BULLETIN

OF THE

NATIONAL SPELEOLOGICAL SOCIETY

VOLUME TWENTY THREE PART ONE

BARTON HILL PROJECT

A Study of the Hydrology of Limestone Terrain, Schoharie, New York

JANUARY, 1961

BULLETIN
of
THE NATIONAL SPELEOLOGICAL SOCIETY

VOLUME 23, PART 1 **JANUARY, 1961**

BARTON HILL PROJECT

A STUDY OF THE HYDROLOGY OF LIMESTONE TERRAIN SCHOHARIE, NEW YORK

PREPARED BY THE NATIONAL SPELEOLOGICAL SOCIETY FOR THE VILLAGE OF SCHOHARIE, NEW YORK

Published twice a year; Editor: William E. Davies, 125 W. Greenway Blvd., Falls Church, Va.; Associate Editors: Nancy G. Rogers, George W. Moore, Mrs. William W. Youdon, Harry M. Meyer, Jr.; Assistant Editors: Thomas C. Barr, Jr.; Richard Anderson, Kenneth Christiansen, Rane Curl. Inquiries relating to the publishing of manuscripts in the BULLETIN should be addressed to the editor.

Office Address:

THE NATIONAL SPELEOLOGICAL SOCIETY
2318 N. KENMORE ST.
ARLINGTON 1, VIRGINIA

Subscription rate in effect January 1, 1961: $4.00.

THE NATIONAL SPELEOLOGICAL SOCIETY is a non-profit organization devoted to the study of caves, karst, and allied phenomena. It was founded in 1940 and is chartered under the law of the District of Columbia. The Society is associated with the American Association for the Advancement of Science.

THE SOCIETY serves as a central agency for the collection, preservation, and publication of information relating to speleology. It also seeks the preservation of the fauna, minerals, and natural beauty of caverns through proper conservation practices.

THE AFFAIRS of the Society are controlled by an elected Board of Governors. The Board appoints National Officers. Technical affairs of the Society are administered by a Research Committee of specialists in the fields that relate to speleology.

PUBLICATIONS of the Society include the BULLETIN published twice a year, the NEWS appearing monthly, and the OCCASIONAL PAPERS. All members receive the BULLETIN and NEWS.

A LIBRARY on speleological subjects is maintained by the Society. Material is available to Society members at a nominal charge to defray the cost of handling and to others through inter-library loan.

The Barton Hill Project

ABSTRACT——Barton Hill is the source area for the water supply of the Village of Schoharie, New York. The village obtains its water from three springs (Youngs, Dugans, and Truax). In late summer of 1959, after a prolonged drought, the springs ceased to flow and the village was without a water supply for a short period of time.

Barton Hill covers an area of about 3000 acres and is formed primarily of limestones, Middle Ordovician to Middle Devonian in age. These limestones total about 600 feet thick and dip 1° or 2° to the southwest. Solution features are developed along two sets of joints at N25°E and N85°W. Flow of ground water is down dip along the solution openings.

Dye tests showed that water for the springs has its source in sink holes, crevices and caves in Barton Hill. The largest spring, Youngs Spring, is the only perennial one supplying the village. It yields about 144,000 gallons per day in normal dry season. The consumption of water by the village in summer is about 200,000 gallons per day. A supplement of 4,000,000 gallons is needed to carry the village through the 6 week dry season.

It is estimated that 720,000,000 gallons of ground water are available in Barton Hill. This is a little less than 10 times the annual consumption of water by the Village of Schoharie. Most of the ground water is discharged through springs and seeps without being utilized by the village.

Studies of the caves and other underground openings in Barton Hill by the National Speleological Society in 1960, show that it is not practicable to increase storage by impounding water in the caves; lack of knowledge concerning joint openings and related features make such storage unpredictable.

The best storage area is Cow Sink where 4,500,000 gallons could be impounded by a dam 5 feet high. This sink connects directly with the main water supply point via solution openings but its floor is impervious making storage possible.

Pollution is not a problem in the village water supply at present. However, steps should be taken to prevent future pollution—catchment basins at the springs should be covered; disposal of garbage and dead animals on Barton Hill should be prohibited; septic tanks for sewage disposal should be strictly controlled.

The Barton Hill Project

A STUDY OF THE HYDROLOGY OF LIMESTONE TERRAIN, SCHOHARIE, NEW YORK

Introduction by RUSSELL GURNEE

Each year the need for water increases. An expanding population accompanied by shrinking of available watersheds causes us to dig or drill deeper and inundate more lowlands in order to supply these demands.

It is small consolation to a farmer with an arid, dust-covered wheat field to know that over three-fourths of the earth's surface is covered with water. His need is for fresh water in the form of rain for controlled irrigation. He can only divert or delay the surface water on his land as it travels relentlessly to the oceans.

All of our drinking water from natural sources ultimately can be traced to rain. The endless cycle of evaporation of water from the earth's surface to the sky and back to the earth as rain has given us our streams and lakes. Trees, vegetation, and ground cover trap some of this water, but about 75 percent of all water which falls as rain returns directly to the sea. Twenty percent seeps into the ground and begins a slower, more gradual course to the sea.

Before man began to alter natural conditions, floods, drought, growth, decay, fire, and famine were controlled by nature. When Europeans first ventured to this continent, the natural resources of the forests, lakes, and plains were untapped. Quickly the land was stripped and the delicate balance of nature upset. Although it is not possible to undo that which has been done, it is possible to study, design, plan, and conserve what we have and utilize these gifts to best advantage.

Since we have not developed an economical means to produce fresh water, our immediate concern is how to store what we have so that we may use it in controlled amounts. The most common means of securing large quantities of fresh water is to impound it by a dam and store it in artificial lakes. This method is utilized in most humid areas where frequent rain quickly replenishes reservoirs. With increased need for cultivated land, inundation of valleys floored with rich soil reduces economic gains from such water storage. Also, the economic life of a reservoir is often cut short because of silting which may be so rapid that many dams are abandoned after only twenty years of use. Instead of providing for future increased water needs, storage actually brings about a decrease in ultimate potential as silt builds up behind the dam.

Many regions of this country without adequate surface water have tapped large reserves that exist below ground and have provided water for irrigation and domestic needs of rural and urban areas. This source of water has made deserts bloom and arid areas habitable. This source, however, must be protected for it is possible to overdraw from the natural storage and possibly ruin the supply by drawing brackish or salt ground water.

Generally removal of ground water by a well does not damage or impair underground storage as long as recharge is equal to or greater than the amount removed. An untapped water table is like a full glass of water under a tap; no more water can be added without causing the glass to overflow. If you drink from the glass with a straw while water flows in, it remains full. In such a case the only noticeable change is a reduction in the amount overflowing. If we assume that 20 percent of rain water is absorbed to become ground water, then it is possible to withdraw an amount of water equivalent to 20 percent of the rainfall from the underground reserve without depleting the storage.

The composition of the earth in which underground water is stored is important in determining how much water it will hold. Dense, unfractured rock will hold little water; clay is nearly solid with openings so small that water will not pass readily through it. Sand has larger openings between the grains and can hold and transport large quantities of water; gravel will carry even more. Under average conditions the best source of water in soil is a strata of gravel below the water table; here water can flow freely from its source to a well.

Much of the earth's land surface is covered with limestone, a sedimentary rock composed mainly of calcium carbonate. In the Schoharie area limestone was deposited hundreds of millions of years ago in the bottoms of ancient shallow seas. With time thick beds of limestone along with other rocks have been raised upwards and in adjacent parts of the Appalachians have been folded and faulted during growth of the Appalachian Mountains.

Limestone is nearly insoluble in pure water; however, rain water as it percolates through decayed vegetable matter forms dilute carbonic acid which attacks and dissolves limestone by formation of calcium bicarbonate. Minute cracks, crevices, and joints in the limestone permit water to seep through; and over a period of many thousands of years it will dissolve channels and chambers in the solid rock.

In the initial stages of growth, openings in limestone are completely filled with water. In a later stage, as the water table drops, water is drained leaving air-filled passages and rooms. These vary from mere crevices in the rock to enormous caverns of huge volume. In many areas, limestone terrains are so cavernous that no surface streams exist. In such areas water supply is often a problem and the only practicable sources are from ground water.

Utilization of cavernous limestone as reservoirs to increase storage of water has been given little attention because of lack of data on extent and interconnection of openings in limestone. Even storage of water in surface reservoirs in limestone areas is difficult because of leakage through subterranean channels. An understanding of cavern origin and development as well as knowledge of the extent of cavern systems is needed to evaluate and properly determine the potential of utilizing underground openings as reservoirs for increased water storage.

The National Speleological Society in 1960 undertook the Barton Hill Project to survey and study a typical limestone area in Schoharie, New York, for the purpose of determining the potential and improving the supply of water for the existing public water system of the village of Schoharie.

ACKNOWLEDGMENT

Many individuals contributed to the compilation of this report, giving their time and talent without remuneration in hope that their effort would prove of benefit to Schoharie and other communities in limestone areas.

In addition to those mentioned in the text, appreciation is given to the following who helped in some specific way to make this paper possible:

Members of the Met (New York) Grotto, Northern New Jersey Grotto, Yale Grotto, Kittatinny Grotto (New Jersey), Central Connecticut Grotto, Pittsburgh Grotto, Boston Grotto, and Nittany (Pennsylvania) Grotto—all chapters of the National Speleological Society.

Also Charles Jones, Gouverneur, N. Y.; C. L. Stratton, Binghamton, N. Y.; Wallace Van Houten, Middleburgh, N. Y.; Joseph Perkins and Edward Wellington, Bristol, Conn.; Harold Davis, Landing, N. J.; Frank Andrews, Schoharie, N. Y.; Charles Barnett, Tenafly, N. J.; Al Mooney, Bronx, N. Y.; Howard Sloane, Philadelphia, Pa.; Richard Burns, Rutherford, N. J. These people along with many others made possible the surface survey and field work throughout the project.

Photographs and assistance with equipment were supplied by John Spence, Brooklyn, N. Y.; Charles Kascur, Staten Island, N. Y.; Robert Reville, Emerson, N. J.; William Wittosch, Rutherford, N. J.; Addison Austin, Norwalk, Conn.; Dr. Thomas Engle, Florida.

Diving equipment and information was provided by Dr. Oliver Wells of Pittsburgh, Pennsylvania.

Assistance in water tracing and pumping of spring No. 1 was given by the Schoharie Fire Department; and the cooperation of the following officials and interested citizens aided greatly in the field work: Harold Warner, Mayor of Schoharie; Floyd Guernsey, Frederick Donegan, James Sitzer, Claude Van Wie and Robert Butcher of Schoharie.

Most of the field work was done on private property and all land owners cooperated in a most courteous manner and aided with information where possible. Special thanks go to Tom Young and James Gage.

Physical Features of Barton Hill

by RUSSELL GURNEE

The Village of Schoharie is the county seat of Schoharie County, New York (fig. 1). It lies in the fertile valley of the Schoharie River just south of the intersection with Fox Creek. The area around Schoharie has been an important agricultural region since the first white settlers entered the valley in the early 1700's. Growth in population has not kept pace with other areas, although the Village of Schoharie developed as the political center of the County.

As Schoharie grew, need for a public water supply became an important consideration, not only for domestic use but for fire protection. When Schoharie was first settled water supplies came from the shallow wells dug by each family and water was drawn by hand. Several springs at the base of the escarpment behind the present court house also supplied water in sufficient quantities that the Town Council planned for a public water supply utilizing this source (then called Becker's Spring or Cold Spring) for the town.

The first village water system was installed in 1800 by Benjamin Miles as a private system from the spring in the present Lutheran Cemetery. Water was piped to homes in the village through wooden logs and the total distance laid was 6,831 feet. This system, long since abandoned, still exists in part and recent excavations show the wood to be sound and firm. An interesting note in the records of the water system was the original cost of this installation, which totaled 130 pounds, 8 shillings and 10 pence, the equivalent today of $396.10.

In 1819 a new company was formed that extended the system, and until 1852 water was supplied to village residents for the cost of 50 cents per year. In 1890 Mr. William T. Michaels sold to Nora Kramer about half an acre of land on which the "Cold Spring" was located. In 1892 Mr. C. C. Kramer leased to the Village of Schoharie six existing fire hydrants and five additional new hydrants to be installed in 1893. This lease provided the first village-owned fire protection system and the hydrants are still being used today. The Village Fire Company purchased its first fire engine in 1867. To supplement privately owned hydrants of the water system, the village built a cistern in the present court yard to provide additional water storage. This cistern is still there and usable. In 1893, in an effort to extend the fire protection of the town, a cistern was built at the Old Stone Fort.

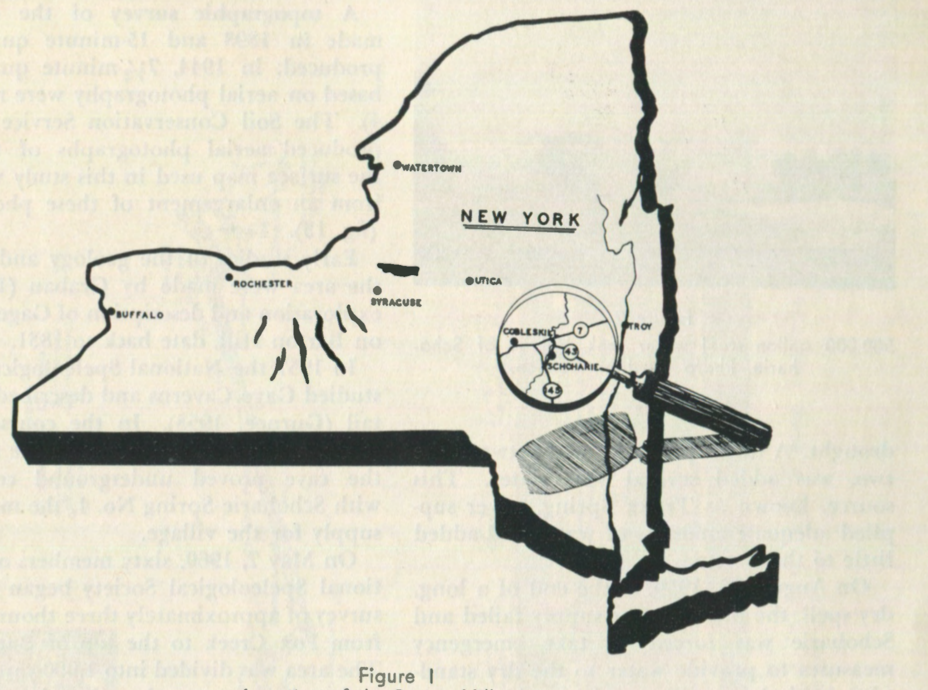

Figure I
Location of the Barton Hill area.

At the turn of the present century, Cold Spring as a source of supply was abandoned and another spring was considered. This swift-flowing "spring" which in the memory of the local residents had never gone dry, was on the southern slope of Barton Hill, on the property of Mr. Thomas Young. The overflow from Youngs Spring formed a small stream down the slope, which flowed through a trout pond, across the Gallupville Road, through a saw mill, and then into Fox Creek. Several families got their water from this spring by gravity flow. The Health Board found this water to be pure and suitable for public use, and in 1904 a small dam was built at the overflow and piped by gravity through a six-inch water main across the valley to an open cement reservoir built on the Mix farm above the village. This open tank, holding about 500,000 gallons, provided adequate storage until the end of the 1930's. In 1940, the present 500,000 gallon enclosed steel tank was built, eliminating the freezing and contamination problems of the open tank (fig. 2).

Youngs Spring showed seasonal fluctuations, flooding in the spring of the year, and reduction in flow in the early autumn. As water needs increased and consumption by the growing population grew, these fluctuations became serious and steps were taken to increase the flow. It was soon discovered that the spring was in reality the dammed entrance to a cave, and in time of low water level, it was possible to enter a low passageway for about 50 feet. The installation of a siphon into the pool, or sump, at the end of this passage proved satisfactory and for many years adequate water was siphoned out of the cave into the main pipe to the town.

Each year as the dry period approached, attention was focused on this spring and additional supplies were sought. A second active spring two miles to the west was also impounded and connected by a four-inch water pipe to the main line to aid in the low water period. This spring, known as Dugans Spring, added to the quantity in wet weather, but invariably went dry in prolonged

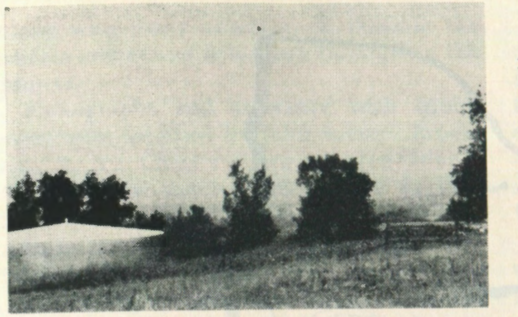

Figure 2
500,000 gallon steel water tank, Village of Schoharie. Photo by John Spence.

drought. A third spring, located between the two, was added several years later. This source, known as Truax Spring, never supplied adequate amounts of water and added little to the system.

On August 26, 1959, at the end of a long, dry spell, the public water supply failed and Schoharie was forced to take emergency measures to provide water to the dry standpipe behind the village. A stand-by pump was installed, and water was pumped directly from Fox Creek until the emergency was over.

Because the main supply came from an unknown source resurging at a cave entrance, the Town Council contacted the National Speleological Society to procure information on the possibility of increasing flow of water from this cave. Preliminary investigation of Youngs Spring by several members of the Society showed the problem to be too complex to solve without a thorough survey of Barton Hill, the watershed supplying the cave.

In March, 1960, the National Speleological Society approved as a national study the Barton Hill Project under the direction of Russell Gurnee. The Town Council at Schoharie agreed to support such a study. The work was accomplished by amateur speleologists who donated their time and talent to the study; in addition to the Village of Schoharie, the results should find application in many of the thousands of small communities and karst areas that get their water supply from limestone caves.

Sources

A topographic survey of the area was made in 1898 and 15-minute quadrangles produced; in 1944, 7½-minute quadrangles based on aerial photography were made (fig. 4). The Soil Conservation Service also has produced aerial photographs of the area; the surface map used in this study was made from an enlargement of these photographs (fig. 13).

Early studies of the geology and caves of the area were made by Grabau (1906) and exploration and description of Gage Caverns, on Barton Hill, date back to 1831.

In 1957 the National Speleological Society studied Gage Caverns and described it in detail (Gurnee, 1958). In the course of this study, a fluorescein dye test in the stream of the cave proved underground connection with Schoharie Spring No. 1, the main water supply for the village.

On May 7, 1960, sixty members of the National Speleological Society began a surface survey of approximately three thousand acres from Fox Creek to the top of Barton Hill. The area was divided into 1,000-yard squares, and each was covered on foot by teams who marked on a master map the surface features that are related to underground drainage. All sink holes, springs, wells, disappearing streams, and swamp areas were plotted and later combined on the master map.

Water tracing dye was placed in all disappearing streams and activated charcoal filters were placed in resurgences to determine the underground route of the water (fig. 7). Fluorescein, a harmless, brilliant green dye, was used effectively and the vivid color was readily discernible at the spring. Also used for the test was Congo Red, a harmless dye which colors the water a bright red. This dye, while not as strong a color as fluorescein, is effective in tracing because it readily dyes cotton. This dye is a fast color and a cotton strip left in a spring several weeks will not wash out or lose the color once it has absorbed it.

Rate of flow of springs was measured and water samples tested for purity. Another team took altimeter readings at the three springs and other points on Barton Hill. These were compared and adjusted to the bench mark at Barton Hill School (fig. 8). A

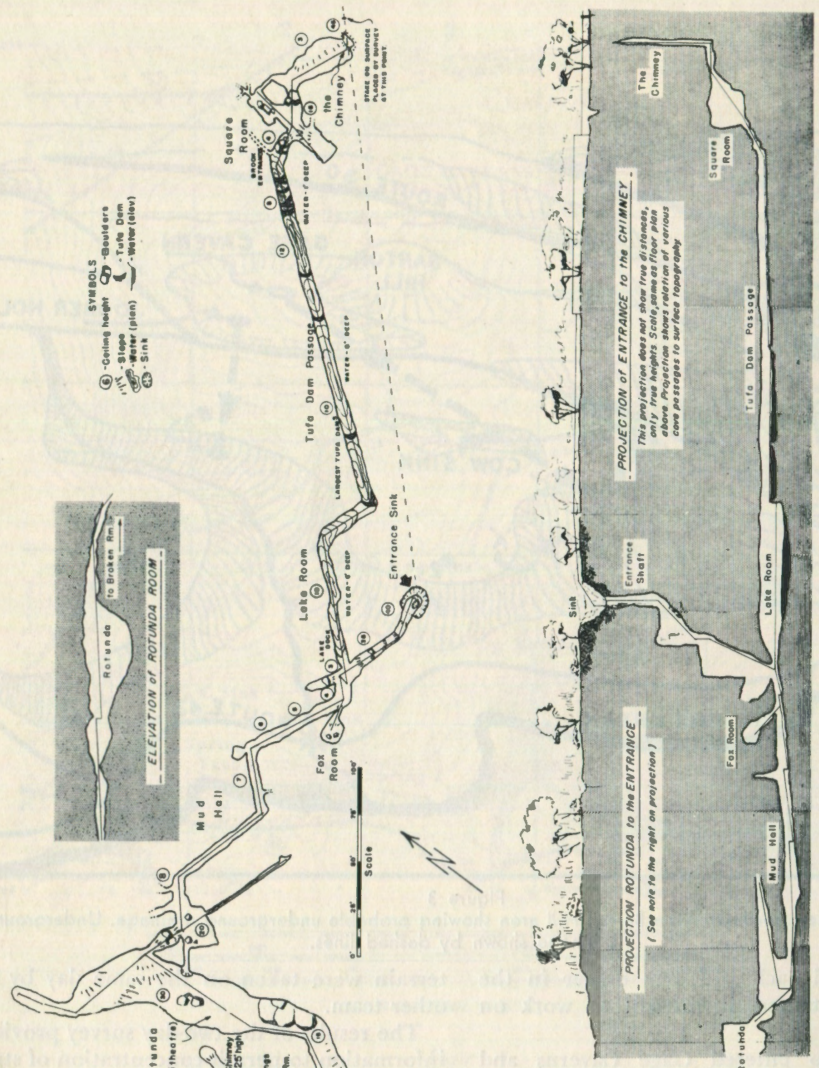

Figure 5
Gage Caverns from surveys by R. Anderson, R. Burns, J. Fisher, H. Davis, E. Bump, September, 1957. Map by R. Anderson and J. Fisher.

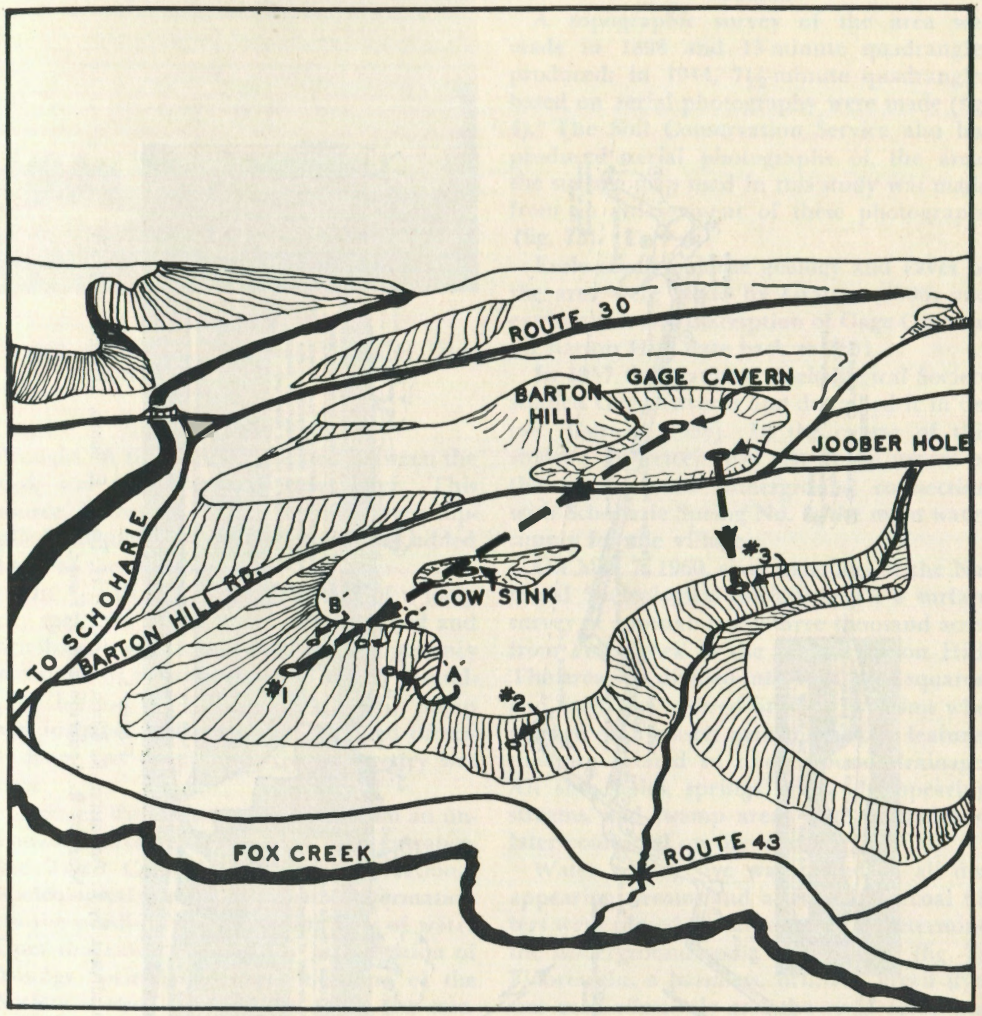

Figure 3
Perspective view north over the Barton Hill area showing probable underground drainage. Underground drainage shown by dashed lines.

group visited each property owner in the area and obtained permission to work on their land.

One group entered Gage Caverns and placed dye in the upstream end of the cave stream in order to time the rate of flow through its 900-foot visible course. This stream, which has never been known to run dry, flows rather slowly through the cave and the dye took nearly six hours to complete the 900-foot trip.

Aerial photographs of specific areas and terrain were taken on the same day by another team.

The results of the two-day survey provided information to permit concentration of study in areas most important to the underground drainage related to the springs. Plotting of joints exposed on the surface of the limestone (fig. 9) was done as part of the geology study. Swallow holes were plotted to aid the hydrology team in testing connections between surface drainage and the village springs.

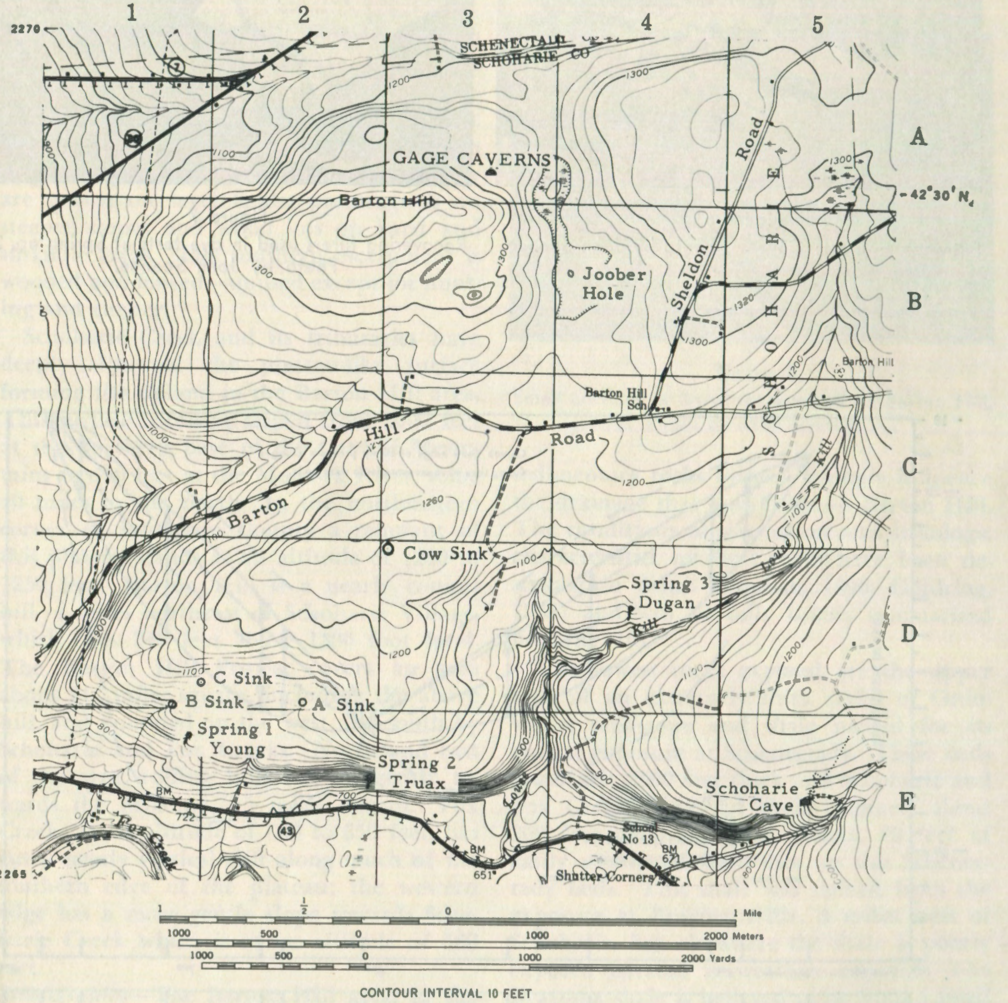

Figure 4
Topographic map of the Barton Hill area. Modified from Schoharie Quadrangle, U. S. Geological Survey.

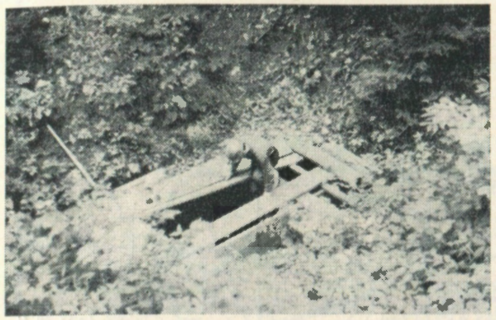

Figure 6
Entrance to Gage Caverns. Photo by John Spence.

Figure 7
Recovering filters used in dye tests at Spring no. 2. Photo by John Spence.

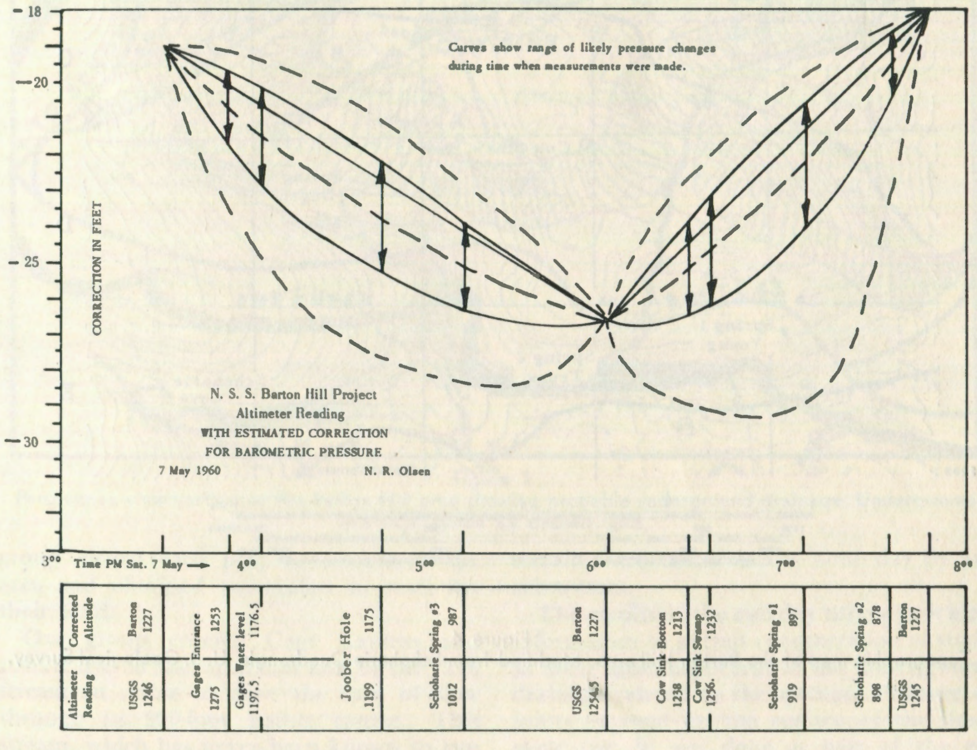

Figure 8
Graph showing altimeter readings in Barton Hill area.

Geology of Barton Hill

by RICHARD ANDERSON

Geography—Barton Hill, highest point on the plateau-like ridge which extends eastward from Schoharie Creek, is named for the Barton family, who still live in the area. The gently rolling land is used for both cash crops and pasturage. Wheat, corn, and clover are grown on level fields; pasturage is on steeper slopes and wood lots on karst and sinkhole areas. The southern escarpment is wooded and fenced—unused except for hunting and timber.

Schoharie Creek and its tributaries have deeply dissected the plateau-like surface forming the upland in the Barton Hill area. This surface formerly sloped from 2000 feet at the northern base of the Catskill Mountains to 450 feet at the Mohawk River, some 40 miles to the north. In the northeastern corner of Schoharie County a remnant of this plateau stands at an altitude of 1200 to 1250 feet. Barton Hill is a nearly conical hill, 4 miles northeast of Schoharie Village, which rises 240 feet above 1200 foot level. The Barton Hill Project covers an area about 2½ miles square, including the above hill, and bounded on the west and south by Schoharie and Fox Creeks. North and east of the area, rolling hills fall off gently towards the Mohawk, 15 miles distant. Fox Creek, at an altitude of 600 to 650 feet, has cut a nearly vertical cliff along much of the southern edge of the plateau; the western edge has a more gentle slope towards Schoharie Creek which is at an altitude of 580 feet.

Stratigraphy—The Barton Hill area, in the extended sense described above, consists of sedimentary rocks of Middle Ordovician to Middle Devonian age. At the time these rocks were deposited, the area that is now central New York was part of a large, fluctuating, generally shallow sea. The fluctuating conditions resulted in various types of deposits—at times relatively pure lime mud; at other times, clay and silt were intermixed with the lime mud. The different types of

Figure 9
Small crevices in limestone exposed on Barton Hill. Photo by John Spence.

sedimentary rocks formed strongly influence the drainage that now exists on Barton Hill. The conditions of deposition and lithologic characteristics of these rocks have been described in detail (Grabau, 1906, Goldring, 1935) and will be only briefly summarized here (fig. 10).

The lowest rocks exposed are the upper beds of an extremely thick series of Ordovician sandstone and shale named for its typical exposure at Schenectady. These beds are nearly 2500 feet thick and Schoharie and Fox Creeks have cut their channels about 300 feet deep in them. About 30 feet of easily weathered shale lies on the Schenectady beds. This shale was named from the exposure at Braymansville, 5 miles west of Schoharie, but elsewhere the shale is poorly exposed because it weathers rapidly. The Brayman shale is believed to be from a fossil soil formed during a hiatus of deposition in late Ordovician and early Silurian time.

When the sea returned in Middle Silurian time, about 6 feet of coralline Cobleskill limestone were deposited. This was followed by 25 feet of shaly limestone, the Rondout waterlime. Certain exposures, including that at Howe's Cave quarry, have the proper proportion of clay and lime to make an excellent natural cement. At others, the amount

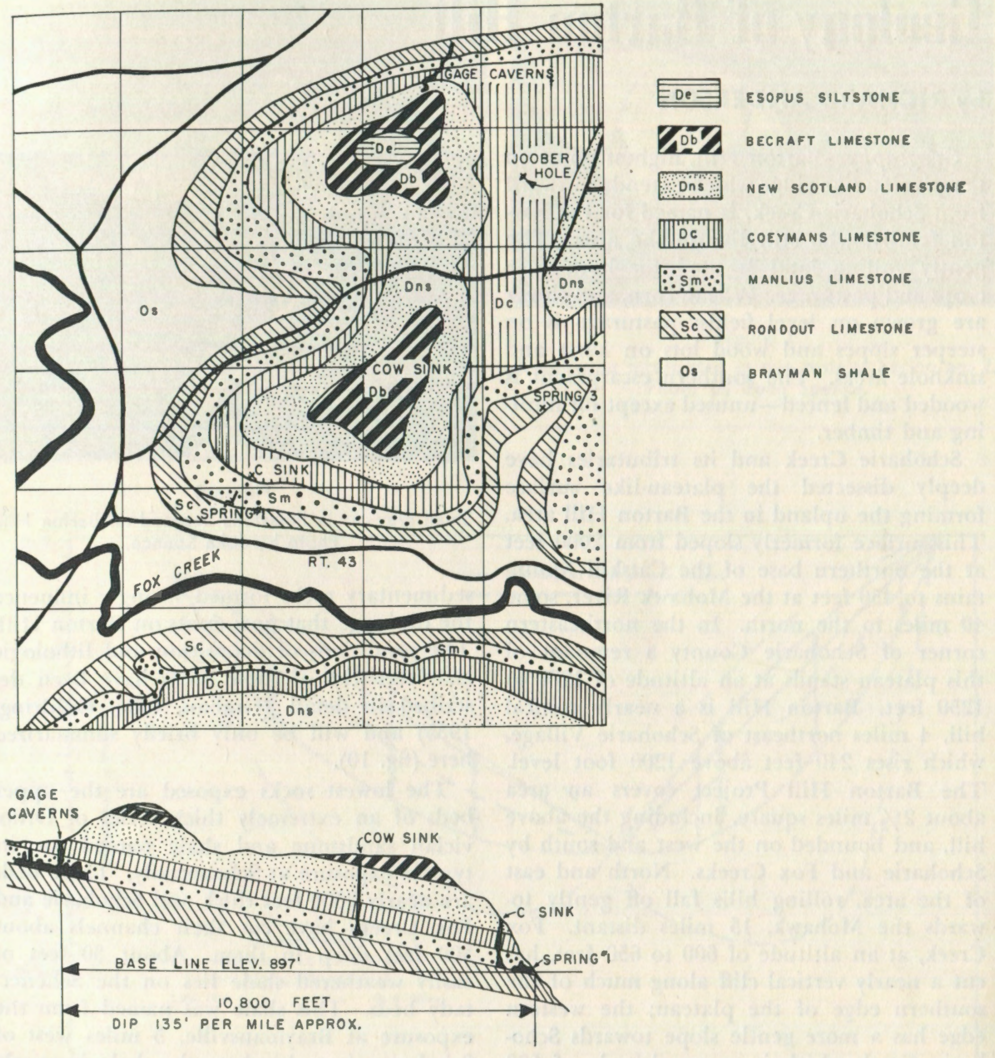

Figure 10
Geologic map and section of the area around Barton Hill.

of clay is greater and retards the downward flow of water resulting in springs at the upper surface of outcrops.

The next two limestone formations, the Manlius and Coeymans, are similar and can be discussed together. A slight depositional break between them is regarded as the boundary between the Silurian and the Devonian systems. Both are about 50 feet thick and relatively pure, though dark colored. The Manlius is thin-bedded, and dark blue; the Coeymans is more massive, gray, and more coarsely crystalline. Both are strongly jointed and resistant to erosion. Because of these characteristics, along with lack of support from more easily eroded underlying beds, the Manlius-Coeymans limestones form cliffs, such as those along Fox Creek and the Helderberg Escarpment at John Boyd Thacher State Park, 15 miles southeast. These limestones are readily dissolved by ground water, and many caves in Schoharie County, including both Gage and Schoharie Caverns in Barton Hill, are developed in them.

Above the Coeymans limestone are about 100 feet of impure shaly limestone and calcareous shale, the New Scotland beds. These weather rapidly and form gentle slopes on the crest of Barton Hill. This formation is similar to the Rondout in many respects. Above the New Scotland, the Becraft limestone is a 30-foot-thick, very pure, massive limestone, similar to the Coeymans. It also forms a minor scarp, and some caves occur along its pronounced joint system. Overlying the Becraft is six feet of Oriskany sandstone followed by what remains of the Esopus grit, a sandy shale or siltstone. These latter form the top of Barton Hill proper, and also many of the hill tops farther south. These resistant sandstones have served as a cap rock to preserve the hill.

Structure—The geologic structure of Barton Hill is simple. The sedimentary rocks have a regional dip to the southwest (S 25° W) at 1° to 2°, about 125 to 135 feet per mile. The rocks have suffered little deformation; there are no apparent folds or faults in Barton Hill, although minor faults are known nearby. There are several prominent sets of joints. Orientation of 83 joints measured on Barton Hill is shown in figure 11. The two most prominent joints (N 25° E and N 85° W) are nearly at right angles to each other, and are locally related to the regional dip and strike. However, Parker (1942) has shown that while the dip is constant over a wide area, the direction of the joints swings through a large arc; the joint oriented along the dip at Barton Hill is found to be oriented along the strike southeast of John Boyd Thacher Park.

Jointing is the most important structural feature controlling the solution of the limestone. Most limestone is impermeable and it is only along joints or fractures that ground water can move in it. Since limestone is soluble in ground water, these small openings tend to enlarge, forming caves, and increasing the water storing capacity. The two prominent joints mentioned above are those along which the most solution and cave development have taken place. The orientation of 2205 feet of passage in Gage Caverns is shown in figure 12. Similarity of cavern development, and joint development (figs. 11, 12), demonstrates joint control of solution passages (Deike, R. G., 1959, Deike, G. H., 1960).

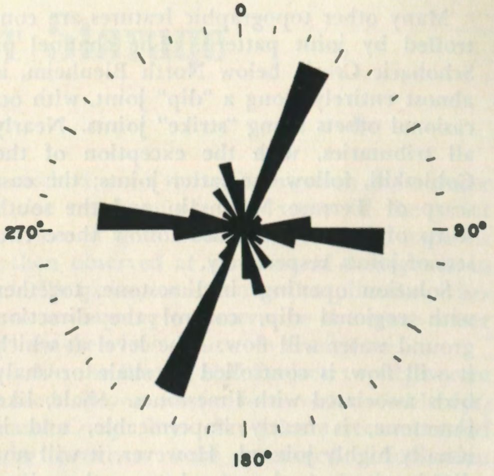

Figure 11
Orientation of 83 joints, Barton Hill and vicinity. Diameter of rosette is equal to 25 joints.

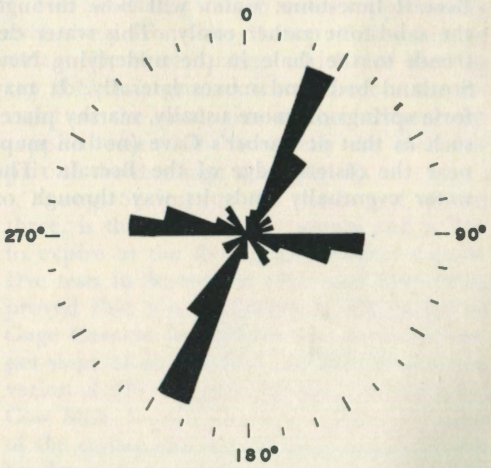

Figure 12
Orientation of 2205 feet of passage, Gage Caverns. Diameter of rosette is scaled to 600 feet.

Many other topographic features are controlled by joint pattern. The channel of Schoharie Creek, below North Blenheim, is almost entirely along a "dip" joint, with occasional offsets along "strike" joints. Nearly all tributaries, with the exception of the Cobleskill, follow the latter joints; the east scarp of Terrace Mountain and the south scarp of Barton Hill also follow these two sets of joints respectively.

Solution openings in limestone, together with regional dip, control the direction ground water will flow. The level at which it will flow is controlled by shale or shaly beds associated with limestones. Shale, like limestone, is nearly impermeable, and is usually highly jointed. However, it will not dissolve in ground water, but weathers into clay or silt which fills, rather than enlarges, any small openings.

Consider what happens to water which falls on Barton Hill. Some will enter the Becraft limestone; water will flow through the sandstone rather easily. This water descends to the shale in the underlying New Scotland beds and moves laterally. It may form springs or, more usually, marshy places such as that at Barber's Cave (not on map) near the eastern edge of the Becraft. The water eventually finds its way through or over the edge of the shale, and descends again into the joints of the Coeymans limestone. At such points, sink holes form, such as those at Joober Hole and Cow Sink. The descending water may also form widened solution joints seen at many places on the upper surface of the Coeymans limestone. These are especially noticeable at, and northwest of, Gage Caverns and along the southern edge of the hill. When the descending water reaches the Rondout, it again moves laterally along solution passages in the Manlius, eventually coming to the surface as springs. These are the type of springs which supply the Village of Schoharie. Similar action is repeated in the Cobleskill limestone and Brayman shale, but is much less important because of the low elevation of the limestone layer. Locally, where the Rondout does not form a perched water table, the Brayman-Cobleskill contact would provide water that reaches it from all the overlying limestones. It is apparent that when the volume of water within Barton Hill is great, the level will rise and water may flow out of openings which intersect the surface at higher levels. In theory it would be possible to impound a large amount of water within the hill by blocking all these openings but in practice it would be very difficult.

Hydrology and Water Storage

by ALBERT C. MUELLER

Adequate water supply is generally found in moist climatic regions (over 40 inches of rain per year). Type of soil, vegetation, and geologic structure has a direct bearing on distribution of the water as it flows towards the sea.

Surface streams carry most of the runoff from rain; water that seeps into the soil travels underground until it reappears as springs or is brought to the surface by wells. In limestone areas, because of joint openings and cracks, there is sometimes no surface drainage and all the rain, with the exception of that which is evaporated or held by vegetation, drains underground.

Limestone varies in compactness. In one area it may lack cracks and joints and may be impervious to water; in another area it may be fractured and broken and water will flow freely through the crevices and interstices ultimately forming caverns.

It is difficult, if not impossible, to detect alignment of major joints in limestone with any degree of accuracy other than to deduce the average direction from many joint readings, made in the field. Because caves primarily follow joints it is equally difficult to deduce the size and extent of a cave system except by actually mapping it. Surface topography has a bearing upon the initial development of a cave system, but topographic changes are comparatively rapid and conclusions as to location of a cave system from present surface features are seldom of real value.

Most underground waters, if they resurge at the surface, appear as springs or ponds. If the water is under hydrostatic pressure, it may be an artesian or free-flowing spring. Some water which is held in underground storage also may reach the surface by transpiration, i.e., the roots of trees and plants may tap this supply and return it to the air in their life processes.

Tracing of underground waters is often a complicated procedure. The most effective method used today is insertion of a tracer (dye or chemical) into water at the point where it goes underground. This tracer is then observed at its point of resurgence in wells, springs or streams. Complication arises in attempting to determine the route water has taken from source to resurgence.

On the Barton Hill Project, two dyes were used: fluorescein (a green, water-soluble dye) and Congo Red. Procedures recommended by previous users provided information about quantities. Activated charcoal filters were used (Dunn, 1957) at resurgences to pick up traces of the fluorescein. Congo Red was detected by means of white cotton "flags" submerged in springs.

The Schoharie Village water supply comes exclusively from the Barton Hill drainage area. The three springs which are used to tap the underground water sources are located on the south side of the hill and are supplied essentially from only the southern part of the drainage area (fig. 3).

Youngs Spring (no. 1), the largest of the three, is the main supply source and is last to expire as the dry season reduces supply. Dye tests in September 1957, and May 1960, proved that a contributary to the spring is Gage Caverns located on the northeast upper slope of Barton Hill. A difference in elevation of 300 feet provides the head for flow. Cow Sink, located about 0.9 miles northeast of the spring and 300 feet higher, was shown by dye tests in April 1960, to be connected also.

Truax Spring (no. 2) is 25 feet lower than Youngs Spring and during periods of high water actually overflows because of backflow from the main spring. No evidence was found during dye testing that any of the sink holes are connected to Truax Spring.

Dugans Spring (no. 3) is located 1.5 miles east of and 90 feet higher than Youngs Spring. Joober Hole, which is 1.1 miles north of Dugans and 200 feet higher, was found to connect to this spring when tested

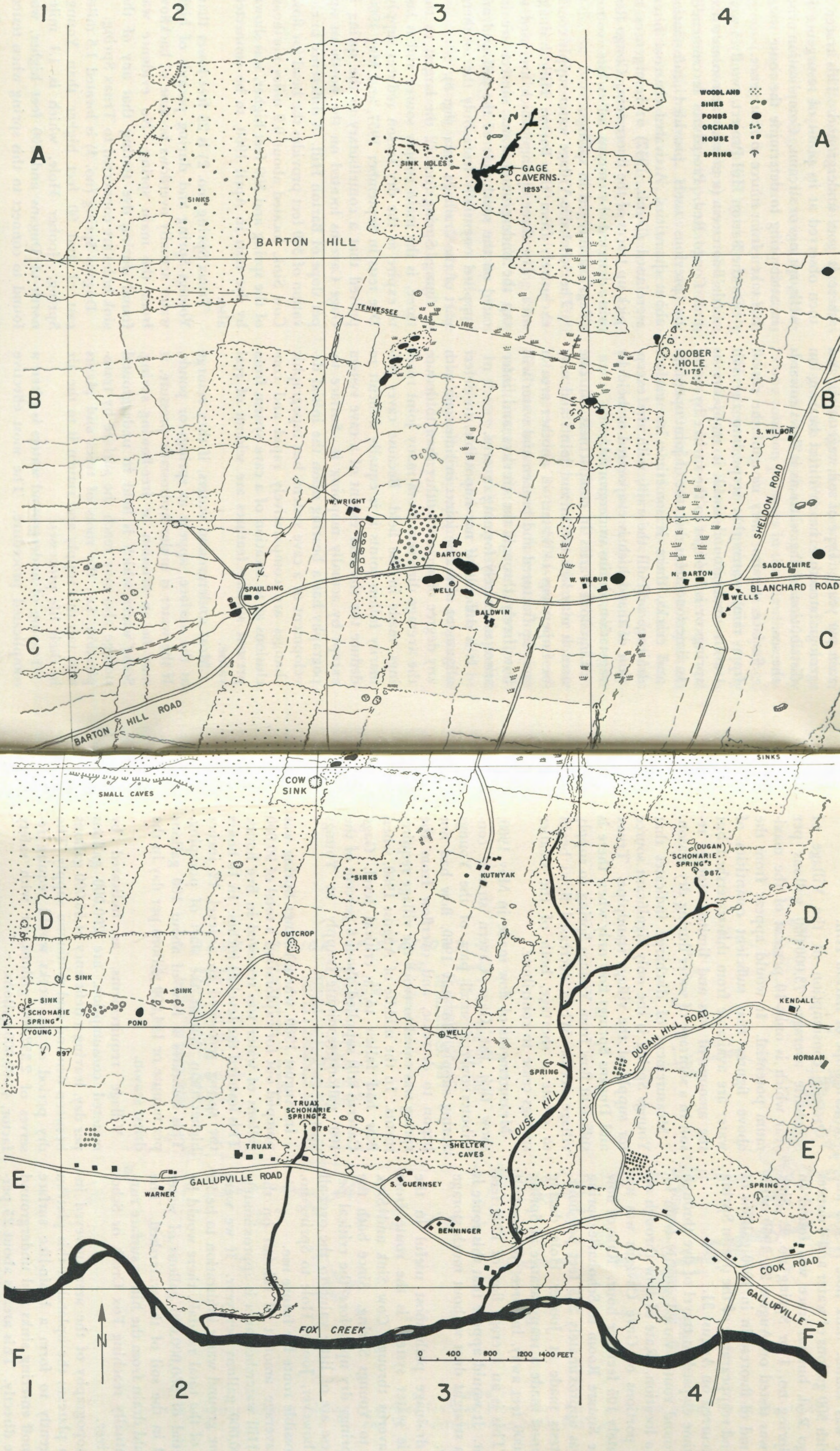

Figure 13
General map of the Barton Hill area. Based on U. S. Department of Agriculture aerial photographs PMA DPZ-1K-27, May 29, 1952 (1:20,000 scale). Drawn by R. Gurnee.

with dye in April 1960. Dye tests conducted throughout the summer did not demonstrate that other major sink holes are connected to the springs.

Sink hole B, 800 feet northwest of Spring No. 1, was tested twice using one pound of fluorescein diluted in 500 gallons of water in the Village Fire Engine (fig. 16). No resurgence was found. Sink hole A was also tested with 500 gallons of water and 4 ounces of Congo Red, but no trace was found in either Spring no. 1 or Spring no. 2. Sink hole C was tested on August 27, 1960, with one pound of fluorescein in 1000 gallons of water, and reappearance of the dye in Spring no. 1 occurred on August 31.

The time elapsed in travel of dye through underground routes varied greatly from location to location. Rate of flow through accessible portions of Gave Caverns was approximately 105 feet per hour. Rate of flow from the Square Room to Schoharie Spring no. 1 was approximately 225 feet per hour.

Dye tests made at Joober Hole during snow runoff made a reappearance at Spring no. 3, 6000 feet away, in three and one-half hours. This is an average flow of 1700 feet per hour. It would appear that this route is almost a straight duct without much storage capacity.

The drainage path most useful in the Schoharie water system is the route from Gage Caverns through Cow Sink and Sink hole C to Youngs Spring. Since both the other springs dry up before the critical period, these are of little value to the over-all system; however, Joober Hole to Spring no. 3 is a possible route for future use.

The average amount of rainfall on the Barton Hill watershed area is approximately 1,800,000,000 gallons per year. If we were to assume ground water infiltration to be 20 percent of the total rainfall, there would be a potential of 360,000,000 gallons of water retained in the soil of the watershed. The rest would drain from the hill as surface runoff eventually reaching Fox Creek or Schoharie River.

The topography of the area surveyed includes a plateau; the upland of this plateau slopes gently to form a basin-like surface with runoff entering sinks and underground drainage directly. This area is about 25 percent of the entire area surveyed so that approximately 450,000,000 gallons of water enter the underground drainage system directly each year. This amount added to water possibly impounded in the soil of the rest of the area gives a potential of 720,000,000 gallons of water from this watershed. This water reappears as springs and seepage on the southern slope of Barton Hill.

Present consumption of the Village of Schoharie averages 73,000,000 gallons per year which is only 10 percent of the maximum potential. It would appear from the above figures that sufficient quantities of water are available from this watershed but the amount of loss and limited storage result in a shortage of water during dry season.

Measurement of discharge indicates that Youngs Spring is the only significant source for supply of the village standpipe. Truax and Dugans Springs flow only when there is sufficient flow from Youngs Spring to supply village needs. When decreased flows begin to create a shortage, both of the smaller springs cease to contribute.

Measurements of flow made in May 1960, show that the Gage Cavern stream contributes only a small part of the Youngs Spring supply. In July 1960, flow had not begun to decrease, and overflow from the spring was equal to twice the village requirements. In the middle of August 1960, when flow had fallen to a critical level, Gage Caverns still supplied about 6 percent of the 100 gallon-per-minute supply at Youngs Spring.

In August 1960, when Youngs Spring was pumped out for exploration a total of 90,000 gallons of water was removed in five hours. This lowered the level 24 inches. In 16 hours the spring recovered to a level 12 inches higher than that at the start of pumping. This indicates a flow of about 100 gallons per minute or 144,000 gallons per day in the driest season.

Village requirements, as indicated by metered consumption, are 200,000 gallons per day, leaving a deficiency of 56,000 gallons between demand and minimum supply. The dry period of six weeks would require reserves of 2,352,000 gallons, or with safety factor, 4,000,000 gallons.

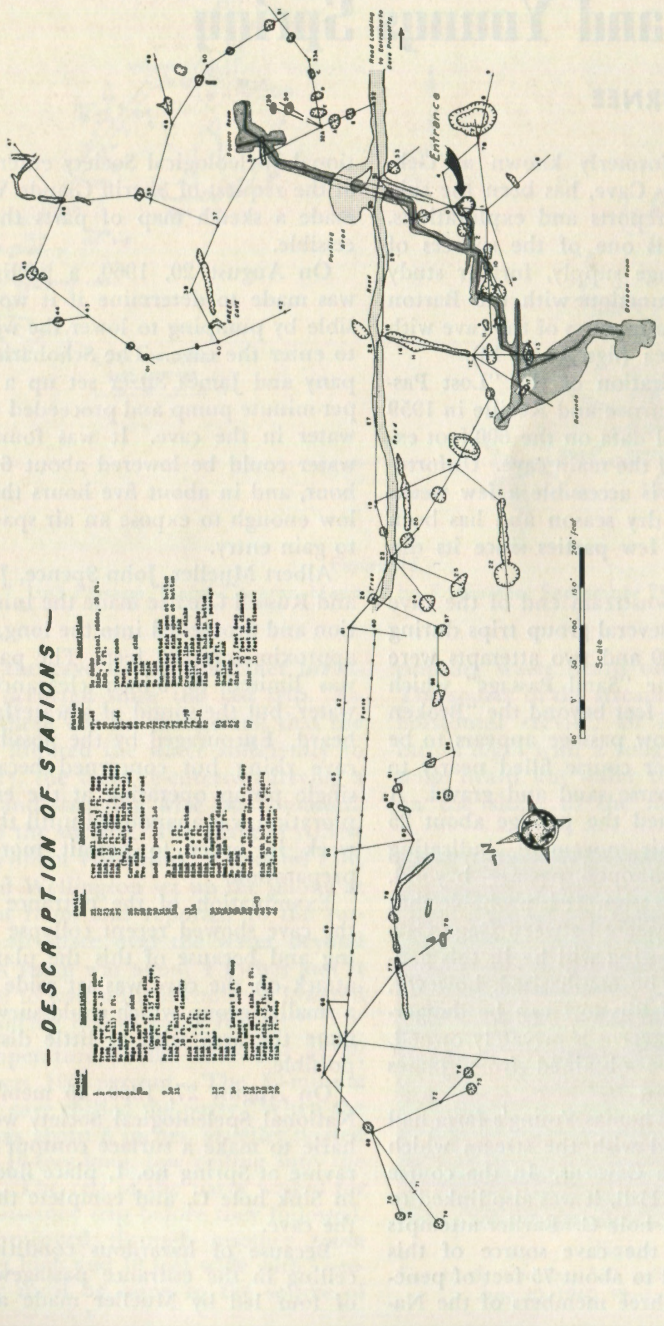

Figure 14
Gage Caverns showing relation to surface features. From plane table and tape survey by A. Hulstrunk and W. Hulstrunk; map by J. Fisher.

Further Exploration in Gage Caverns and Youngs Spring

by RUSSELL GURNEE

Gage Caverns, formerly known as Gebhards Cave or Balls Cave, has been the subject of numerous reports and explorations. Because the cave is one of the sources of water for the Village supply, further study was made in conjunction with the Barton Hill survey to relate features of the cave with the surrounding area (figs. 5 and 14).

An earlier exploration of the "Lost Passage" (fig. 15) by Gurnee and Reville in 1959 provided additional data on the 600-foot extension upstream of the main cave. Unfortunately this passage is accessible a few weeks a year during the dry season and has been entered by only a few parties since its discovery in 1935.

Study of the downstream end of the cave was the subject of several group trips during the summer of 1960 and two attempts were made to extend the "Sand Passage" which continues about 75 feet beyond the "Broken Room." This narrow passage appears to be an abandoned water course filled nearly to the ceiling with coarse sand and gravel. A work party excavated the passage about 25 feet but lack of air movement, indicating little chance of an open passage beyond, caused the group to stop. It is probable that access to the cave system between Gage Caverns and Youngs Spring will be in this general area. It is to be emphasized, however, that exploration of this sort can be dangerous and, as Gage Caverns is privately owned, permission must be obtained from James Gage before entering.

Spring no. 1 on Thomas Young's farm had already been linked with the stream which flows through Gage Caverns. In the course of study on Barton Hill, it was also linked to Cow Sink and Sink hole C. Earlier attempts at exploration of the cave source of this spring were limited to about 75 feet of penetration. In 1959, three members of the National Speleological Society entered the cave at the request of Sheriff Claude VanWie and made a sketch map of parts that were accessible.

On August 20, 1960, a preliminary trip was made to determine if it would be possible by pumping to lower the water enough to enter the cave. The Schoharie Fire Company and James Sitzer set up a 300 gallon-per-minute pump and proceeded to lower the water in the cave. It was found that the water could be lowered about 6 inches per hour, and in about five hours the water was low enough to expose an air space adequate to gain entry.

Albert Mueller, John Spence, José Limeres and Russell Gurnee made the initial exploration and proceeded into the long, low tunnel approximately 200 feet. The passage ahead was limited to 3-inch clearance over the water, but the sound of a waterfall could be heard. Encouraged by the possibility of the cave rising but concerned because of the single pump operating at the entrance, exploration was abandoned until the following week in order to permit more thorough preparation.

Examination of the entrance portion of the cave showed recent collapse of the ceiling and because of this the planned group attack on the cave was set aside in favor of a smaller group which could survey and estimate the area with as little disturbance as possible.

On August 27, 1960, 25 members of the National Speleological Society were at Schoharie to make a surface contour map of the ravine at Spring no. 1, place fluorescein dye in Sink hole C, and complete the survey of the cave.

Because of hazardous conditions of the ceiling in the entrance passageway, a team of four led by Mueller made a reconnais-

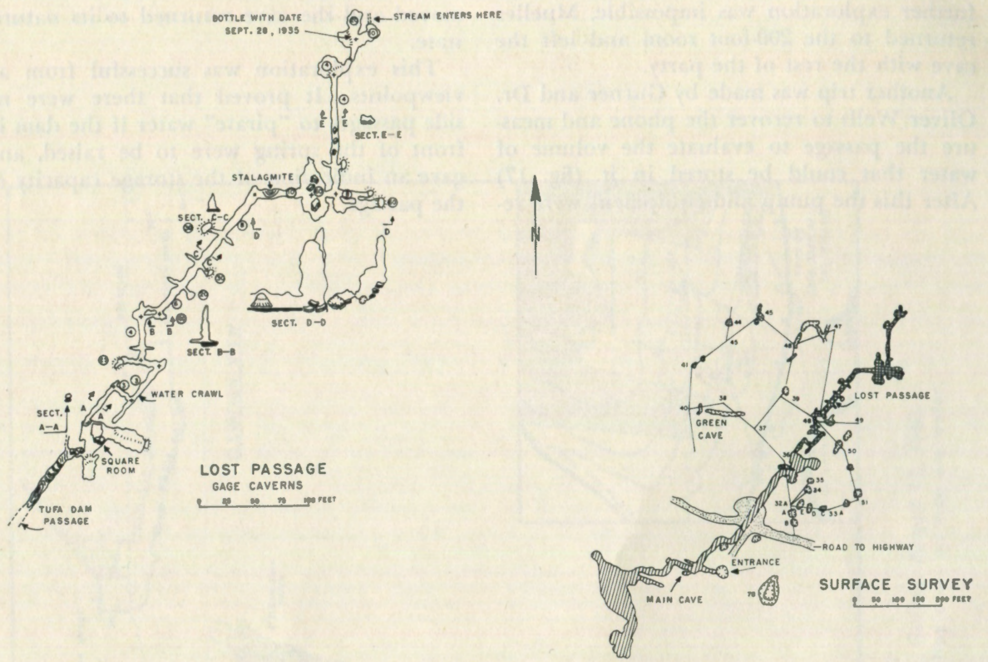

Figure 15
Lost Passage, Gage Caverns. Mapped by R. Gurnee, September 26, 1959.

sance into the cave to see if further breakdown had occurred since the last trip. Assured that there was no change and that the pump had lowered the water sufficiently to permit entry, the team re-entered carrying a telephone and stringing wire for communication with the surface. The team of Albert Mueller, William Hulstrunk, Raymond Eby, and Edward Wellington set up the phone at the 200-foot room and reported to the surface. The air space over the water beyond the 200-foot room was about 4 inches and it was decided to wait until it could be lowered another 4 inches before going further.

The temperature of the cave was 47°F; humidity was 100 percent. The 30-minute wait in the cave chilled the party. When the air space was about 8 inches, Mueller floated under the 10-foot-long, low ceiling into the next room. The rest of the party waited for his reconnaissance trip before they followed. Mueller continued through another room about 5 feet high and 10 feet wide with knee-deep water until he came to the source of running water heard on the previous trip. The source of the stream was from a narrow, horizontal crevice, 20 inches wide and 8 inches high, with a rough gravel floor. The noise heard was water tumbling over gravel on the slope to the main pool. Because

Figure 16
Fire truck pumping 500 gallons of dye into Sink B, July 30, 1960. Photo by R. Gurnee.

further exploration was impossible, Mueller returned to the 200-foot room and left the cave with the rest of the party.

Another trip was made by Gurnee and Dr. Oliver Wells to recover the phone and measure the passage to evaluate the volume of water that could be stored in it (fig. 17) After this the pump and equipment were removed and the cave returned to its natural state.

This exploration was successful from all viewpoints. It proved that there were no side passages to "pirate" water if the dam in front of the spring were to be raised, and gave an indication of the storage capacity of the passage.

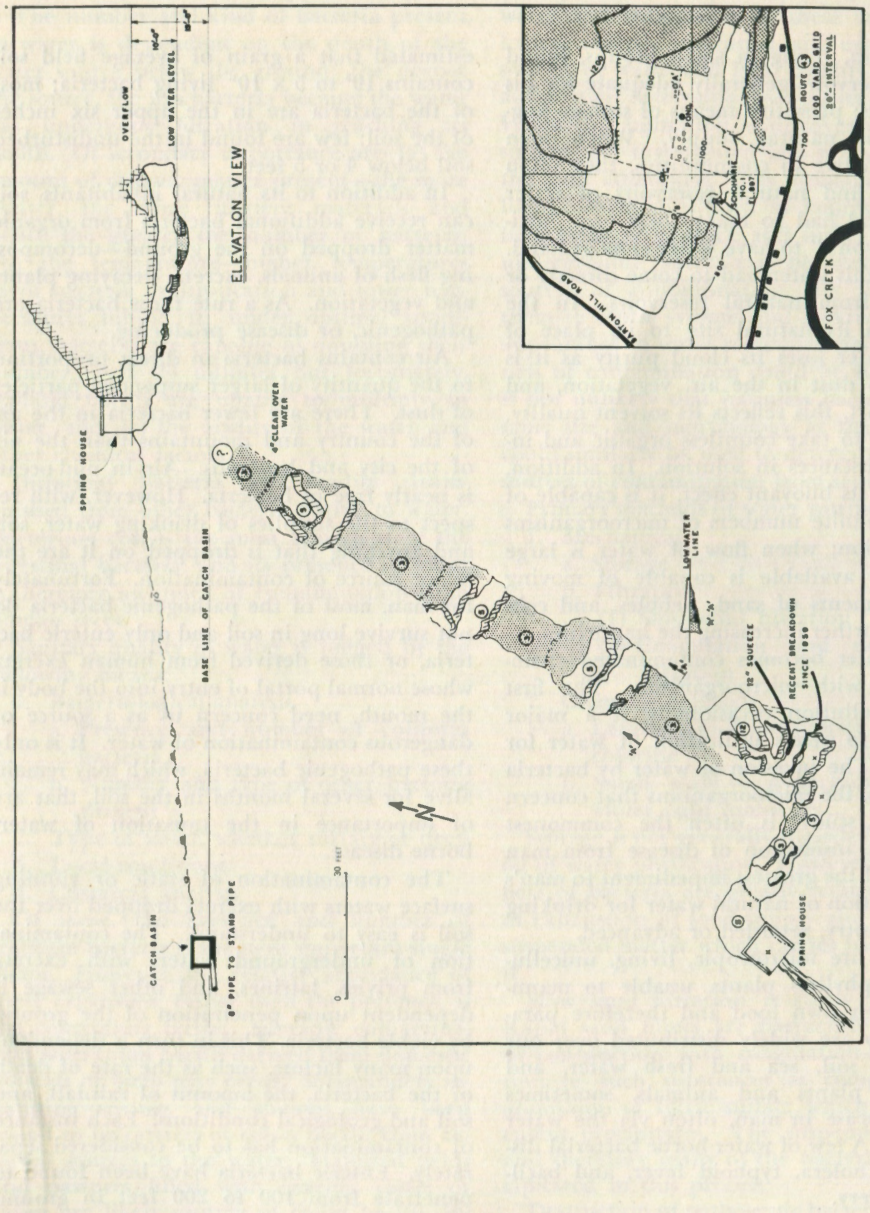

Figure 17
Schoharie Spring no. 1. Map by R. Gurnee, August 13, 1960.
Dotted areas on insert are woods; dotted areas on map are water.

Health and Sanitation

by DR. JOSE LIMERES

Early man, living in small groups, found natural reservoirs generally adequate for his water needs; primitive means of storage augmented his natural supply. When men gathered to live in communities, they often could not find natural reservoirs of water close by and had to make their own "artificial reservoirs," to have water close at hand. However, this water had to come directly or indirectly from natural reservoirs. In the route from its natural site to its place of storage, water loses its cloud purity as it is exposed to dust in the air, vegetation, and soil. In part, this reflects its solvent quality, being able to take countless organic and inorganic substances in solution. In addition, because of its buoyant effect, it is capable of carrying infinite numbers of microorganisms in suspension; when flow of water is large the energy available is capable of moving heavy fragments of sand, pebbles, and cobbles thus further increasing the impurities.

Thus water becomes contaminated chemically and with microorganisms. The first type of pollution occasionally is a major hindrance to man's utilization of water for drinking. The invasion of water by bacteria and viruses, the microorganisms that concern us in this study, is often the commonest means of transmission of disease from man to man and the greatest impediment to man's free utilization of natural water for drinking in any country, retarded or advanced.

Bacteria are microscopic, living, unicellular, chlorophylless plants, unable to manufacture their own food and therefore parasitic. They are widely distributed over our planet, in soil, sea and fresh water, and bodies of plants and animals, sometimes causing disease in man, often via the water he drinks. A few of water-borne bacterial diseases are cholera, typhoid fever, and bacillary dysentery.

Soil contains abundant bacteria, it being estimated that a grain of average field soil contains 10^8 to 5×10^{11} living bacteria; most of the bacteria are in the upper six inches of the soil; few are found in the undisturbed soil below 4 or 5 feet.

In addition to its natural inhabitants, soil can receive additional bacteria from organic matter dropped on the ground—decomposing flesh of animals, excreta, decaying plants and vegetation. As a rule these bacteria are pathogenic, or disease producing.

Air contains bacteria in direct proportion to the quantity of larger suspended particles of dust. There are fewer bacteria in the air of the country and mountains than the air of the city and lowlands. Air in mid-ocean is nearly free of bacteria. However, with respect to the supplies of drinking water, soil and anything that is dropped on it are the major source of contamination. Fortunately for man, most of the pathogenic bacteria do not survive long in soil and only enteric bacteria, or those derived from human excreta whose normal portal of entry into the body is the mouth, need concern us as a source of dangerous contamination of water. It is only these pathogenic bacteria, which may remain alive for several months in the soil, that are of importance in the causation of water-borne disease.

The contamination of static or running surface waters with excreta dropped over the soil is easy to understand. The contamination of underground waters with excreta from privies, latrines, and other sewage is dependent upon penetration of the ground by viable bacteria. This in turn is dependent upon many factors, such as the rate of death of the bacteria, the amount of rainfall, and soil and geological conditions. Each instance of contamination has to be considered separately. Enteric bacteria have been found to penetrate from 100 to 200 feet in ground water. As a rule, fine soils and sands filter bacteria out to a greater extent than sand and gravel. Limestone, because of its solubility in carbonated waters, forms direct communicating underground channels of water flow. Wells drilled in limestone regions have been found to contain typhoid bacilli which have entered the water many miles away.

The number and kind of bacteria present in water is dependent on the depth of the water source below the ground; the deeper the source, the less bacteria because the water has undergone filtration in reaching its depth. Of secondary importance are (a) the amount of organic matter present—the more matter, the more nutrient materials and hence the greater the number of bacteria, (b) the temperature—higher temperatures favor bacteria multiplication and lower temperatures inhibit it; under optimal conditions, bacteria are capable of doubling their number every 20 minutes but fortunately, typhoid bacilli are unable to multiply in water, and (c) the acidity of the water and other chemical factors.

Intestinal bacteria are readily distinguished from other bacteria native to water. Bacterium coli is the most abundant of the intestinal bacteria, and its presence in water is therefore an index of contamination from human feces.

Sanitary quality of water is judged by the following means:

1. Bacteriological analysis
   a. Presence and number of coliform bacteria
   b. Number and type of other bacteria present
2. Type of water, whether surface or deep
3. Local conditions
4. Chemical analysis

Of these, the presence and number of coliform bacteria is the most important single factor. However, the relative abundance of these organisms, rather than the presence, is the controlling factor. Sporadic contamination with colon bacilli derived from domestic animals or birds may occur. Salamanders inhabiting springs and streams have been found to be carriers of colon bacilli from external sources to the water. Manured fields and pastures filled with grazing cattle or sheep are likely sources of colon bacilli, indistinguishable by ordinary procedures from those of human origin. Knowledge of local conditions is essential to interpret the findings properly. Under ordinary conditions chemical analysis is not essential to the study of purity of water.

By periodic collection of many samples of water and submission of these to bacteriological analysis, combined with evaluation of sources of water and local conditions, health authorities determine the purity of water. When contamination is discovered, possible sources are investigated and a correction of the fault attempted. It is probable that brilliant colored dyes such as fluorescein, used in speleology to track and time the flow of underground water, can be used to track sources of contamination. By introducing them in septic systems and looking for their appearance in water reservoirs, possible channels of contamination could be surmised. It is not unlikely that harmless bacteria of the same size and morphology as the coliforms could similarly be used to determine possible sources of contamination from septic systems.

Primary methods of water purification are:

1. Mechanical
   a. Storage
   b. Filtration
      (1) Slow sand filtration
      (2) Coagulation and rapid sand filtration
2. Chemical methods
   a. Large scale—hypochlorite and liquid chlorine
   b. Small scale — hypochlorite, ultraviolet light, ozone, etc.

Storage is not generally regarded as a method of water purification. However, the numbers of bacteria are greatly reduced because of exhaustion of food supply and settling of suspended matter which carries bacteria with it.

Slow sand filtration is rarely used now. Rapid sand filters are frequently employed in conjunction with coagulation—the addition of such substances as compounds of aluminum or ferric sulfate which form flocculent precipitates. The suspended matter, and therefore many of the bacteria, are precipitated in this process.

Destruction of pathogenic bacteria in water supplies is better accomplished with the use of germicidal chemicals. Of these, liquid chlorine is the most frequently used today. It is added directly to water in accurately measured quantities through an automatic feeding device. When chlorine is added to clear and not highly contaminated water in the proportion of 0.5 to 1 part of "available chlorine" per million gallons, the ordinary intestinal bacteria are destroyed, including such pathogens as the typhoid bacillus. The introduction of chlorination of municipal waters has resulted in reduction of the incidence of enteric infections, typhoid fever particularly in the United States. However, this is not a "cure-all." When water is sufficiently highly contaminated, the available chlorine will not kill bacteria imbedded in particles of organic matter. It is generally specified that coliform bacteria in excess of 50 per cubic centimeter is too great for successful use of chlorination.

In the course of investigations of Barton Hill, water samples were taken periodically to determine its potability as it came from each of the three springs supplying the water.

Samples during spring runoff showed little contamination and low bacteria count. However, a marked increase in bacterial growth appeared as the flow of water began to decrease during the summer months. Presence of enteric coli was found in the untreated water of the spring in the tests of July, August, and September, but the results were negative in November and December.

It was not possible to determine the specific sources of contamination, and it was not the purpose of this study to point out situations which are in the province of the Board of Health. However, all of the area between Gage Caverns and Spring no. 1 and between Joober Hole and Spring no. 3 should be open to suspect, and sources of possible contamination should be investigated and conditions corrected.

The physical condition of the springs also presents a possible source of contamination and a number of corrective measures should be taken to minimize this problem. Spring no. 1 does not have a direct connection from the spring to the catch basin. The water is siphoned through three pipes, each 2 inches in diameter, to an open pool which either overflows into the catch basin or over a dam spillway. This permits open contamination from small animals and allows twigs, debris, and organic matter to be carried into the system. This situation would be corrected if a dam were built at the entrance of this spring.

Spring no. 2 spring house, located at the foot of a steep cliff, has collapsed from a rockfall, exposing the pool and open drain. Effort should be made to protect the pool even though the supply of water from this spring provides only a small quantity to the total supply.

Spring no. 3 located at the base of a slope of glacial gravel flows through a 12-foot-long open pool into a cement catch basin, then overflows down a natural stream bed.

Each of the springs requires only maintenance measures to provide adequate sanitary protection. It is the sources of these springs, however, which contribute most to the contamination of the water supply. Water entering Cow Sink, "C" Sink, Joober Hole, and Gage Caverns connects within a few hours to the Village water supply.

It is realized that the practice of using sink holes as garbage dumps is a universal one, not unique to any area but a practice which can contribute to a serious health condition within a municipal watershed. Measures should be taken to remove debris, organic matter, and garbage from all sink holes and a gravel and sand dyke built around the rim to prevent solid matter from draining into the system. The sinks should also be posted to explain that they are watershed preserves to prohibit their use as disposal pits.

The present water supply system with the metered chlorination device in the pump house now provides a safe and sanitary water supply for the Village of Schoharie. However, it is possible to exceed the capacity of chlorination to destroy bacteria in organic matter, and health problems could arise if excessive contamination were to occur.

Conclusions and Recommendations

Physical inspection of 3000 acres of farm land, wood lot, and swamp area for evidence of underground drainage and karst features was the basis for the present survey. The initial inspection pointed out the direction and scope of individual investigations carried on through the remainder of field work.

This study shows that the watershed area is capable of supplying the present needs of the Village of Schoharie and, with care and attention to conservation of this valuable resource, adequate potable water supplies can be enjoyed for many years to come.

The flow of water from Spring no. 1 is the resurgence of an underground stream and is as suceptible to contamination as if it were an open surface stream. Unlike a surface stream, however, it does not have the purifying effect of sunlight or aeration. Neither does it have the advantage of filtering action generally found in gravel, sand aquifers, and most groundwater reservoirs. The limestone channel acts as a pipe or duct and transports the water very rapidly underground.

As a water supply and reservoir, this stream does have decided advantages, which with proper protection, far outweigh the disadvantages. The constant ground temperature of this latitude and the distance the water travels underground provide a uniform 46°F water temperature. This uniform temperature retards bacteria growth and provides a more palatable drinking water for year-round consumption. The underground reservoir is not subject to the evaporation loss of a surface water supply. While silting occurs within the cave, the slow rate of flow permits clearing of water as it flows from pool to pool. Absence of sunlight on the reservoir also eliminates algae growth—a nuisance factor sometimes encountered in surface ponds.

If the surface source of an underground stream is known, the problem of controlling flow and sanitation is made easier and prediction of reserves possible. It should be emphasized, however, that increasing the quantity of water is a useless expense unless measures are taken to control the quality at the same time. Public water supply is a responsibility of all and should be of interest and mutual concern to every person. As such the following steps should be taken to eliminate pollution in the Barton Hill area:

1. The Board of Health should require permit for an inspection of new septic systems on Barton Hill.
2. Fluorescein dye should be introduced into existing septic systems to check for possible connection with water supply.
3. Discontinue disposal of dead animals in sink holes and fence off such areas.
4. Provide monthly tests during summer for bacteria count until all contamination sources are located and corrected.

Extensive exploration of accessible caves which contribute the main source of water supply to the Village of Schoharie shows that, with our present knowledge, internal artificial storage is not controllable. Even the capacity for storage cannot be predicted accurately. It is possible by means of excavation to further our knowledge of this cave system, but the expense involved would probably not justify the results.

The most economical solution, as well as the most positive control, would be to impound on the surface in an inexpensive reservoir a quantity of water during the wet months of the year. By means of a gate valve, it would be possible to meter the stored water by gravity into the system during the dry months in order to bolster the main supply until the wet season returns.

Two locations suggested themselves early in the study: the lowland near the entrance to Joober Hole and the swamp area at Cow Sink. The capacity for storage is much greater at Joober Hole—probably three to four times that of Cow Sink. However, several disadvantages are apparent in this approach. Spring no. 3 (the resurgence of Joober Hole) is the fartherest from the Village standpipe. The present pipe is only 4 inches in diameter and maintenance and replacement of this pipe would incur additional cost in upkeep. The rapid rate of flow between Joober Hole

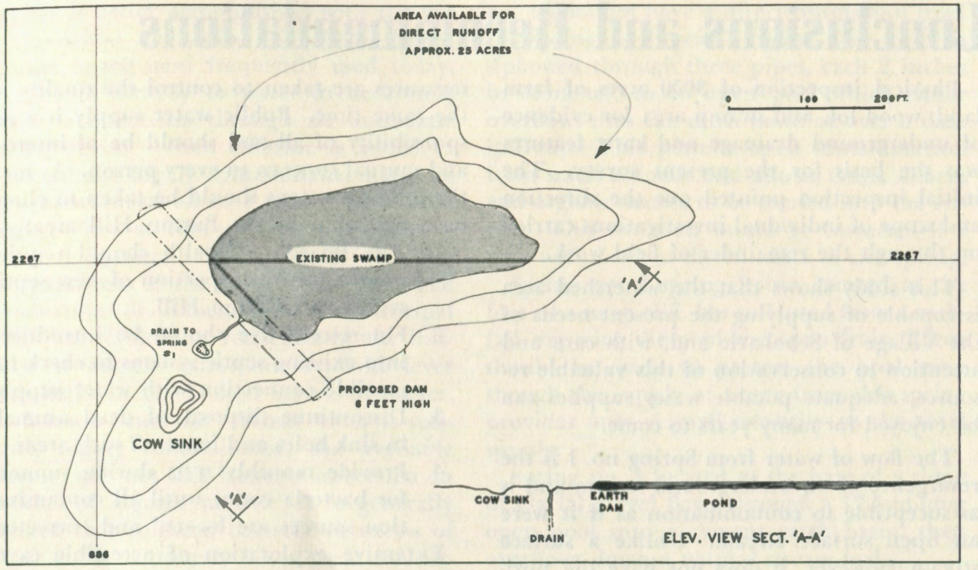

Figure 18
Plan of Cow Sink showing site for proposed dam. Contour interval 3 feet. From a plane table survey, December 1, 1960. Map by R. Anderson and R. Gurnee.

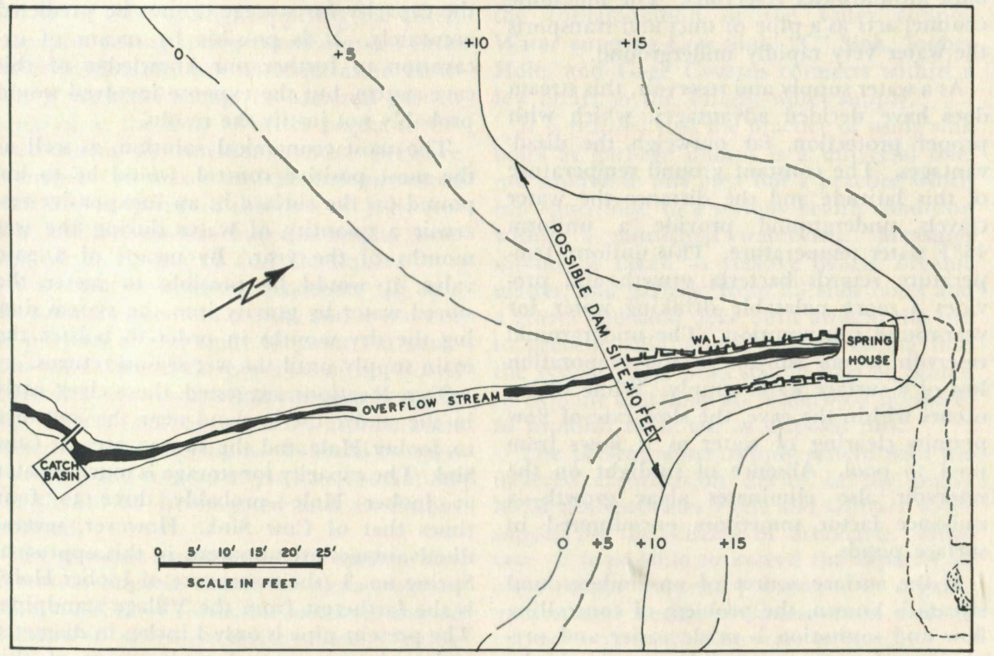

Figure 19
Map of Schoharie Spring no. 1, showing site for proposed dam. Contours are approximate; datum is level of spring house overflow. Surveyed by Anderson, Talbot and Olsen, August 27, 1960.

and Spring no. 3 does not give much capacity for internal storage, settling of silt, and reduction in temperature of the water. There is also the possibility of loss of water in a surface pond at Joober Hole because of the great number of sinks and crevices in that area.

Cow Sink seems to present a better solution to the problem because it connects directly with the main water source and topographically presents a bettter storage area. The limitation of this site, however, is its obvious small capacity. This limitation must be considered in relation to the estimated requirements of the Village and the number of years supply from this source would be adequate.

The estimated capacity of a dammed pond built at the Cow Sink site, as shown in figure 18, at five feet deep would be approximately 4½ million gallons. This pond has a potential water basin area of about 25 acres and, with proper conservation practices, should provide the requirements for reserves as stated in the Hydrology section of this report.

In order to remove the loss and inefficient method of water control now at Spring no. 1, it is recommended that an earth dam be built (fig. 19) to provide better storage and eliminate the present siphon method of discharge. This dam would impound an undetermined quantity of water (because of the unknown capacity of the cave) but a minimum (based on a measured interior cross-section) of 500,000 gallons would be assured. As far as can be determined from the physical exploration of this spring, there are no side passages where water would be lost if this dam were to be built.

An additional recommendation to prevent loss from the system is the installation of a check valve in the 4-inch diameter pipe leading from Spring no. 2 to the pumping station Fox Creek. This valve will prevent backup of water from the main pipe system and overflow at Spring no. 2 when the altitude valve at the standpipe closes.

The estimated increased needs for municipal water consumption in the United States were presented in the President's Materials Policy Commission Report in 1950. This report estimated that average increase in demand for municipal water supply by 1975 would be approximately 50 percent of that used in 1950. This factor applied to Schoharie's present consumption would tax the existing distribution system but would be within the capacity of the potential supply provided by the above recommendations. It would be necessary to provide for the future requirement of adding additional surface storage in the Joober Hole area in order to provide a safety factor in case of drought.

Of further interest to the Village of Schoharie is the Watershed Protection and Flood Prevention Act—Public Law 566 passed by the Congress of the United States in 1954. This act deals with water management measures that are beyond the abilities of individual farmers and small communities and provides for works of improvement that will have greatest significance in small watersheds. It can aid communities in completing those structures and in additional measures which must be made by the community. Assistance can be provided only if the benefits will exceed the costs. Local organizations must apply for these projects and participate in planning, financing, constructing, and maintaining any works of improvement under the Act. They are to be local projects with Federal participation. Application must be submitted for review to the authorized state agency before assistance can be furnished by the Department of Agriculture. Assistance will only be given if local committees make the effort to carry out surveys and participate in every phase of the planning. They must acquire land, easements, right of ways, and accept the responsibility of entering into contracts for the work of improvement. Assistance can also be requested by the community from the Soil Conservation Department for technical advice on watershed technique in conservation and sanitation.

It is sincerely hoped by the members of this project and the National Speleological Society that this survey will be of benefit to the specific needs of the people of the Village of Schoharie and that it may serve as a guide for other communities who may have similar problems.

References

Berdan, Jean M., 1950, The ground-water resources of Schoharie County, New York: New York Dept. Conservation Bull. GW-22, 61 p.

——— 1948, Hydrology of limestone terrain in Schoharie County, New York: Amer. Geophys. Union Trans, vol. 29, no. 2, April, p. 251-253.

Deike, G. H., III, 1960, Cave development in Burnsville Cove, west central Virginia, with special references to Breathing Cave: Univ. Mo. Grad. Sch. M.A. thesis, 155 p.

Dunn, J R., 1957, Stream tracing: Mid-Appalachian Region, National Speleological Society, Bull. 2, Oct., p. 7.

Goldring, Winifred and Plower, Rousseau, H., 1952, Restudy of the Schoharie and Esopus formations in New York State: Amer. Jour. Sci., vol. 240, no. 10, Oct., p. 673-694.

Grabau, A. W., 1906, Geology and paleontology of the Schoharie Valley: New York State Mus. Bull. 92, p. 77-386.

Gurnee, J. (Ed.), 1958, Gage Caverns Report: Northeastern Regional Organization, National Speleological Society, 8 p.

Haas, John L., Jr., 1959, Evaluation of ground water tracing methods used in speleology: National Speleological Society Bull. vol. 21, pt. 2, July, p. 67-76.

Parker, John M., III. 1942, Regional systematic jointing in slightly deformed sedimentary rocks: Geol. Soc. American Bull., vol. 53, no. 3, March, p. 381-408.

U. S. Department of Agriculture, 1955, Water, The Yearbook of Agriculture 1955: U. S. Govt. Printing Office, p. 62-76, 163-170, 649, 653, 656.