Geology of Seneca Caverns, Seneca County, Ohio[1]

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ABSTRACT. **Seneca Caverns were formed along a major fracture which trends N68°W and dips 40°NE in the Columbus and Lucas Formations (Middle Devonian) and possibly the underlying strata. This cavern is a collapse or breakdown-type cavern, probably resulting from deep-seated solution of gypsum in the Bass Islands Group (Upper Silurian). Seven of the 12 known levels or rooms were surveyed and mapped to delineate the elevations, dimensions and unique features of each level. Cavern stratigraphy and paleontology correlated with the stratigraphy of north-central and central Ohio. Fluctuations in the level of the cavern stream ("Old Mist'ry River"), commonly found in the seventh level approximately 30 m (100 ft) below the surface, appear to be the direct result of rate and duration of precipitation and soil moisture content. Lag times range from five hours to five days, 15 hours, and 10 minutes. Geochemical parameters exhibited by the cavern stream were very similar to those of Castalia "Blue Hole". The 1988 drought eliminated a selected dye trace to evaluate the possible connection of these two features.**

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INTRODUCTION

Ohio has approximately 500 solution caves and caverns, and most are confined to a 40-mile (64 km) wide belt running north and south from South Bass Island in Lake Erie through Adams County on the Ohio River. These caves are developed mainly in the Columbus and Delaware Formations (Middle Devonian) and to a lesser degree in the Detroit River and Bass Islands Groups (Middle Devonian-Silurian) (White 1926, Verber and Stansbery 1953). Karst development in Ohio is fairly widespread throughout the western half of the state; however, detailed karst hydrogeologic studies of this region have been seriously lacking. Recent studies by Tintera (1980), Tintera and Forsyth (1980), and Kihn (1988) identified various karst features and the hydrogeologic regime of the Bellevue-Castalia area in north-central Ohio. Kihn's (1988) study placed specific emphasis on one of Ohio's largest caves or caverns—Seneca Caverns—and the cavern stream ("Old Mist'ry River"). The major purpose of this paper is to detail the geology of Seneca Caverns.

Seneca Caverns was first discovered in 1872 by two area youths. In 1897, the upper four levels were opened commercially under the name Good's Cave. The upper three levels, however, were partially filled with sediment that had washed in from the surface. Visitors who ruined their clothes while sliding from one level to another became discouraged and the venture failed. In 1928, Don and Fannie Mae Bell, Bellevue, OH, acquired a lease on the property from owner Emanuel Good. Exploration continued for two years, with eventual discovery of the lower rooms and access to an underground stream. Realizing that this discovery greatly enhanced the commercial potential, Mr. Bell purchased the land and began development of the cavern. On 14 May 1933, the cave was reopened under the name Good's Cave, a name which was eventually changed to Seneca Caverns. Richard Bell purchased the land from his parents in 1964 and continues to operate the cavern commercially. Today, tourists descend a path which zigzags along a fracture exposing approximately 30.5 m (100 ft) of bedrock.

Several short studies have been completed on Seneca Caverns to date. In 1926, White identified 11 major cave systems in Ohio including Seneca Caverns, known then as Good's Cave. A tape-and-compass survey was completed, along with a general cavern description. According to White, Seneca Caverns were not formed by faulting; however, no other explanation was given for their formation. During the summer of 1933, J. Harlan Bretz, University of Chicago Geology Department, and five graduate students visited the cavern while on a geology field trip. Bretz was fascinated by the cavern and, realizing that it was not a typical solution feature, coined the term "The Earthquake Crack". This term was used by Don Bell, proprietor, for many years to advertise the cavern. Grieves (1953) performed the next study of Seneca Caverns and concluded that the cavern was formed by faulting. Short (1970) presented a brief description of the cavern and theorized that Seneca Caverns is a collapse or breakdown-type cavern due to deep-seated solution activity, similar to the theory proposed by Verber and Stansbery (1953) for caves on South Bass Island. Brucker (1979) and Richard Bell changed the popularly known name of the cavern from "The Earthquake Crack" to "The Earth Crack" to define better their theory of origin.

STUDY AREA

Seneca Caverns is located in the extreme northwest portion of Thompson Township in Seneca County, north-central Ohio (Fig. 1). It is situated approximately 1.6 km (1 mi) southwest of the village of Flat Rock and 6.4 km (4 mi) southwest of the city of Bellevue.

The cavern lies within the Till Plains of the Central Lowlands physiographic province (Burgess and Niple, Ltd. 1967). The topography in this region is gently rolling, with poorly drained soils formed from a highly calcareous, clayey glacial till. The bedrock consists of Upper Silurian

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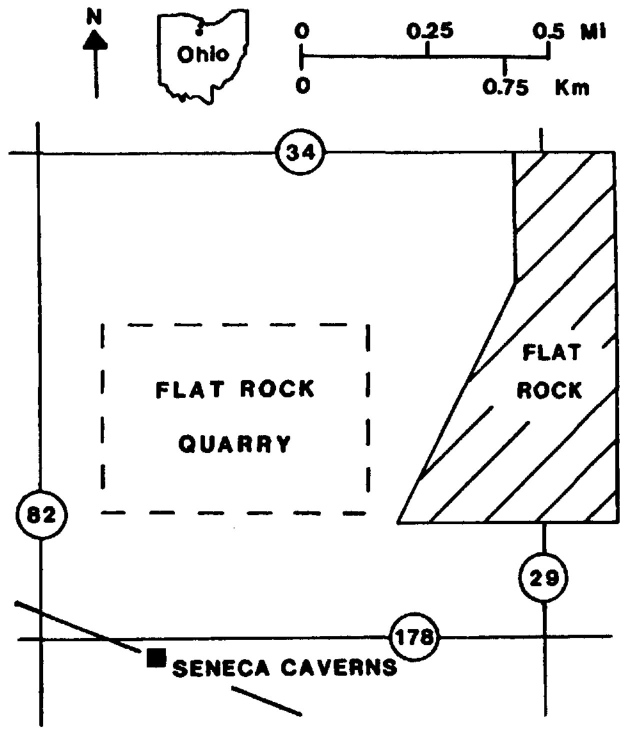

FIGURE 1. Location of Seneca Caverns in north-central Ohio and positioned along a N68°W fracture pattern.

and Middle Devonian limestones and dolomites (Table 1), which represent the regional aquifer system for the area. This carbonate aquifer is primarily a diffuse-flow aquifer in which the flow occurs through joints, fractures, and bedding planes (Kihn 1988). In this area, the only evidence of conduit flow, which occurs through an integrated network of solutionally enlarged conduits, is the abundance of sinkholes that are formed in the highly soluble Columbus Limestone (Middle Devonian).

MATERIALS AND METHODS

The upper seven rooms of Seneca Caverns were surveyed on 18 September 1985. From a bench mark near the cave entrance, an alidade was employed to obtain an elevation at the cavern entrance. Twenty-three survey stations were strategically located throughout the extent of these seven levels. A Wild T1A theodolite was then used to measure the vertical and horizontal angles between stations to obtain an elevation for each station. In smaller rooms where only one survey station was located, tape and compass were employed to obtain values for the length, width, and height of these openings. In levels with larger openings, where two or more stations were located, triangulation determined room dimensions. Data collected were then employed to construct cross-sections of the seven rooms. A stratigraphic section was formed by carefully examining the geology and paleontology of each room and comparing the results with that from north-central Ohio (Swartz 1907, Janssens 1970) and central Ohio (Wells 1947, Stewart 1955). A study was also initiated to determine the relationships between external precipitation events and the level of the water table found within Seneca Caverns. An Omnidata International Easy Logger was installed which measured simultaneously precipitation, water temperature, and the level of the cavern stream. These data were collected at 20-minute intervals from July 1986 - May 1987 and used to determine the lag times between storm events and resulting water-level fluctuations. A photolineament study utilizing low-altitude (scale 1:24,000), black and white, aerial photographs, obtained from Ohio Department of Natural Resources, Soils Division, identified the local bedrock fracture patterns. A field investigation of joint orientations also was undertaken to confirm the existence of the photolineaments. Twenty-five randomly selected joints were measured at each of four nearby quarries — Flat Rock,

TABLE 1

Stratigraphic column for the Seneca Cavern area (from Janssens 1970).

System	Series	Group	Formation	Average Thickness m (ft)
Quarternary	Pleistocene	Wisconsin	Mankato	0 - 30.5
			Cary	
		pre-Wisconsin	Drift?	(0 - 100)
Devonian	Erian		Delaware	10.6 (35)
	Ulsterian		Columbus	18.3 (60)
		Detroit River	Lucas	10.6 (35)
			Amherstburg	15.2 (50)
Silurian	Cayugan	Bass Islands	Raisin River	15.2 (50)
			Put-in-Bay	15.2 (50)
			Tymochtee	45.7 (150)
			Greenfield	13.7 (45)

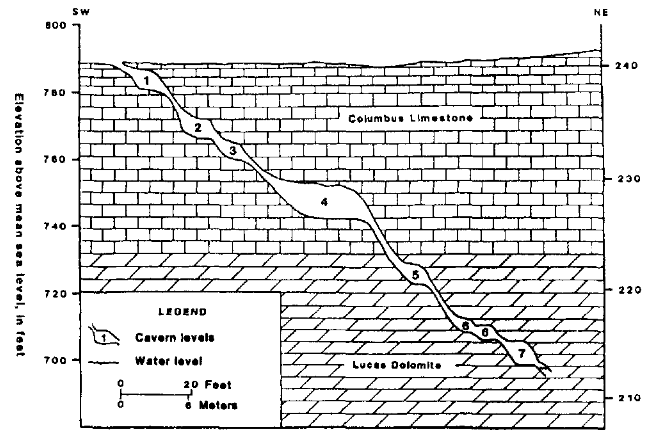

FIGURE 2. Cross-section trending NE-SW showing the dip of the fracture and the room or level arrangement of Seneca Caverns.

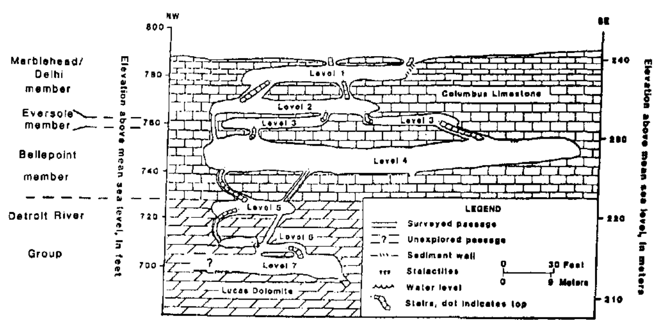

FIGURE 3. Cross-section trending NW-SE illustrating the seven surveyed levels of Seneca Caverns.

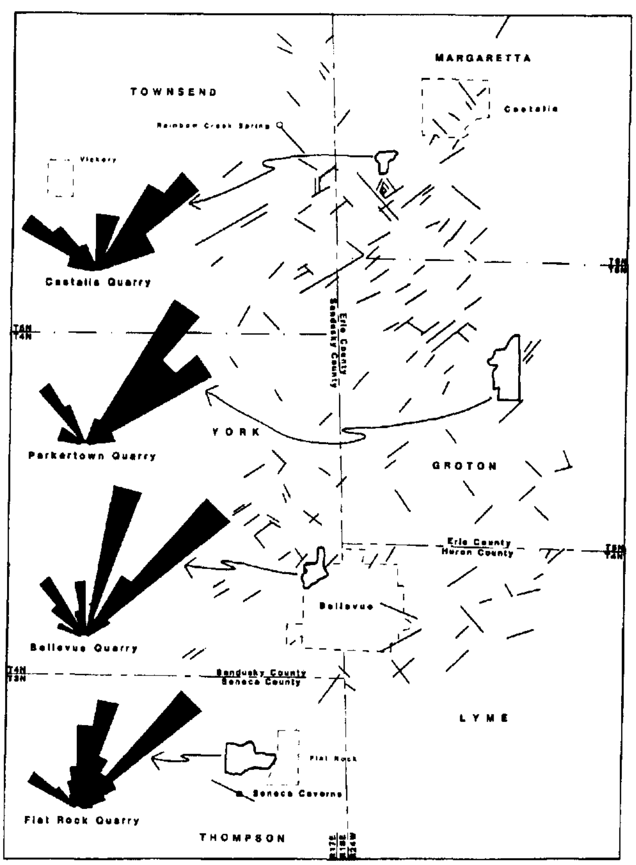

FIGURE 4. Photolineaments for the Castalia-Bellevue area with joint diagrams for the Flat Rock, Bellevue, Parkertown, and Castalia Quarries.

Bellevue, Parkertown and Castalia.

RESULTS AND DISCUSSION

Cavern Geology

Seneca Caverns is a collapse or breakdown-type cavern occurring along a major fracture in the Columbus and Lucas formations and possibly the underlying strata (see Table 1). Evidence for this collapse is visible in the southern wall or block which has moved or slipped downward approximately 2 m (8 ft) and is highly shattered and jumbled. In many rooms the floor appears to fit into the ceiling much like a jigsaw puzzle. This collapse process seems similar to that proposed by Verber and Stansbery (1953) for South Bass Island caves. The collapse was probably initiated by the conversion of anhydrite to gypsum in the underlying Bass Islands Group. This may have led to a 33–62% (White 1926) increase in volume which would be instrumental in deforming stratified rock. The gypsum was then preferentially dissolved by ground water moving vertically through joints and fractures, and laterally along bedding planes.

The photolineament study revealed that the fracture containing Seneca Caverns trends N68°W for at least 3.2 km (2 mi) (Fig. 1). The apparent dip of the fracture, as measured in the cavern, is 40°NE (Fig. 2); however, total vertical extent of the fracture has yet to be determined, because of the presence of water in the lower reaches of the cavern. The cavern survey yielded the dimensions and elevations of seven distinct rooms or levels (Fig. 3). For detailed plan-view diagrams of each level, see Kihn (1988). The rooms are generally rectangular in shape, as caused by the joint pattern exhibited by the strata. During this study, "Old Mist'ry River" was commonly encountered in the seventh level. Because of the drought experienced by the Midwestern states during the spring and summer of 1988, when this study was made, the water receded, exposing a portion of the eighth level. Other periods of drought, especially during February 1937 and January 1971, have also lowered the water table. However, the lowest water level was observed in 1934 when the water dropped an estimated 30 m (100 ft) below the seventh level, exposing an additional five rooms. The fracture, viewed through the crystal clear water, still continued downward below this point.

Results of the photolineament study and the joint orientation measurements at the four quarries near Seneca Caverns revealed a near orthogonal fracture-pattern, with the dominant trend being northeast-southwest and a less dominant trend of northwest-southeast. This fracture pattern and joint diagrams for the four quarries is shown in Figure 4. Armstrong (1976) postulated that this fracture pattern is the result of extensional stress generated in the Findlay Arch region as a result of differential subsidence of the adjoining Appalachian and Michigan basins.

The stratigraphy of Seneca Caverns can be compared because of similar characteristics to the stratigraphy of north-central Ohio (Swartz 1907, Janssens 1970) and central Ohio (Wells 1947, Stewart 1955) (Fig. 5). Confusion exists due to variations in the stratigraphic terminology for the members of the Columbus Formation.

Swartz (1907) recognized three subdivisions of the Columbus Formation in north-central Ohio. The upper member, known as the Venice member, is massive blue limestone with little chert and an intermittently present fish-bone bed at the top. The fossil horizons below the fish-bone bed were designated the "*Spirifer*" *duodenarius* horizon, and the upper *Paraspirifer acuminatus* horizon because of the abundance of these brachiopod species. Wave markings are apparent at the base of this member.

The middle member, known as the Marblehead member, is gray fossiliferous limestone. Three spiriferid horizons, not all present in any one section, were distinguished by Swartz (1907): lower *Paraspirifer acuminatus* faunule (in north), *Brevispirifer gregarius* faunule, and "*Spirifer*" *macrothyris* faunule (in south). This member is equivalent to the lower two-thirds of the Delhi member in Central Ohio (Stewart 1955).

The lowermost member of the Columbus Formation identified by Swartz (1907), the Bellepoint member, is brown, dolomitic limestone. It is typified by many corals and has a 2.5 cm (1 in) sandy layer at the base. This member is only 2 m (6 ft) thick and rests on the Lucas Formation of the Detroit River Group. The total thickness of the Columbus Formation in north-central Ohio, as reported by Stewart (1955), is 18 m (60 ft).

In central Ohio, a detailed analysis of the Columbus Formation by Wells (1947) divided it into three parts or members. The uppermost member, known as the Delhi member, is bluish-gray, relatively pure, often semicrystalline limestone with an average thickness of 17 m (56 ft). A fish-bone bed, 7.6-38 cm (3-15 in) in thickness, is very well developed in the upper portion of the member, more so than in northern Ohio. Below this fish-bone bed are three fossil horizons designated the upper *Paraspirifer acuminatus*, *Brevispirifer gregarius*, and "*Spirifer*" *macrothyris* horizons, from top to bottom.

The middle member, known as the Eversole member, is rather pure limestone similar to the beds above, except for the gray to white chert occurring in somewhat alternate layers with the limestone. The chert is abundantly fossiliferous with the external markings of the original gastropod shells being beautifully preserved in the chalky shell replacement. This layer is approximately 2 m (6 ft) in thickness in central Ohio, but is absent in northern Ohio (Stewart 1955).

The lower member, known as the Bellepoint member, is brown, dolomitic limestone approximately 13 m (43 ft) thick. This member is relatively unfossiliferous except for the upper portion which contains numerous corals and stromatoporoids. The bottom of the Bellepoint member is characterized by a 0.3 m (1 ft) layer of conglomerate which contains large and small water-worn pebbles of the Bass Islands (Silurian) rocks in a Columbus Limestone matrix. It is important to note that the Detroit River Group (Devonian) is absent in central Ohio and the Columbus Formation lies on the Bass Islands Group (Stuart 1955).

In Seneca Caverns, the upper member of the Columbus Formation is light-gray, medium to massively bedded limestone averaging approximately 9 m (30 ft) in thickness. Levels one, two, and the upper portion of level three are composed of this member. Distinct horizons contain-

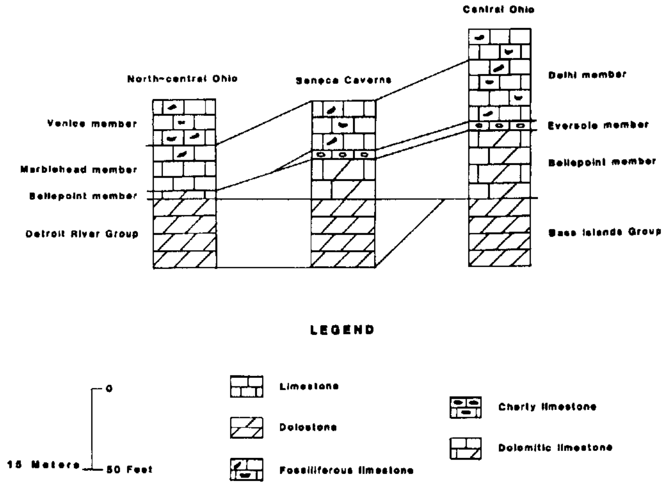

Figure 5. Stratigraphy of Seneca Caverns as it correlates to the stratigraphy of north-central Ohio (Swartz 1907, Janssens 1970) and central Ohio (Wells 1947, Stewart 1955).

ing abundant specimens of brachiopods *Brevispirifer gregarius* were found in the ceiling of level one and *Muscrospirifer mucronatus* were found in the ceiling of level two. Other fossils found in this member include *Leiorhynchus* sp., *Schizophoria propinpua, Chonetes* sp., *Heliophyllum halli, Zaphrentis corniculum*, and *Tentaculites scalariformis.* This member appears to correlate with the Marblehead member in north-central Ohio and the lower two-thirds of the Delhi member in central Ohio.

The middle member is analagous to the Eversole member of central Ohio. It is massive, light-gray limestone which contains gray to white layers and nodules of chert. This member is 2 m (6 ft) thick and is visible in the lower half of level three.

The lowermost member, the Bellepoint member, is light-brown, massive dolomitic limestone which contains two systems of well-developed joints trending N10°E and N45°E. It is relatively unfossiliferous, except for the upper one meter, which contains the coral *Zaphrentis corniculum.* This member is approximately 8 m (25 ft) thick and is apparent in level four and the upper portion of level five. It appears to correlate with the Bellepoint member of north-central and central Ohio. The sandy layer, which marks the contact between the Columbus and Lucas formations as described by Swartz (1907), could not be located in Seneca Caverns. The bedrock, however, abruptly changes colors from light brown to light gray and was determined to be highly dolomitic. The sixth and seventh levels contain an appreciable amount of chert and corals which are indicative of the upper portion of the Detroit River Group (Stewart 1955). The total thickness of the Columbus Formation visible within Seneca Caverns is approximately 19 m (61 ft), which is almost identical to the value given by Stewart (1955) for north-central Ohio.

Cavern Hydrology

An underground stream, known as "Old Mist'ry River," occurs for much of the year in the seventh level. There is only one group of organisms known to inhabit this stream: Amphipods (Page 1968). These shrimp-like troglobitic

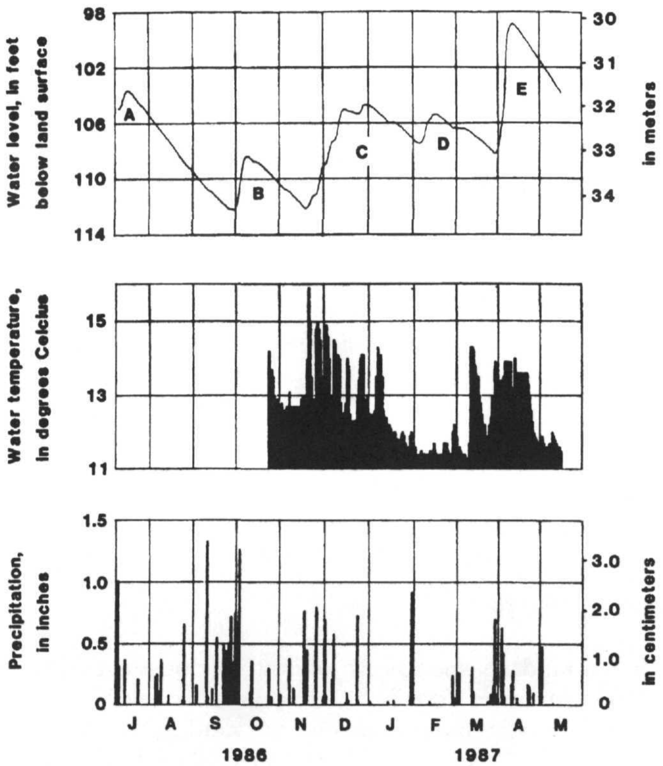

FIGURE 6. Fluctuations in water level and temperature of "Old Mist'ry River" in response to storm events at Seneca Caverns from July 1986 to May 1987.

crustaceans are found mostly in clear cool waters of springs, ponds, lakes, and pools; however, many are restricted to subterranean waters such as the cavern stream. The amphipod found here is a member of the genus *Crangonyx* and is approximately 1.3 m (0.5 in) in length, blind, and lacks pigmentation. The crustacean most commonly feeds on detritus and other allochthanous material, as well as bacterial scum floating on the water surface. They are very sensitive to temperature variation and cannot survive a temperature change of greater than 4° C (Page 1968).

The level of "Old Mist'ry River" is controlled primarily by the amount of runoff, mainly via sinkholes and sinking streams. This was most evident on 4 July 1969, when the area received approximately 23 cm (9 in) of rain in four hours. In two days, the water level rose to the Cavern entrance. It subsequently took four months for the water to return to its original level (Short 1970). For comparison, during the 1934 drought the stream fell to a point approximately 30 m (100 ft) below its normal position, exposing levels 8, 9, 10, 11, and 12. The data logger installed in Seneca Caverns from 10 July 1986 to 12 May 1987, determined the lag time from precipitation events to resulting rises in the water level. Five storm events during this period yielded lag times ranging from five hours to five days, 15 hours, and 10 minutes (Fig. 6). Shorter lag times were recorded when the storm duration was shorter, the precipitation rate was greater, and the soil was moderately saturated, and vice versa.

The cavern-stream hydrograph was very useful in determining the flow types operating within the carbonate aquifer. The short lag times and the steepness of the rising limbs of the hydrograph indicate that the surface runoff was quickly transmitted to the ground-water regime through sinkholes and sinking streams. Thus, conduit flow is the dominant factor for recharge to the carbonate aquifer. The low to moderate slope and length of the recession limbs, however, illustrates that the aquifer, as a whole, acts to store water more readily than to transmit it. This is indicative of the diffuse flow nature of the carbonate aquifer.

The direction of flow of "Old Mist'ry" and the regional ground water is generally in a northerly direction toward the major regional discharge—Lake Erie. It has been postulated in many studies (White 1926, Ver Steeg and Yunck 1932, Brucker 1979, Kihn 1988) that the cavern stream and surface water entering the ground-water regime through nearby sinkholes and sinking streams eventually is discharged by springs in the Castalia area such as the famous Castalia "Blue Hole," 24 km (15 mi) to the north. A detailed geochemical analysis of "Old Mist'ry River" was performed by the United States Geological Survey (U.S.G.S.), Department of Interior (1972) (Table 2). These results were very similar to those obtained for Castalia "Blue Hole" (Table 2), which may indicate a connection between the two. To test this hypothesis, a dye trace originating from Seneca Caverns had been planned for the spring or summer of 1988. Low ground-water levels and the lack of significant rainfall during the drought of 1988, however, precluded such an experiment.

Even though Seneca Caverns is not as spectacular in size or in spelothem development as Mammoth Cave, KY, or Carlsbad Caverns, NM, it is unique in that it is an excellent example of a major cavern formed by the

TABLE 2

Comparison of geochemical parameters of "Old Mist'ry River" in Seneca Caverns with Castalia "Blue Hole" (U.S.G.S. 1972).

Parameter	Seneca Caverns (mg/l)	Castalia "Blue Hole" (mg/l)
Sodium (Na)	8.5	14
Bicarbonate (HCO_3)	260	295
Sulfate (SO_4)	990	930
Chloride (Cl)	16	24
Total Dissolved Solids (calculated)	1,620	1,600
Hardness at $CaCO_3$	1,300	1,240
Specific Conductance (micromhos at 20°C)	1,850	1,850
pH	7.2	7.4

collapse and separation of walls along a large fracture. It is one of the largest caverns in Ohio and is well worth a visit.

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