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DIVISION OF GEOLOGY

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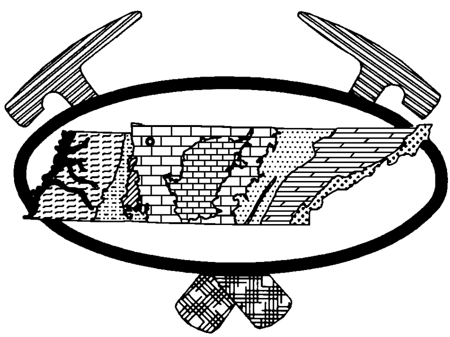
SUBSIDENCE AND SINKHOLES IN EAST TENNESSEE

A FIELD GUIDE TO HOLES IN THE GROUND

By
Martin S. Kohl



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Subsidence and Sinkholes in East Tennessee

A Field Guide to Holes in the Ground

By

Martin S. Kohl[1]

The Division of Geology routinely investigates instances of ground subsidence and other disturbances in East Tennessee. From shallow holes to wide depressions, property owners are concerned about potential geologic hazards that may be threatening buildings and roads, as well as property values. Most calls arise when some type of ground subsidence is taking place at a residence or place of business, but a large number come from people examining property for purchase. Division personnel have found in almost all cases that the disturbance was attributable to one or more of the causes described below. Each cause has identifiable characteristics and poses specific hazards to people, structures, and the environment. Our purpose is to describe and interpret some of the features we have observed during investigations, beginning with the most trivial, and where possible, indicate what may be done when a hazard is present.

Holes caused by rotted-out stumps—These usually are small kettle-shaped depressions up to a foot or so in size and depth. Bark, which is more resistant to decomposition than wood, may persist along the sides of the hole. Because it takes several decades for a low stump to completely rot out, current residents may not realize that a tree once stood there. As the holes are often partly hidden by grass or other debris, these are primarily a hazard to people running, walking, or playing in the area. They can be filled with soil and compacted to prevent additional subsidence.

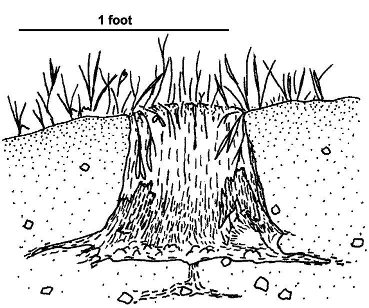

Figure 1. Rotted out stump.

Holes caused by dogs and other animals—Dog holes are usually identified by the presence of fresh dirt and trampled ground, usually to one side of the hole. They are usually not more than a foot deep and wide. Den-making animals usually choose to tunnel into a steep slope.

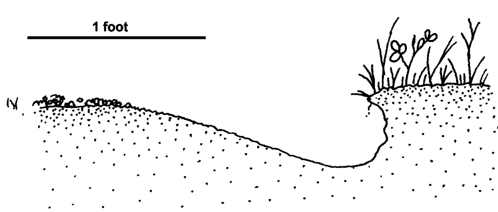

Figure 2. Dog hole.

[1]Geologist, Tennessee Division of Geology, Knoxville.

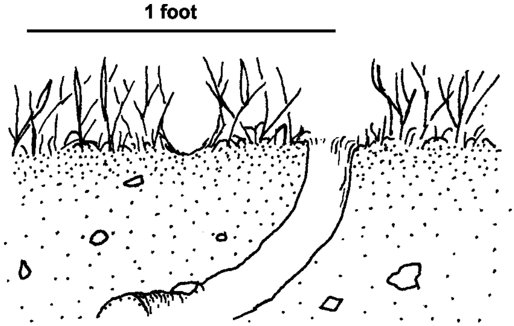

FIGURE 3. Small animal burrow and runway.

Small animal burrows affecting lawns often have areas of clipped grass, horizontal tunnels along the soil surface under the grass, and other evidence of activity, but dirt from the excavations is often not present. Consequences from burrowing animals can be serious if they penetrate earthen dams holding back water.

Underground creek erosion—In the heads of hollows, small intermittent streams may flow underground for short distances. In many cases they are flowing through enlarged animal burrows beneath resistant rooted or moss-covered ground. These are generally not a cause for alarm.

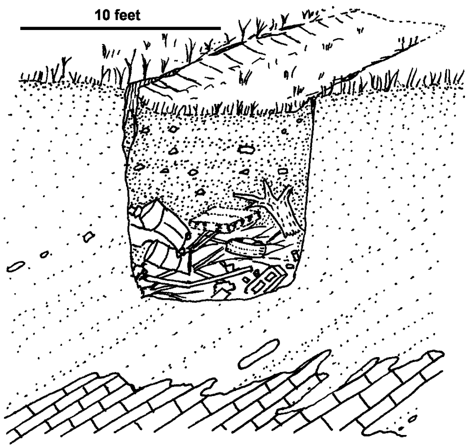

FIGURE 4. Subsidence due to buried trash.

Buried trash and debris—This is the cause of one of the most common ground subsidence phenomena reported by home-owners. Trash pits are common in rural areas, where they may or may not have been covered with earth. Often developers dig pits to dispose of cleared vegetation, construction waste, and other refuse, then cover them over. Eventually the material begins to decompose and compact, and the ground above it subsides. The process is usually gradual over a period of several years, but may show up overnight. The area of subsidence — which is usually oblong, straight sided, and perhaps eight feet wide (the width of a bulldozer blade) — is surrounded by an inward-sloping zone, where narrow open cracks can be observed. Debris can sometimes be seen by looking into the deeper cracks, but usually its presence must be confirmed by digging. The pits are usually a short distance away from nearby structures, and sometimes oriented parallel or perpendicular to them. The possibility of groundwater contamination exists if toxic or hazardous material was buried. Such material should be removed if it is present.

Areas of buried debris usually need to be filled in several times with soil while the underlying material slowly subsides. The final amount required will depend on the thickness of trash and overlying fill. If not corrected, subsidence depressions can funnel surface runoff into the groundwater system, triggering one of the more serious forms of subsidence described later.

Improperly compacted fill— Evidence of fill material on natural topography may be subtle, particularly if the fill has been there for some time, but it is usually apparent if you are looking for it. When not properly compacted during its placement, fill will slowly compact over time, and the overlying ground surface will subside in proportion to the thickness of the fill. Problems with older compacted fill are usually not noticeable unless structural damage such as cracked foundations or broken sidewalks has occurred. The situation will be aggravated if the fill contains boulders or trash, or in the case of wintertime construction, frozen ground. Surface irregularity that forms is typically on the scale of the blocks and clods moved by bulldozer or dump truck. Closely related is the uneven settling resulting from fill placed over rocky or irregular ground. The effects of uneven compaction beneath a structure can be serious, and may include warping and the formation of cracks that threaten its integrity, similar to those described for expansive soils, below. This problem is best avoided by the careful selection and placement of fill material.

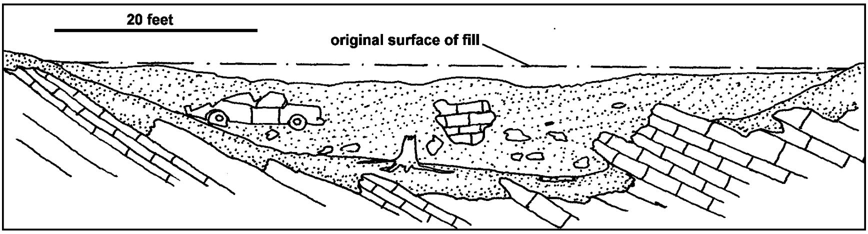

Figure 5. Surface irregularity from improperly compacted fill.

Expansive soil and swelling clays—These soils, because of the presence of certain clay minerals, expand considerably upon being wet. Conversely, in normally moist areas, substantial shrinkage will occur when these soils dry out. Wet soils can be 20 to 50% greater in volume than when dry. Wet-dry cycles, particularly when they penetrate to significant depths as following droughts, can cause foundations to crack or buckle.

Indications of foundation movement attributable to either expansive soils or the improperly compacted fill referred to previously include the following: On the exterior; stair-step cracks in brick walls, sagging brick lines when sighting along a wall, tilting of walls, separation of wood trim joints at corners, separation of concrete driveways, patios, or sidewalks from foundation, and tilting of landscaping or other retaining walls. On the interior one may observe cracks in walls or ceilings, particularly around the corners of doors and windows, warped or tilted walls, walls separating from floors or ceilings, sticking doors and windows, sloping floors, cracks in or around tile, and cracks in concrete floor 1/16th inch across or wider.

Post-construction preventive measures involve maintaining uniform and constant soil moisture around the foundation. Avoid overwatering flower beds and plants adjacent to the foundation, direct downspouts and air conditioner condensate water away from the house, and keep the soils on the dry (southwest) side moist during droughts.

Soil in regions known to be subject to this hazard needs to be tested before construction, and foundation designs modified accordingly. It is much less expensive to treat or excavate and replace soil prior to construction than repair or rebuild a house.

Dug wells and associated subsidence—Found in formerly rural areas, masonry or stone-lined wells may be encountered during excavations, or may eventually collapse on their own. The original holes are typically about four feet in diameter, of considerable depth, and usually located near old home sites. Since these represent a hazard to newer structures, as well as to people and animals, they need to either be filled in with compacted soil materials or restored if they are of historical interest.

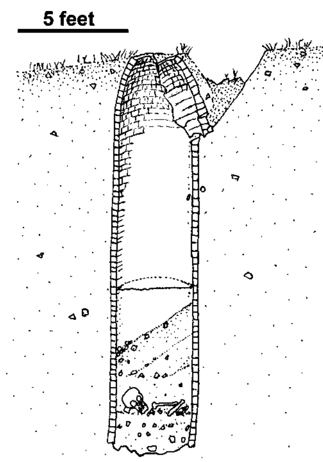

Figure 6. Cave-in associated with well.

Subsidence due to water and sewer line leaks—Sewage or water supply leaks may weaken, erode, and remove the soil supporting the pipe before water ever appears at the surface over the leak. If water enters soil or bedrock conduits, it may issue from a spring or seep some distance away. Also, it may flow considerable distances through gravel packed along a pipeline. The amount of soil removed will depend on leak volume, pressure, time, and the nature of the material. Collapse may be sudden, particularly if the water finds a connection to cavities in underlying rock (see Sinkhole Collapse, below). Leaks can also create unnatural conditions affecting water table and soil stability over a wide area. The remedy in all of these cases is to locate and fix the leak.

Holes resulting from the direct action of water moving upward from a leaky pipe are usually self-evident, though again, water may travel some distance before emerging at the surface.

The results of soil moving down into a cracked or broken storm drain, sewer line, or similar open space can resemble karst sinkhole collapse, described below.

Karst topography—“Karst” refers to landforms and geologic features that have resulted from the dissolving of the carbonate bedrock underground. Karst landscapes occur in many parts of East Tennessee and the surrounding areas. Typical

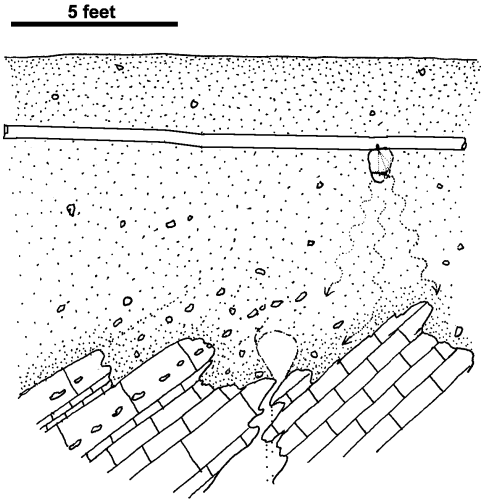

Figure 7. Leak in pipe percolating into subterranean karst system.

features include internally drained circular or elliptical depressions, sinking creeks, clefts and pinnacles in rocky areas, caves and smaller interconnecting subsurface openings, dry creek beds, channeled groundwater flow, and an abundance of springs and underground streams. The presence of karstic conditions can aggravate the effects of pipe leaks, improperly compacted fill, and buried trash. Any of these can act to concentrate water recharge into subsoil and underlying rock, and induce sinkhole formation.

The term "sinkhole" refers to several different features. Here, we will use the term "doline" (Figure 9) for depressions in the buried or exposed bedrock surface, whether narrow crevices or broad valleys, and "sinkhole" (Figure 10) for pits that open in a soil surface. A swallet, or swallow hole, is an opening through which surface water goes underground, while a "sink" or "stream sink" is a more general term for places where surface water goes underground, perhaps by infiltration into gravel.

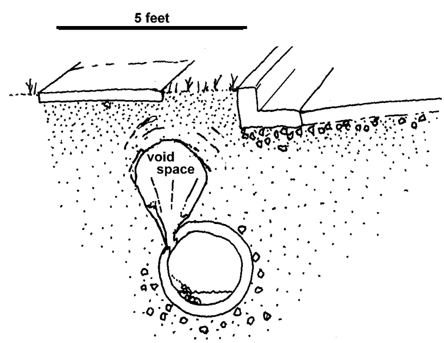

Figure 8. Subsidence into broken storm drain.

Limestone or dolomite bedrock creates the potential for both sinkhole and doline formation. The primary threat from dolines comes from flooding and ponding, particularly when they are so wide and shallow that people have tried to build within them. Dolines should never be used for trash disposal or septic drain fields, whether or not there is an opening in the bottom. They connect to groundwater that can travel considerable distances before appearing in a domestic well, or on the surface again as a spring. Collapse of a cave roof within bedrock is an infrequent occurrence, and not the cause of most dolines or sinkholes.

Sinkhole collapse—People affected by one of the phenomena previously described are often worried about imminent sinkhole collapse. Damage to buildings com-

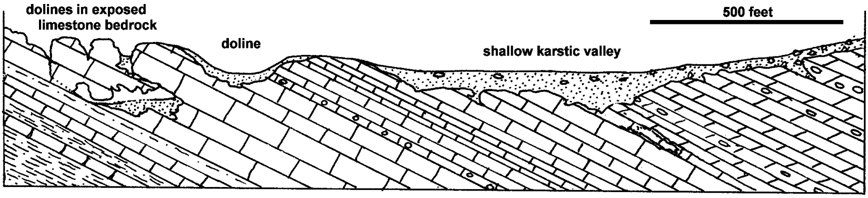

Figure 9. Typical karstic landforms in East Tennessee.

monly results from collapse of soil and/or rock material into a void space near or beneath man-made structures. Ground subsidence into even a small opening may be very costly if a structure exists on the overlying surface. Sinkhole collapses are most often unpredicted and sudden, although they occur more frequently after heavy rainfall. This increases the soil's weight and decreases its strength and stability. Construction can also trigger collapses by directing runoff into a vulnerable area, or weakening the cover of an incipient collapse. Conversely, lowering of the water table from nearby well or quarry pumping can also trigger collapse by removing the buoyancy effect of the groundwater.

The collapse itself is usually more circular than elliptical, and commonly occurs at a site unrelated to man-made structures, unlike the trash pits described above. It may, however, be in line with nearby older sinkholes and dolines. The exception is when a collapse is triggered by the construction itself or associated runoff.

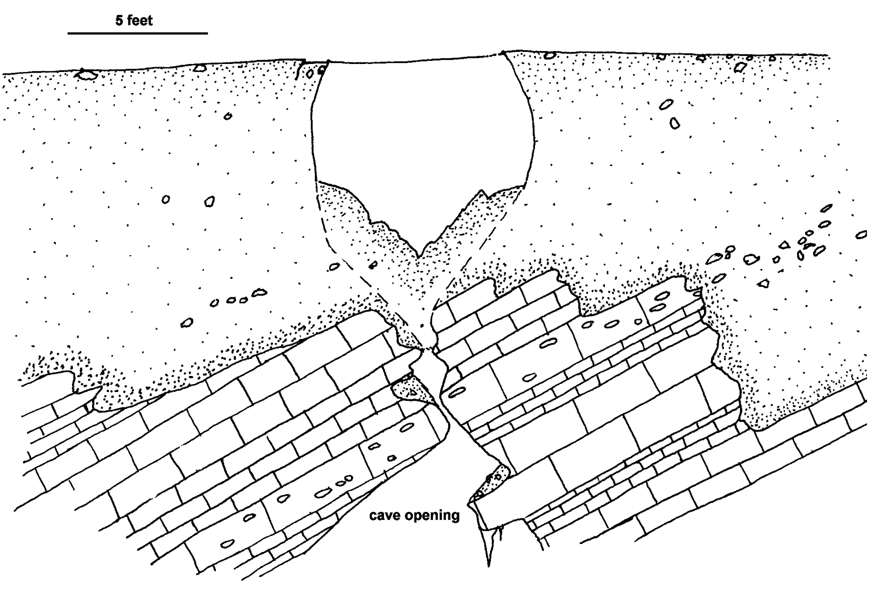

Figure 10. Cross section of new sinkhole collapse.

In karstic areas, conduits or cavernous openings exist in the bedrock into which overlying stony residual soil or "regolith" may slowly move, leaving a void space with an unsupported stony subsoil ceiling, or "regolith arch." Over time the regolith arch moves upward by collapse of the ceiling until it reaches the surface. New collapses appear on the surface as pits, with vertical or overhanging sides. Over the course of years, if undisturbed, this formation further collapses to become a conical hole. Another mode of sinkhole subsidence, and the probable mode of formation of most dolines, involves more gradual surface lowering as material is siphoned off from below without a sudden collapse.

Remediation can be costly, and usually consists of digging down to the "throat" or bedrock opening through which soil and water have siphoned out. The hole is then blocked with large rocks or concrete. Smaller rocks are placed on top and around, then gravel, sand, and compacted soil, so that water can still percolate into the subsurface as before without carrying away material. The surface should then be regraded to prevent runoff from accumulating in that area. In rural areas, it may be more practical just to fence the site off to protect livestock, pets, and the wandering hunter or woodsman who might be out at night.

Karst openings resulting from construction—During earth-moving projects in areas with carbonate bedrock, voids are often encountered in the bedrock, regolith, and soil. Collapse of a pre-existing regolith arch may be triggered by vibration or by thinning due to regrading. Karst openings can be plugged as for sinkhole collapse above, and construction plans altered to reroute runoff away from these openings.

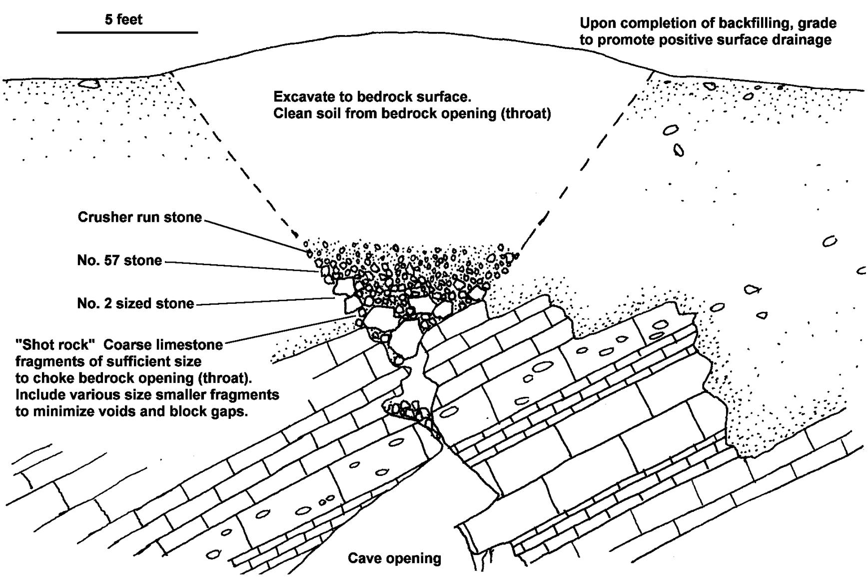

FIGURE 11. Repaired sinkhole.

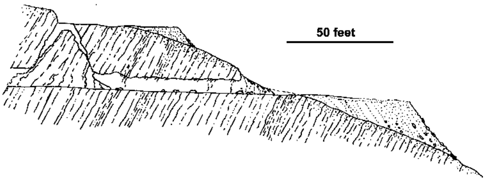

Figure 12. Mine collapse at Coker Creek.

Mine collapse—In areas where mining has occurred, such as the Mascot-Jefferson City District, or the long-abandoned Coker Creek area, old mining tunnels and chambers may exist at shallow depth. Ground subsidence may occur either by soil flowing into a mine opening or through direct collapse of the roof. The maintenance and use of accurate mine maps is essential in avoiding this possibility. Mining in a manner to prevent it is better still.

Coal mine subsidence—Land above underground coal mines in the Cumberland Plateau region may be subject to this subsidence hazard. Bedrock in this area is coal-bearing sandstone and shale. Initially, mining advances as a network of low tunnels within the coal bed separated by pillars of coal supporting the overlying rock. Later, during the retreat phase, the pillars are mined out until the roof collapses downward, along with the overlying land surface. Longwall mining techniques used in other parts of the United States also create this widespread but usually subtle effect. Fractures can allow oxygenated surface water to come into contact with sulfide-bearing rock, generating acid mine drainage.

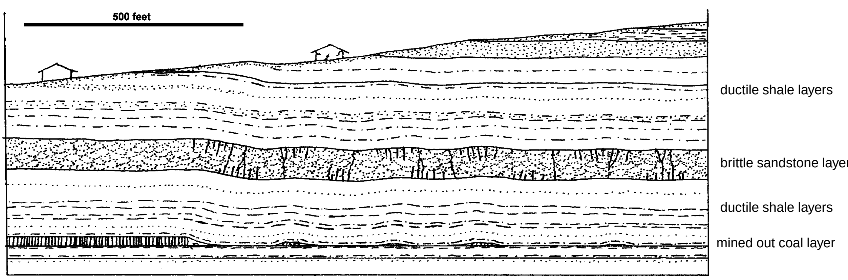

Figure 13. Subsidence above underground coal mine.

Head of Landslide—Where soil is pulling away on its way down a hill, cracks and fissures may open up. These usually occur in a curved, crisscrossing fashion along the upper boundary of the zone of movement. Their opposite sides are typically not on the same level, but arranged stepwise going downhill. At the bottom of the slide, where earth is piling up, material usually bulges outwards. Movement is most common where construction has steepened natural slopes and along the edge of steep embankments. In areas where movement has taken place in the recent past, trees often have continued to grow, but may be conspicuously bent or tilted. There is usually a “hummocky topography” of small ridges or knolls present. Landslides can destroy any structures built on top or in their way. Although expensive, steel pylons driven to well below the zone of movement, or reinforced concrete retaining walls, may be necessary to prevent damage.

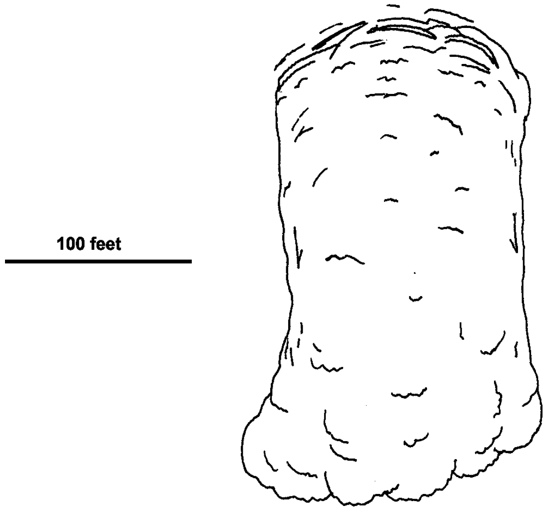

Figure 14. Slumping in fill or residual soil, map view.

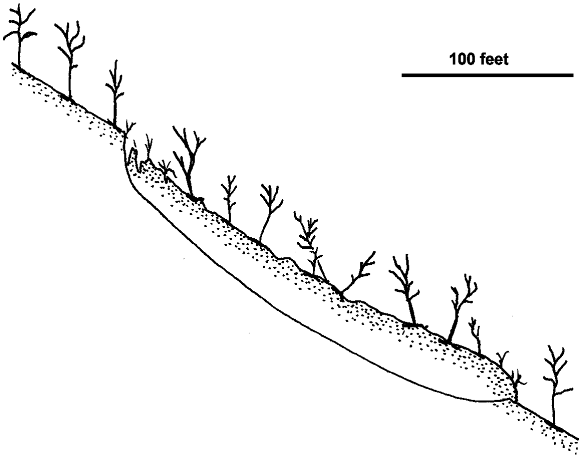

Figure 15. Slumping in fill or residual soil, cross section.

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<u>Internet Resources</u>

<http://www.gcrio.org/geo/chklt.html> Checklist of geo-indicators, from the Global Change Research Information Office site.

<http://water.usgs.gov/pubs/circ/circ1182/> Land Subsidence in the United States by Devin Galloway, David R. Jones, and S.E. Ingebritsen, U.S. Geological Survey Circular 1182, available in PDF format.

<http://wwwga.usgs.gov/edu/earthgwsinkholes.html> Sinkholes for schools.

<http://www.wku.edu/~dettman/matt/prof/papers/sink2.htm>

Commercial Sites with useful information. None of the first three are associated with sites that had anything about karst, or other types of holes.

<http://jungrenduran.com/bull003.htm> Expansive soils, from Jungren & Duran, Inc. Consulting Engineers pertaining to California soils.

<http://www.groundtest.com/what_is_an_expansive_soil.htm> Expansive soils, from Groundtest!, in Tuscaloosa, Alabama.

<http://www.usinspect.com/Soil/soilpaper.asp> Expansive soils, US Inspec, home inspectors.

<http://www.dyetracing.com/karst/ka01019.html> Karstic systems and sinkholes from Nicolas Crawford, Crawford and Associates, Bowling Green, Kentucky.

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