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The Cumberland Plateau of Eastern Kentucky

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EASTERN KENTUCKY contains almost the same Mississippian limestones that appear at Mammoth Cave in south-central Kentucky (Chapter 3). To the east these strata dip below the Appalachian Basin and reappear as the Greenbrier Group in the Virginias. The limestone outcrop in eastern Kentucky follows the western margin of the Cumberland Plateau and forms a ragged ribbon of karst that is continuous from southeastern Ohio through Kentucky and Tennessee and into northern Alabama.

There are more than 2000 documented caves comprising over 470 km of surveyed passage in the Kentucky segment of the Cumberland Plateau (Fig. 2.115). At least 14 are more than 5 km long, and 5 have lengths of more than 15 km (Table 2). This section describes the characteristics of several of the largest caves and their associated karst.

Geologic Setting

The karst of the Cumberland Plateau in Kentucky is developed in Mississippian carbonates, which are locally capped by Pennsylvanian clastic rocks. Figure 2.116 shows a simplified stratigraphic section for these rocks. In northern Kentucky the limestones are thin-bedded, shaly, and less than 20 m thick. Farther south, near the Tennessee border, these same limestones are more than 130 m thick, massive, and relatively pure.

In the northeast, the limestones are components of the Slade Formation, which underlies the transitional marine facies of the upper Mississippian Paragon Formation (Ettensohn et al., 1984). A major unconformity separates the Mississippian strata from the overlying deltaic-fluvial facies of the Pennsylvanian Breathitt and Lee Formations (Rice, 1984). Equivalent strata farther south include the St. Louis Limestone, a thick-bedded, fine-grained limestone, which overlies calcareous shales and sandstones of the Borden and Salem-Warsaw Members. Abundant chert is present in the upper few meters of the St. Louis, particularly in the south, and stands in relief in the walls of cave passages. Where the chert is locally pervasive it may perch or divert groundwater flow.

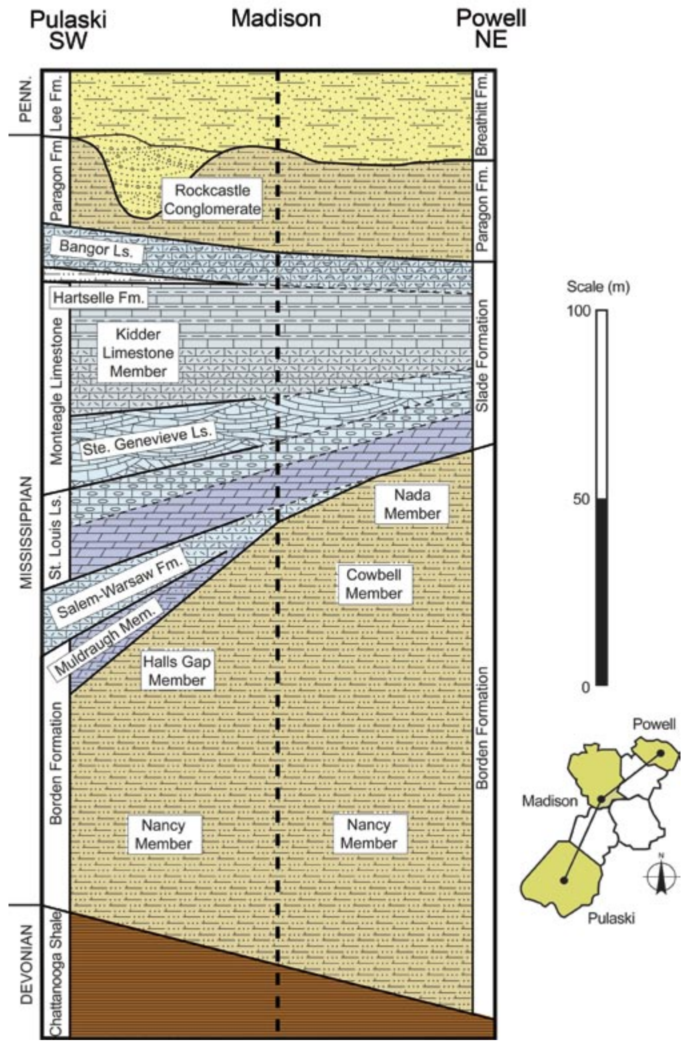

Figure 2.116: Generalized stratigraphic cross section from the southwest to the northeast along the Cumberland Escarpment in eastern Kentucky (adapted from Dever, 1999). The index map at the lower right identifies the location of the cross section.

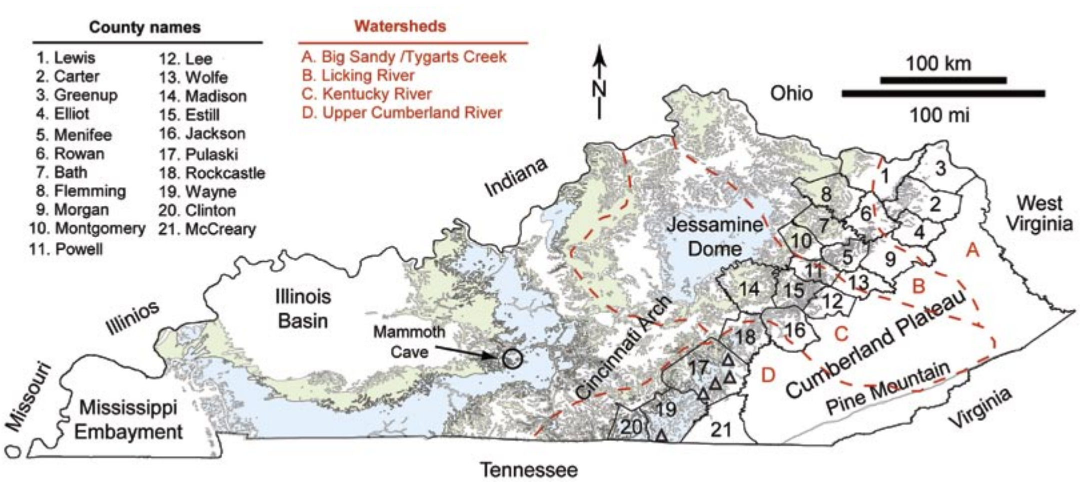

Figure 2.115: Map of karst occurrence in Kentucky (modified from Paylor and Currens, 2002). Light blue regions are underlain by limestones with a high probability of forming caves and other karst features. Light green regions are underlain by limestones that have a lower probability of forming caves and karst features. Numbered polygons are the counties along the Cumberland Escarpment. Dashed lines approximate the boundaries of the major watersheds identified with letters. Open triangles identify the location of the caves discussed in this chapter.

A regional unconformity separates the St. Louis Limestone from the overlying Ste. Genevieve Limestone. To the north, the erosion at the unconformity removed most of the St. Louis. Erosion was less farther south, but paleokarst pockets, filled with Ste. Genevieve sediments, are present in the upper few meters of the St. Louis. The Ste. Genevieve is a shallow-water, light-colored, oolitic, and locally cross-bedded limestone, thicker in the south and thin to absent in the north and along older structural highs in southern Kentucky (Dever, 1980, 1999).

Another unconformity separates the Ste. Genevieve from the overlying Kidder Limestone. The Kidder includes shallow-water limestones interbedded with thin-bedded green clays, especially in the central part of the Plateau. The Hartselle Formation, the uppermost of these intermittent clay units, thickens to a 10-m-thick sandstone near the Tennessee border (Lewis and Thaden, 1966). It separates the Kidder from the dark-gray, fossil-rich Bangor Limestone. The Kidder and Bangor are both absent in the northern half of the Cumberland Plateau, where they were removed by late Paleozoic erosion (Dever et al., 1977).

Physiography

The Cumberland Plateau is bounded on the west by a slowly retreating escarpment along the southeastern flank of the Cincinnati Arch (see Fig. 1.11 in Chapter 1). In northeastern Kentucky, the Cumberland Escarpment is expressed as a series of knobs and ridges that rise about 125 m above the lowlands to the northwest (Fig. 2.115). The relief of the escarpment increases to the south, becoming a dramatic, 250-m-high "green wall" near the Tennessee border, where elevations exceed 550 m in places. It reaches its maximum relief of 450 m and elevation of 650 m in southern Tennessee, northern Alabama, and northwestern Georgia (covered later in this chapter).

Several major rivers drain the karst-rich highlands of the Cumberland Plateau in eastern Kentucky. The entrenched Licking River and other smaller tributaries of the Ohio River (e.g., Tygarts Creek and Little Sandy River) constitute two of the watersheds. The Kentucky River and associated tributaries (North, Middle, and South Forks, and the Red River) drain much of the plateau interior and comprise a third watershed. The fourth watershed, the Upper Cumberland River, collects water from Pine and Cumberland Mountains in far eastern Kentucky and flows through a deep gorge in southern Kentucky. Tributaries along the margin of the plateau have formed deep canyons, cliffs more than 100 m tall, and delicate sandstone arches.

Caves of the Cumberland Plateau

Early exploration

At the beginning of the 19th century, America's growing need for gunpowder spurred commercial mining for nitrate-rich sediments in the Cumberland Plateau. One of the earliest saltpeter operations was at what is now known as Great Saltpeter Cave. The 1805 map of this cave by John James Dufour was the first known cave survey in Kentucky and the second oldest cave map in the USA (reprinted in the *NSS News* Vol. 64 (12), p. 8). Saltpeter mining in the Cumberland Plateau reached its peak during the War of 1812 during the English blockades. Nearby karst springs provided a source of drinking water and power to turn grist mills, and the cool of the caves (12-13°C) allowed refrigeration of food.

Luke Munsell's map of Kentucky in 1818 included several cave and karst features. In 1832, naturalist Constantine Rafinesque, the namesake of the rare Rafinesque's Big-eared Bat (*Plecotus rafinesquii),* catalogued Kentucky caves and their fauna. A.L. Packard, Jr., investigated the cave fauna of Carter County in 1888. In 1896, Oligonuk Caverns, overlooking Carter City, became the first recorded tourist cave in the region.

Modern cave exploration in eastern Kentucky began with the construction of Lake Cumberland on the Upper Cumberland River in 1941, which affected hundreds of caves. From 1940 to 1942 Clyde A. Malott and Floyd C. Malott surveyed more than 12 km of passage in Sloans Valley, including a soon-to-be-flooded show cave in Pulaski County (Malott and McGrain, 1977). W. R. Jillson and students from Transylvania College in Lexington added to this survey in 1950, just before the waters in the lake rose.

Cave exploration and mapping of caves in the Cumberland Plateau in eastern Kentucky started in earnest in the late 1950s and early 1960s by various chapters of the NSS. Their data and maps are archived in the files of the Kentucky Speleological Survey, which was founded in 2001.

Cave Descriptions

Cave entrances and passages in the Cumberland Plateau range in elevation from 200 to 420 m. Because of the southeasterly dip of the limestone strata, caves along the plateau margin tend to lie at higher elevations than those in the interior of the plateau. Caves perched on insoluble strata are common, particularly in the watershed of the Kentucky River. A notable example outside this basin is along Crooked Creek in the Upper Cumberland River basin. Stream incision below the base of the St. Louis Limestone has left segments of abandoned caves above the valley floor. The 1.5-km-long ***Great Saltpeter Cave*** is an example. Many hanging springs drain from actively forming caves, including the 18-km-long ***Goochland Cave System***, near the headwaters of Crooked Creek (Rebmann and O'Dell, 1972; Table 2).

In contrast to perched drainage of this type, large-scale karst groundwater systems have been revealed by dye traces up to several kilometers long where limestones occupy sinkhole plains and valley floors in the watershed of the Upper Cumberland River in Pulaski and Wayne Counties. The longest caves in the plateau are located in these areas and include the five systems described in detail below (Fig. 2.115). The first three are located in the Buck Creek sub-basin, which follows the plateau margin for 35 km. More than 160 km of surveyed passage in 94 caves are known in that basin alone.

Wells Cave, with 18.5 km of surveyed passage, is located in Silvers Hollow on the east side of Buck Creek, 16 km downstream from Sinking Valley (Fig. 2.117–2.120). Silvers Hollow intersects an abandoned meander of Buck Creek just west of an upper-level maze of passages in the cave. The floor of the meander is perched at nearly the same elevation as the maze, about 18 m above the modern elevation of Buck Creek. At a lower elevation, the River Passage is a singular passage almost 2.7 km long that carries the discharge from all of Silvers Hollow to a large entrance on Buck Creek.

East of the abandoned meander, the River Passage collects water from sinkholes and meanders southwest for more than 1.4 km as a passage that in places is more than 30 m wide and 15 m tall. One massive collapse, the Foggy Mountain Breakdown, rises more than 25 m to the top of the Kidder Limestone. West of the abandoned meander, the River Passage continues another 1.3 km to the northwest as a wide passage commonly less than 2 m high that is often sumped during high flow. Sediment bars with widespread flood debris separate deep pools of water. Johnson (1981) proposed that this section represents an earlier phase of cave development below the channel of Buck Creek prior to abandonment of the meander. Tall canyons such as Co-Op, Serpentine, and S-Canyon roughly parallel the upstream River Passage and span the range of elevations between the modern river and the abandoned maze. Many canyon sections are filled to within a meter of the ceiling by sediments. Near the connections with the River Passage, the sediments have been removed by erosion.

More than 60% of the known passage in Wells Cave occurs within the upper-level maze, over a 5-m elevation range averaging 18 m above the present stream levels. Passages in the maze are predominantly dry with elliptical (Fig. 2.119) or rectangular cross sections. Several of the elliptical tubes have been modified by entrenchment, resulting in keyhole-shaped cross sections (Fig. 2.220). These entrenchments commonly diverge, connecting to other passages in the maze, and ultimately empty into the tall canyons and the River Passage.

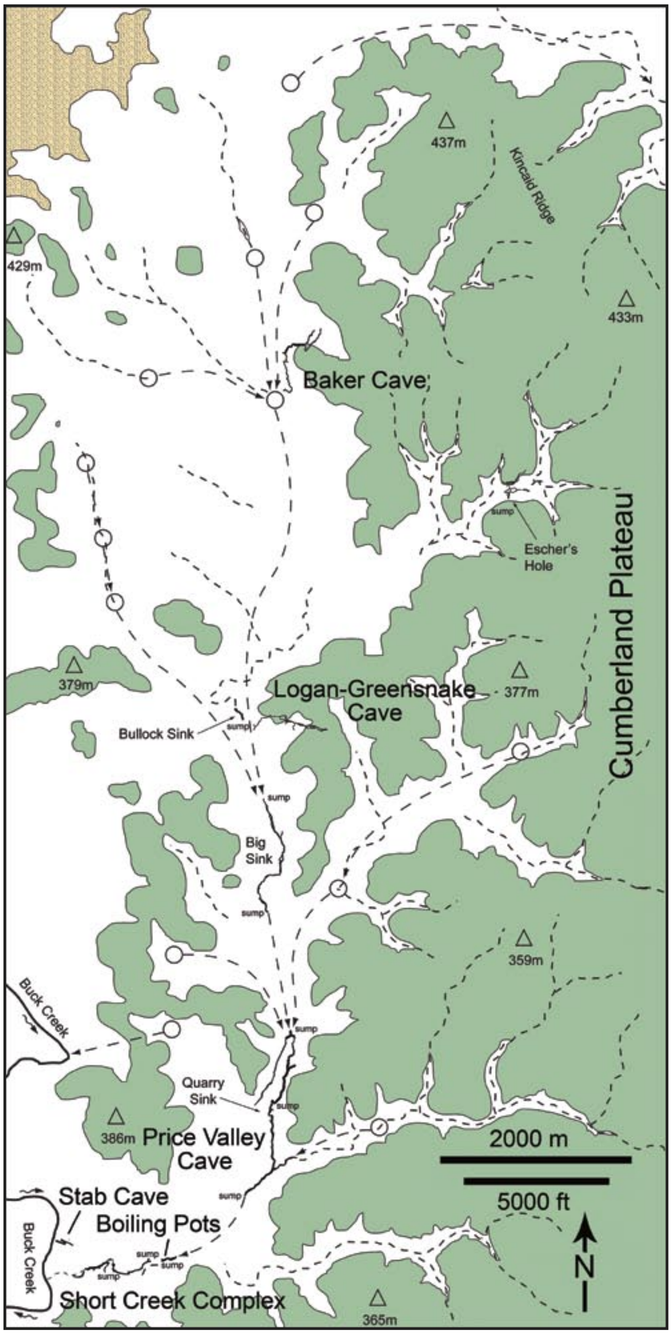

Figure 2.117: Map of Sinking Valley. The green regions are overlain by siliciclastic caprock. Stippled regions are underlain by calcareous shales. Dashed black lines are surface streams. Open circles are dye injection sites and the dashed gray lines with arrows are the inferred path of underground drytraces (Romanik, 1986). Solid black lines are surveyed cave passages. Open triangles denote surface elevations.

The ***Coral and Jugornot Cave Systems*** consist of a series of caves in a complex of ridges and valleys between the confluence of Buck Creek and the Upper Cumberland River. They comprise almost 60 km of surveyed passage and represent the longest known grouping of caves in Kentucky outside of the Mammoth Cave region (Figs. 2.121–2.123). The Coral Cave System encompasses 46 km of this length in 19 separate caves connected by dye traces. Coral Cave, at the heart of the system, 36.5 km long, is the second longest cave in eastern Kentucky. Jugornot Cave, hydraulically separate from Coral Cave, contains 9.6 km of surveyed passage.

Vertically extensive canyon passages are the key feature of these cave systems. Parts of Jugornot consist of a single canyon more than 40 m tall that is traversable at several elevations and very narrow at other elevations (Fig. 2.123). In both caves the canyons diverge and become more complex toward the southwest, where they are intersected by vertical shafts where the insoluble caprock is missing. Some shafts exceed 40 m in height (Fig. 2.123). In Coral, the complexity of the canyons and intersecting shafts southwest of the Big Room is complicated by sediment fills. At one point a tall canyon comes within centimeters of a second deeper canyon as yet unexplored, and connected only by a hole in the wall 10 m above the floor. Nearby, a thin arch of breakdown and sediment delicately spans the canyon walls 20 m above the floor.

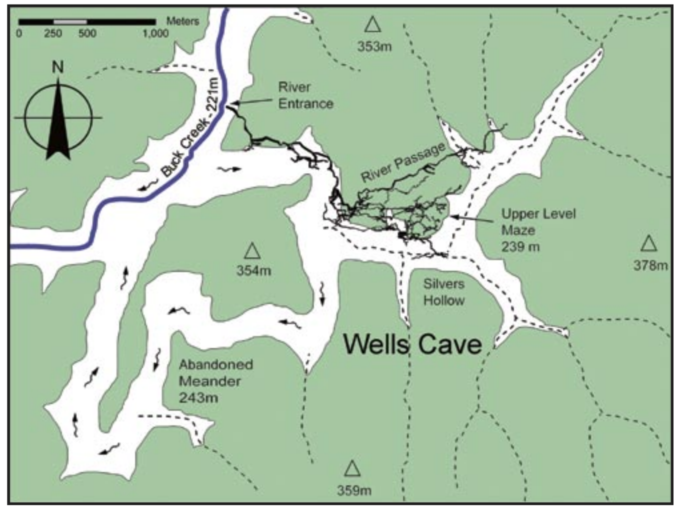

Figure 2.118: Map of Wells Cave and vicinity. The green regions are overlain by siliciclastic caprock. Dashed black lines are surface streams. Solid black lines are surveyed cave passages. Arrows indicate flow direction. Open triangles denote surface elevations.

Some 44% of Coral Cave and more than 90% of Jugornot Cave can be characterized as trans-ridge passages that cross beneath the sandstone caprock from one valley to another (Fig. 2.121). These passages are vertically stacked, with four distinct levels and, in Jugornot Cave, several additional sub-levels (Fig. 2.123). The uppermost passages in the trans-ridge sequence, such as the Richardson Pit section of Coral and the Wonderland - Green Bat passages of Jugornot, have large cross sections and are very dry with copious amounts of sulfate minerals. The Richardson Passage in Coral, for example, is up to 30 m high by 60 m wide – more than twice the size of other passages in the cave. These highest levels are located in the Kidder Limestone near the contact with the Hartselle Formation. In contrast, the lowest passages in the trans-ridge sequence, Turtle Creek in Coral and Jug River in

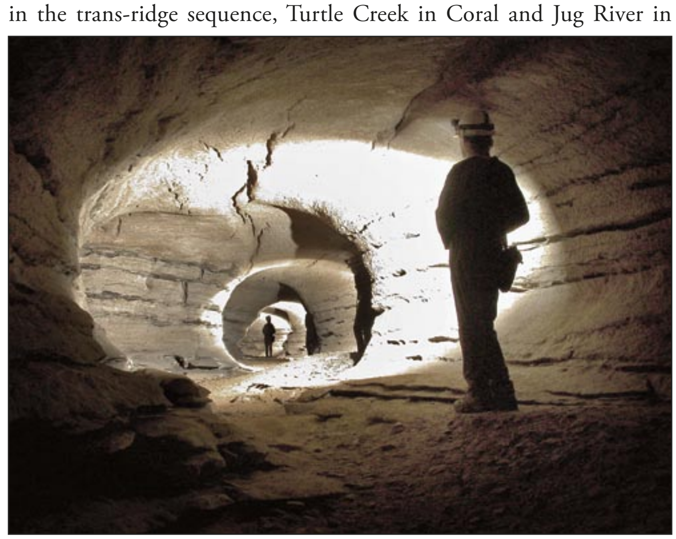

Figure 2.119: The Mainline passage in Wells Cave. Photo by John Agnew.

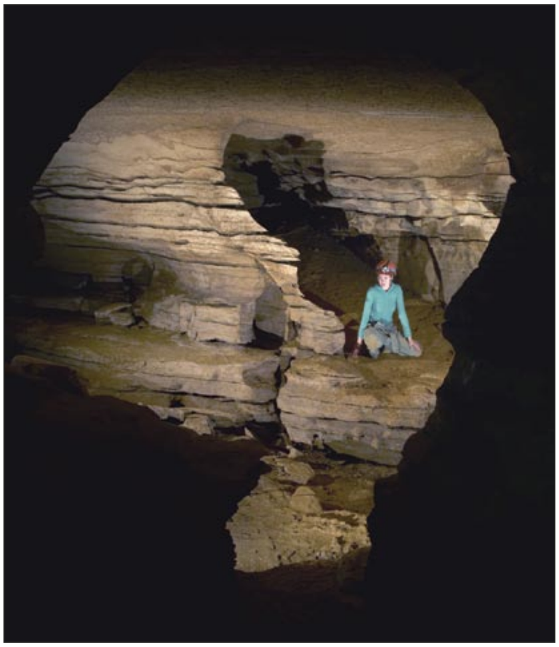

Figure 2.120: Complex upper-level junction in Wells Cave, Pulaski County, Kentucky. Photo by A.N. Palmer.

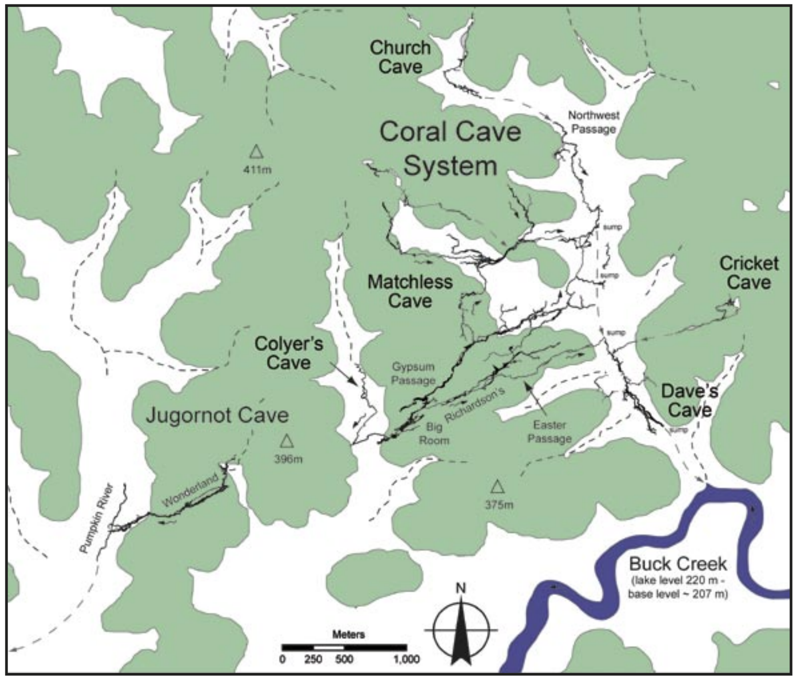

Figure 2.121: Map of the Coral and Jugornot Cave Systems, Pulaski County, Kentucky. The grey shaded regions are overlain by siliciclastic caprock. Dashed black lines are surface streams. Dashed gray lines with arrows are the inferred paths of underground drytraces. Solid black lines are surveyed cave passages. Arrows indicate flow direction. Open triangles denote surface elevations.

Jugornot, are incised beneath the chert in the upper St. Louis Limestone, have smaller average cross sections, and experience frequent flooding. These lowest levels provide many important connections between segments of the cave system.

Trans-ridge passages in the Coral and Jugornot Cave Systems are primarily linear and oriented NE-SW at an average of 240° (Fig. 2.121). Other passage types contain linear segments that follow this same trend. However, the non-trans-ridge portions of both caves are dominated by steeply descending canyons that drain tributaries in a dendritic pattern, such as the Matchless and Colyer sections of Coral, or by low-gradient, sinuous valley drains, such as the Dave's Cave section of Coral (Fig. 2.122) or Pumpkin River of Jugornot). These valley drains include anastomotic mazes that are blocked in places by sediments or dissected by siphons. The valley drains terminate downstream in sumps.

Sloans Valley Cave, with 39.7 km of surveyed passage, is the longest individual cave in eastern Kentucky (Fig. 2.124). This very complex cave is nestled in a hanging valley between the incised gorges of the Upper Cumberland River and the South Fork of the Cumberland River. Originally the Upper Cumberland coursed through whitewater shoals near Sloans Valley at an elevation of 195 m. An old tourist portion of the cave, Cumberland Caverns (or Crystal Cave), exited in the limestone cliffs above the riverbed at the base of the St. Louis Limestone (Malott and McGrain, 1977). Now these and other portions of the cave below 220 m are permanently submerged, and all passages 12 m above this level are subject to seasonal inundation by the damming of Lake Cumberland.

Sloans Valley Cave follows the basic configuration of the valley that contains it (Fig. 2.124). The two branches of the cave, the small northern Railroad Tunnel and Screamin' Willy section, and the much larger southern Minton Hollow and Martin Creek section, are composed of dendritic tributaries that drain sinkholes and karst valleys. These branches convey water from the sandstone plateau and coalesce at the Grand Central Spaghetti, a three-dimensional maze of passages and collapse features. East of the central junction, Sloans is characterized by large breakdown-strewn passages at higher levels, such as the Appalachian Trail and the Big Passage, which have cross sections more than 30 m in diameter. The lower levels contain passages with elliptical cross sections up to 20 m wide, most commonly near the Great Rock Sink (Fig. 2.124).

The ***Redmond Creek System*** is probably affected by storm-generated floods more than any other in the region. Located in Wayne County near

Figure 2.122: The Dave's Cave section of Coral Cave. Photo by John Agnew.

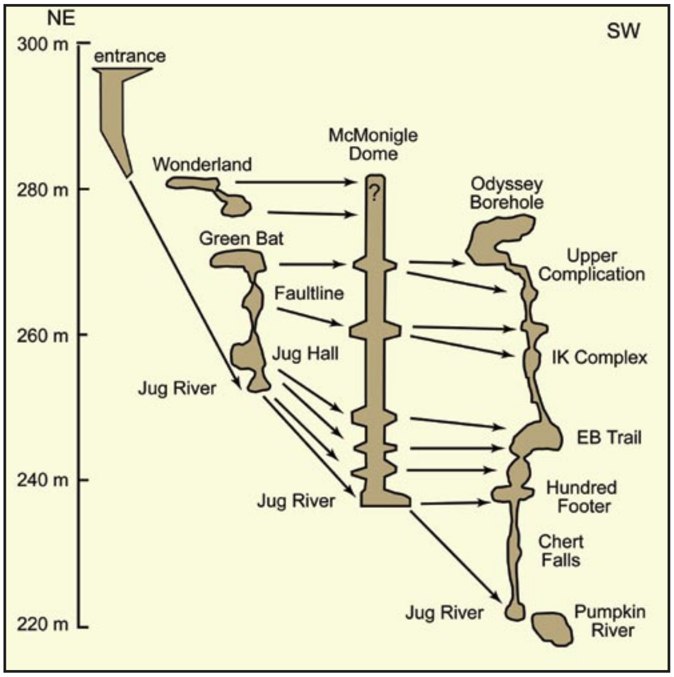

Figure 2.123: Cross-sections of canyons and vertical shafts in Jugornot Cave. Arrows are the inferred connections between levels of passages.

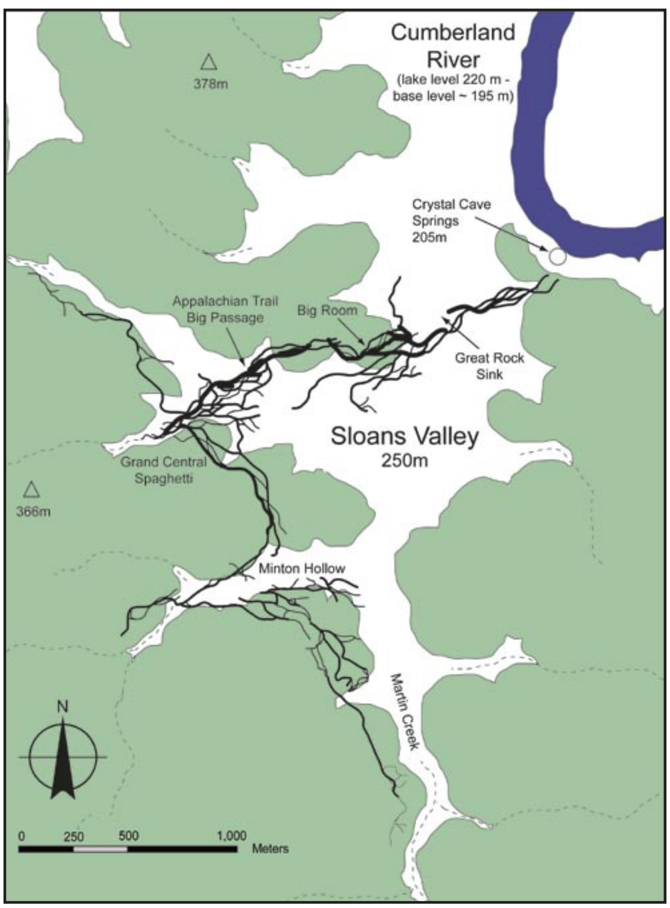

Figure 2.124: Map of the Sloans Valley Cave System. The green regions are overlain by siliciclastic caprock. Dashed black lines are surface streams. Solid black lines are surveyed cave passages. Open triangles denote surface elevations.

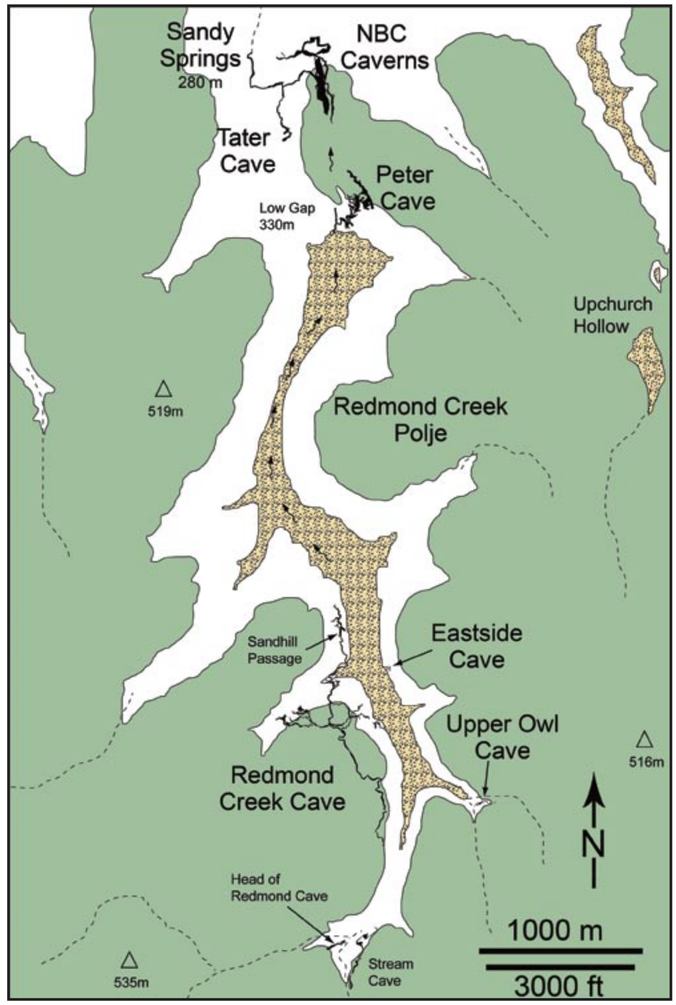

Figure 2.125: Map of the Redmond Creek Cave System and surroundings. The green regions are overlain by siliciclastic caprock. Stippled regions are polje floors underlain by Quaternary alluvium. Dashed black lines are surface streams. Solid black lines are surveyed cave passages. Arrows indicate flow direction. Open triangles denote surface elevations. Redmond Creek Cave has been extended almost 300 m farther south than shown here.

the Tennessee border, it contains 15 km of surveyed passages in 8 separate caves (Fig. 2.125). For 6.6 km the normally dry bed of Redmond Creek traverses the alluviated bottom of a Kentucky-style polje. Storm runoff produces a lake up to several kilometers long and half a kilometer wide. Massive tree trunks lodged in the entrance of Peter Cave are reminders of floodwaters that rose at least 20 m above the polje floor.

All water in Redmond Creek drains through caves at the north end of the polje and reappears at Sandy Springs at the headwaters of Otter Creek. The as-yet unconnected caves that transmit this water, Peter Cave, Stash Cave, and Natural Bridge Caverns (NBC), include nearly 5 km of surveyed passage. Both Peter Cave and NBC have passages and rooms that are among the largest known in Kentucky. The trunk passage of NBC, for example, is 75 m wide and 50 m tall and continues with similar dimensions for more than 500 m (Fig. 2.126). The floor plan of the 40-m-high Big Room in Peter cave covers at least 60,000 m^2.

Evidence for flooding is also noticeable in Redmond Creek Cave, the 7.3-km-long centerpiece of the system in the ridge along the west side of the polje (Fig. 2.125). High-pressure floodwaters in the main passage rise more than 15 m and pour though a highly scalloped passage that exits at the level of the polje floor. However, during normal and low flow, water is minimal in Redmond Creek Cave, even though Sandy Spring maintains a relatively constant discharge. Most of the water discharging from Sandy Springs between floods must therefore come

Figure 2.126: The large passage and terminal breakdown in NBC Cave within the Redmond Creek Cave System. This passage averages 75 m wide by 50 m tall for more than 500 m (photo by Sean Roberts).

from undiscovered passages below the level of Redmond Creek Cave, and/or from within the alluvium in the floor of the polje.

Only the high east-west passages in Redmond Creek Cave remain dry when the polje floods. These consist of trans-ridge canyons and low, wide passages just beneath the base of the Hartselle Formation. Elsewhere in the polje, tributary caves occur in couplets: cave streams in the Bangor are perched on the insoluble Hartselle and feed springs on the hillside, only to sink into lower caves at the top of the Kidder Limestone.

Caves of the Rockcastle River basin

Rockcastle River is the easternmost tributary of the Cumberland whose basin contains karst. It hosts many caves to the north where its tributaries extend into the edge of the plateau and breach the caprock. The Rockcastle basin contains more than 100 caves and 100 km of mapped passages. These caves are known for their karst springs, pits up to 40 m deep, and large segmented trunks, many of which were once mined for saltpeter. A few large systems have dendritic patterns. Most bi-level caves in this area consist of a fossil trunk overlying an active stream passage with connection loops and a vertical difference of less than 30 m.

Extending northward into the heart of the karst, Crooked Creek is the Rockcastle tributary most favorable to cavern development. It is located between two other karst tributaries, Brush Creek and Horselick; all have headwaters at a place called Three Links, and drain into the Roundstone Creek, which flows into the Rockcastle. The ***Goochland System*** is the largest cave, part of a group of related caves that totals 22.6 km. Nearby, at the headwaters of Brush Creek, ***Climax Cave***, is an unusually complex anastomotic maze associated with alluvial deposits. Downstream from Goochland, Crooked Creek has cut through the entire section of limestone, segmenting older cave systems. Many caves feed springs along the banks of the creek.

Great Saltpeter Cave is a large trunk passage, partly excavated by miners, with two entrances that overlook Crooked Creek, which is thought to have once flowed through the cave (Engle and Engle, 1998). Sediments in the cave have been dated by cosmogenic radionuclides at just under a million years (Anthony and Granger, 2004).

About a kilometer south of where Crooked Creek flows into Roundstone Creek is ***Pine Hill Cave***, an extensive multi-level dendritic cave. Its stream has been dye traced to ***Blue Hole***, from which it runs overland to ***Sinks of the Roundstone***. Roundstone Cave features a large trunk passage and a distributary maze at its outflow into the creek. The total length of all related segments is more than 18 km. The geologic section in the vicinity of Pine Hill Cave lacks any Pennington Shale, which may allow more direct infiltration of water through fractures in the sandstone.

Caves of Northeastern Kentucky

Toward the northeast the Cumberland Plateau becomes less distinct, and karst and caves are far less abundant, because the limestones are thinner and topographic relief along the Cumberland Escarpment diminishes.

The southern part of the Kentucky River basin contains a reported 18 km of passages in 34 caves. Many of these were formed by underground stream piracy. The longest is ***River Stykes Cave***, with more than 8.9 km surveyed. North of the Kentucky River, karst remains extensive with many tributary streams containing dry valleys at their upstream ends like narrow leaves at the tips of branches. ***Bobo Cave***, a dendritic, multi-level cave in the St. Louis limestone, is the longest reported in this area (1.6 km). The valley of the Red River, a northerly tributary of the Kentucky, is known for its deep gorge, sandstone arches, and natural beauty – but not especially for caves. The high relief and great amount of rapid dissection may explain the dearth of long caves.

In Carter County, in the very northeastern part of Kentucky, at least 25 major caves have been surveyed with a total mapped length or more than 15.3 km. Most of these are located along the entrenched Tygarts Creek in Carter Caves State Resort Park. This is an old-age karst. The Cave Creek Valley appears to be an unroofed cave and the area contains some excellent natural bridges. Bat Cave, the longest cave in the region at 3.7 km, has bi-level passages with bedding-plane control and collapse rooms. Local anastomotic patterns may be due to a large influx of sediments that is apparent in the caves. Saltpeter was mined during the early 1800s in the ***Saltpeter-Moon System***, and relics of the operation remain in the cave. The highest level of cave development is at the top of the Newman limestone. The Newman is capped by the Carter Caves Sandstone, which replaces the Pennington shale in this area. The ceiling of a 12-m-high collapse rotunda in the Moon Cave section is composed of sandstone. Unlike most of the Cumberland Plateau, where infiltration is retarded by the Pennington Shale, water seeping through fractures in the sandstone is more able to flow directly into the limestone.

Synthesis

Passage Geometry

Crawford (1984) first described the "plateau-margin" model of cave development using examples from the Cumberland Plateau in Tennessee. This model shows the relationship between subsurface stream invasion, cavern development and slope retreat. Crawford explains that caves along the plateau have at least one input where a surface stream sinks, and at least one spring where the stream resurfaces. Surface streams, undersaturated with respect to calcite, normally sink into caves at the contact between the Mississippian limestones and the overlying insoluble rocks and descend through the vadose zone in a series of steps toward base level (Crawford, 1984). The Matchless section of Coral Cave (Fig. 2.121), with its many waterfalls, is a clear example. Low-gradient passages in the lower levels collect water from several such tributaries, as in the Minton Hollow and Martin Creek sections of Sloans Valley Cave (Fig. 2.124), and may transmit the resultant streams for long distances to springs at the base of the escarpment or cave-bearing limestone. These branchwork caves are the underground analogs of surface rivers and are the dominant pattern of caves in the Cumberland Plateau.

Geologic Structure

Sasowsky and White (1994) examined the low-level stream passages and abandoned upper-level trunk passages in plateau-margin caves of Tennessee, Kentucky, and elsewhere in the Appalachians. They defined the "Cumberland Style" of caves as those which consist of one or two large sinuous master conduits with long bend spacings (approximately 100 m), and which generally parallel the surface valley, following

Figure 2.127: The Short Creek karst window. Photo by Larry Simpson.

topographic contours even where tributary valleys join the main valley. Many caves in the Cumberland Plateau of Kentucky differ from this model. However, some segments of the large valley-drain passages in Coral, Jugornot, Sloans Valley, Wells, and the Sinking Valley Caves fit fairly well. Note, for example, where the Minton Hollow section of Sloans Valley makes a peculiar V-shaped bend into a tributary to the main valley (Fig. 2.124).

Stress-release fractures and bedding-plane partings in valley walls, induced by erosional unloading (e.g., Ferguson, 1967) contribute to the orientation of valley-drain passages. These fractures parallel the hillsides and promote the circulation of groundwater in what may otherwise be low-permeability limestones. The result is a concordance between cave passages and valley walls (Sasowsky and White, 1994). Thus surface and subsurface drainage basins in the Cumberland Plateau karst tend to coincide because most passages are constrained within the valleys – as clearly demonstrated in the Sloans Valley and Redmond Creek Systems (Figs. 2.124–2.125).

Stress-release fracturing is only one type of geologic structure that affects Cumberland Plateau caves. In some caves, for example Coral and Jugornot (Fig. 2.121), surface and subsurface drainage basins do not coincide because passages transmit water through ridges between adjacent valleys. These examples suggest that larger structural features are also involved.

The linear trend in the Coral and Jugornot Cave Systems is striking and confined to a narrow NE-SW band (Fig. 2.121). For example, 90% of all surveyed passages in Jugornot fall within a band 52 m wide. There are other alignments for several kilometers in either direction along the same trend, such as passages in other caves, clusters of sinkholes, and hillslope orientations. These suggest a widespread lineament that has influenced karst processes over a long distance. Vertical veins of calcite in the Easter Passage of Coral, slickensides on certain passage walls in Jugornot, and fissure passages in both caves demonstrate a tectonic mechanism. Moreover, seismic data across Coral Cave reveal a normal fault with more than 880 m of offset at the top of the Precambrian basement (Florea, 2002). The upthrown side is to the northwest, which suggests that borders one of a series of half-grabens associated with Cambrian rifting in the Rome Trough (Webb, 1980). A swarm of fractures propagated upward from this ancient fault is the likely cause of the lineament.

Other structural features in caves of the plateau are less dramatic or widespread, but produce similar results. A north-south fault with one meter of offset guides a passage in Escher's Hole in Sinking Valley (Fig. 2.117). Similar minor faults are suspected in the trans-ridge passages of Logan-Greensnake Cave and Redmond Creek Cave (Fig. 2.125).

The gentle dip of the limestone, generally to the southeast between two and four degrees, can also affect cave morphology. Passages oriented down the dip have steeper gradients. For example, the Jug River in Jugornot, and the northern half of Big Sink in Sinking Valley (Figs. 2.117 and 2.121) have downdip streams with sections of rapidly flowing water. In contrast, passages along the strike, such as the downstream halves of Big Sink and Price Valley Caves in Sinking Valley (Fig. 2117), have lower gradients and slower-moving water. Finally, streams in passages that are oriented against the dip, as in Martin Creek in Sloans (Fig. 2.124), and the north-south-oriented Sand Hill and Sandy Spring Passages in the Redmond Creek System (Fig. 2.125), encounter deep water, many sumps, and stagnant pools. Local dip variations, such as that caused by the 13-km-long, 55-m-relief Sunnybrook Anticline north and west of Redmond Creek, are likely to influence passage orientation and morphology.

Floods and their Effects on Passage Morphology and Sediments

Floods of allogenic water that drain from the caprock of the Cumberland Plateau regularly impact all cave systems described in this section. These floods of chemically aggressive allogenic waters and the sediments that they carry create intermittently water-filled, conditions that have a pronounced effect on cave morphology and sediment patterns (Palmer, 2001). The following dramatic examples illustrate the magnitude of flooding that can occur:

• Bits of rafted debris in the Colyers section of Coral Cave can be found atop a sediment wall 12 m above the stream level.

• At Peter Cave, similar flood debris is found 20 m above the floor of the Redmond Creek polje. Moreover, the trunk passage of NBC, downstream from Peter Cave, has a cross section of 3000 m^2 and bedrock scallops that average less than 3 cm long. Scallops of that size indicate an average water velocity of 2 m/s during major floods (Curl, 1974).

• The downstream half of Sinking Valley experiences “valley tides” during major storms (Dougherty, 1985). Cave passages become completely submerged and water under pressure spouts from sinkholes in the valley floor to create ephemeral lakes (e.g., Simpson, 2004).

• One spectacular flood in southeastern Kentucky in May 1984 was generated by more than 20 cm of rainfall and compounded by already high levels of Lake Cumberland. It flooded the section of Buck Creek near Wells and Coral Caves to more than 10 m above normal river level. Water rose to unprecedented heights in both caves. In Wells, water overflowed into upper-level passages 18 m above Buck Creek. A stream ran the length

Figure 2.128: A large base level passage in Hail Cave along Buck Creek in Pulaski County, Kentucky. The shape of the passage indicates that it formed in water-filled conditions, yet the passage is only pipe-full during large rain events. Photo by Rob Coomer.

of Hound Hollow over Coral Cave for the first time in more than 50 years.

Many of the active valley drains in the caves have elliptical cross sections. Examples include the Dave's Cave section of Coral; the Minton Hollow portion of Sloans; the River Passage of Wells; Big Sink, Price Valley, and Short Creek in Sinking Valley (Fig. 2.127); and the Sand Hill passage of Redmond Creek Cave. The traditional interpretation is that such passages formed below the water table (Fig. 2.128). Geochemical and hydrologic data suggest that cave development is dominated by the infrequent storms that fill caves with allogenic floodwaters. For instance, in the main river sections of Mammoth Cave, Groves and Meiman (2001) discovered that floodwaters that fill passages to the ceiling are chemically aggressive and will dissolve considerably more limestone than during times of low flow. In fact, their data demonstrate that waters in the cave stream are capable of dissolving limestone only 31% of the year. Furthermore, Häuselmann (2002) suggests that many dissolution features and passage morphologies previously attributed to the phreatic zone are in fact the result of water-level fluctuations in the zone above the water table. In his words, "most of the well-known, rounded passages that are generally attributed to having been created below the water table, are in fact produced in the epiphreatic zone.... Only in the epiphreatic zone is corrosion sufficiently strong to provide effective solubility."

Floodwaters are also more competent in transporting sediment in large volumes and over a large range of grain size. Cobbles and boulders are tumbled along stream channels, particularly in narrow passages where water velocities are highest. In Escher's Hole, a striking example in Sinking Valley (Fig. 2.117), cobbles armor the floor and finer-grained sediments are winnowed away within a maze of narrow elliptical-shaped passages. Silt and clay are transported long distances and dropped out of suspension away from the main channel, where water velocities are low, for example in passages or rooms of large cross section, in areas of impounded water upstream from constrictions or collapse features, or in older passages not utilized by the modern stream channels.

Over time a dynamic equilibrium between sedimentation and sediment transport is established in cave passages. When large passages with slow-moving water fill with sediment, their cross-sectional areas diminish. The decreased dimensions cause an increase in water velocity and erosive power. Thus, valley drains attain a cross section sufficient to transmit the water provided by floods, and the sediments in these passages travel as "waves" through the system. Sinking Valley provides excellent examples of this phenomenon, specifically the downstream half of Big Sink and Price Valley Caves (Fig. 2.117).

Collapse features caused by weakened overburden or lateral passage enlargement disrupt the balance between deposition and transport. Weak overburden can occur where vertically separated passages cross (White, 1988), as in NBC and Peter Caves at Redmond Creek (Fig. 2.126), or where passage lie at shallow depth beneath the surface, as in Quarry Sink in Sinking Valley (Fig. 2.117). Another mechanism for passage collapse, lateral enlargement, can occur when two passages join, or where the floor of an active passage is armored by siliciclastic sediments that cause the stream to undercut the passage wall, shown in the Big Passage of Sloans Valley (Ewers, 1972) and in the River Passage of Wells Cave.

Collapse and sedimentation causes blocked water to seek alternate paths and may develop mazes of passages that bypass the constrictions (Palmer, 2001, 1991). Mazes of this type are particularly well developed in the upper level of Wells Cave and the Grand Central Spaghetti of Sloans Valley (Figs. 2.118 and 2.124). Additionally, the interplay between collapse, sedimentation, and the formation of bypass passages creates a well-developed anastomotic pattern in the major valley drains of Sinking Valley, Coral, and Sloans (Figs. 2.117, 2.121, and 2.124). An example in Sloans, the Ewers Loop, illustrates the intensity of passage development in these mazes. An inventory revealed 66 side leads that are not surveyed or explored; 35 were not properly labeled, 16 were filled with sediment, 13 were filled with water, and two were blocked by collapse.

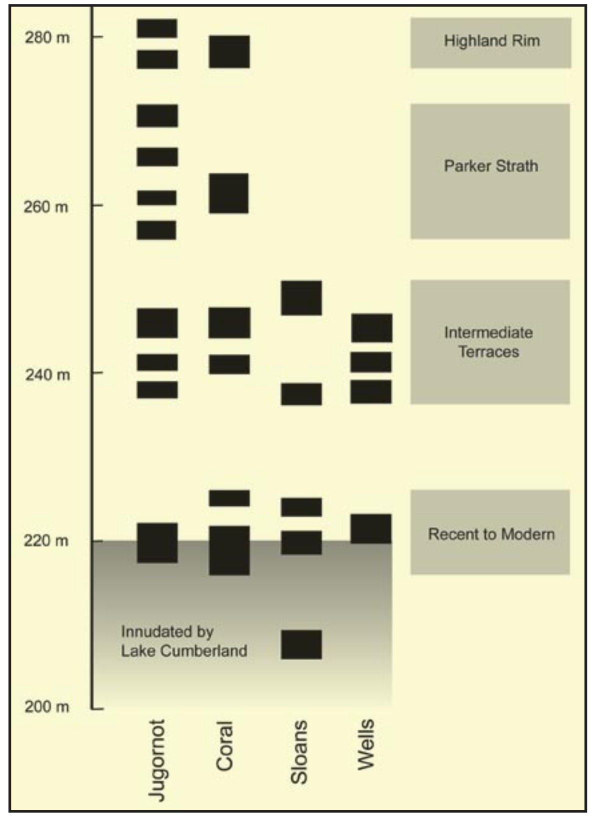

Figure 2.129: Cave levels in Jugornot, Coral, Sloans Valley, and Wells Caves. The data generally cluster at elevations of 0-5, 17-30, 45-50, and 58-63 m above the base level established by the Upper Cumberland River. These clusters align with nearby fluvial terraces on the river.

Many of the large systems in the study area have perennially sumped passages, their lengths inferred from dye traces. Coral Cave has two such low-level passages totaling more than 2 km. One is an underdrain following the southwestern alignment of the trans-ridge passages. The other flows south along the Hound Hollow alignment. This underwater passage is marked by a series of sumps, each downstream sump lower than the last. Sinking Valley may have the most extensive network of underwater passages, with more than 2.6 km of sumped passages, as estimated from dye traces. These underdrains may be formed within a saturated zone a few meters below active vadose passages. The sumped passages of both caves have also been associated with collapse of stream outlets, influx of sediment, and erosion of a widening drainage basin. Some of these sumps have been dived. In one case a diver was trapped under a loose ceiling slab that fell onto him. This instance, as well as that of crushed plastic bottles jammed into a ceiling crevice, suggest that passages are enlarged by high-pressure flood blasting as well as chemical dissolution.

While evidence suggests that for the most part active cave enlargement is storm-driven today, past changes in climate and river levels may be proven to have caused a larger role in a phreatic process over the million or so years of cave development. Large passages of great length, holding immense quantities of silicate sediments, and having large scallops indicating low flow velocities, have been correlated with river terraces. This suggests long periods of upward-climbing rivers atop increasing beds of sediment. Such conditions may be conducive to phreatic cave development.

Cave Levels and Quaternary Landscape Evolution

The near-horizontal, sinuous passages of elliptical cross section that operate as valley drains in the Cumberland Plateau have formed in response to stable water tables (Fig. 2.129). Each of the caves described here contains similar relict passages at higher elevations that reflect episodic changes of base level (Palmer, 1987). Many high cave levels are truncated by valley

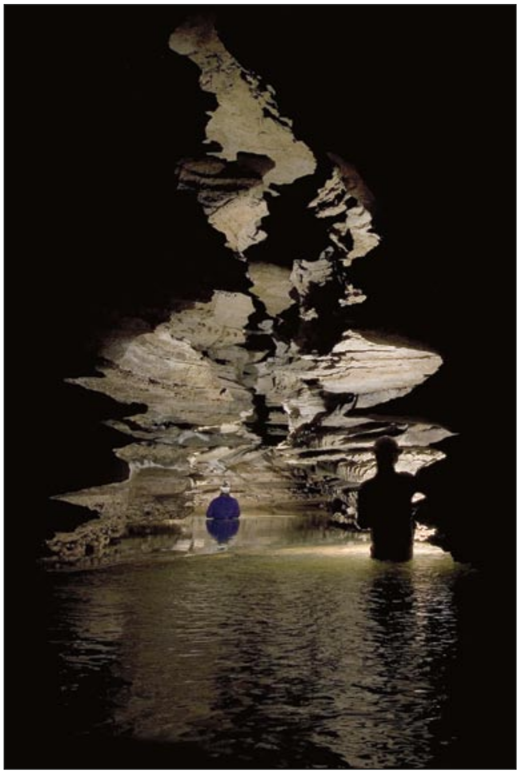

Figure 2.130: Entrenched canyon in Grayson Gunner Cave in Wayne County, Kentucky. Such passages are an indication of periods of rapid base-level incision. Photo by Rob Coomer.

deepening and remain only where protected by intact caprock, as in the trans-ridge passages of Coral and Jugornot.

Sediments in these passages date to the approximate time that the passage was last active. Anthony and Granger (2004) have dated detrital quartz sediments from caves in the Cumberland Plateau of north-central Tennessee and at two sites in Kentucky (Sloans Valley and Great Saltpeter Cave). Their results reveal regional changes in base level caused by stages of incision of the Upper Cumberland River controlled by the advance and retreat of the Laurentide ice sheet during the past four million years. The dates of these events are similar to those of cave levels in Mammoth Cave (Granger et al., 2001).

Expectedly, the caves described in this section contain passage levels similar to those found by Anthony and Granger (2004) in north-central Tennessee. The data generally cluster at elevations of 0–5, 17–30, 45–50, and 58–63 m above the present base level of the Upper Cumberland River (Fig. 2.129). The highest cluster consistently includes one or two closely spaced passages of elliptical or rectangular cross section. The intermediate clusters are more complex, mostly composed of several smaller sublevels (Figs. 2.123 and 2.129). The four principal levels broadly align with nearby sediment terraces on the land surface, which were deposited during periods of glacial impoundment and low hydrologic gradient (Anthony and Granger, 2004).

In contrast, rapid incision between sedimentation events is marked by hanging valleys and abandoned meanders that empty into deep gorges that have been cut into the sediment terraces and the relatively flat sinkhole plains immediately west of the Cumberland Plateau (known in Tennessee as the Highland Rim surface). In caves, these periods of rapid incision are recorded as tall canyons with complex cross sections (Fig. 2.130). Cumberland Falls, on the Upper Cumberland River upstream from Buck Creek and Rockcastle River, may be the remnants of a nickpoint that migrated upstream during the last incision event. The 18-m height of Cumberland Falls is approximately the same as the elevation difference between the lower two passage levels (Fig. 2.129).

Assuming continuity between our observations and those of Anthony and Granger (2004), the available evidence indicates the following major periods of base-level stability separated by periods of rapid incision: (**1**) A stable period prior to 3.5 million years ago (Mya) when base levels ranged between 58 and 63 m above that of today. The highest (and oldest) passages formed at that time (e.g., the Richardson section of Coral and the Wonderland section of Jugornot). (**2**) Incision into the Highland Rim around 3.5 Mya. (**3**) A return to base-level stability between 3.5 and 2.1 Mya, when sediments aggraded to form what is known as the Parker Strath. Passages such as the HA Series in Coral and the Green Bat in Jugornot formed 45–50 m above modern base level. (**4**) Incision into the Parker Strath during a period of mixed stability from 2.1 to 1.5 Mya. During that time, closely spaced levels formed 17–30 m above modern base level in Jugornot and Coral Cave. The upper-level maze formed in Wells Cave and the Grand Central Spaghetti formed in Sloans Valley. (**5**) A major aggradation event around 0.85 Mya filled many of the intermediate level passages. (**6**) Since 0.85 Mya a sharp incision into the lower terraces removed many of the aggraded sediments. The modern active valley drains formed.

Summary

Our examination of some of the largest cave systems along the Cumberland Escarpment in Kentucky leads us to the following generalizations. Younger caves deeper in the interior of the plateau are forming where the limestones have limited surface exposure. Almost all passages are active and at one level, and the flow through them connects a few discrete sinking streams at the edge of the insoluble caprock with springs. Mature caves near the plateau margin collect water from much larger areas with a mix of limestone and clastic sources. They consist of active levels that may connect several sub-basins, and other higher levels of relict passages that record the stages of incision of base-level rivers. Advanced-stage caves on sinkhole plains west of the plateau are in the process of passage truncation and collapse. Recharge to these older caves is derived mainly from the limestones.

The organization of cave passages in eastern Kentucky is similar to that in the Cumberland Plateau of Tennessee and in analogous hydrogeologic settings. A number of small passages “stair-step” through the lithology en route to the local base level and collect into a master drains that generally follows the trends of valley walls. The overall cave pattern is dendritic, but the low-gradient valley drains often have anastomotic characters.

Cave passages tend to alternate in cross section between elliptical and rectangular (indicating development at stable base levels, with pipe-full conditions during floods) and tall canyons that connect the levels and which mark periods of river entrenchment. Regionally, cave levels occur at similar elevations and generally align with nearby fluvial terraces. It is suspected from studies in other nearby regions that these levels record four million years of alternating entrenchment and aggradation related to glacial and interglacial episodes.

Acknowledgments

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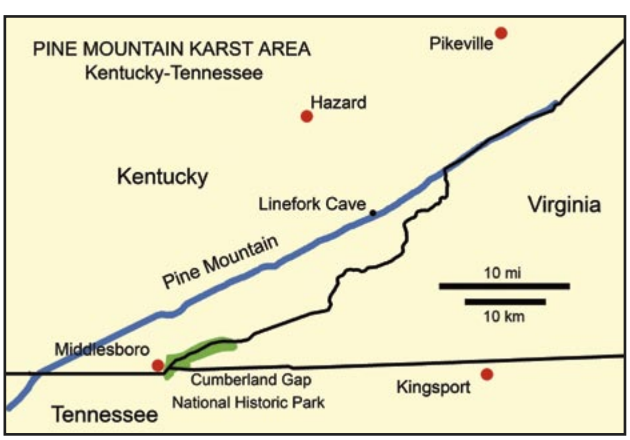

Figure 2.131: Location of Pine Mountain karst area, southeastern Kentucky and northeastern Tennessee. After Saunders (1985).

The Pine Mountain Karst of Eastern Kentucky

Based on the work of Joseph W. Saunders

PINE MOUNTAIN is a long, narrow ridge tat extends 170 km in a NE-SW direction parallel to the Kentucky-Virginia border (Fig. 2.131). It was mentioned briefly in the sidebar on Cumberland Gap at the end of the section on Virginia. The mountain also extends southwestward into Tennessee. The ridge follows the northwestern edge of the Pine Mountain overthrust block and is the westernmost portion of the Ridge and Valley Province in this area (Mitra, 1988). Local relief is fairly high (nearly 500 m). The ridge is breached in only a couple of places, most notably by the Cumberland Gap, where the Cumberland River flows through.

Caves and karst are located mainly along the northwestern flank of the ridge in the Newman Limestone (Mississippian), which is the local equivalent of the Greenbrier Group in the Virginias, the Monteagle Limestone farther west and south, and the limestones of the Mammoth Cave region in central Kentucky. In Pine Mountain the limestone is about 120–180 m thick. It is overlain by the Pennington Formation (Mississippian and Pennsylvanian shale and sandstone) and underlain by the Grainger Formation (Mississippian siltstone and shale).

The limestone is exposed along an escarpment drained mainly by small, steep basins. Surface karst is sparse, and caves are generally small. There are several impressive vertical shafts up to 73 m deep. Springs are numerous but fairly small.

At least two dozen caves are known in Pine Mountain. The longest is Linefork Cave, which has been mapped to about 2.5 km (Fig. 2.132). Its map consists of essentially a straight line oriented along the NE-SW strike of the beds along the base of the mountain ridge. Many of the passages have triangular cross sections with a sloping roof composed of steeply dipping limestone beds and an irregular wall on the other side composed of the exposed edges of beds, many of which have been truncated by breakdown.

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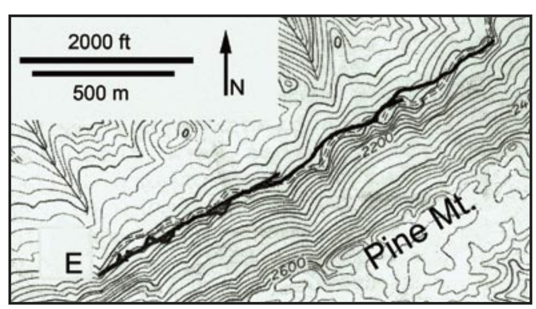

Figure 2.132: Map of Linefork Cave, Pine Mountain, Kentucky. From map by Saunders (1985). The cave is oriented along the strike of the southeast-dipping beds of Newman Limestone. E = entrance.