The Friars Hole System

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Abstract

The Friars Hole Cave System in Greenbrier and Pocahontas Counties, West Virginia, at 73.4 km, is the longest cave in the Appalachian Highlands of eastern USA. The cave System, composed of three internal drainage complexes extending over a linear distance of almost 7 km, has had a long and complex evolution with most of it being over 730,000 years old and one dated speleothem having an age of over 1.67 million years. Although nearly the entire cave System is developed in the upper Greenbrier Group limestones (the Union and Pickaway limestones), two of the cave's three active drainages breach the Taggard formation, a major aquitard below the Pickaway and extending the cave's stratigraphic extent. The cave represents an evolutionary sequence of drainage Systems discharging to two springs 20-km distant from each other with high flows discharge to one and low flows to the other. Drainage patterns have shifted over time as the surface drainage is captured. An estimated age for the entire System is 4.1 million years.

8.1 Introduction

The Friars Hole Cave System is a 73.4-km-long complex cave developed in gently dipping Mississippian limestones. It is the largest cave in terms of surveyed passages in West Virginia. The cave is found in the Appalachian Plateaus Province in the eastern USA and is developed in moderately faulted northwest dipping limestones of the 217-m-thick Mississippian Greenbrier Group. The cave extends over a vertical range of 187 m and contains several currently active internal drainages that were formerly integrated but which now are separated (in terms of human exploration). The cave extends over a linear distance of nearly 7 km, underdraining several valleys above it. The floor plan of the cave shows currently active and abandoned flow paths and internal drainage divides.

Electronic supplementary material
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8.2 Regional Setting

The Friars Hole Cave System is located in northern Greenbrier and southern Pocahontas Counties in eastern West Virginia (Fig. 8.1). The cave is in the central Appalachian Mountains, between the folded and faulted Valley and Ridge Province to the east and gently dipping sedimentary (primarily clastic) rocks of the Allegheny Plateaus Province to the west. The cave is on the west flank of the Browns Mountain Anticline, the largest fold of the central Appalachian Plateau. Although the primary orientation of the cave is along strike, extending for 7-km end to end, it also has a substantial development following the generally 2° dip to the northwest, with passages traversable for up to 1800 m in this direction. The cave underdrains both the Friars Hole Valley and adjacent valleys to the northeast and northwest of it, following the general regional strike of about N30°E. The Friars Hole drainage encompasses 95 km^2 and includes the surface drainages of Hills Creek, the Friars Hole Valley and infeeders to it, and Robbins Run to the west of the Friars Hole Valley.

The cave lies between linear ridges to the east and west (Droop Mt., Brushy Mt., Parker Mt.) with summit elevations

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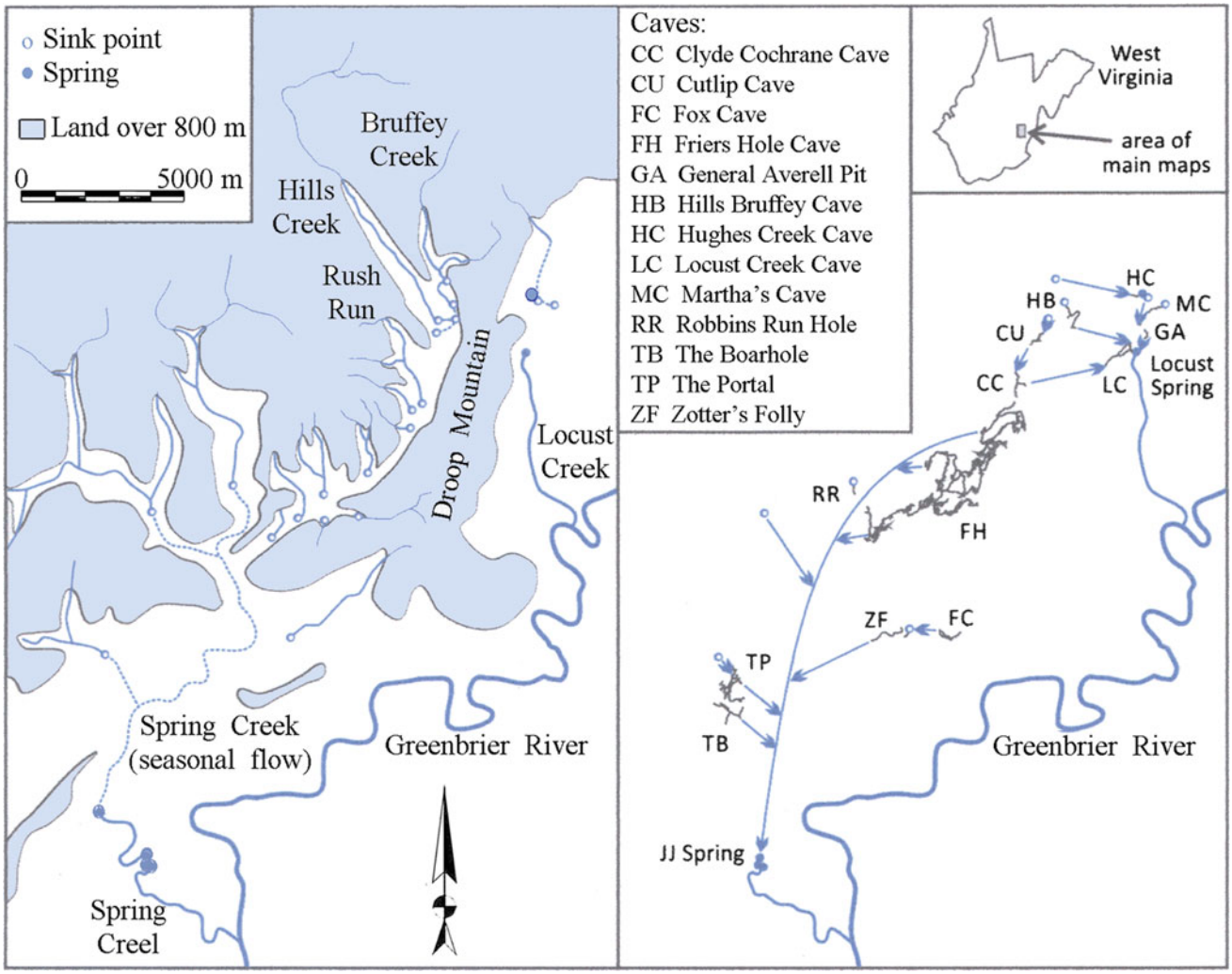

Fig. 8.1 Location, topography, and hydrology of the Friars Hole area. *Arrows* represent simplified flow paths of unexplored cave streams, confirmed by tracer tests

of 850–950 m, about 150 m higher than the valleys beneath which the cave is found. These ridges consist primarily of sandstones and shales of the Mississippian Mauch Chunk Series. Only the upper 20 m of the upper Greenbrier limestones and shales are exposed in a series of strike-oriented inlier valleys (Fig. 8.2). Seven of the nine entrances to the cave are found where streams sink in these limestone inliers. These entrances either consist of or lead to one of a series of vadose shafts dropping through the Union Limestone and into generally horizontal passages below at the contact between the Union and the underlying Pickaway Limestone. A plot of the cave showing its relationship to the local topography is shown in Fig. 8.3.

Streams flowing off of the higher Mauch Chunk clastics either sink into the highest member of the Greenbrier, the roughly 20-m-thick Alderson Formation, or into the upper part of the 48-m-thick Union Limestone below. The Alderson consists of interbedded calcarenites and calcilutites, primarily calacreous shales and siltstones and argillaceous and silty limestones. The basal member of the Alderson is called the Greenville Shale, a 4- to 9-m-thick aquiclude. Streams sinking on the Alderson rise at the top of the Greenville member, flow over it, and then sink again upon reaching the upper Union Limestone. All of the entrances to the cave are in the upper 10 m of the Union. Although the Union is the purest member of the Greenbrier Group, consisting of over 90% oolitic and muddy calcarenites, the majority of passages in the cave are found in the relatively impure 27-m-thick Pickaway Limestone below it, composed of alternating calcilutites with about 25% insolubles and calcarenites with 5–10% insolubles (Jameson 1985).

Both east- and west-dipping thrust faults are visible in many of the passages in the Friars Hole System. These faults

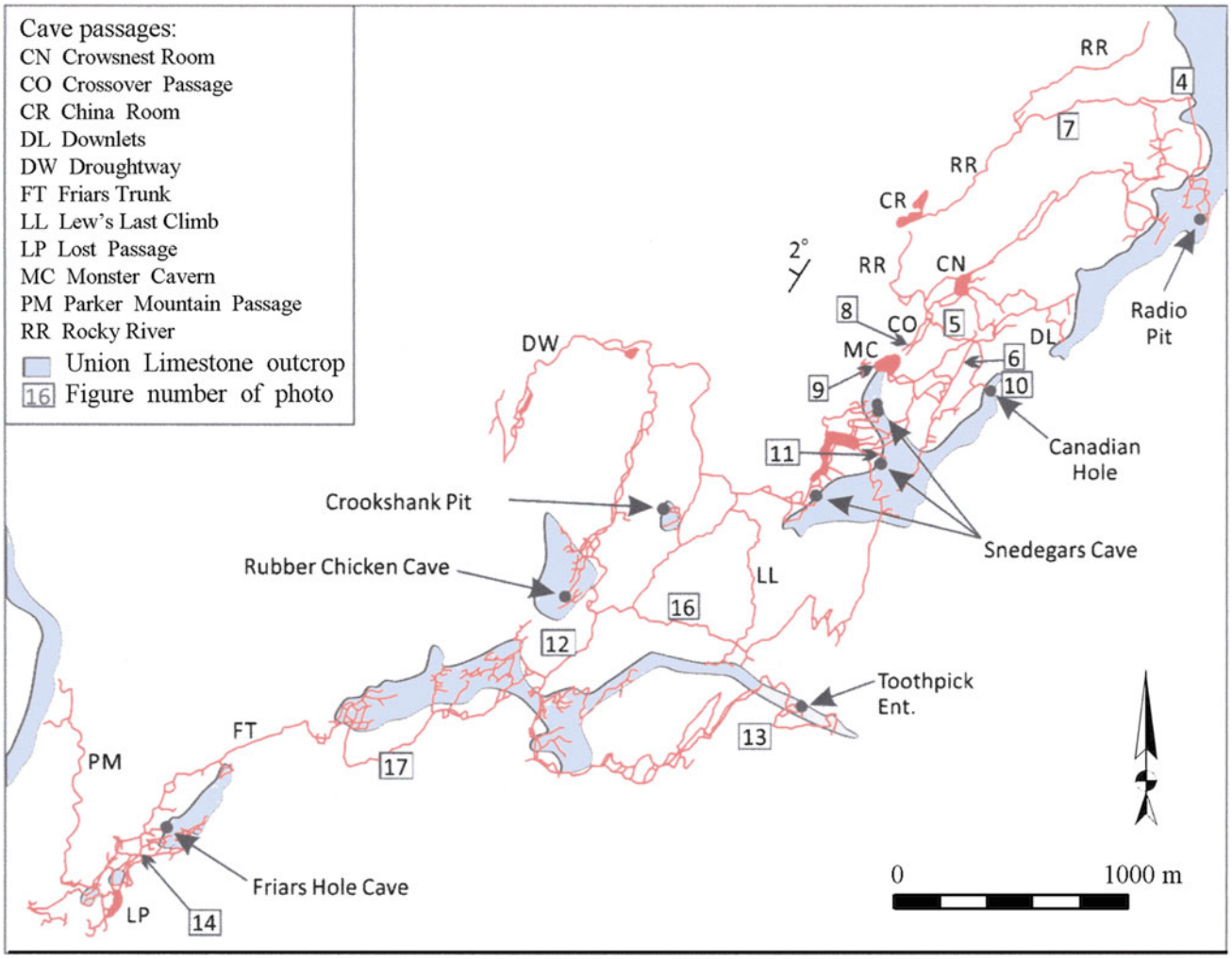

Fig. 8.2 Friars Hole Cave System passages showing surface outcrops and major features

generally strike at about N25°E and have low displacements. In three places in the cave, stream passages cross through the Pickaway Limestone and follow low-displacement faults, breaching the 7-m-thick Taggard Formation below it. The Taggard is a limestone-shale-limestone sequence that serves as an aquitard. It should be noted that all of the cave's drainage rises at a spring (JJ Spring, described below) that is perched on top of the Taggard Formation, and thus, the Taggard must be breached from below by the cave's drainage before rising at the JJ Spring.

8.3 Regional Hydrology

The regional hydrology of the area containing the Friars Hole Cave System as well as other caves is shown on the right side of Fig. 8.1. The solid lines show the traced flow paths of the cave streams in this area. Hills Creek is the largest of the sinking streams along the Friars Hole Valley. Under low-flow conditions, all of Hills Creek sinks in its bed and flows to Cutlip Cave, the upper of two aligned strike-oriented caves (Cutlip and Clyde Cochrane Sinks) before being seen again at the upper (NE) end of the Friars Hole System where it emerges from rockfall as Rocky River (RR in Fig. 8.2). Under higher flow conditions, Hills Creek is a partly losing stream with some of its flow sinking in its bed and entering Cutlip Cave, while the rest flows 500 m east and, with the flow of a parallel stream, Bruffey Creek, enters the Hills–Bruffey Cave, and passes beneath the north end of Droop Mountain in largely inaccessible passages. The stream is seen again in a sequence of caves on the east side of Droop Mountain: Upper and Lower Hughes Caves, Martha's Cave, and General Averall Pit, before flowing through the 3.26-km-long Locust Creek Cave and rising at Locust Spring at the base of the Greenbrier limestones on the east side of Droop Mountain, 2.25 km to the east of the Hills–Bruffey Cave entrance. Finally, under very high-flow conditions, the combined Hills and Bruffey Creek streams

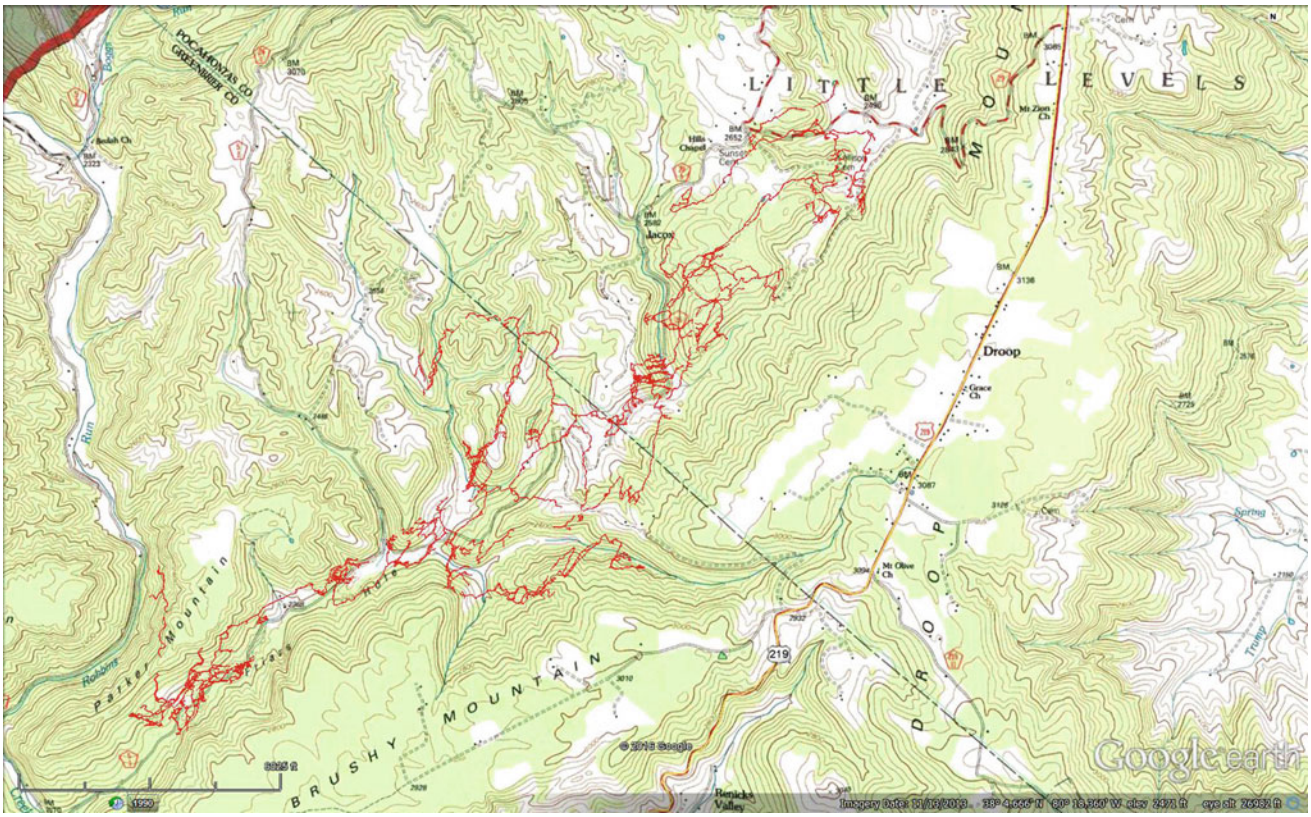

Fig. 8.3 Friars Hole Cave System line plot on topographic map. Base map: USGS Droop 7.5 min quadrangle

fill up the Hills–Bruffey Cave entrance and passages and back floods across the valley to the Cutlip Cave sink point.

The Rocky River (i.e., underground Hills Creek) stream as well as all of the other streams in the Friars Hole System rises 18 km to the southwest of the Cutlip Cave sink point at a spring (JJ Spring) on the east side of Spring Creek, a tributary to the Greenbrier River. JJ Spring is a perennial spring with a measured low-flow discharge of 12.6 ft^3/s (0.36 m^3/s) (Jones 1997). In addition to the Friars Hole Cave drainage, it is the resurgence for Spring Creek and several other streams sinking in a 265 km^2 area, including the Friars Hole drainage. Three other springs on Spring Creek, the Cannon Hole, the circulating Cenote, and Dale's Spring, are a few hundred meters upstream of JJ Spring and, under high-flow conditions, serve as overflow springs for the Friars Hole drainage, i.e., some of the Friars Hole water rises at these higher springs and flows on the surface while the remainder rises at JJ Spring (Jones 1997).

8.4 History of Exploration

A detailed description of the history of exploration of the Friars Hole System through the early 1980s can be found in another publication (Baker 1982) (see also Chap. 5). The text below is a very abbreviated summary with emphasis placed on those efforts that resulted in either the opening of entrances or the linking of major cave segments.

8.4.1 Snedegars/Crookshank

The centrally located dry and horizontal Snedegars Saltpetre entrance was used as access to the cave during the Civil War, where it led to passages used for Saltpetre mining. The earliest documented exploration during the twentieth century was in 1951 when explorers H. Ingalls and G. Moore descended the 30-m-deep Crookshank Pit 1 km to the southwest of the Saltpetre Entrance and explored passages that approached but did not connect to that entrance. The connection between these caves was subsequently made via a semi-sumped crawl in June 1964.

8.4.2 Friars Hole Cave

The southernmost entrance to the cave is a small opening at the bottom of a 15-m-deep doline located in the lower Friars Hole Valley, 3.5 km southwest of the Saltpetre entrance. This entrance was dug open by G. Titcomb and C. Schwab

in August 1964. The opening led to a series of climbdowns and two 8-m pits followed by a 12- to 15-m-wide and 6- to 8-m-high master drain beneath the Friars Hole Valley. This passage contained a stream flowing southwest, along strike. Subsequent exploration and surveys by L. Bicking and others in the mid-1960s led to the discovery of 6 km of the cave. Although Bicking's surveying ended with his untimely death in a motorcycle accident, it was continued by C. and B. Williams. Subsequent exploration and surveys were carried out by numerous others with substantial discoveries made in the early 2000s by B. and S. Preaux and others in passages called Mauckland and Water World and by K. Owens and others in a passage called Big Water, as described under "Friars Hole System Description" below.

8.4.3 Rubber Chicken Cave

In March 1976, a sinking stream 2 km to the northeast of the Friars Hole entrance and 500 m SW of the Crookshank Pit entrance was excavated by D. Medville, B. Baumgartner, and G. Mothes. This led to a 3 m climbdown followed by a 22-m pit. A narrow passage at the base of the pit led to a 6- and 5-m-high passage containing a stream that flowed to the north, away from the Friars Hole stream. Surveys in 1976 resulted in 7 km of passage in a separate cave called "Rubber Chicken," named after a child's toy of that name found during the entrance excavation. In May 1976, the Rubber Chicken Cave was connected to the upper end of the Friars Hole Cave by cavers from McMaster University and then surveyed by US cavers C. and B. Williams, C. Hempel, and E. Strausser.

Comparison of the maps of Crookshank Pit and Rubber Chicken Cave indicated that the ends of two passages in these caves approached each other and were only 10 m apart. In the spring of 1976, parties entering each cave went to the respective ends of these passages and established voice contact. After removing rocks that separated the two passages, another connection was made. By the end of 1976, the combined Snedegars/Crookshank/Friars Hole/Rubber Chicken Cave System had over 24 km of surveyed passages and for simplicity, the entire cave was named The Friars Hole System.

8.4.4 Canadian Hole

A short but sporting wet cave 500 m to the north of the Snedegars Saltpetre entrance was visited in the summer of 1976 by cavers from Alberta, Canada. After descending a five-pitch entrance series, one of them (E. Neilsen) found a way up through breakdown at the cave's end. This led to a substantial canyon passage going downstream to the northwest (First Canyon). Within a year, 8 km of passages were surveyed and the previously short cave was re-named Canadian Hole. In subsequent years, a large majority of the exploration, study, and survey of this cave was carried out by cavers from McMaster University in Hamilton Ontario and by members of the Société Québecoisé de Spéléologie (D. Caron, A. Goupil et al.). The section of the cave discovered in 1976 was named the Alberta Extension. A 500-m-long wet boulder filled crawl (Almost Hell) led north from the end of the Alberta Extension and then opened into another substantial section of Canadian Hole called the Ontario Extension. Because trips to this part of the cave were long and tiring, a cave radio was brought into a passage near the north end of the Ontario Extension by S. Worthington and C. Pugsley, and communication with the surface was established. A 3-m dead bottom hillside pit a few meters from where the cave location was made then became the site of a multi-month dig effort to connect it to Canadian Hole, 39 m below. In May 1987, this effort succeeded, resulting in Radio Pit becoming the northernmost entrance to the Friars Hole System, 1.25 km northeast of the Canadian Hole entrance.

In September 1977, four McMaster cavers (J. Mort, A. Recklies, A. Thurston, O. Slupecki) entered Canadian Hole and, after surveying south through a series of low wet passages, found footprints in the mud floor and a survey station on the wall. The footprints and survey station had been left by US cavers who had previously surveyed north in a 2.3-km-long passage (The Highway) in Rubber Chicken Cave. With this connection, Canadian Hole was added to the Friars Hole System and, as of late 1977, the combined length of the cave had increased to 33 km.

8.4.5 Toothpick Cave

The 30–m-wide, 15-m-high, and 20-m-deep Amphitheater-like entrance to Toothpick Cave is at the bottom of a local drainage called Ravens Nest Hollow, 1.2 km south of the Snedegars Saltpetre entrance and separated from it by a 100-m-high western spur of Droop Mountain. This impressive entrance, named from the logs inside that had the appearance of toothpicks compared to the entrance size, leads to 150 m of vadose passage in the Upper Union Limestone, followed by a 20-m pit. Initial exploration of the cave was carried out in the early 1960s by V. Schmidt, R. Cope, W. White, L Bicking, and others. The stream at the bottom of the 20-m pit flowed west and into a mud-choked sump, limiting further exploration. During very dry weather in 1978, attempts were made to follow the Toothpick stream beyond the sump to see if it could connect to the main Friars Hole System, 1,100 m to the west. These efforts were successful, and in October 1978, three cavers (L. Baker, R.

Anderson, K. MacGregor) squeezed through low airspace passage and into much larger passage going to the southwest. A month later, a survey/exploration party (R. Anderson, L. Baker, P. Mothes) followed the Toothpick cave stream downstream for 1,400 m to a survey station at the upstream end of Rubber Chicken Cave, confirming a connection between Toothpick and the Friars Hole System and adding another 5.8 km of passage to it.

8.5 Cave Hydrology

Numerous streams sink in a series of inlets and blind valleys that are generally aligned along the N20°E strike of the Greenbrier outcrop on the west side of Droop Mountain. These sink points extend over a distance of 8 km and are in the upper few meters of the Union Limestone where the limestone is exposed in inliers between sediment filled surface drainages. Of the over 100 inlets to the cave, seven lead to entrances to the 73.4-km-long Friars Hole Cave System; three other entrances are dry.

After reaching these entrances, the streams flow short distances (up to 150 m) in vadose canyons in the upper Union before descending through the majority of the Union Limestone via one or more vadose shafts leading to the Union/Pickaway contact (Fig. 8.4). Inside the cave, numerous infeeder streams can be followed upstream to shafts carrying water from the surface, generally beneath the limestone inliers above. Passages at the tops of these shafts, where entered, are also vadose canyons in the Union, ending in surface fill or becoming too narrow to follow.

Below these pits, the streams generally flow down dip to the northwest or to the southwest in high, joint-controlled vadose zone passages (Fig. 8.5) or gently dipping bedding planes serving as linking passages before turning to the northeast or southwest in lower gradient main drains. These drains are developed in the lower Union or just below the contact between the Union Limestone and the underlying Pickaway Limestone and can be followed for considerable distances along strike, following bedding planes and/or thrust faults that intersect these bedding planes. Examples of drains in the lower Union include the Friars Hole Cave trunk downstream of the Dung Ho Way, much of the Toothpick Cave trunk, the upper part of the Rubber Chicken Cave highway and further north, the Canadian Highway (Fig. 8.6). These are some of the larger diameter and most linearly extensive passages in the System.

As the System developed, the main drains migrated both down dip to the northwest and down stratigraphically, into the upper and middle Pickaway Limestone below. Examples include the lower part of the Highway in the Rubber Chicken Segment of the System, the Droughtway in the lower Crookshank Segment, and Skid Row/Columbus Avenue in the Canadian Hole Segment (Fig. 8.7). In a couple of places, these drains dropped further, passing through the lower Pickaway and Taggard Shales below it and into the Patton Limestone member of the Denmar Formation. Examples include lower Rocky River in the Canadian Hole Segment and the Water World passages at the southwest end of the Friars Hole Segment of the System.

Fig. 8.4 Vadose shaft in Friars Hole Cave System (Trombone Aven). Photograph by Ron Simmons

Although most of the cave's passages are in the Pickaway Limestone, two long passages are found in the Union. One is the Lew's Last Climb passage, draining the Toothpick Cave Valley 600 m below the Toothpick Cave entrance. Dolines on the surface above the end of this passage may indicate that the Ravens Nest Hollow surface water sank in this area before headward capture by the current Toothpick entrance took place upstream. The Lews' Last Climb Passage was initiated along a low-angle thrust fault and consists of a high canyon in the lower Union Limestone that extends north for 700 m before dropping into the Pickaway Limestone at an 8-m pitch and then continuing to the Snedegars Cave stream.

The second long passage in the Union is the Parker Mountain Passage, a paleo-infeeder originating in domes

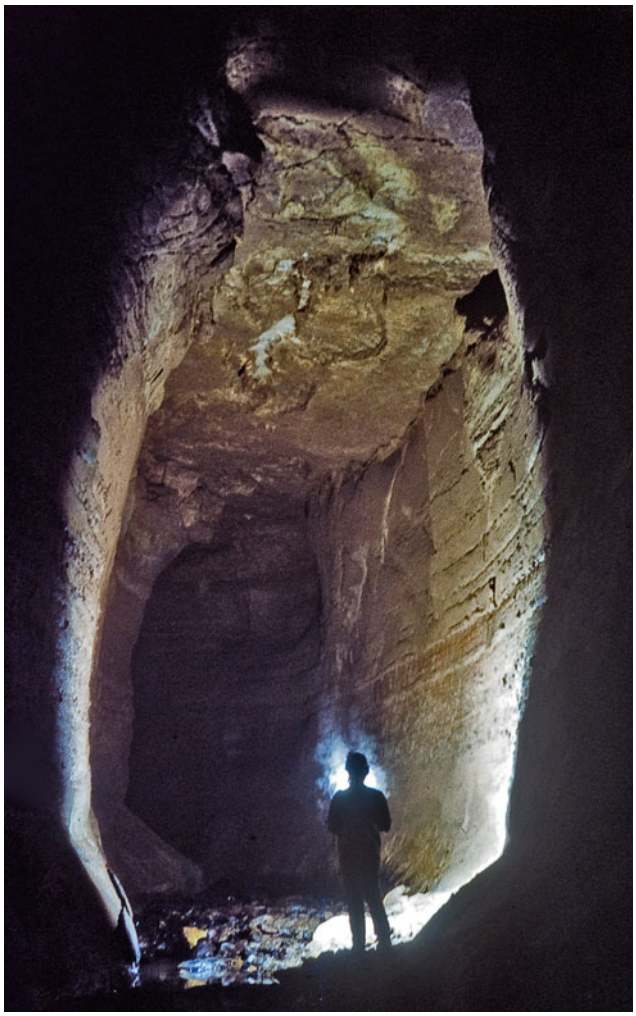

Fig. 8.5 First Canyon in Canadian Hole Segment. Photograph by David Bunnell. Used with permission

beneath the eastern hillside of Robbins Run, the next valley to the west of the lower Friars Hole Valley. Although now dry and almost sand filled, this passage can be traversed for over 1.9 km from the Robbins Run Valley before intersecting the top of the west wall of the lower Friars Hole Cave trunk passage, a few meters downstream of its junction with the entrance passage to this part of the System. A shallow phreatic half tube can be seen in the ceiling of the Friars Hole trunk extending beyond the Parker Mountain passage termination, 9 m above the floor of the Friars Hole trunk, indicating the former continuation of this passage.

The Friars Hole System contains three integrated internal drainages as described below.

8.5.1 Northeastern Drainage

This drainage, in the Canadian Hole part of the System, contains a large stream named Rocky River. This stream represents the part of Hills Creek that sinks in its bed above Cutlip Cave and flows through both Cutlip and another cave to its south (Clyde Cochrane Sinks) before being seen in the Canadian Hole part of the System, 120 m south of the downstream sump in Clyde Cochrane Sinks. Rocky River is a strike-oriented stream draining much of the flow from a 45 km^2 catchment to the north and is the perhaps the largest of the streams in the System. It flows for 1.4 km within the cave, is lost at a sump, and is seen again about 100 m downstream at another sump (Watergate). It continues to flow along strike for another 0.6 km before being lost in a boulder choke on a fault. Although Rocky River flows on the Pickaway Limestone for nearly its entire length, near its downstream end in the Rocky Horror passage (Fig. 8.8), it passes through the underlying Taggard Formation shales and into the upper Patton Limestone member of the Denmar Formation. This downstream end approaches, but is 30 m lower in elevation than the low point in the floor of the System's largest chamber. The appropriately named Monster Cavern is a 110-m by 55-m room containing a 32-m-high waterfall called Monster Falls (Fig. 8.9).

Monster Cavern is directly beneath the valley that contains the stream flowing into the Snedegars Cave North Entrance and is gradually pirating this stream. The vertical separation between the streambed and the highest point in the cave above Monster Falls is about 30 m. Under low-flow conditions, the surface stream sinks in its bed 200 m upstream from the North Entrance and is seen in the cave as Monster Falls. Under higher flow conditions, that part of the surface stream that does not sink in its bed flows into the North Entrance and then into the Snedegars Cave part of the System with more being lost in the first few meters of passage and flowing to Monster Falls.

Tributaries to Rocky River include water entering near the cave's northeast end at passages called Skid Row, Temptation Streamway, and Camp Inlets. Further south, the Canadian Hole entrance stream descends 35 m over three pits, passing through the Union Limestone (Fig. 8.10). This entrance stream then flows down dip on the Pickaway Limestone in a passage called First Canyon before joining Rocky River just above the Rocky Horror passage. The stream probably continues beneath Monster Cavern but cannot be followed and is not seen again in the cave.

Fig. 8.6 Canadian highway in Canadian Hole Segment. Photograph by Ron Simmons

Fig. 8.7 Skid Row in Canadian Hole Segment. Photograph by Ron Simmons

8.5.2 Central Drainage

The central drainage in the System is arguably the most extensive and contains numerous infeeder streams, five of which enter the cave at various entrances and all of which ultimately combine before ending at a sump 146 m lower than the cave's datum at the Saltpetre Entrance. Two of the streams flow into the Snedegars part of the cave. The intermittent stream flowing into the Snedegars North Entrance flows generally down dip for 200 m before entering the large chamber called the Amphitheater in the historic Saltpetre part of the cave (Fig. 8.11). After a few hundred meters, this stream is joined by another, flowing into the Snedegars Staircase Entrance. This stream then descends 35 m over four drops, about the same distance stratigraphically and vertically through the Union Limestone as does the Canadian Hole entrance stream.

Fig. 8.8 Lower Rocky River in Canadian Hole Segment. Photograph by Ron Simmons

Fig. 8.9 Monster Falls in Monster Cavern, Canadian Hole Segment. Photograph by David Bunnell. Used with permission

The third infeeder stream is the water flowing into the 33-m-deep Crookshank Pit. This stream flows north along strike for 250 m before merging with the two Snedegars streams. The combined streams flow north along strike on the Pickaway Limestone through a series of low airspace near sumps for another 800 m before merging with the remaining two infeeder streams entering the cave from the Rubber Chicken and Toothpick entrances, respectively.

The intermittent stream entering the narrow Rubber Chicken entrance near the top of the Union Limestone flows for a short distance and as noted above, drops over several pits passing through the Union, the deepest of which is 22 m. The stream then merges with a larger one flowing from the Toothpick Cave entrance, and the combined streams follow a series of large, strike-oriented passages for 1.9 km to the north before merging with the Snedegars/Crookshank streams (Fig. 8.12).

Finally, the Toothpick entrance stream follows the same patterns as the other streams entering the cave: flowing for a short distance in the upper Union Limestone and then dropping 20 m at a pit that takes it to the Union/Pickaway contact (Fig. 8.13). This stream then flows southwest along strike and then west, sub parallel to the down dip direction for 1.6 km before turning to the north and following a complex series of passages for another 1 km before reaching the junction with the entering Rubber Chicken stream. Along the way, several other infeeders join this stream, entering via domes at their upstream ends.

The junction of the Rubber Chicken/Toothpick stream and the Snedegars/Crookshank stream takes place at a low passage at the upstream end of a 30-m-long sump that has between 0 and 10 cm of airspace, depending on flow conditions. At the downstream end of this sump (Toms Sump), the stream flows north for 120 m and then turns to the west for 400 m in the larger passage. This passage continues to the southwest for another 700 m, passing beneath the last major chamber in this part of the cave, the 100-m-long and 15-m-wide Mint Room. The stream again turns to the north and then to the south before ending at a sump, 181 m lower than the highest entering stream at the Toothpick Entrance.

Fig. 8.10 Canadian Hole entrance. Photograph by David Bunnell. Used with permission

The Toothpick stream can be followed in the cave continuously for over 5.5 km to the final sump, following passages at the basal Union and upper Pickaway Limestones with much of the passage developed along the intersections of thrust faults and bedding planes. Controls on the development of this passage are discussed by Sasowsky et al. (1989).

8.5.3 Southwestern Drainage

The lower Friars Hole Valley is perched 75 m above local base level in Spring Creek, 1 km south of the southwest end of the cave. This hanging valley contains numerous dolines up to 10 m in depth that capture streams flowing in smaller side valleys. The deepest of these dolines is the one containing the Friars Hole Cave entrance. In addition, the Friars Hole Valley 1 km northeast of the Friars Hole entrance is a blind valley with sinking streams entering the trunk passage below in a series of domes and infeeder passages in the Union Limestone. The Friars Hole trunk passage, underdraining the lower Friars Hole Valley, is a 15-m-wide and an 8-m-high strike-oriented conduit containing an underfit stream.

Flow is from northeast to southwest with the stream dropping into and through the Pickaway Limestone (Fig. 8.14) at its southern end before being lost in boulders near a room bounded on its west side by a thrust fault (Avalanche Room). A 22-m-diameter room 100 m to the southwest, called Barbara's Room, is also developed along a

Fig. 8.11 Snedegars Saltpetre passage. Photograph by David Bunnell. Used with permission

Fig. 8.12 Rubber Chicken stream passage. Photograph by Ron Simmons

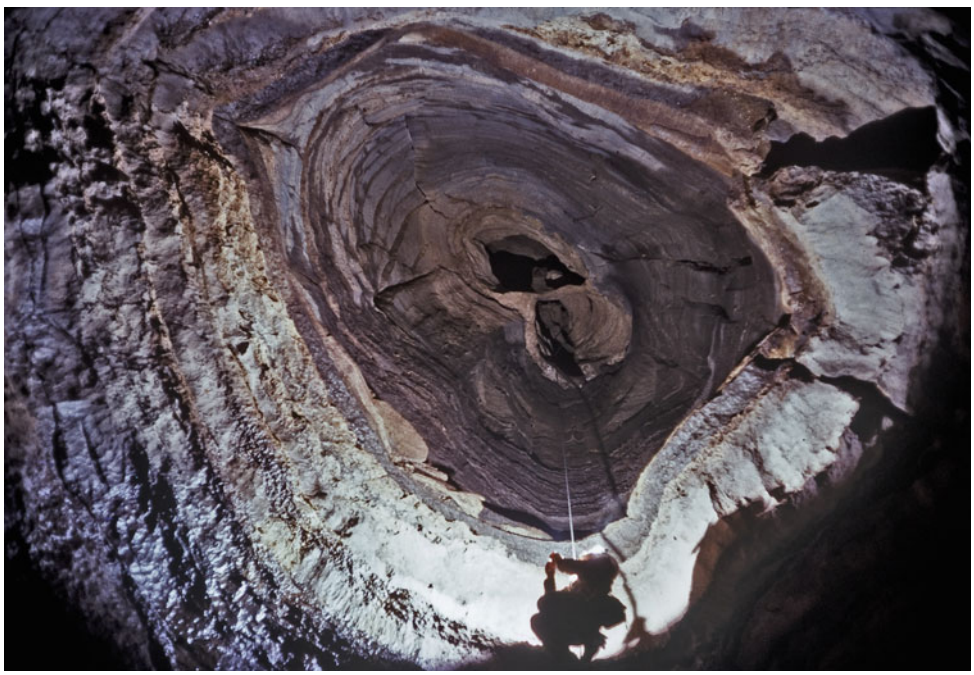

Fig. 8.13 Pit in Toothpick Segment. Photograph by David Bunnell. Used with permission

strike-oriented thrust with slickensides visible on the rooms' northwest wall. A boulder choked passage along this wall descends for 25 m, following the fault plane. At the bottom of this passage, a stream that is substantially larger than the Friars Hole trunk stream is encountered. Sumped at its SW end, the stream can be followed for 300 m to the northeast along a low, boulder filled passage aligned along the strike of the fault. This passage is very similar to the half-km-long Almost Hell passage in Canadian Hole, i.e., developed along a strike-oriented fault. A waterfall entering this passage about halfway along its length and containing surface debris is probably the Friars Hole trunk water, last seen sinking into boulders in a higher passage only 25 m to the south.

This large stream is also seen in another passage (Water World), reached via another route 200 m to the southwest. The two passages are aligned, are at the same elevation, and are separated by a sump. These stream passages are 100–110 m lower in elevation than the Friars Hole Cave entrance.

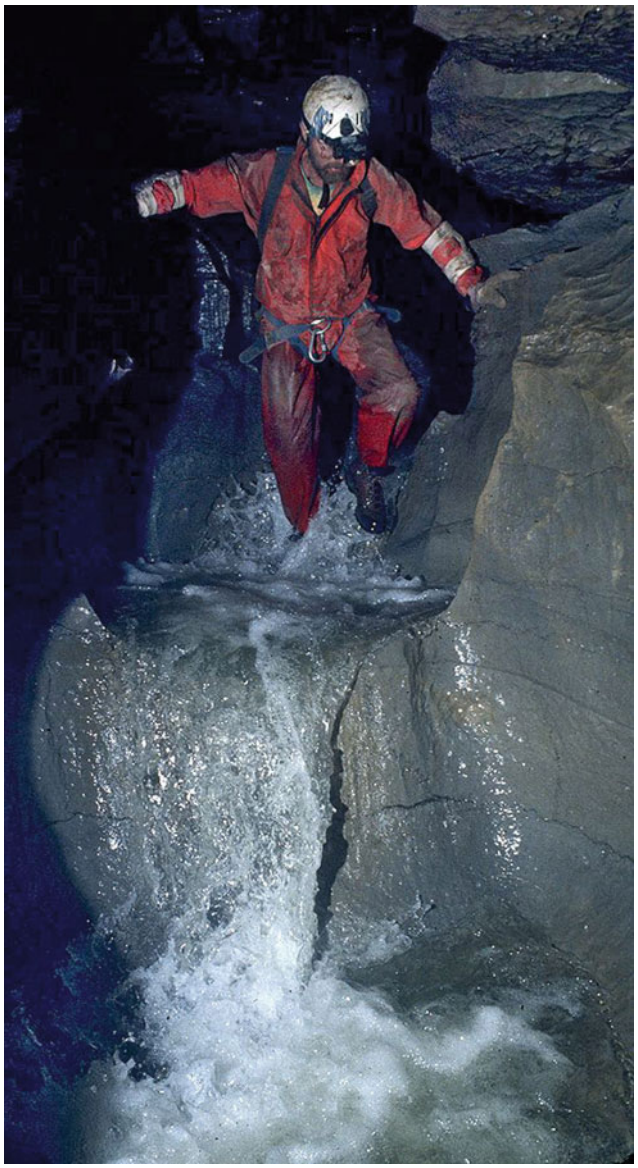

Fig. 8.14 Potholes above Pool Room in Friars Hole Segment. Photograph by David Bunnell. Used with permission

Taking into account the 2°NW dip, the location of the Friars Hole entrance about 5 m below the top of the Union Limestone, the down dip component of the distance from the entrance to the streams and the measured thicknesses of the Union and Pickaway Limestones and the Taggard Shale, the lowest streams in the cave are about 18 m below the top of the Patton Limestone member of the Denmar formation. The passages are also 32 m lower in elevation than the bed of Spring Creek, 1 km to the south. The vertical separation between the southwestern end of these streams, i.e., the lowest point in the cave, and the Friars Hole resurgence at JJ Spring is 21 m; the straight line distance between the two is 7.3 km and the gradient is 0.0029. The 21-m elevation difference implies that there may be substantial lengths of cave passage with airspace, although in high-flow conditions it may be completely flooded.

The large stream that is seen in passages at the southwestern end of the Friars Hole System contains water that has been traced from the Robbins Run valley, 2.3 km to the northwest and draining a 26 km^2 area (Jones, W.K., personal communication, 2016). Although it is possible that the water seen in the central and northern parts of the System also drains into this stream, this has not yet been confirmed by tracer tests.

8.6 Cave Paleohydrology

The paleohydrology of the cave is best illustrated by the passages to the west of the Canadian Hole entrance, where the development of the cave over time is the easiest to understand (Fig. 8.15). Many sink points have developed close to the top of the Union Limestone. Canadian Hole (Fig. 8.10) is one, and this and five other sinks that provide inlets to the cave are shown in Fig. 8.15. Passages from these inlets typically descend one or more pits (Fig. 8.13) to reach the lower part of the Union Limestone and the upper part of the Pickway Limestone, where most of the horizontal development has taken place.

Since the cave was first developed, Hills Creek has provided the largest surface catchment for the cave and has resulted in the formation of some of the cave's largest passages. Its initial sink point was at the Downlets, and from there the Highway, a large phreatic passage, drained the water along the strike (flow path 1 in Fig. 8.15; Figs. 8.6 and 8.16). As the creek eroded down into the limestone, new sink points developed further upstream, capturing the flow which then formed the lower strike-oriented conduits Crossover Passage and Rocky River (flow paths 2 and 3, respectively, in Fig. 8.15). Smaller sinking streams such as at Canadian Hole (Fig. 8.10) formed down dip passages that developed into vadose canyons (Fig. 8.5) and formed tributaries to the major strike-oriented passages. Progressive diversion to more efficient flow paths resulted in the complexity that is now seen in the cave.

The sinking streams that provide the catchments for the substantial flow through the cave also provide a substantial load of sandstone and clay. Active stream passages usually are floored by sandstone gravel and cobbles (Figs. 8.4, 8.5, 8.7, 8.12, and 8.16). Major floods in the cave raise water levels and overflow into normally inactive passages, leaving clay sediments (Figs. 8.6 and 8.17). In addition, some active stream passages also have banks of clay (Fig. 8.16). Where passages are wide, roof collapse can result in breakdown (Fig. 8.11). The largest void in the cave is Monster Cavern (Fig. 8.9), which has a volume of 350,000 m^3.

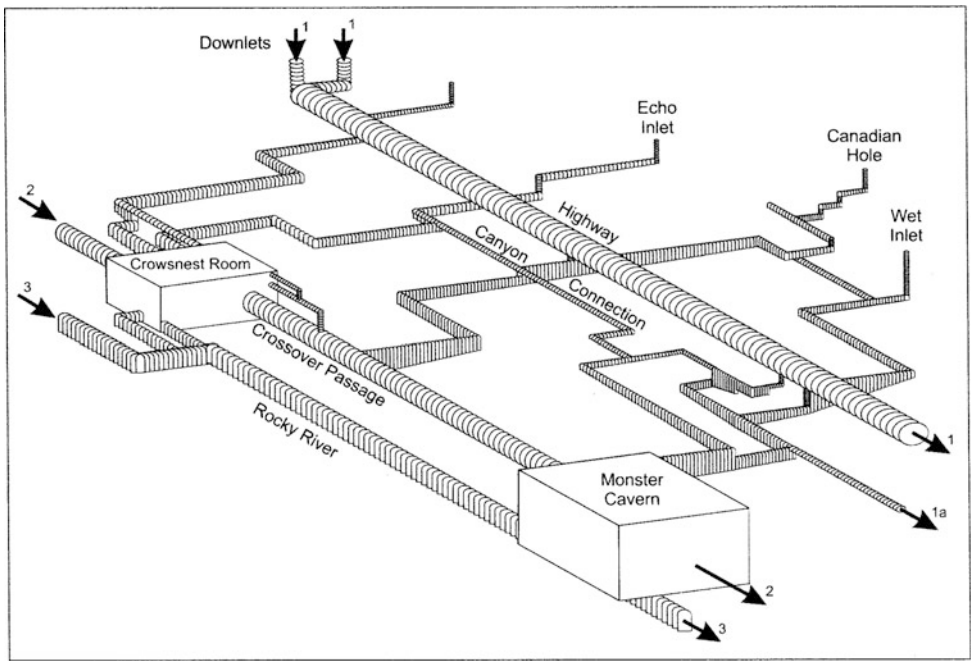

Fig. 8.15 Flow path sequence in Canadian Hole Segment

Fig. 8.16 The highway in Rubber Chicken Segment. Photograph by David Bunnell. Used with permission

A series of tracer tests have demonstrated the links between sinking streams, cave passages, and the resurgences at Locust Spring and JJ Spring (Fig. 8.1). These links represent unexplored cave streams, and it is clear from Fig. 8.1 that such unexplored passages are extensive. At the time when the earliest passages in Friars Hole System such as the Highway were formed, the higher base level and westward dip of the limestone would have meant that no limestone was exposed along the lower part of Spring Creek. Consequently, it seems probable that the Highway would have drained to the south under Droop Mountain to a resurgence along Greenbrier River (Fig. 8.1), and there must be extensive inactive passages that have yet to be discovered.

A detailed analysis of the development of the North Canyon of Snedegars Cave was made by Jameson (1985), and more generalized accounts of the whole cave appear in Worthington (1984) and Worthington and Medville (2012).

Fig. 8.17 Dung Ho Way in Friars Hole Segment. Photograph by Ron Simmons

8.7 Friars Hole System Description

A detailed description of a 73.4-km-long complex cave such as Friars Hole, containing passages at multiple levels and several internal drainages, is challenging. A passage by passage description would be both lengthy and lose the reader in detail. To avoid this, a more general, section by segment by segment description will be given, keyed to the five sheet map that accompanies this chapter (electronic maps M-8.1 to M-8.5). The description begins with the historic Snedegars/Crookshank part of the System, then continues with the large centrally located Rubber Chicken and Toothpick Segments to the south and west, then moves to Canadian Hole at the Systems' northeast end, and ends with the traditional Friars Hole Cave in the southwestern part of the System. Emphasis will be placed on major conduits, infeeders, and linking passages between these segments, taking note of the cave's geological setting and former (paleo) drainage routes that resulted in the cave's current size. The description is not intended to be a guide to navigating the cave but rather a way for the reader to visualize the cave's geography using the map as an aide. An earlier version of this description was provided in (Medville 1981).

8.7.1 Snedegars/Crookshank Segment

With the only three horizontal entrances in the cave, the centrally located Snedegars Cave, shown on map sheets B and C (electronic maps M-8.2 and M-8.3), is the most visited part of the System. The 3-m-high and 3-m-wide North (or Stream) Entrance takes an intermittent stream and leads to a high, joint-controlled canyon passage (North Canyon) that trends west in the Union Limestone (Jameson 1985). A second entrance just above and to the left of the Stream Entrance leads to a series of crawls and connects to the cave's historic Saltpetre section (described below). The North Canyon can be followed for 400 m to the top of a 4-m overhung pit at the Waterfall Room. A 1-m-high phreatic tube at the base of this pit leads to a 30-m-wide chamber called the Amphitheater, in the Saltpetre Trunk.

The Saltpetre Entrance to the System is about 300 m south of the Stream Entrance, on a hillside and on the west side of a field. This 5-m-high and 3-m-wide entrance can be followed west for 100 m and then turns to the northwest, descending over large breakdown blocks for 170 m to the Amphitheater Room passage. Near the top of the large breakdown slope, low passages lead north into the Saltpetre Maze, an extensive series of dry passages on three levels, ultimately connecting to the entrance above the North Canyon Stream, as noted above. These passages trend east, ending beneath the hillside between the North and the Saltpetre Entrances. At the base of the breakdown slope and on the Saltpetre Trunks's south side, a low inlet passage (The Druid Passage) can be followed upstream and to the east for 300 m before becoming too low to follow.

Beyond the Amphitheater, the cave continues south for over 300 m as a 5-m-high and 20-m-wide passage with now-dry inlet passages and an upper level paralleling it along the southeast side, e.g., Snedegars Dome and Formation Loop. Beyond this, the ceiling then lowers 100 m in an almost-choked, 0.3- to 0.6-m-high passage called The Cobble Crawl. At the western end of this crawl/squeeze, a

25-m-long pool with a half meter of airspace in low-flow conditions must be crossed. This pool, the Snedegars Sump, is the backwater from a stream entering on the north side of the passage at the lower (western) end of the pool. The source of the water is another entrance to the System called Snedegars Staircase. The Snedegars Staircase Entrance is at the bottom of a sink 350 m SW of the Saltpetre entrance. Streams rising at the base of the Alderson Limestone above flow over the Greenville Shale and into this entrance. Over the first 100 m, a series of four drops are reached (6, 4, 7, and 18 m, respectively) followed by another 270 m of the passage leading to the downstream end of the Snedegars Sump.

Downstream from the Snedegars Sump, the passage can be followed for 300 m to a junction with a crawl on the left side of the passage (Sloppy Crawl on the map) just before reaching a series of waterfalls. Continuing downstream for another 250 m, a T junction is reached. The passage to the right (downstream) can be followed north for 100 m to a very low airspace near- to total 40-m-long sump named Rick's Syphon. The passage downstream from this pool continues north and west for 400 m to a shorter pool called Doug's Sump. After another 150 m of low passage, a junction is reached with a large stream entering from the left, the Rubber Chicken/Toothpick Cave stream. The combined streams then flow north through another low airspace near- to total sump called Tom's Sump. The passage beyond this point is called The Droughtway and is described under the Rubber Chicken Segment below.

Returning to the T junction noted above, the passage to the left is dry and after 350 m, leads to the base of the 12-m-wide and 33-m-deep Crookshank Pit with canyon passages and dome complexes a few meters beyond the pit's base. The stream flowing into Crookshank Pit sinks into a narrow floor joint and is not seen again in the cave.

The passage called Sloppy Crawl can be followed south for 100 m to another junction. The passage on the left is the Lew's Last Climb passage and continues south for 700 m to an end at domes. The passage on the right is low and can be followed for 300 m to the southwest to "Breakdown Room" on the map and a connecting passage (Terrible Crawl) that also leads to the Crookshank Pit area. The somewhat larger passage beyond Breakdown Room is called the Promised Land Passage and, after 200 m, reaches a breakdown area with the Rubber Chicken Cave Segment of the System beyond. This is labeled "The Connection" on Map sheet E (M-8.5).

8.7.2 Rubber Chicken Segment

Because the original entrance to the Rubber Chicken Segment of the System is sealed, the description of this segment of the Friars Hole System begins at "The Connection" breakdown area at the south end of the Snedegars/Crookshank Segment of the cave System, shown on map sheet E (M-8.5). After following a moderately low passage south for 150 m, a T junction with a much larger passage is reached (Shark Room on map sheet E). This passage, called "The Highway," is a 2.3-km-long paleo-trunk passage that no longer contains an active stream (Fig. 8.16). This passage, averaging 6 m in height and width can be followed west for 150 m to an end at a junction with the north flowing stream passage in Rubber Chicken Cave.

The majority of The Highway is to the left (east) of the Shark Room. Following the Highway in this direction, it continues for over 1 km with minor infeeders along the way. A series of six bends, the Zig-Zags, are then reached where the passage crosses a series of the strike-oriented west- and east-dipping conjugate thrust faults. At the last (easternmost) of the bends, a paleo-downstream passage trends south for several meters but becomes too narrow to follow. At this junction, The Highway turns to the north in large dry passage for another 600 m to a canyon complex entering from the right (east) and ending at a series of vadose shafts (Domes Canyon on map Sheet C (M-8.3)). Although these are beneath the hillside across from and 170 m south of the Saltpetre Entrance, they do not connect to the surface. Beyond this canyon complex, the passage lowers with infeeders entering from the right. The passage continues north, joining the Canadian Hole Segment of the System as described below.

As described above, the western end of The Highway ends at a T junction with the north flowing combined Rubber Chicken/Toothpick stream. Going downstream, it sinks into a lower level. The passage continues north and after 200 m reaches an infeeder from the west that can be followed for 100 m upstream to the base of the Rubber Chicken entrance pit series. Continuing north from the entrance infeeder, a low passage is followed for 200 m to a complex area containing numerous streams entering from the southwest and northwest, beneath the valley containing the Rubber Chicken entrance. To the north of this infeeder complex, a 5-m-high and 5-m-wide dry passage continues north for over 700 m with the stream seen in a separate 1-m-high passage below. These passages eventually converge, continue north for another 250 m, and then join the Snedegars stream passage at the upper end of Tom's Sump as noted above.

The combined Snedegars/Rubber Chicken/Toothpick streams flow through the 60-m-long low airspace Tom's Sump and then turn west and down dip, entering a section of the System called the Droughtway (map sheet B). A 1- to 2-m-high passage can be followed for 750 m downstream through several low airspace pools before opening to the 20-m-high and 20-m-wide, 100-m-long Mint Room, one of the most remote large chambers in the Friars Hole System. The cave stream flows in a separate, lower passage and is

rejoined at the western end of this chamber in 15- to 20-m-high passage that continues west and then abruptly turns north. After 350 m, the cave stream turns to the south, lowers, and within 70 m reaches a sump, 145 m below the cave's Saltpetre (datum) entrance. Based on the stratigraphic horizon of the ceiling of the Mint Room, the lower Union Limestone, the cave stream below is entrenched in the Pickaway Limestone and the final sump appears to be in the lower Pickaway, above the Taggard Shale.

From the lower (western) end of the Rubber Chicken Highway and turning left, the 3- to 6-m-high stream passage can be followed upstream to the south for 500 m to a passage junction where a dry passage enters from the west. This passage leads to a complex of high, joint-controlled infeeder passages, including the connection to the Friars Hole Cave Segment. Continuing upstream from this junction, the cave becomes considerably more complex with numerous loops and passages developed on several levels. Some of the side passages carry infeeder streams; these passages generally ending in domes up to 20 m in height and located beneath overlying sinks and sinking streams. The Rubber Chicken cave stream flows out of a low passage that leads to the Toothpick Segment of the System.

8.7.3 Toothpick Segment

The 30-m-wide and 15-m-high entrance to Toothpick Cave in Ravens Nest Hollow is near the top of the Union Limestone and as is the case with several other entrances, leads to a shaft dropping through much of the Union. This part of the cave System is shown on map sheet E. (M-8.5). From the base of this 20-m pit, passage can be followed upstream to a series of 10-m climbs, above which are infeeder passages leading toward the valley above. Downstream from the pit, the stream enters a 40-m-long near sump beyond which the passage opens to a series of wet crawls and domes for 400 m. The passage then opens to a 6-m-wide and 12-m-high canyon in the lower Union Limestone trending southwest. This passage, developed along joints and faults, can be followed for 1.4 km before lowering and reaching the far upstream end of the Rubber Chicken Cave Segment. In addition to the stream passage, this section of cave contains several km of dry upper-level passages and phreatic tubes that have not been completely explored, and a dense network of interconnected upper-level passages in the lower Union and Upper Pickaway that are aligned along strike, e.g., Elephant's Graveyard.

8.7.4 Canadian Hole Segment

Five hundred meters north of the Snedegars Saltpetre entrance, a small stream, rising at the base of the Alderson Limestone, flows over the Greenville Shale and sinks into the 12-m-deep pit that is the entrance to the Canadian Hole Segment of the Friars Hole System. Map sheets A and C (M-8.1 and M-8.3) show this part of the cave System. This pit is followed by several others descending through the Union Limestone. A short climb at the base of this entrance series leads to a 500-m-long passage at the base of the Union called First Canyon. This canyon and the passages that it leads to are collectively called "The Alberta Extension" as described below.

At the lower (western) end of first Canyon, a 2-m drop leads to the south trending Second Canyon ending at a dry chamber (Canyon Terminus) and a north trending dry passage called Cross Over Passage that can be followed for 250 m to the 100-m-long and 60-m-wide chamber called Crow's Nest Room. Passages on the west side of this chamber (Rubber Boot Route, Irv's Passage) lead west to the System's largest stream, Rocky River, i.e., the underground Hills Creek. This passage can be followed downstream along a fault for 200 m before being lost in rockfall in the Rocky Horror Streamway, 30 m below the lowest point in the breakdown-filled floor of Monster Cavern. Stratigraphically, the downstream end of this passage is below the Taggard Shales, only one of two places in the System where this is seen. Rocky River can also be followed upstream for almost 500 m to a sump called Watergate.

Two passages lead east from the Crow's Nest Room: A Neasy Stroll and McKeever's Passage, both of which contain inlet streams (Echo Inlet and the Downlets). McKeever's Passage also intersects a major strike aligned paleo-passage called the Canadian Highway, a northern continuation of The Highway in the Rubber Chicken Segment. Following this passage south for 350 m, it reaches an intersection with the upper end of Mud Canyon, a passage generally trending west for 450 m and ending at the east side of the 110-m-diameter and 75-m-high Monster Cavern, the System's largest chamber. About halfway along the length of Mud Canyon, a low passage leads south for 500 m through wet crawls before connecting to the far northern end of the Rubber Chicken Highway. The Canadian Highway continues southwest for another 500 m beyond the Mud Canyon junction before ending in breakdown only 50 m to the east of passages at the upper end of the Rubber Chicken Highway. Where it crosses over First Canyon, 10 m below, a hole in the floor of the Canadian Highway connects the two.

This part of the cave is fairly complex, containing linking passages, e.g., the French Connection between First Canyon and the Canadian Highway and the Canyon Connection between First Canyon and the lower end of Mud Canyon as well as a passage above the Canadian Highway called the Skyway.

On the north side of the Crow's Nest Room, a 120-m-long passage called 15th November Avenue leads to a 600-m-long, wet boulder choked and fault controlled crawl, appropriately named "Almost Hell." At the north end of this crawl, the passage becomes much larger and leads to the cave's northernmost passage complex, The Ontario Extension, shown on map sheet A (M-8.1).

Ontario Extension begins with Yonge Street, a large 200-m-long passage that leads to several km of passages, e.g., Almost Heaven and Temptation Streamway that end in several inlet complexes. Following a cave radio location effort to find a shorter way into this part of the cave, crawls at the bottom of a hillside pit were dug open. This led to the top of an 8-m-deep pit and below it, to the upper end of one of the inlet complexes in the Ontario Extension: the Dangling Dan Passages. This is the northernmost entrance to the Friars Hole System.

A passage at the north end of this complex, Tin Can Alley, intersects a 650-m-long, west trending stream passage called Skid Row. At its downstream end, it intersects a large strike-oriented stream, Rocky River II. The Rocky River II passage is also that part of Hills Creek that flows through Cutlip Cave and Clyde Cochrane Sinks to the northeast. This stream is an upstream continuation of Rocky River, seen in the Alberta Extension to the south. The stream can be followed for 500 m upstream before ending at a boulder choke and for 700 m downstream, ending at a deep pool beneath breakdown at the south end of a 30-m-wide chamber called Amphitheater II; only 120 m north of the upstream Watergate sump in Rocky River.

8.7.5 Friars Hole Segment

The entrance to the historic Friars Hole Cave, on map sheet D (electronic map M-8.4), is a small opening at the bottom of a 15-m-deep doline on the west side of the Friars Hole Valley, about 1 km north of Spring Creek. This leads to climb downs followed by two 8-m-deep pitches and an 80-m-long passage. This then opens to the cave's 15- to 20-m-wide and 5- to 10-m-high main conduit, a strike-oriented, NE-SW trending passage containing an underfit stream. The passage is developed along bedding partings in the basal Union Limestone.

Proceeding upstream, the passage can be followed for 1.2 km to an extensive complex of infeeder passages, bringing in water sinking in a blind valley in the middle Friars Hole drainage above. These passages climb through the Union Limestone and generally end in 10- to 15-m-high domes. Going upstream from this area, the ceiling lowers to 1–1.5 m, and the floor is covered in deep mud in a passage called "The Dung-Ho Way" (Fig. 8.17). After 300 m, the ceiling rises to 3–5 m and the passage continues for another 500 m to an infeeder entering from the passage's left (north) side, ending at a chamber called The Broken Room. Another infeeder enters after another 100 m and beyond this point, the passage becomes more complex, with an inter-braided upper-level passage. After another 400 m, a short climb is reached; this was the end of exploration of this cave in the 1960s and the place where it was connected to Rubber Chicken Cave in 1976. The north flowing Rubber Chicken stream lies another 400 m to the north of this point.

Proceeding downstream from the Friars Hole entrance passage, the cave becomes more complex, with passages extending from the middle of the Union Limestone down to the upper Patton Limestone member of the Denmar formation. Less than 50 m downstream of the entrance passage, a 10-m climb on the passage's west wall leads to the 1.9-km-long Parker Mountain Passage, an infeeder that in the past, carried drainage from the Robbins Run valley, 0.75 km to the west of the Friars Hole Valley, beneath Parker Mountain between, and into the Friars Hole trunk passage. The Parker Mountain Passage follows bedding planes to the southwest and then west before turning north in a low, sand floored passage before ending in domes beneath the western hillside of Robbins Run.

The downstream Friars Hole trunk below the entrance passage drops into the middle of the Pickaway Limestone in a series of wet climbdowns leading to the Pool Room, a major junction about 100 m south of the entrance passage (Fig. 8.17). An extensive multi-level network of infeeders containing over two km of passage enters from the east. Straight ahead, a large breakdown-floored passage leads south for 300 m to The Lost Passage, a 30-m-wide and 10-m-high passage floored with low sand and mud rises. This passage becomes smaller, ending at a sediment choke. At a slightly lower level, the passage can be followed for another 100 m to the cave's southern end, the appropriately named Hammer Passage, a breakdown-choked chamber climbing 25 m and apparently bounded at its southern end by a thrust fault striking NW-SE.

About half way between the Pool Room and The Lost Passage, a climbdown called Two Time Pit is reached. A low and wet passage below this pit leads west and then north to a substantial passage, Mauck's Discovery, a 650-m-long generally strike-oriented paleo-drain in the lower Pickaway Limestone that is now dry in all but its upper end. This passage, 8- to 10-m high and wide, abruptly ends at an intersection with a WNW-ESE trending passage, ending in a fault on its northwest end. To the southeast, the passage leads to a 30 vertical meter climbdown through the

Taggard Shales and then to a 75-m-long near sump beyond which is a substantial strike aligned stream flowing to the south in a passage called Water World. One hundred fifty meters downstream the stream passage becomes low and rock choked. The passage can be followed upstream for 500 m to a near sump. The downstream end of this stream is 142 m lower than the cave's datum entrance and at an elevation of 596 m is the lowest point in the System. The entire passage is in the upper Denmar Formation.

An upstream continuation of this stream called Big Water is reached via another route further north in the cave by following the dip of a fault on the west side of a chamber called Barbara's Room. After descending for 25 m following the fault plane downward, a low rock-filled passage similar to Almost Hell in Canadian Hole can be followed along the strike of the fault for 250 m to another segment of the large stream called Big Water. This is probably the same stream seen in Water World; the two streams are aligned and at the same elevation. This stream can be followed for another 150 m upstream to a mud-choked sump.

As noted under Cave Hydrology, the volume of water in these passages is considerably larger than that seen in the Friars Hole Cave stream above. At least some of this water is derived from the Robbins Run stream sinking in its bed 2.3 km northwest as per tracer tests conducted with fluorescein dye in 2015–16.

8.8 Summary

Passages summing 73.4 km in total length have been surveyed in the Friars Hole Cave System since the mid-1960s. The cave System, composed of three internal drainage complexes extending over a linear distance of almost 7 km, has had a long and complex evolution with most of it being over 730,000 years old and one dated speleothem having an age of over 1.67 million years (Worthington 1984). Although nearly the entire cave System is developed in the upper Greenbrier Group limestones (the Union and Pickaway limestones), two of the cave's three active drainages breach the Taggard formation, a major aquitard below the Pickaway and extending the cave's stratigraphic extent. Due to the presence of several long but low flooded passage segments that are entirely water filled in all but the driest of conditions, significant parts of the cave System remain to be explored, surveyed, and studied. These include the extensive Droughtway section of the cave System at the downstream end of the cave's central drainage and the Water World stream complex at the south end of the Friars Hole Cave part of the System; these are also the two deepest parts of the cave System. The potential thus exists for substantial additions to be made to the cave's known extent, subject to the accessibility of these areas.

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