The Contact Caves of Central Greenbrier County

11

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Abstract

Six major cave systems are developed along the eastern border of the basal Hillsdale Limestone (Greenbrier Group) and the underlying Maccrady Shale between the town of Lewisburg and Spring Creek in central Greenbrier County. The total combined surveyed passage is just over 128 km (80 miles). The Hole is the northernmost of the contact caves and drains north to Spring Creek. Ludington, McClung, Maxwelton Sink, Benedict, and Wades caves drain southwest to Davis Spring. These caves are developed in the lower section of the Hillsdale Limestone with many passages entrenched by vadose erosion by up to 12 m (40 ft) into the shale. Recharge is mostly from small surface streams that flow westward on the Maccrady Shale and sink at the contact with the limestone. The pattern of passages is typically dendritic with an overall trend sub-parallel to the regional strike. Folding and faulting influence passage orientation in some of the passages, but the perching effect of the underlying shale forces the conduits downward along the local dip.

11.1 Introduction

The Mississippian age Greenbrier Limestone forms a large karst plateau that stretches uninterrupted for nearly 16 km (10 miles) and is over 5 km (3 miles) wide in central Greenbrier County, West Virginia. The area described in this chapter is bounded on the south by the town of Lewisburg, on the west by a series of clastic hills including Weaver Knob and Anderson Knob, on the north by Spring Creek, and on the east by Maccrady shale (Fig. 11.1). The Greenbrier River and Spring Creek are entrenched several hundred meters below the surface of the plateau. This eastern contact is unique from a geologic aspect and has allowed large cave systems to form in generally the same manner. The caves line up along strike adjacent to the contact and stretch the entire length of the plateau.

On the east side of the plateau, surface drainage on the Maccrady Shale flows east down into the entrenched valley of the Greenbrier River or west to the contact zone with the overlying Greenbrier Limestone. The western contact zone has produced this unique karst area characterized by the large contact cave systems. The surface water on the Maccrady Shale roughly follows the dip of the strata along the western limb of the Sinks Grove Anticline until it encounters the limestone where it immediately sinks. This sinking water enters into the caves via small dolines, cave entrances, and in some cases, classic blind valleys with cliff faces up to 30 m high. Cave development continues along the contact with the main stream passages developed in the Hillsdale Limestone (the lowest formation in the Greenbrier Group). The contact passages are characterized by stream entrenchment into the underlying shale (Fig. 11.2), in some places up to 12 m (40 ft). The entrenchment can form large, wide, walking passages or narrow shale canyons depending on the gradient and the size of the stream.

The term "contact karst" is occasionally seen in the European literature (Gams 1965; Mihevc 1994) and is used

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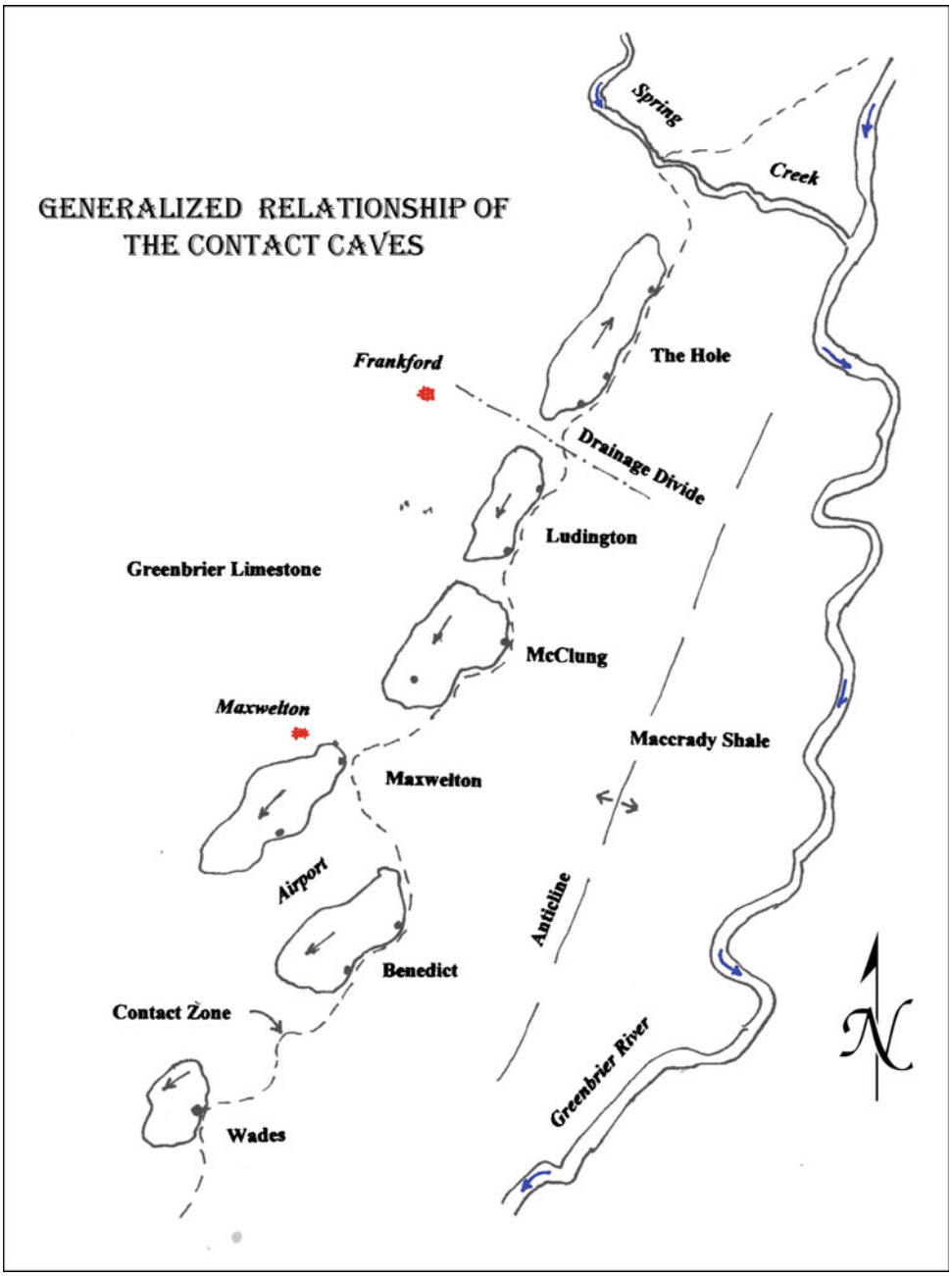

Fig. 11.1 Generalized relationship of the contact caves

to describe karst settings where most of the recharge is allogeneic flow coming from adjacent non-carbonate rocks. Typical sink points are at blind valleys where chemically aggressive water from surrounding clastics first encounters soluble units. However, the defining feature of the contact caves is passage development that may down cut into the Maccrady Shale by up to 12 m below the bottom of the limestone. The six largest contact caves are described in the sections that follow (electronic map M-11.1). Detailed maps of three of them, Benedicts, Maxwelton Sink, and McClungs Caves, are given in electronic maps M-11.2 to M-11.4.

The term "contact caves" was probably first coined by John M. Rutherford (Rutherford 1967) and was originally applied to six caves starting with Wades to the south and ending with The Hole to the north. The Hole was discovered in 1960 and was explored and mapped by members of the West Virginia Association for Cave Studies (WVACS). Organ Cave and several other caves south of the Greenbrier

Fig. 11.2 Typical contact canyon, with limestone ceiling and shale walls—The Hole. Photograph by W.K. Jones. Used with permission

River are also considered contact caves and are described in other chapters of this book.

11.2 General Geology

The structural setting for the contact caves is on the west limb of the Sinks Grove Anticline and the east side of a broad synclinorium and is characterized by minor undulations with an average 3–5° dip to the west (Heller 1980; Price and Heck 1939). Groundwater flow is generally downward along the stratigraphic dip but is sometimes deflected by permeable units along faults or other structural features (Palmer 1974). Locally, some faulting has been observed within the caves and at least one major thrust fault has been observed in two adjacent caves (Fig. 11.3). Surface evidence for faulting and folding is not readily seen due to thick soil cover. The limestone and shale appear to be in fault contact for at least part of the study area. Heller (1980) mapped the Lewisburg Fault and described it as a southeast dipping reverse fault. Wells et al. (1967) suggested it is a normal fault between Lewisburg and Caldwell. This fault does not appear to extend as far north as Spring Creek but may affect the development of caves along the contact just north of Lewisburg.

The central Greenbrier County contact caves are developed almost exclusively within the 30 m (100 ft)-thick Hillsdale Limestone with vadose entrenchment into the underlying Maccrady Shale. A detailed stratigraphic section from Ludington Cave was presented by Palmer (1974).

Fig. 11.3 Drag fold associated with thrust faulting. McClung Cave. Photograph by W.K. Jones. Used with permission

The Hillsdale Limestone is relatively pure but contains beds of nodular chert near its base. The unit is generally massive biomicrosparite until the bottom 3 ms (9 ft) and the section grades to a shaly limestone containing undular shale laminae with a local thick weathering rind of clay and silt. The underlying Maccrady Shale is generally red shale that contains lensatic siltstone units and some thin calcareous zones. The top of the Maccrady Shale is an incompetent limey green shale that grades downward to a flaggy red shale (Palmer 1974). The upper 12 m (40 ft) of the shale is sometimes brecciated and recemented with calcite which makes it easily erodable by the aggressive cave streams.

Palmer (1974) estimated that 60% of the passages in Ludington Cave began at the Hillsdale/Maccrady contact. The contact caves formed under a combination of both phreatic and vadose conditions. Passages that are orientated along components of the dip started under phreatic conditions but have been modified by aggressive vadose action of surface streams that sink along the Hillsdale/Maccrady contact. Depending on the size of the stream that is coming in from the contact, the sink point can be a shallow sinkhole or a very large well-developed blind valley. Once underground, these streams follow the limestone–shale contact down dip.

Most of the entrances to the contact caves involve a sinking stream that begins on the Maccrady Shale and flows on the surface down dip until it intersects the limestone where it immediately sinks into the cave. In the case of Maxwelton Sink Cave, a large spectacular blind valley is developed with an amphitheater cliff face over 30 m high with the entrance at the base (Fig. 11.4). This entrance is usually clogged with flood debris and talus material. During periods of flooding, a large lake tens of meters in depth will back up the valley for over a kilometer. The Green Sink at Ludington Cave is another blind valley; it is not as large as the one at Maxwelton but is equally impressive. No physical entrance has been excavated at this blind valley, but several passages do come very close to the surface at this point.

The six caves that make up the central Greenbrier County contact zone are all formed in a similar pattern. In addition, there are other large cave systems in the area that are formed in the same way; they include Organ Cave and Windy Mouth Cave also in Greenbrier County and Scott Hollow Cave in Monroe County. Another contact zone in central Monroe County has the same geology, but no caves have been opened or excavated as of yet. They will be there; it is just a matter of time before someone finds (or digs open) an entrance.

Fig. 11.4 The blind valley at Maxwelton containing the blocked Cove Creek entrance to Maxwelton Cave. Photograph by W.K. Jones. Used with permission

11.3 Contact Passage Morphology

There are three things that control the shape and size of contact passages: the size and velocity of the underground stream, the gradient of the stream, and the makeup of the immediate top of the shale (Balfour 1973). A large stream and a gentle gradient will usually produce a large rectangular cross section, scouring out the shale on the side of the passage and allowing areas of breakdown to occur. A smaller stream will produce a smaller cross section. A high gradient stream will tend to carve a canyon into the shale that can be several meters deep characterized by waterfalls and plunge pools. Again, based on the size of the stream the canyon can be fairly wide or narrow and sinuous. The third thing that influences passage formation is the immediate contact zone with the limestone. The Maccrady Formation consists of red shale, siltstone and mudrock that are very resistant. However, in some areas the top 6–8 m are cemented loosely with calcite that is easily dissolved and eroded by the vadose stream action. In addition, there are areas within this zone that are brecciated and appear to have been disturbed during deposition.

Contact passages usually follow components of the dip of the strata. Typically the dip is between 2 and 5°. However, faulting has been observed in McClung Cave and Ludington Cave with major implications within the latter (Palmer 1974). Where faulting has occurred, passage formation along major drag folds complicates the overall picture.

11.4 Description of Caves

11.4.1 Wades Cave

The entrance to Wades Cave is in a sink developed along the contact north of the golf course and to the east of the bowling alley. A stream flows from the clastic hills adjacent to the sink. This stream sinks into a swallet developed in the

sediment-floored bottom of the sink. The entrance is in a rock outcrop about 6 m above the base of the sink and is a very small hole that is body sized. Squeezing down through this hole, you come to a 3 m downclimb that bottoms out in a rockpile. Just a few meters further, you encounter the stream. The next several hundred meters is mostly stoop walking in the stream through various sizes of potholes and plunge pools and is developed along the strike to the north (Fig. 11.5). After this entrance section, the stream passage turns west to follow the dip and rapidly enlarges to a spacious trunk channel averaging 7–8 m in height. Shale banks up to 3 m feet high are exposed in the walls. This passage continues for over a kilometer and is interrupted only by a few areas of massive breakdown where intersecting passages are encountered. Several small infeeder streams join the main passage with one apparently coming from the sink at the golf course about 1.5 km away. The discovery of golf balls in the stream seems to indicate this connection. Two other infeeders are coming in from the entrance sink and are probably high water overflow routes.

About 300 m from this junction the main stream intersects another major stream coming from the north. Just beyond this confluence, the combined stream sumps. Going north in the other stream, another sump is encountered after another 300 m. Wades Cave was surveyed by Robert Amundson and members of WVACS in the 1960s, and it contains about 5.6 km (3.5 miles) of mapped passage but is not completely explored. Visitation was always extremely sporadic, and the cave has been off limits for many years.

11.4.2 Benedict Cave

There are two entrances to Benedict Cave, the main Benedict Entrance and the Persinger Entrance, located about 600 m apart. Both entrances are at the end of shale valleys that terminate at the limestone contact, and both are small openings that give access to crawling passage. The Persinger Entrance is owned by the West Virginia Cave Conservancy. The cave was surveyed by Roger Baroody and members of WVACS in the 1960s and resurveyed by Bill Douty in the late 1970s. Benedict Cave contains 23.7 km (14.7 miles) of mapped passage.

The Benedict Entrance is a low crawl in the stream that is approximately 180 m in length. After this crawl, Benedict Creek intersects two other infeeding creeks and immediately enlarges into a breakdown room called No Parking. The passage enlarges into a shale canyon and turns north for 200 m to another junction with another infeeding creek at the Mercury Room. Benedict Creek turns west for 400 m as an impressive trunk passage averaging 10 m high and 5–10 m wide. This trunk passage then turns north for another 200 m with numerous side passages feeding into it. A major stream confluence is developed where the Sinking Creek trunk passage intersects Benedict Creek. Sinking Creek is a large trunk passage that can be followed upstream for over 800 m before an upstream sump is reached. Sinking Creek is the continuation of the Persinger trunk passage that contains Persinger Creek coming in from the other entrance. There is a sump between Persinger Creek and Sinking Creek.

Fig. 11.5 The entrance passage in Wades Cave. Photograph by W.K. Jones. Used with permission

The Sinking Creek trunk passage is a large breakdown-floored passage that is up to 10 m high and 20 m wide.

About 150 m beyond the junction with Sinking Creek, the Benedict trunk passage intersects the master drain for the entire cave. This trunk passage is called Sizeable Creek, and it comes in from the northeast along the strike. From this point, all of the water in the cave is flowing to the southeast in a low-wide cobble-filled trunk passage. This passage is flood-prone and continues to lower until a terminal sump is reached at a point about 600 m from the confluence. The water has been dye-traced to Davis Spring along the Greenbrier River.

Going northeast in upstream Sizeable Creek, the passage can be followed for 2 km before its terminus in breakdown. Several infeeder trunk passages are developed along the master drain and are coming in down dip from the east/northeast. The three main creeks are Mediocre Creek, Turkey Creek, and Trash Creek. Trash Creek and Turkey Creek come together in an area called the Confluent Room about half way up Sizeable Creek. Trash Creek is a very large breakdown-floored trunk passage that extends to the northeast for approximately 1 km before ending in a terminal breakdown at the contact. In places, it is over 30 m wide. Turkey Creek is a much smaller trunk passage and is mostly an incised canyon until it reaches its terminus in a large breakdown room (Fig. 11.6). Numerous upper level routes and abandoned phreatic tubes are developed throughout this area. The North–South Highway is one such abandoned upper level that cuts across to Mediocre Creek.

Mediocre Creek is a more than 1 km shale canyon that intersects Sizeable Creek about 200 m upstream from the Benedicts confluence. This passage also trends east/northeast going up dip in places and along strike in others. Upper level development is not as extensive but does occur. The North–South Highway coming from Turkey Creek is a major shortcut. A continuation of this passage on the south side of Mediocre Creek gives access to the Persinger section of the cave.

The Persinger Entrance is a small hole below a headwall at the end of a small blind valley. This hole gives access to a body-sized tube that is somewhat awkward but quickly opens into a 1 m high stream way that intersects a large trunk passage after about 40 m. The Persinger trunk passage is a pleasant dirt-floored stream channel with occasional breakdown areas. There is an abundance of infeeder passages and upper level development along the Persinger stream (Fig. 11.7). Persinger Creek abruptly ends in a sump after a few hundred meters. The sump is approximately 50 m long and on the other side is the continuation of the trunk passage, Sinking Creek.

Just before the sump, a maze of upper level crawls and small canyons is developed to the west. First Creek is 600 m long and ends in breakdown. A north-trending crawl intersects Rib Bone Creek and eventually intersects Mediocre Creek. This intersection is the only connection from the Persinger side of the cave to the Benedicts side. An 8 m drop has to be negotiated to make this connection, and a rope or cable ladder is required.

11.4.3 Maxwelton Cave (Aka Maxwelton Sink Cave)

Maxwelton Cave is the classic example of a contact cave. Cove Creek drains several square kilometers adjacent to the Greenbrier Valley Airport and is underlain primarily by red shales of the Maccrady Formation. Flowing southwesterly the creek immediately sinks at the contact with the basal portion of the Hillsdale Limestone. The sink is in a rubble pile formed from sluffage off an adjacent cliff face. At 100 m beyond the sink point, the imposing cliff face rises as a semicircular blind valley up to 30 m high. At the base of this cliff is the original entrance to the cave. Cavers opened this entrance in the early 1970s, and a corrugated metal pipe was placed in the excavated crawl. Many kilometers of passage were surveyed during the short time the entrance was open. A hurricane flooded the entrance in 1972 putting it under 10 m of water and backing a lake up the valley for a kilometer. Once the lake drained, there was no sign of the entrance or the pipe and the area had been filled with more rock and flood debris. Over the next 6 months, a concerted effort to reopen the cave eventually proved successful. However, within two weeks the area again was hit by massive flooding and the entrance was sealed once again, even worse than the first time. At that point, efforts to continue exploration were dropped and the cave was declared finished with about 15 km surveyed and a map was drawn.

In the early 2000s, a local caver (Dr. James David Scott) became interested in seeing if another entrance could be excavated on his property. Using micro-gravity techniques on the surface and trying to locate 1970s vintage cave survey proved to be time-consuming, but ultimately an anomaly was identified as possible passage. This passage was next to a surface sink, and a dig was instigated. It became apparent quickly that heavy equipment would be needed so a bulldozer and track hoe were mobilized. After many stops and starts, a hole was opened that blasted air. However, that hole was deemed too unstable and an adjacent area was excavated and broke into actual known cave passage. A 12 m vertical pipe was inserted into the shaft and backfilled. The entrance was named the Scott Entrance after the owner of the property. This gave access to the cave, and within a year the West Virginia Cave Conservancy purchased the property from Dr. Scott for permanent access. A resurvey of the cave was initiated and is still ongoing.

During this time, another caver bought the Cove Creek entrance at auction and a dig was initiated at the original

Fig. 11.6 Typical contact canyon in Benedict Cave. Photograph by Ryan Maurer. Used with permission

entrance. Heavy equipment was also brought into work on this project. Within a year, the Cove Creek entrance was reopened and a few trips were made before another flood sealed the entrance again. To date, no attempt to reopen it has been made.

The Turnpike was a low boulder and breakdown crawl from the Cove Creek entrance. After 140 m, this passage dropped 2.3 m into a large well-decorated trunk passage carrying the main Cove Creek stream (Fig. 11.8). At this junction, the main Cove Creek trunk averages 8 m high and 10 m wide. Going upstream, there are numerous branches that all end in breakdown against the blind valley cliff face. Going downstream, the Cove Creek trunk splits into two and sometimes three distinct parallel passages. These parallel

Fig. 11.7 Large trunk passage near Persinger entrance of Benedict Cave. Photograph by Ryan Maurer. Used with permission

Fig. 11.8 Large flowstone near the original Cove Creek entrance —Maxwelton Cave. Photograph by Ryan Maurer. Used with permission

passages represent abandoned flow routes from the east with the main creek flowing in the most westerly passage. These passages are all developed along the strike of the beds.

Approximately 365 m downstream from the intersection of the Turnpike and Cove Creek, the first major infeeder is encountered. H Canyon is a contact canyon developed mostly in the Maccrady Shale and is coming in down dip from the surface. In places, this canyon is up to 15 m deep with a small stream flowing in the bottom. After 350 m, a large breakdown room is encountered. Several passages lead upstream from this room, and all are blocked by terminal breakdown near the surface outcrop. At one time, the farthest east passage was open to the surface. This entrance was named the Airport Entrance due to proximity of the airport runway. However, the entrance was short-lived as a factory was built and the opening was covered by a parking lot.

Going downstream from the confluence of H Canyon, the main Cove Creek passage enters a low section called Le Mudge where water and mud predominate in about a meter-high section. There are several higher parallel

passages that bypass this section. After Le Mudge, the Cove Creek trunk makes an abrupt turn to the north for about 100 m before it turns southwest along the strike again and opens into the Hall of Kings which is a large breakdown-floored passage.

Just downstream from the Hall of Kings is the intersection of the stream infeeder coming from the Heaven passage. Going up this passage, there are a series of upclimbs up to 15 m that need to be traversed before the upper level passage termed Heaven is reached. Once in the Heaven passage, it is a relatively easy 300 m walk to the base of the pipe at the Scott Entrance. At this time, the Scott Entrance is the only access to the cave. So getting down to the Cove Creek trunk 700 m from the Scott Entrance involves several climb downs and some rope work. Heaven was named because of the abundance of crystal formations and helictites (Fig. 11.9). The major flood of 2016 destroyed many of these delicate formations in an area that had never seen flooding of this magnitude.

Continuing downstream in the Cove Creek trunk about 200 m, the stream flows over an impressive 12 m waterfall (Fig. 11.10). Just before the falls is an upper level bypass that opens into an extensive series of parallel passages that tie back into the main drainage several hundred meters downstream. Where the upper levels tie back, there is a major infeeder passage entering from the south. This infeeder leads to a complicated junction where a passage goes upstream to the southwest and another passage goes northeast to Thunder Hall. The southwest passage eventually gets to small to traverse after 300 m. Climbing up into Thunder Hall involves some canyon traversing and exposed climbs. A large 20 m dome named Thunder Dome has been bolted and more passage discovered that is presently being mapped.

Beyond the area of the upper level development above the main Cove Creek the cave becomes a single master trunk (Fig. 11.11). The passage is wide and 3–4 m high with areas of breakdown. After about 300 m, there is a 6 m waterfall that opens into the continuation of the stream passage which is named the Cascade Causeway. The Cascade Causeway is a low-wide stream passage that is alternately floored by pools of water and cobbles. It ranges from 1 to 3 m in height. After about 750 m, a sump is reached at Gasoline Alley.

In early 2017, a major discovery was made when a breakdown blowhole was pushed at the end of the GOD passage which is a parallel passage just to the west of Cascade Causeway. Several hundred meters of muddy low phreatic tube was encountered beyond the constriction, and a low near sump was encountered. Just beyond this near sump, the passage intersected a large river passage going both upstream and downstream (Fig. 11.12). This river passage is estimated to have at least three times the volume of Cove Creek and is 15 m wide and 8–10 m high. Over 1300 m have been surveyed in the downstream section which continues. Upstream has been surveyed for 1100 m and also continues. Dye tracing has confirmed that this river passage (now named Sweetwater River) is the master trunk carrying the water from McClung and Ludington Caves and perhaps the water from several other significant caves (Higginbothams and Savannah). With this discovery, Maxwelton has grown to 24 km of mapped passage with the potential to add many more kilometers.

11.4.4 McClung Cave

McClung Cave is the next major cave north of Maxwelton. The main entrance is located in an open field. A small wet weather stream drains a shallow swale that ends at the entrance of the cave. The entrance is 3 m wide and 2 m high and opens into a large flat-floored room. Beyond this room, a large passage meanders for 100 m to a breakdown area beyond which the cave takes on a classic contact appearance. The small entrance stream has down cut into the underlying shale and formed a tight sinuous canyon. This is best traversed somewhere along the middle of the canyon along crumbly ledges of shale. The depth of the canyon varies from a few meters up to 10 m. The top of the canyon is a classic phreatic tube developed in the limestone that is up to 10 m wide. The canyon section persists for approximately 500 m until a major collapse is reached. First Breakdown marks a major intersection of upper level passages that fan out in several directions. The entrance stream flows under the breakdown and emerges on the other side into a large trunk passage. It is possible to follow the stream under the breakdown, and it is also possible to climb up and through the breakdown to continue downstream. At the top of the breakdown on the right is a small passage that has an old iron gate. This passage is the gateway to the northern half of the cave.

Dropping back down to the stream level, the characteristic canyon enlarges into a more uniform passage that is occasionally floored with breakdown (Fig. 11.13). Several strike-orientated passages intersect the down dip canyon just beyond First Breakdown some of which carry small infeeder creeks coming from the north. There is one phreatic strike tube developed on the south side of the canyon, and a climb up into it gets into Batbone Crawl. Batbone Crawl extends 220 m to intersect with another down dip canyon complex called Freeman Avenue. Just before this intersection, there is a crawlway that branches to the right off of Batbone Crawl which eventually leads to a very tight constriction that opens into the WVACS Room, one of the most highly decorated rooms in the contact caves.

Continuing down the main canyon, the passage is mostly large walking trunk that averages 5–10 m high. One low area

Fig. 11.9 Helictites and aragonite crystals in the Heaven passage, Maxwelton Cave. Photograph by Ryan Maurer. Used with permission

can be negotiated by a short bypass crawl. After 500 m, another major breakdown area is encountered. Second Breakdown is negotiated by climbing up and over the constriction. Several side passages are developed at this point and go south to join with the paralleling canyon in Freeman Avenue. A hole in the breakdown leads back down into the continuation of the entrance stream canyon. This is a large passage that ends after 200 m at the intersection with Chocolate Avenue. Chocolate Avenue carries the main drainage of the cave, and the water has been traced from the Thunderbolt Passage of Ludington Cave to the north.

Going downstream in Lower Chocolate Avenue, the passage is wide and contains large mud banks associated with the stream. The height averages 5 m with evidence of

Fig. 11.10 Waterfall in the Cove Creek trunk, Maxwelton Cave. Photograph by Ryan Maurer. Used with permission

flooding. After 400 m, a low near sump has to be negotiated before the passage enlarges again. This is short-lived as a terminal sump is soon reached. This sump marks the low point in the cave and is 103 m below the main entrance. Going upstream in Chocolate Avenue, the main stream reaches a low area after 300 m that is an impassable gravel-filled sump. However, just before this sump there are a series of strike-orientated passages that intersect in an area called Third Breakdown. These passages eventually connect into a low-wide avenue termed the Meatgrinder. The Meatgrinder trends northeast for approximately 1500 m and averages 1–2 m high.

There are two major ways to get into the northern half of the cave. One is via the Meatgrinder, and the other is

Fig. 11.11 Cove Creek trunk near the Hall of Kings, Maxwelton Cave. Photograph by Ryan Maurer. Used with permission

Fig. 11.12 Chris Coates (foreground) and Carl Amundson stand in the newly discovered and surveyed Sweetwater River in Maxwelton Sink Cave. Photograph by Nikki Fox. Used with permission

through the gate that opens into the Gateway back at First Breakdown. The trip through the Gateway is the preferred way.

The initial area just past First Breakdown is a complex of intersecting phreatic tubes and vadose canyons that are mostly strike orientated but developed in different vertical horizons. These passages are developed well above the Maccrady Shale. Occasional domes funneling water from the overlying sinkhole plain are encountered in this section. There are several small infeeder streams coming in from the eastern contact zone including Beetle Run. These infeeders are small walking size canyons that terminate in breakdown or domes.

The Wind Tunnel is a phreatic tube that is developed along the last infeeder and is the connection passage with the northern section of the system. It is a dry gypsum-encrusted tube that is 1–2 m high for its entire length of 300 m. As the name implies, it carries a good breeze. The Wind Tunnel intersects a large trunk passage named Liberty Bell Avenue. To the right (east), the passage is a dirt and breakdown-floored trunk for about 150 m where it ends in a series of rooms and flowstone with one formation called the

Fig. 11.13 Typical contact canyon—McClung Cave. Photograph by Ed McCarthy. Used with permission

Liberty Bell. Going straight from the Wind Tunnel intersection, the passage is completely floored with large breakdown that is not easy to traverse (Fig. 11.14). After about 100 m, a 12 m drop ends the upper trunk and drops down into the Crystal Canyon section.

There are several hundred meters of cave below the drop. Of note, there is a well casing that intersects one of the passages coming straight down the middle of the 7 m high passage (Fig. 11.15). At one time, there was another entrance (Kidd Entrance) that was open for a couple of years when the Ludington surface stream collapsed into the cave. This collapse was about 15 m deep and captured the surface stream. Subsequent collapse, flood debris, and silt refilled the entrance allowing the surface stream to renew its previous course and flow unimpeded into the main entrance of Ludington Cave.

Back at the intersection of the Wind Tunnel and Liberty Bell Avenue, there is a climb down to the left that opens into what is called the G Trail. This is a pleasant walking canyon that carries a trickle stream for a portion of its length

Fig. 11.14 Liberty Bell Avenue, McClung Cave. Photograph by Ed McCarthy. Used with permission

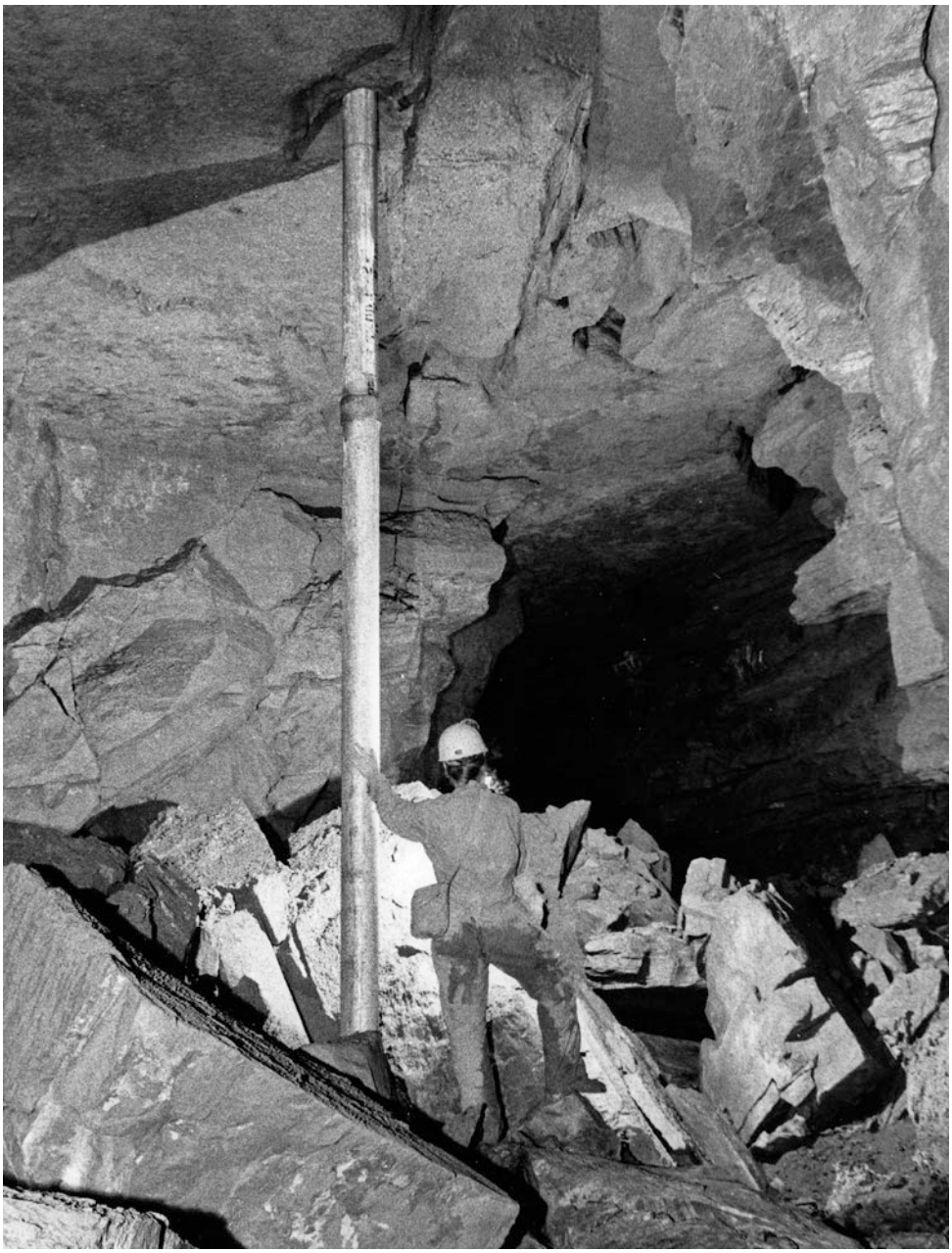

Fig. 11.15 Well casing in Crystal Canyon, McClung Cave. Photograph by W.K. Jones. Used with permission

(Fig. 11.16). G Trail meanders west for several hundred meters until a pit is developed in the floor that drains the stream into a lower level. The pit is about 10 m deep and drops into several hundred meters of small unpleasant canyon passages that eventually are not traversable. Stepping around the pit in the floor, the main passage turns north as a nice silt-floored walkway named Megalithia. There are several junctions off of Megalithia that lead to many hundred meters of passage. After 300 m, Megalithia intersects the Christmas Passage. Going left into the Christmas Passage, the passage trends back toward the entrance of Ludington Cave and comes within 120 m horizontally of the entrance. Halfway out the Christmas Passage is a complex area that contains a 14 m drop to a large breakdown chamber. This room opens into two large breakdown passages that trend north: Big Muddy and Little Muddy. Both of these passages terminate in breakdown and mud mountains and show evidence of back-flooding.

Back at the intersection of Megalithia and the Christmas Passage, there are a series of small passages developed to the left (west). The Mindbender and Wafflefoot Alley intersect the Meatgrinder after 350 m. This forms a several kilometer loop going back to Third, Second, and First Breakdown.

Fig. 11.16 G-trail area in McClung Cave. Photograph by Ed McCarthy. Used with permission

There are two main ways to access the southern portion of the system. One is via Batbone Crawl that opens into Freeman Avenue, and the other is through the Lightner Entrance. The Lightner Entrance was discovered in 1985 and is now the only viable entrance since the main McClung Entrance is usually closed by the landowner. The West Virginia Cave Conservancy owns the Lightner Entrance and has an open cave access policy.

The Lightner Entrance is a small slot in a rock face on the side of a large sink. It is the only natural entrance to a contact cave that is not located at the contact. A 3 m climb down leads to the top of a 15 m drop that bells out at the bottom. A small drain hole at the base of the drop opens immediately into a 7 m drop along a flowstone wall into a well-decorated room. Beyond this room, about 30 m of mostly crawling passage and a squeeze that was excavated leads to another few meters of passage and then another 3 m drop that requires a handline into a lower level passage. The lower level passage ends in a flowstone-filled room to the right and massive breakdown to the left. Pushing through the breakdown via the Champaign Squeeze, the passage opens up and very quickly intersects the Tufa Trail. Going upstream in the Tufa Trail is a continuous climb up rimstone dams for 300 m until a large room is reached with waterfalls coming in from the ceiling.

Going downstream in the Tufa Trail, you climb down the rimstone. After about 300 m is the intersection with the Freeman Avenue trunk. Freeman Avenue is a large breakdown-floored passage that ends in a sump 400 m downstream from this intersection. Upstream, Freeman Avenue parallels the main entrance canyon for almost a kilometer enlarging as it goes upstream and up dip. It is developed along the Maccrady contact but does not have the classic canyon development because of the modification by breakdown. The upstream terminus is in massive breakdown.

Batbone Crawl is about 800 m upstream from the confluence of the Tufa Trail on the left wall of a large breakdown chamber. Batbone Crawl is the major access point to the majority of the cave. A couple hundred meters beyond Batbone is a large junction with a major trunk coming in from the right (south). This passage is called the JEB Stuart Passage and leads to over a kilometer of infeeding canyons developed along the Maccrady contact that drain several surface sinkholes. This area is called the Seven Fingers because the map portrays the surveyed canyons in a hand-shaped fashion (Fig. 11.17).

McClung Cave has a surveyed length of over 26 km and a depth of 103 m. It is a very popular cave and is continuing to be explored.

11.4.5 Ludington Cave

The main entrance to Ludington Cave is in a small blind valley. A creek flowing on the Maccrady Shale flows into this entrance that is approximately 4 m wide and 3 m high. The entrance passage retains these dimensions for a couple of hundred meters until a 13 m (the Old Drop) drop is encountered. Below this drop, the passage encounters the Maccrady Shale zone and decreases in size. This section of the cave is named Old Ludington because it was the first

Fig. 11.17 Seven fingers contact canyon, McClung Cave. Photograph by Ed McCarthy. Used with permission

section to be explored. One hundred fifty meters from the bottom of the drop the main passage reaches a low area that is sumped shut with gravel fill. About 50 m below the drop, a small infeeder canyon averaging 4 m high comes in from the right wall. Going up this canyon for about 200 m, a 10 m waterfall (Half Way Falls) is encountered. Above the waterfall is a complex of infeeder passages coming in from the surface, one of which actually opens in the side of the main entrance.

Approximately 40 m before the Old Drop, an overflow canyon is developed on the left wall. This canyon is named the Polar Passage because of the amount of air that moves through it during the winter. It averages 1–3 m in height for about 300 m before another drop is encountered. The New Drop is a 9 m deep fissure along a drag fold with chert-encrusted walls that drops down to the level of the Maccrady Shale again. A small canyon is developed at the contact and extends 200 m to a junction with a larger passage on the right. This larger passage is the continuation of the main entrance passage that is sumped just downstream of the Old Drop. Several hundred meters of complex canyon maze is developed off of this section going back up dip toward the surface. Continuing downstream the passage gets continually larger and is floored with breakdown in places. The walls are composed of Maccrady Shale. After 200 m, the passage lowers and widens out, turning abruptly west for 50 m before it intersects the Thunderbolt Passage, the master trunk for the cave.

Going downstream from this junction, the Thunderbolt Passage is a large gravel-floored passage that gradually lowers from walking height to stooping. After 450 m, the ceiling lowers to the point that traverse is no longer possible. There is a sump at this point called Odd Man Crawl that is composed of water and gravel that fills the passage. The stream in the Thunderbolt Passage is the main drain for the entire cave and has been dye-traced to Third Breakdown in McClung Cave where it emerges as Chocolate River.

Going upstream, the Thunderbolt passage enlarges into a spacious trunk channel carrying the stream. The floor of the passage is cut into the Maccrady Shale with mud banks and cobble deposits scattered in the meanders of the stream channel. In places, large breakdown blocks have fallen from the ceiling and sides of the passage (Fig. 11.18). The average dimensions are 10 m × 10 m for over 800 m, and the passage follows the strike. At 800 m, there is an infeeding canyon coming into the Thunderbolt Passage from the left (west). This is the only western infeeder at the same level as the trunk within the system. This passage is an incised stream canyon within the Maccrady Shale and has a small ceiling channel developed in the limestone. This stream canyon gradually climbs stratigraphically out of the contact zone and after about 100 m the passage is completely developed in the limestone. This canyon remains a comfortable walking height for another couple of hundred meters before it gradually lowers and becomes a very low wet crawl that has not been pushed. The canyon is approximately 365 m long.

The Thunderbolt Passage in this area is floored with breakdown for much of its length. On the right side (east) is a large chute of breakdown that extends up the flank of a major drag fold that is associated with thrust a fault that is developed 40 m above the Thunderbolt Passage (Palmer 1974). This thrust fault parallels the strike and is developed

Fig. 11.18 Thunderbolt Trunk, Ludington Cave. Photograph by Ed McCarthy. Used with permission

on the limb of the Sinks Grove anticline approximately 1.6 km to the east. Climbing up this chute, the Maccrady Shale turns vertical until it intersects the thrust fault and opens up into a large breakdown chamber called the Belfry (Fig. 11.19). Strata exposed in the Belfry are nearly horizontal and the room is up to 20 m high. At the east end of the Belfry is an infeeder stream passage that within 30 m reaches a surface insurgence. This insurgence is the Bell Entrance and is subject to flooding and siltation; at times it had been a tight muddy crawl, but it had occasionally been a walking canyon. In the early 1990s, a collapse occurred at the entrance that allowed the passage to silt completely shut. Efforts to reopen the entrance stalled when an unfriendly landowner bought the property, and the entrance remains sealed at this time.

Northeast of the Belfry a series of breakdown-floored passages open into the Boulder Room, the largest room in the cave system. The Boulder Room is a large trunk segment developed along the strike and is floored with large blocks of breakdown. It averages 20 m wide and 15 m high and is 300 m long. Numerous side passages are developed on the east side of the room, and they lead back close to the surface contact. Several of these are highly decorated with speleothems due to their proximity to the surface.

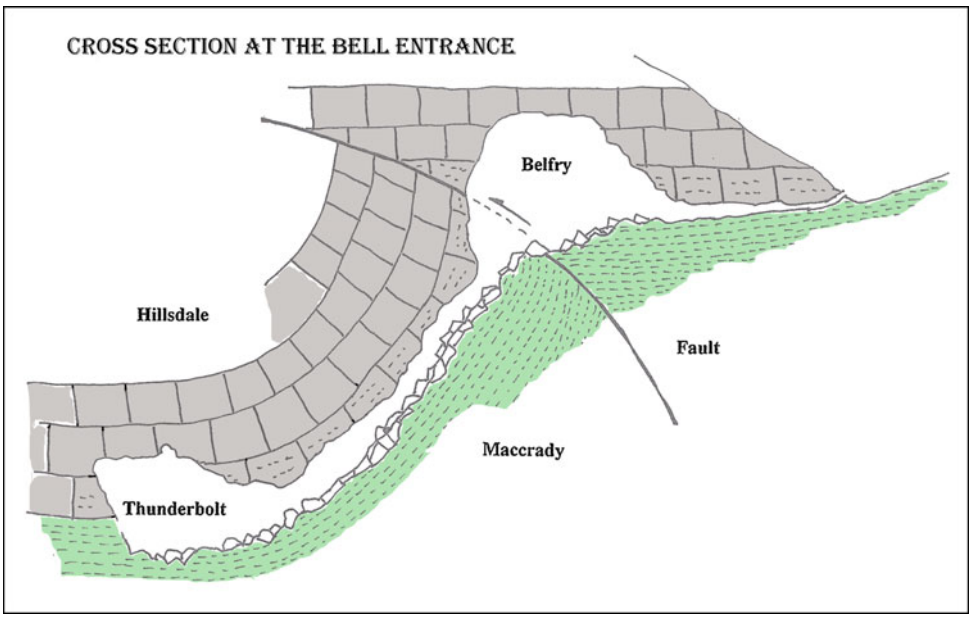

Fig. 11.19 Cross section at the Bell Entrance, Ludington Cave

Within the breakdown floor of the Boulder Room, there are several openings that lead down to a series of parallel passages. These passages contain several hundred meters of breakdown-floored channels. There are also a couple of breakdown chutes, again developed along the drag fold, that empty into the Thunderbolt Passage. The Thunderbolt Passage continues upstream for another 500 m averaging 5–8 m high before eventually branching into several smaller infeeder tubes coming in from surface sinks.

In 2010, a blowing hole on the side of a sink a few hundred meters north of the Bell Entrance was excavated. After much effort and 200 m of extremely tight and wet passage, a connection was made to a hole on the side of the Boulder Room. This new entrance is called the Yates Entrance and now allows entry into the northern portion of the system once again.

A blind valley is developed midway between the Bell Entrance and the main Ludington Entrance. This is the Green sink where a surface stream sinks at the base of a cliff face reminiscent of the Maxwelton cliff but somewhat smaller. Two parallel strike-orientated phreatic tubes terminate at the southern edge of this sink. Boo Boo Boulevard and the Long Hall are thought to be abandoned inflow channels (Palmer 1974). Boo Boo Boulevard is a low-wide cobble-floored tube, while Long Hall is a large breakdown-floored trunk segment. The Green sink is directly over top of the Thunderbolt Passage but is 35 m higher. Water entering from the sink flows rapidly down a series of minor faults and steep dip slopes associated with the main thrust fault (Fig. 11.20). A vertical maze of passages is developed within this section.

From the junction of Boo Boo Boulevard and Long Hall, the passage continues southwest along strike as the Long Hall Crawl. It is a wide cobble-floored tube averaging 1–2 m in height for 230 m to the intersection with X Canyon. Going upstream in X Canyon, there is approximately 500 m of mostly walking height stream canyons developed along the contact. All passages end in surface breakdown. Going downstream in X Canyon Shale Pit is reached after 150 m. Shale Pit is a 10 m drop into a small canyon that within 150 m empties into Lower Ludington just south of its confluence with the Polar Passage.

From the intersection of Long Hall Crawl and X Canyon, the main passage continues southwest and after 200 m opens into the Star Room. To the east of the Star Room are a series of interconnected passages on various levels that trend up dip toward the surface contact. Several of these passages are carrying small streams that all converge in the Star Room. A large canyon exits the Star Room on the west side, and this passage is called Lower Ludington. Lower Ludington intersects X Canyon after 150 m and then continues another 200 m to its confluence with the Thunderbolt Passage.

Ludington Cave has approximately 17 km of surveyed passage. It was originally surveyed by members of the West Virginia Association for Cave Studies in the late 1960s to a length of 8 km. A subsequent resurvey led by Joseph Caldwell and WVACS members in the early 2000s doubled the known extent of the cave.

Fig. 11.20 Waterfall in Thunderbolt passage of Ludington Cave, coming from the Green Sink. Photograph by Ed McCarthy. Used with permission

11.4.6 The Hole

The Hole is the northern most contact cave and the only one that does not drain south to Davis Spring. The Hole resurges at springs associated with Burns #2 Cave along the banks of Spring Creek. From a geomorphic standpoint, The Hole is the least complex contact cave and exhibits classic maze development associated with uniform geologic conditions.

The Hole has three main entrances and a recently discovered fourth entrance that was excavated. The Boggs Entrance is the southernmost and the most upstream entrance to the system. It is a large entrance at the end of a blind valley with a surface stream entering the cave. A little over a kilometer to the north is the Perkins Entrance, a small stream sink in a pasture just below a stock pond. The Gibbs Entrance is approximately 2.2 km north of the Perkins Entrance and is the northern most entrance. The Gibbs Entrance is another small hole on the edge of a sink with a small surface drainage associated with it. The newly excavated Perkins #2 Entrance is not far from the original Perkins Entrance but leads into a different section of the cave.

The cave system consists almost entirely of down dip vadose canyons carrying active streams from the surface and phreatic tubes following the strike. These phreatic conduits usually intersect the stream canyons above the shale layer near the ceiling and are developed entirely within the limestone. The down dip canyons are incised into the Maccrady Shale up to 10 m. The dip of the strata ranges from 3 to 5° and is fairly uniform throughout the entire system. This has allowed a fairly predictable speleogenesis to occur (Fig. 11.21). The cave system exhibits its majority development along the strike, and the parallel phreatic tubes offer the major connections between the various sections of the cave. Where canyons are numerous, maze sections are developed. Vertical development above the contact zone is not common, and most of the passages in The Hole are developed within the lower 20 m of the Hillsdale Limestone member and the underlying Maccrady Shale.

The Gibbs Entrance is a gated small opening in a shallow wooded sink. The entrance opens into a small stream channel less than 2 m high. Within 30 m, a small pool (the Bathtub) is encountered that requires immersion before the passage opens up into the Long Room. The Long Room is a remnant of a strike-orientated phreatic tube that has been modified and enlarged by breakdown near the surface contact. The entrance stream flows across this room and into Barefoot Creek, a down dip canyon developed at the shale contact. Numerous plunge pools are developed as the water cascades quickly down slope. Approximately 100 m down this canyon, there is an intersection in the ceiling with a wide phreatic tube. A 3 m climb gives access to the Crossover. The Crossover is about 12 m long, and then there is another 3 m drop into the Adjacent Stream Passage. This stream passage is completely separate from Barefoot Creek, and the passage has larger dimensions (Fig. 11.22). The Adjacent Stream Passage trends along strike and picks up incoming water from the surface contact via several down dip canyons such as Spike Street, Bullwinkle Boulevard, and the Upper Adjacent Stream Passage.

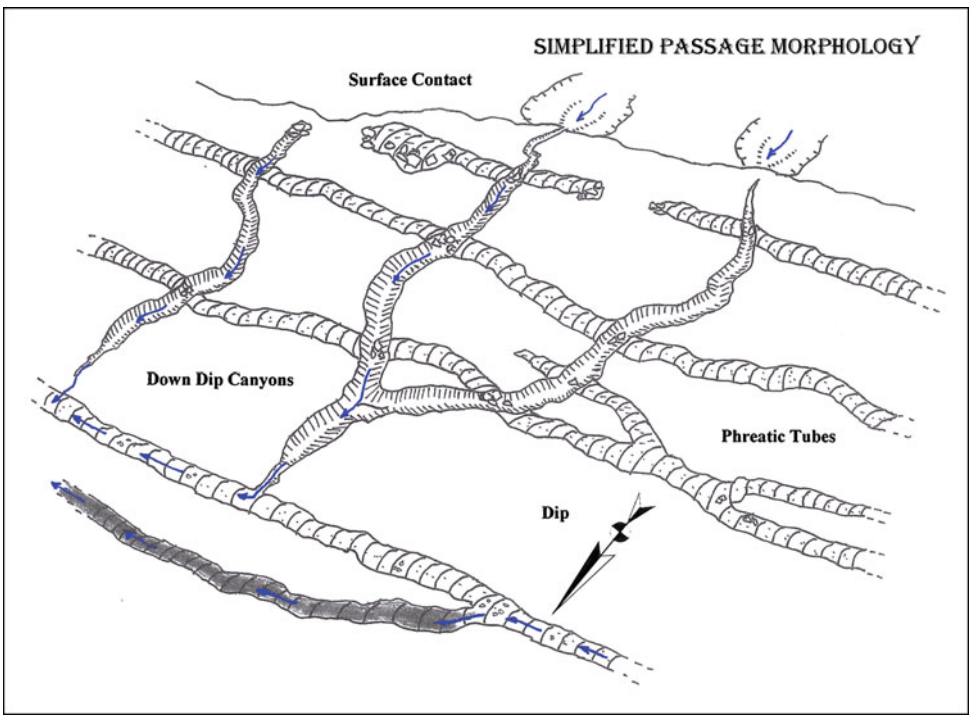

Fig. 11.21 Simplified passage morphology for the hole

Fig. 11.22 Adjacent stream passage in the hole. Photograph by Ed McCarthy. Used with permission

Downstream from the Crossover in Barefoot Creek, the canyon enlarges with the addition of the phreatic tube in the ceiling. Ceiling heights average 6–7 m. After 70 m, the stream exits via a small hole in the floor and an area of dirt-floored crawlways is encountered. Turning north leads into what is called the North Maze. The North Maze consists of hundreds of meters of low phreatic tubes that are parallel to each other and spaced about 30 m apart. They are cut by down dip canyons carrying small trickle streams coming in from the surface. In one section, there are eight parallel tubes along strike, each perched just above the limestone/shale contact. Each one represents a former base level and with subsequent lowering new tubes formed. A ninth tube (Shale River) exists in this area and is completely sumped indicating perched phreatic conditions. Shale River is the master drain for the entire cave and in this section is visible only for a few meters at the northern most point in the cave before it reaches a terminal sump.

Near the end of the Adjacent Stream Passage is a remnant tube named the Broken Crockery Passage. This passage is floored with loose slab breakdown for 150 m before dropping into the north side of the South Maze Stream Passage. Going downstream, there are numerous tubes intersecting at ceiling level on the left side of the canyon. These phreatic tubes are the beginning of the South Maze and are spaced every 10 m. They are wide, dirt or cobble-filled passages that average a meter in height and are interconnected on many levels. As with the North Maze, they represent former water table levels. The South Maze is more dense than the North Maze. The South Maze Stream Passage empties into a segment of Shale River (Fig. 11.23). Just downstream from this confluence, Shale River intersects the Maccrady Shale along the strike. This portion of Shale River follows the contact which abruptly rises 12–15 m above stream level. The stream has down cut a narrow canyon within the shale at this point that is up to 12 m deep. This canyon is about 170 m long and ends as abruptly as it began when the limestone/shale contact returns to level at the beginning of the canyon. Shale River is no longer entrenched in the shale and flows in a wide 2–3 m high tube.

Going southwest out of the South Maze, there are a couple of parallel phreatic tubes. The larger one is named the Long Northeast. The Long Northeast is well named and is the main passage that ties the entire system together. It averages 1–2 m in height 3–4 m in width and is floored with cobbles, sand, and bare bedrock. The Long Northeast extends from the South Maze to Echo Canyon near the Boggs Entrance and has a linear extent of just over 1 km. There are a number of parallel tubes (No Name Northeast, Nice Northeast, Nasty Northeast, Bear Wallow Way, Pittsburgh Section Northeast) that are developed adjacent to the Long Northeast, but none of them are continuous.

Fig. 11.23 Shale River in The Hole. Photograph by Ed McCarthy. Used with permission

Shale River is similar to the Long Northeast except it has water and sumps in several places, it can be followed for 1.3 km. The Long Northeast is the easiest passage to traverse to get from one section of the cave to the other.

The Long Northeast and the other northeast-trending tubes are all cut by down dip stream canyons formed at the contact. The Blue Canyon, Crumbling Canyon, Perkins Canyon, and the Third Stream Canyon are the more notable ones with each having tributaries that extend to the surface contact (Fig. 11.24). The Perkins Canyon breaches the surface just below a farm pond in the base of a sink. This entrance gives access to the middle portion of the system. These canyons cut the northeast-trending tubes at right angles and trend down dip to intersect Shale River. On approach to Shale River, the gradient lessens and the stream rises at the contact zone. The canyon aspect of the passage disappears and the passage is smaller and developed completely within the limestone. Tower Canyon and Echo Canyon mark the end of the Long Northeast. Echo Canyon leads upstream to Bear Wallow Way, which in turn intersects Second Stream Canyon. All of these canyons drop into Shale River. A series of small parallel tubes are interconnected on the south side of Second Stream Canyon and form the Boggs Maze. The Best Way Northeast and Frosted Avenue both cross First Canyon on their way to the Boggs Entrance. A 3 m ladder climb from Frosted Avenue drops into the large entrance room. The Boggs Entrance is the only natural entrance to the cave; the other entrances were excavated.

Members of the West Virginia Association for Cave Studies originally surveyed The Hole in the 1960s. It was the first major cave system found that was not known prior to that time. In the late 1970s, the Pittsburgh Grotto of the NSS discovered what was named the Pittsburgh Section. After mapping that portion, it was decided that the entire system needed to be remapped for better quality. Led by Charlie Williams and other WVACS members, over 70 trips were made and 37 km were mapped. Water quality measurements were taken by Pasquarell and Boyer (1995) in the 1990s in The Hole watershed to study the relationship between agricultural practices and bacteria and nitrate levels in cave waters. A seasonal (summer) increase in bacteria counts correlated with increased cattle grazing on the sinkhole plain above the cave.

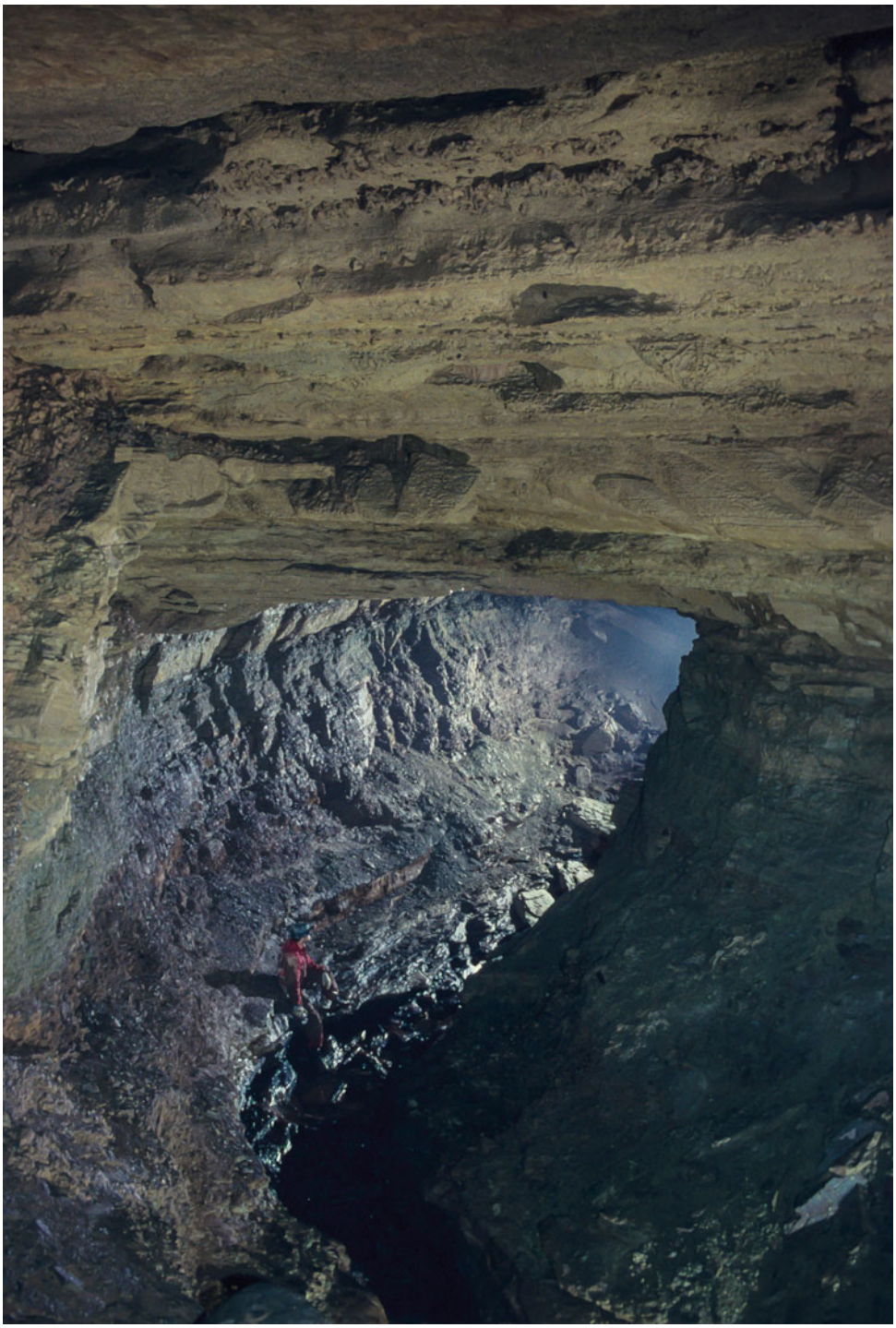

Fig. 11.24 Phreatic tube crossing down dip contact canyon —The Hole

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