

# **The Causes of Sinkholes: Man and Nature, The Culprits**

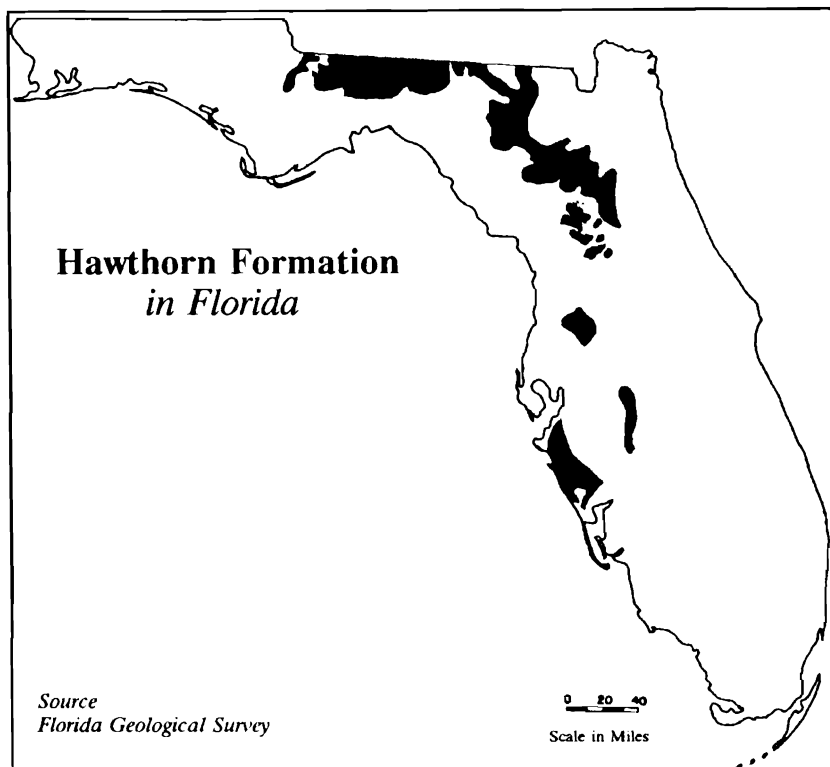
*Louis A. Paganini  
Department of Geography  
University of Florida*

Most of Florida's present day sink holes, in populated areas, are being formed and are appearing because of a disregard for, or a lack of understanding of, underground drainage by engineers, planners, developers and others. Through either reckless or deliberate action they impede, alter, or induce a new course for subsurface water movement in order to construct roads, highways, and buildings or to otherwise improve an area. Little thought is given to the erosive forces of even the smallest amounts of uncontrolled water. Even less thought is given to the great property damage or the great monetary loss that might occur. No thought is given the possible displacement of human beings when their homes are lost in sinkholes--sinkholes that develop from redirected water flow or from water which escapes from swimming pools and sewer lines.

This thoughtlessness in regard to the formation of sinkholes in populated areas may not be solely the fault of planners. Until recently, literature dealing with sinkholes considered only the physical, or natural, aspects of their formation. It is commonly held that their occurrence is a natural phenomenon induced by natural causes. Seldom have the actions of people been considered responsible for the sinkhole formation.

## **The hawthorn formation**

Underlying Central Florida and extending to great depths are limestone deposits (the "Avon Park/Lake City limestone") of marine origin. These are overlain by other limestones of the Ocala formation in which much of the solution of caverns occurs. The Hawthorn formation (Figure 1), a mantle of unconsolidated sands and clays, lies uncomfortably over the Ocala limestones and extends to depths of over 200 feet. A mantle of recent sediments consisting of variegated, thinly laminated and cross bedded sands, gray to white in color, covers the Hawthorn layer. The Hawthorn layer contains many pure deposits of montmorillonite, a clay used chiefly for cat litter, among whose characteristics is the property of great water absorption. This



clay, at one time, covered most of Florida. When saturated, it swells and can form a layer through which water has difficulty penetrating. When ground water percolates through the surface mantle, clays, marls and phosphates are removed and are deposited in an impervious layer forming an aquiclude over thick layers of limestones, several thousands of feet in depth, which underlie almost the entire state of Florida. The limestones are porous layers formed during the Eocene. They and their impenetrable aquiclude form an artesian aquifer under the state of Florida. These limestone layers are said to contain more water than is held in all the Great Lakes put together (Marcus, 1975).

## **Sinkhole formation**

Limestone is soluble in acid laden groundwater. The water enters the limestone through vertical fractures and areas in which the impermeable layer is discontinuous. It dissolves the limestone leaving tubes, channels, and caverns in the remaining limestone.

Sinkholes are formed when surface materials drop into hollow caverns in the subsurface limestone. Contrary to general opinion, they are not always formed through the cataclysmic collapse of a cavern roof. They are more commonly formed by a process called "revelling," in which surface materials collapse and are sucked into the hollow caverns that have been carved into the limestone layers. A "swallow hole" develops and becomes enlarged where running ground water enters a cavern at the juncture of two crossing fractures. Materials from the surface layers drop into the swallow hole creating a domed cavity above the aquiclude. The revelling process continues increasing the size of the dome in width and height, forming a shape that resembles an upright light bulb. Vibrations in the earth (caused by natural and human activity), movement of water below the cavity, and spalling of its sides enlarge the dome until the shear strength of the overburden cannot support it. Then all comes crashing down, falling, sliding and being sucked into the swallow hole. Movement of materials continues until the cavern in the limestone is filled or until the sides of the sinkhole reach a comfortable angle of repose.

## **Florida sinkholes**

A review of precipitation records indicates a severe drought had occurred in the Orlando area in recent years. Many lakes had gone completely dry. In those months of dryness, a decided increase in water consumption occurred. The lack of rainfall necessitated a large use of water from city and private wells for watering lawns and for irrigation. The water pumped from the limestone aquifer caused a serious draw down, providing circumstances conducive to the formation of sinkholes. The removal of water decreased the cohesive quality of the soil, facilitating the collapse of revell cavities with their encompassing soils.

**The Winter Park Sinkhole.** On May 7, 1981, a Friday afternoon, a woman in Winter Park, Florida looked out her kitchen window in

time to see a 40 foot sycamore disappear into the ground. She describes it as going down with a "whoosh." Within a period of hours, a sinkhole had opened in the ground that measured approximately 350 feet in diameter, slightly longer on its east/west axis and slightly shorter on the north/south axis.

According to observers, the hole appeared to measure approximately 75 feet across, with perpendicular sides, after its initial collapse. The sycamore had been growing in the center of the area where the hole appeared. It widened over a period of hours and assumed the shape of a shallow bowl about 60 feet deep. In the center of the bowl a perpendicular swallow-hole could be seen. The limestone in this particular region lies 200 feet below the surface.

The area in which the sinkhole developed is historically known as Lake Menasen. It is situated in one of the lowest portions of the city. It is, at present time, a marshy area that drains surrounding blocks through a culvert system. Through time, much of it has been filled in by the city of Winter Park with landfill materials, refuse, and sands from borrow pits. The filling was done so that an apparently useless marsh could be converted to usable land. Parts of it were made stable enough to sell as commercial property. Much of it remained as marsh and the remainder was used as a public park. Two baseball diamonds and a swimming pool were constructed.

It is precisely the conversion from pure marsh to commercial fill-land and recreational property in a heavily populated area which led to the premature collapse of the sinkhole. Before its reclamation, the marsh most likely served as a recharge area for the limestone aquifer below. The collected water percolated gently through the aquiclude into the porous Floridian aquifer. Faulty construction of an olympic sized swimming pool lead directly to the catastrophic development of the Winter Park Sinkhole.

Swimming pools are constructed with a necessary drain placed in their deepest portions. The pool in Winter Park was done in like manner, except the drainage installation proved inadequate. It developed an enormous leak shortly after completion. It had been known for ten years that the pool was losing many gallons of water each day and the pool was refilled constantly. Because the pool was public property and the city owned the water supply, it was probably thought cheaper to fill the pool than to dig out and replace the drain assembly.

Two weeks before the sinkhole collapsed one of the pool caretakers discovered a slight subsidence in the soil around the south end of the pool. He probed with a long rod and felt a cavity in the soil below, but at the time did not realize the size or the seriousness of the cavity. He neglected to report it.

After the collapse of the sinkhole, a cave was discovered beneath the swimming pool that extended half its length and to a depth of twenty feet below its bottom. The leaking water from the drain area had carved a channel along the top of the Hawthorn layer southward to a point over the fissure created by the crossed fractures and down through a solution tube that had developed. A swallow hole enlarged in the limestone and, over it, a revell cavity opened up. A cavity shaped like an enlarging light bulb developed in the soft overburden. Heavy vehicular traffic, including large trucks, on the four lane highways that border the sinkhole area on three sides contributed a great amount of tremor to the subsurface sands, causing a continual sifting and spalling to occur. The leakage of many gallons of water per day removed the steadily sifting sands to the solution channel. When the thickness of the dome became too thin to bear the weight of the overburden, the structure collapsed and within hours filled the caverns in the limestone.

At the immediate opening of the revell hole, after the sycamore tree had dropped in, a precipitous cavity, not too large in diameter, was revealed. Within seconds, it continued to enlarge and in the hours that followed it opened to a diameter of around 325 feet. Four commercial businesses, one private dwelling, two streets, telephone cables, sewer pipes, water lines, three new automobiles and one camper disappeared into the hole. The pool remained cantilevered over its cavity until the next day when its structure could no longer hold the weight of the water contained in its bowl. Thousands of gallons of water were catapulted into the chasm creating even more instability and havoc. After a year and a half, the sinkhole was more or less stable and is filled with water within twenty feet of its rim.

**Maracaibo Sinkhole.** On July 5, 1982, in south Gainesville, Florida at the Maracaibo Apartments, a student complex, a cavity opened up in the parking lot. In the late evening, the blacktop began to settle beneath the wheels of a brand new Oldsmobile. By ten o'clock the front wheels of the auto were submerged in the pavement. Residents, observing the event, attempted to pull the car from the ground when

the pavement gave way and the car plummeted into the earth. The plunge ended with the car in a nose down position with its rear end 30 feet below the pavement. The front end of the vehicle wedged itself tightly into the swallow hole, thereby preventing any further sloughing of material into the hole. The next day more sand fell from the sides and completely covered the car. The car remains in the hole.

The circumstances leading to the formation of the Maracaibo sinkhole were similar to those that preceded the collapse of the Winter Park sinkhole. The area in which the Maracaibo apartments was built was a low area of subsidence in which there was evidence of sinkhole activity. All of the waters of that portion of south Gainesville drained into the lowland swamp. The builders brought in many loads of fill dirt, filling in the northern half of the swamp area. They recovered it and made it, or so they thought, a suitable foundation on which to construct an apartment complex. The fill raised the contour 25 feet above the original bottom of the swamp and rerouted the flow of drain water. Also, on the southern edge of the fill, a swimming pool was constructed and it, like the Winter Park pool, developed a leak in its drain. Many gallons of water were lost for a period of three years. No estimate was ever made as to the amount lost each day. It was noted that there was a substantial loss and the pool kept filled.

Engineers and sinkhole specialists determined that the surface of the limestone, at this point, was 40 feet below the parking lot. Leaking water from the swimming pool had worked its way downward and along the top of a thin aquiclude in a northward direction and opened a solution pipe in an area of two crossing fractures.

A rell cavity opened over the swallow hole and was aided in its enlargement by the movement of traffic in the parking lot causing ground tremor. The spalled and sifted sands were removed by the steady stream of pool drain water. The cavity continued to enlarge until nothing remained in the dome area except its blacktop roof. All that was needed for its collapse was the weight of a vehicle.

---

Fortunately, the Maracaibo sinkhole was not too large. The management had little difficulty having it filled. The automobile plugged the hole, stopping any further enlargement. Engineers plugged the hole with a mixture of cement and sand and topped it with asphalt.<sup>1</sup>

## Conclusion

In recent years, many other sinkholes have opened up in the Winter Haven, Castleberry, and Gainesville areas. The descriptions of these are beyond the scope of the current paper; but, their occurrences can all be attributed to the same causative factors as the sinkholes reported above. All developed mainly through redirection of surface water flow, leaking drainage, water and sewage systems and in many cases, heavy traffic in their vicinities. Nature provided the porous limestone, fractures, solution channels, and vacant caverns. All of these sinkholes may have developed in time, but, Man's cultural activity clearly hastened their advent.

## References

Marcus, Robert B. (1975). *Florida: A Geographical Approach*, (Dubuque, Iowa: Kendall/Hunt Publishing Co.), p. 64.

---

<sup>1</sup> The sinkhole at the Maracaibo apartments attracted many curious sightseers. Among them were hordes of reporters, television technicians, and experts of every kind. Much discussion ensued among these experts (some of which was pertinent and some of which was not). Many experiences were recounted to the reporters; among these was the revelation from a plumber employed by the city of Gainesville, Florida stating that the municipal pool at Westside Park has been losing a foot of water everyday for the past few years. No estimation was given as to the number of gallons, but the pool is of olympic size and the amount of one foot of drainage per day can be easily determined. Upon examination of the berm and the grassy areas to the south of the swimming pool a definite subsidence can be detected.

The pointing out of the leakage, the consequences of the water loss, the explanation of the soil subsidence, the warning of the disaster that appears imminent were all to no avail. No one with any responsibility feels that it can happen here. "Sinkholes," they say, "only happen under natural conditions."