KARST GEOLOGY

Beneath the surface of southcentral Kentucky lies a world that is virtually unparalled. It is a labyrinth characterized by mile upon mile of dark, seemingly endless passageways. The geological process resulting in this world that we refer to as Mammoth Cave began hundreds of millions of years ago and continues today. Indeed, the complexity of the system adds to its uniqueness and the story of its formation is noteworthy.

The Ancient World

350 million years ago was a very different time than today. The North American continent was located much further south; at that time Kentucky was about 10 degrees south of the equator, and a shallow sea covered most of the southeastern United States. The warm waters supported a dense population of tiny organisms whose shells were made of calcium carbonate (CaCO3). As these creatures died, their shells accumulated by the billions on the floor of the ancient sea. In addition, calcium carbonate precipitated from the water itself. The build-up of material continued during the next 70 million years until some seven hundred feet of limestone and shale was deposited. Late in the deposition of the limestone, about fifty to sixty feet of sandstone was deposited over much of the area by a large river system that emptied into the sea from the north.

About 280 million years ago, the sea level started to drop and the continent began to rise, exposing layers of limestone and sandstone. The stage was set for the formation of the Mammoth Cave. Forces at work beneath the earth's crust caused it to slowly rise, buckle and twist, causing tiny cracks between and across layers of limestone and sandstone. At the same time river systems as we know them today slowly developed. By about three million years ago a sandstone-capped plateau stood above the Green River, and a low, almost flat limestone plain extended southeast of what is now Interstate 65.

"Acid Rain"

Rain water, acidified by carbon dioxide in the soil, seeped downward through millions of tiny cracks and crevices in the limestone layers. This weak carbonic acid (the same acid as in soda pop) dissolved a network of tiny microcaverns along the cracks. As the land continued slowly rising, the Green River eroded its channel deeper. The water in the network of microcaverns drained through the limestone under the plateau toward the river. Just as rivulets converged into streams above ground, water flow paths through the limestone also converged into incrementally larger flow paths.

As rainwater continued to enter the system and more limestone was dissolved, the microcaverns enlarged. Because the major drains carried the most water, they enlarged the most. Caves were forming. As the Green River cut deeper, the water table continued dropping to the same base level as the Green River. New underground drains formed at levels lower than the older ones, and the older channels emptied. Thus the oldest cave passages are the closest to the surface, and the youngest horizontal passages are the deepest underground. At the present water table, cave passages are still being formed.

Surface Clues

As you approach the vincinity of Mammoth Cave, several clues suggest the existence of caves. Roadcuts along highways have vertical exposures of layered grayish rock, often broken into irregular blocks at the top where erosion has widened vertical cracks across layers. Between the layers you may see the tiny openings in the limestone that are the first stage in the formation of a cave.

The landscape along the highway also has special characteristics. You will not see surface streams. Instead, you will see myriads of craterlike depressions called "sinkholes." These sinkholes are places where run-off may quickly enter the limestone aquifer. Cave drains carry the dissolved limestone away, and the surface soil settles, creating the bowl-shaped depression. If the sinkholes drains become plugged with soil, then the water cannot drain underground and a pond forms. Occasionally the drain becomes unplugged and a pond as large as several acres will disappear overnight.This kind of landscape is called karst topography. It is found along and to the southeast of Interstate 65 near Mammoth Cave National Park and referred to as the Sinkhole plain. At its southeast edge surface streams sink underground joining the drainage of thousands of sinkholes. Continuing northwest they become the underground rivers of Mammoth Cave.

The Uplands

Driving northwest from Cave City or Park City, you start to climb a line of bluffs rising some three hundred feet above the sinkhole plain. These bluffs are the Chester Escarpment -- the border between the unprotected limestone of the Sinkhole Plain and the Mammoth Cave Plateau.

Beyond the top of the escarpment the plateau is divided into broad, flat sandstone-capped ridges separated by steep, limestone-floored valleys with many sinkholes. Very little water is able to penetrate the sandstone caprock, so the limestone below is protected from erosion. Most of the early discoveries in Mammoth Cave were beneath these ridges and valleys, and all the entrances are in the valleys.

Putting It All Together

A unique combination of circumstances has made Mammoth Cave the longest cave in the world, with more than 345 miles of mapped passages. First, the karst setting has a large area for potential cave formation. The upstream headwaters of Mammoth Cave are out under the sinkhole plain. Most of the passages large enough for people to enter are under the escarpment, the plateau, and the flat-topped ridges with their intervening valleys. Springs along the Green River are the downstream outlets of ground rivers such as Echo and Roaring Rivers.

Second, the Green River valley has deepened slowly due to many interruptions during the ice ages (Pleistocene). As a result, major passages were formed and Mammoth Cave contains multiple levels.

Third, the limestone is made up of many different layers with different characteristics; therefore as the underground water sought lower and lower levels, each layer provided a different path of flow. The result The result is numerous small to moderate-sized interconnecting passages and only a few large ones.

Fourth, vertical shafts are formed where water flows off the edge of the sandstone caprock and seeps down into the limestone below. These shafts are geologically much younger than the horizontal passages, and they intersect these older passages only by chance. The drains of the shafts, however, eventually join the actively forming passages at the water table, thus adding to the cave's interconnections and complexity.

Finally, the caprock on the plateau protects older upper level passages from destruction. This is in contrast to the situation found on the uncapped Sinkhole Plain. There the surface of the land continues to drop, because upper level passages of caves collapse and are eroded away as fast as newer and lower passages are formed at the level of the water table.

Creation ... and Destruction

Cave passages also collapse in Mammoth Cave. As the valleys between the flat-topped ridges widen and deepen they intersect the oldest upper level passages. Usually this collapse results in a "terminal breakdown"; but, sometimes we can enter the cave at the breakdown of jumbled blocks of limestone and sandstone. The Historic Entrance to the cave is easy to enter because water draining off the sandstone caprock has dissolved much of the breakdown, creating a huge opening to one of the largest passages in the Mammoth Cave system. Because the rapodly flowing water here is not saturated with limestone minerals, it cannot deposit the stalacitite and stalagmite formations we think of as decorating caves.

Artistry in Stone

As water and time enables the removal of limestone and the formation of cave passages, so too, they enable the deposition of "cave decorations" called speleothems. These decorations include both the familiar gypsum flowers and needles. Although these speleothems seem to grow magically from the walls, ceiling, and floors, they are actually formed by the processes of dissolutoin and precipitation. The two most common types are composed of the major mineral in limestone, calcium carbonate ($CaCo_3$) and by salts of a minor component, sulfates (SO_4).

Carbonate speleothems, such as stalactites, are deposited in passages where there is no sandstone caprock above. Here, vertically seeping water dissolves calcium carbonate and can redeposit it if the water drips into an air-filled passage. The water loses carbon dioxide (CO_2) to the cave air, much like a soda pop loses CO_2 bubbles when opened. The loss makes the water less acidic, so it is unable to hold as much calcium carbonate in solution. The calcium carbonate is then precipitated as travertine speleothems.

The shape of the speleothems depends on where and how fast water enters a cave passage. Soda straw stalactites form on the ceiling by slowly dripping water. As each droplet falls it leaves behind a minute deposit around its border and a thin, hollow tube slowly grows toward the floor. If the tube closes and if the water drips quickly, a more conical stalactite forms. Fast-dripping water loses still more cabon dioxide as it falls and deposits a tiny bit of calcium carbonate on the floor to accumulate as a stalagmite growing upward. Because the drops splash when they hit, stalagmites tend to be broader than their "partner" stalactites directly above. If a stalactite and a stalagmite eventually meet, the result is a column.

Water seeping along cracks on a sloping ceiling deposits draperies that are often translucent enough to show banding of colors due to traces of different minerals. Iron, the most common element, tints speleothems hues of brown and orange. If water is sufficient, it spreads into thin sheets on the walls and over ledges and deposits flowstone.

If there is still carbonate in solution when water reaches a gentle sloping floor, then rimstone dams and pools may form. The dams start as a deposition on slight irregularities in the floor. A pool forms behind the dam, which continues to grow along the pool's rim. Sometimes whole series of rimstone dams and pools form.

The Dry Formations

Sulfate speleothems, like gypsum flowers, are deposited in dry passages beneath the sandstone caprock. Calcium sulfate (gypsum) is much more soluble than calcium carbonate and can be carried toward cave passages by the slight amount of water that seeps through the sandstone caprock. The water in the damp limestone is slowly drawn by capillary action into dry passages (85%-95% relative humidity) from all directions. As the water evaporates gypsum is deposited. At its most spectaclar, this mineral ($CaSO_4$) *2(H_2O) forms white to gold flower-like structures that seem to ooze and curl from the wall, ceiling, and floor much like icing from a cake decorator's nozzle. In fact, gypsum speleothems grow from the base. This phenomenon helps explain why they can form loose crusts or blisters and how gypsum growing in limestone cracks can force off bits of limestone and gypsum from the ceiling and wall. This process is extremely slow, however, and passages that appear to be unstable are usually held together by the shining crystals of gypsum in all the cracks and crevices.

We at Mammoth Cave National Park believe we are privileged to be witness to processes that have taken place for millions of years. Not only is Mammoth Cave one of the premier national parks, it is also an international treasure preserved for all people of the world. It was so recognized in October, 1981 when the United Nations Educational, Scientific and Cultural Organization (UNESCO) voted to place Mammoth Cave National Park on its list of World Heritage Sites. Mammoth Cave was also designated as a Biosphere Reserve by the same organization in March, 1990.