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GEOLOGY OF THE OKLAWAHA BASIN

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ABSTRACT

Electric normal resistivity curves, natural gamma ray logs, and drillers' logs from 50 wells were used to investigate the geology of the Oklawaha Basin (portions of Lake, Marion, Orange, and Polk Counties, Florida). A hard, low porosity zone of carbonates contained within the Avon Park Limestone is traced within the Basin from surrounding counties, and its existence under the entire Basin is established. The Avon Park Limestone in the study area is a carbonaceous limestone divisible into three zones: (1) a lower zone with high porosity, (2) a middle zone with very low porosity, and (3) an upper zone with high porosity. The Ocala Limestone within the study area consists of relatively pure limestone and is sometimes low in porosity. The Hawthorn Formation can be divided into a lower unit of phosphatic carbonates interbedded with clay and an upper unit of phosphatic clay and sand. Four local structural elements were located through the use of structure contour maps on the tops of the Avon Park, Ocala, and Hawthorn Formations.

INTRODUCTION

The Oklawaha Basin is located in portions of Lake, Marion, Orange, and Polk Counties, Florida (Figure 1). There are relatively few sources of information in existence detailing the subsurface geology of the Basin. This study was undertaken to determine formation characteristics and the location of their contacts in the Oklawaha Basin. Information obtained will be used by the Water Management District in suggesting the best well construction for any specific location in the area. Logs are on file at the St. Johns River Water Management District office, Palatka, Florida, and are available for public inspection.

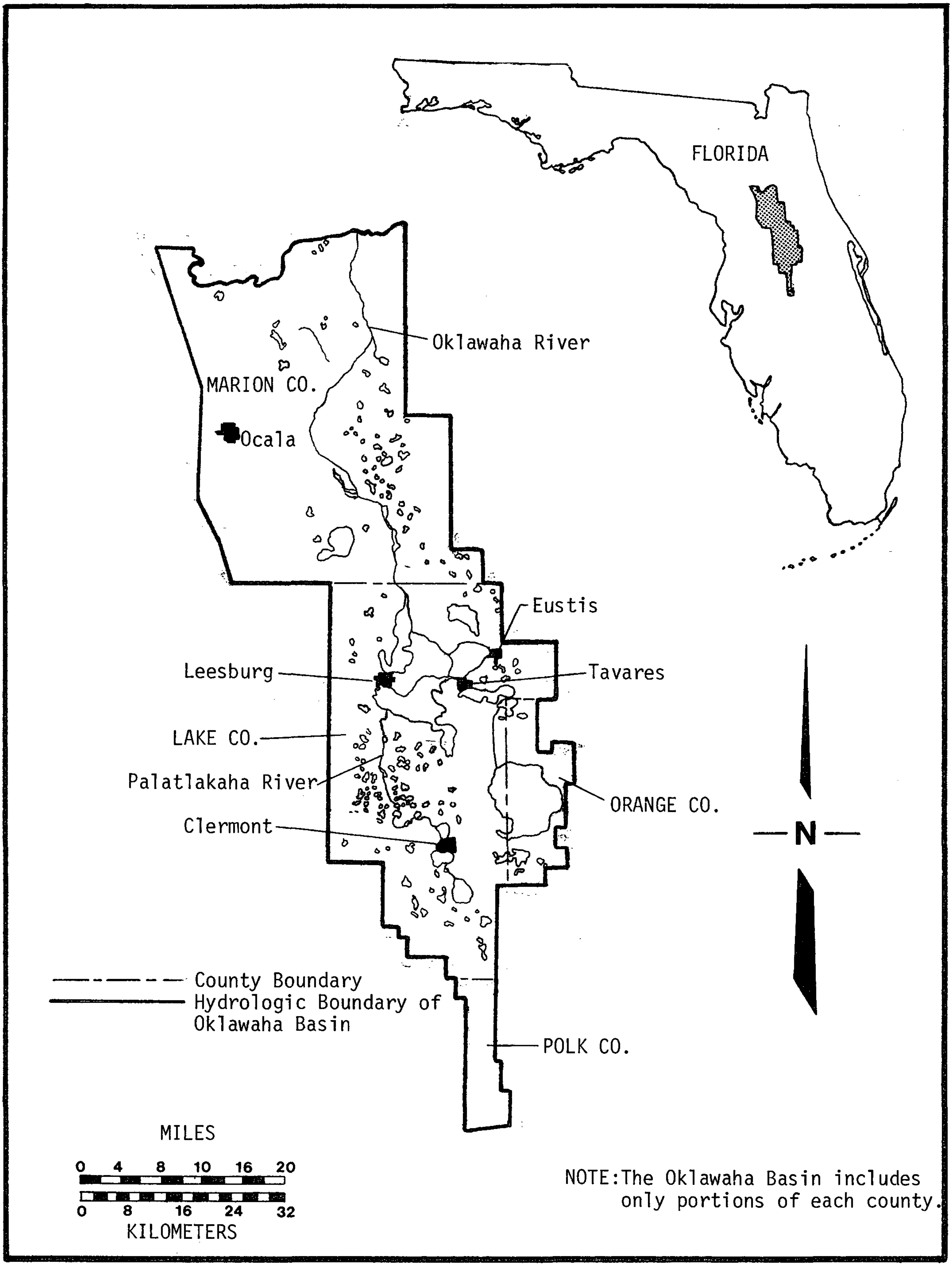


Figure 1. Location of Oklawaha Basin Study Area

EQUIPMENT AND METHODS

Three main sources of information were used to determine the subsurface geology in the Oklawaha Basin. These included: (1) natural gamma ray logs, (2) electric logs, and (3) drillers' logs. It was possible to correlate hard limestone or dolostone zones between wells from caliper logs by the following zonal characteristics: (1) lack of caving, (2) close approximation to bit size, and (3) stratigraphic position. Thus, the caliper log was also used for correlation in some wells when no other information was available. Well to well correlation was based upon an interpretation of all four types of logs: (i.e. gamma ray, electric, drillers, and caliper).

The gamma ray probe that was used included a scintillation detector with a one inch by four inch (2.54 cm. by 10.16 cm.) thallium activated sodium iodide crystal. Because of the large size of the detection crystal, this instrumentation produces extremely accurate logs. A logging speed of 20 feet per minute (6.1 meters per minute) and a five-second time constant were considered most suitable for accurate interpretation of the gamma ray logs.

The electric log consisted of two curves: a 16-inch normal curve and a 64-inch normal curve. "Normal" refers to the arrangement of electrodes and scheme of electronics used in production of the curves. Log scales were set to eliminate off-scale deflections. Typical full-scale deflections ranged from 200 to 1600 ohm-meters. This log was found to be most accurate for correlations in the carbonate sections of the wells. However, this log can only be run in an open hole, since well casing records as zero resistivity on electric logs.

Drillers' logs varied in degree of detail; however, for this study, general lithology, hardness, and color were assumed to be correct; and this information was used to supplement the geophysical logs whenever possible.

Caliper logs were run in each well utilizing a probe with three arms set 120 degrees apart. The scale was set to be as sensitive as possible, and well diameter changes as small as one-quarter inch (6.4 millimeters) were readily apparent.

All geophysical information derived in the field was correlated with information contained in the existing literature. Locations of formation contacts on the geophysical logs were based upon recognition of previously published formation characteristics and marker beds (see Formation Characteristics section).

Information was derived from 50 wells. Of these, 29 were located in Lake County, 12 were located in Marion County, 6 were located in Orange County, and 3 were located in Polk County (Figure 2). Depths of wells ranged from 87 feet (26 meters) to 811 feet (247 meters).

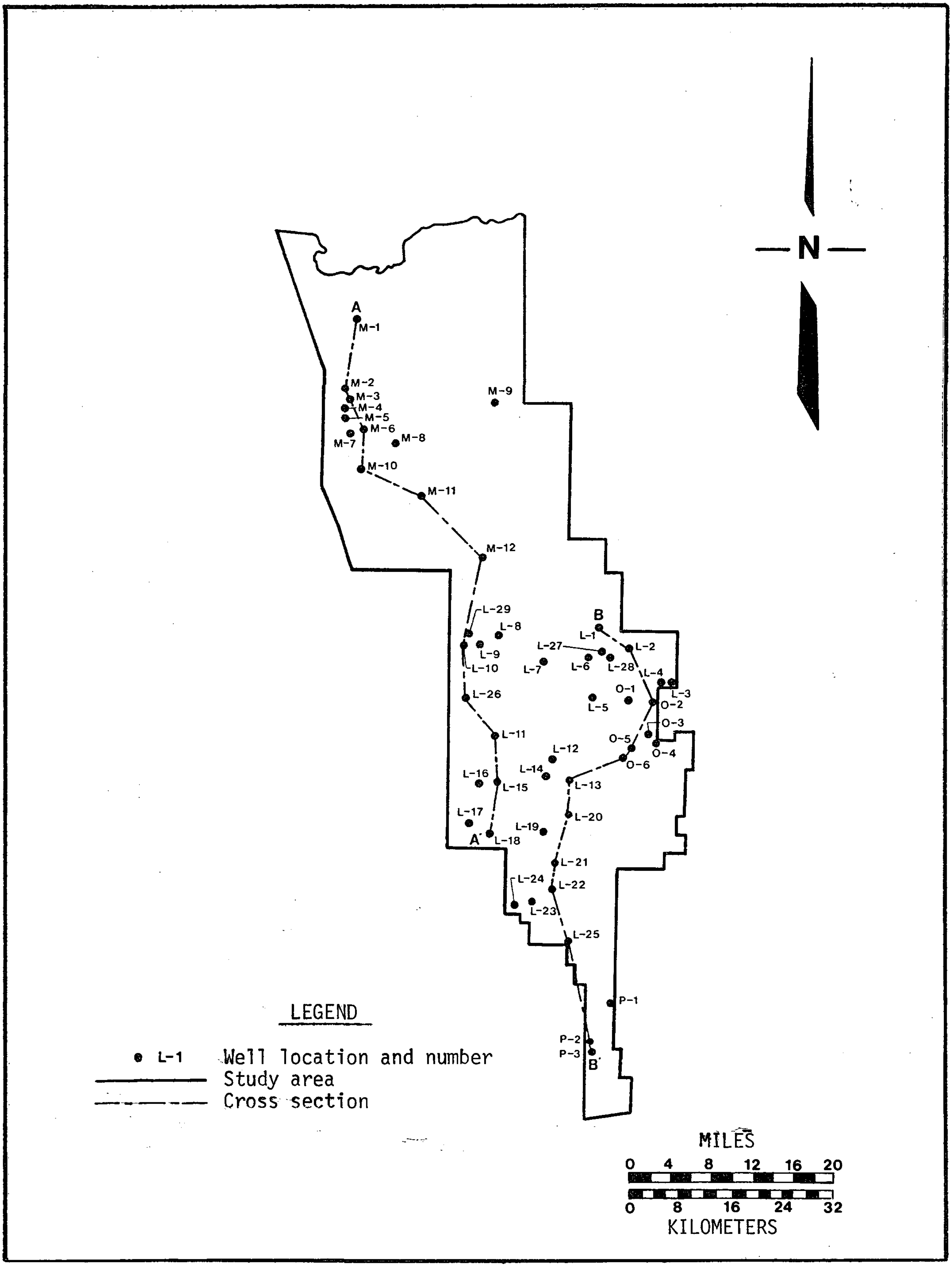


Figure 2. Oklawaha Basin Showing Well and Cross Section Locations.

PREVIOUS INVESTIGATIONS

In most cases, geologic information presented in previous studies was accumulated as a secondary consideration, with the hydrology of the area being the primary interest; and as such, the geology is somewhat generalized. In all cases, the geologic information presented in previous studies is for only a portion of the Oklawaha Basin.

In 1951, Vernon published a cross section that extends into the Oklawaha Basin and a general cross section that extends across north Lake County and south Marion County. In 1961, Pride, et al. published three cross sections of the Green Swamp area with portions extending into the Oklawaha Basin. Only the southern Lake County area in Pride's report is contained within the Oklawaha Basin. Pride, et al. (1966) repeated some of this information, but included different cross sections of the Basin and maps showing the top of the Floridan aquifer, top of the Avon Park Limestone, and depth to the top of the Floridan aquifer for portions of south Lake County. Lichtler, et al. (1964, 1968) published a cross section showing excellent detail that extends into the Oklawaha Basin, as well as an Avon Park structure contour map, an Ocala Limestone[1] structure contour map, and a structure contour map of the Eocene-age carbonates for Orange County (the western portion of which is within the Oklawaha Basin). Unfortunately, data in the northwestern portion of Orange County are sparce.

A geologic map, a cross section, and excellent formation descriptions of Polk County were presented by Stewart (1966). Once again, however, only a very small portion of the Oklawaha Basin is covered. Knochenmus (1971) and Knochenmus and Hughes (1976) published three cross sections and a top of the Floridan

[1]Because the Crystall River, Williston, and Inglis Formations cannot be distinguished in this area, they are collectively called the Ocala Limestone (U. S. Geological Survey terminology).

aquifer map for south and middle Lake County. In 1972, Bush published three well sections in his hydrological report on Lake Minnehaha, south Lake County. Also in 1972, Snedaker and Lugo published a structure map and a geologic map for the Ocala National Forest. This area covers a very small portion of the Oklawaha Basin. In a report on the Cross Florida Barge Canal, Faulkner (1973) discusses the geology of the canal in the immediate vicinity of Ocala.

Thus, while some specific portions of the Oklawaha Basin have been investigated, an integrated geologic picture of the entire basin has been lacking. Also, some of these studies consider formations only as deep as the Ocala Limestone and do not consider the deeper Avon Park Limestone.

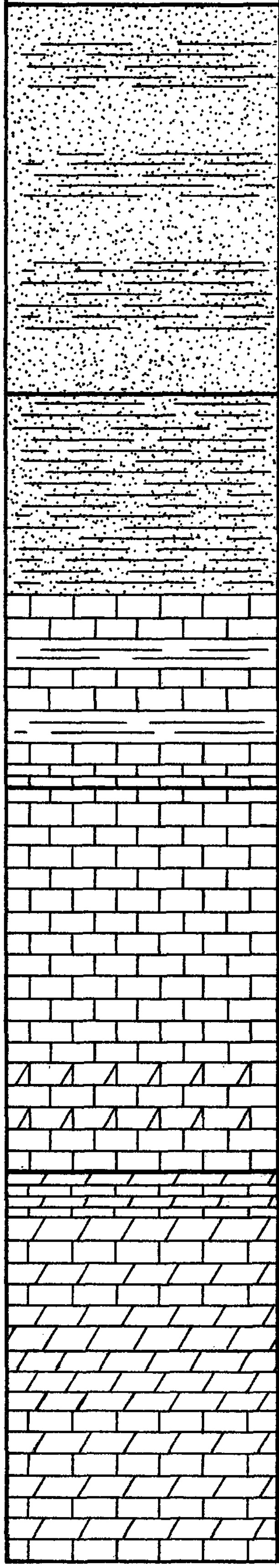
FORMATIONAL CHARACTERISTICS

In this section, each formational unit is considered in detail with regard to lithology, log characteristics, and thickness as it varies across the Basin. Figure 3 shows the generalized geologic column for the Oklawaha Basin. Figures 4 and 5 present two cross sections across the Basin. Cross section locations are given in Figure 2.

AVON PARK LIMESTONE

The Avon Park Limestone consists predominantly of moderately hard to very hard, light tan to dark brown limestone, and dolostone with peat and carbonaceous films occurring throughout. In the deepest wells logged, the lower portion of the formation consists of thick beds of soft carbonate material of relatively high and uniform porosity. This zone is at least 100 feet (30 meters) thick.

Near the middle of the formation, a thick, very hard zone of low porosity (high resistivity) consisting of repeated beds of brown carbonates, probably dolostone, alternating with relatively thin carbonate beds of high porosity (low resistivity) is characteristic. Zone thickness is approximately 100 feet (30 meters). Elevation of the top of the low porosity zone in wells where it was penetrated is given in Appendix A. This low porosity zone is well defined and underlies the entire Oklawaha Basin. It was also found to extend north and east into Flagler, Putnam, St. Johns, Volusia, and Alachua Counties, and is probably equivalent to the hard dolomite zone occurring within the Avon Park Limestone in Polk County. East of the study area, in Orange County, the zone is shown by Lichtler, et al. (1968) to be a hard dolomite zone occurring in the lower half of the Avon Park Limestone.



COLUMN	AGE	FORMATION	DESCRIPTION
	LATE AND POST MIOCENE	UNDIFFERENTIATED SURFICIAL CLASTICS	Sand and clayey sand with discontinuous lenses of clay Thickness: 7-480 ft. (3-146 m.)
	MIOCENE	HAWTHORN FORMATION	Upper: Clay with sandy clay, locally phosphatic Lower: Interbedded clay, limestone, dolomite or dolomitic limestone, gray, phosphatic Thickness: 6-160 ft. (3-50 m.)
	EOCENE	OCALA LIMESTONE	Limestone, relatively pure, white to light brown Thickness: 30-120 ft. (10-37 m.)
		AVON PARK LIMESTONE	Interbedded limestone and dolostone with carbonaceous and clayey inclusions, dark brown Thickness: at least 350 ft. (107 m.)

Figure 3. Generalized Geologic Column for Oklawaha Basin

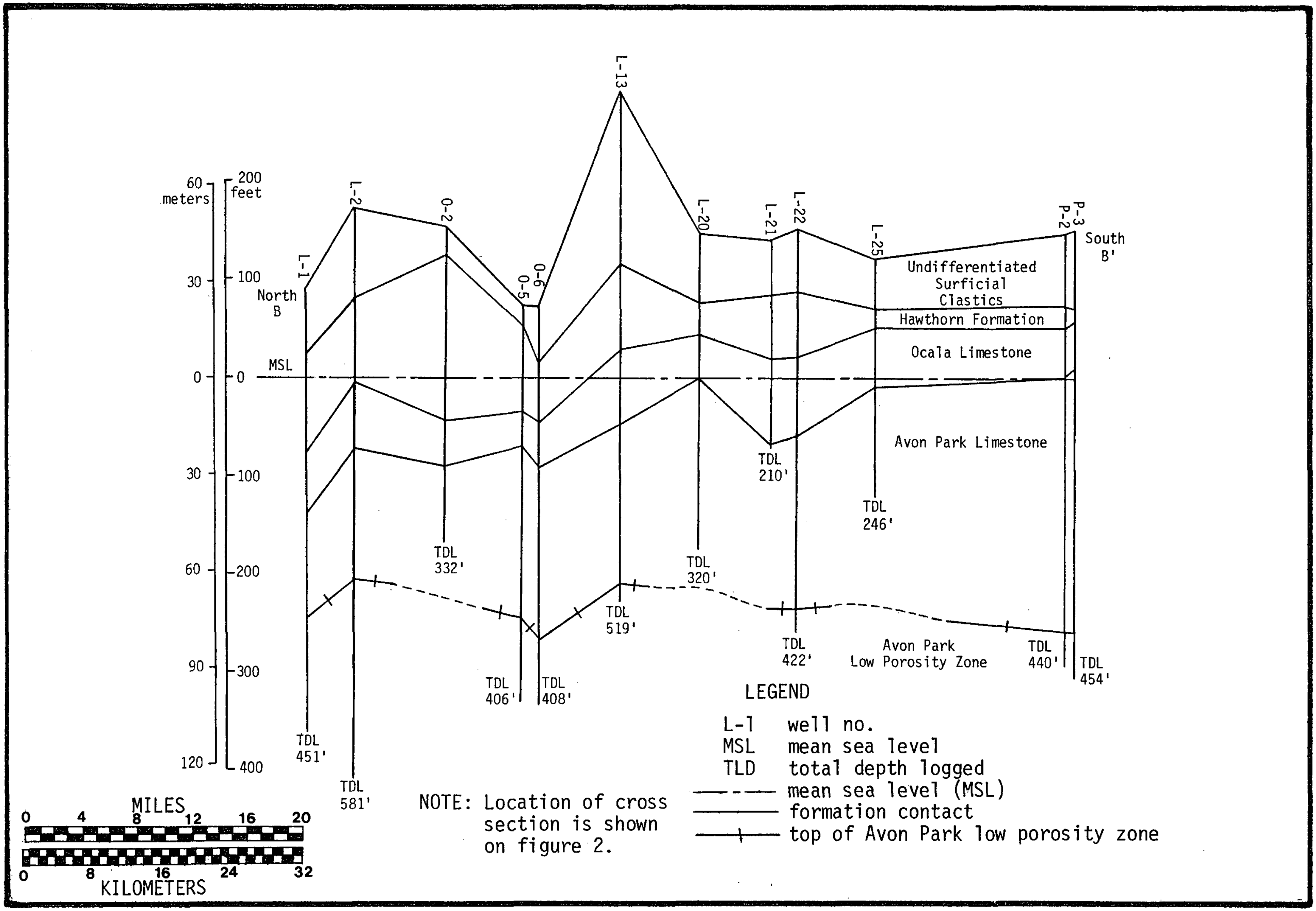


Figure 4. North South Cross Section B-B'

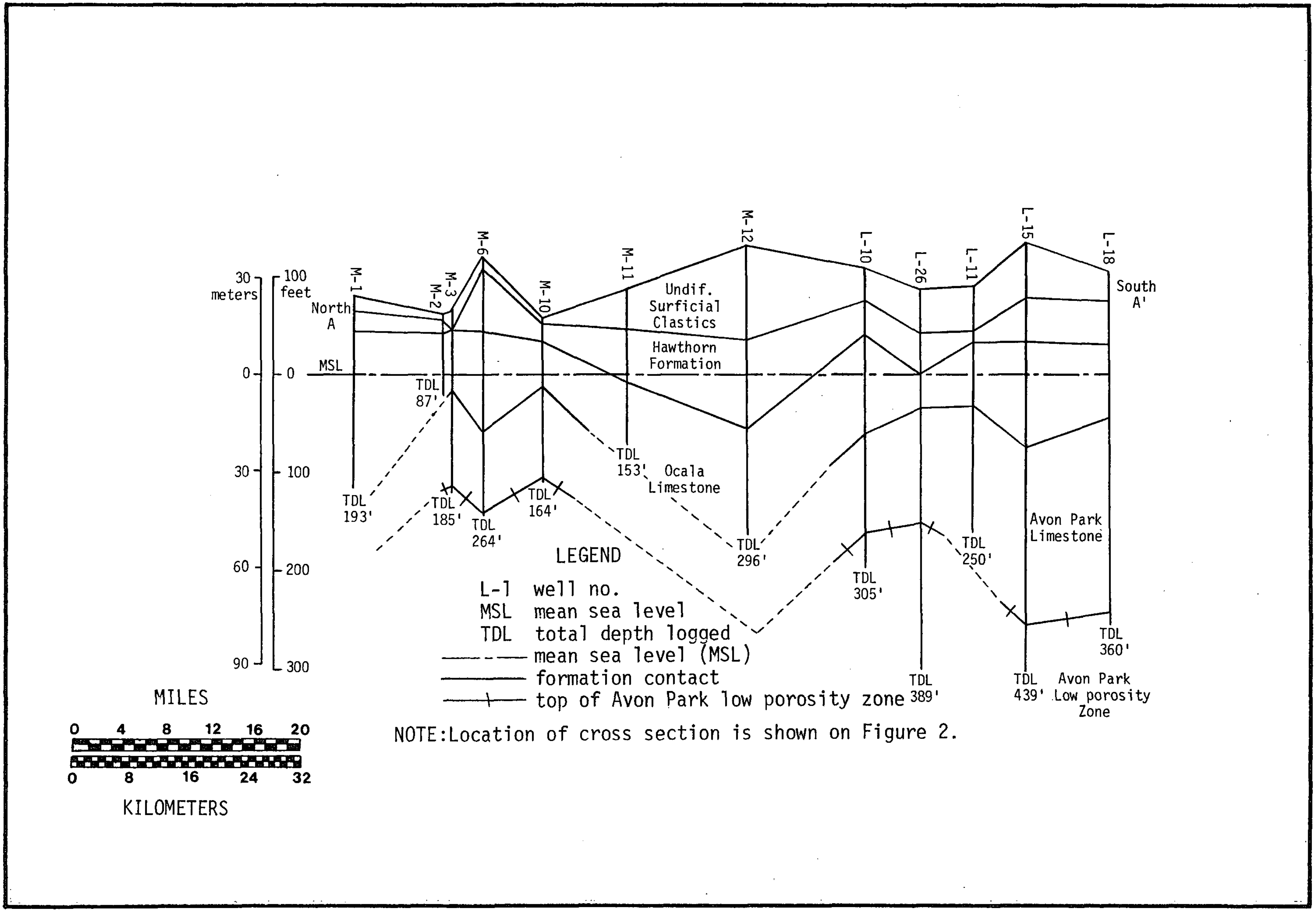


Figure 5. North South Cross Section A-A'

The carbonate section between the hard, low porosity zone and the top of the Avon Park Limestone consists mainly of relatively high porosity tan to brown limestone, alternating with thin beds of hard, dark brown dolostone, containing peat and carbonaceous material. Thickness ranges from 75 feet (23 meters) in Marion County to 243 feet (74 meters) in Polk County.

The top of the Avon Park Limestone is marked by an abrupt change from a lighter-colored Ocala Limestone (white to very light brown) to a much darker brown dolostone, containing peat and carbonaceous material in the Avon Park Limestone. Pride, et al. (1961) states that the Avon Park Limestone is darker brown in color than the overlying tan-colored Ocala Limestone. The top of the Avon Park Limestone was also determined by the presence of an unconformity (Chen, 1965) detected on the logs as peat or clay beds across the entire Oklawaha Basin (Stewart, 1966, Bermes, et al., 1963). Also, as stated above, the Avon Park contains numerous peat or carbonaceous films, especially near its top, whereas the Ocala Limestone is devoid of these films (Vernon, 1951).

The overall thickness of the Avon Park is at least 350 feet (107 meters). The thickness of the low porosity zone in the Avon Park remains approximately 100 feet (30 meters) across the study area (Figures 4 and 5). Near Ocala, the thickness of the Avon Park Limestone above the low porosity zone is less than anywhere else in the study area, ranging from 70 to 90 feet (21 to 27 meters). The thickness of the Avon Park Limestone above the low porosity zone increases to over 260 feet (80 meters) toward the south into Polk County (Figure 4). In all other areas of Lake County, the thickness of the upper zone is always greater than 130 feet (40 meters).

OCALA LIMESTONE

The Ocala Limestone consists of soft to hard, white to tan or very light brown relatively pure limestone. Porosity is sometimes low when compared to the upper Avon Park Limestone; and therefore, the formation is cased off in some wells. The top of the Ocala Limestone was determined by the presence of relatively pure limestone (Ocala) in juxtaposition with either phosphatic carbonate or clay of the lower portion of the Hawthorn Formation (Bermes, et al. 1963).

Thickness of the Ocala Limestone ranges from approximately 30 feet (10 meters) to 120 feet (37 meters). In the northern portion of the study area around Ocala, the Ocala Limestone is extremely close to land surface (Figure 5). Typically, it occurs from 15 to 20 feet (4 to 6 meters) below land surface. North of Ocala, the formation thickens to as much as 150 feet (46 meters) (Figure 5). In the south, the formation is fairly uniform in thickness where it ranges from 30 to 90 feet (9 to 27 meters) thick across the entire area from Eustis south to Polk County. Because of the presence of many paleokarstic features on the surface of the Ocala Limestone, the contact between the Ocala and the Hawthorn Formation can vary considerably in depth over a short distance. Well O-3 (Table 3) illustrates this showing a very thick Hawthorn Formation with the Ocala-Hawthorn contact almost 200 feet (60 meters) below mean sea level, while in all surrounding wells, the contact ranges from 15 to 44 feet (5 to 13 meters) below mean sea level. While all wells logged in Lake County for this study showed the presence of the Ocala Limestone, some geologists recognize localized areas where the formation is absent (Scott, 1979, oral communication).

HAWTHORN FORMATION

In the southern and extreme western portions of Lake County, the Hawthorn Formation consists of a single thin bed. It is composed mainly of yellow clay and sandy clay; however, the color can very from blue to green to brown or gray. Although drillers' logs did not directly mention phosphatic material, gamma ray log interpretation suggests deposits of phosphatic material within the Hawthorn Formation. The thin bed of highly concentrated phosphatic material occurring in some areas of central Marion County is considered to be Hawthorn Formation in this report. In those areas where the Formation is relatively thick (northeast Lake County and northwest Orange County), it can be divided into an upper and lower unit on the basis of drillers' logs and gamma ray logs. The lower portion consists of alternating beds of gray clay and gray phosphatic sandy carbonates and gravel. This portion shows extremely high gamma ray intensity with two or more high intensity peaks recorded on the logs. The upper portion consists of green to brown to yellow clay and sandy clay which appears as a sustained medium intensity trace or as a series of medium intensity peaks on gamma ray logs. The top of the Hawthorn Formation was determined as a change in lithology from mainly sand above the contact to predominantly clay and phosphatic material below the contact (Lichtler, et al., 1968).

South of Clermont, Lake County, the Hawthorn Formation ranges in thickness from approximately 6 feet (2 meters) to 20 feet (6 meters) and increases to a maximum thickness of over 160 feet (50 meters) in the east central portion of the Basin.

The formation is extremely variable in thickness and absent in some wells in Marion County (Figure 5). When present, it ranges up to 60 feet (18 meters) or more. From Ocala, the Hawthorn thickens toward the south (Figure 5). The contact between it and the Ocala Limestone dips below mean sea level in south

Marion County and increases to above mean sea level again in central and southern Lake County. As shown in Figure 5, the Hawthorn Formation is relatively thick in the North Lake County Low and thins greatly toward south Lake County.

In the Eustis and north Orange County portion of the study area (Figure 4), the Hawthorn is rather thick, ranging up to 150 feet (46 meters). The formation thins drastically toward the south end of Lake County, and in some wells, it is less than 20 feet (6 meters) thick.

UNDIFFERENTIATED SURFICIAL CLASTICS

Above the Hawthorn Formation is a blanket of sand and clay with sand predominating. Color ranges from white to brown to red and yellow. The contact of these sands with the Hawthorn Formation is often abrupt and characterized on the gamma ray log as a marked increase in sustained gamma ray intensity and, sometimes on drillers' logs, as a change from predominantly sand to a lithology dominated by clay or sandy clay.

In some wells, a very thick sand overlies the top of a severely eroded limestone section. This can be seen many times in logs of wells located on prominant topographic ridges with the base of the ridge thus exhibiting a root-like structure of coarse clastic material. An example is well P-1 (Table 4), where almost pure silica sand containing thin scattered clay beds overlies the Avon Park Limestone. The contact between the two occurs at a depth of 274 feet (84 meters) below mean sea level. Well P-1 is located on the Lake Wales Ridge (White, 1970).

In well L-13 (Figure 4) near the top of Sugarloaf Mountain, northeast of Clermont, where elevations in excess of 310 feet (94 meters) are encountered, there are also extremely thick undifferentiated surficial clastics; however, the material appears to be "piled" upon existing formations as the lower contacts are more or less continuous with those detected in surrounding wells which are not located on the mountain.

STRUCTURAL FEATURES

Structure contour maps on the tops of the Avon Park Limestone, Ocala Limestone and Hawthorn Formation (Figures 6, 7, and 8) show the structural elements that compose the Oklawaha Basin. There are four main structures that appear on all three maps: (1) North Lake County Low, (2) South Lake County High, (3) Southwest Lake County Low, and (4) Ocala High.

The North Lake County Low is the most pronounced feature, showing 70 to 100 feet (21 to 30 meters) of relief. The Low is best defined on the top of the Ocala Limestone structure contour map (Figure 7) where it occupies a position directly beneath Lakes Eustis, Harris, Griffin, and Dora, between the cities of Eustis and Leesburg. It is possible that the existence of these lakes is due to the presence of this low. A greater combined thickness of clastic material (sand and clay) is present in this area.

The South Lake County High is best defined on the structure map showing the top of the Avon Park Limestone (Figure 6) and is centered at or near Clermont. Relief is greatest on the Avon Park structure contour map (Figure 6) and decreases with each succeeding formation, becoming a broad high area with relief of approximately 15 feet (4 meters) on the top of the Hawthorn structure contour map (Figure 8).

The Ocala High shows greatest relief on the structure contour maps for the tops of the Avon Park and Ocala Limestones (Figures 6 and 7). It is centered 1 to 2 miles (1.6 to 3.2 km.) southeast of Ocala.

The middle and southern portions of Lake County can be considered part of the eastern edge of the Ocala Uplift with the southwest Lake County Low superimposed upon the Uplift as a local feature. The Uplift axis is located outside the Oklawaha Basin and to the west and trends generally north-northwest and

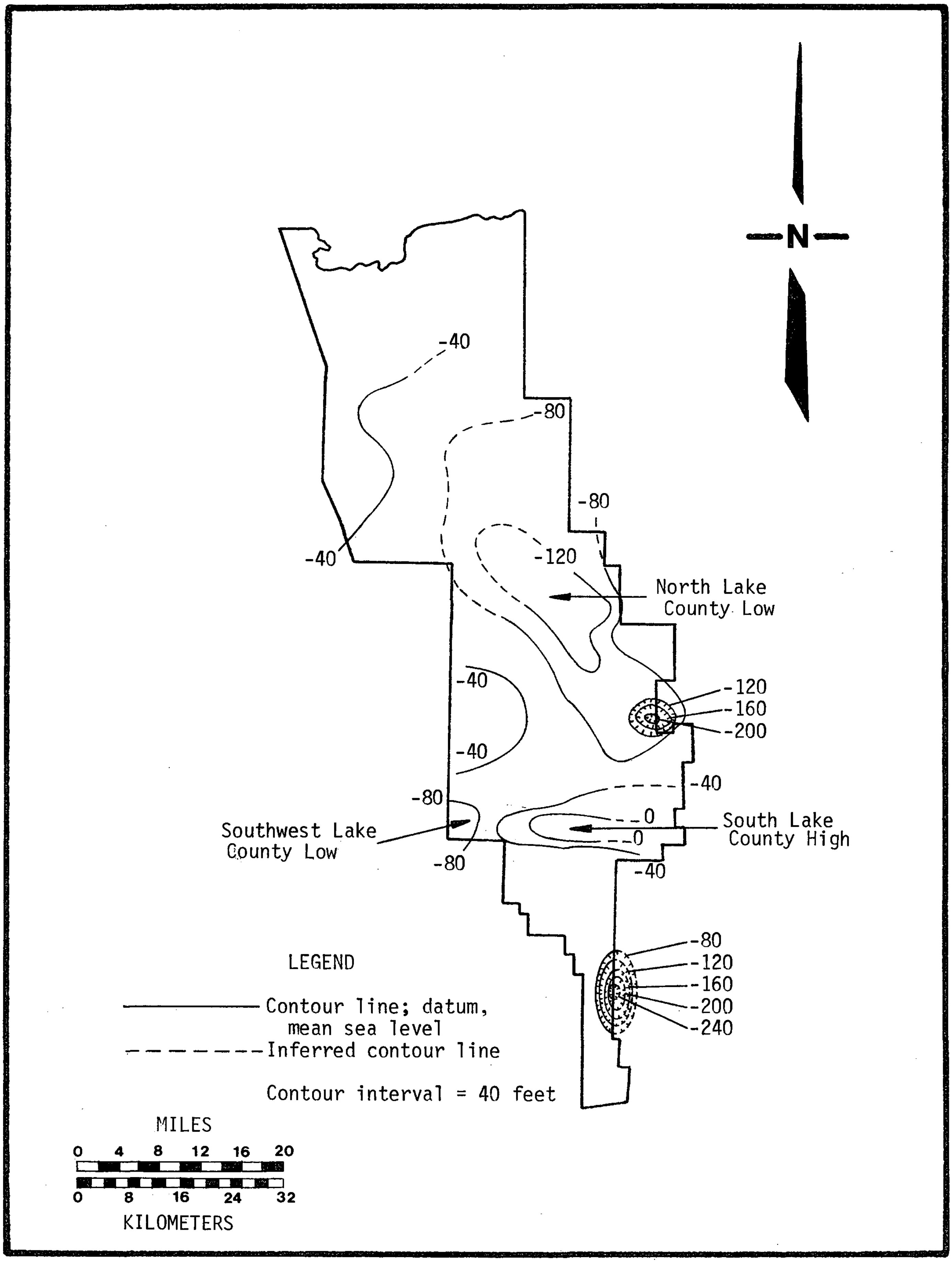


Figure 6. Structure Contour Map of the Top of the Avon Park Limestone, Oklawaha Basin

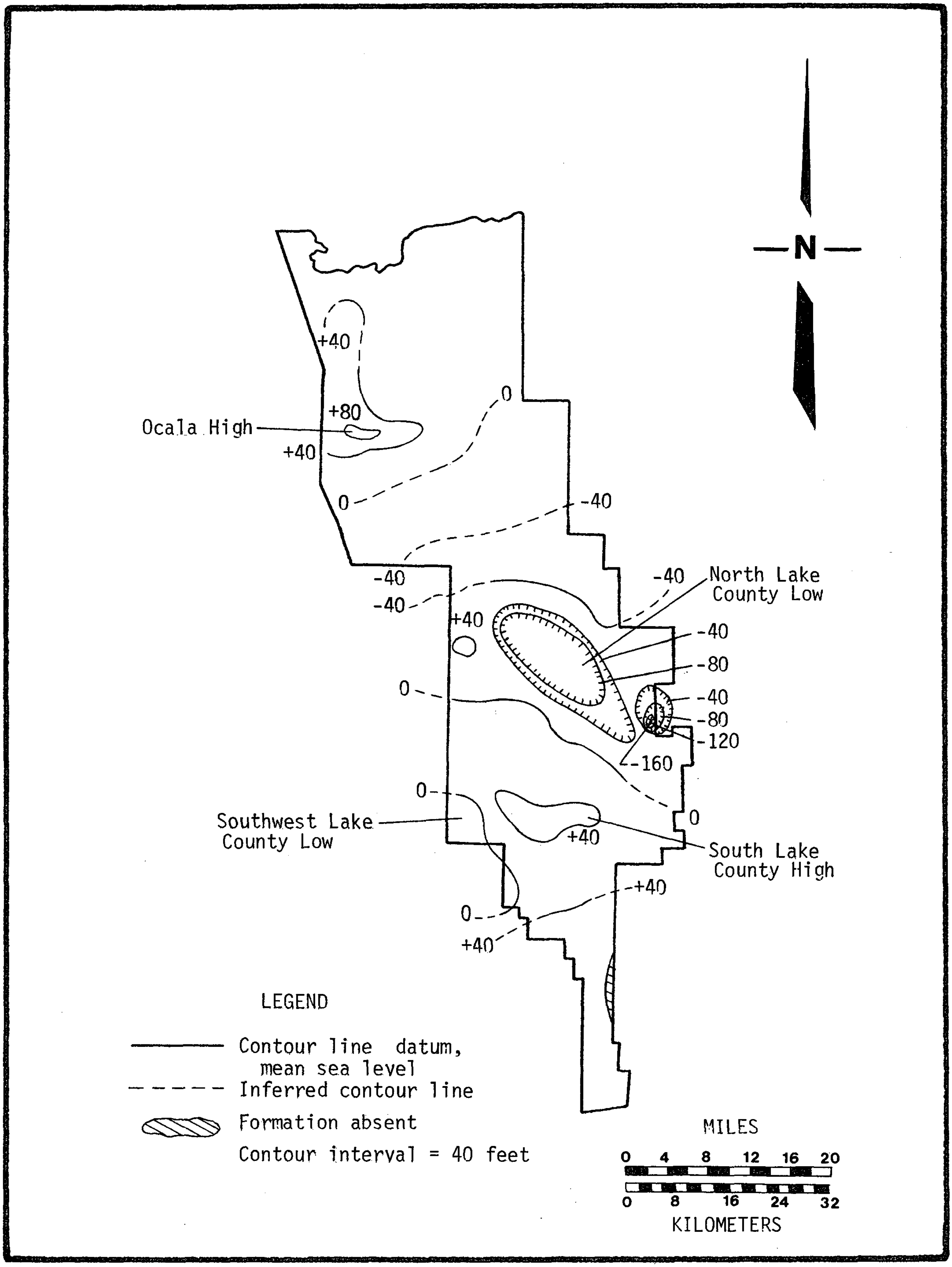


Figure 7. Structure Contour Map of the Top of Ocala Limestone, Oklawaha Basin

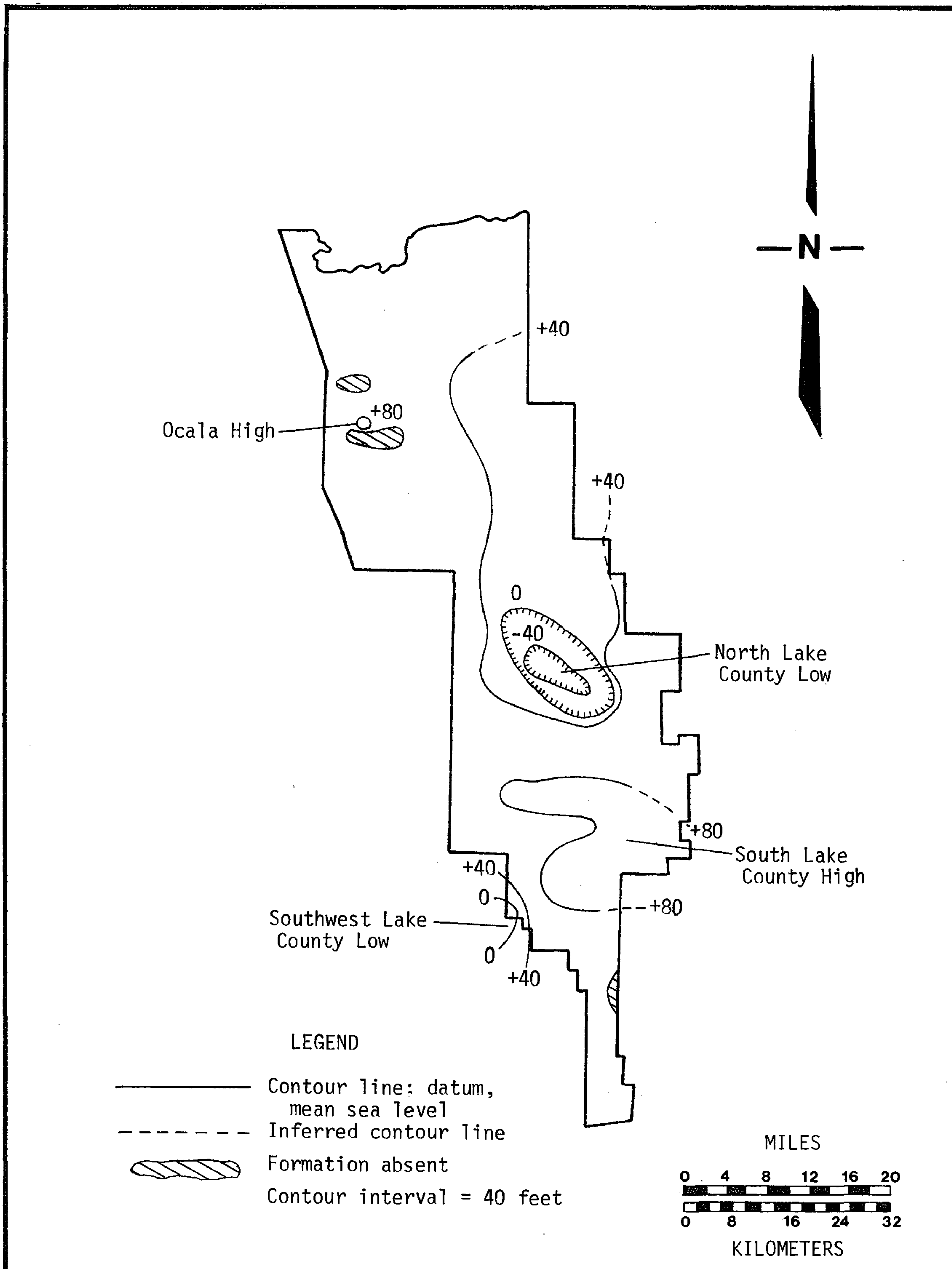


Figure 8. Structure Contour Map of Top of Hawthorn Formation, Oklawaha Basin

south-southeast approximately parallel with a line connecting Ocala and Clermont (Chen, 1965). The North Lake County Low is located some distance to the east of the Uplift axis and could be considered as being located beyond the eastern limit of the Uplift, hence depths to formations would tend to be greater. The local structure was superimposed upon this trend.

SUMMARY

In the Oklawaha Basin, the Avon Park Limestone consists of impure carbonaceous limestone and dolostone. It is divisible into three zones on the basis of electric and drillers' logs characteristics. The lower and upper zones are characterized by high porosity, whereas the middle zone is characterized by low porosity (Avon Park low porosity zone). The Ocala Limestone consists of a relatively thin section of pure limestone. The Hawthorn Formation consists of two zones: the stratigraphically lower zone consists of interbedded phosphatic clay and carbonate material, the upper zone consists of sand and clay with some phosphatic material. Where the formation is very thin, it consists of the upper zone only. Above the Hawthorn Formation is a blanket of undifferentiated clastic material which varies considerably in thickness.

Four local structural elements can be detected in the Oklawaha Basin--two Lows and two Highs. In general, the axis of the Ocala Uplift passes to the west of the study area. All four features appear to be local features, either erosional or depositional, superimposed upon the general Uplift structure. The North Lake County Low which shows much greater relief and underlies the four large lakes in north central Lake County is located on the eastern flank of the Uplift where a local depression was superimposed, and thus enhanced an already deepening trend.

The thickness of the upper zone of the Avon Park Limestone increases to the south in the Oklawaha Basin, whereas the thickness of the low porosity zone remains generally constant. Thickness of the Ocala varies as a result of the erosion surface which marks its upper contact. The Hawthorn Formation is thickest in the general area of the North Lake County Low and in northwest Orange County.

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APPENDIX

TABLE 1. -- Lake County Wells--Construction Information and Formation Contacts

Well No.	Well Depth (feet)	Casing Depth (feet)	Casing Size (inches)	Elevation Bottom Casing	Elevation (Top of) Hawthorn	Elevation (Top of) Ocala	Elevation (Top of) Avon Park	Low Ø Zone
L-1	451	134	8	-44	+28	-69	-132	-241
L-2	581	164	12	+8	+71	-4	-72	-204
L-3	110	85	4	+15	+76	-10	*	*
L-4	136	52	4	+53	+65	-13	*	*
L-5	246	147	6	-54	-35	-116	*	*
L-6	526	239	16	-135	-13	-100	-150	-280
L-7	209	133	4	-57	-56	-101	*	*
L-8	179	132	4	-72	-15	-95	*	*
L-9	102	80	4	-3	+25	-9	*	*
L-10	305	80	8	+27	+75	+41	-60	-161
L-11	250	60	8	+20	+44	+39	-31	*
L-12	302	224	6	-98	+67	+16	-71	*
L-13	519	175	6	+113	+114	+30	-44	-204
L-14	322	104	6	+26	+86	+10	-70	*
L-15	439	165	10	-33	+81	+39	-78	-251
L-16	286	153	6	-48	+52	+31	-44	*
L-17	295	93	6	+33	+71	-17	-88	*
L-18	360	100	8	+5	+70	+32	-40	-237
L-19	811	517	12	-382	+76	+67	+23	*
L-20	320	124	8	+7	+70	+43	0	*
L-21	210	80	4	+57	+85	+20	-67	*
L-22	422	168	8	-17	+84	+23	-56	-229
L-23	245	111	8	+10	+59	+20	-20	*
L-24	451	419	8	-303	-1	-7	-53	*
L-25	246	69	6	+54	+68	+52	-10	*
L-26	389	129	8	-44	+41	-1	-35	-148
L-27	477	172	12	-58	+21	-29	-93	-230
L-28	462	191	16	-68	+57	-30	-83	*
L-29	111	98	4	+37	+73	*	*	*

NOTES:

1. Elevation in feet referenced to mean sea level.
2. Low Ø Zone is the low porosity zone of the Avon Park Limestone.
3. An asterisk (*) indicates well did not penetrate contact or contact obscured in well due to casing.

Metric Conversion: 1 foot = 0.3048 meter, 1 inch = 2.54 centimeter

TABLE 2. -- Marion County Wells--Construction Information and Formation Contacts

Well No.	Well Depth (feet)	Casing Depth (feet)	Casing Size (inches)	Elevation Bottom Casing	Elevation (Top of) Hawthorn	Elevation (Top of) Ocala	Elevation (Top of) Avon Park	Low Ø Zone
M-1	193	63	6	+18	+66	+43	*	*
M-2	87	41	4	+23	+54	+41	*	*
M-3	185	71	6	-6	*	+44	-12	-115
M-4	117	51	4	-3	+61	+48	*	*
M-5	115	51	4	-2	+63	+49	*	*
M-6	264	97	6	+24	+106	+43	-59	-134
M-7	105	26	6	+74	*	+81	*	*
M-8	149	127	4	-35	*	+66	*	*
M-9	126	79	4	-1	+32	-36	*	*
M-10	164	64	8	-7	+50	+35	-13	-103
M-11	153	82	4	+5	+47	-10	*	*
M-12	296	121	6	+7	+38	-56	*	*

TABLE 3. -- Orange County Wells--Construction Information and Formation Contacts

Well No.	Well Depth (feet)	Casing Depth (feet)	Casing Size (inches)	Elevation Bottom Casing	Elevation (Top of) Hawthorn	Elevation (Top of) Ocala	Elevation (Top of) Avon Park	Low Ø Zone
O-1	140	131	4	-28	+85	-15	*	*
O-2	322	163	6	-7	+124	-44	-87	*
O-3	345	309	6	-202	-49	-199	-220	*
O-4	154	62	4	+69	+108	-19	*	*
O-5	406	125	10	-47	+51	-34	-83	-241
O-6	408	125	10	-54	+14	-44	-104	-262

TABLE 4. -- Polk County Wells--Construction Information and Formation Contacts

Well No.	Well Depth (feet)	Casing Depth (feet)	Casing Size (inches)	Elevation Bottom Casing	Elevation (Top of) Hawthorn	Elevation (Top of) Ocala	Elevation (Top of) Avon Park	Low Ø Zone
P-1	541	500	12	-292	*	*	-274	*
P-2	440	138	8	+8	+72	+52	-21	-253
P-3	454	130	8	+21	+72	+55	-9	-252

NOTES:

1. Elevation in feet referenced to mean sea level.
2. Low Ø Zone is the low porosity zone of the Avon Park Limestone.
3. An asterisk (*) indicates well did not penetrate contact or contact obscured in well due to casing or formation absent (Hawthorn).

Metric Conversion: 1 foot = 0.3048 meter, 1 inch = 2.54 centimeter