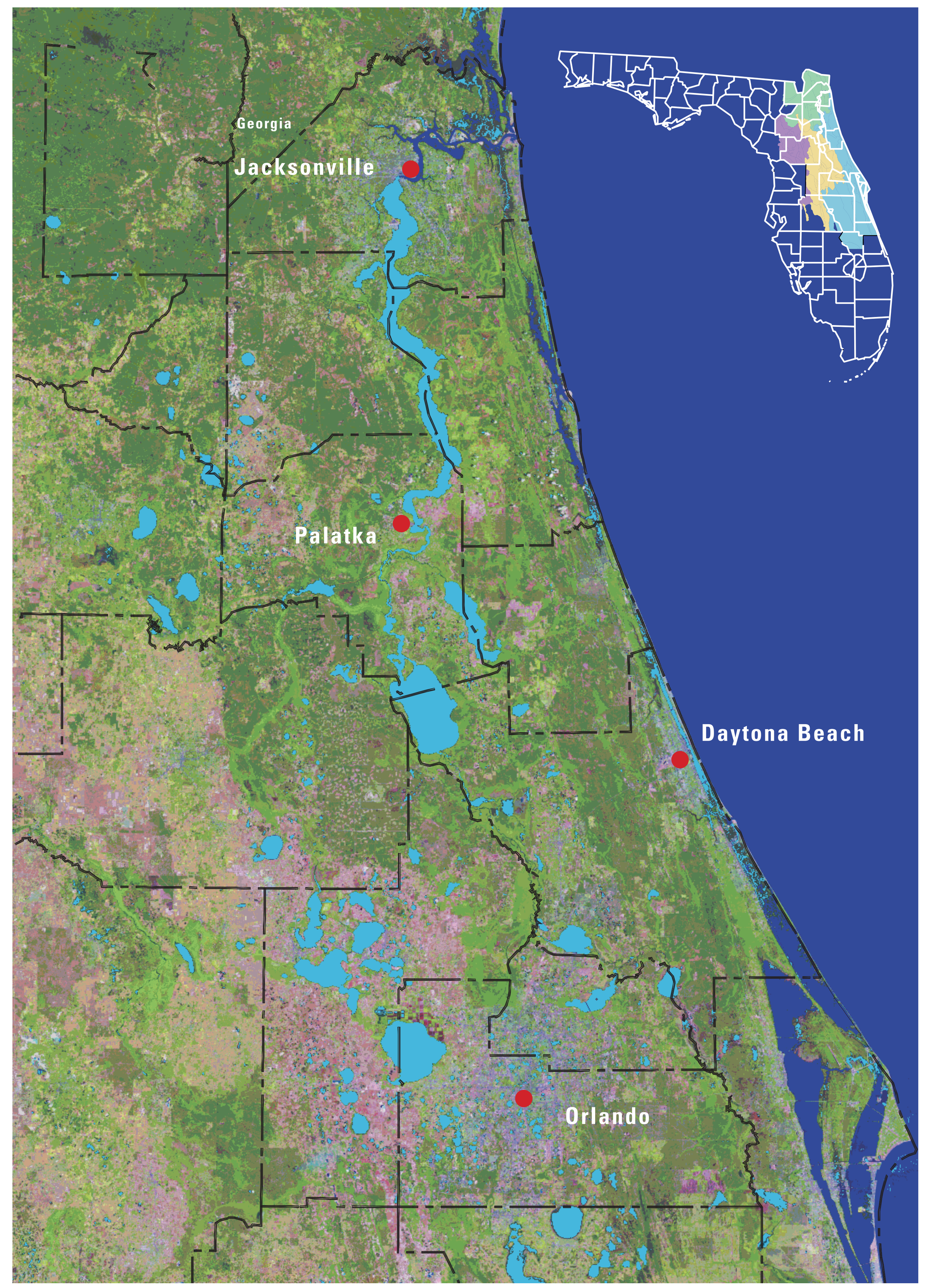
DEPARTMENT OF THE INTERIOR
U. S. GEOLOGICAL SURVEY

Subsurface Characterization of Selected Water Bodies in the St. Johns River Water Management District, Northeast Florida



LANDSAT-TM satellite image, central Florida (courtesy of Florida DEP)

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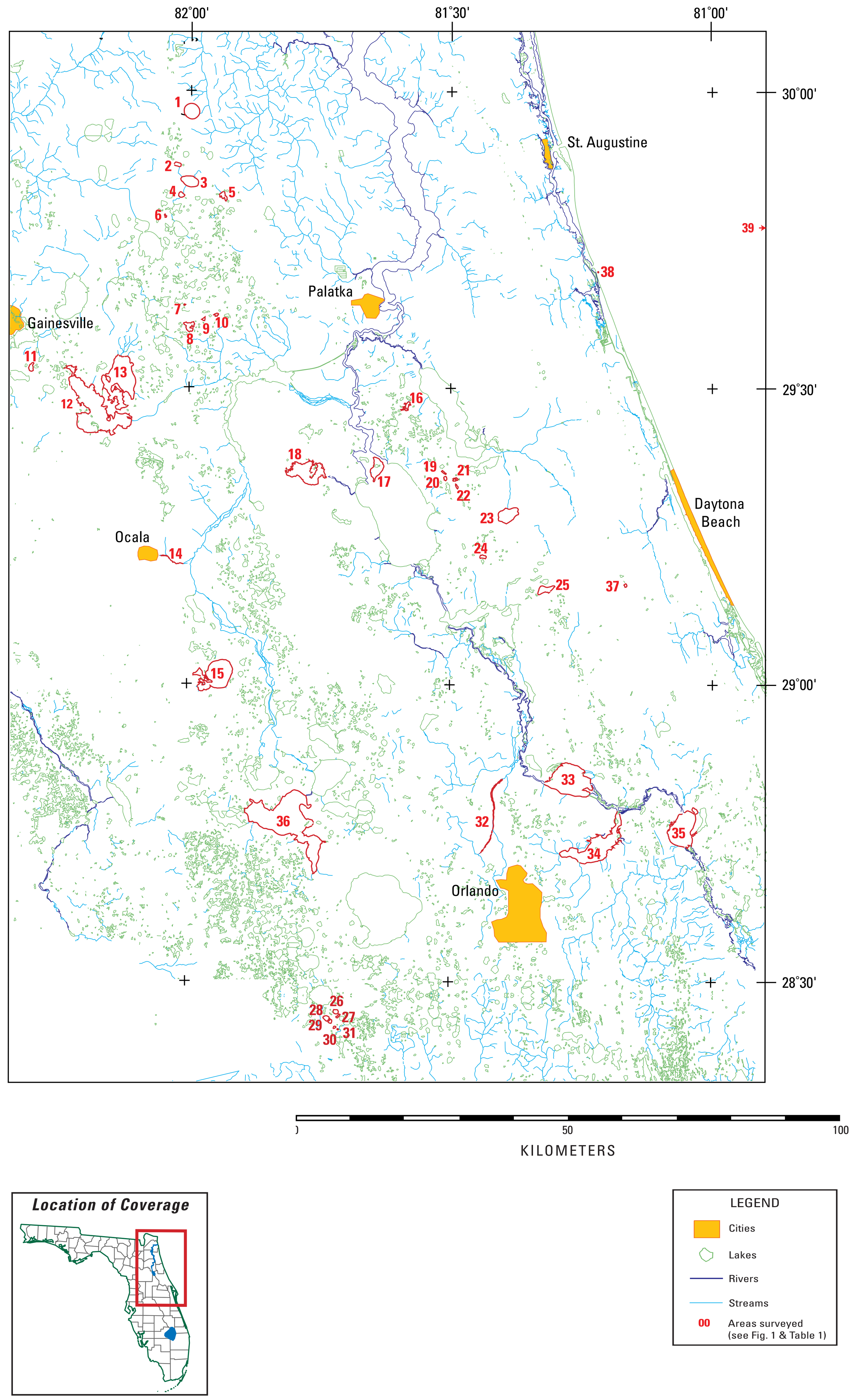
INTRODUCTION

Figure 1. Location of lakes and rivers in northeast Florida from which high-resolution single channel seismic profile data were collected.



Florida is a karst (limestone) platform with abundant sinkholes, springs, and caverns. Karstic erosion of the land surface is controlled by chemical and mechanical processes occurring in the upper portion of the limestone where the most intense dissolution occurs (Beck, 1988). In Florida, surface features characteristic of karst include dolines (sinkholes), solution pipes, broad flat-bottomed prairies and closed circular depressions that either drain underground or fill with water to form lakes.

The term "sinkhole," or doline, implies a form, a function, and a basic mechanism of origin (Waltham, 1989). The form is a closed basin having no surface drainage outlet. The function is to transmit surface water underground to an aquifer or discharge ground water to the surface as a spring. Sinkhole origin is initiated by solution of the underlying host rock. Sinkholes form primarily on terrain of limestone or dolomite, or where either of these rocks occur near from the surface. They can, however, form over any rock that is soluble.

Sinkholes appear as a variety of structures, including cover collapse, solution and cover subsidence sinkholes, or subsidence over buried sinkholes. Individual sinkholes may be <1 m (3 ft) to >100 m (330 ft), in depth and diameter. Sinkholes may be circular or elongate in plan view can be described in cross section as conical, cylindrical, saucer-shaped or irregular.

Surveys of sinkholes were conducted in part to test the effectiveness of shallow-water marine geophysical techniques in determining the geomorphology of karst features. Investigation of subsurface karst features has proven to be a difficult task. Due to their random, unpredictable distribution, natural cavities or buried sinkholes are notoriously difficult and expensive to locate and assess in site studies. There are several direct and indirect methods of mapping and identifying features associated with karst, all of which have limitations. Waltham (1989) provides a review of the methods used for the detection of cavities. Methods of geophysical applications used in cave and sinkhole detection have been reviewed by Bates (1973), McCann and others (1982), Owen (1983), and McCann and others (1987). These authors, however, report that previously applied geophysical techniques had little reliability for widespread use, but the potential cost savings compared to other methods warrant consideration. High-resolution seismic-reflection profiling (HRSP) been used to detect subsurface features related to karst in lakes and rivers with varying degrees (Missimer and Gardner, 1976; Locker and others, 1988; Snyder and others, 1989; Sacks and others, 1991; Subsurface Detection Inc., 1992; Kindinger and others, 1994, 1996, 1998, 1999) and also offshore in the Atlantic Ocean (Meisburger and Field, 1976; Popenoe and others, 1984; Snyder and others, 1989).

Cooperative investigations of north central Florida lakes and rivers were conducted from 1993 to 1996 by the St. Johns River Water Management District (SJRWMD) and the U.S. Geological Survey (USGS) (Fig. 1). This report presents the data from recently developed digital High Resolution Seismic Profiling (HRSP) and identifies subbottom features from selected lakes in Florida. The objectives were: (1) identify evidence of breaches or discontinuities of the confining units between surficial water bodies and the Floridan aquifer, and (2) identify diagnostic features, structure, and geomorphology of sinkhole lakes.

Table 1. North Central Florida lakes and rivers surveyed during this study between 1994-1996.

Map Loc. No.	Lake Name	Profiles (km)	Date Acquired	Lake[1] Stage (ft. NGVD)	Physio.[2] Region	County	Latitude (Deg.)	Longitude (Deg.)	U.S.G.S. Topo Quad	Area[2] (km)	Perimeter (km)	Roundness (4A.π)/P	Features 1	2	3	4	5	6	Well # (used for gamma log correlation)
1	Kingsley	45.9	Aug-93	176	1C	Clay	29°57'54"	81°59'40"	309	6.30	9.00	0.98	X	X	X			X	C-0478
2	Blue Pond	9.3	Dec-95	130	1C	Clay	29°52'28"	82°01'32"	333	1.30	4.60	0.77	X		X	X			C-0439
3	Lowry (Sand Hill)	12.8	Feb-94	129	4B	Clay	29°50'54"	82°00'29"	333	5.05	8.72	0.83		X				X	C-0439, C-0382
4	Magnolia	10.8	Jan-94	125	4B	Clay	29°49'28"	82°01'07"	333	16.4	16.3	0.78		X	X			X	C-0451
5	Johnson	5.2	Dec-95	95	4B	Clay	29°49'30"	81°56'16"	334	2.00	10.0	0.25	X			X			C-0453, C-0457
6	Paradise	3.8	Dec-95	130	4B	Clay	29°47'16"	82°02'50"	333	0.20	1.90	0.70	X	X		X		X	C-0481
7	Levy's Prairie†	2.3	Dec-95	~85	4B	Putnam	29°38'21"	82°00'37"	384	0.05	0.82	0.93							C-0030, P-0797
8	Cowpen	19.4	Dec-95	85	4B	Putnam	29°35'56"	81°59'51"	384	2.80	11.5	0.27	X		X	X			P-0484, P-0038
9	Morris†	6.1	Dec-95	~85	4B	Putnam	29°36'54"	81°58'24"	384	x.xx	2.22	x.xx							P-0464, P-0036
10	Galilee†	6.3	Dec-95	~85	4B	Putnam	29°37'18"	81°57'00"	384	x.xx	2.90	x.xx							P-0464, P-0036
11	Wauberg	12.7	Dec-95	*67	5H1	Alachua	29°31'50"	82°18'06"	381	1.60	5.20	0.74	X						W-15691, A-0096
12	Orange	85.5	Jan-94	*58	5E4	Alachua	29°27'20"	82°10'20"	407	30.0	44.0	0.19	X	X	X	X	X		See Hillshade Map
13	Lochloosa	14.8	Dec-95	57	5E4	Alachua	29°31'38"	82°08'26"	382	18.0	20.9	0.52	X			?			A-0686
14	Silver River†	13.6	Jan-95	~18	5I	Marion	29°12'27"	82°01'17"	484	x.xx	**7	x.xx							M-0416, M-0125
15	Weir	27.0	Jan-95	55	4G	Marion	29°01'24"	81°56'18"	484	30.7	36.3	0.29	X	X	X	X			See Hillshade Map
16	Como	9.3	Aug-95	35	4D	Putnam	29°28'16"	81°34'58"	412	1.40	7.70	0.30	X	X	X			X	P-0114, P-0246
17	Drayton Island	13.8	Feb-94	5	4C	Putnam	29°18'40"	81°35'36"	437	**74	**52	0.34	X		X			X	
18	Kerr	28.1	Aug-95	21	4E	Marion	29°21'30"	81°47'14"	435	17.4	32.5	0.21	X	X		X		X	M-0153, M-0149
19	Davis	11.2	Aug-95	25	4D	Volusia	29°21'29"	81°30'47"	437	1.60	5.00	0.80	X						P-0416, P-0011
20	Upper Louise	9.3	Aug-95	36	4D	Volusia	29°20'55"	81°30'36"	437	1.70	4.90	0.89	X		X	X			P-0416, V-0346
21	Cowpond	6.1	Aug-95	40	4D	Volusia	29°20'48"	81°29'27"	438	0.60	5.00	0.30	X		?			X	V-0184, P-0495
22	Juanita†	9.1	Aug-95	35	4D	Volusia	29°20'00"	81°29'15"	438	0.20	2.30	0.48							V-0184
23	Disston	39.6	Feb-96	14	1A6	Flagler	29°17'30"	81°23'30"	438	10.8	15.5	0.56	X	X	X			X	V-0339, F-0296
24	Cain†	14.8	Aug-95	11	4D	Volusia	29°13'00"	81°26'00"	438	x.xx	3.50	x.xx							V-0338, V-0339
25	Dias	8.3	Aug-94	35	4D	Volusia	29°09'40"	81°19'06"	464	4.30	8.70	0.71	X		X	X		X	See Hillshade Map
26	Trout	14.7	Dec-95	85	4Q2	Lake	28°26'56"	81°42'44"	611	0.35	2.39	0.77	X		X	X		X	L-0677, L-0188
27	Pike	6.4	Dec-95	85	4Q2	Lake	28°26'30"	81°42'28"	611	0.60	3.20	0.74	X			X		X	L-0677, L-0188
28	Dixie	16.1	Dec-95	109	4L	Lake	29°26'16"	81°43'47"	611	1.10	4.00	0.86	X	X	X	X		X	L-0677, L-0670
29	Hammond	9.9	Apr-96	109	4L	Lake	28°25'53"	81°43'25"	611	0.50	3.00	0.70	X		X	X			L-0677, L-0670
30	Keene	5.7	Dec-95	114	4Q2	Lake	28°24'56"	81°43'15"	611	0.20	2.40	0.44	X		X			X	L-0677, L-0679
31	Smokehouse	4.0	Dec-95	114	4Q2	Lake	28°25'10"	81°45'37"	611	0.78	3.26	0.92	X					X	L-0679
32	Wekiva River	7.6	Feb-96	2	4C	Lake/Orange	28°45'00"	81°25'01"	xxx	x.xx	**8	x.xx	X	X	X	X		X	See Hillshade Map
33	Monroe†	n.a.	Jan-95	5	4C	Seminole	28°50'00"	81°34'00"	565	x.xx	22.2	x.xx							V-0375, V-0234, S-1338
34	Jessup	54.7	Jan-95	5	4C	Seminole	28°43'36"	81°12'59"	565	39.7	65.0	0.12	X	X	X	X		X	S-1183, S-0039
35	Harney	23.7	Jan-95	6	1D	Semin/Volus	28°46'10"	81°03'24"	541	27.0	35.0	0.28	X		X	?		X	See Hillshade Map
36	Harris	34.0	Dec-95	63	4G	Lake	28°46'30"	81°49'05"	535	73.8	61.5	0.25	X	X					See Hillshade Map
37	Indian	16.1	Feb-96	37	1C	Volusia	29°10'04"	81°09'51"	465	0.40	2.30	0.95	X		X			X	
38	Crescent Bch. Spring†	x.x	Jan-95	0	na	offshore	29°46'05"	81°12'30"	xxx	0.05	0.39	x.xx			X		X		See Hillshade Map
39	Red Snapper Sink	x.x	Jan-95	0	na	offshore	29°44'30"	80°45'00"	xxx	x.xx	x.xx	x.xx							

Notes:
1 -At acquisition date
2 -See Brooks (1981)
* -From SJRWMD database, independent of seismic acquisition date

** -Of area surveyed
X -Type of feature identified from lake profile (see Subsurface Characterization, p. 6, for details)
? -Feature possible

†The following sites were surveyed but not included in this report:

Galilee, Morris, Cain, Levy's Prairie, Juanita, Monroe, Red Snapper Sink, Silver River, and Silver Spring.

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.

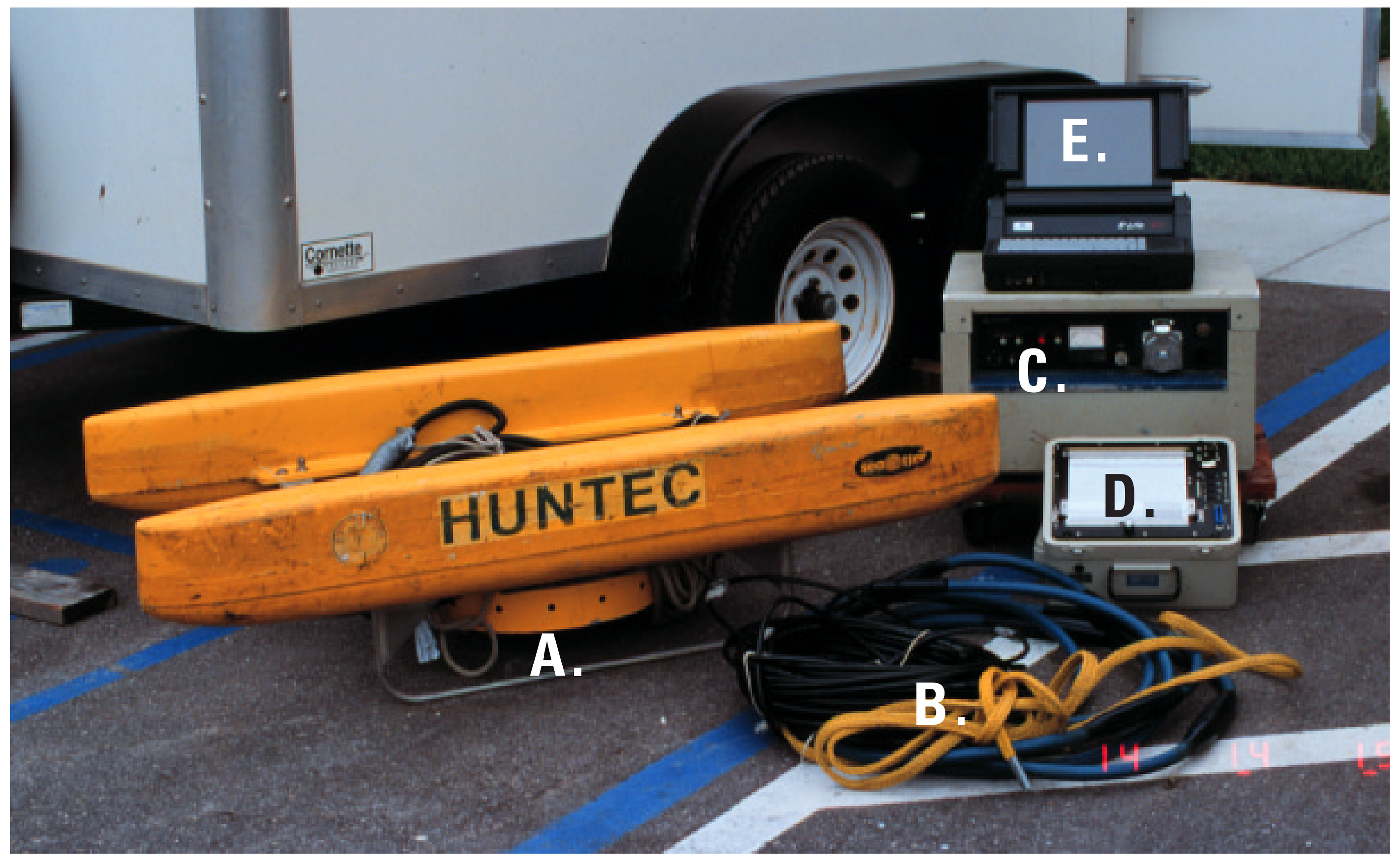
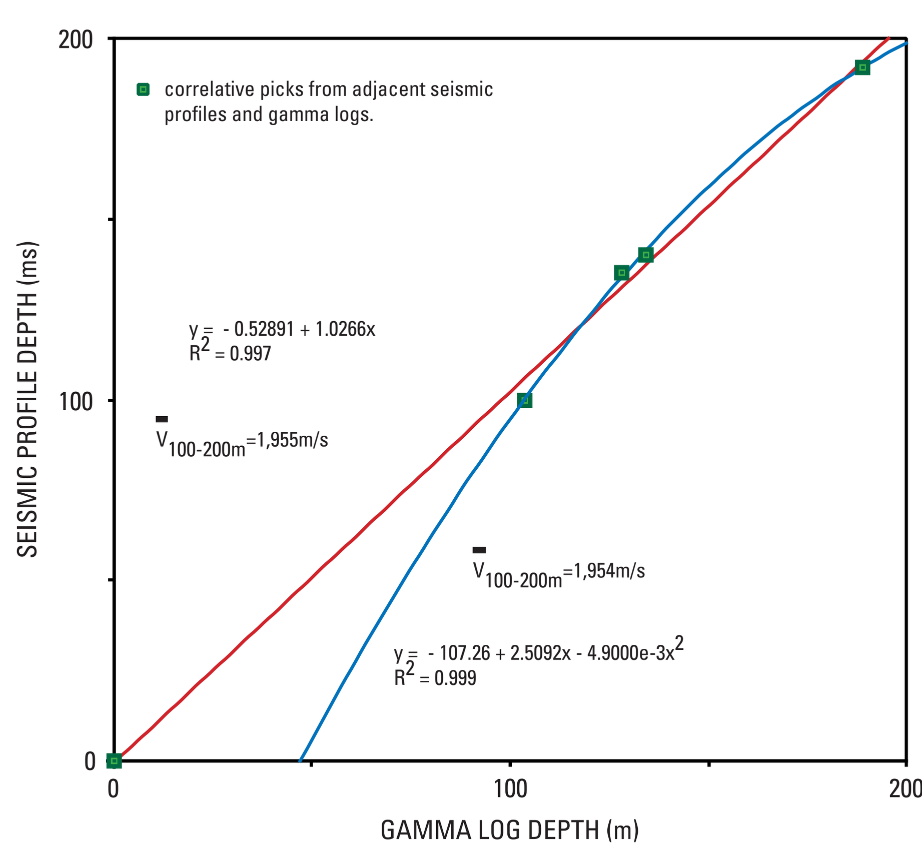


Figure 3. Comparison of depth-to-horizon in milliseconds on seismic profiles to depth-to-peak in meters of a correlative horizon on natural gamma logs. The resulting equations describing the best fit curve (blue) or the best fit curve with zero origin (red) can be used to determine sound velocity for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



Seismic Profiling

The Elics Delph2* High-Resolution Seismic Profile System (HRSP) was acquired with proprietary hardware and software running in real time on an Industrial Computer Corporation 486/33 PC (Fig. 2). A gray scale thermal plotter was used to display hard-copy data. Digital data were stored on a rewritable magneto-optical compact disk. Navigation data were collected using a Trimble Global Positioning System (GPS) or Rockwell Precision Lightweight GPS Receiver (PLGR) these systems provide navigational accuracies of ±10 m. GeoLink XDS mapping software was used to display navigation. The acoustic source was an electromechanical device, the Huntec Model 4425 Seismic Source Module mounted on a catamaran sled (Fig. 2). Occasionally, an ORE Geopulse power supply was substituted for the Huntec Model 4425 due to operational limitations. Power settings were 60 joules or 135 joules depending upon data quality during acquisition. 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 Geophysical 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 1500 to 1800 meters per second (m/s) (Tihansky, pers. comm.; Sacks and others, 1991). Refraction studies conducted in areas within Alachua County, Florida (Weiner, 1982) yielded velocities of 1707 to 4939 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).

More than 750 line-km of data were collected from >40 lakes, rivers and offshore sites, only 34 are presented in this study (Table 1). Best-fit-curves were used to compare well-log depths and seismic depths but an approximate velocity of 1500 m/s was used as a general calculation for depth scales on the HRSP data. Data quality varied from good to poor with different areas and varying conditions. As acquisition techniques improved, data quality in general also improved. The interbedded nature of the lake bottom sediments provides good reflecting surfaces for acoustic signals. These layers appear on the seismic records as convergent, divergent, or parallel bands. Folds, faults and facies changes can be recognized as bands, lateral and vertical discontinuities, and truncations of the bands by other reflections. In some areas, acoustic multiple-reflections masked much of the shallow geologic data. Multiple reflections, an artifact of the acquisition system, are caused by a number of possible factors that reflect the acoustic signal to the water surface and back down more than once.

Geophysical Well Logs

Natural gamma ray logs were used for correlating geologic units to the seismic reflection data. Logs used in this report are part of the St. Johns River Water Management (SJRWMD) geophysical log data base and accessed through GeoSys/4G software version 1.1 developed by Dr. Robert Lindquist and Dr. Daniel Arrington of Gainesville, Florida. Sources of the gamma logs include wells logged using SJRWMD equipment and logs digitized from various agency files or private consultant reports submitted to the SJRWMD.

Gamma logs are scaled in counts per second (cps), which provide a relative indication of gamma ray intensity. Relative gamma ray intensity can be used to identify boundaries between geologic units. The contact between the Miocene Hawthorn Group sediments and the Eocene carbonates is generally identified by low cps (0 to 50) in the Eocene carbonates and higher cps (>50) in the Miocene and younger sediments. Additionally, the Miocene sediments are highly variable and units within the section could vary from 20 to >1000 cps. Many factors influence the absolute values that are recorded (borehole diameter, size of the probe crystal) but a characteristic "signature" can usually be identified. Pliocene and Pleistocene sediments that overlie the Miocene sediments may be identified by a reduction in cps. These sediments are generally sands and sandy clays, commonly reworked Miocene sediments are present and may greatly increase the cps.

Cross sections of the gamma logs available near the surveyed lakes are provided to show the contacts of geologic units that could be readily identified (Fig 4). Elevation of the geologic contacts were interpolated to the sites that were profiled and converted to two-way travel time and correlated to reflections that may represent the contacts. Since the lakes generally represent areas of increased stratigraphic disturbance, the elevation of the contacts are highly variable. Reflections from the least disturbed area within a site were used to correlate to the gamma logs. In some cases, the contact could not be identified but a strong reflector within a geologic unit is identified to show subsurface structure.

Map Generation

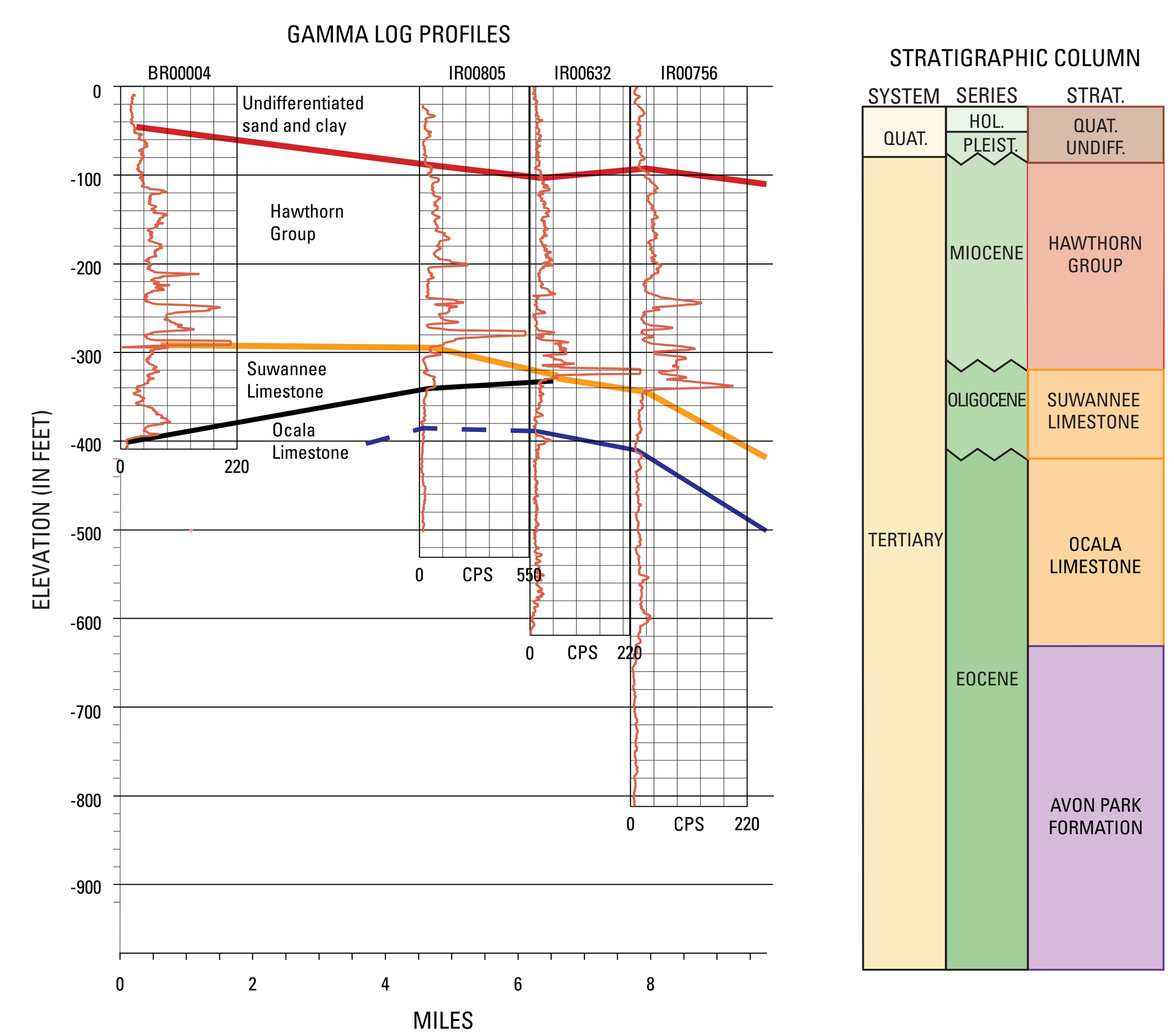
Index maps that show the hydrography of the region and provide background for navigation tracklines were generated from standard USGS Digital Line Graph (DLG) datasets using Qeoquest CPS-3 software products. The hillshade maps showing topographical relief were generated from USGS gridded datasets using ESRI ArcView 3.0. Seismic profiles were scanned from analog copies. All page layout of figures and text was accomplished with the drawing programs Deneba Canvas and to some extent Adobe Illustrator for Macintosh computers.

Reflective horizons from a lake that were laterally continuous and representative of a subsurface feature or the lake bottom were digitized using a standard digitizing table that have been eroded from the areas bordering the lakes have been deposited in the lakes and migrated downward into the space created by dissolution. The elevation of the bottom of these depressions may represent the base level of erosion as constrained by the potentiometric surface of the Floridan aquifer.

The hillshade views commencing the subsections were generated in ArcInfo from a grid of topographic elevations interpolated rom existing five foot contours depicted on USGS topographic maps. Data is projected to UTM, Zone 17, NAD 1983, 1990 correction and copied to double precision. Location of wells used for gamma log cross sections are included to show the proximity of well data to the study sites.

Hillshade views help emphasize the surface characteristics of the physiographic provinces surrounding the sites profiled. Lake distributions varies within high sand ridges to low-lying flood plains of modern and ancient river systems. The hillshade views also show how the topography greatly effects the surface water drainage. Many of the lakes are concentrated within the higher sand ridges and form depressions in the surface. The concentrations of slightly acidic water within the lakes provides a mechanism for enhanced dissolution of the underlying carbonates and other sediments. Many lakes are closed basins with no external drainage. In many cases, sediments eroded from the lake margins have been deposited in the lakes and migrated downward into the space created by dissolution. the elevation of the bottom of these depressions may represent the base level of erosion as constrained by the potentionmetric surface of the Floridan aquifer.

Figure 4. General stratigraphic column for north central Florida. The natural gamma log profiles on the left side of the figure are examples of "signatures" from wells and their regional correlation potential. Modified from Scott (1988) and Miller (1986).



REGIONAL GEOLOGY

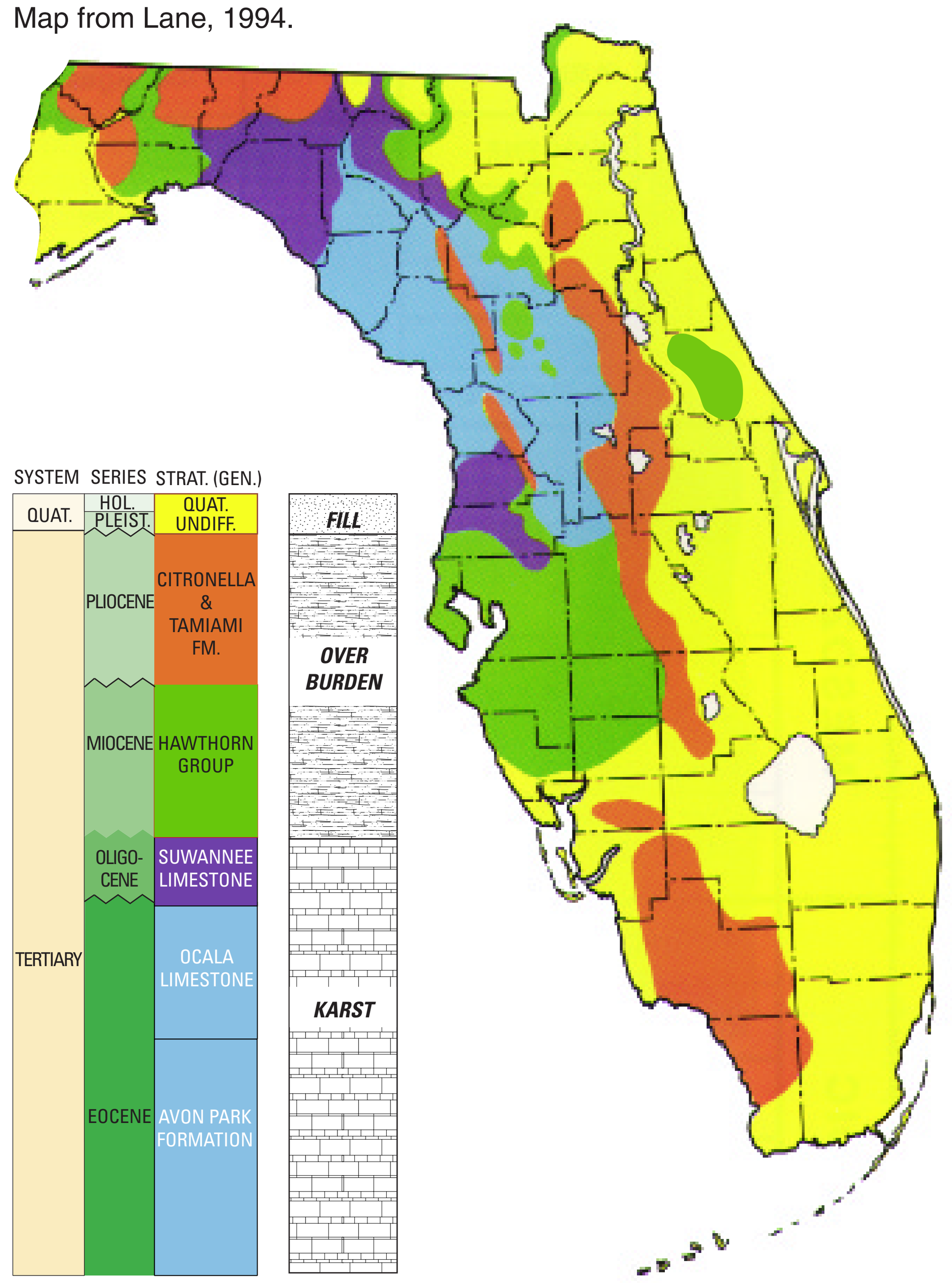


Figure 5. Surface stratigraphy of the Floridan Peninsula. Map from Lane, 1994.

In north-central Florida, sinkholes at the surface are generally related to the dissolution of two host limestone units, the Ocala and Suwannee Limestones. The Eocene-age Ocala Limestone was deposited between 40 and 28 million years ago (ma). Over time, sections of the rock have been recrystallized into dolomite, $CaMg(CO_3)_2$. Ocala Limestone is generally tan to cream, highly fossiliferous lime mud preserved as packstone to wackestone (Scott, 1992). Above the Ocala Limestone is the Oligocene age Suwannee Limestone (28 ma-24 ma) only present as scattered deposits in low topographic areas and typically absent on the topographically high areas. Figure 5 shows the surface distribution of these units.

Overlying the Ocala and Suwannee Limestones is the Hawthorn Group (Miocene 24-5.3 ma). This group is composed of massive impermeable clay and dolomite units. Interbedded with these impermeable units are sands, sandy clays and fractured carbonate units (Miller, 1986). Except where thin or breached, the Hawthorn Group is the main semiconfining unit to the Floridan aquifer in north-central Florida. The thickness, stratigraphic position and confining nature of the Hawthorn Group determines the form and function of sinkholes. The Hawthorn Group is absent from the structural highs such as the Ocala Uplift to the east of the study area and the Sanford High (Fig. 6). It maintains a thickness of 9 to 18 m (30-60 ft) across the St. Johns Platform and thickens to over 46 m (150 ft) over the Jacksonville basin (Mallinson and others, 1994). In most of the sites profiled, the potentiometric surface of the Floridan aquifer lies below lake surface. This condition creates a downward gradient which allows water to permeate through the Hawthorn Group sediment from the lake into the limestone units below. Additionally, breaches in the Hawthorn Group allow enhanced surface groundwater interaction. An example of catastrophic breaching occurred in the late 1800s when a sinkhole collapsed and drained the former Alachua Lake, thereby creating Paynes Prairie (Pirkle and Brooks, 1959b).

Quartz sands, clayey sands and clays of Plio-Pleistocene age (5.3 ma-30 ka) overlie the Hawthorn Group and occur as a surface veneer ~10 m (33 ft) thick or as elongate ridges that may be over 30 m (98 ft) thick. The ridges are expressions of relict shorelines created during Pleistocene interglacial periods (Cooke, 1945; White, 1970). These ridges and related features that developed during the Plio-Pleistocene sea-level cycles form the current physiography of the Floridan Peninsula (Fig. 7). This physiography is highly perforated by karst terrain.

Faulting within the deeper sediments of Florida have long been a source of controversy (Scott, 1997). Faulting occurred during the late Oligocene to early Miocene and again through the Pliocene to early Pleistocene. Williams and others (1977) suggest the movement created the Ocala Uplift (Fig. 6). Pirkle and Brooks (1959a) believe the uplift was a pre-Hawthorn Group occurrence. Opdyke and others (1984) suggest uplift was due to isostatic rebound in response to loss of the carbonate load by dissolution processes, they reported that at least 12 x 108 cubic meters (4 x 1010 cubic feet) per year of limestone are lost from peninsular Florida. This loss, over a period of 38 ka years could result in a rebound of 33 m (108 ft). A deeper and older (early Cenozoic, 60 ma) feature, the Peninsular Arch, has also caused faulting and fractures. The associated weakening of the rocks provides optimum conditions for dissolution and formation of karst.

The term "fault" as used in this report refers to vertical displacement or discontinuities occuring at a specific site. Primarily, these are faults resulting from sediment slumping into a sinkhole depression, or tension faults. No large scale faults that can be mapped regionally and reflect a tectonic origin were identified.

From the surface geology and physiographic regions, Scott (1988) delineated physiographic provinces for the peninsula. Provinces included in the study are shown below (Fig. 8).

Figure 6. Approximate limits of the Hawthorn Group, along with structural controls. Contour intervals in feet. Modified from Scott, 1988.

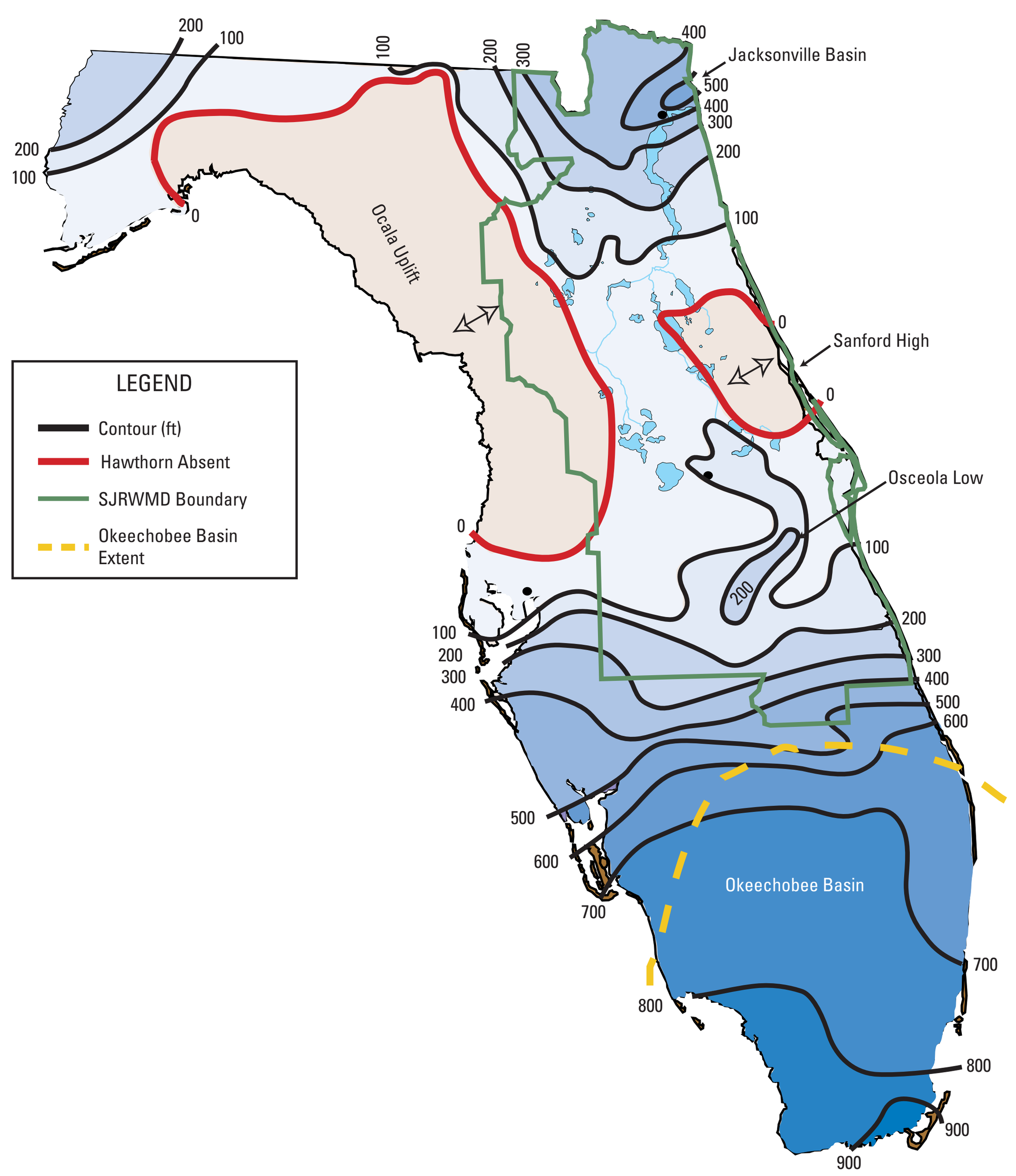


Figure 7. Physiographic regions of Florida. Modified from Randazzo and Jones (eds.), 1997.

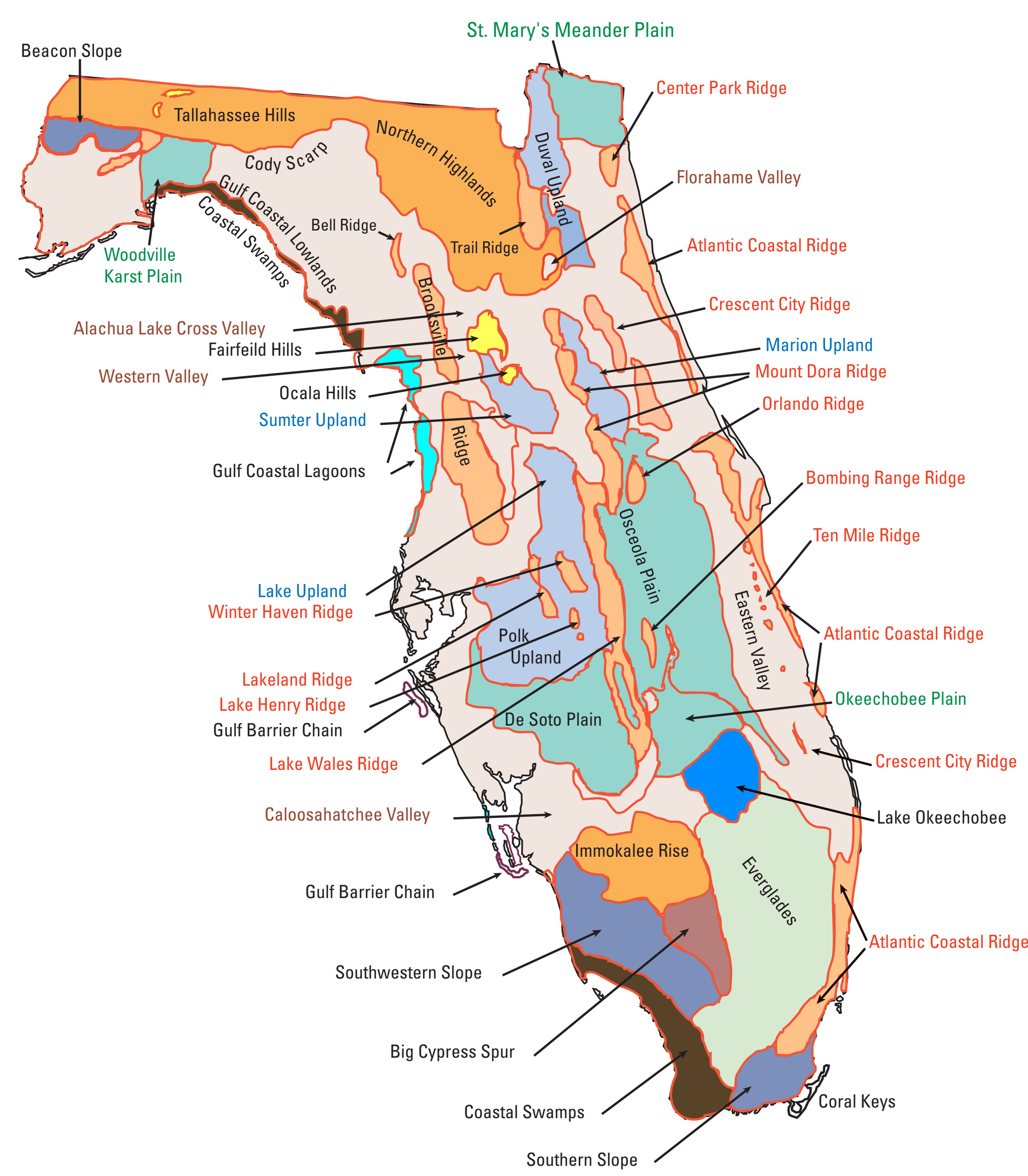
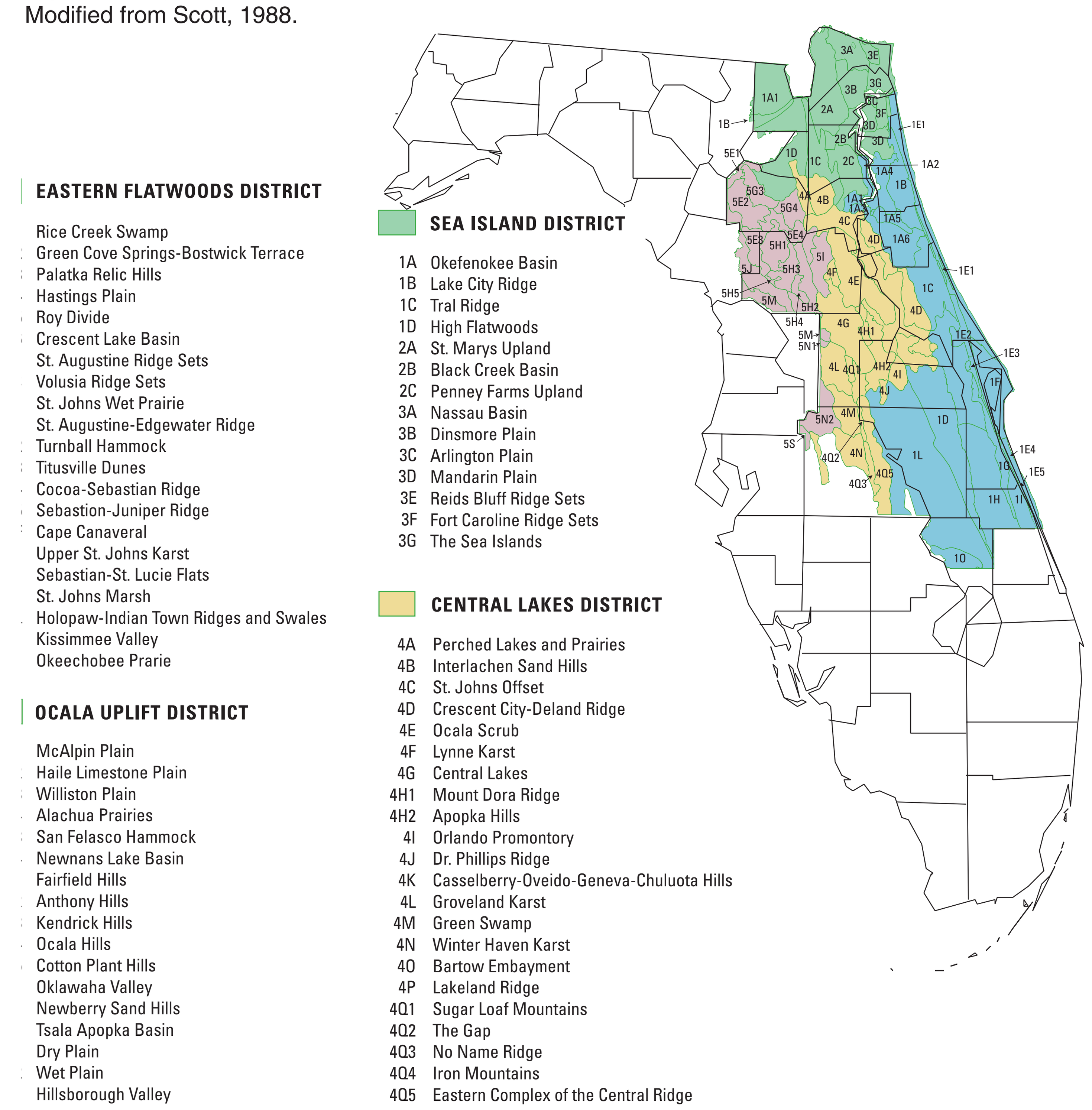
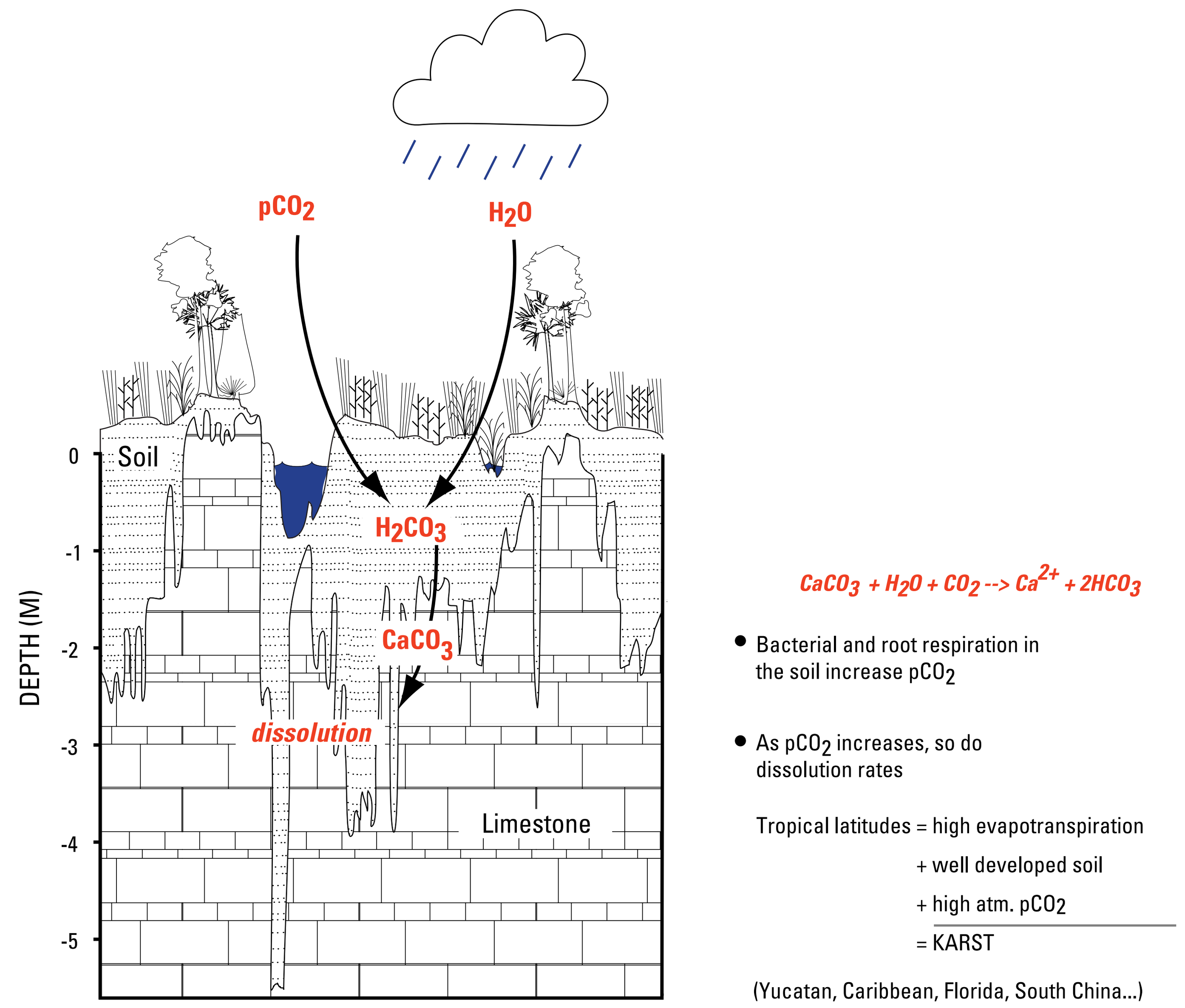


Figure 8. Physiographic provinces of Florida. Modified from Scott, 1988.



KARST DEVELOPMENT AND CHARACTERIZATION

Figure 9. Carbonate dissolution process and karst formation.



Karst Development

Karst topography is created by a chemical dissolution process when groundwater circulates through soluble rock (Fig. 9). Carbon dioxide from the atmosphere is fixed or converted in the soil horizon to an aqueous state, where it combines with rainwater to form carbonic acid, which readily dissolves carbonate rock. Root and microbial respiration in the soil further elevates carbon dioxide partial pressure, increasing acidity (lowering pH). In tropical and subtropical regions such as Florida, abundant vegetation, high rainfall and high atmospheric CO_2 values favor the rapid dissolution of the preexisting limestone.

Karst features develop from a self-accelerating process of water flow along well-defined pathways. As the water percolates downward under the force of gravity, it dissolves and enlarges any pore or fracture in the rock through which it flows. These pathways also include bedding planes, joints, and faults (Fig. 10). Enlarging the fracture allows it to carry more water, which increases the dissolution rate. As the fracture gets larger and transmits more water, it begins to pirate drainage from the surrounding rock mass. This process will create areas where the rock is highly eroded with very little dissolution around it, creating a very jagged appearance to the substructure.

Water will continue to percolate downward until it reaches the water table, below which all pore space is occupied by water. Since the rock is saturated with water at this point, water circulation is not as rapid and dissolution rates slow (the dissolution potential of the water is expended over time). However, the water table itself fluctuates up and down as a result of seasonal change, drought conditions and groundwater removal. This movement creates a zone of preferential dissolution along the zone of fluctuation. Over time this process creates pathways in the rock near the water table and provides a very efficient means to transport water.

During wet cycles, the potentiometric surface of the confined aquifer may be higher than the ground surface. This allows water to flow through breaches in the confining unit and flow at the surface as springs.

Water table fluctuations also occur on larger spatial and temporal scales related to sea-level change. Numerous sea-level cycles have occurred with lowstands extensive enough to expose most of the Florida peninsula and create extensive karst environments. These episodes of paleokarst development have been documented (Randazzo, 1972; Randazzo and Zachos, 1984) and can be identified in the rock record as cycles of shallowing-upward sequences. Geologic evidence includes the presence of evaporite deposits which form during the shallow phase of sea-level cycle. A diagenetic end-member of evaporites is hydrogen sulfide which, when oxidized to sulfuric acid, will greatly enhanced the carbonate dissolution process (Hines, 1997). The presence of paleokarst in the subsurface may influence the development of modern day karst.

Types of Sinkholes

Karst topography is the result of sinkholes: funnel, bowl or cylindrical-shaped depressions that form to accommodate loss of material due to dissolution in the underlying carbonate rock. Dissolution creates a subsurface conduit system that leads to collapse and sinkhole formation at the surface (Arrington and Linquist, 1987). In Florida, sinkhole type and lake development depend primarily on three factors: 1) proximity of the limestone rock to the surface; 2) thickness of the overburden (confining unit); and 3) location of the water table and potentiometric surface. Figure 11 shows a classification of sinkholes that has been developed based on these factors. When the water table is deep below the ground surface, dissolution of the rock occurs within the unsaturated rock, creating a conduit system that transports overlying material downward. If overburden is present, it is removed through the conduit system, causing subsidence at the surface (Fig. 11A). If no overburden is present, the self-accelerating process of dissolution eventually removes all the material at the surface and the conduit system develops progressively downward (Fig. 11B). Where the ground is close to the surface, fluctuations in the water table create a void system along the zone of fluctuation. Downward dissolution above the water table directly undermines the surface, eventually causing a collapse. If overburden is present it will slump into the hole, sometimes catastrophically (Fig. 11C). Lack of overburden will create a direct connection between the surface and any underground void or cave system (Fig. 11D). A transitional type of sinkhole (Fig. 11E) straddles the end member classification in that deposition of material in the depression created by dissolution can occur during subsidence or collapse, or after dissolution has ceased. In Florida this type of sinkhole can be found very near the surface with recent infilling, or deep in the subsurface from paleokarst development. Buried sinkholes can also reactivate since they continue to be preferential pathways for groundwater movement.

Figure 12 incorporates near surface geology (factors 1 and 2 mentioned above) with depth to aquifer (factor 3) to map the distribution of sinkhole types in Florida. When compared to the surficial geology map (Fig. 5, Regional Geology Sheet p. 3), it is apparent that in areas where the competent overburden of the Miocene sediments overlie limestone that is in close proximity to the surface, there is the highest likelihood of cover-collapse sinkholes (Lake and eastern Marion counties). Areas of loose Quaternary fill typically experience the slower developing cover-subsidence sinkholes that are most commonly found along the eastern seaboard.

Figure 10. Solution and collapse features of karst and karren topography.

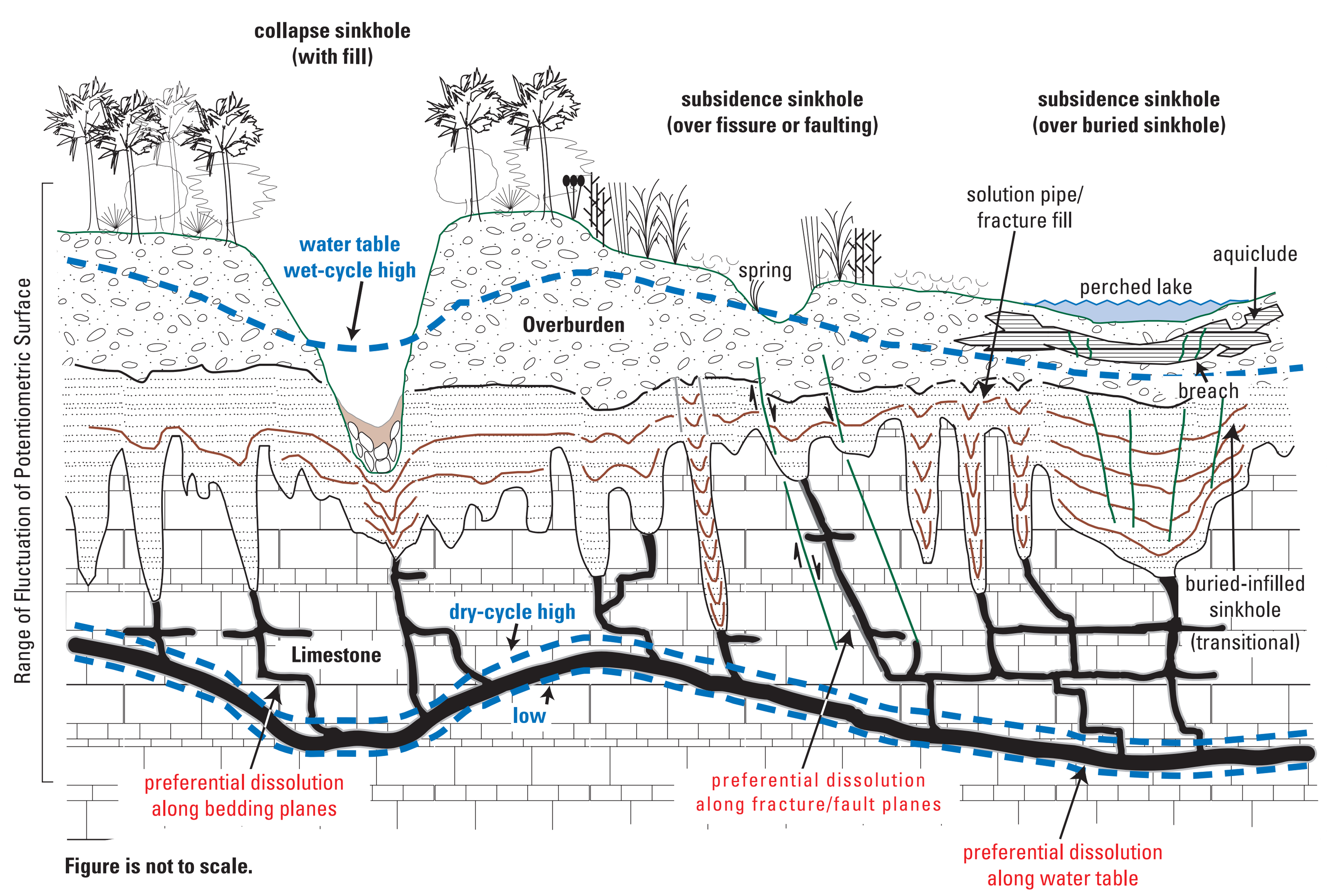


Figure 11. End-member classification of sinkholes. Modified from Culshaw and Waltham (1987); Ogden (1984). Graph shows distribution relative to potentiometric and overburden controls.

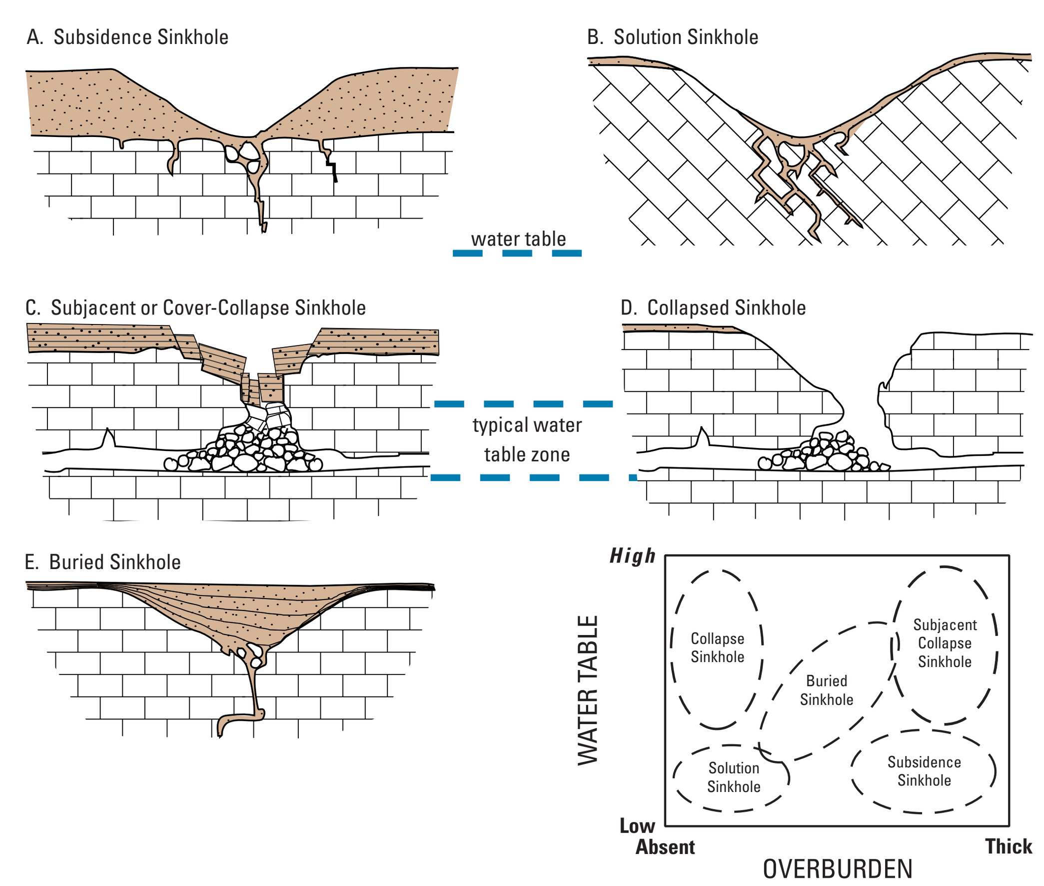
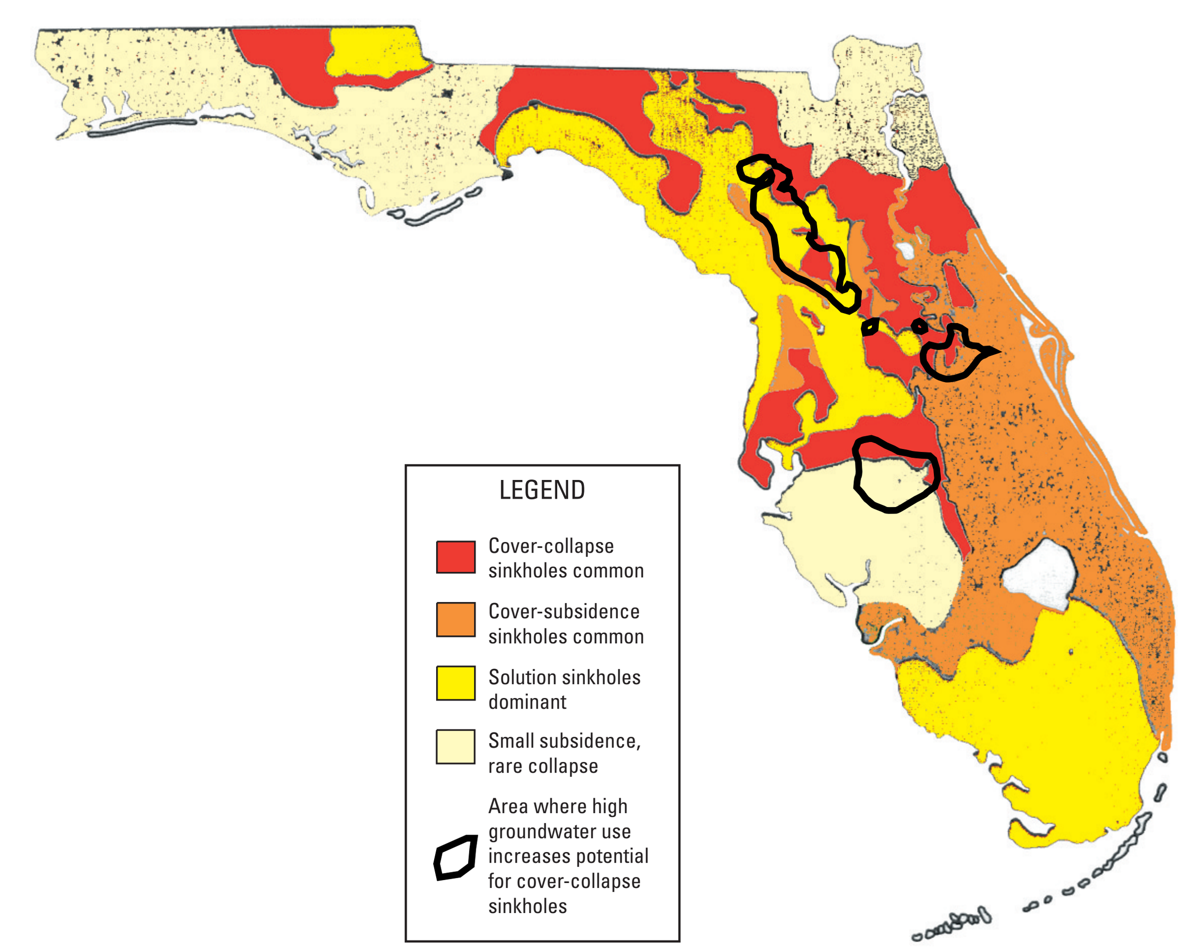
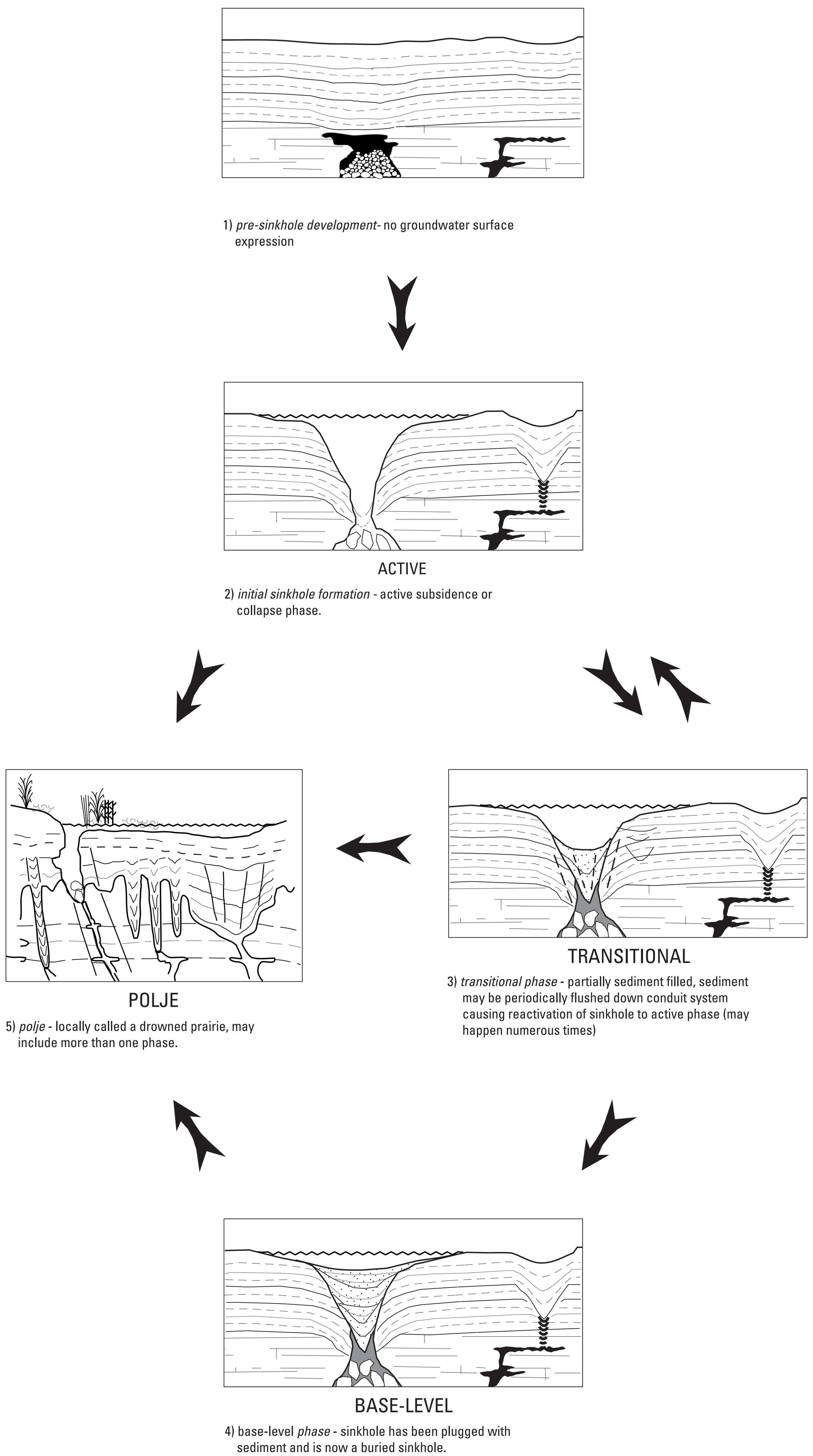


Figure 12. Predicted sinkhole type in Florida. Modified from Randazzo and Jones (eds.), 1997.



SINKHOLE LAKE EVOLUTION AND EFFECTS OF URBANIZATION

Figure 13. Predicted sinkhole type in Florida. Modified from Randazzo and Jones (eds.), 1997.



Sinkhole Lake Evolution

An estimated 95% of the surface waters in northeastern Florida are sinkholes (Brainard, 1982; Lane, 1986). The lakes originate from the direct result of chemical and/or mechanical processes. The mechanical processes that result in lake development are: 1) slumping or subsidence of underlying clastic or carbonate sediments; 2) clustering of sinkholes; or, 3) a combination of the previous two. Sinkhole lakes in Florida occur in areas of thin overburden, typically less than 61 m (100 ft). In areas with an impermeable confining layer and no breaches, a lake might be a perched lake (the lake level is held above the groundwater level) with no communication with subsurface aquifers. Otherwise a lake will form in conditions where a lack of overburden or permeable confining layer allows for increased karstification of the underlying limestone, producing a depression due to limited fill material.

The seismic profiles indicate that sinkhole lakes can be delineated into a progressive sequence of lake evolution based on geomorphic types (Kindinger and others, 1999) (Fig. 13). In central Florida the progression begins with the subsurface dissolution of the limestone host rock (see Karst Development sheet, p. 4), ultimately leading to surface collapse or subsidence. The depression may be dry or, if a portion is below the water table, it may contain water. Erosion of sediments into the depression may cause the sinkhole to become plugged. Further erosion may eventually bury the sinkhole.

Progressive Sequence of Lake Evolution

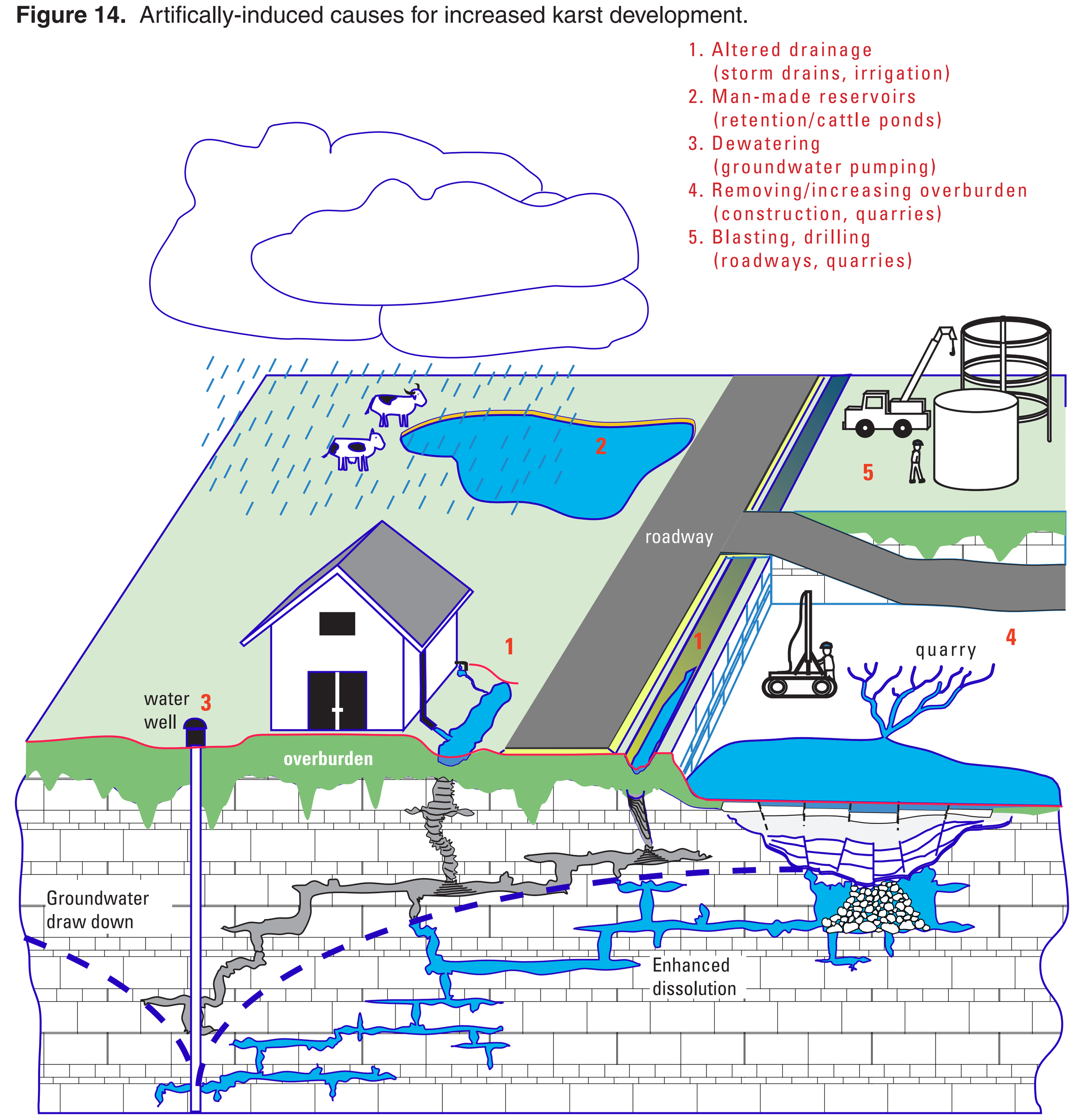
Pre-sinkhole development (no visible expression)- the process begins with subsurface dissolution of limestone below the unconsolidated overburden. Since there is no surficial expression of the dissolution process, predicting areas of sinkhle development is difficult. The process continues, undermining the structural integrity of the overburden, until collapse occurs.

Active subsidence or collapse phase (young) - At the initial surface appearance of a sinkhole, the basin is steep-sided and potentially deep. As surface material is removed by erosion and/or slumping from the expanding perimeter to the center of the sink, the basin walls decrease in angle and the lake basin becomes more extensive. Examples of this phase include sinkholes at Orange Lake, Crescent Beach Spring and Red Snapper Sink (Table 1, Fig. 1).

Transitional phase (middle age) - When the sinkhole becomes partially or completely plugged, the lake begins to develop a shallower and flatter bottom. During this phase the plug may flush through the subsurface conduit system, allowing the sinkhole to reactivate and revert to an active subsidence phase. This may occur several times until sediment accumulates faster than dissolution of the underlying limestone. Many of the lakes in the Interlachen Karst Highlands are in a transitional phase.

Baselevel phase (mature) - Once a transitional phase sink becomes plugged, its growth is limited and the lake becomes shallower. Continual erosion of material into the basin over time will then eventually fill the basin if no reactivation of the sinkhole occurs. The level to which the sinkhole basin erodes is also related to the water table elevation and the potentiometric surface of the Floridan aquifer. Many lakes in the east central study area are in a base-level phase.

Figure 14. Artifically-induced causes for increased karst development.



Polje (drowned prairie) -The lake floor is cut entirely across karst rock (sometimes covered with unconsolidated alluvium) but is located in the epiphreatic zone and is inundated at high stages of the water table. These lakes may have one or all phases of sinkhole development and many karst features. Orange Lake, for example, is a polje and includes active subsidence and transitional features.

The term polje arises from a lowland or depression is flooded by a rising groundwater table -poljes. The Croatian word 'polje' means "field". Gams (1978) identified three criteria for a lake to be classified as a polje: (a) flat floor in rock (which can also be terraced or occur in unconsolidated sediments such as alluvium); (b) a closed basin with a steeply rising marginal slope at least on one side; and (c) karstic drainage. There are three basic poljes -border, structural, and base-level. All poljes have a common hydrologic factor: their development occurred close to the local water table, even though the lake may be perched in some cases (Ford and Williams, 1992). Of the basic types of polje, only the base-level polje (to date) has been identified in north-central Florida and locally described as drowned prairie.

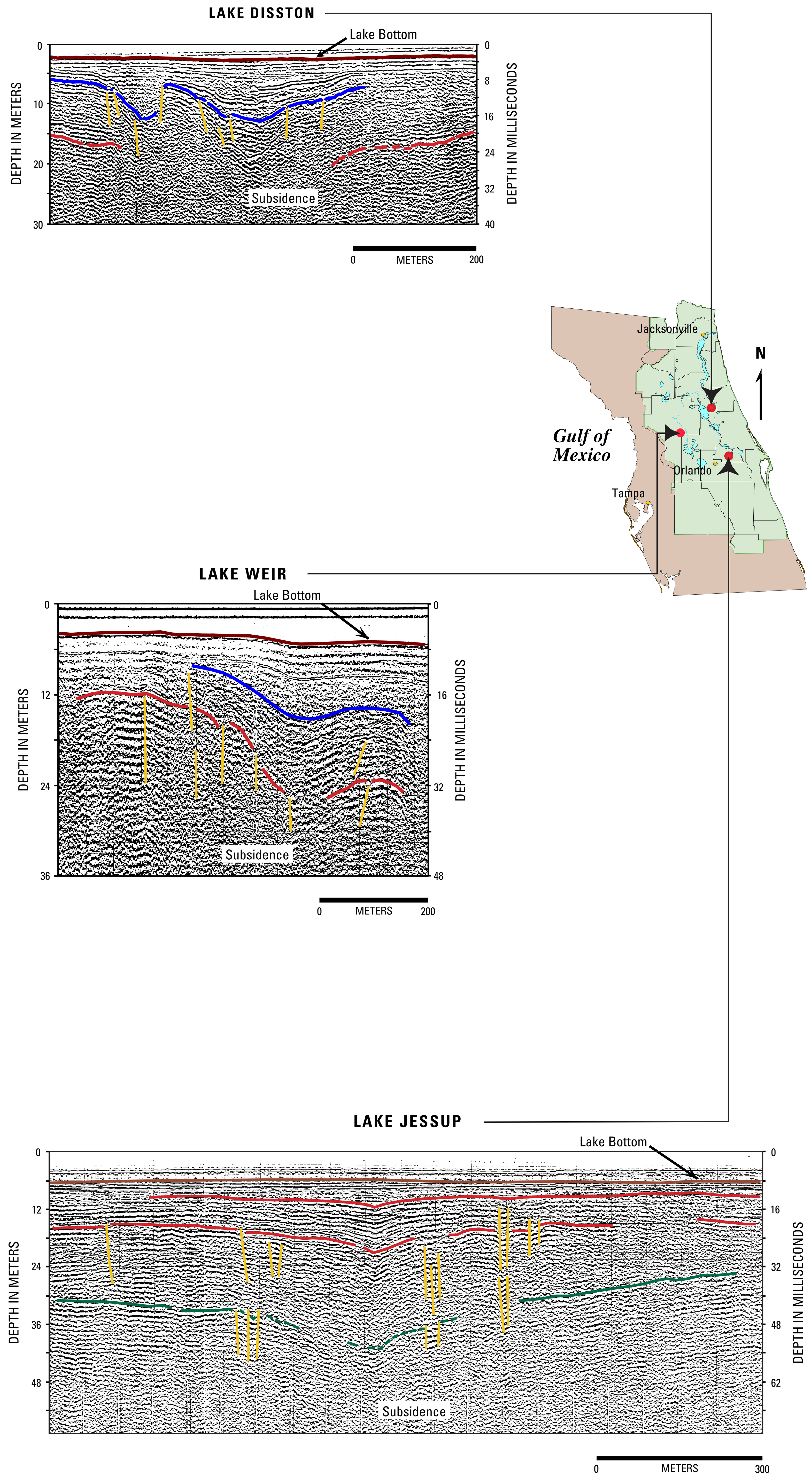
Urbanization and Sinkholes

The process by which sinkholes form in nature is complicated by an additionally important factor: the anthropogenic effect, or urban development in karst areas. As demand for undeveloped land increases, less desirable properties such as karst-prone areas become a target for human construction or development (Ripp and Baker, 1997). Direct contact with an unstable subsurface is the obvious drawback, but not the only geohazard. Other problems related to development of these areas include sources for non-natural sinkhole development. These issues are de-watering, alteration of surface drainage patterns, increase or redistribution of overburden and blasting for quarries and highways (Fig. 14). In Florida, de-watering or aquifer draw down from well field pumping is a major factor (USGS WRI 85-4126), since the potable water supply for metropolitan areas are pumped from aquifers nearby. The magnitude of water removed from the subsurface creates draw down in the aquifer which removes the supporting pressure needed to maintain integrity of the overlying material and land surface. Figure 14 shows typical scenarios where high rates of groundwater withdrawal increase the likelihood of surface collapse. White (1988) estimates that since 1930, artificially-induced collapse has nearly doubled the collapse frequency in karst areas. In the state of Florida, insurance claims for damage from sinkhole collapse have increased from 35 in 1987 to 426 in 1991 (Smith, 1997). Federal Emergency Management Agency (FEMA), 1997 estimates cumulative damage in this state from sinkholes to reach $100 million.

Aside from damage due to surface collapse, sinkholes and related features cannot be considered negative aspects of karst terrain. Many sinkholes, sinkhole lakes and karst-related features in Florida are maintained as state parks for their aesthetic and recreational value (Devil's Millhopper, Blue Spring, Ichetuknee Springs, etc.). Florida Department of Environmental Protection, Recreation and Parks (FDEPRP) estimates that 14 million people visit Florida parks annually (source: FDEPRP). This, along with privately maintained parks, provides millions of dollars in revenue for the state. But more importantly sinkholes and other karst features provide vital conduits for surface water recharge to the aquifer as breaches through the semi-confining layer. However, as breaches they also become sources of contaminants to the potable water supply. Consequently, sinkholes and sinkhole lakes need to be characterized by their hydraulic connection potential and subsequently maintained and protected if development of this terrain is to continue.

IDENTIFICATION OF KARST FEATURES FROM SEISMIC PROFILES

Figure 15. High-resolution seismic profile examples from three lakes located in separate geomorphologic regions of northeastern Florida. Colors are for interpretive purposes and do not indicate correlation between profiles.



Historically, high-resolution single-channel seismic profiling (HRSP) has been used to determine the regional distribution of stratigraphic units having distinct acoustical characteristics. In this study, the lakes are well distributed and have a relatively small diameter, making stratigraphic correlation difficult. HRSP data has been used primarily here to map the shallow subsurface features found beneath selected lakes of northeastern Florida. Subsurface diagnostic features are used to define the structural history and to locate possible breaches in the confining layer that maintains the perched lakes above the Floridan aquifer. In many cases the acoustical records show fine details of karst (>10 m) and karren (<10 m) features (Ford and Williams, 1992). Compilation of these features from seismic profiles acquired from the lake surveys have shown that certain acoustic patterns reoccur from lake to lake. Figure 14 shows similar acoustic patterns from three lakes located in separate geomorphologic regions. In general, low angle, parallel reflectors are down warped to form a depression. These reflectors are accompanied by discontinuous or segmented reflectors that suggest structural displacement and subsurface subsidence. Horizontal reflectors overlying the subsidence indicate subsequent fill.

The reoccurrence of these features in seismic sections from the more than 39 sites profiled (Fig. 1, Introduction) led to the identification of six acoustical signatures of commonly found karst or geologic features. These features are characterized in Figure 16. Included in the summary are patterns indicative of no acoustic return (Fig. 16 type 1). Negligible or noisy acoustic return unfortunately is common in the lake surveys and are typically the result of various environmental and geomorphologic factors. Such factors include organic material collecting in depressions that disperse the acoustic signal, or a lithologically "hard" lake bottom of packed homogeneous sands. A karst surface near the lake bottom may also disperse the signal or cause ringing (multiples) throughout the record. Side-wall reflections from the shoreline or slope of a depression may further obscure return from subsurface features. Acquisitional deficiencies such as electrical noise or faulty grounding may affect entire surveys, as do lake surface wind, chop or waves.

When the record is not obscured, a number of patterns have been identified that relate to karst features. Types 2 and 3 (Fig. 16) represent depressions that have been subsequently filled to the present lake bottom. The fill is represented by horizontal reflectors that may onlap the depression or completely cover the subsided area. Evidence of stress fractures, slumping, faulting, or dissolution fractures around the depression (Type 3) differentiate the two dolines and may indicate more rapid or continuous subsidence, or a more competent overburden. These breaches within the depression may provide a significant hydraulic connection between surface waters and the underlying aquifer. Most of the sinkholes detected using HRSP are of the buried base-level type (Fig. 13, Sinkhole Evolution sheet) and should be a common occurrence beneath dry land as well. Only when these features develop a transitional phase (Fig. 13.), reactivate and cause a surface subsidence or collapse, do they become evident at the surface.

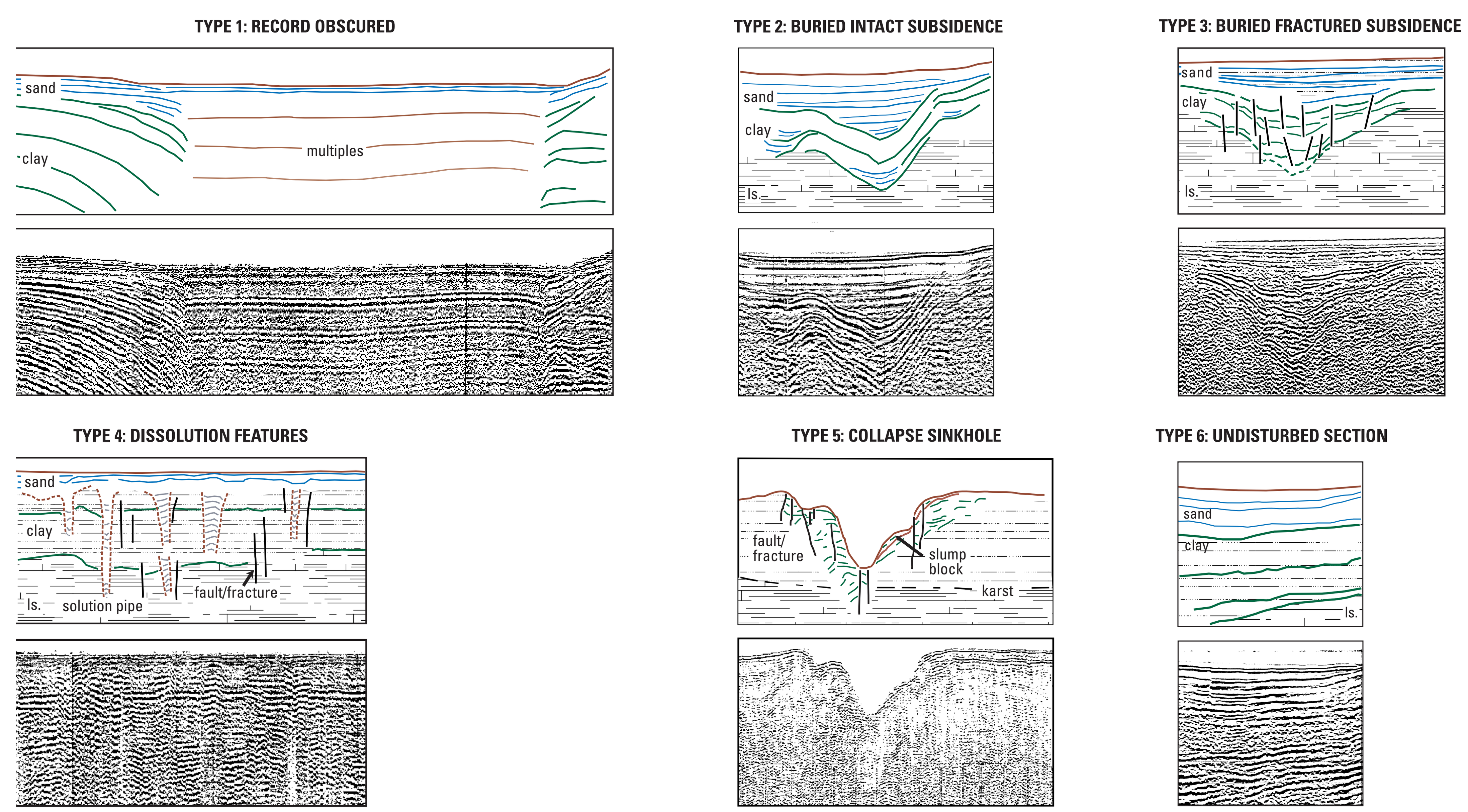
Other common features are high-frequency or chaotic reflections interspersed between horizontal reflections (Type 4). These reflectors indicate a disturbance within a relatively intact stratigraphic sequence and may represent solution pipes or fractures through the overburden. The features may connect to dissolution systems in the underlying limestone and could represent direct hydraulic connection through the semi-confining layer to the underlying aquifer. The disturbed reflections indicate areas of potential subsidence or collapse. These features have a high potential for reactivation since the plugs that fill solution pipes may dislodge during periods of major rainfall variations. There are many examples of this from Marion County (Cain and Hornstine, 1991). Solution pipes and related features commonly occur in areas where cohesive overburden is moderate to thin. Dissolution is focused and material directly over the cavity is washed into the void during the piping process. Type 4 features are widespread throughout the lakes surveyed, they occur in all phases of karst development and are commonly associated with poljes.

The Type 5 feature represents the classic collapse sinkhole, with steep walls that show evidence of slumping and active development along the periphery of the collapse. Freshwater plumes have been imaged emerging from similar collapse features found in marine environments (e. g. Crescent Beach Spring). In seismic profiles, areas of negligible acoustic return below the collapse have been postulated to represent subterranean cavities. These active phase collapse sinkholes are typically evident at the surface without imaging and occur in areas of minimal overburden. They also indicate areas of internal drainage or discharge depending on the location of the potentiometric surface of the Floridan aquifer.

Finally, the Type 6 feature does not necessarily include a karst-related structure but rather represents intact bedding or undisturbed section. A moderate to thick overburden overlies a deeper limestone surface that may not be within the imageable area of the HRSP, in which case depth to limestone is estimated from other methods, such as gamma profiles of well logs. This type of stratigraphy may occur over the entire survey area if there is a thick overburden, or as fill within karst features. Communication between the surface and groundwaters may be minimal in these areas.

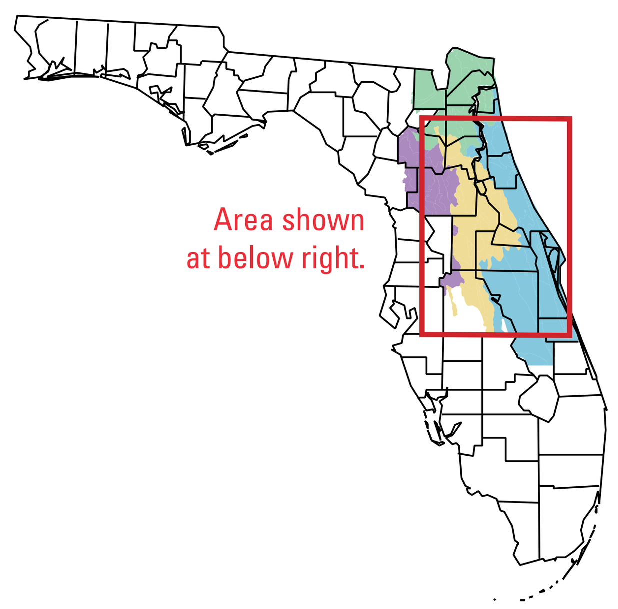
All of the lakes surveyed that have legible seismic profiles show at least one of the features noted in the summary reflections but usually there are multiple features present. Where these features have been identified in the profiles, their corresponding number has been annotated on the index map for each individual lake. The extent of the coverage, along with correlation from other sensing techniques such as gamma logs, and general knowledge of Florida geology, has allowed for some inference as to the type of material associated with the acoustic return. Parallel reflections or "transparent" return infer a stratigraphy of sand and clays. A jagged or noisy return indicates the limestone surface is near the lake bottom. As mentioned earlier, the type of feature present is probably a function of type and amount of overburden, proximity of karst surface to the lake bottom and maturity of karst development. Each of the identified features influence leakage between surface waters and the Floridan aquifer. Studies using seepage meters are being conducted to quantify variations in leakage related to a particular subsurface feature (Hirsch, 1998).

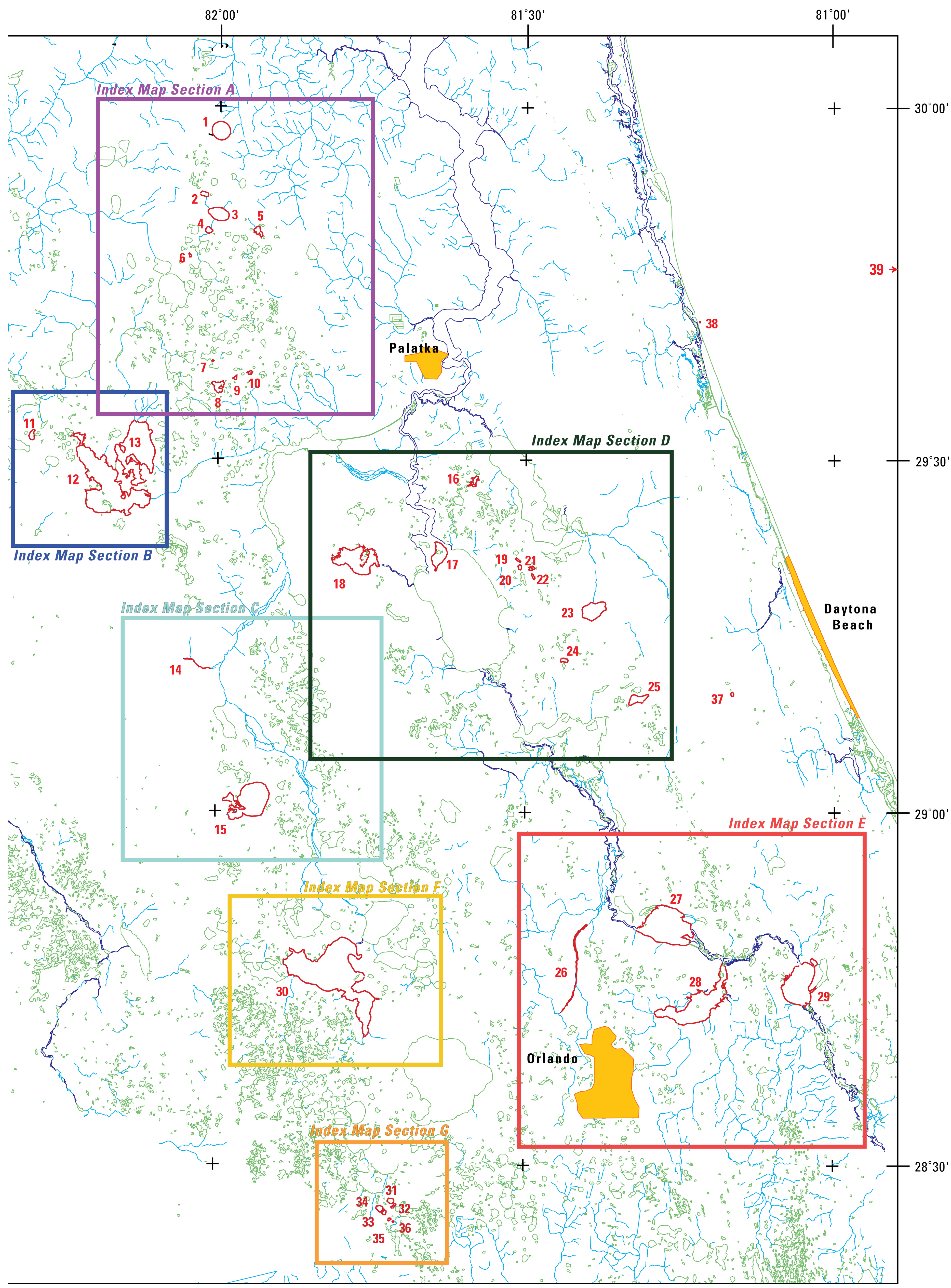
Figure 16. Seismic profiles with line drawing interpretations of six types of features described from the lakes of northeastern Florida.



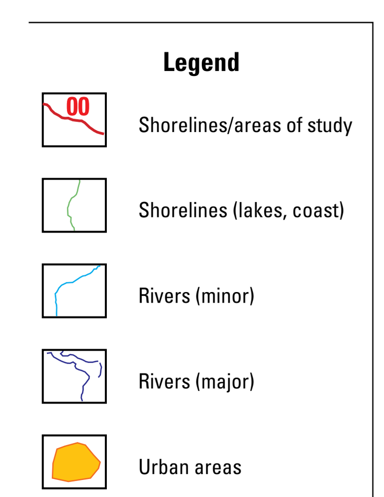
INDEX TO COVERAGE

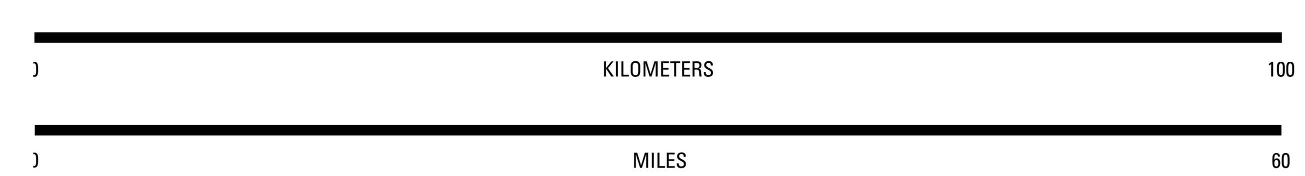
HIGH RESOLUTION, SINGLE CHANNEL SEISMIC PROFILES, NORTHEAST FLORIDA





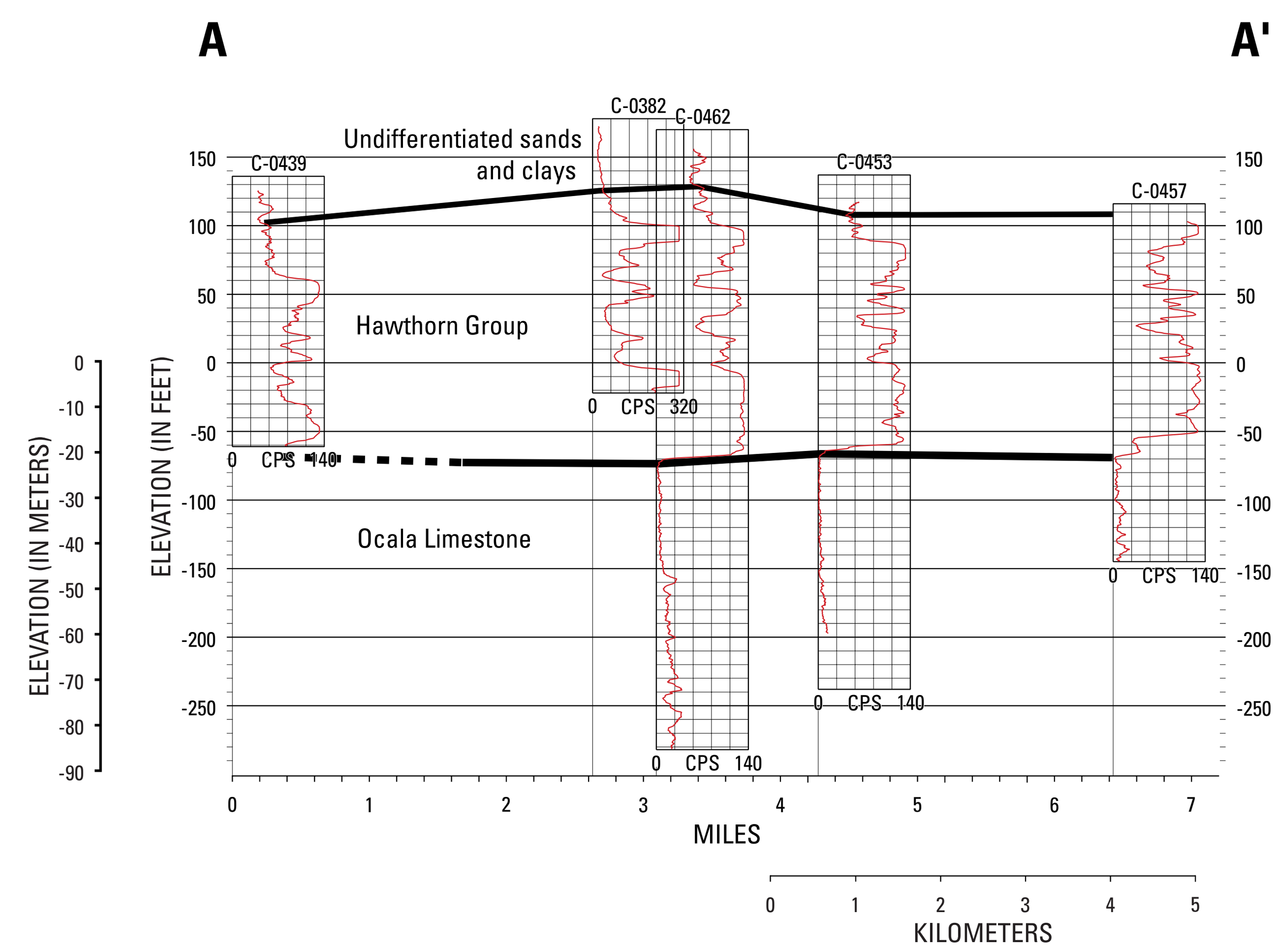
Surveys conducted by the United States Geological Survey and the St. Johns River Water Management District between August 1993 and April 1996.

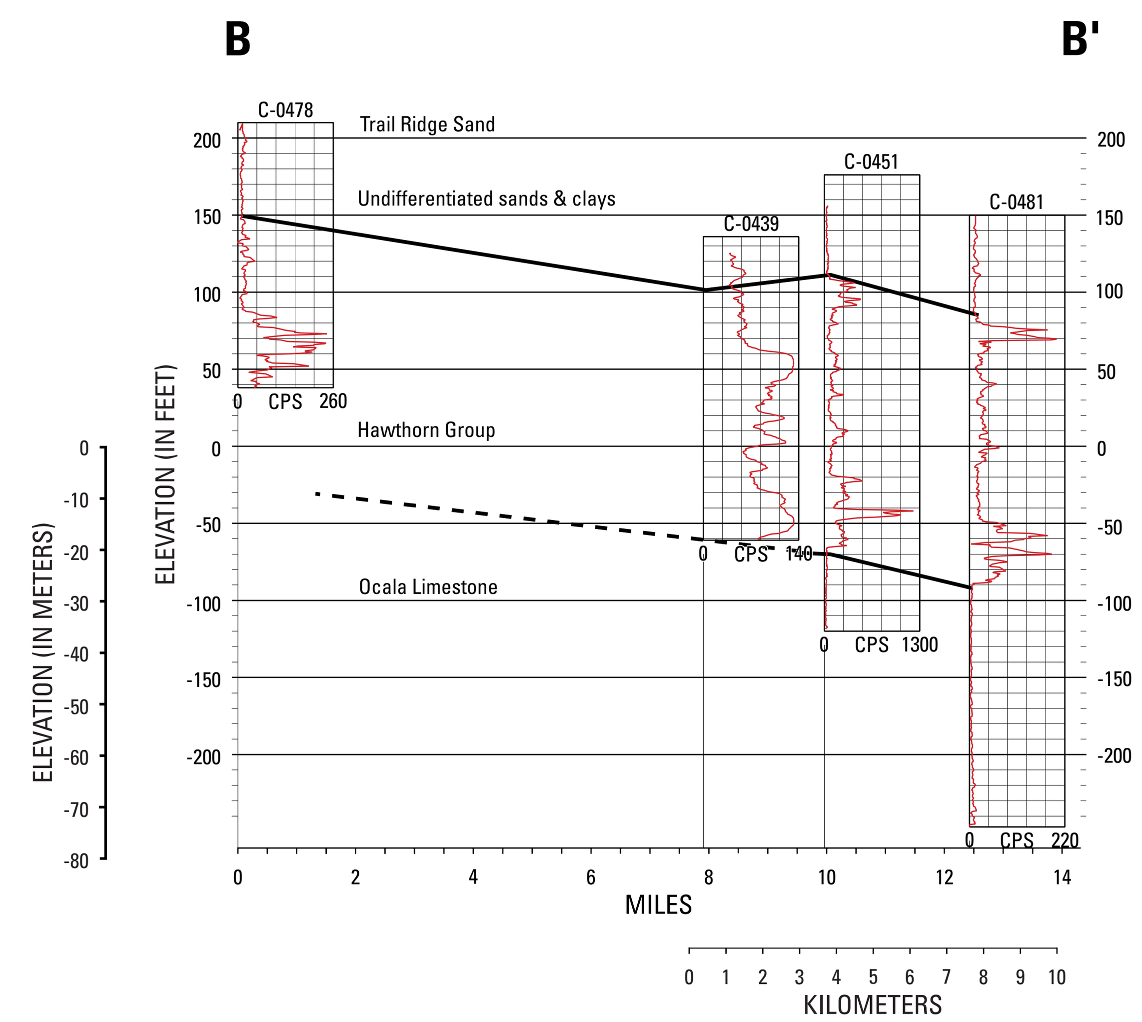


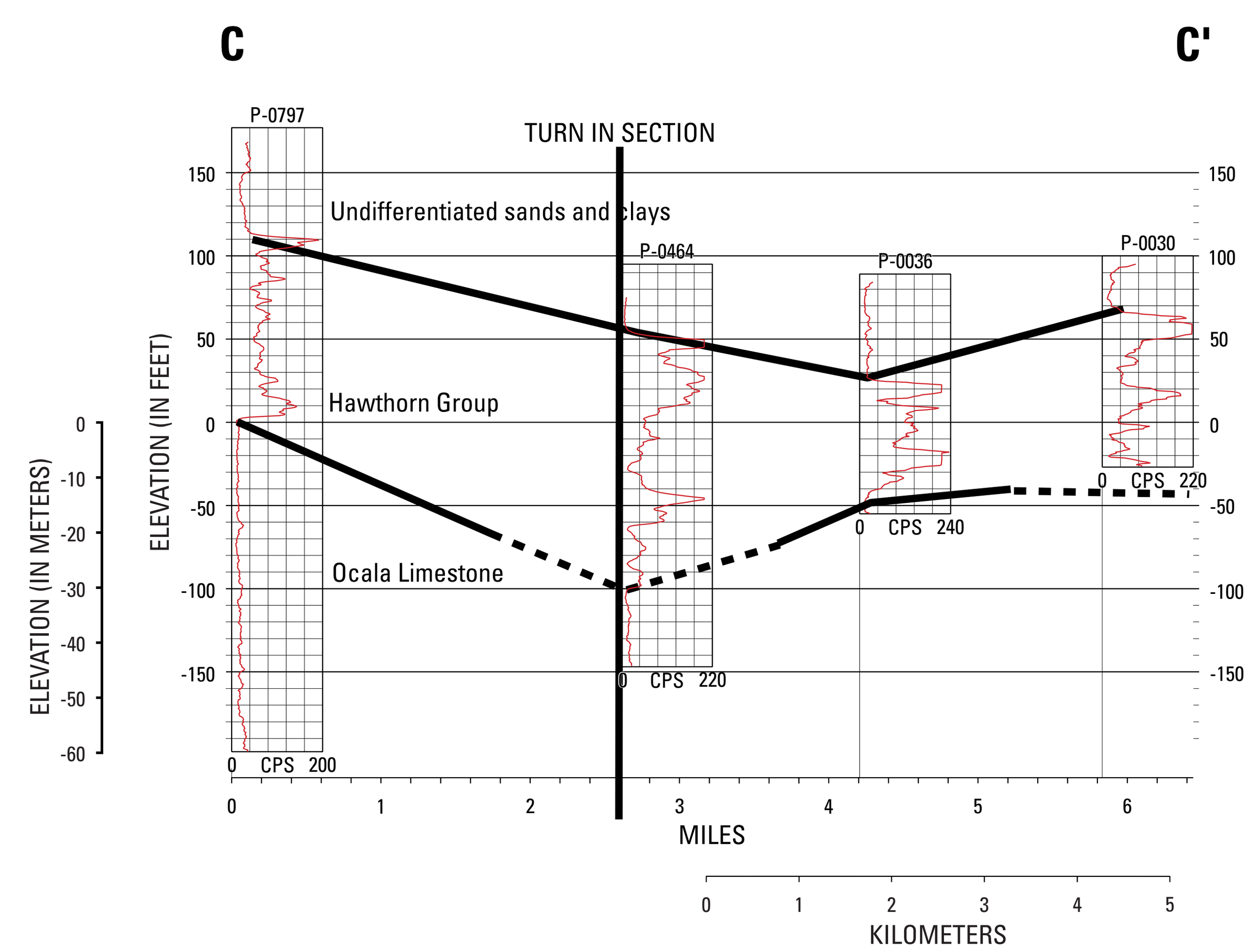


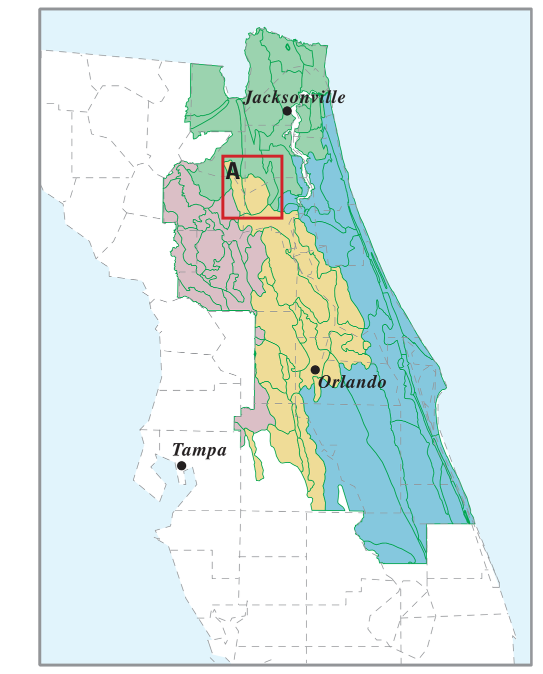
INDEX MAP AND GAMMA LOG

CROSS-SECTIONS, SECTION A

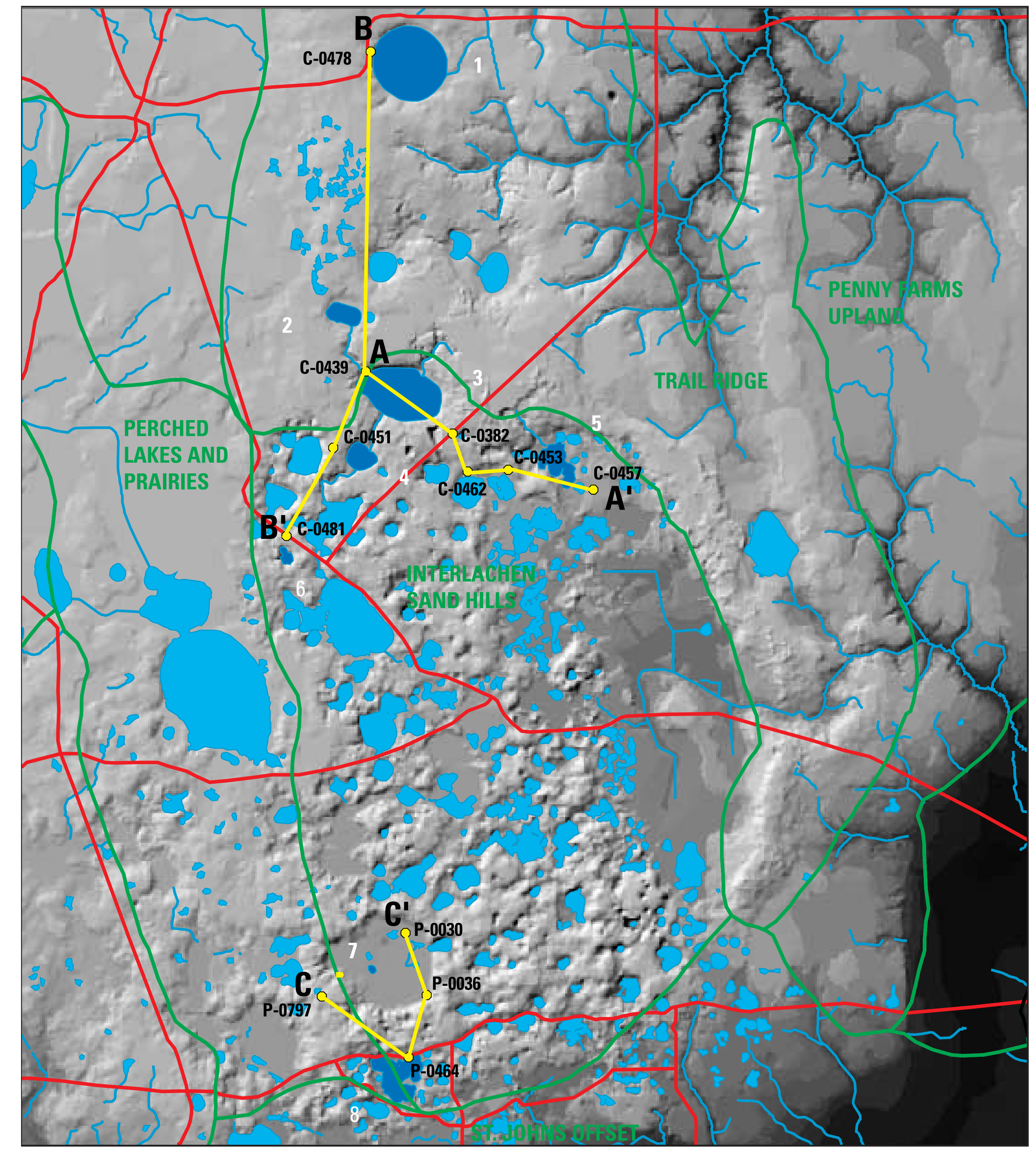


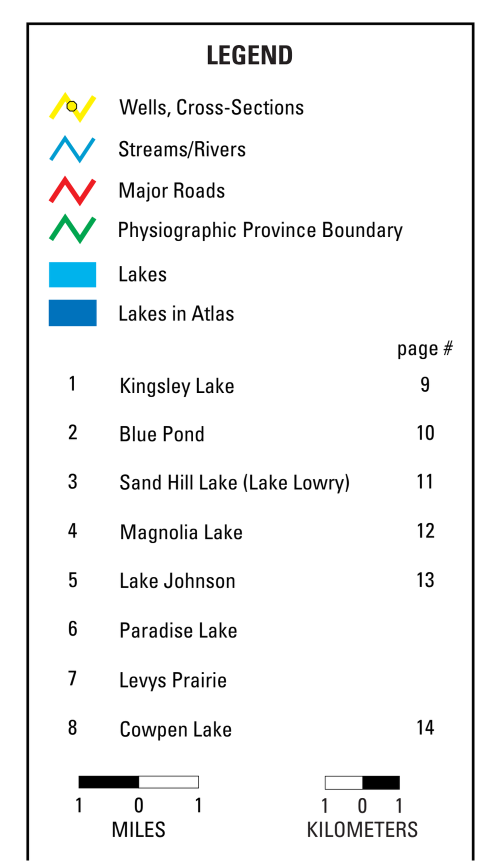






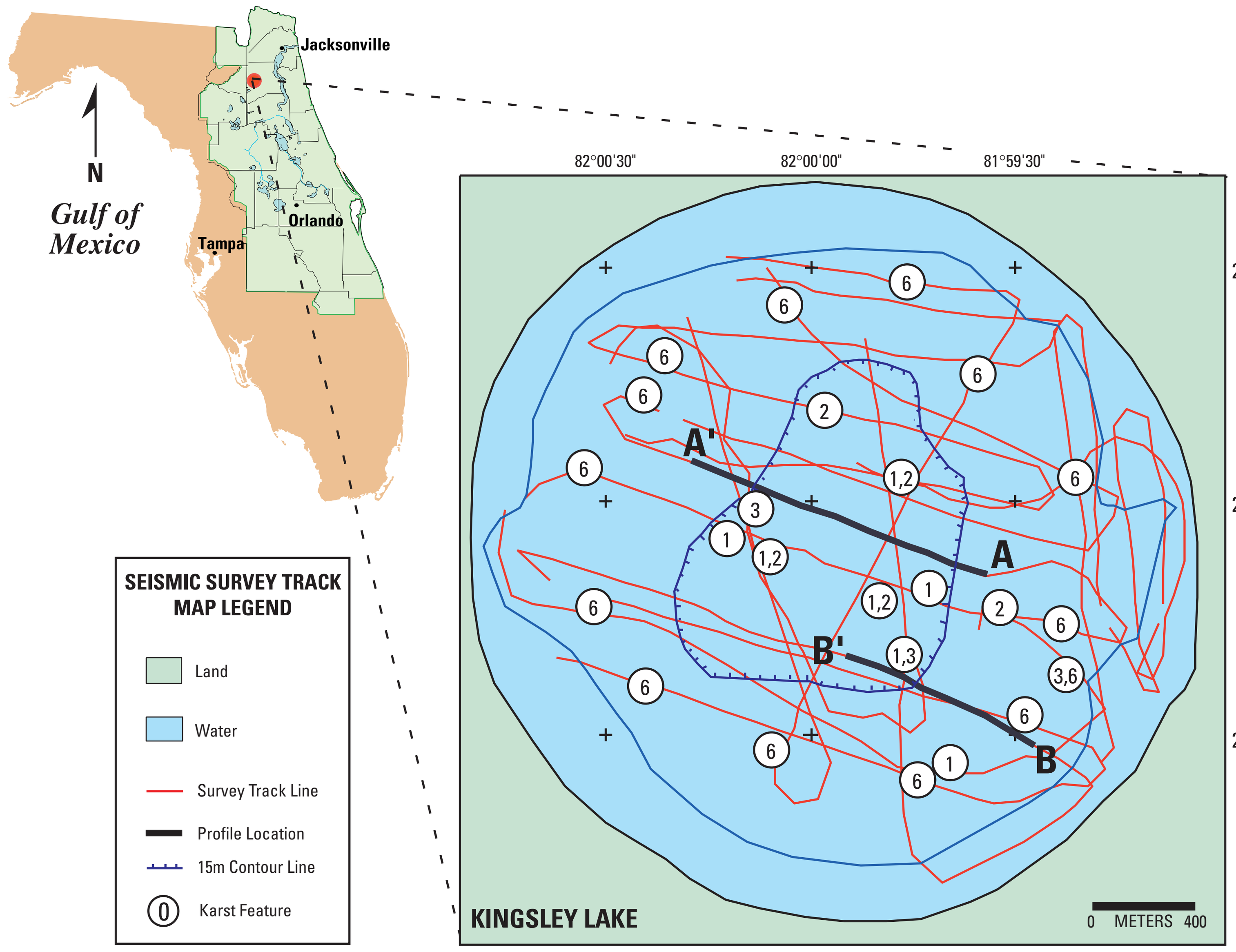
Location of survey area right (red square). Shaded relief map below showing physiographic regions, and location of wells and gamma log cross-section. Gamma Log cross-sections (left) show geologic contacts for correlation to seismic sections.



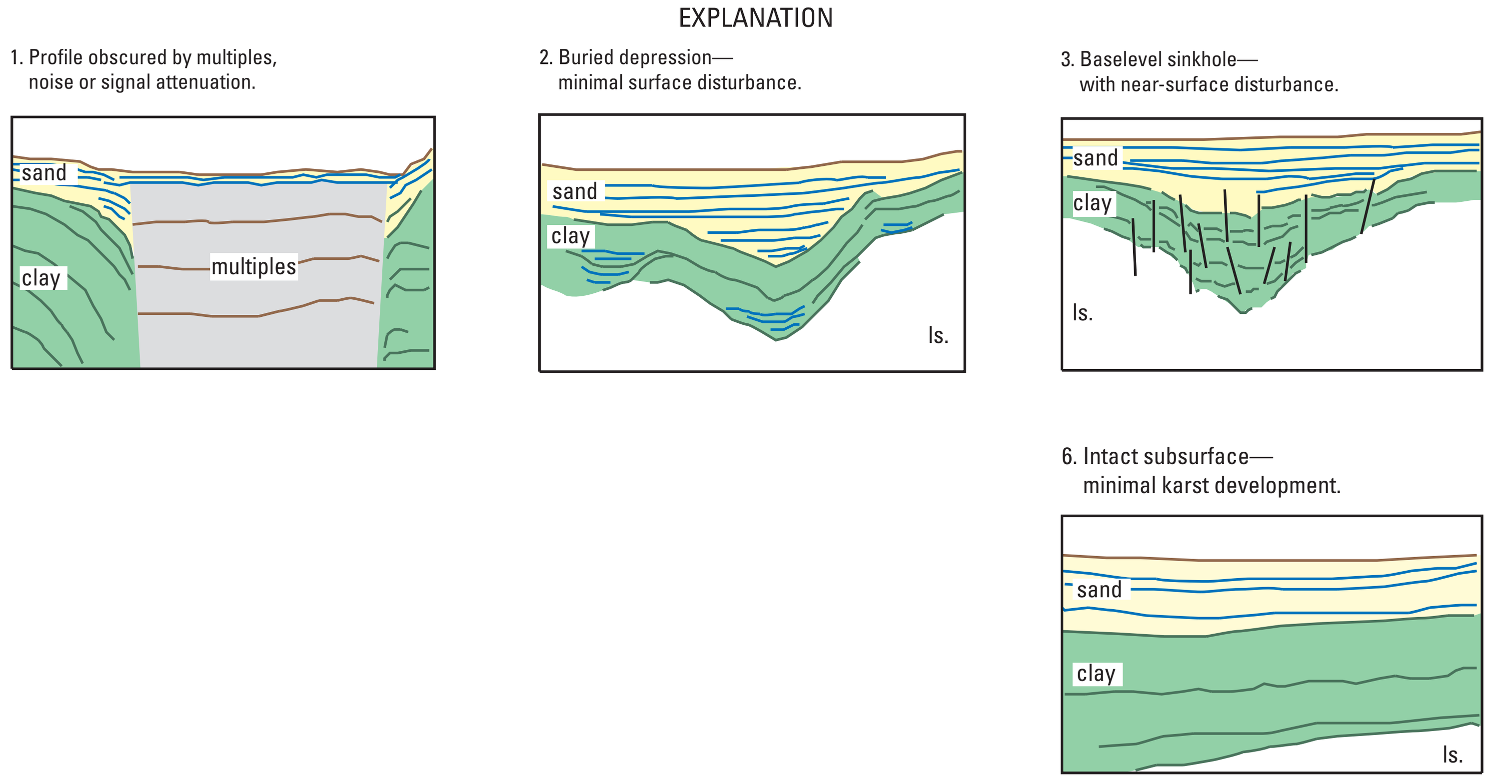


KINGSLEY LAKE

CLAY COUNTY, FLORIDA



EXPLANATION



Introduction

Kingsley Lake is a circular lake centered at approximately latitude 29°57'54"N and longitude 82°W in west-central Clay County, Florida. The lake is located within the Trail Ridge area of Sea Island District. Kingsley Lake is flanked on the west by the Trail Ridge deposits and is underlain and surrounded by Citronelle sediments (Clark, 1964) that consist of a relatively thick section of unconsolidated to semi-consolidated quartz sands, clayey sands, and gravels. The Trail Ridge sands are above an elevation of 45 m (149 ft) and are mined commercially for heavy minerals used in paints and abrasives. These sediments are unconsolidated and completely saturated, this enhances the filling process when sinkholes collapse or sediment is washed into the lakes by surface runoff. Generally the sands are seismically transparent but clay stringers or cementation may provide reflecting horizons.

Lake level at the time of the seismic survey was 54 m (176 ft) NGVD. This circular lake is approximately 3.2 km in diameter with a perimeter of 12.8 km and surface area of 5.6 km^2. The deepest part (40 ms, ~30 m) of the lake southeast is of the center where a large, steep-sided, collapse sinkhole is located. Otherwise, the lake is shallow around the shoreline, gradually deepening to 6 m (see Survey Track Map). Towards the center of the lake the bottom slope steepens and increases in depth from 6 to 15 m (see Survey Track Map).

Subsurface Characterization

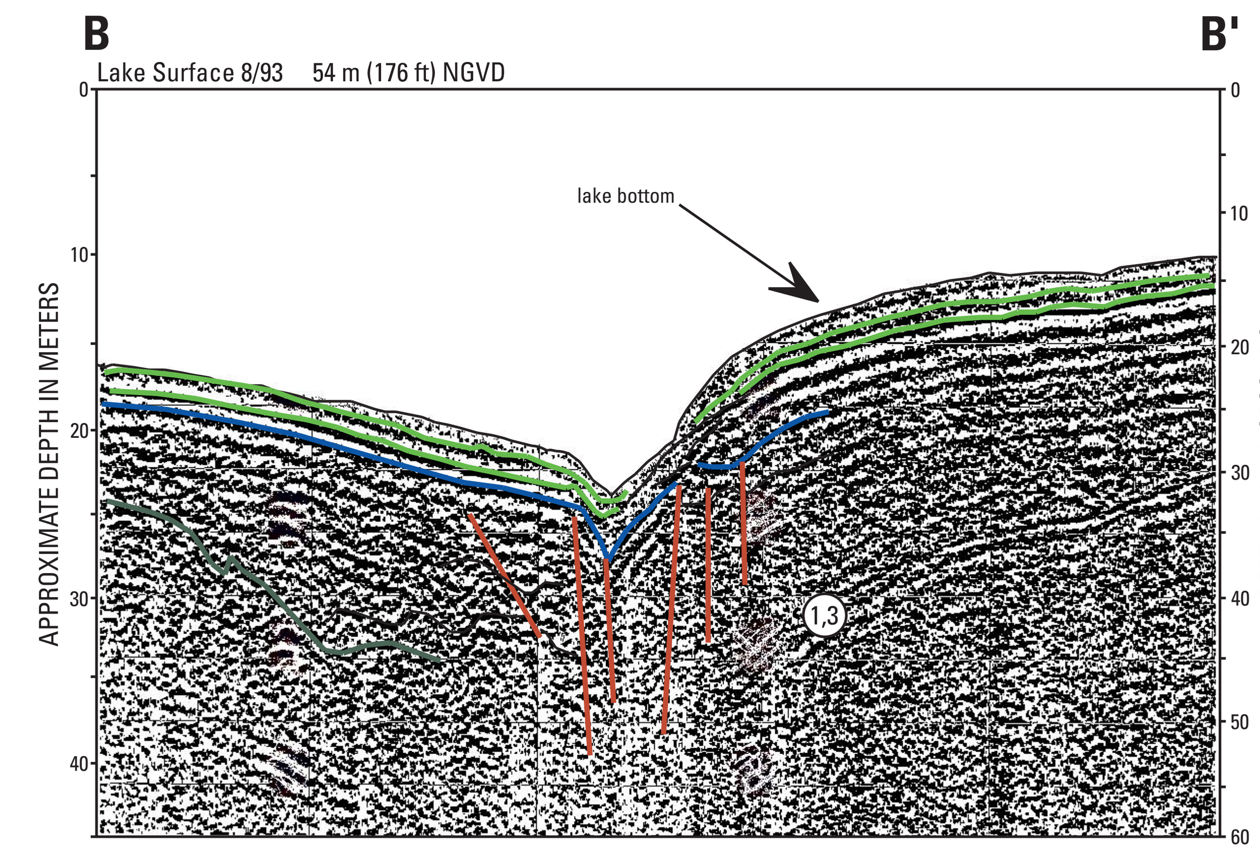
Profile A-A' illustrates the strata in and around the primary sinkhole within the lake. An abrupt change in the lake bottom slope can be seen on the flanks of the sinkhole. This is a filled, collapse-sinkhole with steep flanks overlain by offlapping fill and slumps. The fill is acoustically transparent with few low-amplitude reflections discernible. This is to be expected since the source of the fill is primarily clean quartz sands brought in from the adjacent Trail Ridge deposits. Plotted on the Kingsley Lake survey trackline map are the karst features identified from seismic profiles; Types 1, 2, 3, and 6 karst features were found. Features 1 and 2 represent the primary sinkhole surrounded by Type 6 undistrurbed depostional layers.

The Type 1, 3 feature seen in Profile B-B' appears to be a secondary collapse feature that occurred after the formation of the main doline shown in Profile A-A'. Unlike the main doline, this feature is not completely filled with sediment. The data does not indicate that the feature extends through the surficial and Hawthorn Group sediments into the Floridan aquifer (>95 m).

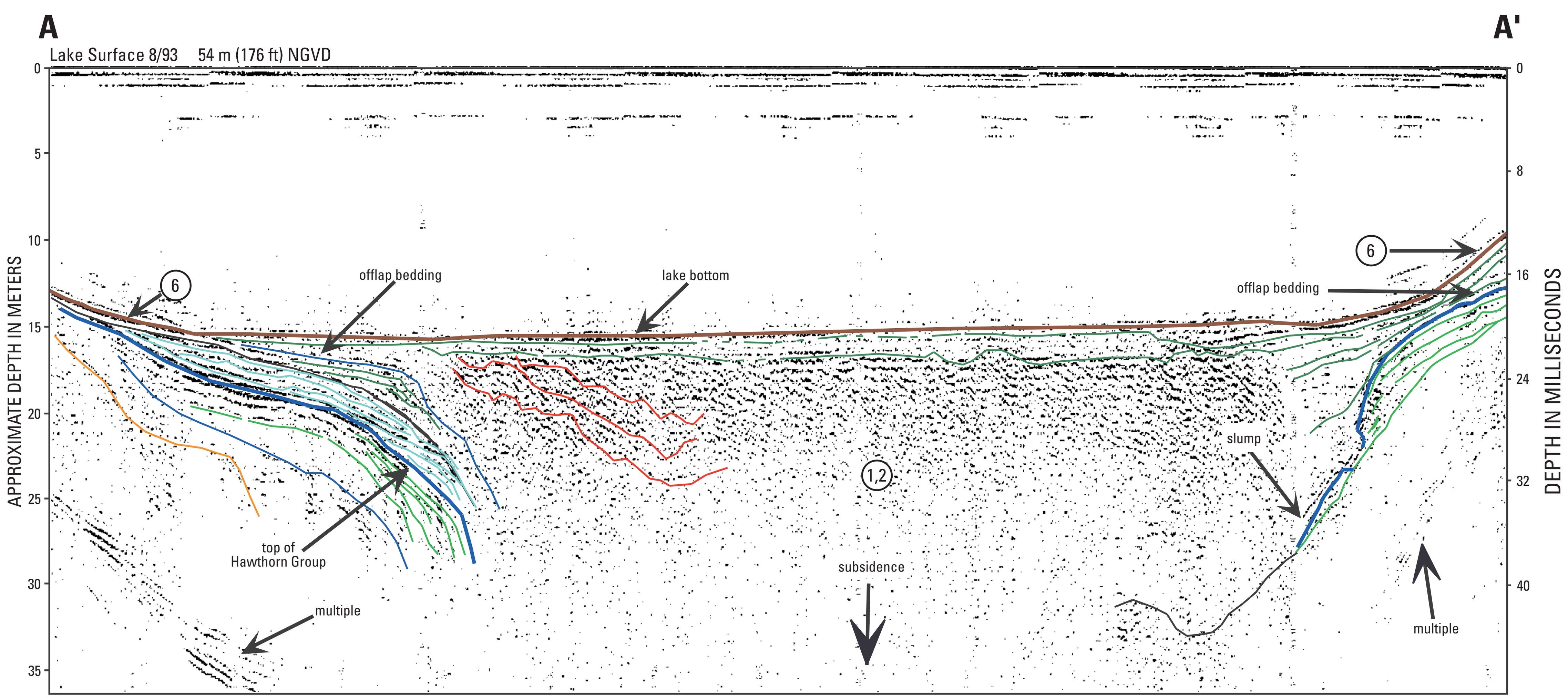
There is only limited borehole data available to correlate the seismic data. Interpolating from the nearest borehole C-0478 (Index Map A, page 8) the top of the Hawthorn Group is seen along the shallow flanks of the lake at approximately 10 ms. In Profile A-A' the top of the Hawthorn Group is shown to be steeply dipping towards the center of Lake Kingsley due to the sinkhole collapse. It is estimated that the top of the Floridan aquifer should be seen in the data at approximately 150 ms. None of the profiles contained data that was resolvable at that depth however.

Processes that control lake development are:
1) karstification or dissolution of the underlying limestone, and 2) the collapse, subsidence, or slumping of overburden to form sinkholes. Initial lake formation is directly related to the karst topography of the underlying host limestone. Lake size and shape are a factor of the thickness of overburden and size of the collapse or subsidence and/or clustering of depressions allowing for lake development. Lake development passes through progressive sequence stages to maturity.

Kingsley Lake is in a late transitional phase (middle age) - the sinkhole becomes plugged as the voids within the collapse fill with sediment. No evidence of active subsidence was located within Kingsley Lake (Profile A-A') though minor, isolated, small scale, subsidence type features were found Profile B-B'). The sediment plug within this main sinkhole is relatively smooth and less disturbed compared to the smaller but active subsidence features of Orange Lake.



Vertical Exaggeration 15.2:1 Not corrected for velocity variations.
Horizons are colored to show structure, not correlation.
Modified from Kindinger and others, 1996.



Vertical Exaggeration 15:1 Not corrected for velocity variations. Horizons are colored to show structure, not correlation.
Modified from Kindinger and others, 1996.

Subsurface Characterizations of Selected Water Bodies in the St. Johns River Water Management District, Northeast Florida

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2000

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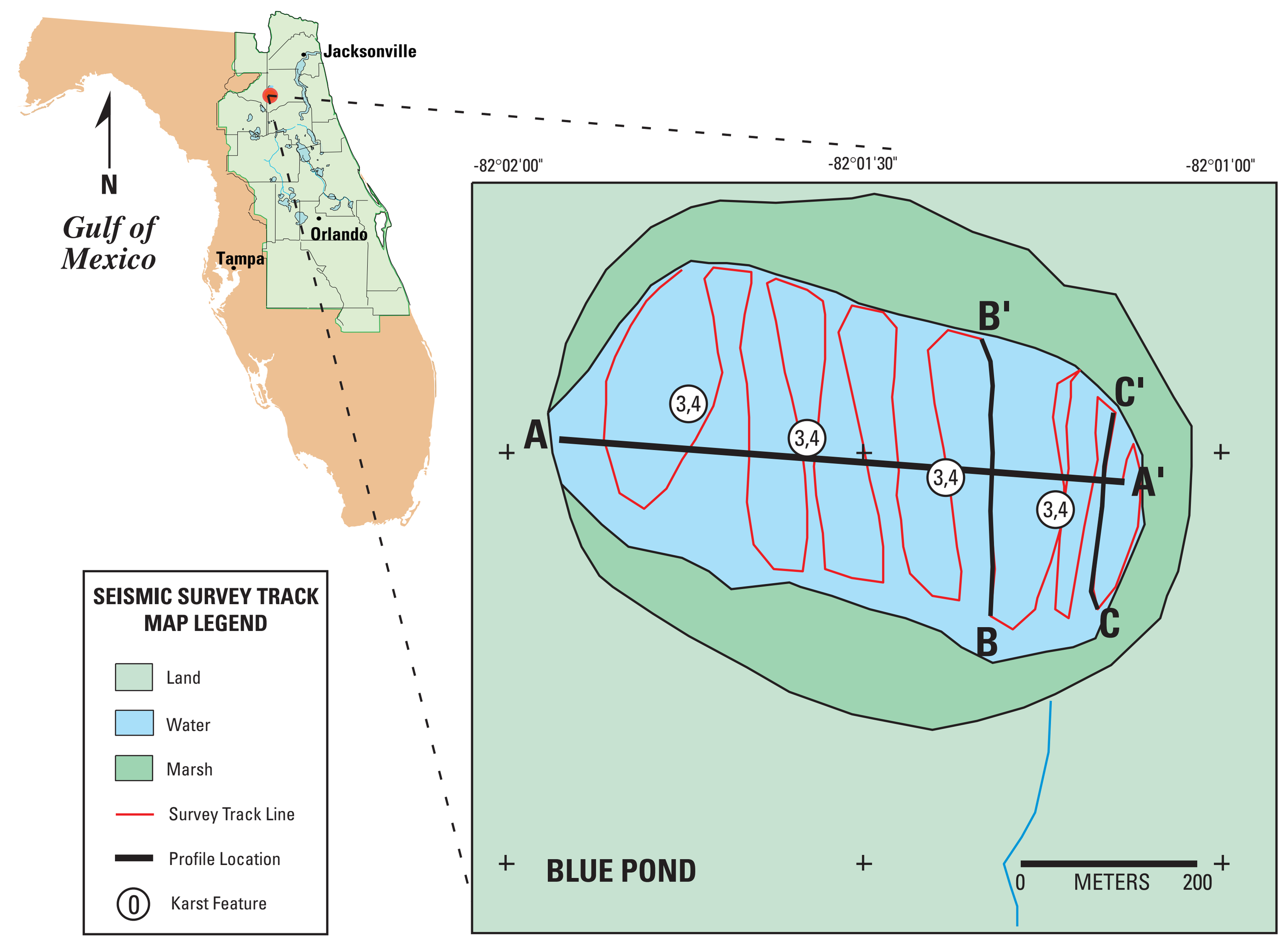
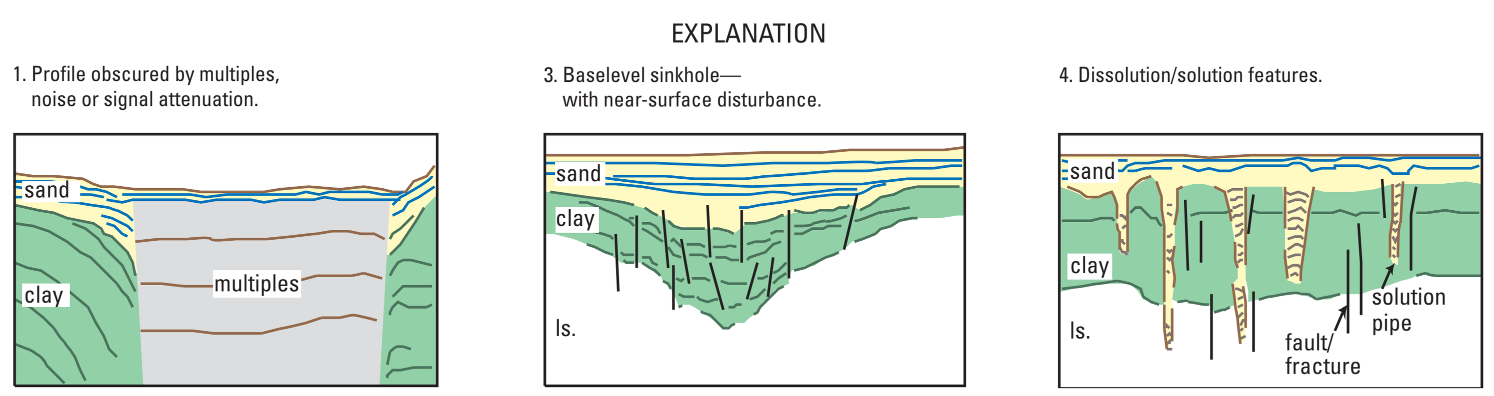
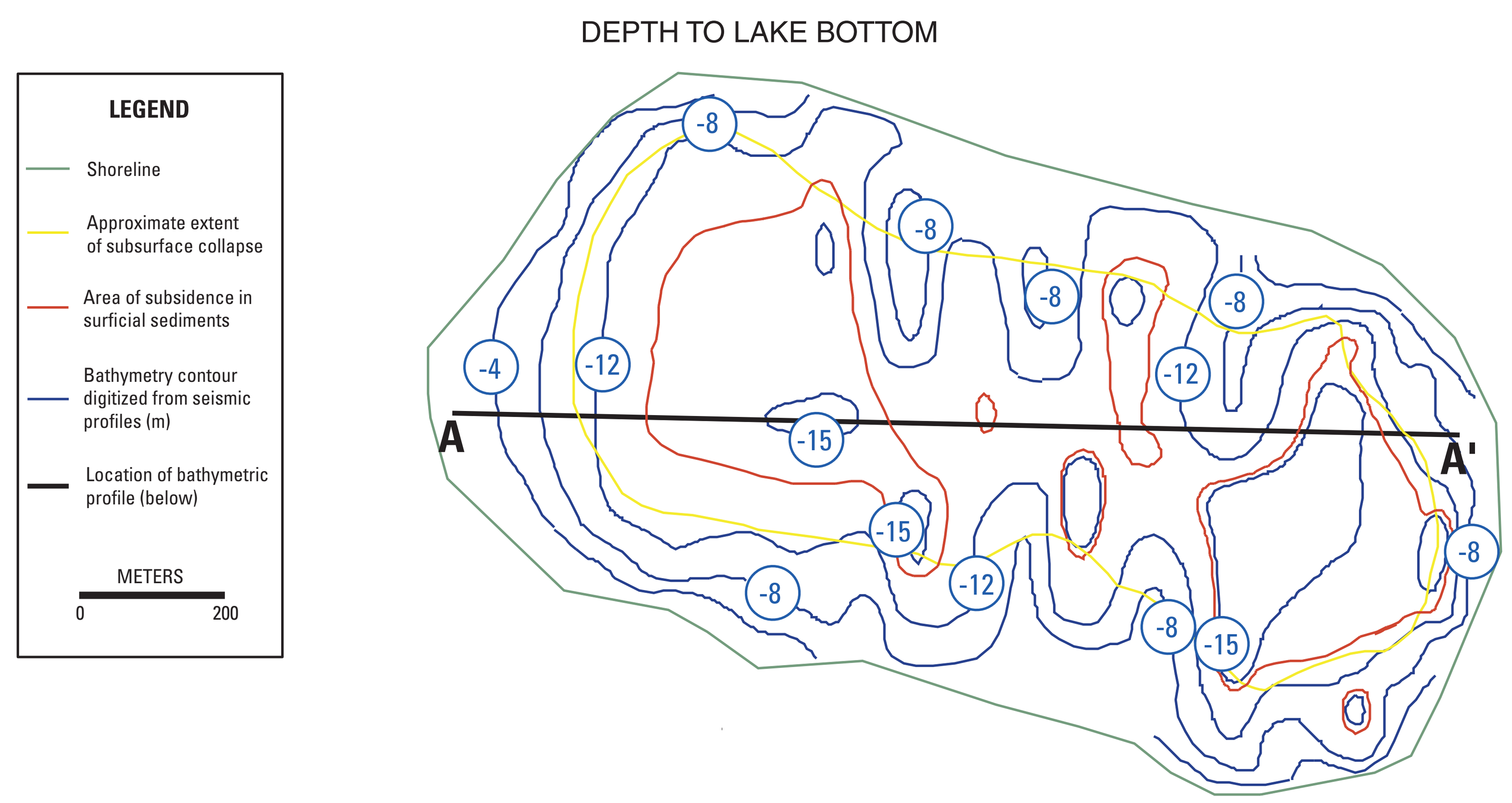
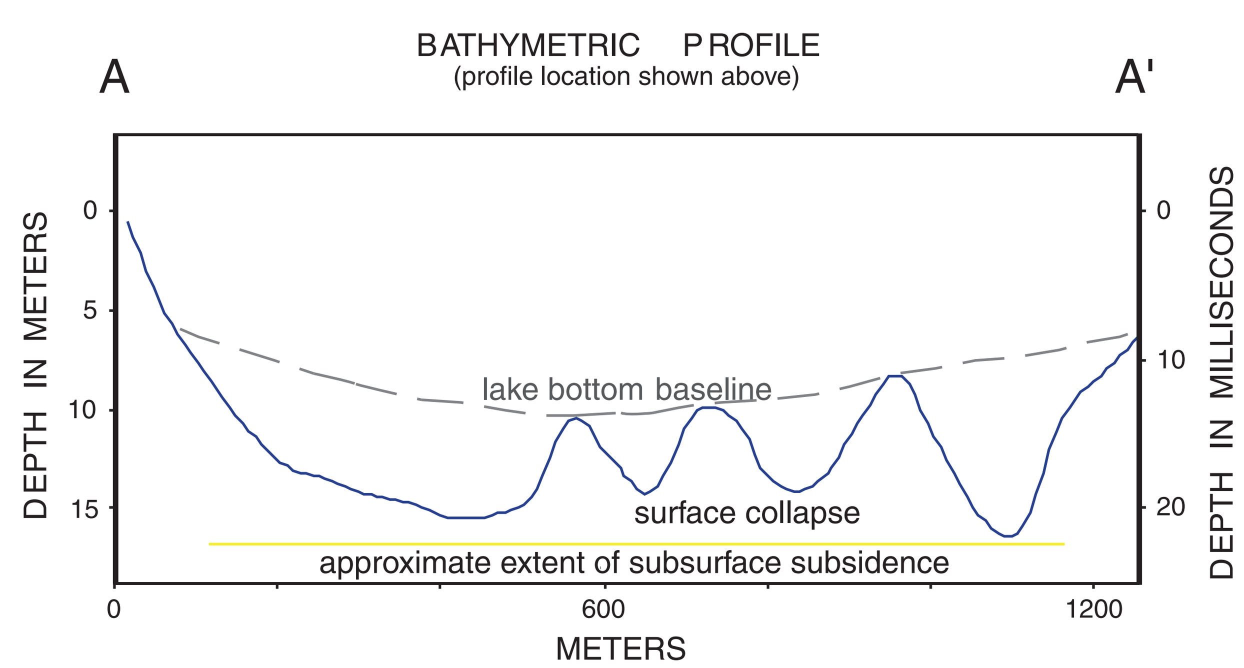
This sheet is Section A page 9 of Open-File Report #00-180 prepared by the U.S. Geological Survey Center for Coastal Geology and the St. Johns River Water Management District. For a detailed description of methods, site locations, explanation of regional geology, physiography, karst development and karst features identified by seismic profiling, refer to pages 1 through 7.

BLUE POND
CLAY COUNTY, FLORIDA







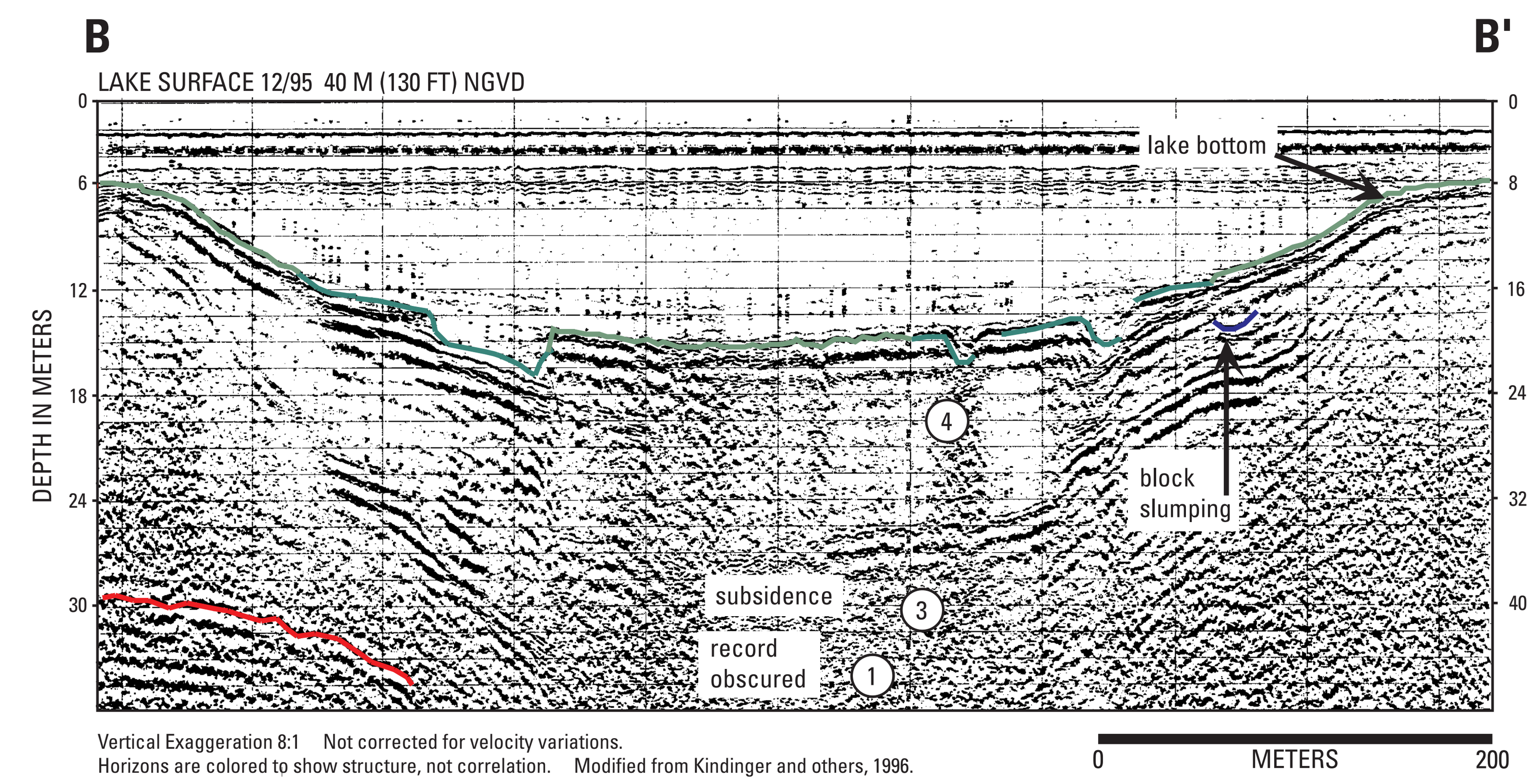


Introduction

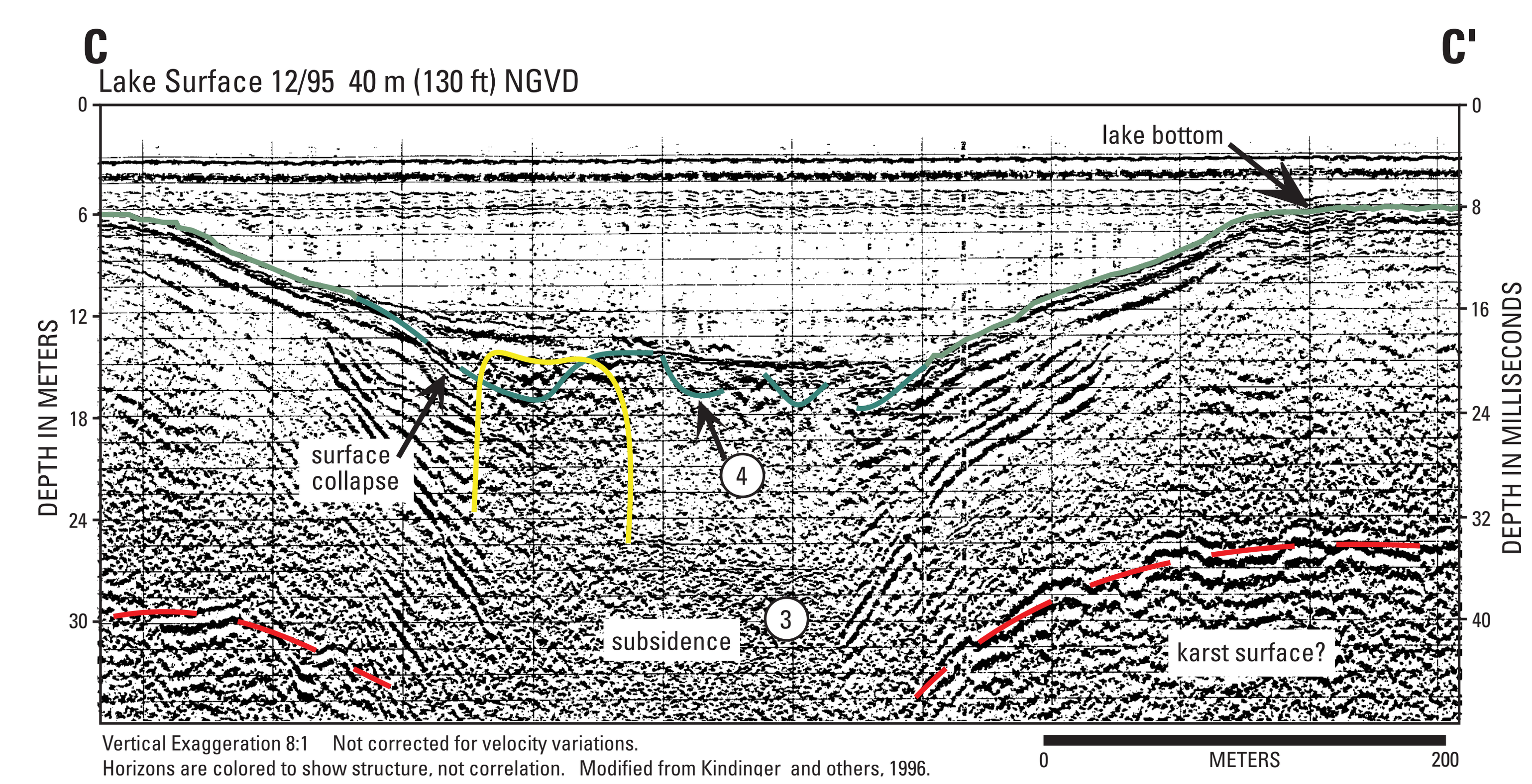
Blue Pond is located in western Clay County. The lake borders on the Volusia Ridge Sets of the Eastern Flatwood District and the Interlachen Sand Hills of the Central Lakes District. Lake level at the time of the seismic survey was about 40 m (130 ft) NGVD. Blue Pond is oval shaped, approximately 750 x 350 meters with a perimeter of 4.6 km and a surface area of 1.3 km^2. Average water depth during the survey was about 9 m (30 ft). Blue Pond is connected surficially to Sand Hill Lake to the south.

Geologic Characterization

Blue Pond appears to be a single large depression, (see seismic profiles B-B' and C-C'). Many lakes surveyed in this area all appear to have this characteristic (i.e. single basin, single sink), whereas others occur as a complex of depressions. The steep sides of these lakes infer they are young and in the active subsidence or collapse phase (Kindinger and others, 1998). At depth, a strong subsurface reflective horizon at about 30 m below lake level (C-C') is interpreted to be the karst surface. However, interpretations of gamma log profiles to the south put the top of the Ocala Limestone at nearly 60 meters below the lake surface. Johnson (1986) a report that the top of the Marks Head Formation at this depth in a well approximately 4.8 km (3 miles) north of the lake. The Marks Head Formation is part of the Hawthorn Group and is characterized as interbedded dolomite, sand and clay. This horizon is collapsed throughout most of the lake as shown in yellow in the bathymetry map below. The subsurface collapse has created general surface subsidence, as well as slumping of the overburden into the depression (B-B'). Smaller areas of surface collapse are evident at the lake bottom (green line, C-C'). The smaller collapse structures may be a result of accommodation during subsidence, or solution features created by water movement. These surface breaches probably provide pathways for aquifer recharge from the surface waters. The areas of surface collapse have been mapped in red in the contour plot (A-A'). The profile below the contour plot (A-A') shows the relationship between the lake bottom, the surface features and the subsurface collapse. Most of the profiles from the survey are obscured by acoustic noise, which masks returns from structure within the depression. The noise and multiples appear to be related to the shape of the seismic lake which produces ringing in the acoustic return. This signature is relatively common (Type 1) and can be compared with similar seismic returns seen in other lakes in the study area.



Vertical Exaggeration 8:1 Not corrected for velocity variations.
Horizons are colored to show structure, not correlation. Modified from Kindinger and others, 1996.



Vertical Exaggeration 8:1 Not corrected for velocity variations.
Horizons are colored to show structure, not correlation. Modified from Kindinger and others, 1996.

Subsurface Characterizations of Selected Water Bodies in the St. Johns River Water Management District, Northeast Florida

Jack L. Kindinger[1], Jeffrey B. Davis[2], and James G. Flocks[1]
2000

[1] Center for Coastal Geology and Regional Marine Studies
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Palatka, Florida 32178

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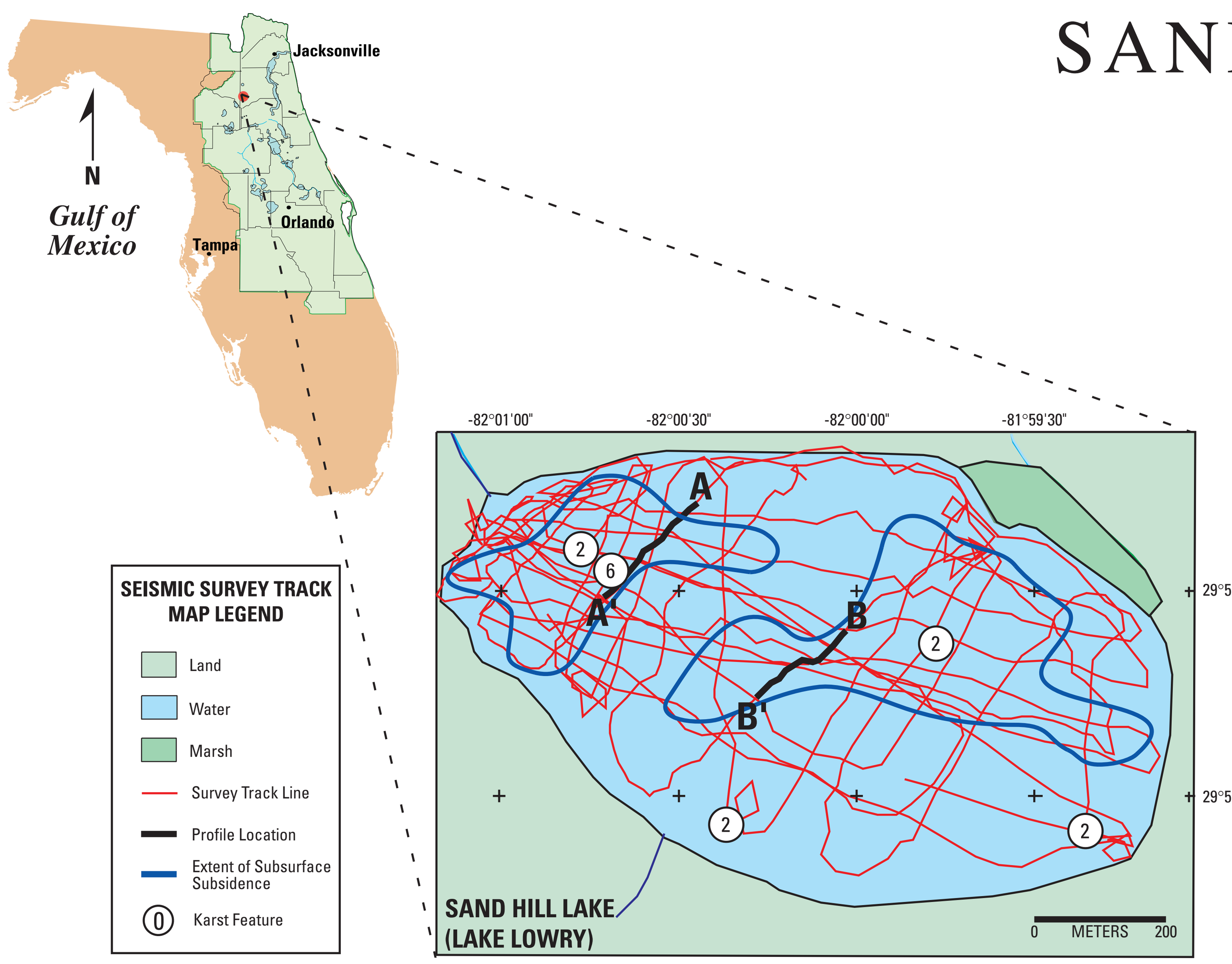
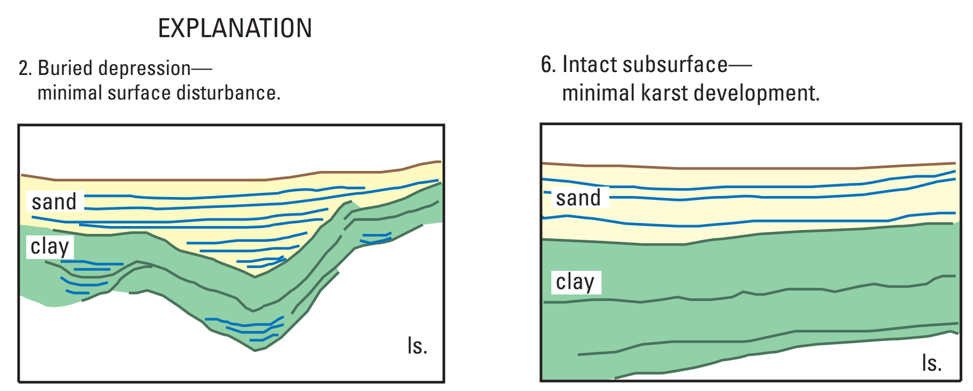
SAND HILL LAKE (LAKE LOWRY)

CLAY COUNTY, FLORIDA





Introduction

Sand Hill Lake (also known as Lake Lowry), located in Clay County (approximate latitude 29°50'22"N and longitude 81°0'12"), is a semicircular lake (about 2 by 3 km) with a 32.5 km perimeter and area of 7.6 km2 (See Survey Track Map). This lake, unlike Kingsley Lake (page 9), has buried and implied active subsidence features (Type 2). Like many of the lakes formed by sinkholes, Lake Lowery has a relatively shallow bottom (2-5 meters) from the shore toward the center of the lake and a central part eight to ten meters deep.

Similar to Lakes Magnolia and Kingsley, Lowry is flanked on the west by the Trail Ridge deposits. The lake is underlain and surrounded by Citronella sediments (Clark, 1964), which consist of a relatively thick section of unconsolidated to semi-consolidated quartz sands, clayey sands, and gravels. The sediments are unconsolidated and completely saturated, this enhances the filling process when sinkholes collapse or sediment is washed into the lakes by surface runoff. Generally the sands are seismically transparent but clay stringers or cementation may provide reflecting horizons.

Subsurface Characterization

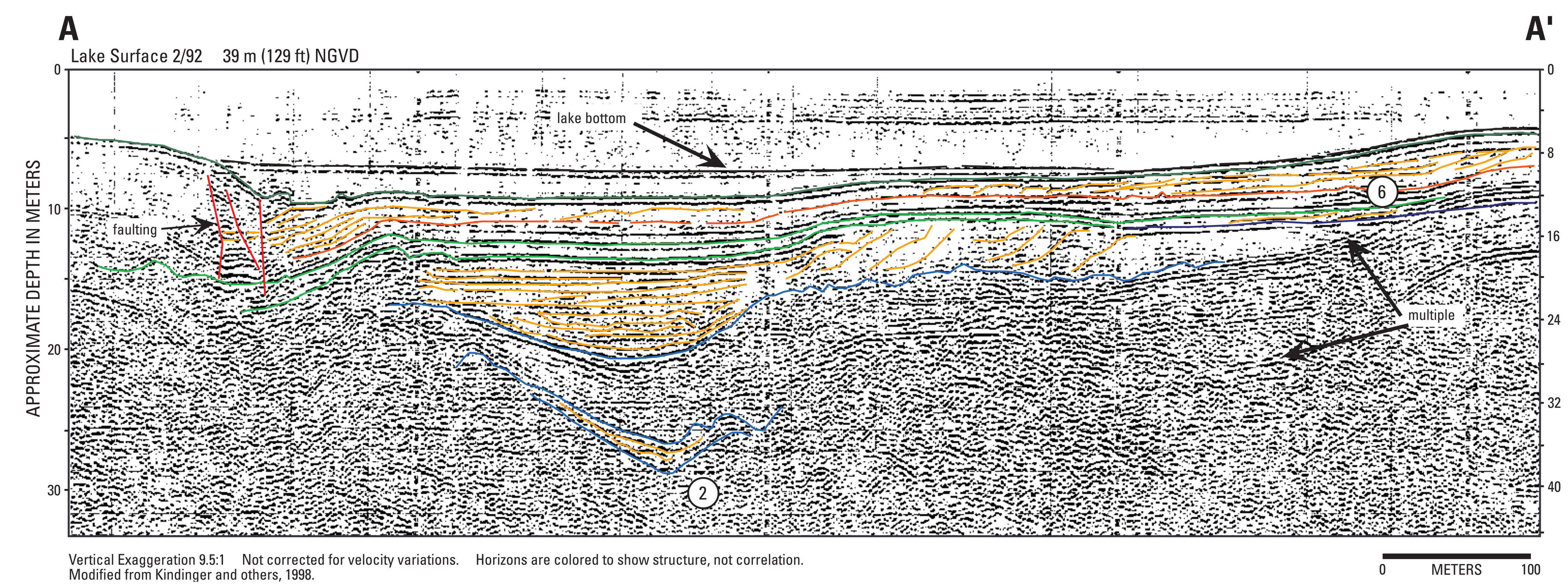
Subsidence features observed from profiles show two areas identified as large (1000 m) subsidence sinkholes (See Survey Track Map). One forms the northwest section of the lake and the other is in the southeast area. Profile A-A' illustrates a large combined subsidence feature that includes buried and active subsidence (Type 2). This cross section shows a variety of depositional fills including cross bedding and onlapping fill. Also found in each profile (Profiles A-A', B-B') is the characteristic pattern of fill and subsidence that indicates rapid subsidence activity and hiatus with slow deposition of sediment. Each of the sinkholes may have developed independently and coalesced over time. Lake Lowry has many of the same characteristic cover-subsidence characteristics found in Orange Lake, but they are much larger.

A ground water well located on the northwest shore of Lake Lowry is used to monitor the Floridan aquifer, indentified as well C-0439 on Cross Section A-A' (Index Map A, page 8). The natural gamma log of the well indicates the top of the Floridan aquifer is at -57 feet NGVD or approximately 80 ms on the seismic data. The majority of resolvable data on the seismic profile is above 20 ms and so it cannot be determined if the entire confining unit is breached.

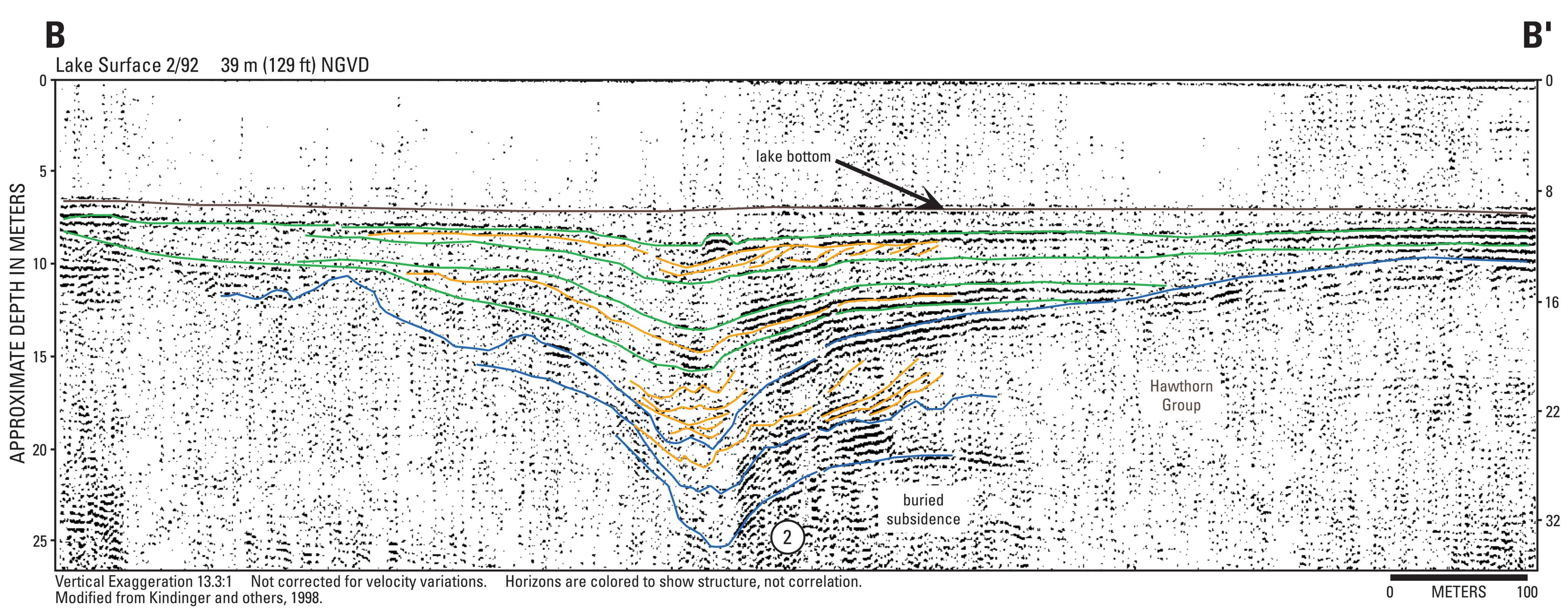
The mechanical processes that result in lake development are a slumping or subsidence of underlying clastics or carbonates, and a clustering of sinkholes. Two factors that effect lake formation are karst development in host limestone and thickness of unconsolidated overburden (the confining unit). If the host limestone is highly karstic then the probability of collapse is greater than in areas of less karst. Thickness of overburden is the other controlling factor. A slight surface depression will form over a collapse in an area with a thick unconsolidated overburden (ten's to 100 m). As the unconsolidated material fills the depression left by solution, there is little or no accommodation space for lake formation. A larger surface depression will form if the same collapse were to occur with two meters of overburden, thereby creating accommodation space for lake formation.

Sinkhole lakes can be delineated into a progressive sequence of lake formation based on geomorphic types (Sinkhole Evolution, page 5). The progression begins with the initial collapse, forming a sinkhole. The depression may be open or, if a portion of the depression is below the water table, it may be filled with water. As sediments are washed into the depression, the sinkhole becomes plugged. The process continues until the sinkhole is buried.

Lake Lowry is in the transitional phase (middle age), when the lake becomes partially or completely plugged, the lake begins to develop a shallower and flatter bottom. During this phase the plug may be flushed into the karst (faults, fractures, and/or solution pipes), allowing the sinkhole to reactivate and revert to an active subsidence phase, described above as subsidence activity and hiatus with slow sediment depostion (Profile A-A' and B-B'). This may occur several times until sediment accumulates faster than dissolution of the underlying limestone.



Vertical Exaggeration 9.5:1 Not corrected for velocity variations. Horizons are colored to show structure, not correlation.
Modified from Kindinger and others, 1998.



Vertical Exaggeration 13.3:1 Not corrected for velocity variations. Horizons are colored to show structure, not correlation.
Modified from Kindinger and others, 1998.

Subsurface Characterizations of Selected Water Bodies in the St. Johns River Water Management District, Northeast Florida

Jack L. Kindinger[1], Jeffrey B. Davis[2], and James G. Flocks[1]
2000

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Palatka, Florida 32178

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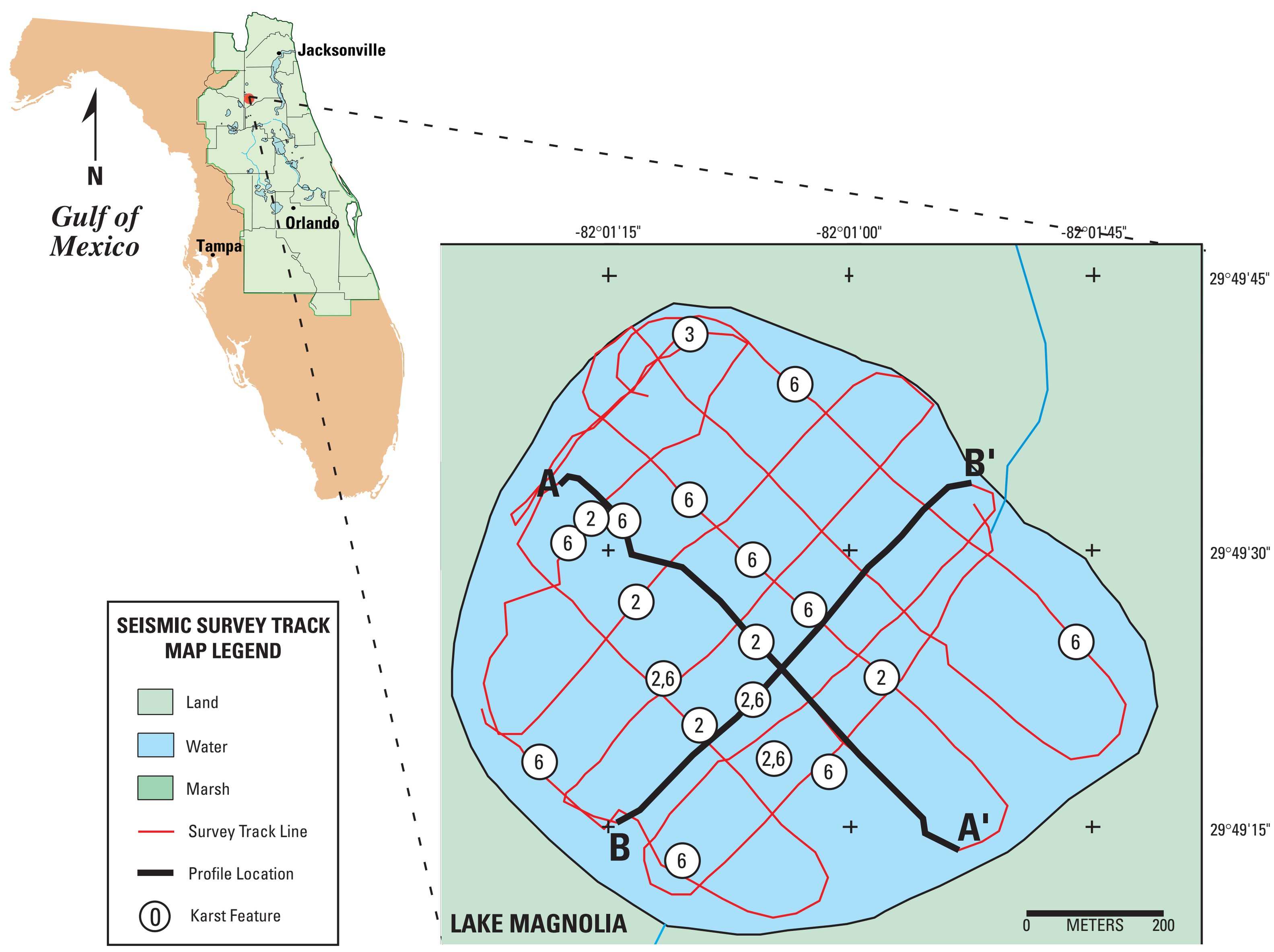
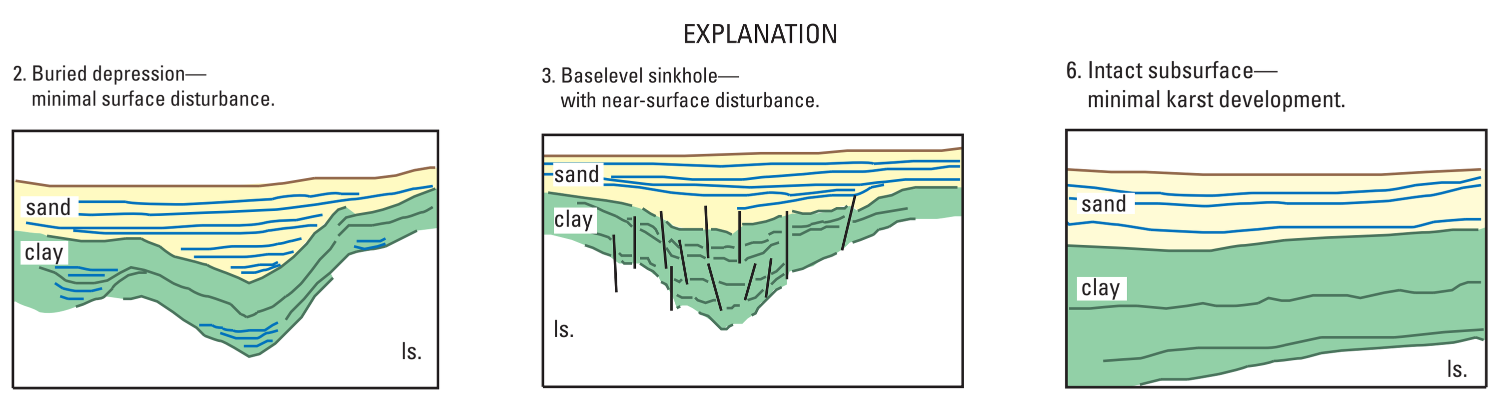
LAKE MAGNOLIA
CLAY COUNTY, FLORIDA





Introduction

Lake Magnolia is on the southwest boundary of Clay County, Florida and is located in the Interlachen Sand Hills of the Central Lakes District. Lake level at the time of the seismic survey was 38 m (125 ft) NGVD. Lake Magnolia is oval shaped approximately 1.1 x 0.9 km with a perimeter of 3.2 km and surface area 0.8 km2. Average water depth during the survey was 6 to 7 m (19 to 23 ft). The lake is bordered by woodlands. Lake Magnolia is flanked on the west by the Trail Ridge deposits with Citronella deposits elsewhere. The lake is underlain by Citronella sediments (Clark, 1964) which consist of a relatively thick section of unconsolidated to semi-consolidated quartz sands, clayey sands, and gravels. The Trail Ridge sands are above an elevation of 45 m (149 ft) and are mined commercially for heavy minerals used in paints and abrasives. The sediments are unconsolidated and completely saturated, this enhances the filling process when sinkholes collapse or sediment is washed into the lakes by surface runoff. Generally the sands are seismically transparent but clay stringers or cementation may provide reflecting horizons.

Subsurface Characterization

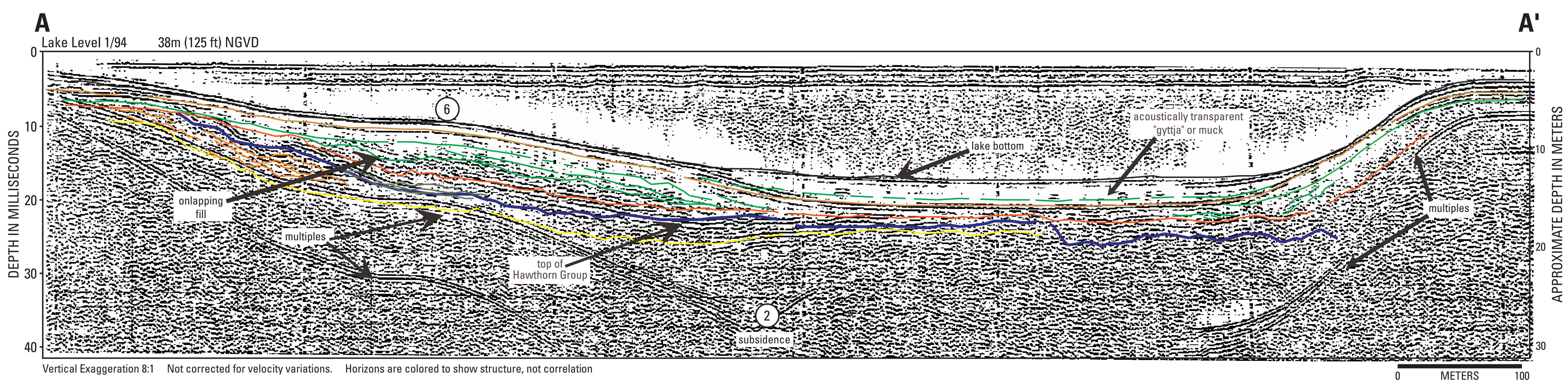
Profile A-A' shows the basic character of Lake Magnolia, which appears to be comprised of a single depression. The characteristics of this lake are very similar to Kingsley Lake, Blue Pond and several other lakes in the region. The subbottom was disturbed during the subsidence then covered and infilled similar to Types 2 and 6 karst features described on page 6. In the northwestern corner of the lake is a buried block that has rotated and slumped into the sink (Type 3 karst feature).

The main depression is continuous across the lake in both of the predominant traverse directions. Profile A-A' from Lake Magnolia shows a singular subsidence that is shallow nearshore with onlapping fill on the northwest flank. The central portion of the lake has an undisturbed surficial layer that is acoustically transparent and is possibly composed of high-organic sediments termed "gyttja". The undisturbed nature of the surficial sediments implies that there has been little to no recent subsidence. In this case, as the sink became plugged, the lake developed a shallower and flatter bottom due to the infilling associated with runoff and eolian processes.

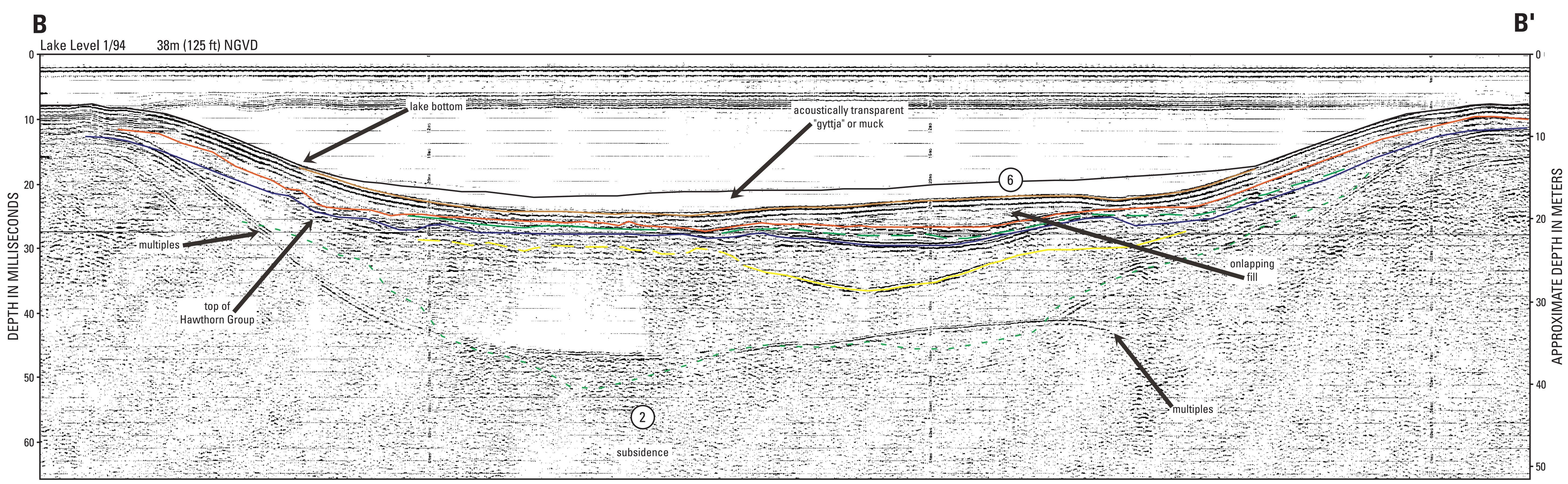
Correlation of gamma logs from the boreholes to contacts seen in the seismic records is tenuous. Log C-0451 is from a well approximately 1 km west of Lake Magnolia and Log C-0439 is from a well located on the northwest shore of Sand Hill Lake (Section A, page 11). The units identified from the gamma logs are the clay confining units of the Hawthorn Group and the top of the Ocala Limestone. The blue horizon in Profile A-A' has been interpreted as a reflection near the top of the Hawthorn Group.

Sinkhole lakes can be delineated into a progressive sequence of lake formation based on geomorphic types (page 5). The progression begins with the initial collapse, forming a sinkhole. The depression may be open or, if a portion of the depression is below the water table, it may be filled with water. As sediments are washed into the depression, the sinkhole becomes plugged. The process continues until the sinkhole is buried.

Lake Magnolia is used as the type description for transitional phase or middle-age lakes. When the lake becomes partially or completely plugged, the lake begins to develop a shallower and flatter bottom. During this phase, the plug may be flushed into the karst (fractures and solution pipes), allowing the sinkhole to reactivate and revert to an active subsidence phase. This may occur several times until sediment accumulates faster than dissolution of the underlying limestone.



Vertical Exaggeration 8:1 Not corrected for velocity variations. Horizons are colored to show structure, not correlation



Vertical Exaggeration 5:1 Not corrected for velocity variations. Horizons are colored to show structure, not correlation.
Modified from Kindinger and others, 1998.

Subsurface Characterizations of Selected Water Bodies in the St. Johns River Water Management District, Northeast Florida

Jack L. Kindinger[1], Jeffrey B. Davis[2], and James G. Flocks[1]
2000

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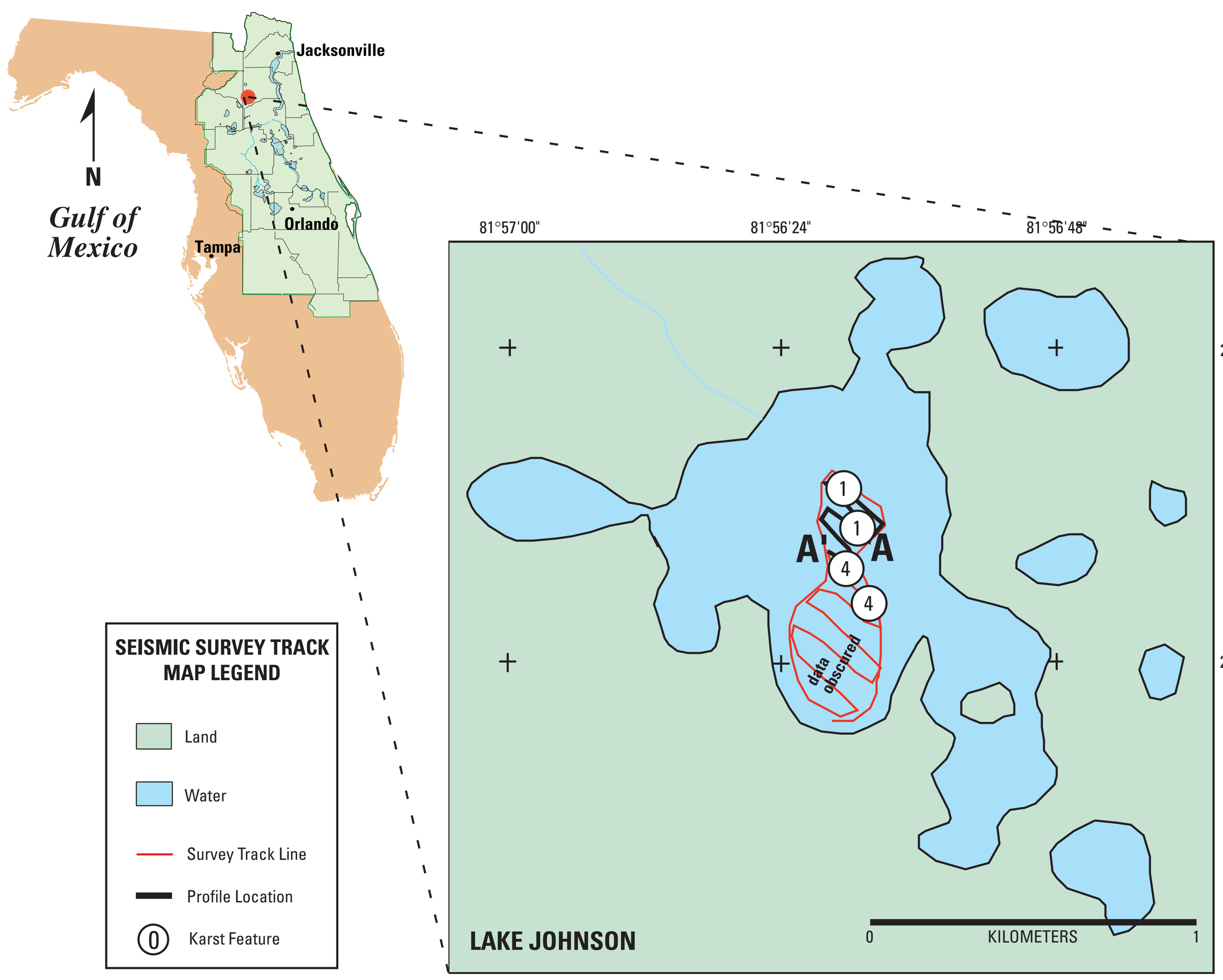
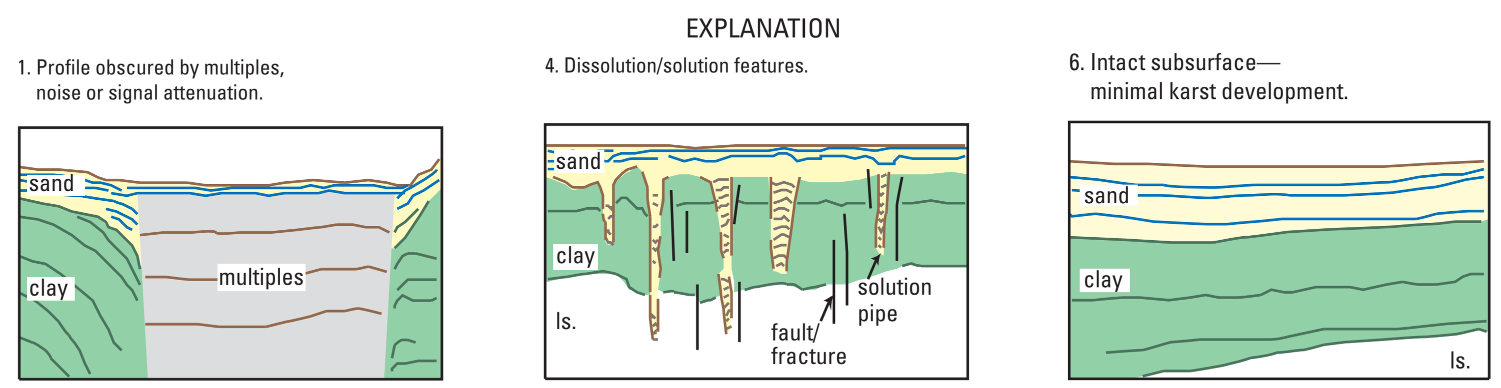
LAKE JOHNSON
CLAY COUNTY, FLORIDA





Introduction

Lake Johnson lies within the Central Lake District physiographic province. It is within the Interlachen Sand Hills subdistrict. The lake is adjacent to the Trail Ridge Sands which is a paleodune ridge that extends north into Georgia. This region includes the largest number of cover collapse sinkholes and provides direct recharge to the underlying Floridan aquifer system. Vegetation that includes longleaf pine and turkey oak is prevalent. Internal drainage through the sinkhole lakes has limited the formation of streams except during periods of high rainfall.

The surficial sands provide storage for rainfall and recharge to the lakes during high water-table conditions. The potentiometric surface of the Floridan aquifer is lower than the lake so a continual downward gradient exists and provides the mechanism for recharge. Pathways for recharge exist where the thick clay and sandy clay units within the Hawthorn Group are breached by collapse sinkholes.

The unique physiography of the region can be seen in the hillshade view presented on Index Map A, page 8. The landscape is dotted with lakes that are incised into the surrounding sand hills. Large, flat bottom prairies, such as Levys Prairie in the southwest section of the Interlachen Sand Hills, attest to the erosional process of internal drainage into sinkholes. There is only a poorly developed surface water drainage system in the sand hills. A well developed drainage can be seen in the northeast section of Index Map A, page 8 in the Penny Farms Uplands. This is related to the thicker section of Hawthorn Group and the lack of sinkhole development.

The irregular shape of Lake Johnson gives it a perimeter of over 10 km, with an area of only 2 km2. Lake level at the time of the survey was 29 m (95 ft) NGVD. Gold Head Branch flows into Lake Johnson from the northwest and there is no surface water outflow points.

Subsurface Characterization

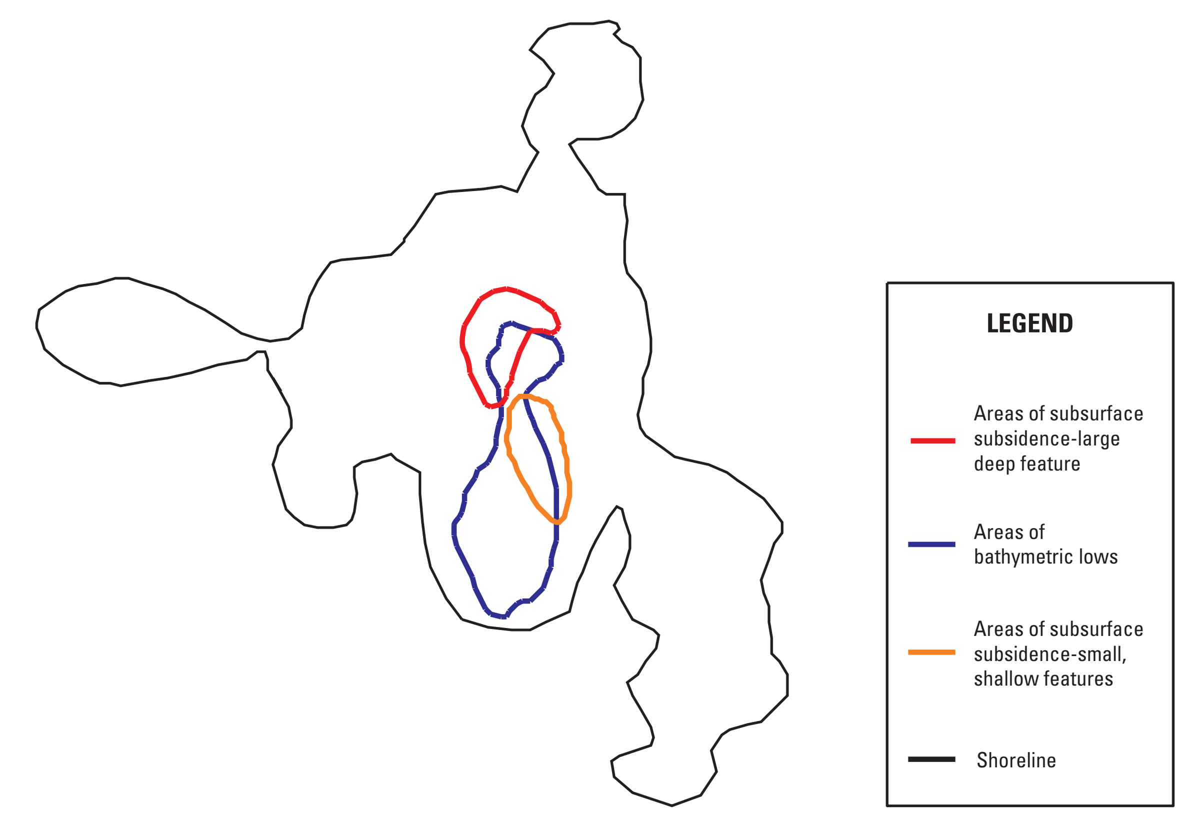
The geologic units present at Lake Johnson are typical of northeast Florida stratigraphy. The surface material consists of Plio-Pleistocene sand hills. The lakes within these hills define the surficial aquifer system of the region. The natural gamma logs from two wells south of Lake Johnson (Index Map A, page 8, wells C-0453 & C-0457) indicate that these sands are present above +28.1 m (90 ft) NGVD on the western side below Lake Johnson and may be missing or only a few feet thick on the eastern section of the lake.

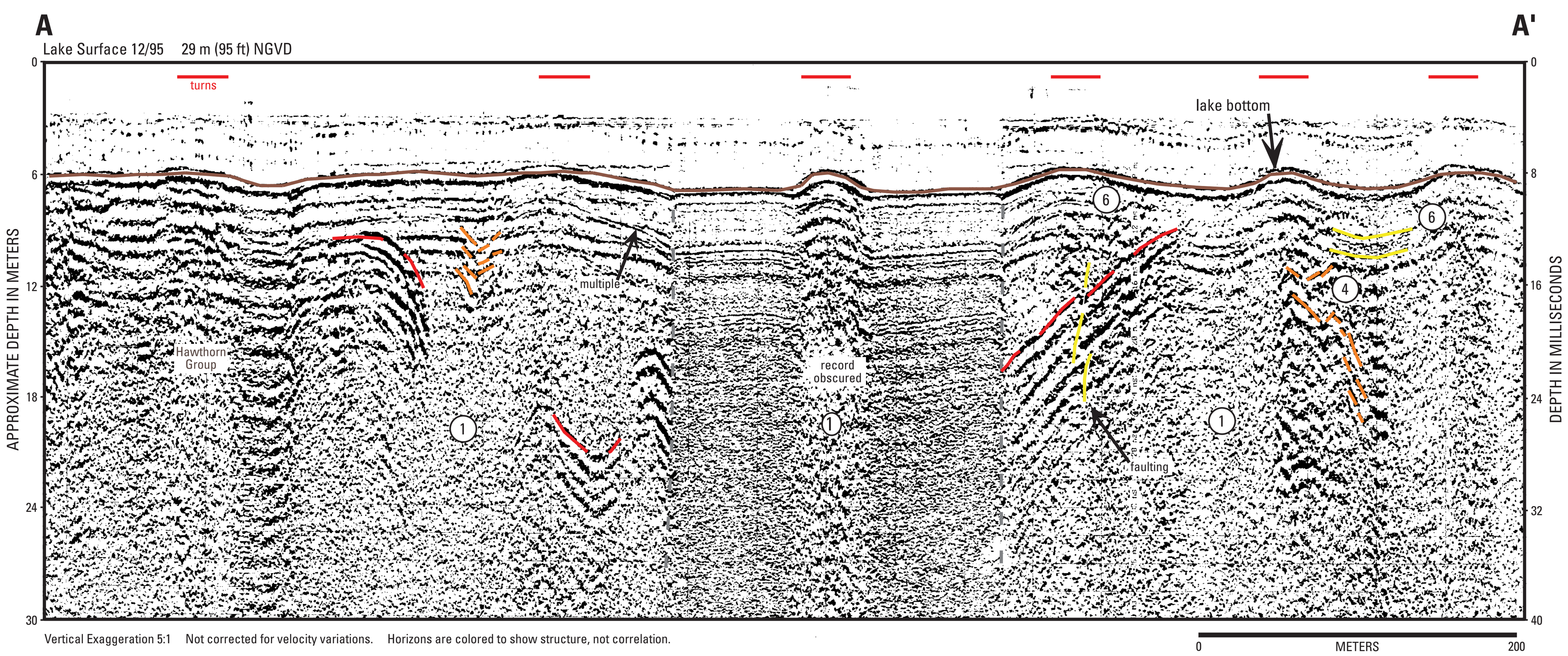
Below the sands, the clay and sandy clay of the Hawthorn Formation can be identified in the gamma logs by the sequence of high peaks between +28.1 m (90 ft) and -21.8 m (-70 ft) NGVD in well C-0453. Most of the imagable area of the seismic profiles is within the Hawthorn Formation. Below -21.8 m (-70 ft), the Eocene carbonates of the Ocala Limestone are identified by the extremely low counts (less than 20 counts per second) on the natural gamma logs. These depths are below the imagable areas of the seismic profiles.

Acoustic data from Lake Johnson is generally poor due in part to a strong lake bottom multiple, signal attenuation and technical difficulties. Parallel, horizontal reflectors are present above 12 ms (8.7 m below lake surface) that may represent in situ and transported Plio-Pleistocene sands (Type 6 feature, seismic profile). Below 12 ms, only "windows" of interpretable data are present. Sections of the data can be resolved to approximately 32 ms (10 m). High angle reflectors suggest collapse of material into a large sink (Type 1 feature, seismic profile) and smaller, concave reflectors that suggest subsidence into smaller sinks or dissolution pipes (Type 4 feature, seismic profile).

Lake Johnson appears to have formed by the coalescing of many collapse sinkholes. After the initial collapse of an individual sinkhole, the sides have eroded into the central portion of the sink, flattening the banks and filling the center. A very steep-sided, deep sink is located near the entrance of the adjacent Gold Head Branch State Park and may represent the younger stages of this process. The area where the seismic profiles were run is relatively flat bottomed and shallow, indicating a more mature feature. Flow into Lake Johnson with no outflow indicates direct recharge to the aquifer.

DISTRIBUTION OF FEATURES
(noted from seismic profiles)





Vertical Exaggeration 5:1 Not corrected for velocity variations. Horizons are colored to show structure, not correlation.

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2000

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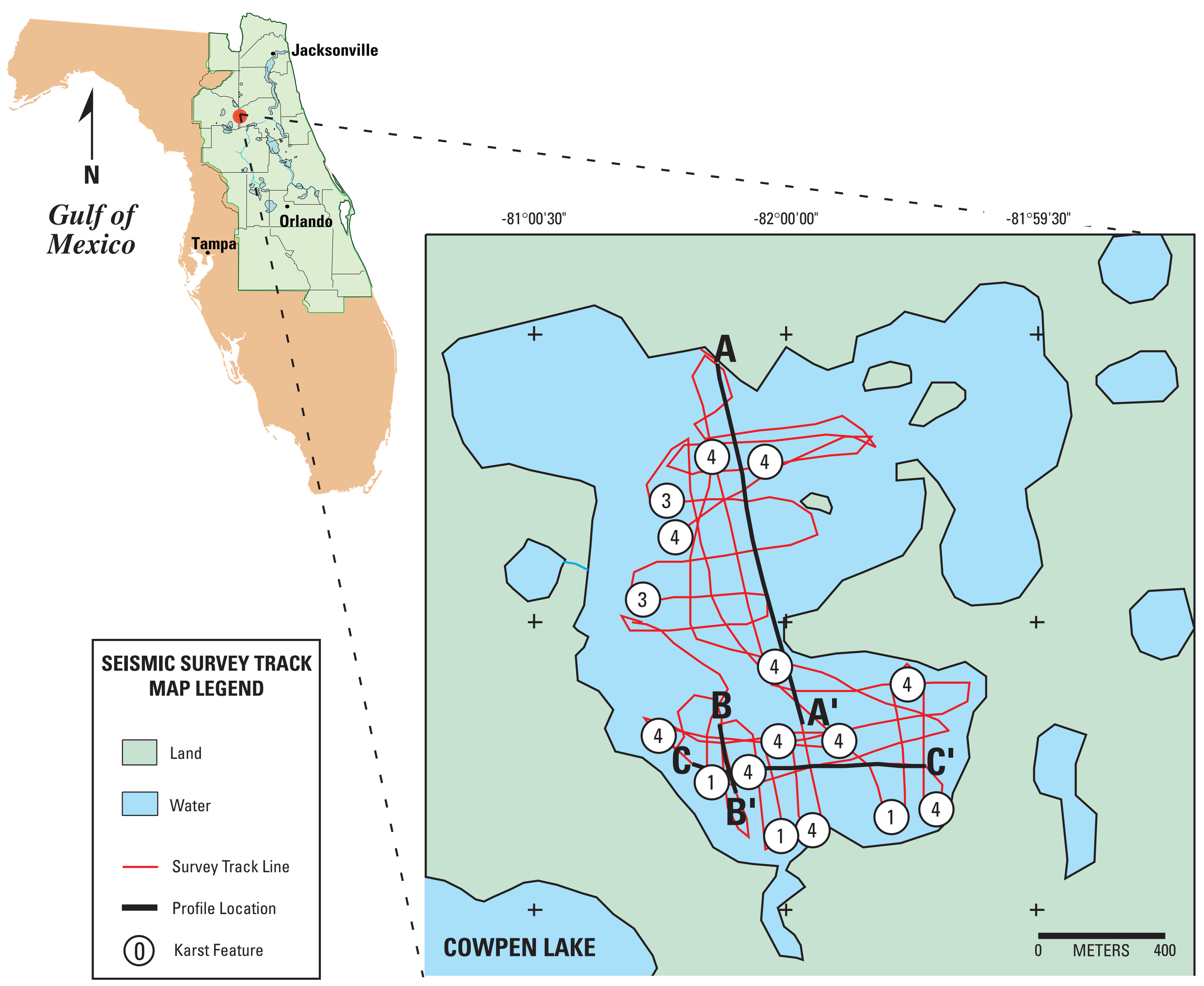
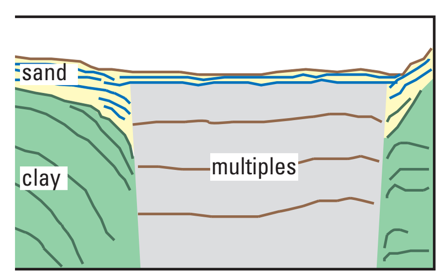
COWPEN LAKE

CLAY COUNTY, FLORIDA

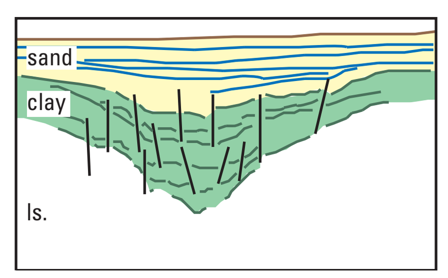


EXPLANATION

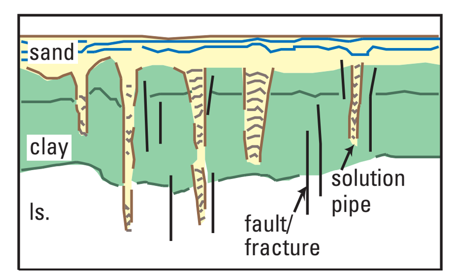
1. Profile obscured by multiples, noise or signal attenuation.



3. Baselevel sinkhole— with near-surface disturbance.



4. Dissolution/solution features.

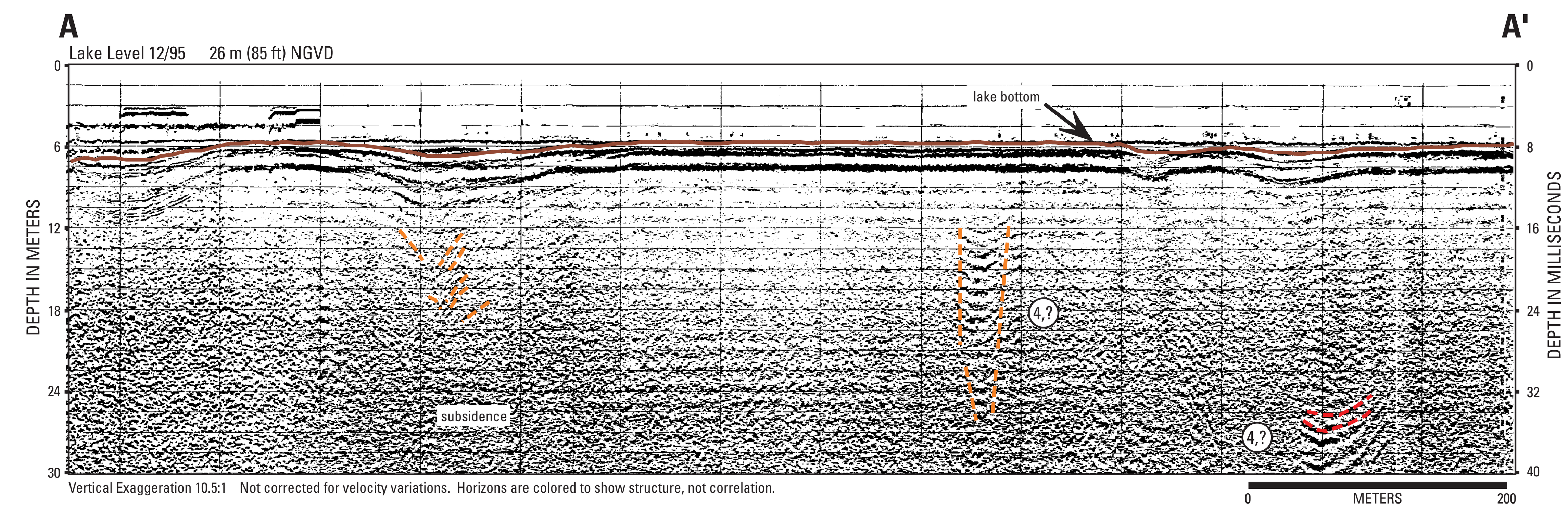


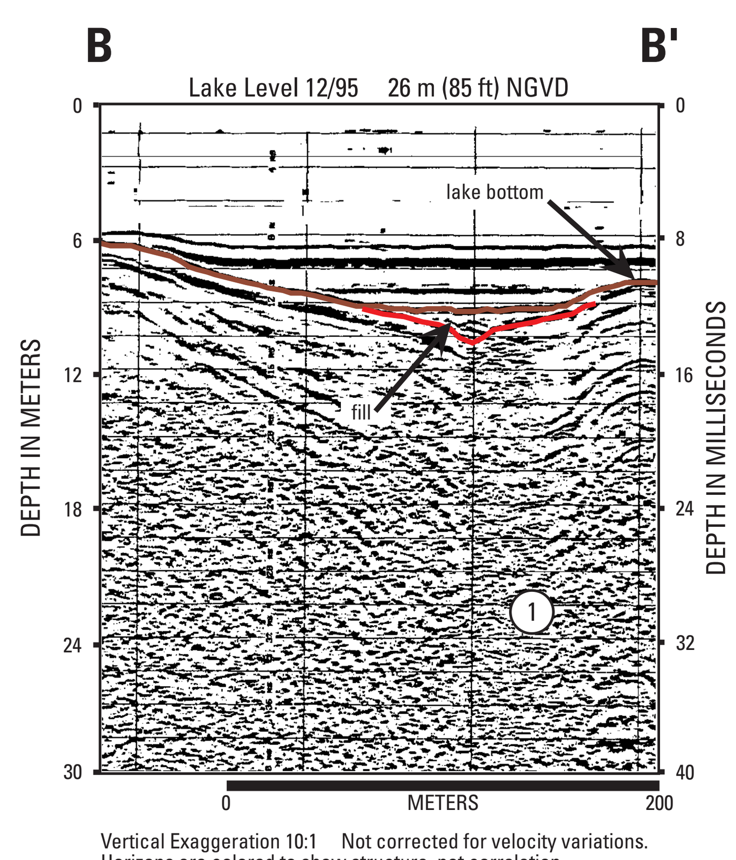
Introduction

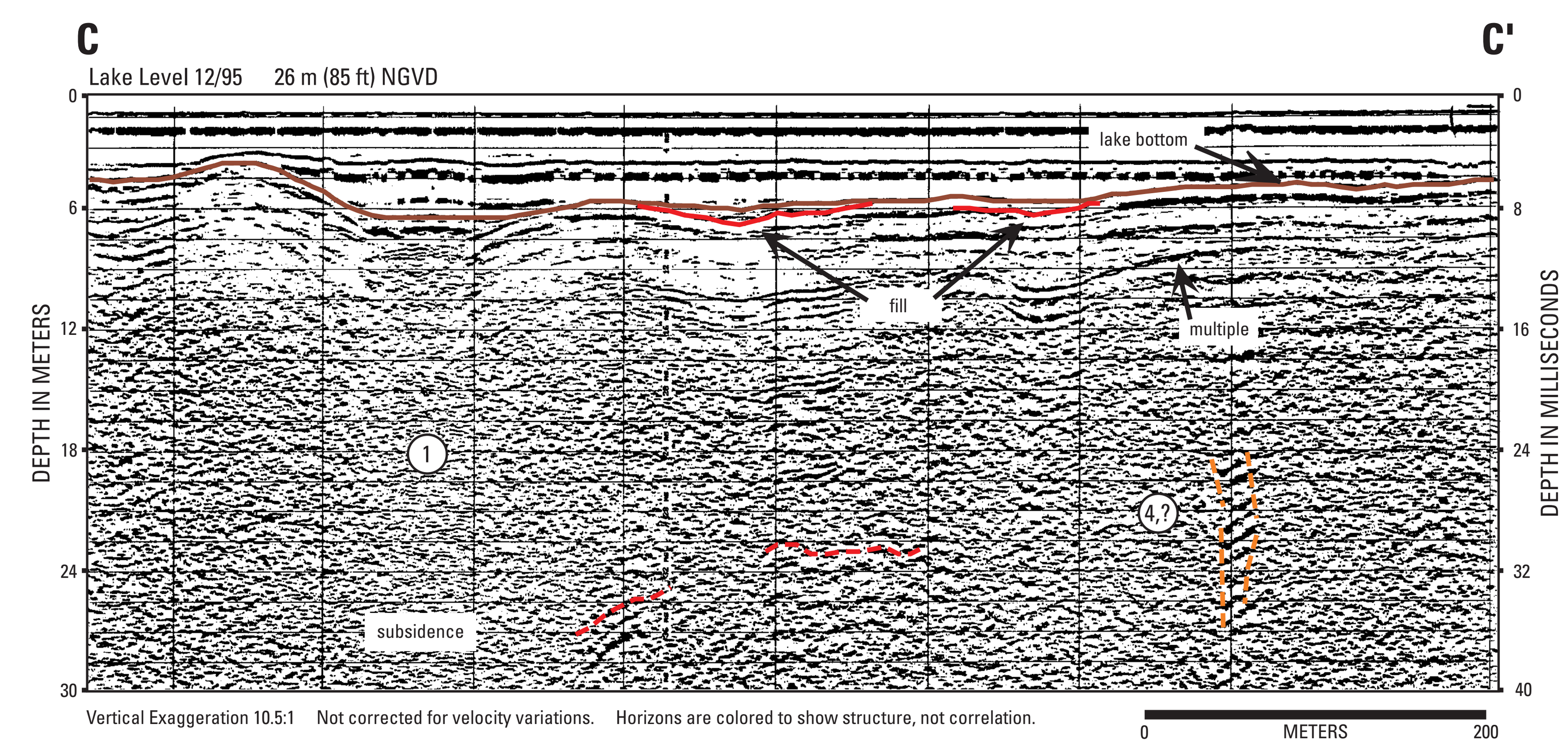
Cowpen Lake is located in western Putnam County, Florida. The lake is located within the Interlachen Sand Hills of the Central Lakes District. The area around the lake is dominated by many small lakes and marshland, particularly Levys Prairie to the north. The lakes and prairies in this region occupy dissolution valleys, where sinkholes coalesce to form small, irregular-shaped lakes. Cowpen's shoreline is very irregular, with a perimeter of 11.5 km and a surface area of 2.8 sq km. Lake level in March of 1995 was 26 m (85 ft) NGVD.

Subsurface Characterization

The acoustic signal in Cowpen Lake as a whole is relatively weak. This is shown in the example profiles (A-A', B-B' and C-C'). Factors which contribute to a noisy or weak acoustical return in the lakes of this study area include proximity of hardbottom (limestone) to the sediment surface, accumulation of organic debris on the lake bottom, shallow water depths and proximity, steepness and irregularity of the shoreline. In Cowpen Lake, the nearby and irregular shoreline could create interference (noise) in the signal, and the marshy area in which it resides could produce organic-rich surficial sediments which dampen the return. As a result, little can be seen in the seismic profiles below about 10-12 m. The lake bottom shows an undulating surface marked by localized subsidence less than tens of meters in width. Accumulations of material is imaged near surface in the bathymetric lows (red lines, profiles B-B' and C-C'). This could represent fill from the surrounding sand hills. In the subsurface, high frequency reflectors occasionally can be seen (orange dashed lines, profiles A-A' and B-B'). These may represent dissolution-type features or disturbed bedding and could indicate breaches in the overburden. The contact between the top of the Hawthorn Group and overlying undifferentiated fill is interpolated to be around 12 m (39 ft) below lake level (see Section A, Index Map). This contact is difficult to detect in the seismic profile because of the signal noise and multiples, but the disturbed bedding at depth would indicate breaches in the confining Hawthorn Group. The top of the Ocala Limestone is estimated to be around 20-30 m (67-98 ft) below lake level (~0 ft NGVD), but is obscured in the profiles. Solution of the limestone at depth could produce dissolution type features which transport material downwards and can create the smaller subsidence areas seen at the surface.







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2000

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[2] St. Johns River Water Management District
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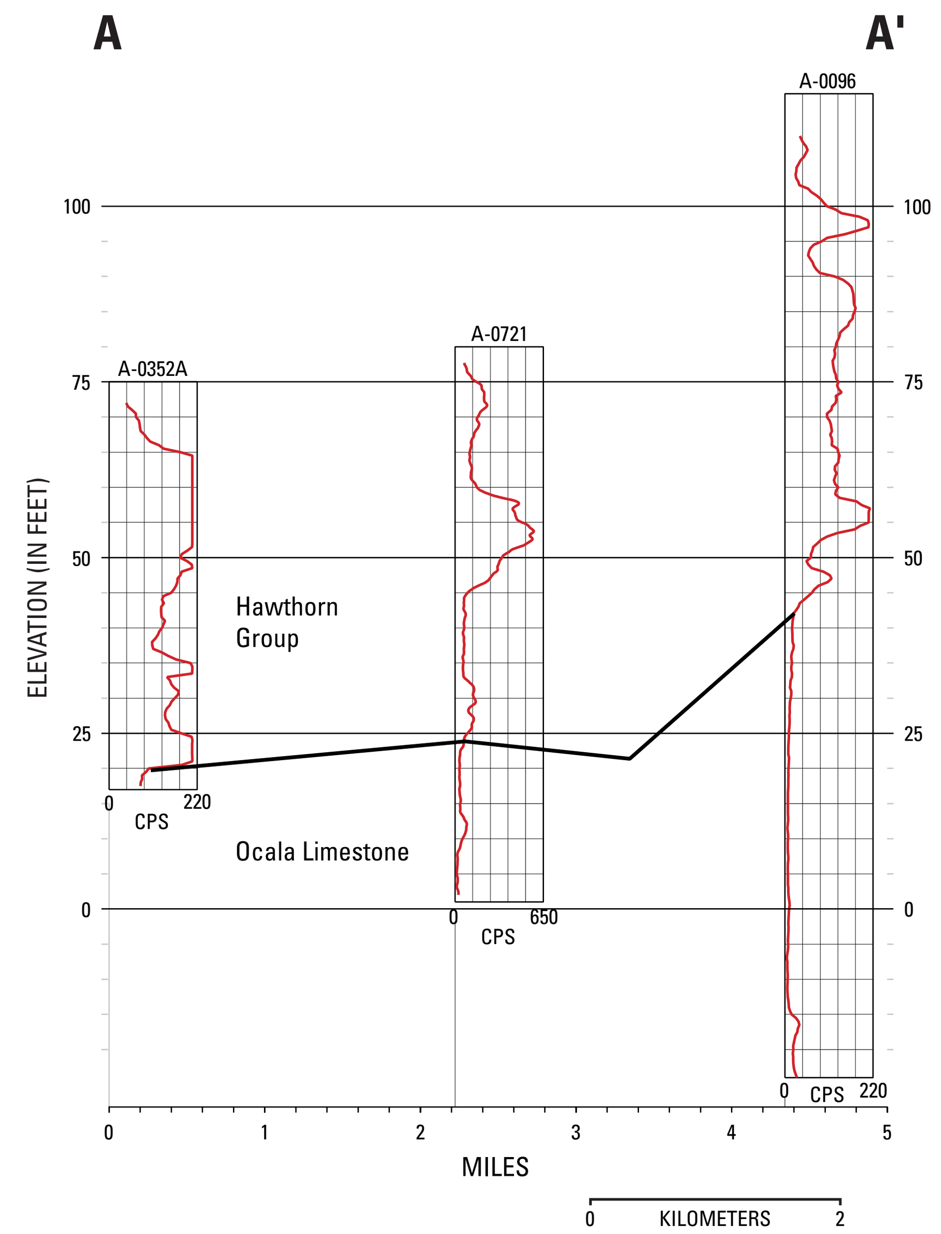
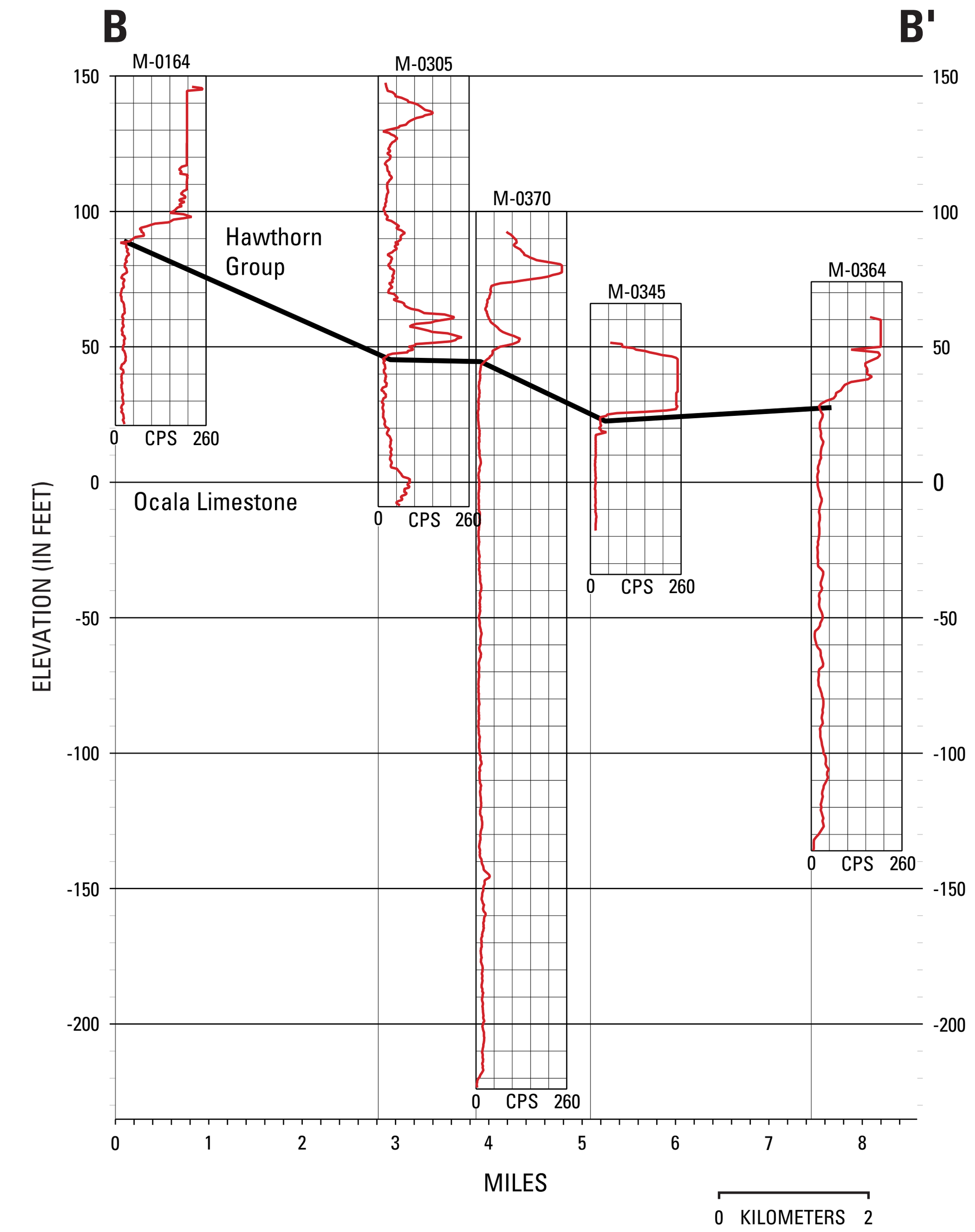
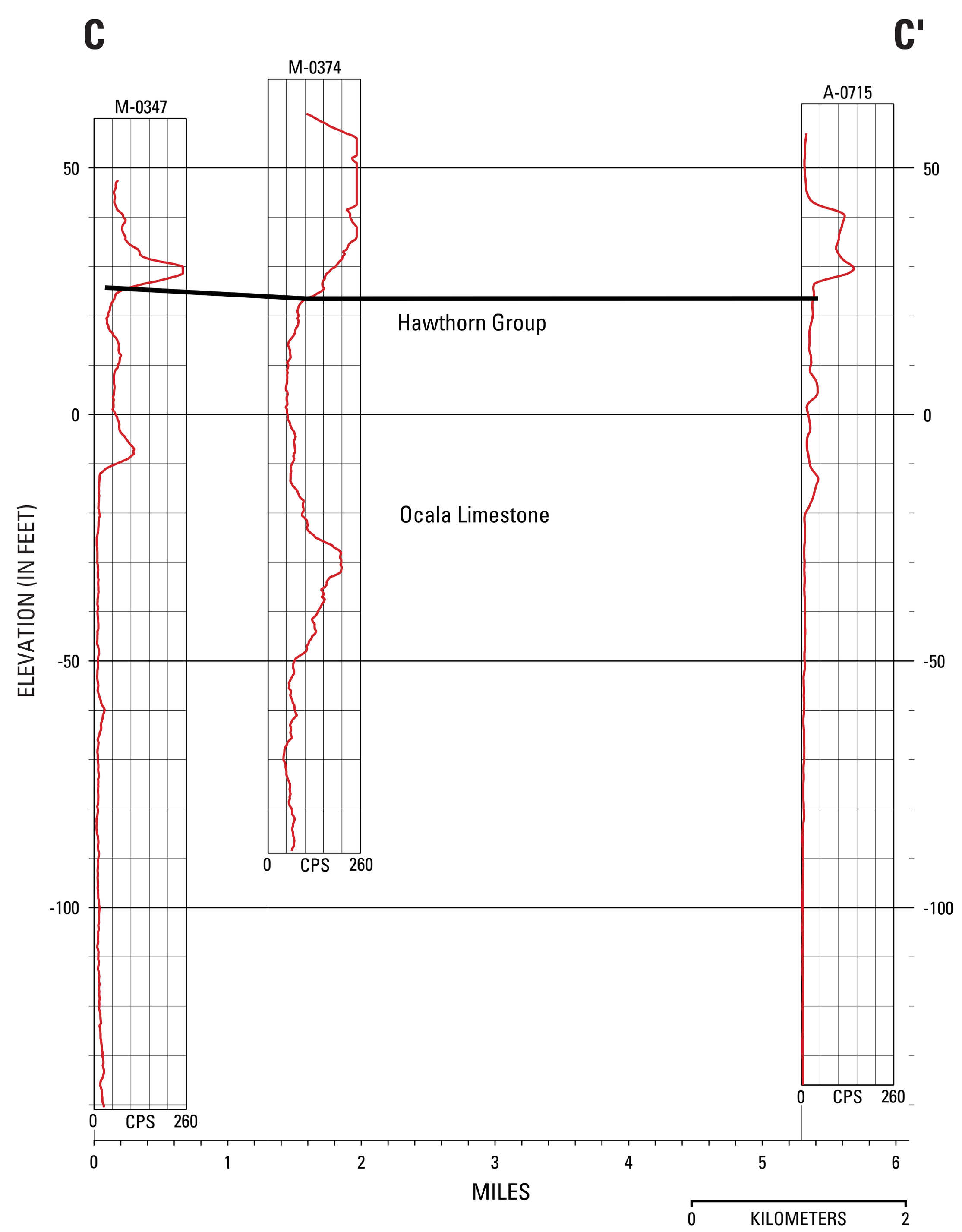
Prepared for the
ST. JOHNS RIVER WATER MANAGEMENT DISTRICT COOPERATIVE STUDY

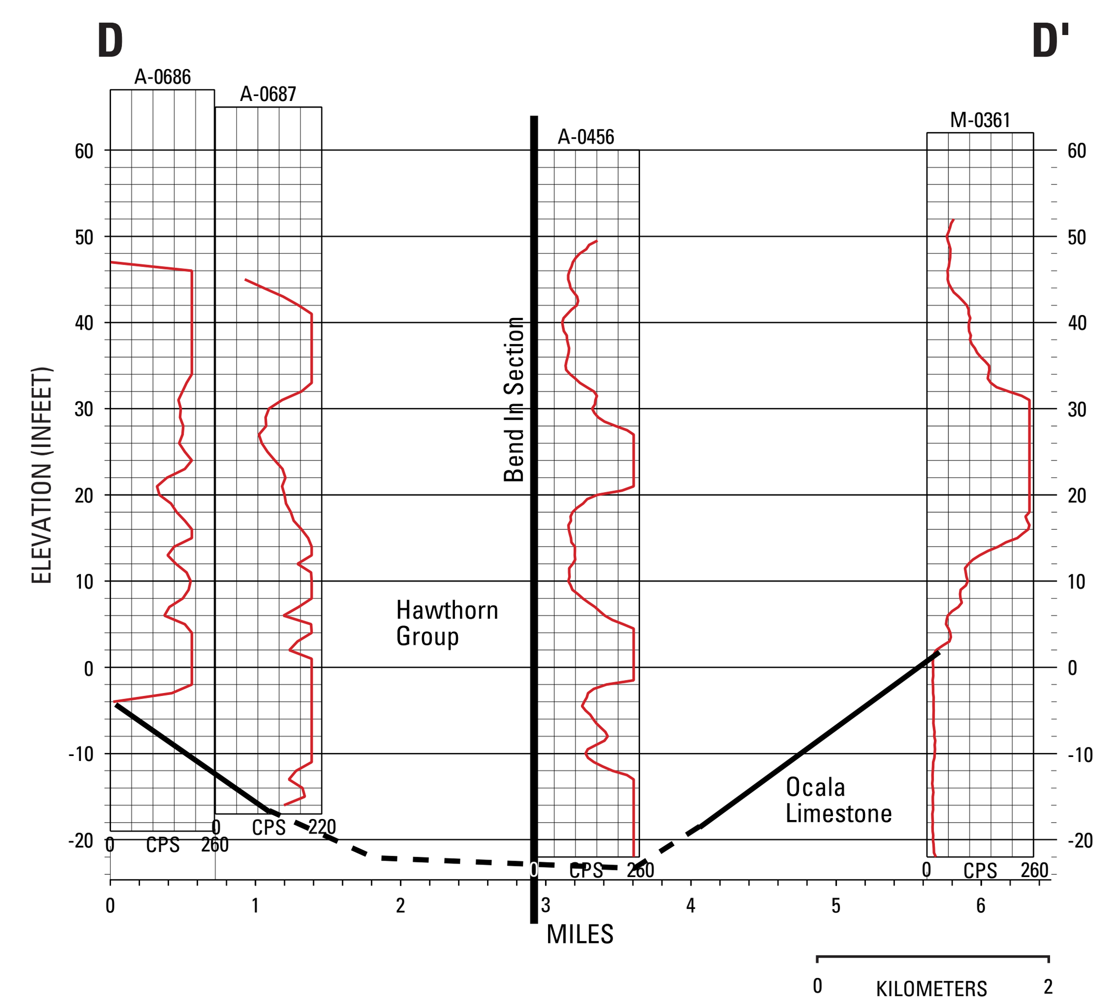
INDEX MAP AND GAMMA LOG

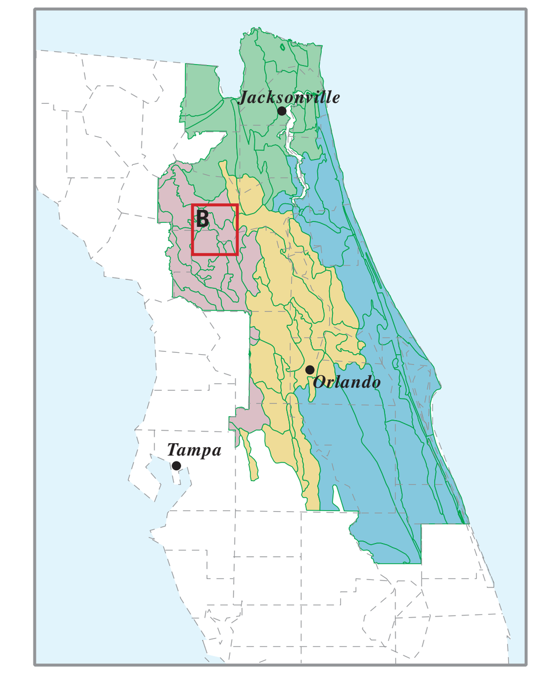
CROSS-SECTIONS, SECTION B



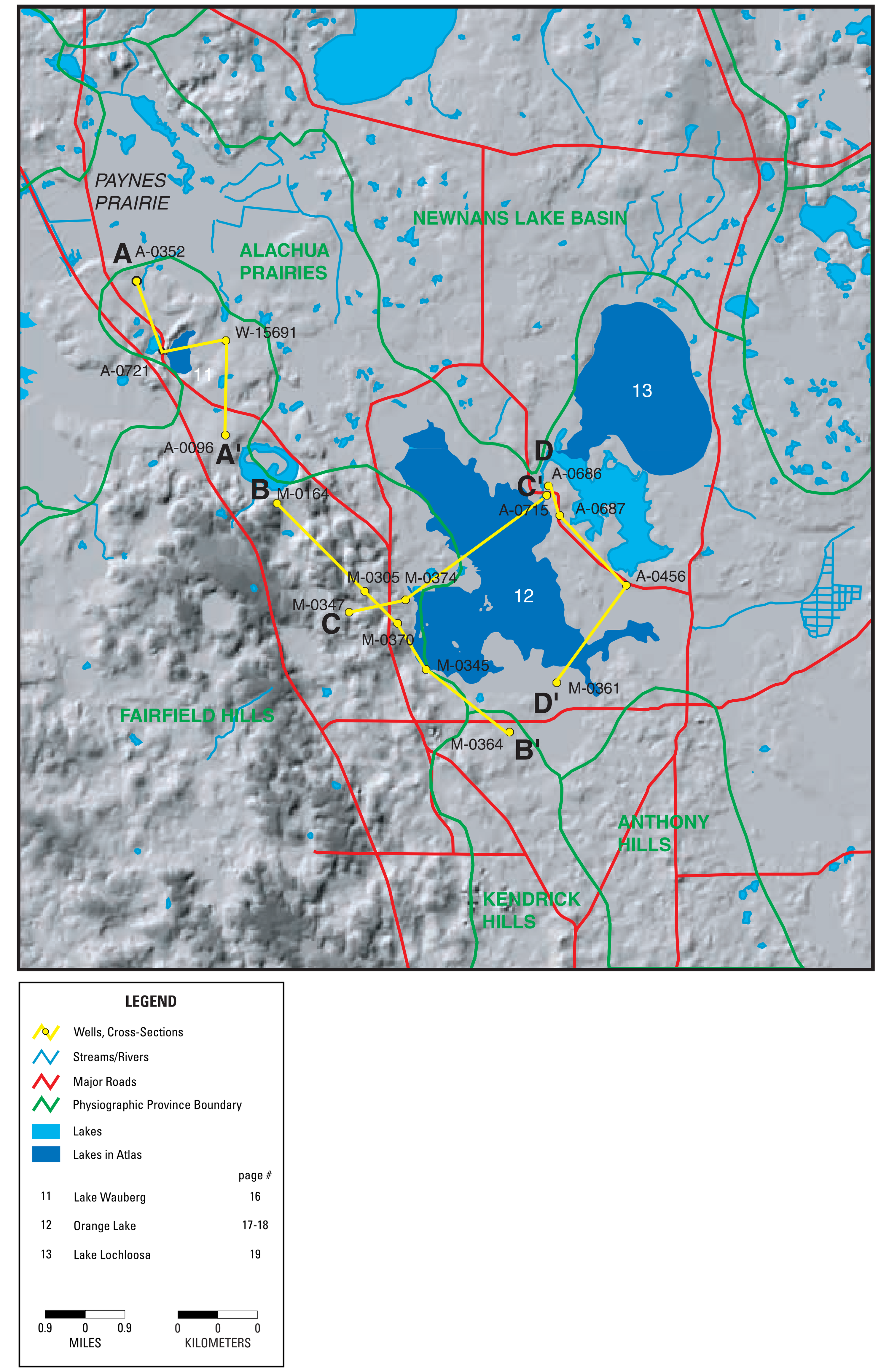






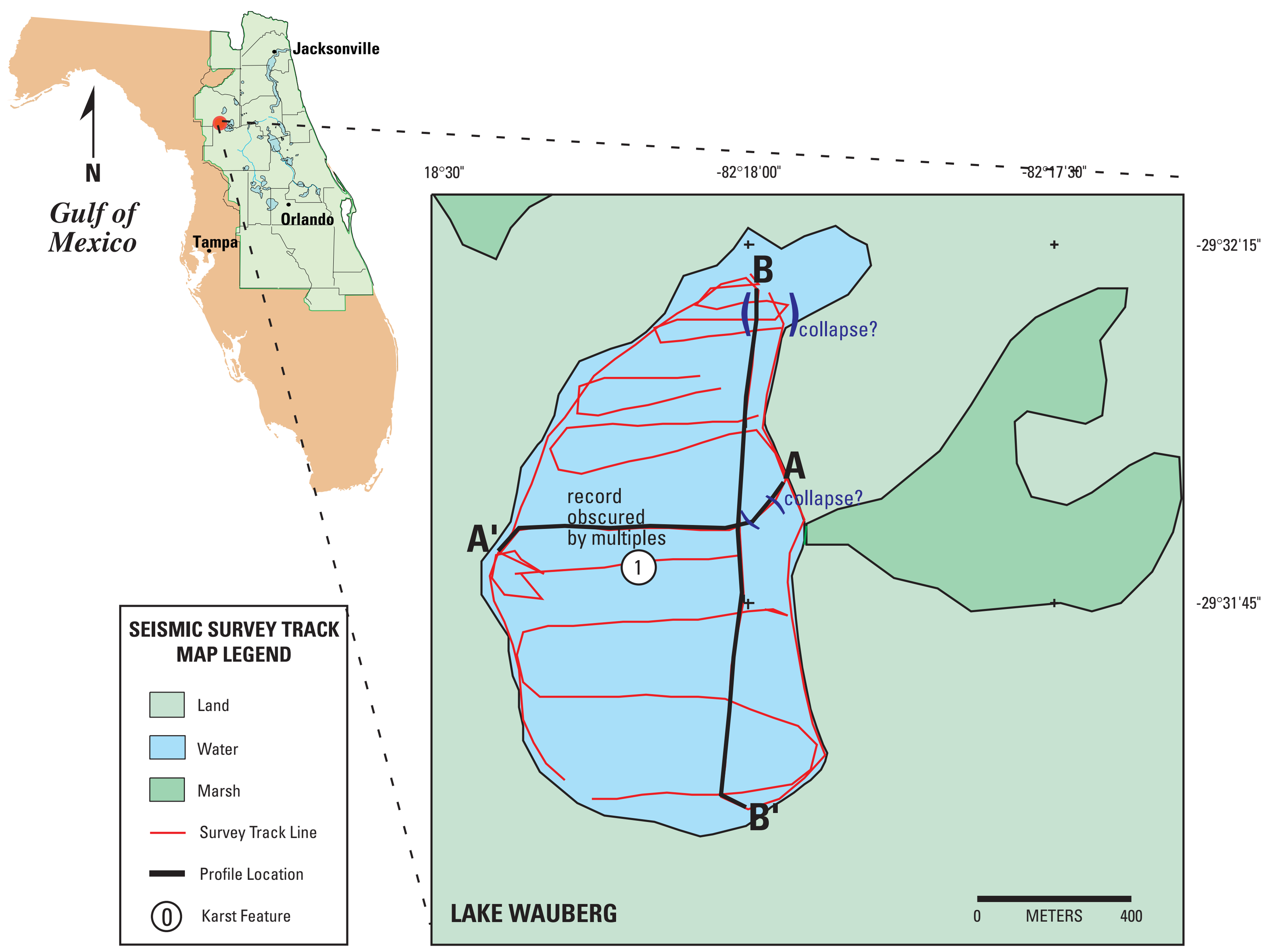


Location of survey area right (red square). Shaded relief map below showing physiographic regions, and location of wells and gamma log cross-section. Gamma Log cross-sections (left) show geologic contacts for correlation to seismic sections.



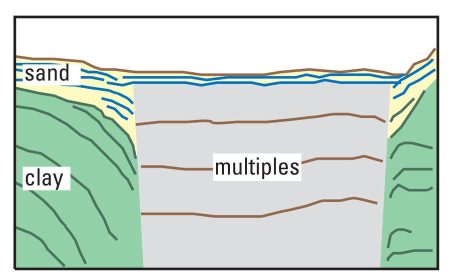
LAKE WAUBERG
ALACHUA COUNTY, FLORIDA

B



EXPLANATION

1. Profile obscured by multiples, noise or signal attenuation.



Introduction

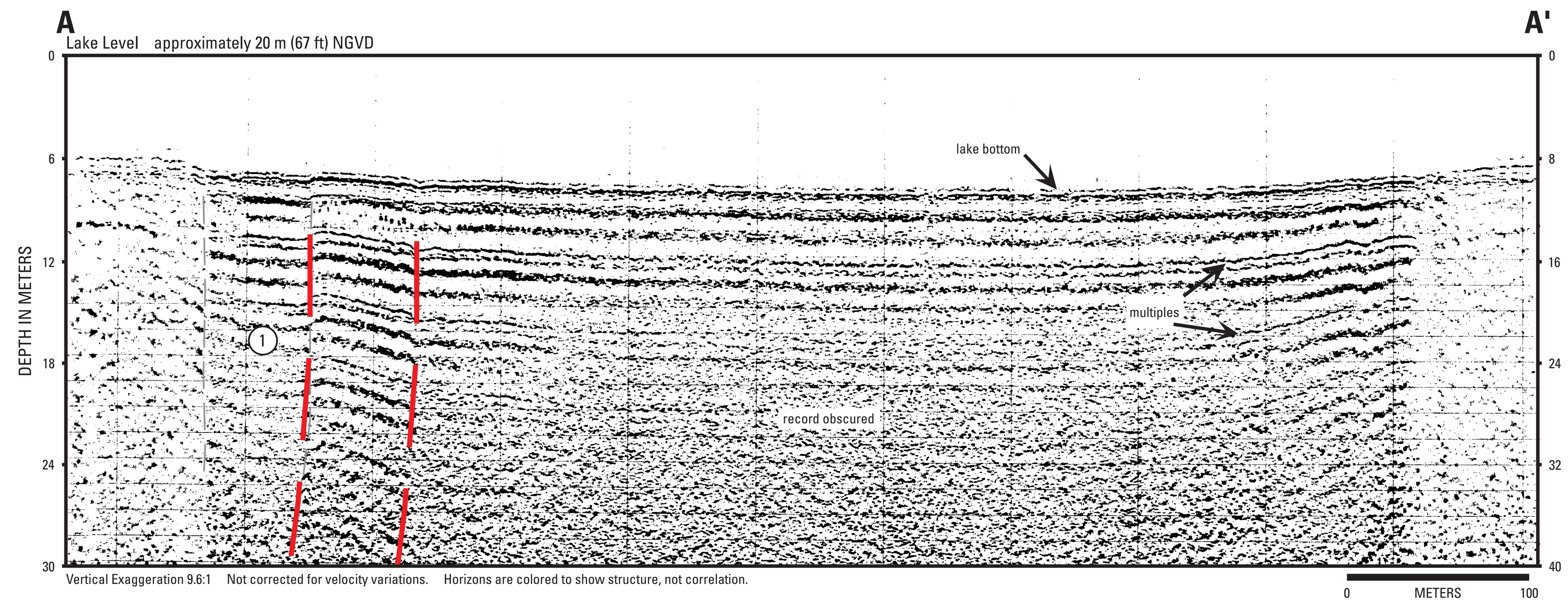
Lake Wauberg is located south of Paynes Prairie in central Alachua County. The lake is in the Ocala Uplift District, situated between the forested highlands of the Fairfield Hills area and the surrounding dissolution valleys of the Alachua Prairies. Lake Wauberg is irregular in shape, covering 1.6 sq km with about 5 km of shoreline. The lake is adjoined to the east by Sawgrass Pond. A marshy area to the northwest is separated from the lake by a topographic high.

Subsurface Characterization

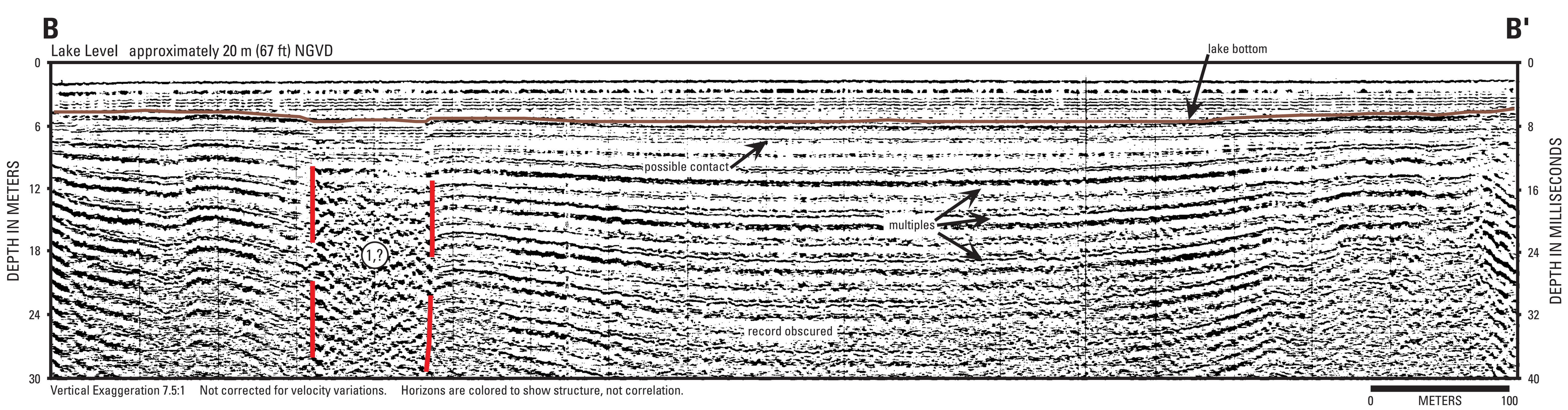
The seismic reflection record acquired from Lake Wauberg is predominantly obscured by strong multiples. In Figure A-A' the multiples appear to be originating from the lake bottom. It is also possible that the multiples may be originating from a hard surface very near the lake bottom as is apparent in Figure B-B'. Typically, strong surface multiples are the result of tightly packed sands or a hard surface near the lake bottom.

A seismic refraction study, completed in the Lake Wauberg area (Wiener, 1982), resulted in a velocity analysis of the sediments and a structural contour map of the top of the Ocala Limestone. A depression in the Ocala surface was identified beneath Lake Wauberg with a minimum elevation of -4.6 m (-15 ft) NGVD. The elevation increased to 22.9 m (75 ft) NGVD below the topographic ridges, with a maximum depth to the Ocala beneath Lake Wauberg of about 82 ft. The elevation contours are further supported by well data in the vicinity of the lake.

Wiener (1982) suggested that the Hawthorn sediments were deposited into the existing depression within the Ocala Limestone and was further thickened as subsidence caused by dissolution of the underlying Ocala Limestone occurred. Subsidence may affect the seismic character of the sediments by disrupting bedding. The seismic record from this site produced very few interpretable features. This is unusual since at lakes where the formation was caused by a central collapse or subsidence there is usually sufficient detail around the perimeter to provide some clues to the underlying structure. It appears that the edges of the subsidence zone extend beyond the surface expression of the lake and cannot be identified by marine seismic methods.



Vertical Exaggeration 9.6:1 Not corrected for velocity variations. Horizons are colored to show structure, not correlation.



Vertical Exaggeration 7.5:1 Not corrected for velocity variations. Horizons are colored to show structure, not correlation.

Subsurface Characterizations of Selected Water Bodies in the St. Johns River Water Management District, Northeast Florida

Jack L. Kindinger[1], Jeffrey B. Davis[2], and James G. Flocks[1]
2000

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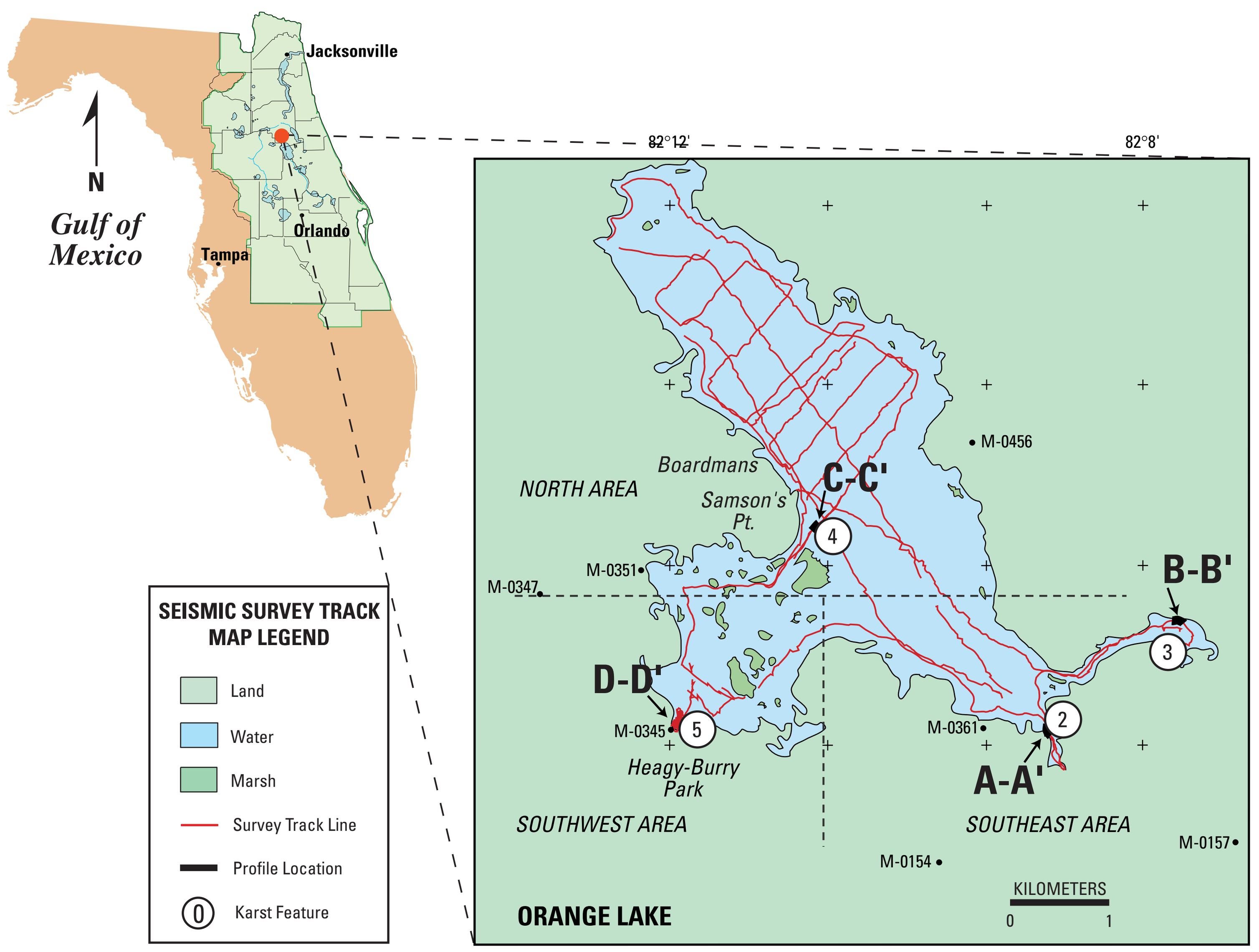
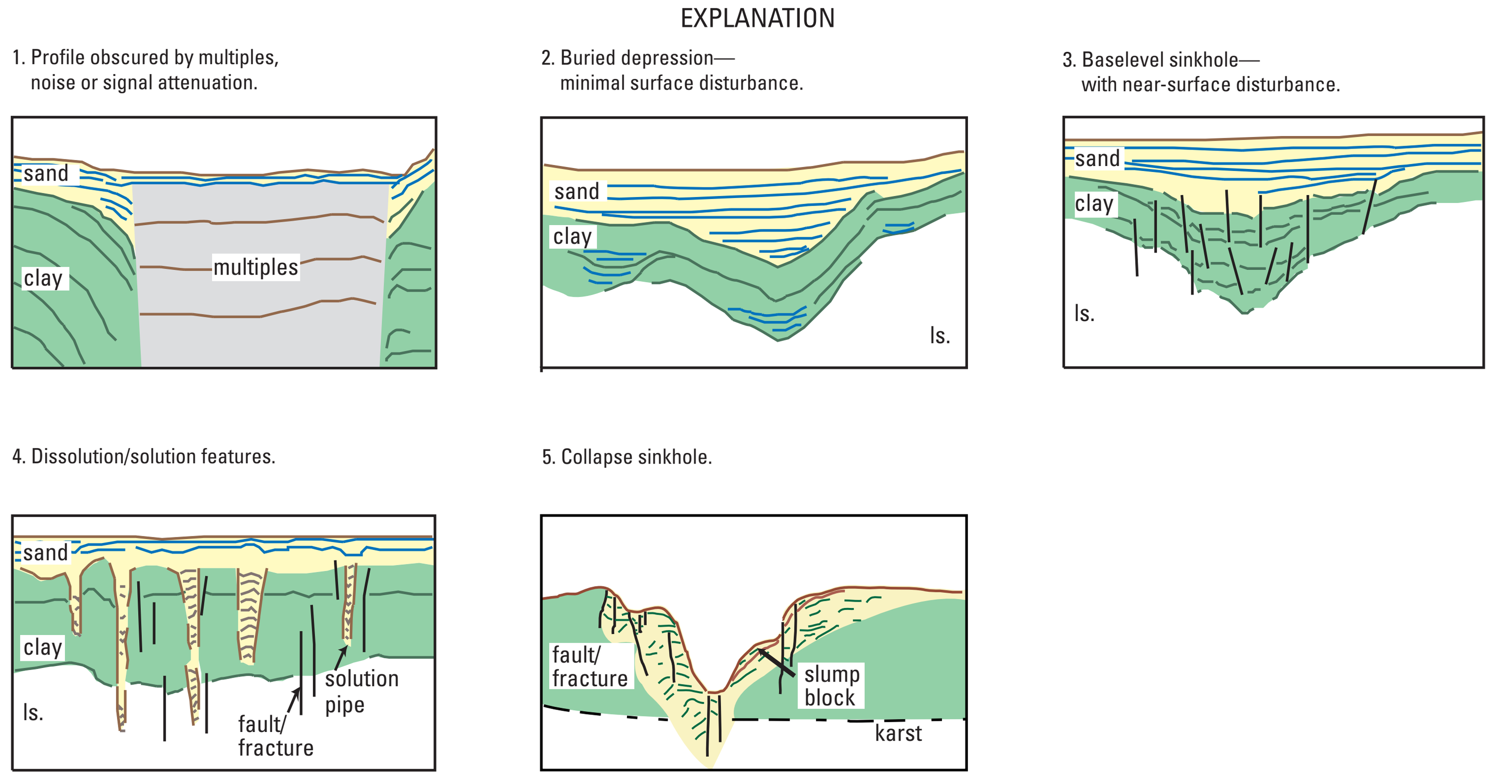
B

ORANGE LAKE
ALACHUA COUNTY, FLORIDA



EXPLANATION



Introduction

Orange Lake is located in Alachua County, north-central Florida. The lake occupies the physiographic division known as the Alachua Prairies (Brooks and Merritt, 1981). Advanced karst development in the subsurface created solution valleys that are characterized by flat-floored depressions with numerous dissolution features. A geologic term for these environments is polje. These broad, drowned prairies occupy the epiphreatic zone and are strongly influenced by fluctuations in the water table. An extreme example is Paynes Prairie to the north which commonly fluctuates from grassland to marsh to completely inundated and was at one time known as Alachua Lake.

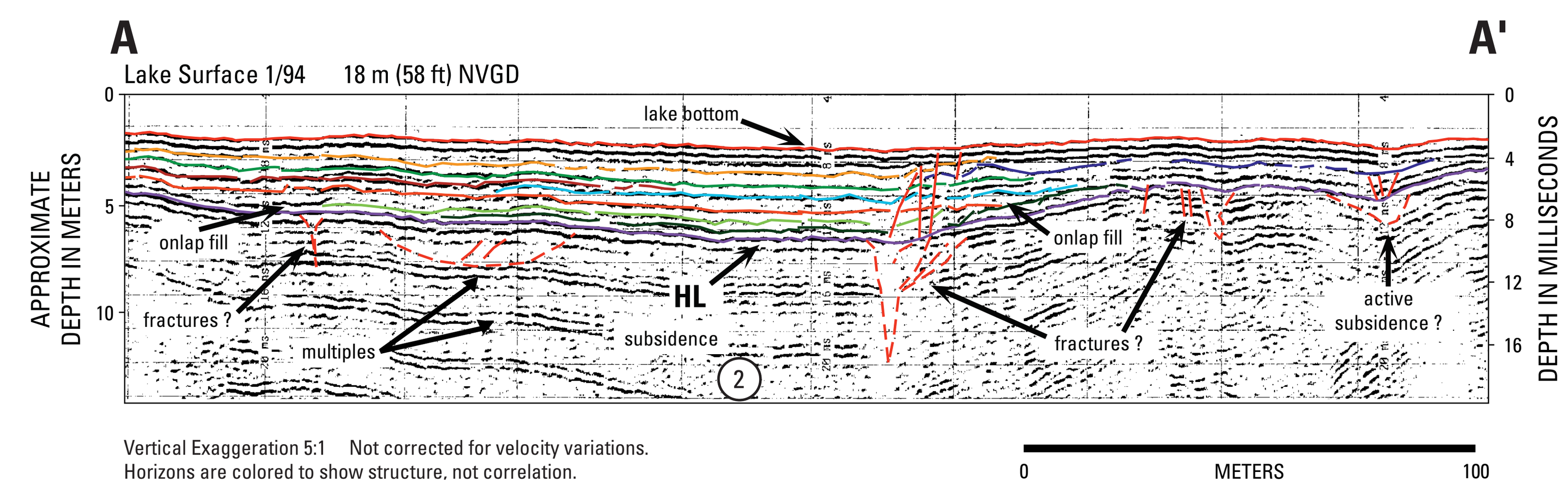
Orange Lake is a relatively shallow, irregularly shaped lake with approximately 44 km (144 ft) of shoreline covering 30 km^2, with much of the shore grading into freshwater marsh. The surficial sediments of the lake bottom are organic and/or organics mixed with sand and clay, transported into the lake by storm runoff and streams (Rowland, 1957).

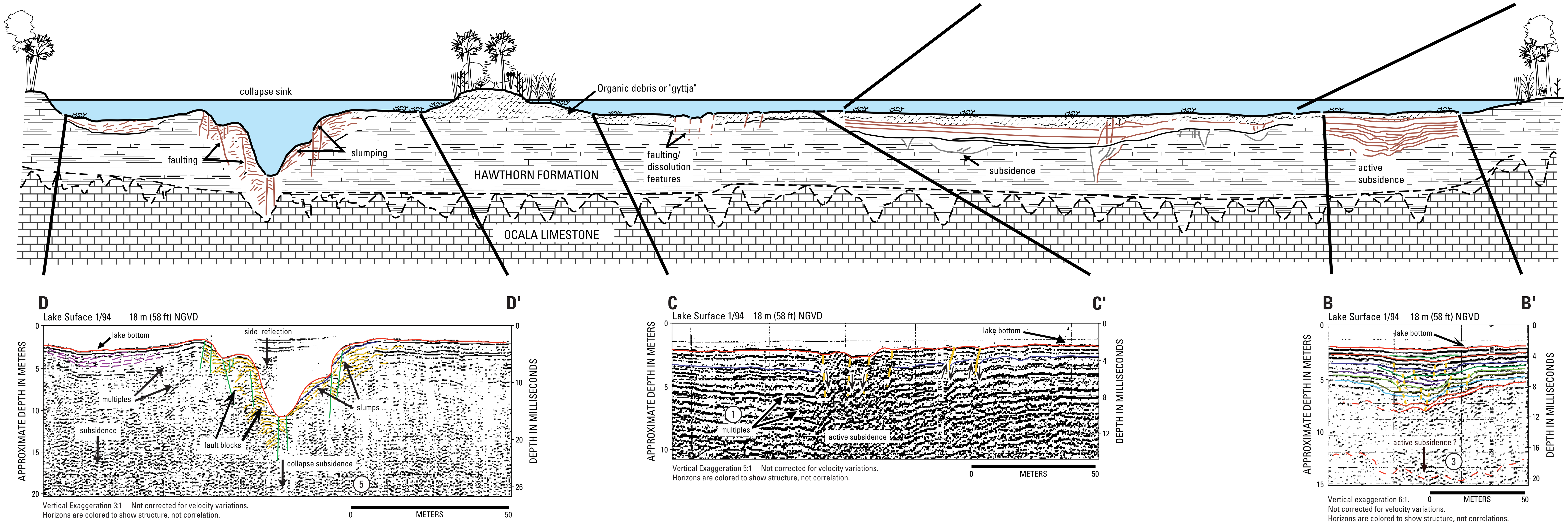
The west side of the lake is flanked by the Fairfield Hills, a Pleistocene sand ridge which may supply some of the sediments to the lake bottom. The ridge overlies the less permeable, Miocene sediments of the Hawthorn Group. In the southwestern corner of the lake, the shallow bottom gives way to a cluster of dolines (sinkhole complex) that penetrate the semi-confining layer into the karst limestone beneath. Pirkle and Brooks (1959a) suggest that the sands and clays of the Hawthorn Group are typically impermeable. When the water table drops, under sufficient hydrostatic pressure from the surface water, this material will fail and be flushed into solution channels in the limestone. Once the outlets are opened, the lake water will adjust to the level of the water table in the limestone unless the sinks again become plugged.

Subsurface Characterization

The geologic structure of Orange Lake in general is a semi-confining unit overlying limestone karst. The Plio-Pleistocene surficial sediments include sands and clays that range in thickness from ~1 m (~3 ft), over most of the area, to about 20 m (67 ft) in the Fairfield Hills. These sediments are underlain by clays, sandy clays and carbonates of the Miocene Hawthorn Group. Natural gamma logs from boreholes adjacent to Orange Lake indicate that the clays range in thickness from about 5 m south and southwest of the lake, to more than 25 m (82 ft) on the east side. Horizon HL in profile A-A' below may represent the top of the Hawthorn Group. The Ocala Limestone carbonates are the oldest units exposed in this area and can be seen in roadcuts and numerous quarries. The contact between units exhibits highly irregular surfaces typical of karst. The top of the Ocala Limestone range from about 6 m to > -6 m (20 to > -20 ft) NGVD, with an overall trend dipping to the northeast. Dissolution of the carbonate is active and can be seen at the Heagy-Burry Park. For years, dirt fill has been periodically brought to an actively subsiding sinkhole on the east side of the park's boat ramp and is representative of cover subsidence sinks in Orange Lake. Land-based ground penetrating radar profiles from the park adjacent to the collapse sinkhole indicate numerous buried sinkholes and cavities (Davis, 1996).

Additional work regarding Orange Lake not included in this summary can be found in Kindinger and others (1994, 1998).

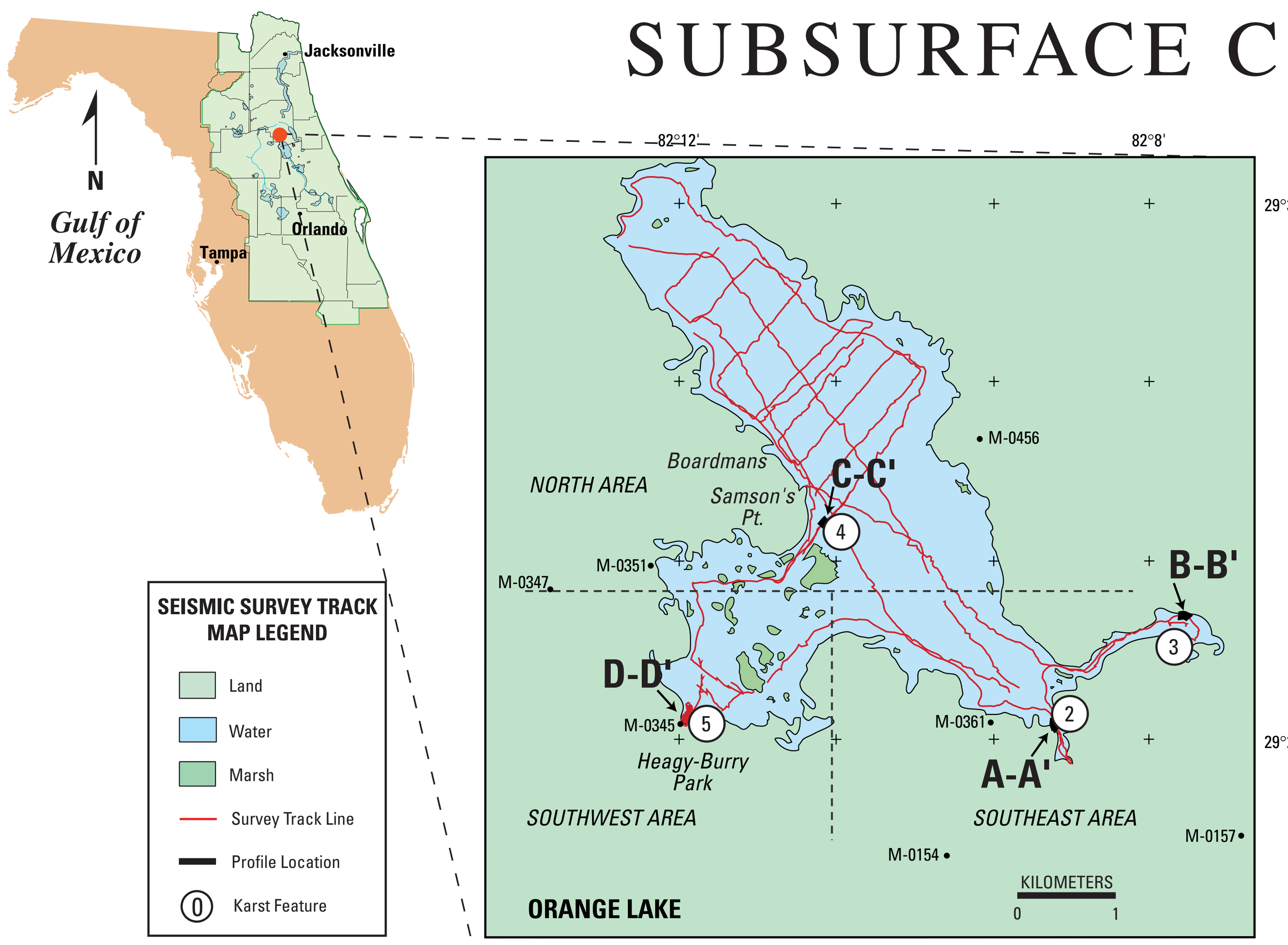




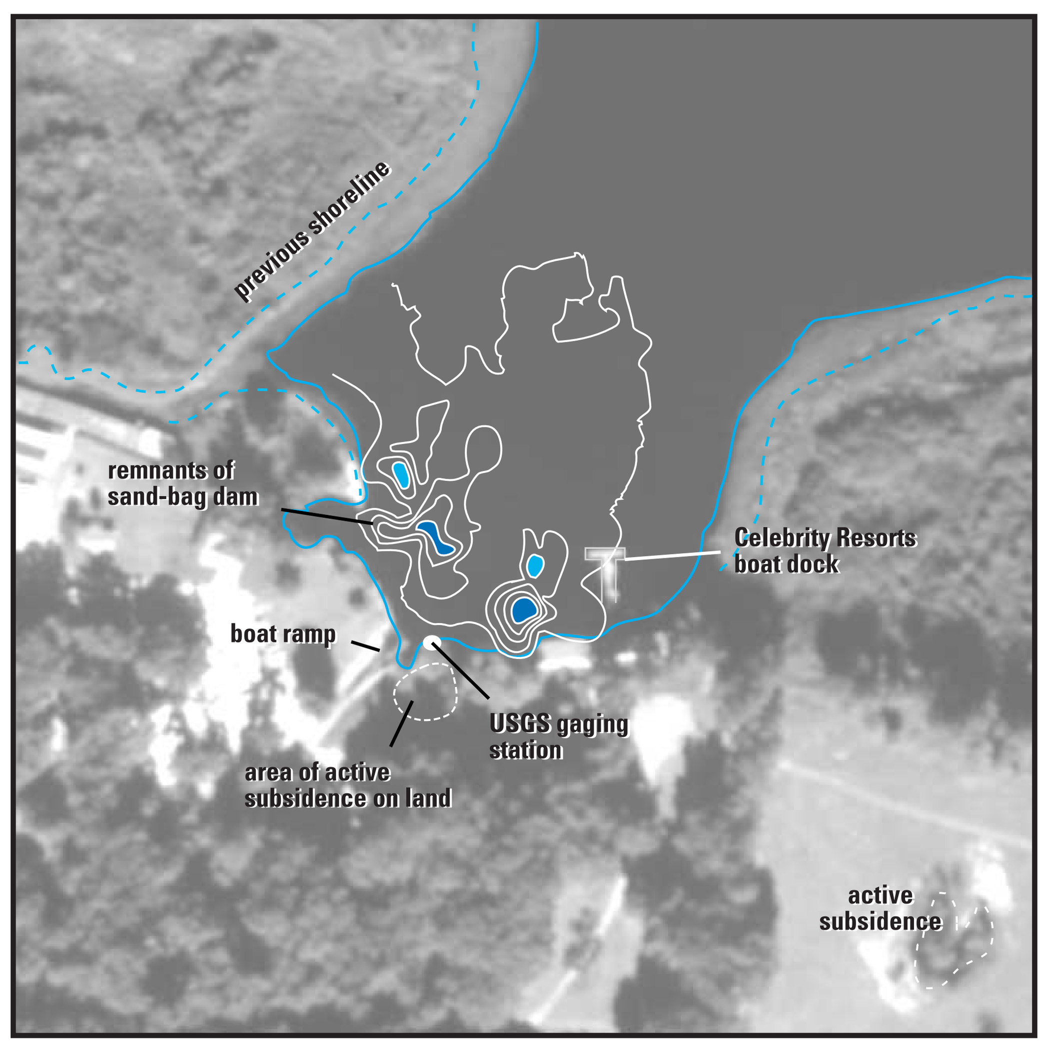
SUBSURFACE CHARACTERIZATION OF ORANGE LAKE

ALACHUA COUNTY, FLORIDA

B



Aerial photograph and contour overlay of the sinkhole complex in Orange Lake.



In the following discussion Orange Lake is divided into three areas (see index map at left) based on distinct geomorphic features identified from HRSP profiles. The primary karst features found within the lake are in various stages of maturity and include cover subsidence, cover collapse and buried sinkholes.

Southeast Area

The southeastern area of Orange Lake has a water depth of 1 to 3 m (3 to 9.8 ft). The primary karst features within this area are cover subsidence sinkholes and associated fissures (A-A', B-B', previous page). These features have type 2 and 3 characteristics (features legend, previous page), where the overburden has subsided to accommodate loss due to solution in the underlying limestone. Less common karst features have also been identified, such as buried sinkholes, faults and dissolution pipes.

The large subsidence along the southern shore measured approximately 400 m (1312 ft) in diameter (A-A'). The surface expression is apparent on the lake bottom as a slight subsidence. Horizon HL (A-A', type 2, HL) forms a depression filled by onlapping cover sediments. Several high-angle faults are present, with little vertical displacement. These features may also represent dissolution pipes. Leakage of lake waters to the aquifer in these and similar areas is controlled by the permeability of the cover sediments or proximity of the faults to the lake floor. Of the features identified in the southeast area, very few appear to breach the lake bottom.

A small number of depressions found in the southeastern area may be linked to more active sinkhole development (B-B', type 3). The type 3 feature is smaller than the type 2 (~ 50m, 164 ft). The pattern of disturbed horizons implies active subsidence with intervening periods of deposition. As the sinkhole subsides, it is subsequently filled by sediment, seen as onlapping reflections within the depressions, followed by differential subsidence. Buried by <1 m (3.3 ft) of sediment, this sinkhole is an example of the composite mature subsidence sinkhole. A proposed model for subsidence sinkhole development is outlined in the figure below (B-B' this page).

North Area

The north and central areas of Orange Lake are geologically similar and will be combined and discussed as one area. The lake bottom and subsurface are relatively flat and intact with small subsidence features throughout. The unconsolidated surficial sediment is a sandy clay that, along with the shallow water depth, produces strong multiple reflections that mask much of the geologic data (type 1 feature, profile C-C' previous page). The vertical features in the cross section may indicate the early stages of a subsidence sinkhole, with the central area actively subsiding and/or collapsing. The high angle reflectors throughout the profile may represent stress fractures created by slumping as the overburden accommodates dissolution at depth. The features may also represent dissolution pipes through the overburden, indicating a breach in the confining layer.

Features in the northern portion of the lake are generally small (1 to 10 m across, 3 to 33 ft) and tend to be isolated. Distribution and size of features in this area are different than the features in the southeast that tend to cluster together to form larger (>100 m, 328 ft) structures. Surface features and shallow horizons (< 2 m, 66 ft) were seen in the HRSP data that indicated a number of subsidence sinkholes in this area (type 3) and type 4 karst features that have clustered to form disturbed areas in the subsurface, up to 40 m (131 ft) across. Most of the area between Samsons Point and Boardman show some form of subsidence.

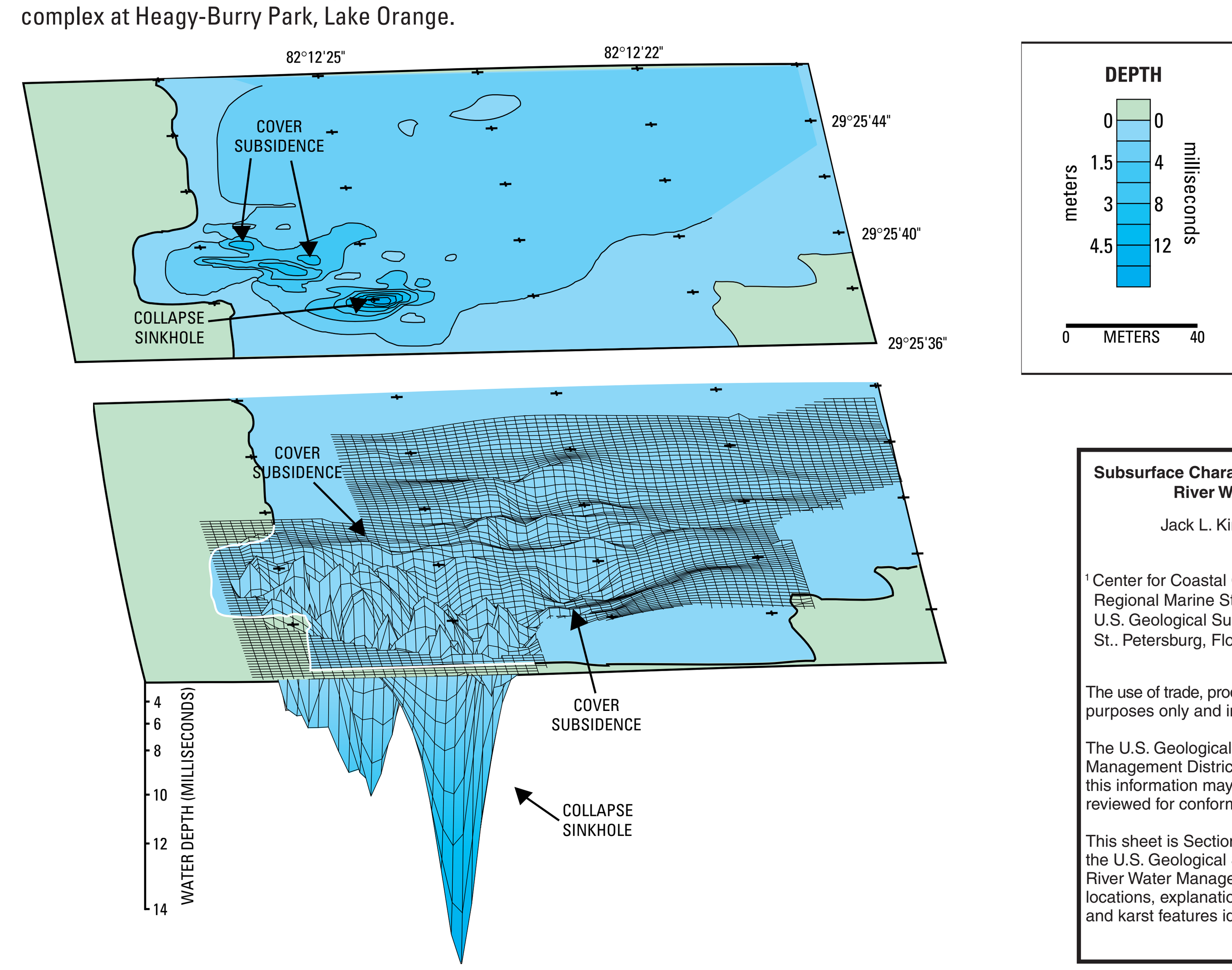
Southwest Area

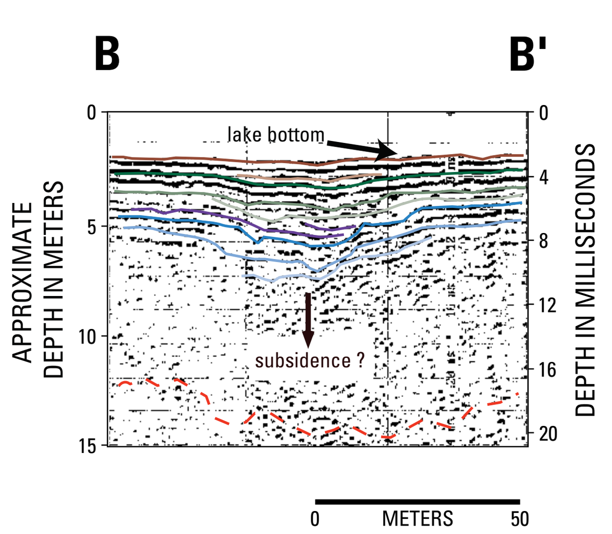
The southwest area consists of a broad flat bottom with a bathymetry very similar to that in the southeast and north areas, except for the collapse sinkhole (type 5 feature, profile D-D', previous page) near the southwestern shore. The sinkhole has completely breached the confining unit. It is possible that other features are present but access was limited by aquatic weeds and the southwest area could not be completely surveyed.

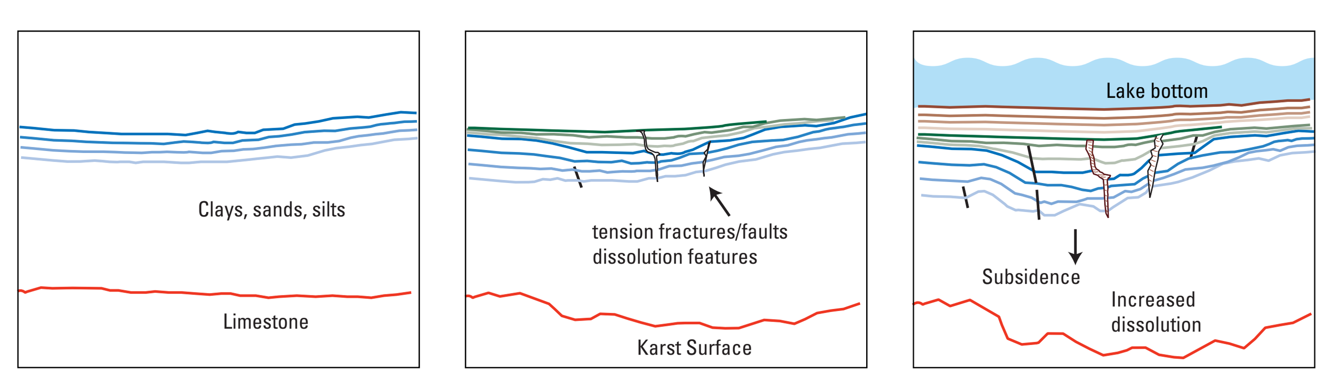
The clustered collapse sinkholes are near the southwestern shoreline adjacent to Heagy-Burry Park and boat ramp. Observations by scuba divers indicate that there is a downward flow of water from the lake into one of the sinks (Spechler and Wilson, 1992). Reports by Pirkle and Brooks (1959b) and Spechler and Wilson (1992) indicate a direct hydraulic connection with the aquifer. During the 1956 drought, water from Orange Lake could be seen draining into the collapse sinkhole of Heagy-Burry Park. Profile D-D' shows the steep slope and fault blocks of the sinkhole. The mass movement of limestone blocks would open pathways for water to migrate along the fractures. Sediment slumping along the steep flanks of the sinkhole also are visible and are part of the natural process that plugs the doline. Adjacent to the collapse are evidence of adjacent cover subsidence sinkholes that ultimately may coalesce in the sinkhole complex.

A three-dimensional bathymetric grid of the clustered sinkholes near Heagy-Burry Park is shown below. The grid model was constructed using the two-way travel time for the lake-bottom reflection (HRSP). Two collapse sinkholes and two adjacent subsidence features are evident from this model. It is not clear if the features are remnants from the sinkhole that was observed in 1956 or are sinks that have formed since. Past reports (Rowland 1957, Jessen 1972) indicate that a single hole approximately 63 m (20 ft) in diameter was exposed. A temporary sandbag and earthen dam emplaced around the hole subsequently collapsed into the hole. Large quantity of fill, a storage tank, and junked vehicles were also placed into the hole. Remnants of the dam, and hence the most northern boundary of the 1956 sink, can presently be seen about 10 m offshore from the park. The figure to the left shows the contours of the sinkhole superimposed on an enlarged aerial photograph of the Heagy-Burry Park area. The photo and overlay show the extent of the collapse and subsidence features, including a sinkhole on land in the southeastern portion of the photograph. An area east of the boat ramp is continually subsiding and fill material is periodically emplaced in the depression. Though the limits of the sinkhole observed in 1956 are not known, it is clear that this area represents a sinkhole complex that is still quite active and expanding.

Bathymetric contour and mesh plot of the sinkhole complex at Heagy-Burry Park, Lake Orange.







A. Model for cover subsidence sinkhole development. Undisturbed, impermeable bedded clays, sands and silts (Hawthorn) overlie Limestone (Ocala).

B. Dissolution of limestone creates loss of material in subsurface. Overburden subsides to accomodate loss. Tension faults develop as bedding is disturbed, creating dissolution pathways (pipes) and breaches in impermeable layer. Continued deposition onlaps onto original sediment surface.

C. Fluctuations in water table or other factors may slow dissolution rates, subsidence decreases or terminates, continued deposition, perhaps fluvial, fills any surface depression and dissolution pipes.

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2000

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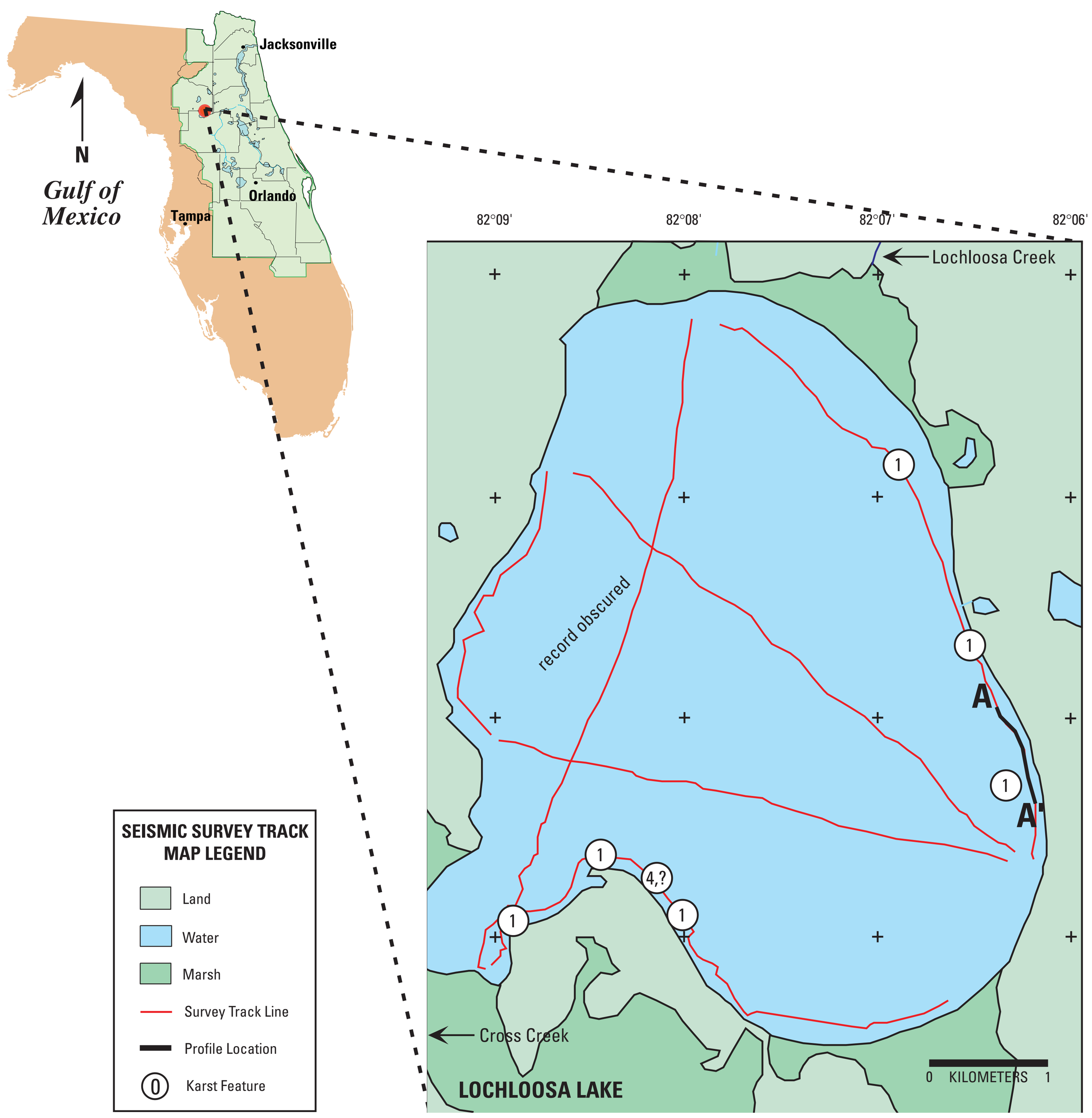
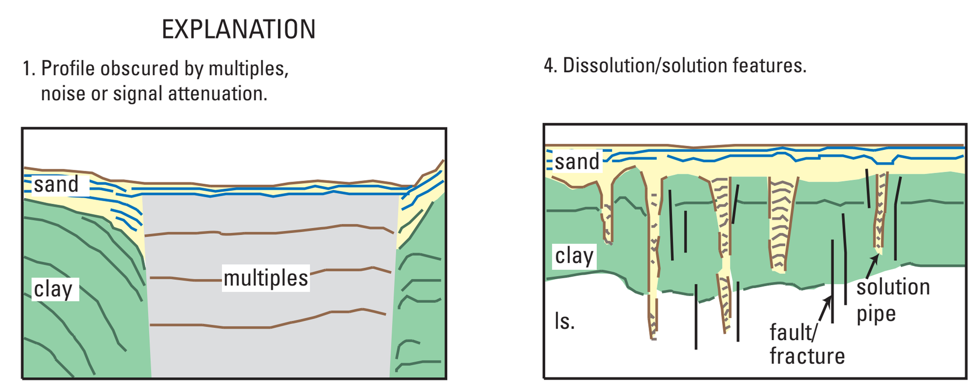
LOCHLOOSA LAKE

ALACHUA COUNTY, FLORIDA

B



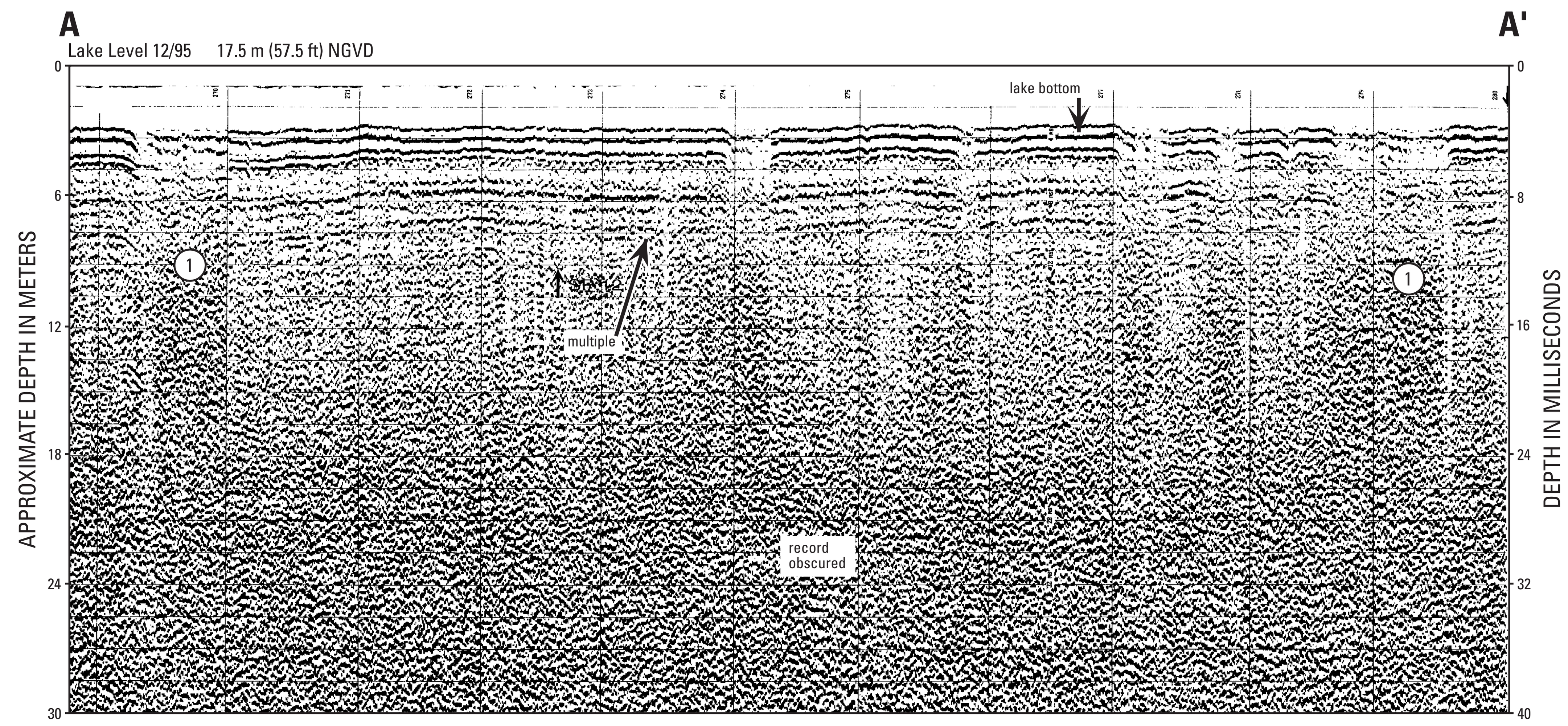


Introduction

Lochloosa Lake is located in the Alachua Prairies, southern Alachua county. Part of the Ocala Uplift, this area of highly mature karst terrain has been dissolved virtually to the water table (Brooks, 1981), creating loosely connected marshlands and lakes. Lochloosa is connected via Cross Creek to Lake Orange, which ultimately connects via canal to Paynes Prairie to the north. The shoreline is predominantly marshland, with Lochloosa creek to the north and Little Lochloosa and Right Arm Lochloosa Lake to the south and west. Lochloosa Lake is irregular in shape, with a perimeter of 21 km (13 mi) and an area of about 22 sq km. Lake elevation at the time of the seismic survey was 17.5 m (57.5 ft) NGVD.

Subsurface Characterization

The quality of the seismic profiles obtained from Lochloosa Lake is generally poor. This is primarily due to both a pervasive bottom multiple throughout the lake and abundant acoustic noise in the subsurface. The latter is probably due to the high organic content in the bottom sediments seen in the marsh lakes of this area. Scott (1988) describes the top of the Hawthorn Group (Coosawhatchie Fm.) to be very near the surface in this area (<6 m, 19.7 ft). Although this is not readily apparent in the seismic profiles acquired in Lochloosa, it does correlate with some of the data obtained in neighboring Lake Orange. In some areas of Lochloosa Lake, there does appear to be a reflector visible at about 8 ms (6 m) although it is not readily mappable due to the noise and bottom multiple. The most characteristic feature visible in the seismic profiles from Lochloosa are similar to the type 1 feature shown in the explanation (profile A-A'). This is a typical return in this type of lake and is probably not related to subsurface structure. In several places it is possible that numerous, high angle reflectors may indicate a type 4 feature (see Survey Track map).



Vertical Exaggeration 9:1 Not corrected for velocity variations. Horizons are colored to show structure, not correlation.

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2000

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[2] St. Johns River Water Management District
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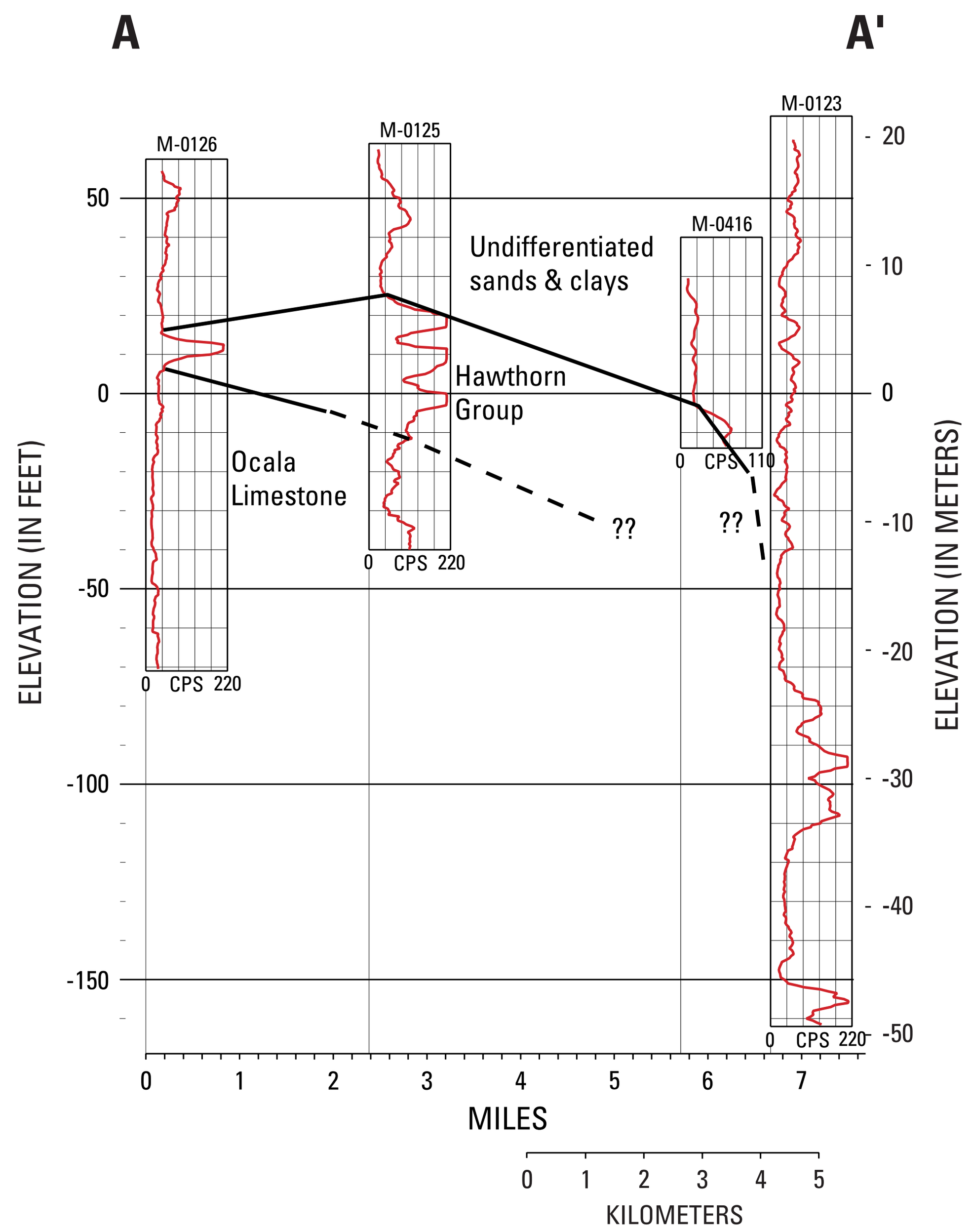
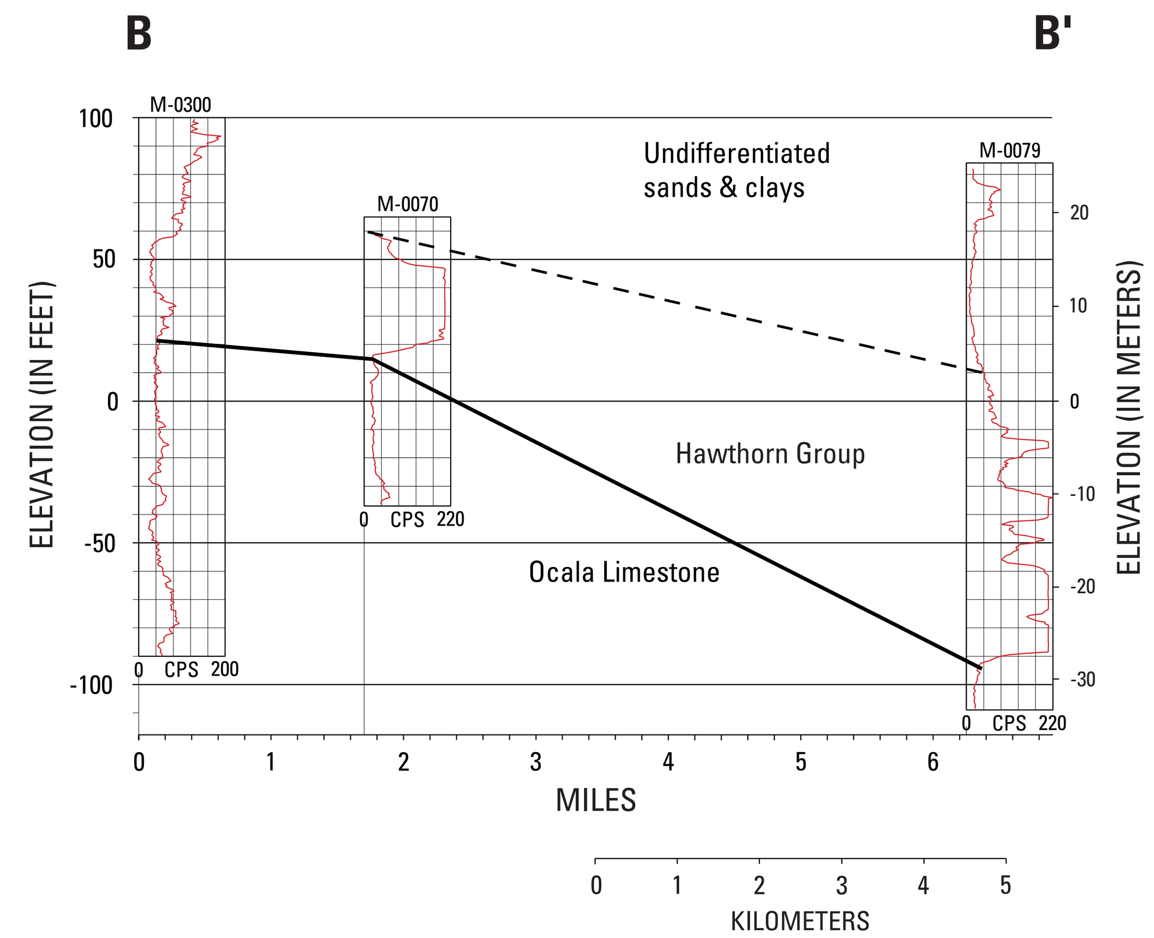
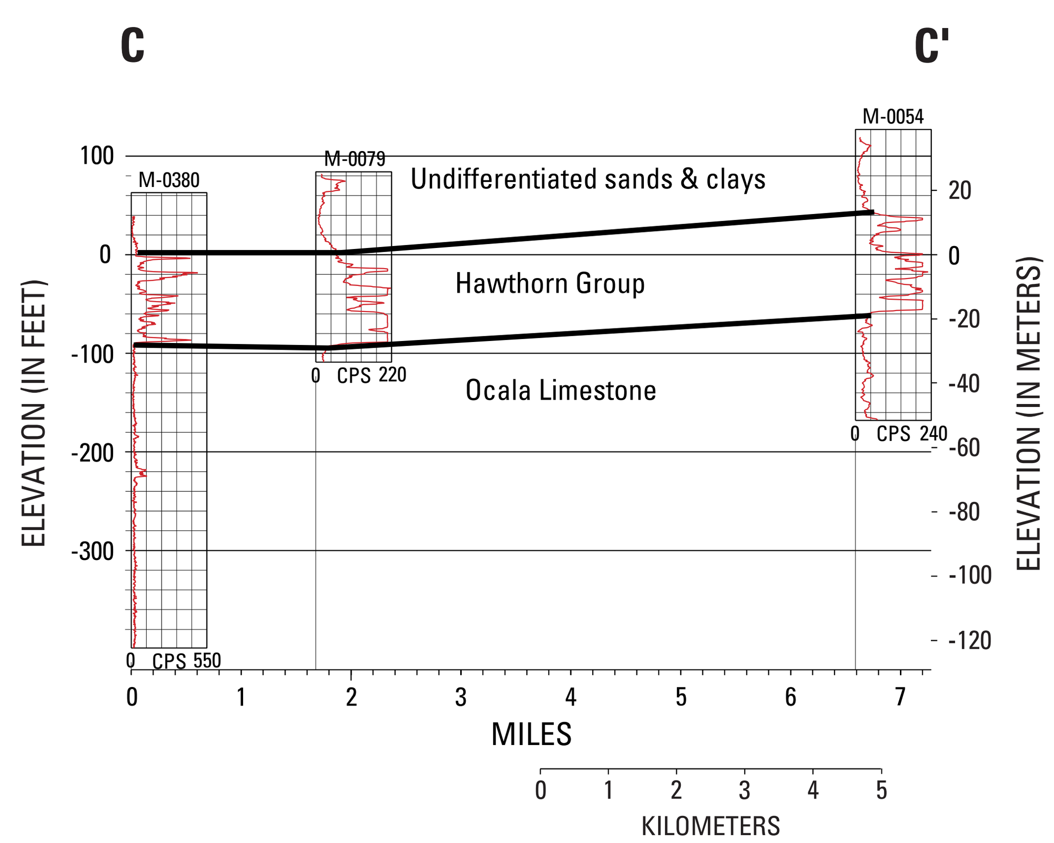
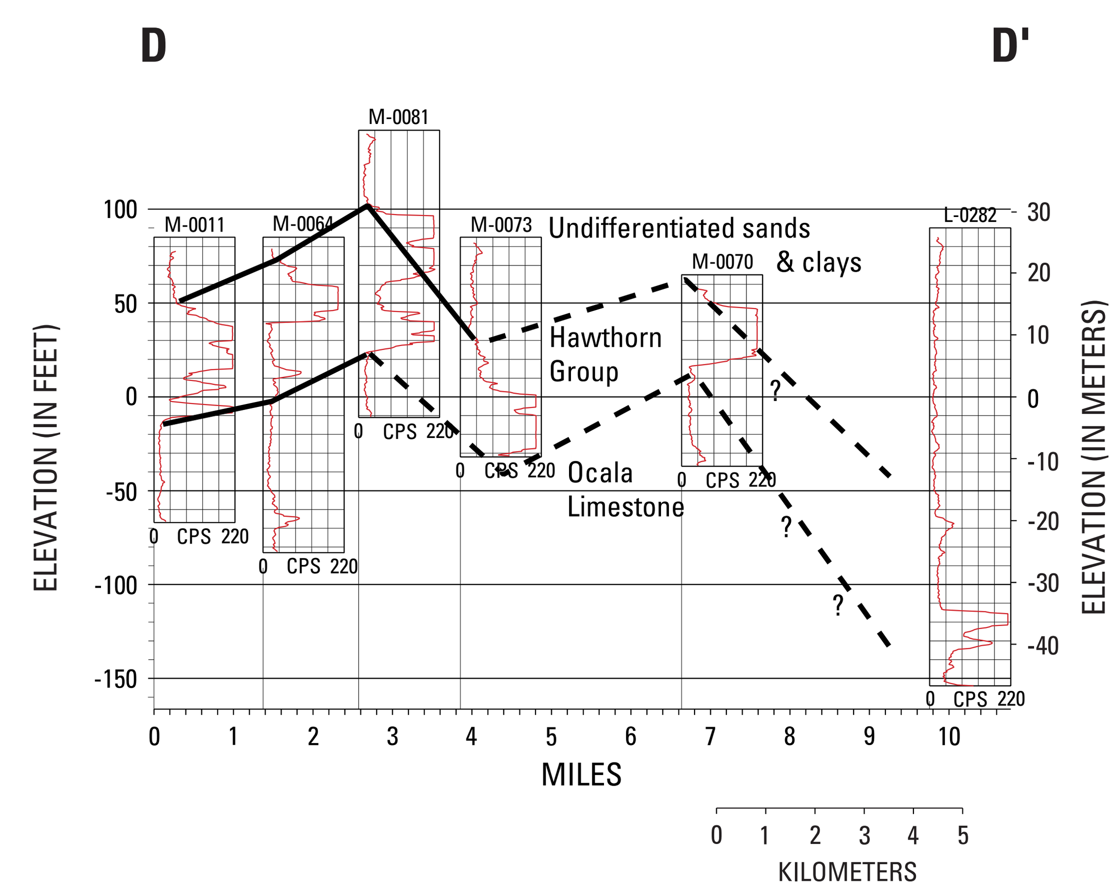
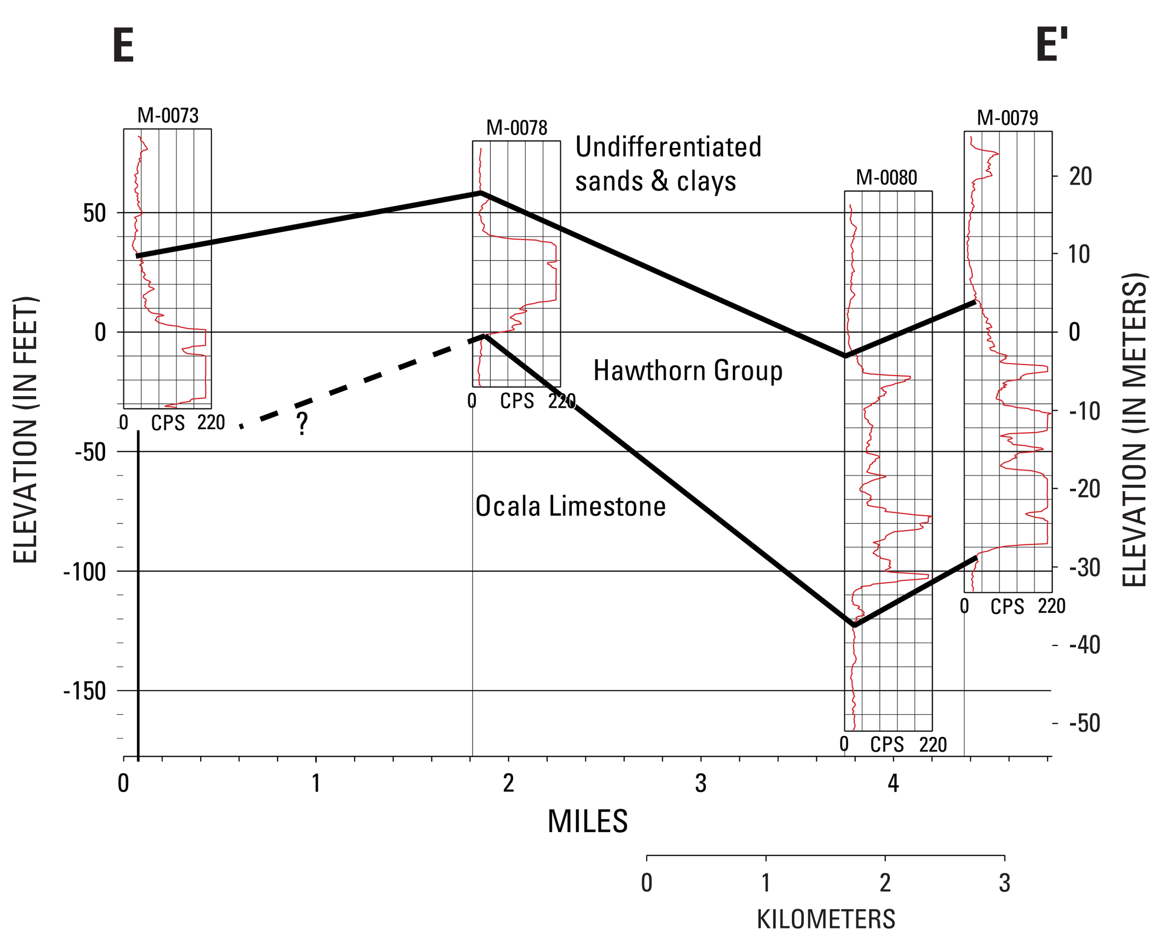
INDEX MAP AND GAMMA LOG
CROSS-SECTIONS, SECTION C

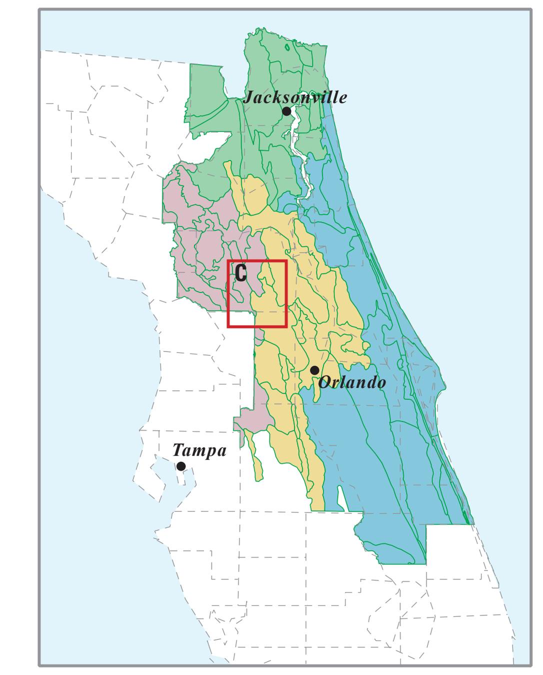






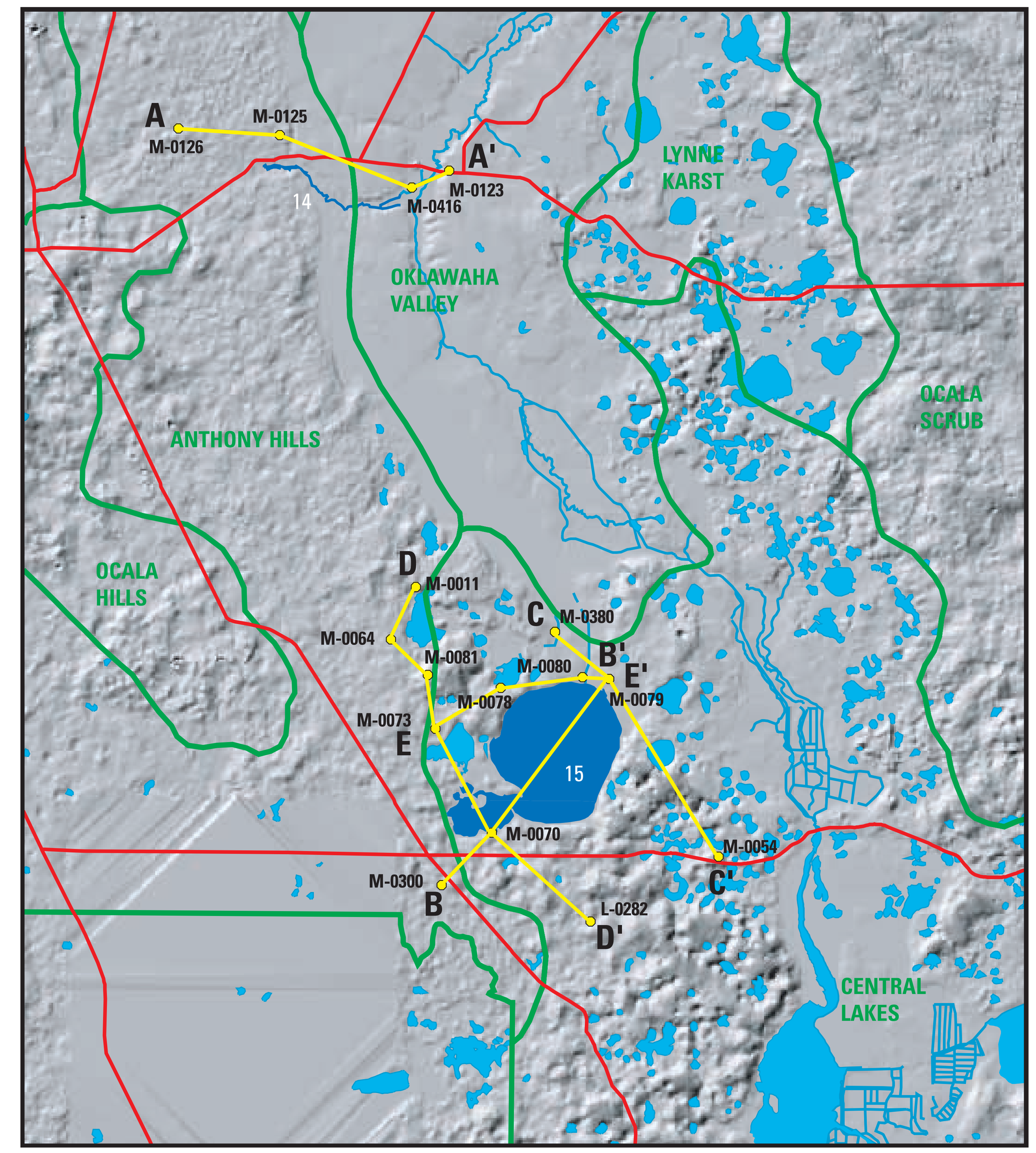


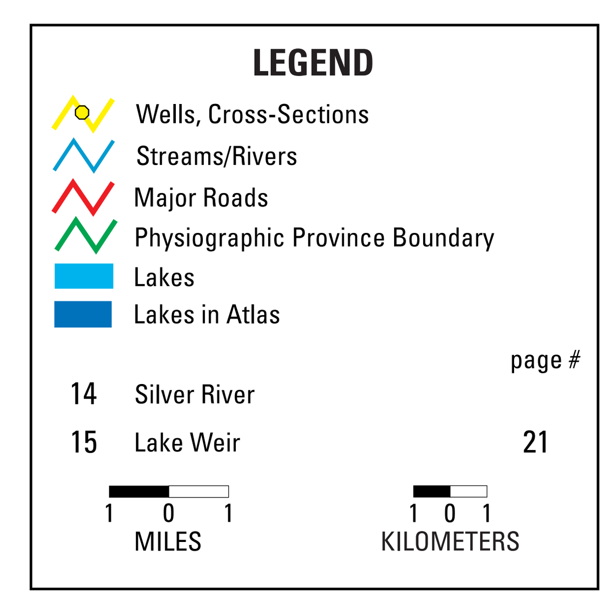




C

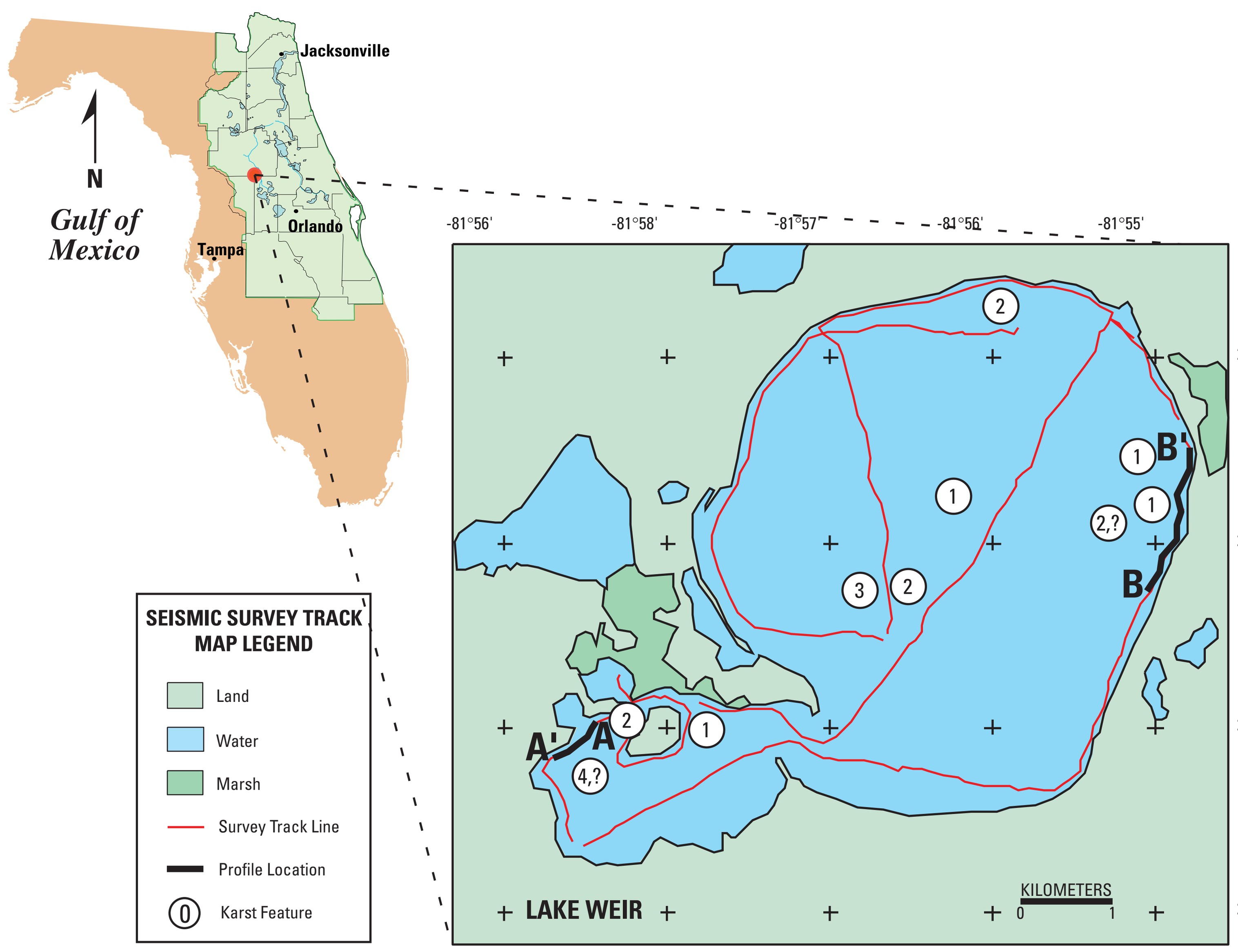
Location of survey area right (red square). Shaded relief map below showing physiographic regions, and location of wells and gamma log cross-section. Gamma Log cross-sections (left) show geologic contacts for correlation to seismic sections.





LAKE WEIR
MARION COUNTY, FLORIDA

C



Introduction

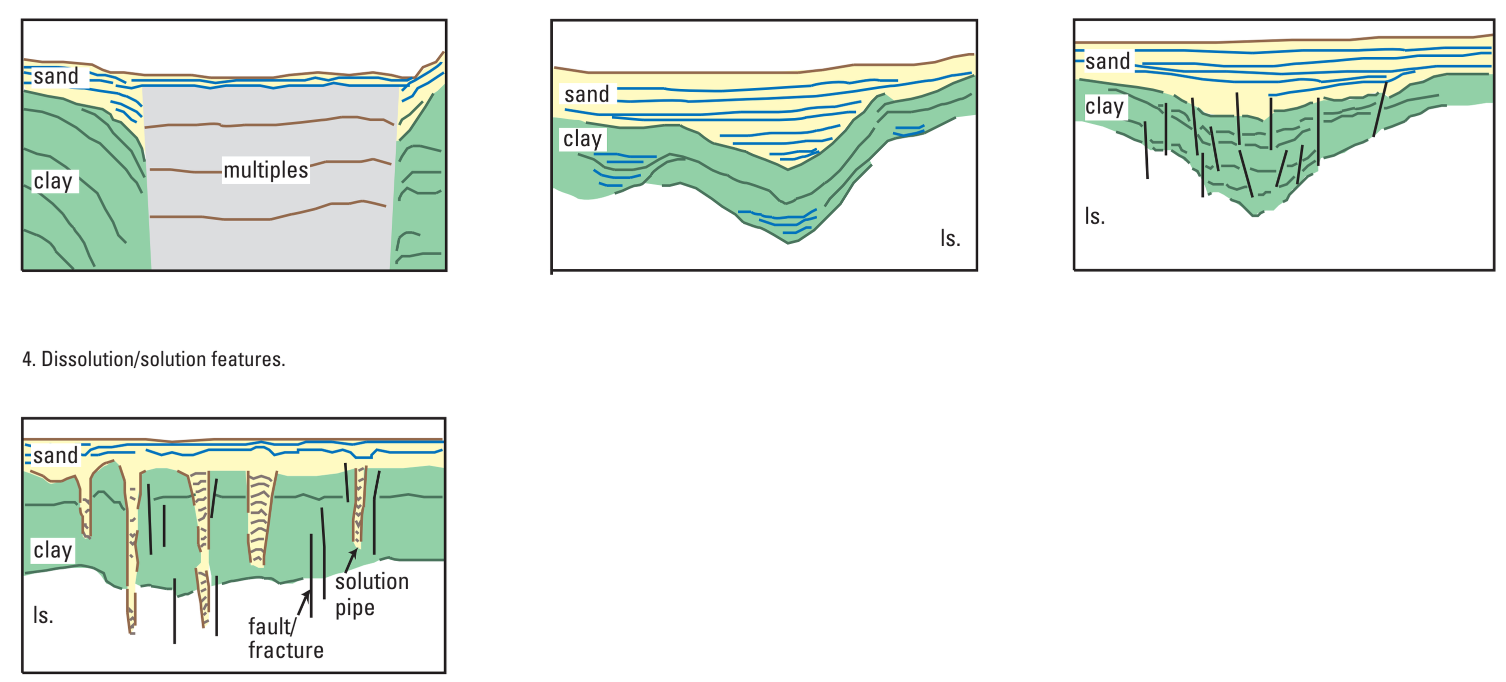
Lake Weir, in southcentral Marion county, is situated along the edge of the Ocala Uplift in the Central Lakes District. This area is comprised of sand hills with water table lakes filling their interstices (Brooks and Merritt, 1981). These sand hills comprise part of the thick, undifferentiated sediments that overlie the Hawthorn Group, which occurs at about sea level in this area (Scott, 1988). The lake wraps around the southern extent of one of these hills to form Little Lake Weir to the west. Lake elevation at the time of the seismic survey was ~16.7 m (55 ft) NGVD. Lake Weir is roughly circular in shape with a perimeter of approximately 35 km and an area of 31 sq km. To the north, the lake is connected via drainage canal to Marshall Swamp which occupies the large Oklawaha valley and river system.

Subsurface Characterization

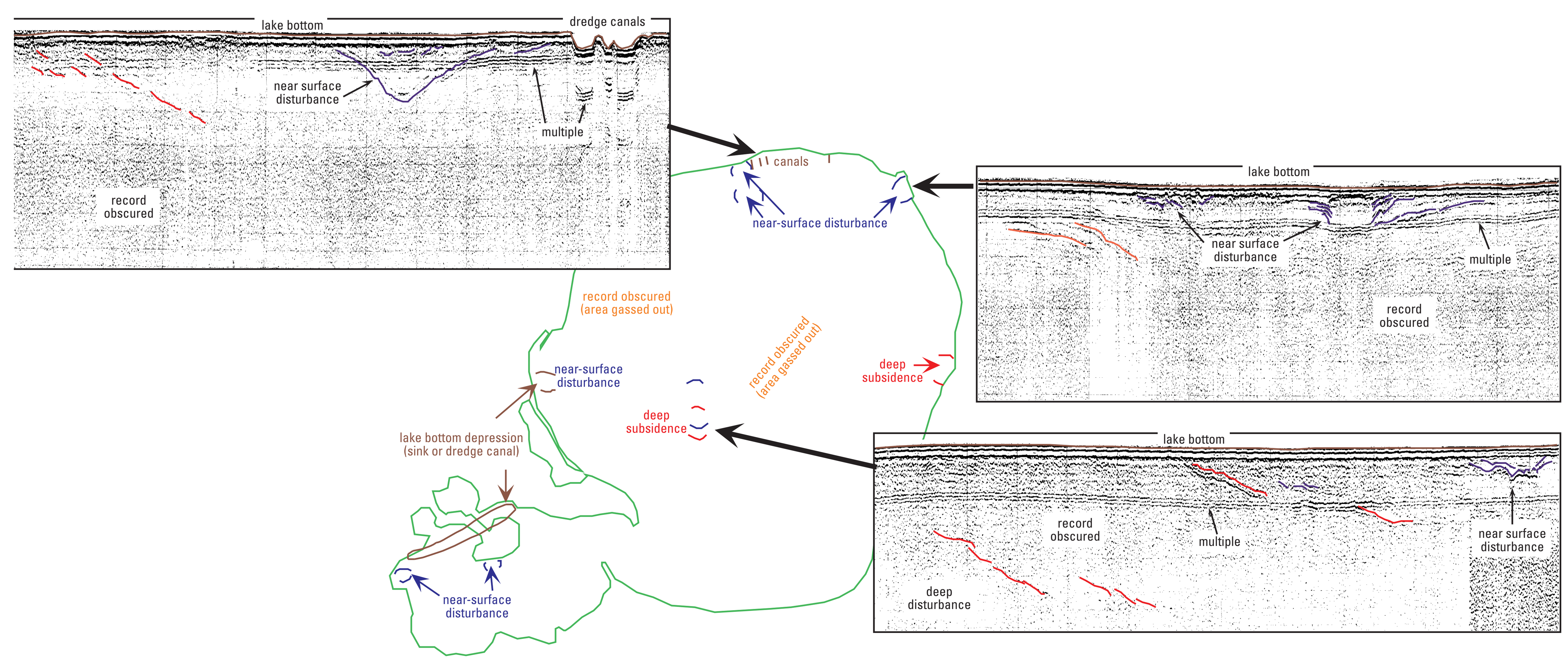
The subsurface disturbance features visible in seismic profiles acquired from Lake Weir generally fall into subsidence type categories (2 and 3) at two different depth levels (see subsidence location map, below). The deeper structures could possibly correspond to subsidence within the Hawthorn Group (Profile B-B'), but detail is obscured by noise in the overlying record. Near-surface features show low-angle reflectors that exhibit disturbed bedding (blue lines in profiles). Relationships between the upper and lower features are seldom apparent due to the generally poor acoustic return. Large areas in the central portion of the lake show a gassed out appearance. This could be due to a hard, sandy lake bottom or high organic content in the surficial sediments. The seismic records to the west show strong multiples, which also obscure the underlying record. This could also be due to a hard sandy lake bottom. Surface features include obvious dredge canals along the northern shore and a very large, long dredge-like structure across Little Lake Weir (Profile A-A', see location map left). This feature is up to 300 m (984 ft) wide and 3 m (9.8 ft) deep (6 m, 19.7 ft water depth). It cannot be determined from the record whether this is a dredge canal or collapse structure. Possible near-surface faulting (red dashed lines) and what could be a real reflector dipping beneath the multiple could indicate subsidence in the area.

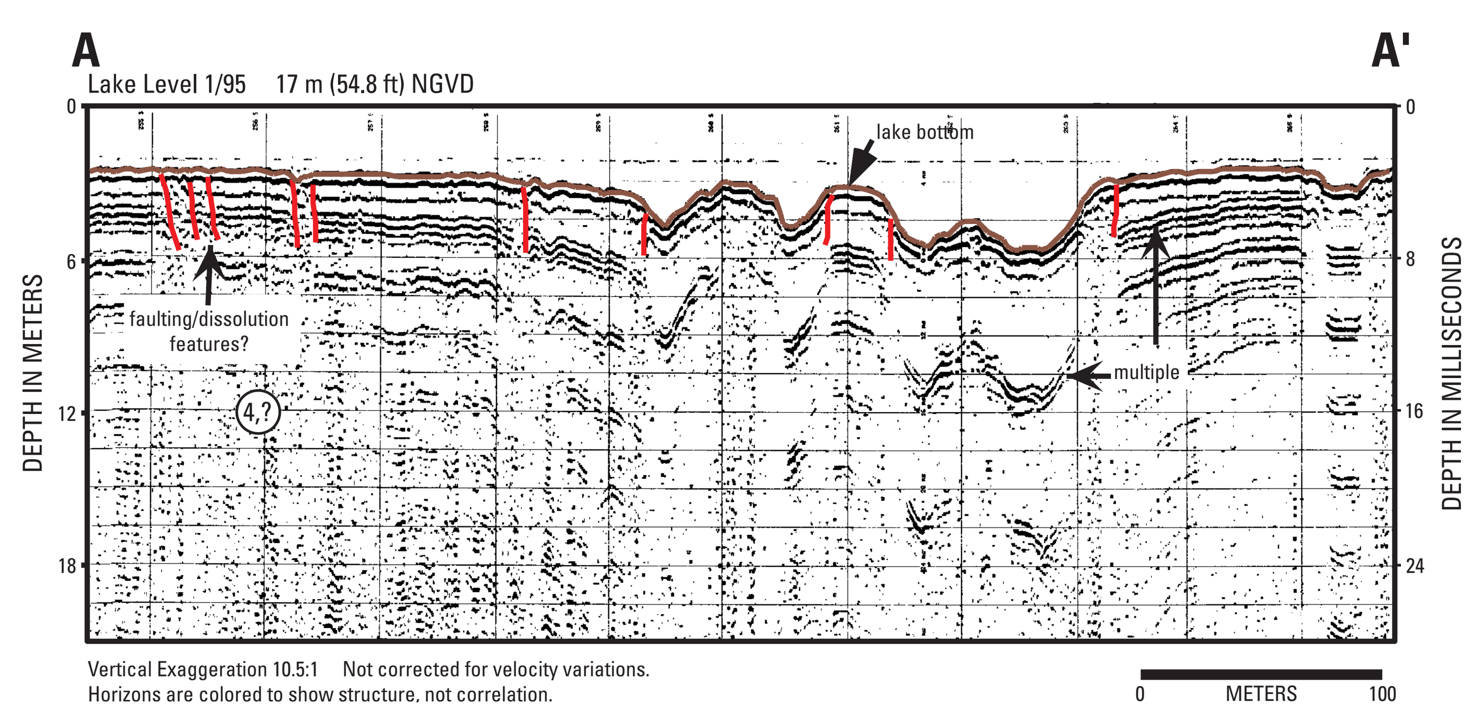
The top of the Ocala Limestone plunges to the east beneath Lake Weir, as indicated from interpretations of gamma-log profiles obtained from wells around the lake. The Ocala surface is at 4.6 m (15 ft) NGVD on the southwest side of the lake (well M-0070, see Gamma-log sheet) and decreases to about 30.5 m (-100 ft) NVGD on the east side (M-0079, M-0080). A well north of the lake (M-0078) shows the contact to be at -5 feet NGVD. This irregular surface may indicate mature karst development beneath Lake Weir and the disturbed nature of the reflective horizons shown in seismic profile B-B' (blue and red lines) could be a result of more recent subsidence in the overburden. Well logs indicate that the Hawthorn Group crop out on the west side of the lake and dip to around zero feet NGVD to the east. This corresponds to approximately 16 m depth in seismic profile B-B' and would suggest the reflective horizons represented by the red and blue lines in the profile to correlate with the top of the Hawthorn Group.

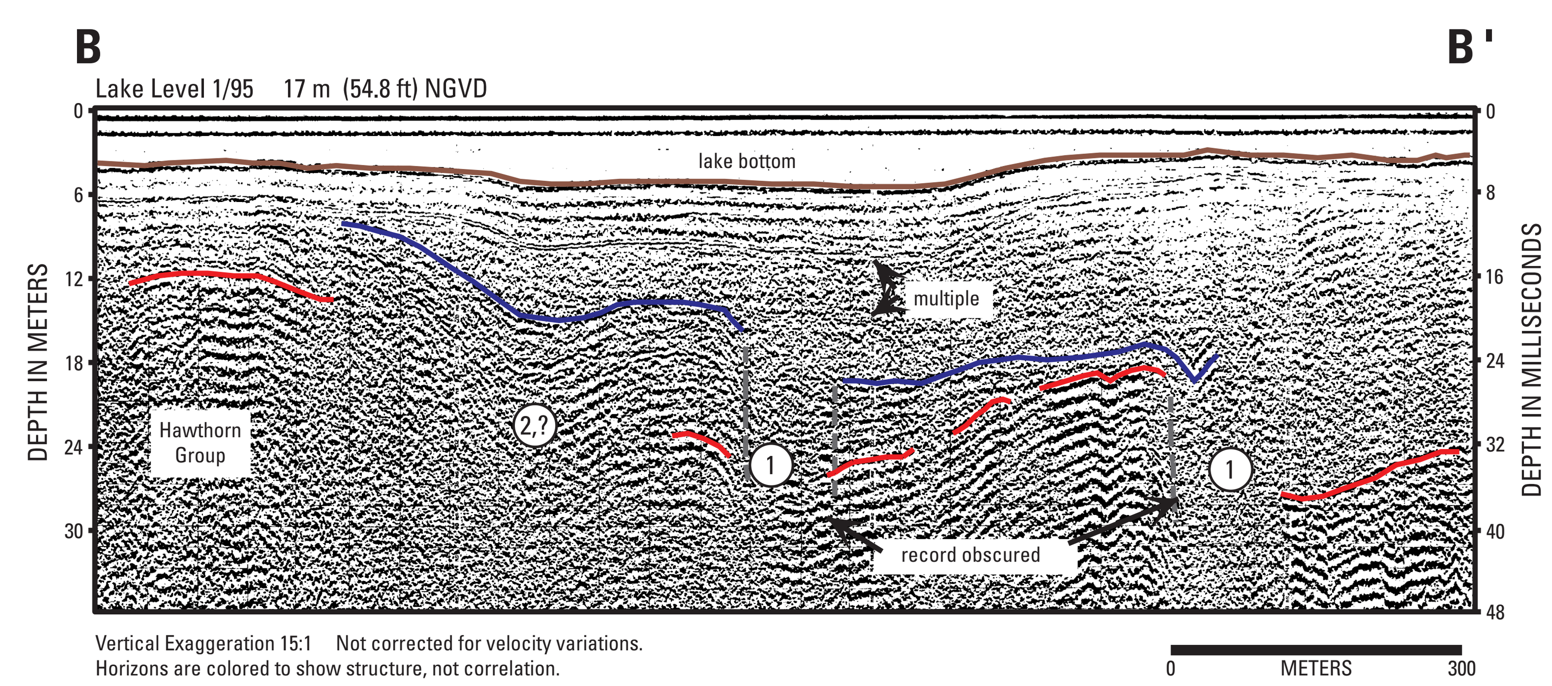
EXPLANATION



LOCATION OF POSSIBLE SUBSIDENCE & RELATED FEATURES INTERPRETED FROM SEISMIC PROFILES







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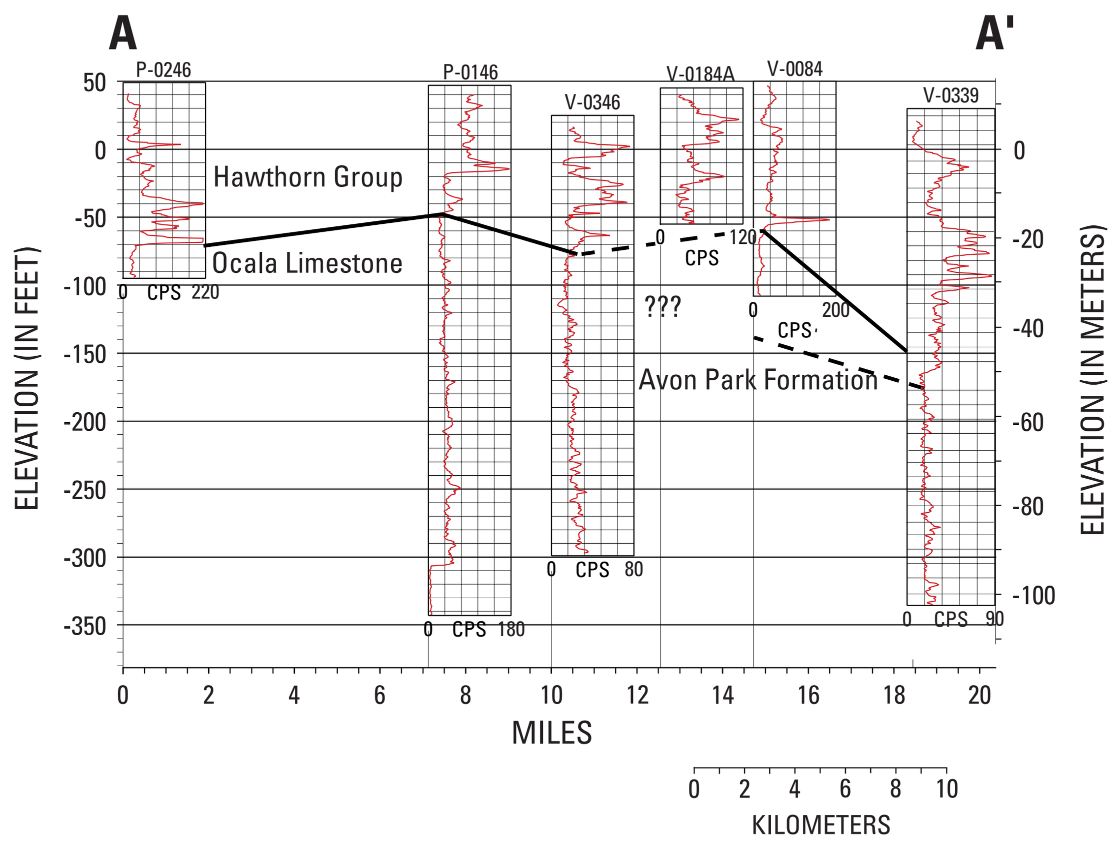
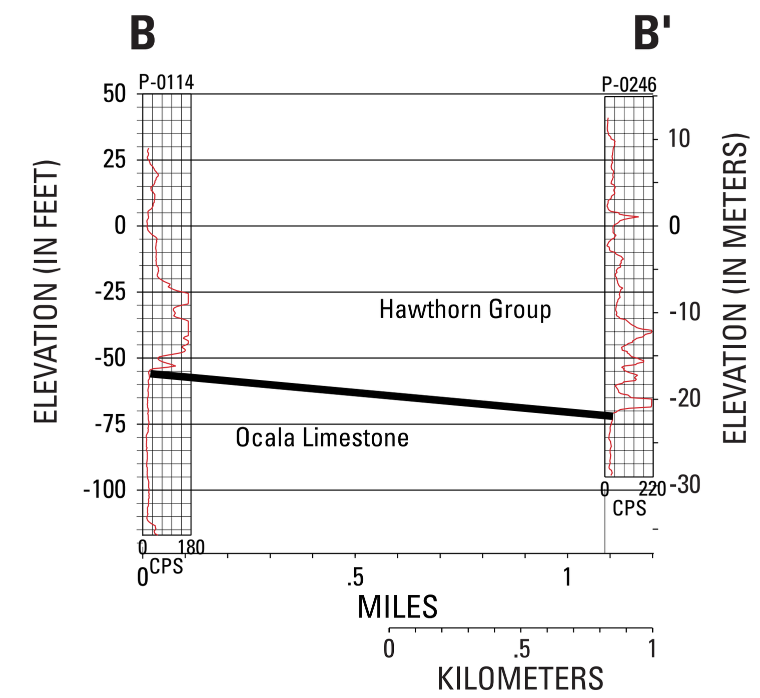
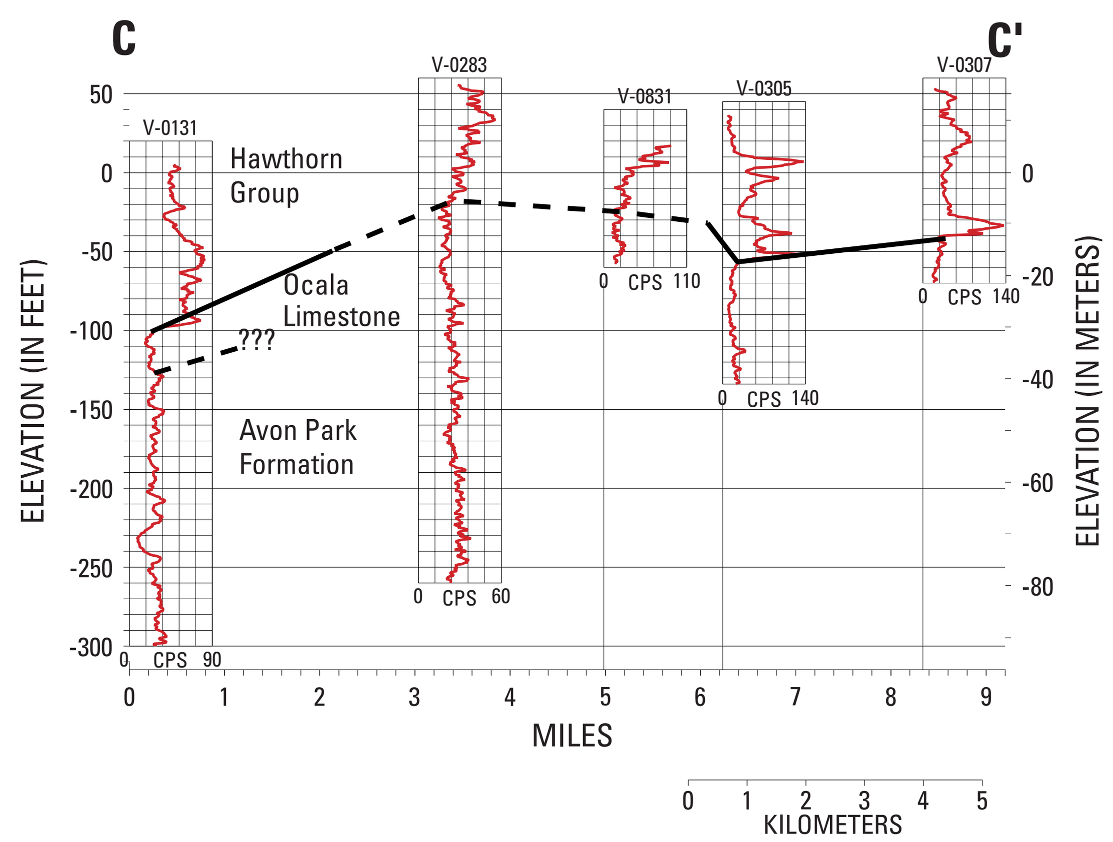
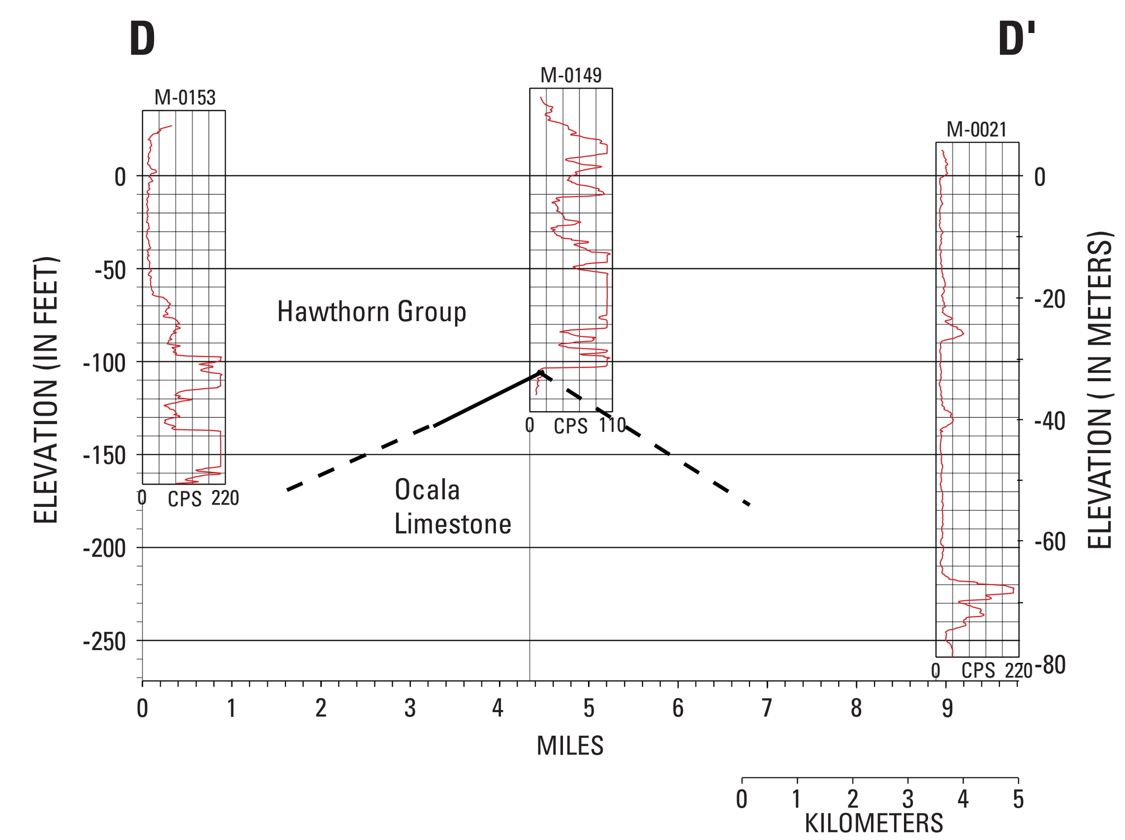
INDEX MAP AND GAMMA LOG

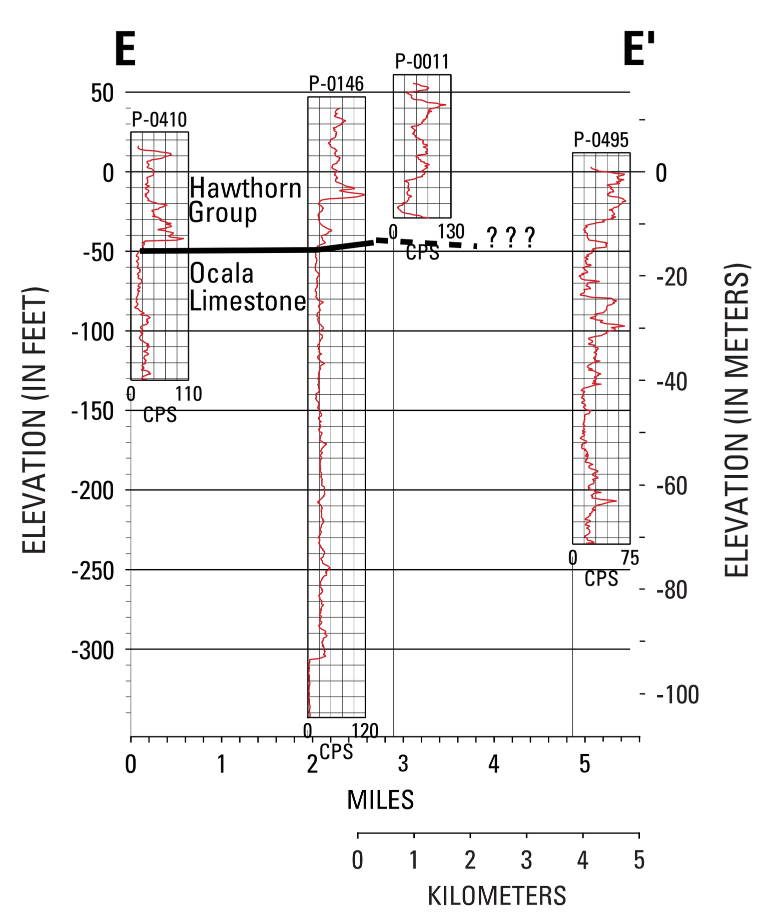
CROSS-SECTIONS, SECTION D

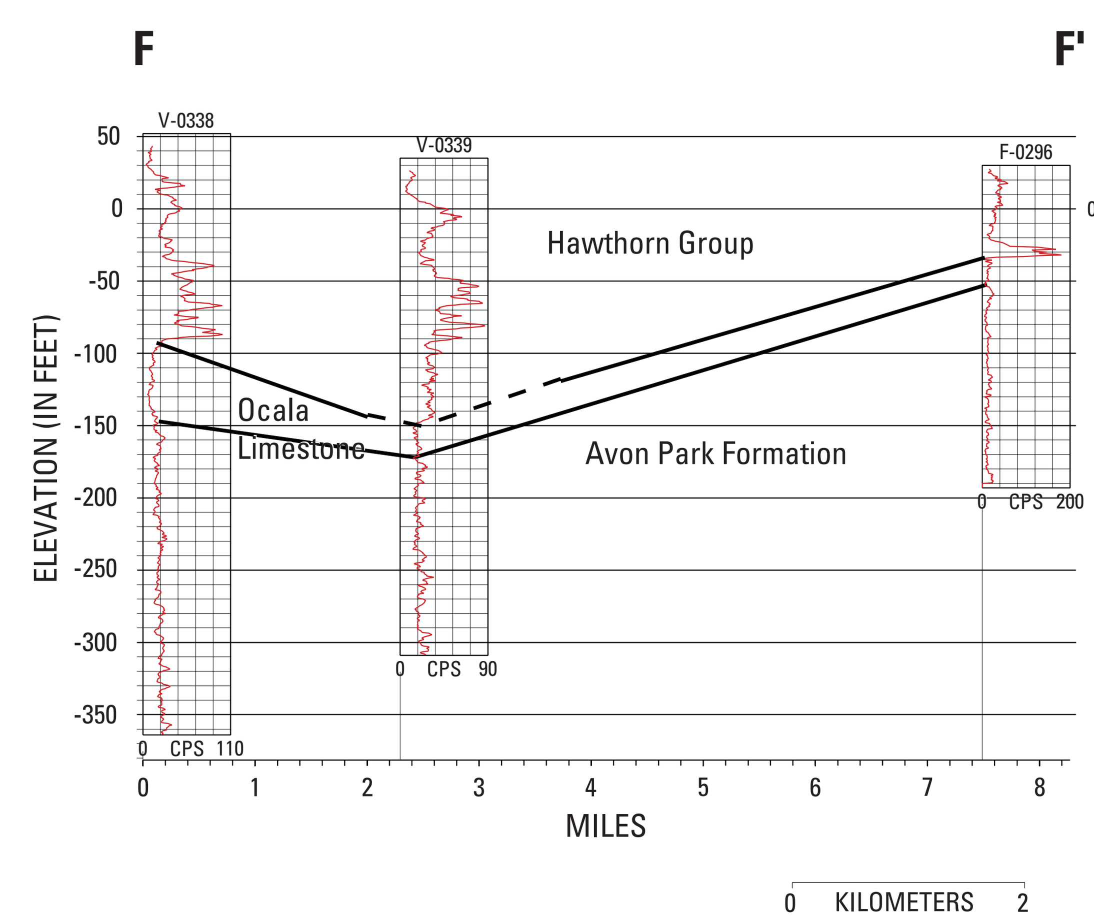




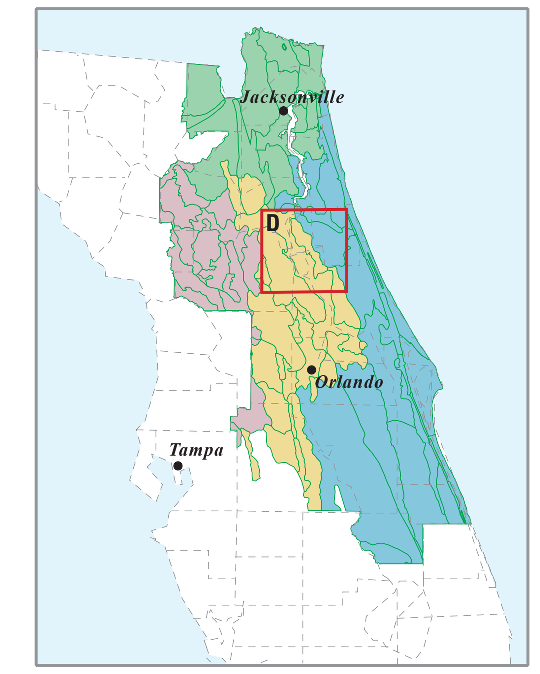




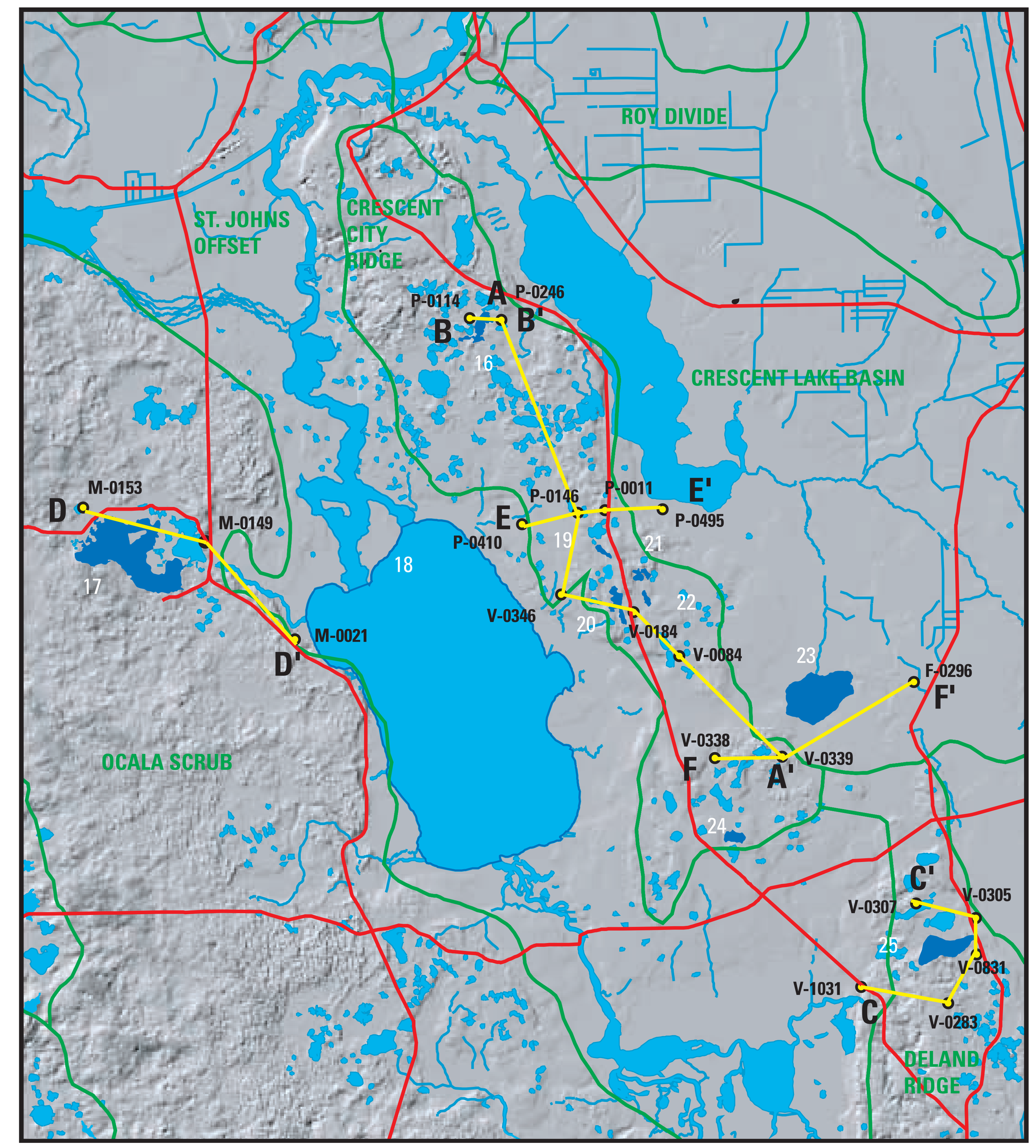




Location of survey area right (red square). Shaded relief map below showing physiographic regions, and location of wells and gamma log cross-section. Gamma Log cross-sections (left) show geologic contacts for correlation to seismic sections.



D



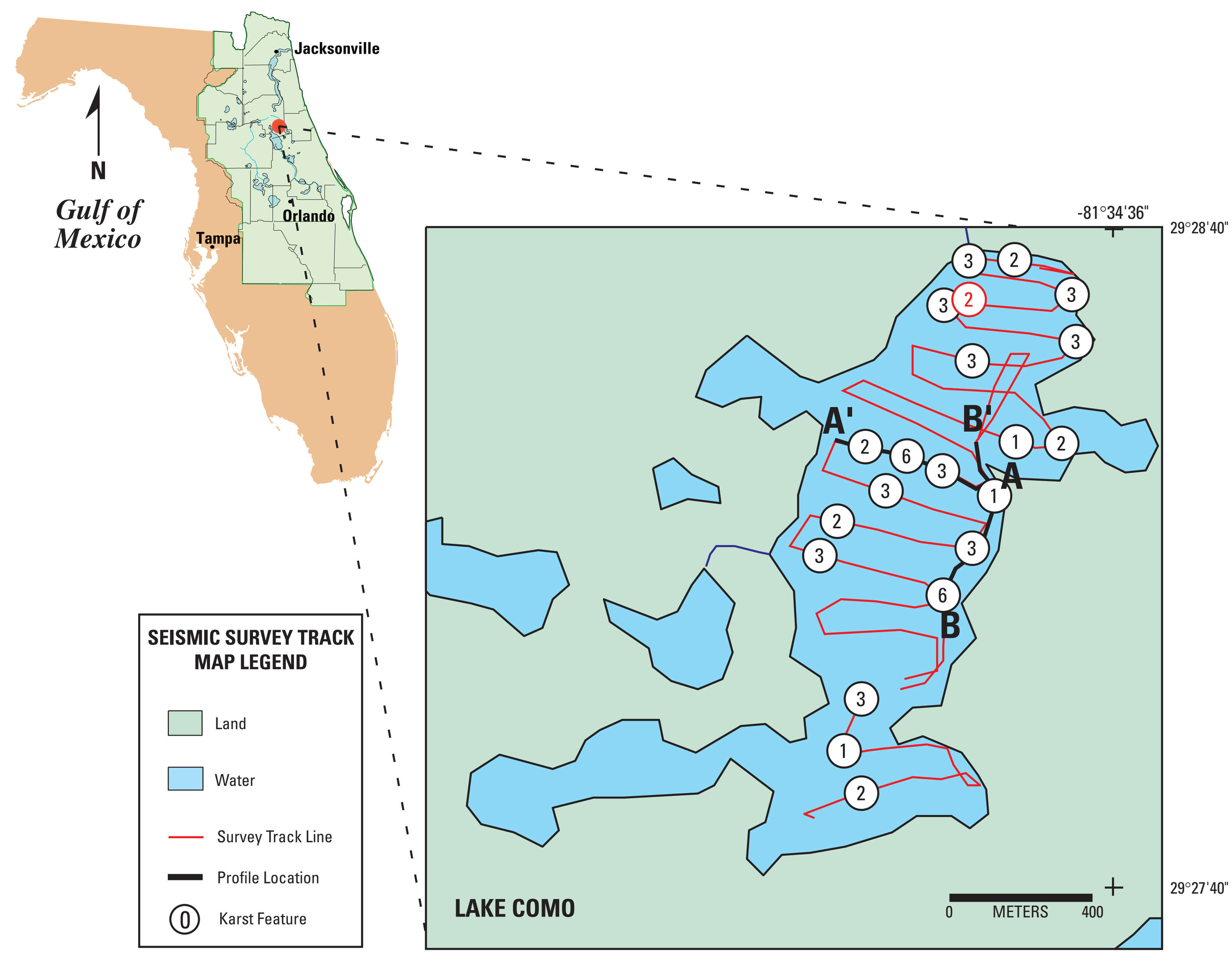
LEGEND

Wells, Cross-Sections
Streams/Rivers
Major Roads
Provinces
Lakes
Lakes in Atlas

		page #
16	Lake Como	23
17	Drayton Island	24
18	Lake Kerr	25
19	Lake Davis	26
20	Upper Lake Louise	27
21	Cow Pond	28
22	Lake Juanita	
23	Lake Disston	29
24	Cain Lake	
25	Lake Dias	30

1 0 1 MILES
1 0 1 KILOMETERS

LAKE COMO
PUTNAM COUNTY, FLORIDA



Introduction

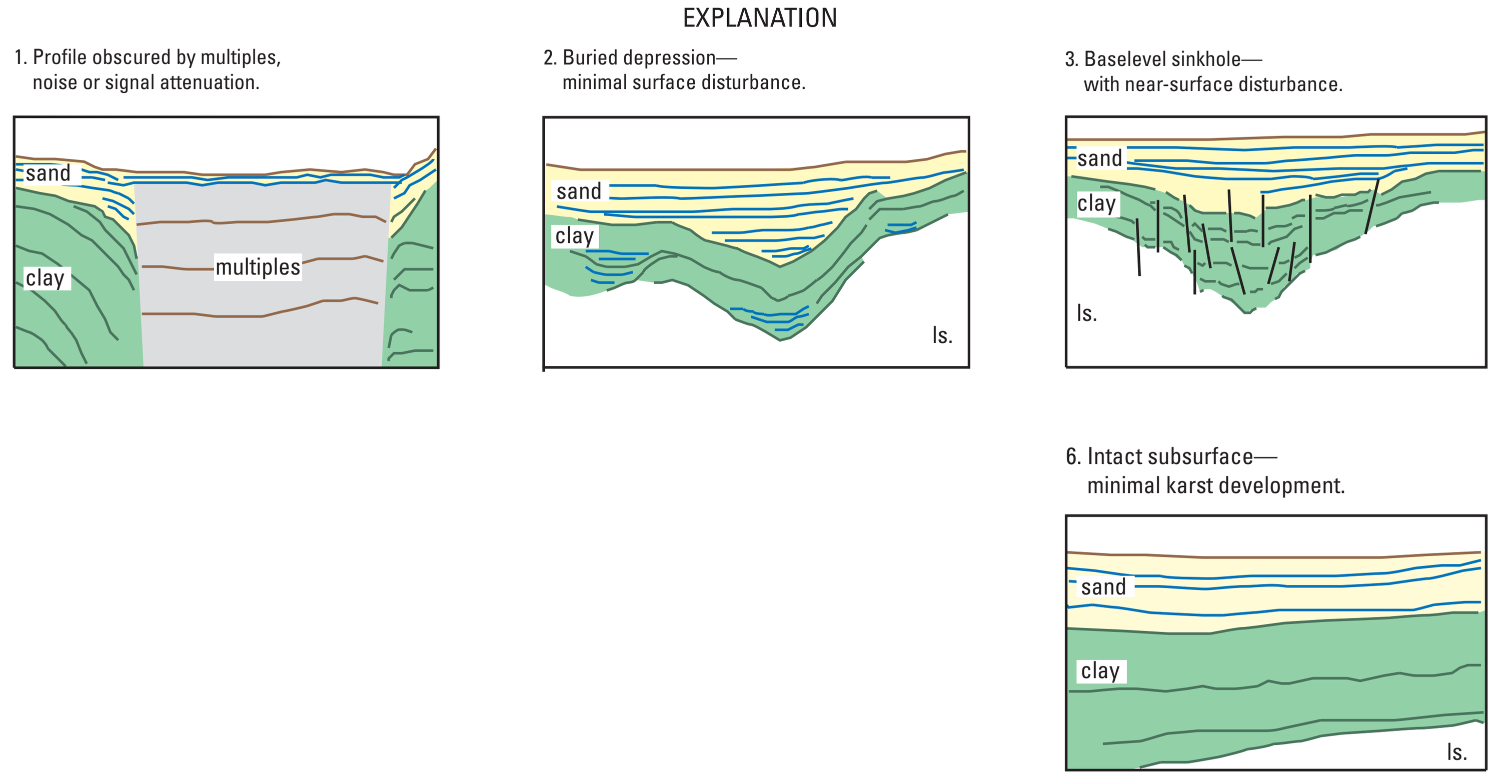
Lake Como is located on the Crescent City Ridge in south central Putnam County, Florida. The area consists of sand hills with peak elevations between 24 to 30 m (80 to 100 ft) NGVD that are bordered on the west by the floodplain of the St. Johns River and Lake George and Crescent Lake basin on the east. Lakes within the ridge system are smaller (< 1 km) and irregular in shape as they occupy troughs within the sand hills. Lake Como is a good example of this irregular shoreline, with a perimeter of just under 8 km (5 mi) yet covering an area of only 1.4 sq km. Lake level is about 12.2 m (40 ft) NGVD. In the immediate vicinity around the lake are numerous smaller lakes. Several are connected via surface flow to Lake Como.

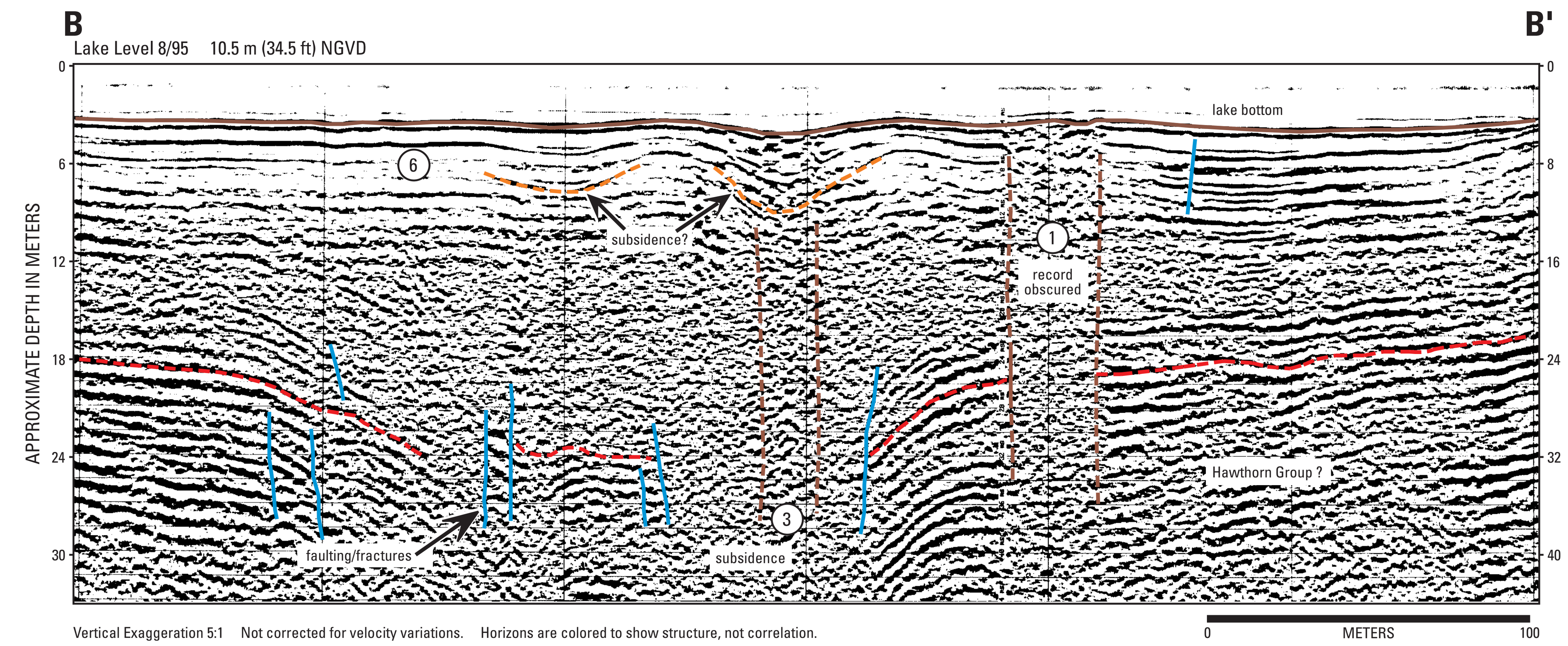
Subsurface Characterization

Seismic profiles in Lake Como show many small (>100 m, 328 ft), low angle reflectors overlain and onlapped by horizontal reflectors (profiles A-A' and B-B'). These features represent small-scale subsidence with subsequent infilling. The areas of localized subsidence have been mapped out in the figure showing areas of subsidence. The subsidence features appear to be controlled at depth by collapse in the underlying structure. This is shown in profile B-B' with downwarped reflectors and subsidence-related faulting (type 3). The near surface fill is nearly acoustically transparent and is possibly homogeneous sands from the surrounding sand ridges infilling the depressions. In places the overburden appears to be displaced and rotated as it slumps into the depression (north shore red number 2, Seismic Survey Track Map). Gamma counts from wells in the vicinity place the top of the Hawthorn Group at about -9 m (-30 ft) NGVD and the top of the Ocala Limestone at about -20 m (-65 ft) NGVD (wells P-0114, P-0246, Index Map D, page 22). The reflector shown as a red dashed line in the seismic profiles may represent a horizon near the top of the Hawthorn Group. Subsidence in the Hawthorn Group sediments, as a result of structural collapse in the underlying Ocala Limestone, would provide recharge pathways to the aquifer. The near surface undifferentiated fill appears to be relatively intact, although some subsidence or breaches may be present as shown in profile B-B'.

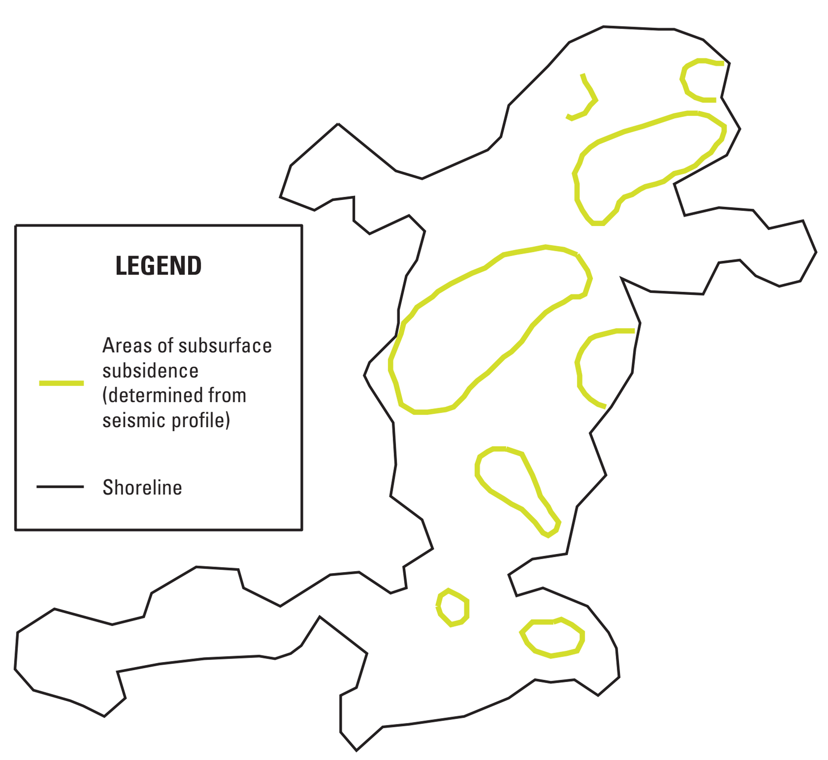
D

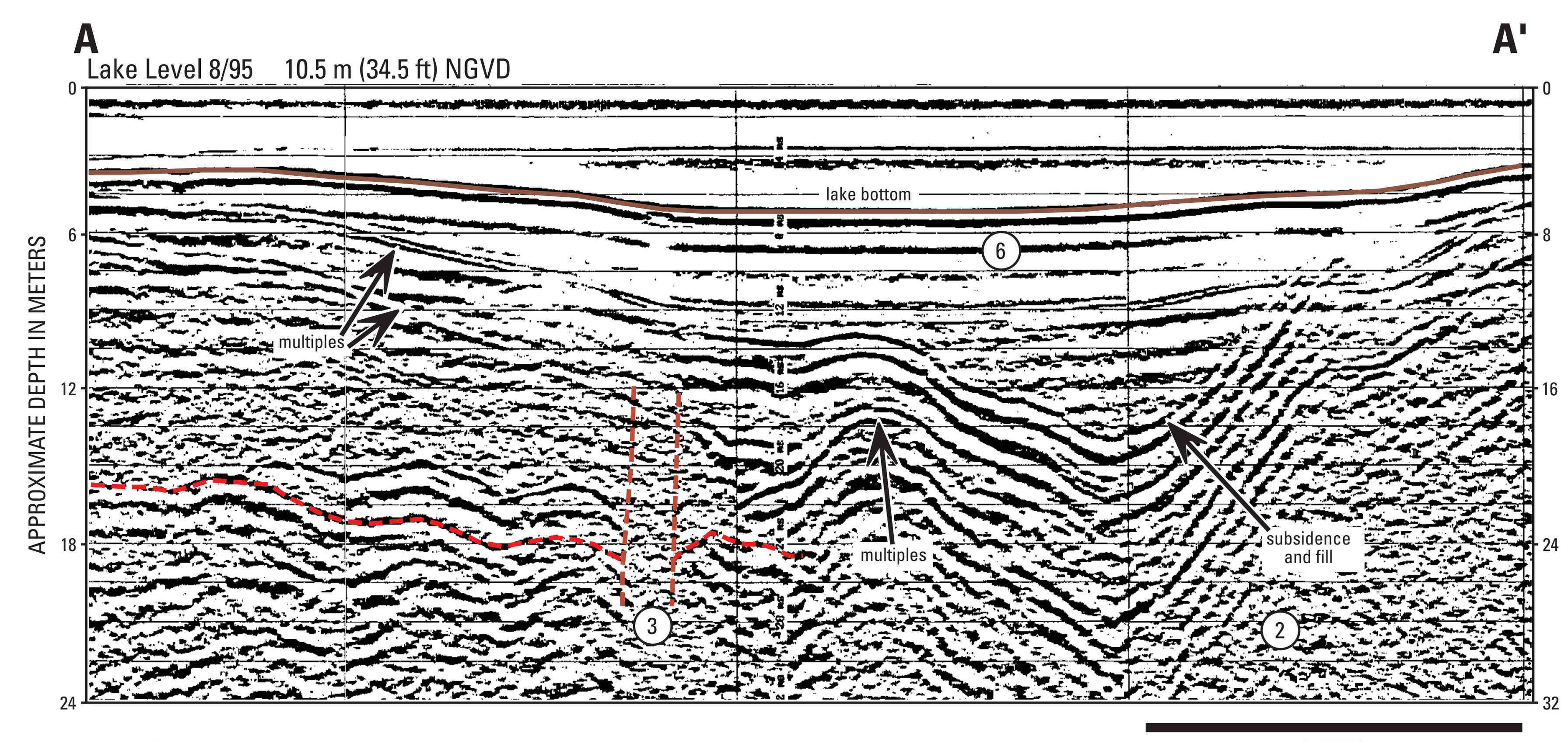
EXPLANATION





LOCATION OF SUBSURFACE SUBSIDENCE AREAS





Subsurface Characterizations of Selected Water Bodies in the St. Johns River Water Management District, Northeast Florida

Jack L. Kindinger[1], Jeffrey B. Davis[2], and James G. Flocks[1]
2000

[1] Center for Coastal Geology and Regional Marine Studies
U.S. Geological Survey
St.. Petersburg, Florida 33701

[2] St. Johns River Water Management District
Palatka, Florida 32178

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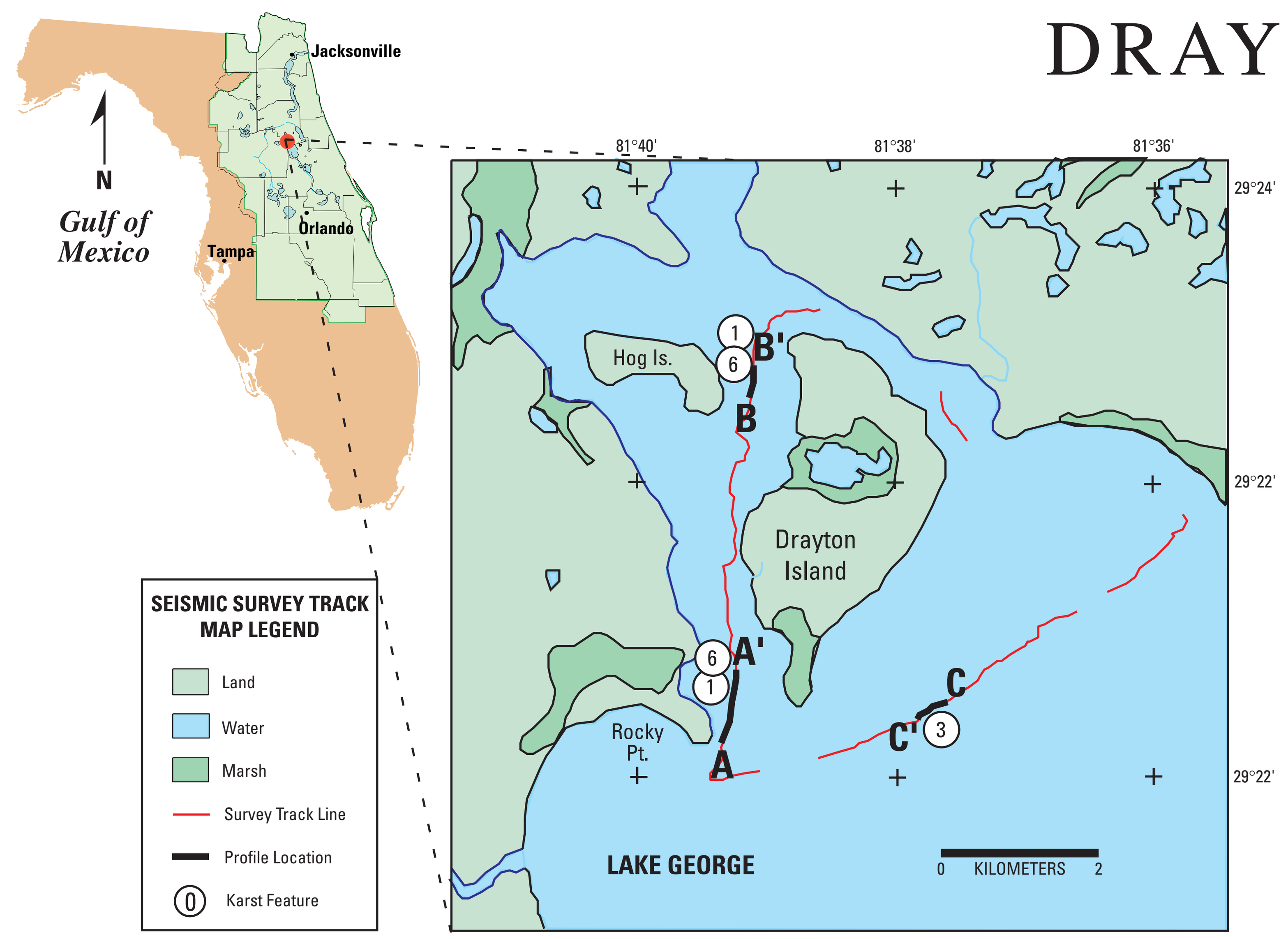
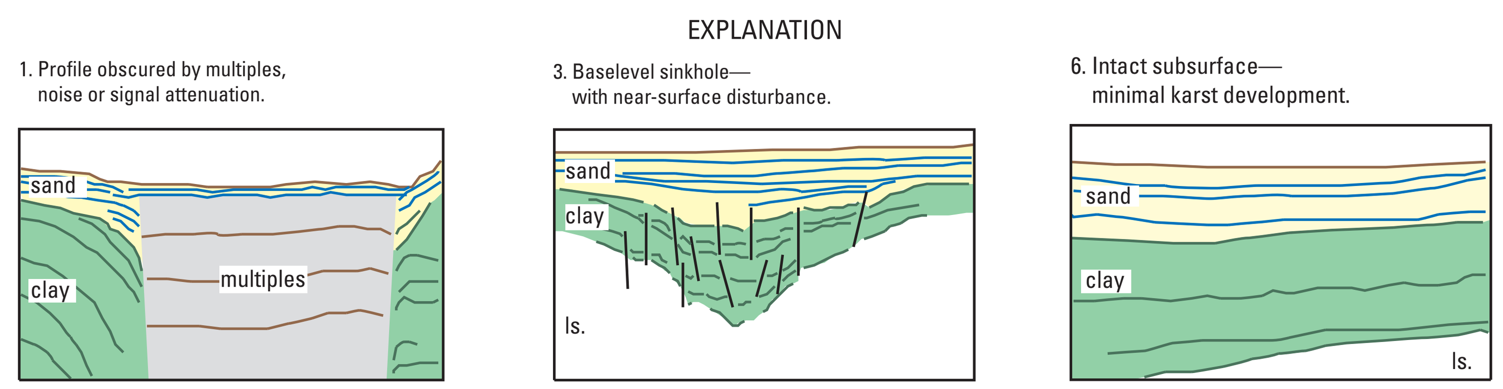


DRAYTON ISLAND, LAKE GEORGE

PUTNAM COUNTY, FLORIDA



Introduction

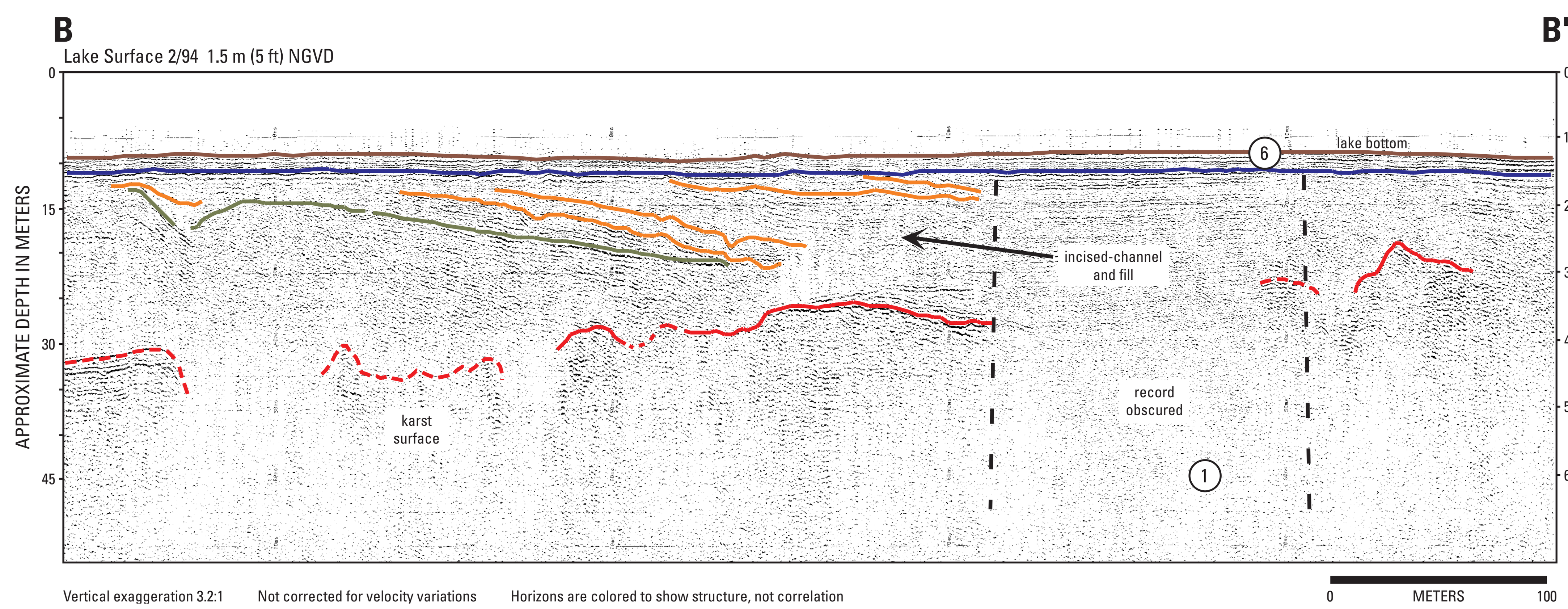
The area surveyed near Drayton Island in Lake George occupies southernmost Putnam County. The lake is part of the St. John's River system and the broad valley of the St. John's Offset. The development of this valley is due in part to solution in the underlying limestone, which nears the surface in this area. The lake is bound on either side by the sand hills of the Crescent City Ridge to the east and the Ocala Scrub physiographic region to the west. The flood plain is characterized by swamp vegetation. Four seismic lines, approximately 12 km (7.5 mi), were run around the island. Data quality is typically poor due to noise and ringing in the acoustic return. Possible reasons include accumulation of organics at the river bottom, tightly packed sand in the near-surface and echoes from the nearby shoreline obscuring the signal.

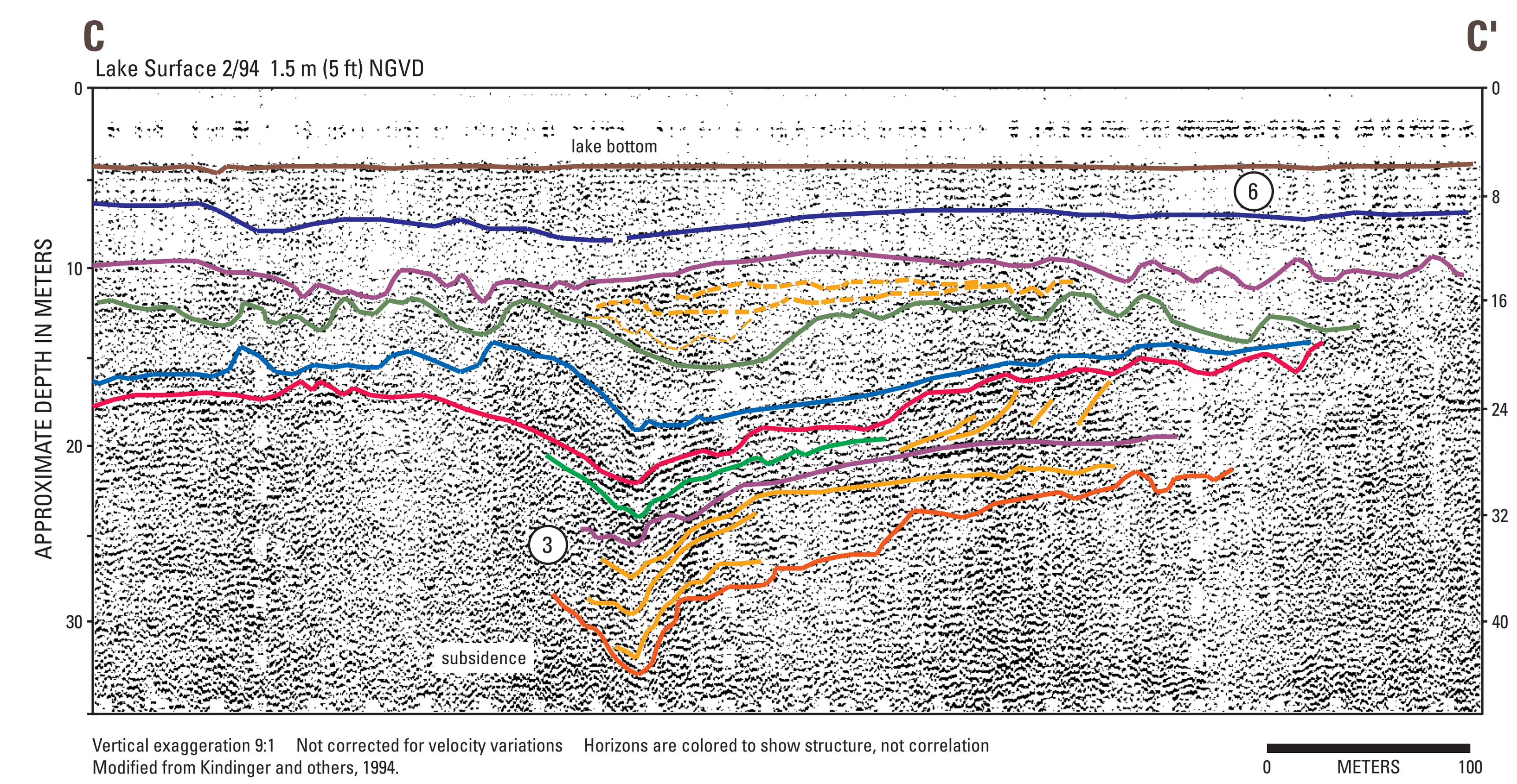
Subsurface Characterization

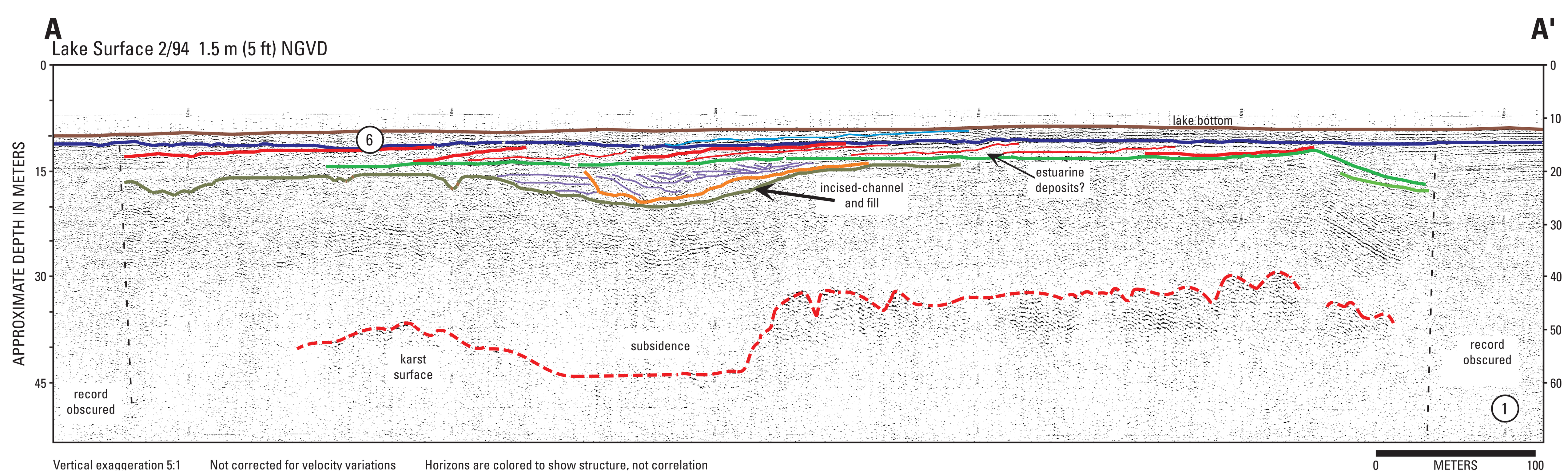
Three example seismic profiles near Drayton Island show several different types of geologic characterization present within the St. Johns River Valley. Karst development in the underlying limestone is accompanied by fluvial-type incised channels, occupying areas of subsidence caused by the loss of material at depth. Profile A-A' shows relatively mature karst development in the limestone, represented by the red dashed line at 30 to 45 m (92 to 148 ft). Gamma log profiles from four wells surrounding the northern portion of Lake George (P-0410, V-0346, M-0149 and M-0021; Index Map D, page 22) show a highly fluctuating upper contact to the Ocala Limestone. Depths to limestone range from greater than -61 m (-200 ft) below sea level southwest of Drayton Island, to -30 m (-100 ft) to the west, to -15 m (-50 ft) at the lake's eastern shoreline. The variability and range are consistent with the contact represented by the red dashed line on profiles A-A' and B-B'. In profile A-A', a fluvially-incised channel (light brown line) appears to reside over one of the more pronounced depressions in the karst surface. Multiple incisions appear within the channel (orange line) with fill (purple lines). Channel development was apparently terminated and a planing surface (green line) is overlain by a more recent depositional event (solid red lines). This sequence can be correlated to spikes in the gamma counts at -12 m (-40 ft) below sea level (P-0410, V-0346 and M-0149), suggesting a fluvial source, possibly a Pleistocene flooding surface and estuarine deposition, as seen elsewhere within the St. John's Offset (Brooks and Merrit, 1981). These low-angle reflectors are also truncated (dark blue line) and what appear to be recent, riverine deposits occupy the nearsurface of the profile. On the right side of the profile there appears to be another drop in the limestone surface which is also occupied by a channel incision (green lines), but most of this feature is obscured by noise in the seismic record.

Profile B-B' exhibits similar fluctuations to the karst surface, with another incised channel taking shape (brown and orange lines) before being obscured by noise in the record. The truncation surface and subsequent depositional event represented by the solid red lines in profile A-A' are not as readily apparent. It is possible that the orange lines in profile B-B' may be correlative with this depositional event. The more recent hiatus (dark blue line) and overlying fluvial deposits are consistent in both profiles. The relationship of these incised channels to subsidence in the underlying geology is probably geomorphologic; channel development occurred within previously existing depressions and was not necessarily concurrent to karst development.

The shape of the channel incisions and the nature of their fill are similar to buried incised channels observed in seismic profiles acquired from the nearshore shelf environments of the Gulf and Atlantic coasts. The feature outlined in profile C-C' is characteristic of karst-type subsidence rather than a fluvial incision. Again the deepest red reflector may be correlative to the top of the Ocala Limestone, the overlying reflectors may represent subsequent subsidence in the sediments of the Hawthorn Group. Reflectors exhibit subsidence up to the near-surface, suggesting the karst feature in this profile post-dates the fluvial deposition shown in the previous two profiles. The uppermost subsurface reflector (dark blue line) is again overlain by high frequency, parallel reflectors which may be representative of recent fluvial deposition.







Subsurface Characterizations of Selected Water Bodies in the St. Johns River Water Management District, Northeast Florida

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2000

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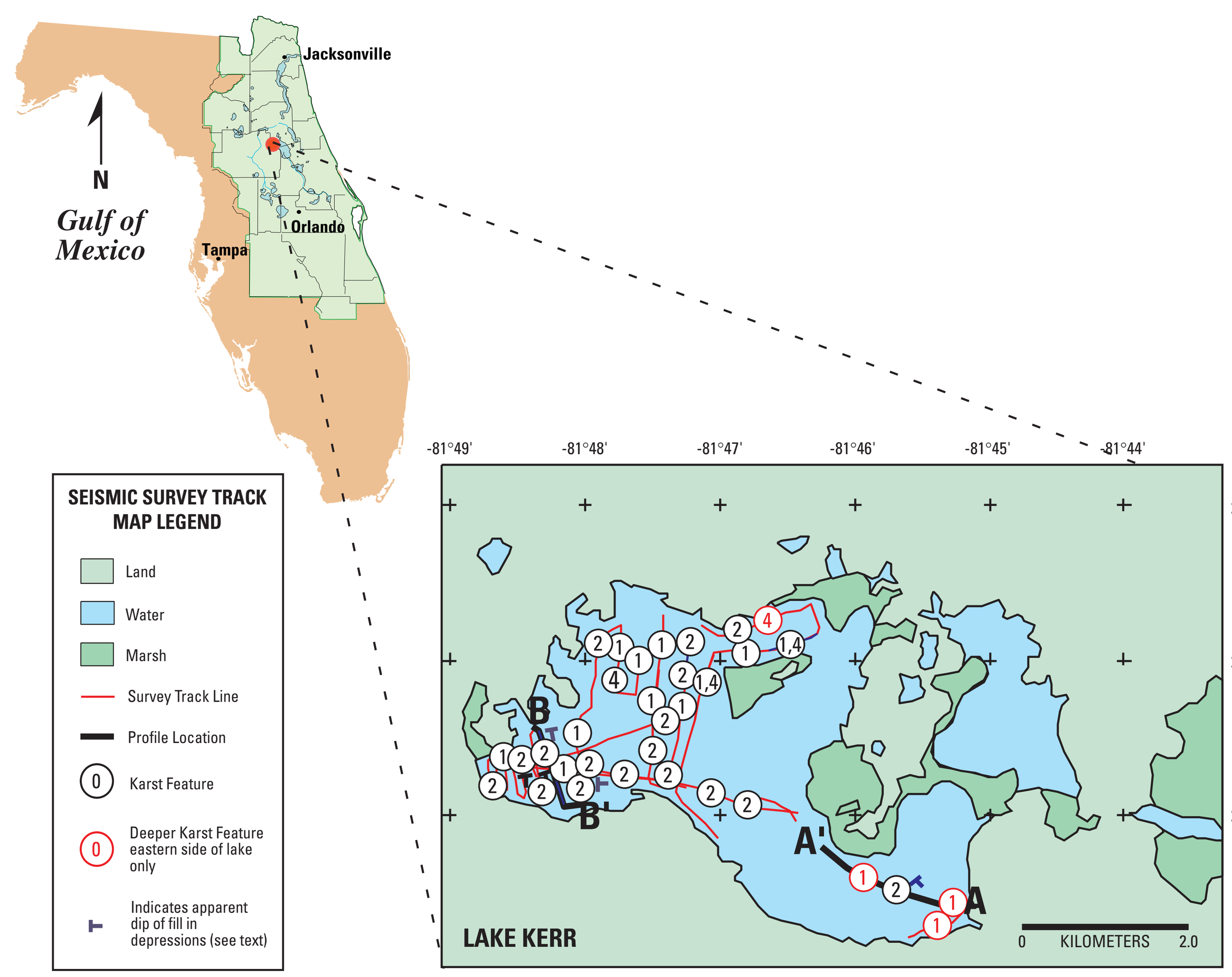


LAKE KERR

MARION COUNTY, FLORIDA

Introduction

Lake Kerr, in northeast Marion county, is located in the Ocala Scrub area of the Central Lake District. The vast Ocala National Forest lies directly to the south. The shoreline is very irregular and nearly divides the lake in two, with a total length of 30 km. The lake covers an area of about 17 sq km, water depth ranges between 2-4 m (~6-14 ft) water depth, but exceeds 5 m (~16 ft) in some areas. Salt Springs is located in the southeast portion of the lake and Salt Springs Run connects Lake Kerr to Lake George and the St. Johns River system to the east.

Subsurface Characterization

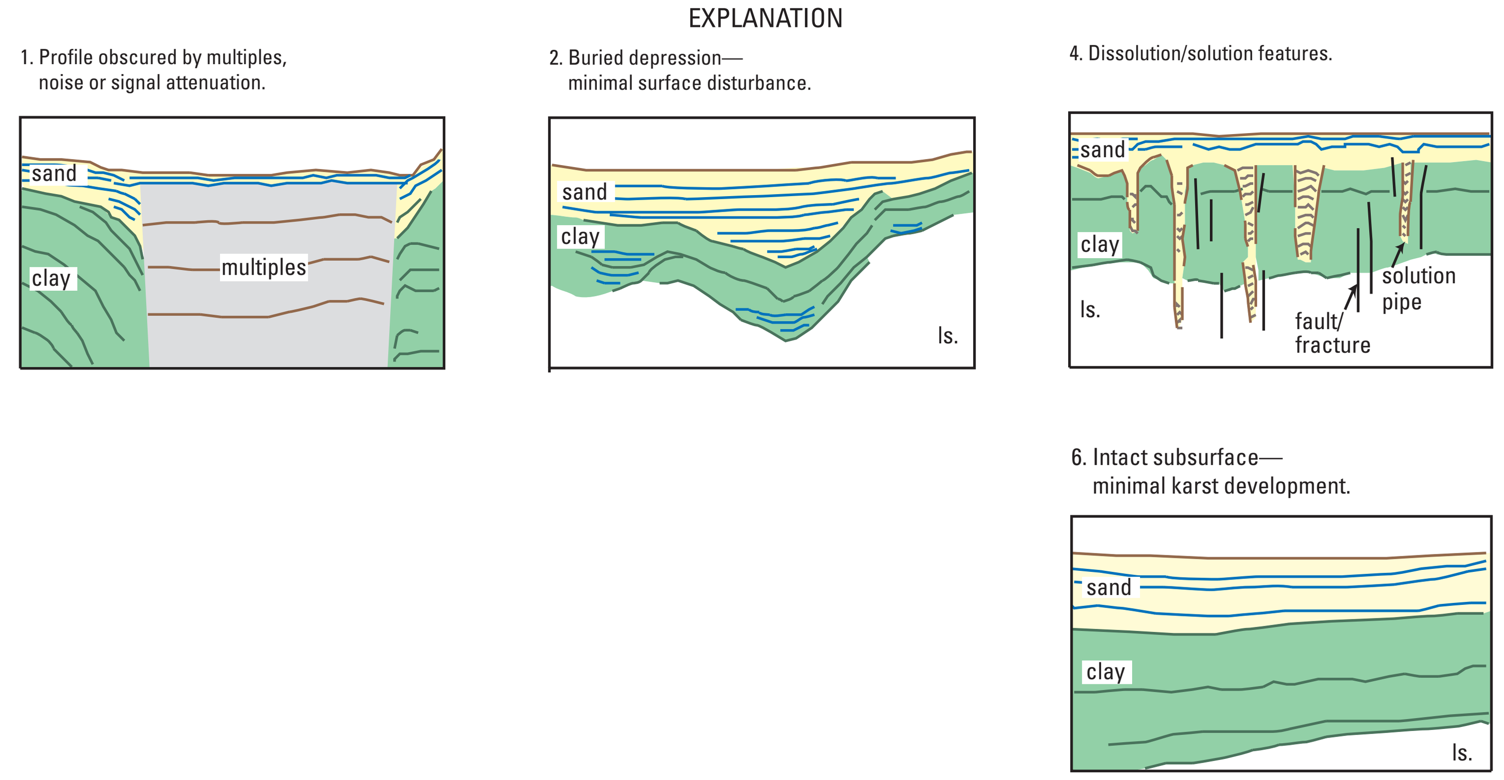
Lake Kerr is characterized by numerous subsidence depressions (type 2) tens to hundreds of meters in width (seismic profiles A-A', B-B'). Parallel to low angle reflectors within the depressions indicate active infilling during subsidence. The low-angle reflectors appear to dip toward the southeast when present in the record (black dip symbols, Index Map D, page 22). This infilling gives the lake a smooth bathymetry (brown line contour map), unlike the highly irregular subsurface in which the subsidence occurs (blue line contour maps and 2-D profiles). The reflective horizons that were digitized to produce the contour maps are shown on the seismic examples. The north and south cross sections, derived from the gridded contour data sets, shows this contrast very well and may indicate that subsidence had matured prior to deposition of the nearsurface sediments.

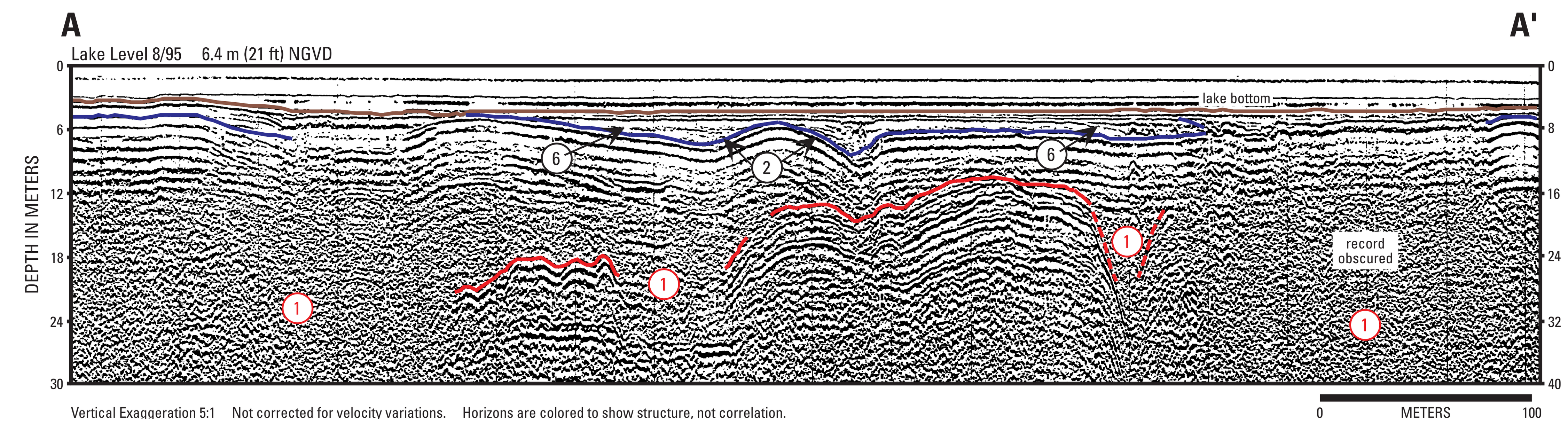
Noise in the seismic record decreases in the eastern part of the lake and deeper reflective horizons can be seen (seismic example A-A', red line). The acoustic signal in the lower horizons is more chaotic and contains very high angle reflectors, whereas the upper horizons have lower angle, intact reflectors. It seems apparent in the seismic profiles that more solution-type collapse has occurred in the lower horizons and that it has influenced a more gradual subsidence in the overlying material (blue line). During subsidence the depressions were filled, possibly during migration of paleo-dunes that define this physiographic region.

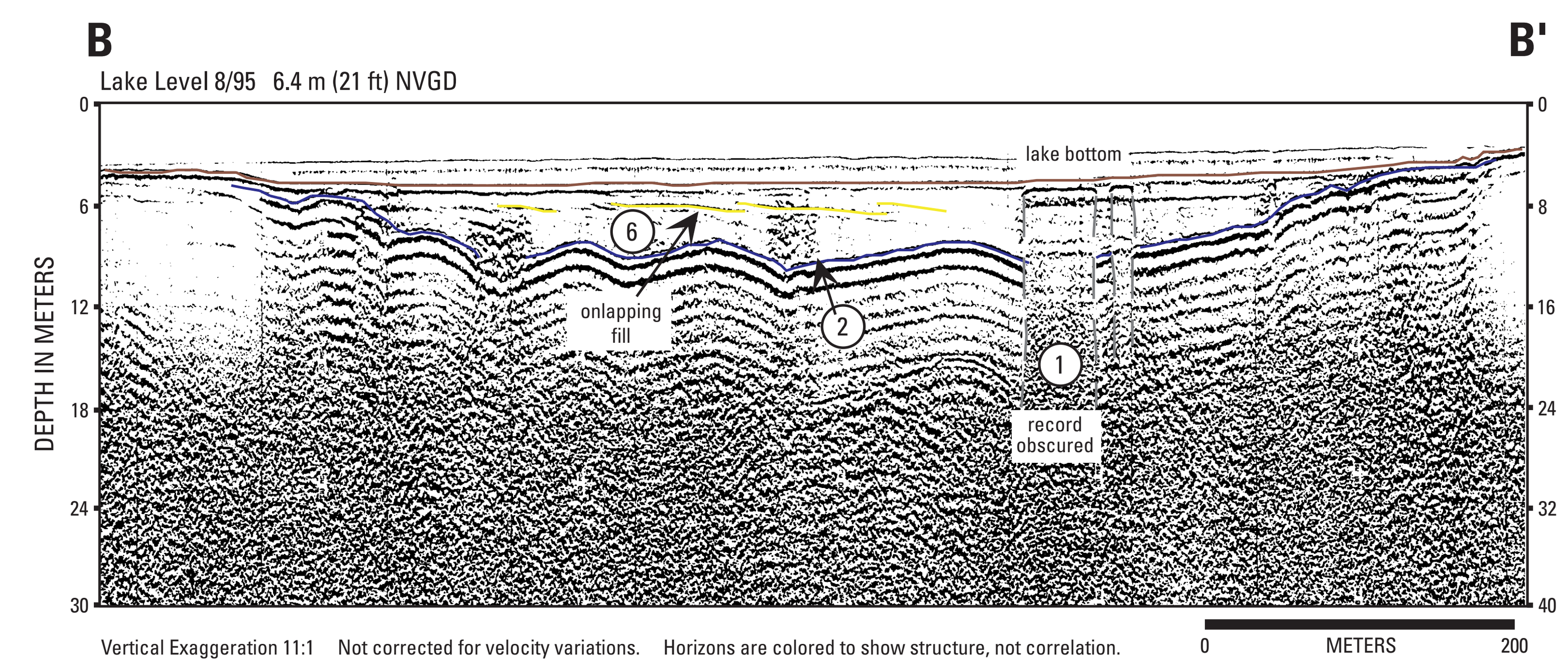
The contact between the Ocala Limestone and the Hawthorn Group, as interpreted from Gamma Log profiles, is deeper than resolvable depth in the seismic profiles. However, changes in Gamma counts in a well northeast of the lake (well M-0149, Index Map D, page 22) within the Hawthorn Group may correlate with the reflective horizons within profile A-A' at about 12 m.

D

EXPLANATION

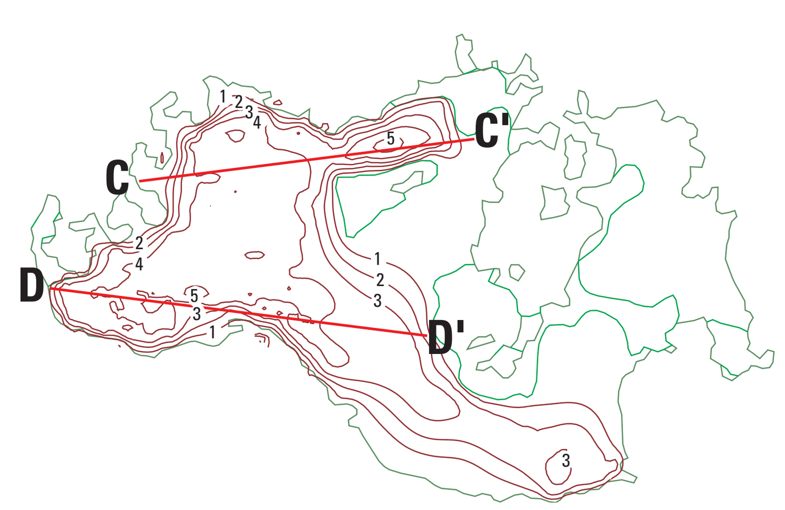


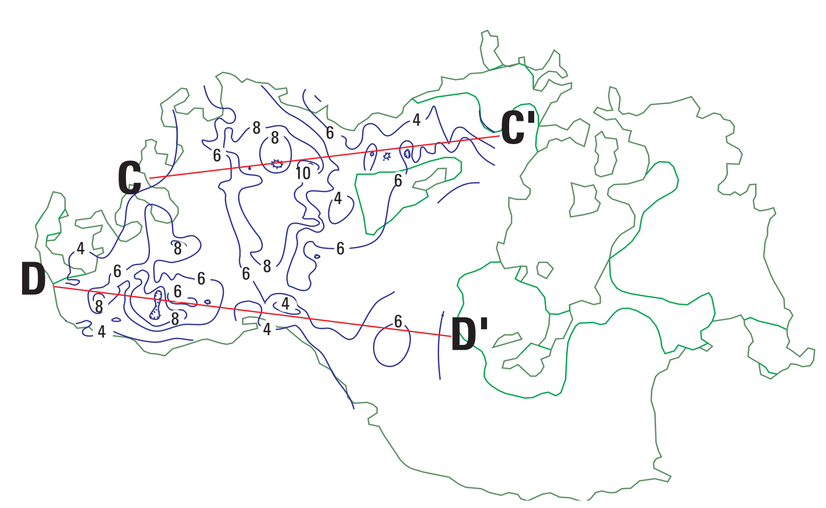




DEPTH TO LAKE BOTTOM **DEPTH TO SUBSURFACE HORIZON**

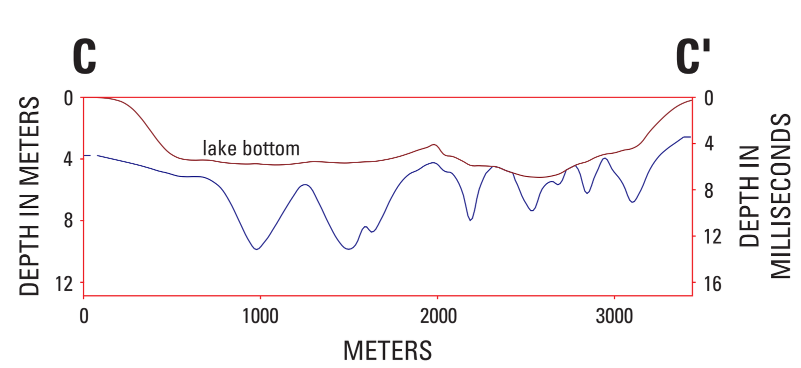
Vertical Exaggeration 87:1
Contours are in Meters from lake level.





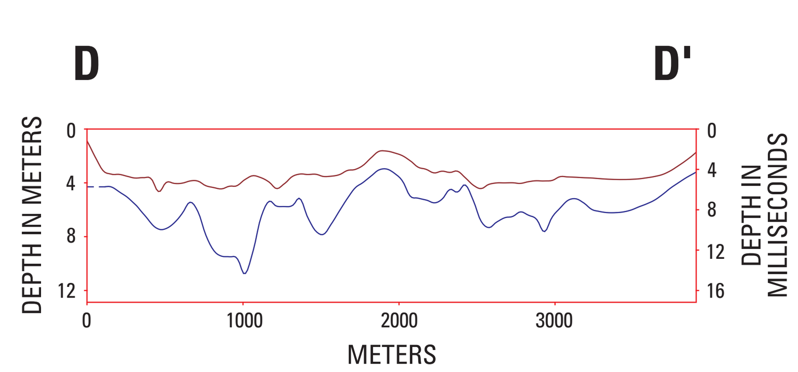
Vertical Exaggeration 87:1
Contours are in Meters from lake level.

CROSS SECTION OF TRANSECT C-C'



Vertical Exaggeration 87:1.

CROSS SECTION OF TRANSECT D-D'



Vertical Exaggeration 87:1.

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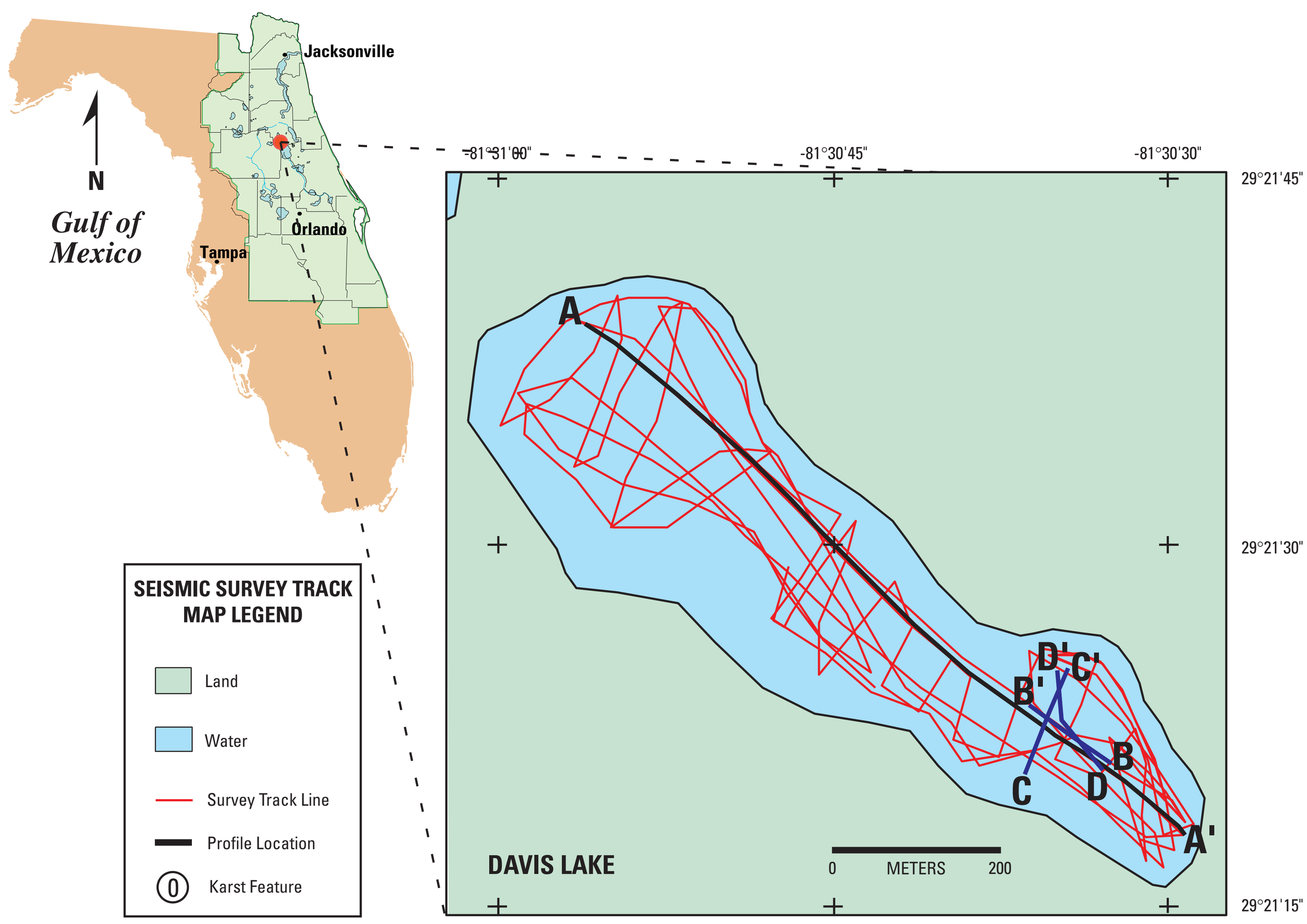


DAVIS LAKE

VOLUSIA COUNTY, FLORIDA

Physiography

Davis Lake is located along the Crescent City Ridge in northwestern Volusia County. The ridge is described by Brooks and Merrit (1981), as a complex of Plio-Pleistocene sand hills resting directly on the Floridan Aquifer, which is within the Ocala Limestone. The active karst development of the uplifted limestone makes this area a principle recharge area for the aquifer, as evidenced by the numerous lakes in Volusia and Lake counties. The Crescent City Ridge bisects the marshy lowlands of the Crescent Lake Basin to the east and the St. John's River valley to the west. The ridge trends southeast-northwest, along with Deland Ridge to the south. Ridge heights reach ~30 m (100 ft) above sea level, lake level at the time of the survey was about 7.6 m (25 ft) NGVD. Lake Davis is elongate in shape, with a perimeter of 5 km covering an area of approximately 1.6 sq km.

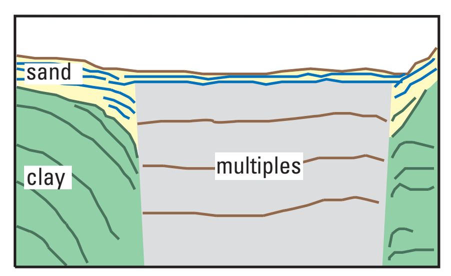
Geologic Characterization

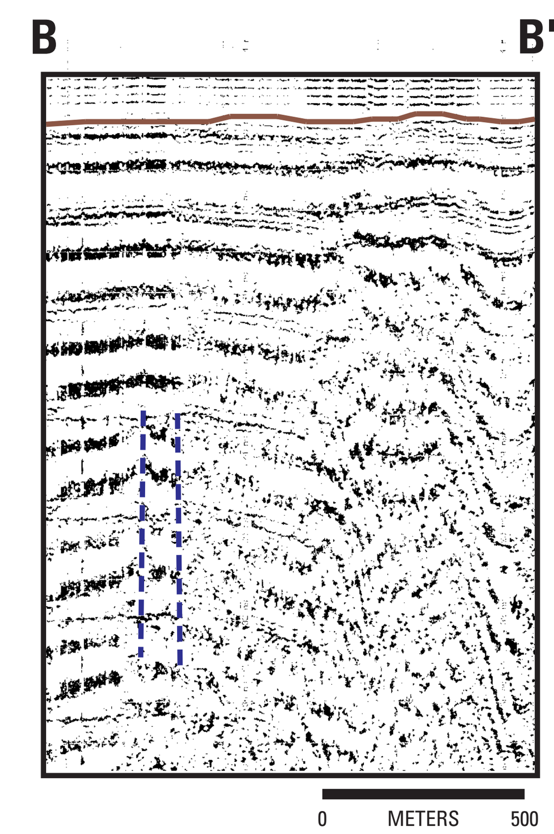
The quality of the seismic profiles obtained from Davis Lake is poor. Multiples of the bottom reflector are seen throughout the data and obscure some of the record in the deeper portions of the lake. The record is also partially obscured in areas where the lake bottom nears the surface, as shown midway in profile A-A'. The multiples may be a result of lithologically homogeneous, hard packed sands near surface which tend to set up ringing in the acoustic return, accumulation of organic material at the lake bottom may also attenuate the signal. Profile A-A' does show one area of potential disturbance (red dashed line). The high angle reflectors, that become obscured by the multiples, may represent a dissolution feature which would indicate a breach in the overburden. The parabolic return (left-most feature bracketed by red dashed lines) unfortunately is also a pattern commonly associated with submerged pipelines.

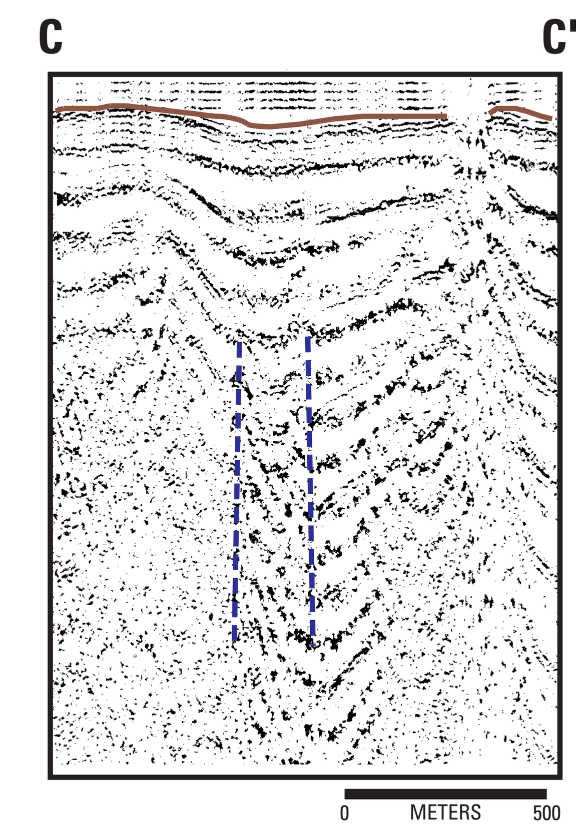
Three other lines that cross the same area are shown below right (B, C, D). The data is obscured by multiples, but inconsistencies in the acoustic return at depth may indicate a subsurface disturbance. Gamma-log profiles in the area (wells V-0346 and P-0146) show the contact between the Ocala Limestone and the overlying Hawthorn Group rising from about 21 m (70 ft) below mean sea level to the southwest, to 15 m (50 ft) below mean sea level north of the lake. This corresponds to approximately 20 m (-65.6 ft) below lake bottom, using an averaged sound velocity of 1500 m/s. This depth puts the top of the aquifer-bearing Ocala Limestone very near the surface. A breach through the overburden would increase the potential for contact between the surface waters and the aquifer.

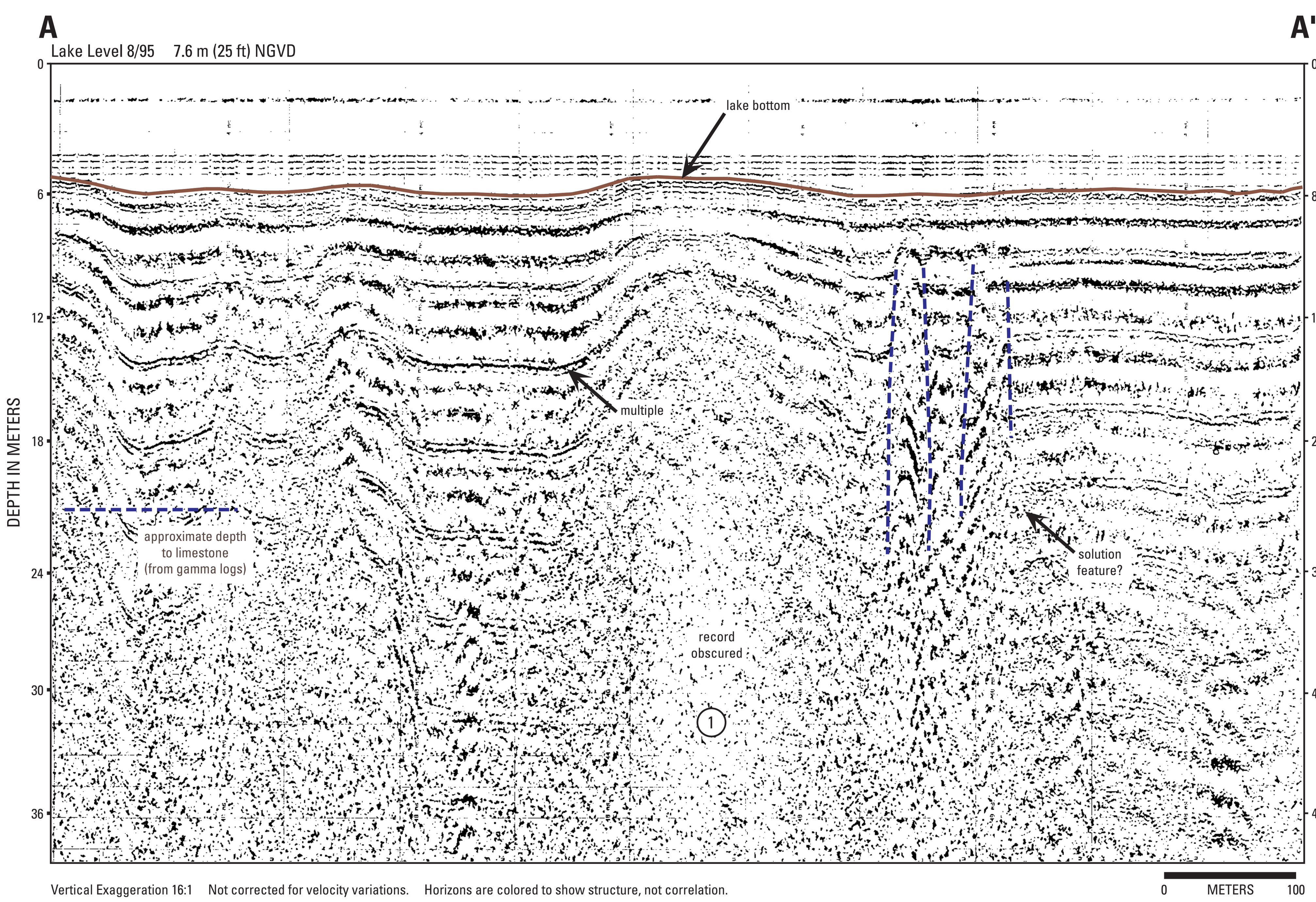
EXPLANATION

1. Profile obscured by multiples, noise or signal attenuation.

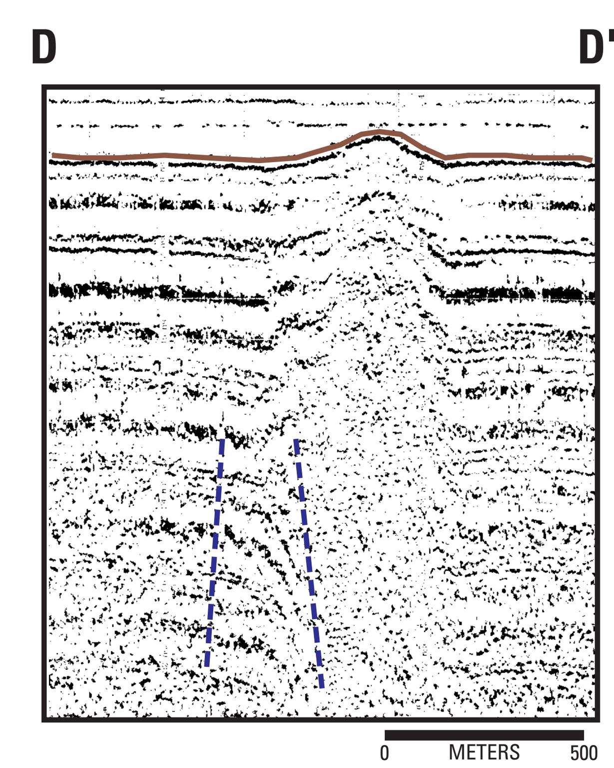








Vertical Exaggeration 16:1 Not corrected for velocity variations. Horizons are colored to show structure, not correlation.



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2000

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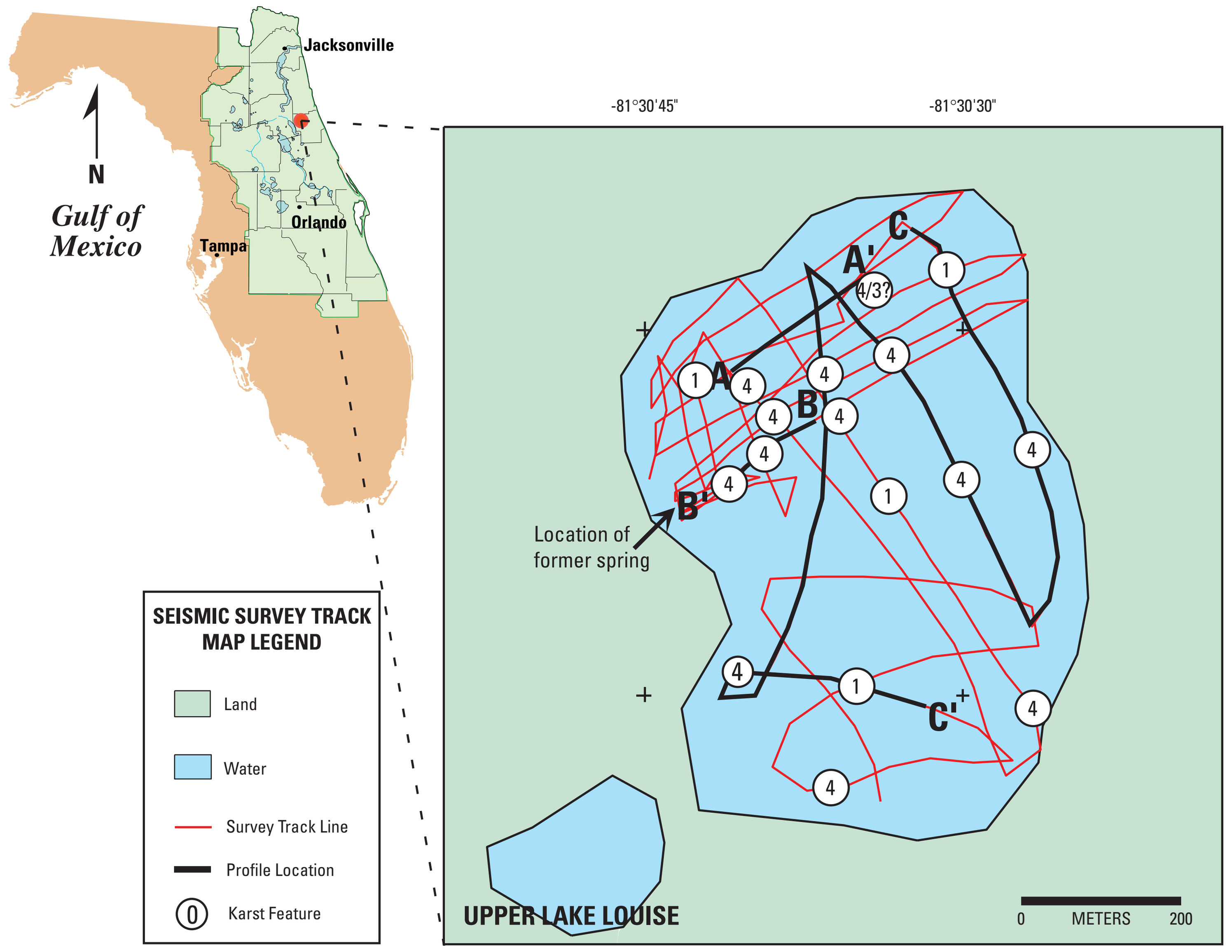
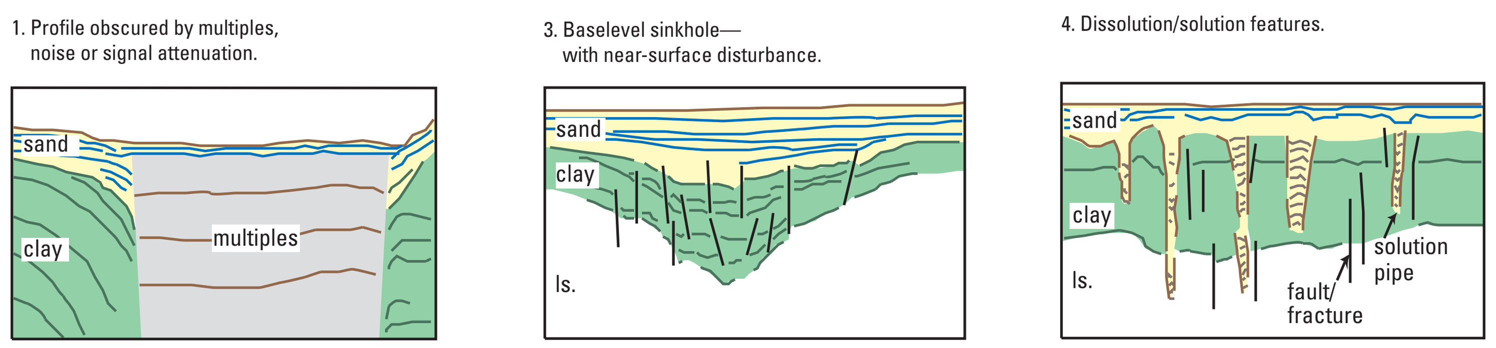
UPPER LAKE LOUISE
VOLUSIA COUNTY, FLORIDA

D



EXPLANATION



Introduction

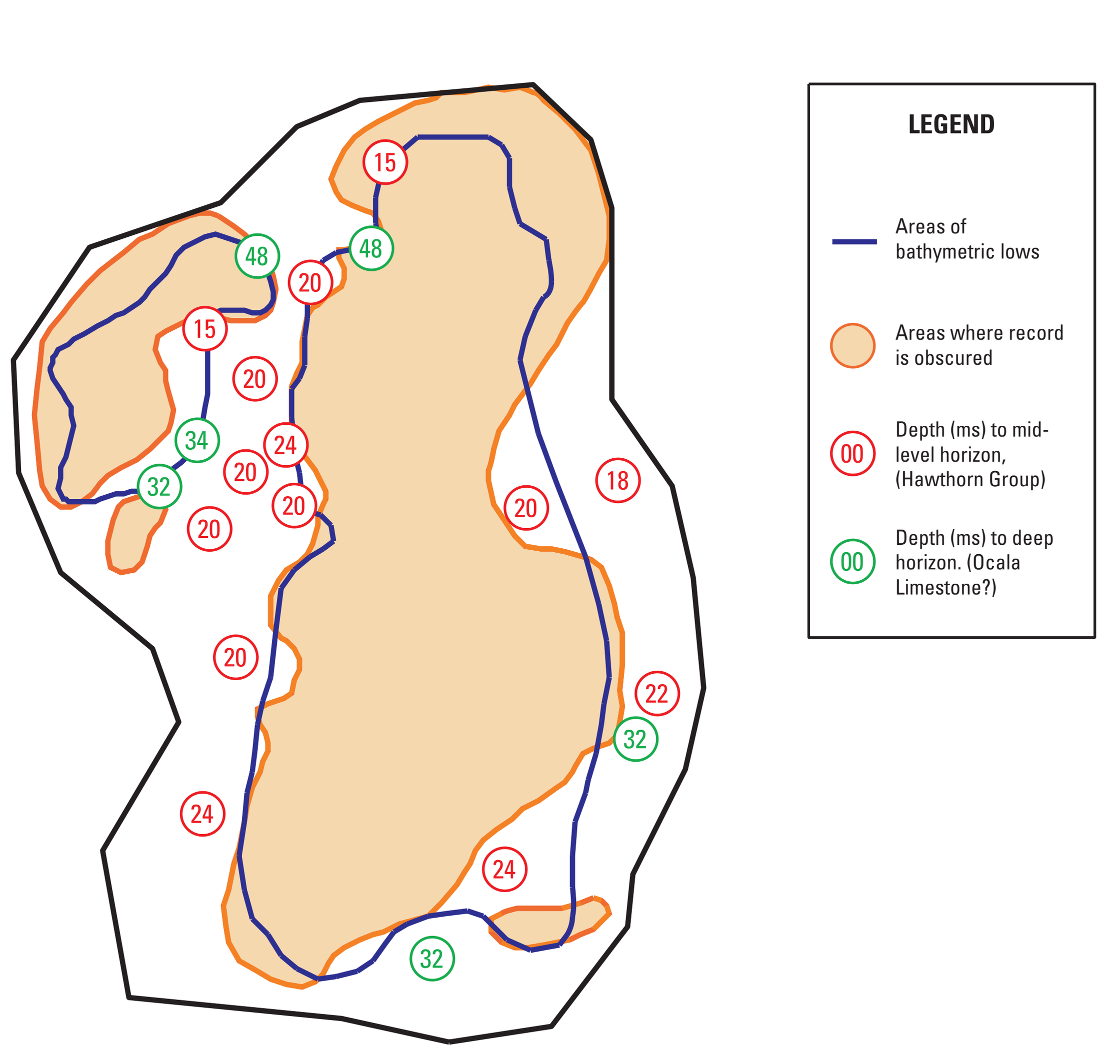
Upper Lake Louise is situated within the Crescent City of the Central Lakes District. The area consists of sand hills with peak elevations between 24 to 30 m (80 to 100 ft) NGVD that are bordered to the west by the floodplain of the St. Johns River and Crescent Lake basin on the east. The elevation of Upper Lake Louise was approximately 12 m (40 ft) NGVD at the time of profiling. The lake covers an area of 1.7 sq km, with about 5 km (3 mi) of shoreline.

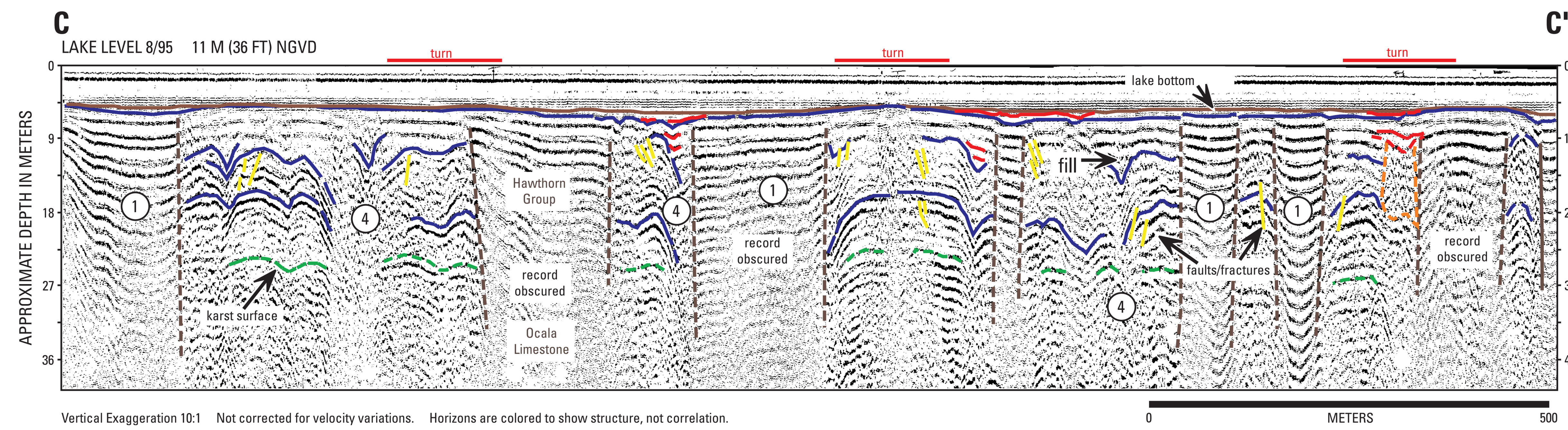
Subsurface Characterization

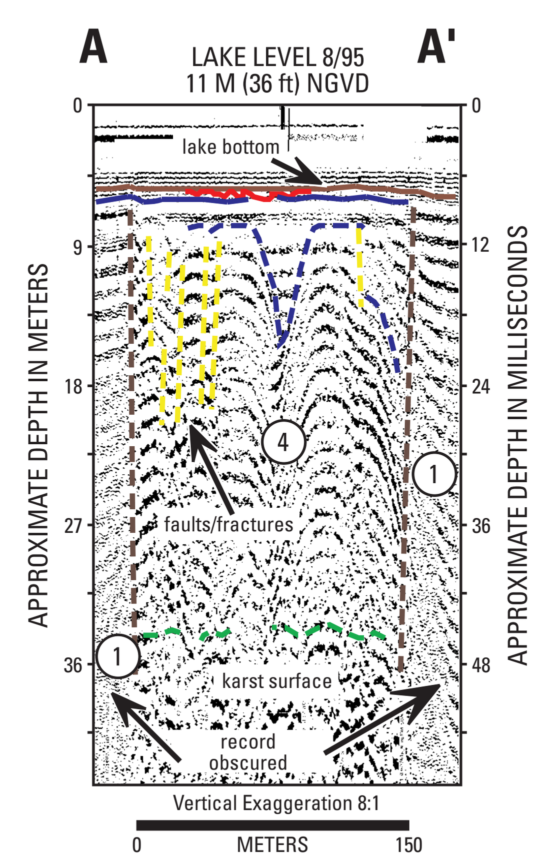
The surficial material of the Crescent City-Deland Ridge is composed of sand and shell. The ridge overlies the Hawthorn Group or in places directly overlies the Ocala Limestone (Brooks, 1981). Johnson (1986) describes a very thin Hawthorn Group (<3 m or 10 ft) at minus 1.5 m (5 ft) NGVD in a well about 5 km (3 mi) northwest of the lake. Natural gamma logs from wells depicted on the Gamma log profile sheet (Section D Hillshade page 24, wells P-0410, P-0146, P-0011) show logs with sufficient counts per second to characterize the Hawthorn Group. In some areas during deposition Hawthorn sediments have been reworked with the surficial Plio-Pleistocene sands of the Crescent City-Deland Ridge. The gamma response from these sediments may drop significantly as in well V-0283 located to the south. This situation makes delineating the Hawthorn Group more difficult. The top of the Floridan Aquifer was contoured by Rutledge (1982). For this area he identified this surface between -12 to -15 m (-40 to -50 ft) NGVD. The natural gamma log profiles also show this contact at -15 m (-50 ft) NGVD in wells P-0410 and P-0146, but it is not identifiable in P-0011 and P-0495 from the gamma logs alone.

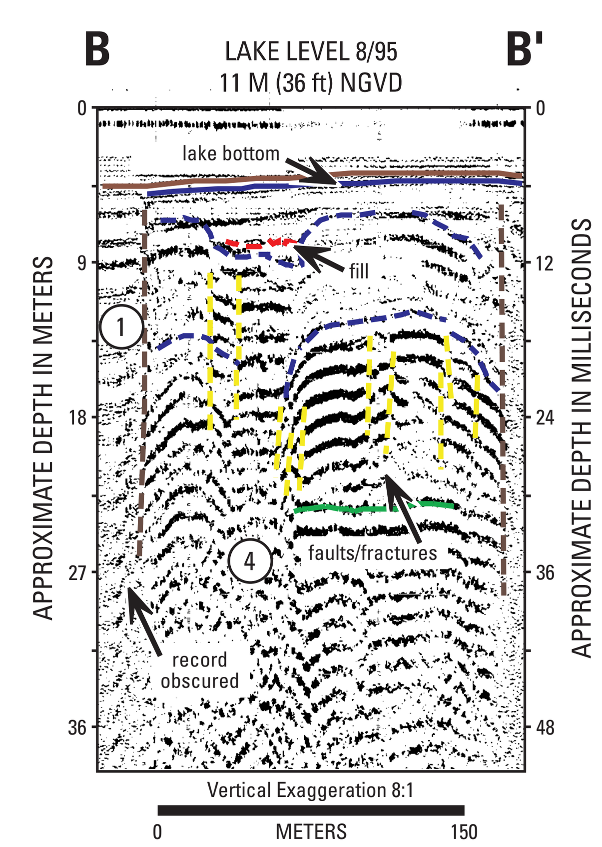
The seismic data from Upper Lake Louise is generally obscured by multiples in areas of bathymetric lows, as shown in the Distribution of Features map. This is consistent with lake bottoms of homogeneous sands, but also may be due to organic material accumulating in the deepest portions of the lake which tend to absorb the acoustic signal. The southern portion of the lake is characterized by a strong reflector at 20-24 ms (solid blue line, middle of profile C-C'). Depth to this mid-level horizon is shown in red numbers on the Features Map, and indicates a slight dip to the south across the lake. Correlation with gamma logs from wells adjacent to the lake would suggest that the horizon represents stratigraphy within the Hawthorn Group. The horizon is overlain by material of low reflective potential, possibly fill material or massive clays (middle of profile C-C'). Sediments within the Hawthorn Group exhibit major slumping and discontinuities, as seen in the example profiles. Profiles A-A' and B-B' show possible sinks, along with accommodation fractures or faults adjacent to the subsidence. The northern portion of the lake is characterized by numerous type 4 features (profiles A-A', B-B', C-C'), or a common characteristic where dip in a reflector is apparent but obscured by noise (profile C-C'). The features extend from near the lake bottom to depth and may indicate areas of potential leakage. A horizon very near the sediment surface can be resolved from the data (solid blue line), with infilling (red lines). At depth, a strong reflective horizon is evident between 30-48 ms (dashed green line). The horizon is punctuated by numerous discontinuities and elevation changes. The gamma logs indicate the top of the Ocala Limestone to be at about -15 to -24 m (-50 to -80 ft) below mean sea level, which correlates with this horizon. Dissolution of the Ocala Limestone would cause the subsidence seen in the overlying material of the Hawthorn Group. If the material above the mid-level horizon is impermeable massive clays, the discontinuities represent major breaches across the confining unit. Evidence of the breaches are substantiated by reports from local residents who indicate that a spring once flowed from the northwest section of the lake decades ago (see Seismic Survey Map). The spring was used as a water supply until flow ceased as the majority of the region changed from an area of discharge to recharge to the Floridan aquifer (Boniol and others, 1993).

UPPER LAKE LOUISE
DISTRIBUTION OF FEATURES
(noted from seismic profi les)









Subsurface Characterizations of Selected Water Bodies in the St. Johns River Water Management District, Northeast Florida

Jack L. Kindinger[1], Jeffrey B. Davis[2], and James G. Flocks[1]
2000

[1] Center for Coastal Geology and Regional Marine Studies
U.S. Geological Survey
St.. Petersburg, Florida 33701

[2] St. Johns River Water Management District
Palatka, Florida 32178

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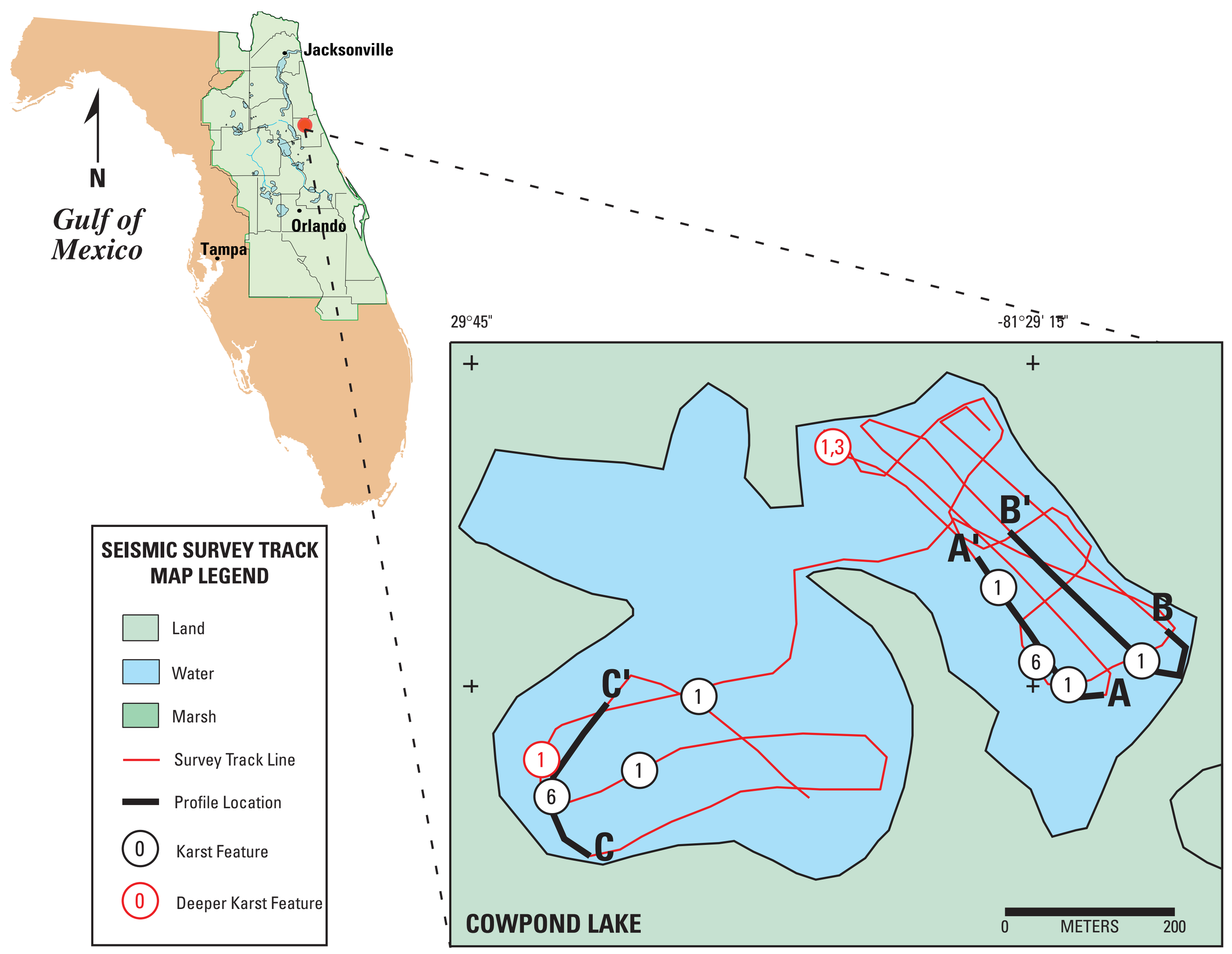
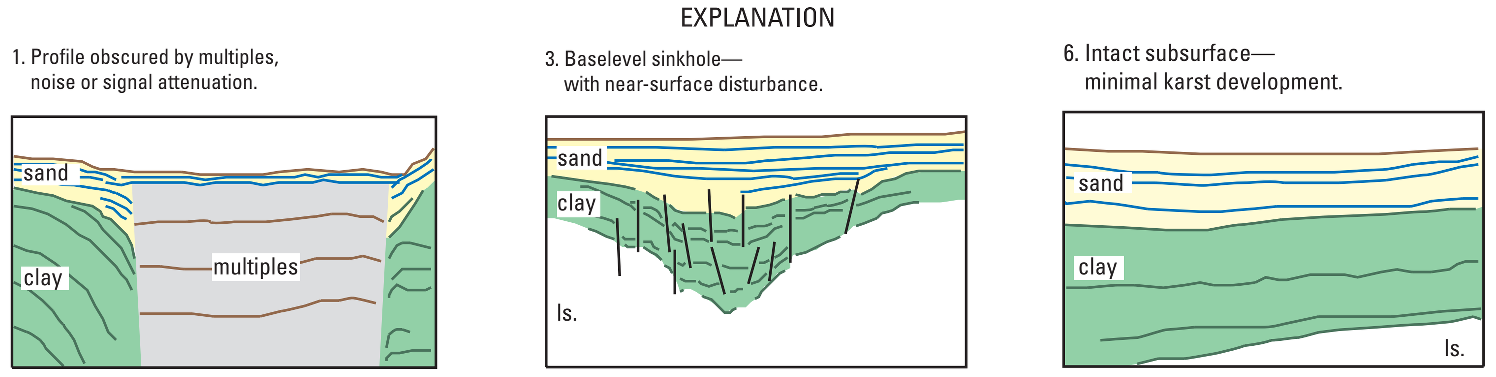
COW POND LAKE
VOLUSIA COUNTY, FLORIDA



EXPLANATION

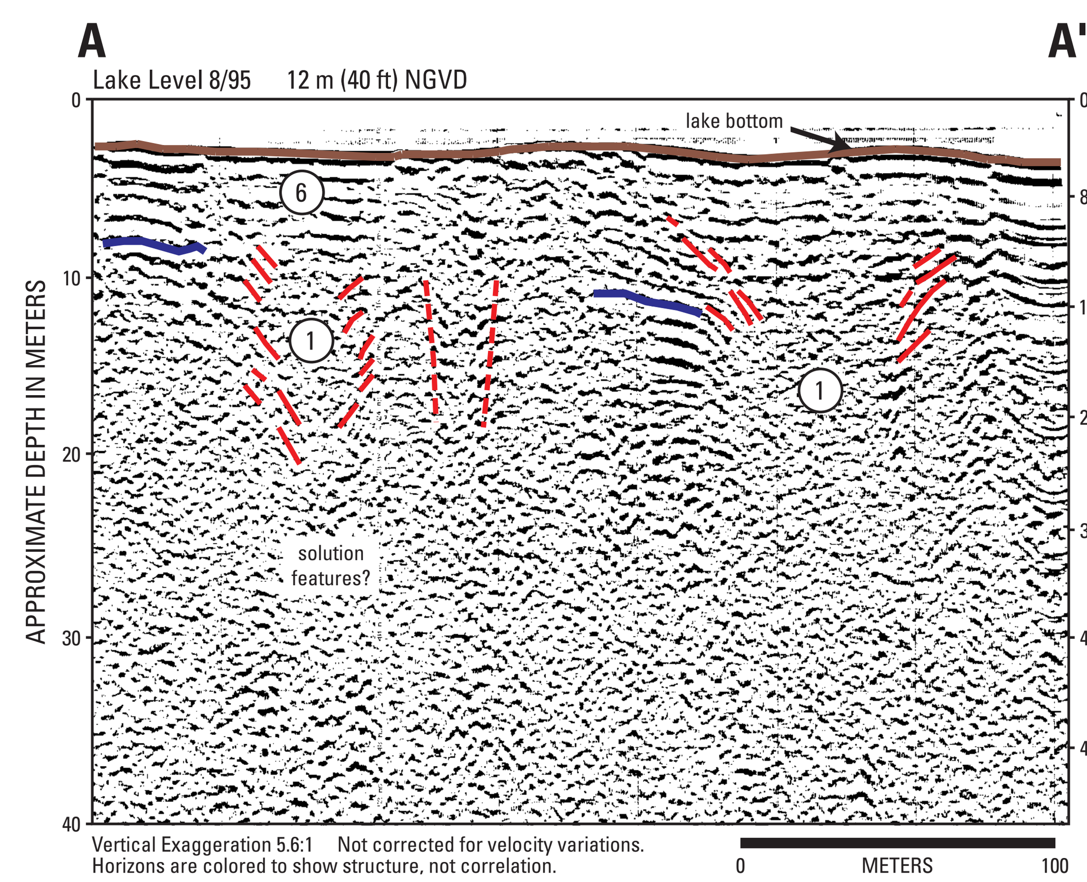


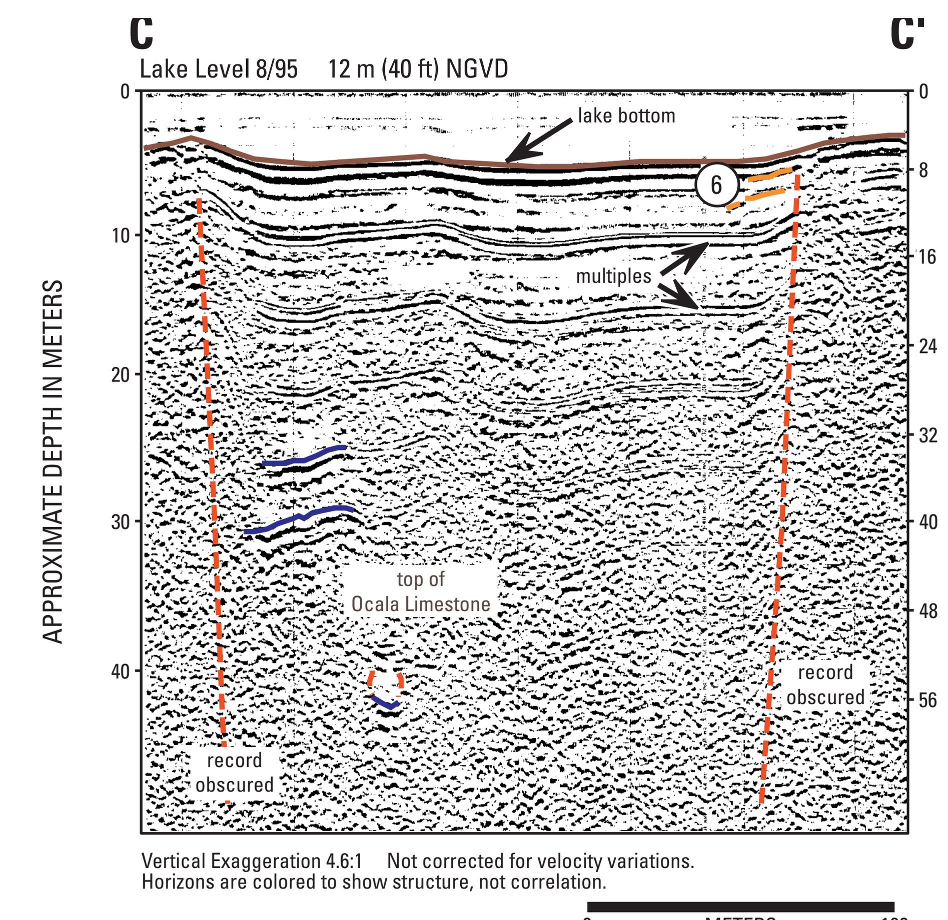
Introduction

Cow Pond Lake is located along the Crescent City Ridge in northwestern Volusia County. The ridge is described by Brooks and Merrit (1981) as a complex of Plio-Pleistocene sand hills resting directly on the carbonates that comprise the Floridan aquifer. Active karst development is evidenced by the numerous lakes in Volusia and Lake counties. The Crescent City Ridge bisects the marshy lowlands of the Crescent Lake Basin to the east and the St. John's River valley to the west. The ridge trends southeast-northwest, along with Deland Ridge to the south. Ridge heights reach 30 m (100 ft) above sea level, lake levels at the time of the survey were about 12 m (40 ft) NGVD. Cow Pond's irregular shape gives it over 5 km of shoreline with an area of only 0.6 sq km.

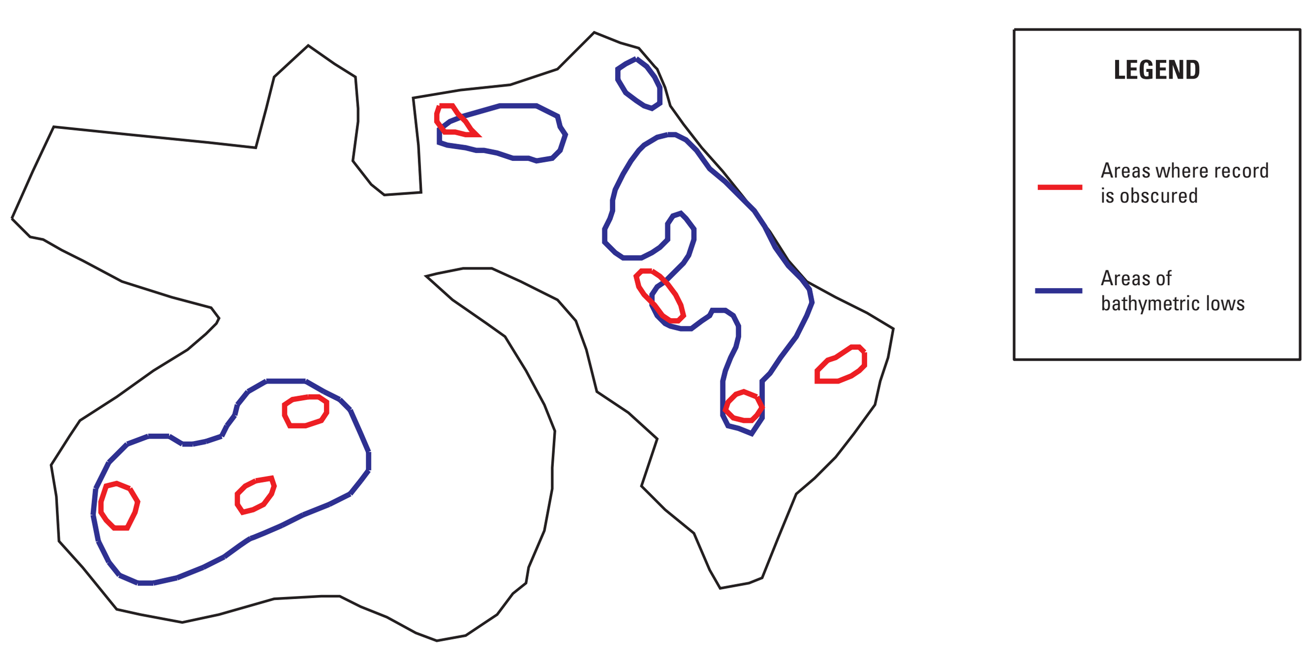
Subsurface Characterization

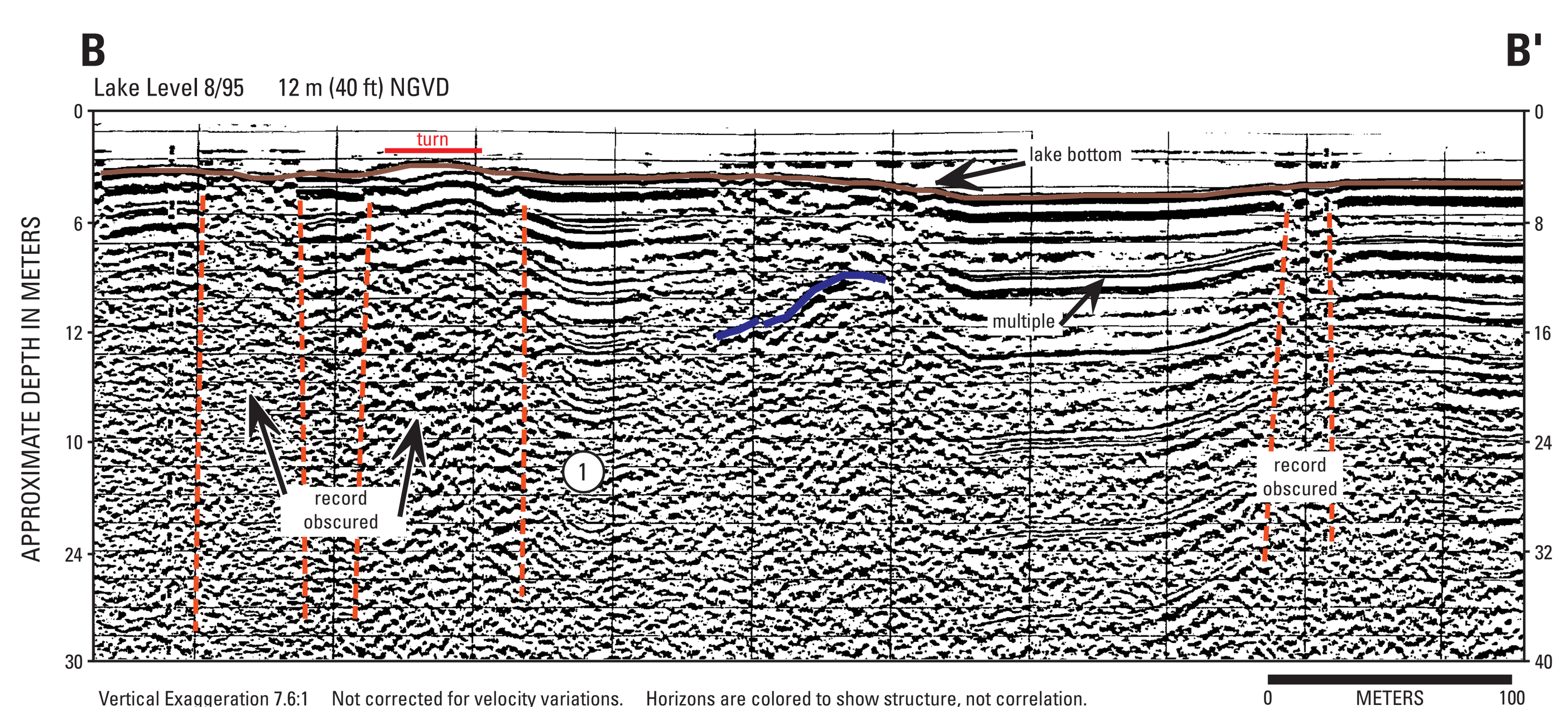
The quality of the seismic profiles obtained from Cow Pond Lake is generally poor. A strong bottom reflector leads to multiples, seen throughout the data, that obscure some of the record in the deeper portions of the lake. The record is also partially obscured in areas where the lake bottom nears the surface (profiles B-B', C-C'). Areas above the first multiple show sediment fill (type 6, profile C-C') and evidence of near surface subsidence (type 1, profile A-A'). These patterns are identical by down-dipping reflections on the flanks of a zone of obscured record. The type 1 features extend to depth in the profiles and occur in numerous, constrained areas throughout the lake. Areal extent of features noted from the seismic profiles can be seen in the map to the lower left. The distribution map shows that the lake is comprised of small solution/ subsidence features rather than one predominant subsidence as seen in other lakes. Most of the type 1 reflection patterns seen in the lake extend to depth from the near lake bottom. Two areas of the lake, however, show deeper solution/ subsidence type features (red numbers, survey track map) that do not extend entirely to the surface. These features may have evolved on a different time scale (earlier and infilled, or later and not fully developed) or hydrologic regime than the other type 1 features. Throughout the seismic profiles, segments of a strong reflector can be seen at depth where the record is not obscured (blue lines). These reflectors may represent the karst surface of the Ocala Limestone. Interpretations of gamma logs from wells in the vicinity (see Index Map D, page 22, wells P-0416, V-0346, V-0184) infer the top of the Ocala Limestone to range from -15 to -22 m (-50 to -75 ft) below sea level. The depth corresponds to 36 to 46 ms below the lake surface, using an averaged sound velocity of 1500 m/s. This correlates with the strong reflector seen in profile C-C'. The material above the Ocala Limestone could be the sands and clays of the Hawthorn Group and subsidence fill from the Plio-Pleistocene ridge sediments.





COWPOND LAKE
DISTRIBUTION OF FEATURES
(noted from seismic profi les)





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2000

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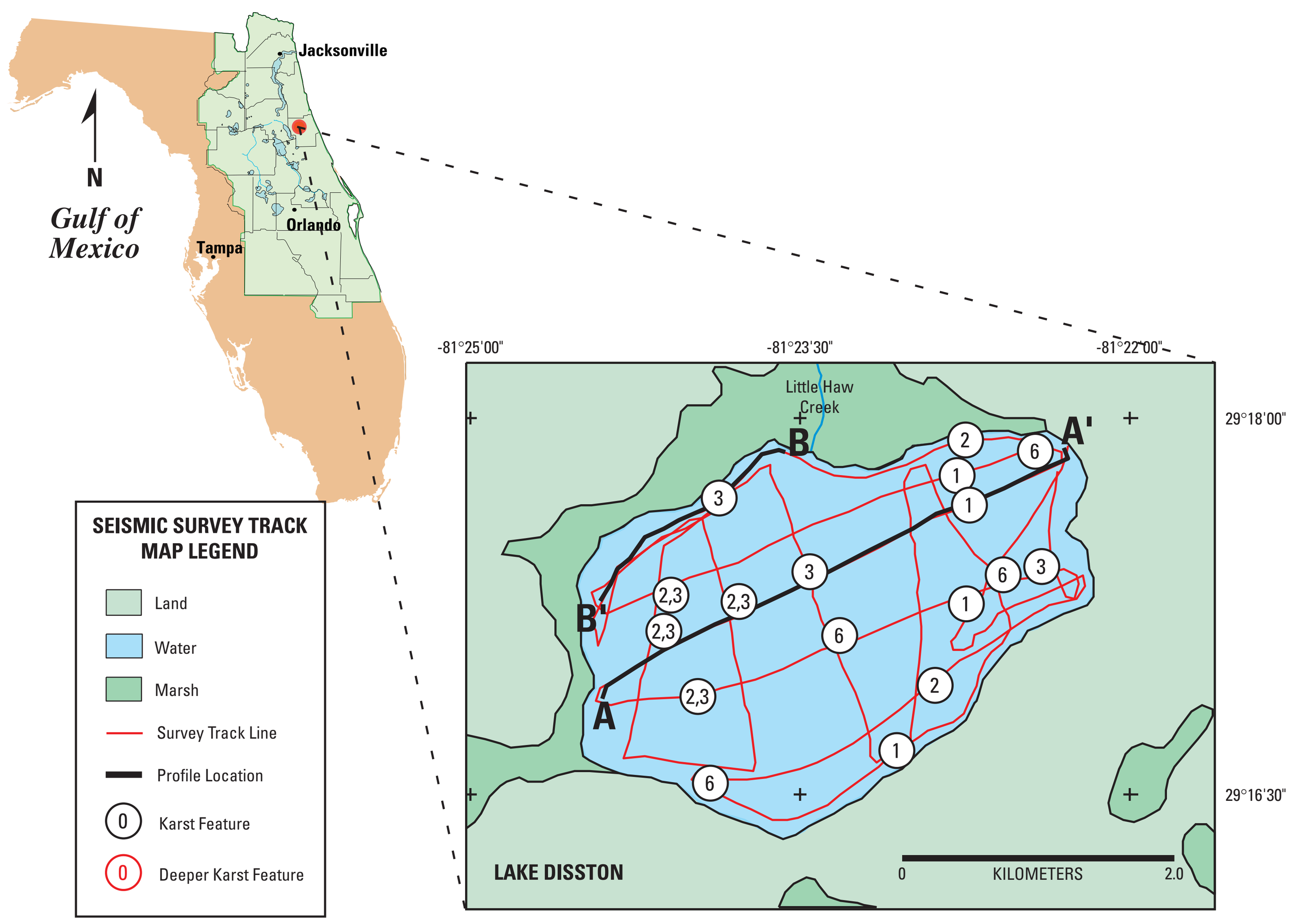
LAKE DISSTON
FLAGLER COUNTY, FLORIDA

D



Introduction

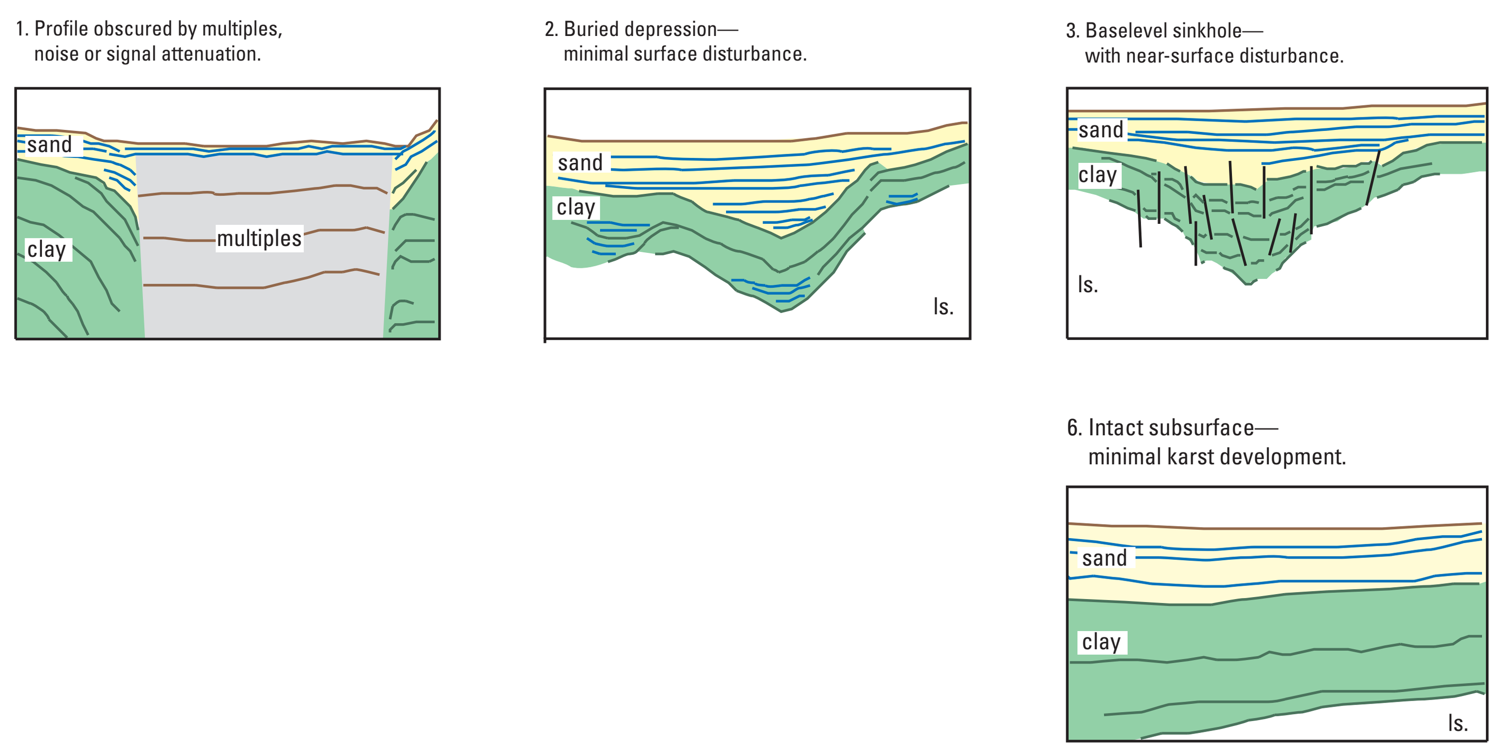
Lake Disston is in the extreme southwestern corner of Flagler County, Florida. The lake is located east of the southern tip of the Crescent City Ridge and northwest of the northern tip of the Deland Ridge. It resides in the Pamlico Terrace. Lake elevation at the time of the seismic survey was ~4.26 m (14 ft) NVGD. Lake Disston is oval shaped, ~4.2 x 2.4 km with a perimeter of 10.8 km and the surface area 15.5 sq km. Average water depth during the survey was 1.5 to 1.8 m (5 - 6 ft). The lake is surrounded by a plain with 61 m (~20 ft) average elevation and is bordered on the north by marsh associated with Little Haw Creek. Woodlands occur to the south.

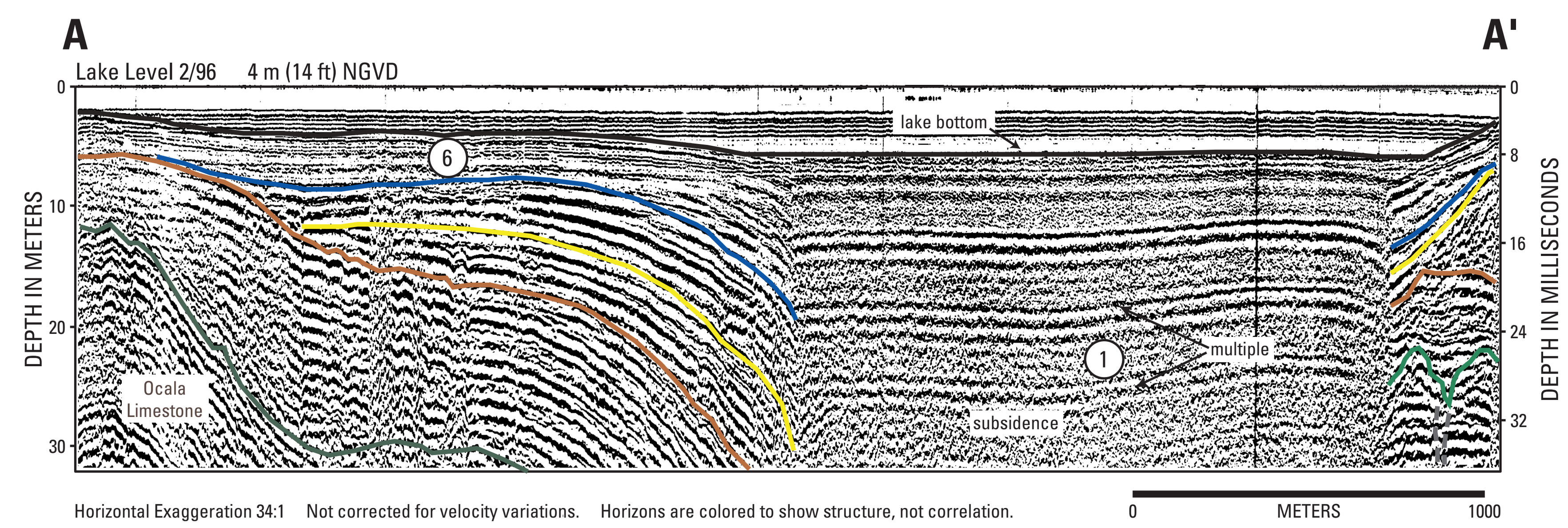
Subsurface Characterization

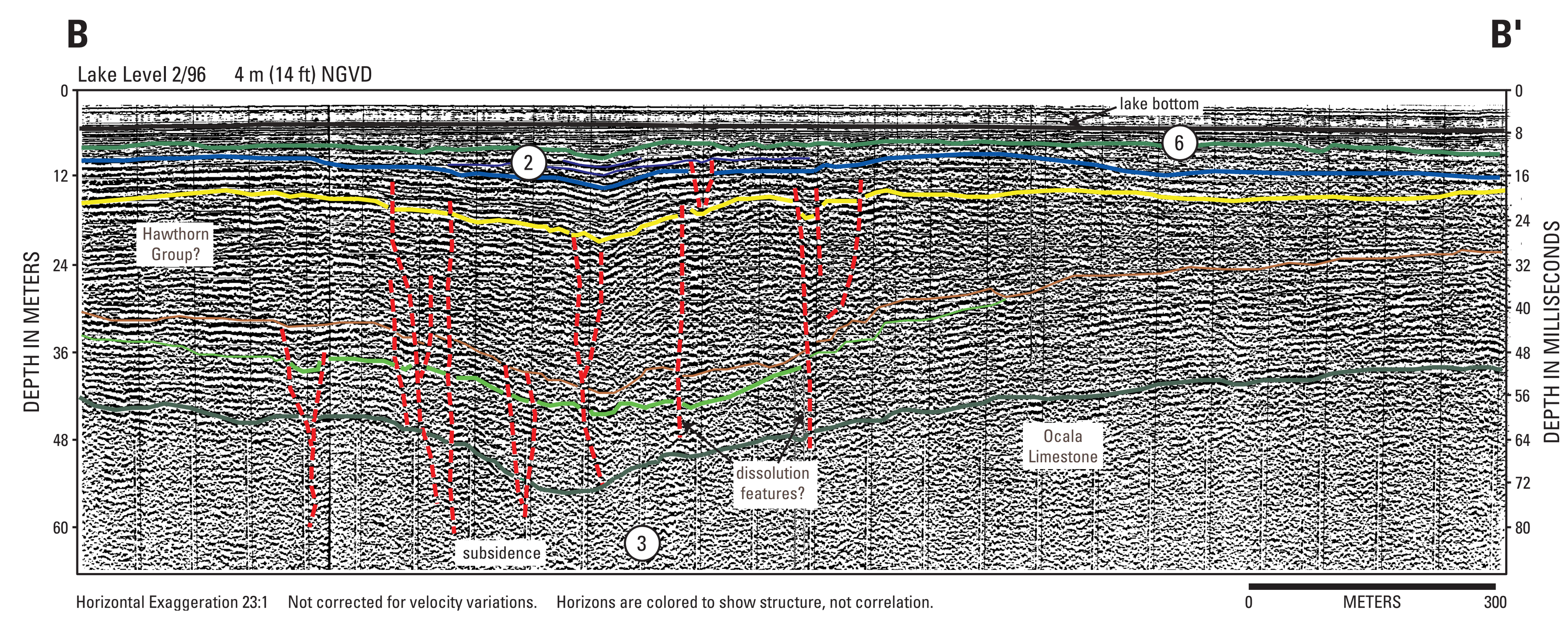
Lake Disston is characterized by a variety of seismic reflectors. These reflectors are consistent throughout the lake and are represented by the colored lines in seismic profiles A-A' and B-B'. The lines have been digitized and the depths to the reflectors plotted as contour maps shown below left. In the eastern part of the lake there is a large subsidence (> 1 km), obscured by noise in the record (Profile A-A' and Contour Maps). The western part has several smaller, near surface and deeper depressions (types 2 and 3, profile B-B'). The deep subsurface relationship between this complex and the larger subsidence is uncertain. Seismic Profile B-B' shows a deeper subsidence (type 3) with infilling by Hawthorn Group sediments that appear to have fracturing or dissolution type features that have distorted the overburden (profile B-B', yellow line). These features may provide conduits for surface water recharge of the aquifer. Except for near surface sediments, the strata has subsided. High frequency, horizontal reflectors near the surface may represent more lacustrine type fill, with no apparent disturbance (above green line).

Logs from wells in the area (Gamma log profile sheet, wells V-0339, F-0296) show the depth to the Ocala Limestone to decrease from about -46 m (-150 ft) NVGD east of the lake to about -15 m (-50 ft) NGVD to the west. The reflective horizon represented by the dark green line in profiles A-A' and B-B', correlates with this contact. The variable relief of this horizon, as expressed on the left side of profile A-A', and in the contour plot (Depth to Limestone) and subsurface two dimensional profile C-C', is characteristic of mature karst development and a subsidence sinkhole. Besides the large depression in the east central portion of the lake (Depth to Limestone contour plot), there also appears to be dip in the karst surface to the northwestern portion of the lake. The plot of the intermediate horizon shows subsequent subsidence in the overlying Hawthorn Group sediments.

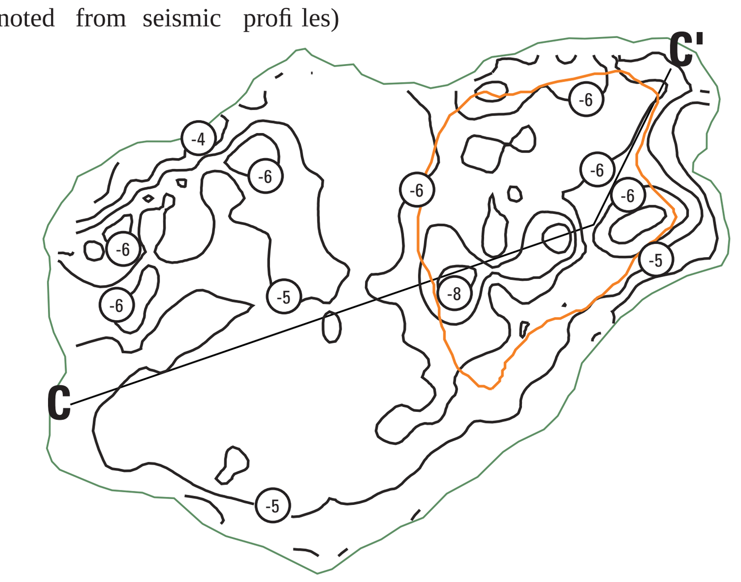
EXPLANATION

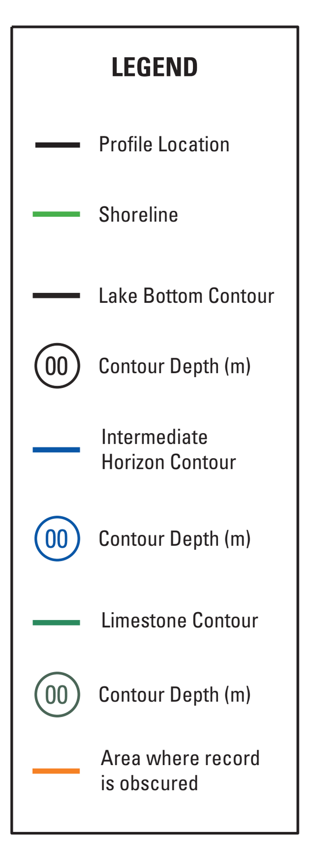




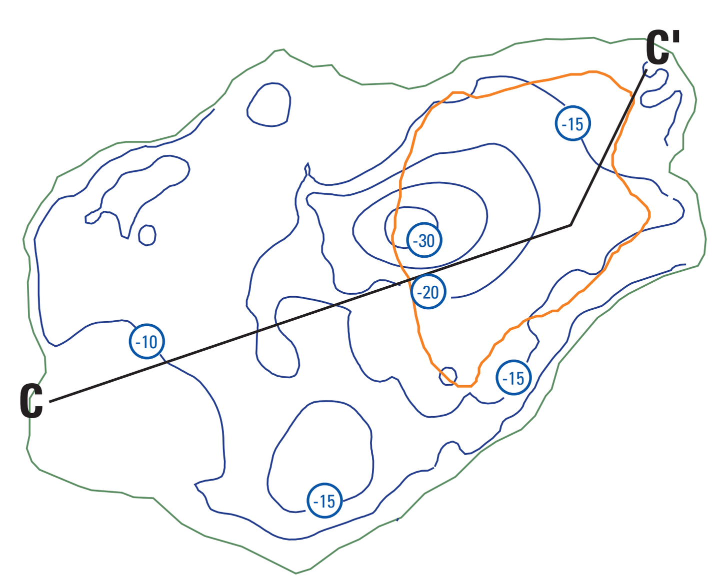


LAKE DISSTON
DISTRIBUTION OF FEATURES
(noted from seismic profiles)

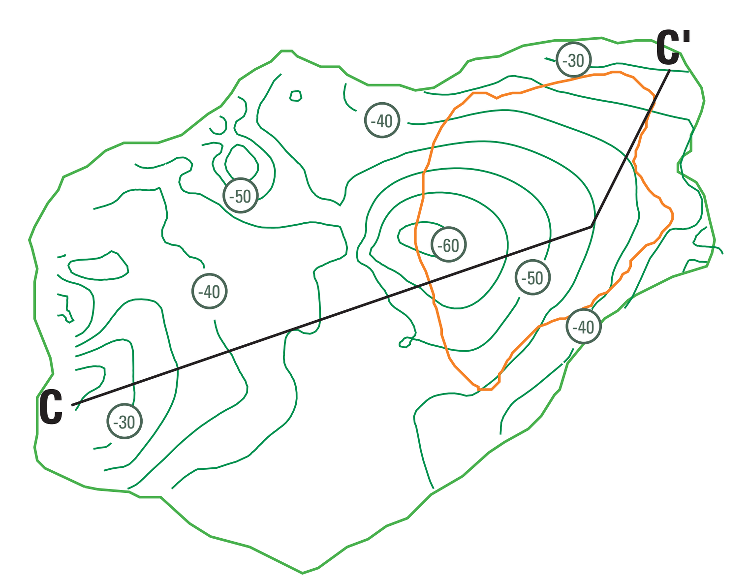


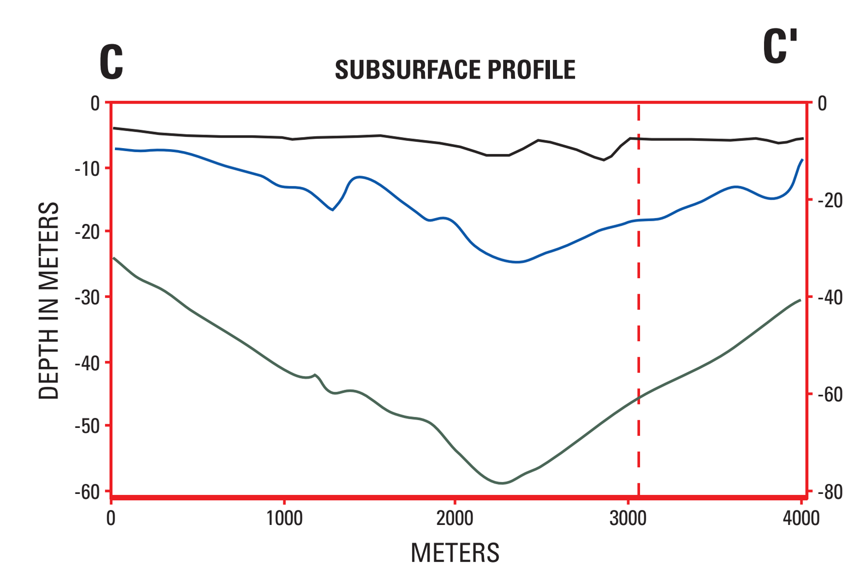


DEPTH TO LIMESTONE



DEPTH TO LIMESTONE





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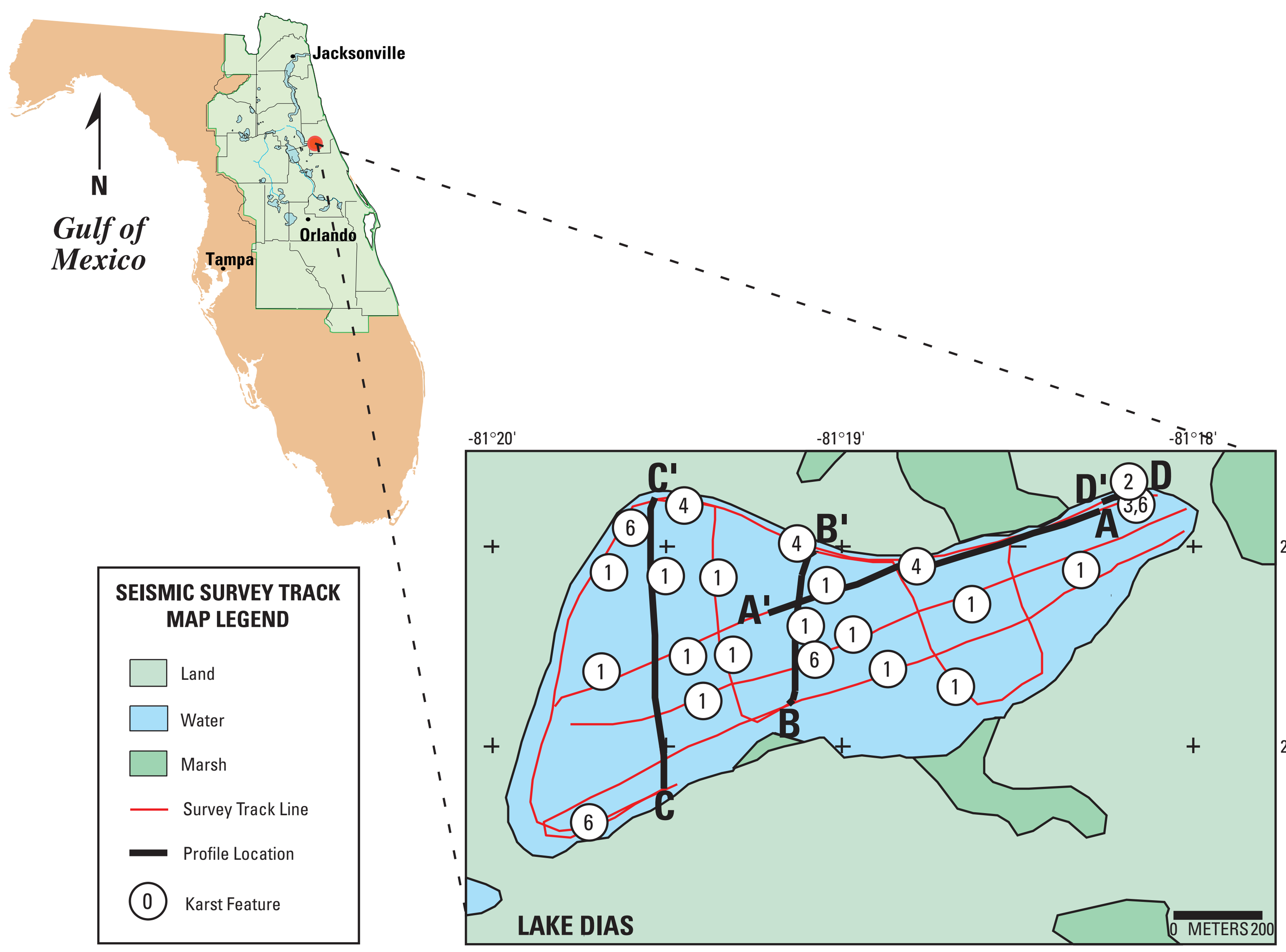
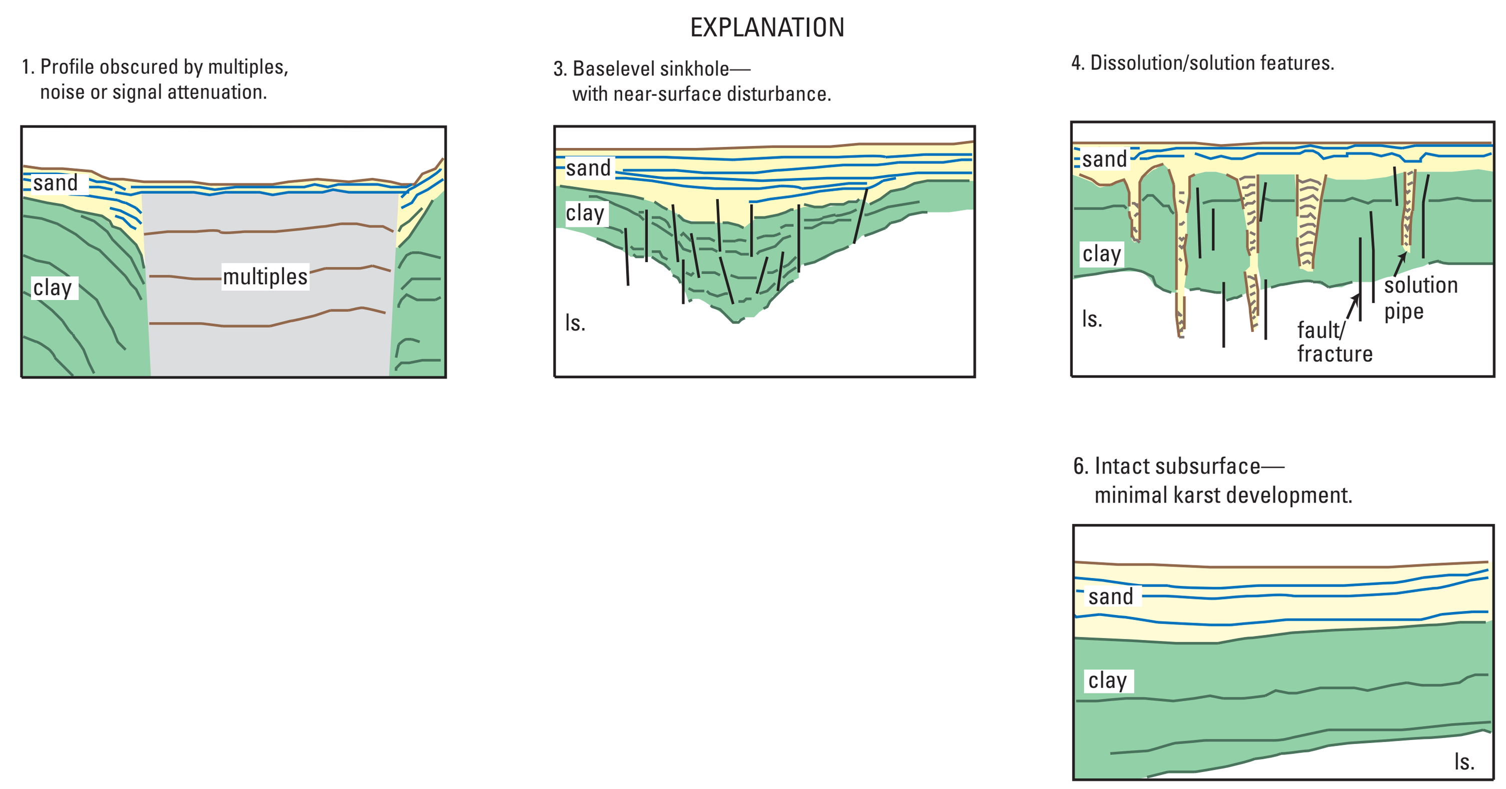
LAKE DIAS
VOLUSIA COUNTY, FLORIDA





Introduction

Lake Dias is located in north-central Volusia County. The lake lies on the northern part of the Deland Ridge, near the eastern edge of the Central Lakes District which is the principle recharge area for the Floridan aquifer. The ridge straddles the swampy lowlands of Lake Woodruff to the west and Little Haw Creek to the east. The Crescent City-Deland Ridge physiographic subdivision consists of sand hills with summits generally between 24 and 30 m (79 and 98 ft) in elevation. Plio-Pleistocene sand and shell rest directly upon the Floridan aquifer. The lake level at the time (August, 1994) of the seismic survey was 10.6 m (35 ft) NGVD. Lake Dias is oval in shape, with a perimeter of 8.7 km, an area of 4.3 sq km, and average water depth of approximately 3 m (6 ft).

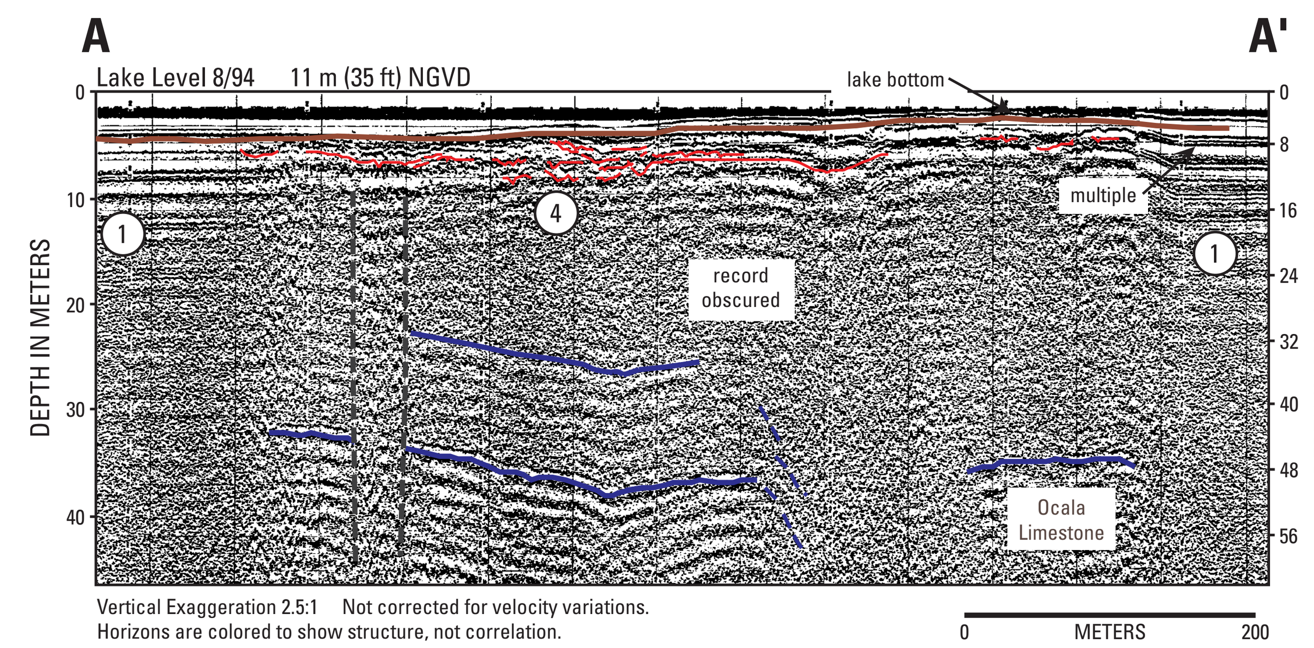
Subsurface Characterization

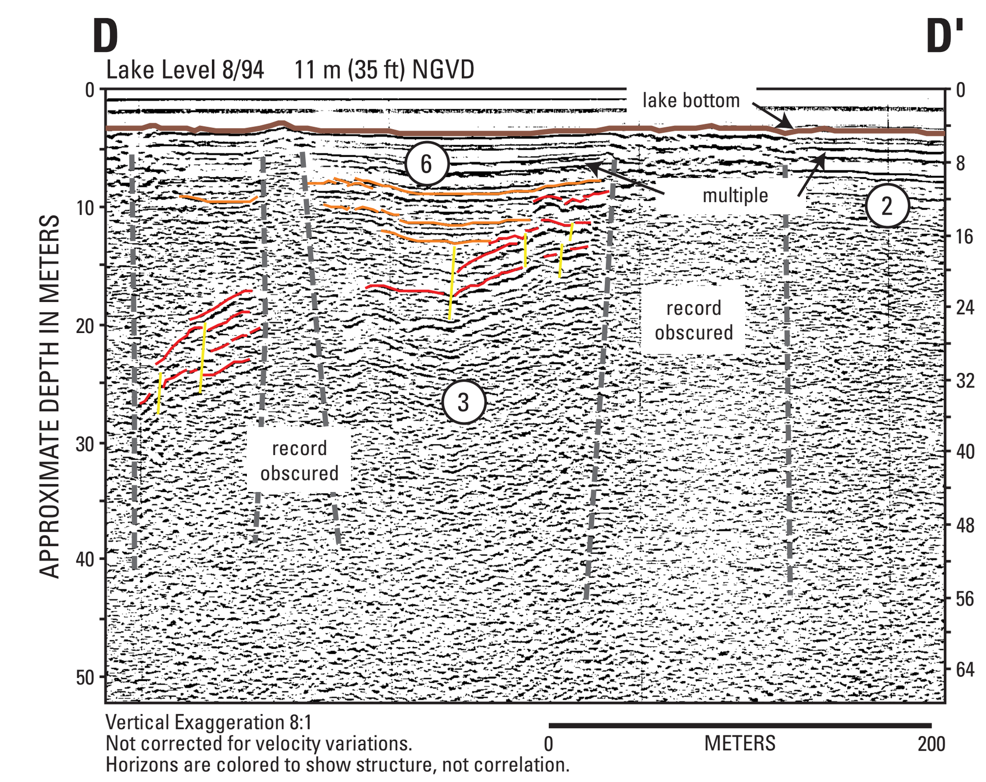
Seismic profiles from Lake Dias are predominantly obscured at depth. A strong bottom reflector leads to multiples seen throughout the data that obscure some of the record in the deeper portions of the lake (profile C-C'). The record is also partially obscured in areas where the lake bottom nears the surface (profile A-A', B-B'). In general the lake is characterized as a single large depression comprising most of the lake (Distribution of Features Map, blue line). Deep reflectors tend to drop prior to becoming obscured near the central portions of the lake (profile B-B', blue lines). This suggests that deep structures influence the lake bathymetry. Low-amplitude, near surface reflectors in some of the profiles near the fringes of the lake have a hummocky appearance (index map, type 4 feature, profiles, A-A', B-B', red lines). The reflectors may represent smaller subsidence features in the fill overlying the deeper subsidence. Profile C-C' also shows some low angle, offlap type reflectors (type 6 feature, red lines) that may represent subsequent fill during subsidence of the lake.

Profile D-D' shows a feature seen in the extreme northeastern portion of the lake. Pronounced high angle reflectors (red lines), overlain by fill-type horizontal reflectors (orange lines) may represent a collapse structure (type 3 feature). A chaotic signal below the horizontal reflectors could be block fill associated with the initial collapse, which was subsequently overlain by fluvial fill. This is the only area throughout the lake where this type feature is present and could represent a major breach in the confining material overlying the aquifer.

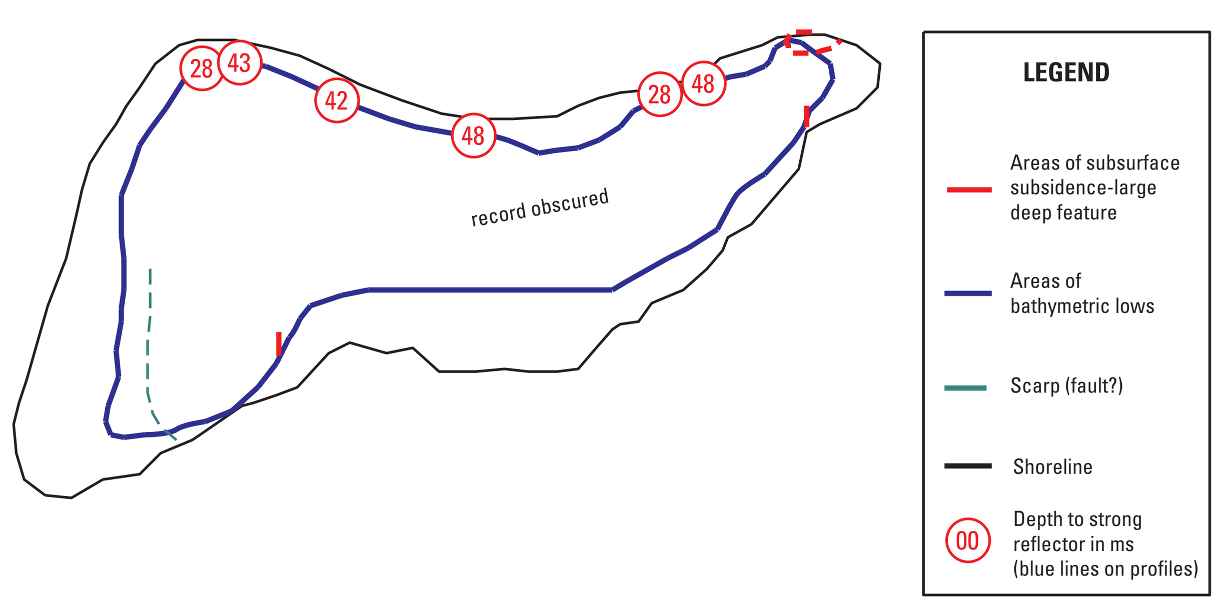
Interpretations of Gamma profiles from wells surrounding the lake (Index Map D, profile C-C') show the top of the Ocala Limestone to be between -9 and -15 m (-20 and -50 ft) NGVD. This would correspond to between 26 and 35 milliseconds depth in the profiles, using an averaged sound velocity of 1500 m/s. This depth would suggest that the blue lines seen in the profiles (A-A', B-B') represent horizons near the top of the Ocala Limestone. Dissolution in the Ocala Limestone at depth would cause subsidence in the overlying material and fill.

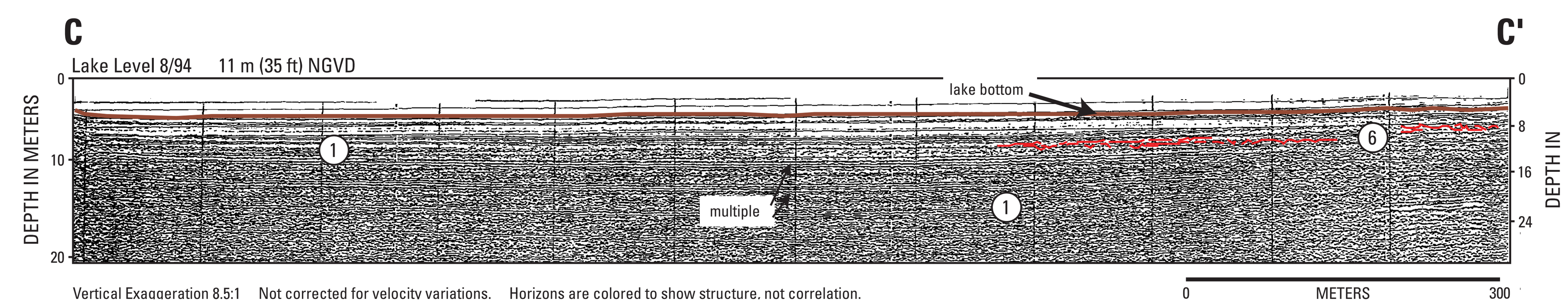
D

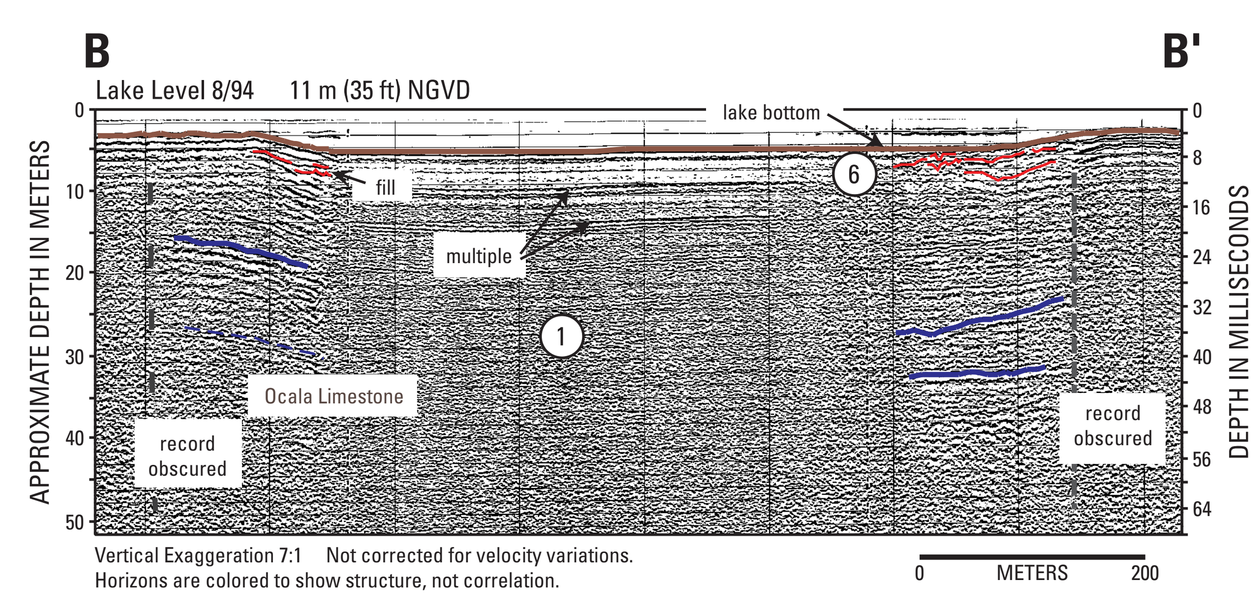




LAKE DIAS
DISTRIBUTION OF FEATURES
(noted from seismic profiles)







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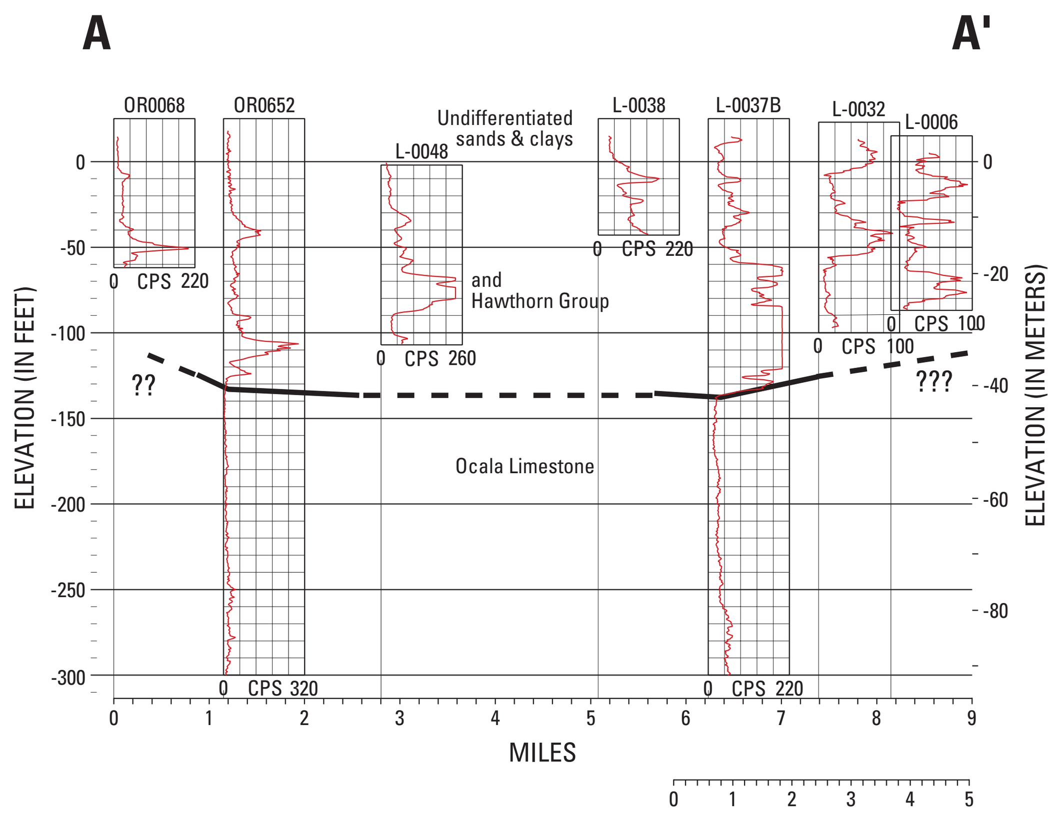
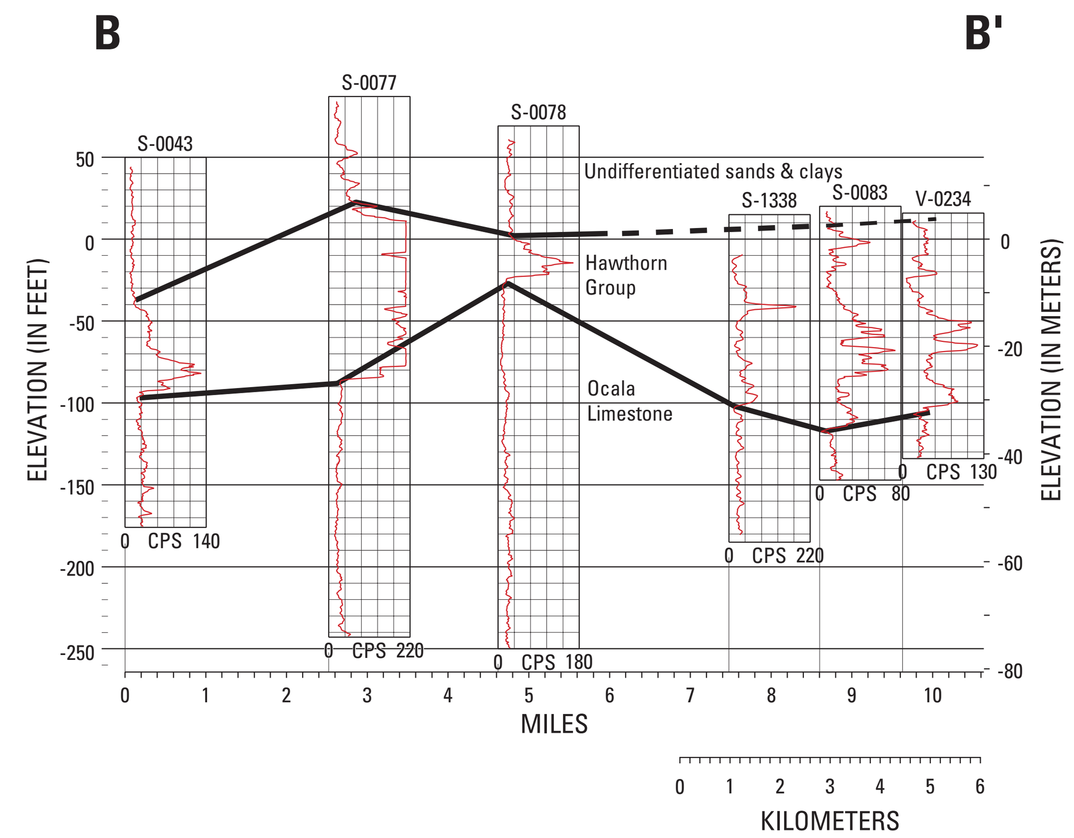
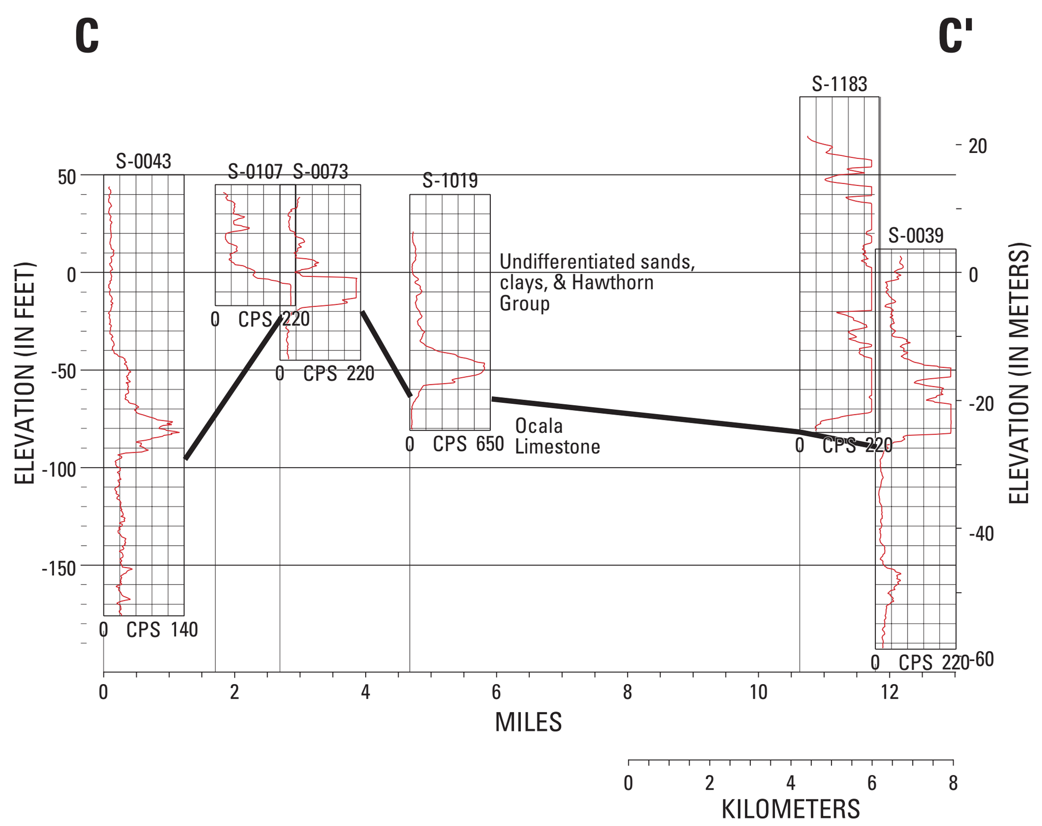
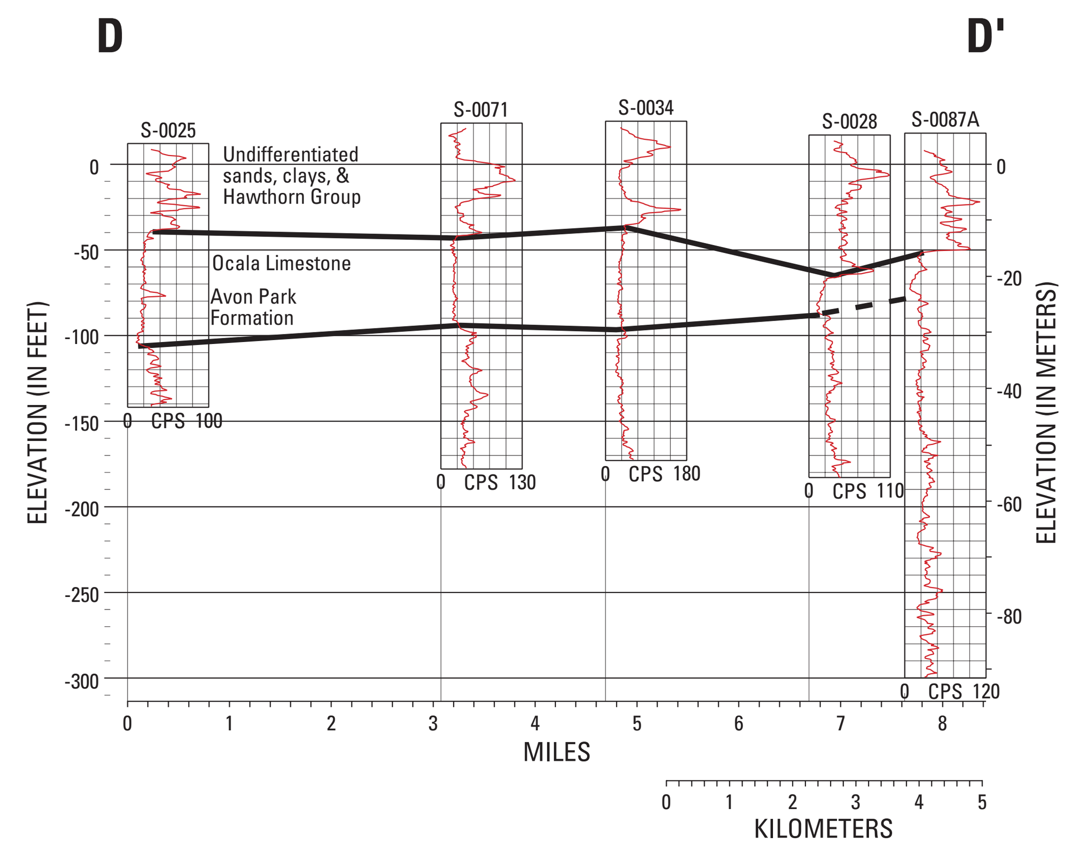
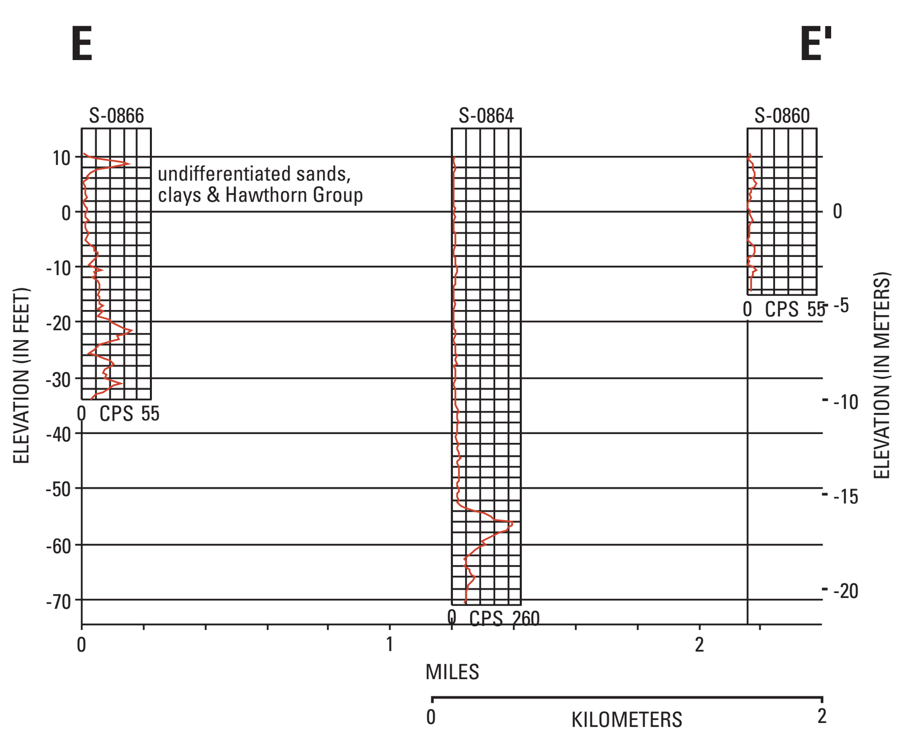
INDEX MAP AND GAMMA LOG
CROSS-SECTIONS, SECTION E

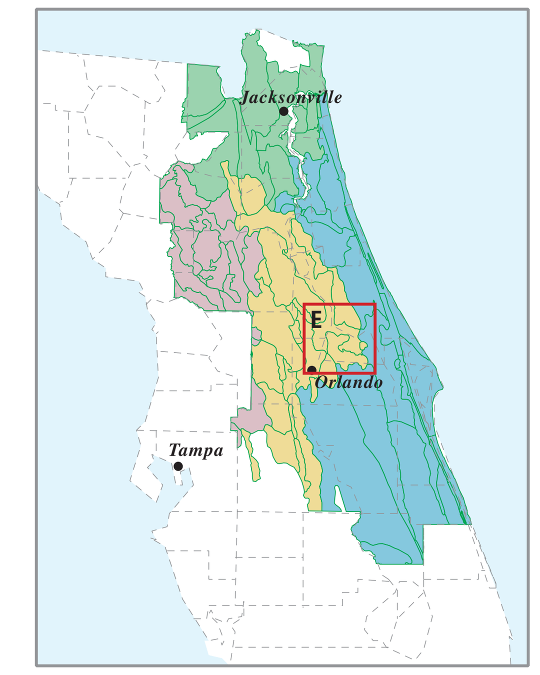




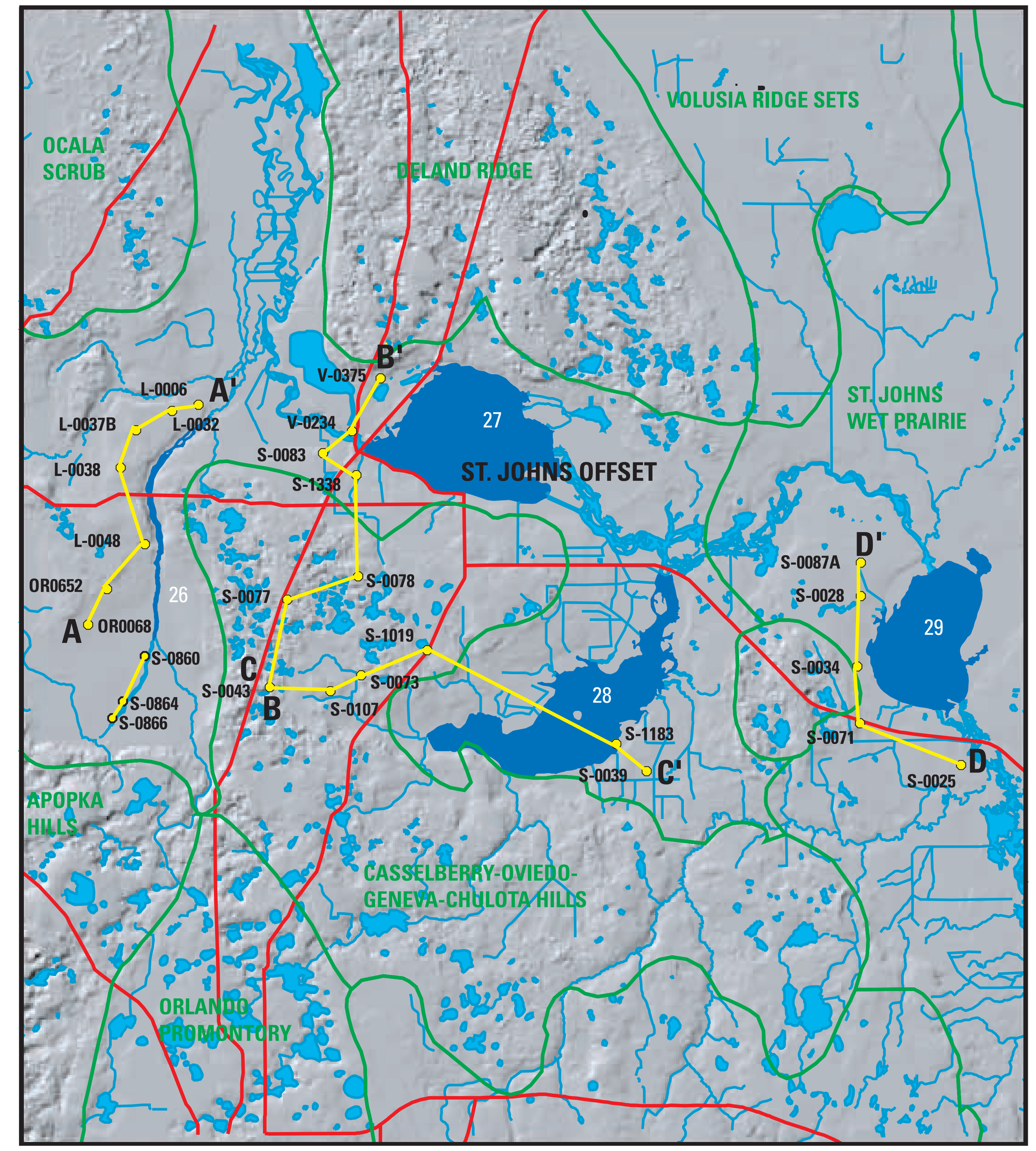


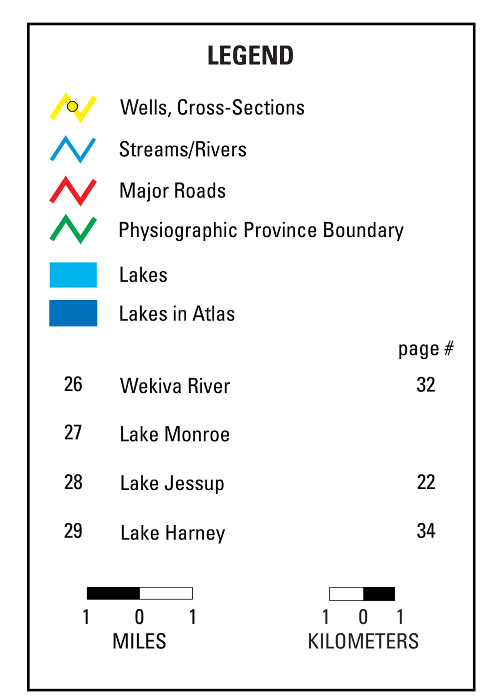






Location of survey area right (red square). Shaded relief map below showing physiographic regions, and location of wells and gamma log cross-section. Gamma Log cross-sections (left) show geologic contacts for correlation to seismic sections.

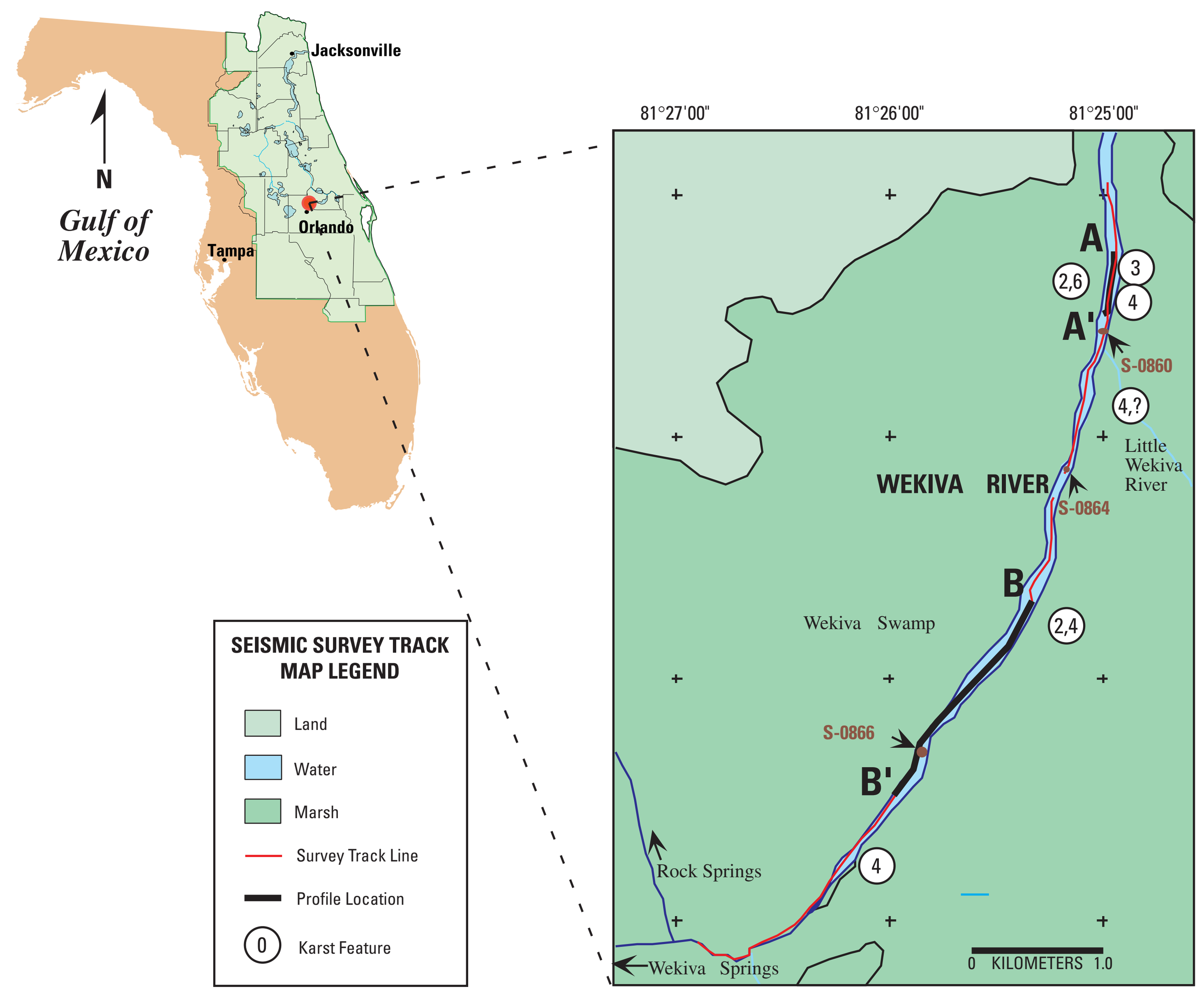


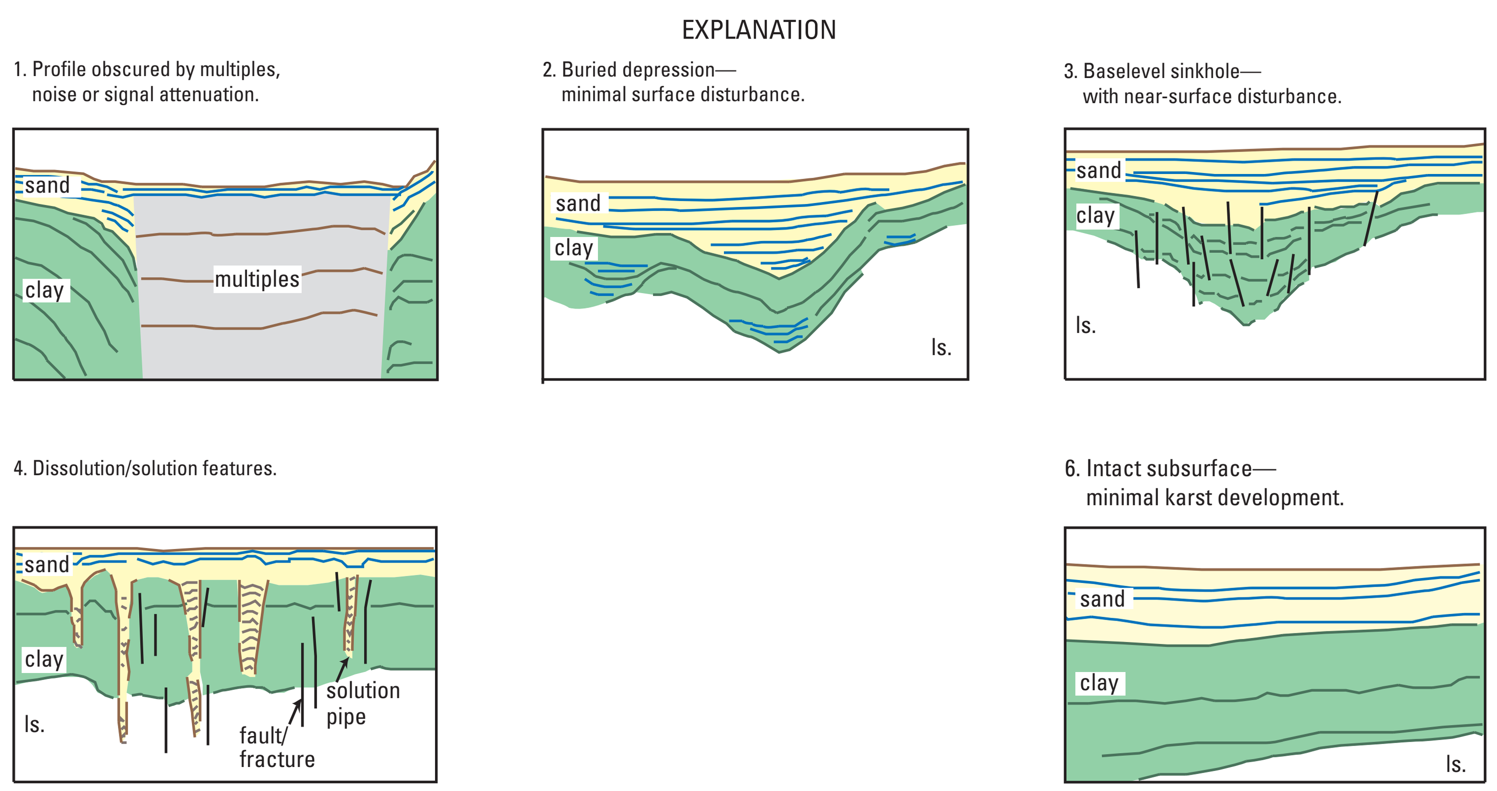


E

WEKIVA RIVER

SEMINOLE COUNTY, FLORIDA





Introduction

The Wekiva River is a northward flowing (exotic) river defining the Seminole/Orange/Lake county lines. The river occupies the solution valley of the St. Johns Offset (see Index Map Section E, p. 31) within the Central Lakes District (Brooks and Merrit, 1981; Merrit, 1981). Wekiva River drains the lowlands of the Offset, but is sourced by the high magnitude discharge springs located along the Apopka Upland to the south. Rock Spring, Wekiva Spring and Spring Lake source the Wekiva and Little Wekiva Rivers. The river flows through the Wekiva Swamp, incises an unnamed highland which supports a highway and the town of Wekiva and empties into the St. Johns River at the Seminole-Volusia border enhanced the broad valley through which the Wekiva, St. Johns and Oklawaha Rivers flow. The flood plain is near sea level, as well as the potentiometric surface of the Floridan aquifer. The area is characterized by numerous lakes which are at or slightly above the potentiometric surface of the Floridan aquifer. Surficial drainage is internal and water is stored in the surficial aquifer within thick sands and gravels that comprise the near surface in the area. During recharge and discharge conditions, breaches through the underlying sandy clays of the Hawthorn Group may provide a direct hydrologic connection with the Floridan aquifer.

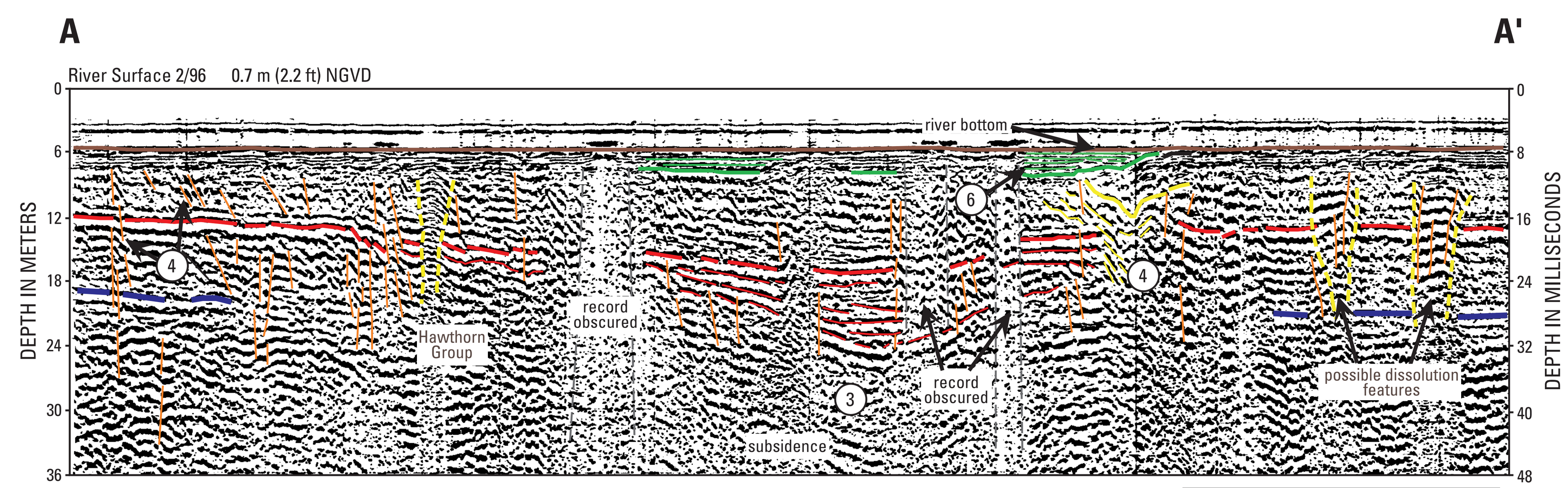
Subsurface Characterization

As often encountered during surveys of rivers in this area, the data quality is generally poor. The common problem is the rivers are shallow and acoustic echoes from the river banks add to noise in the signal which obscure any subsurface features. Profiles A-A' and B-B' are two examples where some subsurface features can be seen. Profile A-A' shows a subsurface depression at depth that has been filled, similar to a type 3 karst feature. Throughout the profile several type 4 dissolution features appear to be present. Horizontal reflectors at the nearsurface (green lines) may represent more recent fill. Profile B-B' exhibits a persistent reflector (blue line) throughout the profile that may represent a horizon within the Hawthorn Group or the contact between the Group and overlying undifferentiated sands and clays. The left side of the profile shows an area of disturbance in the subsurface, where type 4 dissolution features may be present. These features are characterized as distinct parallel and sub-parallel reflectors with a higher amplitude than the surrounding material and may represent filled solution pipes. It appears that some subsidence has occurred with subsequent fill to the present day river bottom, however, the discontinuities at depth do not reach the present day river bottom and may not affect the more recent fill.

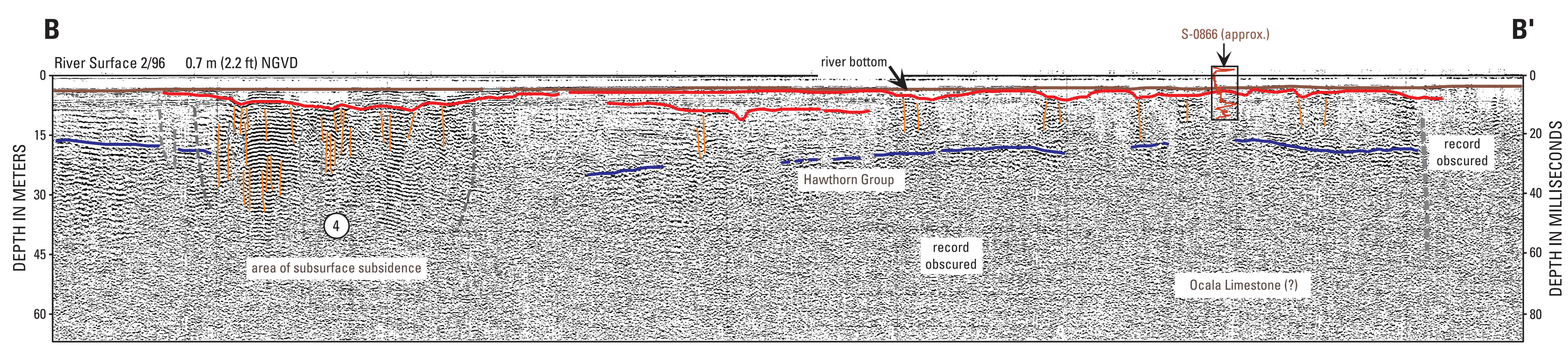
The natural gamma log cross section A-A' shown on the Index Map Section E shows the elevation of the top of the Ocala Limestone in wells OR0652 (-40 m [-130 ft] NGVD) and L-0037B (-43 m [-140 ft] NGVD), below resolvable depth in the seismic records. The areas of disturbance seen in the profiles may represent areas of subsidence within the Hawthorn Group as it accommodates dissolution in the underlying limestone. The gamma log cross sections show how variable the sand and clay units within the Hawthorn Group and overlying undifferentiated sediments are. Peaks in the gamma logs are not laterally continuous and the thickness varies considerably.

An additional cross section comes from three wells drilled on the small islands in the Wekiva River (gamma log profile E-E', Index Map Section E, p. 31). Again, the variability within the post-Tertiary units is apparent, note the high peak in well S-0866 at 3 m (9 ft) NGVD. One mile north in well S-0864, this peak is completely missing as are all of the other clay rich beds in S-0866. The log for S-0864 shows 17 m (55 ft) of clean material, probably sand, below which is a clay unit that may correlate with the blue line in profile B-B' and represent the top of the Hawthorn Group. The gamma peaks in well S-0866 show that the Hawthorn Group may extend to about -6 m (-20 ft) to -8 m (-25 ft) NGVD. These logs probably do not represent the total drilled depth of the wells since they do not penetrate the Ocala Limestone, yet surface flow and water quality are indicative of the Floridan aquifer. Depth to the Ocala is inferred to be at about -32 m (-105 ft) NGVD (~44 milliseconds), beyond the resolvable depth in the seismic profiles in this area.

E



Vertical Exaggeration 7:1 Not corrected for velocity variations. Horizons are colored to show structure, not correlation.



Vertical Exaggeration 5:1 Not corrected for velocity variations. Horizons are colored to show structure, not correlation.

Subsurface Characterizations of Selected Water Bodies in the St. Johns River Water Management District, Northeast Florida

Jack L. Kindinger[1], Jeffrey B. Davis[2], and James G. Flocks[1]
2000

[1] Center for Coastal Geology and Regional Marine Studies
U.S. Geological Survey
St.. Petersburg, Florida 33701

[2] St. Johns River Water Management District
Palatka, Florida 32178

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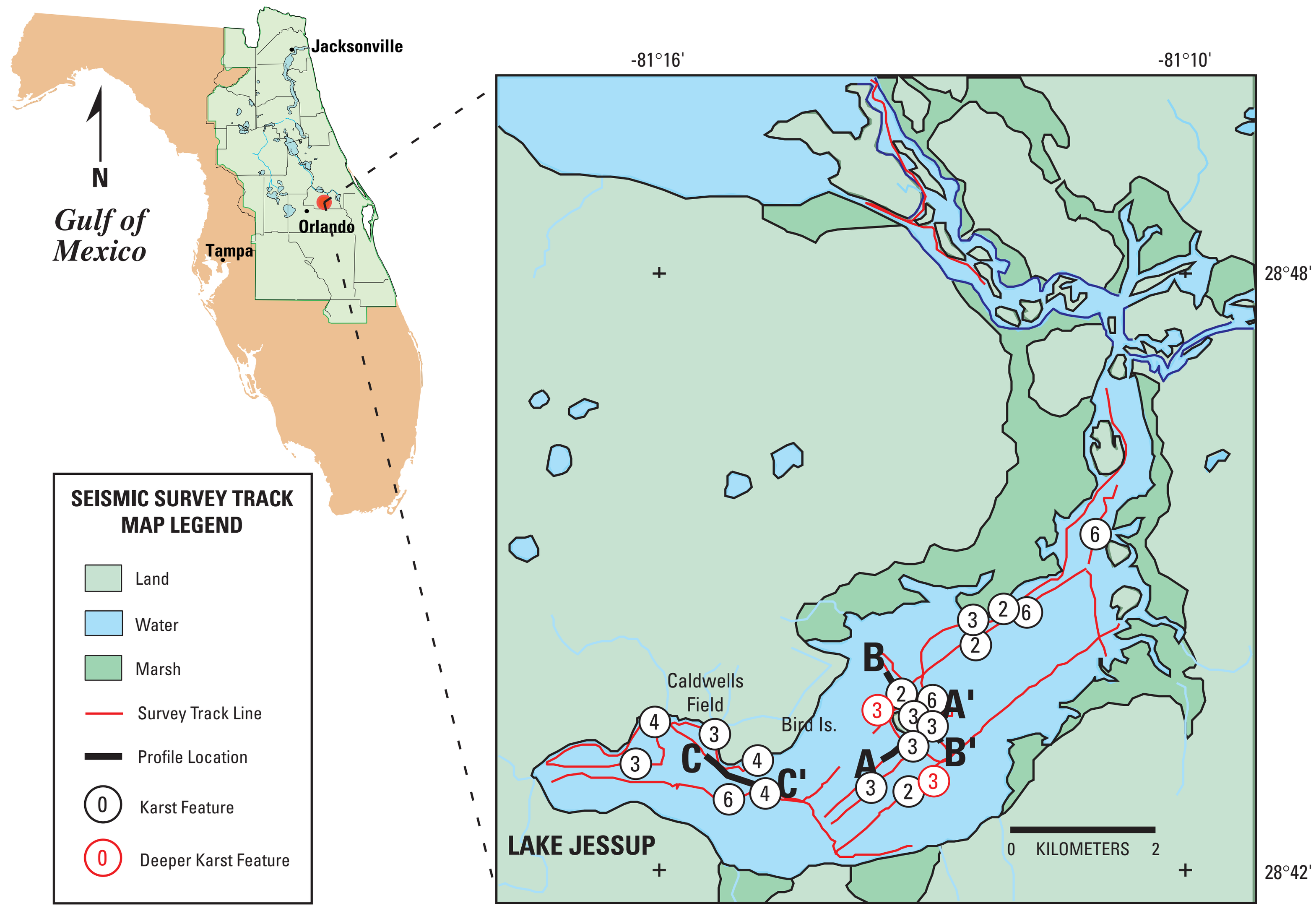


LAKE JESSUP

SEMINOLE COUNTY, FLORIDA

Introduction

Lake Jessup joins the St. Johns River system between Lakes Harney and Monroe, in Seminole county. The lake occupies the broad solution valley of the St. Johns Offset (Books, 1981). Lake elevation at the time of the seismic survey was about 1.4 m (4.7 ft) NGVD. Lake Jessup is irregular in shape, covering about 40 sq km with about 65 km (40 mi) of shoreline. The irregular shoreline of Lake Jessup exemplifies the differences between lakes which occupy dissolution and incised valleys with those that are a single subsidence type lake such as Kingsley Lake (page 9). Low-lying marshland of the solution valley surround much of the lake to the north and east, with higher ground approaching from the south.

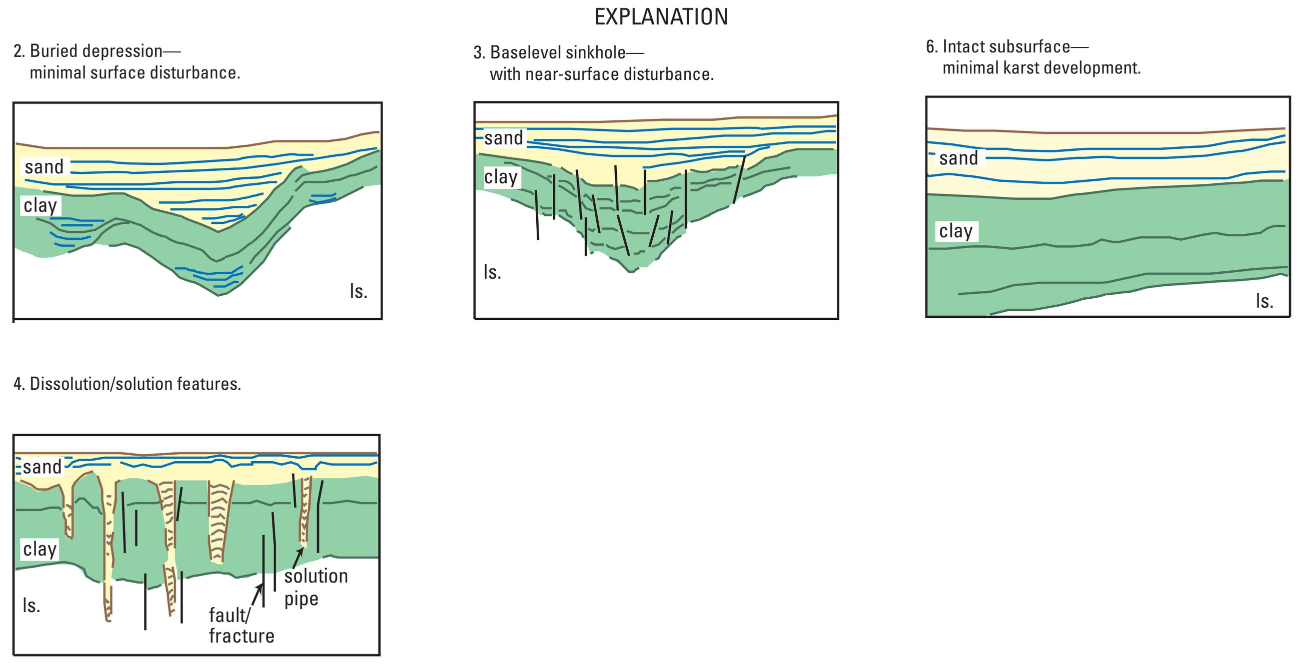
Subsurface Characterization

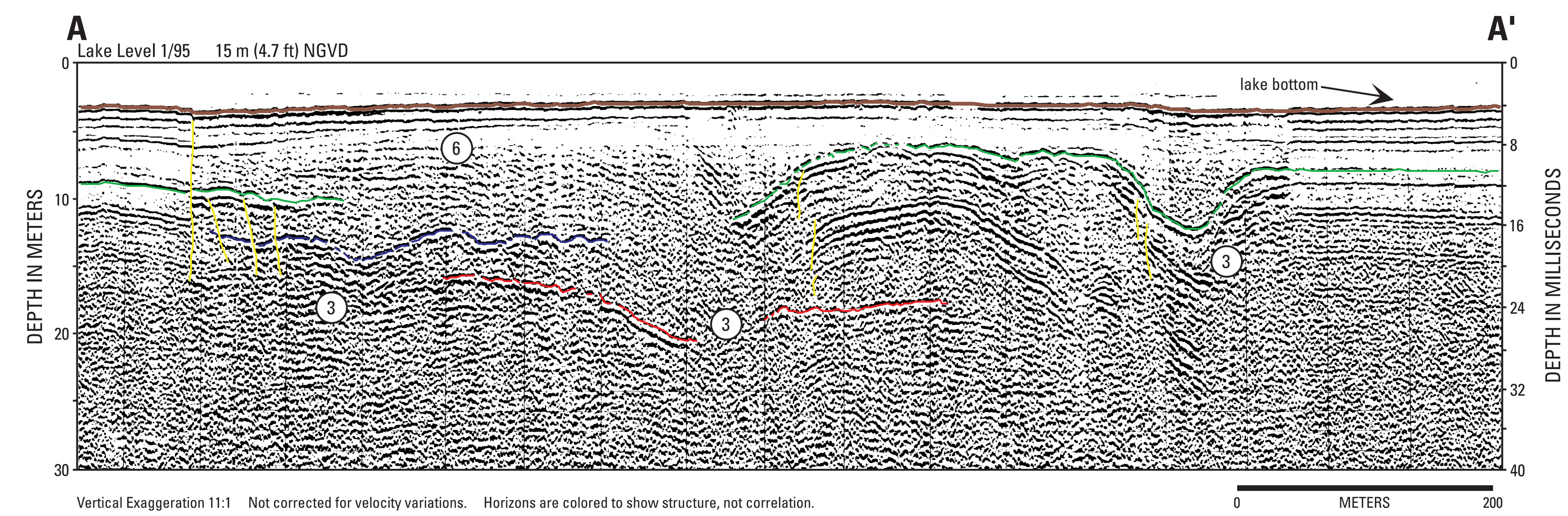
Seismic profiles from Lake Jessup show a high occurrence of subsidence. Areas of subsurface discontinuities predominate in two areas of the lake, around Caldwells Field and Bird Island (see index map). The area around Bird Island shows subsidence extending deep into the subsurface (Profiles A-A' and B-B'), with a discontinuous strong reflector at about 16 m (52.5 ft, red). Gamma logs indicate the top of the Ocala Limestone to be at about 24 m (79 ft) below mean sea level, in close approximation to this reflector. Collapse in the Ocala results in subsequent subsidence in the shallower sediments, shown by the green reflectors in example profiles. These sediments are the competent sands and clays of the Hawthorn Group. Accommodation-related stress fractures and slumping are also apparent around the areas of subsidence. Low-angle to horizontal reflectors within the depressions (B-B'), along with a chaotic signal (A-A'), indicate differing processes of fill; with modes of transport ranging from fluvial to gravity (collapse) driven. The subsurface structure may be responsible for the presence and location of Bird Island. Profiles A-A' and B-B' show a structural high in the lake bottom created by adjacent areas of subsidence. This rise is translated to the surface where island development could have become pinned to this topographic high.

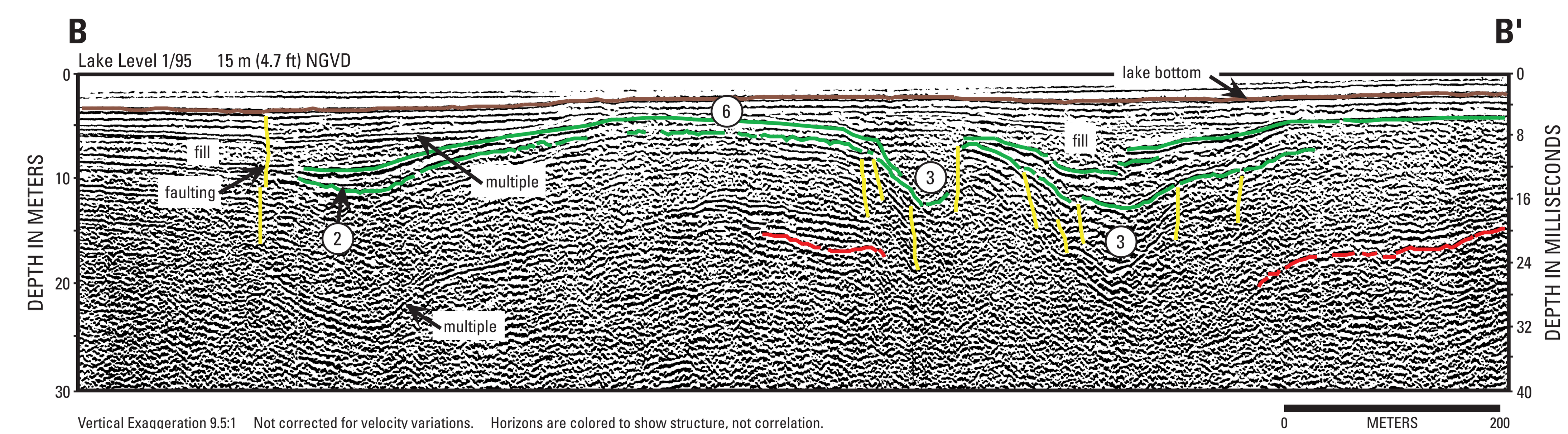
The area around Caldwells Field shows similar subsidence in the shallow subsurface, but collapse in the deeper reflector is not as apparent (Profile C-C'). The distribution of features map shows the area where surface subsidence in this area occurs. The thickness of the overlying fill appears to be greater and is comprised predominantly of low-angle reflectors. The fill appears to be more extensive than the underlying subsidence and is perhaps associated with the deeper areas of subsidence toward the central part of the lake.

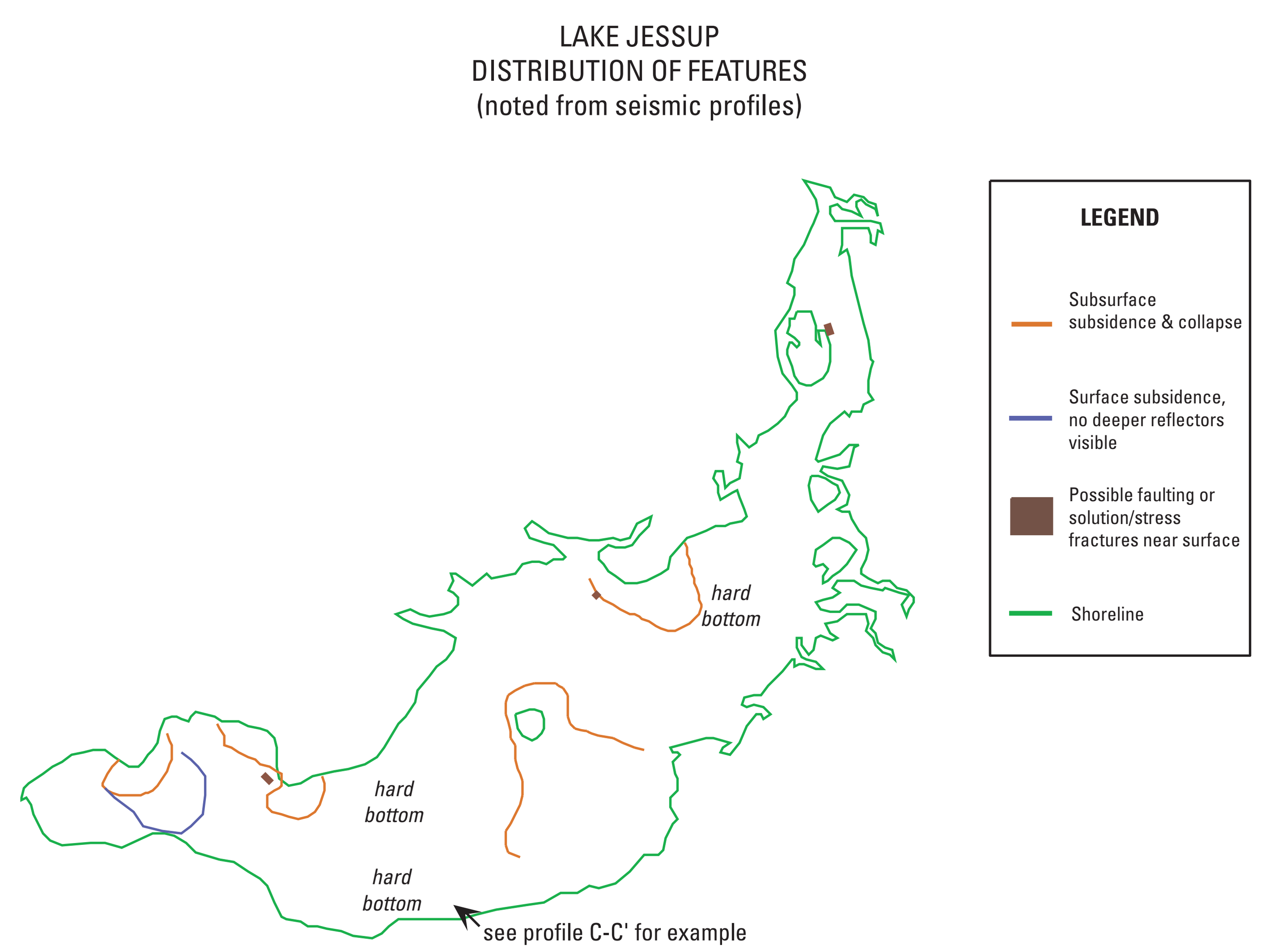
E

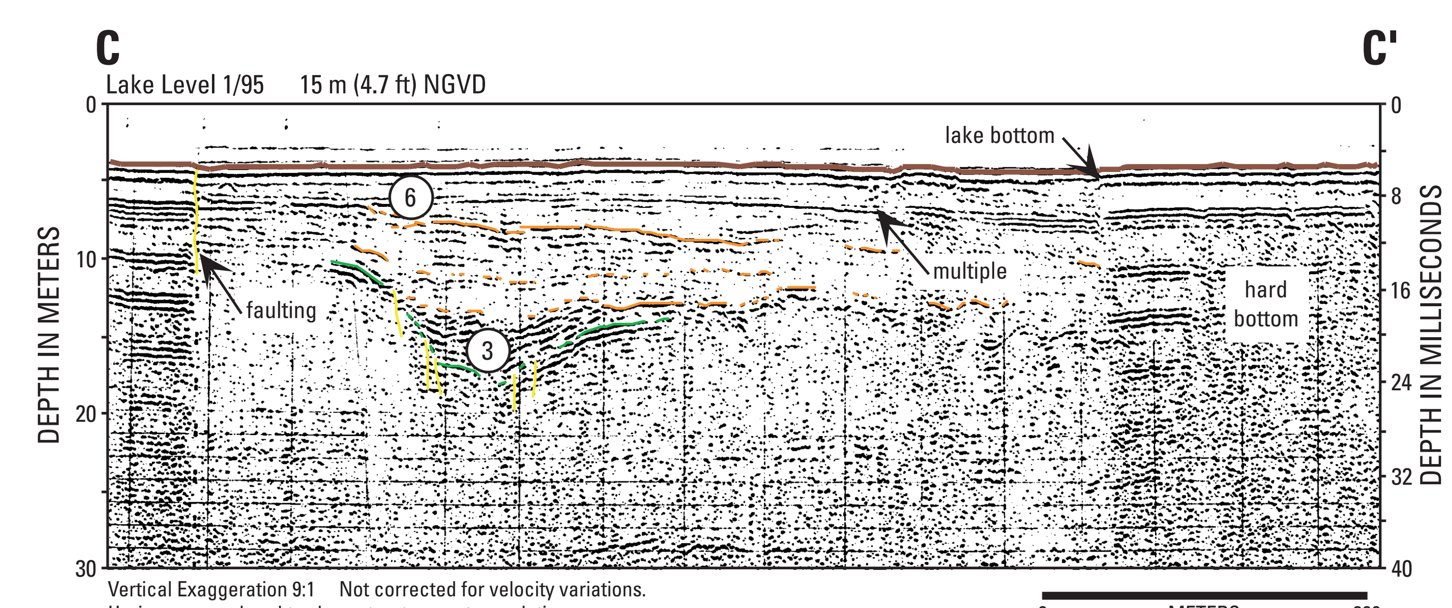
EXPLANATION











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2000

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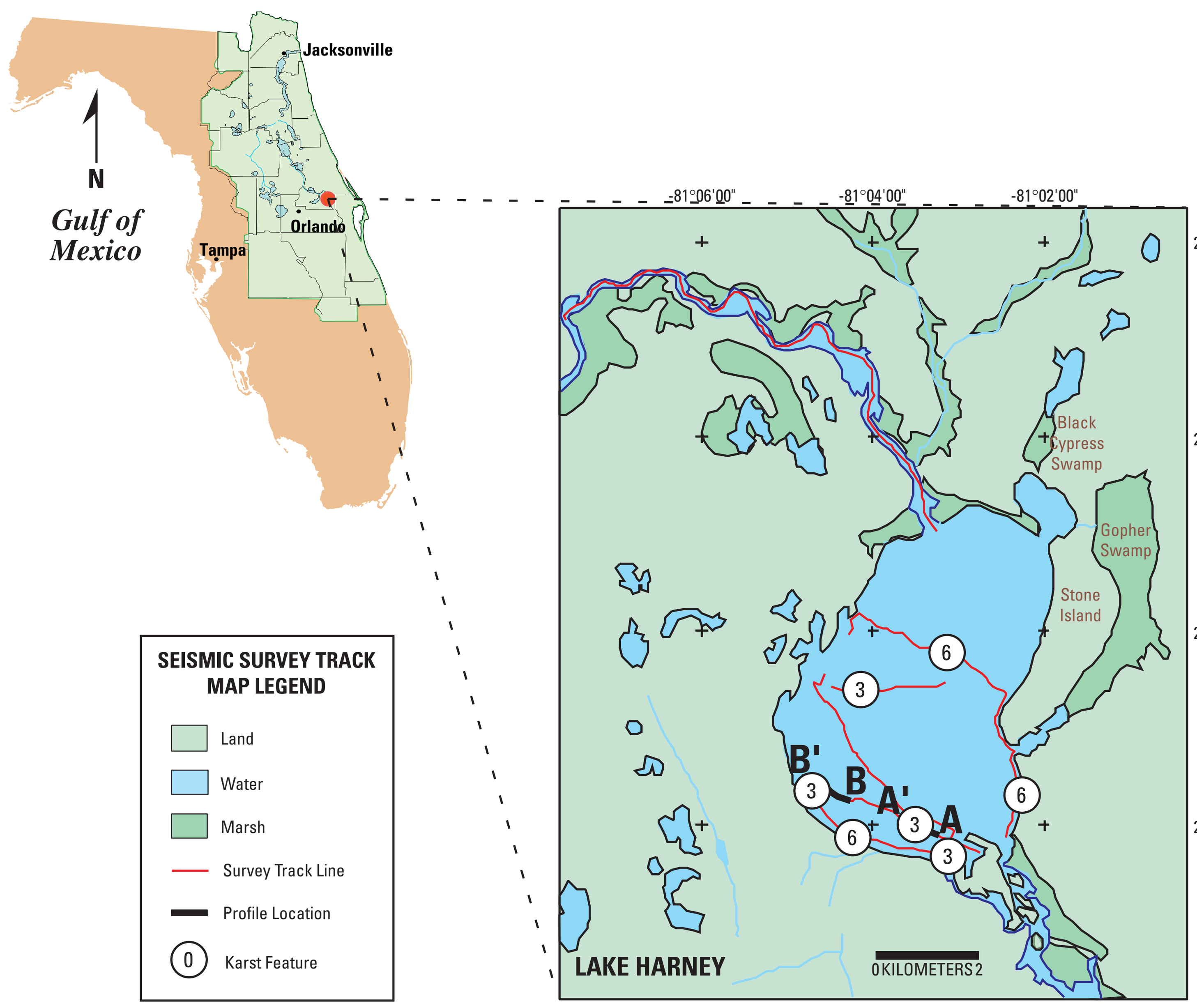
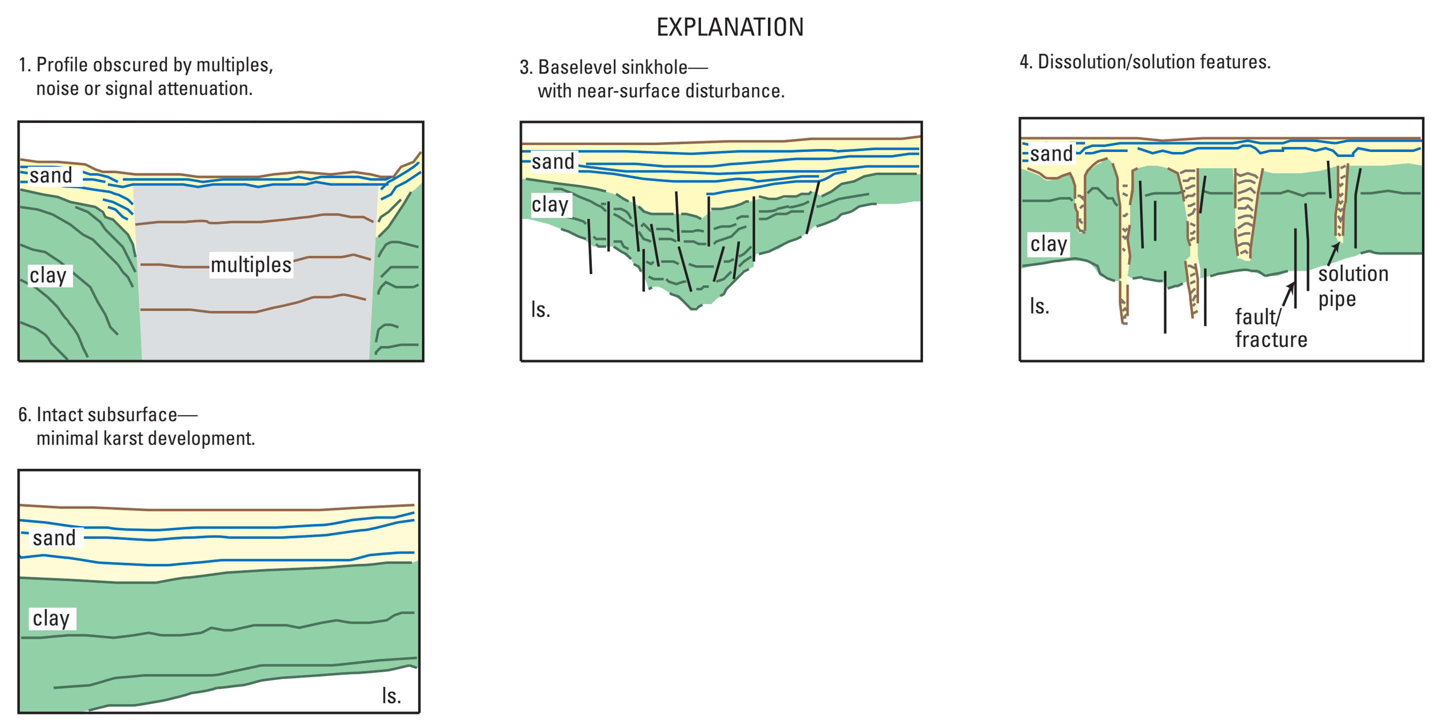
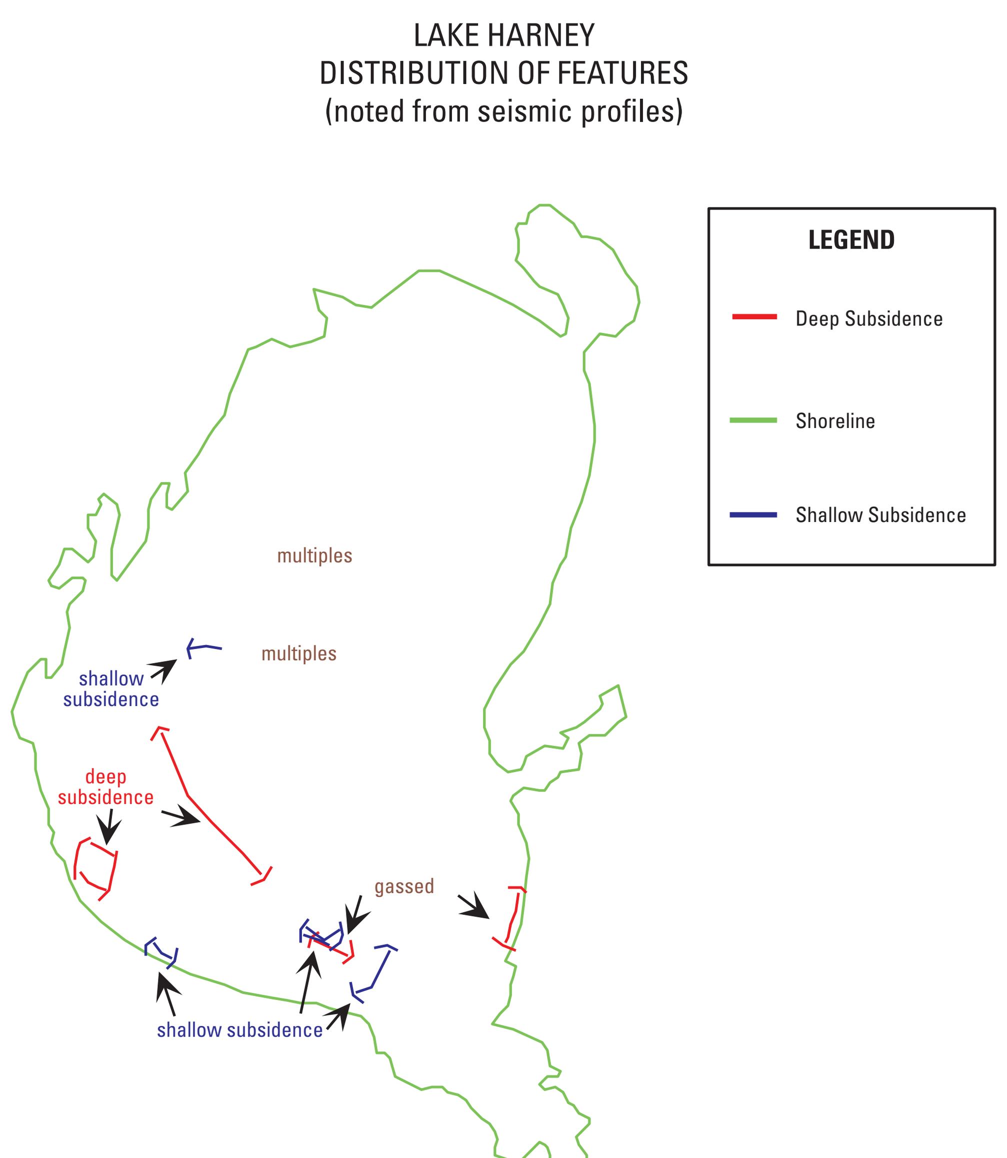
LAKE HARNEY

VOLUSIA/SEMINOLE COUNTY, FLORIDA







Introduction

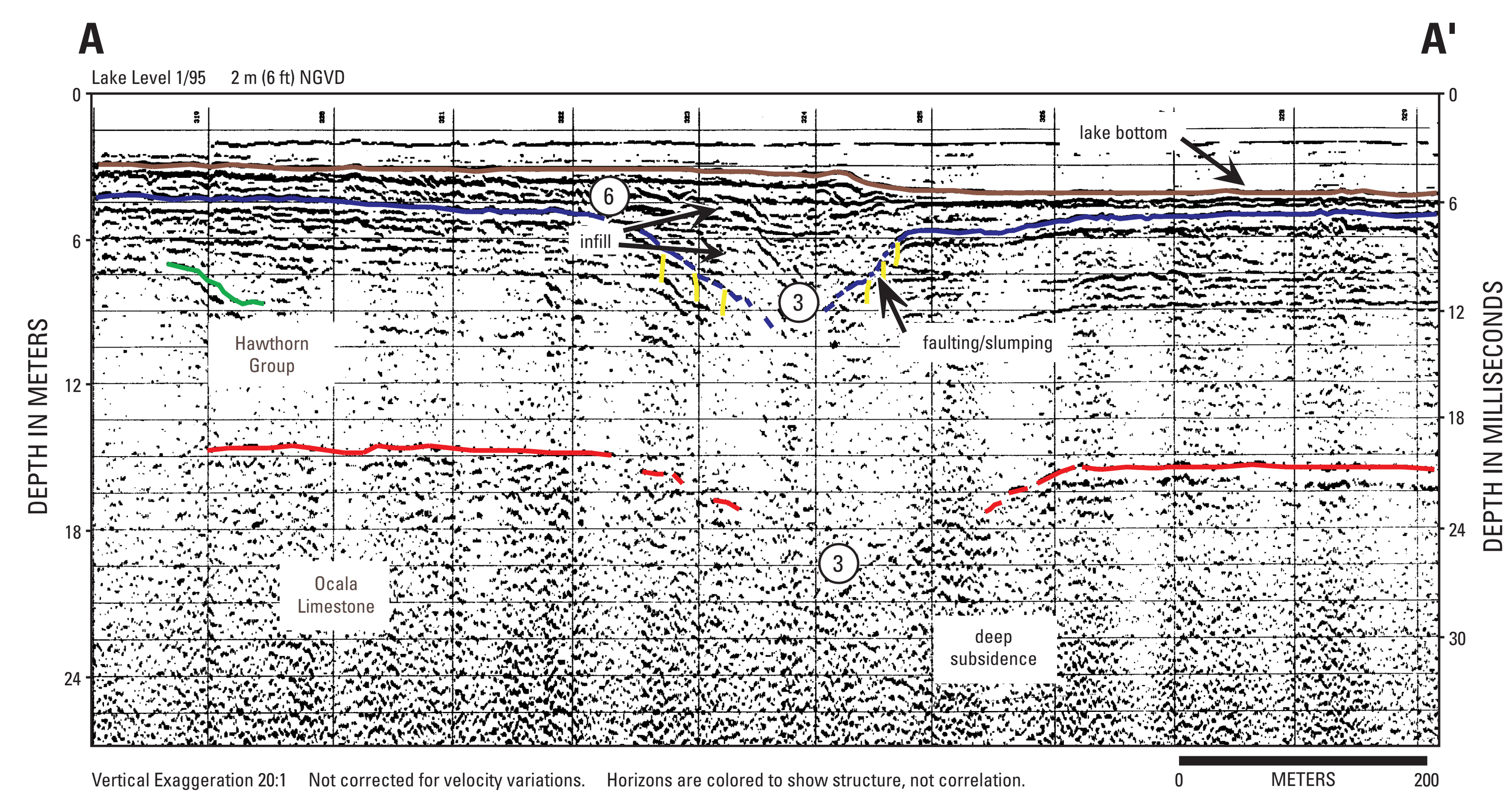
Lake Harney straddles the Volusia-Seminole county line along the St. Johns River. The lake is part of the St. Johns Wet Prairie of the Eastern Flatwoods District (Brooks and Merrit, 1981). The series of lakes along the St. Johns River in this area occupy valleys previously incised by Late Pleistocene fluvial-lagoonal processes. The area is low-lying and predominantly marshland. Lake elevation at the time of the seismic survey was ~1.8 m (6 ft) NGVD. Gopher Swamp appends to the east, separated from the lake by Stone Island. Black Cypress Swamp is connected to the lake via Underhill Slough to the northeast. The St. Johns River enters Lake Harney from the south and flows out to the north. Lake Harney is roughly oval in shape, with 20 km (12 mi) of shoreline and a surface area of about 24 sq km.

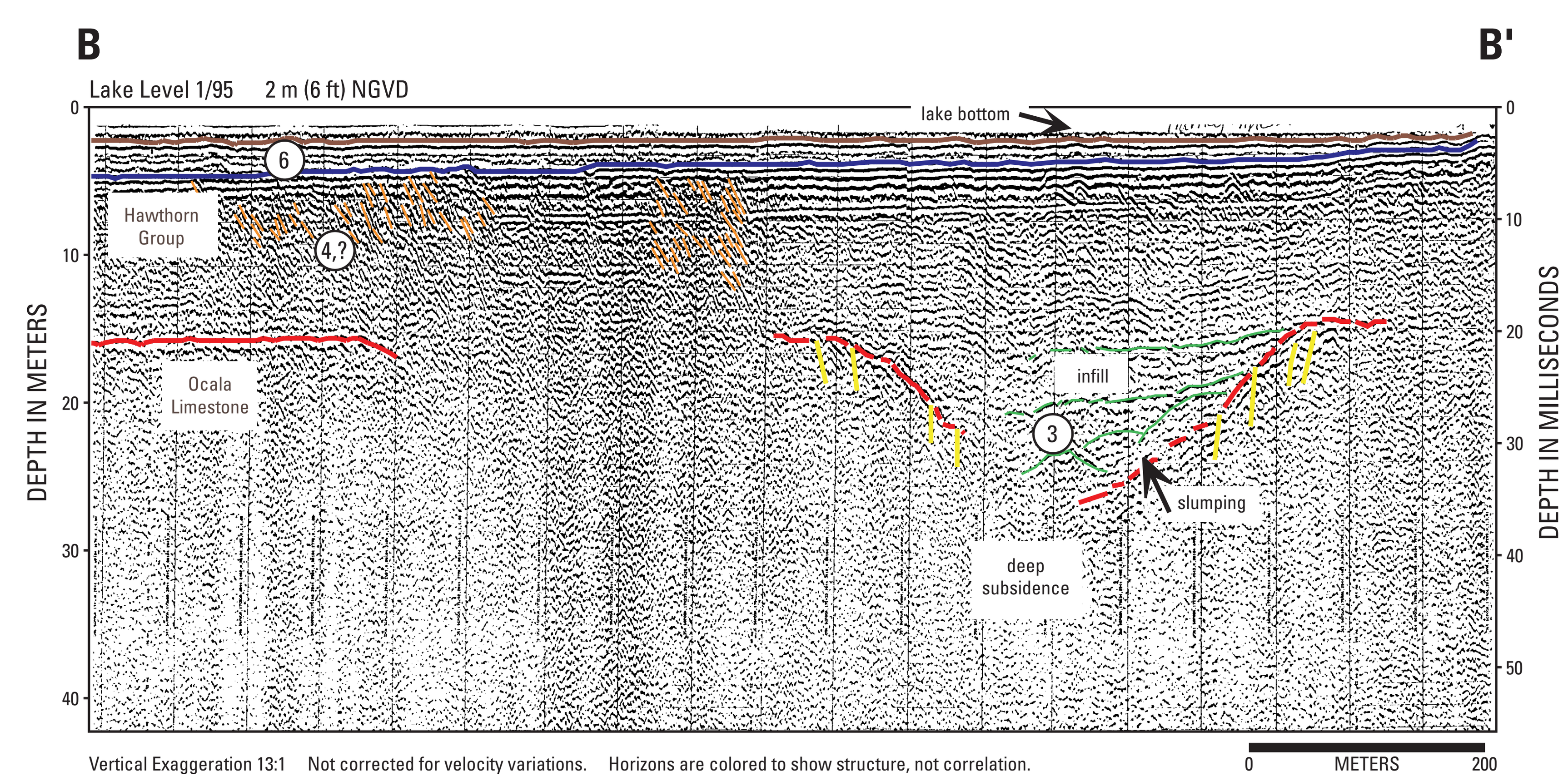
Subsurface Characterization

Seismic profiles from Lake Harney show a good example of subsurface karst imaging (profile A-A', B-B'). Profile A-A' shows a deep reflective surface (red line) with apparent subsidence. This feature is similar to a type 3 feature described in the explanation. This subsidence influences the integrity of the overlying strata, as shown in subsequent collapse across another reflective surface (blue line). Profile B-B' shows another deep collapse structure (red line). Within this subsidence, horizontal reflectors onlap the steeper sides of the structure. This may represent fluvial or aeolian infilling of the depression. This type of infilling may have also occurred in the shallower depression shown in Profile A-A', as evidenced by the patterned texture of the acoustic signal from the overlying material. This pattern could represent foresets or cross-bedding, as opposed to collapse-type infilling, which typically returns a noisier or chaotic signal. Comparison of the deeper subsidence structures between profiles A-A' and B-B' may provide insight into the timing relationships between collapse in the host rock and subsidence in the overburden. The deeper structure in profile A-A' does not appear to have the infilling seen in the B-B' subsidence. Also, the overburden in profile A-A' appears to be more disrupted than that overlying the subsidence in profile B-B'. The infilling might indicate that the deeper subsidence seen in profile B-B' may be a relic sinkhole that was aerially exposed and filled prior to accumulation of the overburden. The structure in profile A-A' represents a continued subsidence, controlled by the deeper featured. The disruption in the overburden in A-A' further supports continued subsidence, whereas the overburden in profile B-B' appears to be undisturbed.

Gamma logs to the west of Lake Harney show the top of the Ocala Limestone at about 12 m below mean sea level along the southern portion of the lake (see Index Map E, p. 31). This depth correlates well with the red reflectors seen in the profiles. The deep structures may represent collapse in the Ocala. Likewise, the blue reflectors in the profiles may represent material in the Hawthorn Group. High angle reflectors (orange and gold) may represent stress in the overburden and indicate breaches through the otherwise impermeable Hawthorn sediments.

E





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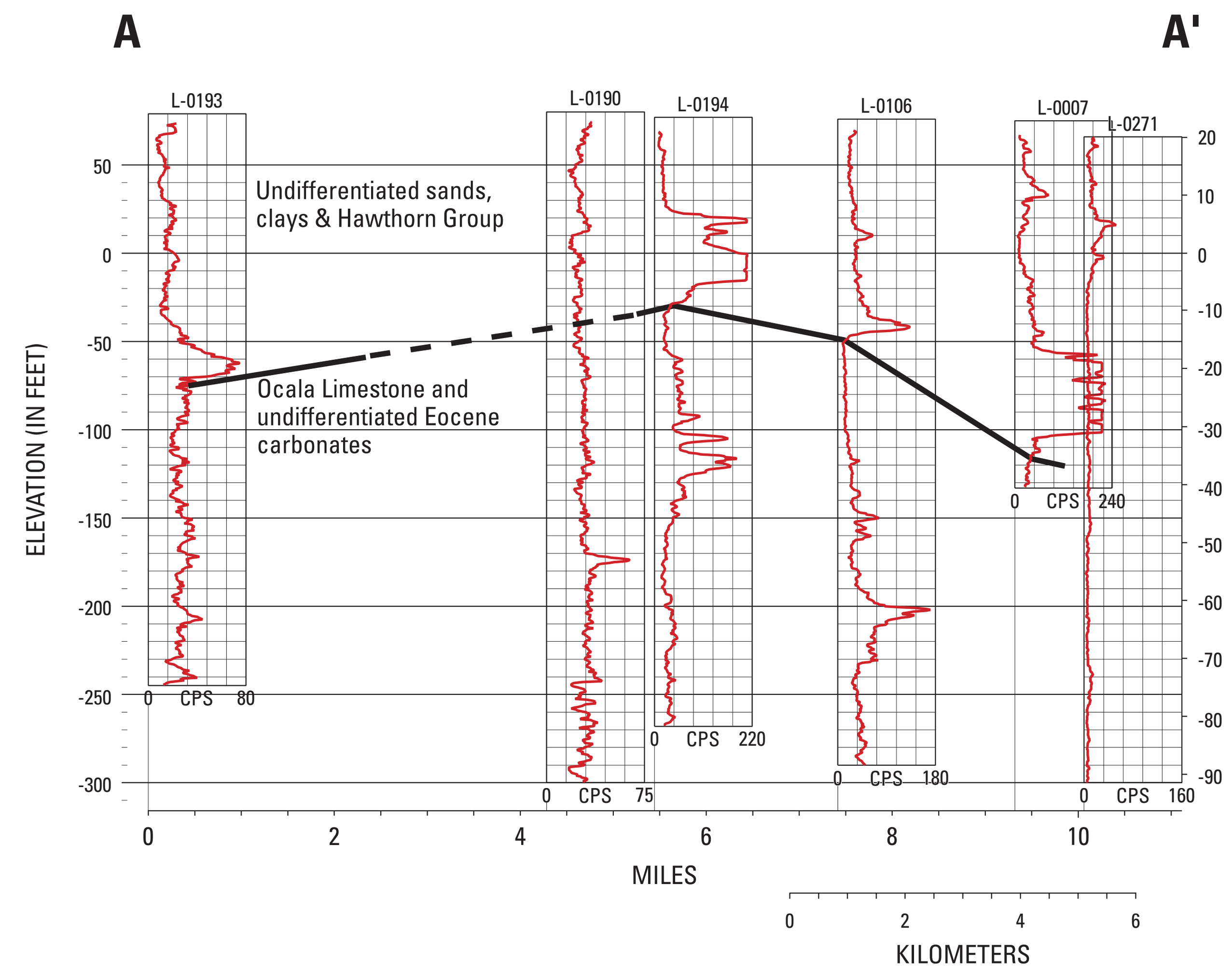
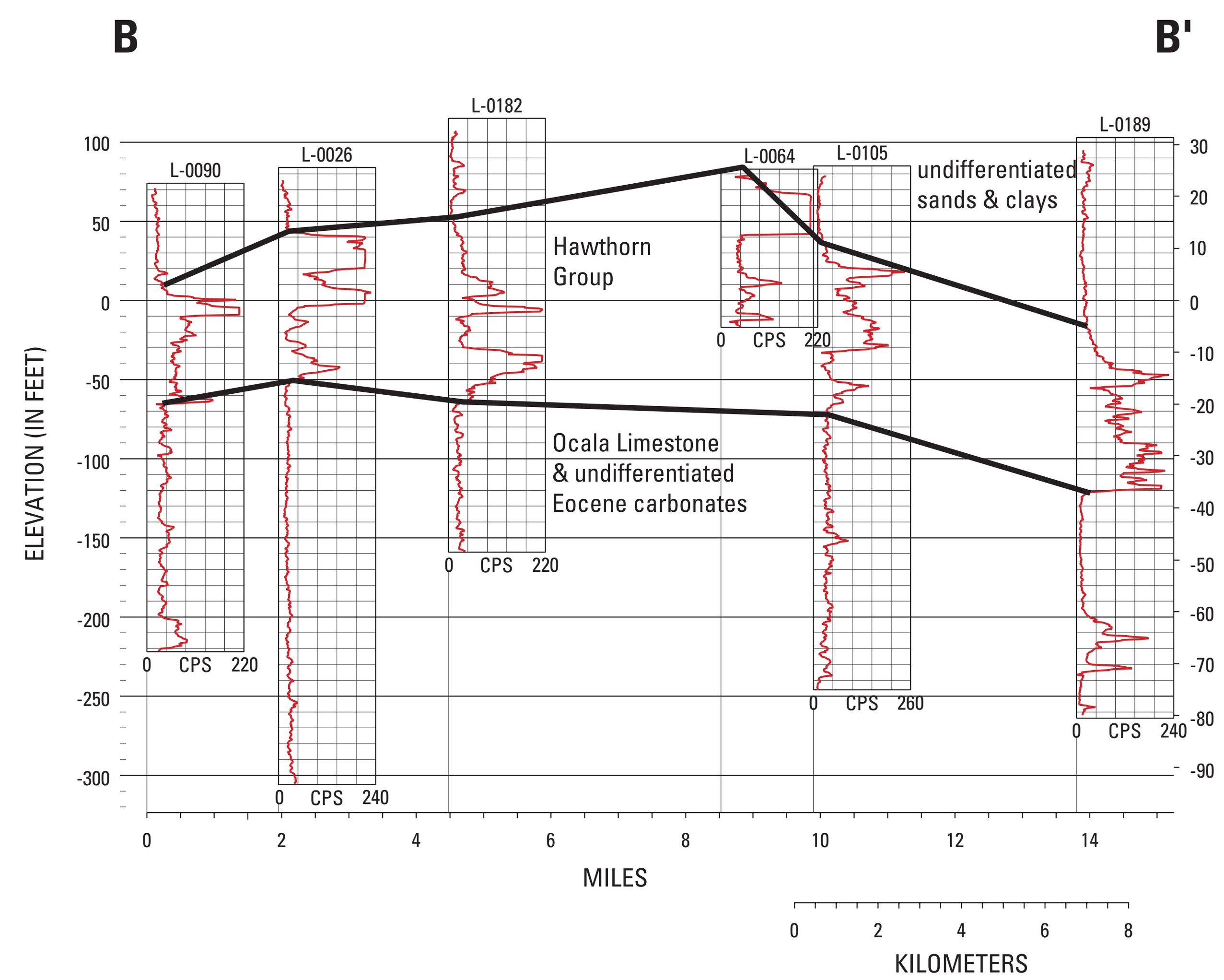
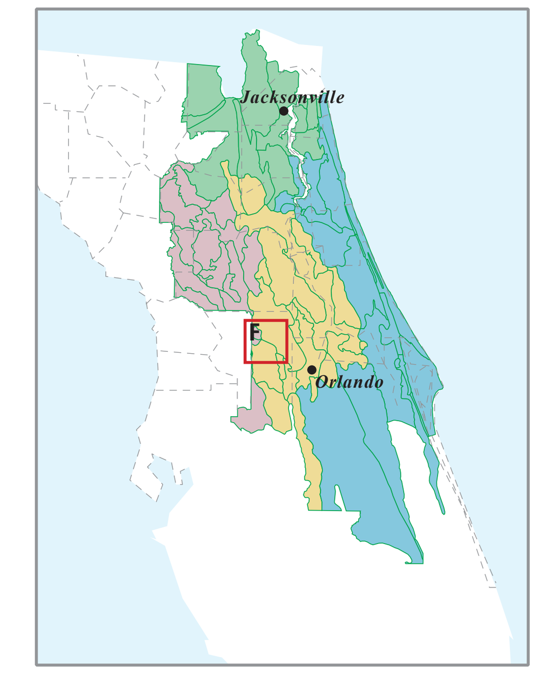
INDEX MAP AND GAMMA LOG

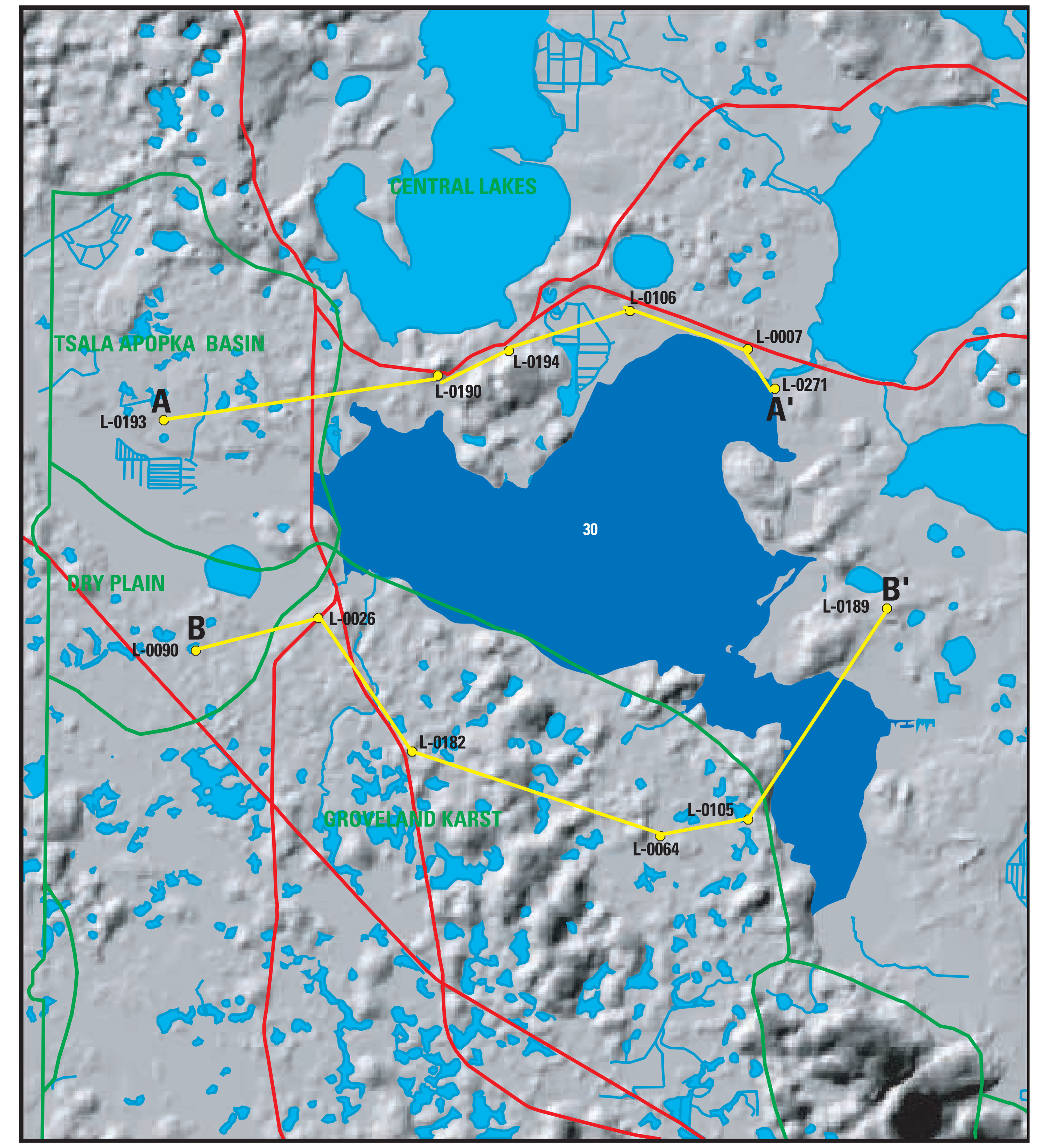
CROSS-SECTIONS, SECTION F







Location of survey area right (red square). Shaded relief map below showing physiographic regions, and location of wells and gamma log cross-section. Gamma Log cross-sections (left) show geologic contacts for correlation to seismic sections.



LEGEND

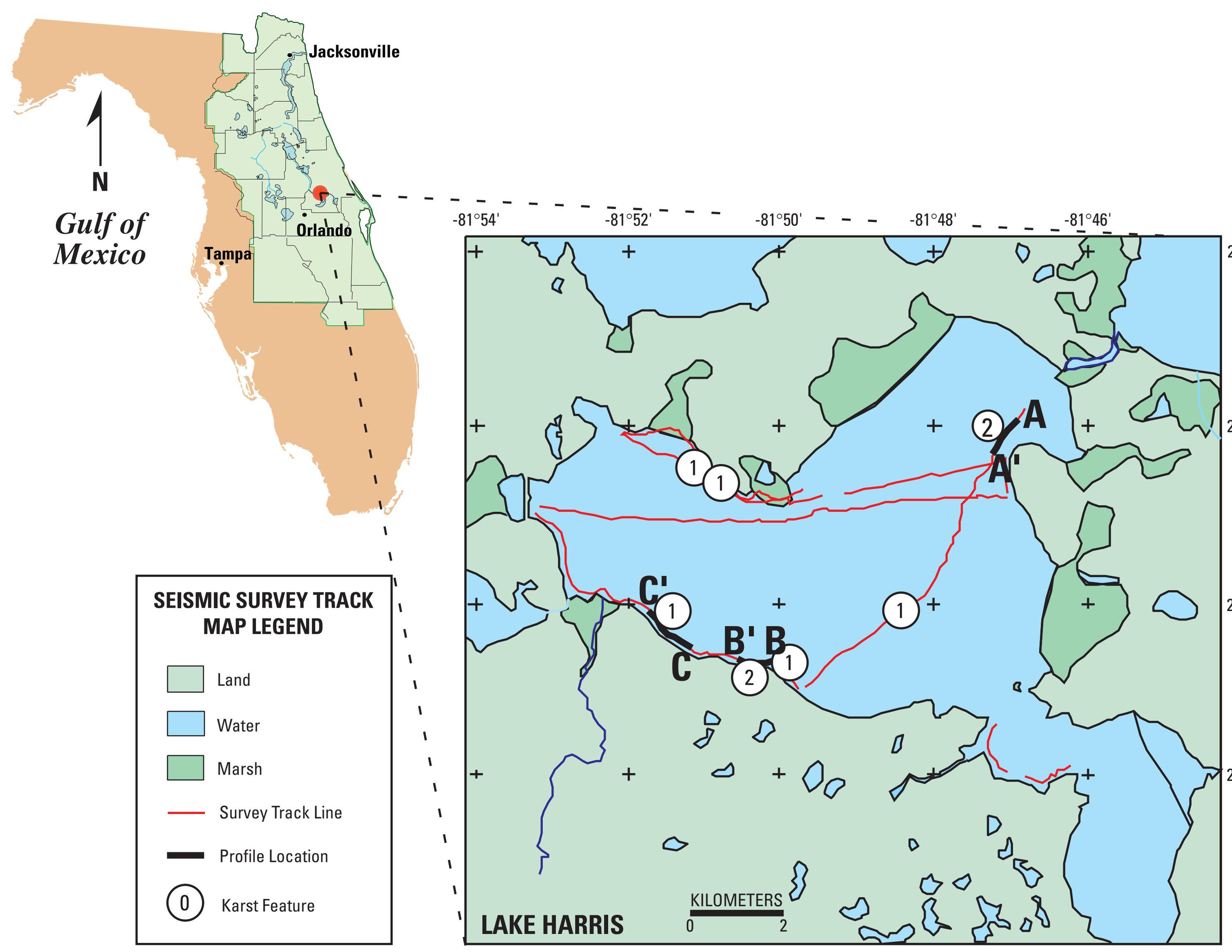
- Wells, Cross-Sections
- Streams/Rivers
- Major Roads
- Physiographic Province Boundary
- Lakes
- Lakes in Atlas

		page #
30	Lake Harris	36

0.9 0 0.9 MILES
0.9 0 0.9 KILOMETERS

F

LAKE HARRIS
LAKE COUNTY, FLORIDA



EXPLANATION

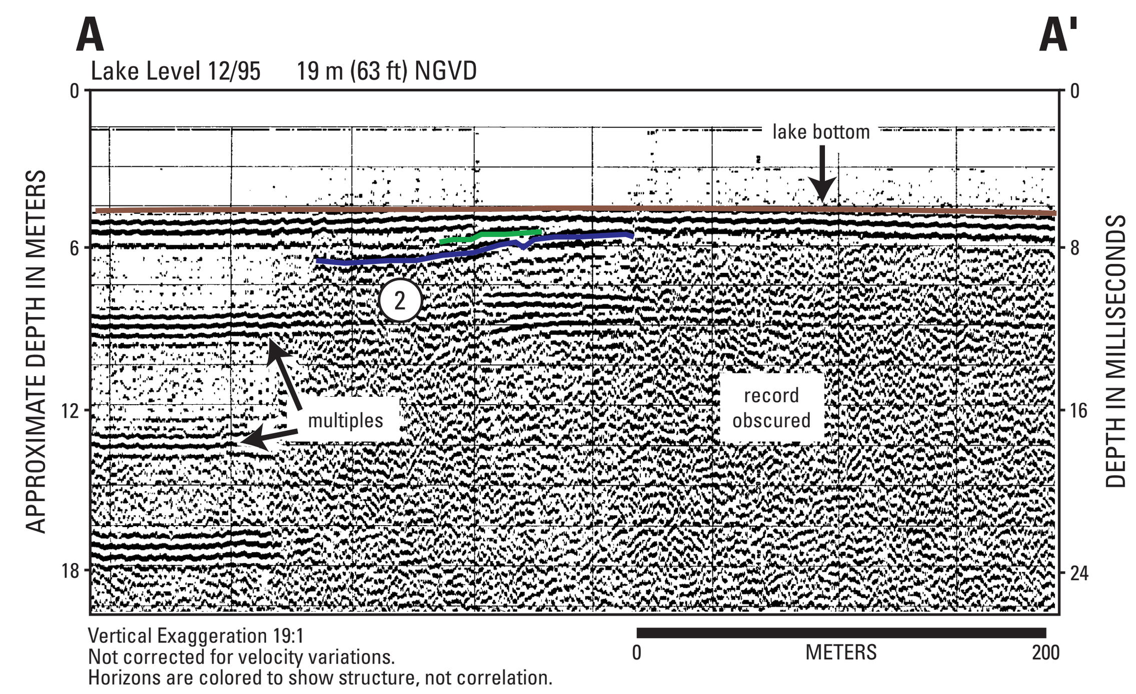
Introduction

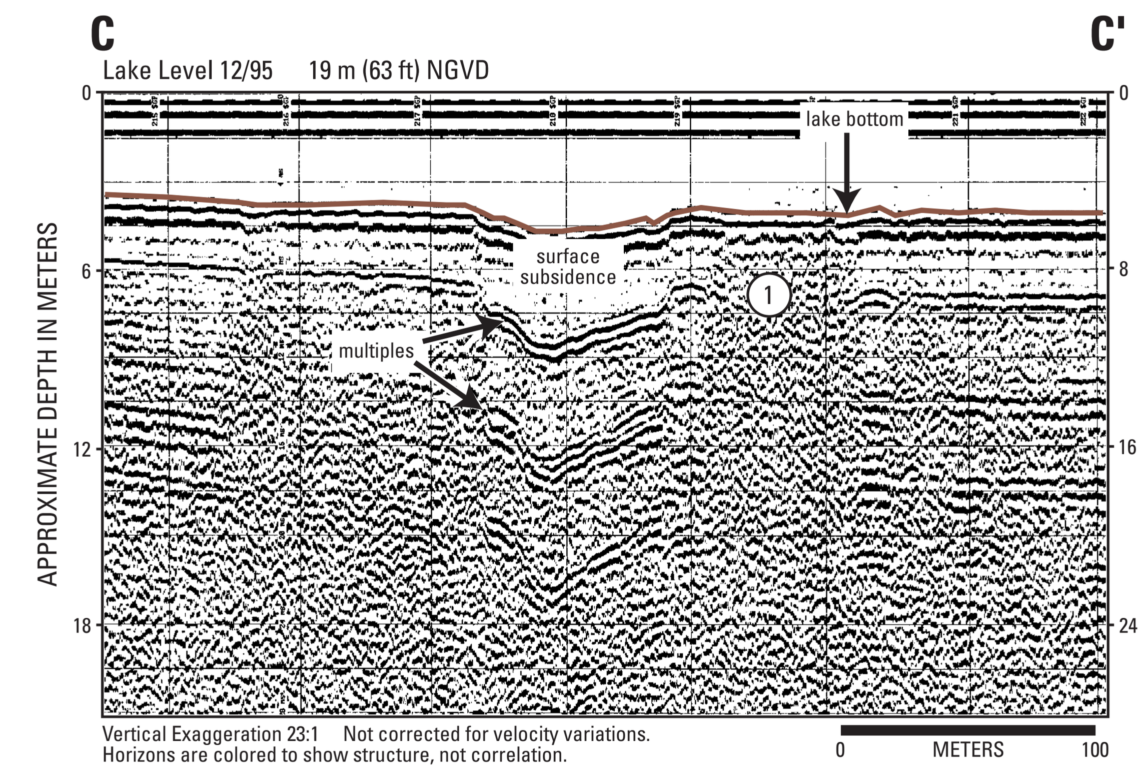
Lake Harris is part of a chain of lakes that comprise the Central Lakes region of the Central Lakes District. The county name, Lake, further attests to the predominance of the water-table lakes in this area. The district is characterized as sand hill karst with solution basins (Brooks and Merrit, 1981). In this area the Hawthorn Group pinches out onto the Ocala Limestone. Lake Harris has an irregular shape, covering 73 sq km with about 62 km (38 mi) of shoreline. The lake narrows to Little Lake Harris to the south and Lake Denham to the west. Dead River joins the lake with Lake Eustis to the northeast. Sand hills with numerous small lakes within their interstices trend southeastward from the southern shore.

Subsurface Characterization

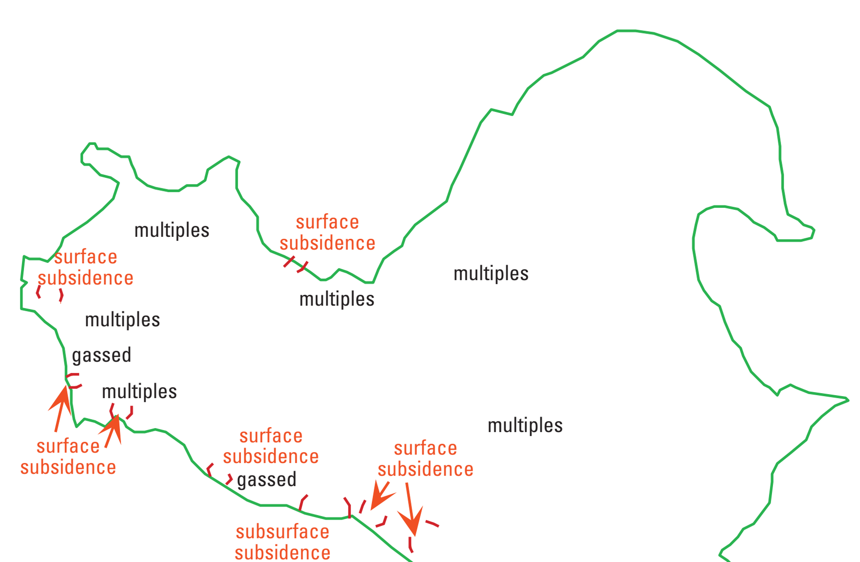
Multiples persist in the seismic profiles throughout the central portions of the lake. This is characteristic in lakes where the bottom sediments are hard sands or rock. Not enough data was collected to produce contours of subsurface features, additional data is necessary to provide adequate coverage. Scott (1988), estimates the top of the Hawthorn Group to be greater than 15 m (50 ft) above mean sea level in a nearby core. Lake level at the time of the survey was 19 m (63 ft) NGVD. This would suggest that the lakes that occupy the interstices of the sand hills in this area are floored within the Hawthorn Group, which contains phosphatic sands, limestone and dolomites. In two places the acoustic return is obscured by noise, or 'gassed out' (profile C-C'). This could indicate an accumulation of organic material in the bottom sediments which acts to disperse the signal. Profiles A-A' and B-B' show areas where a reflective horizon can be seen dipping away from the surface. Associated with this is a subsidence depression in the lake bottom. The feature resembles that of a type 2 feature, although little or no infilling is visible in the record. Another possibility is that the dipping horizon could represent a down-faulted or rotated block that has subsided into a large collapse structure at depth. However, multiples and noise obscure the record so that if any deeper, influencing structures are present they are not visible. Gamma logs indicate the top of the Hawthorn Group to be near the surface from seven meters depth to the west of the lake. The blue horizon from the seismic profiles may correlate with this contact (profiles A-A', B-B' and Index Map F, p. 35). Profile C-C' shows an example of small scale lake bottom subsidence within the lake that could be considered an active sink. No influencing features below the subsidence depression can be seen because of the persistent multiples, although dissolution within members of the Hawthorn Group is probably occurring. The subsidences are similar in size to the numerous small sinks visible to the south of the lake and trending to the northwest. It is possible that the lake bottom subsidences represent a lakeward extension of this karst trend.

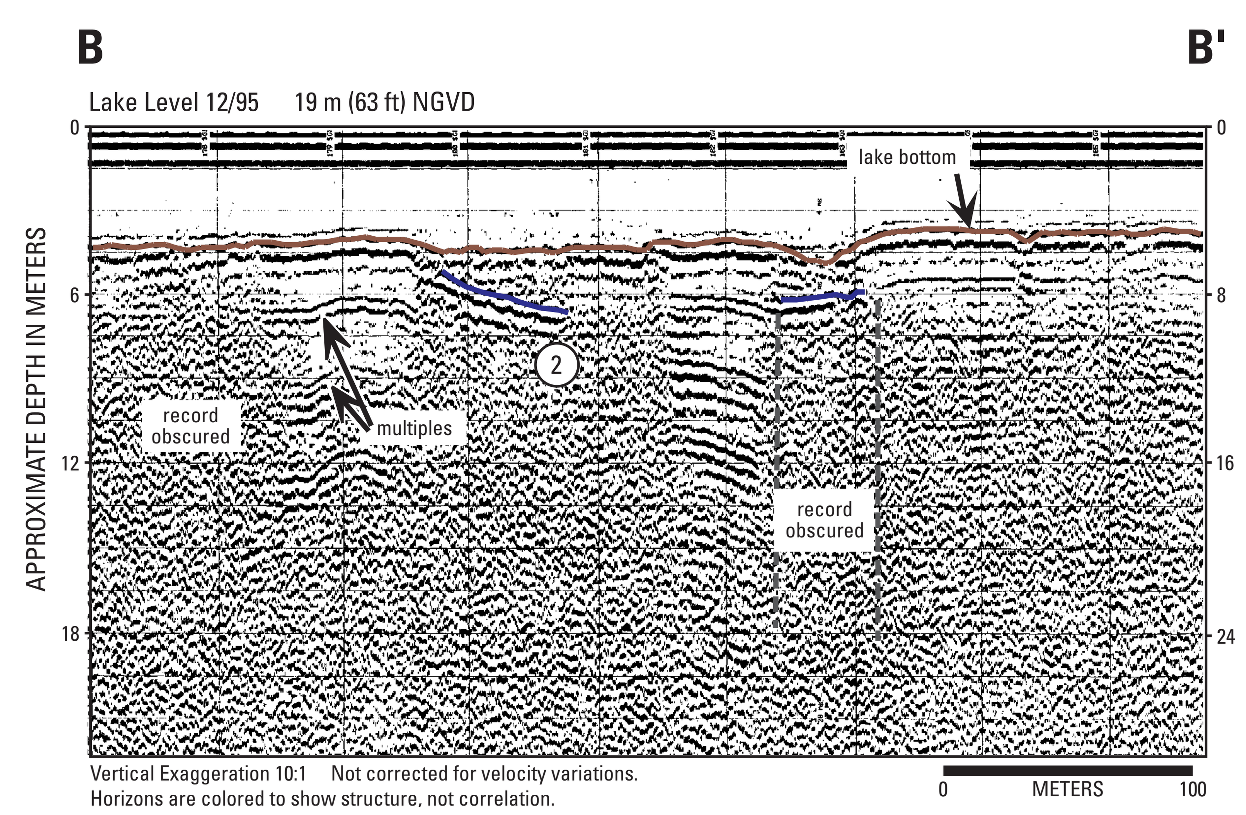
F





LAKE HARNEY
DISTRIBUTION OF FEATURES
(noted from seismic profiles)





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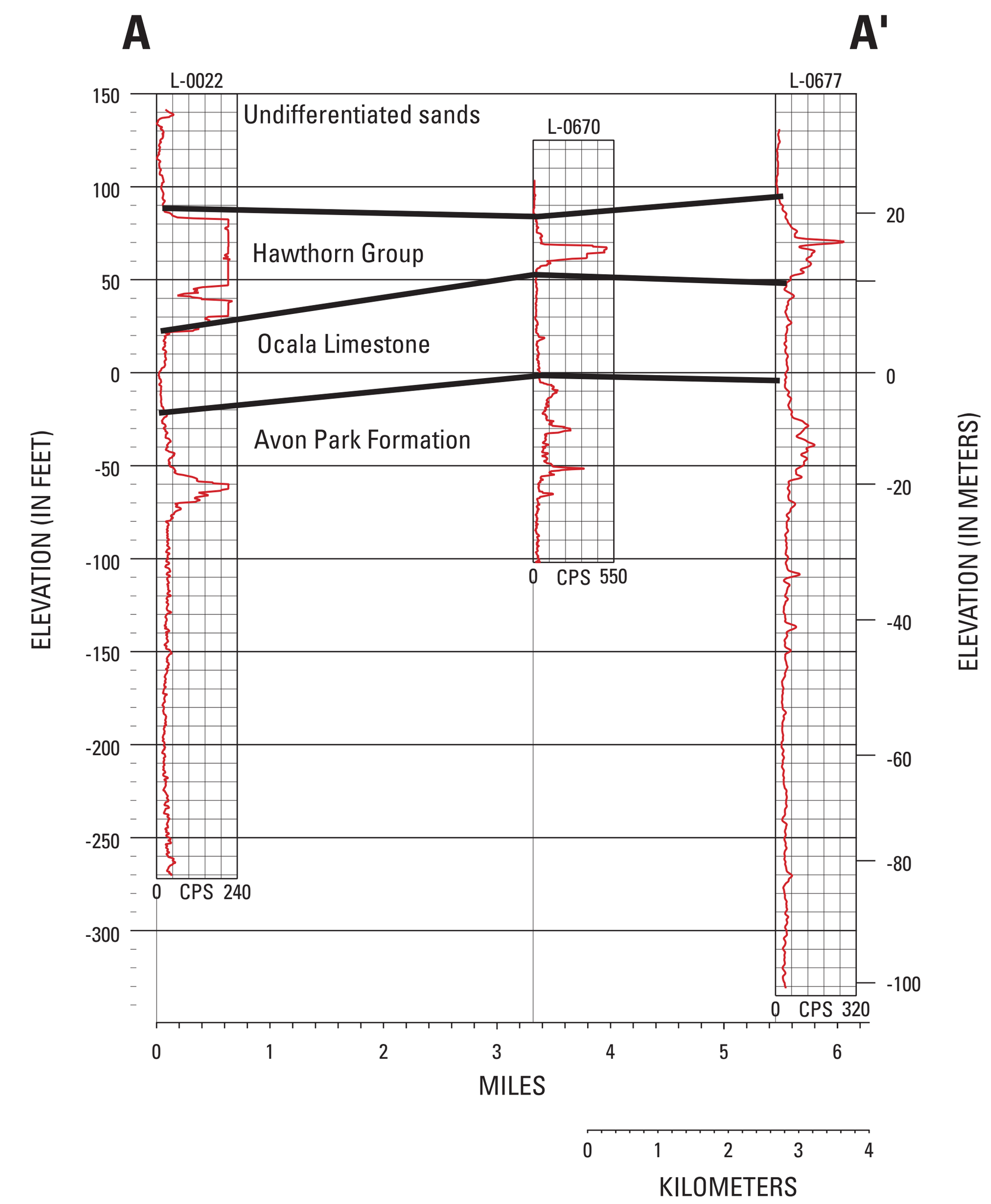
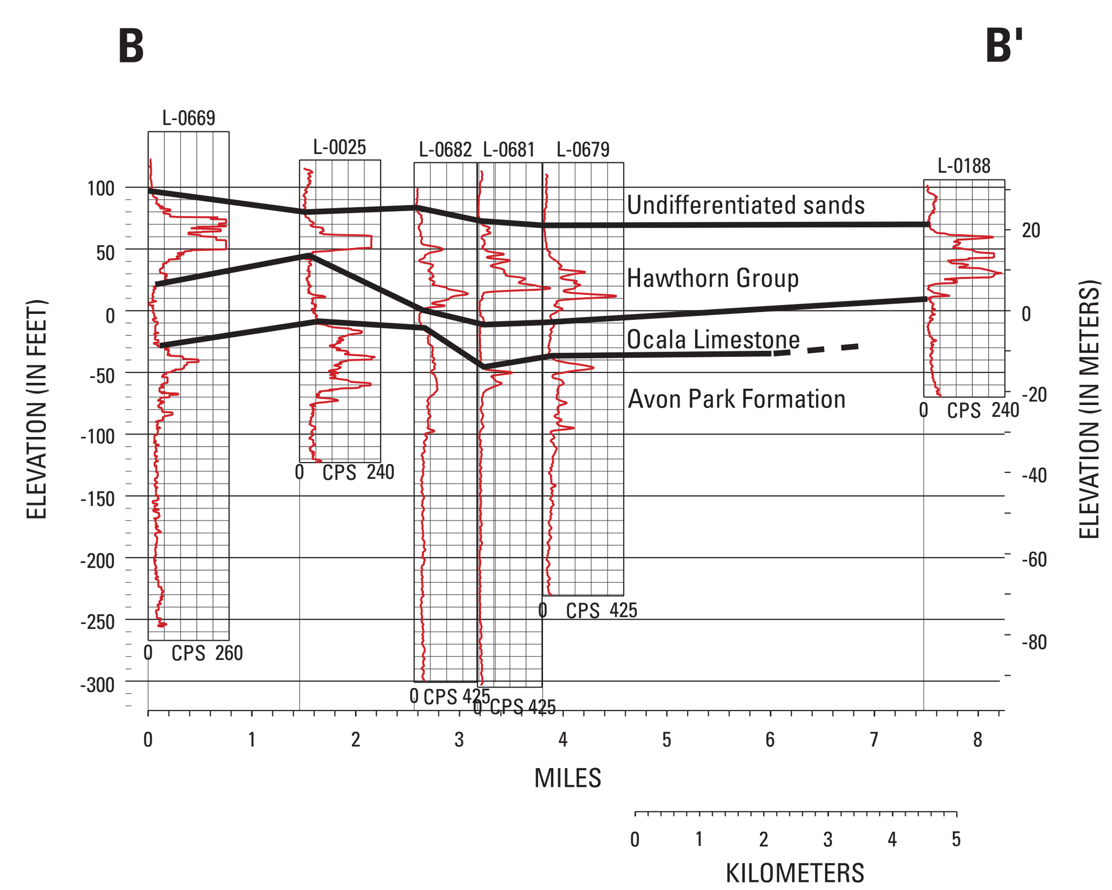
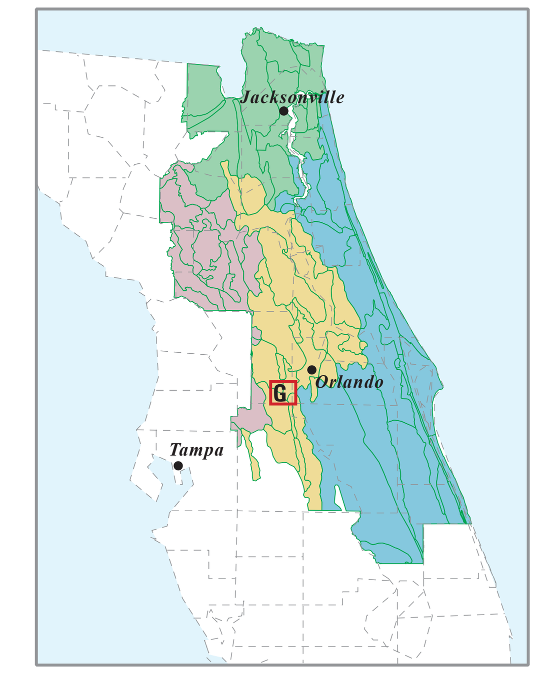
INDEX MAP AND GAMMA LOG

CROSS-SECTIONS, SECTION G







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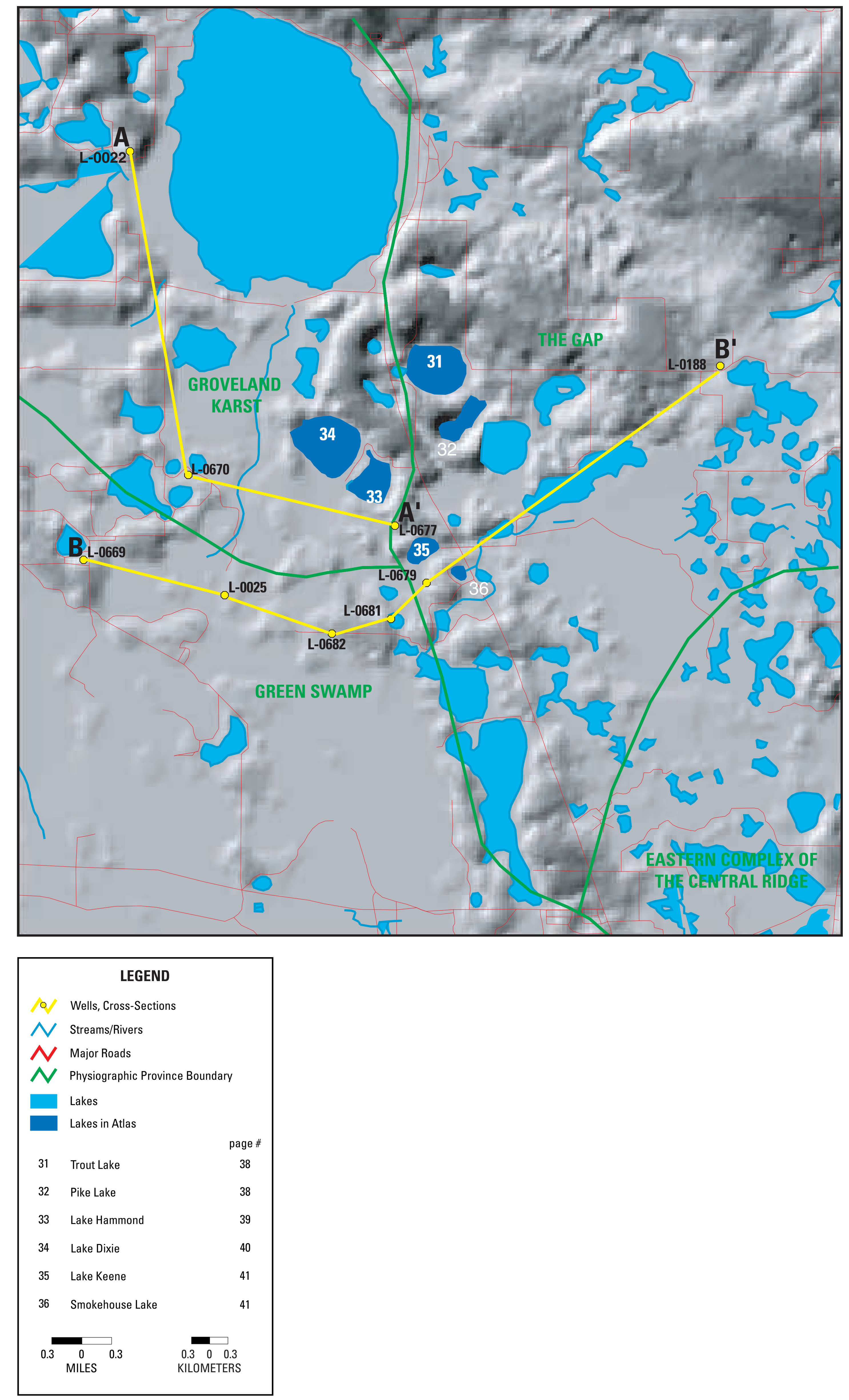
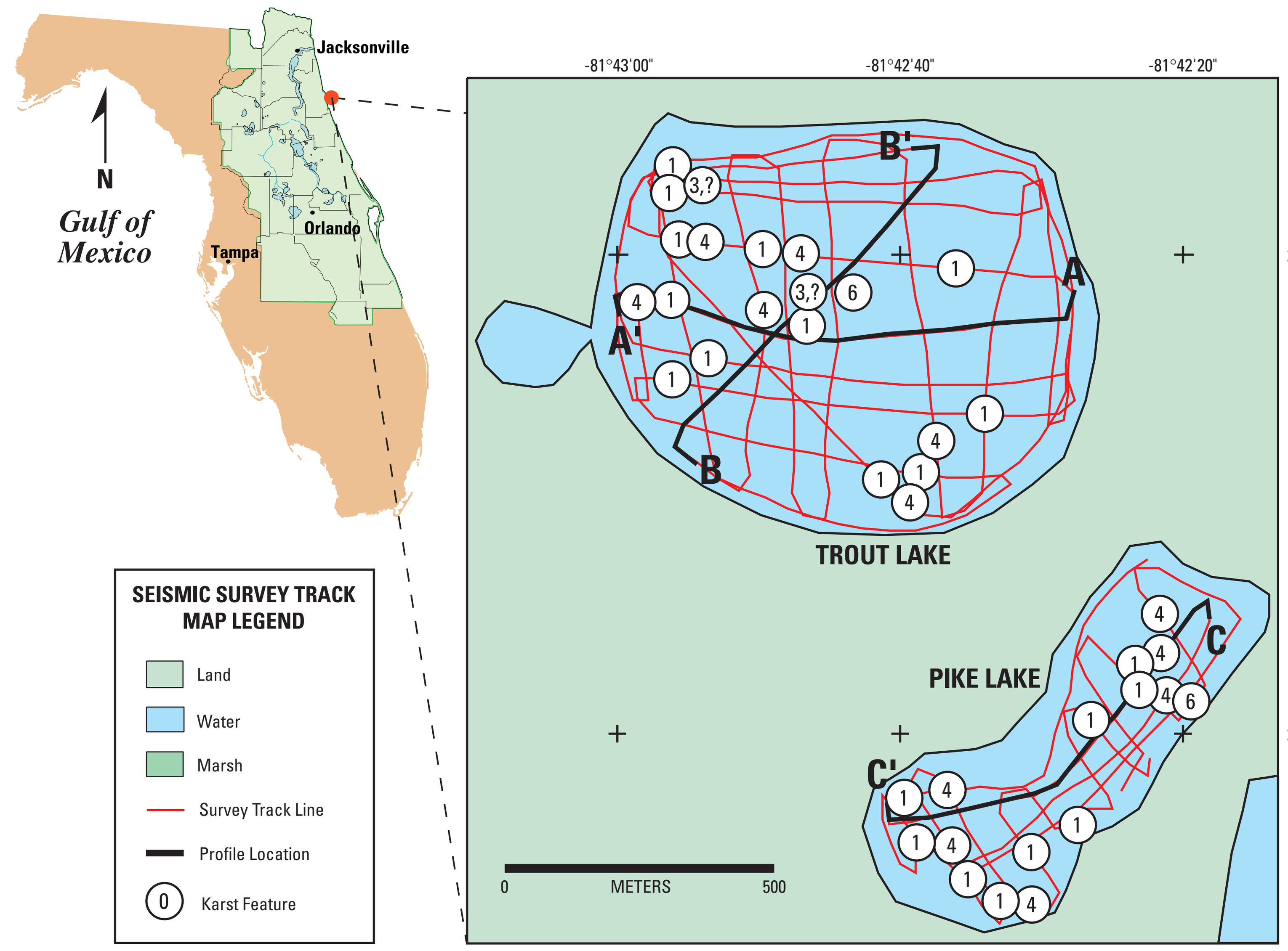
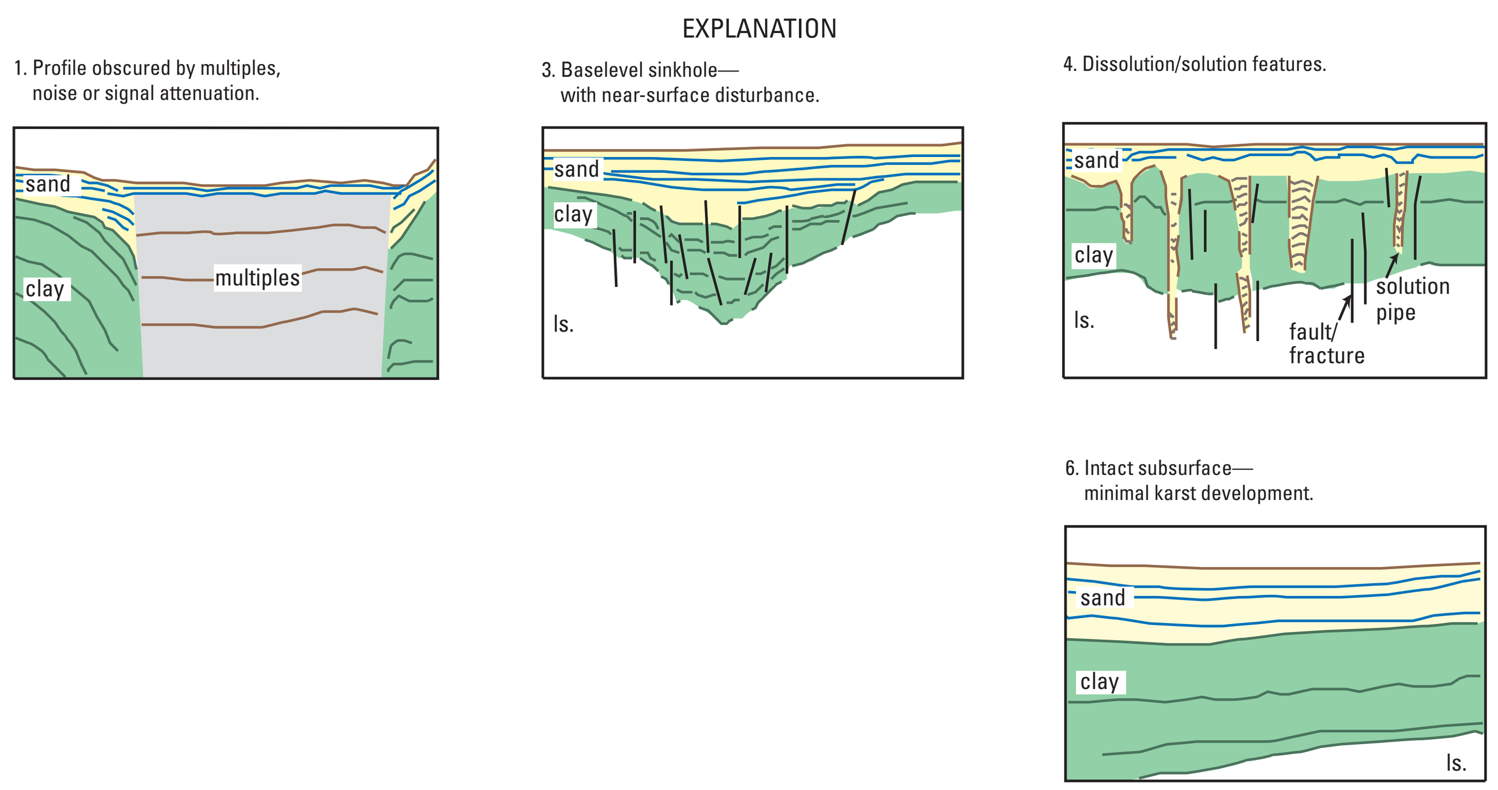
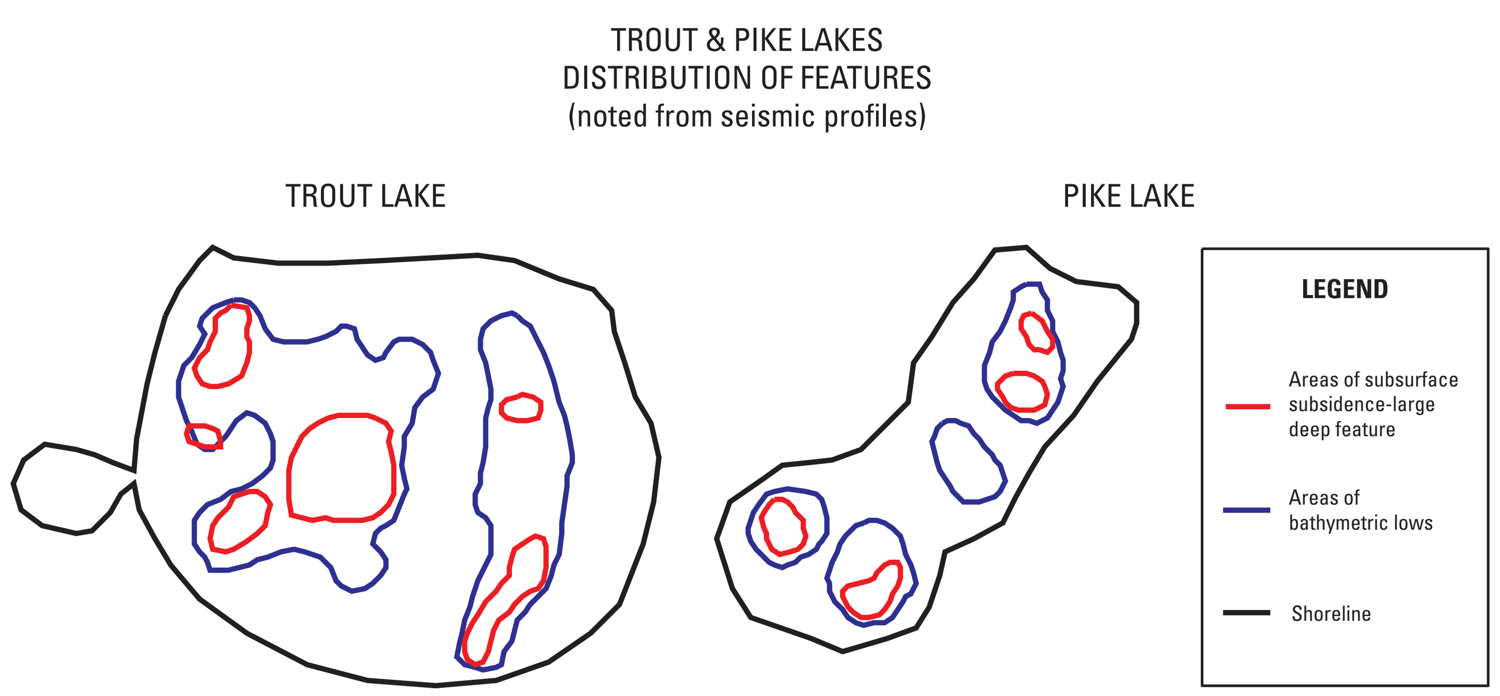


TROUT AND PIKE LAKES
LAKE COUNTY, FLORIDA







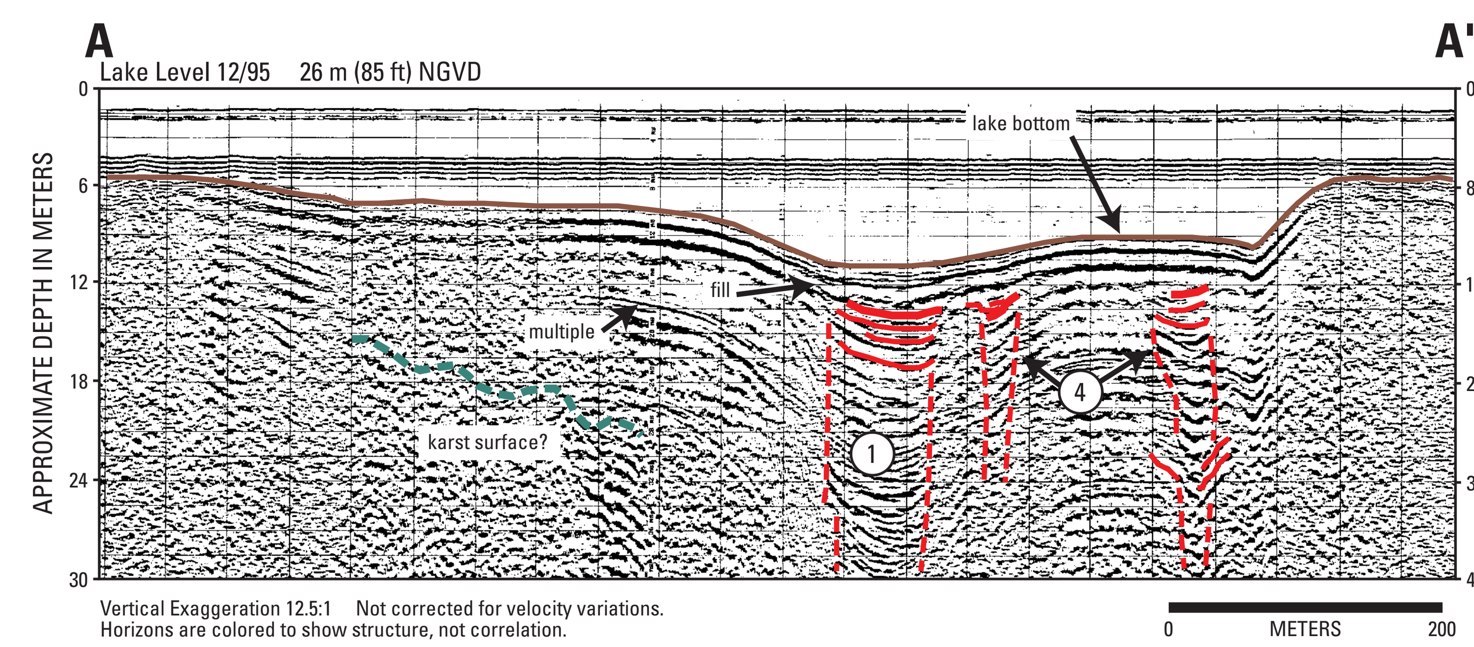
Introduction

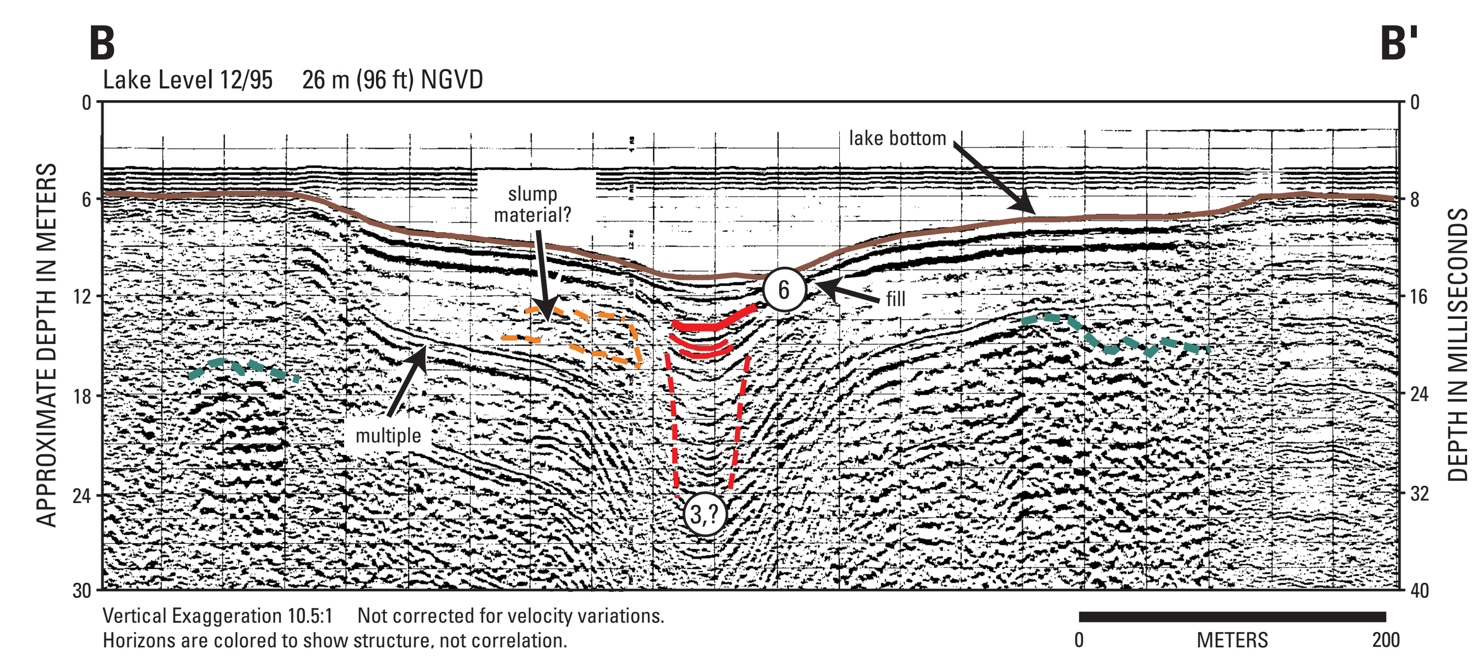
Lakes Trout and Pike are among a cluster of small (<1 km) lakes in southeastern Lake County. The physiography is described by Brooks and Merrit (1981), as The Gap, an area of lower elevation, about 25 to 37 m (85 to 120 ft) between the Sugarloaf Mountain region and No Name Ridge. The lower elevation is a result of increased erosion of the underlying limestone. A number of lakes occupy this lowland, of which Lakes Dixie, Smokehouse and Hammond were also surveyed in this study. The Gap and the flanking highlands are part of the Lake Wales Ridge, which is the topographic crest of Central Florida (Brooks, 1981). The Ridge is characterized by residual sand hills, relic beach ridges and paleo dune fields. The topography on either side of the ridge has been reduced to the water table, forming Green Swamp abour 5 km (3 mi) to the southwest and Sawgrass Bays, 3 km (2 mi) to the southeast. Lake level in December of 1995 was approximately 30 m (98 ft) NGVD. Trout Lake, the larger of the two, is fairly circular, with a perimeter of 19 km (12 mi) and a surface area of about 1 sq km Pike Lake is oblong with an area of 0.6 sq km and a perimeter of about 3.2 km (2 mi).

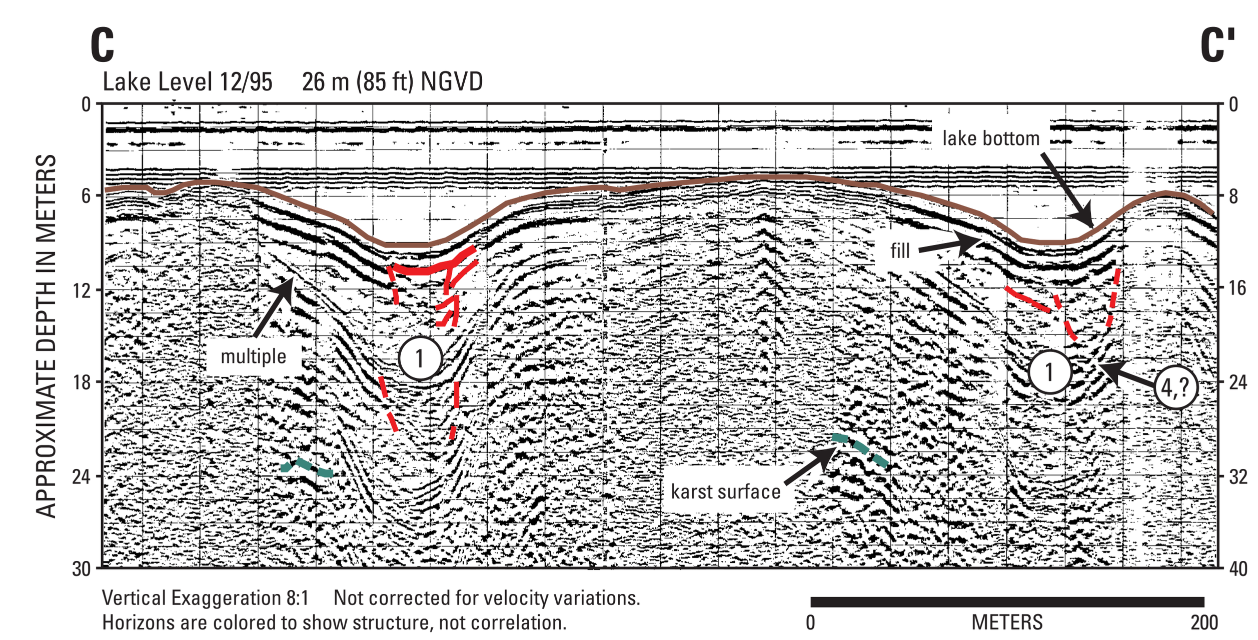
Subsurface Characterization

Seismic profiles from Trout Lake and Pike Lake show a hard bottom reflection, possibly well sorted sands, infilling a deeper karst surface (type 1, profile A-A'). The strong bottom reflector leads to multiples seen throughout the data that obscure some of the record. The record is also partially obscured in areas where the lake bottom nears the surface. The acoustic characteristics and their interpretation in the two lakes are similar. The subsurface is characterized by numerous small low-angle reflectors with high angle reflectors dipping toward their center (profiles A-A', B-B', C-C', type 4). Concentric reflections extend to depth in the profile. These features may represent solution pipes or small subsidence into the karst subsurface, which is in close proximity to the surface in this area. This condition has a high potential for increased leakage. A distribution plot of these features (red line) shows how they tend to define the areas of deeper water in the lakes (blue line). The areas of subsidence seen within the lakes are well constrained and do not have the appearance of large subsidence or collapse sinkholes seen in other lakes. These localized areas of subsidence may lie directly over centers of active karst development. The competent overburden restricts lateral growth of the unstable region, confining dissolution, yet creating a direct conduit for fluid migration from the surficial waters to the Floridan aquifer. Discrete reflectors at 18 m (profile B-B', green line) and 24 m (profile C-C', green line) may represent a karst surface on top of the Ocala Limestone. Interpretations of a gamma log acquired from a well located approximately 1 mile to the south of the lakes (Index Map G, p. 37, well L-0677) show the top of the Ocala Limestone to be around 50 m (15 ft) NGVD, or about 10 m (30 ft) below lake level. The reflector seen in the profiles (green dashed line) may be associated with this surface. Differential dissolution in the Ocala Limestone could lead to subsequent subsidence in the overlying sediments of the Hawthorn Group and the undifferentiated fill.

G







Subsurface Characterizations of Selected Water Bodies in the St. Johns River Water Management District, Northeast Florida

Jack L. Kindinger[1], Jeffrey B. Davis[2], and James G. Flocks[1]
2000

[1] Center for Coastal Geology and Regional Marine Studies
U.S. Geological Survey
St.. Petersburg, Florida 33701

[2] St. Johns River Water Management District
Palatka, Florida 32178

The U.S. Geological Survey, in cooperation with the St. Johns River Water Management District, prepares this information "as is" for its own purposes and this information may not be suitable for other purposes. This map has not been reviewed for conformity with U.S. Geological Survey editorial standards.

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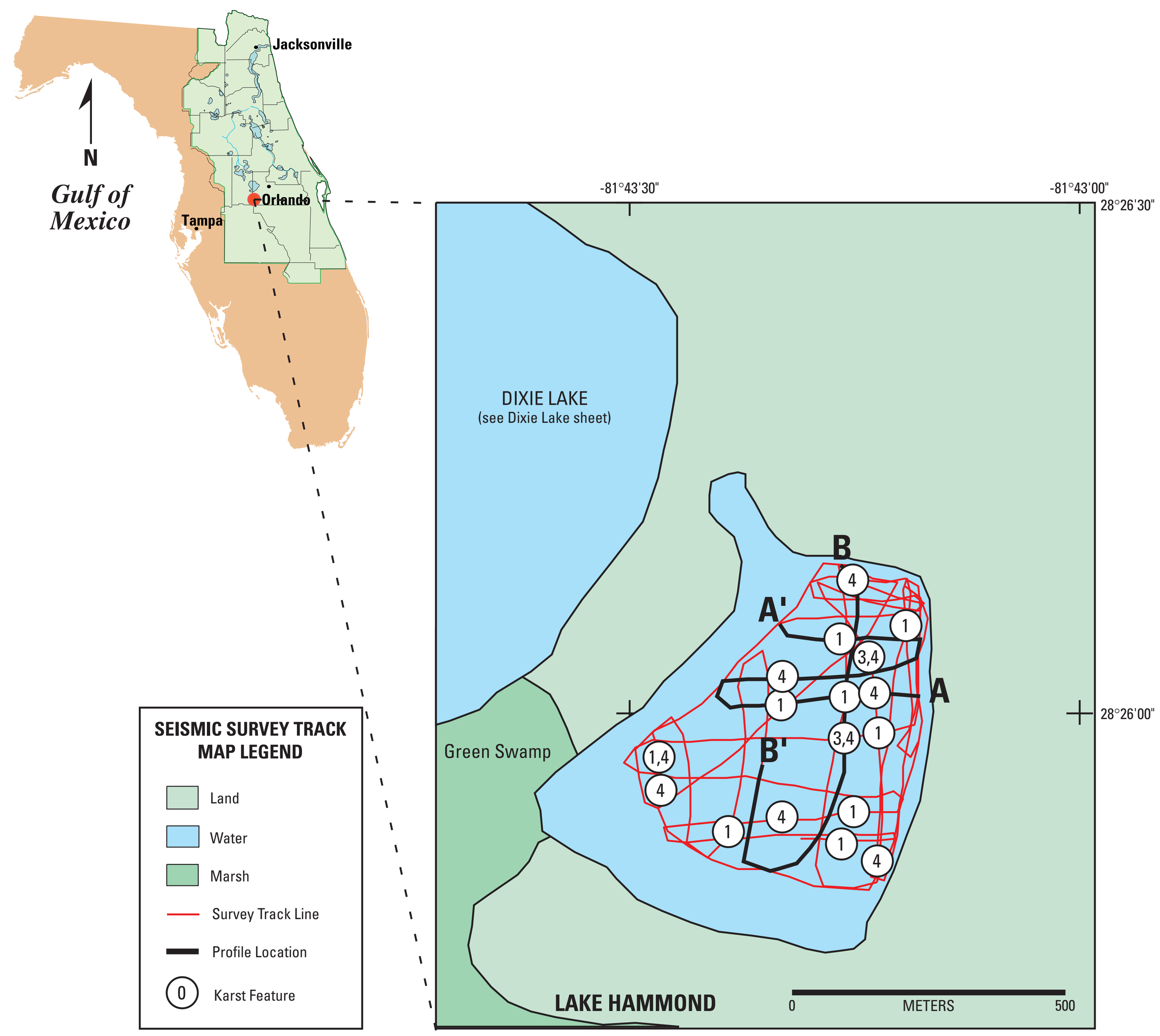
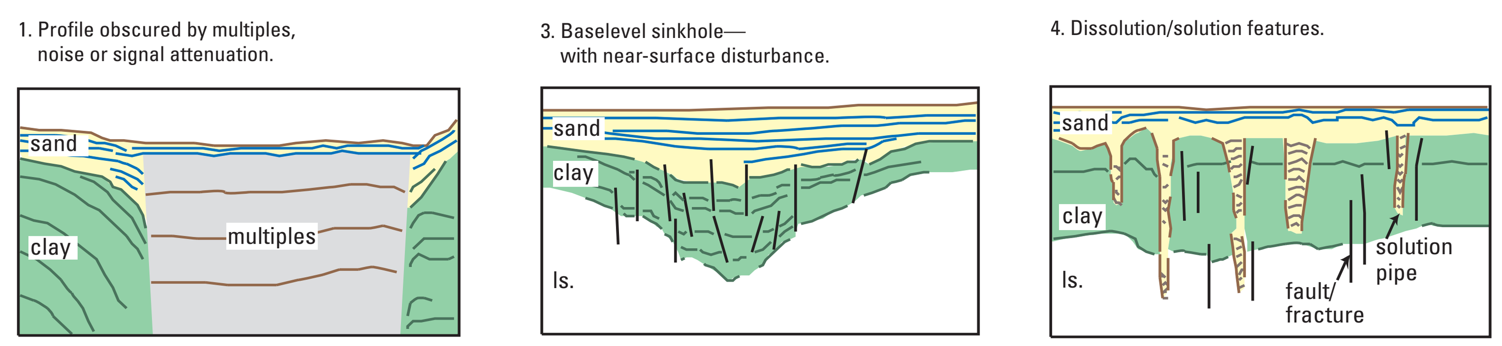
LAKE HAMMOND

LAKE COUNTY, FLORIDA



EXPLANATION



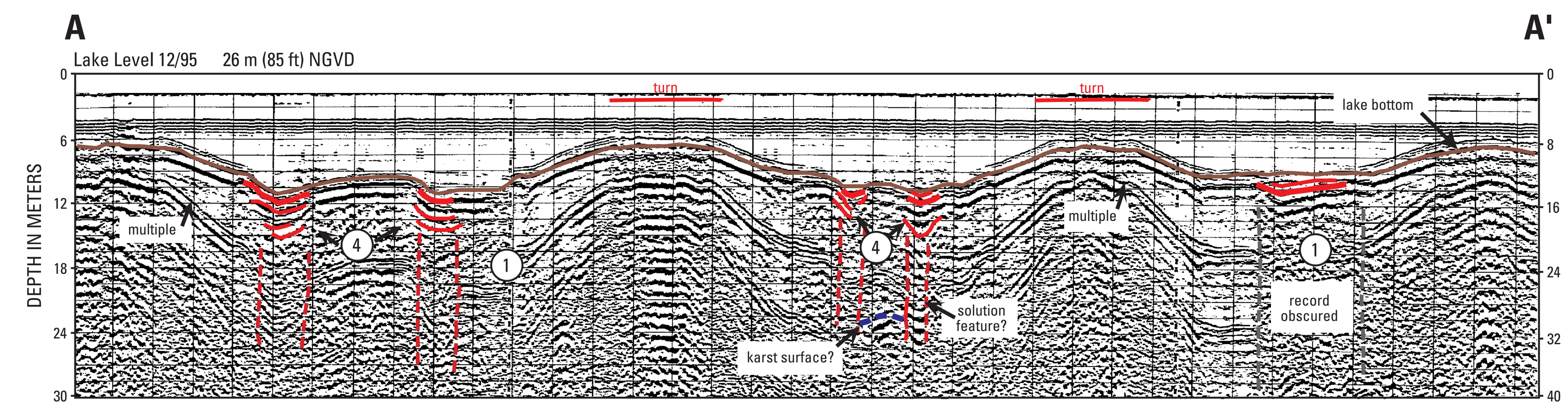
Introduction

Lake Hammond is among a cluster of small lakes in southeastern Lake County (see Index Map Section G, p.37). The physiography is described by Brooks (1981), as The Gap, an area of lower elevation, about 25 to 37 m (85 to 120 ft) in between the Sugarloaf Mountain region and No Name Ridge. The lower elevation is a result of increased erosion of the underlying limestone. The Gap and the flanking highlands are part of the Lake Wales Ridge, which is the topographic crest of Central Florida (Brooks, 1981). The Ridge is characterized by residual sand hills, relic beach ridges and paleo dune fields. The topography on either side of the ridge has been reduced to the water table, forming Green Swamp to the southwest and Sawgrass Bays to the southeast. Lake level in December of 1995 was 26 m (85 ft) NVGD. Lake Hammond is irregular in shape, with a perimeter of 3 km and a surface area of about 0.5 sq km.

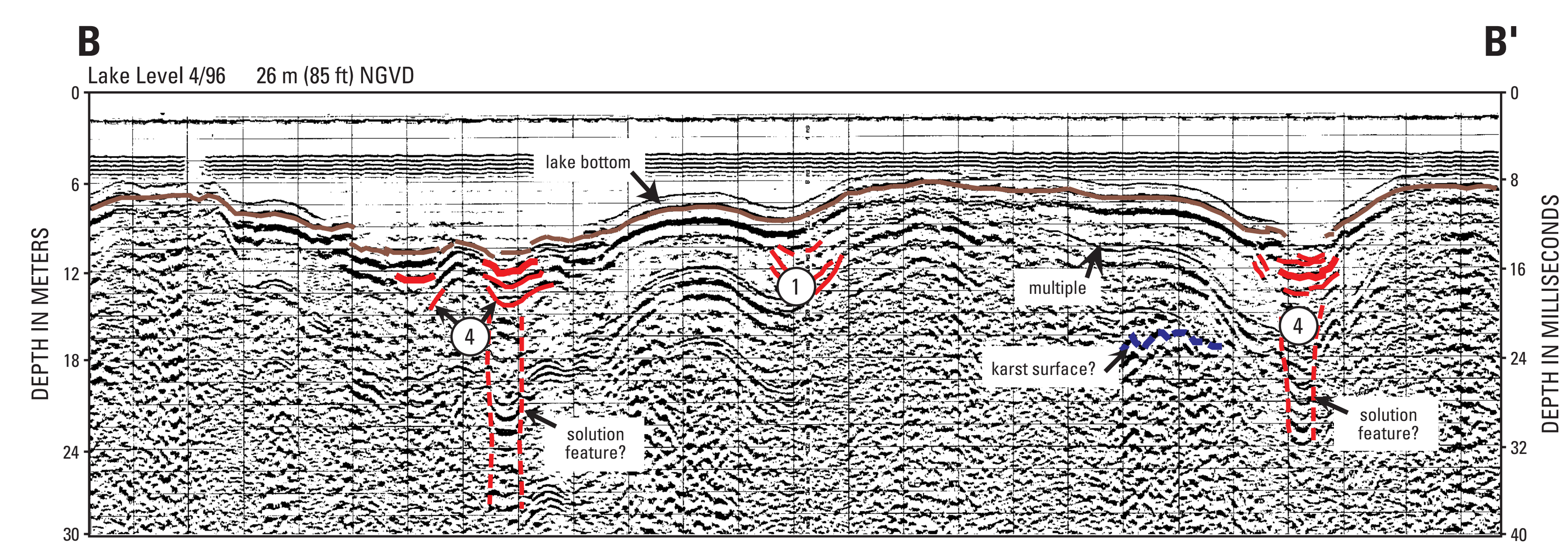
Subsurface Characterization

Seismic profiles from Lake Hammond show a strong bottom reflection, possibly from well-sorted sands. The strong bottom reflector results in multiples seen throughout the data that obscure some of the record (profiles A-A', B-B'). Noise below the topographic lows in the profiles also obscure some of the record (gray lines, profile A-A'). This noise could be a result of the accumulation of organic material in the depressions which attenuates the acoustic signal. The subsurface is characterized by numerous small depressions with mid-to low-angle reflectors dipping toward the centers of the depressions (profile B-B').
Concentric reflectors may extend to depth in the profile (marked by red dashed lines in profiles). These features may represent solution pipes dissolved into the karst subsurface. These areas of subsurface depressions have been plotted in the distribution of features map (brown line), relative to bathymetric lows (blue line) to reveal their relationship.

The seismic reflection data from Lake Hammond overall is similar to that of it's neighbor, Lake Dixie. However, perhaps because of the lake's smaller size, the data quality is generally poorer. The deeper reflector seen in Lake Dixie that correlates with gamma logs to represent the top of the Ocala Limestone (see Lake Dixie, p. 40, blue line), cannot be seen as readily in the Lake Hammond profiles. Certain traces of a horizon are apparent in some of the profiles (blue line, profile B-B'), however because of data quality the reflector is difficult to trace. Still, it is possible to assume that differential dissolution in the Ocala Limestone could lead to subsequent subsidence in the overlying sediments of the Hawthorn Group and the undifferentiated fill.

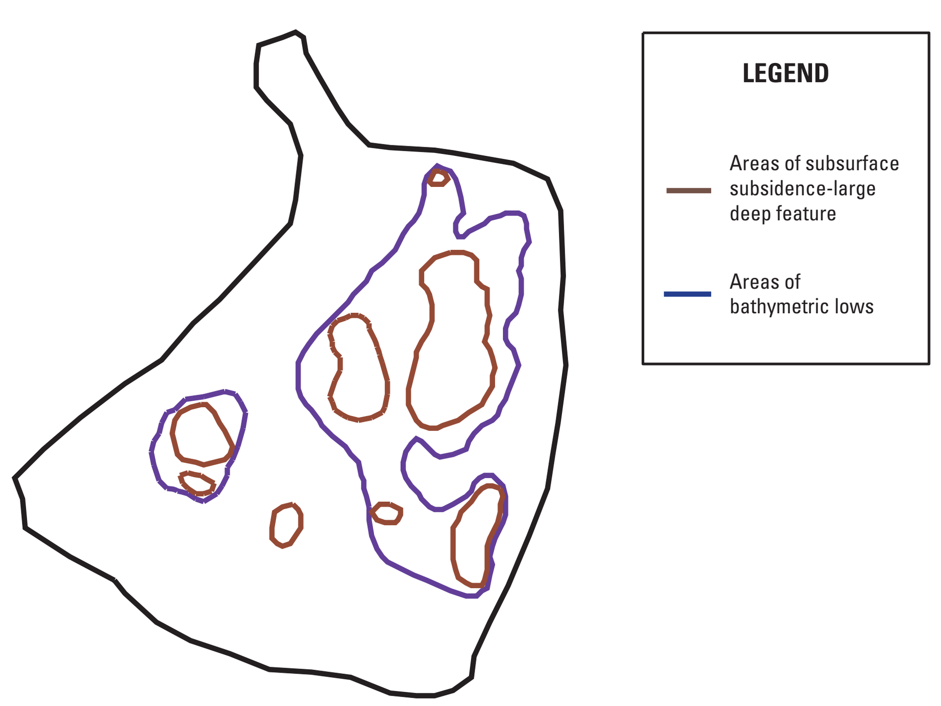


Vertical Exaggeration 5:1 Not corrected for velocity variations. Horizons are colored to show structure, not correlation.



Vertical Exaggeration 5:1 Not corrected for velocity variations. Horizons are colored to show structure, not correlation.

LAKE HAMMOND
DISTRIBUTION OF FEATURES
(noted from seismic profiles)



G

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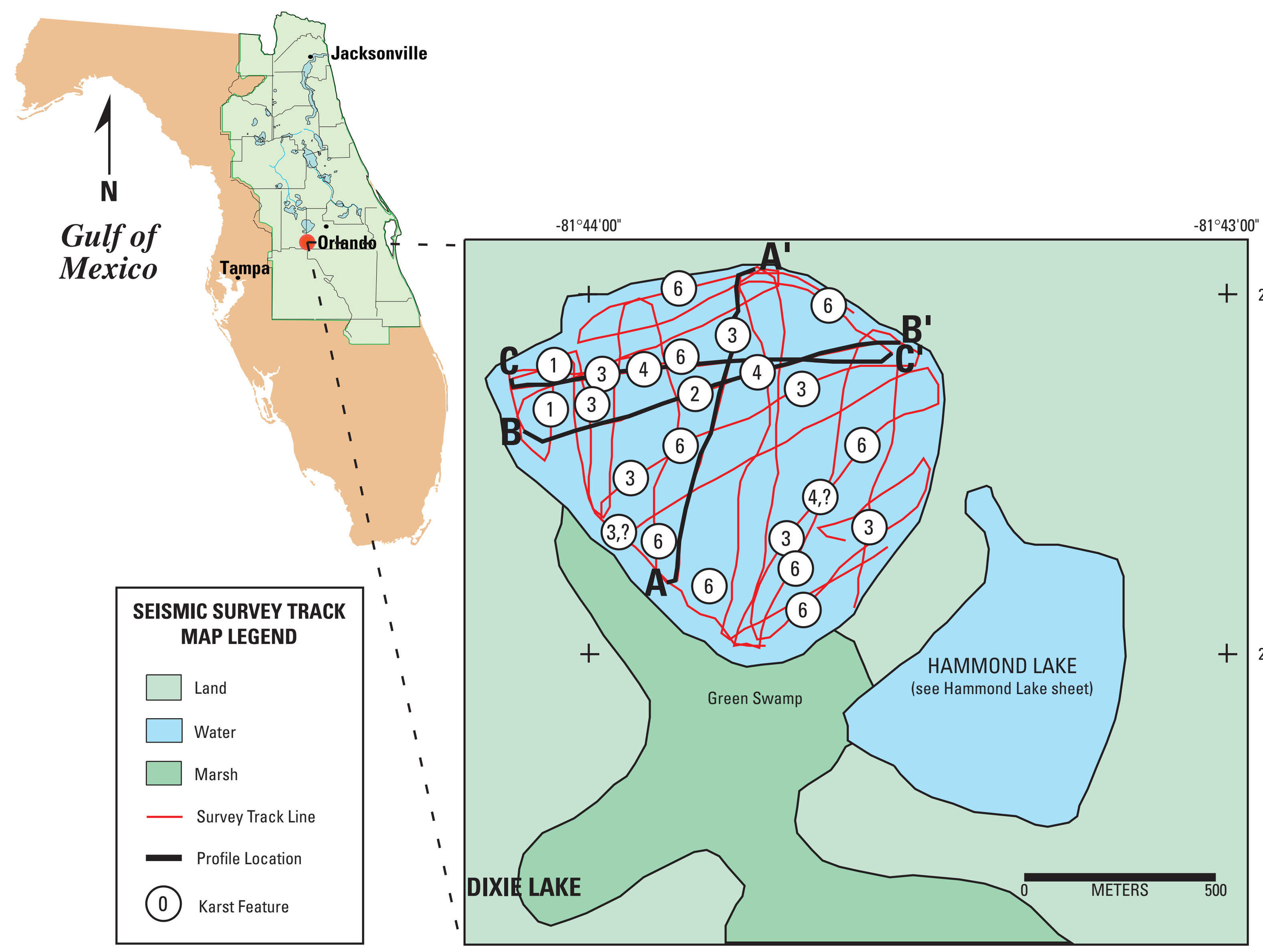
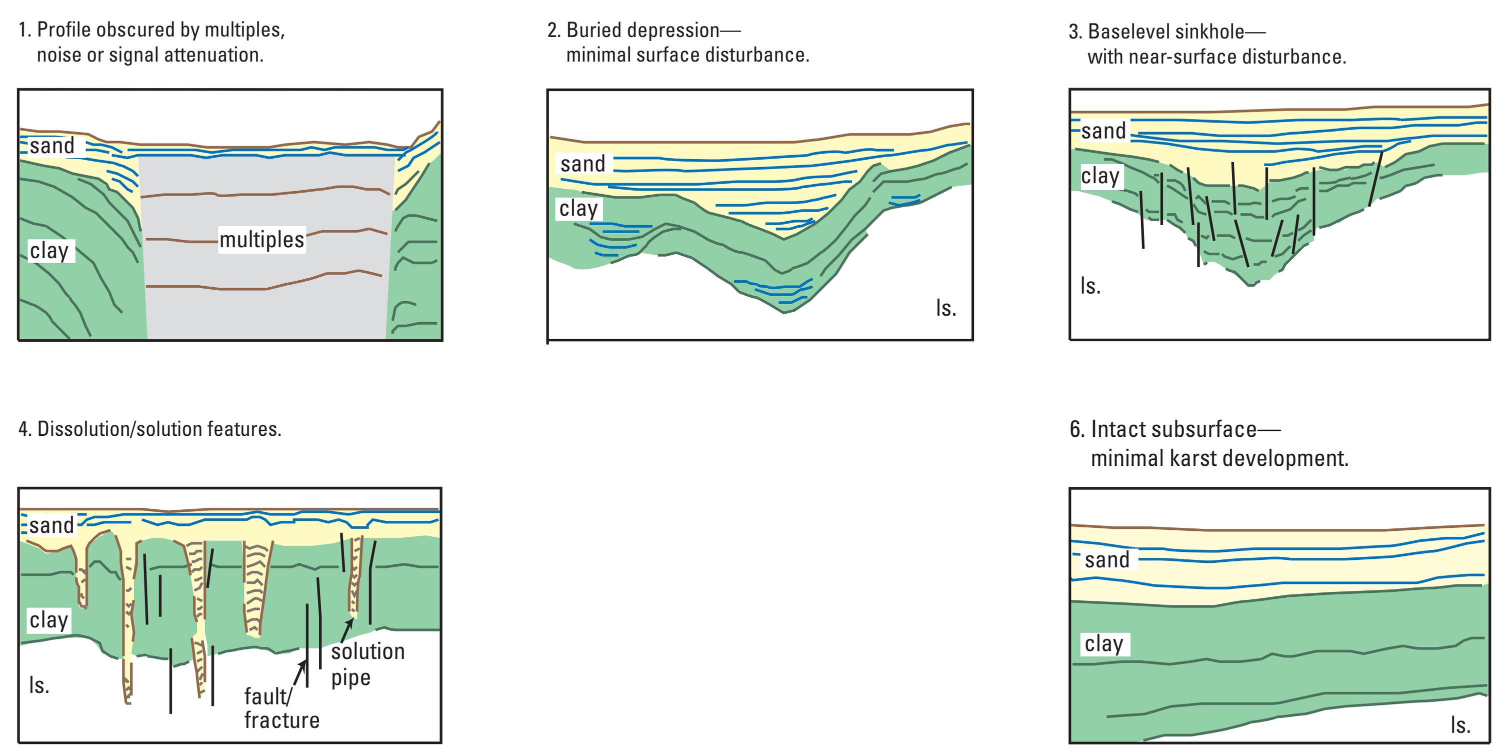
LAKE DIXIE

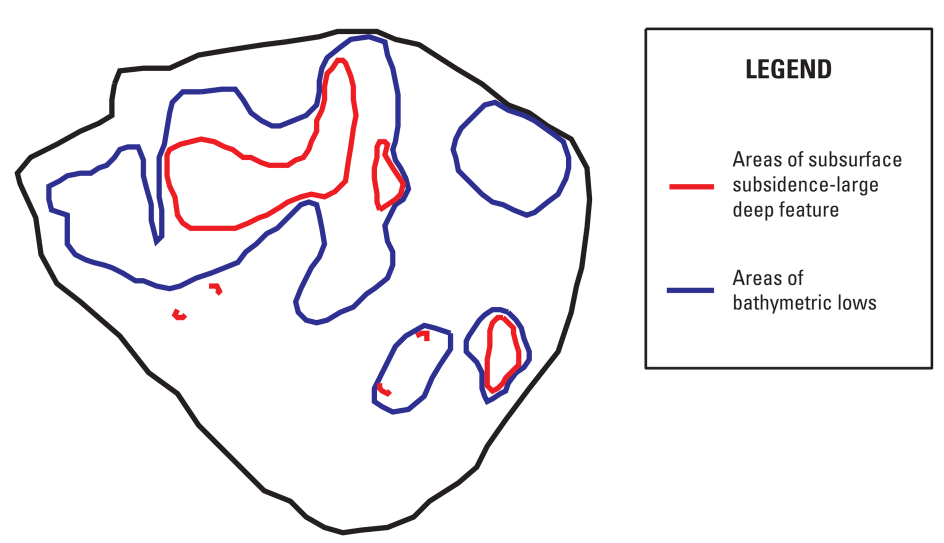
LAKE COUNTY, FLORIDA



EXPLANATION



LAKE DIXIE
DISTRIBUTION OF FEATURES
(noted from seismic profiles)



Introduction

Lake Dixie is among a cluster of small (< 1 km) lakes in southeastern Lake County. The physiography is described by Brooks and Merrit (1981), as The Gap, an area of lower elevation, about 25 to 37 m (85 to 120 ft) between the Sugarloaf Mountain region and No Name Ridge. The lower elevation is a result of increased erosion of the underlying limestone. A number of lakes occupy this lowland, of which Lakes Trout, Pike, Smokehouse and Hammond were also surveyed in this study. The Gap and the flanking highlands are part of the Lake Wales Ridge, which is the topographic crest of Central Florida (Brooks and Merrit, 1981). The Ridge is characterized by residual sand hills, relic beach ridges and paleo dune fields. The topography on either side of the ridge has been reduced to the water table, forming Green Swamp to the southwest and Sawgrass Bays to the southeast. Lake level in December of 1995 was 26 m (85 ft) NGVD. Lake Dixie is roughly circular, with a perimeter of 4 km (2.5 mi) and a surface area of about 1 sq km.

Subsurface Characterization

Seismic profiles from Lake Dixie show a hard bottom reflection, possibly from well sorted sands, infilling a deeper karst surface (Feature 6, profile A-A'). The strong bottom reflector leads to multiples seen throughout the data that obscure some of the record. Noise below the topographic lows in the profiles also obscure some of the record (green lines, profile B-B'). This noise could be a result of the accumulation of organic material in the depressions which attenuates the acoustic signal. Despite the noise in the acoustic record, the proximity of the underlying karst surface to the lake bottom allows for a variety of solution and subsidence type features to be seen. The subsurface is characterized by numerous small depressions with high angle reflectors dipping toward their center (profile C-C'). The high angle reflectors may extend to depth in the profile. These features may represent solution pipes dissolved into the karst subsurface. Larger subsidence features can also be seen in the profiles (type 3, profile A-A'). A plot of their distribution (blue line) shows three distinct areas of subsidence and their influence on the lake's bathymetry (blue line).

A deeper, strong reflector can be seen in many of the subbottom profiles (red line, profiles A-A', B-B'). The highly jagged appearance of this reflector is indicative of an erosional (karst) surface seen in profiles throughout the region. Interpretations of a gamma log acquired from a well located approximately 1.5 km (.9 mi) southeast of the lake (see Section G Hillshade page 37, well L-0677) shows the top of the Ocala Limestone to be around 15 m (50 ft) NGVD. This correlates well with the horizon seen in the profiles. Differential dissolution in the Ocala Limestone could lead to subsequent subsidence in the overlying sediments of the Hawthorn Group and the undifferentiated fill.

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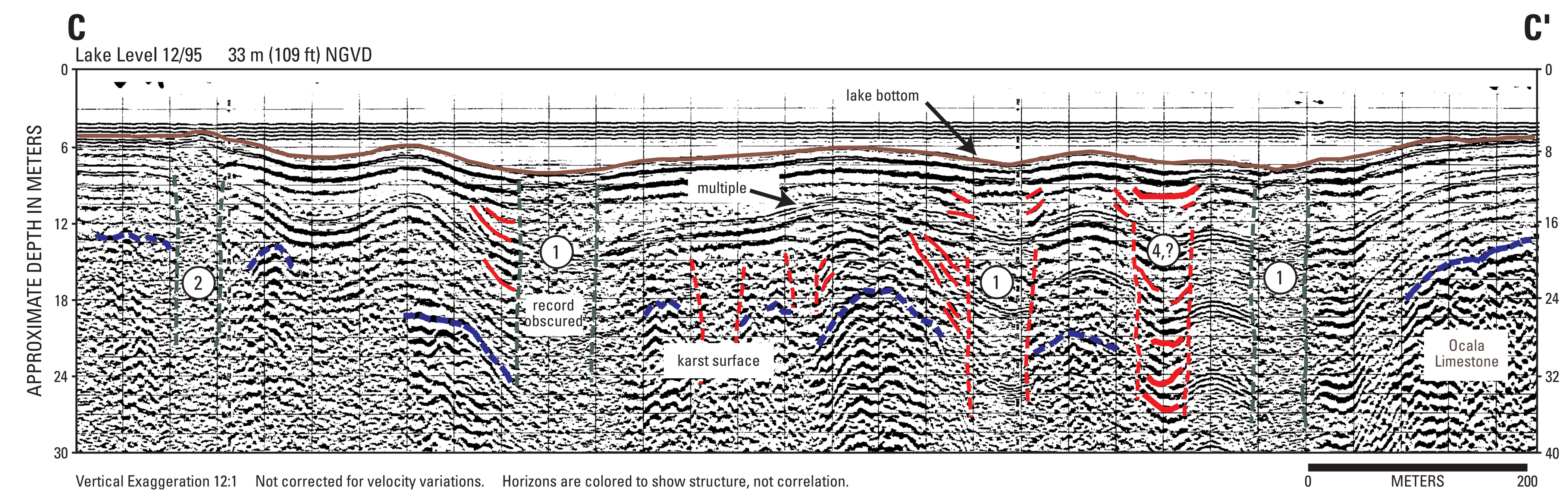

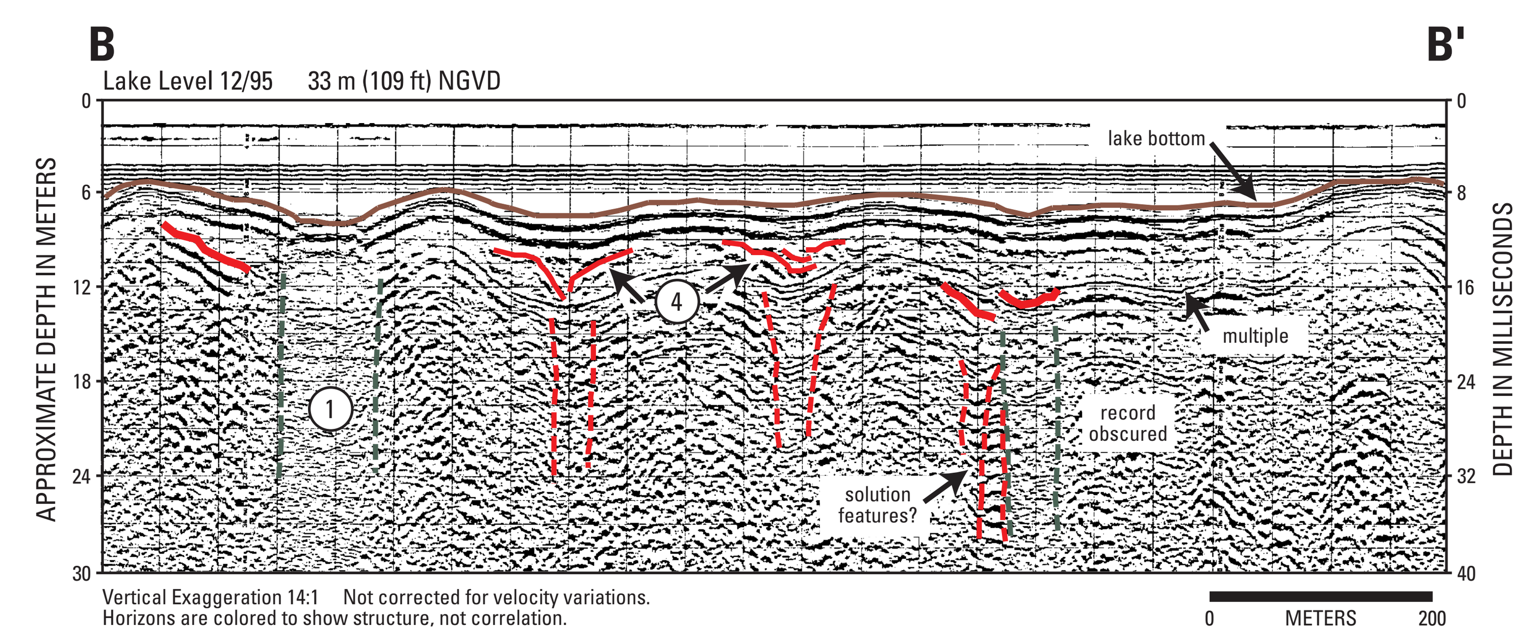

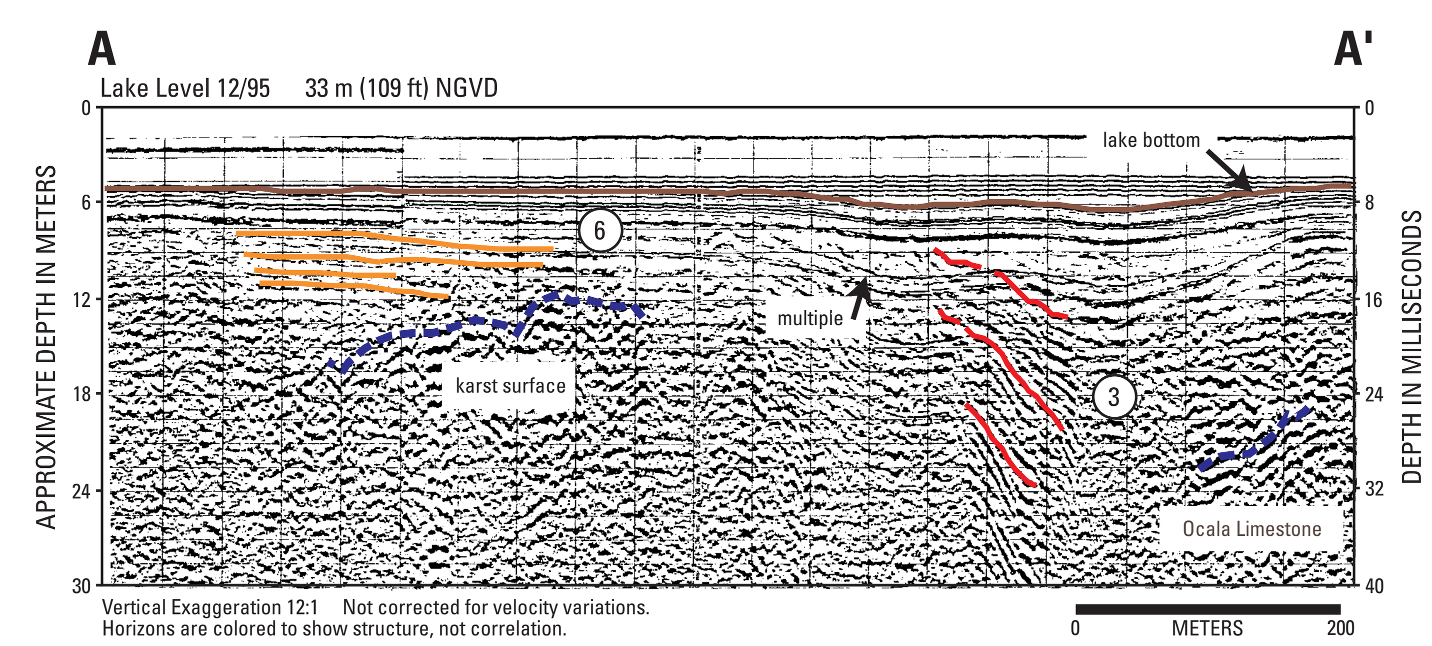

Subsurface Characterizations of Selected Water Bodies in the St. Johns River Water Management District, Northeast Florida

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2000

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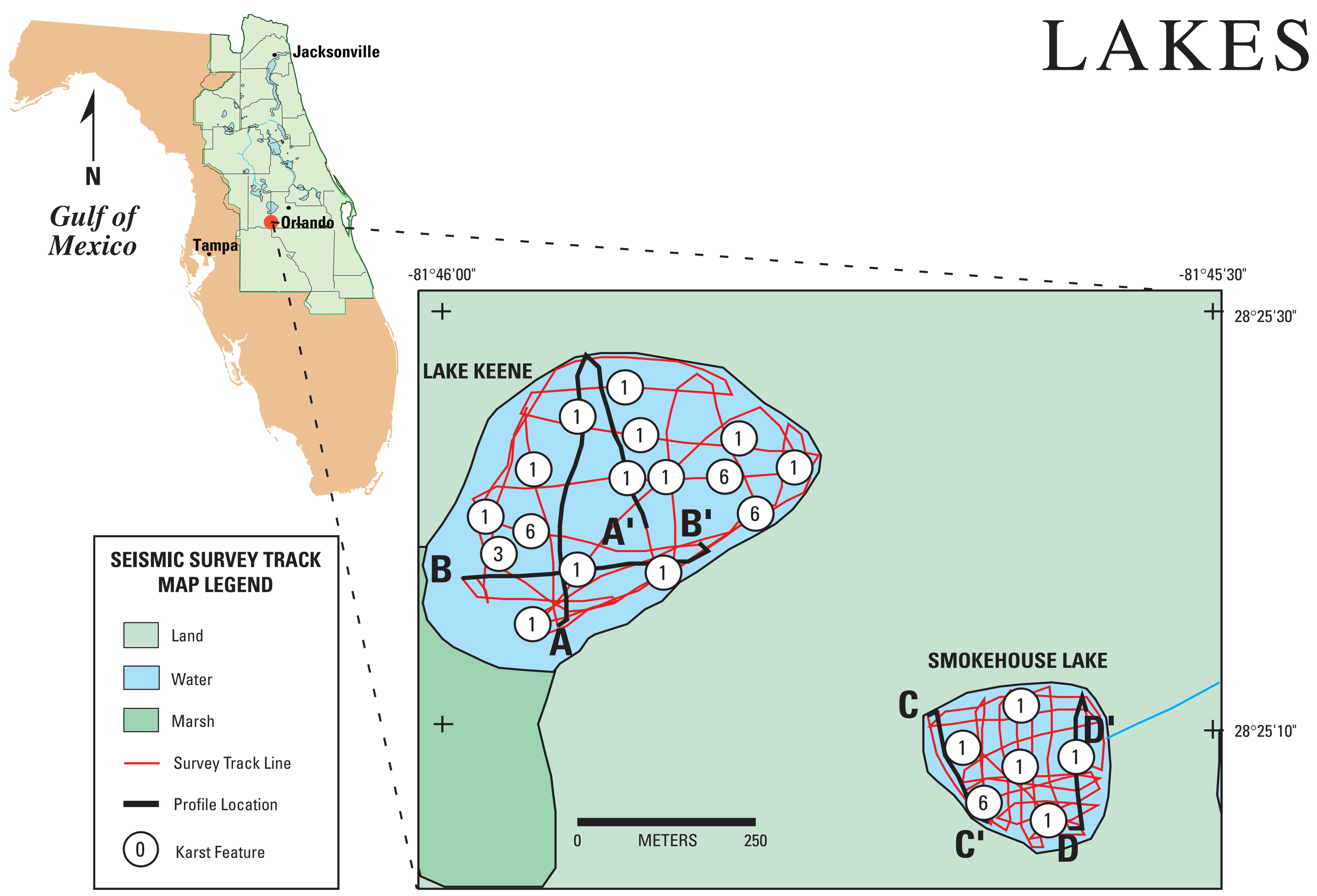
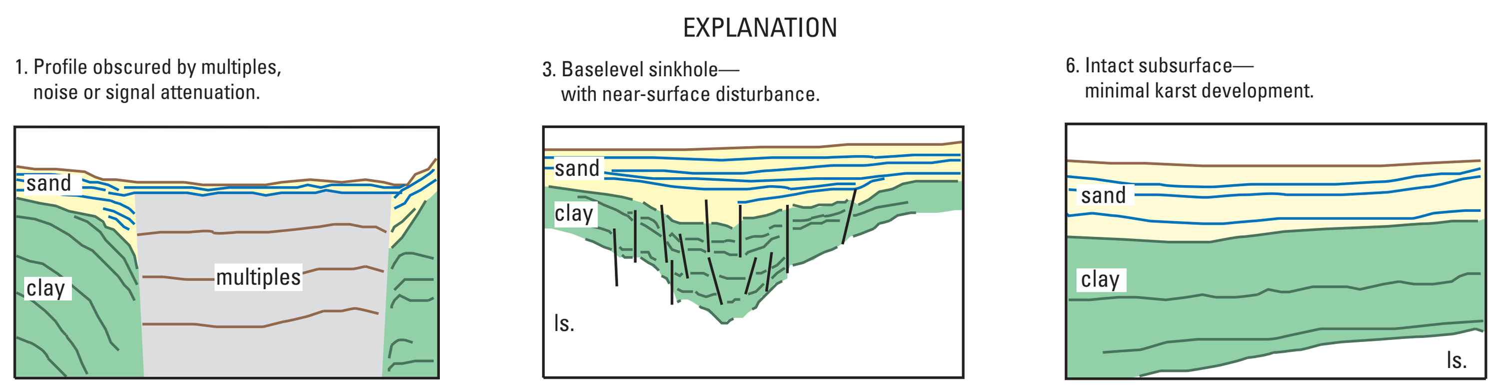
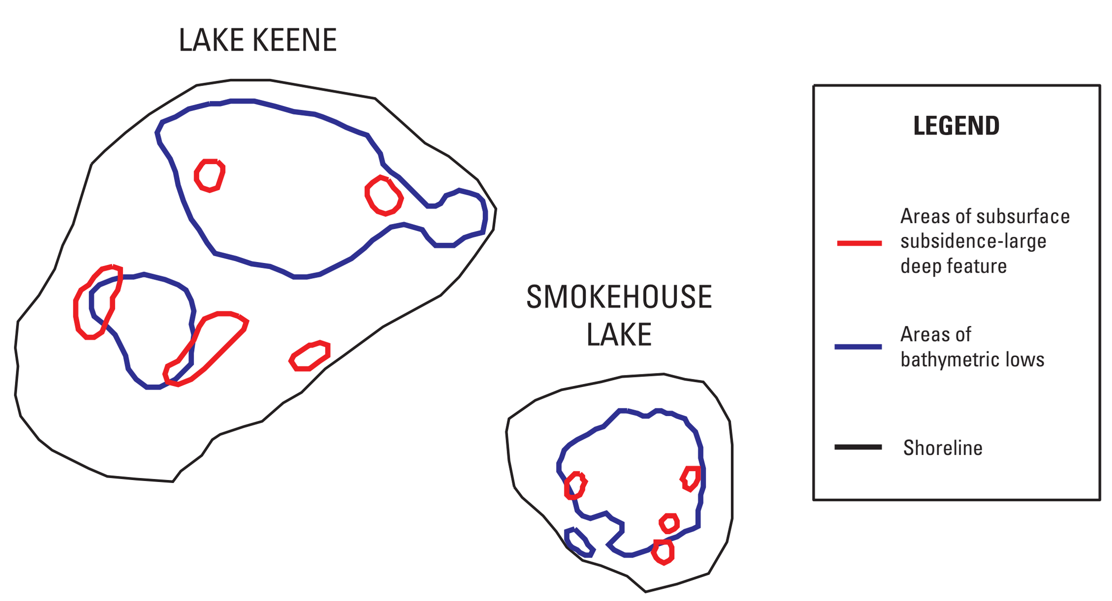
LAKES KEENE AND SMOKEHOUSE

LAKE COUNTY, FLORIDA





LAKES KEENE & SMOKEHOUSE
DISTRIBUTION OF FEATURES
(noted from seismic profiles)



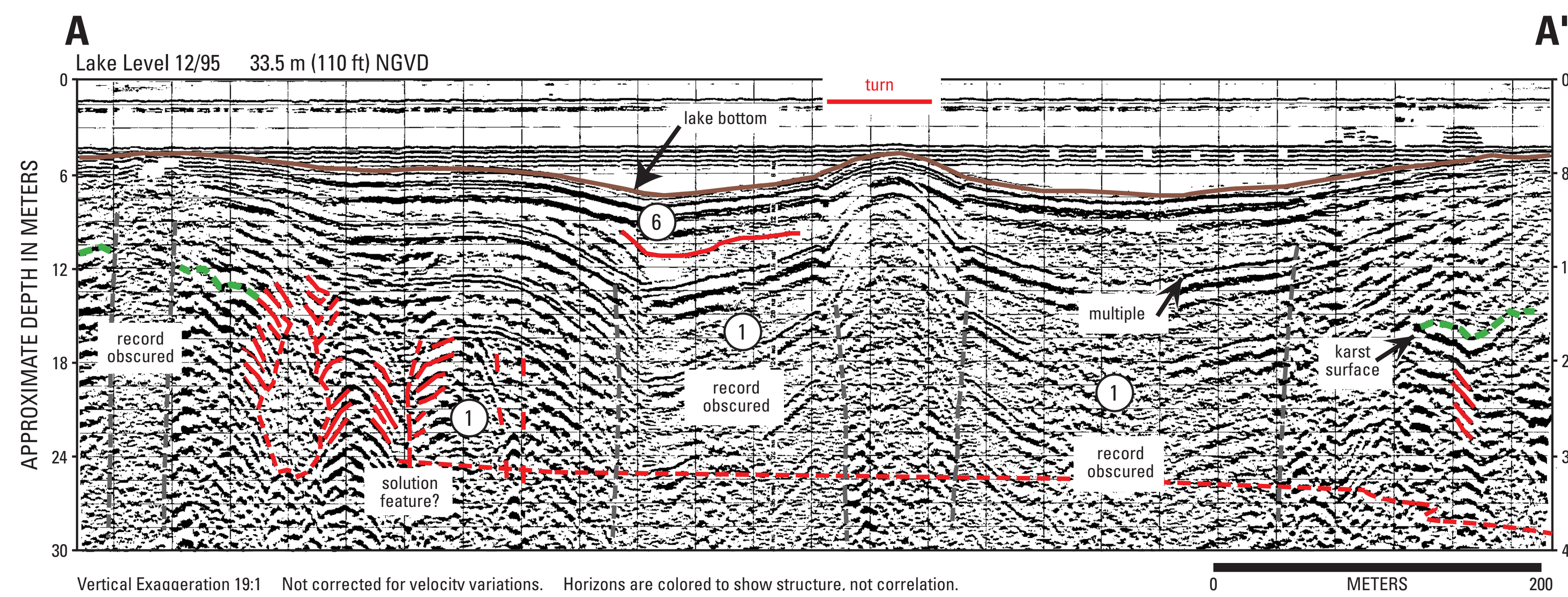
Introduction

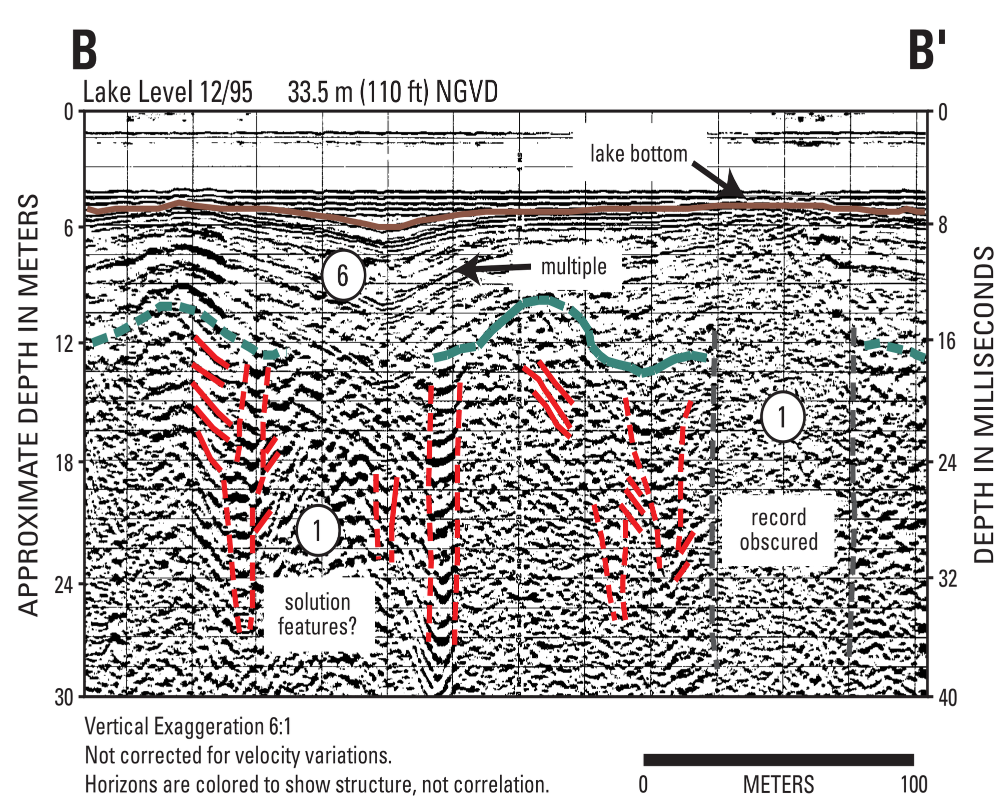
Lakes Smokehouse and Keene are among a cluster of small lakes in southeastern Lake County. The physiography is described by Brooks and Merrit (1981) as The Gap, an area of lower elevation, about 25 to 37 m (85 to 120 ft) between the Sugarloaf Mountain region and No Name Ridge. The lower elevation is a result of increased erosion of the underlying limestone. The Gap and the flanking highlands are part of the Lake Wales Ridge, which is the topographic crest of Central Florida (Brooks and Merrit, 1981). The Ridge is characterized by residual sand hills, relic beach ridges and paleo dune fields. The topography on either side of the ridge has been reduced to the water table, forming Green Swamp about 5 km (3 mi) to the southwest and Sawgrass Bays to the southeast. Lake levels for Lakes Keene and Smokehouse, 3 km (2 mi) in December of 1995 were approximately 34 m (110 ft) and 35 m (114 ft) NGVD, respectively. Lake Keene, the larger of the two, is oblong, with a perimeter of 2.4 km (1.5 mi) and a surface area of about 0.2 sq km. Smokehouse Lake is roughly circular (roundness of 0.92) with an area of 0.1 sq km and a perimeter of about 1 km (0.6 mi). The lake is connected by surface drainage to other small lakes which drain into Sawgrass Lake to the northeast.

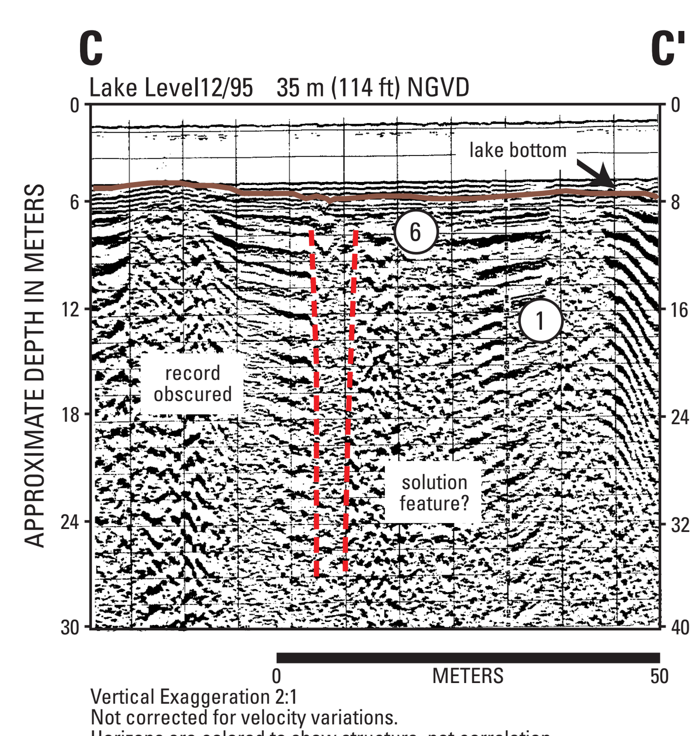
Subsurface Characterization

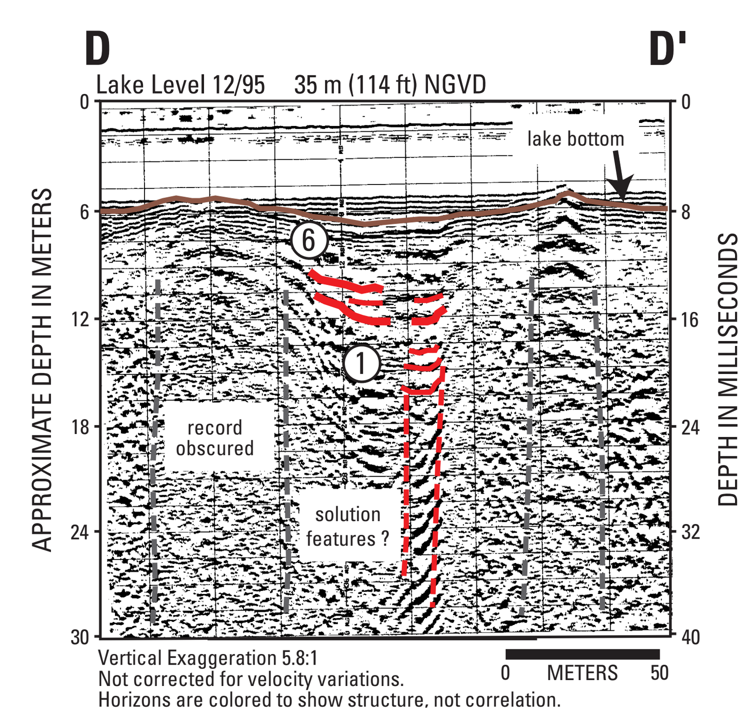
Seismic profiles from Keene and Smokehouse Lakes show a hard bottom reflection, possibly well sorted sands, infilling a deeper karst surface (type 6, profile A-A'). The strong bottom reflector leads to multiples seen throughout the data that obscure some of the record. The record is also partially obscured in areas where the lake bottom nears the surface and in areas of topographic lows (gray lines in profiles). This noise could be a result of the accumulation of organic material in the depressions which attenuates the acoustic signal. The acoustic characteristics and their interpretation in the two lakes are similar. Where the record is not obscured, there are numerous small low angle reflections with high-angle reflections dipping toward their center, where the record is obscured (profiles, type 1). Concentric reflectors extend to depth in the profile. These features may represent solution pipes or small subsidence into the karst subsurface, which is in close proximity to the surface in this area. This condition has a high potential for increased leakage. The distribution of these features (see red outline in plot) shows that they are small and trend along the periphery of the bathymetric lows of the lake (blue line). Other lakes surveyed in The Gap show that the subsurface features better define the bathymetric lows in the lakes (see Lakes Trout [p. 38], Hammond [p. 39], and Dixie [p. 40]). The areas of subsidence seen within the lakes are well constrained and do not have the appearance of large subsidence or collapse sinkholes seen in other lakes. These localized areas of subsidence may lie directly over centers of active karst development. Lake Keene shows some larger solution features at depth in the profiles (type 3, Survey Track Map). These features resemble the subsidence-type features seen in other lakes and could represent a developing sinkhole. Profiles of Gamma-log interpretations across Lake Keene (Index Map Section G, p. 37, wells L-0677 and L-0679) show the top of the Ocala Limestone dropping from +15 m (+50 ft) NGVD to -3 m (-10 ft) NGVD from north to south. Although shallower, the transition between the consistent low angle reflectors in the seismic profiles and the underlying, more jagged reflectors (represented by dashed green lines, A-A' and B-B') may represent this contact. Likewise, the transition may represent a horizon near the contact between the top of the Hawthorn Group and overlying undifferentiated fill. Dissolution in the Ocala Limestone at depth could lead to subsequent subsidence in the overlying sediments of the Hawthorn Group and the undifferentiated fill, as outlined by the red dashed lines in the seismic profiles.

G









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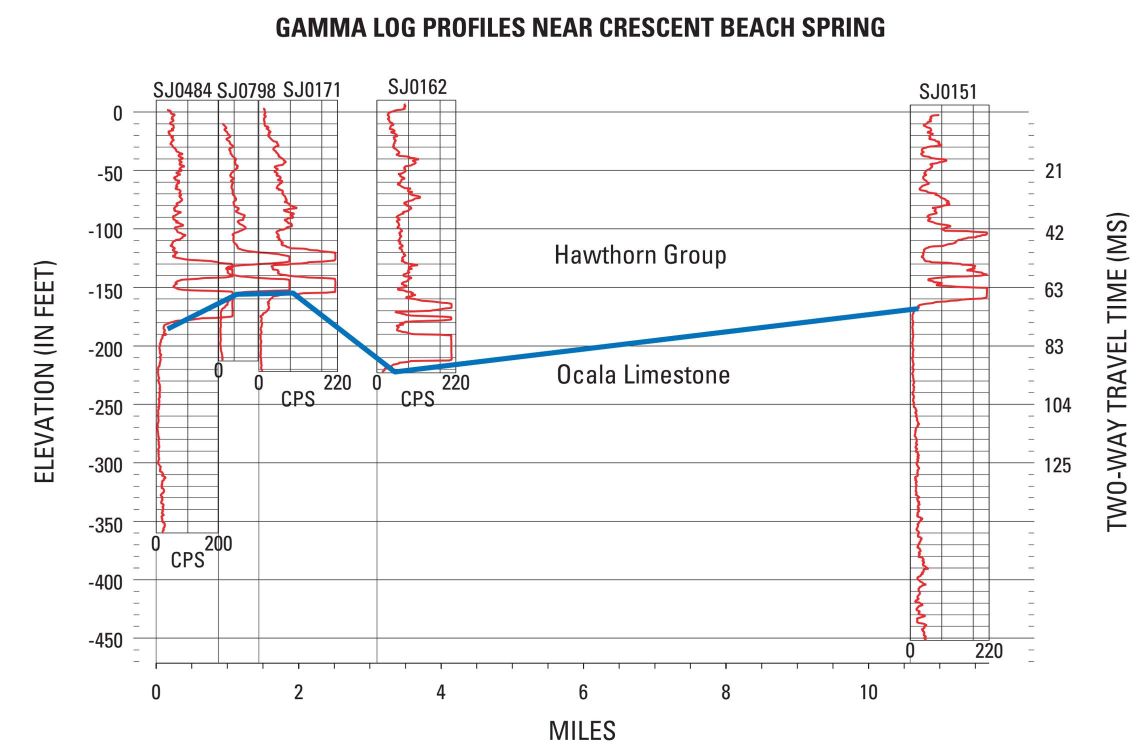
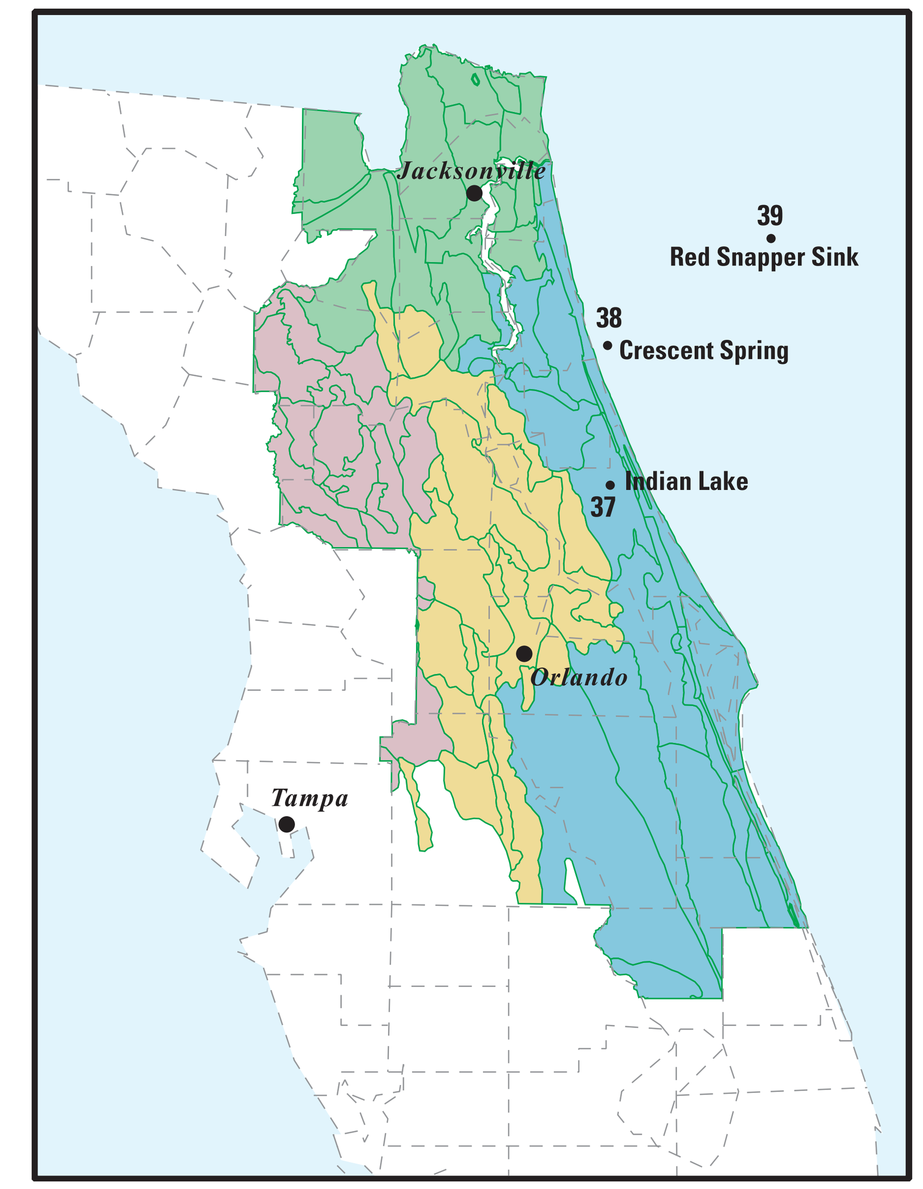
INDEX MAP AND GAMMA LOG

CROSS-SECTIONS, SECTION H



Location of Crescent Beach Spring and Indian Lake, right (Hillshade not available). Gamma log profile onshore adjacent to Crescent Spring above.

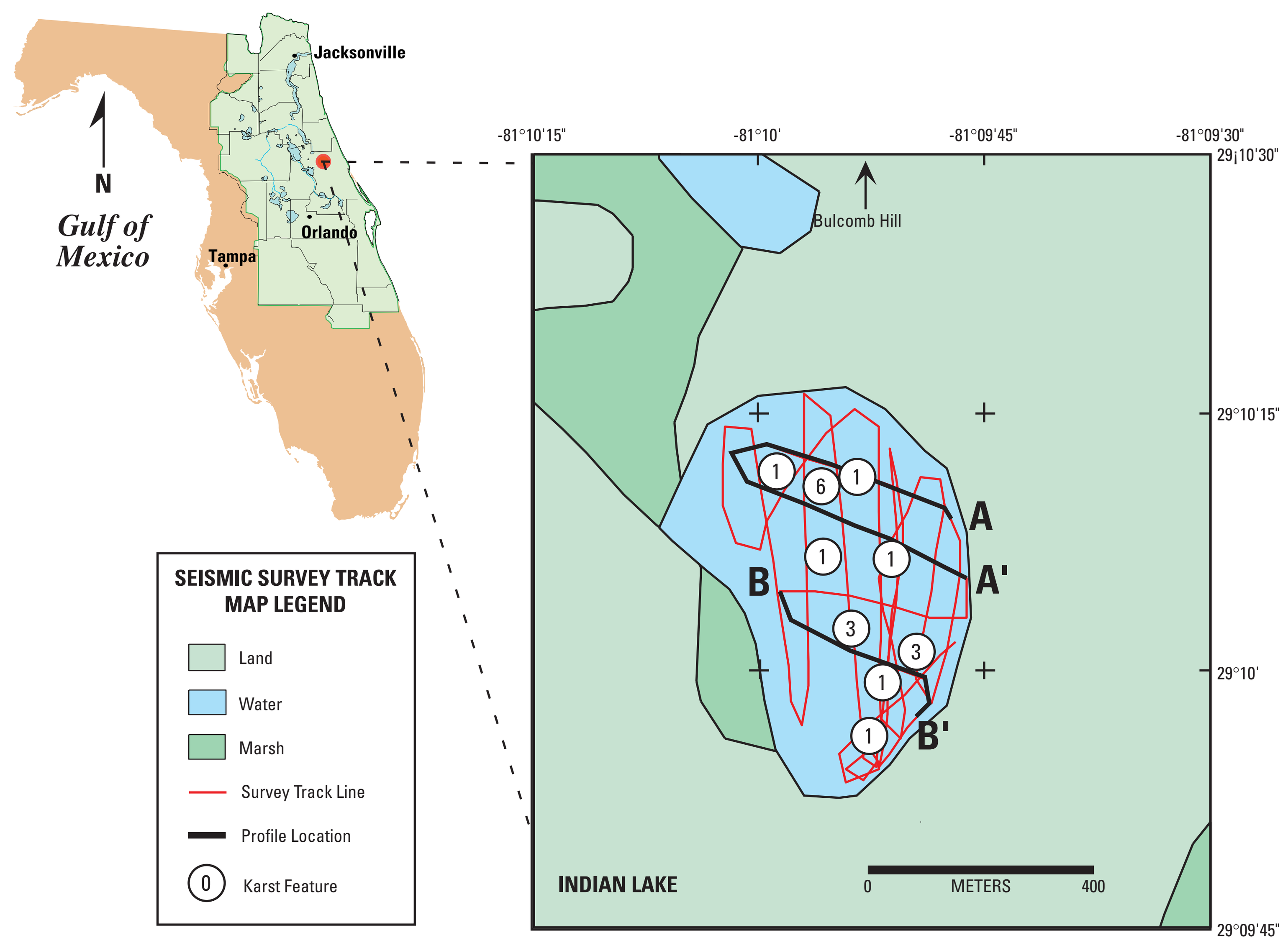


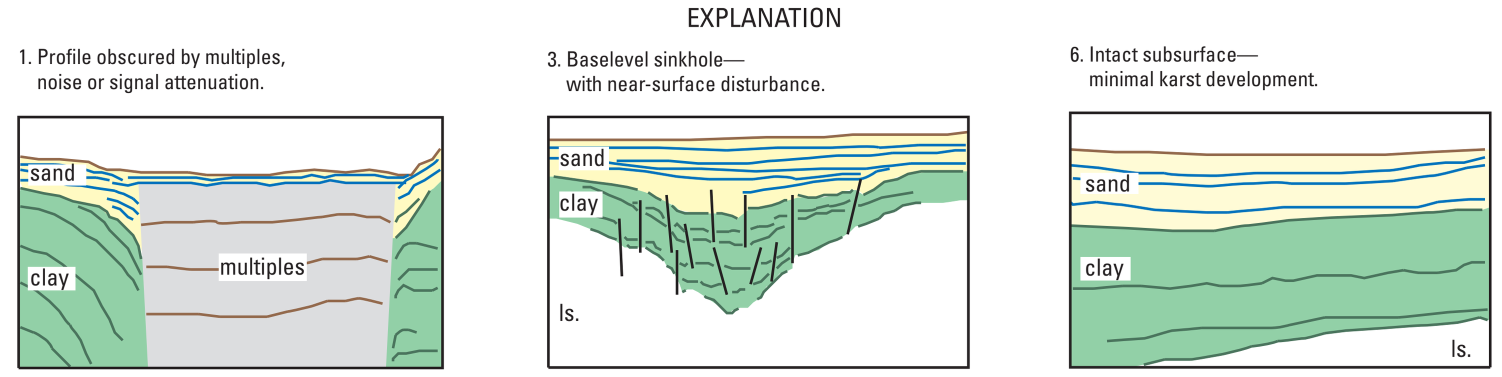
LEGEND

		page #
	Physiographic Province Boundary	
	Counties	
37	Indian Lake	43
38	Crescent Spring	44
39	Red Snapper Sink	

H

INDIAN LAKE
VOLUSIA COUNTY, FLORIDA



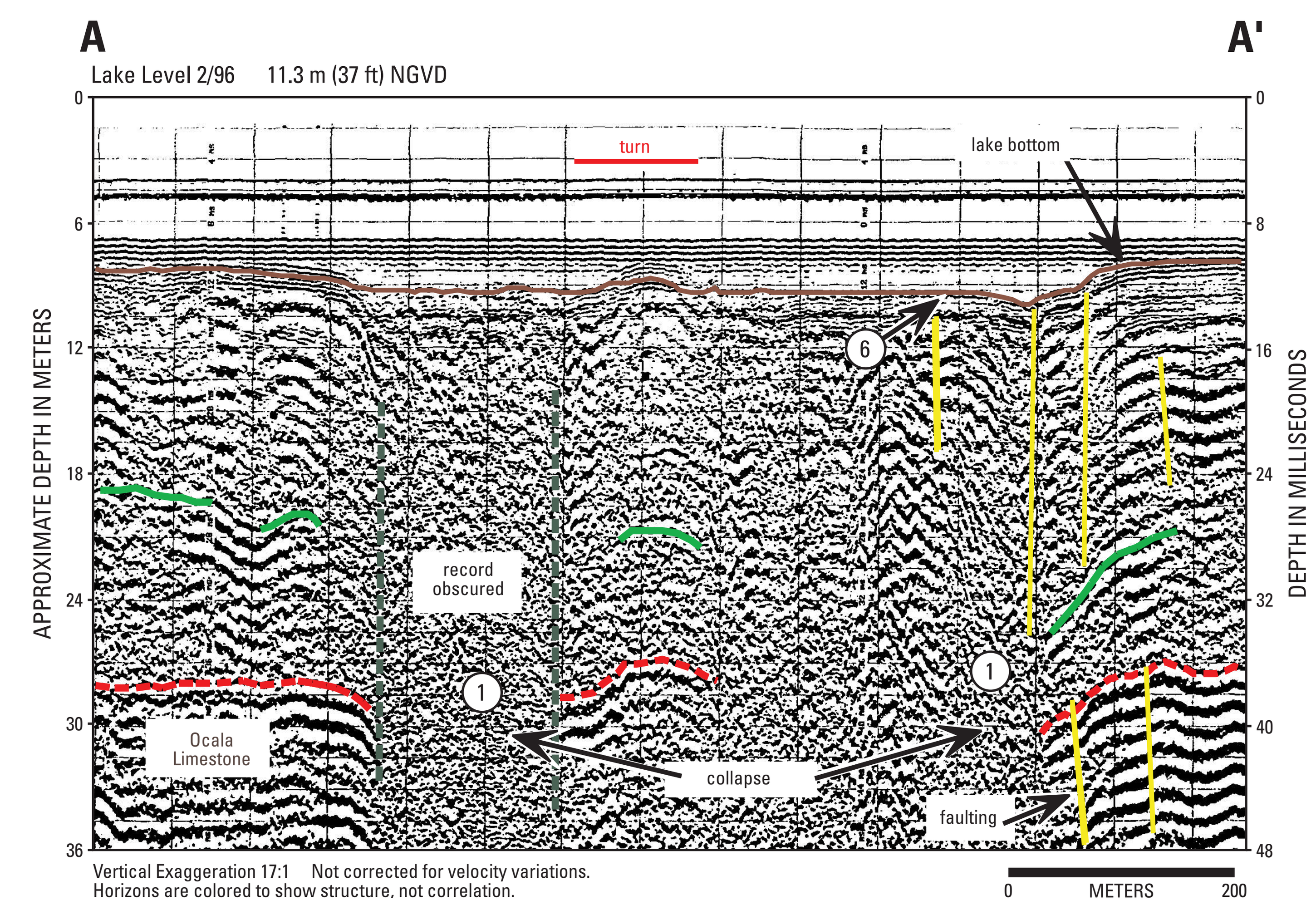


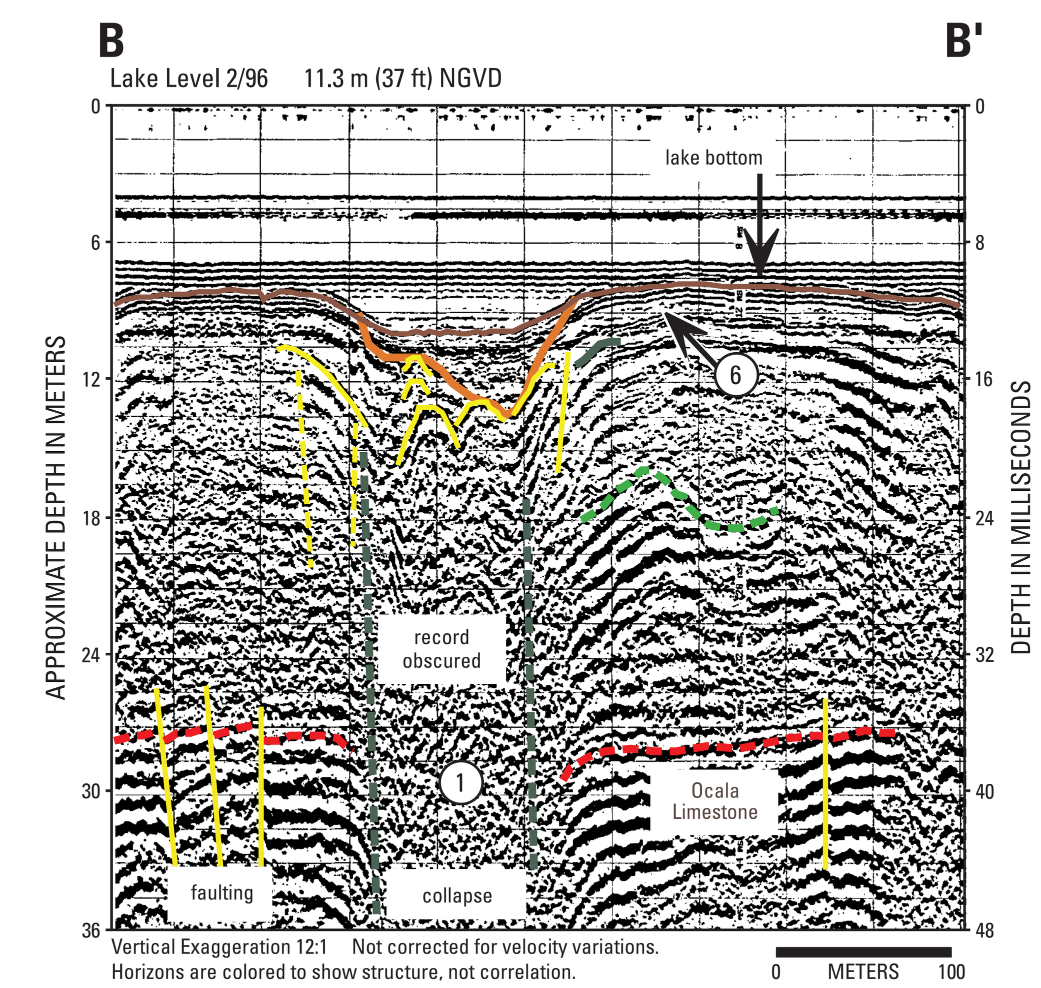
Introduction

Indian Lake is located in north central Volusia County. The lake is situated along Rima Ridge of the Volusia Ridge Sets, in the Eastern Flatwoods District. Lake level at the time of the seismic survey was 11.3 m (37 ft) NGVD. Indian Lake has an oblong shape with a perimeter of 6 km (4 mi) and a surface area of 2.2 sq km. Rima Ridge is bordered on either side by Tiger Bay and Bennet Swamps. Bumcomb Hill is situated to the north of the lake.

Subsurface Characterization

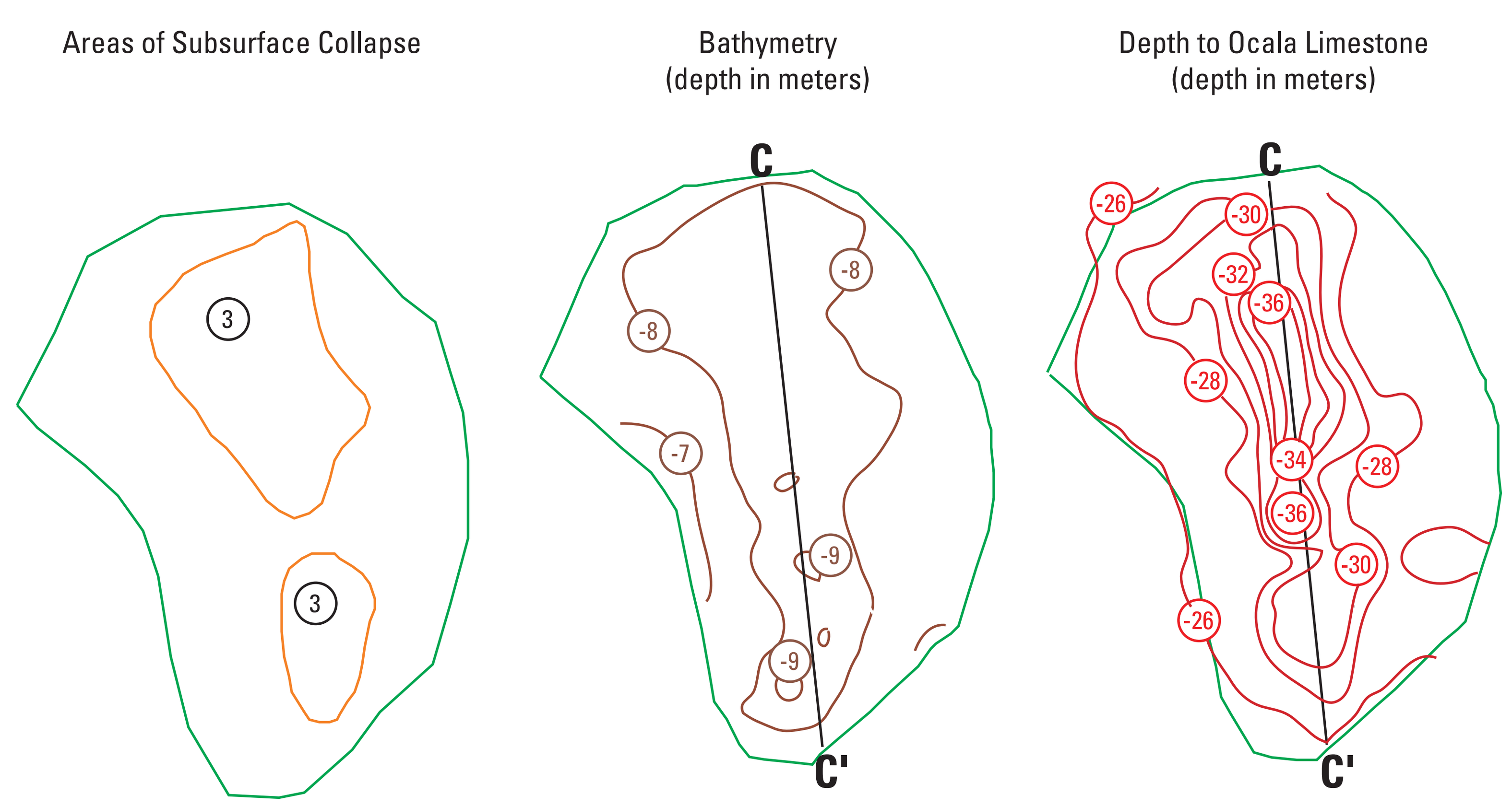
Indian Lake is characterized by two areas of subsidence within the lake. These areas are shown in the map to the lower left. Seismic profiles A-A' and B-B' are oblique cross-sections across the two depressions. Seismic profile A-A' shows a bi-directional view of the larger of the two subsidence areas, as the survey trackline turns and crosses the depression twice. The profile shows a strong reflective horizon (red) about 28 m (92 ft) below lake level (9 m, 29.5 ft above NGVD). This horizon is interpreted to be the top of the Ocala Limestone, as correlated elsewhere in the study area with gamma-log profiles. There appears to be an area of collapse within the Ocala, approximately 150 m (492 ft) wide, that has caused a concomitant subsidence in the overlying structure. Seismic profile B-B' shows a smaller subsidence in the southern part of the lake. Some structure such as collapse-related faulting is better visualized in this record. Because of the lack of visible features within the collapsed areas, these profiles show characteristics similar to a type 1 interpretation as shown in the explanation (left). In the uppermost part of the profiles, a relatively transparent signal characteristic of organic debris and sands (type 6) appear to be infilling the depressions. Contour plots of the lake bottom and lower horizon, digitized from the seismic profiles, are shown to the lower left. The cross section C-C' was generated from the digitized surfaces.



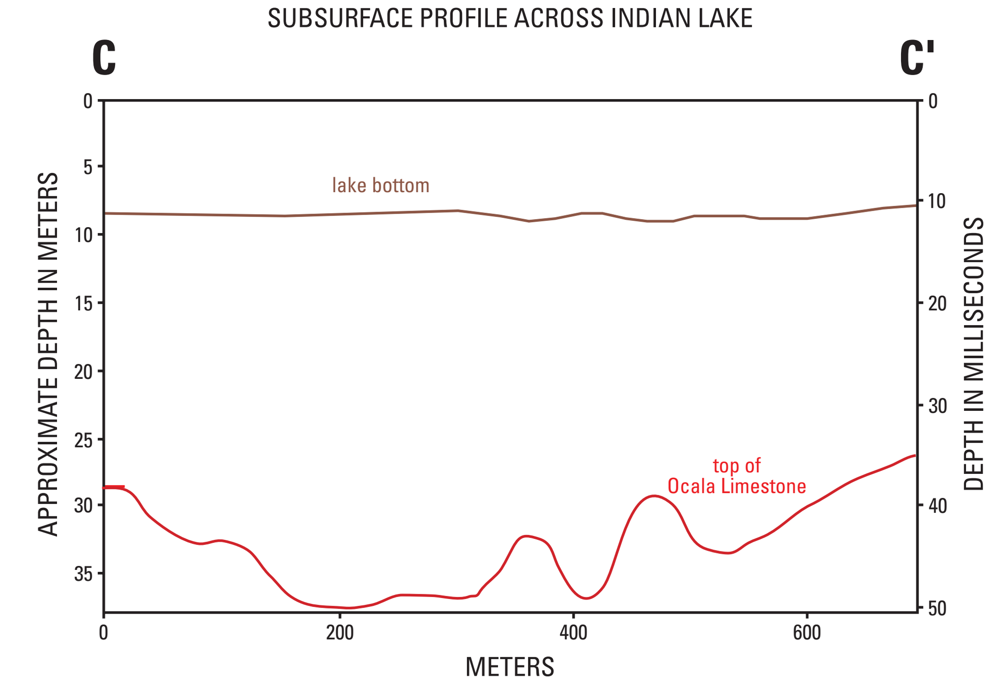


H

LAKES KEENE & SMOKEHOUSE
DISTRIBUTION OF FEATURES
(noted from seismic profiles)



SUBSURFACE PROFILE ACROSS INDIAN LAKE



Location of profile shown in above figures.

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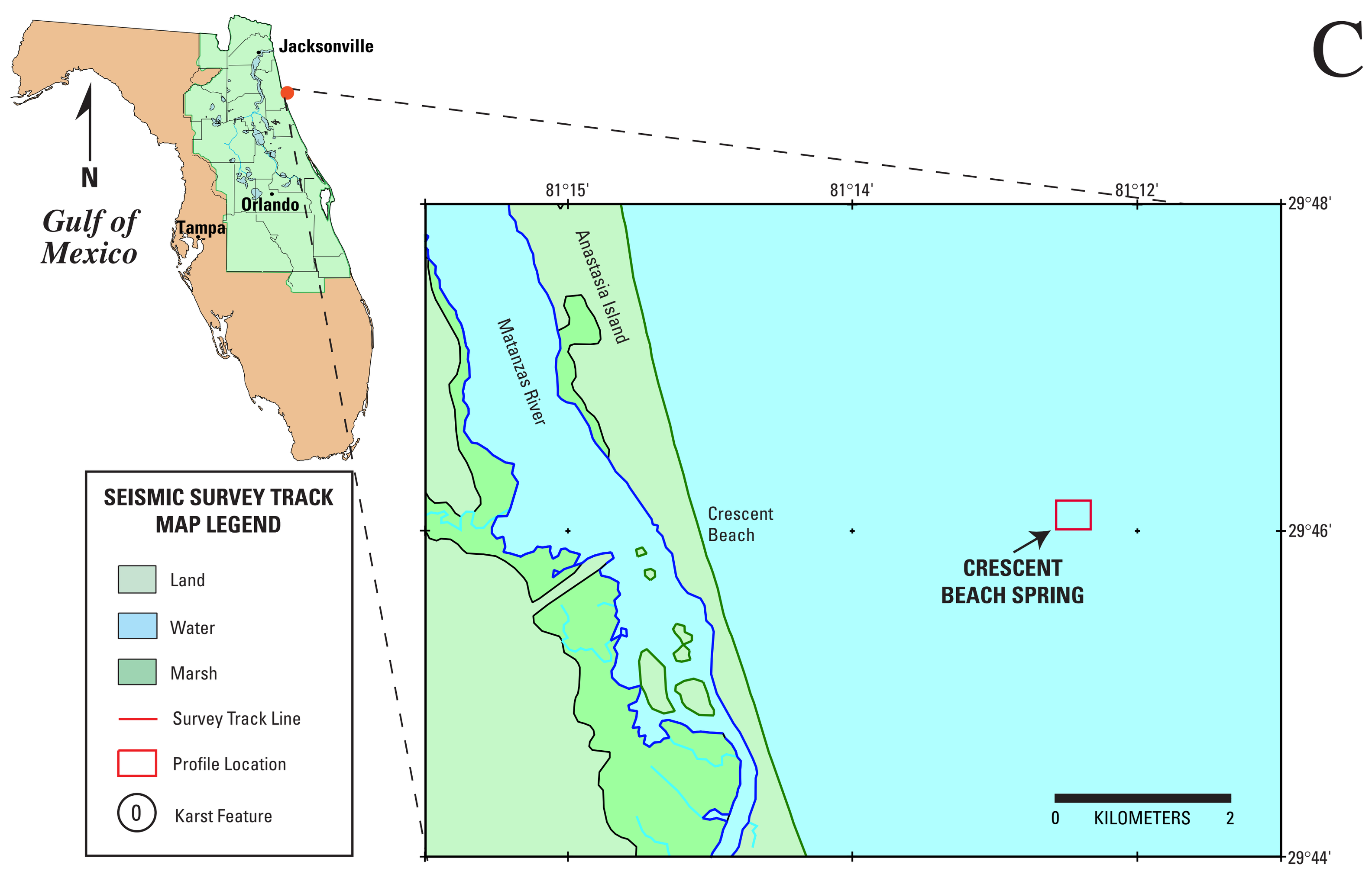
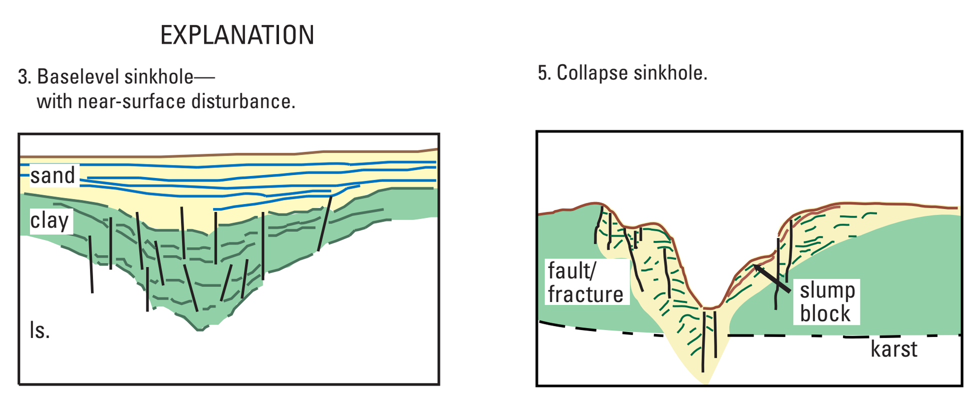
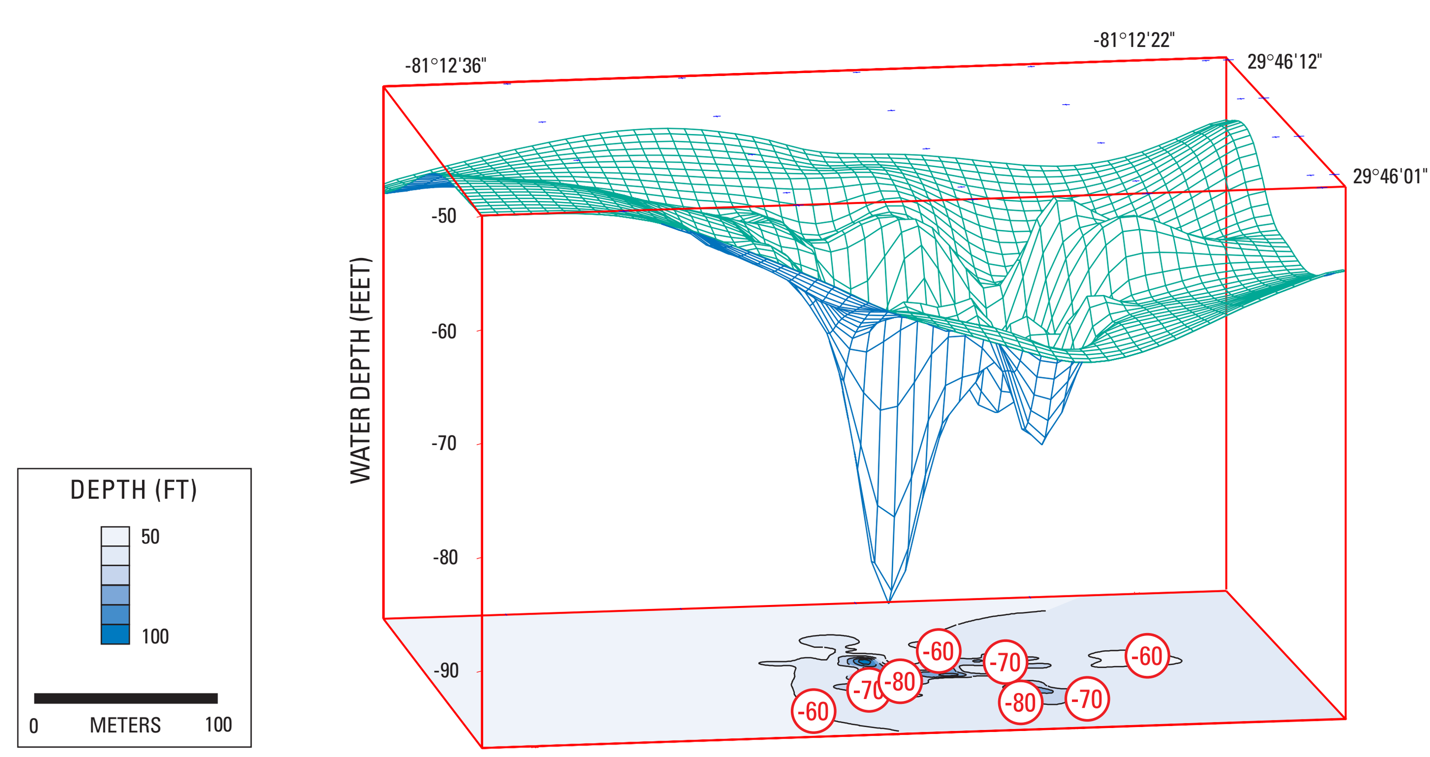
CRESCENT BEACH SPRING

ATLANTIC COAST, FLORIDA





3-D MODEL OF BATHYMETRY AT CRESCENT BEACH SINK



Introduction

The submarine spring near Crescent Beach, St. Johns County, is approximately 4 km (2.5 mi) offshore in 18 m (59 ft) of water in the Atlantic Ocean. The spring is a major discharge point for water from the Floridan aquifer and is evident on seismic profiles to be a spring vent rather than a collapse-type sinkhole. The profiles show a vent area of approximately 90 to 150 m (300-500 ft) in diameter (example profiles A-A' and B-B') and a depth of over 35 m (115 ft) below sea level. NOAA/NOS navigation chart number 11486 lists a water depth of 43 m (140 ft) at the base of the vent. Brooks (1961), conducted a detailed survey of the "sink" using SCUBA, with a maximum recorded depth by diving of 40 m (132 ft). Brooks described the base of the sink to be comprised of secondary craters up to 4 m (12 ft) across. He noted that spring water discharge is from the bottom of these secondary craters. The spring water rises to the sea surface as density driven boils, at the surface these boils can be seen for some distance from the spring. In the seismic profiles, the velocity contrast between the fresher water discharging into the seawater produces reflectors that can be used to define the discharge plume.

In 1923, the U.S. Coast and Geodetic Survey obtained water samples from three areas in the spring that indicate the source water has a chloride content between 7090 mg/l and 7680 mg/l. These values are similar to those of the Floridan aquifer obtained from a well about six kilometers onshore to the west (Brooks, 1981). In 1995 water samples were collected from the spring by USGS staff to determine chlorides and age of the water using isotopes. The Chloride value from samples that isolated the discharge from the seawater was 3630 mg/l and the age based on Carbon-14 techniques was 10500 years (Toth, 1999).

Subsurface Characterization

Numerous transects across Crescent Beach spring were conducted in 1994 to acquire HRSP of the subsurface. Two examples of the profiles are shown as A-A' and B-B'. Unfortunately the navigational fixes attached to the digital seismic data have been lost, so horizontal scale of the profiles and their geographic location cannot be determined at this time. Another survey of the sink using Side-Scan Sonar, HRSP and a fathometer were done in 1998.

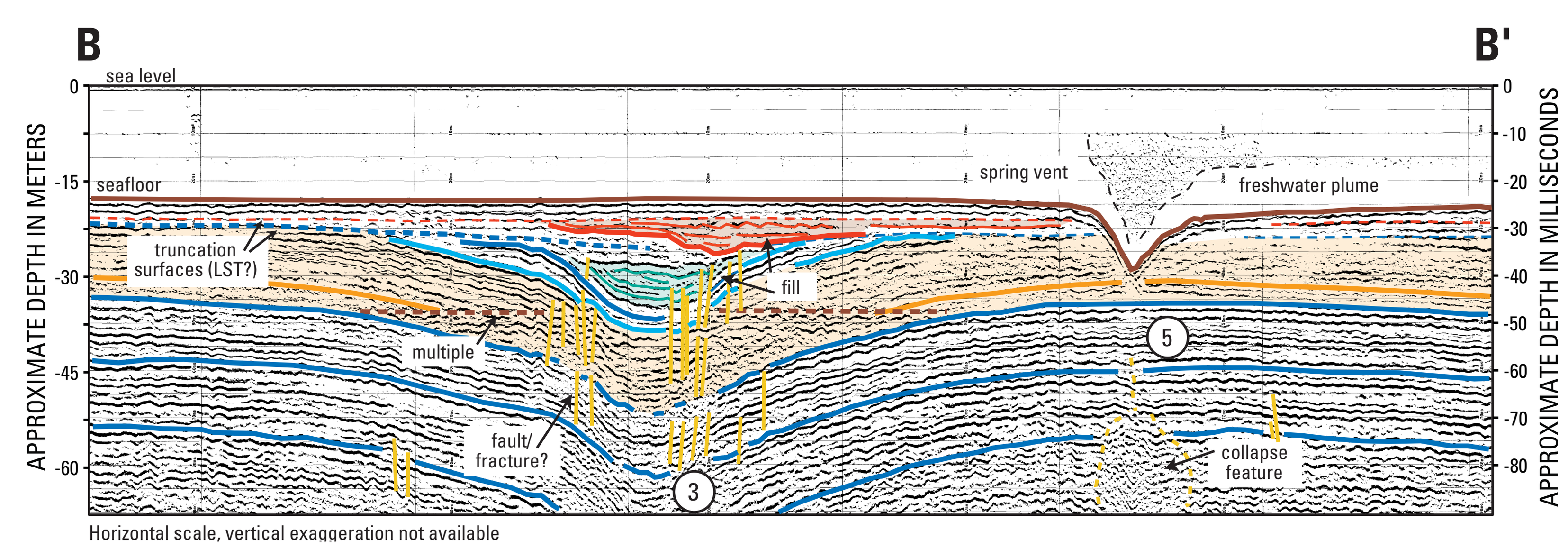
The seismic profiles (A-A' and B-B') show numerous strong, parallel reflectors from about 30 m (98 ft) to 60 m (197 ft) below sea level. Gamma log profiles (Index Map Section H, page 42), interpreted from Gamma counts acquired from inland wells drilled within eight kilometers of the spring show numerous peaks in gamma counts at the base of the Hawthorn Group. These peaks are at similar depths to the strong reflectors in the seismic profiles. The package of reflectors highlighted by an orange background (A-A' and B-B') exhibits a slightly more "noisy" characteristic than adjoining reflectors and may represent different lithologic or stratigraphic parameters. The series may correlate with the higher frequency Gamma count peaks seen in Gamma log profiles SJ0798 and SJ0171 between -21 m (-70 ft) and -30 m (-100 ft). Below 60 m (197 ft) the strong reflectors diminish in the seismic profile (not shown). This change in acoustic return may represent the top of the Ocala Limestone. In the gamma profiles this surface is indicated by a blue line and ranges from an elevation of -53 m NGVD (71 ms or -170 ft) at SJ0151 to -69 m NGVD (92 ms or -220 ft) at SJ0162. Though there is insufficient data to confirm the identity of one reflecting horizon as the top of the Ocala Limestone, it is most likely around 70 ms (53 m, 174 ft) on the seismic data.

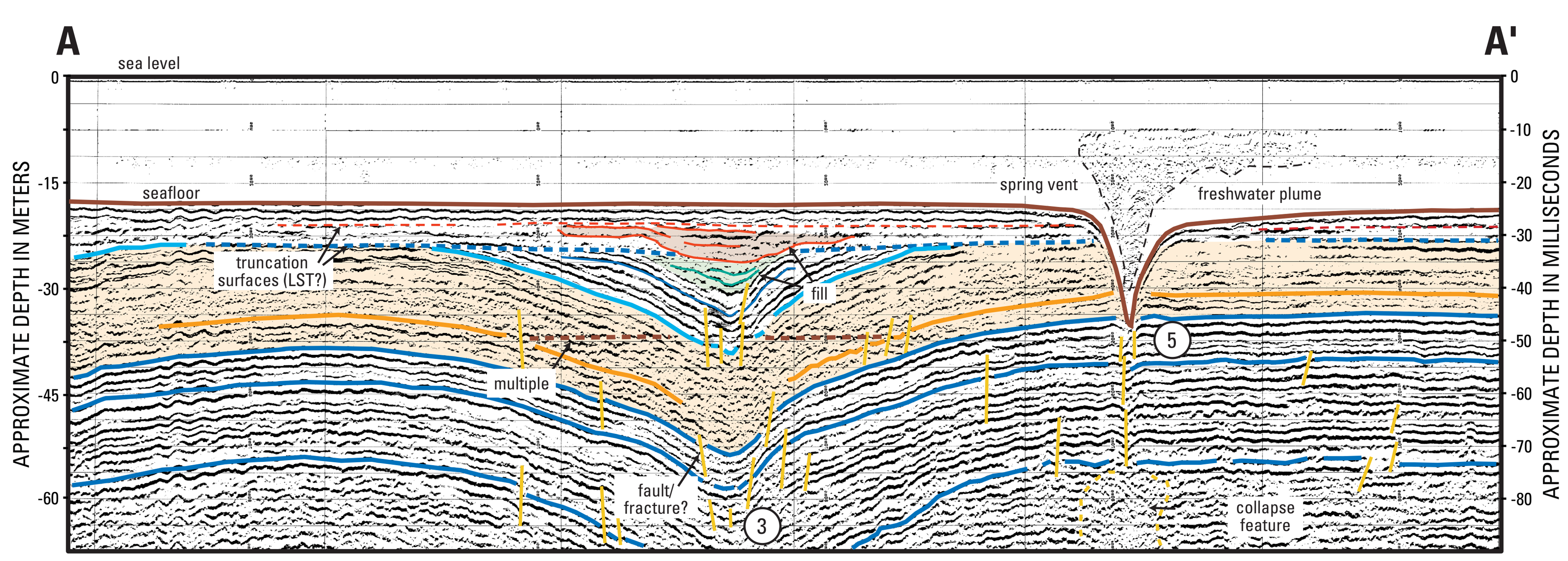
What is readily apparent in the HRSP examples is the very large (~1 km) subsidence feature evidenced by the downwarped reflectors within the Hawthorn Group. Discontinuities in the horizontal reflectors (yellow vertical lines) may represent stress fracturing associated with the downwarping. Meisburger and Field (1976) identify this large subsidence feature as a pronounced fold. Popenoe and others (1984) identified the top of the Eocene on the downward flexure of the fold to be between -47 m (-150 ft) in the undisturbed section to about -75 m (-240 ft) msl at the deepest part. Karst-related dissolution at depth and subsequent near-surface subsidence might be another explanation, rather than a structural fold. The area highlighted by a green background (A-A' and B-B') appears to contain offlap and cross-bedded reflectors that may represent fill when the depression was exposed.

The downwarped reflectors of the Hawthorn Group are truncated at about 22 m depth, shown by the blue dashed line in the example profiles. This surface, and a second one near surface (red dashed line), may represent erosional surfaces related to sea level low stands. The area highlighted by a red background shows a second depression with offlap- and cross-bedded fill. This feature may represent an area of resumed subsidence following the first sea level cycle. It may also be an incised fluvial channel with fill occupying the topographic low created by the original subsidence event. These sequences of truncation surfaces and fill may be remnants of the last two sea level cycles, the parallel reflectors overlying these sequences being the most recent marine deposition.

At the sea floor the spring vent appears to be independent of the large subsurface subsidence feature. Although their relationship at depth is not resolvable from the seismic profiles, their formation is probably a manifestation of major dissolution (mega-void) within the underlying limestone. The vent incises the most recent marine sequence, which suggests that the vent is recent. The north (left) flank of the sink is higher in elevation than the south flank (profile B-B'). Sediment removal from the vent may be accumulating on the prevailing down-current side of the vent. Another possibility is that the vent may occupy a fault line, with the southern flank being a down dropped block. Popenoe and others (1984) mapped numerous downward flexures and fractures traces along the northeast coast of Florida. The reflections within the Hawthorn Group show some minor displacement. There is some definite discontinuity in the reflectors below the sink (profile B-B') which could represent the breach within the Hawthorn and the migration pathway for the freshwater discharge. At depth in the seismic profiles the signal does appear to be slightly more chaotic than the neighboring acoustic return (outlined with yellow dashed line). This effect could be from noise in the signal caused by the sink itself, or it could be a zone of recrystallization or more advanced karst development within the Ocala Limestone. Removal of limestone by dissolution may have created a cavity and caused subsequent roof collapse and fill of the void. Increased dissolution within the Ocala Limestone would be the cause and effect of the fluid-migration pathway related to the spring vent and freshwater discharge at the sea floor.

H





Subsurface Characterizations of Selected Water Bodies in the St. Johns River Water Management District, Northeast Florida

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This sheet is Section H page 44 of Open-File Report #00-180 prepared by the U.S. Geological Survey Center for Coastal Geology and the St. Johns River Water Management District. For a detailed description of methods, site locations, explanation of regional geology, physiography, karst development and karst features identified by seismic profiling, refer to pages 1 through 7.

SUMMARY, ACKNOWLEDGEMENTS AND REFERENCES

SUMMARY

This atlas is the product of an investigation of lakes and rivers in north central Florida, a cooperative effort by the St. Johns River Water Management District and the U.S. Geological Survey. The objectives of the study were to: 1.) identify evidence of breaches or discontinuities of the confining units between surficial water bodies and the Floridan aquifer, and; 2.) identify diagnostic features, structure and geomorphology of the lakes and rivers within the region.

The shallow subsurface of north central Florida is characterized as a mature karst (limestone) overlain by an overburden of clays, silts and sands that act as an impermeable layer between surficial waters and the Floridan aquifer. Breaches through this layer allow recharge or discharge of waters to or from the Floridan aquifer. The development of breaches are influenced by various physical parameters, including the thickness and lithologic composition of the overburden, the maturity of karst development and depth to the potentiometric surface of the aquifer. Knowledge of these parameters and identifying the location and magnitude of the breaches is important in understanding the interaction between the surface waters and the aquifer.

The nature of the breaches within the overburden and dissolution in the underlying limestone take on various dimensions. Subsidence of the overburden due to dissolution at depth forms sinkholes that create large discontinuities within the impermeable layer. Smaller discontinuities include faulting and fracturing within the overburden that provide conduits for water movement, which over time develop solution pipes. With continued water movement and karst development these features reach stages of maturity that may include infilling and/or reactivation. Buried subsidence and dissolution features may not have a surface expression since recent fluvial deposition post-dates subsidence activity. However, the subsurface features may still provide conduits for water movement to and from the aquifer and reactivation is a possibility.

Subsurface geologic characterization beneath the lakes and rivers was determined by High Resolution Seismic Profiling (HRSP). The acoustic profiles provide images of karst features such as subsidence and collapse structures and related fracturing, faulting and dissolution pipes. These features may produce breaches within the confining layer or define subsurface discontinuities that provide a pathway for communication between surface waters and the aquifer. The physical parameters that produce these features, such as thickness of overburden, can also be inferred from HRSP with support from interpretations of gamma-log profiles obtained from water wells in the vicinity. Previous knowledge of geomorphology and regional geology further supports the HRSP and gamma-log interpretations. Compilation of HRSP from across north central Florida shows that certain karst-related features re-occur from lake to lake. By identifying these features, as well as comparing the subsurface physical parameters between lakes, the potential for interaction between surface and groundwater can be determined.

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