Sinkholes

What is a Sinkhole?

Sinkholes are part of the slow, natural process of erosion in Florida's limestone terrain that occur over thousands of years. These common geologic phenomena generally occur where the limestone is within a few hundred feet of the land's surface.

Though most are only 10 to 12 feet in diameter, sinkholes have been known to expand to hundreds of feet in diameter. Many of central and north Florida's lakes actually are the result of old sinkholes.

A sinkhole, also known as a sink, shake hole, swallow hole, swallet, doline or cenote, is a natural depression or hole in the surface topography caused by the removal of soil or bedrock, often both, by water. Sinkholes may vary in size from less than a meter to several hundred meters both in diameter and depth, and vary in form from soil-lined bowls to bedrock-edged chasms. They may be formed gradually or suddenly and are found worldwide.

A sinkhole may capture surface drainage from running or standing water, but may also form in high and dry places in a certain location.

The mechanisms of formation involve natural processes of erosion or gradual removal of slightly soluble bedrock (such as limestone) by percolating water, the collapse of a cave roof, or a lowering of the water able. Sinkholes often form through the process of suffosion. Thus, for example, groundwater may dissolve the carbonate cement holding the sandstone particles together and then carry away the lax particles, gradually forming a void.

A sinkhole is an area of ground that has no natural external surface drainage – when it rains, all of the water stays inside the sinkhole and typically drains into the subsurface. Sinkholes can vary from a few feet to hundreds of acres and from less than 1 to more than 100 feet deep. Some are shaped like shallow bowls or saucers whereas others have vertical walls; some hold water and form natural ponds. Typically, sinkholes form so slowly that little change is seen in one's lifetime, but they can form suddenly when a collapse occurs. Such a collapse can have a dramatic effect if it occurs in an urban setting.

Sinkholes are common where the rock below the land surface is limestone, carbonate rock, salt beds, or rocks that can naturally be dissolved by ground water circulating through them. As the rock dissolves, spaces and caverns develop underground. Sinkholes are dramatic because the land usually stays intact for a while until the underground spaces just get too big. If there is not enough support for the land above the spaces then a sudden collapse of the land surface can occur. These collapses can be small, as this picture shows, or they can be huge and can occur where a house or road is on top.

The most damage from sinkholes tends to occur in Florida, Texas, Alabama, Missouri, Kentucky, Tennessee, and Pennsylvania. The picture shows a sinkhole that quickly opened up in Florida, apparently eating a swimming pool, some roadway, and buildings.

Sinkholes may capture surface drainage for running or standing water, but may also form in currently high and dry locations. The state of Florida in the USA is known for having frequent sinkholes, especially in the central part of the state. The Murge area in southern Italy also has numerous sinkholes. Sinkholes can be formed in retention ponds from large amounts of rain.

Sinkholes are usually but not always linked with karst landscapes. In such regions, there may be hundreds or even thousands of sinkholes in a small area so that the surface as seen from the air looks pock-marked, and there are no surface streams because all drainage occurs sub-surface.

Sinkholes have been used for centuries as disposal sites for various forms of waste. A consequence of this is the pollution of groundwater resources, with serious health implications in such areas.

Sinkholes also form from human activity, such as the rare but still occasional collapse of abandoned mines in places like West Virginia, USA. More commonly, sinkholes occur in urban areas due to water main breaks or sewer collapses when old pipes give way. They can also occur from the over pumping and extraction of groundwater and subsurface fluids.

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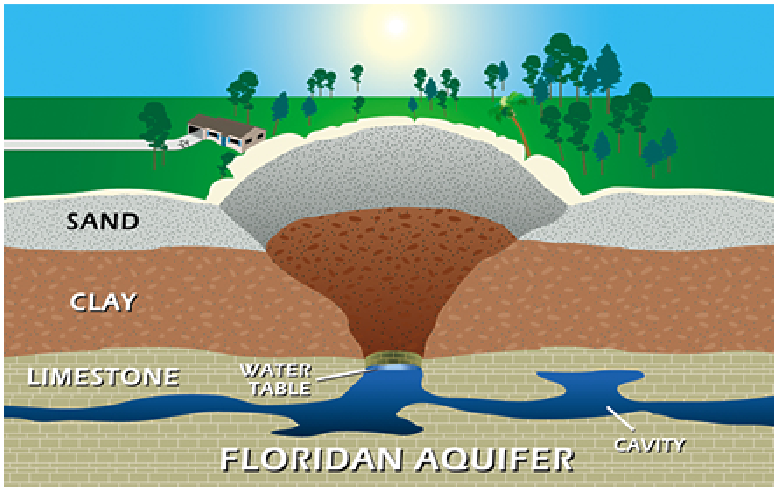
Many sinkholes are also found in Northern Michigan. These are prominent in Alpena County in Northeast Michigan. In Lachine, Michigan you can find up to five very deep sinkholes within two miles of each other. Alpena's visitor information cites their sinkholes as an attraction for visitors to the area. In August 1998 a 16 year old Alpena boy survived a 200+ foot fall in an open sinkhole 3/4 a mile off of Leer road in Lachine, Michigan (The Alpena News 8-21-1998). A majority of sinkholes in Alpena are also found underwater. Many divers explore these on a regular basis.

When sinkholes are very deep or connected to caves, they may offer challenges for experienced cavers or, when water-filled, divers. Some of the most spectacular are the Zacatón cenote in Mexico (the world's deepest water-filled sinkhole), the Boesmansgat sinkhole in South Africa, Sarisariñama tepuy in Venezuela, and in the town of Mount Gambier, South Australia. Sinkholes that form in coral reefs and islands that collapse to enormous depths are known as Blue Holes, and often become popular diving spots.

The overburden sediments that cover buried cavities in the aquifer systems are delicately balanced by groundwater fluid pressure. The water below ground is actually helping to keep the surface soil in place. Groundwater pumping for urban water supply and for irrigation can produce new sinkholes In sinkhole-prone areas. If pumping results in a lowering of groundwater

How sinkholes form

Removing too much groundwater can leave underground holes, leading to sinkholes



Rainfall percolating, or seeping, through the soil absorbs carbon dioxide and reacts with decaying vegetation, creating a slightly acidic water. That water moves through spaces and cracks underground, slowly dissolving limestone and creating a network of cavities and voids. As the limestone dissolves, pores and cracks are enlarged and carry even more acidic water. Sinkholes are formed when the land surface above collapses or sinks into the cavities or when surface material is carried downward into the voids.

Drought, along with resulting high groundwater withdrawals, can make conditions favorable for sinkholes to form. Also, heavy rains after droughts often cause enough pressure on the ground to create sinkholes.

Sinkholes can be triggered by human activities such as:

- Overwithdrawal of groundwater
- Diverting surface water from a large area and concentrating it in a single point
- Artificially creating ponds of surface water
- Drilling new water wells

In urban or suburban areas, sinkholes are hazardous because they can destroy highways and buildings. Sinkholes also can cause water quality problems. During a collapse, surface waters may leak into the aquifer, our underground source of drinking water.

A sinkhole opened in the middle of a highway, near a residential area in 2004.

Can sinkholes be prevented?

Many natural sinkholes cannot be prevented. However, those caused by human activity may be avoided, especially those caused by over-pumping groundwater. During dry conditions, water tables drop in the limestone and cavities under Florida's sand and clay soil. The combination of gravity, loss of buoyancy and water pressure can activate a collapse.

By keeping water tables high, water conservation rules and drought restrictions are tools to help prevent sinkholes from occurring. The St. Johns River Water Management District promotes year-round water conservation and issues watering restrictions to prevent water shortages and over-pumping during Florida's inevitable times of drought.

The District is responsible for providing long-term protection of the water supply. While water restrictions can cause some inconvenience to residents and businesses, limiting outdoor watering is critical throughout the year, and especially during a drought. Public cooperation is vital to ensuring long-term water resource protection.

Areas Prone to Collapse Sinkholes

The map below shows areas of the United States where certain rock types that are susceptible to dissolution in water occur. In these areas the formation of underground cavaties can form and catastrophic sinkholes can happen. These rock types are evaporates (salt, bypsum, and anhydrite) and carbonates (limestone and dolomite). Evaporite rocks underlie about 35-40 percent of the United States, though in many areas they are buried at great depths.

A rapid sinkhole caused by well drilling or other sudden alterations to the terrain may not give any warning signs. Otherwise, the collapse process usually occurs gradually enough that a person may leave the affected area safely. The final breakthrough can develop over a period of a few minutes to a few hours.

Warning Signs

Some warning signs of a naturally occurring sinkhole include:

- Gradual localized ground settlement
- Doors and windows fail to close properly
- Cracks in a foundation
- A circular pattern of ground cracks outlining the sinking area
- Vegetation stress due to a lowered water table
- Turbidity in local well water due to sediment washing into the limestone's pores

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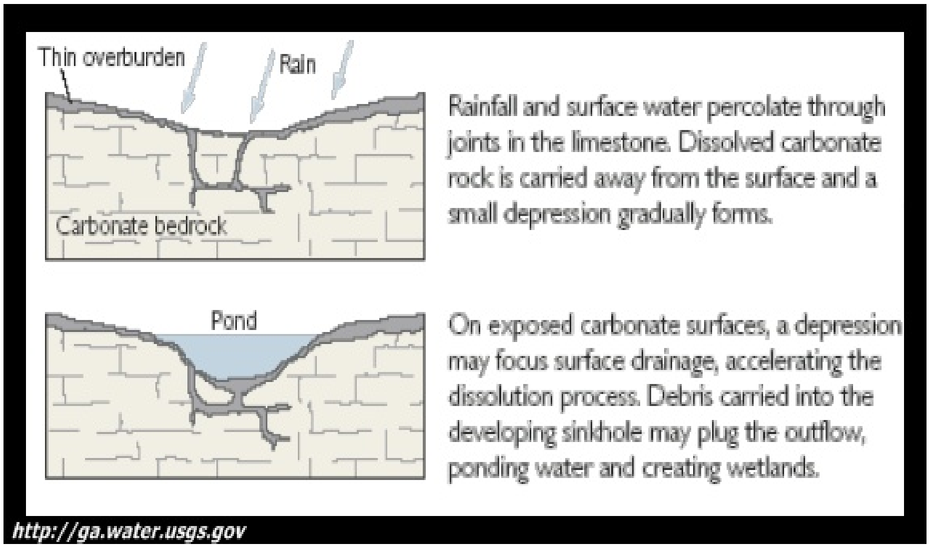
There are many other causes of localized ground settlement and vegetation stress, and depressed areas are not necessarily indications of an imminent sinkhole.

Types of Sinkholes

Since Florida is prone to sinkholes, it is a good place to use to discuss some different types of sinkholes and the geologic and hydrologic processes that form them. The processes of dissolution, where surface rock that are soluble to weak acids, are dissolved, and suffusion, where cavities form below the land surface, are responsible for virtually all sinkholes in Florida.

Dissolution Sinkholes

Diagram of a sinkhole caused by dissolution of subsurface rock, generally limestone. Dissolution of the limestone or dolomite is most intensive where the water first contacts the rock surface. Aggressive dissolution also occurs where flow is focused in preexisting openings in the rock, such as along joints, fractures, and bedding planes, and in the zone of water table fluctuation where ground water is in contact with the atmosphere.



Subsidence

In geology, engineering, and surveying, subsidence is the motion of a surface (usually, the Earth's surface) as it shifts downward relative to a datum such as sea-level. The opposite of subsidence is uplift, which results in an increase in elevation. There are several types of subsidence, listed below in order of increasing scale:

Dissolution of Limestone

Subsidence frequently occurs in karst terrains, where dissolution of limestone by fluid flow in the subsurface causes the creation of voids (i.e. caves). If the roof of these voids becomes too weak, it can collapse and the overlying rock and earth will fall into the space, causing subsidence at the surface. This type of subsidence can result in sinkholes which can be many hundreds of meters deep and can provide areas of ecological isolation which see the evolution of new branches of animal and plant life.

Mining-Induced

Several types of sub-surface mining, and specifically methods which intentionally cause the extracted void to collapse (such as pillar extraction, longwall mining and any metalliferous mining method which utilizes "caving" such as "block caving" or "sub-level caving") will result in surface subsidence. Mining induced subsidence is relatively predictable in its magnitude, manifestation and extent, except where a sudden pillar or near-surface underground tunnel collapse occurs (usually very old workings). Mining induced subsidence is nearly always very localized to the surface above the mined area, plus a margin around the outside. The vertical magnitude of the subsidence itself typically does not cause problems, except in the case of drainage (including natural drainage) - rather it is the associated surface compressive and tensile strains, curvature, tilts and horizontal displacement that are the cause of the worst damage to the natural environment, buildings and infrastructure. Where mining activity is planned, mining-induced subsidence can be successfully managed if there is co-operation from all of the stakeholders. This is accomplished through a combination of careful mine planning, the taking of preventative measures, and the carrying out of repairs post-mining.

Faulting Induced

When differential stresses exist in the Earth, these can be accommodated either by geological faulting in the brittle crust, or by ductile flow in the hotter and more fluid mantle. Where faults occur, absolute subsidence may occur in the footwall of normal faults. In reverse, or thrust, faults, relative subsidence may be measured in the hanging wall.

Isostatic Rebound

The crust floats buoyantly in the plastic asthenosphere, with a ratio of mass below the "surface" in proportion to its own density and the density of the asthenosphere. If mass is added to the crust (e.g. through deposition), the crust is thought to subside minusculely to compensate and maintain isostatic balance.

Extraction of Natural Gas

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If natural gas is extracted from a natural gas field the initial pressure (up to 600 bar) in the field will drop over the years. The gas pressure also supports the soil layers above the field. If the pressure drops, the soil pressure increases and this leads to subsidence at the ground level. Since exploration of the Slochteren (Netherlands) gas field started in the late 1960s the ground level over a 250 km² area has dropped with a current maximum of 30 cm. See also this subsidence lecture.

This type of subsidence can similarly be caused by extraction of other resources, e.g. ground water, petroleum or rock salt.

Groundwater-Related

The habitation of lowlands, such as coastal or delta plains, requires drainage. The resulting aeration of the soil leads to the oxidation of its organic components, such as peat, and this decomposition process may cause significant land subsidence. This applies especially when ground water levels are periodically adapted to subsidence, in order to maintain desired unsaturated zone depths, exposing more and more peat to oxygen. In addition to this, drained soils consolidate as a result of increased effective stress. In this way, land subsidence has the potential of becoming self-perpetuating, having rates up to 5 cm/yr. Water management used to be tuned primarily to factors such as crop optimisation but, to varying extents, avoiding subsidence has come to be taken into account as well.

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Seasonal Effects

Many soils contain significant proportions of clay which because of the very small particle size are affected by changes in soil moisture content. Seasonal drying of the soil results in a reduction in soil volume and a lowering of the soil surface. If building foundations are above the level to which the seasonal drying reaches they will move and this can result in damage to the building in the form of tapering cracks. Trees and other vegetation can have a significant local effect on seasonal drying of soils. Over a number of years a cumulative drying occurs as the tree grows, this can lead to the opposite of subsidence, known as heave or swelling of the soil, when the tree declines or is felled. As the cumulative moisture deficit is reversed, over a period which can last as many as 25 years, the surface level around the tree will rise and expand laterally. This is often more damaging to buildings unless the foundations have been strengthened or designed to cope with the effect.

Cover-Subsidence Sinkholes

Cover-subsidence sinkholes tend to develop gradually where the covering sediments are permeable and contain sand. In areas where cover material is thicker or sediments contain more clay, cover-subsidence sinkholes are relatively uncommon, are smaller, and may go undetected for long periods.

Occurrence

Sinkholes are usually but not always linked with karst landscapes. In such regions, there may be hundreds or even thousands of sinkholes in a small area so that the surface as seen from the air

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looks pock-marked, and there are no surface streams because all drainage occurs sub-surface. The largest known sinkholes formed in sandstone are Sima Humboldt and Sima Martel in Venezuela.

The most impressive sinkholes form in thick layers of homogenous limestone. Their formation is facilitated by high groundwater flow, often caused by high rainfall – such high rainfall causes formation of the giant sinkholes in Nakanai Mountains, New Britain Island in Papua New Guiena. On the contact of limestone and insoluble rock below it there form powerful underground rivers which may create large underground voids.

Sinkholes have been used for centuries as disposal sites for various forms of waste. A consequence of this is the pollution of groundwater resources, with serious health implications in such areas. In contrast, the Maya civilization sometimes used sinkholes in the Yucantan Peninsula (known as cenotes) as places to deposit precious items and sacrifices.

When sinkholes are very deep or connected to caves, they may offer challenges for experienced savers or, when water-filled, divers. Some of the most spectacular are the Zacaton cenote in Mexico (the world's deepest water-filled sinkhole), the Boesmansgat sinkhole in South Africa, Sarisariname tepuy in Venezuela, and in the town of Mount Cambier, South Australia. Sinkholes that form in coral reefs and islands that collapse to enormous depths are known as Blue Holes and often become popular diving spots.

Sinkholes can be Human-Induced

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New sinkholes have been correlated to land-use practices, especially from ground-water pumping and from construction and development practices. Sinkholes can also form when natural water-drainage patterns are changed and new water-diversion systems are developed. Some sinkholes form when the land surface is changed, such as when industrial and runoff-storage ponds are created. The substantial weight of the new material can trigger an underground collapse of supporting material, thus causing a sinkhole.

The overburden sediments that cover buried cavities in the aquifer systems are delicately balanced by ground-water fluid pressure. The water below ground is actually helping to keep the surface soil in place. Ground-water pumping for urban water supply and for irrigation can produce new sinkholes in sinkhole-prone areas. If pumping results in a lowering of ground-water levels, then underground structural failure, and thus, sinkholes, can occur.

Sinkhole Names

Large and visually unusual sinkholes have been well known to local people since ancient times. Also nowadays sinkholes are grouped and named in site specific or generic names. Some examples of such names are:

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- **Cenotes** Characteristic water filled sinkholes in Yucantan Peninsula, Belize and some other regions. Many cenotes have formed in limestone which deposited in shallow seas created by Chicxulub meteorite impact.
- **Tiankengs** These are extremely large sinkholes which are deeper and wider than 100 m, with mostly vertical walls, most often created by the collapse of underground caverns. This term is proposed by Chinese geologists as many of the largest sinkholes are located in China.
- **Sotanos** This name is given to several giant pits in several states of Mexico. The best known is the 372 m deep Sotano de las Golondrinas-Cave of Swallows.
- **Blue holes**. This name initially has been given to the deep underwater sinkholes of Bahamas but often is used for any deep water-filled pits formed in carbonate rocks. Name originates from the deep blue color of water in these sinkholes, which in turn is created by the high lucidity of water and the large depth of sinkholes – only the deep blue color of the visible spectrum can penetrate such depth and after reflection return back. The deepest known undersea sinkhole is Dean's Blue Hole in Bahamas.
- **Black holes**. Group of unique round, water filled pits in Bahamas. These formations seem to be dissolved in carbonate mud from above, by the sea water. Dark color of water is caused by the layer of phototropic microorganisms concentrated in dense, purple colored layer in 15 – 20 metre depth – this layer "swallows" the light. Metabolism in the layer of microorganisms causes heating of water – the only known case in natural world where microorganisms create significant thermal effects. Most impressive is Black Hole of Andros.
- **Tomo** used in New Zealand karst country to describe pot holes.

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