ORIGIN AND HYDROLOGY OF ORANGE LAKE, SANTA FE LAKE, AND LEVYS PRAIRIE LAKES OF NORTH-CENTRAL PENINSULAR FLORIDA[1]

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ABSTRACT

The water table in the Ocala limestone is the local base level of erosion in southeastern Alachua County. The basin of Orange Lake has developed in that area as a result of the erosion of insoluble sediments of the plateau and solution of the Ocala limestone to that water plane. Usually, the lake fluctuates with the water table. The lake water sometimes becomes perched when impervious lake sediments prevent loss of water through the lake bottom and solution channels into the underlying permeable limestone. This situation may develop when the water table falls during periods of diminished rainfall. The recent low stand of water in Orange Lake was caused by factors in addition to the prevailing drought conditions. The regional water table in the limestone fell below the lake bottom. This resulted in sufficient hydrostatic pressure to unlodge sediments plugging a sinkhole. The lake level subsequently fell considerably, due in large part to the quantity of water discharged into the underlying limestone through the sink.

Santa Fe Lake, located in northeastern Alachua County, is largely sealed off from the principal aquifer, the Ocala limestone, by Pleistocene clayey sands and relatively impervious sediments of the Hawthorne formation. Sufficient rain water from the youthful plateau of pine-palmetto flatlands, swamps, and marshes slowly drains and seeps into the lake to largely offset losses from evaporation, transpiration, and seepage even during drought periods. In addition to discharge by seepage in an eastward direction through surficial sands, overflow into a swampy area north of the lake occurs at times of unusually high water. These conditions result in a more stabilized lake level than that of Orange Lake.

Even though the Hawthorne formation and surficial sands are superimposed on the Ocala limestone in the region of Levys Prairie lakes, that part of Putnam County is a recharge area of the Eocene limestones. In this region the upper part of the Hawthorne formation contains considerable carbonate. Solution of both Hawthorne sediments and the Ocala limestone has resulted in slumpage that breached the superimposed, relatively impervious sediments, thus facilitating and, in some cases, allowing free downward movement of water to the principal aquifer, the Ocala limestone. A sink is known to connect one Levys Prairie lake with underlying pervious sediments. The lakes fluctuate markedly with periods of drought and abundant rainfall. The lower parts of this prairie surface coincide approximately with the piezometric surface of the water in the Eocene limestones. It appears that the piezometric surface in this area of subsurface drainage is acting as a temporary base level of erosion despite the surficial insoluble sediments. The topography contrasts markedly with the area of Orange Lake from which most of the insoluble materials of the plateau have been eroded away.

INTRODUCTION

During the recent dry years of 1954 through 1956 considerable concern developed in regard to decreasing lake levels throughout north-central peninsular Florida. Some lakes became dry, others partly dry, and still others maintained a rather constant level. Interest in Florida lakes is likely to become more intense as the population of the state continues to grow and fishing and resort activities intensify. An understanding of the lakes cannot be fully realized without knowledge of their origin.

The graph (fig. 1) gives precipitation data for the Gainesville area over the last twenty years. Also, surface levels of Orange Lake and Lake Lochloosa are indicated. The precipitation readings in the graph are from an area near the border of the watershed of Orange Lake. The average annual precipitation falling throughout the watershed is not available. It is believed that the readings for the Gainesville area are representative and adequate for the purposes of this paper. The average annual precipitation for the 3-year period from 1954 through 1956 was approximately 43 inches. The average annual precipitation for the 11-year period from 1940 through 1950 was 55 inches. Thus, during the period when the lake levels were falling, the annual precipitation averaged 12 inches less than for

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the 11-year period from 1940 through 1950.

The duration of a period of subnormal rainfall is a critical factor in low water levels. In a report by the Florida Water Resources Study Commission (1956, p. 30), it was stated in regard to the 1954–56 dry period: "Although rainfall deficiencies in any one 12-month period were not of record proportions, the prolonged nature of the deficiency coupled with less than normal rains during the intervening normally wet season resulted in one of the severest droughts of record. In many sections of the state, particularly in central and northwest Florida, water levels of 1956 were the lowest of record."

For this report, Orange Lake, located in southeastern Alachua County, was selected for primary consideration because of the interesting geologic controls in its origin and behavior. Santa Fe Lake in northeastern Alachua County and Levys Prairie lakes of western Putnam County are treated briefly. These latter lakes are different in origin from Orange Lake and were selected to illustrate additional factors in the origin and hydrology of lakes in north-central Florida. Principles brought out in the study can be applied to the other lakes in the region. Locations are shown on figure 2.

In this part of Florida, lake water is lost largely by downward drainage through underlying pervious sediments or solution cavities, lateral seepage, discharge through surface streams, evaporation, and transpiration. Many lakes have no surface streams feeding into them. Some lakes continuously or intermittently overflow into creeks or rivers, whereas others have no surface outlet. Subsurface drainage often assumes unusual importance because of the high permeability of underlying materials. A consideration of

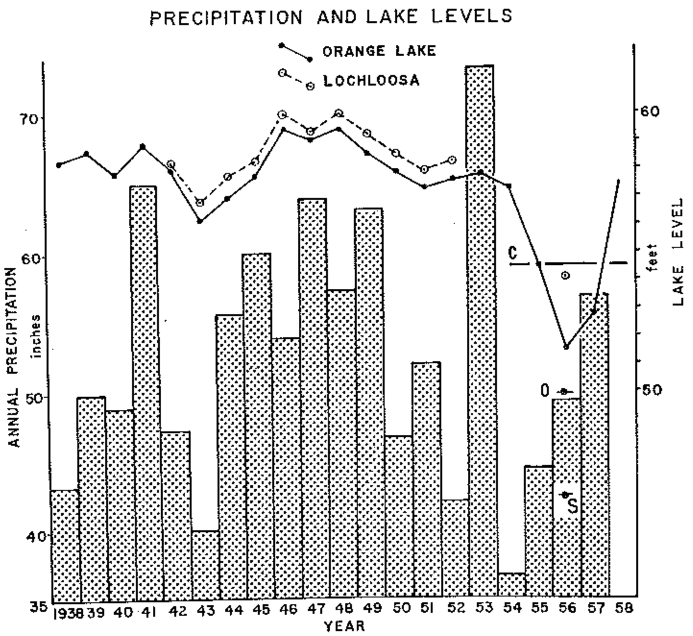

FIG. 1.—Graph of precipitation and lake levels of Orange Lake and Lochloosa Lake. Annual precipitation is indicated by the histogram. The scale in inches of precipitation is given on the left. The arithmetic mean of monthly lake levels for Orange Lake is plotted with dots and connected by a continuous line; Lochloosa by circles and dashes. Scale in feet above mean sea level is given to the right. The level at which Cross Creek ceased to flow during the interval 1954–58 is indicated by *C*. Point *O* represents the lowest stand of Orange Lake, whereas the lowest level of water in Orange Sink is indicated by *S*.

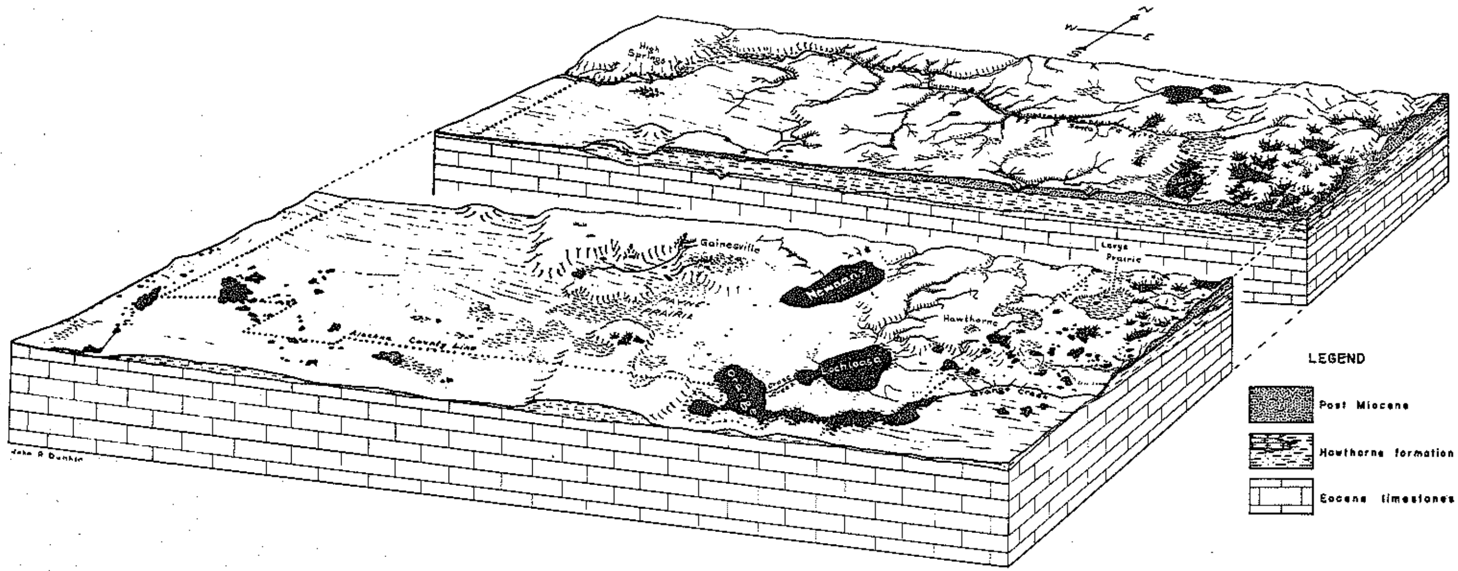

FIG. 2.—Block diagram of Alachua County and vicinity

factors in the behavior of each lake selected for discussion will be undertaken.

Because of the significance of subsurface drainage, brief mention of ground-water conditions in north-central Florida is necessary before discussing the individual lakes. Likewise necessary are comments concerning the major physiographic regions of Alachua County and of areas adjoining that county to the east and northeast.

FLORIDAN AQUIFER

The Floridan aquifer is a part of one of the famous aquifer systems of North America. It contains some Miocene and Oligocene beds but consists mainly of the Ocala (Eocene) and older porous and permeable limestones. Outcrops of the Ocala limestone occur throughout a large region in west-central peninsular Florida. This area of Ocala limestone outcrop is structurally the Ocala arch, an elongate dome with several transverse axes. The Hawthorne formation (Miocene) of phosphatic sands, clays, and limestones forms an aquiclude over the Ocala throughout parts of Florida, making for artesian conditions in various areas of the state. It is the degree of permeability of the Hawthorne formation as compared to that of the Ocala and older limestones that results in artesian conditions. In the region discussed in this report there are very few areas in which Hawthorne sediments will not yield some water to wells. Many lenses and beds of this formation yield considerable quantities of water. Other lenses composed of clay and sandy clay act as an aquifuge.

The hydrostatic pressure level of the ground water in the Eocene and older lime stones is shown in figure 3. The imaginary surface, measured in feet above sea level, expressing the hydrostatic head of water in an aquifer is referred to as the piezometric surface. Thus, as used in this report, the term "piezometric" does not necessarily indicate artesian conditions. In such areas as western Alachua County the piezometric surface is the water table in the Ocala limestone. However, in much of the pleateau of Alachua and Putnam counties, water in the Eocene limestones will rise in tightly cased wells considerably above the aquifer. In the lower areas of the Florida peninsula the pressure is sufficient in the artesian system to raise water above the surface of the ground and thus produce flowing wells.

A piezometric high—called the southern high—occurs in Polk County (east of the city of Tampa, fig. 3); and another high—the northern high—exists in northeastern Alachua, northwestern Putnam, and parts of Clay and Bradford counties (near Santa Fe Lake, fig. 3). The areas of piezometric highs are topographic highs and are underlaid by the Hawthorne formation. In these areas recharge through the Hawthorne is most rapid through sinkholes. The relationship of the piezometric surface of the water in the Eocene limestones to various types of lakes is illustrated in figure 4. In areas of topographic highs the surfaces of lakes that are directly connected by open, underground channels to the Ocala limestone correspond closely with the piezometric surface. For a general treatment of ground-water conditions in central and northern Florida the reader is referred to the report by Cooper *et al.* (1953).

TOPOGRAPHIC REGIONS OF ALACHUA COUNTY

According to Sellards (1912, p. 34), Alachua County can be divided into three physiographic areas: (1) A plateau ranging in elevation from 150 to 200 feet above sea level occurring throughout the north-central and much of the northeastern parts of the county. Santa Fe Lake is located in this plateau. (2) A western plains region developed on the Ocala limestone and varying mostly from 80 to 90 feet in elevation. (3) An area in the south-central and southeastern parts of the county characterized by flat-bottomed lakes and prairies and erosional remnants of the plateau. Orange Lake occurs in this area.

The importance of the Ocala arch in the development of the present topography cannot be overlooked. The Ocala limestone has been uplifted in the western, south-

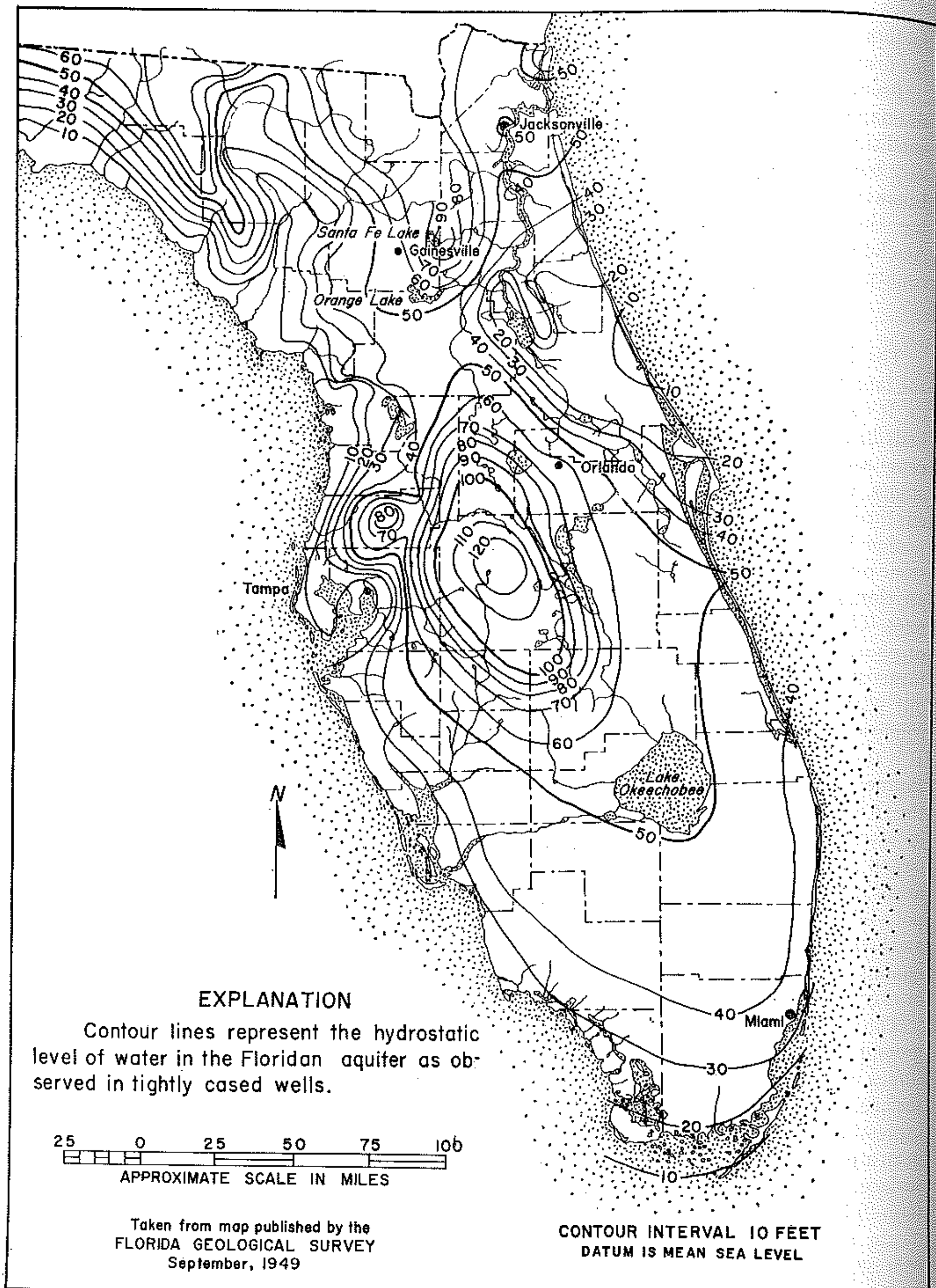

FIG. 3.—Piezometric surface of water in Eocene limestones

central, and southeastern parts of Alachua County as part of the eastern flank of the arch. This structure is the result of both pre- and post-Hawthorne uplift. The Hawthorne formation was laid down as the seas encroached on this area during the Miocene. Hawthorne sediments originally covered all the county but now have been largely eroded away except in the plateau area (fig. 2).

Denudation of the Hawthorne sediments on the Ocala arch resulted in a limestone terrain. As the overlying insoluble sediments of the Hawthorne formation were eroded by surface processes and the Ocala limestone approached, underground drainage became dominant and karst topography developed. The karst surface in western Alachua County has been reduced to a limestone plain coinciding to a former stand of the water table 80 to 90 feet above the present level of the sea. Unaltered remnants of Hawthorne sediments are still to be found underlying hills and slumped into sinkholes. At the present time, the water table in the western plains area of Aalchua County is about 30 to 40 feet beneath the surface of the limestone plain, and karst development has been rejuvenated.

Throughout the plateau, Hawthorne sediments are present. They thicken to the northeast. Pleistocene clayey sands rest unconformably on the Hawthorne formation. As a result, most of the plateau of Alachua County is characterized by stream drainage. Throughout this western part of the plateau (north and northeast of Gainesville, fig. 2), solution features are present but are subordinate. Only a few collapse sinks occur. Prevalent, however, are circular depressions produced by slight slumpage. They can be detected by clumps of cypress trees in an area otherwise forested by pine and palmetto. Subsidence of a few inches to several feet has occurred to produce small basins. Shallow intermittent and permanent lakes are present in many of the depressions.

In the eastern portion of the plateau (from the town of Hawthorne eastward and northeastward, fig. 2), subsurface drainage and solution features again dominate the topography. This region is characterized by hopper-shaped sinks and circular lakes reminiscent of kettle holes in glacial outwash plains. The same formations underlie this part of the plateau as the western plateau section. In fact, throughout much of this area the post-Eocene formations are thicker. The changes in drainage and topography result from an increase in the quantity of calcareous materials in the upper part of the Hawthorne formation and the thicker, coarser, and more sorted character of the overlying sands.

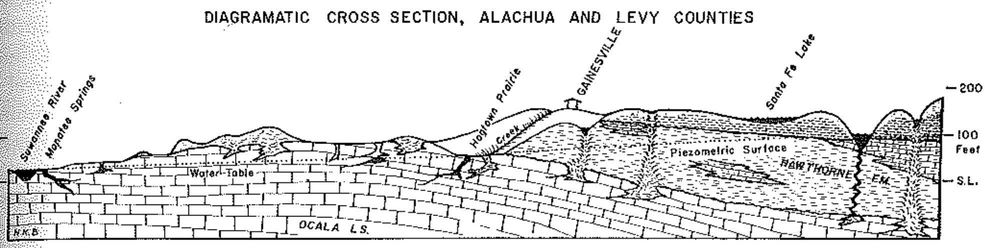

FIG. 4.—Cross section showing relationships of piezometric surface to lakes. Water is indicated by black

ORANGE LAKE

LOCATION, SIZE, AND RECENT FLUCTUATIONS

Orange Lake, located in the southeastern part of Alachua County (fig. 2), is a world renowned fishing and resort lake. For many years this lake has had an important economic influence on surrounding areas because of its value as a tourist attraction as well as its climatic effects. Large citrus groves are concentrated around the southern and southwestern borders.

The watershed of Orange Lake covers 210,000 acres (Rowland, 1957). According to Sellards (1910, p. 66), Newnans Lake at one time drained through Prairie Creek into Orange Lake. Later, Prairie Creek was captured by the development of Paynes Prairie and Alachua Sink (fig. 2). Now, through a system of canals and pumps the drainage from Newnans Lake is channeled back into the drainage area of Orange Lake. The water in Orange Lake normally flows through Orange Creek to the Oklawaha River and thence to the Atlantic Ocean by way of the St. Johns River.

The size of Orange Lake has varied considerably. Over the last 15 or 20 years the lake has covered an area averaging perhaps 16,000 acres. Data collected by the Surface Water Branch of the United States Geological Survey show that during this time the lake surface has ranged in elevation from a high of approximately 61.5 feet above mean sea level in November, 1941, to a low of 50.06 feet in August, 1956. An elevation of approximately 57.5 feet is considered as the normal elevation of the lake surface.

During January, 1954, the lake level began to drop, and by late summer of 1956 Orange Lake covered approximately 5,000 acres, less than one-third its average size. The main channel leading from the lake into Orange Creek dried in the summer of 1955. The principal drainage of the lake after the water fell below the outlet channel was through a large sinkhole in the southwestern part of the lake area. Interested groups began to meet and formulate plans to restore the lake level. However, by the spring of 1958 the lake again had risen to its normal level as a result of abundant rains and a rising water table.

That the low level of water in Orange Lake was due largely to underground drainage through the large sinkhole located in the southwestern part of the lake area is indicated by the fact that Newnans Lake (fig. 2), located higher in the same drainage system and receiving less surface runoff, fell only a fraction of that of Orange Lake. In August, 1956, Orange Lake had lowered 8 feet below normal, whereas Newnans Lake had lowered only 2 feet (Rowland, 1957, p. 116). If evaporation and transpiration over precipitation were the major factors, the water in Newnans Lake should have fallen at least as much as Orange Lake. Observations at the Orange Lake sinkhole showed water draining into the sink and flowing downward into a large opening in the Ocala limestone.

The behavior of Lake Lochloosa likewise indicates the important part played by the sinkhole in the drainage of Orange Lake. Lake Lochloosa (fig. 2) drains through Cross Creek into Orange Lake. At high water the fluctuations of these two lakes are correlative. Usually, the level of Lake Lochloosa is a fraction of a foot higher than that of Orange Lake. However, when the level of Lochloosa falls below 55.4 feet, the elevation of the highest part of the bottom of Cross Creek, the two lakes act independently. During the recent low level of water, after Cross Creek dried in the summer of 1954, Orange Lake dropped more rapidly than Lake Lochloosa. At the lowest stand of the water the surface of Lake Lochloosa was about 4 feet higher than that of Orange Lake proper and 8 feet higher than the water in the Orange Lake sinkhole.

Drainage of lake water into a subterranean passage in limestone is not a new and unique event for Alachua County. Within historic time Alachua Lake, a body of water that covered an extensive area to the northwest of Orange Lake, fluctuated between a shallow lake and a prairie. Prior to its drainage in 1891, Alachua Lake was used as a shipping route for citrus produce. The extensive prairie and marsh that has developed on the lake floor is now known as Paynes Prairie (fig. 2).

The development of such flat-bottomed lake basins and prairies represents a passing phase in the physiographic development of the region. It must be emphasized that the physiographic changes that have taken place in southeastern Alachua County during historic times have been insignificant. But the interest shown by the public concerning the recent low level of Orange Lake stimulates speculation concerning the importance of the ground-water level in the development of major physiographic areas in parts of west-central and north-central peninsular Florida, where pure, permeable limestones occur at the surface throughout extensive areas. That part of Alachua County in which Orange Lake occurs represents one such example in which the ground-water level has played a controlling role in the development of the topography.

IMPORTANCE OF WATER TABLE IN CARBONATE TERRAIN

The behavior of the water table in carbonate terrains is different from that in areas of surface drainage. During normal degradation of a region characterized by surface stream erosion, the water table falls as the area is reduced. This results because the water table is graded to the level of the perennial streams. In contrast, the level of the water table in regions of subsurface drainage is in relation to the elevation of the sites of discharge. The degree of development of the subterranean channels and the permeability of the limestones in a carbonate terrain determine the grade of the water table away from the points or areas of discharge. Thus the level of the water table in limestone terrains may be maintained at nearly the same level or be only slightly lowered during considerable intervals of planation by solution.

A unique example of the changes in behavior of a stream flowing from an area of predominantly surface drainage into a region of subsurface drainage is furnished by the Santa Fe River, which flows along the northern border of Alachua County westward to the Suwannee River (fig. 2). The Santa Fe River begins in a large swampy area north of Lake Santa Fe and is fed by a system of tributaries developed in the plateau area of Alachua and adjoining counties. The headwaters of the Santa Fe River are flowing over relatively impervious materials of the Hawthorne formation and Pleistocene terrace sediments. The source of discharge is the sluggish, surface runoff from the youthful plateau area of pine-palmetto flatlands, swamps, marshes, and lakes. In this region the channel of the stream is above the piezometric surface of the water in the Ocala limestone. To the northeast of High Springs, Florida (fig. 2), at the edge of the plateau, the character of the stream changes abruptly. From High Springs to the Suwannee River the stream is cut into the Ocala limestone and receives discharge from the many springs along its course. The only tributaries are the spring runs. In the short reach of the stream between these two distinctive courses the channel has been eroded practically to the limestone. It is here that the plateau course of the stream suddenly ends in a large circular, sluggish whirlpool. Three miles to the west the subterranean stream is discharged upward through a large orifice. From the point downstream, the Santa Fe is the regional base level of the water table in the surrounding limestone terrain.

It is a recognized fact that the greatest movements of subsurface water, where not channeled by zone of relative impermeability, are the downward movement of the vadose water and the lateral movement of the phreatic water at and immediately below the water table. This would normally result in more active solution of carbonate rock above the water table and to a slight depth beneath it. It should not be inferred that the writers believe that no solution or mechanical erosion takes place below the water table. Some sinkholes have developed from solution below that surface. Many wells drilled at depths below the water table in the Eocene limestones intercepted channels of flowing water. But it is believed that in humid regions of carbonate terrain, solution of carbonate rock in the zone of aeration is most rapid. Thus the water table acts as the level at which or just beneath which rapid solution and mechanical erosion are arrested.

ORIGIN OF ORANGE LAKE BASIN

During the physiographic development of the immediate area surrounding Orange Lake, Hawthorne sediments (Miocene in age) that once completely covered the region were stripped away, exposing in numerous places the Ocala limestone of Eocene age. The occurrence of remnants of the Hawthorne formation prove that the Hawthorne once covered the region. In fact, specimens of *Ostrea normalis* Dall, a characteristic fossil of the Hawthorne formation, were collected in place in an exposure near the west side of Orange Lake. That the Ocala limestone is exposed or is under only a thin cover of sediments throughout most of this region is proved by direct observation of that limestone in place, by abundant residual Ocala limestone boulders and by examination of cuttings from numerous water wells. During the recent low stand of lake water Ocala limestone was exposed in the southwestern part of the Orange Lake Basin.

It should be recognized that in this area some of the contacts as seen today between the Hawthorne formation and the Ocala limestone might not represent the original surfaces of contact. This is indicated by conditions encountered while drilling water wells in some areas of Alachua County. It is not unusual to encounter cavities between the Hawthorne and underlying Ocala limestone. Some of these openings are only a few inches wide, many are several feet wide and, in places, cavities with an observed dimension of 20 feet have been noted. One area where such cavities are numerous is northwest of the city of Gainesville in the vicinity of the Mill Hopper (Sec. 15, T. 9 S., R. 19 E.). Many other examples of such occurrences could be given west of Gainesville and between Gainesville and the town of Alachua. South of Waldo and only a few miles from Orange Lake, openings of as much as 20 feet have been encountered while drilling through remnants of the Hawthorne formation into the Ocala limestone. In most cases these openings have resulted from solution of the upper part of the Ocala limestone. Eventually, slumpage of Hawthorne sediments closes such spaces. At times, slumpage of Hawthorne sediments takes place essentially simultaneously with solution of the Ocala. The resulting contacts, which may later be exposed through erosion or artificial excavations, are not the original surfaces of unconformity between the formations.

As first indicated by Sellards (1910, p. 52 and 63), it is thought that the groundwater table in the Ocala limestone has served as a base level to which the plateau is being reduced. The piezometric surface of the ground water of the Eocene limestones roughly corresponds to the level of the flat-bottomed depressions in south-central and southeastern Alachua County. An examination of figure 3, based on a map published by the Florida State Geological Survey, indicates that the piezometric surface of the Eocene limestones in the area of Orange Lake is from 50 to 60 feet above sea level. The average height of the water surface of the lake is considered to be approximately 57.5 feet. During the spring of 1958, after Orange Lake had risen to its average height, the water table in cased wells surrounding the lake was found to correspond closely with the surface level of the lake. During the recent low stand of water in the late summer of 1956, the surface elevation of Orange Lake reached a low of 50.06 feet above sea level. The greatest depth of the lake water was 4 feet. Water in the sinkhole, through which the lake was being drained by a small stream scoured into lake-bottom sediments, had a surface elevation of 46.30 feet above sea level. At that time in the immediate area the water table had fallen to an elevation of approximately 44 feet (Rowland, 1957, p. 118). Thus the piezometric surface was essentially two feet below the lowest part of the lake basin during the dry period.

Likewise, the extensive flat bottom of Paynes Prairie, located northwest of Orange Lake, corresponds closely with the water table. However, natural conditions in the prairie do not exist because drainage canals have been dug and huge diesel-driven, centrifugal pumps installed to control flood conditions. The level surface of the prairie averages between 53 and 54 feet above sea level. The piezometric surface shown on figure 3 is indicated to be between 50 and

60 feet above sea level. In 1954 the water stood 3 feet beneath the flat surface of the basin in a well, drilled in the central part of the prairie, on property owned by Mr. Bolivar Kincaid. When measured again in 1956, the water level in that well had dropped to a depth of 7 feet. It presently stands just beneath the surface of the prairie. The water plane in cased wells, drilled near the prairie, corresponds closely to the surface of the prairie.

Some of the large flat-bottomed prairies and lakes in Alachua County are solutional surfaces developed on the Ocala limestone; others are erosional surfaces developed through solution of lenses of calcareous materials of the Hawthorne formation (e.g., Newnans Lake Basin); others are erosional surfaces developed on insoluble Hawthorne sediments; and still others are depositional surfaces resulting from the filling of solution features formed in the Ocala. Examples of various types of these depressions have been given elsewhere (Pirkle, 1956). Regardless of type, the flat-bottomed depressions in south-central and southeastern Alachua County occur at approximately the same elevation (Arredondo Quadrangle). This elevation roughly corresponds to that of the water table in the Eocene limestones. Because the flat-bottomed depressions which developed on the Ocala limestone roughly correspond in elevation with the water table in the Eocene limestones and because these lower surfaces constitute a large part of the area of the region, it is believed that the water table is controlling the level of degradation in the present erosional cycle.

LAKE-BOTTOM SEDIMENTS

The flat bottoms of such lakes as Orange Lake may become blanketed with sand and clay transported into the water body by rainwash and streams and deposited along with considerable organic matter. These sediments produce an aquiclude. As the water table in the Ocala aquifer gradually drops during long periods of drought or on becoming readjusted to discharge, the lake water is held above the ground-water level. Under sufficient hydrostatic pressure this material will fail and be flushed into solution channels in the limestone. Once the subterranean outlets are opened, the lake water will adjust to the level of the water table in the limestone unless the sinks again become plugged. Water-table lakes with bottoms developed in permeable materials and with no bottom cover of impervious sediments will rise and fall with the ground-water level.

Most of the bottom of Orange Lake is covered by a sapropel of fine clastic sediments and organic material. In order to determine the nature of the bottom sediments, six lines of borings, spaced so as to give maximum coverage of the lake bottom, were made by the Soil Conservation Service (Rowland, 1957, p. 118). An examination of samples from these borings indicated that the bottom material is sufficiently impermeable to prevent appreciable leakage through the bottom of the lake bed. These impervious bottom sediments are known to be breached by the large sinkhole in the southwestern part of the lake area.

Precipitation in 1953 was 73.3 inches (fig. 1). This was by far the greatest annual precipitation for the period shown on the graph. The following year, when the lake level began to drop, was the driest year in the 21-year period. The dry year of 1954 was followed by two additional, consecutive years of low rainfall. A filled lake basin, resulting from abundant rain followed by a long dry period with the attendant lowering of the water table in the underlying Ocala limestone, resulted in conditions favorable for the flushing out of sink fillings. Drainage of lake water into such an unplugged sink was the major factor in the low stand of Orange Lake in 1956. During the spring of 1958, with increased precipitation, the water table in the limestone rose several feet and presently corresponds essentially to the lake level. Only insignificant amounts of water, if any, are now being discharged into or from the sink.

SUMMARY OF ORANGE LAKE

The basin of Orange Lake has resulted from the erosion of the plateau to the water table in the Ocala limestone. Such lake basins are areas of large confluent sinkholes. At times of drought, lake water may be held above the water table by lake sediments that impede subsurface drainage. Abrupt lowering or dissappearance of this type of lake is due to breaching of the lake sediments by the collapse of underlying solution cavities or by the flushing out of sediment plugs in sinkholes. The hydrostatic head resulting from lowering of the water table is undoubtedly the cause of the breach. The recent low level of Orange Lake resulted from the unplugging of a large sinkhole.

SANTA FE LAKE

LOCATION AND SIZE

Santa Fe Lake, consisting of Big Santa Fe Lake, Little Santa Fe Lake, and Melrose Bay, is located in the northeastern part of Alachua County and adjacent Bradford County (fig. 2). It covers an area of approximately 8 square miles and does not experience the extreme fluctuations recently undergone by Orange Lake. The lake occurs in a closed basin, with drainage during extremely high water stages into the Santa Fe River. No major surface stream empties into Santa Fe Lake.

COMPARISON OF LAKE LEVEL TO PIEZOMETRIC SURFACE

The surface elevation of the lake water is much higher than the piezometric surface of the water in the Eocene limestones. The lake surface in June, 1958, was 141 feet above sea level. The piezometric surface (fig. 3) is about 80 to 90 feet above sea level in the area of the lake, or roughly 55 feet below the lake level.

The piezometric surface was measured in a well, drilled on the west side of Little Santa Fe Lake in November, 1954, on property owned by Mr. George Rippey. Ocala limestone was encountered at a depth of 167 feet. This well was cased into that limestone. The surface elevation of the well is 158.51 feet. Water from the Ocala limestone rose to within 80 feet of the land surface. Thus the piezometric surface was approximately 62 feet below the water level of the lake at the time the well was completed.

NATURE OF SEDIMENTS

It is evident that the lake water is held above the principal aquifer, the Ocala limestone, by impervious sediments. The following summary of a log made from cuttings collected from the Rippey well (SW. ¼, Sec. 21, T. 8 S., R. 22 E.) indicates the materials occurring in the immediate vicinity of Santa Fe Lake:

Depth (Feet)	Material
0–43	Pliocene(?) and Pleistocene sands and clayey sands
43–167	Hawthorne formation
167–199	Ocala limestone
Total 199	

The relatively impervious materials impeding downward movement of water in the area of Santa Fe Lake are the Hawthorne sediments and the overlying clayey sands. The dominant materials of the Hawthorne formation are mixtures of sand, clay, phosphate particles, and carbonate. The carbonate content throughout the upper and middle parts of the Hawthorne is minor but becomes abundant in the lower part of the formation.

Superimposed on the Hawthorne formation are reddish to yellowish clayey sands or sandy clays. These sediments have often been considered as a part of the Citronelle formation. A veneer of loose surface sands, ranging in thickness generally from one to ten feet, blankets the region. The red and yellow "Citronelle" sediments are sufficiently impermeable in areas to effectively retard downward migration of ground water. They constitute an important part of the impervious materials responsible for conveying rain water seeping underground into the Santa Fe Lake Basin. Likewise, these clayey sands play an important part in the behavior of other lakes in the region by impeding downward flow of meteoric water and increasing lateral movement of ground water through surficial sands to low areas and from one lake basin to another. There appears to be significant leakage from Santa Fe Lake through the Pleistocene terrace sands toward lower lakes to the east.

An extensive swamp, covering an estimated 12 square miles, borders Santa Fe Lake on the north. The Santa Fe River rises in the swamp and flows along the northern border of Alachua County to the Suwannee River and thence to the Gulf of Mexico. Drainage into the swamp and Santa Fe Lake from the surrounding youthful, marine Pleistocene terrace is extremely

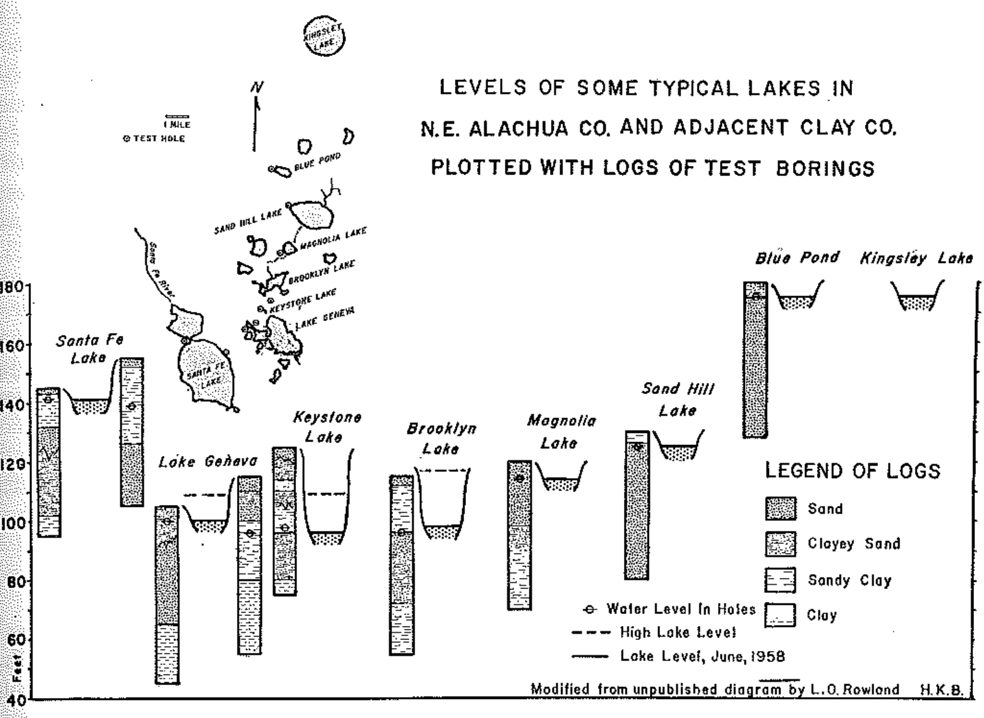

FIG. 5.—Diagram of lake levels of selected lakes with index map

LAKE BEHAVIOR

The lake level of Santa Fe has not varied greatly despite the recent climatic fluctuations. During the period from 1954 through 1956 the level of Santa Fe dropped only an estimated 3 feet, whereas the surface levels of some lower, neighboring lakes with conduits to the Ocala limestone dropped considerably. These latter lakes in some cases went dry. The surface level of Lake Brooklyn, located only about 4 miles northeast of Santa Fe, lowered more than 20 feet (fig. 5).

sluggish, resulting in a reasonably stable lake elevation. Little, if any, water is discharged from the lake downward into the underlying Ocala aquifer. Certainly no direct conduit exists.

SUMMARY OF SANTA FE LAKE

The water of Santa Fe Lake is held above the main aquifer, the Ocala limestone, by impervious materials. The red and yellow clayey sands and sandy clays found outcropping throughout extensive areas in east-central and northeastern Alachua County supplement the action of the Hawthorne formation as an aquiclude. An extensive swamp occurs to the north of the lake. The Santa Fe River rises in this swamp. At very high water level Santa Fe Lake overflows into the swamp and river. During periods of drought it appears that sufficient water stored in swamps, marshes, and Pleistocene sands surrounding the lake drains into the lake to largely offset losses from evaporation, transpiration, and seepage. Because of these conditions, Santa Fe Lake did not experience extreme fluctuations of lake level during the recent drought.

LEVYS PRAIRIE LAKES

LOCATION AND BEHAVIOR

Levys Prairie is located in a recharge area of the Eocene limestones in western Putnam County (fig. 2). It is a region of wet, marshy land covering approximately 5 square miles and surrounded by sand hills. Water in Levys Prairie fluctuates markedly during periods of excessive rainfall and drought. A few years ago much of the bottom of this prairie was covered with water. During the spring of 1955 the level of the water started to drop. Not until October, 1957, did the water begin to rise. At the present time there are several disconnected water bodies covering a total area estimated at no more than 1 square mile. Two of these lakes, located in the western part of the prairie (fig. 2), were investigated during this study.

The most northern of these two lakes dried completely during the recent low stand of lake water. In the last stages of its depletion, water from this lake flowed and seeped into the other. Likewise, the water in the southern lake eventually disappeared with the exception of a small, shallow pool. This small pond was investigated and determined to be a sinkhole with a solution channel at the bottom approximately 3 feet wide leading downward. Lake water drained through this sink as the lake lowered during the recent drought period. Examination made on July 17, 1958, showed the sink had become plugged or partially plugged with lake sediments consisting of clastics and organic matter. At that time the lake water over the sink was 12 feet deep.

RELATIONSHIP TO PIEZOMETRIC SURFACE

The surface of Levys Prairie ranges in elevation from 90 to 100 feet above sea level, except in the western part where the elevation is from 80 to 90 feet (Hawthorn and Interlachen quadrangles). According to figure 3, the piezometric surface in the region of Levys Prairie is close to 80 feet above sea level. Observations made by members of the Ground Water Branch of the United States Geological Survey in May and July of 1957 showed that the piezometric surface of the water in the Eocene limestones in and near the prairie roughly coincided with the lower parts of the prairie bottom. The surface elevation of one cased well, located in the southeastern end of the prairie, is 88.99 feet. The elevation of the groundwater level, measured in the well on July 18, 1957, was 79.13 feet above sea level or roughly 10 feet beneath the land surface. The Ocala limestone was encountered in this well at an estimated depth of 164 feet, 75 feet below sea level.

ORIGIN OF BASIN AND FACTORS IN LAKE BEHAVIOR

Even though a considerable thickness of Hawthorne materials separates Levys Prairie from the underlying principal aquifer, the Ocala limestone, the basin of the prairie is due to solution. Solution features dominate the topography of this part of Putnam County. Solution of underlying carbonate rock, both in the Hawthorne formation and Ocala limestone, has resulted in slumpage and collapse that breached relatively impervious sediments such as the red and yellow clayey sands and sandy clays allowing more rapid downward movement of ground water. The descending lake water seeps into pervious sediments of the underlying Hawthorne formation as well as into the principal aquifer, the Ocala limestone.

Levys Prairie lakes were selected specifically because their origin can be proved. They occur in Levys Prairie, which undoubtedly was formed as a result of solution. Sloping land leads down from all directions into the prairie. That Levys Prairie is a solution basin is further evidenced by the discovery of a sink leading downward through Hawthorne limestone. Solutional activity in and near the prairie is still active. Within the past few years two sinks developed on the western edge of this prairie through collapse of overburden into solution cavities.

A change in facies from impervious clastics to limestone is known to occur in the Hawthorne formation at shallow depths in this area. Limestone was encountered in 1953 while dredging a canal into the southernmost of the Levys Prairie lakes. In places this limestone is silicified.

The downward drainage of lake water is through partially plugged solution channels and permeable Hawthorne sediments. During periods of drought the drainage of the lake waters into the Ocala limestone continues. This results in a continuous drop of the lake level. At times of abundant rainfall the lake levels rise considerably because the water supply from runoff and seepage from the surrounding sand hills is increased, whereas the discharge from the lake is at a rather constant rate.

It is believed that many other lakes in northwestern Putnam County have origins similar to Levys Prairie lakes. Some of these lakes are rather freely connected with the underlying permeable sediments, principally the Ocala limestone. The fluctuations of such lakes would be correlative with the piezometric surface of the water in the Eocene limestones. Regardless of aerial extent, during droughts these lakes would drop with the water table. At times, sinks become clogged with lake sediments restricting the passage of water. During severe droughts these lakes may be perched above the water table. Hydrostatic pressure, under such circumstances, may force out the plug. The lake level then would fall rapidly.

An example of a lake believed to be directly connected with the Ocala aquifer is illustrated by a small lake occurring in the Devil's Pit, a steep-sided sinkhole, located in Sec. 13, T. 10 S., R. 23 E., just a few hundred feet north of Lake Galilee. The surface level of both lakes is between 80 and 90 feet above sea level and corresponds approximately with the piezometric surface of the water in the Eocene limestones. By use of SCUBA diving units, the lake in the Devil's Pit was explored to a depth of 135 feet. The bottom at the center is flat and about 80 feet beneath the water surface. This level bottom slopes off at the sides to greater depths. It is significant to note the contrast in form of the funnel shape of the subaerial sink developed in the "Citronelle" formation and the expanding subaqueous portion developed in the limestones, shales, and sandstones of the Hawthorne. The sink is at least three times larger in diameter at the bottom than at the water level. The lower portion of the Hawthorne section in this sink is predominantly of insoluble sandy clays, whereas in the upper part calcareous sediments are abundant. Obviously, the sink has developed through collapse of the Hawthorne into a large solution cavity below the depths investigated. This would be in the Ocala limestone. The lake has been explored to a depth of 45 feet below sea level. The upper surface of the Ocala limestone in this region usually is encountered at an elevation ranging from 35 to 75 feet below sea level.

SUMMARY OF LEVYS PRAIRIE LAKES

The basin of Levys Prairie has resulted from solution of underlying carbonate rock. Slumpage due to solution has breached relatively impervious sediments such that downward drainage to the Ocala limestone is possible. The southernmost of the two western lakes in the prairie is known to be connected through a sinkhole and lake sediments with underlying pervious materials. The lake level rises with excessive rainfall because downward drainage into rocks is restricted. Over long periods of time these lakes conform closely with the piezometric surface of the water in the Ocala limestone. During droughts which result in a falling level of the piezometric surface, the lakes may or may not become perched because of retardation to subsurface drainage by sediments plugging the channel or channels of discharge. Lake fluctuations, to some extent, represent changes in the pressure level in the aquifer system. However, since these lake basins and sinkholes are sites of recharge of the aquifer, at times of greatest precipitation the lake water stands above the hydrostatic head in the artesian system.

AREAS OF LEVYS PRAIRIE LAKES AND ORANGE LAKE CONTRASTED

Brief comparison of the stage of physiographic development of the areas in the vicinity of Levys Prairie lakes and Orange Lake should be made. The sand-hill region of Putnam County surrounding Levys Prairie is in a much earlier stage of the erosional cycle than the area surrounding Orange Lake. The area of northwestern Putnam County with the many hopper-like depressions, open sinks, subsurface drainage, and relatively rough topography is in a stage of submaturity. Apparently, Levys Prairie has been reduced essentially to a temporary base level, the hydrostatic level of the water in the underlying limestones. In contrast, the region surrounding Orange Lake is characteristic of a later stage in the erosional cycle. The water table in the Eocene limestones is the base level to which high areas are being reduced and low areas are being filled. This region is characterized by numerous, extensive flat-bottomed prairies and lakes, such as Paynes Prairie and Orange Lake, corresponding closely with the water table. Sinks, resulting from solution in the Ocala limestone, have been filled to the water table with sediments transported by rainwash and streams. There are abundant filled sinks in the region and only a very few open sinks.

BRIEF COMMENTS CONCERNING OTHER LAKES IN THE CENTRAL LAKE REGION

In western Putnam County and adjoining Clay County to the north, lakes are numerous. In fact, this is a part of the area that at one time was known as the Lake Region of Florida. The Levys Prairie lakes were selected from this area for brief discussion because their origin is known. It is believed that a large number of the other lakes in the immediate area have similar origins. However, for a treatment of all the lakes other factors would have to be considered. In some parts of this lake section, for example in Clay County, shell marls of Upper Miocene and Pleistocene ages have been encountered many times in drilling water wells. Solution of such carbonate rock must be considered in the origin of some of the lake basins. Also, certain flat swampy and marshy areas that at times contain shallow lakes may represent tidal inlets associated with a Pleistocene high stand of the sea. And still other swampy and marshy areas appear to represent stream valleys that were alluviated during encroachment by Pleistocene seas. Differential compaction of sediments and initial irregularities of a Pleistocene sea floor may be of some importance in the formation of low areas.

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